On the Impact of Backoff Misbehaving Nodes in IEEE 802.11 Networks

Presented by Chi Yi

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Outline

IEEE 802.11

IEEE 802.11 distributed coordination function relies on binary exponential backoff to resolve channel collisions among contending nodes.

Binary exponential backoff is widely used in existing standards, e.g.,

- 802.3 (Ethernet)
- 802.11 (WiFi)
- 802.15.4 (ZigBee)

Binary Exponential Backoff

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Problem:

- The algorithm depends totally on a node's integrity.
- A selfish node can not obey binary exponential backoff to gain more access to the channel. Such behavior is called backoff misbehavior.

Existing Work in the Literature

Existing Work on backoff misbehavior aims mainly on

- using simulations to evaluate the performance gain of misbehaving nodes. [Szott'08]
- providing countermeasures to it. [Kyasanur'05, Guang'08, Rong'06]
- modeling the gain of a single misbehaving node under simplified models. [Radosavac'08]

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However, it is still unclear how one or even multiple backoff misbehaving nodes affect the performance of an 802.11 network.

We are therefore motivated to quantify the impact of backoff misbehaving nodes in IEEE 802.11 networks.

Models of Legitimate and Backoff Misbehaviors

Definition (Legitimate Backoff)

The legitimate random backoff time $T(i)$ after the i-th collision is uniformly distributed on $[0, 2^i w_0)$, where w_0 is the minimum contention window of legitimate nodes.

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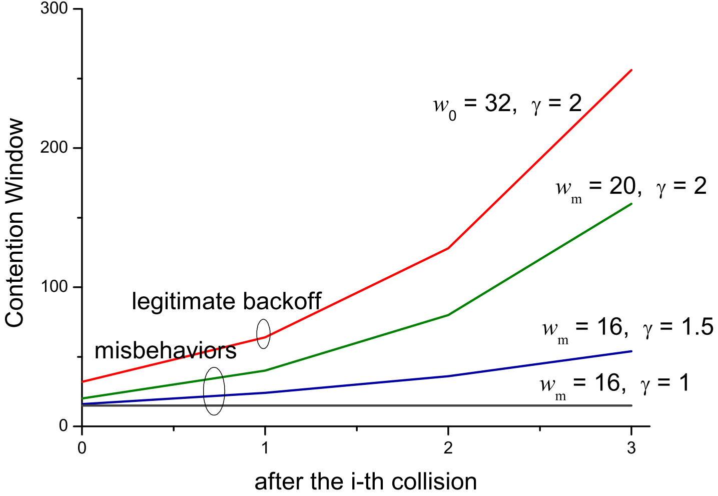
Definition (Misbehaving Backoff)

The legitimate random backoff time $T(i)$ after the i-th collision is uniformly distributed on $[0, \gamma^i w_m)$, where w_m is the minimum contention window of misbehaving nodes. And

1. Backoff multiplier γ satisfies $1 \leq \gamma \leq 2$.
2. $w_m < w_0$, where w_0 is the minimum contention window of legitimate nodes.

Legitimate Backoff vs Misbehaving Backoff



Performance metrics

The impact of backoff misbehavior on a network is two-fold.

1. It brings performance gain to misbehaving nodes.
2. On the other and, it leads to performance degradation of legitimate nodes.

Metric 1: Throughput gain ratio

The throughput gain ratio of a misbehaving node is defined as

$$R_G = \frac{S_m}{S},$$

where S_m and S are the throughputs of a misbehaving node and a legitimate node, respectively.

Metric 2: Throughput degradation ratio

The throughput degradation ratio of a legitimate node is defined as

$$R_D = 1 - \frac{S}{S_o},$$

where S is the throughput of a legitimate node, and S_o is the throughput of a legitimate node when misbehaving nodes do not perform misbehavior.

Throughput Gain Ratio

Theorem (Throughput Gain Ratio)

In a network with n legitimate nodes and n_m misbehaving nodes, the throughput gain ratio of a misbehaving node is

