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Qualitative Investigation of the Performance of Real-Time Application of IEEE 802.16e standard WiMAX Relay Networks

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Abstract
The ability of an application to adapt its behavior to changing network conditions depends on the available bandwidth, throughput, delay and packet loss in a network path. These are of major importance in congestion control, streaming applications, quality of service verification, relay selection and many other areas in WiMAX relay stations. Mobile WiMAX, which is based on the IEEE 802.16e standard, provides support for and enables full mobility to users. In an effort to optimize and enhance the overall network throughput, this paper will propose a mobile relay framework. WiMAX is based on the IEEE 802.16e standard, and can support various types of handovers, while allowing for full mobility from the user endpoint. Different methodologies were used to compare different aspects of WiMAX relay stations including throughput, delay, SNR and network load. OPNET modular was used to develop and measure these set of network performance metrics. To accurately measure and evaluate the aforementioned network parameters we employed techniques that were able to process large amounts of data, this aided in provision of much more informed recommendations as to the type of relay station modes that should be installed engender enhanced, improved and optimal Quality of Service (QoS) within the network perimeter. This paper measured the overall network throughput, delay, SNR and network load of relay networks comprising mainly of multimedia applications.
Keywords: *WiMAX, QoS, Relay Station, Simulation, Topology, Throughput, Delay, Packet Loss*

1. Introduction

The term wireless communication refers to any type of computer networking technology used and accessible without wires. Internet has dramatically changed the ways people communicate with one another and also their lifestyles. There has been much work and research done on the upcoming wireless devices, application and mobile phone technology to achieve better results in terms of improved wireless network optimal performance all in a bid to guarantee network quality of service (QoS).

There are different types of traffic flow in the wireless networks, e.g. traffic which have bursts in traffic and constant bit rates can affect both network performance and QoS for real-time application like voice and video streaming. However, when we compare and measure network parameters to check the QoS demands, it is very important to check all the QoS parameters such as, packet loss, delay and throughput which would be the main elements of real-time applications.

Originally, WiMAX was optimized for fixed access without support for endpoint (or user equipment) mobility. These accesses are Point to Point (P2P) and Point to Multi-Point (PMP) applications. But the second phase of WiMAX called IEEE 802.16e standard was designed with support for user equipment mobility. IEEE 802.16m should support existing IEEE 802.16e standard services which will be more capable and flexible in order to support services required by IMT-advance. The purpose of link budget can be to enhance the network performance for mobile users which are out of the range of base station or at the edge of the cell boundary to provide better throughput and SNR. The different environments like LOS and NLOS can be the main issues or can cause a signal to communicate directly from source to destination or propagate through different elements on the way such as tree, taller buildings, and river.

The IEEE 802.16e standard WiMAX is now evolving into WiMAX2 as named by the IEEE standardization committee given that it would be the leading mobile wireless broadband service provider in the near future. The WiMAX2 is compatible with existing IEEE 802.16e standard WiMAX release to save the deployment cost with improved performance. A WiMAX2 Mobile Station will be able to interoperate with an IEEE 802.16e standard WiMAX Base Station and both releases base stations can co-exist on the same carrier. The mobile stations are supported by both releases.

The evolution of the IEEE 802.16 standard will continue under the IEEE 802.16m project. This IEEE 802.16m project aims at the adoption of IEEE 802.16 for IMT-Advanced, which is an idea from the International Telecommunication Union – the Telecommunication Division (ITU-T) for mobile wireless systems with capabilities beyond IMT-2000. In preparation for IMT-Advanced, the IEEE 802.16m task group has developed documents for system needs, evaluation methodology, and system description.

2. WiMAX Relay Stations

Relay station can be used where

- Poor signal reception exists due to coverage holes.
- Bad Coverage exists due to weak signal. Because of the signal attenuation caused during high speed mobility and operating at higher spectrum.
- Communication is at large distance with high speeds mobility.
- There is too much cost of increasing the base stations.

To enhance the overall system performance both in throughput and in coverage, relay stations are introduced in IEEE 802.16e standard WiMAX system [18, 1-4, 19-21]. The relay stations may be further classified into different categories. The first category of relay station position is fixed, nomadic or mobile. While the fixed and nomadic relay station position is assumed to be fixed when operating, the mobile relay stations are implemented at moving object, for example buses or trains.

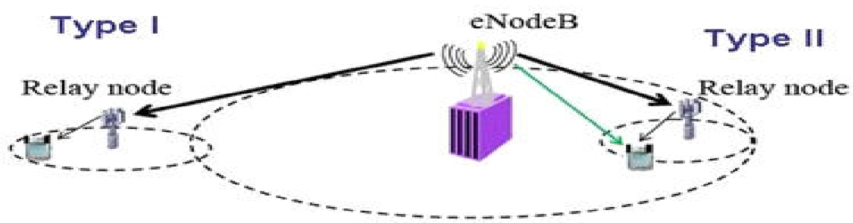


Fig. 1: Relay Station (RS)

2.1 Relay Station Modes

Relay stations are further classified into two main types, namely non-transparent mode and transparent mode.
Non-transparent Relay: In this mode relay station (RS) is placed beyond or at the edge of BS cell coverage area. It improves overall system capacity by increasing the coverage area and data throughput to the end node. In this case there is no direct connection between base station (BS) and mobile station (MS) and the transfer of preamble and other control information are sent through RS along with traffic signals.

