CHAPTER 16

Recent Advances

16.1 Introduction

Wireless and mobile technology has been advancing at an unparalleled rate and its impact is being observed in many facets of our daily lives. Recent advances and future directions are being explored for home, industrial systems, commercial, and military environments. In a house, a central access point (AP) is expected to communicate with various appliances and control them using wireless mode, even from a remote location. HomeRF, Bluetooth, and Jini projects, which are being pursued by a consortium of companies, seem to represent a significant step in this direction. A system like this could support a bracelet, which would constantly monitor various body functions and parameters and indicate abnormalities. However, a lot more effort is needed before such a system can be realized.

In commercial applications, the issues are the range of the system, the number of APs, and the number of users for each AP. For example, in a department store, each floor may have one AP, while in a factory, several uniformly spaced APs per floor may be needed. The communication could be either voice or data packets, or a combination of both. In defense applications, effective communication could be achieved using either an infrastructure system, or could be supported by a decentralized, peer-to-peer, MANET formed with close-by mobile users. In all these systems, security both in terms of authentication and encryption is critical. It is important to optimize power usage and routing table size and sustain a path during a transmission session in MANETs.

A wireless system, in general, is expected to provide "anytime, anywhere" service. This feature is essential only for military, defense, and a few critical areas such as nuclear power, aviation, and medical emergencies. For most applications, "many times, many where" attributes may be adequate. Attempts are being made to move intelligence to the user side as much as possible, and usage charges based on service time and not purely on connection time are being considered. Emphasis is on a scalable communication paradigm. Different kinds of mobility, are being characterized, and the corresponding effect on handoff in various layers needs to be examined. To minimize handoff, the use of a macrocellular infrastructure and multilevel overlapped schemes being investigated are for users with different mobility characteristics. However, it may be better to have a large number of small cells, rather than a few larger cells. On the other hand, small cells cause frequent handoffs, especially for highly mobile users. Therefore, there is a tradeoff, and an optimum solution may depend on service requirements and mobility characteristics.

In second-generation wireless systems, the emphasis was on voice communication, and data loss was not considered. Now, there is a need to provide seamless Internet access, and ways to handle integrated voice and data traffic need to be examined carefully. Third-generation systems must support real-time data communication, while maintaining compatibility with existing second-generation systems. Also, the kind of language support needed to provide a seamless Web access in the sky needs to be examined carefully. The future direction in the wireless and mobile systems area was summarized in a recent National Science Foundation–sponsored workshop [16.1].

A recent FCC approval of additional frequency bands has encouraged the use of ultra-wideband (UWB) communication technology, as multimedia applications demand a lot of bandwidth. This also necessitates the use of a unified model to represent voice and data over mobile IP. One approach being explored is to classify packets as real-time and non–real-time and control the bandwidth by assigning priority to both handoff and real-time calls. This could be considered as an attempt to satisfy QoS for different applications, including protocols for multimedia service as applied to laptops, PDAs, Palm Pilots, and cell phones. The multimedia traffic often needs to be multicasted to a group of subscribers, and each type may need a slightly different type of support.

Another class of networks, described as MANETs, is being explored for numerous applications, and it is important to look at how routes in these networks could be maintained for successful transmission of information between two arbitrary MSs. In this respect, Femtocells, Bluetooth, Wi-Fi, WiMAX devices, and mesh networks are adding another dimension by augmenting existing wireless capabilities. A system-level adaptation of wireless devices employing a minimum level of interaction is desirable, and the impact of software portability and language constraints should be examined carefully. Security issues are critical in all such systems. Many of these are discussed here as an indication of future research endeavors. In this chapter, we consider some of the research areas being pursued in wireless systems.

16.2 Femtocell Network

16.2.1 Introduction

Rapid growth in wireless telecommunication has really encouraged the industry to develop new advanced cellular standards such as 3GPP's UMTS and LTE; 3GPP2's CDMA2000, 1x, EV-DO and WiMAX. High data rate and seamless coverage are always an important objective in developing a wireless system. However, to achieve higher data rate, high-frequency band radio signals used as carrier frequency in existing cellular standard may have difficulty in penetrating walls. Therefore, signal strength is weak inside buildings, or there are no signals at all for wireless handsets. This weakness causes large coverage holes in the macrocell base station (M-BS).

