# TRAFFIC SENSITIVE AND TRAFFIC LOAD AWARE PATH SELECTION ALGORITHM FOR MMR WIMAX NETWORKS

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## ABSTRACT

*The recent developments in the broadband wireless access (BWA) communication systems have introduced several major changes to the existing systems. Legacy IEEE 802.16j is one such amendment to the existing IEEE 802.16 WiMAX family. The key modification introduced by 802.16j system is the concept of relay station (RS), which may be used to enhance the system coverage or to make system throughput optimal. The end terminals, subscriber stations (SS) are unchanged in the standard. The overall change pertinent to the system has raised many unresolved issues related to RS and multi-hop relay base station (MR-BS). The selection of path from a SS to MR-BS via a RS is also one of the issues, need to be addressed. The path selection of a SS in both uplink and downlink directions is left open in the standard. It is very significant to satisfy the traffics of stringent quality of service (QoS) requirements and to appropriately manage the resources of a cell under different circumstances. This paper proposes a path selection algorithm to achieve the aforementioned qualities in the network. The path selection metrics include traffic load of the transparent relay station and traffic sensitivity factor of the SS. An extensive simulation work discusses the performance evaluation of the proposed work using QualNet simulator.*

## KEYWORDS

*IEEE 802.16j, MMR WiMAX, Path selection, Transparent relays*

## 1. INTRODUCTION

Mobile multi-hop relay (MMR) worldwide interoperability for microwave access (WiMAX) technology is a potential ubiquitous wireless access technology, which is intended for a wide geographical area. Since its evolution IEEE 802.16 standards family has come up with a new dimension to facilitate user's requirements. IEEE 802.16j [1-2] is an amendment to its predecessor IEEE 802.16e, has many open issues which attract researchers. To incorporate the coverage extension and throughput optimality RSs have been brought into picture [3-4]. RSs are categorized as non transparent relay station (NT-RS) and transparent relay station (T-RS) [5]. The former is basically used to extend the cell coverage, whereas the latter is used to improve the throughput. NT-RS can be used to have multiple hops and number of hops is restricted to two for T-RS. The basic difference between these two relays is the framing structure [6]. An NT-RS generates its own preamble, also transmits the control messages and acts like a base station (BS) to the SS with which it communicates [7-8]. However a T-RS does not transmit any control message and preamble just relays the data to corresponding SS. There are two types of scheduling techniques followed by these two types of relays. T-RS mandatorily obeys the centralized scheduling; NT-RS may follow either centralized or distributed scheduling [9]. In

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MMR WiMAX network choosing an appropriate path between a SS and MR-BS becomes very crucial. Hence there is a need for new approach to make the path decisions for a MR-BS to SS. The typical path selection metrics include signal to noise ratio (SNR), number of hops, QoS parameters etc. It is very essential to consider the traffic load and traffic sensitivity also into account to decide the optimized path, when the system is heavily loaded and consisting of prioritized traffic. Therefore this work makes an effort to formulate an optimized criterion for adaptive path selection. Path selection metrics include traffic load and traffic sensitivity along with the existing parameters like SNR and MCS. This paper mainly focuses on the centralized path selection algorithm for point to multi point (PMP) mode, two hops MMR WiMAX networks consisting of T-RSs which are fixed.

Rest of the paper is organized in the following order; section 2 reports the related work on path selection issues in MMR WiMAX networks. The background of the topic of discussion is covered in section 3. Section 4 details the system modeling and section 5 discusses proposed algorithm. Section 6 explains the performance evaluation of proposed algorithm using QualNet 5.0.2 with the aid of IEEE 802.16j contributed module and section 7 presents the conclusions.

## 2. RELATED WORK

Many works have addressed the path selection problem of MMR WiMAX networks in the literature.

The relay concept in WiMAX technology has introduced several challenges; work in [10] discusses the network planning in MMR WiMAX network. Authors of [11] have addressed MMR WiMAX network deployment problem and BS/RS placement. However these works discuss about locating the BS and RS in a MMR WiMAX network. Performance evaluation of wireless broadband (WiBro) system with mobile multi-hop relay is assessed in [12]. Comparison of the WiBro system performance is made with RS and without RS.

