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REAL-WORLD LTE PERFORMANCE FOR PUBLIC SAFETY

MOTOROLA

Government and public safety organizations are watching the fast pace of technological advancement in the wireless carrier market and how these advancements will enable new services and increased performance for operators and users.

With the promise of broadband spectrum at 700MHz for public safety, government agencies in the United States are lining up behind LTE as the air interface technology of choice to bring their own set of mobile wireless broadband devices and services into their day-to-day operations. Understanding the design considerations, limitations and realistic performance of LTE is critical for the successful deployment of these new services.

LTE is a new OFDM all-IP, next generation technology which will enable unprecedented broadband service to public safety agencies, achieving fixed line broadband performance while enabling new rich media services and a mobile experience.

Peak data rate has been used to create excitement about the performance of every new generation of wireless technology. But peak performance, as its name implies, is only a theoretical measurement that is not realistically achievable in a live network. Average throughput performance for a single access point radio, or sector, on the other hand, is a much more accurate and realistic measure of network performance; it allows an operator to understand what performance to expect from their network, while also providing a better metric for traffic modeling. Site edge of coverage data rate must also be considered by public safety organizations who need to run their mission critical applications at an assured level of service. Minimum assured throughput performance at the site edge provides a more accurate measure of the applications that can be supported throughout the network coverage area.

With the demand for data services on a very steep growth curve, today's narrowband networks are running out of capacity. New spectrum and technology is needed to deliver higher average sector throughput, better performance at the edge with support of quality of service and reduced latency. LTE will provide an improved user experience for all users while helping agencies to deploy the mobile broadband services they need to enhance their operations.

REAL-WORLD LTE PERFORMANCE

RELATING TECHNICAL CAPABILITIES TO USER EXPERIENCE

Peak data rates are often perceived as actual data rates a user will experience on a wireless network; this is however far from the reality. Peak data rates do not take into account factors like traffic load, fading, attenuation loss and the signal to noise ratio that have an impact on the end user data rate in a fixed line environment, and an even greater impact in wireless networks. In wireless, additional factors such as the surrounding environment and atmospheric conditions also affect the achievable data rates. This results in a real world data rate that is well below the theoretical peak data rate obtained in laboratory environments.

> As agencies are evaluating where to invest in the next generation of wireless technologies, it is important for them to get a realistic view of the true capabilities and performance the technologies will deliver.

There are many different ways to measure performance of wireless technologies; these include peak throughput, average sector throughput, site edge throughput and user data rate, all of which take into account various conditions and scenarios. To accurately predict realistic live LTE network capacity and user experience achievable, public safety agencies need to understand the different performance measurements.

In network modeling exercises, using realistic performance metrics like average sector and site edge throughput deliver greater accuracy and drive more realistic expectations. For example, peak data rates are rarely used because they reflect theoretical rates that very few (if any) users will actually experience in a live network.

This paper defines the most common throughput measures and provides insight into the associated variables, why considering peak rates is misleading, and why average sector throughputs and site edge throughputs are much more realistic when setting performance expectations. We will look at the expected performance of LTE, supported applications, and how other factors such as latency and Quality of Service (QoS) set LTE apart.

RADIO TECHNOLOGY

Radio transmission is broadcast via a radio base station, which transmits the radio signals that are received by a user's device. Usually, the radio signal quality is affected by several factors, such as the signal path loss; this is essentially the reduction in power density of the signal as it moves through the environment in which it is traveling. Other factors that affect the signal strength include free space loss which affects the signal as a user moves away from the transmitting base station. The signal also suffers if its path is obstructed by a factor known as diffraction or if the signal is reflected and reaches the receiver via a number of different paths. This results in performance degradation known as multipath. In effect, the less path loss and susceptibility to interference, the better the signal strength a user device experiences. The better the quality of signal received, the better the performance and throughput achieved by the user.

This is very different from what we experience today with cable and other fixed connections. Fixed connections do not suffer as much from signal attenuation as the fixed connection signal travels in a confined and mostly shielded environment. An exception is xDSL as it uses very old "lossy" and unshielded copper cable, not originally designed to transport high throughputs of data. In comparison Ethernet cables or even fiber connections provide high bandwidth over fairly long distance; and as a result offer more predictable data rates that reflect its actual performance.

Figure 1 illustrates the effects of signal path loss suffered by radio signals due to factors such as free space loss, multipath, buildings and vegetation, diffraction and the general atmosphere.

These factors affect the performance of radio transmission and have led the drive for the development of new adaptive modulation schemes and techniques which aim to compensate for these environmental factors, delivering more capacity and better range in an inherently noisy environment full of obstacles. One example of these sophisticated techniques is adaptive modulation. Adaptive modulation provides a tradeoff between delivered bit rate and the robustness of digital encoding, in order to balance throughput with error resilience.

