5G Technologies: Fundamental Shift in Mobile Networking Philosophy

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Abstract---

Today 3G mobile systems are on the ground providing IP connectivity for real-time and non-real-time services. On the other side, there are many wireless technologies that have proven to be important, with the most important ones being 802.11Wireless Local Area Networks (WLAN) and 802.16 Wireless Metropolitan Area Networks (WMAN), as well as ad-hoc Wireless Personal Area Network (WPAN) and wireless networks for digital TV and radio broadcast. Then, the concepts of 4G is already much discussed and it is almost certain that 4G will include several standards under a common umbrella, similarly to3G, but with IEEE 802.xx wireless mobile networks included from the beginning. The main contribution of this paper is definition of 5G (Fifth Generation) mobile network concept which is seen as user-centric concept instead of operator-centric as in 3G or service-centric concept as seen for 4G. In the proposed concept the mobile user is on the top of all. The 5G terminals will have software defined radios and modulation scheme as well as new error-control schemes can be downloaded from the Internet on the run. 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. 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. The paper also proposes intelligent Internet phone concept where the mobile phone can choose the best connections by selected constraints and dynamically change them during a single end-to-end connection. The proposal in this paper is fundamental shift in the mobile networking philosophy compared to existing 3G and near-soon 4G mobile technologies, and this concept is called 5G.

Keywords: 5G Technology, 5G Network, 5G Mobile Technology

1. INTRODUCTION

Mobile and wireless networks have made tremendous growth in the last fifteen years. Nowadays many mobile phones have also a WLAN adapter. One may suppose that near soon many mobile phones will have WiMAX adapter too, besides their 3G, 2G, WLAN, Bluetooth etc. adapters. Using IP for both, 2.5G or 3G Public Land Mobile Networks(PLMN) on one side

and WLAN on the other, raised research on their integration, which was mainly divided into loose and tight coupling.

Regarding the 4G, its focus is towards seamless integration of cellular networks such as GSM and3G, WLAN and Bluetooth. Multimode user terminals are seen as must have for 4G, but different security mechanisms and different QoS support in different wireless technologies remain a challenge. However, AAA integration among different wireless networks (e.g. PLMN and WLAN) is functioning in practice even today. But, different wireless networks from a single terminal are used exclusively, that is, there is no combining of different wireless access technologies for a same session (e.g., FTP download).

The proposed Open Wireless Architecture (OWA) in [6] is targeted to provide open baseband processing modules with open interface parameters to support different existing as well as future wireless communication standards.

The OWA is targeted to MAC/PHY layers of future (4G) mobile terminals. The referenced work above provides a ground for definition of a concept for beyond 4G mobile networks, referred in this paper as 5G mobile networks.

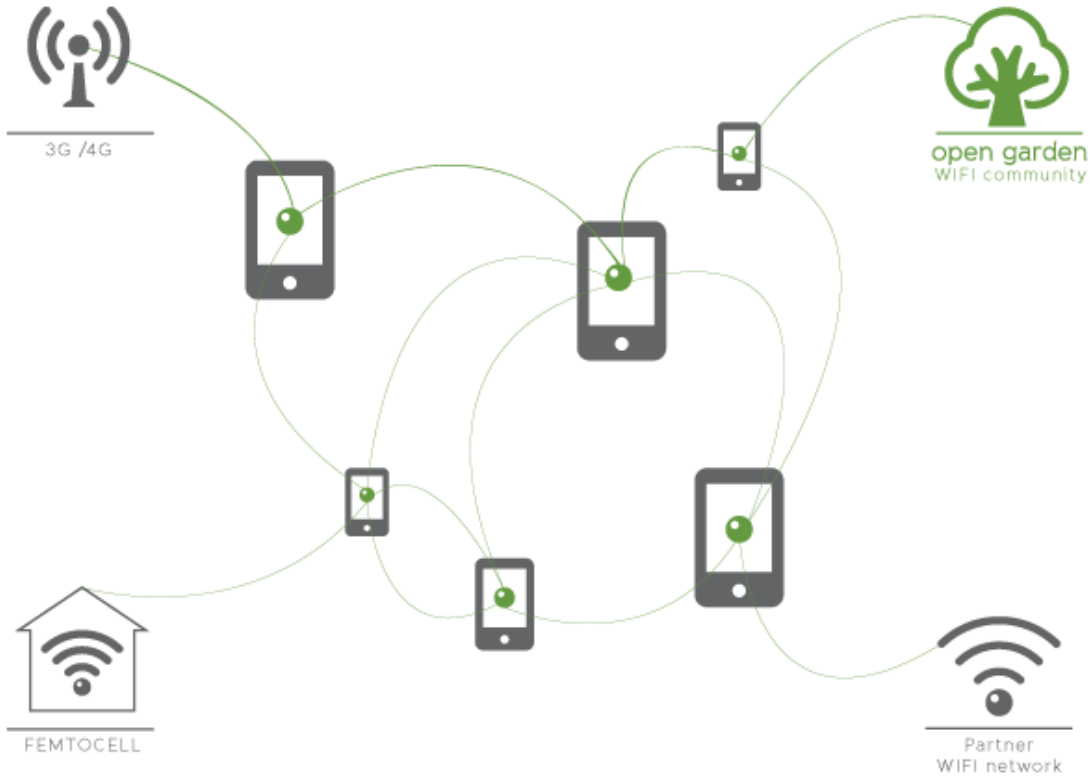

Fig. 1. Seamless connections of networks

2. FEATURES OF FOURTH GENERATION TECHNOLOGY

There are several reasons which are sufficient to answer a simple question- why do we need to adopt 4G technology. Below are some of the features of 4G which make it an "above all" technology.

