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Towards Mobile Computing Technology: The Vision of Fifth Generation Mobile Networks

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ABSTRACT - GSM is the most successful mobile technology nowadays; moreover the market share of GSM is still rising. To maintain this rate of growth new services are needed. As it was in case of fixed telecommunications networks it seems that in the wireless networks mobile data providing is going to be the service driving the market. As mobile network operators face the growing demand, they have multiple choices to make their networks capable of providing higher data rates. The coming era of 4g systems is foreseeing a potential smooth merger of all these heterogeneous technologies with a natural progression to support seamless cost-effective high data rate global roaming, efficient personalized services, typical user-centric integrated service model, high Qos and overall stable system performance. However, every step in such technological advancements presents huge research challenges. This article aims to focus upon some of these potential challenges along with different proposed feasible and non-feasible solutions in the areas of mobile terminals and users, mobile services, mobile and wireless access networks, and communication, in order to give an in-depth view of the next-generation communication systems.

I. 2G-5GNETWORKS: EVOLUTION

The first generation of mobile phones was analog systems that emerged in the early 1980s [5]. The second generation of digital mobile phones appeared in 1990s along with the first digital mobile networks. During the second generation, the mobile telecommunications industry experienced exponential growth in terms of both subscribers and value-added services. Second generation networks allow limited data support in the range of 9.6 kbps to 19.2 kbps. Traditional phone networks are used mainly for voice transmission, and are essentially circuit-switched networks. 2.5G networks, such as General Packet Radio Service (GPRS), are an extension of 2G networks, in that they use circuit switching for voice and packet switching for data transmission resulting in its popularity since packet switching utilizes bandwidth much more efficiently. In this system, each user's packets compete for available Bandwidth and users are billed only for the amount of data transmitted. 3G networks were proposed to eliminate many problems faced by 2G and 2.5G networks, especially the low speeds and incompatible technologies such as Time Division Multiple Access (TDMA) [5] and Code Division Multiple Access (CDMA) [6] in different countries. Expectations for 3G included increased bandwidth; 128 Kbps for mobile stations, and 2 Mbps for fixed applications [7]. In theory, 3G should work over North American as well as European and Asian wireless air interfaces. In reality, the outlook for 3G is not very certain. Part of the problem is that network providers in Europe and North America currently maintain separate standards' bodies (3GPP for Europe and Asia; 3GPP2 for North America). The standards' bodies have not resolved the differences in air interface technologies. There is also a concern that in many countries 3G will never be deployed due to its cost and poor performance. Although it is possible that some of the weaknesses at physical layer will still exist in 4G systems, an integration of services at the upper layer is expected. The evolution of mobile networks is strongly influenced by business challenges and the direction mobile system industry takes. It also relates to the radio access spectrum and the control restrictions over it that varies from country to country.

II.NETWORK ARCHITECTURE

The basic architecture of wireless mobile system consists of a mobile phone connected to the wired world via a single hop wireless connection to a Base Station (BS), which is responsible for carrying the calls within its region called cell (Figure 1). Due to limited coverage provided by a BS, the mobile hosts change their connecting base stations as they move from one cell to another. A hand-off (later referred to as "horizontal handoff" in this article) occurs when a mobile system changes its BS. The mobile station communicates via the BS using one of the wireless frequency sharing technologies such as FDMA, TDMA, CDMA etc. Each BS is connected to a Mobile Switching Center (MSC) through fixed links, and each MSC is connected to others via Public Switched Telephone Network (PSTN). The MSC is a local switching exchange that handles switching of mobile user from one BS to another. It also locates the current cell location of a mobile user via a Home Location Register (HLR) that stores current location of each mobile that belongs to the MSC. In addition, the MSC contains a Visitor Locations Register (VLR) with information of visiting mobiles from other cells. The MSC is responsible for determining the current location of a target mobile using HLR, VLR and by communicating with other MSCs. The source MSC initiates a call setup message to MSC covering target area for this purpose.The first generation cellular implementation consisted of analog systems in 450-900 MHz frequency range using frequency shift keying for signaling and Frequency Division Multiple Access (FDMA) for spectrum sharing. The second generation implementations consist of TDMA/CDMA implementations with 900, 1800 MHz frequencies. These systems are called GSM for Europe and IS-136 for US. The respective 2.5G implementations are called GPRS and CDPD followed by 3G implementations.

