
T-MOBILE | IoT
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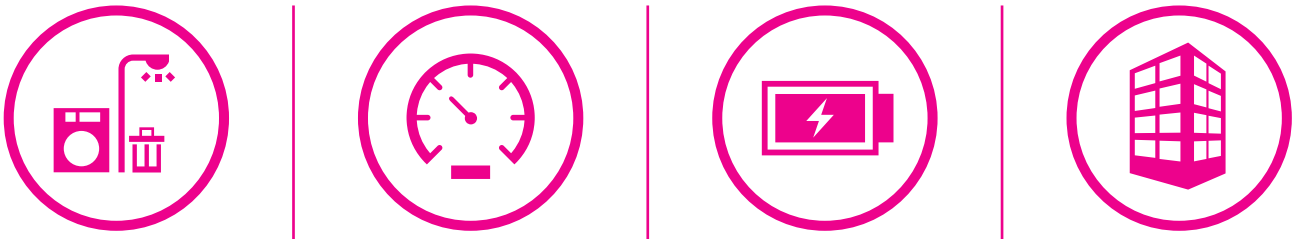
THE GAME CHANGER
FOR THE INTERNET OF THINGS

INTRODUCTION

The Internet of Things (IoT) is rapidly creating new ecosystems, revealing new insights and efficiencies, and enabling a vast array of new services and business models. While headline-grabbing IoT applications such as augmented reality or self-driving cars capture the imagination, many IoT use cases do not need to rely on high-performance wireless modules and low-latency, high-bandwidth connectivity.

For Low Power Wide Area (LPWA) applications—such as smart metering, tracking of assets, and monitoring equipment—the key requirement is the ability to periodically exchange small amounts of data easily, reliably, and cost-effectively. Unlike most other existing mobile communications technologies, Narrowband IoT (NB-IoT) is optimized for these types of applications—making NB-IoT an ideal network technology for a broad array of IoT solutions.



Billions of devices
Up to 100x more devices per cell (compared to GSM)

Low data volume
Bidirectional, infrequent transmission of low data volumes. Data rates avg throughput of ~60bps[1]

Low energy consumption
Up to 10 years of battery-powered operation[2]

Deep indoor penetration
+20 dB link budget (compared to GSM)

[1] Dependent on network utilization and signal strength
[2] Assuming equivalent of 2 AA batteries and typical traffic pattern

Picture 1: NB-IoT's core benefits

Designed for massive IoT

In its 2016 Release 13 standards, the 3rd Generation Partnership Project (3GPP), a worldwide alliance of telecommunications companies and partners, published a series of innovative cellular technologies optimized for IoT. Among these 3GPP-defined standards is Narrowband IoT, a genuine game changer for IoT solution providers that expands the technical possibilities and makes massive IoT deployments economically feasible.

NB-IoT utilizes LTE network operators' existing assets, such as sites, base stations, antennae, backhaul, and licensed spectrum. These licensed bands can handle a massive number of devices while remaining stable and avoiding interference. In contrast, data transmission on unlicensed bands is likely to deteriorate as the number of connected devices increases.

Catering to the low-bandwidth requirements of many IoT use cases in industrial, public, and consumer domains, NB-IoT's advantages include lower costs, reduced power consumption, and deeper indoor coverage. Based on a global industry standard and operated within licensed spectrum, NB-IoT also addresses customers' needs for international operations, stability, reliability, security, cost-effectiveness, and high scalability. As part of its commitment to accelerating IoT innovation, T-Mobile deployed the first nationwide Narrowband network in the US in summer 2018.

LPWA: DIFFERENT NETWORKS FOR DIFFERENT PURPOSES

Long Term Evolution for Machines (LTE-M), also called LTE Cat-M1, Cat-M, or eMTC, is another 3GPP-defined LPWA standard. Like NB-IoT, it serves as an extension of the current LTE standard, but it can transmit higher data rates than NB-IoT. While LTE-M requires significantly more spectrum bandwidth, and LTE-M radio modules are typically more complex and costlier than NB-IoT modules.

