Santander X Innovation Xperts

Infrastructure, hardware & IoT:

key opportunities in industry and services 4.0

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By Santander

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01 Introduction

This paper aims to provide a qualified assessment on promising opportunities stemming from the Internet of things (IoT) eco-system in the short and medium run, with the final purpose of investment advice and jobs and firms' creation in the area. Forecasting, or simply projecting future developments of information technologies is more art than science, so many of our statements carry a high degree of uncertainty and caveats. Nevertheless, we hope that this research piece, based on a critical review of the main statistics and market and economic reports, interviews with experts on the field – developers, entrepreneurs and venture capitalists – and our own experience in IoT business, policymaking and economic analysis, allows having a clearer picture of the IoT sector in a 3-7 years' time horizon.

We will focus on IoT – simply put, *solutions based on machines talking to machines* – and its interplay with other IT developments (hardware, software, services) from a global perspective, although we will present some particular features and challenges for middle-income countries.

The report devotes section 2 to a detailed description of the different components, and connectivity and communication foundations of IoT. This aims not only to clarify some concepts, but more importantly to identify more easily business and investment opportunities oftentimes blurred under the IoT label. As we will stress, IoT is much more than devices, including in the same level of importance communications, computing and analytics. Section 3 describes IoT market and enterprise dynamics, using a variety of well-established sources. Again, caveats apply as most of them use different definitions and oftentimes various concepts. We complement this section with a view on the economic and competitive context, including big technology firms' moves along the digital ecosystem. Section 4 provides a qualitative panorama of a wide set of opportunities according to connectivity speeds. We then focus on three

areas where we see more potential and are less overcrowded in our view: urban planning and smart cities solutions, automation, and health-care. We report numbers on these IoT trends based on analyst's projections up to 2030 in section 5, including market size and maturity judged by on our own criteria. This allows forecasting a solid -but not exponential- growth rates for IoT in most segments.

The challenges, ranging from energy use to data (privacy, security), platform fragmentation, connectivity and scalability are described in section 6. Finally, following the interconnections that exist between technology, society and planet, section 7 closes the paper describing some of the most promising *green* IoT innovations.

Overall, our analysis is cautiously optimistic on IoT. Indeed, IoT solutions with the goal to make our habitats more inclusive and sustainable, our lives easier and healthier, and production smarter and more efficient are flourishing worldwide. But our reading of the evidence also recommends a significant dose of realism, as, so far, the IoT market has failed to deliver the results expected only a few years ago. The current economic and financial context reinforces this assessment.

02 IoT basics

***IoT Definition*. The Internet of Things (IoT) connects the digital and physical worlds by collecting, measuring, and analyzing data to predict and automate business processes. It refers to products connected to a network, such as the Internet, a company intranet, or a network using industrial communication protocols. IoT devices can be anything, from a smart phone to a wind turbine to a refrigerator, as long as they communicate to a "home base" to send or receive data. Data can be used to improve the technical characteristics or the usability of a product or to offer new services to customers, or it can be sold to a third-party[1].**

2.1 IoT economic impact.

IoT can serve various purposes, but the majority of them occur in real-time and increase the automation process in factories processes and services in cities. Its economic rationale is driven by three main reasons:

I. **Increase productivity:**

   Machines can communicate with one another to be significantly more efficient and yield better, faster outcomes.

II. **Reduce costs:**

   IoT improves the efficiency of the systems, saving time and energy.

III. **Retain customers:**

   In real-time, firms can readily access data and information, helping to adapt the solutions to increase the quality and customer satisfaction.

1. Deloitte (several years), Deloitte Insights. Last accessed October 2, 2022.

2.2 IoT basic components

IoT goes well beyond connected devices, and investment opportunities and market dynamics should be analyzed considering its full value chain. Based on the taxonomy devised by ITU and on analysis performed by I-Scoop[2], this value chain and interplay with the digital eco-system includes:

I. **Things.**

Anything that can be tagged or connected, from sensors and household appliances to tagged livestock. Devices can contain sensors, or sensing materials can be attached to devices and items.

II. **Connectivity is IoT core.**

Connection at various levels is needed given the number and plurality of IoT devices, sensors and other electronics, connected hardware.

III. **Communication.**

Devices get connected so they can communicate data. Communication can occur over short distances or a long-range to very long-range—examples: Wi-Fi (wireless fidelity), LPWA (low-power wide-area network), technologies such as LoRa (long range), or NB – IoT (narrow band internet-of-things).

IV. **Data.**

Is the glue of the Internet of Things, the first step towards action and intelligence.

V. **Intelligence.**

Developed from IoT devices' capabilities, and from big data analytics (also artificial intelligence).

VI. **Action.**

Manual actions or automatic decisions based on data, and alerts like those that happen in a smart factory, by automation.

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2. I-Scoop (several years): Reporting on digital transformation, Industry 4.0, Internet of Things, and emerging technologies in context. Last accessed October 2, 2022.

VII. **Ecosystem.**

The place of the Internet of Things from a perspective of other technologies, communities, goals, and the picture in which the Internet of Things fits – the Internet of Everything dimension, the platform dimension, and the need for solid partnerships.

2.3 IoT devices

Probably the most popular part of IoT, also display a very rich variety, including according to ITU:

I. **Data transport device.**

Attached to an object to connect it with communication networks (e.g. modems).

II. **Data acquisition devices.**

That read/write and have the ability to interact with physical objects; for example, dataloggers that measure temperature in vaccines, and transmit the data through a modem to the cloud.

III. **Detection and actuation devices.**

That detect or measure information from its environment and convert it into electronic signals. They can also convert electronic signals from communication networks in operations. For example, a temperature sensor that, according to parameters, activates a valve.

IV. **Generic devices**

With processing and communication capabilities can communicate to a network using wired and wireless technologies, among which equipment and applications of various ranges can be found, such as industrial machines, appliances, and smartphones.

2.4 IoT and other technologies.

IoT is related to other technologies, and, in our view, this is where most of the value-added is created leading to significant synergies. In particular, following International Data Corporation's four pillars[3], IoT contributes and relies on:

I. **Big data and analytics.**

   That enable real-time decision-making and provide the engine for powering new data sources.

II. **Cloud.**

   To allow for variable workloads from connected endpoints and the scalability and flexibility crucial for the deluge of data expected from these endpoints.

III. **Mobile.**

   To enhance field processes and connect endpoints from various (often remote) locations.

IV. **Social**

   To provide an outlet for automated responses from the connected endpoints to interested end-users or decision-makers.

2.5 IoT classification according to enabling technology

IoT can be classified among the so-called *enabling technology and services* according to GSMA (2022)[4], a segment which comprises a great variety of services generally not that visible to users but essential to the Internet infrastructure and online services, along with the aforementioned cloud, analytics or advertisement, among others (Table 1).

3. Yashkova, and A. Das (2022), IDC's Worldwide Internet of Things and Intelligent Edge Infrastructure Taxonomy. IDC, Doc # US49027022.

