Low Power Wide Area Access Technologies

Narrowband IoT, LTE-M and LoRaWAN: an introductory technology overview

Connectivity, respectively the linking of „things“ to the internet, is the elementary basic requirement to make it at all possible to connect the steadily and quickly growing number of „things“ to be networked with each other. The „thing“, regardless of its type, in future will communicate primarily by radio access technologies such as LoRaWAN, Narrow-band IoT and LTE-M or via complementary fixed-wire and non-fixed-wire technologies. Besides the existing and known mobile technologies of the second, third, fourth and by now fifth generation, for the first time two cellular „Low Power Wide Area“ access technologies have been especially defined for IoT applications in the 3GPP Release 13 with Narrowband IoT and LTE-M. Viewed technically, both technologies belong to the Low Power Wide Area (LPWA) family as well as the Swisscom Low Power Network from the unlicensed mobile radio spectrum. All three are very energy-efficient. The various features of the technologies can be taken in detail from the table overview.

Narrowband-IoT (NB-IoT)
Narrowband IoT has very good coverage with a high building-penetration capacity. NB-IoT is suited above all for static applications with small data volumes and without special requirements that are located in “difficult” locales when it comes to access technology, such as in cellars, deep under ground or even in rural and remote areas.

LTE-M
In contrast to the other two “Low Power Wide Area” technologies, NB-IoT and LPN, LTE-M offers greater scalability for the data rates as well as optionally voice functionality. Furthermore, LTE-M ensures full mobility and mobile radio cells handover (for non-static applications) and is therefore well suited for IoT applications in the automotive and transport industry.

Swisscom Low Power Network (LPN)
When it comes to LPN, we are dealing with an extremely energy-efficient complementary network that is based on the open internet LoRaWAN industry standard lora-alliance.org. In contrast to Narrowband IoT and LTE-M, LoRaWAN uses an unlicensed frequency spectrum. Since 2016 LoRaWAN is available throughout Switzerland. Local network enhancements are also realisable very economically.

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Technology	LPN (LoRa)	NB-IoT	LTE- M (LTE Cat.M1)	LTE (Cat.1)
Short description	The LoRaWAN-network is a dedicated network for IoT. It is optimized for low-cost and energy efficient IoT communication with small data volume.	Narrowband IoT is a special extension of the LTE network, which is suitable for very large numbers and densities of low bandwidth end devices.	LTE-M is an extension of the LTE network, which is suitable for quality-sensitive applications in the IoT field. LTE-M also supports mobility and voice.	The lowest device category in the existing LTE network is relatively well suited for IoT applications due to the relatively low data rate.
Radio access technology	Radio network based on the open LoRaWAN specification.	Cellular mobile radio network within the licensed frequency spectrum		
		4G, 3GPP Rel. 13		4G, 3GPP Rel. 8
Suitable for the following IoT application areas	**Massive IoT** › **Smart Utilities:** gas, water and electricity metres, Smart Metering › **Smart Cities;** Traffic control systems, smart parking, waste container management, intelligent traffic lights, street lights, etc. › **Smart Buildings;** smoke detectors, alarm systems, remote heating, shutters, air conditioning › **Consumers;** wearables, children and senior tracking › **Transport & Logistics;** fleet management, goods tracking › **Agriculture;** weather and plant growth monitoring, grazing livestock tracking › **Industry 4.0;** process monitoring and control, O&M, heating, ventilation and air conditioner monitoring		**Critical IoT** › **Road Traffic Safety;** traffic supervision, traffic control, automatic emergency calls › **Health;** health monitoring, remote operations › **Industrial Production;** time-critical and data-intensive cooperation, production control and evaluation › **Self-Driving Vehicles;** vehicle to vehicle, vehicle to object and vehicle to control centre communication › **Security and Surveillance Applications;** video surveillance, object surveillance › **Public Safety;** police, military communication, remote monitoring, control of robots, videos from drones › **Aviation and Train Controls;** drones, helicopters, air traffic control, airspace control › **Train Control;** self-driving trains, subways, trams, signal alarms, collision protection › **Smart Control;** Digital meters with additional network management functionality, Smart Grid Mgmt.	