While LPWAN includes technologies such as NB-IoT and Cat-M, LTE Category 1 devices (LTE Cat 1) are not part of this classification and were originally defined as part of the 3GPP Release 10. LTE Cat 1 is a technology well suited for applications requiring voice services while also supporting the key features required for IoT devices typically associated with NB-IoT. NB-IoT and Cat 1 technologies complement each other by meeting the different needs of diverse IoT use cases.

There are also other commercially available wireless communication modules for connecting to GSM, 3G, or LTE mobile networks. These modules support a wide range of services, many of which are not required for IoT use cases, which drives up the average hardware cost. Plus, as neither of these networks nor the devices are designed for energy saving, they lack the long battery life of NB-IoT devices. Finally, as a global industry standard, NB-IoT benefits from a large ecosystem of chipset and device manufacturers, which ultimately lowers costs and reduces the risk of vendor lock-in from proprietary technologies.

	LTE Cat-1	LTE-M	NB-IoT	LoRa	Sigfox
Spectrum	Licensed	Licensed	Licensed	Unlicensed	Unlicensed
Bandwidth	20 MHz	1.4 MHz	180 KHz	125-500KHz	200 KHz
Biodirectional Data Transfer	Full Duplex	Half Duplex & Full Duplex	Half Duplex	Half Duplex	Half Duplex
Peak Data Rate	10 Mbps (DL) 5 Mbps (UL)	1 Mbps (DL) 1 Mbps (UL)	250 Kbps (DL) 230 Kbps (UL)	50 Kbps (DL) 50 Kbps (UL)	0,6 Mbps (DL) 0,1 Mbps (UL)
Typical Downlink Daily Throughput	Limited only by battery power, radio signaling condition and commercial terms (e.g. monthly data volume, amount of messages/size per period)			~200 B	~24 B
Typical Uplink Daily Throughput				~200 kB	~1,64 kB
Max Coupling (vs. GSM)	144 dB (0 dB)	156 dB (+12 dB)	164 dB (+20 dB)	157 dB (+13 dB)	153 dB (+9 dB)
Expected Module Cost	>10$	<10$	<5$	<7$	<3$
Epected Max. Battery Lifetime[1]	3-5 Years	5-10 Years	10+ Years	10+ Years	10+ Years

[1] Assuming typical traffic pattern and battery size

Table 1: Overview of IoT transmission technologies

NB-IoT – THE TECHNOLOGY

The only thing narrow about NB-IoT is the bandwidth it uses. It enables an incredibly broad range of new IoT applications. NB-IoT is based on proven LTE technology, with the LTE features that are unnecessary for LPWA IoT stripped out. Due to this, NB-IoT provides unique advantages that other technologies like 2G, 3G, or LTE cannot achieve or could only do at greater cost.

Long battery life

One of the largest benefits of NB-IoT is the ability for modules to operate for several years on a battery charge. NB-IoT chipsets are optimized for low power consumption—focusing only on radio features relevant to the devices used. Signaling and overhead are reduced so that data is transferred more efficiently directly over the control plane—a feature referred to as Data over Non-Access Stratum (DoNAS).

Moreover, key 3GPP features such as Power Saving Mode (PSM) put modules into a sleep mode with very low energy consumption while sending occasional tracking area update (TAU) messages to keep them registered at the network and avoid the need to reregister upon wake-up. This long periodic TAU feature allows modules to extend the duration between these tracking messages up to several weeks, enabling very long sleep intervals. In addition, NB-IoT's Extended Discontinuous Reception (eDRX) feature offers a longer low-power paging mode that allows devices to receive downlink data from the server, without sending uplink data, helping to further conserve battery life.

Superior indoor coverage

While other mobile communication technologies offer excellent outdoor coverage, their reception deep within buildings or underground is often limited. Many industrial, enterprise, and municipal IoT use cases require reliable coverage inside buildings, underground, or inside other enclosures.

NB-IoT achieves deeper indoor coverage by concentrating radio transmissions into a narrow 180 kHz carrier bandwidth. Additionally, its Coverage Enhancement (CE) feature offers the capability to repeat the transmission of a message if needed at a lower data rate. Proprietary technologies operating on unlicensed spectrum, in contrast, are legally limited in the number of repetitions (due to prescribed duty cycles), which impedes effective indoor coverage. Plus, sensors incapable of wide area communication require the setup of local gateways and greater ongoing maintenance of peripheral networks.

