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Building Blocks for Smart Networks

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Working Party on Communication Infrastructures and Services Policy

BUILDING BLOCKS FOR SMART NETWORKS

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FOREWORD

This report was presented to the Working Party on Communication, Infrastructures and Services Policy (CISP) in March 2012. It was recommended to be made public by the Committee for Information, Computer and Communications Policy (ICCP) in October 2012. The report was prepared by Mr. Rudolf van der Berg and Mr. Jaesung Song. It is published under the responsibility of the Secretary-General of the OECD.

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MAIN POINTS

This report examines the development of smart networks and services with particular attention to the implications for communication policy and regulation. The word “smart” has become a term that is frequently affixed to an area where the introduction of networked information and communication technologies (ICTs) is expected to have significant implications for economic and social development. In this document it is defined as: *an application or service that is able to learn from previous situations and to communicate the results of these situations to other devices and users.*

Achieving the benefits of smart networks and services may prove to be demanding on regulators. Much of the promise of smart networks and services will depend on the efficiency of communication markets to deliver the requirements increasingly demanded by other sectors of economies and societies, such as coverage, availability, affordable roaming and so forth. Moreover the demands will be closely linked to broader objectives of policy makers, ranging from dealing with the challenges of aging societies to the environment, innovation and economic competitiveness.

Smart networks can be viewed as a further stage in the development and use of the Internet. The initial stages, using fixed and more recently mobile connectivity, have allowed the development of platforms that further services have been built upon. ‘Smart’ is possible because the initial stages have expanded high-speed Internet access, to an extent few would have anticipated prior to the liberalisation of communication markets.

The distinguishing feature of the ‘smart Internet’ is the scale of connected devices. Today, whereas a family with two teenagers may have 10 devices connected to the Internet, in 2022 this may well grow to 50 or more devices. Across the OECD area, for example, the number of connected devices in households may rise from an estimated 1.7 billion today to 14 billion by 2022. It is this scale that redefines how communication with devices is enabled and how the generated data is processed and analysed.

Collection of data will be enabled by the expansion of Machine-to-Machine (M2M) communications. Large scale processing will be delivered by “Cloud Computing” services. Analysis of these data will be undertaken around a process frequently called “Big Data”. These phenomenona together form the “Building Blocks of Smart Networks”. Each distinguishes itself from previous similar developments because the size of numbers of devices, data and elements is orders of magnitude larger than that of previous periods.

Systems can be scaled up, from individual units that are smart, to combinations of devices that make a larger whole smart. Smart transport, for example, needs smart automobiles, smart delivery vehicles and logistical systems, smart public transport and smart roads working together. The better interconnected these independent units and separate systems are, the “smarter” the larger set could be considered.

It is not enough to use sensors, actuators and communication in an existing system for it to be considered smart. The new smart network and system has to fit into the lives of the people that use it. There are several challenges in this context and these include human, lifecycle, business and regulatory. Each of these challenges limits the way certain technologies can be used, but understanding them can also serve to better introduce smart applications and services that benefit businesses and consumers. For communication regulators, for example, smarter networks open up many possibilities to develop greater competition. The repositioning of smart products and services, and the innovation around it, opens up new markets, but it also brings companies that previously were working in different markets into direct competition with each other. Furthermore, the massive scale of smart networks places different requirements on market players, who will reposition themselves and make new demands on their suppliers and regulators. The issue of introducing reforms to allow large-scale M2M users to obtain their own mobile numbering is one example. This is necessary to enable increased competition and the flexibility to increase efficiency in the market. While not considered here in any depth, security and privacy of smart networks and systems are also a large area for consideration. For example, there may soon be a moment, with a smart network, where not doing something leaves as much of a record as any action that is taken.

The other major challenge, for communication regulation, could be broadly termed as the lifecycle challenge. It exists because of the different and possible very long-term life cycles of products that will be connected through smart networks. Before "smart networks", the lifecycles of these devices and systems were not connected, but in the future, smart systems will make them interconnected and interdependent. For example, choices that have been made in the past are now leading to demands on authorities to extend the duration of spectrum licenses because smart systems are still using the spectrum granted under these licenses. In many circumstances, there is not a "greenfield" situation whereby the latest technologies can easily be integrated. These different lifecycles add to the complexity of introducing smart networks and systems on a large scale and means improvements will be gradual.

BUILDING BLOCKS FOR SMART NETWORKS

The word "Smart" has become a term that is frequently affixed to an area where the introduction of networked ICT's is expected to have significant implications for economic and social development. Smart grids, smart transport, smart cities, smart agriculture, smart appliances, smart clothes and textiles, smart government are just a few examples of where the term is widely used in relation to networks. Effectively, the building blocks of economies and societies are being transformed by the potential of networked ICTs and the infrastructures and services that make this possible.

Smart networks can be viewed as a further stage in the development and use of the Internet to transform economic and social activities. The earliest stage was developing services and IP networks to connect business premises and households. This came with applications such as e-mail, e-commerce and websites. However, it largely relied on infrastructures and business models that were developed for telephony and video rather than data. The public switched telecommunication network (PSTN) was one of the initial access pathways to the Internet (*i.e.* dialup access) and, gaining momentum after the turn of the century, was increasingly superseded by 'always-on' broadband access. Cable television networks provided a further such building block. From being largely dedicated to the provision of one-way video delivery services, cable networks were augmented to provide the same converging voice, video and data services. Over time a range of wireless technologies from satellite to fixed terrestrial and mobile wireless also began to be used to provide Internet access. It would be fair to say, however, that all these early networks were under-equipped to meet the rapidly growing demand for bandwidth and continuous use that flourished as new services were developed. The types of services offered were, therefore, quite static and largely not personalised. This changed when broadband, in various forms, became widely available.

A further stage, in the development and use of the Internet, came when new software and hardware enabled the Internet to be made more individual and interactive. These changes made use of the bandwidth offered by broadband. New software platforms enabled and facilitated applications that emphasised the individuality of the user and collective co-operation of individuals. Visible examples are blogs, Wikipedia, Tripadvisor, Twitter and Facebook. Many other innovations were less visible but easily incorporated in how people used the network of networks on a daily basis. Further hardware developments followed with wireless and mobile networks that enabled the Internet to be accessed via laptops and later mobile phones. This way access to the Internet could be consumed anywhere the user was rather than at a fixed location. The use of smartphones, tablets and the apps on them are currently a major expression of such personalisation.

The term "Smart" can be seen as a further stage in the development of the Internet. It is possible because the initial two stages have expanded high-speed access to the Internet almost everywhere in the developed world. There are, of course, some locations and regions that may be better served than others and major challenges exist in deploying greater amounts of fibre infrastructure either direct to end users or to support other "local loop" technologies. That being said, most users in OECD countries have access to fixed broadband and mobile Internet access of some form covering not only their homes and business premises but also the roads and transport networks they take between those and other locations.

With the greater pervasiveness of Internet access one of the first building blocks of smart networks, connectivity has been achieved to an extent many may not have thought possible prior to liberalisation of telecommunication markets. The development of wireless services and networks as well as associated commercial changes, such as the introduction of pre-paid cards, have been key ingredients to growth in access capabilities and affordability. Over six billion mobile telephones, for example, are now used in the world. While not everyone may have a mobile telephone, with Internet access, it may well be the most widely owned piece of modern (electrical) technology, apart from lamps and light bulbs (devices that may themselves increasingly have Internet connectivity).[1] Every year hundreds of millions more handheld mobile devices are produced and increasingly these will be smartphones or tablets with Internet access capabilities. The wide availability of personal devices, and fixed backbone networks that allow the offloading of wireless traffic generated by smartphones and tablets, has brought forth a scale that is needed to produce the components for a "smart networked world". At the same time, the cost of processing continues to decrease while storage capacities continue to increase. Moreover, the growing use of pre-paid cards for Internet access in developing countries promises to have a similar effect, as did this model for voice services.

