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Full Length Research Paper

A new adaptive model for throughput enhancement and optimal relay selection in IEEE 802.16j MMR networks

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Network deployment problem is one of the major issues when base stations and relay stations are jointly deployed. Deploying relay station at suitable position covers throughput enhancement and coverage extension problem in IEEE 802.16j MMR networks. In this paper we have proposed a new adaptive model for throughput enhancement and optimal relay selection in IEEE 802.16j MMR networks and studied about the average output/input throughput. A group of mobile stations are connected to base stations which are moving at a speed of 20 m/s. The Mobile Station is initially placed near to Base station and is moving away from Base station. The average throughput achieved without a relay station is 6.193 Mbits/s and the average throughput achieved with Relay Station is 9.867 Mbits/s. There is 37.2318% increase in the throughput by placing a transparent mode relay Station at suitable position. This paper also discusses optimal relay selection when a group of relay stations are deployed, the user is allowed to select an appropriate relay transmission that provides her required bandwidth and less cost. The mobile station selects a suitable relay station from the group of relay station.

Key words: NCTUns, Institute of Electrical and Electronics Engineers 802.16j, relay modes, optimal relay placement, worldwide interoperability for microwave access.

INTRODUCTION

The new task group IEEE 802.16j-2009 standard of IEEE 802.16 air interface for 'broadband wireless access' (Berezdivin et al., 2002) was officially established in March 2006 in order to support mobile multi-hop relay (MMR) specification, mesh mode is removed in the IEEE 802.16 -2009 standard. The specification of 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 (Genc et al., 2008). This system enables mobile stations to communicate with a base station through intermediate relay station as shown in Figure 1. 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. There are many technical issues in IEEE 802.16j networks such as frequency reuse, modulation and coding, path management, paging, interference management, QoS, network deployment etc. Relay placement is one of the major technical issues in IEEE 802.16j MMR networks. Relay station of equal capacity as base station has smaller coverage area and less cost. There will be cost tradeoff between RS and BS when they are deployed. Achievable data rate and maximize the through put are some of the variables to be considered in network deployment. A better signal to noise ratio (SNR) can be achievable when the link is broken to smaller links through RSs. There will be minimum two hops in this transmission using RSs. In this

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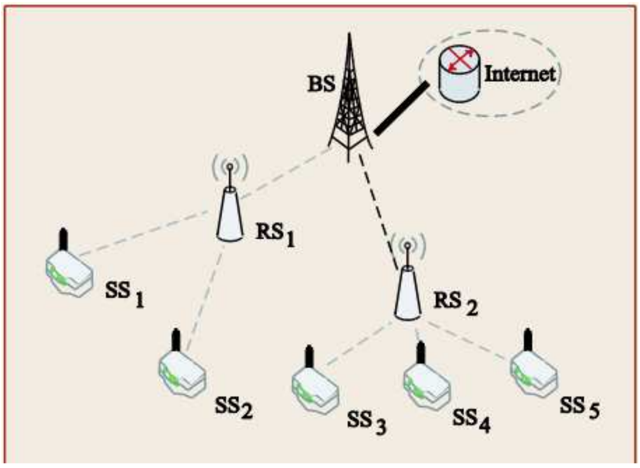

Figure 1. IEEE 802.16j mobile multi hop relay (MMR) network.

paper we studied the problem of throughput enhancement, relay selection, bandwidth allocation in IEEE 802.16j mobile muti-hop relay networks (MMR).

Most of previous studies work on relay assisted networks where relay are used to data aggregation and data forwarding. We focus on placing of relays at suitable position and selection of optimal relay form the group of relays. The relays are helping communication between base station and mobile stations by simply forwarding the data of decoding and forwarding it and the mobile stations may use diversity combination techniques to combine the signals from multiple paths. In this paper we use amplitude and forward decoding techniques of relay. Recently the cooperative communication between relay and base station is considered mainly in IEEE 802.16j MMR networks where the decode and forward relay concept which achieve high capacity is used recently. The rest of the article is organized as follows: Subsequently, the next study briefly discussed about the different Relay modes of IEEE 802.16j for through put enhancement and present a comparative study of the advantages of the different techniques. This is followed by a brief discussion about the different definitions and examples of the IEEE 802.16j technology and their relevancy. Then the simulation model of the IEEE 802.16j technology is given. Conclusions are drawn at last.

Literature review

The relay placement problem is addressed in some papers. In GiriciT (2009), they consider a practical deployment scenario where relay stations are nomadic and they are subject to repositioning. The mobile stations are represented as hot spots. They formulated Single RS Placement Formulation in 3-Node Relay Model and Single RS Placement Formulation in multi-Node Relay Model. They also used cooperative relay strategy for the problem formulation. They have considered relay time allocation and optimal relay placement in single stage with cooperative relay strategy. In Bin et al. (2009), they considered a tandem network with a single relay station. Here relays are used by the base stations to access all service stations. The relay placement problem is considered with resource allocation problem. The Relay placement problem is considered early in wireless ad hoc networks to forward data from the congested environment to the less congested one. The relay nodes were choosed subject to power constraints and other criteria in ad hoc networks. The relay nodes are used for data aggregation in earlier ad hoc networks, in WLANs the relay nodes are deployed for increasing the throughput of networks. In earlier papers, dynamic load balancing and scheduling was discussed in relay based wireless networks. The relay placement problem was formulated in a discrete space, and was solved by a Lagrangian relaxation iterative algorithm. 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.

MATERIALS AND METHODS

This standard defines the physical and the MAC layer specifications for MMR networks as shown in Figure 17. The MAC layer supports functions such as network entry, bandwidth request (Cicconetti et al., 2006), forwarding of PDUs, connection management and hand over. The PHY layer adopts orthogonal frequency division multiple access (OFDMA) 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

Table 1. Transparent and Non-transparent relay modes in IEEE 802.16j.

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.

performed by BS on a per connection basis and the SSs are treated equally. MIMO 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.

RELAY TECHNOLOGIES

Relay modes

Two different relay modes (Genc et al., 2008) are defined in this standard, transparent mode and non- transparent mode.

Transparent mode

The transparent relay mode 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 (So-In et al., 2009) only as scheduling is done only in BS. It uses CID based forwarding scheme and supports embedded and explicit mode of path management.

Non transparent relay mode

The non transparent relay mode (So-In et al., 2009) 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.

OFDMA

The most interesting technologies adopted in WiMAX are OFDM, OFDMA and S-OFDMA scalable 'orthogonal frequency' division multiple access technology which are specified in the IEEE 802.16-2009 standard. The operating spectrum of OFDMA (So-In et al., 2009) is divided into multiple narrow frequency bands; here it groups sub-carriers into sub-channels, each of which consists of multiple sub carriers. The multiple access is achieved by assigning different sub-channels to different users in the network for simultaneous transmission. The available resource can be viewed as transmission blocks (or simply blocks) in a two dimensional structure with mini slots in one dimension and sub channels in the other. The scheduling problem is how to assign such blocks to each link in the network to optimize certain objectives. OFDM is very similar to frequency division multiplexing (FDM), but it effectively squeezes multiple modulated carriers tightly together by keeping the signals orthogonal so that they do not interfere with each other and thus reduces the required bandwidth. OFDMA is a multiple access/multiplexing scheme that provides multiplexing operation of data streams like OFDM. Flexibility to efficiently use the system resources is introduced with Scalable OFDMA (SOFDMA). It allows smaller FFT sizes to further improve performance and reduce the cost for lower bandwidth channels. One key aspect in OFDMA systems is to take advantage of the so called Multi (user diversity as defined by Knopp and Humblet). Multi user diversity means that each user experiences different, time varying and frequency varying signal quality due to time and frequency fading inherent to wireless channels.

As OFDMA allows dynamical assignment of different sub carriers and OFDMA symbols to different users, dynamic sub carrier allocations (DSA) and adaptive power allocation (APA) to multiple users can be used to enhance the system capacity.

