Multiple transceivers based wimax mesh network to optimize routing algorithm

Bashar J. Hamza¹, Thanaa Hasan Yousif²
¹,² Communication Technical Engineering Department, College of Technical Engineering / Najaf, Al-Furat Al-Awast Technical University (Atu), Al Najaf 54001, Republic Of Iraq.
¹bashar.hamza@atu.edu.iq
²thanaa.yousif.chm@atu.edu.iq

Abstract. The Base Station (BS) is a WiMAX (Worldwide Interoperability for Microwave Access) centralized scheduling mesh topology decision maker for scheduling the whole network including allocation of packets between the Subscribers (SSs) in the network through the BS. Hence, the system, which, by interference, especially affects the nodes, close to BS. A network routing algorithm was built for mesh topology named Energy Bit Minimum Routing (EBMR), which is used to optimize the chosen path. all nodes were fitted with a multi-channel and four scenarios were planned: the first scenario is called the Multi-Transceiver fitted both SSs with a multi-transceiver except at the brink without cap the number of parent nodes. Whereas the second scenario was called Closest Multi-Transceiver system no ceiling on the number of parent nodes, in this scenario only the nearest BS is fitted with multi-transceiver SSs. The third scenario used the Multi-Transceiver system but with cap the number of parent nodes by 30% for whole nodes network. The fourth scenario used the closest Multi-Transceiver system but with cap, the number of parent nodes by 30%, for whole nodes network. In scenarios, the system content considers 120 users as maximum. It will improve the network capacity, throughput, channel scheduling range and channel utilization ratio (CUR).
WiMAX mesh topology is used to centralize scheduling and improve the performance system by finding the best route to centralizing the mesh network EBMR; consequently, it increases latency, CUR and distance scheduling, avoiding messing, otherwise. Multi-transceiver network is used to prevent primary interference and multi-channel network used to stop secondary interference. This paper develops two styles of network: the multi-transceiver multi-channel network and the closest multi-transceiver multi-channel device that uses the Time Division Multiple Access (TDMA) algorithm for EBMR-CS³,4 (Energy Bit Minimization Routing and centralized Scheduling). This algorithm is optimizing network efficiency by having higher throughput by preventing interaction with adjacent nodes and the scheduling duration and growing the device’s channel utilization ratio (CUR).
Keyword: WiMAX, Routing, and Mesh topology

1. Introduction
The Worldwide Interoperability for Microwave Access (WiMAX) mesh network (IEEE 802.16) is a form of wireless networking that is used to reach a vast region and has a very wide bandwidth. WiMAX mesh network is broadband and is therefore used for video and audio applications [1, 2].
WiMAX has a Base Station (BS) with backhaul access to all network stations and subscribers (SS). The WiMAX network is divided into two types: point-to-multipoint (PMP) mode and mesh mode. In PMP mode, the (SS) is linked only to the (BS), that would be making traffic for the whole network between the (SS) and the (BS). However, in mesh mode, the (SS) linked directly from source to destination with another (SS) without referred (BS). The mesh mode is stronger in scalability, performance, coverage area and more stable durability link failures than the (PMP) mode [3-5]. Generally the WiMAX bandwidth ranged about from 2 to 11 GHz that is running as Non-Line Of Sight (NLOS) but another consideration the frequencies between the range 10 to 66 GHz is called Line Of Sight (LOS) [6-8]. In WiMAX for (NLOS) the data rate up to 75 Mbps per subscriber for fixed service (SS) is approximately 10 Km for wireless applications (SS) and 30 Mbps per subscriber for mobile applications; the base station affords up to 280 Mbps to provide the needs of many subscribers at same time [9-11].

Using space as a transporter medium in the fixed WiMAX device depends on multiplexing orthogonal frequency division multiplexing (OFDM), It is reduced from multi-path propagation and fading effect. For enhancing performance, the system used an adaptive modulation technique when the link characteristics are variable. When the system operates on the variable frequency bands used the Frequency Division Duplexing (FDD). The MAC layer in WiMAX for downlink (DL) used Time Division Multiplex (TDM). And for uplink (UL), it used Time Division Multiple Access (TDMA) in (PMP) mode [12-15]. The 802.16 mesh mode in MAC layer is based on (TDMA) technology; this used the orthogonal multiplexing frequency division (OFDM) in the physical layer. (OFDM) consists of bits block as symbols and has a constant time period. Such symbols for (OFDM) in groups shape, the sending on separate time slots is an arrangement by the same process [16-19].

