Congestion Avoidance Based on Lightweight Buffer Management in Sensor networks

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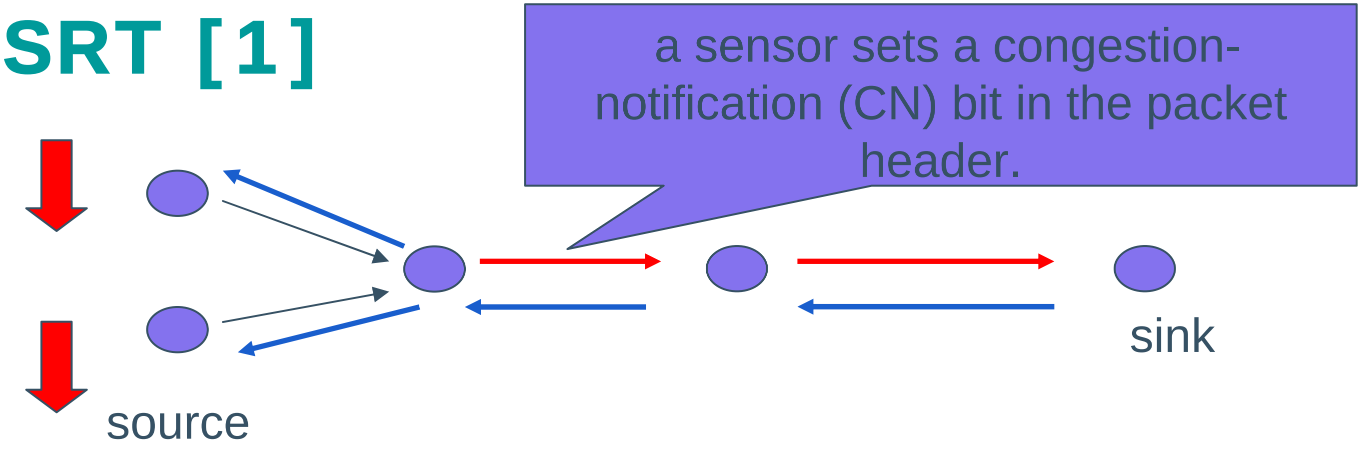
Contents

Introduction

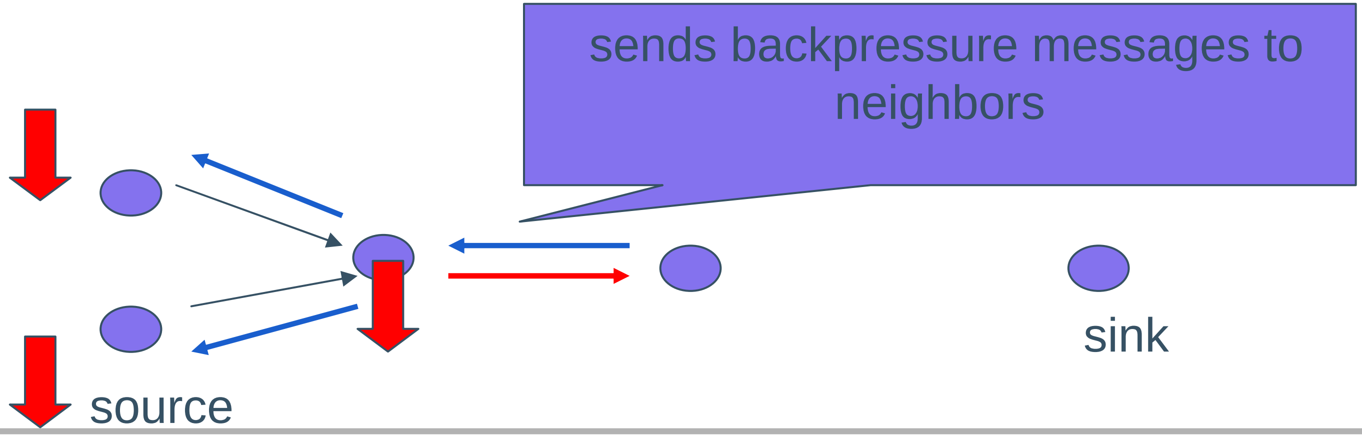
- When a sensor receives more data than it can forward, the excess data has to be buffered.
- **Congestion** occurs when the limited data has to be buffered.
- **Congestion control** studies how to recover from a congestion.
- **Congestion avoidance** studies how to prevent congestion from happening.

Rate-based Congestion Control

- **ESRT [1]**



- **CODA [2]**



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Buffer-Based Congestion Avoidance

Network Model

- A sensor network consists of a set of sensors and a set of base stations (also called sinks).
- There exists a neighbor discovering protocol.
- There exists a MAC protocol, e.g. based on CSMA.
- The sensors are statically located after deployment.
- It makes no difference which particular sink a packet is delivered.
- All data packets have the same size.

