EBA: An Enhancement of the IEEE 802.11 DCF via Distributed Reservation

Jaehyuk Choi, Joon Yoo, Sunghyun Choi, *Member*, *IEEE*, and Chongkwon Kim, *Member*, *IEEE*

Presented By Yu Chu Chang

95/06/22

Outline

- INTRODUCTION
- EARLY BACKOFF ANNOUNCEMENT (EBA)
- PERFORMANCE EVALUATION
- CONCLUSION

Introduction

- The IEEE 802.11 standard specifies two Medium Access Control (MAC) schemes

  - Distributed Coordination Function (DCF)
  - Point Coordination Function (PCF)

- DCF

  - carrier sense multiple access with collision avoidance (CSMA/CA)

IEEE 802.11 Distributed Coordination Function (DCF)

Fig. 1. Basic access mechanism in DCF.

Introduction

- While the random backoff can reduce the collision probability, it cannot completely eliminate the collisions since two or more stations can finish their backoff procedures simultaneously

- This exponential backoff results in a channel idling such that the channel is not efficiently utilized.

Introduction

- This paper proposes a novel distributed reservation-based MAC protocol by enhancing the legacy 802.11 DCF is called Early Backoff Announcement (EBA).

Early Backoff Announcement (EBA)

- By adding their backoff value information into the **MAC header** of each transmitted data frame.

- Stations exchange their future backoff duration information and save this information into their **Reservation Windows**

  - use it to completely eliminate collisions.
  - Backward compatibility with the legacy 802.11 DCF.

IEEE 802.11 versus EBA.
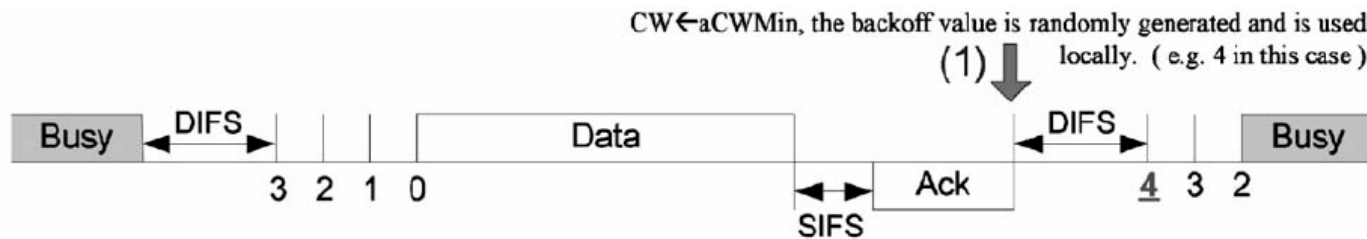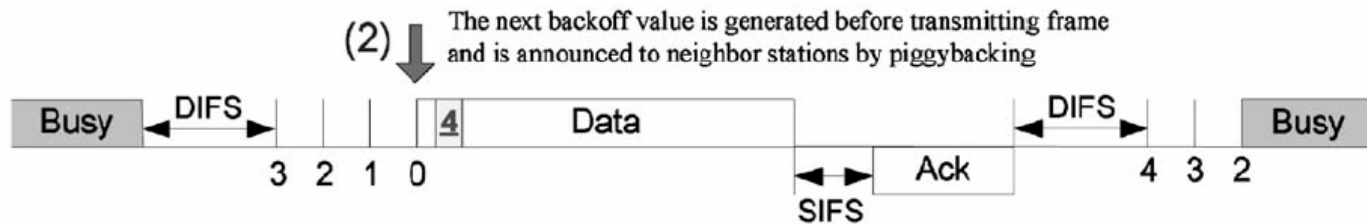
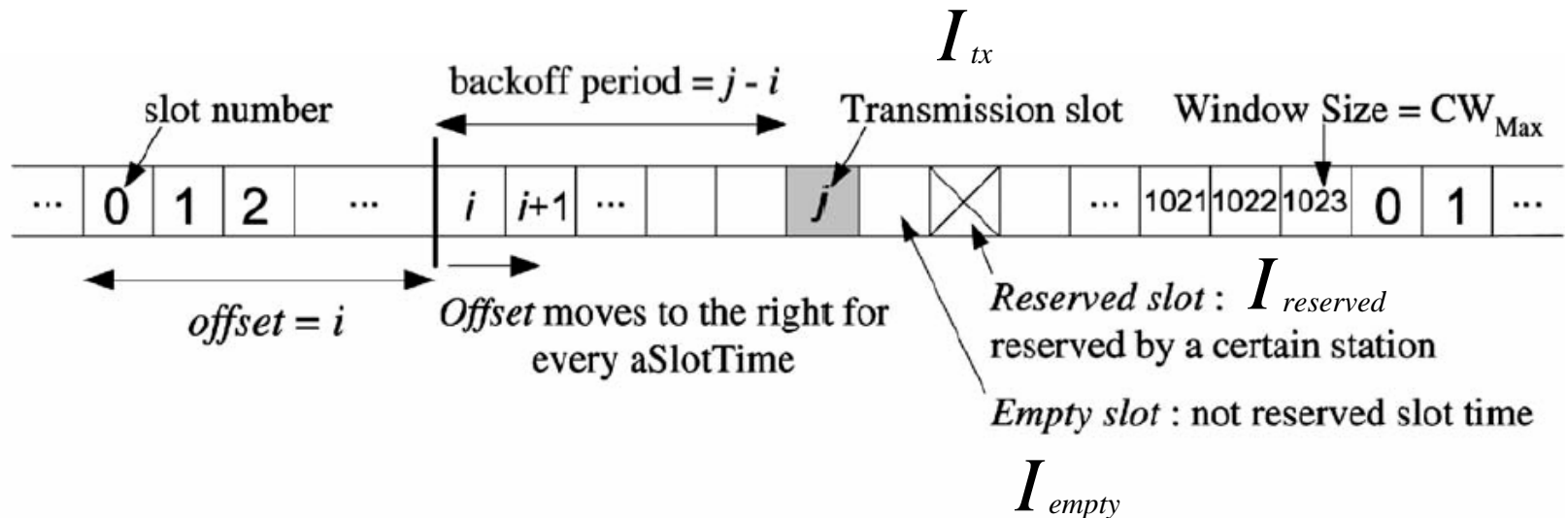Fig. 2. (a) IEEE 802.11 versus (b) EBA.