Relay pairing schemes

Pairing scheme is developed for having collaboration between RSs and BS in data transmission. This will improve the coverage and throughput of the mobile multi hop relay (MMR) networks. There are two pairing schemes proposed, centralized pairing scheme and distributed pairing scheme. The other Relay pairing schemes are Random Relay Pairing Schemes and Opportunistic Relay Pairing Schemes.

Centralized relay pairing schemes

In this scheme the BS will act as a control node and collects the channel and location information from all the RSs and SSs and then make the pairing decision. This information must be formed as a service set and periodically updated in the local BS to capture dynamic changes of SSs. This scheme requires more signaling over head, and can achieve better performance gains.

Distributed relay pairing schemes

In this scheme, RS collects the channel and location information from all the nearby SSs and then makes the pairing decision. First each RS identify its service set of neighborhood SSs and also the channel conditions between its BS as well as its SS, those RS with single service set each randomly selects a time slot from the N-slots in the pairing scheme. If multiple RS choose the same time slot then collusion occurs and those RS will be trying again in the next pairing scheme.

Relay placement

By deploying relay stations in lower SINR cell boundary area, the system capacity, throughput per user and the system reliability can be enhanced. The Relay placement is formulated as an optimization problem and solved by an iterative algorithm under the assumption that MS distribution is uniform. In some cases, large geographic area under non uniformly distributed traffic demand is considered. The locations of BS are determined in the first stage network deployment. An RS location algorithm is designed to locate RSs.

CHARACTERISTICS OF RELAY BASED NETWORKS

Relay based networks has small form factor, low cost relays associated with Base stations. Three main benefits provided from relay based architecture over single (hop architecture are throughput enhancement, coverage increase and deployment cost).

Throughput enhancement

It is expected to increase system capacity by deploying RSs in a manner that enables more aggressive spatial reuse.

Coverage enhancement/extension

The relay technology is expected to improve the coverage reliability in geographic areas that are severely shadowed from the BS and/or to extend the range of a BS.

Cost reduction

Relay based systems have the potential to deliver cost gains over traditional single (hop wireless access systems). Using RSs, an operator could deploy a network with wide coverage at a lower cost than using only (more) expensive BSs to provide good coverage and system capacity.

RELAYING TECHNIQUES

The relaying techniques include the conventional techniques: i) time domain relaying, ii) frequency domain relaying and iii) hybrid time/frequency domain relaying and the current technique that is of interest among the research community, iv) co-operative technique.

Time domain relaying

In this scheme, relays access the medium in time multiplex. The resources are further divided in time in either the DL or UL to allow the relay station to receive and transmit data.

Frequency domain relaying

Relays are operating on different frequency channels. The main advantage of this scheme is that relays can transmit and receive data simultaneously.

Hybrid time/frequency domain relaying

Relays are operating periodically on different frequency channels to forward data. The idea here is to switch between two frequencies in order to allow the BS to transmit to its client while the relay is forwarding data on another frequency.

Cooperative relaying techniques

Such techniques can significantly enhance the performance of relay based systems by multiple RSs cooperatively transmitting the same data to a SS or the BS, that is in the DL or UL. This leads to similar benefits than in MIMO systems with transmit/receive diversity and spatial multiplexing.

Path management

MAC layer provides routing and path management. As 802.16j network comprises multi-hop paths between the BS and MS, the standard defines two approaches for path management, embedded and explicit path management. It also defines network entry management.

Relay path routing

Relay path routing (So-In et al., 2009) is the process of determining most suitable route to BS by considering constrains such as bandwidth available, radio resource, interference etc. In centralized path routing path information is stored in the BS, but in distributed path routing path information is populated in RSs. The relay path information is embedded in the data burst by the BS using source routing mechanism and each RS just navigates the given path from the received data burst. In order to reduce the latency and use the radio resource effectively distributed path routing is preferred as the BS using centralized path routing cannot able to control whole networks. Throughput of a wireless link depends on both the bandwidth of the link and the PHY-layer loss rate, therefore the path selection method should take both the loss rate and the link bandwidth into account.

METHODS FOR INTERFERENCE AND SINR PREDICTION

Each station can measure the received signal strength (RSS) of the relay amble transmitted from other station, here PR,i,j is the RSS of the signal transmitted from node #i and received by node j and PR,j,j is the thermal noise and background interference power received by node j. The method for interference (So-In et al., 2009) and SINR prediction for different topology and radio resource reuse pattern is summarized as follows:

Step 1

Prediction of the interference plus noise power received by node i. The interference is the summation of: 1) the thermal noise plus background interference power received by node i and 2) the signal power not intended for node i.

Step 2

Prediction of the received SINR of node i: The SINR is the ratio of the total signal power destined to node i to the interference plus noise power obtained in Step 1.

Bandwidth allocation

The Base station allocates bandwidth to all the mobile stations based on channel ID which is a 16 bit address used to distinguish between multiple uplink channels associated with same DL channel. The mobile stations request bandwidth by bandwidth request sub header on MAC PDU. The Base station allocates dedicated or shared resource for the users periodically which can be used to request Bandwidth. In WiMAX this process is called polling. The efficiency of resource allocation (time and Frequency in both DL and UL is controlled by the scheduler that is located in each base station. The scheduler provides resource allocation by monitoring CQICH feedback. Throughput is a measure in concern with the portion of the data rates that can be used to successfully transfer pure data across the given network in a given time. The MAC layer reduce throughput by extension of preamble bits, PDU headers and CRC bits.

Centralized scheduling

It is one of the key functionality of the MAC common part sub layer (MAC-CPS), where it provides QoS (constrains to the MAC PDUs). The QoS constrains states latency, jitter, data rate, error rate; system availability should be met for all service flow. IEEE 802.16j standard defines five scheduling services, unsolicited grand service (UGS), real time polling service (rtPS), non-real time polling service (nrtPS), best-effort service (BE) and extended real time polling service (ertPS). The main QoS parameters are maximum sustained rate, maximum latency and tolerated jitter. Schedulers are designed to meet four main important criteria such as: i) The scheduler should use all available UGS slots if there is traffic, it should optimize system throughput; ii) The scheduler should guarantee the delay constraints or maximum latency; iii) It should minimize delay jitter and iv) The scheduler should minimize number of bursts and mobile application part overhead. Hence the scheduler first calculates the number of slots to allocate to each SS and selects on which sub-channel and time interval the data will be transmitted. Schedulers can be broadly classified into channel-unaware schedulers and channel aware schedulers. In Channel unaware schedulers, the decision is independent of the channel condition and only focuses on ensuring the QoS requirements of the different service classes. In channel aware approaches on the other hand, try to take advantage of the channel condition in order to maximize system throughput. Two QoS issues are service flow and bandwidth request. A service flow is defined as a one-way flow of MAC SDUs on a connection associated with specific QoS parameters such as latency, jitter and throughput. There are three basic types of service flows: provisioned service flows, admitted service flows and active service flows. The provisional service flow is defined in the system with an SFID. It might not have any traffic presence. In admitted service flow based on the external request from the specified service, the available bandwidth in admitted. In active service flow a service flow will be activated when all the checks are completed and the resources are allocated.

DEFINITION AND EXAMPLES

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

Base station

Base station provides coverage to a large number of mobile stations. It allocates the bandwidth to mobile station and manages the network. It provides two interfaces, one wireless interface also called radio interface for serving the mobile stations and the other is wired interface also called IEEE 802.3 Ethernet interface to connect to the server. The Ethernet interface consists of Interface, ARP, FIFO, MAC8023 and PHY modules. The main modules in the base station are medium access control (MAC) and OFDMA physical layer module.

Mobile station

Mobile Station is the subscriber station in IEEE 802.16j network. It is compatible with IEEE 802.16e network. The Mobile station has only one interface that is wireless interface connected to the Base station or a Relay station. It consists of same modules as that of Base Station.

