IEEE 802.11s – Mesh Deterministic Access

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***Abstract*—In 2003, interests in the Institute of Electrical and Electronics Engineers (IEEE) 802.11 Working Group (WG) led to formation of Task Group (TG) "S". 802.11s develops an amendment for Wireless Local Area Network (WLAN) Mesh. Unlike existing WLAN Mesh products, 802.11s forms a transparent 802 broadcast domain that supports any higher layer protocols. Therefore, 802.11s provides frame forwarding and path selection at layer-2. While traditional WLANs are Access Point (AP) centered, the WLAN Mesh is fully distributed. Hence, 802.11s considers extensions to the Medium Access Control (MAC) too. The current draft 2.0 of 802.11s denotes the optional MAC as Mesh Deterministic Access (MDA). Due to the high amount of indirect neighbors in a WLAN Mesh, the current single-hop medium access control mechanisms cannot operate efficiently. In contrast, unlike traditional listen-before-talk scheme MDA's advanced medium reservation scheme allows for operation free of collisions. Therefore, MDA enables support for Quality of Service (QoS) and provides more capacity in the WLAN Mesh.**

In this paper, the authors, who have contributed to the standardization of 802.11s since 2003, give insight to the basics of draft 2.0 of 802.11s and its principles. Furthermore, we provide detailed simulation results of 802.11's first WLAN Mesh aware MAC: MDA. Our simulation results show that unlike the traditional Enhanced Distributed Channel Access (EDCA), MDA does not stall when the offered traffic is high. Due to its planned medium access, limited packet delay can be achieved.

***Index Terms*—IEEE 802.11s, Wireless Mesh Network, WLAN, Mesh Deterministic Access**

I. Introduction

For ubiquitous wireless connectivity, Wireless Mesh Network (WMN) provide the solution [1]. Current products address a wide range of applications. However, a standard for WMNs remains unavailable. Because of increasing market demands for interoperability, several groups in the IEEE 802 Working Groups (WGs) work on amendments for WMNs. As they address different market segments, each WG independently develops solutions for WMNs [2]. 802.11s defines an WMN amendment for Wireless Local Area Network (WLAN). 802.15.5 defines a solution for personal low and high rate WMNs. And due to the centralized approach in Wireless Metropolitan Area Networks (WMANs), 802.16j develops an amendment for Wireless Relay Networks (WRNs). Among all of them, 802.11s [3] is most mature.

The introduction of WMNs not only widens the application space and opens new market segments, furthermore it demands new technological approaches as WMNs can have arbitrary topologies. Whereas the classical wireless networks have a logically centralized structure, in WMNs no hierarchy exists. Any device in the WMN may forward traffic and can be final source or destination. Due to the autonomous operation of each device, a WMN is highly robust and benefits from redundant paths between source and destination of traffic. However, as the topology of a mobile WMN constantly changes, devices experience fluctuation in their radio neighborhood. Furthermore, a WMN relies on mutual service provision (frame forwarding, path selection, secure association etc.) of its devices. Thus, instead of opportunistically accessing the medium devices need to cooperate. This paradigm shift not only influences high level frame forwarding but medium access control too.

To deal with the difficult radio environment, the dense radio neighborhood and the increased medium usage due to multi-hop traffic, 802.11s introduces the Mesh Deterministic Access (MDA) as new Coordination Function (CF) [4]. The current draft [3] provides a framework for single- and multi-transceiver Mesh devices. Although an increasing number of radios helps to exploit additional spectrum, because of the effect of adjacent channel interference between the radios, increased power consumption, cost or other constraints a multi-transceiver solution may not be applicable in all usage scenarios. MDA works as radio agnostic Medium Access Control (MAC) scheme. It provides an extensible solution that supports one or more radios in each device. As the most basic scenario, a single-radio, single-channel WMN is difficult to handle. A solution that efficiently shares the available radio resource among all participating devices can be easily extended for multiple radios. Therefore, we focus on a single-channel WMN in this paper.

A. Outline

In this paper, we briefly outline 802.11s and its concepts in section II. Its optional medium access – Mesh Deterministic Access (MDA) – is specifically designed for Wireless Mesh Networks (WMNs). We explain MDA and its design goals in section III-B. In addition to our limited presentation [5] at an IEEE standardization meeting, section IV provides a more detailed discussion of our MDA simulation results. We present a performance analysis in various environments and compare it with the standard 802.11 medium access scheme. Section V concludes our paper.

II. 802.11 ARCHITECTURE

Throughout this paper, the term 802.11 denotes IEEE 802.11-2007 [6] that we describe in the following. Incorporating the amendments 802.11a, 802.11b, 802.11b-Cor1, 802.11d, 802.11e, 802.11g, 802.11h, 802.11i, and 802.11j into a single document it supersedes the previous baseline standard 802.11-1999.

