Performance Evaluation of Handover Technique in Mobile WIMAX Networks

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Abstract:

WIMAX is an emerging wireless technology which is used for creating multi-hop mesh networks offering variable and high data rates, QoS, seamless mobility within a network. Mobile WIMAX is the technology that achieves requirements of broadband wireless access over long distance. It has the ability to provide users with a high speed wireless connection. In mobile WIMAX, it is necessary to provide handoff in order to support effective services mobility and to guarantee continuous network connectivity.

This paper is focused on the performance analysis of handoff technique to provide mobility to the WIMAX networks – based IEEE 802.11e along with enhanced QoS. Also, a performance evaluation of QoS classes (UGS, erTPS, and rTPS) is analyzed and investigated over VoIP applications.

We evaluate our designed scheme in OPNET Modeler simulator and its performance is verified. Simulation results show that the designed WIMAX module – based rTPS scheduling service outperforms WIMAX module – based (erTPS and UGS) services, also some parameters of WIMAX do not have any influence on handoff latency, while others have effect on handoff latency. The results also show that handoff times could vary for different speeds of the Mobile Station (MS).

Keywords: WIMAX, Handoff, QoS, 802.16e, OPNET, Performance analysis

1. Introduction:

WIMAX is a promising alternative to 3G or wireless LAN for providing last mile connectivity by radio link due to its large cover area, low cost of deployment and high speed data rates. The standard specifies the air-interface between a Mobile Station (MS) and a Base Station (BS). The IEEE802.16-2004 standard [1], [2], also known as 802.16d, was published in October, 2004. This was further developed into the mobile WIMAX standard referred to as IEEE 802.16e2005 or 802.16e to support mobile users [3]. IEEE 802.16 can be used not only as XDSL replacement for small business customers but also as a mobile internet access technology.

WIMAX technology is the only wireless system capable of offering high QoS at high data rates for IP networks. One of the top applications for the 802.16 is Voice over Internet protocol (VoIP) service to support bidirectional voice conversation [1]. IEEE 802.16 supports a variety of physical (PHY) layers. Each of them has its own distinct characteristics.

The process of transferring connection of mobile station from one base station to another base station without interruption of service is called handover (HO). In 2005, 802.16e [3] standard
known as mobile WIMAX was introduced which allowed full user mobility [2]. The mobile WIMAX standard supports peak data rates of around 30 Mbps and average data rates between(1) Mbps and 4 Mbps. 802.16e based Base Station (BS) can support both fixed and mobile broadband wireless access (BWA) [2]. As described in [3], the handovers are divided into two main types, Hard Handover (HHO) and soft handover mechanisms. Macro Diversity Handover (MDHO) and Fast Base Station Switching (FBSS) are considered as soft handover mechanisms and are optional whereas the HHO is mandatory [4]. In Mobile WIMAX networks when a Mobile Node (MN) changes its location the MN moves the point of attachment to the network. In this situation it is essential to provide continuous network connectivity to satisfy high levels of mobile service quality. Here the major issue concerning implementation of Mobile WiMAX is providing effective handoff. Handoff is the process of changing a Mobile Station’s (MS’s) network connectivity from one Base Station (BS) to another BS. Providing the support for ongoing video call, or Voice over IP (VoIP), conversations for mobile users makes it necessary to make the handoff process as fast as possible. Therefore, in order to decrease handoff interruption time and unnecessary call drops it is important to implement different handoff optimization methods.

WiMAX gives network operators the opportunity to provide a wealth of services to differentiate their offerings and attract a tiered range of subscribers. WIMAX features a different of flow types that can be used to optimize performance for real time applications. In voice over IP (VoIP) communications require QoS features that can quickly identify voice traffic and prioritize it to assure high-quality audio and service level adherence. Without a robust QoS implementation, it is not possible to ensure low latency and low jitter that are necessary to provide carrier grade services such as VoIP and video conference.

Providing different Quality of Service (QoS) support such as high speed data transmission, low handoff latency, a reduced amount of packet loss in Mobile WiMAX network, and various handoff enhancement approaches have been proposed [3].