Transparent Relay: In this mode a relay is placed within the particular BS cell coverage area in transparent mode [3] the base stations control information can reach the MS but the RS is used to relay the traffic signal between BS and MS. This configuration results in improved throughput within the coverage cell.

The multi-hop relays can make the system more complicated as the capacity obviously will be low when we use or transmit the data through different or more than two hops. Multi-hop system allows the MS to communicate with their neighbouring RS at lower power level; here RS relays the signal to the base station. These type of relays are fixed. Mobile RS operates while in motion, according to IEEE 802.16e-2005 its mobility is restricted to same limits as a MS.

2.2 Multi-hop Communication

Wireless communication faces different types of challenges for the telecommunication community. The IEEE 802.16e standard WiMAX system also suffers radio propagation challenge as the available SNR and the decrease of data rate when distance increase from source to destination degenerate. The factor called Shadowing, can cause or leads to non-line of-sight (NLOS) communication, which can decrease the signal strength and quality. Different types of multi-hop communication exist in IEEE 802.16e standard WiMAX system such as Mesh – Relay.

In order to meet QoS demand from single hop (link where the communication is between an end node and BS) to multi-hop by placing a RS, it will extend the communication process by adding more RS [17]. When all RSs share the same channel bandwidth, then the problem in terminal can also be rectified. If there is no building or obstacle in between the base station relay station communication the more throughput can be achieved [4]. In [4] the writers also defined a network simulator to simulate real time applications. In [9] , they have defined the relay stations usage scenario which are:
I) To improve coverage where no direct communication can be possible.
ii) To provide “coverage inside the building”
iii) To provide temporary coverage such as stadiums or an event.
iv) To provide better coverage for on mobile vehicle such as trains and buses.

The relay stations further classified into different types e.g. the fixed relay stations along with mobile multi-hop relay station can be used to enhance throughput, improve coverage and capacity [17]. Whereas nomadic RSs, which can be used temporarily or short period of time to provide additional coverage where BS could not provide good coverage. The main example of such deployments can be emergency disaster or sporting events. And finally, mobile RS which can be placed on a bus or train and communicate through a mobile link.

The focus of this paper will be based on a criterion that provides information about coverage, throughput, application support and environmental effects on IEEE 802.16e standard WiMAX relay stations to meet the QoS standard. Propagation is important, as the RF coverage in WiMAX offers significant information to aid in real world deployments. A comparative review of the existing published major approaches on WiMAX relay stations planning and optimization have been discussed to identify which gaps remain open in the existing literature. Also to identify the decisive parameters and the most important parts of WiMAX relay stations system for a good network performance.

2.3 Relay station optimization

Mobile relays that possess wireless backhaul links to the main network are capable of reducing deployment costs significantly and also ensure good capacity and coverage. Although fixed relays support many standard use cases, mobile relays ensure that a higher number of use cases which may not be part of the current standards, are enabled.

The relevance of a mobile relay solution is the maintenance of PMP connectivity with the MSs, and the carrying out of network operations for the re-establishment of the user plane and backhauling control.

It is also possible to apply this concept of a mobile relay possessing wireless backhaul links to the main network in the enhancement of network reliability. Radio stations are usually attached to the core network, with a relay link that serves as a wireless backhaul. As such, its reliability is usually not as good as a typical wired backhaul. It has been noted that reliability may present a difficult issue for low cost radio stations with small cells. It will be more ideal to handle any failures in radio link recovery transparent to the attached mobile stations.

With the proposed mobile relay framework, a radio station that is expected to display radio link failure can be made to re-establish the backhaul connectivity with any suitable base station that is near. This can be affected through a handover procedure, thereby ensuring that the problem would just appear as a scheduling glitch for all mobile stations associated with the radio station. This kind of self-repairing wireless backhaul operation can significantly improve the reliability of the network with no need for any special handling.

As with the optimization and enhancement of the relay network, the network might also become capable of aggressively switching the attachment point for the radio station on the basis of the operational status. This can also enable the loading of various base stations and the associated gateway to the network. Another advantage here is that the network would be able to initiate handover for radio stations to a more appropriate base station in order to ensure that load is evenly balanced within the radio access network, as well as for the core network. In [2] the writer writes about data on per-packet delay by providing structural analysis in network delay. Firstly discussed about the aggregation delay and then divide in two behaviours first is “Normal” for smooth periodic and second is “Abnormal” for sparse in time and then describe these behaviours with different methods.
The relay station performance can also be enhanced with adaptive modulation and coding scheme as using this

scheme the base station selects the required modulation and coding scheme by area and channel quality. In [13] the writers showed the comparison analysis of Bit Error Rate for QPSK modulation scheme over SUI-1, SUI-2 and AWGN fading channel and analysis for forward Error connection to evaluate the signal noise ratio for 5dB but on other hand they shows SNR value 8dB, 9dB and 10dB without encoder.

