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Hybrid Access Techniques for Densely Populated Wireless Local Area Networks

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1. Introduction

The IEEE 802.11p Task Group has recently released a new standard for wireless access in vehicular environments (WAVE). It constitutes an amendment to the 802.11 for Wireless Local Area Networks (WLANs) to meet the requirements of applications related to road-safety involving inter- and intra-vehicle communications as well as communications from vehicle to the roadside infrastructure. Indeed, the importance of the targeted applications has forced authorities to allocate some dedicated bandwidth (nearby the 5.9GHz) to ensure the security of the communications. However, despite the suitability of this standard for use in high-speed vehicular communications, it is not possible to pass over the unprecedented market penetration of the popular 802.11 networks, the so-called WiFi networks. Before we can see a world where all the cars are equipped with 802.11p devices, current and near-future applications might probably run on the original 802.11. Moreover, interaction between humans and vehicles will probably be carried out by means of the 802.11, which is the standard that is flooding most of personal tech devices, such as laptops, mobile phones, gaming consoles, etc. Therefore, it is important to keep on working in the improvement of the 802.11 Standard for its use in, at least, some vehicular applications.

This is the main motivation for this chapter, where we focus on the Medium Access Control (MAC) protocol of the 802.11 Standard, and we propose a simple mechanism to improve its performance in densely populated applications where it falls short to provide users with good service. Envisioned applications include those were a high number of vehicles and pedestrians coexist in a given area, such as for example, a crossing in a city where all the cars share information to coordinate the drive along the crossing and prevent accidents.

Into more detail, the Distributed Coordination Function (DCF) is the mandatory access method defined in the widely spread IEEE 802.11 Standard for WLANs [1]. This access method is based on Carrier Sensing Multiple Access (CSMA), i.e., listen before transmit, in combination with a Binary Exponential Backoff (BEB) mechanism. An optional Collision Avoidance (CA) mechanism is also defined by which a handshake Request to Send (RTS) – Clear to Send (CTS) can be established between source and destination before the actual transmission of data. This CA mechanism aims at reducing the impact of the collisions of data packets and to combat the hidden terminal problem. The DCF can be executed in either ad hoc or infrastructure-based networks and is the only access method implemented in most commercial hardware. Despite the doubtless commercial success of the DCF, the simplicity

of a CSMA-based protocol comes at the cost of a trial-and-error approach where a transmission attempt can result in a collision if several users contend for the access to a common medium as the traffic load of the network increases. Therefore, those networks based on the 802.11 suffer from really low performance when either the number of users or the traffic load is high.

In this chapter, we introduce the idea of combining the DCF with the Point Coordination Function (PCF), also defined in the 802.11 Standard, to overcome its limitations under heavy load conditions. The PCF is defined as an optional polling-based access method for infrastructure-based networks where there is no contention to get access to the channel and the access point (AP) polls the stations of the network to transmit data. Therefore, collisions of data packets can be completely avoided and the performance of the network can be boosted.

The hybrid approach of combining distributed access with reservation or polling-based access has been already used in the context of infrastructure-based networks [2]-[6] combining static Time Division Multiplex Access (TDMA) with dynamic CSMA access. Most of these works propose different alternatives to use the empty slots of TDMA in the case that the user allocated to a given slot has no data to transmit. However, to the best knowledge of the authors, there are very few works in the literature dealing with this approach in a distributed manner, i.e., for ad hoc networks without infrastructure. This is the main motivation for the work presented in this chapter, where we define the Distributed Point Coordination Function (DPCF) as a hybrid combination of the distributed access of the DCF and the poll-based access of the PCF to achieve high performance in highly populated networks with heavy traffic load. Indeed, the work presented in this chapter has been motivated by the successful results presented in [7]. In that paper, a spontaneous, temporary, and dynamic clustering algorithm has been integrated with a high-performance infrastructure-based MAC protocol, the Distributed Queuing Collision Avoidance (DQCA) protocol, in order to extend its near-optimum performance to networks without infrastructure. Upon the conclusion of that work, we realized that the same approach could be applied to the IEEE 802.11 Standard access methods and thus be able to extend the high-performance of the PCF under heavy load conditions to the distributed environments where the DCF runs.

We have observed that there are very few works dealing with the PCF, which can indeed potentially achieve better performance than the DCF under heavy traffic conditions. Some contributions related to the PCF improve the overall network performance through novel scheduling algorithms [8]-[12] or by designing new polling mechanisms that can reduce the overhead associated to the polling process [13]. However, there have been almost no efforts in extending the operation of the PCF to ad hoc networks in order to provide them with some degree of QoS. The only exception can be found in [14] where a virtual infrastructure is created into a MAC protocol called Mobile Point Coordinator MAC (MPC-MAC) in order to achieve QoS delivery and priority access for real time traffic in ad hoc networks maintaining both the PCF and the DCF. In summary, a clustering based mechanism is used to achieve the correct operation of the PCF in a distributed environment. The duration of the PCF and DCF periods and the criterion upon which a terminal is chosen to be the MPC (acting as AP) are fixed and they are determined by the MAC protocol configuration. This approach works well in low dynamic environments where the topology does not vary frequently. In this situation the overhead associated to the "hello" messages required for the clustering mechanism can be kept to a minimum. However, it may not be convenient for spontaneous and highly dynamic environments, such as those present in some vehicular

applications, where the clustering overhead could impact negatively on the efficiency of the network. In addition, this protocol does not consider that the responsibility of becoming cluster head should be shared among all the users of the network to ensure certain fairness regarding the extra energy consumption associated to the role of coordinating a cluster.

Taking into account this background and motivated by the success of extending DQCA to become DQMAN [7], we contribute to the field by presenting the DPCF as an extension of the PCF to operate over infrastructure-less networks through smooth integration with the DCF. By combining the DCF and the PCF using a spontaneous and dynamic clustering mechanism at the MAC layer it is possible to extend the higher performance of the PCF to networks without infrastructure. We present a description of the protocol as well as a comprehensive performance evaluation based on computer simulation both for single-hop and multi-hop networks.

The chapter is organized as follows. The DCF and the PCF of the IEEE 802.11 Standard are overviewed in Section II. The DPCF protocol is then described in Section III. In Section IV, we present a comprehensive performance evaluation of the protocol by means of computer simulation. Finally, Section V concludes the chapter and outlines some future lines of research.

2. IEEE 802.11 MAC protocol overview

An overview of the operation of the DCF and the PCF of the IEEE 802.11 Standard is included in this section. A comprehensive description of them can be found in [1]. Following the naming of the standard, we will refer herein to a vehicle or pedestrian equipped with a communications terminal as a mobile station, or simply, a station.

2.1 DCF overview

The DCF is the mandatory coordination function implemented in all standard compliant devices. Two access modes of operation are defined in the DCF:

1. *Basic access (BASIC) mode;* the station which seizes the channel transmits its data packets without establishing any previous handshake with the intended destination.
2. *Collision avoidance access (COLAV) mode;* a handshake RTS/CTS is established between source and destination before initiating the actual transmission of data. These RTS and CTS get the form of special control packets. The COLAV access mode is aimed at reducing the impact of collisions of data packets and at combating the presence of hidden terminals.