The IEEE802.16d WIMAX standard offers categories for the prioritization of the following traffics; Unsolicited Grant Service (UGS), Real-Time Polling Service (rtPS), extended real-time Polling Service (etrPS), Non-Real Time Polling Service (nrtPS), and Best Effort (BE).

Several handoff techniques for mobile WIMAX networks have been studied and compared in terms of handover requirement, power and latency [5, 4, 6, 7, and 8]. Zhang’s mobility pattern scheme [4], is the most efficient among these.

In [3], the performance of the handoff process in Mobile WIMAX network was investigated. The parameters of the WIMAX module were adjusted and investigated to achieve shorter handoff duration time during both handoffs. Authors have seen that some of the parameters have a direct influence on the handoff latency while others do not. The work in [2] discusses the conventional handover procedure along with some of the techniques that deal with handover and latency reduction.

As shown by thorough analysis, it reduces the HO latency by almost 50% when compared to the conventional HO mechanism followed by WIMAX standard.

The performance of the handoff processes are regulated by the parameters of the WIMAX module. Thus, it is need to adjust those parameters in order to increase handoff performance by achieving shorter handoff duration time. The velocity of the MS may also have some effect on the performance of the handoff process. The main focus is to evaluate the performance of the handoff methods in Mobile WIMAX by investigating different performance related parameters with varied MS velocity.

This paper provides an overview of 802.16 followed by one of most widely used tool for studying the performance of existing systems. It is known as Optimized Network Engineering
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Tool (OPNET). This paper is organized as follows. Section 2 explains the multi-carrier Transmission in Mobile WIMAX. Section 3 presents handover in mobile WIMAX networks. Section 4 and 5 illustrate handover scenario algorithm and procedure flow chart. Section 6 provides the design and simulation of system module. The results are presented in Section 7. Finally, Section 8 concludes the research.

2. Multi-carrier Transmission in Mobile WIMAX:

To allow non-line of sight (NLoS) communication, IEEE 802.16 working group designed the Orthogonal Frequency Division Multiplexing (OFDM) PHY using spectrum below 11 GHz [1]. This PHY is designed for fixed subscriber stations. WIMAX Forum has approved several profiles using this PHY. Most of the current WIMAX products implement this PHY. In this PHY, multiple subscribers use a Time Division Multiple Access (TDMA) to share the media. OFDM is a multi-carrier transmission in which thousands of subcarriers are transmitted and each user is given complete control of all subcarriers. For mobile users, it is better to reduce the number of subcarriers so that the subscriber station can use higher transmission power per subcarrier and increase their signal to noise ratio. This combination of time division and frequency division multiple accesses in conjunction with OFDM are called Orthogonal Frequency Division Multiple Access (OFDMA) [9].

In OFDMA, the multiplexed frequencies are orthogonal to each other and their spectra overlap with the neighboring carrier [9]. Orthogonality is a property that allows signals to be transmitted over the common channel and detected without interference [10]. Sub channels are called to the available subcarriers that may be divided into several groups of subcarriers. Mobile WIMAX allows sub channels in both the uplink and the downlink. Sub-channels in the uplink can behave as power saving of a user device since it can distribute power on allocated sub-channel(s) to it only [11].

3. HANDOVER IN MOBILE WIMAX NETWORKS

Mobility is one of the most important features in wireless cellular communication. When a mobile node changes its location from one location to another, it must support the minimum requirements are reliable, efficient, and continuous data transmission. Handoff is a process with the intention of changing the network access point of a mobile node without any data loss or disturbance of the current connection while a call is in progress. Handover is a mechanism to maintain uninterrupted user communication session during a user’s movement from one location to another [12]. When the Mobile Station (MS) moves to another cell and performs handover, the service packets for the MS will be delayed and the service might be disrupted for some time [13]. This delay is known as Latency time.

