A new Adaptive Model for Throughput Enhancement and Optimal Relay selection in IEEE 802.16j 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 adaptive model for transparent mode IEEE 802.16j MMR networks and studied about the 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 Mobile Stations are initially placed near to Base Stations and are moving away from transparent mode base station. The average throughput achieved without transparent mode relay station is 792.045913 Kbps and the average throughput achieved with transparent mode relay station is 1261.856667 Kbps. There is 37.2318 % increase in the throughput by placing transparent mode relay station at suitable position.

Key-Words: - IEEE 802.16j, relay modes, optimal relay placement, WIMAX, NCTUns, etc

1. Introduction

The new task group IEEE 802.16j-2009 standard [1] of IEEE 802.16 air interface for broadband wireless access was officially established in March 2006. In order to support the mobile multi-hop relay specification, mesh mode is removed from the IEEE 802.16 -2009 standard. The specification is an amendment of the IEEE 802.16e standard for achieving throughput enhancement and coverage extension. It provides multi hop wireless connectivity where traffic between a base station and a subscriber station can be relayed through a relay station. This system enables mobile stations to communicate with a base station through an intermediate relay station. Multihop relay station is an optional deployment that may be used to provide additional coverage or performance advantage in an access network. The Relay Station may be fixed in location or, in the case of an access relay station, may be mobile access Relay Station. Most of the time, the relay station will act as a base station and will have its own physical cell identifier, and it should be able to transmit its own synchronization channels and control information. There should be no difference between cell control in there lay station and base station.
The radio link originating or terminating at a mobile station is named as access link and the link between the base station and relay station or between a pair of relay stations is called as relay link. The access link and relay link can be used for uplink and downlink data transmission. This standard defines the physical and the medium access control layer specifications for mobile multihop relay networks. The medium access control layer supports functions such as network entry, bandwidth request, and forwarding of data units, connection management, and hand over. The Physical layer adopts orthogonal frequency division multiple access as the primary channel access mechanism for non-line of sight 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 network topology where resource allocation is performed by the base station on a per connection basis, and the

subscriber stations are treated equally. Multiple input multiple output techniques have the ability to exploit non loss of sight channels and increase spectral efficiency compared to single input single output systems. Those techniques are able to provide high capacity and data rate without increasing bandwidth. The gain of multiple input multiple output includes multiplexing gains, diversity gains, and array gains.

The aim of this paper is to find a solution for throughput Enhancement in IEEE 802.16j mobile multi-hop relay networks. The rest of the paper is organized as follows. In section II, we briefly recapitulate the different relay technologies in IEEE 802.16j mobile multi-hop relay networks such as relay modes, relay transmission schemes, relay pairing schemes, and relay techniques. In section III we briefly discuss the New Adaptive model for throughput enhancement in IEEE 802.16j mobile multi-hop relay networks. This is followed in section IV by a brief discussion about the different terms and their definitions used in IEEE 802.16j mobile multi-hop relay networks and their relevancy. In section V, we briefly discuss the simulation setup and model of IEEE 802.16j mobile multi-hop relay networks. In section VI we driefly disuss about the performance of our simulation setup with graphs showing how the throughput is enhanced. Conclusions are drawn in Section VII.

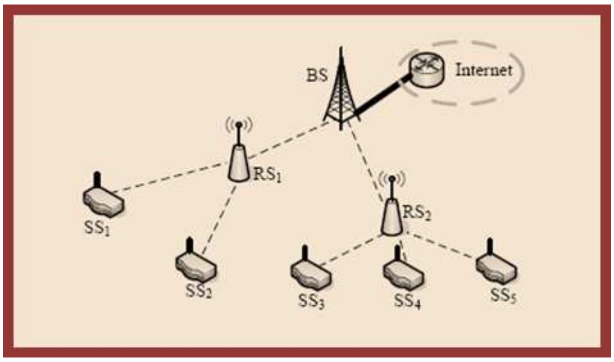

Fig 1: IEEE 802.16j Mobile multi hop relay (MMR) network

2. Relay Modes

Two different relay modes are defined in this IEEE 802.16j standard, the transparent mode and the non-transparent mode.

