COORDINATED DISTRIBUTED SCHEDULING IN WIRELESS MESH NETWORK

Usha kumari
M.Tech (C.S) Student
IIMT Engineering College Meerut(U.P) India

Udai Shankar
Asst. Professor
IIMT Engineering College Meerut(U.P) India

ABSTRACT

IEEE 802.16 based wireless mesh networks (WMNs) are a promising broadband access solution to support flexibility, cost effectiveness and fast deployment of the fourth generation infrastructure based wireless networks. Reducing the time for channel establishment is critical for low latency/interactive Applications. According to IEEE 802.16 MAC protocol, there are three scheduling algorithms for assigning TDMA slots to each network node: centralized and distributed the distributed is further divided into two operational modes coordinated distributed and uncoordinated distributed. In coordinated distributed scheduling algorithm, network nodes have to transmit scheduling message in order to inform other nodes about their transfer schedule. In this paper a new approach is proposed to improve coordinated distributed scheduling efficiency in IEEE 802.16 mesh mode, with respect to three parameter Throughput, Average end to end delay and Normalized Overhead. For evaluating the proposed networks efficiency, several extensive simulations are performed in various network configurations and the most important system parameters which affect the network performance are analyzed.

Keywords: IEEE 802.16, Wireless Mesh Networks, MAC protocol, Time Division Multiple Access, Distributed scheduling procedure.

1. INTRODUCTION

The recent standard for broadband wireless access networks, IEEE 802.16, which resulted in the development of metropolitan area wireless networks, includes two network organization modes: Point to Multi Point and Mesh[1,2,3]. The mesh mode provides distributed channel access operations of peering nodes and uses TDMA (Time Division Multiple Access) technique for channel access modulation. According to IEEE 802.16 mesh, two different coordination modes are defined: centralized and distributed. In the centralized mode the base stations (BS) is responsible for defining the schedule of transmissions in the entire network. a network is partitioned into tree-based clusters.

Each cluster has a BS node that is responsible for allocating network resources to the subscriber stations (SSs) nodes that it services. Although the centralized scheduling mode provides collision-free transmissions for control and data packets, it has several disadvantages, which are described here.

First the number of routes that can be utilized is unnecessarily reduced. The reason is that the centralized scheduling mode uses a tree-based topology, which cannot exploit all possible routes in a network, as compared with a mesh-based topology. Second, it is difficult to efficiently exploit the spatial reuse property of wireless communication in the centralized scheduling mode. The message format defined in this mode only allows a BS node to notify an SS node of the bandwidth allocated to it. There is no field in the message that allows a BS node to specify the start and end minislot offsets for an allocation. As such, to avoid interference, each SS node has to take a conservative approach to derive its own data schedule. Allocating minislots in this way is collision-free but results in only one active SS node per cluster at any given time.

The distributed scheduling mode provides two advantages: First, the distributed scheduling mode uses a mesh topology. This allows all possible routing paths to be utilized to avoid performance bottlenecks. In addition, spatial reuse of wireless communication can be exploited to increase network capacity. Second, the distributed scheduling mode establishes data schedules on an on-demand basis; thus, network bandwidth can be more efficiently utilized.

In the IEEE 802.16 mesh network standard, the distributed scheduling mode is further divided into two operational modes: 1) the coordinated mode and 2) the uncoordinated mode. In the distributed coordinated scheduling mode, the control messages required to establish data schedules are transmitted over transmission opportunities without collisions. In contrast, in the distributed uncoordinated scheduling mode, such control messages can only be transmitted on the transmission opportunities left from the distributed coordinated scheduling mode or on unallocated minislots. Because of this design, the distributed coordinated scheduling mode provides better quality-of-service (QoS) supports than the distributed uncoordinated scheduling mode. In this paper, we focus only on the distributed coordinated scheduling mode.

The remainder of the paper is organized as follows: In the section 2, we introduce the coordinated distributed scheduling. In the section 3 we introduce the election based transmission timing (EBTT) mechanism used in the coordinated distributed scheduling. And section 4 contains the three-way handshaking procedure, and section 5 contains the Multipath Parallel Routing Protocol (MPRP), performance evaluations are described in section 6 and section 7 contains the conclusions.

