CHAPTER 3

TECHNOLOGY PROGRESS AND ADOPTION

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This chapter should be cited as:
Suryanegara, M. (2023), 'Technology Progress and Adoption' in Chen, L., K. Ramli, F.F. Hastiadi, and M. Suryanegara (eds.), *Accelerating Digital Transformation in Indonesia: Technology, Market and Policy*. Jakarta: ERIA, pp.37-76.

1. INDONESIAN PROFILE OF TECHNOLOGY – MOBILE NETWORK

1.1 TECHNOLOGICAL OVERVIEW OF MOBILE BROADBAND COMMUNICATIONS[1]

A continuous change in mobile technology generations – from 1G, 2G, 3G, to 4G – has created a series of progressive key technological innovations as seen in Table 3.1 (Suryanegara, 2020). Beginning with the all-analogue platform in 1G, technological change from 1G to 2G led to a fundamental innovation in the digitalisation of mobile technology, with voice as the main commodity and text messaging (SMS) as the main value-added service. The SMS innovation was globally adopted by the market, creating a prominent and unplanned success story in mobile services. In the 2G era, the global system for mobile communications (GSM) was the world's most popular standard, accounting for more than 70% of global mobile subscribers.

In the transition from 2G to 3G, technological innovation was centred on using increased bandwidth. The technical platform of Code Division Multiple Access (CDMA) as the multiple access technique enabled data communications up to 2 Megabits per second (Mbps). Meanwhile, Wideband Code Division Multiple Access (WCDMA) has been the most popular 3G standard because it supports a continuous evolution from the 2G standard of GSM. The ability of 3G to provide data communications generates pervasiveness and opens up the service innovation underlying such broadband mobile technology. The concept of service innovation started to become significant in the 3G era with the emergence of 3G-enabled multiservice creation over internet and data networks.

Innovations from 3G to 4G are focused on increased data rates by developing technical aspects of multiple-input multiple-output (MIMO) and orthogonal frequency division multiplexing access (OFDMA) as the core in baseband radio. The technical enhancement includes larger bandwidth, a multiple access mechanism, and the use of turbo coding as the channel coding scheme. It enables a peak data rate of up to 1 gigabits per second (Gbps), in which LTE Release 10 is the leading standard for such technical requirements. The introduction of 4G has intensified a massive diffusion of digital services platforms all over the world. It has opened up the early arrival of advanced services, which include smart homes, smart cities, object tracking, industry automation, and IoT.

[1] See Suryanegara (2020) for more details.

Table 3.1 Sequence of Technological Innovations from 1G to 5G

Item	1G	2G	3G	4G	5G
Main technical characteristic	Supporting cellular voice service	Supporting voice and introducing the value-added services such as SMS	Supporting multimedia communications with a data rate of 2 Mbps	Improving 3G performance by introducing a data rate of 100 Mbps for high mobility and 1 Gbps for low mobility	Supporting 3 use case scenarios: - eMBB: to perform 20 Gbps downlink - mMTC: to support 1 million devices per km^2 - uRLLC: to have 1 ms latency
Official name	N/A	N/A	IMT-2000	IMT-Advanced	IMT-2020
Key technological innovation	Analogue techniques	- TDMA - Digital modulation (e.g. GSM standard used GMSK) - Convolutional coding - Speech coding (e.g. linear predictive coding in GSM)	- Using bandwidth up 5 MHz - Multiple access technique: CDMA - Convolutional coding	- MIMO - Larger bandwidth up to 20 MHz - Adaptive modulation and coding up to 64-QAM - Multiple access technique: OFDM of subcarrier spacing up to 15 kHz - Channel coding: Turbo coding (data), convolutional coding (control plane)	57
Some leading standards	AMPS, NMT, TACS	GSM cdmaOne	W-CDMA, CDMA-2000, IP-OFDMA, TS-CDMA	LTE Advanced, IEEE 802.16m	LTE Release 15, LTE Release 16
Prominent service innovation applications	Voice	Voice, text messaging (SMS), and some other value-added services	General-purpose technology: data and internet platform to offer multiple service creation, including multimedia service, video call, internet access, etc.		
				Smart home, smart city, object tracking, industry	
					Mission-critical applications, robotic surgery, self-driving cars, industry automation, augmented reality

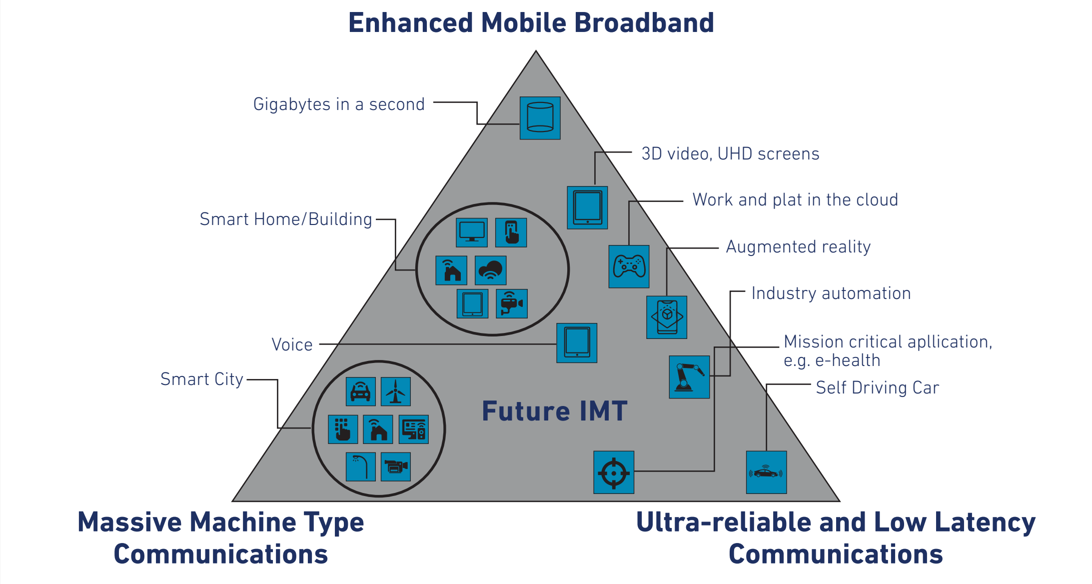
AMPS = advanced mobile phone system; AQM = adaptive modulation and coding; CDMA = code division multiple access; CP-OFDM = cyclic prefix orthogonal frequency division multiplexing; eMBB = enhanced mobile broadband; Gbps = gigabits per second; GMSK = Gaussian minimum shift keying; GSM = global system for mobile communications; IEEE = institute of electrical and electronics engineers; IMT = International Mobile Telecommunications; IP-OFDMA = internet protocol orthogonal frequency division multiple access; kHz = kilohertz; km^2 = square kilometre; LDPC = low-density parity check; LTE = Long-Term Evolution; Mbps = Megabits per second; MHz = megahertz; MIMO = multiple input multiple output; mMTC = massive machine type communications; ms = milisecond ; N/A = not applicable; NMT = Network Media Tank; OFDM = orthogonal frequency-division multiplexing; QAM = quadrature amplitude modulation; TDMA = time-division multiple access; TACS =Total Access Comunications System; TS-CDMA=time-scheduled code division multiple access= ; uRLLC = ultra-reliable low latency communications; W-CDMA = Wideband Code Division Multiple Access.

Source: Suryanegara (2020).

The research and industrial activities are conducted to develop 5G mobile technology under the umbrella of International Mobile Telecommunications (IMT)-2020. This is more than a technical enhancement; it is a technological framework with a vision to create new paradigms in connectivity, supporting a variety of digital platforms and service applications. Unlike preceding generations, 5G is no longer just about increasing speed, but also about how to facilitate massive IoT and applications at extreme low latency. It will enable more advanced services, such as mission-critical applications, robotic surgery, self-driving cars, industry automation, and augmented reality.

There are three use cases for 5G: (i) enhanced mobile broadband (eMBB), with a technical target to perform 20 Gbps downlinks; (ii) massive machine type communications (mMTC), with a technical requirement to support 1 million devices per square kilometre; and (iii) ultra-reliable low latency communications (uRLLC), with a target of supporting 1 ms user plane latency (Figure 3.1).

Figure 3.1 Use Cases of 5G Mobile Technology



Source: ITU (2015).

1.2. INDONESIAN TECHNOLOGICAL ECOSYSTEM

The mobile technology ecosystem has been structured by the service operators deploying the network infrastructure; technological suppliers (vendors) providing the technical software, hardware, and other relevant technological support; the market where the technology is diffused to its users; and the regulator creating the regulatory policies. These entities interact with each other according to their respective roles in implementing mobile technology in Indonesia.

1.2.1. Network Operators

Since the beginning of the cellular era, Indonesia's network operators have been mandated to deploy the network infrastructure throughout the country. To build the infrastructure, operators mainly use technological platforms provided by foreign vendors (i.e. Huawei, Ericsson, Nokia, and others), while local technological firms have not contributed significantly in terms of hardware deployment. Indonesians are subscribing to local mobile services, in which mobile handsets are easily obtained thanks to the free handset market situation. The mobile technology ecosystem is regulated by the national policymaker – the Ministry of Communication and Information Technology.
The early deployment of mobile technology in Indonesia began in 1994 when the country was introduced to 2G GSM technology by a national operator of Telkomsel and Indosat. During the 2G era, operators started rolling out the cellular network throughout the country. From 1997 to 2001, operators concentrated on efforts to respond to the Asian financial crisis. A steady cash flow was ensured by implementing vendor financing and deferring payments of all liabilities to vendors. However, during this period, operators were able to manage significant network development in consecutive years. Through such investment, operators carried out network expansion designed to support new subscribers every year, leading to increases in revenue.