Earlier work has looked at recent developments in machine-to-machine communications (M2M). The report, "*Machine-to-Machine communications: connecting billions of devices*" concluded that M2M could have great potential to enhance economic and social development. To achieve these benefits, however, changes to telecommunication policy and regulatory frameworks may be required. Some of the main areas that will need to be evaluated, and implications of M2M assessed, include: opening access to mobile wholesale markets for firms not providing public telecommunication services; numbering policy; frequency policy; privacy and security; and access to public sector information. These issues need to be considered as policy makers and regulators look to the implications of network developments in related areas such as "Cloud Computing" and "Big Data".

The developments in communication, processing and storage each find, in the phenomenon of M2M, cloud computing and big data, a number of interrelated factors in which massive scale is the defining element. The scale is evident in the number of units and in the amount of data they will potentially produce. Moreover their reach will be far greater than has previously been experienced in terms of what devices are connected. Automobiles enabled with sensors, cameras and so forth, for example, will be able to generate data that can assist drivers to share information (*e.g.* parking spots, road and traffic conditions).

In the case of processing, storage and analysis of data, large scale computing was once seen as being in the sole domain of entities such as banks, tax authorities and retail chains. Today, with hundreds of millions of users online, taking advantage of services such as social media and online commerce, the amount of data generated far exceeds that which was previously handled by entities such as banks and taxation authorities. Not so long ago these entities measured their needs in terms of terabytes (now an amount of storage available to any consumer in an external standard hard-disk). Meanwhile, cloud computing companies measure their storage needs in exabytes, far exceeding anything that was available or needed at tax authorities or banks a few years ago.[2]

The massive increase in the amount of data being generated by people using the Internet, and the services it enables, is about to become compounded by machines and devices connected to the Internet. Take, for example, the amount of data generated by users on online sites that share information they input themselves or generate automatically through their actions (*e.g.* "click behaviour"). While extremely large, these amounts of data can be compared to the amount generated by a company such as TomTom, and the services it provides to motorists and others around the world. To date, TomTom, a Dutch manufacturer of automotive navigation systems, has collected 5 000 trillion data points from its navigation devices and other sources, describing a time, a location, direction and speed. The analysis of such data can potentially provide information and insights across a swath of economic and social activities. It can be used to empower consumers as well as enabling the public and private sector to offer improved services, with potentially very large economic gains. This is exemplified by a competing service of SK Telecom available in Korea (Box 1).

Box 1. SK Telecom's T-MAP service

It is a custom for Koreans to visit their relatives and to have a memorial service for their ancestors on the Lunar New Year holiday, which falls in early February. Over 30 million Koreans make a round trip to their hometown in the three to five days of this holiday. Buses, automobiles, trains and flights combine to create traffic congestion that reaches yearly highs and the time for the journey at least doubles compared to a normal weekday. However, 490 000 Koreans used SK Telecom's T-map service on the Lunar New Year's day of 2011 and saved time on the road. T-map, a real time navigation application, running on smartphones, is popular and known for the accurate forecast on journey time even in the high season.

T-Map recommends the fastest route taking into account the information of user's location and real-time traffic conditions. Traffic congestion is analysed from GPS signals received from around 20 000 buses, taxies, and trucks that are running on the main motorways. To cover traffic situations outside the main roads, mobile handset location information (moving speed), which was collected at base stations is complemented.[3] With the use of T-map and similar services, the time spent for a round trip between major cities in the season of 2011 remained the same or decreased slightly (significantly between some cities) compared with the previous year though traffic volume on motorways in 2011 increased by 1%.[4]

Source: OECD.

DEFINING "SMART"

The term "smart" is not always well defined when used in association with networks. In this document the term smart is applied when:

An application or service is able to learn from previous situations and to communicate the results of these situations to other devices and users. These devices and users can then change their behaviour to best fit the situation. This means that information about situations needs to be generated, transmitted, processed, correlated, interpreted, adapted, displayed in a meaningful manner and acted upon.[5]

What makes this possible is a combination of three distinct phenomenons, each of which represents a further evolution in the development of the Internet:

- Machine to machine communication to transmit the information.
- Cloud computing to process and display data.
- Big data analysis to correlate and interpret the data.

The use of the term smart can be elaborated and an explanation given as to why it needs a combination of the above factors. A mechanical thermostat, for example, is not "smart", because it works only on the current measured temperature and how this relates to the desired temperature as set. A smart thermostat would be able to inform a user on the duration of time before a desired temperature was reached, smooth out warming cycles, save energy, respond to the presence of people in a room and to react to the weather outside by bringing down the blinds or awnings instead of turning up the air conditioning. Another example, of a device that would not be considered in the context of smart networks, is an electricity metre, which only measures values. Even when this device communicates these values to a central server it still is not a smart metre because there is no feedback loop.[6] Only when the data, from such a metre, can be used to change the action of a system, or the behaviour of its users, to best fit a situation, does the system become smart. Thus many applications labelled as "smart metres" are, in fact, not smart. In practice, this means that users and systems, in and around a household, would need regular updates on energy usage for the system to be considered smart.

Systems can be scaled up, from individual units that are smart, to combinations of devices that make a larger whole smart. A smart household might combine a smart energy metre, smart lighting, smart thermostats, alarm system with applications on mobile phones, interaction with televisions and so forth. A smart energy grid can consist of smart energy metres in people's homes, smart loading stations for electric cars, smart distribution networks and many others. Smart transport needs smart automobiles, smart delivery vehicles and logistical systems, smart public transport and smart roads working together. The better interconnected these independent units and separate systems are, the "smarter" the larger set could be considered.

It can be challenging to provide a precise threshold above which a system becomes smart. The system does, however, need to be able to communicate and adapt. The time it takes to send and receive data and to act upon that information is a likely differentiator between smart and "not smart" systems. In electricity grids trades are made on the basis of 15-minute intervals. An electricity system that provides information, that allows the buyers and sellers of energy to base their purchases and usage on actual values, instead of historical estimates, would likely need a similar updates of frequencies of once every 15 minutes. In a household, consumers would probably need more frequent updates on energy usage to allow for smart services, a sample frequency of one to 10 seconds is common.[7] This would allow consumers to see the results of their actions, such as turning on a heater. It may also allow the subsequent analysis of these data. For example, a consumer could see whether the performance of a refrigerator was deteriorating over time and whether it needed to be defrosted.

Not every action that can be actuated over a network could be characterised as smart. Turning on a lamp via a network is in itself not a smart system. However, being able to reach a lamp over a network would make its integration in a smart system much simpler. Some companies working on "smart light bulbs" envision that when consumers buy a starter set of three bulbs, and a remote, these initially will not be connected to a consumer's Internet connection. That being said, because such bulbs can be easily connected through gateways, such as via a smart phone or another connected device that can act as a bridge, these bulbs may become smart after a while. Smart is therefore dependent upon the context.

THE SCALE OF SMART

Moore's Law well reflects the main forces driving the development of smarter networks. The costs of various components of smart systems are being driven lower while, at the same time, incorporating greater capabilities. An ever-increasing number of sensors, actuators and networking chips are becoming available at price points where their integration into products is commercially possible. One question is how many devices will be connected to the Internet in the coming years. Some estimate the number of devices, connected to the Internet, at 20 to 50 billion sometime between 2020 and 2030

The number of connected devices may rapidly increase in such households (Table 1). Estimates vary but at present a four-person family with teenagers, in the OECD area, may have around 10 Internet connected devices. In five years this is likely to be around 25 and in 10 years as many as 50. Where, today, not every family member might have a smart phone, in another five years this will almost certainly be the case for the vast majority. Internet connected televisions and set top boxes, while increasingly available, are currently not the norm across the OECD. However, every new television bought, every new version of a set-top box introduced by a provider of digital television, will increasingly have the capability to be connected to the Internet. In a few years, the same will be true for light bulbs, sporting equipment and automobiles. This potentially enables services such as Pay as you Drive insurance, which require a connection to the Internet. Experience, in the United Kingdom, shows that this type of insurance can change the driving behaviour of individuals. To the extent that this provides benefits it is likely to be replicated elsewhere. Devices that can be used for eHealth applications, while not common today or perhaps even in five years, are likely to be increasingly used over the next decade to address the health issues associated with aging societies. When such devices do become more widely available adoption may be rapid.