Basic Scheme

- The key for congestion avoidance is to make sure that a sensor y sends a packet to another sensor x only when **x has the buffer space to hold the packet.**

- To keep the neighbors of x updated with the x's buffer size, whenever x sends out a packet, **it piggybacks its current buffer state in the frame header.**

Basic Scheme

- **Consider a sensor y that is one of the neighbor sensors of x.**
  - When y receives or overhears a packet to forward x, it caches the buffer state of x.
  - Only if x's buffer is not full, y forwards the packet. Otherwise ,y withholds the packet until it overhears a packet from x, piggybacking a nonfull buffer state.

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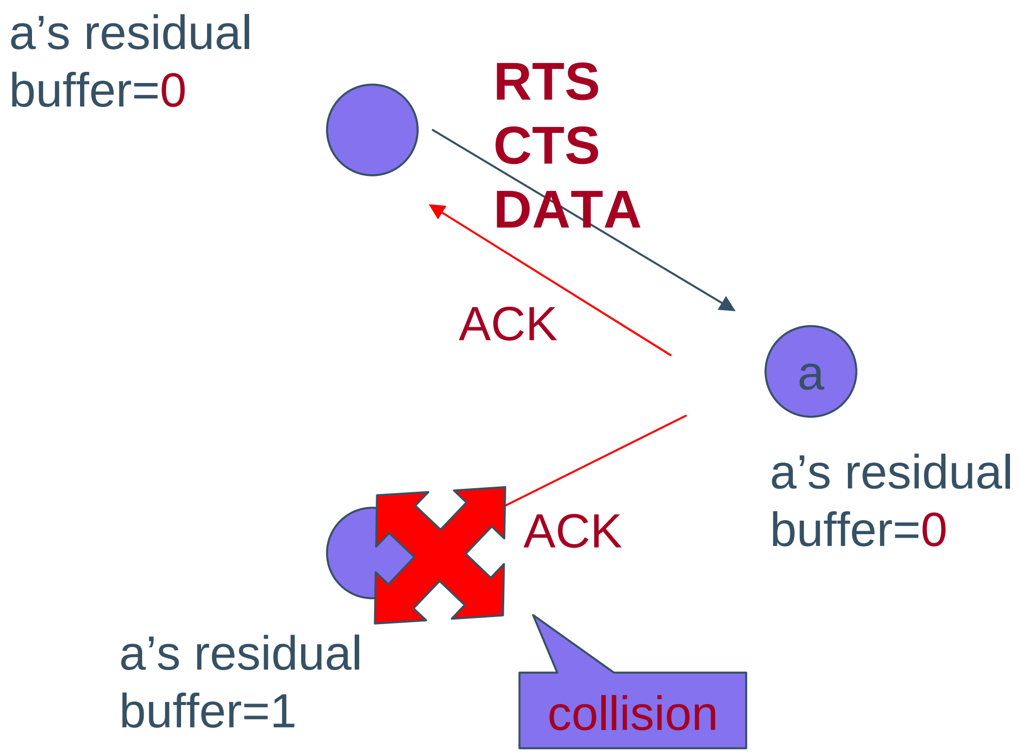
Implement the Basic Scheme with Various MAC Protocols.

CSMA/CA and CSMA with ACK

- Data transmission requires RTS-CTS-DATA-ACK exchange between two neighboring sensors.
- One bit in each packet is used to piggyback whether the sender's buffer is full.
- When a sensor y that is the neighbor sensor of x overhears a frame from x, it caches the residual-buffer size of x.
- Only if x's buffer is not full, y forwards the packet. Otherwise

CSMA/CA and CSMA with ACK



CSMA with Implicit ACK

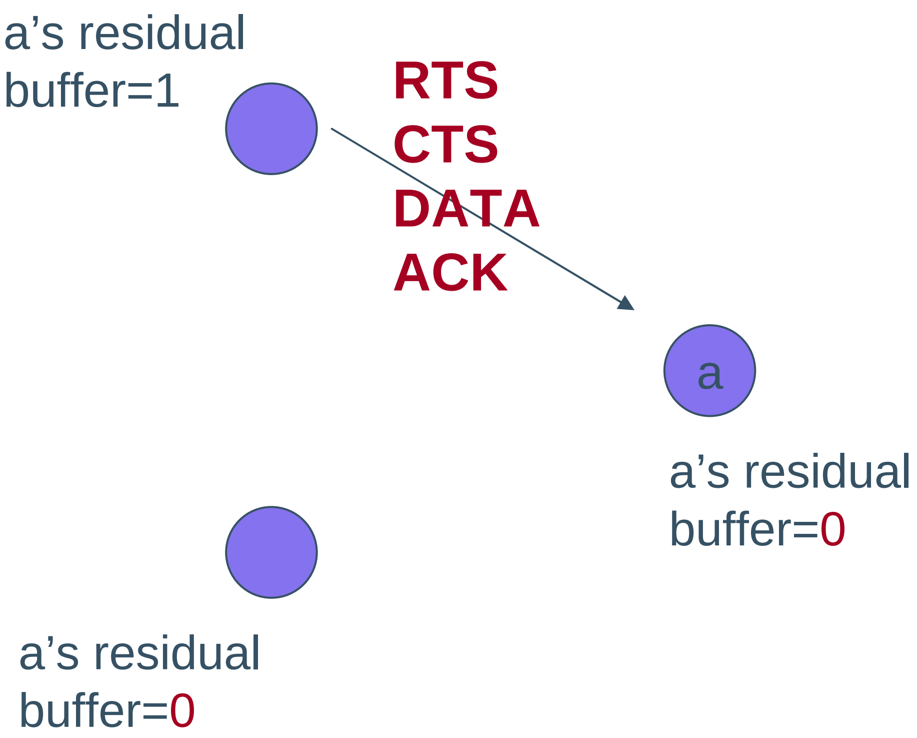
- When the media contention level is not high ,CSMA can be reduced to DATA packets only for the purpose of energy efficiency.

