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Throughput Enhancement in IEEE 802.16j Mobile Multi-hop Relay (MMR) Networks

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Abstract

IEEE 802.16 standard is created to compete with cable access networks. In the beginning end users are immobile and have a line of sight with base station, now it moved to mobile non line of sight (NLOS) with the new standard IEEE 802.16e and IEEE 802.16j. The new IEEE 802.16j standard which is an amendment to IEEE 802.16e is mobile multi hop relay (MMR) specification for wireless networks.

In this paper we have proposed a new model for throughput enhancement, optimal relay placement and spatial reuse techniques. We have used four mobile stations (T-MS) connected to transparent mode base station (TMR-BS), which are moving at a speed of 20 m/sec. The T-MS are initially placed near to TMR-BS and are moving away from TMR-BS. The average throughput achieved without relay T-RS is 800 Kbps and the average throughput achieved with relay T-RS is 1300 Kbps. There is 40 % increase in the throughput by placing transparent mode relays T-RS at suitable position.

Keywords: IEEE 802.16j, relay modes, throughput enhancement, WIMAX, NCTUns, etc

Contents

1. Introduction

The new task group IEEE 802.16j-2009 standard of IEEE 802.16 Air interface for Broadband Wireless Access was officially established in March 2006 "K.Wongthavarawat and A. Ganz(2003)" , in order to support mobile multi-hop relay (MMR) specification, mesh mode is removed in the IEEE 802.16 -2009 standard.. The specification it is an amendment of IEEE 802.16e standard for enhancing coverage throughput and system capacity. It provides multi hop wireless connectivity where traffic between a base station (BS) and a subscriber station (SS) can be relayed through a relay station. This system enables mobile stations to communicate with a base station through intermediate relay station. Multihop relay station (M-RS) is an optional deployment that may be used to provide additional coverage or performance advantage in an access network. The RS may be fixed in location or, in the case of an access RS, it may be mobile access RS. Most of the time the RS will act as a BS and should have its own physical cell identifier, and also it should be able to transmit its own synchronization channels and control information. There should be no difference between cell control in RS and BS.

The radio link originating or terminating at an MS is named as the access link, but the link between BS and RS or between pair of RSs is called relay link. Theses access link and relay link can be used for uplink and downlink data transmission. This standard defines the physical and the MAC layer specifications for MMR networks. The MAC layer supports functions such as network entry, bandwidth request, forwarding of PDUs, connection management and Hand over. The PHY layer adopts orthogonal frequency division multiple access (OFDMA) "K.Wongthavarawat and A. Ganz(2003)" as the primary channel access mechanism for non-line of sight (NLOS) communications in the frequency band below 11 GHz. Where multiple users are allocated separate set of slots, so that they can communicate in parallel. It supports point to multipoint (PMP) network topology where resource allocation is performed by BS on a per connection basis and the SSs are treated equally. MIMO [2] techniques have ability to exploit NLOS channels and increase spectral efficiency compared to single input single output (SISO) systems. It is able to provide high capacity and data rate without increasing bandwidth. The gain of MIMO is multiplexing gains, diversity gains and array gains.