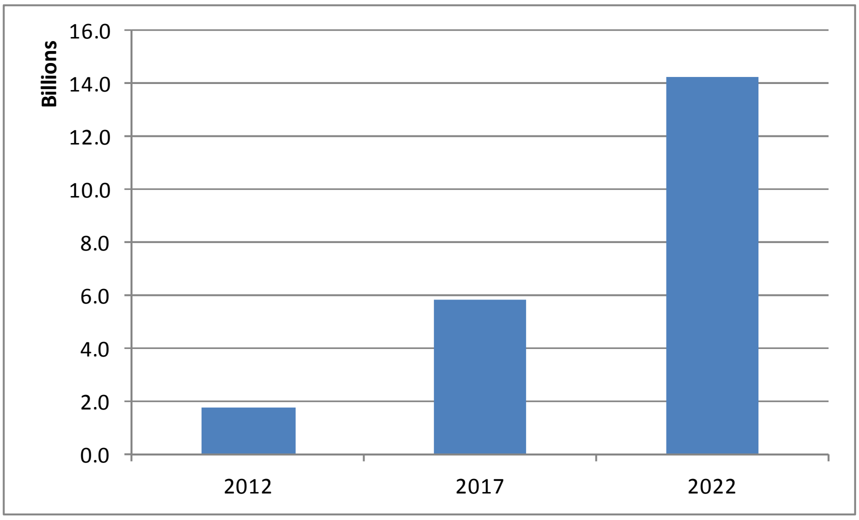
Table 1. Number of connected smart devices in a household of four (2 teenagers)

2012	2017	2022
2 smartphones	4 smart phones	4 smart phones
2 laptops/computers	2 laptops	2 laptops
1 tablet	2 tablets	2 tablets
1 DSL/Cable/Fibre/Wifi Modem	1 connected television	3 connected televisions
1 printer/scanner	2 connected set-top boxes	3 connected set top boxes
1 game console	1 network attached storage	2 e-Readers
	2 eReaders	1 printer/scanner
	1 printer/scanner	1 smart metre
	1 game console	3 connected stereo systems
	1 smart metre	1 digital camera
	2 connected stereo systems	1 energy consumption display
	1 energy consumption display	2 connected cars
	1 Internet connected car	7 smart light bulbs
	1 pair of connected sport shoes	3 connected sport devices
	1 pay as you drive device	5 Internet connected power sockets
	1 network attached storage	1 weight scale
		1 eHealth device
		2 Pay as you drive devices
		1 intelligent thermostat
		1 network attached storage
		4 home automation sensors
Devices that are likely but not in general use		
eReaders	Weight scale	Alarm system
Sportsgear	Smart light bulb	In house cameras
Network attached storage	eHealth monitor	Connected locks
Connected navigation device	Digital camera	
Set top box		
Smart metre		

Source: OECD

The prognosis for growth in the number of smart devices can be expanded to calculate how many devices are connected to the Internet today and may be connected in the coming years in OECD countries. Today households, across the OECD area, have an estimated 1.8 billion connected devices, in 2017 this could be 5.8 billion and in 2022, 14 billion devices (Figure 1). The estimate does not include smart devices outside the domain of the household, such as in business premises, on street lamps and in trains and buses. The total number will far exceed the estimate of 14 billion, but at more than 10 per person in the OECD. The estimates are just that but give some indication of the scale and growth that "smart" can achieve in the next decade.

Figure 1. Estimated number of "smart" devices in households in the OECD



Source: OECD

In some cases it is difficult to foresee what will happen to a product category. For example, eReaders currently have some advantage for reading over tablets and smart phones, because of their size, weight, screen type (E-Ink), price and battery life. It is, however, a product category that did not exist a few years ago and is under strong pressure from tablet like devices. The same goes for the possible integration of certain types of devices. Pay as you Drive insurance might possibly be developed as the equivalent of an application in an automobile, tapping into onboard communication and sensors. However, if such platforms are not standardised among manufacturers, or security is not guaranteed for insurers, they may opt for a separate device installed in a vehicle. Network attached storage devices are becoming more common in households to store media and data, but new cloud based storage offers may make this product category irrelevant.

If the foregoing estimates, for a family of four, hold true, then in a decade from now an insurance company could manage several million pay-as-you-drive devices, that each feed data on time, location, speed and g-forces into a database. Sports equipment companies could see gear such as tennis rackets, golf clubs, sports shoes relay data that need to be translated into meaningful, and entertaining, data for the amateur sports enthusiast. By way of example, Nike has suggested that data generated by their Nike+ basketball shoes assisted users to improve their "jump height".[8] At the same time, light bulb manufacturers (or specialized websites) could manage billions of light bulbs that are controlled using special applications on smart phones.

To reach such expectations, where an entire sector goes from no connectivity to full network connectedness, over a decade, requires a new level of computing scale. However, building such services that support a growth from close to zero market penetration today, to near ubiquity in 10 years, does not allow for the in-house home-built IT-systems that were common until recently. The compound average growth rates for such systems over a 10 year period, starting from near nothing to 80% market penetration are in double digits, some services might well see periods of triple digit growth, or more than doubling every year. Such systems do not scale with the speed of the business and it is therefore that machine-to-machine, cloud computing and big data are so necessary and need to be available in a timely manner.

M2M AND SMARTER NETWORKS

The ability to communicate is essential to network systems being considered smart. Therefore, by definition every device will have to be able to communicate. The type of communication used can be varied, wired and wireless, short or long range, low or high power, low or high bandwidth. In the report "*Machine-to-Machine communications: connecting billions of devices*" many of these options were discussed. A way to order the networking technologies is to look at the geographic distribution and mobility that has to be supported by the networks (Figure 2). An increase in mobility and dispersion comes at a cost to energy and bandwidth, meaning that the applications will likely need a bigger battery and can send less data than those devices that stay in one location. An overview of the choices available can be represented (Table 2).

Figure 2. Machine-to-machine applications and technologies, by dispersion and mobility

	GEOGRAPHICALLY FIXED	GEOGRAPHICALLY MOBILE
GEOGRAPHICALLY DISPERSED	**Application:** *smart grid, metre, city remote monitoring* **Technology Required:***PSTN, broadband, 2G/3G/4G, power line communication*	**Application:** *car automation, eHealth, logistics, portable consumer electronics* **Technology Required:***2G/3G/4G, satellite*
GEOGRAPHICALLY CONCENTRATED	**Application:** smart home, factory automation, eHealth **Technology Required:** *wireless personal area (WPA), networks, wired networks, indoor electrical wiring, Wi-Fi*	**Application:** *on-site logistics* **Technology Required:** *Wi-Fi, WPAN*

Source: OECD

Given the enormous amount of devices that will come online, in the coming years, the question is whether networks will be able to support all these devices. Network interactions initiated by humans are of a more intermittent character with pauses between interactions. However, when people interact over networks they expect interaction within less than 0.2 seconds, which limits the amount of data that can be sent to the user. On a 100 Mbit/s connection this effectively reduces the amount of data that can be exchanged to 1.25 Mbyte or less. M2M is different from traditional applications in that it is more upload focussed and less "bursty". A smart metre may send many times more measurement data than it receives in control data over its lifetime and it does so in a continuous stream. The same goes for any other type of sensor. The data rates achieved are very much dependent upon the data that is collected and the sampling rate.

What the actual data rates will be is also dependent upon the type of processing done on these data. In the case of an automobile, the data may be processed on board and as a result reduced in size to facilitate easier uploads of relevant data. However, an automobile has adequate onboard processing power and energy supply. In other cases the data must first be uploaded because there is no local processing power available or it needs to be combined with other data before it becomes useful. The time sensitivity of data is another concern, if there are real-time feedback loops, then it should be expected that the data is sent uncompressed, if this is not the case than "lossless compression" can save bandwidth. In case of real time data there will be a more streaming character to the data.

