An Efficient Recycling of Bandwidth in WiMAX Networks

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Abstract*-The Worldwide interoperability for Microwave Access (WiMAX), based on IEEE 802.16 standards [1] [2], is designed to facilitate services with high transmission rates for data and multimedia applications in metropolitan areas. In this paper, we consider the scenario of WiMAX- based mesh deployment. A mesh network is managed by a single node, which we refer to as Mesh BS. Bandwidth is reserved for each application to ensure the QoS. For variable bit rate (VBR) applications, however, it is difficult for the subscriber station (SS) to predict the amount of incoming data. To ensure the QoS guaranteed services, the SS may reserve more bandwidth than its demand. As a result, the reserved bandwidth may not be fully utilized all the time. In this paper, we propose scheme, named Efficient Recycling of Bandwidth, to recycle the unused bandwidth without changing the existing bandwidth reservation. The idea of the proposed scheme is to allow other SSs to utilize the unused bandwidth when it is available. Thus, the system throughput can be improved while maintaining the same QoS guaranteed services. Mathematical analysis and simulation are used to evaluate the proposed scheme. Simulation and analysis results confirm that the proposed scheme can recycle 35% of unused bandwidth on average. By analyzing factors affecting the recycling performance, three scheduling algorithms are proposed to improve the overall throughput. The simulation results show that our proposed algorithm improves the overall throughput by 40% in a steady network.

Keywords: **Bandwidth utilization, Recycling, IEEE 802.16, MAC, QoS, WiMAX.**

I. INTRODUCTION

The Worldwide Interoperability for Microwave Access (WiMAX), based on IEEE 802.16 standards [1] [2], is designed to facilitate services with high transmission rates for data and multimedia applications in metropolitan areas. The physical (PHY) and medium access control (MAC) layers of WiMAX have been specified in the IEEE 802.16 standard. Many advanced communication technologies such as Orthogonal Frequency- Division Multiple Access (OFDMA) and multiple-input and multiple-output (MIMO) are embraced in the standards, WiMAX is able to provide large service coverage, high data rates and QoS guaranteed services. Because of these features, WiMAX is considered as a promising alternative for last mile broadband wireless access (BWA).

II. SURVEY ON WIMAX

Version of the 802.16 standard released addressed line-of-sight environments at high frequency bands operating in the 10-66 GHZ range, whereas the adopted amendment 802.16a standard is designed for systems operating in bends between 2 GHz and 11GHZ.the difference between two frequency bands lies in the ability to support Non-line-sight operation in the lower frequencies something that is not possible in higher bands. Although multiple PHYs are specified as in the 802.11 suite of standards (few recall that infrared and frequency hopping were and are part of the base 802.11 standard), the WiMAX Forum has determined that the first interoperable test plans and eventual certification will support the 256 point FFT OFDM PHY(which is common between 802.16a and ETSI HiperMAN), with the others to be developed as the market requires [3].Some of the other PHY layer features of 802.16a that are instrumental in giving this technology the power to deliver robust performance in a broad range of channel environments are; flexible channel widths, adaptive burst profiles, forward error correction with concatenated Reed-Solomon and convolution encoding, optional AAS (advanced antenna systems) to improve range/capacity, DFS (dynamic frequency selection)-which helps in minimizing interference, and STC (space-time coding) to enhance performance in fading environments through spatial diversity.

A. Benefits of IEEE 802.16 standard

256 point FFT OFDM waveform built in support for addressing multipath in outdoor LOS and NLOS environments Adaptive modulation and variable error correction encoding per RF burst ensures a robust RF link while maximizing the number of bits/second for each subscriber unit.TDD and FDD duplexing support address varying worldwide regulations where one or both may be allowed Flexible channel sizes like 3.5MHZ,5MHZ, 10MHZ,etc provides the flexibility necessary to operate in many different frequency bands with varying channel requirements around the world Designed to support smart antenna systems smart antennas are fast becoming more affordable, and as these costs comedown their ability to suppress interference and increase system gain will become important to BWA deployments. While all the features listed above are necessary requirements for basic outdoor BWA operation, flexible channel sizes is required if a standard is to truly address worldwide deployment. This is because the regulations governing what frequency equipment can operate in, and as a result the size of the channels used, can vary country by country. In the case of licensed spectrum where an operator had to pay for every MHz granted, it is imperative that the system deployed use all the allocated spectrum and provide flexibility in either cellular or "big stick" deployments. The standard delivers QoS beyond mere prioritization, a technique that is very limited in effectiveness as traffic load and the number of subscribers increase. The MAC layer in WiMAX certified systems has also been designed to address the physical layer environment where interference, fast fading and other phenomena are prevalent in outdoor operation.

