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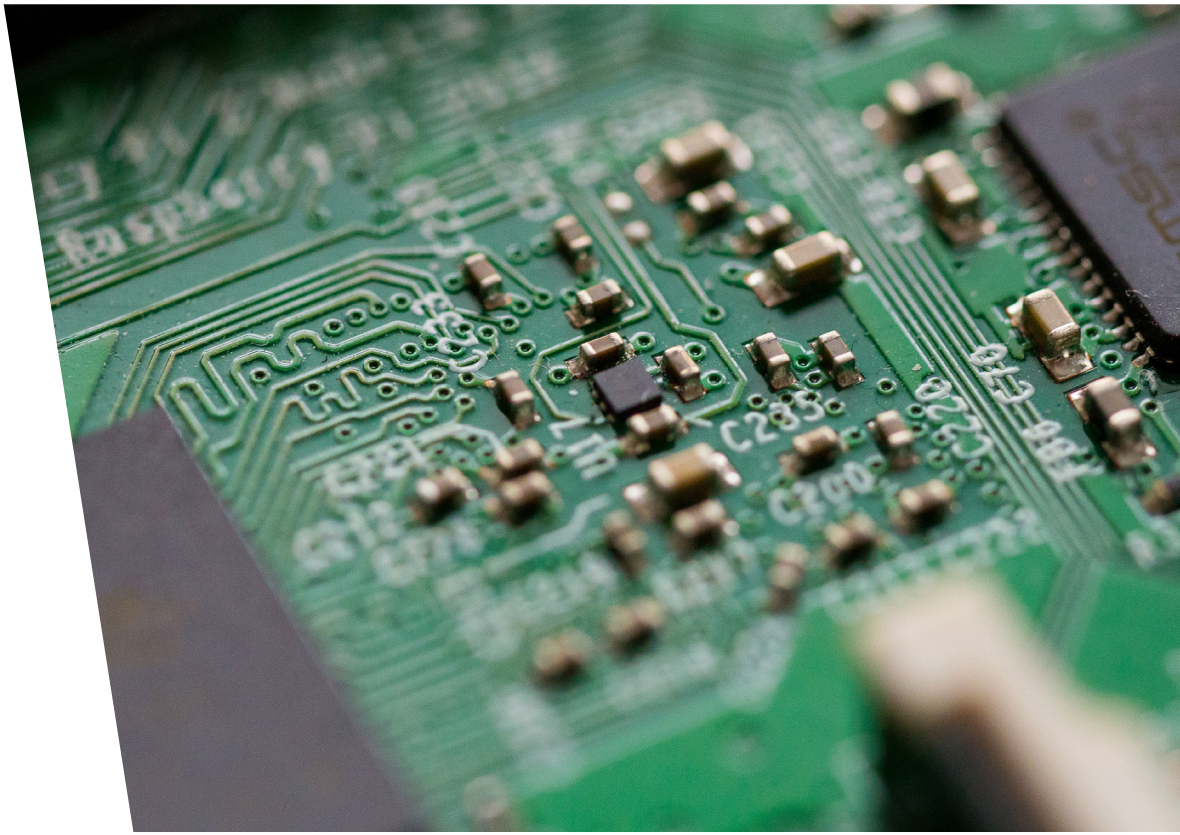
WHITEPAPER

The difference between 4G, 5G, LTE, CAT-M, LTE-M, CAT-1, NB-IoT, and LoRaWAN for a tracking project



v1.0
10/12/2023

Introduction

Communication, sensing, power, control, memory, and computing are the main technologies used in a tracking project.

The mainstream tracking technologies include GNSS, Bluetooth and Wi-Fi RSSI, Bluetooth angle of arrival*, UWB, ultrasonic, SLAM, RFID, network TOF, Infrared ray**, etc. SLAM requires high bandwidth and data rate for image and video streaming; others use several or tens of bytes per positioning message. Considering positioning accuracy, power consumption, product dimension, cost, and network availability or communication distance, there are many options for communication technology, and this paper introduces the most recent mobile network technologies and their characteristics. By comparing similar ones, it analyzes the pros and cons of each technology for a tracking project and helps readers choose which one to use in a personal or asset-tracking project.