Table 2. Upload requirements of smart applications

Application	Upload speed
Camera	0.5 Mbit/s to 40 Mbit/s upload
32 channel Electro Encephalogram (256 samples/s)	200 Kbit/s upload[9]
Smart metre (in home monitoring)	1 Kbit/s upload[10]
Smart metre (energy trading)	1 bit/s

Source: OECD

The geographically concentrated applications of smart systems will generally be in or around a building. In this area, Wi-Fi and other short-range wireless technologies, should be able to handle the demand forecast for the coming years. New versions of Wi-Fi can support up to 1 Gigabit/s, which should suffice for many applications. Should dedicated connectivity be necessary, then wired technologies are also an option. There is, however, a question on whether the last-mile will suffice. It is not likely that in 2022 all of the OECD area will enjoy fibre to the home or technologies with equivalent speeds. Some locations are likely to be still on a form of DSL with limited upload speeds of, for example, 1-5 Mbit/s. Cable networks offer significantly higher upload speeds of 120 Mbit/s, however, this has to be shared by 100 to 1 000 users. Specifically, these upload speeds may limit what consumers can do with their smart homes. A high quality digital camera can take up all available upload bandwidth.

On mobile wireless networks the implications of M2M is harder to ascertain. Camera's that continually feed high quality data streams at 1-40 Mbit/s can create challenges for mobile operators. Specifically, during the busy moments of the day where as many as 7 000 devices can be connected to a single macro cellular node, which using LTE has 75 Mbit/s available.[11] On 2G and 3G networks the available upload bandwidth, per cell site, is significantly lower and it is therefore difficult to ascertain whether the networks would be capable of supporting a few applications that require 200 kbit/s.

In geographically mobile and dispersed M2M applications not only the required bandwidth is of significance. Equally important is the reliability of the network. Recent research into the reliability of mobile networks, for elections in Norway, showed that one in three connections are down more than 10 minutes per day (not counting "large events").[12] Whether this is tolerable for a smart application is dependent upon the application. The research found there is significant room for improved reliability if devices could connect to multiple operators. Some events may have large implications. For example, a fire at a Vodafone data-centre in Rotterdam, The Netherlands in 2012, was reported to have a pan-European impact on its M2M services with services like TomTom Live unavailable for days.[13]

Previous work on M2M systems mentioned a number of issues that have relevance for all stakeholders including policy makers. For example, this work noted that 2G networks may remain longer in operation, than expected, because of regulatory requirements, such as eCall in Europe, which effectively require a 2G network connection. 3G networks will likely never reach the whole population and LTE licenses and networks will be available in many countries only after 2013-2015, with full coverage taking some years. Given the lifespan of smarter networks, this can be a serious problem. The topic of the lifespan of "smart" will be further discussed in this report, as it can have significant implications for government policy.

BIG DATA AND SMARTER NETWORKS

Each of the smart devices discussed in this report will generate data. That data will be transmitted, collected, stored and processed. It is the ubiquity of these devices, and the speed with which that scale will be achieved, that will redefine how data needs to be analysed. A new phenomenon has, therefore, emerged, called "big data". One definition of "big data" refers to the treatment of data. The defining characteristics being that the "size is beyond the ability of typical database software tools to capture, store, manage, and analyse" these data.[14] The concepts and trends around big data are the focus of ongoing OECD work and this document only references some elements of it to show how big data is essential to smarter networks.

Traditional data collection, for a utility, was often on a yearly basis, augmented by some telemetric samples at randomly chosen households. The billing data for the monthly payments exceeded the data on electricity usage by at least one order of magnitude. Processing these data could take some time as it was not necessary to have real-time insights. With smart metering, countries aim to go to 15 minute samples, a 35 000 time increase over yearly collection. For "home automation" a sample frequency of once every one to five seconds is proposed by some, which would be a six to 31 million time increase over the traditional data set. These data then have to be combined and integrated with other data about the state of the home and its surroundings. Not only is the dataset bigger, and it can combine this data with other data, but the conclusions from the dataset need to arrive quicker than before because the analysis is used to drive near real-time processes that depend on complex interrelationships between variables. This requires a different approach to data analysis.

The different approach of Big Data was developed originally in the scientific community, where traditional transaction oriented databases using Structured Query Language (SQL) were not fast enough. The data that researchers in the scientific community collect generally does not change after collection, unlike data in financial institutions such as banks, which are updated constantly. The databases used therefore emphasised analysis speed and not transaction speed, which is vital for traditional databases such as those used by banks. The development of the Internet created more situations with similar needs, for example Google which needed to analyse crawled webpages at high-speed in order to update the ranking of pages on searches and of advertising next to searches and on pages.

As one definition of big data emphasises, it is not necessarily about the size of the dataset, whether this is measured in gigabytes or exabytes.[15] What is relevant is the number of readings, their interaction and the resulting complexity. So analysing a day's worth of data from all the thousands of sensors in an airplane counts as big data, but a video collection of the same size in bytes is not big data as it essentially involves just a few videos. In a smarter world, the interactions between what is measured and how this is acted upon and the measured results are similar to the airplane example. A city would be interested in optimizing routes through and around the city based on actual traffic flows and not the traffic analysis of a few years before. This means factoring in road works, sanitation and delivery trucks, concerts in stadiums, weather and receiving the results within minutes.

The same applies to the analysis of data for home automation, for example with the objective to save energy. Some thermostats can be programmed so that the heating or cooling of an apartment automatically turns itself on or off based on the time of day. When something changes in the schedule of the homes occupants, however, the effect is that energy is wasted. A smart home would be able to predict, based on weather patterns, traffic conditions, and so forth, when its occupants would arrive, and change the heating accordingly. This requires the combination of various non-correlated datasets and then analysing these for past implications for the temperature in the building and the arrival of an occupant.

One characteristic of big data is that it can allow for the testing of hypothesis at a large scale to measure the impacts of changes. This type of analysis was pioneered by large website operators, who tested various website designs to see which designs are the most successful. One of the interesting conclusions of this type of analysis is that it can be very difficult to explain why a particular change is favoured by users, though the analysis clearly shows an enormous preference by the user of one over the other. It also provides instant validation of whether assumptions of designers are correct. This type of analysis can be used in smarter networks to measure the effects of changing parameters with possibly millions of test subjects. For example, it could be measured whether certain warnings (audible as opposed to a warning light) in automobiles would have an effect in a change of behaviour, so that the incidence of traffic congestion is reduced. Or, whether changes to traffic lights have positive or negative effects. Before smart devices and big data, such analysis was done in small-scale laboratories and took years to materialize in products.[16]

Big data is already being used to improve healthcare and, for example, providing insights into the long-term effects of medication. By correlating data from patients across countries well after the use of medication the impacts can still be measured. The use of smart applications adds to this by enabling insight at an unprecedented scale allowing the comparison of heart, temperature, sleep or brain patterns in healthy people during various activities and those in people that report problems. Such data was unavailable before and skewed to those reporting a problem.[17] Smarter applications can now provide researchers with a control group of healthy people that they can compare to in their work.

Big data may in some ways be the most difficult building block of smarter networks. The difficulty being that meaningful analysis of data is not dependent upon technology, but upon insight. That insight cannot be generated by faster analysis but is in the end inherent to the underlying assumptions in the analysis of the data and the capability of those that build the system. If a service provider cannot deliver the promised efficiency gains, whereas another one can, as measured in shorter travel times, less energy use, better health services, and so forth, this will not be because of a lack of sensors, networks and computing power, but because of failures in analytics. It is here that the potential for smarter networks hold out the most promise for economic and social benefits.