EBA Reservation Window

Fig. 3. EBA Reservation Window.

The Reservation Window is used to maintain the channel reservation state of the other stations and itself.
The offset specifies the current slot and it moves to the right for every aSlotTime during a backoff procedure.

EBA Reservation Window

- The Reservation Window maintains the following three per-slot variables:
  - I_{empty} is the initial state that does not have any reservation information on the slot.
  - $I_{reserved}$ denotes that the slot is already reserved by another station
  - I_{tx} is the transmission slot determined by the backoff period selected by the station itself

$$I_{tx} - slot's \text{ Number} = (\text{offset} + \text{backoff}) \mod CW_{max}$$

EBA Algorithms

- EBA-1
  - Minor modification of the IEEE 802.11 DCF
  - Backward compatible with the legacy DCF
- EBA-2
  - Modified version of EBA-1
  - Higher throughput than EBA-1 and DCF
  - Backward compatible with EBA-1

EBA-1

- The EBA-1 station *selects only non-reserved backoff period* using its own Reservation Window. i.e. I_{empty} Slot

- After selecting the next backoff period b_{next}, the station *piggybacks it into the transmitted frame header* (EBA field) and b_{next} *set the (offset +)th slot in the Reservation Window to* I_{tx}
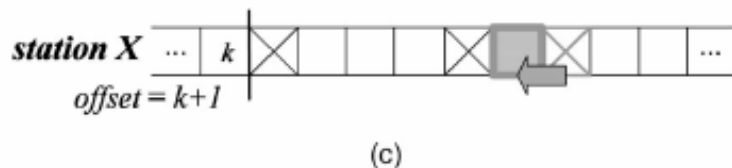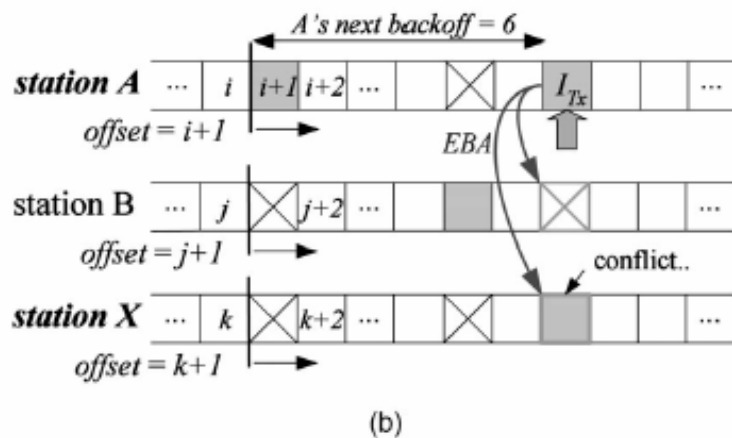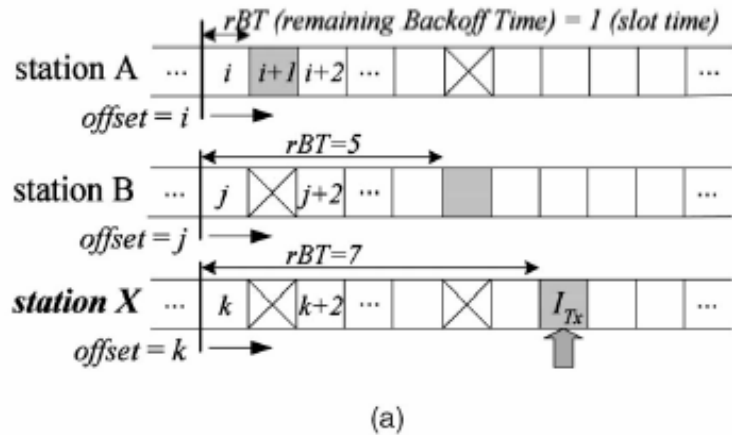
EBA: Additional Collision Avoidance Operations

- However, the reserving station may not have a frame for the reservation, i.e., $TxQ_{busy,idle}$ station. the access procedure is the same as that in DCF.

- Non reserved Transmission of $TxQ_{idle,busy}$

- Newly Arriving Station

Non reserved Transmission of $TxQ_{idle,busy}$

(a)

(b)

(c)

Collision avoidance mechanism for nonreserved transmission of $TxQ_{idle,busy}$ station X. (a) Station X selects 7 as the next backoff value for a newly transmitting frame and performs the backoff procedure. (Other stations do not know this fact because this is locally executed in station X). (b) After one slot time, a station A starts transmission and reserved the channel announcing 6 as the next backoff using EBA. (c) A station X recognizes the conflict and selects neighbor empty-slot to prevent collision.

Newly Arriving Station.

Collision avoidance mechanism for a newly arriving station. (a) The newly arriving station Y selects 1 as its backoff value for its transmission. (Other stations do not know this information.) (b) After one slot time, station Y starts tranmission and reserves the channel by announcing 6 as the next backoff using EBA. (c) Station B recognizes the conflict and selects neighbor empty-slot to prevent collision. Station A also recognizes other station's conflict and sets its neighbor empty slot to $I_{reserved-slot}$

Estimate the Number of Contending Stations

- The initial backoff value is still selected from the range of $[0, CW_{min}]$ CW_{min} is defined to be 31.

    - Thus, the idle period increases and *the channel resources are wasted* when there are a few stations.

    - On the other hand, the CW_{min} value of 31 can result in *frequent collisions* when there are a lot of competing stations.