Relay station

Relay Station is used to increase the capacity of the Base station. It functions similar to that of the Base station and it is of same capacity as that of the Base station. It consists of two wireless interfaces one for Base station and the other for mobile stations. It also consists of MAC and OFDMA module.

Adaptive model

In wireless networks as shown in Figure 16, transmitted power and receiver power and the loss occurred when it is travelling across a medium are playing a major role in design of suitable model. The receiver power (Pr) for wireless channels and the receiver power for wireless channels are given by:

$$Pr = Pt + Gt - PL + Gr$$

Where,

Pr = Minimum receiving power in the receiver,
Pt = Transmitting power,
Gt = Gain of the transmitter,
PL = Path loss,
Gr = Gain of the receiver.

The receiver power depends on the transmitting power and gain of transmitter and gain of the receiver and path loss components. The gains are determines from the manufacturer point of view. Then the minimum receiver power is calculated as follows:

$Pr, min = -114 + SNRRX – 10logR + 10log (Fs + NUSED)/NFFT + IMPloss + NF$

Where,

IMPloss = Implementation loss like phase noise in Wireless channel
NF = receiver noise figure (~5db)
Pt,Gt,Gr are based on the manufacturer.
Fs = Frequency sampling.
NUSED = Number of data subcarriers.
NFFT = FFT size.

The receiver signal strength at receiver with path loss is given by:

$Pt,r = PtGtGrAt,r/Lt,r$

Where,

Pt;r is the received signal power in Watt from transmitter t to receiver r, Pt is the transmission power of the transmitter, Gt is the antenna gain of transmitter, Gr is the antenna gain of receiver, Lt;r is the path loss between the transmitter and the receiver and At;r is the antenna attenuation. The signal to noise ratio (SNR) at receiver is given by:

$SNRr = Pr - 10log (B) - Nf - N0$

Where,

B = effective channel Bandwidth (Hz),
Nf = noise figure (db),
N0 = thermal noise level.

The high bandwidth is achieved by less modulation symbol duration then the high data rate is represented as the Pr,min and is directly proportional to Fs. 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.

$PL(db) = A + 10r log10(a/a0) + Xf + Xn + S$

Where,

S = Log-normally distributed factor (~8.2 to 10.6 db).
A = Intercept parameter.

When a source node s directly transmits data to destination node d, then the achievable data rate CDT is:

$CDT (s, d) = W log2 (1 + SNRsd).$

Where,

SNRsd = signal to noise ration from s to d, W = Bandwidth of the channel.

The throughput capacity is determined from the erlang capacity, where the Erelang capacity corresponds to the traffic load that a cell can support while providing acceptable services to the user and is used as a performance metric for admission control algorithm. Here the idea is each incoming user requires a random number of subcarriers depending upon its position in the cell fading and intercell interference. The capacity of this systems for given blocking probability is determined by the erlang-B formula. The erlang capacity of OFDMA system is then calculated as each cell requires a random number of subcarriers. The modulations and basic code rates (denoted r) that we have used in designing an adaptive model is given as follows and these are the basic modulation and coding used for IEEE 802.16j networks.

QPSK, basic code rate is r = ½ and r = ¾.
16-QAM, basic code rate is r = ½ and r = ¾
64-QAM, basic code rate is r = ½ and r = ¾

The code rates earlier mentioned correspond to the convolutional coding schemes included in the standard, and optional interleaving and other coding schemes such as convolutional turbo codes are not considered. The basic parameters used are:

Let,

Pr denotes the transmission power of an RS.
B denotes one base station.
M = (m1, m2, ………, mn) of n MSs are given; and mobile.

We define the relay station placement and selection problem for IEEE 802.16j MMR networks as follows:

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 raterequirement ci, a set of RSs R = (r1, r2,….., rm) is said to be a feasible RS placement if for any mi ∈ M, there exists an RS rj ∈ R, such that CDF (mi, rj,B) ≥ci. 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 RSs to 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 raterequirement ci, a set of RSs R = (r1, r2,….., rm) is said to be an optimal RS selection if for any mi ∈ M, there exists an RS rj ∈ R, such that throughput gain is maximum. The 'relay station selection for IEEE 802.16j MMR networks seeks' for an optimal RS selection with maximum throughput.

OPTIMAL RELAY SELECTION ALGORITHM (O-RSA)

The optimal relay selection algorithm (O-RSA) is given as follows:

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 for bandwidth.

Figure 2. IEEE 802.16j node icons.

7) The user knowledge statistics is updated periodically.

The aforementioned 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 (λi).

$\Lambda i = hi(qi - \delta i)$

Where,

hi is the channel quality from the BS to the user, qi is is the queue length at the BS for the ith user, and δi is the desired queue length for that user, which corresponds for the delay constraint for that user. The MSs scheduled viaRS, 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:

$SNRBS - MS = PB - 10\eta \log d - N + \xi$

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:

$NR = 2\pi/\theta = \pi/\sin^{-1} (R2^*/R1^*)$

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.

Relay deployment cost

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:

$Ck = cb + kcr/Nk$

Where,

cr = RS cost, including installation, maintenance and hardware, but no backhaul cost;
cr = RS cost, including installation, maintenance and hardware, but no backhaul cost;
k = number of RS deployed per cell;
Nk = the number of users.

BASE STATION AND RELAY STATION DEPLOYMENT ALGORITHM (BRDA)

The Base station and relay station are deployed based on conditions such as the total cost of budget and cost of base stations and relay stations. Then the relay stations are deployed such that it is well connected to the base station. The mobile stations are moving within the coverage area of base and relay stations. The total deployment budget should be fixed so that we can determine the number of relay stations for the specific area. Then there should be no interference between the relay stations, they are placed such that they meet certain threshold limit.

1) The total cost should be less than the deployment budget.
2) The relay stations are placed such that it is well connected to base stations.
3) There should be no interference between the relay stations.
4) Mobile stations are moving and it is well connected to base stations or through a relay stations.
5) The traffic distribution across the area may change so the relay position can be changed so that it serves all the mobile stations.
6) The relay stations are of equal capacity as that of the base stations, but it is less cost.
7) The base station should be backhaul connected to old networks such as IEEE 802.16e.
8) The base station locations are determined and deployed first and then the number relay stations required for the area is determined and deployed.
9) When these are needed more than one base station can be deployed such that it covers the entire hole in the area.

Throughput enhancement simulation model

The 'network' topology without relay is shown in Figure 3 where we specify one base station connected to the host (sender) and four mobile stations all are moving at a speed of 20 m/s. The mobile stations are moving in the path as shown in the figure. There are several node icons in the GUI of the simulator, the nodes icons used in our simulation are shown in Figure 2 were the first three icons are for transparent mode and second three are for non transparent mode. We have not used any relay station because we studied the output throughput without a relay station and then we studied the output throughput with relay station. The simulation model in Figure 3 is without any relay station. The base station uses two IP addresses, one for wired connectivity connected to the host (sender) and another for wireless connectivity connected to the mobile stations, the IP address is generated by the GUI when we group the base stations and mobile stations into subnet. There is subnet icon in the simulator which groups all the stations and

