

For a million devices per square kilometre, 5G needs to be smart, as Sylvia Lu explains

IoT IN THE 5G ERA

BACK IN JUNE 2018, the whole 5G ecosystem reached yet another significant milestone when 3GPP approved a new set of radio specifications for 5G NR Standalone (SA) in RAN#80 in La Jolla, California. This marked the completion of the radio specifications for 5G NR Phase 1 (3GPP Release 15), a major step towards 5G commercialisation.

I have often been asked what 5G could possibly be doing for low power wide area (LPWA) technologies. Isn't 5G designed for power hungry high speed, low latency applications? Aren't the technological solutions like NB-IoT (Narrowband-Internet of Things) and LTE-M, specified in 4G, already addressing LPWA? What else could possibly be done for IoT in the 5G era?

A look at 5G's relationship with NB-IoT and LTE-M helps to answer these questions.

5G, NB-IOT AND LTE-M

The general principle is that, for technology solutions specified in any Standards Development Organisations (SDOs) to be qualified as International Telecommunication Union (ITU) IMT-2020 minimum requirements after evaluations. Nowadays however, 5G has been used in a much wider context, referring to a wide range of new services to be enabled by future wireless technologies.

ITU members have outlined minimum technical performance requirements for 5G IoT and massive machine type communications (5G mMTC): at least 10 years' device battery life (15 years preferred), 20 dB coverage enhancement, and support for a million devices per square kilometre.

3GPP informed ITU early this year that it will submit both NB-IoT and LTE-M technologies as candidate 5G solutions to meet the IMT-2020 5G

mMTC requirements. So both technologies are expected to become vital 5G components. In addition, a decision was made to ensure that LPWA use cases would continue to be addressed by evolving NB-IoT and LTE-M as part of the 5G specifications, thereby confirming the status of both NB-IoT and LTE-M as 5G standards.

There are two main drivers for this decision: investment payback and longevity of installed LPWA devices. The first reason is for the industry to leverage and maximise their LPWA investments already made today globally. More than 60 commercial LPWA networks have already been launched worldwide, according to GSMA. Therefore there are interests to maximise the longevity of the networks, infrastructures and devices.

The second reason is that most LPWA devices are expected to last for more than 10 years and may be deployed in hostile locations, such as down manholes (for water metering), in remote locations (for alarms or environmental monitoring), or in the chassis of vehicles (security alarms), and in smart agriculture. It is therefore crucial to support LPWA devices in 5G core networks to ensure a long IoT service life. To enable that, 3GPP is

investigating options as part of Release 16 for the 5G core network to support NB-IoT and LTE-M radio access networks, as well as to ensure that NB-IoT and LTE-M can coexist with NR in the 5G NR frequency bands, including for example the flexibility of deploying NB-IoT and LTE-M inside an NR carrier. This will enable a smoother migration path to 5G for the LPWA devices deployed today with only a software upgrade in the future, if needed. This again confirms the longer term status of both NB-IoT and LTE-M as part of 5G standards.

WHAT'S NEW IN 5G FOR IOT?

The focus use case for the first phase of 5G NR was about enhanced mobile broadband, although it has added certain features to avoid collision between NR and LTE-M or NB-IoT, such as subcarrier grid alignment (for both uplink and downlink), reserved resource configuration and flexible scheduling units. 5G NR Phase 2 (Release 16), however, will bring connectivity solutions to a variety of verticals, including industrial, manufacturing, automotive and satellite sectors. Most of these demand stringent requirements such as high throughput, high reliability, low latency, high availability, and dense

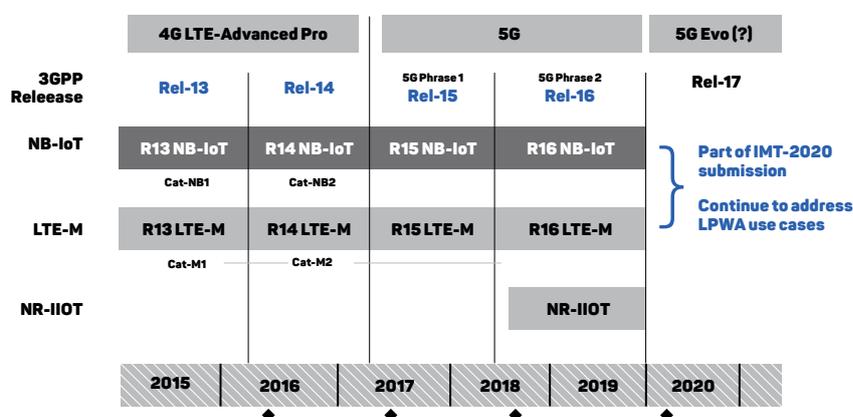


Figure 1: NB-IoT and LTE-M evolution into 5G, in parallel with NR-IIoT

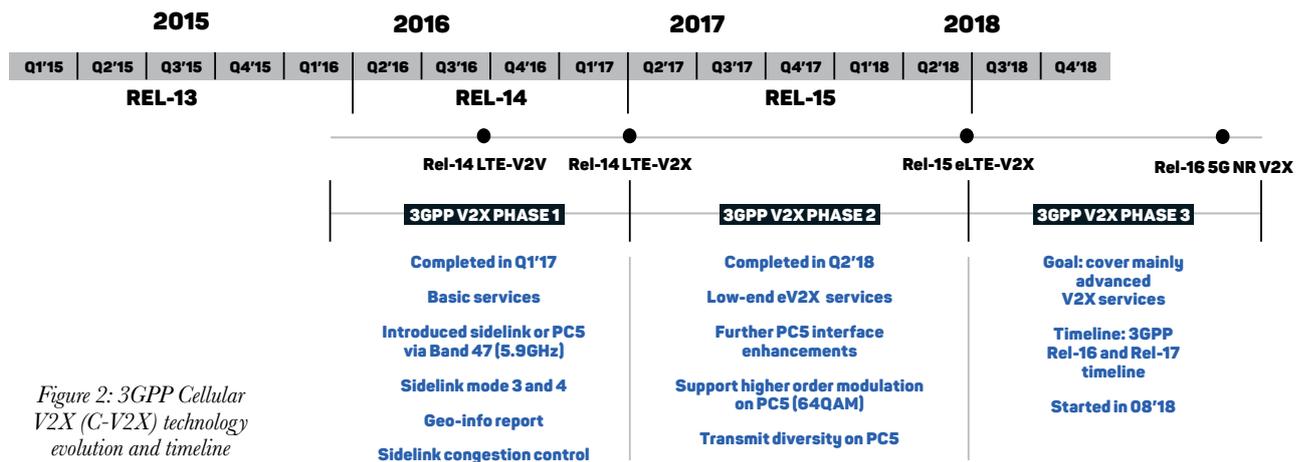


Figure 2: 3GPP Cellular V2X (C-V2X) technology evolution and timeline

connectivity. 5G NR Phase 2 is focused on mMTC and URLLC (Ultra-Reliable Low Latency Communications).

If we look at 3GPP TS 22.261 and TS 22.804, it is evident there are many different use cases supported with a wide variety of different requirements and key performance indicators.

One particular example is the Factory of the Future use case, revolutionising the way goods are produced, shipped and serviced throughout their whole lifecycle. Leveraging wireless connectivity to provide the degree of flexibility, mobility, versatility and ergonomics required is crucial and one of the important use cases in designing NR-IIoT in Release 16.

NR-IIoT (New Radio Industrial IoT) is a new feature to be studied in 3GPP to enable new IIoT use cases, particularly for factory automation, electrical power distribution, and in the transport industry. The new system will leverage short transmission time interval (TTI) structures for low latency as well as methods for improved reliability defined in Release 15 URLLC. Time Sensitive Networking (TSN) will enable key services needed in factory automations, including time synchronisation and accurate reference timing. Both FR1 (Frequency Range 1, 450 MHz to 6 GHz) and FR2 (24.25 GHz to 52.6 GHz) will be considered.