B. Architecture of WiMAX:

Mobile WiMAX adds both the mobility and Multiple Input Multiple Output (MIMO) functionalities to the IEEE 802.16- 2004 standard. It is one of two standards adopted by the WiMAX forum with the other one being the IEEE 802.16 – 2004.Mobile WiMAX network architecture mainly has three components. These include the Access Services Network (ASN), the Core Services Network (CSN) and the Application Services Network (AS). Fig. 1 illustrates the interconnection of these networks [3].The WiMAX network supports the following key functions: All IP Access and core service networks Support for fixed, nomadic and mobile access Interoperability with existing networks via internetworking functions Open interfaces between ASN's and between the ASN and the CSN Support for differential quality of service depending on the application

Unbundling of the Access, core and application Service networks

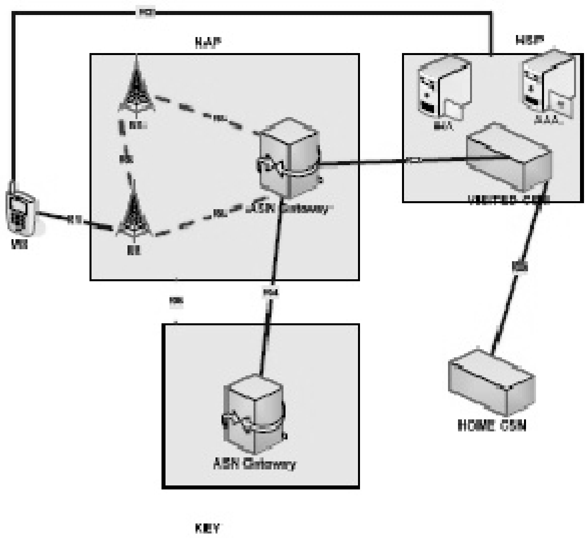

Fig. 1. Architecture of WiMAX

The ASN is the access network of WiMAX and it provides the interface between the user and the core service network .Mandatory functions as defined by the WiMAX forum include the following: Handover Authentication through the proxy authentication, authorization and accounting (AAA) server, Radio resource management, Interoperability with other ASN's Relay of functionality between CSN and MS, e.g. IP address allocation. The cell equipment comprises the basic base station equipment, radio equipment and a base station link to the backbone network. The base station is what actually provides the interface between the mobile user and the WiMAX network. The coverage radius of a typical base station in urban areas is around 500 to 900 meters [3]. In rural areas the operators are planning cells with a radius of 4 kilometer (Km). This is quite a realistic number now and quite similar to the coverage areas of GSM and UMTS/HSDPA base stations today. Deployment is driven either by the bandwidth required to meet demand, or by the geographic coverage required to cover the area. Based on the cell planning of other previous technologies, urban and suburban segments cell deployment will likely be driven by capacity. Rural segment deployment will likely be driven by the cell radius. The ASN Gateway performs functions of connection and mobility management and inter-service provider network boundaries through processing of subscriber control and bearer data traffic. It also serves as an Extensible Authentication Protocol (EAP) authenticator for subscriber identity and acts as a Remote Authentication Dial in User Service (RADIUS) client to the operator's AAA servers.

The CSN is the transport, authentication and switching part of the network. It represents the core network in WiMAX. It consists of the home agent (HA) and the AAA system and also contains the IP servers, gateways to other networks i.e. Public Switched Telephone Network (PSTN), and 3G.WiMAX has five main open interfaces which include reference points R1, R2, R3, R4 and R5 interface [4]. The R1interface interconnects the subscriber to the base station in the ASN and is the air interface defined on the physical layer and Medium Access Control (MAC) sub layer. The R2 is the logical interface between the mobile subscriber and the CSN. It is associated with authorization, IP host configuration management, services management, and mobility management. The R3 is the interface between the ASN and CSN and supports AAA, policy enforcement and mobility management capabilities. The R4 is an interface between two ASN's. It is mainly concerned with coordinating mobility of Mobile Stations (MS's) between different ASN's. The R5 is an interface between two CSN's and is concerned with internetworking between two CSN's. It is through this interface that activities such as roaming are carried out. The unbundling of WiMAX divides the network based on functionality. The ASN falls under the Network Access Provider (NAP). The NAP is a business entity that provides WiMAX network access to a Network Service Provider (NSP). The NSP is a business entity that provides core network services to the WiMAX network and consists of the CSN. The Applications services fall under the Applications Services Provider (ASP).

