Channel Access Unfairness of Wireless LAN Access Methods

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Outline

- Introduction
- Wireless LAN access methods
- Simulation environment
- System performance
- Conclusions

Introduction

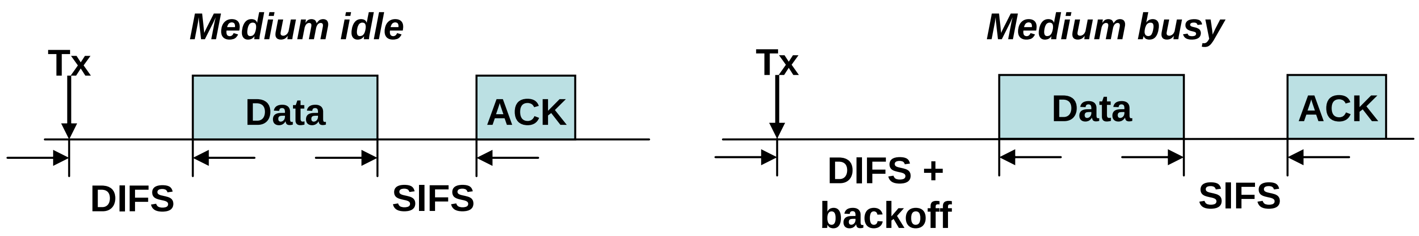
- 1997: IEEE defines the first standard IEEE 802.11 for Wireless Local Area Networks
  - Successive variants have increased the nominal bit rate: IEEE 802.11 b/g/a
  - The MAC layer remains unchanged
  - Much research effort spent on improving MAC performance

Introduction

- Up to now, different proposals have been compared under ideal channel conditions
  - Objective: Performance analysis of different proposals in adverse transmission conditions
  - Realistic scenario in which stations in a BSS may have different BER values.
- Chosen Access Methods:
  - IEEE 802.11 DCF
  - Slow Decrease
  - Asymptotically Optimal Backoff (AOB)
  - Idle Sense

IEEE 802.11 DCF

- Before initiating a transmission, a station senses the channel during a DIFS Time:
  - ✓the medium is sensed idle → transmission allowed
  - ✓the medium is sensed busy → next attempt of transmission at DIFS + backoff time
- *Backoff time*: integer number of time slots distributed uniformly in [0, *CW*-1]
- After each data frame succesfully received, the receiver transmits an ACK after a SIFS Time



Slow Decrease

- Objective: adapting *CW* of each station to the current network congestion level
- After each successful transmission:

$$CW_{new} = \max(CW_{\min}, 2^{-g} CW_{old})$$

- the slowest decrease, which achieves the best performance, for
  - *g=1* $\rightarrow \; CW_{new} = 0.5 \cdot CW_{old}$
- Preserves the exponential backoff mechanism of IEEE 802.11 DCF

Asymptotically Optimal Backoff (AOB)

- Each host computes the *Probability of Transmission:*

$$PT = 1 - \min\left(1, \frac{SU}{SU_{opt}}\right)^{Na}$$

- *Na*: Number of attempts for the transmission of a frame
- *Slot Utilization (SU):*

$$SU = \frac{Num\_Busy\_Slots}{Num\_Available\_Slots}$$

- If the transmission is rescheduled, a new backoff interval is computed
  - ✓ AOB preserves the exponential backoff mechanism of IEEE 802.11 DCF

Idle Sense

- Each host estimates the number of consecutive *idle slots* between 2 transmission attempts
  - By comparing the estimate with a target value, hosts adjust their *CW* using *AIMD* principle
- Contending hosts do not perform the exponential backoff mechanism of IEEE 802.11 DCF

Simulation environment

- Discrete event simulation tool that implements
  - IEEE 802.11 DCF
  - Slow Decrease
  - Asymptotically Optimal Backoff (AOB)
  - Idle Sense
- Simulation parameters
  - Physical layer of IEEE 802.11g
  - Payload size of 1500 bytes and transmission rate of 54 Mbps
  - Greedy hosts