According to a recent study [16.2, 16.3], more than 50% voice calls and more than 70% data traffic start from an indoor environment, which implies that indoor coverage holes in cellular systems have a significant effect on customers' satisfaction. An easier solution is to deploy some indoor devices serving only the indoor users (MSs). Femtocell Network, viewed as an effective way to remedy coverage holes, has been proposed and is being developed rapidly. We present a brief introduction to Femtocell Network infrastructure, associated features, and underlying technical issues.

16.2.2 Technical Features

Femtocell Network, which is a small-size Macrocell network designed for better indoor coverage, began attracting attention from both industry and academy in late 2007. The "femto" means 10^{-15}. Coverage of Femtocell Network is much smaller than a regular Macrocell Network, and that is why this name is given. Femtocell Network, installed by end users at home or in an office environment, connects a small number of MSs with the telephony core network via the Internet. Similar to UMTS Terrestrial Radio Access Network (UTRAN) architecture, the Femtocell Network consists of three components: Femtocell Base Stations (F-BSs), Internet Link, and Femtocell Gateway (FGW).

Femtocell Base Station (F-BS)

Femtocell Base Stations (F-BSs) are short-range, low-cost, low-power indoor devices to provide service for wireless handsets. F-BS, which looks like WLAN Access Point (AP), is a small device with at least two wireless and internet interfaces.

- **Wireless Interface:** This provides wireless radio access to Femtocell MSs. Any existing wireless telecommunication standard, such as UMTS/CDMA200/WIMAX/LTE/EV-DO, can be used at the F-BS wireless interfaces.
- **Internet Interface:** F-BS Internet interface can be connected to users' broadband internet DSL or cable modem. Some F-BS internet interfaces are only allowed to connect to wireless cellular companies own broadband internet, while others can be connected to any ISP internet.

Internet Link

Internet Link is a regular ISP broadband Internet connecting multiple F-BSs with an FGW. Although F-BSs are connected to the Internet similar to an Ethernet connection, different technologies are utilized in the Internet link based on wireless infrastructure.

Femtocell Gateway (FGW)

Femtocell Gateway (FGW) is a service provider's device that acts as a gateway between the Internet and the communication network. One side of FGW connects a large number of F-BSs via broadband Internet, and the other side of FGW is connected to the telephony core network with the dedicated wired link of the service provider. A conceptual Femtocell Network infrastructure is shown as Figure 16.1. In contrast with traditional M-BS, F-BS is connected to FGW via public access Internet, bringing a fundamental change in the network infrastructure.

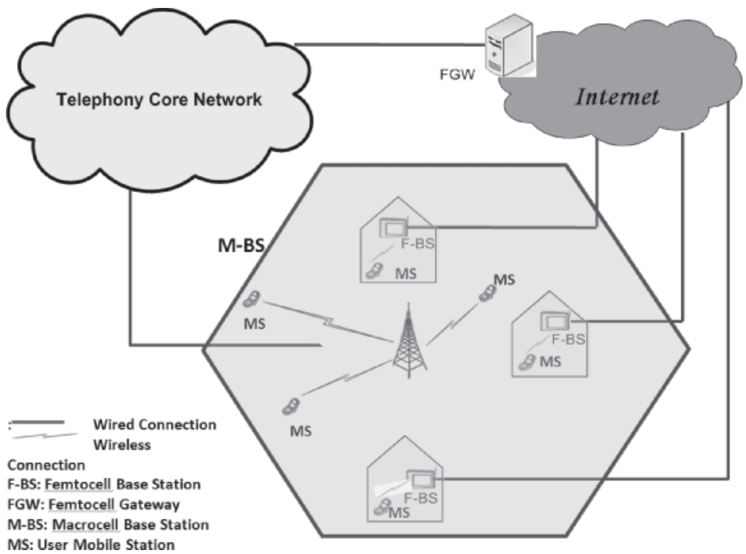

Figure 16.1 Femtocell Organization.

Benefits of Femtocell Network

Femtocell Network is a so-called "double-win" strategy that brings benefits to both cellular users and cellular providers. Some of the specific advantages for **cellular users** include

- Improved, seamless coverage
- Enhanced capacity
- Lower transmit power
- Prolonged handset battery life
- Higher signal-to-interference-noise ratio (SINR)

The benefits for **cellular providers** include

- Improved Macrocell BSs reliability
- Offload data traffic from the Macrocell BSs

- Increasing area spectral efficiency
- Cost benefits

F-BS versus M-BS

F-BS and M-BS (mobile base station) are both designed to serve the wireless MSs and hence have many common characteristics. F-BS is also called mini-Macrocell Base Station in the literature. Comparing to M-BS, we could have a better understanding to F-BS. Comparison between F-BS and M-BS are shown in Table 16.1.