2.1 Transparent Mode

Transparent relay mode increases the throughput , and thus facilities capacity increases within the base station coverage area. It does not support coverage extension because it does not forward framing information to the base station. It is operated in two hop network topology and supports centralized scheduling only as scheduling is done in Base Station. Transparent relay mode uses the channel ID based forwarding scheme and supports embedded and explicit mode of path management.

2.2 Non transparent relay mode

The non transparent relay mode, as shown in Figure 3, increases the coverage extension of the base station. In this mode the relay station generates its own framing information and forwards it to the mobile stations or subscriber stations. It operates in two or more hops and uses centralized or distributed scheduling mode, as scheduling is done in the base station and relay stations. It uses the channel ID and tunnel based forwarding scheme and supports embedded and explicit mode of path management. The transparent relay station does not transmit control messages, permeable, frame control header, and Downlink / Uplink MAP, as it only increases the system throughput. The non transparent relay station transmits control messages, permeable, frame control header, and Downlink / Uplink MAP, as it increases the system throughput and increases cell coverage. Table 1 shows the difference between the transparent and non-transparent mode of operation.

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.

3. Adaptive Model

The Inputs of proposed Adaptive model are

1. $R=\{r_1, r_2..... r_m\}$The set of transparent mode relay stations. (or T-RS)
2. $B=\{b_1, b_2..... b_n\}$The set of transparent mode Base stations (or T-BSs).
3. $M=\{m_1, m_2..... m_o\}$The set of transparent mode Mobile stations (or T-MSs).
4. $L=\{l_1, l_2..... l_p\}$ The set of link efficiency

There are number of path loss models used for wireless channels, some of them are free space model, COST-231 Hata model, SUI model, multipath loss model, of these the SUI model is recommended by IEEE 802.16j committee

$$P_L(db) = A+10r\ log_{10}(a/a_0)+X_f+X_n+S$$

Where

S=Log-normally distributed factor (~8.2db to10.6db)

A=Intercept parameter

The modulations and basic code rates (denoted r) that we have used in designing an adaptive model is given below and these are the basic modulation and coding used for IEEE 802.16j networks

QPSK, basic code rate is r = 1/2 and r = ¾
16-QAM, basic code rate is r = 1/2 and r = ¾
64-QAM, basic code rate is r = 1/2 and r = ¾

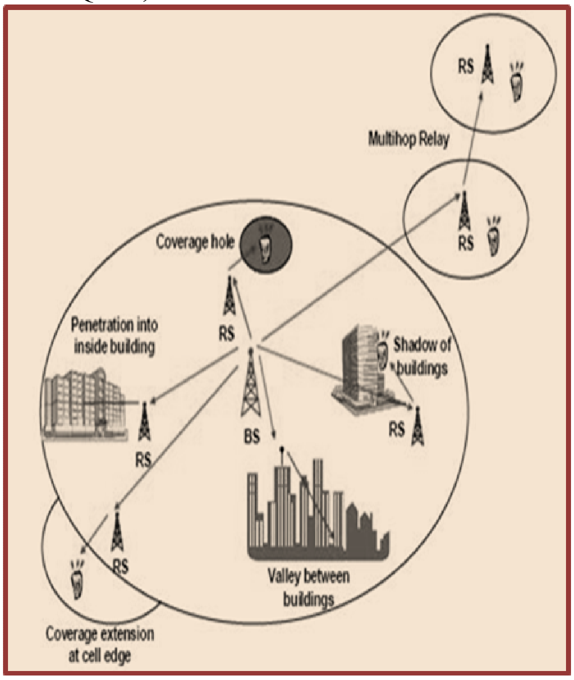

Fig 2: Adaptive model with spatial reuse

Definition 1: (Relay Station Placement for IEEE 802.16J MMR Networks (RSP-802.16J))

Given a BS B and a set M of MSs, each of which has a known location and a fixed rate requirement c_i, a set of RSs $R = \{r_1, r_2, \ldots, r_m\}$ is said tobe a feasible RS placement if for any $m_i \in M$, there exists an RS $r_j \in R$, such that $C_{DF}(m_i, r_j, B) \geq c_i$. The Relay Station placement for IEEE 802.16j MMR networks seeks for a feasible RS placement with minimum size. Our objective is to deploy a minimum number of such RSsto satisfy all the MSs' data rate requirements via CC and to select an optimal relay station when a group of relay stations are deployed. The optimal relay station placement provides minimum cost of deployment and maximizes the cost per user obtained from users.