In the 2G era, no firms supplied applications because voice was the main commodity. The operators' strategy was to use large channel infrastructure with voice traffic, then fasten revenue earnings. Research by Suryanegara and Miyazaki (2010), which characterised the Indonesian business model in the era of 2G, noted the domination of the free handset market – whereby users could easily buy a handset without having to bundle it with an operator's services. In Indonesia, users prefer not to bundle services and handsets. This has pros and cons as operators can focus on increasing the competitiveness of their service without needing to provide handsets to subscribers.

The period from 2006 to 2014 has been characterised as the emergence of data services – the era of 3G – when the three operators (Telkomsel, Indosat, Excelcomindo) launched the nationwide 3G WCDMA network in 2006. By 2008, Indonesia had 11 wireless telecommunication operators that used various 2G and 3G technologies; thus, mobile technology was successfully deployed throughout the country. During this era, the 3G business model was characterised by two main strategies: selling basic services (voice and SMS) and data (content and mobile broadband internet). For Indonesian operators, selling additional content was not very successful because cost was an obstacle that made users reluctant to access 3G content. Intense competition in the same market field forced Indonesian operators to be pragmatic, responding swiftly to competitors' actions. In the era of 3G, data was the commodity, but the multimedia content providers were not firmly established so the commodity was the internet itself.

In 2015, the country started deploying the 4G LTE Advanced network – initiating the era of 4G. During the 4G era, various firms supply both local and global digital content. By 2020, the network operators had experienced industrial merging and rationalisation, with six national operators surviving. The operators serve all populated areas, with Telkomsel controlling the largest market share. Table 3.2 provides details on the operators and technological platforms that provide cellular services in the country. It also shows that mobile technology is connected to 331 million subscribers, exceeding Indonesia's population of 270 million people.

Table 3.2 Indonesian Mobile Network Operator Indicators

Network	Service subscription brand (including once terminated)	Technology offered	Number of subscribers	Percentage of the market
Telkomsel	Simpati, KartU Halo, ByU, Kartu As, Loop	2G, 3G, 4G	171.1 million	51.7%
Indosat Oredoo	IM3 Ooredoo, GiG, Mentari	2G, 3G, 4G	59.3 million	17.9%
XL Axiata	XL Axiata, Axis, XL Prioritas	2G, 3G, 4G	56.7 million	17.1%

Network	Service subscription brand (including once terminated)	Technology offered	Number of subscribers	Percentage of the market
Hutchison 3 Indonesia	Tri	2G, 3G, 4G	30.4 million	9.2%
Smartfren Telecom	Smartfren	4G	13.3 million	4.0%
Sampoerna Telekomunikasi Indonesia (STI)	Ceria, Net1	4G	0.2 million	0.1%
Total			**331.0 million**	**100% of total subscribers**
				122% of Indonesian population

Source: Pusparisa (2020).

1.2.2. The Market

Indonesia's market ecosystem is characterised by 97% prepaid subscribers, and 90% are connected to 3G/4G technology as mobile broadband services. The behaviour of Indonesian market users is reflected in Table 3.3, which shows that they use broadband communications to access various applications, especially chats, social networks, and video applications. More than half the users use 3G/4G for shopping, and only a third use it for banking applications. The top 10 most frequently accessed applications (apps) originate abroad (e.g. WhatsApp, Facebook, and Instagram), while the only domestically made applications are Gojek and Tokopedia.

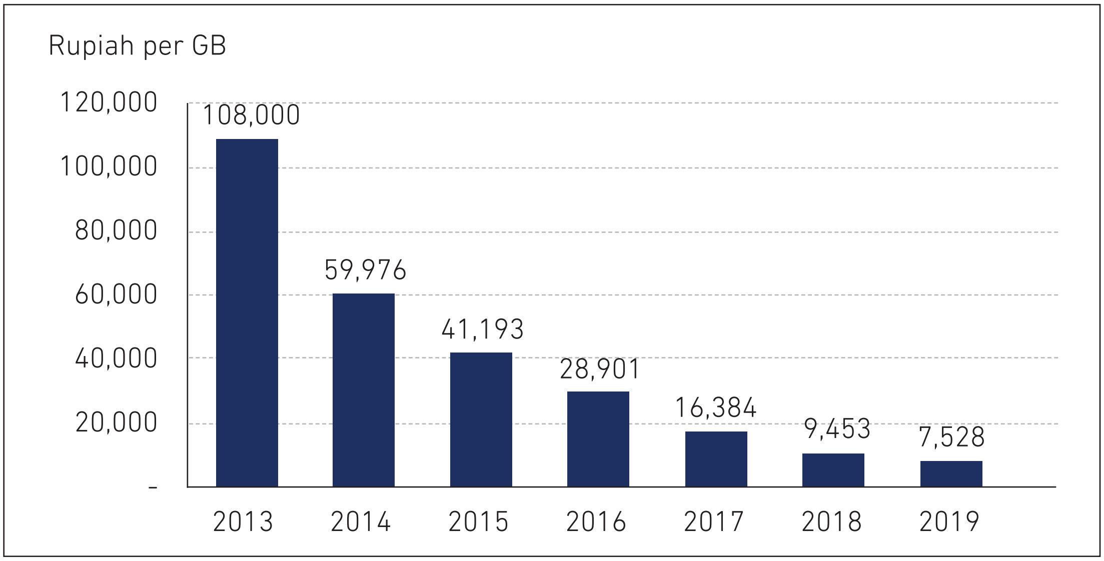
Table 3.3 Highlights of Indonesian Mobile Market Behaviour

Items	Highlights
Use of mobile apps	96% chat apps 96% social network apps 83% entertainment or video apps 55% shopping apps 33% banking apps
Top 10 mobile apps by active users	WhatsApp Messenger, Facebook, Instagram, Facebook Messenger, Line, Gojek, Shopee, Tokopedia

Source: Kemp (2020).

Consequently, the average data payload of the mobile market in Indonesia has increased significantly since 2013. In 2013, the monthly data payload per user was 0.1 gigabyte (GB) on average; whilst in 2019, the figure increased to 5.2 GB. During the same period, the global average monthly payload increased from 0.3 GB to 7.2 GB. The price of data use, measured by Rupiah per GB dropped rapidly as well. Based on statistics from Telkomsel, the telecom operator with the largest market share in Indonesia, the average price of mobile data use has decreased from Rp108,000/GB in 2013 to Rp7,528/GB in 2019. Since 2015, the total revenue generated by mobile data operating has surpassed that of voice operating. (Figure 3.2)

Figure 3.2 Average Price of Mobile Data Use



GB = gigabyte.

Source: Telkomsel (2022).

In terms of the relationship between 5G technology and the forthcoming market, research conducted in 2020 (Suryanegara, 2020) revealed what type of innovation is required to provide appropriate infrastructure and services for 5G deployment in Indonesia. The answer to this question depends on the pattern of innovation enhancement – defined as factors arising from market disorder and uncertainty that can lead the way to successful diffusion of 5G technology in that market.

Suryanegara (2020) analysed the pattern of 5G innovation enhancement (Figure 3.3) and found that the Indonesian market has kept demanding a higher data rate in all market segments. Considering the country's topography, satellites and drones can be regarded as disruptive innovation of the 5G network infrastructure to cover remote areas. As the global trend also comes with non-cellular connectivity (such as Wi-Fi), the market also expects non-cellular connectivity – aiming to be able to access free service applications. This can be to the fact that cellular data tariffs are still deemed expensive for most of the market. To support the ecosystem, the Indonesian market needs better handsets as users mostly access data, but the voice quality over the 5G network is still considered important. Finally, the market also reflects the concern that 5G should increase users' confidence in security and privacy.

