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 Internet of Things

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

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]

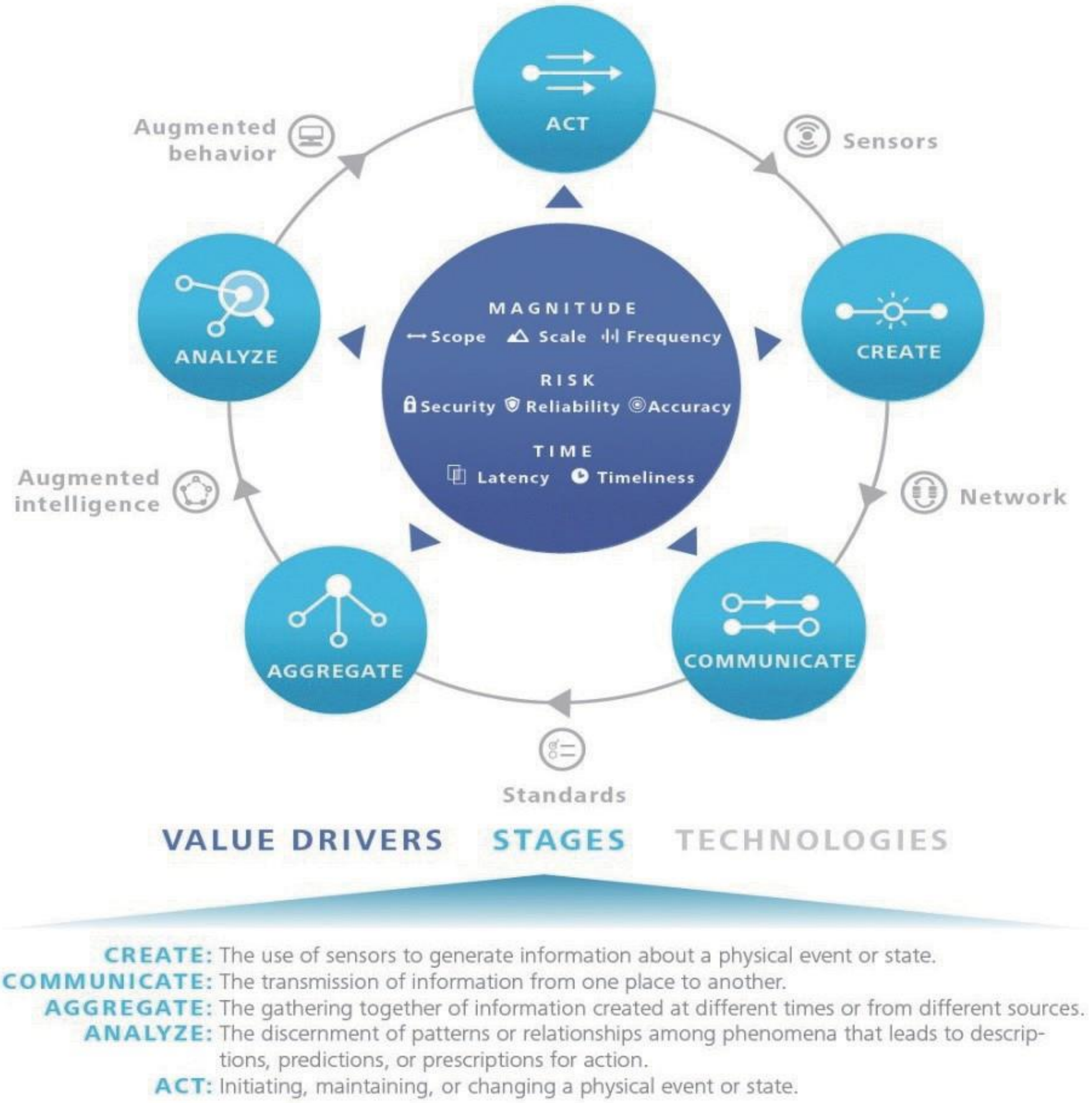
- The reduction in the cost of computing (including sensors) and the growth of Wi-Fi;
- The growth in mobile and the deployment of data-friendly third-generation (3G) networks from 2001 onwards, as well as the expansion of network connectivity across the world in both urban to rural settings (including 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.