4. GSMA (2022), The Internet value chain. Kearney and GSM Association, London.

Table. 1

The Internet value chain

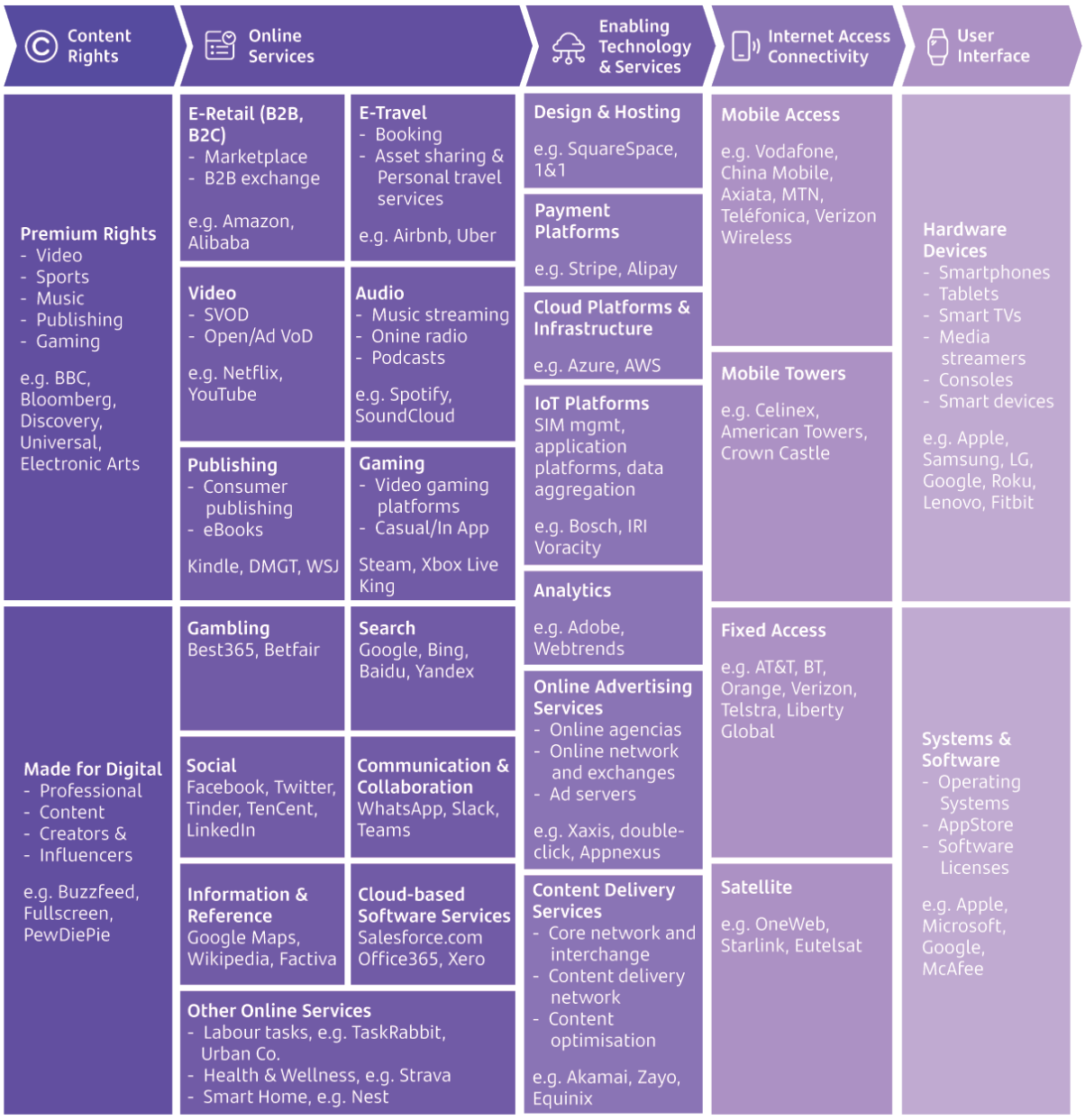


Table 1: Source. GSMA (2022), The Internet Value Chain

03 IoT market evolution: from noise and hype to (solid) fundamentals

Market size projections and even estimates on the size of the market today or the number of connected devices vary significantly among different sources.

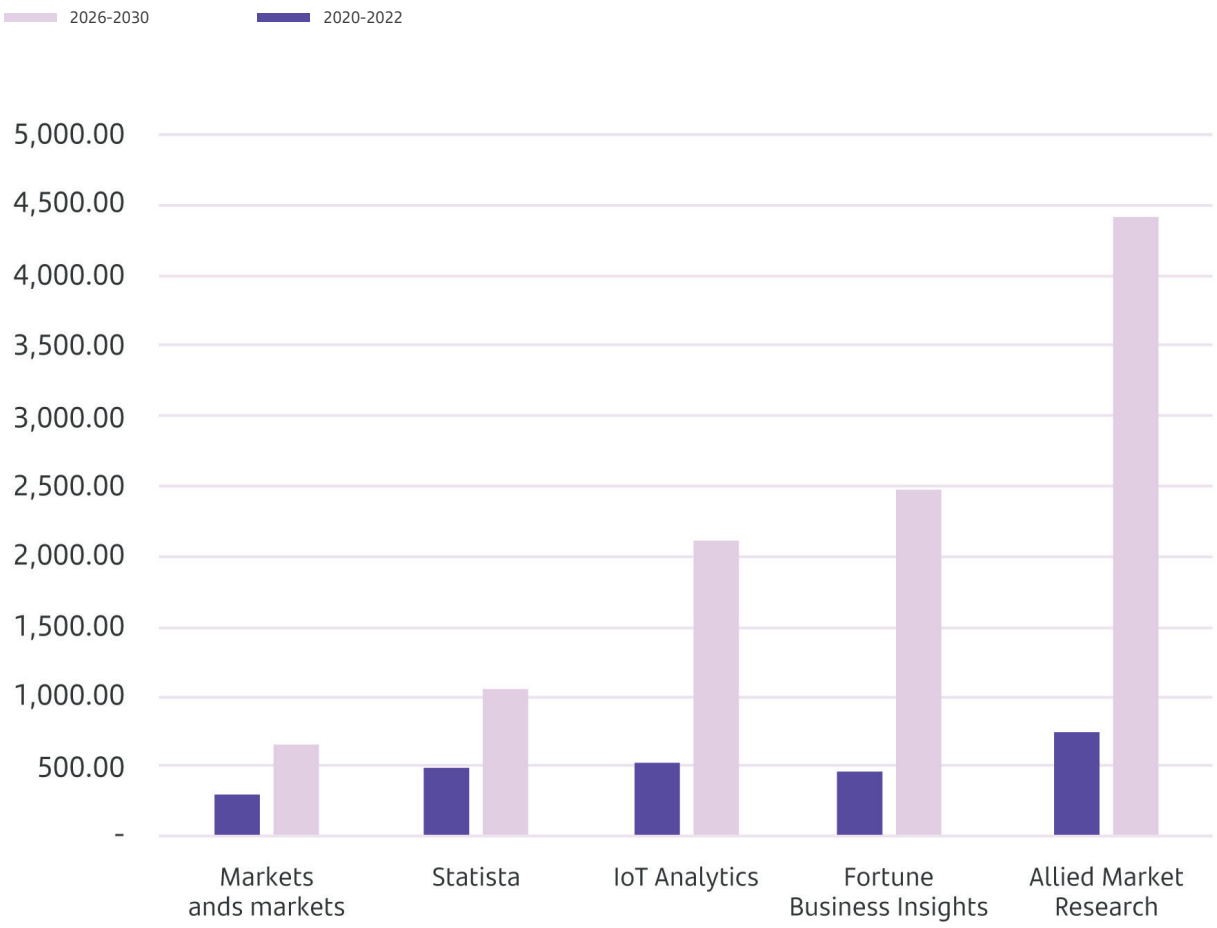
To have an order of magnitude of the market size today and its potential, we collected five of the most respected sources followed by investors, namely Allied Market Research, Fortune Business Insights, IoT Analytics, Market and Markets, and Statista[5] (see Figure 1). On the lower bound, according to Market and Markets, the IoT market size is expected to grow from USD 300.3 billion in 2021 to USD 650.5 billion by 2026, at a compound annual growth rate (CAGR) of 17%. Similarly, Statista projects the IoT market to grow from USD 496.6 billion in 2022 to 1,058.3 (CAGR 11%), that is doubling the market size in 10 years.

On a more bullish side, IoT Analytics forecast the IoT market size to grow from $525 billion in 2022 to 2,111.9 in 2027 (CAGR 22%). Fortune Business Insights projects a growth from $478.4 billion in 2022 to $2,465.3 billion by 2029 (CAGR of 26%). Finally, Allied Market Research valued the IoT market at $740.4 billion in 2020, and is projected to reach $4,421 billion to 2030 (CAGR 20%). Additionally, GSMA (2022) estimates of the mobile connected IoT show a 16% CAGR. This trend is more dynamic than the other enabling technologies and services, and slightly over the overall Internet value chain growth (15%). But indeed, much less dynamic than online services which showed a 57% annual growth in the same period, led by ecommerce and advertising, and more recently gaming.

5. Statista (2022), "Internet of Things (IoT)". Digital and Trends presentation.

Figure. 1

IoT total annual revenue estimates and projections (billion USD)



In sum, the IoT market today is valued at USD 300-700 billion, and will become a USD 1-3 trillion market by 2030 thanks to solid, but not exponential growth rates. Like others, it has a lot of challenges to overcome like cybersecurity risks, deployment, and interoperability (more on this in section 5). We will use Statista for the rest of the report, given its richness by sectors and geographies (Figure 2).

Figure 1: Source. Own elaboration based on analysts' reports

Figure. 2

IoT total annual revenue worldwide projections, Statista

Internet of Things (IoT) total annual revenue worldwide from 2019 to 2030 (in billion U.S. dollars)