*Please refer to **Bluetooth Technology and Common Terms Introduction** whitepaper for detailed information.
For detailed study of the principles of these technologies, please refer to **Lansitec Introduction to the Basic Principles of Positioning Technology whitepaper.

4G and 5G

4G and 5G are two different generations of mobile network technology. They have some key differences in terms of speed, bandwidth, latency, and capabilities. Here is a summary of the main differences:

Speed

5G is much faster than 4G, offering up to 2.5 Gbps download speed and 1.25 Gbps of upload. 4G, on the other hand, can only reach up to 1 Gbps of download speed and 500 Mbps of upload. So 5G can support more data-intensive applications, such as high-resolution video streaming, virtual reality, and cloud gaming.

Latency

5G has lower latency than 4G, meaning it has less delay or lag time in communications between devices and servers. The latency of 5G is about 1 ms, while the latency of 4G is about 50 ms. 5G can enable more real-time and interactive applications, such as remote control of vehicles, robots, and medical procedures, as well as on-line gaming and video conferencing.

Bandwidth

5G has more bandwidth than 4G, meaning it can support more devices and users simultaneously without compromising the quality of service. 5G uses higher frequencies than 4G, such as millimeter waves, which are less congested and can carry more data. 5G also uses smaller and more directional antennas, serving over 1,000 more devices per meter than 4G. This means that 5G can handle the growing demand for internet access from smartphones, tablets, laptops, smart TVs, wearables, and IoT devices.

These are some of the major differences between 4G and 5G. However, these differences also depend on the availability and coverage of the networks, as well as the compatibility and performance of the devices. To enjoy the full benefits of 5G, you will need a 5G-enabled device and a 5G network provider in your area.

In an IoT project, both 5G and 4G are used for data backhaul in the gateway, i.e., LoRaWAN gateway, AoA (Angle of Arrival) gateway, .etc. 4G is often used because:

*4G module is cheaper.
*Speed, bandwidth, and latency do not have a significant influence on the system's performace.

Many vehicle trackers use 4G because 4G has better coverage worldwide than 5G, while 2G and 3G are phasing out. Some high-accuracy GNSS positioning technologies, such as RTK (Real-Time Kinematic) and PPK (Post Processed Kinematic), use 4G because they need faster and more data communication during positioning.

LTE and 4G

LTE and 4G are two terms related to mobile network technology. LTE stands for Long-term Evolution and is a standard for wireless broadband communication. 4G stands for fourth generation and is a general term for the fourth generation of mobile data technology, as defined by the International Telecommunication Union (ITU).

LTE is one of the technologies that can provide 4G speeds, but not all LTE networks can meet the criteria for 4G, such as a peak download speed of at least 100 Mbps. To differentiate between these cases, some carriers use the term 4G LTE to indicate a faster and more advanced LTE network that meets the 4G requirements. However, some carriers may also use the term 4G LTE to market their LTE networks that are actually slower than the 4G standard.

WiMAX is another technology that can provide 4G speeds, which stands for Worldwide Interoperability for Microwave Access. WiMAX is similar to LTE in that it uses radio waves to transmit data but has a different network architecture and frequency range. WiMAX was more popular in the early days of 4G, but LTE has largely replaced it in most markets.

To summarize, LTE and 4G are not exactly the same thing, but they are often used interchangeably by carriers and consumers. LTE is a specific technology that can deliver 4G speeds, but not all LTE networks are 4G compliant. WiMAX is another technology that can deliver 4G speeds but is less common than LTE.

CAT-M and LTE-M

CAT-M and LTE-M (Long-Term Evolution for Machines) are two different names for the same thing: a device category in the LTE family of cellular technologies designed for IoT applications. CAT-M and LTE-M devices have some advantages over traditional LTE devices, such as lower power consumption, longer battery life, better coverage, and lower cost. However, they also have limitations, such as lower data rates, narrower bandwidth, and reduced functionality. The main differences are:

Bandwidth

CAT-M and LTE-M devices use a bandwidth of 1.4 MHz, which is much smaller than the typical 20 MHz bandwidth used by other LTE devices. This means that they can fit more devices in the same spectrum and have less data capacity and speed.