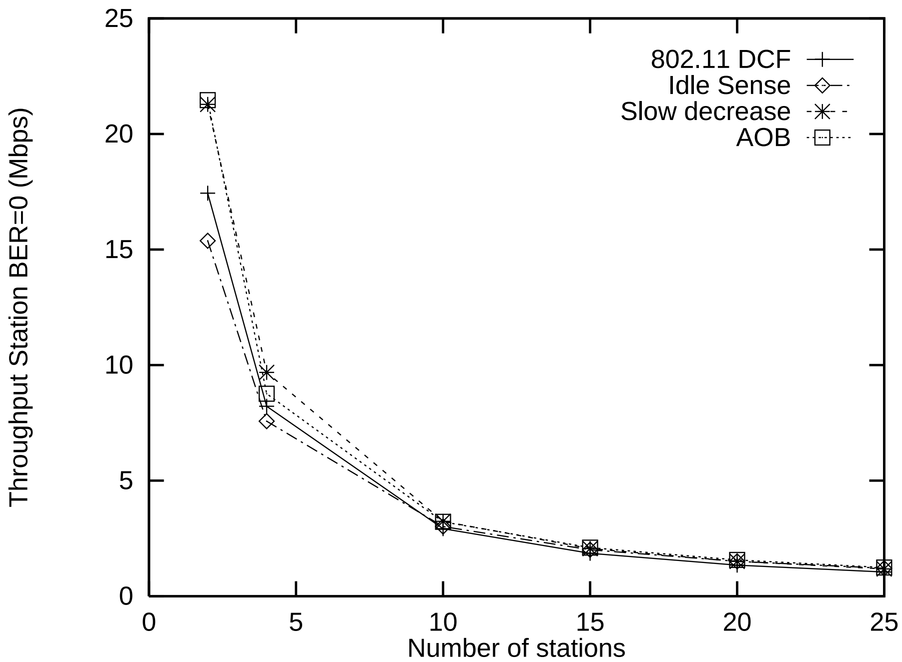
Simulation environment

- 1 BSS: every station subject to different BER values
  - 1 Host with BER ≠ 0 and N-1 hosts with BER = 0
    - ✓ *FER*: Frame error ratio; *l*: frame size in bits
    - ✓ $FER=1-(1-BER)^{l}$

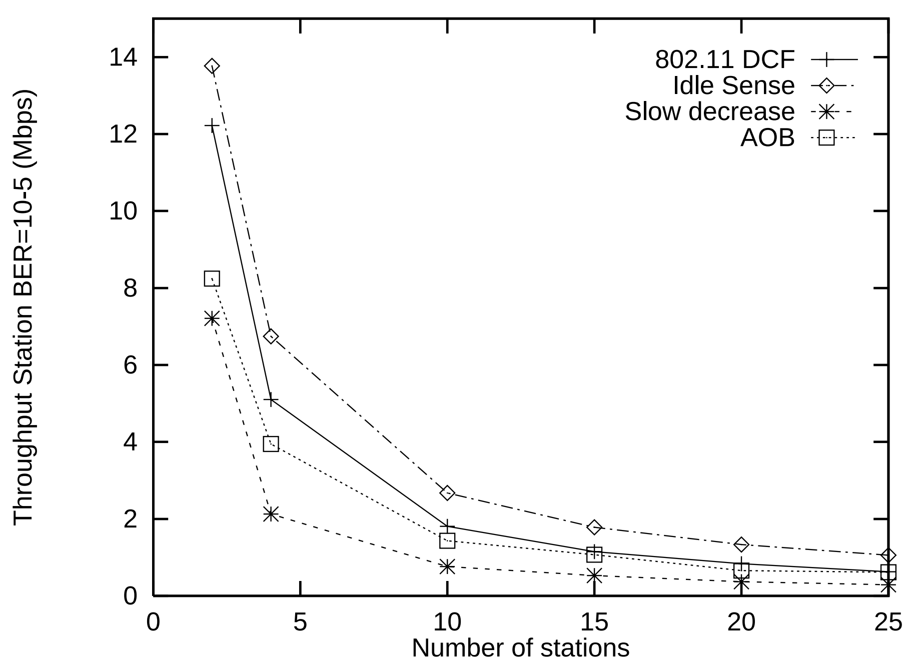
System performance

- Throughput comparison for each access method and different transmission conditions
  - BER=10^{-5} for the host with BER≠0 (FER_{Data}=12%, FER_{ACK}=0.65%)

