A Survey on Scheduling Mechanisms in Broadband Wireless Networks

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***Abstract*—A broadband wireless network performs several operations namely, QoS, resource allocation and scheduling in Multi-hop wireless networks in which Scheduling plays a vital role while transmitting packets in Multi-hop wireless networks. An efficient scheduling mechanism can provide solution to certain problems like collision, delay, interference etc., They are implemented based on the different network topologies namely, Point-to-MultiPoint (PMP) and Mesh mode and they provide improvement over several parameters such as, high-data-rate, scalability and mobility etc., Recently used network topology is Mesh network, which supports Multi-hop communication while transferring data packets in a network. In this paper, we present a wide survey on scheduling mechanisms in broadband wireless networks. We discuss the current mobile WiMAX (Worldwide interoperability for Microwave Access) technology, different scheduling mechanisms and its issues.**

***Index Terms*—multiple-input-multiple-output (MIMO), quality of service (QoS), adaptive modulation and coding (AMC), hold off time, next transmission time (Next_Xmt_Time), medium access control (MAC).**

I. Introduction

Rapid growth in broadband mobile wireless networks provides high-speed internet access over a wide area to mobile users. In a wireless network, one fixed position transceiver acts as the Base Station (BS) and provides radio coverage over a large geographical area. This enables several portable wireless transceivers like mobile phones and Pagers to communicate with each other viathebase station. IEEE 802.16 is referred as fixed broadband wireless network over long distance. Fixed broadband wireless network have some significant disadvantages in certain parameters such as: Mobility and Interoperability. Helmut Bölcskei *et al.* [1] discuss the overview of fixed broadband wireless access technology and its challenges. The MAC layer issues concerning scheduling and QoS are clearly analyzed by Bo Li *et al.* [2]. Scheduling plays a prominent role in the development of broadband wireless network. Qindwen Liu *et al.* [3] have proposed a scheduling algorithm to offer guaranteed QoS in MAC layer. The recent growth in broadband wireless network has been directed towards Mobile WiMAX technology. A comparison of broadband wireless network developments based on different parameters is represented in Table I.

Mobile WiMAX is a broadband wireless technology based on IEEE 802.16m air interface standards. Mobile WiMAX provides bit rate up to 100 Mbits/s and radio coverage up to 5 km.

TABLE I. Comparison of Different Broadband Wireless Networks based on Their Parameters

Wireless Network	Mobility	Range	Bandwidth
IEEE 802.16a	6km/h	75km	70Mbps
WiMAX	100km/h	3km	40Mbps
4G (Mobile)	25km/h	5km	100Mbps
4G	5Km/h	30Km	1000Mpbs

Overviews of next generation mobile WiMAX Technology are discussed by Kamran Etemad and Ming Lai [4]. Ioannis Papapanagiotou *et al.* [5] analyzed the survey on next generation mobile WiMAX and found new challenges and improvements. In Mobile WiMAX technology, WiMAX base station provides high radio coverage to establish connection with mobile station at long distance. Base station acts as a gateway to connect internet.

Salient Features of Mobile WiMAX:

- *High Data Rate:* Based on Mobile WiMAX, flexibility in AMC is maintained by using MIMO antenna techniques.
- *Quality of Service (QoS):* IEEE 802.16 MAC architecture provides QoS and optimal scheduling using TDMA over the air interfaces [3].
- *Mobility:* Mobile WiMAX supports optimized soft/hard handover schemes and ensures efficient VoIP (Voice over Internet Protocol).

There are two modes of wireless transmission in broadband wireless networks viz,

- *PMP Mode:* Consists of a BS and several Subscriber Station (SS). BS acts as a gateway for the Subscriber Station (SS).
- *Mesh Mode:* SSs are organized in ad hoc manner and each SS act as a router to relay packets to its neighboring nodes. BS acts as a gateway to the internet and supports Multi-hop Communication.

MirayKas *et al.* [6] concisely discuss PMP and Mesh modes in IEEE 802.16 networks.Based on the above two modes of topological transmission in broadband wireless

Manuscript received May28, 2014; revised September 17, 2014.

doi: 10.12720/lnit.2.3.214-219

network, scheduling can be performed. There are two types of scheduling mechanisms viz, Centralized and Distributed scheduling mechanisms, to allocate the resource efficiently and provides opportunities to overcome challenges such as: spatial reuse, end-to-end throughput, packet delay etc., Tara Ali-Yahiya and Hakima Chaouchi [7] analyze the resource allocation concept in mobile WiMAX technology. Effective resource allocation is the important challenge in recent broadband wireless network research. Improvements in QoS can also be made by the scheduling mechanism that is clearly discussed in [8]-[10].

