SIERRA WIRELESS WHITE PAPER

LTE CAT-1 or LTE-M or NB-IoT: Which one is right for your cellular IoT deployment?

There are three LTE-based standards of cellular communication specifically intended for use in the Internet of Things (IoT). There's LTE CAT-1, which was introduced in 2009, and there's LTE-M and NB-IoT, which were introduced in 2016 as part of the cellular Low Power Wide Area (LPWA) specification.

CAT-1 and cellular LPWA both offer the benefits of 3GPP standardization and are viable long-term options for the IoT, but they vary in what we at Sierra Wireless refer to as the "4 C's": coverage (and bandwidth), current (power consumption), cost (design complexity), and capacity (massive IoT deployments per cell).

These variations can make it hard to know which one is best for a given deployment. To help simplify selection, we highlight the key considerations CAT-1 and cellular LPWA and identify the use cases best suited to each.

In a nutshell, the decision to use CAT-1 or LPWA depends on two things: geography and use case. In some regions, for example, LPWA is not available. In other regions, CAT-1 won't provide sufficient coverage and may require several SKUs to manage specific bands in specific countries. And in places where both standards provide adequate coverage, the use case is often the deciding factor, since the two standards are designed to meet their own set of requirements.

CAT-1 and LTE-M or NB-IoT Serve Different Purposes

Before getting into specifics on use cases, it can help to understand why there are two different standards to choose from in the first place. That means taking a quick look at how the 3GPP has evolved cellular standards.

In 2009, years before "IoT" became a familiar industry term, the 3GPP identified "machine-to-machine" operation as an important source of cellular expansion and included a protocol for "M2M" connectivity in Release 8, as part of the introduction of Long-Term Evolution (LTE). The new M2M protocol, classified in the User Equipment (UE) Category as LTE CAT-1, had a maximum downlink rate of 10 Mbps and a maximum uplink rate of 5 Mbps. That made it inadequate for consumer mobile broadband use cases, but very useful for networked devices that communicated without human intervention.

Fast forward to 2016, and the 3GPP made what was now called the Internet of Things an even more central part of cellular communication with Release 13. Building on protocols for Low Power Wide Area (LPWA) operation, the 3GPP introduced two standards for low-bandwidth, battery-powered devices: LTE

enhancements for Machine Type Communication (LTE eMTC or LTE-M), and NarrowBand Internet of Things (NB-IoT). Classified under a single UE Category, LPWA, these two additions targeted mobile (LTE-M) and stationary (NB-IoT) use cases that deal in only small amounts of data. LTE-M was defined with a peak downlink/uplink rate of 1 Mbps, and NB-IoT with a peak downlink rate in the range of 200 kbps and 250 kbps in the uplink. The arrival of LPWA cellular standards, with their support for low-power operation over a wide area, essentially "right-sized" cellular for the IoT, making it easier to match more closely the operating requirements of many IoT devices.

They're Designed to Coexist

The introduction of cellular LPWA didn't negate the existence of CAT-1, and the two have supported their own segments of the IoT ever since. CAT-1 remains useful for devices that need higher bandwidth, while cellular LPWA provides a simpler, less expensive, and more efficient way to support the small, battery-powered devices, such as sensors that transmit readings and asset tags that report location, that have become so present in the IoT.

The 3GPP is committed to maintaining both standards. In 2018, they announced that LTE-M and NB-IoT, the two protocols covered by cellular LPWA, will continue to evolve as part of the 5G specifications. That same year, as part of Release 14, the 3GPP revised the original CAT-1 standard. The revised version, called CAT-1 bis, changes the 4G LTE requirement for two receiver antennas to just one. The CAT-1 bis revision reduces device complexity, shrinks the PCB footprint, and lowers Bill of Material (BoM) costs, while also improving the market opportunity for devices that use the standard. Since there is no dedicated signaling for Cat-1 bis, any CAT-1 device with a single antenna design (that is, without Rx diversity) now works on any CAT-1 network.