Two examples are illustrated in Figure 1 and Figure 2 representing the operation of the BASIC and the COLAV access modes, respectively. In summary, any station with data to transmit listens to the channel for a DCF Inter Frame Space (DIFS). If the channel is sensed idle for this DIFS period, the station seizes the channel and initiates the data transmission (or the RTS transmission in the COLAV mode). Otherwise, if the channel is sensed busy, the station backs off and executes a BEB algorithm by which the size of the contention window is doubled up upon any transmission failure and reset to the minimum value upon success. When a data packet is received without errors, the destination sends back an ACK packet after a Short Inter Frame Space (SIFS). This SIFS is necessary to compensate propagation delays and radio transceivers turn around times to switch from receiving to transmitting mode. It is worth noting that since a SIFS is shorter than a DIFS, acknowledgments have more priority than regular data traffic.
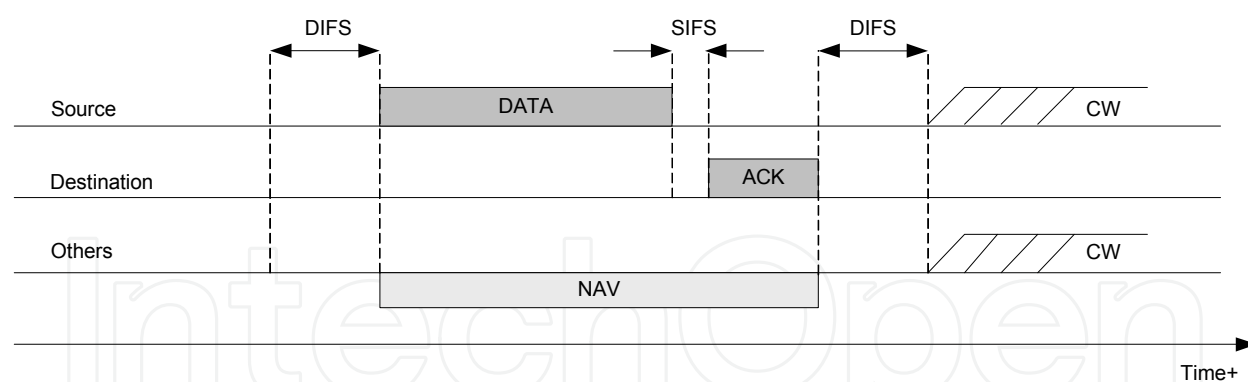
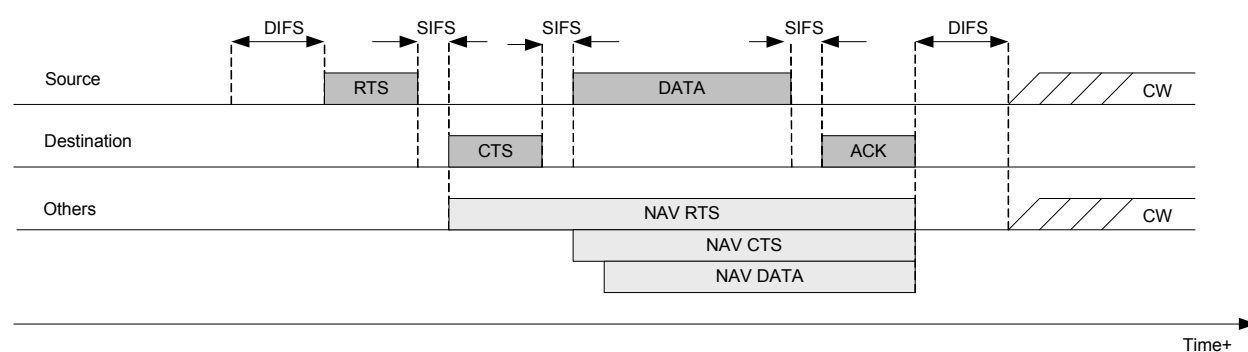Fig. 1. Example: DCF Operation (Basic Access mode)

Fig. 2. Example: DCF Operation (Collision Avoidance mode)

A relevant feature of the DCF is the Virtual Carrier Sensing (VCS) mechanism. Stations not involved in an ongoing transmission defer from attempting to transmit for the time that the channel is expected to be used for an effective transmission between any pair of source and destination stations regardless of the actual physical carrier sensing. To do so, stations update the Network Allocation Vector (NAV) which accounts for the time the channel is expected to be occupied. This information is retrieved from the duration field attached to the overheard RTS, CTS, and data packets. This mechanism is mainly aimed at combating the presence of hidden terminals.

2.2 PCF overview

The PCF can only run on infrastructure-based networks wherein an AP sequentially polls stations to transmit data and thus collisions are totally avoided. This mechanism was initially designed for the provision of QoS over WLANs.

When the PCF is executed, time is divided into Contention Free Periods (CFP), wherein the AP sends poll messages to give transmission opportunities to the stations, and Contention Periods (CP), where the DCF is executed. Since the PCF is an optional coordination function and is not implemented in all standard-compliant devices, DCF periods are necessary to ensure access to DCF-only stations. The interleaving of CFPs and CPs is illustrated in Figure 3. As also shown in this figure, a CFP is initiated and maintained by the AP, which periodically transmits a beacon (B). The first beacon after a CP (DCF access) is transmitted after a PCF Inter Frame Space (PIFS). The duration of a PIFS is shorter than a DIFS but longer than a SIFS, providing thus the initialization of a CFP with less priority than the

transmission of control packets, but with higher priority than the transmission of data packets. The periodically transmitted beacons contain information regarding the duration of both the CFP and the CP and allow a new arrived station to associate to the AP during a CFP. The CFP is finished whenever the AP transmits a CFP End (CE) control packet.
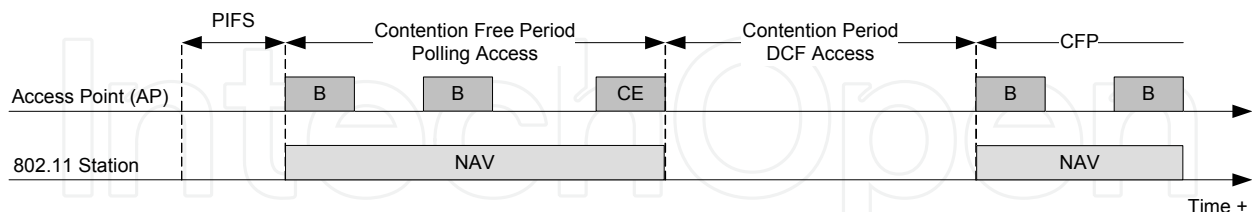

