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Enhanced Channel Access Mechanism for IEEE 802.11s Mesh Deterministic Access

Md. Shariful Islam*, M. Mahbub Alam*, Choong Seon Hong* and Jung-Sik Sung†
*Networking Lab, Department of Computer Engineering
Kyung Hee University, Gyeonggi, Korea
Email: {sharif, mahbub}@networking.khu.ac.kr and cshong@khu.ac.kr
†Electronics and Telecommunications Research Institute, Korea
Email: jssung@etri.re.kr

***Abstract*—This paper presents an enhanced channel access mechanism for the newly introduced Mesh Deterministic Access (MDA) mechanism for IEEE 802.11s based Wireless Mesh Networks (WMNs). The MDA is an optional scheduled access mechanism which enables mesh nodes to negotiate periodic transmission opportunity (referred to as Mesh Deterministic Access Opportunity (MDAOP)) for a collision free transmission of QoS frames. However, the performance of MDA is affected by the presence of contention from non-MDA nodes in the neighborhood. In this work, we first identify how a non-MDA node affects the operation of MDA and then, propose an enhanced channel access mechanism referred to as Enhanced Mesh Deterministic Access (EMDA) that ensures guaranteed access to the medium during an MDAOP by an MDA-owner by means of reduced Interframe Space (IFS) and the preemption capability. Finally, we study the performance of EMDA through simulation, and results show that EMDA outperforms others in terms of throughput, end-to-end delay, packet loss rate and MDA utilization.**

I. Introduction

In recent years, Wireless Mesh Networks (WMNs) have gained enormous popularity by providing ubiquitous wireless access to the end-users with reduced infrastructure costs. The characteristics of WMNs such as self-organization, self-configuration, easy installation and maintenance, makes it a suitable alternative to provide broadband Internet services to the residential and office areas by replacing the existing wired backbone with a wireless back-haul network [1]. The increasing market demand leads to the development of a new standard referred to as IEEE 802.11s for WMNs, which is still in its draft phase, and aim to finalize in the near future. This article considers the draft version D2.02 [2] as the base guideline for IEEE 802.11s WMNs. The core components of a WMN that forms the backhaul wireless backbone are Mesh Points (MPs) (i.e., responsible for relaying traffic), Mesh Access Points (MAPs) (i.e., acts as an access point for legacy IEEE 802.11 nodes (STAs), and also have the relaying functionality), and a Mesh Point Portal (MPP) (i.e., the gateway node that is connected to Internet). Finally, legacy STAs are attached to the MAPs, and acts as a generic IEEE 802.11 WLAN node.

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Most of the traffic in a WMN are either from the gateway MPP to the legacy STAs that are associated with MAPs, or STAs to the MPP. Both downlink and uplink traffic are carried through the intermediate mesh nodes in a multi-hop fashion to STAs/MPP. Therefore, nodes not only responsible for sending/receiving their own packets but also need to forward other nodes' packets. Moreover, legacy STAs, while operating in the same channel, increase the possibility of self-interference. Thus, the capacity of a WMN can be better utilized by efficiently designing a medium access mechanism explicitly intended for use in WMN. The IEEE 802.11s still relies on Enhanced Distributed Channel Access (EDCA) [3] which was not designed for multi-hop wireless communication. In EDCA, devices do not cooperate with each other, and thus, whenever medium is free, a node can transmit and under high load, EDCA becomes less efficient. However, in WMN, nodes need to cooperate. Moreover, WMNs exhibit a flat topology that do not have a device dedicated for central coordination which can guarantee QoS by enforcing Hybrid Coordination Function (HCF) Controlled Channel Access (HCCA) of EDCA. Therefore, IEEE 802.11s makes an enhancement to the channel access mechanism, and introduces an optional distributed medium access mechanism referred to as MDA which enables MPs to reserve future slots in advance, and allows almost collision free transmission. The collection of the reserved slots is known as MDAOP. However, in the presence of non-MDA nodes (i.e., legacy STAs and MPs that do not support MDA), the performance of MDA suffers as the MDA-node has no way to prevent a non-MDA node from accessing the channel [4]. Therefore, we need to design an access mechanism so that the nodes who owns an MDAOP can enjoy a guaranteed access to the medium during its MDAOP period even in the presence of contention from non-MDA nodes in the neighborhood.

