Detection and Handling of MAC Layer Misbehavior in Wireless Networks

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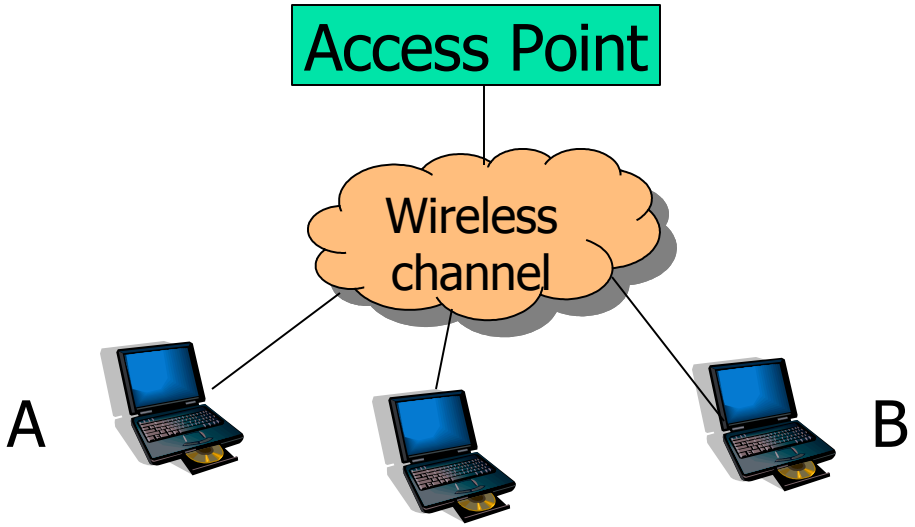
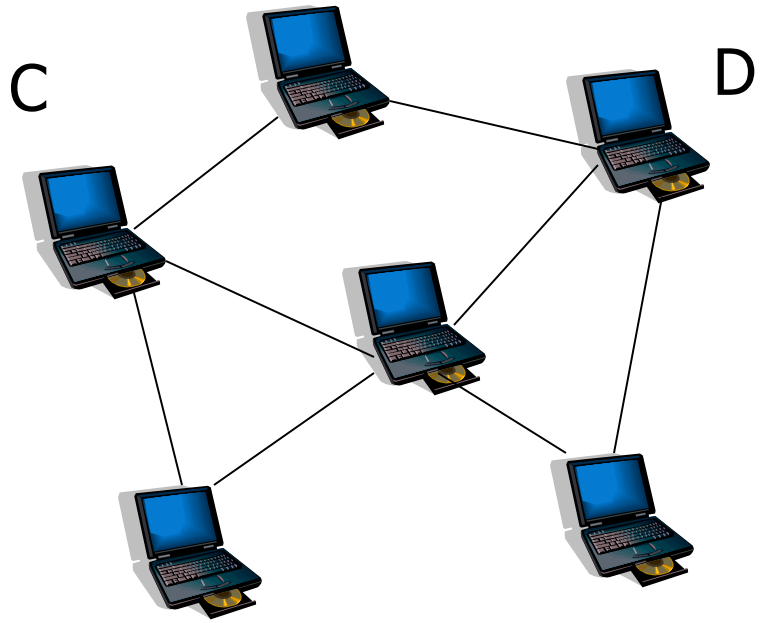
Problem Definition



Infrastructure-based Network



Ad hoc Network

Nodes may violate Medium Access Control rules

IEEE 802.11 overview

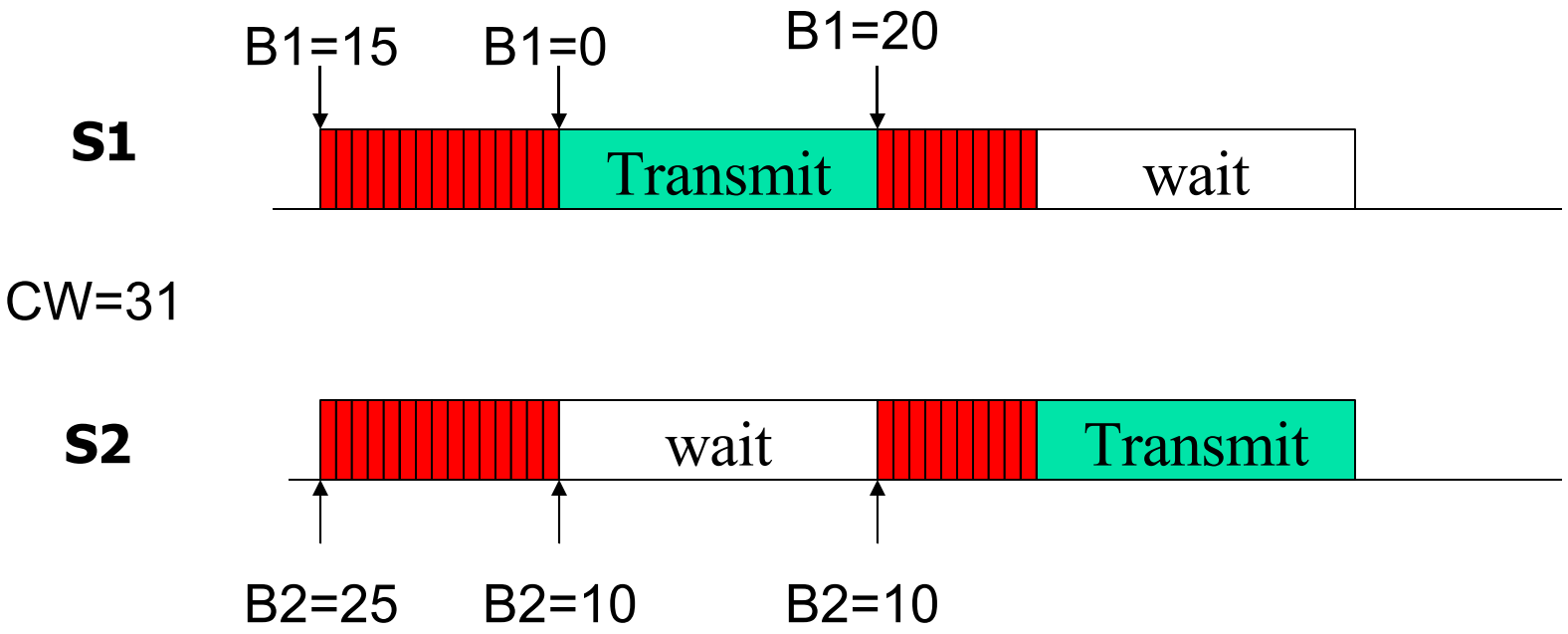
- Distributed Coordination Function (DCF) - Mandatory
  - Widely used for channel access
- DCF is a Carrier Sense Multiple Access/ Collision Avoidance (CSMA/CA) protocol