2.1 High performance

Industry experts say that users will not be able to take advantages of rich multimedia content across wireless networks with 3G. In contrast to this 4G will feature extremely high quality video of quality comparable to HD (high definition) TV. Wireless downloads at speeds reaching 100 Mbps, i.e. 50 times of 3G, are possible with4G.

2.2 Interoperability and easy roaming

Multiple standards of 3G make it difficult to roam and interoperate across various networks, whereas 4G provides a global standard that provides global mobility. Various heterogeneous wireless access networks typically differ in terms of coverage, data rate, latency, and loss rate. Therefore, each of them is practically designed to support a different set of specific services and devices, 4G will encompass various types of terminals, which may have to provide common services independently of their capabilities. This concept is referred to as service personalization.

2.3 Fully converged services.

If a user want to be able to access the network from lots of different platforms: cell phones, laptops, PDAs he is free to do so in 4G which delivers connectivity intelligent and flexible enough to support streaming video, VoIP telephony, still or moving images, e-mail, Web browsing, e-commerce, and location-based services through a wide variety of devices. That means Freedom for consumers.

2.4 Low cost

4G systems will prove far cheaper than 3G, since they can be built atop existing networks and won't require operators to completely retool and won't require carriers to purchase costly extra spectrum. In addition to being a lot more cost efficient, 4G is spectrally efficient, so carriers can do more with less.

2.5 Devices: more user friendly interface

4G devices are expected to be more visual and intuitive rather than today's text and menu based systems. They will be able to interact with the environment around it and act accordingly.

2.6 Enhanced GPS Services

In addition to locating individuals, a 4G version of GPS tech might be able to let people be virtually present in a variety of places.

2.7 Scalability

It is most challenging aspect of the mobile networks. It refers to ability to handle ever increasing number of users and services. Since an all IP core layer of 4G is easily scalable, it is ideally suited to meet this challenge

2.8 Crisis-Management applications

Natural disasters can affect the entire communications infrastructure is in disarray. Restoring communications quickly is essential. With wideband wireless mobile communications Internet and video services, could be set up in hours instead of days or even weeks required for restoration of wire line communications.

3. CHALLENGES IN MIGRATION TO 4G

3.1 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.

3.2 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.

3.3 Security

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

3.4 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.

3.5 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.

3.6 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.

3.7 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.

3.8 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.

4. CONCEPT FOR 5G MOBILE NETWORKS

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. Now, we will go through all OSI layers (Fig. 1) in the 5G mobile terminal design (Fig. 2).

4.1 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].

4.2 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 (Fig. 3) shall maintain address translation from Upper network address (IPv6) to different Lower network IP addresses (IPv4 or IPv6), and vice versa.

4.3 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.

4.4 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. With the available address space and number of addressing bits in IPv6, many innovative coding schemes can be developed for 4g devices and applications that could help in the deployment of 4G network and services. The fourth generation promises to fulfill the goal of PCC (personal computing and communication)—a vision that affordably provides high data rates everywhere over a wireless network [3]. In the future wireless networks there must be a low complexity of implementation and an efficient means of negotiation between the end users and the wireless infrastructure. The Internet is the driving force for higher data rates and high speed access for mobile wireless users. This will be the motivation for an all mobile IP based core network evolution.

5. 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.

5.1 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.

5.2 FLAT IP ARCHITECURE

5.2.1 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. As data traffic is increasing rapidly, this voice centric architecture has become cumbersome and harder to manage with too many network entities. Flat network architecture removes that voice-centric hierarchy from the network. Instead of overlaying a packet data core on the voice network, separate and much-simplified data architecture can be implemented that removes the multiple elements from the network chain. BSC functions are divided between Base station and media gateway router. Base station will communicate directly via 3GDT (3G direct tunnel) with media gateway over WAN (Carrier Ethernet, MW, DWDM etc). Some of the functions of BSC/RNC such as Radio resource management, Radio Bearer Control, and Dynamic allocations of resources will be handled by base stations, while functions such as Distribution of paging messages, Security will be function by mobility manager, located in Gateway router.

This approach has clearly visible advantages. It will save significant amount of Capex and Opex as, service provider will have fewer hopes and fewer network entities. By reducing the number of hops on the network, data travels faster between end points, greatly reducing the network latency to help support real-time applications such as voice over IP (VoIP), gaming and videoconferencing. The flat IP architectures have emerged with WiMAX, and future LTE networks will be flat by definition.

6. CONCLUSIONS

In this paper we have proposed 5G mobile phone concept, which is the main contribution of the paper. The 5G mobile phone is designed as an open platform on different layers, from physical layer up to the application. 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. Finally, we propose possibility for selection of different wireless technologies upon different QoS constraints (and cost constraints) for different services, real-time (VoIP, streaming, IPTV etc.) or non-real-time (web, messaging, gaming etc.). For such

purpose, 5G mobile terminals should maintain database which will keep statistical information regarding the services and the available wireless technologies in the phone. Currently, the ongoing work is on the modules that shall provide the best QoS and lowest cost for a given service using one or more than one wireless technology at the same time from the 5G mobile phone.

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