The primary contribution of this paper can be summarized as: i) we first identify the problems with current MDA mechanism in the presence of contention from non-MDA nodes, ii) we introduce an enhanced channel access mechanism for MDA, iii) we propose a preemptive MDA for cases where a transmission just before the MDAOP could have foreshortened the MDAOP, and finally, iv) through extensive simulations, we show that our proposed EMDA mechanism performs better than the existing mechanisms.

The remainder of this paper is organized as follows. We discuss the existing extensions to MDA in Section II. Section III briefly introduces MDA mechanism. In Section IV, we present the detailed design of the proposed EMDA, and in Section V, we investigate the performance of EMDA. Finally, we present our conclusions in Section VI.

II. Related works

As of now, very few works regarding the enhancement of MDA mechanism exist in the literature. In [5], the authors have proposed a scheduled medium access (SMA) mechanism to be used with MDA. In SMA, an MP is allowed to continue accessing the channel even after the end of its reserved period. It allows MPs to complete the delayed transmission caused by an ongoing transmission by a non-MDA node prior to the start of an MDAOP. However, allowing to extend the reserved time will cause the MDAOPs of its neighbor MPs to be unsynchronized. Since, the already established MDAOPs based on the TX-RX times report of the prior MP would now be invalid. SMA also assumes that in case of a failure to initiate a transmission during MDAOP, the owner MP should immediately get access to the channel after the MDAOP. However, if both MDA and non-MDA nodes use the same contention parameters (as considered in [5]), the access for an MDA node cannot be guaranteed. Cicconetti et. al in [6], showed how MDAOPs can be positioned within a mesh Delivery Traffic Indication Message (DTIM)[1] interval, so that the number of fragmentation can be minimized. They also identified that nodes outside the two-hop neighborhood can interfere during an MDAOP, and proposed a dynamic relocation scheme for the interfered MDAOPs. However, as the basic access mechanism remained the same, performance would be degraded because of the presence of non-MDA nodes.

Authors in [7] have proposed an enhanced beaconing scheme to improve the performance of MDA. They proposed to combine multiple beacons in a Beacon Transmission Window (BTW), and increase the BTW size, such that, MPs can complete their MDAOP reservation in the BTW. However, advertising TX-RX report only in the beacon period is not sufficient, since, this will prevent an MP to use a slot that becomes available during the DTIM, but not yet advertised till next BTW. Apart from these, Hiertz et al. [8], have proposed Mesh Network Alliance (MNA) that uses contention free period (CFP) explicitly for MPs and contention periods (CP) for legacy STAs. In MNA, MPs reserve their slots in the beacon transmission period which is the concept used in distributed reservation protocol (DRP) [9] by the same authors. Finally, the operation of MDA is illustrated briefly in [10] and [11].

[1]DTIM interval is defined as the time between two consecutive mesh DTIM beacon frames and calculated in Time Units ($1\ TU = 1024\mu s$). It is the product of Beacon Interval and Mesh DTIM period.

III. MDA- An Overview

Through MDA mechanism, MPs that are capable of performing MDA, need to reserve (i.e., setting up MDAOP) the channel first, and then, access the channel during reserved MDAOP. In the following, we describe the channel reservation and access mechanism.

A. Channel Reservation

An MDA node requires obtaining an MDAOP with a peer MDA enabled node by means of a two-way handshaking. First, it transmits an MDAOP setup request information element to the intended receiver with the chosen number of MDAOP slots and offset. However, before sending the request, a requesting MP needs to know about the MDAOP slots used by its neighborhood MPs. Each node that has MDA active needs to advertise MDA Advertisement (MADV) information element (IE) which includes TX-RX and Interfering times report (IR). The TX-RX of an MP includes all MDAOP slots for which the MP is either a transmitter or a receiver, and all other times that it knows to be busy like self or neighbors' expected beacon times. In contrast, IR includes the slots in which the MP is neither a transmitter nor a receiver, but the slots are busy because of transmission/reception of its neighbor(s) [2]. Thus, by examining both TX-RX and IR, an MP can know which slots are free in its two-hop neighborhood. The MADV message includes another important parameter named MDA Access Fraction (MAF)[2] which is used to limit the use of MDA in an MP's mesh neighborhood. After getting the MDAOP request message, the receiver first checks whether the requesting slots overlap with its neighborhood MDAOP times or not. It also needs to ensure that requesting MDAOP times do not cause its neighbor MPs' MAF limit to exceed. If both are satisfied, then, the receiver issues an MDAOP setup reply message to the sender and an MDAOP is setup between the sender and receiver.