In a mesh mode, all network nodes are on the same stage. The frames for the uplink (UL) and downlink (DL) traffic are not isolated. Each frame has two sub-frames for control, and one for data. The control frame was used to monitor packages (signalling messages) and to transfer used data frames for data packets. The control frame is divided into two types: network control sub-frame and scheduling control sub-frame. The control frame is responsible for scheduling time slots for each data sub-frame. Scheduling of control sub-frames is frequently created in the network [20-22]. Moreover, the sub-frame data is used to handle traffic for nodes on the network, transmitting the amount of bits as a signal by utilizing (OFDM) technology the depends on the form of modulation and coding used [4, 23, 24]. The scheduling in WiMAX can be defined as an allocated time slot used a multi-channel MAC layer to lower length of schedule. A multi-channel MAC may be a multi-channel multi-transceiver or multi-channel single-transceiver. In the multi-channel single-transceiver system, all node for network are provided by only one transceiver; thus, each node cannot provide transmissions concurrently. However, the further transmissions can be operating at the same time as each node transmission on the channel will concurrently send another node transmission if another channel is used; this decreases the length of schedule. In the multi-channel multi-transceiver network, both nodes (PN and edge) simultaneously have a multi-channel supporting radio and the different channels are compatible within the MAC layer [25-27].

In this paper, two types of system are verified: the first system is a multi-transceiver multi-channel and the second nearest multi-transceiver multi-channel system by using EBMR-CS3,4 (Energy/bit Minimization routing and centralized scheduling) algorithm for (TDMA). This algorithm improves the system performance by getting higher throughput by avoiding interference with neighboring nodes, minimizing the duration of scheduling, and raising the channel utilization ratio (CUR) of the system. The WiMAX has supported two types for scheduling the centralization and the distribution.

2. Literature Survey
Various types of planning algorithms have been suggested in state-of-the-art science, and methods have been presented to address the issue of WiMAX networks scheduling in order to solve the interference problem over the past years.

In 2007 Peng, et. al [1]: Authors used the multi-channel method, single transceiver and used the routing algorithm depending on less ID number for pick the parent node, in this method, each node
optimized for various channels, as the node switches between the different channels, it takes time to turn.

In 2008 Wang, et. al [2]: They used algorithm named Breadth-First Search (BFS); this algorithm builds the routing tree by firstly assign the BS in the first level then select PN as neighbouring by select the node which has least ID number. Thereby, all nodes may select the same node which has least ID number, thus causing the interference in the network.

In 2011 Behfarnia, A. and V.T. Vakili [3]: In this study, multi-channel and single channel systems were used. The routing tree was designed based on an algorithm involving four elements that operate in sequential order: the least number of hops, failing that, least interference then least load volume and finally lower ID number as a tiebreaker. Assuming each node has only one packet for uplink and downlink transmission. Thus, obtaining an increase in time reuses and improves the concurrent transmission, and hence shortening the length of scheduling.

In 2013 Jabbar, A. [4]: The authors determined the location of BS, supposing that the area is equal to 100 by100 units, and after determining the center of this area it becomes the location to BS, and impose every process of transmission contains one packet, relying on the establishment of the routing tree on several factors, which is less child BW, then less group degree value, then blocking metric for all neighboring node, finally relied on ID number. Thus, it reduces the secondary interference and improve the CUR and output system.

In 2013 Farej, Z.K. and O.Y. Alani [5]: The author used two algorithms to determine the routing tree: The first: Relies on the lowest ID number and this is the distribution of ID to the nodes by its precedence of the nodes with its connection to the BS, i.e. it is the number one to the first node associated with the BS and the largest number to the last node linked of the network. The second algorithm is based on the breadth-first test by locating each node by its distance from the BS, by the number of hops separated from the BS, by the lowest number of hops, and if there is more than one node at the same level, the choice is by the lowest ID and thus by the lowest. The data is the shortest path.

