UNITED NATIONS
APCICT - ESCAP

ICT Trends

Digital Healthcare | Mobile Payment | Assistive Technologies | Internet of Things (IoT)

5th Generation Mobile Networks (5G) | Artificial Intelligence and Machine Learning

Blockchain and Shared Ledgers | 3D Printing

ICT Trends

APCICT
ASIAN AND PACIFIC TRAINING CENTRE FOR INFORMATION
AND COMMUNICATION TECHNOLOGY FOR DEVELOPMENT

ICT Trends

Correspondence concerning this publication should be addressed to the email: apcict@un.org

Contact:
Asian and Pacific Training Centre for Information and Communication Technology for Development (APCICT/ESCAP)
5th Floor G-Tower
175 Art Center Daero
Yeonsu-gu, Incheon
Republic of Korea
Tel +82 32 458 6650
Fax +82 32 458 6691/2
Email: apcict@un.org
http://www.unapcict.org

ISBN: 979-11-88931-01-9

ABOUT

The 2030 Agenda for Sustainable Development provides a plan of action for achieving an economically, socially and environmentally sustainable future. Information and communication technologies (ICTs) are recognized as enablers of the 2030 Agenda for Sustainable Development. Their diffusion and application in all sectors of society provide new solutions to persistent development challenges.

As new technologies, along with increased connectivity, spread rapidly and transform the ICT landscape around the world, it is important for policymakers and government officials to understand the current trends in order to fully leverage the potential benefits of ICT.

This publication aims to provide timely and relevant information on the major ICT trends and the implications of these trends. It serves as a knowledge resource for policymakers and government officials in Asia and the Pacific to increase their awareness and appreciation for the continuously evolving ICT landscape. It intends to present a broad understanding of how new and emerging ICT trends could be utilized to support sustainable and inclusive development.

This publication is a collection of brief write-ups on the following eight ICT trends:

1. Digital Healthcare
2. Mobile Payments
3. Assistive Technologies
4. Internet of Things
5. 5th Generation Mobile Networks
6. Artificial Intelligence and Machine Learning
7. Blockchain and Shared Ledgers
8. 3D Printing

This set of topics was selected based on their relevance to achieving the Sustainable Development Goals (SDGs). The topics selected also aim to provide a broadly representative sample covering a wide range of technology areas spanning hardware, networking, software and data, as well as application domains (i.e., healthcare, finance and disability).

Each write-up introduces the topic by first describing the technology features and components, and then proceeds to highlight potential application areas and use cases, with examples from the Asia-Pacific region and beyond. This is followed by a discussion on the policy implications involving regulatory aspects, standards and linkages to the SDGs. Each write-up may vary slightly to highlight relevant aspects.

The write-ups can be read independent of the other. Although the topics have been presented in a certain sequence, readers may start with any topic of interest and move on to any other topic that they find of relevance or interest. While going through the write-ups, readers may find multiple connections across application domains and technology areas. This has been intentional to foster a better appreciation of the potential use of the new and emerging technologies for sustainable development. As these are brief descriptions, interested readers are advised to go through the references provided at the end of the write-ups for a more comprehensive understanding of the topics.

ACKNOWLEDGEMENTS

ICT Trends was prepared by the Asian and Pacific Training Centre for Information and Communication Technology for Development (APCICT) of the Economic and Social Commission for Asia and the Pacific (ESCAP) under the overall guidance of Tiziana Bonapace, Director of the Information and Communications Technology and Disaster Risk Reduction Division and Officer-in-Charge of APCICT. Amit Prakash, Angel Jeena, Apoorva Bhalla, Rajesh Hanbal, Sanjay V.P., Supriya Dey and Vidhya Y. from the Centre for Information Technology and Public Policy, International Institute of Information Technology Bangalore were part of the core team as external experts.

This publication benefited greatly from internal reviews by Atsuko Okuda, Eric Roeder, Yungman Jun, Nuankae Wongthawatchai and Robert de Jesus, and external reviews by Usha Vyasulu Reddy, Nag Yeon Lee, Kamolrat Intaratat, Shahid Uddin Akbar, Sholpan Yessimova, Almaz Bakenov, Asomudin Atoev, Yudho Giri Sucahyo, Chi Kim Y and Bolorchimeg Ganbold. Editing support was provided by Christine Apikul.

Kyoung-Tae Kim, Hyunji Lee and Kevin Drouin provided research assistance. Joo-Eun Chung and Hyeseon Do undertook administrative support and other necessary assistance for the issuance of the publication.

TABLE OF CONTENTS

Ⅰ. Digital Healthcare

Contents

List of Figures

1. Introduction

Throughout Asia and the Pacific, the demand for healthcare has increased significantly. However, the supply of healthcare has failed to catch up with the requirements of the population, largely because of limitations in infrastructure, human resources and financial resources.[1] While out-of-pocket expenditures on health have been on the rise, public health spending by governments has been more or less stagnant. According to World Health Organization (WHO) statistics, countries like Afghanistan, Cambodia, India, Myanmar and Pakistan spend over half of their total health expenditure on out-of-pocket expenses.[2] Moreover, around 44 per cent of WHO member countries have reported poor physician density of less than 1 per 1,000 population.[3] Given these trends in healthcare and the ever-growing and developing field of information and communication technology (ICT), innovations in digital healthcare can help to address the challenges facing the healthcare sector today.

1.1 Digital Healthcare and the SDGs

Sustainable Development Goal (SDG) 3 focuses specifically on good health and well-being. The targets for this goal cover prevention of deaths due to HIV/AIDS, ending various epidemics and communicable diseases, and improving access to medicines and vaccines.[4] To achieve these targets, as well as ensure universal health coverage (which has been emphasized by WHO), countries have been formulating policies and implementing initiatives to improve healthcare access. A key strategy in this direction has been the use of ICT in healthcare. In fact, a WHO report positions electronic health (e-health) as a means of moving towards the goal of universal health coverage and achieving the SDGs.[5]

1 PricewaterhouseCoopers, "The Digital Healthcare Leap", February 2017. Available from https://www.pwc.com/gx/en/issues/high-growth-markets/publications/the-digital-healthcare-leap.html.

2 Out-of-pocket expenditure is any direct outlay by households, including gratuities and in-kind payments, to health practitioners and suppliers of pharmaceuticals, therapeutic appliances, and other goods and services whose primary intent is to contribute to the restoration or enhancement of the health status of individuals or population groups. It is a part of private health expenditure. World Health Organization, "Global Health Observatory (GHO) data". Available from http://www.who.int/gho/en/.

3 Ibid.

4 World Health Organization, "SDG 3: Ensure healthy lives and promote wellbeing for all at all ages". Available from http://www.who.int/sdg/targets/en/.

5 World Health Organization, *Global Diffusion of eHealth: Making Universal Health Coverage Achievable – Report of the Third Global Survey on eHealth* (Geneva, 2016). Available from http://www.who.int/goe/publications/global_diffusion/en/.

1.2 Digital Healthcare Definitions and Scope

According to the Economist Intelligence Unit, digital health is, "the convergence of technologies to support healthy living around the world".[6] There are various terms used when referring to digital healthcare such as e-health, health information technology, health 2.0, telemedicine, telehealth and connected care. All these terms, while pointing out their various components, tend to overlap in terms of their scope. The term e-health emerged around the year 2000 and has been widely used since then. However, the concept has been prevalent much before that. For example, between the 1980s and 1990s, studies on electronic health records revealed their potential in improving quality and efficiency in the delivery of healthcare.[7]

Over the past decades, ICTs have been expected to play an important role in, "health and health-related fields, including healthcare services, health surveillance, health literature, and health education, knowledge and research".[8] While most of the efforts in this area have been on improving existing systems of healthcare service delivery, there have also been efforts towards developing technologies that could provide stand-alone healthcare services. These developments have implications on the way the three main players in the health system, namely the providers, patients and payers, interact with each other.

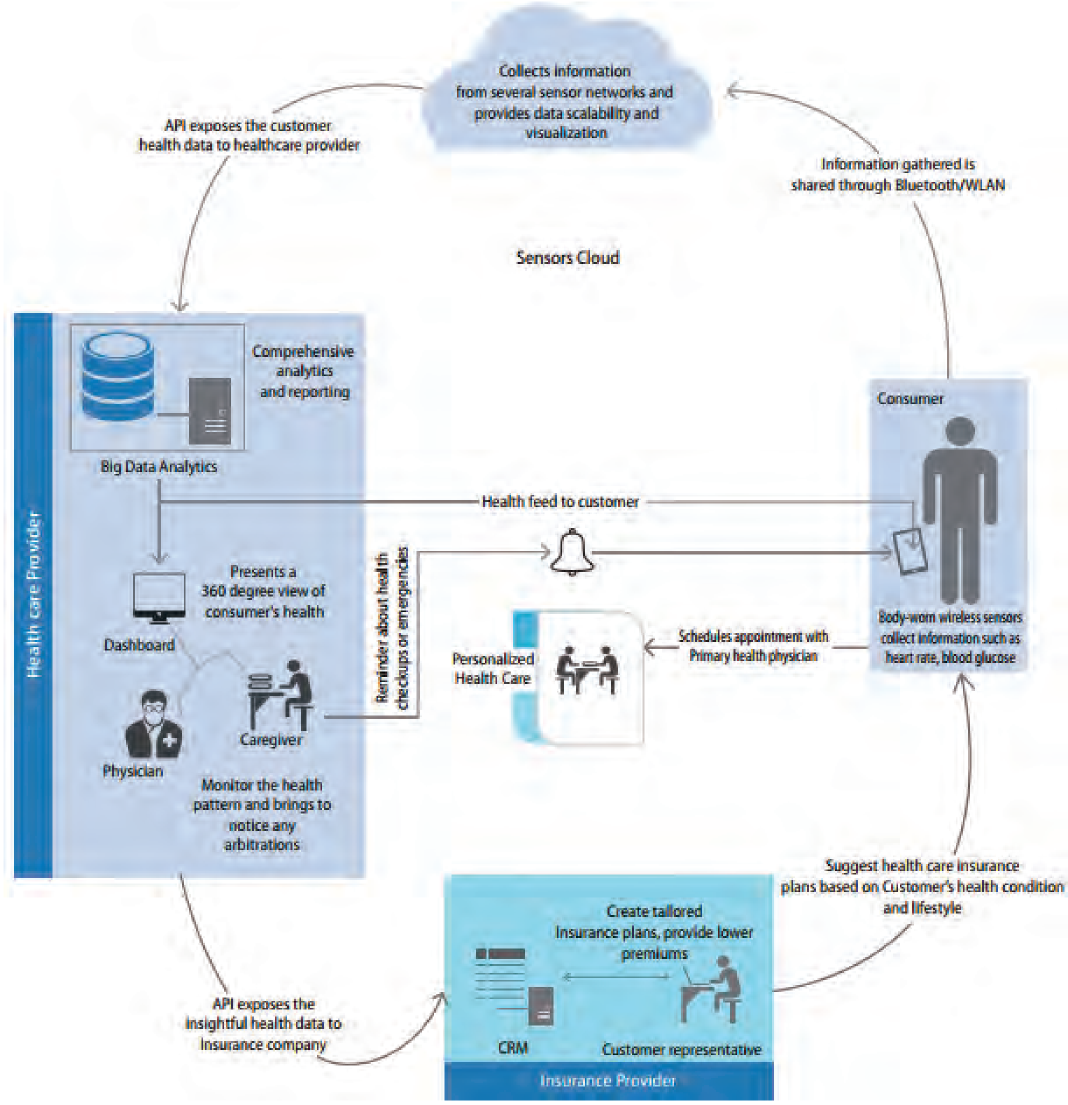
---

6 The Economist Intelligence Unit, *Digital Health: Total Convergence Integrating Technology to Solve the World's Healthcare Challenges* (2017). Available from http://www.eiu.com/digital-health.

7 Hossein Riazi, Maryam Jafarpour and Ehsan Bitaraf, "Towards National eHealth Implementation: A Comparative Study on WHO/ITU National eHealth Strategy Toolkit in Iran", *Studies in Health Technology and Informatics* (September 2014), pp. 246-250. Available from https://www.ncbi.nlm.nih.gov/pubmed/25160183.

8 World Health Assembly, "Resolution WHA58.28: eHealth", 2005. Available from http://www.who.int/healthacademy/media/WHA58-28-en.pdf.

Figure 1: Intersection of Various Stakeholders in the Digital Healthcare Ecosystem



Source: Uday Kiran Kotla and Ginni Jain, "Digital Healthcare Ecosystem", Infosys Whitepaper, 2017.

2. Various Components in the Digital Healthcare Space

2.1 M-health and Healthcare Applications

With the expansion of mobile technologies and the increase in global mobile data traffic over the years, there has been an increasing use of mobile computing and communication technologies in healthcare and public health.[9] Mobile health (m-health) has become a major component of digital healthcare as is evidenced by the wide range of m-health initiatives and implementations worldwide.

Text messaging features are the most commonly used while designing m-health solutions. Other features include add-ons (like a glucometer), voice, video, multimedia messaging services and native applications[10] that are generally used for communication between healthcare providers and the patients, for consultations, emergency management, health monitoring and surveillance, and information and education.[11]

While some of the m-health technologies and solutions have been successfully scaled up within the health system, many have run into roadblocks.

Case: Mobile Alliance for Maternal Action (MAMA)

MAMA was developed in partnership with mHealth Alliance, United Nations Foundation and BabyCenter, and funded by the United States Agency for International Development and Johnson & Johnson. This m-health solution uses text messages to create awareness among expectant and new mothers, with the aim to reduce maternal and new-born deaths due to various complications like bleeding, high-blood pressure and infections. MAMA has been implemented in Bangladesh, India and South Africa, taking advantage of the rapidly growing usage of mobile phones in these countries. The text messages sent seek to influence health behaviour like those regarding, "birth spacing, regular antenatal care, exclusive breastfeeding, hand washing, and the use of insecticide-treated bed nets to prevent malaria".[12]

---

9 Caroline Free and others, "The effectiveness of M-health technologies for improving health and health services: A systematic review protocol", *BMC Research Notes* (2010). Available from https://www.ncbi.nlm.nih.gov/pubmed/20925916.

10 Maddalena Fiordelli, Nicola Diviani and Peter J. Schulz , "Mapping mHealth research: A decade of evolution", *Journal of Medical Internet Research*, vol. 15, no. 5 (2013). Available from https://www.ncbi.nlm.nih.gov/pubmed/23697600.

11 World Health Organization, *Global Diffusion of eHealth: Making Universal Health Coverage Achievable – Report of the Third Global Survey on eHealth* (Geneva, 2016). Available from http://www.who.int/goe/publications/global_diffusion/en/.

12 mHealth Alliance, *Five Years of Mobilizing for Health Impact: Key Achievements & Future Opportunities* (2013). Available from http://www.mhealthknowledge.org/resources/five-years-mobilizing-health-impact-key-achievements-and-future-opportunities.

Case: mSehat Mobile Platform, India

mSehat, which translates as m-health, is a mobile-based platform developed for frontline health workers in India, including the accredited social health activists, Anganwadi workers and auxiliary nurse midwives. mSehat was implemented by the Ministry of Health and Family Welfare as an integrated Android and web-based, multimedia-enabled m-health platform, which can be accessed via smartphones and tablets. The platform provides multimedia-based training and information on demand. It is also used for registration, tracking, counselling, reporting, screening and referral. Other features include automated report generation and the monitoring of medicine stocks.[13] This m-health platform is expected to support the Mother and Child Tracking System, which was launched by the Government of India to monitor the indicators related to pregnancy and child tracking, especially maternal and neonatal outcomes. The use of this mobile solution aims to make data entry and reporting more efficient and quicker, and reduces duplication of efforts that tends to happen in a paper-based data recording system.[14]

2.2 Telemedicine

Telemedicine refers to the use of telecommunications to provide healthcare services to people at a distance. This could include various forms of clinical diagnosis and monitoring of patients. Over time, the term has evolved to becoming synonymous with "telehealth" and it includes the use of ICT in non-clinical activities associated with the health system. The link between the healthcare provider and the patient may be established via telephone, email or a video link, which may be in real time or asynchronous (store and forward). According to WHO's third global survey on e-health, the different types of telehealth initiatives that were reported include teleradiology, teledermatology, telepathology, telepsychiatry and remote patient monitoring.[15]

Similar to m-health, telehealth also includes initiatives or programmes that seek to improve access to information and knowledge, provide a platform for networking and collaboration among stakeholders, support policymaking, health education and training, and improve public accountability in the health system.[16]

Case: Telemedicine in China

The rapid growth of telecommunications in China in recent years has given the required push for the development of major telemedicine networks in the country. Some examples are the Golden Health Network, the International MedioNet of China Network and the People's Liberation Army Telemedicine Network. In the 1980s, China had a system of telemedicine that was dependent on the store-and-forward model. With improved technologies, these telemedicine networks are

13 Government of Uttar Pradesh, India, "About mSehat". Available from http://msehat.in.

14 World Health Organization, *Global Diffusion of eHealth: Making Universal Health Coverage Achievable – Report of the Third Global Survey on eHealth* (Geneva, 2016). Available from http://www.who.int/goe/publications/global_diffusion/en/.

15 Ibid.

16 Ibid.

able to connect medical professionals and various equipment for teleconsultations in real time, and enable file sharing between patients and specialists. This is done via the Internet, wireless communication, satellite communication and Bluetooth.

Case: Tele-ophthalmology by Aravind Eye Care Systems, India

The vision centres set up by Aravind Eye Care Systems especially in the rural communities of India seek to provide primary eye care services. These centres are equipped with wireless and broadband connections, and videoconferencing capabilities that enable specialists to provide basic consultation to patients living in the rural areas. At the same time, this reduces the need for the rural population to travel long distances to consult specialists at the main hospital.[17]

2.3 Health Information Systems

Health information systems of any country are designed to perform the following functions—"data generation, compilation, analysis and synthesis, and communication and use".[18] The objective of health information systems is to aid decision-making at different levels of the health system—individual, facility and country. The establishment of effective and efficient health information systems is expected to enable better monitoring and evaluation, management of diseases and epidemics, management of patients and health facilities, and support research and planning.[19]

Case: Health Information Systems Programme (HISP)

HISP, established by the Department of Informatics at the University of Oslo, is a global network that includes implementing partners like HISP India and HISP South Africa, as well as universities, ministries of health, and international agencies like WHO and the Norwegian Agency for Development Cooperation. HISP was established with the mission to support the design and implementation of sustainable health information systems. It involves the use of participatory approaches that aim to better understand the local health information flows and healthcare delivery systems. Free and open source software solutions guide the design, development and implementation of these local systems. The District Health Information Software or DHIS is the software used for implementing the health information system for online data management, capturing, validation and analytics. It can be adapted to a variety of use cases based on the local conditions and has been implemented in over 50 countries.[20]

17 Aravind Eye Care System, "Case Studies on Aravind Eye Care System". Available from http://www.aravind.org/default/aboutuscontent/casestudiesOnAravind.

18 World Health Organization, "Health Information Systems: Toolkit on monitoring health systems strengthening", June 2008. Available from http://www.who.int/healthinfo/statistics/toolkit_hss/EN_PDF_Toolkit_HSS_InformationSystems.pdf.

19 Ibid.

20 PATH, "An Interim Review of the Health Information Systems Programme—University of Oslo—with Recommendations for Future Action", 15 June 2016. Available from https://www.mn.uio.no/ifi/english/research/networks/hisp/hisp-assessment-report.pdf.

2.4 Electronic Medical Records and Medical Practice Management Software

An electronic medical record (EMR) consists of a patient's medical history from a particular health facility. Many healthcare providers, both in the private and public sectors, are gradually moving from a paper-based health records system to a digital records system. Ease in storage and retrieval are cited as the main reasons for this shift. Medical practice management software enables medical professionals and other healthcare staff to keep track of the patients that visit their facility, and provides a platform to share relevant details with patients. Practo Ray is an example of such software, which, in addition to managing patient records, includes features like appointment reminders for patients, along with billing and accounts management for administration and finance.[21]

2.5 Electronic Health Records

An electronic health record (EHR) consists of a more comprehensive record of the patient's medical history than an EMR as it includes other providers that are involved in providing care. Authorized medical professionals are able to update and exchange patient records, which may consist of doctors' notes, diagnostic results and medications.

A well-designed EHR system ensures easy accessibility of relevant elements of patient records for both patients and doctors at different facilities. By following appropriate interoperability standards, EHR systems enable patients to move from one medical facility to another by equipping them with the relevant medical records of their former interactions within the health system. This avoids unnecessary duplication of efforts by the doctors and medical professionals when they chart out appropriate treatment plans for the patients, and thus enhances the efficiency of healthcare provision. Furthermore, doctors, other healthcare professionals and the government can use aggregated patient data from the EHR system to better understand trends in diseases and health-related habits of patients for whom the data is available.

Some key concerns that arise from the use of EMRs and EHRs are related to the privacy and confidentiality of health data, ownership and access, security, and the legal implications of such records. There are also challenges related to rolling out the systems, which requires changing the behaviour and practices of medical professionals. Other barriers include the lack of standardization and interoperability of systems, along with high costs of implementation and maintenance. All these challenges prompted WHO to publish a manual on the implementation of EHRs for developing countries.[22]

21 Yourstory, "Practo Online Patient Care", 23 June 2011. Available from https://yourstory.com/2011/06/practo-online-patient-care/.

22 World Health Organization, *Electronic Health Records: Manual for Developing Countries* (Geneva, 2006). Available from http://www.wpro.who.int/publications/docs/EHRmanual.pdf.

Case: Singapore's National Electronic Health Record (NEHR)

The Singapore Ministry of Health along with Accenture designed and launched the NEHR, a nationwide patient data exchange system that aims at achieving its vision of, "One Patient, One Health Record". The project started in 2009, but it was only in 2013 that the system was made available to public health institutions and some private ones. It provides a consolidated view of a patient's medical history to healthcare professionals who are part of the network. According to the NEHR brochure, the information in the NEHR includes the following: admission and visit history, hospital inpatient discharge summaries, laboratory results, radiology results, medication history, past operations details, allergies and adverse drug reactions, and immunizations.[23] Figure 2 gives the stated objectives of the project.

One of the challenges that the NEHR system is trying to overcome is the lack of uptake among the private healthcare practitioners. This adversely affects the comprehensiveness and continuity in EHR data and may hamper effective decision-making. Issues like privacy and confidentiality and patient autonomy with regard to records are also being discussed by the Ministry of Health and the Singapore Medical Association (the national association for medical practitioners).[24]

Figure 2: Objectives of Singapore's National Electronic Health Record System

Stakeholder	Definition	EHR Objective
Clinician	Doctors, nurses, pharmacists, diagnostic clinicians, allied health and clinical support staff who provide services to patients in care delivery settings	To transform the way clinicians make decisions and deliver care through better information and cognitive support
Health Administrator	Ministry of Health, health statutory boards, hospital executives/management and health insurance companies	To gather information that will aid future resource allocations through deeper understanding of healthcare needs
Patient	Individuals who receive care from the Singapore healthcare system, including citizens, permanent residents, work permit holders and others	To improve the overall health of the population through better targeted interventions and confidence that clinicians have immediate critical information available to deliver high-quality care

Source: Accenture, *Singapore's Journey to Build a National Electronic Health Record System* (2012).

23 Ministry of Health, Singapore, "NEHR Singapore, Brochure – English". Available from https://www.moh.gov.sg/content/dam/moh_web/Publications/Educational%20Resources/Brochure_Eng.pdf.

24 SMA News, "SA's Letter to MOH on patient privacy and confidentiality under NEHR", June 2017.

2.6 Other Trends in Digital Healthcare

Virtual Reality

Virtual reality has been defined as technology that, "provides a computer-generated 3D environment that surrounds a user and responds to that individual's actions in a natural way, usually through immersive head-mounted displays".[25] It also involves technologies that enable head and hand tracking. A survey[26] on the applications of virtual reality-based technologies pointed out the benefits of using such technologies for improvements in quality and reduction of costs in healthcare. It revealed that virtual reality can be used in performing actual surgical procedures through remote surgery or telepresence, and augmented or enhanced surgery. Medical education and training is a major area for applying virtual reality as it can be used to perform computer-simulated surgeries and other procedures for training healthcare professionals. Some administrative uses of the technology include visualization of massive medical databases and architectural design for healthcare facilities. An individual patient can also use it for various kinds of medical therapy, for example, managing pain or fears/phobias, physical therapy and cognitive rehabilitation.[27]

Wearables, Sensors and the Internet of Things

"The Internet of Things (IoT) is a collective term for any one of the many networks of sensors, actuators, processors and computers connected to the Internet".[28] The development and use of wearable technologies, sensors and other connected devices for providing various healthcare services in the hospital, as well as at home, has been increasing over the past decade. In addition to tracking patients, it can also be used for tracking equipment and medicines.

For example, an IoT-enabled smart fridge was developed by Weka Solutions using Microsoft IoT to support supply chain management of vaccines. Each vaccine has an attached sensor that helps in storage at right temperature, dispensing of right dosage and automatic tracking of inventory. With sensors that collect real-time data, the IoT platform in the smart fridge also enables 24x7 monitoring and analysis.[29]

---

25 Gartner, "IT Glossary: Virtual Reality (VR)". Available from http://www.gartner.com/it-glossary/vr-virtual-reality/.

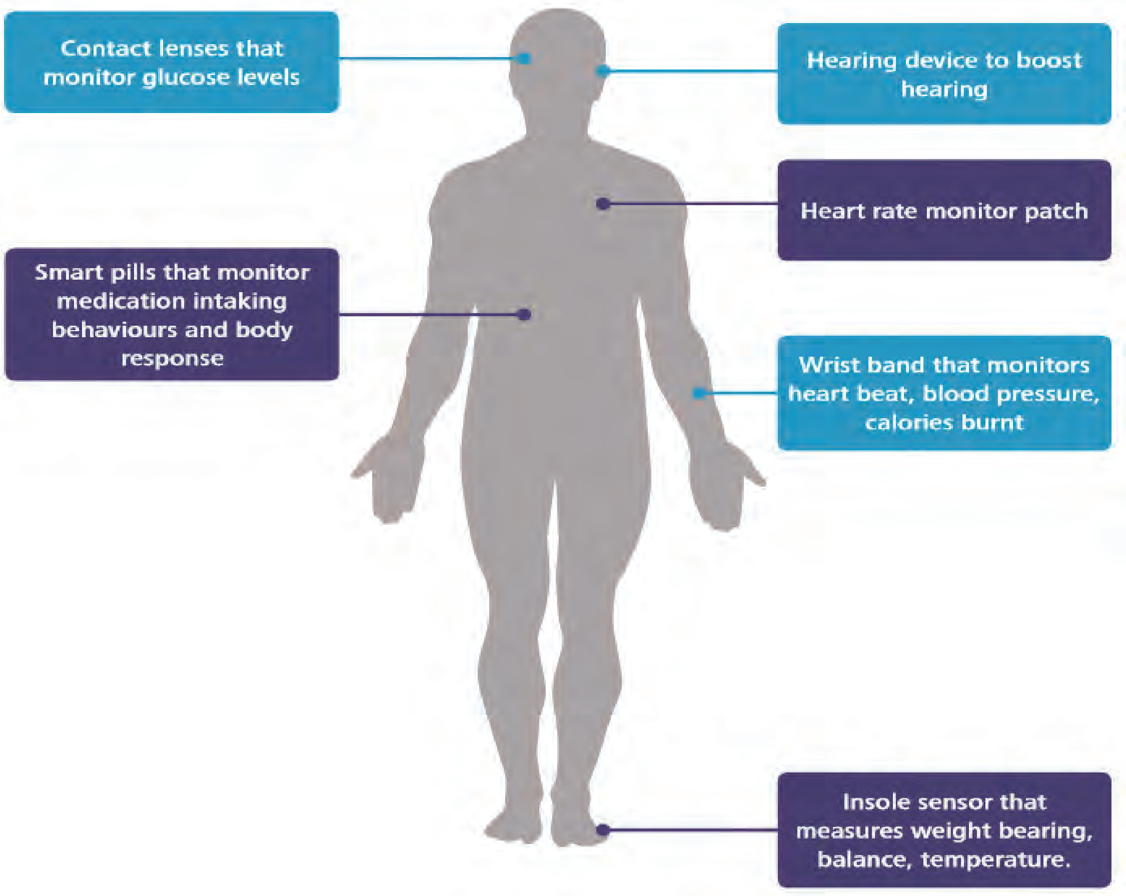
26 Judi Moline, "Virtual reality for health care: A survey", *Studies in Health Technology and Informatics* (1997), pp. 3-34. Available from https://www.ncbi.nlm.nih.gov/pubmed/10175341.

27 Wendy Powell, "Five ways virtual reality is improving healthcare", *Independent*, 26 June 2017. Available from http://www.independent.co.uk/life-style/health-and-families/five-ways-virtual-reality-is-improving-healthcare-a7801006.html.

28 Phillip A. Laplante and Nancy Laplante, "The Internet of Things in Healthcare: Potential Applications and Challenges", *IT Professional*, vol. 18, no. 3 (May-June 2016), pp. 2-4. Available from http://ieeexplore.ieee.org/document/7478533/.

29 Barb Edson, "IoT-enabled Smart Fridge helps manage vaccines and saves lives", *Microsoft*, 16 August 2016. Available from https://blogs.microsoft.com/iot/2016/08/16/iot-enabled-smart-fridge-helps-manage-vaccines-and-saves-lives/.

Figure 3: Innovations in Wearable and Sensor Technologies



Source: *Deloitte, Connected health: How digital technology is transforming human and social care* (2015). Available from https://www2.deloitte.com/content/dam/Deloitte/uk/Documents/life-sciences-health-care/deloitte-uk-connected-health.pdf.

Big Data, Artificial Intelligence and Machine Learning

Large amounts of health data are generated on a daily basis through the various modes of technologies that have permeated the healthcare industry. Artificial intelligence and machine learning play a huge role in providing meaning to the collected data, which tends to be largely unstructured. In health, artificial intelligence improves clinical diagnosis by analysing complex medical data.[30] This involves training machines with various kinds of health data in order to mirror the processes of human learning and cognition. IBM's Watson technology, which involves artificial intelligence or cognitive computing, has been used by multiple organizations for its potential application in storing and rapidly analysing vast amounts of data.[31]

30 ESCAP, *Artificial Intelligence and Broadband Divide: State of ICT Connectivity in Asia and the Pacific* (Bangkok, 2017). Available from http://www.unescap.org/resources/artificial-intelligence-and-broadband-divide-state-ict-connectivity-asia-and-pacific-2017.

31 PricewaterhouseCoopers, "What doctor? Why AI and robotics will define New Health", June 2017. Available from https://www.pwc.com/gx/en/industries/healthcare/publications/ai-robotics-new-health.html.

Robotics

The use of robotics in surgery has been prevalent for over 30 years, with the first known surgical robot being PUMA or programmable universal machine for surgery, which was used for urology surgery.[32] Robotics may be used to either assist the surgeon or may even be programmed to perform procedures on their own. For example, RoBear, a bear-shaped nursing care robot developed in Japan, is capable of taking care of elderly patients who may need to be lifted and assisted to sit on a wheelchair.[33]

3D Printing

3D printing or additive manufacturing technologies have been used in healthcare to create implants and prosthetics, as well as medical models and devices. The latest development is 3D bioprinting, which involves printing using cells. While the costs of printing generally depend on the materials used, 3D printing is considered a cost-effective technology because of the precision it brings to the process.

3D-printed skin has been used for treating burn victims in the past. Implants for babies as young as three months have been designed in such a manner that they grow along with the patient.[34] Researchers in Princeton University, USA have created a fully functional "bionic ear" that can surpass human hearing capabilities using 3D printing of cells and nanoparticles combined with a small coil antenna, thereby "merging electronics with tissue".[35]

32 Ibid.

33 Stuart Dredge, "Robear: The bear-shaped nursing robot who'll look after you when you get old", *The Guardian*, 27 February 2015. Available from https://www.theguardian.com/technology/2015/feb/27/robear-bear-shaped-nursing-care-robot.

34 Drew Hendricks, "3D Printing Is Already Changing Health Care", *Harvard Business Review*, 4 March 2016. Available from https://hbr.org/2016/03/3d-printing-is-already-changing-health-care.

35 John Sullivan, "Printable 'bionic' ear melds electronics and biology", *Princeton University*, 8 May 2013. Available from https://www.princeton.edu/news/2013/05/08/printable-bionic-ear-melds-electronics-and-biology.

3. Potential Benefits of ICT in Health

A systematic review of around 100 studies on telehealth revealed that a major impact of using ICTs in health has been improvements in the quality of healthcare. This was followed by improvements in access and cost effectiveness or minimization.[36]

From the perspective of healthcare providers, digital health technology has helped by reducing paperwork time, hospital admissions and bed days, and improving patient face time. A lot of these technologies have a focus on preventive care, promote patient independence and minimize use of healthcare services that can be avoided. All these have positive effect on patient outcomes. In such a scenario, patients are empowered through self-management, education and awareness, and supported with alternative communication platforms to interact with their healthcare providers. This implies a shift from a "paternalistic model of healthcare" to an "empowered patient sharing ownership" model.[37]

Figure 4 lists benefits of different types of digital healthcare technologies. As can be seen from the table, cost savings and better quality of healthcare are considered some of the main benefits of these technologies.

Figure 4: Summary of Benefits of Digitizing Healthcare for Patients, Providers and Payers

	Patients	Providers	Payers
EMR	Easier to read and understand	Easy storage and retrieval; improved efficiency and productivity	
EHR	Better diagnosis and treatment	Coordination and informed decision-making	Faster reimbursements
Personal Health Records	Personal wellness management	Consistency of information	Links to healthcare plans and lower claims
Remote Diagnostics	Reduces duplicated tests and referrals	Easy access	Lower cost
Remote Monitoring	Patient-centric integrated care	Reduce emergency and re-admissions	Lower cost
Telecare	Access to specialist care	Improves productivity and reduces burden of healthcare resources	Lower cost
mHealth applications	Greater patient engagement and saves time	Proactive and targeted care	
Big Data/Analytics	Accurate diagnosis, better treatment	Improves diagnostics and accuracy of treatment	Lower cost

* EMR – Electronic Medical Records; EHR – Electronic Health Records

Source: PricewaterhouseCoopers, "The Digital Healthcare Leap", February 2017. Available from https://www.pwc.com/gx/en/issues/high-growth-markets/publications/the-digital-healthcare-leap.html.

36 Hammad Durrani and Shariq Khoja, "A systematic review of the use of telehealth in Asian countries", *Journal of Telemedicine and Telecare*, vol. 15, no. 4 (2009), pp. 175–181. Available from https://www.ncbi.nlm.nih.gov/pubmed/19471028.

37 Deloitte, *Connected health: How digital technology is transforming human and social care* (2015).

4. Policies and Strategies for Digital Health

With the proliferation of different kinds of technologies in healthcare, there is an urgent need for well-articulated policy and regulatory frameworks regarding the various aspects of e-health. These policies are required not just within countries but also at a global level. At the same time, every country or region needs a policy framework that considers the context in which ICT is being implemented. This is important, especially for developing countries, wherein replicating or emulating successful ICT interventions from developed countries can be problematic if the context is ignored.[38]

Against this background, WHO and the International Telecommunication Union collaborated to develop the National eHealth Strategy Toolkit. Published in 2012, it details the components and processes that are to be considered while developing e-health strategies or refining existing ones. The toolkit provides guidelines for governments to formulate a national e-health vision document for the country along with an action plan and monitoring framework.[39] WHO has also published specialized manuals and guidelines for the implementation of health information systems and EHRs, with a special focus on developing countries.

In 2015, the Broadband Commission for Sustainable Development formed a Working Group on Digital Health. It launched a report in 2017 that highlighted the role of government leadership and cooperation for advancing the role of ICTs in healthcare by focusing on financing, governance and the setting up of national frameworks that takes into consideration issues like connectivity, interoperability and common standards.[40]

According to a survey by the WHO Global Observatory for eHealth, 73 out of the 125 responding member states (i.e., around 58 per cent) reported to have any form of e-health strategy in place. However, a higher percentage (around 66 per cent) reported to having a health information system policy in place. In the case of privacy legislations, around 78 per cent of these countries have reported having any policies that regulated personally identifiable information.[41]

38 Hammad Durrani and Shariq Khoja, "A systematic review of the use of telehealth in Asian countries", *Journal of Telemedicine and Telecare*, vol. 15, no. 4 (2009), pp. 175–181. Available from https://www.ncbi.nlm.nih.gov/pubmed/19471028.

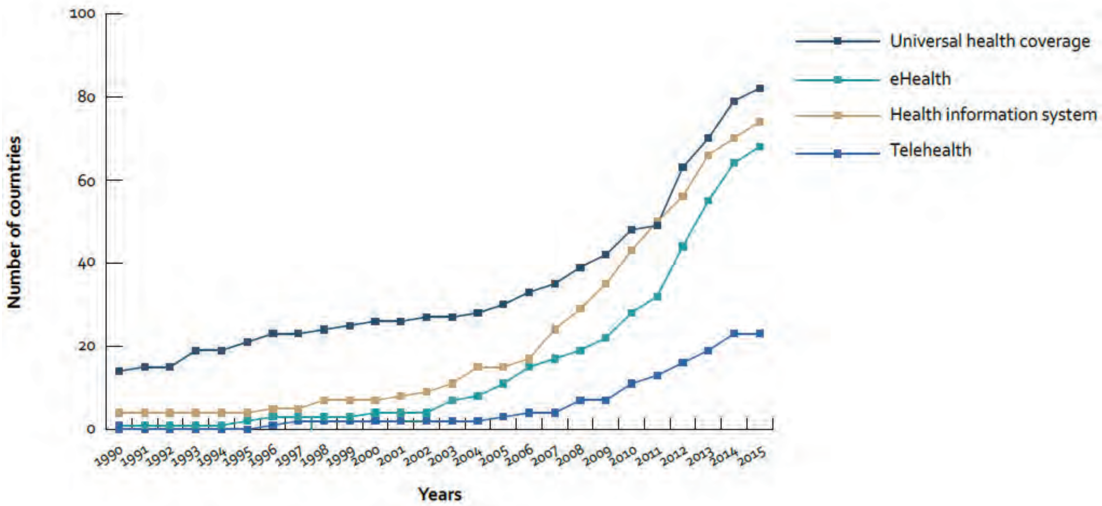
39 World Health Organization and International Telecommunication Union, *National eHealth Strategy Toolkit* (Geneva, 2012). Available from http://www.itu.int/pub/D-STR-E_HEALTH.05-2012.

40 Broadband Commission for Sustainable Development, "Working Group on Digital Health". Available from http://www.broadbandcommission.org/workinggroups/Pages/digitalhealth.aspx.

41 World Health Organization, *Global Diffusion of eHealth: Making Universal Health Coverage Achievable – Report of the Third Global Survey on eHealth* (Geneva, 2016). Available from http://www.who.int/goe/publications/global_diffusion/en/.

However, such policies sometimes tend to be vague and nebulous as to what it wants to achieve. A few countries in Asia like China, India, Indonesia, Malaysia, Republic of Korea, Singapore and Thailand have some form of national e-health policy in place. However, it has only been a few years since their implementation and hence, it is still quite early to assess their impact. Figure 4 gives the timeline of adoption of e-health strategies by countries during 1990-2015.

Figure 5: Number of Countries with Universal Health Coverage, E-health, Health Information System and Telehealth Policies or Strategies, Cumulatively by Year of Adoption, 1990-2015



Source: World Health Organization, *Global Diffusion of eHealth: Making Universal Health Coverage Achievable – Report of the Third Global Survey on eHealth* (Geneva, 2016). Available from http://www.who.int/goe/publications/global_diffusion/en/.

Case: Malaysia's Telemedicine Act 1997

Malaysia is considered to have a, "proactive, moderately comprehensive, structured policy" when it comes to e-health.[42] The Telemedicine Act of 1997 along with the Digital Signature Act of 1997, Communication and Multimedia Act of 1998, and Personal Data Protection Act of 2003 provided the necessary environment for its e-health strategies to grow.[43] Telehealth was implemented as a flagship application by the Ministry of Health in Malaysia as part of the Multimedia Super Corridor Project. It included components on personalized health information and education for individuals, distance education and learning for medical professionals, teleconsultation, and EHR. The initiative introduced the concept of a Lifetime Health Plan for its citizens that includes activities such as health promotion, illness care plans for specific disease and conditions, alerts and reminders, and health status monitoring. The initiative was expanded in 2004 to include an online health portal for health promotion and call centre services.[44]

42 Richard E. Scott, Penny Jennett and Maryann Yeo, "Access and authorisation in a Global e-Health Policy context", *International Journal of Medical Informatics*, vol. 73, no. 3 (2004), pp. 259-266. Available from https://www.ncbi.nlm.nih.gov/pubmed/15066556.

43 Ibid.

44 M. H. Mat Som, A. N. Norali and M. S. A. Megat Ali, "Telehealth in Malaysia: An overview", *2010 IEEE Symposium on Industrial Electronics & Applications* (October 2010), pp. 660-664. Available from ieeexplore.ieee.org/abstract/document/5679384/.

Case: E-health Policies and Strategies in India

The Government of India proposed the establishment of a National eHealth Authority as the regulatory body to ensure the promotion and development of the e-health ecosystem in the country. This involves regulating EHRs, health information exchange and other digital health initiatives. Its functions also include policy formulation, development and release of standards, regulating privacy and security, and certification for e-health solutions and products.[45] In 2016, the e-health section of the Ministry of Health and Family Welfare formulated and released standards for implementing EHR systems across the country. These standards have been devised for disease classification, medicine and clinical terminology, laboratory data exchange, digital imaging and communication, and unique identifiers for patients for interoperability.[46] Other initiatives include an online registration system for managing appointments, the National Telemedicine Network Scheme for teleconsultation and tele-follow-up services at primary healthcare facilities in the public health system, and computerization of public health facilities to support implementation of health information systems.[47]

---

45 Ministry of Health and Family Welfare, India, “Concept Note: National eHealth Authority”, no date.

46 Press Information Bureau, India, “Online Prescription”, 2 December 2016. Available from http://pib.nic.in/newsite/PrintRelease.aspx?relid=154775.

47 Ibid.

5. Role of Standards in Digital Health

Policy frameworks should be supported by standards, architectures and solid partnerships among stakeholders.[48] Multiple organizations like the International Organization for Standardization, Standards Association of IEEE and Health Level Seven International have emphasized the importance of standards in the area of digital health. Interoperability is an important keyword when it comes to designing an e-health system, and standards play an important role in ensuring seamless exchange of information and better management of complex health data.[49] According to Health Level Seven International, standards provide, "a comprehensive framework for the exchange, integration, sharing and retrieval of electronic health information that supports clinical practice and the management, delivery and evaluation of health services". This can be achieved through an ongoing collaboration among various stakeholders associated with the health system and by establishing affiliate organizations that support the use of these standards at the local level.[50] The Standards Association of IEEE has developed relevant standards for, "the promotion and expansion of connectivity and communication between personal health and wellness devices". Through its studies it has tackled important issues, including ways that standards can help to mitigate technological risks, facilitate interoperability, help save costs and promote adoption in the marketplace.[51]

48 World Health Organization, *mHealth: New horizons for health through mobile technologies* (Geneva, 2011). Available from http://www.who.int/goe/publications/goe_mhealth_web.pdf.

49 International Organization for Standardization, "Strengthening national health systems through a capacity-based eHealth architecture", no date. Available from https://www.iso.org/iso/14639-brochureversionv7.pdf.

50 Health Level Seven International. Available from http://www.hl7.org/.

51 IEEE Standards Association, "eHealth". Available from http://standards.ieee.org/innovate/ehealth/.

6. References

Aravind Eye Care System. Case studies on Aravind Eye Care System. Available from http://www.aravind.org/default/aboutuscontent/casestudiesOnAravind.

Broadband Commission for Sustainable Development. Working Group on Digital Health. Available from http://www.broadbandcommission.org/workinggroups/Pages/digitalhealth.aspx.

Deloitte. Connected health: *How digital technology is transforming human and social care*. 2015. Available from https://www2.deloitte.com/content/dam/Deloitte/uk/Documents/life-sciences-health-care/deloitte-uk-connected-health.pdf.

Dredge, Stuart. Robear: the bear-shaped nursing robot who'll look after you when you get old. *The Guardian*, 27 February 2015. Available from https://www.theguardian.com/technology/2015/feb/27/robear-bear-shaped-nursing-care-robot.

Durrani, Hammad, and Shariq Khoja. A systematic review of the use of telehealth in Asian countries. *Journal of Telemedicine and Telecare*, vol. 15, no. 4 (2009), pp. 175–181. Available from https://www.ncbi.nlm.nih.gov/pubmed/19471028.

Edson, Barb. IoT-enabled Smart Fridge helps manage vaccines and saves lives. *Microsoft*, 16 August 2016. Available from https://blogs.microsoft.com/iot/2016/08/16/iot-enabled-smart-fridge-helps-manage-vaccines-and-saves-lives/.

ESCAP. *Artificial Intelligence and Broadband Divide: State of ICT Connectivity in Asia and the Pacific*. Bangkok, 2017. Available from http://www.unescap.org/resources/artificial-intelligence-and-broadband-divide-state-ict-connectivity-asia-and-pacific-2017.

