CHAPTER I

CHAPTER I

INTRODUCTION TO MOBILE WIRELESS COMMUNICATION TECHNOLOGIES AND QoS

CHAPTER I

INTRODUCTION TO MOBILE WIRELESS COMMUNICATION TECHNOLOGIES AND QoS

Mobile wireless communication technologies are used to provide network connectivity to users who may be living in an urban, sub-urban or even sparsely populated area which cannot be reached, practically, by using any other communication technology. Hybrid networks employ multiple platforms of mobile wireless communication technology and realize the vision "anywhere, any time and for anyone" in its true sense. Mobile wireless communication technologies consist of various standards, architectures, characteristics etc. All these different technologies naturally may share some common characteristics, but there are also many important differences. However, different technologies may not coexist and interoperate easily because they may be supporting different Quality of Service (QoS). Mobile wireless communication technology have been changing rapidly due to the immense demand for better QoS; thus standards are also continuously evolving due to the requirements of bandwidth, spectrum flexibility, efficiency and performance. Thus, providing guaranteed QoS to various applications (and users) has become an important objective in designing the next-generation of mobile wireless communication networks. Users with different applications may therefore need very diverse QoS, in terms of bandwidth, delay, jitter, latency, packet loss, and so on.

This chapter therefore introduces the subject of mobile wireless communication technology. It also reviews the state-of-the-art of QoS, it's techniques and parameters as used in different mobile communication technologies.

1.1. Introduction

The dream of every communication expert is to develop a mobile wireless communication technique which will have the advantages of a wide area coverage, low propagation delay and little multipath fading. Due to the tremendous growth in the demand of efficient communication services, wireless infrastructure providers are under a continuous pressure to exploit the limited radio spectrum as efficiently as possible.

Currently, there are two well-established methods for providing mobile wireless communication services viz. terrestrial and satellite systems. These systems are currently used worldwide for delivering communication services from low speed to a very high speed date rate. However, each system indeed, has specific advantages and disadvantages.

The initiatives to advance various mobile wireless communication technologies started because of the customer’s rising demands for better quality of services. Initially, the First Generation (1 G) mobiles came into picture. With increasing requirements for customer's QoS, the evolution of future generation like Second Generation (2 G), Third Generation (3 G) and Fourth Generation (4 G) took place till the Fifth Generation (5 G) in the present scenario. Figure 1.1 shows the future trend of mobile wireless communication technologies.

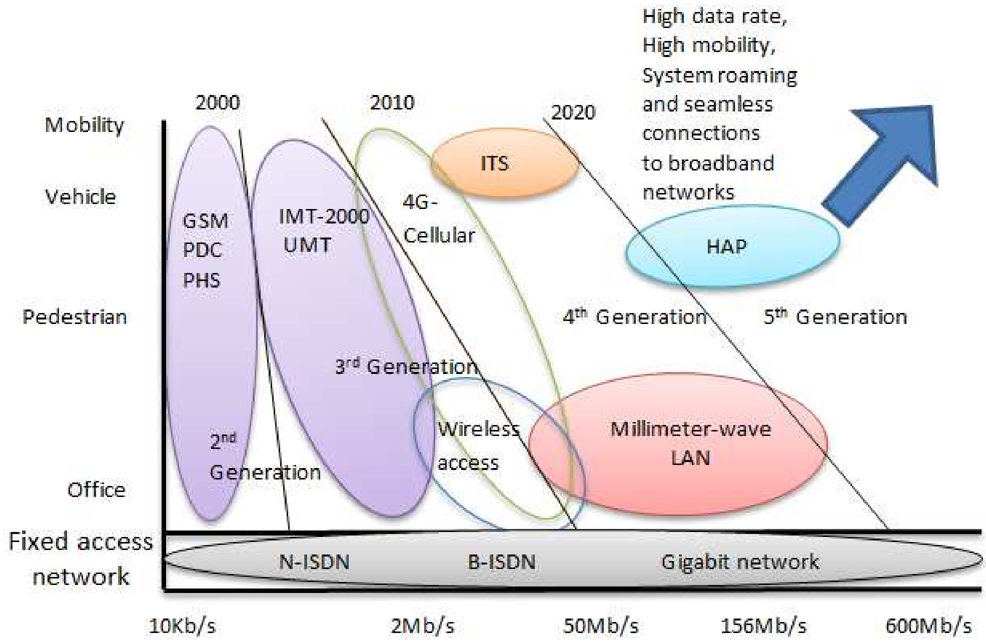

Figure 1.1 Generation of Mobile Communication Techniques [1]

