QUECTEL
Build a Smarter World

A technology for all

Why LTE Cat-1 is transforming cellular connectivity

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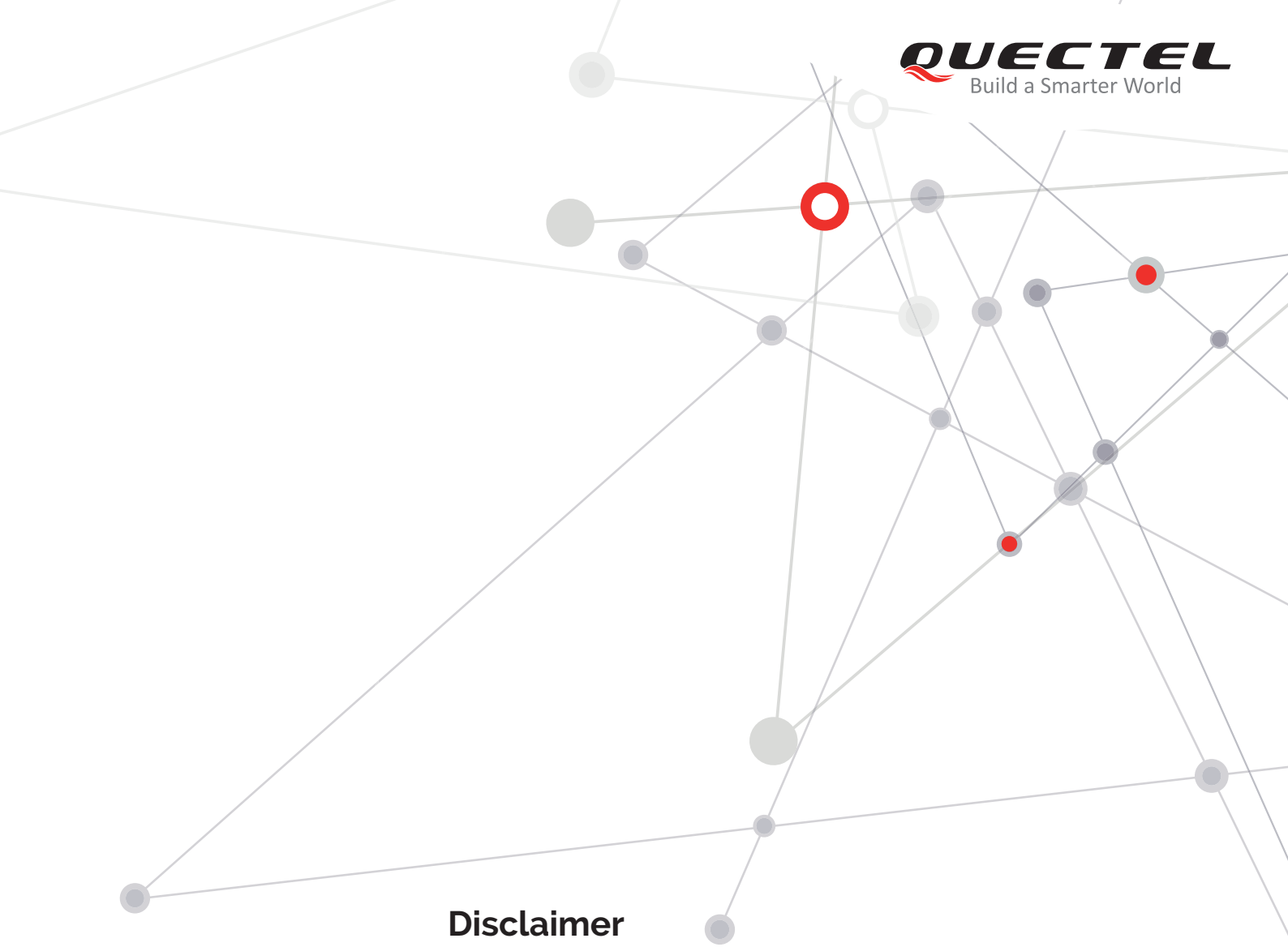

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Introduction

We are living in a hyper-connected world in which basically every connectable thing either has already been connected, or is in the process of being connected. We are also witnessing unprecedented situations and facing challenges, such as the Covid-19 pandemic, climate change, wildfires, an ageing population, to name but a few.

There is little doubt that IoT plays an important role in combating the pressing challenges the world faces.

When it comes to companies, IoT is definitely a key enabler in increasing their efficiency and productivity. As a result of new revenue streams in tech companies, IoT can also contribute to a country's economy by increasing its GDP.

It's absolutely remarkable how IoT technology has evolved in a very short span of time. As a result of rapid development, companies now need to take into account many different aspects of IoT technology and carefully evaluate the pros and cons of various technologies before they can decide which one to use. One aspect of IoT technology is especially important and still remains an essential concern both for IoT device makers and designers. That is, connectivity. Finding and deploying an appropriate and optimum solution for an IoT network is not an easy task. The right decision would create competitive advantage, resulting in a faster and higher RoI. Conversely, selecting an inappropriate connectivity solution may result in a project failure. Original design and equipment manufacturers (ODMs/OEMs) have to answer many questions concerning total cost of ownership (TCO) of the selected connectivity technology. These questions include cost of module, global coverage, communication costs, technology sunset and the maturity of an ecosystem, and so on.

As 2G/3G sunset is inevitable, the IoT industry is going through a transition period that involves the migration to a modern network. There is a wide range of choices available, including CAT-M1 and even NB-IoT. However, an increasing percentage of the IoT industry is looking for an all-in-one solution: excellent coverage that ensures reliability, cost advantage, future-proven technology, optimal airtime and data tariffs, global spectrum allocation for perfect roaming, seamless cell handover, VoLTE, and so forth.