Fiordelli, Maddalena, Nicola Diviani and Peter J. Schulz. Mapping mHealth research: A decade of evolution. *Journal of Medical Internet Research*, vol. 15, no. 5 (2013). Available from https://www.ncbi.nlm.nih.gov/pubmed/23697600.

Free, Caroline, and others. The effectiveness of M-health technologies for improving health and health services: A systematic review protocol. *BMC Research Notes* (2010). Available from https://www.ncbi.nlm.nih.gov/pubmed/20925916.

Gartner. IT Glossary: Virtual Reality (VR). Available from http://www.gartner.com/it-glossary/vr-virtual-reality/.

Government of Uttar Pradesh, India. About mSehat. Available from http://msehat.in.

Health Level Seven International. Available from http://www.hl7.org/.

Hendricks, Drew. 3D Printing Is Already Changing Health Care. *Harvard Business Review*, 4 March 2016. Available from https://hbr.org/2016/03/3d-printing-is-already-changing-health-care.

IEEE Standards Association. eHealth. Available from http://standards.ieee.org/innovate/ehealth/.

International Organization for Standardization. Strengthening national health systems through a capacity-based eHealth architecture. No date. Available from https://www.iso.org/iso/14639-brochureversionv7.pdf.

Laplante, Phillip A., and Nancy Laplante. The Internet of Things in Healthcare: Potential Applications and Challenges. *IT Professional*, vol. 18, no. 3 (May-June 2016), pp. 2-4. Available from ieeexplore.ieee.org/document/7478533/.

mHealth Alliance. *Five Years of Mobilizing for Health Impact: Key Achievements & Future Opportunities*. 2013. Available from http://www.mhealthknowledge.org/resources/five-years-mobilizing-health-impact-key-achievements-and-future-opportunities.

Ministry of Health and Family Welfare, India. Concept Note: National eHealth Authority. No date.

Ministry of Health, Singapore. NEHR Singapore, Brochure – English. Available from https://www.moh.gov.sg/content/dam/moh_web/Publications/Educational%20Resources/Brochure_Eng.pdf.

Moline, Judi. Virtual reality for health care: A survey. *Studies in Health Technology and Informatics* (1997), pp. 3-34. Available from https://www.ncbi.nlm.nih.gov/pubmed/10175341.

PATH. An Interim Review of the Health Information Systems Programme—University of Oslo—with Recommendations for Future Action. 15 June 2016. Available from https://www.mn.uio.no/ifi/english/research/networks/hisp/hisp-assessment-report.pdf.

Powell, Wendy. Five ways Virtual Reality is improving healthcare. *Independent*, 26 June 2017. Available from http://www.independent.co.uk/life-style/health-and-families/five-ways-virtual-reality-is-improving-healthcare-a7801006.html.

Press Information Bureau, India. Online Prescription. 2 December 2016. Available from http://pib.nic.in/newsite/PrintRelease.aspx?relid=154775.

PricewaterhouseCoopers. The Digital Healthcare Leap. February 2017. Available from https://www.pwc.com/gx/en/issues/high-growth-markets/publications/the-digital-healthcare-leap.html.

PricewaterhouseCoopers. What doctor? Why AI and robotics will define New Health. June 2017. Available from https://www.pwc.com/gx/en/industries/healthcare/publications/ai-robotics-new-health.html.

Riazi, Hossein, Maryam Jafarpour and Ehsan Bitaraf. Towards National eHealth Implementation: A Comparative Study on WHO/ITU National eHealth Strategy Toolkit in Iran. *Studies in Health Technology and Informatics* (September 2014), pp. 246-250. Available from https://www.ncbi.nlm.nih.gov/pubmed/25160183.

Scott, Richard E., Penny Jennett and Maryann Yeo. Access and authorisation in a Global e-Health Policy context. *International Journal of Medical Informatics*, vol. 73, no. 3 (2004), pp. 259-266. Available from https://www.ncbi.nlm.nih.gov/pubmed/15066556.

SMA News. SA's Letter to MOH on patient privacy and confidentiality under NEHR. June 2017.

Som, M. H. Mat, A. N. Norali and M. S. A. Megat Ali. Telehealth in Malaysia: An overview. *2010 IEEE Symposium on Industrial Electronics & Applications* (October 2010), pp. 660-664. Available from ieeexplore.ieee.org/abstract/document/5679384/.

Sullivan, John. Printable 'bionic' ear melds electronics and biology. *Princeton University*, 8 May 2013. Available from https://www.princeton.edu/news/2013/05/08/printable-bionic-ear-melds-electronics-and-biology.

The Economist Intelligence Unit. *Digital Health: Total Convergence Integrating Technology to Solve the World's Healthcare Challenges*. 2017. Available from http://www.eiu.com/digital-health.

World Health Assembly. Resolution WHA58.28: eHealth. 2005. Available from http://www.who.int/healthacademy/media/WHA58-28-en.pdf.

World Health Organization. *Electronic Health Records: Manual for Developing Countries*. Geneva, 2006. Available from http://www.wpro.who.int/publications/docs/EHRmanual.pdf.

World Health Organization. Health Information Systems: Toolkit on monitoring health systems strengthening. June 2008. Available from http://www.who.int/healthinfo/statistics/toolkit_hss/EN_PDF_Toolkit_HSS_InformationSystems.pdf.

World Health Organization. *mHealth: New horizons for health through mobile technologies*. Geneva, 2011. Available from http://www.who.int/goe/publications/goe_mhealth_web.pdf.

World Health Organization. *Global Diffusion of eHealth: Making Universal Health Coverage Achievable – Report of the Third Global Survey on eHealth*. Geneva, 2016. Available from http://www.who.int/goe/publications/global_diffusion/en/.

World Health Organization. Global Health Observatory (GHO) data. Available from http://www.who.int/gho/en/.

World Health Organization. SDG 3: Ensure healthy lives and promote wellbeing for all at all ages. Available from http://www.who.int/sdg/targets/en/.

World Health Organization and International Telecommunication Union. *National eHealth Strategy Toolkit*. Geneva, 2012. Available from http://www.itu.int/pub/D-STR-E_HEALTH.05-2012.

Yourstory. Practo Online Patient Care. 23 June 2011. Available from https://yourstory.com/2011/06/practo-online-patient-care/.

Glossary

E-health : The use of ICT for health.

Interoperability : The ability of different information technology systems and software applications to communicate, exchange data and use the information that has been exchanged.

Telemedicine : The practice of medicine when the doctor and patient are widely separated using two-way voice and visual communication (by satellite or computer).

Universal health coverage : Ensuring that all people have access to needed promotive, preventive, curative and rehabilitative health services, of sufficient quality to be effective, while also ensuring that people do not suffer financial hardship when paying for these services.

Acronyms

E-health	Electronic Health
EHR	Electronic Health Record
EMR	Electronic Medical Record
ICT	Information and Communication Technology
IoT	Internet of Things
M-health	Mobile Health
SDG	Sustainable Development Goal
WHO	World Health Organization

Ⅱ. Mobile Payments

Contents

List of Figures

1. Introduction

An important component of any financial system is its payment system, which consists of platforms, mechanisms, rules and procedures to, "facilitate the clearing and settlement of monetary and other financial transactions".[1] Cash is the traditional payment instrument. At the same time, there are many physical and virtual payment instruments, like debit cards and credit cards, that enable cashless transactions around the world. Developments in technologies, along with innovations in the financial sector, have influenced the way the financial system (especially the payment system) and its participants/stakeholders interact.

1.1 Benefits of Mobile Payment Systems

The goal of achieving a "cashless society" has received more impetus with the advent of digital payment technologies. Studies have shown the direct and indirect costs of dealing with cash to be high and a burden on society, especially the lower-income group.[2] This has been used to incentivize various cashless payments, especially using digital/mobile payment technologies. The existing means of cashless payments (like debit and credit cards) have also been integrated with the online and mobile payment systems.

Providing access to traditional financial services is costly, especially in the case of rural areas. However, the proliferation of mobile phones has provided an opportunity to take various financial services to the unbanked and the underserved groups, as well as to the larger population. For example, banks can make huge cost savings as the use of mobile phones for banking and money transfers reduces the investment in ATM kiosks and machines. Cross-border payments and sending of remittances have become cost-efficient and convenient through the adoption of mobile payment systems. Such money transfers are expected to promote growth through increased transactions and money transfers between countries. Mobile operators can also get cost benefits as tapping the potential for mobile payments market in the rural and developing regions is expected to improve their average revenue per user.[3] The reduction in transaction costs and improved efficiency (that enables speed and liquidity of money) have been major factors in improving productivity.

1 World Bank, "Payment Systems". Available from http://www.worldbank.org/en/topic/paymentsystemsremittances.

2 Bhaskar Chakravorti, "The hidden costs of cash", *Harvard Business Review*, 26 June 2014. Available from https://hbr.org/2014/06/the-hidden-costs-of-cash.

3 Ernst & Young, *Mobile Money: An Overview for Global Telecommunications Operators* (2009). Available from http://www.ey.com/Publication/vwLUAssets/Mobile_Money./%24FILE/Ernst%20%26%20Young%20-%20Mobile%20Money%20-%2015.10.09%20(single%20view).pdf.

Mobile payments are considered to be less prone to theft, loss and fraud than cash payments, as most of these platforms are equipped with relevant security features.[4] This promotes adoption among both merchants as well as customers. Increased use of some mobile payment services can result in value-added services like loyalty and credit for both merchants and customers. Moving to mobile/digital payments is also expected to promote transparency and accountability as it leaves a clear trail of records.[5]

1.2 Financial Inclusion and the SDGs

The development of mobile financial technologies and mobile payment systems has been supported by the need to achieve the goal of financial inclusion. A large number of people especially in the developing regions do not have an account at any financial institution. These technologies are expected to help the efforts in taking banking and financial services to the "unbanked" population, in addition to improving the quality and accessibility of such services to the population in general.[6] Financial inclusion is important for development, and helps in creating an environment that enables the achievement of the Sustainable Development Goals (SDGs). In this context, the role of digital (including mobile) payment technologies in achieving the SDGs is discussed below.

4 Kevin Donovan, "Mobile money for financial inclusion", in *Information and Communications for Development 2012: Maximizing Mobile*, World Bank (Washington, D.C., 2012), pp. 61-73. Available from https://elibrary.worldbank.org/doi/abs/10.1596/9780821389911_ch04.

5 Ernst & Young, *Mobile Money: An Overview for Global Telecommunications Operators* (2009). Available from http://www.ey.com/Publication/vwLUAssets/Mobile_Money./%24FILE/Ernst%20%26%20Young%20-%20Mobile%20Money%20-%2015.10.09%20(single%20view).pdf.

6 International Telecommunication Union, "Mobile Money Revolution Part 2: Financial Inclusion Enabler", May 2013. Available from https://www.itu.int/oth/T0B15000016/en.

2. Mobile Payment Technologies and Services

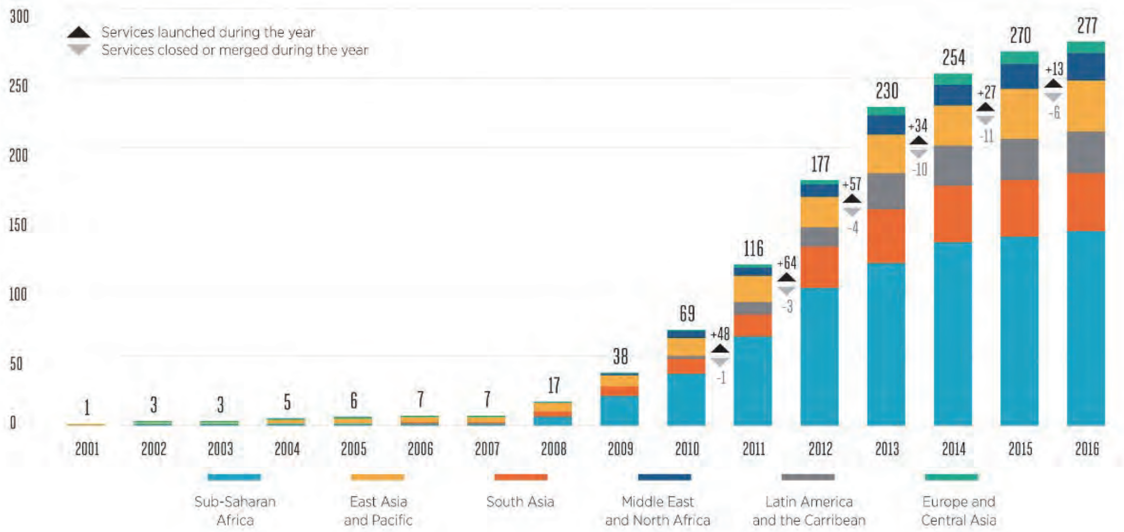
Mobile devices like mobile phones, smartphones or personal digital assistants can be used for making payments and other financial transactions, with the help of wireless and telecommunications technologies.[7] The different kinds of mobile payments that are possible include: person-to-person, government-to-person, business-to-business and business-to-person/consumer.[8] The number of mobile payment services that are being launched has increased over the past decade (Figure 1). This has mainly been due to the digitization in the banking sector and the rise of e-commerce. The growing penetration of mobile phones (especially smartphones), along with developments in telecommunications and other technologies have given an impetus to efforts in this direction.

There are various financial and monetary transactions that can be made using a mobile phone, covering scenarios like e-commerce, banking and money transfer (Figure 2). There are multiple stakeholders in the mobile payment ecosystem. Firstly, there are the users or consumers of mobile payment services, which could be individuals, merchants, businesses or governments. Secondly, there are providers of mobile payment services, which include banking and financial institutions, as well as non-banking institutions like mobile operators, mobile money stores and cryptocurrency exchanges. Thirdly, there are those institutions that provide the necessary infrastructure and support services to the providers and consumers. This typically includes the technology providers and regulators (Figure 3).

7 Tomi Dahlberg and others, "Past, present and future of mobile payments research: A literature review", *Electronic Commerce Research and Applications*, vol. 7, no. 2 (Summer 2008), pp. 165-181. Available from dl.acm.org/citation.cfm?id=1377314.

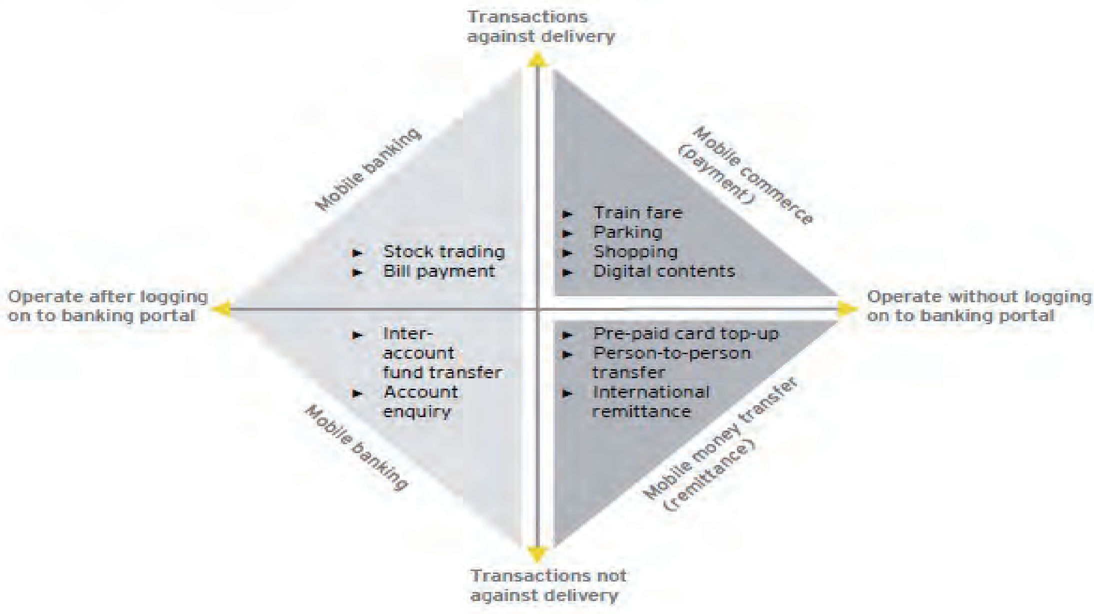
8 Kevin Donovan, "Mobile money for financial inclusion", in *Information and Communications for Development 2012: Maximizing Mobile*, World Bank (Washington, D.C., 2012), pp. 61-73. Available from https://elibrary.worldbank.org/doi/abs/10.1596/9780821389911_ch04.

Figure 1: Number of Live Mobile Payment Services by Region



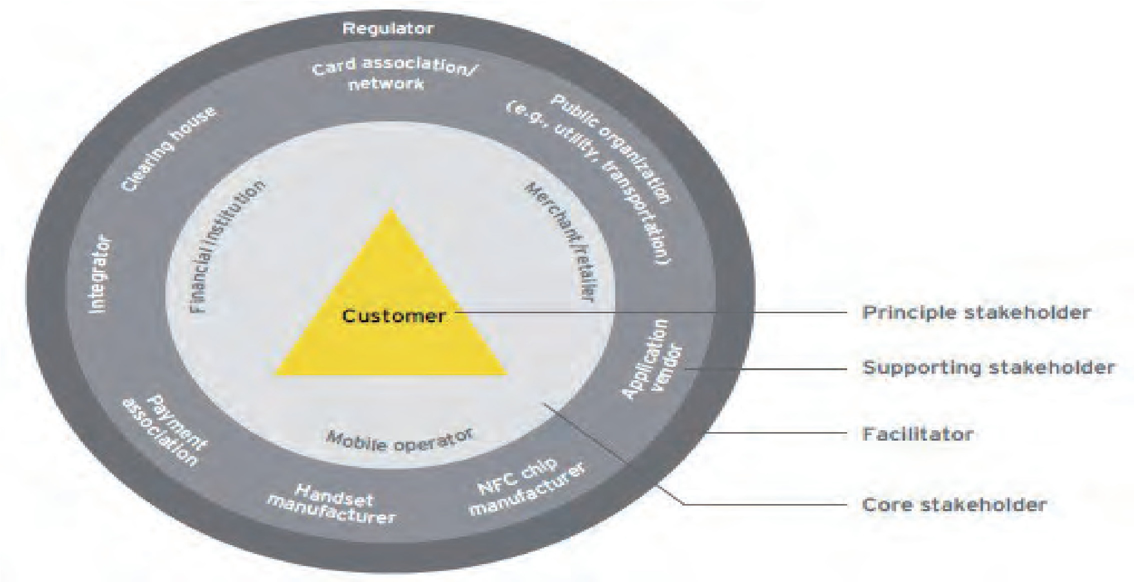
Source: GSMA, "Global Mobile Money Dataset", 2017.

Figure 2: Types of Mobile Payment Services



Source: Ernst & Young, *Mobile Money: An Overview for Global Telecommunications Operators* (2009). Available from http://www.ey.com/Publication/vwLUAssets/Mobile_Money./%24FILE/Ernst%20%26%20Young%20-%20Mobile%20Money%20-%2015.10.09%20(single%20view).pdf.

Figure 3: Stakeholders in the Mobile Payment Ecosystem



Source: Ernst & Young, *Mobile Money: An Overview for Global Telecommunications Operators* (2009). Available from http://www.ey.com/Publication/vwLUAssets/Mobile_Money./%24FILE/Ernst%20%26%20Young%20-%20Mobile%20Money%20-%2015.10.09%20(single%20view).pdf.

2.1 Mobile Banking

Mobile phones can be used to perform Internet banking on a website or a mobile application developed by the respective bank. Online services include deposits and withdrawals, bill payments, fund transfers, and viewing of balances and statements.

Case: Unified Payment Interface in India

India's apex bank—the Reserve Bank of India—has released vision documents for payment systems for the years 2012-2015 and 2018, which state the goal of achieving a "less-cash" India. These documents recognize the growing volume of electronic transactions, especially the usage of mobile banking services and mobile payment applications.[9] In this context, the National Payments Corporation of India[10] developed the Unified Payments Interface—a system that enables easy and efficient transfer of funds between any two bank accounts (of participating banks) in the country.[11] The main features of this system include the following: it is open source, involves easy and secure authentication, integrates with Aadhaar—the national digital identification system, and captures banking credentials on smartphones.

9 Reserve Bank of India, "Payment System Vision Document (2012-15)", 2012. Available from https://rbi.org.in; and Reserve Bank of India, "Vision 2018: Payment and Settlement Systems in India", 2016. Available from https://rbi.org.in.

10 The National Payments Corporation of India was established by the Reserve Bank of India and a conglomeration of Indian banks to supervise retail payments.

11 National Payments Corporation of India, "UPI Product Overview". Available from https://www.npci.org.in/product-overview/upi-product-overview.

2.2 Mobile Money

Although the term "mobile money" has been used to include a gamut of mobile payment systems, it typically refers to, "money stored using the subscriber identity module (SIM) in a mobile phone as an identifier, as opposed to an account number in conventional banking".[12] As a result, mobile money can be transferred through short message service (SMS). In such a system, an important role is played by intermediaries at stores that sell vouchers for topping up calling balance. They act like banks by taking cash from mobile phone users and storing it in their mobile money account or a digital wallet. This can be sent to another user of the service through a text message. The receiver can convert the mobile money into cash at a similar voucher store. In the case of some mobile money services, the receiver need not be a registered user of the service, and can redeem the money using a code received in the text message.[13]

Case: Mobile Money Transfer Services – M-Pesa and Easypaisa

M-Pesa, where "pesa" is the Swahili word for money, is a mobile-based platform that allows easy transfer of money among mobile phone users without requiring customers to have a bank account. It involves the conversion of cash into digital money on the platform, which can be sent across as a simple SMS to a fellow subscriber, who can convert that to physical cash again. It was launched in Kenya in 2007 by Safaricom (part of Vodafone group), Kenya's largest mobile network provider. The key users of this payment system are mobile phone users who usually do not have a bank account. The customers are required to register and open an electronic money account with an M-Pesa store, which enables them to convert physical cash to digital money and vice versa. Transfer of money is enabled through a secure, PIN-protected channel from one M-PESA user to another.[14]

Telenor Pakistan, in partnership with Tameer Microfinance Bank, established Pakistan's first mobile-based money transfer platform called Easypaisa in 2009. Similar to M-Pesa, individuals can visit any of the Easypaisa outlets across the country to deposit or withdraw cash from their mobile accounts, make bill payments, and transfer money to other individuals. They need not have a mobile phone or an account with Telenor to use the service. The mobile phone with the merchant at the Easypasia outlet can be used for the same. In 2013, Easypaisa introduced a mobile savings platform called Khushaal Munafa, which aimed to promote savings among the users and promised to earn them interest of up to 9 per cent.[15]

12 United Nations Conference on Trade and Development, *Mobile Money for Business Development in the East African Community* (Geneva, 2012). Available from unctad.org/en/PublicationsLibrary/dtlstict2012d2_en.pdf.

13 The Economist, "The power of mobile money", 24 September 2009. Available from http://www.economist.com/node/14505519.

14 Vodaphone, "M-Pesa". Available from http://www.vodafone.com/content/index/what/m-pesa.html.

15 Telenor Group, "Easypaisa – banking services made easy", May 2013. Available from https://www.telenor.com/easypaisa-banking-services-made-easy/.

2.3 Mobile Wallet Applications

Digital wallets are a place to, "store secure information necessary to authenticate a user and initiate an authorization process to make a transaction to purchase goods and services".[16] This involves linking an individual's banking, credit card or debit card information to the wallet. In recent years, these wallets are being used for cryptocurrencies. In the same way, mobile wallets are, "transaction accounts managed by mobile devices".[17] It is a mobile-based application that can be used to store and use cash and other currencies in a digital format. For example, iTunes wallet on an iPhone can be used to pay for mobile commerce transactions through its application. The browser on the mobile devices can also be used for conducting transactions using mobile wallets.

2.4 Contactless Payments

Contactless payments or tap-and-go payments typically involve the use of debit, credit or smart cards. Payments can be made at point-of-sale (PoS) terminals by simply tapping or waving the card on a device. Now, even mobile devices can be used to make such contactless payments.

There are various technologies that enable such transactions to take place. Near-field communication (NFC) technology enables two electronic devices to interact (e.g., read or write information) through the use of short-range wireless technologies. For example, in the case of NFC-based mobile payments, a mobile device with a payment application can communicate with a device at a PoS terminal. The PoS device would read the payment information that is embedded in the mobile device and complete the payment. Apple Pay service uses NFC chips embedded in their latest iPhone devices, whereas Android devices use host card emulation technology that enables the creation of a virtual copy of one's debit or credit card on the phone to make NFC-based payments.

Even Bluetooth technologies can be used to allow communication between devices and enable payments. Services like Samsung Pay use magnetic secure transmission technology that allows magnetic signals emitted from mobile devices to be read by the traditional swipe-and-pay PoS terminals. This means that the use of the magnet secure transmission technology does not require additional investment on PoS terminals by merchants.[18]

---

16 Gartner, "IT Glossary: Digital Wallet". Available from http://www.gartner.com/it-glossary/digital-wallet.

17 International Telecommunication Union, "ITU-T Focus Group Digital Financial Services: The Digital Financial Services Ecosystem", May 2016. Available from https://www.itu.int/en/ITU-T/focusgroups/dfs/Documents/09_2016/FINAL%20ENDORSED%20ITU%20DFS%20Introduction%20Ecosystem%2028%20April%202016_formatted%20AM.pdf.

18 Vivina Vishwanathan, "Contactless payment technology", *LiveMint*, 17 April 2017. Available from http://www.livemint.com/Money/Bsu06u3AF6KL3PYNPGCWfM/Contactless-payment-technology.html.

2.5 Cryptocurrency

Digital currency is an umbrella term used for currencies that can be stored and transferred electronically. Some forms of digital currency have a corresponding physical form as they are digital representations of usual currency notes and coins, for example, the money in a mobile wallet or an online bank account. Technologies like blockchain have been used to create virtual currencies (e.g., Bitcoin, Ethereum) that enable peer-to-peer seamless and secure transactions using cryptography.[19] Such cryptocurrencies are not pegged to an underlying asset, but can be used to purchase goods and services as many merchants and retailers are now accepting currencies like bitcoin. There are many companies that are developing mobile cryptocurrency payment platforms. These are either existing platforms/wallets (like Airbitz and Circle) that have been extended to cryptocurrencies, or are like Easbit and Coinbase, which are solely used for cryptocurrencies like bitcoins. In recent times, central banking institutions are also planning to issue their versions of cryptocurrencies.[20]

Case: Bitcoins and Mobile Payments

Bitcoin is a digital currency that typically functions outside the financial system and uses cryptography to control its creation, administration and security. It was developed in 2009, but rose to prominence in 2013 as the world's first cryptocurrency. It is decentralized, in the sense that there is no central authority regulating its distribution and functioning. To make or receive bitcoin payments, one needs to install a mobile wallet that supports bitcoins. The wallet application generates a new address for which bitcoins can be acquired. The currency can be obtained from bitcoin exchanges directly or through platforms like BitInstant. In order to make a payment, the intended recipient will send his/her bitcoin address to which the payment has to be made (Figure 4). The transfer usually takes seconds, however, the verification process could take around 10 minutes.[21] Bitcoins are gaining popularity over the past few years. Many payment platforms have begun to support bitcoin payments, including China's major payment platforms Alipay (Alibaba group), Wechat Pay (Tencent group) and Unionpay (People's Bank of China).[22]

---

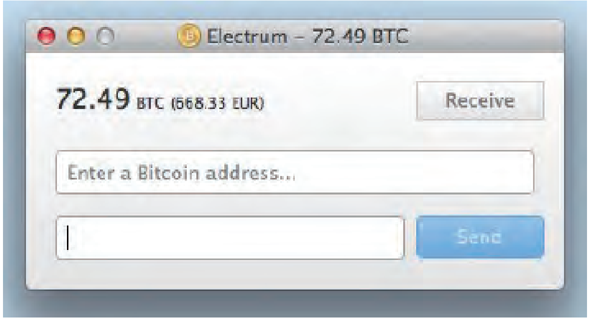
19 Boston Consulting Group and Google India, *Digital Payments 2020: The Making of a $500 Billion Ecosystem in India* (2016). Available from http://image-src.bcg.com/BCG_COM/BCG-Google%20Digital%20Payments%202020-July%20 2016_tcm21-39245.pdf.

20 Bank for International Settlements, "Central bank cryptocurrencies", 17 September 2017. Available from https://www.bis.org/publ/qtrpdf/r_qt1709f.htm.

21 Investopedia, "How Bitcoin Works", *Forbes*, 1 August 2013. Available from https://www.forbes.com/sites/investopedia/2013/08/01/how-bitcoin-works.

22 Kevin Helms, "Bitpoint Adds Bitcoin and Ether Payments to Platform with Unionpay, Wechat Pay and Alipay", *Bitcoin.com*, 28 June 2017. Available from https://news.bitcoin.com/bitpoint-bitcoin-ether-payments-platform-unionpay-wechatpay-alipay/.

Figure 4: Bitcoin Transaction Window



Source: International Telecommunication Union, "Mobile Money Revolution Part 2: Financial Inclusion Enabler", May 2013. Available from https://www.itu.int/oth/T0B15000016/en.

3. Mobile Payments in Asia and the Pacific

Japan and the Republic of Korea are leaders in contactless payment solutions from the Asia-Pacific region with telecom company DoCoMo in Japan and various payment gateway service providers in the Republic of Korea implementing contactless payment systems as early as 2004. Mature markets like Singapore have developed and deployed NFC-based payment systems since 2007. At the same time, significant efforts towards financial inclusion through the use of mobile phones, especially basic phones, are evident in countries like Bangladesh, India and the Philippines that have large unbanked populations.[23]

The Asia-Pacific region is expected to lead globally in the mobile payments market due to key drivers like increasing number of smartphones, supportive regulations, growth in e-commerce and remittances.[24]

Case: Smart Money and GCASH Services, Philippines

The Philippines has a low banking penetration rate of around 30 per cent and high mobile phone penetration rate of around 72 per cent unique subscribers.[25] These factors along with the large number of non-bank institutions and the country's large remittances market have made the Philippines one of the leading mobile money markets in the world. In 2001, Smart Communications launched Smart Money, which enabled users to buy airtime and make domestic and international money transfers via mobile. Smart Communications became the first to deploy a one-way person-to-person remittance. In 2004, Globe Telecom launched an SMS-based mobile money transfer service called GCASH, in which users can create an account or a mobile wallet to send or receive money. The service can be accessed through SMS syntax or menus generated from the SIM toolkit integrated in users' SIM. Studies have shown a clear preference among users towards the use of SMS.[26] GCASH service has also been used to make bulk payments like government-to-person transfers. The Philippines' Department of Social Work and the United Nations World Food Programme have used the service for cash disbursement. They credited the GCASH accounts of the beneficiaries, which could then be withdrawn or used for making

---

23 Ernst & Young, *Mobile Money: An Overview for Global Telecommunications Operators* (2009). Available from http://www.ey.com/Publication/vwLUAssets/Mobile_Money./%24FILE/Ernst%20%26%20Young%20-%20Mobile%20Money%20-%2015.10.09%20(single%20view).pdf.

24 Frost & Sullivan, *Asia-Pacific Mobile Payments: Spearheading Cashless Societies* (2016). Available from http://www.frost.com/p903.

25 Sophia Hasnain, Abigail Komu and Christopher Blackburn, "Mobile money in the Philippines: Market conditions drive innovation with Smart Money and GCash", *GSMA*, 23 June 2016. Available from https://www.gsma.com/mobilefordevelopment/programme/mobile-money/mobile-money-philippines-market-conditions-drive-innovation-smart-money-gcash-philippines-becoming-mobile-money-innovation-hub.

26 GSMA, "Mobile Money in the Philippines – The Market, the Models and Regulation", 2012. Available from https://www.gsma.com/mobilefordevelopment/wp-content/uploads/2012/06/Philippines-Case-Study-v-X21-21.pdf.

payments within the GCASH ecosystem.[27] Both Smart Communications and Globe Telecom have entered into partnerships with Western Union and other remittance providers to tap the international remittances market.

Case: Osaifu-Keitai Wallet Phone, Japan

Japan's NTT DoCoMo launched the Osaifu-Keitai (translated as mobile wallet) in 2004 and it grew to prominence as Japan's most frequently used payment technology. Osaifu-Keitai is basically a mobile phone embedded with a wireless smart card chip developed by Sony, called FeliCa. The mobile FeliCa payment technology is used for short-range contactless payments. FeliCa uses radio frequency identification (RFID), which enables the wallet phones to interact with other RFID-enabled devices (like vending machines and PoS terminals with FeliCa readers) to enable payments.[28] By combining existing smart card models with the mobile wallet, DoCoMo has expanded its services to scenarios like e-purchases and commuter pass at railway gates (provided by Suica smart card). DoCoMo and Sony jointly developed these FeliCa circuits/chips and provided them to rivals like Vodafone and KDDI, who in turn have launched their versions of mobile wallets.[29]

27 eServ Global, "Bulk Payments", White Paper, 2015. Available from https://www.eservglobal.com/wordpress/wp-content/uploads/2015/03/Bulk-Payments-White-Paper.pdf.

28 Vodafone, "Tokyo drift: How Japan leads the way on m-payments". Available from http://www.vodafone.com/business/global-enterprise/tokyo-drift-how-japan-leads-the-way-on-m-payments-2013-08-13.

29 John Boyd, "Here comes the wallet phone", *IEEE Spectrum*, 1 November 2005. Available from https://spectrum.ieee.org/consumer-electronics/portable-devices/here-comes-the-wallet-phone.

4. Some Concerns and Challenges

The mobile financial services market is largely fragmented in nature as most companies/banks have their own wallet application or payment platform. It is a complex environment with rising number of innovations in mobile payments. In such a scenario, standardization and interoperability are some of the main concerns that need to be addressed.

The prominence of cash-based transactions in rural areas and in developing economies is both a challenge and an opportunity for mobile payment systems. The rural-urban divide plays a role in how technology is used by individuals. This implies that financial institutions and the non-financial stakeholders in the system need to put efforts towards devising relevant alternatives for the rural context.

While smartphone penetration and broadband connectivity is increasing across the globe, there are many regions, especially the developing economies, which fare quite poorly in these indicators. The development of required infrastructure, along with adoption of necessary technologies, is very essential for the uptake of mobile payment technologies.

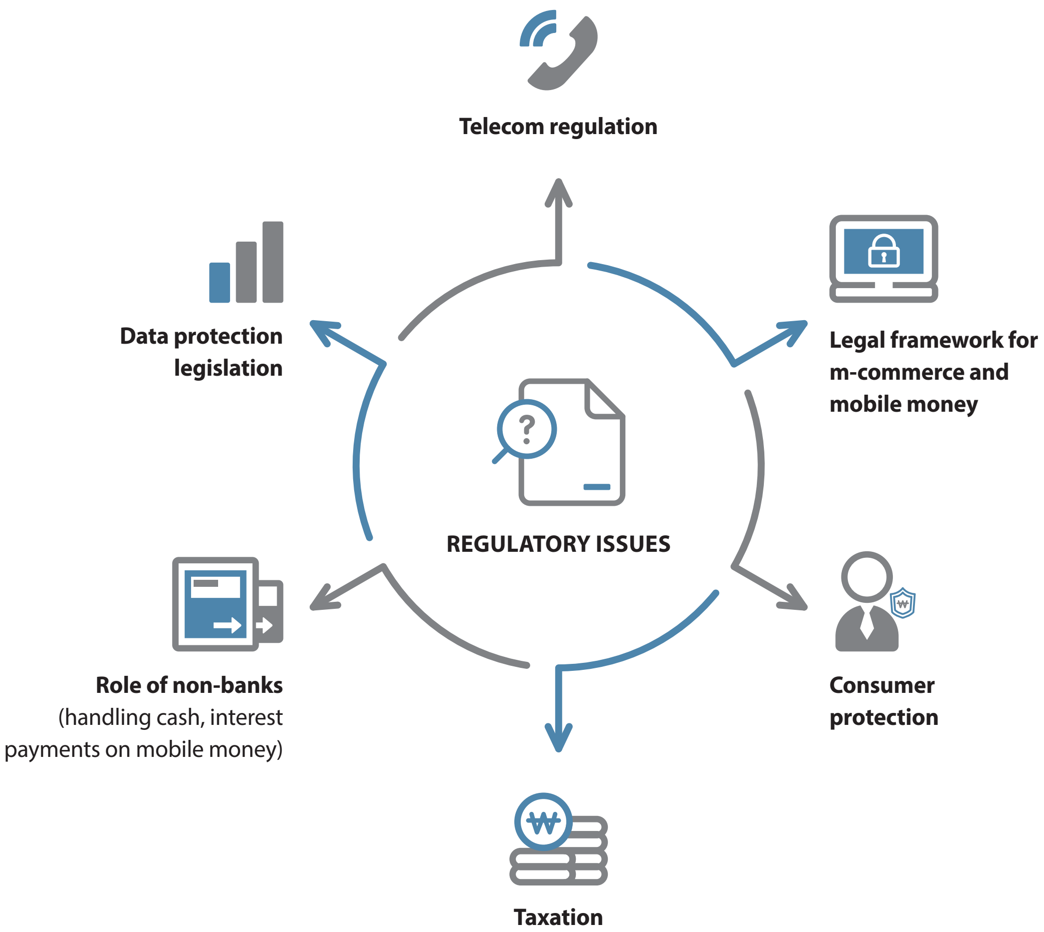
While mobile payment services are expected to provide cost benefits to the providers, decreasing costs are possible over time if the number of users and transactions increases. Moreover, certain technologies like NFC-based payments require huge investments, which are justified if they attract enough customers to be profitable.

Security and privacy are other issues to be considered while designing these payment systems. Confidentiality should be ensured for those involved in a transaction. The payment system should not be susceptible to modifications by outside parties. Without proper authentication and authorization mechanisms, mobile payment systems could be prone to denial-of-service attacks and other malicious software or code that could bring down the system. End-to-end encryption and authentication using PIN and Secure Sockets Layer are some ways of making the system secure.

5. Policies, Regulations and Global Initiatives for Mobile Payment Technologies

The mobile payment ecosystem lies at the intersection of banking and finance, telecommunications and information technology industries. The key regulatory bodies are the central banks and the telecommunications regulatory authorities. Some of the measures that need to be taken involve setting up a common payment infrastructure and establishing a framework for addressing grievances.[30]

Figure 5: Regulatory Issues



Source: International Telecommunication Union, "Mobile Money Revolution Part 2: Financial Inclusion Enabler", May 2013. Available from https://www.itu.int/oth/T0B15000016/en.

30 Boston Consulting Group and Google India, *Digital Payments 2020: The Making of a $500 Billion Ecosystem in India* (2016). Available from http://image-src.bcg.com/BCG_COM/BCG-Google%20Digital%20Payments%202020-July%20 2016_tcm21-39245.pdf.

Case: Regulatory Framework in the Philippines

With the goal to achieve financial inclusion, the central bank of the Philippines, Bangko Sentral ng Pilipinas, has created an enabling environment and level playing field for both non-banking and banking institutions to offer mobile money services. In 2009, Bangko Sentral ng Pilipinas released Circular 649, a set of guidelines on issuing e-money in the country. The non-bank entities are given licenses as e-money issuers, enabling them to perform cash in/out operations. In effect, the Philippines has used the test-and-learn approach to regulation, wherein the mobile money operators are given a no-objection certificate to test their mobile payment model. The test period helps the operators understand how the market is responding to the system. It is this approach that has played an important role in the success of Smart Money and GCASH services, discussed above.[31]

The Basel Committee on Banking Supervision of the Bank for International Settlements released Risk Management Principles for Electronic Banking in 2003 as a set of guidelines for banks across the globe. The intention was to raise awareness of the changes in risks and benefits that arise with the rapid innovations in financial technologies, and their subsequent effects on the payment systems.[32]

The Telecommunication Standardization Sector of the International Telecommunication Union formed a focus group on digital financial services in 2014, and has released technical reports on issues like policy and regulation, interoperability, consumer protection, security, service quality and digital identity.[33] One report on the digital financial ecosystem looked at the products and services, as well as the stakeholders in the ecosystem. It also detailed the infrastructures, policies, laws and regulations that make up the system and enable accessible and efficient service delivery.[34] Their next report studied the digital payments value chain and explored various business models and structures that could improve merchant acceptance of digital payments.[35] Another study pointed out the increasing number of national biometric identity programmes and their role in providing digital financial services.[36] The quality of services provided in the digital financial ecosystem was the focus

---

31 GSMA, "Mobile Money in the Philippines – The Market, the Models and Regulation", 2012. Available from https://www.gsma.com/mobilefordevelopment/wp-content/uploads/2012/06/Philippines-Case-Study-v-X21-21.pdf.

32 Basel Committee on Banking Supervision of the Bank for International Settlements, "Risk Management Principles for Electronic Banking", 2003. Available from https://www.bis.org/publ/bcbs98.pdf.

33 International Telecommunication Union, "Digital Financial Inclusion", Issue Brief Series, Inter-agency Task Force on Financing for Development, July 2016. Available from http://www.un.org/esa/ffd/wp-content/uploads/2016/01/Digital-Financial-Inclusion_ITU_IATF-Issue-Brief.pdf.

34 International Telecommunication Union, "ITU-T Focus Group Digital Financial Services: The Digital Financial Services Ecosystem", May 2016. Available from https://www.itu.int/en/ITU-T/focusgroups/dfs/Documents/09_2016/FINAL%20ENDORSED%20ITU%20DFS%20Introduction%20Ecosystem%2028%20April%202016_formatted%20AM.pdf.

35 International Telecommunication Union, "ITU-T Focus Group Digital Financial Services: Enabling Merchant Payments Acceptance in the Digital Financial Ecosystems", May 2016. Available from https://www.itu.int/en/ITU-T/focusgroups/dfs/Documents/09_2016/FINAL%20ENDORSED%20Enabling%20Merchant%20Payments%20Acceptance%2030%20May%202016_formatted%20AM.pdf.

36 International Telecommunication Union, "ITU-T Focus Group Digital Financial Services: Review of National Identity Program", May 2016. Available from https://www.itu.int/en/ITU-T/focusgroups/dfs/Documents/09_2016/Review%20of%20National%20Identity%20Programs.pdf.

of their next report, which detailed some performance indicators for the purpose of evaluation.[37] In 2017, another focus group was created to discuss emerging questions about digital currency, especially digital fiat currency, like economic benefits, impact, interoperability, policy and regulation, and security and trust.[38] The International Telecommunication Union also released a two-part Technology Watch report on mobile money in 2013 that focuses on NFC mobile payments and the financial inclusion aspect of such payments.[39]

The United Nations Capital Development Fund supports a global programme called Mobile Money for the Poor that aims to take the benefits of mobile money technologies to the poor. Its programme targets low-income and rural households in Benin, Lao People's Democratic Republic, Liberia, Malawi, Nepal, Senegal, Uganda and Zambia.[40]

The International Finance Corporation of the World Bank Group has prepared mobile money scoping reports for a few countries in Asia and Africa. The reports assess the financial and telecom sectors and the policy and regulatory framework in place, and evaluate existing mobile financial services in order to identify opportunities for support.[41]

The rate at which innovations in these industries keeps changing makes the formulation of policies, laws and regulations a complex task. Governments, banking and financial institutions, mobile and telecom companies, regulatory bodies, and other stakeholders need to work together to ensure efficient functioning of the payment system.

37 International Telecommunication Union, "ITU-T Focus Group Digital Financial Services: QoS and QoE Aspects of Digital Financial Services", May 2016. Available from https://www.itu.int/en/ITU-T/focusgroups/dfs/Documents/09_2016/FGDFSQoSReport.pdf.

38 International Telecommunication Union, "Focus Group on Digital Currency including Digital Fiat Currency". Available from http://www.itu.int/en/ITU-T/focusgroups/dfc/Pages/default.aspx.

39 International Telecommunication Union, "Technology Watch: Mobile Money". Available from http://www.itu.int/en/ITU-T/techwatch/Pages/mobile-money-standards.aspx.

40 United Nations Capital Development Fund, "Mobile Money for the Poor". Available from http://mm4p.uncdf.org/.

41 International Finance Corporation, "IFC Mobile Money Scoping Reports". Available from http://www.ifc.org/wps/wcm/connect/industry_ext_content/ifc_external_corporate_site/financial+institutions/resources/ifc+mobile+money+scoping+reports.

References

Bank for International Settlements. Central bank cryptocurrencies. 17 September 2017. Available from https://www.bis.org/publ/qtrpdf/r_qt1709f.htm.

Basel Committee on Banking Supervision of the Bank for International Settlements. Risk Management Principles for Electronic Banking. 2003. Available from https://www.bis.org/publ/bcbs98.pdf.

Boston Consulting Group and Google India. *Digital Payments 2020: The Making of a $500 Billion Ecosystem in India*. 2016. Available from http://image-src.bcg.com/BCG_COM/BCG-Google%20Digital%20Payments%202020-July%202016_tcm21-39245.pdf.

Boyd, John. Here comes the wallet phone. *IEEE Spectrum*, 1 November 2005. Available from https://spectrum.ieee.org/consumer-electronics/portable-devices/here-comes-the-wallet-phone.