2. DISTRIBUTED SCHEDULING SCHEMES FOR WMNS

Firstly, in this Section we describe the IEEE 802.16 protocol for Wireless Metropolitan Networks that has been recently standardized to meet the needs of wireless broadband access [9, 10, 11], focusing on the Coordinated Distributed Scheduling scheme (CDS). Secondly, we suggest a simple criterion to set in a dynamic fashion some parameters of the Coordinated Distributed Scheduler scheme of the Std. IEEE 802.16 and we describe an enhanced version of the CDS. Thirdly, we describe two different scheduler schemes that represent extensions of the CDS scheme and allow better performance of the network to be obtained when single path is used as shown in [12, 13], respectively.

2.1 Coordinated Distributed Scheduling (CDS)

The Medium Access Control (MAC) layer of the IEEE 802.16 has point-to-multipoint (PMP) mode and mesh mode. In the mesh mode, all nodes are organized in an Ad hoc fashion and use a pseudo-random function to calculate their transmission time. Almost all the existing works about the IEEE 802.16 focus on the PMP mode [14, 15]. The TDMA frame is divided into the control is used only for the transmission of control messages. Sub-frames are fixed in length and consist of transmission opportunities (TOs). The number of transmission opportunities in the control-subframe is a network parameter (MSH_CTRL_LEN) and can have a value between 0 and 15. Every TO consist in 7 OFDM symbols time. The data subframe is situated after the control sub-frame in a frame and is divided into minislots. The minislot is the basic unit for resource allocation. In the CDS mechanism all the stations shall indicate their own schedule by sending a MSH DSCH (Mesh Distributed Scheduling message) regularly. MSHDSCH messages are transmitted during the Schedule Control sub-frame.

2.2 Parameters for Distributed Scheduling

There are two parameters used in Distributed MeshNetworks for scheduling: *NextXmtMx* (NXM) and *XmtHoldoffExponent* (XHE). These two parameters are contained within MSH-DSCH messages. Since in Distributed Scheduling there is not a Mesh Base Station (M-BS) which schedules and controls the transmission of each node, it is necessary a distributed manner to schedule the transmissions.

The concept is based on communicating all nodes when any node is going to transmit (MSH-DSCH messages including the information of the neighbors) thus every station has the knowledge of the scheduling of its two-hop neighborhood. In CDS the MSH-DSCH messages are scheduled in a conflict-free manner, there are not collisions. To the following we show how NXM and XHE are used to compute the XHT and the NXT values:

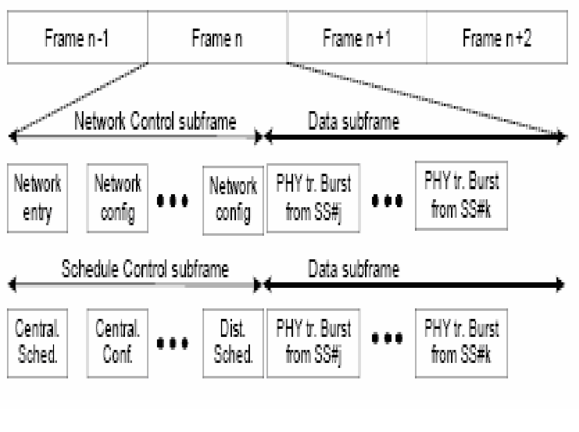

Fig 1: Frame structure in mesh mode.

XHE: in the standard XmtHoldoffTime (XHT) is the number of MSH-DSCH transmits opportunities after NextXmtTime (NXT) that this station is not eligible to transmit MSH-DSCH packets.

$$XHT = 2(XHE + 4) \qquad (1)$$

NXM: in the standard is the next MSH-DSCH

eligibility interval for this station

$$2XHE * NXM < NXT \leq 2XHE * (NXM + 1) \qquad (2)$$

For example, if NXM = 2 and XHE = 4 the station would be eligible between 33 and 48 transmission opportunities.