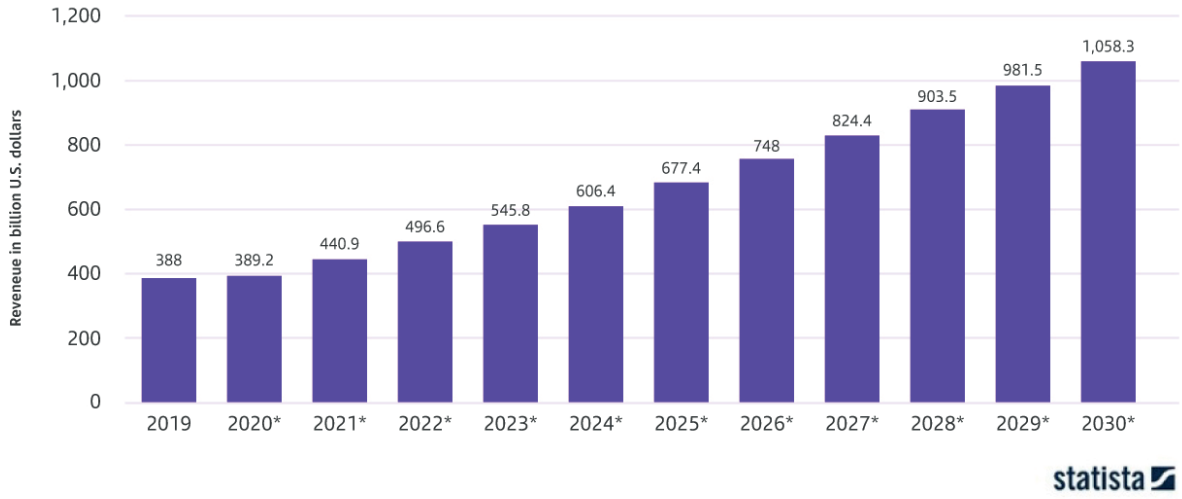
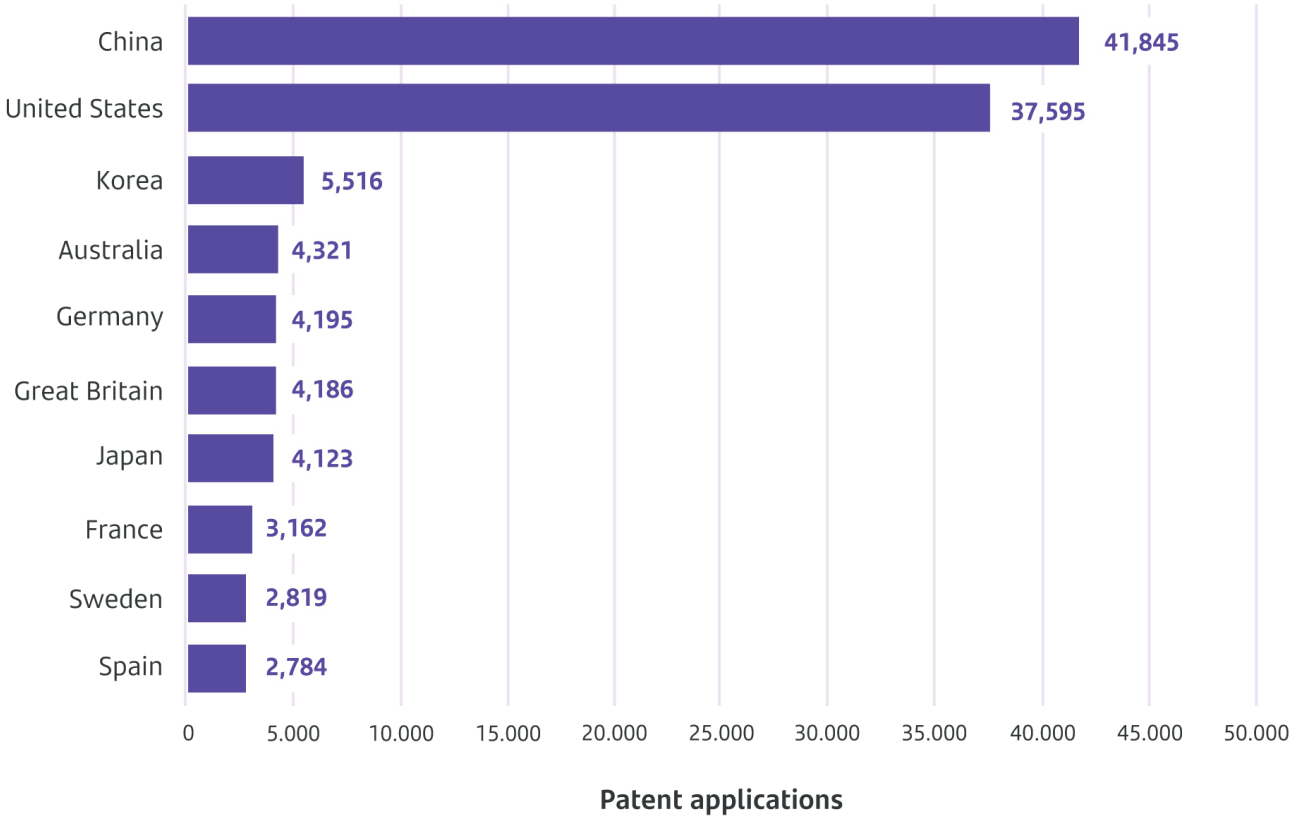


Figure 2: Source. Statista (2022). Note(s): Worldwide; 2019 to 2020; *Forecast. Source(s): Transforma Insights

In terms of regions, using patents as a proxy, the largest market is China, followed by the US, Korea and Europe (see Figure 3). Acknowledging many of the limitations of patent statistics, we find this could give investors an additional foundation to judge the IoT projects of small capitalization and relatively low price-to-earnings (P/E) ratio (Hirschey and Richardson, 2004)[6]. Information at company level is limited, notably on China. In spite of that, Table 2 reports the top IoT companies worldwide.

Figure. 3

Number of IoT patent applications worldwide as of 2019, by country



6. Hirschey, M. and V.J. Richardson, (2004). "Are scientific indicators of patent quality useful to investors?", Journal of Empirical Finance, 11(1), 91/107.

Figure 3: Source. Statista (2022)

Table. 2

Top IoT companies worldwide as of 2022

Company	Country	Employees	Revenue (Billion)	Founded
Huawei	China	10.000+	92.6	1987
Bosch (IoT Suite)	Germany	10.000+	78.7	1906
Siemens (IoT Analytics)	Germany	10.000+	71.9	1847
IBM	US	10.000+	60.5	1911
Cisco	US	10.000+	51.5	1984
SAP	Germany	10.000+	30.8	1972
ARM (IoT Security)	UK	5.000-10.000	2.7	1990
iTechArt	US	1.800+	0.54	2002
Vates	US	550	0.07	1991

Table 2: Source: own elaboration based on Bloomberg, Growjo, RCR Wireless news and ARM website.

A glance to the external environment: big tech competition and investment trends

Analyzing big technology firms can shed some light on market changes and (open and missed) opportunities. Again, data is scarce due to the lack of granularity in most public financial reports, so alternative methods should be used. According to a quite innovative analysis by The Economist (2022)[7] exploding data on the number of acquisitions and investments, and words in employees LinkedIn profiles of the *Big Five* (Alphabet, Apple, Amazon, Meta and Microsoft) shows a clear move towards robotics, healthcare, metaverse, fintech, cars, crypto and quantum computing. Therefore, in addition to some core competition (on cloud and advertisement) and some very mediatic moves (streaming and media), the big technology platforms are indeed getting into IoT, or very close to IoT segments.

More broadly, GSMA (2022) report on Internet value confirms Apple, Google and Microsoft are entering the IoT market (Figure 4). This is probably a secondary effect of some strategic moves, but it shows how IoT, not being the core, drives significant synergies with other exponential digital businesses.

Table 2: Source. Own elaboration based on Mobile Magazine (S. Steers)