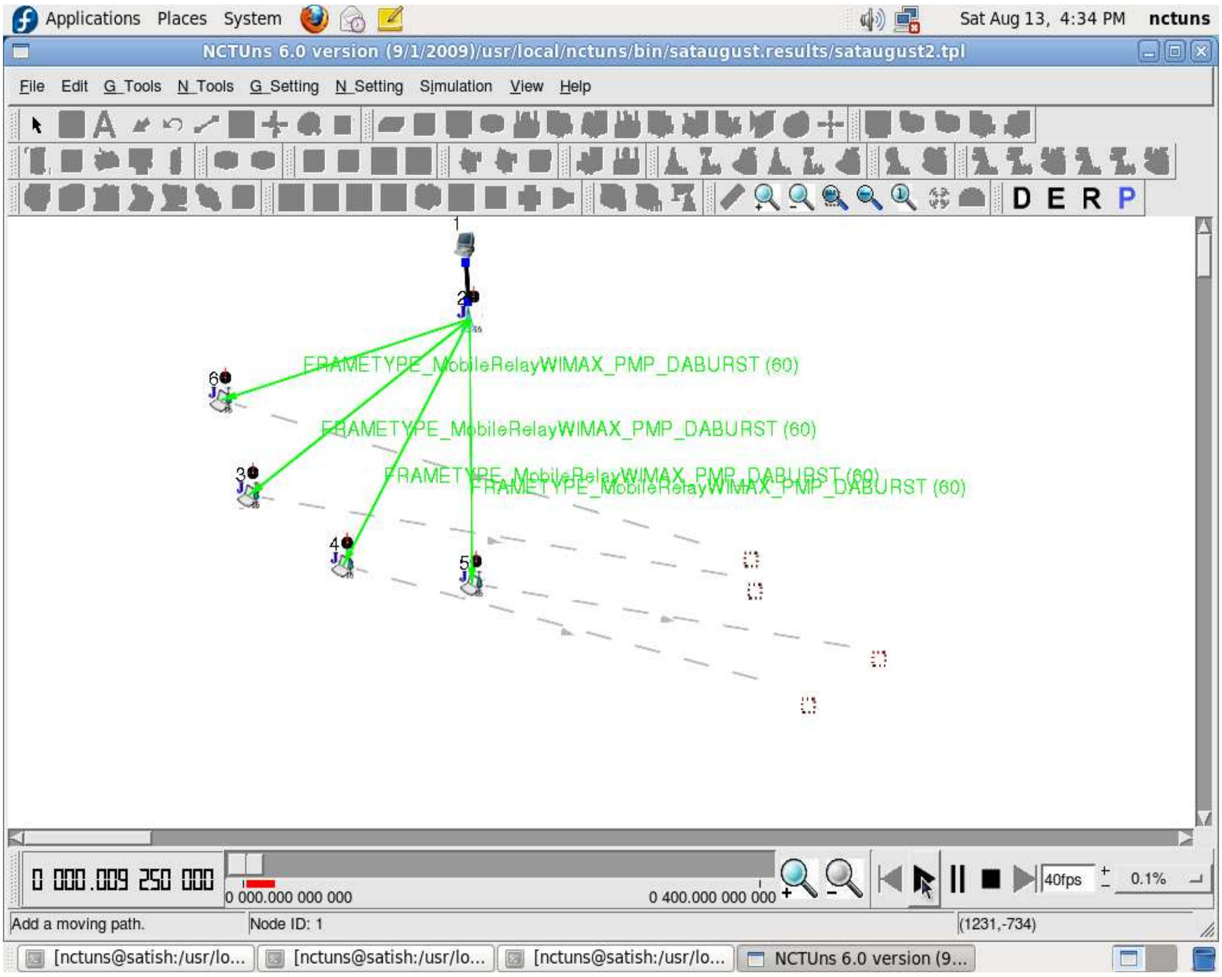

Figure 3. Network topology with out relay.

Table 2. Simulation Parameters

Channel Parameters	Path loss model= two ray ground
	Frequency = 2300 MHz
	Fading Variance=10.0
	Ricean Factor=10.0
	System Loss=1.0
	Transmitting power=43dbm
	Average antenna height=10m
	Average building distance=80 m

generates its IP address. Then the simulation time is set as 3 to 60 s and the sender host is set as “stcp –p 1.02.1 9000” where 9000 is port used to transmit and 1.0.2.1 is the IP address of the receiver. Similarly, the stcp is set for all the mobile stations. In mobile stations, “rtcp 9000” is set for receiving the packets. Then we specified the channel parameters for base station and relay station using their respective node editors as shown in Table 2. The node editor for base station is shown in Figure 4; it consists of the following modules CM, OFDMA, MAC FIFO, ARQ PHY and interface. The OFDMA module specifies the OFDMA channel channel parameters and CM module specifies the power settings and path loss model for base stations as shown in Figure 5. The MAC module logs all the data transmitted i to a file which will be used for studying the data transmission. Similarly, the Node editor of T-RS consists of the following modules: CM, OFDMA, MAC and interface, here also the power setting is specified.

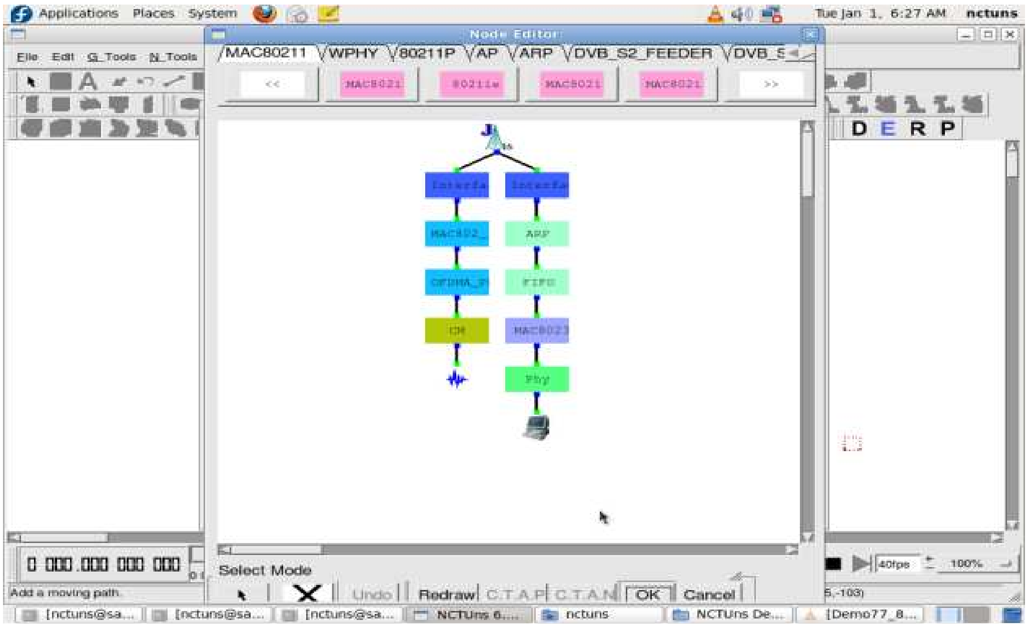

Figure 4. Node editor of TMR-BS.

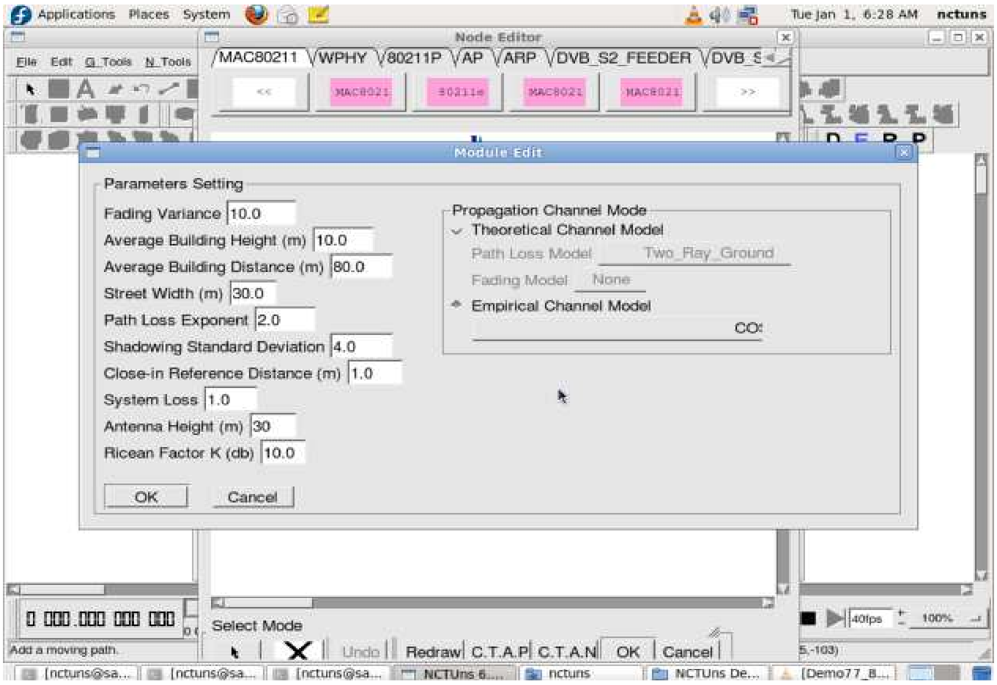

Figure 5. Power setting for adaptive model.