In paper [13], a path selection metric named normalized number of mini slots (NNM) enable a SS to choose a path that satisfies its application rate and delay requirements. This work concentrates mainly on IEEE 802.16j based mesh networks and the performance evaluation is carried out using ns2 simulator. Authors in [14] have improved their previous research work in which they proposed novel path metric effective radio resource index (ERRI). The ERRI metric used to indicate the effectiveness of radio resource of a link used to transmit data in turn improved to select an effective relay path in the error-prone IEEE 802.16 multi-hop relay (MR) network. Work in paper [15] select proper paths from BS and RSs to achieve the maximum degrees of freedom with the desired SNR under a LOS (line of sight) MIMO (multiple input multiple output) channel. To do this, the proposed scheme selects paths by the order of decreasing SNR among uncorrelated paths until the maximum degrees of freedom. Authors of paper [16] have proposed a cross-layer tree based path construction mechanism to adjust the system deployment when a new SS accesses the network. Furthermore, an interference based path selection scheme is suggested to facilitate the improvement of per-user throughput as well as system throughput in MR network**.** But a detailed performance evaluation of the algorithm is not assessed. In paper [17], authors have proposed a path selection method for IEEE 802.16j MMR network in which path selection metrics include link available bandwidth, SNR and hop count. However the performance of the proposed algorithm is evaluated by using only numerical results. Authors of [18] have investigated relay selection algorithm based on QoS. The algorithm is compared with shortest distance selection algorithm by simulation. A path selection method called optimal path relay association (OPRA) is proposed in paper [19]. In this method, each RS in the MMR network is capable of finding its optimal path with path metrics which are available link bandwidth, SNR, and hop count. OPRA algorithm is compared with another path selection method named as signal strength based relay association (SSRA), in which a new RS is associated with the RS or BS with the best signal based on the signal strength received from surrounding BSs or RSs when the new RS is placed. Performance evaluation is assessed using C++ programming and MATLAB simulator.

## 3. BACKGROUND

IEEE 802.16j MMR WiMAX is based on orthogonal frequency division multiple access (OFDMA) physical layer, which adopts relaying feature in WiMAX family. T-RS and NT-RS have different advantages and disadvantages; there can be some scenarios and circumstances where it makes sense to have both the types of RSs or else only any one of these. Introducing a T-RS into the network can increase the system capacity [19], where as the NT-RS enhances the MR-BS coverage substantially. Table 1 gives the comparison of T-RS and NT-RS. The outcome of relays in MMR architecture introduces path selection problem. An efficient path should be determined from MR-BS to SS on the basis of path selection metrics such as availability of radio resource, radio quality of the link, load condition of an RS. However standard does not define how the decision should be made, which is an open issue left for vendors. IEEE 802.16j mentions two approaches for the path management: the embedded approach and explicit approach [20]. The basic difference between these two approaches is how signalling information to manage the path is distributed in the system. The path management mechanisms are used to create a fair and efficient path.

Table 1. Comparison of T-RS and NT-RS

| | **T-RS** | **NT-RS** |
|---|---|---|
| Number of hops | 2 | $\geq 2$ |
| Coverage extension | No | Yes |
| Complexity | Low | High |
| Scheduler | Centralized | Centralized/Distributed |
| Signalling overhead | Low | High |
| Cost | Low | High |

### 3.1. Embedded Path Management Approach

In embedded path management approach a hierarchical connection identifier (CID) allocation is followed in the system. The MR-BS allocates CIDs to its subordinate stations in such a way that the CIDs allocated to all subordinate RSs of any given station is a subset of the allocated CIDs for that station. Hence there is no specific routing table in each RS and there is a reduced need for signalling to update path information [20]. This is a very simple approach to path management.

### 3.2. Explicit Path Management Approach

This approach utilizes an end to end signalling mechanism to distribute the routing table along the path. The MR-BS sends necessary information to the related RSs in a path when a path is created, removed or updated. A path is always given a path ID to which CIDs are bound. This leads to smaller routing table at the RSs and a reduction of the overhead required to update the routing tables [20].