Chakravorti, Bhaskar. The hidden costs of cash. *Harvard Business Review*, 26 June 2014. Available from https://hbr.org/2014/06/the-hidden-costs-of-cash.

Dahlberg, Tomi, and others. Past, present and future of mobile payments research: A literature review. *Electronic Commerce Research and Applications*, vol. 7, no. 2 (Summer 2008), pp. 165-181. Available from dl.acm.org/citation.cfm?id=1377314.

Donovan, Kevin. Mobile money for financial inclusion. In *Information and Communications for Development 2012: Maximizing Mobile*, World Bank. Washington D.C., 2012. Available from https://elibrary.worldbank.org/doi/abs/10.1596/9780821389911_ch04.

Ernst & Young. *Mobile Money: An Overview for Global Telecommunications Operators*. 2009. Available from http://www.ey.com/Publication/vwLUAssets/Mobile_Money./%24FILE/Ernst%20%26%20Young%20-%20Mobile%20Money%20-%2015.10.09%20(single%20view).pdf.

eServ Global. Bulk Payments, White Paper. 2015. Available from https://www.eservglobal.com/wordpress/wp-content/uploads/2015/03/Bulk-Payments-White-Paper.pdf.

Frost & Sullivan, *Asia-Pacific Mobile Payments: Spearheading Cashless Societies*. 2016. Available from http://www.frost.com/p903.

Gartner. IT Glossary: Digital Wallet. Available from http://www.gartner.com/it-glossary/digital-wallet.

GSMA. Mobile Money in the Philippines – The Market, the Models and Regulation. 2012. Available from https://www.gsma.com/mobilefordevelopment/wp-content/uploads/2012/06/Philippines-Case-Study-v-X21-21.pdf.

Hasnain, Sophia, Abigail Komu and Christopher Blackburn. Mobile money in the Philippines: Market conditions drive innovation with Smart Money and GCash. *GSMA*, 23 June 2016. Available from https://www.gsma.com/mobilefordevelopment/programme/mobile-money/mobile-money-philippines-market-conditions-drive-innovation-smart-money-gcash-philippines-becoming-mobile-money-innovation-hub.

Helms, Kevin. Bitpoint Adds Bitcoin and Ether Payments to Platform with Unionpay, Wechat Pay and Alipay. *Bitcoin.com*, 28 June 2017. Available from https://news.bitcoin.com/bitpoint-bitcoin-ether-payments-platform-unionpay-wechatpay-alipay/.

International Telecommunication Union. Mobile Money Revolution Part 2: Financial Inclusion Enabler. May 2013. Available from https://www.itu.int/oth/T0B15000016/en.

International Telecommunication Union. ITU-T Focus Group Digital Financial Services: Enabling Merchant Payments Acceptance in the Digital Financial Ecosystems. May 2016. Available from https://www.itu.int/en/ITU-T/focusgroups/dfs/Documents/09_2016/FINAL%20ENDORSED%20Enabling%20Merchant%20Payments%20Acceptance%2030%20May%202016_formatted%20AM.pdf.

International Telecommunication Union. ITU-T Focus Group Digital Financial Services: QoS and QoE Aspects of Digital Financial Services. May 2016. Available from https://www.itu.int/en/ITU-T/focusgroups/dfs/Documents/09_2016/FGDFSQoSReport.pdf.

International Telecommunication Union. ITU-T Focus Group Digital Financial Services: Review of National Identity Program. May 2016. Available from https://www.itu.int/en/ITU-T/focusgroups/dfs/Documents/09_2016/Review%20of%20National%20Identity%20Programs.pdf.

International Telecommunication Union. ITU-T Focus Group Digital Financial Services: The Digital Financial Services Ecosystem. May 2016. Available from https://www.itu.int/en/ITU-T/focusgroups/dfs/Documents/09_2016/FINAL%20ENDORSED%20ITU%20DFS%20Introduction%20Ecosystem%2028%20April%202016_formatted%20AM.pdf.

International Telecommunication Union. Digital Financial Inclusion. Issue Brief Series, Inter-agency Task Force on Financing for Development, July 2016. Available from http://www.un.org/esa/ffd/wp-content/uploads/2016/01/Digital-Financial-Inclusion_ITU_IATF-Issue-Brief.pdf.

International Telecommunication Union. Focus Group on Digital Currency including Digital Fiat Currency. Available from http://www.itu.int/en/ITU-T/focusgroups/dfc/Pages/default.aspx.

International Telecommunication Union. Technology Watch: Mobile Money. Available from http://www.itu.int/en/ITU-T/techwatch/Pages/mobile-money-standards.aspx.

Investopedia. How Bitcoin Works. *Forbes*, 1 August 2013. Available from https://www.forbes.com/sites/investopedia/2013/08/01/how-bitcoin-works.

National Payments Corporation of India. UPI Product Overview. Available from https://www.npci.org.in/product-overview/upi-product-overview.

Reserve Bank of India. Payment System Vision Document (2012-15). 2012. Available from https://rbi.org.in.

Reserve Bank of India. Vision 2018: Payment and Settlement Systems in India. 2016. Available from https://rbi.org.in.

Telenor Group. Easypaisa – banking services made easy. May 2013. Available from https://www.telenor.com/easypaisa-banking-services-made-easy/.

The Economist. The power of mobile money. 24 September 2009. Available from http://www.economist.com/node/14505519.

United Nations Capital Development Fund. Mobile Money for the Poor. Available from http://mm4p.uncdf.org/.

United Nations Conference on Trade and Development. *Mobile Money for Business Development in the East African Community*. Geneva, 2012. Available from unctad.org/en/PublicationsLibrary/

dtlstict2012d2_en.pdf.

Vivina Vishwanathan. Contactless payment technology. *LiveMint*, 17 April 2017. Available from http://www.livemint.com/Money/Bsu06u3AF6KL3PYNPGCWfM/Contactless-payment-technology.html.

Vodafone. Tokyo drift: How Japan leads the way on m-payments. Available from http://www.vodafone.com/business/global-enterprise/tokyo-drift-how-japan-leads-the-way-on-m-payments-2013-08-13.

Vodafone. M-Pesa. Available from http://www.vodafone.com/content/index/what/m-pesa.html.

World Bank. Payment Systems. Available from http://www.worldbank.org/en/topic/paymentsystemsremittances.

Glossary

Cashless society : A society characterized by the exchange of funds by cheque, debit or credit card, or electronic methods rather than the use of cash.

Contactless payments : Use of technologies that recognize electronic data, and does not require the customer's signature or personal identification number for making payments. It does not involve any contact between the buyer's device and the payment terminal.

Mobile money : Money stored using the SIM in a mobile phone as an identifier, as opposed to an account number in conventional banking.

Mobile payments : Use of a mobile device to make payments.

Mobile wallet : A data repository that houses consumer data sufficient to facilitate a financial transaction from a mobile device, and the applicable intelligence to translate an instruction from a consumer through a mobile handset/bearer/application into a message that a financial institution can use to debit or credit bank accounts or payment instruments.

Near-field communication : A short-range wireless connectivity standard (Ecma-340, ISO/IEC 18092) that uses magnetic field induction to enable communication between devices when they are touched together, or brought within a few centimetres of each other.

Acronyms

NFC	Near-field Communication
PoS	Point-of-Sale
RFID	Radio Frequency Identification
SDG	Sustainable Development Goal
SIM	Subscriber Identity Module
SMS	Short Message Service

Ⅲ. Assistive Technologies

Disability, Accessibility and Assistive Technologies

Contents

List of Figures

1. Introduction

1.1 Disability

The International Classification of Functioning, Disability and Health[1] defines disability as an umbrella term for impairments, activity limitations and participation restrictions. Impairment is a problem in body function or structure; an activity limitation is a difficulty encountered by an individual in executing a task or action; while a participation restriction is a problem experienced by an individual in involvement in life situations. The World Health Organization divides the type of disabilities into nine broad categories: (1) behavioural disabilities; (2) communication disabilities; (3) personal care disabilities; (4) locomotor disabilities; (5) body disposition disabilities; (6) dexterity disabilities; (7) situational disabilities; (8) particular skill disabilities; and (9) and other activity restrictions.

According to the World Health Organization,[2] over a billion people are estimated to live with some form of disability. This corresponds to about 15 per cent of the world's population. Between 110 million (2.2 per cent) and 190 million (3.8 per cent) people 15 years and older have significant difficulties in functioning. Disability is on the rise, due to ageing populations and a higher risk of disability in older people, as well as the global increase in chronic health conditions such as diabetes, cardiovascular disease, cancer and mental health disorders.[3]

Disability is not just a health problem. It is a complex phenomenon, reflecting the interaction between features of a person's body and features of the society in which he or she lives. Society disables people with impairments by failing to take into account their rights and needs, as groups or individuals. Overcoming the difficulties faced by persons with disabilities requires interventions to remove environmental and social barriers.[4] The United Nations Convention on the Rights of Persons with Disabilities (UNCRPD) recognizes disability as a human rights issue and a development issue. Addressing the importance of disability inclusion for development, the 2030 Agenda for Sustainable Development includes several development targets for persons with disabilities and for accessible environments for them.[5]

1 World Health Organization, *Towards a Common Language for Functioning, Disability and Health: ICF – The International Classification of Functioning, Disability and Health* (Geneva, 2002). Available from http://www.who.int/classifications/icf/training/icfbeginnersguide.pdf.

2 World Health Organization, "Disability and Health Fact Sheet", November 2017. Available from http://www.who.int/mediacentre/factsheets/fs352/en/.

3 Ibid.

4 World Health Organization, *World Report on Disability* (Geneva, 2011). Available from http://www.who.int/disabilities/world_report/2011/report/en/.

5 United Nations Department of Economic and Social Affairs, *Global Status Report on Disability and Development Prototype 2015* (New York, 2015). Available from http://www.un.org/esa/socdev/documents/disability/2016/GlobalStatusReportonDisabilityandDevelopment.pdf.

1.2 Accessibility and Existing Institutional Frameworks

The Decent Work Agenda from the International Labour Organization defines "decent work" as work that, "sums up the aspirations of people in their working lives". This means that enforcing right to work would imply, "promotion of full, productive and freely-chosen employment".. The International Labour Organization Convention No. 159 requires that members provide equality of opportunity in the labour market to disabled persons through rehabilitation measures that will ensure retention and advancement of the jobs that they are in.[6]

Similarly, the United Nations envisages treating persons with disabilities as, "beneficiaries and agents of change in society and development". It calls for, "urgent action towards creating policies and development initiatives intended to lead to an inclusive, accessible and sustainable society". The UNCRPD, adopted in 2006, requires that parties to the treaty recognize the right to work of disabled persons. Particularly, Article 9 of the convention covers accessibility and the right for people with a disability to participate fully in all aspects of life, including the aim to, "promote access for persons with disabilities to new information and communications technologies and systems, including the Internet", and to, "promote the design, development, production and distribution of accessible information and communications technologies and systems at an early stage, so that these technologies and systems become accessible at minimum cost".[7]

In response, frameworks and models have been developed to incorporate issues faced by persons with disabilities into policymaking. The Sustainable Livelihoods Framework was developed by the United Kingdom Department for International Development mainly as a poverty reduction tool for development programmes. This framework helps us understand the access to resources and entitlements by disabled persons, so that relevant policies can be formulated. The community-based rehabilitation model of the World Health Organization covers health, education, livelihood, social and empowerment issues to improve the equalization of opportunities for persons with disabilities. The livelihood component includes guidelines to promote skills development, self-employment and wage-employment opportunities, as well as social security measures and financial inclusion. A United Nations report[8] pointed out that being cognizant of accessibility during the planning, designing and developing stages of any virtual or physical environment will lead to a higher chance that the final products and services will be accessible to all. This will avoid retrofitting, which can be more costly.

6 International Labour Organization, "C159 – Vocational Rehabilitation and Employment (Disabled Persons) Convention, 1983 (No. 159)". Available from http://www.ilo.org/dyn/normlex/en/f?p=NORMLEXPUB:12100:0::NO::P12100_INSTRUMENT_ID:312304.

7 United Nations, "Convention on the Rights of Persons with Disabilities: Article 9 - Accessibility". Available from https://www.un.org/development/desa/disabilities/convention-on-the-rights-of-persons-with-disabilities/article-9-accessibility.html.

8 United Nations Department of Economic and Social Affairs, *Global Status Report on Disability and Development Prototype 2015* (New York, 2015). Available from http://www.un.org/esa/socdev/documents/disability/2016/GlobalStatusReportonDisabilityandDevelopment.pdf.

In a study of access to assistive technology in the European Union in 2003, Deloitte and Touche estimated the existence of more than 20,000 assistive-technology-related products, which represent a market volume of over EUR 30 billion.[9] Yet, disability has rarely been included in national policies or programmes until very recently. The recent United Nations 2030 Sustainable Development Agenda specifically targets, "areas related to education, growth and employment, inequality, accessibility of human settlements and means of implementation".[10] In response to the Agenda, governments across the world have begun to focus on the promotion of inclusion, participation and development of persons with disabilities through provision of accessible services.

Accessibility generally refers to the provision of special needs of persons with disabilities. However, the 2015 United Nations report on mainstreaming disability in the 2030 Sustainable Development Agenda treats accessibility as, "a precondition for an inclusive society for all, and may be defined as the provision of flexibility to accommodate each user's needs and preferences".[11] Accessibility is, therefore, not only a means and a goal of inclusive development, but also considered an enabler of, "an improved, participative economic and social environment for all members of society". The UNCRPD[12] links the provision of accessibility to empowering persons with disabilities to live independently, be included in the community, and exercise personal mobility, freedom of expression and opinion, and access to information. The United Nations identifies accessibility as, "a global public good and not a defined benefit for a particular group".[13]

9 European Commission, *Access to Assistive Technology in the European Union* (2003). Available from http://www.acessibilidade.net/at/access_AT_EU.pdf.

10 United Nations General Assembly, Seventieth Session, 70/1. Transforming our world: the 2030 Agenda for Sustainable Development (A/RES/70/1), 21 October 2015. Available from http://www.un.org/ga/search/view_doc.asp?symbol=A/RES/70/1&Lang=E.

11 United Nations, *Accessibility and Development: Mainstreaming Disability in the Post-2015 Development Agenda* (New York, 2015). Available from http://www.un.org/disabilities/documents/accessibility_and_development.pdf.

12 United Nations, "Convention on the Rights of Persons with Disabilities". Available from https://www.un.org/development/desa/disabilities/convention-on-the-rights-of-persons-with-disabilities.html.

13 United Nations, *Accessibility and Development: Mainstreaming Disability in the Post-2015 Development Agenda* (New York, 2015). Available from http://www.un.org/disabilities/documents/accessibility_and_development.pdf.

2. Need for Assistive Technologies

The World Report on Disability[14] defines assistive technology as, "any item, piece of equipment, or product, whether it is acquired commercially, modified, or customized, that is used to increase, maintain, or improve the functional capabilities of individuals with disabilities". Whether a technology is assistive or otherwise may affect how people acquire the technology.[15] According to the Assistive Technology Industry Association,[16] assistive technologies are essential for disabled persons to navigate their daily environment, participate in society and contribute to different kinds of livelihood opportunities. With the spread and near ubiquity of smart devices there have been efforts to develop life-enhancing applications for disabled users. New access technologies that involve the use of microelectronics, robotic mechanics and biotechnology to create assistive and adaptive technologies for the disabled becomes relevant. For example, a special keyboard that takes into account certain functional disabilities of people is a new access technology. Through the use of such technologies, persons with disabilities can expand the avenues of employment that are available to them in today's age.[17] The development of accessible information and communication technologies (ICTs) has been a major policy objective in international frameworks concerning the advancement of persons with disabilities and sustainable development since the 1990s.[18]

Persons with disabilities have to grapple with issues such as inaccessibility, exclusion and inability to participate fully in daily living. Poverty, deeply held attitudes about the disabled, and lack of awareness of policies and laws debilitate persons with disabilities.[19] Multiple factors in the environment and the physical condition of persons with disabilities create barriers in performing normal routine tasks. This discourages many employers from hiring persons with disabilities, and self-employment options are infeasible without adequate support.

Technological breakthroughs in productivity have helped businesses get the most from employees of all backgrounds and capabilities. However, according to the World Health Organization, only 5-15 per cent of persons with disabilities have access to assistive devices and technologies for accessibility in low and middle-income countries. In tandem with technologies that enable better management of day-to-day lives, there is an urgent need for developing technologies that enhance the skills and capabilities of persons with disabilities for employment and livelihood, especially as increased accessibility in workplaces leads to more participation of persons with disabilities in the labour market and, consequently, more diversity in society, capturing persons of all talents and abilities.[20]

---

14 World Health Organization, *World Report on Disability* (Geneva, 2011). Available from http://www.who.int/disabilities/world_report/2011/report/en/.

15 Marilyn J. Field and Alan M. Jette, eds., "Assistive and Mainstream Technologies for People with Disabilities", in *The Future of Disability in America* (Washington D.C., National Academies Press, 2007). Available from https://www.ncbi.nlm.nih.gov/books/NBK11418/.

16 Assistive Technology Industry Association, "What is AT?" Available from https://www.atia.org/at-resources/what-is-at/.

17 H. Allan Hunt and Monroe Berkowitz, *New technologies and the employment of disabled persons* (Geneva, International Labour Office, 1992).

18 United Nations Department of Economic and Social Affairs, *Global Status Report on Disability and Development Prototype 2015* (New York, 2015). Available from http://www.un.org/esa/socdev/documents/disability/2016/GlobalStatusReportonDisabilityandDevelopment.pdf.

19 Ajit Mondal and Jayanta Mete, "Education of Children with Disabilities in India: Policy Perspective and Concerns", *Indian Journal of Educational Research*, vol. 2 (2013), pp. 56-67.

20 Adolf Ratzka, "The case for accessibility legislation in a market economy", Report of the CIB Expert Seminar on Building Non-Handicapping Environments, 1991. Available from http://www.independentliving.org/cib/cibbudapest28.html.

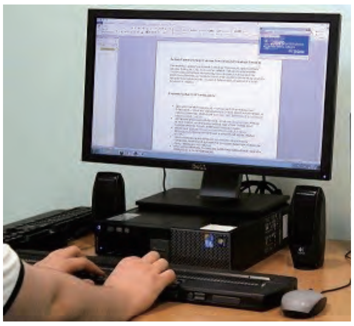
3. Types of Assistive Technologies

Assistive technologies can be classified into the following three types—personal assistive devices, adaptive assistive devices and cognitive assistive devices.

1. Personal assistive devices act as extensions of a person's physical capacities. These include canes, scooters, hearing aids and magnifying glasses.

2. Adaptive assistive devices make an inaccessible mainstream or general use device usable by a person with a disability, although usually at additional cost. The computer screen reader (Figure 1), which allows blind or visually-impaired people to hear text displayed on a computer screen, is one such device.

Figure 1: Screen Reader



Source: Freedom Scientific, "Blindness Solutions: JAWS®". Available from http://www.freedomscientific.com/Products/Blindness/JAWS.

The screen reader software takes the standard output from a computing or mobile device and presents it to a user in an audio form or tactile output such as a braille display—although the audio form is the more popular option for blind and low-vision users.[21] The screen reader software can either be installed on computers and mobile devices, or hosted as applications on the cloud on a pay-per-use basis.

21 Ted McCarthy, Joyojeet Pal and Edward Cutrell, "The "voice" has it: Screen reader adoption and switching behavior among vision impaired persons in India", *Assistive Technology*, vol. 25, no. 4 (Winter 2013), pp. 222-229. Available from https://www.ncbi.nlm.nih.gov/pubmed/24620705.

There are also a number of mobile applications for the visually-impaired that can be readily available on one's mobile device. For example, colour identification applications help people who are blind decide what to wear, and currency identifiers help users distinguish between currency notes. Waving a phone camera over the piece of clothing or the currency enables it to identify the item. These applications can be downloaded on mobile devices at low or no cost.[22]

Another example for the visually-impaired is glasses with technology-enabled cameras that can help the visually-impaired hear any text appearing on any surface, and recognize the faces of people they know (Figure 2).

Figure 2: Glasses with Technology-enabled Cameras

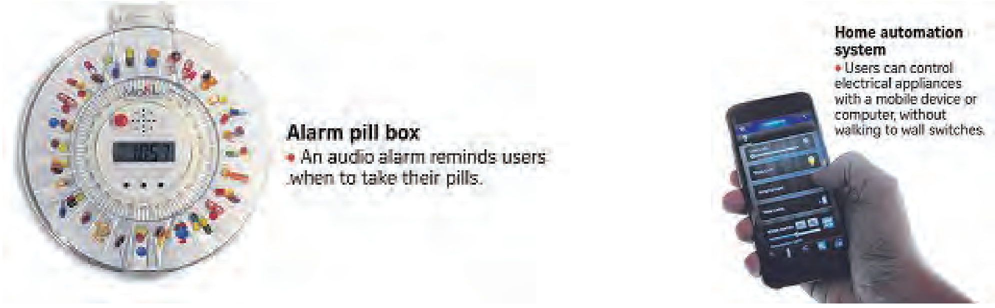
Source: OrCam, "My Eye". Available from https://www.orcam.com/myeye/.

Examples of adaptive assistive devices for people with hearing impairments are speech recognition software and real-time captioning on phones that display every word the caller says throughout the conversation.

3. Cognitive assistive technologies include visual or auditory prompting devices or schedule reminders that provide simple cues to help people perform a task or remember things that they need to do.

22 Dave Zielinski, "New assistive technologies aid employees with disabilities", *Society for Human Resource Management*, 20 December 2016. Available from https://www.shrm.org/resourcesandtools/hr-topics/technology/pages/new-assistive-technologies-aid-employees-with-disabilities.aspx.

Figure 3: Cognitive Assistive Devices



Source: Priscilla Goy, "More people with disabilities tapping enhanced tech fund", *The Straits Times*, 21 July 2016. Available from http://www.straitstimes.com/singapore/more-people-with-disabilities-tapping-enhanced-tech-fund.

Examples include simplified versions of email applications or alarm devices for warning caregivers that a disabled person may be in danger, by tracking devices that use Global Positioning System technology to determine the location of an individual. Other examples of such technologies are predictive texting, speech recognition, text-to-speech, built-in calculator and large and simple display screens.

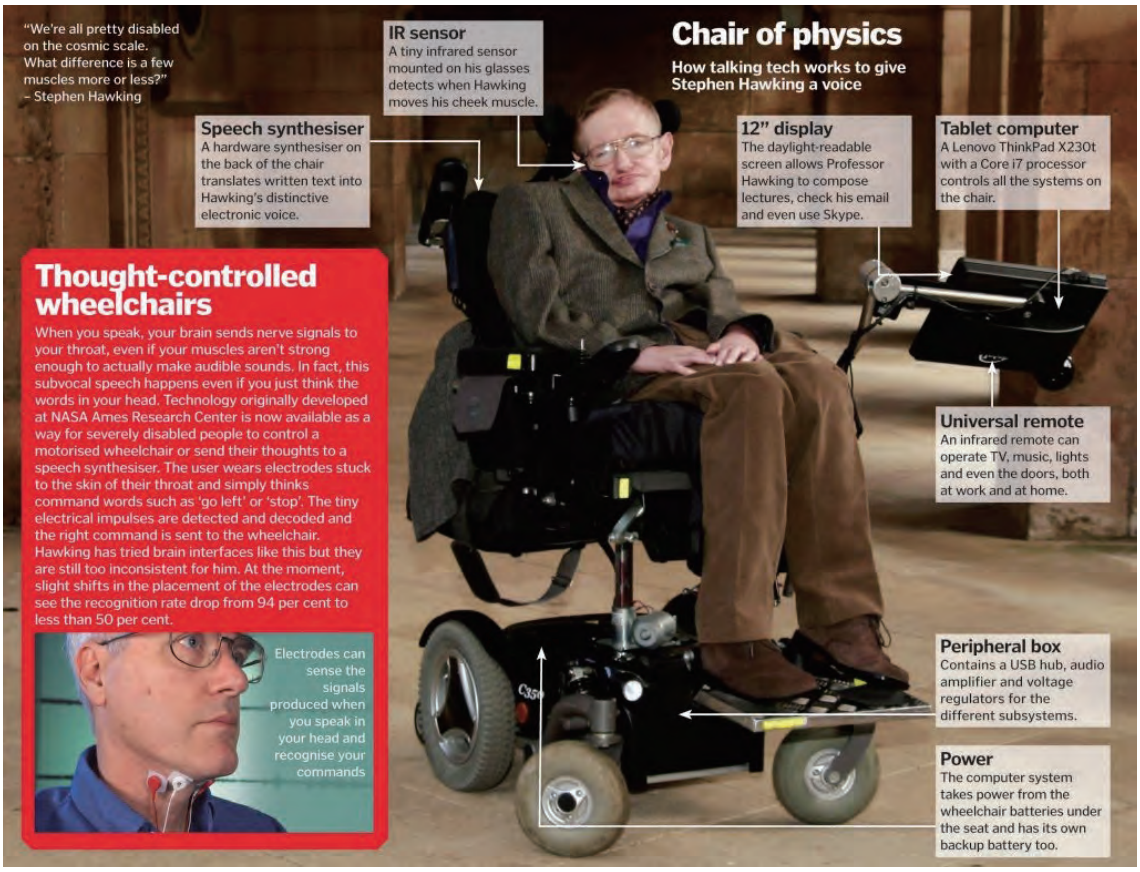
A range of new assistive technologies are being developed to take advantage of advances in electronics and computing power, such as communications devices based on the tracking of individual eye movement (e.g., for people with severe speech and movement impairments because of a stroke), and complex prosthetic devices that respond to neural impulses and are, therefore, controlled by the mind (Figure 4).

Figure 4: Complex Prosthetic Devices

Source: Freethink cited in Maddie Stone, "How a Hillbilly Delivery Man Is Trailblazing Our Cyborg Future", *Gizmodo*, 31 August 2016. Available from https://gizmodo.com/how-a-hillbilly-delivery-man-is-trailblazing-our-cyborg-1785993977.

The renowned scientist, Stephen Hawking for example, has been using various assistive technologies to communicate since he lost his ability to speak in 1985. Since 2008, Hawking has also lost the ability to move his fingers to click. Yet, he writes emails, browses the Internet, writes books and speaks, using only one cheek muscle. A switching device called the "cheek switch", is attached to his glasses and detects when Hawking tenses his cheek muscle via a low infrared beam.

Figure 5: Stephen Hawking's Wheelchair



Source: How It Works, "How Stephen Hawking's wheelchair works", 2015. Available from https://www.howitworksdaily.com/how-stephen-hawkings-wheelchair-works/.

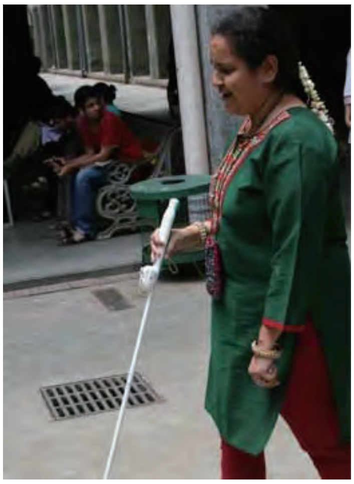
Text-to-speech readers are now available from many vendors and as open source software products. Technology for the blind has generally been based on audio cues. Latest technologies, however, use vibrations to guide people around. They do this through wearables (e.g., the Wayband™ wristband – Figure 6) that connect to a mobile device and can guide users to where they wish to go. The device buzzes when the user faces the wrong way and stays silent when the person is on the right track.

Figure 6: Wayband™

Source: Wear Works, "Wayband". Available from https://www.wear.works/wayband-product.

Innovations in assistive technologies are emerging in the Asia-Pacific region. For example, the SmartCane™ (Figure 7), an electronic travel aid that detects hanging obstacles above the knee, is designed by Assistech at the Indian Institute of Technology Delhi.

Figure 7: SmartCane™



Source: Assistech, "SmartCane™ Device: About". Available from http://assistech.iitd.ernet.in/smartcane.php.

In India, a biennial conference, Techshare India,[23] brings together creators of assistive technology. It offers assistive and accessible product demos as well as a space for policymakers to have seminars. The 2016 seminar saw the launch of the Newz Hook app and website—the first ever news portal for persons with disabilities.[24]

In Pakistan, the Pakistan Telecommunications Authority led a Mobile App Awards initiative in 2016 that focused on addressing the needs of persons with disabilities.[25]

In Bangladesh, the Prime Minister Office's Service Innovation Fund offers grants to initiatives that promote economic and social development. Currently, about 10 per cent of the projects are targeted at meeting the needs of persons with disabilities. Additionally, a Disability Innovation Lab has been established under this scheme to support the creation, testing and commercialization of disability-inclusive products and services.[26]

23 Techshare India 2016, "Exhibition at Techshare India". Available from http://techshare.barrierbreak.com/exhibition-at-techshare-india/.

24 Newz Hook, "About Us". Available from https://newzhook.com/about.

25 Pakistan Mobile App Awards. Available from http://mobileawards.pta.gov.pk/. View a video about the winners of the awards at https://isoc.box.com/s/h8fktk0qagph5r21d5ltqanhg682ez3a.

26 A2I Prime Minister's Office Bangladesh, "Exhibition and Discussion Forum on 14 Disability related Innovations held". Available from http://a2i.pmo.gov.bd/exhibition-and-discussion-forum-on-14-disability-related-innovations-held/; and A2I Prime Minister's Office Bangladesh, "Disability Innovation Lab". Available from http://a2i.pmo.gov.bd/innovation-lab/lab/disability/.

4. Design Considerations for Assistive Technologies

In the 1990s, the universal design philosophy was introduced by architect Ronald L. Mace to describe the concept of designing all products and the built environment to be aesthetic and usable to the greatest extent possible by everyone, regardless of their age, ability or status in life.[27] It is defined as a framework for the design of places, objects, information, communication and policy to be usable by the widest range of people operating in the widest range of situations without special or separate design or adaptation.[28] Other common terms for this process are "design for all", "inclusive design" and "accessible design". The concept of accessible design ensures both "direct access" (i.e., unassisted) and "indirect access" meaning compatibility with a person's assistive technology (e.g., computer screen readers). Although coming from quite different histories, the purpose of universal design and assistive technology is similar—to reduce the physical and attitudinal barriers between people with and without disabilities. However, the specificity of the environment in which persons with disabilities live, impacts their level of participation in everyday life. Hence, a proper understanding of the medical, legal, economic and socio-cultural phenomena driving the disabled populations is pertinent while designing and developing technology solutions. The United States National Task Force on Technology and Disability advocates this approach for the designers and users of assistive technology.[29]

Accessible design of technologies can benefit all persons in a given population, not only persons with disabilities. For instance, the mobile phone vibration mode and short message service are not only useful for persons with hearing loss but to a larger population who may benefit from sensory alteration. Similarly, magnifying application in smartphones that increases the size of text can enhance usability for older persons, as well as for those with visual impairments, who find it difficult to read small text fonts.[30]

27 Centre for Universal Design, "About the Center: Ronald L. Mace". Available from https://projects.ncsu.edu/ncsu/design/cud/about_us/usronmace.htm.

28 Marilyn J. Field and Alan M. Jette, eds., "Assistive and Mainstream Technologies for People with Disabilities", in *The Future of Disability in America* (Washington D.C., National Academies Press, 2007). Available from https://www.ncbi.nlm.nih.gov/books/NBK11418/.

29 National Taskforce on Technology and Disability, "About Us". Available from http://ntftd.com/.

30 United Nations Department of Economic and Social Affairs, *Global Status Report on Disability and Development Prototype 2015* (New York, 2015). Available from http://www.un.org/esa/socdev/documents/disability/2016/GlobalStatusReportonDisabilityandDevelopment.pdf.

Another path to safer and more useful products is human factors engineering, which considers how people use products and how human capacities and expectations interact with the characteristics of products in different environments. As is also true of universal design, one focus of human factors engineering is the design of products and processes to reduce the opportunity for human error. Human factors engineering was not intended to consider the capacities of people with visual, hearing, mobility or other impairments. Nonetheless, its principles and methods can be applied to the design of mainstream and assistive technologies to take into account how people with different kinds of impairments interact with such technologies. Although the application of human factors standards appears to have made some medical equipment more accessible, "a disturbing proportion of new devices still have significant shortcomings".[31]

31 Michael E. Wiklund, "Human Factors Standards for Medical Devices Promote Accessibility", in *Medical Instrumentation: Accessibility and Usability Considerations*, Jack M. Winters and Molly Follette Story, eds. (Boca Raton, CRC Press, 2006).

5. Policies and Regulations on Accessibility and the Use of Assistive Technologies

5.1 Challenges

Despite these design principles and the growth of the digital economy with increasing digital inclusion, persons with disabilities still tend to be excluded from mainstream activities and workspaces. Accessibility is a major concern as technologies are not designed according to standards and guidelines devised to benefit the disabled.

While the potential for ICTs and other technologies to be drivers of change has been well documented, technologies have also been known to widen economic and social disparities. Furthermore, a limiting factor affecting the usage of accessibility features and applications is language, as these applications are not always available in local languages. This is accentuated in countries with many local languages such as India and African countries.

Most of the assistive technologies today are designed in the industrialized world, for people living in those countries. This is especially true in the case of assistive technologies for people with vision impairments—market-prevalent technologies are both very expensive and are built to support the language and infrastructure typical in the industrialized world.[32] Although there are a growing number of accessibility applications for smartphones, many of which are available free of charge, the affordability of smartphones, screen readers and text-to-speech applications remains a major issue in developing countries.

Further, the lack of access to higher education among persons with disabilities reduces awareness of the advantages of access to ICTs.

More broadly, the provision of accessibility requires active government intervention, and the implementation of measures to reduce barriers and provide means to ensure equal access and participation.

32 Joyojeet Pal and others, “Assistive technology for vision-impairments: An agenda for the ICTD community”, *Proceedings of the 20th International Conference Companion on World Wide Web* (March 2011), pp. 513-522.

5.2 Standards and Global Good Practices

Employment opportunities for the disabled are scarce due to inaccessible work places and information, discrimination, negative attitudes towards persons with disabilities, and misconceptions about their capacity to work.[33] In most countries, persons with disabilities are more likely to be self-employed than non-disabled people, and are also more likely to be in low-paid jobs with poor career prospects and working conditions.

Frameworks from international bodies[34] encourage governments and other organizations to provide equal opportunities for all by taking appropriate measures to ensure accessibility in the physical and digital environments. In response, governments of many developing countries have created anti-discrimination legislation in employment. To enhance the employability of persons with disabilities, some countries such as Bangladesh have mainstreamed disability in technical and vocational education and training, and reserved a percentage of seats in polytechnics, technical schools and colleges for persons with disabilities. The Hunan Disabled Persons' Federation in China chose 10 non-governmental organizations and vocational training centres as pilot organizations to train and create opportunities for employing the disabled. Subsequently, work opportunities were identified and matched to the interests of persons with disabilities.

Based on the principles of universal design, performance standards and technical requirements for accessibility are expected to produce results for persons with disabilities and non-disabled persons alike. The European Committee for Standardization, for example, has developed Europe-wide standards on accessible built environments. Similarly, various countries such as Australia, Cambodia, Canada, France, South Africa, Sri Lanka and the United States of America have passed national legislations on accessibility of any public space for any person with disability.[35]

Accessibility is a major concern as various kinds of technologies, such as electronic goods, websites and mobile phone applications, are not designed according to standards and guidelines devised to benefit the disabled. As ICTs are increasingly becoming an integral part of our environment, ensuring their accessibility to disabled persons should gain greater priority. ICTs and particularly web access, is a priority accessibility requirement of most national policies.

---

33 United Nations Department of Economic and Social Affairs, *Global Status Report on Disability and Development Prototype 2015* (New York, 2015). Available from http://www.un.org/esa/socdev/documents/disability/2016/GlobalStatusReportonDisabilityandDevelopment.pdf.

34 United Nations, "World Programme of Action Concerning Disabled Persons". Available from https://www.un.org/development/desa/disabilities/resources/world-programme-of-action-concerning-disabled-persons.html; United Nations, "Standard Rules on the Equalization of Opportunities for Persons with Disabilities". Available from https://www.un.org/development/desa/disabilities/standard-rules-on-the-equalization-of-opportunities-for-persons-with-disabilities.html; and United Nations, "Convention on the Rights of Persons with Disabilities". Available from https://www.un.org/development/desa/disabilities/convention-on-the-rights-of-persons-with-disabilities.html.

35 United Nations Department of Economic and Social Affairs, *Global Status Report on Disability and Development Prototype 2015* (New York, 2015). Available from http://www.un.org/esa/socdev/documents/disability/2016/GlobalStatusReportonDisabilityandDevelopment.pdf.

The Web Content Accessibility Guidelines (WCAG) 2.0[36] and e-accessibility checker software has been developed to assist those who wish to verify if their websites satisfy the ISO accessibility criteria.

Figure 8: WCAG 2.0

Source: ACRL TechConnect, "Making Your Website Accessible Part 1: understanding WCAG", 15 October 2012. Available from http://acrl.ala.org/techconnect/post/making-your-website-accessible-part-1-understanding-wcag.

The WCAG 2.0 forms the basis of national guidance documents and legislation on developing accessible websites in many countries, including countries of the European Union, Australia, Hong Kong (SAR, China), Japan, New Zealand and the United States of America. In line with WCAG 2.0, the United Nations assesses websites using criteria such as, the availability of options to configure font size and colour, and read content aloud (useful for visual disabilities), and view videos with sign language or captions (useful for hearing disabilities). Other criteria include making all functionalities available from a keyboard (so an alternate keyboard can be used for those with mobility disabilities), and providing text alternatives for non-text content, such as the addition of descriptions to images (so that those using a screen reader can understand the content and functionality of the image).

36 International Organization for Standardization, "ISO/IEC 40500:2012 (W3C)". Available from http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=58625.

6. National Policies/Projects Using ICTs to Make Workplaces/Public Spaces Inclusive

The Model ICT Accessibility Policy Report[37] offers a comprehensive framework for national policymakers and regulators creating their own ICT accessibility policies and programmes, in consultation with persons with disabilities and ICT stakeholders. The report is targeted at ICT policymakers, regulators and other stakeholders active in ICT and/or disability issues, including non-governmental organizations, organizations working with persons with disabilities and parliamentarians.

While countries across the world have in principle adopted equal opportunity provision for the disabled, specific schemes adopted by governments across the world can be representative of existing global best practices in the field. Examples of such schemes from Brazil, the European Union, South Africa, Japan and the United States of America are presented below.

Case: Brazil

According to Brazil's 2010 census, there are 45 million persons with disabilities in the country, which is about 23.9 per cent of its population.[38] In Brazil, the UNCRPD and its Optional Protocol was ratified in 2008 and has the same legal status as a constitutional amendment. All companies may obtain a voluntary accessibility certification issued by the Brazilian Association of Technical Norms. One of the accessibility initiatives by the federal government called the Accessible Tourism Guide is a website that compiles accessibility ratings of tourist destinations. The collaborative website allows Internet users to rate the accessibility features of hotels, restaurants and various attractions. The website's database currently provides accessibility information on approximately 530,000 establishments in the country.

Case: European Union

The European Disability Strategy 2010-2020 has been framing actions in the European Union as the main instrument to support implementation of the UNCRPD. Actions include, among many others, adoption of the first European ICT accessibility standard in 2014, revision and adoption of legislation related to rail, maritime, air and road transport, to enhance the accessibility for and assistance to persons with disabilities, and compulsory accessibility requirements in actions financed by the European Structural and Investment Funds Regulations. In 2016, the web and mobile accessibility directive for public sector bodies was adopted. The rules include the following:[39]

37 International Telecommunication Union, *Model ICT Accessibility Policy Report* (2014). Available from http://www.itu.int/en/ITU-D/Digital-Inclusion/Persons-with-Disabilities/Documents/ICT%20Accessibility%20Policy%20Report.pdf.

38 James Thurston, "Public Policy & Digital Inclusion in Brazil", *Global Initiative for Inclusive ICTs*, 20 September 2017. Available from http://buyict4all.org/blog/public-policy-digital-inclusion-in-brazil.

39 Emily Griffin, "EU Commits to Web Accessibility Rules", *3Play Media*, 4 May 2016. Available from http://www.3playmedia.com/2016/05/04/eu-commits-to-web-accessibility-rules/.

- All websites or web applications owned by the European Union member governments must be fully accessible to people with disabilities. New websites must be accessible and existing content must be updated.
- Archival content and documents will be available on demand in accessible form.
- Government videos must be closed captioned. Live video has a window of 14 days since first broadcast to get captions.
- Online services, like paying fines or fees, will have to be accessible.
- The European Union government websites must indicate if (and why) parts of their website are inaccessible.
- The European Union member states must regularly monitor and report to both the public and the European Commission on the accessible status of their web services.

Case: South Africa

The disability rights movement in South Africa emerged in the 1980s as part of the broader liberation struggle against apartheid. Disabled People South Africa spearheaded the strategy to mobilize and organize persons with disabilities to resist oppression on the bases of both race and disability.[40] One of their demands was that, "disabled people shall have the right to mainstream education with personal assistance where necessary, appropriate assistive technology and specialized teaching".[41]

Subsequently, South Africa ratified the UNCRPD and its Optional Protocol, established the Ministry of Women, Children and Persons with Disabilities, and developed an Integrated National Disability Strategy. South Africa's Parliament introduced policies that contain extensive support measures for Members of Parliament and employees with disabilities. South Africa's Department of Public Works developed a Disability Policy Guideline to move from policy to practice, while adhering to the principles of universal design.[42] The guideline advocates the design of products, environments, programmes and services that are usable by all people to the greatest possible extent, without the need for adaptation or specialized design. This includes assistive devices for particular groups of persons with disabilities.

40 South African Human Rights Commission, "Towards a barrier-free society: A report on accessibility and built environments", November 2002. Available from https://www.sahrc.org.za/home/21/files/Reports/towards_barrier_free_society.pdf2002.pdf.

41 Disability Rights Charter of South Africa, 2008. Available from https://www.safmh.org.za/documents/policies-and-legislations/Disability%20Rights%20Charter.pdf.

42 Department of Public Works, South Africa, *Disability Policy Guideline* (no date). Available from http://www.publicworks.gov.za/PDFs/documents/WhitePapers/Disability_Policy_Guideline.pdf.

Figure 9: Sign Language Interpretation Service at the Parliament of South Africa

Source: Zero Project, "South Africa's equal access for Members of Parliament". Available from https://zeroproject.org/policy/south-africa/.

Case: Japan

In 1995, the Japanese government adopted the "Government Action Plan for Persons with Disabilities: A Seven-Year Strategy to Achieve Normalization". Subsequently, a legislation promoting barrier-free access in transportation was passed in May 2002. This law has through multiple amendments assisted in enabling access to public buildings, and in developing a policy to reduce access-to-information disparities by improving ICT systems.

Since 2010, Japan has launched an ICT policy of Ubiquitous-Net-Japan (U-Japan).[43] It aims to connect everyone and everything using unique, user-friendly and universal principles of design. It adopts the universal as well as individualized design approach to address accessibility issues and remove barriers that impede persons with disabilities.

The main measures taken include: providing subsidies[44] for research and development to improve communications and broadcast services for elderly and persons with disabilities; enforcement of laws such as, "the promotion of project for facilitation of use of telecommunications by people with disabilities contributing to improved convenience of people with disabilities"; ensuring information accessibility through operational models for local government websites; and enforcing national[45] and international[46] standards for accessibility of telecommunications equipment and services.

43 Yokota Kazuma, "Policy for the Information and Communication Accessibility in Japan", presentation made at the International Conference for Information Society and the Elderly: Global Perspectives, no date. Available from http://www.soumu.go.jp/main_sosiki/joho_tsusin/eng/presentation/pdf/080227_2.pdf.

44 These subsidies are provided by the National Institute of Information and Communications Technology.

45 National standardization (JIS X8341-4).

46 International standardization (ITU-T recommendation F.790).

Case: United States of America (USA)

USA passed the Americans with Disabilities Act (ADA) in 1990 as a comprehensive law that covers most issues of accessibility for persons with disabilities.[47] It applies to all state and local government offices and buildings and other spaces that are available to the general public. ADA guarantees both physical accessibility and non-discrimination in employment and the delivery of goods, services, programmes and education.

Based on ADA, the United States government offers tax incentives for money spent on equipment, materials and labour leading to increased access for persons with disabilities. Since 1993, all TV sets sold in the USA are required to be equipped with closed-captioning receivers that can be turned on through an on-screen menu or a remote. When turned on, closed captioning displays a text version of what is being said on the screen, enabling deaf or hearing-impaired viewers to experience any show with captions.

According to Section 508 of the Rehabilitation Act, the United States government is required by law to make government websites and those of any organizations or institutions that are federally funded accessible and WCAG 2.0 compliant. This includes ensuring compatibility with software and hardware devices that make it possible for people with visual or hearing difficulties, or for those who cannot use a mouse or keyboard, to have full access to the content of a website. The Access Board provides training on its accessibility guidelines and standards to various organizations and groups across the country. Most training sessions focus on the ADA Accessibility Guidelines that cover the built environment and transportation vehicles. The Department of Education mandates that when schools use technology to provide educational benefits, services or opportunities, the technology must be fully accessible to students with disabilities.