Data Rates

CAT-M and LTE-M devices have peak data rates of up to 1 Mbps in both downlink and uplink, which is sufficient for most IoT applications but not for high-bandwidth services like video streaming or gaming. Other LTE devices can reach up to 10 Mbps in downlink and 5 Mbps in uplink (CAT-1) or even higher (CAT-4 and above).

Power Consumption

CAT-M and LTE-M devices have lower power consumption than other LTE devices, meaning they can operate on batteries for longer periods. They also support power-saving features like Power Saving Mode (PSM) and Extended Discontinuous Reception (eDRX), which allow them to sleep or reduce their activity when not in use.

Coverage

CAT-M and LTE-M devices have better coverage than other LTE devices, especially in indoor and rural areas. They can use repetition and link adaptation to improve their signal quality and reliability. They also support Coverage Enhancement Mode (CEM), which allows them to transmit at higher power levels and receive at lower signal levels.

Complexity

CAT-M and LTE-M devices have lower complexity than other LTE devices, meaning they have simpler hardware and software requirements. They also have fewer features and functionalities, such as voice support, carrier aggregation, or multiple antennas.

LTE Cat-4 and Cat-1

Cat-4 and Cat-1 are two categories of user terminal devices in the 4G LTE network, differing in speed, bandwidth, complexity, and functionality. Here are some of the main points of comparison:

Speed

Cat-4 devices are faster than Cat-1 devices, offering up to 150 Mbps download speed and 50 Mbps upload speed. Cat-1 devices, on the other hand, can only reach up to 10 Mbps of download speed and 5 Mbps of upload. This means that Cat-4 devices can support more data-intensive applications, such as video streaming or gaming, while Cat-1 devices are suitable for low-bandwidth applications, such as IoT or telematics.

Bandwidth

Cat-4 devices use a bandwidth of 20 MHz, the typical bandwidth normal LTE devices use. Cat-1 devices use a smaller bandwidth of 1.4 MHz, equivalent to a typical LTE resource. This means that Cat-1 devices can fit more devices in the same spectrum but have less data capacity and speed.

Complexity

Cat-4 devices have higher complexity than Cat-1 devices, meaning they have more hardware and software requirements. They also have more features and functionalities like voice support, carrier aggregation, or multiple antennas. Cat-1 devices have lower complexity than Cat-4 devices but have less capabilities and flexibility.

Cost

Cat-4 devices are more expensive than Cat-1 due to their higher performance and complexity. Cat-1 devices are cheaper than Cat-4 due to their lower performance and complexity.

These are some of the main differences between Cat-4 and Cat-1 technologies. However, these differences also depend on the availability and coverage of the networks, as well as the compatibility and performance of the devices. To choose the best technology for your application, you should consider your specific needs and requirements, such as data rate, battery life, mobility, voice support, cost, etc. You can also consult your network provider or device manufacturer for more guidance.

LTE-M and Cat-1

LTE-M and Cat-1 (Category 1) are cellular communication technologies, but they are designed for different use cases and have some key differences.

Data Rates

LTE-M: LTE-M offers relatively low data rates, typically 375 Kbps for downlink and 300 Kbps for uplink. This is sufficient for many IoT applications that transmit small amounts of data at infrequent intervals.

Cat-1: Cat-1 provides higher data rates, with speeds ranging from 10 to 100 Mbps for downlink and 5 to 10 Mbps for uplink. This is more suitable for applications that require real-time or higher-bandwidth data communication.

Power Consumption

LTE-M: LTE-M is optimized for low power consumption, making it suitable for battery-powered IoT devices that must operate for extended periods without frequent recharging or battery replacement.

Cat-1: Cat-1 consumes more power than LTE-M, which may not be as suitable for battery-constrained devices that require long-term operation on a single charge.

Coverage and Availability

LTE-M: LTE-M typically offers better coverage in areas with weak signal strength or in-building coverage. It is designed to penetrate obstacles and provide reliable connectivity in challenging environments. However, CAT-M or NB-IoT are simply not yet ready in most markets.

Cat-1: Cat-1 may offer faster data rates but might have slightly less coverage in certain situations than LTE-M. Cat-1 is available today and widely supported by carriers worldwide. Thus, Cat-1 network availability is actually better in most markets.

Cost

LTE-M: LTE-M modules and services are often designed to be cost-effective, making them attractive for low-cost IoT deployments.

Cat-1: Cat-1 modules and services are more widely used and relatively less expensive than LTE-M.