CSMA/CA

- Carrier sense
  - Don’t transmit when channel is busy
- Collision avoidance
  - Defer transmission for random time *after* channel goes idle

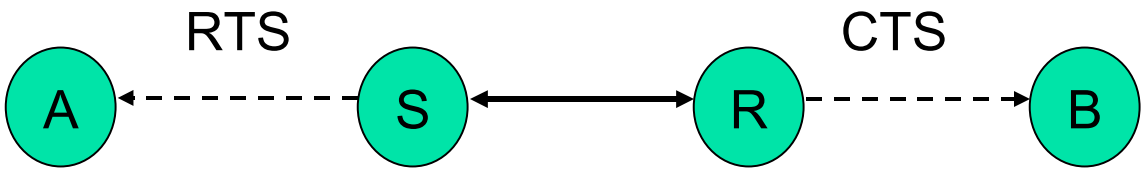
Backoff Example

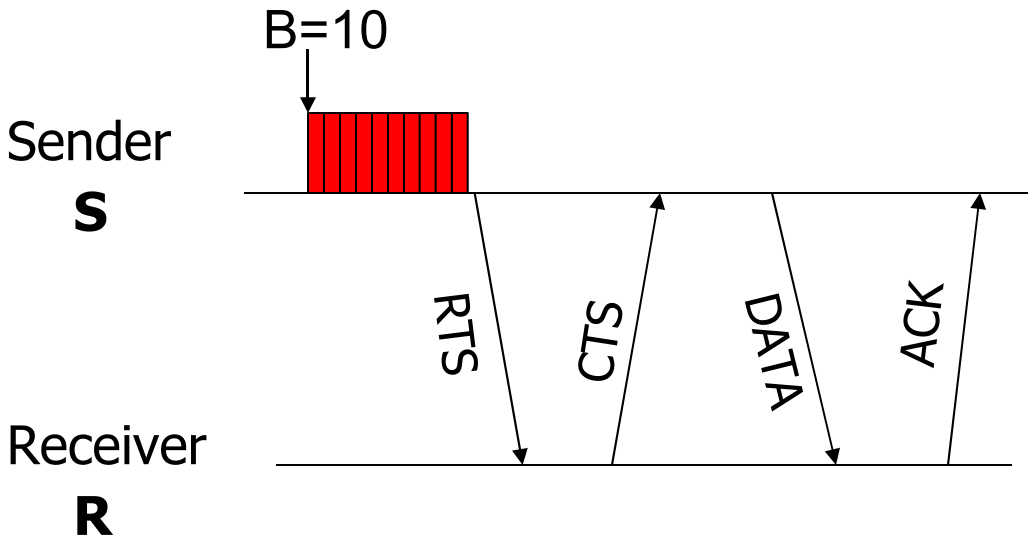
- Choose backoff value B in range [0,CW]
  - CW is the Contention Window
- Count down backoff by 1 every idle slot



Data Transmission

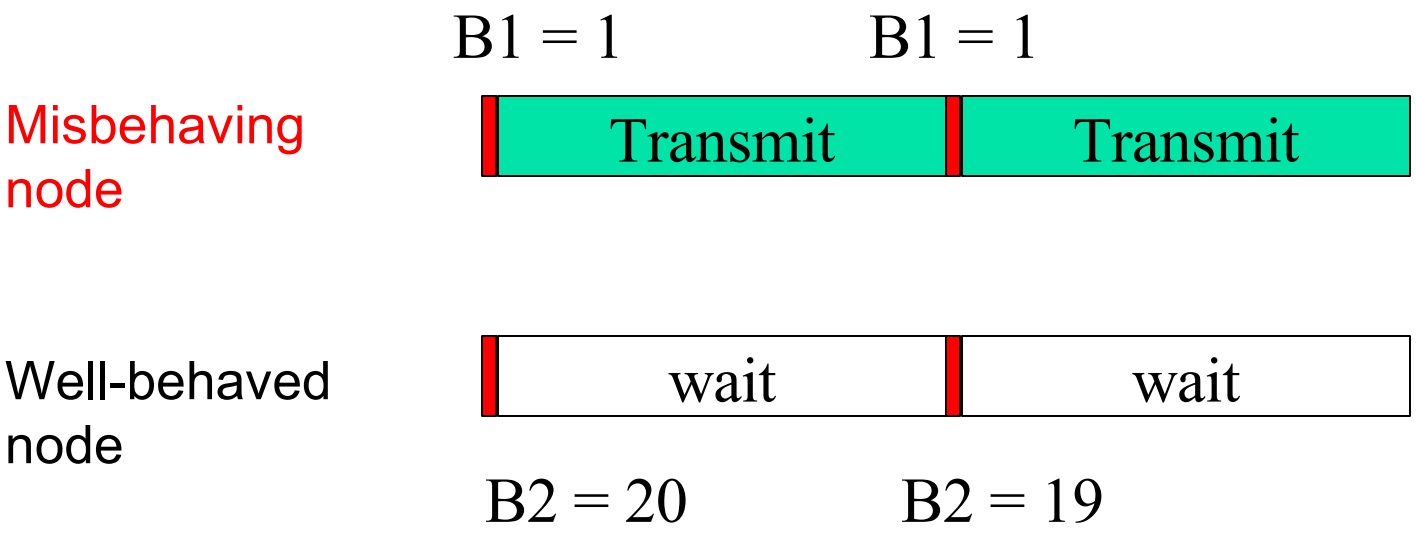
- Reserve channel with RTS/CTS exchange





Possible Misbehavior

- Backoff selected from different distribution
  - Select a small constant backoff always