Estimate the Number of Contending Stations

- By means of ***adjusting the CW value depending upon the number of competing stations***, the channel idle time as well as the number of collisions can be further decreased.

- EBA-2 is developed by implementing this idea.

Estimate the Number of Contending Stations

- Under EBA, the number of competing stations can be estimated easily by counting the number of reserved slots in the Reservation Window.

EBA-2

- EBA-2 sets the ***CW value adaptively***.

- Before randomly selecting a backoff value, EBA-2 counts the number of reservation slots, n, in its Reservation Window, and then **_sets the CW value to 2n_**.

- $C_{min,EBA-2}$ is 7.

Reservation Window Synchronization

- It is very important to synchronize the offset of Reservation Window with other stations.

- Only active stations move its offset, while idle stations do not move their offset.

- To resolve a synchronization problem, EBA attaches not only its future backoff value b_{next}, but also ___its current offset value i in the MAC header as the reservation information___.

EBA Frame Structure
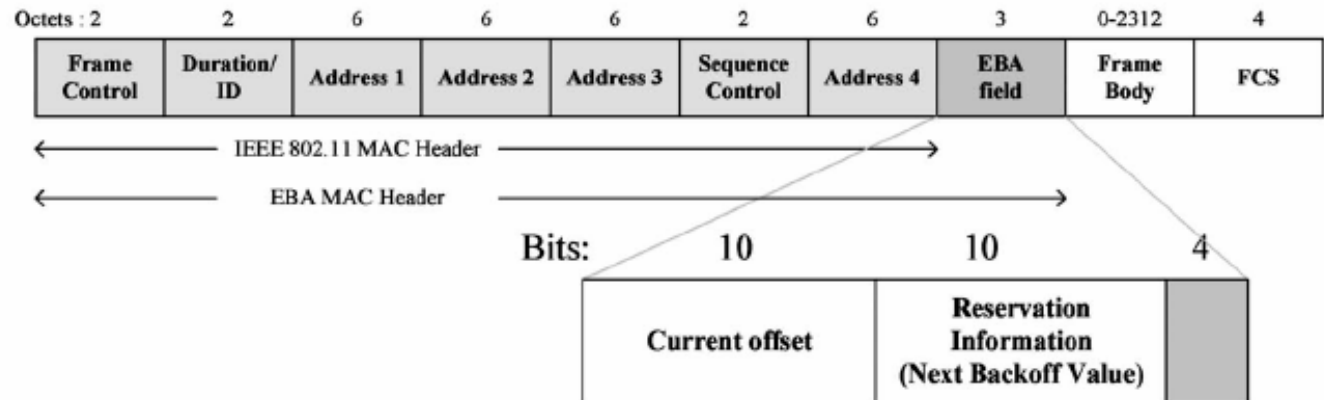
Fig. 7. EBA frame structure.

Performance Evaluation

- This paper has performed simulations for the following three different scenarios in order to simulate the WLAN environments:

  - Scenario 1: All nodes can hear to each other without channel errors.

  - Scenario 2: All nodes can hear to each other with channel errors.

  - Scenario 3: Hidden terminals exist.

PERFORMANCE EVALUATION

TABLE 1
Simulation Parameters for MAC and 802.11b PHY Layers

Parameter	Value
SIFS	10 μsec
DIFS	50 μsec
aSlotTime	20 μsec
aPreambleLength	144 μsec
aPLCPHeaderLength	48 μsec
Data transmission rate	11 Mbps
ACK transmission rate	2 Mbps

Performance Evaluation
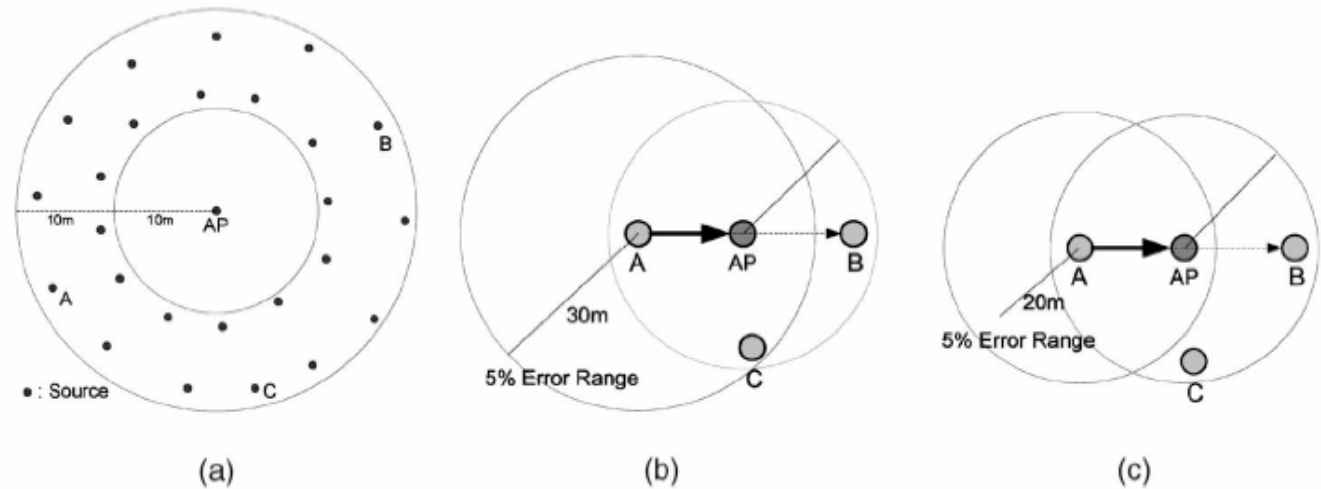
Fig. 8. Simulated network topologies: (a) Scenarios 1 and 2, (b) Scenario 2-1, and (c) Scenario 2-2.