Use Cases

LTE-M: LTE-M is primarily designed for low-power, low-data-rate IoT (Internet of Things) and M2M (Machine-to-Machine) applications. It is optimized for devices that transmit small amounts of data intermittently and have long battery life.

Cat-1: Cat-1, on the other hand, is designed for applications that require higher data rates and are not as concerned about power consumption. It offers faster data transmission speeds compared to LTE-M and is suitable for applications like video streaming and certain types of IoT devices that require more bandwidth.

In summary, the choice between LTE-M and Cat-1 depends on the specific requirements of your IoT or M2M application. If your priority is low power consumption, small data payloads, and cost-effectiveness (like a tracking project), LTE-M may be a better choice. However, if you need higher data rates and can accommodate higher power consumption, Cat-1 might be more suitable for your application.

The other factor that should be considered when deploying a national or worldwide tracking project is network availability. LTE-M and NB-IoT networks are still under development in most countries, but Cat-1 has more coverage. This means your devices can always be on-line.

LTE-M and NB-IoT

LTE-M and NB-IoT are two types of cellular technologies that are designed for low-power wide-area network (LPWAN) applications, such as IoT devices. They have some similarities and differences in terms of speed, bandwidth, coverage, power consumption, and complexity. Here is a brief summary of the main differences:

Speed

LTE-M is faster than NB-IoT, offering up to 1 Mbps of data rate in both downlink and uplink for 4G networks, and up to 4 Mbps for 5G networks. On the other hand, NB-IoT can only reach up to 26 kbps in downlink and uplink for 4G networks and up to 127 kbps for 5G networks.

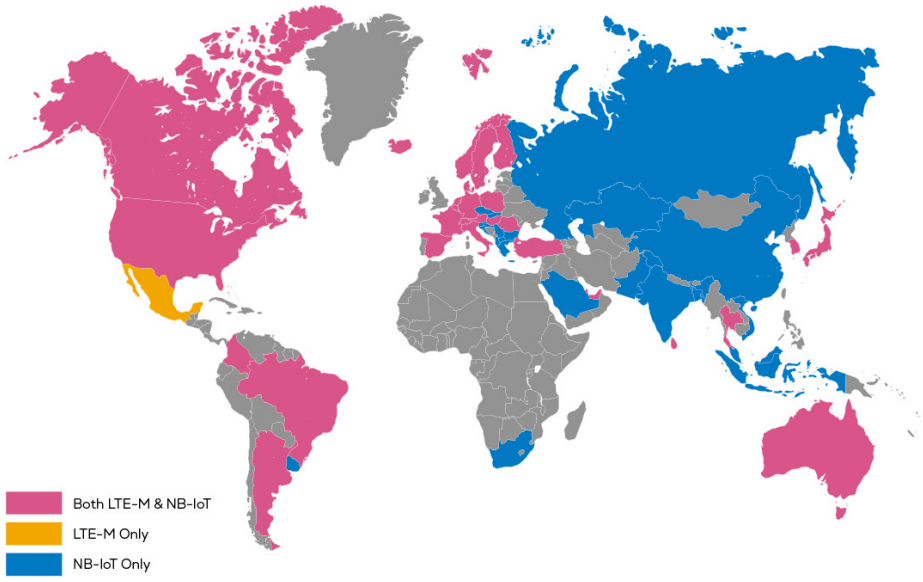
Bandwidth

LTE-M uses a bandwidth of 1.4 MHz, which is the same as a typical LTE resource block. NB-IoT uses a narrower bandwidth of 200 kHz, equivalent to one physical resource block within a typical LTE resource block. This means that NB-IoT can fit more devices in the same spectrum and has less data capacity and speed.

Coverage

Both LTE-M and NB-IoT have better coverage than regular LTE devices, especially in indoor and rural areas. They can use techniques like repetition and link adaptation to improve their signal quality and reliability. They also support coverage enhancement mode (CEM), which allows them to transmit at higher power levels and receive at lower signal levels. However, some sources claim that NB-IoT has a slight advantage over LTE-M in terms of maximum coupling loss (MCL), which measures the maximum loss in the conducted power level that a system can tolerate and still be operational. According to 3GPP standards, the MCL for NB-IoT is 164 dB, while the MCL for LTE-M is 160.7 dB for 4G networks and 164 dB for 5G networks. However, other sources argue that this difference is not significant and that LTE-M can achieve the same or better coverage than NB-IoT with proper configuration.