III. MOTIVATION AND PROBLEM DEFINITION

In comparison to IEEE 802.11a/b/g based mesh network, the 802.16-based WiMax mesh provides various advantages apart from increased range and higher bandwidth. The TDMA based scheduling of channel access in WiMax-based multi hop relay system provides fine granularity radio resource control, as compared to RTS/CTS-based 802.11a/b/g systems. This TDMA based scheduling mechanism allows centralized slot allocation, which provides overall efficient resource utilization suitable for fixed wireless backhaul network. (The WiMax based mesh backhaul application differs from the 802.11a/b/g based mesh, which targets mobile ad hoc networks). However, the interference remains a major issue in multi-hop WiMax mesh networks. To provide high spectral usage, an efficient algorithm for slot allocation is needed, so as to maximize the concurrent transmissions of data in the mesh.

The level of interference depends upon how the data is routed in the WiMax network. In this paper, we consider the following scenario of WiMAX- based mesh deployment. A mesh network is managed by a single node, which we refer to as Mesh BS. Mesh BS serves as the interface for WiMax-based mesh to the external network. We provide an algorithm for interference-aware multi-hop route selection for a given capacity-request matrix, which leads to efficient scheduling. Bandwidth in the current frame can be utilized. It is different from the bandwidth adjustment in which the adjusted bandwidth is enforced as early as in the next coming frame. Moreover, the unused bandwidth is likely to be released temporarily (i.e., only in the current frame) and the existing bandwidth reservation does not change. Therefore, our scheme improves the overall throughput while providing the same QoS guaranteed services. Table provides mesh mode acronyms.

TABLE III.

IEEE 802.16 MESH MODE ACRONYMS

BS	Base Station
SS	Subscriber Station
MSH	Mesh
SN	Sponsoring Node
CN	Candidate Node
MSH-NCFG	Mesh network Configuration Message
MSH-NENT	Mesh Network Entry Message
MSH-CSCH	Mesh Centralized Scheduling Message
MSH-CSCF	Mesh Centralized Scheduling Configuration Message

Quality of Service is important in application systems to improve the QoS ensure guaranteed services; the SS may reserve bandwidth more than the amount of its transmitting data. Result reserved the bandwidth may not be fully utilized all the time. We propose a scheme, named Bandwidth Recycling, to recycle the unused bandwidth without changing the existing bandwidth reservation. The idea of our scheme is to allow other SSs to utilize the unused bandwidth when it is available Thus, not only the same Quality of service guaranteed services can be provided but also the system throughput can be improved. QoS is provide guaranteed services such as bandwidth, delay, jitter and packet delivery rate to users. QoS routing protocol either provides feedback about the available bandwidth to the application or admits a flow with to [4] requested bandwidth. The issue of QoS supporting for mobile users (also referred as Mobile QoS, denoted by MQoS), has been addressed in the literature for many years. The typical strategy for MQoS is to reserve necessary bandwidth at neighbouring nodes before the mobile user handoff to the new node, which inevitably results in low bandwidth utilization. Extension of RSVP (Resource Reservation Protocol) was adopted in traditional MQoS mechanisms, such as Mobile RSVP [5].