SMARTER NETWORKS AND THE CLOUD

Because smarter networks generate big data, the processing of this data has to be done on systems that fit the type of data and processing well. Big data is particularly well suited to solutions that favour massively parallel processing. The data is sliced into smaller units and processed, and the various results are later combined. This is different from traditional computing, where faster processors, memory and so forth would deliver the speed increases that are needed. Systems that support massively parallel processing are essentially large quantities of servers, tied together by a common network and software stack that treats the servers as one common pool of processing and storage. Some companies such as Amazon, Google, Microsoft, Rackspace and Salesforce.com have tens if not hundreds of thousands of servers available. This is not an exhaustive list and many companies offer cloud services. These include, for example, some telecommunication operators on the Microsoft Azure platform. Managing such large systems is not trivial and that is why other companies, such as Twitter and Dropbox are buying these servers as a service from these companies. This is what has become known as "the cloud".

Cloud computing is defined as "a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (*e.g.* networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction."[18] They can be classified into three sub-categories according to the resources it provides: Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS):

- IaaS provides users managed and scalable raw resources such as storage, computing resources;
- PaaS provides computational resources (full software stack) via a platform on which applications and services can be developed and hosted;
- SaaS offers applications running on a cloud infrastructure.

Sometimes, clouds are classified into private, public, and hybrid clouds according to their ownership and control of management of the clouds.[19]

Benefits of cloud computing services can be summarised as efficiency, flexibility, and innovation. Cloud computing reduces computing costs through demand aggregation, system consolidation, and improved asset utilisation. In addition, it provides near-instantaneous increases and reductions in capacity on a pay-as-you-go model, which enables service users to act more responsively to their needs and their customers' demand without much initial investment in IT infrastructure.[20] All these factors of cloud computing services lower entry barriers of the cloud-using markets for startups and SMEs and consequently make the markets more competitive and more innovative. Applying this logic to smart networks, cloud computing network/service providers enables smart application providers to focus on developing and marketing innovative consumer-oriented services without giving much concern about scaling computing and networking to fit demand. A number of consulting companies have forecast similar developments trajectories for cloud computing. They expect tremendous growth in the public cloud computing market, particularly in the field of SaaS, in the next decade.[21]

In addition, the use of cloud computing brings certain possible benefits that could greatly facilitate the introduction of smart services. Many cloud computing platforms come with standardized interfaces that make it easier to couple several services together or to interconnect with another smart service that is operating on the same or another cloud platform. As a result it becomes easier to integrate these services in a way that allows for the development of innovative services.

Not all services will be provided by the manufacturers or operators of the hardware. There is likely going to be a market for companies that provide a service that integrates the data from various devices into one total package. A home management service may integrate lights, energy, temperature, movement and other types of sensors and devices in a home into an integrated overview. Based on the data collected from many homes the system may be able to predict that the cloud cover will break soon, bringing in sunlight to heat the room, so that the heating can stay low. Such services could be effective on a very wide scale with large amounts of customers. As a result, the facilitators of cloud services could offer these services to a global market.

Some of these cloud services for smart networks are already available. Cloud computing adoption, in smart grids, is at an early stage. It has been growing up around the metre data management (MDM) market, which some expect to grow quickly from USD 54 million in 2009 to USD 221 million by 2014.[22] MDM covers the collection of consumption data from metres to provide data to downstream grid systems and end users, and to support additional functions for further analysis on electricity usage patterns. In line with this belief, two leading companies in the market Itron and eMeter marketed cloud-based MDM software running on their cloud partners IBM and Verizon in 2011. They mainly targeted smaller utilities that cannot pay the large costs of servers.[23] Lockheed Martin has also announced a cloud-based smart metre and demand response platform — reducing power loads in factories, office buildings or homes to help utilities manage peak power loads — for co-operative utilities.[24] In November 2011, General Electric (GE) announced its first smart-grid-as-a-service client, 25 000 utility customers of the city of Norcross, in the United States. These examples also shows the different types of companies entering the market for cloud services such as IT-service providers, metre suppliers, telecommunication operators and energy grid suppliers.

Beyond smart grids, the use of cloud computing is expanding into closely-related energy management markets. For example, Schneider Electric, a global energy management company, offers a cloud-based building management system for intelligent monitoring, control, and management of energy, lighting, fire safety, and security.[25] From 2011, IBM is selling its cloud-based smarter city solution that covers almost all functions of a city such as infrastructure (transportation, energy and water, building management), deployment (social service, citizen health, education, culture), development (public safety, economic development, environment), and management (municipal administration, strategic planning).[26]

CHALLENGES TO SMARTER NETWORKS

In the previous sections of this document, the technical possibilities were described without the practical constraints and challenges that may surround the introduction of these services. M2M and cloud computing by themselves warrant such an approach, as in this context both are rather mechanical parts of smarter networks and system. If the technology can supply the requested functionality at a particular price point, then this will likely stimulate the introduction of smarter networks and systems. For big data this is rather different as its limitation is less technology and more the insight that the analysis of data provides. Understanding the correct correlations and their causations is required, certainly because, of course, correlation does not always imply causation.

In the implementation of smarter networks and systems as a whole the same limitations exist. It is not enough to use sensors, actuators and communication in an existing system and for it to become smart. The new smart network and system has to fit into the lives of the people that use it. There are several challenges that are relevant in this context which:

- Human challenges.
- Lifecycle challenges.
- Business challenges.
- Regulatory challenges.

Each of these challenges limits the way certain technologies can be used, but understanding them can also serve to better introduce smart applications and services.

Human challenges

The way people interact with networks and systems that limit, or enable some of the possible functionality and effects of a system, can be called “Human Challenges”. The standard question a user will ask when confronted with a new technology is; why would or should they use it. They will ask what need does the device or service satisfy. This question can be asked in respect to several smart technologies. For example, why would a user need an Internet connected television. Experience so far seems to show that if the Internet functions on televisions are used, it is mostly to access Video on Demand content over a network. Other possibilities, such as using web browsing are largely not used yet. The software around televisions has not yet become smarter in suggesting what to watch. For designers of human-machine interaction the coming years will contain new opportunities. This is because the introduction of smart technology will potentially change the interaction with devices that before were only controlled by hand.

An example of such a constraint is the use of portable eHealth equipment. If the data is streamed in near real time, to a central server, then how should the care provider react when an anomalous reading appears? Users of portable Electro Cardiogram equipment may have mixed reactions to calls from their carers resulting from such readings. The connected ECG is both adding to their potential security as well as their possible anxiety.[27]

Box 2. Smart light bulbs, a building block of smart homes?

An example of a potential human constraint could be the interaction with the smart light bulb. Before the advent of LED-lighting a smart light bulb had not been foreseen, because integrating electronics in an incandescent light bulb is not part of the production process and does not change the abilities of the lamp. LED-lighting technology allows a low energy bulb, which can change colour and brightness. Using the ability to change colours, or the brightness, changes required special lamps that support this functionality, because standard lamps only have an on/off switch or a dimmer. An LED-light is different from an incandescent light bulb in that it is produced as a piece of electronics and it needs circuitry to function. Integration of a communication chip is necessary to allow the lamp to communicate with the bulb, so that brightness and colour can change. By using a wireless communication chip, a special lamp is not needed and the bulb can function in any lamp fixture, instantly increasing the potential market share for the light bulb.

From a technical perspective adding M2M to a lamp is not a large step. Such a bulb, however, does work differently when placed in a lamp. One question is how to securely establish that a particular light switch is for a particular group of lights. A further question is how to make sure that the bulbs cannot be easily hacked, either via the Internet or some remote control. Many of these questions did not exist before with standard light bulbs or had not been thought about, because the rules around the use of light bulbs were implicit or dictated by the physical environment.

One important question with the smart light bulb, or any smart technology, is whether it needs an Internet connection to function, or whether it could work without a connection to the Internet. In the introduction of smart light bulbs it is foreseen that many people will first introduce them in the same way as they have for current remote controls for lamps. Consumers are expected to be able to buy a pack with three bulbs and a remote control in a supermarket or DIY store. These bulbs and the remote will self organize. More units can be added later. A smart phone could act as a control or gateway, provided it had the right wireless technology on board. Full Internet control is only possible after a gateway is used. The gateway could be integrated into a set-top box, television or modem. As the technology is self-organizing it can use multiple gateways and every smart bulb can relay messages for other bulbs or devices in the home and thus the network can develop organically in and around the house.

