4G Networks: To Cut Through All the "Fast" Talk

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Abstract— Advances in cellular technology have increased demand of accessing the Internet dramatically. Cellular technology not only enables mobility, but also allows redundant connectivity using multiple wireless paths to improve availability, reliability, and performance. Nowadays the use of 3G mobile communication systems seem to be the standard, while 4G stands for the next generation of wireless and mobile communications. 4G wireless communication is expected to provide better speed, high capacity, lower cost and IP based services. The growing interest in 4G networks is driven by the set of new services will be made available for the first time such as accessing the Internet anytime from anywhere, global roaming, and wider support for multimedia applications. In this paper describe 3G and 4G networks, its features, some of the key opportunities will be made available by 4G networks, its implementation, business benefits of 4G-enabled services, present key challenges and point to some proposed solutions.

***Keywords*— Wireless communication, WiMAX, Hand-Off, Ad-Hoc, IPv6**

I. INTRODUCTION

With the ubiquitous deployment and rapid evolution of cellular data networks, the demand of accessing the Internet for mobile users has soared dramatically. Not long after the third generation (3G) standards were released, 3G services have attracted a tremendous number of users due to the convenience of mobile devices. 3G is currently the world's best connection method when it comes to mobile phones, and especially for mobile Internet. 4G wireless is expected to be launched by 2010, but there are numerous challenges faced by researchers in achieving the desired features. Most of the ongoing researches are in the area of distributed computing, mobile agents, multimedia support etc. Some other research area is to improve the Quality of Service from the viewpoint of both the user and service providers. 4G wireless infrastructures are expected to be deployed in an environment where many other types of wireless and wired communication systems already exist.

In January 2009, the first operating 4G Network was established by a joint venture between Clearwire and Intel, which reflected an opportunity for residents and businesses in Portland, Oregon to "connect wirelessly anywhere in Portland at true broadband speeds". However, with the technology quickly approaching a widespread rollout, many cities, states, and countries will soon possess similar capabilities, as consumers and businesses alike will be provided with different opportunities to expand their networks and interfaces with advanced capabilities. Furthermore, it is evident that the Clearwire strategy is not without its disadvantages, and additional efforts must be made to overcome any technology-related problems that might persist before a widespread rollout is even considered.

This paper is organized as follows. Section II provides a brief review of the features of 3G. Section III provides some proposed developments on the road to 4G. In Section IV, 4G vision, its features are discussed. Section V deal with architecture and multimedia support for 4G. Section VI deal with Hand-Off mechanisms for 4G. Section VII provides some applications of 4G, some challenges of 4G is discussed in Section VIII. Finally section IX gives the conclusion.

II. FEATURES OF 3G

3G telecommunications is a generation of standards for mobile phones and mobile telecommunication services fulfilling the International Mobile Telecommunications-2000 specified by the International Telecommunication Union. Application services include wide-area wireless voice telephone, mobile Internet access, video calls and mobile TV, all in a mobile environment. To meet the IMT-2000 standards, a system is required to provide peak data rates of at least 200 kbit/s. Recent 3G releases often denoted 3.5G and 3.75G also provide mobile broadband access of several Mbit/s to smart phones and mobile modems in laptop computers.

The following standards are typically branded 3G:

1) The UMTS system, first offered in 2001, standardized by 3GPP, used primarily in Europe, Japan, China and other regions predominated by GSM 2G system infrastructure.
2) The original and most widespread radio interface is called W-CDMA.
3) The TD-SCDMA radio interface was commercialised in 2009 and is only offered in China.

4) The latest UMTS release, HSPA+, can provide peak data rates up to 56 Mbit/s in the downlink in theory (28 Mbit/s in existing services) and 22 Mbit/s in the uplink.

IMT-2000 is an ITU term that defines globally recognized 3G technologies for use in IMT-identified radio frequency bands. Technologies currently recognized as meeting these requirements include WCDMA, CDMA2000, TD-CDMA and EDGE. Over the last decade, several incremental improvements in radio technology and command-and-control software have been classified as 3G technologies. To denote their significance properly, the technologies are commonly named as higher and higher variants of 3G such as 3.5G and 3.9G.