A key aspect of 802.16j systems which has a significant impact on the achievable throughput is the path selection algorithm, i.e. the decision to associate a SS to either the BS or a RS. As there is a cost in terms of overhead associated with the selection of a relay, the design of an intelligent path selection algorithm is necessary to ensure good performance of the system in terms of throughput and delay. The modern trend of communication involves many interactive multimedia services. The real time services (RTS) are more sensitive towards the delay requirements, whereas non-real time services (NRTS) are required to be throughput optimal.

## 4. SYSTEM MODELING

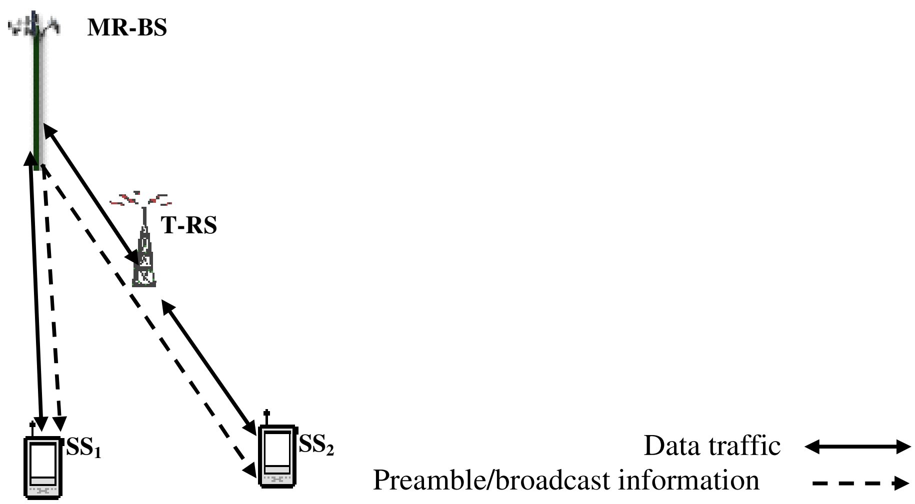


Figure 1. System modeling of MMR WiMAX network

The MMR WiMAX network considered in this work is as shown in Figure1. A single cell consisting of MR-BS, T-RS and fixed SSs is considered, SSs are associated with MR-BS via a T-RS or directly. The traffic generation is considered in such a way that $SS_1$ carries NRTS traffic more compared to RTS traffic. Whereas $SS_2$ traffic generation is opposite to $SS_1$, it transmits more RTS traffic compared to NRTS. The path selection is mainly focused for uplink traffic.

## 5. PROPOSED ALGORITHM

The basic path selection algorithm implemented in IEEE 802.16j contributed module [20] for QualNet [21], determines the path between a MR-BS and SS. The work considers a weight associated with each possible link based on modulation and coding scheme (MCS) which reflects the time required to transmit the data on the link. The weights represent the cost in OFDMA symbols associated with a specific MCS to transmit a bit on the medium. The path for a SS is then chosen based on the sum of the weights on any available two-hop paths: if the sum of these weights is strictly smaller than the weight of the direct BS-SS path, then the two hops path is more efficient and is selected as the route to carry traffic for the SS in the system; otherwise the direct path is used. In the case that multiple RSs provide similar path efficiency, the RS with the highest signal to interference noise ratio (SINR) link to the SS is chosen.

The proposed algorithm considers additional path selection metrics, such as traffic load of RS and the traffic sensitivity factor to the above mentioned algorithm. Hence the proposed path selection algorithm enhances the basic path selection algorithm by considering aforementioned parameters. The RS_LOAD is a measure of traffic load which can be obtained by taking a count of range response (RNG_RSP) messages from BS. The RS_LOAD is considered as a path selection metric in the selection of a RS. After this a measure of traffic sensitivity factor of RTS and NRTS traffics is taken into consideration, this metric is used to decide whether the SS should get connected to MR-BS directly or through RS. Figure 2 demonstrates the flowchart of proposed algorithm. Part of the flowchart imbedded in dotted line is basic algorithm and with solid line covers the proposed improvement to the basic algorithm.