7. The Economist (2022), "What America's largest technology firms are investing in". January 22.

Figure. 4

Illustration of service portfolios of selected major digital players

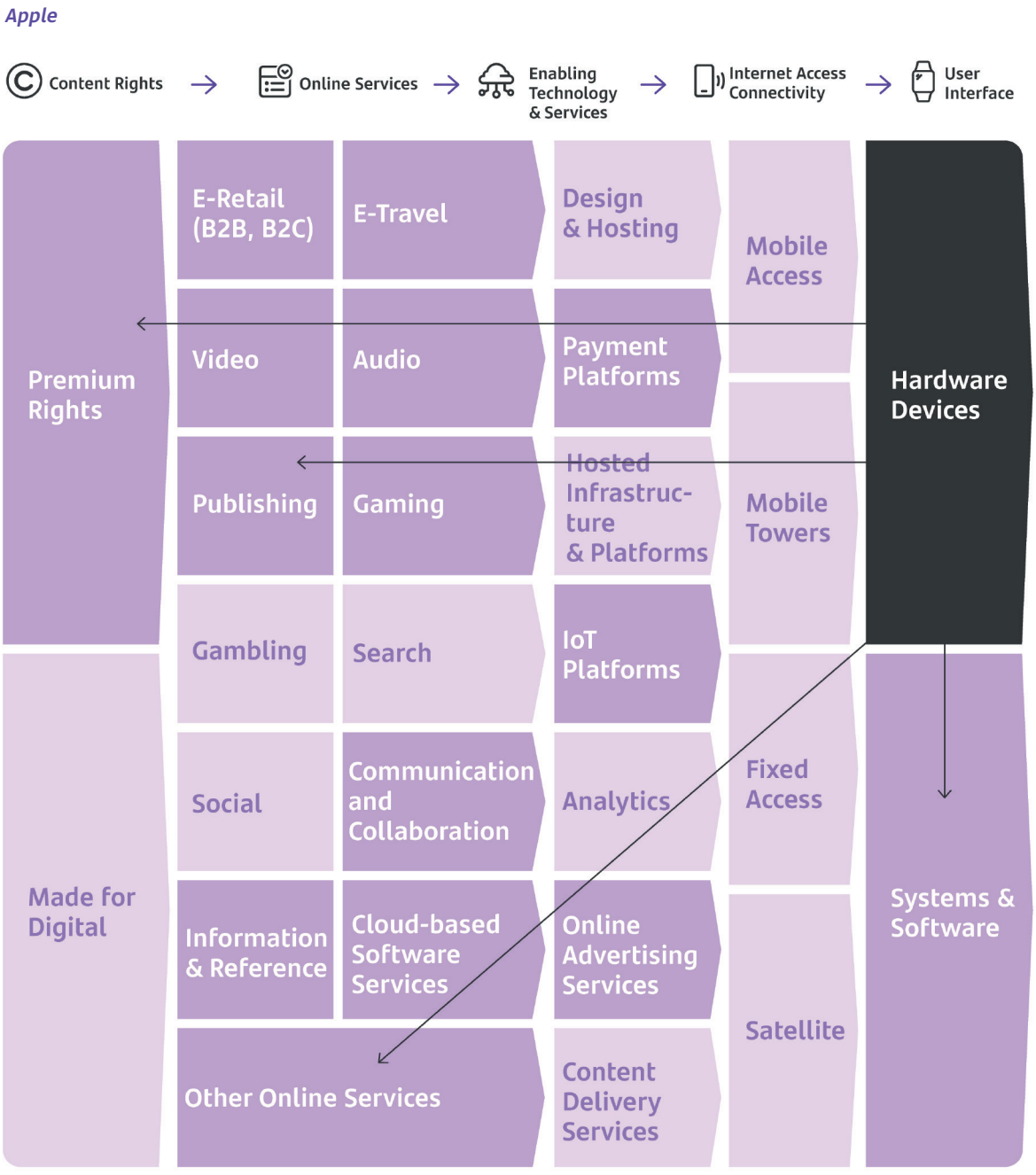


Figure 4. Source: GSMA (2022), The Internet Value Chain

TenCent

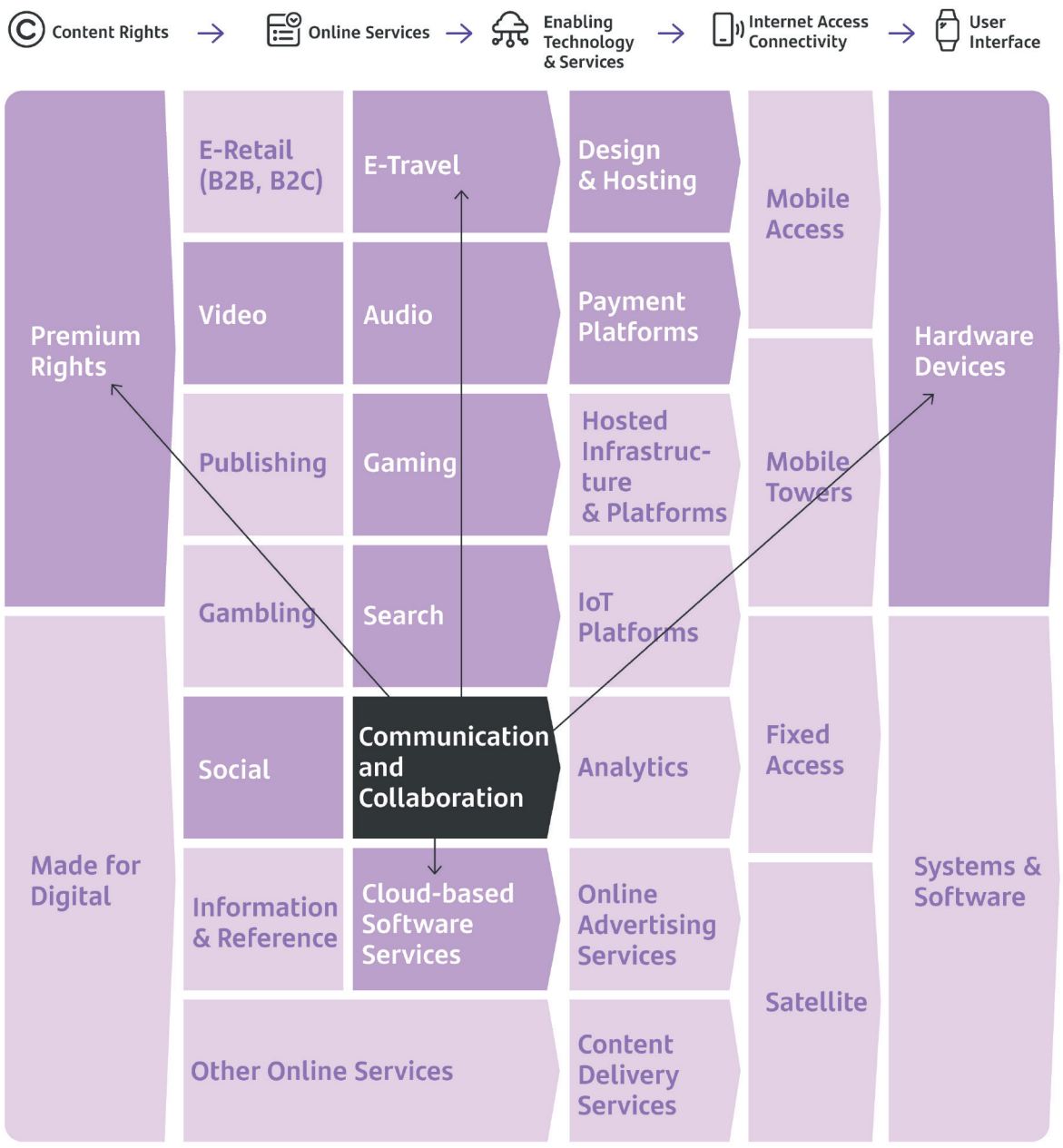


Figure 4. Source: GSMA (2022), The Internet Value Chain

Amazon

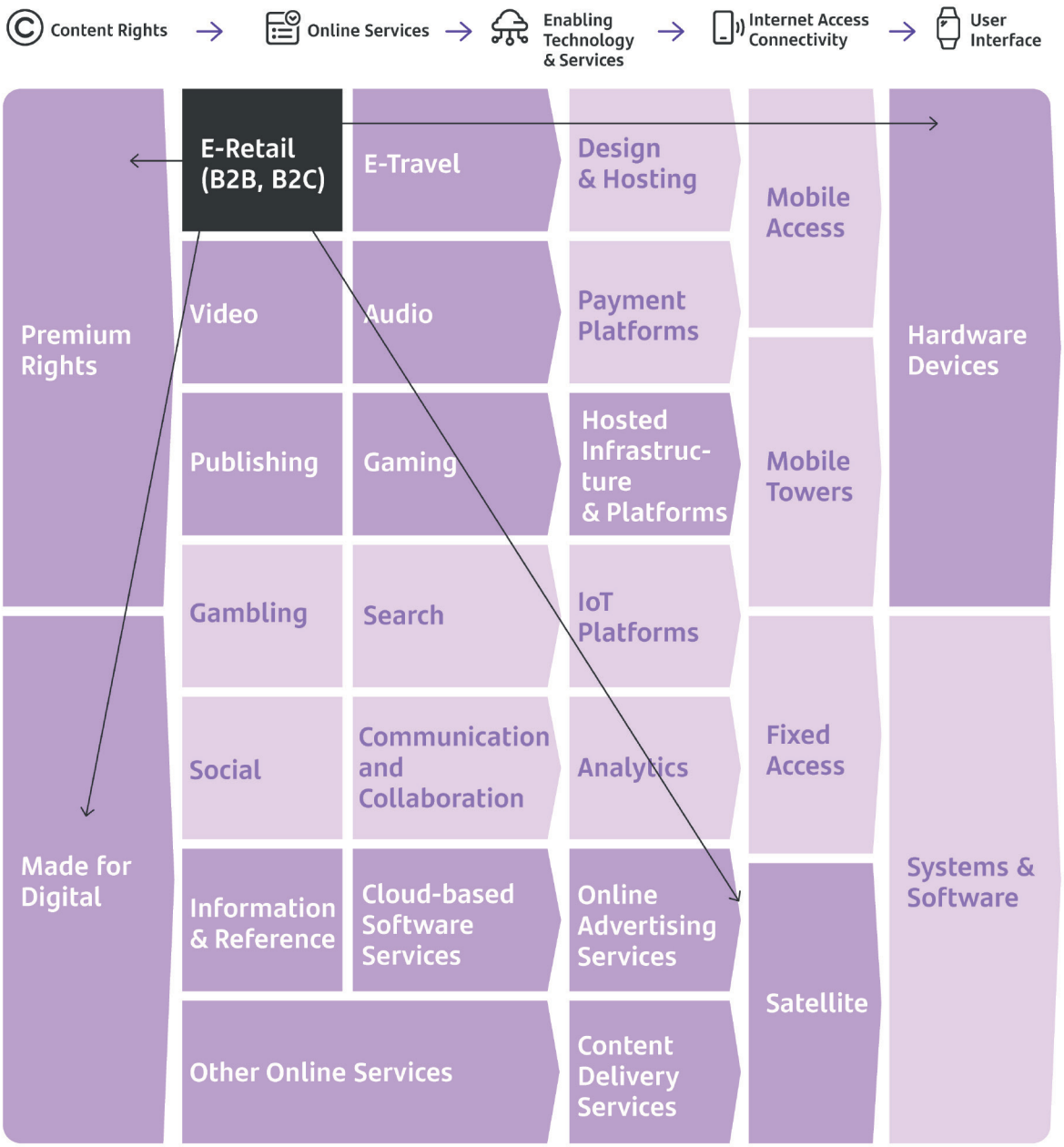


Figure 4. Source: GSMA (2022), The Internet Value Chain

Google

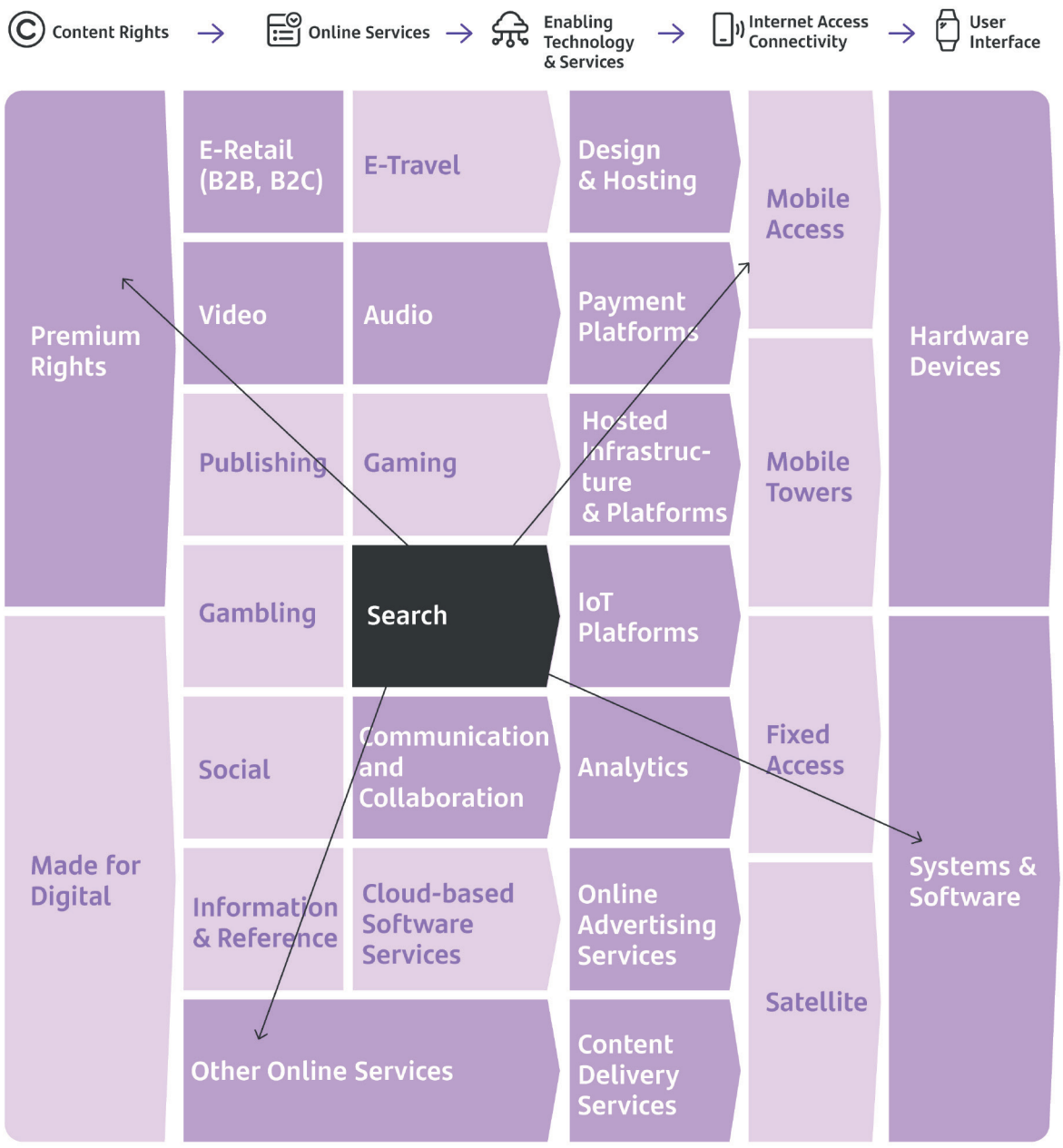


Figure 4. Source: GSMA (2022), The Internet Value Chain

Microsoft

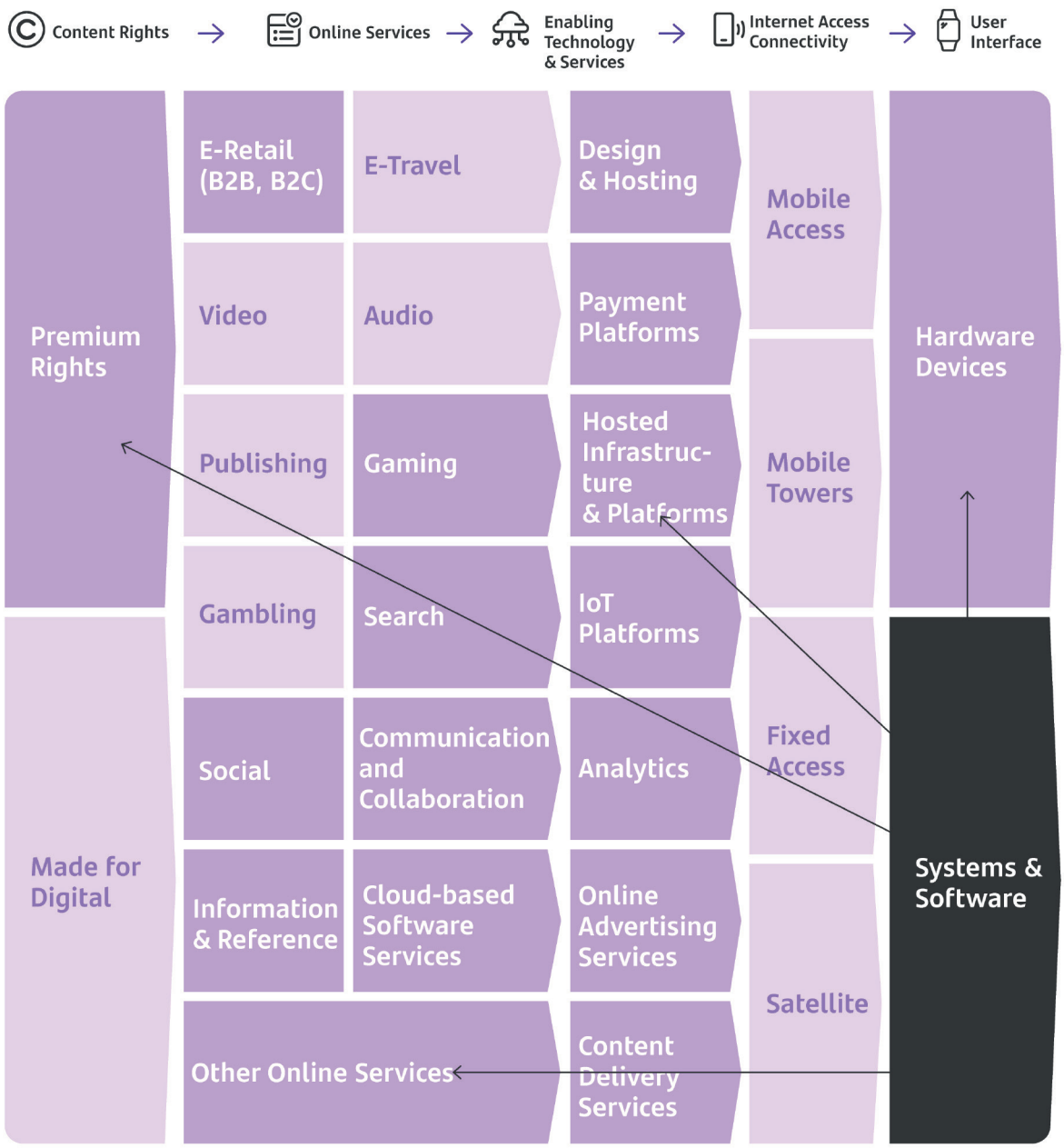


Figure 4. Source: GSMA (2022), The Internet Value Chain

Low-growth rates, high and persistent inflation rates forecasted worldwide anticipate further a persistent tightening of financial conditions globally, with a fly to quality in most investment strategies, both in terms of regions and industries. This will significantly reduce funding for high-risk entrepreneurship, probably demanding in a more traditional way shorter periods before break-even and lower seed capital.

Softbank evolution, beyond the impact of new regulation, is probably one of the clearer examples of the new market tone[8]. According to Reuters, the Japanese giant's founder and CEO Masayoshi Son unveiled on a conference call marking the end of its fiscal 2022 year that the SoftBank group as a whole lost $13.15 billion. Its two Vision Funds, which account for 50 percent of SoftBank's net asset value, alone lost $27.4 billion between them.

For IoT, with its capital-intensive nature and relatively high initial investment requirements in communication infrastructures and devices, the context is not particularly good. But within the digital ecosystem, its more solid trend coupled with the interplays with many of the other services could actually represent an asset. And IoT revenues, once infrastructure is deployed, are recurrent.