3. DISTRIBUTED ELECTION ALGORITHM

Every node calculates its NXT during the current transmission according to the distributed election algorithm defined in [12]. In this algorithm one node sets the first transmission slot just after the XHT as the temporary Next Transmission Opportunity (NXTO). In this instant, this node (let us to call this node as node A) shall compete with all the competing nodes in the two-hop neighborhood. There are different types of competing nodes (Figure 3) defined as follow:

- NXT includes the temporary transmission slot (Node B)
- EarliestSubsequenceXmtTime (ESXT, equal to NXT + XHT) is $\leq$ the temporary transmission slot (Node C)
- The Next Time is not known (Node D)

This algorithm is a pseudo-random function which uses the slot number and the Node's ID as the inputs and is executed at each node. It generates pseudo-random values depending on the input. The node wins when its result is the largest mixing value (Figure 4). When any node wins, it sets the temporary transmission opportunity as its next transmission time sub-frame and the data sub-frame (Figure 2). While the slots of the data-sub-frame are mainly used for the transmission of data packets, the control sub-frame and logically it shall communicate this information to all the neighbors by sending the corresponding packet.

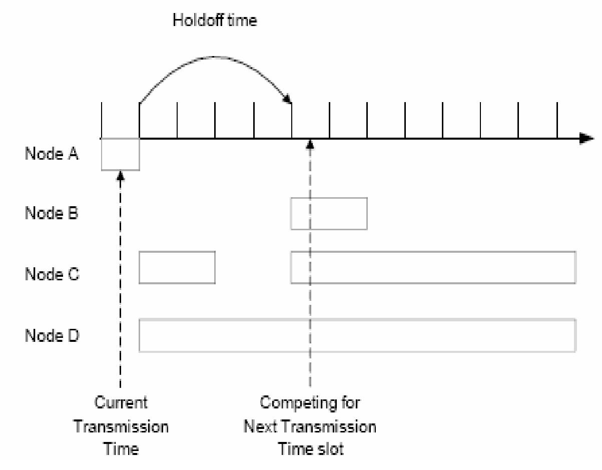

Fig 2: Competing Nodes for Next Transmission time slot.

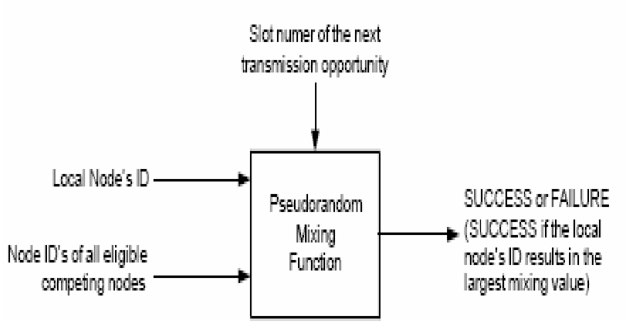

Fig 3: Pseudo-random Mixing Function.

In the case a node has not won, it chooses the Next Transmission Opportunity (NXTO) and repeats the algorithm as many times as it needs to win. The assignment of Transmission Opportunities (TOs) in the data-subframe is managed by a scheduling mechanism. The MSH-DSCH message of the distributed scheduling mechanism carries the Requests, Grants and Confirmations and all stations (Mesh Base Station, M-BS and Mesh Subscriber Stations, M-SSs) shall coordinate their transmissions in their two-hop neighborhood. MSH-DSCH messages are transmitted regularly by every node throughout the whole mesh network to distribute nodes schedules. As we already outlined, in this paper we focus on the CDS and analyze the transmission timing of the MSHDSCH messages as this has much influence on the overall network performance. In order to evaluate the impact of the control schedule on the network performance, we developed a simplified data scheduler instead of considering a data scheduler based on the three-way-handshake mechanism. The three-way handshake mechanisms are follows.

4. THE THREE-WAY HANDSHAKE MECHANISM

Connection setup is a three-way handshake messaging procedure which two nodes perform in order to negotiate upon the data slots prior to exchange data as shown in Figure 4[13,14]. Connection setup in distributed scheduling is done in three steps:

Step 1: Request

Before initiating the message exchange procedure, the requester node checks, if the data transmission rate it needs is available using all the free slots it has or not. If it has enough number of slots itself, it sends a request message in the MSH-DSCH packet along with the data sub-frame availability to the destination node that it wants to send data to or receive data from (destination) node. The information in the request message is the link ID, number of requested data slots per data frame and number of data frames requested. If numbers of slots are not available the requester node quits the connection procedure.