B. Access Mechanism

Though the MDA mechanism allows an MP to reserve slots for future transmission, access during the MDAOP is not guaranteed. The owner of an MDAOP needs to contend for the channel during MDAOP period using IEEE 802.11e EDCA access mechanism [3], and thus, the contention and backoff parameters are set based on the access category of the frame. Only after successfully obtaining an EDCA Transmission Opportunity (TXOP), an MDA-owner node can transmit a frame to the intended receiver during its MDAOP. The MP can transmit additional frames associated with the MDA session by obtaining a subsequent TXOP if it reaches the TXOP limit before the end of MDAOP. In case of a failure to obtain either an initial or subsequent TXOP, the MDAOP owner MP needs to perform the backoff procedure of EDCA access mechanism. Note that, all other nodes that are MDA-enabled/MDA-aware,

[2]MAF of an MP is the ratio of the total duration of busy slots (found from both TX-RX and Interfering times report) to the duration of the Mesh DTIM interval. The maximum value of MAF allowed at an MP is specified in *dot11MAFlimit* parameter and the value is always a multiple of $1/16$ [2].

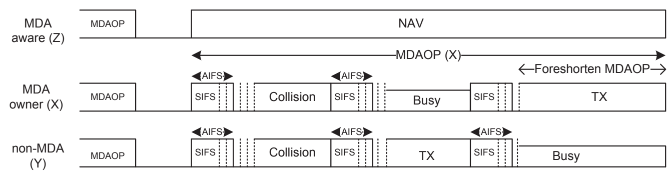

Fig. 1. Node X can not start at the beginning of its MDAOP due to simultaneous transmission attempt from a non-MDA STA Y.

set their Network Allocation Vector (NAV) by overhearing MDA reservation and cannot initiate a transmission during any known MDAOP. However, MPs that are not MDA-enabled or MDA-unaware and non-MDA STAs, can contend for the channel using the same access mechanism (i.e., EDCA) during the MDAOP of its neighbor MPs. This allows non-MDA nodes to affect regular MDA operation, and we show this in the next section.

IV. Proposed access mechanism

A. Problem description and motivation

The main motivation of mesh deterministic access is to allow an MP to reserve future slots to ensure an almost guaranteed and collision free transmission of QoS aware traffic. But, in practice, the performance of MDA is affected due to the presence of non-MDA nodes in the network. Note that, in a WMN, mesh points can be categorized in three types based on whether they are the owner of an MDAOP, aware or capable of performing MDA and non-MDA or MDA unaware MPs. Moreover, legacy STAs do not support MDA and act as a potential interferer for MDA-enabled MAPs. The MDA reservation mechanism guarantees that all MDA aware MPs in the neighborhood of an MDAOP, set their NAV values such that they refrain from accessing the channel during the MDAOP. Moreover, the access mechanism of MDA strictly states that the owner of an MDAOP should access the channel by obtaining an EDCA TXOP [2] with the contention and backoff parameters based on the access category of the traffic. But, a non-MDA node may contend for the channel with the MDA-owner during the MDAOP. Thus, the probability of collision increases with the increase of the non-MDA nodes. Furthermore, the MDAOP may be foreshortened if a non-MDA node wins the backoff process, and gets the access to the channel in a reserved MDAOP period.

We illustrate the problem in more detail in Fig. 1 which shows how the performance of an MDAOP owner (X) can be degraded by the presence of contention from a non-MDA node (Y). Note that MDA-aware node (Z) cannot initiate a transmission during the advertised MDAOP of node X, and this is true for all other neighbors of X those are MDA-aware. Thus, the only contending nodes present in the neighborhood of node X are those that are not MDA-aware such as node Y. Therefore, if both nodes X and Y choose the same backoff parameters and have equal AIFS, then there will be a collision. Moreover, if the non-MDA node wins the backoff procedure, then the owner of the MDAOP have to wait until it senses the medium idle again, and can initiate a transmission only by successfully obtaining an EDCA TXOP. Thus, MDA-owner will now have a shorter MDAOP to complete its transmission as the MDA mechanism does not allow an MDA-owner to continue its transmission beyond the reserved MDAOP.