- One approach of implementing implicit ACK is for data packets to carry an one-byte acknowledgement field in their headers

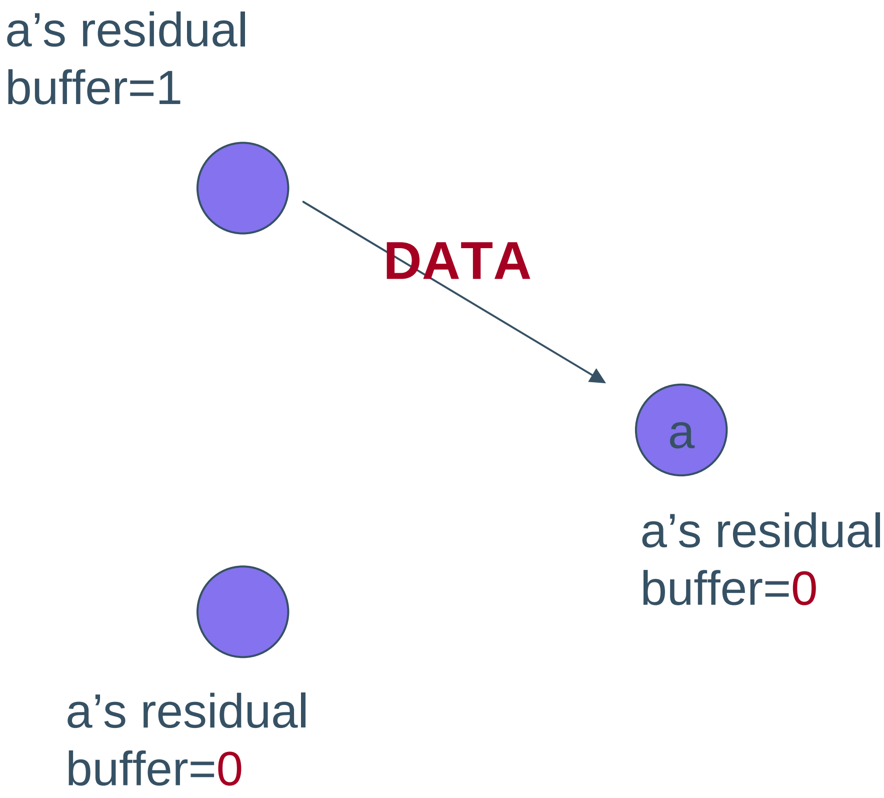
CSMA with Implicit ACK

- When a sensor x sends out a DATA packet. It piggybacks its residual-buffer in the frame header.
- When a sensor y that is the neighbor sensor of x overhears a frame from x, it caches the residual-buffer size of x.
- When y overhears a packet that is sent by another sensor to x, it reduces the residual-buffer size of x by one.

