freeRAN™ Base Station

pLTE solution in ISM band 902-928 MHz

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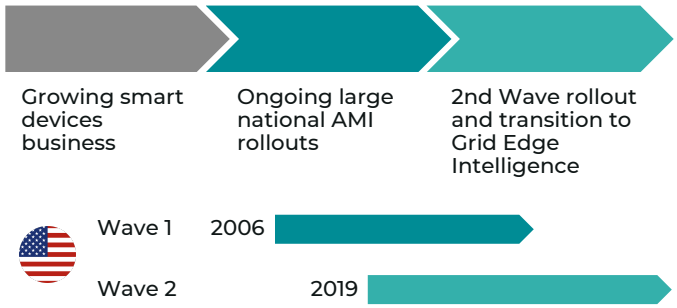
PRIVATE LTE-M AT THE CORE OF ADVANCED UTILITY COMMUNICATIONS

Introduction

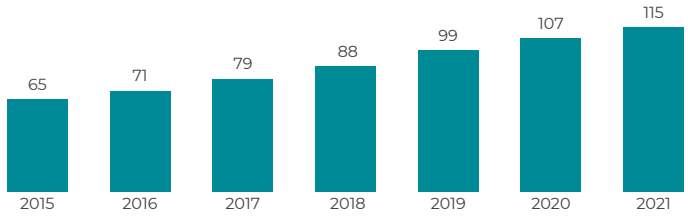
The global utility sector is experiencing a growing need for reliable, cost-effective, and secure communication solutions. LTE-M (Long-Term Evolution Machine Type Communication) technology in conjunction with 3GPP (The 3rd Generation Partnership Project) standardization is poised to meet this need by enabling the development of private LTE (pLTE) solutions for utility use. The freeRAN™ Base Station (freeRAN™) can provide coverage on the US 915 MHz unlicensed band, making it ideal for utility companies that need to read their remote meter data effectively, as well as to monitor their assets in distant and challenging environments. The purpose of this white paper is to provide an overview of how freeRAN™, which uses standardized 3GPP technology such as LTE-M to operate on unlicensed bands, can be utilized to establish standalone private networks for AMI and DA (Advanced Metering Infrastructure and Distribution Automation) and other deployments, including streetlight sensors, line sensors, EV charging stations, and more.

Needs of the utility industry

The digitization of the utility sector is having a profound impact on how resources, such as electricity, water and gas, are managed. Automation of resource management can help reduce wastage and increase efficiency. AMI and DA are designed to help facilitate this automation and are capable of collecting consumption data from meters, monitoring the operating status of equipment, and monitoring the quality of resources. It can also detect and prevent issues such as tampering with devices or leaking gas or water pipes. The right side shows the growth trends of the smart metering market in the US. As AMI and DA technology become increasingly widespread, the need for reliable communication infrastructure grows.



US electricity smart device deployment
Source: Landis+Gyr (2023)



Number of smart meters installed in the US, in millions
Source: Mordor Intelligence (2023)

Utilities face a variety of challenges when attempting to integrate a wide range of controlling parameters into their business processes. The use of outdated radio and proprietary technologies can lead to a lack of reliable data delivery. Furthermore, these technologies often cannot provide the necessary level of data security and interference stability, both of which are particularly essential for unlicensed frequency bands. As hacking activity increases each year, utilities need to ensure that the technology they use is secure and supported long-term, in order to keep up with new threats. In other words, utilities want to spend money once without risk of having to change the equipment after some time, whether increased interference or insufficient security is identified during a hacking attempt.

In addition, utilities want to minimize their costs by utilizing a single radio technology for current solutions and potential future upgrades, such as metering upgrades, environmental control sensors and asset trackers. To meet the Utility's expectations, the chosen solution must provide reliable data delivery, interference resistance, and sufficient security.