Another problem with the MDA operation is that an MDA-owner might not start the scheduled transmission at the beginning of its MDAOP due to an ongoing transmission from a non-MDA node that starts ahead of the MDAOP. Furthermore, an MDA-owner must need to finish its transmission within the MDAOP boundary. Therefore, such a delayed access might hinder the transmission of all the scheduled frames of the MDA-owner during its reserved MDAOP. The problem is illustrated in Fig. 3a.

We propose an Enhanced Mesh Deterministic Access (EMDA) mechanism that can successfully address the issues discussed in this section. We describe EMDA in detail in the following sub-sections.

B. Proposed Access mechanism

As discussed earlier, an MDA-owner needs obtaining an EDCA TXOP (9.1.1.3 in [2]) before initiating the transmission in the reserved MDAOP period to avoid collision from a non-MDA node. All MDA-aware MPs can track the neighborhood MDAOP times and know when they or their peer MPs are either transmitter or receiver. Therefore, MDA aware nodes do not transmit during the known MDAOP periods of others. However, an MDA-owner is unable to prevent a non-MDA node from accessing its EDCA TXOP which degrades the performance of the MDA. On the other hand, the access mechanism should not perform in a way such that non-MDA nodes starve. Our proposed access mechanism EMDA finds a way to prevent non-MDA nodes from accessing the channel that an MDA node already reserved.

We introduce a new Interframe Space (IFS) time for an MDA owner node. We named this new IFS as MDA Interframe Space (MIFS) and the duration is set to:

$$MIFS = SIFS + aSlotTime \tag{1}$$

Note that the duration of MIFS is equal to that of Point (coordination function) Interframe Space (PIFS) used by an Access Point (AP) in the Contention Free (CF) period while operating with 802.11e HCF [3]. However, as there is no centralized node in a WMN, this feature cannot be used while communicating between MPs. We therefore exploit this feature, and set the MIFS value as shown in Eq.1 for MPs when MDA is active. At the beginning of the reserved MDAOP, the MDA-owner should check whether the medium is idle for an MIFS period. If it senses the medium as idle, it initiates a transmission right after the MIFS period without initiating a backoff process.

Remember that, nodes accessing the channel through EDCA mechanism, need to wait for an Arbitration Interframe Space (AIFS) period before going into the backoff process where the value of AIFS is set to:

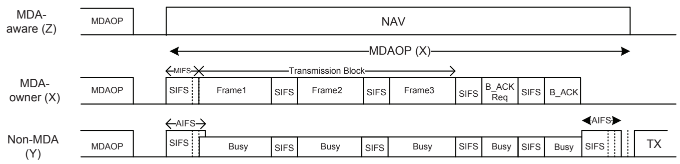

Fig. 2. Proposed access mechanism. MDA-owner node (x) starts transmitting after sensing the channel idle for an MIFS period.

$$AIFS = SIFS + AIFSN[AC] \times aSlotTime \quad (2)$$

As defined in [3], the value of Arbitration Interframe Space Number (AIFSN) is varied based on different access categories and for the highest priority traffic, this value is 2. Thus, all EDCA nodes need to sense the channel as idle for at least $2 \times aSlotTime$ after the Short Interframe Space (SIFS) period (i.e., equivalent to Distributed (coordination function) Interframe Space (DIFS)) before initiating the backoff process. Therefore, if an MDA-owner starts transmitting after the MIFS period (i.e., only 1 slot after SIFS), all contending non-MDA nodes will find the medium as busy after their respective AIFS period, and thus, must defer their transmission. Note that even if the value of backoff counter is zero, it will not be able to win the contention as the medium becomes busy before the AIFS ends. However, it is possible for a non-MDA node to gain access to the channel if an MDA-owner finishes its transmission before the end of its MDAOP, and there are no more frames left in the queue to transmit.

Fig. 2 illustrates the EMDA access mechanism in detail where node X is the owner of MDAOP (X), node Y is the non-MDA node that can contend for the channel during MDAOP (X) and node Z is an MDA-aware node who knows about the MDAOP (X) and does not initiate any transmission within the known MDAOP (X). Note that, node Y finds the medium as busy before its AIFS expires. In this case, we assume that the value of AIFSN=2 (i.e., the node have a voice data to transmit). In the EDCA default settings [12], the AIFSN values defined for different access categories like $AC\_VO(voice)$, $AC\_VI(video)$, $AC\_BE(best-effort)$ and $AC\_BK(background)$, are 2, 2, 3 and 7, respectively. Therefore, no matter what is the type of traffic a non-MDA node wants to transmit, the AIFS values will always be larger than our defined MIFS period. Thus, irrespective of the number of non-MDA nodes and their loads, our access mechanism ensures that they refrain from transmission while an MDA owner transmits.