47 Community Tool Box, “Section 4. Ensuring Access for People with Disabilities”. Available from http://ctb.ku.edu/en/table-of-contents/implement/physical-social-environment/housing-accessibility-disabilities/main.

7. References

ACRL TechConnect. Making Your Website Accessible Part 1: understanding WCAG. 15 October 2012. Available from http://acrl.ala.org/techconnect/post/making-your-website-accessible-part-1-understanding-wcag.

Assistech. SmartCaneTM Device: About. Available from http://assistech.iitd.ernet.in/smartcane.php.

Assistive Technology Industry Association. What is AT?. Available from https://www.atia.org/at-resources/what-is-at/.

Centre for Universal Design. About the Center: Ronald L. Mace. Available from https://projects.ncsu.edu/ncsu/design/cud/about_us/usronmace.htm.

Community Tool Box. Section 4. Ensuring Access for People with Disabilities. Available from http://ctb.ku.edu/en/table-of-contents/implement/physical-social-environment/housing-accessibility-disabilities/main.

Disability Rights Charter of South Africa. 2008. Available from https://www.safmh.org.za/documents/policies-and-legislations/Disability%20Rights%20Charter.pdf.

European Commission. *Access to Assistive Technology in the European Union*. 2003. Available from http://www.acessibilidade.net/at/access_AT_EU.pdf.

Field, Marilyn J., and Alan M. Jette, eds. Assistive and Mainstream Technologies for People with Disabilities. In *The Future of Disability in America*. Washington D.C.: National Academies Press, 2007. Available from https://www.ncbi.nlm.nih.gov/books/NBK11418/.

Freedom Scientific. Blindness Solutions: JAWS®. Available from http://www.freedomscientific.com/Products/Blindness/JAWS.

Goy, Priscilla. More people with disabilities tapping enhanced tech fund. *The Straits Times*, 21 July 2016. Available from http://www.straitstimes.com/singapore/more-people-with-disabilities-tapping-enhanced-tech-fund.

Griffin, Emily. EU Commits to Web Accessibility Rules. *3Play Media*, 4 May 2016. Available from http://www.3playmedia.com/2016/05/04/eu-commits-to-web-accessibility-rules/.

How It Works. How Stephen Hawking's wheelchair works. 2015. Available from https://www.howitworksdaily.com/how-stephen-hawkings-wheelchair-works/.

Hunt, H. Allan, and Monroe Berkowitz. *New technologies and the employment of disabled persons*. Geneva: International Labour Office, 1992.

International Labour Organization. C159 – Vocational Rehabilitation and Employment (Disabled Persons) Convention, 1983 (No. 159). Available from http://www.ilo.org/dyn/normlex/en/f?p=NORMLEXPUB:12100:0::NO::P12100_INSTRUMENT_ID:312304.

International Organization for Standardization. ISO/IEC 40500:2012 (W3C). Available from http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=58625.

International Telecommunication Union. *Model ICT Accessibility Policy Report*. 2014. Available from http://www.itu.int/en/ITU-D/Digital-Inclusion/Persons-with-Disabilities/Documents/ICT%20 Accessibility%20Policy%20Report.pdf.

Kazuma, Yokota. Policy for the Information and Communication Accessibility in Japan. Presentation made at the International Conference for Information Society and the Elderly: Global Perspectives, no date. Available from http://www.soumu.go.jp/main_sosiki/joho_tsusin/eng/presentation/pdf/080227_2.pdf.

McCarthy, Ted, Joyojeet Pal and Edward Cutrell. The "voice" has it: Screen reader adoption and switching behavior among vision impaired persons in India. *Assistive Technology*, vol. 25, no. 4 (Winter 2013), pp. 222-229. Available from https://www.ncbi.nlm.nih.gov/pubmed/24620705.

Mondal, Ajit, and Jayanta Mete. Education of Children with Disabilities in India: Policy Perspective and Concerns. *Indian Journal of Educational Research*, vol. 2 (2013), pp. 56-67.

National Taskforce on Technology and Disability. About Us. Available from http://ntftd.com/.

Newz Hook. About Us. Available from https://newzhook.com/about.

OrCam. My Eye. Available from https://www.orcam.com/myeye/.

Pal, Joyojeet, and others. Assistive technology for vision-impairments: An agenda for the ICTD community. *Proceedings of the 20th International Conference Companion on World Wide Web* (March 2011), pp. 513-522.

Ratzka, Adolf. The case for accessibility legislation in a market economy. Report of the CIB Expert Seminar on Building Non-Handicapping Environments, 1991. Available from http://www.independentliving.org/cib/cibbudapest28.html.

South African Human Rights Commission. Towards a barrier-free society: A report on accessibility and built environments. November 2002. Available from https://www.sahrc.org.za/home/21/files/Reports/towards_barrier_free_society.pdf2002.pdf.

Techshare India 2016. Exhibition at Techshare India. Available from http://techshare.barrierbreak.com/exhibition-at-techshare-india/.

Thurston, James. Public Policy & Digital Inclusion in Brazil", *Global Initiative for Inclusive ICTs*. 20 September 2017. Available from http://buyict4all.org/blog/public-policy-digital-inclusion-in-brazil.

United Nations. *Accessibility and Development: Mainstreaming Disability in the Post-2015 Development Agenda*. New York, 2015. Available from http://www.un.org/disabilities/documents/accessibility_and_development.pdf.

United Nations. Convention on the Rights of Persons with Disabilities. Available from https://www.un.org/development/desa/disabilities/convention-on-the-rights-of-persons-with-disabilities.html.

United Nations. Standard Rules on the Equalization of Opportunities for Persons with Disabilities. Available from https://www.un.org/development/desa/disabilities/standard-rules-on-the-equalization-of-opportunities-for-persons-with-disabilities.html.

United Nations. World Programme of Action Concerning Disabled Persons. Available from https://www.un.org/development/desa/disabilities/resources/world-programme-of-action-concerning-disabled-persons.html.

United Nations Department of Economic and Social Affairs. *Global Status Report on Disability and Development Prototype 2015*. New York, 2015. Available from http://www.un.org/esa/socdev/documents/disability/2016/GlobalStatusReportonDisabilityandDevelopment.pdf.

United Nations General Assembly, Seventieth Session, 70/1. Transforming our world: the 2030 Agenda for Sustainable Development (A/RES/70/1), 21 October 2015. Available from http://www.un.org/ga/search/view_doc.asp?symbol=A/RES/70/1&Lang=E.

Wear Works. Wayband. Available from https://www.wear.works/wayband-product.

Wiklund, Michael E. Human Factors Standards for Medical Devices Promote Accessibility. In *Medical Instrumentation: Accessibility and Usability Considerations*, Jack M. Winters and Molly Follette Story, eds. Boca Raton: CRC Press, 2006.

World Health Organization. *Towards a Common Language for Functioning, Disability and Health: ICF – The International Classification of Functioning, Disability and Health*. Geneva, 2002. Available from http://www.who.int/classifications/icf/training/icfbeginnersguide.pdf.

World Health Organization. *World Report on Disability*. Geneva, 2011. Available from http://www.who.int/disabilities/world_report/2011/report/en/.

World Health Organization. Disability and Health Fact Sheet. November 2017. Available from http://www.who.int/mediacentre/factsheets/fs352/en/.

Zero Project. South Africa's equal access for Members of Parliament. Available from https://zeroproject.org/policy/south-africa/.

Zielinski, Dave. New assistive technologies aid employees with disabilities. *Society for Human Resource Management*, 20 December 2016. Available from https://www.shrm.org/resourcesandtools/hr-topics/technology/pages/new-assistive-technologies-aid-employees-with-disabilities.aspx.

Glossary

Activity limitations : A difficulty encountered by an individual in executing a task or action.

Assistive technology : Any item, piece of equipment or product, whether it is acquired commercially, modified or customized, that is used to increase, maintain or improve the functional capabilities of individuals with disabilities.

Decent work : Work that sums up the aspirations of people in their working lives.

Disability : An umbrella term for impairments, activity limitations and participation restrictions.

Impairments : A problem in body function or structure.

Participation restrictions : A problem experienced by an individual in involvement in life situations.

Prosthetic : An artificial substitute or replacement of a part of the body.

Universal design : The concept of designing all products and the built environment to be aesthetic and usable to the greatest extent possible by everyone, regardless of their age, ability or status in life.

Acronyms

ADA	Americans with Disabilities Act
ICT	Information and Communication Technology
UNCRPD	United Nations Convention on the Rights of Persons with Disabilities
WCAG	Web Content Accessibility Guidelines

Ⅳ. Internet of Things

Contents

List of Figures

List of Tables

1. Introduction

The Internet of Things (IoT), also known as the Internet of Everything, is the concept of connecting a device to the Internet and to other connected devices.[1] It could be seen as a giant network of connected things and people—all of which collect and share data about the way they are used and about the environment around them.[2] The International Telecommunication Union has defined IoT as, "a global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable information and communication technologies (ICTs)".[3] There is a wide consensus that IoT is a disruptive technology with transformative impact on the economy and society, and has the potential to increase both the efficiency and effectiveness of development interventions.[4]

IoT enables devices to collect, send and act on data they acquire from their surrounding environments using embedded sensors, processors and communication hardware.[5] These devices, often called "connected" or "smart" devices, can sometimes talk to other related devices, a process called machine-to-machine communication, and act on the information they get from one another. Humans can interact with the devices to set them up, give them instructions or access the data, but the devices do most of the work on their own without human intervention.[6]

IoT is a shift from an Internet used for interconnecting end-user devices to an Internet used for interconnecting physical objects that communicate with each other and/or with humans.[7] This is a major development that promises to change our way of doing things through better information in real time and improved learning opportunities.[8] World Bank lists it among the six digital technologies to watch for.[9]

1 Jen Clark, "What is the Internet of Things?" 17 November 2016. Available from https://www.ibm.com/blogs/internet-of-things/what-is-the-iot/.

2 Ibid.

3 International Telecommunication Union and CISCO, *Harnessing the Internet of Things for Global Development* (Geneva, 2016). Available from https://www.itu.int/en/action/broadband/Documents/Harnessing-IoT-Global-Development.pdf.

4 Daniele Miorandi and others, "Internet of things: Vision, application and research challenges", *Ad Hoc Networks*, vol. 10, no. 7 (September 2012), pp. 1497–1516. Available from https://doi.org/10.1016/j.adhoc.2012.02.016.

5 Bernadette Johnson, "How the Internet of Things Works", *How Stuff Works*, no date. Available from http://computer.howstuffworks.com/internet-of-things.htm.

6 Ibid.

7 Daniele Miorandi and others, "Internet of things: Vision, application and research challenges", *Ad Hoc Networks*, vol. 10, no. 7 (September 2012), pp. 1497–1516. Available from https://doi.org/10.1016/j.adhoc.2012.02.016.

8 International Telecommunication Union and CISCO, *Harnessing the Internet of Things for Global Development* (Geneva, 2016). Available from https://www.itu.int/en/action/broadband/Documents/Harnessing-IoT-Global-Development.pdf.

9 World Bank, *World Development Report 2016: Digital Dividends* (Washington D.C., 2016). Available from https://doi.org/10.1596/978-1-4648-0671-1.

The strong growth currently observed in IoT applications is attributable to several major underlying trends that are just now coming to fruition:[10]

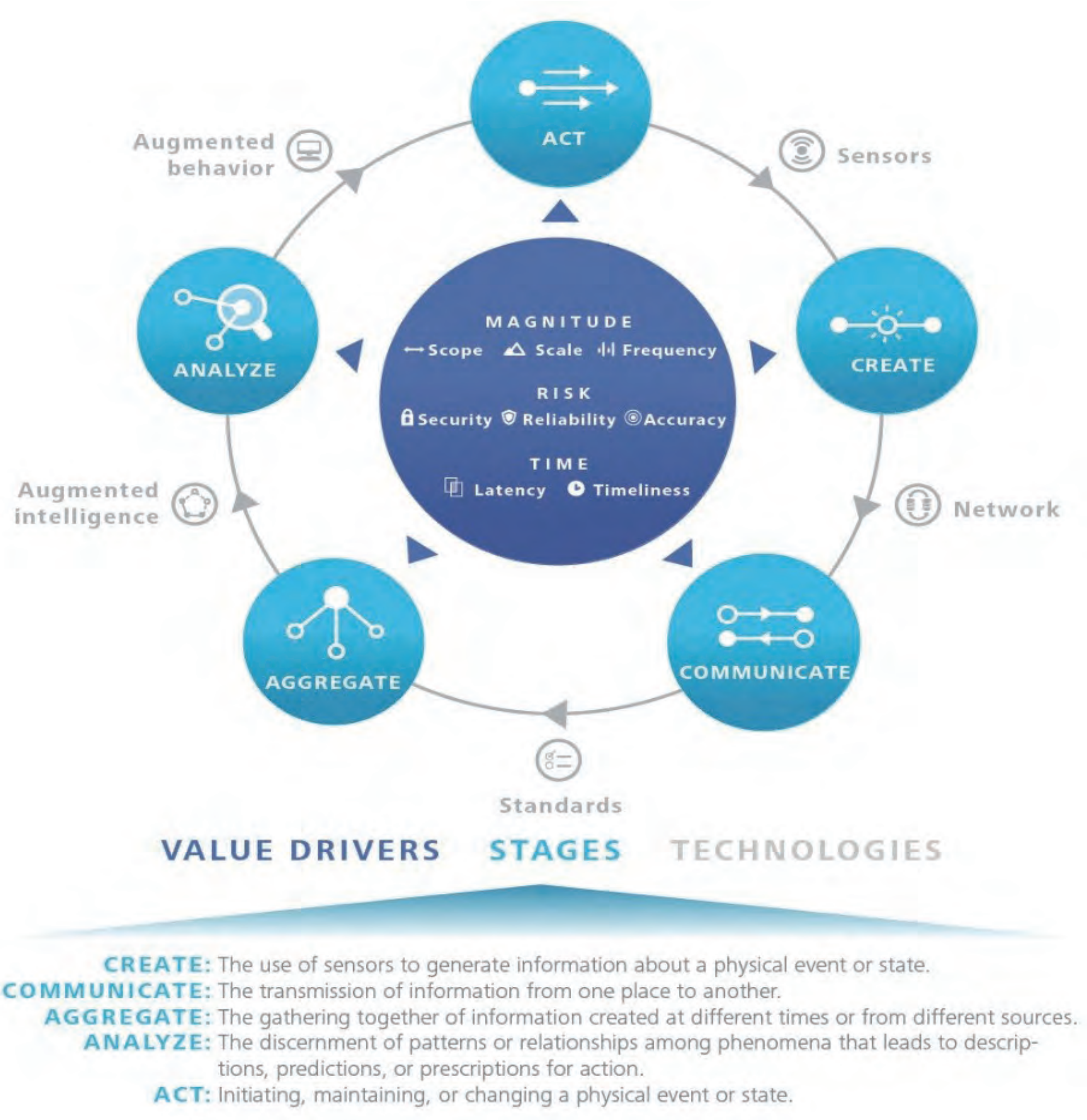
- The reduction in the cost of computing (including sensors) and the growth of Wi-Fi;
- The growth in mobile and the deployment of data-friendly third-generation (3G) networks from 2001 onwards, as well as the expansion of network connectivity across the world in both urban to rural settings (including Wi-Fi, but also macro cell connectivity);
- The proliferation of software development, partly attributable to economies of scale; and
- The emergence of standardized low-power wireless technologies.

10 International Telecommunication Union and CISCO, *Harnessing the Internet of Things for Global Development* (Geneva, 2016). Available from https://www.itu.int/en/action/broadband/Documents/Harnessing-IoT-Global-Development.pdf.

2. Functional Components of an IoT System

The building blocks of an IoT system can be divided into five functional stages and depicted in an information value loop (Figure 1). Data is **created** through the sensors attached to physical devices, which is **communicated** to another node. Data from various sources is **aggregated** and broad patterns are **analysed**. Finally, data is visualized for human **action** or in the case of automated system, suitable action is initiated.

Figure 1: Functional Stages of an IoT System



Source: Jonathan Holdowsky and others, "Inside the Internet of Things (IoT)", *Deloitte Insights*, 21 August 2015. Available from https://dupress.deloitte.com/dup-us-en/focus/internet-of-things/iot-primer-iot-technologies-applications.html.

IoT has emerged due to developments in sensor technology, high speed communication networks and availability of tools for data analysis. Development in each of these enabling technologies is contributing to widespread proliferation of IoT systems. Table 1 defines and provides examples of each of these technology components.

Table 1: Technology Components of an IoT System

Technology	Definition	Examples
Sensors	A device that generates an electronic signal from a physical condition or event.	The cost of an accelerometer has fallen from USD 0.52 in 2006 to USD 0.40. Similar trends have made other types of sensors small, inexpensive and robust enough to create information from everything, from foetal heartbeats via conductive fabric in the mother's clothing to jet engines roaring at 35,000 feet.
Networks	A mechanism for communicating an electronic signal.	Wireless networking technologies can deliver bandwidths for 300 Mbps to 1 Gbps with near-ubiquitous coverage.
Standards	Commonly accepted prohibitions or prescriptions for action.	Technical standards enable processing of data and allow for interoperability of aggregated data sets. Industry consortia and standards bodies have been working on various technical and regulatory IoT standards.
Augmented intelligence	Analytical tools that improve the ability to describe, predict and exploit relationships among phenomena.	Petabyte-sized databases can now be searched and analysed, even when populated with unstructured (for example, text or video) data sets. Software that learns may substitute for human analysis and judgement in a few situations.
Augmented behaviour	Technologies and techniques that improve compliance with prescribed action.	Machine-to-machine interfaces are removing fallible human intervention and developing optimized processes. Insights into human cognitive biases are making prescriptions for action based on augmented intelligence more effective and reliable.

Source: Jonathan Holdowsky and others, "Inside the Internet of Things (IoT)", *Deloitte Insights*, 21 August 2015. Available from https://dupress.deloitte.com/dup-us-en/focus/internet-of-things/iot-primer-iot-technologies-applications.html.

2.1 Sensors

A sensor is any device that converts a non-electrical input into an electrical signal that can be sent to an electronic circuit. Sensors create information from action. Different sensors capture different types of information such as temperature, pressure, linear motion, speed, motion, light and so on (Table 2). The reducing prices of sensors accompanied by their miniaturization have aided in their deployment in IoT systems.[11]

Table 2: Different Type of Sensors and their Use Cases

Measurement	Functionality	Sensor Examples	Use Cases
Proximity/Position	Detect and respond to angular or linear position of device	• Radio frequency identification • Linear position sensors • GPS position sensors • Location finding	• Land management • Natural resource/ wildlife management • Illegal activity tracking
Motion/Velocity/ Displacement	Detect movement outside of component within sensor range	• Ultrasonic proximity • Optical reflective sensors • Passive infrared • Inductive proximity • Accelerometers • Gyroscopes	• Emergency preparedness • Land management • Illegal activity tracking
Weather/Temperature	Detect amount of heat in different mediums and metrics	• Thermometers • Resistant temperature detectors • Thermocouples • Infrared thermometers	• Water access • Water treatment • Agriculture • Emergency preparedness • Land management
Acoustic/Sound/Vibration	Detect decibel level sound or seismic disturbances	• Seismography • Firearm sensors • Commercial security	• Emergency preparedness • Illegal activity tracking
Flex/Force/Pressure/Load	Detect force(s) being exerted against device	• Pressure monitors • Capacitive transducers • Piezoresistive sensors • Strain gauges	• Natural resource management
Chemical/Gas/Electric	Detect chemical, gas or electrical changes in composition of substance	• DC/AC electrical current sensors • Voltage transducers • Smart home sensors • Humidity monitoring	• Agriculture • Natural resource management • Health • Water treatment
Light/Imaging/Machine Vision	Detect colour and light shifts through digital signalling	• Real-time temperature monitoring (infrared)	• Health

Source: International Telecommunication Union and CISCO, *Harnessing the Internet of Things for Global Development* (Geneva, 2016). Available from https://www.itu.int/en/action/broadband/Documents/Harnessing-IoT-Global-Development.pdf.

11 International Telecommunication Union and CISCO, *Harnessing the Internet of Things for Global Development* (Geneva, 2016). Available from https://www.itu.int/en/action/broadband/Documents/Harnessing-IoT-Global-Development.pdf.

2.2 Networks

While information is created through sensors, it needs to be transmitted to other locations for aggregation and analysis. Such transmission of data happens over a network. IoT devices communicate using a range of different communication protocols, which may include: short-range radio protocols (such as ZigBee, Bluetooth and Wi-Fi); mobile networks; or longer-range radio protocols (such as LoRa). These technologies can be segmented based on wireless versus wireline, and the wireless technologies can be grouped by personal area network, local area network or wide area network technologies.[12]

Each of the communication protocols has different ranges, bandwidth and power requirements (Figure 2). The selection of a communication protocol is thus based on the particular use case.

Figure 2: Communication Protocols

Source: International Telecommunication Union and CISCO, *Harnessing the Internet of Things for Global Development* (Geneva, 2016). Available from https://www.itu.int/en/action/broadband/Documents/Harnessing-IoT-Global-Development.pdf.

Given their high speeds, fourth-generation (4G) and fifth-generation (5G) technologies are most favourable for IoT applications. Over the last few decades, data rates have been increasing rapidly and prices for data transfer decreasing.

12 International Telecommunication Union and CISCO, *Harnessing the Internet of Things for Global Development* (Geneva, 2016). Available from https://www.itu.int/en/action/broadband/Documents/Harnessing-IoT-Global-Development.pdf.

2.3 Standards

The third stage involves aggregation of data collected through sensors at different locations so that meaningful conclusion can be drawn. Aggregation increases the value of data by increasing the scale, scope and frequency of data available for analysis. Aggregation is achieved using various standards, depending on the IoT application. Aggregation requires network protocols, communication protocols and data aggregation standards.

2.4 Augmented Intelligence

Augmented intelligence refers to technologies that help analyse the collected data from the sensors over the network. Advances in machine learning and artificial intelligence have enabled augmented intelligence. Such tools provide descriptive analytics, predictive analytics and prescriptive analytics. Descriptive analytics tools augment our intelligence by allowing us to work effectively with much larger or more complex data sets than we could otherwise easily handle. Predictive analytics exploits the large quantity and increasing variety of data to build useful models that can correlate seemingly unrelated variables. Finally, prescriptive analytics takes on the challenge of creating more nearly causal models.

2.5 Augmented Behaviour

The final stage involves augmented behaviour that goes beyond augmented intelligence. It provides for observable action in the real world based on the preceding stages.

3. Application Domains of IoT

IoT has found application in a variety of domains, including personal healthcare, home automation and urban service delivery. For example, the use of wearable sensors, together with suitable applications running on personal computing devices enable people to track their daily activities (e.g., steps walked, calories burned, exercises performed). The applications can provide suggestions for enhancing the user's lifestyle and prevent the onset of health problems.[13] Similarly, home automation involves instrumenting buildings with advanced IoT technologies that help to reduce the consumption of resources (electricity, water), as well as improve the satisfaction level of persons who live there[14] (Figure 3). In smart homes, for example, machine learning can recognize and learn patterns of the various home activities, and adapt to provide smart usage of the connected devices and appliances that saves energy.[15]

Figure 3: Different Type of Sensors and their Use Cases

Source: Jim Chase, "The Evolution of the Internet of Things", *Texas Instruments*, September 2013. Available from http://www.tij.co.jp/jp/lit/ml/swrb028/swrb028.pdf.

The use of IoT in the urban context supports the "smart city" vision, which aims to exploit the most advanced ICTs to provide added-value services for the administration of the city and for the citizens.[16] Such applications respond to the strong push of many national governments to adopt ICT

13 Daniele Miorandi and others, "Internet of things: Vision, application and research challenges", *Ad Hoc Networks*, vol. 10, no. 7 (September 2012), pp. 1497–1516. Available from https://doi.org/10.1016/j.adhoc.2012.02.016.

14 Ibid.

15 ESCAP, *Artificial Intelligence and Broadband Divide: State of ICT Connectivity in Asia and the Pacific* (Bangkok, 2017). Available from http://www.unescap.org/resources/artificial-intelligence-and-broadband-divide-state-ict-connectivity-asia-and-pacific-2017.

16 Andrea Zanella and others, "Internet of Things for Smart Cities", *IEEE Internet of Things Journal*, vol. 1, no. 1 (February 2014), pp. 22–32.

solutions in the management of public affairs.[17] Urban IoT, indeed, may bring a number of benefits in the management and optimization of traditional public services, such as transport and parking, lighting, surveillance and maintenance of public areas, preservation of cultural heritage, and garbage collection. Furthermore, the availability of different types of data, collected by a pervasive urban IoT, may be exploited to increase local government transparency and promote citizen-centric actions, enhance citizens' awareness of the status of their city and stimulate their active participation in the management of public administration, and at the same time, fuel the creation of new services upon those provided by IoT.

Figure 4: Smart Solutions Indicated in India's Smart Cities Mission Guidelines

Source: Ministry of Urban Development, India, "Smart Cities: Mission Statement and Guidelines", June 2015. Available from http://smartcities.gov.in/upload/uploadfiles/files/SmartCityGuidelines(1).pdf.

Some examples of urban IoT applications across domains are presented below.

3.1 Transportation and Urban Mobility

IoT based on motion sensors have been widely used in the urban transport sector. Some of the applications include intelligent transport system, smart parking, bike sharing and traffic control system.

17 Daniele Miorandi and others, "Internet of things: Vision, application and research challenges", *Ad Hoc Networks*, vol. 10, no. 7 (September 2012), pp. 1497–1516. Available from https://doi.org/10.1016/j.adhoc.2012.02.016.

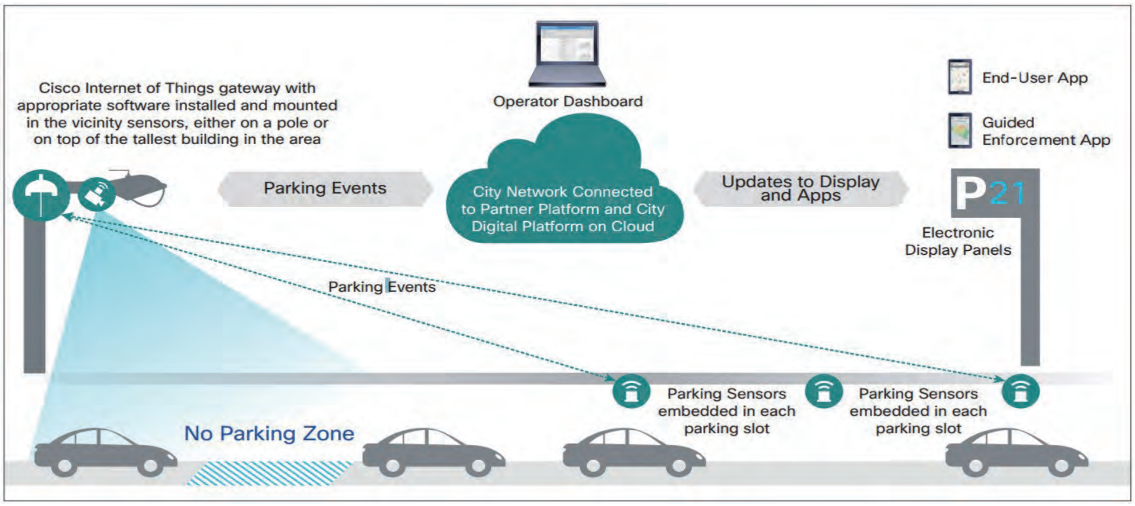
Intelligent Transport System

In Tel Aviv, Israel, the Ministry of Transportation has deployed IoT-based information screens at over 100 transit stops around the city. These transit stops, powered by solar energy, show when the next buses will arrive at the stops using real-time Global Positioning System (GPS) data. Based on this system, Moovit, a local start up, has developed a mobile application that provides trip planning capabilities and local transit timetables. Another application compares transportation options in the city by sharing data about their time, cost, pollution and effects on health.[18]

Smart Parking

Singapore has launched the Parking Guidance System since 2008, which provides drivers with real-time information on parking availability. This reduces the amount of circulating traffic searching for available spaces and promotes a more efficient use of existing parking facilities. Parking information is displayed on electronic sign boards, online on the One Motoring Portal, or on mobile applications such as MyTransport.SG.[19] Faster time to locate a parking space means fewer carbon emissions from the car, less traffic congestion and happier citizens.[20]

Figure 5: Smart Parking Service



Source: Cisco, "Cisco Kinetic for Cities Parking Solution", 2017. Available from https://www.cisco.com/c/dam/en/us/products/collateral/se/internet-of-things/at-a-glance-c45-735612.pdf.

18 Eran Toch and Eyal Feder, "International Case Studies of Smart Cities: Tel Aviv, Israel", Inter-American Development Bank Discussion Paper No. IDB-DP-444, June 2016. Available from https://doi.org/10.18235/0000416.

19 Sang Keon Le e and others, "International Case Studies of Smart Cities: Singapore, Republic of Singapore", Inter-American Development Bank Discussion Paper No. IDB-DP-462, June 2016. Available from https://doi.org/10.18235/0000409.

20 Andrea Zanella and others, "Internet of Things for Smart Cities", *IEEE Internet of Things Journal*, vol. 1, no. 1 (February 2014), pp. 22–32.

Traffic Management

IoT has been deployed to monitor traffic congestion in cities, using sensing capabilities and the GPS installed in modern vehicles, and adopting a combination of air quality and acoustic sensors along a given road. The information collected can be used by city authorities to manage traffic, and by citizens to plan the optimal travel route.[21]

The Republic of Korea has implemented a Traffic Signal Control System in the city of Songdo. During peak hours, all signal indications operate as regular signals. During non-peak hours, however, detectors at left turn lanes are used to monitor the flow of traffic and flexibly manage signal indications, for instance, by skipping indications for left turns when there are no cars that need to turn left.[22]

Singapore has implemented a smart electronic device called, "Your Speed Sign", which displays the real-time speed of vehicles and alerts drivers if they are violating the speed limit. It encourages drivers to stay under the speed limit and thus improve safety on the roads.[23]

Bike Sharing

The city of Tel Aviv, Israel has deployed a bike-sharing system called, "Tel-O-Fun". The system includes a mobile and a web application that allow users to see the location of the nearest station and whether it has available bikes.[24]

3.2 Public Utilities

Smart Lighting

Smart lighting attempts to optimize street lamp intensity according to the time of the day, the weather condition and the presence of people. The addition of a fault detection system could easily be included to support maintenance and speed up repairs.[25]

Case: Smart Lighting in the City of Semarang, Indonesia

The manual maintenance of 50,000 dated street lighting points in an area of 374km^2 in the city of Semarang was a cost burden and a drain on resources. The offices that managed the lighting had to work in shifts to find faulty lights and wait for complaints from the public, which, in addition to being costly and time consuming, was affecting the quality of customer service.

---

21 Ibid.

22 Sang Keon Lee and others, "International Case Studies of Smart Cities: Singapore, Republic of Singapore", Inter-American Development Bank Discussion Paper No. IDB-DP-462, June 2016. Available from https://doi.org/10.18235/0000409.

23 Eran Toch and Eyal Feder, "International Case Studies of Smart Cities: Tel Aviv, Israel", Inter-American Development Bank Discussion Paper No. IDB-DP-444, June 2016. Available from https://doi.org/10.18235/0000416.

24 Ibid.

25 Andrea Zanella and others, "Internet of Things for Smart Cities", *IEEE Internet of Things Journal*, vol. 1, no. 1 (February 2014), pp. 22–32.

With interconnected devices and remote management, the smart lighting system now provides near-real-time information on street lighting failures during the night. In addition, dimming capabilities allow the city to focus light where it is needed and dim the light when an area is not being used. The result is a city that is brighter and more beautiful, but more importantly, one that can track and reduce energy consumption, save costs and easily manage its lighting infrastructure.[26]

Smart Grid

A smart grid is an energy generation, transmission and distribution network enhanced by digital control, monitoring and telecommunications capabilities. In addition to providing real-time, two-way flow of electrical power, it enables automated, bidirectional flow of information. Consequently, all stakeholders in the electricity chain—from generation plant to commercial, industrial and residential users—gain insight into both the electricity flow and the infrastructure transporting it. To add intelligence to existing infrastructure, new digital equipment and devices are strategically deployed to complement existing equipment. This new layer of digital equipment connects all assets and is enabled by IoT.[27]

IoT creates opportunities to realize the potential of data that resides in existing, unconnected infrastructures, and with data analysis, extracts insight and intelligence from the data.[28] Through predictive analysis, supply-demand mismatch can be avoided, thus enhances energy efficiency. Predictive analysis also aids in preventive maintenance, dynamic pricing based on demand-supply conditions and prevention of losses due to thefts.

Case: Smart Grid in Puducherry, India

A smart grid pilot project in Puducherry, India, uses sensor-embedded transformers with IoT technology to monitor real-time energy use, alerting command centres when unusual usage spikes are noted. Maintenance crews then act upon the alerts in a timely manner to check for possible energy theft, as well as the overall reliability of energy distribution systems.[29]

Water Management

IoT systems have been used to improve supply of clean drinking water and for automated metering services. For example, in Bangladesh, a network of 48 arsenic sensors is being used to monitor water

26 Philips, "Transforming Semarang into a smart city", 2016. Available from http://images.philips.com/is/content/PhilipsConsumer/PDFDownloads/Global/ODLI20160708_001-UPD-en_AA-15077-CS_SEMARANG_v6R.pdf.

27 C. Donitzky, O. Roos and S. Sauty, "A Digital Energy Network: The Internet of Things & the Smart Grid", Intel White Paper, 2014. Available from https://www.intel.com/content/dam/www/public/us/en/documents/white-papers/iot-smart-grid-paper.pdf.

28 Ibid.

29 Arun Ramamurthy, "Let's use ICT effectively to implement smart grids in Asia and the Pacific", *Asia Development Blog*, 26 May 2016. Available from https://blogs.adb.org/blog/let-s-use-ict-effectively-implement-smart-grids-asia-and-pacific.

quality.[30] Similarly, in the city of Pangyo, Republic of Korea, sensors capture and transmit data on the flow and pressure of water in real time. This enables the service provider to monitor and respond to leaks, as well as reduce the influx of pollutants.[31]

3.3 Environment

Noise Monitoring

IoT can offer noise monitoring service to measure the amount of noise produced at any given hour in the places that adopt the service and alert citizens.[32]

Air Quality Monitoring

Air pollution is a critical issue in today's cities. In Beijing, for example, IBM's Green Horizons Initiative is utilizing IoT and artificial intelligence (AI) to predict pollution levels and lower pollutant concentrations. The numerous factors that contribute to air pollution (traffic levels, weather, humidity, wind patterns, etc.) are captured by connected sensors all over China's capital, and then analysed by the AI system. While the data is too complex for human analysts, AI and IoT technologies can detect patterns in big data to pinpoint trends. Following predictive analysis, the system can make forecasts far more effectively than ever before. Since launching the initiative in 2014, IBM has been able to generate high-resolution pollution forecasts 72 hours in advance, giving citizens more warning and planning time. The forecasts have not only helped citizens prepare for daily conditions, they also intend to help the city of Beijing reach its goals of reducing smog-generating particulate matter by 25 per cent by the end of 2017. The combination of sensors, IoT data, AI and human analysis can identify polluters and help to design smarter cities, highways and coping methods.[33]

Waste Management

Case: Smart Bins

In 2015, smart waste bins were introduced in Singapore as a part of its smart waste management programme. The sensing monitors attached on bin lids collect information on content and location, which is sent to a waste collection team through a central server. This helps the team optimize route planning and at the same time, constantly keep public spaces clean.[34]

30 Marco Zennaro, Bjorn Pehrson and Antoine Bagula, "Wireless Sensor Networks: a great opportunity for researchers in Developing Countries", *Proceedings of WCITD2008 Conference, Pretoria, South Africa*, vol. 67 (2008). Available from http://users.ictp.it/~mzennaro/WSN4D.pdf.

31 Sang Keon Lee and others, "International Case Studies of Smart Cities: Singapore, Republic of Singapore", Inter-American Development Bank Discussion Paper No. IDB-DP-462, June 2016. Available from https://doi.org/10.18235/0000409.

32 Andrea Zanella and others, "Internet of Things for Smart Cities", *IEEE Internet of Things Journal*, vol. 1, no. 1 (February 2014), pp. 22–32.

33 Liza Cooper, "Air pollution in China and IBM green initiatives" *IBM*, 26 August 2016. Available from https://www.ibm.com/blogs/internet-of-things/air-pollution-green-initiatives/.

34 Sang Keon Lee and others, "International Case Studies of Smart Cities: Singapore, Republic of Singapore", Inter-American Development Bank Discussion Paper No. IDB-DP-462, June 2016. Available from https://doi.org/10.18235/0000409.

Figure 6: Smart Bins

Source: Sang Keon Lee and others, "International Case Studies of Smart Cities: Singapore, Republic of Singapore", Inter-American Development Bank Discussion Paper No. IDB-DP-462, June 2016. Available from https://doi.org/10.18235/0000409.

3.4 Safety and Citizen Security

Abnormal Sound Monitoring

In the city of Songdo, Republic of Korea, an abnormal sound monitoring solution based on IoT has been installed for citizen security. If a citizen shouts or screams in an urgent situation, sound sensors detect this and CCTVs nearby automatically turn their angle to show centre operators images of the situation (Figure 7). The centre operator checks the situation through video footage and communicates the location and other details of the emergency to relevant organizations for swift action.[35]

Figure 7: Abnormal Sound Monitoring

Source: Sang Keon Lee and others, "International Case Studies of Smart Cities: Singapore, Republic of Singapore", Inter-American Development Bank Discussion Paper No. IDB-DP-462, June 2016. Available from https://doi.org/10.18235/0000409.

35 Ibid.

4. Challenges

Despite the many promises of IoT in urban spaces described above, there are many challenges that need to be addressed. Some of them are covered below.

Power Supply

Sensors and network communication devices of an IoT system need to be powered either through in-line connections or batteries. In-line power sources are constant but may be impractical or expensive in many instances. Batteries may represent a convenient alternative, but battery life, charging and replacement, especially in remote areas, may present significant issues.[36]

Ubiquitous Connectivity

Data created from various sensors needs to be transmitted to a centralized location for aggregation and analysis. This requires ubiquitous network connectivity. While a few IoT applications, such as smart homes, will require short-distance connections from sensors to the central aggregating hub, most urban IoT applications will need ubiquitous connectivity, which is not yet available, particularly in developing economies.[37]

Security

IoT applications, especially in the urban context discussed above involve multiple sensors and networks connected to each other. Thus, every node in the IoT system is a potential entry point and the interconnection may spread the damage.[38] A compromised IoT system controlling physical systems (such as the electric supply) may have catastrophic effects. Moreover, due to limited resources available with the sensors (processing power, memory and power supply), implementing security measures such as complex cryptographic algorithms may be a challenge.[39]

Interoperability and Standards

Interoperability implies the ability of devices and networks of IoT to recognize each other and exchange data. Most of the sensor systems currently in operation are proprietary and are designed for specific applications.[40] Also, different devices use different protocols. According to one source, there are at least 115 different protocols used by IoT devices to connect to the cloud today.[41]

---

36 Jonathan Holdowsky and others, "Inside the Internet of Things (IoT)", *Deloitte Insights*, 21 August 2015. Available from https://dupress.deloitte.com/dup-us-en/focus/internet-of-things/iot-primer-iot-technologies-applications.html.

37 Michael Chui, Markus Löffler and Roger Roberts, "The Internet of Things", *McKinsey & Company*, March 2010. Available from http://www.mckinsey.com/industries/high-tech/our-insights/the-internet-of-things.

38 Ibid.

39 Jonathan Holdowsky and others, "Inside the Internet of Things (IoT)", *Deloitte Insights*, 21 August 2015. Available from https://dupress.deloitte.com/dup-us-en/focus/internet-of-things/iot-primer-iot-technologies-applications.html.

40 Ibid.

41 International Telecommunication Union and CISCO, *Harnessing the Internet of Things for Global Development* (Geneva, 2016). Available from https://www.itu.int/en/action/broadband/Documents/Harnessing-IoT-Global-Development.pdf.

Currently, there is no agreed standard and multiple industry consortiums have their own standards while IEEE, the industry standards body, is in the process of formulating the IEEE P2413 standard, which will provide a unified approach to defining IoT architectures.[42]

Case: Draft IEEE Standard on IoT

The architectural framework defined in this standard will promote cross-domain interaction, aid system interoperability and functional compatibility, and further fuel the growth of the IoT market.

This standard defines an architectural framework for IoT, including descriptions of various IoT domains, definitions of IoT domain abstractions and identification of commonalities between different IoT domains. The architectural framework for IoT provides a reference model that defines relationships among various IoT verticals (e.g., transportation, healthcare) and common architecture elements. It also provides a blueprint for data abstraction and the quality "quadruple" trust that includes protection, security, privacy and safety.

Furthermore, this standard provides a reference architecture that builds upon the reference model. The reference architecture covers the definition of basic architectural building blocks and their ability to be integrated into multi-tiered systems. The reference architecture also addresses how to document and, if strived for, mitigate architecture divergence. This standard leverages existing applicable standards, and identifies planned or ongoing projects with a similar or overlapping scope.[43]

Data Analytics

The real value of IoT applications comes from analysing data from multiple sensors and making decisions based on this data.[44] Sensors in an urban IoT application will probably generate huge amounts of data that need to be aggregated and analysed. However, algorithms for analysing such data will require specialized skills and training. Inadequate human and organizational capacity is frequently a major challenge.[45]

Privacy

IoT heightens risks to personal privacy. With IoT applications, consumers often have no idea what kind of information is being acquired about them.[46] With data being aggregated from multiple sources and networks, the privacy of an individual may be further violated.

42 Stephen Lawson, "Is this the year IoT standards will finally make sense?" *PCWorld*, 13 January 2017. Available from https://www.pcworld.com/article/3157826/internet-of-things/is-this-the-year-iot-standards-will-finally-make-sense.html.

43 IEEE Standards Association, "2413 - Standard for an Architectural Framework for the Internet of Things (IoT)". Available from http://standards.ieee.org/develop/project/2413.html.

44 Michael Chui, Markus Löffler and Roger Roberts, "The Internet of Things", *McKinsey & Company*, March 2010. Available from http://www.mckinsey.com/industries/high-tech/our-insights/the-internet-of-things.

45 International Telecommunication Union and CISCO, *Harnessing the Internet of Things for Global Development* (Geneva, 2016). Available from https://www.itu.int/en/action/broadband/Documents/Harnessing-IoT-Global-Development.pdf.

46 Michael Chui, Markus Löffler and Roger Roberts, "The Internet of Things", *McKinsey & Company*, March 2010. Available from http://www.mckinsey.com/industries/high-tech/our-insights/the-internet-of-things.

5. Policy Implications

To fully harness the potential of IoT, policymakers will need to address the following aspects:

- Policymakers will need to update and strengthen their policies on data privacy and security.[47]
- Coordination among different departments will be needed to ensure interoperability across different applications in a smart city.
- Certain new organizational capacities will need to be built to derive insights from data being generated.
- Government agencies and institutions can promote IoT interoperability by supporting standards. This will have a significant impact on reducing costs and ensuring greater IoT penetration.[48]

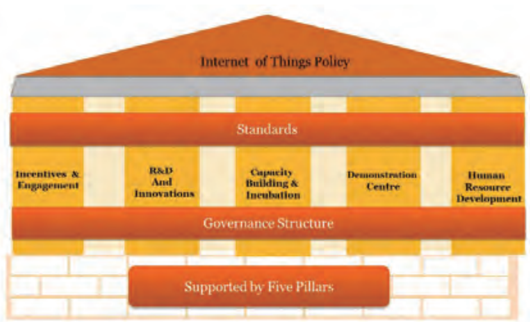
Case: India's IoT Policy

India's Department of Electronics and Information Technology has developed a draft IoT Policy that focuses on the following objectives:

- Create an IoT industry in India of USD 15 billion by 2020. It has been assumed that India would have a share of 5-6 per cent of global IoT industry.
- Undertake capacity development (human and technology) for IoT specific skill sets for domestic and international markets.
- Undertake research and development for all the assisting technologies.
- Develop IoT products specific to Indian needs in all possible domains.

The IoT policy is comprised of five vertical pillars—(1) demonstration centres; (2) capacity building and incubation; (3) research and development and innovation; (4) incentives and engagements; and (5) human resource development—and two horizontal supports—standards and governance structure (Figure 8).[49]

Figure 8: IoT Policy, India



Source: Ministry of Electronics and Information Technology, India, "IoT Policy Document (Draft)". Available from http://meity.gov.in/sites/upload_files/dit/files/Draft-IoT-Policy%20%281%29.pdf.

47 Ibid.

48 Ibid.

49 Ministry of Electronics and Information Technology, India, "IoT Policy Document (Draft)". Available from http://meity.gov.in/sites/upload_files/dit/files/Draft-IoT-Policy%20%281%29.pdf.

6. IoT and the Sustainable Development Goals

IoT can contribute significantly towards realizing some of Sustainable Development Goals (SDGs) (Table 3).