Third generation mobile systems are intended to provide a global mobility with wide range of services including voice calls, paging, messaging, Internet and broadband data. IMT-2000 defines the standard applicable for North America. In Europe, the equivalent UMTS standardization is in progress. In 1998, a Third Generation Partnership Project (3GPP) was formed to unify and continue the technical specification work. Later, the Third Generation Partnership Project 2 (3GPP2) was formed for technical development of CDMA-2000 technology. 3G mobile offers access to broadband multimedia services, which is expected to become all IP, based in future 4G systems ([11], [12]). However, current 3G networks are not based on IP; rather they are an evolution from existing 2G networks. Work is going on to provide 3G support and Quality of Service (QoS) in IP and mobility protocols. The situation gets more complex when we consider the WLAN research and when we expect it to become mobile. It is expected that WLANs will be installed in trains, trucks, and buildings. In addition, it may just be formed on an ad-hoc basis (like ad-hoc networks [13-[15]) between random collections of devices that happen to come within radio range of one another .In general, 4G architecture includes three basic areas of connectivity ([16]-[19]); PANs (such as Bluetooth), WANs (such as IEEE 802.11), and cellular connectivity. Under this umbrella, 4G will provide a wide range of mobile devices that support global roaming ([20]-[23]). Each device will be able to interact with Internet-based information that will be modified on the fly for the network being used by the device at that moment .In 5G mobile IP, each cell phone is expected to have a permanent "home" IP address, along with a "care-of" address that represents its actual location. When a computer somewhere on the Internet needs to communicate with the cell phone, it first sends a packet to the phone's home address. A directory server on the home network forwards this to the care-of address via a tunnel, as in regular mobile IP. However, the directory server also sends a message to the computer informing it of the correct care-of address, so future packets can be sent directly. This should enable TCP sessions and HTTP downloads to be maintained as users move between different types of networks. Because of the many addresses and the multiple layers of subnetting, IPv6 is needed for this type of mobility. For instance, 128 bits (4 times more than current 32 bit IPv4 address) may be divided into four parts (I thru IV) for supporting different functions. The first 32-bit part (I) may be defined as the home address of a device while the second part (II) may be declared as the care-of address allowing communication between cell phones and personal computers. So once the communication path between cell and PC is established, care-of address will be used instead of home address thus using the second part of IPv6 address.

A. Standards

The role of standards is to facilitate interconnections between different types of telecommunication networks, provide interoperability over network and terminal interfaces, and enable free movement and trade of equipment. There are standard bodies in different countries that develop telecommunications standards based upon the government regulations, business trends and public demands. In addition, international standard organizations provide global standardizations. In telecommunications area, International Telecommunications Union (ITU) and International Standards Organization (ISO) have been recognized as major international standards developer. Many popular telecommunications and networking standards are given by other international organizations such as Institute of Electrical and Electronics Engineers (IEEE) and Internet Engineering Taskforce (IETF). Among other organizations, the most well known are Telecommunications Industry Association (TIA) and American National Standards Institute (ANSI) in US, European Telecommunication Standards Institute (ETSI), China Wireless Telecommunications Standards Group (CWTS), Japan's Association of Radio Industries and Businesses (ARIB) and Telecommunications Technology Committee (TTC), and Korea's Telecommunication Technology Association (TTA).