Step 2: Grant

Upon receiving the request message, the receiver node checks the availability of free slots to provide the data transmission rate the requester node requires. The destination node responds with a grant message indicating whether a full or partial request of the requester node can be fulfilled. The grant message contains the IDs of the available minislots which have been selected for transmission. It also contains the listing of the channels of the available slots. If the number of matching slots matches the data transmission rate needed, then the destination node sets the states of these slots as receiving otherwise it quits the connection procedure.

Step 3: Confirmation

When the requester node receives the grant message, it means the framework for distributed scheduling is ready. The requester node sends out a confirmation message to the receiver node in the form of MSH-DSCH message which contains the information of all the slots granted and sets the states of the slots as transmitting.

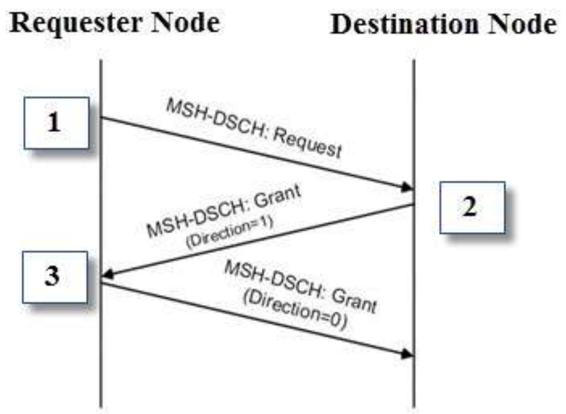

Fig 4: Three-way handshaking procedure.

4.1 Link establishment

During initialization, every node is assigned an ID randomly. To communicate among nodes, communication links have to be established. This is achieved by the three-way handshaking procedure as shown in Figure 3 with the transmission of MSH-DSCH messages in link establishment packets. Handshaking is initiated by the node with lowest ID. The exponent value determines a node eligible interval and the channel contention. In our simulations, the set of possible exponent values is {0, 1, 2, 3 and 4}.

5. MULTIPATH PARALLEL ROUTING PROTOCOL (MPRP)

In the literature, there is much research on multi-path routing for ad hoc networks [16]. There are several philosophies that approach the problem of multi-path in different ways. In this paper we use all multiple paths at the same time and packets are split among these. This is because the Network Model as considered in the previous section is static or quasi-static and although some topological changes can happen they are very low with respect to network in which mobility is supported. For this reason it seems more useful to considering paths used simultaneously that permit a load balancing to be obtained. In fact, the use of multiple paths as backup paths seems more appropriate for the fault-tolerance in a mobile context.

5.1 Multipath Parallel Routing Protocol (MPRP)

The Multiple Parallel Routing Protocol [15,16] is a simple distance vector routing protocol that allows multiple paths for a single couple of nodes source and destination to be built. In the MPRP, each mobile host maintains a multiple path routing table. Each entry of the table contains following information:

destination address, next hop address, hop count, sequence number and a pointer to the list of multiple paths (route-list). As well as in Ad hoc On-demand Distance Vector routing protocol (AODV) the value of sequence is used for determining the freshness of a route. Each element of the multiple list contains next hop address, hop count and Route Expiration Time (REXP).

5.1.1 Computation of Multiple loop-free paths: Route Discovery Phase

In the original version of the Ad hoc On-demand Distance Vector routing protocol (AODV), duplicated Route Request packets (RREQs) are discarded. In MPRP, all duplicated RREQ copies should be processed. However, using all duplicated route copies to obtain multipath, may cause routing loop. In MPRP all duplicated copies are examined, but only those which permit the preservation of the loop-freedom property are considered in building multiple paths. The integration between the CDS and the MPRP permits the interference between the paths to be eliminated. This is due to the fact the all the scheduler schemes considered are based on a TDMA approach and compute in a distributed fashion conflict-free schedules. In this paper we are interested to evaluate the impact of using multiple paths to split data traffic. In fact, we do not consider any specific policy or link quality measure to select a path. Simply, we randomly select an available path to split data traffic. We borrowed the concept of advertised-hopcount from the Ad hoc On-demand Multipath Distance Vector routing protocol (AOMDV) [23]. The advertised-hopcount of a node *i* for a destination *d* represents the “maximum” hopcount of the multiple paths for *d* available at *i*. “Maximum” hopcount is considered, as the advertised hopcount can never changes for the same sequence number. The protocol only allows accepting alternate routes with lower hopcounts. This invariance is necessary to guarantee loop-freedom property. The advertisedhopcount is initialized each time the sequence number is updated. A node *i* updates its advertised-hopcount for a destination *d* whenever it sends a route advertisement for *d*.

