ENABLING WIRELESS IoT NETWORKS

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Lifting the barriers to eco-system development.

Why are low power wide area wireless networks important for IoT to reach its full potential? And what characteristics are required of a wide area wireless IoT network? Which are the emerging technologies and standards and what is the route to removing the technical barrier enabling the eco-system to develop?

Telecommunications have enabled a world where people are connected as never before. A key to this success has been industry co-ordination, co-operation and standardisation. These processes have been the bedrock which has enabled services to develop from the earliest days through to today's wireless and mobile broadband. The next big challenge is to ensure that a thriving Internet of Things (IoT) industry is enabled to support the future needs of the digital economy.

The current needs for IoT services has resulted in multiple initiatives to develop Low Power Wide Area (LPWA) wireless network technologies. A common industry approach has not yet emerged. The current environment represents a technology barrier which is preventing the eco-system of devices and services to develop. The lack of a common wireless technology which is sufficiently widely adopted to enable sensor manufactures, service developers and communication providers to invest with confidence is a major road block.

From Machine-to-Machine to IoT

The capability to allow billions of everyday objects to communicate with each other over the Internet has enormous potential to change lives, and is driven by increases in technical capability, such as processing power, storage capacity and internet connection speeds, coupled with decreases in costs to provide these services. This is creating an environment where it is economically feasible to connect billions of devices to the Internet and create the Internet of Things.

The key difference between the IoT and current Machine-to-Machine (M2M) services is that whereas the latter are mostly vertically integrated solutions, with sensors connected over a specific network to provide data for a single application, the ambition for IoT is that the data can be made available for sharing by a range of applications, subject to certain security and access control issues. Also, there is an essential need for standardised network protocols and interfaces to enable sensor manufacturers and service developers to invest and scale delivery capability.

At a high level, it is possible to split the emerging market into two directions. Firstly, those use cases, such as connected cars and autonomous vehicles that require high bandwidth, secure, low latency networks with a high quality of service. Secondly, there are another set of use cases, such as smart lighting and smart parking sensors that only require transmission of small amounts of data very infrequently, where lower quality of service and higher latency solutions are acceptable. The overriding requirement for these use cases is a low cost of connectivity. Whilst there are a range of predictions, it is expected that IoT services will be supporting billions of connections within five years. Current cellular technology is suitable for the most widely deployed M2M applications. However, to support the predicted very large number of low cost IoT devices that only need to send small amounts of data on an infrequent basis, a different type of network is required, and the rest of this paper focusses on the requirements for this and the different technical solutions being proposed.

Figure 1: Car parking sensor

Figure 2: Sensor to monitor soil moisture levels

Figure 4: Example of an UNB transmitter

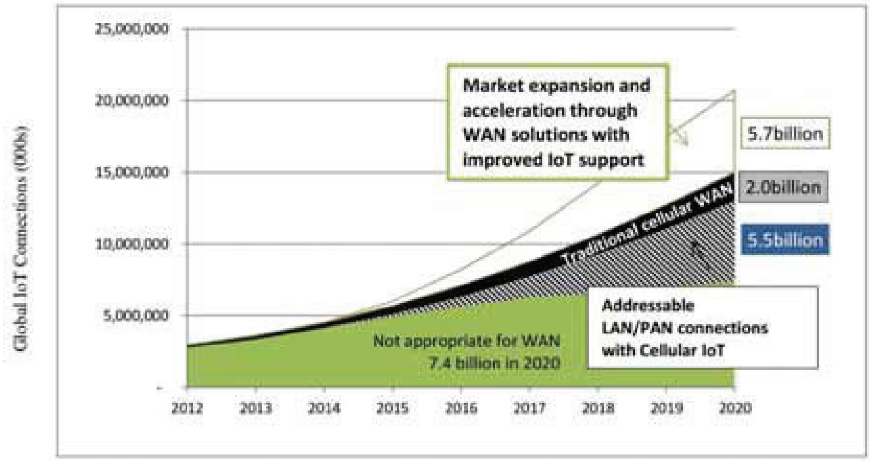

Figure 3: Projected growth of IoT connections
Source: Cambridge Wireless white paper "A choice of future M2M technologies for Mobile Network Operators" [1]

Key features

This change from M2M to IoT is based on a number of key features.

Very cost effective network connectivity – perhaps as low as a few pounds per year, linked to low cost radio modules. The overall cost of connectivity is crucial.

Low power consumption – the ability for sensors to operate for several years on a single battery, especially in remote locations or where the costs involved in changing batteries or providing power are prohibitive, is key to enabling many use cases. Services that can operate for many years on the same batteries opens many new market opportunities, and a good example of this are smart parking sensors (see Figure 1).

Long range radio with good penetration into buildings – sensors may be located in or out doors and it is fundamental to reduce the cost of network deployments that long range coverage is needed to keep the number of base stations to a minimum. Many of the use cases involve sensors in rural locations (smart agriculture), in buildings or even buried under the streets to monitor sewers and pipes. This dictates a spectrum choice of less than 1GHz, a frequency range which enables long range and good building penetration at the expense of high data rates.

