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A Technology Overview of IP Based 4G-Networks

Computer Science

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ABSTRACT

Wireless broadband technology is now in motion to provide higher data rate, wider coverage and improved mobility. In this direction, 4G wireless technology offers higher data rates and the ability to roam across multiple heterogeneous wireless networks. The goal of 4G will be to replace the entire core of cellular networks with a single worldwide cellular network completely standardized based on the IP (Internet Protocol) for video, packet data utilizing Voice over IP (VoIP) and multimedia services. Moreover 4G-networks will be entirely packet switched systems so bandwidth will be utilized efficiently. One of the research challenges for 4G-Network is the design of intelligent mobility management techniques to achieve global roaming among various access technologies. In this paper we will discuss the major 4G features, some technical aspects and challenges to 4G network. The migration of 4G mobile communication systems towards an Internet Protocol (IP)-based wireless networks will also be discussed.

1. Introduction

Wireless communications has experienced explosive growth in the past two decades. It began in the 1980s with 1G, which were handled cellular phone calls using analog voice encoding. Second generation (2G) introduced in the 1990s, advanced to digital encoding of calls. 2G technology expanded mobile capabilities with the introduction of features such as short message service (SMS), or text messaging. Typical speeds were around 10 kilobits per second (kbps). 2G included Global System for Mobile communication (GSM) and Code Division Multiple Access (CDMA). With digital technologies, digitized voice can be coded and encrypted. Therefore, the 2G cellular network is also more secure. GSM was constantly upgraded. This is manifested by the introduction of High Speed Circuit-Switched Data (HSCSD), General Packet Radio Service (GPRS), Enhanced Data Rates for Global GSM Evolution (EDGE), Enhanced Circuit-Switched Data (ECSD) and Enhanced GPRS (EGPRS). This forms intermediate generations, called 2.5G and 2.75G, also increased data transfer speeds to around 100 kbps and offered Internet access [2].

The third generation (3G) integrates cellular phones into the Internet world by providing high-speed packet-switching data transmission in addition to circuit-switching voice transmission. The 3G revolution allowed mobile telephone customers to use audio, graphics and video applications [4]. Over 3G it is possible to watch streaming video and engage in video telephony. 3G phone speeds deliver up to 2 Mbps, but only under the best conditions and in stationary mode. Moving at a high speed can drop 3G bandwidth to a mere 145 Kbps [4].

The 4G has been developing with the aim of providing transmission rates up to 20Mbps while simultaneously accommodating Quality of Service (QoS) features. According to the ITU, 4G peak data rates will go from 100 Mbps for "high mobility" connections (highway speed) up to 1Gbps for "low mobility" connections (pedestrian speed). 4G is an all-IP standard, meaning that 4G will be more compatible with internet capabilities [5].

2. 4G-networks basics

The fourth generation of mobile networks will truly turn the current mobile phone networks, in to end to end IP based networks. 4G is set to deliver 100Mbps to a roaming mobile device globally, and up to 1gbps to a stationary device. With this speed, it allows for video conferencing, streaming picture perfect video and much more. A 4G system is expected to provide a comprehensive and secure all-IP based mobile broadband solution to laptop computer wireless modems, smartphones, and other mobile devices. Facilities such as ultra-broadband Internet access, IP telephony, gaming services, and streamed multimedia may be provided to users. After successful implementation, **4G-Network** is likely to enable ubiquitous computing, that will simultaneously connects to numerous high data speed networks and offers faultless handoffs all over the geographical regions [3].

Based on the study, 4G mobile technology is in a determining and standardization stage. Although 4G wireless technology offers higher data rates and the ability to roam across multiple heterogeneous wireless networks, several issues require further research and development. Since 4G is still in the cloud of the sensible standards creation, ITU and IEEE form several task forces to work on the possible completion for the 4G mobile standards as well. 3GPP LTE [10] is an evolution standard from UMTS, and WiMAX is another candidate from IEEE. These technologies have different characteristics and try to meet 4G characteristics to become a leading technology in the future market [7]. The advantage of 4G wireless systems has created many research opportunities [6]. The expectations from 4G are high in terms of data rates, spectral efficiency, mobility and integration. The figure 1 shows the architecture of "ALL-IP based 4G-network.

