Impact of Multicast Flow for Performance of IEEE 802.11e in Wireless LAN

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Impact of Multicast Flow for Performance of IEEE 802.11e in Wireless LAN

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Introduction

Background – IEEE 802.11

IEEE 802.11 a,b,g,n

- differ in speed, frequency, range, compatibility
- 802.11b, g protocols are popular
- DCF (distributed coordination function)
- Support a best effort, not guaranteeing QOS

IEEE 802.11 e

- EDCF (Enhanced DCF)
- Support QOS
- EDCF provides differentiated channel access to frames with different priorities

<table>
<thead>
<tr>
<th>TABLE 1. USER PRIORITY TO AC MAPPING</th>
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<tbody>
<tr>
<td>Priority</td>
</tr>
<tr>
<td>Lowest</td>
</tr>
<tr>
<td>Lowest</td>
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<tr>
<td>Highest</td>
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<td>Highest</td>
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<table>
<thead>
<tr>
<th>TABLE 2. DEFAULT EDCA PARAMETER SET</th>
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<tbody>
<tr>
<td>AC</td>
</tr>
<tr>
<td>AC_BK</td>
</tr>
<tr>
<td>AC_BE</td>
</tr>
<tr>
<td>AC_VI</td>
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<tr>
<td>AC_VO</td>
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</table>
Introduction

Background – MAC layer

Problems

- Fails to provide local reliability
- Prevents the multicast sender from performing a back off process
Introduction

Objective

- How negatively the single multicast flow affects multiple the unicast flows when they compete for a single communication channel access.

- the transition of the channel condition by progressively applying conservative back-off scheme for the multicast flow.
Modification of Multicast Back-off

For unicast flows

\[ B[i] = \text{random}(W_i) \cdot S_e \]

Where \( i \) is a priority of given flow

\( \text{random}(W_i) \) is a random integer \([0, W_i]\)

\( S_e \) is a slot time

The sender sets its New contention window size \( W_{\text{new}} \)

\[ W_{\text{new}} = [(W_{\text{old}} \pm 1) \cdot \alpha] - 1 \quad (W_{\text{new}} \leq W_{\text{max}}, \text{and } \alpha \geq 1) \]

Process is repeated until the \( W_{\text{new}} \) reaches the maximum size or the frame is successfully received at the receiver.

Where \( \alpha \) is the persistence factor and its size is dependent on the priority of the flow

✓ Multicast sender maintains its minimum window size \( W_{\text{min}} \) (\( \alpha \) to 1)
✓ With modification, a new scale value \( \beta \) such that \( \beta < \alpha \) - resize the \( \beta \) value.
✓ To send NAKs for incorrectly received frames to request retransmission from the sender.
Consider n contending senders including one a multicast sender.

- First case – One multicast sender uses the legacy IEEE802.11e EDCF scheme by setting $\beta$ to 1
- Second case - One multicast sender uses the back-off scheme by setting $\beta$ to $\alpha$

How the two different schemes affect the throughput of the multiple low-priority unicast flows by showing the saturation throughput for n different number of senders.

$s(t)$ - back-off stage [0-m]

$b(t)$- back-off time counter for a given station at time $t$

$P_c$ - independent probability that a transmitted frame is collide in a slot time

$$P \{ i_1, j_1 | i_0, j_0 \} = P \{ s(t+1)= i_1, b(t+1)=j_1 | s(t) =i_0, b(t)=j_0 \}$$
Performance analysis

\[ P\{i, j \mid i, j+1\} = 1 \ (0 \leq i \leq m, \ 0 \leq j \leq W_1 - 2) \]

The decrement back off the counter

\[ P\{0, j \mid i, 0\} = (1 - P_c) / W_0 \ (0 \leq i \leq m, \ 0 \leq j \leq W_0 - 1) \]

New packet following a successful transmission start with a back off stage 0

\[ P\{i, j \mid i-1, 0\} = P_c / W_1 \ (0 \leq i \leq m, \ 0 \leq j \leq W_1 - 1) \]

\[ P\{m, j \mid m, 0\} = P_c / W_m \ (0 \leq j \leq W_m - 1) \]

after an unsuccessful transmission at backoff stage, the backoff interval is uniformly chosen

\[ S_{i,j} \text{ and } p_{i,j} \]

be the stationary distribution of the Markov chain for multicast flow with back-off and without back-off

Closed form solution for \( S_{i,j} \)

\[ S_{i,j} = P_c \cdot S_{i-1,0} = P_c^i \cdot S_{0,0} \ (1 \leq i \leq m) \]

\[ P_c \cdot S_{m-1,0} = (1 - P_c) \cdot S_{m,0} \]

\[ S_{m,0} = P_c^m \cdot S_{0,0} \]

\[ (1 - P_c) \]
Performance analysis

Determine the normalized saturation throughput $T$

$$T = \frac{P_s P_l L_f}{(1 - P_l) S_e + P_s P_l T_s + (1 - P_s) P_l T_c},$$

$L_f$ – average frame length
$S_e$ – average size of a slot time
$T_s$ – average time that channel is busy for frame transmission
$T_c$ – average time that channel is busy for frame collision
$P_c$ – simply set it to 0.25

We can get $P_c, P_s,$ and $S_{0,0}$

$1 < \beta < \alpha$, to adaptively adjust size of $\beta$ brings acceptable compromise of the throughput

Figure 3. Saturation throughput

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In simulation

- First, a single communication channel is shared with four unicast-only senders running an exponential back-off mechanism.

- Second, substitute a multicast sender using a legacy EDCA multicast mechanism for one of the four unicast senders.

- Third, the multicast sender to use the modified, back-off scheme by linearly increasing its contention window size by 1 and 1.5, respectively.
First, a single communication channel is shared with four unicast-only senders running an exponential back-off mechanism.

For 10 seconds
Sender1 : 18%
sender2 : 25%
sender3 : 29%
sender4 : 28%

If the session lasts long-term, the four senders will eventually have equal chances for fair channel access.
Simulation

✓ *Second*, substitute a multicast sender using a legacy EDCA multicast mechanism for one of the four unicast senders.

One multicast flow can negatively affect the performance of other unicast flows.

*Figure 6. Result with one multicast sender without back-off*

- Multicast sender1: 92.2%
- sender2: 1.3%
- sender3: 5.5%
- sender4: 1%
Simulation

Third, the multicast sender to use the modified, back-off scheme by linearly increasing its contention window size by 1 and 1.5, respectively.

![Graph showing bandwidth consumption](image)

**Figure 7.** Result with one multicast sender with linear back-off by 1

Compared to Figure 6, even though the difference is not too significant, the bandwidth consumption of multicast sender is decreased.
Simulation

Increase the contention window size of the multicast sender by 1.5

Better performance

**Multicast sender1 : 57% sender2 : 11% sender3 : 21% sender4 : 11%**
Conclusion

- How one greedy multicast flow negatively affects the throughput of the multiple, low-priority, unicast flows.

- We observe
  - the expected amount of negative impact through numerical performance analysis.
  - the amount of the impact using a simulation.

- The contention window size of the multicast flow should be adaptively adjusted depending on the level of population over the same QBSS.
Thank you for listening

Q & A