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Excerpt
More Information

1 The world of machine communications

1.1 What defines a machine?

Wireless communications are widespread, but tend to be used predominantly by people. Mobile phones allow people to talk or send emails, Wi-Fi systems allow people to surf the Internet from a laptop and Bluetooth links allow people to use cordless headsets. There is an entirely different class of applications for devices that do not directly have users and whose communications are not instigated by people. A good example of this is a smart electricity meter. It might send meter readings to a database every hour. It has no direct linkage with any person – although indirectly it makes their life somewhat better by enabling smart grids and automating the meter-reading process.

There are so many different applications and machines that a clear definition of one is not possible. Broadly, these are devices where transmissions occur due to the function of the machine rather than any person. They send information not to another person but typically to a database within the network from where it can be processed by other machines. Of course, sooner or later someone benefits from the service provided, but typically not from the radio transmission itself. Applications include automotive engine management updates, healthcare monitoring, smart city sensors and actuators, smart grids, asset tracking, industrial automation, traffic control and much more.

This type of communications is often referred to as machine-to-machine (M2M). This can be confusing as it might be taken to imply one remote device talking to another remote device (e.g. one smart meter talking to another smart meter). In practice, the communications are typically machine to network, or machine to control node. In this book the terminology ‘machine communications’ or ‘machine network’ is used rather than M2M.

1.2 Range: short or long?

Machine communications fall into two key types as regards the use of wireless communications – short or long range. Short-range applications are typically those that occur within a building such as a home or office. This might include wireless control of a building's lighting from a central controller within the building. The range of such applications is typically around 100 m, although this can be extended using mesh-architectures or repeaters within the building. This type of solution is sometimes called a home area network (HAN). There is a range of technologies already available for HANs including Zigbee, Bluetooth, Wi-Fi and some proprietary solutions.

Long-range applications are those that need to communicate wherever they are and sometimes as they move around. Automotive is a good example of such an application. They often require near-ubiquitous coverage of a country or even globally. As a result, they require the deployment of a cellular-like network and many similar arrangements as for cellular communications including billing and roaming.

This begs the question as to why not use cellular networks for long-range machine communications. Cellular networks are already used for some machine applications such as monitoring vending machines and within some cars. They bring the benefit of widespread coverage, good availability and widely available components. But cellular is far from ideal for machine communications. Issues include:

- Coverage is not perfect, especially within buildings.
- Terminals cannot run off batteries for extended periods – more than a week is problematic.
- Cellular networks are not well adapted to short messages and so are very inefficient for most machine applications.
- Treating each terminal as a subscriber adds costs including SIM cards, expanded billing systems and more.
- Cellular networks are moving towards higher data rates and away from the functionality required for machine communications.

These issues mean that while cellular has addressed a small, high-value segment of the machine market it cannot be used for the much broader marketplace. Indeed, if it were well-suited to this it would have been adopted years ago.

Determining whether an application is short or long range is not always simple. For example, a smart meter in a home could communicate via the HAN and then the home broadband connection into the network. However, this is complex to set up and leaves the energy supply companies vulnerable to the home user changing their HAN, or even just the password on their Wi-Fi router, and disabling the smart meter. For that reason, long-range communications are preferred for many devices even within the home.

Weightless is a standard for long-range machine communications. Hence, it is expected that Weightless networks will be deployed by network operators and a service provided to companies interested in machine applications. This will be explained in more detail in the coming chapters.

1.3 Possible applications

One of the key design aims of Weightless is to be application-agnostic – that is to provide a platform on which as many machine applications as possible can be based. One shared platform across multiple applications is clearly much more economic than separate networks for each major application. Hence, Weightless has not been designed with any one specific application in mind. It seems likely that once the networks are deployed many hundreds or thousands of applications will emerge – just as 'apps' are developed for Apps Stores.

However, it is helpful to have possible applications in mind so that the requirements for these can be understood and the technology designed to meet as many of these requirements as possible. At the time of writing, key applications include:

- *Smart grid*. The ability to interact remotely with electricity, gas and water meters. Initially this might be to regularly collect meter readings but it could expand to remote demand management and monitoring the quality of the supply. For gas and water meters a key requirement is to be able to operate for a decade or more from a battery. For all meters excellent coverage deep inside buildings is required.