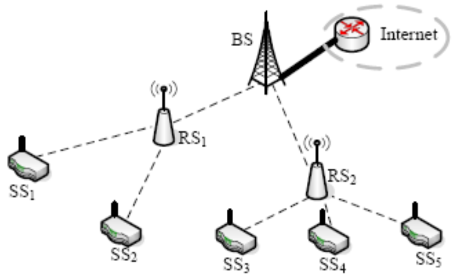

Fig 1: IEEE 802.16j Mobile multi hop relay (MMR) network

The aim of this paper, to the best of our knowledge the first of its kind, is to find a solution for throughput Enhancement in IEEE 802.16j MMR networks along with the different proposed and probable research solutions, starting right from the advent of IEEE 802.16e technology until today, thus identifying the research directions related to the existing and future throughput Enhancement techniques of WiMAX. In this article, we focus on the mobile WiMAX , IEEE 802.16j mobile multi hop relay (MMR) technology and will use the acronym ' "IEEE 802.16j' instead of Mobile WiMAX IEEE 802.16j mobile multi hop relay (MMR) in the rest of the paper. The rest of the article is organized as follows. In section II we brief discussed about the different Relay modes of IEEE 802.16j and present a comparative study of the advantages of the different techniques. This is followed in section III by a brief discussion about the different Definitions and examples of the IEEE 802.16j technology and their relevancy. This is followed in section IV by simulation model of the IEEE 802.16j technology. Section V consists of performance study and Conclusions are drawn in Section VI.

2. Relay Modes

Two different relay modes are defined in this standard, transparent mode and Non- transparent mode.

a. Transparent Mode

The transparent relay mode "K.Wongthavarawat and A. Ganz(2003)" increases the throughput which facilities capacity increases within the Bs coverage area. It has no support to coverage extension because it does not forward framing information to BS. It is operated in two hop network topology and supports centralized scheduling only as scheduling is done only in BS. It uses CID based forwarding scheme and supports embedded and explicit mode of path management.

b. Non transparent relay mode

The Non transparent relay mode "K.Wongthavarawat and A. Ganz(2003)" in fig 3 is to increase the coverage extension of BS, here RS generate its own framing information and forward it to SSs. It operates is 2 or more hops and uses centralized or distributed scheduling mode, as scheduling is done in BS and RSs. It used CID and Tunnel based forwarding scheme and supports embedded and explicit mode of path management.

The transparent relay station does not transmit control message, permeable, FCH (frame control header, and DL/UL-MAP, as it only increases system throughput. The non transparent relay station transmit control message, permeable, FCH (frame control header, and DL/UL-MAP, as it increases system throughput and increases cell coverage. Table 1 shows the difference between transparent and non transparent mode of operation.

3. Definition and Examples

We first give simple definitions for key terms as they will be used in the rest of this paper:

*TMR-BS***:** A TMR-BS plays the same role as the base station in a conventional WiMAX PMP network. It is the central controller in the network to allocate link bandwidth for the T-RSs and T-MSs that it manages. The TMR-BS provides services through a wired backhaul network and therefore it has two interfaces --- one for the wired network and the other for wireless communications with T-RS and T-MS. One is an IEEE 802.3 Ethernet interface for connecting with the backbone network and the other is an IEEE 802.16j radio interface for communicating with T-RSs and T-MSs. The IEEE 802.3 Ethernet interface uses the IEEE 802.3 protocol stack, which is composed of the Interface, ARP, FIFO, MAC8023, and PHY modules. An IEEE 802.16j radio interface has the following modules: an Interface module, an MAC802_16J_PMPBS module, an OFDMA_PMPBS_MR module, a CM module, and a LINK module. The main modules in the protocol stack of the TMR-BS are the MAC802_16J_PMPBS module and the OFDMA_PMPBS_MR module. The MAC802_16J_PMPBS module performs the functions of the MAC layer of a TMR-BS and the OFDMA_PMPBS_MR module performs the physical-layer functions, which use the OFDMA technology.

*T-MS***:** The T-MS is transparent mode mobile station, which is a wireless interface to TMR -BS. A T-MS, which is fully compatible with IEEE 802.16e network, can work normally without any modification. When a T-MS wants to join the IEEE 802.16j transparent mode network, the TMR-BS is responsible for choosing an access station for the T-MS. The access station can be a TMR-BS or a T-RS. One can use a T-RS as the access station to make Line-Of-Sight transmission possible both between the TMR-BS and the T-RS and between the T-RS and the T-MS. The T-MS has one interface, which is an IEEE 802.16j wireless interface, to communicate with the TMR-BS and T-RS. The protocol stack of the T-MS is composed of an Interface module, an MAC802_16J_PMPMS module, an OFDMA_PMPMS_MR module, a CM module, and a Link module. The MAC802_16J_PMPMS module performs the functions of the MAC layer of a T-MS. These functions include receiving / transmitting messages from/to its TMR-BS and T-RS. The OFDMA_PMPMS_MR module performs physical-layer functions.