C. Proposed Preemptive MDA

Our proposed access mechanism ensures that a non-MDA node cannot gain access to the channel if both non-MDA and MDA-owner node try to contend at the same time when MDAOP starts. However, it is possible that an MDA-owner might not start accessing the channel from the beginning of its MDAOP because of an ongoing transmission from a non-MDA node which has been initiated ahead of the MDAOP starting

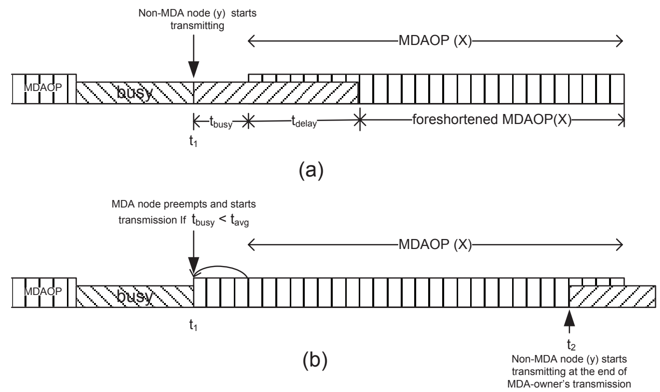

Fig. 3. a. MDAOP of node x is foreshortened due to an ongoing transmission from non-MDA node y that starts at t_1, b. MDA-owner (x) preempts and starts its transmission at t_1 before its reserved MDAOP and releases at t_2.

time. Therefore, the reserved MDAOP is foreshortened, and the node may not be able to transmit all its queued packets within the MDAOP boundary. Fig. 3a illustrates the scenario in more detail, a transmission from a non-MDA node (Y) starting at t_1, causes the MDAOP of node X to be delayed for t_{delay} period. However, the effect of this delayed access depends on where the non-MDA node starts its transmission. In other words, how much is the busy time (t_{busy}) just before MDAOP(X). A transmission that starts just before the MDAOP might have a worse effect (a much longer t_{delay}) than a transmission that was initiated far ahead (long t_{busy}) from the MDAOP. We propose a novel preemptive MDA mechanism that will preempt the transmission of a non-MDA node if it detects that the transmission might foreshortened the MDAOP by a large margin.

Note that a node in the WMN, be it an MDA node or not, can always sense the channel. Therefore, it can track individual transmissions from a non-MDA node within its neighborhood, and know when the medium becomes idle last time before its MDAOP. As illustrated in Fig. 3, node X can sense that the medium becomes idle at time t_1. We assume that nodes use same packet size and thus, know the average transmission time (t_{avg}) of a packet during the DTIM interval. Furthermore, it updates the value of t_{avg} using Exponentially Weighted Moving Average (EWMA) method. Whenever an MDA-node finds that the channel becomes idle before its MDAOP, it measures expected t_{busy} and compares that with estimated t_{avg}. If the expected busy period is less than t_{avg}, it is likely that the transmission would carry over within the MDAOP slots and the MDA node will be forced to delay its transmission. In this case, the MDA-owner should start ahead of its MDAOP period and preempts any transmission from non-MDA node by contending the channel at the time it becomes idle (t_1 in Fig. 3b). Note that an MDA node will start transmitting after the MIFS period, so that the non-MDA nodes will not be able to gain access to the channel.

However, the preempted node will be able to transmit at the end of MDA node's transmission (at time t_2 in Fig. 3b) as early

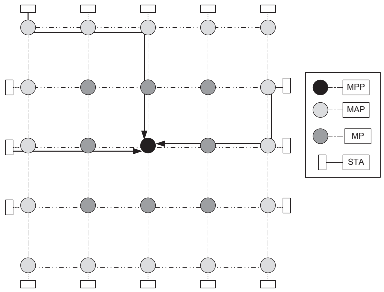

Fig. 4. 25 mesh nodes (16 MAPs, 8 MPs and 1 MPP) are placed in a 5x5 grid. All the STAs transmit voice data to the MPP using 3, 4 or 5-hop routes.

