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A Novel Algorithm for Optimizing Quality of Service in WIMAX System

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Abstract – **In this paper, a new algorithm for optimizing centralized scheduling in mesh mode (standard 802.16) has been studied. In available algorithms, overhead related to guard symbol between time slots in 802.16 networks is not mentioned. In this algorithm, switching overload for effective utilization of radio resources and interference model for time scheduling optimization of QOS(Quality of Service) have been considered. The comparison between proposed algorithm and available algorithms based on simulation of different scenarios show that QOS parameters e.g. better application of channel bandwidth, reduction of scheduling latency, and fair dedication of bandwidth are improved.**

Keywords – **WIMAX, Wireless Mesh Network, Quality of Service, Centralized Scheduling.**

I. Introduction

Wideband Wireless systems are rapidly developing. The IEEE 802.16 Workgroup has introduced a new standard known as WIMAX (Worldwide Interoperability for Microwave Access) for Wideband wireless accessing. This standard presents some good features such as high speed, low cost, and simple measure for optic fiber infrastructures development. Moreover, this standard is employed mesh topology in addition to one point to multiple points, respectively.[1]

The main objectives of this standard are dealing only with physical layer and MAC(Media Access Control) layer. Wireless standards are using TDMA (Time Division Multiple Access) to provide quality of service in networks.[2, 3] Although these standards defined sending algorithm, but they didn't determine time scheduling algorithms and sending intervals. In recent years, scheduling of TDMA links is one of the research subjects, but suggested solutions didn't render good performance in standard 802.16 mesh operation because of two main reasons.[3] Firstly, some of them do not consider all possible interferences in TDMA networks. Secondly, some of them didn't pay attention to the overload caused by time guard [4, 5, 6]. The centralized scheduling algorithms (which includes IEEE 802.16 standard algorithm), firstly establishes link ranking upon the distance of link from central station, respectively. Closer links get lower ranks and the dedicated bandwidth to each link is calculated based on these ranks. Moreover, if total sending opportunities for all links are exceeded than maximum available sending interval, each dedicated bandwidth to a specific links is decreased by a constant coefficient of k, which is calculated as:

$$K = \frac{N_m}{\max\ \{N_m, N\}} \quad (1)$$

Where N is maximum possible scheduling length upon time slot, and Nm is the number of required slots for scheduling all links, respectively. Some problems including latency and scheduling are not considered in this algorithm.[7] The minimum latency IEEE802.16 standard algorithm is utilizing the "ranking upon number of steps to central station" idea in order to minimizing latency.[8] However, in this algorithm in scheduling for a separate frame, we hit every node just two times (once in forward and once more in backward direction), but the situations is different in IEEE802.16 algorithm. On the other hand, in centralized scheduling algorithm with frequency reuse(that is sending being restricted to only once in each frame in order to reduce overloading, all links which don't have any first and second interference with selected link can send in same time slot, respectively. In this algorithm, a frame that uses larger bandwidth gets a smaller rank, which increases scheduling latency.[9]

In this paper, a new scheduling algorithm for optimizing QOS parameters e.g. reducing latency, better utilization of bandwidth and fairly bandwidth dedication is proposed to overcome drawbacks of compared available algorithms (inconvenient latency, limited bandwidth, and spatial reuse) by proper ranking and link selection, and requests modification (i.e. re-calculating of K coefficient) if necessary.

II. Standard Mesh Mode 802.16

Standard mesh mode 802.16 only supports MAC that is based on TDMA technology and is constructed based on a TDMA physical layer [10, 11]. This standard employs orthogonal frequency division multiplexing (OFDM) to implement the physical layer. OFDM constructs blocks from bits that are like symbols with constant time lengths. Symbols in OFDM are like a group and their manipulation is simplified by classifying them in different time slots. In a mesh network, since all nodes are seen at same level, frames for uplink and downlink traffic are not separated. A mesh frame is consisted of two control and one data sub-frames. Control frame is used for control packages (signaling messages) and data frame is used for data packages sending. There are two types of control frame: network control sub-frame and scheduling control sub-frame. In a network, nodes distribute configuration definition packages by control sub frame. Scheduling control sub-frame, On the other hand, is applied for scheduling time slots within each data sub-frame. A scheduling control Sub-frame itself includes two types:

1- Centralized scheduling

2- Distributed scheduling [12, 13, 14]

Scheduling control sub-frame is frequently generated in a network. Data sub-frame, on the other hand, is utilized to carry traffic of network nodes. The number of bits that can be transported by a OFDM symbol depends on modulation and coding method used by transmitter, e.g., if BPSK1/2 is utilized, then 12 bits shall be transported by each symbol. The length of time slot in each data sub-frame (data TxOPP Size) is calculated as:

$$\text{data TxOPP Size} = \left\lceil \frac{N_f - 7 * MSH\_CTRL\_LEN}{256} \right\rceil \quad (2)$$

Where the number of OFDM symbols (N_f) depends on the frame length and channel bandwidth, and the notation MSH_CTRL_LEN stands for number of time slots in control sub frame. For example, if the frame length is assumed to be 10 ms and bandwidth is 20 MHz, the number of symbols in each frame becomes 800, respectively. Since in a control sub-frame, each time slot equals seven OFDM symbols, hence a coefficient of 7 is applied in equation (2). Total number of time slots in a data sub-frame is limited to 256, which consists of two parts. The first part is scheduled by centralized mechanism, while the second one is scheduled by distributed mechanism. The parameter of MSH_CSCH_DATA FRACTION determines that how many of slots in a data frame can be used for centralized algorithm. Therefore, the symbol guard is considered as 2 or 3 OFDM. In order to show the effect of transmission overload, consider the BPSK-1/2 modulation and assume that the time slots length is calculated as three OFDM symbols according to eq.(1), while each transmission uses 3 symbol guards. Thus, the smallest data package length becomes 36 bytes and needs two time slots for transmission, which results in 100 % transmission overload. The next selection is to send packages of 72 bytes length in each slot, which results in 50 % of overload, respectively.

III. Spatial Reuse Procedure

There are two issues that should be noted in scheduling: 1- Timing of sending control messages 2-Allocation of time slots in data sub frame for network nodes to carry the traffic. [15] The Standard 802, 16 defines scheduling algorithms for control messages transmission in mesh mode. Although The signals timing and message structure are determined, but details of scheduling, efficient & fair access of nodes to transmission channel, and reservation of time slots in data sub frames have not been explained and left for implementation time.

In this paper, we focus on time slots allocation in a data sub frame based on centralized algorithm.

In centralized scheduling mechanism, each State Station (SS) estimates the bandwidth request for source to destination according to related terminals traffic, and sends the request to Base Station (BS) by MSH:CSCH: Request control message. Afterwards, the BS calculates bandwidth assigned to each network link according to the routing tree, respectively. Therefore, efficiency of centralized scheduling is also depends on the routing tree on which time algorithm will be applied. Consequently, the BS informs the SS about routing tree and its possible changes by MSH-CSCF message. Afterwards, BS or Base Station multicasts the bandwidth allocation to the nodes in a MSH- CSCH: GRANT control message and informs it to the SS in mesh network. The bandwidth dedication should satisfy requested bandwidth of all SS, respectively. When SS receives a MSH_CSCH message, it must calculate the bandwidth for each link according to the assigned end to end bandwidth to each SS, Thus BS and SS use same algorithm for calculation. Ultimately, each SS determines sending start instant and its length by executing an identical algorithm and applying network topology (routing tree) and bandwidth dedication, respectively. The new scheduling is engaged in the 1st frame after the last node on routing tree received MSH_CSCH message from its ascendant, respectively. The scheduling that calculated in each period is applied for the next timing period.