In 802.11, any device that consists of a standard compliant Medium Access Control (MAC) and Physical Layer (PHY) is denoted as station. The station is the most basic element in the 802.11 Wireless Local Area Network (WLAN). A WLAN may have different topologies. Without a central entity, stations may form an Independent Basic Service Set (IBSS). In an IBSS, stations can exchange frames when in mutual range. The current 802.11 does not define a multi-hop scheme that would enable communication with stations outside radio range. To exchange frames with stations outside communication range, stations must associate with an Access Point (AP). The AP forms the head of the so called infrastructure Basic Service Set (BSS). In it, stations send and receive all frames via the AP. Currently, all APs in the market are collocated with a portal. Via the portal functionality, the AP connects the WLAN with a non-802.11 network. Over the non-802.11 network APs can interconnect. The backbone allows stations to move from one infrastructure BSS to another. The non-802.11 network enables roaming to them.

Currently, 802.11 Task Group (TG) "s" develops an amendment that introduces the Mesh Point (MP). In contrast to a station's functionality, an MP may be capable to forward frames. MPs support path selection at the MAC layer and communicate over multiple wireless hops without a dedicated infrastructure. Unlike stations, MPs do not associate with APs. However, an MP may be collocated with an AP. Then, the AP provides the infrastructure BSS services and the MP integrates the device wirelessly in a larger scale network. An MP that collocates with an 802.11 portal integrates the Mesh with a non-802.11 network. In either case, MPs span a network fully transparent to higher layer protocol. As the Mesh supports any uni-, multi-, and broadcast traffic it seamlessly integrates into the IEEE 802 set of Local Area Network (LAN) and Metropolitan Area Network (MAN) standards.

Due to the arbitrary topology of a Wireless Mesh Networks (WMNs), no hierarchy exists. MPs operate autonomously. Therefore, 802.11s describes the Hybrid Wireless Mesh Protocol (HWMP) that is an ad-hoc path selection protocol. HWMP is the mandatory default protocol. MPs may optionally implement vendor specific protocols. Details von HWMP can be found in [7].

III. SPECTRUM SHARING IN WIRELESS MESH NETWORKS

From a device's perspective, other devices belong to its neighborhood if they are in communication range. To form a Wireless Mesh Network (WMN), the neighborhoods must overlap. For successful reception of a neighbor's frame, the transmission must meet a specific Signal to Interference plus Noise Ratio (SINR) at the receiver side. The SINR depends on

- Transmission power,
- Distance between transmitter and receiver,
- Path loss,
- Thermal noise in the receiver, and the
- Sum of power of concurrent transmissions at the receiver side.

The SINR is the important value to consider for frame reception. With efficient Modulation and Coding Schemes (MCSs) high Physical Layer (PHY) data rates can be enabled. However, an increase in transmission speed requires a high SINR and vice versa. To avoid SINR lowering interference from concurrent radio transmissions, devices within a large area around the receiver must remain silent. To allow the transmitter to receive an Acknowledgment (ACK) frame for successful frame reception, devices around the transmitter need to remain silent too. Thus, each transmission blocks all devices in large areas around the transmitter and the receiver.

Since frames in a WMN traverse on multiple wireless hops, the Wireless Medium (WM) becomes a precious resource. Frame collisions and unnecessary contention on the WM severely impact the performance. Devices rely on the mutual provision of frame forwarding. In WMN, the transmitter must assist to provide a sufficient SINR of the frame transmission to the neighbor's neighbor. Instead of opportunistic medium usage, a cooperative approach is needed. Therefore, the traditional access methods for single-hop networks cannot be applied.

A. Medium Access Control in 802.11s

Out of the proposals submitted for 802.11s, the Task Group (TG) considers one Medium Access Control (MAC) enhancement only. The so called Mesh Deterministic Access (MDA) bases on scheduled medium access. In contrast to the basic Enhanced Distributed Channel Access (EDCA), MDA is an optional feature of [3]. Unlike EDCA, MDA is specifically designed with multi-hop connections in mind.

1) Enhanced Distributed Channel Access: 802.11 bases on a Carrier Sense Multiple Access / Collision Avoidance (CSMA/CA) implemented by the Distributed Coordination Function (DCF). With DCF, stations apply Physical Carrier Sense (P-CS) and Virtual Carrier Sense (V-CS). Both mechanisms ensure that a station does not interfere with an ongoing transmission. With P-CS, a station applies Energy Detection (ED). If there is a certain threshold exceeded, the Wireless Medium (WM) is sensed as busy. The station will not attempt to transmit. With V-CS, stations overhear nearby frame exchanges and refrain from channel access for a duration indicated in the frames.

Once the WM is detected as idle, a station may initiate a transmission. To avoid multiple stations from transmitting at the same time, each station needs to wait for a random period of time. As soon as a station detects the medium as busy, it halts its random timer. When the WM becomes idle again, it resumes the countdown. Therefore, the longer a station waits the higher its medium access probability becomes.

To differentiate different traffic classes, 802.11 provides the Enhanced Distributed Channel Access (EDCA). In contrast to DCF, EDCA introduces means to support Quality of Service (QoS) on a probabilistic basis. [8] describes eight different Traffic Categorys (TCs). In 802.11, these are mapped to four different Access Categorys (ACs):

- Voice,
- Video,
- Best Effort, and
- Background.

An AC has a specific parameter set that defines its probability to access the WM. A detailed introduction, an analysis and according simulation results of EDCA for single-hop networks can be found in [9].