Our intention in writing this booklet is to assist you in choosing the right connectivity technology, and in doing so simplify your decision-making process. We will cover various LTE technologies, but will pay special attention to LTE CAT-1, as it has the potential of being one of the most appropriate technologies to optimally address connectivity issue in a wide range of applications, in a cost-effective manner. Maybe it could even be that all-in-one solution for your particular case?

1. LTE Evolution

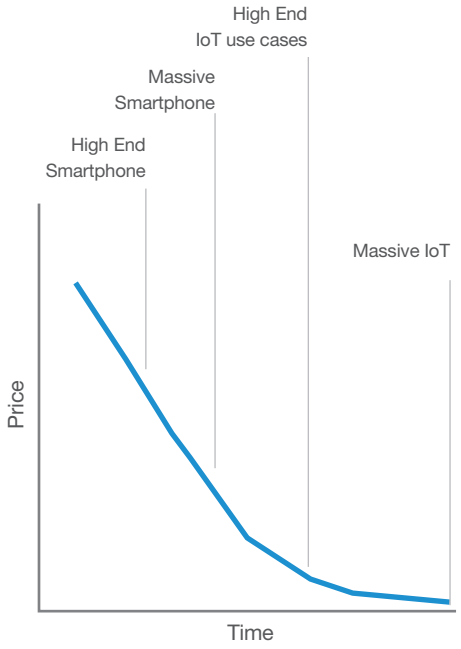


Figure 1, LTE journey towards Massive IoT

Parameters	2G	3G	CAT-1	CATM1
Hardware cost (Module)	10.00	5.82	5.73	7.09
Global Coverage	7.64	7.18	8.64	3.00
Ecosystem	7.73	5.73	8.36	4.27
Future Proven Technology	1.00	2.27	8.36	7.82
Link Budget	5.27	5.73	6.18	8.27
Power Consumption	5.18	4.64	5.36	8.18
OTA	6.27	8.45	9.91	8.36
Speed UL	3.00	7.36	9.09	6.73
Speed DL	2.27	7.36	9.09	6.73

Table 1, Key Metrics Evaluation (relative)[1]

During the 2G era, the Global System for Mobile Communication (GSM) never became a true global standard as its name might suggest, although it was a breakthrough in communication technology. It could be said that 3GPP was basically formed to develop a Universal Mobile Telecommunications System (UMTS), a system based on the GSM standard, albeit capable of avoiding issues encountered in GSM. Unfortunately, again, no unique standard was agreed upon.

For almost a decade, 3GPP carried on standardizing the next generation of radio access networks called Long-Term Evolution (LTE), mainly to address a big threat created by the rival Wi-Max standard. This is when LTE categories were introduced and LTE evolution began.

Before LTE was introduced, there was Quadrature Amplitude Modulation (QAM), a technology with a few decades of history and yet capable of offering more bits per hertz compared to other modulation schemas. In fact, a more powerful digital signal processor (DSP) can handle more vectors to be multiplied and then solve mathematical equations in the receiver in order to harvest data. Due to affordability as well as low consumption of RISK processors, which are ideal for handling QAM, LTE was soon able to scale up and dominate the connectivity market.

As processors evolved, so did the LTE standard. At the same time, the price of matured versions of LTE devices started to decrease. The price reduction created a positive feedback since economies of scale could reduce the price even further and thus make LTE technology (or some of its categories at least) more affordable to a wider range of IoT use cases. But this didn't happen overnight.

LTE was primarily launched as the high-end connectivity technology for smartphones. Higher categories of LTE, as well as 5G, are very power-hungry and complex, and thus difficult to fabricate as a system on a chip (SoC). As a result, higher LTE categories are more expensive and only suitable for high-end IoT categories where latency and bandwidth are pivotal. By contrast, lower LTE categories require weaker processors and are, therefore, more cost-effective.

In order to satisfy requirements for a wider range of IoT use cases, LTE Category 1 (LTE Cat-1, or just CAT-1) was introduced in the 3GPP Release 8, and later on further enhanced with a new set of Power Saving Mode (PSM) features in Release 12, which was published in December 2014. CatM1/NB is optimized for lower data rates and includes a power saving feature. Nowadays, CAT-1 is considered as an indispensable connectivity technology for IoT due to its widespread coverage and cost advantages.

So, as time goes by, LTE technology is becoming more and more available and affordable for mass deployment in IoT devices (see **Figure 1**).

1Source: internal research, please refer to the description in this chapter.