Throughput performance: DCF versus EBA; no channel error
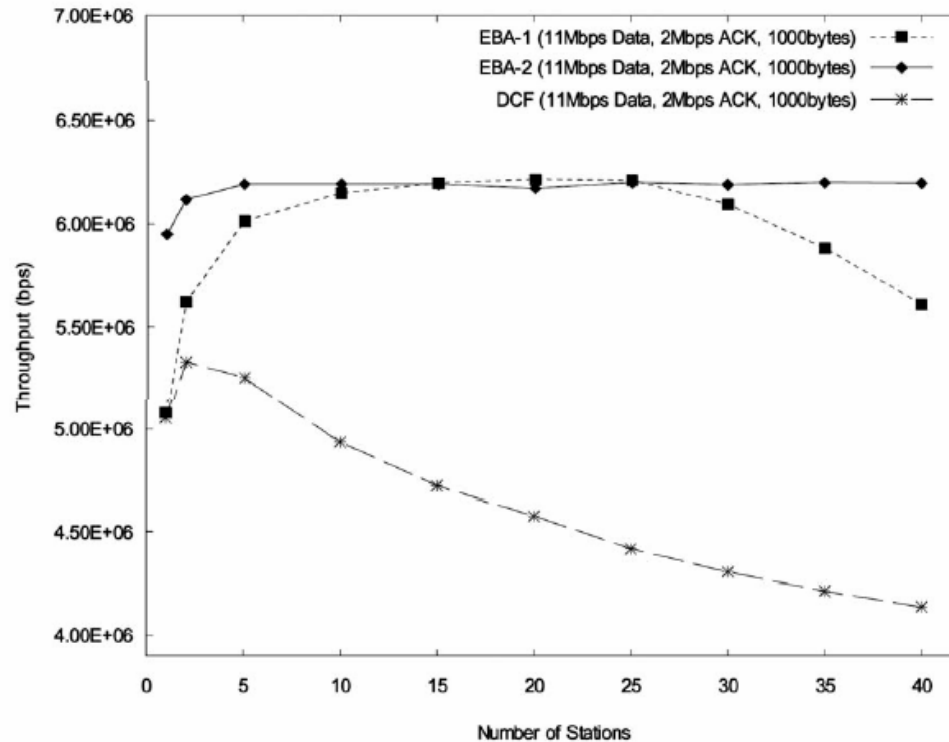
Fig. 9. Throughput performance: DCF versus EBA; no channel error.

Throughput DCF versus EBA: channel error 5 percent at 30m
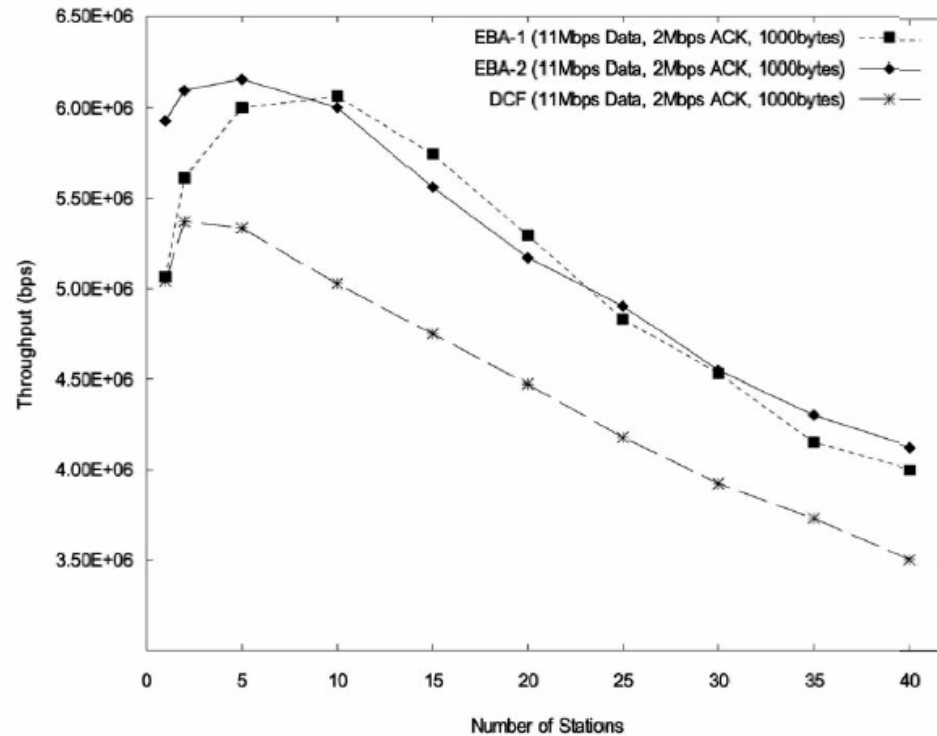
Fig. 10. Throughput DCF versus EBA: channel error 5 percent at 30m.

Throughput DCF versus EBA: channel error 5 percent at 20m
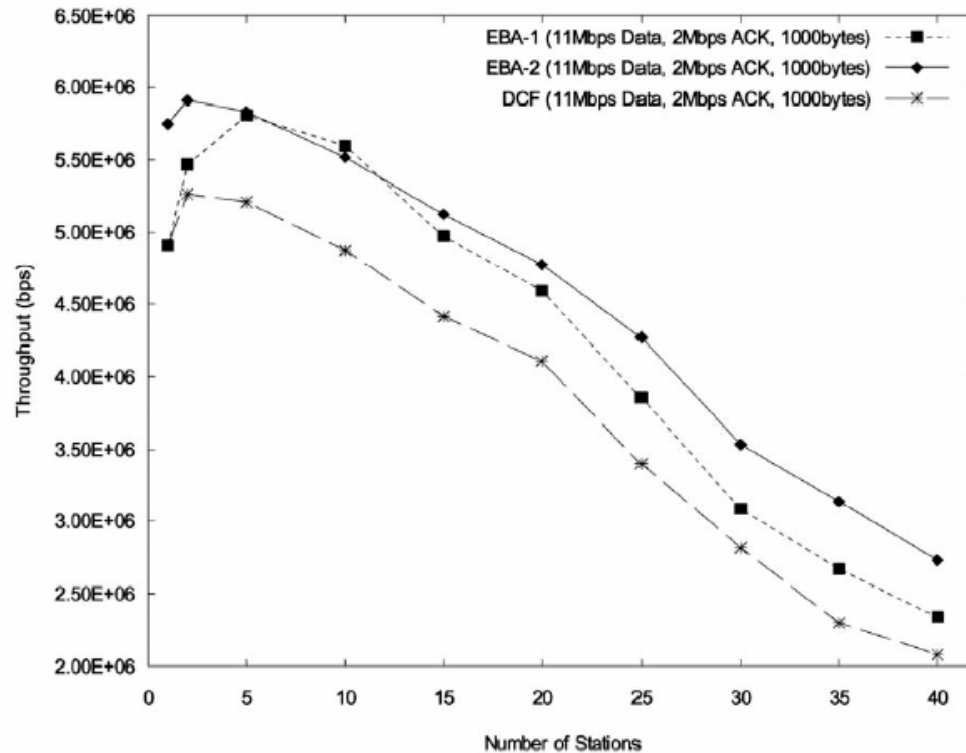
Fig. 11. Throughput DCF versus EBA: channel error 5 percent at 20m.