The PHY module specifies the channel ID used in our simulation. The QoS of IEEE 802.16j standard as shown in Figure 6 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.

In our simulation we used only best effort service. The maximum uplink sustained rate (in Kbps) in Kbps is defined as 500 kbps for each mobile station. In our simulation we used only hard hand over mechanism for hand over from base station to relay station. Data tranfer occurs when the mobile stations are moving as shown in Figure 3, but the throughput decreases when the mobile stations

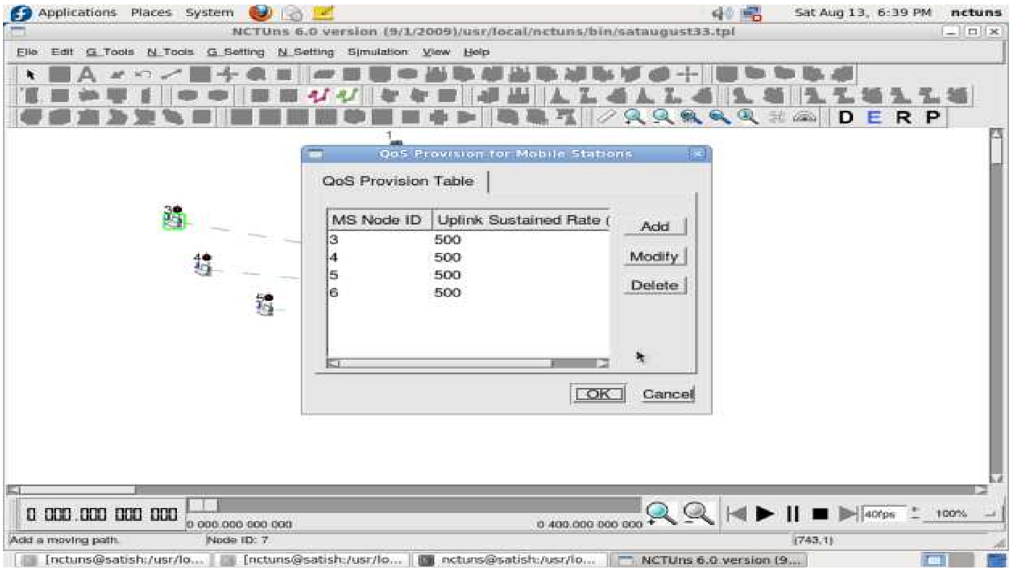

Figure 6. QoS setting for four mobile stations.

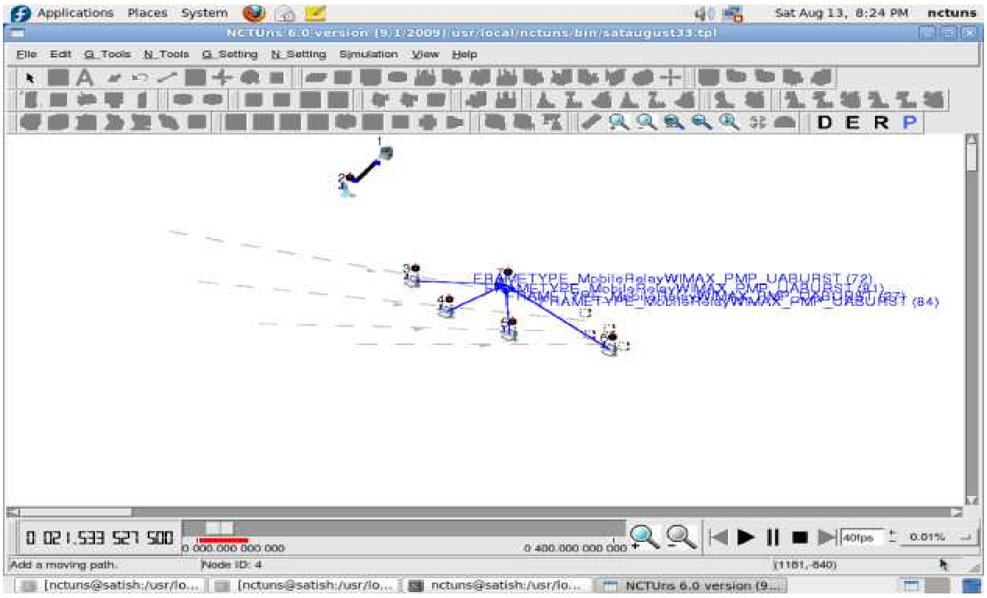

Figure 7. Network topology construction with relay station.

are moving away from base station. The low throughput due to tranmission path between them is NLOS. The network topology with relay station is shown in Figure 7 where we specify one base station connected to the host (sender) and a relay station connected to the base station and four mobile stations all are moving at a speed of 20 m/s. The mobile stations are moving in the path as shown in the figure. The relay station is also connected to base station through fifth link, as initially all the nodes are connected to the TMR-BS. The mobile station select the relay station based on optimal relay selection procedure, it is optimally calculated in PHY module. The mobile stations which are away from the TMR-BS are connected through T-RS as shown in Figure 8.

Optimal relay selection simulation model

The ‘network’ topology for ‘optimal relay’ selection problem is shown in Figure 9, here the mobile stations are moving in the specified direction and when they are moving away from the base station and when their coverage area is near to the relay stations (there are more than one relay station) the mobile stations has to

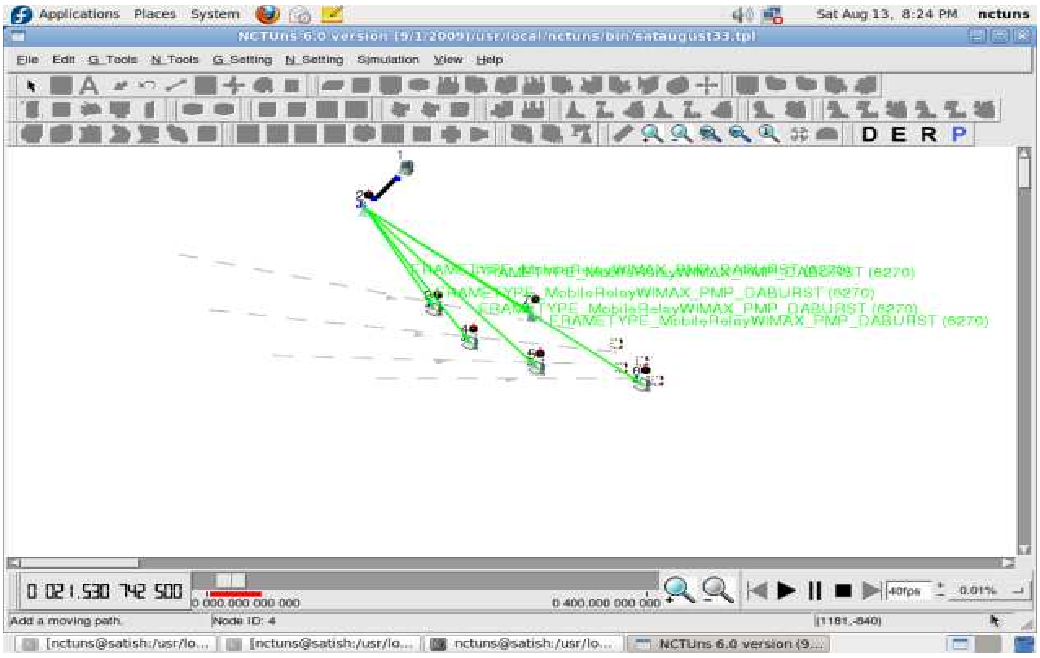

Figure 8. Data transfer through TMR-BS and T-RS.