LTE-M & NB-IoT Coverage Map



NB-IoT Network Global Coverage Info 1

Country/Region	Operator	Bands
Argentina	Claro	4, 28
Argentina	Movistar	4, 28
Australia	Telstra	28
Australia	Vodafone	8
Australia	Optus	28
Austria	A1	20
Austria	T-Mobile	8
Bangladesh	Grameenphone	3, 8 (TBC)
Belarus	A1	/
Belarus	Velcom	8
Belgium	BASE (Telenet)	3, 20
Belgium	Proximus	20
Belgium	Orange	3,20
Brazil	Claro	3, 28
Brazil	Vivo	3, 28
Brazil	Telecom Italia/TIM	28
Canada	Rogers	4, 5, 12
Chile	Claro	28
Chile	Movistar	28
Chile	Entel	28
China	China Mobile	8
China	China Telecom	5

Country/Region	Operator	Bands
China	China Unicom	3, 8
China(Hong Kong)	3	8
China(Hong Kong)	China Mobile	3
China(Hong Kong)	SmarTone	8
China(Taiwan)	APTG	8
China(Taiwan)	Chunghwa	8
China(Taiwan)	FarEasTone	28
China(Taiwan)	Taiwan Mobile	28
Colombia	Claro	5
Colombia	Movistar	5
Croatia	A1	20
Croatia	T-Mobile (DT)	8, 20
Czech	Vodafone	8, 20
Denmark	Telenor	20
Denmark	Telia	20, 8
Denmark	TDC	20
Estonia	Telia	20
Estonia	Elisa	20
Finland	Telia	20
Finland	DNA	20, 3
Finland	Elisa	20, 3
France	SFR	20

Country/Region	Operator	Bands
Germany	Telefónica	8, 20
Germany	Vodafone	20
Germany	Deutsche Telekom	8, 20
Greece	Vodafone	20
Greece	T-Mobile	20
Hungary	T-Mobile	20
Hungary	Vodafone	20
India	Reliance Jio	3, 5
Indonesia	Telkomsel	8
Indonesia	XL Axiata	8
Ireland	Vodafone	20
Italy	Vodafone	20
Italy	Telecom Italia/TIM	20
Japan	SoftBank	1, 8
Kazakstan	KCELL	/
Latvia	Bite	20
Latvia	LMT	20
Latvia	Tele2	20
Malaysia (6 Cities)	Maxis	3
Malta	Vodafone	/
Mexico	ALTAN	28
Mexico	AT&T	5

NB-IoT Network Global Coverage Info 2

Country/Region	Operator	Bands
Mexico	Telcel	5
Netherlands	T-Mobile (DT)	20
Netherlands	Vodafone	20
New Zealand	Vodafone	28
Norway	Telenor	8, 20
Norway	Telia	20
Peru	Claro	28
Peru	Movistar	28
Poland	T-Mobile (DT)	20
Portugal	Altice	20
Portugal	Vodafone	8, 20
Portugal	NOS	3, 20
Romania	Vodafone	20
Russia	MegaFon	20, 8, 3
Russia	MTS	3
Saudi Arabia	Zain	3
Saudi Arabia	Mobily	20
Saudi Arabia	STC	12
Serbia	Vip Mobile (A1)	20
Singapore	M1	8
Singapore	StarHub	3, 8
Singapore	Singtel	8

Country/Region	Operator	Bands
Slovakia	T-Mobile	20
Slovakia	A1	20
Slovakia	Telekom Slovenije	20
South Africa	Vodafone	8
South Korea	KT	3
South Korea	LGU+	5
Spain	Telefónica	20
Spain	Vodafone	8, 20
Spain	Orange	20
Sri Lanka	Dialog Axiata	3, 8
Sri Lanka	Mobitel	3, 8
Sweden	Telia	20
Switzerland	Swisscom	20
Thailand	AIS	8
Thailand	TRUE	8
Turkey	Turkcell	20
Turkey	Vodafone	8, 20
UAE	DU	20
UAE	Etisalat	20
Ukraine	Kyivstar	3
Ukraine	Vodafone	3
United Kingdom	Vodafone	20