Using the proposed mobile relay framework, it will be possible for the network to dynamically perform operations without negatively affecting the connectivity of any mobile stations associated with the radio station, and this is one feature that is quite attractive in network operations nowadays. This mobile relay framework can also be leveraged for various use case scenarios. The essence of mobile relay frameworks is the maintenance of PMP connectivity with the MSs, during the performance of network operations intended to re-establish the user plane and backhauling control to the MS.

There has been a real need for the provision of Internet-related services that can be provided within lower costs and high throughput in the past few years. This has been highlighted by a growing need for advanced applications that will guarantee the desired QoS and which will ensure continued open access to such services. As we can see in [4] where the writer shows the concept of flow management function of multi-hop mobile radio systems and with static priorities it applies QoS Scheduling on it. Flow concept in data link layer allows distinguish application. Some of main aspects like signaling, handover and flow establishment are also discussed in this.

From the user point end, it is desirable to have a functionality that enables better access to preferred services in a reasonable manner when mobile. Several main parameters can be evaluated to ascertain the QoS levels. Those parameters are throughput, bit error rate, jitter, latency, [1-4, 7]. IEEE 802.16e standard WiMAX was designed to support different types of applications with different QoS requirements based on their usage. To support multiple applications with different QoS requirements such as voice for IP telephony, video for video gaming and video conferencing, to address this, mobile WiMAX defines different scheduling services based on each individual type of services requested. ."

To enhance the overall system performance both in throughput and in coverage, relay stations are introduced in WiMAX system [9, 2-4]. The relay stations may be further classified into two categories [12, 13]. A relay station can be either transparent or non-transparent. The transparent relay station does not transmit control information at the beginning of frame [12]. Consequently, the only purpose of transparent relay stations is to enhance throughput within base station cell. Therefore, a transparent relay station is implemented in cooperation scenarios when data are sent through several independent radio channels.

3. Simulation and Topology

The OPNET topology and the parameters used in the simulation where transparent and non-transparent mode discussed and depicted in three cell topology as shown in Fig. 1. The topology based on both transparent and non-transparent mode and three cells have been taken and each cell assumed a distance of 10 km. Three base stations also placed in each cell in order to get full coverage and cover the territory of each cell. We have placed random subscriber station (SS) within the cell for transparent relay station and out of cell for non-transparent relay station. The base station (BS) connected with a host via Ethernet connection model. The transparent relay stations are placed within the range of BS and adaptive modulation and coding scheme applied to each mode individually for getting enhance performance. However, non-transparent relay stations are placed nearside the boundary of the cell which is within the range of BS. In both modes, two links has been established called access link which can be defined as the link between BS and relay station and the second is relay link.

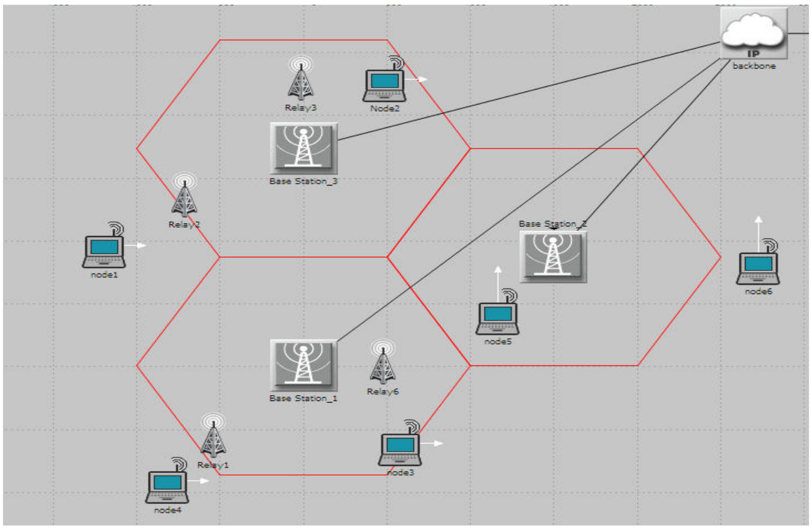


Fig.2: Three cell topology

The above topology shows different scenarios within the topology. As we can see, there are three cells with three base stations in each cell located at the centre of the cell. In base station1 cell, two relay stations have been placed as transparent and non-transparent and two nodes are connected with relay stations accordingly, one with relay two which is non-transparent relay station and relay four which is transparent. We applied adaptive modulation and coding scheme in this cell in order to get enhanced performance.