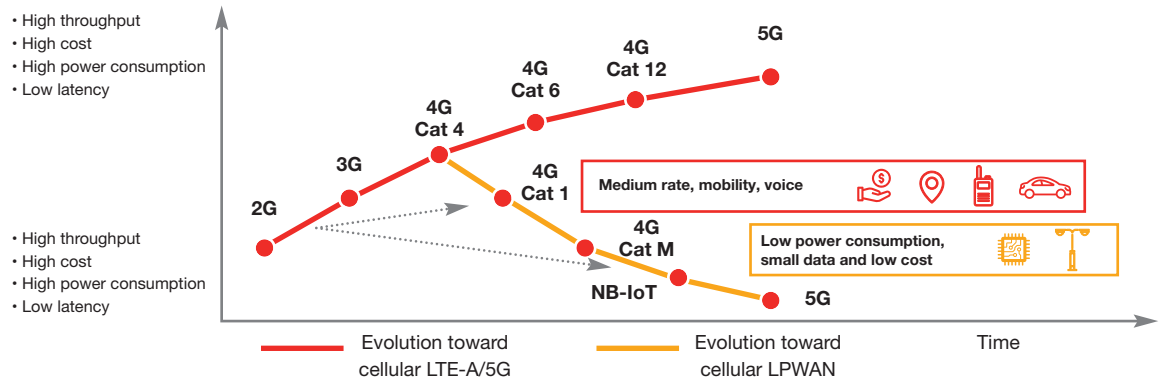


Figure 2, Cellular Technology Comparison

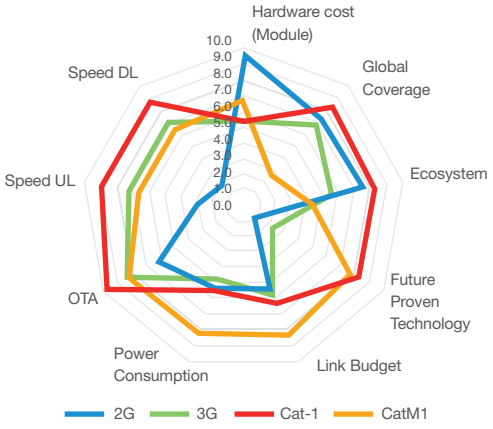


Figure 3, Radar Illustration of Table 1

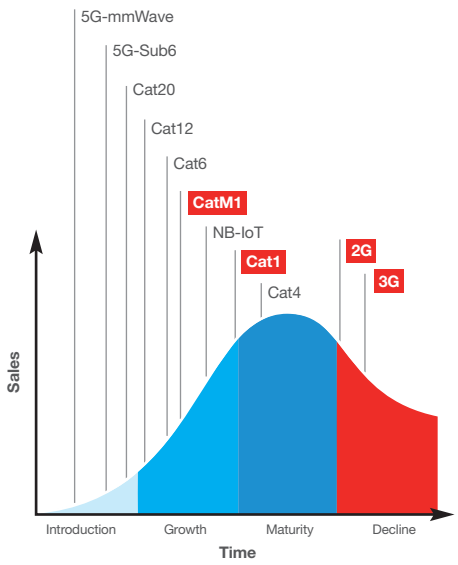


Figure 4, An estimated illustration of global IoT connectivity life cycle

2. Technology Comparison

IoT is a vast market with very broad use cases. There is no superior or prevalent technology, however, as different applications might use different connectivity technology due to various reasons. While for instance 2G is still very attractive in developing countries because of its ubiquity, the same technology is not suitable in North America due to its sunset. Therefore, there is no universal prescription for selecting the best cellular connectivity.

In the following diagram (**Figure 2**), we see that all cellular technologies developed after 3G tend to fall into two groups. The first group, depicted by a red line, continues the trend set forth by 2G and 3G technology. Namely, all these technologies are characterized by increased throughput, costs, power consumption and decreased latency when compared to their predecessors. This group represents the evolution of cellular networks towards the LTE Advanced (LTE Cat-4, LTE Cat-6, and LTE Cat-12) and 5G networks. The second group, on the other hand, is characterized by decreased throughput, costs, power consumption, and increased latency. This group, depicted by a yellow line, shows the evolution towards Low Power Wide Area Networks (LPWAN), and includes LTE Cat-1, LTE Cat-M, NB-IoT, and low-power 5G networks.

In this booklet, we will mainly talk about the latter group, as the focus of this article is CAT-1 technology and its relationship to 2G / 3G technology and other LPWAN networks.

In April 2020, we conducted an internal research study with the aim of comparing the key metrics of four different technologies. The technologies that were analyzed were 2G, 3G, CAT-1, and CAT-M1. More than 10 highly qualified experts contributed to the study. The findings are illustrated in **Table 1** and **Figure 3**.

Each expert was asked to give a score between 1 to 10 for each parameter, with 1 being the lowest score and 10 the highest. The higher the score, the better the overall results are. For instance, all experts gave the score 10 for hardware costs of 2G modules. In other words, all experts believe that 2G is the best choice (compared to other technologies) if the cost of a module is a decisive parameter.

Based on these key metrics, we can see that CAT-1 shows the best or second-best results for most parameters compared to other technologies. However, it is important to emphasize that these findings should be treated just as general guidelines. The authors recommend that every company conduct their own due-diligence based on the actual facts that may differ geographically and vary from one vertical to another, or even between various use cases.

The life cycle of various cellular technologies is illustrated in **Figure 4**. While 2G and 3G technologies are moving towards the end of their respective life cycles, new technologies are emerging and are becoming more and more suitable for new use cases. We can see that CAT-1 becomes an essential technology in IoT.

Figure 4, An estimated illustration of global IoT connectivity life cycle.

Before we compare CAT-1 technology to other LPWAN technologies, let's first briefly see what the main characteristics of this technology are.

In short, CAT-1 supports a terminal with a maximum downlink rate of 10Mbps and an uplink rate of 5Mbps, by using 20MHz carrier. CAT-1 can also support full-duplex FDD/TDD modes, as well as Voice Over LTE (VoLTE).

2.1 CAT-1 vs. NB-IoT

NB-IoT was released by 3GPP in September 2015. Mobile network operators and original design manufacturers have widely adopted the technology as their first choice due to its unique features and the commercial prospects in the future. NB-IoT provides improved indoor coverage, support for large number of low throughput networks for the IoT, has high sensitivity, ultra-low device cost, lower power consumption, and optimized network architecture.

NB-IoT is suitable for smart metering, smoke sensors, and other similar applications, where CAT-1 is viewed as overkill. All these applications are stationary or require basic low speed mobility.

Generally speaking, NB-IoT is not considered a competitor of CAT-1.

