indosat
OOREDOO HUTCHISON

DIGITAL TECHNOLOGY RADAR

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B2B Solution – CDO
Web: ioh.co.id

Foreword by:

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The current scenario of digital transformation has led to massive changes in the way business is accomplished. Transformation of urbanization is the major result because of these initiatives[1]. The use of advanced data analytics for utilizing data for delivering quality services has given rise to innovative models for conducting business[2]. Organizations across the globe have adopted e-business models and frameworks for managing their business processes in a more efficient and effective manner (Wu et al., 2003). Literature states several evidence of how digitization and the use of data analytics can completely reshape the business models[3].

There are several emerging e-business models, especially using mobile computing paradigms, in the academic literature that focus on product innovation, customer relationships, infrastructure management and financial aspects[4]. This issue reflects these digital transformations across various domains including joint ventures in business, social media and customer relationship management, ICT advancements in the manufacturing industry and the trending domain of IOT and fog computing.

This paper covers seven potential technologies from Cloud, IOT, and Connectivity. It discusses the high-level perspective of the technologies and how it can bring impact to telco companies, especially Indosat Ooredoo Hutchinson (IOH) from the business sides.

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[1] Chauhan, S., Agarwal, N., &Kar, A. K. (2016). Addressing big data challenges in smart cities: a systematic literature review. INFO, 18(4), 73-90.

[2] Brynjolfsson, E., & McAfee, A. (2014). The second machine age: Work, progress, and prosperity in a time of brilliant technologies. WW Norton & Company.

[3] Loebbecke, C., & Picot, A. (2015). Reflections on societal and business model transformation arising from digitization and big data analytics: A research agenda. The Journal of Strategic Information Systems, 24(3), 149-157.

[4] Osterwalder, A., &Pigneur, Y. (2002). An eBusiness model ontology for modeling eBusiness. BLED 2002 Proceedings, 2.

We hope that our readers would find the blend of conceptual and application-based articles valuable and intellectually gratifying. We however look forward to your valuable feedback and constructive suggestions that would help us in our journey of nurturing the journal towards excellence.

Document Control

Version History

Date	Version	Comments
17/06/2022	0.0	Released Version

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1. Introduction

1.1. Background

The telecommunications industry is a rapidly evolving and capital-intensive industry. Investments made today shall serve the business requirements of today and the future. It is also a technology driven industry; companies that invest in the right technology and integrate successfully can develop a significant competitive advantage.

Vendors and research institutes globally produce a massive number of new technologies and innovations. A process is necessary to actively scout for interesting new technologies and innovations and to assess these for their relevance for Indosat Ooredoo Hutchinson. This document presents a methodology for technology scouting and assessment. Furthermore, it includes an assessment of the most relevant technologies and innovations for the Indosat Ooredoo for the year 2022.

This document provides input to the Technology Strategy on the availability of new technologies and innovations, key trends, and their maturity. As such this document is a key instrument to achieve the Technology Group's strategic objectives:

- Best Customer Experience
- Technology Leadership
- 5G Readiness (infrastructure and use cases)
- Technology partnership

1.2. Objective of the Digital Technology Radar

The goals of the Technology Radar are:

- **Early identification of new technologies and technological trends**
  Technology identification processes determine the type of technology and nature of the services together, giving priority at the strategic and operational levels. This process has its significance in forming the strategy in selecting the services and technologies.
- **Enable informed strategic decision-making**
  Technology intelligence, together with market, competitor, and customer intelligence, enables informed strategic decision-making.
- **Stimulate innovation**
  New technologies are at the core of product and service innovation. They provide new routes to differentiation, cost reduction, and lead to new business opportunities. By disseminating information about novel technologies developed both inside and outside of Indosat Ooredoo Hutchinson (IOH), the Digital Technology Radar paves the way for open innovation. It also enables IOH to show its Technology Leadership.

1.3. Methodology

The IOH's Digital Technology Radar draws on best practices and methodologies from Deutsche Telekom and Cisco[5]. It is a collaborative effort where all IOH employees have a role to play. Its process is articulated around a knowledge funnel divided into four phases: identification, selection, assessment and dissemination (Figure 1).

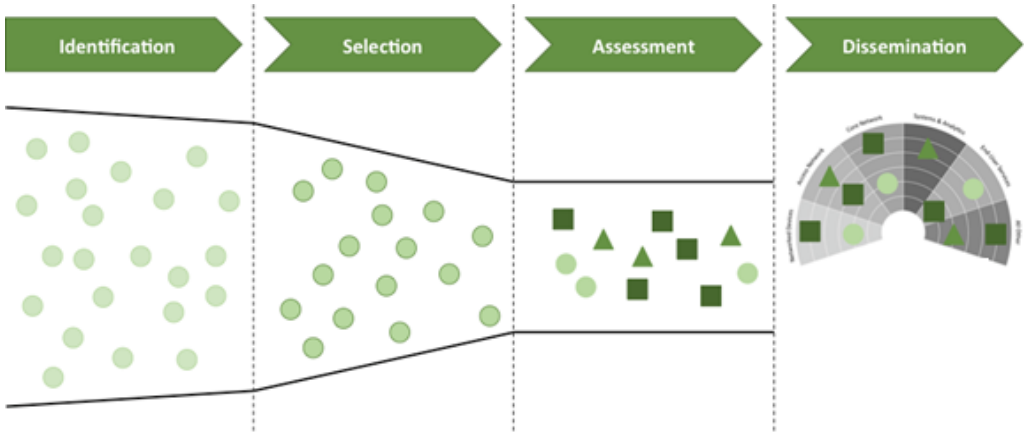


Figure 1.1.1. Technology Scouting Methodology

Identification Phase

An international network of technology scouts submits novel technologies for inclusion in the Technology Radar. All IOH group employees can become technology scouts by leveraging their expertise, or their strong social network to get firsthand information. Apart from the opportunity to influence IOH's strategy, incentives for scouting include visibility, development opportunities and formal recognition.

Additional mechanisms are being planned or deployed to gather inputs on novel technological developments from academia and IOH's ecosystem of customers and partners.

Selection Phase

The Technology Radar team works with a panel of senior technical experts and product development specialists, to review all submitted technologies on an annual basis. Technologies that are included in previous versions of the technology radar are also reviewed, ensuring that aging information is handled appropriately.

[5] *"The Technology Radar: An Instrument of Technology Intelligence and Innovation Strategy"*, Rohrbeck, Heuer, Arnold (Deutsche Telekom), 2006. *"Cisco Technology Radar"*, Cisco, 2013.

The selection criteria for being included or kept in the Technology Radar are built upon the concepts of Technology, Impact and Novelty, as detailed below:

- **Test 1: Technology**
  Does this submission describe engineering or scientific knowledge that can be applied to the conception, development, manufacturing or application of a product or a service?
- **Test 2: Impact**
  Could this technology impact IOH, either positively or negatively, in a way that requires decision-making at executive level?
- **Test 3: Novelty**
  Is this technology new to the industry and/or the Indonesia? Consider:
  (a) Technologies that are completely new.
  (b) Important changes in a technology or its application.
  (c) Important rise in the awareness of a technology or its application.
  AND is this technology new to IOH? Consider:
  (a) Technologies not used in any part (network, platforms, IT, etc.) of the Technology Platform.
  (b) Technologies where there is a clear need to raise or broaden awareness across the company.
  AND is this entry new to the Digital Technology Radar?

Assessment Phase

The selected technologies undergo a deeper analysis. A one-page technology profile is created, describing the technology, its maturity and impact on the market and on IOH in particular. This technology profile is written for an executive audience, putting the technology in business context and limiting the content to unbiased facts and findings.

Once this profile is created, a cross-functional panel of senior technical and business leaders will assess the relevance of each selected technology for IOH using their knowledge and experience. The assessment criteria are based on two axes: market impact and implementation risk for IOH, as detailed below:

- **Market Impact Axis**
  (a) Potential market size
  (b) Disruptive potential
  (c) Customer value
  (d) Cost saving potential
- **Implementation Risk Axis**
  (a) Internal Risk
  (b) External Risk
  (c) Maturity
  (d) Cost

Figure below illustrates the methodology.

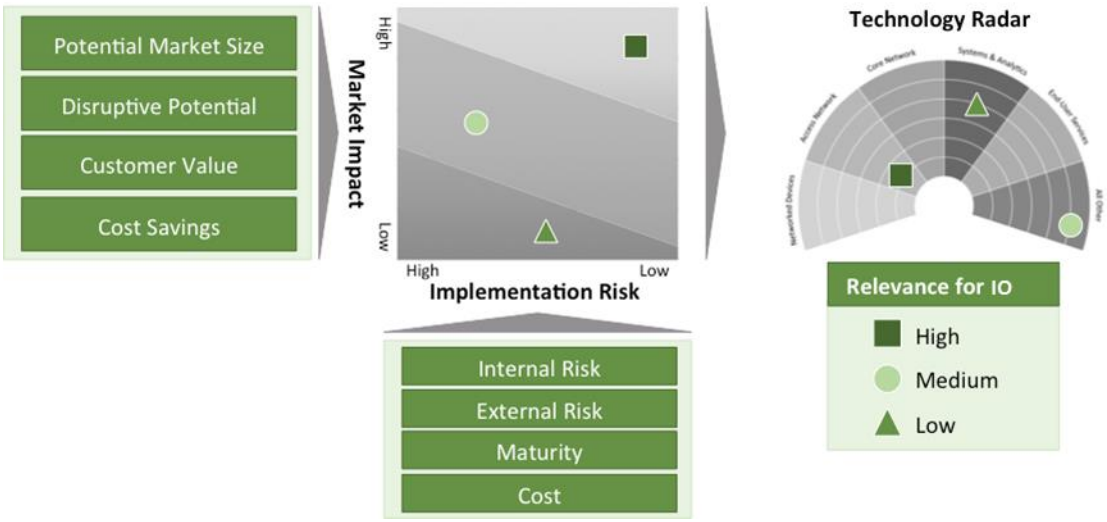


Figure 1.1.2. Technology Assessment

Dissemination

The IOH's Digital Technology Radar is published every year. The format of the radar screen displays all technologies along with their maturity, their position in the IT/Telecom value chain, and their relevance as rated by the assessment panel. The Technology Radar is distributed to key stakeholders within the group and published on the Intranet.

The intelligence produced by the IOH's Digital Technology Radar feeds into the business and technology strategy processes. It is also used to monitor academic research, along with identifying investment opportunities.

Other elements to raise technology awareness are:

- **Feature Paper:**
  - In depth coverage of one specific topic from scouting to feature paper to workshop;
  - Based on selected technology profiles an expert workshop is set up in order to discuss recent trends and innovative developments related to the feature paper;
  - The outcome of the workshop is a feature paper that can be used for internal and external knowledge sharing.

- **Opinion Paper:**
  - Derived from selected business, technology, and R&D trends detailed opinion papers are created;
  - Opinion papers are created by IOH experts and reflect the view of IOH on a certain topic.

- **Press Releases, Interviews and Panel Participation:**
  - Expert interview with national and international (industry) media to present IOH's opinion on a certain topic;
  - Participation in industry events and conference to present IOH's opinion on a certain topic.

1.4. Document Structure

A model to assess the technology maturity is presented in chapter 2. The technology radar as well as executive briefings for the most relevant new technologies and innovations are included in chapter 3. More detailed information as well as references for further reading are included in the annex.

2. Technology Maturity Model

This chapter proposes a model to assess the maturity of a new technology or innovation. Section 2.1 presents the maturity model and section 2.2 defines the technical domains.

2.1. Maturity Model

The technology maturity model considers the following two elements:

- The Porter's Five Forces, which consists of:
  - *Competition in the industry* describes what other competitors' uniqueness on the products and the competition among companies;
  - *Supplier power:* used to solve a specific, practical problem of an individual or group. The study and research to find solutions to a specific problem or to develop a specific technology;
  - *Buyer power:* the interest and needs of the market towards the product;
  - *Threat of substitution:* the potential technology that might have the similarity with the technology and how it differs with its alternatives.
  - *Threat of new entry:* describe the possibility of new competitors and the barrier to entry in the industry.

These elements have their own level from 1 (low) to 3 (high). The level of maturity for the technology based on Porter's Five Forces and Diffusion of innovations which will be put into product life cycle on the following below.

- The product lifecycle phase. It's divided into 4 phases (score), which are:
  - *Introduction (1-3):* The product is relatively new and there is no proven demand for it yet. The sales are slow.
  - *Growth (4-6):* More companies are aware of the product and the competition for the product in the space is growing along with the growth of demand and sales.
  - *Mature (7-12)*: The competitions that are going on are competitive, and the sales tend to slow off. The companies are looking to reach out to more market segments.
  - *Decline (13-15)*: The product began to lose appeal in the market and the demand dropped. Customers' behavior changes and they begin to look for other alternatives.

- Diffusion of innovations that has 5 stages of adopters (score), which are:
  - *Innovators (1-2):* In this stage technologies have high risks; the technologies are not very mature and there are only few people that look for this technology.
  - *Early adopters (3-5):* Some people adopt these technologies even though it is still risky and see the potential in this technology.

- *Early majority (6-9):* At this stage, technology starts to become common, and more people are adopting it. However, some still choose other technologies.
- *Late majority (10-13):* Technology has become very common for almost everyone, mature, and it's no longer considered as something new.
- *Laggards (14-15):* The technology is left behind as it can be replaced by latest technology.

2.2. Technology Domains

The radar distinguishes between the following technology domain categories:

- **Access Network**
  Fixed and wireless access technologies to connect the end-user's Network Devices to the network and its services. Examples include base stations, optical line terminals (OLT), optical network units (ONU), etc.

- **Core Infrastructure**
  These are all the hardware and software that comprise the actual network and the services it provides. Examples include routers, data switches, soft (voice) switches, subscriber databases, deep packet inspectors, data policy functions, online charging systems, and so on.

- **Management, orchestration, and business support**
  The technologies that can be used for the efficient and effective operation of the technology platform and the business. Examples include customer service platforms, network provisioning systems, etc.

- **Service Enablers**
  The technologies that can be used to create new and innovative services. Examples include software development kits for artificial intelligence, IoT platforms, etc.

- **End-User Solutions**
  Services and solutions that can be delivered to a residential or corporate end user.

3. Technology Radar

The following diagram presents an overall radar for the various technologies that are described in more detail in this document. The closer the technology is to the center; the more mature technology is. IOH needs to find the way to include those technologies in its business. There are also innovations that are far from the center because they are considered high impact. IOH should begin to initiate and pursue products and services for those technologies starting from pilot projects/trials rather than the more mature ones. There are technologies called “Service Enablers” that are going to be immediately consumable as is but nevertheless IOH needs to find products that use these technologies or initiate to develop product and service using them.

Connectivity

Summary
Categorization: ● Maturity: Early Majority ● Technology Field: End-user solutions ● Relevance for IOH Business: High
Reason to watch: ● 5G wireless connectivity to guarantee low latency service and high reliability for industrial use cases
IOH Status: ● Year added: 2023

3.1. 5G URLLC for Enterprise

3.1.1. Introduction

The fifth generation (5G) wireless communication system is expected to support new emerging applications on top of regular mobile broadband services. One of the main usage scenarios in 5G coverage is ultra-reliable and low-latency communications (URLLC). Among active researchers from academia and industry, one common view is that URLLC will play an important role in providing connectivity for new services and applications from vertical domains, such as factory automation, autonomous driving, etc. The most important key performance indicators (KPIs) associated with URLLC are latency, reliability, and availability.

Up to now, the Third Generation Partnership Project (3GPP) has made good progress in the design of 5G New Radio (NR). Three different service categories have been considered: enhanced mobile broadband (eMBB), massive machine-type communications (mMTC), and ultra-reliable and low-latency communications (URLLC). Like traditional mobile services, eMBB addresses the human-centered use cases for accessing multi-media content, service, and data. mMTC is characterized by many connected devices typically transmitting a relatively low volume of non-delay-sensitive data. URLLC is a communication service for successfully delivering packets under strict requirements, especially in terms of availability, latency, and reliability. URLLC will enable supporting the emerging applications and services.

Based on the results of Telecom.com's survey of 344 worldwide professional industries in 2020, the strongest attraction for enterprise businesses, based on the three pillars of 5G technology service categories that specifically pertain to businesses is ultra-reliable low latency communications (URLLC) with 47% of respondents answering as such. URLLC enables specialized industrial services, such as autonomous vehicles and manufacturing automation control.

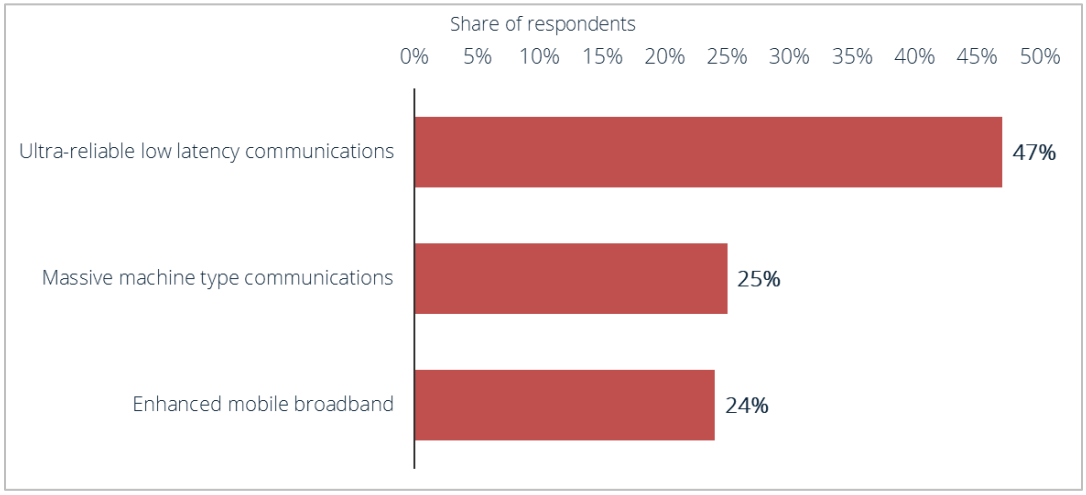


Figure 3.1.1. 5G technologies: strongest business appeal in 2020[6]

3.1.2. Definition and Scope

URLLC (ultra-reliable low latency communications) is one of the three key pillars of 5G New Radio (NR) (see figure 3.1.1) to accommodate emerging services and applications having stringent latency and reliability requirements such as advanced wearables, real-time human machine collaboration, cloud robotics and real-time coordination and control of machines and processes, and autonomous vehicles. With 4G LTE, latency is currently in the 4-millisecond range under 3GPP Release 14. URLLC is part of Release 15 and has a target of 1 millisecond. URLLC is also ideal for applications requiring end-to-end security and 99.999 percent reliability. This combination of capabilities requires an almost fundamentally different approach to system design and operation compared to previous cellular wireless technologies. The physical layer is undoubtedly the most challenging because URLLC must satisfy two conflicting requirements: low latency and very high reliability. This combination is a very different type of quality of service (QoS) compared to traditional mobile broadband applications.

[6] Statista, 5g-technologies-strongest-business-appeal, 2020

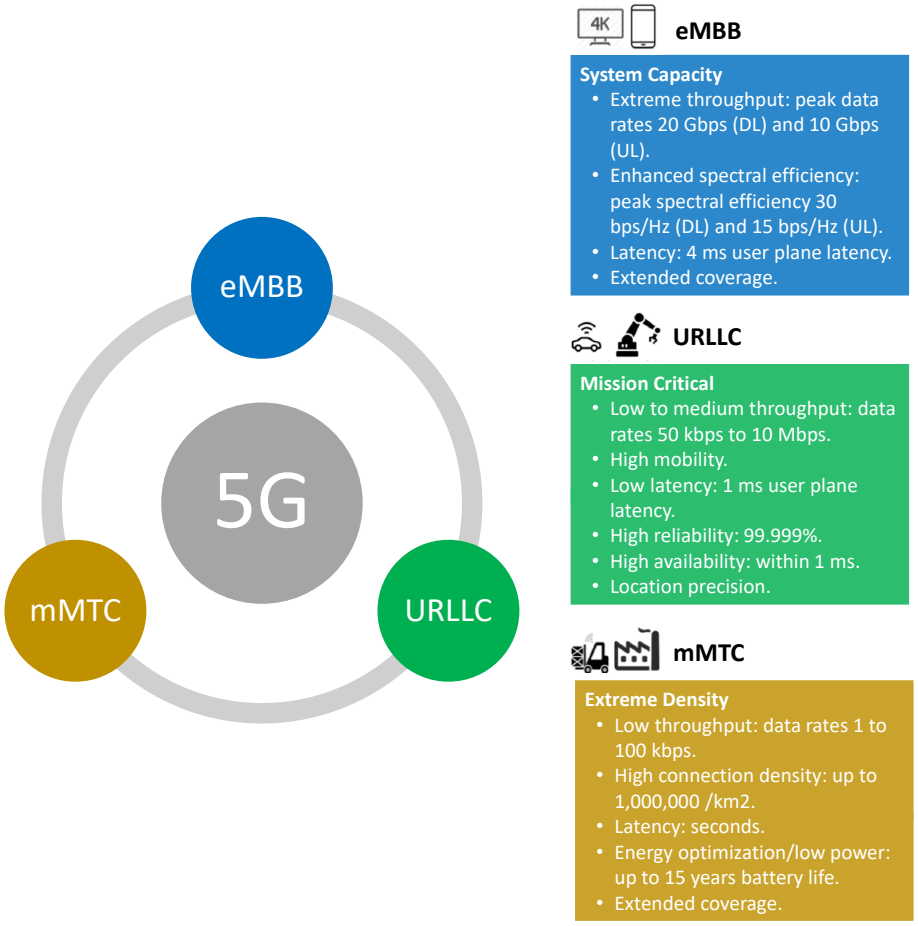


Figure 3.1.2. Three pillars of 5G New Radio[7]

5G NON-STANDALONE (NSA), STANDALONE (SA) AND ITS FREQUENCY

5G networks are classified into two, Non-standalone (NSA) and Standalone (SA). 5G NSA is a 5G network supported by an existing 4G infrastructure. In 5G NSA, devices that support 5G will be connected to 5G radio frequencies (NR) to get better data output than 4G but by using the core network of 4G. The 5G NSA is regulated in 3GPP release 15. The 5G NSA will focus on improving cellular broadband (eMBB) to provide increased BW data and connection reliability through two frequency allocation ranges[8].

[7] Huawei's Position Paper_5G Application, 2019

[8] Huawei's Position Paper_5G Application, 2019

Table 3.1.1. 5G NSA frequency allocation ranges

Frequency Range	Operating Frequency	Numbered Band	Remark
Frequency range 1 (FR 1)	450MHz to 6GHz	1 to 255	a. FR 1 is commonly called New Radio (NR) or sub-6GHz. b. FR 1 still overlaps with 4G frequencies. c. The "Coverage Layer" exploits a spectrum below 2 GHz (e.g., 700 MHz) providing wide-area and deep indoor coverage. d. The "Coverage and Capacity Layer" is spectrum in the 2 to 6 GHz range (e.g., C-band) that delivers the best compromise between capacity and coverage.
Frequency range 2 (FR 2)	24GHz to 52GHz	257 to 511	a. FR 2 is commonly called millimeter waves (mm Wave). b. The "Super Data Layer" is spectrum above 6 GHz (e.g., 24.25–29.5 and 37–43.5 GHz), used to address specific use cases requiring extremely high data rates (e.g., FWA and hotspot).

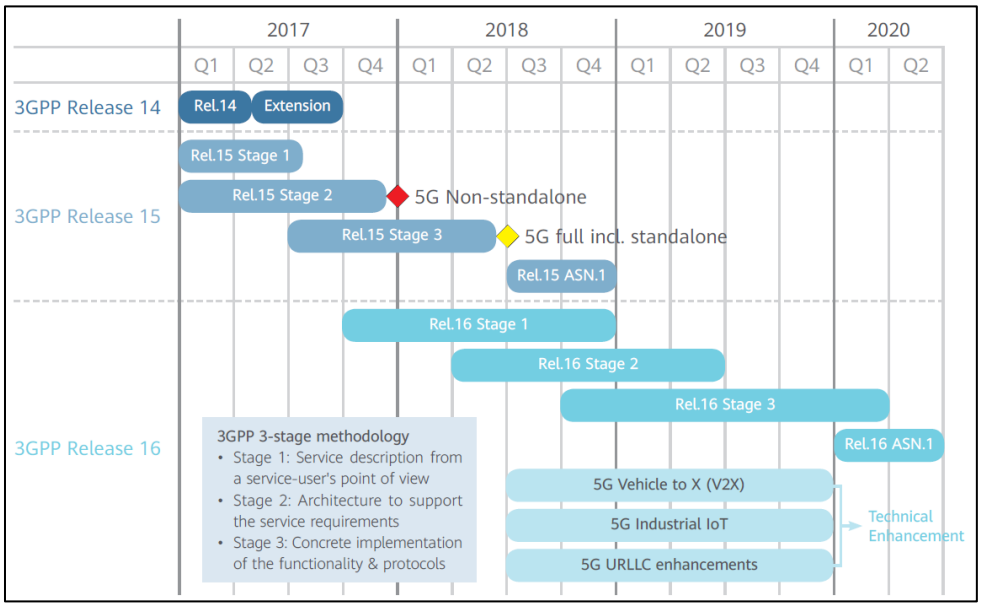


Figure 3.1.3. 5G standardization roadmap and milestones[9]

[9] 3GPP.org

5G SA is a 5G network supported by a 5G infrastructure. In 5G SA, devices that support 5G will be connected to 5G radio frequencies to get better data output than 4G using the 5G core network (5GC). SA is regulated in 3GPP release 16. There are three main services that can be delivered via 5G SA: Network slicing, Mobile Edge Computer (MEC) and Ultra-reliable Low Latency Communication (URLLC).

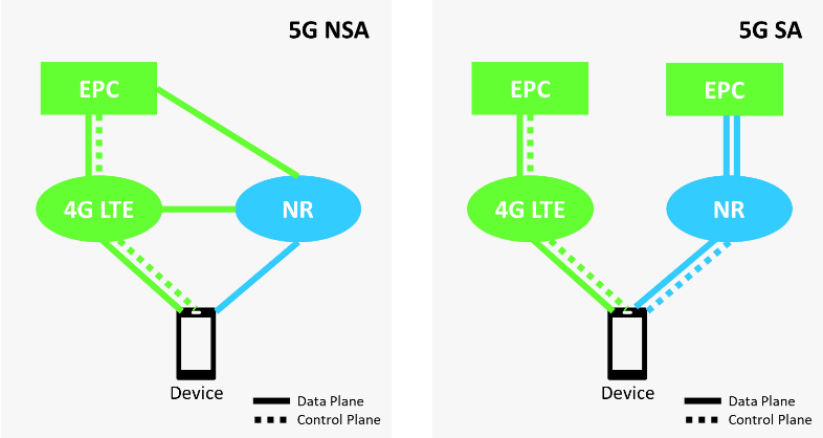


Figure 3.1.4. 5G NSA and SA Topology[10]

5G URLLC SPECTRUM OPTIONS

The 5G URLLC service can be deployed in FDD, TDD and millimeter wave bands. The 5G frequency allocation range is needed across all bands to support all use cases. 5G spectrum needs to be made available and examines the current state of spectrum assignment across countries. It then sets out a roadmap for governments and regulators to follow to enable this to be achieved in an efficient and effective way.

