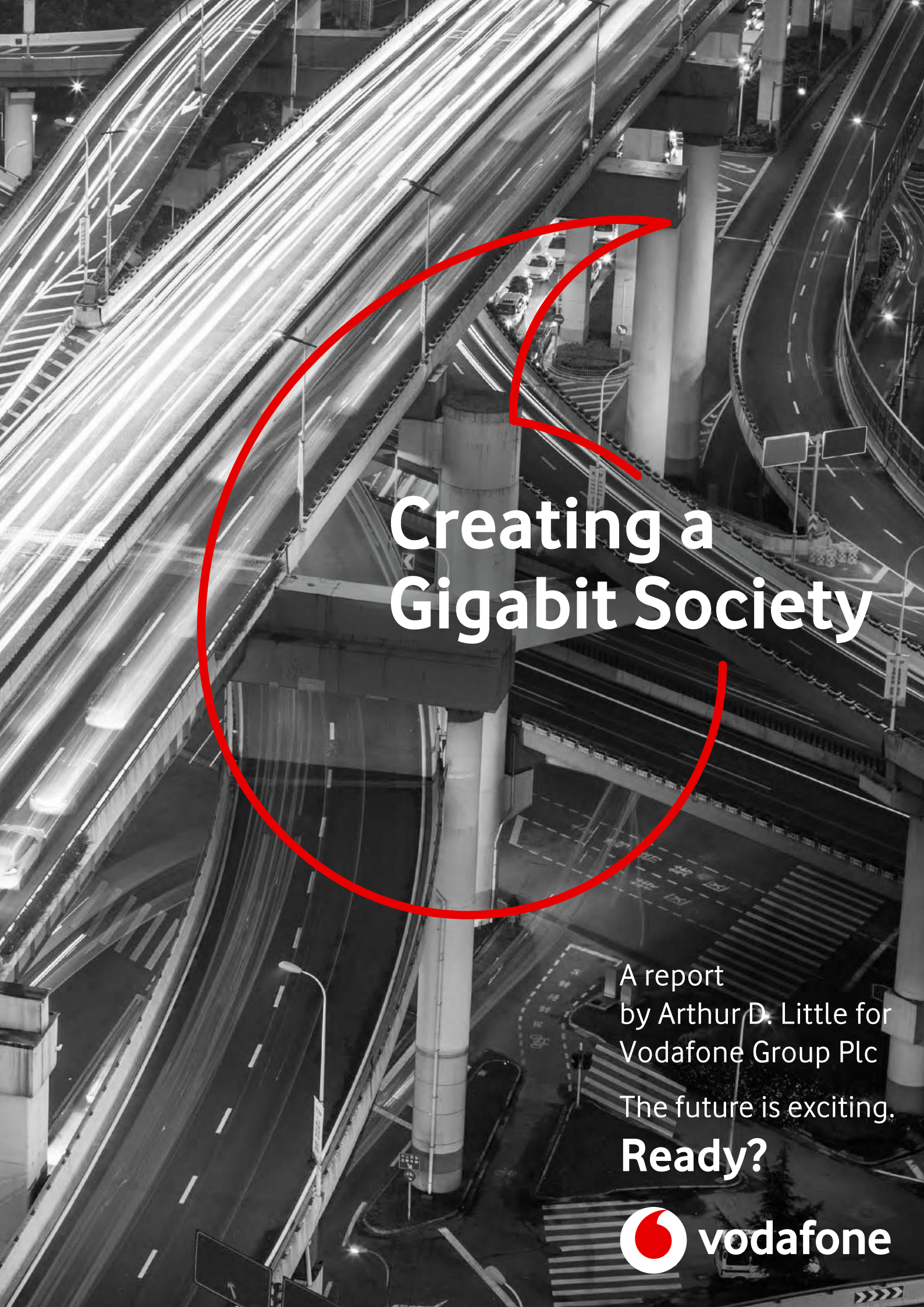




Creating a Gigabit Society

A report
by Arthur D. Little for
Vodafone Group Plc

The future is exciting.

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vodafone

Creating a Gigabit Society

How fibre-based networks are helping to create smarter cities and thriving economies...



Healthcare

Remote patient care and digitisation of health research



Public sector

Smart cities based on integrated strategies



Energy and utilities

Smart grids that use computer-based remote control and automation for greater efficiency



Communication and IT

Advanced video communication solutions and enhanced cloud computing solutions



Media and entertainment

Higher-quality communications and formats such as live HD programmes



Education

Increased digital learning, immersive virtual reality training and remote interactive education



Retail

New in-store experiences and engagement with customers passing the store

The digitisation of European industry depends on our capacity to deploy the right connectivity. Europe should aim for a society where citizens and businesses benefit from widespread connectivity of 1 gigabit per second, low latency and reliable performance.

Creating a Gigabit Society will require...



Building infrastructure for the long term



Facilitation of investment in fibre networks by competing operators



Prioritising network deployment to businesses and public sector institutions

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Author

Richard Swinford,
Partner, Head of
Telecommunications,
Information, Media &
Entertainment (TIME)
Practice, UK

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About

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Arthur D. Little has been at the forefront of innovation since 1886. We are an acknowledged thought leader in linking strategy, innovation and transformation in technology-intensive and converging industries. We navigate our clients through changing business ecosystems to uncover new growth opportunities. We enable our clients to build innovation capabilities and transform their organisation.

Our consultants have strong practical industry experience combined with excellent knowledge of key trends and dynamics. Arthur D. Little is present in the most important business centres around the world. We are proud to serve most of the Fortune 1000 companies, in addition to other leading firms and public sector organisations.

Arthur D. Little's TIME Practice focuses on Telecommunications, Information, Media & Entertainment. The TIME practice has supported well-known brands across the globe in defining growth strategies, business transformation and public policy.

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Foreword

by Markus Reinisch,
Group Public Policy Director,
Vodafone Group

Vodafone believes strongly that Europe should aim for a Gigabit Society: one where citizens and businesses benefit from widespread connectivity of 1 gigabit per second, low latency and reliable performance delivered by robust, future-proof fixed and mobile technologies.

So we fully agree with the European Commission's view that when we speak about infrastructure, we need to think forward and long term, because we cannot afford to build networks that will be obsolete in a few years, or even in a decade. Europe has to be the best place for investing in state-of-the-art networks. The digitisation of European industry depends on our capacity to deploy the right connectivity.

This is why we asked ADL to carry out this study – to document how business and organisations across a range of industry sectors, including healthcare, utilities, education and gaming, as well as smart cities, view their future connectivity requirements. The need for gigabit networks will ultimately be driven by the high speed, low latency and best-in-class reliability that will be inherent features of these networks.

Based on the results set out in this report, it is clear that, if we want Europe's industrial innovators to generate the gigabit applications of the future, we can't depend on 20th century copper infrastructure. Only with gigabit fibre direct to homes and businesses (FTTH) will Europe be able to compete with other advanced economies that have invested in modern digital infrastructure. Only with gigabit fibre backhaul will Europe take on leadership in 5G and retain its position as a leader in the internet of things (IoT).

To deliver on this vision, smart policy decisions are needed to ensure investment is forthcoming and that it achieves the best possible outcomes. To secure innovation and differentiation in the services that will create the gigabit platform for industry, policy goals should aim to facilitate investment in fibre networks by competing operators. This can be encouraged by reducing the costs of rolling out gigabit networks, where the reuse of physical infrastructure that supports digital networks has an important role to play. We can learn from countries, such as Portugal and Spain, which have developed comprehensive regimes that ensure regulated access to passive infrastructure such as ducts, poles and dark fibre, and encouraged co-investment in networks.

In countries that are less advanced in gigabit network rollout, where policies are needed to mobilise investment, a digital spine connecting communities to high-capacity fibre can accelerate progress towards the Gigabit Society. Prioritising network deployment to businesses and public sector institutions like the ones featured in this report not only connects these drivers of the economy to fibre faster, it extends high-capacity backhaul networks that operators can then use to supply FTTH and 5G services to citizens and smaller businesses in communities that would otherwise have been left behind. Where such open access passive networks are deployed, public subsidies can be directed where they are needed into extending the digital spine, taking Europe faster towards achieving gigabit ambitions.

With these policy and regulatory measures in place, we can achieve the European Commission's vision for the digitisation of industry.

My thanks to all the companies and organisations that participated in this study. We share your view that Europe must deliver the gigabit connectivity that you need.

Executive summary

This report envisions the 'Gigabit Society', a world in which European homes and businesses benefit from pervasive broadband communications that offer gigabit speeds and instantaneous services, and enable a range of new applications for collaboration, productivity and entertainment. The technologies for many of these applications already exist, but further development is often constrained by existing broadband connections. Fibre networks will be a key enabler for the development of these future-oriented applications, and will play a role in every gigabit connection, not only fixed but also mobile, as for most of the mobile connections 99% of the distance the signal is being carried over a physical 'wire', which is increasingly made of fibre optic cables.

Fibre optic connections are, and will remain, the predominant means of delivering 'gigabit' connectivity. On top of high throughput, fibre-to-the-home (FTTH) networks are characterised by a number of other advantages when compared to legacy copper connections. It is the only technology that can deliver the same quality of service consistently to every connected customer independent of the distance to the cabinet, while being highly reliable and hence requiring very low maintenance. It can offer extremely low latency speeds and dynamic symmetry, enabling reconfiguration of up- and download throughput, which is not possible with legacy copper networks.

We have identified a number of business and residential applications or use cases benefitting from gigabit connectivity across a range of vertical industries, which can be categorised as follows:

- Use cases that already exist today but would be radically enhanced by FTTH networks, eg downloading files can happen much faster through a fibre connection versus a legacy connection
- Use cases where the best service always wins (due to the lowest latency and highest bandwidth), eg gamers with the fastest connection will have a competitive advantage in online gaming
- Use cases that are currently not possible on existing networks but the technology exists, eg using intelligent robots to perform dangerous tasks remotely
- Use cases that are currently not possible on existing networks and the technology does *not* exist; this would include any use case still to be discovered.



FTTH is the only technology that can deliver the same quality consistently to every connected customer



Gigabit networks will be required, and will enable a whole range of new applications for entertainment, health and smart homes. Direct and indirect benefits of a Gigabit Society can be grouped into six categories that will ultimately positively impact the gross domestic product (GDP) of a country:

1. Better healthcare
2. Better education
3. Increased security
4. Positive social impact
5. Positive impact on the environment
6. Increased employment.

The need for gigabit services is emerging across several vertical industries, and potential applications are appearing that require or would benefit from gigabit networks.

In the **healthcare sector**, fibre networks will be crucial for digital health such as remote patient monitoring, remote care and rehabilitation, professional operative consultations, digitisation of health records (eg digital X-rays) and research (eg next generation genome sequencing). Many applications and solutions already exist but are currently constrained by latency, limited reliability and bandwidth of existing internet infrastructure (digital subscriber line (DSL) or copper-based).

Energy and utility companies are increasingly moving towards smart grids (for electricity, but also for water) and looking at online real-time power rebalancing, automated demand response and edge of grid generation and distribution. Smart grids are slowly being built and integrated, but some utilities state that they are over-reliant on legacy equipment that is prone to failure, has rising costs and has limited cyber resilience. Being able to shape load and supply in a manner that corrects rather than worsens out-of-phase generation requires control at the millisecond, not 10s–100s of milliseconds, which cannot be provided by legacy copper networks.

Media and entertainment companies are constantly pushing data requirements with larger file formats as video/sound quality is constantly increasing and display devices are evolving. The ability of existing networks to support multiple high-definition (HD) streams to the household during peak hours with contention is already in question. Differential latency is also an issue, for example where neighbours are watching the same 'live' sports event, or in a gaming environment where gamers with a faster connection have a competitive advantage.

Future formats of media files such as 4K and 8K require greater throughput. Capture equipment for these formats is already available to consumers at low cost, and movies can be shot in 4K/8K. The gaming industry is increasingly moving towards virtual gaming with very low latency requirements as any minor delay in gesture versus response can quickly induce nausea in participants. In the long run, only fibre networks will be able to provide this.

In the **education sector**, new tools and applications are being enabled by fibre networks, such as immersive virtual reality training for professionals and remote interactive learning. Fibre networks will support increased digitisation within the classroom (eg to download content on tablets or laptops). Large education providers are currently often forced to look at solutions that require low bandwidth because current off-campus internet infrastructure is insufficient to support 'basic' remote online video courses.

In the **retail sector**, collaborative online shopping using video, voice, virtual viewings and new in-store experiences offering benefits to both shoppers and shopkeepers are in every retailer's

mind. Many benefits can only be achieved for consumers and retailers if fibre networks are in place to support this. Fibre connections would allow multiple instantaneous video streams as well as virtual reality applications that enable an in-store experience and the personalisation of products online through a collaborative platform.

In the **communication and IT sector**, advanced video communication solutions (eg holographic or ambient telepresence) and cloud computing solutions are the two main applications that will be massively enhanced if FTTH networks are put in place. These require a combination of high-quality, resilience and a low opportunity cost of connectivity (ie ample bandwidth that does not diminish other users/use cases). These applications are ideally suited to fibre-based installations.

In the **public sector**, we see smart cities evolving around the globe but these are often driven by fragmented pilots rather than integrated strategies. Smart technologies rely on urban fibre networks and create huge opportunities for cities.

Gigabit Societies have already begun to emerge, and the time has come for a number of barriers and other factors to be considered before we can move to a full 'gigabit continent' in Europe. The awareness of the benefits offered by fibre networks is insufficient among some key stakeholders, especially in government bodies, and inconsistent regulatory approaches are adopted to investment incentives. Moreover, extremely high service levels are required to be globally competitive and keep up with other leading 'gigabit nations' around the globe.