In addition, the telecoms industry is keen to expand the platform for the automotive industry, providing connectivity solutions for V2X (vehicle-to-everything: vehicle-to-vehicle, vehicle-to-infrastructure, vehicle-to-network, vehicle-to-pedestrian) on Band

47 (5.9 GHz) and beyond. Initial standards on supporting basic V2X services (not safety critical) were completed in Releases 14 and 15. In the 5G era, it is expected to focus on advanced use cases including vehicles platooning, extended sensors, advanced and remote driving. These all require stringent performance in terms of reliability, latency and availability. 3GPP is currently looking at this in the NR-V2X study.

WHAT'S NEW IN RELEASE 16?

NB-IoT and LTE-M were introduced in Release 13, which provided the essential and fundamental narrowband air interface for ultra-low complexity LPWA devices. It allows devices to be connected to a network in massive numbers in extremely challenging coverage while having a very long battery life. Several enhancements and additional features were added in Releases 14 and 15.

Release 14 was about power consumption reduction (the introduction of Release Assistance Indicator, for example) and use case extension. For the latter, additional features were added including support for positioning, multicast, connected mode mobility, higher data rate, and support for User Equipment (UE) power class 6 (14 dBm) to enable use of small form-factor batteries with limited peak-current capability.

Common features for NB-IoT and LTE-M in Release 15 include further latency and power consumption reductions (in the form of NWUS and MWUS, the wake-up signals for NB-IoT and LTE-M respectively), and

further system acquisition time reduction. NB-IoT also added Time Division Duplex (TDD) and support for small cell.

The ongoing Release 16 work for NB-IoT and LTE-M is about network operation and efficiency improvements (for example, UE-group wake-up signal), as well as preparing for a smoother migration to 5G core networks.

As the technologies for IoT expand in the next few years, more devices will join the list of 'things' forming new IoT ecosystems in the verticals. NB-IoT and LTE-M technology will continue to play a vital role in the 5G era.

In addition to this, it will be crucial to leverage wireless connectivity to provide the degree of flexibility, mobility, versatility and ergonomics that is required to meet the requirements of the Factory of the Future and the demands of connected, autonomous vehicles. All of this will provide an important step in showcasing the full potential of 5G technologies in the 5G Internet of Things era. **CWJ**

SYLVIA LU

Senior engineer at u-blox

Sylvia is a Senior Engineer at u-blox, CW Board Member and member of UK5G advisory board with a decade's experience in the cellular industry. Her background includes algorithm design, DSP development, global standards and technology strategy. Sylvia represents u-blox in 3GPP and leads its standardisation activities incl. IoT, V2X and 5G.

Continue the conversation on Twitter. Follow us on @cwjpress hashtag #cwlots5G



Rolling Out NB-IoT

With a portfolio of devices and a standards based approach Huawei is pushing back boundaries of RF, Silicon and network technology to connect tens of billions of 'things' to the global internet. Charles Sturman explains.

NB-IoT has been the fastest 3GPP technology from standard to deployment. Following early-stage technology trials, NB-IoT first appeared in pre-standard silicon in 2016 and was updated later that year to the first 3GPP NB-IoT release 13 standard. Second generation silicon was designed for mass roll-outs with multi-band support for global coverage (following global standardisation on the available bands) and optimised for lower power (through silicon techniques and Release 14 standards enhancements). Higher SoC integration has also driven both cost and power down. Today, there are a large number of commercial networks in full operation around the world and the emphasis is now on specific use cases and achieving real Return on Investment.

During this time, Huawei has partnered with a number of leading M2M module vendors to ensure developers have the widest possible choice of solutions available to them, such as Quectel, u-blox, Telit and Gemalto and together with other market players, we now see a significant market. According to a recent report from Berg Insight's Tobias Ryberg: "Global shipments of NB-IoT devices will grow from around 100M units in 2018 to a staggering 600M in 2023". In China NB-IoT is set to rapidly replace 2G M2M and the country has embarked on one of the world's largest digital infrastructure projects resulting in billions of new connected devices.

Industrial IoT (IIoT) is widely talked about and is expected to increase productivity by combining AI, cloud computing and advanced analytics to automate manufacturing processes and enable businesses to monitor and interpret data from multiple production lines and complex machinery in real time to anticipate faults, manage infrastructure and mitigate risk. Over time, the resulting insights will drive efficiencies, optimise productivity and decrease costs in many important economic sectors beyond manufacturing,

such as energy and telecoms.

For the next generation of devices, we can expect to see release 15 (5G first wave) and later 5G massive MTC (mMTC). For NB-IoT, the move from release 14 to 15 and 16 (5G mMTC) is evolutionary not revolutionary. This is a key point to recognise, as enterprises are already making major deployments today and these investments will be maintained and enhanced going forward. Ultimately, the standards focus is on massive volume deployment, requiring network optimisations to support billions of connected devices. In the device, system optimisation and integration for ultra-low power and further cost reduction will be key. Enhancements for small infrequent payloads and end-to-end link reliability and security will be important as in-field longevity, reliability and assurance must be measured in multiples of years. Fully integrated RF front end technology, SIM and power management will eventually make IoT connectivity integration no more difficult than adding Bluetooth to a product is today.

GSMA's figures show that 51 of the 67 commercial IoT services currently being operated by MNO's globally are using NB-IoT. China has been the fastest to exploit NB-IoT and the world's largest MNO, China Mobile who pioneered the NB-IoT rollout, already support several hundred million IoT connections.

NB-IoT is designed from the ground up to offer the ultimate combination of low power consumption, low cost and high reliability to enable the tens of billions of device connections required to deliver on the vision of a fully connected intelligent world.

THE CHINA PERSPECTIVE

In 2015 the Chinese government outlined the 'Made in China 2025' strategy which aims to boost manufacturing innovation, smart appliances and Industrial IoT over a 10 year period. The related 'Internet Plus Action Plan' targets the integration of the internet, cloud computing, big data and IoT with traditional industries to create a new engine for economic growth.

China's mobile operators have seized the opportunity to play a fundamental role in these developments by providing secure and reliable connectivity to enterprises across the country. A fantastic example of this is the so-called "Smart City"; Yingtan. With a population of 1.3 million, Yingtan has been expanding its use of smart technology for several years. However, working with the major Chinese MNO's and Huawei, the city deployed the world's first NB-IoT network last year with full coverage, consisting of 970 NB-IoT base stations achieving 95% availability with 100,000 connected devices supporting a range of 30 different applications including Water Meters, Street Parking, Street Lights, Smoke Detectors, Water Filters, Waste Management and Bike Sharing, see www.x.co/huawei.

WORLDWIDE NARROWBAND

Today, we can see other regions ramping up their activities. Although last year saw a polarisation on initial roll-outs with LTE-M popular in the US, Korea and Australia and NB-IoT in Europe and Asia. Today, we see global roll-outs of both technologies and a clear understanding of the merits of each for a different range of use cases, with the choice being made on topics such as signal penetration, range, power consumption, cost and mobility.

Today wide scale commercial service is offered by China Mobile, China Telecom and China Unicom but also by TIM Brazil, Deutsche Telekom, Vodafone, Telstra and in the US AT&T and Verizon have committed to nationwide service by late 2018 / early 2019 with T-Mobile already providing NB-IoT service since this summer.

So far, we have seen Industrial IoT use cases in China as the biggest drivers for NB-IoT, however, this is rapidly changing as the technology becomes better suited to an increasing number of use cases and the networks and billing approach becomes more attractive to users. In the next 12 to 18 months, we should expect to see the rest of the world catch-up.