Table 16.1: ▶
Comparison between F-BS and M-BS

Characteristics	Femtocell	Macrocell
Air interface	Telecommunication standard	Telecommunication standard
Backhaul	Broadband Internet	Telephony network
Cost	$200/year	$60,000/year
UE power consumption	low	high
Radio range	10-50 meters	300-2000 meters

F-BS VS WLAN Access Point

Wireless LAN, as one of most popular wireless network technologies, has mostly been deployed in a home or office environment. Like WLAN, Femtocell Network is also for serving indoor wireless users. However, there are several clear differences between F-BS and WLAN AP from technical aspects. These are listed in Table 16.2.

Table 16.2: ▶
Comparison between Femtocell Network and WLAN

Characteristics	F-BS	WLAN AP
Spectrum	Licensed	Unlicensed
Wireless MAC	Connection-based	Contention-based
Backhaul	Broadband Internet	Broadband Internet
Power	100mW	~1.5 W
Air interface	Telecommunication standard	802.11a/b/g/n
Range	10-50m	35-70m
Service	Primarily voice	Primarily data
Current cost	$200-$250	$50-$100

16.2.3 Challenges

Several wireless network companies and manufacturers have released their F-BS products, and multiple wireless service providers have already started field trials in some regions. However, the performance of existing devices is still far below users' expectation. A large number of research challenges are yet to be addressed, and many technical issues are discussed here.

Interference

A large number of F-BSs and one M-BS coexist in the same Macrocell region. The M-BS could utilize the entire available frequency spectrum in wireless standards so as to achieve higher spectrum efficiency. To serve small numbers of subscribers, F-BS could use either the whole frequency spectrum or a part of the spectrum. It is not possible to avoid operating frequency overlap between F-BS and M-BS. The interference falls into two categories: interference between many Femtocells or interference between a Femtocell and a Macrocell.

The spectrum overlapping brings us a two-tier network infrastructure in one Macrocell. Due to this characteristic, interference is a key issue in Femtocell Network.

Quality of Service (QoS)

As Femtocell Network utilizes nondedicated broadband Internet, QoS has become an important issue. F-BS might share Internet backhaul with WLAN AP and LAN Hub/Switch at home or in the office. A cellular provider has no control over the Internet link in allocating higher priority to F-BS traffic. A QoS scheme needs to be carefully designed for cellular users' delay-sensitive traffic.

Access Control

F-BS could be operated in three basic access control modes: open, closed, and hybrid.

- Open access mode: In open access mode, all cellular users belong to open subscribers group (OSG) and can access F-BS unconditionally. Several cellular service providers have plans to deploy F-BS for better service quality to cover public hole areas.
- Closed access mode: In this mode, a closed subscribers group (CSG) is set by F-BS owner to allow only small portion of cellular users to be served in the Femtocell Network. For example, people can install F-BS in their house and only household members can access F-BS to attain better service. No other handset can access their F-BS.
- Hybrid access mode: Hybrid access mode is the trade-off between open and close access mode.

Handoff

Since a large number of F-BSs could be installed by users in one Macrocell, a desirable handoff procedure needs to be developed. Three hand off categories are possible.

- Hand-Out: user handset handoff from a Femtocell to a macrocell
- Hand-In: user handset handoff from a Femtocell to a macrocell
- Hand off: user handset handoff from a Femtocell to close-by another Femtocell

Handoff issues such as unnecessary handoff and frequent handoff must be addressed before it is possible to have high-density large-scale F-BS deployment.

Synchronization

Several network operations, such as hand off, minimizing multi-access interference, ensuring a tolerable carrier offset, depend on accurate synchronization schemes. Software solutions such as precision timing protocol over IP and hardware solutions such as GPS or high-precision crystal oscillators have been proposed.

Self-Configuration, Self-Operation, and Location Tracking

F-BS is a user-installed device and it should integrate itself into the telephony core network. A configuration function should be capable of adjusting parameters under various environments. Self-operation is also desirable in the WiMax network. For example, handoff and radio resource management (RRM) can be directly controlled by F-BS and M-BS. Location tracking function is a mandatory requirement, other than a service function in F-BS. At the least, regulatory laws and emergency calls make location tracking an unavoidable issue.