Why do we need 4G? To answer this question we need to understand some of the major limitations of 3G. Some of the reasons for a new generation of mobile communication are listed below,

- Difficulty of CDMA to provide higher data rates.
- Need for continuously increasing data rate and bandwidth to meet the multimedia requirements.
- Limitation of spectrum and its allocation.
- Inability to roam between different services.
- To provide a seamless transport end-to-end mechanism.
- To introduce a better system with reduces cost.

III. DEVELOPMENTS ON THE ROAD 4G

There's been widespread debate about the definition of real "4G" service. Many operators have marketed WiMax, LTE and HSPA+ as 4G services. No current 4G offering meets the ITU's requirements. But, some service providers and equipment manufacturers have already staked claims to 4G services by providing mobile access rates above 3G's 1–5 Mbps along with lower latencies. Rival camps claim services with higher data rates under the banner of 3.5 or even 3.9G. But, just improving access speeds alone should not qualify as 4G without an entire suite of network-level integration. The dilemma faced by 3G groups — 3GPP and 3GPP2 — is that they cannot claim anything to be 4G under their 3G banner. The evolution is shown in Figure 1.

The ITU IMT-A Standard

The ITU emerged as the authority to define what constitutes 4G.To add to the 4G definition debate, the ITU recently agreed on specifications for IMT-Advanced, what some would argue is the "true" 4G technology. The group decided that LTE-Advanced and Wireless MAN-Advanced both qualify for IMT-Advanced status. ITU's IMT — Advanced (IMT-A) is a concept that intends to build on the success of IMT-2000 as a benchmark for 3G. IMT-A systems are envisioned to have capabilities surpassing those of IMT-2000 by orders of magnitude. IMT-2000-based 3G systems generally provide peak data rates of around 1–5 Mbps. The IMT-A concept outlined in the ITU IMT-2000 document states: "With the expectation that there will be a need for commercial services in multi-user environments targeting peak data rates approaching 100 Mbps for 'highly mobile' users, and up to 1 Gbps for nomadic (low mobility or stationery) users, the IMT-A concept requires mandatory backward compatibility with prior systems to match these high data rates."

Where Does WiMAX Fit In?

ITU delegates declared WiMAX as an IMT-2000 technology. The technology under consideration for inclusion in IMT-2000 is IPOFDMA. A specific variant of this technology is used by the IEEE 802.16e mobility standard, commonly referred to as WiMAX. As a result, WiMAX gained the coveted status of a 3G technology. While contradicting claims that WiMAX is a 4G technology, it nevertheless is significant that the IEEE standards embedded in WiMAX gained an official standard status from the ITU.

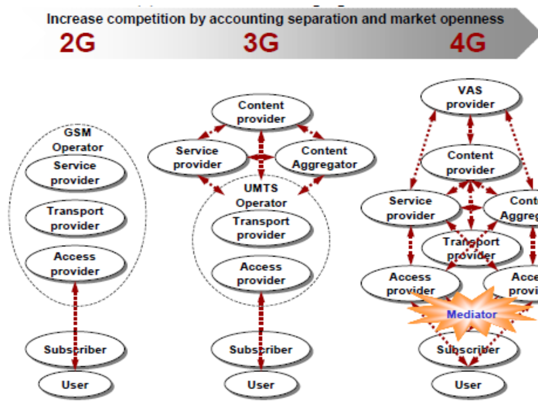

Figure 1.Evolution of the mobile value chain toward 4G

IV. FEATURES OF 4G

There is no doubt that 4G systems will provide higher data rates. Traffic demand estimates suggest that, to accommodate the foreseen amount of traffic in the 2010 – 2020 timeframe in an economically viable way, 4G mobile systems must achieve a manifold capacity increase compared to their predecessors. Figure 2 provides an illustration of the future 4G mobile network architecture comprising ad-hoc, cellular, hot-spot, and satellite radio components.