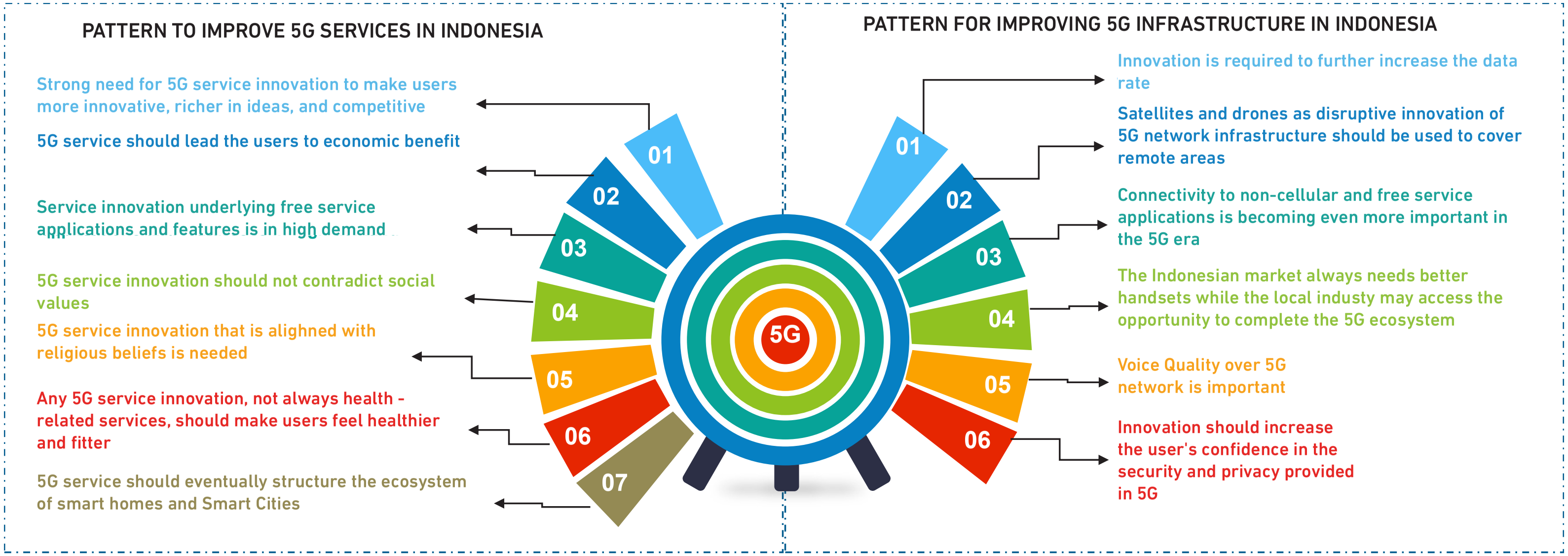
From the perspective of final benefits, Figure 3.5 emphasises that the Indonesian market expects the emergence of 5G to lead users to economic benefits and improved social values. There is a major expectation that any service innovation should not contradict society norms, and as a religious society, it should be in accordance with religious beliefs. This creates opportunities for service developers to provide a new stream of application content matching the values of local people in Indonesia.

1.2.3. Technological Suppliers

The technological supplier, commonly referred to as the vendor, is the actor in the ecosystem providing network technology for network operators and handset technology for the Indonesian market. Leading European information and communication solutions providers, such as Ericsson, Nokia, Motorola and Siemens, entered the Indonesian market at the early stage when cellular technologies were introduce to the country, and dominated the market of mobile phones in the 2G era. Apple and Samsung joined the competition and quickly took the lead of the market when the 3G technology became the mainstream. Their domination continued to the 4G era. But Chinese brands, such as Huawei, ZTE, XIAOMI, VIVO and OPPO, have been on the rise and getting Indonesian users' favor. Nexian was the first Indonesian brand during the 3G era, while Polytron is another local brand that has survived in the era of 4G.

The existence of foreign technology suppliers is clearly indicated by data on import values – the import value of Indonesia's telecommunications equipment was $2.2 billion in 2019. This value is 1.2% of the total import value and 0.1% of the GDP in Indonesia. At the beginning of the 4G era, imports reached a peak of $6.3 billion in 2013, which is 3.3% of the total import value and 0.6% of Indonesian GDP. This phenomenon indicates that the Indonesian market and industry are very excited, but they were dominated by imports. The import value of telecommunications equipment averaged $4.4 billion per year from 2003 to 2019 (CEIC, n.d.).

Figure 3.3 Pattern of 5G Innovation Enhancement in Indonesia, 2020



Source: Suryanegara (2020).

Selected technical profiles of the Indonesian mobile network are shown in Table 3.4. More than half a million base transceivers provide capacity of 2.5 million terabytes. The current use is around 96% of the total capacity, which is critical as it has almost reached the peak value. On the other hand, the need for capacity is increasing along with people's online behaviour, so it is necessary to provide additional spectrum frequency band for the operators.

Table 3.4 **Technical Profile of Mobile Networks in Indonesia in 2020**

Mobile technical parameters	Number
Total spectrum used by the operators	467 MHz
Number of base stations	521,329 unit
Monthly national capacity (provided)	2,650,592 terabytes
Monthly capacity per user (used)	7.2 gigabytes
Monthly national capacity (used)	2,485,440 terabytes (94% of total provided)

MHz = megahertz.

Source: Author (compiled from operators' reports).

1.3. INDONESIA'S MOBILE CELLULAR TARGET: BUILD UP INFRASTRUCTURE

The strategic plan for 2020–2024 of the Ministry of Communication and Information Technology, the mobile regulatory policymaker, states that the first strategic objective is to establish infrastructure and accelerate the rollout of Information and Telecommunications Technology (ICT) infrastructure to the entire territory of Indonesia. This indicates that the Government of Indonesia has made infrastructure the foundation of national digitalisation. The focus is for infrastructure to guarantee access to communication technology for all Indonesians. As an archipelagic country, half of the country's population live in 74,957 villages in rural areas. Cellular coverage has reached more than 97% of those populated areas, but broadband access (4G-based technology) is still concentrated in commercial areas such as Java, Sumatra, and parts of Kalimantan – leaving areas unserved by access telecommunications in non-commercial areas. There are 12,548 villages that have not been served by a full 4G cellular signal, of which 3,435 are in areas that are classified as the outermost and isolated locations, commonly known as 3T (*tertinggal, terluar, terpencil*) areas. The government is eager to rectify this unfair distribution and connect people in these locations by building up mobile broadband infrastructure in non-commercial areas so that 4G internet can be provided immediately.

The second strategic objective is to accelerate digital transformation in the application framework for industry, governance, and community utilisation. For this reason, it is very important for Indonesia to be able to provide high-speed mobile broadband services that support these various applications. The Speedtest Global Index in January 2020 ranked Indonesia's mobile broadband internet 120th in the world, with an average download speed of 14.16 Mbps and upload speed of 9.50 Mbps – below the global average (download speed of 31.95 Mbps and upload speed of 11.32 Mbps). For fixed broadband speed, Indonesia was ranked 115th with a download speed of 20.60 Mbps and an upload speed of 12.53 Mbps – still far below the global average (74.32 Mbps for download and 40.83 Mbps for upload).

1.4. CHALLENGES AND OPPORTUNITIES FOR UPGRADING MOBILE NETWORK IN INDONESIA

5G technology will bring the network to the next stage. Mobile network operators in Indonesia realise that to keep pace of technology progress, they must know invest more in developing the latest 5G technology. How to cultivate the new market seems challenging – the market needs continuity to grow, but the pace of technology updates seems too fast to catch up with. Moreover, the development and the update of ICT infrastructure needs intensive capital input. It is critical to create new demand and motivate the market to adopt the new generation technology.

Cellular phones are the main tool for most Indonesian internet users – 96% of internet users use their mobile phones to access the internet. When going shopping online, 91% use mobile access compared with 22% who use personal computers/desktops. (Table 3.5). This tells us a two-sided story. On the one side, such high dependence on the mobile network must thank to the country's rapid technology adoption and substantial economic growth. On the other side, the coverage and quality of fixed broadband infrastructure are still relatively low when compared to many other Asian countries. That is, the alternative for users to move from the mobile network to the fixed broadband network is limited, and when the network upgrades to 5G, it is likely that most users will arm themselves to adopt it. This could be an advantage for Indonesia in terms of upgrading its mobile network, as far as the cost of upgrade and transition is affordable.

Table 3.5 Overview of Internet Access in Indonesia

Situation in January 2020	Remarks
175.4 million internet users	• Users may access the internet from various devices, i.e. mobile phones (96%), smartphones (94%), mobile phones (21%), computer desktops (66%), and tablets (23%). • Internet users increased by 17% or 25 million per year.
160.0 million social media users	• Social media users increased by 12 million (+8.1%) from April 2019 to January 2020. • Social media penetration was 59% in January 2020.
338.2 million mobile connections	• Mobile connections increased by 15 million (+4.6%) from January 2019 to January 2020. • The number of mobile connections in January 2020 was equivalent to 124% of the total population.

Source: Author, based on Kemp (2020).

2. INDONESIAN PROFILE OF TECHNOLOGY – INTERNET OF THINGS

2.1. TECHNOLOGICAL OVERVIEW OF IOT

IoT is a network of objects connected to the internet. IoT can be described as a world in which objects can feel, communicate, and share information with one another through public or private internet Protocol (IP) networks (Patel, Patel, and Scholar, 2016). These interconnected objects have data that are regularly collected, analysed, and used for decision making. The goal of IoT is to connect objects to the internet anytime and anywhere.

In the Agriculture industry, IoT can be used to detect the number of livestock in real time, sense soil moisture and quality, sense room temperature to maintain food quality, and maintain food supply chains by using the IoT tracking application. The value of IoT in this industry is predicted to be 34.9 billion by 2027 (GlobeNewswire, 2020). WEF (2018) projected that adopting IoT in the manufacturing industry (i.e. automotive and transportation, pharmaceutical[2]) will increase value added of around $14 trillion in 2030.

[2] IoT can help maintain the quality of chemicals or medicines through sophisticated storage media such as temperature, pressure, and other sensors that are useful for maintaining the quality of drugs in storage media; and the continuity of medical drug production.

The potential benefit of IoT adoption will be even bigger in the non-manufacturing industry, especially service sectors such as medical and healthcare, retail, logistics, supply chain management[3] and environmental monitoring.