Security Issues

Traditional M-BS is connected to the telephony core network by a dedicated link from the service provider. In contrast to M-BS, F-BS is connected to FGW via broadband Internet. Both 3GPP and 3GPP2 have proposed a secure link between F-BS and FGW based on the IPsec and IKEv2 standards. However, F-BS backhaul broadband Internet can be accessed by anyone, including hackers. Therefore, all security problems could also be issues in Femtocell Network.

16.2.4 Concluding Remarks

Femtocell Network has the capability to help Macrocell Network achieve seamless coverage and attain higher network capacity by transmitting over an Internet link. Although Femtocell Network has gained a rapid development in a short time, many technical challenges remain to be overcome, and F-BS device cost must be lower before large-scale deployment can occur.

16.3 Ultra-Wideband Technology

Ultra-wideband (UWB) technology, also known as impulse or zero-carrier radio technology, appears to be one of the most promising wireless radio communication technologies of our time. Unlike conventional radio systems, which operate within a relatively narrow bandwidth, the UWB radio system operates across a wide range of the frequency spectrum by transmitting a series of extremely narrow (10–1000 per second) and low-power pulses [16.4]. The low-power signaling is accomplished by reusing previously allocated RF bands by hiding the signals under the noise floor of the spectrum [16.5]. When properly implemented, UWB systems can share this spectrum with other traditional radio systems without causing noticeable interference and provide a highly desirable way of easing the bottleneck due to the scarcity of the radio spectrum [16.5].

This technology is not an entirely new concept. Some early pioneers—Heinrich Hertz [16.6] and others—used spark gaps to generate UWB signals even before sinusoidal carriers were introduced at the beginning of the 20th century. However, only recently, has it been possible to generate and control UWB signals and apply modulation, coding, and multiple-access techniques to make UWB attractive for wireless communication applications [16.6]. Early UWB systems were developed mainly as a military surveillance tool, because they could "see through" trees and walls and below ground surfaces. Now, UWB technology is focused on consumer electronics device communications as well.

16.3.1 UWB System Characteristics

The UWB signal is defined as a signal with bandwidth greater than 25% [16.7, 16.8] of the center frequency or with bandwidth greater than 1 GHz. This wide bandwidth makes it possible to share the spectrum with other users. Recent results reveal that UWB signals are naturally suited for location-determination applications. There are several methods of generating these UWB signals. Two of the popular methods are low duty cycle impulse UWB implemented as time modulated—UWB (TM–UWB), and high duty cycle direct sequence phase coded UWB (DSC–UWB) [16.7]. Wide spectra are generated in these two methods. The propagation characteristics and application capabilities vary considerably in these two methods [16.7].

- **TM–UWB technology**: The basic element in TM–UWB technology is the monocycle wavelet. Typically, wavelet pulse widths are between 0.2 and 1.5 nanoseconds, corresponding to center frequencies between 600 MHz and 5 GHz. The pulse-to-pulse intervals are between 25 and 1000 nanoseconds [16.7]. In TM–UWB, the system uses a modulation technique called pulse position modulation [16.7]. The TM–UWB transmitter emits ultra-short monocycle wavelets with tightly controlled pulse-to-pulse intervals, which are varied on a pulse-by-pulse basis in accordance with an information signal and a channel code. The modulation makes the signal less detectable, as the signal spectrum is made smoother by the modulation [16.7]. A pulse generator generates the transmitted pulse at the required power. The transmitter also has a picosecond precision timer that enables precise time modulation, pseudonoise (PN) encoding, and distance determination. The TM–UWB receiver directly converts the received RF signal into a baseband digital or analog output signal with the help of a front-end cross correlator. There is no intermediate frequency stage, which reduces the complexity of the transmitter and the receiver design [16.7]. Generally, multiple monocycles carry a single bit of information, and at the receiver these pulses are combined to recover the transmitted information. The precise pulse timing inherently enables accurate positioning and location capability in a TM–UWB system [16.7].

- **DSC–UWB technology**: A second method of generating useful UWB signals is the [16.7] DSC–UWB approach. Here, the signal is spread by direct sequence modulating a wavelet pulse trains at duty cycles approaching that of a sine wave carrier [16.7]. The spectrum spreading, channelization, and modulation are provided by a PN (pseudonoise) sequence, and the chipping rate is maintained as some fraction of the carrier center frequency.