In areas where signal strength is good, the modulation switches to a higher bit rate with less robust encoding, while in areas where signal strength is poor or there are a lot of multi-path reflections, the modulation switches to a lower bit rate with more robust encoding to minimize errors. This is the reason that the highest throughput occurs closer to the tower.

The use of multipath-resistant wireless techniques such as Orthogonal Frequency Division Multiplexing (OFDM) also minimizes the impact of faded, multipath signals in a mobile wireless environment, enabling non-line of sight (NLOS) operation.

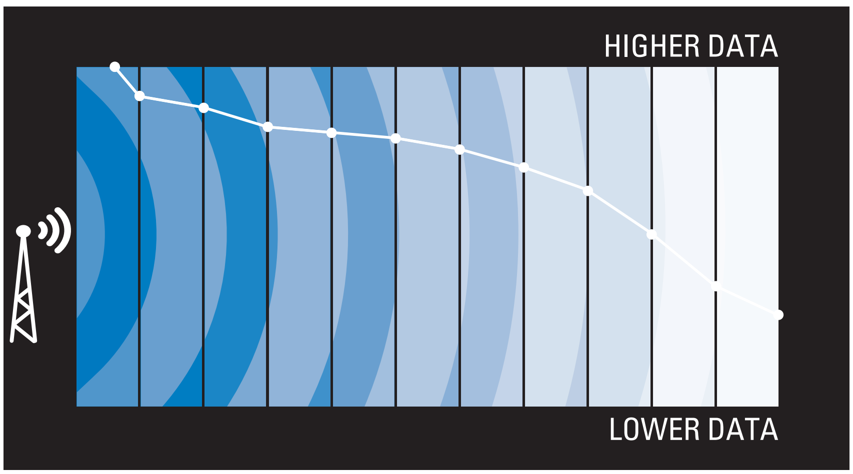

FIGURE 1 Data throughput adjusted based on radio conditions

THROUGHPUT RATES

End user expectations are often misguided because there are different methods and metrics for throughput measurement. Several factors such as those described in the previous section impact the practical throughput in RF systems. The additional overhead added by adaptive modulation and error correction coding affect the actual data rate experienced by a user, significantly lowering the user experienced data rate compared to the physical layer peak data rates measured in the lab. The most significant throughput measurements are explained below, starting with the most theoretical measure and moving to measurements that better reflect actual performance on a real life network.

PHYSICAL LAYER PEAK DATA RATE

This is often the throughput measure highlighted in media and marketing materials. It is a fixed measure, based on the physical layer, and hence determines the actual capacity available per sector at the base station without any error coding, media access control (MAC) signaling, or overhead due to UDP/IP or TCP/IP protocols that enable applications access. Physical layer peak data rate is useful in comparing laboratory performances against theoretical values, this measure does not consider any data correction techniques, signal quality, interference, scheduling, terminal performance, or mobility and hence is not a practical representation of the data performance.

APPLICATION LAYER PEAK DATA RATE

The application layer represents the top of the Open System Interconnection (OSI) reference model layer, The OSI is a description for layered communication and network protocol design. It breaks up the network architecture into seven unique layers, one of which is the application layer where actual data is being sent to the users. The application layer peak data rate achieved here assumes there is only a single user on the network with the best possible atmospheric conditions; for example the user is sitting directly under the base station. The rate is also dependent on the type of error rate coding type applied on the link. Error coding is a method of applying error control on a data transmission, where the system inserts additional data (redundant) to its messages, allowing the receiver to detect and correct errors without having to request a full retransmission of the affected data. The absence of error coding may lead to several retransmissions which will affect the effective throughput rate.

AVERAGE SECTOR THROUGHPUT

The average sector throughput is the aggregate of the individual user data rates and is used to quantify the total capacity of a site or sector. In other words, this is the total number of bits capable of being delivered to users distributed through the sector coverage area. Figure 2 illustrates simultaneous network access by various users on a sector. Individual user throughput is often affected by a set of conditions such as distance from site, number of concurrent users, mobility, interference, indoor/outdoor coverage, tower heights, and the types of devices being used on the network. Average sector throughput is the measure that best represents the capacity of a sector serving all users in a real world environment. Engineers will often use average sector throughput during system design to determine if they have designed in enough network capacity to support the expected traffic in a geographic area.