8. The Economist (2022), "After a bruising year, SoftBank braces for more pain". May 16; and The Economist (2022), "The great Silicon Valley shake-out". June 28.

04 IoT solutions: identifying opportunities

Recently, Madden (2021)[9] from Mobile Experts completed eight individual vertical market studies in cellular IoT, uncovering different growth dynamics and business models. Different forces drive each individual market, and each market area has its own challenges in regulatory, business model, or technical areas that drive potential

- **Agriculture** has applications on the low-end (moisture sensors) and the high-end (vehicle automation), but growth has been relatively slow.
- **Building Automation** started with smoke detectors and other simple sensors, thanks to significant subsidies.
- **Automotive** infotainment and telematics. Adoption has become standard in most cars. Additional adoption of vehicle-to-vehicle (V2V) communications will come eventually.
- **Asset tracking (Machinery) applications** are growing steadily, but not as quickly as many hoped due to device cost limitations.
- **Smart City** applications have not proliferated. Street lighting has been adopted at some scale, but the shift to multiple applications and use cases has not occurred.
- **Electric utilities** are progressing, especially in China, where state-ordered priorities are strictly followed by water, gas, and electric utilities.
- **Healthcare** applications have rapidly shifted during COVID, with CPAP machines and other monitoring applications booming.

9. Madden, J. (2021), Cellular IoT devices. MEXP-C-IOT-21. Mobile Experts report prepared for Intel Corporation.

- **Consumption.** Simple consumer applications such as white goods have made incredible progress. Smart homes, linked with healthcare applications are probably one of the promising venues, given urban rates and ageing.