TECHNICAL HIGHLIGHTS: CAT-1 VS LTE-M OR NB-IOT

	LTE CAT-1 (AND CAT-1 BIS)	CELLULAR LPWA CATEGORIES	
		LTE-M	NB-IOT
First 3GPP Release	Rel 8 (2009) Rel 14 (2018)	Rel 13 (2016)	Rel 13 (2016)
Peak downlink rate	10 Mbps	1 Mbps	200 kbps
Peak uplink rate	5 Mbps	1 Mbps	250 kbps
Power consumption	Medium	Low	Low
Complexity	Medium	Low	Low
Mobile vs fixed	Mobile	Mobile	Fixed

Both are Sound IoT Investments

Inclusion in 3GPP releases means CAT-1, LTE-M, and NB-IoT are all part of the Global Cellular Network family, and offer the same benefits of security, billing, and SIM control as other 2G/3G/4G/5G cellular standards.

What's more, having CAT-1, LTE-M, and NB-IoT on the 3GPP's long-term roadmap makes them all viable options for new IoT investment, even for deployments that will be in the field for years to come. CAT-1, LTE-M and NB-IoT are also good candidates for the migration of legacy 2G/3G devices deployed in networks that are being sunset.

Global standardization is a particularly important consideration with cellular LPWA, since LTE-M and NB-IoT are the only LPWA formats defined by the 3GPP and included in the definition of 5G. Other LPWA options, such as SigFox and LoRa (which is proprietary), operate in narrowly defined portions of unlicensed spectrum and may not have the same kind of longevity as either LTE-M or NB-IoT.

A Look at Current Availability and Growth

CAT-1, LTE-M, and NB-IoT are all actively in use today and are expected to continue growing.

CAT-1 module shipments will represent 20% of annual cellular IoT module shipments by 2026

Source: ABI Research, 2021

CAT-1: GLOBAL AND GAINING MARKET SHARE

Introduced as part of the original LTE standard, CAT-1 has been available since the first 4G LTE networks were put in place. Today, CAT-1 coverage can be found where 4G LTE is available, which means it's available just about everywhere. According to signal measurements provided by data-gathering site SpeedChecker.com, as of December 2021, of the 195 countries in the world, 106 had an in-place LTE infrastructure. Similarly, the Global mobile Suppliers Association (GSA) reports that there were, as of January 2022, 797 operators with commercially launched public mobile or broadband fixed-wireless access networks. And, according to the analyst firm Omdia, there were 6.2 billion LTE subscriptions globally at the end of Q1, 2021, accounting for nearly two thirds (63.8%) of all mobile subscriptions globally.

Looking at CAT-1 specifically, the analyst firm ABI Research reports that shipments of CAT-1 modules grew from 0.7 million in 2016 to 43 million in 2020, representing 22% of all 4G module shipments and 14% of overall cellular module shipments. ABI expects CAT-1 to continue growing, too, and estimates that, by 2026, CAT-1 module shipments will reach 233 million units a year, representing 20% of an anticipated 1.4 billion annual cellular IoT module shipments.

Cellular LPWA module shipments will represent 58% of annual cellular IoT module shipments by 2026