2.2 CAT-1 vs. CAT M1

CAT M1, also known as LTE-Machine-to-Machine, is an IoT technology based on the LTE evolution. It is called low-cost machine-type communication (low-cost MTC) in Release 12 and LTE-enhanced MTC (eMTC) in Release 13. It was defined to be a native part of 5G in Release 16. CAT M1 aims to meet the needs of IoT devices based on the existing LTE carriers. eMTC is deployed on the basis of cellular network and supports the maximum peak rate of 1Mbps for uplink and downlink.

There are some differences on VoLTE between CAT-1 and CAT M1. As already stated, CAT-1 can fully support VoLTE at its high bandwidth. Due to the fact that CAT M1 belongs to the narrow bandwidth category, it cannot provide the best user experience.

CAT M1 needs to replan frequency resources on the FDD900 or FDD1800 of the existing network. Both the base station and the core network need to upgrade software.

So, the question remains: what are the key advantages of CAT-1 over CAT-M1? The key missing item is cellular network readiness. CAT-1 is considered as native in LTE, whereas CAT-M1 has to be purchased by the mobile network operators (MNO) as an add-on. CAT 1 doesn't require software and hardware upgrades for the base station, so there are no network coverage costs. China's and India's MNOs have selected CAT-1 since they advocate that whatever CAT-M1 can offer is already incorporated in CAT-1. The debate is ongoing and many other MNOs across the globe have either given up on the implementation of CAT-M, or have postponed it. Obviously, in the absence of network coverage for CAT-M1, CAT-1 remains the optimal alternative for multiple IoT use cases.

2.3 CAT-1 vs. CAT-4

The main difference between the two networks is the fact that the CAT-4's focus is mainly the high rate market, whereas CAT-1 is suitable for the medium rate market.

As already mentioned, CAT-1 supports a maximum downlink rate of 10Mbps and an uplink rate of 5Mbps, whereas CAT-4 has a maximum download rate of 150Mbps and an uplink rate of 50 Mbps. Both CAT-4 and CAT-1 support 20MHz RF and baseband bandwidth, and have dual antennas, although CAT-1 widely uses a single antenna (if near the 3 dBm level).

As both technologies use the same network, there are no extra costs of deployment on the MNO's side. Since LTE has been developing for some years now, the network is relatively mature.

Traditionally, Qualcomm was the main supplier of CAT-1 and CAT-4 chipsets and platforms, and the cost difference between the two technologies was not attractive enough to boost CAT-1.

However, the market dynamism is changing due to the demand for CAT-1 from China's ODMs/OEMs. Qualcomm and other players introduced the new CAT-1 platform with a clear cost advantage over CAT-4. It's foreseen that there will be a significant impact on CAT-1 shipments due to economies of scale and technology advancements in designing and producing a low-cost CAT-1 platform. The new CAT-1 platform was preliminarily designed and produced to satisfy domestic market consumption, but it is expected that it will become an optimal IoT solution worldwide.

Figure 5 illustrates some of the use cases suitable for NB-IoT, LTE-M, or CAT-1 technology, respectively.

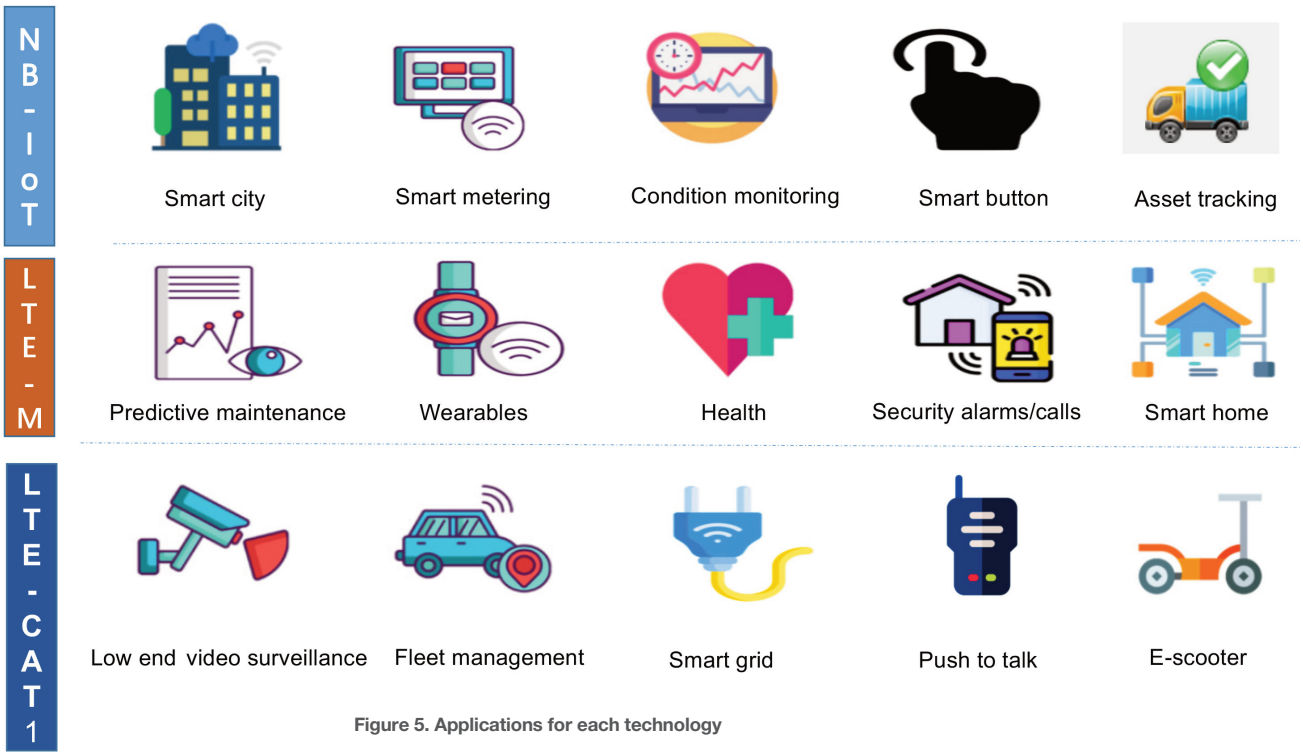


Figure 5. Applications for each technology

Figure 6. IoT market segmentation per data speed[3]