The gigabit vision

Imagine a world where the following is widely possible:

- Patients can receive expert healthcare services while remaining in the comfort of their home, particularly for diagnosis and for post-operative care
- Doctors can assist each other through HD videoconferencing solutions during surgeries
- Power grids are balanced in real time, automatically shutting down some industrial processes that have buffer capacity, without loss of productivity, to cope with power peaks
- Gamers can play exciting online virtual reality games with friends who are in a different location
- Students can attend some of their classes remotely – even from different countries – and interact with the teacher and each other in real time through HD video
- Researchers can share huge amounts of data with each other online in a matter of seconds
- Parents can pick children up from school in driverless cars, where the only thing they have to do is provide the destination
- Cities are equipped with large sensor networks and other IoT devices to collect data and resolve issues around pollution, traffic congestion and assisted living for the elderly.



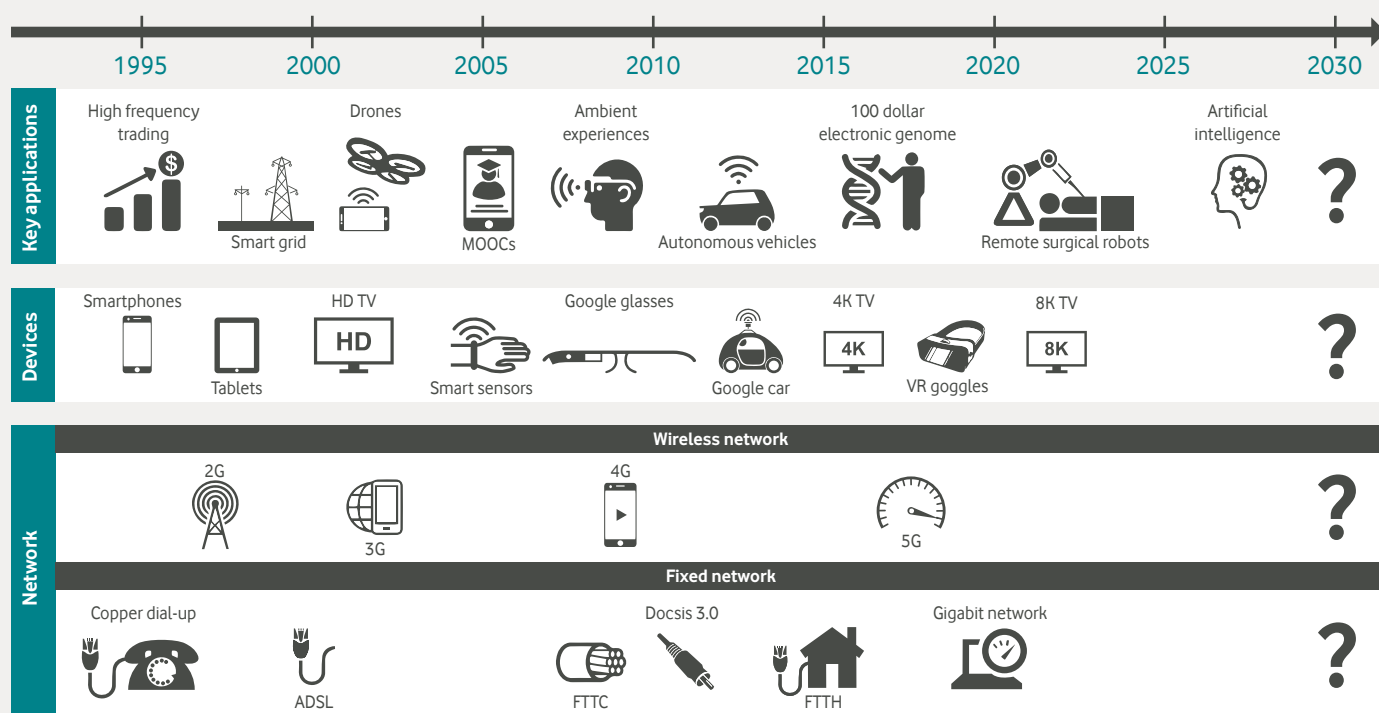
Many gigabit applications already exist but are constrained by the capabilities of available technology

In reality, we are not so far away from this. As this report will show, many of these applications already exist, but are currently constrained by the availability and capabilities of technology, cost of devices and services, and the ability of regulation to keep up with socioeconomic and technical change. Future devices and networks have to be intelligent, pervasive, responsive and affordable to further enable this vision.

In the last decade we have witnessed amazing scientific breakthroughs and new product genres emerge. Similarly, we foresee radical improvements in devices, and perpetual investment by operators in the upgrade of networks with new technologies to allow new services to be deployed. With the commitment of stakeholders, we have no reason to doubt future progress will be just as fast.

Fibre networks will be a key enabler for the development of these future-oriented applications, and will play a role in every gigabit connection (both mobile and fixed).

Figure 1: Technology roadmap



Source: Arthur D. Little

At this rate of change, with no sign of a slowdown in the development of new solutions, the willingness of investors to fund technology-oriented 'game changer' ventures, and the appetite of consumers for new applications, this future is closer to us today than many might think. Given the large number of socioeconomic benefits, government policies should favour the rollout of fibre networks at a European level.

What is a gigabit infrastructure?

A gigabit network is essentially characterised by the 'bandwidth' or 'effective data throughput' offered by a connection. A gigabit network is capable of transmitting a peak achievable speed of 1 gigabit, or roughly 125 megabytes of data, in one second. Where typical copper-based legacy networks need hours to download large gigabyte files, an FTTH network will be able to do this in a matter of minutes or seconds (see Table 1 and [Annex 2](#) for definitions).

FTTH networks, modernised cable networks and next generation mobile connections are currently the only technologies able to deliver gigabit speeds. In reality, 'wired' technologies such as FTTH, transmitting signals over glass optical fibre and 'wireless' technologies such as 5G, transmitting signals over electro-magnetic waves, are often used together. Many devices connect to networks wirelessly in some way at the end of the connection, even if for 99% of the distance the signal has been carried over a physical 'wire' (for example using fibre backhaul). Most handheld devices rely on a wireless link to an antenna – which could be in the same room (ie Wifi) or several hundred metres or more away (ie a mobile macro network), but as wireless networks are modernised, fibre comes ever closer to the antenna.

Mobile networks are already capable of delivering gigabit/s of throughput using special configurations of antennae and vast quantities of spectrum, and will become more capable with the arrival of '5G' technology. But for the majority of connections, both in number and in proportion of total distance covered, fibre optic cable is, and will remain, the predominant means of delivering 'gigabit' connectivity.

Fibre optic networks also offer advantageous key characteristics other than throughput. These include:

- **Low latency:** the ability to support instantaneous connections and transit data almost without any 'delay', measured in just milliseconds over distances greater than 1,000km, and only microseconds at distances in the 100's of km
- **Availability:** these networks are inherently stable, offering extremely high availability
- **Security:** such networks, given the physical and often buried nature of the cable, are harder to interfere with than wireless networks (or even 'radiating' copper-based cables)
- **Packet loss and low jitter:** near zero packet loss and variance in packet delay, ie 'smooth signals'
- **Distance agnostic:** grade of service is essentially the same almost regardless of distance
- **Consistent performance:** combining the above guarantees the same experience for all, with the need for reformatting content or complex bandwidth mitigation measures
- **Dynamic symmetry:** such networks can be configured to allow flexibility in assigning upload and download throughput for each connection, depending on the use case
- **Low maintenance:** fibre is inherently reliable, hence little maintenance is needed
- **Future proof:** transmitting equipment can be easily replaced and raw medium is future proof
- **No radio frequency interference:** signals travelling over fibre are not subject to radio frequency interference versus copper, which is susceptible.

Table 1: What is throughput? – measured as 'time to download'¹

Digital item (examples)	Typical size	Legacy network	FTTH network
Average Kindle eBook	2.6 megabytes	1 second	50 milliseconds
CT scan (sent across hospitals)	2 gigabytes	14 minutes	40 seconds
Virtual reality game	5 gigabytes	34 minutes	1.7 minutes
Blu-ray movie	25 gigabytes	2.8 hours	8 minutes
Galaxy S7 storage	32 gigabytes	3.6 hours	11 minutes
4K movie	100 gigabytes	11 hours	33 minutes
Hard disc of a PC	240 gigabytes	27 hours	1.3 hours
Medium-sized corporate server restore	6 terabytes	28 days	33 hours
Human genome (uncompressed)	7 terabytes	33 days	39 hours

What are gigabit applications?

Gigabit networks are appearing in an environment already full of applications. So what will they actually deliver? We see four types of generic use cases for gigabit connectivity:

- 1. Use cases that already exist** today but would be radically enhanced by FTTH networks: typical use cases in this category are download/upload of large data files which can happen much faster, or videoconferencing at higher quality on fibre networks.
- 2. Use cases where the best service always wins** (due to lowest latency and highest bandwidth): the best example of this use case is online interactive gaming, where gamers with the fastest connection and lowest latency will have the best gaming experience and have a competitive advantage over gamers with a less good connection.
- 3. Use cases that are currently not possible (but the technology exists)** on existing (technologically limited) networks: a good example of this is industrial automation, where intelligent robots can be used remotely to perform difficult or dangerous tasks, and require real-time instantaneous feedback for the tasks that they address.
- 4. Use cases that are currently not possible (and the technology does not exist)** on existing (technologically limited) networks; this would include any use case still to be discovered.

Applications can be derived from residential/consumer and business use cases across all four of these types. For example:

Table 2: Gigabit use cases

1. Enhanced existing use cases	Residential application	Business application
	Download/upload of full-length 'Ultra High Definition' movies in a few seconds to home entertainment devices	Upload of security images for remote monitoring, in 'forensic' quality with high frame rate in real time
	Challenges File formats will increase in size (but compression techniques will improve) New screen formats will be developed (but questionable if perceived by human eye) Evolution of compression techniques Need for real time required?	
2. Best service always wins	Residential application	Business application
	Competitive gaming (where low latency offers a key advantage for players)	High-frequency financial trading (acting on real-time information) Cybersecurity (real-time response to hacking/intrusion attempts)
	Challenges A large part of latency defined by electronics used (versus the connection itself). However, in these use cases, gamers and traders will typically also invest in the 'best' hardware available.	
3. Use cases currently not possible (for which technology exists)	Residential application	Business application
	Telepresence recreating the sense of touch (for social interaction, education, etc)	Smart grid: load balancing and control; 'in-phase' demand management Remote surgery, diagnostics, life support
	Challenges Some technological/device developments required, but the main challenges are societal and the acceptability of removing human 'physical' presence from the application domain.	
4. Use cases currently not possible (for which technology doesn't exist)	Residential application	Business application
	...and future use cases yet to be discovered	
	Challenges Challenges unknown but might be related to 'adoption' barriers if use cases are enabled by technologies that are too different from what we know today. Another barrier could be end-user connectivity, also for customers on the move.	

In the following chapters we explore real current and future use cases and applications, drawn from a variety of countries and vertical industries.

Where will Gigabit Societies appear?

Citizens repeatedly show appetite and ingenuity to utilise new technologies wherever their deployment has proved technically, economically and socially acceptable. With fibre optic networks and gigabit switches/devices already available at low cost, we already see clusters of Gigabit Societies appearing, and users changing behaviour and the nature of work as they adapt to this environment.

Figure 2: Gigabit Societies

Exists	✓	✓	✓	✓	✓	✓
	Building	Cluster	District	City	Region	Nation
						
Example	• Homes • Banks/offices with 10 gigabit switches	• University with several campuses and facilities • Large hospital complex • Business park	• Silicon Valley • Manhattan	• Seoul • New York • York, UK	• 200 municipalities in NL served by Reggefiber • Schleswig-Holstein	• Portugal • Singapore • Hong Kong • Netherlands • Malta

Gigabit Societies are already starting to appear at a different level and a different pace in different countries:

- **Gigabit offices** are already becoming common place in commerce, given the low cost of gigabit and 10-gigabit switches. The marginal investment to deploy Cat 6A Ethernet cables or plastic optical fibre is now very low, and helps future proof office buildings on fit out
- **Gigabit homes** are also already present. Gigabit network cards and 802.11n wireless routers are extremely cheap, and increasingly used in multiple person households for mainly entertainment purposes. Bandwidth 'around the home' is often vastly higher than bandwidth 'to the home' today
- **Gigabit clusters** are also already widespread. Typically these include academic campuses (eg University of Cambridge), industrial parks (eg Sutton Fields in the UK), and small city zones (Soho in London for the media industry, working with very large 'raw' media files, for example)
- **Gigabit districts** are increasingly promoted to support the development and regeneration of some urban areas, and **cities** are already appearing, particularly in the US and Asia, but also around Europe, including the UK (York, Bristol, Bath, Coventry):
 - Seoul in South Korea has widespread gigabit service provision, with all three of the large telecoms providers offering gigabit home broadband services
 - In the US, early adopter cities include Kansas, Atlanta and Austin, among others.

- With the right regulatory and policy frameworks, promoting investment in fibre, we can move to fully **gigabit regions and nations**:
 - Fibre networks already reach the majority of households in Portugal and vast areas of Spain for example
 - Singapore, Hong Kong, the Netherlands and Malta are likely to be other pioneers given their size and 'easiness' to roll out fibre everywhere. Andorra is already extensively deployed, with near ubiquitous access to fibre services.

It will become an unavoidable truth than modern industrialised nations will require gigabit infrastructure to support 'smart cities' and remain economically and socially competitive on the global stage.



Modern industrialised nations will require gigabit infrastructure to remain competitive on the global stage

Benefits offered by the Gigabit Society

What can the Gigabit Society bring?