The freeRAN™ Base Station meets market challenges

The freeRAN™ Base Station is an innovative solution to create a standalone private network, which is utilizing LTE-M technology, announced by 3GPP in 2016 through Release 13, to serve the utility and IoT sectors. It is engineered to operate within the 3 MHz bands of uplink (902-915 MHz) and downlink (925-928 MHz), which fall within the ISM (Industrial, Scientific, and Medical) unlicensed bands of 902-928 MHz.

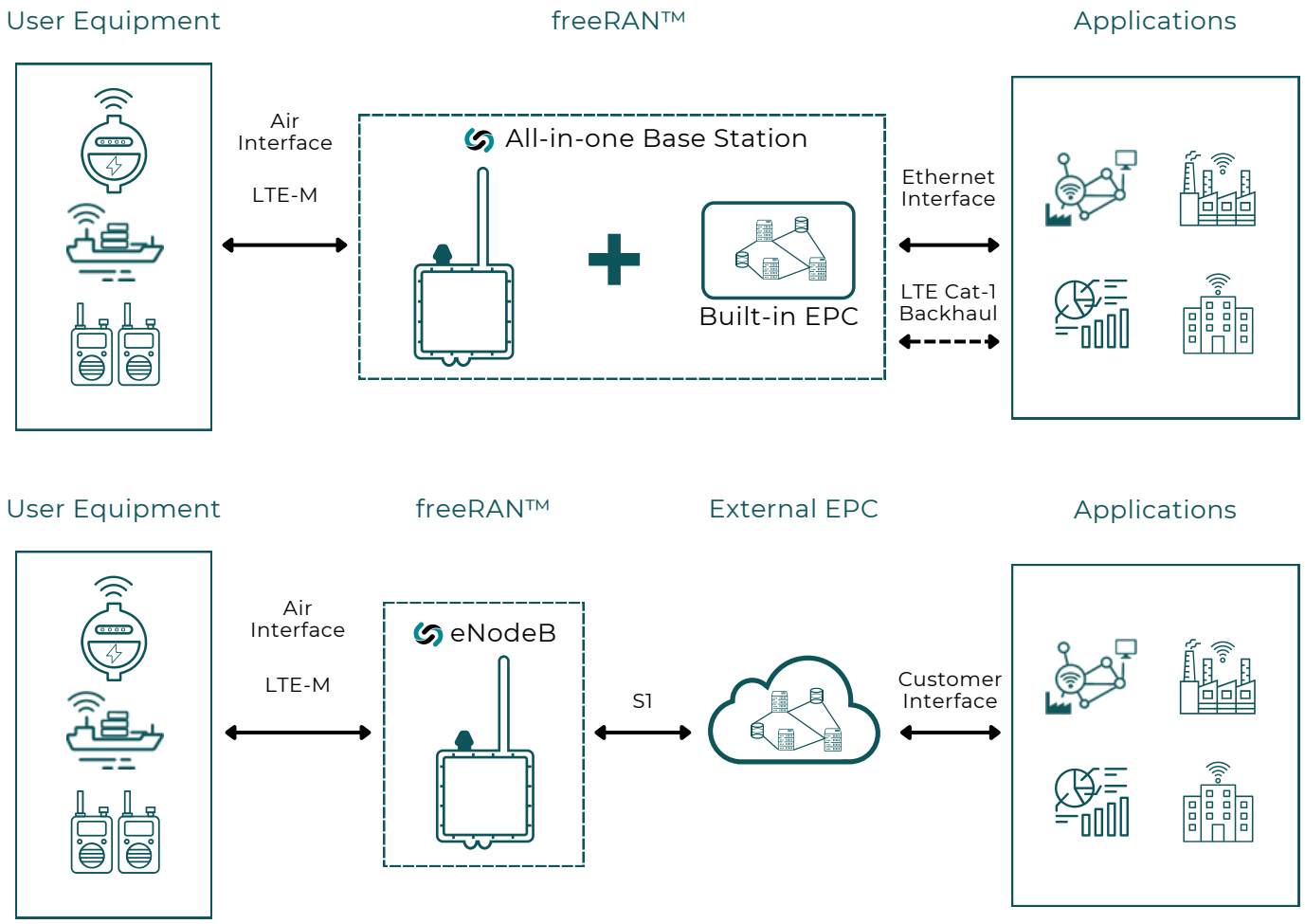
The freeRAN™ Base Station is certified according to Part 15c of the FCC (Federal Communications Commission) Rules.

freeRAN™ provides a solution-in-a-box approach for remote data collection, monitoring and management of IoT devices with full two-way communications.