It is updated as follows.

$\text{Advertised-hopcount}_i^d := \max_k\{\text{hopcount}_k \mid (\text{nexthop}_k , \text{hopcount}_k) \in \text{routr-list}_i^d\}$

The same rule as in AOMDV is used in order the loop-freedom property to be guaranteed as shown in figure 5.

```
if ($seqnum_i^d < seqnum_j^d$) then
        $seqnum_i^d := seqnum_j^d$;
        if ($i \neq d$) then
        $advertised\text{-}hopcount_i^d := \infty$;
        $route\text{-}list_i^d = NULL$;
        insert(j, $advertised\text{-}hopcount_j^d + 1$)
                into $route\text{-}list_i^d$;
        else
            $advertised\text{-}hopecount_j^d := 0$;
else if ($seqnum_i^d == seqnum_j^d$)&&
    (($advertised\text{-}hopcount_i^d$)> ($advertised\text{-}hopcount_j^d$))
    Insert(j, $advertised\text{-} hopcount_j^d + 1$)
                Into $route\text{-}list_i^d$;
endif
```

Fig 5: Route update rules. This is used whenever a node *i* receives a route advertisement to a destination d from a neighbor *j*. The variable $seqnum_i^d$ $advertised\text{-}hopcount_i^d$ and $route\text{-}list_i^d$ represent the sequence number, advertised-hopcount and route-list for destination *d* at node *i* respectively.

Example:

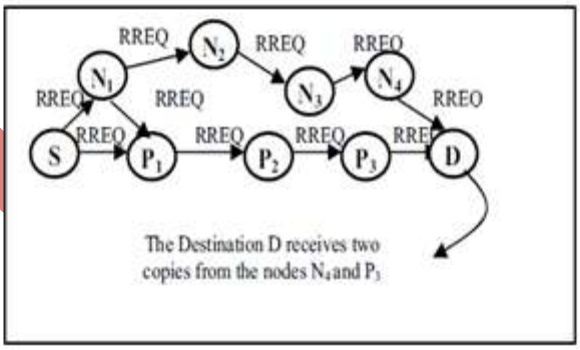

Fig 6: The RREQ packet is propagated from the source node S to the destination node D in the rote discovery phase

Let us to consider an example of MPRP works. In Figure 6 a route-discovery phase is shown. The RREQ packet is sent out from the source node S to its neighbors. Suppose that node N_1 receives the RREQ packet from the node S and the node P1 receives the RREQ packet from the node N_1 before to receive it from the node S.

The RREQ packet will be propagated in the network until it will reach the destination D. Each intermediate node can process a new RREQ packet and the destination node D receives two RREQ packets, the first one from the node N_4 and the other from the node P_3. In this case two paths with a common link will be built: the S-N_1-N_2-N_3-N_4-D path and the S-N_1-P_1-P_2-P_3-D path (see Figure 7). Note that the rule used to guarantee the loop-freedom property excludes the second path found to be greater (that is, with a higher number of hops) than the first one found. Assume a data packet is sent from source node S to N_1 for the destination D. N_1 has two different paths for the destination D, the first one has the next-hop N_2 and the other has the next-hop P_1. N_1 randomly will select the path without considering any link quality measure or queue length.

Lemma: two parallel paths for the same couple source-destination (SD) do not interfere to each other even if they are simultaneously used. This is because a conflict-free schedule scheme is used at MAC layer that permits nodes belonging to the two paths have different control slots and cannot interfere to each other.

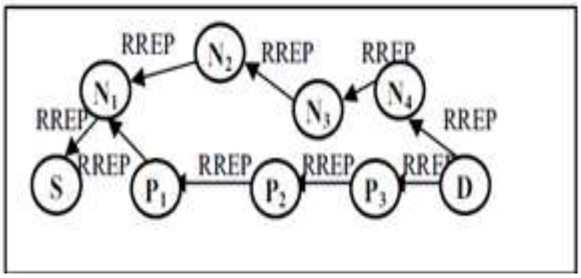

Fig 7: In this phase RREP packet is propagated.