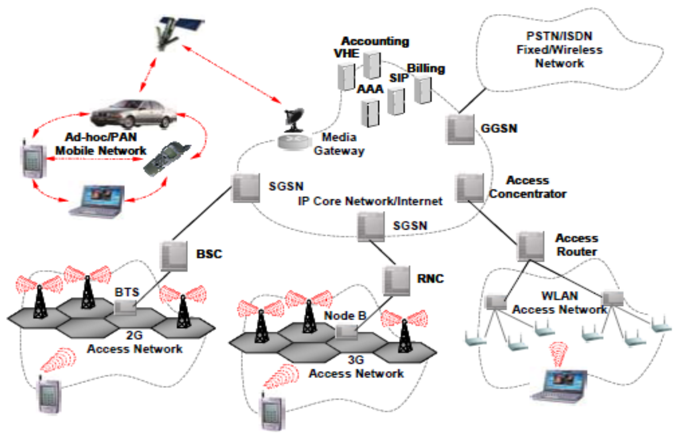

Figure 2.The generic 4G mobile network architecture.

High usability and global roaming: The end user terminals should be compatible with any technology, at anytime, anywhere in the world. The basic idea is that the user should be able to take his mobile to any place, for example, from a place that uses CDMA to another place that employs GSM.

Multimedia support: The user should be able to receive high data rate multimedia services. This demands higher bandwidth and higher data rate.

Personalization: This means that any type of person should be able to access the service. The service providers should be able to provide customized services to different type of users.

Quality of Service: Consistent application of admission control and scheduling algorithms regardless of underlying infrastructure and operator diversity.

Network Detection and Network Selection: A mobile terminal that features multiple radio technologies or possibly uses software defined radios if economical, allows participation in multiple networks simultaneously, thereby connecting to the best network with the most appropriate service parameters for the application. This requires establishing a uniform process for defining eligibility of a terminal to attach to a network and to determine the validity of link layer configuration.

Seamless Handover and Service Continuity: A "base station" that features intra- and inter-technology handovers, assuring service continuity with zero or minimal interruption, without a noticeable loss in service quality. Support for this function requires continuous transparent maintenance of active service instances and inclusion of various access technologies, from WiFi to OFDMA.

V. ARCHITECTURE OF 4G

With 4G, a range of new services and models will be available. These services and models need to be further examined for their interface with the design of 4G systems. Figure 3 and 4 demonstrate the key elements and the seamless connectivity of the networks.

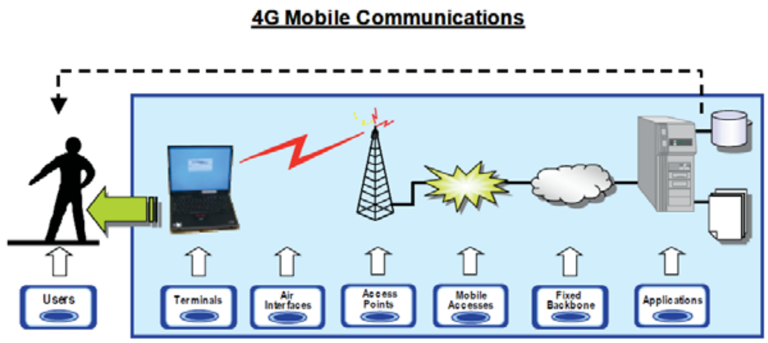

Figure 3.4G key elements

The fourth generation will encompass all systems various networks, public to private; operator-driven broadband networks to personal areas; and ad hoc networks. The 4G systems will interoperate with 2G and 3G systems, as well as with digital (broadband) broadcasting systems. In addition, 4G systems will be fully IP-based wireless Internet.