Table 3: IoT and the SDGs

SDG	Goal	Indicative IoT Applications
6 CLEAN WATER AND SANITATION	Ensure availability and sustainable management of water and sanitation for all.	Automated metering and water quality monitoring.
7 AFFORDABLE AND CLEAN ENERGY	Ensure access to affordable, reliable, sustainable and modern energy for all.	Smart grids to reduce transmission and distribution losses, and thefts. Smart homes to improve energy efficiency in consumption. Smart street lightings for fault detection and energy optimization.
11 SUSTAINABLE CITIES AND COMMUNITIES	Make cities and human settlements inclusive, safe, resilient and sustainable.	Air quality monitoring. Solid waste management through smart bins. Traffic monitoring applications and intelligent transport systems. Citizen safety through monitoring devices.

The International Telecommunication Union has been promoting the use of IoT in smart cities through its Study Group 20. The study group has been working to develop standards to enable the coordinated development of IoT technologies in smart cities, including machine-to-machine communications, ubiquitous sensor networks and big data analytics.[50]

50 International Telecommunication Union, "SG20: Internet of Things (IoT) and Smart Cities and Communities (SC&C)". Available from http://www.itu.int/en/ITU-T/studygroups/2017-2020/20/Pages/default.aspx.

Further, a United Nations initiative called, "United for Smart Sustainable Cities" was launched in May 2016.[51] According to the initiative, a smart sustainable city is an innovative city that uses ICTs and other means to improve quality of life, efficiency of urban operation and services, and competitiveness, while ensuring that it meets the needs of present and future generations with respect to economic, social, environmental as well as cultural aspects. This initiative advocates for public policy to encourage the use of ICTs to facilitate and ease the transition to smart sustainable cities.

51 International Telecommunication Union, "United 4 Smart Sustainable Cities". Available from http://www.itu.int/en/ITU-T/ssc/united/Pages/default.aspx.

7. References

Chase, Jim. The Evolution of the Internet of Things. *Texas Instruments*, September 2013. Available from http://www.tij.co.jp/jp/lit/ml/swrb028/swrb028.pdf.

Chui, Michael, Markus Löffler and Roger Roberts. The Internet of Things. *McKinsey & Company*, March 2010. Available from http://www.mckinsey.com/industries/high-tech/our-insights/the-internet-of-things.

Cisco. Cisco Kinetic for Cities Parking Solution. 2017. Available from https://www.cisco.com/c/dam/en/us/products/collateral/se/internet-of-things/at-a-glance-c45-735612.pdf.

Clark, Jen. What is the Internet of Things? 17 November 2016. Available from https://www.ibm.com/blogs/internet-of-things/what-is-the-iot/.

Cooper, Liza. Air pollution in China and IBM green initiatives. *IBM*, 26 August 2016. Available from https://www.ibm.com/blogs/internet-of-things/air-pollution-green-initiatives/.

Donitzky, C., O. Roos and S. Sauty. A Digital Energy Network: The Internet of Things & the Smart Grid. Intel White Paper, 2014. Available from https://www.intel.com/content/dam/www/public/us/en/documents/white-papers/iot-smart-grid-paper.pdf.

ESCAP. *Artificial Intelligence and Broadband Divide: State of ICT Connectivity in Asia and the Pacific*. Bangkok, 2017. Available from http://www.unescap.org/resources/artificial-intelligence-and-broadband-divide-state-ict-connectivity-asia-and-pacific-2017.

Holdowsky, Jonathan, and others. Inside the Internet of Things (IoT). *Deloitte Insights*, 21 August 2015. Available from https://dupress.deloitte.com/dup-us-en/focus/internet-of-things/iot-primer-iot-technologies-applications.html.

International Telecommunication Union. SG20: Internet of Things (IoT) and Smart Cities and Communities (SC&C). Available from http://www.itu.int/en/ITU-T/studygroups/2017-2020/20/Pages/default.aspx.

International Telecommunication Union. United 4 Smart Sustainable Cities. Available from http://www.itu.int/en/ITU-T/ssc/united/Pages/default.aspx.

International Telecommunication Union and CISCO. *Harnessing the Internet of Things for Global Development*. Geneva, 2016. Available from https://www.itu.int/en/action/broadband/Documents/Harnessing-IoT-Global-Development.pdf.

Johnson, Bernadette. How the Internet of Things Works. *How Stuff Works*, no date. Available from http://computer.howstuffworks.com/internet-of-things.htm.

Lawson, Stephen. Is this the year IoT standards will finally make sense? *PCWorld*, 13 January 2017. Available from https://www.pcworld.com/article/3157826/internet-of-things/is-this-the-year-iot-standards-will-finally-make-sense.html.

Lee, Sang Keon, and others. International Case Studies of Smart Cities: Singapore, Republic of Singapore. Inter-American Development Bank Discussion Paper No. IDB-DP-462, June 2016. Available from https://doi.org/10.18235/0000409.

Ministry of Electronics and Information Technology, India. IoT Policy Document (Draft). Available from http://meity.gov.in/sites/upload_files/dit/files/Draft-IoT-Policy%20%281%29.pdf.

Ministry of Urban Development, India. Smart Cities: Mission Statement and Guidelines. June 2015. Available from http://smartcities.gov.in/upload/uploadfiles/files/SmartCityGuidelines(1).pdf.

Miorandi, Daniele, and others. Internet of things: Vision, application and research challenges. *Ad Hoc Networks*, vol. 10, no. 7 (September 2012), pp. 1497–1516. Available from https://doi.org/10.1016/j.adhoc.2012.02.016.

Ramamurthy, Arun. Let's use ICT effectively to implement smart grids in Asia and the Pacific. *Asia Development Blog*, 26 May 2016. Available from https://blogs.adb.org/blog/let-s-use-ict-effectively-implement-smart-grids-asia-and-pacific.

Toch, Eran, and Eyal Feder. International Case Studies of Smart Cities: Tel Aviv, Israel. Inter-American Development Bank Discussion Paper No. IDB-DP-444, June 2016. Available from https://doi.org/10.18235/0000416.

World Bank. *World Development Report 2016: Digital Dividends*. Washington D.C., 2016. Available from https://doi.org/10.1596/978-1-4648-0671-1.

Zanella, Andrea, and others. Internet of Things for Smart Cities. *IEEE Internet of Things Journal*, vol. 1, no. 1 (February 2014), pp. 22–32.

Zennaro, Marco, Bjorn Pehrson and Antoine Bagula. Wireless Sensor Networks: a great opportunity for researchers in Developing Countries. *Proceedings of WCITD2008 Conference, Pretoria, South Africa*, vol. 67 (2008). Available from http://users.ictp.it/~mzennaro/WSN4D.pdf.

Glossary

Artificial intelligence : Learning systems, which with training, can ascribe the correct label to a previously unknown data set with sufficient accuracy.

Augmented intelligence : Technologies that help analyse the collected data from a network of sensors.

Economies of scale : The cost advantage that arises with increased output of a product.

GPS : A radio navigation system that allows land, sea and airborne users to determine their exact location, velocity and time 24 hours a day, in all weather conditions, anywhere in the world.

Intelligent transport system : A technology, application or platform that improves the quality of transportation, or achieves other outcomes based on applications that monitor, manage or enhance transportation systems.

Machine learning : An approach to create artificial intelligence with a focus on developing intelligent systems without the need to explicitly define rules that determine behaviour.

Machine-to-machine communication : Technologies that enable networked devices to exchange information and perform actions without the manual assistance of humans.

Miniaturization : The trend to manufacture ever smaller electronic products and devices.

Sensors : A device that generates an electronic signal from a physical condition or event.

Wearable Sensors : Consumer electronic devices that can be worn on the body as implants or accessories such as a smart watch or a hearing aid.

Acronyms

AI	Artificial Intelligence
GPS	Global Positioning System
ICT	Information and Communication Technology
IoT	Internet of Things
SDG	Sustainable Development Goal

V. 5th Generation Mobile Networks

Contents

List of Figures

1. Introduction

The fifth generation (5G) of mobile communications technology refers to the next mobile wireless standard that is currently under development and will hit the market in 2020. Compared with the current fourth generation (4G) Long Term Evolution (LTE) technology, 5G is targeting to reach higher speed, lower power[1] and lower latency (1ms or less).[2] The minimum requirements for peak data rate are 20 Gbps on the downlink and 10Gbit/s on the uplink.

The following are some of the expected features of the 5G network:

- 10-100 times greater bandwidth than 4G;
- 90 per cent reduction in the ratio of power consumption to service provided, particularly in mobile devices;
- A reliable network to connect over 7 trillion devices in the Internet of Things (IoT) that are controlled by over 7.5 billion people;
- A faster, secure and robust network with near-zero downtime; and
- Enable advanced user controlled privacy.

Previous generations of mobile networks, like the third generation (3G) mobile networks, were considered a breakthrough in communications. 3G receives a signal from the nearest cell tower and is used for phone calls, messaging and data. 4G works the same way as 3G but with a faster Internet connection and lower latency. 4G claims to be around five times faster than existing 3G services and theoretically, it can provide download speeds of up to 100Mbps.

Two significant trends[3] are driving the wireless industry to develop 5G—the explosive increase in demand for wireless broadband services needing faster, higher-capacity networks that can deliver video and other content-rich services; and IoT that is fuelling a need for massive connectivity of devices, and a need for ultra-reliable, ultra-low-latency connectivity over Internet protocol.

1 A low-power wide-area network (LPWAN) interconnects low-bandwidth, battery-powered devices with low bit rates over long ranges. Created for machine-to-machine and IoT communications, LPWANs operate at a lower cost with greater power efficiency than traditional mobile networks. They are also able to support a greater number of connected devices over a larger area.

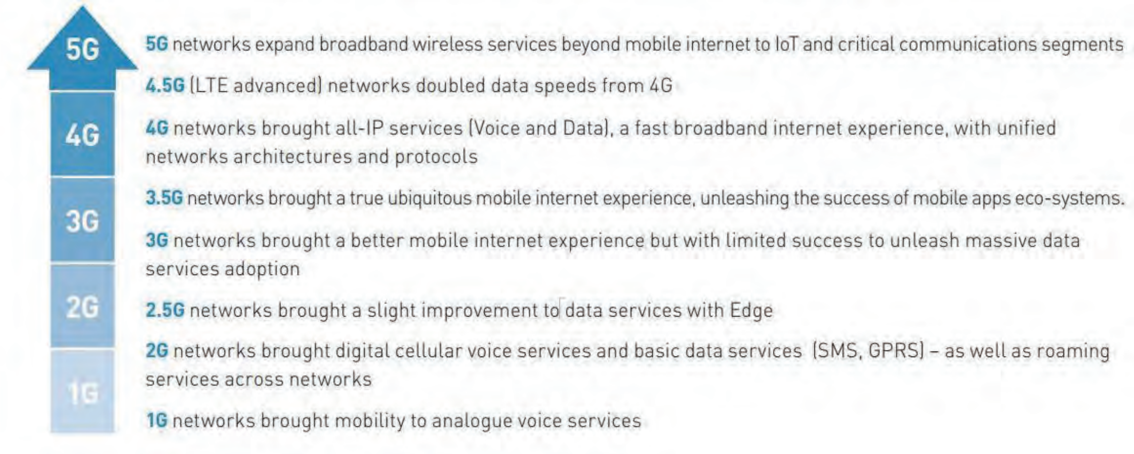
2 Latency is the amount of time a message takes to traverse a system. In a computer network, it is an expression of how much time it takes for a packet of data to get from one designated point to another. It is sometimes measured as the time required for a packet to be returned to its sender. A low latency network is a network in which the design of the hardware, systems and protocols are geared towards minimizing the time taken to move units of data between any two points on that network.

3 Global Mobile Suppliers Association, “The Road to 5G: Drivers, Applications, Requirements and Technical Development”, November 2015. Available from http://www.huawei.com/minisite/5g/img/GSA_the_Road_to_5G.pdf.

The next (5th) generation of mobile communications technology is looking beyond mobile Internet to powering IoT.[4] For example, low latency will provide real-time interactivity for services using the cloud, which is key for the success of self-driving cars. In addition, low-power consumption will allow connected objects to operate for months or years without the need for human assistance.

Unlike current IoT services that make performance trade-offs to get the best from existing wireless technologies, 5G networks are expected to be designed to bring the level of performance needed for massive IoT. It will enable a perceived ubiquitous connected world.

Figure 1: Evolution of Mobile Wireless Networks



Source: Gemalto, "Introducing 5G networks – Characteristics and usages", 2016. Available from http://www.gemalto.com/brochures-site/download-site/Documents/tel-5G-networks-QandA.pdf.

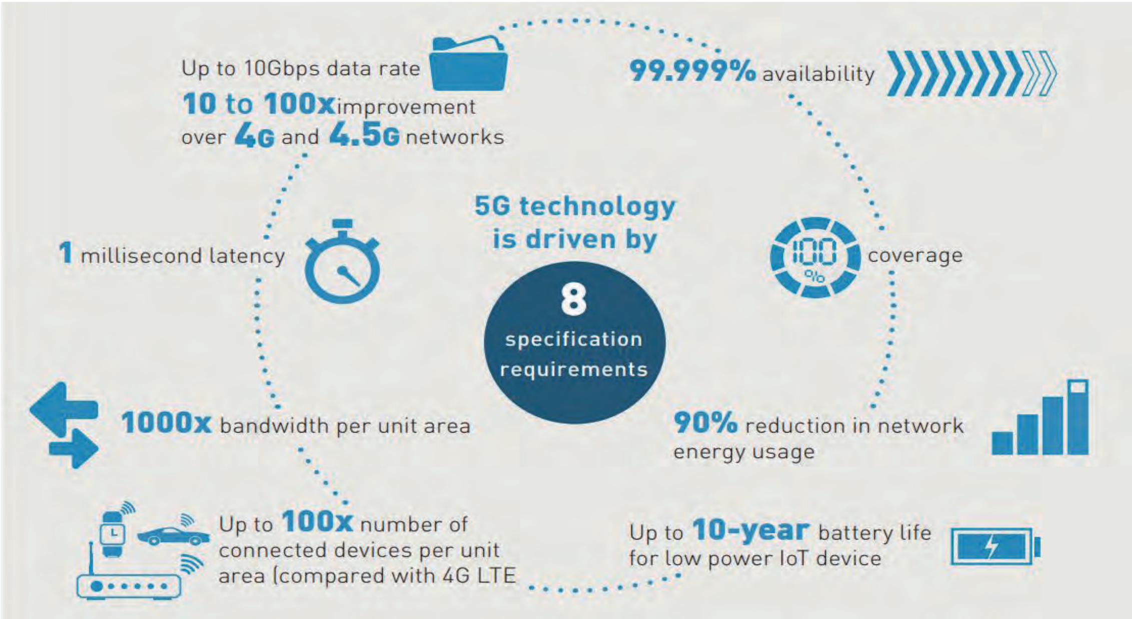
4 IoT is a system of interrelated computing devices, mechanical and digital machines, objects, animals or people that are provided with unique identifiers and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction. IoT has evolved from the convergence of wireless technologies, micro-electromechanical systems and the Internet.

2. Technology and Ecosystem

The ecosystem of 5G consists of network and radio equipment manufacturers, hardware platform providers, software providers, handset providers, app providers, digital service providers and consumers (individuals and industries).

For a connection to qualify for 5G, it should meet eight criteria,[5] which relate to connectivity speeds, round trip delay, minimum bandwidth per unit, scalability of the connected devices, coverage, availability, green initiatives like reduction of the network energy usage and battery life of devices. Figure 2 provides the criteria details.

Figure 2: Criteria to Qualify for 5G



Source: Gemalto, "Introducing 5G networks – Characteristics and usages", 2016. Available from http://www.gemalto.com/brochures-site/download-site/Documents/tel-5G-networks-QandA.pdf.

5 GSMA, *The Mobile Economy* 2017 (London, 2017). Available from https://www.gsmaintelligence.com/research/?file=9e927fd6896724e7b26f33f61db5b9d5&download.

The development of 5G is introducing a re-architecture of the core, incorporating new technologies and approaches that have emerged in the networking industry such as software-defined networking,[6] network functions virtualization,[7] and mobile edge computing,[8] to name a few. In addition, the architecture is required to support sharing infrastructure, providing various levels of "as-a-service" offerings leading to complex architectures. As 5G will be driven by software and network, functions will run over a unified operating system. In fact, 5G can be considered a completely different system rather than an evolution of 4G.

5G will support a heterogeneous set of integrated interfaces from evolutions of previous generations to brand new technologies. Seamless handover between heterogeneous wireless access technologies like Wi-Fi to mobile and vice versa will be a native feature of 5G. It will use simultaneous radio access technologies[9] to increase reliability and availability. The deployment of ultra-dense networks[10] with numerous small cells[11] will require new interference mitigation,[12] backhauling[13] and installation techniques. 5G will ease and optimize network management operations.[14] The exploitation of data analytics and big data techniques will pave the way to monitor users' quality of experience.

---

6 Software-defined networking is an architecture purporting to be dynamic, manageable, cost-effective and adaptable, seeking to be suitable for the high-bandwidth, dynamic nature of present day applications. Software-defined networking architectures decouple network control and forwarding functions, enabling network control to become directly programmable and the underlying infrastructure to be abstracted from applications and network services.

7 Network functions virtualization is a network architecture concept that uses the technologies of information technology virtualization to virtualize entire classes of network node functions into building blocks that may connect, or chain together, to create communication services. Network functions virtualization relies upon, but differs from, traditional server-virtualization techniques, such as those used in enterprise information technology. A virtualized network function may consist of one or more virtual machines running different software and processes, on top of standard high-volume servers, switches and storage devices, or even cloud computing infrastructure, instead of having custom hardware appliances for each network function.

8 Mobile edge computing is a network architecture concept that enables cloud computing capabilities and an information technology service environment at the edge of the cellular network. The basic idea behind mobile edge computing is that by running applications and performing related processing tasks closer to the cellular customer, network congestion is reduced, and applications perform better. This technology is designed to be implemented at the cellular base stations, and enables flexible and rapid deployment of new applications and services for customers. Combining elements of information technology and telecommunications networking, mobile edge computing also allows cellular operators to open their radio access network to authorized third parties, such as application developers and content providers.

9 5G radio access will be built upon both new radio access technologies and evolved existing wireless technologies (LTE, HSPA, GSM and Wi-Fi).

10 Ultra-dense network is a technique to meet the requirements of explosive data traffic in 5G mobile communications.

11 Small cells (also known as femtocell and picocell) can improve the coverage and capacity of cellular networks by exploiting spatial reuse of limited spectrum. Dense small cells can also offload the wireless data traffic of user equipment from traditional macrocells, especially for an indoor environment where more than 80 per cent of data traffic takes place.

12 Interference is the chief limiting factor in high-capacity mobile communications. Interference is responsible in many cases for dropped calls, slow download speeds and shortened battery life. Using high speed parallel processing digital signal processors and computer processing units (DSP/CPU@50 billion operations per second) for signal processing in combination with multiple-input and multiple-output antenna systems, the interference can be mitigated from multiple sources.

13 Backhaul is a challenge in 5G due to the use of small cells supporting high bandwidth. Densification of small cells produces massive backhaul traffic in the core network, which inevitably becomes a bottleneck in the system. Employing fibre or cable in dense small cell backhaul would result in prohibitively high cost and practical difficulty in implementation. Wireless backhaul in millimetre wave is considered a possible cost-effective solution.

14 Network management is the process of administering and managing the 5G network covering fault analysis, performance management, provisioning of network and network devices, and maintaining the quality of service.

The service provider has many new challenges to address in 5G as the type of usage, network design and architecture of the system go through complete changes. 5G will trigger mobile edge computing as it enables massive amounts of data to pour in from the edge. This will require shared edge computing resources at switching centres and base stations using network functions virtualization. All this computing, coupled with the associated management and orchestration required to operate it, will result in a distributed and dynamically configurable service provider infrastructure. Hence, a service provider has to shift from being a telecom operator to a digital service provider covering the mobile infrastructure and computing to support the new applications and surge of data that will come because of the new applications.

5G is expected to be a convergence of network built on virtualized computing platforms, using ultra-dense network architectures, radio technologies with small cells and millimetre wave backhauls. The convergence encompasses usage of big data and analytics for enhancement of the service experience. Hence, many institutions, including technological companies and research organizations are collaborating to develop these technologies. Some of the key areas of research are described below.

Centimetre and Millimetre Wave

There is a significant amount of spectrum available at higher frequencies. 5G technology is looking beyond the congested centimetre waves that are occupied by the current 3G and 4G networks. The advantage of using millimetre waves for mobile communication is their wide channel bandwidth of 1-2 gigahertz in contrast to the current bandwidths of 10-20 megahertz.

Massive Dense Networks

Massive dense networks provide higher data rates to more users. It is being used in existing technologies like LTE (4G) and Wi-Fi, but the number of antennas is restricted. With the use of millimetre waves in 5G communication, massive dense networks can theoretically use an infinite number of antennas.

Battery Life

Batteries that can last for years are very important in IoT networks as the machine connected to the network may not be near a power source. 5G technology will be characterized with more efficient use of power for extended battery life. This will cover terminal devices, network elements and the network as a whole, including data centres. For example, recommendations are to enable a 10-year battery life for a battery-powered sensor. However, it is not very clear how this efficiency will be achieved in the practical roll out of 5G.

Cognitive or Smart Radio Technology

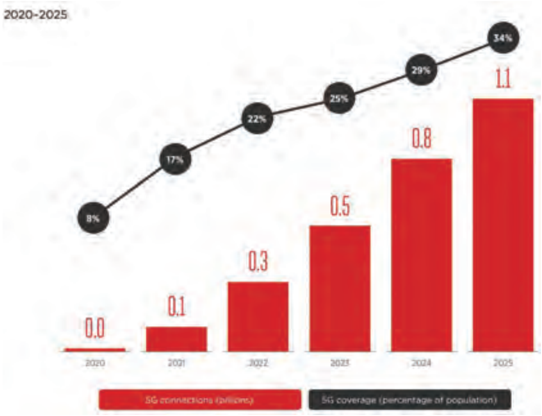
Cognitive or smart radio technology is a dynamically programmable radio system where the transmission and reception of signals is designed to use the best available channel in the proximity.

Pervasive or Ubiquitous Network

Ubiquitous network allows the user to be connected to different wireless technologies like 2G, 3G, 4G and Wi-Fi simultaneously, and can switch between them without any issues.

3. 5G Opportunity

Figure 3: 5G Adoption



Source: GSMA, *The Mobile Economy* 2017 (London, 2017). Available from https://www.gsmaintelligence.com/research/?file=9e927fd6896724e7b26f33f61db5b9d5&download.

Early 5G networks[15] will be deployed in dense urban areas as operators look to supplement existing mobile broadband capacity, and at the same time provide a test-bed for 5G use cases to emerge. Operators are expected to roll out 5G at a similar rate to the deployment of 4G, attaining coverage of 34 per cent of the global population (2.6 billion people) by 2025. Adoption will scale rapidly, as device vendors see the technology as a means to differentiate devices, while the fact that average selling prices for smartphones have declined since the launch of 4G means affordability will prove less of a barrier to ownership. 5G connections (excluding cellular machine-to-machine connections) are anticipated to reach 1.1 billion by 2025. Industry reports claim that by 2035, "5G's full economic benefit should be realized across the globe", and could produce up to USD 12.3 trillion worth of goods and services.[16] Qualcomm's study indicates that the 5G value chain itself is seen as generating up to USD 3.5 trillion in revenue by 2035. The study further claims that, over time, 5G will boost real global GDP growth by USD 3 trillion cumulatively from 2020 to 2035, roughly the equivalent of adding an economy the size of India.

Ovum[17] estimates that 5G services will be available in over 30 countries worldwide by the end of 2021, with services in all four major world regions. However, the report indicates that the vast majority of 5G subscriptions will be concentrated in China, Japan, Republic of Korea and United States of America where major operators have revealed aggressive timelines for launching 5G

15 GSMA, *The Mobile Economy* 2017 (London, 2017). Available from https://www.gsmaintelligence.com/research/?file=9e927fd6896724e7b26f33f61db5b9d5&download.

16 Qualcomm, "Landmark Study on Impact of 5G Mobile Technology Released", 17 January 2017.Available from https://www.qualcomm.com/news/releases/2017/01/17/landmark-study-impact-5g-mobile-technology-released.

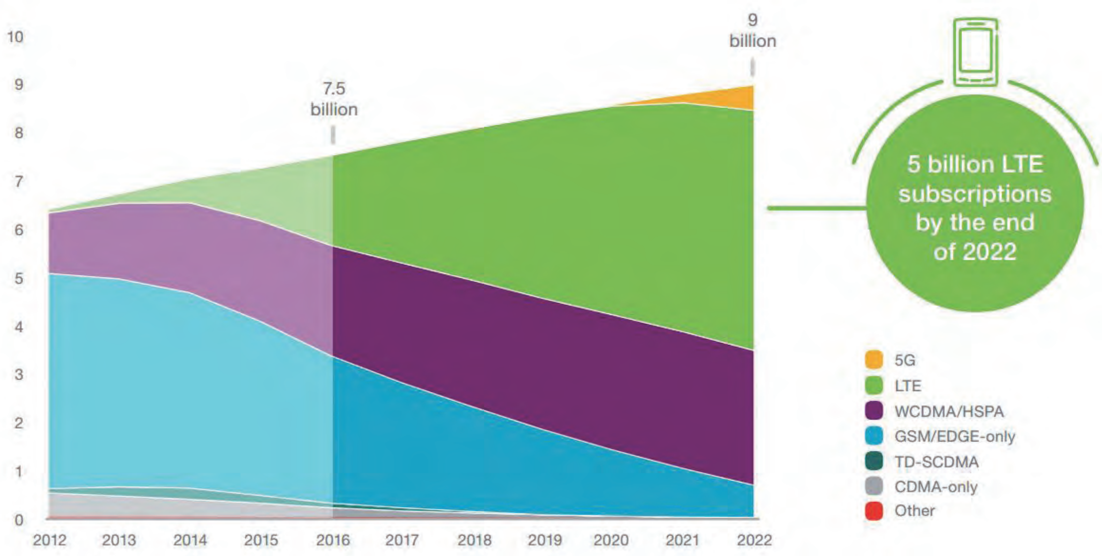
17 Mike Roberts, "Ovum: 5G will be available in nearly 30 countries by 2021", *Telecom Asia*, 7 February 2017. Available from https://www.telecomasia.net/content/ovum-5g-will-be-available-nearly-30-countries-2021.

services. Industry reports state that by 2023, the number of 5G subscriptions[18] will reach more than 500 million.[19]

In April 2017, United States telecoms giant AT&T[20] announced a list of 20 cities where it will initiate its first 5G roll out campaigns. The company has dubbed the high-speed network plans the "5G Evolution" and has indicated that it will we be able to provide top speeds of up to 400Mbps.

AT&T is racing against its top rival, Verizon, to deploy the first commercial 5G in the USA. Verizon is in the midst of launching ten 5G market trials across the country in both dense urban and suburban areas beyond its local exchange carrier footprint. Verizon[21] released its 5G specifications to vendors in 2016, which it said was intended to assist vendors in developing interoperable 5G equipment for pre-standard testing and fabrication. The company has been trialling, what it calls "wireless fibre", since February 2017.

Figure 4: Mobile Subscriptions by Technology



Source: Ericsson, *Ericsson Mobility Report* (Stockholm, 2017). Available from https://www.ericsson.com/assets/local/mobility-report/documents/2017/ericsson-mobility-report-june-2017.pdf.

18 A 5G subscription will require a device capable of supporting 5G services and use cases, which is connected to a 5G-enabled network.

19 Ericsson, *Ericsson Mobility Report* (Stockholm, 2017). Available from https://www.ericsson.com/assets/local/mobility-report/documents/2017/ericsson-mobility-report-june-2017.pdf.

20 AT&T, "AT&T Plans to Bring 5G Evolution to Over 20 Metros by End of Year", 25 April 2017 Available from http://about.att.com/story/5g_evolution_to_over_20_metros_in_2017.html.

21 Diana Goovaerts, "Verizon Announces 5G Customer Trials in 11 Cities with 5G Forum Partners", *Wireless Week*, 22 February 2017. Available from https://www.wirelessweek.com/news/2017/02/verizon-announces-5g-customer-trials-11-cities-5g-forum-partners.

Case: 5G-Related Efforts being Adopted by Different Countries

The Government of the Republic of Korea has recently announced plans to expand the bandwidth allocated to 5G mobile services by 2018, when the country will host the Pyeongchang Winter Olympic Games. The Ministry of Science and ICT will share bandwidth in the 1.3GHz range between the country's three mobile carriers, Korea Telecom, SK Telecom and LG Uplus.[22]

In China, the leading telecom operator China Mobile said that it would begin major trials for 5G in 2018, kicking off a new round of billions of dollars in investment to usher in the high-speed communications era of the IoT. The company said it would test the technology for about two years and launch 5G commercial services in 2020.[23]

Press statement from Nokia announced partnerships with Airtel and BSNL for preparing 5G networks in India to support IoT and future smart cities. The partnerships will explore operations, cost-effectiveness, quality and reliability, and develop a strategy for rolling out 5G.[24]

22 The Korea Herald, "South Korea mobile carrier KT begins installing 5G network in PyeongChang", 18 September 2017. Available from http://www.nationmultimedia.com/detail/Startup_and_IT/30326959.

23 Qin Min and Yang Ge, "China Mobile Plans to Launch 5G Trials in 2018", *Caixin Global*, 21 December 2016. Available from https://www.caixinglobal.com/2016-12-21/101029326.html.

24 Money Control, "Nokia inks MoUs with Airtel and BSNL to bring 5G network in India", 10 April 2017. Available from http://www.moneycontrol.com/news/business/companies/nokia-signs-mous-with-airtel-and-bsnl-to-bring-5g-network-in-india-2255549.html.

4. 5G Standards

As 5G develops globally, it is the adoption of standards that will define its ubiquitous use and widespread deployment. The International Telecommunication Union launched "International Mobile Telecommunications for 2020 and Beyond" in 2012, setting the stage for 5G standards development and roll out. A number of standards bodies are actively working towards the goal of setting standards for 5G by 2020. They include, but are not limited to the Institute of Electrical and Electronics Engineers, Internet Engineering Task Force, International Telecommunication Union and the 3rd Generation Partnership Project (3GPP).[25] The first set of 5G standards is scheduled to be released by 3GPP in 2018.

In addition, Audi, BMW, Daimler, Ericsson, Huawei, Intel, Nokia and Qualcomm announced in September 2016 the formation of the "5G Automotive Association"[26] with the goal of addressing issues around connected mobility and road safety in the IoT era. Vodafone has joined the association and has begun testing LTE-V2X, a new technology for vehicle-to-vehicle communications.

The main activities of the association include: defining and harmonizing use cases, technical requirements and implementation strategies; supporting standardization and regulatory bodies, certification and approval processes; addressing vehicle-to-everything technology requirements, such as wireless connectivity, security, privacy, authentication and distributed cloud architectures; and running joint innovation and development projects.

Meanwhile, a large number of joint research and trials are going on to ensure a strong presence and play in the 5G arena by equipment manufacturers, service providers and governments of many countries. Some of the trials and announcements of trials include the following:[27]

- Japan and the Republic of Korea started to work on 5G requirements in 2013.
- Samsung, Huawei and Ericsson started 5G prototype development in 2013.
- NTT DoCoMo, Japan conducted the first set of 5G experimental trials in 2014.
- AT&T tested 5G wireless service in Austin, Texas in 2017.
- Fujitsu demonstrated speed rates at 56 Gbps in 2017.
- The Republic of Korea's SK Telecom plans to demo 5G in 2018 at the Pyeongchang Winter Olympics.

25 3GPP unites seven telecommunications standards development organizations—ARIB, ATIS, CCSA, ETSI, TSDSI, TTA and TTC—known as "Organizational Partners" and provides their members with a stable environment to produce the reports and specifications that define 3GPP technologies. The project covers cellular telecommunications network technologies, including radio access, the core transport network and service capabilities, including work on codecs, security and quality of service, and thus provides complete system specifications. The specifications also provide hooks for non-radio access to the core network, and for interworking with Wi-Fi networks. 3GPP specifications and studies are contribution-driven, by member companies, in working groups and at the technical specification group level. See 3GPP, "About 3GPP". Available from http://www.3gpp.org/about-3gpp.

26 Sacha Kavanagh, "What is the 5G Automotive Association?" *5G.co.uk*, no date. Available from https://5g.co.uk/guides/what-is-the-5g-automotive-association/.

27 Gemalto, "Introducing 5G networks – Characteristics and usages", 2016. Available from http://www.gemalto.com/brochures-site/download-site/Documents/tel-5G-networks-QandA.pdf.

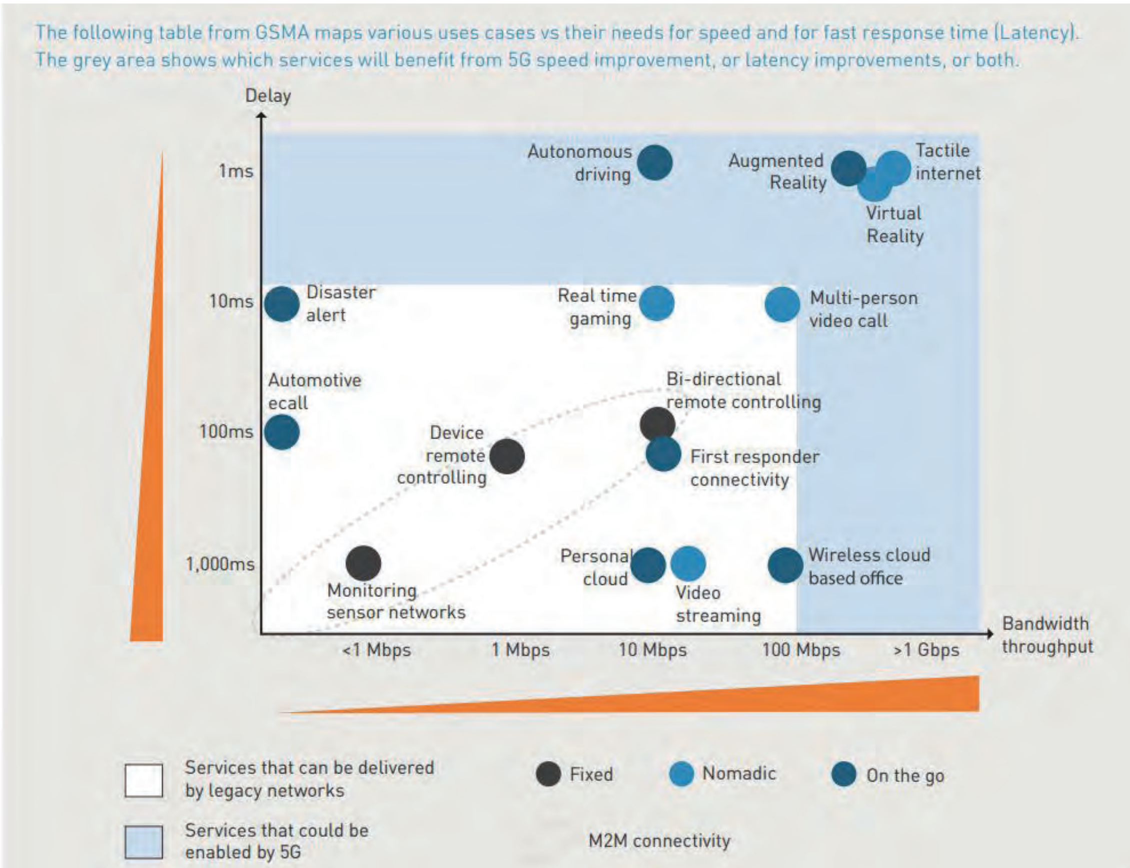
- Megafon, Russia has started to trial 5G networks for eleven cities hosting the FIFA 2018 World Cup, involving machine-to-machine connections and human users.
- Ericsson and Telia Sonera plan to make 5G commercial service available in Stockholm and Talinn by the end of 2018.
- Japan’s target is to launch 5G for the 2020 Tokyo Summer Olympics.

5. 5G Applications

5G technology will contribute significantly to the growth of many industries, including education, health, information technology, entertainment, automobiles and manufacturing, many of which have links with various SDG goals and targets. Before going into specific use cases of 5G, it is important to understand the relation between the type of services and technology capabilities in various generations.

Figure 5 shows the applications and the speeds that are needed for usage of various applications on a mobile network. In Figure 5, the applications in the blue area will benefit from higher speeds and throughputs that are available in 5G, which makes them the first types of use cases by default. Some key applications like self-driving cars require very aggressive latency (fast response time) while they do not require fast data rates. Conversely, enterprise cloud-based services with massive data analysis will require speed improvements more than latency improvements.

Figure 5: Applications and Required Speeds



Source: Gemalto, "Introducing 5G networks – Characteristics and usages", 2016. Available from http://www.gemalto.com/brochures-site/download-site/Documents/tel-5G-networks-QandA.pdf.

Figure 6 gives a good overview of how the current services and new use cases will evolve as a response to the availability of 5G, including the gains that will accrue due to usage of 5G in those services.

Figure 6: Services and 5G Experiences

Examples of use case evolution and supporting network technologies

	Current services	On the road to 5G	5G experiences
Enhanced mobile broadband	Browsing, social media, music, video	Fixed Wireless Access, interactive live concerts and sport events	4K/8K videos, mobile AR/VR gaming, immersive media
Automotive	Wi-Fi hotspots, on-demand GPS map data	Predictive vehicle maintenance, capturing real-time sensor data for different services	Autonomous vehicle control, cooperative collision avoidance, vulnerable road user discovery
Manufacturing	Connected goods, intra-inter enterprise communication	Process automation and flow management, remote supervision and control of machines and materials	Remote control of robots, augmented reality support in training, maintenance, construction, repair
Energy and utilities	Smart metering, dynamic and bidirectional grid	Distributed energy resource management, distribution automation	Control of edge-of-grid generation, virtual power plant, real-time load balancing
Healthcare	Remote patient monitoring, connected ambulance, electronic health records	Telesurgery, augmented reality aiding medical treatment	Precision medicine, remote robotic surgery
Network technologies	> Multi-standard network > Cat-M1/NB-IoT > Cloud optimized network functions > VNF orchestration	> Gigabit LTE > Massive MIMO > Network slicing > Dynamic service orchestration > Predictive analytics	> New Radio (NR) > Virtualized RAN > Federated network slicing > Distributed cloud > Real-time machine learning/AI

Source: Ericsson, *Ericsson Mobility Report* (Stockholm, 2017). Available from https://www.ericsson.com/assets/local/mobility-report/documents/2017/ericsson-mobility-report-june-2017.pdf.

Some of the applications enabled by 5G are described below.

5.1 Virtual Reality or Tactile Internet

An example of the use of virtual reality or tactile Internet technology is the remote-controlled surgery robot, which requires high bandwidth and low latency. Such systems are still in early stages of development and are highly dependent on other systems like motion sensors and displays. They are defined as super-low latency Internet applications to meet human level response time. When available this will find use in critical areas such as medical nano-surgery where surgeons may use intra-body robotics systems to perform microsurgeries. The impact of tactile Internet has the potential to also revolutionize the gaming industry. It may enable new virtual reality user interfaces where applications will meet human senses response time.

5.2 Autonomous Cars

Autonomous driving or smart cars and connected cars are automobiles that can communicate with the external environment or with other cars so that the road journey will be safer. The need for 5G specifications for autonomous cars is better explained with an example. A car running at 100km/h will move 27.6m every second, or 2.7cm every millisecond. If the road sensors capture an unexpected event on the road, <1ms network(s) latency specified by 5G means that the information will reach the car from the cloud in a time frame that corresponds to less than 1-metre motion (between the time the event occurred and the time the car control system gets the information).

5.3 Drones

Drones and unmanned flying vehicles are finding increasing use in military and civilian applications. Usage of drones for aerial mapping, photography and warfare are established use cases. Amazon is planning to use drones to deliver packages to homes. As the drone-based delivery system is being considered, the issue of managing them, collecting information from them and being able to control them are limited by the latency and bandwidth of today's networks. With 5G, low latency will lead to fast response time, LAN and WAN combination will support fast moving drones, high-speed data rates will allow the exploitation of massive quantities of navigation data, and sensors to actuators communications will enable complex navigation software heuristics.

5.4 Internet of Things

IoT is a concept where a number of devices—machines, appliances or systems—are connected to each other and sense, process and transfer data among them without any human control. These could include industry and production systems in automotive, manufacturing and precision services sectors, logistics and distribution, and the consumer goods sector. Such systems require a reliable, high-bandwidth and low-latency network, and will work with the specifications of large bandwidth and high connection density over small areas, which is offered by 5G.

5.5 Machine-to-Machine Connectivity

The best example of machine-to-machine communication is in a smart home automation system where different devices like meters, temperature controls, security alarms and smoke detectors are connected and communicate with each other, and work efficiently. Some of the other machine-to-machine communication systems are deployed in consumer electronics, automobile telemetry and automated health monitoring. Most of these connections are still using either 2G or 3G networks. There may not be an immediate transition to 5G technology but eventually all machine-to-machine connections will make use of 5G technology.

5.6 Wireless Cloud Computing

A wireless cloud office is where huge amounts of data can be stored and accessed remotely. This is possible with high-bandwidth communication systems. The present 4G network has the potential to deliver this service. However, with user data running into 71 exabytes per month by 2020[28] and content that is based largely on video, such applications need 5G.

5.7 Multi-Person Video Calling

Another service where bandwidth and latency are important is multiple-person video conference. The application requires low latency and committed throughputs that the existing 4G technology can barely provide.

---

28 Ericsson, *Ericsson Mobility Report* (Stockholm, 2017). Available from https://www.ericsson.com/assets/local/mobility-report/documents/2017/ericsson-mobility-report-june-2017.pdf.

6. Policy and Regulatory Issues

In the mobile world, regulators have a huge influence on the ability to deliver innovative services to the end users. The value of 5G will be unleashed when regulators respond to the needs of the operators while safeguarding spectrum and ensuring a level playing field for all the service providers.

Customers may be increasingly looking to buy virtualized services, not simple network access, as a dynamic way to enhance their experience. As part of this strategic approach, competitive carriers are looking at technologies like Internet protocol switches that have virtualized components, or other network equipment that is beginning to contemplate virtualization, as well as the spectrum to deliver a 5G experience.

High-band spectrum can carry large data at fast speeds, but its reach is only a few hundred metres. With exponentially more small cells and dense networks, the need for dedicated backhaul will skyrocket as wireless carriers purchase business data services from wireline providers. The regulator plays a significant role in how this market operates, and decisions on these issues could jumpstart deployment or act as a barrier. In addition to backhaul, these new small cells must be constructed, but first cleared for historical and environmental review. Policies must reflect that the “towers” of today and tomorrow may fit in one’s palm in order to be relevant for years to come.

To ensure their citizens and companies can harness the potential benefits of 5G mobile technologies, governments need to act now. In particular, policymakers need to take steps to make sufficient spectrum available once the first commercial 5G networks go live from 2020.

The World Radiocommunication Conference in 2019 is an important conference in this respect. In the process of preparing for the conference, governments have the opportunity to identify harmonized spectrum for 5G. Global harmonization of the frequency bands used for mobile technologies and services enables the industry to develop low-cost devices, support international roaming and minimize cross-border interference. If governments fail to agree to a common set of bands, then 5G spectrum could become fragmented, which could drive up device costs and undermine access to widespread and affordable 5G. Mobile operators will need internationally harmonized spectrum in three different ranges—below 1 GHz, 1-6 GHz and above 6 GHz.

Governments will also need to ensure that regulation, the cost of spectrum and the obligations placed on licence holders support the roll out of 5G and do not create unnecessary roadblocks. Given the large number of small cell sites required to deliver ultra-high speeds, 5G deployments will require significant network investment. An unfavourable regulatory environment and/or excessive fees could compromise the speed of 5G deployments, quality of service and coverage levels.

For smaller carriers serving markets that the largest carriers do not, transitioning to 5G networks can provide new opportunities to work collaboratively with developers and their peers to bring the latest mobile services to the market. Hosted platforms, in whole or in part, may unlock new services and opportunities for carriers at lower costs and faster time to market than if they do it alone.

For carriers, real growth will come from the new and innovative connected services. For instance, in the rural parts of a country where mobile broadband may be the only access to the Internet, how can local carriers provide functionality that allows farmers to monitor crops or livestock via the 5G network? What remote healthcare services will be developed, and how can rural carriers deliver these services via telemedicine?

4G networks today use the universal subscriber identity module (USIM) application to perform strong mutual authentication between the user, his/her connected device and the networks. The entity hosting the USIM application can be a removable SIM card or an embedded UICC chip. Such a strong mutual authentication is crucial to enable trusted services. Security solutions today are already a mix between security at the edge (device) and security at the core (network). Several security frameworks may co-exist in the future and 5G is likely to re-use existing solutions used today for 4G networks and for the cloud. The standard for strong mutual authentication for 5G networks is not finalized yet. The need for security, privacy and trust will be as strong as for 4G if not stronger with the increased impact of IoT services.

5G needs new bands of frequency spectrum and many of these bands have never been allotted before. The allocation size spans many megahertz and as a limited resource, it needs to be shared between many operators in a transparent and fair manner. The prices for spectrum should balance against the development agenda and enable sustainable development.

5G needs ultra-small towers (cells) and these need a completely different method of regulation, far different from that applied to the cell towers today. The frequency reuse and spectral efficiency are achieved only with the right quality of equipment and when power is managed stringently.