The freeRAN™ Base Station

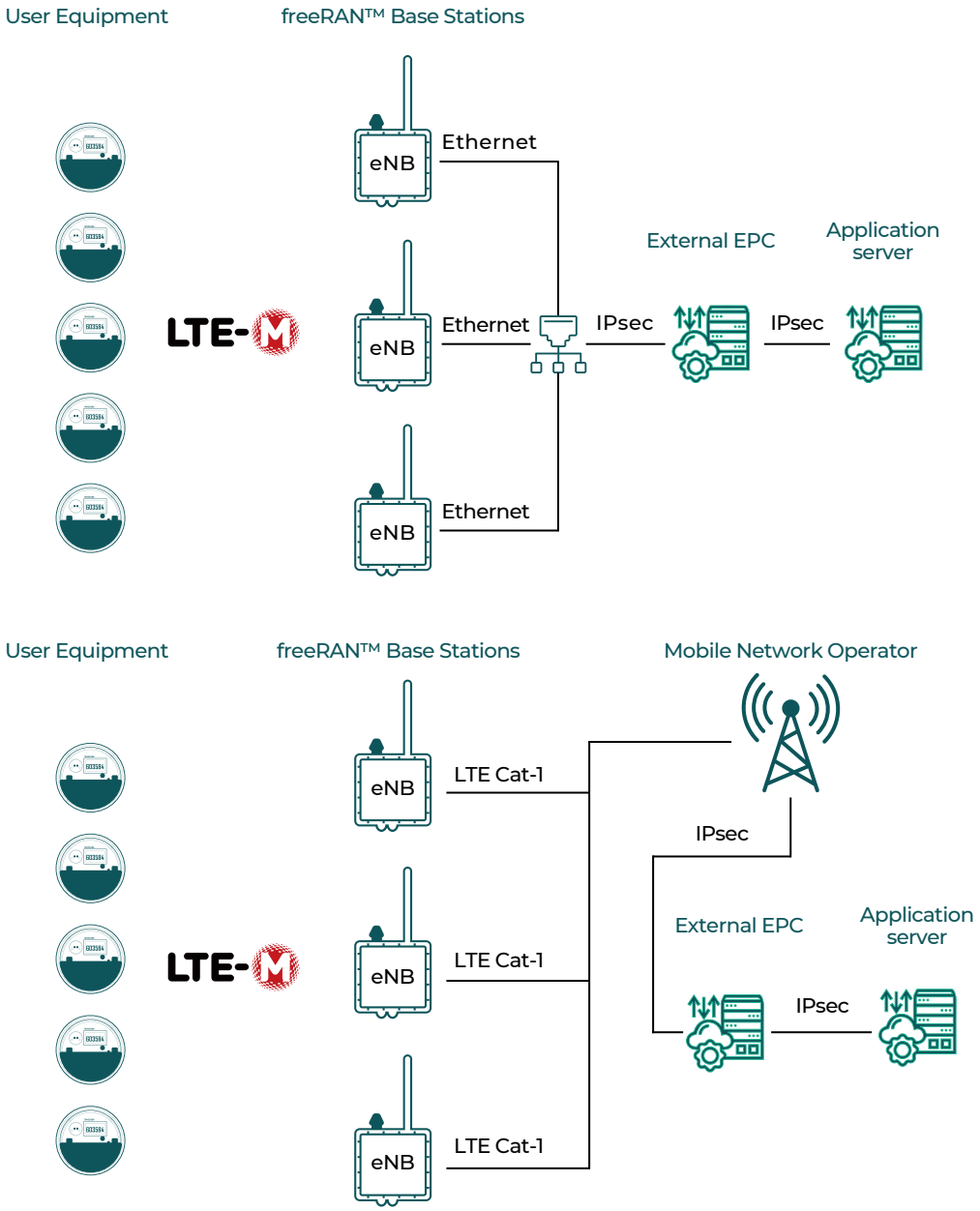
freeRAN™ is equipped with an RF antenna and onboard GPS. The unit connects to the cloud in two ways, via LTE Cat-1 backhaul, or using a router through PoE (Power over Ethernet). It offers advanced functionality, including integrated base station and core functions, along with the Linux operating system, enabling seamless plug-and-play operation. The base station serves as the interface between the user's device and the core network, transmitting and receiving data to and from the user devices, managing connections, and assigning radio resources as needed in order to provide wireless connectivity. The core of the network, known as the EPC (Evolved Packet Core) in 3GPP terms, is responsible for managing the connections and the data traffic between the base station and external networks, as well as user mobility and authentication, and security. One of its core components is the HSS (Home Subscriber Server), which contains user authentication profile information and provides this information to the other core components.