CASE STUDIES

- T-Mobile Poland and Geotermia Podhalańska - the largest geothermal energy supplier in Poland - are building an end-to-end telemetry and remote meter reading system of more than 1,500 devices to enable automated reading of heat meters. The five year contract is valued around half a million dollars.
- Telia Norway and StalkIT - The waste container tracking specialist - will rollout an NB-IoT based solution for waste container tracking with an expectation of around 100,000 devices over three years. Their reasons for choosing NB-IoT are low cost and ease of deployment: "All our customers need to do is mount the tracking device on the container and the service provides a complete overview of where the containers are and what status they have".
- Vodafone UK and Scottish Power - one of the national UK energy suppliers - has deployed a NB-IoT based heat sensor in subterranean "link boxes" to detect overheating to avert fire hazards. If the link box becomes dangerously hot, a notification is

CREATION OF NB-IOT

In 2014 Neul, was acquired by Huawei. The UK based company had developed a narrow band RF system designed to fit within the guard bands of existing LTE spectrum making deployment possible within existing infrastructure. Two years after the acquisition the technology was adopted by 3GPP as the global IoT standard.

sent via the NB-IoT network to dispatch an engineer. The sensor itself runs on a double-A battery for a minimum of five years and costs less than two euros.

- Proximus Belgium and Fluvius - the national energy supplier - have embarked on a national rollout of over a million NB-IoT connected digital smart meters for gas and electricity between 2018 and 2022.

CONCLUSION

The combination of small packet data, non-real time, low deployment cost and long term battery operation has made NB-IoT ideal for industrial and smart-city applications, delivering significant savings and ROI in use cases as diverse as asset tracking, remote monitoring, safety, utility metering and streetlighting. The resulting benefits in reliability and accuracy and removal of the need for 'boots on the ground' has driven the rise of Industrial IoT.

As interest spreads and the technology matures, new use cases are arising in enterprise, smart-home and consumer sectors where the same technology attributes provide benefits in smart-parking, home appliance diagnostics,

wearables (people tracking, on-body fitness and health monitoring), and bike sharing.

To illustrate the utility of NB-IoT, smoke sensors have recently been identified as a major application for minor public buildings such as bars, restaurants and shops, where existing fire alarm systems may not be well managed. Recent forecasts suggest a market of hundreds of millions of devices in China alone and many more globally.

Global network deployments are providing country-wide penetration, and we can expect to see the number of connected things in IoT rapidly build.

At Huawei, we are already working with customers and partners to deliver on this vision and we are excited to discover and learn about new use cases as we do so. From connected cattle, to asset trackers, from smart meters to street lighting, and from bike sharing to consumer wearable devices. In the future, if we can gain insight or value by quantifying or controlling the behaviour of a device, then likely, it will become part of the IoT.

For more information please see www.x.co/huawei/iot

YINGTAN SMART TOWN POWERED BY NB-IOT TECHNOLOGY



Street parking



Street lights



Luggage tracking



Smoke detectors



Sharing bikes



Water filters



Manhole covers



Waste management



Water meters



Shoe pad

Phil and Mary-Anne Claridge of Mandrel Systems look at best practice, based on their practical experience, that signals LoRa may be ready for prime time.

IS LORA READY FOR PRIME TIME?



SMALL AND REMOTE things often need to work on batteries for long periods. Semtech's LoRa (Long Range) is one of the options available. LoRa only defines the physical and link-layer protocols and developments around it may not be compatible with other LoRa-based projects, but the LoRaWAN initiative, guided by the LoRa Alliance, adds the network layer and offers the necessary accreditation for product interoperability.

Semtech acquired LoRa in 2012 and it has taken a while for the protocol to mature. The radio link is based on chirp spread spectrum, operating in the ISM band at 868 MHz in Europe, with a maximum transmit duty cycle of one per cent. It can transport datagrams, with a variable maximum data payload size and without guaranteed delivery, between nodal end points over low-cost, low-power radio links.

Nodes may communicate simultaneously with one or more gateway base stations, managed by a core network server. These network servers may be privately operated or provided as a public shared Software as a Service (SaaS) facility.

Network servers decrypt and de-duplicate messages passing received messages to the appropriate application server that has the specific code to process them. In the reverse direction, datagrams from the application server are routed via the network servers to the gateway nearest to the node.

LoRa uses an unusual spread-spectrum modulation scheme based on chirp FM for low complexity. This helps to make it more resistant to in-band interference; and its flexibility allows a datagram transmission to be spread over a long period, effectively reducing the bandwidth and giving better link budget for long range or in difficult propagation conditions. Depending on the noise level both nodes and gateways may transmit with different spread spectrum encoding, called the spreading factor (SF).

Most LoRa modules operate at SF12 at maximum power by default. We try to engineer systems operating at SF9 or



lower. This has many benefits: larger payloads, less time on air to maximise battery life, and network capacity.

When applications are designed for use in commercial and government buildings where it is often impractical or impossible to connect reliably to any in-building data network, units can be mains powered, and gateways can incorporate a cellular modem for backhaul. Typical payloads range from small messages of under 20 bytes from room-occupancy and environmental sensors, to utility meter readings where



messages may be over 100 bytes.

In tall buildings, depending on their construction, a gateway has to be deployed every four to eight floors but if the site involves adjacent buildings, the number of gateways can be reduced as nodes can transmit between the buildings through non-thermally coated windows. Gateway density is determined by ensuring every node can be seen by more than one gateway. By using spreading factor SF9, or below, we have consistently transferred over 90 per cent of datagrams first time – and better than 95 per cent in many cases.

With SF10 or higher we had to

fragment large payloads, such as utility meter data. At high SF the idle time required between transmissions could introduce a couple of minutes of latency to transmission of fragmented

SMART SENSORS
Beringer makes LoRa compatible sensors which can collect 15 data points in real time including sound, temperature, air quality, occupancy, and light levels.

data, even assuming one of the fragments did not corrupt.

We've had some fun with gateways as well. Simply-configured gateways using a SIM card will send every LoRa packet they receive back over the cellular network, using more data than expected. Another hard lesson was that the inherent one per cent duty cycle also limits total gateway transmit time – and message acknowledgments sent by the gateway count towards this, too.

Antennas continue to be a dark art. Chip antennas failed to give consistent results. PCB planar antennas proved to be directional though used on commercial nodes. Internal antennas are compact and suit in-building gateways, but external gateways often use vertical arrays about a metre long which give useful elevation gain.

It's important to pay attention to the management of radio information provided in each packet received by the core LoRa network. Here are the questions to ask (our custom software routinely provides answers):

How many, and which, gateways can see a node? Ideally, do two gateways (or more) see a node. Most networks will report the SNR and received signal strength (RSSI) of any datagram received from a node at each gateway.

How many packets are getting lost? Look for gaps and step-changes in the sequence number that is incremented with every LoRa transmission (the gateway and node maintain separate counts as part of the LoRa over-the-air protocol). Step changes to zero in this sequence may indicate nodes are being reset, gaps indicate lost packets.

Is the adaptive data rate (ADR) and power management



working? Is the spreading factor and data rate reported by the network changing as expected?

What's the estimated battery life? For simple nodes, track the time the node's transmitter has been active (payload size combined with the spreading factor reported by the gateway).

Firmware revisions added periodic messages from the nodes to our application management information to further monitor the system operation. This included signal strength and percentage loss of packets received by the node. Data was layered into existing status messages from the node that sent information, such as: why the unit last reset (power-on or watchdog-device fired), the current firmware version, or had the on-device management switch been pressed? For mains-powered devices, we switch nodes to Class C operation wherever possible so data can be received at any time.

The most useful feature added to help install was a routine to make a Class A node send a status message to the network whenever a hidden button on the node was pressed to make it "call home". This provided an opportunity for the network to transmit back configuration and install data, and a flash of an LED on the device in acknowledgement.

The most common operational problem had nothing to do with LoRa: how to prevent mains-powered nodes from being unplugged during tests, and accessible antennas being unscrewed.