6) PERFORMANCE EVALUATION

6.1 Simulation Environment

The simulations are conducted using NS2. We study the synergic effect of the CDS of the Std. 802.16 and the MPRP proposed in this work. Different simulation campaigns have been conducted varying the number of nodes in the simulation area to show how multiple paths permit more data packets to be delivered. Also, the average end-to-end delay decrease when we use multiple paths to split data traffic even if no specific parameter has been introduced to choose a path. We considered 30,40,50,60 and 70 nodes in order to obtain different densities in the network. Nodes are randomly placed over 1000×1000 sq. meter area. 40 nodes are randomly chosen to be CBR (constant bit rate) sources. Each source is characterized by a rate of 5,50,or 500 pkts/sec. Node 1 is chosen as Internet Gateway (IGW) and each path is between a source node (a generic Mesh Router, MR) and this node..

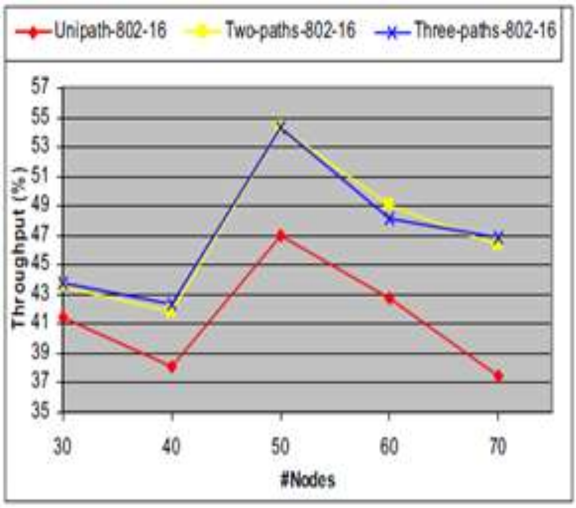

Fig 8:Throughtput (%) (1000×1000 grid).

In figures unipath is the AODV and Multipath is our MPRP. The transmission range of each node is constant (250 m). MRs are considered quasi-static in the networks and topological changes are considered only when a MR switches off or a new MR enters the network. In the beginning, the nodes are randomly placed in the area and each node remains stationary. In this works we evaluate how multi-path routing behaves in a synergic fashion with the CDS we introduced three different parameters,1) Throughput 2) Average end-end data packet delay 3) Data Packets Lost

In this sub-section we show simulation results. We compare results of the unipath version of our routing protocol and the MPRP with two and three multiple paths used in a parallel fashion over all the scheduler schemes implemented at MAC layer. As we already outlined, in this work we did not introduce any specific criteria to split data traffic, but we evenly distributed data packets on the different available paths. In Figure 8 we evaluated Data Delivery Ratio when the CDS scheme of the Std. is considered. Results show how multiple paths allow increased Data Delivery Ratio to be achieved. As we can observe, the positive effect of multiple paths increases when the density of the network increases too. We can justify this behavior because the possibility to find more available paths between a pair of nodes increases when we have more nodes in the network. On the other hand, the resources as the number of control slots and their re-usability become less effective when the density of the network increases. For this reason it is interesting to evaluate the effect of the two layers together, the network and the MAC layers. In fact, we can observe that the throughput increases in correspondence of 50 nodes and starts to decreasing in correspondence of 60 and 70 nodes. We explain this behavior considering the two opposite effects of the routing and the MAC protocols. Another important observation that we can do is that this behavior is similar when unipath routing is considered. Probably, this is due to the fact that, when a smaller number of nodes are considered in the network the average length of the paths is greater. Concerning the average end-to-end data packet delay we can observe as this parameter increases for unipath version on all the scheduler schemes considered. In fact, in Figure 9 the delay for the CDS scheme is shown and the best value is obtained in correspondence of 50 nodes. As we already observed for throughput is also available for the delay. In fact,50 nodes seem to represent a good trade-off between the two opposite behaviors. The TDMA-based protocols react better when the density of the network is smaller because the resources are enough for all the users, but if the number of nodes is too small it is difficult to find "good" paths (in terms of number of hops) and a node can be loaded for different simultaneous transmissions. On the other hand when the density increases the resources of the networks are not sufficient for simultaneous requests and a node can be "delayed" to reserve slots and to send data packets, but it is possible to find better paths and above all it is possible to find more available paths that work in a simultaneous fashion. In Figure 10 we evaluated the percentage of lost data packets in the network because the data buffer is full over the total number of lost data packets. This parameter is very interesting because is a kind of measure of the load balancing obtained through the multiple approach. In fact, we expect that data packets are frequently lost due to the full buffer when the multiple paths have a small impact. When multiple paths allow to distributing data packets on different nodes we obtain more data packets delivered to the destination and data buffers will be regularly "emptied" and the percentage of data packets lost for full buffer will decrease.