In 2019 Afzali, M., K. AbuBakar [6]: This study of the network structure depends on the transmission range, meaning that each node that wants to belong to the network must be within the transmission range. Configure the routing tree by relying on the node do not having a primary and secondary interface, enhancing the mechanism for allocation and reusing slot.

3. Diagram of EBMR-CS3,4 WiMAX Mesh Network

Designing the EBMR-CS3,4 for WiMAX mesh network centralize scheduling which suitable for the multi-channel system. This procedure includes four stages; build the WiMAX mesh network construction, routing procedure; multi-channel allotment and multi-transceiver equipping; and scheduling procedure as illustrate in Fig.1.
Fig. 1: EBMR-CS$^{3,4}$ Optimal Route
4. Procedure of Build the WiMAX Mesh Construction

This section displays how building fixed mesh network for WiMAX. Generate specified number of nodes N is randomly arranged; only one from N considers the base station and the remaining of the nodes consider the subscriber station by method directed graph G (V, E), where the V represents the nodes for mesh network and E represents the edges nodes of the network.

In the wireless communication, the transmission signal suffered from the attenuation; one of this attenuation is path losses, which depend on the range (R) between two nodes and affects on the quality of the signal. Determine the value of the path losses by using the NLOS equation [7].

\[ P_L = 122.5 + 26.5 \times \log_{10}(R) \]  

(1)

Where \( P_L \) is path loss and \( R \) distance between two nodes.

The connection can be achieved between any nodes if only if the following condition [8]:

\[ SNR > SNR_{threshold} \]

\[ SNR = P_{Tx} - 10 \times \log_{10}(BW) + G_{Tx} + G_{Rx} - P_L - 10 \times \log_{10}(KT_0) + NF \]  

(2)

Where \( P_{Tx} \) refers to the power for antenna transmission; \( BW \) bandwidth; \( G_{Tx} \) gain of antenna transmission; \( G_{Rx} \) gain of antenna receiver, \( KT_0 = -1.44dBW/MHz \) (Equipartition Law) and \( NF \) is the noise figure.

The minimum amount of SNR threshold as shown below table must be the amount of SNR for the link between two nodes bigger than SNR threshold according to the type of the modulation to connect.

Table-1: SNR Threshold [9]

| No. | Modulation types | Coding rate | SNR threshold (dB) |
|-----|------------------|-------------|-------------------|
| 1   | BPSK            | ½           | 6.4               |
| 2   | QPSK            | ½           | 9.4               |
|     |                 | ¾           | 11.4              |
| 3   | 16-QAM          | ½           | 16.4              |
|     |                 | ¾           | 18.2              |
| 4   | 64-QAM          | 2/3         | 22.7              |
|     |                 | ¾           | 24.4              |

By using method direct graph G (V, E) to build the mesh topology; it depends on the amount of the SNR threshold according to sort of modulation for example; when used QPSK ½ all the amount SNR for all links must be bigger than 9.4 (SNR>9.4) to fulfill the connection between the two nodes.

5. EBMR-CS\(^{3,4}\) Optimum Route

This procedure applies for choosing the optimum route from the node to the BS. It depends on the energy per bit, and evaluates the lower energy usage along the road, regardless of the remaining
variables that are assisted for route selection. For WiMAX mesh network, the Mesh Network Configuration (MSH-NCFG) signal executes this algorithm. The equation has been used to measure the energy consumption per bit [8].

\[ Eb(node) = Eb(node, PN) \] ........................ (3)

Where \( Eb \) energy bit.

Assuming the node (T) is the new node; it needs a link to the common mesh network; node (T) is inside the parent node (I), parent node and (J) parent node (K) communication domain; the three nodes will become parent node for the new node (T). If necessary, however, the best route has been obtained; select the parent node with less energy consumption along the way. Assuming, as seen in Fig.2, parent node (K) has fewer energy usage matrices; hence this node may better be a parent node nominee to the new node, node (T) to get the optimal path.