T-RS: A T-RS simply forwards incoming data for its subordinate TMSs and leaves the scheduling of these data to the TMR-BS. The T-RS and the T-MS have only one interface, which is a wireless interface to communicate with the TMR-BS. Because a T-RS does not transmit framing messages such as preamble and DL-MAP, T-MSs will not notice the existence of a T-RS. This is the reason why a T-RS is called a “transparent” RS. The T-RS has only one interface – an IEEE 802.16j wireless interface, which is used to communicate with the TMR-BS and T-MS. The protocol stack of a T-RS is composed of an Interface module, an MAC802_16J_PMPRS module, an OFDMA_PMPRS_MR module, a CM module, and a Link module. The MAC802_16J_PMPRS module performs the functions of the MAC layer of a T-RS, which include exchanging the messages and relaying the data between a TMR-BS and a T-RS. The OFDMA_PMPRS_MR module performs the physical layer function. It encodes and decodes the data transferred to TMR-BS and T-MS.

OFDMA: It is modulation scheme called orthogonal Frequency division multiple access (OFDMA) used in IEEE 802.16j.

TABLE-1

S.No	Transparent Mode	Non Transparent Mode
1.	Supports Centralized scheduling - as scheduling done only in base station	Supports Centralized or Distributed scheduling- as scheduling done in base and relay station
2.	Use CID based forwarding scheme	Use Tunnel based or CID based forwarding scheme
3.	Use only 2 hops	Use 2 or more Hops
4.	Does not provide coverage extension	Provides BS coverage extension.
5.	Low Relay station cost.	High Relay station cost.

4. Simulation Setup

The desired network topology “H. L. Vu, S. Chan, and L. L. H. Andrew (2010)” is specified in the GUI environment. As shown in Figure 2, there are several node icons on the GUI’s tool bar at the top. In this case, we choose to create one host (Node 1), one TMR-BS (Node 2), one T-RS (Node 3), and four T-MSs (Node 4, 5, 6, 7), respectively.

The TMR-BS connects with the host (on the backhaul network) through a wired link and it communicates with other nodes in this topology through an IEEE 802.16j wireless interface. The GUI needs to generate an IP address for each node in the topology. To help the GUI know that Node 2 (MR-BS), Node 3 (T-RS), Node 4, 5, 6, 7 (T-MS), are on the same IP subnet, we need to group them together in the GUI. We use the following steps to form a subnet