With most nodes defaulting to SF12,

every network with static nodes now has LoRa's ADR support enabled to adjust the spreading factor and, depending on network, transmit power both for nodes and gateways.

In some cases, ADR had to be enabled in the node and in the network server. We saw most of our links start dropping from SF12 to between SF9 and SF7 after about 20 messages had been exchanged. There was also some reduction in the number of gateways that received the data transmitted by a single node.

All of the ADR heavy lifting is implemented in the network server rather than the nodes or gateways. It's always wise to ask any LoRa server provider for details of their ADR operation before signing up. ADR algorithms are not standardised in the network server, though Semtech has published recommendations.

SERVER REQUIREMENTS

Most LoRa gateways communicate with the LoRa server network using variations on the Semtech packet forwarder specification. This is quite a basic protocol compared with the S1 protocol used by 3GPP networks. It typically forwards every packet received by the gateway to the server network, together with radio information: SNR, RSSI, and additional information such as timestamp, that may be GNSS/GPS derived for geolocation. To send data to a node from the network server the appropriate gateways are sent the packet together with other information such as



the power level and spreading factor to be used.

The network server has a number of key roles in optimising operations. The server determines to which gateway(s) a packet should be sent to reach a given node: usually the gateway with the best received signal strength for a node.

The server also determines and sets the power and spreading factor embedded in each packet sent through a

DIFFERENCES BETWEEN CELLULAR AND LORA

For those more familiar with cellular there are some radical differences when working with LoRa:

You are working in unlicensed spectrum which means there are no licences to pay and you can operate your own gateways and network servers, or in

many cases use a hosted third-party network server. The downside is there is no guarantee that someone else will not deploy their system at the same frequencies – with no comeback if they do.

All nodes and gateways just transmit alternately on one of eight frequency channels (typical EU configuration).

All LoRa operators share the 868 MHz frequency band in Europe, 915 MHz in North America.

Gateways receive all of the

encrypted packets from every LoRa device within range, even if the data is intended for another customer or operator. All the packets are sent to the gateway's associated network server where the datagrams intended for other networks cannot be decrypted and are discarded.

There is no 'listen before transmit' to check for congestion or collisions, also there are no reserved time slots to avoid transmit collisions from nodes.

To save power, battery-operated nodes typically only listen for a few seconds after every transmission in LoRa Class A operation.

Radios in the gateway are far more expensive than in nodes. A LoRa radio for a node costs a few dollars, but a good gateway module with parallel receivers is more than \$100.

Gateways can receive from a number of nodes in parallel on different 125 KHz channels and, in some

cases, receive multiple nodes on one channel with different spreading codes.

Power and encoding control is part of the LoRa standard but is generally ignored – or is misunderstood and typically not enabled by default (just like very early Wi-Fi deployments). Many LoRa devices will transmit at the highest possible power by default, with the lowest data rate, and the smallest possible maximum datagram size.



given gateway to a node. It can also monitor received messages from a node, as an option in ADR, and send the node a message to set the power and SF values for transmissions to the gateway.

LORA 'NORDER

Policing the security of a link in shared spectrum is clearly important. Superficially, LoRa is reasonably provisioned with encryption at the link level to determine if a message is going to a valid destination. All commercial LoRa servers allocate a system-wide application key, decrypt the data payload, and pass it to the application server by default so the system is easy to use. We prefer to apply different application keys to each device.

Many networks can be configured to allow the data to remain encrypted but, depending on the network server vendor, success is not guaranteed. When a node joins the network, application keys are part of the key exchange and you have to effectively duplicate functions of the network

server to independently manage them.

For very secure applications, LoRa should only be part-trusted, and a secure element can provide another layer of encryption above LoRa. The most common use for the secure element is, ironically, not to encrypt data sent from the node, but to digitally sign commands sent to the node. Nodes that can control actuators, regardless of network connection technology, require much more stringent security features than most sensor-reporting applications.

While configuring security we had a mild panic. Associated with every device there is an application Extended Unique Identifier (EUI), a device ID and associated application security keys. What happens if you fall out with your network service provider? You can't afford to reprogram every node.

Tests have now confirmed that IDs can be transferred between different network service providers and the LoRa ID (application EUI) is configured for more than one of our selected providers to ensure the same IDs can be reused across multiple networks. We are now taking this a stage further and will be registering some of our own LoRa addresses (strictly IEEE EUI64).

GATEWAY MANAGEMENT

The integration between the gateway and the network server is probably the most immature part of a LoRa deployment but this is improving and is likely to get significantly better as the LoRa market consolidates.

The protocol between the gateway and the network may vary and a given gateway software load may have to be patched to work with a given network. Many gateways are Linux-based and allow secure socket shell access. There is no standard management protocol between the gateway and the network server. Even basic commands for resetting a gateway may require a vendor-specific login.

A typical LoRa gateway using a cellular backhaul will involve: a dynamic DNS service to find a gateway's IP address on the mobile network; connection security through an HTTPS server on the gateway; and further support using VPN tunnels.

Looking to the future for active buildings, there is a lot of fun to be had mixing LoRa and Bluetooth mesh to integrate additional very low-cost sensors into a sensor cluster. It's also hoped that gateway vendors and network service providers will get together and standardise more of the upper layers of the network.

Most of our focus is now more mundane – to streamline manufacturing, provide software that can test and provision nodes in the factory after manufacture, and pre-provision devices in our network and application servers – or try novel things like printing QR codes on nodes so an installer can scan a node and get directly to configuration web pages on a tablet or phone.

The bottom line is that LoRa is ready for production, provided it is realised that systems integration and operational issues will dwarf the node hardware design effort as a project moves from a bench prototype to an integrated system. **CWJ**

MARY-ANN CLARIDGE
VIRTUAL CTO

Mary-Ann Claridge is a practical consulting data scientist working in domains including: speech, education, building management, retail supply chain and international logistics. She as a love of elegant data design, her career originating in sonar and signal processing. Mary-Anne founded and runs Cambridge consultancy Mandrel Systems, providing information science and analytics to startup and large companies. She is also a CW Smart Cities SIG champion.



PHIL CLARIDGE
VIRTUAL CEO

As a Virtual CEO, Phil Claridge supports startups achieve minimum demonstrable development, and large organisations with large scale architectures (including IoT, LoRa, cloud and machine learning). Has wide and deep experience in all telco technologies as CTO and chief architect for companies including: Geneva/Convergys and Arieso/Viavi – this ex-hardware geek will still solder. Phil is a CW AI SIG champion.



Continue the conversation on Twitter. Follow us on @cwjpress hashtag #cwjournal.

IMAGE KEYSIGHT

UNDERSTANDING NARROWBAND



While the mobile industry has rushed headlong for more bandwidth and faster data, the fully-connected future will need narrowband. WiFore's Nick Hunn and Cambridge Consultants' Tim Whittaker look at the radio technologies that will enable this well-connected future.

IN 2010 ERICSSON predicted there would be 50 billion connected devices by 2020. While that was optimistic, it highlighted the need for low-cost radio networks to provide the connectivity for numerous devices.

Connecting tens of billions of devices presents a number of challenges, many of which differ from the ones on which the mobile industry was focused in 2010. At that point, it was clear that consumers were taking to the idea of smartphones. The launch of the iPhone in 2007 had caught their imagination. When the App Store appeared a year later it highlighted the need for greater data capacity and download speeds. Operators started to gravitate towards unlimited data packages and put pressure on the industry to concentrate on evolving the 3GPP standards to meet that need.

Although 2010 was still in the very early days of the smartphone revolution – Symbian being the best-selling smartphone operating system at that time – and the consumer appetite for data was nascent, operators saw the writing on the wall and concentrated efforts on driving down the cost of smartphone data. That meant one thing to them – more data capacity in high population areas.