Future generations such as 4 G and 5 G have been reviewed widely [1-3]. The candidates for future systems are: 4 G - cellular, Broadband Wireless Access (BWA) and High Altitude Platform (HAP). These technologies have to satisfy the growing demands of high data rate, high mobility, and seamless coverage. As well as, the system performance e.g. cell size and transmission data rate, greatly depends on frequency bands.

Recently, mobile communication services are in high demand and used widely. Therefore, advanced wireless techniques and ubiquitous infrastructure is required to meet the demand and harness the significant radio spectrum. Various limitations with current wireless mobile communication technologies has therefore attracted the researcher's interest to find a new technology which could meet the telecommunication requirements and coexist with current communication technologies.

Consequently, HAPs have been identified as the candidate technology to provide wireless communications in the future. It has also been considered as an infrastructure of the third layer of telecommunications after satellite and terrestrial services [4-6]. An innovative way of overcoming the shortcomings of both the terrestrial and satellite systems is to provide cellular communication via HAP, which is being considered as 5 G. HAP is defined as an airship or a platform with a massive potential [6, 7]. In this evolution process of wireless telecommunication technology, from 1 G to 5 G, Quality of Service (QoS) has received much attention, considering the requirements of various consumer applications.

This chapter therefore provides an introduction to mobile wireless communication technologies followed by a review of previous research studies on hybrid Networks (satellite and terrestrial wireless technologies, particularly Worldwide interoperability for Microwave Access (WiMAX), Digital Video Broadcasting Return Channel through Satellite (DVB-RCS), Long Term Evolution – Advance (LTE-A) and HAP to connect these technologies with the kind of QoS which they support.

1.2. Mobile Wireless Communication Technologies

Mobile wireless communication technologies provide connectivity to various users living either in urban area or sub urban area or in the rarely populated rural area. Mobile communications systems have revolutionized the way people communicate, getting connected together, on the fly.

The 1G has fulfilled the basic mobile voice, while the 2G has introduced capacity and coverage. This is followed by the 3G, which has quest for data at higher speeds and to open the gates for truly “mobile broadband” experience, which will be further realized by the 4G [8]. 4G provides access to wide range of telecommunication services, including advanced mobile services, as supported by mobile and fixed networks.

Some important mobile communication techniques are: Global System for Mobile Communications (80% Users*) (GSM) [9], General Packet Radio Service (over 80% Users*) (GPRS) [10], WiMAX (83% Users*) IEEE 802.16 [11].

1.3. Recent advances in Mobile Wireless Communication

Mobile Wireless communication technologies are being developed with different standards and protocols.

1.3.1. Worldwide interoperability for Microwave Access (WiMAX)

WiMAX is based on the IEEE 802.16e standard and operates in the spectrum bands of 2.3 GHz, 2.5 GHz, 3.3 GHz, and 3.4-3.8 GHz. The coverage area of WiMAX spans 30 - 50 km and provides high speed of data rates more than 100 Mbps in 20 MHz bandwidth [12]. WiMAX can inter work with satellite and terrestrial wireless existing as well as emerging technologies. WiMAX is an effective metropolitan area access technique with many encouraging features such as cost efficiency, fast, and flexibility [13], which provides wireless access as well as serves as a wireless expanding for wired network access.

*World

1.3.2. Long Term Evolution-Advanced (LTE - A)

LTE - A is new technology that allows users with option of various access [14]. LTE - A started working as the demand for mobile broadband services with higher data rates and QoS are increasing. LTE-A is intended to define both the Radio Access Network (RAN) and the network core of the system. Akyildiz et al. (2010) have provided an in depth view on the technologies being considered for LTE-A [14].