Support for low bandwidth and throughput – Many LPWA network use cases require both low bandwidth and throughput – some sensors may only need to send a few bytes of data once or twice a day, so networks dimensioned to support high data rates are not appropriate.

Support for a large number of devices per base station – This is essential, especially given that communications is mostly off and, when connected, only short bursts of data are sent or received.

These features are exemplified in one of the use cases for an IoT network; to monitor soil moisture levels. The sensors need to be battery powered, only need to transmit once an hour in order to provide useful data, and can be deployed in a number of locations across a city or rural environment. As such, LPWA networks are well-suited for such sensors. A number of these sensors (such as the one shown in Figure 2) have been deployed in Milton Keynes as part of the MK:Smart project, using an Ultra Narrow Band LPWA network in the city.

Spectrum choice

The key component of a wireless solution is the radio spectrum employed. There are two models for access to spectrum, the first of which is licensed spectrum. An operator (or group of operators) has sole access to the spectrum and is the only organisation allowed to use it. The second is unlicensed where local regulators determine the rules for using the spectrum and any organisation compliant to these rules can use the radio frequencies. For example, mobile services are delivered by licensed spectrum and WiFi by unlicensed.

Mobile operators are the obvious companies to operate standards-based networks for IoT using existing spectrum. The use of spectrum which is owned by the mobile operators allows them to offer services where high bandwidth and quality of service are key requirements.

The alternative is to provide connectivity for IoT using unlicensed or shared spectrum, which could be offered by a range of new or existing companies. The main unlicensed spectrum available for IoT networks is generally referred to as the ISM (Industrial, Scientific and Medicine) bands, but these vary depending on the regulatory environment in each country which determine exactly which frequency bands are available and how they are accessed, particularly related to the duty-cycle, which controls how often sensors can use the network. As the spectrum is shared, it is difficult to offer services with guaranteed quality of service, and the use of ultra-narrow band and spread-spectrum techniques (discussed later) trade-off longer coverage with bandwidth. Services based on these technologies will be used for use cases where there are only infrequent, small amounts of data transmitted.

Technology options

The key characteristics of LPWA network IoT technology are:

- Long range, at least 15 - 20km.
- Support for millions of nodes.
- Long battery life in excess of 10 years.
- Very low cost.
- Globally available radio frequencies in a narrow band.

Not all IoT applications can be supported by current mobile technology. The addition of LPWA network technology will expand the opportunities as projected in Figure 3.

Several radio solutions are emerging, and proprietary protocols have been developed, designed from the outset to meet the requirements of LPWA networks. These include consortia-driven systems such as LoRa (https://www.lora-alliance.org/) and Weightless (http://www.weightless.org/), as well as single company proprietary systems such as Sigfox (http://www.sigfox.com/en/). Cellular solutions are being adapted from existing high data rate protocols, with modifications for lower data rates and extended battery life. Table 1 summarises the LPWA network technologies mentioned in this article.

Technology	Type	Frequency	Licensing
LoRa	DSSS	868MHz ISM	Unlicensed
Sigfox	UNB	868MHz ISM	Unlicensed
Weightless (N-Wave)	UNB	868MHz ISM	Unlicensed
Telensa	UNB	868MHz ISM	Unlicensed
Ingenu	DSSS	2.4GHz (Europe)	Unlicensed
LTE-M	Cellular	Mobile ranges	Licensed
NB-IOT*	Cellular	Mobile ranges	Licensed

Table 1
*NB-IoT is the latest 3GPP work item on LPWA networks and incorporates NB-LTE and Cellular IoT.

The three main types are described in more detail below.

Ultra Narrow Band (UNB)

UNB is a good example of a technology purposely designed for LPWA networks and is already in wide use with different versions used by companies like N-Wave (http://www.nwave.io/), Sigfox and Telensa (http://www.telensa.com/). Sigfox have networks already deployed in several countries. Telensa recently announced that they have connected over 9 million UNB devices in 30 countries.

In UNB systems, uplink signal bandwidths of around 100Hz are typical, providing capability to support a sub-100bit/s data rate requirement. The simplest implementations are uplink only with no device receiver to consume precious battery energy. Where downlink capability is required, for example parameter setting on a sensor, it is achieved by powering up a device receiver only during known time windows after each uplink transmission.

Devices transmit short bursts of data at random time intervals and randomly selected frequencies within a wider defined band. Transmissions are repeated to mitigate message loss due to collisions. Software defined radio is used at the base station to detect localised energy in the wider frequency band and focus processing on the incoming narrow band signals. Signals are blindly transmitted, received by the nearest base stations and are forwarded to the correct destination by the network. Downlink messages are routed to the appropriate base station based on the uplink reception. Transmissions are short and infrequent. The simplicity of the devices makes them very cheap to produce. No

mobility support is required in devices, eliminating the requirement for signalling, which itself consumes power.
An example of an UNB transmitter is shown in Figure 4.

