4G Wireless Technology

96-822 Mobile Ecosystem

Course Paper

S'14

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ABSTRACT

The Fourth Generation (4G) network is expected to be a heterogeneous network that encompasses 2G and 3G networks while providing higher performance features. Higher bandwidth and more cost-effective services will lead to the support of rich multimedia content such as video conferencing and multimedia services. According to Hong and Leon-Garcia (2005), personalized mobile services that focus on the mobility of the user as opposed to the device will be possible with 4G. However, creating this heterogeneous environment has many challenges. This paper discusses the technology of 4G networks and its capabilities. Technical requirements and services supported by 4G and their current status are discussed. Existing device technologies and their use of 4G is also discussed as well as how user experience can be enhanced by the next generation of mobile devices using 4G. Finally, the future of 4G is analyzed and one 4G application that would not work well over 3G is discussed.

INTRODUCTION

The transition from 2G to 3G saw the addition of a few new services, hence 3G was not able to replicate the success of 2G. 4G is supposed to be revolutionary in providing high data rates that conform to the technology-centric mobile user of today. 4G therefore has several advantages over 3G and preceding networks. Seamless human-computer interaction can be achieved with applications that use speech recognition such as Apple's Siri. Services offered to users can also be personalized due to the ubiquitous nature of 4G networks. Devices can be configured to operate in modes preferred by the user based on their context. Terminals can also be heterogeneous and provide common services to users regardless of their underlying implementation. Interoperability across networks as well as intelligent networking all provide the user with seamless interaction when using mobile services. Network convergence ensures better use of existing bandwidth, with voice and multimedia applications co-existing on the same networks.

4G networks however pose challenges. Network discovery and selection by a terminal/ device poses security issues. How should devices be verified before joining a network for example?

Implementing multimode user devices will also require complex implementation such as the use of software that adapts itself to the wireless network. These challenges have led to interested design decisions by researchers.

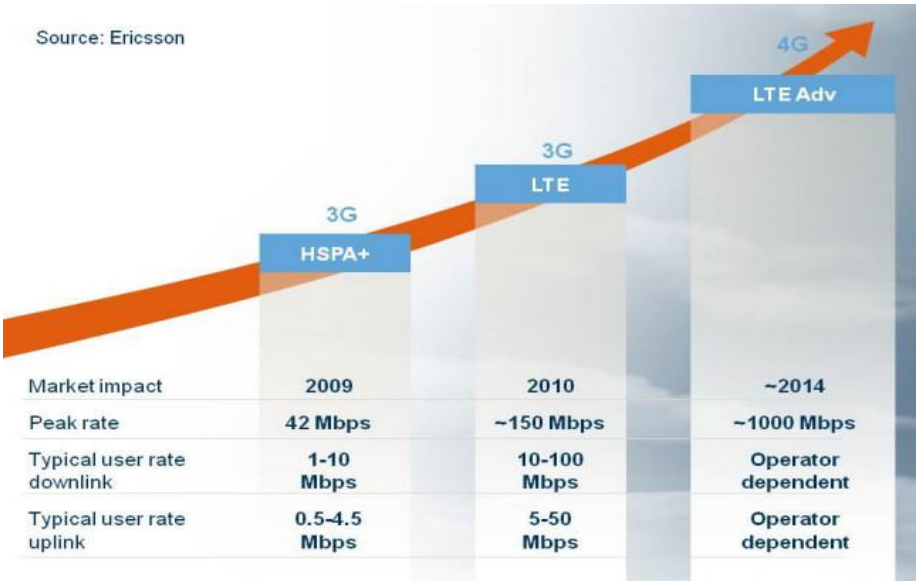

Figure 1: Source Ericsson

SCOPE OF PAPER

Background and motivation

The 4G technology is coming to our life, more and more countries and people begin to use 4G system.

New mobile generations have appeared about every ten years since the first move from 1981 analog (1G) to digital (2G) transmission in 1992. This was followed, in 2001, by 3G multi-media support, spread spectrum transmission and at least 200 kbit/s peak bit rate, in 2011/2012 expected to be followed by "real" 4G, which refers to all-Internet Protocol (IP) packet-switched networks giving mobile ultra-broadband (gigabit speed) access[13].

LTE is one kind of technology of 4G. The Figure 2 shows the adoption of LTE all over the world. It shows that this technology is expanding fast through the whole world. So it is the right time to talk about 4G and its future.

The question has come to us: What is 4G? What 4G can bring to us? What is the difference between 4G and 3G? Why we use 4G instead of 3G. In this paper, we try to find out the answer of them.

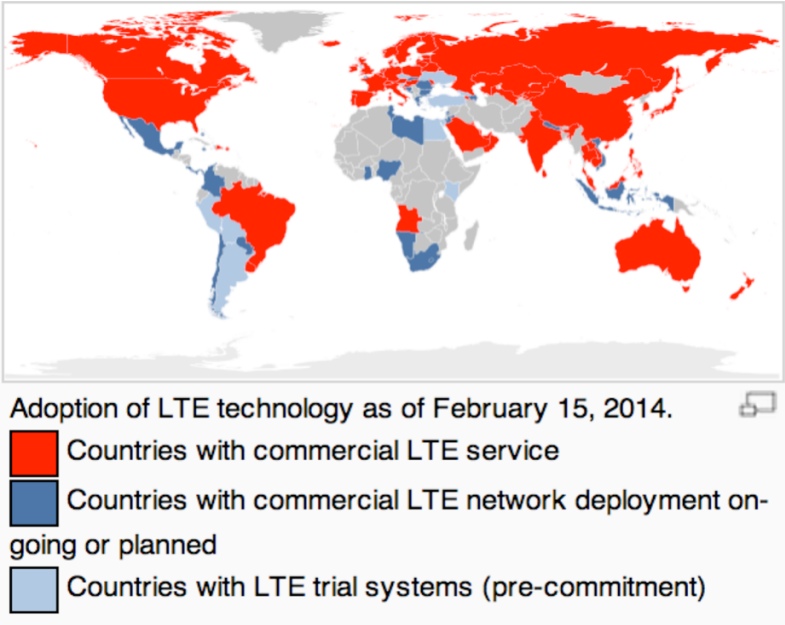

Figure 2 The Adoption Of LTE Technology In The World

The main content of the Paper

1. This paper studies the new capabilities offered by 4G wireless technologies and their ability to leverage existing device technologies and software capabilities.

2. The paper describes how the next generation of mobile applications can combine 4G technologies and device/software technologies to enhance the user experience.