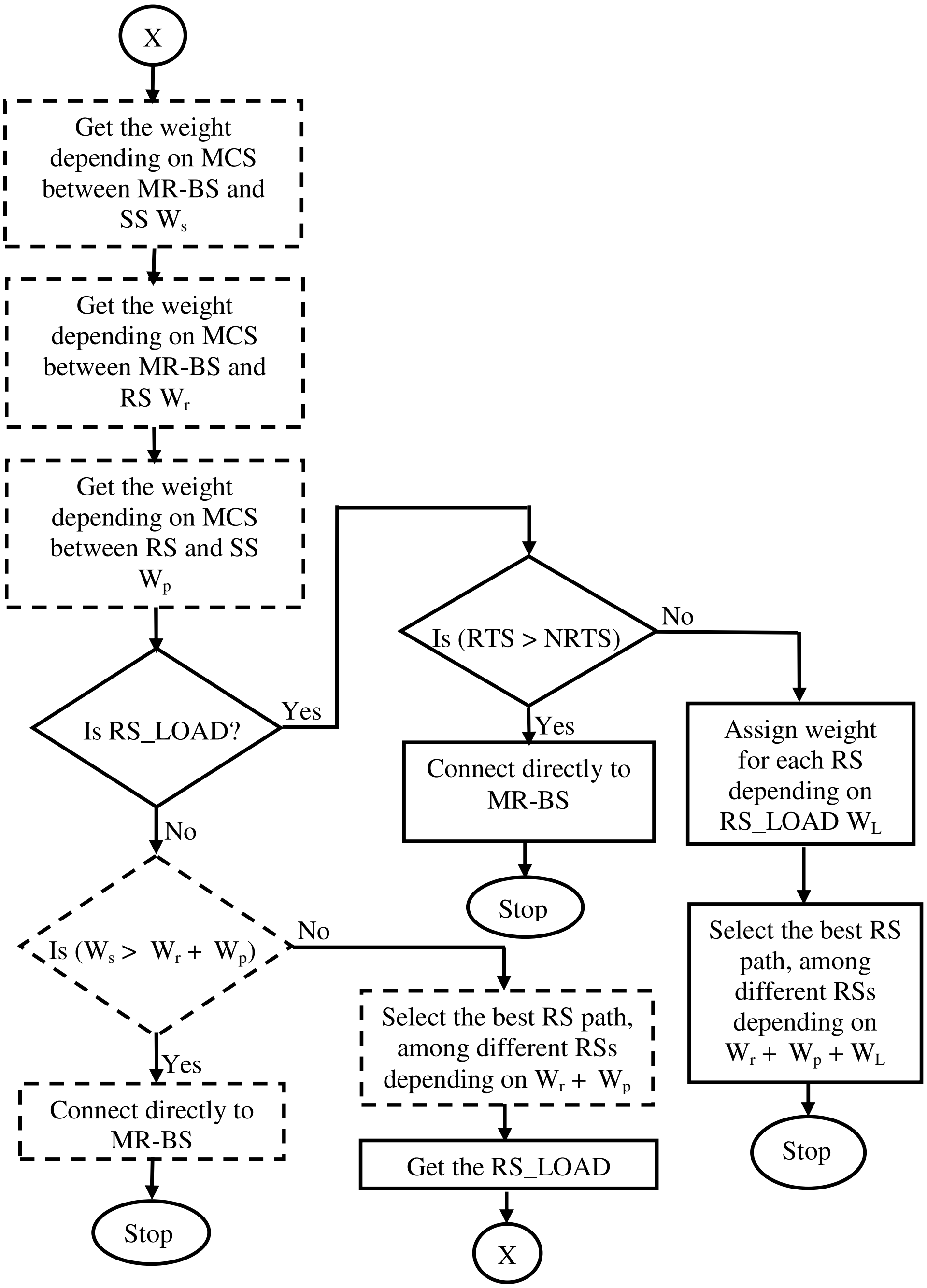


Figure 2. Flowchart of proposed algorithm

## 6. SIMULATION AND RESULTS

Performance of the proposed algorithm is evaluated using QualNet 5.0.2 [21] with the aid of 802.16j [20] contributed module. The contributed module is based on the early specifications of

IEEE 802.16j. This module includes the capabilities to model a T-RS, transparent frame structure and basic path selection algorithm. The working of RSs depends mainly on the position and transmission power of it. Hence a simple simulation scenario is considered for the performance evaluation of proposed path selection algorithm and its performance is compared with the performance of basic algorithm. Simulation parameters selected are listed in Table 2. Major performance metrics include delay of RTS traffic, throughput of RTS and NRTS traffics and bytes received by the destinations. RTS traffics include the applications mapped on extended real time polling service (ertPS) and real time polling service (rtPS). NRTS traffics comprise applications mapped on non-real time polling service (nrtPS) and best effort (BE). The traffic generation for simulation is as followed, variable bit rate (VBR) data service flows are generated to map on RTS. Constant bit rate (CBR) data service flows are generated to map on NRTS.