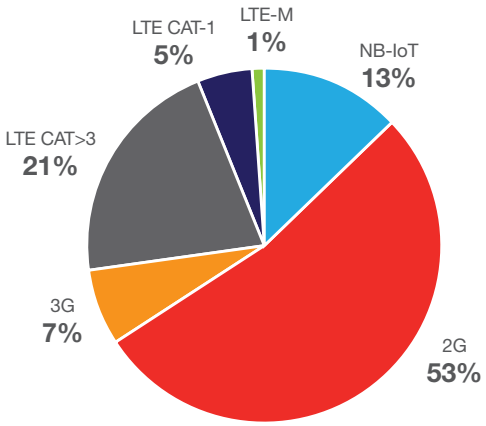


Figure-7 Module Market by Shipment in 2019[4]

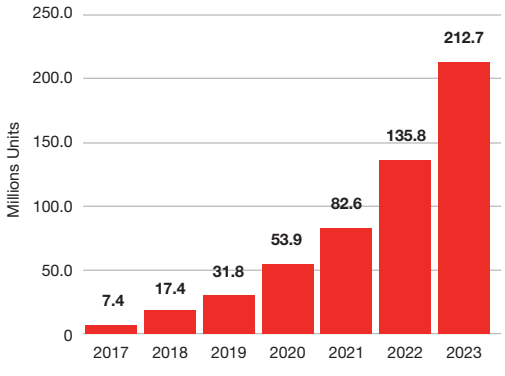


Figure 8, LTE-CAT-1 Module Shipment[5]

3. CAT-1 Market at a Glance

As IoT evolves and becomes ever-expanding, the number of possible IoT use cases increases as well. Individual applications will often require different data speed. A rough estimation of the IoT market according to data speed is given in **Figure 6**. As can be seen from the diagram, 60% of use cases belong to the low-bit rate segment, while only 10% need very high throughput. The medium rate market, in which LTE Cat-1 plays an important role, accounts for 30%. This matches Ericsson's prediction that by the end of 2025 the number of cellular IoT connections will have exceeded 5 billion, out of which 28% will be LTE[2]. The mid-range applications demand reliable and cost-effective communication solutions, and these requirements are successfully fulfilled by LTE Cat-1 technology.

As can be seen from **Figure 7**, the CAT-1 module comprised 5% of market share in 2019. According to Techno System Research (TSR), total CAT-1 module shipments in 2018 exceeded 22 million units worldwide, whereas Berg Insight's (**Figure 8**) estimated close to 28 million units for the same year. In the same report, Berg Insight forecasted that CAT-1 module shipments in 2020 would exceed 55 million units worldwide. Whilst ABI Research forecasts that shipments will continue to grow and will exceed 212m pieces in 2023. Although forecasts have to be re-adjusted due to the impact of the Covid-19 pandemic, it claims that LTE CAT-1 will play a vital role in connecting devices in upcoming years. The upward trend is forecasted to continue mainly due to the CAT-1 dynamism and its market size in China to be followed by India.

As a general rule, when a new technology is introduced, its costs are high. Over time and with the evolution of new technology applications, the module costs gradually decrease. The cost reduction has, therefore, a positive impact on IoT module shipments, which will continue to grow. This is illustrated in **Figure 9**.

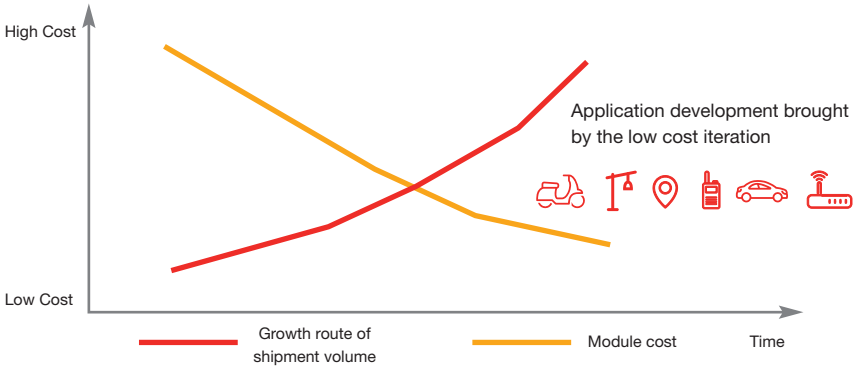


Figure 9. The correlation between connectivity costs and IoT shipment volume

2 Source Ericsson Mobility Report | November 2019
3 Source estimation Quectel
4 Source Berg Insight
5 Source ABI Research

3.1 Global Coverage

LTE is the most ubiquitous network ever seen. In fact, except for a few exceptions (see **Figure 10**), all other countries have already rolled out LTE. According to the General Service Association (GSA), in early 2020 there are already 791 operators with commercially launched LTE networks (offering broadband fixed wireless access and / or mobile services). Such high adoption essentially ensures that CAT-1 devices are globally deployable.