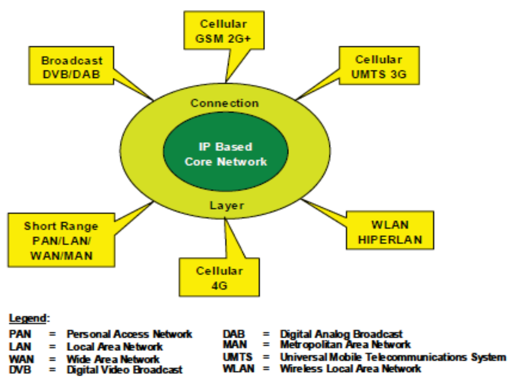

Figure 4.Seamless Connections of Networks

A. Architectural Core-

4G wireless system is expected to be built on an IP- based core network for global routing along with more customized local area network that supports dynamic hand off mechanism and Ad-Hoc routing. Mobile IPv6 (MIPv6) is the standardized IP- based mobility protocol for IPv6. The core architectural model is shown in Figure 5. In 4G LANs will be installed everywhere like in trains, vehicles etc or might be formed in an Ad-Hoc basis by random collection of devices that happens to come in a specific radio range. New routing protocols have to be designed for such systems.

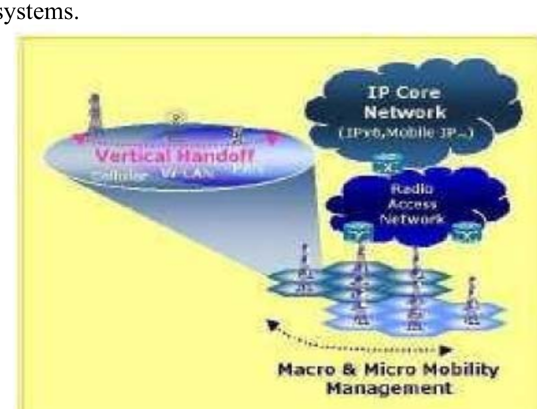

Figure 5.Core architecture model

In 4G mobile systems, each terminal is assigned a home agent, which has a permanent home IP address. When terminal moves to another location it obtains a new temporary address called the care-of address. The user terminal regularly updates the home agent with its current care-of address. If the user is at home, another device can communicate with the user using its home IP address. When the user moves to some other location communication is carried out using another procedure. If a host wants to communicate with the user, it first sends a setup message to the user's home agent (which the host knows). The home agent knows the care-of address of the user and it forwards the setup message to the user terminal. The home agent also forwards the care-of address of the user to the host so that future messages can be sent directly to the user.

B. Proposed Architectures-

Multimode Devices: In this configuration, a single terminal employs multiple interfaces to access different wireless system. Figure 6(a) shows the framework of this architecture. The requirement for this scheme is that the device should incorporate the required hardware necessary to access the different technologies. The flaw with this is that it increases the complexity of the user device which might make it more expensive to the common user. One advantage of this architecture is that it does not require any network modification or internetworking devices.

Overlay network: In this type of architecture, a user can access an overlay network which consists of several UAP (universal access points). The architectural model for this is shown in figure 6(b). The UAP selects an access point depending on user choice, availability and desired QoS. In this case the overlay network performs the major operations such as hand off, frequency translation, content adaptation etc, instead of the terminal performing it. So the overlay network will suffer an increase in complexity.

Common Access Protocol: This architecture can be used if a wireless network can support one or two different protocols. Figure 6(c) shows the framework for this architectural model. One solution to this is to use wireless ATM (Asynchronous Transfer Mode), which might need internetworking between different networks. To implement this all wireless networks must be capable of transmitting ATM cells with additional headers. This allows the user to communicate with different wireless networks using the same protocol.

VI. Hand Off Mechanisms

Whenever a mobile node moves to a new location it takes some time to establish a care-of address and to inform the home agent it's new care of address. This accounts for the handover latency which is undesirable.

