

Narrowband-IoT: pushing the boundaries of IoT

Narrowband-IoT (NB-IoT) is a new standard connecting internet of things projects.

vodafone.com/iot/nb-iot

The future is exciting.

Ready?

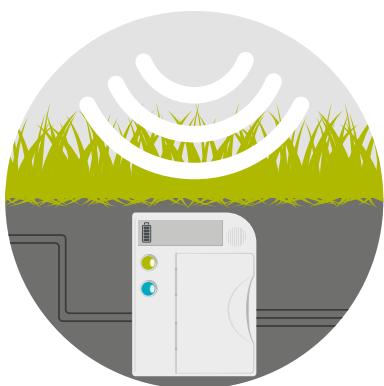


Executive summary

This paper gives technical decision-makers an overview of NB-IoT, the communications technology that will underpin industrial-grade internet of things deployments.

Introducing LPWA and NB-IoT

Low Power Wide Area (LPWA) describes a category of wireless communication technologies designed to support internet of things (IoT) deployments. LPWA technologies are designed to deliver:



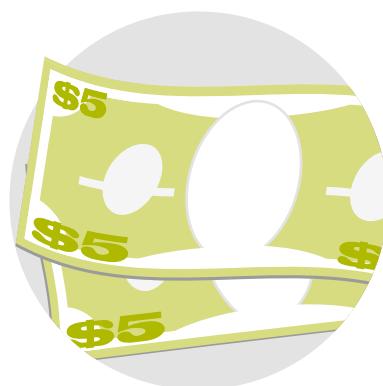
Strong coverage over large areas, even when devices are underground or deep within buildings



Great power efficiency, so devices can run on batteries for 10 years or more without a charge



Massive scale, connecting potentially millions of devices at once in a single deployment



Low cost communications hardware, enabling data collection devices to be built for less than \$10



Low bandwidth, with most use cases requiring just a few bytes of data to be transmitted per device per day

A number of different technologies have been developed to fulfil LPWA requirements, and we believe Narrowband IoT (NB-IoT) not only offers enterprise-grade technical specifications, but is also the practical choice for carriers, device manufacturers and ultimately enterprise users. To understand why NB-IoT is uniquely suited to business IoT deployments, we compare NB-IoT against two LPWA alternatives, LoRa and Sigfox.

For more detail about LPWA, NB-IoT and its competition, see page 5.

Key findings

The evolution of the Internet of Things means that there is an urgent need for a low-power way to connect thousands of devices in field. NB-IoT fits the bill perfectly.

Industrial grade technology:

NB-IoT offers great range, throughput and power efficiency at a low price.

- **Coverage in challenging deployments.** NB-IoT offers coverage penetration in difficult environments that characterise LPWA use cases. Because it uses licensed spectrum bands (just like 3G and 4G) NB-IoT isn't significantly affected by interference.
- **Faster data throughput,** without limitations on usage. NB-IoT isn't limited by legal restrictions on how often each device can transmit — so-called "duty cycle". This gives it a performance boost, which is vital when planning ahead a decade or more.
- **Flexible power management for 15-year operational lifespans.** Despite its coverage and performance advantages, NB-IoT offers comparable battery life to

other LPWA technologies, thanks in part to advanced power-saving modes that minimise unnecessary chatter over the network.

- **Simple designs for cost-effectiveness.** NB-IoT has been designed to minimise hardware costs, from chipset fabrication to antennas. We forecast that communications component costs will drop to \$2 once full production is reached.

For more about the technical advantages of NB-IoT, see page 6.

The practical choice:

NB-IoT is an open standard based on LTE. It has the backing of major equipment manufacturers, and is based on familiar technology for easier integration into existing infrastructure and processes.

- **Fast and flexible for carriers to deploy.** NB-IoT can be flexibly deployed on any existing network, either leveraging the LTE network footprint in-band or co-existing with other network technologies in standalone mode.
- **Broad market support as an open 3GPP standard.** NB-IoT is an open standard. A critical mass of network operators and hardware manufacturers are backing NB-IoT. It's the safe bet for long-term commitment globally, and benefits from economies of scale.

- **Easy to integrate into traditional cellular technology ecosystems.** In many ways NB-IoT behaves like LTE, so it's familiar to network engineers, application developers and hardware developers.

For more about the practical reasons in NB-IoT's favour, see page 10.

Secure and available

Security is important in any IoT deployment. NB-IoT inherits LTE's strong security features, making it the safest choice.