Country/Region	Operator	Bands
Uruguay	Antel	3,28
USA	AT&T	2, 4, 12
USA	T-Mobile	2, 4, 12, 66, 71, 85
USA	Verizon	13

LTE-M Network Global Coverage Info

Country/Region	Operator	Bands
Argentina	Claro	28
Argentina	Movistar	4,28
Argentina	Personal	4,28
Australia	Telstra	28
Belgium	Orange	20
Brazil	Claro	3, 28
Brazil	Vivo	3, 28
Canada	Bell	12
Canada	Rogers	4, 5, 12
Canada	Telus	2, 4, 5, 12
Chile	Claro	28
China(Taiwan)	APTG	8
China(Taiwan)	Chunghwa	3
Colombia	Claro	5
Colombia	Movistar	4
Colombia	Telefonica	2
Denmark	Telenor	20
Estonia	Elisa	/
Finland	DNA	20, 3
France	Orange	20
Germany	Deutsche Telekom	8, 20
Germany	Telefónica	20

Country/Region	Operator	Bands
Hungary	MVM Group	31
Japan	KDDI	18, 26
Japan	NTT DOCOMO	1, 19
Japan	SoftBank	1, 3, 8
Latvia	LMT	20
Mexico	ALTAN	28
Mexico	América Móvil	4
Mexico	AT&T	4
Mexico	Movistar	2
Mexico	Telcel	4
Netherlands	KPN	20
Netherlands	T-Mobile (DT)	8
Netherlands	Vodafone	20
New Zealand	Spark	28
New Zealand	Vodafone	28
Norway	Telenor	20
Peru	Claro	28
Peru	Entel	28
Peru	Movistar	4
Romania	Orange	3
Singapore	SingTel	3, 8
South Korea	KT	3

Country/Region	Operator	Bands
South Korea	LGU+	5
South Korea	SKT	3, 5
Spain	Orange	3, 20
Spain	Telefonia	20
Sri Lanka	Dialog Axiata	8
Sweden	Telenor	20
Sweden	Telia	20
Switzerland	Swisscom	20
Thailand	AIS	3, 8
Turkey	Turkcell	20
UAE	Etisalat	5
UK	O2 Telefonica	20
Uruguay	Antel	3, 28
US	USCC	2, 4, 5, 12
USA	AT&T	2, 4, 12
USA	Verizon	4, 13
USA	Sprint	25

NB-IoT and LoRaWAN

NB-IoT and LoRaWAN are two types of low-power wide-area network (LPWAN) technologies that are designed for IoT applications. Here is a summary of the main differences:

Bandwidth

NB-IoT uses a bandwidth of 200 kHz, equivalent to one physical resource block within a normal LTE resource block. This means that NB-IoT can fit more devices in the same spectrum and has less data capacity and speed.

LoRaWAN uses a bandwidth of 125KHz on 8 channels in 1 band. In US915, AU915, and CN470, there are 8 bands, so there are multiple ways to expand the network capacity. Please contact us on how to expand the network capacity with LoRaWAN.

Spectrum

LoRaWAN is optimized for ultra-low power and long-range applications. LoRaWAN networks operate in the unlicensed ISM (Industrial, Scientific, and Medical) band, so it is free to use. So there may be interferences from other devices in the same band.

NB-IoT operates in spectrum licensed for cellular (LTE) networks and is optimized for spectrum efficiency over everything else. License fees paid by cellular operators to use these frequency bands are very high, limiting the number of licensees that can afford to pay to operate NB-IoT services.

Deployment

LoRaWAN networks can be set up in different ways: public, private, open communities, or hybrid networks, indoors or outdoors. LoRaWAN can send signals over long distances and through obstacles, so it works well in cities where you need to connect devices inside buildings or underground and in rural areas where you can cover up to 50km per gateway.

NB-IoT depends on LTE cellular infrastructure. This means the networks are outdoor public networks that use 4G/LTE base stations (cellular towers). You cannot easily move base stations to other places if sensors are not in range of the tower. The cost of making an LTE network suitable for IoT use cases is high.

Speed

NB-IoT is faster than LoRaWAN, offering up to 200 kbps of data rate in downlink and uplink. LoRaWAN, on the other hand, is from 293bps to 50 kbps.