Goals of proposed scheme

- Diagnose node misbehavior
  - Catch misbehaving nodes
- Discourage misbehavior with MAC layer scheme
  - Punish misbehaving nodes

Related work at other layers

- Many proposals for securing network layer
- Designing protocols resilient to misbehavior
  - [Savage99, Nisan99, Buttyan01]
- Explicitly detect and penalize misbehavior
  - [Marti00, Zhang00, Buchegger02, Hu02]

Related work at MAC Layer

- Game-theoretic solutions proposed for selfish misbehavior at MAC layer
  - [Konorski01, MacKenzie01, Konorski02]

- Game-theoretic approach
  - \+ Protocols resilient to misbehavior
  - \- Assumptions not always valid
  - \- Performance may not be good

Solution Approaches

- Misbehaving node can gain more bandwidth

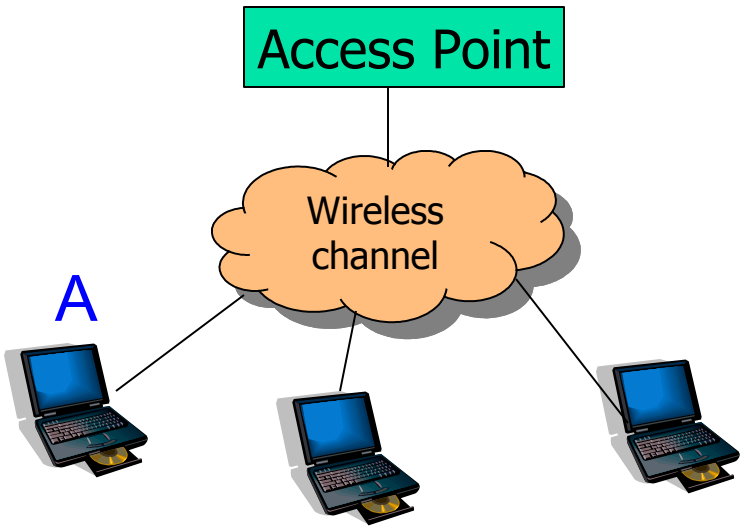
  Use payment schemes, charging per packet

- Misbehaving node can achieve lower delay
  - Send burst of packets ignoring MAC rules
  - Average delay is less with same cost

Payment based schemes not sufficient

Proposed Approach

- Receivers detect sender misbehavior
  - Assume receivers are well-behaved (can be relaxed)



- Receiver does not know exact backoff value chosen by sender
- Wireless Channel introduces uncertainties

Use long-term statistics

- Observe backoffs chosen by sender over multiple packets
- Backoff values not from expected distribution ➔ Misbehavior

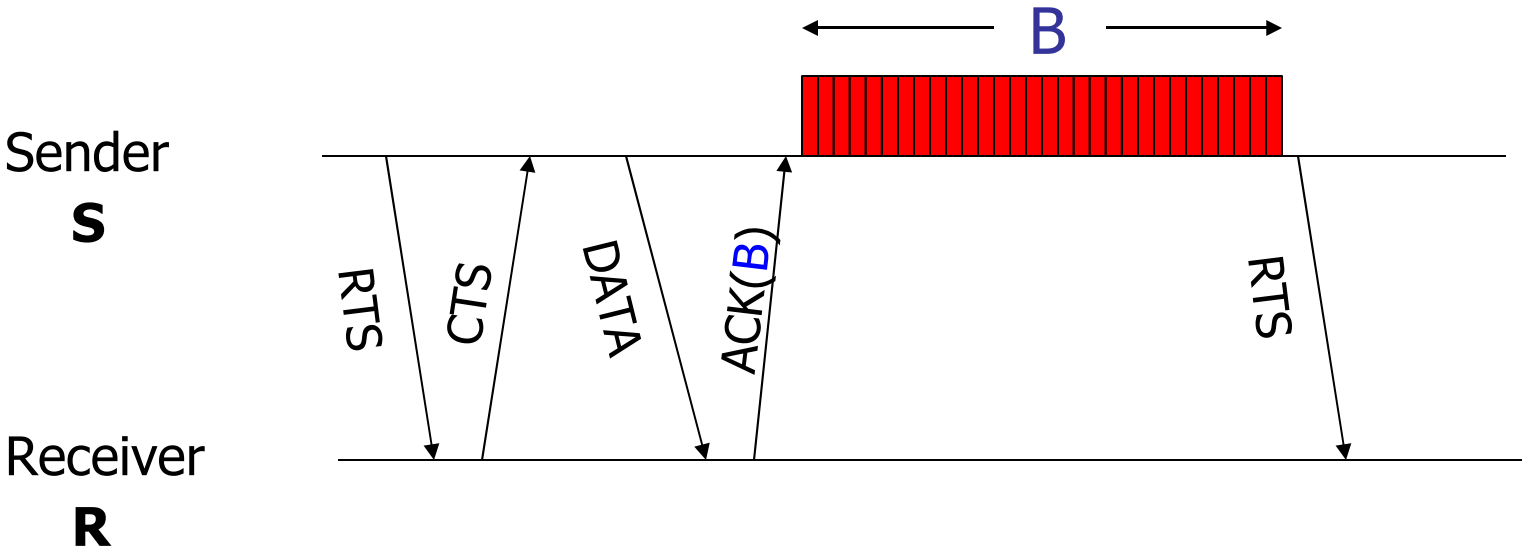
Selecting right observation interval difficult

Alternate Approach

- Receiver provides backoff values to sender
  - Send in current transmission backoff value for next transmission
- Receiver can then accurately observe sender behavior

Uncertainty of sender's backoff eliminated

Modifications to 802.11



1. R provides backoff B to S in ACK

   B selected from [0,CW_{min}]