Simulation network topologies of Scenario 3—hidden terminal
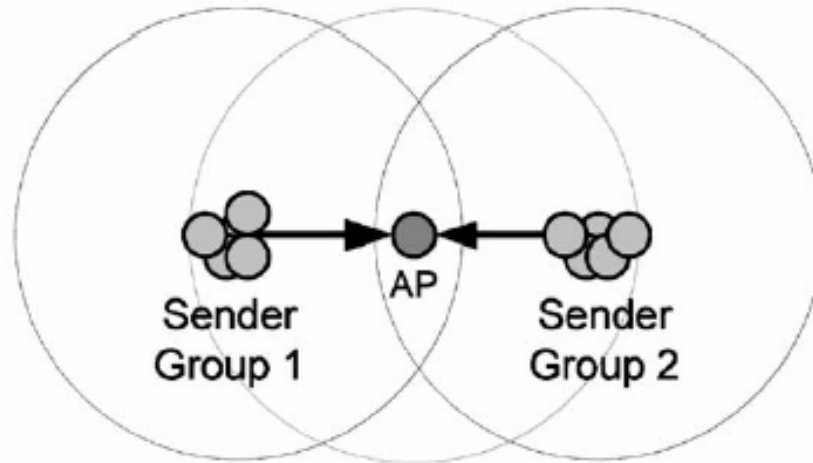
Fig. 12. Simulation network topologies of Scenario 3—hidden terminal.

Throughput DCF versus EBA: Hidden terminal with RTS/CTS
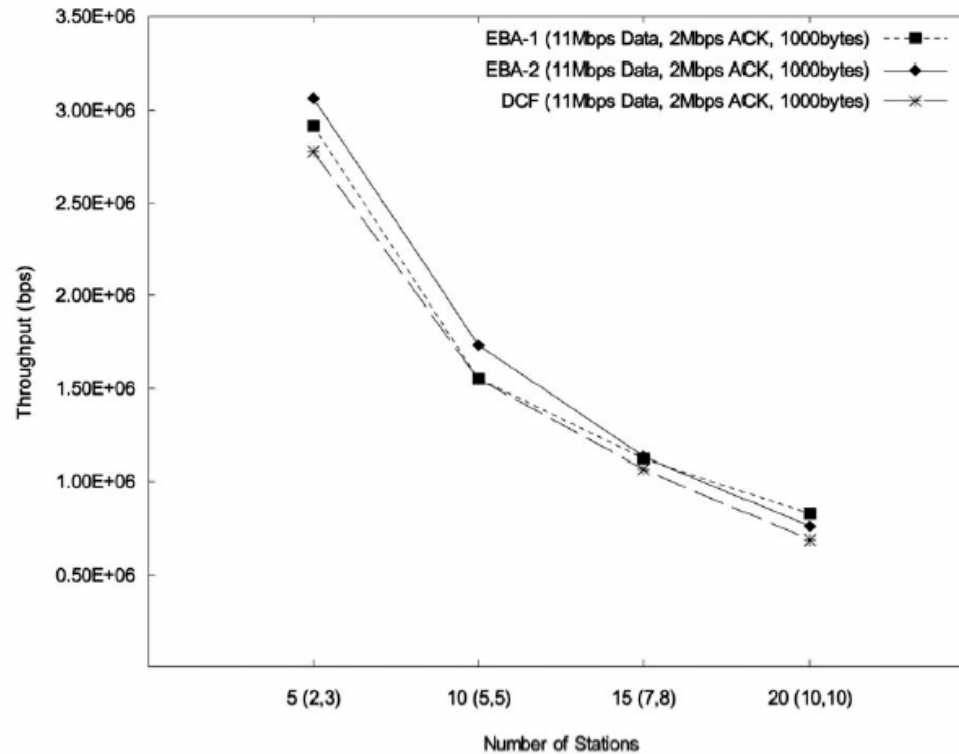
Fig. 13. Throughput DCF versus EBA: Hidden terminal with RTS/CTS.