[10] Rresearchgate, 2019

Table 3.11.2. 5G Key Pillars Spectrum Options[11]

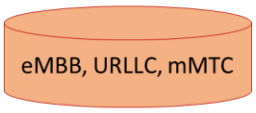
5G Key Pillars	Band	Frequency Band
	High-bands **Super Data Layer** *Addressing specific use cases requiring extremely high data rates.*	**Above 24 GHz** • At least 400-800 MHz contiguous • e,g, 5925-7125 MHz
	Mid-bands **Coverage & capacity Layer** *Best compromise between capacity and coverage (wide area but no deep coverage).*	**2 to 8 GHz** • At least 80-100 MHz contiguous • e.g., TDD bands at 2300, 2600, 3300-3800, 3800-4200 or 4800-4990 MHz
	Low-bands **Coverage Layer** *Wide area and deep indoor coverage.*	**Below 2 GHz** • up to 20 MHz (paired/unpaired) • e.g., FDD bands at 600, 700, 900, 1800, or 2100 MHz

Table 3.11.3. 5G Frequency Bands Across the World[12]

No.	Country	5G Frequency		
		Low-Band (Sub-1GHz)	Mid-Band (Sub-6GHz)	mm-Wave
1	Argentina	Upcoming	Upcoming	Upcoming
2	Australia	Unavailable	Available	Upcoming
3	Austria	Available	Available	Upcoming
4	Belgium	Upcoming	Upcoming	Upcoming
5	Bhutan	Upcoming	Upcoming	Upcoming
6	Brazil	Upcoming	Upcoming	Upcoming
7	Canada	Available	Upcoming	Upcoming
8	Chile	Upcoming	Upcoming	Upcoming
9	China	Unavailable	Available	Upcoming
10	Colombia	Upcoming	Upcoming	Unavailable
11	Costa Rica	Upcoming	Upcoming	Upcoming
12	Denmark	Available	Available	Upcoming
13	Estonia	Upcoming	Upcoming	Upcoming
14	Finland	Unavailable	Available	Available
15	France	Unavailable	Upcoming	Available
16	Germany	Unavailable	Available	Upcoming

[11] Huawei 5G Spectrum public policy, 2020

[12] Newsletter, EverythingRF, Oct 2020

No.	Country	5G Frequency		
		Low-Band (Sub-1GHz)	Mid-Band (Sub-6GHz)	mm-Wave
17	Greece	Upcoming	Upcoming	Upcoming
18	Hong Kong	Unavailable	Available	Available
19	India	Unavailable	Upcoming	Upcoming
20	Indonesia	Unavailable	Upcoming	Upcoming
21	Ireland	Unavailable	Available	Upcoming
22	Italy	Available	Available	Available
23	Japan	Unavailable	Available	Available
24	Luxemborg	Available	Available	Upcoming
25	Mexico	Available	Available	Upcoming
26	New Zealand	Unavailable	Available	Upcoming
27	Norway	Unavailable	Upcoming	Available
28	Peru	Unavailable	Upcoming	Upcoming
29	Portugal	Upcoming	Upcoming	Unavailable
30	Russia	Upcoming	Upcoming	Upcoming
31	South Korea	Unavailable	Available	Available
32	Spain	Upcoming	Available	Upcoming
33	Sweden	Available	Upcoming	Upcoming
34	Taiwan	Unavailable	Available	Available
35	Thailand	Available	Available	Available
36	UK	Upcoming	Available	Available
37	USA	Upcoming	Upcoming	Available
38	Uruguay	Unavailable	Available	Available
39	Vietnam	Upcoming	Upcoming	Upcoming

BUSINESS AND INVESTMENT IN 5G URLLC

More than any previous generation of technology, 5G URLLC technology brings together Mobile Network Operators (MNO), Equipment Vendors, System Integrators, and other Industry Stakeholders as 5G opens various technical and business opportunities. The challenge is how to monetize low latency.

a. Mobile network operators (MNO) have a central role in 5G deployment as they will run the 5G network. They will do most of the required CAPEX and OPEX.
b. Equipment vendors develop hardware/software of 5G technology, define and introduce 5G products (RAN, core network, services, handset).
c. Mobile network operators and equipment vendors will need to engage with vertical-specific systems integrators and application developers to create the applications that will use reliable and low-latency services.
d. Industry stakeholders are brought into the paradigm with new opportunities with 5G. Many sectors are involved as 5G will enable massive innovation both on the product side (e.g., connected vehicles, smart cities) and on the productivity side (e.g., industrial IoT).

Good collaboration and partnership with revenue sharing system between them will greatly help accelerate the implementation of 5G URLLC to customers. In addition, government support in the form of affordable 5G spectrum fees will make 5G prices to customers more competitive than 4G. For mobile network operators, various operators are experimenting with low latency offerings. For example, Verizon is leveraging its 5G Multi-Access Edge Computing platform through a partnership with Amazon Web Services (cloud service provider). Partnerships and the like make sense, as it is very difficult for operators to set up their own cloud. While the business model is not yet clearly defined in this space, each partnership will feature a revenue share, with a percentage share depending on the sector in question. Besides, for obtaining optimal revenue, MNOs can not only offer connectivity services to the enterprise. They need to offer bundling solution as a service (connectivity solutions, IoT solutions, managed services, and other product solutions).

5G technology standards be required for microprocessors, devices, and device modules, as well as the 3 main layers of 5G network infrastructure (Core network, Radio Access Network, and Services (voice, data)). Each of these layers requires the coordination of multiple hardware and software elements that were developed by the technology vendors. Interoperability amongst them is necessary to ensure good network performance and economic efficiency in production. As 5G involves stakeholders from other industries, the standardization process is more complex because it includes standards for specific application interfaces. For successful universal 5G, it is vital to produce hardware with a general design based on common standards with flexible network capabilities. If modules and user devices have standardized interfaces and specifications, the industry will benefit from better scale effects and faster 5G adoption.

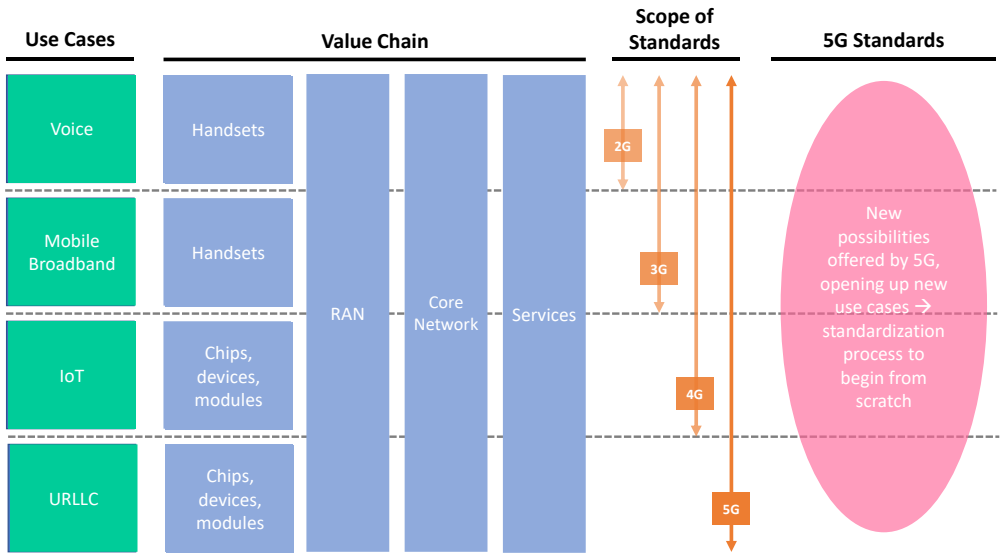


Figure 3.1.5. 5G Technology Scope of Standards[13]

[13] Huawei's Position Paper_5G Application, 2019

3.1.3. Maturity

URLLC focuses on an ultra-responsive connection with ultra-low latency. The data rate is not expected to be very high in URLLC but offers high mobility. URLLC supports use cases that require high network reliability (99.99%), and extremely low latency of approximately 1 millisecond for data transmission. For example, autonomous driving would require a connection capable of this, as there is such high risk involved. Autonomous driving has a whole host of benefits, from timesaving to improving safety by eliminating user error. However, it would need all vehicles to be connected to each other vehicle-to-vehicle, and to roadside systems, vehicle-to-infrastructure, such as traffic light systems, emergency services and road maintenance programs. Data would need to be shared in real-time, with minimal latency, as safety requirements demand ultra-reliable connections.

Several operators, enterprises and vendors around the world have collaborated to test URLLC capabilities and implementing URLLC in several industrial sectors.

- In March 2022, Optus joined forces with Ericsson, SICK (safety sensors) and Universal Robots in the first-ever demonstration of 5G mmwave Ultra Reliable Low Latency Communications (URLLC) technology capability for enabling advanced automation in Australia[14].
- In year 2020, Ericsson and Audi have tested 5G mmwave Ultra Reliable Low Latency Communication (URLLC) capabilities for factory automation at the car manufacturer's P-Labs facility in Germany[15].
- In 2019, ZTE Corporation together with China Mobile and MediaTek, has completed all the test items of 5G mid-band URLLC key technologies in Guangzhou, China. This is the first URLLC verification on the live network in industry[16].

URLLC maturity based on Porter's Five Forces analysis and Diffusion of Innovations theory is described in the following table.

Table 3.11.5. The Maturity of URLLC

Competitive forces	Level	Reasoning
Competition in the industry (*Uniqueness, competitor power, and healthy profits*)	1	There are 3 main industry types based on URLLC use cases: intelligent transportation, remote surgical operations, and industrial automation. Currently, the industry is still preparing devices and systems to support 5G URLLC. In addition, the results of studies and research on 3GPP releases 17 and 18 related to advanced 5G are also eagerly awaited as the URLLC standard for these industries (est. end of 2023).

[14] Manmonthly news/australian-first-demo-5g-urllc-technology, 2022

[15] Ericsson news/5g-for-factory-automation, 2020

[16] Mobile world live/china-mobile-and-zte-complete-industrys-first-urllc, 2019

Competitive forces	Level	Reasoning
Supplier power (*Suppliers, competitive price, and product uniqueness*)	1	The main 5G URLLC suppliers are divided into three: Mobile Network Operators (MNO), Equipment Vendors and System Integrators (developers). To be able to run a URLLC business, partnerships between suppliers are needed with the aim that the URLLC costs to be delivered to end users are competitive and affordable. Currently, only 12% countries in the world (24 of the 193) have started or have implemented 5G.
Buyer power (*Volume forecast, costing, and supplier capacity)*	2	Currently, there are several companies in Indonesia and abroad who are interested in using URLLC, such as the IoT industries or hospitals implementing remote medicine. They expect reasonable fees for URLLC service from suppliers.
Threat of substitution (*Customer experience, best in class customer treatment*)	1	Currently there is no new technology that can be used as a substitute for 5G URLLC. If use 4G technology, the results will be different and cannot be compared with 5G technology.
Threat of new entry (*Market landscape, technology protection, and barriers*)	1	The main barriers to entry of URLLC business are that there is no mature underlying infrastructure to develop it this time which makes it hard for new entry.

The URLLC's maturity based on The Porter's Five Forces analysis on Table 3.1.5 has the total score of 6 of 15, where URLLC is considered at the growth phase. Meanwhile, based on the adopter category on Diffusion of Innovations theory, this technology is in the early majority stage because it is still considered to be applied to customers by the operator.

The Porter's Five Forces	**Introduction**			**Growth**			**Mature**						**Decline**		
Score	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Diffusion of innovations	**Innovators**		**Early Adopters**			**Early Majority**				**Late Majority**				**Laggards**	

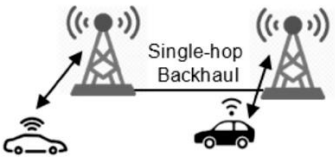
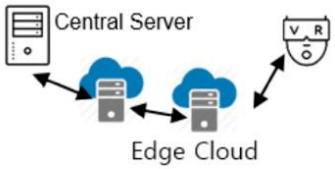
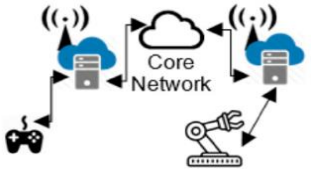
3.1.4. Relevance

5G is a wireless technology designed not only for mass market mobile Internet, but also industry verticals. In particular, URLLC (Ultra Reliable Low Latency Communication) is envisioned as an enabler to transform the factory floor. Together with MEC (Mobile Edge Computing), 5G can enable PLC software and create advanced Artificial Intelligence (AI)/Machine Learning (ML) based applications that can control factory devices in real time. For example, a video analysis application can be used to identify faulty products based on the video stream provided by the URLLC 5G camera and instruct the URLLC 5G robotic arm to remove the faulty product from the assembly line in a timely manner. This example demonstrates that consistently low latency and reliability are critical to intelligent factory assembly line automation.

3.1.5. Implementation and Use Case

URLLC-focused applications require end-to-end data delivery with minimum reliability, security, and latency. Channel quality and lack of dedicated bandwidth can be obstacles to meeting the desired latency requirements for URLLC. To achieve the desired reliability in URLLC is also a challenge. The physical layer plays a major role to achieve low latency and reliability. Researchers have provided three edge communications solutions to overcome the stringent QoS requirements in URLLC. Current mobile networks follow a centralized approach, while edge communications bring resources closer to the UE. The three-edge communication-based solutions, namely mobile edge computing (MEC), local area communication, and wide area communication, are very promising solutions for deploying URLLC. Apart from E2E QoS issue, there are also some radio-side issues to be aware of to ensure URLLC runs properly (URLLC package design, URLLC scheduling, URLLC handover, URLLC error handling). [17]

Table 3.11.4. Possible solutions to improve existing issues in communication methods[18]

Current Issue	Possible Edge Communication Solution	Visualization
Shadowing, channel estimation overhead	**Local area communication**: providing multi-connectivity, 5G NR, and grand free access.	
E2E delay and reliability, optimizing communication	**Mobile edge computing**: optimizing scheduling methods in computing system and communication.	
Reliable and precise communication between slave and master controller	**Wide area communication**: forecasting mobility and communication methods to be co-design to improve QoS.	

5G adoption continues to grow rapidly in terms of customers and deployments. 5th generation cellular networks enable applications and services that require greater reliability, increased energy efficiency, massive connection density and lower latency. This adoption makes industry faster, more efficient, and our connected lives better. In The Fourth Industrial

[17] URLLC Implementation Challenges and Operational Issues, MDPI's journal, 2019

[18] URLLC Implementation Challenges and Operational Issues, MDPI's journal, 2019

Revolution (4IR), URLLC is one of the technology drivers, alongside other technologies such as artificial intelligence, genetic engineering, 3D printing, quantum computing, Internet of Things, and robotics[19]. Ultra-Reliable Low Latency Communication Services (URLLC) makes it possible to support use cases that require very high reliability and very low latency. Examples of these use cases include industrial automation, intelligent transportation, and remote diagnosis and surgery.

3.1.5.1. Industrial Automation or Smart Factory

The manufacturing industry is growing rapidly. Industry leaders are looking for ways to stay ahead in their factories by increasing flexibility in automation of production and assembly processes while also reducing personnel safety risks. Manufacturing companies automate industrial control by developing networks in production plants. Thanks to URLLC technology that can help make that happen. URLLC is capable of automating manufacturing processes and the power system. Companies are replacing humans with robots in the manufacturing process to achieve higher productivity and reliability.

In automobile assembly lines, URLLC helps achieve high reliability to avoid damage to auto parts during assembly and achieve minimum latency to follow moving trays along the assembly line. Industry technical standards, such as PROFINET, demand low latency. PROFINET is a communication protocol that allows data exchange between devices and controllers via industrial Ethernet. They require tight latency bonding with the level of assurance required to ensure security in the system. 5G URLLC can meet PROFINET's demands with greater flexibility, security, and efficiency in the production line.

Figure 3.1.6. URLLC in Automotive Smart Factory[20]

3.1.5.2. Intelligent Transportation

URLLC can empower several technological transformations in the transportation industry, including automated driving, road safety and traffic efficiency services. These transformations will make cars fully connected so they can react to increasingly complex road situations by cooperating with others rather than relying on their local information. These

[19] innovate.ieee.org

[20] ericsson.com/en/cases, 2020

trends will require information to be disseminated among vehicles reliably within extremely short time duration. In fully automated driving with no human intervention, vehicles can benefit by the information received from roadside infrastructure or other vehicles. The typical use cases of this application are automated overtake, cooperative collision avoidance and high-density platooning, which require tighter end-to-end latency and high reliability.

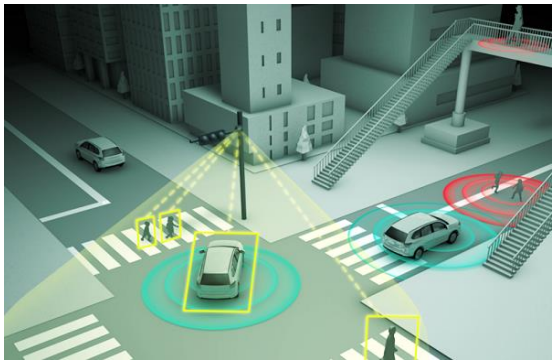


Figure 3.1.7. URLLC in Transportation Industry[21]

3.1.5.3. Remote Healthcare

There is a need for remote patient monitoring and communications with devices measuring vital signs such as ECG, pulse, blood glucose, blood pressure and temperature. The remote treatment and response based on monitored data can be life critical for a patient, requiring immediate, automatic, or semi-automatic response. The URLLC are used for remote surgical consultations and remote surgery. Remote surgery is about applications in a mobile scenario in ambulances, disaster situations and remote areas requiring providing precise control and feedback communication mechanisms for surgeons in terms of low latency, high reliability, and tight security. In a remote surgery scenario, the entire treatment procedure of patients is executed by a surgeon at a remote site, where hands are replaced by robotic arms. In these two cases, the communication networks should be able to support the timely and reliable delivery of audio and video streaming.

[21] Panasonic.com

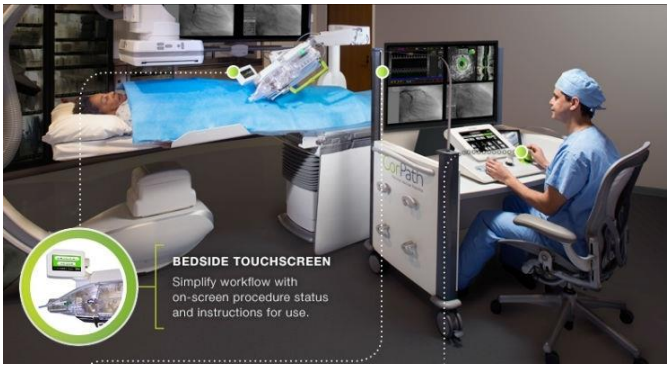


Figure 3.1.8. URLLC in Healthcare Industry [22]

3.1.6. Market Size

Based on analysis data from *IndustryARC* (India's leading market research provider), URLLC market size was valued at $20.4 billion by 2026, and it is estimated to grow at a CAGR 34.5% during 2021-2026. The increased penetration of Industry 4.0 enables data transmission between intelligently connected devices for real-time quality control of critical applications has fueled the market significantly. URLLC provides wireless connectivity to meet the demand for high speed M2M (machine-to-machine) communication in connected factories and thereby accelerate adoption. With advanced capabilities and benefits such as higher data transmission speed, low latency, and higher reliability for critical applications such as process automation, driving assistance, automated guided vehicle (AGV), remote diagnosis the demand for URLLC has gained a huge traction.

[22] Medical Product Outsourcing Magazine, 2019

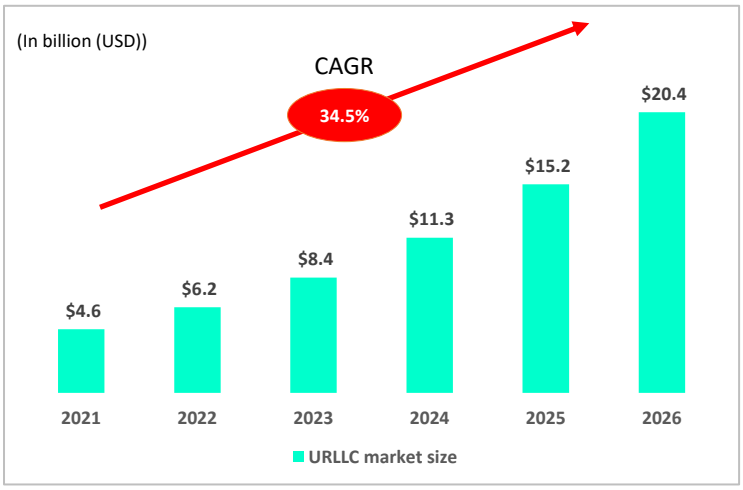


Figure 3.1.9. URLLC market size[23]

Meanwhile, based on GSMA's analysis of 5G contribution to global GDP from 2020 to 2030, by the four main use cases that will enable 5G (eMBB, FWA, URLLC, & MIoT) shows that eMBB and FWA are expected to account for 66 percent of the total 5G-associated economic benefits. URLLC is in the last place with 16 percent contribution of the total 5G-associated economic benefits.

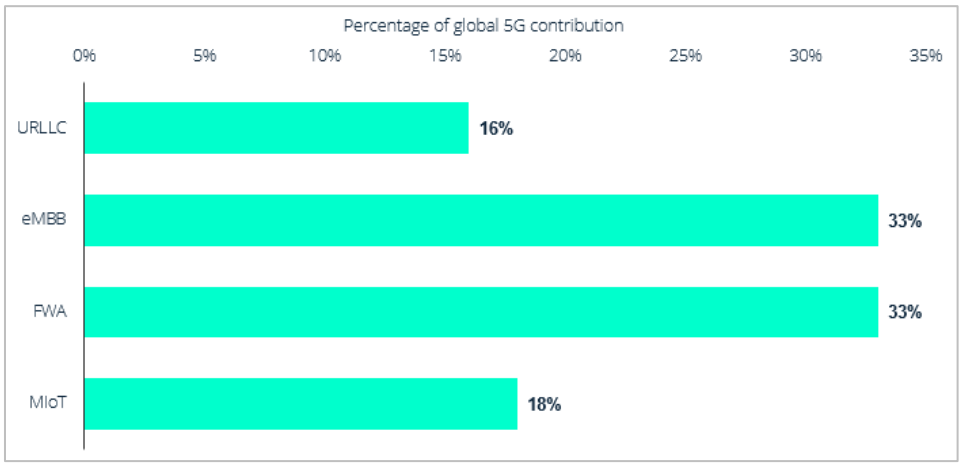


Figure 3.1.10. Global GDP 5G contribution 2020-2030, by use case[24]

[23] IndustryARC Report, 2021

[24] Statista, global-gdp-5g-contribution-2020-2030-by-use-case, 2020

3.1.7. Market Segment

IndustryARC, the leading provider of market research which based in India and US, has segmented the URLLC market based on four categories[25].

Table 3.1.6. URLLC market segment

No.	Category	Market Segment
1	URLLC offering	[3]: Hardware, Software, Services
2	Application	[8]: Industrial automation (process automation, discrete automation), remote diagnosis, telesurgery, autonomous driving, traffic management, smart grid, smart office buildings, others
3	End User	[2]: Industrial (automotive, chemical, oil & gas, food & beverage, pharmaceuticals, Mining, power, others), Commercial (office buildings, stadiums, Retail & e-commerce, utilities, public & government sectors, logistic & transportation, others)
4	Geography	[5]: North America, Europe, Asia Pacific, South America, RoW (Middle East & Africa)

The following is an example of a URLLC classification based on its use case and market segment.

Table 3.1.7. URLLC's market segment

USE CASES	MEDIA & ENTERTAINMENT	MANUFACTURE	SERVICE
Automotive		Intelligent transportation	
Healthcare			• Remote surgical operation • Remote medicine
Engineering	• Live event reporting • Online gaming with AR/VR	Smart factory	

3.1.8. Technology Solution Providers

As mentioned in the previous section, URLLC will require development in the following domains:

- Infrastructure domain (MNO)
- Equipment domain
- Device and application ecosystem
- End-to-End System Considerations

Therefore, collaboration between relevant stakeholders is mandatory to implement URLLC.

[25] IndustryARC Report, 2021

Table 3.1.8. URLLC technology solution provider

Companies	Domain	Description	Scale (Local/Global)
Ericsson	5G Solution Vendor	The Swedish networking and telecommunications company offers services, software and infrastructure in information and communications technology for CSPs. Ericson's end-to-end 5G offerings includes its Ericsson Radio System, 5G Core, Orchestration and 5G Transport along with top notch professional services.	Global
Huawei	5G Solution Vendor	Huawei offers more scale and breadth in its 5G-related portfolio. The company has various series of radio products, strong features such as scenario-based beamforming and network slicing, as well as AI-based network operation and automation.	Global
Nokia	5G Solution Vendor	The Finland-based company is undergoing a new operating model and strategy refresh around its focus on focuses on mobile, fixed IP and optical networks, cloud, and network services. Nokia is currently one of the market leaders in terms of numbers of 4G LTE and 5G deals.	Global
Samsung	5G Solution Vendor	Samsung contributed to the world's earliest massive commercial adoption of 5G in South Korea, leading in share at the top three local CSPs. The company has driven advanced capabilities such as millimeter wave radio, in-house chipsets and virtualized solutions.	Global
ZTE	5G Solution Vendor	ZTE provides many innovative 5G technologies and features such as SuperDSS, massive MIMO, concise multi-RAT and multiband site, AI-driven smart operation, and energy saving, as well as network slicing and converged 5G core.	Global
NEC	5G Solution Vendor and SI	The Japanese communications specialist, along with its Netcracker subsidiary, is providing highly reliable 5G networks to CSPs and industry players through the	Global

Companies	Domain	Description	Scale (Local/Global)
		integration of IT and network technologies. NEC is striving to become a system integrator in addition to being a product supplier in Open RAN by expanding its NEC Vertical Business Platform.	
Mavenir	5G Solution Vendor	The Texas-based company specializes in network software for the telecommunications industry. Mavenir launched a fully virtualized 4G and 5G open RAN solution in 2019 with plans to help CSPs break the vendor lock-in situation and discontinue old legacy business models.	Global
Broadcom, Qualcomm, MediaTek, Intel Corporation, Samsung, ZTE, Qorvo, Fujitsu	Chip/Device/Application	Solution partners who provide chip/device/application to support 5G technology and other technologies running on 5G (such as IoT).	Global

Summary
Categorization: ● Maturity: Early Majority ● Technology Field: Management and business support ● Relevance for IOH Business: High
Reason to watch: The powerful new tools for managing and analyzing heterogeneous data across the enterprise.
IOH Status: ● Year added: 2022

3.2. Graph Technology for Enterprise

3.2.1. Introduction

The results of research reported by Gartner (2021), state that the development of innovation and digital technology will be increasingly rapid. Along with these advances, the data that supports the digital world will be more intensely managed. One of the trends that will develop rapidly in the future is Graph Technology. Graph technology will be the item every company is looking for when it comes to data management. In 2025, the trend of implementing Graph Technology is predicted to increase to 80 percent compared to the total utilization of Graphic Technology, which until 2021 is only around 10 percent.

The massive data sets, complex processing capabilities and advanced analytical models in the current digital business landscape create the perfect storm of opportunity for data and analytics. As data volumes grow, traditional analytics often fail to address complex business operations, delivery, and analytics issues. Graph technology helps find unknown relationships in data that were not identified or analyzed through traditional means. It has become an innovative way for organizations everywhere to efficiently address uses those other methods cannot cope with.

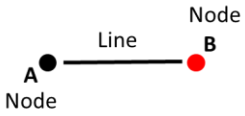
3.2.2. Definition and Scope

Graph technology is a technology that works by organizing unstructured data sets as a structure of connected nodes and edges and processing the data using machine learning algorithms and techniques, which are specific to linked data structures. Graph technology is formed around the idea of building databases using mathematical graph theory to store data and the links between data as relationships. While the underlying math is quite complex, the point is that graph databases emphasize the connections between data as much as the individual data points by explicitly storing those connections as relationships. Graph is a NoSQL data structure (not only SQL or non-table based, i.e., document, key-value, wide-column stores or graph format).

GRAPH ELEMENTS

The study of graphs is known as Graph Theory. Graph is a mathematical term, and it represents relationships between entities. Two elements make up a graph: nodes and edges. The nodes in a graph represent entities (animals, organizations, cities, countries, etc.) and the edges represent relationships among them. There are many synonyms for the term's "node" and "line".

- Node = vertice/vertex, point, actor
- Edge = line, link, tie, arrow



In real-world scenarios, nodes can be people (e.g., customers, employees), or places (e.g. retail stores, airports), or represent things (e.g. assets, bank accounts, URLs). Edges can stand for likes and dislikes, emails, payments, phone calls, etc. The ancillary information or attributes that describe a node are called properties.

TYPES OF GRAPH MODEL

There are two types of graphs model: property graph and RDF graph.

RDF (Resource Description Framework) is a standard model for data interchange on the Web. RDF has features that facilitate data merging even if the underlying schemas differ, and it specifically supports the evolution of schemas over time without requiring all the data consumers to be changed[26]. RDF has a special nomenclature for naming nodes and edges in a graph. The source node is called a subject, the edge name is called a predicate, and the target node is called an object. RDF graph consists of a set of logical assertions of the form subject, predicate, object, known as a triple. Note that in a graph a node can be in the subject position in one triple and in the object position in another triple.

[26] w3.org

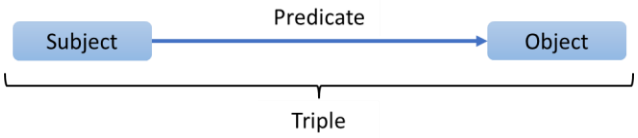


Figure 3.2.1. RDF Terminology[27]

The following figure illustrates a simple RDF graph (a triple).

Figure 3.2.2. Example of Simple RDF Graph

Based on the triple above, the subject is Budi, the predicate is likes and the object is chocolate. If there are several additional triples (Lina likes Joko, Lina is a woman, Joko likes Budi, Joko is a man), when joined together a set of triples forms a RDF graph consisting of nodes and edges. The example below illustrates RDF graph consisting of several triples (complex RDF graph).