2. S uses B for backoff

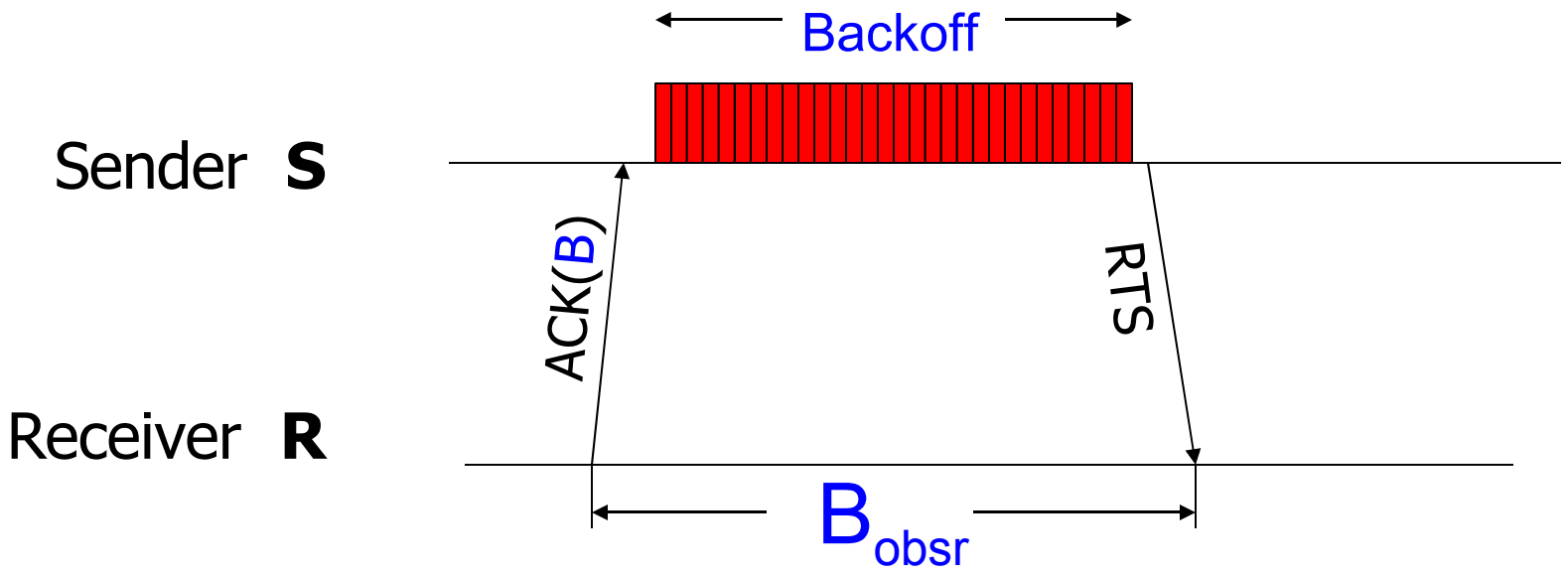
Protocol steps

1. Detect deviations: Receiver observes one transmission from the sender

3. Penalize deviations: Penalty is added, if the sender appears to have deviated

5. Diagnose misbehavior: Based on last W observations, diagnose misbehavior

Detecting deviations

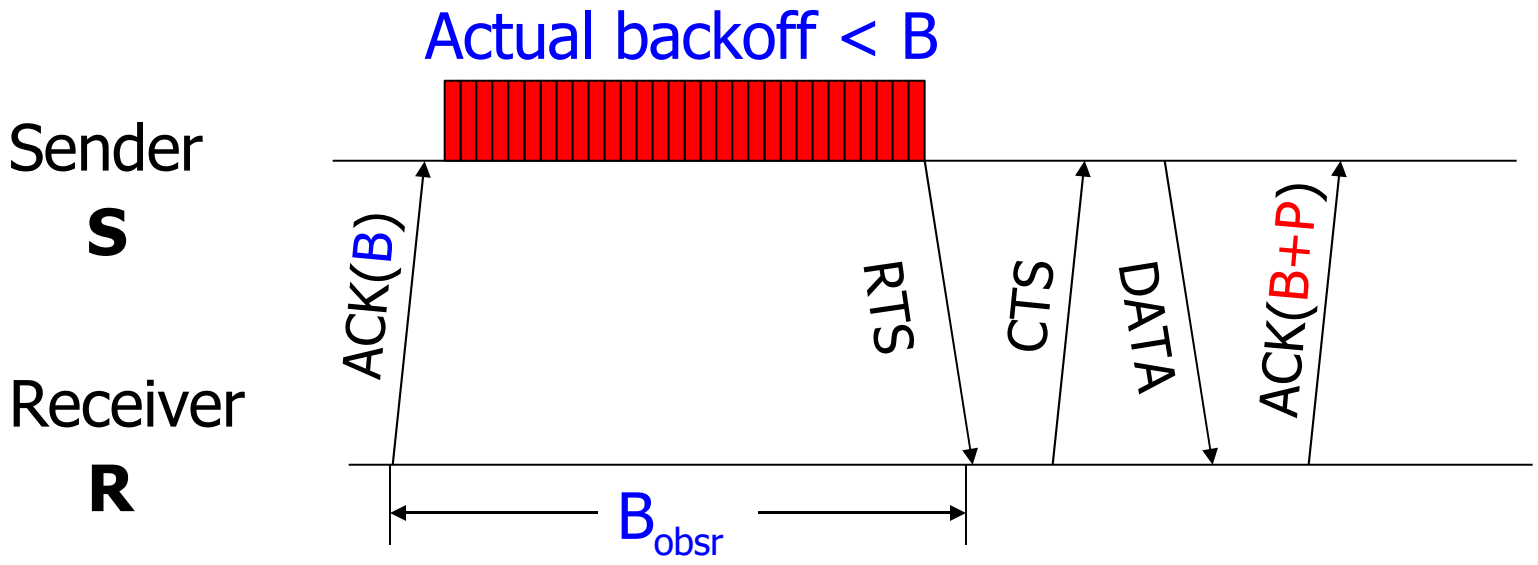


- Receiver counts number of idle slots B_{obsr}

Condition for detecting deviations:

$B_{obsr} < \alpha B$ $\quad 0 < \alpha <= 1$

Penalizing Misbehavior



- When $B_{obsr} < \alpha B$, penalty P added
  - P proportional to $\alpha B - B_{obsr}$
- Total backoff assigned = B + P