- **LPWA security matters.** Even the simplest networked devices can cause business disruption if they're breached. Security is critical.
- **Securing ultra-simple devices is challenging.** The limited bandwidth and processing power makes even foundational security practices like authentication and encryption non-trivial.
- **Proprietary LPWA technologies don't do enough.** While LoRa encrypts its traffic, Sigfox doesn't. And both are vulnerable to jamming.

- **NB-IoT inherits LTE's authentication and encryption.** NB-IoT mutually authenticates the network and the device, and encrypts traffic between the device and deep within the core network.

For more about the security considerations around LPWA, see page 14.

Introduction:

Why LPWA technologies matter

The right connectivity can make or break your IoT project. We believe that NB-IoT is the right option for most low-power, wide-area, business IoT use cases. Let us show you why.

Massive-scale IoT projects have specific connectivity needs

Look at many of the most promising applications for IoT and you'll find the same basic wireless connectivity needs. Whether it's smart water meters, connected agriculture, smart cities or asset tracking, these connected devices need:

- **Long lifespans in the field:** devices, such as soil condition monitors in precision agriculture, are often deployed without reliable access to power. Batteries must last for the lifetime of the device — perhaps a decade or more.
- **Deep coverage:** devices, such as water and gas meters, may be deployed in rural areas, beneath manhole covers or deep within building basements. The network connection must offer strong penetration and reach.
- **Massive scale, at low cost:** devices, such as smoke or fire alarms or smart rubbish bins, may be deployed in their thousands or millions. The device and connectivity cost must be low and networks must be able to support high density of devices while guaranteeing QoS.
- **Low bandwidth:** devices may often send only a few bytes of data each day — for instance, smart parking sensors may only ping the network when a bay becomes free. These use cases don't need to support voice or even duplex data transmission.

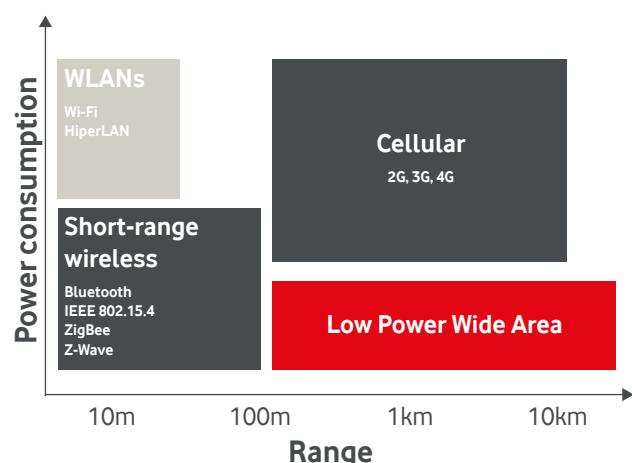
No conventional connectivity standard satisfies all of these criteria. Wired connections are ideal for IoT deployments in buildings and offices, but out of the question when looking at devices in the field, especially where there is no cabling or power. Some wireless technologies — like Wi-Fi, Bluetooth or Zigbee — don't have the range for large-scale deployments. Others — like 3G and 4G — do offer multi-kilometre range, but are designed for high data throughput. And this makes them expensive and power-hungry. For example, a typical 4G IoT module might cost \$40 and have a battery life of less than a year — which is not an issue when installed in a connected car or digital signage, but would be unfeasible for an application like a smart parking sensor.

Machina Research has tracked that there are now more than 40 million active LPWA endpoints, as of June 2016, and predicts that LPWA technologies will account for more than half of all wireless IoT connections by 2024.

The “five 10s” of LPWA

What's needed in applications like these is a low-power, low-cost, long-range wireless technology. That's why in the past few years we've seen the rise of a new category of connectivity: LPWA, or low-power wide-area.

There's no precise definition of LPWA, but here's a rule of thumb: an LPWA device should be able to last for **10 years** in the field, connect as far as **10km** from the cell, and cost under **\$10**, when transmitting down to **10s of bytes** per hour. Each cell or base station should be able to support more than **10k** devices.