Throughput DCF versus EBA: Hidden terminal with RTS/CTS
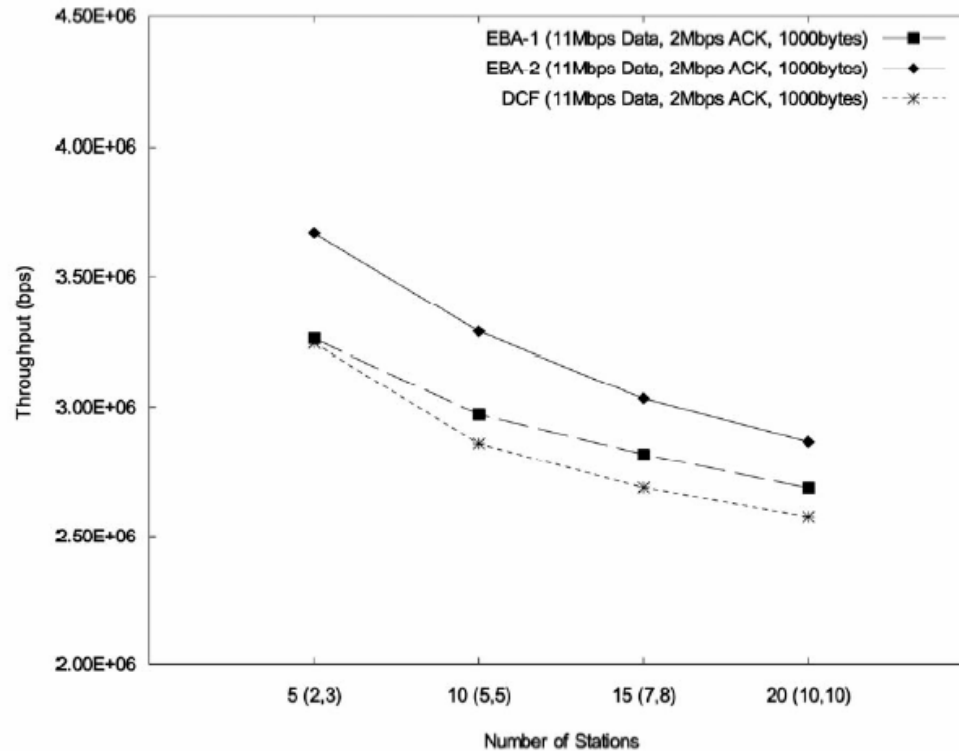
Fig. 14. Throughput DCF versus EBA: Hidden terminal with RTS/CTS.

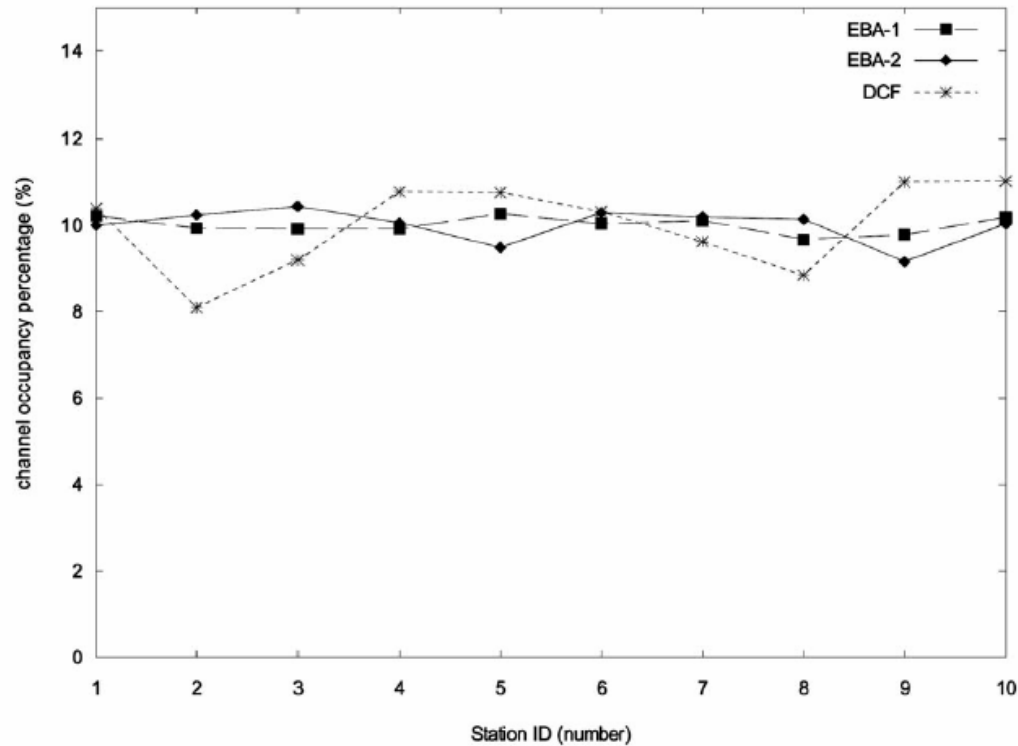# Channel occupancy of DCF, EBA-1, and EBA-2

Fig. 15. Channel occupancy of DCF, EBA-1, and EBA-2.
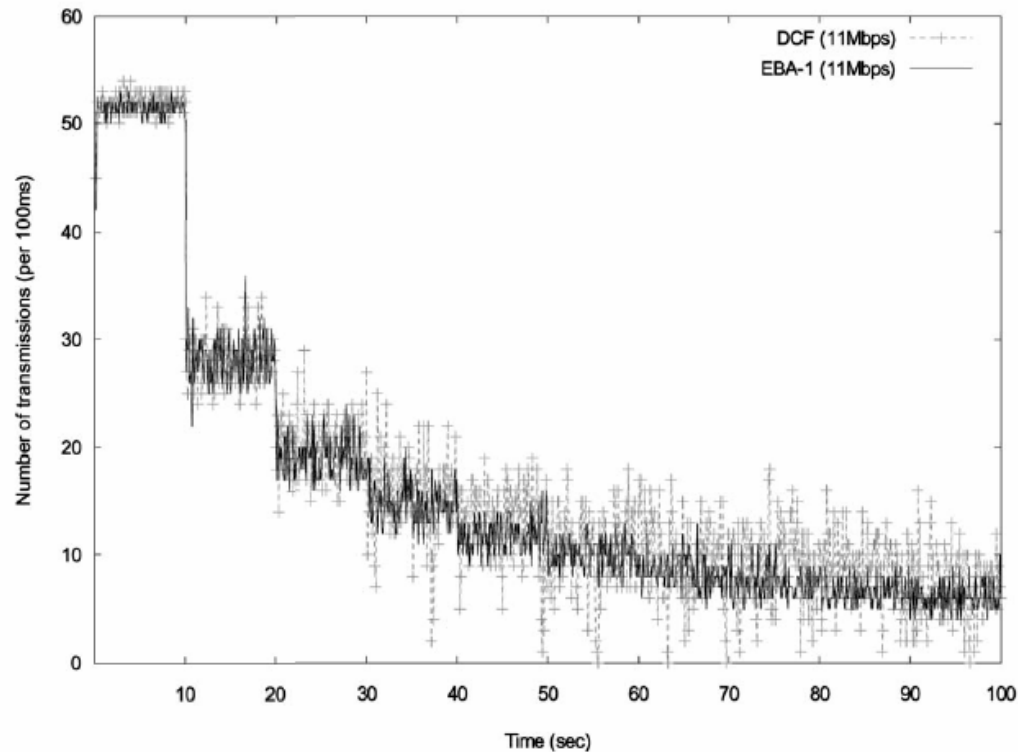
Short-term throughput of station 1