3. The paper gives some new type of 4G applications that would not work well over 3G.

The rest of this paper is organized in the following way: first we discuss the background of arising of 4G technology, then present the evolution from 1G to 4G. We talked about technical requirements in order to support 4G specifically and underlying technologies of 4G including network architecture. We further talks about the candidates system of 4G and the services we identified to be only supported by 4G. A business case is studied and we describe some future of mobile space and 4G at the end.

PRE 4G SYSTEMS

There are 3 generations of wireless communication systems before 4G system. The evolution follows the trend from analog signal to digital signal, from telephony circuit-switch networks to extension of packet-switch networks, from single service to multi-services. In this section, we will discuss the evolution of mobile systems before the 4G systems to find the trend and factor that drives the evolution.

1G

The first generation of wireless communication transfers analog signal. The most popular system in North America is Advanced Mobile Phone System (AMPS) led by Bell Lab in 1978. This system utilizes frequency division multiplex access (FDMA) mechanism to multiplex the frequency band. Therefore, the number of users to make phone call simultaneously is limited by the total bandwidth assigned to it and sub-channel bandwidth for each phone call.

In AMPS, several interesting services such as pre-origination, three-way calling, call-waiting and speed-calling, were firstly introduced. Pre-origination allows users to dial the phone number before go off-hook. Users firstly dial the phone number into the device and the rest phone call connection was accomplished by phone automatically. And three-way calling is another feature in AMPS. It allows users to stay online and accept the phone calls from third-party at the same time. With company of call-waiting, users can switch back and forth. And speed calling was also introduced in AMPS. This feature is to let user store frequent number into their devices and dial the number by pushing one button.

Besides AMPS, another popular 1G mobile telephone system is Nordic Mobile Telephone (NMT). NMT works on the frequency band at 450MHz. It utilizes 463-467.6MHz as its downlink and 453-457.5 as its uplink. The analog signal was modulated by frequency modulation at speed of 600 – 1200 bps. The cell size for NMT varies from 2 km to 30 km. With smaller cell size, more simultaneous users are supported and frequency is reused more than larger one. NMT is the first automatic mobile telephone system in terms of switching and handover between different channels, which was not addressed in its preceding standards.

An obvious disadvantage of NMT is its security flaws. At the beginning stage of NMT, data was transmitted as plaintext. As a result, scanner can detect the signal in channels, collect data and read information transmitted over the wireless interface. The later version of NMT added scrambler to enhance its security part. Scrambler is alike encryption but is often used in analog signal and its effectiveness of encryption is worse than digital signal. If two mobile stations, which are connected, are equipped with scrambler, the scrambling option will be turned on. All signal transmitted should be scrambled at the sender and descrambled at receiver side. In other words, information in wireless interface, base station and Public Switched Telephone Network (PSTN) is all encrypted.

2G

The second generation of mobile system, aimed at providing better voice service and introducing the slow packet data transferred between mobile stations, was firstly commercially launched in Finland in 1991[22]. 2G is distinguished with its preceding generation in the form of data transmitted over wireless interface. As discussed in previous sections, data were modulated in analog signal. Since 2G, data is transmitted in the digital signal. Two most popular 2G mobile standards are GSM and cdmaOne.

With digital signal, 2G achieves several advantages. Firstly, the security is enhanced by 2G. Since data were encrypted digitally, more encryption options and more robust and reliable encryption methods are implemented. Besides, as digital signal is obtained by sampling the analog signal, the reduced information is transmitted to save for more users. As with the development of channel coding algorithms, compressed data is transferred to reduce the redundancy further, and error detection and correction are also available to recover the wrong data and improve the efficiency of bandwidth. Thirdly, with the decreasing size of

single cell, the less power on the handset side is required and saves more battery. And smaller cell also implies higher reuse on same frequency by users in different cells. At the other hand, it also suggests lower up-front cost of equipment as more base stations are needed with same region.

Another breakthrough with 2G is the introducing data service to mobile system. The data service like SMS text messages, multi-media messages adds more functions to mobile services. SMS has now been the most widely used data application with an estimated number of 3.5 billion users, which consists of 80 mobile users at the end of 2010[23]. SMS came along with GSM and has evolved from point-to-point pattern to cell-broadcast patter to allow broadcasting messages within a geographical region.

Motivated by improving data service, 2G evolved into 2.5G, which adds the packet switch network to previous pure circuit switch network. Two major standards in 2.5 G are General Packet Radio Service (GPRS) and Enhanced Data Rates for GSM Evolution (EDGE), running at 50kbps and 250 kbps respectively. Unlike usual phone-call service, the GPRS is calculated by data transferred by mobile stations. It supports SMS message which is said to enlarge the capacity of SMS amount by using GPRS. However, current SMS are mostly transmitted over control channel of GSM[24]. GPRS was used for wireless application protocol (WAP) to provide basic web application service to users, such as news and emails. And EDGE, which was deployed in America since 2003[25], is supplementary for GSM and GPRS. It is 4 times faster than GPRS and more importantly EDGE only requires upgrades in core network and base stations. It provides a smooth pathway for operators to evolve to offer better service to users.

3G

3G is the synopsis of third generation mobile system aimed at providing hybrids of packet-switch data service and circuit-switch data service. Specifically, it is expected to support services such as voice, mobile Internet, fixed wireless Internet access, video calls and mobile TV[26].

3G is standardized by International Mobile Telecommunication-2000 led by International Telecommunication Union. There are in total six 3G family members recognized by ITU[27]:

- IMT Direct Spread (IMT-DS; also known as UMTS/UTRA-FDD);
- IMT Multicarrier (IMT-MC; also known as CDMA2000);
- IMT Time Code (IMT-TC; also known as UMTS/UTRA-TDD, TD-CDMA and TD-SCDMA "narrowband TDD");
- IMT Single Carrier (IMT-SC; also known as UWC-136 or EDGE);
- IMT Frequency Time (IMT-FT; also known as DECT)
- IMT OFDMA TDD WMAN (also known as mobile WiMAX)

According to IMT-2000, 3G systems are expected to offer peak data rates at 2Mbps, 348kbps for devices at high velocity[28]. As shown in the below picture, in practice, most of operators provide data speed higher than the requirements in specs according to the real test of data speed conducted by Novarum.