IoT will also have wide application in our daily life. For example, IoT can help improve home automation by collecting and processing real-time data related to room conditions such as temperature and humidity; detect objects, animals, and humans outside the home via home surveillance; and control home appliances using applications connected to the internet. IoT is the backbone of smart cities – it helps manage cities more effectively through applications such as traffic lights that are directly integrated with sensors and using video surveillance system to monitor vehicle flows, vehicle plates, and speed limits; and to regulate traffic. By doing so, adopting IoT can make the public administration more efficient and energy efficient.

IoT platforms can be classified based on parameters such as the data transmission rate or transmission distance. Based on the data transmission rate, IoT communication services can be classified into two categories: high-speed data services (e.g. video services) and low-speed data services (e.g. metre readings). Based on the transmission distance, IoT communication technology can be classified into two categories: short-distance communication and long-distance communication (commonly referred to as a wide area network (WAN)).

The most popular platform is IoT services that have low data rates and cover a large area – low-power wide-area network (LPWAN) technology. LPWAN technology can be classified based on the operating spectrum frequency band. The technology may operate in the licensed spectrum as well as the non-licensed spectrum. Examples of technologies that work in the non-licensed spectrum are LoRa and Sigfox. While the Narrowband Internet of Things (NB-IoT) platform works in the licensed spectrum of 3G and 4G, Table 3.6 compares Sigfox, NB-IoT, and LoRa.

[3] The value of IoT in this industry is predicted to reach $100.9 billion by 2030. (Research and Markets, 2020)

Table 3.6 Technical Comparison of IoT Platforms – Sigfox, NB-IoT, and LoRa

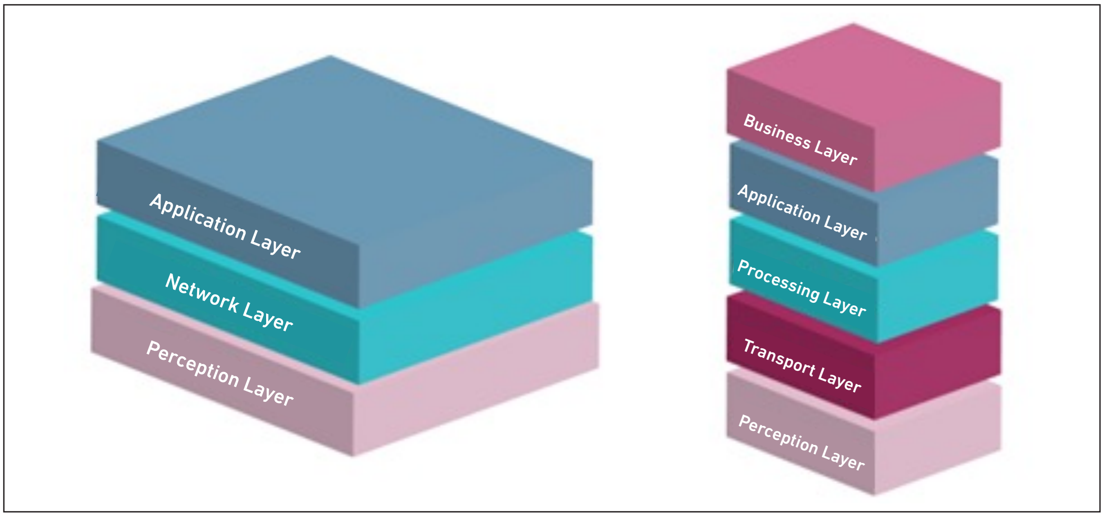
Item	Sigfox	NB-IoT	LoRa
Standard	Sigfox	3GPP	LoRa Alliance
Modulation	BPSK	QPSK	CSS
Frequency	ISM (433 MHz, 868 MHz, 915 MHz)	Licensed on LTE band	ISM (433 MHz, 868 MHz, 915 MHz)
Coverage (Tx radius)	10–40 km	2–20 km	1–10 km
Bandwidth	100 Hz	200 kHz	125 kHz, 250 kHz
Tx limit	140 packet per-day	Unlimited	Limit duty cycle
Maximum data rate	100 bps	200 kbps	50 kbps

bps = bit per second , BPSK = Binary Phase Shift Keying, CSS = Chirp Spread Spectrum, Hz = hertz, IoT = internet of things, ISM = industrial scientific and medical , kbps = kilobit per second , kHz = kilohertz, km = kilometre, LTE = Long-Term Evolution, MHz = megahertz, NB-IoT = Narrowband Internet of Things, QPSK = Quadrature Phase Shift Keying, Tx = Transmitter.

Source: Author's compilation.

There is no universally agreed IoT architecture. Three- and five-layer architectures are the most commonly used (Sethi and Sarangi, 2017). These are divided into three basic layers and five special layers, as illustrated in Figure 3.4.

Figure 3.4 Three- and Five-Layer IoT Architecture



Source: Author, based on Sethi and Sarangi (2017).

The three-layer architecture defines the main idea of IoT under the following layers:

i. Perception layer: a physical layer that has sensors to gather information about the environment around it. The sensor also detects physical objects in the surrounding environment.
ii. Network layer: responsible for connecting smart devices, network devices, and servers. The feature is also used to transmit and process sensor data.
iii. Application layer: responsible for delivering specific application services to users. It defines the various applications in which IoT can be used, e.g. smart home, smart city, and smart healthcare.

The five-layer architecture is a more complete or specialised architecture that offers a more detailed version of the three-layer architecture. It adds the transport layer to the perception layer – to transfer sensor results from the perception layer to the processing layer. The processing layer is an extended version of the network layer, which functions as middleware on the application layer side where there are many technologies such as databases, cloud computing, edge computing, and big data processing. The top layer is the business layer, which plays a role in managing the system.

2.2. INDONESIA'S IOT ECOSYSTEM

The IoT market in Indonesia is expected to reach Rp444 trillion by 2022 and Rp1,620 trillion by 2025. About 70% of the state budget will be supported by IoT-based industries. Indonesia currently has around 250 companies involved in the Indonesian IoT ecosystem. Figure 3.5 illustrates the Indonesian blueprint of a smart IoT ecosystem.

Figure 3.5 A Smart IoT Ecosystem in Indonesia

Source: ASIOTI (2020).

The IoT Indonesian Association identified three different types of roles in the ecosystem (ASIOTI, 2020). The main task of the network providers is supplying the hardware, network infrastructure, and operating platform. Foreign technology suppliers (e.g. Huawei, Nokia, and ZTE) provide the hardware, while local firms (e.g. Telkomsel, Indosat, XL Axiata, and PT Telkom) act as the network providers. Regarding the use of wireless platforms, the network providers also deal with spectrum regulatory issues – e.g. the IoT unlicensed spectrum for the LoRA platform works on 920–923 megahertz (MHz) in Indonesia. The second is undertaken by IoT service enablers, including mobile virtual network operators, IoT service delivery platforms, and firms providing deployment support. A local Indonesian company performing this role is Alita, which provides payment machine systems for the commuter railway express throughout Jakarta. The third is undertaken by companies that provide IoT applications such as Prasimax, DycodeX and Intel.

2.3. IOT IN SUPPORTING INDONESIAN INDUSTRY 4.0

In IoT technology, the government's work is driven by the Ministry of Industry, as the government views the role of IoT technology in supporting the digital transformation mainly in terms of the industrial sector. This is inseparable from the evolution of Industry 4.0, which makes IoT one of its core technologies. The establishment of an Indonesian IoT ecosystem will rely heavily on the government's commitment to implementing the 'Making Indonesia 4.0 roadmap' – an integrated roadmap to implement strategies to enter the Industry 4.0 era, developed in 2019 to achieve targets by 2030. Five sectors will serve as pilots to strengthen the fundamentals of the country's industrial structure to operationalise the roadmap: (i) food and beverage industry, (ii) automotive industry, (iii) electronic industry, (iv) chemical industry, and (v) textile industry.

The food industry has the biggest total investment (both foreign and domestic), at about Rp302.8 trillion. This is followed by basic metal, metal goods, machines, and electronics (Rp299.0 trillion); basic chemicals, chemical goods, and pharmaceuticals (Rp285.5 trillion); and other transportation industry (Rp160.3 trillion). The textile industry, as the last component of the main Industry 4.0 sectors, is in eighth place with total investment of Rp58.3 trillion (Ministry of Investment, n.d.).

Following this strategy, the country regards IoT technology as a platform for transforming Indonesian industry. Thus, such technological development is directed at the creation of application use cases that could be beneficial for Indonesian industry.

2.4. CHALLENGES AND OPPORTUNITIES FOR IOT DEVELOPMENT

The main challenge for Indonesia is to create an ecosystem involving heterogeneous types of corporate, small, medium-sized, and large technology developers. From the technology implementation point of view, the IoT network is still not perfectly formed. For its openness and easiness, the LoRa network is expected to be widely deployed. NB-IoT infrastructure has not been implemented well, although it could be a new revenue source for cellular operators. Industry is more enthusiastic about developing LoRA-based use cases and private IoT networks circulating in the community.