Penalty Scheme issues

- With penalty, sender has to misbehave more for same throughput gain

- Misbehaving sender has two options
  - Ignore assigned penalty ➔ Easier to detect
  - Follow assigned penalty ➔ No throughput gain

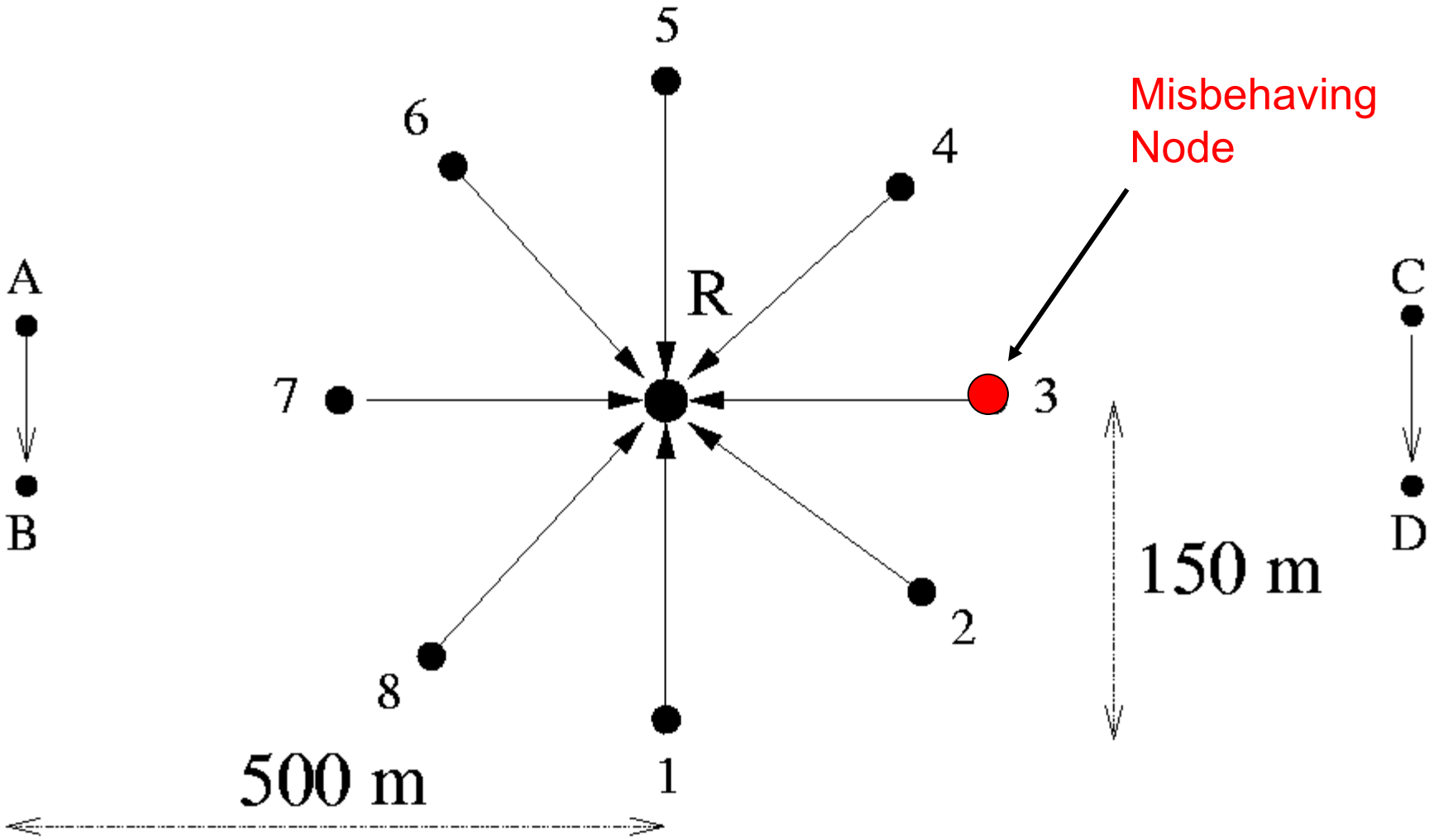
Diagnosing Misbehavior

- Total deviation for last W packets used
  - Deviation per packet is $B - B_{obsr}$
- If total deviation > THRESH then sender is designated as misbehaving
- Higher layers/ administrator can be informed of misbehavior