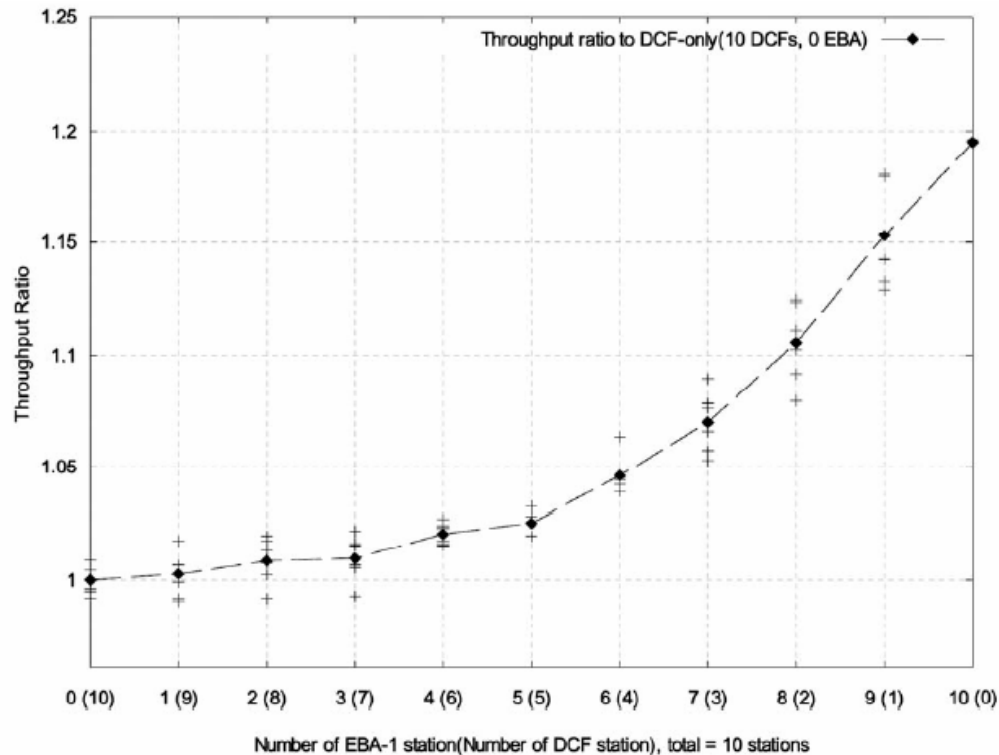Fig. 16. Short-term throughput of station 1.
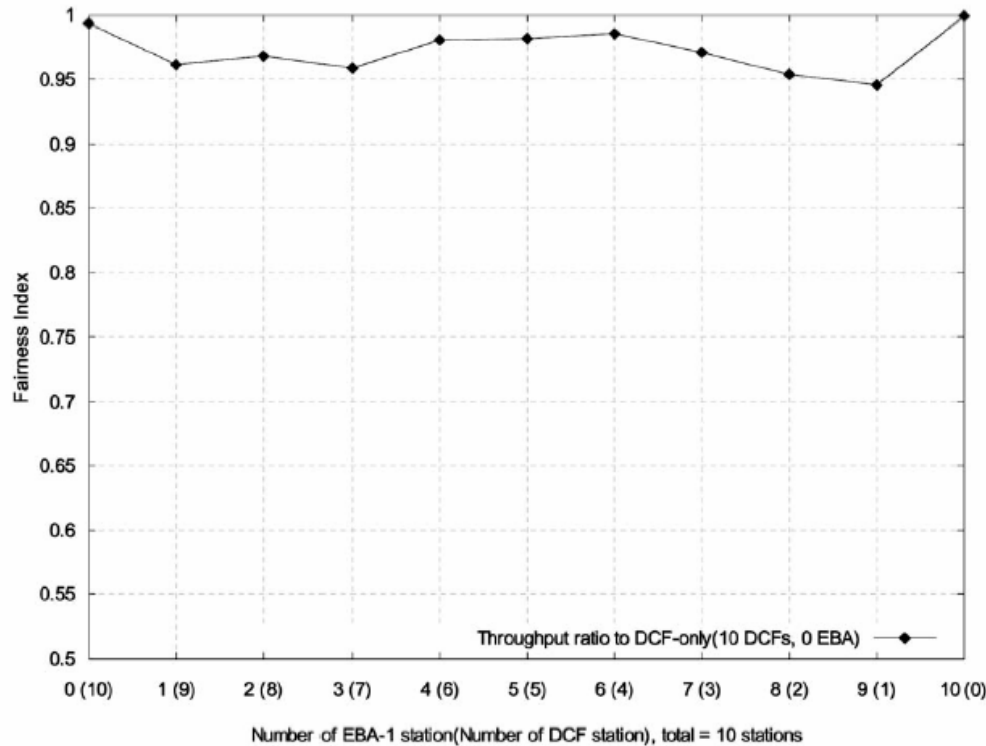
EBA-1's compatibility with DCF.