freeRAN™ can be configured to operate with its built-in internal EPC function. In this case, the freeRAN™ Base Station shapes the entire network, comprising of the RAN (Radio Access Network) and EPC.



freeRAN™ architecture with built-in EPC and external EPC

In some cases, customers already have their own core infrastructure that can be deployed on-premise or in the cloud. In such cases, freeRAN™ acts as a base station without core functions, shaping the RAN. It is worth noting that enabling or disabling the internal core is a simple programming process, which can be easily performed if the customer's network configuration is changed. Depending on the size of the area to be covered and the business case, deploying a multiple base station network, similar to how mobile operators create their public networks with several base stations and one centralized EPC, may be necessary. Due to the scalability provided by the 3GPP standards, the freeRAN™ Base Station can be used to form networks of various sizes.



Multiple freeRAN™ configurations

For multiple deployments, each freeRAN™ is connected to a single centralized EPC via a standard S1 interface, and the internal EPC of freeRAN™s is not used. Deploying a dedicated EPC, either on-premises or in the cloud, is necessary for this type of network configuration. It is possible to deploy a network with a variety of freeRAN™s, ranging from two to several hundred, providing the customer with flexibility and scalability. The customer can add a new base station to the existing network at any time, after having initially deployed the freeRAN™ network with one external EPC.

The figures above illustrate the two types of network configurations for freeRAN™ backhaul interfaces: the first utilizes Ethernet, whereby all freeRAN™s connect and interact with the EPC through the local network infrastructure; while the second employs LTE Cat-1 backhaul interface. If freeRAN™ is configured to use the LTE Cat-1 backhaul interface, the data from freeRAN™ is transferred to the mobile operator network, which then sends the data to the customer endpoint, usually using a dedicated APN (Access Point Name) and secure communication channels. freeRAN™ provides reliable and proper connectivity for both Ethernet and LTE Cat-1 backhaul network configurations, which can be defined by the customer, allowing for the possibility of utilizing both backhaul types on a single network.

The freeRAN™ Base Station can be configured and monitored with advanced program tools provided by Ubiik.

One of them is BSMS (Base Station Management System), a GUI-based tool for configuring network parameters, such as PLMN (Public Land Mobile Network) and external EPC IP-addresses. ACT (Admin Config Tool) is not only used for configuring, but also for monitoring purposes - one more tool in the arsenal. freeRAN™ operating logs can be accessed through ACT, and one of its most useful features is the ability to check the status of each device attached to the base station. Unlike other base station vendors that merely monitor the whole RAN, the freeRAN™ Base Station, with its extended RAN + EPC architecture, can provide more detailed information on each device connection state. The Figure on the right shows an example of an ACT page with device states attached to freeRAN™.