Low module costs

T-Mobile has reached the industry-specified cost target of less than USD 5 per NB-IoT module. This was achieved through strategic partnerships with module vendors and by eliminating a range of unnecessary LTE features. Without the need to support carrier aggregation, voice, multistream transmissions, parallel processing, connected mode mobility measurements, turbo decoders, and inter- and intra-RAT handovers, the NB-IoT modules are produced more cost-effectively than regular LTE, 3G, or GSM modules.

THE THREE PILLARS OF PERFORMANCE

The technical performance of NB-IoT devices are influenced by three factors:

1. **Coverage condition:** Where is the device located? (E.g., deep within a building, underground, etc.) The answer indicates whether CE level 0, 1, or 2 is required.
2. **Traffic profile:** How often should the IoT device send data to the server? How large is the average uplink and downlink traffic payload?
3. **Battery lifetime:** How long should the battery be able to power the device without maintenance? What type of battery is required?

These factors are interdependent and, depending on which of them is the most important for an application, users have to accept concessions on the others. For example, an IoT device located deep within the basement of a building (assuming CE level 2) that needs to send numerous messages per hour will likely consume more power, resulting in shorter battery life.

The NB-IoT network

Since NB-IoT is based on LTE, it can easily integrate into existing LTE infrastructures. Most of the time, operators are able to deploy it on their LTE radio access network through software upgrades. In addition, core network elements such as the Cellular Serving Gateway Node (C-SGN) and a few components specified by the 3GPP for NB-IoT also need to be set up. NB-IoT can be deployed both in the GSM and LTE spectrum with no additional spectrum licenses required. It supports different spectral operation modes, making its deployment flexible and adaptable to different regional network implementations (e.g., stand-alone, guard band, or in-band operation).

There are two possibilities for data transmission between Narrowband IoT devices and application servers:

IP: Depending on the capabilities of the radio module and the operator, IPv4 and IPv6 are supported. UDP is the common and recommended transport protocol for this. As specified in the 3GPP standard, TCP is supported for NB-IoT, but it's not recommended due to the resulting higher data volume. Likewise with HTTP and HTTPS since they rely on TCP and demand additional data volume for their overhead.

Non-IP: If possible, non-IP-based data transmission is recommended for NB-IoT because it reduces the transmitted data volume and saves overhead. Data is then forwarded by the network to the application via IP. Plus, since data can only be sent to one target IP address (server), this method further increases the security of the device by reducing the risk of fraud.

In all cases, application protocols like MQTT, CoAP, LwM2M, and oneM2M can be used.