Fig. 3. IEEE 802.11 PCF Interleaves CFPs with CPs

During a CFP, the only station allowed to transmit data is the one being polled by the AP or any destination station which receives a data packet and has to acknowledge (ACK) it, if applicable, and can combine the ACK with data in a same packet. In PCF, some packets can be combined together in order to reduce the number of MAC and PHY headers and thus increase the efficiency of the communications. In any case, the access to the channel is granted one SIFS after the reception of either the poll or the data packet, respectively. A polled user can either transmit a data packet to the AP or to any other station in the network, establishing a peer-to-peer link. If a polled station has no data to transmit, it responds with a special type of control packet, referred to as NULL packet.
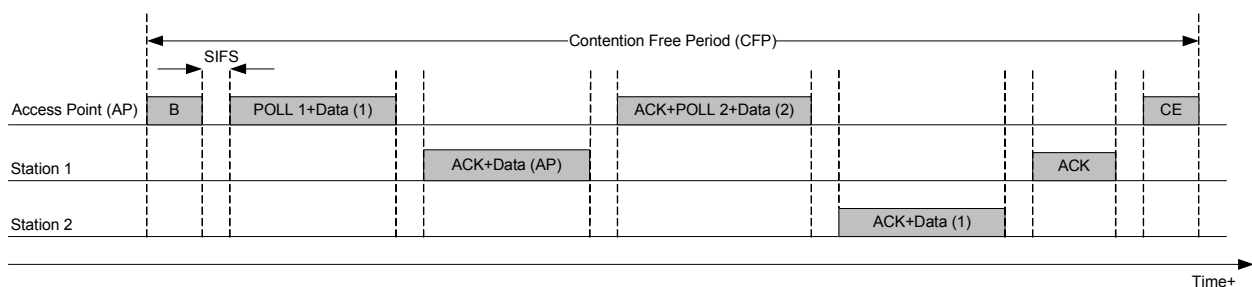

Fig. 4. Example: PCF Operation

An example of PCF operation is illustrated in Figure 4. In this example, the AP initiates a CFP by transmitting a beacon (B). After a SIFS, it combines a poll packet with data to station 1. Upon the reception of this combined packet, station 1 acknowledges the data packet received and responds to the poll by transmitting a data packet to the AP. Note that this is also a combined packet. Then, the AP acknowledges the data packet received from station 1 and combines a poll packet with data to station 2. Upon the reception of the packet, station 2 acknowledges the packet to the AP and transmits data to station 1. Upon the reception of the packet, station 1 acknowledges the received packet. The CFP is finished with the transmission of a CE packet.

3. A new MAC protocol: DPCF

The Distributed PCF (DPCF) protocol is presented in this section as an adaptation and extension of the PCF to operate on distributed infrastructureless wireless ad hoc networks.

As already mentioned before, the main idea is to use the DCF to create spontaneous and temporary clusters wherein the PCF can be executed, having a station acting as the AP for the life time of each cluster.

We consider a set of terminals equipped with WLAN cards forming a spontaneous ad hoc network. Any station must be able to operate in three different modes regarding the clustering mechanism: *idle*, *master*, and *slave*. Initially, all the stations operate in idle mode but they must be able to change the mode of operation when necessary.

Idle stations with data to transmit get access to the channel using the regular DCF. Whenever a station gets access to the channel, it transmits an RTS targeted to the intended destination of the data packet. This packet initiates a clustering process. Upon the reception of the RTS, the intended destination of the packet becomes master and responds to the RTS with a beacon (B) followed by a poll targeted to the station which transmitted the RTS. A cluster is established and a CFP is initiated inside this cluster. All the idle stations which receive the beacon become slaves and get synchronized to the master at the packet level. Cluster membership is spontaneous and soft-binding: there are no explicit association and disassociation processes and a station belongs to a cluster as long as it can receive the beacons broadcast by the master. As in the PCF, a cluster is broken when the master transmits a CE packet. Upon the reception of this CE packet, all the slaves revert to idle mode and execute a backoff in order to avoid a certain collision if more than one station has data to transmit and initiates the DCF access period. Therefore, according to this operation, the clustering algorithm of DPCF is spontaneous in the sense that the first idle station with data to transmit initiates the clustering algorithm.
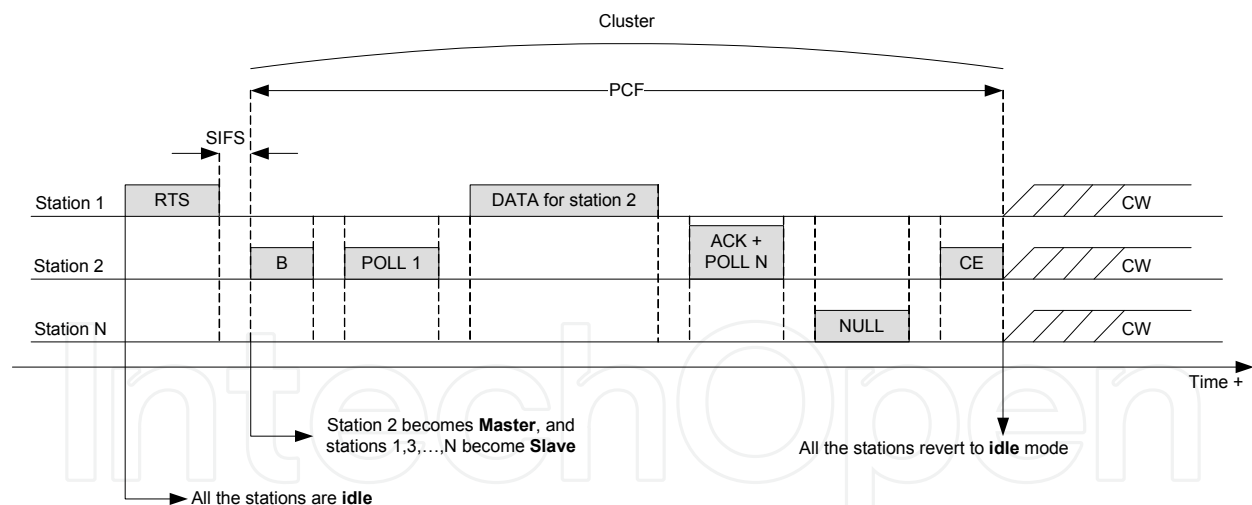

Fig. 5. Example: DPCF Operation

An example of operation is represented in Figure 5. In this example, station 1 has data to transmit to station 2. Once the station 1 successfully seizes the channel executing the rules of the DCF, it transmits an RTS to station 2. Upon the reception of the packet, station 2 becomes master and transmits a beacon. The first poll is then sent to station 1, which has a data packet ready to transmit. Station 1 transmits the data packet to station 2. Then, station 2 acknowledges the reception of the packet and polls station *N* with a combined packet. Since station *N* has no data packets to transmit, it sends a NULL packet. Finally, station 2 transmits the CE packet to indicate the end of the cluster phase. All the slave stations revert

to idle mode and execute a backoff to reduce the probability of collision if more than one station has data to transmit.

Within a cluster, the master can poll the slaves following any arbitrary order. Regardless of the specific polling policy, the master has to have some knowledge of the local neighborhood in order to be able to carry out the polling mechanism. To do so, all the stations overhear the ongoing packet transmissions in their vicinity in order to create a neighbor table with an entry for each station in the local neighborhood. This table should be updated along time. The specific scheduling of the polling mechanism is out of the scope of the basic definition of DPCF. Only as an example, a round robin polling scheme can be executed following the entries of the neighbor table. In any case, once a station is polled by the master, it may transmit a data packet to any other slave (peer-to-peer communication model) without routing all the data through the master. Therefore, the master only acts as an indirect coordinator of the communications, but not necessarily as a concentrator of traffic (as the AP does in a regular centralized network).