2) Efficiency limiting problems of EDCA in WMNs: Like 802.11's basic Distributed Coordination Function (DCF), Enhanced Distributed Channel Access (EDCA) works as a fully distributed concept. Each station autonomously applies the concept. Due to the absence of medium reservation, EDCA cannot guarantee Quality of Service (QoS) parameters. Other, centrally scheduled schemes such as the Point Coordination Function (PCF) or HCF Controlled Channel Access (HCCA) provide QoS guarantee. However, none of the current products implement them. Furthermore, those concepts cannot be applied in a Wireless Mesh Network (WMN) as it has logical flat topology without a dedicated centrally coordinating device.

EDCA has been designed for single-hop communication. As such, devices access the Wireless Medium (WM) whenever they detect it as idle. In case of high load, EDCA devices throttle themselves as unsuccessful transmission lead to increasing Contention Window sizes. Thus under high medium usage, EDCA becomes less efficient. Furthermore, EDCA devices have no means of cooperation. A device that is at the edge of the WMN detects the WM significantly more often as idle than devices in the core of the WMN. Thus, without feedback the edge Mesh Point (MP) can easily congest its neighbor. Either higher layer protocols such as Transmission Control Protocol (TCP) need to provide the necessary rate control or the Medium Access Control (MAC) layer must inhere a congestion control mechanism. 802.11s defines the according scheme. However, it is optional to implement. Furthermore, an Access Point (AP) that is collocated with an MP has associated stations that do not respect the congestion status information. Thus, 802.11s' congestion control scheme relies on an exclusive frequency channel where all MPs obey to its rules.

Due to conservative Energy Detection (ED) threshold settings in 802.11, devices in large areas around the receiver and transmitter refuse from access to the WM. However, devices outside the ED range detect the WM as idle. A frame transmission to stations inside the area becomes very likely. This is known as the unaware station problem [4]. If the intended station successfully receives the frame, it sends an Acknowledgment (ACK) frame that causes interference to the ongoing frame exchange. It the intended station cannot decode the frame, the sender attempts to retransmit. However, those retransmission further limit the efficiency as they may occur several times during an ongoing frame exchange.

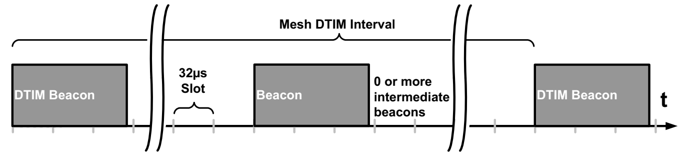


Figure 1. Two consecutive DTIM beacons form a Mesh DTIM interval. MDA divides the interval in slots of 32 µs duration.

B. Mesh Deterministic Access

The Mesh Deterministic Access (MDA) bases on scheduled medium usage. With MDA, the time between consecutive Delivery Traffic Indication Message (DTIM) beacon frames (Mesh DTIM interval) is divided into slots of 32 µs, see Fig. 1. Mesh Points (MPs) reserve the Wireless Medium (WM) for MDA Opportunitys (MDAOPs). To reserve an MDAOP, MPs exchange management frames of type "action". The MP that intends to set-up an MDAOP, includes an MDAOP Setup request Information Element (IE) in the action frame. The Setup request IE includes

- the MDAOP Duration (1 B length),
- the MDAOP Periodicity (1 B length), and
- the MDAOP Offset (2 B length)

field. Accordingly, an MDAOP has a maximum duration of 4096 µs. The MDAOP periodicity indicates the amount of subintervals during the Mesh DTIM interval. An MDAOP Periodicity of zero indicates a single reservation that will not be repeated. The MDAOP offset defines the beginning of the MDAOP relative to the begin of the Mesh DTIM interval, see Fig. 2.

The MP that receives the MDAOP Setup request message checks the included IE. If the intended MDAOP does not conflict with other MDAOPs the receiver is involved in or with MDAOPs of neighboring MPs it is aware of, the MP may accept the MDAOP Setup. From then on, both the MDAOP initiator and the intended receiver inform their neighborhood about the MDAOP Setup. MPs perform the MDAOP advertisement with the help of management unicast (action) or broadcast (beacon) messages. In the TX-RX times report, an MP includes

- all MDAOPs it is involved in as receiver or transmitter,
- its own or expected neighboring beacon transmissions, and
- any other periods that are unavailable.

Furthermore, MPs send an Interfering times report. The latter is a copy of an MP's neighbors' TX-RX times report. Thus, the MDAOP reservation information spreads out in the direct and indirect neighborhood. Thereby, MDA avoids the unaware station problem. In addition, the information provided in the MDAOP advertisement helps MDA capable MPs to identify