Many technologies are competing in LPWA

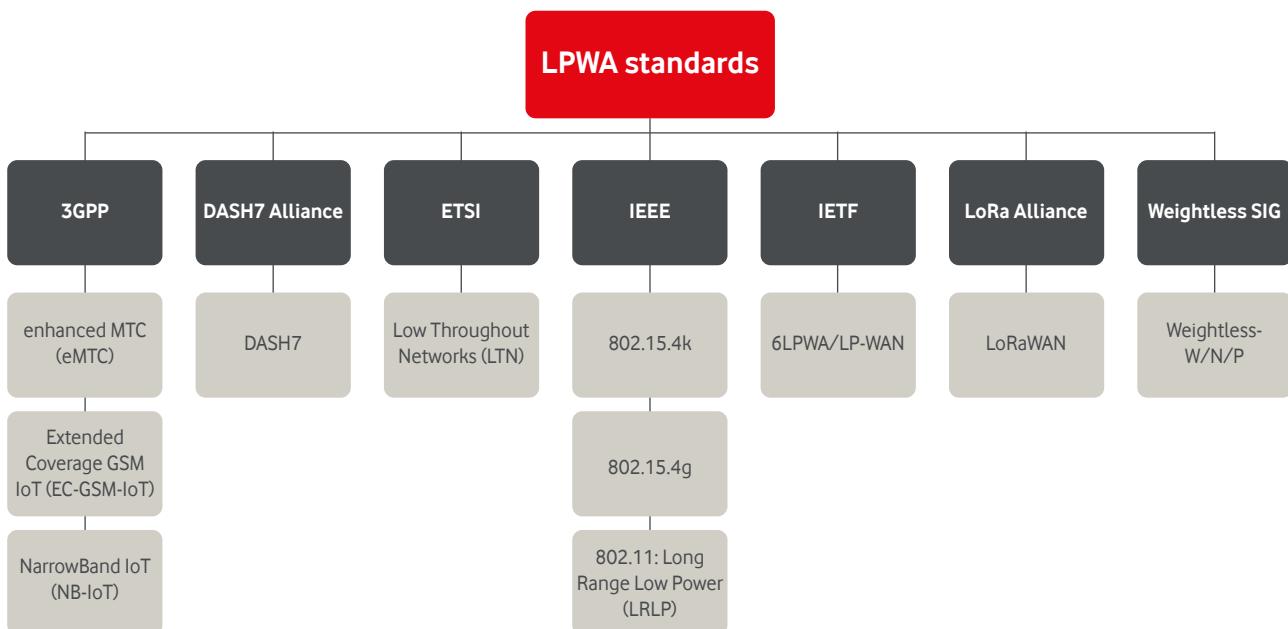
Many different technologies are being developed to meet these or similar criteria, sponsored by a wide variety of private companies, consortia, standards bodies and alliances. Weightless, DASH 7, 802.11ah, Ingenu, LTE-M, EC-GSM-IoT — these, and many others, are all competing for market share, and they often take very different approaches to meet the criteria that LPWA use cases need; not least, whether they're based on open standards or built on proprietary technology stacks.

However, a few technologies — notably Sigfox, LoRa and NB-IoT — have emerged as the front-runners in LPWA. Each has multiple high-profile deployments in the field and sufficient technological maturity and market support that they are likely be considered by any enterprise developing LPWA IoT projects.

Which is the right technology for your LPWA project's connectivity needs? And which is the safest option for your organisation to bet on in the long run? After all, your business cases are based on devices operating in the field for a decade or more.

Vodafone has evaluated each LPWA technology under development, and made the decision to commit to NB-IoT. We believe that global standard technologies are the way forward to guarantee security, interoperability, scalability, quality of service and longevity. In particular, NB-IoT is designed to address low-power wide-area requirements and we believe it to be both suited to large-scale deployments and have impressive prospects for widespread market success.

This paper describes the many factors that led us to our decision. If you're involved in technology decisions for your IoT projects, we urge you to consider our findings.



NB-IoT in a nutshell

NB-IoT is a specification developed by 3GPP, and standardised as part of 3GPP Release 13 in June 2016. It's a cellular technology related to LTE, designed specifically for LPWA applications, using licensed spectrum on a range of possible bands. It was designed to offer 20dB coverage improvement versus GSM, 12–15 years operation on a single battery charge, low device cost, and compatibility with existing cellular network infrastructure, with the same level of security as LTE. It can be deployed in a variety of frequency bands using a bandwidth of only 200 kHz as a self-contained carrier.

Find out more detail about the features of NB-IoT as described in the 3GPP specification Release 13 from June 2016, available here: http://www.3gpp.org/images/PDF/R13_IOT_rev3.pdf

NB-IoT:

Industrial grade

LPWA is designed to deliver the greatest coverage for the lowest power consumption, and at the lowest cost, while still maintaining sufficient real-world data throughput. We have compared NB-IoT against LoRa and Sigfox in all four areas.