A. The Proposed Algorithm

In order to mitigate drawbacks of existing algorithms, a new algorithm is proposed by combination of advantages of investigated algorithms and avoids disadvantages. Moreover, new introduced algorithm performance is observed by simulating in a 7 nodes mesh network, whilst bandwidth allocated to the network links, is calculated similarly to the 802.16 algorithm as

$$R_j = \frac{(d_j - h)b_j}{T_f} \quad (3)$$

In this algorithm, link ranking is calculated based on its distances to central station in a similar manner to that of minimum latency algorithm. During each bandwidth allocation stage, the least ranked link that hasn't sending yet is selected. Among identical ranked links, however, the link with smaller number has the priority. For maximum frequency reuse, all links that have no primary and secondary intervention with selected link are allowed to send. This procedure is continued repeatedly while all links have at least one transmission in the frame. On the other hand, if total number of sending opportunities allocated to links is more than permissible maximum number, all assigned bandwidths are reduced by a coefficient of K, which is derived from randomly selection of K and finding the optimum point via repeated trial.

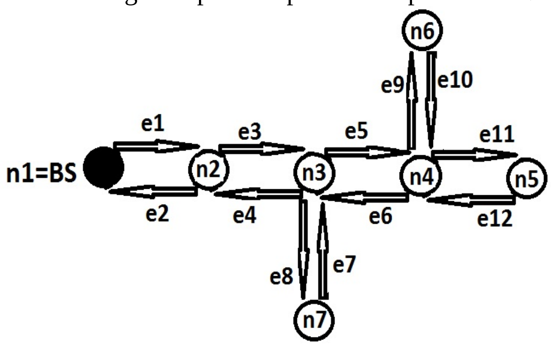

Fig. 1. Mesh topology

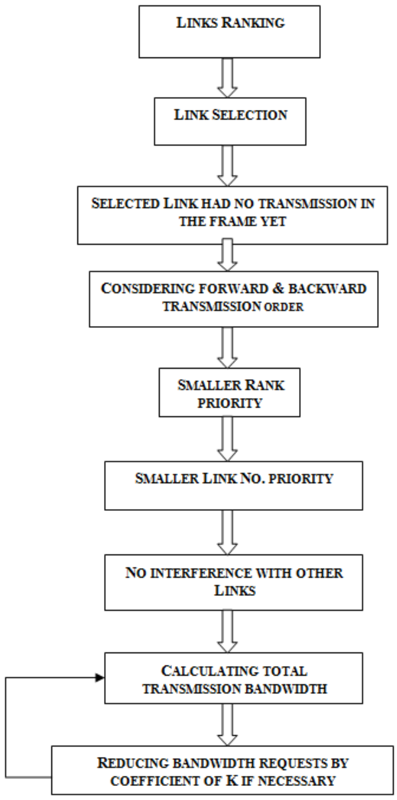

Fig. 2. Stepwise diagram of proposed algorithm

IV. Simulation Results

The new proposed algorithm is presented upon combination of studied algorithms (i.e. standard 802.16 algorithm, minimum latency algorithm, and maximum frequency reuse algorithm) in order to optimize bandwidth utilization and time delay efficiency compared to the previous algorithms. Thus, all afore-mentioned algorithms are simulated by NS-2 network simulation software with same parameters as shown in Table I.

I. Simulation parameters

Parameters	Value
Modulation	BPSK-1/2
length frame	10ms
MSH-CTRL-LEN	10
MSH-CSCH-DATA-FRACTION	%100
The number of guard symbol OFDM	3
The number of bits per time slot	96
Bandwidth reduction factor	0.7

According to simulation results, allocated bandwidths to links of each node is calculated for the assumed topology (fig. 1), and reported in table 2, respectively. Since in the second algorithm, only transmission order is different to that of the proposed one, thus allocated bandwidths are equal. In the 3rd algorithm, no limitations put on the order of transmission and maximum frequency reuse is applied. Therefore, the bandwidth dedicated to each network link is equal to its requested bandwidth. In contrast with the 1st and 2nd algorithms, the frequency reuse is employed in proposed algorithm by consideration of minimal average delay. Thus, the proposed algorithm shows better performance compared to the other algorithms as can be concluded from both Table.2 and Table.3.