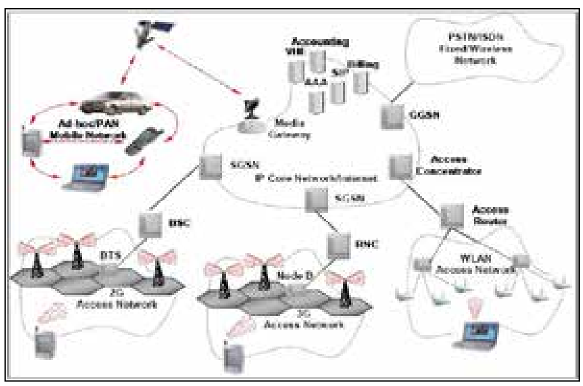

Fig. 1: Architecture of "ALL-IP based 4G-network

3. Need for 4G

Due to advancement in recent technology there is a rise in need for higher bandwidth. 4G assumed to offer higher bandwidth, which is one of the main advantages of 4G over 3G. There are other reasons which explain the need for 4G as listed below.

- Increased use of mobile devices: As prices get more attractive, more and more people will use wireless networks for data applications. Consequently, bandwidth demand will rise. In 4G cost for accessing network is very less as compared to 3G.
- Support for Multimedia content: Multimedia applications require higher bandwidth. But bandwidth provided by today's standard is not sufficient.

- Voice over IP: The fixed line world is rapidly moving towards Voice over IP these days. VoIP requires much more air interface bandwidth than the voice codecs which are currently used for circuit switched voice calls over wireless networks. The air interface has been optimized on all layers of the protocol stack for circuit switched voice. The same is not possible for VoIP as the IP stack is a general data transmission stack and thus it cannot be optimized for voice. The only solution is to increase the available bandwidth.

4. Key Components of 4G

Based on the requirements for seamless interaction between networks, 4G is characterized by the following key components:

4.1 Multiplexing and Access schemes

As the wireless standards evolved, the access techniques used also improved in efficiency, capacity and scalability. New access schemes like Orthogonal FDMA (OFDMA), Single Carrier FDMA (SC-FDMA), Interleaved FDMA and Multi-carrier CDMA (MC-CDMA) are considered important key for the next generation systems. WiMax is using OFDMA in the downlink and in the uplink. For the next generation UMTS, OFDMA is used for the downlink. The advantage of the above mentioned access techniques are that they require less complexity for equalization at the receiver. This is an added advantage especially in the Multi Input Multi Output (MIMO) environments since the spatial multiplexing transmission of MIMO systems inherently requires high complexity equalization at the receiver [12].

4.2 IPv6 Support

4G will be based on packet switching only. This will require low-latency data transmission. By the time that 4G was deployed, the process of IPv4 address exhaustion was expected to be in its final stages. Therefore, in the context of 4G, IPv6 support is essential in order to support a large number of wireless-enabled devices. By increasing the number of IP addresses, IPv6 removes the need for network address translation (NAT) [13].

4.3 Multimode devices

One configuration uses a single physical terminal with multiple interfaces to access services on different wireless networks. Which means that single mobile device is equipped with more number of interfaces. By their nature, multi-mode small cell devices help operators increase the available coverage area for subscribers by extending the network and enabling subscribers to leverage the best radio. It is clear that multi-mode devices shall play a key role as to solve capacity and coverage challenges in 4G [7].

4.4 Advanced antenna systems

The performance of radio communications depends on an antenna system, termed smart or intelligent antenna [8]. Recently, multiple antenna technologies are emerging to achieve the goal of 4G systems such as high rate, high reliability, and long range communications. Spatial multiplexing, gained importance for its bandwidth conservation and power efficiency. Spatial multiplexing involves deploying multiple antennas at the transmitter and at the receiver. Independent streams can then be transmitted simultaneously from all the antennas. This technology, called MIMO, multiplies the base data rate by the number of transmit antennas or the number of receive antennas.