BER=0



BER=10^{-5}



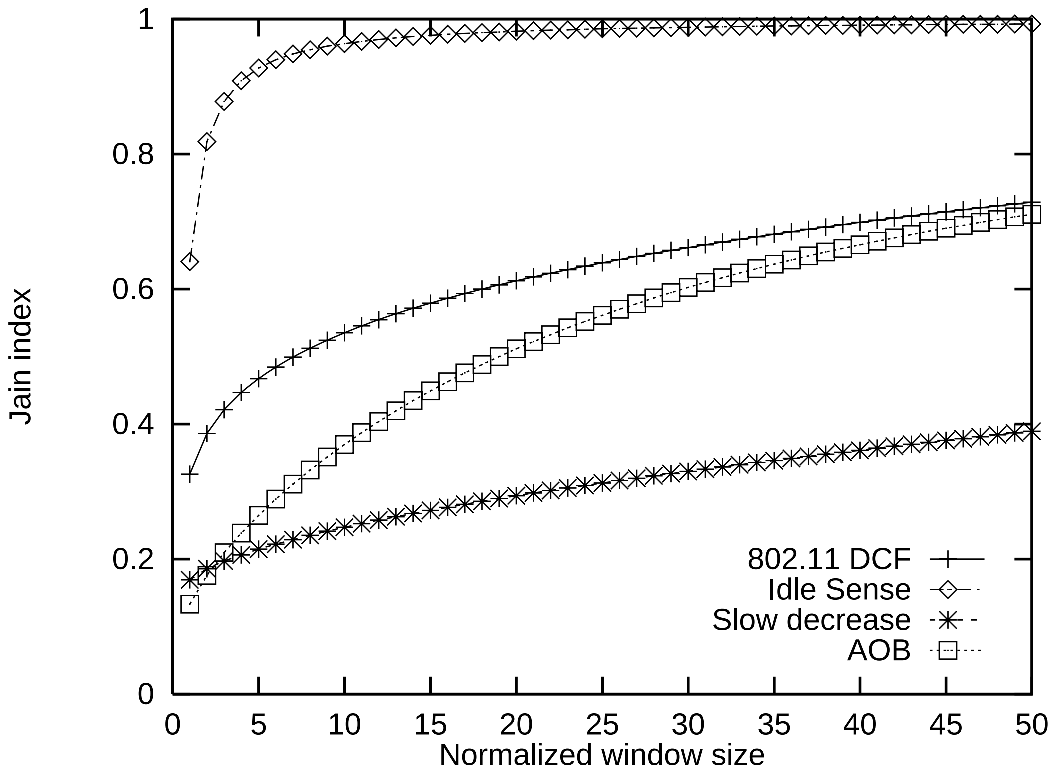
System performance

- Comparison of CW for each access method and different transmission conditions
  - Large differences for IEEE 802.11 DCF, Slow Decrease and AOB
  - For Idle Sense, stations with different BER obtain similar CW values

Number of stations	2	4	10	15	20	25
IEEE 802.11 DCF, $BER = 0$	17.71	22.25	36.55	47.01	56.36	65.74
IEEE 802.11 DCF, $BER = 10^{-5}$	22.16	30.70	51.93	64.88	80.14	96.34
Difference	25.15%	38.01%	42.09%	38.01%	42.19%	46.54%
Slow Decrease, $BER = 0$	9.21	16.09	36.48	52.63	66.48	82.23
Slow Decrease, $BER = 10^{-5}$	23.47	57.05	124.52	164.63	205.75	264.23
Difference	154.77%	254.56%	241.37%	212.78%	209.48%	221.33%
AOB, $BER = 0$	19.11	30.95	55.92	70.95	81.75	95.34
AOB, $BER = 10^{-5}$	33.38	51.13	91.77	109.02	137.49	148.79
Difference	74.66%	65.21%	64.12%	53.65%	68.18%	56.06%
Idle Sense, $BER = 0$	29.23	54.80	122.17	169.87	213.22	256.74
Idle Sense, $BER = 10^{-5}$	29.28	54.37	121.92	170.11	213.68	257.23
Difference	0.16%	0.79%	0.21%	0.14%	0.22%	0.19%