The duration of a cluster is variable and depends on the traffic load of the network. An *inactivity mechanism* is considered to avoid the transmission of unnecessary polls when there are no more data packets to be transmitted. This mechanism consists of the following: any master maintains a counter that is incremented by one unit upon each NULL packet received from a polled station with no data to transmit. This counter is reset to zero whenever a station responds to a poll with the transmission of a data packet. If the counter gets to a specified value (tunable), the cluster is broken and a CE packet is sent.

On the contrary, it may happen that under heavy traffic conditions once a station becomes master it operates as such for the whole operation of the network due to the absence of idle periods. This would be unfair in terms of sharing the responsibility of being master in the network among all the stations. Therefore, it is necessary to upper-bound the maximum time that a station can operate as master without interruption. This limit is especially important in infrastructureless networks where fair energy consumption is a must. The approach in DPCF is the following: any master has a *Master Time Out* (MTO) counter which determines the maximum duration of a cluster. The value of the MTO corresponds to the maximum number of beacons (MTO=$N_{beacons}$) that a master can transmit without interrupting the operation of its cluster. The MTO counter is decremented by one unit after each beacon is transmitted. Whenever the MTO counter expires, a CE packet is transmitted and the cluster is broken regardless of the traffic load or activity of the stations. Therefore, the maximum time that a station can operate as master is denoted by T_{MAX} and can be computed as

$$T_{MAX} = N_{beacons} \cdot N_{polls} \cdot MIFS = MTO \cdot N_{polls} \cdot MIFS. \tag{1}$$

N_{polls} denotes the number of polls transmitted between beacons, which can also be tuned, and MIFS is the Maximum Inter Frame Space whose duration corresponds to the *maximum* time between two consecutive polls. The duration of a MIFS can be computed as the time elapsed when:

1. The master station combines an ACK of a recently received data packet with a poll and a data packet.
2. The station polled acknowledges the reception of the data packet from the master and combines the ACK with data for a third station.
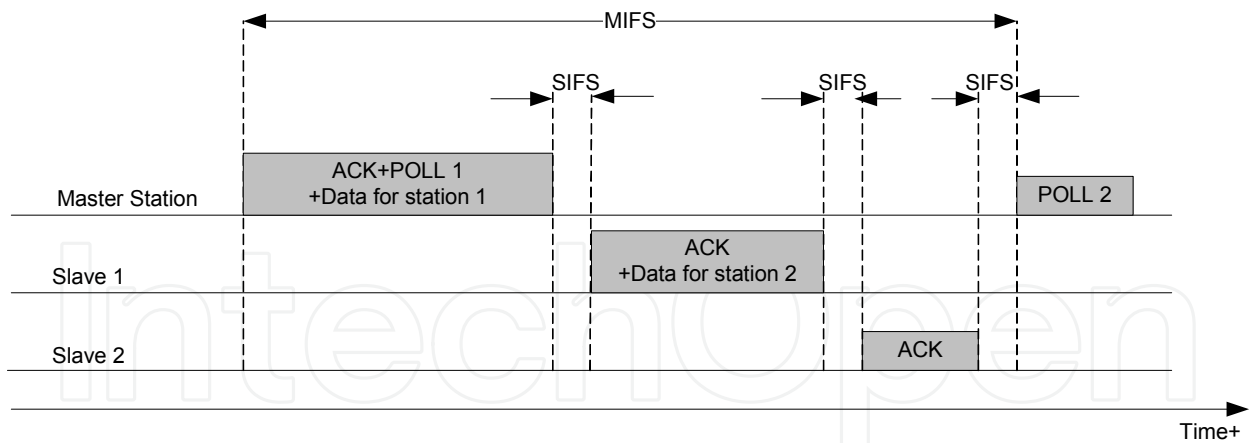3. The third station transmits the ACK of the data packet received from the second station.

Fig. 6. Definition of MIFS

(a) Station becoming master   (b) Station triggering clustering
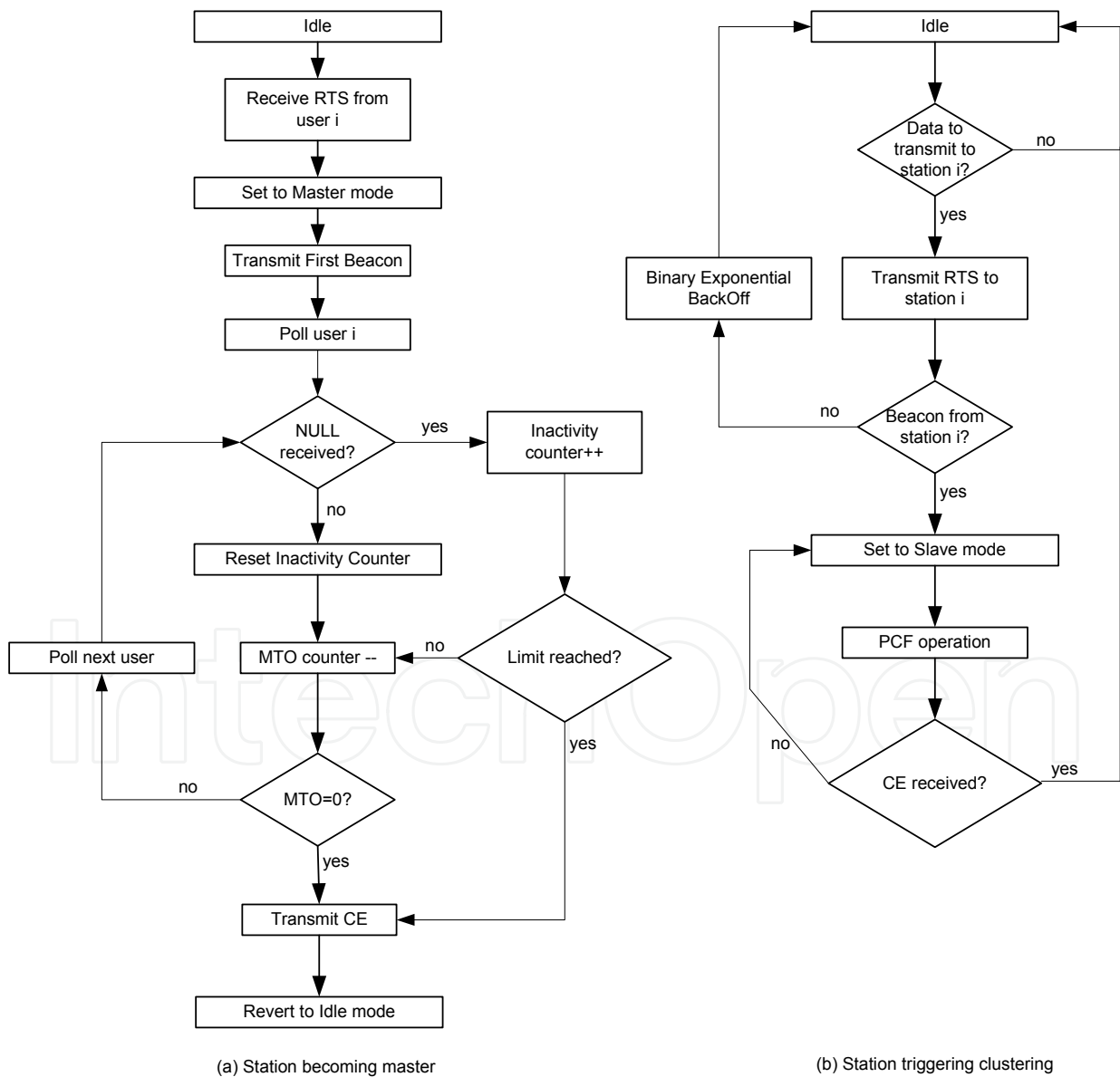
Fig. 7. DPCF Clustering Flowchart

The definition of a MIFS is illustrated in Figure 6. Note that it also corresponds to the minimum period of time that a station has to listen to the channel before establishing a new cluster in order to reduce the probability that another master is present.