On the other hand, opportunity lies in the creation of IoT service applications for multiple market segments – especially for small and medium-sized enterprises (SMEs). There are around 3.7 million SMEs in Indonesia, making them the most potential users of IoT service applications. This is in line with an optimistic view that IoT creates significant opportunities for Indonesia because this technology will be effective if the solutions it offers are specific and local, i.e. based on the problems that exist in Indonesia.

In terms of non-industrial applications, Suryanegara et al. (2019) indicated the varied uses of IoT in the public sector. The strategic implications of these findings concern niche markets, for which prospective IoT operators must pay close attention to the types of applications desired by the market. Sometimes, the desired applications are not mainstream but rather are focused on specific demands. Research has shown that more than 50% of the Indonesian market wants IoT applications that benefit their jobs, while about 13% of respondents want IoT applications that provide benefits for domestic work. An interesting finding is that about 9.52% of respondents want IoT applications that will be beneficial in improving the quality of their family relationships. In addition, 5.24% of Indonesians feel that IoT technology could contribute to their religious lives.

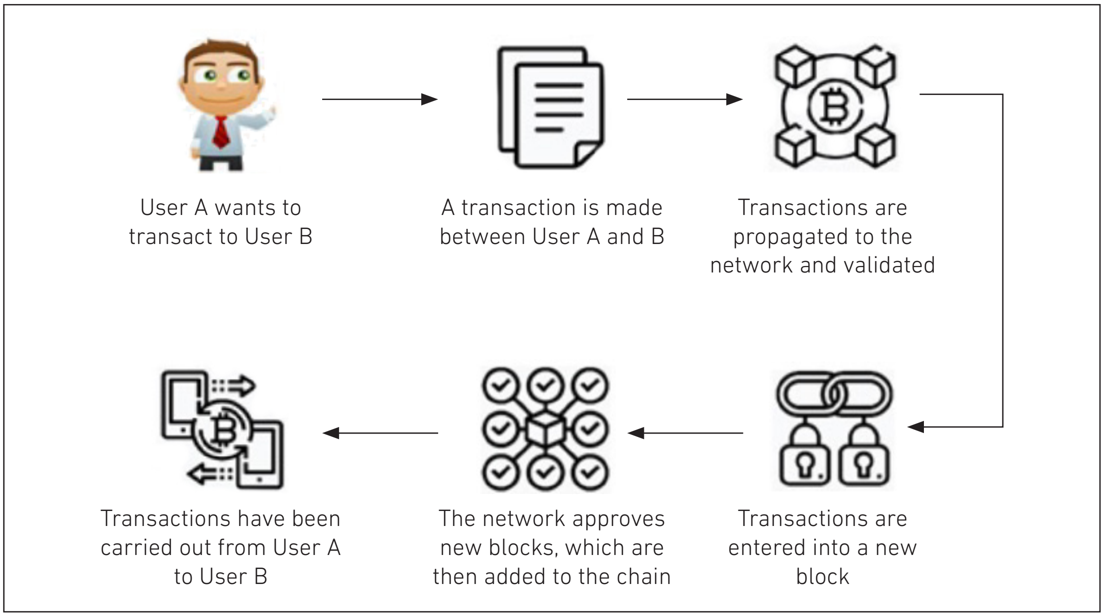
3. INDONESIAN PROFILE OF TECHNOLOGY – BLOCKCHAIN AND CRYPTOCURRENCY

3.1. TECHNOLOGICAL OVERVIEW OF BLOCKCHAIN AND CRYPTOCURRENCY

Blockchain is a decentralised ledger, originally used to record digital currency transactions on a digital currency network in a peer-to-peer (P2P) manner. This technology was developed by Satoshi Nakamoto as Bitcoin (Nakamoto, 2008). The system used by Bitcoin does not require a centralised server to store transaction history. Instead, it only stores a copy of the blockchain in all nodes of the blockchain network, making it a decentralised ledger. Each node has a copy of the ledger. Transactions are verified using public and private-key cryptography before adding new blocks to the blockchain network (Hackius and Petersen, 2017). Each transaction is carried out, starting with the necessary information regarding the sender, recipient, time, transaction information, and identification of the transaction from the previous sender (Gemeliarana and Sari, 2018).

Figure 3.6 illustrates a sample cryptocurrency flow: when user A wants to make a transaction to user B through the blockchain network in a P2P manner, the identity of the cryptographic proof is used, which is a pair of public keys and private keys on the network that can identify that user A and user B are unique. The transaction is broadcast to the memory pool on the blockchain network to verify and validate it. Then a number of approved nodes are obtained, and a new block is generated, which is also known as reaching the consensus stage. After reaching the consensus stage, new blocks across the blockchain network are formed, and each node in the blockchain network updates its respective ledger. This block contains all transactions that have occurred by following the original block on the blockchain network through a digital signature.

Figure 3.6 **Method of Blockchain Operation**



Source: Kückelhaus and Chung (2018).

In reaching the consensus stage, a consensus algorithm is used – i.e. it occurs when the P2P network has reached consensus on the distribution of the ledger that has occurred. Each existing node can choose CPU power to receive a valid block by fetching or rejecting an invalid block. Each transaction on the block is marked with a specific timestamp and blockchain data continue to grow, which means that the blockchain is a distributed variant that adapts the timestamp service.

The function of the cryptographic hash of the blockchain is usually called the secure hash algorithm 256 (SHA256). This function can generate a 16-digit hash using the sender's public key and transaction information. This encrypted transaction information is translated to verify whether the transaction was made by the sender, and the transaction can only be decrypted by the recipient who has the public key/private key (Chen et al., 2018). Each block has three core components: hash from the previous block, timestamp, and hash. The hash of the previous block is linked to the entire blockchain so the block cannot be updated once the block has been verified and validated. Changing the value of transactions that have been verified by all nodes will be difficult because hackers must obtain 51% or more of all computing power in the blockchain network/system (Tijan et al., 2019). Each new block verifies the previous block, so this mechanism makes the blockchain more immune to malicious activities.

3.2. INDONESIA'S BLOCKCHAIN AND CRYPTOCURRENCY ECOSYSTEM

From the theoretical explanation above, we know that blockchain technology cannot be separated from cryptocurrency. In fact, blockchain can be used for projects in many sectors, including the telecommunications industry, environmental surveillance, transportation, banking, agriculture, and even government. In Indonesia, this technology is growing – mainly driven by Bank Indonesia as the central bank and by major national banks.

The implementation of blockchain technology is also generally induced by the creation of a new form of trust. Therefore, the application of blockchain can redefine trust so that it can bring about an evolution of 'minimisation of trust' in dealing and transacting between humans. The government considers that blockchain technology could foster digitalisation of the government service platform, and ultimately increase trust in – and the transparency, effectiveness, and efficiency of – government administration. Another benefit of implementing blockchain is the utilisation of smart contracts, which will facilitate governance in tax supervision and compliance. In terms of technology users, blockchain has the concept of 'redistribution of value', whereby the concentration of technology users tend to decentralise.

In the financial sector, blockchain and crypto assets have grown exponentially in Indonesia since 2015. The estimated number of traders in Indonesia reached more than 1.5 million in 2020, increasing by 2,263% from 2015. Cryptocurrency has operated legally since 2019, and at the end of 2020, the Commodity Futures Trading Regulatory Agency (Bappebti) recognised 229 cryptocurrencies that can be traded on the physical crypto asset market, including Bitcoin, Ethereum, Tether, XRP/Ripple, Bitcoin Cash, Binance coin, Polkadot, and Chainlink. Even in the third quarter (Q3) of 2020, Rp22,671 trillion was recorded in crypto transactions in Indonesia. Table 3.7 shows the growth of the blockchain and crypto asset industry in Indonesia from 2017 to 2020.

Table 3.7 Blockchain and Crypto Asset Industry Growth in Indonesia, 2017–2020

2017		2018		2019		2020(until Q3)	
Asset	Total	Asset	Total	Asset	Total	Asset	Total
Bitcoin	16,032	Bitcoin	16,847	Bitcoin	11,905	Bitcoin	10,087
Bitcoin Cash	6,969	Stellar	9,814	Ethereum	2,233	Tether	1,894
Zcoin	6,236	Ripple	6,013	Tron	1,107	Ethereum	1,781
Stellar	5,068	Tokenomy	5,859	Ripple	920	Dogecoin	930
NXT	4,131	Ethereum	4,265	Dogecoin	686	Aurora	653

Source: Asosiasi Blockchain Indonesia (2020), 'Indonesia Crypto Outlook Report'. Jakarta: Asosiasi Blockchain Indonesia. https://asosiasiblockchain.co.id/wp-content/uploads/2020/09/Indonesia-Crypto-Outlook-2020-Report.pdf.

3.3. BLOCKCHAIN IN SUPPORTING THE FINANCIAL SECTOR

The government's target for the implementation of blockchain technology in the financial sector is undefined as the technology is nascent. However, we can identify the service behind the emergence of this technology – fintech applications. Indonesian financial inclusion was 67.0% in 2017 and 76.1% in 2019, lagging many of Indonesia's neighbours, while the government has set a target of 90.0% by 2024 (Hu and Isjwara, 2021). Therefore, access to financial services – including the means to save, grow, and use one's wealth – is a key part of the Indonesian initiative to reduce poverty and promote more inclusive economic growth.