CSMA/CA and CSMA with ACK



CSMA with implicit ACK



The Hidden-terminal problem of CSMA with implicit ACK

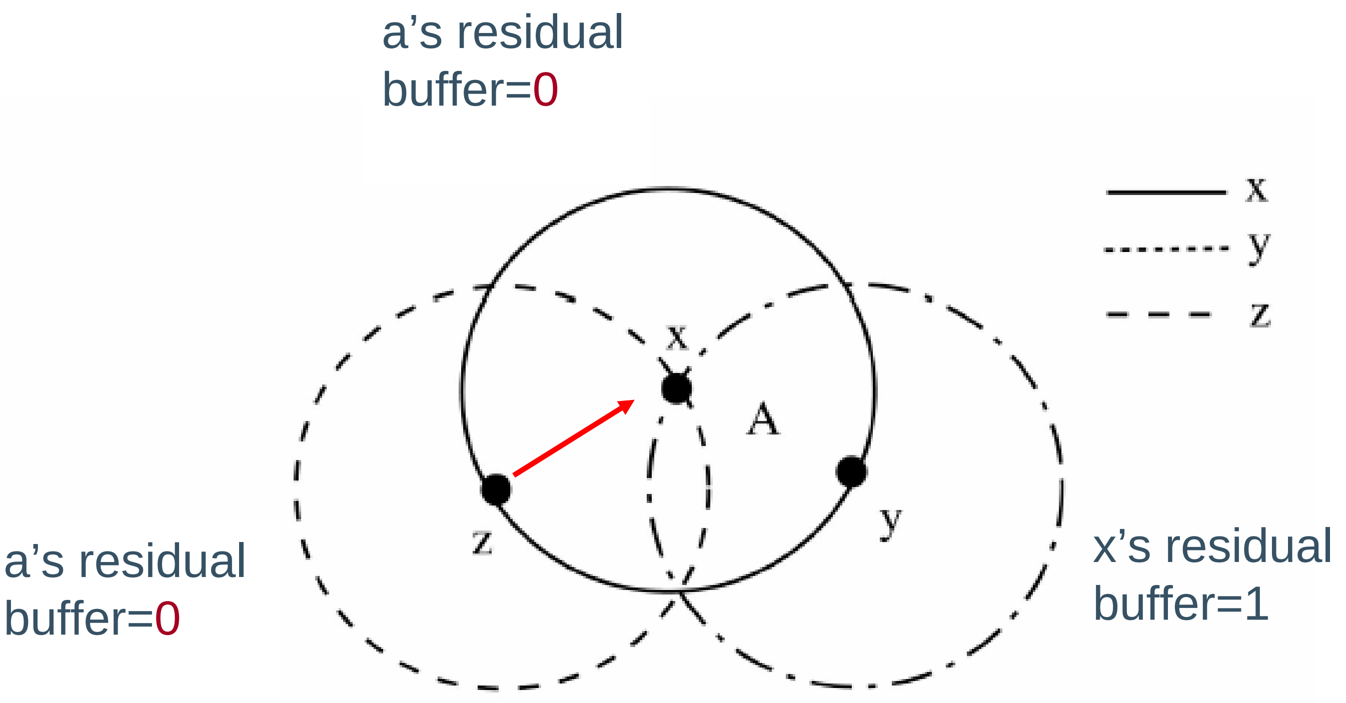
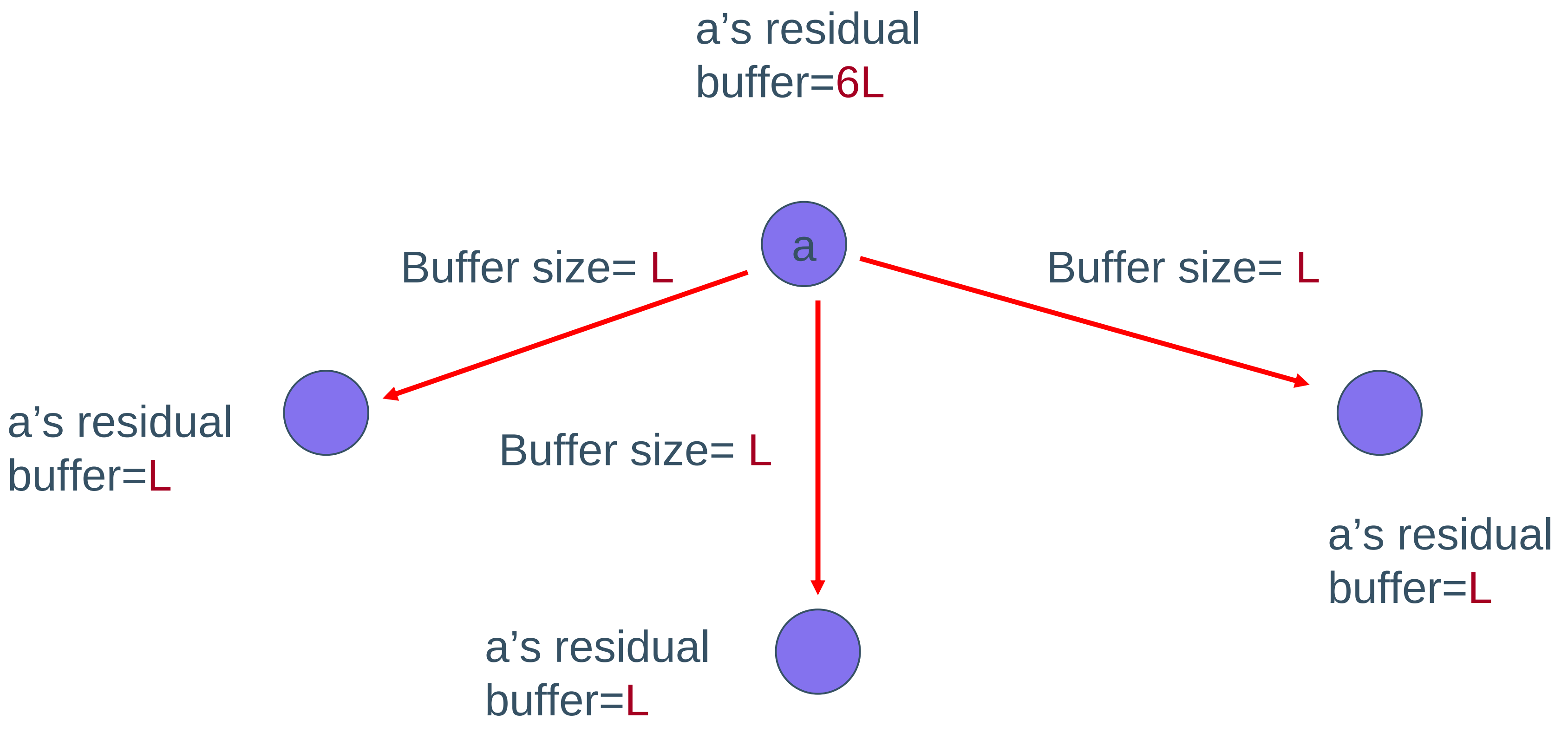
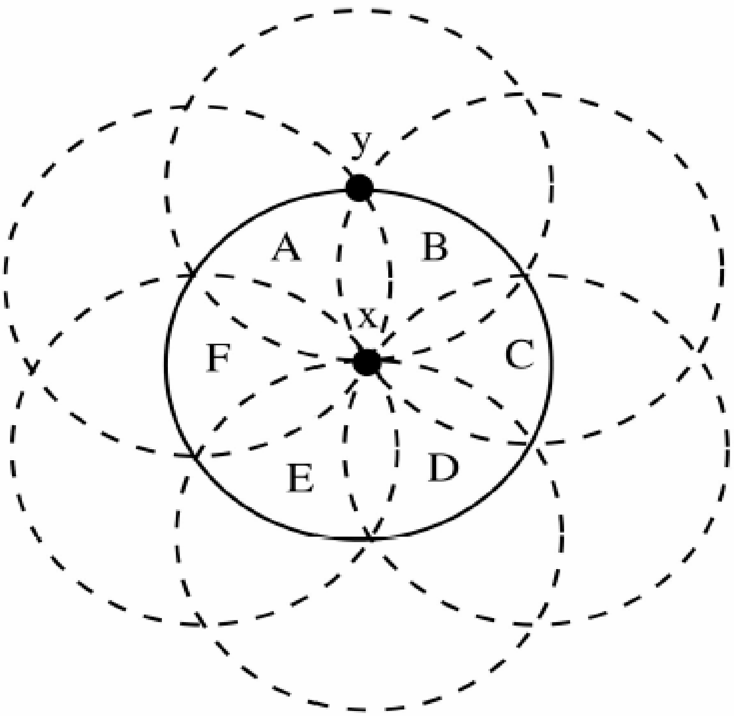