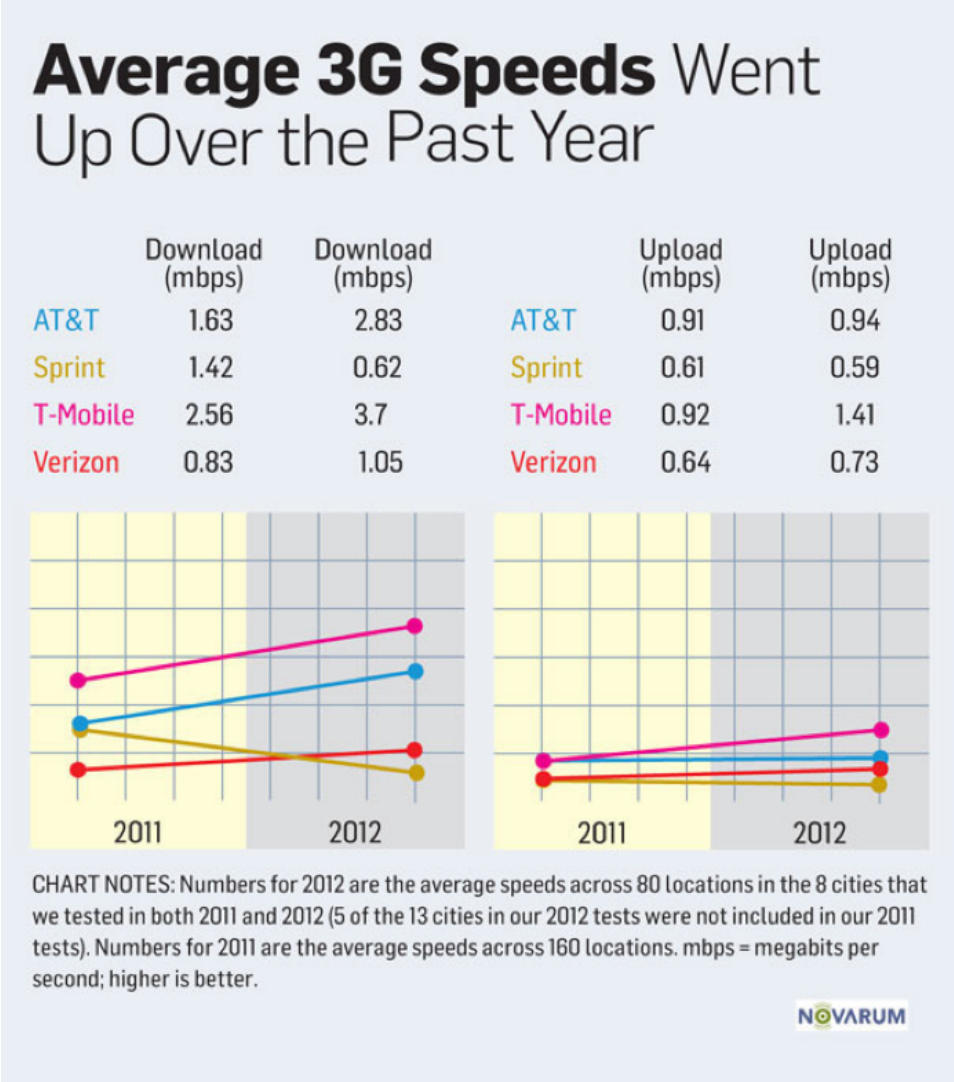

Figure 3 Average 3G speeds. (Source: Novarum)

There are 2 major 3G mobile systems included in IMMT-2000 that utilizes spread spectrum are widely used around the world. One is Universal Mobile Telecommunication System (UMTS) and the other is CDMA-2000.

UTMS is led by 3GPP and based on GSM system. The UTMS shares the same core network with GSM and EDGE, and thus makes it economically easier to evolve from GSM and EDGE. Because of that, most of UTMS phones also back support GSM and GSM phones manufacturer becomes the major UTMS phones manufacturer. UTMS defines three air interfaces, i.e. W-CDMA, TD-CDMA and TD-SCDMA. Its core network is connected to backbone telephone network and Internet. Another feature of UTMS is to use Universal Subscriber Identity Module. Therefore, each mobile devices could be identified globally even they belong to different operators, which is beneficial in roaming among different operators. Besides, USIM also provides a small amount of storage for mobile contacts. UTMS has been deployed in China, Europe and Japan.

CDMA-2000 is led by 3GPP2. CDMA-2000 evolves from cdmaOne (IS-95) standards. It requires narrower bandwidth, which is its advantage when issues come to spectrum scarcity. Operators that deploy CDMA-2000 are using hybrids network of IS-95 and CDMA-2000. It is regarded as UMTS's major competitors.

Besides, there are some systems that evolve from 2G, such as a revision of EDGE and DECT.

TECHNICAL REQUIREMENTS FOR 4G

Intelligent communication architectures are needed to support the heterogeneous network that is 4G. The formal definition for 4G is contained in an ITU circular letter that was published in July 2008, calling for candidate systems to be proposed on the basis of meeting the requirements of International Mobile Telecommunications-Advanced (IMT-Advanced) systems. According to the ITU (2008) document, These 4G requirements are as follows:

1. A high degree of commonality of functionality worldwide while retaining the flexibility to support a wide range of services and applications in a cost efficient manner;
2. Compatibility of services within IMT and with fixed networks;
3. Capability of interworking with other radio access systems;
4. High quality mobile services;
5. User equipment suitable for worldwide use;
6. User-friendly applications, services and equipment;
7. Worldwide roaming capability;
8. Enhanced peak data rates to support advanced services and applications (100Mbps for high and 1Gbps for low mobility were established as targets for research). Data rates sourced from Recommendation ITU-R M.1645 - ´Framework and overall objectives of the future development of IMT-2000 and systems beyond IMT-2000´.

LTE-Advanced was designed to excel the performance features of IMT-Advanced. The table below contains the comparisons between LTE, IMT-Advanced and LTE Advanced.

Parameter	Transmission path	LTE	IMT-A	LTE-A
Peak data rate	Downlink	300 Mbps	1Gbps	1Gbps
	Uplink	75 Mbps	-	500 Mbps
Peak spectrum efficiency (bps/Hz)	Downlink	15	30	30
	Uplink	3.75	15	15
Capacity (bps/Hz/cell)	Downlink	1.69	2.2	2.4
	Uplink	0.74	1.4	1.2
Cell edge user throughput (bps/Hz/cell/ user)	Downlink	0.05	0.06	0.07
	Uplink	0.024	0.03	0.04

Table 1 Data sourced from Akyildiz et. al. (2010).

According to a Tellabs Solutions white paper (2012) there are 4 access layers that are implemented in 4G:

- Fixed: (DSL, cable, fiber). These are fixed wired networks
- Personal (Bluetooth). Cars, cellphones
- Hotspots (Wifi). Restaurants etc.
- Cellular (UMTS, WiMAX). For highly mobile users.