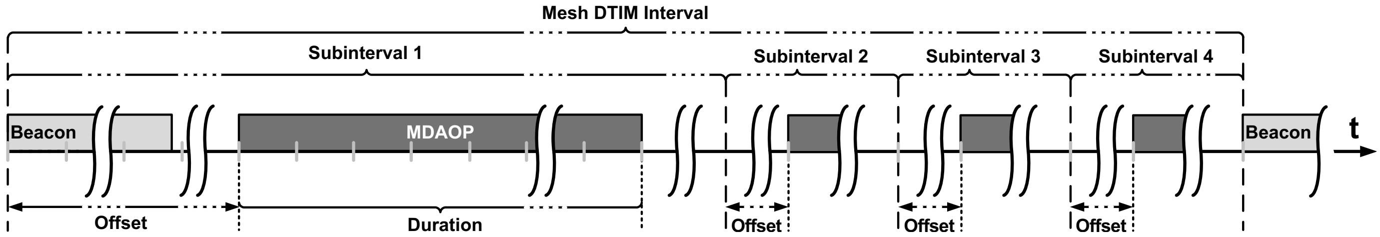


Figure 2. Besides non-periodic, single MDAOP reservations, an MDAOP setup may allow for periodic medium reservation. Here, the MDAOP periodicity divides the Mesh DTIM interval into four subintervals. The MDAOP offset defines the start time of each MDAOP relative to the beginning of the subinterval.

unused time slots and to proactively arrange their MDAOP schedules.

At the beginning of an MDAOP, the owner access the WM with highest priority. While all over devices perform a random backoff, the MDAOP owner uses special medium access settings to immediately grab the channel. However, if the WM is busy due to non-MDA capable devices that do not respect the reservation settings the MDAOP owner needs to defer until the WM becomes idle again. Its MDAOP is foreshorten then. The MDAOP end cannot be extended as this would affect other MPs' schedules.

To consider concerns about excessive medium usage by MDA capable MPs, the Mesh wide MDA Access Fraction (MAF) threshold limits the maximum percentage of the Mesh DTIM interval that each MP may be using MDA for MDAOPs as a receiver or transmitter. The lower the MAF, the more frame exchanges must use Enhanced Distributed Channel Access (EDCA) for medium access. If an MP's total duration of all MDAOPs it is involved in exceeds the MAF, it cannot accept or set-up futher MDAOPs.

IV. Simulation results

We use event-driven stochastic simulations based on the IEEE 802.11a Orthogonal Frequency Division Multiplexing (OFDM) Physical Layer (PHY). The simulations were performed using the Wireless Access Radio Protocol 2 (WARP2) simulation environment developed at the Chair of Communication Networks, Faculty 6, RWTH Aachen University [10]. It is programmed in Specification and Description Language (SDL) using Telelogic's TAU SDL Suite. The channel model used in WARP2 to accurately simulate erroneous radio propagation on the Wireless Medium (WM) is presented in [11]. In accordance with IEEE recommendations, all mathematical notations and unit descriptions are given according to [12].

In all simulations we assume a path loss exponent $\gamma = 3.5$. Devices have a single transceiver that transmits at a power level of 20 dBm (100 mW). Our simulator implements the 802.11a PHY that operates in the 5 GHz license exempt band. In accordance with recent hardware designs, we assume a receiver noise level of -95 dBm. As our simulation tool calculates the Packet Error Rate (PER) based on a received frame's Modulation and Coding Scheme (MCS) and Signal to Interference plus Noise Ratio (SINR), we consider attenuation from obstacles and interference from concurrent transmissions too.

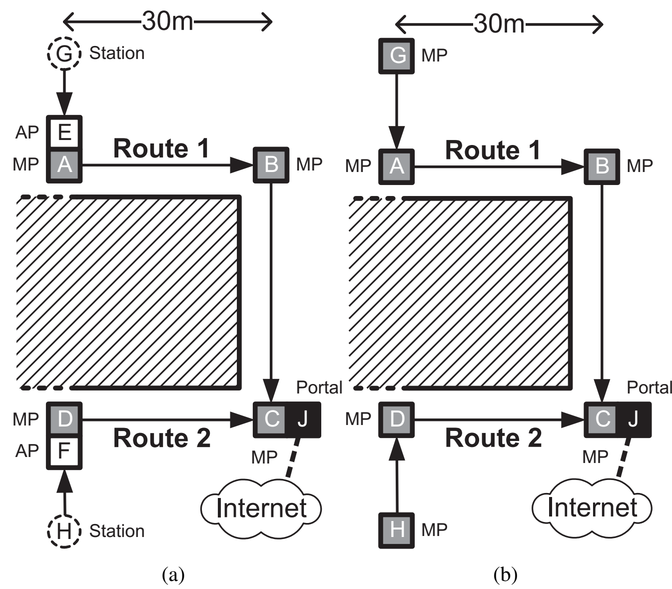
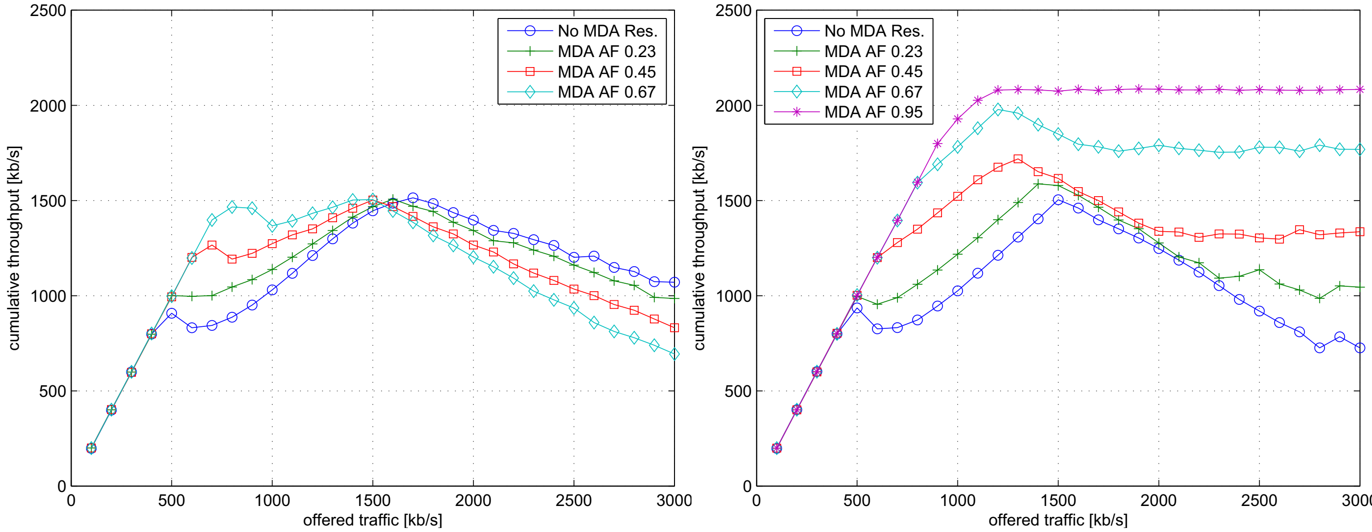