In this paper, we present a comprehensive survey of different scheduling mechanisms. The different scheduling mechanisms, their issues and challenges are discussed in Section II. QoS principles, methodologies and issues are discussed in Section III. Finally we present our conclusion in Section IV.

II. Scheduling Mechanism in Mobile WiMAX

There are three types of scheduling mechanisms: Centralized Scheduling, Coordinated Distributed Scheduling and Uncoordinated Distributed Scheduling.

A. *Centralized Scheduling*

In Centralized Scheduling, BS and SS are arranged as centralized routing tree and all the activities performed by each SS are maintained and controlled by the BS. Data transmission from one node to another node is performed using three-way handshaking (connection establishment) and is represented in Fig. 1. BS gathers the request information from each SS to provide grant for each individual node. MSH-CSCH (Mesh centralized scheduling) messages are used to perform requests and grants operation. In uplink, transmission occurs over the link from SS3 to SS1 in which SS1 is closer to BS; BS act as controller to perform downlink. In downlink, transmission link occurs from BS to SS2. Finally SS3 establishes connection with SS2 to perform data transmission. The centralized routing tree is updated by adding new nodes. MirayKas, BurcuYargicoglu *et al.* [6] discuss three steps of centralized scheduling and its functionalities. Li-Der Chou *et al.* [11] discuss centralized scheduling over VoIP in real systems.

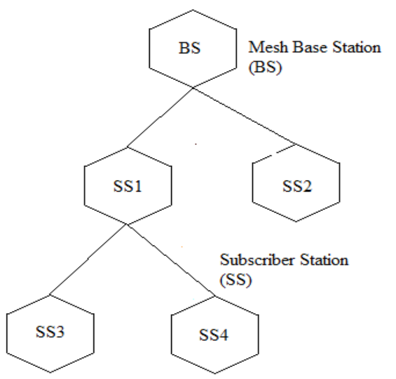

Figure 1. Centralized Scheduling in mesh mode

1) *Issues related to centralized scheduling.*

Scheduling plays a significant part in effective network design and mainly focuses on reducing the delay problem. Petar Djukic and Shahrokh Valaee [12] discuss delay problem in scheduling mechanism and its importance.

Bokraejung *et al*. [13] focus on the issue of packet delay in the architecture of EPON (Ethernet Passive Optical Network) and WiMAX. To reduce the packet delay, they have proposed the centralized scheduling mechanism that performs independent transmission scheduling between EPON and WiMAX. When multiple links are scheduled at the same time in centralized scheduling, interference occurs. When more number of data are transmitted, they may collide in two ways namely, primary and secondary interference. Primary interference occurs when the station can do both sending and receiving in a single time slot. Secondary Interference occurs when a transceiver turns to an adjacent transceiver and receives wireless signal. To eliminate interference, Yuliang Tang *et al*. [14] proposed optimizing channel assignment MDFS (Maximum Degree First Select) algorithm in WiMAX Mesh Networks. To determine the resource allocation, SS sends its bandwidth request to BS and then BS determines the amount of resource to provide grant to each SS. Request and grant operation is performed by sending MSH-CSCH message and Mesh Centralized Scheduling Configuration (MSH-CSCF). MSH-CSCF message is used to broadcast link, node and routing tree configuration to each node.

B. *Distributed Scheduling*

Distributed scheduling is further classified as:

- Uncoordinated *Distributed Scheduling:*
  Direct connection establishment without scheduling.
- Coordinated *Distributed Scheduling:*
  Establishment of data connection and data transmission are modulated by scheduling concept.

The various scheduling concepts in Multi-hop WiMAX networks including centralized scheduling, Coordinated and uncoordinated distributed scheduling are discussed in [15].

Coordinated Distributed Scheduling has two phases,

- EBTT (Election Based Transmission Timing) phase.
- Three-way handshaking (Connection setup with neighbor) phase.

1) *Issues related to distributed scheduling*

Hua Zha *et al.* [15] found two weaknesses in the existing CDS (Coordinated Distributed Scheduling) algorithm,

- It does not guarantee collision free scheduling in real-time environment. But CDS provides collision free transmission in quasi-interference environment (wired connectivity).
- Three-way handshaking mechanism is used to achieve data transmission scheduling but effective resource allocation algorithm is left unstandardized.