The challenge of 5G is much more than the previous generation of mobile communications technology. Until 4G, the devices are limited to mobile devices, tablets, laptop dongles and other similar devices. However, in 5G, machine-to-machine type of networks like IoT, autonomous cars and drones could be involved. The regulation has to go beyond the purview of information and communication technology, and enter into realms of industrial electronics, industrial process and control, and automobiles. The complexity arises from the cross-domain reach that is necessary for both specifications and regulation of the technology in its production as well as its use.

The dangers of fallouts are unfathomable. A drone useful for delivery of a book can well be used for delivery of a bomb. The number of connected subscribers and the reach of the network are overwhelming, and the ability to do anything and everything with the network is an opportunity and a threat at the same time. The use cases involving complex industrial systems in a network open up a Pandora box of issues relating to how the network is secured from the core to the edge from any attacks by hackers.

Every technology wave brings along certain opportunities and threats. 5G is such a technology, which is on the horizon, promising a great deal of value to society, and at the same time opening a set of issues that is completely new for policymakers and government to deal with.

7. References

AT&T. AT&T Plans to Bring 5G Evolution to Over 20 Metros by End of Year. 25 April 2017 Available from http://about.att.com/story/5g_evolution_to_over_20_metros_in_2017.html.

Ericsson. *Ericsson Mobility Report*. Stockholm, 2017. Available from https://www.ericsson.com/assets/local/mobility-report/documents/2017/ericsson-mobility-report-june-2017.pdf.

Gemalto. Introducing 5G networks – Characteristics and usages. 2016. Available from http://www.gemalto.com/brochures-site/download-site/Documents/tel-5G-networks-QandA.pdf.

Global Mobile Suppliers Association. The Road to 5G: Drivers, Applications, Requirements and Technical Development. November 2015. Available from http://www.huawei.com/minisite/5g/img/GSA_the_Road_to_5G.pdf.

Goovaerts, Diana. Verizon Announces 5G Customer Trials in 11 Cities with 5G Forum Partners. *Wireless Week*, 22 February 2017. Available from https://www.wirelessweek.com/news/2017/02/verizon-announces-5g-customer-trials-11-cities-5g-forum-partners.

GSMA. *The Mobile Economy 2017*. London, 2017. Available from https://www.gsmaintelligence.com/research/?file=9e927fd6896724e7b26f33f61db5b9d5&download.

Kavanagh, Sacha. What is the 5G Automotive Association? *5G.co.uk*, no date. Available from https://5g.co.uk/guides/what-is-the-5g-automotive-association/.

Money Control. Nokia inks MoUs with Airtel and BSNL to bring 5G network in India. 10 April 2017. Available from http://www.moneycontrol.com/news/business/companies/nokia-signs-mous-with-airtel-and-bsnl-to-bring-5g-network-in-india-2255549.html.

Qin Min and Yang Ge. China Mobile Plans to Launch 5G Trials in 2018. *Caixin Global*, 21 December 2016. Available from https://www.caixinglobal.com/2016-12-21/101029326.html.

Qualcomm. Landmark Study on Impact of 5G Mobile Technology Released. 17 January 2017. Available from https://www.qualcomm.com/news/releases/2017/01/17/landmark-study-impact-5g-mobile-technology-released.

Roberts, Mike. Ovum: 5G will be available in nearly 30 countries by 2021. *Telecom Asia*, 7 February 2017. Available from https://www.telecomasia.net/content/ovum-5g-will-be-available-nearly-30-countries-2021.

The Korea Herald. South Korea mobile carrier KT begins installing 5G network in PyeongChang. 18 September 2017. Available from http://www.nationmultimedia.com/detail/Startup_and_IT/30326959.

Glossary

2G : Second generation of mobile communications technology (GSM, CDMA 1x).

3G : Third generation of mobile communications technology (WCDMA/HSPA, TD-SCDMA, CDMA EV-DO, Mobile WiMAX).

4G : Fourth generation of mobile communications technology (LTE, LTE-A)

App coverage : The geographical area within which an app works as expected by the user. This means that each app has its own coverage map. App coverage can be measured as the probability that a mobile broadband network delivers sufficient performance for a good user experience for that app.

Smartphones : Mobile phones with open operating systems, for example, iPhones, Android phones and Windows phones, as well as Symbian phones and BlackBerry phones.

Acronyms

2G	Second Generation (of Mobile Communications Technology)
3G	Third Generation (of Mobile Communications Technology)
3GPP	3rd Generation Partnership Project
4G	Fourth Generation (of Mobile Communications Technology)
5G	Fifth Generation (of Mobile Communications Technology)
GHz	Gigahertz
Gpbs	Gigabits per Second
IoT	Internet of Things
LTE	Long Term Evolution
Mbps	Megabits per Second
USIM	Universal Subscriber Identity Module

Ⅵ. Artificial Intelligence and Machine Learning

Contents

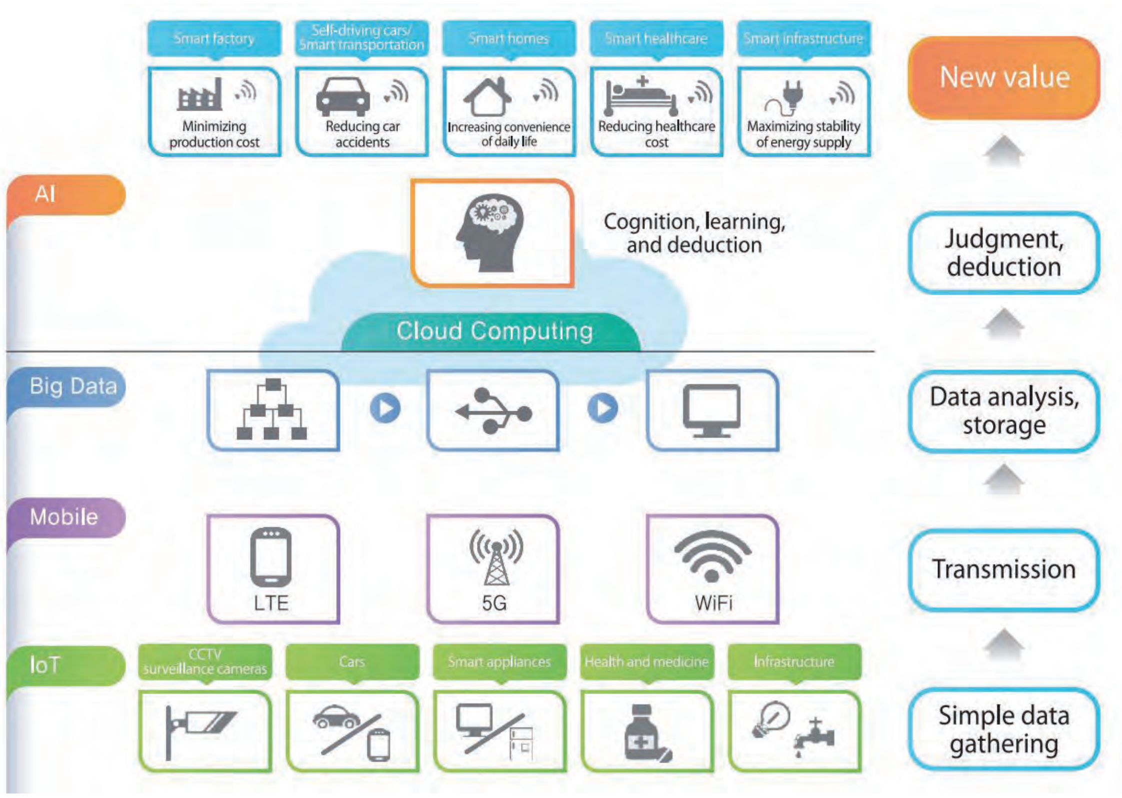
List of Figures

1. Introduction

The essence of intelligence is learning. Just as humans learn how to communicate, identify visual patterns or drive a car, efforts are underway to train machines to perform such tasks based on powerful learning algorithms. A common method of training machines consists of providing them with labelled data, e.g., photographs of cats combined with the word "cat" as a label. Such machines are then said to possess artificial intelligence (AI) if they can, given their training, ascribe the correct label to a previously unknown data set with sufficient accuracy. Following the previous example, a machine would then be able to identify a cat in an unfamiliar photograph.

Typical applications of AI include autonomous driving, computer vision, decision-making and natural language processing (NLP). AI holds the benefit of being adaptable to very heterogeneous contexts just like humans. Well-trained AI is capable of performing certain tasks at the same skill level as humans but with the additional advantages of high scalability, error-free operations and continuity. AI can discover patterns in the data that are too complex for human experts to recognize. In some specific applications such as computer vision, AI has already achieved performance levels surpassing that of humans (e.g., in skin cancer diagnostics and finger print analysis). Some potential application areas of AI and their linkages to other emerging information and communication technologies (ICTs) are given in Figure 1.

Figure 1: AI and the Emerging ICT Landscape



The idea of AI dates back to the 1950s when AI successes were largely limited to the scientific field. In the last few years, the gap has been bridged between science and business applications. Their usage is fuelled by the abundance of data, algorithmic advances and the application of high-performance hardware for parallel processing.

In the industrial sector, AI application is supported by the increasing adoption of devices and sensors connected through the Internet of Things (IoT),[1] production machines, autonomous vehicles[2] and devices carried by humans, which generate enormous amounts of data.

Among the many branches and connections feeding into AI, machine learning (ML) is the dominant methodology or major component of implementing AI. ML is an approach to creating AI and is focused on developing intelligent systems without the need to explicitly define rules that determine behaviour. ML allows a system to evolve with changing environmental conditions and this is critical for a system or service to move from the state of being managed to one of being optimized.

As most AI systems today are based on ML, both terms are often used interchangeably. In this report, both terms will also be used interchangeably.

According to Tractica, the global AI software industry will grow from USD 1.4 billion in 2016 to USD 59.8 billion by 2025.[3] Many enterprises are working on different areas of AI and approaching it from very contrasting dimensions. IBM has pledged to invest USD 3 billion to make its Watson cognitive computing service a force in the IoT. Baidu, the Chinese Internet giant announced in September 2017 that their Apollo Fund would invest CNY 10 billion (USD 1.5 billion) in over 100 autonomous driving projects over the next three years.[4]

AI is expected to enable the automation of knowledge work, or tasks that require judgement or creative problem solving.[5] AI-based solutions can potentially increase productivity by 40-50 per cent for 290 million knowledge workers globally by 2025, generating a USD 5.2 trillion-6.7 trillion economic impact annually, of which USD 4.3 trillion-5.6 trillion will be felt in developed markets, where increases in automation could drive additional productivity equivalent to 75 million-90 million full-time workers.

---

1 IoT is a system of interrelated computing devices, mechanical and digital machines, objects, animals or people that are provided with unique identifiers and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction. IoT has evolved from the convergence of wireless technologies, micro-electromechanical systems and the Internet.

2 An autonomous vehicle, also called driverless car, self-driving car or automated car, is a robotic vehicle that is designed to travel between destinations without a human operator.

3 Tractica, “Artificial Intelligence Software Revenue to Reach $59.8 Billion Worldwide by 2025”, 2 May 2017. Available from https://www.tractica.com/newsroom/press-releases/artificial-intelligence-software-revenue-to-reach-59-8-billion-worldwide-by-2025/.

4 Baidu, “Baidu Announces Apollo 1.5 and a 10 Billion yuan Autonomous Driving Fund”, 21 September 2017. Available from http://globenewswire.com/news-release/2017/09/21/1125651/0/en/Baidu-Announces-Apollo-1-5-and-a-10-Billion-yuan-Autonomous-Driving-Fund.html.

5 Jaques Bughin and others, “Artificial intelligence: The Next Digital Frontier?” McKinsey Global Institute Discussion Paper, June 2017. Available from https://www.mckinsey.de/files/170620_studie_ai.pdf.

2. Technology

AI is intelligence exhibited by machines, with machines mimicking functions typically associated with human cognition. AI functions include all aspects of perception, learning, knowledge representation, reasoning, planning and decision-making. The ability of these functions to adapt to new contexts, i.e., situations that an AI system was not previously trained to deal with, is one aspect that differentiates an AI from any other piece of software code.

History & Evolution of AI

The idea of computer-based artificial intelligence dates to 1950, when Alan Turing proposed what has come to be called the Turing test: can a computer communicate well enough to persuade a human that it, too, is human? A few months later, Princeton students built the first artificial neural network, using 300 vacuum tubes and a war surplus gyropilot.

The term "artificial intelligence" was coined in 1955, to describe the first academic conference on the subject, at Dartmouth College. That same year, researchers at the Carnegie Institute of Technology (now Carnegie Mellon University) produced the first AI program, Logic Theorist. Advances followed often through the 1950s: Marvin Lee Minsky founded the Artificial Intelligence Laboratoryat MIT, while others worked on semantic networks for machine translation at Cambridge and self-learning software at IBM.

Funding slumped in the 1970s as there were no visible practical applications for AI.

University researchers' development of "expert systems"—software programs that assess a set of facts using a database of expert knowledge and then offer solutions to problems—revived AI in the 1980s only to slump again due to unviable applications.

Interest in AI boomed again in the 21st century as advances in fields such as deep learning, underpinned by faster computers and more data, convinced investors and researchers that it was practical and profitable to put AI to work. To come to age AI needed killer applications, high speed communications and computing which has finally come together in the beginning of 21st Century.

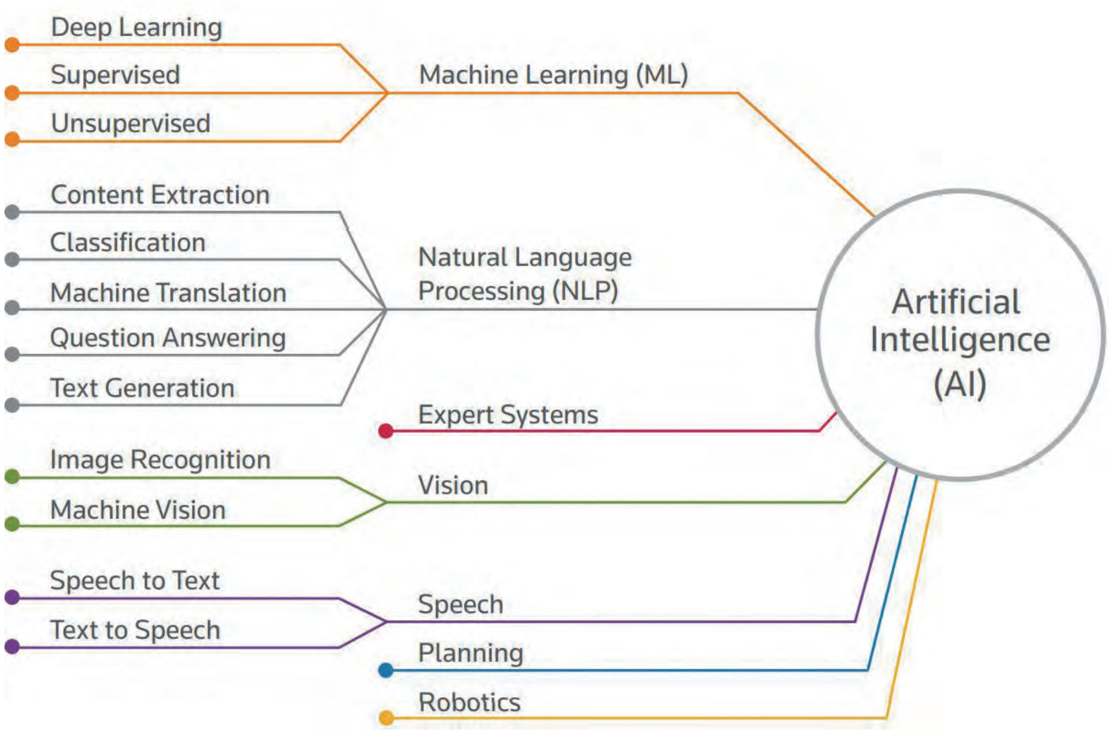
Source: Bughin, J, Hazan, E & et al, 2017, Discussion Paper, Artificial Intelligence the next digital frontier? Mckinsey Global Institute

Source: Jaques Bughin and others, "Artificial intelligence: The Next Digital Frontier?" McKinsey Global Institute Discussion Paper, June 2017. Available from https://www.mckinsey.de/files/170620_studie_ai.pdf.

2.1 AI Ecosystem

AI has many branches with many significant connections and commonalities among them that make up for the whole ecosystem. The most active ones are shown in Figure 2.

Figure 2: Branches of AI



Source: Michael Mills, "Artificial Intelligence in Law: The State of Play", *Thomson Reuters Legal Research Institute*, 2016.

As ML and NLP are the two most important areas of applications in the AI ecosystem, the report dwells deeper into these areas.

2.2 Machine Learning

ML uses a learning and refinement process to modify a model of the world. The objective of the process is to optimize an algorithm's performance on a specific task so that the machine gains a new capability. Typically, large amounts of data are involved. The process of making use of this new capability is called inference. The learned ML algorithm predicts properties of previously unseen data.

There are three main types of learning within ML, namely supervised learning, reinforcement learning and unsupervised learning. They differ in how feedback is provided. Supervised learning uses labelled data ("correct answer is given") while unsupervised learning uses unlabelled data ("no answer is given"). In reinforcement learning, feedback includes how good the output was but not what the best output would have been. In practice, this often means that an agent continuously attempts to maximize a reward based on its interaction with its environment.

Since the late 2000s, deep learning has been the most successful approach to many areas where ML is applied. It can be applied to all three types of learning mentioned above. Neural networks with many layers of nodes and large amounts of data are the basis of deep learning. Each added layer represents knowledge or concepts at a level of abstraction that is higher than that of the previous one. Deep learning works well for many pattern recognition tasks without alterations of the algorithms as long as enough learning data is available.

2.3 Natural Language Processing

NLP is a field of computer science, AI and computational linguistics concerned with the interactions between computers and human (natural) languages, and, in particular, concerned with programming computers to fruitfully process large body of natural language. Challenges in NLP frequently involve natural language understanding, natural language generation (frequently from formal, machine-readable logical forms), connecting language and machine perception, dialog systems, or some combination thereof.

The development of NLP applications is challenging because computers traditionally require humans to "speak" to them through a limited number of clearly enunciated voice commands or by using a programming language that is precise, unambiguous and highly structured. Human speech, however, is not always precise—it is often ambiguous and the linguistic structure can depend on many complex variables, including slangs, dialects and social contexts. The ultimate goal of NLP is to build conversational interfaces that handle interactions between machines and humans in the preferred language of the human.

Current approaches to NLP use ML to analyse patterns in data and continually improve the program's own understanding. Much of the research being done on NLP today revolves around search and chatbots.[6]

Common NLP tasks in AI software programs today include:

- Automatic speech recognition – Converts audio signals to text;
- Part-of-speech tagging and parsing – Divides written text and spoken words into meaningful units;
- Machine translation – Translates one human language to another;
- Natural language understanding – Analyses text to extract meta-data about sentiment and speaker intent;
- Co-reference resolution – Identifies mentions that refer to the same entity.
- Deep analytics – Applies sophisticated data processing techniques to gather information from unstructured and semi-structured data; and
- Named entity extraction – Finds and classifies names of people, companies, countries and other pre-classified categories in text and spoken word.

6 A chat robot (chatbot for short) is designed to simulate a conversation with human users by communicating through text chats, voice commands or both.

3. Applications and Use Cases

AI as an idea is very old, was always in the realm of science fiction, and touted to have surfaced as soon as digital computing became a reality. Every time an AI or ML system appeared on the horizon, it was renamed and moved away from the domain of AI. John McCarthy, an American computer scientist and cognitive scientist, considered the founder of the discipline of AI once remarked, "as soon as it works, no one calls it AI anymore". Examples of AI technologies that are used in daily life are shown in Table 1.

Table 1: Examples of AI in Daily Life

Area	Examples of Use
Expert Systems	Flight tracking systems
Natural Language Processing	Google Now feature, search engines, Apple's SIRI – digital assistant, speech recognition
Neural Networks	Pattern recognition systems such as face recognition, character and handwriting recognition
Robotics	Industrial robots
Fuzzy Logic	Consumer electronics appliances

Source: Tutorial Points, "Artificial Intelligence Tutorial in PDF". Available from https://www.tutorialspoint.com/artificial_intelligence/artificial_intelligence_pdf_version.htm.

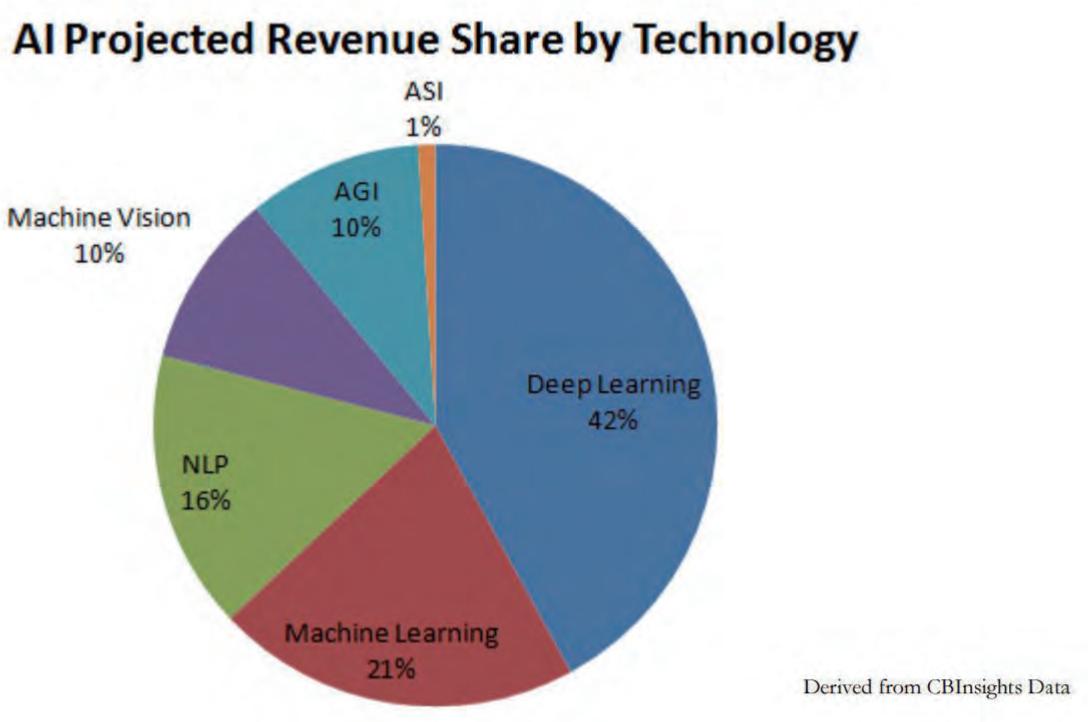
In effect, AI has not yet experienced wide-scale commercial deployment, but many technologies based on AI are in use under various nomenclatures. AI has become an essential part of the technology industry including the more than 3.5 billion Google searches made every day, and is providing solutions to many of the most challenging problems in computer science. The combination of AI, ML and natural user interfaces (such as voice recognition) is making it possible to automate many knowledge workers' tasks that were regarded as impossible or impractical for machines to perform (i.e., decision-making under uncertainty, learning, speech recognition, translation and visual perception).

Advances in AI and ML have been facilitated by the availability of large and diverse data sets, improved algorithms that find patterns in mountains of data, and powerful graphics processing units, which have brought new levels of mathematical computing power. Advances in the speed of graphics processing units have accelerated the training speed of deep learning systems by five or six-folds in the last two years.

The data that the world creates[7] every day translates into more insights and higher accuracy because it exposes algorithms to more examples they can use to identify correct and reject incorrect answers. ML systems enabled by these torrents of data have reduced computer error rates in some applications, for example in image identification, to about the same as the rate for humans.

Figure 3 shows the share of revenue in popular areas of AI usage.

Figure 3: Popular Areas of AI Usage by Revenue, 2017-2025



Source: Kartik Gada, "Artificial Intelligence: The Ultimate Technological Disruption Ascends", *Woodside Capital Partners*, January 2017. Available from http://www.woodsidecap.com/wp-content/uploads/2017/01/Artificial-Intelligence-Report.pdf.

AI can create value in four areas: (1) enabling companies to better project and forecast to anticipate demand, optimize research and development, and improve sourcing; (2) increasing companies' ability to produce goods and services at lower cost and higher quality; (3) helping to promote offerings at the right price, with the right message and to the right target customers; and (4) enabling rich, personal and convenient user experiences.

7 About 2.2 exabytes.

Figure 4: AI Value Chain

Source: Jaques Bughin and others, "Artificial intelligence: The Next Digital Frontier?" McKinsey Global Institute Discussion Paper, June 2017. Available from https://www.mckinsey.de/files/170620_studie_ai.pdf.

While ML can bring highly valuable benefits to all sectors, some technologies are particularly suited for business application in specific sectors, such as robotics for retail and manufacturing, computer vision for healthcare, and NLP for education. IoT is another area that is expected to involve AI in a significant manner.

3.1 Projection and Forecasting

The first area in which AI can create value is projection and forecasting. Organizations need to constantly anticipate the future to gain competitive advantage. AI allows businesses to provide better forecasts for their supply chain and design better offerings through its ability to digest disparate data, automatically adjust to new information, and discern trends and patterns that can be acted upon. This includes forecasting demand to stock only the specific quantities of specific products, and anticipating sales trends to order more soon-to-be-popular items. The benefits of projections and trending go beyond traditional business sectors—for example, by using sophisticated algorithms, health systems can increasingly predict and prevent major epidemics.

When it comes to matching supply and demand, electric utilities are a special case where real-time need exists. Making short-term load forecasts more accurate in order to adjust supply to meet anticipated demand can deliver enormous savings, reduce waste and carbon emissions, and add to system resilience. An example of this is the National Grid in the United Kingdom that is collaborating with DeepMind, an AI start up bought by Google in 2014, to predict supply and demand variations based on weather-related variables and smart meters as exogenous inputs.[8] The goal is to cut national energy use by 10 per cent and maximize the use of renewable power. AI is also used to briefly switch off air conditioning at participating businesses as it forecasts the approach of peak consumption, easing the load for all and postponing or even forgoing the need to fire up peak generating capacity.

8 Madhumita Murgia and Nathalie Thomas, "DeepMind and National Grid in AI talks to balance energy supply", *Financial Times*, 12 March 2017. Available from https://www.ft.com/content/27c8aea0-06a9-11e7-97d1-5e720a26771b.

Using AI to forecast demand allows businesses to optimize their sourcing more broadly, including fully automating purchases and order processing. Otto, a German online retailer, uses an AI application that is 90 per cent accurate in forecasting what the company will sell over the next 30 days. The forecasts are so reliable that the retailer builds inventory in anticipation of the orders that the AI application forecasts, enabling it to speed deliveries to customers and reduce returns.[9]

AI-powered technologies can help deliver more efficient designs than were previously achievable by eliminating waste in the design process. An AI start-up[10] has compressed design processes that used to take months (sometimes a year or more), to roughly four weeks, saving chipmakers the cost of iterations and testing.[11]

3.2 Production and Maintenance

The second area where AI can help create value is in product development (e.g., semiconductors, aircraft engines) and services provision (e.g., education, healthcare, energy, consumer goods distribution). In these roles, AI can replace humans through automation or complement teams of people. For example, at the warehouse of a British online supermarket where it has embedded AI and robotics at the core of its operations, robots steer thousands of product-filled bins over a maze of conveyor belts and deliver them to human packers just in time to fill shopping bags. Other robots move bags to delivery vans whose drivers are guided to customers' homes by an AI application that picks the best route based on traffic conditions and weather.[12]

Advances in computer vision are behind many developments in collaborative and context-aware robots. Enhanced vision is enabled by computers that are more powerful, new algorithmic models and large training data sets. Within the field of computer vision, object recognition and semantic segmentation (or the ability to categorize object type, such as distinguishing a tool from a component) have advanced significantly in their performance. They allow robots to behave appropriately in the context that they operate, for example by recognizing the properties of the materials and objects they interact with. They are flexible and autonomous systems that are capable of safely interacting with the real world and humans.

---

9 Mike Kaput, "This Ecommerce Company Uses Artificial Intelligence to Accurately Predict What You'll Buy Next", *Marketing Artificial Intelligence Institute*, 27 April 2017. Available from https://www.marketingaiinstitute.com/blog/this-ecommerce-company-uses-artificial-intelligence-to-accurately-predict-what-youll-buy-next.

10 Jaques Bughin and others, "Artificial intelligence: The Next Digital Frontier?" McKinsey Global Institute Discussion Paper, June 2017. Available from https://www.mckinsey.de/files/170620_studie_ai.pdf.

11 Ibid.

12 Rory Cellan-Jones, "Shopping robots on the march", *BBC News*, 7 February 2017. Available from http://www.bbc.com/news/technology-38892383.

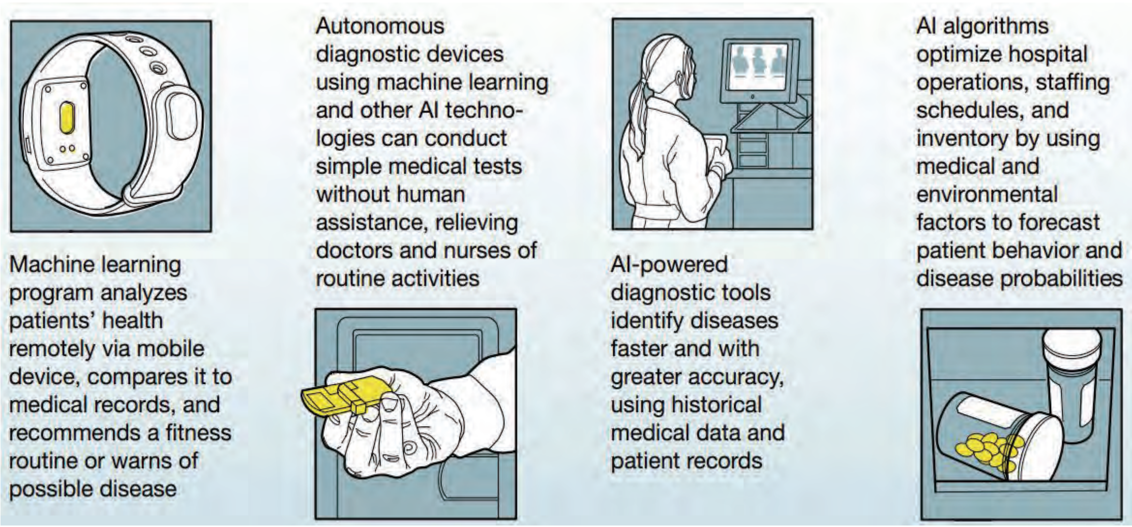
AI-enhanced, camera-equipped logistics robots can be trained to recognize empty shelf space. Deep learning can also be used to correctly identify an object and its position. This enables robots to handle objects without requiring the objects to be in fixed, predefined positions.

In addition to speeding up processes, reducing costs and increasing output, AI has the huge potential to improve quality by reducing errors. Semiconductor manufacturers are starting to use AI engines to identify root causes of yield losses[13] that can be avoided by changing production processes.

In asset-heavy businesses, keeping complex systems running with minimal downtime is another key opportunity for AI. Utility companies can shift from regularly scheduled maintenance of their extensive electrical grids to condition-based maintenance run by AI. Using data from sensors, drones and other hardware, ML applications can help grid operators avoid decommissioning assets before their useful lives have ended, while simultaneously enabling them to perform more frequent remote inspections and maintenance to keep assets working well.

AI is also enabling preventive care. Clinicians use AI to manage patients' health remotely via wearable wireless sensors, with the aim to keep them healthy, fit and out of hospitals. To do this, AI tools will take into account not only patients' medical histories and genetic makeup, but also environmental factors that can influence health, such as pollution and noise where they live and work.

Figure 5: AI in Healthcare



Source: Jaques Bughin and others, "Artificial intelligence: The Next Digital Frontier?" McKinsey Global Institute Discussion Paper, June 2017. Available from https://www.mckinsey.de/files/170620_studie_ai.pdf.

13 Yield losses are losses incurred during manufacturing when products have to be disposed of or reworked due to defects.

3.3 Sales and Marketing

The third area where AI can create value is promotion, or marketing offerings at the right price, with the right message and to the right target audience. With big data, companies can use AI to price goods and services dynamically, raising prices when demand rises or a consumer appears willing to pay more, and lowering them when the opposite happens.

Consumers are well connected on the Internet and social media and use them to continuously redefine value by comparing prices online. The optimal price for a product depends on many factors: the day of the week, season, time of day, weather, channel and device, competitors' prices, and much more. The challenge is to set the optimal price in relation to time. The right price at the right time increases customer satisfaction and leads to more sales and higher profit. AI can determine the price elasticity for every item and automatically adjust prices according to the chosen product strategy.

AI can also help identify most valuable or profitable customers to target in marketing campaigns. The size of the discount, the merchandise on offer and other variables can be determined by an AI program that has looked for clues about what customers will like based on previous purchases, age, home address, web browsing habits and mounds of other data.

3.4 User Experience

The fourth area where AI can create value is in enhancing the user experience[14] and creating new sources of value to make it richer, more tailored and more convenient. For example, when a regular supermarket shopper puts a bunch of bananas in the cart, cameras or sensors could relay the information to an AI application that would have a good idea of what the shopper likes based on previous purchases. The app could through a video screen on the cart, suggest that bananas would be delicious with a chocolate fondue, which the purchase history suggests the shopper likes, and remind the shopper of where to find the right ingredients. Another example is an AI application from an athletic shoe company that could record and monitor a runner's exercise routine and running paths, and also recommend appropriate footwear.

Amazon has built a retail outlet in Seattle, USA, that allows shoppers to take food off the shelves and walk directly out of the store without stopping at a checkout kiosk to pay. The store, called Amazon Go, relies on computer vision to track shoppers after they swipe into the store and associate them with products taken from shelves.

14 Accenture, *Technology for People: The Era of the Intelligent Enterprise – Technology Vision 2017* (2017). Available from https://www.accenture.com/t00010101T000000Z__w__/de-de/_acnmedia/Accenture/next-gen-4/tech-vision-2017/pdf/Accenture-TV17-Full.pdf.

Delivery drones will significantly benefit from breakthroughs in deep learning, which will help them categorize and handle anomalous situations, such as when no one is home to accept a delivery.

Personalizing user experiences has huge advantages in healthcare and education. In healthcare, treatment decisions based on AI analysis of existing science, data from tests and patient monitoring with remote diagnostic devices carry the promise of significantly increased efficacy.

Several companies already use AI technologies to tailor treatments to individuals. One of the examples is Mindmaze[15] that has developed an AI application for the rehabilitation of patients who have suffered brain injuries through strokes or other incidents to retrain their bodies to work again.

Figure 6: AI for Patient Rehabilitation

Source: Sramana Mitra, "Billion Dollar Unicorns: MindMaze Channels Virtual Reality into Healing", *One Million by One Million Blog*, 8 July 2016. Available from http://www.sramanamitra.com/2016/07/08/billion-dollar-unicorns-mindmaze-channels-virtual-reality-into-healing/.

3.5 Some Use Cases

Case: Use of AI in the Banking Industry

The banking industry has been using AI to improve customers' banking experience, gain insights into customers' needs to design customer acquisition and marketing strategies, and prevent fraud.

For instance, banks are using chatbots to help with customer service inquiries. DBS Bank launched India's first mobile-only bank called, "Digibank" in 2016, which allows customers to access banking services through the Digibank mobile app or through various mobile messaging apps like Facebook Messenger. Digibank uses conversational AI technology to enable customers to use natural language while banking. For example, if customers want to check their balance in their

15 Sramana Mitra, "Billion Dollar Unicorns: MindMaze Channels Virtual Reality into Healing", *One Million by One Million Blog*, 8 July 2016. Available from http://www.sramanamitra.com/2016/07/08/billion-dollar-unicorns-mindmaze-channels-virtual-reality-into-healing/.

bank accounts, they can simply text "How much do I have?" which will be answered promptly. According to DBS, the AI-driven bot and virtual assistant handles 82 per cent of customer inquiries and requests without a live agent's involvement in India.[16]

Another principal application of AI in the banking industry is wealth management and advisory services. The Bank of America is launching an AI bot for its smartphone app by 2018. The AI bot, "Erica", will use AI to learn consumers' personal spending habits and offer financial advice in response.[17]

Banks are using AI to obtain a more comprehensive and insightful understanding of customers, by introducing the automation of insights that helps to maximize the efficiency and reach of marketing programmes. The banking system has streams of data coming in from digital channels such as, customer information systems, mobile applications, websites, call centres and third-party data sources. The use of AI in analytics has enabled financial institutions to learn about individual customer needs and preferences, the kinds of tailored products and services to offer, and how best to personally engage with customers within and across the channels.[18]

Additionally, some banks have used AI to improve upon efficiency in terms of detecting fraudulent phone calls. The AI software can build an audio fingerprint of each caller based on different features of the human voice and use this to confirm each user.

Case: AI in Language Translation

Traditionally, applications of AI were focused around numeric challenges. However, recent AI applications that process text across languages are quickly changing the perspective of where AI and ML techniques can be applied to solve complex language-based problems.

AI applications are looking into behavioural models and predicting culture, as well as using speech-to-text and text-to-speech combined with advanced predictive models for a range of applications. One of the examples is using AI for machine translation. A Thailand-based technology company has developed a hybrid neural machine translation platform that can translate over 100 billion words of patent content from English into Japanese, Chinese and Korean.[19]

---

16 Kasisto, "DBS leverages Kasisto's conversational AI platform to launch digibank, an entire bank in the phone, in Indonesia", *PR Newswire*, 8 September 2017. Available from https://www.prnewswire.com/news-releases/dbs-leverages-kasistos-conversational-ai-platform-to-launch-digibank-an-entire-bank-in-the-phone-in-indonesia-300516273.html; and DBS Bank, "DBS to roll out conversational banking in mobile messaging apps by year end", 17 August 2016. Available from https://www.dbs.com/newsroom/DBS_to_roll_out_conversational_banking_in_mobile_messaging_apps_by_year_end.

17 Tanya Macheel, "Inside the development of Erica, Bank of America's AI-powered bot", *Digiday*, 28 July 2017. Available from https://digiday.com/marketing/inside-development-erica-bank-americas-ai-powered-bot/.

18 CIO Academy Asia, "We are well on our way into the era of AI and ML". Available from http://cioacademyasia.org/rethink_faas_deepak-ramanathan_interview/.

19 Sheila Lam, "The state of AI adoption and development in Asia", *Enterprise Innovation*, 24 August 2017. Available from https://www.enterpriseinnovation.net/article/state-ai-adoption-and-development-asia-2077211976.

AI is being adopted among e-commerce providers to translate their product catalogue into different languages. Before being translated, a number of AI processes and models are used to analyse, improve and control the source content.

Case: Application of AI in Facial Recognition for Safety and Security

China has been applying AI in facial recognition to improve safety and security. In Chinese cities across the provinces of Fujian, Jiangsu, Guangdong and Shandong, facial recognition is being used by traffic management authorities to tackle jaywalking issues.[20] China Southern Airlines uses facial recognition technology in Jiangying Airport in Nanyang city to manage the boarding process. At the airport, passengers do not have to get a boarding pass at check-in. Instead, cameras verify the passenger faces against their passport photos to clear them or hold them at the gates.[21]

20 Priyankar Bhunia, "A brief look at artificial intelligence developments in China and the national AI plan for 2030", *OpenGovAsia*, 27 October 2017. Available from http://opengovasia.com/articles/7864-a-brief-look-at-artificial-intelligence-developments-in-china-and-the-national-ai-plan-for-2030.

21 Factor Daily, "Chinese Southern Airlines introduces facial recognition at airport", 29 June 2017. Available from https://factordaily.com/news/chinese-southern-airlines-facial-recognition-airport/.

4. Challenges

The applications and use cases are spanning different sectors and imagination is the only limit. However many of these developments are limited to a few countries. AI seems to be widening the already pervasive development gaps among countries and people by providing exponentially expanding transformative opportunities to those with infrastructure, access, capacity, resources and knowledge, while those without are left further behind.[22]

There is still significant uncertainty about how the technology will develop, and for firms, governments and workers, this may suggest a "wait and see" approach. However, there is a need for timely action in terms of policy and regulation as the usage will increase drastically in all spheres of society.

Governments will need to come up with regulations and policies to enable the technology to flourish while ensuring that the upheavals of AI adoption do not affect employment, safety and the market. Public education systems and workforce training programmes will have to be reviewed to ensure that workers have the relevant skills in AI-related areas.

Many factors contribute to the challenges faced by stakeholders with the development of AI, and these include:[23]

- Decision-making transparency and interpretability – With AI performing tasks ranging from self-driving cars to managing insurance pay-outs, it is critical to understand decisions made by an AI agent. However, aspects related to corporate or state secrecy or technical literacy sometimes limit the transparency around algorithmic decisions. ML further complicates this since the internal decision logic of the model is not always understandable, even for the programmer.
- Data quality and bias – In ML, the model's algorithm will only be as good as the data it uses for training. This means biased data will result in biased decisions. For example, algorithms performing "risk assessments" are in use by some legal jurisdictions in the United States of America to determine an offender's risk of committing a crime in the future. If these algorithms are trained on racially-biased data, they may assign greater risk to individuals of a certain race over others.
- Safety and security – As the AI agent learns and interacts with its environment, there are many challenges related to its safe deployment. They can stem from unpredictable and harmful behaviour, including indifference to the impact of its actions. One example is the risk of "reward hacking" where the AI agent finds a way of doing something that may make it easier to reach

22 ESCAP, *Artificial Intelligence and Broadband Divide: State of ICT Connectivity in Asia and the Pacific* (Bangkok, 2017). Available from http://www.unescap.org/resources/artificial-intelligence-and-broadband-divide-state-ict-connectivity-asia-and-pacific-2017.

23 Internet Society, "Artificial Intelligence and Machine Learning: Policy Paper", April 2017. Available from https://www.internetsociety.org/resources/doc/2017/artificial-intelligence-and-machine-learning-policy-paper/.

the goal, but does not correspond with the designer's intent. There are risks in autonomous systems of being exploited by malicious actors trying to manipulate the algorithm. The ability to manipulate the training data, or exploit the behaviour of an AI agent also highlights issues around transparency of the ML model.

- Accountability – The strength and efficiency of learning algorithms is based on their ability to generate rules without step-by–step instructions. While the technique has proved efficient in accomplishing complex tasks such as face recognition or interpreting natural language, it is also one of the sources of concern. When a machine learns on its own, programmers have less control. While non-ML algorithms may reflect biases, the reasoning behind an algorithm's specific output can often be explained. It is not so simple with ML. Not being able to explain why a specific action was taken makes accountability an issue.

- Economic and social impact – It is predicted that AI technologies will bring economic changes through increases in productivity. However, the benefits from the technology may create vastly different outcomes for the business owners, labour markets and society as a whole. AI will create new jobs or increase demand of existing ones. However, it means that some of the current jobs may be automated in the next few years. Automation may also influence the global division of labour. Over the past several decades, production and services in some economic sectors have shifted from developed economies to the emerging economies, largely because of comparatively lower labour or material costs. These shifts have helped propel some of the world's fastest emerging economies and support a growing global middle class. With the emergence of AI technologies, these incentives could lessen. Some companies, instead of offshoring, may choose to automate some of their operations locally.

- Governance – The institutions, processes and organizations involved in the governance of AI are still in the early stages. Largely, the ecosystem overlaps with subjects related to connectivity, the Internet and mobile regulations, as well as privacy and cyber laws. A central focus of the current governance efforts relates to the ethical dimensions of AI and its implementation.

5. Standards

The Institute of Electrical and Electronics Engineers (IEEE) and the International Telecommunication Union (ITU) are two international bodies that are working on formulating appropriate standards along with various governments and industry groups to ensure that the technologies of AI and ML are used for the benefit of society. These efforts of IEEE and ITU are explained briefly below.

5.1 IEEE Standards for AI Affecting Human Well-being

The IEEE Standards Association has created three new projects under the Global Initiative for Ethical Considerations in Artificial Intelligence and Autonomous Systems. The ethical development of AI is important to avoid the risk of machine-to-machine decisions that could affect where personal data ends up.

The IEEE P7000TM set of standards aims to allow organizations to demonstrate that their products conform to a high level of ethics. For example, the Standard for Child and Student Data Governance (IEEE P7004TM) focuses on the collection of data from children and students. This standard helps create governance and certification processes for organizations that collect data from children and students. Parents deserve to understand who has access to their children's data, when and what is being collected, how it will be used and when it will be deleted. In terms of student data, the standard defines specific methodologies to ensure transparency of how data is collected by educational institutions. The Standard for Transparent Employer Data Governance (IEEE P7005TM) provides organizations with guidelines and certifications about the collection, usage and protection of employee data. The Standard for Personal Data Artificial Intelligence Agent (IEEE P7006TM) describes the technical elements required when developing AI ethically and keeping a human involved in all decision-making. This will ensure that personal data use remains transparent even when an AI agent is being used.