While it was thought smartphones might contribute to around three billion of the connected devices in 2020, the bulk of the 50 billion was predicted to come from what we now term ‘Internet of Things devices’. Some of these, such as connected cars, would require high data rates but the majority were envisaged to be far simpler devices, such as sensors, which would exist in everything from smart agriculture and smart cities to smart homes. They would be far more taciturn, in many cases sending their data to the cloud only a few times per day.

The majority of these devices could not be recharged daily like smartphones, but would have to rely on long-life batteries or energy harvesting. If they were as hungry as an iPhone 4, those 50 billion devices would consume around 50 TWh of energy each year, an

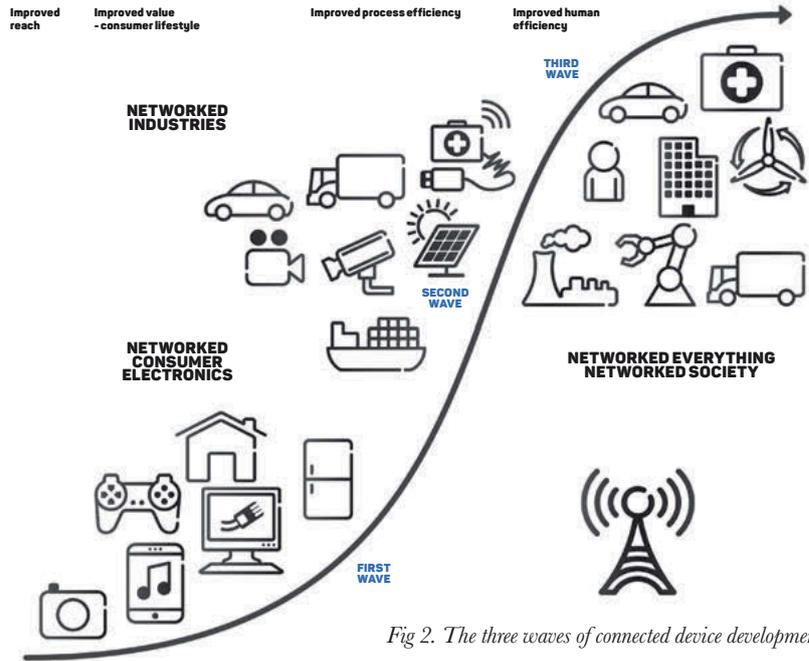


Fig 2. The three waves of connected device development

amount equivalent to 150 per cent of the UK’s current electricity generation. To allow these devices to run off batteries for years at a time, a fundamentally different design approach was needed at the radio level, compared to the way smartphone technology worked.

Another key difference is that many of these IoT devices were expected to be located in places with poor mobile coverage. Although many would be in smart cities, they might be deep within buildings or underground. A large


A FUNDAMENTALLY DIFFERENT DESIGN APPROACH WAS NEEDED AT THE RADIO LEVEL


proportion would also be outside these urban areas, with smart agriculture and environmental monitoring needing sensors where people weren’t around, and therefore there was little existing cellular coverage. Economically, operators wanted a solution that didn’t require new basestations.

Equally important was the cost of connection. Consumers might be happy to pay £500 for a smartphone and £20 a month or more for their phone

contract but the economics of deploying billions of sensors needed a different cost model. Here, the connectivity hardware had to cost under £5 and the data contract just a few pounds a year.

To keep data contracts low, operators would prefer not to install new basestations, but to upgrade what they already had. To meet the requirement of in-building and rural coverage, they needed a solution which provided a longer range so they didn’t have to infill infrastructure. To encourage the growth of IoT devices, the radios also needed to be cheap and able to run on batteries for years. These were all requirements that ran in the opposite direction to those for more data capacity to support smartphones – which brings us to narrowband.

THE CASE FOR NARROWBAND

Narrowband is a word which is applied to communications systems where the frequency content of the transmission is generally within the coherence bandwidth of the frequency channel. Broadly, this means that transmission is confined to a very narrow range of frequencies which will all be affected by noise or fading. Because the energy is confined to a narrow frequency range, the received signal can be kept above the noise even at very low signal power.

Narrowband inherently limits



the data rate, which plays to the physics of a trade-off between data rate and receiver sensitivity – as the data rate goes down, the receiver sensitivity improves. This gives narrowband an advantage in terms of overall link budget, which translates into longer range. It means basestations can be placed further apart, reducing the need for new infrastructure; where stations are already installed, it improves in-building signal penetration. A further advantage is that a narrowband radio design is generally relatively simple compared to broadband radios, which helps to reduce the silicon cost.

There's a fundamental reason why narrowband is preferred for devices that have transmit power and supply current limitations imposed through reliance on battery technology. It's a consequence of Shannon's theorem which shows that, for a given peak power, there is a ceiling on maximum data rate irrespective of transmit bandwidth. So, if your peak power is limited by battery current, there is little benefit in having a bandwidth much greater than a few kilohertz (see below *Why Narrowband?*).

Almost since the beginning of radio, systems have sought to minimise their bandwidth to get maximum range. HF and VHF radio systems, used in numerous private radio networks in industry and defence for monitoring and control, as well as in critical voice-based systems, such as Tetra (Terrestrial Trunked Radio) which is used by the emergency services, involve relatively low volumes of devices, rarely deploying more than a few million, generally in a

specific vertical application. A consequence of this is that, apart from Tetra, none had promoted itself as a global, industry standard.

PROPRIETARY STANDARDS ARISE

Despite the excitement generated by Ericsson's prediction of 50 billion devices, 3GPP and network operators' attentions were dominated by the evolution of mobile broadband in the form of LTE. The industry was concentrating on faster data and higher capacities, and largely ignoring the requirements of the fledgling M2M or the future IoT markets.



This allowed a group of companies to develop proprietary narrowband solutions to fill the gap and to promote them as potential industry standards. Collectively, they described their technologies as low-power wide area networks (LPWANs) and this has come to signify any radio network targeting IoT applications.

The first to show global ambition was Sigfox, a French company founded in 2009 that developed an ultra-narrowband radio specification, operating in the sub-GHz industrial, scientific and medical (ISM) bands of 868 MHz in Europe and

902 MHz in the US. Based on low-cost, commercial radio chips which were widely used in toys and remote controls, the Sigfox protocol allowed up to 140 uplink messages to be sent from a device to a basestation each day, with a payload of 12 bytes. The receive sensitivity of around -130 dBm and maximum transmit powers of 100 mW (Europe) and 1W (US), gave a potential range of around 30km in rural and 5km in urban areas. Sigfox is fulfilling its aim to become a global IoT network provider and claims to have deployed coverage in 45 countries. Sigfox is essentially a one-way ; and its short messages and lack of a proper reverse channel are limiting for applications and security.

Following closely on Sigfox's heels came LoRa (Long Range), operating in the same spectrum but with a wider bandwidth. LoRa can still be classed as narrowband radio, although its protocol adds spread spectrum to make it more robust against interference and to provide a flexible way to reduce bandwidth to improve link budget up to a similar level as Sigfox. This gives a higher data rate, allowing 242 bytes to be carried in each upload, with enhanced download rates.

Like Sigfox, LoRa also originated in France but from a startup called Cycleo which developed the underlying radio coding to address a variety of water metering applications. Founded in 2009, the company was acquired by Semtech in 2012 and 'Lora' was incorporated with its radio chips and restyled as LoRa. The new owner then formed the LoRa Alliance as an independent organisation to develop the higher-layer

WHY NARROWBAND?

There was a time when all radio systems were narrowband, in the sense that only the bandwidth needed to transmit the desired signal and get the longest possible range was used, given the limited transmit power available. Modern systems use a variety of 'broadband' techniques in the interests of multiple channel access, better spectrum co-existence,

interference rejection, and so on; and also to exploit advanced signal processing, by using redundancy to correct reception errors, for example.

Whatever the technology, all systems are ultimately subject to Shannon's law which tells us the highest possible error-free information rate we can transmit through a channel, with a given bandwidth and channel noise, using a given signal power. Shannon tells

us that wider channels can carry more bits – but, of course, they let more noise through. No assumptions are made about coding or modulation, with a mathematical upper bound showing what is possible – but not how to do it.