Fintech is the use of technology in the financial sector or the implementation of technology in financial services (Wulan, 2017). According to the International Organization of Securities Commissions (IOSCO), fintech is divided into eight categories: payment, insurance, lending and crowdfunding, planning, trading and investment, blockchain, data and analytics, and security (IOSCO, 2017).

The security as a service feature is a crucial element of all fintech services (Tuan, 2020). To ensure such a security feature, blockchain technology is used as the base of the security platform, along with encryption, biometrics, multifactor authentication, and other security systems.

Indonesia has large fintech opportunities because it is home to a largely cash-based community, and huge swaths of the population – up to 80% – remain unbanked. Great potential can be seen from the fact that the value of electronic money transactions surged by 207% in 2019 to Rp145.2 trillion and nearly nine out of 10 internet users in Indonesia use a digital wallet (Jakpat, 2020).

3.4. CHALLENGES AND OPPORTUNITIES

The technology of blockchain and fintech is still mainly driven and determined by the financial sector. The ideal condition is for all sectors to continue to be enthusiastic about developing relevant services, such as blockchain, for logistics and other areas. Yet, with the fourth largest population in the world, all kinds of economic and financial transactions will have big implications. The correlation is that fintech will be encouraged to grow along with community activities.

Indonesia had 115 banks in 2020, with total money supply of around Rp1,855 trillion. Meanwhile, money supply circulating in the public, outside banking, totalled Rp760.0 trillion. This reflects the growth potential for fintech services in Indonesia. Since 53% of Indonesia's population already shops online and uses a digital financial platform, the financial sector can be a leader in the transformation of society. Thus, the technology utilisation relevant to this sector is in relation to the financial platform, while strengthening of related technology is necessary.

Table 3.8 provides basic data on Indonesian financial inclusion, showing the country's potential for the growth of fintech operations. Only 48.0% of the Indonesian adult population has access to a banking institution, while 3.1% have a mobile money account and 11.0% pay bills online. On the other hand, 168.3 million Indonesians purchased consumer goods online in 2019.

Table 3.8 Basic Data on Indonesian Financial Behaviour as a Fintech Opportunity

Factors	Basic data
Financial inclusion	**Reference adult population in Indonesia** • 48.0% have an account with a financial institution • 2.4% have a credit card • 3.1% have a mobile money account • 11.0% make online purchases or pay bills online
Online purchase of consumer goods	• 168.3 million people purchased consumer goods online in 2019 • $18.76 billion market value for online consumer goods • $111 average annual revenue of the shopper • 2.9% of GDP per capita of the online consumer goods ARPU
E-commerce purchases by payment method	• 35% using credit cards • 13% using cash • 24% via bank transfer • 14% using an e-wallet

ARPU = average revenue per user , GDP = gross domestic product.

Source: Author, based on Kemp (2020).

In particular, fintech lending (or P2P lending) received increasing attention in Indonesia. Fintech lending is a type of service that provides loan funds to businesspeople who want to develop their own businesses and manages funds from investors who are willing to lend to businesspeople. There are two types of fintech lending: conventional fintech lending and sharia fintech lending. Indonesia has 149 conventional fintech lending companies and only 12 Islamic sharia fintech lending companies. Since Indonesia is the largest Muslim country in the world, it presents a significant opportunity in the financial industry in terms of Islamic finance.

4. INDONESIAN PROFILE OF TECHNOLOGY – ARTIFICIAL INTELLIGENCE

4.1. TECHNOLOGICAL OVERVIEW OF AI

AI is a field of computer science that emphasises the creation of intelligent machines/robots that work and react like humans (Marr, 2018). It can be integrated with various cognitive functions, such as language, attention, planning, memory, and perception. Recent research on AI – including machine learning, deep learning, and predictive analysis – intends to improve the planning, learning, reasoning, thinking, and acting abilities of machines (Shabbir and Anwer, 2018).

To bring AI into real applications, mathematical and algorithmic analytic core technology is transformed into computer language programming. Such computer language programs are then built into AI software or service applications, as well as AI hardware products. AI applications may range from simple decision-making software for business to complicated robots for space missions.

There are four types of AI or AI-based systems: reactive machines, limited memory machines, theory of mind, and self-aware AI (Joshi and Cognitive World, 2019).

i. Reactive machines are the oldest type, indicated by a non-memory capacity that only responds to different stimuli. A popular example of a reactive AI machine is IBM's Deep Blue, a machine that beat chess Grandmaster Garry Kasparov in 1997.
ii. Limited memory machines refer to a type of AI that is capable of learning from historical data to make decisions. Examples of this application are chatbots and virtual assistants for self-driving vehicles.

iii. Theory of mind AI is the next level of AI systems that researchers are innovating. It will be able to better understand the entities it is interacting with by discerning their needs, emotions, beliefs, and thought processes. Robotic technology that is made to help people's daily work is an example of this category.
iv. Self-aware AI currently exists only hypothetically. It has human-like intelligence and self-awareness. It mimics the concept of a human brain that has developed self-awareness, and not only evokes emotions in those it interacts with but also has emotions, needs, beliefs, and potentially desires of its own.

4.2. AI ECOSYSTEM IN INDONESIA

The current development stage of AI ecosystem in Indonesia still falls in the limited memory category. The relevant technologies are supported by well-known branded AI software platforms provided by foreign technology suppliers (e.g. Google Tensor Flow, IBM Watson, and Microsoft Azure) as well as software for data visualisation (e.g. Tableau and Microsoft Power BI). However, as the nature of AI mainly works on the basis of software programming, many local start-ups may develop unique applications using programming languages such as R, Python, JAVA, Lips, and Prolog. The programming languages finally create AI-based service applications, which are diffused into large corporate and governmental agencies. Table 3.9 shows some prominent Indonesian AI start-ups and samples of the users of their service applications.

Table 3.9 Indonesian AI-Based Service Applications and Users

<table>
<tr><th>AI Indonesian start-ups</th><th>Main service applications</th><th>Large companies using the services</th></tr>
<tr><td>Bahasa.ai</td><td>Developing conversational modules based on NLP/NLU with specific Indonesian language specifications.</td><td rowspan="5">Bank Sinarmas, Dana, Smartfren, Panorama JTB, Johnson & Johnson, Unilever, P&G, Nestle, Uber, Skyscanner, Zomato, Telkomsel, BRI, dan Unilever, Facebook, OVO, BNPB, COVID-19 task force in Indonesia, Suzuki Finance, BCA, Indonesia's National Police (POLRI), NVIDIA, Highway Toll Operator Jasa Marga, HP Enterprise, IBM, Asian Games 2018 Committee, and IMF–World Bank 2018 Committee</td></tr>
<tr><td>Snapcart</td><td>Developing mobile application that gives shoppers cashback for scanning their receipts. Analysing it and offering real-time insights and analytics to the company regarding its purchase data.</td></tr>
<tr><td>BJTech</td><td>Developing Indonesian chatbots for business, virtual friends, and an intelligent banking app.</td></tr>
<tr><td>Datanest.io</td><td>Offering data science services and AI customisation</td></tr>
<tr><td>Kata.ai</td><td>Developing conversational AI solution applications supported by NLP/NLU such as light conversations and virtual assistants, answering frequently asked questions, and personalised product offerings; can be integrated with various chat applications, including WhatsApp.</td></tr>
</table>

AI Indonesian start-ups	Main service applications	Large companies using the services
Konvergen.ai	Developing data entry applications by using AI technology, a service to observe and analyse consumer behaviour in more detail.	
Nodeflux	Developing AI-based solutions, including face mask detection, physical distancing, and public mobility monitoring.	
Pind.ai	Developing artificial visual and IoT systems such as visual computing, facial recognition, and machine learning; and analysing big data.	
Prosa.ai	Developing AI services for Indonesian text and voice processing services, customer interaction analysis, business optimisation, fraud detection, image processing, chatbot services to convey information about COVID-19, and social media monitoring.	

AI = artificial intelligence, COVID-19 = coronavirus disease, IoT = internet of things, NLP = natural language processing, NLU = natural language understanding.

Source: East Ventures (2019).

4.3. INDONESIA'S AI ROADMAP

In 2020, the Ministry of Research and Technology established an AI Indonesia roadmap that focused on five main areas (BPPT, 2020). If the government is committed to implementing this roadmap, it is hoped that the creation of AI technology may come from local industry and academia, then increase the widespread adoption of AI technology in the industrial and public sectors.