End Devices

Devices 47 Registered 47 Connected 0

#	Device Type	UE IMSI	Status	Last Updated
0	ForeignED	001010000000039	Registered	15:36:46 2023-04-24
1	ForeignED	001010000066351	Registered	15:36:46 2023-04-24
2	ForeignED	001010000000243	Registered	15:36:46 2023-04-24
3	ForeignED	001010000000248	Registered	15:46:13 2023-04-24
4	ForeignED	001010000000020	Registered	15:36:46 2023-04-24
5	ForeignED	001010000000003	Registered	15:45:03 2023-04-24
6	ForeignED	001010000000023	Registered	15:36:46 2023-04-24
7	ForeignED	001010000000022	Registered	15:55:43 2023-04-24
8	ForeignED	001010000000256	Registered	15:59:13 2023-04-24
9	ForeignED	001010000000007	Registered	15:49:53 2023-04-24
10	ForeignED	001010000000251	Registered	15:36:46 2023-04-24
11	ForeignED	001010000000245	Registered	15:46:53 2023-04-24
12	ForeignED	001010000000046	Registered	15:50:53 2023-04-24
13	ForeignED	001010000000252	Registered	15:58:23 2023-04-24
14	ForeignED	001010000000019	Registered	15:53:23 2023-04-24
15	ForeignED	001010000000005	Registered	15:51:43 2023-04-24
16	ForeignED	001010000000250	Registered	15:36:46 2023-04-24
17	ForeignED	001010000000010	Registered	15:36:46 2023-04-24
18	ForeignED	001010000000244	Registered	15:36:46 2023-04-24
19	ForeignED	001010000000035	Registered	15:36:46 2023-04-24
20	ForeignED	001010000000000	Registered	15:36:46 2023-04-24

Devices status monitoring

freeRAN™, as an LTE-M technology base station, not only supports machine-to-machine data exchange services, like many other LPWA (Low Power Wide Area) solutions, but also provides VoLTE (Voice over LTE) and SMS (Short Message Service). It could be used for business cases with voice service, such as PTT (Push To Talk), and customers may implement this service as a dedicated or additional service to the classic M2M service.

LTE-M standard serves as a foundation for private networks

The freeRAN™ Base Station operates with LTE-M technology, also known as LTE Cat-M1, which is a standard developed by 3GPP specifically designed for machine-to-machine communications. It is a type of wireless communication technology designed for low-power, low-bandwidth devices and related to the category of LPWA networks. LTE-M provides a peak data rate of 1 Mbit/s for both Downlink (directed from the base station to the device) and Uplink (directed from the device to the base station). LTE-M can operate in Half Duplex mode with a minimum bandwidth of 1.4 MHz. The OFDM (Orthogonal Frequency Division Multiplex) channel division mechanism is used to transmit signals; Downlink utilizes OFDMA (Orthogonal Frequency Division Multiple Access), while Uplink utilizes SC-FDMA (Single Channel Frequency Division Multiple Access). The freeRAN™ Base Station technically supports bandwidths of 1.4 MHz, 3 MHz, and 5 MHz, as well as both duplex modes - FDD and TDD.

The FCC has certified the freeRAN™ Base Station with a 3MHz bandwidth and FDD mode for operation in the 902-928 MHz unlicensed band. The bandwidth of 3 MHz provides sufficient capacity for connecting devices in both rural and urban areas, and FDD mode effectively spaces Downlink and Uplink transmissions. These radio parameters are widely supported by manufacturers of chips, modules, and devices all around the world. Obtaining further certification for TDD mode will provide more flexibility for adjusting radio resources.

Depending on the amount of data being transmitted and the signal quality of the wireless channel, LTE-M employs two main modulation types: QPSK (Quadrature Phase-Shift Keying) for data transmission at lower rates (typically below 10 kbps) and 16QAM (16 Quadrature Amplitude Modulation) for higher rates (typically above 10 kbps).

In addition to these modulation types, LTE-M also uses AMC (Adaptive Modulation and Coding) techniques. AMC is used to optimize the transmission rate and error correction based on the signal quality of the wireless channel; this helps to ensure reliable communication and efficient use of network resources, while also allowing for a flexible adjustment of device data rate depending on the signal quality.