The ITU began its studies on global personal communications in 1985, resulting in a system referred to as International Mobile Telecommunications for the year 2000 (IMT-2000). Later, ITU Radio Communications Sector (ITU-R) and ITU-Telecommunications (ITU-T) groups were formed for radio communications and telecommunications standards, respectively. In Europe, the concepts of Universal Mobile Telecommunications System (UMTS) have been the subject of extensive research. In 1990, ETSI established an ad hoc group for UMTS that focused on the critical points to be studied for systems suitable for mobile users since 1998, ETSI's standardization of the 3G mobile system has been carried out in the 3G Partnership Project (3GPP) that focuses on the GSM-UMTS migration path. The 3GPP2 is an effort headed by ANSI for evolved IS-41 networks and related radio transmission technique. The standard organizations propose the mobile system standards that change as new technologies emerge, and the regulations and market demand change. The changing features and used technologies from first to fifth generation mobile systems are summarized in Table 1. It is noticeable that the fifth generation system not only provides a horizontal handoff like the previous systems but also provide a vertical handoff. While a global roaming may be provided by satellite systems, a regional roaming by 5G cellular systems, a local area roaming by WLANs, and a personal area roaming by wireless PANs, it will also be possible to roam vertically between these systems as well as support www services. One technology (or its variation) that is expected to remain in future mobile system is CDMA, which is a use of *spread spectrum* technique by multiple transmitters to send signals simultaneously on the same frequency without interference to the same receiver. Other widely used multiple access techniques are TDMA and FDMA mostly associated with 3G and previous systems. In these three schemes (CDMA, TDMA, FDMA), receivers discriminate among various signals by the use of different codes, time slots and frequency channels, respectively. Digital cellular systems are an extension of IS-95 standard and are the first CDMA-based digital cellular standard pioneered by Qualcomm. The brand name for IS-95 is CDMA. It is now being replaced by IS-2000 and is also known as CDMA-2000, which is a 3G mobile telecommunications standard from ITU's IMT-2000. CDMA-2000 is considered an incompatible competitor of the other major 3G standard WCDMA. Due to its importance in future systems, let's now examine the different CDMA standards currently available. CDMA-2000 1x, also known as CDMA-2000 1xMC (Multi-Carrier), is the core 3G CDMA-2000 technology. The designation Multi-Carrier refers to the possibility of using up to three separate 1.25 MHz carriers for data transmission, and is used to distinguish this from WCDMA. It is generally deployed separately from voice networks in its own spectrum. CDMA2000 1xEV-DV (Evolution-Data and Voice), supports circuit and packet data rates up to 5 Mbps. It fully integrates with 1xRTT voice networks. CDMA-2000 3x uses three separate 1.25 MHz carriers. This provides three times the capacity but also requires three times more bandwidth.

B.Network Services

Users relate to different systems with the help of available applications and services that are directly a function of available data rates. The key difference between the 2G and 3G is the data rate support enabling the later to provide interactive video communication, among other services. A type of service that gained popularity in 2G systems is the messaging service known as Short Messaging Services (SMS), which is a text messaging service for 2G and later mobile phones. The messages in SMS cannot be longer than about 160 characters. An enhanced version of SMS known as Enhanced Messaging Service (EMS) supports the ability to send pictures, sounds and animations. A newer type of messaging service, Multimedia Messaging Service (MMS), is likely to be very popular for 3G systems and beyond. MMS provides its users the ability to send and receive messages consisting of multimedia elements from person to person as well as Internet, and serves as the email client. MMS uses Wireless Application Protocol (*WAP*) technology and is powered by the well-known technologies, EDGE, GPRS and UTMS (using WCDMA). The messages may include any combination of text, graphics, photographic images, speech and music clips or video clips The most exciting extension of messaging services in MMS is a video message capability. For instance, a short 30 seconds video clip may be shot at a location, edited with appropriate audio being added and transmitted with ease using the mobile keys on the cellular phones. In addition, by using Synchronized Multimedia Integration Language (SMIL), small presentations can be made that incorporate audio and video along with still images, animations and text to assemble full multimedia presentation by using a media editor. With MMS, a new type of service Interfacing Multimedia Messaging Services (IMMS) is expected to emerge that integrates MMS and Mobile Instant Messaging (MIM) allowing the users to send messages in their MIM buddy list. This will bring full integration of state-of-the art mobile messaging services including MIM, MMS and chat into all types of mobile devices.

