Next-Generation Wireless in Logistics

A DHL perspective on the evolution of wireless networks and the future of IoT in logistics

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Preface

How did you access this report? There's a very good chance that you did so via some type of wireless technology, perhaps using Wi-Fi or cellular data on a mobile device.

As we write this, the value of wireless networks has become especially vivid. Millions around the world are staying at home, with new quarantine and social distancing rules as part of the global response to the COVID-19 pandemic. With physical movement restricted, digital activity has seen an unprecedented spike. Remote access systems, media streaming services, and video calling technologies have become critical links to the outside world as people strive to maintain contact with friends, families, and work colleagues.

Even before the crisis, wireless communication technology was making headlines. Much recent interest has focused on 5G mobile data networks that are being rolled out in many countries. 5G promises a host of benefits for end users, businesses, and telecommunication system operators alike including higher speeds, greater capacity, and tailored services for a new generation of smart connected devices.

It is important to recognize, however, that progress across a wide range of different wireless communication technologies is now creating new opportunities for industry to improve visibility, enhance operational efficiency, and accelerate automation. These next-generation wireless technologies will enable the next step in the communication revolution, moving beyond today's goal of connecting everyone to a new world in which everything, everywhere can be connected.

The digital revolution has already transformed asset-light industries from media and entertainment to financial services. Now the rapid evolution of the Internet of Things (IoT) is allowing more asset-heavy industries, from automotive and manufacturing companies to healthcare providers, to accelerate their own digital transformations. Our own sector, logistics, will be both a major beneficiary of the IoT-enabled digital revolution and an enabler of it.

IoT is already alive and well in logistics, and this new generation of wireless technologies will usher in an era of expanded capabilities that build upon today's successes. The ability to monitor, track, and interact with assets through wireless connections will make supply chains faster, more flexible, more efficient, more predictable, and more resilient.

In this report, we have pooled the logistics and technology expertise within DHL to help you answer the following questions:

- What is next-generation wireless? Why is it relevant for logistics and why now?
- Which next-generation wireless technologies are relevant for logistics and what new use cases will they enable?
- How can I get started applying next-generation wireless in my supply chain?

Looking ahead, we believe next-generation wireless technologies will be critical in advancing the visibility, autonomy, and predictability of logistics operations. None of these benefits will accrue automatically, however. To take advantage of better wireless connectivity in logistics operations, companies will have to overcome many challenges, from reducing power consumption to meeting complex standards and regulatory frameworks.

We believe that there has never been a more exciting time to explore next-generation wireless technologies, and we are eager to begin this journey together with you, our customers and partners.

Matthias Heutger
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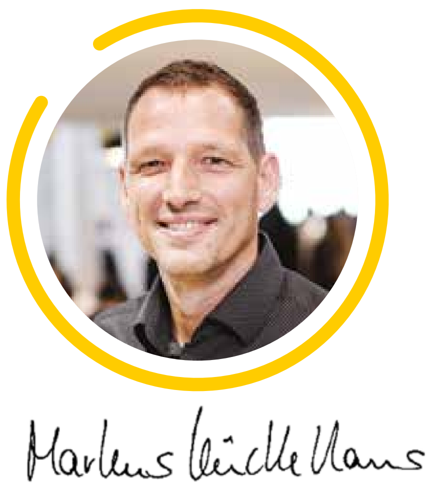

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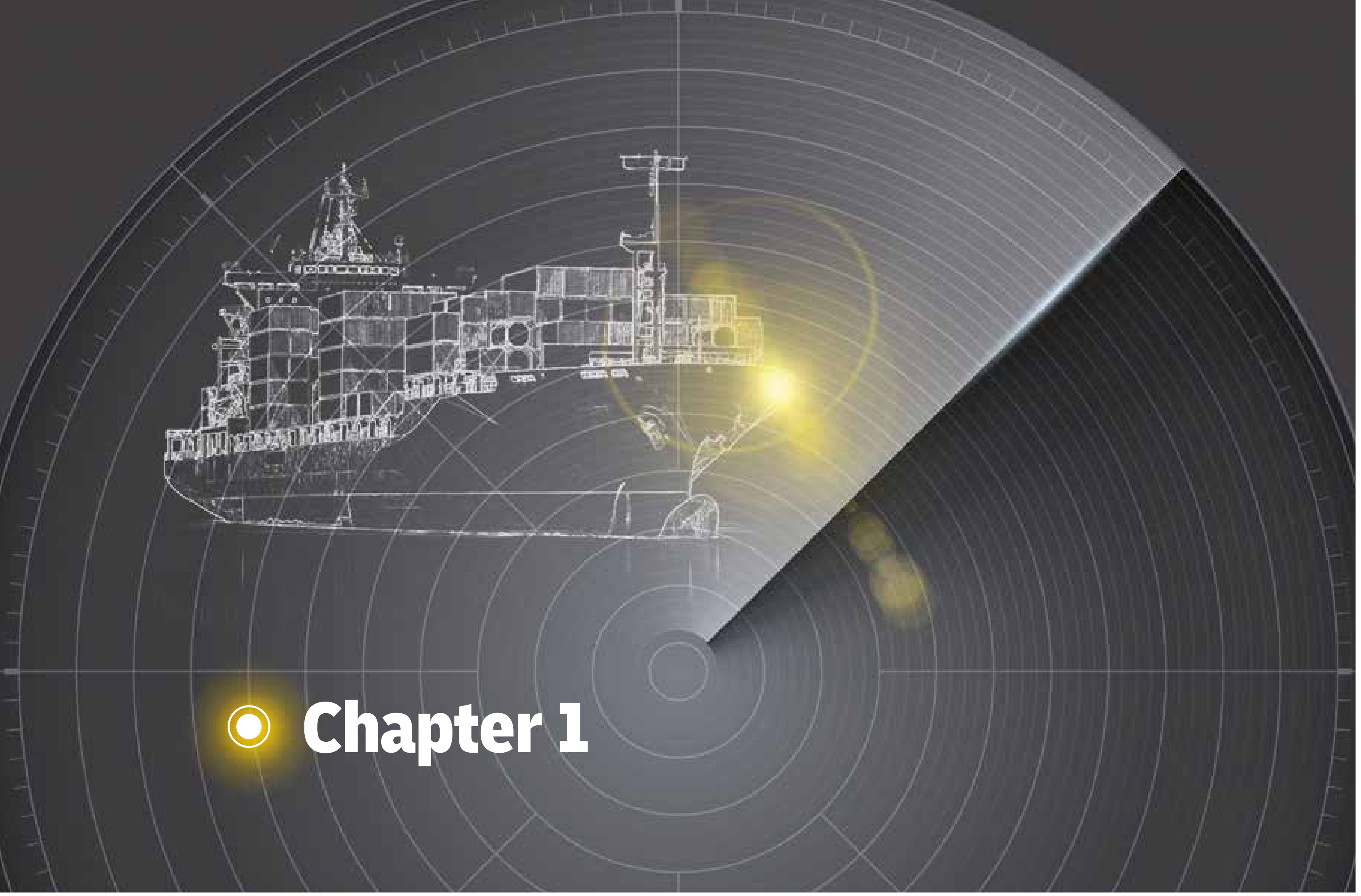


Understanding Next-Generation Wireless

1.1 WIRELESS HAS CHANGED THE WORLD

For many people around the world, it is hard to imagine life without wireless access to the internet. Alongside food, water, and shelter, Wi-Fi is increasingly seen as a necessity in today's modern world.

It did not take long for wireless connectivity to become ubiquitous. The first 3G mobile phone networks capable of high-speed data transmission were only introduced in 2002. The launch of the iPhone in 2007 pictured in figure 2 triggered the smartphone revolution, putting a fully functional multimedia computer into the pocket of millions of consumers.

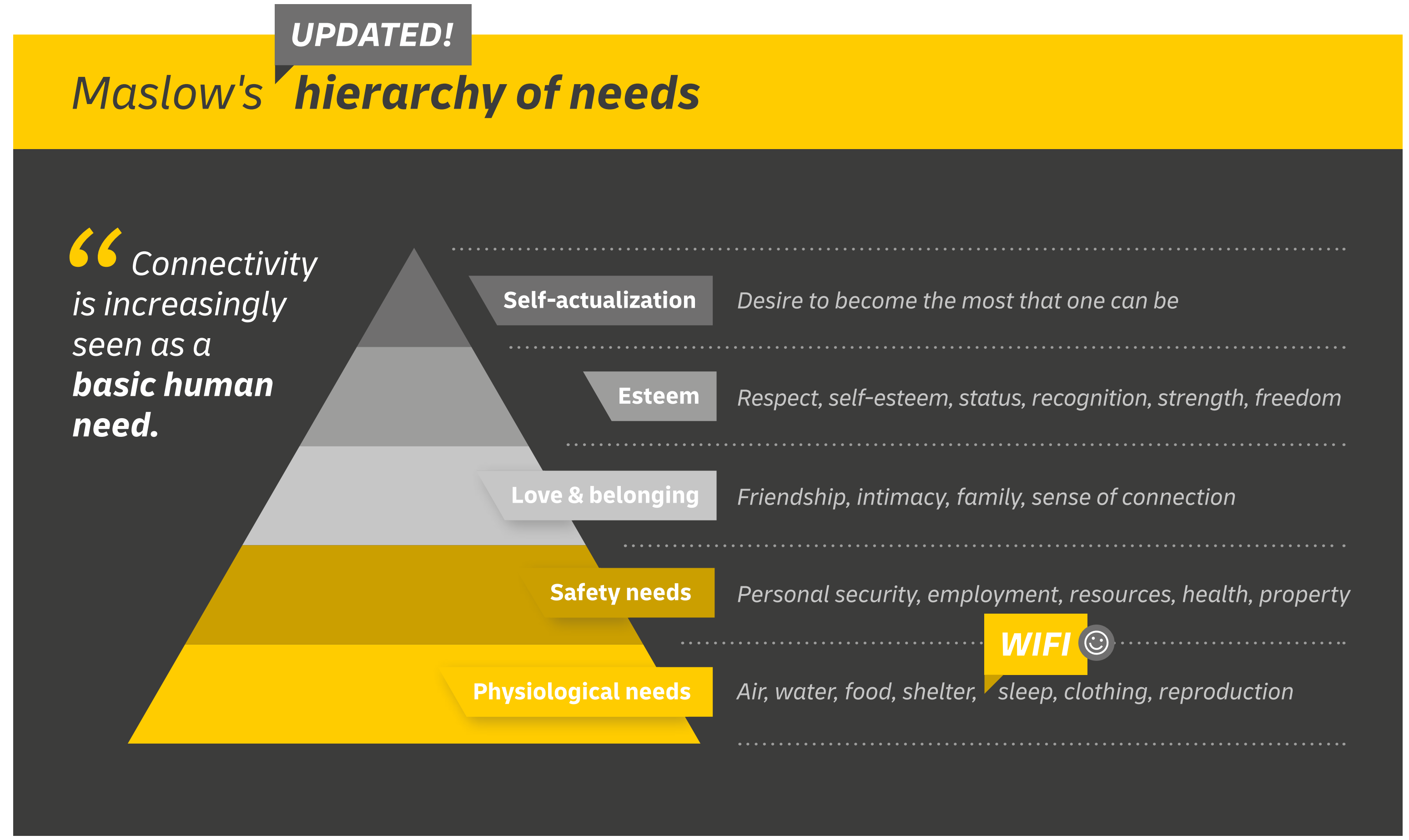


Figure 1

The wireless communication technology underpinning the smartphone revolution helped create a second wave in the internet revolution. In 2000, only half of Americans accessed the internet every day, almost exclusively from a desktop or laptop computer. By 2016, nearly 287 million people in the US were accessing the internet, and nine out of ten did so almost exclusively from mobile devices. Put differently, in 2008 the Apple App Store had 552 apps for download whereas today it has 2.2 million and Google Play has 2.8 million. Instant, convenient access has been instrumental in the success of thousands of these online services, from email and online banking to social media platforms and e-commerce.

Wireless technology has achieved much more than mere convenience, however. Wireless networks are quicker, easier, and cheaper to build than their wired counterparts. In less-developed economies, mobile networks have brought internet access to hundreds of millions of people. In Africa, for example, the internet now reaches almost 40% of the population, up from around 0.5% at the turn of the millennium.

Figure 2

Figure 1: Maslow's updated hierarchy of needs.
Source: DHL (2020)

Figure 2: The launch of the iPhone in 2007 and its subsequent adoption pushed cellular data transmission far beyond usage levels of previous devices.
Source: MacStories (2017)

Figure 3 shows an overview of mobile and mobile internet use in several key African countries. Globally, 4.5 billion people have internet access, with 3.5 billion smartphone users. Perhaps more interestingly, as of 2019 a mobile device was the only form of internet access available to 2.75 billion people, around three quarters of all internet users.

Wireless technology has not just helped people get online. Many of the same technology stacks used to connect people to the mobile internet have also brought billions of things online using wireless technology across various industries. In the energy sector, 14% of all electricity meters in use globally are considered smart meters – they use wireless networks to exchange energy consumption and price information between homes and energy suppliers. In logistics and transportation, GPS tracking devices on vehicles and shipping containers like the ones in figure 4 use mobile networks to let their owners know where they are. And the market shows no signs of slowing down, with a CAGR of 14.4% through 2023 and annual shipments of 75 million tracking devices. Within the manufacturing sector, machines operating at remote sites are monitored centrally via wireless links. Already today, B2B devices and machinery connected to the internet are expected to number 5.8 billion by the end of 2020.

For all its extraordinary success so far, wireless technology still has plenty of work to do. Almost half the people in the world still do not have access to the internet. Access to wireless data networks remains patchy. Huge swathes of the Earth's surface are beyond the range of conventional mobile data networks. Even in highly developed regions, plenty of rural locations have poor or non-existent coverage. In busy urban centers, demand for connectivity often exceeds supply, with congestion slowing data transfer rates to the frustration of users.

Figure 4

Experience has shown that people's appetite for connectivity is constrained by the devices and networks they use. Just over a third of mobile device connections today use 4G, the fastest widely available technology, but they account for 72% of all mobile data use. Around half of the devices connected to today's mobile networks are smart (offering advanced multimedia and computing capabilities), but those devices generate 92% of mobile data traffic.

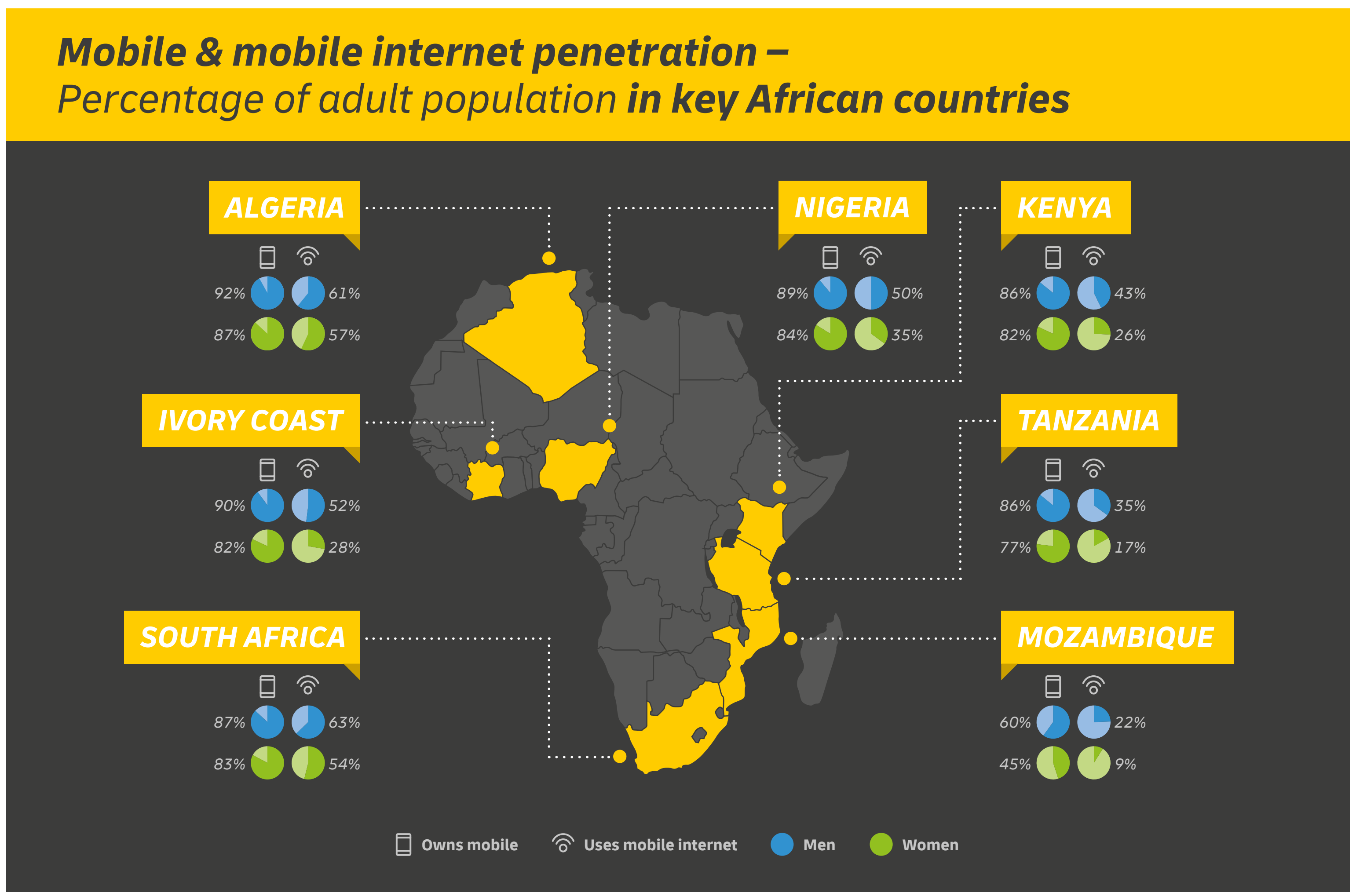


Figure 3

Figure 5

While the number of devices already connected to the Internet of Things (IoT) is estimated to be around 20 billion, there are many billions more for which today's wireless communication options are unviable, being too expensive, too power hungry, or simply incapable of providing the necessary performance or coverage.

If wireless technology is to fulfil its potential, these limitations will need to be overcome. Addressing that challenge is the goal of not just a single technology like 5G but a collection of new and emerging "next-generation" wireless technologies.

1.2 CONNECTING EVERYONE, EVERYTHING, EVERYWHERE

Next-generation wireless describes the latest advances in a series of wireless technologies. Beyond the current hype surrounding 5G, known technologies like Wi-Fi and Bluetooth and lesser-known technologies like low-power wide area networks (LPWANs) and low-Earth orbit (LEO) satellites are all making significant progress, advancing capabilities for the modern world. These next-generation wireless technologies are intended to fill the world's remaining connectivity white spots, shifting online access from the ubiquitous to the universal. To do that, technology must achieve three major objectives:

1. Bring **everyone** online
2. Bring **everything** online
3. Deliver connectivity **everywhere**

Everyone

Wireless connectivity has already helped to connect more than half the world's population to the internet, and it is expected to connect another billion people in the next five years alone. The benefits of that connectivity are hard to overestimate: even with millions adhering to social distancing, quarantine ordinances, and home office policies in the wake of COVID-19, humans can still communicate with each other, trade with each other, learn from each other, and entertain each other with more freedom than at any other time in history.

Where home office policies were a luxury for senior managers and forward-looking corporations, this mode of working became an overnight necessity for many professionals at some point in the first quarter of 2020. Perhaps most spectacularly, the cloud-based video platform Zoom shown in figure 5 became the *de-facto* tool for many homebound professionals and their families.

This young technology company experienced a 728% increase in the download rate of its mobile app, from 56,000 daily downloads in January 2020 to 2.13 million daily downloads in March 2020.