For non-real-time service such as e-mail or file transfer, Latency time is not an issue. However, the delay sensitive applications, such as video streaming service, should be delivered within the delay of 20 to 25ms. If the transmission delay of real-time packets is longer than the play out delay, those packets will be discarded and packet loss probability is increased [13]. Therefore, in mobile WIMAX, the basic meaning of handoff process is to provide uninterrupted connectivity when a MS transfers from the air interface of one BS to the air-interface of another BS. Though handoff is usually understood as a change of physical connection of a serving BS, it does not mean that the BS must be changed. Sometimes handoff can occur within different channels; this means changing from one frequency to another while the serving BS remains the same. In mobile WIMAX, it is called intra-cell handoff while the second option is called inter cell handoff. Again, in some other cases, handoff can occur within different network technologies. When handoff occurs within a single network it is known as horizontal handoff, while handoff between different networks is known as vertical handoff. To implement a handoff process requires at least two BSs, the currently serving BS and target BS, and a Mobile Station (MS) within the range of the two
BSs [5]. Mobile WIMAX supports two types of handover at the link layer, i.e., inside a network. Hard handover is the default handover mechanism in a WIMAX network and soft handover is the optional handover mechanism. Hard handover is a Break-before-make procedure whereas soft handover is a Make-before-break procedure. Macro-diversity handover (MDHO) and Fast Base Station Switching (FBSS) are the soft handover mechanism in mobile WIMAX [14, 15]. Both these handovers follows the initial scanning phase and the final actual handover phase. During the scanning phase the MS scans the neighboring base station for finding the target base station. Once the target base station is selected the actual handover process is performed and MS is connected to the new target base station [1].

4. WHY HAN DOVER

- When the MS is moving away from the area covered by one BS and entering into the area covered by another BS, then handover is needed to transfer the connection of MS form current BS to other BS before the MS moves out of the range of first BS, to avoid call termination.
- When the traffic handling capacity of any BS is exhausted then in order to accommodate more or new calls, loaded BS by means of handover transfers the ongoing or newly originated call to the neighboring BS with overlapping coverage area.
- In order to avoid interference on any channel by different MS from different cells (BS) using the same channel (but in different cells) then call is transferred to another channel in same cell or another cell,
- In non-CDMA environment when an fast moving MSs connected to umbrella type cell, slows sown or stops then in order to shift the call from umbrella type (in order to efficiently use the umbrella cell capacity) to macro or micro type (whichever is needed) cell handover is needed.
- In order to avoid or reduce interference due to “near-far” effect in CDMA networks, soft handover is useful in such scenarios.

5. Handoff Algorithm

The handoff procedure can be listed by the following algorithm steps:
1. The Connected Base Station (CBS) send the information of the cluster base stations (broadcasting the information).
2. Mobile Station receives the information, scan the base stations, and then select the Target Base Station (TBS).
3. MS then, transmit the Handover(HO) request message to CBS
4. CBS transmit the HO information with Candidate Base Station then select it.
5. MS disconnect with CBS and connect with TBS.
6. TBS will receive security information from CBS.
7. TBS will authorize and synchronize the new uplink and downlink, this step is named Re - entry process.
8. Now, MS could send or receive the traffic.
9. If MS still move, the procedure will begin from step one. Else, mean that MS will be Fixed Station, and HO process stopped.

The flowchart of handoff procedure between base stations (BS) and mobile station (MS) is illustrated in Figure (1).
6. WIMAX MODULE DESIGN AND SIMULATION

Simulation aims to analyze the effect of variables of the WIMAX module during handoff as well as checking the properties of Mobile WIMAX. A simple scheme was designed so as to keep the simulation process simple as shown in Figure (2). To implement handoff in Mobile WIMAX we have used the OPNET. The simulation scenario consists of four 802.16e BSs (BS0, BS1, BS2, and BS3) and one MS; where the BSs are adjacent to each other and the MS travels through the coverage areas of these four BSs. The BSs are located in such a way that there will not be any overlap within the coverage areas of the neighboring BSs. The module elements such as cell size, transmission power of BSs, and the route of the MS are selected constant values. The scenario module is simulated as indicated in Table 1 with speeds of 50km/h to 200 km/h with 10km/h steps from SS move BS to another's.
Table 1: Parameters of Simulation