The offer of bandwidth QoS available end-to-end bandwidth along a route from the source to the destination must be known. Throughput is a concave parameter which is determined by the bottleneck bandwidth of the intermediate hosts in the route. The estimating end-to-end throughput can be simplified into finding the minimal residual bandwidth available among the hosts in that route. To calculate the residual bandwidth using the IEEE 802.11 MAC is a problem because the bandwidth is shared among neighboring hosts and an individual host has no knowledge about other neighbouring host traffic status. Two methods for estimating bandwidth are hosts to listen to the channel and estimate available bandwidth based on the ratio.
Each host can listen to the channel to track the traffic state and determine how much free bandwidth it has available every second. The IEEE 802.11 MAC utilizes a physical carrier sense and a virtual carrier sense network allocation vector which can be used to determine the free and busy times.
Requirements to follow the MAC detects the channel is free.
NAV's(network allocation vector) values is less than the current time

- Receive state is idle
- Send state is idle

MAC claims that channel is busy
when NAV sets a new value

- Receive state changes from idle to any other state
- Send state changes from idle to any other state.

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A host estimates its available bandwidth for new data transmissions as the channel bandwidth times the ratio of free time to overall time, divided by a weight factor. The weight factor is introduced due to the nature of IEEE 802.11. The DIFS, SIFS, and back-off scheme represent overhead, which must be accounted for in each data transmission. This overhead makes it impossible in a distributed MAC competition scheme to fully use the available bandwidth for data transmission.

Mobile network managed by MR1 that has three network interfaces such as GPRS/UMTS, IEEE802.11x and WiMAX and connect to the internet. Maximum data rate for WiMAX is 70-75 Mbps and for IEEE 802.11x is54Mbps. Maximum data rate for GPRS is 172.2 Kbps. Comparing WiMAX, IEEE 802.11x and GPRS/UMTS offer high medium and low data rates respectively. There is a difference between data rate and actual throughput. The data rate is determined by both control packets and payload packets but the actual throughput is determined only by payload packets. Generally the actual throughput is approximately half of the data rate. Example throughput for WiMAX is 40[5] Mbps.

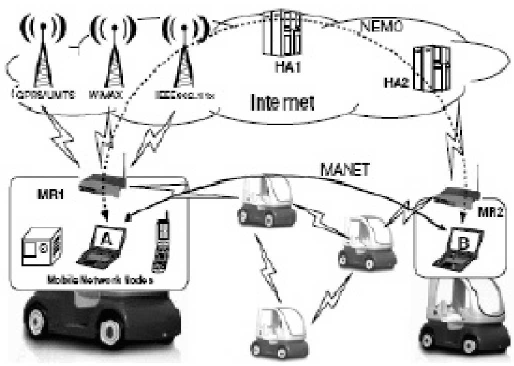

Fig. 2. Network Example

III. PERFORMANANCE ANALYSIS

An intelligent technique to forward packets based on the application demand and network performance is ANT TECH helps to match the application demand and network performance.[6].This technique can be used in the Root MR.

The following steps explain the ANT TECH.
Step 1: Identify the number of network interfaces available
Step 2: Determine the data rates / actual throughput of network interfaces and assign its performance in terms of High / Medium / Low
Step 3: Determine the application demand in terms of High / Medium / Low
Step 4: Receives packets from MNN / child-MR
Step 5: Determine the type of packets (High / Medium / Low)
Step 6: If type_of_packets = High then forward packets to high performance network interface (WiMAX)If type_of_packets = Medium then forward packets to medium performance network interface (IEEE 802.11x)If type_of_packets = Low then forward packets to low performance network interface(GPRS)
Step 7: Repeat steps 4-6 until the data transfer is over.

A mobile router in a mobile network has to identify the number network interfaces available such as WiMAX, IEEE 802.11x, etc. A mobile network inside another mobile network creates nested MN. In other words, Root-MR can have zero / one / more child-MRs. If the number child-MR is increased, the overhead is also increased. A Root-MR determines the data rates / actual throughput of all the network interfaces. After determining them, it assigns the performance of network interfaces as high, medium, low. Here, high, medium and low denotes the network interfaces that have high, medium and low data rates respectively. A Root-MR receives packets from all nodes such as mobile network node (MNN), local fixed node (LFN), visiting mobile node (VMN), child-MR, etc. Each node has some differences in mode of operation. Based on the application demand, the types of packet is determined. For example, video conference application is highly sensitive to delay. Hence, the type of packet for video conference application is said to be high. Likewise, it determines the type of packets for all other applications. Now, the Root-MR has to check the type of packets. If type_of_packets is equal to high then forward packets to high performance network interface (WiMAX).If type_of_packets is equal to medium then forward packets to medium performance network interface (IEEE 802.11x). If type_of_packets is equal to low then forward packets to low performance network interface (GPRS). The steps 4 - 6 are repeated until the data transfer is over. Definitely, forwarding packets via appropriate network Interface saves network resources, gives customer satisfaction, reduces wastage of resources, etc. This in turn helps to improve QoS in the multi hoped mobile networks.