To overcome these existing algorithm weaknesses, CF-CDS (Collision Free – Coordinated Distributed Scheduling) algorithm is proposed. It is used to prevented collision while coordinating more number of nodes in non-quasi interference environment (Realistic environment). CF-CDS provides effective scheduling in two or three-hop neighborhood. The description and graphical illustration of CF-CDS algorithm is displayed in [15]. Bih-Hwang Lee and Chun-Ming Chen [16] have proposed the new Enhanced Election Based Transmission Timing (EEBTT) mechanism to overcome the collision and data delay problem. Shie-Yuan Wang *et al.* [17] analyze collision problem in MSH-NCFG messages and nodes aspects in distributed coordinated scheduling. Collision occurrence with MSH-NCFG messages. Node A and C send MSH-NCFG messages simultaneously to node B, that leads to collision and represented in Table II.

Yu Liang and Zhang Zhengbing [18] have proposed an enhanced mechanism which combines adaptive hold-off time with REGRANT solution.

Enhanced mechanism focuses on the problem listed below:

- To reduce the collision in control sub-frame.
- Reduce the wastage in allocating mini-slots.

TABLE II: COMPARISON OF VARIOUS PARAMETERS AND FUNCTIONALITIESRELATED TO SCHEDULING IN WIRELESS NETWORK

	End-to-end throughput	**Packet Delay (Packet Loss)**	**Modulation Scheme**	**Latency**	**Delay Jitter**	**Spatial Reuse**
Integrated network architecture of EPON and WiMAX [13]	Increase based on cycle time = 1ms & 2ms	Decreases based on cycle time and frame size in IS and CS	QPSK, 16-QAM and 64-QAM	----------	----------	----------
optimizing channel assignment MDFS (Maximum Degree First Select) algorithm in WiMAX Mesh Networks [14]	Increases in MDFS algorithm, when number of neighbor = 30	Scheduling delay decreases in MDFS algorithm based on the number of neighbor = 30	----------	----------	----------	----------
CF-CDS (Collision Free – Coordinated Distributed Scheduling) [15]	Throughput in two-hop neighborhood (increased to 1 Mbps)	End-to-end delay (Less than 20ms)	----------	Enhancing throughput and packet delay will improve data latency	----------	----------
EEBTT Mechanism (Enhanced Election Based Transmission Timing) [16]	Based on the delay parameter, throughput gets increased	Reduce Error ratio to less than 0.5% in EEBTT mechanism	----------	----------	End-to-end delay decrease	Multi-hop environment
Static and Dynamic approach related to hold-off time parameter [19]	Increased throughput < 600 as no of hop count > 2 in dynamic approach	Delay reduced based on hold-off time value as throughput increases	Scheduling Mini-slot information based on 1-Mb/s bandwidth	----------	----------	No spatial use modulation/ coding scheme
Adaptive hold-off algorithm with regrant solution [18]	91% End-to-end throughput – exponent values (bytes/s)	End-to-end delay reduced to 25%	----------	REGRANT operation to control latency value	----------	----------

III. QOS IN WIRELESS NETWORKS

QoS has certain parameters such as, transmission rates, error rates, etc., to calculate and provide improvement to offer guaranteed QoS.

Ex: Based on the data transmission occurs between two nodes, to calculate their data rate. Packets transfer from source to destination in reliable way. To calculate the data rate, Quality of Service requires certain limits such as, throughput, delay, etc., QoS in terms of reliability values is required to calculate the distance (Euclidean distance).

A. Challenges and Issues

QoS parameters like BER (Bit Error Rate), data throughput, jitter, latency, etc., are discussed in [20].

- Distance between the terminals i.e, from the transmitter to the receiver and amount of traffic on both uplink and downlink affects QoS delivery.
- Multiple paths and weather conditions greatly affect QoS delivery i.e., BER. Bit error and packet loss have negative influence in voice communication, while doing retransmission process.
- Multi-path interference has certain services that influence delay on communication and transmitting time interval. Ji-won Park *et al.* [17] discuss the interference cancellation algorithm in other contexts.
- Call admission control and scheduling functions implements in both the BS and SS to provide improved QoS level [21].

- Scheduling in Mobile WiMAX networks is the prominent research issue that handles different QoS parameters. Mesh mode also has several parameters associated to Multi-hop and guaranteed QoS level during handover.

