Vertical Handover Study on 4G Category vs. 5G Category for 3GPP Generation Mobile Systems and Non-3GPP Wireless Networks

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ABSTRACT

Nowadays, wireless communication technologies have become an integral part of people’s daily life and businesses all over the world. Due to the rapid increase in the number of the Mobile Users (MUs) who demand the service of communicating via wireless access networks, the wireless communication technologies have evolved from the first generation to the fifth generation. The Next Generation Wireless Systems (NGWSs) consists of heterogeneous wireless access networks of 3GPP generation mobile Systems (e.g., UMTS, LTE) and non-3GPP wireless networks (e.g., WiFi, WiMAX), where MUs can access these technologies and services using a single device. This paper presents a study for Vertical Handover (VHO) approaches of 3GPP and non-3GPP proposed in the literature and classifies them into two categories for which their characteristics are discussed.

Keywords: Vertical Handover; Mobile Systems; Wireless Networks; 4G; 5G.

1 Introduction

The rapid evolutions in broadband wireless communication technologies and the growing Mobile Users’ demand (MUs) for communication services anywhere, anytime are driving an evolution toward the seamless integration between different Radio Access Technology (RATs) in heterogeneous wireless communication technologies to provide the best connected services to the MU constantly [1]. The benefits of heterogeneous wireless communication technologies are many and varied. These include: flexibility, reducing cost, simplifying the operation and maintenance, rapid deployment of services and applications, new services, high data transmission, customisation, support multimedia services at lower cost of transmission, the mobility of the sessions and the possibility to transfer the context [1].

The Next Generation Wireless Systems (NGWSs) consists of heterogeneous wireless communication technologies of 3GPP and non-3GPP, where MUs can access these technologies and services using a single device. This device is equipped with multiple radio interfaces include devices capable of supporting multiple RATs by incorporating several interface cards and appropriate software for switching between multiple access systems (Vertical Handover (VHO)).
This paper presents background information on heterogeneous wireless communication technologies. Then, it overviews VHO approaches of 3GPP and non-3GPP proposed in the literature and classifies them into two categories for which their characteristics are discussed. The rest of the paper is organized as follows: In section 2, background information on heterogeneous wireless communication technologies is presented. In section 3, classifications for VHO approaches of 3GPP and non-3GPP are presented. In section 4, a comparison for VHO approaches of 3GPP and non-3GPP is presented and finally, section 5 concludes the paper.

2 Background on Heterogeneous Wireless Communication Technologies

In this section, background information on heterogeneous wireless communication technologies is presented to answer the following questions: how have wireless communication technologies evolved? What are heterogeneous wireless communication technologies? Who needs heterogeneous wireless communication technologies? Why are heterogeneous wireless communication technologies necessary? and finally, what is the handover management within heterogeneous wireless communication technologies.

1. How Have wireless communication technologies Evolved?

During the last few years, telecommunication authorities were busy while working out how to emerge to the next generation of wireless technology environment which was motivated by the growing demand for advanced telecommunication services which require wider spectrum and higher QoS [2]. Besides, the telecommunication industry experts are required to develop an interoperability strategy for new mobile wireless systems which can satisfy MUs’ demands of telecommunication systems [2]. This section presents a background of the main wireless communication technologies, as shown in Table 1.

2.1 GSM

GSM is a 2G mobile system which is the first one to specify digital modulation and network level architectures and services, the first important set of Radio Frequency (RF) for GSM standard started at 1900 MHz [3]. GSM was first introduced in Europe in 1991 and today is one of the most popular digital mobile telecommunications systems widely used over the world [3]. Due to the increase of the number and the requirement of GSM subscriber the GSM is still an attractive area for research in the field of mobile telecommunication [3-5].