A new term, "Mobile Decision Support (MDS)" has been coined recently for a unique set of services and applications that will provide instant access to information in support of real-time business and personal activities for vehicle based 3G systems. Some example services are navigation, emergency services, remote monitoring, business finder, email, and voicemail. It is expected that MDS based services will generate a huge non-voice traffic over the net. WAP is an open international standard for applications that use wireless communication on mobile phones. The primary language of WAP specification is Wireless

Markup Language (WML), which is the primary content based on XML (A general purpose markup language to encode text including the details about its structure and appearance). The original intent in WAP was to provide mobile replacement of World Wide Web. However, due to performance limitations and costs it did not become quite popular as originally expected. Although WAP never became popular, a popular WAP-like service called i-mode has recently been developed in Japan that allows web browsing and several other well designed services for the mobile phones. i-mode is based upon Compact HTML (C-HTML) as an alternate to WML, and is compatible with HTML allowing the C-HTML web sites to be viewed and edited using standard web browsers and tools.

III.CHALLENGES IN 4G

A.Multimode user terminals

With 4G there will be a need to design a single user terminal that can operate in different wireless networks and overcome the design problems such as limitations in size of the device, its cost and power consumption. This problem can be solved by using software radio approach i.e. user terminal adapts itself to the wireless interfaces of the network.

B.Selection among various wireless systems.

Every wireless system has its unique characteristics and roles. The proliferation of wireless technologies complicates the selection of most suitable technology for a particular service at a particular place and time. This can be handled by making the selection according to the best possible fit of user QoS requirements and available network resources.

C.Security

Heterogeneity of wireless networks complicates the Security issue. Dynamic reconfigurable, adaptive and lightweight security mechanisms should be developed.

D. Network infrastructure and QoS support

Integrating the existing non-IP and IP-based systems and providing QoS guarantee for end-to-end services that involve different systems is also a big challenge.

E. Charging/ billing

It is troublesome to collect, manage and store the Customers' accounts information from multiple service providers. Similarly, billing customers with simple but information is not an easy task.

F. Attacks on application level

4G cellular wireless devices will be known for software applications which will provide innovative feature to the user but will introduce new holes, leading to more attacks at the application level.

F.Jamming and spoofing

Spoofing refers to fake GPS signals being sent out, in which case the GPS receiver thinks that the signals comes from a satellite and calculates the wrong co-ordinates. Criminals can use such techniques to interfere with police work. Jamming happens when a transmitter sending out signals at the same frequency displaces a GPS signal.

G.Data encryption

If a GPS receiver has to communicate with the central transmitter then the communication link between these two components is not hard to break and there is a need of using encrypted data.

IV. Concept for 5G Mobile Network

The 5G terminals will have software defined radios and modulation schemes as well as new error-control schemes that can be downloaded from the Internet. The development is seen towards the user terminals as a focus of the 5G mobile networks. The terminals will have access to different wireless technologies at the same time and the terminal should be able to combine different flows from different technologies. The vertical handovers should be avoided, because they are not feasible in a case when there are many technologies and many operators and service providers. In 5G, each network will be responsible for handling user-mobility, while the terminal will make the final choice among different wireless/mobile access network providers for a given service. Such choice will be based on open intelligent middleware in the mobile phone.

A.Physical/MAC layers

Physical and Medium Access Control layers i.e. OSI layer 1 and OSI layer 2, define the wireless technology. For these two layers the 5G mobile networks is likely to be based on Open Wireless Architecture [6].

B.Network layer

The network layer will be IP (Internet Protocol), because there is no competition today on this level. The IPv4 (version 4) is worldwide spread and it has several problems such as limited address space and has no real possibility for QoS support per flow. These issues are solved in IPv6, but traded with significantly bigger packet header. Then, mobility still remains a problem. There is Mobile IP standard on one side as well as many micro-mobility solutions (e.g., Cellular IP, HAWAII etc.). All mobile networks will use Mobile IP in 5G, and each mobile terminal will be FA (Foreign Agent), keeping the CoA (Care of Address) mapping between its fixed IPv6 address and CoA address for the current wireless network. However, a mobile can be attached to several mobile or wireless networks at the same time. In such case, it will maintain different IP addresses for each of the radio interfaces, while each of these IP addresses will be CoA address for the FA placed in the mobile Phone. The fixed IPv6 will be implemented in the mobile phone by 5G phone manufactures. The 5G mobile phone shall maintain virtual multi-wireless network environment. For this purpose there should be separation of network layer into two sub-layers in 5G mobiles (Fig. 3) i.e.: Lower network layer (for each interface) and Upper network layer (for the mobile terminal). This is due to the initial design of the Internet, where all the routing is based on IP addresses which should be different in each IP network world wide. The middleware between the Upper and Lower network layers shall maintain address translation from Upper network address (IPv6) to different Lower network IP addresses (IPv4 or IPv6), and vice versa.