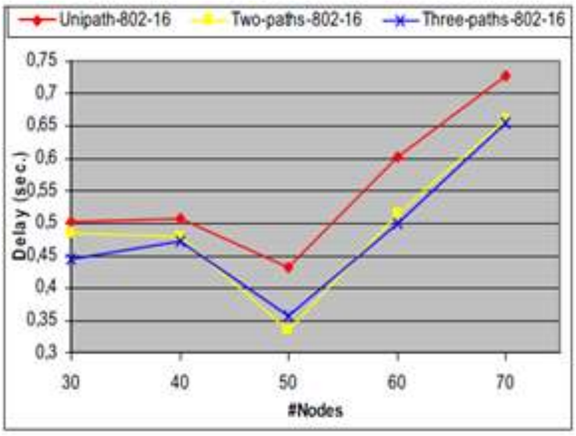

Fig 9: Average end-to-end data packet delay (sec) (1000×1000 grid)

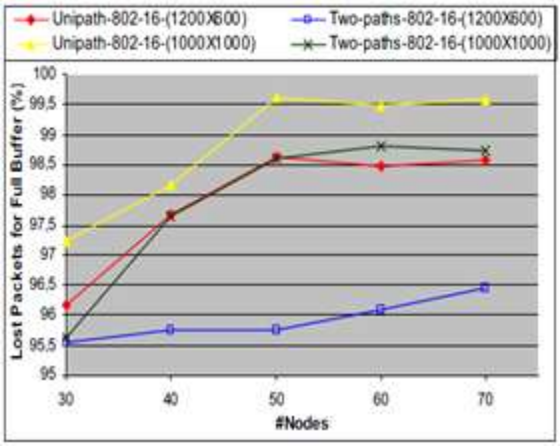

Fig 10: Lost data packet for full data buffer over lost data packet (%).

7. CONCLUSION

In this works we considered a simple multipath routing approach the Multipath Parallel Routing Protocol, MPRP. MPRP is a distance-vector routing protocol that permits two or more path to be recorded in the routing table of each node with a little bit of additional overhead. The MPRP does not build multiple paths considering node or link disjointedness property to be satisfied to and this increase the probability to find more multiple paths. Multiple paths are simultaneously used but they do not interface to each other because a conflict-free scheduling scheme has been incorporated in the MAC layer. Through the use of a well-known simulation tool, NS2, we showed how the synergic effect of the multi-path routing and the CDS of the Std. 802.16 permit good performance in terms of throughput and delay to be obtained without increase the overhead. In the future we would like to study some different criteria to split data traffic among multiple paths based on congested paths for example and different coordinated distributed scheduling scheme like Randomized – MAC (R-MAC).

8. ACKNOWLEDGMENTS

It is my privilege to express my profound sense of respect, gratitude and indebtedness to IIMT IET Director S.B Gupta, Dept. HOD Mr Pawan Singh, IIMT Director Sir ,Deputy Director Deepa Sharma, M.tech HOD Mr.Arun Singh,and Mr Udai Shankar Associate Professor, Department of Computer Science & Engineering, IIMT Engineering College, Meerut for his keen interest, indefatigable inspiration, innovative suggestions and invaluable co-operation throughout this research paper.

9. REFERENCES

[1] Ian F. Akyildiz[a], xudong Wang[b,*,] Weilin Wang[b] Wireless mesh networks: a survey, 1 January 2005.

