THE INTEGRATE LTE-M IN LTE CELLULAR NETWORK

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Abstract

For machine-to-machine (M2M) communications in cellular networks, optimizing LTE for IoT is still a major challenge. This paper investigates the performance of LTE-M (LTE extension for M2M services) based on physical layer parameters and network performance. It also shows what needs to be improved in LTE-M to meet the requirements of 5G applications in terms of higher throughput, minimum latency, and the ability to satisfy a high level of QoS.

Current mobile networks still unable to meet M2M communications needs. Therefore, the efforts of researchers are aimed, among other things, at increasing throughput and creating new architectures. M2M communications allow machines to communicate with each other without human assistance. The Internet of Things allows for better automation and optimization of workflows in various industries, these processes also affect our lives, and part of this improvement will be driven by cellular IoT.

The popularity of the cellular Internet of Things is also driven by the use of the well-developed existing GSM infrastructure. This gives an increase in both productivity and economy. Standard 2G, 3G, or LTE cellular networks consume a lot of power and are not suitable for IoT, as small amounts of data are sent intermittently. This way of connecting smart things has many advantages, using the existing infrastructure of GSM, UMTS, LTE and further 5G, but there are also problems.

EXpAnding LTE for Devices [1] was the first project in which LTE-M was published as a sys-tem capable of extending the LTE specification for machine-to-machine communications, which is accepted by many cellular operators as a potential technology for optimizing LTE IoT. This project also supports cellular communication systems to expand coverage, energy efficiency and the ability to support more connected devices mobile broadband standard. 3GPP Release 12 presented user equipment (UE) category Cat-0 for LTE-MTC. 3GPP Release 13 introduced new narrowband cellular technologies for IoT devices as a subcategory of the LTE-M and NB-IoT layer standards.

For cellular IoT-based connectivity of low power and energy saving devices, NB-IoT and LTE-M are the leading standards, which differ in the type and magnitude of low power devices. LTE-M runs on the already existing LTE infrastructure, which is a huge advantage of this technology Ma-chine-to-machine communications characterized by a very large number of low power and low speed devices. LTE-M is a Low Power Wide Area Network (LPWAN) technology for low bandwidth IoT applications. LTE-M uses licensed spectrum, coexists with NB-IoT and non-standard LPWA technologies (Sigfox, LoRa) where licensed spectrum is not required.

The network architecture integrates LTE-M into the LTE cellular network. For this architecture, communication between LTE-M devices and LTE mobile phones occurs over the same LTE/LTE-M network. Each M2M device can interact with other devices as a separate device. The device can connect directly to the application server via the LTE-M network, can also form a capillary network with other similar M2M devices and connect to the server via the LTE-M network. The M2M gateway is the most important element of the LTE-M network architecture. The gateway works with the same applications and functions as other M2M devices and performs protocol translation and data aggregation before sending messages to the application server through a specific LTE-M interface. LTE-M base stations (LTE-M eNodeB) provide network access to LTE-M devices and M2M gateways. To support the LTE-M for IoT function, LTE base stations need to be upgraded rather than creating new ones. 1.4 MHz bandwidth adopted by LTE-M for M2M communication, latency is 10–15 ms. The Evolved Packet Core (EPC) remains the same as for the LTE network.

Not all machine-type devices support LTE-M technology, such devices are considered non-LTE-M devices. LTE-M devices support the LTE-M protocol stack. Thus, there is no need for protocol translation, and all data is transmitted directly to the application server. However, in the case of non-LTE-M devices, protocol conversion from the capillary network to the LTE-M protocol stack is mandatory through the M2M gateway, which is also responsible for data extraction and re-encapsulation on the destination side. Devices with an LTE-M connection enjoy a more reliable signal and lower energy usage than you would see with a mobile phone.

When deploying LTE-M or NB-IoT, we will highlight the main directions of their development. These are faster uplink and downlink speeds up to 1 Mbps, support for VoLTE and mobility for devices on the move. The following advantages of LTE-M can be directly noted. It is used for IoT applications that have low data volume, low bandwidth, and low cost. LTE-M has very good coverage and higher data rates, but not very high data rates compared to other cellular technologies - 4G, 5G, etc. The LTE-M network uses TCP/IP protocol and can be connected to any server. The LTE-M system is very energy efficient, the devices themselves have a long battery life.

LTE-M is compatible with LTE networks and is easy to deploy and can accommodate a large number of devices per cell. However, the LTE-M system has a higher cost than some other technologies.

When comparing the performance of a single M2M for LTE-M device and for LTE Cat-0 depending on the change in distance as the device moves away from the eNodeB, let's compare throughput, delay, coverage, i.e. the maximum distance that the M2M device is still transmitting data to the remote host.