Smart light bulbs may change the way people interact with light in the home. The integration of a few light sensors and a sensor that measures whether someone is in the room, and where that person is in a room, could allow for automatic changes in the lighting conditions. If the system measures that the natural light levels are below a certain level, the lights are turned on or up and similarly turned down when the light is turned off. Integration of movement sensor would make the concept of turning a light off when leaving a room old fashioned. Though LED-lighting is more energy efficient than incandescent light bulbs, some experts warn that some of the savings will be traded in for more convenience by using more lights.

The smart light bulb is expected to become, by some in the industry, a building block the smart home is built on. By using a few more light bulbs the network is extended from one end of the home to the other, without the need for wiring. This makes it easier to integrate other sensors, like home alarms, locks, thermostats, lights and so forth.

Source : OECD, presentations by NXP at IETF Paris

Smarter networks promise to allow more insight into the use made of services and devices. Big data analysis of the data may allow for A/B tests that aim to test how behaviour of people is changing. These A/B tests can divide populations into various tests and see how they change their behaviour when parametres are changed. Service providers that offer consumers data analysis to lower their energy bills could test various incentives, (*i.e.* by changing the warnings on energy use displays to see which generate the best responses). An open question is whether end-users are willing to accept being tested upon in order to determine the most optimal management strategy.

Privacy and security are one of the most cited concerns of a smarter world. The introduction of smart metres in the Netherlands has changed from mandatory to voluntary after debates in parliament on the privacy implications of the 15 minute samples of energy usage. Such samples could, for example, give an insight into whether the resident was at home or not and even an indication of what they were doing. Such concerns are not easily alleviated without consultation and appropriate safeguards that empower consumers. Smart applications can potentially give insight into many details of peoples lives and security breaches are an ever-present risk. Devices such as EEG, ECG, electricity metres and a black box in an automobile all potentially provide personal information to third parties as well as offering better services for consumers.

Lifecycle challenges

Every product has a lifecycle, from a few days for fresh vegetables to a few years for durable consumer goods to decades for some industrial products. Until recently these lifecycles were independent of each other. The lifecycle of the slowest product can influence the possibilities of other applications. This is important for policy makers as they are often involved with sectors that have some of the smart applications that work with the slowest lifecycles. A choice now can have a long-term influence (Table 3).

Table 3. Lifecycles of smart applications

Application	Lifecycle
Energy networks	15-50 years
Roads	30 years (10 years maintenance)
Vehicles	15 years
Home appliances	10 years
Lighting	2 500 hours for incandescent light bulbs and 25 000 for LED. (2 years to 20 years)
Consumer electronics	2-10 years
Telecom networks	10-50 years

Source: OECD

The choices made today, around smart networks, will influence policies for decades to come. A requirement for automobiles to carry a particular technology means that in 15 years the first vehicles with that technology will reach the end of their economic life and a particular model will be available for five to 10 years. When two lifecycles come together the impact may be even larger. For example, charging infrastructure for electric cars are under normal circumstances part of an electricity network that is designed for a 30 year lifecycle. Effectively the standard chosen today will need to be active for up to 45 years. That is the lifetime of two to three cars and four to six automobile models. To put it differently, a choice now influences automobiles design for the next 30 years. It is not easy to imagine technology choices of 1980 influencing automobile design today.

An associated challenge is that upgrading a nation's energy network to become smart can take a significant amount of time. If normal maintenance and upgrade schedules are followed, it could take between 10-30 years before every unit has been updated. Many systems face this limitation, as companies are less willing to upgrade what has been installed only a year ago. What is more, technology choices today may no longer be rational in a few years. For example, some towns are researching whether to embed sensors in roads under parking spaces. This technology could be used to inform motorists of available spaces, to their obvious benefit, as well as potentially increasing the usage and income for their providers. However, there may be alternative ways to achieve the same goal. A modern automobile can contain up to seven cameras used for functions such as assisting with parking. These cameras and sensors can measure the distance between two parked vehicles, even when driving past these vehicles at normal speeds. By combining this data with GPS information, and city information on the location of parking spaces, it may be possible to create a map of where parking spaces are available, without the need for the expense of embedded sensors in roads.

Telecommunication networks have a lifespan that is often undetermined when they are implemented. Analogue mobile networks were phased out 10-15 years after introduction. Mobile 2G using GSM and CMDA is expected to stay available for decades to come because of its abundant use in M2M. The future of 3G is uncertain, its coverage still limited and the introduction of LTE quickly superseding it. In fixed networks the lifespan of networks can be much shorter. There is little use for the Data Over Cable Service Interface Specification first standard (DOCSIS 1) modem once the network has switched to Docsis 3. For anyone introducing a smart system based on mobile networks this uncertainty is difficult to manage. In some cases it is difficult to make a modular system that allows easy replacement of the radio components. These choices influence the products and policies for years to come. For example, choices taken in the past lead to demands on authorities to extend the duration of spectrum licenses because smart systems are still using the spectrum granted under these licenses.

Lifecycle challenges make prognosis of the implication of smart networks outside the home more challenging than those in the home. In many circumstances there is no green-field situation where the latest technologies can easily be integrated. In practice smart systems will have to be integrated into existing systems that may not have been designed with smart technologies and applications in mind and upgrading them may not be easy. At the same time, some systems are smart, but they only provide the functionality that was necessary a decade before, which means that new functionality may have to wait a few years before it is added. This adds to the complexity of introducing smart networks and systems on a large scale and it means improvements will be gradual.

Business challenges

Smarter networks open up many possibilities to develop new products and services. Businesses are looking at these innovations to reposition their products. While the term smart is affixed to more and more products, businesses also face several challenges while introducing smart technologies. Some of the areas that involve challenges include the following:

- The future implications of communication regulation (*e.g.* level of competition and the further need for liberalisation in telecommunication markets)
- Complexity
- Return on investment
- Horizontal and vertical separation of markets

A key issue noted in *"Machine to Machine communication"* are the challenges regarding coverage, availability and costs of mobile networks. Some providers of M2M services, from health to transport, would like greater flexibility and control around the options they have in meeting their requirements to provide services to their business and consumer users. One way to deal with this would be to increase competition in areas where it is insufficient (*e.g.* to support the use of M2M across borders). A second, and related way, would be to further liberalise markets so that smart network and service providers could make their own choices in terms of communication technologies and services. They could self-provision or use intermediaries that did this for them alongside traditional providers of these services.

Even though mobile networks are the best fitting network for many geographically mobile and dispersed applications, in reality there are still many challenges to overcome. Coverage is a major issue for eHealth applications. Users of portable ECG devices mention the difficulties that are caused by going out of coverage. For example, the device may give off warnings, which create anxiety for the users, but also the company providing the service will have to be aware of what is going on and adequately respond. Not being able to guarantee coverage and uptime causes significant costs for providers of these services.

Adding to the difficulty of having coverage is the challenges for international coverage. International mobile roaming is expensive for data applications. With some of the data roaming prices seen between OECD countries the costs of eHealth applications could go up to USD 1 000 for 50 MB of data roaming. Whether or not insurance and service providers are willing to cover such costs is unknown. These prices are far removed from the prices that would be expected in a competitive market. The largest operator of mobile network infrastructure in the world has suggested that mobile data costs on 3G networks are between USD 0.12 and USD 1.2 per gigabyte. [28] Rates closer to these would allow different business models to be more successful than today. However, a lack of competition makes this currently difficult to achieve.