Gigabit networks have already begun to emerge, but as they become more widespread and interconnected, they will accelerate change in our societies. World-class telecoms infrastructure and resilient energy services, as well as smart transportation networks and cities will become essential to national competitiveness and comparative wellbeing of citizens.

Gigabit networks will be required by industry, and will afford consumers pervasive broadband communications enabling a whole range of new applications for entertainment, health and safety and smart homes. Direct and indirect benefits can be grouped in six categories, which will ultimately positively impact the GDP of a country.

1. **Better healthcare:** fibre networks will be crucial for digital health such as remote patient monitoring, remote care and rehabilitation, professional operative consultations and research (eg next generation genome sequencing). Patient services are being improved, healthcare is delivered in a more efficient way, more patients can be reached and benefit from specialists' attention and the cost of healthcare will ultimately be reduced. This sector still relies on antiquated infrastructure and many 'pre-digital' working practices today
 2. **Better education:** new educational tools and applications are being enabled by fibre networks such as immersive virtual reality training for professionals and remote interactive learning. Fibre networks will support increased digitisation within the classroom (eg to download content on tablets or laptops). This has allowed education to become more personalised, tailored to the need of each individual student, increasing buy-in and motivation. Moreover, a larger network of students can be reached, teaching tasks distributed and education delivered in a more efficient way
 3. **Increased security:** monitoring public or private environments, recognising suspicious activity and alerting security services can happen better and faster when fibre networks are in place. More and higher-quality images can be captured (subject to privacy safeguards) and analysed, while artificial intelligence (AI) can recognise potentially dangerous situations and automatically trigger emergency response
 4. **Positive social impact:** fibre networks enable a range of new applications for entertainment, collaboration and social inclusion. Social relationships between people can be maintained regardless of distance, age or level of mobility, eg through high definition video streams or ambient presence
 5. **Positive impact on environment:** next generation smart grid and smart mobility applications can be enabled by fibre networks and will have a positive impact on energy consumption and CO₂ emissions. Applications like automated energy demand response reduce the production and consumption of energy, enabling more efficient use of renewables. Smart highways, autonomous transportation and smart traffic management tools – with core fibre networks – will lead to more efficient mobility
 6. **Increased employment:** new jobs are created to construct and set up the new fibre infrastructure. But more importantly, new applications and business models enabled by fibre networks appear and create new job opportunities, and the wider availability of such connectivity nationwide also distributes economic benefits and promotes modern commerce outside urban centres.
- These six categories of benefits will ultimately have a cumulative positive impact on the GDP of countries, as numerous studies have already indicated.

Ericsson, Arthur D. Little and Chalmers University of Technology² have in the past highlighted the socioeconomic benefits of advanced telecommunications infrastructure and the direct impact that broadband speeds have on economic outcomes. There are direct links between broadband services and economic growth in OECD countries. Direct economic production increases in the short term thanks to the deployment of fibre network facilities. Increased productivity will also appear in the medium and long term due to time saved and increased mobility, as well as through improvements in the health, education and skill levels of workers.

A study by Analysis Group³ of the United States suggests that communities where gigabit broadband was widely available enjoyed higher GDP, relative to similar communities where gigabit broadband was not widely available. They studied 14 communities in nine US states with widely available gigabit broadband (50% household penetration or more), which enjoyed over USD 1 billion in additional GDP when gigabit broadband became available, relative to (geographically proximate and similar) communities where gigabit broadband was not widely available. According to Analysis Group, these gains are likely due to numerous factors, including the direct effect of infrastructure investment and increased expenditures, as well as early shifts in economic activity (eg job creation and occupational changes) and productivity gains.

Impacts on industry

Understanding the opportunity within each vertical

In the following chapter we will analyse the need for gigabit services across each vertical industry, and discuss potential applications that are appearing and that require or benefit from gigabit networks, supported by case study examples.

Healthcare

Karolinska University Hospital – Digital health innovation

Philips – HealthTech

Energy and utilities

REstore – Data-driven virtual power plants

Media and entertainment

nDreams – Virtual reality gaming

Jagex – Massive multiplayer online role-playing games

SDNsquare – Sending media content

Education

University of Cambridge – Own fibre network

Benesse – Shinkenzenmi correspondence courses

Retail

Proxama – Marketing engagement utilising beacon technology

Communication and IT

Ryanair – Aircraft connectivity solutions

Public sector

Bristol Is Open – Smart city

Dundee City Council – Smart city

Healthcare

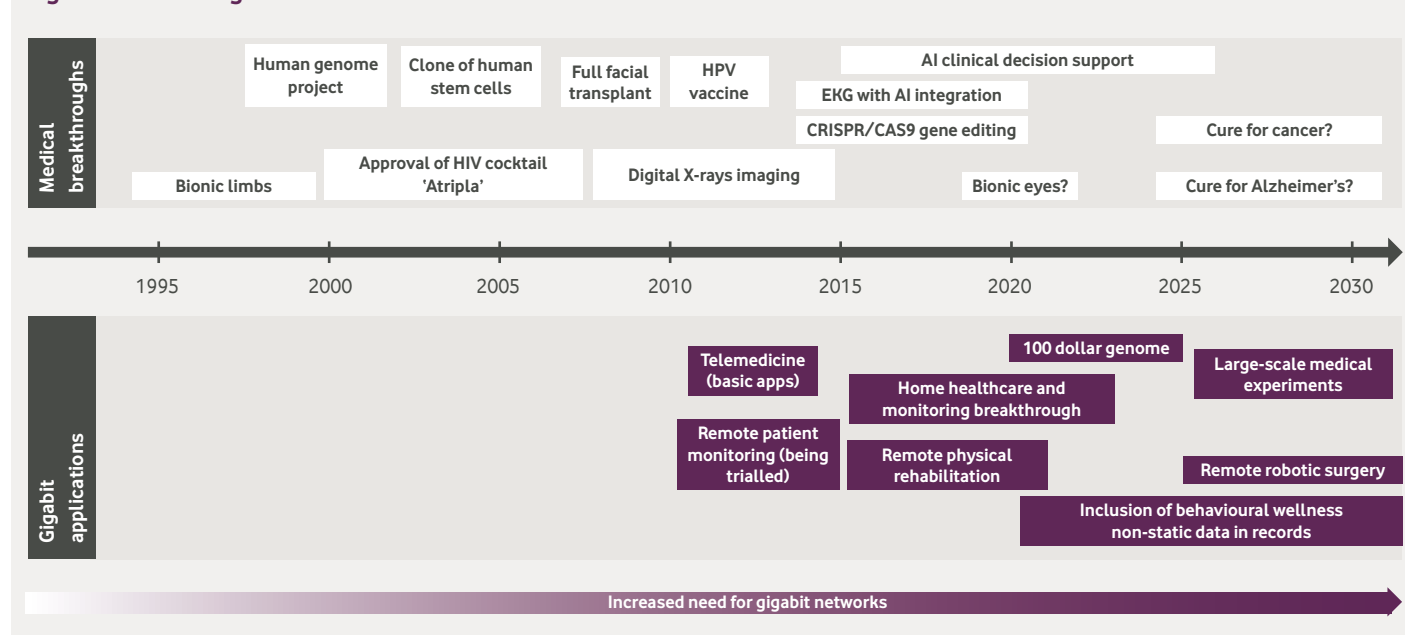
Pace of change in the industry and the need for gigabit services

Hospitals and other healthcare facilities are increasingly leveraging digital technologies, offering opportunities for new players entering the digital health sector. Globally, the digital health market is expected to double in the next three years, surpassing USD 200 billion⁴ by 2020. Digital patient data (eg electronic medical records and digital X-rays), telehealth and wireless health are just a few examples driving this growth. Many digital health programmes are in an evaluation and pilot phase today but most of these will be implemented over the next five years.

Hospitals are increasingly producing huge amounts of digital patient data and equipment providers are starting to offer platform solutions (eg Philips HealthSuite digital platform or GE Health Cloud) enabling the consolidation of this data. As the amount of data these platforms store is increasing, high throughput networks will be required to work with this on a daily basis among patients, hospitals and other care givers. Emerging transformational technologies, such as next generation sequencing, will further add to the data volumes (eg human genome requires approx. 3 GB of storage, when compressed).

The advancement of telehealth technologies (ie remote healthcare) and wireless health (eg WLAN, Bluetooth, RFID) is another major change occurring in the healthcare industry. We see more and more telehealth providers appearing and the global telehealth market is expected to grow at a compounded annual growth rate (CAGR) of 46% between 2013 and 2020 to USD 6.3 billion. Secure and low latency networks are essential to deal with some of these highly critical applications.

Figure 3: Technological timeline – healthcare



Potential applications using gigabit networks

- **Remote (patient) monitoring:** remote continuous monitoring of chronic care patient vitals, issuing warnings when critical situations occur, of patient adherence to treatment plan, of patient symptoms through smart devices to determine the most adequate treatment plan or of disabled/elderly people who need help (eg fall detection)
- **Telemedicine:** remote doctor's appointment and video diagnosis of a patient, by clinician or artificial intelligence (AI) devices reducing clinician's workload
- **Next generation sequencing:** storing, updating and sharing patients' varying human genomes, throughout the life of patients to predict the development of the human body
- **Large-scale medical experimentation:** trialling new treatment plans where a large group of test subjects are monitored remotely in their natural environment (vs closed clinical co-located trials, which are occurring today)
- **Physical rehabilitation:** rehabilitation of patients in their homes using smart imaging sensors and systems
- **Remote robotic surgery:** robotic surgery that is controlled by surgeons remotely.

Example of advanced countries – Sweden

Sweden is a frontrunner in digital health, building on strong ICT infrastructure and a history of tracking population healthcare information, and it is becoming an innovation hub for the healthcare and ICT industry.

It is the second most prolific tech hub in the world, behind Silicon Valley, producing one USD 6.3 billion company per million inhabitants⁵ and with an FTTH penetration⁶ of 34% at December⁷ 2014, enabling many telehealth applications.

Due to high market readiness and the most mature market conditions for digital health, many start-ups in this area have been launched in Sweden. For example, Kry started a service offering online primary care services that allow patients to consult with clinicians through video services 'in one click'.





CASE STUDY

Karolinska University Hospital – Digital health innovation

Karolinska University Hospital is a frontrunner in digital health innovation. In order to advance digital healthcare, Karolinska is trialling new applications in the field of telemedicine and distributed healthcare.

Background information

Karolinska University Hospital (Karolinska) is located in the urban area of Stockholm in Sweden with two main sites: Huddinge and Solna. The majority of the research is carried out in close collaboration with the University Karolinska Institutet (KI).

KI has been consistently ranked among the top medical institutions globally and is responsible for over 40% of the medical academic research conducted in Sweden. Both organisations are frontrunners in the field of digital health innovation.

The solution

Karolinska has developed and tried out a concept in which Parkinson's patients follow a treatment programme from their home. The concept is now implemented and used in daily work. During video consultations the patient is asked to perform specific exercises and the neurologist is able to monitor the movements and tremors via HD videoconferencing. This enables the neurologist to diagnose the status of the patient and, if necessary, recommend a change in the medicine dosage remotely. In order for the practitioner to examine the patient and monitor the tremor, it is crucial that the video communication is of high quality and in real time, hence high bandwidth and low latency FTTH networks are necessary.

In addition to home care, Karolinska is using HD videoconferencing for professional consultations – ie specialists assisting a surgery remotely to provide guidance and advice. An expert within endoscopic retrograde cholangiopancreatography (ERCP), a treatment method used primarily to diagnose and treat conditions of the bile ducts, remotely observes the operating room at a local hospital, receiving radiology images and

endoscopy video streams in real time. The experts at Karolinska can, through the live HD video streams, guide the endoscopist at the local hospital.

Besides the benefits for the patient, this also allows for more extensive training of less-experienced practitioners as they can be assisted during procedures more easily, ie the competence at the local hospital increases. Secured, high-bandwidth, low-latency fibre networks are crucial for this type of application.

Karolinska and Stockholm County are currently deploying a system for centralised storage of radiology images as opposed to storing it locally. The heaviest traffic will be uplink (uploading CT scans, MR scans and even digital pathology from different locations to the cloud). Downloading images to different sites will move towards streaming of images resulting in lower bandwidth requirements downstream. However, for advanced 3D operations or printing 3D models of organs from MR images, the entire image package will have to be downloaded. Fibre networks will be mandatory to support this.

“Doctors are not willing to compromise on their diagnosis due to constraints posed by the connection. Secured, low-latency and high-bandwidth fibre networks are crucial for our telemedicine applications and could potentially save lives.”

Peter Håkansson

Project Manager, NKS medical device data repository – Karolinska

Benefits

- More efficient use of specialist surgeon's time
- Facilitation of professional consultations
- Sharing of patient data across different sites of the hospital.

Challenges

Human resources form the bottleneck: teleconsultations are limited by the number of practitioners that are available to conduct the consultations.



CASE STUDY

Philips – HealthTech

Philips is on a journey to become a global leader in HealthTech, leveraging advanced technology and its deep clinical and consumer insights to deliver integrated solutions across the health continuum, which spans a range of care settings. The company offers several digital health solutions enabled by high-bandwidth, low-latency and secure networks in the areas including home patient monitoring, treatment and care, image-guided surgical interventions and remotely managing intensive care units.

Background information

Philips is a diversified health and wellbeing company, focused on improving people's lives through meaningful innovation. In the HealthTech space, Philips is the global leader in image-guided interventions, sleep and respiratory care, and ultrasound with many other strong market positions.

Philips' HealthTech strategy aims to connect solutions across the health continuum, underpinning the need for strong fibre connectivity. Healthcare is increasingly moving to the home, reinforcing the need for strong public broadband networks.