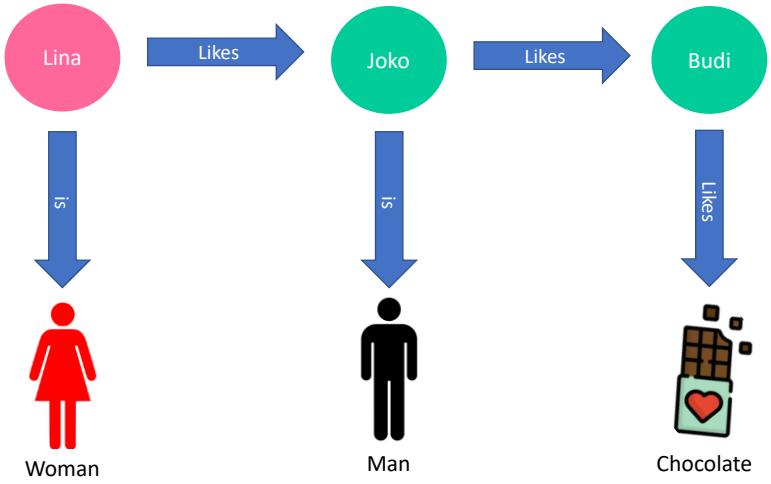


Figure 3.2.3. Example of Complex RDF Graph

[27] RDF Graph Data Model, Stardog Tutorial document, 2020

RDF graphs are designed to represent statements and are best for representing complex metadata and master data. They are often used to represent complex concepts in a domain, or in situations that require rich semantics and inferences on data. In the RDF model a statement is represented by three elements: two vertices connected by an edge. Every vertex and edge are identified by a unique URI (Unique Resource Identifier, a unique sequence of characters that identifies a logical or physical resource used by web technologies). The RDF model provides a way to publish data in a standard format with well-defined semantics, enabling information exchange. *Government statistics agencies, pharmaceutical companies, and healthcare companies* are among the types of organizations that have adopted RDF graph.

A property graph consists of a set of objects or vertices, and a set of arrows or edges connecting the objects. Vertices and edges can have multiple properties, which are represented as key-value pairs.
Each vertice has a unique identifier and can have:

- A set of outgoing edges
- A set of incoming edges
- A collection of properties

Each edge has a unique identifier and can have:

- An outgoing vertice
- An incoming vertice
- A text label that describes the relationship between the two vertices
- A collection of properties

For vertices and edges, each property is identified with a unique name.

The following figure illustrates a simple property graph with two vertices and one edge. The two vertices have identifiers A and B. Both vertices have properties name and age. The edge is from the outgoing vertex A to the incoming vertex B. The edge has a text label knows (buddy) and a property type identifying the type of relationship between vertices A and B (A is buddy of B).

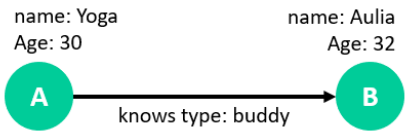


Figure 3.2.4. Example of Simple Property Graph[28]

[28] Graph Developer's Guide for Property Graph by Oracle, 2021

Following is example of Complex Property Graph. From this example every vertice and edge has a unique identifier.

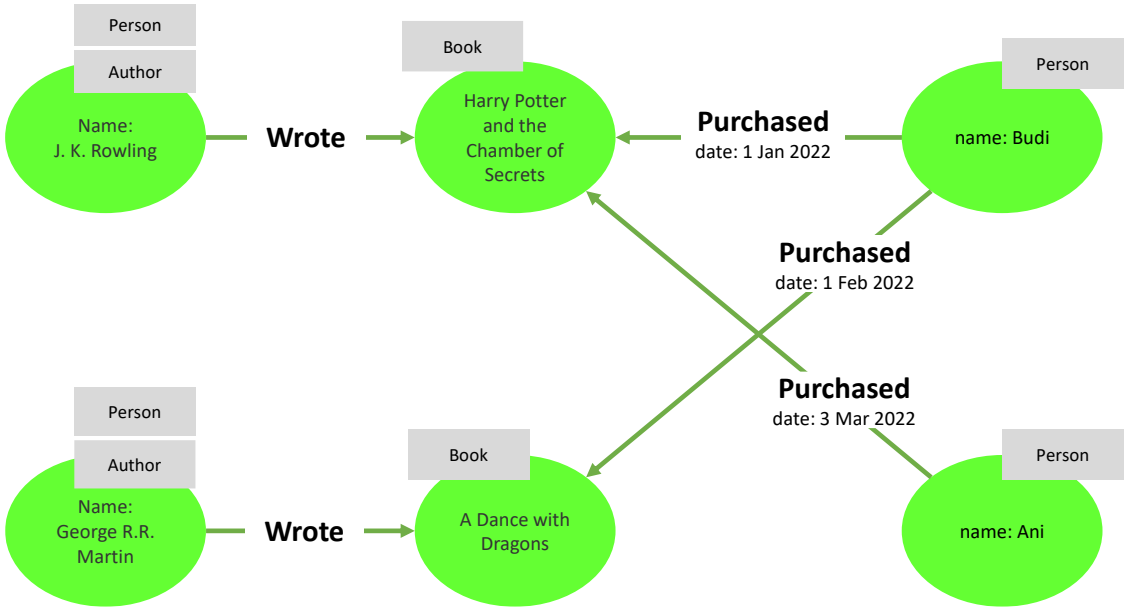


Figure 3.2.5. Example of Complex Property Graph

The property graph focuses on analytics and querying, while the RDF graph emphasizes data integration. Both types of graphs consist of a collection of points (vertices) and the connections between those points (edges). But there are differences as well. Property graphs are used to model relationships between data, and they enable query and data analytics based on these relationships. A property graph has vertices that can contain detailed information about a subject, and edges that denote the relationship between the vertices. Because they are so versatile, property graphs are being used in a broad range of industries and sectors, such as *finance, manufacturing, public safety, retail*, and many others.

COMPARISON OF RDF AND PROPERTY GRAPH MODEL

Below is a comparison of the two types of graph model (RDF and Property graph).

Table 3.2.1. Graph Models and Their Characteristics[29]

No.	Subject	RDF Graph	Property Graph
1	Special nomenclature for naming node and edge	The source node is called a subject, the edge name is called a predicate, and the target node is called an object, a set of logical assertions of the form subject, predicate, object, known as a triple.	Node is called vertice/vertex, edge that connecting the objects is called edge/line/arrow.
2	Vertices	Every statement produces two vertices in the graph.	Vertices are identified with a unique name and have multiple properties, which are represented as key-value pairs.
3	Edges	Every statement produces an edge.	Edges are identified with a unique name and have multiple properties, which are represented as key-value pairs.
4	Internal structure	Vertices or edges have no internal structure.	Vertices or edges have internal structure.
5	Standardization	Driven by W3C working groups (World Wide Web Consortium).	Different competing vendors.
6	Query language	SPARQL (SPARQL Protocol and RDF Query Language)	PGQL (Property Graph Query Language)
7	Data processing	Offline data processing.	Real-time data processing capability.
8	Designed for	Linked open data (semantic web).	Graph representation for analytics.
9	Analytics Execution	In-database.	In-memory and in-database.
10	Development process	More complex to develop.	Simpler to develop.
11	Main use case	Artificial Intelligence, Linked data, semantic metadata management	Operational applications, graph analytics, path search

BUSINESS AND INVESTMENT IN GRAPH TECHNOLOGY

Graph database technology contrasts traditional databases (e.g., SQL) by taking a relationship-first approach to data from the ground up. It treats relationships as first-class citizens through every part of the data lifecycle from the model to the storage engine, to the query language. As a result, in addressing some of the most complex data challenges, graph technology can offer the following business advantages[30]:

a. Performance at scale

[29] Knowledge Fundamentals, ontotext.com

[30] Why Your Business Should Use a Graph Database, Memgraph document, 2020

One of the main drawbacks of relational databases when dealing with interconnected data is a severe drop in performance as the number and depth of relationships increases. This means that with proper optimization, SQL databases can perform well for small data sets on queries with a depth of two or even three expectations, but that will inevitably fail as your data scales. In contrast, graph databases are designed to maintain predictable performance for queries with 3+ expectations on datasets with millions and even billions of relationships.

b. Flexibility and agility

With a graph technology, data scientist can easily model complex business scenarios in an intuitive and easy way since graph data models map very well how we think about real world problems. A modeling process that could take days in SQL can be done in a few hours. But it doesn't stop there. The graph data model is also very flexible and can be easily changed at any time. Unlike the relational model, organization doesn't have to spend hours getting the previous model up and then spending a long time adjusting it as the business use case changes.

c. Low total cost of ownership

When using a database that wasn't built to store and query highly interconnected data, organization will need to implement multiple solutions and redundancy to get the job done. This may lead to the need to combine different systems, which may be expensive to maintain or use more hardware to improve performance and scalability. With a graph technology, you will avoid operational complexity and keep your total cost of ownership affordable and predictable.

Generally, most software businesses have a mix of revenue streams to cater to different market needs. Likewise with the graph technology business. It is possible to combine multiple revenue streams to balance the two main goals of a software business: gaining users and increasing revenue. Some business model characteristics of software business are:

Table 3.2.2. Business model characteristics of software business[31]

No.	Business model characteristics	Options	What is suitable for software business (e.g., graph technology)?
1	Distribution approach	• On-premises • Cloud • Hybrid	**Cloud** distribution approach or SaaS (software as a service) • Faster implementation for clients • Users will be able to access products remotely from anywhere at any time • Doesn’t require any initial setup costs from users • Suppliers can provide the same software version for all their customers. This means that only a single version to maintain • The main revenue stream of the cloud distribution approach is subscriptions
2	Source code licensing	• Proprietary	**Proprietary** software

[31] Altexsoft document, 2018

No.	Business model characteristics	Options	What is suitable for software business (e.g., graph technology)?
		• Open source	• Most companies make their software products proprietary to protect it from copying, changing, or emulating • Users will be sure that the product will work properly due to a single source for support, bug fixes, security fixes, and regular upgrades • Software is protected by copyright and can be monetized
3	License-based Revenue Stream	• Perpetual • Subscription	**Subscription** with usage-based license • A subscription objective is to retain customers (enterprises) under a long-term contract and secure monthly/weekly/annual revenue flow. Enterprises lease the software instead of buying it. • The subscription payment includes not only software licenses, but also support services and new versions of the software as they are released. • A usage-based license is often employed in B2B products. It means that clients subscribe to "a pay-as-you-go" license based upon some measure of consumption, paying for only what they use.

3.2.3. Maturity

Based on the research conducted by DB-Engines on the following 6 database parameters in January 2022: website mentions, search frequency, technical discussion frequency, current job offers, professional network profiles, and social network relevance, the results show that the popularity of relational database management systems (RDBMS) still dominates the world, accounting for 72.2 percent of the overall DBMS rating score. RDBMS is a SQL database and the most popular of it in the world was Oracle. While NoSQL databases (e.g., graph database) are behind Relational DBMS and the total only accounts for about 25 percent of the overall DBMS ranking score[32].

[32] Statista, popularity-distribution-of-database-management-systems-worldwide, Jan 2022

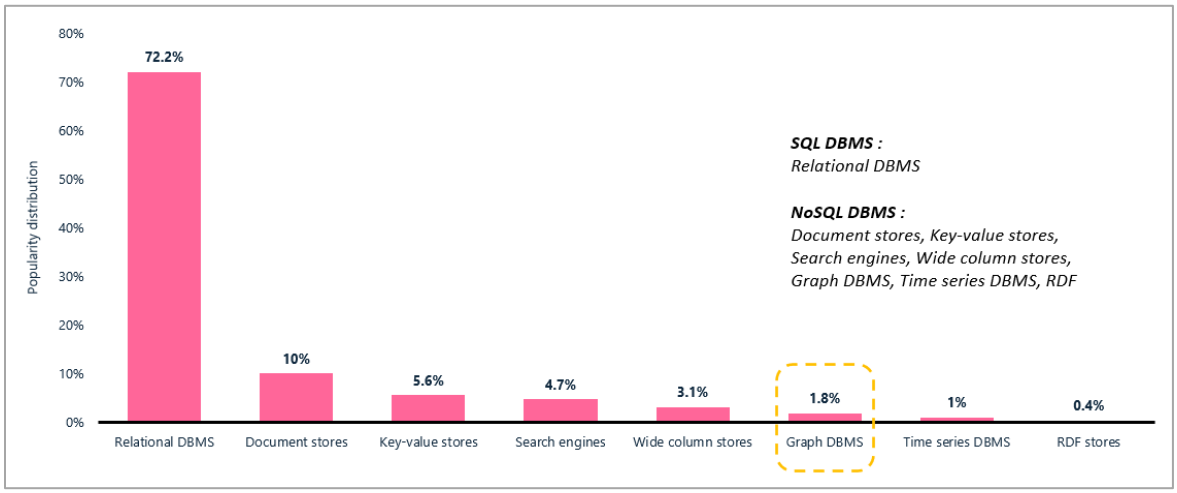


Figure 3.2.6. Popularity distribution of database management systems (DBMS) worldwide (January 2022)

Many companies in the contemporary business environment are dealing with Big Data and need to use the right tools to manage large volumes of data. Companies are constantly facing extreme competition and the business world is constantly changing when it comes to how businesses handle data. For this reason, businesses must find ways to leverage their data by using the best database technology (graph technology). They need a database system that can represent and visualize data simply and clearly. Graphs are very powerful tools because they help people in businesses and other settings to understand data sets by representing data in simplified forms. With the right graphing technology, businesses can visualize their data in graphical form and manage it to improve their overall performance.

Organizations have used graph databases because they realized the importance of this database technology. Some examples of the implementation of the latest graph technology that has occurred in the world:

- In March 2021, the Technical University of Denmark (DTU) broadcasted a strategic partnership with TigerGraph which is a leading provider of graph database and graph analytics software. The purpose of this partnership is to improve the treatment of acute lymphoblastic leukemia with TigerGraph's superior graph analytics with machine learning and artificial intelligence (AI) techniques.
- In October 2020, Microsoft introduced a new AI system that can caption and describe images. The new AI system helps caption and describe images even better than humans.
- In April 2019, Neo4j Inc. announced a strategic partnership with Google Cloud offered by Google LLC. The intention of this partnership is to offer the Neo4j a seamless and enhanced experience after the integration of the Google Cloud Platform console, support services, and billing.

Graph technology maturity based on Porter's Five Forces analysis and Diffusion of Innovations theory is described in the following table.

Table 3.2.2. The maturity of graph technology

Competitive forces	Level	Reasoning
Competition in the industry (*Uniqueness, competitor power, and healthy profits*)	2	The need for graph technology in industry is very high considering technological developments (such as big data, IoT) and many vertical industries that require variations of derivative applications from graph solutions to run their business.
Supplier power (*Suppliers, competitive price, and product uniqueness*)	1	Currently there are several graph technology suppliers (such as Neo4j, TigerGraph, ArangoDB, OrientDB, Stardog, Ontotext GraphDB) who provide graph solutions based on the type of applications required by the industries.
Buyer power (*Volume forecast, costing, and supplier capacity)*	1	As the size and complexity of data continue to escalate, organizations will increasingly turn to graph technology as a means of harnessing their data to drive decision-making. There are many vertical industries (such as Banking, Retail, Telecom, IT, Healthcare, Government, Manufacturing etc.) that currently need graph solution in their business. But most of them are still not aware of the usefulness of graph technology and are still focused on using the budget to run or expand their business.
Threat of substitution (*customer experience, best in class customer treatment*)	1	Because graphics technology is a software-based technology, it is very unlikely that this technology will be replaced by other non-software-based technologies.
Threat of new entry (*market landscape, technology protection, and barriers*)	1	Because graphics technology is a software-based technology, it is very possible for new IT/software companies to enter this graph database business. However, as supplier credibility is needed to convince companies, these new entrants may find it difficult to compete with incumbents in the market.

Based on The Porter's Five Forces analysis on Table 3.2.2, the total score of graph technology is 6 of 15 and considered Growth phase. While based adopter category on Diffusion of Innovations theory, this technology is in the early majority stage because it is still considered to be applied to customers and other technologies that intersect with graph technology are in a growing phase (e.g., IoT).

The Porter's Five Forces	**Introduction**			**Growth**			**Mature**						**Decline**		
Score	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Diffusion of innovations	**Innovators**		**Early Adopters**			**Early Majority**				**Late Majority**				**Laggards**	

3.2.4. Relevance

The emergence of graph technology brings major changes to the IT landscape related to the fields of metadata and asset management, data governance and analytics due to its unique and empowering characteristics. Furthermore, graph technology being theoretically superior allows enterprises to take a step further in storing large datasets that encompass and lock connections between unstructured data points, thus enabling the creation of data networks. In the end, it can be said that graph technology will be a game-changer for online commerce, social media platforms, and cybersecurity as it has a huge impact on route optimization, detection of money laundering and fraud cases.

TRACKING ADOPTION OF GRAPH TECHNOLOGIES IN BUSINESSES

The adoption of graphing-related technologies by businesses follows a maturity curve that typically goes from the early phase of using graphs in single use cases to ideal situations where companies successfully exploit graph data and tools on a recurrent basis. In this case it can be divided into four phases[33].

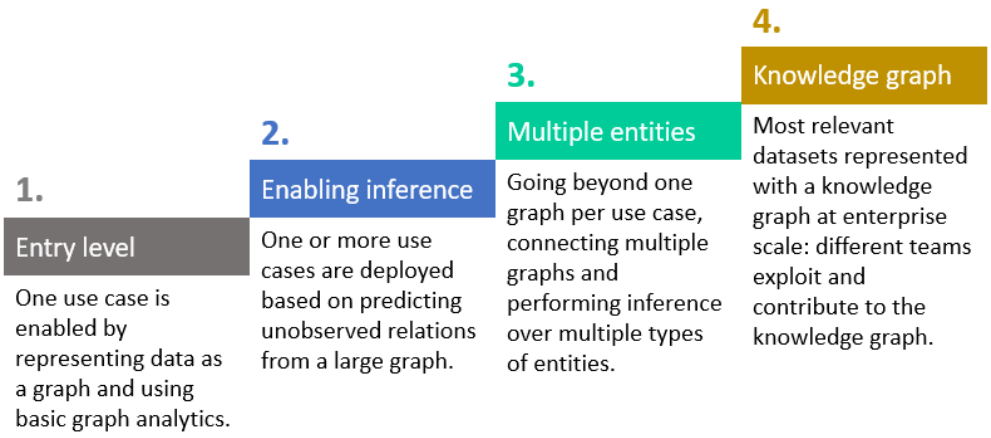


Figure 3.2.7. Maturity curve of graph technology adoption

3.2.5. Implementation and Use Case

The architecture for implementing RDF graphs on the network is described as follow.

a. The RDF Graph Server and RDF REST services can be used to create a SPARQL endpoint for RDF graphs.
b. SPARQL short for SPARQL Protocol and RDF Query Language, is RDF request language, enables users to query information from databases or any data source that can be mapped to RDF.

[33] BBVA AI Factory, Journal, 2020

c. The RDF Graph allows user to run SPARQL queries and perform advanced RDF graph data management operations using a REST service (API).
d. The features of the RDF Graph Query UI are:
    - Uses RDF REST services to communicate with RDF data stores (existing or external RDF data source).
    - Allows user to execute SPARQL queries and update RDF data.
    - Provides a graph view of SPARQL query results.
    - Have user application web pages.

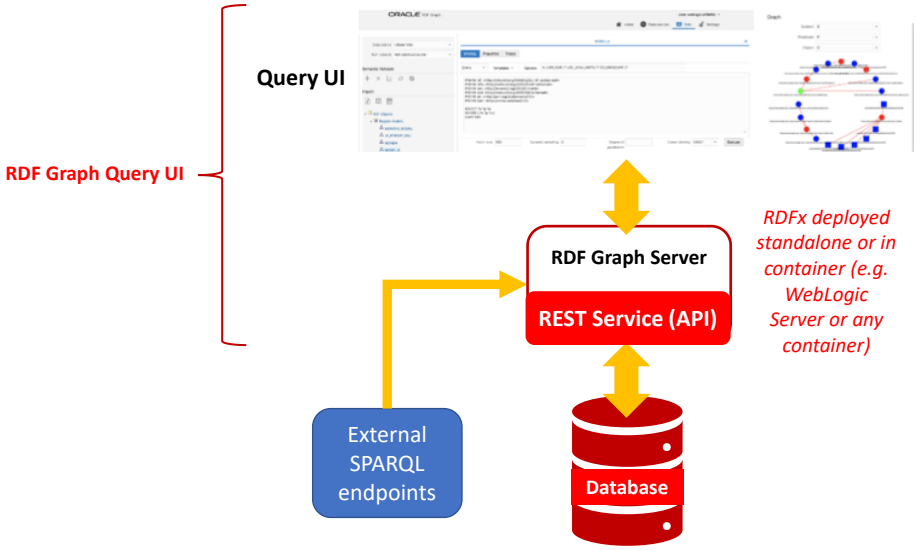
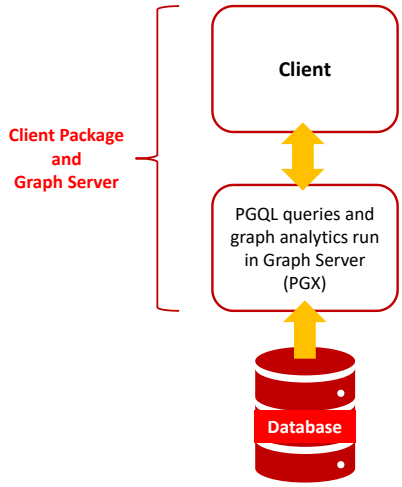
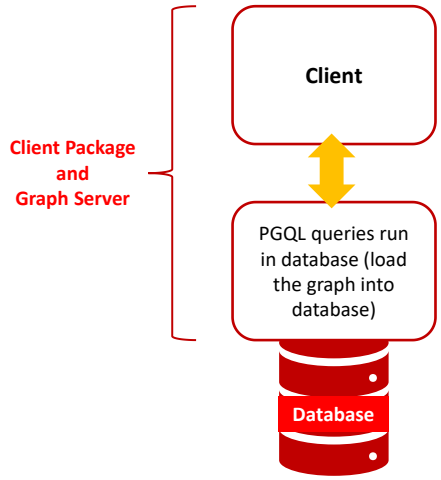


Figure 3.2.8. Architecture for implementing RDF graph technology

Meanwhile, there are two architecture options for implementing property graphs on the network[34]: run graph query and analytics in the In-memory Graph Server (PGX) (3-Tier) and load the graph into existing database system (2-Tier).

[34] Graph's Developer Guide Rel.21.3, Oracle, 2021

Table 3.2.3. The architecture for implementing property graph technology

Subject	3-Tier	2-Tier
Architecture		
PGQL queries	PGQL queries run in Graph Server (need additional server)	PGQL queries run in existing database system (no need additional server)

Businesses in every major sector leverage a graph technology to address use cases, including supply chain optimization, fraud detection, anti-money laundering, customer intelligence, risk analysis, product and service recommendations, and machine learning. Organizations should always use the right tool to run their business. Graph technology is suitable for such applications. However, if an organization's data has many many-to-many relationships or even one-to-many relationships that have a depth of three or more, the organization strongly recommends using a graph technology. Several of the graph's technology use cases are explained below[35].

3.2.5.1. Real-time fraud detection

The problem. In today's world, consumers demand instant access to services and money transfer. This opens opportunities for criminals. For example, payment service apps try to deliver money as quickly as possible to legitimate users while also ensuring money is not sent for illicit purposes or hiding the real receiver by being sent via a detour. This requires real-time fraud detection.

The graph solution. Because graphs allow lightning-fast answers to queries and expand access to data, they have become a popular technology in the real-time fraud detection field. When investigating transactions with graph technology, it is not only transactions that can be modeled on a graph. Graphs are very flexible, which means that heterogeneous

[35] 17 use cases for graph database, ebook by Oracle, 2021

surrounding information can also be modeled. For example, a client's IP address, ATM geolocation, card number, and account ID can all be nodes, and connections can all be edges. Property graph is the best choice for real-time fraud detection, especially in online banking and ATM location analysis because users can design rules to detect fraud based on datasets. For instance, detection rules can be set to IPs which log in with multiple cards registered in different places, cards used in different places with very far distances, and accounts receiving one-time inbound transactions from other accounts registered in various places.

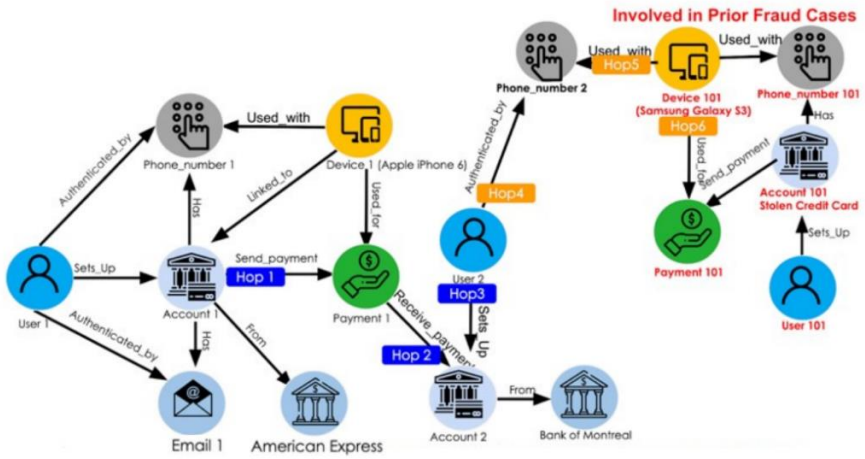


Figure 3.2.9. Illustration of real-time fraud detection by using advanced analytics with graph (6-hop)[36]

3.2.5.2. Traceability in manufacturing

The problem. Traceability is very important in the world of manufacturing. An automobile company might have to issue a recall for a car model because that specific model has a component which was produced from a factory during a limited time slot. The company must trace the causal components and then find the cars that are in market or on the road from the factory. This can be very difficult. Most companies have production databases that manage a lot of information on products. But they also have a separate retail database, a separate sales database, and a separate shipping database. It's hard to find all the relevant information to find the problematic cars, where they were shipped, and to whom they were sold.

The graph solution. Without graph technology, analysts would have to combine all the databases and run traversal queries from one specific car to the factory database that manages the production line. All of this requires complex data modeling and multiple joins unless the company has a graph database to link all the relationships and graph algorithms to highlight the connections and relevant information. RDF graph is suitable for use cases like this in manufacturing. RDF graph is able

[36] Tigergraph, 2020

to model different components and taking advantage of the relationships and connections they have with each other. It can also be used in the pharmaceutical world, to identify various chemicals, drugs, and generic names.

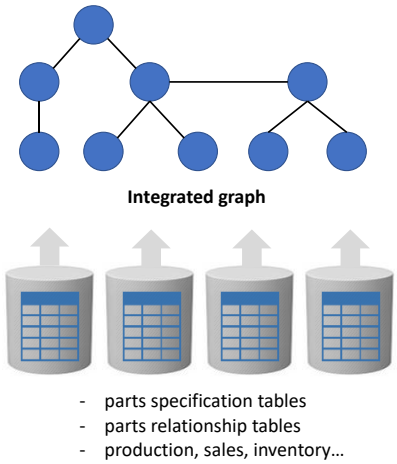


Figure 3.2.10. Illustration of traceability in manufacturing by using graph technology

3.2.5.3. Product recommendations for marketing purpose

The problem. Non-graph technologies can support recommendation engines, but graph creates faster time value. Graph databases are built so the relationships between customers and the products they like to buy are organized, making it easy and fast to run algorithms through the data to find recommendations. In addition, real-time recommendations are becoming more important than ever. But this requires the ability to correlate product information, customer inventory, past customer behavior, current supplier information, logistics, and even social data such as ads clicked, and products explored via social media. This is extremely difficult to implement in non-graph technologies.

The graph solution. The technology for gathering all those data and forming connections to get quick insights into customer needs and product trends then providing real-time recommendations is graph databases. In fact, many large companies rely on chart analysis to provide their recommendations because relationships are already laid out, and analysis of these relationships to provide recommendations is very fast.

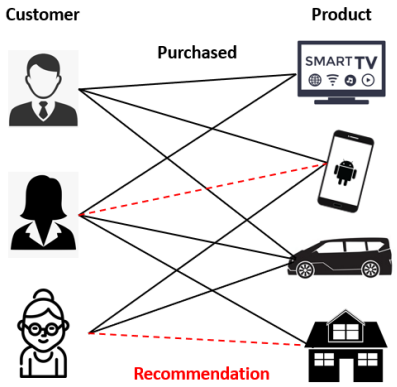


Figure 3.2.11. Illustration of product recommendation by using graph technology

3.2.6. Market Size

As the size and complexity of data continue to escalate, organizations will increasingly turn to graph technology as a means of harnessing their data to drive decision-making. According to a new market research report and global forecast to 2028 published by Zion Market Research, the graph analytics market size value is USD 1827.5 Million in 2021 with revenue forecast USD 5996.24 Million in 2028 and the growth rate CAGR of almost 21.9% during 2022-2028.