Figure 3. Scenario 1 (a) shows two stations G and H that connect to AP E resp. AP F. Both APs are collocated with an MP. MP A forwards G's traffic via MP B to MP C that is collocated with a portal. MP D forwards H's traffic directly to the portal. In Scenario 1 (b), station G and H become MPs. Thus, they do not need to associate with an AP anymore. Furthermore, MPs G and H are MDA capable.

To survey the lower bounds in the scenarios, we assume an 80 B payload. Such small packet size occurs due to Voice over IP (VoIP) traffic. Without explicit notice, we assume the Enhanced Distributed Channel Access (EDCA) Voice Access Category (AC) and the according parameter set for the Arbitration Interframe Space (AIFS), Contention Window minimum and maximum size.

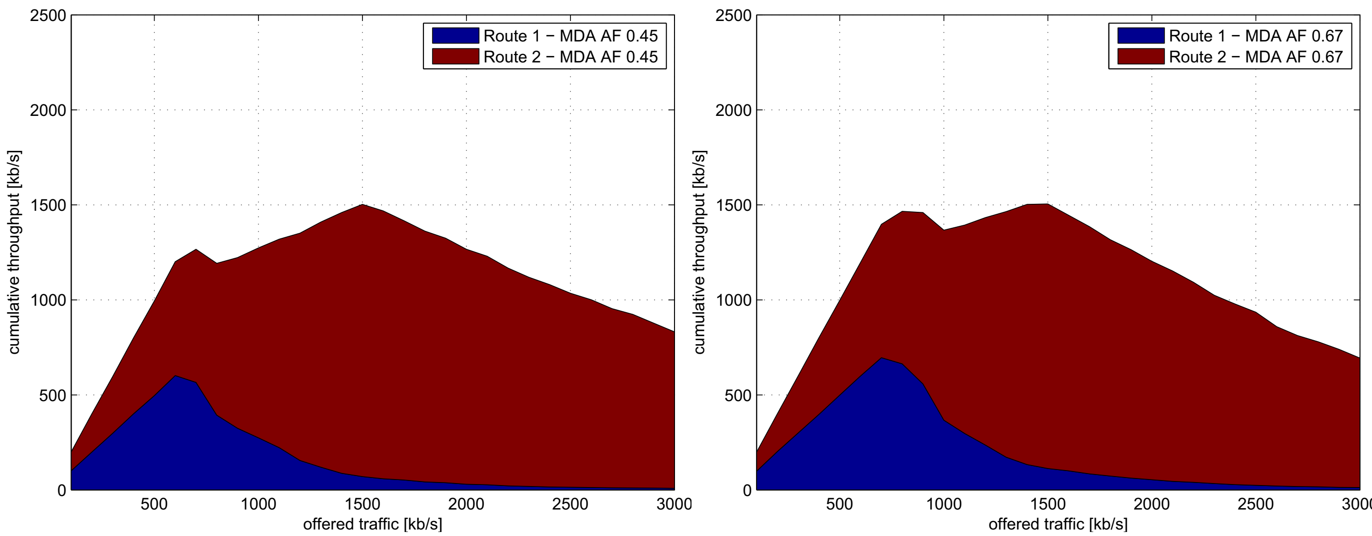
A. Scenario 1

Fig. 3 presents the first simulation scenario. The building separates A, B, E and G from D, F and H by 100 dB attenuation. In Fig. 3 (a), G and H are stations that associate with the Access Points (APs) E resp. H. Each AP collocates with a Mesh Point (MP) (A resp. D). Station G sends its data via A and B to C that collocates with a portal J. Station H sends its data via D and C. Thus, route 2 has one hop less than route 1. In Fig. 3 (b), stations G and H transform to MPs. Thus, no AP is needed for connectivity. In both scenarios, devices transmit at 12 Mb/s Physical Layer (PHY) data rate



(a) (b)

Figure 4. Graph (a) resp. (b) present the cumulative throughput in dependence of the traffic offered to each route relating to Scenario 3 (a) resp. (b).