Figure 3: In key African countries, mobile and mobile internet represent the most pervasive form of connectivity.
Source: DW (2019)

Figure 4: The logistics and transportation industries are the main drivers of GPS tracking device adoption.
Source: Samsara (2019)

Figure 5: Zoom meetings have gone from a startup niche activity to a household name during the COVID-19 crisis.
Source: Business Insider (2020)

Figure 6

As the world moves online, connectivity is rapidly becoming a necessity. People without access to the internet are increasingly excluded from vital services and opportunities. As one example, 500 million people in India have internet access, of whom 450 million have smartphones, and yet 1.3 billion people in India still do not have internet access. One solution from Google, as announced in 2019, is to use Google Assistant on inexpensive feature phones by dialing a free hotline. This brings modern internet-like experiences to a large new population that would otherwise be left behind in the progress of the modern world. Closing this digital divide may be one of the key social and economic challenges of the coming years, and it won't be easy to do.

Everything

If the challenge of connecting the world's people is entering its latter stages, the challenge of connecting the world's objects is only just beginning. According to the Bluetooth Special Interest Group, 48 billion devices will have internet access by 2021.

The majority of those devices will no longer be computers or smartphones but automobiles, machines, personal possessions, and appliances that communicate with each other, usually wirelessly. That number represents a ten-fold increase in connected devices over today's levels.

Figure 7

Just as connecting people created demand for new services, higher performance, and greater network capacity, so the growth of the Internet of Things is driving demand for connectivity across an ever-greater range of product types and conditions. And this new generation of devices requires an extremely broad range of connectivity.

Some machine monitoring systems like the one from industrial IoT startup Augury shown in figure 7 must be able to oversee fleets of machinery that operate unattended for years.

Often these systems are deployed in remote and hard to reach places, communicating regularly and reliably while consuming minimal power.

At the other extreme, shown in figure 8, an emerging generation of virtual- and augmented-reality (VR and AR) systems will need extremely high data rates and low latency to share ultra-high-resolution video content, generated and modified in real-time in response to user actions.

Figure 8

Figure 6: Google plans to bring its Google Assistant to feature phones in India via a free hotline. Source: TechCrunch (2019)

Figure 7: Whether designed-in or retrofitted, industrial machinery is increasingly becoming connected to the Internet of Things. Source: Augury (2020)

Figure 8: VR and AR will raise the bar, making new wireless connectivity demands in order to render high-resolution graphics and video content. Source: BD Tech Talks (2020)

Figure 10

Figure 9

Everywhere

To connect everyone and everything, next-generation wireless must overcome the challenge of geography. Universal connectivity requires networks that operate everywhere there are people and things. That includes remote rural communities in low-income countries, underground rail networks in major cities, and busy music festivals in the countryside. If a device depends on wireless connectivity to do its job, the networks it uses must reach all the places that the device might go. For some devices, especially those used to track and monitor logistics assets, this will require networks that encompass the world's oceans, deserts, and polar ice-sheets as depicted in figure 9.

1.3 NEXT-GENERATION WIRELESS: NO ONE SIZE FITS ALL

To achieve these goals, next-generation wireless technology must meet a broad variety of user and industry requirements. Networks need to accommodate rapidly rising levels of traffic, as users' appetite for data-intensive services increases and as billions of new devices vie for network access. They must operate at higher speeds to support demand from consumers for high-definition video streaming and online gaming. In enterprises, increasing use of data analytics and machine learning platforms place greater demands on the collection and processing of data both at the edge and in the cloud. Wireless networks must enable end users, professional or private, to perform these functions seamlessly and reliably in the busiest cities and the most remote rural communities.

As depicted in figure 10, the world's cities and urban centers hit hardest by the coronavirus crisis also experienced a larger proportion of internet congestion. According to the telecommunications giant Vodafone, one fifth of internet traffic travels across its networks and it experienced the equivalent of six months' demand growth in March 2020 alone. The earliest European countries to introduce lockdown policies, Spain and Italy, saw internet traffic surges of up to 50%.

Perhaps most importantly, next-generation wireless networks must also support the requirements of IoT systems. These may only need to exchange a few bytes of data in each transmitted message but must do so with complete reliability with minimal power consumption and at the lowest possible hardware cost.

Figure 9: Bringing connectivity everywhere presents a significant geographical challenge for the logistics industry. Source: Vodafone (2020)

Figure 10: Next-generation wireless must enable end users, professional or private, to deploy a host of applications seamlessly and reliably anywhere in the world. Source: Getty Images (2017)

UNDERSTANDING WIRELESS TECHNOLOGY

Almost without exception, modern wireless networks exchange data using electromagnetic waves. The electromagnetic spectrum is a continuum with low-frequency long waves at one end and high-frequency short waves at the other.

Visible light, the most familiar electromagnetic waves to most of us, occupies a slice of the spectrum with frequencies of around 10^{15} Hz (waves per second). The electromagnetic waves used to carry data in wireless networks occupy a broad range of frequencies at the lower end of the spectrum, generally referred to as radio waves between 10^{3} Hz (1 kHz) and 10^{10} Hz (10 GHz).

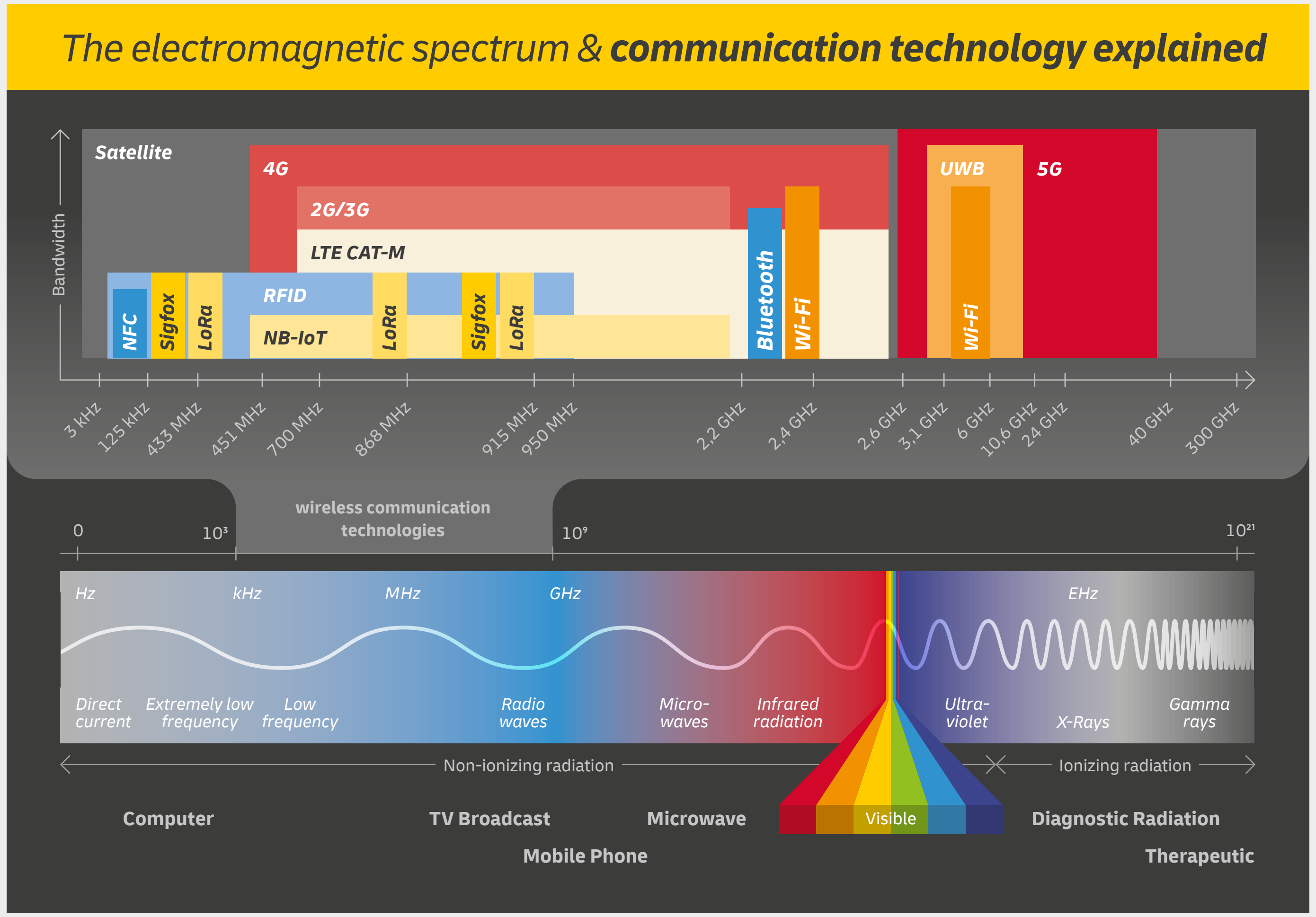


Figure 11

Different frequencies offer different advantages and disadvantages for network designers. Low frequencies are better at operating over long distances while high frequencies support faster speeds. Different services working in the same range of frequencies can interfere with one another, so some parts of the spectrum are licensed by government communications agencies and militaries, limiting their use to permitted operators and services.

A number of specialist terms describe the characteristics and performance of different wireless technologies. Here is a guide to some of the most common, as well as visuals in figures 11 and 12 to help put the following in context:

- **Frequency.** This is the part of the spectrum in which the technology operates. Some wireless technologies can work at several different frequencies, or channels, depending on local licensing requirements or the generation of the technology in use.
- **Bandwidth.** Wireless systems do not normally operate at a single fixed frequency but across a range of frequencies. That range is known as bandwidth. The theoretical maximum data-carrying capacity of a wireless channel is closely related to its bandwidth, hence the term broadband is used to describe high-speed, high-capacity networks.
- **Data rate.** Measured in bits per second, this is the maximum data transmission speed of a given wireless channel.
- **Capacity.** This is a measure of the maximum number of users or devices that a network can support. It depends on the design of the network and the speed, latency, and throughput requirements of connected devices.
- **Range.** The physical distance from a host/originating device in which wireless technology can transmit information.
- **Throughput.** Not every packet of data transmitted across a wireless network will be successfully picked up by the recipient. Lost packets are present until a complete message is received, and the term throughput is used to describe the actual rate of data exchange achieved.
- **Latency.** This is the time required for a round-trip message between two communication partners across a network. Latency is important in communications with a high degree of interactivity, such as online gaming or the real-time control of vehicles or industrial equipment. It is related to the speed of the network and the distance travelled by the message. Satellite data systems, for example, can achieve high absolute transmission speeds but they usually suffer from high latency.

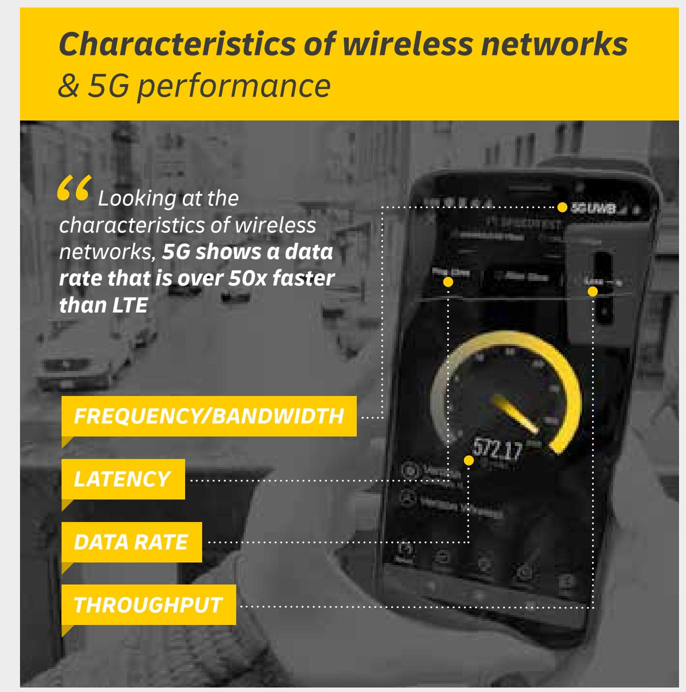


Figure 12

Between these extremes there are hundreds of other current and emerging use cases, each with their own unique combination of speed, bandwidth, range, power, and cost requirements. Some smart tags used in product identification and tracking, for example, only need to communicate over a distance of a few centimeters. Others require consistent levels of coverage across the entire surface of the Earth.

No single approach will be able to meet all these diverse requirements. Instead, the next-generation wireless world will involve an ecosystem of competing and complementary technologies. Makers of products and services will need to pick the most suitable wireless approach for their specific application. As already the case today, many applications will use a combination of approaches, switching between technologies and networks according to service availability or application-specific communication needs at the time.

For a better understanding of wireless technology, refer to the separate section which outlines core attributes relevant to all wireless technologies. It also clarifies technical terminology used throughout this report – terms that you are likely to encounter on your journey to bring IoT and next-generation wireless into your supply chain.

Figure 11: A diagram of the electromagnetic spectrum, highlighting the bands capable of data transmission. Source: DHL (2020)

Figure 12: Ookla's Speedtest app can be used to test connectivity performance on any device. Source: DHL (2020)

1.4 WHY IS IT HAPPENING NOW?

Wireless and digital technology will soon bring everyone online. Already entire industries have been disrupted and reinvented for the digital era. Media, banking, insurance, and telecommunications have been the first industries swept up by a wave of digital technology. Unlike these relatively asset-light verticals, the next industries on the brink of disruption, shown in figure 13, have asset-heavy business models and operations. These industries include retail, automotive, and logistics; they will have to first connect everything in order to truly leverage the capabilities of digital transformation. Assuming these industries succeed, researchers at McKinsey Global Institute predict a fully digitalized world in which two thirds of all enterprise EBIT, and three quarters of revenue, will come from efficiencies and new opportunities in digital supply chains.

Although IoT is not a new trend in logistics, the industry is benefitting from an increasing technology push. Wireless technologies have made significant progress in recent years across all parts of the wireless spectrum to advance the reach and capabilities of IoT. Technology companies at all levels of

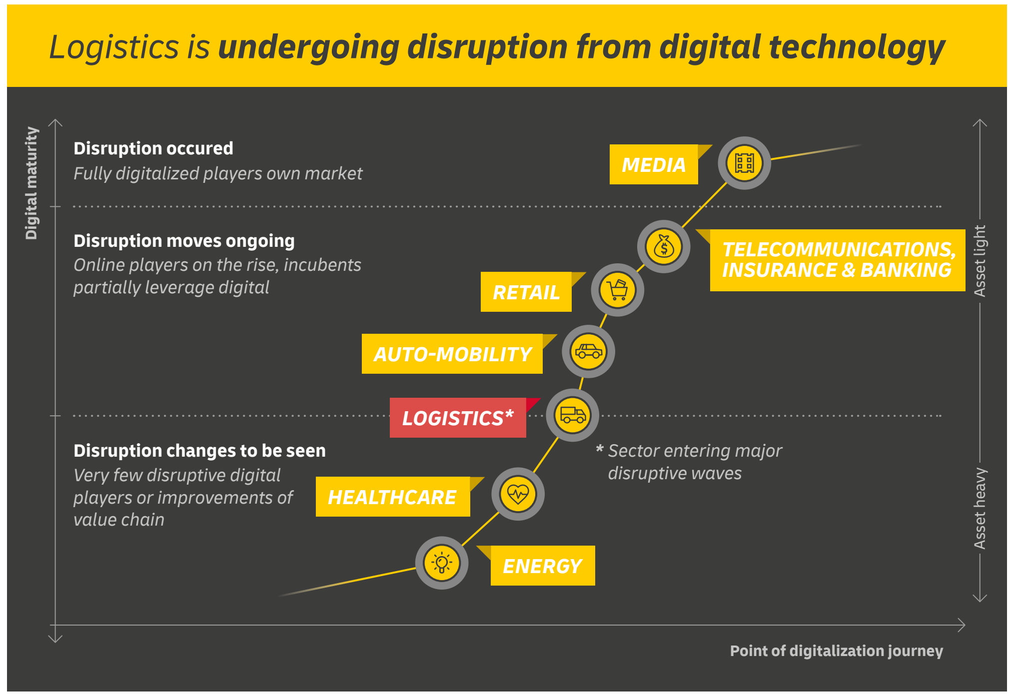


Figure 13

the IoT technology stack are enabling new capabilities such as 5G, Wi-Fi 6, and other wireless innovations in their newest product offerings.

The next generation of wireless technologies coming to market will play a pivotal role in turning logistics into a truly digital industry. As illustrated in figure 14, by connecting everyone and everything in all the places (everywhere) that global supply chains operate, logistics can achieve unparalleled visibility, infrastructure simplification, further optimization, and data-driven decision making. Logistics will then also discover new opportunities for efficiency gains to increase service quality at lower cost.

The recent arrival of 5G has sparked interest among supply chain leaders about the capabilities offered by next-generation wireless technologies. The next chapter examines precisely what these technologies are, exploring the next-generation wireless technology ecosystem and considering how all this will transform the business of logistics.

Figure 14

Figure 13: Industries at different stages of adopting digital technology. Source: DHL (2020)

Figure 14: Next-generation wireless will bring unparalleled visibility to supply chains. Source: Web Ecommerce Pros (2019)

Next-Generation Wireless Technologies & Logistics Use Cases

In the previous chapter of this report, we looked at the way wireless connectivity has already had a huge impact on business, technology, and society. There are still plenty of places, people, and objects sitting beyond the reach of today's wireless technologies. These cannot be addressed because current wireless technologies are unable to deliver the necessary combination of geographical reach, technical capability, and low cost.

This chapter takes a deeper dive into emerging next-generation wireless technologies capable of addressing those gaps. For each technology, we outline its key benefits and major use cases, with particular focus on applications in the field of logistics.

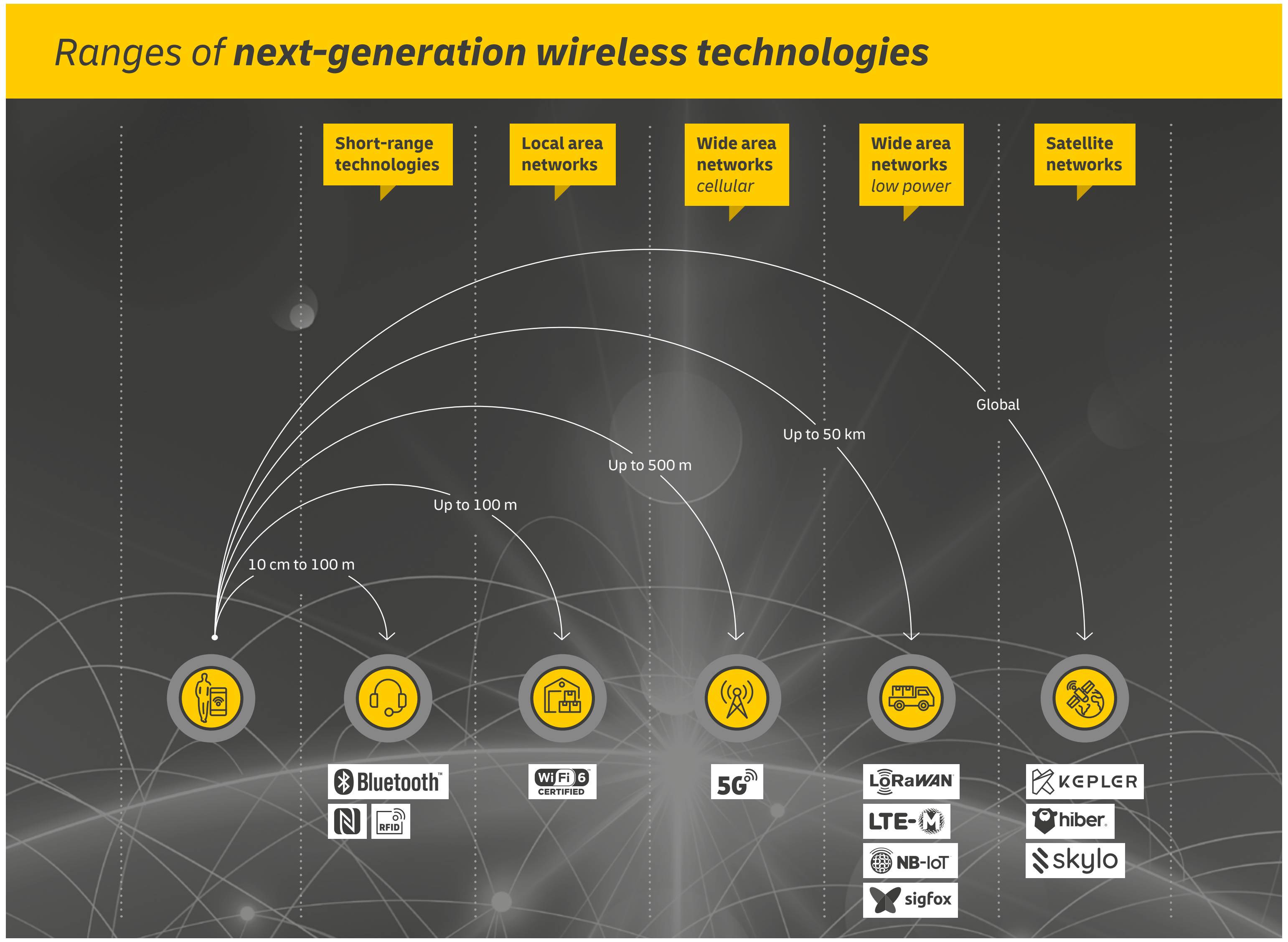


Figure 15

As previously noted, different end uses require different types of wireless connectivity. To meet the needs of an ever-growing variety of applications, next-generation wireless technologies differ in terms of speed, capacity, power requirements and, one of the most fundamental differentiators, range. The latter shown in figure 15 can be categorized in the following broad groups:

- **Short-range network technologies** such as radio frequency identification (RFID), near-field communication (NFC), and Bluetooth connect devices across distances of a few millimeters to several tens of meters. They are typically used for connectivity within the same room or between different parts of a single larger object.
- **Local area network technologies** such as wireless fidelity (Wi-Fi), light fidelity (Li-Fi), and ultra-wideband (UWB) connect devices across distances of a few meters to a few hundreds of meters. They are typically used to provide coverage across a specific area, such as a home, office, warehouse, or factory.
- **Wide area network technologies** such as 5G, Sigfox, LoRa, LTE-M, and NB-IoT connect devices across distances of a few hundred meters to several hundred kilometers. They are typically used to provide coverage at a regional or national level. In the remainder of this report, we will delineate low power wide area networks and traditional cellular networks as separate groupings of wide area network technologies.
- **Global area network technologies**, involving low-Earth orbit and geospatial satellites, connect devices across large parts of the Earth's surface. They are typically used to provide connectivity in remote locations and to maintain connection to devices that may travel long distances in ships and aircraft.