The solution

Philips has introduced several products and services enabled by strong connectivity: home monitoring, home treatment and care, image guided surgical interventions and remotely managed intensive care units (ICU) are just a few examples.

Philips' home telemedicine solutions provide patients with the ability to receive expert healthcare services while remaining in the comfort of their home. Patients use Philips' technologies to take their own health readings while medical staff closely monitor the situation of the patient remotely and are alerted about complications.

Connectivity solutions allow practitioners to stay in close contact with patients and manage them remotely.

A pilot showed that this solution reduces hospitalisation of patients by 45% and healthcare costs by 27%⁸.

Through partnerships with external companies, Philips' image-guided intervention solutions now include integrated audio and video, and live streaming technologies. The result is a connected, collaborative environment, enabled by secure and easy data sharing both in the hospital and remotely. Low-latency networks play a crucial role to ensure real-time connectivity.

Philips' remote ICU solutions enable centralised real-time remote monitoring and control of several ICUs for several hospitals in different locations. Patients are being monitored in real time through video and an increasing amount of live data series on patients' vitals are continuously being sent to the central control room. Secure, high-bandwidth, low-latency networks are crucial for this.

“Connectivity is crucial for digital health solutions, going from remote patient diagnosis and monitoring to specialist home care and guided surgeries. The amount of data being sent will keep increasing and low latency and reliability is paramount to save lives using critical care solutions.”

Patrick van Beers

Senior Director Digital Platform Solutions – Philips Research

Benefits

- Reduction in hospitalisation rates of patients
- Reduction of healthcare costs
- More efficient use of care givers' time
- More people can benefit from specialist care and lower waiting times for patients, through wide reach of networks and care services.

Challenges

There are restrictions in EU Member State regulation that prevent healthcare data being used, stored and shared within and across Member States and this prevents the industry from the rollout of new innovation in healthcare within the EU.

Energy and utilities

Pace of change in the industry and the need for gigabit services

The energy and utility sector has changed dramatically over the past decade. Historically, energy networks were designed to 'passively' transmit power from power plants to end users. Mission-critical assets were connected through private basic lines (eg PSTN/ISDN) or low-speed broadband copper connections. With the emergence of more distributed power generation (eg renewable energy and edge-of-grid generation), smart solutions have started to appear that rely greatly on communication networks.

Many energy and utility companies are still relying on their private outdated communications infrastructure, which prevents them from grasping the benefits that these smart solutions could offer. Energy and utility organisations continue to invest in their current infrastructure because it is cheaper to do so and because they are regulated to be responsible for the reliability of their power supply, hence they do not want to outsource the critical communication infrastructure to a third party.

Smart solutions rely on real-time two-way communication between the utility organisations on one side and the consumers as well as suppliers on the other, to enable load balancing, integrate a wider pool of players or measure and deal with sudden demand or supply changes. For example, currently there are significant challenges with regards to the deviation of the energy supply due to intermittent (ie wind, solar) renewable energy generation, which is often also decentralised. A smart network identifies grid stability issues and takes appropriate action in real time by analysing the data that originates from the two-way communications infrastructure. The National Infrastructure Commission in the UK estimated that, by managing the use of electricity more efficiently, there is potential for savings of up to £8 billion a year⁹. Smart grid is an element of this but also using energy storage more efficiently.



A smart energy network identifies grid stability issues and takes action in real time

In order to provide this real-time control, a low-latency and highly secured connection such as that offered by fibre networks will become more important, especially where there is a need to keep this generation and demand 'in-phase' with 50/60Hz electricity supply cycles (ie 60 times a second).

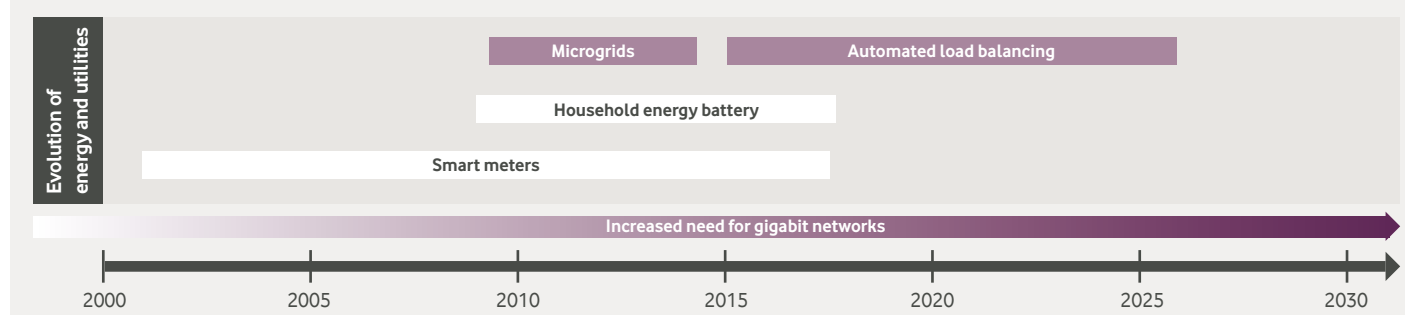
To facilitate this change, it is inevitable that the industry will become increasingly more reliant on third-party network providers. Although much of the connection infrastructure is currently often owned by the organisation itself, it is unlikely that they will make the high investments that are required to update their current infrastructure and extend it to the edges of the distribution and consumption grid.

The utility industry also faces rising cyber threats and is overhauling the embedded devices and communications networks currently controlling and protecting critical national infrastructure (transformer stations and flood control devices).

Potential applications using gigabit networks

- **Automated demand response:** automated real-time system that allows for load balancing based on supply and demand
- **Protection applications:** to predict and contain faults or blackouts
- **Smart metering:** smart devices that track and share usage in real time and enable remote adjustments
- **IoT sensors:** vibration, temperature or voltage sensors measuring the state of the distribution network.

Figure 4: Technology timeline – energy and utilities





CASE STUDY

REstore – Data-driven virtual power plants

REstore, an Industry 4.0 leader, has developed an innovative data-driven cloud platform Flexpond™, which balances power grids in real time. REstore's patented platform creates clean, fast and reliable virtual power plants by using 'flexible' power of industrial processes across Europe.

Background information

REstore was founded in 2010 to address a major challenge of the European power market: the rapid penetration of intermittent renewable energy production in Europe causing an increasing amount of imbalances on the power grid. Grid operators look for reliable, clean and cost-effective ways to offset these imbalances and prevent power outages.

Rather than building expensive and polluting production plants, REstore uses flexible power available in industrial processes. Examples include furnaces to melt metal, which have thermal inertia, and pulp grinding processes at paper factories, which have buffer capacity.

In return for offering their flexible power to REstore, industrial companies get significant recurring payments, helping them to save money and contribute to a sustainable energy market.

The solution

REstore developed an innovative cloud-based data-driven software platform called Flexpond™, which works as a virtual power plant. This patented Industry 4.0 platform connects to a portfolio of industrial players and captures and processes thousands of factory sensor data in real time on the cloud. This allows REstore to know, 24/7, the amount of flexible power that is available to balance the grid.

Power utilities and grid operators have a real-time connection with this platform, which can release the flexible power in a matter of a few seconds, to re-balance the power grid when

needed. REstore is the only party offering primary frequency control to European grid operators in this way, as sub-second monitoring and control becomes technically achievable.

“We would welcome public fibre networks if they can bring significantly lower latency and higher reliability and security for our Industry 4.0 platform. As we seek services with extensive reach, all the way into the industrial site, where legacy wiring can be an issue, we rely on quality infrastructure to ensure we can instantly provide power.”

Jan-Willem Rombouts

Co-founder and Co-CEO, REstore

On the industrial side, more than 125 industrial and commercial consumers including ArcelorMittal, Praxair, Sappi and Total are using Flexpond™, and through it are partaking in the Industry 4.0 and IoT transformation

REstore balances power grids across Europe, including the UK, Benelux and France and is expanding rapidly, growing its revenues by 700% from 2013 to 2014 and continuing with triple-digit growth.

Benefits

- Reduction of polluting power production hence lower CO₂ emissions
- Improved intraday balancing for power utilities and optimised generation/supply portfolio
- Lower risk of power shortages
- Lower energy costs for consumers
- Faster than a production plant and the most reliable real-time platform to deliver balancing power to power grids.

Challenges

Latency and stability of the network are extremely important to have an accurate real-time view on availability and control of flexible power.

Media and entertainment

Pace of change in the industry and the need for gigabit services

The media and entertainment industry has been at the forefront of digital innovation and is driving demand for better broadband connections. The global gaming industry, for example, is now bigger than other content genres (film, music) and was estimated at USD 91.5 billion¹⁰ in 2015.

In recent years, the streaming revolution has taken place, with video and music streaming becoming the norm. Consumers are increasingly expecting higher quality across different media types. 4K high resolution streaming has been introduced in the European market, with some players rapidly expanding their offering and devices supporting this. Even though 4K is not widespread yet, broadcasters are already shifting their focus to 8K and beyond, which will inevitably drive demand for ultra-fast broadband.

In addition to higher video quality, consumers are expecting more immersive experiences. The rollout of virtual reality devices, which seems to have taken off in 2015 – and will accelerate with a raft of products launched in 2016 – outlines the demand for these realistic experiences, whether it is gaming or watching a live sports broadcast.

Augmented reality, which blends virtual reality and real life, will be the next step. Not only will this increase the demand for high throughput, it will also increase the need for very low-latency connectivity to have a good experience and avoid cyber sickness because of discrepancy between the motion of the simulation and the motion that the user expects. These services will demand ultrafast, highly stable networks.

It is not only consumers who are driving the need for gigabit networks. Broadcasting and media companies are increasingly replacing their satellite connection with a fibre network to send the live recorded images to the TV studios for post-production before being broadcast. Highly valuable images are sent through



The global gaming industry is now bigger than the films and music industries at USD 91.5 billion in 2015

a more secure connection and post-production can happen in the studio using a large number of video streams (versus only a few streams that can be sent through satellite, where post-production has to happen on site).

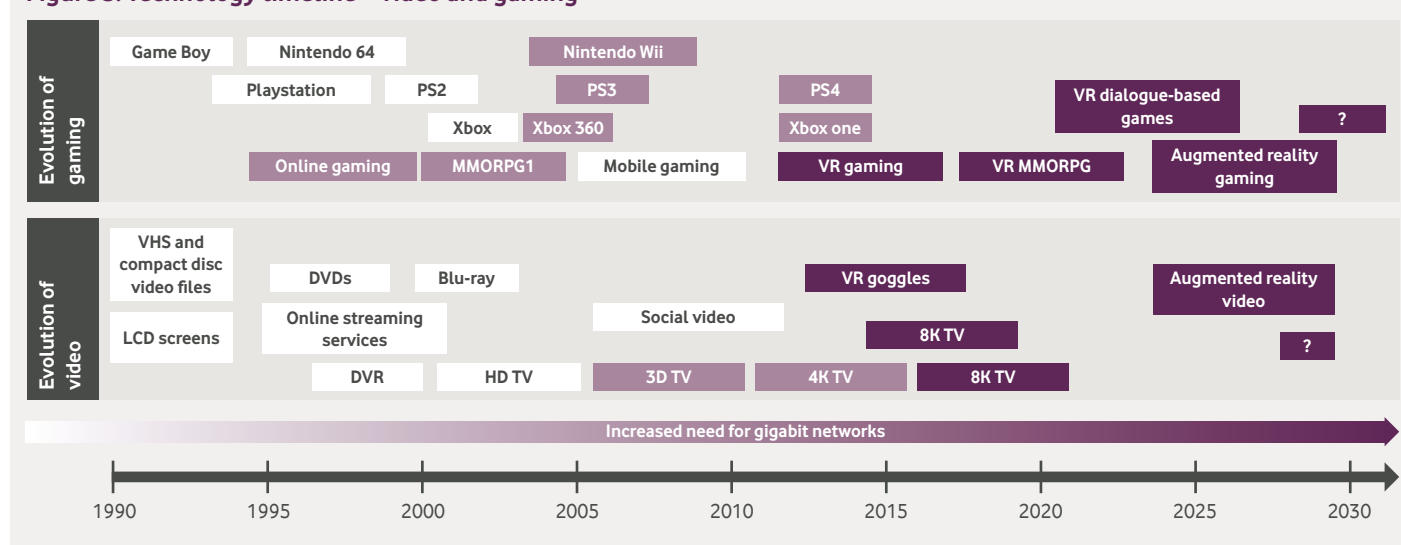
Potential applications using gigabit networks

- **Real-time 4K/8K and future standards for streaming video or gaming:** next generation ultra-high definition video content for broadcasting, streaming, gaming, etc. Screen resolution is just one factor – further advances including wider colour gamut and higher-frequency screen refresh rates also increase technical requirements
- **Massive online gaming:** an online or cloud gaming platform that is capable of supporting large numbers of players simultaneously on the same platform with video streams rendered in high quality
- **Virtual reality gaming:** an online or cloud gaming platform that provides an immersive gaming experience. With accuracy for voice recognition technology and open-ended dialogue with computers being developed, this could evolve towards voice interaction with virtual characters
- **Augmented reality video or gaming:** gaming experiences that combine both physical and virtual environments, enabling users to feel as though they are within the game realm while in a specific location.

Example of advanced countries – Korea

The Korean online gaming market is considered the most advanced in the world, driven by the country's advanced web infrastructure.

Figure 5: Technology timeline – video and gaming





CASE STUDY

nDreams – Virtual reality gaming

nDreams is the largest UK software developer to be solely focused on creating virtual reality entertainment content. High-bandwidth connections are necessary to download the games in a reasonable amount of time from a digital store, and for future cloud-based gaming applications.