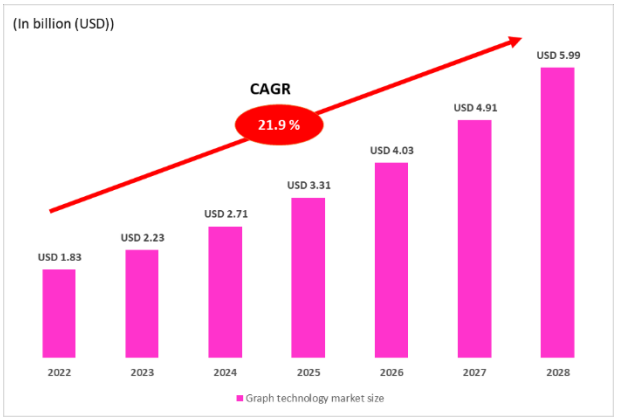


Figure 3.2.12. Graph technology market size[37]

[37] Bloomberg, press-releases, 2022

3.2.7. Market Segment

Zion Market Research has segmented the overall graph analytics market based on seven categories[38].

Table 3.2.4. Graph analytics market segment

No.	Category	Market Segment
1	Component	[2]: Software, Services
2	Deployment Mode	[2]: On premise, Cloud
3	Organization Size	[2]: Large Enterprise, Small & Medium Enterprise (SME)
4	Type	[2]: RDF Graph, Property Graph
5	Application	[12]: Customer Analytics; Risk, Compliance and Reporting Management; Recommendation Engines; Fraud Detection and Prevention; Supply Chain Management; Operations Management and Asset Management; Infrastructure Management, IoT, Industry 4.0; Knowledge Management; Content Management, Data Extraction and Search; Metadata and Master Data Management; Scientific Data Management; Others (Chatbot, digital twin, scientific, Product and Technical Information Management, and Human Capital Management)
6	Vertical Industry	[11]: Banking/Financial; Retail & eCommerce; Telecom & IT; Healthcare & Pharmaceuticals; Government & Public Sector; Manufacturing & Automotive; Media & Entertainment; Energy & Utilities; Travel & Hospitality; Transportation & Logistics; Others
7	Geography	[5]: North America; Europe; Asia Pacific; Latin America; Middle East & Africa

3.2.8. Technology Solution Providers

The following are some providers that provide graph technology solutions whose credibility has been recognized by the worldwide (with a rating of 7.6 out of 10)[39].

Table 3.2.5. Graph technology providers in the market

Graph Technology Provider	Description	Scale (Local/Global)
Neo4j	Neo4j is a provider which employs the application of graphs to give a detailed insight into a chunk of data. There are many connections inside a big data and Neo4j helps companies to find the intertwining links between them with the help of its visually interactive graphs.	Global

[38] Bloomberg, press-releases, 2022

[39] top-graph-databases by predictive analytics today

Graph Technology Provider	Description	Scale (Local/Global)
TigerGraph	TigerGraph, a company that provides a graph database and analytics software, has expanded its data science library with 20 new algorithms, bringing its total to more than 50 algorithms. TigerGraph can help data scientists analyze relationships among millions or billions of entities, and TigerGraph outperforms other types of databases for many deep learning applications.	Global
Oracle	Oracle provides support for both property and RDF graph, and simplifies the process of modeling relational data as graph structures. Interactive graph queries can be run directly on graph data or on a high-performance in-memory graph server. Extensive integration with Oracle Database, Oracle Autonomous Database, and third-party and open-source features makes it simpler to apply and use graph analytics.	Global
ArangoDB	ArangoDB helps to arrange the data in a very creative and flexible way. The data can be stored as key or value pairs, graphs or documents and all of this can be accessed by just one query language. For safer option mode than declarative models can be used in the query.	Global
OrientDB	OrientDB features a 2nd generation distributed graph database that is unique, multi model graph database that offers flexibility for documents all in one product.	Global
Stardog	Stardog provides more insight, faster and easier. It unifies enterprise data that is based on semantic graphs, schema alignment, data modeling and deep reasoning.	Global
Ontotext GraphDB	Ontotext GraphDB is a semantic graph database that helps organizations manage, store and organize contents into a smart data.	Global

Internet of Things

Summary
Categorization: ● Maturity: Early Majority ● Technology Field: End-User Solutions ● Relevance for IOH: High
Reason to watch: Opportunity to expand IOH of IoT business and technology that leveraging with technology such as Digital Twin on healthcare solution.
IOH Status: ● Year added: 2022

3.3. Digital Twin for Smart Health Solutions

3.3.1. Introduction

Digital twin is not a new term, but paired with advancements in AI, it is increasingly valuable in transforming health industrial, creating additional business value. The use of digital twins in healthcare is revolutionizing clinical processes and hospital management. Increasing demand for digital twins in the healthcare and pharmaceutical industries due to the outbreak of COVID-19 pandemic, the changing face of maintenance, and growing adoption of digital twin solutions to cope up with the COVID-19 pandemic are the key factors driving the growth of the digital twin market. The global digital twin market size was valued at USD 3.1 billion in 2020 and is projected to reach USD 48.2 bn by 2026. It is expected to grow at a CAGR of 58% during the forecast period. On healthcare sector, there will USD 0.29 Bn by 2020 and USD 3.81 Bn by 2025.

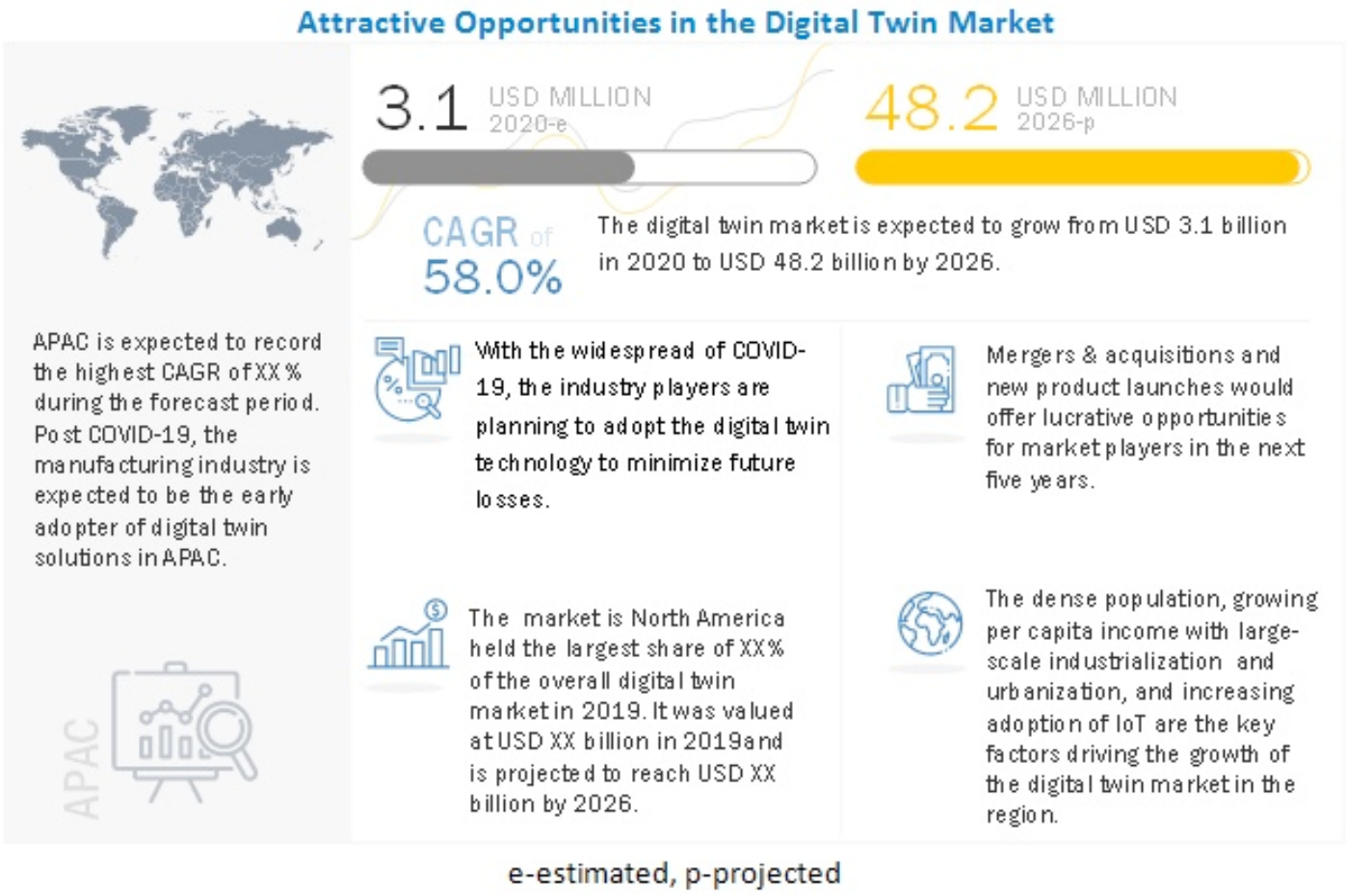


Figure 3.3.1. Digital twin market opportunities

Digital twin would be applicable for any industries such as hospitality. It expects improve services and hospitality. Furthermore, DT would happen employing reliable connectivity. The use of digital twins in healthcare is revolutionizing clinical processes and hospital management by enhancing medical care with digital tracking and advancing modelling of the human body. These tools are of great help to researchers in studying diseases, new drugs, and medical devices (equipment).[40] A digital twin is a digital replica of the tools, people, processes, and systems that businesses employ. In healthcare systems, digital twins are utilized to build digital representations of healthcare data, such as hospital environments, lab results, human physiology, etc. through computer models. To construct virtual twins, data that covers the individual, population traits, and environment are used. This is because digital twins improve healthcare organization

[40] https://www.embs.org/the-role-of-digital-twin-in-healthcare-current-trends-and-challenges/

performance, discover areas for improvements, provide customization and personalization of medicine and diagnosis, and enable the development of new medicines and devices.

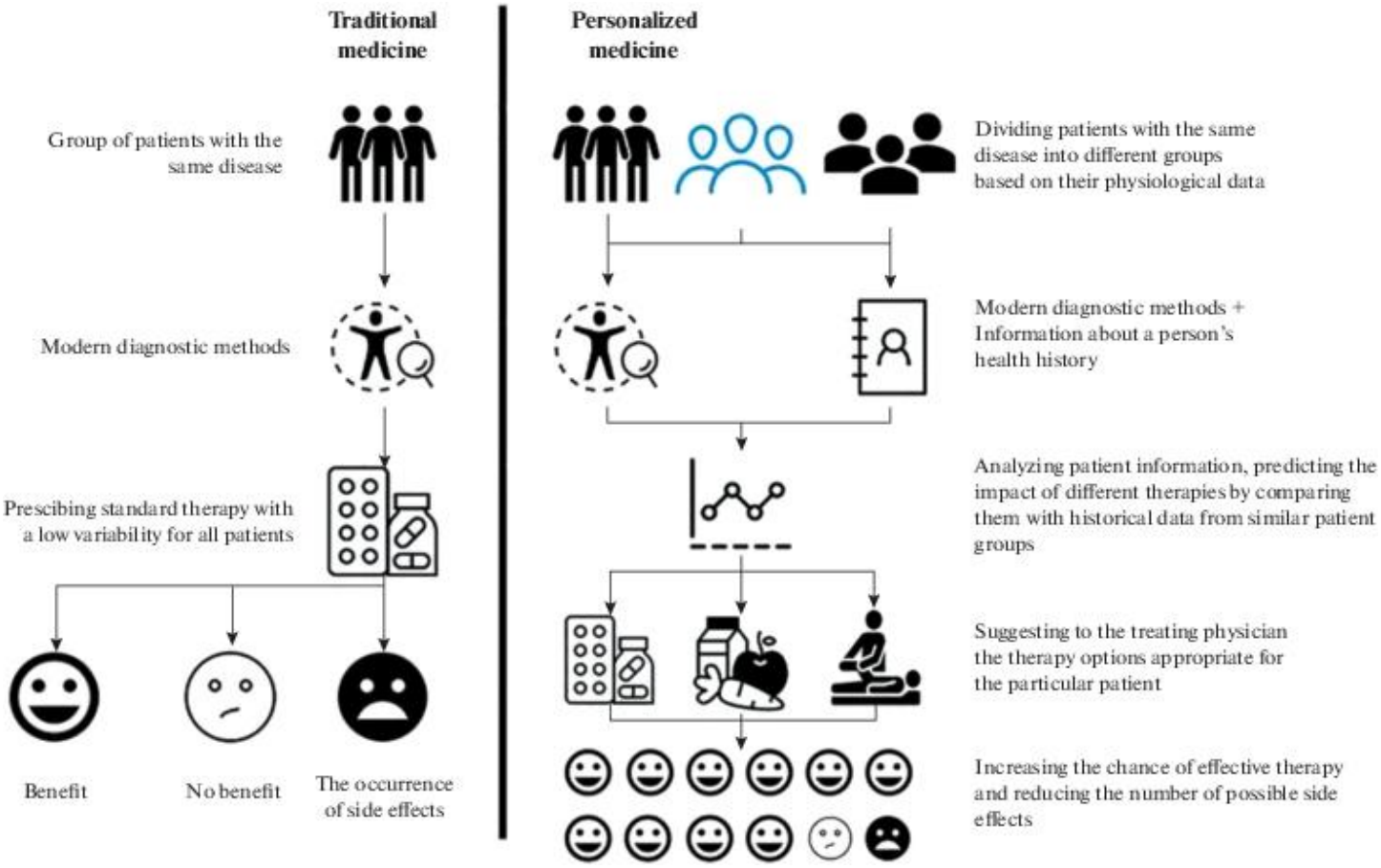


Figure 3.3.2. Comparison traditional medicine and personal medicine respective technology applied[41]

One of the industries that starts to utilize IoT is healthcare solutions. IoT helps healthcare facilities and patients to get early-stage diagnoses through connected devices. Besides, the pandemic also urges healthcare to shift into IoT. The use of IoT in healthcare is known as *Internet of Health Things* (IoHT). However, in healthcare, the concept of a Digital Twin is not yet so clearly defined due to the incredible complexity of the human being, an object of the physical world[42], for which

[41] https://link.springer.com/article/10.1134/S0361768821080284

[42] https://link.springer.com/article/10.1134/S0361768821080284

a Digital Twin must be created. As for the components of industrial systems today, there is a hope that modeling will provide the desired accuracy of results. But unfortunately, it is much more challenging to offer universal methods and approaches to modeling the human being. Also, despite breakthroughs in creating new sensors and data collection methods, obtaining up-to-date data on key indicators of the human body in an operational mode is a difficult task, which can be implemented, most often, only in laboratory clinical research settings.

3.3.2. Definition & Scope

The applications of digital twins require gathering more and more individual level data by healthcare organizations and insurance companies. Over time, these health organizations grasp a detailed portrait of a biological, genetic, physical, and lifestyle related information of a person. Such personalized data might be in use benefitting the company's interest instead of the individuals. One example would be that insurance company might leverage the data to increase precise distinctions significant to personal identity. Not only can utilizing digital twin technology help improve patient care (the primary goal), but it can also allow clinicians to determine the right therapy and enable cost reductions at hospitals through efficiency optimizations.[43]

At the micro level, patient monitoring is a prime space to build digital twins that would enable personalized care. The process of obtaining real-time data from patients would start with a remote patient monitoring device that captures vitals (e.g., heartbeat, blood pressure), streaming it into the cloud, feeding it into a platform and analyzing it using algorithms (based on parameters/thresholds) to predict the probability of potential risks, with an alerting protocol for clinicians as needed. This process can be virtually modeled as a digital twin. Expanding on this, decision support for chronic diseases would also be a good use case, as the digital twin could help earlier disease detection through the analysis of data (e.g., from radiology, genetics, labs). Other use cases include the use of early warning signs to reduce the number of code blue calls and early intervention for sepsis, both major cost areas for hospitals.

A smart hospital digital twin brings together data from subsystems and real-time interactions between people, process and connected things. It provides a contextual model of the past, present and, as AI/ML evolves, potentially even predicted future states of a hospital that can be manipulated, analyzed and optimized. This data can also be exposed to various interfaces, applications, and systems to truly make a hospital 'smart' through awareness. [44]

To implement a smart hospital digital twin, four key enabling factors are required.

a. Data: across the entire smart hospital is needed, such as data about people, processes, connected devices, operational building systems, Hospital/Clinical Information Systems, and external health systems.

[43] https://www.forbes.com/sites/forbesbusinesscouncil/2021/05/24/disrupting-healthcare-through-the-use-of-digital-twin-technology/

[44] https://blog.thoughtwire.com/what-is-a-smart-hospital-digital-twin

b. Context: includes real-time information about the actual state of the hospital, the people within it and their interactions between each other. The key element here is capturing the status of people, systems and things and making them more visible.
c. Reasoning: a method for applying reasoning to data is needed to drive action. Most commonly, reasoning is based on asynchronously processed rules, artificial intelligence (AI) or machine learning (ML) models, or temporal reasoning for varied frequency of events.
d. Key Performance Indicators (KPIs): required to provide meaningful business context and to ensure alignment between hospital objectives and performance measurement.

In this way, smart hospital digital twins help create what Gartner defines as a real-time health system, which is the desired future state for the digital transformation of healthcare delivery organizations. A real-time health system uses technology to unlock better outcomes for patients and healthcare organizations by enabling intelligent operations, real-time analytics, real-time orchestration of information and improved overall situational awareness.

Smart hospital digital twins also enable greater clarity into past, present and future hospital performance and provide recommendations on how to improve outcomes. This can be understood as follow:

a. Past: rewind time to view high resolution historical data and create smart benchmarks.
b. Present: interact with your real-time operational environment of people, process and connected things and drive better outcomes.
c. Future: predict the future states and proactively adjust as needed.

Today, data in most hospitals is siloed. Data repositories for operational information and patient data lack any meaningful integration and the proliferation of data generated by IoT devices only exacerbates the problem. Many hospitals want to be more *data driven* and *value based*, with less siloed, but they often lack the tools to derive meaningful insight from their disparate data sets.

A smart hospital digital twin provides a new way of modeling, managing and actioning data from hospitals. The benefits of a smart hospital digital twin can include:

a. Enhanced patient experience
b. Optimized resource utilization
c. Improved clinical outcomes
d. Lower facility operating costs
e. Enhance safety
f. Reduce energy consumption

In fact, digital twins allow hospitals to achieve a real-time health system by:

a. Analyzing the whole picture in real-time. Hospital management can examine the complete hospital environment from data to workflows to patients to clinicians.

b. Taking immediate action. If a patient's condition is deteriorating or there is an emergency on a certain floor, the right action can be taken in real-time to respond.
c. Tracking and improving. Context-rich semantic linking provides a picture of the past, present and future state of the hospital.

3.3.3. Challenges that face digital twin implementation in healthcare

3.3.3.1. Limited adoption

Digital twin technology is not widely adopted in he clinical routine. Healthcare units (e.g., hospitals and labs) should increase the impact of technology on digital simulations, vital clinical processes, and overall improvement of medical care. On the other hand, even though healthcare systems use digital twins increase, it is argued that it will remain expensive and not accessible for everyone. Digital twin technology will become a benefit reserved for people with higher financial capabilities, which would generate inequality in the healthcare system.

3.3.3.2. Data quality

Artificial intelligence system in digital twins learn from the available biomedical data but as the data is gathered through private companies, the data quality might turn out bad. Consequently, the analysis and representation of such data becomes problematic. That eventually affects the models negatively, which also affects the reliability of the models in the diagnosis and treatment processes.

3.3.3.3. Data privacy

The applications of digital twins require gathering more and more individual level data by healthcare organizations and insurance companies. Over time, these health organizations grasp a detailed portrait of a biological, genetic, physical, and lifestyle related information of a person. Such personalized data might be in use benefitting the company's interest instead of the individuals. One example would be that insurance company might leverage the data to increase precise distinctions significant to personal identity.

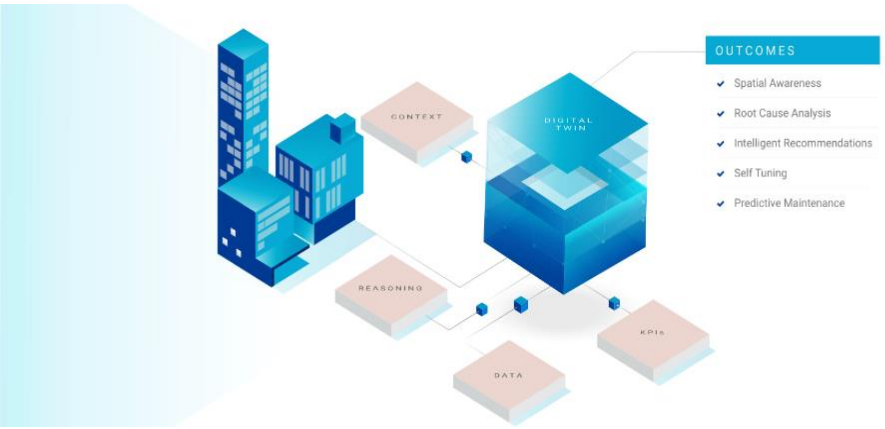


Figure 3.3.3. Component of DT for smart healthcare solutions

3.3.4. Maturity

Digital twins have matured significantly in the past several years, making them well suited for use in hospitals. In fact, since hospitals are full of *connected* or *connectable* things that can be unified in a digital twin, the technology has opened incredible opportunities for solving big challenges facing healthcare today. A good example of where digital twins is being used in hospitals is at the organizational level. By creating a digital twin of a hospital, hospital administrators, doctors and nurses can obtain powerful, real-time insights into patient health and workflows. Using sensors to monitor patients and coordinate equipment and staff, digital twins offer a better way of analyzing processes and alerting the right people at the right time when immediate action is needed.

Furthermore, digital twins can be used to address *human middleware* issues, interoperability issues and *hidden or locked data* issues. Digital twins do this by transforming workflows that traditionally rely on linear transactional interactions into ones that can be done through parallel processing. For instance, digital twins allow hospitals to use an input from a sensor to kick off a notification automatically, rather than waiting for a user to manually trigger the notification. As a result, emergency room wait times can be reduced and patient flow can be improved, decreasing operational costs, and enhancing the patient experience. One hospital measured a numerous gaining improvement in cost savings after implementing digital twin technology to remove bottlenecks in patient flow and bed management.

Moreover, digital twins can predict and prevent patient emergencies like cardiopulmonary or respiratory arrest, known as code blues emergencies, resulting in more lives saved. In fact, one health care network that implemented digital twin technology in their hospitals saw a 61% reduction in code blue events. Using the digital twin technology within a hospital, assists in predicting emergencies like cardiopulmonary and respiratory arrest, thereby helping the hospital organization in better precautionary maintenance while providing personalized health care cost. Creates proper patient-specific treatment plans.

Table 3.3.1. The maturity of graph technology

Competitive forces	Level	Reasoning
Competition in the industry (*Uniqueness, competitor power, and healthy profits*)	1	The use of this technology in the health industry is still limited considering that health is a vital matter and requires in-depth study, standardization, and trial to use a new technology in the health sector.
Supplier power (*Suppliers, competitive price, and product uniqueness*)	2	There are many big suppliers working on the DT healthcare market such as Siemens, ANSYS, Microsoft, IBM, and General Electric. Each has its own uniqueness and specifications.
Buyer power (*Volume forecast, costing, and supplier capacity)*	1	For the onboard digital twin in the hospital business, a sophisticated IT infrastructure at a high cost is required. Although for some hospitals there is no budget problem, most hospitals are still holding back from spending a large budget for digital twins.
Threat of substitution (*Customer experience, best in class customer treatment*)	1	This technology is a new technology which is still being developed in line with IoT technology. There is currently no substitute for technology like digital twins.
Threat of new entry (*Market landscape, technology protection, and barriers*)	1	To enter the digital twin industry, companies need large capital as well as technical capabilities in the IoT and IT fields. Thus, the presence of new players in this industry is still unlikely.

Based on the analysis above, the total score maturity analysis for Digital Twin for Smart Healthcare Solution based on Five Forces is 6, which is in the Growth phase. While according to diffusion of innovation framework, this technology is in Early Majority stage.

The Porter's Five Forces	Introduction			Growth			Mature						Decline		
Score	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Diffusion of innovations	Innovators		Early Adopters			Early Majority				Late Majority				Laggards	

3.3.5. Relevance

Digital twins are exciting because they provide a way to tackle healthcare's *wicked problems* in a way that's no longer just about addressing symptoms, but instead approaches the entire environment holistically. Additionally, digital twins can be used to improve efficiencies, optimize processes, detect problems before they occur and innovate for the future.

Some common *wicked problems* hospitals face today include:

a. Long wait times
b. Downtime on medical facilities and devices

c. Transcription and translation errors
d. Poor interdisciplinary communication or coordination
e. Budget and staffing issues

When up against these challenges, more hospitals are turning to real-time health systems to help solve their problems holistically. In fact, some digital twins can be used to detect patient and workflow problems before they occur, improve operational efficiencies, optimize processes improve patient experience, reduce staff burnout and create better patient outcomes through a unified real-time model. This contrasts traditional models, like Message Broker or Enterprise Service Bus (ESB), which uses different models, depending on application needs, to send and receive rapidly changing patient data.

3.3.6. Implementation and Use Case

3.3.6.1. Digital twin of a healthcare facility

Digital twin technology can be used to generate a virtual twin of a hospital to review operational strategies, capacities, staffing, and care models to identify areas of improvement, predict future challenges, and optimize organizational strategies. Therefore, digital twins of hospitals can be used for generating facility replicas, and in turn this enables:

a. Resource optimization: leveraging historical and real-time data of hospital operations and surrounding environment to create digital twins enables hospital management to detect bed shortages, optimize staff schedules, and help operate rooms. Such information increases the efficiency of resources and optimized the hospitals and staff's performance, while decreasing costs.
b. Risk management: digital twins provide a safe environment to test the changes in system performance (staff numbers, operation room vacancies, device maintenance, etc.) which enables implementing data-driven strategic decisions in a complex and sensitive environment.

3.3.6.2. Digital twin of the human body

Digital twins are also applied for modeling organs and single cells or an individual's genetic makeup, physiological characteristics, and lifestyle habits to create personalized medicine and treatment plans. These replicas of the human body's internal systems improve medical care and patient treatment by[45]:

a. Personalized diagnosis:
    1) Digital twins allow collection and usage of vital data (e.g., blood pressure, oxygen levels, etc.) at the individual level which helps individuals to track persistent conditions and, consequently, their priorities and interactions with doctors by providing basic information. Thus, such personalized data serves as the basis of clinical trials and research data at labs.

[45] https://research.aimultiple.com/digital-twin-healthcare/

2) By focusing on everyone separately, doctors do not derive treatments from large samples. Rather, they rely on customized simulations to track the reactions of each patient to different treatments, which increases the accuracy of the overall treatment plan. Despite the interest and increasing number of efforts for personalized medicine, there are no digital twins' applications for actual patients. One of the centers specialized in personalized medicine is Linköping University in Sweden who mapped mice RNA into a digital twin to predict the effects of medication.

b. Treatment Planning: With advanced modeling of the human body, doctors discover the pathology before the disorders are evident, experiment with treatments, and improve preparation for surgeries.

3.3.6.3. Digital twins for medicine and device development

Digital twins can improve the design, development, testing, and monitoring of new drugs and medical devices. Here are detail examples as below:

a. Drugs: digital twins of drugs and chemical substances enable scientists to modify or redesign drugs considering particle size and composition characteristics to improve delivery efficiency.

b. Devices: a digital twin of a medical device enables developers to test the characteristics or uses of a device, make alterations in design or materials, and test the success or failure of the modifications in a virtual environment before manufacturing. This significantly reduces the costs of failures and enhances the performance and safety of the final product.

3.3.7. Market Size

As mentioned earlier the global digital twin market size was valued at USD 3.1 billion in 2020 and is projected to reach USD 48.2 bn by 2026. It is expected to grow at a CAGR of 58% during the forecast period. On healthcare sector, there will USD 0.29 Bn by 2020 and USD 3.81 Bn by 2025.