Figure 15: The ranges of different next-generation wireless technologies. Source: DHL (2020)

2.1 SHORT-RANGE NETWORK TECHNOLOGIES

Radio Frequency Identification (RFID)

RFID technologies are designed to provide low-cost, short-range sharing of small amounts of data. As the name suggests, this technology is typically used to identify objects. Common applications include access cards for buildings, as in figure 16, and public transit systems, security tags on retail goods, and contactless payment card systems.

RFID is actually a family of related technologies shown in figure 17 which use different frequencies to provide different performance characteristics. Most RFID systems are passive: the tag or card containing the RFID chip and antenna has no power source of its own. Instead, it harvests its energy from radio waves transmitted by the reading device. Active tags, which contain their own battery, offer higher data rates and longer transmission ranges, but the trade-off is increased cost per device. RFID is a bi-directional communication protocol; a tag can both send information to a reader as well as receive information from it.

Despite widespread use in other areas, early attempts to introduce RFID tags in logistics failed spectacularly. The technology was anticipated as a breakthrough, a replacement for the ubiquitous barcode label used to identify products and shipments during transportation and storage. RFID held the promise of low-cost, end-to-end supply chain visibility that barcodes could not deliver. The aim of the change was efficiency improvement, since information can be exchanged not just bi-directionally but also read at a distance without requiring line of sight between tag and reader, and a single reader can collect information from multiple tags.

In practice, however this promise was never realized beyond a handful of implementations. RFID tags, though inexpensive, were not cost-competitive to simple printed labels. A lack of global standards across reading infrastructure and tags, as well as a swarm of heterogeneous proprietary systems, made global deployments complicated and expensive. Also, multiple stakeholders had to be involved to ensure availability of uniform, consistent infrastructure across complex and inherently fragmented supply chains.

RFID

Data rate	640 kBit/s
Energy consumption	Low
Range	100 m
Infrastructure investment	Proprietary antennas
Availability	Dedicated infrastructure

Figure 17

Today, there is a resurgence of interest in new RFID applications thanks to cheaper tags, like the one shown in figure 18, as well as lower-cost, more readily available reading equipment. The popularity of RFID has also benefited from the integration of near-field communication (NFC) technologies into many smartphones (see next section).

Figure 16

Figure 16: Many building access cards in enterprises use RFID. Source: Deister Electronic (2020)

Figure 17: Technical details of RFID technology. Source: DHL (2020)

Figure 18

Emerging RFID applications tend to involve well-controlled environments where the availability of tags, readers, and the necessary software links can be assured. Technology benefits remain the same: data transfer without the need for a line-of-sight connection and the ability to complete multiple simultaneous reads.

RFID Logistics Use Cases

In the logistics sector, RFID is now being used to automate inventory management and asset tracking across warehousing and retail stores, as well as enabling end-to-end supply chain visibility of goods.

Intelligent Retail Stores & Inventory Management

Apparel retailer Lululemon uses RFID technology to provide retail information on in-store inventory to its sales associates. The company says that the system has increased inventory accuracy to 98%, with staff using a handheld device to tell customers immediately if their desired product is available in the store.

Sportswear brand Nike is rolling out RFID technology across many of its product lines, with tags built into shoes and other products. The company says it is using its system to track inventory at multiple points in the supply chain, from manufacturing plants to the storerooms of its retailer customers.

Fashion retailer Inditex has developed a series of innovations based on RFID to increase efficiency and improve customer service in its retail stores, as well as enhance the customer and employee experience, as shown in figure 19. In addition to 80% faster stocktaking in stores, using RFID tags in clothing and Bluetooth beacons in stores has greatly enriched customer points of interaction. RFID tags are combined with a smart mirror and tablet in changing rooms to help recognize customers, allowing them to call for help, recommending different sizes and colors, and even matching with other similar or complementary clothing articles. RFID paired with mobile payment simplifies the checkout process by remembering customers, orders, and returns history.

Figure 19

Figure 20

Autonomous Inventory & Asset Tracking

Cobot manufacturer Fetch Robotics has paired up with control systems provider Surgere to build TagSurveyor, an autonomous mobile robot with in-built RFID readers shown in figure 20. The machines do inventory tracking and cycle counting autonomously in large warehouse environments where they can roam the aisles reading the tags of products on the shelves without the need for tedious and sometimes dangerous human intervention. Important to note here is that for a 100% accurate stock count, all stock units must be equipped with an RFID tag that is readable within range of the robot. Even an accuracy of 98% may not be good enough for warehouse operations with hundreds of thousands of stock units.

Perhaps more promising than inventory visibility with RFID is asset tracking. Working with customers in the healthcare sector, DHL has implemented an RFID-based system to aid the tracking of medical equipment and devices in busy hospitals. Using a network of readers, the system can pinpoint the location of an asset to within one or two meters, cutting the time wasted searching for equipment by more than two thirds. In addition, hospital staff can use a handheld scanner to indicate that a specific item is in use, ensuring colleagues are directed only to items that are available.

Figure 18: RFID labels today can be printed, significantly lowering costs. Source: Universe of Delivery (2018)

Figure 19: The rollout of RFID across Inditex stores has decreased stocktaking time by 80%. Source: Inditex (2020)

Figure 20: Fetch Robotics has developed an autonomous mobile robot equipped with RFID readers to automate inventory stock counting. Source: Fetch Robotics (2019)

NFC	
Data rate	430 kBit/s
Energy consumption	Low
Range	10 cm
Infrastructure investment	Smartphone
Availability	Every smartphone

Figure 21

Near-Field Communication (NFC)

A newer technology derived from RFID, near-field communication (NFC), might be the innovation that finally allows RFID to fulfil its original potential. As outlined in figure 21, NFC uses the same basic protocols as its simpler cousins but in a more flexible way. A single NFC device can operate as an RFID tag or as a reader. Two NFC devices can use the technology for bi-directional communication.

NFC technology is built into a large number of modern smartphones and other consumer devices. It powers "touch-to-pay" services such as Apple Pay and Google Pay, for example, shown in figure 22. NFC technology integrated into products such as wireless headsets allows users to pair with their smartphones by touching the two devices together.

Figure 22

NFC Logistics Use Cases

Shipment Condition Monitoring

DHL routinely equips sensitive pharmaceutical shipments with logging devices like the SmartSensor near-field communication temperature device shown in figure 23. SmartSensors can record not just temperature but also humidity, shock, light, and even air pressure during transit. Earlier iterations of these loggers required proprietary readers to access their data, but the latest version uses NFC, allowing authorized users to read data via a dedicated app on a conventional smartphone. This change has simplified technology deployment and improved the user experience.

In logistics applications, the key advantage of NFC technology over RFID is its ubiquity. With over 2 billion NFC devices in existence, companies can make use of the technology across extended networks without the need to deploy proprietary equipment as with RFID in the past. As the component cost continues to go down, NFC could be used for a host of other use cases that require short-range transmission.

Figure 23

Bluetooth

Bluetooth is a two-way short-range communication technology. Whereas NFC is great for transferring small amounts of data over a very short distance, Bluetooth was designed for a more extended range of connectivity between devices. Originally intended as a replacement for the data communication cables used to link desktop computers with printers, scanners, and other peripherals, Bluetooth has evolved over more than a quarter of a century to become a mainstay of short-range wireless connectivity in both consumer and business applications. The first commercial Bluetooth device was a wireless earpiece for a mobile phone, and today the technology is used to connect not only headphones and fitness trackers like in figure 24, but also speakers, computer keyboards and mice, toothbrushes, and bicycle pumps.

Figure 21: Technical details of NFC technology. Source: DHL (2020)

Figure 22: NFC is the technology behind mobile contactless payments thanks to its short transmission range. Source: 9to5Mac (2020)

Figure 23: This DHL SmartSensor uses an NFC-based logger to track the temperature of sensitive shipments across the supply chain. Source: DHL (2018)

Figure 24

Part of the reason for Bluetooth's success is the continual evolution of the technology since its inception. That process is managed by the Bluetooth Special Interest Group (SIG), a non-profit standards organization with more than 20,000 members, including several of the world's biggest technology companies.

Bluetooth 4, launched in 2010 saw the introduction of Bluetooth Low Energy (BLE) outlined in figure 25. The approach extends the range of the technology from 10 to 300 meters, while reducing energy consumption and the cost of components. BLE has since been widely adopted in IoT applications.

Further developments are on their way. The latest iteration, Bluetooth 5, offers extra flexibility for devices which can achieve short-distance communication speeds up to twice those of previous versions or communicate over four times the distance at lower speeds.

Features in the most recent versions of the Bluetooth 5 specification have potential to significantly extend the capabilities of devices using the protocol. For example, devices can infer each other's relative angle and distance, which is useful for location tracking, and new options allow the creation of mesh networks to relay messages from device to device across longer distances. In the right circumstances, that could allow Bluetooth to operate in roles previously requiring longer-range local area network technologies.

Bluetooth Use Cases in Logistics

In logistics, Bluetooth technologies are being applied in a growing range of tracking and monitoring applications, mainly around the use of Bluetooth beacons. Bluetooth beacons are simple, low-cost devices that can be attached to packages or pallets, totes, unit load devices (ULDs), and other pool assets in logistics networks. The beacons communicate with fixed base stations nearby or with mobile devices in workers' hands, allowing specific items to be easily located.

Bluetooth Low Energy (BLE)

Data rate	1 MBit/s
Energy consumption	Very low
Range	100 m
Infrastructure investment	Bluetooth gateways
Availability	Every smartphone

Figure 25

Figure 26

Figure 27

Autonomous Asset Interaction

One of the most challenging aspects of deploying robots in an existing warehouse environment is the multitude of offline assets and obstacles the robot must be able to navigate around. The autonomous mobile robots that move products around factories and warehouses like the one shown in figure 26 can now use Bluetooth to communicate with local building controls. Robotics company Mobile Industrial Robots (MiR) outfitted a multistory warehouse with Bluetooth beacons to allow the robots to intelligently interact with the other previously offline assets. By activating a Bluetooth beacon by proximity, the robots are able to open automated doors, for example, and access elevators completely autonomously.

Condition Monitoring with Sensor Mesh Networks

Bluetooth beacons are also making their way out into the supply chain. Roambee produces low-cost BLE tags that can be included in every carton in a container or on a pallet, for example. Those beacons communicate with a "mother" sensor attached to the load. The system confirms all items in the shipment are present; it also uses a mobile data connection to send an alert if the shipment is tampered with or broken down for storage and onward distribution.[24] This can be particularly helpful when tracking high-value goods or sensitive shipments such as bulk pharmaceuticals and machinery, especially for airfreight. Building up ULDs can often require breaking down pallets to meet the contour of the given aircraft. In some cases multiple pallets may end up in separate ULDs or trucks and yet sensor networks like those from Roambee can ensure these multi-piece shipments arrive together at their destination.

Figure 24: Bluetooth is the technology behind many mainstay wireless accessories such as headphones, smartwatches, and other smartphone and computer peripherals. Source: Fitbit (2020)

Figure 25: Technical details of Bluetooth Low Energy. Source: DHL (2020)

Figure 26: An MiR picking robot with the ability to open doors and use elevators with the help of Bluetooth beacons. Source: Mobile Industrial Robots (2020)

Figure 27: The combination of BLE tags and a "mother" GSM sensor from Roambee allows logistics operators to track multi-piece shipments with unparalleled visibility. Source: DHL (2020)

Wi-Fi 6

Data rate	9.6 GBit/s
Energy consumption	Medium
Range	50 m
Infrastructure investment	Upgrade WiFi network
Availability	Dedicated infrastructure

Figure 28

2.2 LOCAL AREA NETWORKS

Wi-Fi

In high-income countries, Wi-Fi is one of the most well-known and widely used wireless technologies. Not only is it fast, with data rates up to 3.46 Gbps, but it also offers wide range indoors and is the *de-facto* wireless technology for private homes, public spaces, and every computer and smartphone in use today.

The biggest challenge facing Wi-Fi today is its own success. The technology uses unlicensed parts of the radio spectrum, usually around the 2.4 GHz and 5 GHz frequencies, with the available frequencies divided up into a number of overlapping channels. In busy environments – and that means most homes, offices, and urban spaces today – multiple Wi-Fi networks are likely to be in operation, all competing for the same limited parts of the radio spectrum. Also Wi-Fi gateways

Figure 29

are limited in the number of simultaneous connections they can support. The result is interference, congestion, and poorer performance.

The latest iteration of Wi-Fi, which goes by the brand name Wi-Fi 6 or the technical standard 802.11ax, is the industry's attempt to provide a more robust solution to its modern challenges. Outlined in figure 28, the technology offers peak speeds of 9.6 Gbps, around three times faster than its predecessor, but most of the changes in the new standard are designed to improve the performance of busy networks with multiple devices.

Wi-Fi 6 allows a router to communicate with twice as many devices simultaneously in a one-to-many fashion in parallel with many devices. In practice this can dramatically increase capacity in environments like sports stadiums where many people might want access to the same data streams.

Wi-Fi 6 also includes features designed specifically for IoT devices which often prioritize low power consumption over high data rates. Those devices can schedule check-in times with a router, allowing them to shut down their radio systems to save energy and then quickly reconnect to send or receive data.

Wi-Fi 6 is available now but, since it requires new hardware and software both in devices and network infrastructure, its widespread adoption may take some time. Upgrade cycles could be long and costly as the cabling, gateways, switches, and other infrastructure may need replacement. Regulators in many countries are expected to allow devices to operate in the new part of the spectrum during 2020, a change that will add welcome additional capacity.

Wi-Fi 6 Use Cases in Logistics

Within indoor logistics environments such as warehouses, cross-docks, and sorting facilities, Wi-Fi is already the standard wireless technology. Wireless scanners are the most ubiquitous and important tool in the warehouse, and almost unequivocally use Wi-Fi. Logistics users are likely to welcome the additional capacity offered by Wi-Fi 6, as the number of devices on their networks continues to rise.

Figure 28: Technical details of Wi-Fi 6. Source: DHL (2020)

Figure 29: Locus Robotics' swarm navigation and fleet management depends on Wi-Fi connectivity in warehouses and fulfillment operations. Source: DHL Supply Chain (2019)

Figure 30

Empowering Robotics & Wearables Deployment

With the growth of warehouse robotics estimated at a CAGR of 12% through 2027, the logistics industry is embracing a new normal in warehouse automation. Industry analysts have an even more bullish outlook on the growth of industrial wearables with an estimated 50% CAGR through 2024 as augmented, mixed, and virtual reality headsets finally break through to widespread use in daily operations. The common thread in both of these technologies is that fast, reliable Wi-Fi connections are an essential enabler for their deployment, as they require reliable, high-frequency communication with a warehouse management system (WMS) to perform their tasks. Already today, DHL is using fleets of autonomous mobile robots from Locus Robotics, as seen in figure 29, for assisted order picking. Wearables, smart glasses, and ring scanners, shown in figure 30, are an increasingly commonplace innovation within DHL facilities.

Flexible Peak Equipment Scalability

Wi-Fi 6 also allows more wired devices to make the jump to wireless. In warehouses and manufacturing environments, that simplifies the installation and maintenance of equipment, and makes it easier for owners to rapidly reconfigure their spaces to accommodate changes in processes or demand. During the busy holiday seasons, fulfillment operations become overwhelmed with order volumes, requiring the onboarding

Figure 31

and outfitting of seasonal staff with the appropriate equipment. Wi-Fi 6 holds the promise to provide headroom in the wireless network to deploy up to hundreds of new scanners, mobile workstations, and additional items of material handling equipment like those in figure 31.

Li-Fi

Wi-Fi might be the dominant player in wireless local area networks but it isn't the only one. One emerging alternative to the use of radio frequencies is networking systems that operate with visible light. Li-Fi technology takes advantage of the fact that LED light sources can adjust their brightness extremely rapidly, allowing them to transmit a signal by flickering at speeds too fast to be detected by the human eye. An optical sensor in a receiving device, however, can see the changes and decode the information.

Signify (formerly Philips Lighting) is a pioneer in this space, having recently launched its Trulifi system, depicted in figure 32. This can be integrated into the lighting units used to illuminate rooms and public spaces, and suitable light sources and sensors are commercially available as dongles for laptops and mobile devices. Because Li-Fi operates in the visible light spectrum and not the radio

Figure 32

Figure 33

spectrum, it holds the promise of immunity from the congestion problems that afflict current generations of Wi-Fi. This also means it is suitable for operation in environments where radio frequencies can present safety issues, including healthcare settings and facilities handling hazardous goods.

Though still in its infancy, perhaps the biggest value-add of Li-Fi is the cost reduction from eliminating dedicated network cabling and equipment, especially in green-field builds of new logistics facilities. The Li-Fi infrastructure is effectively built-in along with the lighting, as in figure 33. Scanning equipment, pack tables, and other fixed machinery can be deployed wherever there is visible light and can benefit from high-throughput secure connectivity. In this way, the material and labor costs of cabling are avoided.

Figure 30: Ring scanners and other wearable technology place greater demands on supply chain Wi-Fi infrastructure. Source: DHL (2020)

Figure 31: Better Wi-Fi infrastructure is critical to quickly onboard new equipment during peak operating times. Source: Miles Data Technologies (2020)

Figure 32: Li-Fi delivers Wi-Fi capabilities via the visible light spectrum at speeds up to 250 Mbps. Source: Signify (2020)

Figure 33: Li-Fi simplifies delivering Wi-Fi coverage in facilities by being built into lighting systems. Source: Signify (2019)

Figure 34

Ultra-Wideband (UWB)

Originally derived for radar positioning and communication technology in the mid-20th century, ultra-wideband is today making a comeback in the industry – with more impact than at its inception – for smaller-scale positioning to localize assets indoors.