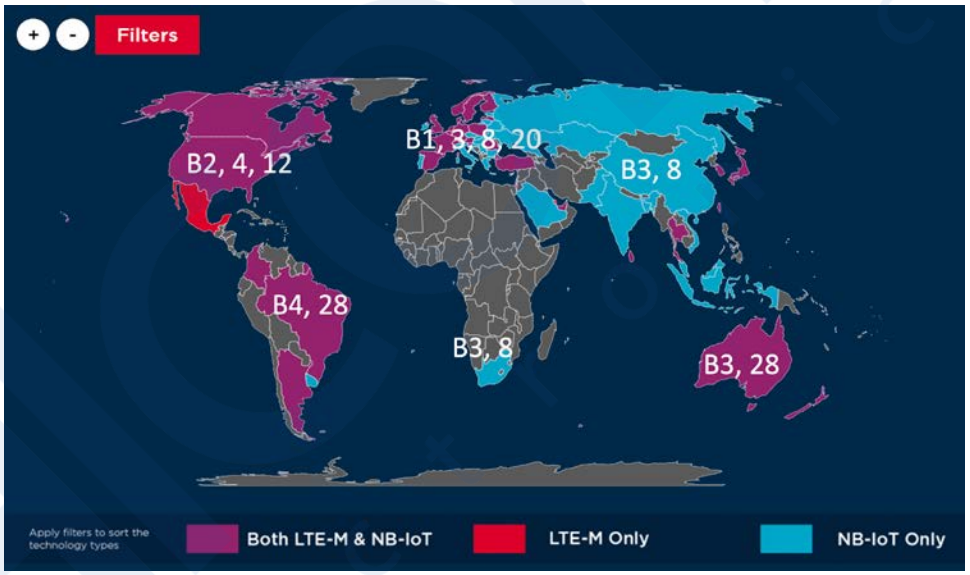
Source: ABI Research, 2021

LTE-M AND NB-IOT: RAMPING UP QUICKLY

In the six or so years since the 3GPP introduced cellular LPWA, LTE-M and NB-IoT have expanded rapidly. The GSA reports that, as of February 2022, there were 140+ cellular LPWA (LTE-M or NB-IoT) networks deployed commercially in 60+ countries.

As shown below, in the February 2022 version of the Mobile IoT Deployment Map published and maintained by the GSM Association, some regions offer access to both LTE-M and NB-IoT, while others offer access to only one or the other.

Mobile IoT Deployment Map as of February 2022



Source: GSMA

Only 7 frequency bands are required for global LTE-M coverage

The map also shows that, of the 28 frequency bands allowed for LTE-M operation, only seven (B1, 3, 4, 8, 12, 20, and 28) are required to cover all the countries which have deployed LTE-M networks (see in Appendix for more details). Knowing which frequency bands are used in a given deployment region can simplify antenna design and reduce certification costs.

As far as growth is concerned, cellular LPWA is expected to continue growing quickly. As part of their above-cited analysis of the cellular module market, ABI estimates that, by 2026, NB-IoT and LTE-M module shipments will reach 661 million units a year, representing 58% of their anticipated 1.4 billion annual cellular IoT module shipments. Also, in their November 2021 Mobility Report, Ericsson predicts that, by 2027, NB-IoT and LTE-M will make up 51% of what they expect will be 5.9 billion active cellular IoT connections.

Where CAT-1 and LTE-M or NB-IoT Excel

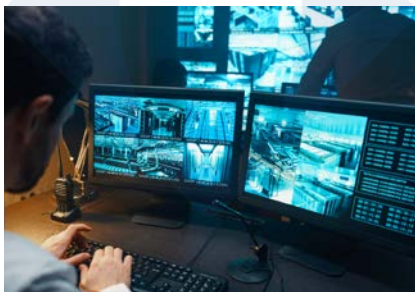
The biggest difference between CAT-1 and LTE-M or NB-IoT, in terms of suitability for various use cases, is bandwidth (and the amount of power required to support the amount of data being transmitted). As described above, CAT-1 is optimized for 10 Mbps downlink and 5 Mbps uplink, which is well suited for applications that deal with larger amounts of data, while cellular LPWA operation, using either LTE-M or NB-IoT, is the better choice for applications that need low power, extended coverage, and deal in only small amounts of data. Here's a closer look at how that breaks down.

RECOMMENDED CAT-1 USE CASES

Delivering faster down- and uplink speeds than LTE-M and NB-IoT, CAT-1 is ideally suited for applications that benefit from a compact and cost-effective (single-antenna) format but have higher demands, in terms of bandwidth, than LPWA use cases.