As highlighted in section 2, connectivity is one of the four key components of IoT (along with devices, computing and analytics), but contrary to some popular views, low-speed is not a deterrent for many IoT-based solutions. Following Thales taxonomy, solutions according to speed are summarized in Table 3:

Table. 3

IoT-based solutions according to speed

Highest Speed	Mid-Speed Smart IoT	Mission Critical IoT - (multiple users, with different wireless technologies, in the same spectrum)	Small Efficient Data (Energy Efficient Data Transmission in IoT Platforms)
Car infotainment	Telematics	First responder	Tracking
Smart phones	Smart home	Drones / UAV	Connected sensors
Connected gaming	Connected retail	Industrial	Connected agriculture
Computing	Smart metering	Autonomous vehicles	Simple metering
Augmented reality	Smart city	Critical Infrastructure	-
-	Alarm systems	V2X	-
-	E-health	-	-

Potential IoT use cases

IoT solutions impact many sectors, supported in the analytics of the information collected through sensors than helps to increase efficiency in decision making in real time, the productivity of companies through preventive maintenance, control of supply chains and logistics, improvement of repetitive processes, cost and quality adjustments, and collection of diverse and complex data in sectors such as health, environment, automotive and others.

Table. 4

Potential IoT use cases by sectors, McKinsey Global Institute

Sector	Potential Solutions	Bandwidth	Range	Reliability	Capacity
Agriculture	Performance optimization, remote monitoring	Low	Short	High	Low
Automotive	Predictive maintinance	Low	Medium Longe	High	Low
Cities	Traffic Control, Security	Low	Medium Longe	High	Low Medium
Construction	Predictive maintinance and special operations	Low	Longe	Medium	Low
Consumer	Productivity, customiza-tion, Energy, Monitoring	Medium	Short	Medium	Low
Defense	Asset management, remote monitoring	Medium	Long	High	Medium
Healthcare	Remote Monitoring, Safety	Low	Medium Short	Medium	Low
Insurance	Asset management	Low	Long	Medium	Low Medium
Manufacturing	Operations optimization, predictive maintinance	Low	Medium Short	High	Low
Mining	Proactive maintinance and operations	Low	Medium Longe	High	Low Medium
Oil and Gas	Performance production and prevention	Low	Medium Longe	High	Low
Public Services	Asset management, remote monitoring and Energy Control	Low	Long	High	Low
Transport and Logistics	Proactive maintinance and operations, logistics, automatization	Medium	Long	High	Low

Table 4: Source. Adapted from Alsen, Patel and Shangkuan (2017)

Selected IoT solutions

I. Urban planning and smart cities.

Smart cities are the development that relies the most on IoT solutions. Urban mobility and transportation to avoid traffic congestion and pollution, energy and environment management or building automation concentrate promising developments thanks to sensors measuring real-time weights, temperatures and flows of people and vehicles. Examples worldwide (mostly in high-income economies) of IoT–based solutions for more liveable cities are flourishing, from geo-location of gas station prices to collective transportation times (Valencia, Spain), real-time parking slots (San Francisco, US), electric bicycles (London, UK), or smart waste collection (Seoul, Korea).

II. Productivity.

Integrate platforms, data, objects and people for risk management, maintenance prediction, increasing efficiency, traceability, and transparency. Access and management of accurate information, which helps to better plan and efficiently monitor the entire production process. Real-time monitoring, anomaly detection and alerts, failure prediction. Less downtime for machines and fewer bottlenecks in supply lines.

> **Examples:** Caterpillar (US) reported a 45% efficiency in its production by using IoT. Airbus (Europe) launched a digital manufacturing initiative known as Factory of the Future to streamline operations and increase production capacity. ABB (Switzerland) is using industrial IoT for connected oil and gas production. Remote access to data allows for earlier detection, better diagnostics, and therefore facilitates faster service which results in more cost-effective operation. Jhon Deere (US) deployed telematics technology for predictive maintenance applications.

III. Healthcare.

IoT devices offer new opportunities for healthcare professionals to monitor patients, as well as for patients to monitor themselves. The data supplied those devices, and more specifically, the analysis and usage of the insights resulting from the data, are transformational. Cost reduction, error reduction, improved patient experience, reduce hospital admissions and readmissions, faster disease diagnosis, better drug and equipment management.

> **Examples:** Remote patient monitoring, glucose, hearth rate, depression and mood, and Parkinson disease monitoring. Ingestible sensors, robotic surgery.

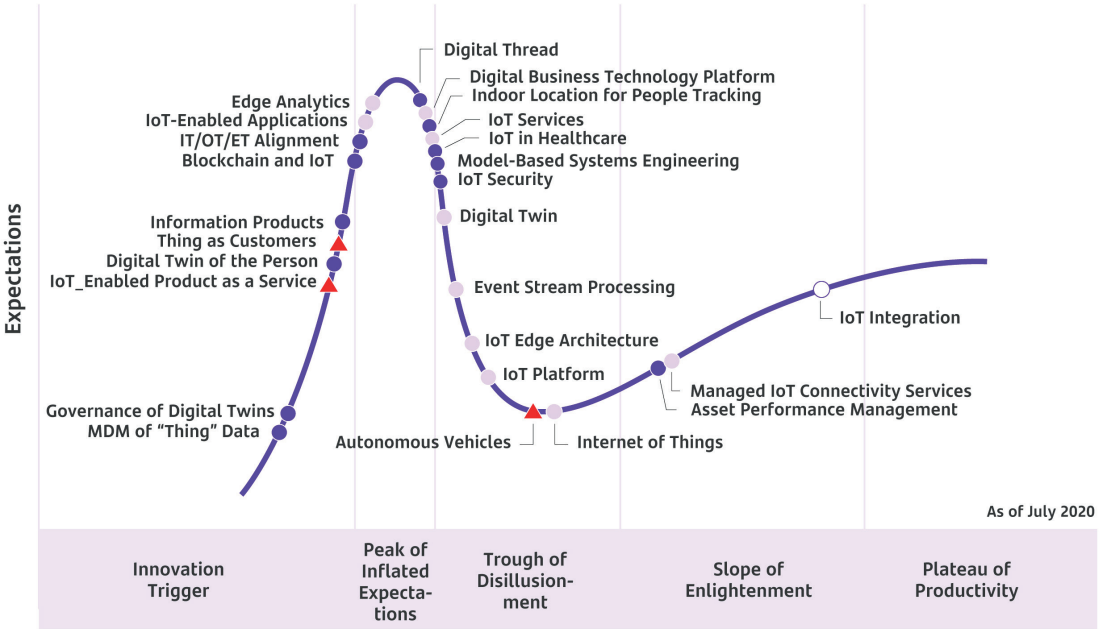
05 IoT market prospects: from solutions to market size and maturity

In 1999, Bill Joy spoke at the World Economic Forum in Davos about device-to-device technology, and Kevin Ashton introduced a quote to Internet of Things in the title of a presentation at Procter & Gamble. After 20+ years, some IoT solutions are showing some degree of overcrowding.

According to Gartner Hype Cycle (2020)[10] technologies such as IoT integration and Asset Performance Management are close to the plateau of productivity, but many others are still undergoing the evolution of technology maturity, such as Blockchain and IoT (Figure 5).

Figure. 5

Hype cycle for Internet of Things, 2020



10. Gartner (2020), Hype cycle for the Internet of Things. July 15.

Figure 5: Source.Gartner (2020)

Getting into some specific figures and always based on Statista (2022), IoT total revenues (reported in Figure 2) for the coming years can be analyzed specifying the sectors and services that it impacts. Doing so, **optimization of operations, human productivity, health and condition-based maintenance**, concentrate most of IoT economic value, up to 83% for the total. Based on the use cases, the results are observed mainly in Industry – **factories, human health, work sites, city, and retail environments** (Figure 6), as described in section 4. In particular, automation in factories, human health and smart cities are the most developed areas, representing 54% of the projected market value. Again, there is a high degree of uncertainty, as the potential economic value of IoT in 2030 estimated by Statista ranges from USD 5.5 trillion to USD 12.5 trillion.

Figure. 6

Potential economic value by IoT use case in 2030, Statista

Potential economic value from IoT worldwide in 2030, by use case (in billion U.S. dollars)

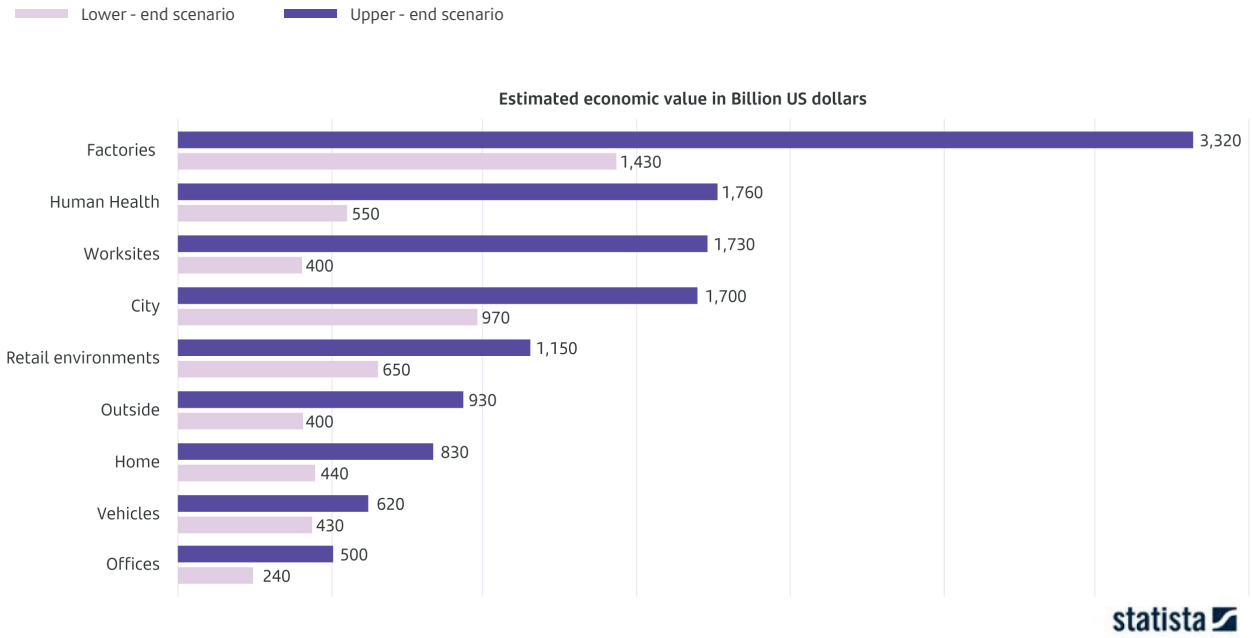


Figure 6: Source. Statista (2022). Note(s): Worldwide; November 2021. Source(s): McKinsey

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"Even in the most pessimistic scenario the potential economic value of IoT is well above 5 trillion."