The cause for the lack of coverage and competition is that large users of M2M communication on mobile networks cannot switch mobile operators when crossing borders, when out of range or when they want to change contracts. One potential solution to this problem would be to allow large scale M2M users to use their own mobile numbering, which Ericsson calls Private Virtual Network Operators.[29] In this role they could contract networks as needed. For in-home connectivity they may contract with an ISP to use the Wi-Fi that is part of the broadband subscription. For national or international connectivity it would be the large scale deployer of devices that chooses which networks to use and not, as is currently the case, the telecommunications company. Unfortunately, most telecommunication regulation does not allow private, non-telecommunication operators to use their own mobile numbering. Liberalisation of the telecommunications market is necessary to give large scale users access to telephone numbers and SIM-cards that are required for this to occur. Doing so could potentially deliver very significant savings for large scale users with wider benefits for economic and social development. If countries do not take the initiative in this area it will be challenging for them to compete in global markets in areas such as trade and travel.[30]

Another challenge smarter networks pose is complexity. This is because of the number of parties involved. Smart transport requires the co-operation of cities, villages, regional and national governments to integrate data on roads, traffic lights, road works and the co-operation of private enterprise such as automobile manufactures, public transport organisations and logistics companies. And innovation is constantly adding new functionality, new demands and new solutions. What, for example, if parking facilities charged a dynamic price, based on how busy it is and the stated intent of drivers to park at a specific location? Such systems do not exist at the moment, but might become possible, which would mean another level of dynamic routing, so that people can decide to park outside the city. Fortunately in many cases the complexity can be increased gradually in a system, though there may be limitations imposed by lifecycles.

For all stakeholders a key question is, as ever, who benefits from the smart systems and ensuring that tools such as a competitive and responsive market equitably distribute these benefits and reward initiative and innovation. At the Mobile World Congress 2012, a number of utilities including British Gas, stated that a significant part of its income in the future would depend on the sale of information about energy consumption.[31] This implies that some utilities believe the data generated by their metres are for them to "monetize". This may well be the case but consumers may wish to share these data with other service providers. They may also wish to "crowd source" the data for their own personal benefit or for societal benefits. At the same time, some of the utilities said, at Mobile World Congress 2012, that in discussion with communication providers they were offered equal partnerships. They also said that a 50% share of the income generated from these data was not what they envisaged and would make their business plans uneconomic.

If the data is accessible to outside parties and the access to data is not a limit to market entry, the dynamics of how these services develop will evolve depending on the amount of competition, including for communication services, that exist in the future. Business and consumers would undoubtedly like the same portability in smart networks and services that they have for other communications services. At the same time, a challenge for a commercial enterprise could be that installing a smart metre is a significant investment, which could be paid back by use of the data. If there is, however, a significant chance there is no corresponding revenue stream, or that the user may change such as with the sale of a house, then why would service providers invest in new capabilities?

Another way of looking at the business challenges is to ask how the horizontal and vertical separation of the market will evolve. In a smart home it would be possible to manage the house as an integrated whole. This is a horizontal separation. A vertical separation happens when every smart system comes with its own management interface controlled by a different company -- a different one for lighting, media and for smart metering. Some companies notably energy companies and telecommunication companies see themselves moving up higher in the stack, not just delivering connectivity, bits and energy, but actively managing devices in the home. AT&T Digital Life is an example. Other telecommunications companies have invested in smart metering joint ventures like Vodafone with British Gas.[32] In developing cloud services, for smart metering, telecommunication operators, IT companies, metering companies and energy grid providers are all potential competitors in this market.

When companies use Private Virtual Network Operators, the effect is that an automobile company or energy company moves down in the vertical to gain more benefits and control, potentially reducing the role of a telecommunication operator to a "pipe provider". It is difficult to predict what the distribution of market power and influence will be in smart networks and services. In fact, integration is necessary to gain many benefits, so a certain amount of openness is needed. This openness will stimulate competition, because it can allow alternative players to enter the market. It might well be that new global players emerge that manage smart systems for millions of people and businesses.

The forgoing means that discussions about next generation networks and, in particular, the market structures that surround them will take on new dimensions (*e.g.* the implications of functional and structural separation as well as end-to-end competition). The openness and competitiveness of these networks will become more critical and the directions chosen have implications for service providers in areas, beyond traditional communication providers, in terms of the types of networks that seek to interconnect their "smart networks and services".

Regulatory challenges

Achieving the benefits of smart networks and services may prove to be demanding on regulators. Much of the promise of smart networks and services will depend on the efficiency of communication markets to deliver the requirements increasingly demanded from other sectors of economies and societies. Moreover the demands will be closely linked to objectives of policy makers ranging from dealing with the challenges of aging societies to the environment, innovation and economic competitiveness.

Health, transport, energy and communications are predicted to be transformed by smarter networks. This will require policies that embed the use of M2M, Big data and cloud computing into these areas. It will also require the integration of the public sector's use of smarter networks with that of citizens and companies. Public policy and regulation will be influenced, by way of examples, in some of the following areas:

- Effectiveness of government policy.
- Privacy and security.
- Markets and competition.
- Public sector information.

Data from smart systems are influencing the effectiveness of public policy in areas such as transport. The implications of road works, the policies to mitigate the effects of the work and the benefits of the completed work are evaluated using data provided by in-vehicle GPS. This type of use of smart systems is valued by all stakeholders. The use of the same data to better plan the location of speed radars, however, may not be welcome by all. Better health care data through smart applications may detect illnesses earlier and enable early treatment at a lower cost. It may also have the opposite effect with more false positives or more treatments because something was detected. With the advent of more data or improved analytics, governments will be asked to assess and substantiate the costs and benefits of particular policies.

Privacy and security will be a topic in any smart system. In a few years time, it will be difficult to spend a day without leaving a digital record around smart networks. The location of mobile phones, vehicles, public transport is all traced. Homes will have records of energy use. Televisions store viewing preferences and record shows watched and not watched. Where in the past it might have been possible to not do something and therefore not leave a record, in the near future, not carrying a phone, not turning on the heating or cooling, not watching television is represented in data too. Public policies could potentially make this even more of a concern without adequate safeguards and greater appreciation of the benefits. Debates surrounding the privacy implications of smart metering are just one example. Some countries are thinking of using GPS based road pricing, effectively creating a database of every movement of every vehicle.

The security of smart systems can be a major concern for all stakeholders. Early examples of smart systems, like the SCADA systems used to operate energy networks and factories have in recent years come under scrutiny for security errors. Well known manufacturers and operators of SCADA systems have sometimes shown a disregard for security standards and policies (Figure 3). Their systems contained exploitable backdoors, web access and undocumented "features". Smarter networks scale up similar applications to each home. It will allow the control of devices and services on top of collection of data. The implications of a security breach can be much more severe than just a data breach. What happens when a hacker gains control over millions of devices for example home lighting or cars? What would happen to a nation's energy grid if a hacker can turn up the air conditioning or heating in 10 0000 homes? Privacy and Security of smart applications are topics that need further consideration by all stakeholders.

Figure 3. Vulnerabilities in some SCADA systems in 2012

Red X: easily exploitable. Yellow !: difficult to exploit

	A·B	Schneider Electric	GE	SEL	Koyo
Firmware	!	X	!	!	!
Ladder Logic	!	!	X	!	X
Backdoors	!	X	X	✓	✓
Fuzzing	X	X	X	!	!
Web	!	X	N/A	N/A	X
Basic Config	!	!	X	!	!
Exhaustion	✓	✓	X	✓	✓
Undoc Features	!	X	X	!	!

Source: Wired, www.wired.com/threatlevel/2012/01/*scada-exploits/*

Smarter networks may have significant effects on competition at various levels in the network. Competition in telecommunication networks will likely be effected by the advent of new "million device companies", who could be insurance companies, car manufacturers or energy companies. As noted, the market at this moment does not deliver national and international roaming in a way that fits the needs of these companies. Policy makers and regulators need to consider opening the use of numbering to these firms. It could allow them to efficiently change their M2M communication providers. This is for much the same reason that regulators apply number portability to ensure lower barriers for consumers to change providers in fixed and mobile telecommunication services. It could have the added benefit of increasing competition for international roaming but, in any case, allow firms to more efficiently manage cross border offerings and in the creation of global products and services. This could bring significant benefits for economies including the ability of firms to create new products and services as well as potential financial gains for the firms involved and their customers. In Europe organisations such as the European Conference of Postal and Telecommunications Administrations are looking into this challenge and other public authorities and regulators will soon turn their attention to do so if they have not already done so. See the green paper by the CEPT working group on Naming and Numbering.[33]

Competition in access to data is a challenge policy makers and regulators will face more and more in the future. The requirements of all stakeholders will encourage the further development of certain smart systems and networks across economies and societies. The policies surrounding access to those data will be of great influence on the value of the systems to these economies and societies. In some cases the systems will be controlled by public sector entities, in others they will be controlled by private sector entities that have to conform with public requirements. Smart metering is an example of the latter case with some governments requiring their introduction. Consumer access to current and historical data can be an important requirement for these systems. Some governments have required access to values in the metre so that in-home energy monitors can access the data. Such data then seems to be under the control of the user who can choose to forward it to third parties. This could allow innovation in services.