The main technologies for LTE-A are explained, together with possible improvements and some approaches that have been considered to tackle those challenges [15]. They have also discussed carrier aggregation structure LTE - A with reference to LTE release 10 to scale the system bandwidth beyond 20 MHz up to 100 MHz [15].

1.3.3. Satellite

Satellite systems will always have the key role to play, may it be for any ordinary or during emergency situations. An in depth review, modulation, QoS, synchronization methods and security issues have been reported in [16]. Very Small Aperture Terminal (VSAT) offers satellite-based services which supports data, voice and teleconference communications, dependable private and public network communications across geographically distributed locations [17, 18]. A VSAT setup consists of three components namely master earth station, remote earth station, and geostationary satellite. VSAT technology is a proven solution for those who are interested in independent communications connecting areas.

Other satellite technologies can also be used as distribution networks such as Digital Video Broadcasting (DVB) of Satellite (DVB - S) which allows unidirectional links while DVB - Return Channel through Satellite (DBS -RCS) supports bi-directional links. Song et al. (2006) presented the design of a Mobile Broadband Interactive Satellite Access Technology (MoBISAT), based on DVB-S/ DVB-RCS standard. MoBISAT system is described as a solution of mobile broadband interactive satellite multimedia service. The DVB-RCS operates mainly Ku bands with transmit frequency band 14 to 14.5 GHz and receive frequency band 10.7 to 12.2 GHz [19].

1.3.4. High Altitude Platforms

In a ground breaking article [6], in September 1997, again called the attention of the international community to the then ‘emergent’ technology and its potentials for serving the ever-growing need of telecommunication service subscribers. In the succeeding year, ITU published a report titled “High Altitude Platform stations: An Opportunity to Close the Information Gap” to outline the HAP technology [20]. Ever since then, several studies have been carried out. Three years later, Thornton et al., have shown the applications and features of HAP, along with some specific development programmes [21].

In recent years, the HAP infrastructure for mobile wireless communication technology has gained the attention of wireless world. HAPs are quasi-stationary aerial platforms located at a height of 17–22 km above the earth’s surface and operate in the stratospheric region of the atmosphere [21-25]. HAPs exploit the best features of both terrestrial and satellite communication systems in many ways, i.e. large area coverage and low propagation delays, and hence strong signals as compared to satellites. They also offer better broadcast/multicast capability, low upgrading cost, incremental deployment, less ground-based infrastructure, and short landing and takeoff times for maintenance purposes [26].

1.4. Comparison of Mobile Wireless Communication Technologies

In this section, comparison of various wireless technologies has been done. Table 1.1 gives a general overview of the Hybrid mobile wireless technologies, standards, modulation techniques, data rate, bandwidth and frequency [27].

Table 1.1 Comperson of Advence Mobile Wireless Technologies [27]

Technology	**1G**	**2G**	**3G**	**4G**	**5G**
Deployment	1970/1984	1980/ 1999	1990/ 2002	2000/ 2010	2010/ 2015
Bandwidth	2 kbps	14.4-64 kbps	2 Mbps	200 Mbps-1 Gbps	Higher than1 Gbps
Standards	AMPS	2G: TDMA, CDMA, GSM 2.5G: GPRS, EDGE,1xRTT	WCDMA, CDMA-2000	Single unified standard	Single unified standard
Technology	Analog cellular technology	Digital cellular technology	Broad bandwidth CDMA, IP technology	Unified IP and seamless combination of broadband ,LAN/WAN and WLAN	4 G + wwww
Service	Mobile telephony (voice)	2G: Digital voice, short messaging 2.5G: Higher capacity packetized	Integrated high quality audio, video and data	Dynamic information access, wearable devices	4 G with AI capabilities
Multiplexing	FDMA	TDMA,CDMA	CDMA	CDMA	CDMA
Switching	Circuit	2G: Circuit 2.5G: Circuit for access network	Packet except circuit for air interface	All packet	4 G
Core Network	PSTN	PSTN	Packet network	Internet	Internet
Hand-off	Horizontal	Horizontal	Horizontal	Horizontal and Vertical	4 G