This list of sample applications is neither exhaustive nor is the assignment binding. The optimal IoT technology for your application may differ from this list. Our IoT Specialized Sales are available for individual advice (contact IoT.spoc@swisscom.com).

Overview of the most important features

Technology	LPN (LoRa)	NB-IoT	LTE- M (LTE Cat.M1)	LTE (Cat.1)
Data rate	●○○○○	●○○○○	●●○○○	●●●●●
Range	●●●●●	●●●●●	●●●●○	●●●●○
Energy efficiency	●●●●●	●●●●○	●●●○○	●○○○○
Voice	No	No	Yes	Yes
Module costs	●○○○○	●●○○○	●●○○○	●●●●○
Availability	Since 2016	Since Q4 2018	Since Q4 2018	Since 2014
Security	●●●●○	●●●●●	●●●●●	●●●●●
Mobility	Yes	Yes	Yes	Yes
Roaming	Available internationally [1]	Available internationally on request [2]	Available internationally [3]	International (More than 500 networks)
Miscellaneous	Cheap local extensions	Extended indoor cover		

1) LoRaWAN Roaming is being continuously expanded and is now available in the following countries: Belgium, France, The Netherlands and Finnland.
2) August 2020: NB-IoT is limited in international availability, but is continuously being expanded.
3) This wireless access technology will also be available to Swisscom customers on all LTE roaming networks that introduce LTE-M. Can also be queried via the following link https://www.gsma.com/iot/deployment-map/

Disclaimer: The specifications for data rate, range and energy efficiency depend on the configuration of the customer application as well as on the radio communication conditions. All radio technologies offered by Swisscom are based on "best effort" in the access area. Please also note that the topography, the terrain, the properties of building envelopes, the existing mobile infrastructure and the number of users may influence the availability and quality of the services. The values given for radio coverage are based on a model calculation that depends on a wide variety of factors. In reality, coverage may differ from these values. For an exact assessment of provision possibilities, on-site clarification is required.

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Detailed overview of network properties and features

Technology	LPN (LoRa)	NB-IoT	LTE- M (LTE Cat.M1)	LTE (Cat.1)
Frequency band	SRD band [4] 868 MHz, not licensed	LTE band 20 800 MHz licensed [5]	LTE band 20 800 MHz licensed [5]	LTE band (frequency in MHz) 20 (800); 3 (1800); 1 (2100); 7 (2600) licenced
Data rates	DL 1,7 – 5,4 kBit/s UL 0,3 – 5,4 kBit/s	DL 0,4 – 30 kBit/s UL 0,1 – 60 kBit/s	DL & UL 0,1 kBit/s – 1 MBit/s	DL 10,3 MBit/s UL 5,2 MBit/s
Max. path loss (MCL)	159 dB	164 dB	155 dB	140 dB
Max. coverage Switzerland [6] Outdoor	97,5%	99,9%	99,9%	99,9%
Coverage Enhancement [7]	Chirp Spread Spectrum	› Max. 64/128 retransmissions › PSD / UL single-tone/ multi-tone transmission	› Coverage enhancement A › Max. 32 retransmissions › Frequency hopping	› Rx diversity › Frequency diversity gain
Receiving antenna UE	No MIMO, but Rx diversity	No MIMO, no Rx diversity	No MIMO, no Rx diversity	No MIMO, but Rx diversity
Max. battery life [8]	To 10 years	To 10 years	Max. 5 – 10 years	Days – a few months
Voice telephony	No	No	Yes, VoLTE (Packet Switched)	Yes, VoLTE (Packet Switched)
Real-time application	No	No	Yes	Yes
Latency	1 – 10s	1,4 – 10s	~10 – 200ms	~10 – 100ms
Duplex transmission [9]	Half-duplex	Half-duplex FDD only	Full & half-duplex FDD	Full and half-duplex FDD & TDD
Max. device density	> 10'000 devices per radio cell			≤ 1'000 devices per radio cell