Many IoT systems have to carry information from low-power devices in hostile locations. The transmit power has to be low, to make the most of battery energy and to limit peak

supply current. The path loss can be very high, so the received energy is small. In the NB-IoT system, for example, the maximum transmit power is 200 mW (23 dBm) and the system has to work with a coupling loss between device and base station of 164 dB, giving a received power of -141 dBm (which is about 80 attowatts).

Such systems operate in the 'low SNR' limit of Shannon's equation, where

the maximum error-free information rate is given by $1.44(S/N)$, S being the average received power and N the noise density in watts per hertz. N is about -171 dBm for a very good receiver and the maximum possible error-free information rate is about 1.4 kbps. It turns out that this can be achieved with a channel bandwidth of about 3.75 kHz – there is little or no benefit from using wider channel bandwidths for power limited systems.



protocols and evangelise the standard.

LoRa is unusual in the way it is marketed. The LoRa Alliance has been working with existing network operators to deploy LoRa as part of their existing networks by adding low-cost access points and offering IoT users a managed service. However, it has also encouraged other companies, and even individuals, to buy and install their own gateways. As LoRa operates in an unlicensed ISM band, this led to the formation of the Things Network which encourages enthusiasts and companies to build an open IoT network. At the time of writing, there are over 4,500 independent LoRa gateways operating around the world, all connected to the Things Network.

The do-it-yourself capability also makes LoRa an interesting option for companies that want to deploy their own local IoT network. The LoRa Alliance claims to have deployed coverage in 49 countries as a result of partnering with 83 network operators.

RAMPING UP IN THE USA

In America, another company had been thinking along similar lines. On-Ramp had developed LPWAN solutions which were being deployed in some metering applications. These differed slightly in combining narrowband with some extreme direct-sequence spread spectrum (DSSS) to achieve good sensitivity in the heavily used 2.4 GHz band, which requires a lot of interference rejection.

By taking this approach, On-Ramp claims higher data rates and greater range than either Sigfox or LoRa. Note that the US allows higher transmit power than most regions and at 2.4 GHz propagation loss will be nine times higher for equivalent antennas.

In 2015, On-Ramp changed its name to Ingenu and started rolling out its Machine Network. Unlike Sigfox and LoRa, Ingenu appears to be acting more as a dedicated metering and smart city network operator, rather than trying to be a general purpose IoT operator.

The specialised-network provider role

has also served another player well – the UK-based Telensa in Cambridge.

Spun out of engineering consultancy Plextek in 2010, Telensa developed an ultra narrow band solution which has now become the most successful communication standard for street lighting in the world. Building on these deployments, the company is also expanding into other smart city applications, leveraging its installed street lighting networks.

Cyanconnode, another Cambridge-based company, has developed a self-healing, narrowband mesh network which is making inroads in smart metering. Both Cyanconnode and Telensa see themselves as serving vertical markets rather than being general-purpose IoT operators.

JOURNEY INTO WHITESPACE

While Sigfox and Semtech were busy promoting themselves as alternatives

BACKHAUL BENCH

Capacity from urban wifi such as the smartbench which has wifi with 4G backhaul and solar charging can provide useful links for IoT devices

to the traditional cellular networks, a third Cambridge-based startup Neul was taking narrowband radio in a different direction. The company was working on the premise that the whitespace spectrum that

existed between TV channels could be freed-up for the new generation of devices in the Internet of Things. Neul developed demonstration chips and took the step of publishing its specification as Weightless, bringing on board a number of major companies to give it credibility as an open standard. The company found its aspirations to use whitespace thwarted by the elephantine pace of regulatory reform, but its technology was able to find another, and very important, outlet.

While Sigfox, LoRa and the other LPWAN contenders were fighting among themselves to persuade the world they were the solution to IoT connectivity, 3GPP, the organisation which everyone had assumed would





BATTLE OF THE TECHNOLOGIES

NB-IOT

NB-IoT delivers up to 144 kbps – significantly higher than other LPWAN options and, being simpler technology, will have a lower component cost than LTE and draw less power from the battery. From the operator's point of view, NB-IoT can use re-farmed 200 kHz GSM channels, 180 kHz 'resource blocks' in a standard LTE channel, or guard bands at the edges of allocated mobile bands. NB-IoT does not support mobility. If an end terminal is moved, it needs to seek and re-join the network, which takes extra energy to run the receiver and transmitter during the process. It does not support TCP/IP and a proxy server, usually supplied by the operator, is needed to convert between NB-IoT data and standard internet traffic. What's more important is that it operates more like other LPWAN solutions than existing cellular options, allowing devices to sleep for most of their lives but with relatively low latency to wake and connect. Unlike other cellular devices, NB-IoT devices do not spend time and energy interrogating the cellular network. This makes it more suitable for static applications, rather than fast-moving mobile ones. The NB-IoT link budget is better than LoRa and Sigfox, giving it significantly better range than LTE and GPRS. Probably most important for its success is that it can be implemented as a software upgrade on many basestations, making it the lowest cost option for a network operator.

EC-GSM-IOT

Extended Coverage GSM for IoT (EC-GSM-IoT) is an extended version of GPRS. It will deliver up to 10 kbps, and the end terminal hardware can be based on 'obsolete' GSM silicon designs. It requires the terminal to transmit up to 2W to achieve the link budget, which is very difficult to achieve with small long-life primary batteries.

BLUETOOTH LONG RANGE

Bluetooth Long Range, part of Bluetooth 5.x, offers long-range mode at a low data rate of 125 kbps (Bluetooth normally runs at 1 Mbps to 3 Mbps), and a range of up to two or three kilometres is claimed. Bluetooth is also standardising a mesh networking scheme, though it's not clear whether this will be particularly low-power. Again, no direct-to-cloud offering is available for this technology, though its long range makes it probable that gateways will be developed. Bluetooth uses licence-exempt spectrum at 2.4 GHz.

LTE

LTE Cat-M1 up to 1 Mbps. At the base station it uses the same hardware as normal 4G voice and data services, so it's easily rolled out by the operator. Full mobility is supported, though the end terminal takes less power if it's static, and Cat-M1 talks internet protocols (TCP/IP) directly. When data transmissions are small and can be sent infrequently, the end terminal can go to sleep and scheduled wake-ups occur when the end needs to receive anything. On the down-side, the silicon is quite complicated and will continue to cost tens of dollars for a while, and being based on the standard LTE air interface power consumption and cost are likely to be higher than NB-IoT. The subscription for LTE Cat-M1 is likely to be over \$1 per month for each end terminal.

SIGFOX

Sigfox, uses licence-exempt spectrum (around 868 MHz in Europe and 915 MHz in the USA). The target data rate is 50 bps, targeting 10 bytes to 20 bytes per day for each end terminal – which may sound crazy but is all that a simple sensor application needs. Transmission is primarily one-way (uplink) and the small message size and lack of an effective reverse channel are undesirable if the system is to be secure. The transmit power is exceedingly low at just a few milliwatts and the end terminal hardware costs around \$3. Roll out of the service is quite good in Europe but still patchy in the USA. Subscriptions are likely to be around \$1 per year, per end terminal. Because Sigfox has the capacity only to deliver a few bytes per day from the base station to the end terminals and, as this is scheduled with other transmissions, it may take many minutes or even hours to send. There is no mobility and, like NB-IoT, a proxy server is needed between Sigfox data and standard internet traffic.

LORA

LoRa technology (LoRa is the physical layer; LoRaWAN defines the MAC layer, or alternative higher layers) can be procured for a non-operator service. Silicon chips, modules and complete products are available for end terminals or base stations, and referenced open-source software is available. The Things Network is a crowd-sourced LoRa network users can join after buying a base station.