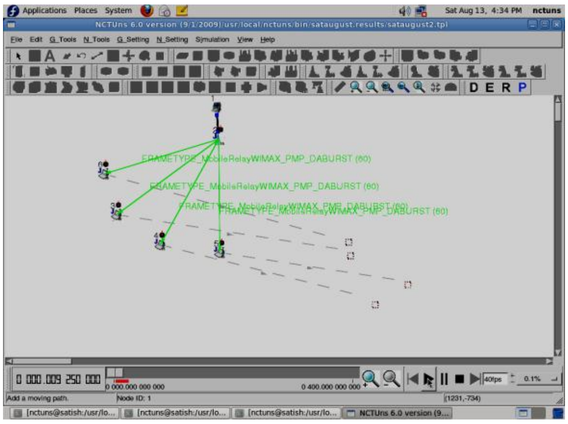

Fig 2 : topology construction

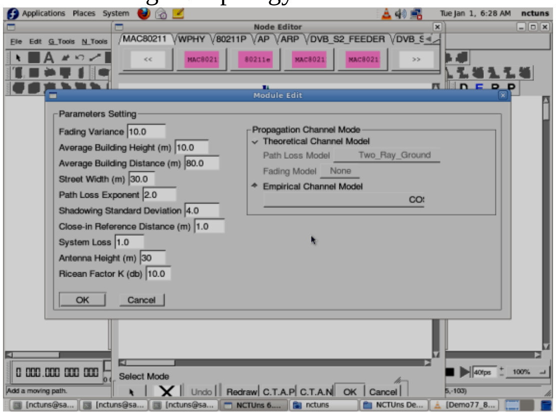

Fig 3 : power setting for adaptive model

In the NCTUns design, the default channel ID “H. L. Vu, S. Chan, and L. L. H. Andrew (2010)”chosen for the TMR-BS is the same as its Node ID. To ensure that T-RSs and T-MSs can communicate with the TMR-BS on the same channel, one should set the channel ID of T-RSs and T-MSs to the channel ID of their TMR-BS. In the “**Node Editor**” window, double-clicking the PHY module box. The name of the PHY module box is OFDMA_PMPXX_MR_WIMAX, where XX may be “BS,” “RS,” or “MS,” depending on the node type. A dialog box for this PHY module will pop up and inside this dialog box one can specify or modify the channel ID or other parameter values

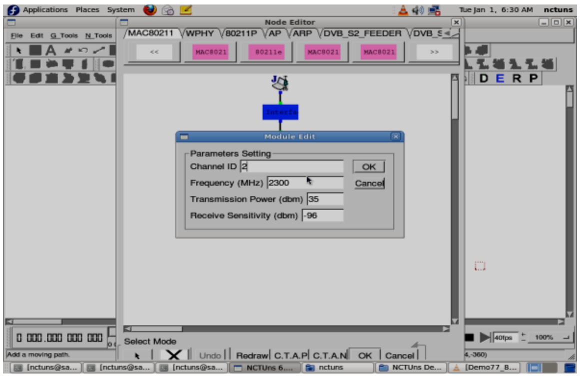

Fig 4: Channel ID setting by PHY module box

The Network topology "H. L. Vu, S. Chan, and L. L. H. Andrew (2010)"consists of not only nodes but also links between them. Links can be added to the network topology easily. When nodes and links are added to the network topology, a node ID and the ID of its ports will be automatically assigned and adjusted by the GUI program. The Node editor of TMR-BS consists of the following modules CM, OFDMA, MAC FIFO, ARQ PHY, interface. The CM is used to set channel ID for the TMR-BS, frequency, transmission power and receive sensitivity. According to the IEEE 802.16j standard, the communications among all the transparent mode stations within the same cell should take place on the same channel. Therefore one must make sure that the used channel Ids of the T-RS and T-MSs are set to the channel ID used by the TMR-BS.

The Node editor of T-RS consists of the following modules CM, OFDMA, MAC, and interface as shown in fig 8.

The IEEE 802.16j standard "H. L. Vu, S. Chan, and L. L. H. Andrew (2010)"defines five scheduling services: (1) Unsolicited Grant Service (UGS), (2) Real-time Polling Service (rtPS), (3) Non-real-time Polling Service (nrtPS), (4) Best Effort (BE), and (5) Extended real-time Polling Service (ertPS), respectively..

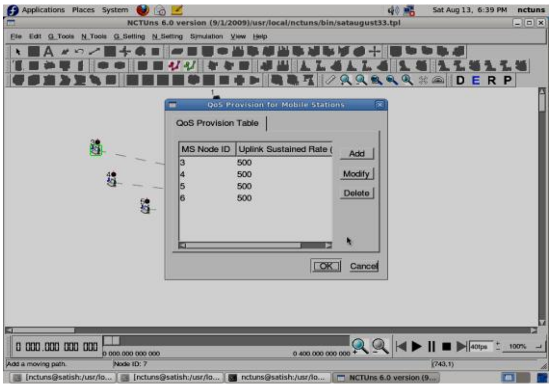

Fig 5: QoS setting for four T-MSs (Node 4, 5, 6, 7), respectively

At present, NCTUns only supports Best Effort (BE), which provides a uplink bandwidth for a T-MS. Here we illustrate how to set the QoS provisions for T-MSs. Figure 4.6 shows how to set the QoS provisions for T-MSs. In the popped-up dialog box, one can click the "Add" button to set the maximum uplink sustained rate (in Kbps) for every T-MS. NCTUns Tool for IEEE 802.16j Mobile WiMAX Relay Network Simulations.