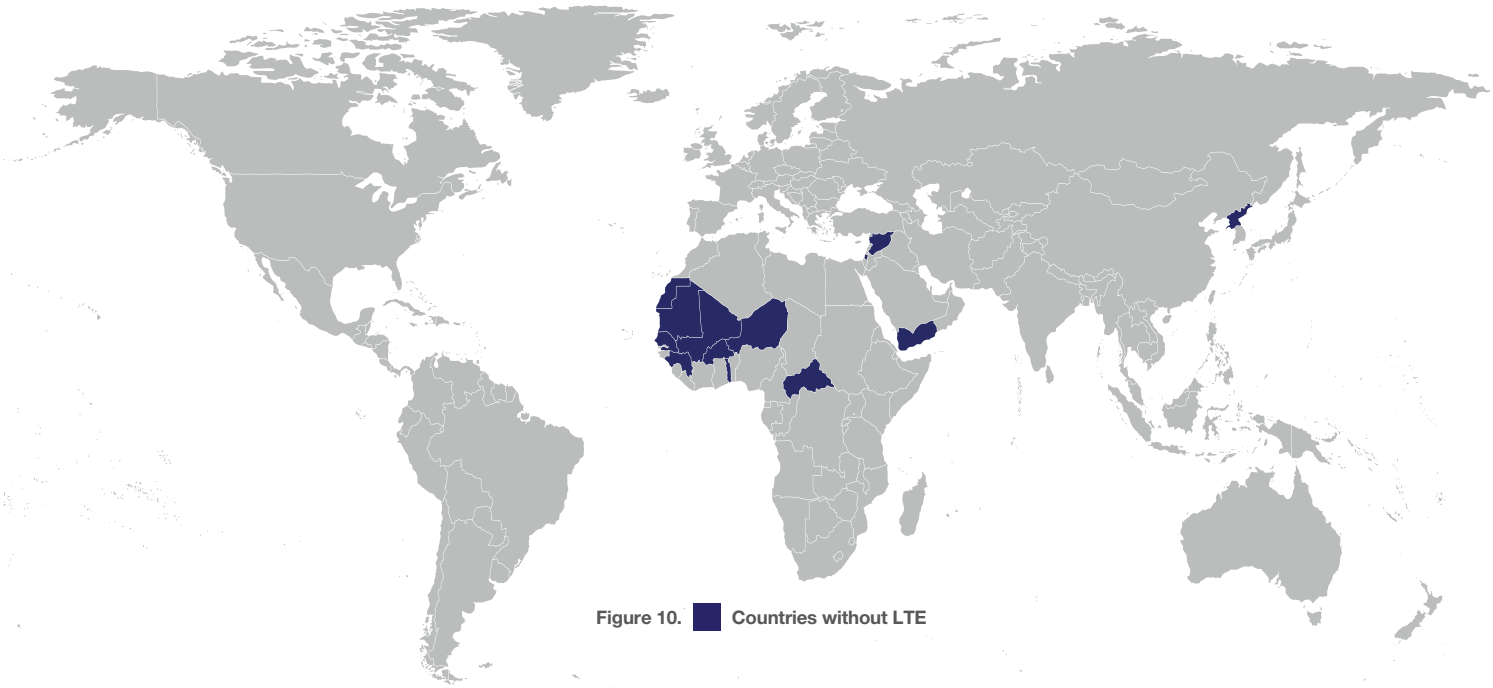


Figure 10. Countries without LTE

3.2 Existing Use Cases

CAT-1 has proven to be suitable for a wide range of legacy use cases, which have millions of devices already connected:

- Smart Grid
- Tracking
- Wireless Payments
- Portable Batteries

Smart Grid | Tracking | Wireless Payments | Portable Batteries

Figure 11, Examples of existing use cases

3.2.1 Smart Grid

Leveraging cellular connectivity is an irreversible trend in utilities. However, selecting the right communication "pipe" is becoming a real challenge, mainly because of business process changes. The companies have to decide whether they want to outsource ICT as a Service, that is, Infrastructure as a Service (IaaS), or to build and run their own communication and IT infrastructure. In other words, they have to decide between an OPEX-oriented approach and CAPEX-oriented approach, respectively.

Thanks to the decreasing cost of modules, and rapid LTE and LPWA coverage enhancements by mobile network operators internationally, utilities now have a greater tendency to use cellular connectivity as the backhaul of their Smart Grid communication network. **Table 2** compares technical and communication requirements for three cellular networks. It's quite evident that in regions in which CAT-M1 is not available, CAT-1 can be used instead due to its technical superiority and cost advantages.

Application	Technical Requirements		Technology		
	Speed (kb/s)	Latency	NB-IoT	Cat-M1	CAT-1
1 Smart Meter 1Phase	10-20	Minutes	√√	√	X
2 Smart Meter 3Phase-DC	20-50	Seconds to Minutes	√	√√	√
3 Smart Meter 3Phase-CT/PT	50-100	Seconds	X	√√	√√
4 Demand Response	14-100	500msec to Minutes	√	√√	√√
5 Renewable and Distributed Energy	10-60	20msec to 15 Sec	X	√√	√√
6 Storage Systems	10-60	20msec to 15 Sec	X	√√	√
7 Electrical Vehicle Charging Station	10-100	2 Sec to 5 Minutes	√	√√	√
8 Alarms and Monitoring (RTU)	600-1500	20-200msec	X	√	√

Table 2, Smart Grid Application and Cellular Networks

3.3 Future Use Cases

With the development of CAT-1, new use cases will appear in the near future, such as:

- Low-End Cameras (Cloud-Based Cameras)
- Push to Talk over Cellular (PoC).
- Voice over LTE (VoLTE)
- Smart Wearables

POC

VoLTE

Smart Wearables

Low-End Cameras

Figure 12, Examples of emerging use cases

3.3.1 Low-End Cameras (Cloud-Based Cameras)

Businesses are moving to cloud-based video surveillance solutions due to cost advantages and reliability. Video Surveillance as a Service (VSaaS) is projected to gain 52.98% at a compound annual growth rate (CAGR) of 12.9% by 2026. CAT-1 is considered a suitable technology to fulfill technical requirements for low-end cameras.