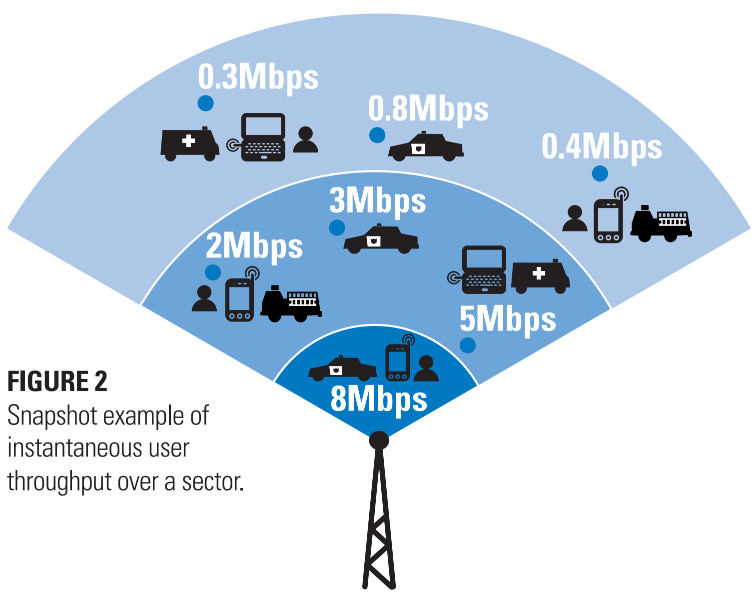

FIGURE 2
Snapshot example of instantaneous user throughput over a sector.

COVERAGE EDGE THROUGHPUT

Edge throughput is quantification of the performance for the individual user and is typically specified for a percentage at the edge of coverage, such as the outer 5% ring of the total coverage area. A modulation technique that is robust in the presence of weak signal or interfering conditions is used at the coverage edge, which trades better signal recovery with lower throughput. Coverage edge throughput is important as it specifies a "minimum" data rate that a user will experience throughout the entire coverage area.

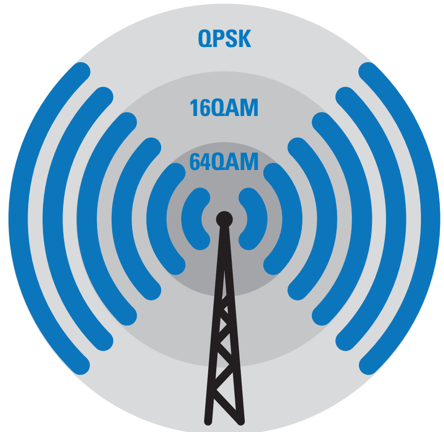

FIGURE 3 Higher-order modulation techniques work best near the tower

LTE PERFORMANCE

LTE uses multiple methods aimed at improving data rates. The ability to adjust modulation schemes based on signal quality allow LTE to use higher-order modulation, up to 64QAM, in strong signal areas and lower-order modulation, such as QPSK, with better signal recovery in poor signal quality areas. Smart antenna technologies such as MIMO use multiple antennas to increase the signal quality and allow a user device to maintain higher-order modulation and higher data rates over a larger area.

LTE AVERAGE SECTOR THROUGHPUT

While peak data rates show the theoretical throughputs, the most significant figure that defines network capacity is the average sector throughput. As previously noted, a number of factors affect actual data rates. Nevertheless, Table 1 estimates how much bandwidth can be delivered within a sector under real world conditions. The aggregate throughput can then be used to estimate how many concurrent users can be served in the sector.

TABLE 1 Average sector throughput under real world conditions

Channel Size	Downlink MIMO 4x4	Downlink MIMO 2x2	Uplink
5 MHz	13 Mbps	8.55 Mbps	3.8 Mbps
10 MHz	26 Mbps	16.7 Mbps	7.6 Mbps

Source: Rysavy Research, CDG-QCOM, Motorola

COVERAGE EDGE THROUGHPUT

Assured minimum throughput rates per user up to and including the coverage edge is variable in the system design. The distance to tower is a significantly contributing factor in determining the throughput at the coverage edge. Placing sites closer together will increase the both the edge and the average sector throughput, while increasing costs associated with building additional sites. Understanding minimum end user requirements helps to better identify the deployment costs and operating costs to serve a defined user base.

DIFFERENTIATING PERFORMANCE

In the public safety environment, perhaps the most demanding load expected is at the scene of a multi-response incident. Multiple users at one location each vying for sector bandwidth can have a noticeable effect on end user experiences. LTE uses certain techniques such as Quality of Service (QoS) which can prioritize services and mitigate congestion. QoS is discussed in more detail later in this paper.

Nonetheless, based on simulation and trials, LTE is capable of providing a true broadband experience with multi-megabit data rate over much of the site coverage area, and is effective in delivering wireless broadband.