	Sigfox	LoRa	NB-IoT
Coverage	160dB	157dB	164dB
Technology	Proprietary	Proprietary	Open LTE
Spectrum	Unlicensed	Unlicensed	Licensed (LTE/any)
Duty Cycle restrictions	Yes	Yes	No
Output power restrictions	Yes (14dBm = 25mW)	Yes (14dBm = 25mW)	No (23dBm = 200mW)
Downlink data rate	0.1kbps	0.3 – 50kbps	0.5 – 200kbps
Uplink data rate	0.1kbps	0.3 – 50kbps	0.3 – 180kbps
Battery life (200b/day)	10+ years	10+ years	15+ years
Module cost	<\$10 (2016)	<\$10 (2016)	\$7 (2017) to <\$2 (2020)
Security	Low	Low	Very high

Fig 1. Key technical specifications for NB-IoT (from R1-157741, Summary of NB-IoT evaluations results, 3GPP RAN1#83, Nov 2015), Sigfox, and LoRa (from LoRaWAN: a technical overview of LoRa and LoRaWAN, LoRa Alliance, Nov 2015).

1. Deeper coverage in challenging deployments

LPWA deployments often involve devices being installed across a large area in less than ideal spots for a strong radio signal. Devices may be installed underground, deep within buildings, or in rural areas far from the nearest mast.

A connectivity technology that delivers better coverage not only means that devices in “edge” deployments are more likely to be able to connect to the network: it also means each device is likely to be able to communicate at closer to peak throughput, and it means that the network can manage with fewer base stations (or gateways, repeaters and signal concentrators, depending on the network type) to cover a given area.

Maximum link budget is a way of quantifying a connection’s performance accounting for attenuation and other losses, and it gives us a simple way of comparing different radio communications technologies fairly. Figure 1 shows the maximum link budget for NB-IoT, LoRa and Sigfox.

NB-IoT offers deeper coverage than alternative LPWA technologies, and compared to conventional GSM/GPRS, a huge 20dB advantage, which equates to a sevenfold increase in coverage. In our live trials, NB-IoT has been shown to penetrate an additional two to three double-brick walls, enabling reliable connectivity of devices in underground car parks and basements.



LoRa



Sigfox



NB-IoT

Fig 2. NB-IoT delivers a huge increase in coverage.

2. Faster data throughput, without duty cycle limitations

Many LPWA use cases require only minimal bandwidth, instead prioritising coverage and power efficiency. But all other factors being equal, having more bandwidth available is a good thing. It gives customers more headroom to evolve their use of the technology in the years ahead. But perhaps more importantly, it also ensures performance is acceptable even in extended coverage situations.

NB-IoT has a theoretical bandwidth advantage over both Sigfox and LoRa, with downlink rates of up to 235kbps (when deployed standalone). By comparison, LoRa's maximum data rate is 27kbps. But at the extreme limits of coverage, with a signal to noise ratio of -12.6dB, a standalone deployment of NB-IoT transfers 3kbps downlink (as Figure 3 shows) — a significant speed drop due to repetitions. Apply the same kind of signal degradation to a slower technology like Sigfox and LoRa and the data transfer rates drop close to zero.

	Good	Cell-edge	Deep coverage +10dB	Extreme coverage +20dB
	SNR > 7.4dB	SNR = 7.4dB	SNR = -2.6dB	SNR = -12.6dB
Downlink (kbps)	235	75	34	3

Fig 3. NB-IoT downlink throughput at different coverage levels (from R1-157741, Summary of NB-IoT evaluations results, 3GPP RAN1#83, Nov 2015).

The most significant bandwidth constraint for network technologies like LoRa and Sigfox is that, on their unlicensed spectrum bands, they're subject to heavy legal restrictions on duty cycle — the percentage of time that a channel may be actively occupied on the network. Duty cycle restrictions are typically 1%.

Let's see how that impacts real-world data transfer using Sigfox, for example. A Sigfox message has a maximum payload of 12 bytes, and takes about six seconds to transmit. At 1% duty cycle maximum, a Sigfox device can send up to 144 messages per 24-hour period, for a daily data maximum of about 1.6KB.

This may not be a problem during normal usage, where a device is only expected to transmit a daily status update payload of a few bytes. But it may be a real limiting factor during periods of high activity, when interference demands that a high percentage of packets are retransmitted, or in exceptional circumstances — such as pushing a new firmware version to a device over the air to secure a vulnerability.