4.5 Software-defined radio (SDR)

SDR is one form of open wireless architecture (OWA). SDR is a radio communication system where components that have been typically implemented in hardware are instead implemented by means of software on a personal computer or embedded computing devices. Since 4G is a collection of wireless standards, the final form of a 4G device will constitute various standards. This can be efficiently realized using SDR technology, which is categorized to the area of the radio convergence [8].

5. Technologies used in 4G

Several technologies available today may play a roll in 4G as it develops. In this section we will discuss five of them. The main technologies used in 4G-networks are- Orthogonal Frequency Division Multiplexing (OFDM) and OFD Multiple Access (OFDMA), WiMAX, Ultra Mobile Broadband (UMB), Long Term Evolution (LTE).

5.1. OFDM and OFDMA OFDM

spread spectrum technique distributes the data over a large number of carriers that are spaced apart at precise frequencies. This spacing provides the "orthogonality", in this technique which prevents the demodulators from seeing frequencies other than their own. The benefits of OFDM [12] are high spectral efficiency, resiliency to RF interference, and lower multi-path distortion. This is useful because in a typical terrestrial broadcasting scenario there are multipath-channels. Since multiple versions of the signal interfere with each other, it becomes very hard to extract the original information. So OFDM is the key technology for 4G-networks.

5.2. WiMAX

WiMAX [1] is short for Worldwide Interoperability for Microwave Access. The mobile WiMAX supports optimized handover schemes with latencies less than 50ms to ensure real-time applications such as Voice over Internet Protocol (VoIP). These systems offer scalability in both radio access technology and network architecture, thus providing a great deal of flexibility in network deployment options and service offerings. WiMAX can provide broadband wireless access up to 50 km for fixed stations, and 5 - 15 km for mobile stations. The current WiMAX revision provides up to 40Mbit/s with the IEEE 802.16m update expected to offer up to 1Gbit/s fixed speeds. The new technologies employed for Mobile WiMAX result in lower equipment complexity and simpler mobility management due to the all-IP core network.

5.3 Ultra Mobile Broadband

The UMB system is based on Internet (TCP/IP) networking technologies running over a next generation radio system, with peak rates of up to 280Mbps. It offers data speed capabilities of nearly 275Mbps downstream as well as 75Mbps upstream. UMB represents a major break-through in next generation mobile broadband services by enabling the transfer of native IP, variable length, data packets at speeds that are orders of magnitude higher than what is commercially available today. It uses OFDM/OFDMA air interfaces. UMB possesses IP network architecture so plays significant role in 4G-network [8].

5.4 Long Term Evolution

Long Term Evolution has long been seen as the first advancement towards stronger, faster and more efficient 4G data networks [11]. LTE also defines multiple input multiple output (MIMO) operation that uses several transmitter-receiver-antennas. The data stream is divided between the antennas to boost speed and to make the link more reliable. Using OFDM and MIMO lets LTE deliver data at a rate to 100 Mb/s downstream and 50 Mb/s upstream under the best conditions. It is also a scalable bandwidth technology for carriers operating anywhere from 20MHz town to 1.4MHz. It is also designed with a full Internet Protocol (IP) network infrastructure. This means it can support full voice in packet domains, while also offering advanced radio techniques for achieving higher performance levels beyond what basic CDMA networks and 3G data packets can currently achieve.

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7. Conclusion

In a fourth-generation wireless system, cellular providers have the opportunity to offer data access to a wide variety of devices. The cellular network would become a data network on which

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cellular phones could operate — as well as any other data device. The current cellular network does not have the available bandwidth necessary to handle data services well. Therefore a move towards 4G "All-IP" based network is necessary to provide advanced services. The 4G network tries to integrate all different wireless technologies. A 4G system is expected to provide a comprehensive and secure all-IP based mobile broadband solution to mobile devices. It is being developed to accommodate the quality of service (QoS) and rate requirements set by forthcoming applications "anytime-anywhere". In summary, the 4G system should dynamically share and utilize network resources to meet the minimal requirements of all the 4G enabled users. A variety of working groups have been established to help develop the 4G network. In this paper we have presented briefly some technical aspects of 4G-networks.

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