Table 2. Simulation Parameters

| **Properties** | **Values** |
|---|---|
| Cell Area | 3Kmx3Km |
| Antenna model | Omnidirectional |
| Transmission power BS/RS/SS | 30dBm, 20dBm, 20dBm |
| Antenna gain BS/RS/SS | 10dBi, 5dBi, 0 |
| Antenna height BS/RS/SS | 10m, 5m, 1.5m |
| Frame size | 20ms |
| Channel bandwidth | 20MHz |
| FFT size | 2048 |

## 6.1. Scenario 1

In this scenario a single cell consisting of MR-BS and a T-RS is considered. Fixed SSs are deployed uniformly in the cell. Two SSs are selected for the data transmission, which are object of the study of this performance evaluation. The traffic is generated in such a way that $SS_1$ among these two selected SSs is generating five NRTS services and two RTS services, vice-versa for $SS_2$. The intention is to test the proposed path selection algorithm for the above mentioned uplink traffic.

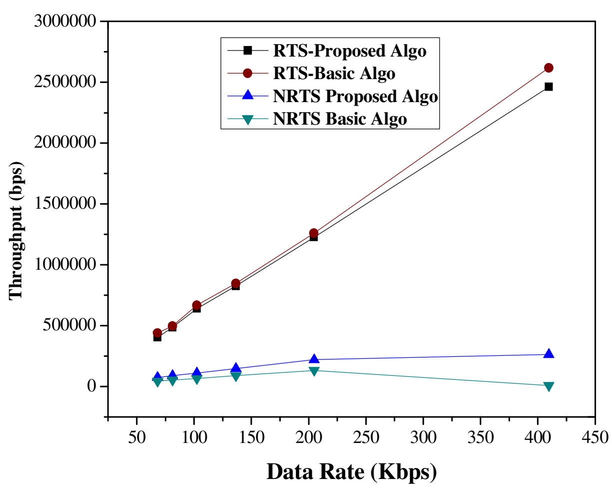


Figure 3. Throughput performances of RTS and NRTS traffics

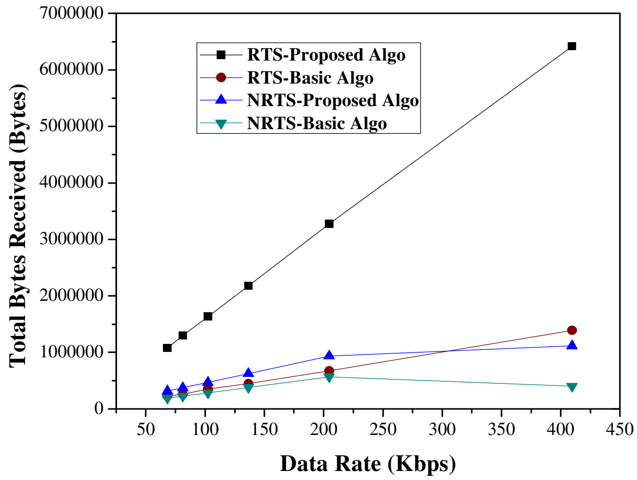


Figure 4. Bytes received at destinations

The traffic data rate of RTS and NRTS are varied and results are plotted to compare the proposed path selection algorithm with basic algorithm. Simulation time is set to 45 seconds. The scenario design is not optimal to consider the average end to end delay performance as individual stations are sending RTS and NRTS traffics to different stations. Hence throughput performance (Figure 3) and bytes received at the destinations (Figure 4) are plotted to evaluate the performance study. It can be observed that the proposed algorithm outperforms with respect to basic algorithm. The path selection metrics traffic load and traffic sensitivity, optimize the path selection of a SS with MR-BS and this has an impact on the stringent QoS parameters of the traffics.