Calculate the amount of energy per bit from new node (T) to parent node (K) as shown below:

\[ EpS(T, PN (K)) = 10 \left( \frac{PTX_{10}}{BpS} \right) + EpS \] ........................ (4)

\( EpS \) energy per symbol and \( BpS \) bit per symbol.

![Image of the EBMR-CS^3,4 Procedure](image)

**Fig.2:** Illustrate of the EBMR-CS^3,4 Procedure

### 6. Simulation Setup and Results

This section presents and addresses in the outcomes obtained from modeling WiMAX mesh topology centralizing scheduling which is ideal for four scenarios according to the EBMR-CS algorithm for multi-channel system; multi-transceiver system and nearest multi-transceiver system using simulation MATLAB R2019a.

### 7. Network model

Creating the mesh topology by using the connection is based on the path losses, the SNR and SNR threshold are according to the modulation type. The modulation QPSK1/2 was used, hence the SNR threshold is equal to 9.4 for this application. If SNR for link greater than SNR threshold consequently
the link is complete; So, if the SNR is smaller than the SNR level, the connection will not be completed and another node will be chosen to satisfy this condition.

The nodes are differentiated by the number of links per node in color and size, thereby identifying one node as the BS, which has the highest links. In addition, the number of subscribers is selected to the network as needed. Showing the layout in Fig.3, the mesh topology consists of ten nodes one of which is BS, and another node are subscribers. The node 6 would be the BS, as it has the highest number of connections.

![Fig. 3 Mesh Topology Network contain 10 nodes and the BS node 6](image)

8. Routing Tree

After completing the configuration for the network, the node containing the BS and the rest of the nodes is known as the subscribers. The routing tree was designed according to the EBMR-CS algorithm by adding the node one by one per time the parent node is selected from prospective nodes according to the energy consumed per bit; hence, the prospective nodes have the least energy consumed per bit as parent node.

If more than one prospective node has fewer collision metrics for all paths to tiebreaker, the option procedure always relies on the hop-count for all routes; thus, the prospective nodes with the least hop count as the parent node for all directions.

Lastly, if more than one prospective node is identified, the hop-count for all route to break the tie depends also on the ID number of the election operation; thus, the prospective nodes have the smallest ID number as the parent node.

The cycle proceeds to iterate at the amount of nodes in the network, until the network's last node. in Fig. 4. the BS is node 3 with total number nodes in the network being 70 nodes.
Fig. 4: Routing Tree for Network Contain 70 Nodes and the BS node 3.

9. Scheduling Tree
The scheduling tree is determined according to the scheduling algorithm used in this study, after constructing the tree routing according to the routing algorithm, the BS receives all traffic demand from all the SSs and assigns the amount of service token for the whole network according to traffic demand. When the service token number is zero, it indicates that no packets are transmitted throughout the network. To schedule the node with the current time slot to select the node with the lowest number of hops nearest to the BS, when fined more than one the nodes have the less hop count to tiebreaker depending even on the node, which has a higher number of packets, from the election process (shown in Fig. 5).

If more than one is found, the nodes will have a higher number of packets to tiebreakers depending on the operation of the election also having less interference on the node. When more than one is found, the nodes have the least access to tiebreaker based on the voting process and the node with the lowest ID number. If the node is received, add one to the service token, the packets will deduct one to the service token if the node sends the packet. This processing iteration until the service token equals zero.
Fig.5: Scheduling Tree for Network Contain 20 Nodes and the BS node 11.

10. Simulation Setup and Results

Through utilizing the algorithm, EBMR modeled four scenarios that rely on the transceiver process; every node is fitted for.

The first scenario is the multi-transceiver network that fits the two transceivers for each node excluding the nodes located in the edges and shown by EBMR-CS1 for each.

The second scenario is the nearest multi-transceiver system, which fitted the two transceiver with for the nodes closest to the BS as suggested by EBMR-CS2 and compared to the result obtained from EBMR-CS1, EBMR-CS2, and Peng [1].