LTE-M's ability to operate at lower signal levels and a high noise level, to save devices battery power, and to penetrate deep inside buildings, providing better coverage than other wireless technologies, makes it an ideal choice for applications such as smart metering, remote monitoring, and asset tracking, as well as other IoT use cases.

The LTE-M technology provides the required characteristics through its various features, such as:

- Closed-loop transmit power control and adaptive modulation and coding scheme for throughput maximization depending on the link quality real-time monitoring,
- The mechanism of repetitions of the transmitted information (Coverage Enhancement),
- Power-saving features, including PSM (Power Saving Mode), allow devices to enter a deep sleep mode when not in use and wake up periodically to transmit data.

Data security is the highest priority for industries

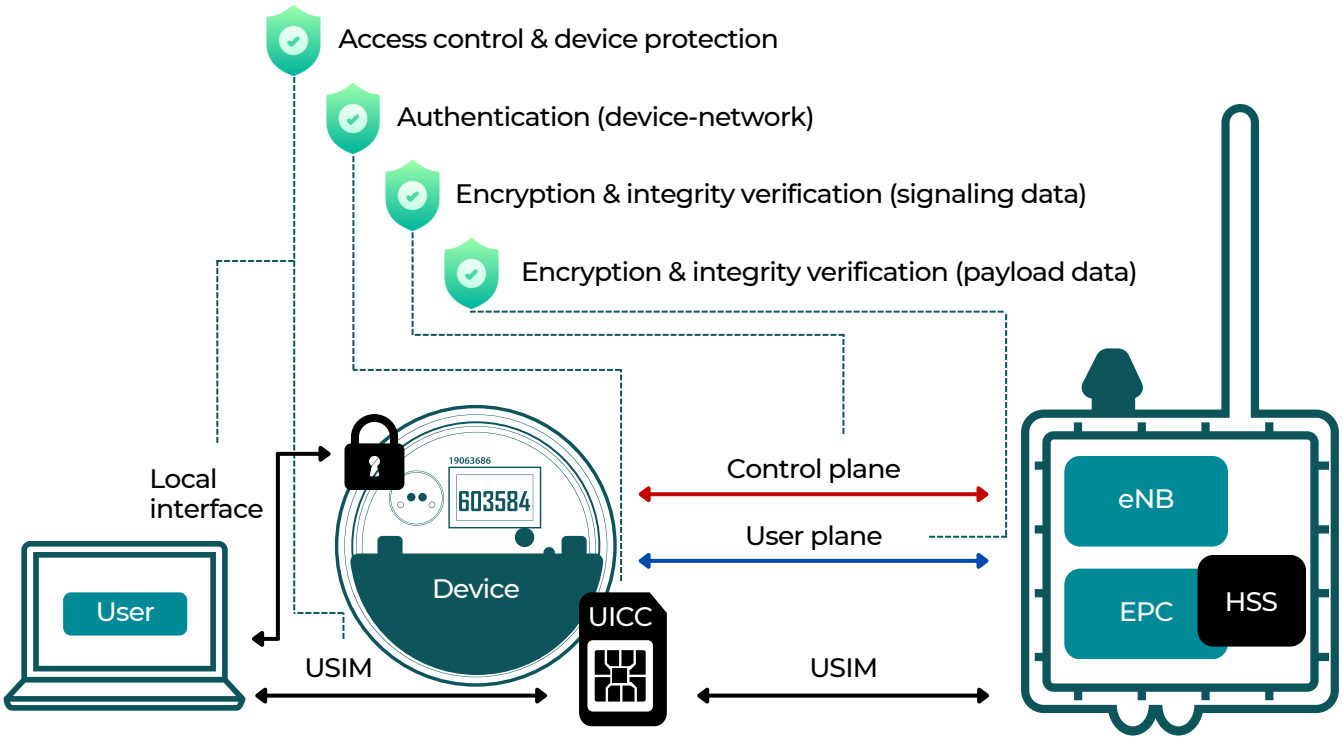
freeRAN™ provides a high data security standard that is defined by LTE design. LTE is the only mature wireless technology to enable protection of session set-up and administration signals (control plane) separately from the data payload itself (user plane). Through its Authentication and Key Agreement protocol, LTE secures control plane communications independently from user plane data. LTE includes cryptographic protections for control plane communications between the device and three different network elements to prevent attackers from spoofing devices and/or network elements to compromise the system.