2.2 UMTS

2G like GSM were originally designed for efficient delivery of voice services. 3G systems like UMTS were designed from the beginning for mobile voice and data users [6]. Therefore, UMTS is the evolution of GSM system and General Radio Packet Service (GPRS) developed by Third Generation Partnership Project (3GPP) to increase the support for some features such as data rate in radio interface and the compatibility for the two services domains: Packet Switched (PS) and Circuit Switched (CS) data transmission [7]. Some of the most common keys drive of this type of UMTS access technology [8]:

- Growth in the market for fixed networked multimedia services.
- Increasing demand for rapid and remote access to information.
- E-Commerce and transaction based applications.

http://dx.doi.org/10.14738/tnc.62.4353
2.3 Wi-Fi

The Wi-Fi (IEEE 802.11) is wireless networks designed to provide broadband for Wireless Local Area Network (WLAN) where the MUs use the mobile devices (e.g., mobiles and laptops) to access the internet in small geographic area such as university's buildings, airports and railway stations. Over 97% of laptops today come with Wi-Fi as a standard feature and an increasing number of handhelds and Consumer Electronics (CEs) devices are adding Wi-Fi capabilities [9] as Wi-Fi technology in conformance with IEEE 802.11 are growing every year [28, thesis]. The initial standard IEEE 802.11, which came in 1997, had a data rate of 1 Mbps [10]. By year 1999 this was changed; 802.11a (54 Mbps at wider frequency band), 802.11b (11 Mbps, same frequency band but a different modulation technique) and 802.11g (using modulation technique of 802.11a but frequency band of 802.11b) [10]. During the period between 1990-2000, the IEEE committee, which had already created wired LAN standards (802.3 Ethernet), started processing wireless LAN standard [10]. As Ethernet was dominant at that time, the committee decided to make wireless standard 802.11 compatible with Ethernet above data link layer; however, it was different from Ethernet in link layer and physical layer due to various issues faced the wireless communication [10].

2.4 4G

Growing demand for new applications required to be supported by new mobile systems such as Voice over Internet Protocol (VoIP), video conference, Push to-talk-over Cellular (PoC), multimedia messaging, multiplayer games, Virtual Private Networks (VPNs), web browsing, email access, audio and video Streaming, content download of ring tones, video clips and File Transfer Protocol (FTP) [11]. These applications require higher throughput, wider bandwidth, smaller delay and innovative transmission methods which will give higher spectral efficiency and good quality [2]. Therefore, WiMAX and LTE wireless communication technologies are considered as candidates to achieve the 4G requirements announced by International Telecommunication Radio Communication Sector (ITU-R) which is known as International Mobile Telecommunication-Advanced (IMT-Advanced) [2]. Figure 1 shows the geographical locations of the deployment of 2G, 3G and 4G.

2.4.1 WiMAX

WiMAX (IEEE 802.16) is a telecommunication mobile system designed to provide high speed broadband wireless access which is a probable replacement candidate for mobile system (e.g., GSM) or can be used as an overlay to enhance capacity [12]. There are many versions of WiMAX (IEEE 802.16) standards. The IEEE 802.16d (802.16-2004) provides fixed WiMAX network while IEEE 802.16e (802.16-2005) is an amendment to 802.16-2004 and it is directed to support for mobility; therefore, also known as “Mobile WiMAX” [12]. The WiMAX revision IEEE 802.16m expected to offer peak rates of at least 1 Gbps fixed speed and 100 Mbps to MUs [13].

2.4.2 LTE

3GPP’s LTE standard evolved from the high speed packet access cellular standards. LTE is a telecommunication mobile system designed to provide higher data rate, higher throughput and lower air-interface latency compared with 2G and 3G systems [14]. This higher performance makes it possible to enhance the broadband data on demanding applications beyond web browsing and voice which require higher data rate and stricter QoS constraints such as video service [14].
2.5 5G

5G is defined as upcoming mobile system beyond 4G (B4G) which provides substantial features compared to the current mobile systems [15, 16]:

- Better coverage area.
- Higher data rate (around 1Gbps).
- Lower battery consumption.
- Higher security.
- Better spectral efficiency and Energy efficiency.
- Availability of Artificial Intelligence inspired applications.
- Not harmful for human health.
- Economic services due to low deployment cost.
- It has been concluded in [16] that "the final success of 5G will depend upon when it is fully implemented and the new services and contents made available to MUs". Figure 2 shows the geographical locations of the deployment of 2G, 3G, 4G LTE and 5G.