The second cell with base station2 represents direct communication scenario without relay station and the nodes 5 and 6 are directly communicating with base station and the trajectory of these two nodes set to Vector for base station to provide services to these two nodes. The both nodes placed within the cell and other out of the cell in order to compare with relay modes scenarios in other cells. The cell three with base station3 represents one transparent and one non-transparent mode with relay 2 and 3 accordingly.

4. Results and discussion of Relay stations modes

In different scenarios like where we simulated QoS parameters such as delay and throughput, the RS can be either in LOS or NLOS with the BS and SSs. The main focus of this section is to quantify the maximized throughput gain and the minimized the overall IEEE 802.16e standard WiMAX network delay that can be achieved with transparent and non-transparent mode relays alongside the multi-cell systems under different deployment scenarios with all other scenarios such available SNR, traffic received and traffic sent.

After complete analysis and network performance evaluation based on transparent and non-transparent relay station where evaluations were made on each individual mode. The different scenarios taken within three cell topology consist of different environments and indicate different results. The parameters chosen while designing our topology can be measured in any wireless technology and can evaluate the performance of the network by

- The number of bits sent per second
- The delay and its effects on real-time communication
- The available SNR for better signal reception
- The traffic received by end nodes to measure the performance of end users with QoS
- The traffic sent by end nodes to measure the capability of having guaranteed QoS.

4.1 Transparent Relay

Transparent relay station are helpful in dense urban area where base station cannot communicate directly with end node, so the transparent relay station help as a middle man to get the data from base station and deliver it to end node, same as it get the data from end node and deliver it to base station. However, there are some advantages and disadvantages of transparent relay station which are as follows:

The main advantages of transparent relay stations are, it cover the communication holes where there is no direct base station communication with end node. It extends the capacity of the network in order to get better reception at the other end. The transparent relay station can also be very useful in mobility e.g. on buses and trains to provide services for mobile users.

4.2 Non-Transparent Relay

As compared to transparent relay station, non-transparent relay station has advantage over transparent relay station, but we cannot take the bit of disadvantages out of this content as there are also some disadvantages are well. The major advantage of non-transparent relay station is:
It extends the cell coverage to provide the service to users out of the range of base station and out of the cell. It sends its own preamble to nearside end nodes to check and show its availability and its presence. On the cell boundary where the signal power fades, the non-transparent relay station can also be useful on this spot to provide extra coverage in order fulfill QoS demands.
As we have checked through simulation results, non-transparent relay station provides more throughputs and there is no interference of base station signals in between as compared to transparent relay station which can have the signals from base stations which can cause the traffic burst to go with errors and with delay.

4.3 Adaptive modulation and coding

The adaptive modulation and coding scheme used in above topology and the parameters set to adaptive modulation and coding scheme are:
The gold service has been used to get better performance as the picture below shows under service class name tag, however there are other classes supported in OPNET can use for performance analysis like bronze and silver.