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simulation time</td>
<td>22 minutes</td>
</tr>
<tr>
<td>Number of BS</td>
<td>4</td>
</tr>
<tr>
<td>Number of MS</td>
<td>1</td>
</tr>
<tr>
<td>MS speed</td>
<td>50-200km/h</td>
</tr>
<tr>
<td>Scheduling type</td>
<td>UGS, rtps, ertps</td>
</tr>
<tr>
<td>Frame duration (millisecond)</td>
<td>5</td>
</tr>
<tr>
<td>Symbol duration (millisecond)</td>
<td>100.8</td>
</tr>
<tr>
<td>Base frequency (MHZ)</td>
<td>5.8</td>
</tr>
<tr>
<td>Antenna Gain BS (dbi)</td>
<td>15</td>
</tr>
<tr>
<td>Maximum transmission power (W)</td>
<td>0.5</td>
</tr>
</tbody>
</table>

7. Simulation Results

Simulation considered that (MS) is travelled with different velocities from (50 –to -200) Km/h. Figure (3) shows the average throughput of mobile WIMAX system which is taken with different scheduling services (i.e. UGS, rtps, and ertps). From Fig.(3), the WIMAX module-based rtps service outperforms the module - based ertps and UGS services. Since, rtps service has capability to deal with different data patterns, also the amount of data rate is variable with (MS) mobility, and then data rate transmission is decreased at speeds of 50 km/h for UGS and ertps.
Figure (3): average throughput of WIMAX module

Fig.(4) shows the overall delay of the WIMAX module. It shows that the change in data transmission rate leads to insert some delay and this delay has minimum values for the WIMAX module – based rtps service as compared with the two other services. Since rtps service is changed adaptively with data size change, while UGS and erpts services dealt with unchanged data rate, and then data processing becomes very complicated and led to increase delay in network.

Figure (4): Overall Delay in WIMAX module

Handover delay time appeared when a user is travelled from one (BS) to another (BS). From Fig (5) it is shown that maximum handover delay time value (21.8ms) is resulted by WIMAX module – based rtps service at velocities between (130 – to – 160) km/h (i.e., at high velocities). But for WIMAX module – based UGS service, the handover delay time value (22ms) at velocity120 km/h and the WIMAX module – based erpts service has the worst case as shown in Fig (5).It is shown that maximum handover delay time value (23.2ms) at speed velocity170 km/h.
As shown by thorough analysis, it reduces the handoff latency by almost 56.4 % when compared to [3]. The drop in data packets of WIMAX module is illustrated in Fig. (6). comparison between scheduling services shows that WIMAX module based - rtps service has less data packets drop at various velocities, since the loss in data packets began at 150 km/h.

The jitter in WIMAX module is illustrated in Fig.(7). It represents delay that resulted from starting transmit voice call until receiving it. WIMAX module – based rtps service outperforms other services, since it reached near acceptable delay time and therefore, achieves best quality delay voice at high velocities.
The degree of purity of voice versus velocity is illustrated in Fig (8), which shows that WIMAX module – based rtps service achieved highest and unchanged value (3.5) compared with changed values of WIMAX module – based rtps and UGS services (3.07 and 3.02) respectively.

Figure (7): Jitter in WIMAX module

Figure (8): MOS in WIMAX module
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8. Conclusions

In this paper the performance of the handoff process in Mobile WIMAX network was investigated. Simulation was done with the OPNET simulator.

Through results show that the designed WIMAX module that use category rtps is better than module that use UGS and ertps techniques in terms of Voice over IP (VoIP) rate as well as even in the case of a handover is need less time to move to the other BS as it have seen in Figure 5. This is because of the variable of packets data size where it observed effect be clarified when increasing data. We have seen that some of the parameters; WIMAX module topology, application type, base station coverage area, handoff algorithm type, have a direct influence on the handoff latency while others do not. As shown by thorough analysis, it reduces the handoff latency by almost 56.4 % when compared to the conventional handoff mechanism followed by WIMAX standard.

References:


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