LORAWAN

LoRaWAN, the LoRa Alliance implementation of LoRa, generally uses the same licence-exempt spectrum as Sigfox and delivers between 1 kbps and 22 kbps depending on various parameters. End-terminal hardware costs around \$5 and typical use cases are from one message per day (of a few tens of bytes each) up to one message every five minutes. Two companies are rolling out networks in the USA and several operate in Europe. Like NB-IoT, there is no mobility and a proxy server is needed between LoRaWAN data and standard internet traffic. Part of the LoRaWAN protocol runs on the server to save costs at the base stations. Subscriptions are likely to be a few dollars per year, per end terminal.

develop the appropriate standard, was doing a very good job of dropping the ball. What little work was taking place outside mainstream LTE development mainly took the form of talking shops for competing companies to gather support for their individual proposals, driven more by their intellectual property licensing aspirations than by the growing demands of the blossoming narrowband market.

In late 2014, as more operators signed agreements to support LoRa or Sigfox, it became apparent that the chatty competitors could lose hold of the IoT opportunity unless some positive actions were taken. On behalf of the network operators, the GSM Association (GSMA) lit the blue touch paper under the various committees and demanded to see a specification by early 2016.

The timing was opportune for Neul. With no sign of whitespace spectrum becoming available, it had started looking at migrating its technology into the licensed LTE spectrum for use by cellular operators.

A RATIONAL APPROACH

During 2015, the various proposals within 3GPP were rationalised, leading to the publication, in March 2016, of the Narrowband-IoT (NB-IoT) specification. It was the first standard for radio to use the term narrowband as a branding, possibly because the 3GPP marketing machine had failed to match the pace of the engineering teams. Just in case, the GSMA started calling it an LPWAN the following year and even came up with a logo – which probably illustrates how desperate it was.

A significant factor in the evolution of NB-IoT was the LTE-M Sig, set up by Vodafone in early 2013 and including Huawei, Ericsson, Nokia, u-blox, and a few others. Its objective was to develop a replacement for GSM for M2M but with a 20 dB better link budget, and offering between 10 and 15 years operation “on two AA alkaline batteries”.

Neul joined the Vodafone SIG, and combined its technology with similar proposals from Huawei – and, in the process, was acquired by the Chinese giant. This led to a partnership with Vodafone and u-blox to develop a low-



cost solution which became an important contribution to the development of the standard.

Neul joined around August 2013 and the group reported in early 2014.

There were huge and bitter ‘political’ battles in its development but it led to a new work item in GSM Edge Radio Access Network (GERAN) out of which emerged two main proposals: EC-GSM and NB-IoT. This all ran parallel with the GSMA activity.

The jury is still out on which standard will succeed. Both Sigfox and LoRa have struggled to reach their connections targets – but that probably has less to do with their technologies than the fact that IoT deployments are complicated. The connection is just one part of the equation and deployments are probably being delayed by other parts of the chain.

NB-IoT has found strong support in China with around 20 different companies designing NB-IoT chips. Marketing statements claim that silicon prices could fall to the \$1 mark by 2020. This may sound optimistic but there is nothing to suggest the \$1 price point will not be breached as volumes reach the billions – NB-IoT’s advantage is that narrowband chips are relatively simple to produce.

The cost of data is also falling. IoT network aggregator Ince has recently announced a “data for life” SIM, at the cost of €10 (\$11.60) for 500MB and 2500 SMS messages spread over 10-years.

The major suppliers claim that over 100 million NB-IoT chips have already been shipped, with a prediction of 180 million by the end of 2018. How many

of those will be actively sending data back to the cloud is another question, but volume helps.

The technologies mentioned so far are just the visible part of the narrowband iceberg. While the IoT community debates Sigfox, LoRa and NB-IoT, hundreds

LORA DEPLOYED

Low power and low cost, for both the device and spectrum mean that LoRa was the right technology for a network of flood detecting sensors.

of other narrowband companies are busily deploying networks around the world. Some of the larger ones, like Telensa and Ingenu, have secured tens of millions in investment dollars and have seen their names rise above the parapet.

Many others are quietly continuing to ship substantial numbers of narrowband products into vertical applications.

While much of the mobile world is obsessed with reaching higher data rates and streaming video, the narrowband industry is preparing to deploy connections by an order of magnitude that will never be achieved by smartphones or broadband radios. **CWJ**

NICK HUNN
CTO WiFore

Nick Hunn is the CTO of WiFore Consulting, a leading consultancy in the wireless technologies space, in particular M2M, smart energy, wearables and mHealth. He is also a SIG Champion for the CW Connected Devices group. Nick is currently working on the next generation audio standard for Bluetooth as well as advising companies on their IoT strategy.



TIM WHITTAKER
Senior consultant Cambridge Consultants

Tim Whittaker is a senior consultant at Cambridge Consultants, with particular responsibility for radio systems for data communications and voice. Over more than 20 years he has been a design leader, responsible for the overall system design of low-power wireless systems using Bluetooth, DECT, Wi-Fi and proprietary systems, as well as long-range radio and wireline systems..



 Continue the conversation on Twitter. Follow us on @cwjpress hashtag #NBtech

Consumer acceptance of The Internet of Things isn't something we are aiming at. It's already here with a diverse number of devices as Simon Rockman explains.

CONSUMER IOT



DIFFERENT DEVICES

While the handset market is dominated by identikit black rectangles, the IoT market is re-introducing design innovation to mobile devices. With a huge variety of applications comes the freedom to make technology look cool, friendly and innovative.

Top left to bottom right, devices from TCL, Leakbot, Vodafone Auto, Bleepbleeps, Alcatel, Arlo, Bleepbleeps and Kippy demonstrate that consumer IoT needs the product to look good.





M EET SNOOPY, AN eighteen-month-old spaniel and he's just taken out a Vodafone subscription. His V-Pet tracker cost £55 for the hardware plus a flat rate subscription of £4 per month. What Snoopy knows and most operators do not is that the internet of things is already here. It's not waiting for the sexy new standards like NB-IoT, it uses 3G and GPRS, or sending location data by SMS.

And the selection of products is hugely diverse. The one operator which has woken up to consumer IoT is Vodafone which has six products: V-Pet, V-Kids Watch, V-SOS Band, V-Bag, V-Auto, and V-Camera. Beyond this the Internet of Things market is being reshaped by devices enabled with Amazon Alexa, Google Home and other voice assistants. You'll be able to buy a Samsung Bixby device by Christmas.

More mainstream are devices like Nest and Hive. Central Heating control works well for a connected service because there

is already a recurring billing model and a clear customer benefit. Expect to see connected cookers and a bath which can be drawn online. We might even see the connected refrigerator, a technology promise which has mirrored the flying car in having been just around the corner since the 1950s.

LEARNING CURVE

One aspect of the new devices which is a challenge for the mobile industry is that they are being sold through new channels. British Gas is the reseller for Hive, and while the company is on a learning curve with the products (CWJ was told of one installation which took three engineer visits) it's something the installing companies are learning to live with. There are lots of standalone smart devices, things like the Ring doorbell which shows you who has pushed a "you were not in" card through your letterbox and the Nest smoke alarm which shows the history of your burning toast, even if it's not enough to trigger the alarm. Crucially it will message you if there is

smoke in the house when you are out.

Pulling all the IoT devices together is both a challenge and an opportunity. Sensor technology will be crucial to the development of IoT, but one sensor which is sometimes ignored is the mains network in a house. With machine learning a system can be developed which understands the habits of a householder – particularly an older person living alone, spotting that the 1 KW kettle goes on between 8:00 and 8:30 in the morning, when the oven, dishwasher or various lights are switched on and raising the alarm if, say the bathroom light goes on at 3:00am and isn't switched off. It may mean the householder has fallen. Or that they have left the light on, so combine other sensors – like one in the mattress – and a non-intrusive network can be built that will allow older people to live longer in their own homes.