1.5. Quality of Service (QoS)

QoS refers to the ability of mobile wireless communication networks to provide superior guaranteed services on selected network traffic using various technologies and to prioritize different applications to the committed level of performance. The future requirements from wireless networks is to provide pervasive coverage across diverse technologies offering a wide range of services with variable bandwidth and QoS, anytime, anywhere for anyone [3]. The goal of QoS is to provide requisite bandwidth, control delay and priority to traffic required by real time and interactive applications (the user). The integration of satellite and terrestrial wireless networks is normally evaluated on the basis of QoS, availability and cost. QoS in a mobile wireless networks is very complicated and difficult to predict [28]. QoS requirements for multimedia applications such as audio and video conference are: specified bandwidth, delay and jitter guarantee [29].

The QoS to subscribers and the concept of network quality manager tool to monitor quality of experience, QoS and key quality indicator for users are discussed in [30]. This study ensures that QoS can be set for each subscriber user group. However, this study does not consider the cost implications for different level of QoS. The end-to-end QoS functionalities are QoS control, resource management and bandwidth on demand [31].

Miloucheva et al. (2007) studied various approaches on QoS advances for mobile applications and proposed advance resource allocation architecture to provide seamless handover for QoS aware applications [32]. On the other hand, in satellite communication, the packet loss is due to several reasons, including jitter and noise in the satellite channel itself [33]. Typical latency for Geostationary Earth Orbit (GEO) one way is 275 ms from earth station to earth station.

1.5.1. QoS in WiMAX

The QoS in Wi-Fi relates to bandwidth [34] with maximum rates specified in IEEE Wi-Fi 802.11 standards. Distributed Coordination Function (DCF) mode in the IEEE 802.11 standard delivers Best Effort (BE) service [35] and there is no guarantee for service in terms of delay and bandwidth.

Ni et al. (2007) studied the comparison of delay Vs performance characteristics of two bandwidth request mechanisms as per the 802.16 standard i.e. random access and polling [36]. The five QoS categories are included such as UGS (Unsolicited Grant Service), rtPS (real time Polling Service), nrtPS (non real-time Polling Service, Extended rtPS and BE [11]. The rtPS and BE are common services. The rtPS supports real time service flows while for BE there is no priority for this service and it is available on required basis.

1.5.2. QoS in LTE-A

LTE has been designed with further improved multiple data services with enhanced QoS. In this process, LTE packet scheduling plays an essential role as part of LTE's Radio Resource Management (RRM) to enhance QoS requirements of mobile services. There are specialized models that are used to sustain the QoS against dynamically changing user load [37]. This study has used algorithms for scheduling and prioritizes traffic based on the requirements of users. In majority situations user priority will be classified based on the QoS as indicated by his priority settings [37].

1.5.3. QoS in Satellite

In the current telecommunication scenario, applications are continuously growing and as a consequence the total amount of traffic that must be managed is dramatically increased. For this reason QoS issues have become extremely important. In fact, QoS - oriented solutions for satellite broadcasting systems is discussed in [38].

Vargas et al. (2010) discussed with more detail the analysis of different methods for constructing a satellite broadcasting system with different levels of QoS in the framework of the DVB–SH standards [38]. The proposed solutions have also been extended by [39, 40] in the adaptive call admission and bandwidth control in DVB - RCS systems. Pasqiuale Pace et al. (2004) designed and tested a DVB-RCS architecture using a multi-spot beam geostationary satellite [41]. In this study they have reported that by using the Connection Admission Control algorithm it is possible to obtain a given source peak data rate increase (up to the 50%) over the return link without the necessity of again performing the CAC procedure. This also guarantees QoS for different types of supported services.

1.5.4. QoS in HAP

In the early days of mobile wireless communications, the systems suffered from poor coverage and poor performance in terms of blocking probability and dropping probability. Differences in QoS properties between satellite and terrestrial wireless networks and applications have a considerable effect on the performance quality.