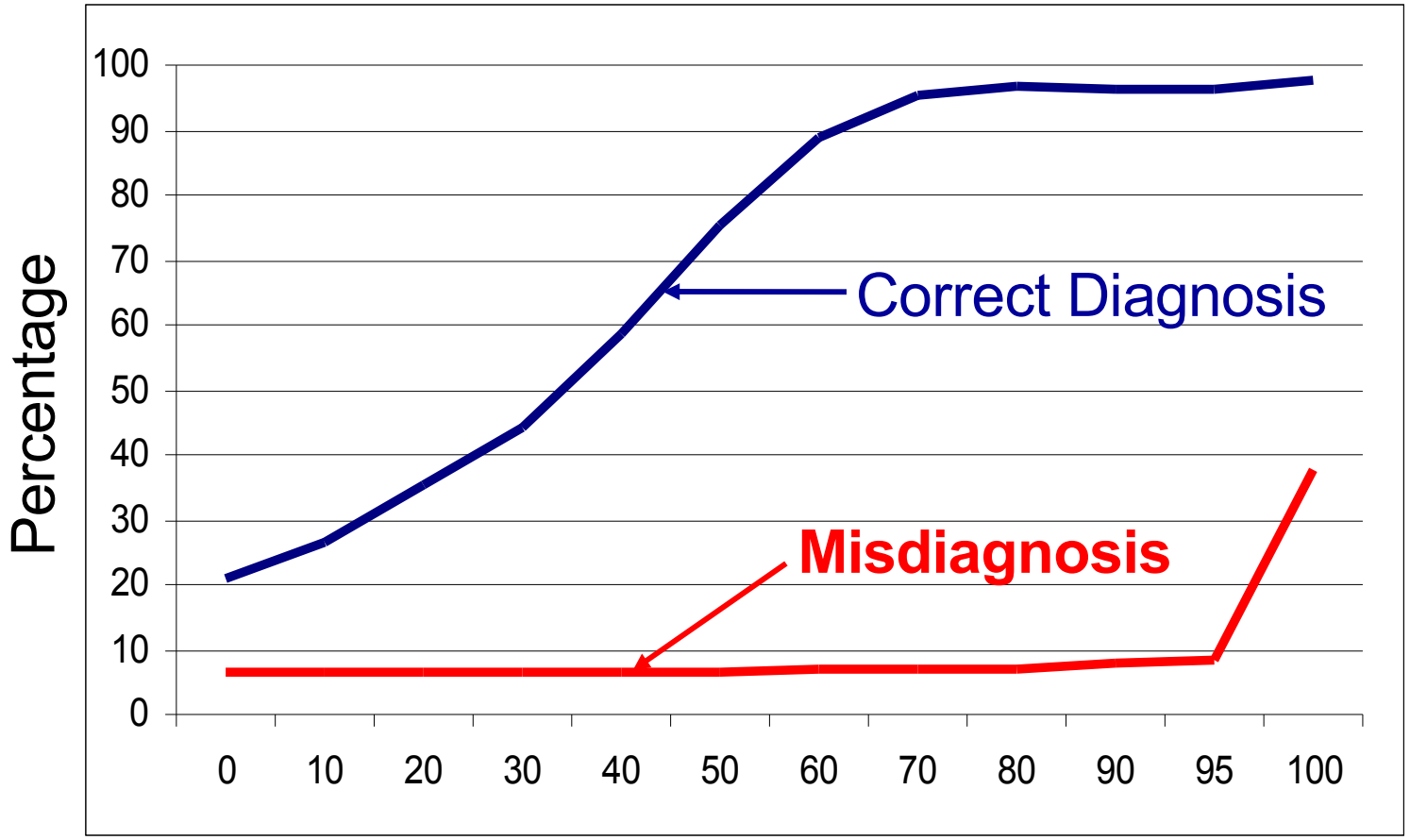
Simulation Results

- Using ns-2 simulator
- Misbehavior modeled by parameter – "Percentage of Misbehavior (PM)"
  - PM = 0% ➔ well-behaved
  - Larger PM ➔ greater misbehavior
- Results for one receiver, multiple senders with single misbehaving sender