The five priority areas identified by the government are:

(1) Health: supporting a predictive, preventive, personal, and participative (4P) health framework. AI has an important role to play in processing and providing insights from big data collected through genetics and sensors within the 4P health framework.
Sample targets:
- using big data analytics and AI to build alert systems for the spread of the coronavirus disease (COVID-19) using applications and machine learning
- easing access to the availability of health facilities using a conversion interface
- providing recommendations for access to and use of medical facilities and personnel
- providing recommendations for pandemic prevention

(2) Bureaucratic reform: driven to be in line with Presidential Regulation No. 95 of 2018 on Electronic Based Government Systems (SPBE). The goal is realising clean, effective, transparent, and accountable governance – as well as quality and trusted public services – through support for the use of ICT in an integrated government system.
Sample targets:
- developing a chatbot platform for government services
- developing AI for government budget management to detect irregularities in government budgets, which will facilitate evaluation
- personal identification using face, voice, and other types of biometric recognition
- sentiment analysis, which makes use of data from social media to identify the perception of society towards government policy or the implementation of government programmes
- big data governance analysis that uses data from multiple sources – both structured data held by the government as well as unstructured and dynamic data taken from various social media and internet sites – to assist the government in decision-making

(3) Education and research: forming reliable human resources. The government plans to boost the creation of AI platforms to support the education and research activities.
Sample targets:
- providing intelligent online education by developing multimedia content, educational games, and adaptive assessments for learning as a fun experience, not as a burden
- developing smart course content with augmented and/or virtual reality, and virtual laboratories
- developing an adaptive learning system that adapts to students' abilities – students will be provided material according to their abilities, with a difficulty level that can be increased or decreased based on the evaluation results
- creating an adaptive assessment system and intelligent student classification that classifies students based on certain abilities so that the provision of subject matter can be adjusted to the class

(4) Food security: creating advantages for Indonesian people by using relevant applications to strengthen national food security.
Sample targets:
- providing alert systems for types of food that are in short supply and need to be restocked
- providing recommendations for access to and use of food through demand and balanced supply for each region

- increasing land productivity and using resources more efficiently
- achieving financial inclusion of low-income farmers
- using satellite images to determine disadvantaged areas, identify the commodities grown in an area, and provide harvest predictions for each commodity
- predicting harvest failures from historical data combined with variables such as weather, and anticipating the spread of new food diseases to minimise crop failures
- predicting food stocks and its relevant recommendation – AI can be used to predict the stock of staples throughout a city and relocate food availability so that no area experiences food shortages

(5) Mobility and smart cities: helping the government establish smart cities.
Sample targets:

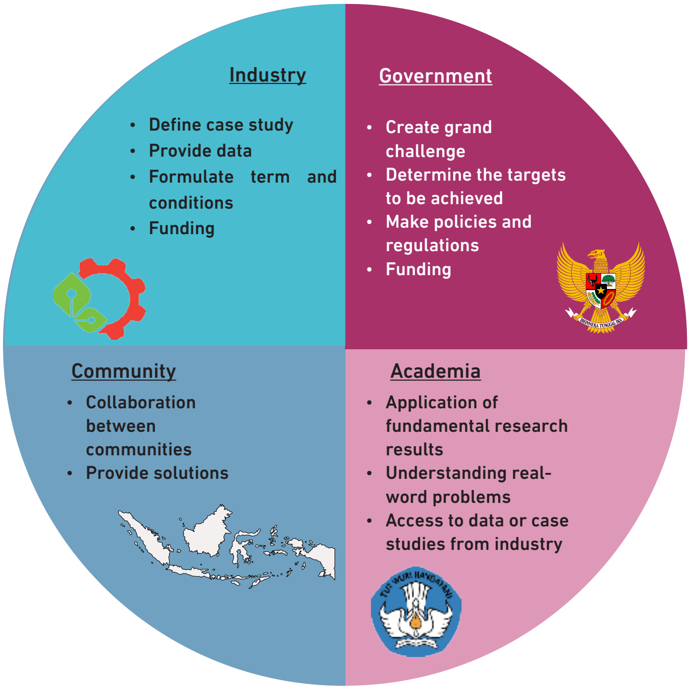
- using AI for intelligent traffic management
- using AI for intelligent waste management
- using AI for disaster risk management
- using AI for citizen information management
- using AI for quality assessment of contractors
- using AI for spatial management
- using AI for operational management of public facilities

4.4. CHALLENGES AND OPPORTUNITIES

The development of AI technologies and the application of AI are still constrained by the lack of qualified human capital. Indonesia still has insufficient human resources in the field of information technology (IT). The use of AI is limited to a few large private companies.

To accelerate the growth of AI, the government of Indonesia harnessed the concept of quadruple helix collaboration – consisting of the government, industry, academia, and the community (BPPT, 2020). Various national research and innovation resources (contributions from actors involved in the quadruple helix umbrella) need to be maximised to achieve the objectives of the AI industry research and innovation mission. This can be done by forming a quadruple helix collaboration ecosystem orchestrator called Research Collaboration and AI Industry Innovation (KORI-KA). The roles of each actor and the quadruple helix synergy in KORI-KA is shown in Figure 3.7.

Figure 3.7 Concept of Quadruple Helix Synergy in Indonesian AI Roadmap



AI = artificial intelligence, KORI-KA = Kolaborasi Riset dan Inovasi Industri Kecerdasan Artifisial.

Source: BPPT (2020).

5. TARGET AND READINESS FOR DIGITAL TRANSFORMATION

The National Research Master Plan (RIRN) 2017–2045 (Presidential Decree (Perpres) No. 38/2018)[4] defines four pillars of the 2045 vision of Indonesia and states the creative and digital economy development platform as one of the indicators of sustainable economic development.

[4] Some relevant regulations include National Medium-Term Development Plan (RPJMN), 2020–2024 (Presidential Decree (Perpres) No. 18 /2020), Road Map of the Ministry of Industry (Making Indonesia 4.0), Electronic-based government system (Presidential Decree (Perpres) No. 95/2018), and One Data Indonesia (Presidential Decree (Perpres) No. 39/2019).

Table 3.10 **Four pillars of RIRN**

Pillar	Description
Human development and mastery of science and technology	Achieving an equitable increase in the level of education, the role of culture in development, the contribution of science and technology to development, improving the health status and quality of life of the people, and undertaking labour reform. This includes preparing capable Indonesian human resources through science, technology, engineering, and mathematics (STEM) education and innovative research higher education activities, which represents a significant investment in the development of the Indonesian people who will act as producers in the era of the digital economy.
Sustainable economic development	Improving the investment climate, achieving open and fair international trade, harnessing industry as a driver of economic growth, realising creative and digital economic development, developing Indonesia as a leading tourist destination, undertaking maritime economic development, stabilising food security and improving the welfare of farmers, strengthening water security, increasing energy security, and fulfilling environmental commitments.
Equitable development	Accelerating poverty alleviation, equal distribution of income, equitable distribution of areas, and equitable and integrated infrastructure development.
Strengthening national resilience and governance	Enhancing Indonesia's democracy towards a democracy that carries the mandate of the people, reforming the bureaucracy and institutions, strengthening the national legal system and anti-corruption, implementing a free and active foreign policy, and strengthening defence and security.

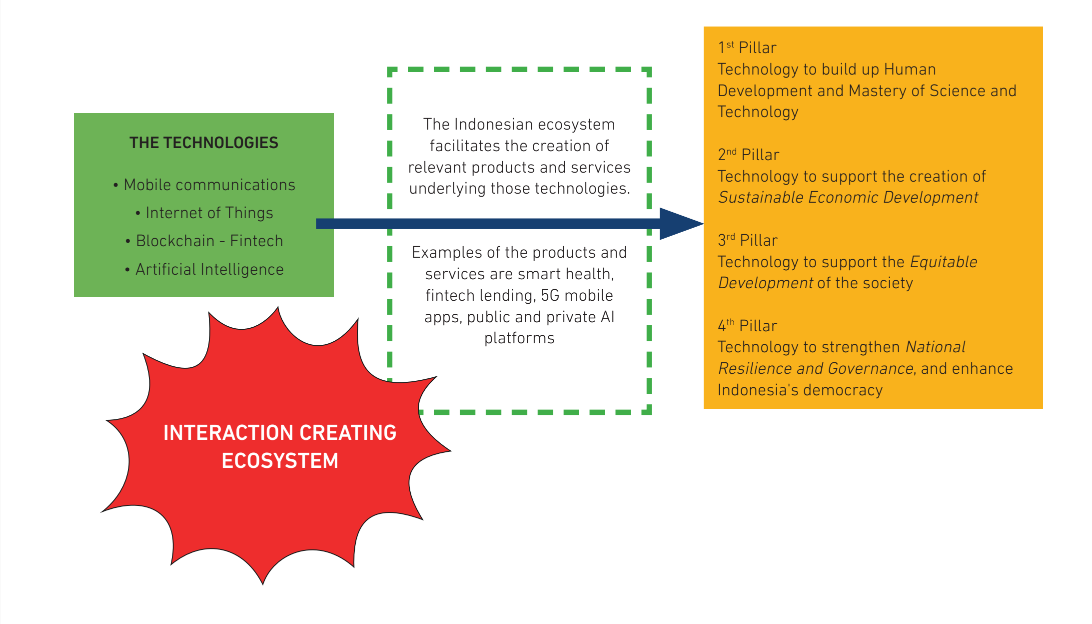
Source: RIRN, 2017-2045.

RIRN highlights the significance of science and technology in creating added value to an innovation-driven economy. Although the know-how of the technology is only an enabler of digital transformation, and in the end, the market cultivation to accommodate the applications of the new technology and the consequent new business models will be crucial to the economic and social transformation triggered by digitalisation, technology advance is fundamental.

TECHNOLOGY DEVELOPMENT APPROACH AND INTERACTION

Digital transformation requires technological areas interact with each other with focus on the main technological role. The government will take the role in coordinating interactions amongst all stakeholders of the technologies. Figure 3.8 shows how the technologies of mobile communications, IoT, blockchain, and AI play a role in achieving the four pillars of Indonesia 2045. The figure shows the first pillar, which makes science and technology an enabler of Indonesia's 2045 vision, and its relation to the economic pillar.