System performance

- Channel Access Fairness comparison for 25 active stations



- Idle Sense provides much better fairness than other access methods
  - ✓ It does not perform the exponential backoff algorithm

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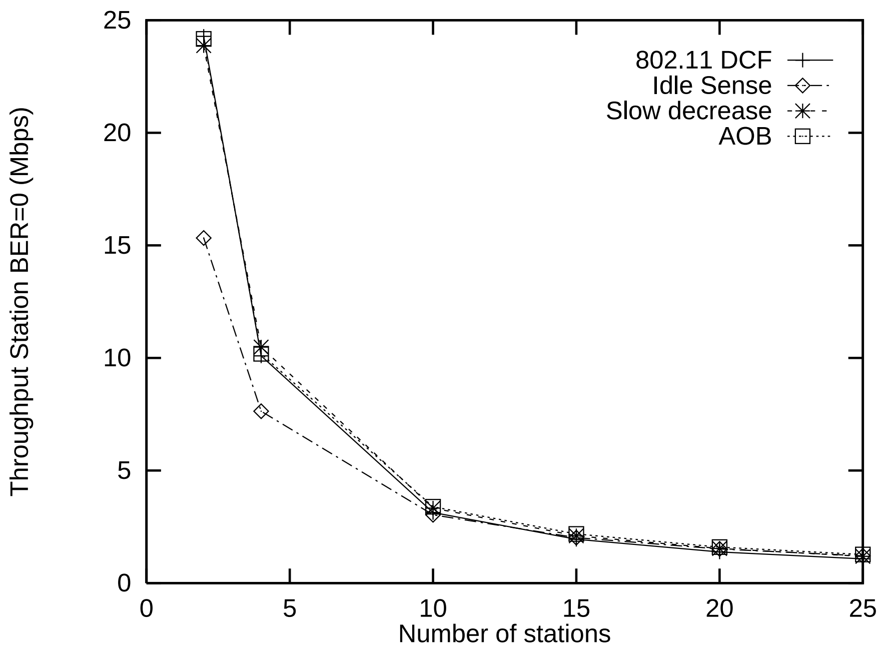
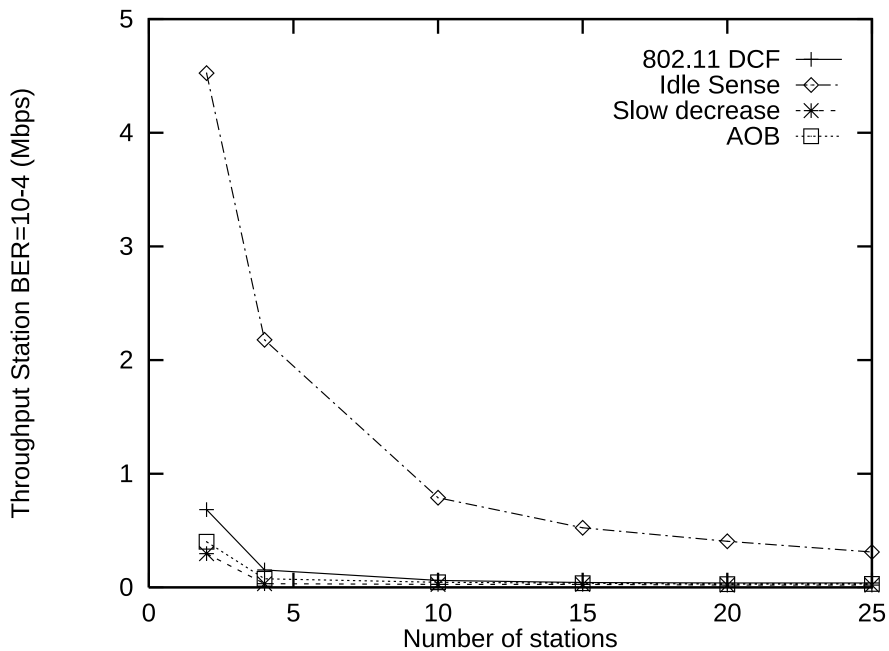
System performance