In order to summarize the whole operation of DPCF, a general flowchart is shown in Figure 7. The left branch of the chart models the operation of any station becoming master when requested by any other stations and the right branch of the chart represents the operation of the station initiating the clustering algorithm when it has data to transmit.

4. Performance evaluation

In order to evaluate the performance of DPCF, we have implemented the protocol rules in a custom-made C++ link-level simulator. The simulator works in an object-oriented basis and the source code of each station runs in parallel. The implemented code could be directly integrated in a wireless card to execute the protocol rules. The main motivations for implementing the protocol in a custom-made C++ simulator rather than in any other well known system simulation platform (such as ns-2, for example) are:

1. The faster execution of the simulations.
2. The possibility of isolating the MAC protocol performance from the rest of the network.
3. The possibility to implement the protocol in a hardware testbed.

The system parameters have been set according to the PHY layer of the IEEE 802.11g Standard [1] and they are summarized in Table 1.

Parameter	Value	Parameter	Value
Data Packet Length (MPDU)	1500 bytes	Constant Message Length	1500 bytes
Data Tx. Rate	54 Mbps	Control Tx. Rate	6 Mbps
MAC header	34 bytes	PHY preamble	96 μs
SIFS, PIFS, DIFS	10, 30, 50 μs	SlotTime (σ)	10 μs
RTS, BEACON, CF_END and POLL packets	20 bytes	CTS and ACK packets	14 bytes
CW_{min}	16	CW_{max}	256
MTO	3	Polls per beacon	19

Table 1. System Parameters for Evaluation of DPCF

4.1 Single-hop networks

We first consider the case of a single-hop network composed of 20 stations, all of them within the transmission range of each other. All the stations generate data packets of fixed-length following a Poisson arrival distribution and they contribute equally (homogeneously) to the total aggregate data traffic of the network. The destination of each packet is randomly selected among all the stations of the network with equal probability. In order to focus on the MAC layer, all the packets are assumed to be received without errors and thus the results herein presented correspond to an upper-bound of the performance of the protocol.

It is also assumed that an ideal round robin scheduling is performed to poll all the stations once a cluster is established. Three different networks have been studied (they all have been implemented in the simulator):

1. **DCF:** a network wherein all the stations only execute the DCF with the collision avoidance access method.
2. **PCF:** a network wherein an AP manages the access to the channel. However, stations transmit directly to the intended destination without routing traffic through the AP. In this network, we consider that the AP also has data to transmit as any other regular station.
3. **DPCF:** a network wherein all the stations execute the proposed DPCF protocol.

According to the parameters presented in Table 1, the number of polls between beacons has been set to 19 and it indicates that all the slaves within a cluster are polled exactly once by the master between the transmission of two consecutive beacons. In addition, the setting MTO=3 indicates that all the slaves are polled at most three times when a cluster is established unless the inactivity mechanism is triggered by the master.
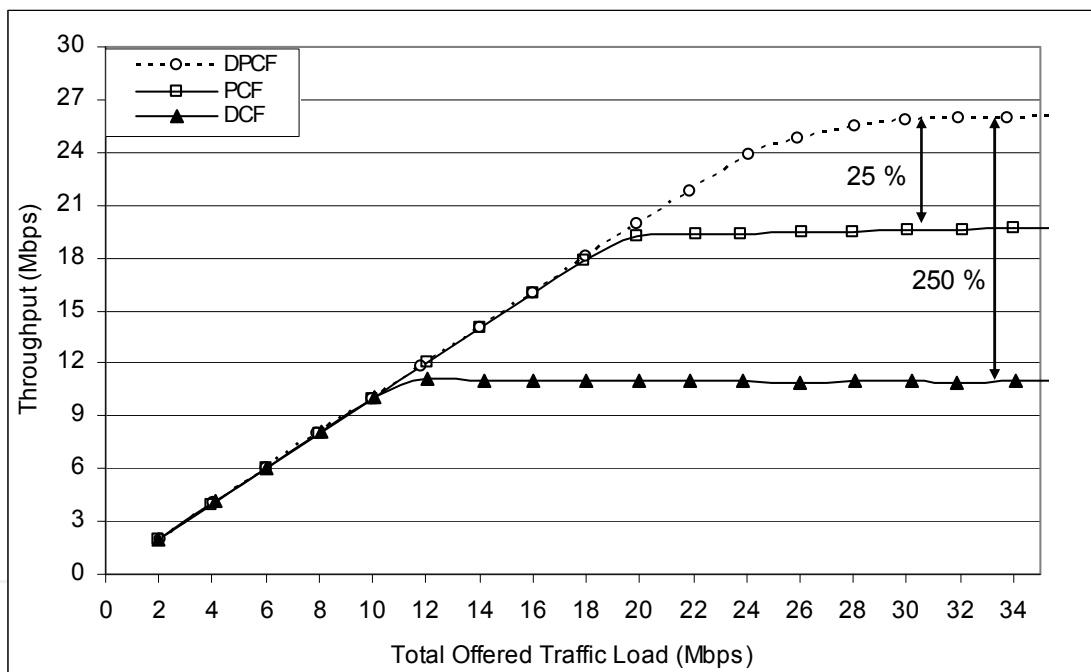