In Peng [1], the java-code is used for simulation; the dimensions of the network as a square is 100×100 unit. Additionally, the range of transmitting is equivalent for entire nodes; delegate the BS to the square center; using the multi-channel system and the one-transceiver equips all the nodes for the network.

11. Length of Scheduling

The scheduling period is a significant metric for the output system; the amount needed to complete the transfer of all data packets is from the time slot; assigned the time slot amount is relative to the number of packets transmitted across the network.

The EBMR-CS3, has shorter the length of scheduling than EBMR-CS1 as the two situations used the multi-transceiver, however, in the EBMR-CS3 there was a small number for the parent nodes requiring just 30 per cent to be the PN recommended to minimize the bottleneck in the nearest BS, although in the EBMR-CS1 there is no cap on the number of PN.

recommended to minimize the bottleneck in the nearest BS, although in the EBMR-CS1 there is no cap on the amount of the PN. And in the EBMR-CS4, has shorter the length of scheduling than EBMR-CS2 as the two scenarios used the nearest multi-transceiver however in the EBMR-CS4 there was small number for the parent nodes requiring only 30 percent to be the PN recommended to minimize the bottleneck in the nearest BS, while in the EBMR-CS2 there was no cap on the number of PN.

Assuming in this case the node-to-other transmission process involves the random number in range from one packet to three packets. In Fig.7 the schedule length of random packets from one packet to three packets is indicated.

The EBMR-CS3, has shorter length of scheduling than EBMR-CS1 as the two situations used the multi-transceiver; however, in the EBMR-CS3 there was small amount for the parent nodes enabling only 30 percent to be the PN advisable minimizing the bottleneck in the nearest BS, although in the EBMR-CS1 there is no cap on the number of PN. In EBMR-CS2 and EBMR-CS4, the nearest multi-
transceiver was used, the result in EBMR-CS4 were better though since the number of parent nodes was capped to 30 per cent, to limit the bottleneck in the nearer BS.

**Fig. 6:** Length of scheduling for one packet for Individual Nodes (120 Nodes).

**Fig. 7:** Length of Scheduling with Random Packets for Individual Nodes (120 Nodes)
Assuming that the amount of packets submitted is random number between the one to three packets at each transmission. And in the EBMR-CS4, has shorter than EBMR-CS2 although the two-scenarios are used.

In the describing Fig. 8, the CUR has one packet for each node for the EBMR-CS1, EBMR-CS2, EBMR-CS3, and EBMR-CS4. From Fig.8 the EBMR-CS3 has the better CUR than the EBMR-CS1 as the two scenarios used the multi-transceiver but in the EBMR-CS3 the number of the parent nodes was reduced, enabling just 30 percent the PN to minimize the bottleneck in the nearest BS and then raise the concurrent transmission.

Although in the EBMR-CS1 there is no cap on the amount of the PN; therefore, the concurrent transmission of EBMR-CS1 is less than transmission EBMR-CS3 and consequently the time slot of reuse of EBMR-CS1 is less than the time slot of reuse of EBMR-CS3 therefore the duration of scheduling rises therefore, the CUR decreases. And even for in the EBMR-CS4, has the better the CUR; EBMR-CS2 as the two scenarios used the nearest multi-transceiver but in the EBMR-CS4 was small number for the parent nodes require just 30 percent to be the PN advisably reducing the bottleneck in the nearest BS, hence the EBMR-CS4 has the better CUR than the EBMR-CS2.

In this case, the node-to-other transmission process involves the random number in range from one packet to three packets. The CUR, with random packets from one packet to three packets, was indicated in Fig. 4.10.

From Fig. 4.10 the EBMR-CS3 has the best CUR than the EBMR-CS1 although the two strategies used the multi-transceiver but in the EBMR-CS3 the number of the parent nodes was limited, allowing only 30 percent the PN to reduce the bottleneck in the nearest BS and then increase the concurrent transmission.