Satellite communications enforce particular constraints as compared to terrestrial systems in terms of bandwidth, delays, jitters, latency and so on. Here, the CAC is required to manage the bandwidth required to satisfy the QoS requirements for different applications. Also, a lot of investigations on diverse parameter of QoS in conventional terrestrial and satellite systems have been already reported in previous sections of this write-up. However, to our best knowledge, QoS for HAP are not much investigated. Therefore, the QoS requirement and respective techniques to enhance QoS for HAP are such as hand-off, channel reservation, CAC etc. have been investigated in this thesis.

1.5.5. QoS: The Techniques & Processes

In order to provide guaranteed QoS, the network architecture for mobile wireless communication networks should generally consist of certain components such as: traffic specification, call admission control, resource reservation, packet scheduling etc.

The end user uses a traffic specification procedure to specify the source traffic characteristics and desired QoS. Then, the base station employs QoS to find path(s) between source and destination(s) and check whether destination has sufficient resources to support the requested QoS.

In each BS there are Radio Network Control (RNC) which characterizes the wireless channel as the statistical measure of QoS delivery e.g. available channels, data rate, delay, user characteristics and requirements. This information is then used by CAC. CAC is used to decide whether a connection request should be accepted or rejected, based on the requested QoS. If a connection request is accepted, resource reservation at each network node allots resources such as wireless channels, bandwidth, and buffers that are required to satisfy the QoS guarantees.

The next-generation of mobile wireless networks is aimed at supporting diverse QoS requirements and traffic characteristics. The success in the deployment of such networks will critically depend upon how efficiently the wireless networks can support traffic flows with QoS guarantee [42]. To achieve this goal, QoS provisioning mechanisms (e.g. CAC, resource reservation and traffic specification etc.) need to be efficient and practical. For this reason, this work has focused primarily on designing efficient and practical CAC, resource reservation and traffic specification.

1.6. The Possibility of Coexistence

One of the key objectives of future mobile communication systems is the seamless integration and delivery of advanced multimedia services through heterogeneous networks e.g. Fixed Wireless Access (FWA), GSM, UMTS, WiMAX, LTE, Wi-Fi, HAP, Satellite based communication systems etc. Coexistence means that more than one system is providing communication services in the same coverage area and by operating in the same frequency band [43]. Tseng et al.(2013) have investigated coexistence of multiple radio access technologies to improve spectral efficiency. This study presented a game-theoretic network selection scheme in a cognitive heterogeneous networking environment with time-varying channel availability [44]. Coexistence of such systems especially HAP with terrestrial systems can be possible after mitigating mutual interferences by using different methods [45-48].

1.6.1. Coexistence of Mobile Wireless Techniques

Increasing demand for more capacity in the next generations of mobile wireless techniques and applications, the radio environment is split into a number of small cells supported by a large number of transmission stations and mobile devices may be transmitting at a shared frequency band in the same geographic area. This has been realized in the applications of Wi-Fi, Bluetooth and WiMAX i.e. by using heterogeneous devices in shared frequency bands [49, 50].

1.6.2. Coexistence of Terrestrial and Satellite Based Comm. Systems

Many communication applications are very similar, both in terrestrial and satellite networks and can benefit from the advancement of mobile wireless techniques. Salhani et al. (2009) focused on class to service mapping using CAC procedures in WiMAX, in coexistence with DVB-RCS based cooperative system for sharing both the satellite and terrestrial communication networks [51]. Also, Centonza et al. (2006) proposed a hybrid network solution for the coexistence of WiMAX and DVB-RCS [52]. The proposed architecture employs DVB-RCS as a backhaul for content delivery in WiMAX domains.

Evans et al. (2005) discussed an integration of satellite communication with terrestrial networks and proposes that there is a need for integration of satellite systems with terrestrial systems as satellite systems cannot exist in isolation except in niche areas [3]. Also, Chitra et al. (1995) discussed the integration of satellite and terrestrial networks for communication for remote coverage and access in rural areas with bandwidth on demand feature [53].