High network load causes interference in LoRa

Like all radio networks, LoRa's performance degrades the further away clients move from the gateway or base station — for LoRa, this starts to be significant at about 2km. LoRa and Sigfox operate in unlicensed ISM bands at 868 MHz (in Europe) and 902 MHz (in the USA). These bands are regulated with duty cycling and output power restrictions. Additionally, various other services such as wireless alarm systems and remote controls also operate in this band. These factors significantly affect performance (see Ofcom Final Report, Short Range Devices operating in 862–686 MHz band, Ovum, Aug 2010). But more problematically, LoRa's throughput also degrades dramatically when the network is congested and under high load. Its weak traffic management results in high levels of packet loss due to collisions and interference. This starts to become an issue when more than just a few hundred devices are communicating, which is a significant problem — one of the defining characteristics of LPWA is that it can scale to millions of devices. And by contrast NB-IoT is designed to carry 100k–200k devices per 200kHz carrier on a cell, while Sigfox claims up to a million devices per access point.

3. Flexible power management for up to 15-year operational lifespans

All LPWA technologies prize power efficiency by design. While actual battery lifespan depends totally on the strength of the device's network reception and how much data it transfers each day, most LPWA devices can happily endure for ten years without a charge, even accounting for battery self-discharge and other factors.

NB-IoT does even better than that. It has been rigorously engineered and in our statistical models can comfortably achieve lifespans of around 15 years even on the very edge of coverage, as Figure 4 shows.

Years of battery life for a 5 Watt-hour battery:	Cell edge (144dB MCL)	Deep coverage (154dB MCL)	Extreme coverage (164dB MCL)
50 bytes/day	36.7	33.1	20
200 bytes/day	36.3	29.7	14.2

Fig 4. Estimated battery life (in years) for different coverage levels and data volumes. Source: R1-157741, Summary of NB-IoT evaluation results, 3GPP RAN1#83, Nov 2015.

There are many ways to reduce power usage and achieve these kinds of lifespans. Most simply, you can keep the device in idle mode or deep sleep, so it doesn't waste power chatting to the network between communication sessions. Power management is fundamentally a balance between message frequency, device sleep cycles and business case needs.

LTE-M: extra bandwidth for more demanding use cases

For applications where greater bandwidth is needed than NB-IoT, 3GPP standards have defined another LPWA technology: LTE-M, also known as LTE Cat M1. LTE-M is less flexible in its deployment models and its coverage is not as strong, but it offers up to 5x the downlink data rate. NB-IoT and CAT-M are complementary communications technologies that Vodafone can support on its LTE networks. We have prioritised the deployment of NB-IoT technology initially across our networks to address the immediate need for low power and deep penetration applications that have not historically been served by cellular connectivity.

South East Water: coverage underground

In Australia, the use of NB-IoT has been trialled with South East Water to monitor rainwater tanks and pipe flow, as well as to guard against unauthorised entry to sewers, car parks and other sites. South East Water ultimately wants to be able to analyse performance, asset condition and fault management across its networks in real time. Because many of the monitoring sensors will be installed under manhole covers and underground, it's ideal proof of NB-IoT's ability to offer strong signal penetration.

NB-IoT features two power-saving capabilities that work in tandem to maximise performance and efficiency: Extended Discontinuous Reception (eDRX) and Power Saving Mode (PSM).

When a device is connected to the network, the network periodically sends paging messages on its control channels, which devices listen for and can respond to. Typically these messages happen at least every few seconds, enabling the network to maintain accurate information about the devices connected to it, but at the cost of battery life: the devices are effectively always awake. For maximum efficiency, Power Saving Mode (PSM) enables devices to slip into a deep sleep state for up to 310 hours, only then waking to update the network and listen to pages for a brief period before sleeping again. During deep sleep the device is not reachable. Extended Discontinuous Reception (eDRX) extends the paging interval cycle up to nearly three hours, eliminating unnecessary receiver activations while still allowing the network to reach the client device when needed.

4. Simple designs for cost-effectiveness

One of the main arguments for Sigfox and LoRa is that GSM-family technologies are generally complex. But NB-IoT has been designed from a cellular standpoint to minimise many of the factors that have conventionally increased hardware costs for GSM client devices.

NB-IoT hardware modules for example need limited memory (which is of the more affordable PSRAM variety), only a single antenna, and have no need for full-duplex operation, thereby avoiding the cost of an RF duplexer. Compared to LTE, they have very relaxed constraints on timing delays, making chip design and production less stringent. NB-IoT devices have lower clock rates and can therefore be produced on larger dies in more mature semiconductor fabs, at a lower cost. The use of limited 200kHz bandwidth reduces the size of buffers and processing blocks, while the choice of decoder simplifies the design of the modem and digital signal processor (DSP).

As a result of all this, we expect that NB-IoT devices, including baseband and RF chipsets, will cost as little as \$2 by end of 2020, compared to approximately \$40 for an LTE device today. This will make NB-IoT communications components at least as affordable as LoRa and Sigfox.