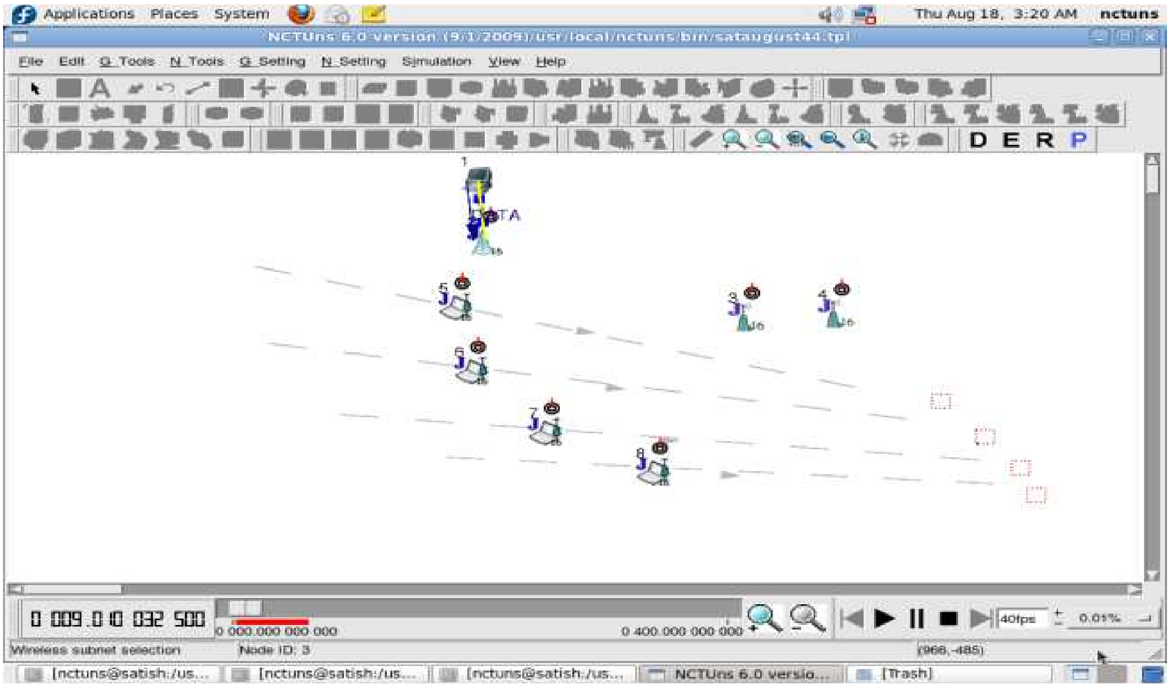

Figure 9. Network topology for optimal relay selection.

select a relay station for capacity enhancement. The relay stations are initially connected to the base stations as shown in Figure 10. The mobile stations are moving at a speed of 20 m/s. When the mobile station reaches near the relay stations, it automatically selects a suitable relay station and enhances its through put. The mobile stations while moving, they search for nearby base station/relay station, if it finds any such station then it automatically have a tie up with the nearby station; this is otherwise called as

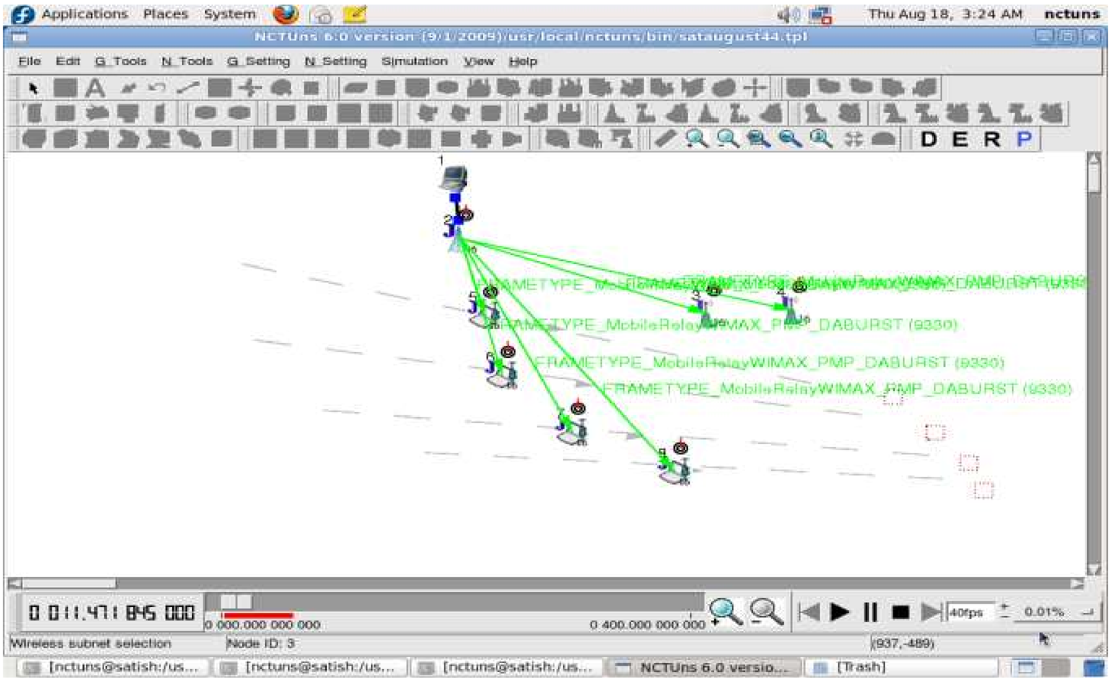

Figure 10. Relay stations connected to base station.

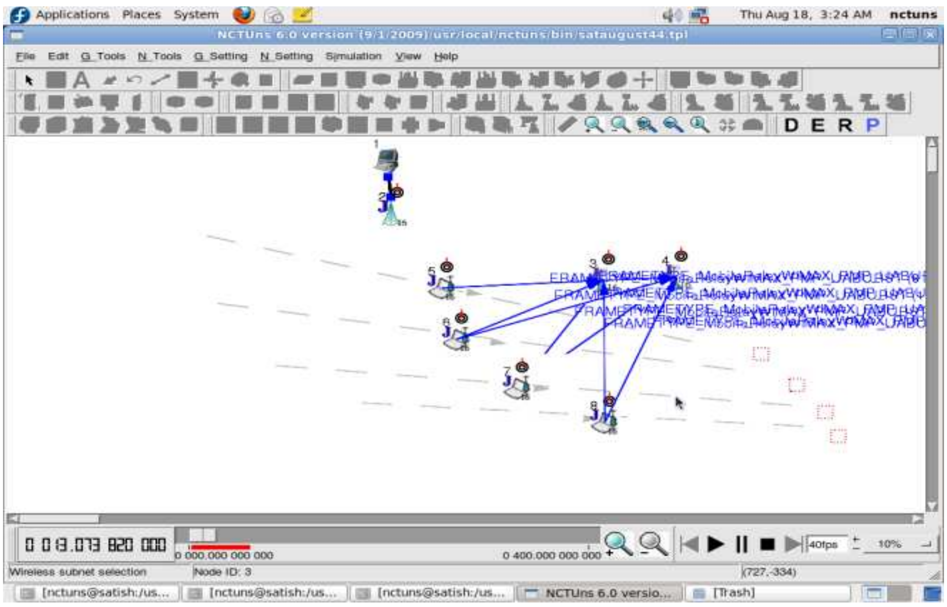

Figure 11. Mobile stations select an optimal relay station.