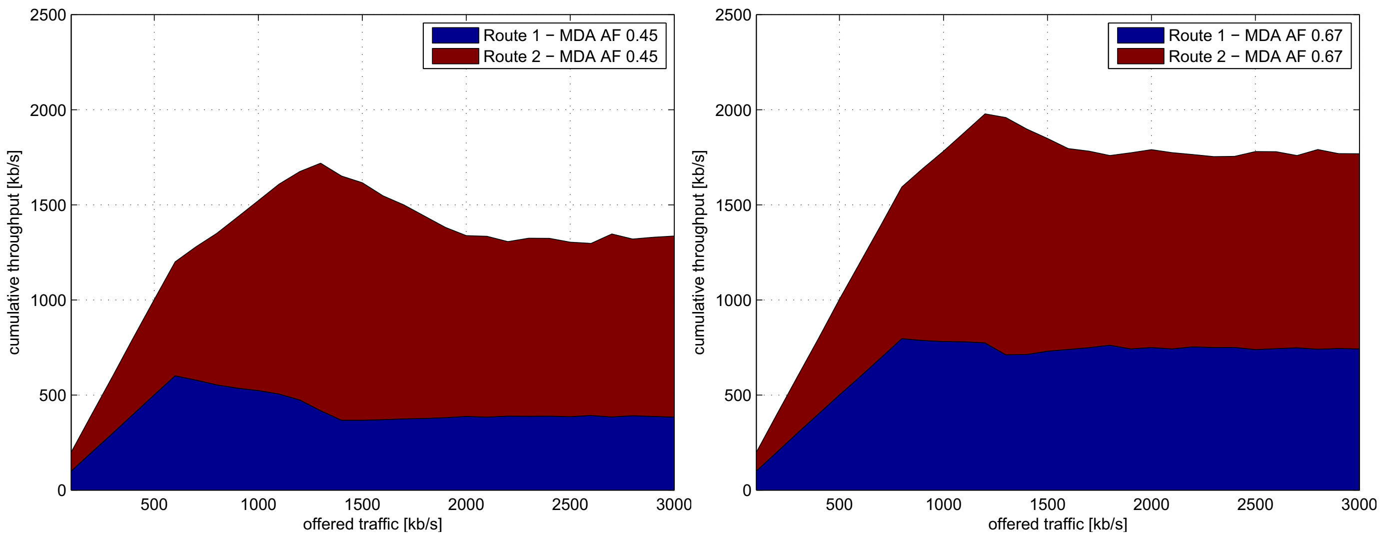
(a) (b)

Figure 5. Both graphs refer to scenario 3 (a). The graphs show the end-to-end throughput subject to the traffic offered per route. With (a), an MDA Access Fraction of 0.45 is used. The MAF increases to 0.67 in (b). With a higher MAF, the routes share the capacity more equally. After the saturation threshold of 600 kb/s (a) resp. 700 kb/s (b), route 2 dominates route 1 due to its lower hop count.

(Quarternary Phase Shift Keying (QPSK) 1/2). While all MPs are Mesh Deterministic Access (MDA) capable, the stations cannot apply MDA.

Fig. 4 (a) presents cumulative throughput of route 1 and 2 subject to the offered traffic per route. When no device applies MDA, the system saturates at about 1 Mb/s (both routes carry 500 kb/s). When stations transmit via an AP over the Wireless Mesh Network (WMN) to the portal, their unscheduled transmissions interfere with MPs that use MDA. However, the more often MDA can be applied (increasing MDA Access Fraction (MAF)), the higher the total system throughput becomes. Fig. 5 (a) and (b) show the throughput per route. Until 500 kb/s resp. 500 kb/s traffic offered per route, both equally share the Wireless Medium (WM). Then, the the system saturates. With increasing traffic offered on both routes, route 2 dominates route 1. The latter starves due to its higher hop count. The system saturates a second time at 1500 kb/s, when almost only route 2 delivers its traffic, see Fig. 4 (a) and Fig. 5 (a) and (b).

When all devices support MDA as in Fig. 3 (b), significant performance increase becomes possible. With an MAF of 0.95, almost no collisions occur. Then, the achievable throughput almost doubles up to 2 Mb/s, see Fig. 4 (b). Furthermore, a higher MAF limits the negative impact of Enhanced Dis-



(a) (b)

Figure 6. Both graphs refer to scenario 3 (b). The graphs show the end-to-end throughput subject to the traffic offered per route. With (a), an MDA Access Fraction of 0.45 is used. The MAF increases to 0.67 in (b). Since all devices are MDA capable, a higher MAF allows to equally share the wireless medium. The short-hop-count route 2 does not starve route 1.