4) SRD (Short Range Devices) band is a frequency range for low power devices, also known as "everyone radio applications" for voice and data transmission. The 868 MHz frequency can be used license-free throughout Europe. This is also used for the following IoT standards; LoRa, Weightless P and Sigfox EU.
5) In Liechtenstein LTE-M and NB-IoT are in operation on the band 3/ 18000 MHz frequency.
6) The values given for radio coverage are based on a model calculation that depends on a wide variety of factors. In reality, coverage may differ from these values. For an exact assessment of provision possibilities, on-site clarification is required.
7) The following coverage enhancement functions cause the data rate to decrease:
   - PSD (Power Spectrum Densitiy), the available energy of the UE is concentrated on a smaller bandwidth.
   - Coverage Enhancement Mode with corresponding numbers of retransmissions
   - More robust modulation; LTE-M 16QAM & QPSK and NB-IoT QPSK modulation and additionally the maximum stable BPSK.
8) The battery life is influenced by the following factors: the data transmission cycle (eDRX/PSM), the amount of data transmitted in each cycle, the radio communication conditions or the number of retransmissions required, the parameterisation of PSM and eDRx in the network and the quality/self-discharge of the batteries.
9) Duplex transmission method FDD = Frequency Division Duplex & TDD = Time Division Duplex

Detailed overview of network properties and features

Technology	LPN (LoRa)	NB-IoT	LTE- M (LTE Cat.M1)	LTE (Cat.1)
Standard powersave function (DRX) [10]	n/a	10,24s	2,56s	2,56s
Extended powersave function (PSM)	Specific device classes & ADR [11]	eDRX [12] max. 10'485,76s (ca. 2,9hrs)	eDRX [12] max. 2'621,44s (~44 min)	not supported
	[13] PSM / periodic TAU timer max. 413,3 days + [14] HLCom			
Mobility	Broadcast	Cell reselection	Handover (connected mode) & cell reselection (idle mode)	

Supported network features

Technology	LPN (LoRa)	NB-IoT	LTE- M (LTE Cat.M1)	LTE (Cat.1)
Coverage Enhancement	n/a	Yes [15]	Yes [15]	No
eDRX	n/a	Yes [16]	Yes [16]	No
PSM / periodic TAU timer	Broadcast /ADR	Yes [17]	Yes [17]	No
HLCOM	No	Not intended [18]	Not intended [18]	No
Network positioning	GPS und TDoA [19]	GPS and ECID	GPS and ECID	GPS and ECID
PSD boosting in downlink	Yes	Yes	Yes	No
Multicast	Since Q1 2020	From introduction 3GGP Rel. 14	From introduction 3GGP Rel. 14	No
Voice/VoLTE	No	No	Yes	Yes
SMS	No	Yes [20]	Yes	Yes

10) Discontinuous reception means switching off the receiver in periods when there is little or nothing to transmit. This applies especially to times when the UE is in idle mode.
11) With ADR = adaptive data rate and use of the appropriate device class, energy-efficient operation is possible. The LPN device classes are:
- For Class A end devices, each uplink transmission is followed by two short downlink reception windows
- For Class B end devices, in addition to the random Class A reception windows, additional reception windows open at fixed times

Class C end devices have an open reception window almost continuously. These are only closed during transmission.
12) eDRX delivers additional energy savings. It stretches on the one hand the maximum DRX cycle length in connected mode from 2,56s to 5,12s & 10,24s. Furthermore, in idle mode, the energy requirement is additionally reduced by long sleep periods T(eDRX) between the page monitoring of the UEs:
- For LTE-M (Cat. M2) and LTE Cat. 1 n x 10,24s to max. 2'621,44s (approx. 43,7 min)
- With NB-IoT n x 10,24s up to max. 10'485,76s (approx. 2,9h)