Definition 2: (Relay Station Selection for IEEE 802.16J MMR Networks (RSS-802.16J))

Given a BS B and a set M of MSs, each of which has a known location and a fixed rate requirement c_i, a set of RSs $R = \{r_1, r_2, \ldots, r_m\}$ is said tobe a optimal RS selection if for any $m_i \in M$, there exists an RS $r_j \in R$, such that throughput gain is maximum. The Relay Station selection for IEEE 802.16j MMR networks seeks for a optimal RS selection with maximum throughput.

The Relay seelction algorithm provides the user to select an appropriate transmission from the available transmission. Here we allowed the mobile station to choose an appropriate relay based transmission.

The Relay path is selected based on the link bandwidth and loss rate. The hop count is taken into consideration for calculating the relay path selection.

In IEEE 802.16j MMR networks a separate scheduling is needed in RS , as once handover occurs from base station to relay station the mobile station has to transfer all the packets through the RSs and hence we in our model the RS performs its own scheduling. We have considered scheduling with delay constrain index (λ_i)

$$\lambda_i = h_i(q_i - \delta_i)$$

Where h_i the channel quality from the BS to the user, qi is is the queue length at the BS for the i th user, and δ_i is the desired queue length for that user, which corresponds for the delay constraint for that user. The MSs scheduled via RS, the BS scheduler needs to compute the index by taking into consideration the channel states and queue lengths for both the BS-RS and RS-MS links.

The received SNR at the MS is,

$$SNR_{BS\text{-}MS} = P_B - 10\eta \log d - N + \xi.$$

ξ is a Gaussian random variable with standard deviation σ on the BS-MS link.

The mobile station has to correctly decode the signal received from relay station, so the relay station should be deployed at suitable hot spot.

The optimal RS placement radius R* should be calculated, for placing a relay station at specific radius from the base station. There are more than one relays placed. The relays are placed such that there is no coverage hole. The approximate number of RSs required is,

The mobile station chooses a path based on the link efficiency, if the link through the RS is more efficient than the link through the BS it chooses the relay link

The relay station are deployed in IEEE 802.16j networks to increase the capacity or coverage area, hence the deployment cost of relay station should be calculated so that it should be minimized in order to achieve better deployment. The Network cost is calculated using the formula

$C_k = c_b + kc_r / N_k$

where

c_b= BS cost, including *backhaul*, installation, maintenance and hardware

c_r=RS cost, including installation, maintenance and hardware, but *no backhaul cost*;

k =number of RS deployed per cell;

N_k= the number of users

The optimization is performed over the set of data rates delivered to each MS and the amount of resources allocated to the access zone, as determined by p. The constraints are (i) ensure that the amount of transmissions in the transparent zone does not exceed the resources allocated to the zone (assuming no spatial reuse). (ii) ensures the transmission in the access zone do not exceed access zone resources; (iii) natural constraints on ***p*** and $\boldsymbol{x_s}$, respectively.

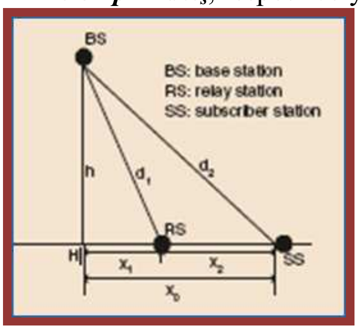

Fig 3: optimal relay selection.

Optimal Relay Selection Algorithm (O-RSA)

The Optimal Relay selection algorithm (O-RSA) is given below.

1. The knowledge of the mobile users is get form the usage statistics.
2. If the transmission distance is greater, than the user is asked for relay based transmission, where the bandwidth is high.
3. The user is allowed to check for cost per minute of relay based transmission.
4. Then the user chooses either relays based transmission or normal transmission.
5. When there are two or more relay transmission networks available, then the user is allowed to select an appropriate transmission within the network that provides more bandwidth and less cost per minute.
6. The bandwidth available in all types of transmission should be displayed to user, he is allowed to select and suitable bandwidth.
7. The user knowledge statistics is updated periodically.