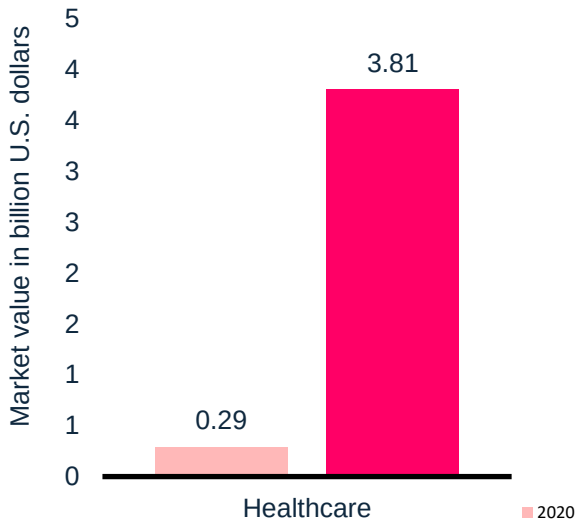


Figure 3.3.4. Global market employing digital twin in healthcare sector from 2020 to 2025

3.3.8. Market Segment

Based on IoT in healthcare market report published by MarketsandMarkets, the IoT in healthcare market can be categorized based on component, application, and end user.

By component, the IoT in healthcare market is divided into four segments:

a. Medical Devices
    1. Wearable External Medical Devices
    2. Implanted Medical Devices
    3. Stationary Medical Devices
b. Systems and Software
    1. Remote Device Management
    2. Network Bandwidth Management
    3. Data Analytics
    4. Application Security
    5. Network Security
c. Services
    1. Deployment and Integration
    2. Consulting
    3. Support and Maintenance
d. Connectivity Technology

By application, the IoT in healthcare market is divided into nine segments:

a. Telemedicine
b. Store-and-forward Telemedicine
c. Remote Patient Monitoring
d. Interactive Medicine
e. Clinical Operations and Workflow Management
f. Connected Imaging
g. Inpatient Monitoring
h. Medication Management
i. Others (Fall detection, sportsmen care, and public safety)

By end user, the IoT in healthcare market is divided into four segments:

a. Hospitals, Surgical Centers, and Clinics
b. Clinical Research Organizations
c. Government and Defense Institutions
d. Research and Diagnostic Laboratories

Below is an example of a IoHT classification based on its use case and market segment.

Table 3.3.2. IoHT's market segment

Use cases	Hospital	Laboratory	Government
Digital twin of a healthcare facility	Leveraging historical and real-time data of hospital operations		
Digital twin of the human body		Collection and usage of vital data (e.g., blood pressure, oxygen levels, etc.)	
Digital twins for medicine and device development			Enables public health office to test the characteristics or uses of a device, make alterations in design or materials

3.3.9. Technology Solution Provider

There are several providers who offer IoT for healthcare as a part of their solutions for the enterprises. These companies offer different services, which is provided further in the table below.

Table 3.3.3. IoHT's providers in the market

Companies	Solutions	Scale (Local/Global)
Siemens AG	With digitization, smart infrastructure and cybersecurity at its core, German technology giant Siemens AG is a leading provider of IoT-based healthcare solutions. The company specializes in on-site testing and digital healthcare solutions that provide high-quality patient care in cardiology, oncology and other clinical specialties.	Global
Abbott Laboratories	Located in Abbott Park, Illinois, U.S., Abbott Laboratories is a leading American healthcare company recognized globally for its best medical devices, diagnostic solutions, branded generics, and a wide variety of nutritional products. Pedialyte, Ensure, Similac, Glucerna, FreeStyle Libre, ZonePerfect and MitraClip.	Global
Honeywell Life Care Solutions	he renowned Irish American medical device company Medtronic Plc is a global leader in medical devices and solutions and operates in more than 140 countries. The company is committed to providing innovative and cost-effective healthcare solutions to improve patient care and improve clinical outcomes. Some of Medtronic's flagship products that support IoT include oximeters, portable ventilators, pacemakers, defibrillators and neurostimulators.	Global
GE Healthcare	Leading global medical technology and diagnostics company, GE Healthcare, is committed to digitizing healthcare infrastructure and specializes in imaging, diagnostics, and patient monitoring devices and solutions. Remote patient monitoring solutions are a specialty of GE Healthcare.	Global
Philips Healthcare	Philips Healthcare is the healthcare arm of the Dutch technology conglomerate Koninklijke Philips N.V. The company provides healthcare providers, nurses and patients with innovative, lower-cost solutions to improve patient care and management. The company specializes in advanced imaging, diagnostics, respiratory care, oncology, and centralized and mobile patient monitoring solutions.	Global

Summary
Categorization: ● Maturity: Early Majority ● Technology Field: Service Enablers ● Relevance for IOH: High
Reason to watch: Technology which can build a distributed and secure edge computing architecture that can amplify the security and integrity of IoT data throughout its lifetime, as the number of applications and their need for secure, real-time data access grows.
IOH Status: ● Year added: 2022

3.4. Hyperscale Edge Computing Integrated with Blockchain

3.4.1. Introduction

The evolution of hyperscale data centers is being driven by the development of more sophisticated services and greater compute/storage demand. Edge computing helps solve this issue by bringing compute, storage, and analytics closer to users and the devices that generate the data. As a result, data travels over shorter distances, which can result in lower latency and faster response times. IoT devices are also vulnerable to cyberattacks. Blockchain's consensus algorithms validate every transaction, ensure that the data transmitted by IoT devices is verified and valid, and has not been tampered with during transit. Blockchain is a decentralized ledger of every transaction across a peer-to-peer network. By using this technology in smart contracts, participants can confirm transactions without the need for a central certifying authority. This will create trust among parties while being cost efficient. Smart contracts allow for a few agreement creations which can be executed automatically when certain conditions are met. Elaboration of blockchain with hyperscale to distribute

edge computing would be specific on security area. The capability of blockchain would fulfill vulnerable area of distributing edge hyperscale computing with decentralized verify and accounting of it.

The global Edge Computing (hyperscale edge computing) market size is expected to gain market growth in the forecast period of 2020 to 2025, with a CAGR of 42% in the forecast period of 2020 to 2025 and will expected to reach USD 5 Bn by 2025, from USD 1,2 Bn in 2019.

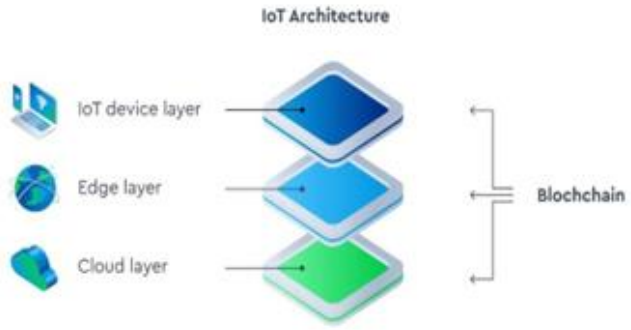


Figure 3.4.1. Architecture edge computing integrated with blockchain[46]

The pillars are compute, storage, memory, and networking. When going beyond the data center, it is probably fair to define hyperscale computing as the cycle of sensing and creating data, transmitting it through networks, and processing and storing it to eventually make sense of that data to create actionable results.

[46] https://thenewstack.io/edge-computing-integrated-with-blockchain/

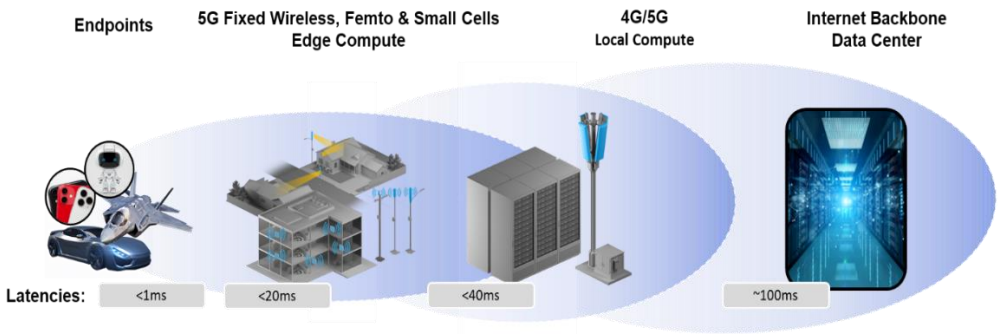


Figure 3.4.2. Comparison latencies among edge computing and data center (cloud) [47]

3.4.2. Definition and Scope

There are different types of edges in play, some closer to the network, like an *inner edge*, as well as *outer edges* closer to the sensors in the real world. Topics like low power, compute latencies, security, network coverage and speed play a key role that translate into measurable effects for the consumer. For instance, think of the time it takes to compute an athlete's performance during a workout measurement or the time it taxes Siri, Alexa, and others to respond to an audio captured question. This time drives consumer decisions and is directly impacted by network latency, availability for data at the edge, speed, and compute performance, whether at the inner or outer edge or in the data center.

For data volume, traffic through networks is a key indicator, and the networks will throttle the amount of data that can be transmitted for processing outside of sensors itself. The latest Ericsson mobility report, *Mobile Network Evolution* from June 2020, provides a treasure trove of insights into the underlying drivers generating data and about the expected speed of transition from 4G to 5G. Video already accounted for 63% of the traffic of 2019's 33 exabytes per month and is predicted to become 76% of the estimated 164 exabytes per month in 2025. At that time, 5G adoption could reach 2.8 billion subscriptions, and 5G population coverage is forecast to reach 55%, plus 10% via existing 4G networks. As for storage, IDC predicts that the *global datasphere* will grow from 175 Zettabytes by 2025. The Seagate Technology report, *DataAge 2025 The Digitization of the World,* gives some key insights into how much data there is estimated to be, and where and how it is stored. For instance, the percentage of storage is predicted to *plummet* in 2025 to just above 20% at the end point, about 10% at the edge and the rest in core data center storage.

Just five years from now, by 2025, sensors will create exabytes of data per day that will be transmitted through next-generation networks with the lowest latencies possible where zettabytes of data need to be stored in the global datasphere. When combined with consumer expectations for instantaneous responses to all their needs, networks,

[47] https://semiengineering.com/hyperscale-and-edge-computing-the-what-where-and-how/

storage, and compute must *hyperscale* to speeds and capacities that are hard to comprehend, coining the term hyperscale computing.

3.4.2.1. Independent of single edge but ubiquitous

Driven by the arrival of 5G networks and the promise of IoT and virtual reality applications, the popular conception of the edge that has taken hold is one of modular, micro data centers sitting at the base of cell towers to speed the delivery of content and application data by being *one hop away* from end user devices (i.e., cell phones). However, the truth is, the edge is developing in a much more ubiquitous and multi-modal manner.

In one sense, the edge is geography specific and will exist everywhere from large tier 1 cities to rural markets. Most video, SaaS, and e-commerce applications will continue to be adequately served by data centers, cloud platforms, and CDNs in tier 1 and 2 metros that deliver 25-75 ms of latency to users hundreds of miles away. The edge is also application specific, with infrastructure configurations that vary from business to business. A hyperscale or technology provider may need several thousand square feet of data center space and several MW of power, whereas a network or CDN operator may require only a few cabinets or small cage of capacity. Finally, there's another element of the edge that is performance and latency specific. Emerging IoT applications may need sub 10ms latency times, only capable by locating infrastructure within a few miles of end users. It can also be in highly specific geographic locations, for example, industrial or logistics hubs.

3.4.2.2. The role of hyperscale's in developing the edge

While it will take time for the edge to fully develop in all these varying forms, today it's being driven not by next-generation IoT or virtual reality applications but by hyperscale cloud providers and the customers that fuel their growth. When we speak of AWS, Google, or Microsoft, we sometimes forget they are not just three companies, but they are platforms supporting the requirements of millions of discrete customers who have a wide range of problems they look to hyperscale's to solve. For SaaS, content companies, and creators of other digital assets, that means delivering bits to as many smartphones, tablets, desktops, and network appliances as possible. Since the volume of those items exist in direct correlation to where populations exist, it's no wonder hyperscale providers are building availability zones in more population centers. AWS has announced *Local Zones* in four markets while Microsoft has announced plans for Azure Edge zones in three initial markets, all major metros. The hyperscale edge is happening today in tier 1 and tier 2 markets, not at the base of a remote cell tower. That's because those cities and their surrounding areas are where most of the consumers of digital content are physically located.

3.4.2.3. The Hyperscale Edge Strategy

Hyperscale providers and the customers they support are moving away from just a handful of regional availability zones to deliver their digital services to a much larger number of locations, perhaps, as many as 25-30, over the next five to ten years. What is not yet clear is what applications and use cases will require such a highly geographic distributed footprint

and how application developers and content producers will manage, scale, and make geographic resource allocation decisions in such a fragmented construct.[48]

Regardless, as the cloud and technology providers transition to a local-zone edge strategy, they will look to solve three distributed challenges:

a. Metro Diversity: just as hyperscale built their initial regional availability zones in tripod groups of three for resiliency, they will look to do the same in the metro or local availability zones into which they expand. This requires a minimum of three data centers in each market and requires a different kind of data center partner one with multiple facilities in a metro as opposed to the single location wholesale data centers hyperscale's have traditionally turned to.
b. Network Connectivity: local availability zones also need access to ample fiber networks and carrier neutral interconnection hubs in order connect the nodes in that metro to one another, but also to link the local zone to those in other regions. Hyperscale's will seek to locate their local zones in metros that have a diversity of neutral interconnect hubs and fiber paths in and out of the metro.
c. Speed to Market: to meet demand, Hyperscale's have traditionally relied on a mix of building their own facilities and using wholesale data center partners. However, this approach isn't quick or cost-effective for local zone deployments needing only 1-5MW of power. Therefore, existing enterprise data centers with meaningful capacity in tier 1 and tier 2 metros will provide an attractive third option.

3.4.2.4. The Smart Approach to Designing the Hyperscale Edge

To solve these challenges, cloud providers can turn to enterprise *multi-tenant data center* (MTDC) providers, as telco company will ensure the connectivity data center (hyperscale), so that it is elaborated more hyperscale and edge computing. The leading providers operate more than one facility in each market that span from downtown areas to suburban locations. This allows hyperscale's to mimic their nationwide three-node availability zone model within a metro and provide redundancy, at the same time moving infrastructure far closer to end users.

MTDCs also own and operate secondary interconnect hubs in tier-two markets. These facilities attract additional network providers and create new fiber routes in and out of these metros which creates more connectivity reach akin to tier 1 markets. Hyperscale cloud providers will also find MTDCs are efficient at building and scaling facilities using smart design templates. This makes it possible to quickly bring new capacity online by deploying data halls in existing facilities or entirely new facilities on adjacent property. MTDCs can also design with a higher density of power for use cases where 52U cabinets with 100kW are required to generate more compute per square foot.

[48] https://datacenterfrontier.com/a-look-at-the-edge-from-the-perspective-of-hyperscale-cloud-providers/

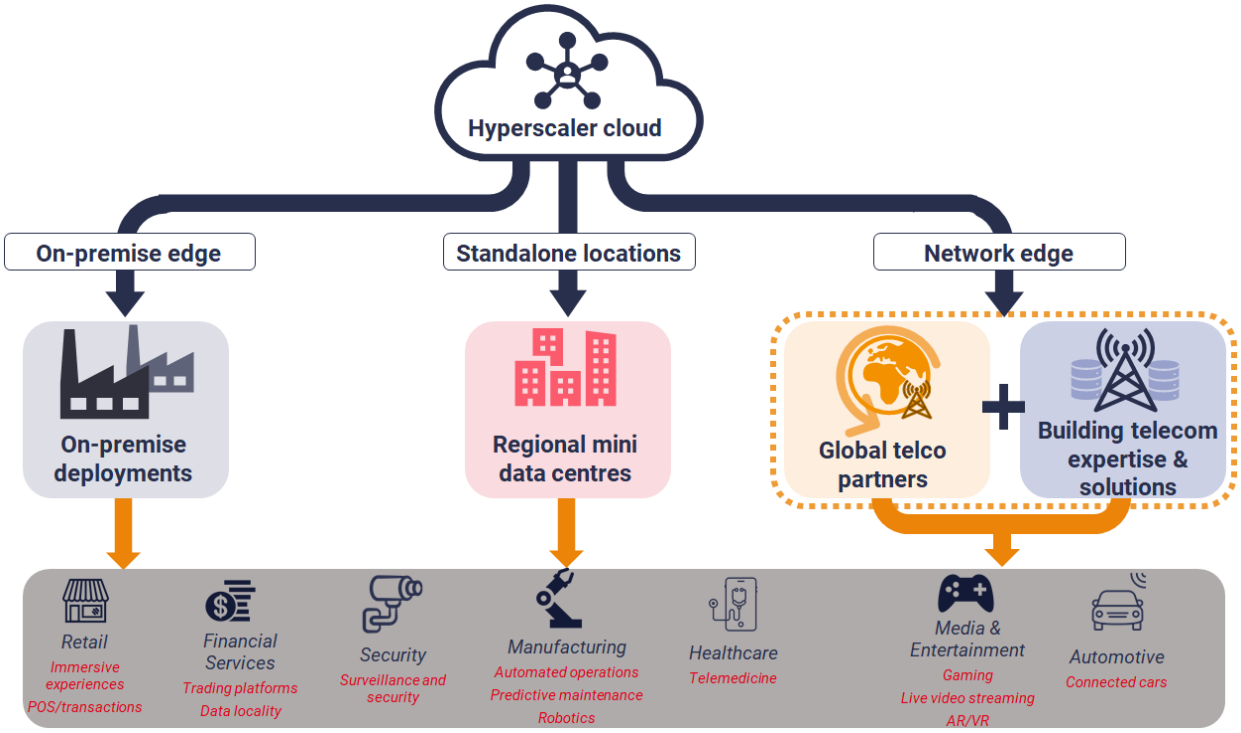


Figure 3.4.3. Hyperscale edge strategy for Telcos[49]

Hyperscale's are moving rapidly to expand their presence at the edge and create and exploit different opportunities. By 2018, Google, AWS and Microsoft Azure launched their stacks that support on-premises deployment and extend their services to hybrid cloud environments. Namely, Google Anthos, AWS Outposts and Azure Stack. Within the last year, all these hyperscale's have released versions of their solutions that are dedicated to the telecom network pushing further into edge locations and closer to the users.

3.4.3. Maturity

Table 3.4.1. The maturity of Hyperscale Edge Computing Integrated with Blockchain

Competitive forces	Level	Reasoning
Competition in the industry (*Uniqueness, competitor power, and healthy profits*)	3	This is technology recently adopted by several OTT players and hyperscalers including the big five. Hence, as a telco company, we will take part as an orchestrator to combine

[49] https://stlpartners.com/insights/partnering-on-telco-edge-computing-hyperscalers-edge-strategy-chart/

Competitive forces	Level	Reasoning
		newest technology such as blockchain to bring more value. Domestically, there is no significant competition among telcos in Indonesia.
Supplier power (*Suppliers, competitive price, and product uniqueness*)	2	Since this is a new value proposition there would not be pricing war, furthermore elaborating hyperscalers capability and blockchain would make IOH as a major player in Indonesia.
Buyer power (*Volume forecast, costing, and supplier capacity)*	1	It is expected to have more incoming customers, particularly enterprise. Typically, enterprise customers are familiar with centralized systems and will be introduced to the other value on top of baseline services.
Threat of substitution (*Customer experience, best in class customer treatment*)	2	The number of competitions would be there since hyperscalers easily reach out telco's providers and again the new technology blockchain will be measured the absorption on the market.
Threat of new entry (*Market landscape, technology protection, and barriers*)	1	Since this is a new approach of centralized system with blockchain technology, sufficient effort would be needed to educate the market.

Based on the analysis above, the total score of hyperscale edge computing integrated with blockchain based on Five Forces is 9, which is in the Mature phase. While according to diffusion of innovation framework, this technology is in Early Majority stage.

The Porter's Five Forces	Introduction			Growth			Mature						Decline		
Score	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Diffusion of innovations	Innovators		Early Adopters			Early Majority				Late Majority				Laggards	

3.4.4. Relevance

Telco companies such as Indosat Ooredoo Hutchinson might take part as major to provide solution hyperscallers of edge computing with more secure and reliable by employing blockchain as futuristic technology for IoT products and solutions. Connectivity sits at the center of the technical chain of any IoT project, and so the way in which devices are connected to the IoT application server represents a key security consideration. However, looking from distinct perspective, partnering with hyperscalers provider will provide significant advantage for IOH and possibility to monetize the other value chain particular increasing customer experience with reliable and secure to the enterprise clients such as manufacturing, retails, logistics, FSI and utility.

At the point where securing E2E IoT solution is commonly used by the enterprise segment, IOH might need to cater their IoT product and solution to meet the E2E IoT solution requirement. The need for the product, combined with the IOH

customer base, will provide an additional revenue source for the company to be competitive in the business. From the product marketing perspective, securing E2E IoT solution opens possibility to do advanced security E2E layer for IOH base enterprise customer reflected on IoT solution and product. The product will be bundled with existing IoT solutions and products. Furthermore, this is enabled by leveraging IOH infrastructure and customer enterprise base.

3.4.5. Implementation and Use Case

3.4.5.1. Hyperscale's across the edge value chain

This includes edge for partner applications, private LTE/5G networks, RAN and core networks. CSPs are most engaged with hyperscale's for computing infrastructure and software platforms. Furthermore, elaboration with blockchain will bring more value on top of connectivity. Edge computing, integrated with blockchain, helps allow us to build a distributed and secure edge computing architecture that can promote the safety and integrity of IoT data throughout its lifetime.

3.4.5.2. Data virtualization

It has already been over the wonders that Blockchain and Data Virtualization can separately do for businesses. Finally, it's time for our two heroes to join forces. As such, two patterns can be found of blockchain and data virtualization technologies working together:

a. Pattern 1
   Data is delivered by data virtualization to the blockchain ecosystem. All data sources are pooled together at a large scale and this data is provisioned to the blockchain ecosystem. Virtualization has proven to be the key to such a blockchain project's success.
b. Pattern 2
   The data virtualization layer hosts the blockchain database as a source within it where blockchain data can merge with other contextual data in the business. The blockchain database is leveraged in this way for reporting and analytics.

3.4.6. Market Size

As mentioned earlier, the global Edge Computing (hyperscale edge computing) market size is expected to gain market growth in the forecast period of 2020 to 2025, with a CAGR of 42% in the forecast period of 2020 to 2025 and will expected to reach USD 5 Bn by 2025, from USD 1,2 Bn in 2019.

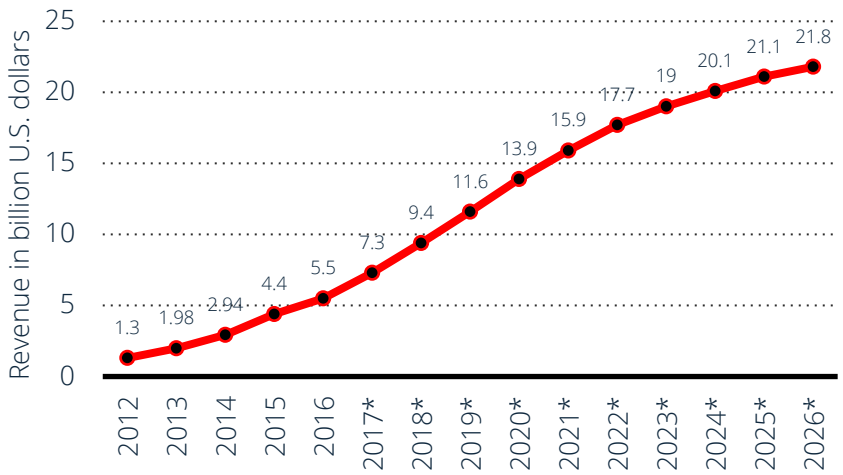


Figure 3.4.4. Hyperscale SAN revenues worldwide from 2012 to 2026 (In Bn Dollars)

3.4.7. Market Segment

Table 3.4.2. Market Segment of Hyperscale Edge Computing

Use cases	Finance	Media & Ent.	Govt	Man. & Trading	Service	Mining
Fraud prevention	Lending Acquisition & Credit scoring	Hoax alerting & video validation	Public policy and Identity management	Error checking	Social security	Data validation
Identity Management	Customer management	Editor management	Public policy and Identity management	Employee management	Customer profiling	Employee management
SLA Monitoring	Lending monitoring			Production monitoring		Production monitoring
Supply Chain Optimization	Fintech & Money management	Distribution management	Social responsibility	Machine health monitoring		Machine health monitoring
Data Management	Credit scoring	Information management	Public policy and Identity management			

3.4.8. Technology Solution Provider

Currently there aren't many blockchain providers especially for local companies. However, there are some hyperscalers who offer blockchain as a service. Partnerships between operators and hyperscalers are starting to take place and shape

the market, impacting edge computing short- and long-term strategies for operators as well as hyperscalers and other players in the market. Examples of major publicly known deals are listed in the table below (as listed below still under assessment involving blockchain capability).

Table 3.4.3. Hyperscalers who offer blockchain as a service in the market

Operator	Platform	Infrastructure	Region	Use cases
AT&T	Google cloud, Azure	No announced plans	USA	AI/ML, Video analytics, Enterprise AR
Etisalat	Azure	No announced plans	UAE, Middle east	Smart cities, IoT, Public safety, vRAN
KDDI	AWS	No announced plans	Japan	Gaming & entertainment, AR/VR, Video optimization
Proximus	Azure	No announced plans	Belgium	Manufacturing, AR/VR, Gaming, Healthcare, Logistics
Rogers	Azure	No announced plans	Canada	Smart campus, Gaming, AR/VR
SK Telecom	AWS, Azure, Internal (MEC open platform), MobiledgeX	Planned 12 data centers	South Korea	Video optimization, AR/VR, Gaming, Smart factory, Autonomous vehicle
Telecom Italia	Google cloud, Azure	No announced plans	Italy	
Telefonica	Google cloud, Azure	No announced plans	Spain	Automotive (assisted driving), Entertaiment & media, Finance services
Telkomsel	Azure	No announced plans	Indonesia	Manufacturing, IoT, AI, AR/VR
Telstra	Azure	Identified 500 potential locations	Australia	Financial services, Gaming
Verizon	AWS	12 edge locations 2020	US	AI-powered facial recognition software, AR/VR
Vodafone	AWS, Azure	24 sites planned for Europe	UK, France	Video analytics, real time asset inspection, AR, Drone, AI-powered media editing

Summary
Categorization: ● Maturity: Early Majority ● Technology Field: Service Enablers ● Relevance for IOH: Medium
Reason to watch: Technology that enabling true collaboration between smart systems, smart devices, intelligent equipment**,** and cloud services for enterprise solutions with a focus on performance and reliability.
IOH Status: ● Year added: 2022

3.5. IIoT Platform: Securing E2E IoT Solutions

3.5.1. Introduction

The Industrial Internet of Things (IIoT) brings together critical assets, advanced predictive and prescriptive analytics, and modern industrial environments. It is the network of a multitude of industrial devices connected by communications technologies that results in systems that can monitor, collect, exchange, analyze, and deliver valuable new insights. The process would be accomplished by enabling E2E IoT security.

Industries everywhere are digitizing, which is creating a multitude of new security requirements for the Internet of Things (IoT). End-to-end (E2E) security management will be essential to ensuring security and privacy in the IoT, while simultaneously building strong identities and maintaining trust. As the diversity of IoT services and the number of connected devices continue to increase, the threats to IoT systems are changing and growing even faster.

The global IoT security market was valued at USD 8,7 Mn in 2019 and is expected to be valued at USD 58 Mn by the end of 2027 registering a significant CAGR of 27% over the forecast period, 2019-2027. The Asia Pacific market is the fastest

growing and will continue to expand throughout the forecast era. The region is dominated by major market players, such as India, China, and Japan.

3.5.2. IoT actors and trust

IoT systems support new business models that involve new actors in conjunction with traditional telecommunication services. Aside from consumers and mobile network operators, enterprises, verticals, partnerships, infrastructure, and services play increasingly vital roles. All these actors affect trust.