OTHER PERFORMANCE FACTORS THAT INFLUENCE END USER EXPERIENCE

Real-time positioning/tracking, browsing the internet, or streaming video all require high bandwidths and low latency to deliver great user experiences. Below is a description of some of the capabilities that the LTE standard delivers in support of these services.

IDLE TO ACTIVE STATE

The number of connection states is dependent on the number of network elements involved in the access network path. The more elements, the longer it takes to establish a session. Fewer elements leads to a better system performance and a reduced transition mechanism, hence allowing for better user experience.

LTE introduces a flat all IP architecture that reduces the number of network elements in the access path, reducing the time it takes to access the radio and core network resources. Flat IP architecture enables a simpler network structure and a reduced number of elements in the network.

Today, bandwidth is a challenge and in other systems, it can be difficult to maintain a constant connection. Each user's connection might be severed and placed in idle state when there is no longer a data transmission for a defined time period.

For example, some technologies shift to an idle state while a user unit reads a completely loaded page; when the user clicks to request a new link, the connection needs to be re-established, resulting in a delay.

In LTE the connection remains constant thus eliminating the delay to re-establish each time a user makes a request. This results in a user experience that approaches wired broadband's "always-on" service.

LATENCY

Latency is the interval between the time a service request is made by a user, such as clicking on a link, and the time the user receives a response from the system. Latency can either be measured as one-way or round trip; round trip is the common measurement as it covers the time from the initiation of a service request on the user device through the network and back down the network until it displays a response on the user device – for example, the time between when a request to query a database is made to when the database information begins to be received. In addition to increased data rates, the latency enhancements of LTE provide a significant improvement in the user experience. The low latency of LTE, combined with its high throughput, makes it an ideal platform for demanding services like real-time video. LTE's roundtrip latency compares favorably to the typical latency on today's fixed line broadband infrastructure, delivering an instantaneous response. This will have a significant impact on user experience and satisfaction.

With improvement in both data rate and latency, it is expected that applications on LTE will provide a user experience very similar to that experienced with a wired broadband network providing the true realization of broadband services that go anywhere.

QUALITY OF SERVICE (QOS)

Quality of service (QoS) in a network is the ability of the network to enforce different service priorities for different application types, users, or data sessions, while guaranteeing a certain level of performance to a data session. As an all IP network, LTE defines QoS to not only guarantee the quality of a service but also support different level services for other latency or bit-rate sensitive applications.

As all data on the network becomes packetized, some data packets will be more critical than others. QoS classes ensure the network can prioritize certain types of packet for immediate and secured delivery; this is an extremely important feature and one which has a major impact on agency operations.

The class of QoS and Guaranteed Bit Rate (GBR) are significantly dependent on the level of latency (delays in packet transmission), jitter (variation in latency), and dropped packets that occur in the network. Without a QoS implementation on a loaded network, users will experience choppy videos, and delays for time sensitive data.

LTE FOR VIDEO SERVICES

The demand for video in the public safety industry is growing exponentially and will continue to grow. This is fueled in part by the recognition of the value that video can play but also in part by the advancement and availability of digital video technology.

It is critical that investments made today will support mobile video in the future. LTE's high capacity and ability to deliver true broadband will help agencies cost effectively deliver a multitude of applications used today on fixed line broadband networks anywhere. LTE will not only be able to deliver multiple simultaneous video streams but will also increase the quality of the video with higher resolution and better encoding to provide a better video experience.

The flat IP network architecture similar to the internet architecture drives lower cost application delivery and enables hand over between IP access technologies. LTE will support unicast and multicast IP data flows for the delivery of high quality video.

CONCLUSION

Mobile wireless broadband is more than just peak data rates. LTE technology combines innovations in its architecture and air interface to deliver fixed-like broadband experiences to personnel in the field.

Peak data rate marketing has lead to a misaligned comparison of many wireless broadband technologies, leaving agencies confused about the actual performance of existing and future wireless broadband technologies. The true performance of wireless broadband network is reflected in more than just the peak data rate number. In effect, this theoretical peak rate figure fails to give a fair picture of what users are likely to experience when using the technology in a real world situation.

Average sector throughput and edge rates offer a more realistic measure of real life network capacity and user experience, hence giving agencies a more accurate basis for planning future operations. The quality of user experience is not only a factor of data rate but also directly impacted by connection time and latency; for that reason LTE is the first technology that will provide users with a true mobile broadband experience. LTE is clearly positioned to address the challenges of next generation networks and with increased commitment from the commercial carrier industry and public safety organizations. LTE offers a true cost effective network that can offer the ability to provide a wide range of services and deliver next generation performances.

Motorola is ready to lead public safety with the applications, devices, components and services designed to meet the demanding needs of first responders.

NEXT GENERATION PUBLIC SAFETY

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