UWB is attractive for industrial indoor positioning applications because it is spread across a large number of frequencies with a range of up to 200 meters. This means no disturbance to other wireless technologies in a relatively large space. UWB can safely coexist among existing Wi-Fi networks and Bluetooth devices. Thanks to leveraging high frequencies on the electromagnetic spectrum, UWB signals can also penetrate obstacles like walls and doors. This greatly simplifies the infrastructure requirement to achieve effective UWB coverage across a given area. Also UWB generates short pulses that can be measured very precisely. This enables applications based on the technology to achieve precision location readings down to even a few millimeters.

UWB Logistics Use Cases

For the logistics industry, UWB brings the promise of highly accurate visibility through indoor positioning of materials, assets, and personnel in increasingly complex warehouse environments.

Real-Time Location Systems

One family of technologies that is of particular interest in the logistics industry is real-time location systems (RTLS). In these systems, tags attached to people or objects exchange short messages with a number of base stations located around a warehouse, sorting facility, or similar distribution center. It should be noted that RTLS can be provided by other network technologies, including Bluetooth, Wi-Fi, and RFID, but makers of dedicated UWB location technologies claim that these systems offer unparalleled range, localization accuracy, and power consumption benefits.

Efficiency in logistics operations – especially sorting, fulfillment, and distribution – relies on a host of totes, as seen in figure 35, as well as roller cages and other material handling equipment. In addition to managing the flow of goods, it has become essential to also manage the flow of these handling units. UWB positioning solutions like the Kinexon solution shown in figure 34 can be used to locate and manage the usage of such equipment and tools in busy environments. This is becoming increasingly prevalent in manufacturing and production environments today.

The key advantage of UWB in a real-time location system is the precision of the technology – it provides localization down to a few centimeters compared to Wi-Fi which may be accurate to a few meters. Additionally the range and reach of UWB makes it more attractive than Bluetooth or RFID, as it can

Figure 36

Figure 35

localize assets over a greater distance while requiring less infrastructure and it isn't hindered by the physical layout of dense warehouses and sorting equipment.

Warehouse Layout Optimization

Going a step beyond positioning individual items, UWB can be used to gain a detailed picture of the operations of an entire facility. This allows managers to identify opportunities to reduce congestion and cut travel times by reconfiguring the space. DHL and Redpoint Positioning, a leader in UWB-based real-time location services for industry, have partnered to deliver a host of intelligent warehousing applications. By equipping parts of a warehouse in Singapore with Redpoint UWB tags, the DHL team has been able to improve worker safety by creating proximity alerts to avoid collisions with forklifts and material handling equipment. Beyond safety, tracking the movement of materials, assets, and people has helped realize productivity gains through reduced congestion, improved resource planning, and better workload allocation.

Figure 34: German startup Kinexon has a portfolio of indoor positioning systems based on ultra-wideband for industrial applications. Source: Kinexon (2020)

Figure 35: Managing the flow of logistics assets in complex indoor environments is boosted by UWB-based real-time location systems. Source: Bloomberg (2018)

Figure 36: UWB offers the potential to optimize facility layout and thereby boost productivity. Source: DHL (2019)

2.3 WIDE AREA NETWORKS

Cellular Technology & the Rise of 5G

The wireless wide area networks used by modern mobile phones are based on cellular radio technologies. In these systems, network operators install base stations, or masts, across the area they wish to serve. Each mast creates a cell which can cover an area anything from a few meters to several kilometers around the base station. Devices in a cell exchange data or voice calls with the cell's base station and, behind the scenes, network software manages hand-offs between cells to provide a seamless experience as a device moves from cell to cell.

The first cellular networks were built primarily to support mobile telephony services but since 2009 they have been supporting more data traffic than voice calls. Cellular technologies have evolved in response to this changing demand, with third- and fourth-generation networks (called 3G and 4G by the industry) providing higher speeds and greater capacity to support fast downloads and multimedia content streaming.

Like Wi-Fi, however, mobile networks are facing a capacity crunch. The combination of increasing user numbers, rising data consumption per device, and the growth in IoT device connections means that demand will exceed supply across today's networks by the middle of the current decade. The industry is responding to this challenge with the roll out of its own next-generation wireless solution: 5G.

5G networks will offer similar peak speeds to Wi-Fi 6, with the first commercial networks expected to deliver speeds of up to 10 Gbps. Much higher speeds have already been achieved in test conditions. As with Wi-Fi, however, speed is only part of the story. The biggest benefit of 5G for operators and the majority of users is expected to be the extra

5G	
Data rate	*500 GBit/s*
Energy consumption	*Very high*
Range	*500 m*
Infrastructure investment	*New antennas & more towers*
Availability	*Limited public deployments*

Figure 37

capacity it provides. 5G networks will be able to support up to 1 million connections per square kilometer, ten times more than today's 4G systems. Technical details of 5G are depicted in figure 37.

In another departure from earlier networks, 5G technology has also been designed to support a wider range of use cases. The International Telecommunication Union Radiocommunication Sector (ITU-R), which sets the standard for global mobile networks, has defined four fundamental scenarios that future 5G networks should support:

- **Enhanced Mobile Broadband (eMBB)** is the evolution of today's 4G networks, offering more capacity for operators and higher speeds for end users.
- **Massive Machine Type Communication (mMTC)** connections are designed specifically for IoT devices, with an emphasis on low-cost, low-power consumption, and the ability of networks to support large numbers of devices.
- **Ultra-Reliable Low-Latency Communications (URLLC)** network connections are designed to support equipment that depends on robust wireless connections for real-time control activities. This new type of connection is expected to be important in future mobility applications, such as communications between autonomous vehicles and traffic infrastructure, and for connecting industrial equipment.
- **Network Slicing** allows network operators to segment and allocate dedicated portions of the 5G spectrum to specific applications with tailor-made requirements, such as a guaranteed data capacity and latency.

Figure 37: Technical details of 5G. Source: DHL (2020)

Figure 38: 5G-capable phones are becoming available from all major smartphone makers.
Source: Nikkei Asian Review (2019)

Figure 38

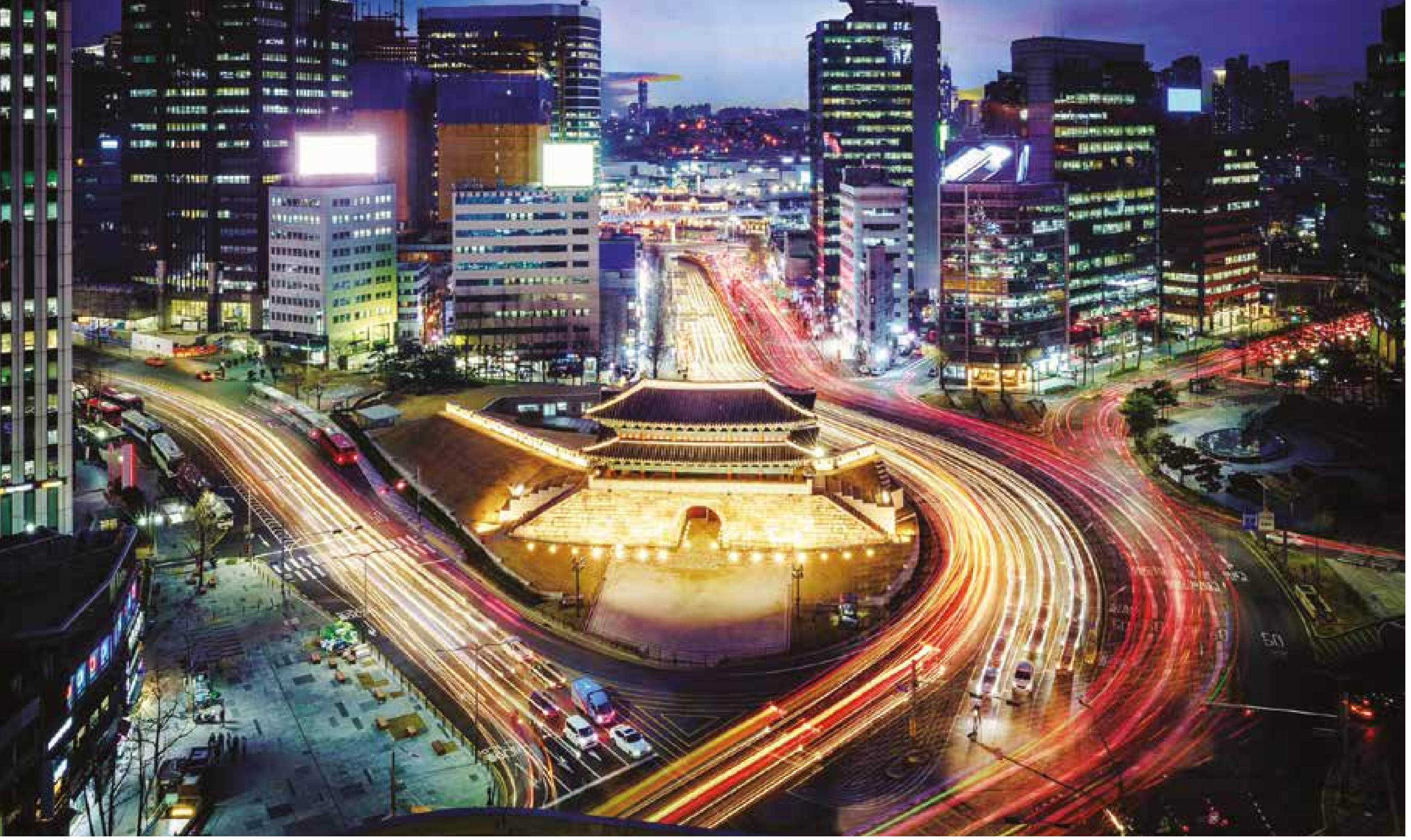


Figure 39

Private 5G

The world's mobile network operators are currently in the early stages of the rollout of their public 5G networks. In most developed countries, coverage is still patchy, with operators focusing their attention on major cities and other areas of high demand. South Korea, which had the most highly developed public 5G networks at the end of 2019, has installed more than 90,000 base stations, making the technology accessible to an estimated 93% of the population.

The initial business case for public 5G investments concentrates on the eMBB use case, with operators looking to shift existing and new smartphone users over to 5G, and to compete with fixed-line broadband providers by offering 5G connections to homes and workplaces. In some countries, security, environmental, and safety concerns have delayed the installation and activation of 5G infrastructure.

Businesses won't have to wait for public infrastructure before they can start benefiting from 5G, however. Many early adopters of the technology are expected use private networks, installing their own 5G base stations in factories and industrial parks.

Private 5G networks offer some compelling benefits to organizations. The technology promises improved performance in environments filled with metal objects and radio-frequency interference, for example. And 5G offers significant new network control options. Using the network slicing capability of 5G, owners can fine-tune the connectivity offered to different devices on the same network, so that autonomous robots could be guaranteed fast, reliable connections, for example, without having to compete for bandwidth with less safety-critical applications.

5G Logistics Use Cases

Logistics Campus Hyper-Connectivity

For logistics companies, 5G promises to address multiple connectivity challenges with a single technology. The first major use case is expected to be the application of private 5G networks at logistics hubs such as ports, airports, and warehouse complexes. One major benefit of 5G is the ability to cover both indoor and outdoor applications with a single network. The example shown in figure 40 is a recent collaboration announced between Lufthansa Technical Services, Vodafone, and Hamburg Airport to deliver a 5G campus network. By equipping a hangar and the surrounding building with 5G, Vodafone and Lufthansa aim in the near future to bring rich media experiences like augmented reality to aviation technicians and immersive video conferencing to office workers, among other capabilities.

Figure 40

Figure 39: South Korea is the first country with widespread public 5G. Source: BD Destinations (2019)

Figure 40: Lufthansa Technical Services and Vodafone have partnered to bring 5G into aircraft maintenance operations. Source: Vodafone (2020)

Figure 41

Consultancy Deloitte expects a third of the investment in private 5G networks over the next five years to come from such applications, noting that 5G is the only wireless technology currently capable of connecting every container, vehicle, crane, and other asset used at a major port complex. European network operator Orange has teamed up with the Port of Antwerp, chemical company Borealis, and polymer manufacturer Covestro to explore this opportunity. Using a private 5G network provided by Orange, the four companies plan to pilot real-life industrial applications as shown in figure 41 that make use of the massive machine-type (mMTC) and incoming ultra-reliable low-latency (URLLC) strands of the new 5G standard.

As the reach and coverage of 5G technology expands, so will its logistics applications. Some of those applications will be industry specific, including the use of 5G-enabled tracking devices to monitor the location and status of vehicles, containers, and loads both within facilities and between them. Others will emerge as part of the larger-scale, long-term development of 5G.

Smart Roads & Logistics Transport

Initiatives to enable highways and transportation infrastructure with 5G are already underway today. Smart mobility solutions such as 5G connected traffic control systems illustrated in figure 42 will help to reduce road congestion, making journey times shorter, more predictable, and more fuel efficient.

Chinese network carrier China Mobile has developed city-scale plans for 5G road networks within Hubei province that are capable of supporting cellular network-coordinated transportation services. Its first use can be seen with 5G toll booths that allow for automated toll collection without slowing down traffic or requiring any toll workers. As well as ushering in new levels of connectivity and visibility for logistics, 5G technology will be a key building block in the development of autonomous driving systems for trucks especially in the case of platooning and long-haul transport.

Figure 41: The Port of Antwerp has launched its exploration of private 5G. Source: Browsify (2019)

Figure 42: Highways equipped with 5G can potentially optimize traffic orchestration. Source: Fleet Complete (2019)

Figure 42

Figure 43

Dynamic Pop-Up Logistics Facilities

Retailers and supply chain leaders are embracing trends towards faster delivery, urban fulfillment centers, and a longer peak season every year-end. This puts increased pressure on the capacity of logistics facilities, both physically and digitally.

After building fit-out, staffing up, and process engineering in any new logistics facility, it remains costly and complex to deploy a wireless network infrastructure. 5G offers the potential to reduce setup costs and simplify the management of logistics facilities. This is especially true for facilities that may even need to be established at relatively short notice, for example urban fulfillment centers during the holiday season like the one shown in figure 43 and logistics to serve construction and mining sites. Most spectacularly, 5G played a critical role in building the Huoshenshan Hospital and Leishenshan Hospital in Wuhan, China in only ten and twelve days, respectively. From design plans to real-time coordination of construction machinery via an industrial internet platform, and from seamless orchestration of materials from over 3,000 Chinese companies to remote procedures and communication practiced within the hospital when operational, China's 5G networks were a key enabler to creating these facilities quickly from a bare plot of land.

As a single wireless technology capable of covering a wide area and connecting a myriad of devices, 5G could eliminate the need for costly wiring and infrastructure that accompanies Wi-Fi networks. What's more, the network slicing capability of 5G enables IT and facility teams to dynamically adjust how much dedicated bandwidth is needed for their operations at any given time.

Supply Chain Digital Twins

Perhaps the most ambitious application of 5G in logistics is to create perfect, real-time precision digital twins of supply chain facilities. A digital twin is a virtual representation of a unique physical asset that allows for the visibility, management, and operation of both the digital and physical asset as one.

Digital twins have become a revolutionary tool for the the aerospace, manufacturing, engineering, and energy sectors to design, develop, build, and manage all aspects of a physical product throughout its lifecycle.

In the logistics industry, developing digital twins of complex supply chain infrastructure, such as ports and large warehouses, is just now in its early stages. Major ports around the world, including Singapore and Rotterdam, Netherlands shown in figure 44, are turning to digital twins to design, plan, and manage future operations. The top three challenges to the advancement of digital twins in logistics are cost, precise representation, and data quality. 5G and next-generation wireless could provide solutions to the latter two challenges.

Precise representation of digital twins is dependent on real-time connectivity between the physical asset and its virtual representation. Given the complexity of modern warehouses and increasingly automated logistics facilities, collecting, transferring, and visualizing the data in a 1:1 dynamic virtual model has been limited by the capabilities of existing wireless networks. Now, with the ultra-low latency and enhanced broadband of 5G, this problem could eventually be eliminated. In terms of data quality, digital twins today must gather data from a host of sources, both traditional IT systems as well as an array of sensors in the physical world. In the near future, the ideal wireless gateway, likely based on 5G but also capable of harmonizing signals and information from other next-generation wireless technologies, would help solve the data quality issue by truly allowing the collection of any types of data stream.

Figure 44

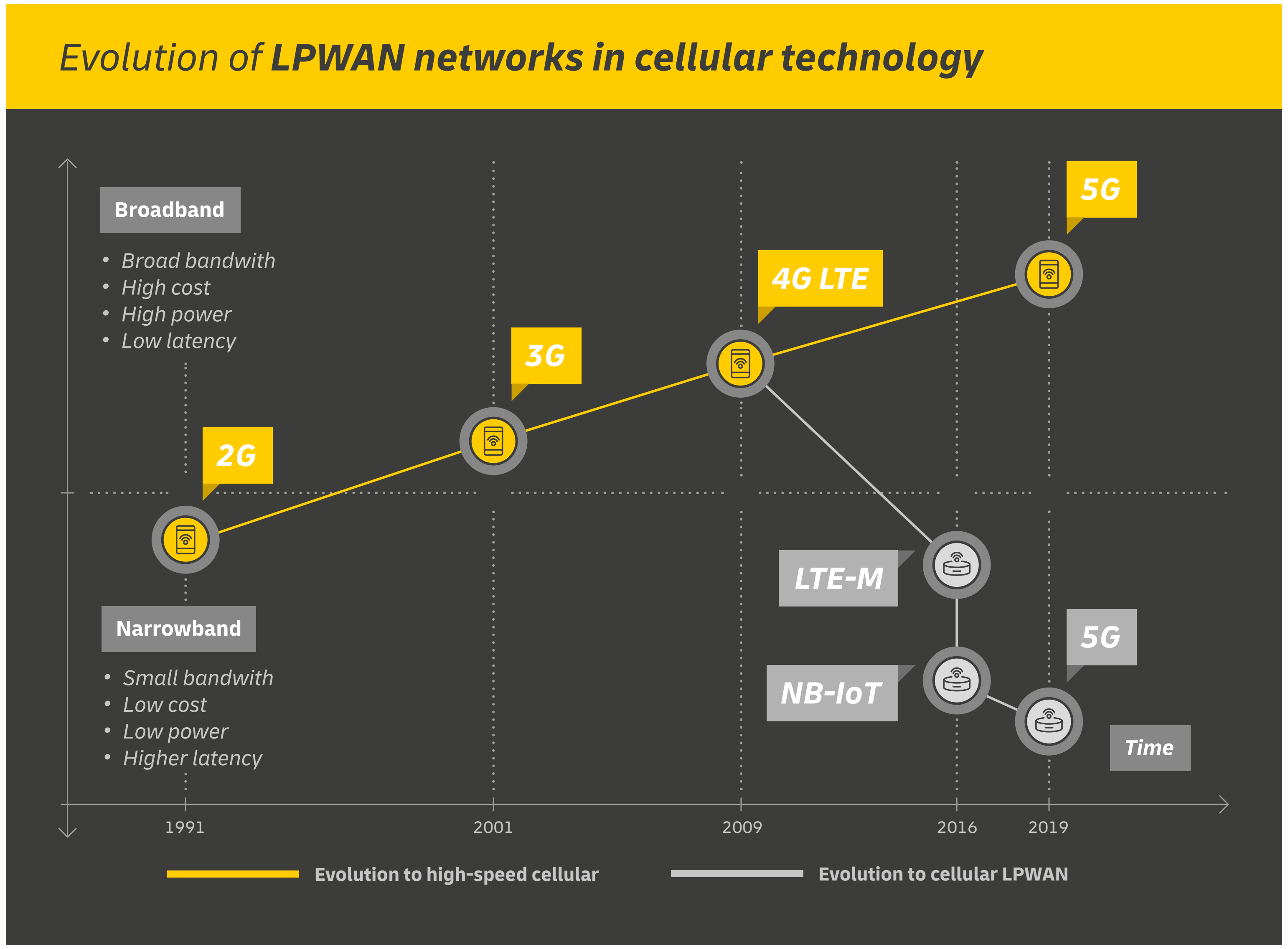


Figure 45

2.4 LOW-POWER WIDE AREA NETWORKS

5G has probably been the most widely publicized next-generation wireless technology but it is not the only contender in the race to connect the billions of devices that will form the Internet of Things. A number of alternatives have emerged, designed to match the particular needs of IoT devices: low cost, low-power consumption, and high reliability.