To protect control plane communications between the device and the HSS (Home Subscriber Server) core network element, LTE uses an application called USIM that typically runs on the UICC (Universal Integrated Circuit Card). Through USIM, LTE supports the authentication of the user to the device as well as authentication of the device to the HSS, which manages customer information and authorizes the device's access to the network.

The MME (Mobile Management Entity) is also a core network element; it manages device mobility on the network. Using a feature called NAS (Non-Access Stratum) security, LTE verifies, encrypts, and protects the integrity of control plane signaling between the device and the MME separately from other interfaces.

For protection of the device's control plane communications with the radio network, LTE employs AS (Access Stratum) security, which provides verification and integrity protection as well as encryption for control plane signaling between the device and the base station. LTE provides enhanced security measures to protect the user data contained in the payload of the communication. For the user plane, LTE utilizes integrity verification and encryption of data sent between the device and the core network.

LTE-M devices provide an additional layer of security, due to their strict adherence to 3GPP specifications, the high-security level industry standard, and the highly competitive market they are produced in. LTE-M devices are typically designed with built-in security features, such as secure access, secure boot and firmware updates, to help prevent unauthorized access and tampering. The figure below shows described security levels. Supported by major mobile equipment, chipset and module manufacturers, LTE-M networks benefit from all the security features of 3GPP standards, such as support for user and device authentication, data encryption, data integrity verification and mobile equipment protection.



LTE-M security levels

ISM 902-928 MHz REDUCES COSTS

Unlicensed band and interference mitigation

The Industrial, Scientific, and Medical (ISM) band in the United States is a group of frequencies that can be used for unlicensed communication and transmission of signals, spanning from 902 to 928 MHz. The ISM band has several benefits, including its availability for unlicensed use, eliminating the need for expensive licenses. The band's initial purpose was to enable scientific and industrial users to operate their equipment without the need for expensive licenses, enabling technological progress and innovation. The band's use was later expanded to include consumer electronic devices and wireless communication technologies. The use of the ISM band has significant economic benefits, as it enables the development of low-cost and low-power devices, creating new markets and applications. The availability of unlicensed spectrum promotes competition and innovation, as companies can develop new wireless products and services without the need for large investments in spectrum licenses.

However, the ISM band's unlicensed nature also poses challenges, such as the potential for interference from other devices operating in the same frequency range. To mitigate interference, the Federal Communications Commission (FCC) imposes several regulations on ISM band usage, including limiting the output power of transmitters, specifying the permissible modulation types and bandwidths, and defining usage restrictions to avoid interference with other services. It is essential to comply with these regulations to ensure efficient and safe use of the ISM band frequencies.

Using ISM band requires effective interference mitigation methods to ensure reliable service. freeRAN™ utilizes LTE-M technology, which, as with other LTE technologies, has advanced interference mitigation mechanisms:

- Adaptive modulation and coding (AMC): Previously mentioned in relation to data rates - also allows for the dynamic changing of modulating and coding schemes, increasing noise margin.

- Power control: LTE networks utilize power control mechanisms to adjust the transmission power of both the base station and the device, thus reducing interference between different users and improving network performance.

Furthermore, the freeRAN™ uplink frequency range of 902-915 MHz enables the deployment of four independent carriers with a 3 MHz bandwidth each. This allows for the selection of a specific carrier for a particular area, providing an additional opportunity for interference mitigation.

Cost-effective and future proof solution for Utilities

Going back to the business needs of the Utility, AMI and DA industry, there are a few principles of cost-saving that can be crucial when choosing a solution:

- Whenever possible, it is best to avoid extra costs for license bands. Not having to buy the license when using a private network will decrease CAPEX, and not having to pay for user data when using a public network will reduce OPEX. Therefore, the ideal solution is to use the unlicensed spectrum.