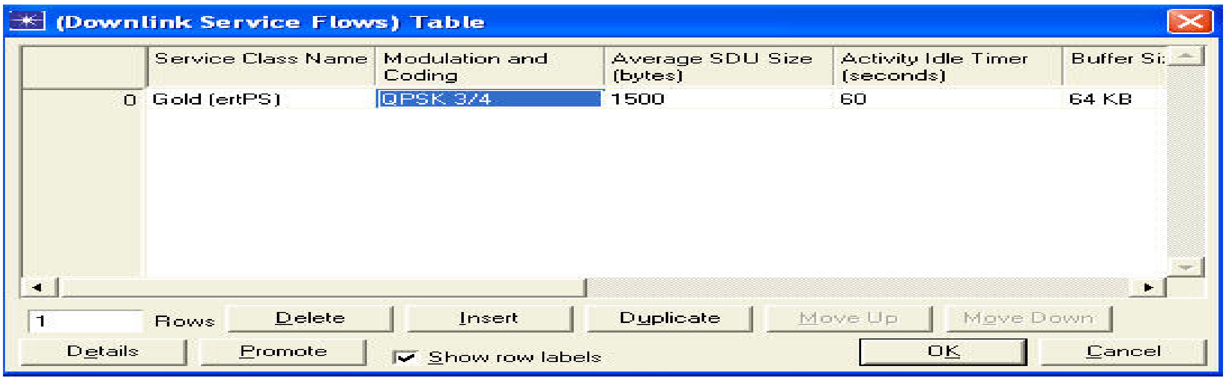


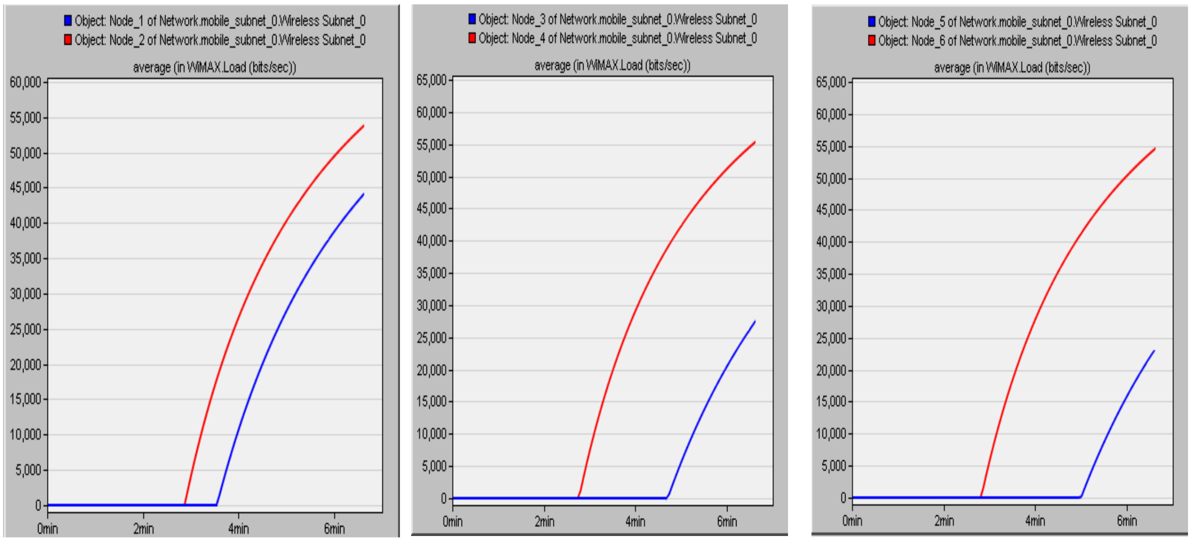
Fig 3: Downlink service flow using adaptive modulation and coding

The modulation and coding tag shown in the picture above where QPSK with coding rate ¾ have been used for base station to select higher coding rate for better performance. The remaining tags above in picture are default set parameters such as average SDU size, activity idle timer and buffer size. The main parameters in this topology are shown in Rows tag selected to voice as an application in the server.

4.4 Network Load with Transparent and non-transparent relay stations

Three different scenarios have been taken within three cells in order to check the load on the network. In Scenario1, the comparison of network was made on transparent and non-transparent mode. The graph shows the network load of both modes and the end nodes, node 1 and node 2 in simple topology, then in second scenario with adaptive modulation and coding scheme compared. And finally, the multi-hop scenario with node 5 and 6 has been compared.

The graph showing in chpater4 where the load of node 2, 4 and six is high as node 2 in the cell is connected with transparent relay station and the base station providing services to non-transparent relay station is well. The node 1 is out of the range of base station and node 2 is within the range of both relay and base station.



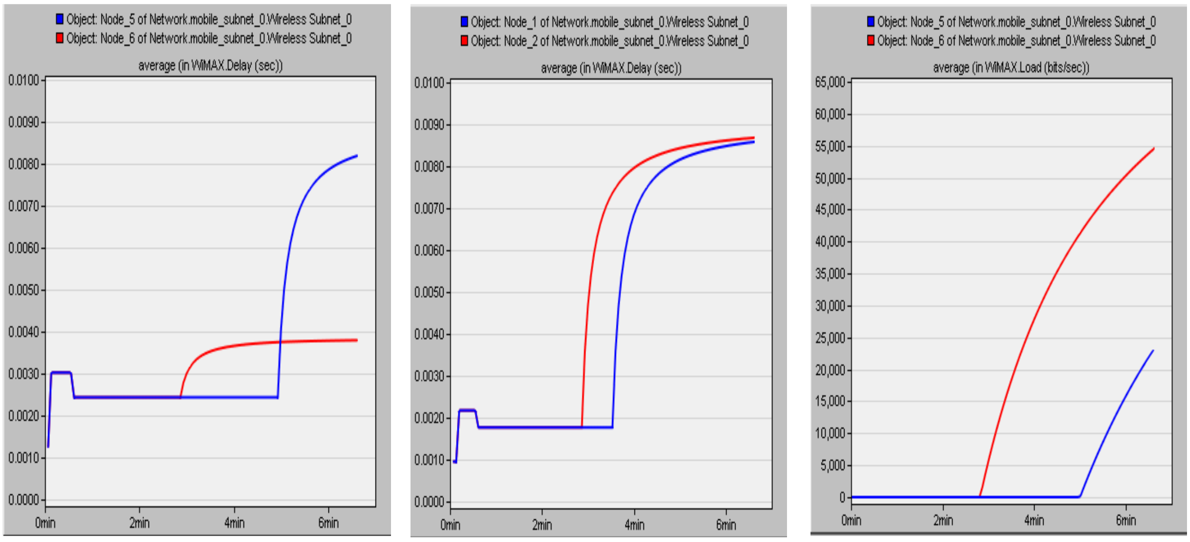
Scenario 1 Scenario 2 Scenario 3

Fig. 4: Graphs showing the load on each node connected with transparent and non- transparent mode individually.