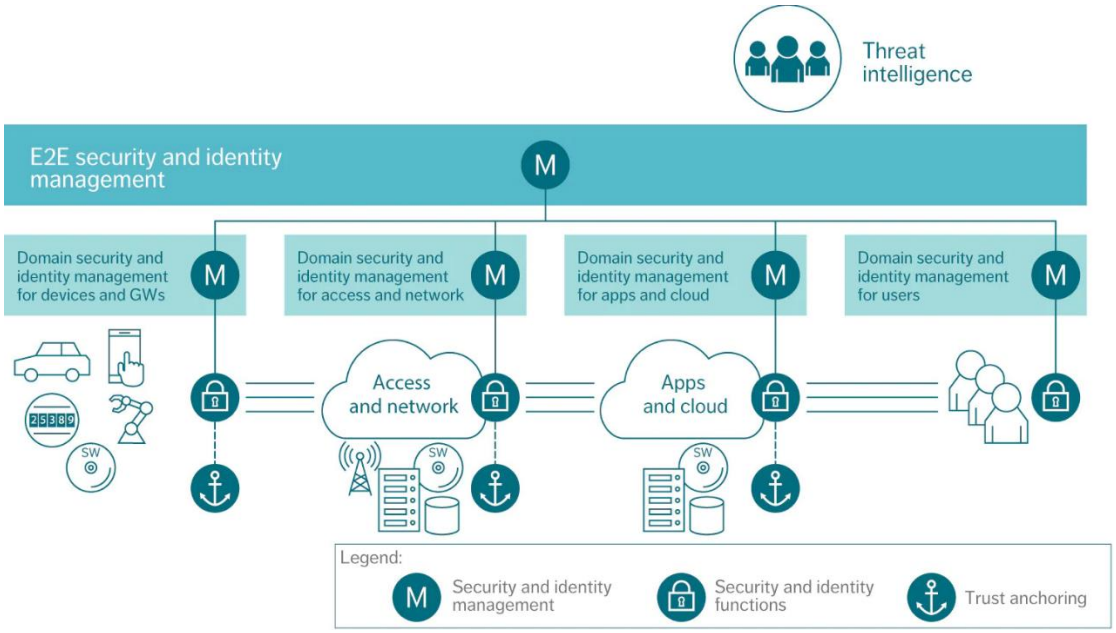


Figure 3.5.1. E2E approach to security and identity[50]

The trustworthiness of services and service use depends on how the actors govern identities and data, security and privacy, and the degree to which they comply with the agreed policies and regulations. The combination of the security and identity functions is important for defining the trust level. For example, hardware-based trust does not help if the application does not make use of it. A fully trusted application does not help if the communication cannot be trusted. An E2E approach is therefore essential to ensure trust among all actors across the system.

[50] https://www.ericsson.com/en/reports-and-papers/ericsson-technology-review/articles/end-to-end-security-management-for-the-iot#:~:text=E2E%20IoT%20security%20architecture,for%20example%20%E2%80%93%20against%20other%20systems.

3.5.3. E2E IoT solutions

The purpose of an E2E IoT solutions (each of layers IoT solutions) is to ensure the security and privacy of IoT services, protect the IoT system itself and prevent IoT devices from becoming a source of attacks a *Distributed Denial of Service* (DDoS) attack, for example against other systems even could affect lower layer of IoT. This is one critical point to IoT solutions E2E layers (*devices, network, platform, and application*). As a telco company will act as an orchestrator incorporated and bundled E2E security. Each of layers reflected as users behind and of course the end of customers will be landing on vertical apps (applications layer) with don't care below layers.

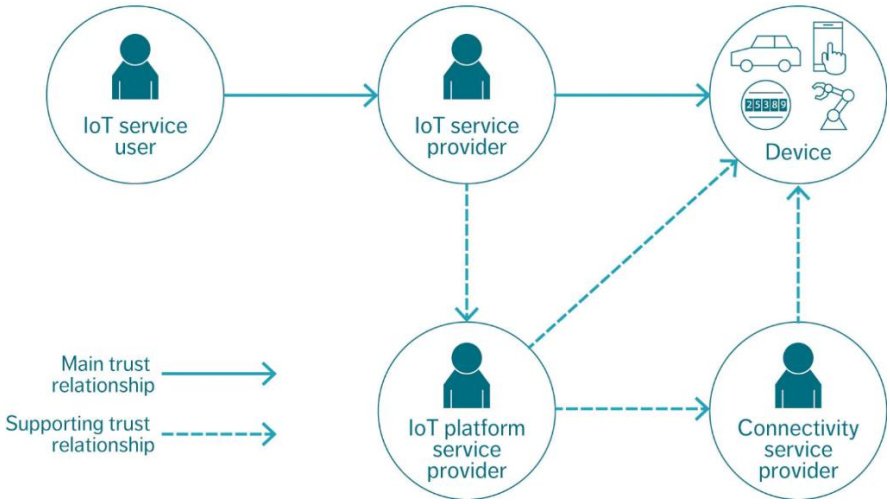


Figure 3.5.2. The main and supporting IoT actors and their trust relationships

An IoT system spans from the device via different network interfaces to the cloud that hosts the platform and applications that provide services that are consumed by IoT service users. Each element of the chain must be considered when designing an E2E approach to security and identity in the IoT. This approach leverages advanced security analytics and machine learning to provide threat, risk, and fraud management at both E2E and domain management layers. To meet industry security and privacy standards, an E2E security management solution must also oversee overall security and privacy policies and compliance and be able to coordinate across a multitude of domain management systems through the establishment of cross-domain identities and relevant policies.

Domain management of security and identity functions within domains ensures that security and identities are properly managed, configured and monitored within the domain according to policies, regulations, and agreements. Vulnerability

and security baseline management also occurs at the domain management layer based on E2E level policies. According to this approach, the IoT service provider is responsible for managing IoT service security and identities E2E, whereas *domain level* management can be delegated to the IoT platform service provider and connectivity service provider.

Vertical security from hardware to application can be used in every domain to provide hardware-based root of trust, ensuring the integrity of the domain. The domains are built on trusted hardware and software. When required by the industry and the use case, trust is anchored to hardware. The domains include security and privacy functions to handle identity and access management, data protection and right to privacy, network security, logging, key and certificate management, and platform/infrastructure security (including virtualization security and hardware-based root of trust). For critical IoT services, the level of security functions must be set high in accordance with the risk management results and service provider security policies. For less critical IoT services, a lower level may be sufficient.

3.5.4. Definition and Scope

3.5.4.1. Security policy and compliance management

Business optimalization and trust centric IoT security is dependent on continuous risk management that balances criticality, cost, usability, and effectiveness to fulfill different types of security Service Level Agreements in multi-tenant IoT systems. Since the current management of IoT security is spotty at best, it must be transformed into unified security management with adaptive protection, detection, response, and compliance driven by security policies. Only in this environment can service providers and their customers leverage E2E network and application knowledge to secure assets across all contexts.

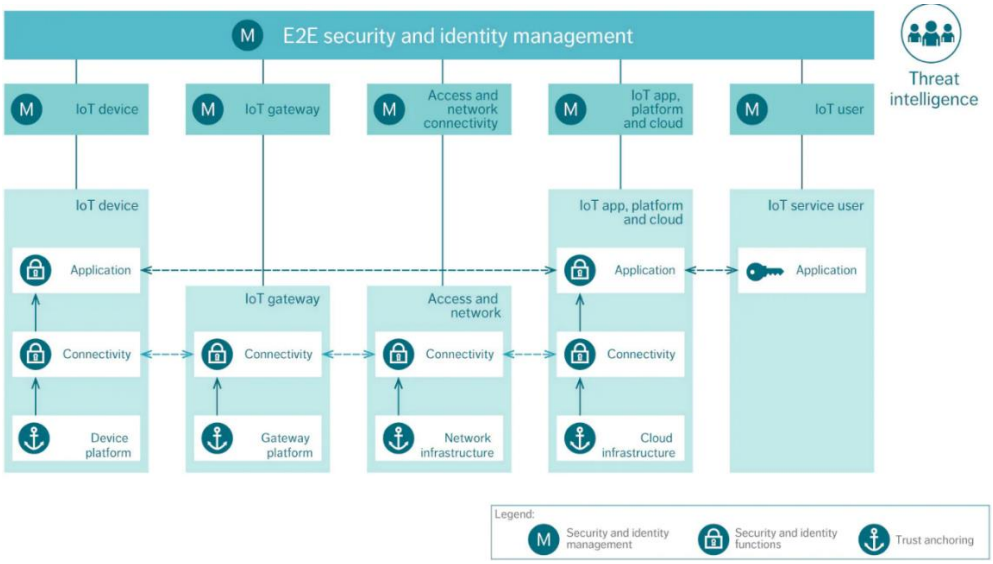


Figure 3.5.3.5 E2E approach to security and identity

Domain level security management requires an accurate asset inventory including all the assets that must be protected in the managed domain, such as authorized IoT devices and software. Automation of asset discovery and continuous monitoring is essential to keep the asset inventory updated. The vulnerability information is also correlated with the asset inventory to monitor and remediate the vulnerabilities of protected assets. Rapid detection of attacks is crucial. Security monitoring and analytics functionalities must have the ability to analyze logs, events, and data from IoT domain components combined with external data about threats and vulnerabilities. Machine learning technology makes it possible to learn from and make predictions based on data. Coupling a machine learning analytics engine with central threat intelligence improves the detection of zero-day attacks and reduces the response time for known threats.

On top of a monitoring and analytics engine, solutions relating to vulnerability, threat, fraud, and risk management, along with security policy and orchestration components, are also required to automate security controls and maintain them at desired levels in a changing threat landscape. Combining the information feeds for vulnerability, threat, and fraud management results in timely and accurate information for evaluating potential risks and helps to direct efforts in protecting the most exposed critical assets. A high degree of automation is necessary to ensure a swift response to any identified threats and anomalies.

Since not all security breaches and attacks can be prevented, it is crucial to have an efficient security incident management process that ensures rapid response and recovery. Real-time insights and audit trails from tools such as security

monitoring, analytics, and log management help to find the root cause of an incident. The same information can be also used as the evidence in digital forensic investigations.

3.5.4.2. Identity management

The main purpose of identity management is to manage the life cycle of identities and provide identification, authentication, and access control services for identities. There are various identities that serve different purposes in the IoT approach, but the main ones are for device and user identification. The others are used for management of devices, functions, and services. Identifiers and keys are also used to sign data, including software and firmware. These different device identities are needed to identify the devices for connectivity within the access and network domains, and to identify device applications in the IoT platform and cloud domain.

The level of trust in the device identity depends on the strength of authentication both at the connectivity (for example, 3GPP, Wi-Fi and fixed) and application layers. For device identity to be trusted, strong authentication and follow-up of the device integrity with the help of hardware-based root of trust in the device. A device will have different identifiers depending on where it is in its life cycle. Life cycle management of device identities is part of the security management layer. More than one security management domain is involved when provisioning identities. Connectivity and IoT service provider could be different players where each player takes care of its own identity life cycle management.

When a device is manufactured, the vendor will give it an identifier that could have different trust levels. Vendor credentials could be protected in hardware (preferred) or they could be nothing more than a serial number printed on the device. The device must be authenticated by the IoT system, and newly given identifiers and credentials (bootstrap process) will be used for connectivity and application accesses. Identifiers and credentials can be changed during the device life cycle depending on different triggers such as expiration of credentials, change of service provider and so on. Connectivity identities are dependent on the connectivity type and have different life cycle management processes. For example, 3GPP access is based on SIM identities. SIMs are either physically removable ones or SIMs (i.e., eUICC) that can be remotely provisioned.

The user identities are needed to identify the users of the services within the applications and cloud domain. There may be several different ways to verify the user identities such as single- or multi-factor authentication, federated authentication, or authentication tokens. Each of these provides a certain level of authentication strength. Due to layered security management architecture and the involvement of several actors (including industries) in the IoT, any identity and access management solution must be able to cooperate with and adapt to external identity and access management systems. On top of identification and authentication, there must also be access control for users so that only the permitted services are authorized.

3.5.4.3. Threat intelligence

Threat intelligence is built and shared in communities. Therefore, a centralized threat intelligence solution must be able to interface with different threat intelligence sources to learn about existing and new threats. Consolidation and

correlation of security audit feeds from different domains are necessary to provide a clear view of threat insights across all IoT domains. Automation and machine learning can be used to great advantage in threat intelligence, to create and share indicators of compromise that are actionable, timely, accurate and relevant to support strategic *decision making* and to understand business risks in detail. Targeted threat intelligence feeds are a great way to generate *customer specific* threat intelligence.

3.5.5. Maturity

Table 3.5.1. The maturity of E2E IoT Solutions

Competitive forces	Level	Reasoning
Competition in the industry (*Uniqueness, competitor power, and healthy profits*)	2	Considering that so many industries are currently competing to digitize their operational processes using the IoT use cases, then II0T is not a new thing among the industry.
Supplier power (*Suppliers, competitive price, and product uniqueness*)	2	Many suppliers from within and outside the country have run their business in Indonesia. Each of them brings their own iiot products with different offerings, depending on the use case and scale of the industry.
Buyer power (*Volume forecast, costing, and supplier capacity)*	2	Currently, large and medium-sized industries are competing to increase productivity and work on the market by digitizing the production process. Therefore they have prepared funds for digitization purposes.
Threat of substitution (*Customer experience, best in class customer treatment*)	2	Considering the number of suppliers and the rapid development of IoT technology, in the future it is very possible to appear technology or similar products that can replace this IoT technology.
Threat of new entry (*Market landscape, technology protection, and barriers*)	1	In this IoT business, supplier credibility is needed (how many solutions from suppliers are used by the industry). Therefore, it is not easy for new suppliers to stay long in the IIoT world.

Based on the analysis above, securing E2E IoT solution has a total score of 9 based on Five Force. Hence, this technology is at a mature phase. As for diffusion of innovations, securing E2E IoT solution is at Early Majority.

The Porter's Five Forces	Introduction			Growth			Mature						Decline		
Score	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
Diffusion of innovations	Innovators		Early Adopters			Early Majority				Late Majority				Laggards	

3.5.6. Relevance

Telco company such as Indosat Ooredoo Hutchinson might take part as major to provide of the E2E securing IoT solution. Connectivity sits at the center of the technical chain of any IoT project, and so the way in which devices are connected to

the IoT application server represents a key security consideration. However, looking from distinct perspective, partnering with service providers that have E2E IoT solution will provide significant advantage for IOH and possibility to monetize the other value chain to the enterprise clients such as manufacturing, retails, logistic, FSI and utility.

At the point where securing E2E IoT solution is commonly used by the enterprise segment, IOH might need to cater their IoT product to meet the securing E2E IoT solution requirement: device layer (end point), a connection layer, platform, and application layer (application enablement platform/AEP). The need for the product, combined with the IOH customer base, will provide an additional revenue source for the company to be competitive in the business. From the product marketing perspective, securing E2E IoT solution opens possibility to do advanced security E2E layer for IOH base enterprise customer reflected on IoT solution and product. The product will be bundled with existing IoT solutions and products.

3.5.7. Implementation and Use Cases

Two concrete examples of how an E2E security management solution can help address IoT challenges are provided below.

3.5.7.1. DDoS detection and prevention

In October 2016, the Mirai botnet exploited a vulnerability in IoT devices to launch a DDoS attack against a critical DNS server that disrupted several the internet's biggest websites, including PayPal, Spotify, and Twitter. Mirai was designed to exploit the security weaknesses of many IoT devices. It continuously scans for IoT devices that are accessible over the internet and are protected by factory default or hardcoded usernames and passwords. When it finds them, Mirai infects the devices with malware that forces them to report to a central control server, turning them into bots that can be used in DDoS attacks.

Strong detection and prevention mechanisms are needed against DDoS attacks that attempt to saturate the network by exhausting the bandwidth capacity of the attacked site, the server resources or service availability. In our view, an optimal outbound DDoS (botnet) detection and mitigation solution includes remote attestation to verify device trustworthiness and detect malware, monitoring of outbound traffic, anomaly detection, infected entities isolation or blocking and setting of traffic limit policies. Optimal inbound DDoS detection and mitigation includes monitoring of inbound traffic, anomaly detection, setting of traffic limit policies and redirecting malicious traffic to a botnet sinkhole. The security management layer plays a critical role in detecting and mitigating DDoS attacks. In our framework, DDoS attacks are detected by the security monitoring and analytics functions through the observation of device and network behavior and identification of anomalies. Once an anomaly is detected, immediate mitigation actions can be triggered.

3.5.7.2. GDPR compliance

There is a legitimate expectation in society that IoT solutions will be designed with privacy in mind. This is becoming especially evident in certain jurisdictions: for example, in the European Union with the new General Data Protection Regulation (GDPR). Data integrity, data confidentiality, accountability and privacy by design are all fundamental to the

protection of sensitive personal data. Such data can be protected via appropriate privacy controls. These controls include personal data identification and classification, personal data management and fair data processing practices. When actual personal data might be exposed, additional privacy protective measures will be applied such as data encryption and data anonymization.

Another focus area in the IoT security domain is the privacy breach response. Dedicated privacy logging and audit trail functionality can be used to improve the ability to prevent, detect and respond to privacy breaches in a more prompt and flexible way. Such capabilities will be essential to respond to privacy breaches swiftly (within 72 hours (about 3 days), as prescribed by the GDPR). Implementing a GDPR compliance tool in the security management layer makes it easier to meet GDPR requirements. To do its job right, it must be able to provide identification and classification of personal data, enforcement of data privacy policies according to the GDPR, demonstration of compliance to the GDPR, detection, response, and recovery from privacy incidents.

3.5.8. Market Size

As mentioned earlier the global IoT security market was valued at USD 8,7 Mn in 2019 and is expected to be valued at USD 58 Mn by the end of 2027 registering a significant CAGR of 27% over the forecast period, 2019-2027. The Asia Pacific market is the fastest growing and will continue to expand throughout the forecast era. The region is dominated by major market players, such as India, China, and Japan.

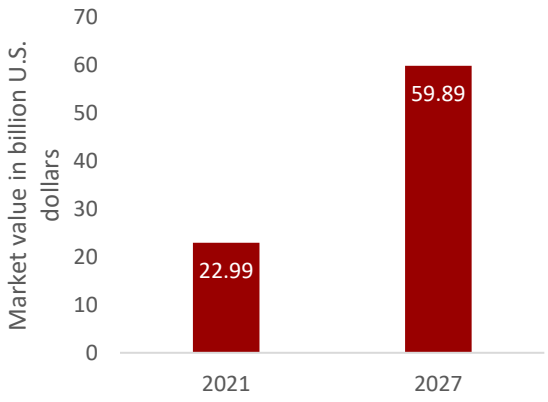


Figure 3.5.4. Global zero trust security market value in 2021 and 2027[51]

[51] https://growthmarketreports.com/report/global-iot-security-market-report

3.5.9. Market Segment

Table 3.5.2. Market Segment of E2E IoT Solutions

Use cases	Finance	Govt	Man. & Trading	Service	Mining
Improving business processes	Funding and Lending management	Public policy management	Production management and monitoring	Customer profiling and management	Production management and monitoring
Threat intelligence	Security	Social monitoring	Unauthorized access monitoring	Security	Security and vulnerable monitoring
Identity management	Customer management	Data management	Intruder monitoring	Accessibility	Employee management
Trustworthiness	Accessibility & Security	Citizen monitoring	Data management	Transactions	Transactions

3.5.10. Technology Solution Provider

Table 3.5.3. Providers of E2E IoT Solutions

Companies	Solutions	Scale (Local/Global)
Ericsson	E2E security IoT Solution	Global
TNF Global Connectivity	Security bundled with mobility connectivity	Global
ARM	Arm technology is the industry standard for IoT and embedded devices	Global
Bayshore Networks	Cyber Security in the Era of Industrial IoT	Global
Cisco	Cisco SAFE security model and methods to simplify end-to-end security	Global
Device Authority	Device Authority provides solutions to address the challenges of Identity and Access Management for the Internet of Things (IoT) without human intervention.	Global
Dell	Enterprise-grade, end-to-end safety and security solution, utilizing the latest technology from Dell and Intel	Global

Companies	Solutions	Scale (Local/Global)
Endian	Provide complete Industrial IoT Security to your network. Centralized Network Management Centrally manages all your Endian appliances.	Global
Forescout Technologies	Enterprise of Things by identifying, segmenting and enforcing compliance of every connected thing	Global
Gemalto	End-to-end security to IoT devices connecting on the booming LoRa® networks.	Global
HPE	Mobile IoT edge applications and solutions.	Global
IBM	Secure End to End Communications and Data Analytics in IoT Integrated Application Using IBM Watson IoT Platform.	Global
Infineon Technologies	An off-the-shelf security solution based on a certified Secure Element and pre-provisioned at Infineon's Common Criteria certified facility.	Global
Intel	Intel Software Guard Extensions (SGX) to create a secure system on untrusted platforms.	Global
Kaspersky Labs	Kaspersky Security Network is a global system	Global
Microsoft	Azure Sphere helps to protect devices and deliver end-to-end IoT security	Global
NXP	Ready-to-use secure element for IoT devices provides a root of trust at the IC level and delivers real end-to-end security	Global

ICT & Cloud

Summary
Categorization: • **Maturity:** Early Adopters • **Technology Field:** Core Infrastructure • **Relevance for IO:** High
Reason to watch: Next-gen platform for various enterprise and consumer activities
IO Status: • **Year added:** 2022

3.6. Metaverse

3.6.1. Introduction

Metaverse is a term for a virtual world created within internet that can be facilitated using various technology such as Augmented Reality (AR), Virtual Reality (VR), and social media for communication while making use of backend support systems such as Decentralized Finance / Digital Currency and Artificial Intelligence to provide real-life-like experience.

The term Metaverse originated in the 1992 science fiction novel *Snow Crash* as a blended words of meta and universe. Recent technology advancement of Blockchain and Web 3.0 has driven world-wide interest of Metaverse, backed with certain enterprises changing and bringing the concept of Metaverse to real-life implementation.[52]

3.6.2. Definition and Scope

Years before term 'Metaverse' become popular and hyped world-wide, gaming industry already have genre of game that puts the user into a virtual avatar and do activity in the virtualized environment. The genre is called Massive Multiplayer Online Role-Playing Game (MMORPG) with large player such as ROBLOX, Minecraft, World of Warcraft, and Final Fantasy XIV has millions of users logging in and playing hundreds of hours monthly.

Figure 3.6.1. MMORPG and the 'early phase' of Metaverse

[52] https://www.techtarget.com/whatis/feature/The-metaverse-explained-Everything-you-need-to-know

The MMORPG genre allows the user to customize its own avatar, follows the story (or any casual activity - also called sandboxing) in the virtual world, and socialize with other users via chat. The 'purpose' of playing game is told directly by the storyline in game while utilizing social aspect to make the game more interesting.

In 2014, more casual socialization platform was released under the name 'VRchat'. It was the first socialization platform that utilizes Virtual Reality (VR) equipment to bring more immersive experience of meeting each other in the virtual world. [53] Initially released for Microsoft Oculus, VRchat later become available for other VR equipment and open source the software development kit (SDK) for everyone to contribute. Right now, there are thousands of VRchat servers running worldwide, with hundred thousand of users casually socializing in the virtual world.

The current state of Metaverse is tightly related to the well-established VRchat platform combined with the Massive-Multiplayer Online Role-Playing Game (MMORPG) platform and social media functionality. Metaverse itself consists of multiple servers communicating with each other, providing an application platform to the user's client application.

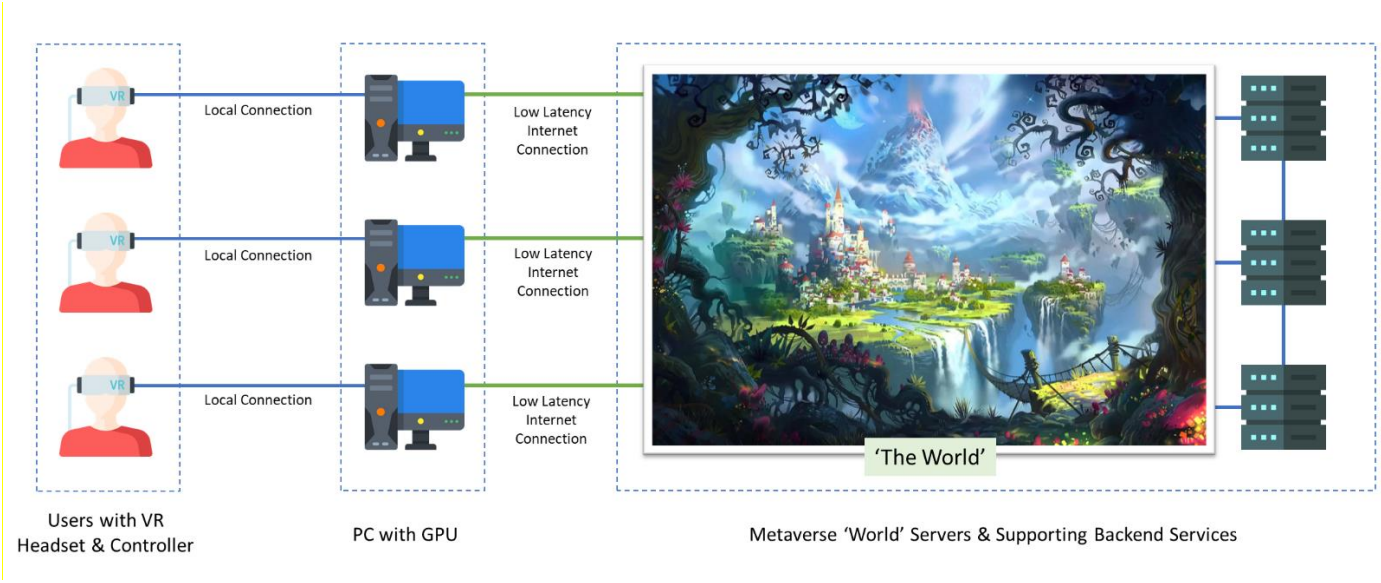


Figure 3.6.2.6 Simple High-Level Topology to Participate in Metaverse

The platform servers can be located anywhere in the world if it's connected to the internet. However, considering the graphical load for the Metaverse platform, <100ms connection is preferred for maximum experience to the users.

[53] https://hello.vrchat.com/

From the user perspective, they can log into the selected Metaverse server (will be called as 'Universe' or 'World' from this point forward) and perform various, but not limited to, activity below[54]:

- Customize their 'avatar', this means create a human-like or customized 'avatar' that roams the 'World'
- Do a voice chat with other users in the 'World' in extend to create private chat channel with other users
- Do various movement or emotions, such as jumping and sitting down
- Access personal 'dashboard' screen containing multitude of application with various functionalities from productivity to leisure / gaming

Depending on the Metaverse owner, they may charge user with various business models, starting with annual / monthly access fee or freemium, purchasable items to decorate or bring certain cosmetic change to their avatar. Backed up with the trending blockchain and decentralized finance, these business model has its own market for unique or limited digital items that can be owned and has certain real-life monetary value. As an addition, Metaverse creates opportunity for existing real-life enterprise customer goods company to expand their business into the virtual world. Such concept allows the goods manufacturer to market and create their own product in the virtual world and paid using real-life money.

However, Metaverse has its own issues and concern need to be covered before it becomes massively adopted technology such as[55]:

1. Privacy issue, in a simplest form, marketers and metaverse owners can take advantage of the VR headset eye-tracking feature to quickly define which way or part of metaverse is being most watched at. This would define certain spot or area in Metaverse to be a 'perfect' ads space
2. Social and content interaction protection, since Metaverse allows all kinds of people to join and participate, voice chat channel might be uncontrollable and not suitable for certain age due to possibility of abuse or improper communication
3. Desensitization, Metaverse content might be R-rated and sensitive content such as gore or violence is allowed in the Metaverse platform. Since the experience feels very real, this could alter users' behavior to think that improper action is allowed and does not bring any impact or disturb other people in real life
4. Addiction and health issues, since the nature of Metaverse is based on a game, the issue of addiction and physical / mental health issue from overusing the technology is still there and one thing to consider

[54] https://xpertvr.ca/what-is-the-metaverse/

[55] https://bernardmarr.com/7-important-problems-disadvantages-of-the-metaverse/

3.6.3. Maturity

Using Porter's five forces theory, Metaverse technology is regarded as an early adopter's level since there's not much to be shown in the practical terms of technology and only a few experimental universes are running on demand for certain events.

Table 3.6.1. The maturity of Metaverse

Competitive forces	Level	Reasoning
Competition in the industry	1	Tech giants such as Google, Facebook, and Amazon are the only one capable of deploying a whole Metaverse from the scratch, this includes the universe platform, social media platform, and the decentralized finance platform for transactions.
Supplier power	1	There aren't many suppliers that can provide the whole system for building Metaverse. Several of the platform are open source already but still requires expertise to implement and integrate it with each other.
Buyer power	1	Since Metaverse is targeted for both consumer and enterprise segment, with the current state of progress, it might take a while before both segment is willing to spend their capital in the Metaverse platform since the consumer required to purchase VR equipment to enjoy the full experience of Metaverse itself.
Threat of substitution	1	Metaverse plays as foundation for the future technologies. Instead of substitution, Metaverse will act to drive both hardware and software company to adapt their product for the virtual world uses.
Threat of new entry	1	As mentioned above, broad range of expertise is required to successfully deploy and operate Metaverse platform. With additional difficulty of having ecosystem of users that actively use the service, it is considered to be hard for anyone to enter and provide Metaverse service to the public and enterprise alike.

Based on the maturity analysis above, total maturity score of the technology is 5 which means that the technology is considered within growth phase and in early adopter phase with only few enterprises willing to invest in the technology.

Product Lifecycle Phase	Introduction			Growth			Mature						Decline		
Score	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Diffusion of innovations	Innovator		Early Adopters			Early Majority				Late Majority				Laggards	

3.6.4. Relevance

Telco company such as Indosat Ooredoo Hutchinson might not become the major player or sole provider of the Metaverse service. However, looking from different perspective, partnering with service provider that have Metaverse will provide significant advantage for IOH and possibility to 'sell' the Metaverse platform to the enterprise clients such as education, retails, and gaming.