hand over. The mobile station are exchange initial packets with nearby station and then it has to choose a particular relay station from our proposed optimal relay selection algorithm. We have studied here how the mobile station selection of a particular relay station. We have shown in Figure 11 that the mobile stations are selecting their relay station. The relay station should be selected based on its bandwidth offered. As the relay station is used to capacity enhancement, the serving relay station should have enough bandwidth so that it meets the application criteria of mobile station such as video on demand, large file transfer. As shown in Figure 12, the mobile station selects their relay station; so the mobile station and the relay stations are placed at a suitable

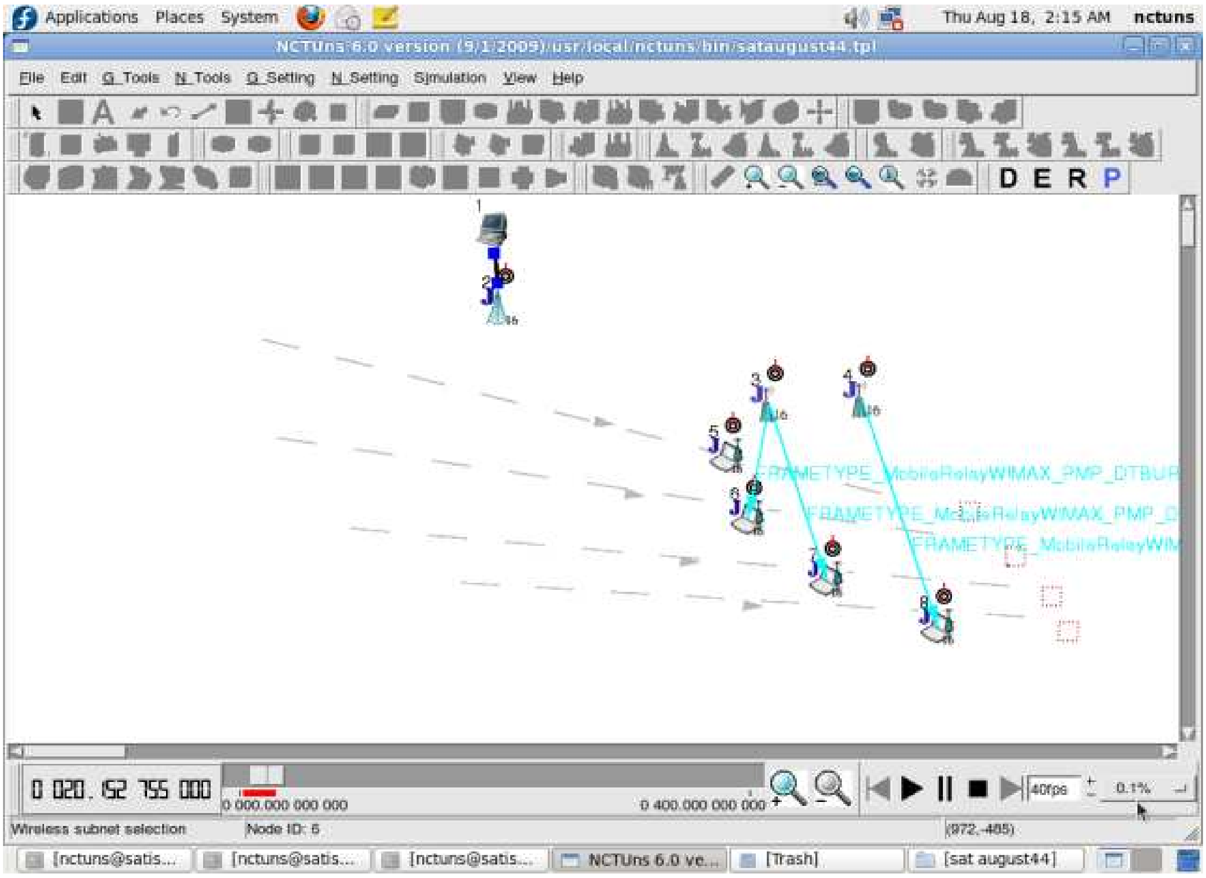

Figure 12. Optimal relay selection.

position.

RESULTS AND DISCUSSION

The ‘relay station’ deployed between the base station and mobile station solves the NLOS problem; and the end to end throughput achieved between them is high when we place a relay station as shown in Figure 15. The average throughput of the T-MSs without relay touches maximum at 11 s, 1200.418 Kbps and then it gradually decreases to 900.738, 649.064 and 371.596 Kbps which is very low and it occurs at 24 s (Annexure 1) when the mobile station moves to NLOS as shown in Figure 13. The total average throughput (xs) of all the T-MS is 792.045913 Kbps (Annexure 1). The average throughput of the T-MSs with relay (Figure 14) touches maximum at 12 s, 1810.98 Kbps (Annexure 1) and then it gradually decreases to 1388.336, 1255.814 and 930.226 Kbps as shown in figure. The total average throughput (xs) of all the T-MS is 1261.856667 Kbps (Annexure 1), thus the total average throughput remains steady throughout the cycle of operation. 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.

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 a relay station is 6.193 Mbits/s and the average throughput achieved with Relay Station is 9.867 Mbits/s. There is 37.2318% increase in the throughput by placing transparent mode relays T-RSs at suitable position. The optimal relay selection algorithm selects a suitable relay from the group of relays. The relay deployment cost is calculated as shown in the aforementioned procedure. The deployment algorithm for base station and relay station is proposed which finds a suitable location for base and relay stations. In future we are planning to combine all the network deployment problems and form a solution that addresses all other issues such as frequency reuse, interference management,

Annexure 1.

Time (s)	Throughput with relay (KBPS)	Throughput without relay (KBPS)
1	0	0
2	0	0
3	0	0
4	1264.706	877.616
5	1269.048	901.692
6	1431.474	918.39
7	1551.84	1176.894
8	1480.05	1115.73
9	1574.166	1156.716
10	1679.05	1208.11
11	1698.322	1200.418
12	1810.98	1103.592
13	1609.464	1089.568
14	1667.328	935.73
15	1329.206	900.738
16	1388.336	878.934
17	1393.856	753.26
18	1535.576	688.538
19	1502.512	649.064
20	1382.696	661.534
21	1348.812	580.752
22	1255.814	645.156
23	1181.098	403.028
24	930.226	371.596
Average	1261.856667 Kbits/s	792.045913 Kbits/s
Simulator average	9.86771915 Mbits/s	6.19379904 Mbits/s

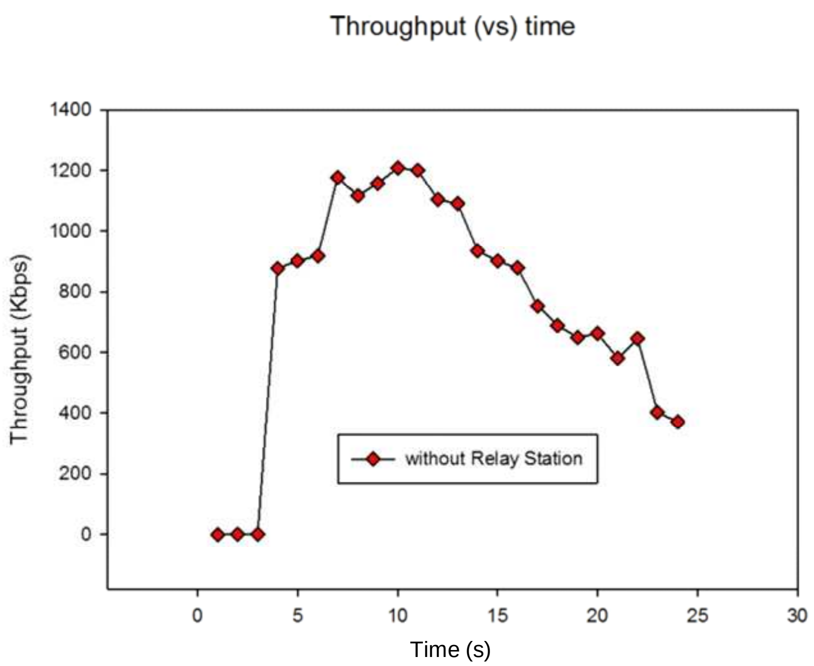

Figure 13. Throughput without relay station.