![Figure 1. 2G, 3G and 4G world coverage map [17]](http://dx.doi.org/10.14738/tnc.62.4353)

![Figure 2. 2G, 3G, 4G LTE and 5G world coverage map [18]](http://dx.doi.org/10.14738/tnc.62.4353)
Table 1. Advantages and disadvantages for UMTS, Wi-Fi, WiMAX, LTE and 5G [1, 12, 14-16, 19-27]

<table>
<thead>
<tr>
<th>Access Technology</th>
<th>Type</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
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<tbody>
<tr>
<td>UMTS (3G, Wide Area</td>
<td>3GPP</td>
<td>- Wide coverage area.</td>
<td>- Not suitable small indoor and densely populated area.</td>
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<tr>
<td>Network (WAN))</td>
<td></td>
<td>- High security.</td>
<td>- High service cost.</td>
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<td>- Low deployment cost.</td>
<td>- High deployment cost.</td>
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<td></td>
<td></td>
<td>- Support rates from 1 Mbps to 56 Mbps.</td>
<td>- Low medium data rate from 144 Kbps to 2 Mbps.</td>
</tr>
<tr>
<td>Wi-Fi</td>
<td>Non-3GPP</td>
<td>- Cheap service cost.</td>
<td>- Limited in large space mobility.</td>
</tr>
<tr>
<td>(Wireless Local Area</td>
<td></td>
<td>- Low deployment cost.</td>
<td>- Weak security.</td>
</tr>
<tr>
<td>Network (WLAN), IEEE</td>
<td></td>
<td>- Support rates from 1 Mbps to 56 Mbps.</td>
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</tr>
<tr>
<td>802.11, Local Area</td>
<td></td>
<td>- Medium coverage area.</td>
<td></td>
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<tr>
<td>Network (LAN)</td>
<td></td>
<td>- Medium service cost.</td>
<td></td>
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<td></td>
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<td>- Medium deployment cost.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Medium security.</td>
<td></td>
</tr>
<tr>
<td>WiMAX (Metropolitan</td>
<td>Non-3GPP</td>
<td>- Medium coverage area.</td>
<td>- Limited in large space mobility.</td>
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<tr>
<td>Area Network (MAN)</td>
<td></td>
<td>- Medium service cost.</td>
<td></td>
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<td></td>
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<td>- Medium deployment cost.</td>
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<tr>
<td></td>
<td></td>
<td>- Medium security.</td>
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<tr>
<td></td>
<td></td>
<td>- Scalability.</td>
<td></td>
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<td></td>
<td></td>
<td>- The current WiMAX revision IEEE 802.16m expected to offer peak rates of</td>
<td></td>
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<td></td>
<td></td>
<td>- at least 1 Gbps fixed speed and 100 Mbps to MUs.</td>
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<td>LTE (E-UTRAN, 4G)</td>
<td>5GPP</td>
<td>- Wide coverage area.</td>
<td>- High service cost.</td>
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<td></td>
<td></td>
<td>- High security.</td>
<td>- High deployment cost.</td>
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<td></td>
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<td>- High throughput.</td>
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<td></td>
<td></td>
<td>- Low air interference latency compared with 3G/3G system.</td>
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<tr>
<td></td>
<td></td>
<td>- As set by ITU for IMT-Advanced: increased peak data rate. Di: 3 Gbps and</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>- EE: 1.5 Gbps (LTE-Advanced).</td>
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<tr>
<td>5G (SA)</td>
<td>5GPP</td>
<td>- Better coverage area.</td>
<td>- The final success of 5G will depend upon when it is fully implemented and</td>
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<td></td>
<td></td>
<td>- Higher data rate (up to 10Gbps).</td>
<td>the new services and contents made available to MUs.</td>
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<td>- Economic services due to low deployment cost.</td>
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<td>- Availability of Artificial Intelligence inspired applications.</td>
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2. What are heterogeneous wireless communication technologies?
The growing demand for services (e.g., web browsing, file downloading and e-mail) from MUs anywhere, anytime is on the increase regardless of the technological constraints which are associated with different types of RATs such as UMTS, WiMAX and LTE, besides, there is no single RAT is able to satisfy the requirements for all different wireless communications scenarios. Therefore, the telecommunication operators are required to develop an interoperability strategy for these different types of existing networks to get the best connection anywhere, anytime between heterogeneous wireless communication technologies [28].