NB-IoT:

The practical choice

NB-IoT is gaining support from a wide number of industry participants, making it a safe choice for long-term deployments.

1. Fast and flexible for carriers to deploy

When you choose an LPWA technology, you need to be sure that there will be networks available where you plan to deploy, with significant national and international coverage for you to scale up your business.

NB-IoT is a 3GPP standard closely related to LTE technology. As a result, it can be deployed on almost all LTE base stations, alongside LTE traffic, through a straightforward software upgrade to the radio access network (RAN). Vodafone is in the process of adding NB-IoT to about 85% of its network through a software upgrade, with the rest upgradeable after a small hardware modification, and the goal is to enable all LTE sites with NB-IoT by 2020. Trials so far have demonstrated that NB-IoT is able to co-exist with legacy technologies.

Network operators can choose from three deployment options to suit different network environments, making NB-IoT perhaps the most flexible LPWA technology. It's designed to fit into 180KHz of spectrum, so it fits neatly within one or more standard LTE Physical Resource Block (PRB). Where it's undesirable to divert any capacity away from LTE, NB-IoT can also be deployed within the "guard band" at the edge of an LTE allocation — the gap between frequency bands that's designed to prevent interference. NB-IoT can also be deployed standalone on a single GSM carrier spectrum, for example in locations where a carrier's full 4G rollout plans aren't yet defined, or standalone alongside an LTE spectrum band. Whichever way it's deployed, NB-IoT does not rely on any other system's signalling resources.

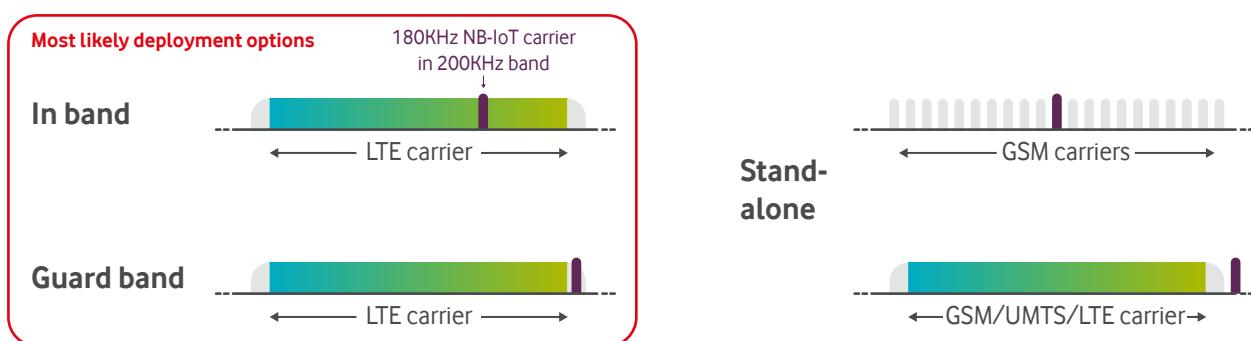


Fig 5. NB-IoT is closely related to 4G LTE.

This flexibility of deployment and ability to reuse existing network assets is a huge advantage over proprietary radio technologies like Sigfox and LoRa, where new network infrastructure — gateways, masts, repeaters and so on — must be deployed and managed separately, either by a carrier or by an enterprise or consortium of enterprises directly.

Such deployments are not only costly and slow, but may also involve challenges around planning permission, backhaul provisioning and other intractable problems, particularly in dense urban areas.



Aguas de Valencia: remote monitoring, without the hassle of network management

Aguas de Valencia is multinational water provider. It's committed to innovation, and was an early adopter of automated meter reading. Today it manages more than 600,000 automated meter reading devices, which until now used a proprietary technology that required Aguas de Valencia to install and maintain its own infrastructure. It wanted to migrate to a new communications technology that enabled it to remotely monitor meters without running its own infrastructure.

NB-IoT was the ideal candidate. Aguas de Valencia worked with Vodafone on a trial, testing NB-IoT's ability to provide coverage in hard-to-reach meter locations.

"The most important aspect of the trial was to identify locations where it's harder for a signal to reach, such as meter rooms in basements with little or no coverage, meter boxes below ground, and recess niches with metal covers that block the signal. So far the results have been very promising as the signal has been able to reach its destination without any issues in all of the locations tested. We'll be able to outsource communications to a telecoms carrier that guarantees data quality and security. The life of a meter is about 10 years, aligned with battery life that this technology will be able to provide."