- *Automotive*. There are myriad roles for machine communications in cars including engine management data and upgrades, safety-related information and emergency calling.
- *Transport*. Outside of cars, machine communications in public transport can help with time-of-arrival information, tracking of assets and more.
- *Healthcare*. There is an immediate need to be able to remotely monitor individuals with particular healthcare needs, such as some diabetics and this is an area where many more monitoring and location functions could be envisaged.
- *Asset tracking*. Monitoring of goods and parcels as they move around the world.
- *Financial*. Replacement of cellular transmission in credit card terminals and similar.
- *Smart cities*. A very wide range of applications sourcing data from sensors and processing this to provide valuable information. Sensors might include temperature, parking space availability, traffic level or even whether garbage bins need emptying. Information might include pre-planning routes for snow ploughs or salting vehicles, provision of guidance to the nearest parking space for drivers with connected sat-nav systems and so on.

Experience suggests that many more applications will rapidly emerge once networks are available. Some of these applications are considered in more detail in Chapter 10.

1.4 Key requirements

While each application has slightly different requirements, a network that aims to support all of them needs to have the following features or characteristics:

- *Support of a large number of terminals*. It seems quite plausible that there could be 10 connected devices per person. Some suggest that this may rise towards 100 devices per person. At 10 per person this implies approximately 10 times as many devices as mobile phones, which themselves are typically distributed across 2–4 national networks. A typical cell in a Weightless network might have between 100 000 and 1 million devices within it and a national network could easily cover 1 billion devices. Networks need to be scaled to enable this.
- *Long battery life*. A subset of applications is unpowered and there will often not be a user nearby to recharge batteries. Ten-year lifetimes from one battery are needed in many cases.
- *Mobility*. A subset of applications has moving terminals which need to be supported as they move, potentially across national borders.
- *Low-cost equipment*. For most terminals the value of the sensor will be very low – often in the region of $10. Hence, the wireless chipset to be integrated into the terminal needs to be much less than this. The lower the price the more applications that can be enabled, costs of $2 per chip or less would appear to be necessary.
- *Low cost service*. Equally, the owners of terminals will typically only be prepared to pay a few $ a year for a network subscription. Hence, the network costs must be low and the marginal cost of each terminal very low.
- *Global availability*. Some applications will require global roaming. Others, like automotive, will require that one solution can be fitted into all vehicles regardless of their country of destination.
- *Ubiquity*. Excellent coverage, including within buildings, is needed.
- *Guaranteed delivery*. Some applications require certainty that messages have been delivered. This may also require strong authentication and encryption.
- *Broadcast messages*. This may be sending the same data to multiple terminals – e.g. a software update. Or it may be sending a common message to terminals – e.g. to reduce energy requirements temporarily.

The technology will need to work with the following characteristics of terminals and applications:

- *Small bursts of data*. Most machines send data packets of the order of 50 bytes. Networks must be able to transmit these with minimal overheads if network traffic levels are not to become excessive.
- *Sub-optimal terminals*. In many cases terminals will be small and low cost and will have poor-quality antenna and limited power supplies. Antenna alignment/polarisation cannot be assumed.
- *Stimulated transmission*. Some events, e.g. a power outage, might cause a large number of terminals to simultaneously send alert messages. The network needs to be able to accommodate and control the resultant peak in loading.

However, there are some requirements which are needed for personal communications but less so for machine communications. These include:

- *High data rates*. Machines rarely need data rates in excess of a few kbits/s.
- *Low delay*. Most applications can tolerate a few seconds of delay on message transmission.
- *Seamless handover*. Most applications do not need seamless handover and can tolerate a few seconds break in communication while contact is re-established with the new cell.

The impact that all of these has on system design will be explained in subsequent chapters. Weightless is designed to meet all of these criteria and to benefit from those areas where requirements can be relaxed. Note that Weightless is not intended as a viable alternative for personal communications – it is assumed that cellular systems address this market adequately.

1.5 Market size

The likely size of the machine market is important information for those planning on investing in delivering services. However, at this embryonic stage, any predictions are more guesswork than science. History has shown that we often over-predict the short-term impact and under-predict the longer term. This was certainly the case for cellular communications.

Our approach has been to estimate the likely number of devices per person, counting those people that already have a mobile phone of which there are around 5 billion worldwide. It might be envisaged that the average person could have:

- Around three smart meters. Each building will have electricity, gas and water metering. There are multiple inhabitants per building but equally business premises with no inhabitants.
- Around one car.
- Around 0.5 healthcare related sensors – some people will have none, others multiple.
- Around one smart city sensor per person assuming a range of sensors for temperature, parking spaces, etc.
- Around two asset tracking terminals per person.
- Many others in the home, on the person and in the wider area.