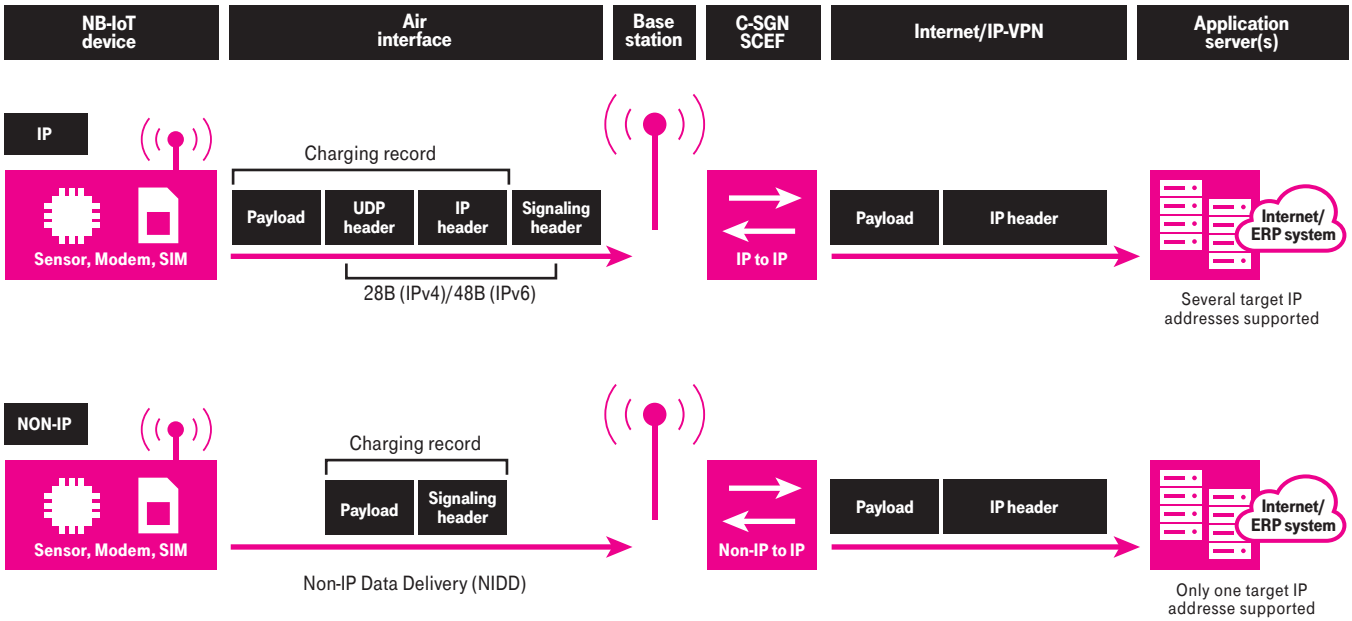


Figure 1: Data transmission on a NB-IoT network

SECURE ON ALL LEVELS

Overall, Narrowband IoT provides higher security than proprietary technologies, as its protection measures cover all aspects, from the UICC in the device to the application servers. By utilizing specific NB-IoT radio modules or chipsets and SIM cards, NB-IoT devices also feature LTE-like security. Plus, being a global industry standard, NB-IoT (like LTE) benefits from a large international ecosystem of vendors and other experts to constantly review and enhance security functions and algorithms as new threats arise.

Integrity and authentication: When accessing the NB-IoT network, both the identities of the subscriber (device) and the network are verified. This mutual authentication is done via the SIM card, on which sensitive credentials and subscriber data are stored and protected against unauthorized access. Integrity of the transmitted data is ensured by means of a specially generated key, independent of the encryption function. To increase the security level, NB-IoT uses longer encryption keys (128 to 256 bits) than many technologies. Manipulation of data is reliably detectable by the device and the C-SGN.

Confidentiality: User data is encrypted between the NB-IoT modem and the core network using a separately generated key and algorithm. Between the core network (C-SGN) and the application server, data traffic is protected via an IPsec tunnel, so the device cannot be reached from the internet. Furthermore, the user can choose to encrypt or hash the data end to end from the client application on the device up to the server or ERP system.

NB-IoT IS NOW

In 2017, T-Mobile began NB-IoT trials with scaled deployments throughout the year, then launched the first nationwide NB-IoT network in the US in summer 2018. It operates wherever T-Mobile's existing LTE networks are, benefiting from a proven infrastructure and decades of mobile network operating experience. Its C-SGN is geo-redundant for high availability, and redundant connections from the core network to the application server are also possible, further enhancing availability. T-Mobile also launched geo-redundant, highly available SCEF for non-IP traffic.

In addition to C-SGN and SCEF, T-Mobile has introduced a fully capable SCS node as an IoT enabler that will allow application servers to connect seamlessly to its core network across technologies or transport. T-Mobile SCS provides functionalities like device management, data collection, and data management, in addition to secure service exposure to application partners.

T-Mobile enables customers, partners, and other interested parties to easily start exploring the possibilities of NB-IoT. CONNECT, T-Mobile's IoT partner program, is building a best-of-breed ecosystem of innovators to help accelerate IoT success for solution and hardware providers, system integrators, resellers, and others. CONNECT provides the support and connections to help partners accelerate time to market for IoT solutions while gaining exposure and reducing their risk. In addition, T-Mobile has partnered with Twilio to give developers the network connectivity, platform, APIs, and tools to bring game-changing Narrowband IoT solutions to market. To help wholesale partners, such as resellers, connect and accelerate time to market for new IoT solutions, T-Mobile has a number of network-certified radio modules that are ready to use on T-Mobile's Narrowband network. Plus, it has a streamlined process for certifying new devices.