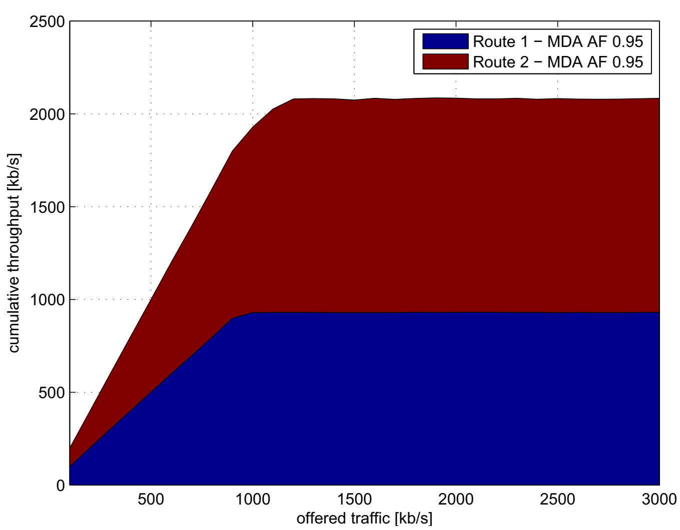


Figure 7. The graph shows the end-to-end throughput subject to the traffic offered per route for scenario 3 (b). The high MDA Access Fraction of 0.95 allows to perfectly share the wireless medium.

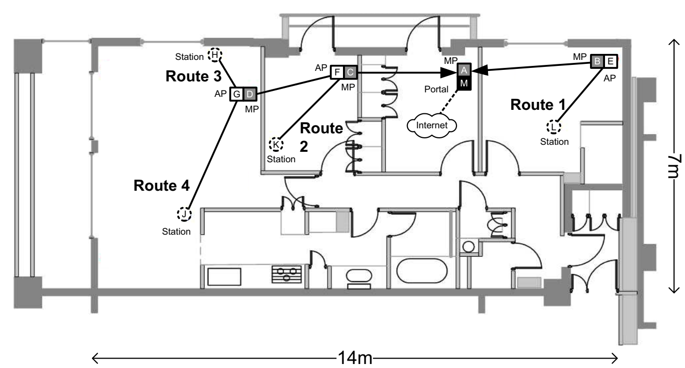


Figure 8. Scenario 2: Stations J and H associate with AP G. Station K associates with AP F and station L associates with AP E. All stations send traffic to the portal M. All APs and the portal M collocate with an MP. The MPs form a WMN.

tributed Channel Access (EDCA) on the WMN performance. The higher the MAF, the more fairly MPs share the bandwidth among different routes, see Fig. 6 (a) and (b) and Fig. 7. Even when the low hop-count route 2 dominates route 1 as in Fig. 5 (a), the pure MDA Mesh network (Fig. 7) provides ⅓ more capacity.

B. Scenario 2

Fig. 8 presents an indoor scenario as defined by 802.11s in [13]. Stations send frames of 80 B payload using the 64-Quadrature Amplitude Modulation (QAM)¾ Modulation and Coding Scheme (MCS) that achieves 54 Mb/s Physical Layer (PHY) data rate. A wall attenuates the radio transmission by 10 dB, a door attenuates it by 3.5 dB. Stations H and J associate with Access Point (AP) G. Stations K and L associate with AP F resp. AP E. All APs collocate with a Mesh Point (MP). MP A collocates with a portal that has Internet connection. Together, the MPs form a Wireless Mesh Network (WMN). Fig. 9 presents the total system throughput. With Mesh Deterministic Access (MDA), about 400 kb/s more traffic can be carried. In any case, in an overload situation the performance drops less if stations apply the Distributed Coordination Function (DCF) instead of the Enhanced Distributed Channel Access (EDCA). As the latter uses aggressive settings for the Voice Access Category (AC), the network limits itself due to an increasing amount of collisions.

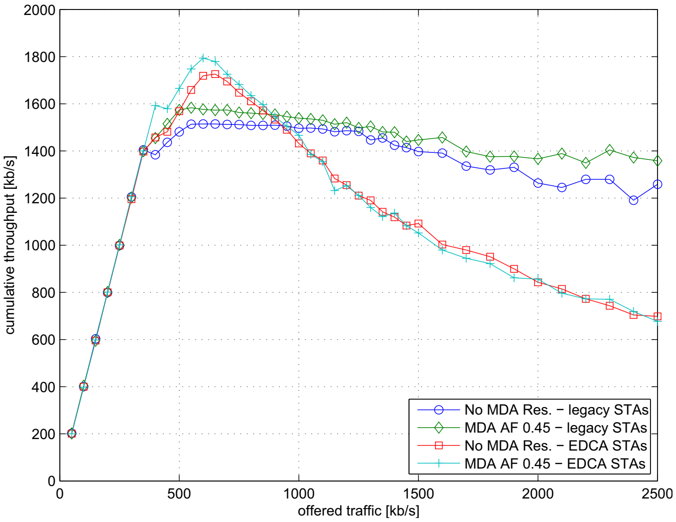


Figure 9. The stations denoted as "legacy" apply DCF and its according MAC parameter set. Stations that implement EDCA use the MAC parameter set for the voice Access Category. Due to its aggressive settings for the Arbitration Interframe Space and the minimum Contention Window size, the throughput drops sharply when the WMN congests.