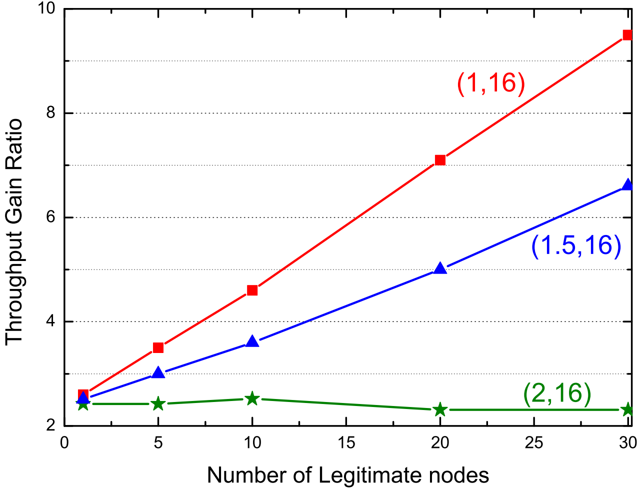
$$R_G = \frac{w_0 - 4}{w_m - 4} + \Theta\left(\frac{1}{n}\right) \qquad \gamma = 2$$

$$R_G = \Theta(n) \qquad 1 \leq \gamma < 2$$

Observations

1. If a misbehaving node also adopts binary exponential backoff ($\gamma = 2$), $R_G \rightarrow \frac{w_0-4}{w_m-4}$ as $n \rightarrow \infty$.
2. If a misbehaving node has $\gamma < 2$, R_G increases linearly as n increases.

Legitimate backoff: (2, 32)(IEEE 802.11b). One misbehaving node.



Throughput Degradation Ratio

Theorem (Throughput Degradation Ratio)

In a network with n legitimate nodes and n_m misbehaving nodes, the throughput degradation ratio of a legitimate node $R_D \in [0,1]$ satisfies

$$R_D = \Theta\left(\frac{1}{n}\right) \qquad \gamma = 2$$

$$R_D = n_m c + \Theta\left(\frac{1}{n}\right) \qquad 1 \leq \gamma < 2$$

where $c > 0$ is a constant.

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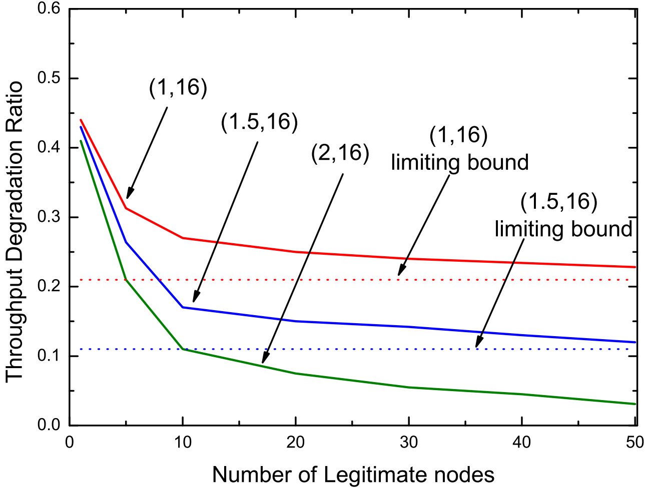
where $c > 0$ is a constant.

Observations

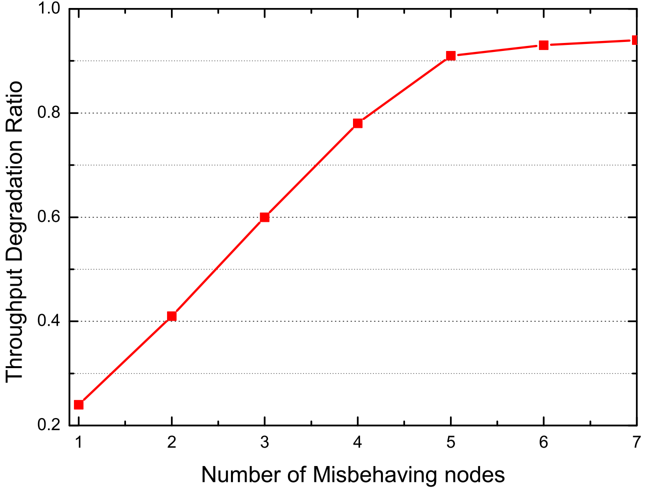
1. If a misbehaving node also adopts binary exponential backoff ($\gamma = 2$), $R_D \to 0$ as $n \to \infty$.
2. If a misbehaving node has $\gamma < 2$, $R_D \to n_m c$ as $n \to \infty$. Therefore, $n_m c$ is a limiting bound of R_D.

Legitimate backoff: (2, 32) (IEEE 802.11b). One misbehaving node.



Throughput degradation ratio:

10 legitimate nodes (2, 32) and multiple misbehaving nodes (1, 16)



Conclusions

- We introduce
  1. throughput gain ratio to quantify the gain of misbehaving nodes
  2. throughput degradation ratio to quantify the performance loss of legitimate nodes
- The throughput gain ratio increases linearly with the number of legitimate nodes. The throughput degradation ratio increases linearly with the number of misbehaving nodes.
  - Exception: backoff misbehavior with binary exponential backoff ($\gamma = 2$).

Thank you!