Although in the EBMR-CS1 there is no cap on the amount of the PN therefore the concurrent transmission of EBMR-CS1 is less than transmission EBMR-CS3 therefore consequently the time slot of reuse of EBMR-CS1 is less than the time slot of reuse of EBMR-CS3 therefore the duration of scheduling rises therefore the CUR decreases. And even for in the EBMR-CS4, have the better the CUR; EBMR-CS2 as the two scenarios used the nearest multi-transceiver but in the EBMR-CS4 was small number for the parent nodes require just 30 percent to be the PN advisably reducing the bottleneck in the nearest BS, hence the EBMR-CS4 has the better CUR than the EBMR-CS2. Assuming that the amount of packets submitted is random number between the one to three packets at each transmission.
Fig. 8: CUR for One Packet Individual Nodes (120 Nodes).

Fig. 9: CUR for One Packet Individual Nodes From 100 To 120 Nodes.
Fig. 10: CUR for Random Packets Individual Nodes (120 Nodes).

Fig. 11: CUR for Random Packets Individual Nodes From 100 To 120 Nodes.
12. Comparison of The EBMR Algorithms (Throughput)

In Fig. 11 reflecting, the result of each node has one packet for the EBMR-CS1, EBMR-CS2, EBMR-CS3 and EBMR-CS4. Clearly from Fig. 11 the result in the EBMR-CS3 better from the EBMR-CS1 as the two situations used the multi-transceiver but in the EBMR-CS3 the amount was reduced for the parent nodes makes just 30 percent the PN to advisably minimize the scheduling period.

And even for in the EBMR-CS4, provide the better performance; EBMR-CS2 since the two scenarios used the closest multi-transceiver, however in the EBMR-CS4 the amount was restricted for the parent nodes enabling just 30 percent to be the PN recommended scheduling range, thereby improving the efficiency.

In the Fig. 13 indicated the throughput with random packets from one packet to three packets. Clearly from Fig. 13, the throughput in the EBMR-CS3 is better from the EBMR-CS1 as the two examples used the multi-transceiver; however, in the EBMR-CS3 the number was reduced for the parent nodes makes only 30 percent to be the PN advisable restricting the duration of the scheduling so that the throughput improves. However even for in the EBMR-CS4 provides the better performance; EBMR-CS2 as the two scenarios used the closest multi-transceiver, but in the EBMR-CS4 the amount was reduced for the parent nodes allows just 30 percent to be the PN recommended scheduling range, thus improving the performance. Considering that the number of packets sent is random number between one to three packets at each transmission.

![throughput for one packet](image)

**Fig. 12:** Throughput with One Packet Individual Nodes (120 Nodes).
13. Conclusion

These are the observations taken from the simulation and data gathered from multiple tests of the system, such as: WiMAX Mesh Network was strongly built in this research by keeping all connections for network effects and depending on the amount of PL and SNR to connect the nodes in order to get better routing. Then, the routing process is regulated by developing a routing algorithm that depends on the amount of energy consumed and other considerations such as collision matrix, hop number and ID number to satisfy the optimal path.

The Fairness packet scheduling system is got by applying this algorithm. The virtual results obtained from the systems have a maximum of 120 nodes, which designed the multi-channel system suitable EBMR-CS1, EBMR-CS2, EBMR-CS3, and EBMR-CS4. The scheduled length decreased by raising the existing transfer and thereby raising the reused time slots and shortening the scheduling period by comparing the findings with Peng [1] for the EBMR-CS1, EBMR-CS2. This schedule length is shorter by growing the existing transfer and therefore growing the time slots that have been repeated, thereby achieved the highest CUR and the best throughput system.

We have obtained the shortest scheduling duration by reviewing the outcomes of the EBMR-CS3 and EBMR-CS4 with Wang [2], by raising the existing transmission and thereby growing the reused time slots, thereby obtaining the lowest CUR and the best output system.

the four scenarios EBMR-CS1, EBMR-CS2, EBMR-CS3, and EBMR-CS4, that obtained good results and the all the system the performance continued as well although increment the number of nodes to 120 nodes in contrast, what happened in the systems for Peng [1] and Wang [2].

Fig. 13: Throughput for Random Packets Individual Nodes (120 Nodes).
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