C.Open Transport Protocol (OTA) layer

The mobile and wireless networks differ from wired networks regarding the transport layer. In all TCP versions the assumption is that lost segments are due to network congestion, while in wireless networks losses may occur due to higher bit error ratio in the radio interface. Therefore, TCP modifications and adaptation are proposed for the mobile and wireless networks, which retransmit the lost or damaged TCP segments over the wireless link only. For 5G mobile terminals will be suitable to have transport layer that is possible to be downloaded and installed. Such mobiles shall have the possibility to download (e.g., TCP, RTP etc. or new transport protocol) version which is targeted to a specific wireless technology installed at the base stations. This is called here Open Transport Protocol - OTP.

Fig. 1 Open Wireless Architecture

D.Application layer

Regarding the applications, the ultimate request from the 5G mobile terminal is to provide intelligent QoS management over variety of networks. Today, in mobile phones the users manually select the wireless interface for particular Internet service without having the possibility to use QoS history to select the best wireless connection for a given service. The 5G phone shall provide possibility for service quality testing and storage of measurement information in information databases in the mobile terminal. The QoS parameters, such as delay, jitter, losses, bandwidth, reliability, will be stored in a database in the 5G mobile phone with aim to be used by intelligent algorithms running in the mobile terminal as system processes, which at the end shall provide the best wireless connection upon required QoS and personal cost constraints. 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. The process of IPv4 address exhaustion is expected to be in its final stages by the time that 4G is deployed. Therefore, IPv6 support for 4G is essential in order to support a large no. of wireless- enabled devices. IPv6 removes the need for NAT (Network Address Translation) by increasing the no. of IP addresses.

E.5G Architecture

5G is being developed to accommodate the QoS and rate requirements set by forthcoming applications like wireless broadband access, Multimedia Messaging Service (MMS), video chat, mobile TV, HDTV content, Digital Video Broadcasting (DVB), minimal services like voice and data, and other services that utilize bandwidth. The definition of 5G is to provide adequate RF coverage, more bits/Hz and to interconnect all wireless heterogonous networks to provide seamless, consistent telecom experience to user.

F.Evolved Packet Core (EPC)

Evolved Packet Core is the IP-based core network defined by 3GPP (Telecom standard) for use by LTE and other access technologies. The goal of EPC is to provide simplified all IP core network architecture to efficiently give access to various services such as the ones provided in IMS (IP Multimedia Subsystem). EPC consists essentially of a Mobility Management Entity (MME) & access agnostic gateways foe routing of user datagram. EPC will be a completely new architecture for wireless operators, one that emulates the IP world of data Communication rather than the voice- centric world of wireless. EPC is based on flat IP network theory.

G.Premise of 5G, is resting on All IP architecture

Mobile networks have been designed up to this point — for circuit- switched voice. Wireless networks were designed in a hierarchal fashion to aggregate, authenticate, manage and direct calls. A BSC aggregates calls from multiple base stations, allocates radio channels, enables handoffs between base stations and passes on calls to an even more centralized mobile switching centre. As packet data networks emerged, they were overlaid on the existing voice-centric architecture, using the BSC for the same mobility management functions and adding the SGSN and GGSN in the case of GSM/UMTS and a PDSN in the case of CDMA to route and manage data sessions, as well as to connect to the Internet or appropriate IP network.

V.*CONCLUSIONS*

The current and future trends in mobile systems is considered that includes the evolutionary path starting from first generation mobile phone systems and is continuing to the development of 5th generation systems. The proposed concept adapts Open Wireless Architecture proposed for 4G mobile terminals, and provides further changes from network up to application layer. The network layer is divided into two sub-layers to provide all-IP connectivity in environment with plenty of wireless/mobile technologies as well as network and/or service providers. Open Transport Layer is proposed with aim to allow usage of wireless specific implementations of transport protocols.

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