II. Comparison of time delays

Algorithm	delay average(ms)
standard 802, 16	20.85
Standard (minimum Latency) 802, 16	7.22
Interference-Aware	28.2
Proposed	7.22

III. Comparison of bandwidth

Algorithm	*Allocated bandwidth to links of each Node(kb/s)* *N2 N3 N4 N5 N6 N7*					
standard 802, 16	950.4	777.6	460.8	144	144	144
Standard 802.16 minimum Latency	950.4	777.6	460.8	144	144	144
Interference-Aware	1468.8	1209.6	720	230.4	230.4	230.4
Proposed	1017.6	835.2	489.6	153.6	153.6	153.6

It is obvious from the results that the bandwidth of proposed algorithm is a little more than standard 802 .16 and minimum latency algorithms and less than Interference-Aware algorithm, respectively. On the other hand, the time delay for proposed algorithm is equal to minimum latency algorithm, which is much more less than that of standard 802.16 and Interference-Aware algorithms. Furthermore, the proposed algorithm benefits from frequency reuse, in contrast with 1st and 2nd counterparts, respectively. Thus, from bandwidth and latency points of view, the proposed algorithm demonstrates improved performance than other studied algorithms, because it makes a compromise between delay and bandwidth constraints. The comparison of studied algorithms bandwidth and delay are shown in Fig.3 and Fig.4, respectively. As can be seen from the results, average delay time is much reduced compared to standard 802.16 and Interference-Aware algorithms. The bandwidth utilization is much better than Interference-Aware algorithm, but almost comparable with standard and minimum latency 802.16 algorithms. However, frequency reuse is the advantage of proposed algorithm over standard and minimum latency 802.16 algorithms, which insures reduction of time overload, respectively.

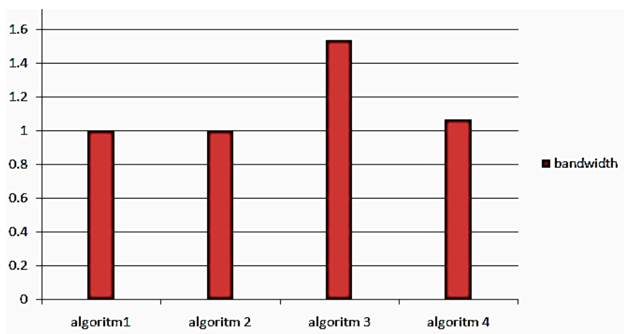

Fig. 3. Comparison of bandwidth for studied algorithms (algorithm 2 selected as base)

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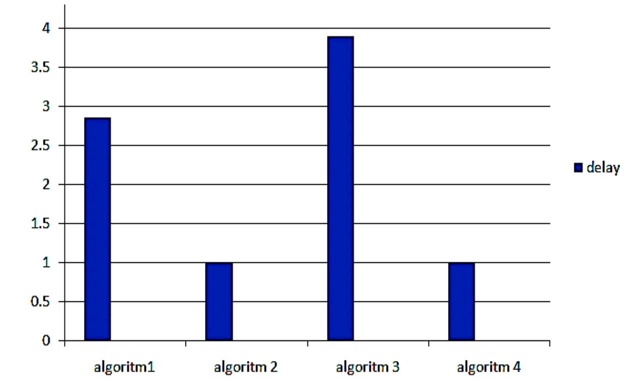

Fig. 4. Comparison of t delay for studied algorithms (algorithm 2 selected as base)

V. Conclusion

In this paper, a new algorithm is proposed in WiMAX network system in order to optimize QOS (Quality of Service) and resources usage based on compromising frequency reuse in centralized scheduling scheme, and fair access of nodes to transmission channel; that is expected to improve the bandwidth utilization efficiency and reduce data transmission latency, respectively. This algorithm allocates OFDM resources to the users to meet their QoS requirement and optimization of system performance, which is dependent on user's distance, equal access opportunity, and bandwidth reduction. Proposed algorithm and three other studied algorithms (including standard 802.16, minimum latency 802.16 and Interference-Aware algorithms) are simulated by NS-2 software in order to investigate the validity of analysis. Results show reduction of required bandwidth, time overload, and latency; which has advantages and mitigating short comes of other existing similar algorithms. Future works may focus on the implementation of the algorithm in real networks in order to validate of above-mentioned advantages in real applications.

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