A. Mobile IPv6

When a mobile moves from its home to another location, it obtains a new care-of address by contacting the subnet of that particular network. When a mobile node moves from one network to another, it detects the new subnet by analysing the router advertisement that is periodically sent out by the access router. By using the subnet of the new network, which the mobile gets from the router advertisement, the mobile node configures itself a new care-of address. The mobile then needs to verify if there is any duplicate address in the same radio range. So it performs the DAD (Duplicate Address Detection) process and it scans the neighbourhood for any duplicate addresses. If the mobile duplicate address, it has to reconfigure itself a new care-of address. Once a new care-of address is obtained, the mobile updates the home agent with its new care-of address. Figure 7 shows Network model for MIPv6.

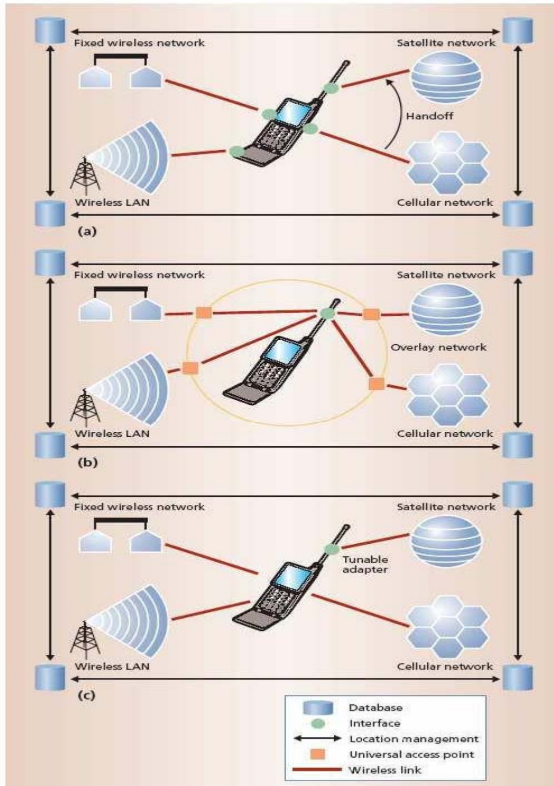

Figure 6.Different architectural models

The problem with this hand off scheme is that, to perform DAD the mobile take a lot of time. This increase she handover latency. One solution to this problem is the mobile should perform the DAD operation in parallel with its communication.

B. Hierarchical Mobile IPv6

The main idea behind this scheme is to reduce the signalling load between the mobile and the home agent there by reducing the hand off latency. The global internet is divided into regions defining local area mobility. These domains are generally managed by a unique administrative authority.

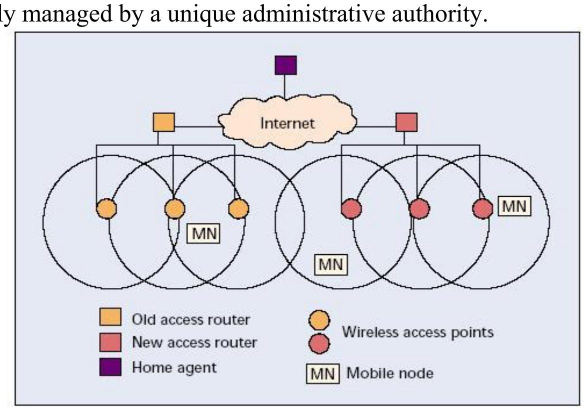

Figure 7.Network model for MIPv6

Each domain is connected to the internet through a mobility anchor point. When a mobile first enters a domain it has to regionally register with that domain to advertise to its home agent its new localization. When the mobile moves across different access routers in the domain, it has to send a local registration to the mobility anchor point to update its localization. So the communication load between the mobile and the home agent is reduces since the mobility anchor point acts as the home agent.