There will also be discussion over whether users can take their data from one provider of smart services to another provider of smart services. The history of data can be of great value and not being able to use the historical data can be considered a switching barrier. Some webservices have explicitly stated that consumers can export their data, (*e.g.* e-mail to other services). However, there are also indications that data for building control is managed in proprietary formats on proprietary systems and it is difficult to switch management or to have interoperable services. With the market moving more and more towards consumers, the size of these issues will increase, whereas the knowledge of the individual user may decrease. It could be imagined that the certified data from one Pay As You Drive insurance could be of great value when moving to another insurance as this would allow the insurance company to better validate the risk. And consequently it may be in the interest of an insurance company not to provide the data as it would only serve to inform a competitor in calculating a price.

Governments collect large data sets through smart and non-smart means. These datasets are not only of interest to the government, but also to society at large. The OECD Recommendation of the Council for enhanced access and more effective use of public sector information [C(2008)36], recommends that governments implement principles like openness, access and transparent conditions for re-use, where possible no cost or marginal cost for access and access that fosters competition. When implementing smarter systems governments should evaluate the possibilities of access to this data. Many countries have started to create centrally accessible lists of data assets on websites like: data.gov, *data.gov.uk* and *data.gouv.fr.*

NOTES

1 An often quoted statistic is that more people own a mobile phone than own a toothbrush. http://60secondmarketer.com/blog/2011/10/18/more-mobile-phones-than-toothbrushes/ It is likely true. Phone sales were estimated at 1.7 billion for the year 2011. www.gartner.com/it/page.jsp?id=1924314, of which 31% were smartphones.

2 This does not mean that the storage and processing capacity needs of banks and tax services have not increased. New tasks and new analysis methods have developed. Some tax services are now using in house developed search engines to analyse the web for unreported sources of income. Banks are now active in high speed trading where the rapid analysis of data sources such aslike news feeds and Twitter may provide an edge in trading.

3 www.hani.co.kr/arti/economy/economy_general/434144.html (in Korean)

4 www.segye.com/Articles/NEWS/ECONOMY/Article.asp?aid=20110208004996&subctg1=&subctg2 (in Korean)

5 Some definitions of smart grids can be found in Smart Sensor Networks:Technologies and Applications for Green Growth, December 2009 DSTI/ICCP/IE(2009)16/CHAP6

6 Automatic Meter Reading is the term for the situation where the meter is read from a distance.

7 The Dutch standard NTA8130 requires sampling once ever 10 seconds. In the United Kingdom a 5 second sampling interval is required, www.decc.gov.uk/assets/decc/Consultations/smart-meter-imp-prospectus/1478-design-requirements.pdf a do-it-yourself smart meter the DIY Kyoto Watson uses samples of 3 second-20 seconds. Other devices can sample every second ehttp://ase.org/resources/realizing-energy-efficiency-potential-smart-grid.

8 www.wired.com/reviews/2012/08/nike-plus-basketball/

9 Scheuer, Mark, *Continuous EEG Monitoring in the Intensive Care Unit,* Epilepsia, 43(Suppl. 3):114–127, 200, Blackwell Publishing, Inc notes that a day of continuous EEG sampling at 32 channels and 256 samples/s will generate up to 1.5 gigabytes of data per day. This translates to 45 gigabytes per month, or 150 kbit/s. Reducing the number of channels is done to make EEG's more portable, so in actual use the rates may be lower.

10 Given a sampling frequency of once every 1-5 seconds and depending on the number of data points collected the amount of data will not be large, however there will be some encryption and digital signatures of the data which may add some extra data. If the data is used for energy trading the system may send only 1KB of data every 15 minutes, which amounts to roughly 1 bit/s.

11 Dr. Kim Kyllesbech Larsen, Deutsche Telekom AG, *The ultra-efficient network factory,* Broadband MEA, 26 March 2012, Dubai, www.slideshare.net/KimKyllesbechLarsen/ultraefficient-network-factory-network-sharing-and-other-means-to-leapfrog-operator-efficiencies

12 Kvalbein, Amund, *Measuring Mobile Broadband in Norway,* Simula Research Laboratory, RIPE 64, 19 April 2012, https://ripe64.ripe.net/presentations/172-Mobile_Broadband_Measurements.pdf

13 www.telecompaper.com/news/vodafone-nl-services-still-disrupted-after-fire, uk.support.tomtom.com/app/answers/detail/a_id/16072/~/live-services-outage and webwereld.nl/nieuws/110113/vodafone-brand-nekt-tomtom-live-in-heel-europa.html

14 See also Dumbill (2012), for which "big data" is "data that exceeds the processing capacity of conventional database systems. The data is too big, moves too fast, or doesn't fit the strictures of your database architectures. To gain value from this data, you must choose an alternative way to process it". radar.oreilly.com/2010/09/the-smaq-stack-for-big-data.html.

15 mike2.openmethodology.org/wiki/Big_Data_Definition An exabyte is 1 billion gigabytes. One Exabyte is equivalent to 1 day global internet traffic in 2012 according to Cisco. The Square Kilometer Array telescope will generate 1 exabyte of measurements every day.

16 www.wired.com/epicenter/2012/04/ff_abtesting/

17 online.wsj.com/article/SB10001424052970204468004577169073508073892.html Health care is the next frontier for big data.

18 National Institute of Standards and Technology (2009), *The NIST Definition of Cloud Computing,* csrc.nist.gov/groups/SNS/cloud-computing/cloud-def-v15.doc.

19 OECD (2011), Cloud computing, DSTI/ICCP(2011)19

20 Vivek Kundra (2011), *Federal cloud computing strategy,* US Chief Information Officers Council, www.cio.gov/documents/federal-cloud-computing-strategy.pdf

21 Forrester (2011), Sizing the cloud, http://blogs.forrester.com/stefan_ried/11-04-21-sizing_the_cloud

22 www.greentechmedia.com/research/report/the-emergence-of-meter-data-management-mdm

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26 www.ibm.com/smarterplanet/us/en/smarter_cities/overview/index.html

27 www.medhelp.org/posts/Heart-Rhythm/Why-does-cardionet-event-monitor-record-when-nothing-is-wrong/show/1393291 and www.medhelp.org/posts/Heart-Rhythm/30--day-Cardionet-Monitor-going-off-by-itself/show/1089961

28 Blennerud, Greger, *Mobile broadband – bursting the myth of the scissor effect,* Ericsson Business Review, number 2 , 2010, www.ericsson.com/ericsson/corpinfo/publications/ericsson_business_review/pdf/210/210_strategy_mobile_broadband.pdf

29 This term was invented by Ericsson. A presentation of this concept won the Network and Communications Award 2012 at the European Smart Metering Awards. www.smartmeteringuk2012.com/2012_awards.html

30 A more in depth discussion can be found in the *"Machine to Machine communication"*.

31 Alex Jones of British Gas speaking at Mobile World Congress 2012, Barcelona.

32 www.mobiletoday.co.uk/News/14409/Operators_slug_it_out_for_%C2%A34.5bn_Government_contract.aspx

33 See the green paper by the CEPT working group on Naming and Numbering www.cept.org/ecc/groups/ecc/wg-nan/page/green-paper-on-long-term-evolution-in-numbering,-naming-and-addressing-2012-2022