Figure 3.8 **Digital Transformation for Achieving Indonesia's Targets in 2045**

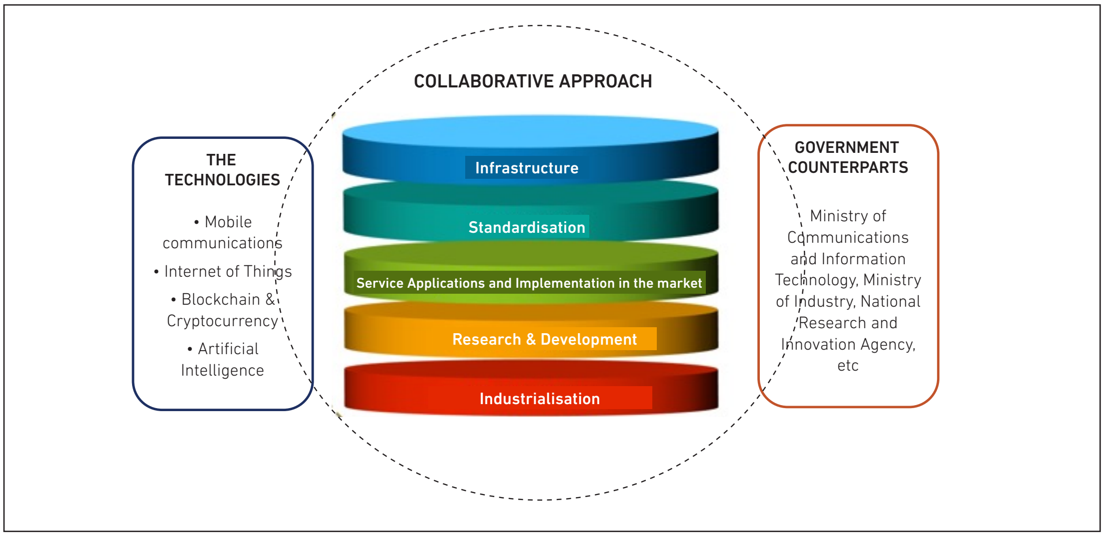


Source: Author, based on The National Research Master Plan (RIRN) 2017-2045.

Although the role of technology seems to be related only to the second pillar of the economy, the third and fourth pillars have an indicator for the achievement of the vision, whereby technology must be directed to achieve the related parameters. These include poverty alleviation, income redistribution, and even democratisation of government and national resilience. For example, the implementation of 5G should be able to facilitate the growth and development of various mobile apps that can help increase people's income, such as marketplaces. IoT has applications that help increase the quality of public health, e.g. by implementing smart health. Blockchain could help improve good governance in the financial and bureaucratic sectors. If applied to government services, blockchain could increase the security of the system so that it would have an indirect positive impact on public trust in the government.

Figure 3.9 proposes a collaborative approach that balance the approach of general development and that of area-specific development, which could help the government facilitate digital interactions across sectors.

Figure 3.9 Collaborative Approach to Developing ICT in Indonesia



ICT = Information and Telecommunications Technology.

Source: Author.

By analysing the functions of each of these institutions, we can take a formulation that is related to digital transformation. Such a formula requires an approach related to infrastructure, standardisation, and services applications. In terms of infrastructure and standardisation, each technology has its own characteristics, so a specific approach is needed. The Ministry of Communication and Information Technology can lead the infrastructure development, as technology is part of the ICT sector. Concerning standardisation, each technology has a specific function. For example, in relation to security standards for fintech that implements blockchain, it will involve the role of the central bank, the financial services authority, and the national body in charge of cybersecurity.

In terms of service applications, although each technology has a specific function, all of them lead to the same utilisation – supporting the vision of Indonesia 2045. Therefore, a collaborative approach is needed in the development of services and applications. Ideally, there should be very close coordination between the institutions and private parties that comprise the ecosystem. For example, IoT applications for health are a concern for four parties: (i) the Ministry of Health as the supervisor of health standards; (ii) the Ministry of Communication and Information Technology as an accelerator of the IoT network infrastructure; (iii) the National Research and Innovation Agency as a facilitator of R&D in terms of technical and technological aspects; and (iv) the Ministry of Industry, which encourages the development of domestic industry.

5.1. TOP CHALLENGES

5.1.1 Limited domestic capacity in production and R&D

The Indonesian industry of high-tech hardware is still at its early stage of development. With the country's progress in digitalisation, the market demand for digital products is fast expanding. On the supply side, however, the growth of domestic capacity lagged. A significant amount of semiconductor devices and parts and components heavily relies on imports. In 2016, the country reported a $35 billion deficit from trade in medium and high tech-insensitive products (BRIN, 2019). This highlights the importance of accelerating the catch-up process of technology adoption and increasing domestic innovation capacity.[5]

The value added of domestic R&D activities as a share of national economic output is relatively low – it contributed less than 1% of total economic growth in 2019. In Indonesia, the main source of R&D funding is still the government, which burdens over 80% of the total budget. The country's low output level looks not surprising, given its annual input in R&D is equivalent to only 0.25% of GDP, which seems an utterly inadequate measure to support domestic innovative activities.

5.1.2. Human Capital for Digital Transformation

Lack of skilled human resources is another significant challenge faced by Indonesia. According to Kemkominfo (2020), the Ministry of Communication and Information Technology projected Indonesia to have around 430,000 ICT graduates by 2020, while the national industry needs as many as 320,000 ICT workers. This suggests that Indonesia is experiencing an oversupply of ICT workers. However, the number only considers quantity while a gap (mismatch) can exist in terms of quality between industrial needs and resources from educational institutions. Such a gap can be caused by a quality mismatch gap or a field mismatch gap. One of the ways the government can solve this problem is by developing government programmes to accelerate the competence of national digital human resources – targeting 300,000 trained/certified ICT professionals by 2024.

By estimation, Indonesia will need 9 million skilled workers for digital and digital-related sectors over the next 15 years (2020–2035).[6] Even though most Indonesian universities now offer program of computer science, the profile of university graduates could not well match the demands from the industry. In Indonesia, the university curriculum only gets updated every 4 years – much slower than that of technological advance. In addition, the IT instructor who educates the candidate of skilled workers must also periodically improve their competence.

[5] Based on the 2021 Global Innovation Index, Indonesia was ranked 87th out of 132 countries.

[6] https://edukasi.kompas.com/read/2021/09/01/133356071/kemendikbud-ristek-indonesia-butuh-9-juta-talenta-digital-hingga-2035?page=all

As part of the policy response to the current situation, the Ministry of Education and Culture has launched the *Merdeka Belajar* (Freedom to Learn) programme to promote the development of human capital. In the concept of independent learning, every university student in Indonesia has the right to carry out activities for two semesters (out of eight semesters) outside the field of study in which they are engaged. Facilitated activities include taking certifications and training in IT, and internships in the industrial world. The purpose of this programme is for Indonesian university graduates to obtain competencies that meet the needs from the fast-moving industry. It also tries to bring together the university's formal education curriculum, which has been considered very rigid, with a certification curriculum that is proven to be more suitable and in line with the times.

6. POLICY RECOMMENDATIONS

From the perspective of technological progress, digitalisation should be seen as a national transformation process developed collaboratively and driven by the development of infrastructure and that of the service ecosystem. Insights from the country's selected technology profiles reveal some priorities of development that are worthy of consideration. First, promoting the infrastructure of mobile broadband technology. Indonesia already has very high mobile penetration (more than 132%). Mobile phones have become most users' preferred tool to access the internet. Improving digital connectivity is a top priority in enabling digital transformation. The increasing demand for data capacity can fuel the development and application of new network technologies, such as 5G.

Second, focusing on the development of IoT and AI technology and the promotion of localised innovation-oriented service applications. Developing IoT and AI technology requires Indonesia to steadily build up its capacity in production and innovation. Localising applications and services to match the local problems and needs of the Indonesian people could be a good starting point. IoT technology can focus on local tastes, implemented in national industries. For example, Indonesia, which is rich in palm oil, could develop IoT applications for this sector. National start-ups have developed local applications, e.g. for e-fishery, using various IoT intelligence devices that are beneficial for Indonesian fisheries and the marine industry.

Third, prioritising the implementation of AI and blockchain for financial services. The financial sector drives blockchain technology in Indonesia, although it can also be used for various projects in the telecommunications industry, environmental surveillance, transportation, banking, foreign exchange, agriculture, and even government. The growth of fintech services in Indonesia could be used as a means of seeding blockchain and AI technology, as the technology increases public trust in digital financial applications. This would be beneficial for the government because trust is needed to build effective governance in the digital economy. SMEs could be the initial target for implementation, harnessing their vast quantity and scope to contribute directly to improving people's daily activities. If such a programme were successful, SMEs could spearhead the digital transformation process in shaping the digital economy.

Fourth, to accelerate technology adoption and innovation, the government can take the driving seat, but it needs collaboration from the private sector. The technologies that contribute to the digital transformation cannot stand alone. A collaborative approach is highly recommended to ensure the achievement of the Indonesia 2045 goals. The government will not only be responsible for setting regulation and standardisation of technology, but also act as the guarantor of social welfare that promotes the equitable diffusion of technology and increases quality of life.

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