Direct sequence spread spectrum (DSSS)
DSSS transmission is another technique that can be employed for low data rate and long range. This technique helps the signal resist interference and is loss tolerant, making it very suitable for low power, long range and low data rate applications.

Two examples of vendors employing DSSS in their solutions are Ingenu (www.ingenu.com) and Semtech (http://www.semtech.com/). Ingenu use it in their established private Random Phase Multiple Access networks, of which there are said to be around 35 deployed. They have also recently announced an intention to build a nationwide M2M network in the USA. The technology has been published as an open standard via IEEE 802.15k.

Semtech employ DSSS in their LoRa protocol which forms the basis for the emerging LoRa Alliance LPWA network standard. The protocols and modulation schemes employed differ significantly in the two solutions but DSSS is used for the same purpose in both.

Long Term Evolution (LTE) 3GPP 4G technology
3GPP, the body responsible for mobile standards, is working on modifications to existing 4G Long Term Evolution (LTE) technology to better support machine-type communications. LTE was primarily specified to support high bandwidth broadband to fast moving devices. Using such an existing protocol as it stands for IoT is far from optimal. The capacity and speed is far in excess of that required for small data M2M.

Several options are being investigated to make LTE more suitable for IoT applications. LTE-M with a bandwidth of 1.4MHz uses a combination of signal repetition/ retransmission, power boosting of the more vulnerable elements of the signal and relaxed performance requirements in areas such as initial synchronisation and network access, to improve range. LTE-M also introduces extended sleep times for devices by reducing the need for regular signalling. LTE-M is seen as the best option for high data rate devices. A big attraction of LTE-M for existing mobile network operators is that it can be deployed within an existing LTE channel alongside the regular LTE protocol, eliminating the need for dedicated spectrum and, in software defined base stations, added radio infrastructure.

Also under development in 3GPP is a Narrow Band version of LTE (NB-LTE) which seeks to serve a lower data rate longer range M2M requirement than LTE-M. The 3GPP Radio Access Network group plan to standardise NB-LTE in July 2016. Huawei are also promoting their “Clean Slate” narrowband solution in 3GPP. Investigations are also underway into the possible standardisation of some of the proprietary LPWA solutions.

It is yet to be seen which options will dominate in the cellular mobile arena.

Removing the barriers
Wide area low power wireless networks have the potential to become a core part of the future digital economy. There are key enablers which need to be put in place to allow for the widest possible development and exploitation of services. It is worth taking a look at how two of the most successful wireless service infrastructures developed to illustrate what would need to be put in place for wide area, low power applications.

Firstly, WiFi has developed to become the most widely available network technology. This has been enabled by 1) a set of globally available standards set by the IEEE, dictating a single set of technologies and 2) harmonised (globally agreed) licence-exempt spectrum with minimal regional or national variations. This has led to the environment we see today where WiFi carries 80% of all wireless consumer traffic. Secondly, the

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cellular mobile industries success is also built on harmonised spectrum and common standards. The rapid deployment and user adoption of LTE is partly due to the standards being the first global standard without regional variations. In the UK, these enablers combined with a regulatory environment targeted at balancing the needs of consumers with the need to invest, has resulted in one of the most price competitive and thriving markets globally.

Today's LPWA network environment is characterised by unproven demand and unrealistic expectations on the speed and volume of adoption, limited harmonised spectrum availability, proprietary technology and nascent standards. There is a compelling need for co-ordination across industry if LPWA networks are going to achieve their transformation potential. This should include:

- Identification of the early use cases with sufficient market demand to drive infrastructure deployment.
- A joint approach on spectrum ensuring the WRC agrees appropriate bandwidth is made available on a global or regional basis.
- Engagement with national regulators ensuring that spectrum is made available to allow markets to develop.
- Coalescing on common radio technology and information exchange standards to enable a thriving equipment supply industry and services.

There is significant industry activity aiming towards solving elements of this puzzle. The 3GPP Radio Access Network group is targeting the specification of a standard in Release 13 NB-LTE (Narrow Band LTE). An industry group has formed to advance the LoRa specification. The support for IoT use cases, from mission critical robotics through to LPWA network applications is seen a fundamental need to the next generation of mobile technology, 5G.

Encouragingly, the Wireless IoT forum was formed in 2015 to provide an industry forum for the development of LPWA network technology and services. There is a compelling case for organisations interested in seeing the success of LPWA networks and for the future digitally connected society to engage with organisations like the Wireless IoT forum.

REFERENCES

1. Cambridge Wireless White Paper. A Choice of Future m2m Access Technologies for Mobile Network Operators. Mar 2014. Available at: http://www.cambridgewireless.co.uk /docs/Cellular%20IoT%20White%20 Paper.pdf

ABBREVIATIONS

IoT	Internet of Things
ISM	Industrial, Scientific and Medicine
LPWA	Low Power Wide Area
LTE	Long Term Evolution (3GPP 4G technology)
M2M	Machine-to-Machine
NB-LTE	Narrow Band – Long Term Evolution

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