Fig. 8. Throughput Comparison DPCF, PCF, and DCF in a Single-hop Network

The throughput of the three different networks is plotted in Figure 8 as a function of the total aggregate offered load to the network. As expected, the three curves grow linearly until they reach the saturation throughput. The three protocols are stable for heavy traffic conditions without entering in congestion and thus they can operate under sporadic situations of peak high traffic loads without collapsing the network. The saturation throughput of DPCF is remarkably higher than that of DCF, achieving an improvement of approximately 250%. Collisions and backoff periods are reduced in the DPCF network compared to the DCF network, thus yielding higher performance. In addition, the performance of DPCF is even superior to the regular PCF, attaining 25% higher saturation throughput.
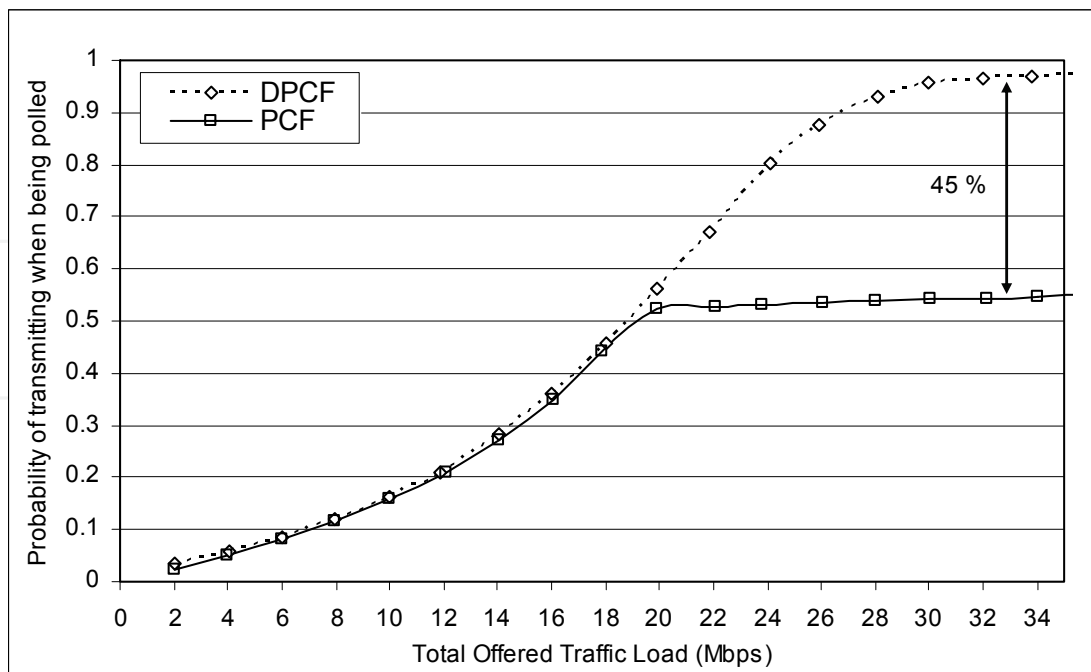
Fig. 9. Probability of Transmitting when Being Polled in a Single-hop Network

In order to further analyze this apparently counter-intuitive result, Figure 9 shows the probability that a station transmits a data packet when it is polled. It has been considered for this calculation that the AP (in the PCF network) and the masters (in the DPCF network) are *virtually* polled every time they poll a station as they have the possibility to combine the polls with data and ACK packets. The probability of transmitting data when being polled is quite similar in the two networks for low traffic loads. However, this probability is much higher in the DPCF network than in the PCF network for high traffic loads. While the efficiency of the polling in DPCF gets close to 98% for high traffic loads, it remains close to 55% in the PCF network. This efficiency translates directly into a higher efficiency of DPCF, since the ratio of data packets transmitted per control overhead is higher. The reason for these figures is that there is a severe unbalance between the channel access opportunities between the AP and the regular stations in the PCF network. This can be seen in Figure 10, where we plot again the probability of actually transmitting when being polled. Now, two different curves for the PCF network are represented corresponding to the average probability among of all the regular stations and to the probability for the AP alone, separately. The AP has a channel access opportunity every time it polls another station, but most of these transmission opportunities are not used for the actual transmission of data (note that the probability of transmitting when being polled is below 10% in all cases for the AP), decreasing the overall efficiency of the polling mechanism.

This unbalance between the AP and the stations is avoided in DPCF by sharing the responsibility of being master among all the stations of the network. It is well known that the DCF is fair in the long-term, and so is the clustering algorithm of DPCF. Since all the stations of the network get the role of master periodically, the unbalanced access of the AP in the PCF network is shared in the DPCF network. Every time a station is set to master it can transmit all its backlogged data packets and thus take advantage of the prioritized access to empty its data buffers while operating as master. Indeed, the fact that a station

operating in master mode has more channel access opportunities than a slave station can be seen as an implicit mechanism to provide with some incentive to stations to become master despite the extra actions they must carry out and the corresponding increase in energy consumption.
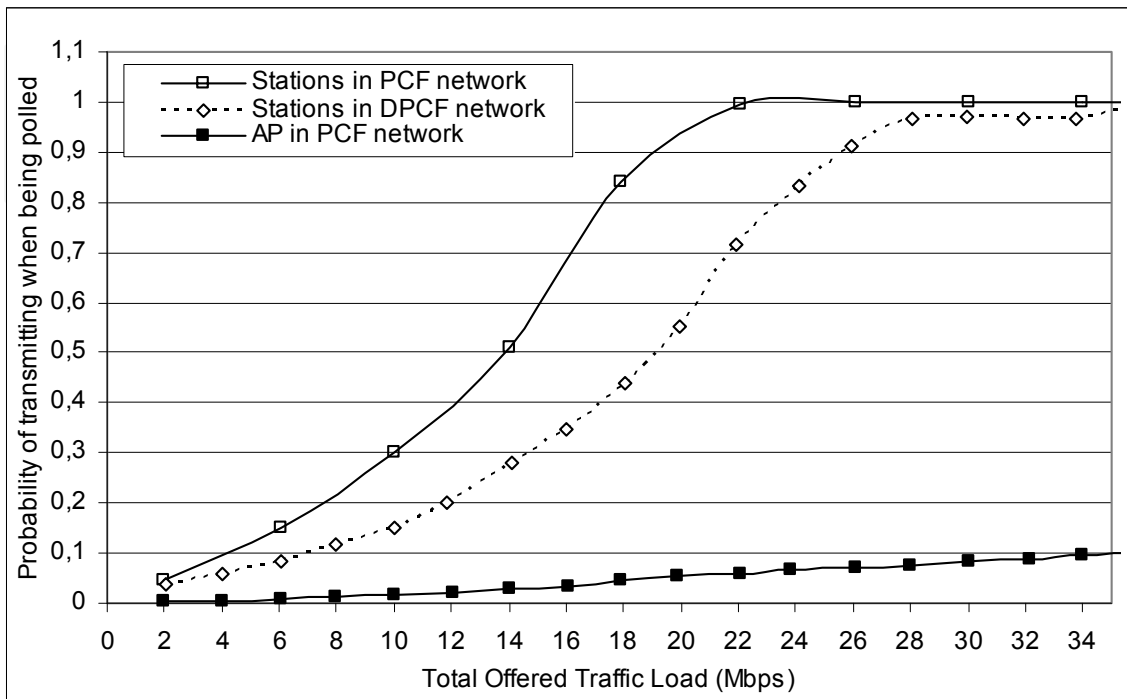