Low-power wide area network (LPWAN) technologies exploit the fact that IoT devices exchange much smaller quantities of data than full-sized computers or multimedia-enabled smartphones. As outlined in figure 45, LPWAN technologies are sometimes described as narrowband, to differentiate them from their more powerful broadband cousins. They are designed to fill a big space in the next-generation wireless ecosystem, offering the functionality of short-range technologies like Bluetooth and RFID but working over distances measured in kilometers like more costly 4G and 5G mobile technologies.

Besides their low cost, another important benefit of LPWAN technologies over 5G is their availability. Several LPWAN technologies are already in widespread commercial use today, allowing users to link into existing infrastructure. And where coverage is not yet available, it can often be introduced quickly and cheaply with a single base station being sufficient to connect an area the size of a city.

Figure 43: Urban micro-fulfillment centers need wireless networks as flexible as their operations. Source: DHL (2020)

Figure 44: Digital twins are in early use for port management and design. Source: Siemens (2020)

Figure 45: Low-power wide area network technology is a contributor to the evolution of cellular networks. Source: DHL (2020)

Cellular-derived LPWANs

One approach to the LPWAN is derived from today's mobile technologies. These networks are designed to use the same licensed spectrum that currently carries 4G data traffic, and to deliver services over the same hardware infrastructure. That makes it easy for network operators to introduce such services in existing coverage areas. Today's cellular LPWAN systems come in two flavors, narrowband IoT (NB-IoT) and LTE-M.

NB-IoT

Data rate	60 kBit/s
Energy consumption	Low
Range	40 km
Infrastructure investment	Existing infrastructure
Availability	All cellular networks country-specific

Figure 46

- **Narrowband IoT (NB-IoT)** is an approach supported by the world's three largest telecommunications equipment makers. It has been designed to maximize coverage using existing base station infrastructure while keeping energy consumption and device hardware costs as low as possible.

LTE-M

Data rate	375 kBit/s
Energy consumption	Low
Range	100 km
Infrastructure investment	Existing infrastructure
Availability	All cellular networks country-specific

Figure 47

- **LTE-M** is a simplified version of the LTE technology that underpins 4G mobile networks, the M signifying machine communication. It offers slightly higher data rates and lower latency than NB-IoT, but requires more power to operate.

Independent LPWANs

The growth potential of LPWAN technology has encouraged other organizations to enter this space, offering solutions that operate over unlicensed parts of the spectrum and work using their own infrastructure. The long range of a single LPWAN base station makes building a network from scratch far less costly than attempting to replicate a conventional cellular network. Today, two rival technologies have made significant inroads in this area, Sigfox and LoRa.

Sigfox

Data rate	100 Bit/s
Energy consumption	Very low
Range	50 km
Infrastructure investment	Proprietary base stations
Availability	70 countries

Figure 48

- **Sigfox** offers a narrowband technology using its own proprietary protocol. Through open source development, the company has been able to set the standards for a 0G network with ultra-low power and wide range. The company says that its network now works in 70 countries, covering 5.3 million square kilometers of the Earth's surface and a population of 1.1 billion people.

LoRa

Data rate	50 kBit/s
Energy consumption	Very low
Range	50 km
Infrastructure investment	Proprietary base stations
Availability	157 countries

Figure 49

- **LoRa** is an open standard for LPWAN technology. Today, only one company manufacturers the necessary chipsets but a certification program run by the LoRa Alliance allows any organization to build compatible devices. The organization says that its technology currently operates in 157 countries, with public and community networks covering Europe, Asia, the Americas, Australasia, and significant parts of the Middle East and Africa.

Figure 46: Technical details of NB-IoT. Source: DHL (2020) Figure 47: Technical details of LTE-M. Source: DHL (2020)
Figure 48: Technical details of Sigfox. Source: DHL (2020) Figure 49: Technical details of LoRa. Source: DHL (2020)

Coverage map of **LPWAN technologies**

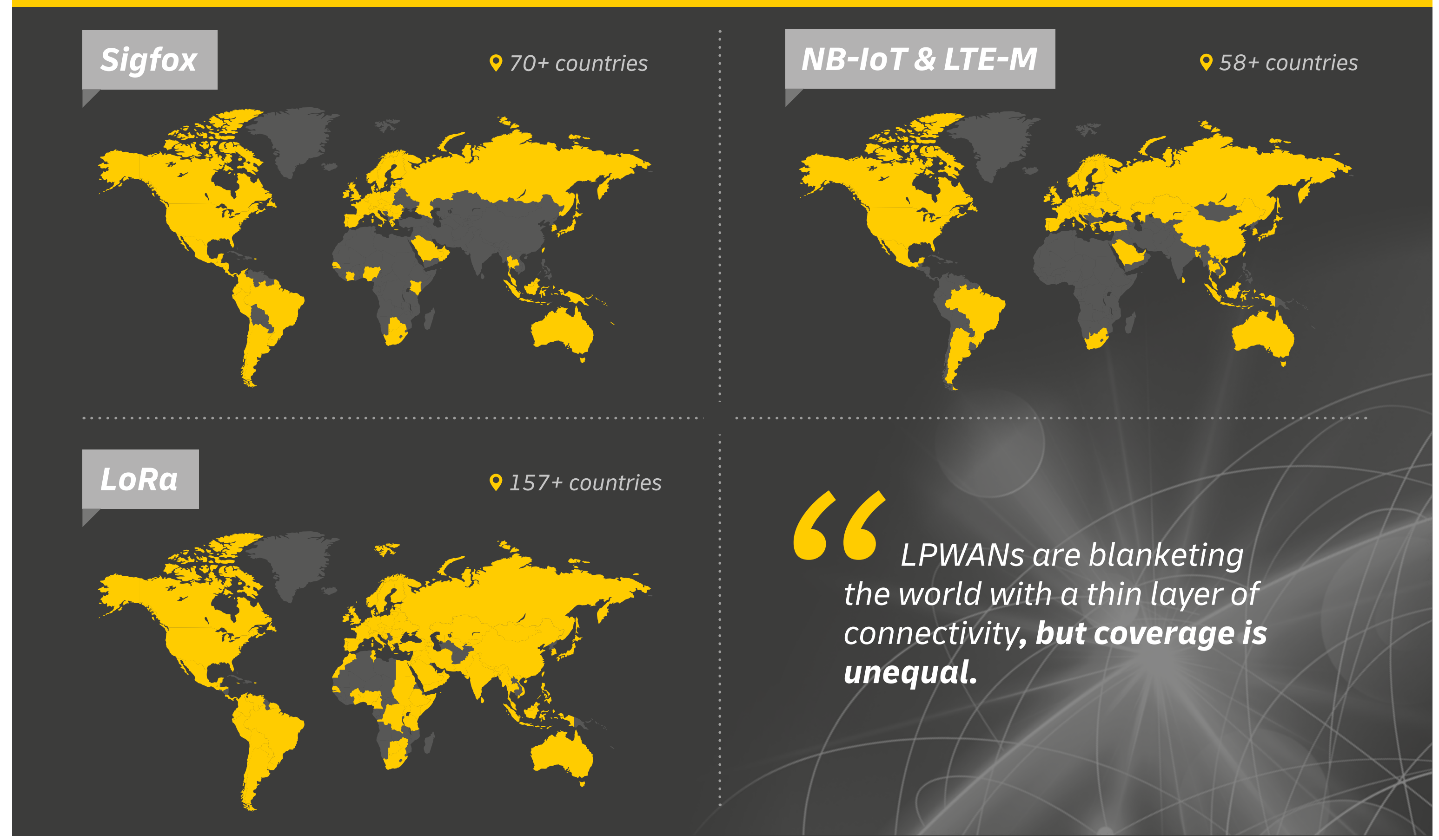


Figure 50

LPWAN Applications

LPWAN technologies are ideal for the simplest and cheapest connected devices, anywhere that the amounts of data exchanged are small and a short delay in communication has little impact on the service delivered. Major application areas for these technologies include a host of smart city use cases like energy and water metering applications and controls for streetlights and similar infrastructure. LPWAN is being used for remote machine monitoring and to run access control systems in car parks and hotels. It is also ideal as a tracking technology, with inexpensive, long-lasting tags able to monitor the position and status of anything with a lifecycle in excess of five years – for example, rental bicycles, livestock, and pets.

LPWAN Logistics Use Cases

LPWAN technologies are used in a growing range of logistics and supply chain activities, but the killer apps relate to asset tracking and monitoring for greater supply chain visibility.

Logistics Asset Tracking & Monitoring

Airport ramps are busy and complex environments where efficiency and coordination of all ground support activities are crucial to ensure flights leave on time and in line with aviation safety. For both passenger and cargo airports, this can mean coordinating thousands of ground support equipment items and vehicles. French IoT company Adveeze, for example, uses LoRa in an asset tracking system for exactly this purpose at many major airports around the world. The system monitors the location of baggage handling equipment, vehicles, and other mobile assets both indoors and outdoors and can help increase vehicle safety by reducing their speed when entering critical zones. Similarly, as seen in figure 51, over 1,000 ground support equipment vehicles at Istanbul Airport have been equipped with LoRa-based tracking technology from Skysens to monitor their location, condition, and usage to drive down airport operational expenses.

Figure 51

Figure 50: A coverage map of Sigfox, LoRa, NB-IoT, and LTE-M. Source: DHL (2020)

Figure 51: Asset tracking at Istanbul Airport using LoRa technology. Source: IoT Business News (2019)

Figure 52

Figure 53

Another value driver for asset tracking via LPWANs is loss prevention. Perhaps unknown outside post and parcel operations, roller cages play a crucial role in the collection, sorting, transportation, and delivery of millions of letters daily all around the world. In Germany, DHL's post and parcel business is using a combination of Sigfox and Wi-Fi technology to track the movement of over 250,000 roller cages throughout the country's mail and parcel network, like the one seen in figure 54. Having complete visibility of these assets not only helps operational efficiency but also helps to prevent costly inventory shrinkage.

Figure 54

Intelligent Fleet & Yard Management

If achieving visibility of logistics assets or fleets by connecting them via LPWANs is the first step, then the second is to orchestrate them differently and more effectively. In China, DHL has partnered with Huawei to test an NB-IoT system designed to improve yard management at a major automotive logistics site. In-ground sensors at warehouse dock doors, parking spaces, and staging lots feed operational data to a central yard management dashboard, helping to orchestrate the movement of around 100 DHL drivers and vehicles as they manage the inbound handling of parts headed for car production lines.

The facility realized significant benefit too. Dispatching efficiency leapt by 87% on average, aided by more agile responses from visualized yard information. Visibility over the yard and docks allowed workers to actually use less machinery and drive shorter distances, bringing security up 80% and required manpower down 50% in some cases. The same approach can be applied to any large industrial complex or container yard like the one shown in figure 52 to boost operational efficiency through improved visibility.

GPS tracking devices have been standard equipment in commercial fleets for decades now, but many fleet telemetry systems are outdated and costly compared to LPWAN-based new entrants. American company CalAmp has developed a suite of fleet telemetry solutions based on GPS and more recently LTE-M. Its LTE-M vehicle tracker offers low power consumption in a small form factor, making it ideal for non-powered assets like containers and swap bodies, as well as for rented and subcontracted fleets like the one in figure 53 which are commonplace in many logistics networks.

Figure 52: NB-IoT is one potential solution for intelligent yard management in logistics. Source: DHL (2020)

Figure 53: LTE-M offers an economical, low-power, small form-factor tracking solution for rented fleets. Source: Volvo (2020)

Figure 54: A roller cage equipped with a Sigfox tracking device. Source: Sigfox (2019)

Figure 55

2.5 GLOBAL AREA NETWORKS

Even the longest-range wireless technologies discussed so far in this report reach their limits eventually, at distances of a few tens of kilometers. If network operators want to provide coverage over a wider area, they need to replicate their base stations at suitable intervals to divide the territory into manageable cells.

That approach runs into problems when there is a need to provide connectivity to remote or sparsely populated regions where it is technically impossible or economically unfeasible to provide the necessary infrastructure. The solution to this challenge lies in the sky. Man-made satellites have been used in communications since the 1960s, and commercial satellite internet services have been available since the early 2000s.

Most satellite-based internet services use geostationary satellites like the one seen in figure 55. These are positioned in a special orbit 35,786 kilometers above the equator, where they move at the same speed as the Earth's rotation, appearing to remain in a fixed position in the sky. A geostationary orbit makes it easier for users on the ground to communicate using a fixed antenna but the approach has some important limitations. Because geostationary satellites fly above the equator, the curvature of the Earth makes them inaccessible to users in the far north or south. And the long round-trip distances taken by radio signals increases latency to half a second or more, a delay that can be annoying to users and which makes some internet services unusable.

A more recent alternative to geostationary satellites are systems that use satellites in low-Earth orbit (LEO). These satellites fly just a few hundred kilometers above the earth, reducing both latency and the power needed for wireless transmission.

Satellite networks

Data rate		*144 Bit/ message*
Energy consumption		*Medium*
Range		*Everywhere*
Infrastructure investment		*Satellites*
Availability		*Global*

Figure 56

LEO satellites travel extremely fast, orbiting the Earth in around 100 minutes. Providing a consistent connection to the ground requires a constellation of craft that share the job between them. The Iridium network, one of the first LEO communications networks, has around 82 operational satellites, for example.

Figure 55: Example of a geostationary satellite. Source: Wired (2020)

Figure 56: Technical details of global area networks. Source: DHL (2020)

Until recently, satellite internet services have remained very expensive and this has limited their uptake, especially in the type of IoT applications with the most to gain from universal connectivity regardless of location. Today, however, satellite technology has advanced, allowing the development of smaller cheaper nanosatellite designs. Moreover, the entry of private companies such as SpaceX shown in figure 57 into the commercial launch market has significantly reduced the cost of delivering payloads into orbit that can include multiple nanosatellites.

Several companies are taking advantage of these advances to develop new satellite data services. Amazon, Google, and Facebook all have plans to use large constellations of LEO satellites to deliver low-cost worldwide internet access, as illustrated in figure 58.

Others are pursuing new satellite technologies specifically for IoT applications. Toronto-based Kepler Communications, for example, is developing a constellation of LEO nanosatellites capable of providing both broad and narrowband IoT connectivity. LPWAN provider Sigfox has announced plans to launch a single satellite that will provide a twice-daily IoT connection to every point on the Earth's surface. Skylo uses existing geostationary communication satellites to deliver its new narrowband services, which it says will cut the cost of satellite data connections by as much as 95%.

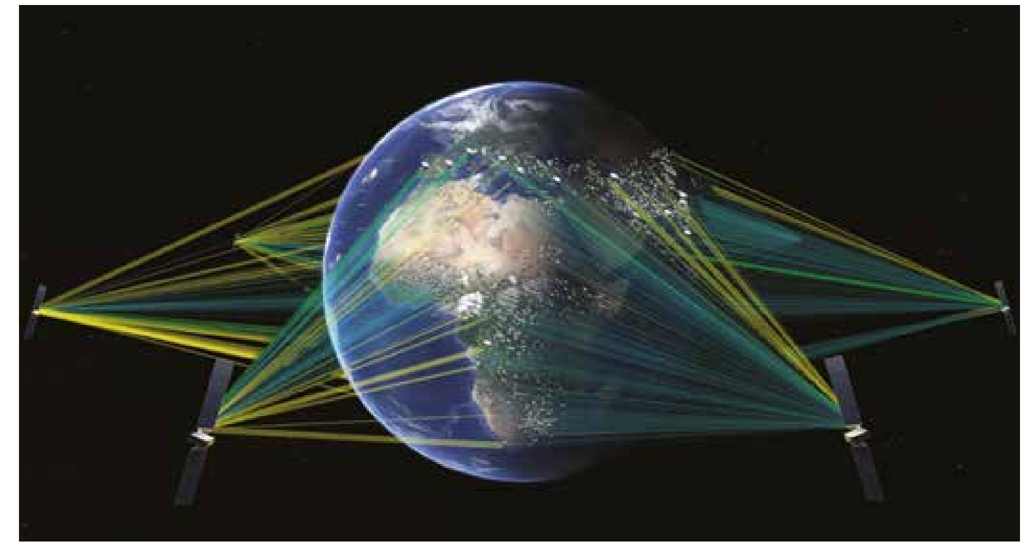


Figure 58

Figure 57

Figure 57: SpaceX has lowered the entry bar to the satellite launch market. Source: The Nation (2019)

Figure 58: Satellites covering the Earth with wireless connectivity. Source: Via Satellite (2020)

Figure 59

Global Area Network Use Cases in Logistics

Outdoor Asset Tracking & Monitoring in Remote Areas

Low-cost satellite-based connectivity holds significant appeal for logistics companies. The technology could enable continuous tracking of shipments across the globe, eliminating important connectivity blackspots such as vessels in the open oceans and flights over the poles.

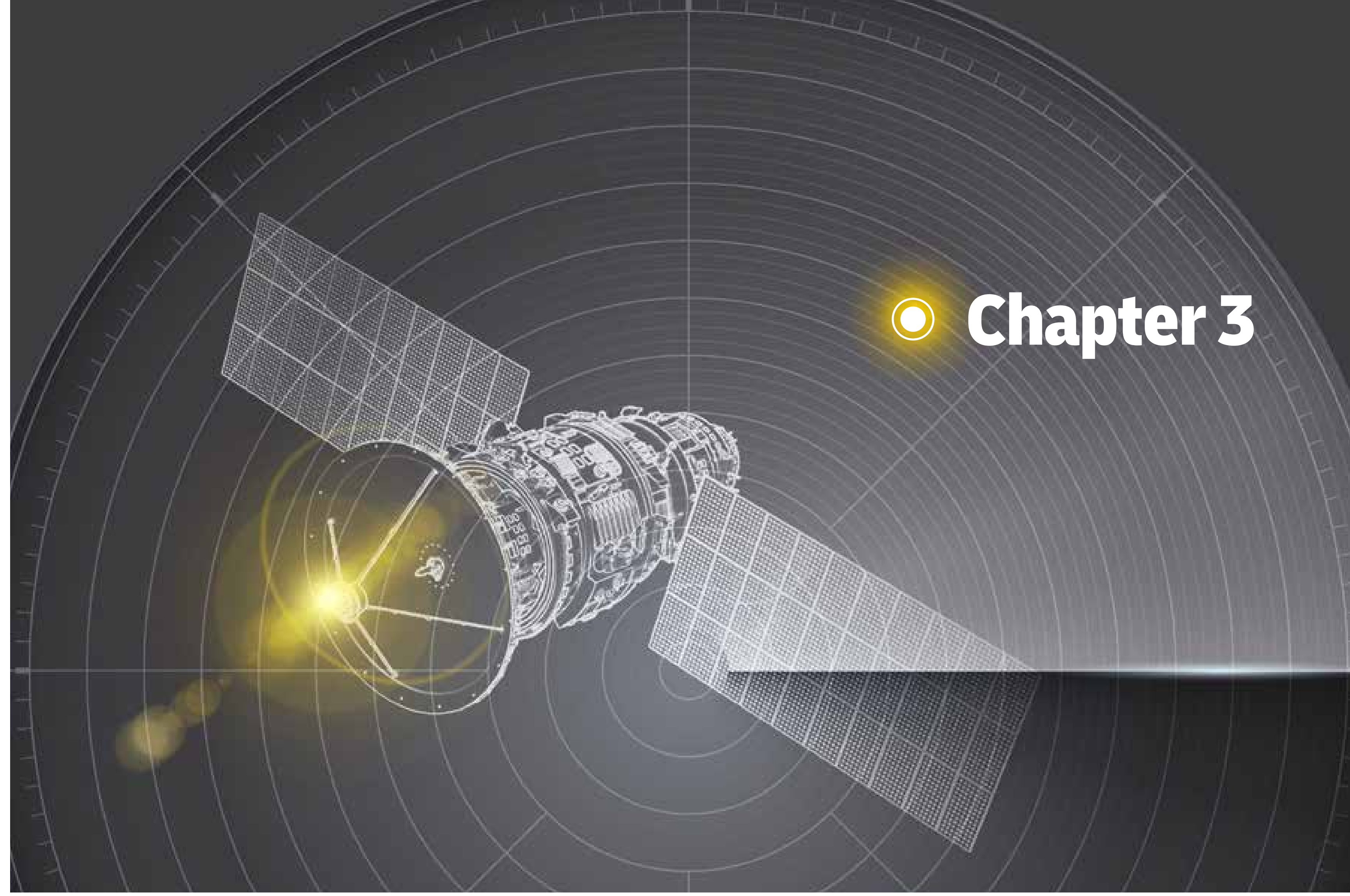
Already today in Indonesia, DHL and Skylo are exploring how to bring visibility to domestic sea freight. The objective is to establish connectivity to remote islands in the country's vast archipelago, making material flows visible in the supply chain where never before thought possible.