Throughput C is the rate of successful received bits over LTE channel within time is ordered to express throughput in Kbps.

$$C = Nrb / t * 1024,$$

where: Nrb – number received bits.

It is known that both technologies LTE-M unlike LTE Cat.0 differ in the maximum transmit power of the M2M device, the bandwidth, and the number of resource blocks per subframe.

An LTE-M device can transmit data at a higher bandwidth and over a longer distance. Smallest resource unit used by LTE-M device is one PRB pair mapped over two slots. One PRB pair spans 12 subcarriers with 15 KHz subcarrier spacing. This gives total bandwidth of 180 KHz for 12 subcarriers. This is due to the power spectral density, i.e., since this signal power depends on the number of re-source blocks (RBs) per subframe, for the same power distributed over RB, the power per block is higher for a bandwidth of 1.4 MHz. Therefore, LTE-M devices can transmit data over a longer dis-tance and LTE-M where it provides much better coverage. At the same distance where bandwidth degradation is detected, packets start to be lost.

Reference Signal Received Power (RSRP) [2]

$$RSRP = (RSRQ + RSSI) / N_{RB}$$

where :RSRQ - Reference Signal Received Quality (is handover or cell re-selection),

RSSI - Received Signal Strength Indicator is the received power from the serving cell,

N_{RB} - number of RBs per subframe.

Consequently, decreasing the number of RBs will increase RSRP value.

LTE-M has a more powerful resource block than LTE Cat-0 due to which the packet transmission time from the sender to the node is less. Therefore, while changing the distance and keeping all other parameters constant, LTE-M has better latency than LTE Cat-0. The number of HARQ retries that occur when an M2M device uploads data to a remote host at higher power will have fewer HARQ retries and therefore lower retransmission delay, resulting in better overall latency for LTE-M. However, the random access procedure for a large number of devices for LTE-M has a delay value larger than for LTE Cat-0, due to the lower throughput. The amount of delay created by LTE-M devices to support M2M services and a large number of real-time applications requires extremely low delays, on the order of 1 ms.

Nevertheless, LTE-M is still not capable to support future applications for M2M which demands a better jitter and a delay less than 1 ms. Uplink throughput can be improved by increasing the number of LTE-M devices connected to the eNodeB using different scheduling algorithms. But this number is still not enough for IoT which requires a massive number of connected MTDs and a more reduced throughput. To achieve this goal in cellular networks, protocol modifications are considered by reducing the bandwidth in LTE-M to reach an enhanced transmission efficiency in terms of energy and to support a larger number of connected LTE-M devices in a single cell. Throughput it can be improved if we use the appropriate scheduling policy.

MTC will become one of the dominant applications of 5G systems. The main problem is the problem of scalability when there are more than one hundred thousand machine-type communication nodes (MTC) in the cell at low cost and long service life. New key PHY layer technology components such as a unified frame structure, multicarrier waveform design including a filtering functionality, sparse signal processing mechanisms, a robustness framework, and transmissions with very short latency. These components enable indeed an efficient and scalable air interface supporting the highly varying set of requirements originating from the 5G drivers [3].

One of the ways to deploy M2M communications may be instead of synchronism and orthogonality in cellular networks a broader non-orthogonal robustness concept, is the introduction of new non-orthogonal waveforms that carry the data on the physical layer. Admitting some crosstalk or interference and control these impairments by a suitable transceiver structure and transmission technique. UFMC,FBMC,GFDM - all of them with disruptive advantages over OFDM for non-orthogonal asynchronous waveforms over conventional OFDM modulation. The technological implementation is required more complex transceiver designs. But 5G inner receivers will have plenty of headroom for complexity increases, compared to 3.5G–4G for processing non-orthogonal asynchronous signals. Moreover, for a base station new dimensions of processing capabilities are enabled by a change from mere transistor scaling to 3D integration of chips with wireless high-speed interconnection among the chips outperforming today's processing by a factor of at least 10^5.

Conclusion

There is not one single wireless technology that meets the needs of each and every IoT applica-tion. Each LPWAN (low power wide area network) technology encompasses trade-offs between data rate, range, power consumption, security etc. The paper considers the requirements for the transmis-sion of data in M2M taking into account the advantages and disadvantages of the LTE-M that is proposed to use in M2M communications.

LTE-M a broader coverage distance can be while offering a better performance than LTE Cat-0 in terms of throughput and delay. Synchronism and orthogonality as applied in LTE prevents efficiency and scalability, to improve the performance of M2M communications, so it is also proposed to use non-orthogonal waveforms at the physical layer when deploying 5G networks.

References

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