- The technology employed should be designed to minimize the need for future replacements, while also prioritizing enhanced security measures. Particularly urgent due to the increasing hacking activity in recent years and the negative worldwide prognoses on this topic. As such, a highly secure and future-proof technology such as LTE-M is preferred.

- Given the trend of digitization, grid modernization and electrification, the topic at hand is the extension of the network of wireless devices. Once deployed, the RAN could be reused, with LTE-M being a viable choice due to its extensive ecosystem, numerous vendors, and wide range of devices on the market.

The LTE-M specified features, such as sophisticated OFDM and SC-FDMA 16 QAM modulation, advanced security and interference protection mechanisms, and the availability of voice service, distinguish freeRAN™ from other proprietary LPWAN technology solutions utilizing unlicensed spectrum. Comparing freeRAN™ with cellular technologies, such as LTE/LTE-M on private or public networks in licensed spectrum, it is evident that the freeRAN™ is a more cost-effective solution, as it does not involve payment for spectrum licenses or user data.

The combination of freeRAN™'s standardized LTE-M technology and unlicensed spectrum utilization makes it an outstanding solution compared to other technologies:

- **Better coverage and capacity balance:** 3GPP standard LTE-M solution provides better coverage and capacity compared to proprietary technologies. This is because they are based on cellular networks, which are designed to handle high volumes of traffic over large geographic areas.

- **Better security:** 3GPP standard LTE-M solutions have superior security features with SIM cards and USIM protocols allowing authentication of devices along with encrypted control and user traffic channels.

- **More flexibility:** LTE-M networks are more flexible than proprietary networks because they can support a wider range of use cases and applications. LTE-M supports voice, data, and SMS services, and can be used for both IoT and non-IoT applications.

- **More cost-effective:** Unlicensed spectrum utilization promotes reduced costs compared to licensed cellular technologies. This is because there are no spectrum licensing costs associated with it, unlike other private networks; and there are no costs for user data, unlike public networks.

Conclusion

The utility industry is facing significant communication challenges that require tailored solutions. From unreliable coverage in remote areas to concerns over security, these challenges have driven utility companies to seek new technologies that can address their specific needs. In this context, LTE-M technology supported by 3GPP standardization emerges as a promising future-proof solution.

As a low-power, wide-area technology designed for IoT, LTE-M provides superior coverage, lower operational costs, and enhanced security compared to legacy communication technologies. Additionally, the 3GPP standardization ensures interoperability between devices from different manufacturers and network operators, facilitating the deployment and management of the technology. However, the cost of licensed spectrum remains a significant burden for many companies, including utilities. Furthermore, the usage scenarios of LTE technologies have been exclusively available for licensed spectrum so far. As a result of high spectrum cost, many organizations have turned to unlicensed bands as a cost-effective alternative, despite their potential downsides such as interference and limited coverage. Nevertheless, the freeRAN™ Base Station can be an optimal solution for companies that prefer to use unlicensed bands while keeping the power of trusted LTE technologies, such as LTE-M.

The freeRAN™ Base Station's integration of royalty-free ISM bands and LTE-M based technologies empowers utility companies to establish cost-effective, secure, and future-proof private LTE-based AMI and DA networks, which is a crucial element in grid infrastructure modernization to enhance grid reliability and resilience.

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About Ubiik

Ubiik is an IoT solution provider specializing in deploying private wireless networks. Established in 2016 with headquarters in Taiwan, Ubiik has offices all around the world, including the US, Canada, Japan, France, and India. At present, Ubiik is the world's leading manufacturer of devices using the Weightless™ LPWAN open standard for industrial and national scale long range IoT solutions. Ubiik, a leader in pLTE and LPWAN technologies, prides itself on supplying dependable, highly secure, and cost-effective private networks with a lower total cost of ownership.

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Contact us

info@ubiik.com | ubiik.com

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