Beyond tracking shipments, many industrial enterprises operate large and complex machinery in very remote areas. This is especially true for the energy, mining, and construction industries. Though many assets like wind turbines and oil rigs are equipped with basic connectivity for remote access, this is not always the case and, even when it is, this is not necessarily a simple task. Low-Earth orbit satellites like those from Skylo could bring connectivity to remote mines and construction sites, as well as to energy assets both onshore and offshore like those in figure 60.

Figure 60

Figure 59: Supply chain visibility of outdoor assets in remote areas via low-Earth orbit satellites. Source: Skylo (2020)

Figure 60: LEO satellites can be used to monitor outdoor assets in remote areas. Source: Wikipedia (2018)



Building a Fully Connected Future for Logistics

The rapid evolution of wireless networking technology offers the prospect of a brave new world for the logistics sector. It is a world of total transparency in which carriers and shippers can see exactly where their shipments are, anywhere on the planet at any time. A world of automation and autonomy, in which machines work with each other to complete more logistics tasks in the office, the warehouse, and on the road. A world where arrival times can be predicted to the minute and where assets and packages never go missing. It is a world in which logistics supply chains can adapt rapidly, and often automatically, to cope with disruptive events, changes in demand, and emerging capacity constraints.

The picture on the next page illustrates a potential future powered by next-generation wireless technologies.

The fully connected ***future of logistics***

> ***"Next-generation wireless technologies*** *will enable total visibility, large-scale autonomy, and predictability for supply chains.*

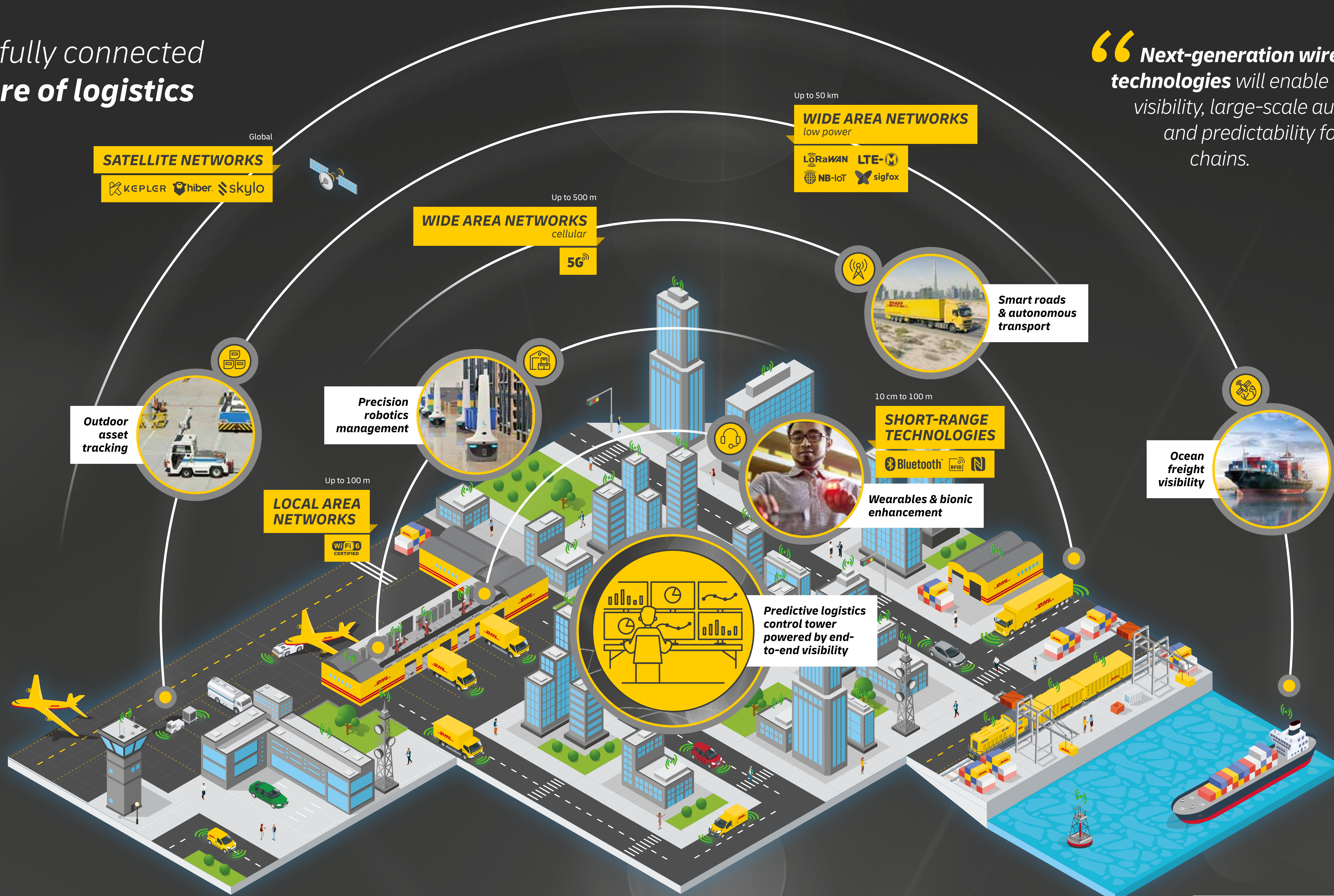


Figure 61

Figure 61: The fully connected future of logistics.
Source: DHL (2020)

3.1 TOTAL VISIBILITY, LARGE-SCALE AUTONOMY & PERFECTING PREDICTION

Much of the future shape of the logistics sector will build upon trends already emerging today. In a recent survey of 700 supply chain leaders conducted by DHL, 75% stated that achieving true end-to-end visibility across all transport modes is their most significant challenge at present. Large enterprises and their logistics providers already run control towers; these provide a centralized, high-level overview of network operations like the one in figure 62. Universal connectivity could supercharge these facilities to become mission control centers for remote monitoring of every shipment and asset movement. They could include sophisticated alert systems that allow companies to intervene and take action as potential problems emerge.

End customers and fleet managers can already exploit improved visibility of freight

Figure 62

movements and last-mile deliveries. As wireless technologies continue to evolve and tracking solutions continue to decrease in price, up-to-the-minute location information about delivery vehicles and shipments will become common, helping to improve the management of assets and the predictability of deliveries. Universal connectivity will extend the geographic reach of those capabilities significantly, allowing precise identification of asset location even in distant places and monitoring of marine shipments in the remotest parts of the ocean. US startup Spire Global is already today leveraging a constellation of nanosatellites, data analytics, and machine learning to deliver ocean vessel tracking in an anticipatory manner.

A visualization of these capabilities can be seen in figure 63.

As distribution centers steadily grow in size, complexity, and SKU quantity year after year, next-generation wireless technologies will help logistics companies drive up efficiency by accelerating the pace of automation. In warehouses, wireless local area networks will provide the connectivity needed to pass instructions between human operators, mobile robots, edge servers, and the cloud seamlessly in real time. They will allow machines to communicate with one another to avoid conflicts and coordinate their actions.

Fast, reliable wide area networks like 5G, meanwhile, will allow automation to be extended further into the world. Autonomous vehicles will become increasingly common beyond the four walls of the warehouse where adoption is scaling up today. Their usage in ports, industrial parks, and warehouse yards will eventually give rise to their use on public roads.

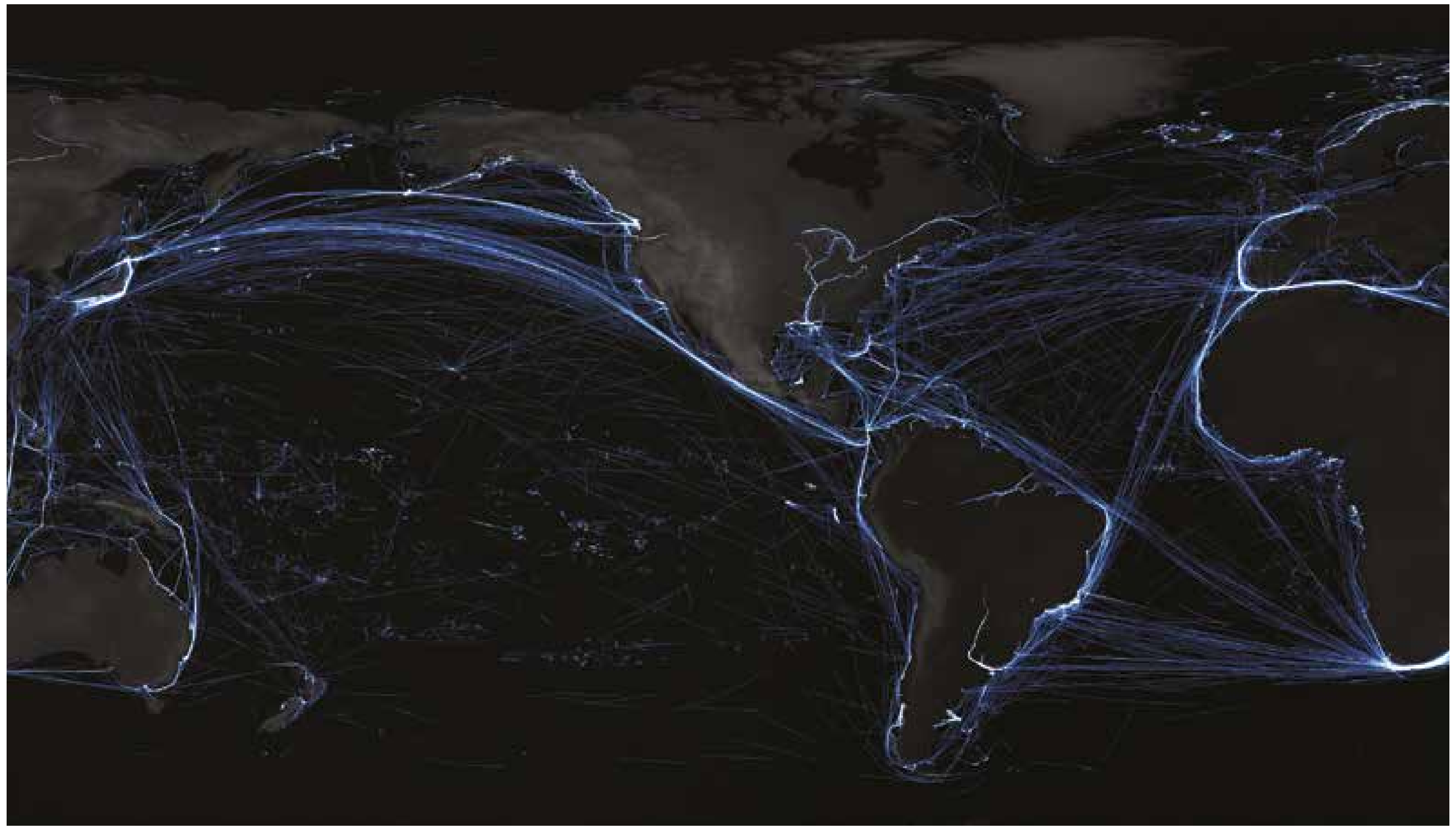


Figure 63

Autonomy will bring significant benefits to the industry's workforce too. The logistics sector will still require plenty of people but their jobs are likely to become safer, less physically demanding, and less repetitive. In warehouses, for example, autonomous mobile robots and forklifts will take care of point-to-point horizontal movements of goods as well as even vertical movements for picking and storage, empowering workers to focus on higher-order tasks. Last-mile delivery vans will still carry human crew but much of the driving may be automated, allowing staff to focus on interactions with customers and communities.

For every supply chain and logistics operation, perfect predictability is the ultimate goal. Companies want advanced warning of where, when, and how their customers would like to receive products and services, as this allows them to schedule production and distribution appropriately. In recent years and across all industries there has been profound growth in understanding of supply chain performance. In a recent DHL survey, the use of smart forecasting systems and advanced analytics technologies remains among the top three priorities as supply chain leaders seek to improve the speed and accuracy of planning processes and the responsiveness of operational decision making.

Next-generation wireless networks will dramatically improve the availability of every kind of supply chain data, from customer demand signals to the precise location and condition of assets and inventory in production and distribution networks. The promise of universal connectivity at near-zero latency will allow companies to receive, process, and analyze significantly larger complex datasets much more rapidly and at lower cost than current IoT systems. The ability to collect larger, more complete datasets is foundational to creating better predictive capabilities.

Figure 64

This predictability revolution will enhance almost every aspect of supply chain planning and operations illustrated in figure 64. Facility and fleet managers will be able to move beyond today's scheduled and reactive monitoring approaches to embrace true predictive maintenance: fixing vehicles, infrastructure, and sortation machinery before they break down, for example. Transport operations will combine real-time movements with information from advanced supply chain risk management tools, such as the DHL Resilience360 platform, to identify the most reliable, timely, and cost-efficient lane for every shipment.

Logistics and supply chain networks will be connected with powerful AI systems to interpret the influx of data collected from next-generation wireless networks. Outputs will then feed into robotics process automation software tools, and this will allow many decisions to be taken autonomously. Companies will adopt no-touch planning approaches and self-driving supply chains that sense changes and automatically adapt to normal levels of variability. That will free up human supply chain managers to focus on strategic decision making, long-term continuous improvement, and managing only exceptional events that algorithms cannot handle.

Figure 62: Next-generation wireless technologies will amplify the remote monitoring effectiveness of logistics control towers. Source: Supply Chain Beyond (2018)

Figure 63: Greater track-and-trace visibility on the high seas, thanks to next-generation wireless. Source: TechCrunch (2017)

Figure 64: Next-generation wireless networks greatly improve the availability of every kind of supply chain data. Source: Bosch Industry Consulting (2020)

Figure 65

3.2 RISKS & CHALLENGES OF NEXT-GENERATION WIRELESS

It is important to realize this compelling future of total visibility, widespread autonomy, and perfect predictability in the logistics industry will not happen automatically. As outlined earlier in this report, we can already see the technological breakthroughs, favorable cost and performance trends, and steady march towards the end of unconnected. But any organization hoping to adopt next-generation wireless technologies at scale must consider the following challenges and potential risks.

Power

Wireless devices need power and the more data they share the more power they consume. As logistics organizations ramp up the number of IoT devices in their networks, keeping everything switched on and adequately charged will become a significant challenge.

For data loggers on shipments and beacons on simple assets such as containers and roller cages, we cannot assume the availability of an external power source. Complicating things further is the infinitely varying lifecycle and value of each IoT asset to be tracked. Wireless devices need sufficient onboard storage or power generation capacity, together with a suitable infrastructure for monitoring, recharging and, potentially, mid-life battery replacement, for the full useful life of any item they are intended to track.

Solutions to the power challenge are under development. The Singapore-based start-up Transferfi has developed a wireless power system, shown in figure 65, delivering sufficient power to multi-sensor devices up to 55 meters away. The company says that its approach halves the installed cost of IoT sensors and cuts installation time by 80%. Other companies such as IoT startup Wiliot are developing energy-harvesting technologies that can generate electricity from ambient heat, light, vibration, and electromagnetic radiation.

Security

Logistics services depend upon trust. Shippers entrust their goods, and their reputations, to their service providers on the assurance that products will be protected in transit and delivered safely and securely to their destination. Wirelessly connected supply chains will become tempting targets for cybercriminals who may try to intercept communication to gather information on goods and customers, and disrupt networks to interfere with operations. Poorly secured IoT equipment has already been exploited by criminal groups. As these devices play an ever more critical role in business activities, security by design is an important philosophy to consider when selecting any IoT solution.

Malevolent actors don't have to break into a wireless network to cause problems. Specialized radio equipment can be used to jam local wireless networks by flooding the appropriate frequencies with noise or meaningless data. In February 2020, Berlin artist Simon Weckert successfully faked a traffic jam. As shown in figure 66, he transported 99 smartphones on city streets while each of them simultaneously used Google Maps to highlight the risks of technology dependence in modern society. More sophisticated spoofing attacks use tailored transmissions to deliver erroneous information to local devices. In the maritime industry, for example, these can cause ships to disappear from radars or show up somewhere else entirely. The root cause of 50% of all casualties at sea is navigation issues resulting in collisions and unintended groundings. Approaches like these are already used to interfere with GPS signals. To reduce the impact of such attacks, systems relying on wireless infrastructure will need to be designed to cope with service interruptions and to identify and handle potentially erroneous data.

Figure 66

Figure 65: The Transferfi Wireless Power Network. Source: Transferfi (2020)

Figure 66: 'Google Maps Hack' by artist Simon Weckert draws attention to the risks of depending on technology. Source: Simon Weckert (2020)

Infrastructure Availability

Logistics activities often take place across large geographical areas. Applications that rely on wireless connectivity must ensure that the chosen technology is available everywhere it is needed. Narrowband WAN solutions such as LoRa require end users to install and run their own network base stations, but many next-generation wireless technologies rely on third-party infrastructure like the LoRa gateway shown in figure 67.

As they plan the roll out of new wireless solutions, companies will need to select an approach that fits their supply chain requirements. That calls for careful assessment of the current reach of any available networks, along with considering the company's medium- and long-term development plans. Where no solution provides complete coverage, the application must find a way to fill the gap. This might involve the use of a secondary wireless technology along with a process that accommodates partial or complete offline operation.

Network Access & Roaming Costs

The use of third-party wireless infrastructure such as 5G and Narrowband IoT (NB-IoT) networks requires compatibility with the chipsets in IoT devices; they must be capable of running on different frequencies. Those frequencies vary not only by technology but also from country to country. Assuming there is technical interoperability, companies must pay each network operator for access, typically on a country level and, for international access, via the operator's roaming agreements with other providers, which is not always straightforward and may incur substantial cost.

In some regions, such as the EU, extra costs for roaming are limited by law but in other regions there may be no control and expenditure can quickly escalate. Logistics, which tends to be a high-volume, low-margin activity, is particularly sensitive to any source of additional cost. Excessive roaming charges could undermine the business case for some connectivity applications.

When applications involve significant cross-border movement of connected devices, companies need to analyze the implications of roaming costs carefully. Some network access providers are responding to demand for international tracking solutions by providing global SIM cards with a flat-rate access charge wherever they are used.

Standards & Protocols

As with any fast-moving area of technology, next-generation wireless is seeing an explosion of innovation. New solutions are flooding onto the market, with providers offering products based on established and emerging standards or on their own proprietary approaches.

For some in the logistics sector, this proliferation of offerings will bring back uncomfortable memories of early experiments with RFID, where lack of standardization hampered widespread adoption of a promising technology. The same risks surround the selection of next-generation wireless technologies, and no organization wants to invest in an approach that will prove difficult to scale up and support in the long term.

While it is impossible to know if any given technology will succeed in the market, companies can maximize the probability of success by choosing approaches that meet two basic tests. First, the underlying technology used by the solution should be based on a published standard supported by one of the major international industry groups or standards bodies such as the IEEE, 3GPP, or Bluetooth SIG. Picking a proprietary approach requires careful balancing of the potential benefits of the technology against the risks of being unable to scale or becoming locked-in to a specific vendor. Second, there should be evidence that the chosen approach has significant traction within the logistics sector and beyond it. Technologies with other major markets, especially high-volume consumer applications, benefit significantly from the presence of better infrastructure, cheaper hardware, and a larger ecosystem of vendors.