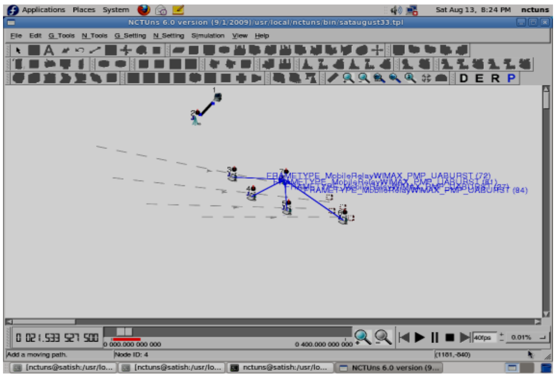

Fig 6: Relay selection by T-MSs

IEEE 802.16j standard supports MS mobility. The standard defines three kinds of handover mechanism: hard handover, macro diversity handover (MDHO), and fast BS switching (FBSS). Since the hard handover mechanism is mandatory and the macro diversity handover mechanism and the fast BS switching mechanism are optional in the IEEE 802.16j standard, at present NCTUns only supports the hard handover mechanism for IEEE 802.16j networks. The Topology is constructed without using a T-RS relay station where four T-MS mobile stations are connected to TMR-BS base stations through a wired back haul to sever host. The four T-MS mobile stations are moving at a without using a T-RS, the TMR-BS and a T-MS need to exchange their packets directly. This may result in a low throughput between them when the transmission path between them is non-line-of sight (NLOS). The reason is that in such a condition the signal received by the T-MS and TMR-BS is very weak and this forces them to use a more robust but lower efficiency modulation/coding scheme to transmit data The T-MSs are connected to TMR-BS as shown in the fig 12, the T-MSs are moving at a speed of 20 m/sec, and the path is specified as shown above figure. The throughput of the T-MSs decreases when it moves away from the TMR-BS

The T-MSs and T-RS are connected to TMR-BS as shown in the fig 13, the T-MSs are moving at a speed of 20 m/sec, and the path is specified as shown above figure. The throughput of the T-MSs on an average remains steady when it moves away from the TMR-BS. As shown above the T-RS is also connected to TMR-BS through fifth link, as initially all the nodes are connected to the TMR-BS. The T-MSs are exchanging their Bandwidth information with the T-RS as shown in fig 14, here they select the T-RS based on the Optimal relay selection procedure, the distance (x_s) between T-RS and T-MS is optimally calculated in PHY layer before assigning the T-RS to T-MSs. as shown in fig 14,

The mobile stations which are away from the TMR-BS are connected through T-RS as shown in fig 15 and it is shown in fig.

The simulation time is set as

1. Simulation start time=1 sec
2. MS Starting time=3 sec
3. MS Stop time=60 sec
4. Simulation close time=60 sec.

Host channel parameters.

1. Bandwidth= 50 Mbps
2. Bit error rate=0
3. Propagation delay=0.0 Micro seconds.
4. IP address = 1.0.1.1
5. Net mask=255.255.255.0
6. ARP protocol.

802.16j Base station channel parameters.