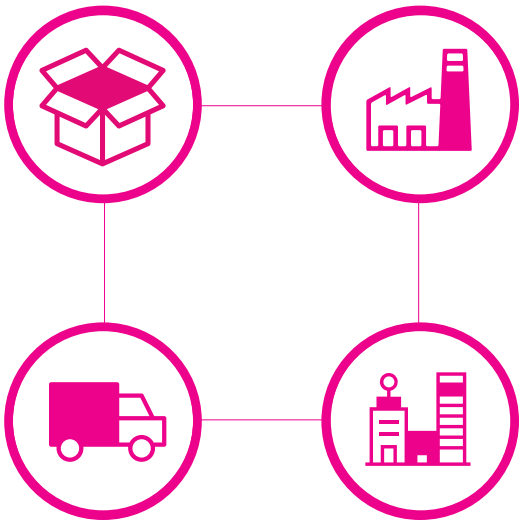
NB-IoT USE CASES

While exciting applications such as augmented reality and autonomous driving generate hype for the IoT future, there are innumerable LPWA IoT use cases that are perfectly suited for the low costs, low power consumption, and deep indoor coverage that NB-IoT offers today.

NB-IoT addresses use cases and applications that previously could not be served efficiently by available networks and technologies. Now, enterprises are not only able to increase the efficiency of existing IoT applications, but they can also tap into new markets and develop entirely new products and services. Opportunities abound for use cases and applications that require only periodic exchanges of data, where the ability to cost-effectively monitor, control, and capture data from remote devices and things will increase efficiency, provide valuable insights, and deliver rapid ROI.[1]

Notable examples are found throughout utilities, logistics, manufacturing, consumer and agriculture, as well as many applications that enable the smart cites and buildings. Real-world IoT solutions that are revolutionizing things today include:

Asset tracking:
NB-IoT solutions help enterprises improve efficiency, optimize logistics, and gain deeper insights into their operations with solutions that track assets in near-real time. Customers are using T-Mobile's NB-IoT network to improve loss prevention, item-level monitoring, and cold-chain monitoring.



Smart buildings:
Connecting innovative IoT solutions for building access, HVAC controls, resource monitoring, and predicative maintenance, NB-IoT helps maximize the comfort and safety of building occupants while minimizing energy and resource use.

Fleet:
T-Mobile's nationwide NB-IoT network gives fleet operators the data they need to cut vehicle costs, make better routing decisions, enable predictive maintenance, and improve driver productivity.

Smart cities:
From environmental monitoring to public safety, NB-IoT is the ideal network for a broad range of innovative, cost-effective IoT solutions that help municipalities improve livability, safety, and efficiency.

OUTLOOK

T-Mobile's NB-IoT network expansion across the US is enabling commercial introduction of new, innovative, and cost-effective NB-IoT services from coast to coast. As more NB-IoT devices and modules are developed and certified, the array of IoT solutions for novel use cases and business models will continue to expand.

Moreover, the June 2017 release of the 3GPP specification Release 14 established additional standards that further improve NB-IoT. Among other technical enhancements, the new release supports single-cell multicast, enhanced device positioning, reduced latency, and improved power consumption (14 dBm output power reduction to enable further module cost savings). Release 15 in 2018 includes additional enhancements that help further minimize battery consumption. The technical specifications of Releases 14 and 15 will gradually be integrated into network components, chipsets, and modules according to their usual development cycles—further improving NB-IoT technology. T-Mobile's NB-IoT technology integrates Release 14 and 15 enhancements such as idle-mode interfrequency mobility, idle-mode load distribution, and higher transport block size (2,535 bytes).

Even as the revolutionary new possibilities of 5G technology come to market, NB-IoT will play an important and growing role in the evolution of the IoT network landscape. For massive IoT applications and LPWA use cases, NB-IoT is a crucial technological innovation that unlocks the door for the next generation of IoT architectures and game-changing services—today.

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1. Worldwide roaming not yet available.