As depicted in Figure 3 throughput performance is better for proposed path selection algorithm compared to basic algorithm, after certain data rate throughput with basic algorithm comes down for NRTS traffic but this performance is optimized with proposed path selection algorithm. The result plotted in Figure 4 reveals that, bytes received at destinations for RTS traffic with proposed algorithm is noticeable and also it is better for NRTS traffic compared to basic algorithm.

## 6.2. Scenario 2

In this scenario, all the settings and configurations of scenario1 are retained. Unlike two SSs for the study and observation, in this simulation number of SSs carrying uplink data traffics are varied. Each SS is sending five RTS traffic flows and two NRTS traffics. The data rate of CBR and VBR are set to 8Mbps. Number of uplink traffics are varied from one to five and results are plotted for delay (Figure 5), throughput (Figure 6) and bytes received by destinations (Figure 7). The intention of this performance evaluation is to test the proposed path selection algorithm for varying uplink load.

The delay performance of the network is better for proposed path selection algorithm compared to basic algorithm (Figure 5). It is noticed that up to certain load, delay increases uniformly and for five SSs load the delay reaches to saturation. The throughput performance of RTS and NRTS traffics for the proposed algorithm traces the performance of basic algorithm. Bytes received at destinations outperforms for proposed algorithm compared to basic algorithm, it is observed that the performance starts deteriorating after a certain load, in this case four SSs load. In spite of that it still performs better compared to basic algorithm.