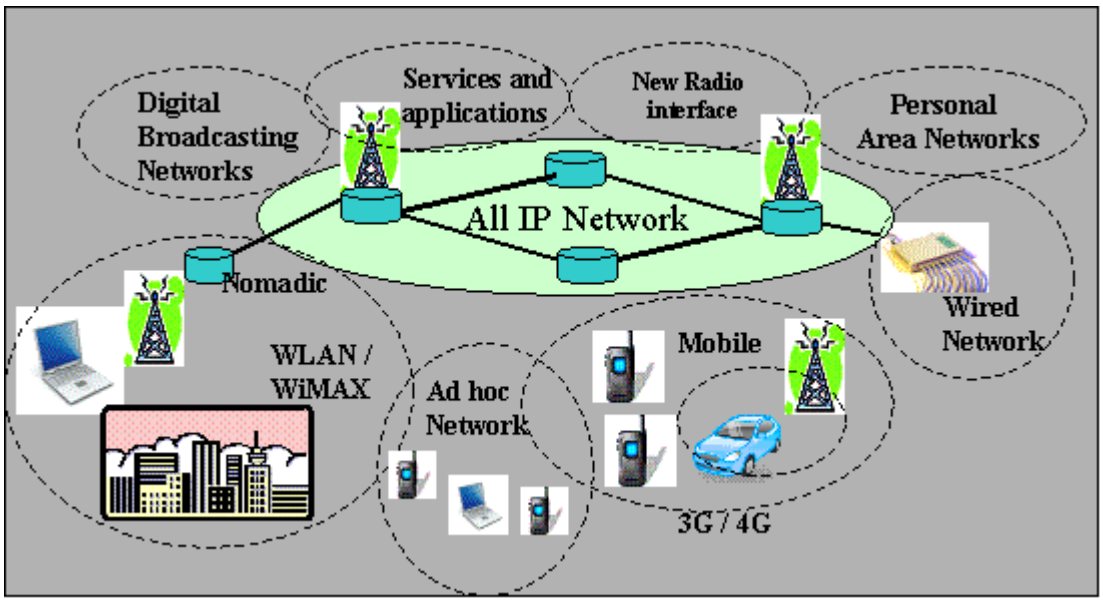

Figure 4 Different network layers within 4G (Source www.cse.wustl.edu)

These layers are described by ITU based on the geographic coverage and the extent of mobility of each layer. Interactions between layers are both internetwork and intra-network. They also encompass complex standardization functions across providers such as billing and QoS (quality of service). There should be vertical and horizontal handovers between systems as one moves across or between layers. This requires that most of the logic be built into the network in order for users to access the system without requiring prior knowledge of the underlying topology, geographical coverage, underlying technology or operators. The following attributes are therefore key to 4G in order for this seamless network interaction to be implemented:

- Multiple applications and services support: Minimally services need to be delay sensitive, loss sensitive and best effort. Support for broadcast, unicast and multicast applications must be built into the network.
- Quality of Service (QoS): Efficient scheduling algorithms must be implemented in a network-agnostic fashion.
- Network detection and selection: A homogenous method of verifying the eligibility of a device to join a network as well as validity of the configuration of the link layer is needed. Mobile devices with different radio technologies will need to connect to the best available network without degradation in service.
- Seamless handover and continuity of service across networks: Continuous maintenance of multiple network services is required without loss in quality.
- Technology and topology agnosticism: Services should outlive the underlying technologies and be independent of them.

UNDERLYING TECHNOLOGIES

Network Architecture

Although the technical implementation details of 4G are outside the scope of this paper, a brief architectural overview of the network is given in this section.

The 4G network is divided into the following layers/ abstractions:

1. Core network (Evolved Packet core EPC). This is an IP-based flat core network which can be accessed using different types of radio access e.g. WiMax, LTE. Security functions, roaming, handovers across networks are handled at this layer. This part of the architecture is not undergoing major changes compared to the non-core sections.
2. Radio Access Network (EUTRAN). This contains an enhanced Node B (eNB) which are logical components that provide the network "with the necessary user and control plane termination protocols" (Akyildiz et. al. 2010).
3. Air interface (EUTRA). This forms the communication link between the device and the base station.(Akyildiz et. al. 2010).

Figure 3:Wireless Network transition from 3G to 4G

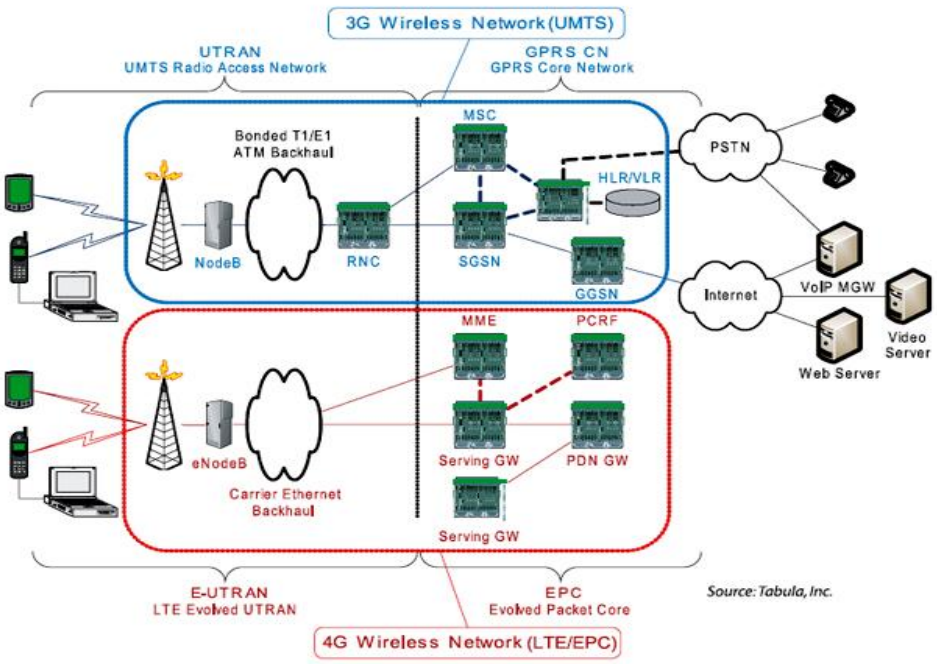

Figure 5 4G network architecture (Source www.tabula.com)

According to Gupta and Patil (2011), the key 4G technologies include:

1. OFDMA: Orthogonal Frequency Division Multiple Access. It is used for downlink transmission providing full use of available bandwidth. It uses a large number of parallel sub-carriers instead of a single band to carry data with low interference.