- **Smart Commercial Buildings**
  Keeping mission-critical building applications, like surveillance cameras and security alarms, up and running requires more data than LPWA technologies can typically manage. CAT-1 devices can also be used as part of Smart City infrastructures, to integrate data-intensive smart features, such as digital signage, interactive kiosks, and ATM machines, into commercial and public environments.
  Building Management: [use case TBD]

- **Fleet Management (Transport & Telematics)**
  One of the fastest-growing segments of the IoT is vehicle telematics, a group of applications that use tracking devices to gather vehicle data and then transmit the information to a back-end applications, where it can be processed, viewed, and analyzed. Vehicle telematics has its origins in fleet management and vehicle tracking, but now includes things like car sharing, bike rentals, and even golfcarts at clubs and resorts.
  Fleet Management: Maestro gets global coverage with a single, compact footprint
  https://www.sierrawireless.com/resources/case-study/maestro/



RECOMMENDED LTE-M AND NB-IOT USE CASES

In general, LTE-M is used to connect mobile assets, with handover support, while NB-IoT is used more specifically to connect stationary assets. Having said that, roaming has been a secondary concern for both standards, but especially for NB-IoT, where entirely new roaming agreements need to be established between carriers based on the number of roaming devices and not the amount of data transported. However, LTE-M and NB-IoT are still the only true LPWA networks that support roaming.

Compared to Legacy LTE, LTE-M and NB-IoT offer coverage enhancements, such as frequency hopping and subframe repetitions (CE modes A/B), that yield sensitivity that is up to 128 dB higher. As a result, LTE-M and NB-IoT are good choices for use cases that require coverage deep indoors or underground, and for deployments that need wide-area coverage in rural areas. With new UE power classes, LTE-M and NB-IoT also meet the 5G coverage requirement of 164 dB Maximum Coupling Loss (MCL).

For IoT use cases that require low power consumption – think battery operation – LTE-M and NB-IoT offer several features, including Power Saving Mode (PSM), Extended Discontinuous Reception (eDRX), and Release Assistance Indication (RAI), which support much lower power consumption than legacy LTE. As a result, an LTE-M device can operate on a single battery for more than a decade. (PSM and eDRX are not yet available from all network operators in roaming scenarios, but Sierra Wireless supports both on some networks, based on extended roaming agreements.)

- **Logistics**
  LTE-M and NB-IoT operate without a fixed power supply and doesn't need regular recharging, so it's a good choice for tracking assets that are on the move. Also, thanks to its extended coverage compared to legacy LTE, LTE-M and NB-IoT allow location tracking in a wide area, whether it's inside warehouse complex or along a rural delivery route. Sensors can be used to monitor the condition of goods in transit and quickly respond to situations that exceed thresholds set for humidity, temperature, light exposure, shock, vibration, and more.
  Logistics: Hive-Zox uses cold-chain tracking to protect vaccines
  https://www.sierrawireless.com/resources/webinars/digital-transformation-in-healthcare/

- **Industry/Manufacturing**
  The industrial IoT is already improving the safety and efficiency of production lines, but when it comes to monitoring things like petrochemicals, hazardous chemicals, waste materials, and water pollution, the remoteness of the location and the risks associated with direct handling of dangerous substances add an extra degree of difficulty. The low-power, low-cost sensors enabled by LTE-M and NB-IoT address the challenge and add value, by enabling better use of manpower, keeping safety standards high, and saving money by catching problems early.
  Logistics: Aquamonitrix detects nitrate and nitrite levels in effluent water https://www.sierrawireless.com/resources/case-study/water-quality-monitoring-octave/

- **Smart City Infrastructure**
  Mass deployment of IoT devices throughout the city infrastructure, from streets, traffic lights and parking lots to buildings, public spaces, and public transport, make city life easier to navigate in any number of ways, whether that means knowing where to find a free parking space or when the next bus will arrive. It can also keep public areas more secure with real-time monitoring. Very large-scale deployments impose strict cost requirements on project budgets, making LTE-M and NB-IoT true enablers for these kinds of use cases.
  Sustainable Street Lighting: Signify (Philips Lighting) monitors and manages streetlights remotely https://www.sierrawireless.com/resources/case-study/philips-citytouch/