Background information

nDreams was founded in 2006 by former Eidos Creative Director Patrick O’Luanaigh, and quickly established itself as the leading publisher in PlayStation Home, a virtual 3D social gaming platform. Today, it is the largest UK software developer to be solely focused on creating virtual reality entertainment content.

The solution

nDreams has already worked on a number of virtual reality (VR) titles (including *SkyDIEving*, *Gunner*, *Perfect Beach*) and will launch its newest title *The Assembly* later this year.

The Assembly is an upcoming first-person interactive story game, designed from the ground up with the full use of VR in mind. The player is immersed in an entire virtual world and is tasked with completing a number of trials (ranging from puzzles to complex dilemmas). The game is being developed for the Oculus Rift (PC), HTC Vive (PC) and PlayStation VR (PS4) headsets.

Gamers will need to download the entire VR game from an online digital store to their gaming system, which will be about 5–6 GB in size (depending on the amount of foreign languages that are included). A connection with an actual download speed of 3 Mbps would need about 4 hours to download the game, 8 Mbps would need 1.5 hours and 24 Mbps would still need 0.5 hours. Fibre connections can significantly reduce this time to minutes or even seconds.

Digital videogame stores clearly indicate the size of games, so a limited connection is an important ‘addressable market’ barrier to videogame companies like nDreams developing large-size VR games.



We estimate that around 20% of our potential customers may have a broadband connection that makes downloading our games problematic and frustrating. As our VR games become more complex and increase in quality, the bandwidth requirement will become even more important. It would be a dream if all our customers had fibre connections; it would enable us to do so much more.”

Patrick O’Luanaigh
CEO, nDreams

nDreams was a leading publisher in PlayStation Home, a virtual 3D social gaming platform supporting millions of players, which was discontinued in 2015. One of the main reasons for this was because the connectivity of most players was not good enough to allow the seamless downloading of new spaces. Another issue was the difference in latency among players, which created an unfair advantage in some of the games for gamers with better connections.

Benefits

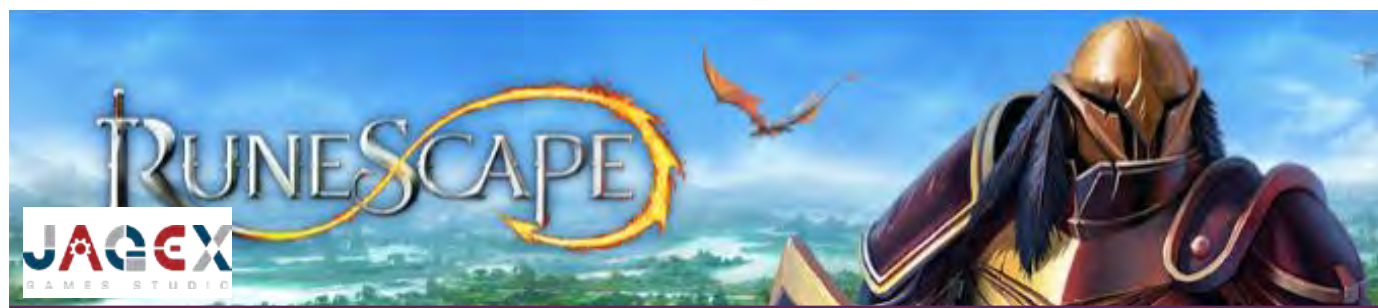
- More ‘real’ and immersive experiences through VR games
- VR games can be used for training or educational purposes and recreate a real-life environment.

Challenges

Next generation VR videogames will continue to increase in quality and size and will require pervasive broadband connections to download them.

Future

nDreams is looking to add other features in its future VR games, such as online cloud gaming where a virtual world is created in the cloud, in which players could log-in and play against each other. Connectivity requirements are even higher for such next generation VR games and experiences.



CASE STUDY

Jagex – Massive multiplayer online role-playing games

Jagex is a leading games studio within the massive multiplayer online role-playing games genre and the creator of *RuneScape*. Jagex creates a unique experience for its users in a persistent virtual world for which high-bandwidth, low-latency networks are crucial.

Background information

Founded in Cambridge in 2001, Jagex is the UK's largest independent developer and publisher of online games. The company's flagship title, *RuneScape*, is a longstanding title in the massive multiplayer online role-playing games (MMORPG) sector.

Celebrating its 15th anniversary this year, *RuneScape* has welcomed over 245 million players to its world of adventures and has been recognised by Guinness World Records as the largest free online multiplayer game. Jagex attracts gamers from across the globe, with the main customer base in the US, UK and Europe.

The solution

In MMORPG games, a large number of individual players interact in real time with each other in a fictional, persistent virtual world. Every month, over two million gamers will play *RuneScape*, each looking to interact with thousands of other players in the game world simultaneously. Players engage in activities such as the trading of virtual goods, communicating through chat services and taking part in adventures and quests. *RuneScape* is a graphically rich browser game.

Enabling many thousands of users to interact simultaneously, Jagex hosts its games in remote datacentres across the world. Consumers download a light application – the client – that corresponds with the datacentres and streams the game's rich content. Two-way communication between gamers and the datacentres creates the need for high-bandwidth and low-latency connections. To guarantee a good gaming experience, Jagex requires players to have a high-speed connection.

April 2016 saw the introduction of a new *RuneScape* client and graphic engine, which will enable players to experience the world with a much greater degree of fidelity.

Further innovations in the field of MMORPGs and gaming in general will require consumers to use increasingly better broadband connections that offer higher throughput capacity as well as lower latency. Being restricted to slower download speeds means that the game world's environment would take longer to load as players move from one game location to another and also limits game developers in the quality of game experience they can provide to players.

“The need for ubiquitous connectivity is vital for companies like Jagex to create successful gaming experiences.”

Rod Cousens

Chief Executive Officer, Jagex

“Guaranteed high-speed connectivity can enable companies like Jagex to create better customer experience by providing richer content and game dynamics.”

Saumitra Ganguly

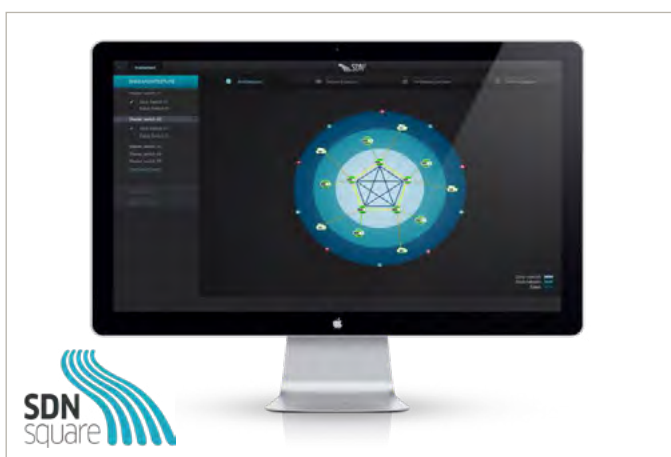
Vice President, Technology, Jagex

Challenges

- Limited broadband limits the reach to a larger market
- Limited broadband also inhibits the richness of content that games can offer.

Future

Looking towards the future, virtual/augmented reality could be a game changer within the MMORPG sector. This would enable companies such as Jagex to offer fully immersive MMORPG games, driving the need for high bandwidth and low latency even further. They are ready to embrace this if infrastructure is in place to guarantee a good market size to support distribution.



CASE STUDY

SDNsquare – Sending media content

SDNsquare offers media companies software solutions that guarantee the dataflow on wide area networks (WAN) with zero packet loss. Their solution enables media organisations to share mission-critical data on a reliable high-speed publicly available fibre network.

Background information

SDNsquare was established as a software company in 2010 in Belgium to solve the storage and networking challenges faced by media companies.

Among other software products, SDNsquare offers its 'Grid' solution that allows for guaranteed dataflow on datacentre, LAN and WAN networks. The product offers the opportunity to set up data paths with zero packet loss and guarantees bandwidth to send important media files.

The solution

At present, the majority of broadcasting companies refrain from using IP services as the quality of the connection cannot be guaranteed. The 'best-effort' service that most IP solutions offer does not provide the reliability required by media companies, eg missing a few seconds of video when broadcasting the finals of a major football league would be catastrophic. Therefore, media companies are forced to use more expensive dedicated leased lines or microwave technologies to share mission critical content over long distances. However, sending media files over public fibre networks yields significant benefits for media companies in areas such as video processing flexibility and general cost efficiency, if the service can be guaranteed.

SDNsquare provides media companies with a grid solution that guarantees 100% quality of service over public fibre networks without packet loss. SDNsquare's solution allows companies to assign a specific throughput to certain operations at a specific time, providing the reliability demanded by media companies.

For example, their MECaNO project demonstrated the potential of the Grid solution for efficient, decentralised media (post) production of media in Belgium. During this project, a WAN network with guaranteed quality of services, zero packet loss regardless of distance and in-time delivery was established.

Currently, SDNsquare is participating in the Elastic Media Distribution (EMD) project where they focus on how audio, video and digital content can be distributed in a guaranteed way over corporate and public networks.



Our solution enables media broadcasting companies to send their content over public fibre networks, which yields significant benefits."

Lieven Vermaele
CEO, SDNsquare

Benefits

- **Easier central processing of media:** media companies can easily send raw video streams to a centralised content processing centre over public networks instead of having to rely on on-site post-production facilities
- **Cost benefit:** it can be cheaper to send media files over public networks than over private, more expensive lines
- **Accounting:** network usage is tracked and facilitates direct costing models
- **Outsourcing of activities:** media companies can send their media files to third parties over public networks to outsource content production and focus on content processing.

Challenges

- **Rollout of fibre networks:** at present public fibre lines are not available or are not economically viable, and hence there is a need for further deployment of fibre to enable media companies to share their content more efficiently.

Education

Pace of change in the industry and the need for gigabit services

Digitisation is increasingly innovating the way of teaching and changing business models have started to appear over the past 10 years. The internet emerged heavily on campuses, and many internet exchanges were initially university developments.

Online platforms and tools to assist teachers and students are being introduced by exciting start-ups (eg Pobble, allowing students to showcase work on online walls, and TeachPitch, a cloud-based learning platform helping teachers to identify teaching methods and online resources).

Hybrid solutions – ie the combination of paper and online education – are increasingly being implemented to optimise the learning experience. This market is expected to grow by almost 25% per year, reaching USD 447 billion by 2020¹¹.

Online classrooms are being trialled in advanced countries (eg by Benesse in Japan) but this is still far from being mainstream yet.

Universities around the world are reorganising the way they teach and moving towards a decentralised business model allowing 'à la carte' curriculums where students can attend classes from different universities across the world online. Massive open online courses (MOOCs) continue to gain traction and we see courses attracting followings of up to 100,000 students for popular subjects. The global MOOC market is expected to grow at a CAGR of 46% in the period 2015–2019¹² and will reach USD 8.5 billion by 2020.

An alarming trend in the education sector is that major players providing learning and teaching tools are forced to look at solutions that will decrease the need for bandwidth because current networks are unable to fulfil their needs, which is clearly unbeneficial for end users (eg by distributing content locally over content delivery network (CDN) or moving to low-quality video streams).

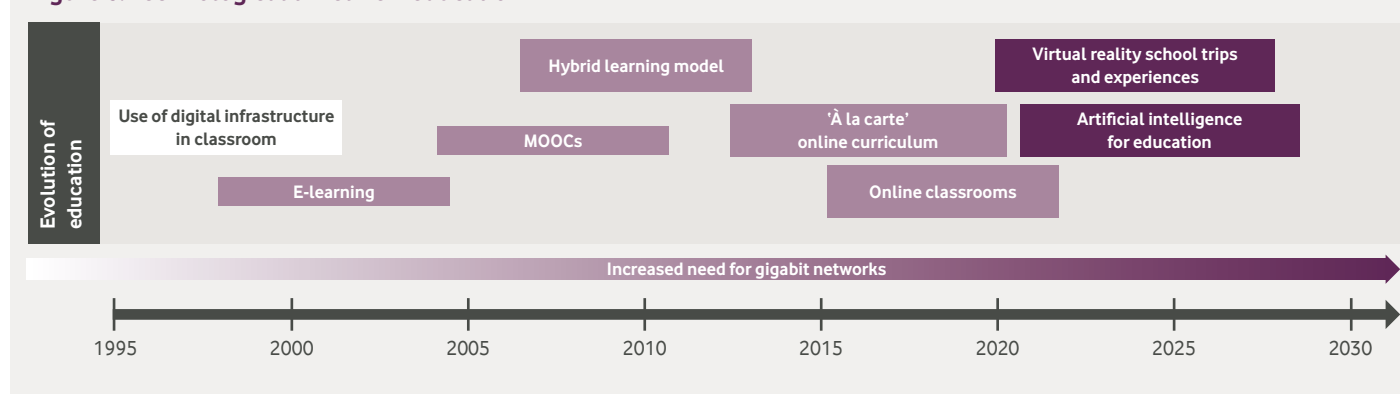
Potential applications using gigabit networks

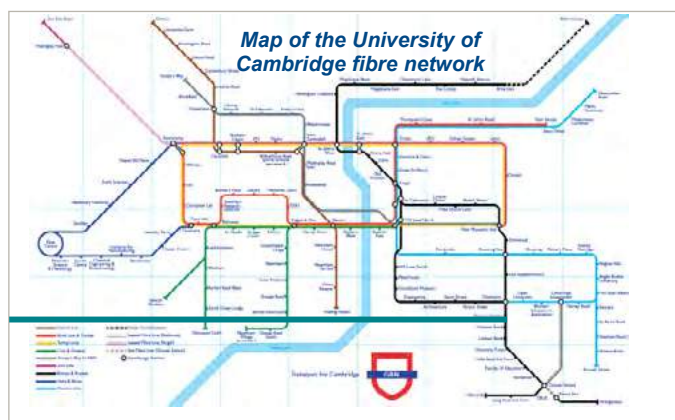
- **Digital learning in the classroom:** schools are increasingly equipping students with tablets and laptops to download educational content from the Cloud (with up to 500 students downloading large data files at the same time)
- **Dedicated virtual training:** professional training in an Immersive Virtual Learning Environment (IVLE) (eg training for pilots, engineers, rescuers or astronauts)
- **Virtual reality field trips:** use of live streams to visit remote places (eg the North Pole, the Amazon or the sub-sea)
- **MOOCs:** massive open online courses where classes or conferences are being streamed by thousands of end users
- **Online classrooms:** online courses that resemble real classrooms allowing two-way interaction between teachers and students, collaboration between students and online coaches
- **Adaptive online education using AI:** use of AI to optimise learning solutions and keep motivation high.