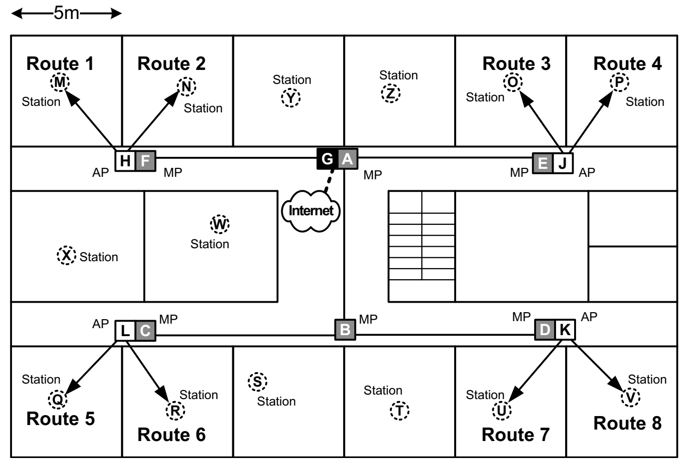


Figure 10. Scenario 3: Stations M and N associate with AP H, stations O and P with AP J, stations Q and R with AP L and stations U and V associate with AP K. The aforementioned stations receive data from the Internet. MP A collocates with the portal G. MPs A-F form a WMN that works as backbone for the APs.

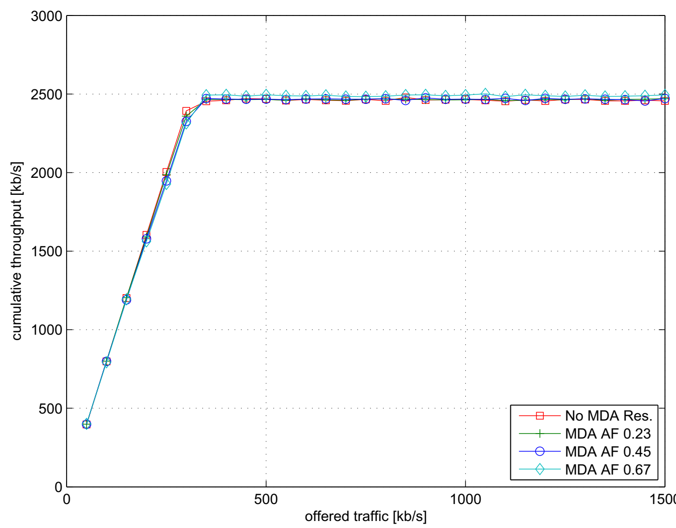


Figure 11. With a single source of traffic, the scenario in Fig. 10 favors EDCA. Remarkably, MDA's efficiency outweighs its signalling overhead. Thus, even in the pure down-link scenario MDA is not in disadvantage to EDCA.

C. Scenario 3

The scenario in Fig. 10 depicts an office environment. All devices use the 64-Quadrature Amplitude Modulation (QAM)¾ Modulation and Coding Scheme (MCS) for frame exchange. Walls attenuate the radio signal by 13 dB. Mesh Point (MP) A collocates with a portal that provides Internet connectivity over the Wireless Mesh Network (WMN) to the stations M, N and O, P and Q, R and U, V that are associated with Access Points (APs) H, J, L resp. K. APs H, J, K and L collocate with MPs F, E, D resp. C. Due to Line Of Sight (LOS) conditions between the single source of traffic – MP A with its collocated portal G – and MPs B, E and F, Enhanced Distributed Channel Access (EDCA) finds ideal conditions. Furthermore, the APs are significantly separated and thus may transmit concurrently to their associated stations. Although Mesh Deterministic Access (MDA) incorporates additional overhead due to MDA Opportunity (MDAOP) setup request and advertisement messages, it does not perform worse than EDCA.

V. Conclusions

Wireless Mesh Networks (WMNs) have difficult radio environments. To form a WMN devices' reception ranges must overlap. Due to the high device density, the traditional 802.11 Carrier Sense (CS) has low performance. Too many devices become blocked because of its conservative Energy Detection (ED) threshold. Thus, 802.11s has low spatial frequency reuse. Furthermore, 802.11 does not provide the necessary means to deal with unaware station problem. While in a single-hop Wireless Local Area Network (WLAN) the absence of an Acknowledgment (ACK) almost always indicates a transmission failure or frame collision, in a WMN the assumption does not hold. Here, the addressed Mesh Point (MP) even may have successfully received frame. However, as it may be blocked due to neighboring transmissions, it cannot acknowledge the frame reception or indicate its current unavailability to the sender.

Mesh Deterministic Access (MDA) avoids the aforementioned problems. Its scheduled medium access allows for planned transmission that have high probability of transmission success. Although scheduling of MDA Opportunitys (MDAOPs) incurs additional overhead, the gain in efficiency outweighs it. The MDAOP advertisement broadcasts the necessary information to the immediate and indirect radio neighborhood to limit the amount of unsuccesful transmissions to a limit. Our simulation results are in line with independently gained results that are published at a recent 802.11s Task

Group (TG) meeting [14].

MDA is the first approach towards a standardized Mesh aware Medium Access Control (MAC). With future amendments of 802.11 that aim at data rates of more than 1 Gb/s, new solutions are needed. The basic 802.11s MAC – the Enhanced Distributed Channel Access (EDCA) – becomes a bottleneck in WMNs. New distributed approaches need to be specifically designed for wireless multi-hop communication. Further extensions of the 802.11 single-hop MAC cannot provide the desired efficiency.

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