4.5 Delay with Transparent and non-transparent relay station

Delay has different output for different scenario. It is very hard to analyze delay in real-time traffic as the number of packets in the buffer and the number of packet dropped during the communication process is hard task to implement. However, the results (Fig. 4) show the delay in first topology with node 1 and node2. The delay of node 2 started earlier compare to node1 as node 2 connected with transparent mode of relay station. The delay started earlier due to SNR but remain constant with node 1 after completion of ranging and selection process. And node 1 delay gets constant with node 2, same as competing processes and due to direct communication, the delay can be decreased

As we can see, the node 3 and 4 delay is different due to AMC and delay of node 4 is less in early stage as it is connected with non-transparent relay station with AMC but node 3 after running at several moments kept constant with node 4 as it is connected with transparent relay station and due to interference in the cell it started late but become constant after 4 minutes. Same as node 1, 2 and 3, 4 the node 5 and 6 which are in multi-hop topology, the delay of node 6 started after two minutes in non-transparent mode and node 5 delay started after 4 minutes due to transparent mode.

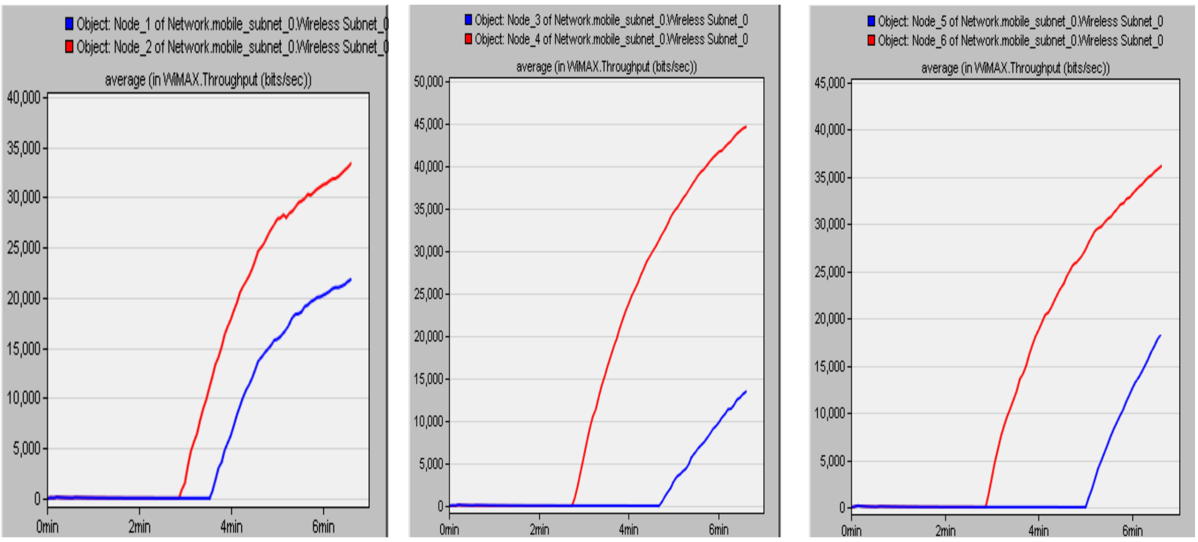


Scenario 1 Scenario 2 Scenario 3

Fig. 5: Graphs showing the network delay on each node connected with transparent and non- transparent mode.

4.6 Available throughput with Transparent and non-transparent relay

The available network throughput for both modes varies. As is evident on Fig. 6, the throughput is based on the area and the numbers of transmitted bits send per second's time to designated users.