- **Utilities**
  LTE-M and NB-IoT enable monitoring of remote infrastructure and assets, such as underground pipelines and wind, solar, and thermal-generation equipment, along with smart meters. The result is increased efficiency, with support for predictive maintenance (which in turn generates cost savings), and access to vital real-time information, such as energy consumption, for improved sustainability. The low latency of LTE-M, compared to other LPWA technologies, also supports quick triggering of actuators in the field. Sensors can also be used to monitor for leaks in aging water-supply systems, for faster responses, higher efficiency, and cost savings.
  Smart Meters: The EDF (Électricité de France) LPWA rollout https://www.sierrawireless.com/resources/webinars/lpwa-5g-energy/

- **Agriculture/Environment**
  LTE-M and NB-IoT make it easy to track and monitor livestock and wildlife, and support a range of crop-monitoring using cases, including connected greenhouse sensors, soil-quality monitors, and environmental sensors for temperature and humidity. Government agencies and scientists can also use LTE-M and NB-IoT to analyze water levels, predict floods, and issue early warnings.
  Fertilizer Tank Monitoring: Ekatra prevents soil degradation and environmental damage
  https://www.sierrawireless.com/resources/case-study/octave-fertilizer-tank/

Start with Sierra

At Sierra Wireless, we've been helping organizations design, manage, and protect connectivity for more than 28 years. We've participated in the development of many IoT standards and protocols, and are deeply committed to cellular IoT.

Cellular IoT, whether it's based on CAT-1, LTE-M, or NB-IoT, is the heart of what we do, and our experts are ready to guide you through the entire process, from start to finish. We offer an extensive range of tailored solutions for CAT-1, LTE-M, and NB-IoT, and optimize performance to help maximize the return on IoT investment. Our hardware and software solutions also work seamlessly with our tools for data orchestration, thereby simplifying the tasks associated with day-to-day maintenance, and making it easier to manage any size IoT deployment with a central point for deploying, updating, and monitoring devices.

Take the Next Step

To learn more, visit us at www.sierrawireless.com.

About Sierra Wireless
Sierra Wireless (NASDAQ: SWIR) (TSX: SW) is a world leading IoT solutions provider that combines devices, network services, and software to unlock value in the connected economy. Companies globally are adopting 4G, 5G, and LPWA solutions to improve operational efficiency, create better customer experiences, improve their business models, and create new revenue streams. Sierra Wireless works with its customers to develop the right industry-specific solution for their IoT deployments, whether this is an integrated solution to help connect edge devices to the cloud, a software/API service to manage processes with billions of connected assets, or a platform to extract real-time data to improve business decisions. With more than 25 years of cellular IoT experience, Sierra Wireless is the global partner customers trust to deliver them their next IoT solution.

For more information, visit www.sierrawireless.com.

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APPENDIX: LTE BANDS FOR UE CATEGORY 1, LTE-M, NB-IOT

BAND NUMBER	FREQUENCY (MHZ)	MODE	LTE CATEGORY		
			LTE-M	LTE-CAT1	NB-IOT
1	2100	FD	●	●	●
2	1900 PCS	FD	●	●	●
3	1800+	FD	●	●	●
4	AWS-1	FD	●	●	●
5	850	FD	●	●	●
7	2600	FD	●	●	
8	900 GSM	FD	●	●	●
11	1500 Lower	FD	●		●
12	700 a	FD	●	●	●
13	700 c	FD	●	●	●
14	700 PS	FD	●		●
17	700 b	FD			●
18	800 Lower	FD	●	●	●
19	800 Upper	FD	●		●
20	800 DD	FD	●	●	●
21	1500 Upper	FD	●		●
25	1900+	FD	●		●
26	850+	FD	●	●	●
27	800 SMR	FD	●		
28	700 APT	FD	●	●	●
31	450	FD	●	●	●
39	TD 1900+	TD	●	●	
40	TD 2300	TD	●		
41	TD 2500	TD	●	●	
66	AWS-3	FD	●	●	●
70	AWS-4	FD			●
71	600	FD	●		●
72	450 PMR/PAMR	FD	●	●	●
73	450 APAC	FD	●		●
74	L-band	FD	●		●