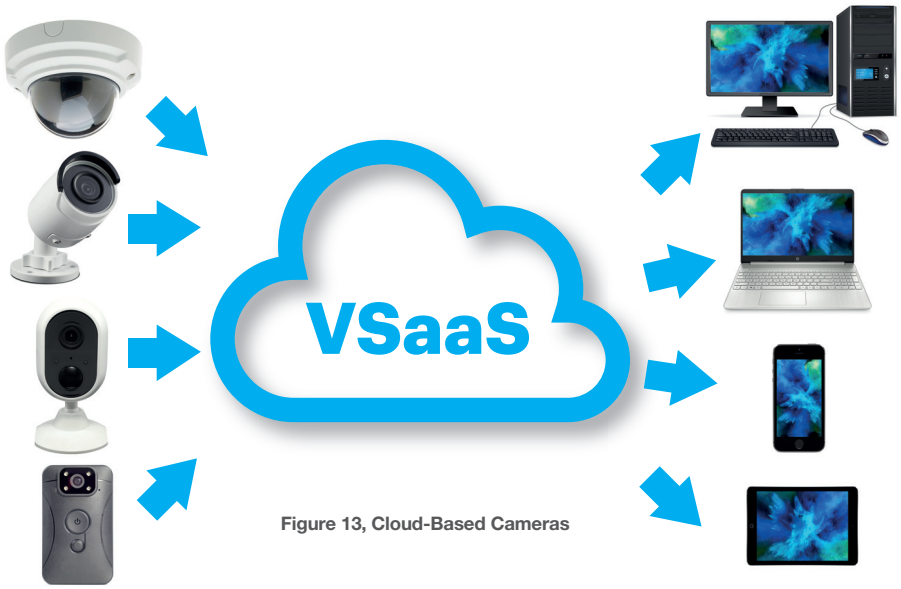


Figure 13, Cloud-Based Cameras

4. Quectel Advanced CAT-1 Modules

Quectel offers many CAT-1 modules, which meet a wide range of customer requirements.

Based on the package format, we can divide them into two groups:

LCC format

Module	Features
EC21 series	Optimized for regional coverage. DFOTA/GNSS/VoLTE support, OpenLinux.
EG21-G	Global coverage, GNSS multiple constellation support

LGA format

Module	Features
EG91 series	Embedded PMU, cost-effective and low-power LTE connectivity optimized for broadband IoT applications. Pin-to-pin compatible with 2G/3G/LPWA/Cat.4 module:M95/UG95/BCx5/BG9x/EG95
EG912	Cost effective, pin-to-pin compatible with 2G/3G/LPWA/CAT 4 module: EC100Y/M95/UG95/BCx5/BG9x/EG95

Quectel's CAT-1 products are based on Qualcomm and ASR platforms, so they can satisfy all possible requirements.

5. QuecOpen

QuecOpen™ is an open source embedded development platform based on the Linux system, which is intended to simplify the design and development process of IoT applications. In the QuecOpen solution, the module acts as the main processor. The ever-developing communication technologies and changing market make it hard for customers to find the right solution for their needs. QuecOpen is capable of meeting many customers' needs when it comes to the design and development process of IoT applications. Therefore, more and more customers are recognizing the advantages of QuecOpen. Firstly, with the assistance of QuecOpen, the hardware and software design flow for wireless application is much simplified. Secondly, the solution effectively reduces the product costs, which is greatly valued by customers.

QuecOpen integrates enough services and API libraries in the upper layer, so that customers can develop their own functions directly by the services. Some of the supported services and API libraries include voice call service, SMS service, firmware update service with firmware over the air (FOTA) and delta firmware upgrade over the air (DFOTA) modes, data connection service, security service, C runtime library, OEM component libraries, and so on. If developers are familiar with Qualcomm chipsets, they can call QMI and MCM libraries to simplify their development.

QuecOpen supports multi-language compile, including C, C++, Perl, Python and shell script. Also, Open SDK is supported to provide source code and demo for developers' research and development work.

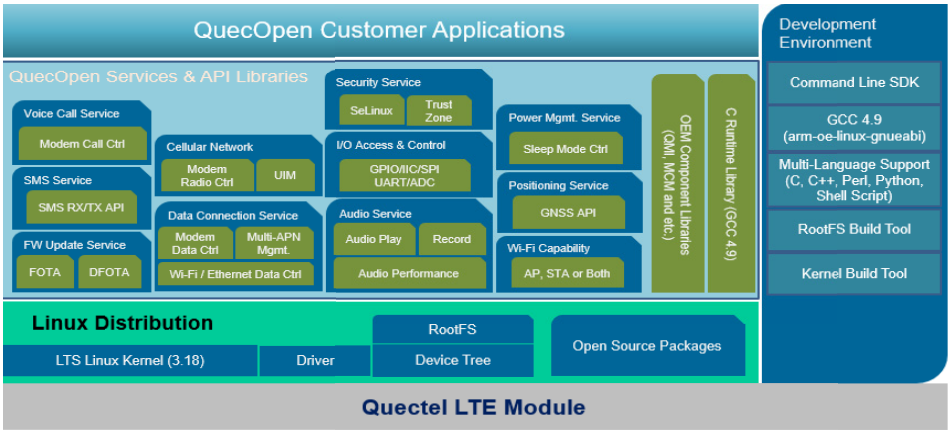
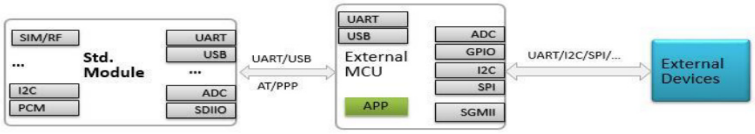