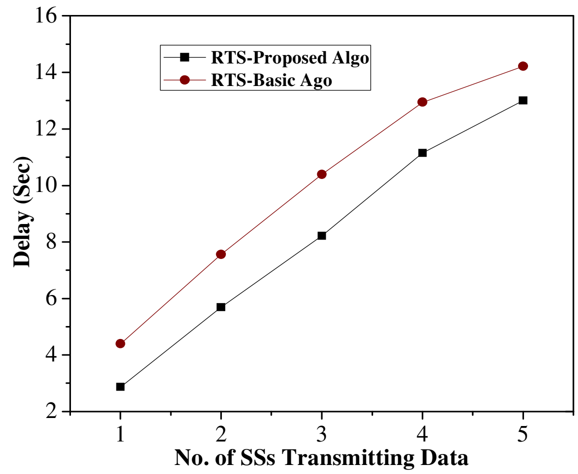


Figure 5. Delay performance of RTS traffic

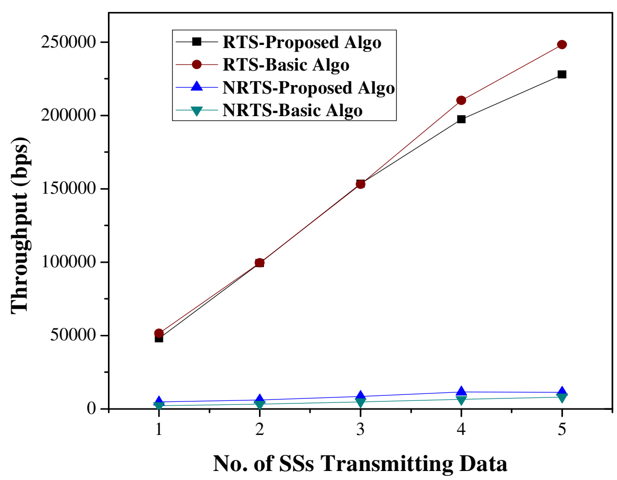


Figure 6. Throughput performances of RTS and NRTS traffics

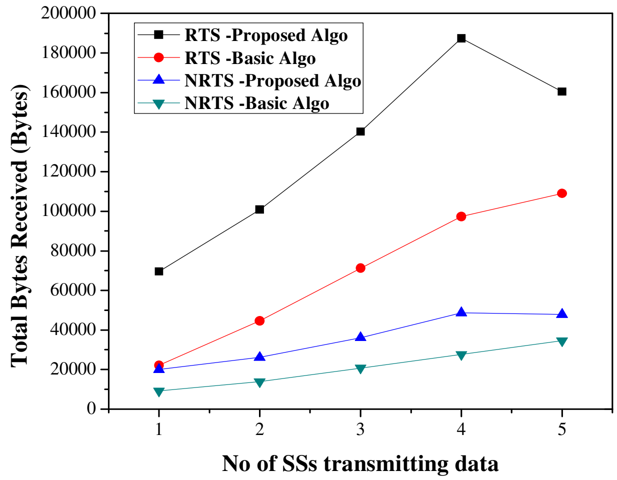


Figure 7. Bytes received at destinations

### 6.3. Scenario 3

This simulation scenario configuration and settings are same as that of scenario 1. Two SSs carrying RTS and NRTS traffics as discussed for scenario 1 are retained in the same manner. This simulation study is intended to study the entire system behaviour by varying the number of SSs in the cell and results are plotted. Figure 8 and Figure 9 demonstrate the throughput performances of RTS and NRTS traffics and bytes received at destinations for RTS and NRTS traffics respectively. It is observed that the proposed algorithm performs with high system load and this is very preferable as this quality makes the networks scalable. The throughput performance of the proposed path selection algorithm for RTS traffic traces the basic algorithm; however the NRTS throughput performance is enhanced in case of proposed algorithm. It is noticeable that the bytes received at destinations for proposed algorithm is enhanced.

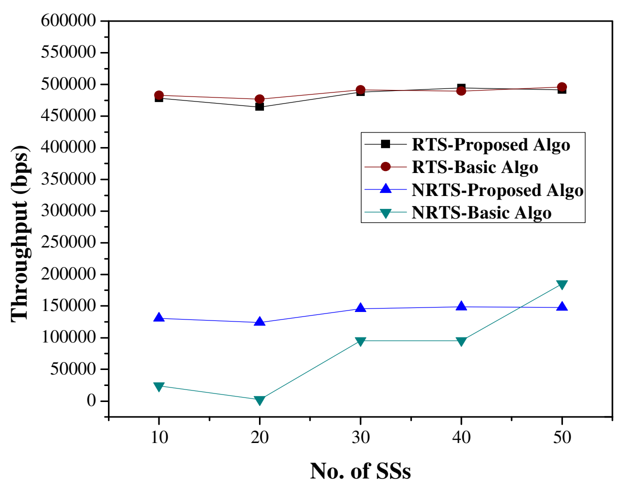


Figure 8. Throughput performances of RTS and NRTS traffics

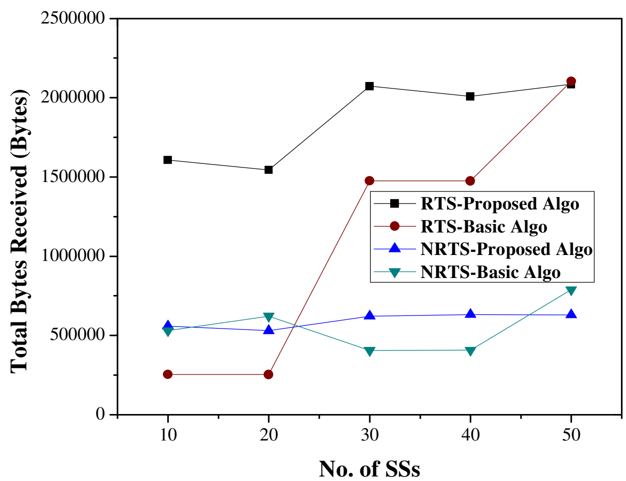


Figure 9. Bytes received at destinations

## 7. CONCLUSIONS

In order to maintain an appropriate balance between the QoS requirements of real time and non-real time traffics, an intelligent path selection algorithm is very essential for multi-hop communication networks like MMR WiMAX networks. With the general path selection metrics like SNR, MCS and number of hop counts, it is vital to consider the traffic load and traffic sensitivity parameters to maximize the system performance. In this work the basic path selection algorithm is enhanced by considering the traffic load and traffic sensitivity parameters. Implemented path selection algorithm is compared with basic path selection algorithm. Performance evaluation results of the implemented algorithm are produced to validate the insertion of additional path selection parameters. The additional path selection metrics ensure the QoS metrics of real time and non-real time traffics respectively.


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