The Adaptive model of the network is formulated here in order to determine whether or not spatial reuse is possible in the DL. The essential consideration in spatial reuse problems is to determine which transmissions can take place simultaneously. Typically, graph theory techniques are used in which some mechanism is employed to determine which transmissions interfere and these are then used to determine how to arrive at some appropriate schedule to ensure successful transmissions. The incorporation of the Adaptive model into the analytical model and the calculation of the system capacity with spatial reuse are discussed in following sections.

Fig 4: Node Icons of TMR-BS, T-RS, T-MS

4. Definition and Examples

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

4.1 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..

4.2 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.

4.3 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.

4.4 OFDMA

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

5. Simulation Setup

The desired network topology is specified in the GUI environment. As shown in Figure 5, 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.

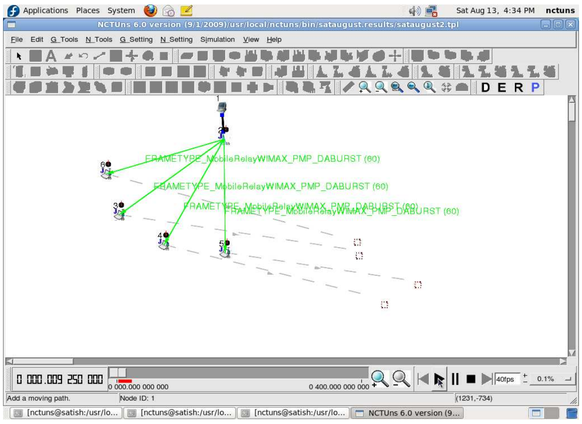

Fig 5 : Adaptive model topology construction

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.

In the NCTUns design, the default channel ID 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.

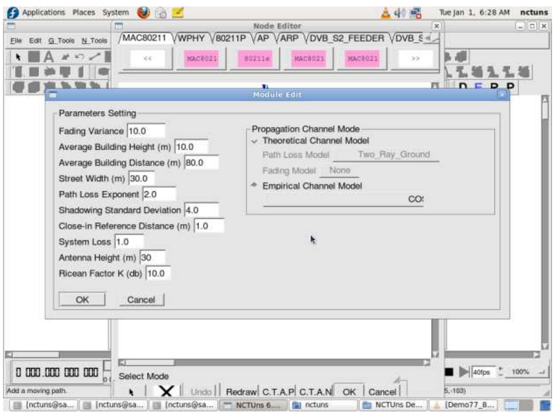

Fig 6 : power setting for adaptive model

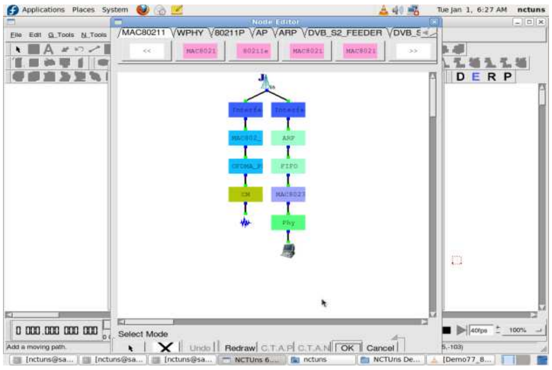

Fig 7: Node Editor of TMR-BS

The Network topology 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.