Víctor González, Director of Meters and Remote Reading, Aguas de Valencia



2. Broad market support as an open 3GPP standard

When you commit to an LPWA technology for ten years or more, you need to be sure that your chosen technology has a stable future.

Because NB-IoT is an open 3GPP standard, it gives enterprises the reassurance that they're making a low-risk, long-term technology commitment, free of the risks associated with proprietary technology.

Sigfox is an entirely proprietary technology. Although there are a number of manufacturers making Sigfox client device hardware, and network operators deploying Sigfox networks, all data moves through the Sigfox cloud, where it can be accessed through APIs. Enterprises choosing Sigfox could be dependent on the fortunes of its controlling company for future support. You have to think about the long-term security of your smart-metering deployment and choose the safest technology for you.

For its part, LoRa is backed by the LoRa Alliance and the LoRaWAN networking protocol (co-developed with IBM) is open source, but the underlying radio technology is proprietary, so again customers are locked in to a single provider.

Proprietary solutions are also not subject to the same multilateral scrutiny as open standards, nor do they have the same access to R&D resources during their development. This can be an important consideration when it comes to issues like security or performance optimisation.

A proprietary technology built on a single vendor's commercial intellectual property will always bear some degree of additional cost. Sigfox, and LoRa's developer, Semtech, license their technologies to network equipment manufacturers and device manufacturers for a fee; this fee is passed on to enterprise customers. When devices are heading toward \$2–\$10 each, and when enterprises are potentially buying millions of devices, the intellectual property overhead becomes significant.

Conversely, customers that choose NB-IoT benefit from all the effects of market forces. Already NB-IoT has broad support from network operators like AT&T, Telefonica, China Unicom, China Mobile, Deutsche Telekom, Verizon and Telstra, as well as Vodafone. Even operators that are deploying LoRa and Sigfox, like Orange, are also investing in NB-IoT.

Overall, NB-IoT is supported by over 30 of the world's largest operators, which provide communications for more than 3.4 billion customers and geographically serve over 90% of the IoT market.

This popularity will naturally snowball and reinforce NB-IoT's position as the most widely available LPWA technology. It also means that customers can standardise on a single LPWA technology for deployments around the world.

These same trends apply to device manufacturers. Leading equipment makers like Ericsson, Huawei, Nokia, Qualcomm and Intel are all committed to NB-IoT, meaning customers will get a wider choice of end devices to suit different use cases, at a lower cost. As already discussed, it is anticipated that the end cost of NB-IoT terminals will be noticeably lower than that of Sigfox and LoRa devices.

“If you look at the history of wireless, the only successful technologies are open standard. There are no examples of proprietary ones being very successful, so I can't see how the proprietary LPWAN vendors can last long-term”

Professor William Webb, CEO, Weightless; former President, IET; former Director, Ofcom

3. Easy to integrate into traditional cellular technology ecosystems

Communications technologies should work well with other elements of the IoT solution. If they're challenging to integrate into the applications and processes that need them, the overall ROI of the project will suffer.

NB-IoT behaves very much like traditional cellular communications technologies, with predictable traffic handling, security features and so on. On the Vodafone IoT network in particular, NB-IoT connections can be managed seamlessly alongside other IoT SIMs on the Global IoT Platform, including reporting, self-service control over SIM states, use of alerts and business rules, and API access. Customers don't need to maintain separate processes, user access rights, software platforms or documentation to manage their LPWA deployments.

Other LPWA technologies may have unusual behaviour or limitations that application developers must understand and plan for.

For example, LoRa's traffic-handling is extremely limited, and under high traffic load, packet loss can reach more than 60%. LoRa does support an unsophisticated flag-based method of confirming packet delivery, but in order to confirm delivery a second packet must be sent — which further increases load on the network and results in more collisions and even greater packet loss, and unpredictable latency caused by retransmission of data. This creates real headaches for developers that rely on assured, timely packet delivery.

NB-IoT Testing Labs will simplify solution development

The industry community behind NB-IoT is opening a number of Open Labs across the world, giving hardware developers and enterprises a place to build, test and certify NB-IoT-based solutions on a sandboxed network environment. The world's first NB-IoT Open Lab, based in Newbury, was launched by Vodafone and Huawei in 2016, and a second opens in Düsseldorf in February 2017. China Mobile, Etisalat and many others will follow in short order throughout 2017. To arrange a visit to our Open Lab, contact your Vodafone Account Manager. Or for more details about NB-IoT, visit: www.vodafone.com/business/iot/nb-IoT



Security and availability

LPWA deployments need protecting just as much as any IoT solution. NB-IoT inherits all the well-proven security measures of LTE.