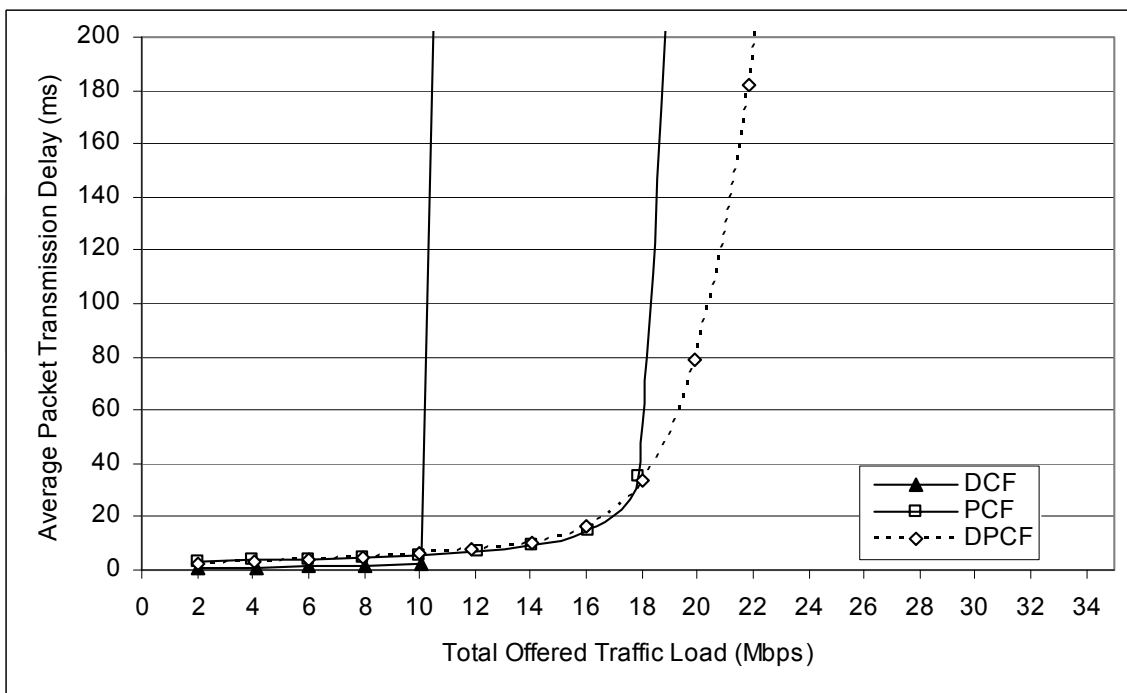Fig. 10. Probability of Transmitting when Being Polled in a Single-hop Network

Fig. 11. Average Packet Transmission Delay in a Single-hop Network

The performance in terms of average packet transmission delay is plotted in Figure 11. We define this delay as the average time elapsed since a packet arrives at the MAC layer until it is successfully acknowledged by the intended destination. It is worth seeing that for low offered loads, the best performance is attained in the DCF network. This is an expected result since every time a station has data to transmit it can successfully seize the channel immediately without needing to wait for being polled (the probability of finding the channel busy and the probability of collision are low due to the low offered traffic load). However, as the offered load grows, the average packet transmission delay in the DCF network grows sharply for traffic loads over 10 Mbps. On the other hand, the DPCF attains average delays below 200 ms for traffic loads up to 22 Mbps, increasing the throughput of the standard DCF network and attaining superior performance than the PCF. These results confirm the idea that PCF-like mechanisms are worthy when the traffic load and the number of transmitting stations are relatively high.

4.2 Multi-hop networks

We now consider a multi-hop network. Without loss of generality and as a representative example, we consider a tandem network formed by 5 static stations set in line and equally spaced as the one represented in Figure 12. The distance between the stations, the transmission powers, and the channel propagation parameters have been adjusted so that:
1. Every station can transmit directly to immediate neighbors at one-hop distance.
2. Every station at two hops of a transmitting station can sense the channel busy, but cannot decode the transmitted information.
3. Every station at three hops of a transmitting station is oblivious to the transmission.
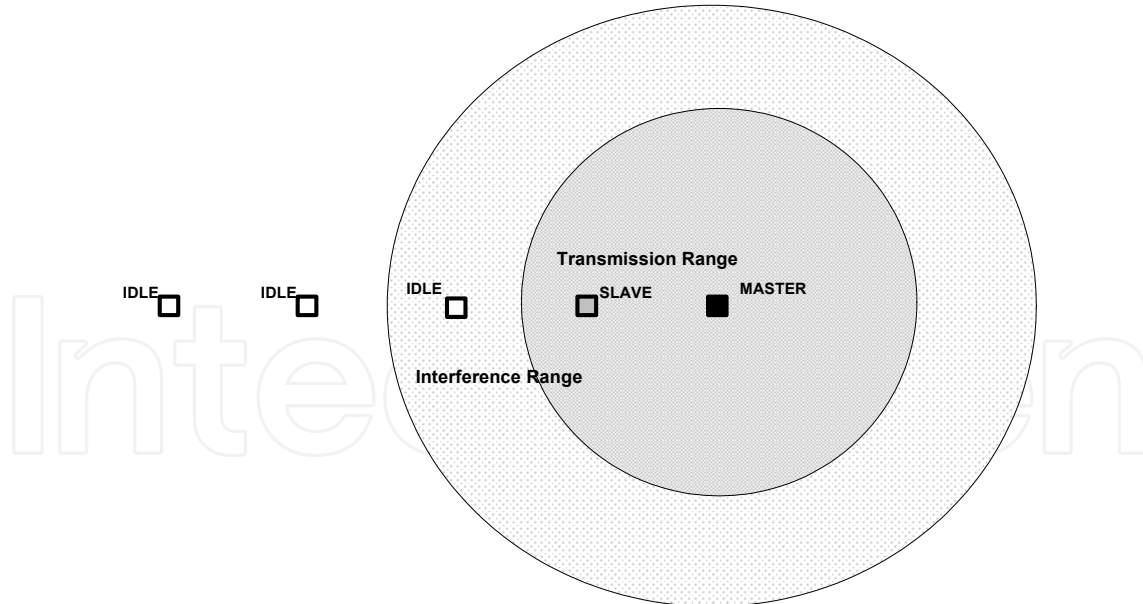