Fig. 2. Hidden-terminal problem.

1/6-buffer Solution for the Hidden-terminal problem



Theorem 1. *Suppose all sensors have the same circular transmission range. Hidden terminals do not cause buffer congestion when the* 1/6-buffer *solution is used.*



Adaptive 1/k-buffer Solution

- In reality, the radio transmission range is highly irregular.
- To handle the general case, an adaptive 1/k-buffer solution is used.

Adaptive 1/k-buffer Solution

- If there is no buffer overflow for a long time, the sensor concludes that K is set too conservatively and it **reduces** k by one.

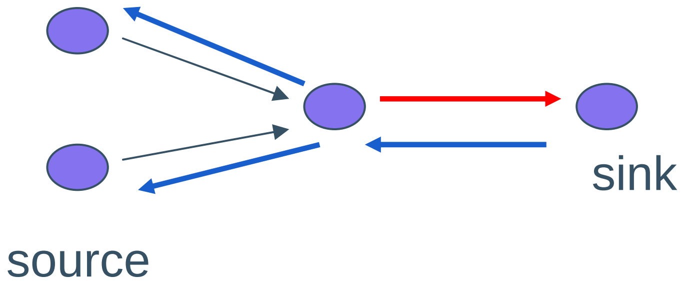
- Whenever there is buffer overflow, the sensor knows that K is set too aggressively and it **increases** k by one.

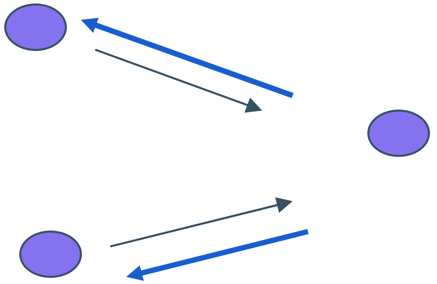
- The idea is to dynamically adjust k to **a minimum value** that does not cause buffer overflow.