Focusing on gadgets, the number of devices per industry will grow more than 15.9 billion in 10 years, more than 150% increase between 2020 and 2030, while revenue will grow 100% (Figure 7), showing once again the non-exponential nature of IoT markets. These projections also anticipate a slowdown in devices in sectors such as public services, construction and transportation; while consumption and manufacturing will benefit from their strong and accelerated growth rates, confirming the opportunities in automation of processes, factories, cities and patient-based health.

Figure. 7

IoT connected devices worldwide by industries, Statista

Number of Internet of Things (IoT) connected devices worldwide from 2019 to 2030, by vertical (in millions)

Figure 7: Source.Statista (2022). Note(s): Worldwide; 2019 to 2020; *Forecast IoT connections are defined as connections to remote sensing and actual devices. This includes associated aggregation devices such as hub devices. Source(s): Transforma Insights

Finally, Figure 8 illustrates the positioning of technologies according to the maturity level, the level of adoption by sectors and the market size according to our own judgement, commonly used for investment decisions and strategies. Based on our reading of the main analysist's reports, interviews and experience in the industry, most opportunities for investment should arise from startups providing IoT solutions in manufacturing, automation, healthcare and smart cities.

Figure. 8

IoT market potential, maturity and adoption

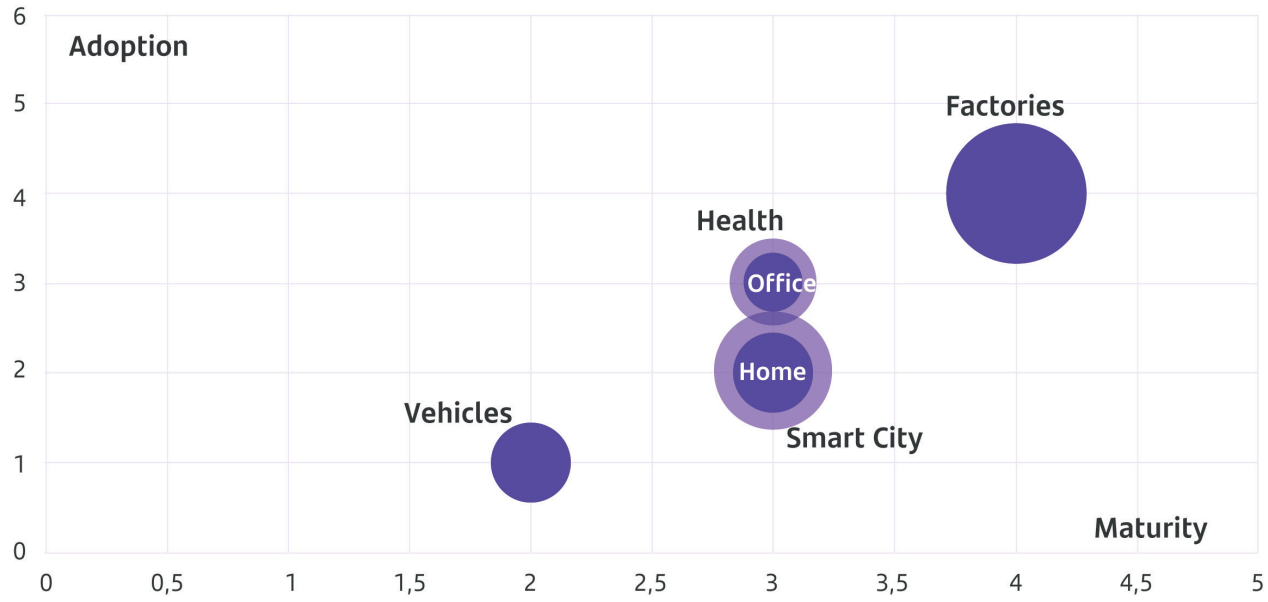

Figure. 8: Note: The size of the bubbles represents 2030 market potential, ranging from USD 1.4 trillion for factories to USD 240 billion for offices
Source: Own elaboration.

06 Challenges in IoT market dynamics

Even when devices, communication, computing and analytics are aligned and set in place, IoT developments face notable challenges, many of them common to other digital innovative segments, raised (following Deloitte, 2020[11], and our own assessment):

I. **Energy:**

Electric gridline sources are constant, but they are often impractical or expensive. Batteries represent a convenient alternative, but battery life, charging and replacement, especially in remote areas, can represent essential problems; limitating companies in terms of environmental sustainability and cost management. On the optimistic side, some analysts have called this decade the 'decade of the battery' (Smith, 2022)[12], as 'feeding and keeping energy' devises will the so-called general-purpose technology that will lead forthcoming digital developments.

II. **Cybersecurity:**

Poor memory capacity in these devices may limit the ability to provide safe and reliable data collection, as there is a correlation between the security level and memory and bandwidth requirements.

III. **Privacy:**

Although data is key for IoT technologies, generally there is a lack of transparency on who has access to this data and how it is used to develop products or services, or sold to third parties. Related to it, under the political push from the European Union, further regulation worldwide can be expected, potentially impacting existing -and potential- business models.

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11. Deloitte (2020), Internet of Things (IoT). The rise of the connected world. Deloitte Touche Tohmatsu India.

12. Smith, N. (2022), "Decade of the battery", Noahpinion, August 29.

IV. Interoperability:

Most sensor systems in operation today are proprietary (brand or standard) and designed for specific applications and thus driving platform fragmentation. This leads interoperability issues in sensor systems related to the communication, sharing, storage, and security of data and scalability.

V. Scalability:

The potential growth and expansion of IoT projects is naturally limited due to initial infrastructure investments and the replacement costs (time and money) of obsolete devices; in addition to the limitations stemming from the lack of interoperability. Actually, GSMA (2022) estimates that enabling services (the segment that includes IoT) showed from 2015 a flat/slightly decreasing return on capital close to 10%, only beating the connectivity business. One of the few ways out of expected modest growth rates is to link the IoT solution (device or analytics, for instance) with other exponential Internet services (as shown in section three).

By contrast, a commonly quoted area, that of communications is less of an issue, as even in cutting-edge solutions such as those in smart cities solutions, most of the devices can work in 4G, 3G and in GPRS technology.

In focus

A view on middle-income countries

There is a widespread consensus that embarking the digital revolution is one of the few (even last) opportunities for middle-income economies to catch-up with high-income regions.

Far from being just another commonplace, it is evident that digitization of economic activity is unstoppable, and could amplify the gaps between countries, firms and citizens if not nurtured. According to AlphaBeta (2020)13, by 2030 digital transformation could generate as much $3.4 trillion of economic value (i.e., 25-35% higher GDP level) in a set of 16 middle-income countries from Asia, Eastern Europe, Middle East and Africa labeled as digital sprinters, with a combination of investment in physical infrastructure (connectivity) and human capital, pro-competitive regulation and more intensive and widespread technology use, from data, to cloud, AI and IoT.

This policy shock (i.e. higher investment and smart rules) can interact with some structural strengths than emerging regions show: rapid technology adoption, relatively young population and high urban rates, prone to IoT smart cities developments. These economic benefits (higher output) would not be focused on the tech & telco sector, as 26% would be allocated in primary industries, 25% in manufacturing and infrastructures, and the rest on health, education, and mobility among others.

13. AlphaBeta (2020), The digital sprinters. Report prepared for Google, Singapore.

Focusing on IoT, a component of the technology pillar, it is imperative for middle-income regions to face and solve a series of short-term challenges:

- Particularly tight financial context in the short-term, driven by high interest rates and safer investment opportunities.
- Human capital shortages.
- Regulatory catch-up (data privacy and security, competition, taxes) with high-income economies, notably Europe.
- Some IoT solutions could be limited by connectivity quality (speed and delays on 5G deployment) and lower affordability.

In focus

Towards a green(er) IoT

Beyond its purely financial potential, IoT innovation can be a game-changer for the progress towards a healthier and virtuous planet → tech → people equilibrium. According to the World Economic Forum (2018)[14], 85% of IoT deployments were addressing the Sustainable Development Goals. Indeed, more generally, digital transformation can be the missing piece to consolidate the so-called ESG (Environment, Social, Governance) initiatives by the private sector (Benjamins and Melguizo, 2022)[15].

Organizations across many vertical industries use IoT technology to optimize their operations to reduce environmental impact and make more environmentally sustainable decisions (Locke, 2021)[16]. Businesses today are embracing energy-efficient practices to enhance their operations while reducing the environmental impact of digital devices in three ways:

- Reducing the impact of heat-producing devices through energy efficiency and heat mitigation.
- Offsetting their impact through environmentally sound practices, including use of clean energy, tree planting and increased development of heat sinks that reduce carbon emissions.