A real-time database is often used by applications such as tracking. Since we cannot predict how many objects need to be tracked and when they appear, we assume randomly arriving transactions. Each transaction is assigned an initial priority and a start-timestamp when it is submitted to the system. The initial priority can be based on the deadline and the criticalness of the transaction. The start-timestamp is appended to the initial priority to form the actual priority that is used in scheduling. When we refer to the priority of a transaction, we always mean the actual priority with the start-timestamp appended. Since the start-timestamp is unique, so is the priority of each transaction. The priority of transactions with the same initial priority is distinguished by their start-timestamps.

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Note that the start-timestamp is only used to distinguish transactions with the same initial priority. Most likely, the transaction which started earlier than other transactions with the same initial priority should be treated favorably by comparing their start time stamps.

Priority-based Scheduling Algorithm

Input: T is the set of TSs scheduled on the UL map.
Q is the set of SSs running non-real-time applications.
Output: Schedule CSs for all TSs in T.
For i = 1 to ||Tk || do
a. St <-Tsi.
b. Qt Q <- Ot.
c. Calculate the SF for each SS in Qt.
d. If Any SS 2 Qt has zero granted bandwidth,
If Any SSs have nrtPS traffics and zero granted bandwidth,
Choose one running nrtPS traffics with the largest CR.
Else
Choose one with the largest CR.
Else
Choose one with largest SF and CR.
e. Schedule the SS as the corresponding CS of St.

End

In a dynamic resource reservation mechanism is proposed. It can dynamically change the amount of reserved resource depending on the actual number of active connections. The investigation of dynamic bandwidth reservation for hybrid networks is presented in. Evaluated the performance and effectiveness for the hybrid network, and proposed efficient methods to ensure optimum reservation and utilization of bandwidth while minimizing signal blocking probability and signalling cost. In, the enhanced the system throughput by using concurrent transmission in mesh mode.

Out of the network services lies in existing technology. Routing and switching are the main methods of delivering the data through the network. Both have their disadvantages and benefits and there are many variations of them applying in different ways to different situations.

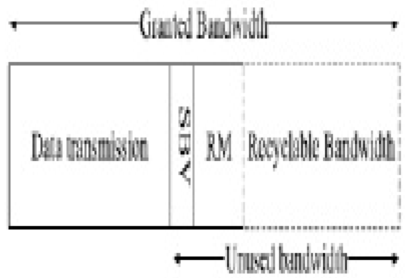

Fig. 3. Example of bandwidth utilization

IV. COMPARATIVE STUDY

Another big issue is the resource handling with QoS. In IP world, there are a few proposals to resource handling problems and besides that there are a few technologies providing different approaches to QoS problems. These include for instance ATM and Gigabit Ethernet. Bandwidth reservation allows IEEE 802.16 networks to provide QoS guaranteed services. The SS reserves the required bandwidth before any data transmissions. Due to the nature of VBR applications [8], it is very difficult for the SS to make the optimal bandwidth reservation. It is possible that the amount of reserved bandwidth is more than the demand. Therefore, the reserved bandwidth cannot be fully utilized. Although the reserved bandwidth can be adjusted via BRs, however, the updated reserved bandwidth is applied as early as to the next coming frame and there is no way to utilize the unused bandwidth in the current frame. In our scheme, the SS releases its unused bandwidth in the current frame and another SS pre-assigned by the BS has opportunities to utilize this unused bandwidth.

V. CONCLUSION

We proposed bandwidth recycling to recycle the unused bandwidth once it occurs. It allows the BS to schedule a complementary station for each transmission stations. Each complementary station monitors the entire UL transmission interval of its corresponding TS and standby for any opportunities to recycle the unused bandwidth. We survey on WiMAX and IEEE 802.16and priority-based scheduling algorithm to improve the recycling effectiveness. Our analysis confirms that scheme can not only improve the throughput but also reduce the delay with negligible overhead and satisfy the QoS requirements.

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