This suggests that a value of 10 terminals per person is perfectly plausible and that if there are applications not yet foreseen this could easily rise much higher. For the sake of being conservative, the number 10 is taken for the remainder of this analysis. These terminals could be rolled out in a few years, but some industries such as healthcare and automotive are historically slow adopters of new technologies so a 10 year deployment horizon may be appropriate.

For terminals this suggests an annual market of the order 5 billion chips. With target prices of around $2 per chip this is a $10 billion market. Many new terminals may be developed and deployed as well – we make no attempt to determine the size of such a downstream market.

In terms of networks, a global deployment of at least one network per country would be needed over the next five years or so. This might equate to around 200 networks each with an average of around 5000 base stations, leading to a total market for 1 million base stations, or 200 000 per year. If multiple competing networks were deployed this could be two to three times greater. If base stations cost $5000 each then the annual market would be around $1 billion.

Annual service revenue per terminal is very uncertain and likely to vary dramatically depending on the traffic volumes and quality-of-service requirements. If the average annual fee were \$10 per device then by the time market maturity is achieved around a decade from now the annual service revenue would be of the order \$500 billion. It may be that over time annual fees decrease but even if they fall to \$1 per device per year this is still a \$50 billion/year global market.

Many analyst reports are likely to be written that will forecast in a much more scientific and detailed manner the likely market size – this section is more for illustration. It clearly shows this has the potential to be an enormous market, perhaps one of the largest growth areas in the communications sector in the coming decade.

1.6 How machine communications could change our world

Not everything is about money and it is worth thinking about what a world with widespread machine communications would be like to live in. Cellular communications have dramatically changed the way we live our lives both at work and in leisure and it seems quite possible that a successful widespread deployment of machine communications could make an equally dramatic change. Broadly, it might be expected to 'make everything work better'.

Machine communications could be the key enabling factor behind smart grids. This might enable us to reduce power requirements, have fewer stand-by power stations and charge electric vehicles without causing overload problems to the supply network. It could be at the core of 'green' energy solutions that enable us to dramatically reduce our carbon footprint.

Smart cities could make the lives of commuters and residents much better. Transport systems could become more efficient, street lights could be repaired when needed, garbage bins emptied as required, congestion avoidance and routing to an empty car parking space be provided and so on. Costs could be reduced due to saving unnecessary activities or automating others and the impact of reduced congestion and greater efficiency would also extend to environmental benefits.

Healthcare monitoring could save lives and enable many to live at home rather than stay in hospital. As well as increasing quality of life this could also reduce the burden on healthcare systems.

These are just some examples – with many other applications envisaged much greater benefits could be expected.

A very important observation is that machine communications could make a difference to what are currently seen as the major challenges facing us today – an aging population and global warming. Indeed, without machine communications it is hard to see how these can be addressed effectively. It may not be an overstatement that Weightless provides the mechanisms to save the planet!

2 The need for a new standard

2.1 Machine communications does not yet have the necessary standard

The observation, noted in the last chapter, that there was massive potential in machine communications is not a new one. Over the last few decades many have noted that the installation of a wireless connection into myriad devices would bring a range of benefits. However, the market for machine communications to-date has been weak. There are some cars with embedded cellular modems and some relatively high-value items such as vending machines are equipped with cellular packet-data modems. But the market today is only a tiny fraction of the size it has long been predicted to grow to. This is predominantly due to the lack of a ubiquitous wireless standard that meets the needs of the vast majority of the machine market as set out in Chapter 1. There is no current wireless system that comes close to meeting all of these requirements.

Cellular technologies do provide sufficiently good coverage for some applications but the hardware costs can be $20 or more depending on the generation of cellular used and the subscription costs are often closer to $10 per month than $10 per year. Battery life cannot be extended much beyond a few months. Cellular networks are often ill-suited to the short message sizes in machine communications resulting in massive overheads associated with signalling in order to move terminals from passive to active states, report on status and more. So while cellular can capture a small percentage of the market which can tolerate the high costs and where devices have external power, it will not be able to meet the requirements of the 50 billion device market. Indeed, if it could, it would have done so already and there would be no further debate about the need for new standards.