- Throughput comparison for each access method and different transmission conditions
  - BER=10^{-4} for the host with BER≠0 (FER_{Data}=72%, FER_{ACK}=6.4%)

BER=0



BER=10^{-4}



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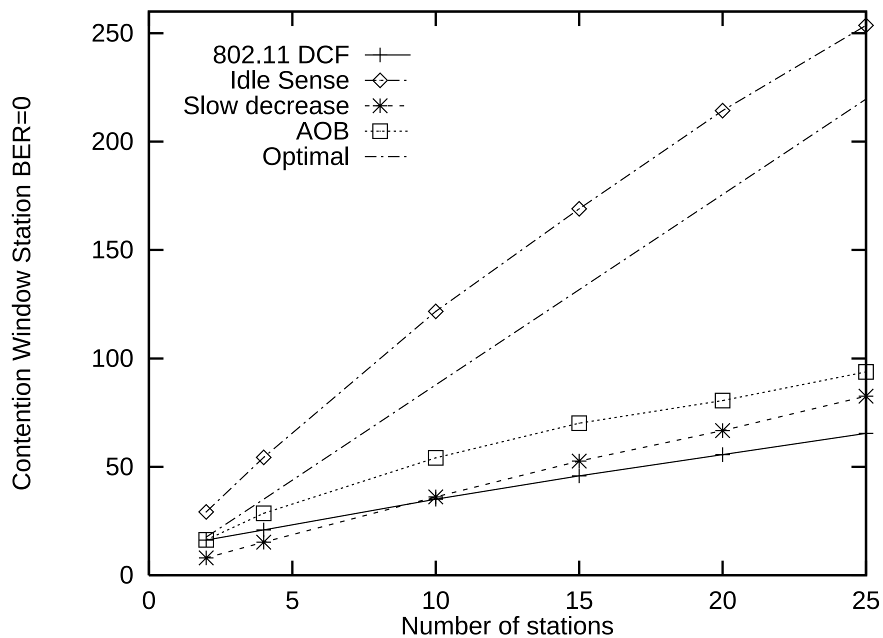
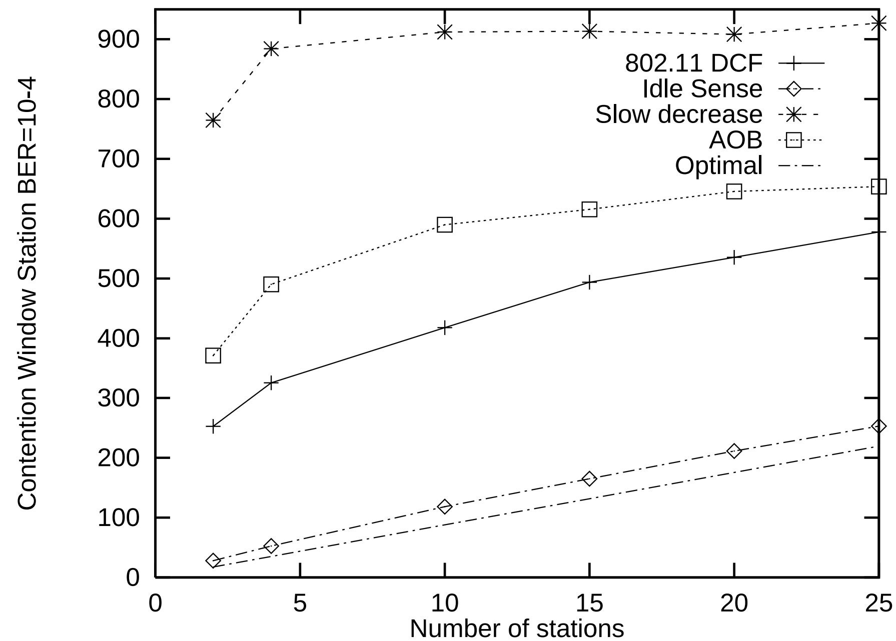
System performance