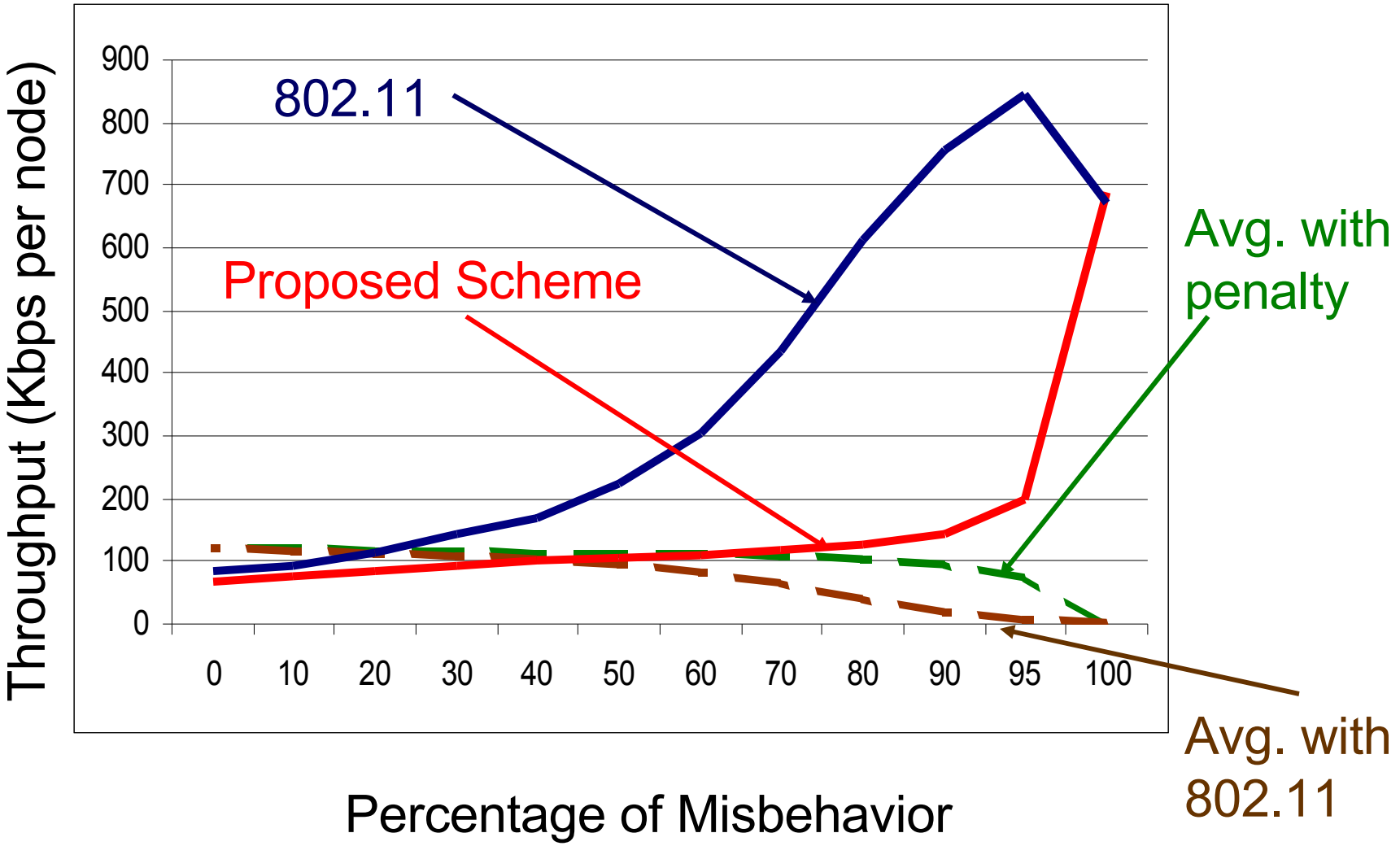
Simulation Setup



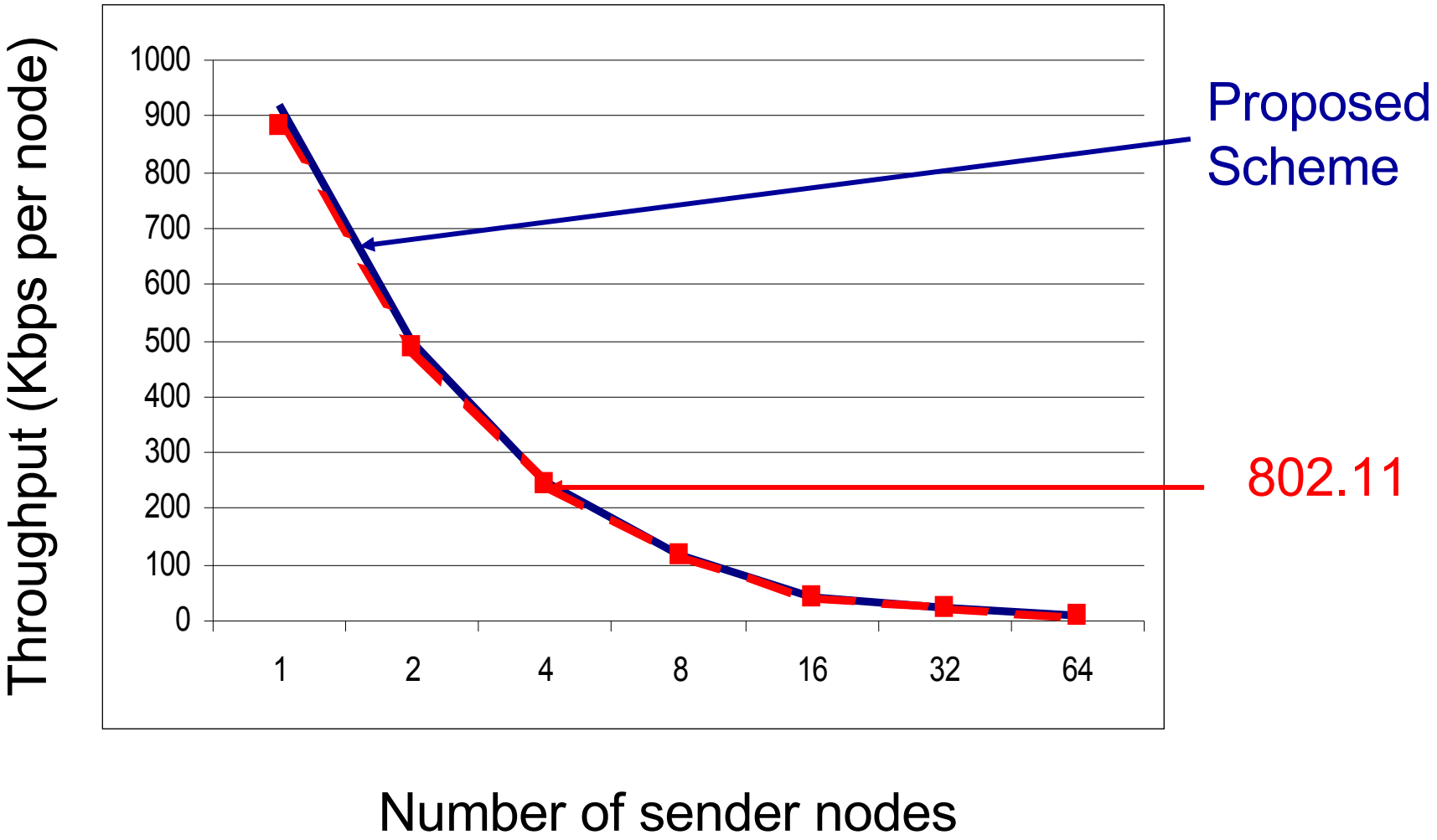
Results – Diagnosis Accuracy



Misbehaving node throughput



Throughput – no misbehavior



Simulation Observations

- Diagnosis accuracy is high
  - Diagnosis accuracy depends on channel conditions
  - Persistent misbehavior detected with high accuracy
- Adding penalty negates throughput advantage
  - Can discourage misbehavior

Additional details in paper

- Mechanisms to address protocol response after packet collisions
- Extensions for catching certain receiver misbehavior
- Preliminary ideas for addressing collusion

Conclusion

- MAC layer misbehavior can severely affect throughput of well-behaved nodes
- We present simple modifications to IEEE 802.11 to detect/penalize misbehavior
- Open issues:
  - Collusion detection
  - Integrate diagnosis scheme with higher layers

Thanks!

