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 successfully 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):**
  \[ SU = \frac{\text{NumBusySlots}}{\text{NumAvailableSlots}} \]
- 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**

![Graph showing throughput comparison for BER=0](image1)

**BER=10^{-5}**

![Graph showing throughput comparison for BER=10^{-5}](image2)
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

<table>
<thead>
<tr>
<th>Number of stations</th>
<th>2</th>
<th>4</th>
<th>10</th>
<th>15</th>
<th>20</th>
<th>25</th>
</tr>
</thead>
<tbody>
<tr>
<td>IEEE 802.11 DCF, (BER = 0)</td>
<td>17.71</td>
<td>22.25</td>
<td>36.55</td>
<td>47.01</td>
<td>56.36</td>
<td>65.74</td>
</tr>
<tr>
<td>IEEE 802.11 DCF, (BER = 10^{-5})</td>
<td>22.16</td>
<td>30.70</td>
<td>51.93</td>
<td>64.88</td>
<td>80.14</td>
<td>96.34</td>
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<tr>
<td>Difference</td>
<td>25.15%</td>
<td>38.01%</td>
<td>42.09%</td>
<td>38.01%</td>
<td>42.19%</td>
<td>46.54%</td>
</tr>
<tr>
<td>Slow Decrease, (BER = 0)</td>
<td>9.21</td>
<td>16.09</td>
<td>36.48</td>
<td>52.63</td>
<td>66.48</td>
<td>82.23</td>
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<tr>
<td>Slow Decrease, (BER = 10^{-5})</td>
<td>23.47</td>
<td>57.05</td>
<td>124.52</td>
<td>164.63</td>
<td>205.75</td>
<td>264.23</td>
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<tr>
<td>Difference</td>
<td>154.77%</td>
<td>254.56%</td>
<td>241.37%</td>
<td>212.78%</td>
<td>209.48%</td>
<td>221.33%</td>
</tr>
<tr>
<td>AOB, (BER = 0)</td>
<td>19.11</td>
<td>30.95</td>
<td>55.92</td>
<td>70.95</td>
<td>81.75</td>
<td>95.34</td>
</tr>
<tr>
<td>AOB, (BER = 10^{-5})</td>
<td>33.38</td>
<td>51.13</td>
<td>91.77</td>
<td>109.02</td>
<td>137.49</td>
<td>148.79</td>
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<tr>
<td>Difference</td>
<td>74.66%</td>
<td>65.21%</td>
<td>64.12%</td>
<td>53.65%</td>
<td>68.18%</td>
<td>56.06%</td>
</tr>
<tr>
<td>Idle Sense, (BER = 0)</td>
<td>29.23</td>
<td>54.80</td>
<td>122.17</td>
<td>169.87</td>
<td>213.22</td>
<td>256.74</td>
</tr>
<tr>
<td>Idle Sense, (BER = 10^{-9})</td>
<td>29.28</td>
<td>54.37</td>
<td>121.92</td>
<td>170.11</td>
<td>213.68</td>
<td>257.23</td>
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<tr>
<td>Difference</td>
<td>0.16%</td>
<td>0.79%</td>
<td>0.21%</td>
<td>0.14%</td>
<td>0.22%</td>
<td>0.19%</td>
</tr>
</tbody>
</table>
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
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\%)

![Graphs showing throughput comparison for BER=0 and BER=10^{-4}](image-url)
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}

![Graph showing system performance comparison for different conditions and BER values]
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