16.3.2 UWB Signal Propagation

Fundamentally, UWB impulse wavelets propagate by the free space law. The coherent interaction of signals arriving by many paths causes the Rayleigh or multipath fading in RF communications. Inside buildings, when continuous sine waves are transmitted wherein the channels exhibit multipath differential delays in the nanosecond range, the multipath fading occurs naturally [16.7]. This issue cannot be resolved by relatively narrowband channels, and hence a significant Rayleigh fading effect must be contended within systems such as IS-95.

Properly designed UWB systems can have bandwidths exceeding 1 GHz and are capable of resolving multipath components with differential delays of a fraction of a nanosecond. For example, when a monocycle arrives at the receiver using two different paths [16.7], the receiver can lock on to either pulse and receive a strong signal. More than one correlator can be used to lock on to different signals, and energy from the signals can be added, thereby increasing the received S/N. It is natural and possible that a given pulse may interfere with another late-arriving reflection from the previous pulse in a train of transmitted pulses. However, these interfering pulses can be ignored, as each individual pulse is subject to PN time modulation and more than one pulse carries the bit energy. Consequently, this multipath interference may not cause any loss at an UWB receiver; instead, in an in-building environment the UWB system architecture can improve the performance (S/N) by 6 to 10 dB [16.7].

16.3.3 Current Status and Applications of UWB Technology

The application of UWB technology was once restricted to military, police, and firefighter systems. However, in early 2002, the FCC cleared the way to use UWB technology for commercial wireless applications. Concerns about interference with frequencies currently in use by radio, TV, and mobile phone carriers prompted the

FCC to put restrictions on which frequencies UWB could be operated in, taking special care to avoid interference with those used by the military and GPS services. Various companies and research organizations around the world have been involved in developing prototype applications to study the feasibility of commercial use of UWB technology. TM–UWB has the potential to create more bandwidth in the increasingly crowded radio spectrum. This technology has three distinct application capabilities [16.7]: communications, advanced radar sensing, and precision location and tracking.

The noiselike spectral characteristics of UWB signals enable secure communication with a greatly reduced probability of detection. Short pulse wavelets of TM–UWB that are relatively immune to multipath interference are suitable for robust in-building communications, especially in urban areas [16.7]. The precision timing of pulses (in TM–UWB) has enabled the development of through-the-wall radar with detection, ranging, and motion sensing of personnel and objects with centimeter precision [16.7]. Another more accurate radar—ground penetrating and vehicle anti-collision radar—is also feasible [16.7].

Precision timing also enables applications involving accurate location and tracking capabilities as well as unmanned vehicle applications [16.9]. DSC–UWB is suitable for most data communication applications [16.7]. UWB technology is appropriate for the high-performance wireless home network, which mandates support for large bit rate (50 Mbps), high-speed, affordable connectivity between devices, simultaneous data transmission from multiple devices, and full-motion video capability [16.10].

Since the UWB signal can provide undetectable interference with other signals, UWB can coexist with other technology (Bluetooth, 802.11a/b/g) without mutual disruption. UWB technology can also be useful for a lot of WPAN applications, such as enabling high-speed wireless universal serial bus (WUSB) and wireless PC peripheral connectivity, and replacing cables in next-generation Bluetooth technology devices, such as 3G cell phones, high-speed and low-power MANET devices. [16.11].

16.3.4 Difference Between UWB and Spread Spectrum Techniques

As stated previously, UWB technology differs from conventional narrowband RF and spread spectrum technologies. UWB uses an extremely wide band of RF spectrum to transmit more data in a given period of time than the other traditional technologies.

The spread spectrum techniques include direct sequence spread spectrum and frequency-hopping spread spectrum, along with applications such as Bluetooth technology, IEEE 802.11a/g. In such spread spectrum systems, the spread spectrum signal is modulated by a carrier with a PN pseudorandom code or hopping pattern to move the already spread signal to the most suitable band for transmission. UWB is a time-domain concept and there is no carrier modulation. Actually, the spread bandwidth for a UWB waveform is generated by time-hopping modulation, and this modulation process is limited to a very short duration pulse. Since individual transmission bits are subdivided into biphase-modulated chipping intervals or distinct frequency changes in spread spectrum systems, the carrier of such systems always has 100 percent duty cycle. While in UWB, pulse durations are very short compared with its pulse interval durations; therefore, the duty cycle is an extremely small percent (about 0.5 percent) and such a low-duty cycle leads to a large peak-to-average ratio and low power consumption.