At the point where Metaverse is commonly used by the consumer segment, IOH might need to cater their product to meet the Metaverse requirement: a connection service that has low latency and high reliability to ensure maximum user experience while using the VR equipment. The need for the product, combined with the IOH customer base will provide additional revenue source for the company to be competitive in the business.

From the marketing perspective, Metaverse opens possibility to do advanced marketing activity for IOH existing product. Having IOH branding in certain event in Metaverse world will allow IOH product to reach more customer and increase chance of migrating competitor's customer base. As from the productivity perspective, Metaverse will help in creating conducive Work-From-Anywhere (WFA) method compared to current method. This is due the capability of Metaverse allowing their users to virtually 'sees' each other avatar and track any body movement for better socialization experience while maintaining the flexibility of devices and application used during working hours.

3.6.5. Implementation and Use Case

Metaverse implementation and use case mostly will focus on consumer segment with few opportunities laying for B2B / enterprise segment explained below.

3.6.5.1. Virtual Education Platform

Metaverse expands the remote / virtual education activity to an extend that it mirrors physical education activity in school or campus. With the unlimited capability of material modeling and creation in Metaverse, physical activity such as laboratory activity, exams, and classroom session can be done virtually from any location.[56]

[56] https://101blockchains.com/metaverse-use-cases/

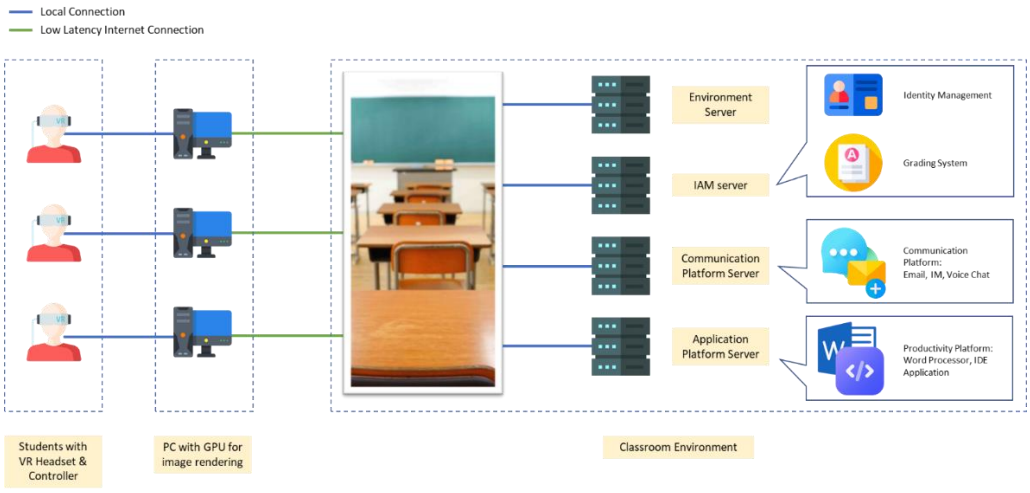


Figure 7 Components of Virtual Education Platform in Metaverse

3.6.5.2. Virtual Office

Pandemic outbreak in 2019 forces enterprises to shift their working model into work-from-anywhere (WFA) to avoid unnecessary cost in keeping the employees healthy and reduce the chance of virus spreading. This WFA method has been done almost three (3) years and not all enterprise company are going well with this method due to lack of physical interaction / expression, text-based communication, and less time limitation. With the Metaverse capability to simulate office and meeting rooms, company might need to 'reserve' their own Metaverse world to create the 'virtual office' environment.[57]

[57] https://101blockchains.com/metaverse-use-cases/

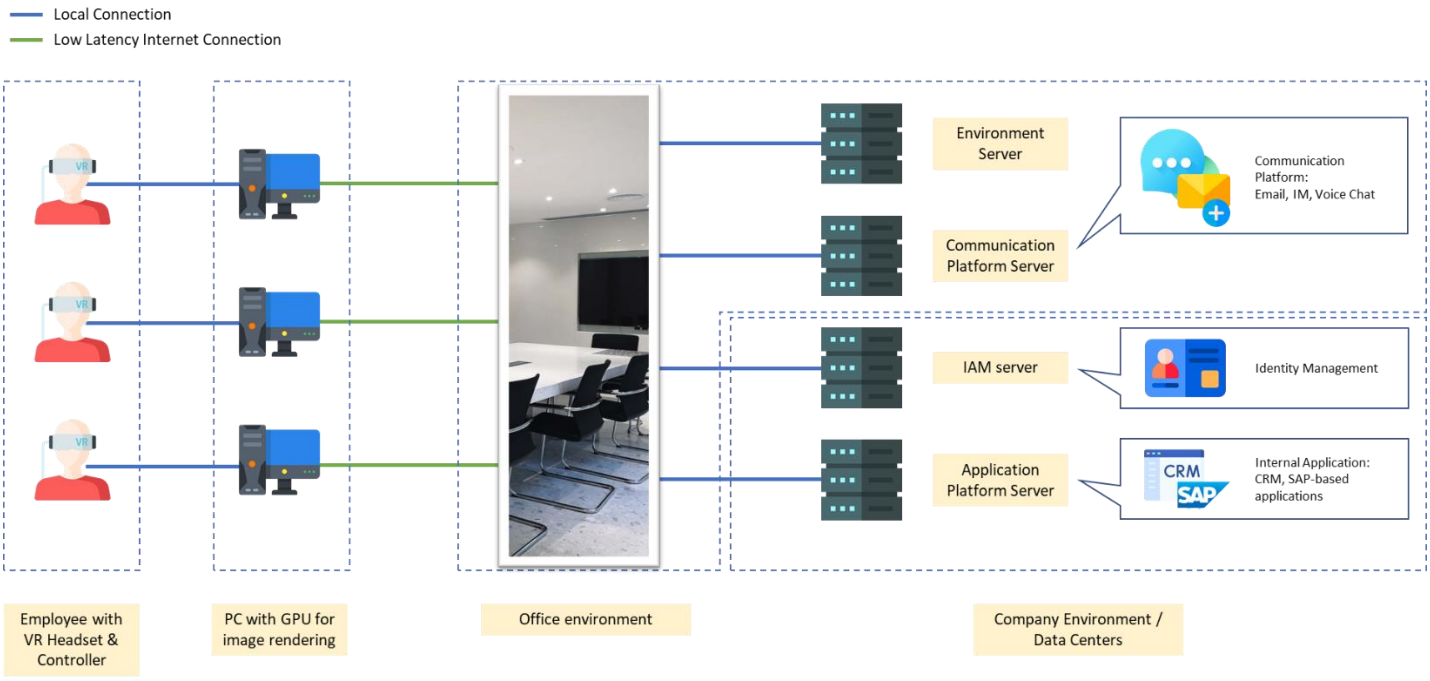


Figure 3.6.4. Components of Virtual Office in Metaverse

Even though the communication still done digitally via voice channel or chat rooms, Metaverse will reduce the distrust due to lack of physical interaction and limits time availability for each employee. Company such as Gather and FrameVR are currently developing the virtual-office-as-a-service to enterprise as an alternative for collaboration tools such as Microsoft Teams and Zoom.

3.6.5.3. Virtual Market

Having limitless capability to created virtual version of a real-life objects might evolve the already-thriving eCommerce platform into the next step in which the customer can physically see the real scale of items they are going to purchase. With an integration of Decentralized Finance (DeFi) service platform, eCommerce can integrate their transaction to the blockchain technology, allowing accurate documentation of limited item purchases and ownership.

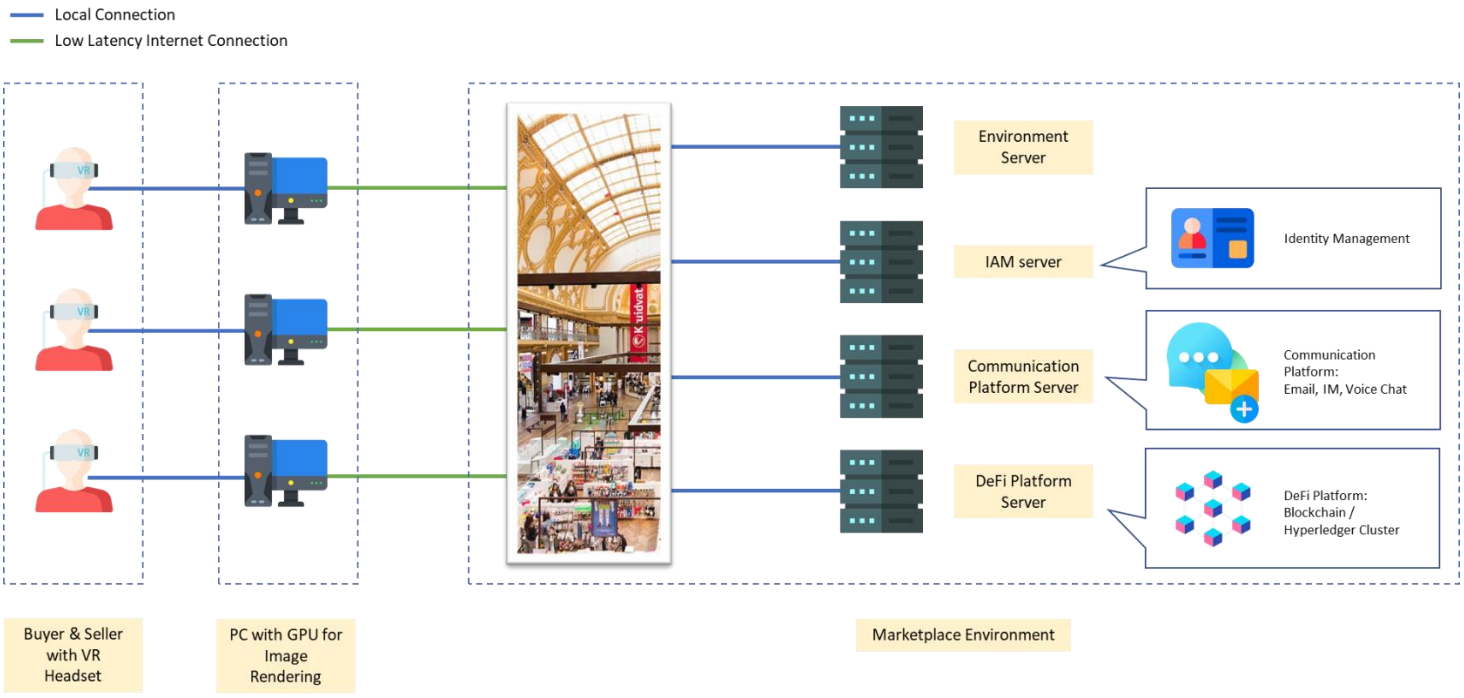


Figure 3.6.5. Components of Virtual Marketplace Platform in Metaverse

The virtual market also opens the possibility of virtual product that specifically can only be used within the Metaverse. However, it might need a lot of integration between the eCommerce company, product company, and the Metaverse provider. The latest example of Virtual Market that has been tried out for PoC is Walmart Virtual Shopping Experience created by SXSW, however, these are only for the purpose of experiencing virtual market without any integration to financial and goods delivery system.[58]

3.6.6. Market Size

Since the term of metaverse has just recently surfaced, market size for Metaverse only available globally from 2021. According to report from Statista, Metaverse market size is reported to be around 38.85B USD in 2021 with estimated 22% yearly growth.

[58] https://mutualmobile.com/work/walmart

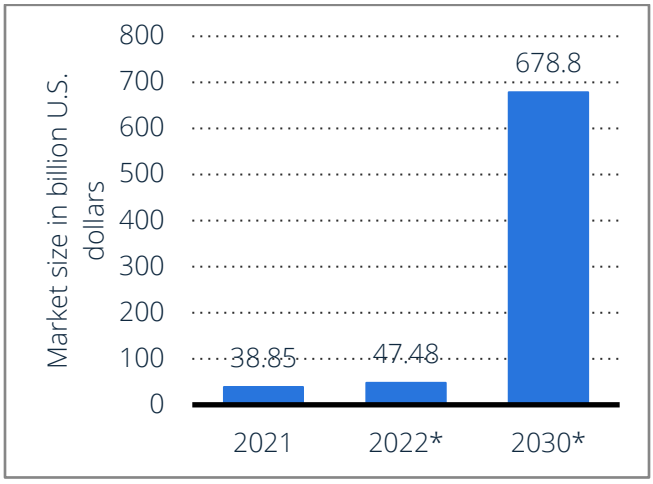


Figure 3.6.6. Metaverse Market Size[59]

However, the specific market size for southeast Asia or specifically Indonesia region is still unknown up until now and the number provided by Statista is calculated using the assumption of spending in 'early-phase' Metaverse platform such as Roblox and Fortnite.

3.6.7. Market Segment

While Metaverse is aimed toward consumers, there are several factors that could affect enterprise to utilize or requires the capability of Metaverse technology:

1. Enterprise or company that requires real time interaction with physical world mirroring capability
2. Enterprise or company which has product that can be digitalized into virtual form
3. Enterprise or company that sells digital entertainment service to its user

Table 3.6.2. Metaverse Market Segment

Segment	Govt. & Public Sector	Supply Chain & Retail	Industry & Manufacturing	Media
Criteria 1	Education Institute Healthcare	Retail Stores	Basic Goods Capital Goods	Social Media Company VOD / Streaming Company
Criteria 2	Education Institute Healthcare	Retail Stores	Basic Goods Capital Goods	Social Media Company VOD / Streaming Company
Criteria 3				Social Media Company VOD / Streaming Company

[59] https://www.statista.com/statistics/1295784/metaverse-market-size/

3.6.8. Technology Solution Provider

Table 3.6.3. Providers of Metaverse

Companies	Solutions	Scale (Local/Global)
Meta Group	As the one who put words 'Metaverse' into a popular word, Meta Group (a.k.a. Facebook) currently one of the social media companies that can provide Metaverse for temporary event or social activity. Currently Meta does not disclose any service or functionality regarding their Metaverse platform.	Global
Decentraland	Decentraland is the first Metaverse that is fully connected to the Ethereum (ETH) blockchain. The launching of Decentraland was sometime around April 2022 and they planned to have a full-fledged Metaverse in which uses Ethereum block for transaction and digital asset trading.	Global
TeamFlow	Focusing on functionality, TeamFlow provides forementioned 'Virtual Office' as a service starting from free tier up to premium / enterprise tier. TeamFlow lacks the other 'real-world' functionality such as DeFi and social media platform as explained in the Metaverse concept and focuses on collaboration function.	Global
Gather	Gather is a minimalist, pixel-based approach for virtual office services provided for startups and big companies. Gather has capability of creating user's avatar, real-time voice communication, private meeting rooms, and application window sharing. Gather can be seen as a transition to the 'real' Metaverse since it eliminates the required heavy hardware investment.	Global
Virbela	Virbela is a company that focuses on 3D collaboration space and enterprise metaverse service. With their basic products, Virbela can provide on-demand, multipurpose virtual space. This virtual space can be extended for specific functionality such as virtual classroom and virtual office room. As for now, it's still lack integration into any blockchain platforms.	Global
Hyperscalers (AWS, GCP, Azure)	Instead of providing the Metaverse virtual space directly, hyperscalers can provide almost all the required component to run the Metaverse platform. So far, there aren't any integrated solutions in the Hyperscalers marketplace that can directly deploy Metaverse platform automatically.	Global
Hyperledger	Hyperledger fabric is an open-source project created by Linux Foundation and used mainly for DeFi platform in the metaverse. Even though the Hyperledger platform is provided free as an open source, deploying and integrating Hyperledger recommended to be done via Hyperledger Certified Service Provider such as IBM & TechMahindra.	Global

Summary
Categorization: • **Maturity:** Early Adopters • **Technology Field:** End Users Solution • **Relevance for IO:** Medium
Reason to watch: Ensuring gaming network capability may nets additional revenue source for consumers in specific segment.
IO Status: • **Year added:** 2022

3.7. Cloud Gaming Service

Gaming has been an exciting market dominated by consumer (B2C) segment and services are provided mostly as one-time purchase by the game publisher and developer. In past few years, gaming has coined a term called Gaming-as-a-Service with subscription-based model and sustainable service revenue over long term.

3.7.1. Introduction

Started from a proprietary, stand-alone, console-based gaming, gaming segment has been growing to accommodate various kind of consumer from casual gamers to hardcore gamers. To provide the best experience to various consumer, game companies are trying to minimize the entry barrier for gaming itself while keeping the revenue sustainable for the environment and not sacrificing the overall gaming experience to the consumers.

Since the main idea is to reduce cost, with the advancement in computation and network technology the gaming companies works with the infrastructure provider to create various cloud-based gaming service for the consumers. There are multitudes of gaming services available now such as:

1. Online multiplayer gaming
2. Online game marketplace / store
3. Online game library subscription
4. Game streaming service

Each has their own business and technology model, but all services use similar, cloud-based infrastructure to expand and shrink the required resource as necessary with the network component fully provided by end-users.

3.7.2. Definition and Scope

Based on the classification above, each of the services are represented by simple diagram below.

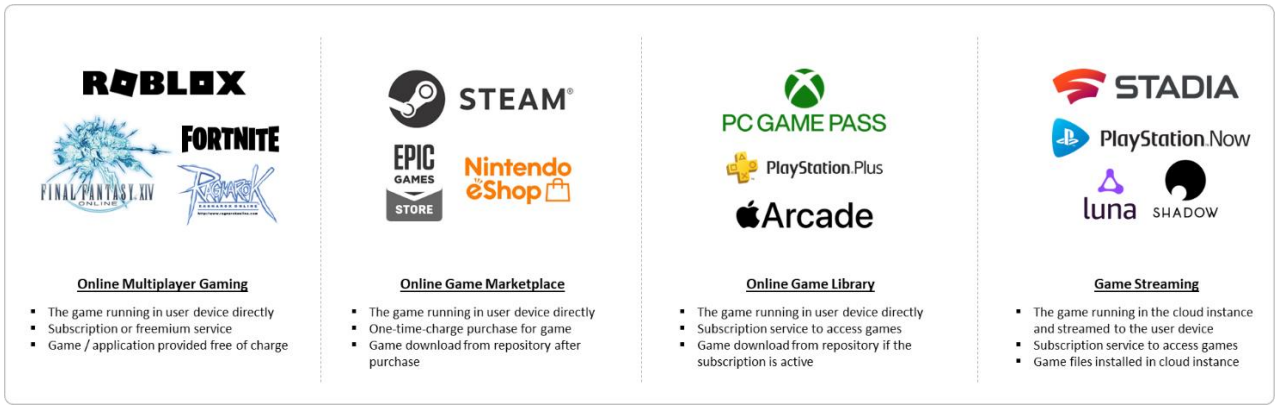


Figure 3.7.1. Cloud Gaming Classification

3.7.2.1. Online Multiplayer Gaming

Moving from offline multiplayer gaming (a.k.a. couch co-op gaming), online multiplayer game has been around since early 1990s, approximately 5 years since internet has been released to the public. Online Multiplayer Gaming has various genre of game with the various level of interaction. Technology-wise, online multiplayer gaming relies on the cloud-based server to provide 'meeting point' between players and the experience of playing the game solely depends on users' network access and gaming hardware. [60]

[60] https://www.techtarget.com/whatis/definition/gaming

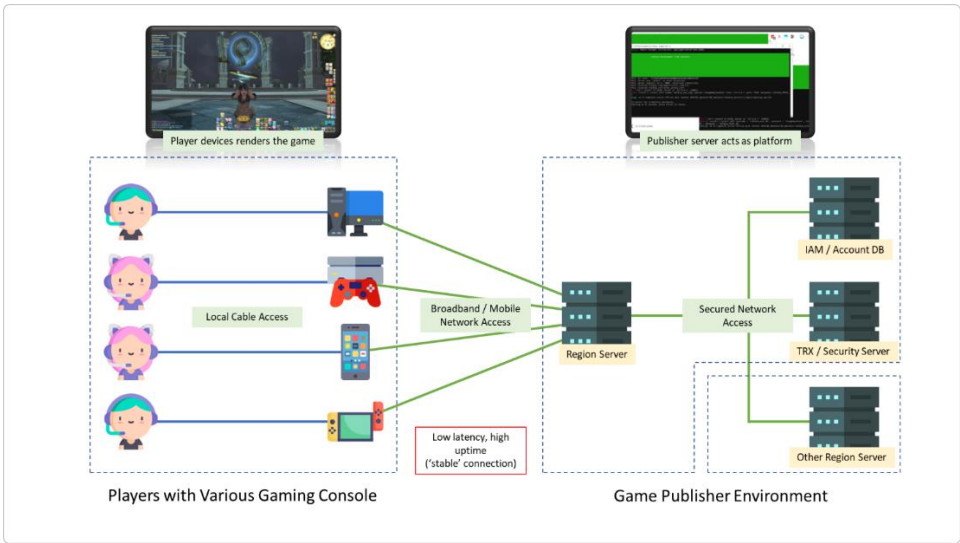


Figure 3.7.2. Multiplayer Online Game Service Topology

The monetization of online multiplayer gaming coming from the subscription-based access to the game (later known as pay-to-play) or in-game 'item mall' (later known as free-to-play / freemium) that provides cosmetic or gameplay experience enhancement to the players.

Up until now, online multiplayer gaming does not require advanced gaming hardware nor high performance internet connection which mostly works on standard personal computer with Windows / x86 systems. To make the gameplay as smooth as possible, game publisher usually put multiple servers across the globe, allowing certain users to connect to the closest server and minimize connection latency.

3.7.2.2. Online Game Marketplace / Store

The ever-growing technology and network capability modernize a traditional on the store, CD/DVD-based video game delivery into a fully digital, online store that enables user to purchase and download the video games anytime using internet connection.[61]

[61] https://store.steampowered.com/about/

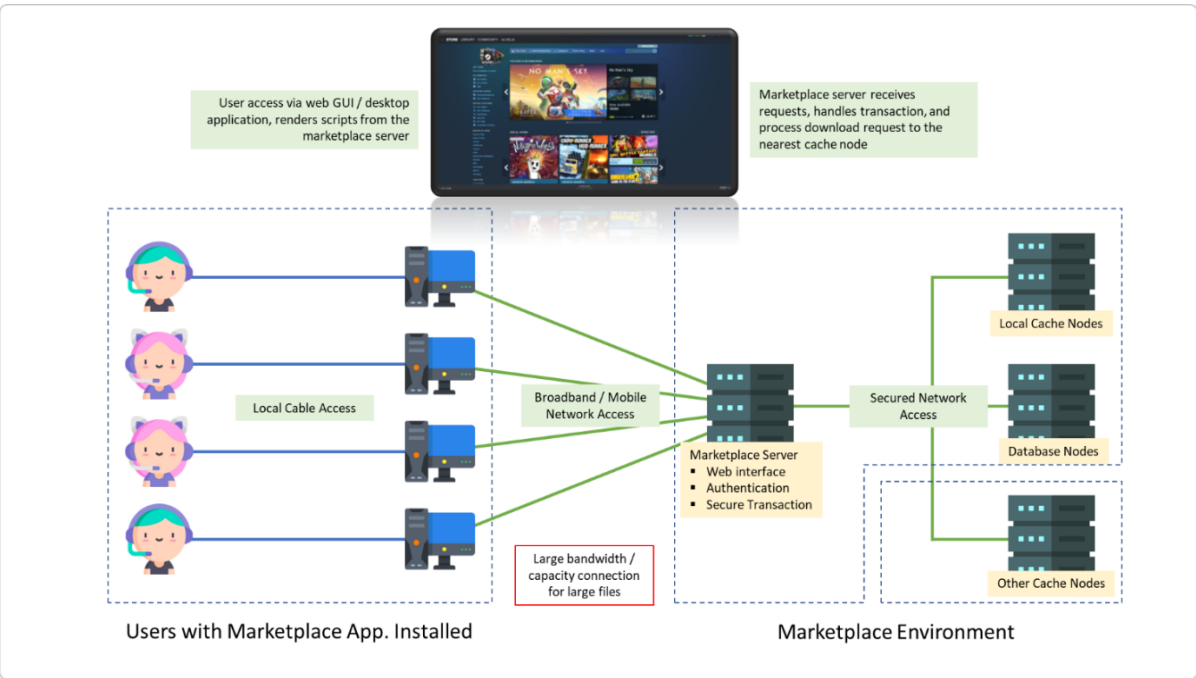


Figure 3.7.3. Online Game Marketplace Service Topology

As easy as purchasing goods in the online marketplace, online game marketplace currently becomes a standard for purchasing video games in both personal computer and video game console with credit cards to handle the transaction of goods. Since the game files usually have large size (more than 1GB), online game marketplace enterprises utilize the content delivery network technology to cache large files and enables faster download speed for enhanced customer experience.

3.7.2.3. Online Game Library Subscription

With the online game store becoming popular, the game publisher realizes that each game has its own 'age' and most of the times are not played after the storyline ends. To keep the interest of players, publisher shifted the one-time purchase model into subscription models. [62]

[62] https://www.redbull.com/ie-en/games-as-a-service-changing-gaming-forever
https://www.gdcvault.com/play/1015035/Emerging-Trends-In-Games-as

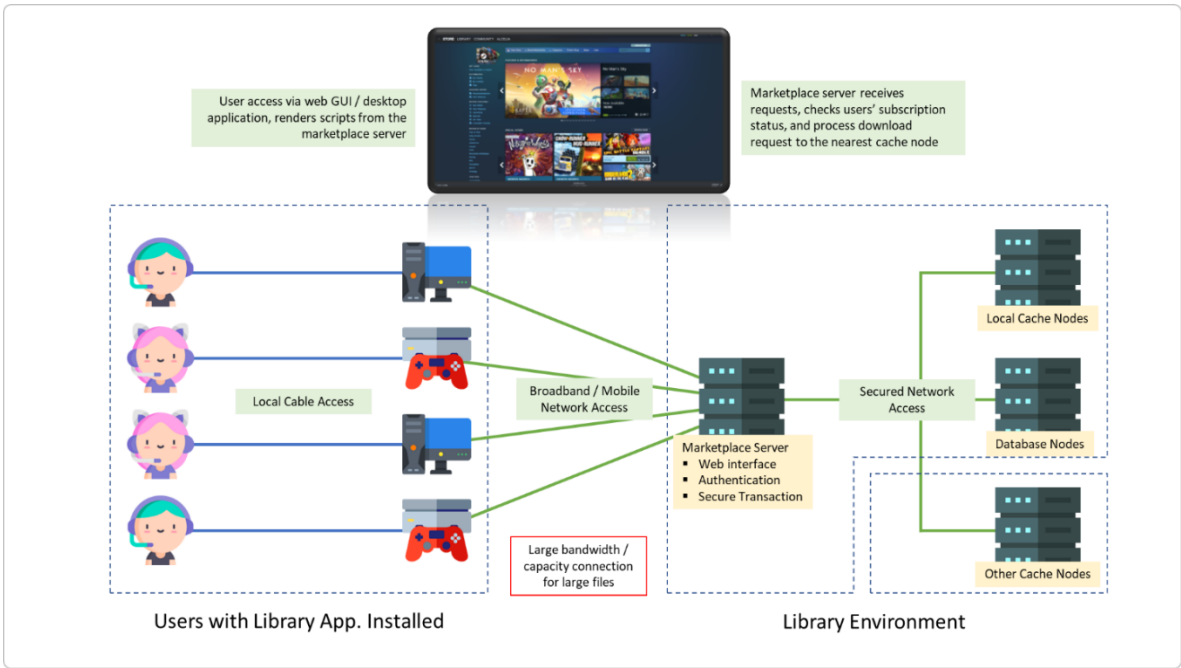


Figure 3.7.4. Online Game Library Service Topology

In this subscription model, users do not 'own' the game, instead they 'rent' out the game by playing subscription fee. Users can download, install, and play the game anytime during the subscription period. Main advantage of this model is reduced cost to play and finish a game, access to the various game with single, fixed monthly cost, and freedom to start or stop the subscription anytime while game publishers can gain steady revenue stream from the subscription.

However, there is a catch for the online gaming library subscription. Most of the time it requires users to have high performance gaming hardware to run the most recent game (a.k.a. AAA games) and constantly upgrades their hardware to meet ever-increasing hardware demand.