5.2 ITU and AI Standards and Regulations

According to ITU, the development and adoption of relevant international standards can help to realize the benefits of AI advances on a global scale and assist in the achievement of the Sustainable Development Goals (SDGs). At the same time, SDG 17 on Partnerships for the Goals offers crucial support to establishing regulations and standards for the governance of AI technologies under the auspices of the United Nations.[24] Various ITU forums and conferences, including the ITU World Telecommunication Standardization Assembly, ITU Telecom World and ITU Kaleidoscope Academic Conference, have planned to hold a series of talks on AI.

5.3 Industry Partnerships and Standards Initiatives

Industry is a large part of the AI and ML ecosystem and is at the forefront of defining the technology and deriving the standards based on their own development initiatives. There are individual companies that have already developed their own set of best practices, as well as consortiums of industry across sectors coming together. There are also collaborations between industry, non-profit entities and governments. Facebook, Microsoft, Google, Amazon and IBM have announced that they are joining forces to develop a set of standards and best practices for AI as part of their partnership on AI to benefit people and society.[25]

24 ITU, "Could technical standards for Artificial Intelligence help us achieve the Sustainable Development Goals?" 13 September 2016. Available from https://itu4u.wordpress.com/ 2016/09/13/could-technical-standards-for-artificial-intelligence-help-us-achieve-the-sustainable-development-goals/.

25 Klint Finley, "Tech giants team up to keep AI from getting out of hand", *Wired*, 28 September 2016. Available from https://www.wired.com/2016/09/google-facebook-microsoft-tackle-ethics-ai/.

6. Policy Implications[26]

AI-based innovations can be central to the achievement of the SDGs by capitalizing on the unprecedented quantities of data now being generated on sentiment behaviour, human health, commerce, communications, migration and more. For instance, ML and reasoning can extend medical care to remote regions through automated diagnosis and effective exploitation of limited medical expertise and transportation resources (SDG 3: Good Health and Well-being). AI can help to build a better understanding of how to design more effective education systems (SDG 4: Quality Education). Ideas and tools created at the intersection of AI and electronic commerce may uncover new ways to enhance novel economic concepts, such as microfinance and microwork (SDG 8: Decent Work and Economic Growth). AI can also serve as a key resource in curbing greenhouse gas emissions in urban environments and supporting the development of smart cities (SDG 11: Sustainable Cities and Communities and SDG 13: Climate Action).

Governments around the world are considering the policy implications of advances in AI and ML, some of which are discussed below.

6.1 Employment and Skills Development

One possible implication is related to the disruptions that AI systems could bring to the labour market. Concerns are raised that automated systems will make some jobs obsolete and lead to unemployment. There are also opposing views, according to which AI advancements will generate new jobs, which will compensate for those lost, without affecting the overall employment rates. Given that there are deep implications it is important for governments to monitor changes in the job trends, to better understand the real risks and opportunities brought by AI.

One of the ways that jobs can be increased and protected is by educating and training the workforce to new digital skills requirements. The rapid growth of AI generates an increasing need for individuals to be equipped with the necessary skills allowing them not only to make use of AI technologies, but to contribute to their development. Governments have to plan and commit to actions aimed towards addressing the broader digital skills crisis, and emphasize the fact that adapting the workforce to AI requirements does not only mean preparing the new generations, but also allowing the current workforce to re-skill and up-skill itself.

26 This section is drawn from Sorina Teleanu, "Artificial intelligence: Policy implications", *DiploFoundation*, 29 October 2016. Available from https://www.diplomacy.edu/blog/artificial-intelligence-policy-implications.

6.2 Safety and Security

AI applications in the physical world (such as autonomous cars) bring into focus issues related to human safety, and the need to design systems that can properly react to unforeseen situations and have minimum unintended consequences. AI also has implications for cybersecurity. As AI is increasingly embedded in critical systems, they need to be secured to potential cyberattacks. On the other hand, AI has applications in cybersecurity, and such applications are expected to play an increasingly important role in defensive and offensive cybermeasures. AI is, for example, used in email applications to perform spam filtering, but it is also increasingly employed in applications aimed to detect more serious cybersecurity vulnerabilities and address cyberthreats. The use of AI in offensive systems in defence and military complex must adhere to international humanitarian laws and conventions similar to the way the present day systems are governed.

6.3 Privacy

AI systems work with enormous amounts of data, and this raises concerns regarding privacy and data protection. AI applications need to ensure the integrity of the data they employ, as well as protect privacy and confidentiality. Identity anonymity and re-use of data are two key aspects that need to be addressed along with data protection guarantees. Standards bodies' involvement is critical in the development of appropriate provisions to handle the concepts of privacy by design, privacy by default, informed consent and encryption in AI systems.

6.4 Ethics

As AI systems involve judgements and decision-making including replacing similar human processes, there are concerns relating to ethics, fairness, justice, transparency and accountability. The risk of discrimination and bias in decisions made by AI systems is one such concern. One way of addressing some of these concerns is to combine ethical training for AI practitioners with the development of technical methods for designing AI systems in a way that can avoid such risks. Although there seems to be a general understanding on the need for algorithms and architectures to be verifiably consistent with existing laws, social norms and ethics, achieving this may be a challenge because of ethical issues varying according to culture, religion and belief.

6.5 Intellectual Property Rights

There is a need for a balanced approach to intellectual property rights when applied to hardware and software standards. Government policies should encourage increased availability of open-source software libraries and toolkits providing access to cutting-edge AI technologies for developers. The policies should foster development while protecting the intellectual property.

6.6 Legal Aspects

AI brings into focus the need for new legal and regulatory frameworks to address the issues of safety, privacy and data protection, and ethics. The approach to regulation of AI-enabled products should be informed by assessment of the aspects of risk that the addition of AI may induce. Attention should be paid to ensure that such approaches do not hinder innovation and progress. Different strategies and approaches may be adopted including formation of bodies or commissions that are tasked to identify principles for the development and application of AI, provide advice to the government, and foster public dialogue. In certain cases, the existing legal frameworks may be adequate while in other cases a completely new set of regulations may need to be developed.

Aspects related to accountability and liability in AI systems are also viewed as important legal issues to consider. For example, who is responsible if something goes wrong in an autonomous transport system—is it the manufacturer, the software developer or the owner of the vehicle? This question raises issues of civil, and even criminal liability, and there is a need to further discuss whether such issues should be tackled in courts, or whether new legislation is needed. The bigger issue is how one would consider the legal status of AI machines.

6.7 International Cooperation

The policy implications of AI are global in nature and needs involvement and support of the United Nations, Group of Seven (G7), Organisation for Economic Co-operation and Development (OECD), other regional groupings and governments. AI would benefit from international cooperation in promoting research and development, and identifying suitable solutions to the challenges discussed.

7. References

Accenture. *Technology for People: The Era of the Intelligent Enterprise – Technology Vision* 2017. 2017. Available from https://www.accenture.com/t00010101T000000Z__w__/de-de/_acnmedia/Accenture/next-gen-4/tech-vision-2017/pdf/Accenture-TV17-Full.pdf.

Baidu. Baidu Announces Apollo 1.5 and a 10 Billion yuan Autonomous Driving Fund. 21 September 2017. Available from http://globenewswire.com/news-release/2017/09/21/1125651/0/en/Baidu-Announces-Apollo-1-5-and-a-10-Billion-yuan-Autonomous-Driving-Fund.html.

Bhunia, Priyankar. A brief look at artificial intelligence developments in China and the national AI plan for 2030. *OpenGovAsia*, 27 October 2017. Available from http://opengovasia.com/articles/7864-a-brief-look-at-artificial-intelligence-developments-in-china-and-the-national-ai-plan-for-2030.

Bughin, Jaques, and others. Artificial intelligence: The Next Digital Frontier? McKinsey Global Institute Discussion Paper, June 2017. Available from https://www.mckinsey.de/files/170620_studie_ai.pdf.

Cellan-Jones, Rory. Shopping robots on the march. *BBC News*, 7 February 2017. Available from http://www.bbc.com/news/technology-38892383.

CIO Academy Asia. We are well on our way into the era of AI and ML. Available from http://cioacademyasia.org/rethink_faas_deepak-ramanathan_interview/.

DBS Bank. DBS to roll out conversational banking in mobile messaging apps by year end. 17 August 2016. Available from https://www.dbs.com/newsroom/DBS_to_roll_out_conversational_banking_in_mobile_messaging_apps_by_year_end.

ESCAP. *Artificial Intelligence and Broadband Divide: State of ICT Connectivity in Asia and the Pacific*. Bangkok, 2017. Available from http://www.unescap.org/resources/artificial-intelligence-and-broadband-divide-state-ict-connectivity-asia-and-pacific-2017.

Factor Daily. Chinese Southern Airlines introduces facial recognition at airport. 29 June 2017. Available from https://factordaily.com/news/chinese-southern-airlines-facial-recognition-airport/.

Finley, Klint. Tech giants team up to keep AI from getting out of hand. *Wired*, 28 September 2016. Available from https://www.wired.com/2016/09/google-facebook-microsoft-tackle-ethics-ai/.

Gada, Kartik. Artificial Intelligence: The Ultimate Technological Disruption Ascends. *Woodside Capital Partners*, January 2017. Available from http://www.woodsidecap.com/wp-content/uploads/2017/01/Artificial-Intelligence-Report.pdf.

Internet Society. Artificial Intelligence and Machine Learning: Policy Paper. April 2017. Available from https://www.internetsociety.org/resources/doc/2017/artificial-intelligence-and-machine-learning-policy-paper/.

ITU. Could technical standards for Artificial Intelligence help us achieve the Sustainable Development Goals? 13 September 2016. Available from https://itu4u.wordpress.com/ 2016/09/13/could-technical-standards-for-artificial-intelligence-help-us-achieve-the-sustainable-development-goals/.

Kaput, Mike. This Ecommerce Company Uses Artificial Intelligence to Accurately Predict What You'll Buy Next. *Marketing Artificial Intelligence Institute*, 27 April 2017. Available from https://www.marketingaiinstitute.com/blog/this-ecommerce-company-uses-artificial-intelligence-to-accurately-predict-what-youll-buy-next.

Kasisto. DBS leverages Kasisto's conversational AI platform to launch digibank, an entire bank in the phone, in Indonesia. *PR Newswire*, 8 September 2017. Available from https://www.prnewswire.com/news-releases/dbs-leverages-kasistos-conversational-ai-platform-to-launch-digibank-an-entire-bank-in-the-phone-in-indonesia-300516273.html.

Lam, Sheila. The state of AI adoption and development in Asia. *Enterprise Innovation*, 24 August 2017. Available from https://www.enterpriseinnovation.net/article/state-ai-adoption-and-development-asia-2077211976.

Macheel, Tanya. Inside the development of Erica, Bank of America's AI-powered bot. *Digiday*, 28 July 2017. Available from https://digiday.com/marketing/inside-development-erica-bank-americas-ai-powered-bot/.

Mitra, Sramana. Billion Dollar Unicorns: MindMaze Channels Virtual Reality into Healing. *One Million by One Million Blog*, 8 July 2016. Available from http://www.sramanamitra.com/2016/07/08/billion-dollar-unicorns-mindmaze-channels-virtual-reality-into-healing/.

Murgia, Madhumita, and Nathalie Thomas. DeepMind and National Grid in AI talks to balance energy supply. *Financial Times*, 12 March 2017. Available from https://www.ft.com/content/27c8aea0-06a9-11e7-97d1-5e720a26771b.

Teleanu, Sorina. Artificial intelligence: Policy implications. *DiploFoundation*, 29 October 2016. Available from https://www.diplomacy.edu/blog/artificial-intelligence-policy-implications.

Tractica. Artificial Intelligence Software Revenue to Reach $59.8 Billion Worldwide by 2025. 2 May 2017. Available from https://www.tractica.com/newsroom/press-releases/artificial-intelligence-software-revenue-to-reach-59-8-billion-worldwide-by-2025/.

Tutorial Points. Artificial Intelligence Tutorial in PDF. Available from https://www.tutorialspoint.com/artificial_intelligence/artificial_intelligence_pdf_version.htm.

Glossary

Algorithm : A set of rules or instructions given to an AI, neural network or other machines to help it learn on its own. Classification, clustering, recommendation and regression are four of the most popular types.

Artificial intelligence : A machine's ability to make decisions and perform tasks that simulate human intelligence and behaviour.

Artificial neural network : A learning model created to act like a human brain that solves tasks too difficult for traditional computer systems to solve.

Autonomic computing : A system's capacity for adaptive self-management of its own resources for high-level computing functions without user input.

Chatbot : A chat robot that is designed to simulate a conversation with human users by communicating through text chats, voice commands, or both. It is a commonly-used interface for computer programs that include AI capabilities.

Cognitive computing : A computerized model that mimics the way the human brain thinks. It involves self-learning with data mining, NLP and pattern recognition.

Data mining : The examination of data sets to discover and mine patterns from that data that can be of further use.

Deep learning : The ability for machines to autonomously mimic human thought patterns through artificial neural networks composed of cascading layers of information.

Machine learning : A facet of AI that focuses on algorithms, allowing machines to learn without being programmed and change when exposed to new data.

Natural language processing : The ability for a program to recognize human communication as it is meant to be understood.

Supervised learning : A type of ML in which output data sets train the machine to generate the desired algorithms, like a teacher supervising a student.

Acronyms

AI	Artificial Intelligence
ICT	Information and Communication Technology
IEEE	Institute of Electrical and Electronics Engineers
ITU	International Telecommunication Union
ML	Machine Learning
NLP	Natural Language Processing
SDG	Sustainable Development Goal

VII. Blockchain and Shared Ledgers

Contents

List of Figures

1. Introduction

The concept of blockchain was introduced by Satoshi Nakamoto in 2008,[1] and then implemented for the first time in 2009 as part of the digital bitcoin currency. Blockchain and bitcoin are, however, not the same. Blockchain technology can be applied in many different domains such as healthcare, finance and supply chain management, and can be used in peer-to-peer payment services and supply chain tracking.[2]

A blockchain is a record of transactions, where a group of transactions is called a block. When they are put together, they form a structure/chain called a blockchain. These transactions could involve movement of money, goods, services and data. Examples include online payment through a banking application or the assignment of a national identification number.[3] Figure 1 shows the record of a blockchain transaction.

Figure 1: A Blockchain Transaction

Source: Goldman Sachs, "Blockchain: The New Technology of Trust". Available from http://www.goldmansachs.com/our-thinking/pages/blockchain/.

Blockchain consists of a network of computers having an identical copy of the database distributed among themselves, which changes its state (records) by a common agreement based on some mathematical logic.

This type of database that is shared, replicated and synchronized among the members of a network is referred to as a distributed ledger. Distributed ledger records transactions, such as exchange of assets or data, among the participants in the network. Participants in the network govern and agree by consensus on the updates to the records in the ledger. No central, third-party mediator, such as a financial institution or clearinghouse, is involved. Every record in the distributed ledger has a

1 Wikipedia, "Satoshi Nakamoto". Available from https://en.wikipedia.org/wiki/Satoshi_Nakamoto.

2 Bernard Marr, "A complete beginner's guide to blockchain", *Forbes*, 24 January 2017. Available from https://www.forbes.com/sites/bernardmarr/2017/01/24/a-complete-beginners-guide-to-blockchain/#9d812166e607.

3 Deloitte, "Blockchain Technology in India: Opportunities and Challenges", April 2017. Available from https://www2.deloitte.com/content/dam/Deloitte/in/Documents/strategy/in-strategy-innovation-blockchain-technology-india-opportunities-challenges-noexp.pdf.

timestamp and unique cryptographic signature, thus making the ledger an auditable history of all transactions in the network.[4]

1.1 The Role of Ledgers

In today's interconnected world, many economic activities take place in networks spanning national and international jurisdictions. These networks generally come together at marketplaces where the participants are typically producers, suppliers, consumers and other stakeholders. These participants own, control, and exercise their rules, rights, privileges and entitlements on objects of value to them, or assets. Assets are of two kinds: tangible and physical, and intangible and virtual. Cars and homes are tangible and physical assets whereas patents and stock certificates are examples of intangible and virtual assets. The ownership and transfer of ownership are transactions that create value in a network.

Transactions essentially happen in the presence of various participants such as buyers, sellers and intermediaries (like banks, auditors or notaries) whose business agreements and contracts are recorded in ledgers. Any organization, be it a business or a bank, typically uses multiple ledgers to keep track of asset ownership and asset transfers between participants. Ledgers are, therefore, a system of records related to a business' economic activities and interests. Figure 2 shows a typical ledger.

Figure 2: A Typical Ledger

LEDGER

ACCOUNT TYPE	CASH				
TRANSACTION DATE	TRANSACTION DETAIL	REFERENCE	DEBIT	CREDIT	BALANCE
1/1/16	Expenses for Jan	Ref#1	$100.00		$100.00
2/1/16	Tax withheld	Ref#2		$110.00	($10.00)

Source: Sloane Brakeville and Bhargav Perepa, "Blockchain basics: Introduction to distributed ledger", *IBM*, 9 May 2016. Available from https://www.ibm.com/developerworks/cloud/library/cl-blockchain-basics-intro-bluemix-trs/index.html.

4 This section is drawn from: Sloane Brakeville and Bhargav Perepa, "Blockchain basics: Introduction to distributed ledger", *IBM*, 9 May 2016. Available from https://www.ibm.com/developerworks/cloud/library/cl-blockchain-basics-intro-bluemix-trs/index.html.

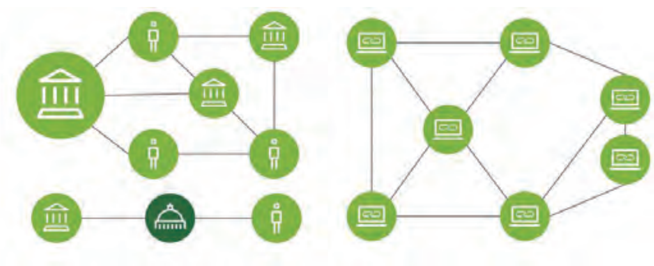
1.2 Problems with Current Ledgers

Current business ledgers are often found to be inefficient, costly, non-transparent, and subject to fraud and misuse. These problems are seen to stem from reliance on centralized, trust-based and third-party systems, such as financial institutions, clearing houses and other mediators of existing institutional arrangements. These centralized, trust-based ledger systems can lead to slowdowns of transaction settlements. Whenever there is a lack of transparency, as well as susceptibility to corruption and fraud, disputes may arise. Having to resolve disputes and possibly reverse transactions or provide insurance for transactions is costly.

Furthermore, out-of-sync copies of business ledgers on each network participant's respective system may lead to faulty business decisions made on temporary and incorrect data. At best, the ability to make a fully informed decision is delayed while differing copies of the ledgers are resolved.

On the other hand, blockchain being a shared digital ledger, relies on the nodes in the network to confirm and validate transactions. There are less chances of tampering with transaction data because all the transactions are linked from the beginning of the chain to the most current block. The blockchain as a whole acts as a single source of "truth" where only members with a given set of permissions available to them can make relevant changes.

Figure 3: Traditional Centralized System vs. Blockchain-based Distributed System



Source: Deloitte, "Blockchain Technology in India: Opportunities and Challenges", April 2017. Available from https://www2.deloitte.com/content/dam/Deloitte/in/Documents/strategy/in-strategy-innovation-blockchain-technology-india-opportunities-challenges-noexp.pdf.

2. The Blockchain Technology

The basic principles on which the blockchain technology works are described in the subsections below.[5]

2.1 The Consensus Model

Instead of relying on a third party, such as a financial institution, to mediate transactions, member nodes in a blockchain network use a consensus protocol to agree on ledger content, and cryptographic hashes and digital signatures to ensure the integrity of transactions. Consensus ensures that shared ledgers are exact copies and lowers the risk of fraudulent transactions because tampering would have to occur across many places at exactly the same time.

A cryptographic hash function takes an input and returns an output in the form of a fixed-size alphanumeric string. The string produced is called the "hash" value. The hash value of any given data can be calculated if the function that has been used is known. Cryptographic hashes ensure that any alteration to transaction input results in a different hash value being computed, which indicates potentially compromised transaction input.

A digital signature is a digital code that is generated and authenticated by public key encryption, which is attached to a digital document transmitted over a network to verify its content and the sender's identity. The digital signature ensures that the sender is not an imposter.

2.2 Distributed Database

Each party on the blockchain network shares the ledger, providing them with access to the entire database and its complete history. Every time a transaction happens, the data is replicated among all the peers in the network and the information gets updated. No single party controls the data or the information. Every party can verify the records of its transaction partners directly, without an intermediary.

5 The principles are drawn from: Sloane Brakeville and Bhargav Perepa, "Blockchain basics: Introduction to distributed ledger", *IBM*, 9 May 2016. Available from https://www.ibm.com/developerworks/cloud/library/cl-blockchain-basics-intro-bluemix-trs/index.html; and Allison Berke, "How safe are blockchains? It depends", *Harvard Business Review*, 7 March 2017. Available from https://hbr.org/2017/03/how-safe-are-blockchains-it-depends.

2.3 Peer-to-Peer Transmission

Instead of a central node, the blockchain network ensures that information across the ledger is updated through peer-to-peer replication every time a transaction takes place. This means each node acts like a subscriber, which receives the updated information, as well as a publisher (the one updating the information). In other words, each node stores, updates and forwards information to all other nodes. This way, the data is in-sync across the network as it is transferred.

2.4. Transparency with Pseudonymity

The details of every transaction are visible to all parties (nodes) associated with the ledger. Each node on the blockchain has a unique 30-plus-character alphanumeric address that confirms its identity. A party can choose to remain anonymous or provide proof of identity to others.

2.5. Irreversibility of Records

Once the transaction has taken place, it gets written to the database and all associated accounts of the parties will be updated. The records then cannot be altered as they are linked to every transaction that happened before them. Hence, the term "chain", which comprises of a series of blocks with two blocks initiating the formation of a chain and the rest becoming a part of it.

Various computational algorithms and approaches have to be exercised to ensure that the records in the database are correct, permanent, chronologically ordered and available to all other nodes on the network that have access.

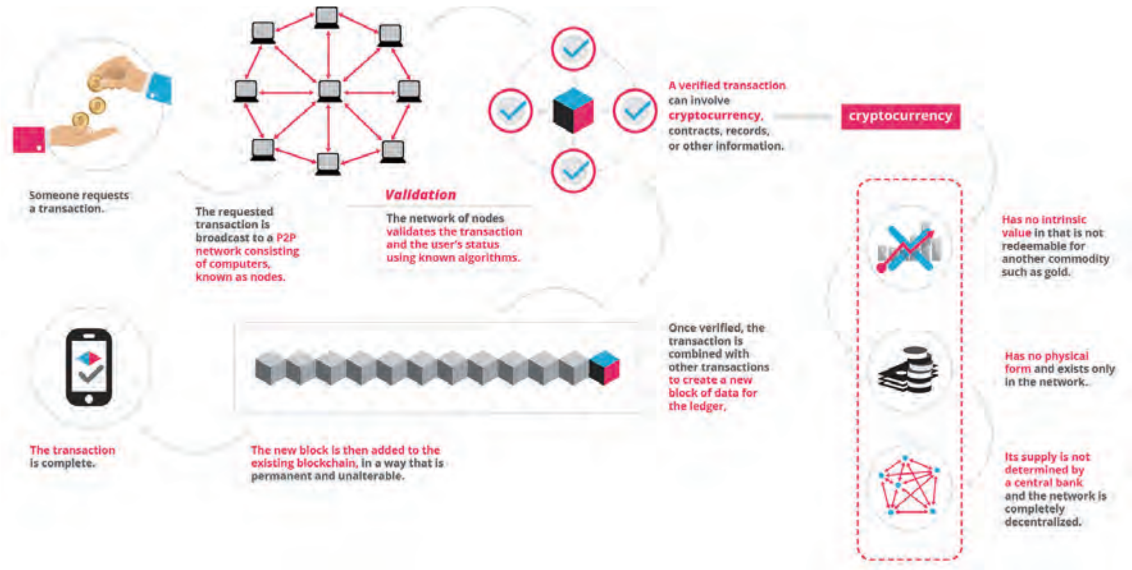
2.6. Computational Logic

Every transaction in the ledger is tied to a computational logic ensuring its validity and security. In other words, every transaction is programmed, so parties can set up rules and algorithms to automatically prompt an order to start the transaction.

Based on these principles, a blockchain network is considered economical and efficient as it is seen to eliminate the need for an (inefficient) intermediary and the duplication of effort by different intermediaries involved in one transaction. For example, many of us are now familiar with sharing information through a decentralized online platform—the Internet. But when it comes to transferring money, many are forced to fall back on centralized financial establishments like banks. Even online payment methods like PayPal require integration with a bank account or credit card. In such a case, when an online transaction takes place it has to be recorded by both the bank and PayPal separately.[6]

Figure 4 provides an overview of the various stages involved in the working of the blockchain technology.

Figure 4: Working of Blockchain Technology



Source: Blockgeeks, "What is Blockchain Technology? A Step-by-Step Guide for Beginners". Available from https://blockgeeks.com/guides/what-is-blockchain-technology/

6 Bernard Marr, "A complete beginner's guide to blockchain", *Forbes*, 24 January 2017. Available from https://www.forbes.com/sites/bernardmarr/2017/01/24/a-complete-beginners-guide-to-blockchain/#9d812166e607.

3. Applications of Blockchain

Blockchains can be of the following three types:[7]

- **Public** – Public blockchains are fully decentralized and transparent by design. Any node in the network can read, send transactions and participate in the consensus process.
- **Permissioned** – Permissioned blockchains are quasi-decentralized, where consensus is controlled by pre-selected set of nodes and read permission is restricted to participants.
- **Private** – Private blockchains are centralized blockchains, where write permission is centralized to one entity and read permission may or may not be given to all participants.

3.1 Public Blockchain Applications

Case: Bitcoins

Bitcoin, the most popular use case of blockchain, is a form of digital currency that is created and traded electronically in a decentralized manner where no central authority verifies or monitors the transactions between participants. Bitcoin is neither printed nor minted like fiat currencies, but is instead created digitally by a community of people that anyone can join. Bitcoins are mined on the Blockchain network using computing power in a distributed nature by solving a mathematical puzzle. The software is open source, thus, anyone with the requisite capabilities and resources can join the Blockchain network and use it to transact or buy things electronically, which is very similar to how fiat currencies are being used digitally.[8]

In India, people have started investing in bitcoin, which has given rise to a number of bitcoin exchanges. Bitcoin exchanges facilitate exchanges of currency between people who own bitcoins. They specify the amount and the price at which they would like to sell the bitcoin. All those requests are placed in a common ledger known as the "order book". When a person wants to buy a bitcoin, they either look for a good order in the order book or create one of their own for others to buy, specifying the details of the deal. Whenever they find a deal, they buy and sell bitcoins at price they had mentioned and trade. In bitcoin exchanges, people behind the orders are matched and put in touch through the exchange software. This removes the presence of intermediaries from the entire process. Some players have created mobile wallets for bitcoin exchanges to increase the convenience of trading.

7 Deloitte, "Blockchain Technology in India: Opportunities and Challenges", April 2017. Available from https://www2.deloitte.com/content/dam/Deloitte/in/Documents/strategy/in-strategy-innovation-blockchain-technology-india-opportunities-challenges-noexp.pdf.

8 Ibid.

At this stage, the Reserve Bank of India, "has not given any license/authorizations to any entity/company to operate or deal with bitcoin or any virtual currency, and even cautioned those investing in the instruments".[9] The central bank has raised concerns over the decentralized nature of bitcoin and also flagged issues surrounding its valuations.[10] Quite recently however, the Reserve Bank of India is looking at the possibility of a flat cryptocurrency that would become an alternative to the Indian rupee for digital transactions, called Lakshmi.[11] Some examples of bitcoin exchanges/wallets in India are Zebpay, Unocoin, Coinsecure and Coinmama.

Bitcoin exchanges have also emerged in other countries including, China (Yunbi, Huobi, OKCoin), Japan (BTCBox) and Singapore (CoinHako, FYB-SG).

3.2 Permissioned Blockchain Applications

Case: Trade Finance Application

Letters of credit are one of the most commonly used trade finance instruments today and rely on highly manual, paper-based processes (Figure 5). It has been reported that due to extended processing time in a trade transaction, purchasers and suppliers are not making the most efficient use of their capital. The authenticity of trade documents is required throughout the process to prevent fraudulent transactions. A blockchain-based solution can capture the details contained in a purchase order, bill of lading, invoice and tracking of shipment in a smart contract on the blockchain (Figure 6). Blockchain can reduce the turn-around-time of letter of credit processing by a huge margin, thereby reducing the processing cost and efforts.[12]

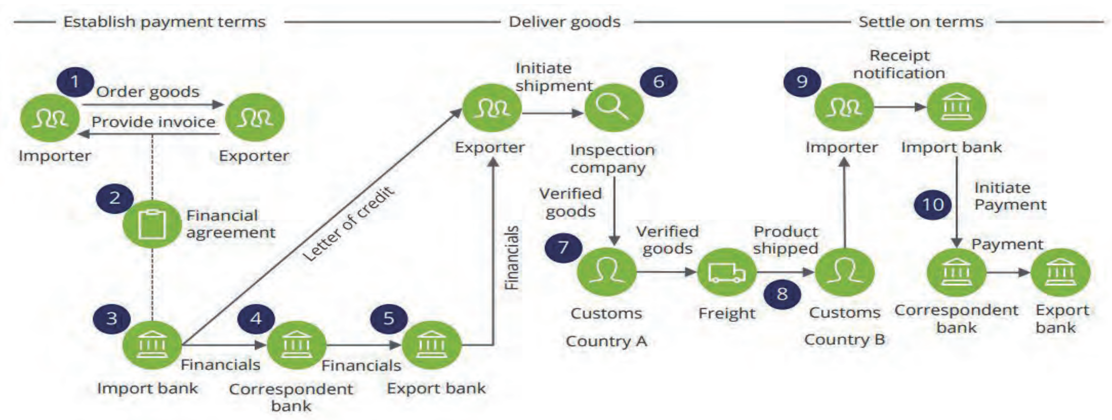
9 Goldman Sachs, "Blockchain: The New Technology of Trust". Available from http://www.goldmansachs.com/our-thinking/pages/blockchain/.

10 LiveMint, "RBI says it hasn't authorized use of Bitcoins, flags risks", 1 February 2017. Available from http://www.livemint.com/Industry/xma89nytKOwcDu4hBT30RO/RBI-says-it-hasnt-authorised-use-of-Bitcoins-flags-risks.html.

11 The Economic Times, "Another experiment with currency? RBI is looking at its own Bitcoin", 16 September 2017. Available from https://economictimes.indiatimes.com/news/economy/policy/another-experiment-with-currency-rbi-is-looking-at-its-own-bitcoin/articleshow/60710700.cms.

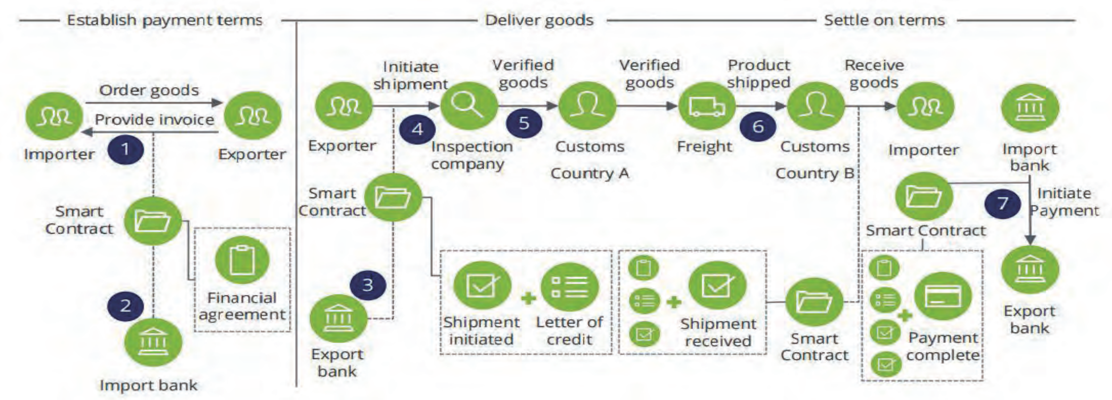
12 Deloitte, "Blockchain Technology in India: Opportunities and Challenges", April 2017. Available from https://www2.deloitte.com/content/dam/Deloitte/in/Documents/strategy/in-strategy-innovation-blockchain-technology-india-opportunities-challenges-noexp.pdf; and World Economic Forum (August 2016). The Future of Financial Architecture.

Figure 5: Current Letter of Credit Processing



Source: World Economic Forum, "The Future of Financial Architecture", August 2016. Available from http://www3.weforum.org/docs/WEF_The_future_of_financial_infrastructure.pdf.

Figure 6: A Proposed Blockchain-based Letter of Credit Processing



Source: World Economic Forum, "The Future of Financial Architecture", August 2016. Available from http://www3.weforum.org/docs/WEF_The_future_of_financial_infrastructure.pdf.

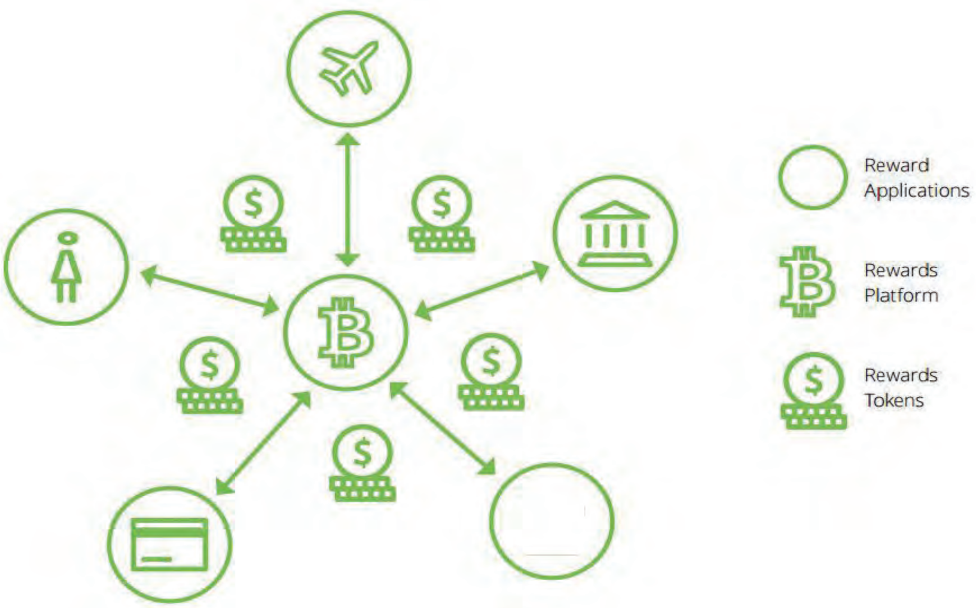
3.3 Private Blockchain Applications

Loyalty-based programmes are strategic investments for many types of organizations. Amazon's Prime and eBay's joint loyalty programme (Common Threads Initiative) are two such examples. Loyalty reward programmes are generally fragmented, costly, inactive and slow. Some of the key problems include the following:

- High lag between availing of service and credit of loyalty points;
- Customers cannot use or check points instantly;
- Inherent inefficiencies with the system (and high associated cost);
- Poor data integrity leading to security threat and data privacy abuse; and
- Usage of reward points does not live up to the potential due to limited redemption options.

Blockchain, as a distributed ledger can allow participants such as loyalty programme providers, managers, administrators and customers to interact in one system without intermediaries and without any sense of competition. Blockchain has the potential to streamline regulation and execution of such programmes. It can also help bring real-time transparency in the system and contribute to cost savings.

Figure 7: Proposed Blockchain-based Loyalty Programme



Source: Deloitte, "Blockchain Technology in India: Opportunities and Challenges", April 2017. Available from https://www2.deloitte.com/content/dam/Deloitte/in/Documents/strategy/in-strategy-innovation-blockchain-technology-india-opportunities-challenges-noexp.pdf.

3.4 Blockchain Applications in Government Agencies

Case: Honduras Land Title Registration[13]

To help stem long-standing corruption in Honduras' land title registry system, the World Bank announced in 2011 that it would loan the Honduran government USD 328 million to digitize title files and upgrade tools and processes. While subsequent efforts did help modernize and standardize the government's administrative capabilities, they also made it easier for corrupt players to hack into central databases and illegally alter digital land records.

In May 2015, Factom, the organization that manages open source software for securely recording transactions through a distributed and decentralized protocol, announced that it would be working with Epigraph, a land title software vendor, to help the Government of Honduras recreate its digital land title registry system in a blockchain. The initiative aims to use blockchain technology to create a transparent land title registry system in which digitized records are tamper proof.

The system being developed addresses existing security vulnerabilities in several ways. First, individual land records are digitized—"hashed" or encoded with an immutable fingerprint—and stored permanently on the blockchain. The system then tracks and documents every change of ownership, every loan made against a single piece of land, and every contract made against mineral rights. Users can track the entire history of a land title instantly. They cannot, however, alter anything currently in the system. They can use a stored version to create a new document, but they will not be able to recreate or replace a hash once it is filed.

This initiative is being piloted in a single city at this stage, with a system built and capable of accepting entries. In the coming years, project leaders plan to roll out the pilot to additional municipalities.

Case: Blockchains in the United Arab Emirates[14]

The Department of Economic Development in Dubai is working on shifting its entire business registration and licensing services to blockchain. The system will be made available to other Dubai entities to cut down on duplication, and ease and accelerate the process of setting up businesses in Dubai.

In February 2017, Emirates NBD, Dubai's largest bank, started working with IBM and other Dubai entities to explore the use of blockchain for trade finance and logistics. Trade is Dubai's biggest business. It has used its ports and free zones to become a major import-export hub, connecting markets in Asia with those in Africa, Europe and beyond. Non-oil foreign trade in the emirate totalled

13 Deloitte, "Blockchain Technology in India: Opportunities and Challenges", April 2017. Available from https://www2.deloitte.com/content/dam/Deloitte/in/Documents/strategy/in-strategy-innovation-blockchain-technology-india-opportunities-challenges-noexp.pdf.

14 Smart Dubai, "Dubai Blockchain Strategy", December 2016. Available from http://www.smartdubai.ae/dubai_blockchain.php; and Nikhil Lohade, "Dubai aims to be a city built on blockchain", *The Wall Street Journal*, 24 April 2017. Available from https://www.wsj.com/articles/dubai-aims-to-be-a-city-built-on-blockchain-1493086080.

about USD 348 billion in 2016. The aim is to replace paper-based contracts with smart contracts that will help reduce complex documentation for the tracking, shipping and movement of goods.

3.5 Other Applications of Blockchain

Sharing Economy

Many Silicon Valley companies such as Google, Facebook, Uber and Airbnb are dependent on contributions by their users to generate value within their own platform. But recently, there has been a shift from the traditional and centralized model towards a decentralized one where there is no single player in the market providing service to a particular set of users. Rather, it is moving into the hands of large operators who now aggregate resources from multiple users to serve a larger group of consumers. The problem with this system is that the value produced by users is not equally shared among those who actually contributed, and the larger intermediaries who operate the platforms appropriate most of it. This has created an imbalance in the sharing economy. In order to bring back the balance and provide value producers with their share of profit, blockchain may find a potential use. With blockchain, software applications no longer need to be running on a centralized server. Instead, they can be deployed on a peer-to-peer network that is not controlled by any single party. These blockchain-based applications, in ways similar to the aggregators, could be used to coordinate large number of service providers as well as consumers or users, who can organize themselves without the help of a third party.[15]

Healthcare

A key problem that healthcare systems face across the world today is maintaining the integrity, security and privacy of patients' data when it is shared with concerned stakeholders. Blockchain may provide a solution to this problem by holding the complete medical history of each patient, and giving patients, doctors, hospitals, insurers and other related stakeholders the control of it. This would ensure a secure mechanism to manage the record in a decentralized way.[16]

Internet of Things (IoT)

IoT processes take place at different levels and among many parties—e.g., manufacturers, shippers, customer agents and insurers in the case of logistics management. Although interactions occur between the parties and they are often dependent on each other for the processes to reach an end, they may have different goals and use different systems to track shipments. In such a scenario, an IoT-enabled blockchain could be used to record all shipment-related information as they move through systems and organizations. Smart contracts could be automated and even optimized to keep track of international trade through blockchain.[17]

---

15 Primavera de Filippi, "What Blockchain Means for the Sharing Economy", *Harvard Business Review*, 15 March 2017. Available from https://hbr.org/2017/03/what-blockchain-means-for-the-sharing-economy.

16 John D. Halamka, Andrew Lippman and Ariel Ekblaw, "The Potential for Blockchain to Transform Electronic Health Records", *Harvard Business Review*, 3 March 2017. Available from https://hbr.org/2017/03/the-potential-for-blockchain-to-transform-electronic-health-records.

17 Christian Catalini, "How blockchain applications will move beyond finance", *Harvard Business Review*, 2 March 2017. Available from https://hbr.org/2017/03/how-blockchain-applications-will-move-beyond-finance.

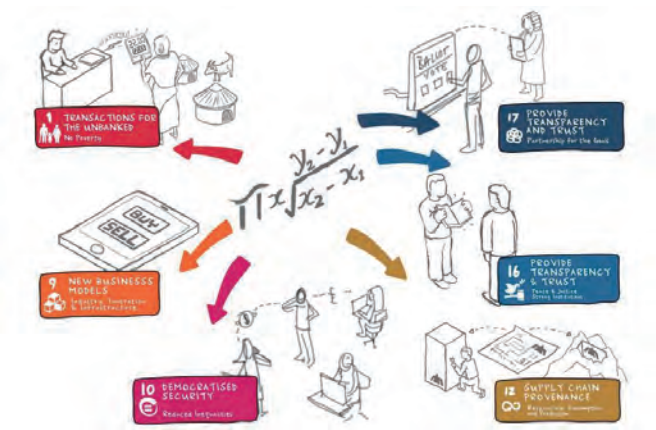
4. Policy and Regulatory Issues

4.1 Blockchain Technology and the SDGs

The United Nations and many other international development organizations consider blockchain to be a promising technology, particularly in making financial systems more efficient and equitable. As blockchain technology promises to bring in transparency, security, reliability and cost efficiency through its distributed ledger system, governments, start-ups, businesses and international organizations have shown interest in incorporating it within their policies and programmes. The United Nations Global Compact's Project Breakthrough, for example, lists down the following areas of convergence between blockchain technology and the SDGs:

- SDG 1 (No Poverty) – Blockchain can open up opportunities for those without bank accounts to trade and transact.
- SDG 9 (Industry, Innovation and Infrastructure) – Blockchains can contribute to the:
  - Creation of an infrastructure that leads to increased level of trust, transparency and efficiency across supply chains;
  - Removal of friction from value chains; and
  - Improvement of tracking mechanisms.
- SDG 10 (Reduced Inequalities) – Blockchain can contribute to the:
  - Provision of opportunities for the unbanked population to participate in trading activities; and
  - Enablement of new ways to exchange values between all the devices connected through IoT.
- SDG 16 (Peace, Justice and Strong Institutions) – Blockchain can contribute to the:
  - Building of transparency and trust;
  - Provision of a mechanism to establish identity and cast votes; and
  - Enablement of open and trusted mechanisms for tasks such as property registration and paying taxes.

Figure 8: Blockchain and the SDGs



Source: Project Breakthrough, "Disruptive Technologies: Blockchain – Building trust in a complex world", 11 July 2017. Available from http://breakthrough.unglobalcompact.org/disruptive-technologies/blockchain/.

4.2 Regulatory Concerns and Challenges

Despite its revolutionary potential, blockchain may be undermined by governance issues as humans are still very much in charge of setting the rules that the blockchain enforces. Moreover, its technical performance tend to lag behind other technologies. For example, the bitcoin network can process about seven transactions per second, whereas the Visa payment network has a peak capacity of 56,000 transactions per second.[18]

To prevent money laundering, terrorism financing and illegal use (including trading of child sexual abuse material) Australia, China and Japan have introduced regulations for digital currency exchanges because they allow transactions without the entity at either end disclosing their real identity. Such regulations signify the growing recognition of bitcoin and other cryptocurrencies as influential value transfer protocols by governments.[19]

18 Vili Lehdonvirta, "The blockchain paradox: Why distributed ledger technologies may do little to transform the economy", *Oxford Internet Institute*, 21 November 2016. Available from https://www.oii.ox.ac.uk/blog/the-blockchain-paradox-why-distributed-ledger-technologies-may-do-little-to-transform-the-economy/.

19 Luke Graham, "Another major country joins China and Japan in cracking down on bitcoin exchanges", *CNBC*, 17 August 2017. Available from https://www.cnbc.com/2017/08/17/bitcoin-faces-regulations-crackdown-by-asia-pacific-country.html.

5. References

Berke, Allison. How safe are blockchains? It depends. *Harvard Business Review*, 7 March 2017. Available from https://hbr.org/2017/03/how-safe-are-blockchains-it-depends.

Brakeville, Sloane, and Bhargav Perepa. Blockchain basics: Introduction to distributed ledger. *IBM*, 9 May 2016. Available from https://www.ibm.com/developerworks/cloud/library/cl-blockchain-basics-intro-bluemix-trs/index.html.

Catalini, Christian. How blockchain applications will move beyond finance. *Harvard Business Review*, 2 March 2017. Available from https://hbr.org/2017/03/how-blockchain-applications-will-move-beyond-finance.