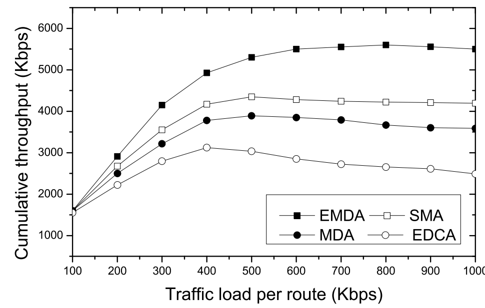

Fig. 5. Cumulative throughput with increasing offered load in each route. With EMDA, system saturates at 5.2 $mbps$.

start of the MDAOP will allow the MDA-owner to finish its transmission ahead of the reserved MDAOP boundary. This, in turn, ensures that non-MDA nodes do not starve. Furthermore, our proposed preemptive MDA mechanism will not disorder the synchronization of other MDAOP reservations since it never stretched the MDAOP boundary, and preempts only when finds feasible. More specifically, the TX-RX and IR of other MPs will not be affected as the preempting node does not advertise any new TX-RX or IR. It keeps the original MDAOP reservation and preempts in non-MDAOP period only.

However, if the MDA-owner finds that the expected busy time is larger than t_{avg} , it will allow the non-MDA node to start its transmission. Because, in this case, the transmission from the non-MDA node is more likely to be finished before the MDAOP or in the worst case, a small portion of MDAOP slots might be affected.

D. Acknowledgment policy

Our access mechanism ensures that the owner of an MDAOP will always win the contention and gain access to the channel. However, a general requirement of wireless medium access mechanisms (i.e., DCF, EDCA, MDA etc.) is that every frame need to be acknowledged by the receiver with an ACK frame. This imposes extra overhead and reduces the channel efficiency as MAC and PHY overhead are major causes of system inefficiency. Therefore, to further increase the efficiency of channel usage, we include the immediate block ACK [13] policy in our scheme.

With MDA mechanism, an MP reserves some contiguous slots (MDAOP) of fixed size to transfer a stream/block of QoS data to its peer MP (intended receiver of the MDA). Moreover, with EMDA, all other adjacent non-MDA nodes defer their transmission during this period. Thus, there will be no frame loss because of collision caused by simultaneous transmission from the neighbors or transmission from the hidden nodes [3] , and only a noisy channel can cause a frame loss. Therefore, channel efficiency can be increased if the owner of an MDAOP transmits the block of data frame with a SIFS interval between consecutive frames. As shown in Fig. 2, after transmitting the block of frames, it requests for a block acknowledgment ($B_{ACK}Req$) from the receiver. After getting the B_{ACK} frame from the receiver, the owner is confirmed about the frames that are transmitted successfully. If there are frames that are not acknowledged in the B_{ACK} frame, the owner can send them within the same MDAOP (or the next reserved MDAOP) either individually or in another block.

[3]MDA reservation implicitly assumes that nodes outside the 2-hop neighborhood of a link do not interfere with the MDAOP on that link.

V. PERFORMANCE ANALYSIS

In this section, we measure the performance of the proposed mechanism and compare it with MDA, SMA and EDCA mechanisms. We have used ns-2 as the simulation tool.

A. Topology and simulation settings

We consider a medium size mesh network consisting of 25 mesh nodes that are placed in a 5×5 grid and covers an area of $250m \times 250m$. The MPP is located in the center and there is atleast one legacy STA attached with each MAP as shown in Fig. 4. All STAs transmit voice data of 80 Byte size to the MPP through 3, 4 or 5-hop routes. So, 16 routes are established from the STAs to MPP. All nodes are equipped with an 802.11a radio and, configured to communicate over the same channel in the 5.8 Ghz band. The Auto Rate Fallback (ARF)[14] mechanism is implemented in each node so that the best possible rate is selected for a particular transmission. Moreover, we assume that the transmission power for both MAPs and STAs are set to be 20 dBm and the path loss factor γ is set to be 3.5 to abstract the shadowing effect. A frame is assumed to be received correctly if the Signal to Interference plus Noise Ratio (SINR) is greater than or equal to the minimum threshold required by 802.11a Orthogonal Frequency-division Multiplexing (OFDM) physical model. Finally, we have set the MAF limit as 0.43 to allow an almost equal opportunity to the non-MDA nodes during the DTIM interval.