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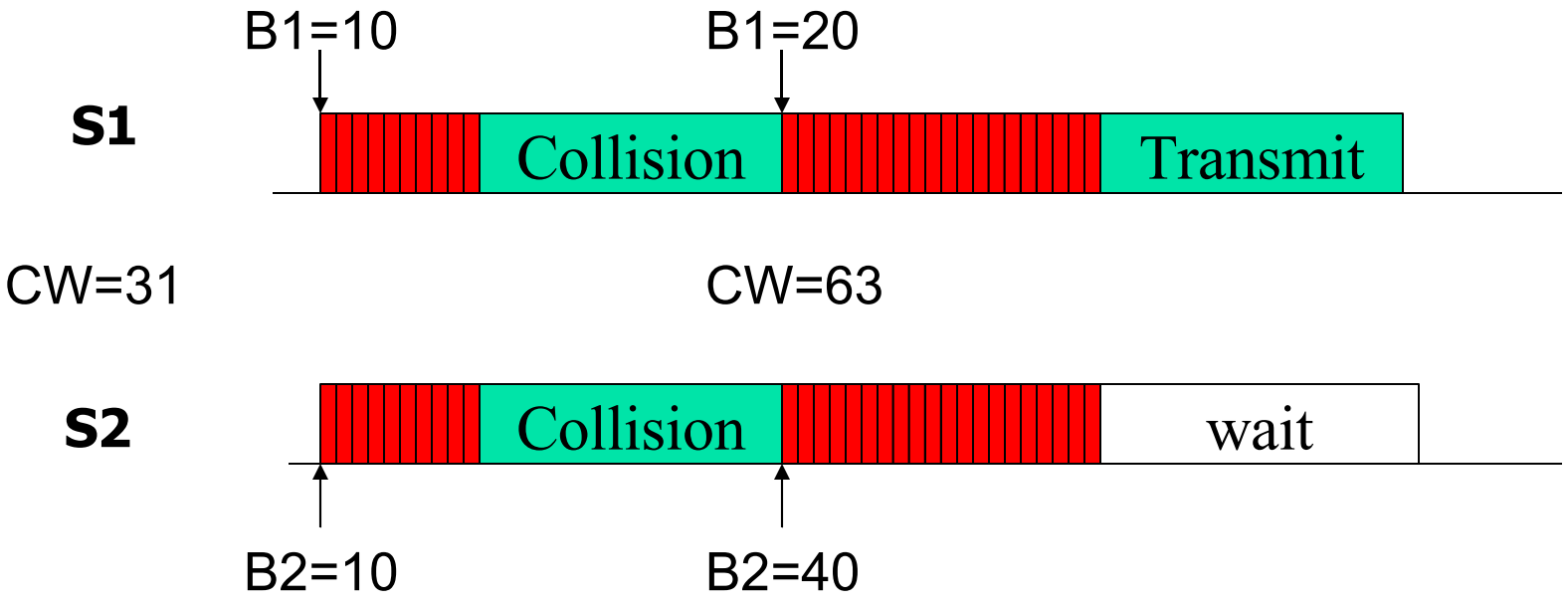
References

- [Savage99] TCP Congestion Control with a misbehaving receiver
- [Nisan99] Algoithms for Selfish Agents
- [Buttyan01] Stimulating Cooperation in Self-Organizing Mobile Ad Hoc Networks
- [Marti00] Mitigating Routing Misbehavior in Mobile Ad hoc Networks
- [Zhang00] Intrusion Detection in wireless ad hoc networks
- [Buchegger02] Nodes Bearing Grudges: Towards Routing Security, Fairness and Robustness in Mobile Ad Hoc Networks
- [Hu02] Ariadne: A secure on-demand routing protocol for ad hoc networks
- [Konorski01] Protection of Fairness for Multimedia Traffic Streams in a Non-cooperative Wireless LAN setting
- [MacKenzie01] Selfish users in Aloha: A Game-theoretic Approach
- [Konorski02] Multiple Access in Ad Hoc Wireless LANs with Noncooperative stations

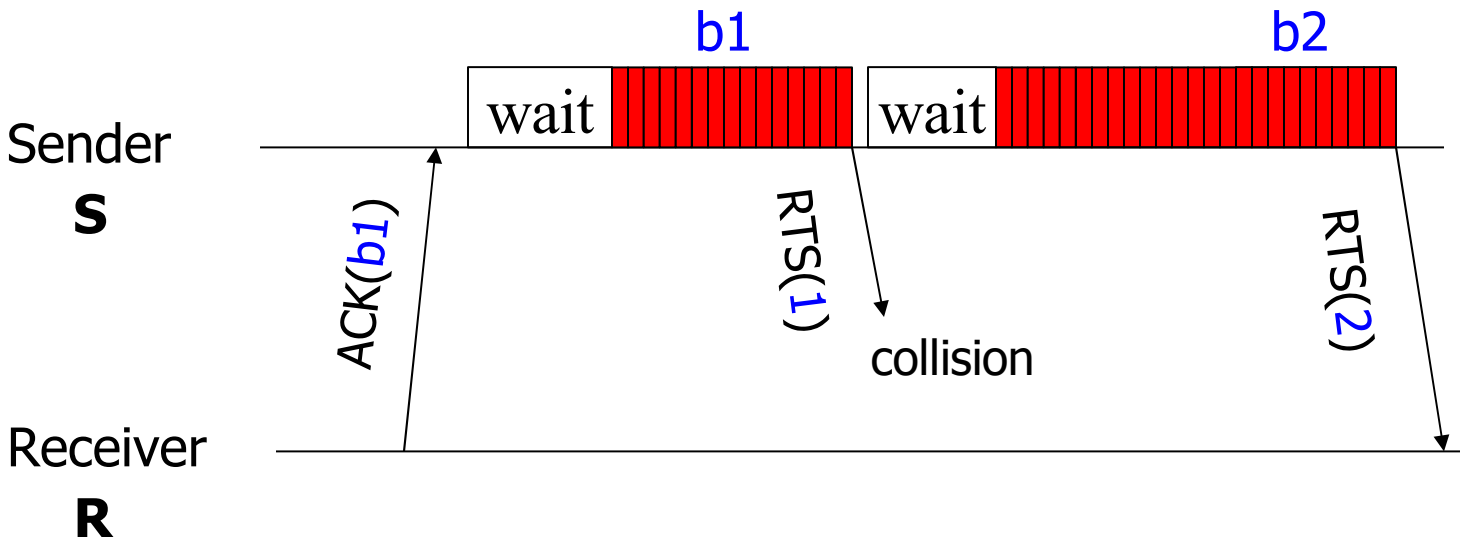
- Extra Slides follow ....

Collision Example

- On collision double CW
  - Binary exponential backoff algorithm
- Pick new backoff and send again



Modifications to 802.11



1. On collision new backoff b2 is

   b2 = f(b1, nodeId of S, attempt number)

2. RTS contains attempt number

Handling other misbehavior (1/2)

- Receiver may misbehave by assigning large or small backoff values
- Sender can detect receiver assigning small backoff values
  - Backoff assigned by receiver has to follow well-known distribution
  - Sender uses larger of assigned backoff and expected backoff

Handling other misbehavior (2/2)

- Detecting receiver assigning large backoff values not handled
  - Equivalent to receiver not responding at all
  - Need higher layer mechanisms
- Collusion between sender and receiver
  - Harder to detect
  - Requires third party observer

Simulation Metrics

- Correct Diagnosis percentage
- Misdiagnosis Percentage
- Average throughput of well-behaved nodes
- Misbehaving node throughput

Fairness - no misbehavior