LPWA security matters

Every survey of enterprise IoT adopters — including **Vodafone's IoT Barometer** — highlights the importance of security in IoT deployments. Enterprises are concerned that their IoT devices and connections will be vulnerable to hackers looking to steal data, bring down services, or cause disruption by taking control of remote assets.

It's tempting to view LPWA devices as too limited or uninteresting to need protecting. After all, what's the worst that can happen if a hacker can tamper with a simple sensor, for example in a smart bin or smoke alarm? The reality is that the security of these devices does matter. If an attacker could trigger ten thousand smoke alarms simultaneously, tell a council's refuse team that every bin in the city needs emptying all at once, or overload a farmer's fields with fertiliser by tampering with soil sensors, chaos would ensue.

Securing ultra-simple devices is challenging

The challenge is how to adequately secure these devices in practice, using the foundational security pillars such as authentication and encryption. Most LPWA deployments, by design, have little room for security.

For a \$2–\$5 device that needs to conserve power, the processor overhead of encrypting and decrypting traffic is meaningful. And under the limitations of a 1% duty cycle, it can be difficult to spare the few extra bytes needed to authenticate a communications session. That same limited throughput also leaves no spare capacity for patching devices to close vulnerabilities discovered during their in-field lifespan. Layering a central traffic monitoring solution over the top to identify suspicious traffic is one response, but it does little to actually prevent or react to disruption.

Other LPWA technologies don't do enough

In the eyes of the security community, there are inherent disadvantages to both LoRa and Sigfox: proprietary code reduces the ability to scrutinise it and identify vulnerabilities before hackers can exploit them.

That aside, neither LoRa nor Sigfox build in sufficiently robust security. Sigfox has hardly any: the communications channel is not encrypted and there is no authentication built in; Sigfox recommends that security is managed at the application layer instead. LoRa encrypts the message payload using an application session key, and message integrity is verified using a network session key, each provided when the device joins the network. But cryptographic key management is challenging.

Furthermore, because ISM radio frequency bands need no licence to transmit on, it's legal for anyone — including malicious hackers — to transmit data compatible with the LoRa specification and thereby jam legitimate LoRa data transmissions, creating a denial of service effect. Denial of service is just as damaging as a security breach.

NB-IoT inherits LTE's authentication and encryption

NB-IoT is a 3GPP standard closely related to LTE and inherits all of the security techniques associated with it. A secret key built into the NB-IoT SIM at point of manufacture is used to mutually authenticate the network and the device, and to generate frequently updated session keys for encrypting traffic between the device and deep within the core network.

Obviously, where necessary and practical, additional "over the top" layers of security can be applied to the device, communications and application to increase the level of protection.

Next steps

We believe the technological and market advantages make NB-IoT the clear choice for any enterprise pursuing a LPWA solution today. But you'd be right to test the technology for yourself before making any commitment. We're here to help.

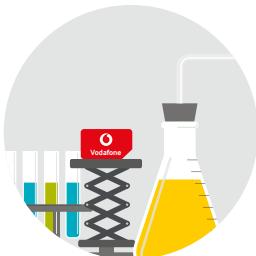
Here are three steps you can take:

1



Discuss NB-IoT as part of the NB-IoT Forum, formed by the GSMA — contact us for details of how to participate.

2



Experience NB-IoT at our Open Labs in Newbury, UK or Düsseldorf, Germany, to test example hardware modules and examine our network testbed, and request the latest information on field trial applications.

3



Contact your Vodafone Account Manager for sample NB-IoT modules and SDK support to accelerate your solution development. Find out more at: www.vodafone.com/business/iot/nb-IoT.

About Vodafone

Vodafone is at the forefront of IoT and of NB-IoT.

We have more than 25 years of experience in IoT and over 45 million active IoT connections. Our IoT customers represent every sector, giving us deep insight into the kinds of applications that are driving demand for LPWA technologies. And we're putting that insight to work, as chair of the NB-IoT Forum and one of the leading developers of 3GPP IoT standards.

Of course, we're best known as operators of one of the world's largest communications networks, and we've committed to fully rolling out NB-IoT across it by 2020. Already we've demonstrated live NB-IoT trials and customer pilots in cities and rural communities across the globe.

But our offering extends far beyond just network connectivity. From our professional services and testing facilities to support you at the start of your project, we offer everything you need: our market-leading IoT connectivity platform, a range of secure, global SIM types, and market-leading hardware both Vodafone-branded and from a wide range of partners.

To find out more about who we are and what we do, visit vodafone.com/iot

vodafone.com/iot/nb-iot

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