1. Fading variance=10
2. Average building height=10m
3. Average Building distance=80m
4. Street width=30m
5. Pass loss exponent=2.0
6. Shadowing standard deviation=4.0
7. Close in reference distance(m)=1.0
8. System loss=1.0
9. Antenna height=30m and 20 m for RS
10. Ricean factor (k)=10.0 db

OFDMA parameters for BS

1. Channel ID=2
2. Frequency=2300 MHz
3. Transmission power = 35 dbm
4. Receive sensitivity=-99dbm

802.16j Mobile station channel parameters

1. Frequency=2300 MHz

2. Transmission power = 35 dbm
3. Receive sensitivity=-99dbm
4. Speed= 20 m/sec

5. Performance Study

Deploying a T-RS between the TMR-BS and the T-MS "C. Cicconetti, A. Erta, L. Lenzini, and E. Mingozzi (2007)" can solve this NLOS problem because now there is a LOS path between the TMR-BS and the T-RS and a LOS path between the T-RS and the T-MS"H. L. Vu, S. Chan, and L. L. H. Andrew (2010)". The result is that on both paths a less robust but higher-efficiency modulation/coding scheme can be used to transmit data. Therefore, the end-to-end throughput achieved on the TMR-BS -> T-RS -> TMS path can be higher than that achieved on the TMR-BS -> T-MS direct path. For a T-MS, depending on the quality of the path between it and the TMR-BS, it is not always better to use a T-RS to relay its packets. Whether to use a T-RS is determined by the path selection algorithm, which is presented in NCTUns

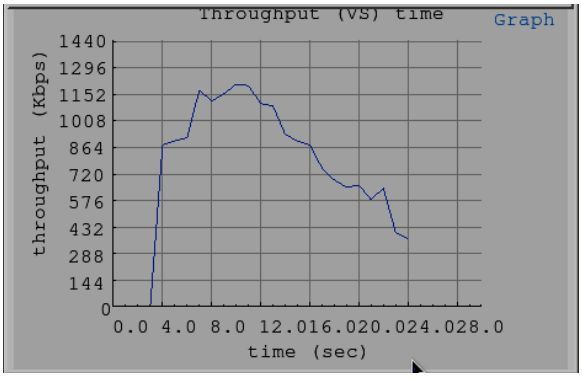

Fig 7: Throughput without relay station

The average Throughput "C. Cicconetti, A. Erta, L. Lenzini, and E. Mingozzi (2007)" of the T-MSs with out relay touches maximum at 11 sec , 1200.418 Kbps and then it gradually decreases to 900.738 Kbps, 649.064 Kbps, and 371.596 Kbps which is very low and it occurs at 24 sec when the mobile station moves to NLOS as shown in the fig 16. The Total average throughput (x_s) of all the T-MS is 792.045913 Kbps.

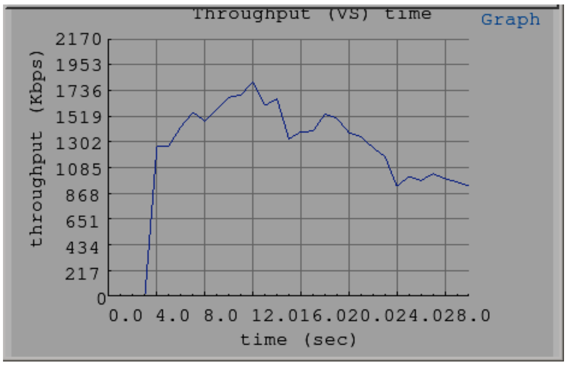

Fig 8: Throughput with relay station

The average Throughput "C. Cicconetti, A. Erta, L. Lenzini, and E. Mingozzi (2007)" of the T-MSs with relay touches maximum at 12 sec , 1810.98Kbps and then it gradually decreases to 1388.336 Kbps, 1255.814 Kbps, and 930.226 Kbps as shown in the fig 16. The Total average throughput (x_s) of all the T-MS is 1261.856667 Kbps, Thus the total average throughput remains steady throughout the cycle of operation.

6. Conclusion and Future Works

IEEE 802.16j Mobile Multi hop Relay (MMR) networks increase the capacity and coverage area of single hop IEEE 802.16 networks. The new Adaptive model increases the throughput and selects suitable relay based on optimal relay selection procedure. The average throughput achieved without relay is 800 Kbps and the average throughput achieved with relay is 1300 Kbps. There is on average 40 % increase in the throughput by placing transparent mode relays T-RSs at suitable position.

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