3.7.2.4. Game Streaming Service

The newest gaming service available on the market is a game streaming service, in which the users stream the game throughout the internet and constantly provide feedback / controls to play the game running in the cloud infrastructure.[63]

[63] https://www.digitaltrends.com/gaming/what-is-cloud-gaming-explained/

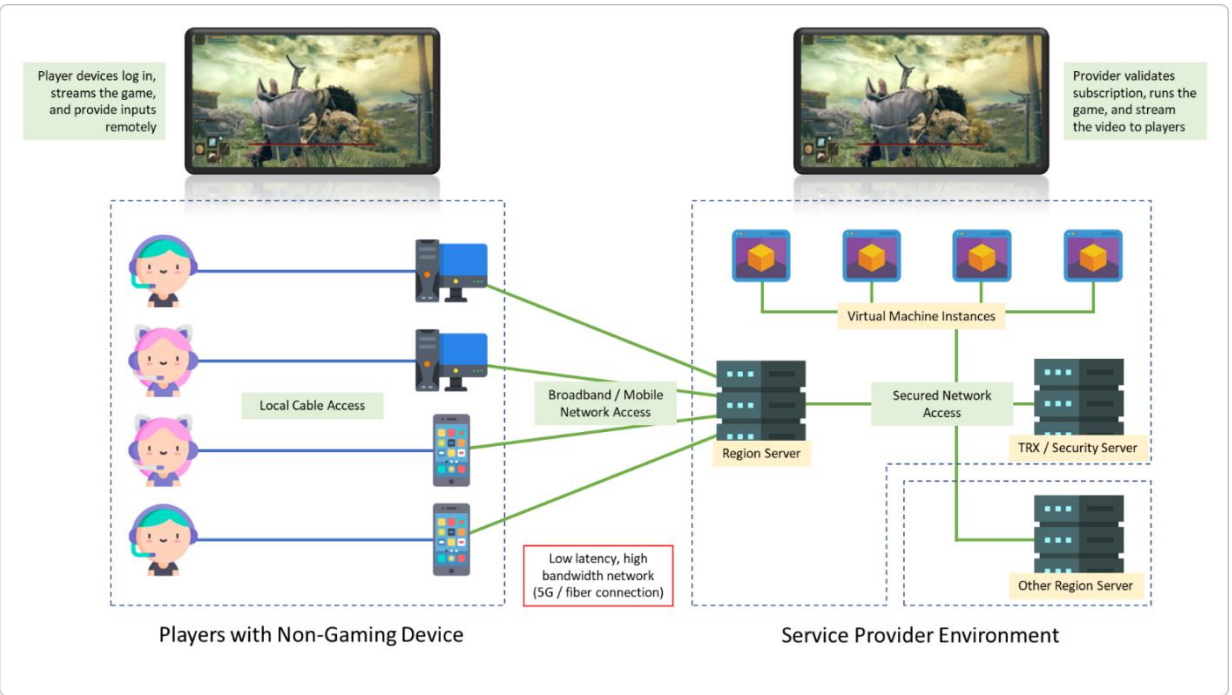


Figure 3.7.5. Game Streaming Service Topology

Game streaming service relies on the capability of GPU virtual memory reservation to 'slice' single GPU hardware to be used by several virtual machine at the same time. The virtual machine then assigned to the users account and streamed directly to client via internet connection. If the user chooses to play the game, client application instructs the machine to run certain game while keeping the input feedback from the user to play the game. This approach allow users with low or non-gaming hardware to play AAA games with high quality configuration by utilizing the virtual machine and GPU in the cloud.

To deliver the best experience, a high-performance network connection with low capacity is required to stream the game from the cloud infrastructure to the users' hardware.

Table 3.7.1. Bandwidth Table for Various Resolution[64]

Resolution	Frame Per Second (FPS)	Required Bandwidth
576p	30 FPS	2 Mbps
720p	30 FPS	5 Mbps
720p	60 FPS	10 Mbps
1080p	30 FPS	10 Mbps
1080p	60 FPS	25 Mbps
2160p	30 FPS	25 Mbps
2160p	60 FPS	50 Mbps

Considering the bandwidth required for streaming, 5G or fiber connection is required as a minimum requirement. Added with the subscription-based service, this technology converts the initial large investment cost into a more acceptable, monthly-based investment to play AAA games.

3.7.3. Maturity

Network-based gaming service has been around for some time, however, game streaming service just recently offered publicly for consumers and some companies are trying to play in the market. The maturity level will only discuss ***game streaming service*** since it's the newest technology on the market.

Table 3.7.2. The maturity of Cloud Gaming Service

Competitive forces	Level	Reasoning
Competition in the industry	1	Game streaming service requires an expertise in the cloud infrastructure provisioning and streaming technology. Added with the platform requirement, there isn't many companies providing this service yet. Large enterprises such as Google and Microsoft are already in the game and offers subscription services to the consumers.
Supplier power	2	From the required resources, there are various cloud providers that offers virtual instance with GPU. However, a willing company still required to develop their own platform for customer access.
Buyer power	0	In the few years after the game streaming has been released to the public, the traction isn't going well due to limitation in the network services. Consumers can't afford the expensive 5G or high bandwidth fiber optic network service, hence holding back the business in general.

[64] https://www.researchgate.net/figure/Bandwidth-requirements-recommendations-for-various-video-on-demand-and-cloud-gaming_tbl1_326430239

Competitive forces	Level	Reasoning
Threat of substitution	1	Game streaming may change the gaming industry entirely. Company such as Sony, Microsoft, and Nintendo which relies on part of business in selling gaming hardware will have to change the strategy. Instead of being substituted, game streaming will substitute the existing business model of console and PC gaming.
Threat of new entry	1	With the barrier of entry mostly in technical capability and platform development, entering this business is tough. The service itself also requires the service provider to have agreement with the game publisher to provide the game for the consumers.

Based on the maturity analysis above, total maturity score of the technology is 5 which means that the technology is considered early adopter and in growth diffusion phase.

Product Lifecycle Phase	Introduction			Growth			Mature						Decline		
Score	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Diffusion of innovations	Innovator		Early Adopters			Early Majority				Late Majority				Laggards	

3.7.4. Relevance

Since the gaming service mostly requires proper network connection, IOH can treat this as an opportunity to provide reliable network service for the gamer segment. Utilizing traffic signature, network slicing, and upcoming 5G capability, IOH can provide a mobile data subscription to fulfill gamer segment demand for high speed and low latency connection, making this technology a relevant for the upcoming 5G service offering. IOH might want to move and partner with the upcoming cloud gaming service provider in Indonesia for the first step toward maximizing gamer consumer segment in mobile data subscription.

Aside from the network aspect of the cloud gaming service, IOH should focus on developing mobile edge computing (MEC) service to specifically serve cloud gaming use case since the MEC is required to cut amount of data travel time from the users to the game server's environment. Also, using MEC will massively boost the potential lags and provide significant amount of backbone cost saving for the data carriers.

3.7.5. Implementation and Use Case

Since cloud gaming service mainly relies on network and platforms, the use case for cloud gaming will be seen from network perspective and the business model itself.

3.7.5.1. Gaming Network Slicing in 5G

With the capability of 5G network, telco provider such as IOH have potential to develop specific network slice exclusively to handle cloud gaming traffic. The monetization comes from providing channel to cloud gaming service provider and creating specific data package for 5G mobile data subscribers. [65]

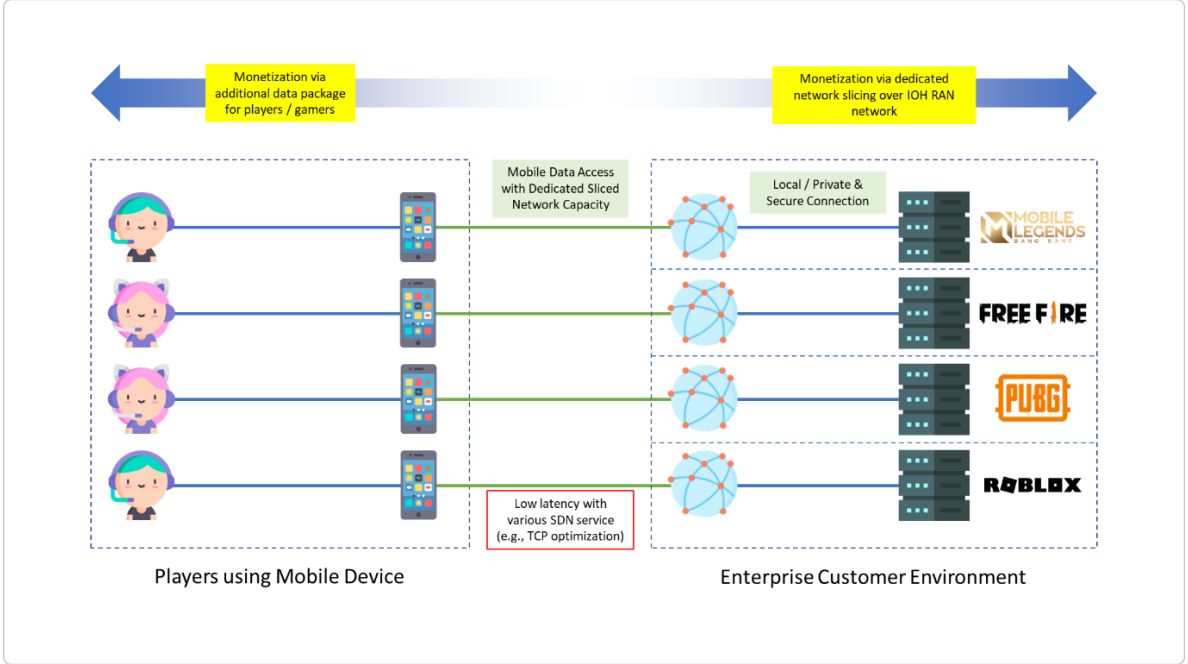


Figure 3.7.6. 5G Network Slicing for Gaming Service

To implement this use case, IOH required to have direct connection to the gaming service provider infrastructure (located in cloud provider data center or gaming service provider data center) integrated with the existing 5G network infrastructure. In the IOH side, a firm backbone capacity planning is required in the area with high-density of gamer users.

3.7.5.2. Game Streaming

The state-of-art gaming services implemented by utilizing GPU virtual memory reservation to render game played by the consumer. The challenge in game streaming implementation is to adjust amount of required GPU virtual memory and other virtual resources reservation based on the games played by the users. To ensure lowest cost, the game streaming platform required to adjust accordingly required GPU virtual memory based on maximum amount required by the game

[65] https://www.ericsson.com/en/blog/2021/9/cloud-gaming-enabled-by-5g-and-end-to-end-network-slicing

played and ensure that the server location is close to the user's proximity. For this use case, it is recommended to distribute the data processing and image rendering to the Mobile Edge Computing (MEC) nodes located in the data carrier or ISP location for significant reduction in both latency and network stability.[66]

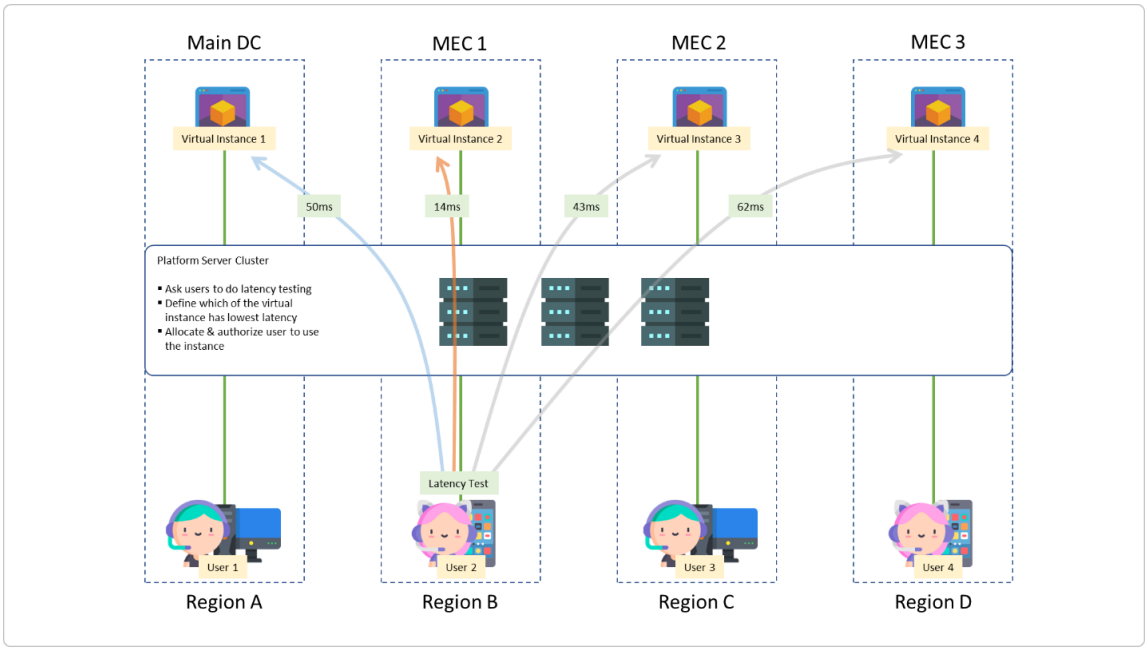


Figure 3.7.7. Game Streaming Use Case with Mobile Edge Computing (MEC)

From the telco perspective, accommodating game streaming service is in line with the 5G network slicing for gaming segment as stated in the previous use case. However, both telco provider and service provider need to ensure that the segment purchasing power can purchase both subscriptions required to enjoy the best experience. Telco providers might want to consider developing MEC functionality in their GGSN node to capture game developer market that interested in game streaming business.

66 Zhang, Xu et al., "Improving Cloud Gaming Experience Through Mobile Edge Computing", IEEE Wireless Communication, 2019 https://vision.nju.edu.cn/_upload/article/files/a3/0d/e342067a4b2b94d401d8780af13c/c27e6018-c7a9-49f7-aa34-116f2df6391a.pdf

3.7.5.3. Online Gaming Library

Another possible trend of Cloud Gaming service is a subscription-based, online gaming library. Simpler than game streaming service, online gaming library allows the users to download, install, and play the game within library any time if the subscription is active.

Compared to game streaming, online gaming library puts the game rendering processing in the user's side and does not require advanced infrastructure requirement or high-performance network support. Instead of requiring high bandwidth, low latency network – online gaming library requires large traffic transmission within a short time to download the required files for the games. While this requirement can be covered easily using content distribution network located near ISP / telco provider gateway site – ISP / telco provider might want to set up specialized data subscription package and backbone to cover these large file access.

3.7.6. Market Size

Currently there are no specific market size forecast specifically for Cloud Gaming service. Based on Statista, with the CAGR of 9.5%, worldwide video gaming market size in general is forecasted around 268.6 Bio. USD in 2025.

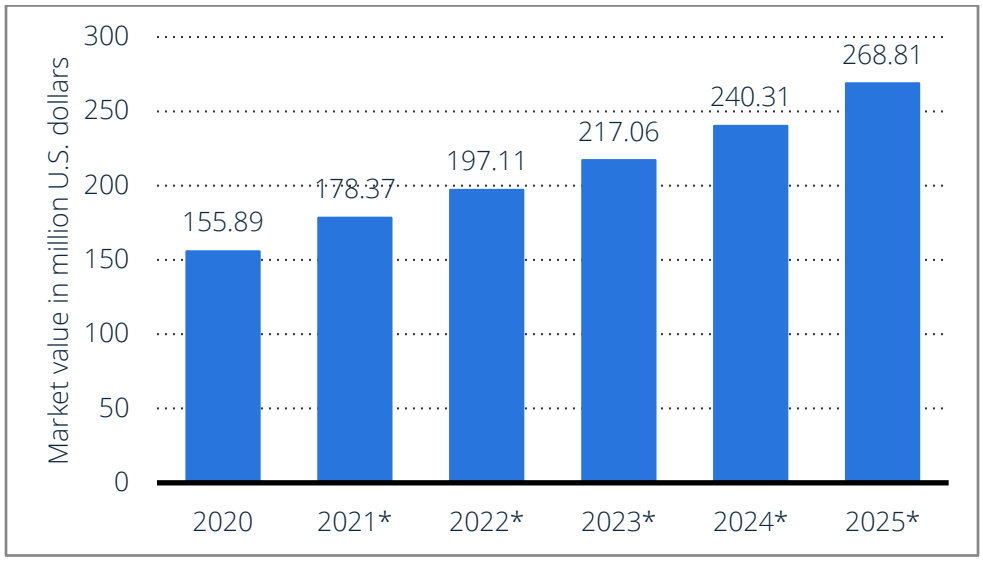


Figure 3.7.8. Video Game Market Size[67]

[67] https://www.statista.com/statistics/292056/video-game-market-value-worldwide/

Since the number considers purchase of console gaming, video game ads spending, and online game calculation, further research is required to pinpoint how big is the converted market when Cloud Gaming becomes publicly available when the infrastructure can cover the requirement.

3.7.7. Market Segment

Since gaming service is an entertainment service with primarily consumer as target market segment, instead of the market segment part will focus primarily what type of enterprise in the Gaming industry

1. Enterprise or company that owns dedicated game developer and has capability to develop and release their own game
2. Enterprise or company that understand monetization process of game and has well-known reputation as video game publisher or has capability to release its own game console
3. Enterprise or company that has marketplace platform and hold license to sell game from other publisher or developer

Based on the criteria, our analysis of market segment and potential customer is shown in following table:

Segment	**Media & Entertainment**
Criteria 1	Game Developer
Criteria 2	Game Publisher
Criteria 3	Game Store / Distribution Service

3.7.8. Technology Solution Provider

To support the requirement for Cloud Gaming Service, various technology and components are integrated depending on the use case implemented. Following list of technology solution provider is included in deploying Cloud Gaming Service, each with its own distinct specialization and technology.

Table 3.7.3. Providers of Cloud Gaming Service

Companies	Solutions	Scale (Local/Global)
Hyperscalers (GCP, AWS, Alicloud, Azure)	Hyperscaler that sells on-demand or dedicated virtual resource is the main component on providing base infrastructure for the Cloud Gaming Service. Since the game streaming requires virtual instance with GPU and automation capability, GCP and AWS can provide these instances seamlessly using API interfacing. IOH might want to settle partnership to deploy future MEC nodes for better network and infrastructure performance.	Global
CDN Provider (Akamai, Limelight, Cloudflare, etc.)	CDN provider with global network reach has capability to do large file caching service to improve customer's experience for downloading game or updates / patch. IOH might want to have partnership with these CDN provider to improve mobile data consumer experience in gaming and gain significant cost reduction in transport network capacity.	Global

Companies	Solutions	Scale (Local/Global)
Microsoft	Microsoft is considered as one of the game publishers that focuses on PC game and running its own game console called Xbox. Right now, Microsoft is running the beta version of online game library called Xbox PC pass in certain country and might shape the future of game retail industry.	Global
Sony Entertainment	As a competitor of Microsoft, Sony Entertainment is a game publisher that focus on gaming console called Playstation(PS). With the affiliation of various game developer around the globe, Sony Entertainment serves wide range of gamer from casual to hardcore. Currently Sony Entertainment PS plus as online gaming library service and PS now as game streaming service.	Global
Skyegrid	Skyegrid is the first game streaming service in Indonesia. Utilizing GCP servers in Singapore, Skyegrid provides a dedicated virtual machine to render and stream the game for their customers. Skyegrid currently uses Steam as a platform to run various game in the provisioned virtual machine with a preloaded game library to be used by customers.	Global
Google Stadia	Google Stadia is the first global game streaming service released back in late 2019 and remains active until now. With subscription-based model, Google Stadia provides game streaming services in a unique fashion using special controller provided only to subscribers. The downside though, Google Stadia only available in certain country in US and Europe.	Global

4. Recommendations

4.1. Connectivity

As the first commercial 5G deployments are focused on enhanced mobile broadband (eMBB) use cases, the future is gearing up for use cases characterized by ultra-high reliability and low-latency features. Low latency is seen as a crucial ingredient for ensuring usable and interactive applications whether communication is human-to-human, human-to-machine, or machine-to-machine. Based on Telecom.com survey results of 344 professional industries worldwide in 2020, the strongest attraction for enterprise businesses based on the three pillars of the 5G technology service category is ultra-reliable and low-latency communications (URLLC) with 47% of respondents responding that way. URLLC enables specialized industrial services, such as autonomous vehicles and manufacturing automation control.

To implement this 5G-based technology, there are still many challenges to be faced. Significant design, frequency spectrum selection, government regulations, standardization (infrastructure and devices), engineering challenges and what kind of business model is expected by each stakeholder involved in this business (MNOs, equipment vendors, device/application vendors, enterprises, and government) are being overcome to deliver a reliable and low-latency network. Good communication and collaboration between all stakeholders will be very helpful in finding solutions to all the challenges faced so that URLLC technology can be delivered and used properly by enterprise customers.

On the other hand, as newer and better data technologies continue to emerge, more advanced database technologies will also emerge to keep pace with the challenges of fast-growing business Data Management. Today's data is not only high-speed and high-volume, but also multi-channel, sensor-driven, and complex. Thus, database technology must match the needs of advanced data analytics and BI in the enterprise. We are in an era of artificial intelligence that offers the potential for deep learning to uncover new patterns and provide insights that will drive innovation in the future. Deep learning, however, requires data, a lot of data and the more examples of traits or relationships that can be identified, the more accurately deep learning can pick out patterns. Graph technology is perfect for this – its expressions are ideal for creating business logic algorithms (network analysis, abnormal pattern matching, community detection) across complex data. Graphs are better at representing relationships between concepts than their relational database predecessors. If an organization's data has many many-to-many relationships or even one-to-many relationships that have a depth of three or more, the organization strongly recommends using a graph technology.

MNOs like IOH need to consider the reliability of this technology and encourage their enterprise customers to apply graph technology to their business. Of course, IOH needs to know the details of the business needs of each enterprise customer because not all enterprises require the same type of graph technology.

4.2. IoT

IoT business is projected to show rapid growth of use for the next few years. It has the capabilities to be utilized for many use cases, covering more vertical segments. The important note of adopting these technologies focuses more on operating model possibilities and ecosystem governance.

There are several steps required to move towards becoming an orchestrator platform. IOH as a telecommunication company can start by leveraging the core connectivity capabilities such as having strategic partnership with the right IoT key players both local and global. Then IOH should explore use cases in every single vertical while also emphasizing the security of IoT perspective and future trends. Eventually, IOH can play as an orchestrator platform with building cross-industry use cases. Of course, IOH must show the *unique selling points* (USP) among product propositions that it offers to the market.

Adopting blockchain, IOH needs to collaborate across sectors to maximize the potential of blockchain and hyperscallers including vertical apps providers that will likely drive new revenue streams for the business. The collaboration is necessary to tackle the challenges of blockchain (decentralized) and to keep up with the latest innovation coming up in the future. This can be done not only by collaborating with the big companies within the industry, but also with small medium enterprise (SME) and start-ups that are potentially more agile and innovative. Moreover, IOH should also explore more use cases from blockchain and do an assessment/trial/PoC to select respected use cases that bring more value to customers.

4.3. ICT & Cloud

As both consumer and enterprise segment embracing the upcoming 5G technology, IOH needs to develop an out-of-the-box packaging or method for 5G consumption in both segments. This is where the upcoming Metaverse and Cloud Gaming segment kicks in and helps in accelerating 5G consumption. As the topics discussed in the ICT & Cloud segment, most of the 5G consumption is driven through the needs of high bandwidth streaming or file access service with low-latency and jitter become mandatory requirement. To fulfill these requirements, telco need to be aggressive in reducing physical limitation of network such as closing the location gap and improve the backbone capacity.

Technology	Recommendation	Challenge	Mitigation / Workaround
Metaverse	Embrace the Metaverse concept and technology both for internal and external usage by providing best in class connectivity	▪ Limited technical capability to handle Metaverse technology ▪ Finding right business model for enterprise customer ▪ Lowering entry barrier for consumer-level Metaverse service	▪ Develop partnership with Metaverse and hardware providers to minimize technical load on IOH side ▪ Learn-by-experience to develop business model for both enterprise and consumer ▪ Develop readiness for edge computing capability in both

Technology	Recommendation	Challenge	Mitigation / Workaround
			infrastructure and network level[68] ▪ Ensure security aspect for Metaverse implementation and take advantage of analytics and AI technology to bolster revenue sources
Cloud Gaming Service	Treat Cloud Gaming Service as a new potential revenue source for IOH from both enterprise and consumer segment	▪ Develop gaming-specific service for the consumer segment ▪ Create relationship and provide required service for Cloud Gaming Service provider for B2B business	▪ Develop partnership with global provider to provide required service by Gaming Service Provider such as Mobile Edge Computing and CDN service ▪ Establish direct network connection with the Cloud Gaming Service provider for upcoming 5G network slicing service

In case of upcoming Metaverse technology, the economics of scale will take a while to develop due to high investment entry barrier in the user side. As we know, not all people can afford VR headset and personal computer with middle-high end spec to comfortably use Metaverse daily. The users also must consider the recurring cost of fiber internet or mobile data package subscription to run voice and video chat over VR. In this scenario, IOH should look to develop the Metaverse together with certain partner to open business opportunity for both enterprise (e.g., creating a rental, Metaverse location-as-a-Service) and consumer (e.g., specialized 5G package with direct access for low latency communication) segments.

Cloud Gaming technology has been around for a long time, and it just keeps improving. Moving on from the legacy, offline gaming store into an online marketplace or video game rental service, Cloud Gaming is ready to break the entry barrier by eliminating the investment cost for the consumer to experience the content. This comes at a cost though – the required connectivity standard went from low latency / jitter into massive amount of bandwidth to stream required video resolution

[68] https://www.ey.com/en_sg/telecommunications/seven-ways-telecom-operators-can-power-the-metaverse

5. Abbreviation

3D printing	*Three-dimensional printing*
3GPP	*The 3rd Generation Partnership Project*
4G	*4th Generation*
4IR	*The Fourth Industrial Revolution*
5G	*5th Generation*
5G NSA	*5G Non-standalone*
5G SA	*5G Standalone*
5GC	*5G Core*
AAA games	*Triple-A games*
AGV	*Automated Guided Vehicle*
AI	*Artificial Intelligence*
APAC	*Asia-Pacific*
API	*Application Programming Interface*
AR	*Augmented Reality*
ATM	*Automated Teller Machine*
AWS	*Amazon Web Services*
B2B	*Business to Business*
B2C	*Business to Consumer*
CAGR	*Compound Annual Growth Rate*
CD/DVD	*Compact Disk/Digital Versatile Disk*
CDN	*Content Delivery Network*
COVID-19	*Coronavirus disease*
CSP	*Communication Service Provider*
DDoS	*Distributed Denial-of-Service*
DeFi	*Decentralized Finance*
DL	*Downlink*
DSS	*Dynamic Spectrum Sharing*
DT	*Digital Twin*
E2E IoT	*End to End Internet of Things*
ECG	*Electrocardiogram*
eMBB	*enhanced Mobile Broadband*
ESB	*Enterprise Service Bus*
eUICC	*Embedded Universal Integrated Circuit Card*
FDD	*Frequency Division Duplexing*
FR 1	*Frequency range 1*
ICT	*Information and Communications Technology*
ID	*Identity*
IOH	*Indosat Ooredoo Hutchison*
IoHT	*Internet of Healthcare Things*
IOT	*Internet of Things*
IP	*Internet Protocol*
ISP	*Internet Service Provider*
IT	*Information and Technology*
KPI	*Key Performance Indicator*
LTE	*Long Term Evolution*
M2M	*Machine to Machine*
MEC	*Multi-access Edge Computing*
MIMO	*Multiple Input, Multiple Output*
MIoT	*Internet of m-health Things*
ML	*Machine Learning*
MMORPG	*Massively Multiplayer Online Role-Playing Game*
mMTC	*massive Machine Type Communications*
mm-Wave	*Millimeter wave*
MNO	*Mobile Network Operator*
MTDC	*Multi-Tenant Data Center*
NR	*New Radio*
OLT	*Optical Line Terminals*
ONU	*Optical Network Units*
OTT	*Over The Top*
PoC	*Proof of Concept*
QoS	*Quality of Service*
R&D	*Research and Development*
RAN	*Radio Access Network*
RDBMS	*Relational Database Management System*
RDF	*Resource Description Framework*
SDK	*Software Development Kit*
SIM	*Subscriber Identification Module*
SPARQL	*SPARQL Protocol and RDF Query Language*
SQL	*Structured Query Language*
TDD	*Time Division Duplexing*

FR 2	*Frequency range 2*
FSI	*Financial Services Industry*
FWA	*Fixed Wireless Access*
GCP	*Google Cloud Platform*
GDP	*Gross Domestic Product*
GDPR	*General Data Protection Regulation*
GGSN	*Gateway GPRS Support Node*
GPU hardware	*Graphics Processing Unit hardware*
GSMA	*Global System for Mobile Communications*
UE	*User Equipment*
UL	*Uplink*
URI	*Uniform Resource Identifier*
URL	*Uniform Resource Locator*
URRLC	*Ultra-Reliable Low Latency Communications*
US	*United States*
USP	*Unique Selling Points*
VR	*Virtual Reality*
W3C	*World Wide Web Consortium*
WFA	*Work-From-Anywhere*

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