Power Consumption

Both NB-IoT and LoRaWAN have lower power consumption than regular LTE devices, meaning they can operate on batteries for longer periods. They also support power-saving features like power saving mode (PSM) and extended discontinuous reception (eDRX), which allow them to sleep or reduce their activity when not in use. However, for NB-IoT, building the TCP connection takes time (and power), which consumes extra power while waiting. And UDP is not stable. LoRaWAN does not have these problems.

Mobility

LoRaWAN devices can roam between gateways in the same country. However, it is challenging if devices roam between countries because the frequency plans differ.

NB-IoT is limited to idle mode cell reselection, which is not well optimized for mobile asset tracking because devices must be activated again when they roam between different base stations.

Satellite

LoRaWAN (which supports LR-FHSS data rates) is perfectly adapted to direct device-to-satellite communications, limiting downlink communications to prevent interferences with terrestrial devices, optimizing battery lifetime, and reaching a high link budget under harsh radio conditions.

NB-IoT has frequent downlink communications and high power consumption due to message repetitions under harsh radio conditions, which is a challenge for device-to-satellite communications.

Please find the detailed comparison of the two technologies the next page.

NB-IoT vs. LoRaWAN

	LoRaWAN	NB-IoT
Modulation	Chirp spread spectrum modulation	Quadrature phase shift keying modulation
Frequency	“Unlicensed ISM bands 868MHz in Europe 915MHz in North America 470MHz in China”	Licensed LTE frequency Bands.
Bandwidth	125KHz, 250KHz and 500KHz	200KHz
Link Budge	165dBm	164dBm
Maximum message/day	Maximum Message it can send per day is unlimited.	Maximum Message it can send per day is unlimited.
Data Rate	300bps~21Kbps	158.5Kbps (UL), 127Kbps (DL)
Payload Length	11~242 bytes.	Max. 1600bytes, depending on the operator
Range	5 km in urban, 20 km in rural area.	1 km in urban, 10 km in rural area.
Interference Immunity	Very high	Low
Device Movement	Support	Not appropriate for moving devices
Authentication and Encryption	AES 128b	256-bit 3GPP encryption
Adaptive Data Rate	Adaptive Data Rate (ADR).	Does not support ADR
Gateway	“8 uplink and 1 downlink channels, 16 uplink and 2 downlink channels”	Not needed
SIM Card	Not needed	Yes
Network Capacity	The capacity can be expanded according to the needs. Please reach out to us for further information	Depending on the operators’ network
On-Premise Deployment	Yes	No
Cloud Deployment	Yes	Yes
Battery Power Consumption	x	2x
Continous TX Deplay	4s	0s
Gateway Deployment	Need to deploy gateways	No need to deploy a gateway
SIM Card	No SIM card is needed	SIM card is needed
Network	Expandable network	Depends on the operator
Server Deployment	On-premise deployment	Cloud Server
Roadming	Hard	Worldwide roaming is possible
Battery Life	Long battery-life compared with NB-IoT	

Summary

In general, 4G and 5G are good options for data backhaul for larger data communication devices such as gateways, cameras, etc. 4G can also be used for trackers, especially for vehicles that continuously power the tracker.

LTE-M, NB-IoT, and Cat-1 can be good options if you need a nationwide or even worldwide low-power tracking ability. For example, containers, vehicles, packages, machines for renting, etc. Please confirm the network availability with the operator or SIM card vendor before you expand your project.

LoRaWAN is a good option for tracking projects in a relatively small area, such as a factory, port, farm, work platform on the sea, or even a city. There are also nationwide LoRaWAN networks in some European countries such as France, Belgium, and Netherlands.

Long term availability

There are a few other options, like Sigfox. A client may use the system for many years and you may want to expand the same solution to different clients. So the technology's long-term availability is a crucial yet not-so-obvious factor that must be evaluated..

Eco-system

LoRaWAN and 4G have a perfect eco-system where you can find all kinds of resources on end nodes, algorithms, network service, application service, and consultants. They expedite your project and provide alternatives as your business expands.

A tracking project is usually a combination of several communication technologies, i.e. long distance + near field. So accuracy, distance, power supply, dimension, and support are some other factors we should consider.

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