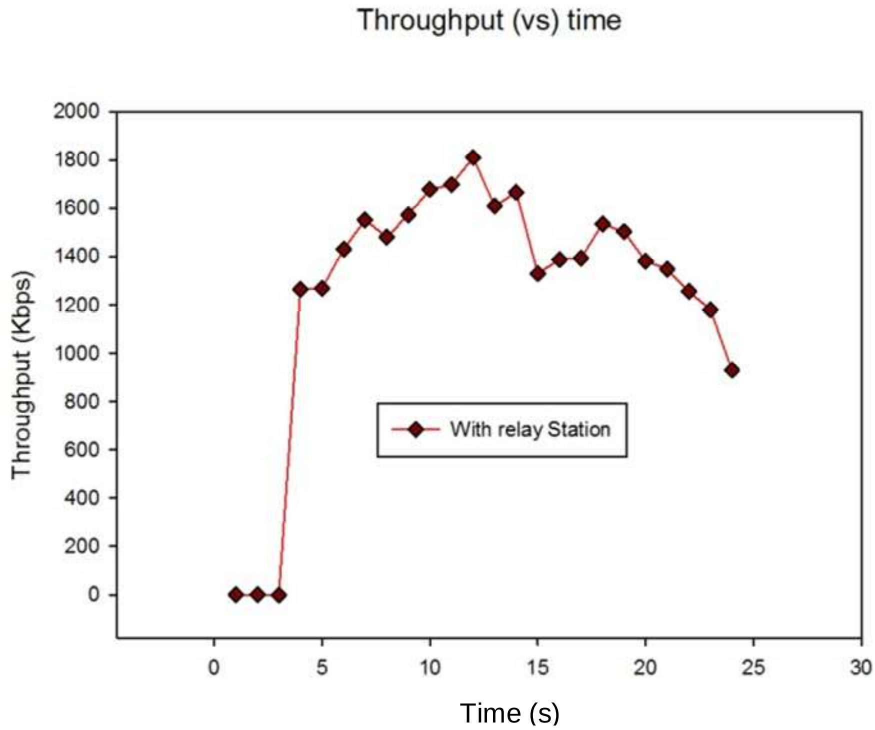

Figure 14. Throughput with relay station.

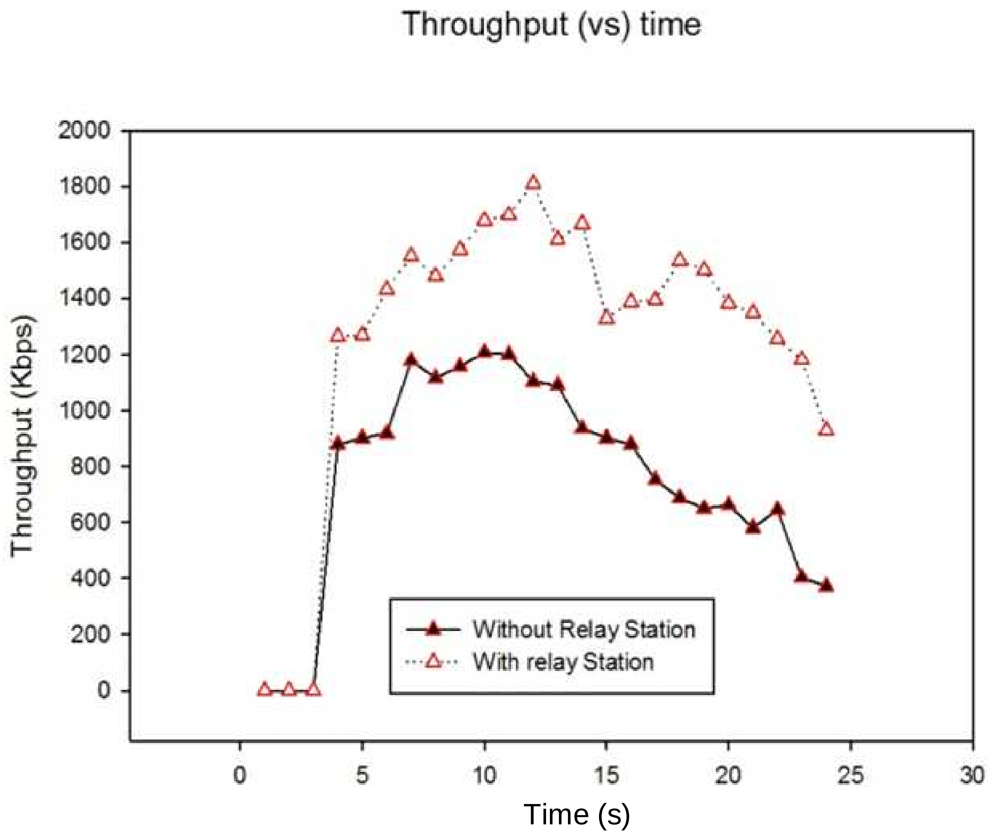

Figure 15. Throughput with and without relay station.

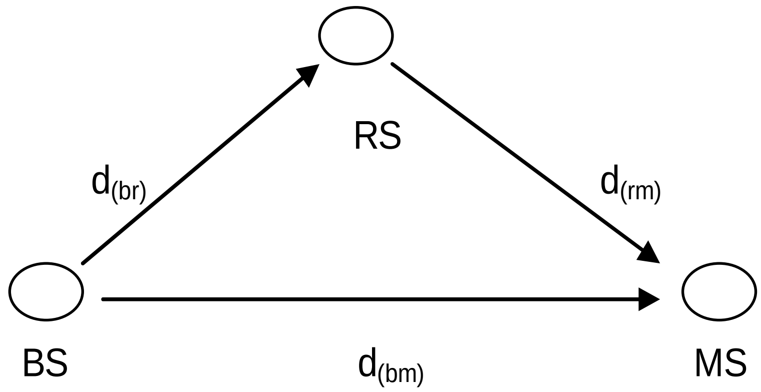

Figure 16. Adaptive model for IEEE 802.16j.

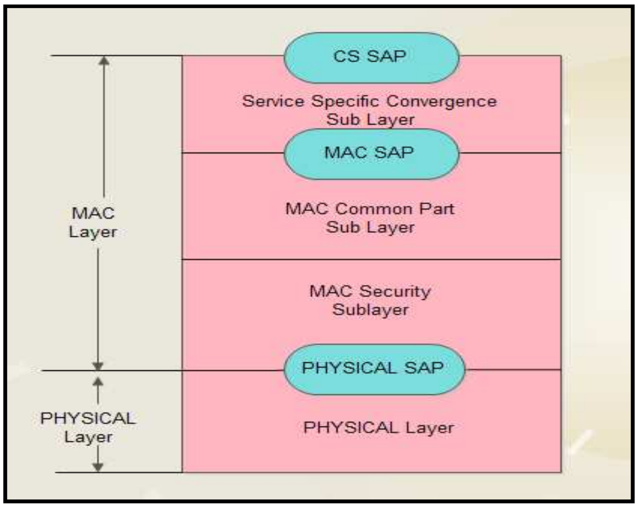

Figure 17. Layers of IEEE 802.16j Network

topology management, relay placement and relay selection.

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