2. Multiple Input & Multiple Output (MIMO): This technology provides functions of both transmitter and receiver of data signals.
3. Multiuser MIMO: Many radio terminals can be used.
4. Software Defined Radio (SDR): This is radio communication that is implemented as software allowing devices to be easily added to a network. The device downloads the software for a particular network and configures itself accordingly.
5. SCFDMA: Single-carrier FDMA (Frequency Division Multiple Access). This is used for uplink transmission of data. According to Gupta and Patil (2011)

> "In this scheme, as the data is transmitted along the multiple subcarriers and if one subcarrier is in problem it is easy to recover the data from the other subcarriers based on frequency selection for the channel. But the recovery of data at the receiver side requires the selection of the data from the multiple subcarriers and requires more efforts for removing the error in the data."

CANDIDATE SYSTEMS

For 4G systems, the two main candidates are, the Third Generation Partnership Project's (3GPP's) Long Term Evolution (LTE) and WiMAX technology, based on IEEE802.16 standards, both of which are being further enhanced at the time of this publication to be considered and potentially endorsed by ITU-R as IMT-Advanced systems.

While in details LTE and WiMAX have somewhat different designs, there are many features, concepts, and capabilities commonly used in both systems to meet a common set of expectations and requirements. At the physical layer both technologies deploy orthogonal frequency-division multiple access (OFDMA)-based designs combined with various modes of multiple-input multiple-output (MIMO) configurations and fast link adaptation with time-frequency scheduling. Also, medium access control (MAC) of both systems support heterogeneous networks of cells and multicarrier operation, consisting of a mix of femtocells, macrocells, and relay nodes, which bring all kinds of challenges and solutions for mobility, interference, and traffic management.

Long Term Evolution (LTE):

Even though significantly higher bit rates are delivered by 3G technologies than 2G technologies and contribute to ARPU growth for wireless data services, there is still more opportunity for wireless operators to capitalize on the ever-increasing demand for "wireless broadband", even multi-megabit throughput and lower latency. Consequently, it is only the next- generation networks that can that can satisfy a growing pool of underserved consumers from whom, there is an expanding revenue opportunity. The solution is "LTE" (3GPP Long Term Evolution), the next-generation network beyond 3G. In addition to enabling fixed to mobile migrations of Internet applications such as Voice over IP (VoIP), music downloading, mobile TV video streaming, and many others. From a new generation of consumer devices tailored to those new mobile applications, LTE networks will also have the capacity to support an explosion in demand for connectivity.

Definition: LTE (Long Term Evolution) is a wireless broadband technology designed to support roaming Internet access via handheld devices and cell phones. As over older cellular communication standards, LTE offers significant improvements, some refer to it as a 4G (fourth generation) technology along with WiMax.

Long Term Evolution (LTE) refers to a standard for efficient and smooth transition toward more advanced leading-edge technologies to increase the speed and capacity of wireless data networks. LTE is often used to refer to mobile network technologies or wireless broadband.

Unlike many other cellular Internet protocols, with its architecture based on Internet Protocol (IP), Long Term Evolution supports browsing, VoIP, Web sites and other IP-based services well. LTE can theoretically support downloads at 300 Megabits per second (Mbps) or more based on experimental trials. However, significantly less is the actual network bandwidth available to an individual LTE subscriber sharing the service provider's network with other customers.

LTE is also regarded as 3GPP Long Term Evolution. 3GPP is an acronym for 3rd Generation Partnership Project, operates under a name trademarked by the European Telecommunications Standards Institute. LTE is also known as LTE Super 3G and LTE Super 4G.

Long Term Evolution service is only available in limited geographic areas, but telecommunications providers have been actively expanding their LTE services.

LTE features include an all- end-to-end quality of service (Qos), IP flat network architecture, higher download rates approaching 300 mbps and upload rates of 75 mbps, supporting fast moving mobiles and expanding cell capacity to accommodate 200 active users.

With the capacity to support a high demand for connectivity from new consumer devices tailored to new mobile applications, LTE is regarded as the next generation network beyond 3G. In an LTE live air demo, Web browsing, HD video, and telecommunications are demonstrated simultaneously inside a single computer moving within a vehicle at 108 kilometers per hour.

LTE encompasses the pillars of next- generation networks:

- Broadband wireless as the new access reality — High-throughput, efficiently delivering unicast, low- latency mobile access based on OFDM/MIMO, multicast and broadcast media.

- Convergence of networks and technology — A single applications domain serving customers across devices and multiple networks.

- Intelligence at the services edge — Implementing policy enforcement and decisions at the network edge, in an access-agnostic but access-aware framework.

- Embedded security — A multi-layer, multi-vendor approach to security is critical to ensure that security is not just focused on point solutions and endemic to the network.

Two key enabling technologies will help the industry exceed and meet the LTE performance objectives:

- Orthogonal Frequency Division Multiplexing (OFDM) is intrinsically able to handle the most common radio frequency (RF) distortions, scales easily to fit different bandwidth requirements, without the need for complex equalization techniques.

- Multiple Input/Multiple Output (MIMO) increases peak throughput by transmitting and receiving multiple streams of information within the same spectrum. Typical in wireless environments, MIMO exploits the multi-path effects.

In maximizing usage of scarce spectrum typically controlled by regulatory bodies, the combined use of OFDM and MIMO will improve the spectral capacity and efficiency of the wireless network, and will prove to be a very valuable asset.

In brief, the Migration to 4G Networks is simplified by Long-Term Evolution. Beneficial effects of an LTE network include:

- Simple migration from 2G or 3G to 4G without a complete equipment upgrade - in a single common core platform

- Smooth, fast transition to Evolved Packet Core (EPC), an all-IP core network that supports lower latency higher throughput, , and mobility between 3GPP and non-3GPP radio access technologies

- Backhaul is optimized by Core network solution

- Converged mobility and policy management so operators can choose any access technology without a complete overhaul of IP core overlay or existing IP core

- Intelligence in the network to deliver higher-bandwidth multimedia services - interacting with and understanding key elements within the multimedia core.

Currently ranging from 700 MHz up to 2.7GHz, LTE is developed for a number of frequency bands – E-UTRA operating bands. Starting with 1.4 MHz up to 20 MHz, the available bandwidths are also flexible. LTE is developed to support both the frequency division duplex (FDD) and the time division duplex technology (TDD).

WiMAX Technology:

WiMax is a wireless broadband technology that delivers WiFi-like speeds to wide areas. WiMax technology is the basis of Sprint's 4G wireless data network.

Sprint says its 4G WiMax network, with peak download speeds of more than 10 mbps , can normally offer download speeds that average between 3 megabits per second and 6 mbps,.