Fig. 17. EBA-1's compatibility with DCF.

Fairness index for 120 sec. simulation (DCF-EBA1 coexist)

$$\text{Fairness Index} = \frac{\left(\sum_i T_i/\phi_i\right)^2}{n \sum_i (T_i/\phi_i)^2}$$

Fig. 18. Fairness index for 120 sec. simulation (DCF-EBA1 coexist).

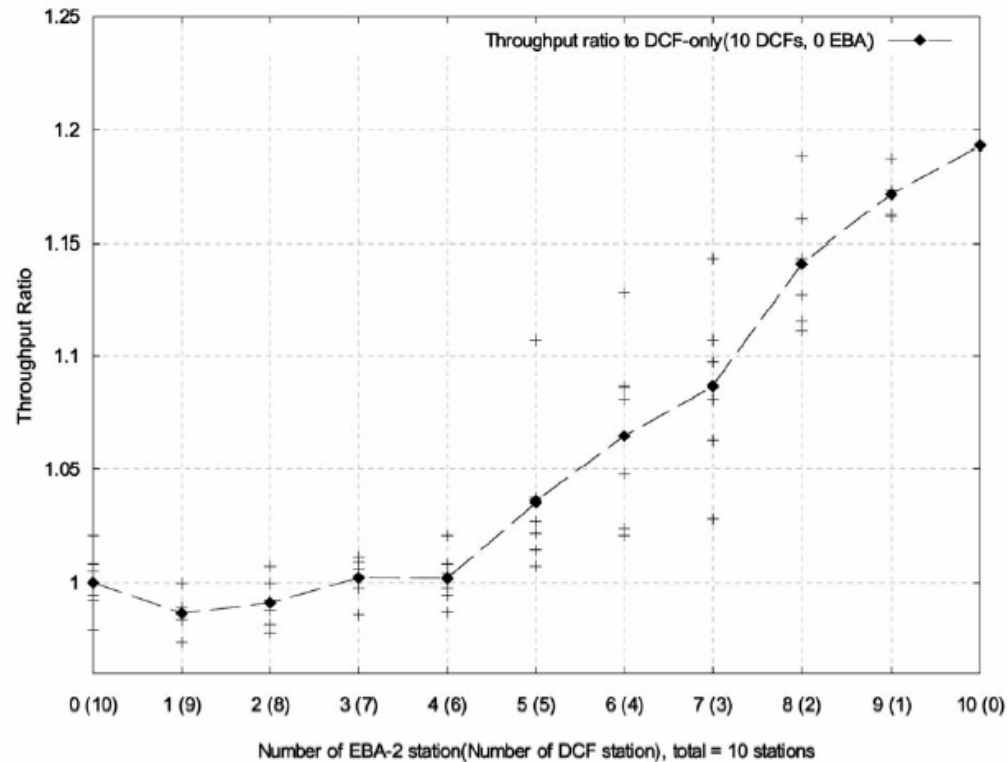# EBA-2's compatibility with DCF

Fig. 19. EBA-2's compatibility with DCF.

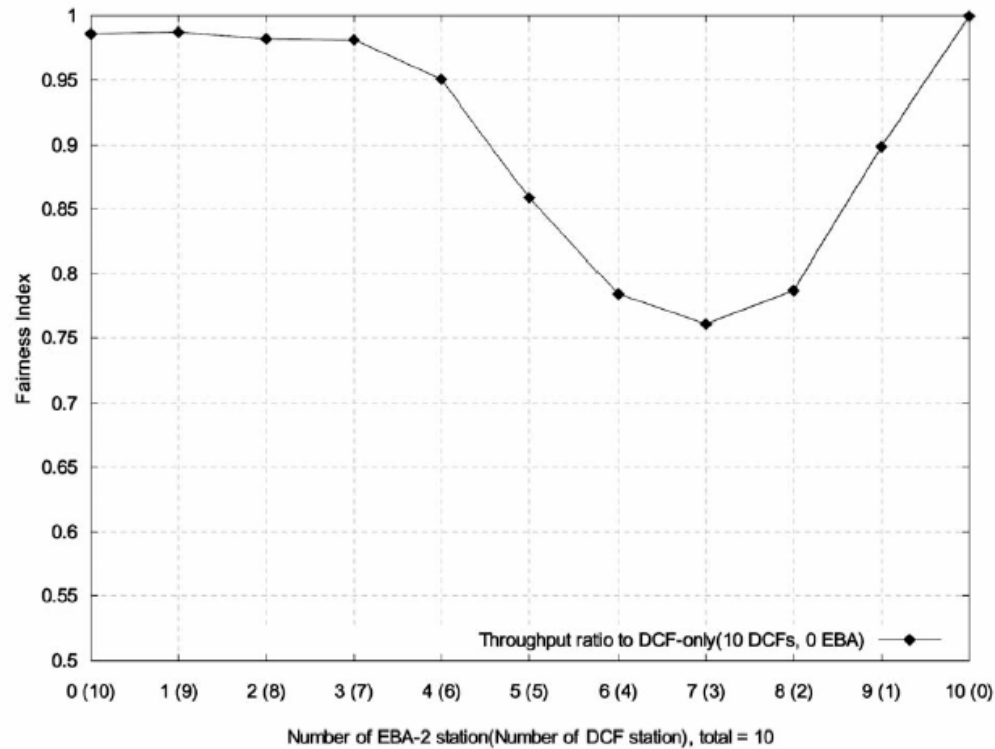# Fairness Index for 120 sec. simulation (DCF-EBA2 coexist)

Fig. 20. Fairness Index for 120 sec. simulation (DCF-EBA2 coexist).

Conclusion

- This paper proposes a novel distributed reservation-based MAC protocol EBA that can be used for the enhanced IEEE 802.11 WLAN.
  - A minor modification of the 802.11 DCF
  - Backward compatible with the legacy DCF
  - Both EBA and DCF stations can coexist smoothly
  - A higher degree of fairness compared to the legacy DCF.