TABLE III. COMPARISON OF VARIOUS PARAMETERS AND FUNCTIONALITIES RELATED TO QOSSCHEDULING IN WIRELESS NETWORK

	Throughput	**Packet Delay (loss Ratio)**	**Modulation Scheme**	**Call blocking rate**	**Channel Capacity**	**Latency**
Call Admission control to estimate the resource [23]	Increased throughput by Round Robin scheduling	For 0.8 user arrival Rate, error ratio is less than 0.1%	Rayleigh Fading	User arrival rate= 0.80 to 2% call blocking rate in COCAC algorithm	Shannon capacity	-----------
CAC to guaranteed users QoS [24]	Class E5 (0,0,0,1) has increased throughput	Delay based on new call arrival rate in E5	-----------	-----------	Proportional Fairness (FS)	Latency value calculated based on delay ratio
Guaranteed end-to-end QoS [25]	Depends on Call arrival rate and blocking probability, increase throughput in EQRP	EQRP delay: 120 milli/sec and less than 120	ARQ mechanism	EQRP: call arrival rate = 1/12000, call blocking rate = 0.1%	-----------	-----------
End-to-end resource allocation [26]	Increase throughput in Greedy/DRR 2.5, as no of node increases to 9	Delay decrease to 100ms as traffic load is minimum	QPSK-1/2, 16 QAM-1/2, 64 QAM-2/3	-----------	Pseudo random channel capacity	Latency value based on amount of Bandwidth
To minimize the scheduling delay and provide QoS [12]	Increase throughput depends on scaling factor	Number of source = 4; delay 10ms.	-----------	Blocking probability depends on 1/6000 call arrival rate	-----------	-----------
Adjusting the Scheduling parameters to meet QoS [11]	Increase throughput in DH algorithm, based on delay parameter	Number of nodes = 45, Delay of 6.5ms	-----------	-----------	Channel capacity – dynamically adjusting hold-off time	-----------

1) Issues related to QoS in scheduling mechanism:

Y. Ahmet Sekercioglu *et al.* [20] clearly discusses various QoS methodologies related to scheduling mechanisms, resource allocation and routing. Eden Ricardo Dosciatti *el al.* [22] discusses scheduling mechanism related to CAC. Generally scheduling mechanism allocates certain amount of resource for the connection in a network. In this network connection, overload can be controlled by applying CAC concept. Hao Wang *et al.* [23] proposed CAC combined with CS (Cumulative rate distributed Scheduling)and ORR (Opportunistic Round Robin) by locating new user with CAC decision and to provide guaranteed Quality of Service (QoS). Hyang-Woo Lee *et al.* [24] proposed scheduling mechanism combined with Call Admission Control (CAC) that provides guaranteed QoS to the users. In [25] the author has proposed scheduling mechanism combined with QoS based protocol to provide guaranteed QoS. Ankit Kapoor and Vinay J. Ribeiro [25] proposed End to end QoS aware bandwidth Reservation Protocol (EQRP), which provides efficient QoS aware routing and call admission control in distributed environment. Reserving QoS path that connects source to destination during resource allocation module (Path reservation phases). Comparative analysis graph shows that greedy forwarding algorithm used by EQRP is more efficient than existing flooded approach used by RFP (Race Free Protocol). End to end throughput maximization depends on the path length (path length is inversely proportional to throughput. To provide end to end QoS, resource allocation (scheduling) plays a significant part and is discussed in [26]. Claudio Cicconetti [26] proposed Fair End to end Bandwidth allocation (FEBA) algorithm.

EQRP protocol has the functionality listed below:

- Maintain probe-map table to identity the status of the data sent.
- Greedy forwarding algorithm finds the efficient path from source to destination.
- To identity the correct link between source to destination and nodes are capable of forwarding packets.

Table III summarizes the different aspects of QoS Scheduling in section III. It highlights the different criteria (throughout, delay, Call blocking rate) to schedule the resources efficiently by combining QoS methodologies.

IV. CONCLUSION

In this paper, we have described scheduling mechanisms and their related techniques in mobile broadband wireless networks. First future mobile wireless networks with different topologies and also two different scheduling mechanisms were discussed. Related issues were discussed with the existing papers and recent research carried out in wireless communication includes QoS improvement, resource management, scheduling delay, reduce interference, etc.

ACKNOWLEDGEMENT

This Research was supported by AnnaCentenaryResearchFellowship (ACRF), Anna University Chennai, India.

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