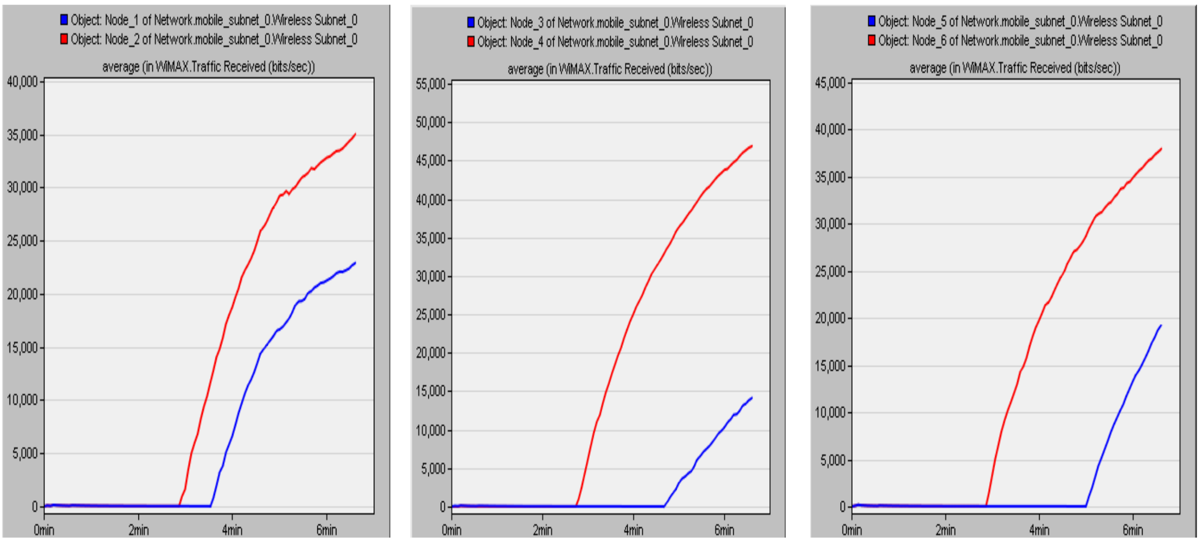
Scenario 1 Scenario 2 Scenario 3

Fig. 6: Graphs showing the network throughput on each node connected with transparent and non- transparent mode.

The available throughput shown in Fig. 6 above for all the above mentioned topologies based on simple transparent and non-transparent relay station, based on both modes with AMC and based on multi-hop scenario. The available throughput of nodes 2, 4 and 6 is high and it started scanning it after 2 minutes, however, the throughput for node 1, 3 and 5 showing in blue bar is low at two minutes but increased after three minutes in scenario1 and after four minutes in scenario2 and it took almost more than 5 minutes in scenario3. The throughput in scenario three of node 6 appeared high because it covers more area with the help of relay station and in scenario 2 of node four is high as it is using adaptive modulation and coding scheme.

4.7 Traffic received with Transparent and non-transparent relay station

The traffic received by end nodes through relay station in transparent and non-transparent modes are shown in detail in Fig. 7 as seen below with the variance as witnessed in each scenario.



Scenario 1 Scenario 2 Scenario 3

Fig. 7: Graphs showing the network traffic received on each node connected with transparent and non-transparent mode.

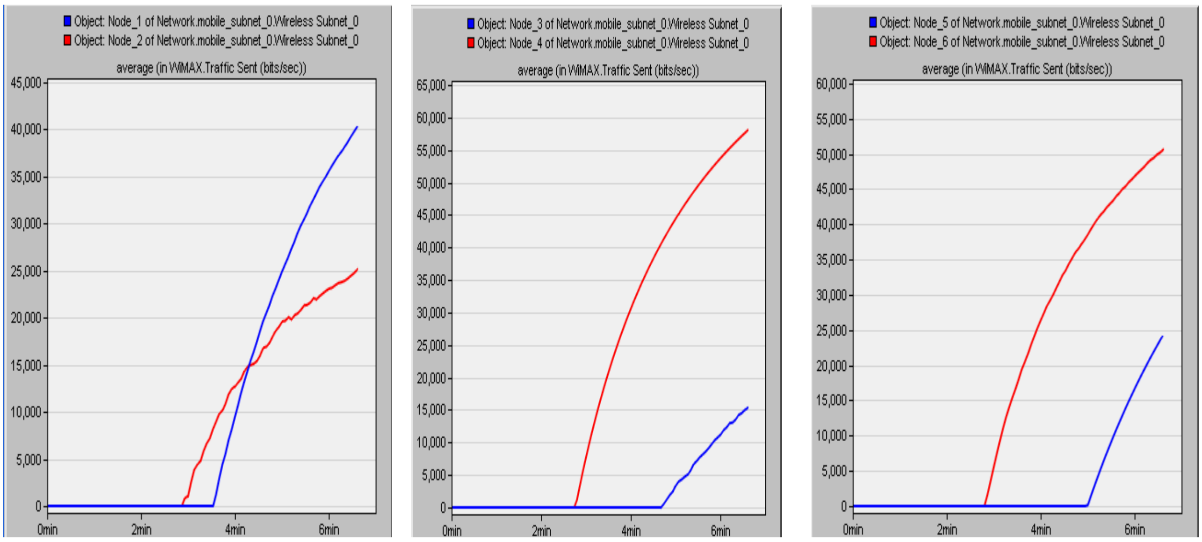
In scenario1 the traffic received by node2 is high as it is connected with transparent mode and also nearside of base station so there are more likely to get better reception in this area where node one has been placed. Hence, as a result of better reception, it can receive more data.

In scenario2, using AMC the non-transparent mode which is providing services to node 4 recorded higher ratios of received signal using AMC but due to interference within the cell, it started scanning after three minutes for transparent relay station and received traffic were quite low compare to node 4.

In third scenario, the received traffic in multi-hop node 6 started from three due to the short distance of relay stations antenna gain of both relay stations for node 6. However, the node 5 scanned the received traffic ranging process and started with a bit network delay due to base station and relay station signal interference.

4.8 Traffic sent with Transparent and non-transparent relay station

The traffic sent to each node by base station and with the help of relay station is showing below.



Scenario 1 Scenario 2 Scenario 3

Fig. 8: Graphs showing the network traffic sent on each node connected with transparent and non- transparent mode.