Fig. 12. Tandem Multi-hop Network

A collision occurs if two simultaneous transmissions are received within either the transmission or the interference range of the transmitters. We assume that all the stations have perfect routing information and thus route the packets through the station in its transmission range that is closer to the intended destination. The rest of the parameters have been set as in the previous section for the single-hop evaluation.
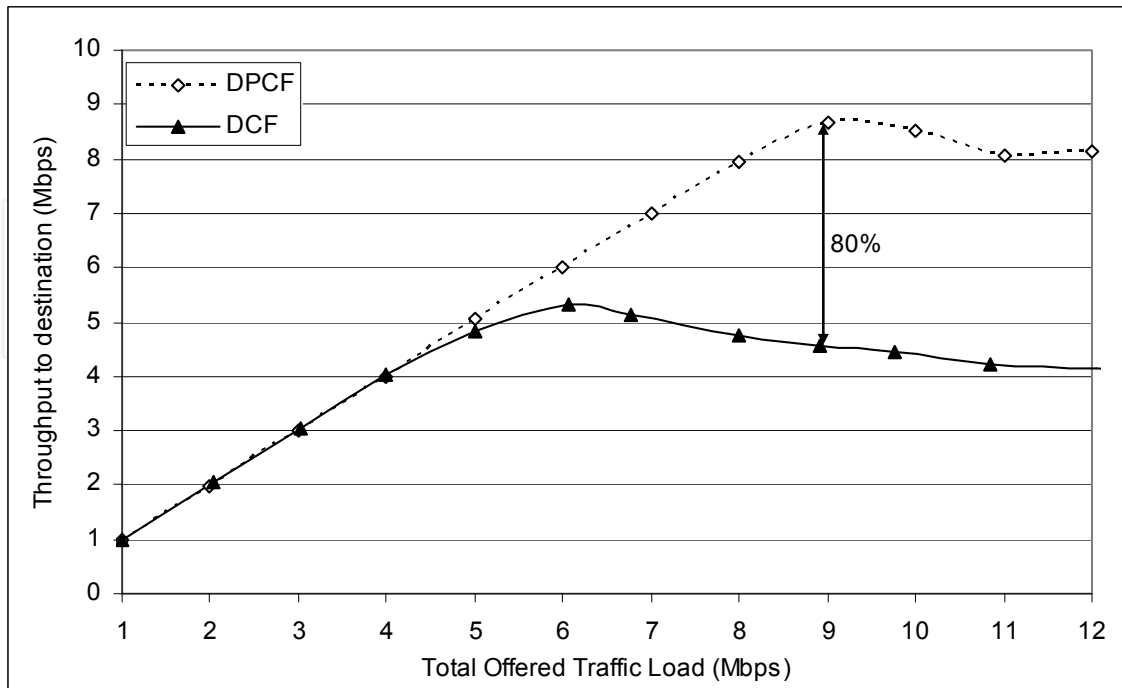
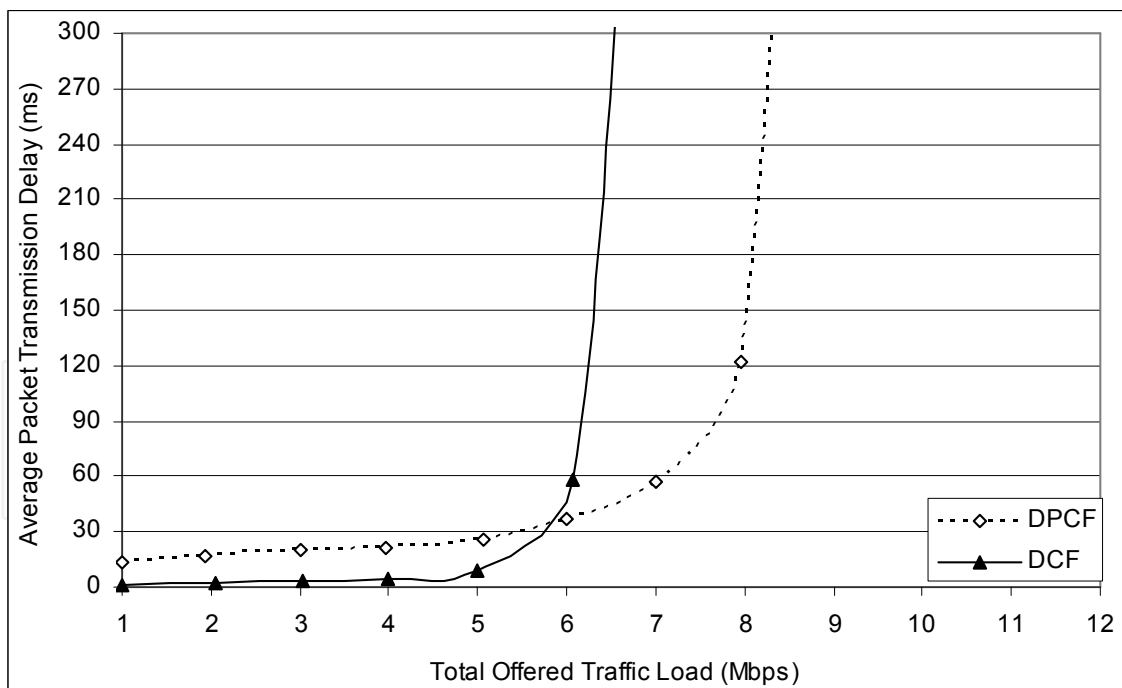Fig. 13. Throughput to Destination of DPCF in a Multi-hop Network

Fig. 14. Average Packet Transmission Delay of DPCF in a Multi-hop Network

The total throughput delivered to destination is plotted in Figure 13 as a function of the total offered load to the network. Note that the traffic delivered to the intermediate stations in a multi-hop route is not accounted for this calculation. The curves show that DPCF outperforms DCF for all traffic loads. Indeed, for low traffic loads both protocols behave

almost identically delivering all the data traffic offered to the network. However, while DCF saturates around 5 Mbps, DPCF is capable of delivering up to 9 Mbps (80% higher saturation throughput), almost doubling up the capacity of the legacy DCF. Comparing these results to the ones obtained for the single-hop case, it is possible to see that the total offered load that can be conveyed in the multi-hop network is considerably lower. This is mainly due to the fact that in the multi-hop environment some packets need to travel along several hops to get to the final destination.

The average packet transmission delay is plotted in Figure 14 for both the DPCF and the DCF networks. In this case, this measure is defined as the average time elapsed from the moment a packet arrives at the MAC layer of the source station until it is successfully delivered to the final destination (end-to-end time). The curves show that the DCF attains lower average packet transmission delay for low traffic loads. Two are the main reasons for this lower average delay. First, the longer MIFS of DPCF (compared to the DIFS of DCF) adds latency to all the transmissions, increasing the average packet transmission delay in the DPCF network for low traffic loads. In addition, in the DPCF network, slaves cannot transmit immediately whenever they have data to transmit but they have to wait to be polled by a master, increasing thus the average access delay. However, note that the average delay is lower than 300 ms for loads up to 8 Mbps in the DPCF network and it gets unbounded in the DCF network for traffic loads over 6 Mbps. Therefore, the DPCF protocol attains better performance when the traffic load of the network is higher, attaining up to 25% better performance than the DCF in this multi-hop setting.

5. Conclusions

We have presented in this chapter a simple mechanism to improve the performance of the 802.11 Standard under heavy loaded conditions. These conditions appear in some vehicular scenarios, such as in traffic-light crossings, where vehicles and pedestrians meet together and a number of safety applications may arise.

The key idea consists in combining both distributed and point coordinated access methods to manage the access of the users to the wireless channel. The specific approach has been based on an extension of the PCF of the IEEE 802.11 Standard to operate over distributed wireless ad hoc networks without infrastructure. The main idea of DPCF is that the stations of the network get access to the channel by executing the rules of the DCF. Any station which seizes the channel transmits its data and also establishes a temporary dynamic cluster to manage the pending transmissions of all the neighbors with data ready to be transmitted. The key of this mechanism is that there is no cluster head selection, but clusters are created in a spontaneous manner. This reduces the control overhead to establish a fixed clustering architecture and increases the capability of the network to dynamically adapt to the unpredictable nature of ad hoc networks. Comprehensive performance evaluation of the protocol through link-level computer simulation shows that the new proposal improves the performance of ad hoc networks when compared to current standards.

The results presented in this chapter are rather promising and, in fact, future work will be aimed at theoretically evaluating and optimizing the design of DPCF and at implementing the protocol in a testbed to evaluate its actual performance in a real environment. Ongoing work is being carried out to evaluate the coexistence feasibility of this new approach with legacy implemented networks based on the 802.11.

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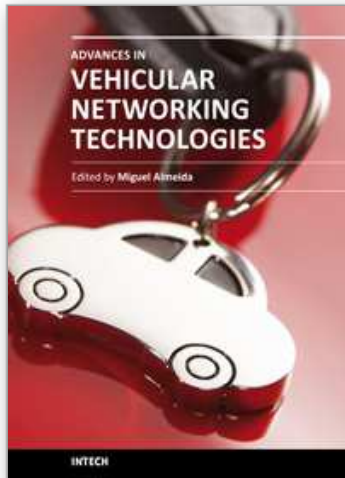
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