Example of advanced countries – Japan

Japan has benefited from very strong FTTH penetration and optimised the learning experience of students. Japan is increasingly adopting a hybrid teaching model that utilises traditional (paper and pen) writing and reading exercises as well as electronic tools and devices to enhance the learning experience. AI is used for online examinations, tailoring questions to the students and adapting the questions to keep motivation high. Japan has recently been trialling fully remote classrooms, which enable students who live in remote places to attend school.

Figure 6: Technological timeline – education





CASE STUDY

University of Cambridge – Own fibre network

The University of Cambridge's private fibre optic network enables cutting-edge big data research and has led to a competitive advantage when competing globally against other research universities.

Background information

The University of Cambridge is among the world's oldest universities and has been consistently ranked as a top-tier academic institution. The University consists of 31 constituent colleges and more than 100 academic departments.

The University of Cambridge started the rollout of its own optical fibre network in the 1990s. Initially, its purpose was to share academic texts and data among different academic departments. Today, the network has become the cornerstone for both faculties and students and supports an annual data usage of approximately 36 petabytes (PB)¹³ (ie 36,000,000 GB) of which approximately 60% is to support research and education.

The solution

The fibre network is crucial for the research activities that are taking place at the University of Cambridge and even acts as a competitive advantage for winning research grants.

Whereas research departments such as astronomy, physics and engineering were historically the largest data consumers, today these have been overtaken by web sciences, biological sciences and medical research. Large data amounts are transmitted between departments or to high-performance computers.

For example, in medical research a human genome accounts for approximately seven terabytes in its raw format (before compressing). Analysis is performed on the raw data in a different location to sampling, so high bandwidth is crucial to support this ground-breaking research on an everyday basis.

Several external research organisations located in Cambridge are also connected to the high-performance fibre network enabling more efficient collaboration with the University.

The low latency of the fibre network is specifically important for life sciences, where the visualisation will be performed by researchers within their institution, but the data files (~100 GB) are stored and computed by a high-performance computing facility, which is located remotely.

Without our own modern fibre network it would be impossible to perform high-impact research in fields such as genome sciences."

Jon Holgate

Head of Networks – University of Cambridge

Benefits

- **Increased bandwidth capacity:** the fibre optic network resulted in a significant increase in data sharing capacity, internally and when collaborating with other institutions
- **Cost efficiency:** optical fibre offers a cheaper solution as compared to other forms of infrastructure
- **Flexibility in property development:** due to the fibre optic network there is no need for specific properties to be adjacent as the infrastructure facilitates good connectivity even at a distance.

Challenges

In contrast to telecom or utility companies, institutions such as the University of Cambridge have to go through an approval process for further rollout of the fibre networks, which often turns into a long bureaucratic process.

Future

The University of Cambridge is focused on expanding its fibre network to further facilitate collaboration with the increasing number of external research organisations.

Data requirements will continue to increase. For example, the Square Kilometre Array radio telescope is projected to generate data of approximately 100 PB per annum.



CASE STUDY

Benesse – Shinkenzemi correspondence courses

Shinkenzemi is Benesse's correspondence course brand, which provides tailored courses that match school material with the individual pace of learning. Students are given a hybrid learning solution that combines the use of both technological devices, for example tablets, and traditional paper exercises.

Background information

Benesse, founded in 1955, is a global multinational headquartered in Japan, active in the fields of education, language and global leadership training, lifestyle, and senior/nursing care. Benesse aims to optimise the learning experience of students through tailored learning.

The company has operations in over 70 countries and regions across Asia, Europe and the Americas and reported revenues of USD 4.1 billion in 2015.

The solution

Shinkenzemi, a correspondence course solution from Benesse, focuses on primary and middle-school students, and provides tailored courses that match educational material with the individual level and pace of students. Additionally, it allows for customisation based on the objectives of students – eg tailored to prepare for a specific school entry test.

Shinkenzemi offers students a hybrid learning solution that combines the use of digital devices, for example tablets, with traditional paper-based material. The digital parts of the course take full advantage of audio and real-time video features. Throughout the duration of a module, a mentor is assigned to a student to enable them to ask questions when needed and provide individual attention to every student, hence the importance of low-latency and high-bandwidth networks.

The online examination tool of Shinkenzemi uses the original Study Route Map System to adjust subsequent questions

in real time to optimise the learning experience and keep motivation high.

Benefits

- **Benefits of online tools combined with benefits of paper-based education:** paper-based material is supplemented with audio and video material, online coach and online adaptive examination tools
- **Reduced stress levels:** remote learning solutions provide the possibility to study from home, limiting potential stress levels associated with the classroom
- **Tailored to the individual student:** students learn at their own level and pace, allowing them to focus on their main areas of improvement
- **Increase in motivation:** hybrid solution that combines both playful learning on tablets as well as paper-based exercises creates an environment that keeps motivation high.

“Japan has benefitted from strong fibre penetration over the past decade, enabling us to develop solutions like Shinkenzemi. Fibre networks are crucial for development of further applications like virtual classrooms, where latency and bandwidth will become even more important.”

Kotaro Ueda

Chief Strategy Officer, Benesse Group

Future

Optimising the learning experience will continue to drive innovation in education. Advanced adaptive learning will be further enabled by AI. Bandwidth and latency provided by fibre networks will be crucial to enable a whole range of new applications and ensure their widespread availability throughout Japan to all students.

Retail

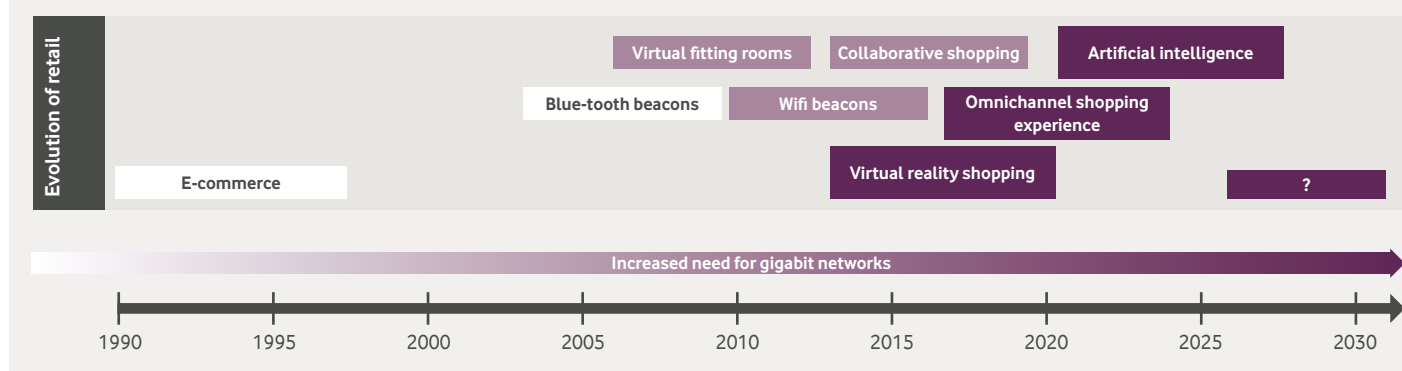
Pace of change in the industry and the need for gigabit services

The retail industry has embraced the opportunities that digitisation has offered. Customers wish to shop on their terms, when they want and where they want – and rapidly evolving mobile and online sales platforms enable this. Currently, a large majority of retailers have an accompanying website for their brick and mortar stores.

Moving forward, retailers will focus on U-channel retailing – ie ubiquitous, universal and unique retailing focused on the customer. In practice a U-channel is the ability to ensure 'one face to the customer' throughout all channels.

Additionally, as an increasing amount of business is conducted via the internet, there will be a move towards personalisation of the non-traditional sales channels, eg e-shopping and mobile, through two-way communication platforms. Consumers crave personal interaction and information while shopping, and retailers will aim to provide this through media such as chat, voice, video, screen sharing and virtual reality.

Figure 7: Technological timeline – retail



Toward the future, AI will play an important role in retail. AI will provide support to retailers by utilising big data and inform store agents about the previous purchasing behaviour of the client, allowing for a tailored service offering for each individual customer, online or offline.

Potential applications using gigabit networks

- **Cloud POS applications:** web-based point of sale (PoS) software (eg Applestore) enabling customer transactions and provisioning in store, handled in real time via remote backend systems
- **Collaborative shopping:** collaborative online shopping allows a consumer to shop at an e-commerce website or brick and mortar location accompanied by remotely located shopping partners, such as friends or family
- **Virtual fitting rooms:** virtual fitting rooms are near-ubiquitous store changing rooms that allow consumers to fit clothing via an online platform
- **Virtual reality shopping:** virtual reality shopping allows consumers to experience a product before purchasing or see a particular product in a different setting, eg clothing worn by models on a catwalk

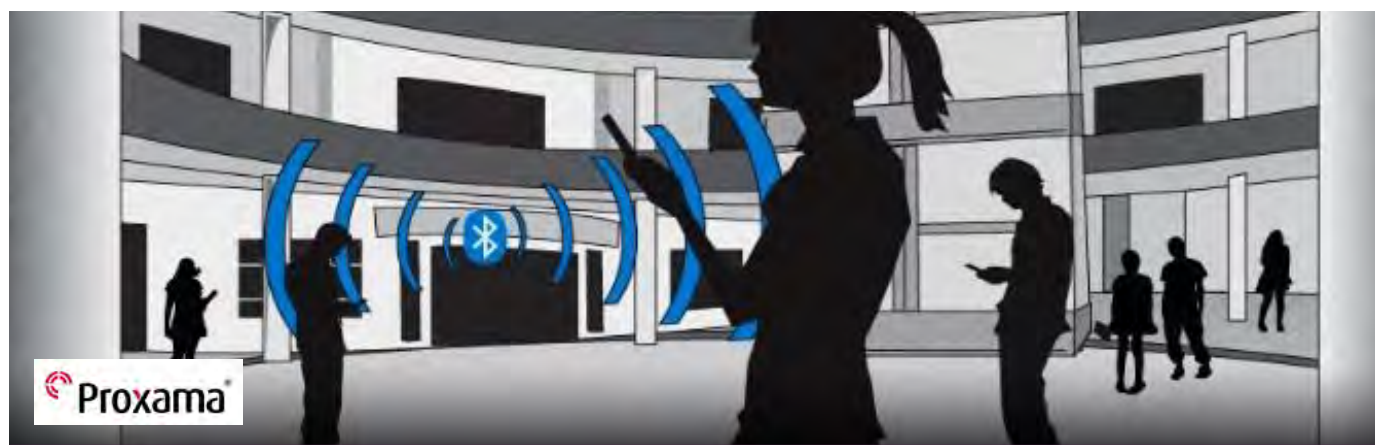
- **Use of beacons:** beacons within stores will enable the analysis of each consumer and provide tailored communications, such as real-time deals.

Example of advanced countries – UK

The UK is the global leader in terms of the e-commerce versus total retail sales ratio¹⁴, with the e-commerce market reaching £52.25 billion in 2015¹⁵. In total, 29% of these purchases were made on mobile devices whereas the rest was purchased through PCs¹⁶.

In addition, more than 50% of UK retailers are investing in in-store location-based technologies in order to further facilitate a personalised digital experience similarly found online¹⁷. 30% of retailers are specifically focused on introducing IoT applications for further consumer engagement¹⁸.

Consumers have embraced in-store experience, with 90% of total smartphone users indicating that they have used their phone in retail stores¹⁹. Clearly, retailers in the UK are using the consumer readiness to enhance loyalty and continue to focus on offering additional in-store personalised service.



CASE STUDY

Proxama – Marketing engagement utilising beacon technology

Proxama provides proximity marketing solutions that allow organisations to engage in real time with nearby smartphone users. This enables organisations to 'creatively' engage with customers.

Background information

Proxama Plc is an international mobile commerce company, with headquarters in the UK, specialised in mobile proximity marketing engagement which enables brands to connect physical and digital assets to increase consumer engagement, retail sales and loyalty across a network of high footfall locations.

The mobile proximity solution

Organisations are increasingly looking to connect to consumers in real time, for marketing or other purposes. For example, a retail store might want to offer a discount to consumers in store in order to 'push them over the edge' for a purchasing decision, or to offer better in-store experience.

Proxama provides proximity marketing engagement solutions that allow organisations to send consumers relevant, sophisticated and contextual call-to-action messages on their smartphones via beacon technology. iBeacons transmit a low-energy Bluetooth signal to smartphone apps that are enabled with Proxama's TapPoint® Software Development Kit (SDK), which will activate the targeted messages. Hence, all smartphones in the range of the iBeacon that have Bluetooth turned on and at least one app enabled with SDK, will receive the targeted messages.