1.6.3. Coexistence of HAP and Terrestrial WiMAX Based Networks

HAP can effectively coexist in a heterogeneous radio environment. Therefore, it is a competitive solution both in urban and suburban region, in terms of capacity and coverage. These features make HAP a viable competitor and a complement to conventional terrestrial infrastructures as well as to satellite systems [54, 55]. Alsamhi et al. (2014) discussed the performance of delivering broadband services from HAP to users and other systems users [56]. The investigation objectives are concerned with delivering WiMAX via HAP in the same and shared frequency band. Holis et al. (2008) and Yang et al. (2005) have investigated the performance of terrestrial and HAP based services and have founded the possibility of coexistence by calculating CNR and CINR [57, 58]. The capability of HAP for serving larger coverage areas using considerably less ground infrastructure than conventional terrestrial systems has also been investigated [59]. Here, different coexistence and deployment techniques for reducing the interference from HAP to terrestrial systems and for improving the cellular system performance has been investigated [60, 61]. The system scenario consists of a single HAP and WiMAX located inside the HAP coverage area as in Figure 1.2.

The main purpose of this coexistence scenario is to investigate the impact on either of the existing HAP or WiMAX system, typically when another system is using the same frequency band.

Spectrum etiquettes are used for such combinations and enable the coexistence of HAP and WiMAX system in same coverage area [43]. Hence, coexistence of HAP and WiMAX requires a minimum separation distance which must be achieved in terms of both co-channel and adjacent channel frequencies.

The important feature of HAP is that it is compatible with other existing services which led to conduct several researches on its coexistence while sharing the same frequency band and by mitigating interference between HAP and other terrestrial systems [55, 56, 62, 63].

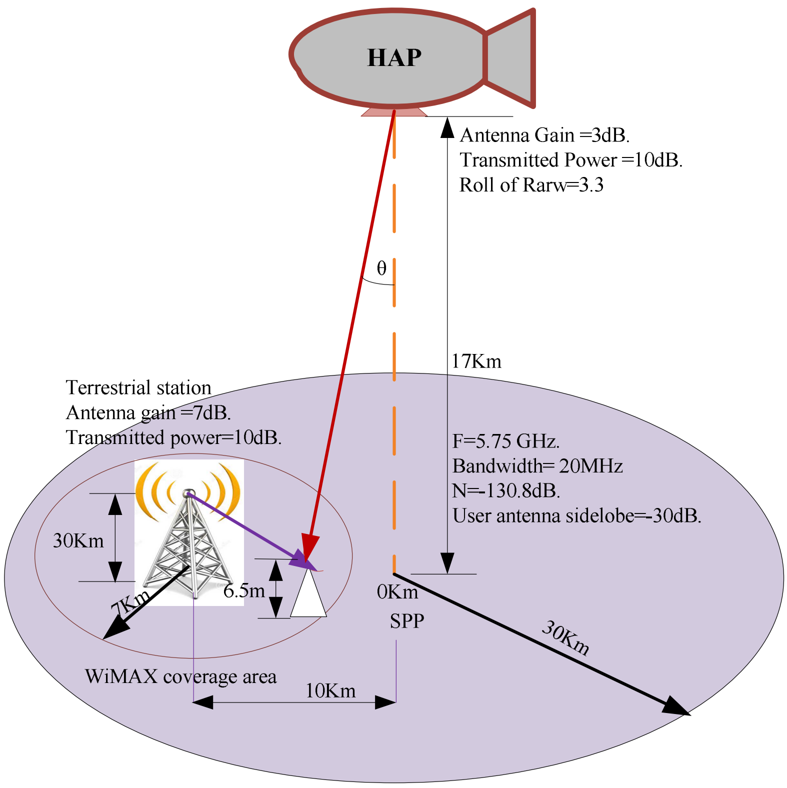

Figure 1.2 Coexisting HAP and Terrestrial BS Scenario

1.7. Performance of Integrated Terrestrial-HAP and Satellite Systems

Generally conceptual framework of heterogeneous wireless systems incorporating HAP for the next generation communication is shown in Figure 1.3. The environment is built to imitate an HAP system to coexist in a heterogeneous radio environment, which includes the well-established terrestrial and satellite systems. These systems have illustrated the growing demand for broadband mobile communications due to their rapid development.