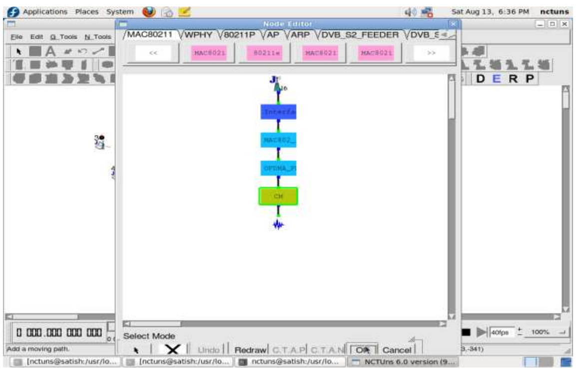

Fig 8: Node Editor of T-RS

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

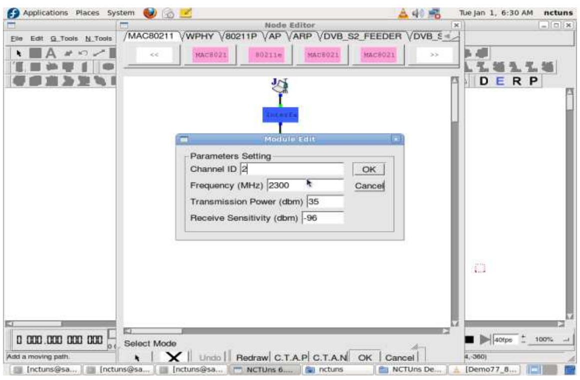

Fig 9: Channel ID setting by PHY module box

The IEEE 802.16j standard 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..

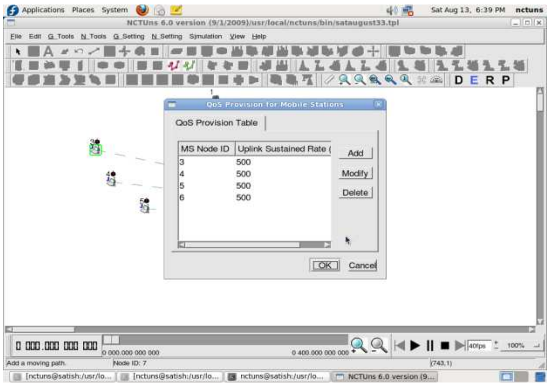

Fig 10: QoS setting for four T-MSs (Node 4, 5, 6, 7), respectively

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.
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.

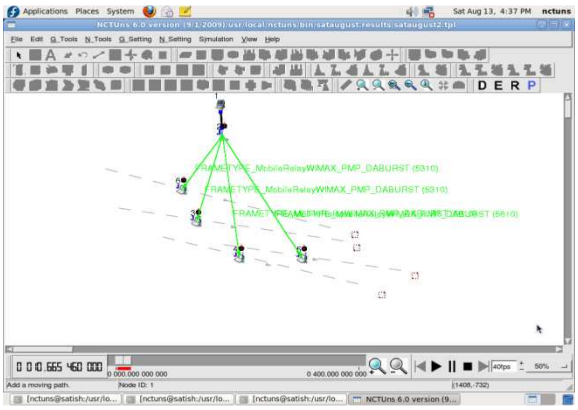

Fig 11.Network Topology without T-RS

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.

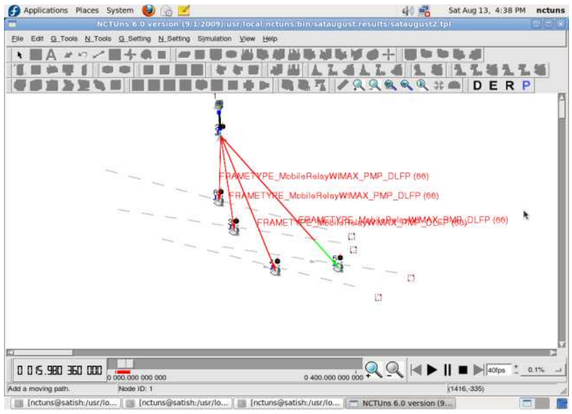

Fig 12: Data transfer with TMR-BS

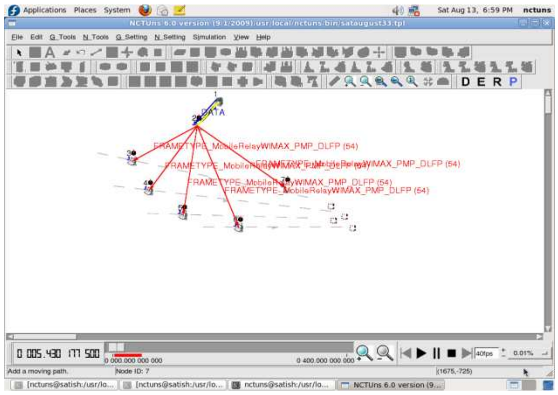

Fig 13: Network Topology with help of T-RS

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.