On the other hand, WiMax, is already available in some locations, makes sense especially in areas where 3G cellular service is not currently available. However, the initial deployments done for WiMax have been concentrated in densely populated areas like Las Vegas (Nevada, USA), Portland (Oregon, USA), and Korea where other high-speed Internet options like cable, fiber, and DSL already exist.

WiMax, which is short for worldwide interoperability for microwave access, operates on the 2.5-GHz band and is based on the IEEE 802.16e specification,.

A large number of small base station antennas are used by Worldwide Interoperability for Microwave Access (WiMAX) technology to provide wireless broadband access. As you move around our coverage area with your vivid wireless Wi-Fi enabled device, your WiMAX modem connects you to the closest base station for seamlessly fast Internet access.

Prioritising on different types of traffic, WiMAX also supports Quality of Service (QoS). Voice traffic is given the highest priority, then standard web and email traffic, and then peer-to-peer (such as file-sharing) traffic.

No fixed band for its wireless signaling has been defined by WiMax. Generally outside the U.S., WiMax products have conventionally targeted 3.5 GHz as that is an emerging standard for mobile broadband technologies. In the U.S., the government, mostly reserves the 3.5 GHz band for use.

WiMax v.s. LTE

Presently, for fourth generation mobile telephony, there are two contending technologies. On one side is WiMAX (Worldwide Interoperability for Microwave Access), and on the other LTE (Long-Term Evolution).

- WiMAX is a wireless digital communication system defined in the IEEE 802.16 standard for metropolitan area networks (MAN, Metropolitan Area Network). With coverage up to 31 miles for fixed stations or 3 to 9 miles for mobile stations, it provides broadband communications. Cellular companies for 4G services will use the 802.16m standard, known as mobile WiMAX, will be used by.

- LTE is a technology defined by the organization 3GPP (3rd Generation Partnership Project) where there are more than 60 operators, manufacturers and research institutes defining standards for LTE.

LTE has a key performance advantage: It's better integrated with other cellular technologies, making for smoother transitions between 3G and 4G. Once WiMAX phones drop into a 3G area they tend to have problems finding 4G again. In this regard, LTE phones have less of an issue.

When it comes to wireless data networks, besides knowing the difference between 3G and 4G, there's another question: Which flavor of 4G do you need? With 4G, Sprint was the first major wireless carrier in the U.S., but is now upgrading its networks from WiMAX to LTE. Virgin and Boost, meanwhile, are just getting WiMAX.

SERVICES SUPPORTED BY 4G

Always-on Phone Call

And as LTE-Advanced will abandon the circuit-switch network, and start a total packet switch network, the current telephony service over public switched telephone network will be out-of-date. The mobile

VoIP will be another change by embracing the 4G. Currently, a prevailing mobile VoIP way is to run a soft-VoIP phone on mobile devices and utilize the WiFi to transfer voice data in achieving a reliable data speed and a better user experience. With such a dependable data connection between mobile device and mobile network offered by 4G, VoIP is going to develop a lot. As pointed out in [31], since it might be difficult for operators to distinguish streaming data and VoIP data, how the operators charge users' phone becomes a challenge. And with such network, the phone call service is likely to be charged by how much users speak instead of how long they stay online, because IP-based network charges users by data rates. And this allows telephone service to be always-on and people can stay online as long as they want without any costs if they don't speak. Telephone becomes more instant than Pre-4G times.

Faster Speed

As discussed in previous sections, the most significant improvement in 4G is supposed to be the data speed. Among countries where 4G has been deployed in mature, data speed is higher on average in area where population density is higher. [32] points out it is due to the difficulty to roll out LTE to cover a larger geography country. In spite of that, LTE data rate is as 3 times as HSPA+ and WiFi, 10 times as 3G. This could be a promising substitution of wire network. With such a high speed, a lot of service is supposed to emerge that requires high speed and couldn't be accomplished by 3G and its predecessors. However, it is worthwhile to point out that, due to the unreliable and unpredictable wireless channel, applications assuming to work under a high data speed 4G network will suffer a lot when they experience a low data speed environment.

With the emergence of 3G, the video streaming takes up a major percentage of monthly data consumption on mobile devices. But video chatting is somewhat not that popular. And as people's increasing demand on HD resolution, HD video chatting is even more difficult to achieve. The following is from Skype official website [29], which shows different minimum and recommended bandwidth requirements for different Skype voice and video chatting services.

Call type	Minimum download / upload speed	Recommended download / upload speed
Calling	30kbps / 30kbps	100kbps / 100kbps
Video calling / Screen sharing	128kbps / 128kbps	300kbps / 300kbps
Video calling (high-quality)	400kbps / 400kbps	500kbps / 500kbps
Video calling (HD)	1.2Mbps / 1.2Mbps	1.5Mbps / 1.5Mbps
Group video (3 people)	512kbps / 128kbps	2Mbps / 512kbps
Group video (5 people)	2Mbps / 128kbps	4Mbps / 512kbps
Group video (7+ people)	4Mbps / 128kbps	8Mbps / 512kbps

Table 2 Data rates of different Skype service

From Table 2, HD video chatting (e.g. Skype) requires at least 1.2Mbps for both downlink and uplink and Skype recommends users to be equipped with 1.5 Mbps. According to the snapshot measurements taken in 13 major cities of the U.S.[30], the average data rates of downlink provided by AT&T, Sprint, T-Mobile are shown in the following chart, whose unit is Mbps:

Mobile Operator	AT&T	Sprint	T-Mobile	Verizon
Downlink	2.62	0.59	3.84	1.05
Uplink	0.85	0.56	1.44	0.75

Table 3 3G average data rate (unit: Mbps)

From the Table 3, we found that 2 out of 4 major mobile operators couldn't provide a stable video chat service. And the uplink conditions make things worse. None of those mobile operators meet the desired bandwidth. Therefore the uplink data rates seem to be the bottleneck for HD video chatting.

But when we are in the 4G network, it is much better.

Mobile Operator	AT&T	Sprint	T-Mobile	Verizon
Downlink	9.12	2.81	5.53	7.35
Uplink	4.91	0.97	1.32	5.86

Table 4 4G average data rate (unit: Mbps)

The average uplink data rates are much better form AT&T as well as Verizon. And T-Mobile also meets the minimum requirement of bandwidth, which provides the possibility for stable HD video chatting.

And from the Table 4, it is also glad to see that group video becomes possible in 4G. The group video could really work as remote conference. And with mobile equipment and flexible network assess, it is desired to allow people to set up a meeting anytime and anywhere.