De Filippi, Primavera. What Blockchain Means for the Sharing Economy. Harvard Business Review, 15 March 2017. Available from https://hbr.org/2017/03/what-blockchain-means-for-the-sharing-economy.

Deloitte. Blockchain Technology in India: Opportunities and Challenges. April 2017. Available from https://www2.deloitte.com/content/dam/Deloitte/in/Documents/strategy/in-strategy-innovation-blockchain-technology-india-opportunities-challenges-noexp.pdf.

Goldman Sachs. Blockchain: The new technology of trust. Available from http://www.goldmansachs.com/our-thinking/pages/blockchain/

Graham, Luke. Another major country joins China and Japan in cracking down on bitcoin exchanges. *CNBC*, 17 August 2017. Available from https://www.cnbc.com/2017/08/17/bitcoin-faces-regulations-crackdown-by-asia-pacific-country.html.

Halamka, John D., Andrew Lippman and Ariel Ekblaw. The Potential for Blockchain to Transform Electronic Health Records. *Harvard Business Review*, 3 March 2017. Available from https://hbr.org/2017/03/the-potential-for-blockchain-to-transform-electronic-health-records.

Lehdonvirta, Vili. The blockchain paradox: Why distributed ledger technologies may do little to transform the economy. *Oxford Internet Institute*, 21 November 2016. Available from https://www.oii.ox.ac.uk/blog/the-blockchain-paradox-why-distributed-ledger-technologies-may-do-little-to-transform-the-economy/.

LiveMint. RBI says it hasn't authorized use of Bitcoins, flags risks. 1 February 2017. Available from http://www.livemint.com/Industry/xma89nytKOwcDu4hBT30RO/RBI-says-it-hasnt-authorised-use-of-Bitcoins-flags-risks.html.

Lohade, Nikhil. Dubai aims to be a city built on blockchain. *The Wall Street Journal*, 24 April 2017. Available from https://www.wsj.com/articles/dubai-aims-to-be-a-city-built-on-blockchain-1493086080.

Marr, Bernard. A complete beginner's guide to blockchain. *Forbes*, 24 January 2017. Available from https://www.forbes.com/sites/bernardmarr/2017/01/24/a-complete-beginners-guide-to-blockchain/#9d812166e607.

Project Breakthrough. Disruptive Technologies: Blockchain – Building trust in a complex world. 11 July 2017. Available from http://breakthrough.unglobalcompact.org/disruptive-technologies/blockchain/.

Smart Dubai. Dubai Blockchain Strategy. December 2016. Available from http://www.smartdubai.ae/dubai_blockchain.php.

The Economic Times. Another experiment with currency? RBI is looking at its own Bitcoin. 16 September 2017. Available from https://economictimes.indiatimes.com/news/economy/policy/another-experiment-with-currency-rbi-is-looking-at-its-own-bitcoin/articleshow/60710700.cms.

Wikipedia. Satoshi Nakamoto. Available from https://en.wikipedia.org/wiki/Satoshi_Nakamoto.

World Economic Forum. The Future of Financial Architecture. August 2016. Available from http://www3.weforum.org/docs/WEF_The_future_of_financial_infrastructure.pdf.

Glossary

Block : A group of transactions.

Blockchain : A record of transactions i.e., blocks when put together in a structure.

Cryptographic hash function : A function that takes an input and returns an output in the form of a fixed-size alphanumeric string.

Digital signature : A digital code that is generated and authenticated by public key encryption, which is attached to a digital document transmitted over a network to verify its content and the sender's identity.

Distributed ledger : Database that is shared, replicated and synchronized among the members of a network.

Acronyms

IoT	Internet of Things
SDG	Sustainable Development Goal

VIII. 3D Printing

Contents

List of Figures

1. Introduction

Three-dimensional (3D) printing has been around since the 1980s, but it was not until recent advances in the technology that its potential at solving problems in fields such as medicine and healthcare, sports, and the automotive industry was realized. 3D printing spans a range of processes and technologies that contain the capacity to produce a variety of products using different materials.[1]

In the conventional two-dimensional printing most of us are familiar with, we take an electronic representation of a document on a computer screen and output a replica of that onto a paper. In 3D printing, however, one takes a 3D computer model, and layer by layer in an additive process, creates a 3D version of it in plastic or other compatible materials. This is why, 3D printing is also called additive manufacturing. 3D printing is a process of making 3D solid objects from a digital file.[2]

Businesses, governments and industries across the world are realizing the potential of 3D printing.[3] However, a recent Bloomberg article classifies it as a technology still in its infancy,[4] and it may be a long way before we can see the actual breakthroughs it would bring. According to the Wohlers Report 2017, the additive manufacturing industry grew by 17.4 per cent in worldwide revenues in 2016, down from 25.9 per cent the year before. Although the industry saw a slight slowdown in 2016,[5] innovations with 3D-printed products are visible among a wide range of industries.

1 3D Printing Industry, "The Free Beginner's Guide". Available from https://3dprintingindustry.com/3d-printing-basics-free-beginners-guide.

2 Tanveer Khorajiya, "3D Printing at India's FabLab CEPT", *3D Printing Industry*, 14 August 2017. Available from https://3dprintingindustry.com/news/3d-printing-indias-fablab-cept-120089/.

3 Ibid.

4 Jeanna Smialek, “How 3-D Printers Could Erase a Quarter of Global Trade by 2060”, *Bloomberg*, 4 October 2017. Available from https://www.bloomberg.com/news/articles/2017-10-03/how-3-d-printers-could-erase-a-quarter-of-global-trade-by-2060.

5 Kenneth Wong, “Wohlers 2017 Report on 3D Printing Industry Points to Softened Growth”, *Rapid Ready*, 11 April 2017. Available from http://www.rapidreadytech.com/2017/04/wohlers-2017-report-on-3d-printing-industry-points-to-softened-growth/.

2. 3D Printing Technology

The 3D printing process begins with having a 3D model that can be created using computer-aided design software or scanned using a 3D scanner. The model is sliced into thin pieces and made readable by a 3D printer. The material processed by the 3D printer is then layered as per the design of the 3D model. Different technologies within 3D printing process different materials in different ways in order to create the final 3D object.[6]

The presence of different technologies for different processes brings challenges to the working of 3D printing technology as no printer can fit all technologies and hence, the basic printer needs modifications. For instance, one type of 3D printer uses powdered materials such as nylon and plastic to create a 3D object, which requires less use of heat to melt and mould the material. A few kinds of polymers, however, need a laser to solidify/melt the material and convert into a 3D object.[7]

Some details of a few types of 3D printing technologies available in the market today are provided below.

2.1 Vat Photopolymerization

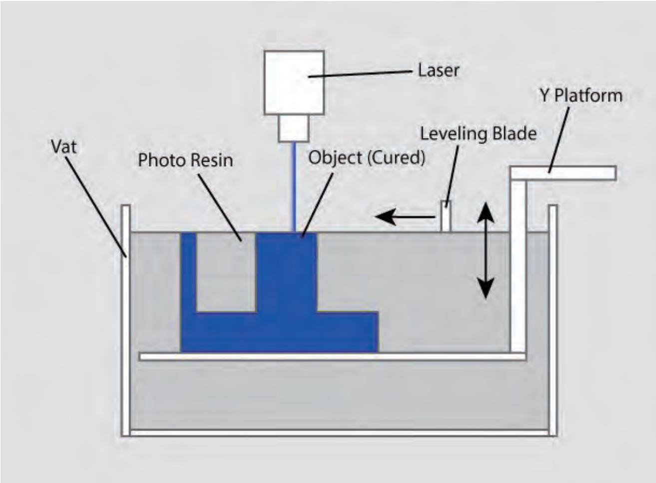
This method consists of a container filled with liquid resin that is hardened with ultraviolet light radiation. This resin is called photopolymer. There are three main configurations available for the process namely, vector scan, mask projection and two photon. In vector scan, a mirror is used on which the laser beam is directed to trace a pattern. This results in formation of a layer. Mask projection uses an optic system to make the pattern shine on the surface, which eventually turns into a layer. Finally, two photon makes use of two lasers, which when pointed and meet at a spot on the liquid surface result in polymerization.[8] Figure 1 shows the basic process. It further consists of two separate processes—stereolithography and digital light processing (DLP).

6 3D Printing Industry, "The Free Beginner's Guide: 3D Printing Technology". Available from https://3dprintingindustry.com/3d-printing-basics-free-beginners-guide#03-technology.

7 Ibid.

8 D'Janky, "Vat Polymerization: Additive Manufacturing & 3D Printing". Available from https://medium.com/@djanky/vat-polymerization-additive-manufacturing-3d-printing-520812cfe7b2/.

Figure 1: Vat Photopolymerization Mechanism



Source: 3DPrinting.com, "What is 3D Printing: Vat Photopolymerisation". Available from https://3dprinting.com/what-is-3d-printing/#Vat Photopolymerisation.

Stereolithography

This 3D printing technology uses a laser-based process to react with the photopolymer (liquid) resins. These resins react with the laser, solidifying each successive layer, finally forming an object in a very precise way.[9] It is not an easy process because of its degree of precision. Due to the organization of the system, the process needs support structures while printing objects with overhangs or overcuts. Later, these extra structures have to be manually removed.[10] This technique is used in medical modelling of various anatomical regions of a patient from computer scans. The data from computer scans consists of a series of cross sectional images of the human anatomy. A particular set of tissues is selected based on the relevant range of grey values and a region of interest is then chosen. This process is called as segmentation. The segmented data is then translated into a format suitable for stereolithography. This technique can assist with diagnosis and help surgeons perform surgeries.

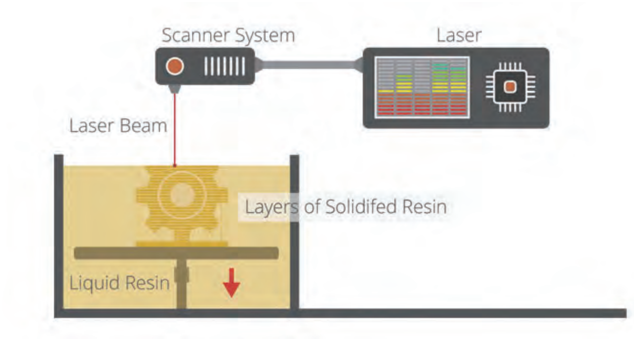
The post-processing steps mostly include cleaning and curing. Curing is the hardening of the object surface under intense light in an oven-like machine. Stereolithography is considered the most accurate of all the processes available today because of its capability to add extra finished layer to the object printed.[11]

9 3DPrinting.com, "What is 3D Printing: Stereolithography (SLA)". Available from https://3dprinting.com/what-is-3d-printing/#sla.

10 Ibid.

11 Ibid.

Figure 2: Stereolithography Mechanism

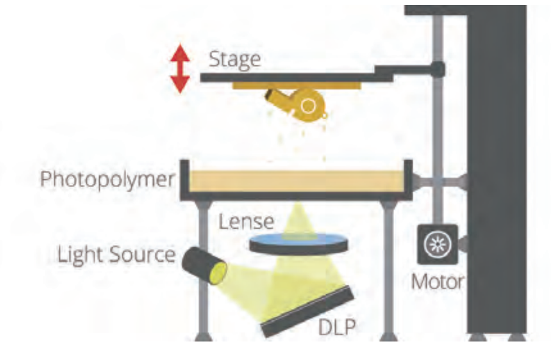


Source: 3D Printing Industry, "The Free Beginner's Guide". Available from https://3dprintingindustry.com/3d-printing-basics-free-beginners-guide.

Digital Light Processing

This method uses light and photosensitive polymers for 3D printing. The working of DLP is similar to that of stereolithography except for the light source. DLP uses more traditional light sources such as an arc lamp with a liquid crystal display panel or a deformable mirror DLP device, which are applied to the entire surface of the tank of photopolymer resin in a single pass, generally making it faster than stereolithography.[12]

Figure 3: Digital Light Processing



Source: 3D Printing Industry, "The Free Beginner's Guide: 3D Printing Processes". Available from https://3dprintingindustry.com/3d-printing-basics-free-beginners-guide#04-processes.

2.2 Material Extrusion

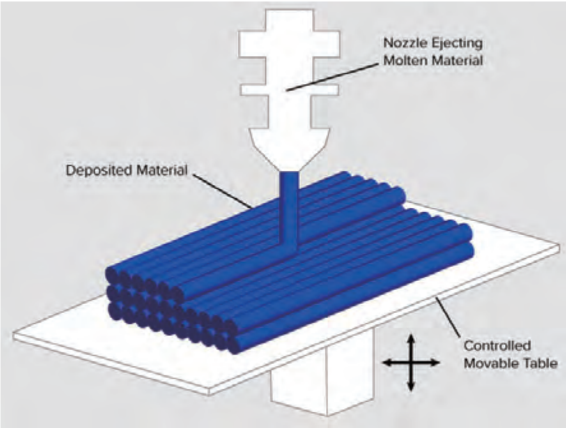
Fused Deposition Modelling

This method works using a metal wire or a plastic filament that is unwound from a coil. The material is then supplied to an extrusion nozzle that is responsible for turning on and off the flow. The material melts as the nozzle heats up. The nozzle can be moved in horizontal and vertical directions based on a numerically-controlled mechanism of the computer-aided manufacturing software package.

12 3D Printing Industry, "The Free Beginner's Guide: 3D Printing Processes". Available from https://3dprintingindustry.com/3d-printing-basics-free-beginners-guide#04-processes.

After the extrusion of molten material, the object is produced. As the material hardens, the layers are formed. This technique is used mostly with two plastic filament material types—acrylonitrile butadiene styrene and polylactic acid.[13]

Figure 4: Fused Deposition Modelling

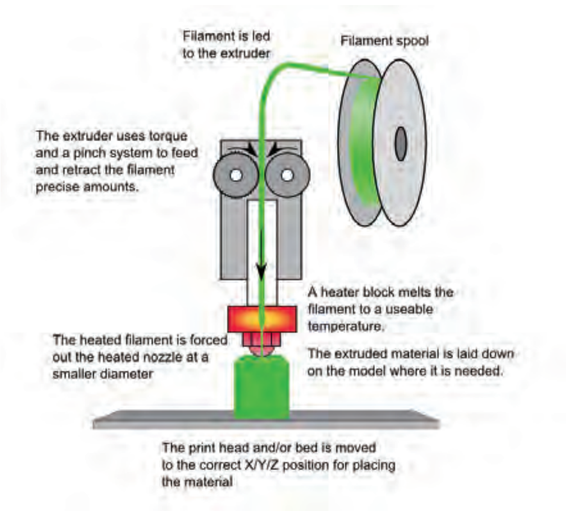


Source: 3DPrinting.com, "What is 3D Printing: Fused Filament Fabrication (FFF)". Available from https://3dprinting.com/what-is-3d-printing/#fff.

Fused Filament Fabrication

This is a process by which a machine deposits a filament of a certain material on top of the same material so as to form a joint by the help of heat. Common inks include acrylonitrile butadiene styrene and polylactic acid polymers and thermoplastics, which become semi-liquid above a specific temperature and come back to a solid state when cooled down.[14] This technique is beneficial in easily customizing the infills of the objects being printed. It means this method is very useful for printing prototype models even if they are hollow as it helps save a lot on material and printing costs.

Figure 5: Fused Filament Fabrication Process



Source: David Feeney, "FFF vs. SLA vs. SLS: 3D Printing", *SD3D Printing*, 29 August 2013. Available from https://www.sd3d.com/fff-vs-sla-vs-sls/.

13 3DPrinting.com, "What is 3D Printing: Fused Filament Fabrication (FFF)". Available from https://3dprinting.com/what-is-3d-printing/#fff.

14 Ibid.

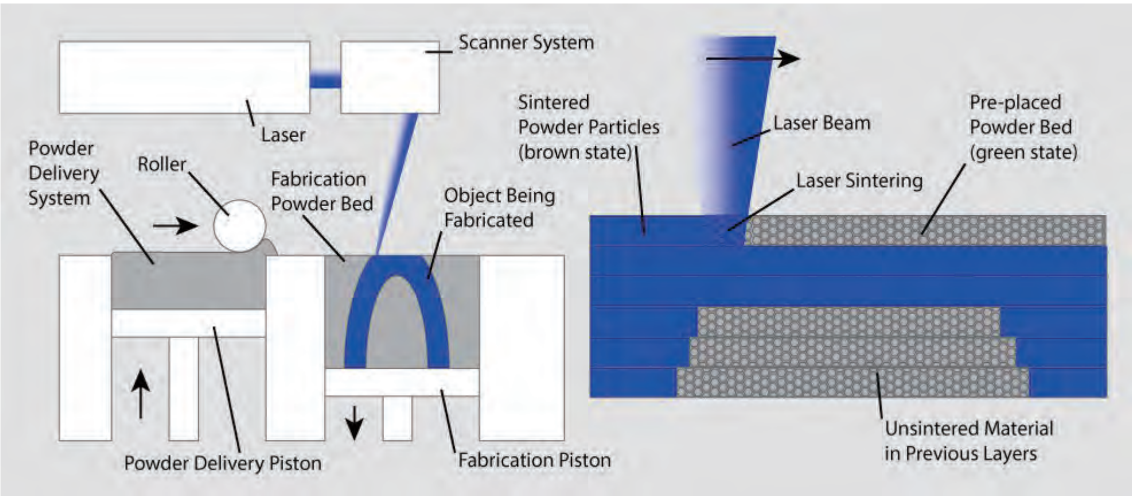
2.3 Powder Bed Fusion

This is another commonly used technology in the 3D printing process. It consists of selective laser sintering and direct metal laser sintering.

Selective Laser Sintering

This technique uses powdered materials (such as nylon, titanium, aluminium, polystyrene and glass). Powder is jetted from many nozzles onto the print surface, much like an inkjet printer. It uses laser to fuse particles in powder form layer by layer. As the printing continues, the powder bed keeps lowering itself for each new layer that is being added. This technique is exciting because of the flexibility it provides in terms of materials that could be used. Both plastics and metals could be fused leading to creation of much stronger and more durable prototypes. However, due to low fabrication speed and resolution, this method is mostly suitable for low volume production of small and precise parts.[15]

Figure 6: Selective Laser Sintering



Source: 3DPrinting.com, "What is 3D printing: Selective Laser Sintering (SLS)". Available from https://3dprinting.com/what-is-3d-printing/#sls.

Direct Metal Laser Sintering

Direct metal laser sintering is similar to selective laser sintering but instead of using materials like plastic, ceramic or glass, it uses metal. The untouched powder works as the support structure for the object, which is its advantage over selective laser sintering.[16]

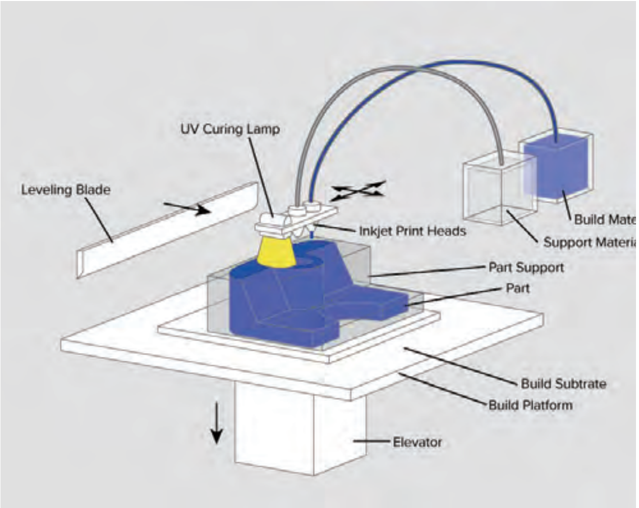
15 3DPrinting.com, "What is 3D printing: Selective Laser Sintering (SLS)". Available from https://3dprinting.com/what-is-3d-printing/#sls.

16 3DPrinting.com, "What is 3D printing: Direct Metal Laser Sintering (DMLS)". Available from https://3dprinting.com/what-is-3d-printing/#dmls.

2.4 Material Jetting

In this process, material is applied in droplets through a small diameter nozzle, similar to the way a common inkjet paper printer works, but it is applied layer-by-layer to a build platform making a 3D object and then hardened by ultraviolet light.[17]

Figure 7: Material Jetting



Source: 3DPrinting.com, "What is 3D printing: Material Jetting". Available from https://3dprinting.com/what-is-3d-printing/#Material Jetting.

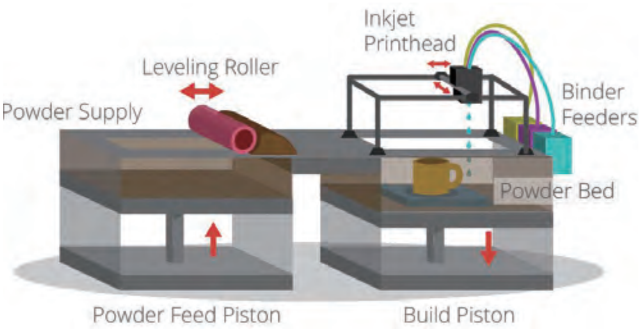
2.5 Binder Jetting

With binder jetting two materials are used—powder base material and a liquid binder. In the build chamber, powder is spread in equal layers and a binder is applied through jet nozzles that "glue" the powder particles in the shape of a programmed 3D object. The finished object that is "glued together" by binder remains in the container with the powder base material. After the print is finished, the remaining powder is cleaned off and used for 3D printing the next object. This technology was first developed at the Massachusetts Institute of Technology in 1993, and Z Corporation obtained an exclusive license in 1995.[18]

17 3DPrinting.com, "What is 3D printing: Material Jetting". Available from https://3dprinting.com/what-is-3d-printing/#Material Jetting.

18 3DPrinting.com, "What is 3D printing: Binder Jetting". Available from https://3dprinting.com/what-is-3d-printing/#Binder Jetting.

Figure 8: Binder Jetting

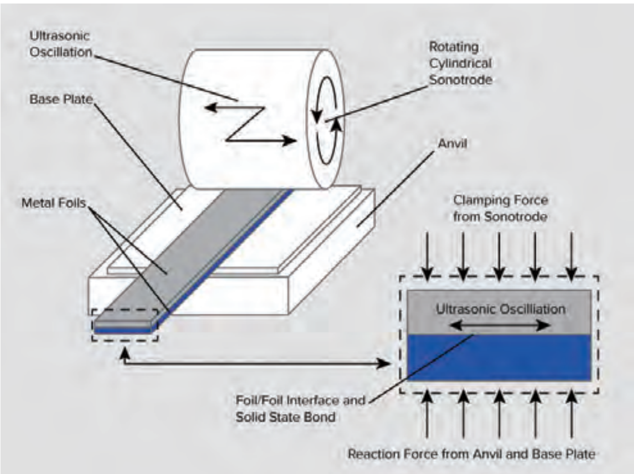


Source: 3DPrinting.com, "What is 3D printing: Binder Jetting". Available from https://3dprinting.com/what-is-3d-printing/#Binder Jetting.

2.6 Sheet Lamination

Sheet lamination processes involve ultrasonic additive manufacturing and laminated object manufacturing. Ultrasonic additive manufacturing binds materials in the form of sheets with the help of an external force. The material of the sheet could be metal, paper or any form of polymer. Ultrasonic welding is used to bind the metal sheets together and then milled into a proper shape using computer numerical controlled technology. With paper sheets, adhesive glue is used to hold them together while they are cut into the required shape by precise blades.[19] Laminated object manufacturing uses the cross-hatching method during printing as it allows for easy removal of extra metal after build. Laminated object manufacturing are often used for aesthetic and visual models and are not suitable for structural use.[20]

Figure 9: Sheet Lamination



Source: 3DPrinting.com, "What is 3D printing: Sheet Lamination". Available from https://3dprinting.com/what-is-3d-printing/#Sheet Lamination.

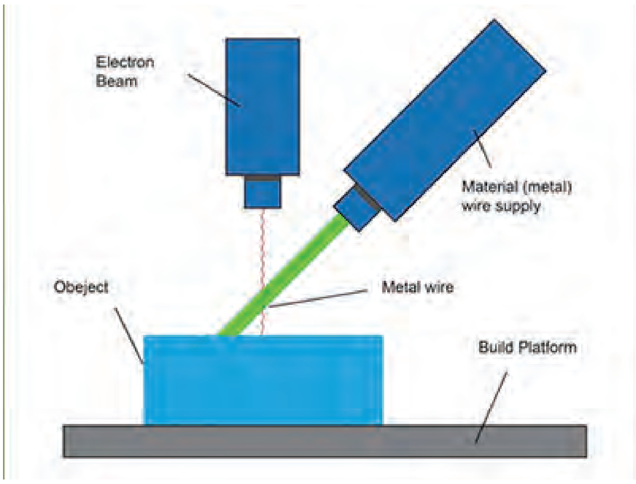
19 3DPrinting.com, "What is 3D printing: Sheet Lamination". Available from https://3dprinting.com/what-is-3d-printing/#Sheet Lamination.

20 Loughborough University Additive Manufacturing Research Group, "About Additive Manufacturing: Sheet Lamination". Available from http://www.lboro.ac.uk/research/amrg/about/the7categoriesofadditivemanufacturing/sheetlamination/.

2.7 Directed Energy Deposition

Directed energy deposition is comparatively a complex printing process. It covers a range of terminology used in the domain of 3D printing such as laser engineered net shaping, directed light fabrication, direct metal deposition and 3D laser cladding. In this process, the directed energy deposition machine consists of a nozzle that is mounted on a multi-axis arm. The molten material is deposited on the surface where it solidifies with time. In principle, this process is similar to material extrusion mentioned above except that the nozzle here can move in multiple directions. The laser or electron beam is used to deposit the material after melting it. The materials used in this process are ceramics, polymers and metals in the form of either powder or wire. It mostly finds its applications in the repair and maintenance of structural parts.[21]

Figure 10: Directed Energy Deposition



Source: Loughborough University Additive Manufacturing Research Group, "About Additive Manufacturing: Directed Energy Deposition". Available from http://www.lboro.ac.uk/research/amrg/about/the7categoriesofadditivemanufacturing/directedenergydeposition/.

21 Loughborough University Additive Manufacturing Research Group, "About Additive Manufacturing: Directed Energy Deposition". Available from http://www.lboro.ac.uk/research/amrg/about/the7categoriesofadditivemanufacturing/directedenergydeposition/.

3. Materials Used in 3D Printing[22]

The materials used and available for 3D printing have increased substantially since its initial days. Now, there are a wide variety of materials available in different forms such as powder, resin and granules. With growing demands in the 3D printing industry, special materials are being developed for specific platforms dedicated to printing various kinds of objects. Some of the widely used materials are plastics, metals, biomaterials, paper and ceramics.

Plastics

Nylon or polyamide is commonly used in powder form with the sintering process, or in filament form with the fused deposition modelling process. It is a strong, flexible and durable plastic material that has proved reliable for 3D printing. It is naturally white in colour, but it can be coloured, pre- or post-printing. This material can be combined (in powder format) with powdered aluminium to produce another common 3D printing material for sintering—alumide.

Acrylonitrile butadiene styrene is a petroleum-based polymer. It is very resistant to high temperature, which makes this material perfect for realworld components. It is a relatively cheap material allowing for costeffective prototyping. Acrylonitrile butadiene styrene is the go-to material for most 3D printers. Along with polylactic acid, it is the most common material used for desktop 3D printing.

Made from renewable resources, polylactic acid is a green 3D printing material. It is moderately priced, and has various desirable properties and technical specifications that makes it the perfect 3D printer filament for hobbyists.

Polypropylene is a plastic used for many different purposes such as textiles, ropes and stationery. It is also resistant to multiple chemicals and solvents. Polypropylene is one of the most cost-efficient materials. The most common shaping technique for producing polypropylene is injection moulding. It ranks as one of the most coveted materials in the world.

Metals

A growing number of metals and metal composites are used for industrial grade 3D printing. Two of the most common are aluminium and cobalt derivatives. One of the strongest and, therefore, most commonly used metal for 3D printing is stainless steel in powder form for the sintering/melting/electron beam melting processes. It is naturally silver, but can be plated with other materials to give a gold or bronze effect.

22 This section is drawn from: 3DPrinting.com, “3D Printer Materials Guide”. Available from https://3dprinting.com/materials/; and 3D Printing Industry, "The Free Beginner's Guide: 3D Printing Materials". Available from https://3dprintingindustry.com/3d-printing-basics-free-beginners-guide#05-materials.

In the last few years, gold and silver have been added to the range of metal materials that can be 3D printed directly, with obvious applications across the jewellery sector. These are both very strong materials and are processed in powder form.

Titanium is one of the strongest metal materials and has been used for 3D printing industrial applications for some time. Supplied in powder form, it can be used for the sintering/melting/electron beam melting processes.

Biomaterials

There is a lot of research being conducted in the potential of 3D printing biomaterials for a host of medical and other applications. Living tissue is being investigated at a number of leading institutions with a view to developing applications that include printing human organs for transplant, as well as external tissues for replacement body parts. Other research in this area is focused on developing food stuffs—meat being the prime example.

Paper

Standard A4 copier paper is a 3D printing material employed by the proprietary selective deposition lamination process supplied by Mcor Technologies. The company operates a notably different business model to other 3D printing vendors, whereby the capital outlay for the machine is in the mid-range, but the emphasis is very much on an easily obtainable, cost-effective material supply that can be bought locally. 3D-printed models made with paper are safe, environmentally friendly, easily recyclable and require no post-processing.

Ceramics

Ceramics are a relatively new group of materials that can be used for 3D printing with various levels of success. The particular thing to note with these materials is that, post printing, the ceramic parts need to undergo the same processes as any ceramic part made using traditional methods of production, namely, firing and glazing.

4. Applications of 3D Printing

4.1 Healthcare and Medicine

Healthcare is the first industry to have adopted the 3D printing technology. Medical technologies are often expensive in the initial phases when they become available in the market, and become cheaper only over time. Many of the new 3D-printed solutions can be introduced at a reasonable price. This shift has the potential to disrupt the trajectory of rising healthcare costs.

For example, experts have developed 3D-printed skin for burn victims, and airway splints for babies with tracheobronchomalacia, which makes the tiny airways around the lungs prone to collapsing. Other examples include bespoke patient-specific products such as hearing aids, orthotic insoles for shoes, personalized prosthetics, and one-off implants for patients suffering from diseases such as osteoarthritis, osteoporosis and cancer, along with accident and trauma victims. 3D-printed surgical guides for specific operations are also an emerging application that is aiding surgeons in their work and patients in their recovery.

In the research phase, scientists at Princeton University, USA, have used 3D-printing tools to create a bionic ear that can hear radio frequencies far beyond the range of normal human capability, in a project to explore the feasibility of combining electronics with tissue.[23]

There are plenty of other advances in the field of 3D bioprinting,[24] and many of them have been a part of successful surgeries and treatments. In cancer treatment alone, 3D printing is making huge leaps forward. In 2014, researchers developed a fast and inexpensive way to make facial prostheses for patients who had undergone surgery for eye cancer using facial scanning software and 3D printing.[25] In 2015, another team of researchers found that it is possible to print patient-specific, biodegradable implants to more effectively cure bone infections and bone cancer.[26]

---

23 John Sullivan, “Printable ‘bionic’ ear melds electronics and biology”, *Princeton University*, 8 May 2013. Available from https://www.princeton.edu/news/2013/05/08/printable-bionic-ear-melds-electronics-and-biology.

24 T. J. McCue, “$4.1 Billion Industry Forecast in Crazy 3D Printing Stock Market”, *Forbes*, 30 July 2015. Available from http://www.forbes.com/sites/tjmccue/2015/07/30/4-1-billion-industry-forecast-in-crazy-3d-printing-stock-market/.

25 American Academy of Ophthalmology, “3-D Printed Facial Prosthesis Offers New Hope for Eye Cancer Patients Following Surgery”, 20 October 2014. Available from http://www.aao.org/newsroom/news-releases/detail/3d-printed-facial-prosthesis-offers-new-hope-eye-c.

26 David Sher, “Ordinary Replicator 2X Used to 3D Print Bone Cancer Treatments”, *3D Printing Industry*, 3 February 2015. Available from http://3dprintingindustry.com/2015/02/03/amazing-3d-printing-app-uses-replicator-2x-cure-bone-infections-cancer/.

3D-printed ankle replacements,[27] 3D-printed casts[28] and 3D-printed pills[29] have all been developed in the past few years, with encouraging success rates. The 3D-printed cast, for example, heals bones 40-80 per cent faster than traditional casts. 3D-printed pills allow for interesting new pill shapes that completely alter the drugs' release rates.

4.2 Automotive and Industrial Manufacturing

Another early adopter of 3D printing is the automotive sector, particularly motor sport and F1 racing companies, for rapid prototyping of automotive parts. These prototypes are used to develop and adapt their manufacturing processes.

At the beginning of 2017, the Government of the Republic of Korea announced its plan to invest KRW 41.2 billion (USD 37 million) towards the development and expansion of 3D printing technology and the additive manufacturing industry.[30]

4.3 Aerospace

The aerospace sector is also an early adopter of 3D printing for product development and prototyping. Companies including GE / Morris Technologies, Airbus / EADS, Rolls-Royce, BAE Systems and Boeing, in partnership with academic and research institutes, have been pushing the boundaries of the technology for manufacturing applications.

Wipro, an Indian information technology services corporation has successfully collaborated with German additive manufacturing giant EOS to produce a 3D-printed functional metal satellite component. The "North West Feed Cluster" was printed in aluminium for the Indian Space Research Organisation's GSAT-19 communications and research satellite launched on 5 June 2017.[31]

---

27 Heidi Milkert, "3D Printed Ankle Replacement Surgery a Success for Texas Woman", *3DPrint.com*, 1 July 2014. Available from http://3dprint.com/7783/3d-printed-ankle-replacement/.

28 Sarah Buhr, "A 3D printed cast that can heal your bones 40-80% faster", *TechCrunch*, 29 May 2014. Available from http://techcrunch.com/2014/05/29/a-3d-printed-cast-that-can-heal-your-bones-40-80-faster/.

29 Brian Krassenstein, "Researchers 3D Print Odd Shaped Pills on a MakerBot, Completely Changing Drug Release Rates", *3DPrint.com*, 10 May 2015. Available from http://3dprint.com/64223/3d-printed-drugs/.

30 Tanveer Khorajiya, "3D Printing at India's FabLab CEPT", *3D Printing Industry*, 14 August 2017. Available from https://3dprintingindustry.com/news/3d-printing-indias-fablab-cept-120089/.

31 Jeanna Smialek, "How 3-D Printers Could Erase a Quarter of Global Trade by 2060", *Bloomberg*, 4 October 2017. Available from https://www.bloomberg.com/news/articles/2017-10-03/how-3-d-printers-could-erase-a-quarter-of-global-trade-by-2060.

4.4 Education

Educators and students have long been using 3D printers in the classroom. 3D printing enables students to materialize their ideas in a fast and affordable way. Mattel has recently unveiled a 3D printer for children called the ThingMaker,[32] allowing kids to build their own toys. 3D printing at FabLab CEPT University, Ahmedabad and many other locations in India provide students with an opportunity to make their own toys and games using 3D printing techniques that are taught in a learn-by-play manner.

Projects such as Create Education[33] (funded by Ultimaker) enable schools to integrate additive manufacturing technologies into their curriculum for essentially no cost. The project lends a 3D printer to schools in exchange for either a blog post about the teacher's experience of using it or a sample of their lesson plan for class. This allows the company to show what 3D printers can do in an educational environment.

4.5 Architecture

Architectural models have long been a staple application of 3D printing processes for producing accurate demonstration models of an architect's vision. 3D printing offers a relatively fast, easy and economically viable method of producing detailed models directly from 3D computer-aided design, building information modelling or other digital data that architects use. Many successful architectural firms now commonly use 3D printing as a critical part of their workflow for increased innovation and improved communication.

4.6 Food

Although a late-comer to 3D printing, food is an emerging application (and/or 3D printing material) that is getting people very excited and has the potential to truly take the technology into the mainstream. 3D printing is emerging as a new way of preparing and presenting food. Initial forays into 3D printing food were with chocolate and sugar, and these developments have continued apace with specific 3D printers hitting the market. Some other early experiments with food include the 3D printing of "meat" at the cellular protein level. More recently, pasta is another food group that is being researched for 3D printing food. Looking to the future, 3D printing is being considered as a complete food preparation method and a way of balancing nutrients in a comprehensive and healthy way.

---

32 RT US News, "Move over Santa: 3D printer lets kids make their own toys", 16 Feb 2016. Available from https://www.rt.com/usa/332688-mattel-3d-toy-printer/.

33 CREATE Education Project. Available from https://www.createeducation.com/.

4.7 Fashion

3D-printed accessories including shoes, head pieces, hats and bags have all made their way on to global catwalks. Some more visionary fashion designers have demonstrated the capabilities of the technology for haute couture by producing dresses, capes, full-length gowns and even underwear. Iris van Herpen is a pioneer in applying 3D printing to fashion design and production. She has produced a number of collections that has been modelled on the catwalks of Paris and Milan. Many have followed in her footsteps and are producing wholly original results.

5. Policy and Regulatory Challenges

5.1 3D Printing and the SDGs

The United Nations Global Compact's Project Breakthrough lists down the following areas of convergence between 3D printing and the Sustainable Development Goals (SDGs):

- SDG 1 (No Poverty) – 3D printing can contribute to:
  - Reduction in cost of manufacturing or purchase of advanced products; and
  - Availability of cheaper and easier repair options by making spare parts even when they are no longer available in the market.
- SDG 2 (Zero Hunger) – 3D printing can contribute to:
  - Decrease in the quantity of food that gets wasted during the production cycle; and
  - Lowering of cost and increase in food availability.
- SDG 3 (Good Health and Well-being) – 3D printing can contribute to:
  - Improvement in quality of healthcare services and comfort for users at lower costs;
  - Access to customized medical devices and prosthetics; and
  - Production of body parts instead of depending on donors.
- SDG 8 (Decent Work and Economic Growth) –3D printing can contribute to:
  - Improvement in efficient consumption and production of global resources; and
  - Increase in support for economic productivity – With access to required materials at a particular place, a whole range of products could be manufactured resulting in reduced logistics and shipping costs. This would also enable availability of products at places where they would not generally be produced.
- SDG 9 (Industry, Innovation and Infrastructure) – 3D printing can contribute to:
  - Improvement in the share of gross domestic product coming from industry;
  - Access to tools and capabilities for producing complex yet needed products;
  - Lowering of capital costs in manufacturing for small-scale producers because of increased access;
  - Flexibility in manufacturing, and less or no requirement for expensive tools; and
  - More room for innovation with access to precise ingredients.

Figure 11: 3D Printing and the SDGs

Source: Project Breakthrough, “Disruptive Technologies: Additive Manufacturing – The Rise of the Makers”, 11 July 2017. Available from http://breakthrough.unglobalcompact.org/disruptive-technologies/additive-manufacturing/.

5.2 Regulatory Concerns and Challenges

Although the effects of 3D printing may seem compelling, it is still an evolving technology, currently stuck in its growth by issues of cost, speed, different needs of materials and hardware architecture. Moreover, 3D printing still has not reached a point where it could match the quality of products developed otherwise with smoother finishing. But, like other technologies, with time and higher production, its price can come down and its usage capability can improve.

Certain challenges at policy and regulatory levels are mostly related to safety. This wave of 3D printing across the world has led to the birth of 3D printing labs in large numbers. But what poses a huge concern is how the printed products will behave over time because essentially every part manufactured has to go through a quality check. These products need to be consistent over time in terms of quality and should not be harmful to the surroundings.[34]

Apart from concerns of long-term behaviour and quality of 3D-printed products, there is the challenge of regulating harmful and illegal use cases. 3D-printed weapons, for example, could be a serious law and order concern and would need suitable regulatory guidelines involving production and use.

34 Robert McCutcheon, “Limitations of 3D printing”, *PricewaterhouseCoopers*, 24 March 2014. Available from http://usblogs.pwc.com/industrialinsights/2014/03/24/limitations-of-3d-printing/; and Robert Wright, “Regulatory concerns hold back 3D printing on safety”, Financial Times, 23 November 2014. Available from https://www.ft.com/content/bfab071c-6abc-11e4-a038-00144feabdc0?mhq5j=e5.

6. References

3D Printing Industry. The Free Beginner's Guide. Available from https://3dprintingindustry.com/3d-printing-basics-free-beginners-guide.

3DPrinting.com. What is 3D Printing. Available from https://3dprinting.com/what-is-3d-printing/.

American Academy of Ophthalmology. 3-D Printed Facial Prosthesis Offers New Hope for Eye Cancer Patients Following Surgery. 20 October 2014. Available from http://www.aao.org/newsroom/news-releases/detail/3d-printed-facial-prosthesis-offers-new-hope-eye-c.

Buhr, Sarah. A 3D printed cast that can heal your bones 40-80% faster. *TechCrunch*, 29 May 2014. Available from http://techcrunch.com/2014/05/29/a-3d-printed-cast-that-can-heal-your-bones-40-80-faster/.

CREATE Education Project. Available from https://www.createeducation.com/.

Feeney, David. FFF vs. SLA vs. SLS: 3D Printing. *SD3D Printing*, 29 August 2013. Available from https://www.sd3d.com/fff-vs-sla-vs-sls/.

Khorajiya, Tanveer. 3D Printing at India's FabLab CEPT. *3D Printing Industry*, 14 August 2017. Available from https://3dprintingindustry.com/news/3d-printing-indias-fablab-cept-120089/.

Krassenstein, Brian. Researchers 3D Print Odd Shaped Pills on a MakerBot, Completely Changing Drug Release Rates. *3DPrint.com*, 10 May 2015. Available from http://3dprint.com/64223/3d-printed-drugs/.

Loughborough University Additive Manufacturing Research Group. About Additive Manufacturing. Available from http://www.lboro.ac.uk/research/amrg/about/.

McCue, T. J. $4.1 Billion Industry Forecast in Crazy 3D Printing Stock Market. *Forbes*, 30 July 2015. Available from http://www.forbes.com/sites/tjmccue/2015/07/30/4-1-billion-industry-forecast-in-crazy-3d-printing-stock-market/.

McCutcheon, Robert. Limitations of 3D printing. *PricewaterhouseCoopers*, 24 March 2014. Available from http://usblogs.pwc.com/industrialinsights/2014/03/24/limitations-of-3d-printing/.

RT US News. Move over Santa: 3D printer lets kids make their own toys. 16 Feb 2016. Available from https://www.rt.com/usa/332688-mattel-3d-toy-printer/.

Smialek, Jeanna. How 3-D Printers Could Erase a Quarter of Global Trade by 2060. *Bloomberg*, 4 October 2017. Available from https://www.bloomberg.com/news/articles/2017-10-03/how-3-d-printers-could-erase-a-quarter-of-global-trade-by-2060.

Sullivan, John. Printable ‘bionic’ ear melds electronics and biology. *Princeton University*, 8 May 2013. Available from https://www.princeton.edu/news/2013/05/08/printable-bionic-ear-melds-electronics-and-biology.

United Nations Global Compact. Project Breakthrough. Available from http://breakthrough.unglobalcompact.org/.

Wong, Kenneth. Wohlers 2017 Report on 3D Printing Industry Points to Softened Growth. *Rapid Ready*, 11 April 2017. Available from http://www.rapidreadytech.com/2017/04/wohlers-2017-

report-on-3d-printing-industry-points-to-softened-growth/.

Wright, Robert. Regulatory concerns hold back 3D printing on safety. *Financial Times*, 23 November 2014. Available from https://www.ft.com/content/bfab071c-6abc-11e4-a038-00144feabdc0?mhq5j=e5..

Glossary

3D printing : Takes a 3D computer model, and layer by layer in an additive process, creates a 3D version of it in plastic or other materials.

Digital light processing : This method uses light and photosensitive polymers for 3D printing.

Direct metal laser sintering : This technique uses metal, and the untouched powder works as the support structure for the object.

Fused deposition modelling : This method uses a metal wire or a plastic filament that is unwound from a coil. The material is then supplied to an extrusion nozzle that is responsible for turning on and off the flow.

Fused filament fabrication : This is a process by which a machine deposits a filament of a certain material on top of the same material to form a joint by the help of heat.

Material jetting : In this process, material is applied in droplets through a small diameter nozzle, similar to the way a common inkjet paper printer works, but it is applied layer-by-layer to a build platform making a 3D object and then hardened by ultraviolet light.

Selective laser sintering : This technique uses powdered materials (such as nylon, titanium, aluminium, polystyrene and glass) instead of the liquid polymers used in fused filament fabrication. Powder is jetted from many nozzles onto the print surface like an inkjet printer. It uses laser to fuse particles in powder form layer by layer.

Stereolithography : This technique uses a laser-based process to react with the photopolymer (liquid) resins that react with the laser, solidifying each successive layer, finally forming an object in a very precise way.

Vat photopolymerization : This method consists of a container filled with photpolymer resin that is hardened with an ultraviolet light source.

Acronyms

3D	Three Dimensional
DLP	Digital Light Processing
SDG	Sustainable Development Goal

APCICT/ESCAP

Asian and Pacific Training Centre for Information
and Communication Technology for Development
5th Floor G-Tower, 175 Art center daero,
Yeonsu-gu, Incheon City, Republic of Korea

www.unapcict.org