Additionally, Proxama's platform is compatible with Eddystone, the open beacon format from Google, facilitating beacon engagement via the Physical Web. The service boosts the reach and capability of beacon campaigns because it enables any smartphone with a Chrome browser to receive a notification without the need to download an app. After receiving a beacon notification, consumers can complete the call-to-action, for example downloading vouchers, viewing rich media content (eg video), installing apps or receiving directions to the nearest store.

Call-to-action notifications are increasingly moving away from low content (eg mobile advertising) towards sophisticated content-rich engagements such as watching HD videos (eg watch a new movie trailer). For this content-rich marketing engagement to take place, the user must have access to a high-bandwidth connection, even in highly congested areas or places that are not well served by mobile, such as metro stations, and general high footfall venues or deep in retail stores.

Proxama also offers 'closed or private beacon networks', which trigger notifications to smartphones of people who are in a specific 'closed' venue such as exhibitions, events and stadia. A stable and resilient high-bandwidth Wifi solution is crucial to trigger content-rich actions from smartphone users in those closed venues.



Fibre is the fastest and most secure network. This would not only provide ease of use, but would also protect consumers and create an increase in the acceptance and ability to engage effectively with a proximity engagement opportunity."

Gavin Talbot

Commercial Director – Proxama Plc

Benefits

- **Targeted engagement opportunities:** the use of beacon proximity marketing solutions allows brands to deploy targeted, relevant and contextually creative engagements to consumers.

Challenges

- **Educating consumers about beacons:** educating consumers in proximity marketing will naturally evolve with accepted behaviours in interacting with mobile devices
- **Connectivity to support call for action:** in order for consumers to complete the call to action, connectivity will become increasingly important and expected.

Communication and IT

Pace of change in the industry and the need for gigabit services

Innovations in the communication and IT sector have revolutionised how people and business collaborate and operate today. Many applications and communication tools exist, allowing people to interact with each other across the globe with ease at low cost. In addition, the rise of social media has created a platform for mass communication for both enterprises and individuals.

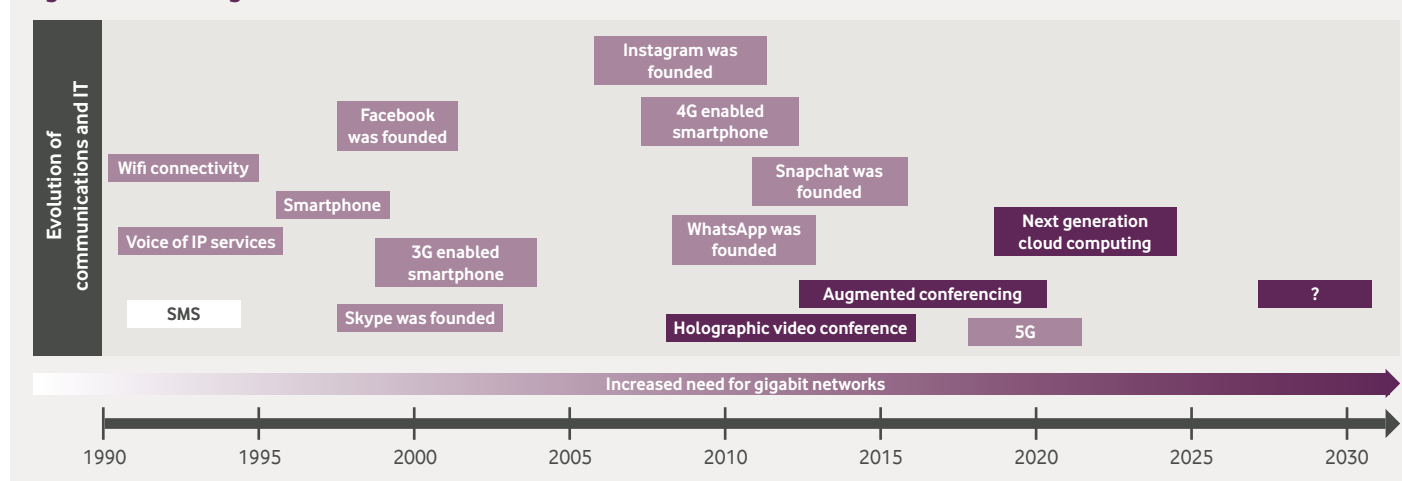
Communication solutions within enterprises have almost fully moved from analogue phone services towards voice over IP (VoIP) and videoconferencing solutions. Given that major enterprises already use videoconferencing solutions on a frequent basis, the critical mass to adopt further innovations, such as augmented reality and holographic videoconferencing, is present, and will further improve remote collaboration. In addition to pure bandwidth, low latency and dedicated quality of service (QoS) connections play a crucial role in customer experience for these next generation videoconferencing solutions.

Within the IT sector, there has also been a steep increase in use of cloud computing solutions across enterprises. Whereas initially thought to only benefit large business, the global SME cloud computing market reached USD 99 billion in 2015 and is expected to grow to USD 159 billion by 2018²⁰. Moving forward, we expect that the use of cloud computing services will increase significantly due to its flexibility, disaster recovery capabilities, low capital expenditure, security and remote access of content. Furthermore, next generation cloud computing solutions will enable the use of the high processing power to complete complex analytics on large data sets in real time.

Fibre networks are a key enabler for advanced cloud computing as the high bandwidth is necessary to deal with enormous sets of big data, low latency is needed to perform distributed cloud computing in real time and the increased security of the network is key when dealing with mission-critical or customer-sensitive data.

In addition to cloud computing, the IT industry will have to adjust to the expected increase in machine-to-machine (M2M) devices. As society adopts more smart solutions and devices with embedded computational and communicative power, it is projected that the amount of IoT units installed will increase to over 20 billion by 2020, up from 5 billion in 2015²¹. While the first wave of such devices mainly used M2M capabilities, the generation brings video/audio requirements and the need for precise control.

Figure 8: Technological timeline – communication and IT



Potential applications using gigabit networks

- **Holographic videoconferencing:** full-motion, 3D videoconferencing system that projects realistic images of a remote environment
- **Augmented conferencing:** conferencing with real-life images combined with augmented reality input
- **Next generation cloud computing:** complex analytics on big data sets that are stored in the cloud in real time.

Example of advanced countries – USA

In the US, the top 100 metropolitan areas contain 65% of the total population²². A significant amount of these areas, and hence the vast majority of the total population, are connected by fixed FTTH connections of 100 Mbps or higher. In addition, companies such as Google are rolling out their fibre connection across the US to further improve connectivity. Utilising this advanced connectivity network, companies seek to test the capabilities of new videoconferencing innovations in the US. For example, Cisco has successfully tested holographic videoconferencing and Microsoft has recently started testing augmented videoconferencing solutions.



CASE STUDY

Ryanair – Aircraft connectivity solutions

Ryanair has implemented a number of new methodologies and systems to better connect its head office with pilots, cabin crew and ground staff, and provide them with the right information at the right time for which guaranteed high-bandwidth connections are needed.

Background information

Ryanair carries over 106 million passengers per year on more than 1,800 daily flights from 84 bases, connecting 200 destinations in 32 countries on a fleet of 330 Boeing 737 aircraft, with a further 350 Boeing 737s on order, which will enable Ryanair to lower fares and grow traffic to 180 million passengers per year by FY24. Ryanair has a team of more than 10,000 highly skilled aviation professionals delivering Europe's No.1 on-time performance, and has an industry-leading 31-year safety record.

Ryanair operates on an average turnaround time²³ of approximately 25 minutes, hence it is crucial to have the right communications infrastructure in place to facilitate this.

The solution

Ryanair has equipped its pilots and cabin crew with portable devices to provide them with the right information at the right time. Until about two years ago, pilots were obliged to carry heavy briefcases on-board containing all the flight information they need. Some of these documents had to be re-issued before taking off, sometimes leading to delays. This system has been replaced by a paperless solution, providing pilots with the right information in real time, eg regarding weather updates, flight plans or technical issues. A stable and reliable connection is crucial to avoid delays due to missing information.

Moreover, pilots sometimes have to download content-heavy documents or applications when they return to base via the local Wifi network (eg some maps are 600 MB or higher). It is a regulatory requirement that some of these documents are downloaded or IOS application updates have been completed before the aircraft can take-off. Having a high-bandwidth Wifi connection (with appropriate backhaul) is paramount to limit delays related to download times. When the turnaround time is 25 minutes, every minute, even second, counts.

Ryanair also introduced a new on-board electronic point of sale (EPOS) system that verifies payments through an M2M SIM, which connects with the central network as soon as the aircraft lands. This system identifies fraudulent payments before passengers disembark.

Ryanair has to rely on the airport broadband connection at each of its 84 bases, which is often DSL based, to provide pilots and crew with the right information for their flights. The limited bandwidth and 'unguaranteed' aspect of the connection can cause delays.

“**Flights are sometimes delayed simply because the bandwidth offered at the airport is insufficient for pilots to download the right information on time. We would welcome fibre networks at all of our bases, as this would provide us with guaranteed bandwidth that we currently do not have through DSL connections and which can't be provided by mobile.**”

John Hurley
CTO, Ryanair

Benefits

- **Faster turnaround times** with paperless solution
- Pilots and crew members have **access to real-time information**.

Challenges

Bandwidth is a major issue Ryanair has to deal with. New ideas or applications consuming bandwidth at the airport base have to be refused because bandwidth has to be reserved for pilots and crew.

Future

Ryanair will take delivery of a further 350 aircraft over the next eight years. This will lead to more pilots and cabin crew consuming bandwidth, and fibre connections will be crucial in dealing with this.

Ryanair would like to implement videoconferencing to the different bases for training, safety and flight briefings. This is currently not possible because of limited bandwidth.

Public sector

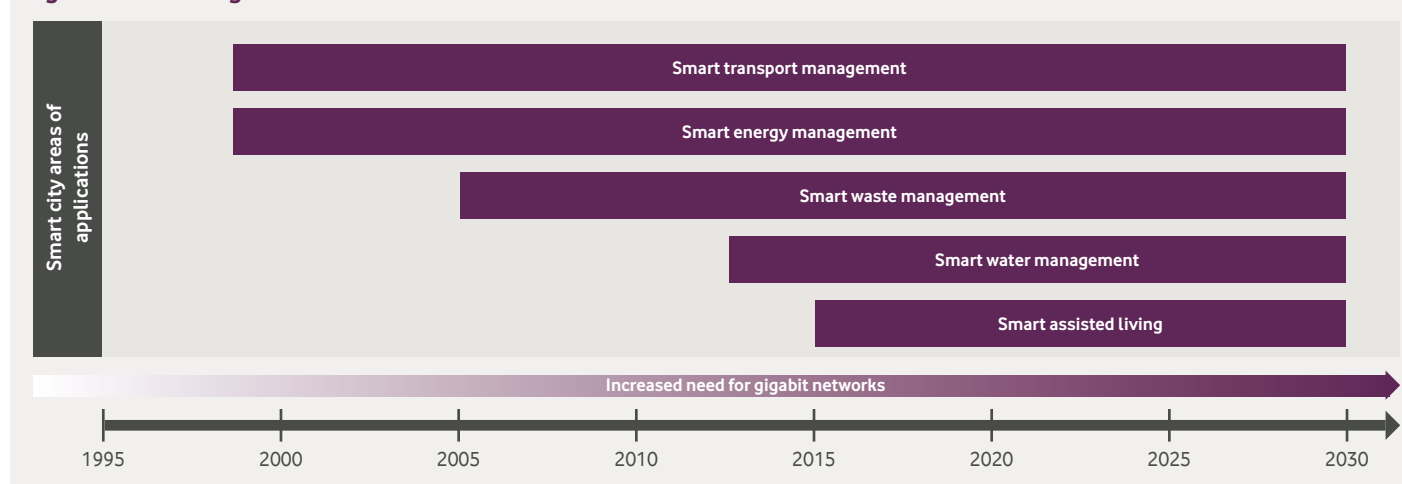
Pace of change in the industry and the need for gigabit services

The general goal of the public sector is to improve the quality of life for citizens – measured in many ways – employment, wellbeing, security, etc. Progressively new technologies have been deployed to meet this aim. The introduction of communication platforms that facilitated the dialogue between citizens and governments has brought significant convenience and efficiency gains. Governments are now looking into further opportunities that yield similar results.

At present, local and federal governments around the world are incentivising the investments in smart cities. Smart cities can revolutionise the operation model of most public sectors by integrating multiple information and communication systems that can help manage critical assets. Smart city technologies can lead to significant efficiency by collecting and analysing all sorts of data affiliated to cities and their inhabitants.

The majority of smart city investments are related to smart grids, carbon emissions reduction, public broadband (eg free Wifi) and building automation. In the near future, however, we expect a shift in focus towards more complex solutions such as smart transportation, smart health and smart governance systems, which will drive the overall market potential.

Figure 9: Technological timeline – smart cities



We predict that the global smart city market will increase from USD 0.95 trillion in 2014 to USD 2.1 trillion in 2020 (13.9% CAGR)²⁴.

In addition to the social benefit from the investment in smart cities, enterprises will be able to reap significant benefits as well. More and more cities open up their smart city infrastructure assets and data, which enables companies to roll out their technologies while using the public network as backbone infrastructure and offer services based on aggregated, 'big data' analytics. These open source networks will eventually become a crucial part in the establishment of an IoT society, which consequently could assist governments to achieve their goal of improving the quality of their citizens.