Static IP

As Verizon and Sprint announced to support static IP for 4G devices, a new field of applications which is tied to fixed IP address will emerge in the near future.

With static IP, VoIP is more straightforward as static IP address could act as the destination address while currently the account information which is associated with the IP that are used in present is acting as a temporary destination address.

On top of that, IP-specific applications would become practical under with the help of static IP address. For example, with static IP address, the mobile devices can be uniquely identified by IP address. For security sake, companies could control the networking behavior of employee's personal devices which is known as Bring Your Own Devices(BYOD) issues. And more control and management could be done via IP address. Besides, virtual private network (VPN) feature could also be enhanced by static IP. For example, in present mobile VPN solutions, it is the mobile devices that starts to establish the tunnel between itself and remote endpoint. The opposite direction is impractical due to the unknown dynamic IP address and even the private IP address in mobile system. But a public static IP address is of great value in addressing the active VPN establishment from remote fixed endpoint to mobile devices and even between two mobile devices. With such new VPN, mission-critical applications are available.

A BUSINESS CASE FOR 4G

4G provides new opportunities to network providers and vendors for providing ubiquitous, converged and capacity-agnostic services. As global LTE (and LTE-A) subscriptions grow, several factors make 4G a technology to look out for from a business standpoint:

- Technology pull: The processors needed to support 4G are becoming more affordable as hardware costs for mobile devices are falling. Innovations in radio and power technology make the 4G adaptability more viable.

- Business opportunity: future revenue in the mobile ecosystem no longer comes from voice data and selling ringtones but from Internet downloads and multimedia streaming.
- Sophisticated apps: mobile device owners are using increasingly sophisticated apps that merge user profiles with security and ubiquitous computing features. 4G will support this high rate of app innovation.
- IP standardization: this makes it possible to implement a wide variety of services within the heterogeneous 4G network. Radio technologies are likely to become standardized as well with time.
- New revenue streams: ad-based business models are becoming widely accepted as well as packages for broadband from operators that are entry-level. This will quicken 4G adoption among different economic brackets of users.
- Wireline technological developments: Video and streaming technologies in wired devices have incentivised wireless technologists to replicate the same data rates/ quality in wireless networks.

As a result of the above factors, the global subscriptions of LTE-A/ 4G are steadily growing worldwide.

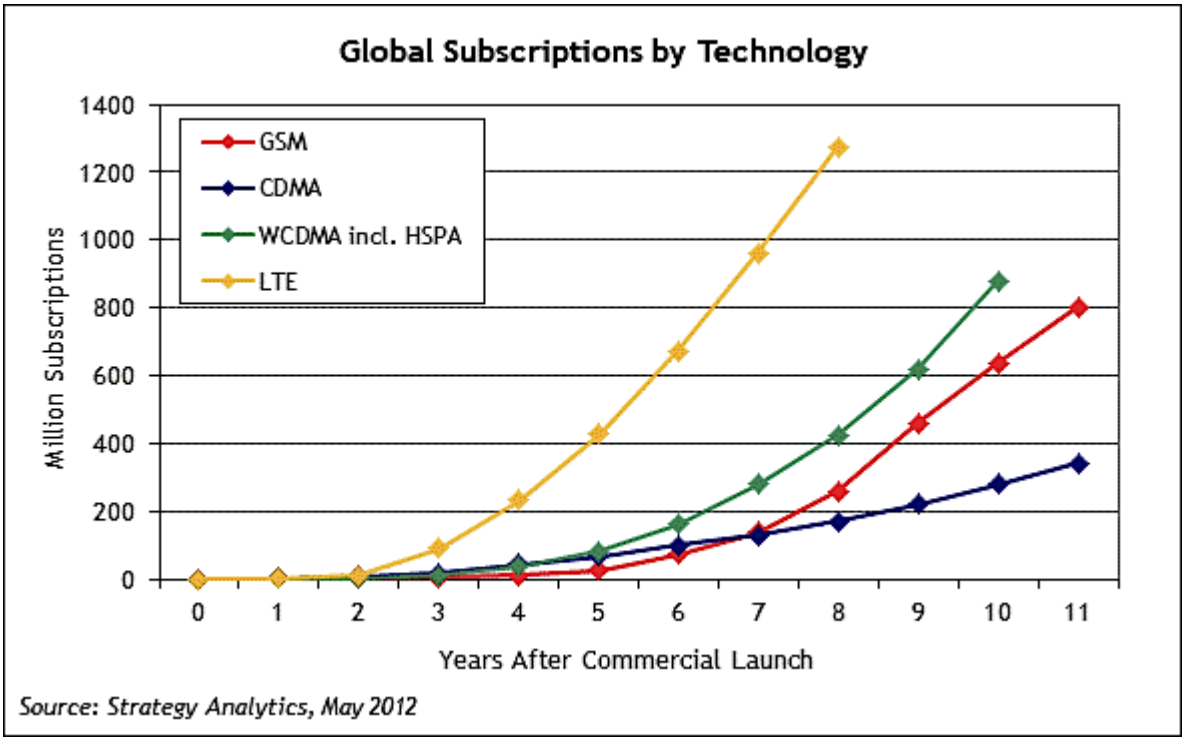

Figure 6: LTE global subscriptions

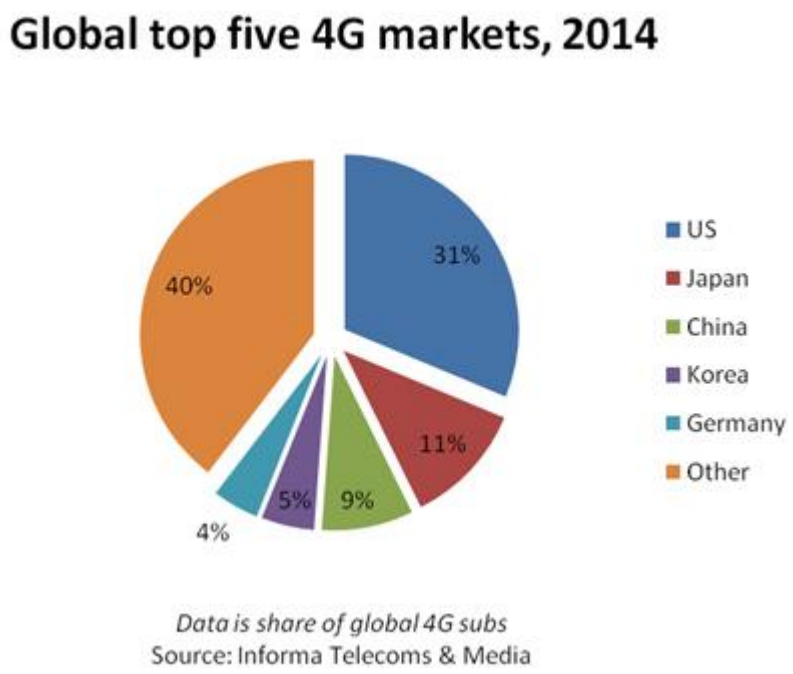

Figure 7 4G Geographical markets (Source www.telecoms.com)

The US remains in the lead in 4G adoption, with Asian economies quickly adapting its use.