Figure 14. QuecOpen Software Architecture

Standard Module Mode



QuecOpen Mode

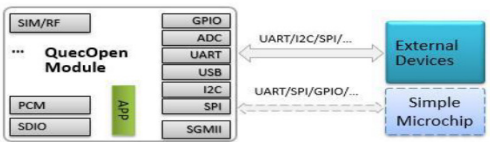


Figure 15. Standard module mode vs. QuecOpen mode

Key features:

High-powered platform
With high real-time performance, and multi-threaded and micro kernel, QuecOpen transparently manages all LTE-related activities to help developers natively execute C, C++ and shell script-based programs on the processor or in the memory of Quectel modules.

Fast development
QuecOpen SDK provides characteristic examples, which assist developers in fast development. Supporting C-based runtime libraries offers developers more flexibility during the software and program design.

Greater competitiveness
By directly downloading and running the embedded applications within Quectel modules, it is now possible to remove external host processor, memory, and a range of product-specific ASICs, such as IO expanders, audio DSPs, and many other analog and digital devices.

6. Conclusion

Quectel's CAT-1 product portfolio covers a wide variety of modes and applications that can address a comprehensive range of use cases. Thanks to the ubiquity and unique attributes of LTE, we believe CAT-1 is the most suitable technology to replace the existing use cases for 2G/3G technology within this decade. CAT-1 can also cover all CAT-M1 use cases wherever there is a lack of CAT-M1 coverage. Even when CAT-M1 coverage exists, there is also an emerging CAT-1 market for the following use cases: low-end video surveillance, e-scooters and Push to Talk over Cellular (PoC), to name but a few.

As a trustwothy and global company, Quectel has shipped over a hundred million IoT modules and is therefore well-positioned in the LTE IoT supply chain.

Quectel is becoming synonymous with speed in the industry thanks to our Same Day Action Plan business culture. Quectel has a global sales and technical support network that provides support as close as possible to end users.

For more information about Quectel's market leading portfolio of modules, please contact:
marketing@quectel.com
or visit our website:
www.quectel.com

Glossary

3G	3rd Generation
3GPP	3rd Generation Partnership Project
4G	4th Generation
5G	5th Generation
API	Application Programming Interface
ASIC	Application-Specific Integrated Circuit
ASR	Automatic Speech Recognition
BOM	Bill of Materials
CAGR	Compound Annual Growth Rate
CAPEX	Capital Expenditure
Cat 1	Category 1
Cat 4	Category 4
Cat 6	Category 6
DFOTA	Delta Firmware Upgrade on the Air
DSP	Digital Signal Processor
eMTC	Enhanced Machine Type Communication
eSIM	Electronic Subscriber Interface Module
eUICC	Embedded Universal Integrated Circuit Card
EVB	Evaluation Board
FAE	Field Application Engineer
FDD	Frequency Division Duplexing
FOTA	Firmware Updates Over the Air
Gbps	Gigabits Per Second
GDP	Gross Domestic Product
GNSS	Global Navigation Satellite System
GHz	Gigahertz
GSA	General Service Association
GSM	Global System for Mobile Communication
IaaS	Infrastructure as a Service
ICT	Information and Communication Technology
IIoT	Industrial Internet of Things
IoT	Internet of Things
IMU	Inertial Measurement Unit
Khz	Kilohertz
LPWA	Low Power Wide Area
LPWAN	Low Power Wide Area Network
LTE	Long Term Evolution
LTE-M	Long Term Evolution – Category M1
MCU	Microcontroller Unit
MHz	Megahertz
MIMO	Multiple Input, Multiple Output
MNO	Mobile Network Operator
MTC	Machine Type Communication
ODM	Original Design Manufacturer
OEM	Original Equipment Manufacturer
OPEX	Operational Expenditure
QAM	Quadrature Amplitude Modulation
QMI	Qualcomm MSM Interface
PCB	Printed Circuit Board
PMU	Power Management Unit
PoC	Push to Talk Over Cellular
POS	Point of Sales
PSM	Power Saving Mode
R&D	Research and Development
RISC	Reduced Instruction Set Computer
SDK	Software Development Kit
SMS	Short Message Service
SoC	System on a Chip
TDD	Time Division Duplexing
TCO	Total Cost of Ownership
TSR	Techno System Research
VoLTE	Voice over LTE
VSaaS	Video Surveillance as a Service
UE	User Equipment
UMTS	Universal Mobile Telecommunications System

QUECTEL
Build a Smarter World

About Quectel

Quectel's passion for a smarter world drives us to accelerate IoT innovation. A highly customer-centric organization, we create superior cellular and GNSS modules backed by outstanding support and services. Our growing global team of 1600 professionals, the largest in the IoT modules industry worldwide, ensures we are first to market and continue to set the pace of development. Listed on the Shanghai Stock Exchange (603236.SS), our international leadership is devoted to advancing IoT across the globe.

Headquarters

Building 5, Shanghai Business Park Phase III (Area B), No.1016
Tianlin Road, Minhang District, Shanghai 200233, China
Tel: +86-21-5108 6236
Marketing: marketing@quectel.com
Support: support@quectel.com

www.quectel.com