Regulatory Approval

While most of today's major next-generation wireless technologies are based on global standards, the regulatory environment for wireless technologies remains extremely fragmented. Radio spectrum availability, for example, varies by region. That means companies may need to use different hardware in different parts of their supply chain. Devices that are required to operate anywhere in the world may need to employ different frequencies depending on their location.

The process of gaining approval for the operation of devices and networks is even more convoluted. Despite pressure for standardization, countries have widely differing test and certification requirements, forcing wireless devices to undergo a lengthy and sometimes costly approval process for every territory of intended operation. Most of this regulatory burden will fall on hardware companies rather than end users but any company wishing to roll out a wireless solution internationally must establish whether the proposed hardware is acceptable in every targeted country.

Figure 67

Figure 67: Off-the-shelf LoRa gateways. Source: Sensing Labs (2020)

3.3 IMPLEMENTING NEXT-GENERATION WIRELESS IN YOUR SUPPLY CHAIN

Having considered the potential future, as well as obstacles that must still be overcome, one question remains: How can you get started using next-generation wireless technologies in your supply chain?

These technologies are set to impact every supply chain and, while simply upgrading network infrastructure and IT assets will bring in some next-generation technology by default, many organizations will seek to actively exploit the benefits of universal connectivity to drive improvements in the quality, efficiency, and flexibility of their supply chains.

If your business is considering such a journey, here are six key checks to set you on the right path.

1 Start with the Business Case

Technology investments don't automatically deliver business benefits, especially in high-volume, narrow-margin industries like logistics. Organizations need a clear, quantifiable business case against which they can measure the costs and benefits of any next-generation wireless application.

- What is the primary objective of the application? Cost reduction? Revenue generation? Customer satisfaction? Quality control?
- What is the monetary value of the application to your organization?
- What is the minimum level of visibility or connectivity required to deliver the proposed benefits?
- What do you intend to do differently with the insights and data you collect?
- How could the organization build on the initial business case to create more value over a longer term?

Logistics professionals should resist the shiny new object appeal of technology and focus their next-generation wireless investments on clear goals such as optimizing or reducing asset costs and increasing customer retention through better service quality from visibility tools.

2 Choose the Right Wireless Technology

The choice of next-generation wireless technologies is determined by the underlying connectivity requirements: The bandwidth and coverage required and the resources available to deliver them.

- Bandwidth: What volume of data (both upstream and downstream) will devices need to share?
- Latency: How much is tolerable – do you need real-time data, near real-time, or at intervals of minutes, hours, or days?
- Range: If two things must exchange information, how far apart might they be?
- Coverage: What amount is required – indoors or outdoors; local, regional, or global?
- Power: For how long must devices operate on stored energy? When, where, and how will batteries be recharged and replaced?
- Accuracy: How precise must the data be about a given use case or problem you're trying to solve?

Many technologies have similar applications and capabilities. Indoor localization, for example, can be solved by multiple different approaches including but not limited to Ultra-wideband (UWB), Wi-Fi, and Bluetooth. It is important to understand the capabilities of each and consider which is the most realistic for your operations in terms of coverage, cost, and existing infrastructure.

3 Assume Some Assembly Required

In most logistics applications, IoT solutions that leverage next-generation wireless technologies will not be plug and play. Often systems will be built largely from off-the-shelf products and components but organizations will need to assemble unique combinations of hardware and software to meet their specific needs. Similarly, where global supply chains cover long distances, multiple technologies may be required.

- Will more than one wireless technology be needed to meet our requirements? How will these technologies work together?
- What infrastructure will be required to operate the network? Will this be operated in house or by an external service provider?
- Which technology types already exist in our organization's infrastructure? Do we have the experience and skills to manage them?

One unsung hero in many IoT solutions is end-device firmware. Highly fast and efficient next-generation wireless networks will not deliver the full value of an IoT solution if the on-device firmware is inefficient or fails to report data as efficiently as the network.

4 Data Quality & Device Durability

The value of IoT comes from the organization's ability to change the way it works based on analysis of new sources of data. But excitement about the high-level potential of new connected approaches can lead companies to underestimate or ignore the challenges of deploying a reliable sensor network.

- Do we understand the capabilities and limitations of the sensors in our network?
- How will we manage missing or erroneous data?
- Are our field devices sufficiently protected from dust, moisture, and extremes of temperature?

Upstream insights from devices in the field are only useful if they can be acted upon downstream. The ability to maintain devices in the field, collect data reliably, and act on it effectively without any gaps is critical to a holistic next-generation wireless deployment.

5 Platforming & Future Proofing

The first use case for any next-generation wireless technology is unlikely to be the last. While immediate business benefits of new deployments can be compelling, every organization should keep an eye on their future needs by building reusable infrastructure that can be easily reapplied to new use cases without extensive re-programming.

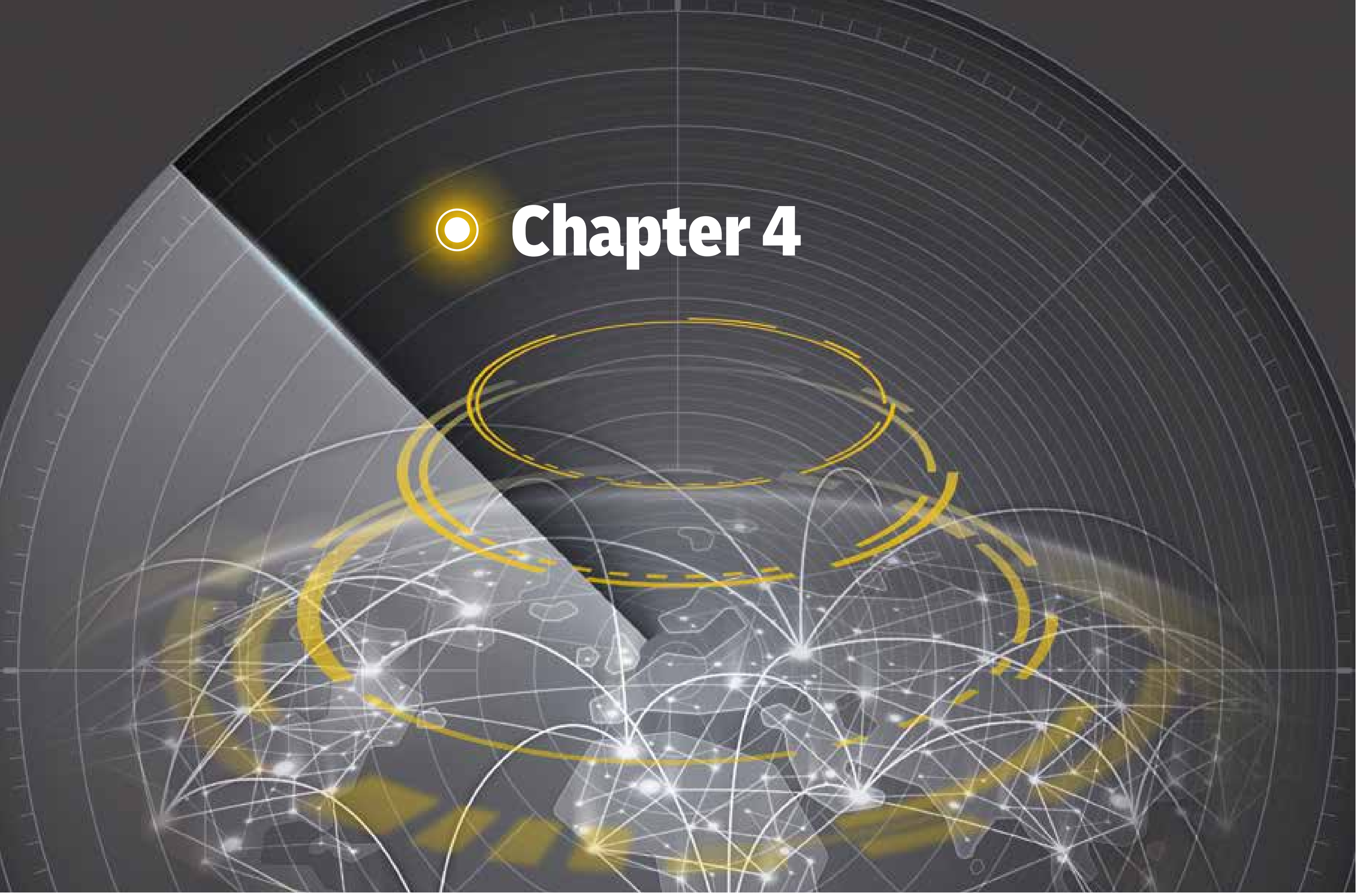
- How are our requirements for bandwidth, users, and numbers of device likely to scale up over time?
- Do we have a centralized IT platform easily capable of hosting and supporting the desired use cases of the organization?
- Are we ready to extend our capabilities and infrastructure to encompass alternative use cases, different data, and/or new types of device?

6 Governance, Culture & Capabilities

When new technologies fail to deliver on their promise, the root cause is often human. Innovations require people to change, developing new skills, adopting new processes, and adapting long-established working methods. Connected logistics will be no different.

- How will we ensure our organization has the capabilities it needs to deploy and support new wireless technologies?
- How will our organizational structure, processes, and management systems need to change?
- How will we give our people the know-how and motivation to make the most of new approaches?
- How will we enable the organization to create new business from the data collected?

Supply chain leaders wanting to make most effective use of next-generation wireless technologies will ideally empower their organizations to discover new ways to succeed through upskilling, training, and fundamentally raising the capabilities of their organization in the long term. At best, the right setup of next-generation wireless technologies and IoT will empower the organization to create new business models and revenue streams from the data and insights these systems generate.



Conclusion & Outlook

Large-scale digital connectivity is an extraordinary technological and societal success story. Half the population of the world can now access the internet and most individuals do so using wireless connections. The next chapter of the story promises even more. In the coming years, wireless connectivity will reach millions more people and billions more devices, paving the way for a dramatic expansion in digital services and IoT applications.

While much of this forecasted growth will be achieved using technologies that are familiar to many of us today, truly universal connectivity will require approaches that can offer new capabilities, including higher capacity, greater reach, faster speeds, better energy efficiency, and lower costs. Next-generation wireless is a broad portfolio of technologies promising to deliver on each of these diverse – and often competing – objectives

The logistics industry relies upon the efficient coordination of large numbers of people, assets, goods, and materials. As such, it stands to benefit significantly from a more powerful, accessible Internet of Things (IoT). Every category of next-generation wireless technology is likely to find its place in the world of logistics.

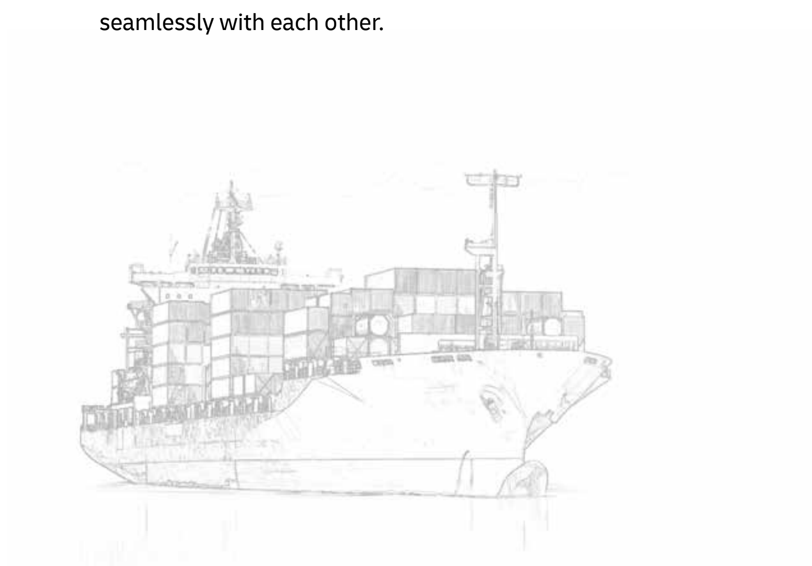
- **Radio Frequency Identification (RFID)** will enjoy a revival in warehouses and other controlled environments, giving companies a faster, more accurate way to track assets and shipments.
- **Near Field Communication (NFC)** will find new uses cases beyond today's applications in shipment temperature loggers, allowing logistics data to be transferred securely with just a finger tap on a mobile phone.
- **Bluetooth Low Energy (BLE)** beacons will allow local logistics infrastructure, assets, and shipments to communicate seamlessly with each other.
- **Wi-Fi** will enable more efficient, more automated warehouses, overcoming today's capacity limitations and gaining new capabilities – such as the ability to precisely locate objects in complex indoor environments.
- **5G** mobile technology will power hyper-connected factories and logistics campuses, and be a key enabler for autonomous transport.
- **Low-Power Wide Area Networks (LPWANs)** will provide basic connectivity to more of the world and allow wireless assets powered by batteries and by energy harvesting technologies to operate unattended for months and years.
- **Low-Power Global Area Networks (LPGANs)** will use satellites to extend connectivity to the remotest corners of the world.

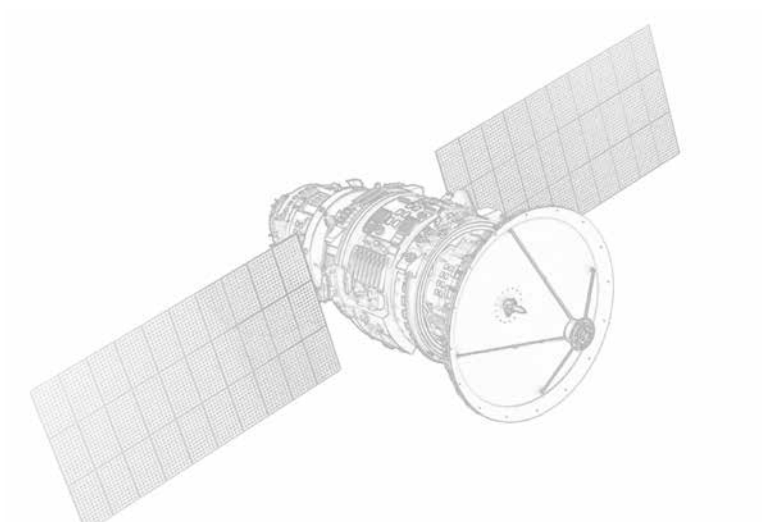
Next-generation wireless technologies hold great promise for the logistics sector. They will help companies address long-standing challenges such as poor end-to-end visibility across networks. They will play a critical role in the sector's efforts to improve efficiency through greater automation of both planning and execution. They could even enable the creation of entirely new processes, services, and business models.

Capturing these benefits will require organizations to take a systematic approach to their investments. It will be essential to identify the most appropriate use cases for new wireless technologies and then build a robust business case for each. The next vital step is to select the right combination of technologies to achieve business objectives and decide how to source and run new hardware, infrastructure, and services. And it will be critically important to adapt the organization's capabilities, business processes, and culture.

While the logistics sector is already taking significant steps to incorporate wireless connectivity and IoT, we believe there has never been a better time to explore the opportunities offered by next-generation wireless technologies. We look forward to collaborating with you to implement this exciting new wave of IoT in your supply chain, and together embarking on the journey to connect everyone, everything, everywhere.

On behalf of DHL, we hope you have enjoyed reading this report as much as we have enjoyed putting it together for you.





Next-generation wireless technology cheat sheet

	Frequency	Range	Data rate	Energy consumption	End nodes per gateway	Availability
RFID	125 kHz – 960 MHz	100 m	640 kBit/s	Very low	1	Dedicated infrastructure
	13.56 MHz	10 cm	430 kBit/s	Low	1	Every smartphone
Bluetooth	2.4 GHz	350 m	1 MBit/s	Very low	Unlimited	Every smartphone & some gateways
Wi Fi 6 CERTIFIED	1, 2.4, 5 & 6 GHz	50 m	10 GBit/s	Medium	250	Every smartphone & new infrastructure
4G LTE	410 - 5900 MHz	10 km	1 GBit/s	Low	600	Public deployment
5G	2.5 GHz - 49 GHz	500 m	50 GBit/s	Very high	1 million	Limited public deployment
LTE-M	500 - 5900 MHz	100 km	375 kBit/s	Low	Not available	All cellular networks *country-specific*
NB-IoT	698 - 2170 MHz	40 km	250 kBit/s	Low	ca. 20,000	All cellular networks *country-specific*
LoRaWAN	490 MHz 868 MHz 915 MHz	50 km	300 Bit/s	Very low	1 million	157 countries
sigfox	433 MHz 915 MHz	50 km	100 Bit/s	Very low	1 million	70 countries
	400 MHz	Global	144Bit/s	Medium	Not applicable	Global

Some specifications may vary by country/region or future releases.

Sources

Bluetooth SIG (2019)
Bluetooth 5 Go Faster Go further.
https://3pl46c46ctx02p7rzdsvsg21-wpengine.netdna-ssl.com/wp-content/uploads/2019/03/Bluetooth_5-FINAL.pdf

Buildfire (2019)
Mobile App Download and Usage Statistics. https://buildfire.com/app-statistics/

Business of Apps (2020)
Zoom Revenue and Usage Statistics.
https://www.businessofapps.com/data/zoom-statistics/

BusinessWire (2020)
CORRECTING and REPLACING Skylo Emerges From Stealth With $116M in Funding and World's Most Affordable Satellite Network for IoT Data.
https://www.businesswire.com/news/home/20200121005339/en/CORRECTING-REPLACING-Skylo-Emerges-Stealth-116M-Funding

CGTN (2020)
Huawei builds 5G network at Wuhan Huoshenshan Hospital.
https://news.cgtn.com/news/2020-03-13/Huawei-builds-5G-network-at-Wuhan-Huoshenshan-Hospital-OP6qhHRc1G/index.html

Cisco (2018)
Annual Internet Report.
https://www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/white-paper-c11-738429.pdf

CNX Software (2019)
Sigfox Targets Worldwide Coverage with Satellite Launch.
https://www.cnx-software.com/2019/03/21/sigfox-satellite-lpwan-worldwide-coverage/

Deloitte (2019)
Technology, Media, and Telecommunications Predictions 2020.
https://www2.deloitte.com/content/dam/insights/us/articles/722835_tmt-predictions-2020/DI_TMT-Prediction-2020.pdf

Drift (2020)
The 3 Secrets Behind Zoom's Triple-Digit Growth.
https://www.drift.com/blog/how-zoom-grew/

Fetch Robotics (2018)
RFID Inventory Tracking and Cycle Counting with Autonomous Mobile Robots.
https://fetchrobotics.com/fetch-robotics-blog/rfid-inventory-tracking/

Fetch Robotics (2018)
Verify your inventory count multiple times per day.
https://fetchrobotics.com/products-technology/datasurvey/tagsurveyor/

Financial Times (2020)
Data traffic outstrips mobile voice calls.
https://www.ft.com/content/c6d6edce-3792-11df-88c6-00144feabdc0

Gartner (2019)
Gartner Says 5.8 Billion Enterprise and Automotive IoT Endpoints Will Be in Use in 2020.
https://www.gartner.com/en/newsroom/press-releases/2019-08-29-gartner-says-5-8-billion-enterprise-and-automotive-io

GSMA Intelligence (2020)
Global Mobile Trends 2020.
https://www.gsmaintelligence.com/h/?file=c5f35990dcc742733028de6361ccdf3b&download

IEEE Spectrum (2016)
Why Wi-Fi Stinks—and How to Fix It.
https://spectrum.ieee.org/telecom/wireless/why-wifi-stinksand-how-to-fix-it

Internet World Stats (2019)
Internet Users Statistics for Africa.
https://www.internetworldstats.com/stats1.htm

IoT Analytics (2019)
Smart Meter Market 2019: Global penetration reached 14% – North America, Europe ahead.
https://iot-analytics.com/smart-meter-market-2019-global-penetration-reached-14-percent/

IoT Analytics (2018)
State of the IoT 2018: Number of IoT devices now at 7B – Market accelerating.
https://iot-analytics.com/state-of-the-iot-update-q1-q2-2018-number-of-iot-devices-now-7b/

Iridium (2018)
Satellites 101: LEO vs. GEO.
https://www.iridium.com/blog/2018/09/11/satellites-101-leo-vs-geo/