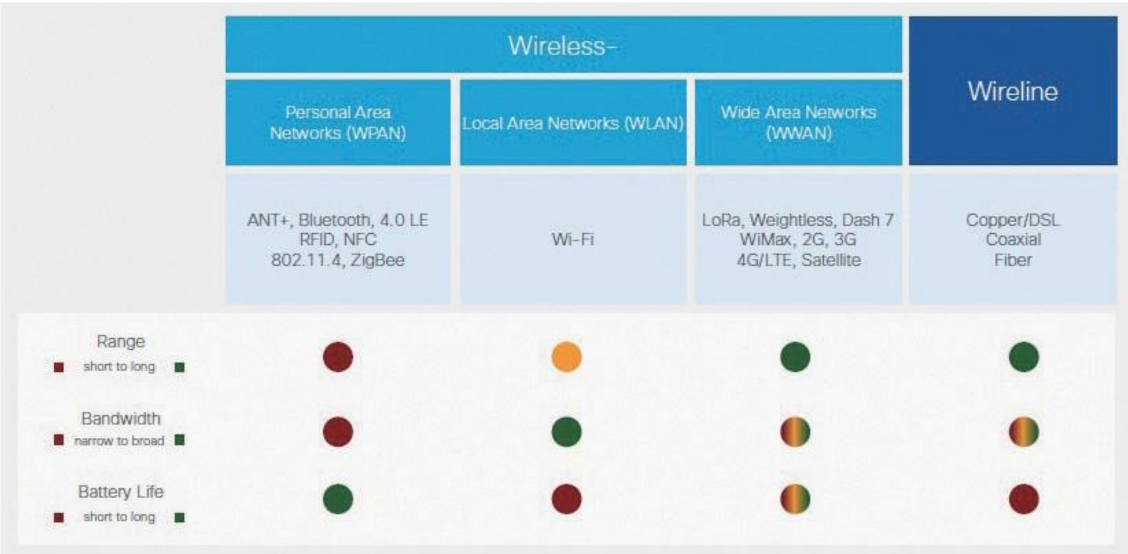
11 International Telecommunication Union and CISCO, *Harnessing the Internet of Things for Global Development* (Geneva, 2016). Available from https://www.itu.int/en/action/broadband/Documents/Harnessing-IoT-Global-Development.pdf.

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.

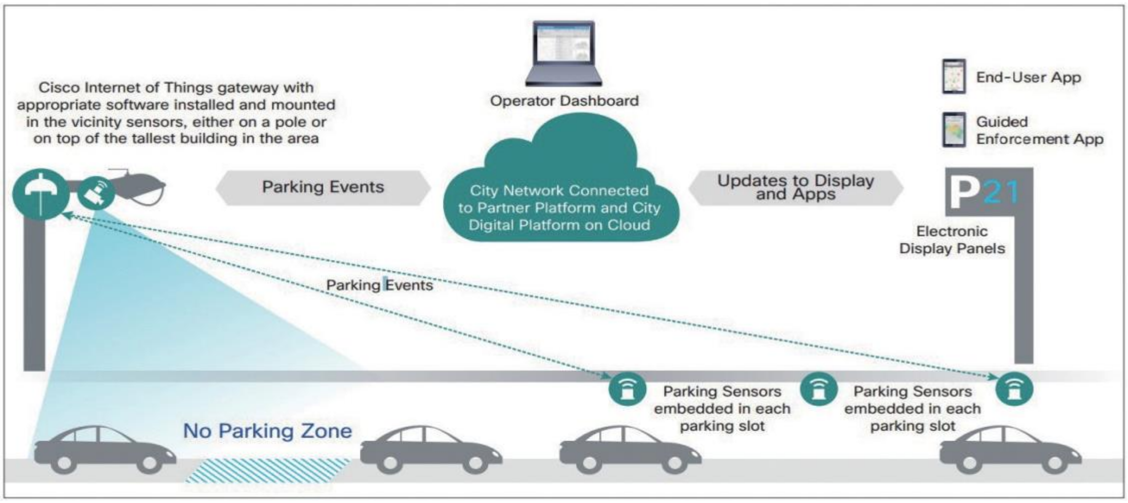
Intelligent Transport System

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]

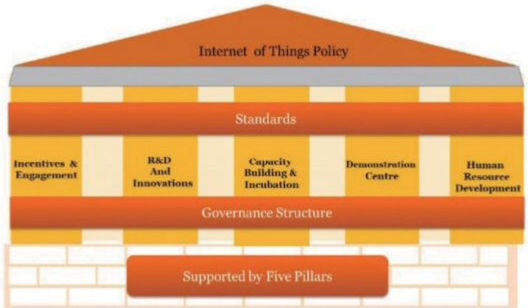
Case: India's IoT Policy

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
	Ensure availability and sustainable management of water and sanitation for all.	Automated metering and water quality monitoring.
	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.
	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

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