IS IOT TO BE OTT2?

Operators have seen the Over The Top apps market slip away from them. Belief that they own the IoT market will be similarly arrogant. Giving over control of your home, car, pet and children implies a level of trust. It may be organisations, such as the other utilities, the post office or supermarkets which take on the role of service provider, each using the connected home as a mechanism to sell value added services. The consumer IoT perfectly demonstrates the William Gibson quote: "The future is already here — it's just not very evenly distributed." →



BABAHU X1

This smart toothbrush uses an AI partitioning algorithm to divide your teeth into six areas and brush them at different frequencies.



CONNECTED CURLERS

Smart really is getting everywhere. CW is working with ghd the haircare products company famed for its curlers and hair straighteners, which is looking to move from making products to supplying products with an online support element. To do this CW and ghd have created a new accelerator programme called the Innovation Hive. Five chosen companies will be invited to spend three months from October 2018 working alongside ghd R&D, the CW community and local technology mentors to co-design a prototype connected hair styling device. The work will be funded and if intellectual property from the ghd Innovation Hive is taken to market, start-ups may benefit from commercial terms. The areas ghd is most interested in exploring are connected and smart devices, sensor technology, IoT, apps, User experience, Machine learning and data processing, and Data security.

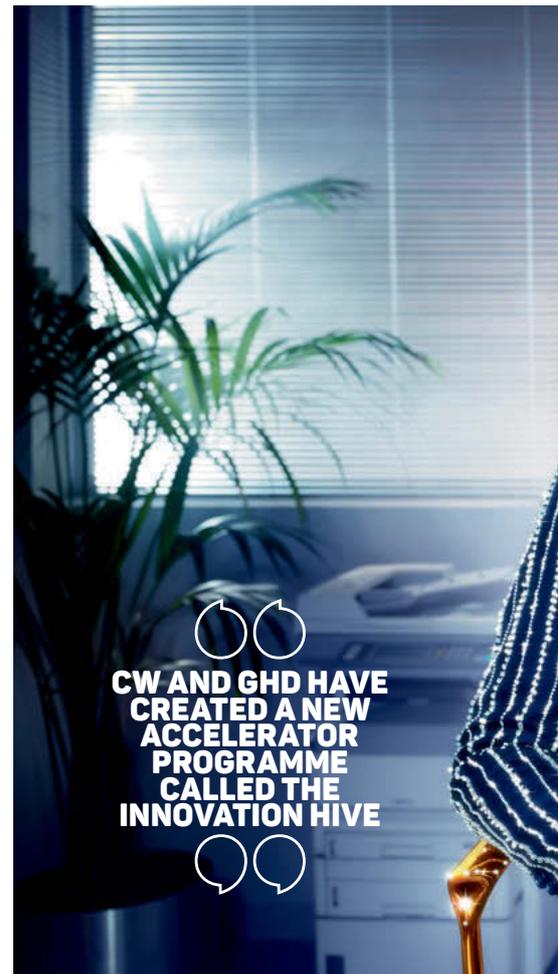
It's interesting to see a manufacturer from an area so far removed from communication technology getting involved with CW.

V-PET is a cross between a tracker and a Fitbit-style fitness app for dogs and is made by Kippy. It's physically quite big so while it was fine on Snoopy the Spaniel you'd find it too big for a

Chihuahua. Indeed, Vodafone says it's for pets over 4kg - but that's probably erring on the light side. It also says V-Pet is suitable for cats, but it would have to be a pretty sturdy kitty. The Kippy Vita smartphone base station app offers geofencing - the ability to set a safe zone which triggers an alarm if the boundaries are crossed - but the alarm has a delay and one Amazon reviewer says it doesn't keep up with his escape-artist dog.

The device uses an accelerometer and a six-axis gyro, Bluetooth Low Energy (BLE) and super low-power GPS. This enables the app to understand different activities including running, walking, playing, resting, sleeping, and jumping. It can send messages based on the breed, size and age of the dog to ensure it is getting sufficient exercise. Bluetooth is useful for finding your pet when it has wandered out of sight but is still within BLE range. Kippy offers developers support to offer applications beyond the standard live tracking, geofencing, messaging and notifications through access to its server.

Snoopy behaves well and is excellent on recall response, so geofencing isn't much of an issue, but the overall set-up time required does raise the question of whether IoT is ready for prime time. Installing the core V by Vodafone app requires both SMS and email registration. In response, Vodafone sends a code to your phone which has to be typed into the app (yes, the app could use an API to read it automatically - but it doesn't). Then you need to register the email address in the app and then do something similar with Kippy Vita. It's a lot of to-ing and fro-ing and that really



CW AND GHD HAVE
CREATED A NEW
ACCELERATOR
PROGRAMME
CALLED THE
INNOVATION HIVE

isn't what IoT should be about. There is also an issue that a dog-walker might think you're spying on them - which, indeed, you may be.

V-CAMERA shows Vodafone's approach allows it to cherry-pick products and a camera expert tells us that the Arlo Go security camera offered is the best of breed for wireless. The tariff of £4 a month is an amazing bargain for the 4G camera. This is because the usual setting is not for live-streaming but for motion detection and the Vodafone deal gives you seven days of storage.

The **ARLO GO** is truly wireless with great battery life of up to 30 days according to Vodafone (our expert says he gets a month and a bit). In size, the 4G Arlo Go is quite a bit chunkier than the Wi-Fi version and the publicity shots have been taken from an angle that hides this. What makes these cameras great is that they are so simple. Video quality is excellent



GHD



LEAKBOT

with strong night vision and the app supports multiple cameras. Nest cameras actually give better quality than Arlo but it's a USB wired solution and only suitable for locations where a cable can reach. There are, however, some more elegant options on the Nest app such as defining specific hotspots for spotting action or for live feeds from multiple cameras.

The V-Camera two-way sound – which is great if you want to put it by the front door to tell the Amazon courier where to hide that parcel. What it won't do is measure temperature, humidity or detect noxious gases – there is a Withings camera that does this but it bears a penalty in video quality.

V-AUTO is unusual in that it's a piece of hardware actually made by Vodafone, having bought the automotive tracker product maker Cobra based in the Northern Italian town of Varese, in June 2014. Most of the products which issued



V-AUTO

from this marriage have been for the corporate market, so a consumer product is a brave new world and a price tag of £85 marks serious IoT intent.

V-Auto plugs into a car's OBD-II port which is a connector for on-board diagnostics and has been mandatory in the EU since 2001 for petrol cars and 2003 for diesels.

LEAKBOT is a device which measures the temperature of the water in your pipes to spot leaks. Clipped next to a stopcock it measures both the air and water temperatures in your home. If you have a leak it will continually draw colder water from outside into your home, creating a consistent drop in temperature. LeakBot senses the prolonged and consistent drop in temperature and alerts you to the problem. There is a dedicated app and integration with insurance company apps.

SUZY SNOOZE is a connected nightlight and baby monitor which helps with sleep training, it was launched as a Kickstarter project and has done well in part thanks to the technology and in part thanks to its cute design. It has a soothing orange glow and plays gentle music which can be controlled from the Bluetooth linked app. Volume can be controlled either from the app or the hard buttons in the base. There is traditional baby alarm audio – but not video – and a child-friendly alarm clock function, although getting small children to saty in bed is usually more of a problem than waking them, you can tell the children it's not time to get up until Suzy wakes up. **CWJ**

SIMON ROCKMAN

Publisher, CW Journal

Simon is an experienced technology writer and was Editor of Personal Computer World in the late 1980s. He also created the world's first consumer magazine about telecoms, What Mobile. He has held senior roles at Motorola, Sony Mobile, and the GSMA. He is also founder of Fuss Free Phones, a unique MVNO catering for the telecom needs of older people.

Continue the conversation on Twitter. Follow us on @cwjpress hashtag #ConsumerIoT