13) Power Saving Mode / periodic tracking area update; PSM/ periodic TAU timer; in deep sleep phases of PSM operation, the UE consumes even less energy than during DRX operation. However, the UE can no longer be reached, but it is still registered in the network. The UE remains in PSM mode until a transaction such as another TAU or data transmission is triggered from the mobile device. PSM can be used for Cat-0, Cat-M1 and Cat-NB1 UEs. The TAU timer is a maximum of 11'520 s in Rel. 8-12 and a maximum of 413,3 days in Rel. 13.
14) High Latency Communication. Data that is sent to the terminal while it is in sleep mode (sleep periods or deep sleep phases) is buffered by the network and sent to the terminal as soon as it logs back into the network.
15) Coverage Enhancement: Single Tone Transmission Mode and Multitone Transmission Mode are available for NB-IoT. Mode A is available for LTE-M, and Mode B is being tested if it should be integrated in the Swisscom network.
16) eDRX: For NB-IoT and LTE-M eDRX is available and is currently in the testing and optimizing phase.
17) PSM: For NB-IoT and LTE-M Power Saving Mode is available and currently in the test phase.
18) For NB-IoT and LTE-M it is being tested whether this function should be integrated in the Swisscom network.
19) GPS and Time Difference on Arrival in Zurich region already available
20) At present it is being tested whether the SMS function should be integrated in the Swisscom NB-IoT network.

Security

Technology	LPN (LoRa)	NB-IoT	LTE- M (LTE Cat.M1)	LTE (Cat.1)
Subscriber Identity [21]	Optional HSM possible	USIM [22]	USIM [22]	USIM [22]
Protection of identity	Device ID	Devices and subscriber ID [23]	Devices and subscriber ID [23]	Devices and subscriber ID [23]
Authentication	Radio module and network	Radio module and network	Radio module and network	Radio module and network
Encryption	128 Bit encryption	128 Bit encryption	128 Bit encryption	128 Bit encryption
Integrity check	Subscriber and network side	Subscriber and network side	Subscriber and network side	Subscriber and network side

Devices and properties

Technology	LPN (LoRa)	NB-IoT	LTE- M (LTE Cat.M1)	LTE (Cat.1)
Device classes	Class A/ battery powered Class B/ battery powered Class C / Mains supply [24]	NB IoT Cat.1 NB IoT Cat.2	LTE-M Cat. M1 LTE-M Cat. M2	LTE Cat. 1
Power class	14dBm / 25 mW	23dBm / 200 mW 20dBm / 100 mW [25]	23dBm / 200 mW 20dBm / 100 mW	23dBm / 200 mW
Max. data rates	n/a	NB IoT Cat.1 30/60 kBit/s NB IoT Cat.2 120/150 kBit/s [26]	LTE-M Cat. M1 1MBit/s LTE-M Cat. M2 2,4 MBit/s [26]	LTE Cat. 1 10 – 5 MBit/s
Receiving antenna	Rx diversity	No MIMO, no Rx diversity	No MIMO, no Rx diversity	No MIMO, but Rx diversity
Firmware upgrade OTA (over the air)	In evaluation	Yes	Yes	Yes

21) Manufacturers can optionally produce their devices as HSMs (Hardware Security Modules) to ensure efficient and secure execution of cryptographic operations or applications. (a cost issue).
22) NB-IoT and LTE-M are very secure in comparison with 2G.
- USIM cards offer more security, extended possibilities for user applications and more storage space than the old 2G SIM cards. Furthermore, they cannot be cloned.
- In the 4G network there is a mutual verification of authenticity between the LTE network and the radio module. In 2G, only the radio module is authenticated.
- In the 4G network, signalling and user data between the network and the radio module are encrypted with a 128-bit algorithm and checked for integrity. In 2G only a 64-bit algorithm is used to encrypt the data.

23) To protect the subscriber identity (IMSI), a temporary IMSI is always used during the unencrypted connection setup phase – except during the initial connection setup in a network. Only transfer device identity (IMEI) in encrypted form.
24) Short description of LPN UE classes
- For Class A end devices, each uplink transmission is followed by two short downlink reception windows
- For Class B end devices, in addition to the random Class A reception windows, additional reception windows open at fixed times
- Class C end devices have an open window almost continuously. These are only closed during transmission.

25) NB-IoT will also offer device classes with just 14dBm / 25 mW as of Release 14.
26) NB-IoT Cat. 2 and LTE-M Cat. 2 devices will be available on the IoT platform when 3GGP Rel. 14 features are activated.