16.3.5 UWB Technology Advantages

The combination of larger spectrum, lower power, and pulsed data means that UWB causes less interference than narrowband radio designs while yielding low probability of detection and excellent multipath immunity. This wide spectrum signature provides UWB with even greater advantages, like very precise range information, which could be used for security purposes in a WLAN/WPAN environment, as well as a strong capability for overcoming very high levels of interference from other narrowband devices [16.4]. In addition, UWB systems are much less complex, allowing for significantly lower cost and smaller size, since they do not use any radio frequency/intermediate frequency (RF/IF) conversion stages, local oscillators, mixers, and other expensive surface acoustic wave (SAW) filters common to traditional radio technologies [16.4]. Broad consumer adoption of wireless networking technology can finally become a reality [16.4].

16.3.6 UWB Technology Drawbacks

UWB is a disruptive technology for wireless networking applications [16.4], and its use would not be appropriate for a WAN deployment such as wireless broadband access. UWB devices are power limited because they must coexist on a noninterfering basis with other licensed and unlicensed users across several frequency bands. Furthermore, antenna gain cannot be increased to operate at greater range since power limits on UWB devices are angle independent. An implementation in low-voltage CMOS (complementary metal oxide semiconductor) is not possible as some UWB systems might exhibit a high peak-to-average ratio (PAR) [16.4]. For UWB systems using PPM as their modulation technique, limited jitter requirements could be an issue.

16.3.7 Challenges for UWB Technology

To make the highly promising new UWB technology a popular scheme for commercial wireless applications, the following challenges need to be addressed:

- UWB system designers need to provide an extremely accurate pulse design that produces emissions with flat and wide power spectral densities [16.12, 16.13].
- Harmful interference effects of UWB signals to narrowband receivers and those of narrowband transmitters to UWB receivers must be understood completely [16.12, 16.13].
- Requirements for the PHY and MAC functions of wireless devices based on UWB-radio technology (UWB-RT) [16.6] must be understood.

- Since UWB radio devices are suitable for communications and location tracking applications and services, there is a need to determine under what conditions and in what way the functions of communication and location tracking can or should be combined [16.12, 16.13].
- It is necessary to ensure that implementation of UWB technology does not cause interference to systems operated in the radio spectrum used for aeronautical safety, public safety, emergency and medical, military, and other consumer and business product services.
- New measurement techniques are needed to measure the characteristics of noiselike UWB signals having transient behavior [16.12, 16.13].
- It is necessary to identify and standardize the requirements and characteristics for a wireless home network with a variety of devices connected to each other [16.10].

16.3.8 Future Directions

UWB technology has several unique characteristics, including high capacity, low probability of multipath fading, interference immunity, low probability of detection, and frequency diversity, which allow for a simpler and more cost-efficient radio design. UWB is suitable for a broad variety of applications and, when implemented efficiently, has the potential to address the "spectrum drought."

16.4 Push-to-Talk (PTT) Technology for SMS

Push-to-talk (PTT) is a "walkie-talkie-type" service implemented over cellular networks to provide short message service (SMS). It is also abbreviated as P2T or PoC (PTT over Cellular). PTT terminals have a PTT button that a user presses to start a conversation. The conversation can be a person-to-person conversation or one of various types of group conversations. It is an instant, half-duplex communication medium that allows callers to connect rapidly with each other. Nextel, the U.S. operator of PTT, first introduced the service on its integrated digital enhanced network (iDEN) almost ten years ago.

PTT is a quick, short, and spontaneous communication from the users' perspective. The users of PTT pay only for the resources consumed, which is measured in the number of bits transferred carrying talk burst rather than the period of connection. Once a PTT call has been established, the participants can communicate immediately. PTT can be implemented over packet networks, and users can be reached through traditional circuit switched household telephones.

From a mobile systems point of view, PTT is a new type of service with distinctive features. It is an add-on feature to normal cell phones, and its underlying streaming characteristics makes it very suitable for packet networks, such as always connected. However, it can significantly increase the GPRS traffic in today's networks. It is also considered as a front-runner in peer-to-peer services over IP,