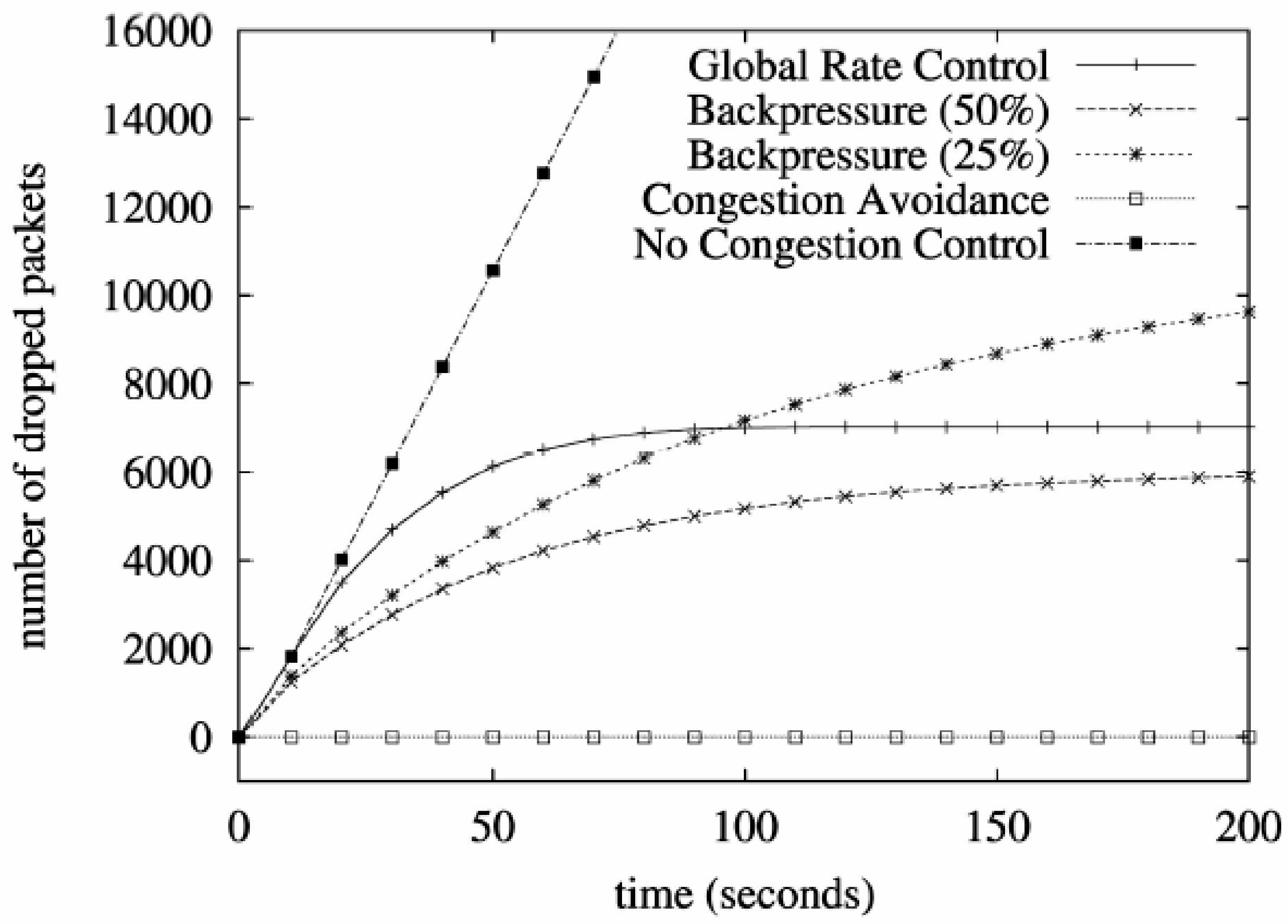
5 Simulation Results

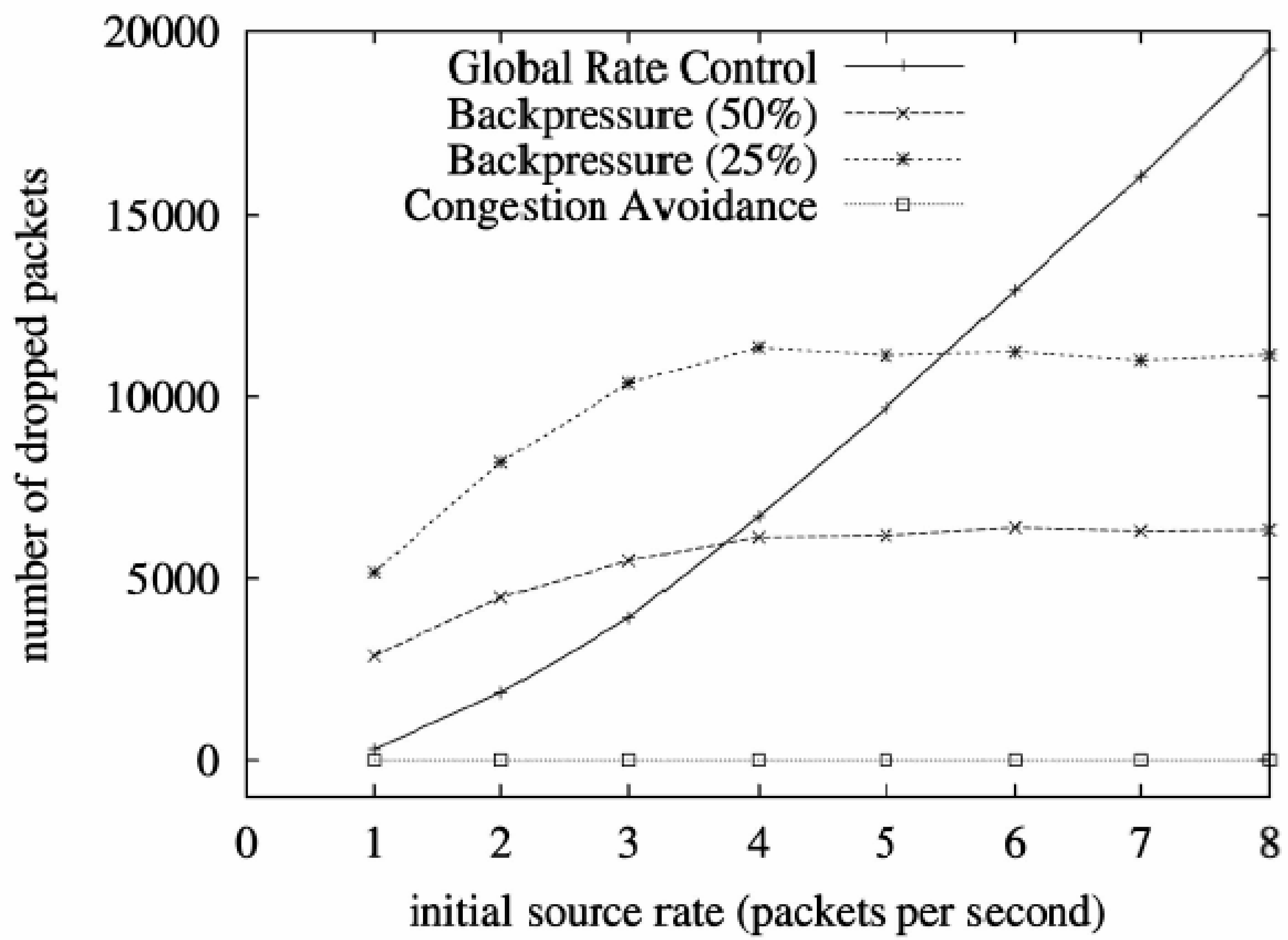
❖ **The following four congestion control / avoidance schemes are implemented:**