Nevertheless, there is still a long way to go before operators adopt "true 4G" as defined by the standards from the ITU. Data rates currently offered by the leading operators in the U.S. for example are still below those stipulated by the 4G specifications.

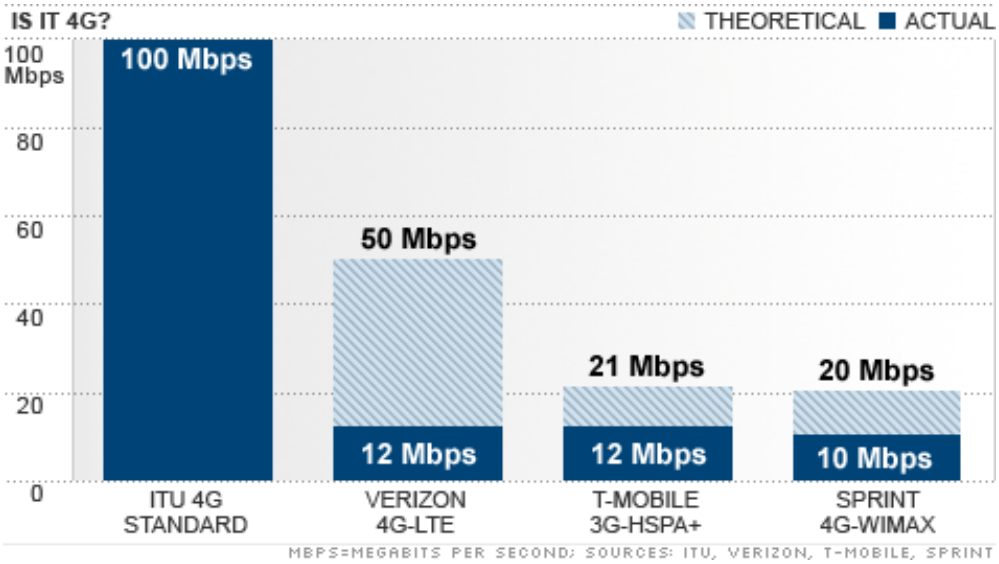

Figure 8 Is it really 4G? (Source money.cnn.com)

4G PRODUCTS AND AVAILABILITY

A 4G system provides mobile ultra-broadband Internet access, for example to laptops with USB wireless modems, to smartphones, and to other mobile devices. Conceivable applications include amended mobile web access, IP telephony, gaming services, high-definition mobile TV, video conferencing, 3D television and Cloud Computing. Not only will mobile phones will leverage its ultra-broadband Internet, but also we will see more mobile products could utilize its feature.

BMW is one example of a manufacturer that is beginning to use 4G LTE for in-car connectivity. The first product enhancement, expected to be released in November 2012, will be an in-car LTE mobile hotspot. This removable device provides Wi-Fi connectivity to any car passengers. The device connects to the vehicle aerial when plugged into the car, improving reception, and can operate for 30 minutes when removed from the car. The device is backward- compatible, able to plug into older vehicles with little adaptation.

A US fuel station chain has replaced fixed broadband lines with 4G LTE, for all of its locations where 4G is available. LTE's high bandwidth allows the chain to run all its applications reliably on a standard platform. These applications include systems for point-of-sale (POS) and inventory control, connected to a centralized back office, and a cloud-based timekeeping system. The LTE connection is also used to run a VOIP telephone system, and to connect company-owned ATMs on-site.

FUTURE OF MOBILE SPACE AND 4G

1. Can you imagine being able to download a full-length movie on your phone in just a second?
2. Imagine playing a graphic intense game on XBOX streaming at home on your handheld play-station at your workplace which has 4G enabled as 3G will not work in those graphic intense games.
3. Skype video calls at 10 ETP High definition.

A consortium of technology companies and universities brought together by the European Commission is investigating a concept called the super-dense network, which could put multiple tiny cells in every room. With the help of grant for the European Union, Metis (the network vendor spearheading) is tasked with identifying the network technologies beyond the LTE-Advanced standards being developed today.

These so-called 5G technologies could take the form of new radio air interfaces, new cellular architectures such as heterogeneous networks and wide-area mobile mesh, and even the virtualization of the network itself, says Jan Färjh, head of standardization and industry for Ericsson (ERIC), the network vendor spearheading Metis. "We have to be prepared for the world 10 years after LTE and LTE-Advanced," Färjh says. While vendors and the standards bodies have some good ideas about what the capabilities of our networks should be in 2020, Färjh said, it's not obvious what those networks should look like[14].

CONCLUSION

Most existing mobile networks have until recently been relying purely on 3G/UMTS technology, which is now 10 years old and struggling to cope with the needs of today's data hungry users. 4G/LTE (Fourth Generation / Long Term Evolution) is the next stage in mobile network development and provides users with much faster data speed than what 3G is able to achieve.

The 4G LTE technology is nothing less then ground breaking. The advancements that have been made from 3G to 4G LTE alone are mind blowing. With the data processing speed being increased to at least 100 Mbit/sec the possibilities are limitless in the wireless communication world. Everything with this new technology has been brought to a new standard. The security, with the complete IP-based solutions allows the user to use the full capability of the phone as well as feel completely secure at the same time, this is one of the most vital aspects that has been upgraded from the previous wireless communication technologies. Even though the hardware and coverage areas aren't up to par yet though, isn't that big of a set back. The technology is still considered brand new and will only be improved in the coming years. As mentioned in the paper, this technology is truly ground breaking and makes the average person really think about what is possible with wireless communication? If there ever is a 5G network, how powerful will it be and what will it possibly be able to do that the 4G doesn't already do[16].

In conclusion, it is evident that 4G technologies will expand on web-based communications around the world. 4G technology will allow for improved applications such as telemedicine that may save lives. It is a fully IP-based network and will improve data transfer dramatically. Signal disruptions will be minimal and downloads will be done in a matter of seconds, faster than ever before. In the near future, a 5G cell phone will be created along with a 5G network based on 4G technologies allowing for the world to connect limitlessly[15].

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