As positioned intermediately between the satellite and terrestrial systems, HAPs can be integrated into a terrestrial - satellite communication scenario and possibly communicate with satellites or remote ground BSs as an alternative back haul. Communications between different HAPs in the overlapping or adjacent coverage areas could happen commonly referred to as inter-platform communications.

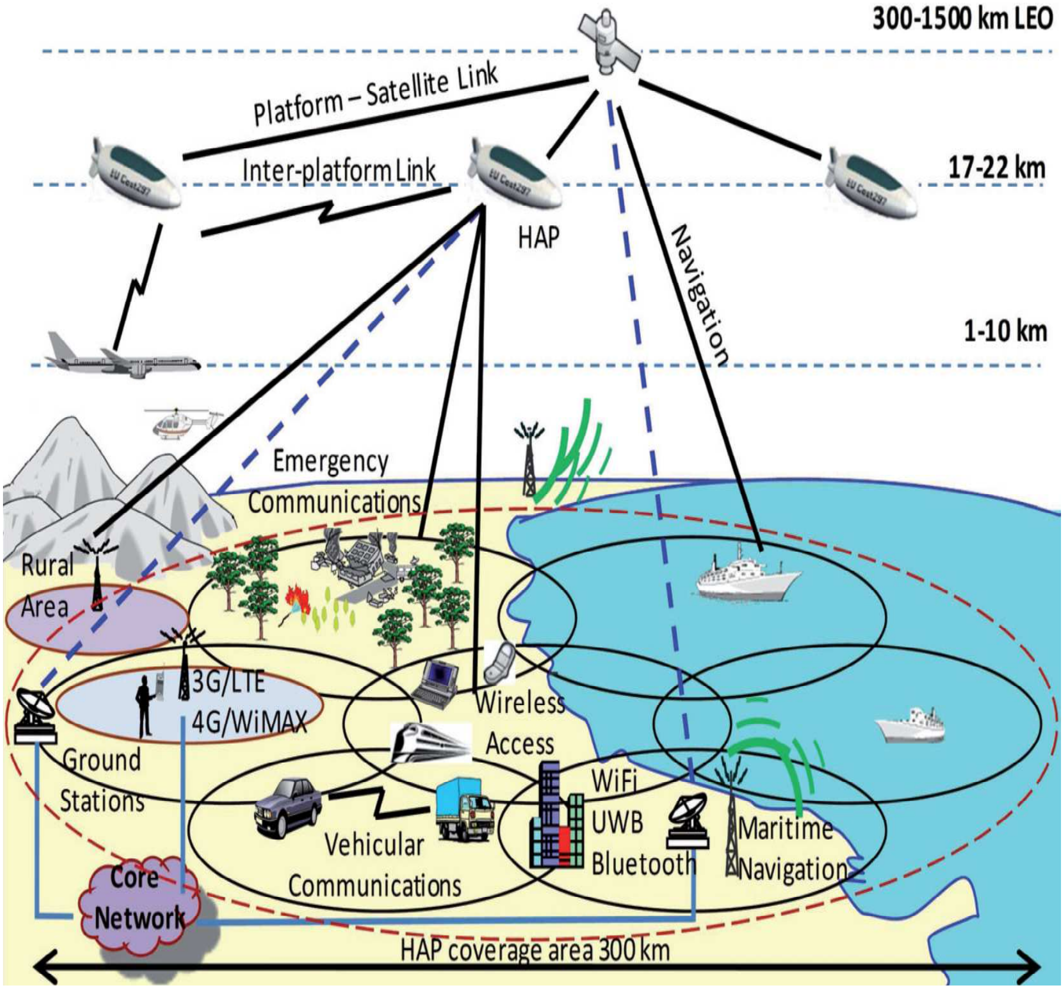

Figure 1.3 Heterogeneous Wireless Systems Incorporating HAP [64]