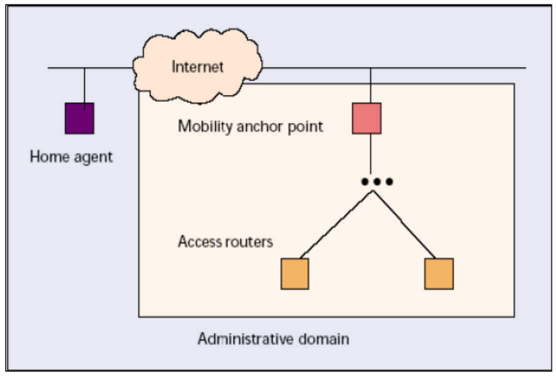

Figure 8.Hierarchical MIPv6 architecture

Hierarchical MIPv6 operates in two modes. When a mobile enters a visited domain it must perform a home registration in which the mobile informs the mobility anchor point its home address. Then when the mobile moves within the cell, it switches between two modes, the basic mode and the extended mode. In basic mode, the mobile station has two addresses, a regional care of address based on the mobility anchor point prefix and an on-link care-of address based on the current access router prefix. Here the mobility anchor point acts as the home agent. It is shown in Figure 8.

VII. Applications

The emerging applications for 3G and 4G wireless systems typically require highly Heterogeneous and time varying quality of service from the underlying protocol layers. So adaptability will be one of the basic requirements to the development and delivery of new mobile services. Promising techniques and possible topics may include: Mobile application should refer to a user's profile so that it can be delivered in a way most preferred by the subscriber, such as context-based personalized services. This also brings the applications with adaptability to terminals that are moving in varying locations and speeds. Techniques such as adaptive multimedia and unified messaging take the terminal characteristics into account and ensure that the service can be received and run on a terminal with the most suitable form to the host type.

The 4G technology will be able to support Interactive services like Video Conferencing (with more than 2 sites simultaneously), Wireless Internet, etc. The bandwidth would be much wider (100 MHz) and data would be transferred at much higher rates. The cost of the data transfer would be comparatively very less and global mobility would be possible. The networks will be all IP networks based on IPv6. The antennas will be much smarter and improved access technologies like OFDM and MC-CDMA (Multi Carrier CDMA) will be used. Also the security features will be much better.

VIII. Challenges

The main challenge that 4G networks are facing is integrating non-IP-based and IP-based devices. It is known that devices that are not IP address based are generally used for services such as VoIP. On the other hand, devices that are IP address based are used for data delivery. To reduce operating costs, devices that operate on 4G networks should have the capability to operate in different networks. This will not only reduce the operating cost but will also simplify design problems and will reduce power consumption. However, accessing different mobile and wireless networks simultaneously is one of the major issues 4G networks have been addressing. One mechanism that has been proposed to handle this problem is termed "multi-mode devices". This mechanism can be achieved through a software radio that allows the end-user device to adapt itself to various wireless interfaces of the networks. Figure 9 shows an example of such solution. Due to the heterogeneity of 4G networks, wireless devices have to process signals sent from different systems, discover available services, and connect to appropriate service providers. Various service providers have their own protocols which can be incompatible with each other as well as with the user's device. This issue may complicate the process of selecting the most appropriate technology based on the time, place and service provided, and thus, may affect the Quality of service provided to the end user. Managing user accounts and billing them has become much more complicated with 4G networks. This is mainly due to heterogeneity of 4G networks and the frequent interaction of service providers.