Kepler (2020)
everywhereIOT.
https://www.keplercommunications.com/industries/shipping-and-logistics

LoRa Alliance (2020)
Company Website.
https://lora-alliance.org

Markets And Markets (2019)
GPS Tracking Device Market.
https://www.marketsandmarkets.com/Market-Reports/global-GPS-market-and-its-applications-142.html

Mobile Industrial Robots (2020)
iAM-R.
https://www.mobile-industrial-robots.com/de/solutions/mirgo/products/iconsys-iam-r/

MIT Technology Review (2019)
Ghost ships, crop circles, and soft gold: A GPS mystery in Shanghai.
https://www.technologyreview.com/2019/11/15/131940/ghost-ships-crop-circles-and-soft-gold-a-gps-mystery-in-shanghai/

Mobile Industrial Robots (2020)
Automation of Internal Transportation.
https://www.mobile-industrial-robots.com/media/3777/white-paper_what_every_business_owner_needs_to_know_about_amrs.pdf

Mobile World Live (2019)
South Korea hits 3M 5G subs as base stations double.
https://www.mobileworldlive.com/featured-content/top-three/south-korea-hits-3m-5g-subs-as-base-stations-double/

Noodle (2017)
10 Cool Things We've Done with RFID for Events.
https://www.noodlelive.com/blog/10-cool-things-weve-done-with-rfid-for-events/

Philips Lighting (2018)
LiFi: broadband data through light.
https://www.signify.com/global/our-company/news/press-release-archive/2018/20180316-philips-lighting-introduces-lifi-broadband-data-through-light

Redpoint (2020)
Redpoint.
https://www.redpointpositioning.com/en.php/technology/list-18

Roambee (2020)
On-demand Goods & Asset Monitoring.
https://www.roambee.com

Semtech (2017)
Track In-Motion Assets at Global Airports.
https://www.semtech.com/company/press/Adveez-and-Semtech-Track-In-Motion-Assets-at-Global-Airports

Shopify (2017)
5 Examples of Innovative Uses for RFID Technology in Retail.
https://www.shopify.com/retail/5-examples-of-innovative-uses-for-rfid-technology-in-retail

Skylo (2020)
Mobilizing the world's machine data.
https://www.skylo.tech/

Sigfox (2020)
Sigfox Story.
https://www.sigfox.com/en/sigfox-story

Silca (2020)
TATTICO BLUETOOTH® MINI-PUMP.
https://silca.cc/products/tattico-bluetooth-mini-pump

Statista (2020)
Smartphone users worldwide 2016-2021.
https://www.statista.com/statistics/330695/number-of-smartphone-users-worldwide/

Supplychain Dive (2019)
When it comes to speed, Nike says RFID is key.
https://www.supplychaindive.com/news/Nike-RFID-speed-inventory/557875/

Tech Crunch (2017)
Spire's ship tracking satellite data makes it easier to monitor vessels from space.
https://techcrunch.com/2017/08/29/spires-ship-tracking-satellite-data-makes-it-easier-to-monitor-vessels-from-space/

The Verge (2019)
Wi-Fi 6: is it really that much faster?.
https://www.theverge.com/2019/2/21/18232026/wi-fi-6-speed-explained-router-wifi-how-does-work

Transferfi (2018)
The world's first long-range, safe & efficient wireless power network.
https://www.transferfi.com/

Visualistan (2019)
The Internet Then and Now.
https://www.visualistan.com/2015/07/the-internet-then-and-now-infographic.html

Vodafone (2020)
An update on Vodafone's networks.
https://www.vodafone.com/covid19/news/update-on-vodafone-networks

Wall Street Journal (2014)
Oral-B SmartSeries Bluetooth Toothbrush Has Bite.
https://www.youtube.com/watch?v=R557SEiwwlE

Wi-Fi Alliance (2020)
Eight Wi-Fi® trends expected in 2020.
https://www.wi-fi.org/beacon/the-beacon/eight-wi-fi-trends-expected-in-2020

Wired (2020)
An Artist Used 99 Phones to Fake a Google Maps Traffic Jam.
https://www.wired.com/story/99-phones-fake-google-maps-traffic-jam/

Pictorial Sources

Figure 1: DHL (2020)
Maslow's updated hierarchy of needs.

Figure 2: Macstories (2017)
The launch of the iPhone in 2007 and its subsequent adoption pushed cellular data transmission far beyond usage levels of previous devices.
https://www.macstories.net/news/10-years-ago-the-iphone-redefined-mobile-computing/

Figure 3: DW (2019)
In key African countries, mobile and mobile internet represent the most pervasive form of connectivity.
https://www.dw.com/en/africas-innovative-response-to-internet-repression/a-51199067

Figure 4: Samsara (2019)
The logistics and transportation industries are the main drivers of GPS tracking device adoption.
https://www.samsara.com/blog/gps-trailer-tracking-for-fleets

Figure 5: Business Insider (2020)
Zoom meetings have gone from a startup niche activity to a household name during the COVID-19 crisis.
https://www.businessinsider.com/how-to-share-screen-on-zoom

Figure 6: TechCrunch (2019)
Google plans to bring its Google Assistant to feature phones in India via a free hotline.
https://techcrunch.com/2019/09/18/google-assistant-no-internet-india/

Figure 7: Augury (2020)
Whether designed-in or retrofitted, industrial machinery is increasingly becoming connected to the Internet of Things.
https://iot.do/augury-oem-industrial-iot-2016-09

Figure 8: BD Tech Talks (2020)
VR and AR will raise the bar, making new wireless connectivity demands in order to render high-resolution graphics and video content.
https://bdtechtalks.com/2019/01/31/augmented-reallity-dominant-immersive-technology/

Figure 9: Vodafone (2020)
Bringing connectivity everywhere presents a significant geographical challenge for the logistics industry.
https://www.vodafone.com/what-we-do/services/roaming/maritime/vodafone-near-shore

Figure 10: Divvy (2017)
Next-generation wireless must enable end users, professional or private, to deploy a host of applications seamlessly and reliably anywhere in the world.
https://www.divvyparking.com/what-smart-cities-and-what-future-do-they-offer-us/

Figure 11: DHL (2020)
A diagram of the electromagnetic spectrum, highlighting the bands capable of data transmission.

Figure 12: DHL (2020)
Ookla's Speedtest app can be used to test connectivity performance on any device.

Figure 13: DHL (2020)
Industries at different stages of adopting digital technology.

Figure 14: Web Ecommerce Pros (2019)
Next-generation wireless will bring unparalleled visibility to supply chains.
https://www.webecommercepros.com/artificial-intelligence-making-your-ecommerce-store-smarter

Figure 15: DHL (2020)
The ranges of different next-generation wireless technologies.

Figure 16: Deister Electronic (2020)
Many building access cards in enterprises use RFID.
https://www.deister.com/en/solutions/access-control/

Figure 17: DHL (2020)
Technical details of RFID technology .

Figure 18: Universe of Delivery (2018)
RFID labels today can be printed, significantly lowering costs.
https://universe.consignor.com/rfid-tips-how-a-small-chip-improves-e-commerce-logistics-and-transport/

Figure 19: Yahoo News (2014)
The rollout of RFID across Inditex stores has decreased stocktaking time by 80%.
https://news.yahoo.com/zara-rfid-tags-let-know-size-stock-152849066.html

Figure 20: Fetch Robotics (2019)
Fetch Robotics has developed an autonomous mobile robot equipped with RFID readers to automate inventory stock counting.
https://fetchrobotics.com/fetch-robotics-blog/fetch-robotics-expands-tagsurveyor-to-provide-customers-with-real-time-inventory-visualization/

Figure 21: DHL (2020)
Technical details of NFC technology.

Figure 22: 9to5Mac (2020)
NFC is the technology behind mobile contactless payments thanks to its short transmission range.
https://9to5mac.com/2019/10/16/apple-pay-eu-antitrust/

Figure 23: DHL (2018)
This DHL SmartSensor uses an NFC-based logger to track the temperature of sensitive shipments across the supply chain.

Figure 24: DHL (2020)
Technical details of Bluetooth Low-Energy.

Figure 25: Fitbit (2020)
Bluetooth is the technology behind many mainstay wireless accessories such as headphones, smartwatches, and other smartphone and computer peripherals.
https://dev.fitbit.com/blog/2017-09-26-fitbit-sdk-preview-get-started/

Figure 26: Mobile Industrial Robots (2015)
An MiR picking robot with the ability to open doors and use elevators with the help of Bluetooth beacons.
https://www.mobile-industrial-robots.com/de/solutions/mirgo/products/iconsys-iam-r/

Figure 27: DHL (2020)
The combination of BLE tags and a "mother" GSM sensor from Roambee allows logistics operators to track multi-piece shipments with unparalleled visibility.

Figure 28: DHL (2020)
Technical details of WiFi 6.

Figure 29: DHL Supply Chain (2019)
Locus Robotics' swarm navigation and fleet management depends on Wi-Fi connectivity in warehouses and fulfillment operations.
https://twitter.com/dhlsupplychain/status/960930609127477248

Figure 30: DHL (2020)
Ring scanners and other wearable technology place greater demands on supply chain WiFi infrastructure.

Figure 31: Miles Data Technologies (2020)
Better Wi-Fi infrastructure is critical to quickly onboard new equipment during peak operating times.
https://www.milesdata.com/blog/3-ways-mobile-workstations-eliminate-waste-and-improve-warehouse-efficiency/

Figure 32: Signify (2020)
Li-Fi delivers Wi-Fi capabilities via the visible light spectrum at speeds up to 250 Mbps.
https://www.signify.com/global/innovation/trulifi

Figure 33: Signify (2019)
Li-Fi simplifies delivering Wi-Fi coverage in facilities by being built into lighting systems.
https://enterpriseiotinsights.com/20191210/channels/news/signify-installs-smart-lighting-system-automotive-facility-germany

Figure 34: Kinexon (2020)
German startup Kinexon has a portfolio of indoor positioning systems based on ultra-wideband for industrial applications.
https://kinexon.com/technology/real-time-locating-system-rtls

Figure 35: Bloomberg (2016)
Managing the flow of logistics assets in complex indoor environments is boosted by UWB-based real-time location systems.
https://www.bloomberg.com/news/articles/2016-07-14/germany-wins-eu-court-challenge-over-deutsche-post-aid-clawback

Figure 36: DHL (2019)
UWB offers the potential to optimize facility layout and thereby boost productivity.

Figure 37: DHL (2020)
Technical details of 5G.

Figure 38: Nikkei Asian Review (2019)
5G-capable phones are becoming available from all major smartphone makers.
https://asia.nikkei.com/Spotlight/5G-networks/Sources-Google-set-to-release-5G-smartphone-ahead-of-Apple

Figure 39: BD Desintations (2019)
South Korea is the first country with widespread wpublic 5G.
https://www.businessdestinations.com/destinations/mind-body-and-seoul-south-koreas-thriving-mice-capital/

Figure 40: Vodafone (2020)
Lufthansa Technical Services and Vodafone have partnered to bring 5G into aircraft maintenance operations.
https://www.vodafone.de/newsroom/netz/vodafone-und-lufthansa-starte-5g-campus-netz/

Figure 41: Browsify (2019)
The Port of Antwerp has launched its exploration of private 5G.
https://browsifyapp.com/industry-news/iot-building-news/orange-corrals-industrial-players-around-private-standalone-5g-in-port-of-antwerp/

Figure 42: Fleet Complete (2019)
Highways equipped with 5G can potentially optimize traffic orchestration.
https://blog.fleetcomplete.com/mwc-2019-5g-will-bring-new-tech-revolution

Figure 43: DHL (2020)
Urban micro-fulfillment centers need wireless networks as flexible as their operations.

Figure 44: Siemens (2019)
Digital twins are in early use for port management and design.
https://new.siemens.com/global/en/markets/cranes.html

Figure 45: DHL (2020)
Low-power wide area network technology is a contributor to the evolution of cellular networks.

Figure 46: DHL (2020)
Technical details of NB-IoT.

Figure 47: DHL (2020)
Technical Details of LTE-M.

Figure 48: DHL (2020)
Technical Details of Sigfox.

Figure 49: DHL (2020)
Technical Details of LoRa.

Figure 50: DHL (2020)
A coverage map of Sigfox, LoRa, NB-IoT, and LTE-M.

Figure 51: IoT Business News (2019)
Asset tracking at Istanbul Airport using LoRa technology .
https://iotbusinessnews.com/2019/06/20/06031-semtechs-lora-technology-connects-thousands-of-assets-at-istanbul-airport

Figure 52: DHL (2020)
NB-IoT is one potential solution for intelligent yard management in logistics.

Figure 53: Volvo Trucks (2020)
LTE-M offers an economical, low-power, small form-factor tracking solution for rented fleets.
https://www.volvotrucks.us/our-difference/uptime-and-connectivity/fleet-management/

Figure 54: DHL (2019)
A roller cage equipped with a Sigfox tracking device.

Figure 55: Wired (2020)
Example of a geostationary satellite.
https://www.wired.com/story/can-these-small-satellites-solve-the-riddle-of-internet-from-space/

Figure 56: DHL (2020)
Technical details of global area networks.

Figure 57: Wired (2017)
SpaceX has lowered the entry bar to the satellite launch market. https://www.wired.com/story/spacex-launches-its-12th-resupply-mission-to-the-iss/

Figure 58: Via Satellite (2020)
Satellites covering the Earth.
http://interactive.satellitetoday.com/via/january-2020/how-o3b-mpower-challenges-the-conventional-wisdom-of-satellite-networks/

Figure 59: Skylo (2020)
Supply chain visibility of outdoor assets in remote areas via low-Earth orbit satellites.

Figure 60: Wikipedia (2018)
LEO satellites can be used to monitor outdoor assets in remote areas.
https://de.wikipedia.org/wiki/Offshore-Windpark_Arkona#/media/Datei:OWP_Arkona_5028.jpg

Figure 61: DHL (2020)
The fully connected future of logistics.

Figure 62: A-Star (2020)
Next-generation wireless technologies will amplify the remote monitoring effectiveness of logistics control towers.
https://www.a-star.edu.sg/simtech/model-factory@simtech/overview

Figure 63: TechCrunch (2017)
Greater track-and-trace visibility on the high seas, thanks to next-generation wireless.
https://techcrunch.com/wp-content/uploads/2017/08/ship-traffic-pacific.png?w=1390&crop=1

Figure 64: Bosch Industry Consulting (2020)
Next-generation wireless networks greatly improve the availability of every kind of supply chain data.
https://www.bosch-industry-consulting.com/media/images/erde_netzwerk_16zu9.png

Figure 65: Transferfi (2020)
The Transferfi Wireless Power Network.
https://www.electronics-lab.com/wp-content/uploads/2020/05/TFI-Sense-Turin-1.jpg

Figure 66: Simon Weckert (2020)
Google Maps Hack' by artist Simon Weckert draws attention to the risks of depending on technology.
http://www.simonweckert.com/googlemapshacks.html

Figure 67: Sensing Labs (2020)
Off-the-shelf LoRa gateways.
https://sensing-labs.com/pico-gateway-and-8-channels/

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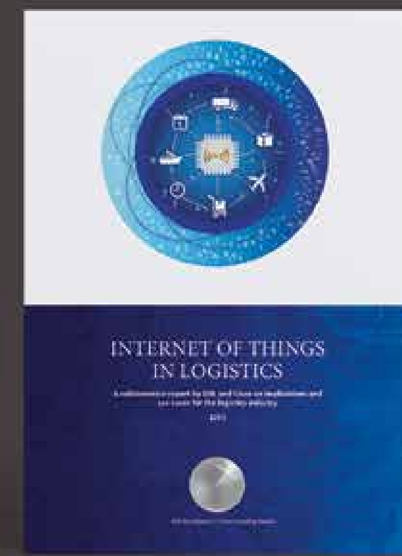

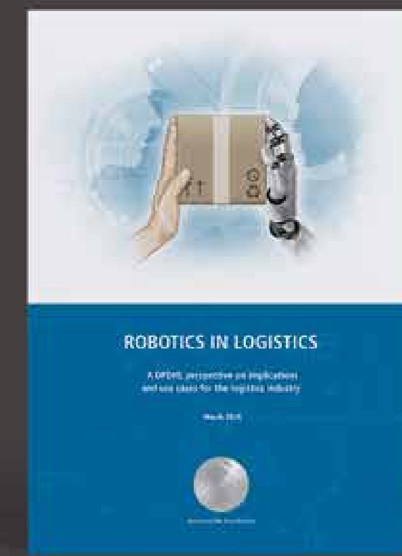

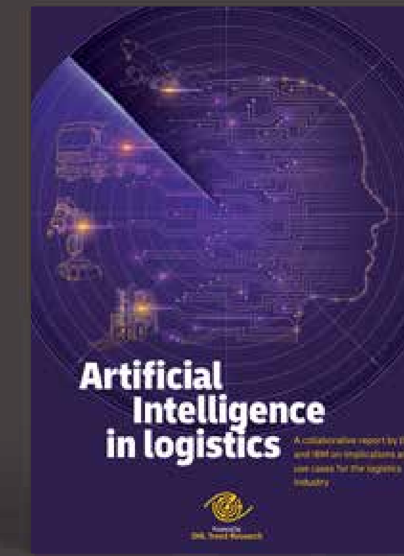

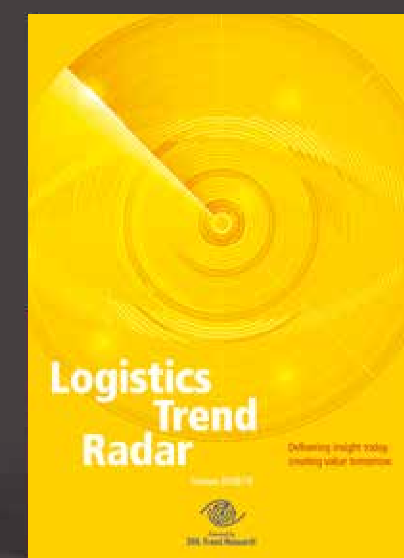

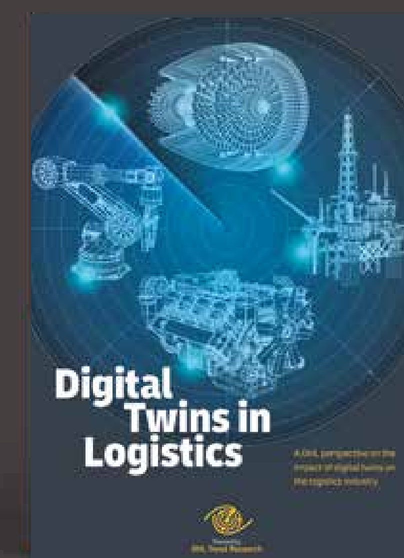

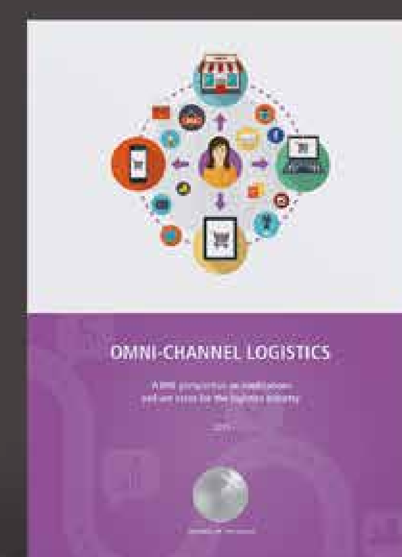

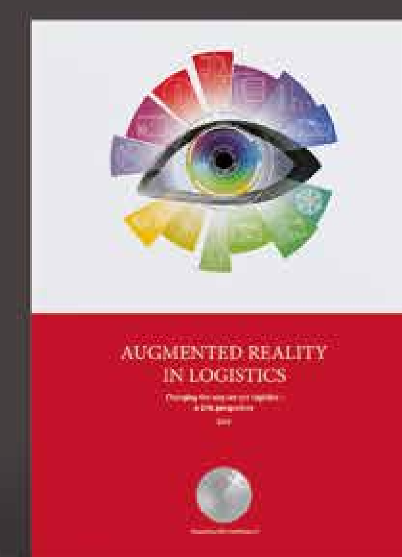

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