The traffic sent parameter shown above for the traffic sent by all the nodes in each scenario, here we can see that the traffic sent by all the nodes connected with non-transparent relay station were high in first place as there is no NLOS and signal interference in-between the base station or between relay station and end nodes.

In transparent modes, the traffic sent by all the nodes was low as there were possibility of signal interference and NLOS communication due to coverage holes.

In scenario1 the traffic sent by node 2 was high in scanning process and due to strong signal in the area but decrease after base station and relay station downlink and uplink communication in dense environment ensues.

In scenario2, using AMC the non-transparent mode which is providing services to node 4 recorded higher ratio of received signal using AMC but due to interference within the cell it started scanning after three minutes for transparent relay station and traffic sent by node 3 was low compare to node 4. However, the base station selects the higher and lower modulation scheme based on channel quality.

In third scenario, the traffic sent in multi-hop node 6 was high and it kept its position due to the short distance of relay stations antenna gain of both relay stations for node 6 where two relay stations were placed in-between the base station and end node, however the node 5 is scanning the received traffic after completing ranging process.

5. Conclusions

With the increasing demand for wireless technologies growing very quickly, IEEE 802.16e standard WiMAX playing an important role in the field of broadband and wireless industry to meet the QoS demands and end users satisfaction. The technologies like WiMAX and LTE use relay stations to enhance and improve the coverage of their network across a wider range in order to accommodate greater number of user equipment.

Firstly, the performance of both transparent and non-transparent modes of RS have been measured with simulated results using OPNET Modeler version16.0 where three different scenarios have been taken to evaluate and compare the QoS analysis in both modes of relay stations. The three scenarios taken were: (i) based on no relay mode topology, (ii) based on transparent and non-transparent relay modes and (iii) based on transparent and non-transparent mode with adaptive modulation and coding scheme.

When we analyzed the performance of WiMAX network with no relay modes, it was not good as there were little or no direct communication between base station and end node. We needed relay stations to cover the holes or gaps in direct communication. However, the performance with transparent and non-transparent mode was different as we used relay station in-between in order to cover or extend the coverage. But it was more reliable and enhanced when we applied adaptive modulation and coding scheme on second cell. In the results, we calculated and evaluated the overall network throughput, network delay, traffic sent and traffic received. These network performance parameters were chosen because they are the major parameters that determine network QoS.

We can evaluate and achieve a better radio resources management by implementing the solution for both modes of relay station. For example, in WiMAX network, the OFDM used with adaptive modulation and coding scheme as QPSK, 16QAM and 64QAM as modulation techniques in three cell topology, then on a particular cell depending upon available resources. Nonetheless, there are still some more topics such as scheduling, placement, resource allocation with enhanced antenna technique like MIMO that can be researched on, in future work.
On a final note, we can conclude that both transparent and non-transparent modes have their own advantages and disadvantages as both modes' usage are different. From our research exercise, the main disadvantage of transparent mode is that it can cause interference with neighbouring base station signals and the main disadvantage of non-transparent relay station is that it is expensive compared with transparent relay station. Nevertheless, their advantages are so many as opposed to disadvantages.

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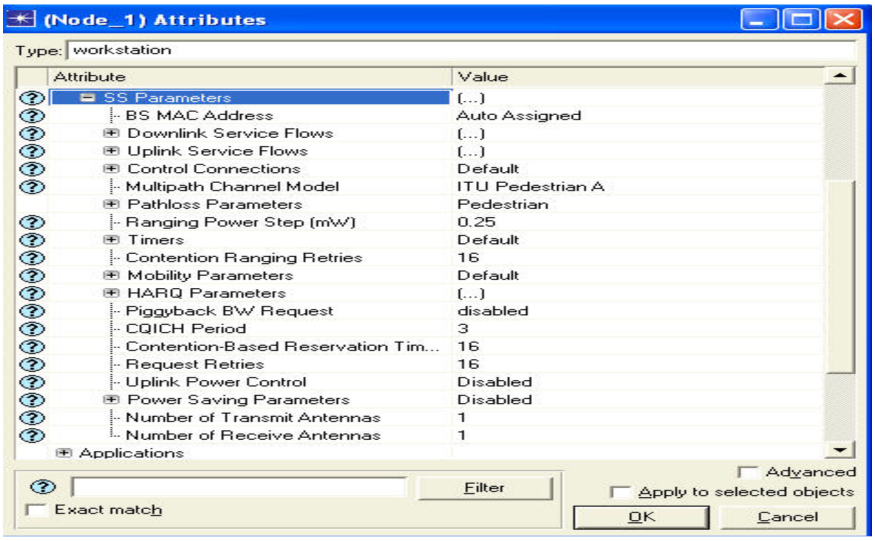
Appendix:



The above picture represents the parameters set in the topology; the SS parameters in this window are set as downlink service flow and uplink service flow where voice application has been selected for real-time application.

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