Potential applications using gigabit networks

- **Intelligent parking:** providing drivers with real-time parking availability, which in turn will increase parking availability, reduce traffic congestion and improve air quality
- **Smart waste management:** integrated waste management solutions that move beyond the traditional use of labour, diesel trucks and conventional landfills

- **Control of appliances:** remote control of any type of electric appliance in the home
- **Intelligent air conditioning:** systems and tools for intelligent management of air conditioning, enabling interaction and automatic adjustments based on external information (eg weather forecast)
- **Smart lighting:** use of advanced technologies and sensors enabling remote control of lighting in public and private places.

Example of advanced countries – UK

The UK is the third biggest country of the EU with regard to population and has one of the EU's highest shares of population living in a city or commuting zone. Via the Future Cities Demonstrator Programme, the UK Government has funded 29 cities²⁵ to develop new applications to integrate and improve services.

Two UK cities were finalists of the World Smart City Awards in 2015, Peterborough and Milton Keynes, out of 280 proposals that were submitted from 52 countries around the world. UK smart city expertise is focused around the convergence and integration of healthcare, transport, education, energy, smart grids, the built environment and digital media²⁶.



CASE STUDY

Bristol Is Open – Smart city

Bristol has a world-leading software defined fibre, wireless and mesh network enabling next generation research and development.

Background information

Bristol, a city in the southwest of England, is home to research and development projects that use Bristol's own sophisticated digital infrastructure. Ten years ago, the city council bought a network of redundant ducts from a TV cable company, which formed the basis for this infrastructure. This duct access has been key for the success of Bristol Is Open.

Today, the infrastructure consists of a super-fast fibre network in the ground (terabits per second); a mesh network utilising lampposts across the city; and a mile of experimental wireless connectivity along Harbourside. Each project is managed by Bristol Is Open – a joint venture between the University of Bristol and Bristol City Council.

The solution

Bristol Is Open, will turn the city into a giant laboratory and look at how big data can be used to solve problems related to pollution, traffic congestion and assisted living for the elderly. The network could also be used to collect and understand data from the city's trial of self-driving cars or even for entertainment (eg the city's 3D, 4K data dome enables many data visualisation possibilities).

Sensors and other IoT devices will be attached to the network to collect huge amounts of data over the fibre network (eg measuring air quality, traffic data, data from driverless cars, crowd movements and weather conditions).

An operating system will provide access to the network and the data it collects in real time, for research and development.

In order to manage all the data being collected the network will be split up into 'slices', with each application handed a portion of available bandwidth from the city-wide terabits per second fibre network. Such network bandwidth would, for example, allow for multiple streams of 4K video to be carried at once²⁷.

The new planetarium is already connected to the network and will be used, for example, to aid academic research with huge files being sent from the university supercomputer, allowing academics to manipulate scientific data in 3D, and for development of new forms of virtual-reality presentation.

Without the city's fibre network, most of these applications would not be possible.

“Duct access has been vital to the success of Bristol Is Open. As we bring our infrastructure live throughout 2016 we are looking forward to demonstrating new levels of connectivity that will be the hallmarks of the smart city of the future.”

Paul Wilson

Managing Director – Bristol Is Open

Benefits

The fibre network is used beyond data consumption to improve the quality of life of citizens.

Challenges

The ground-breaking project has been challenging in every regard, from convincing funders, deploying equipment in fast timescales, to attracting customers. But within just two years a large amount of progress has been made.

Future

Bristol is becoming an open laboratory for businesses to find new ways to make the city smarter and develop technology and software to solve urban problems. Commercial companies will be able to access and contribute to the smart city network for R&D projects too.

Bristol will also look at mirroring smart city and smart facility technology from around the world. The network has a built-in network emulator that allows it to simulate any smart facility or city in the world, making it possible to mirror Guangzhou's digital infrastructure on Bristol's network as if it were real²⁸, and trial and test new applications and methods.



CASE STUDY

Dundee City Council – Smart city

Dundee City Council is currently in the process of deploying various smart city projects as well as a fibre-based open wireless network to facilitate connectivity for tourists and citizens, as well as enabling the collection of big data that would allow for better public policy decision making.

Background information

The Dundee City Council represents approximately 150,000 citizens in the city of Dundee, Scotland. The city is in the midst of a £1 billion waterfront transformation project, which encompasses five zones totalling 240 hectares of land stretching 8km alongside the river Tay. It is a strategic, focused and forward-looking 30-year project (2001–2031) that aims to propel the city to international acclaim. As part of this project, the city council is actively looking at how a move to IoT technology would benefit the growth of the city as a whole.

The solution

As part of its smart city efforts, Dundee is developing among others a smart mobility hub, a data analytics system and a security alarm operation centre that has over 6,000 clients. These projects, aimed at improving the quality of life of the citizens, are part of the process of digitalising the current city infrastructure.

In order to facilitate the smart city applications, Dundee is looking to deploy a world-class scalable connectivity solution throughout the entire city. Dundee is planning to deploy its own fibre network supporting an open wireless network for public Wifi by 2018.

In addition, the city aims to use this network to gather real-time data across a range of city activities that will enable the council to make better-informed decisions on public matters. The fibre backhaul infrastructure will allow for data collection of smart street lighting, smart bins, smart parking meters, IP CCTV and many more smart devices across the city.

The network will need to be capable of transmitting high levels of data to support public Wifi and collecting data in real time.

“Dundee will implement a world-class scalable connection throughout the city that will facilitate big data collection solutions. In order to achieve this, as well as being prepared for future technologies, high bandwidth connectivity with low latency is crucial.”

Alan Dobson

Business Development Officer

Benefits

- **Better-informed public policy decisions** on mobility, security or energy through the use of big data
- **Synergies across different city service departments** through the use of advance systems and sharing of information.

Challenges

- **Cross data integration:** different departments within the city services have a tendency to operate with the use of primary data and function. Not sharing or having open data by default, can slow down the development and rollout of secondary use data-based solutions.

Future

Although cities across the world are implementing advanced technologies in order to reap the benefits of a true smart city, the concept of a smart city is continuously changing. Innovation will lead to even smarter and more efficient solutions for city problems. Therefore, smart cities will have to continuously adapt as well and will have to be supported by future-proof connectivity solutions.

Dundee is planning to deploy its own fibre network supporting an open wireless network for public Wifi by 2018.

How can we realise the Gigabit Society?

Gigabit Societies have already begun to emerge, and a number of barriers and other factors need to be considered before we can move to a full 'gigabit continent' in Europe:

- Awareness of the benefits offered by fibre networks is insufficient with some key stakeholders, especially in government bodies
- Extremely high service levels are required to be globally competitive and keep up with other leading 'gigabit nations'
- Inconsistent regulatory approaches are adopted to investment incentives and structural interventions
- Increasing importance of cloud-based services, M2M, IoT, Industry 4.0, requiring <1ms latency.

Four types of barrier impede the realisation of the Gigabit Society and should be tackled, where possible, in a consistent fashion across the continent:

Political. Fibre services offer many advantages to consumers and businesses, and inspire political promises from many parties towards electorates. These need to be met with long-term commitment, given the deployment timelines and payback periods on fibre projects, along with appropriate incentives, where the standalone economic case is challenging. Political awareness about fundamental socioeconomic mechanisms need to be increased: broadband quality and speed correlates strongly with social and economic welfare, job creation and an innovation eco-system driven by the pace of Moore's law. Therefore national policies should encourage fibre investments. In addition, high consumption of ultra-fast (fibre) broadband drives GDP growth and supports a strong ICT ecosystem.

Legal/Regulatory. Planning conditions, environmental guidance and historic rights of way impede or delay the rollout of fibre services in many countries; though this is slowly changing as communities recognise the impact of a lack of fibre on their residents, updates to planning, environmental and historical preservation laws and consolidating the number of parties with whom operators must liaise to deploy new infrastructure. Regulatory predictability and stability are key to avoiding disruptive effects in the market and to enable a solid business case. Regulation should be made cognisant that there are infrastructure investment cycles and regulators should ensure that operators have sufficient certainty of regulatory regimes to ensure that they can be appropriately financed. Regulation should support a positive investment climate by applying the right tools and cost accounting standards.

Financing. The circumstances of and returns from fibre projects vary significantly. To ensure maximum access to capital, authorities should be open to all types of financing approaches (ie to private and public investment, to participation by asset owners, users and communities, and to outright ownership, sale and leaseback, vendor financing and other approaches) rather than being too prescriptive. Incentives may be needed in some areas, and regulators should not oppose solutions that bring together operators or operators and asset owners (like other utility providers or government/civic bodies).

Technical. Fibre technologies already offer vast capacity and many other benefits, but will continue to improve with new generations of technology. Regulation should not be technology specific – provided the roadmap is future proof. Fibre installation technologies also improve rapidly, for example the use of micro-trenching technologies allowing very fast rollouts in some UK cities or in the US (eg in New York).

Other commentators have raised similar concerns – notably many trade and industry bodies representing European businesses (Institute of Directors²⁹, National Federation of Self Employed & Small Businesses), and leading European research institutes, such as the Fraunhofer Institute³⁰ as well as Nokia³¹.

Annex 1: Key characteristics of fibre

Attribute	Definition	Example
Throughput	Throughput refers to how much data can be transferred from one location to another in a given amount of time. This is typically measured in megabits per second (or Mbit/s or Mbps).	A full movie in 4K definition of approximately 100 gigabyte would need 1 minute and 25 seconds to download on a 1 Gbps connection (versus 1 hour and 11 minutes on a 20 Mbps connection).
Latency	Latency indicates how much time it takes for a packet of data to get from one designated point to another and is typically measured in seconds or milliseconds.	An acceptable latency for high-definition videoconferencing is up to 300 milliseconds (ie 0.3 seconds). A higher latency would lead a noticeable delay before seeing and hearing the other party's voice.
Availability	Availability relates to the ability to provide and maintain an acceptable level of service in the face of faults and challenges to normal operation. It is measured in percentage of time that the network is available.	A 99.99999% availability of a network means that on average only 0.00001% of the time the network will not work. On an annual basis this would mean that the network is unavailable for 5 minutes and 25 seconds per year.
Security	Network security relates to how hard it is for an unauthorised person or engine to tap signals without being detected. To do so, the unauthorised person would need to get access to the fibre optic cable, which are typically secured in ducts and harder to tap than copper lines.	Misuse involves physically cutting the cable and splicing a device into the fibre that can be used to pick up the data or using devices for collecting light emitted by optical fibre, allowing hackers to reconstruct the data (eg by bending the fibre and picking up stray light emission or putting a photo sensor around the cable).
Packet loss/jitter	Packet loss is the failure of one or more transmitted packets to arrive at their destination. It is typically measured as the percentage of packets or frames that did not arrive at their destination. Jitter measures the variable time arrival of different packets.	Packet loss could, for example, result in a loss of a few seconds of video and you would see a 'frozen frame' on your screen and a brief interruption or distortion of audio.
Symmetry	Relates to the symmetry of the upload and download links or a network. When the symmetry is 'dynamic' this means that the user can choose the bandwidth used for uplink and downlink.	Media companies who have to upload a lot of video material and send it to the studio will opt for a high upload link and lower download link.
RF interference	Relates to the level to which radio frequency waves will interfere with signals travelling over the fixed network.	Signals travelling over fibre networks will have zero RF interference, while signals travelling over copper networks will be impacted and can be distorted.

Annex 2: Glossary

Abbreviation	Definition
4K	Horizontal resolution on the order of 4,000 pixels
8K	Horizontal resolution on the order of 8,000 pixels
ADSL	Asymmetric digital subscriber line
AI	Artificial intelligence
CAGR	Compounded annual growth rate
CDN	Content delivery network
CT	Computerised tomography scan
DOCSIS 3.0	Data over cable services interface specification 3.0
DSL	Digital subscriber line
EPOS	Electronic point of sale
ERCP	Endoscopic retrograde cholangiopancreatography
FTTC	Fibre to the cabinet
FTTH	Fibre to the home
Gb	Gigabit (1 Gb = 1,000 Mb = 1,000,000 Kb)
GB	Gigabyte (1 GB = 8 Gb)
Gbps	Gigabit per second
GDP	Gross domestic product
HD	High definition
HDTV	High definition television
Hz	Hertz
ICT	Information and communication technology
ICU	Intensive care unit
IoT	Internet of things
IPTV	Internet protocol television
ISDN	Integrated services digital network
IVLE	Immersive virtual learning environment
LAN	Local area network
M2M	Machine-to-machine
Mb	Megabit (1 Mb = 1,000 Kb)
MB	Megabyte (1 MB = 8 Mb)
Mbps	Megabits per second
MMORPG	Massively multiplayer online role-playing games
MOOC	Massive open online course
MRI	Magnetic resonance imaging
ms	Millisecond
OECD	Organisation for economic co-operation and development

Annex 2: Glossary continued

Abbreviation	Definition
PC	Personal computers
POS	Point of sale
PSTN	Public switched telephone network
QoS	Quality of service
RF	Radio frequency
RFID	Radio frequency identification
SDK	Software development kit
SME	Small and medium enterprise
Tb	Terabit (1 Tb = 1,000 Gb = 1,000,000 Mb)
TB	Terabyte (1 TB = 8 Gb)
TIME	Telecommunication, information, media and entertainment
USD	United States dollar
VOIP	Voice of internet protocol
VR	Virtual reality
WAN	Wide area network
WLAN	Wireless local area network

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Digital Greenwich	REstore
Dundee City Council	RWE
Ericsson	Ryanair
Flexeye	SP Energy Networks
iMinds	SDNsquare
Inition	Steigenberger Hotel Group
Jagex	TeachPitch
Karolinska University Hospital	Transport for Greater Manchester
Mouchel	University of Cambridge
nDreams	Urban Foresight
Nokia	

End notes

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Vodafone Group Plc
Registered Office:
Vodafone House
The Connection
Newbury
Berkshire
RG14 2FN

www.vodafone.com

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