[2] Fast Channel Establishment for IEEE 802.16 Wireless Mesh Networks
K.S. Vijayalayan, Aaron Harwood and Shanika Karunasekera Department of Computer Science and Software Engineering, The University of Melbourne,
111, Barry St, Carlton, VIC 3053, Australia.
Email:{ksv,aaron, shanika}@csse.unimelb.edu.au
978-1-4244-5637-6/10/$26.00 ©2010 IEEE

[3] M. Cao, W. Ma, Q. Zhang, X. Wang, and W. Zhu, “Modelling and performance analysis of the distributed scheduler in IEEE 802.16 mesh mode,” in Proceedings of the 6th ACM international symposium on Mobile ad hoc networking and computing (Mobi Hoc ’05). New York, NY, USA: ACM, 2005, pp. 78–89.

[4] Link establishment and performance evaluation in IEEE 802.16 wireless mesh networks Mohammad Siraj1,2* and Kamalrulnizam Abu Bakar2 International Journal of the Physical Sciences Vol. 6(13), pp. 3189–3197, 4 July, 2011.

[5] Wang SY, Lin CC, Chu HW, Hsu TW, Fang KH (2008). Improving the Performances of Distributed Coordinated Scheduling in IEEE 802.16 Mesh Networks. IEEE Trans. Vehicular Technol., 57(4): 2531-2547.

[6] Zhu H, Tang Y, Chlamtac I (2008). Unified Collision Free Coordinated Distributed Scheduling (cf-cds) in IEEE 802.16 Mesh Networks. IEEE Trans. Wireless Communication, 7(10): 3889-3903.

[7] Coordinated Scheduling in IEEE 802.16Mesh Networks Shie-Yuan Wang, *Senior Member, IEEE*, Chih-Che Lin, *Student Member, IEEE*, Han-Wei Chu,Teng-Wei Hsu, and Ku-Han Fang IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY, VOL. 57, NO. 4, JULY 2008.

[8] N. Bayer, B. Xu, J. Habermann, and V. Rakocevic, “Improving the performance of the distributed scheduler in IEEE 802.16 mesh networks,” in *Proc. IEEE VTC—Spring*, Dublin, Ireland, Apr. 2007, pp. 1193–1197.

[9] S.-M. Cheng, P. Lin, D.-W. Huang, and S.-R. Yang, “A study on distributed/centralized scheduling for wireless mesh network,” in *Proc. IWCMC*, Vancouver, BC, Canada, Jul. 3–6, 2006, pp. 599–604.

[10] A New Approach to Improve the Efficiency of Distributed Scheduling in IEEE 802.16 Mesh Networks S. Lakani1, M. Fathy2, and H. Ghaffarian2 1 Department of Computer Engineering, Science and Research Branch, Islamic

Azad University, Tehran, Iran Email: s.lakani@srbiau.ac.ir 2 Computer Engineering School, Iran University of Science and Technology, Tehran, Iran Email: {mahFathy, Ghaffarian}@iust.ac.ir International Journal of Recent Trends in Engineering, Vol. 1, No. 1, May 2009

[11] V. Loscri', "A new distributed scheduling scheme for wireless mesh networks," in the Proceedings of the 18th IEEE International Symposium on Personal, Indoor and Mobile Radio Communication (PIMRC'07).

[12] V. Loscri', "MAC protocols over wireles mesh networks: Problems and Perspectives," Elsevier Journal of Parallel and Distributed Computing, vol.68, Issue 3, pp. 387-397, March 2008.

[13] Lee BH, Chen CM (2009). An Enhanced Election-Based Transmission Timing Mechanism in IEEE 802.16 Mesh Networks. ISAP 2009 October 20-23, 2009, Bangkok, Thailand.

[14] Vejarno G, Mcnair J (2010). WiMAX-RBDS-Sim: An OPNET simulation Framework for IEEE 802.16 Mesh Networks, SIMUTools 2010, Torremolinos, Malaga, Spain.

[15] Wang SY, Lin CC, Chu HW, Hsu TW, Fang KH (2008). Improving the Performances of Distributed Coordinated Scheduling in IEEE 802.16 Mesh Networks. IEEE Trans. Vehicular Technol., 57(4): 2531-2547.

[16] A routing Protocol for Wireless Mesh Networks V. Loscri D.E.I.S Department, University of Calabria via P. Bucci, 42/c 87036 Rende, CS , Italy e-mail: vloscri@deis.unical.it