B. Results

We first measure the cumulative throughput achieved by all the routes under increasing offered load. The results are shown in Fig. 5. Note that, with only EDCA, the network saturates quickly at 3.03 $Mbps$ and throughput tends to decrease as the offered load increases. With MDA, as the offered load is increased, legacy STAs get more access during

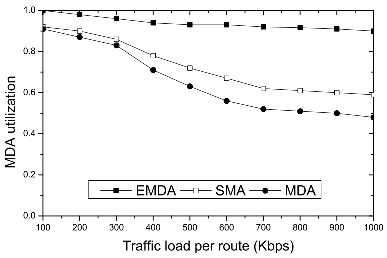

Fig. 6. Impact on MDA utilization as the offered load increases. Due to guaranteed access, EMDA's MDA utilization is more than 90%.

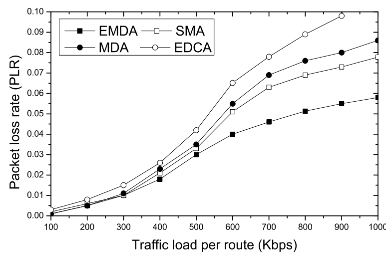

Fig. 7. Impact on packet loss rate (PLR) as the offered load increases. With EMDA, PLR remains less than 6%.

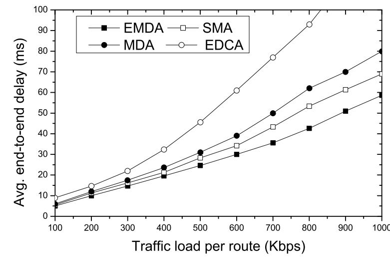

Fig. 8. Impact on end-to-end delay as the offered load increases. With EMDA, average end-to-end delay achieved is minimum.

MDAOP and the achievable throughout drops. By allowing to extend MDAOP times, SMA might cause the MAF limit to exceed and non-MDA STAs might starves and thus, overall performance degrades. In contrast, EMDA allows to complete transmission of an MDA-owner during the scheduled MDAOPs, non-MDA STAs do not starve and thus, the achievable throughput reached as much as $5.6\ Mbps$.

In Fig. 6, we show the MDA $utilization$ which is defined as ratio of the actual transmission time used by MDA during a DTIM interval to the total reserved MDAOP time. By guaranteeing access to the medium during an MDAOP, EMDA achieves a very high MDA utilization as compared with others. This is because, a non-MDA STA can not gain access during an MDAOP due to EMDA's MIFS setting and an ongoing transmission can only cause a delayed start of MDAOP where the delay is negligible. In contrast, as the offered load is increased, both MDA and SMA face delayed start of MDAOP and might not complete transmitting all its queued frames during MDAOP and thus, MDA utilization decreases.

Fig. 7 shows the average packet loss rate (PLR) experiences by the compared mechanisms with increasing offered loads. Note that, simultaneous transmission attempts by a non-MDA node can not succeed due to EMDA's MIFS setting and thus, collision during MDAOP is less likely. Frames need to be retransmitted for channel error only and, we found PLR for EMDA does not exceed 6% which is a base requirement for QoS aware voice traffic. In contrast, while using only EDCA, PLR becomes very high as the offered load increases. Because of the reservation scheme, SMA and MDA experiences moderate PLR at low traffic load, but, as the load increases, PLR exceeds 6%. Finally, in Fig. 8, we show the average end-to-end delay experiences by all the paths. Note that, with EMDA, access during the reserved period is guaranteed and retransmissions caused by packet loss due to collision is negligible. In contrast, as the traffic load increases, probability of collision increases which results in more number of retransmissions that lead to high end-to-end delay for EDCA, MDA and SMA. Therefore, EMDA outperforms others in terms of end-to-end delay as the medium access delay and PLR are negligible.

VI. Conclusion

In this paper, we showed how the effectiveness of the MDA mechanism can be increased by proposing an enhanced channel access mechanism that allows MDA-owner nodes to gain access to the channel even in the presence of contention from non-MDA nodes. In doing so, we first identified the ways a non-MDA node could disallow an MDA-owner from guaranteed access during MDAOP. We also showed that an ongoing transmission from a non-MDA node just before an MDAOP might cause a delayed start for an MDA-owner and therefore, proposed a preemptive MDA mechanism such that MDAOP is not foreshortened. Finally, we evaluated the performance of the proposed EMDA mechanism through simulations, and results demonstrate that it performs better than existing access mechanisms.

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