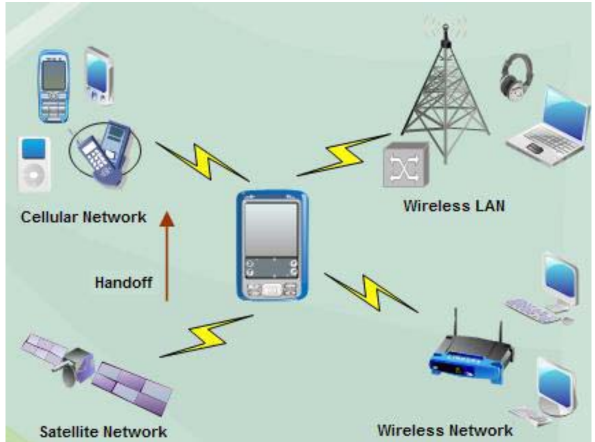

Figure 9.Accessing multiple networks and services through multi-mode software

A major issue in 4G systems is to make the high bit rates available in a larger portion of the cell, especially to users in an exposed position in between several base stations. In current research, this issue is addressed by macro-diversity techniques, also known as group cooperative relay, and also by Beam-Division Multiple Access (BDMA).Pervasive networks are an amorphous and at present entirely hypothetical concept where the user can be simultaneously connected to several wireless access technologies and can seamlessly move between them. These access technologies can be Wi-Fi, UMTS, EDGE, or any other future access technology. Included in this concept is also smart-radio (also known as cognitive radio) technology to efficiently manage spectrum use and transmission power as well as the use of mesh routing protocols to create a pervasive network.

IX. CONCLUSION

4G seems to be a very promising generation of wireless communication that will change the people's life to wireless world. There are many striking attractive features proposed for 4G which ensures a very high data rate, global roaming etc. New ideas are being introduced by researchers throughout the world, but new ideas introduce new challenges. Table 1 shows the features and comparison between the different generations. New ideas are being introduced by researchers throughout the world, but new ideas introduce new challenges. There are several issues yet to be solved like incorporating the mobile world to the IP based core network, efficient billing system, smooth hand off mechanisms etc.

Generation	Technology	Features
1G Wireless	Advanced Mobile Phone Service. (AMPS).	Analog voice service. No data service.
2G Wireless	Code Division Multiple Access. (CDMA). Global System for Mobile Communication. (GSM). Wide-band Code Division Multiple Access. (WCDMA).	Digital voice service, 9.6K to 14.4K bit/sec. CDMA, TDMA and offer one-way data transmissions only. Enhanced calling features like caller ID.
3G Wireless	Based on the Interim Standard-95 CDMA standard. (CDMA 2000). Time-division synchronous code division multiple access (TD-SDM).	Superior voice quality and data always add on. Up to 2M bit/sec. always-on data. Broadband data services like video and multimedia. Enhanced roaming. Circuit and packet switched networks.
4G Wireless	Orthogonal Frequency Division Multiplexing (OFDM) & (WOFDM). Multi Carrier CDMA. (MC-CDMA). LAS-CDMA.	Converged data and voice over IP. Entirely packet switched Networks. All network elements are digital. Higher bandwidth to provide multimedia services at lower cost (up to 100Mbits/sec).

Table I. Comparison of different generations

Based on the above observations, some sources suggest that a new generation of 5G standards may be introduced approximately in the early 2020s. However, still no transnational 5G development projects have officially been launched, and there is still a large extent of debate on what 5G is exactly about. Prior to 2012, some industry representatives have expressed skepticism towards 5G but the trends clearly changed since

2012.New mobile generations are typically assigned new frequency bands and wider spectral bandwidth per frequency channel (1G up to 30 kHz, 2G up to 200 kHz, 3G up to 20 MHz, and 4G up to 100 MHz), but skeptics argue that there is little room for larger channel bandwidths and new frequency bands suitable for land-mobile radio. From users' point of view, previous mobile generations have implied substantial increase in peak bitrate (i.e. physical layer net bitrates for short-distance communication).

If 5G appears, and reflects these prognoses, the major difference from a user point of view between 4G and 5G techniques must be something else than increased maximum throughput; for example higher system spectral efficiency (data volume per area unit), lower battery consumption, lower outage probability (better coverage), high bit rates in larger portions of the coverage area, lower latencies, higher number of supported devices, lower infrastructure deployment costs, higher versatility and scalability or higher reliability of communications. In Europe, Neelie Kroes, the European Commissioner, committed in 2013 50 million euros for research to deliver 5G mobile technology by 2020. In particular, the METIS project aims at reaching world-wide consensus on the future global mobile and wireless communications system. The METIS overall technical goal is to provide a system concept that supports 1000 times' higher mobile system spectral efficiency as compared with current LTE deployments. Here the goal is to develop guidelines for the definition of new generation network with particular care of energy efficiency, sustainability and affordability aspects.

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