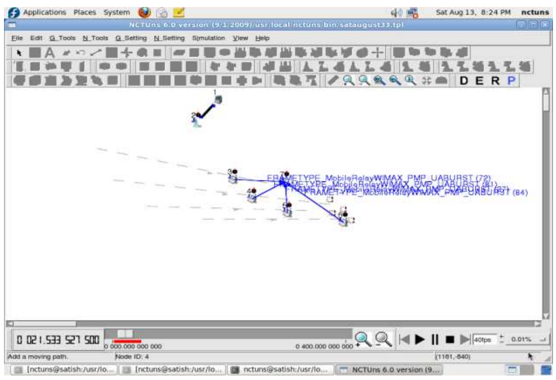

Fig 14: Relay selection by T-MSs

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,

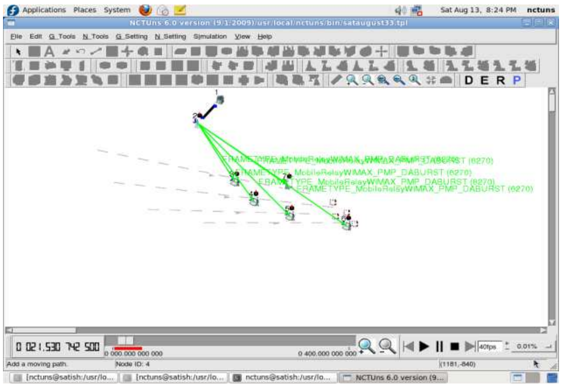

Fig 15: Data transfer through TMR-BS and T-RS

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

6. Performance Study

Deploying a T-RS between the TMRBS and the T-MS 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. 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.

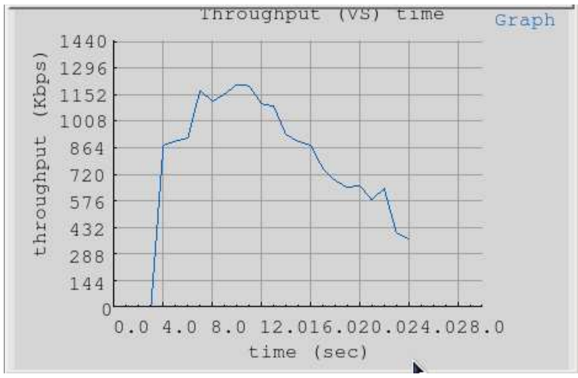

Fig 16: Throughput without T-RS

The average Throughput 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.

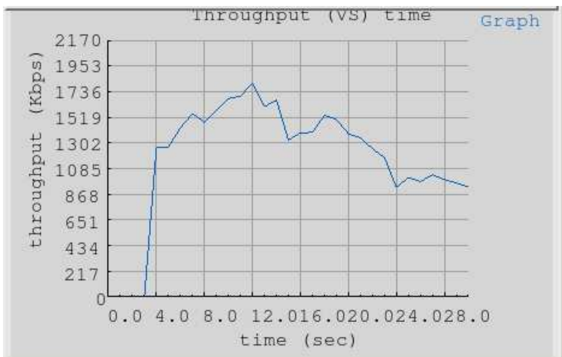

Fig 17: Throughput with T-RS

The average Throughput 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.

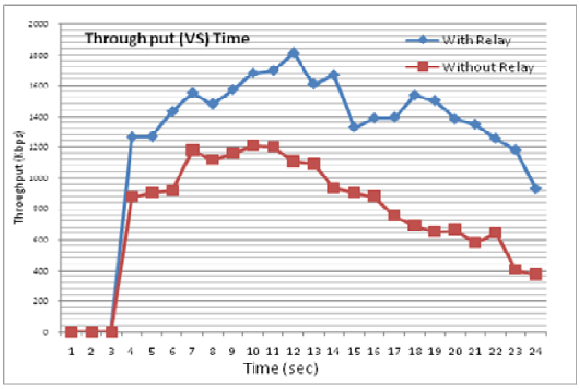

Fig 18: Throughput With and without relay T-RS

The comparison chart shows the throughput with and without relay placement. The throughput of all the T-MS is high, when we place a relay at suitable position.

7. 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 792.045913 Kbps and the average throughput achieved with relay is 1261.856667 Kbps. There is 37.2318 % increase in the throughput by placing transparent mode relays T-RSs at suitable position.

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