- Comparison of CW for each access method and different transmission conditions
  - Larger differences for IEEE 802.11 DCF, Slow Decrease and AOB than the observed with BER=10^{-5}

BER=0



BER=10^{-4}



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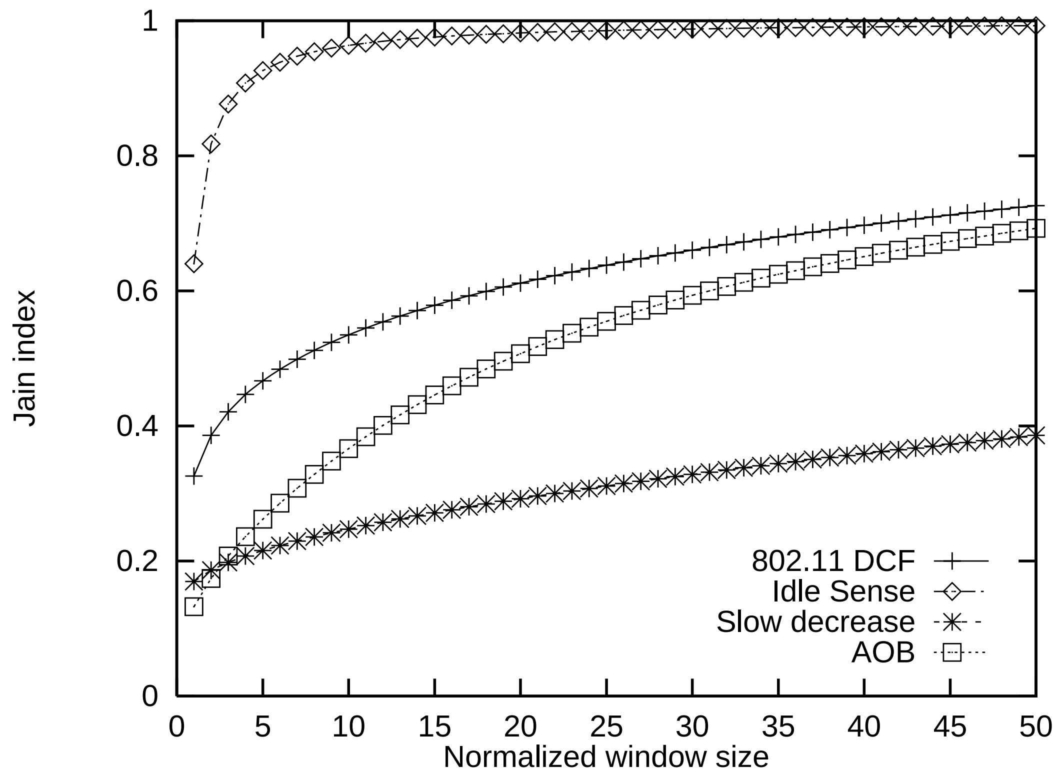
System performance

- Channel Access Fairness comparison for 25 active stations



- Idle Sense provides much better fairness than other access methods
  - ✓ It does not perform the exponential backoff algorithm

Conclusions

- Evaluation of chosen access methods in adverse transmission conditions
  - IEEE 802.11 DCF
  - Slow Decrease
  - Asymptotically Optimal Backoff
  - Idle Sense
- IEEE 802.11 DCF, Slow Decrease and AOB
  - do not provide sufficient independence of transmission conditions
  - penalize the stations subject to adverse transmission conditions
- Idle Sense
  - does not use the *exponential backoff algorithm*
  - the difference in throughput is only due to experienced transmission errors