3. Who needs heterogeneous wireless communication technologies?
There are two main parties that need heterogeneous wireless communication technologies; the first one is the operator and the second is the MUs. The operators always seek to improve the final user experience and optimum use of the network by making a transition from the source network to target network as transparent as possible. The thing which will be reflected positively on operators to get more subscribers (users’ loyalty) and more profit eventually; this is shown in Fig. 3. On the other side, the MUs need to maintain network capability anywhere, anytime without interruption on their ongoing sessions.
4. Why are heterogeneous wireless communication technologies necessary?
3GPP and non-3GPP include multiple integrated mobile systems and wireless networks and all of them coexist in a heterogeneous wireless access environment. At the same time each RAT has its advantages and disadvantages. Therefore, the complementarity between RATs is still required due to their characteristics. For example, the integration between WiMAX and LTE would satisfy MUs’ demands to ongoing their sessions without noticeable degradation. Consequently, it would allow the service provider to get more profit.

5. What is the handover management within heterogeneous wireless communication technologies?
Handover management is a process which allows the MUs to continue their ongoing sessions when moving within the same RAT coverage areas or traversing different RATs. In heterogeneous wireless communication technologies, the handover management is crucial because RATs typically differ in terms of multiple parameters such as RSS, data rate, reliability, service cost, security, power consumption requirements, coverage area and latency. Therefore, complementarity to these RATs through VHO interworking architectures is essential to provide ubiquitous wireless access ability with the best available access network which suits the MU’s requirements (e.g., high coverage area, high data rate and low cost).

3  Classifications for VHO Approaches of 3GPP and non-3GPP
This section presents VHO approaches of 3GPP and non-3GPP proposed in the literature and classifies them into two categories based on 4G and 5G for which their characteristics have been discussed. We identify the two categories as: (A) 4G based category which includes 4G and/or the rest of 3GPP previous generation mobile systems (2G-3G) and/or non-3GPP wireless networks. (B) 5G based category which includes 5G and/or the rest of 3GPP previous generation mobile systems (2G-4G) and/or non-3GPP wireless networks.

3.1 4G Category
In this category, plenty of VHO approaches have been proposed in the literature. In [29], [30] and [31], seventeen, fifteen and ninety nine VHO approaches have been surveyed, respectively. It has been noticed in [29-31] that the VHO approaches are mostly in the practical where the evolution methods in these surveys are various between real environment, testbed, simulation experiment and analytical modeling.
3.2 5G Category

Although one of the most important goals of 5G is to provide ubiquitous wireless access abilities [15], it would not be perfectly able to achieve the goal without cooperating with the rest of wireless communication technologies of 3GPP and non-3GPP. To the best of my knowledge the current research works of this category are mainly confined in 5G where the recent overview of VHO in 4G and 5G has showed that in [32].

4 Comparison for VHO Approaches of 3GPP and non-3GPP

Section III has presented two categories of VHO approaches based on 4G and 5G for which their characteristics have been discussed. 4G Category has substantially presented and evaluated its VHO approaches using various evaluations methods. As the final success of 5G will depend upon when it is fully implemented and the new services and contents made available to MUs, it would be preferable to design and develop scenarios of 5G Category for evaluating real-world deployments, testbed, simulation experiment and analytical modeling compared with the huge number of previous works in 4G Category.

5 Conclusion

This paper has presented a study for VHO approaches of 3GPP and non-3GPP proposed in the literature and classified them into two categories based on 4G and 5G for which their characteristics have been discussed. It has been concluded that the 5G Category should be an active area of research compared with 4G Category which has obviously succeeded in presenting and evaluating plenty of VHO approaches.

REFERENCES