14. World Economic Forum (2018), Internet of Things: Guidelines for Sustainability. WEF, Geneva.

15. Benjamins, R. and A. Melguizo (2022) "Sin digitalización no hay sostenibilidad", El País, September 6.

16. Locke, J (2021), Internet of Things, Environmental Sustainability, and the Circular Economy. DIGI.

- Deploying IoT and green technology in renewable energy and environmental stewardship projects across industries to eliminate or offset emissions with a net zero goal.

Among the multiplying examples of the IoT environmental 'green(er)' applications, we would highlight:

- Smart agriculture and water management: Water management projects optimize use in farming with the use of sensors and smart devices.
- Clean energy production: Developing smart methodologies for renewable energy production and efficiency.
- Energy use savings: Optimizing energy use in homes, businesses and transit systems, and using energy-efficient smart devices.
- Smart infrastructure building and management: smart city lighting, water use management and infrastructure for electric vehicle charging.

In sum, beyond the hypes and various estimates of IoT financials, and ubiquitous green and digital strategies of companies and governments, the positive impact of the IoT on citizens, businesses, and governments will be significant.

"IoT solutions are showing solid market growth based on fundamentals, increasing linkages with many other segments in the digital ecosystem and with potential key role towards environmentally sustainable businesses and cities"

07 Concluding remarks

This paper aims to provide a qualified assessment on opportunities stemming from the Internet of things (IoT) eco-system in the short and medium run to advice on investments strategies, both from their inception and to speed their value growth and job creation.

It is based on our critical review of the main statistics and market and economic reports, interviews with experts on the field – developers, entrepreneurs and venture capitalists -, and our own experience in IoT business, policymaking and economic analysis. We take a global perspective on IoT solutions and their interplay with other relevant IT developments focused on market potential worldwide, although we also include a focus on middle-income economies, and a reflection on its potential to a green economic transition.

Overall, the analysis is cautiously optimistic on IoT. In our view, based on desk work and 1-1 interviews, most IoT opportunities are and will keep on arising in the areas of urban planning and smart cities, production automation, and health-care services. IT developments, social demand and relatively less supply fundament this assessment. From this starting point, opportunities should be carefully analyzed considering all IoT value chain components – devises, connectivity, communication and data -, and its main challenges - notably energy use, data privacy and security, potential platform fragmentation, connectivity needs, and scalability -, and under a financial framework of solid but not exponential growth rates.

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Annex: IoT supporting technologies

IoT runs on a series of other technologies, notably infrastructure and communications.

Focusing on infrastructure, many organizations are revaluating the traditional cloud to include an IoT layer, from core to endpoint. This edge layer invokes the use of computing, networking, and storage at the enterprise edge. This taxonomy update has reorganized the primary market segments as described below and shown in Table 5:

A. IoT edge infrastructure: Hardware and software deployed in edge locations.

- **End Points:**

  Sensors collect data from the environment or object under measurement and turn it into useful data.

- **Endpoint Connectivity:**

  Solutions that address the broad range of network needs with specific IoT applications spanning (WAN), (LAN), and (PAN).

- **Light edge platforms:**

  Are designed to perform functions such as; data, aggregation, condensation and optimization, local data storage, real-time, clock synchronization, IPv6 to v4 translation, local caching for firmware updates, proxy services, and core connectivity.

B. IoT core infrastructure: Hardware and software deployed in a core data center or public cloud.

IT resources available to enterprises solutions: traditional on premise (non-cloud), private cloud and also public cloud as a service.

C. IoT software: Software that spans both core and edge locations, including management and control.

- AD&D software with IoT components include Analytics and artificial intelligence, data management, integration and orchestration.
- The categories of systems infrastructure software with IoT components include system and service management, network, security, endpoint management, physical and virtual computing.

D. IoT Technology Domains.

- **Storage:**

External OEM storage, internal OEM storage, and ODM Direct storage.

- **Compute:**

Extensible, autonomous, programmatically accessible, architecturally diverse, open or proprietary, centricity/peering.

- **Networking:**

Ethernet switch, SD – WAN, WLAN, VoIP, Video, ADCs, ADCaaS, IaaS, Fiber Channel, Infiniband Switching, Network Management, SDN / Network virtualization.

Table. 5

IoT infrastructure taxonomy

IoT Edge Infrastructure	IoT Core Infrastructure	IoT Software	IoT Technology Domains
Endpoints	Traditional (noncloud)	Application development and deployment	Storage
Endpoint-to-edge connectivity	Dedicated cloud	Systems infrastructure software	Compute
Light edge computing platforms	Public cloud		Networking

Most IoT solutions now require a combination of cloud and edge computing (i.e, processing data closer where it´s being generated enabling processing high speeds and volumes). Compared to only cloud solutions, those that incorporate this latter type of technological tool will be able to increase scalability and improve access to information so that better and faster decisions can be taken, as well as increase

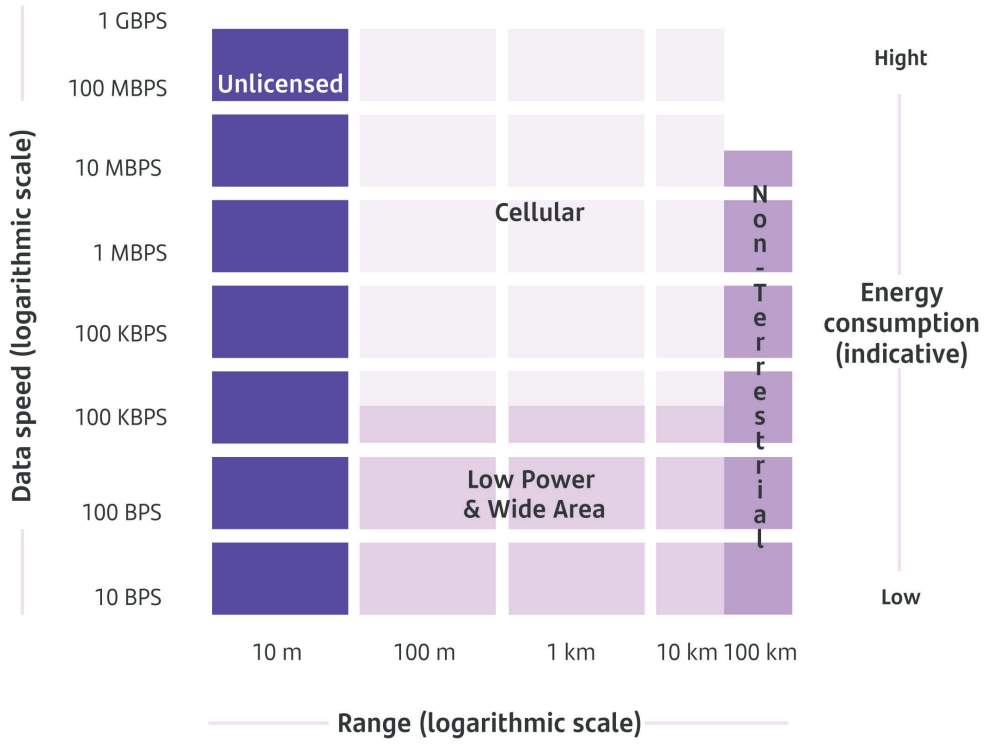
Tabla 5:. Source: Adapted from Yashkova and Das (2022).

access to information so that better and faster decisions can be taken, as well as increase company's agility (Dahlqvist et al, 2019)[17].

The other component we believe crucial but sometimes not sufficiently considered, is **connectivity and communications.** Many wireless technology standards are currently used to connect IoT devices, from familiar technologies like Bluetooth, Wi-Fi, and Zigbee, while others are less-common proprietary solutions. IoT connectivity solutions fall into four categories – unlicensed, low power & wide area, cellular and non-terrestrial - with a significant overlap of specifications (Figure 9).

Figure. 9

IoT solutions according to connectivity [18]



17. Dahlqvist, F., M. Patel, A. Rajko, and J. Shulman (2019), Growing opportunities in the Internet of Things. McKinsey & Company, July 22.

Figure 9: Source: AdapteAdapted from Alsén et al (2017)[18].

18. Alsén, D., M. Patel and J. Shangkuan (2017), The future of connectivity: Enabling the Internet of Things. McKinsey & Company, December.

Connectivity in unlicensed bands solutions does not grant anyone the right to use the spectrum exclusively. Therefore, the general public can use mentioned frequency bands to communicate with IoT devices. However, this free use generally translates into low coverage range and congestion due to concurrent user overload.

I. **Low-power & wide-area connectivity solutions are marked by two essential features.**

- **Low power:**

  They allow devices to work for years, assuming they collect and analyze data on a relatively low frequency and, in addition, consider the discharge by operation natural and battery degradation.

- **Wide Area:**

  They allow a wide range of coverage from the gateway device to the endpoint, covering up to a few hundred kilometers away. Coverage is lower in challenging deployment environments, such as urban or underground locations.

II. **Cellular connectivity.**

Current 4G LTE technology offers significant bandwidth of up to 100 megabytes per second and an ample range of more than ten kilometers. However, being proprietary technology, its costs can make an IoT application unfeasible. It is expected that 5G technology can increase coverage ranges and transmission capacity while it reduces the costs of access to the technology.

III. **Non-terrestrial network (NTN).**

Has become an umbrella term for any network that involves non-terrestrial flying objects. The NTN family includes satellite communication networks, high altitude platform systems (HAPS), and air-to-ground networks. The interesting part of IoT is that it generally uses it only when cellular and other network options are not feasible due to its high costs.

Exclusive developments on this front have a low market opportunity and a lower growth rate due to this type of system's high maturity and field of application, but their robustness is a must for any IoT investment.

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