- Global Rate Control
- Backpressure
- Congestion avoidance
- No congestion control

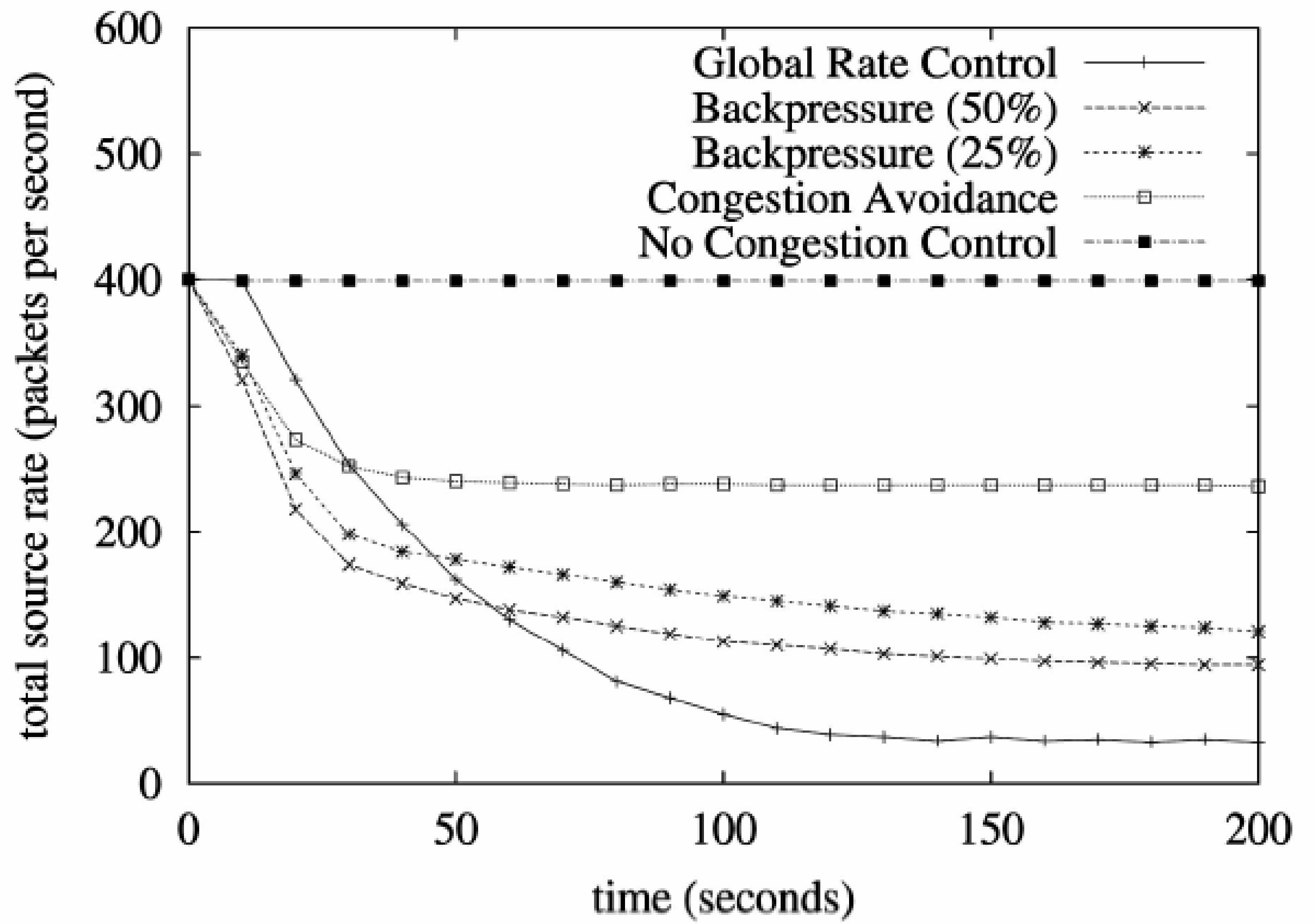


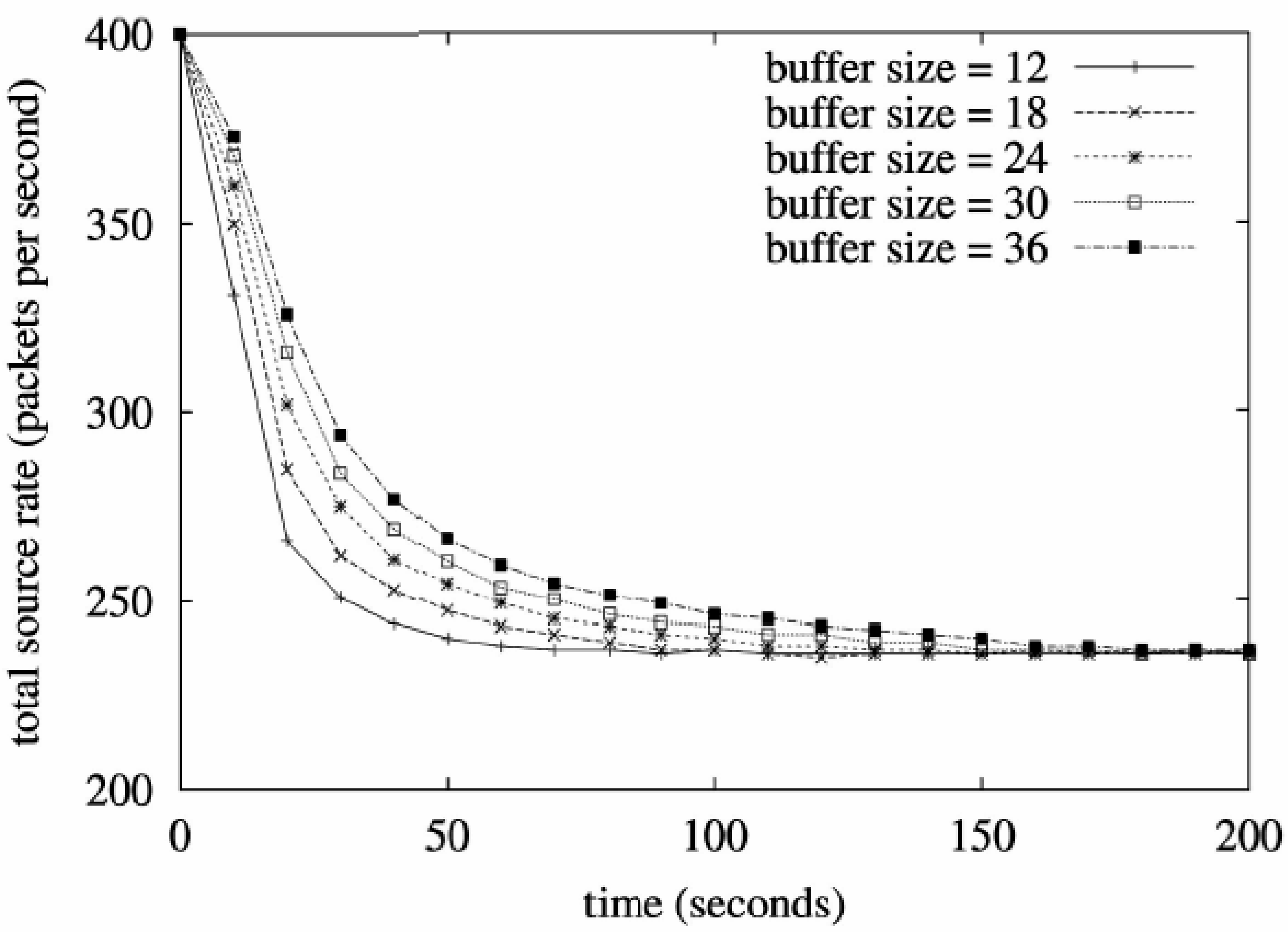



Global Rate Control
Backpressure (50%)
Backpressure (25%)
Congestion Avoidance
No Congestion Control
number of dropped packets
16000
14000
12000
10000
8000
6000
4000
2000
0
0
50
100
150
200
time (seconds)



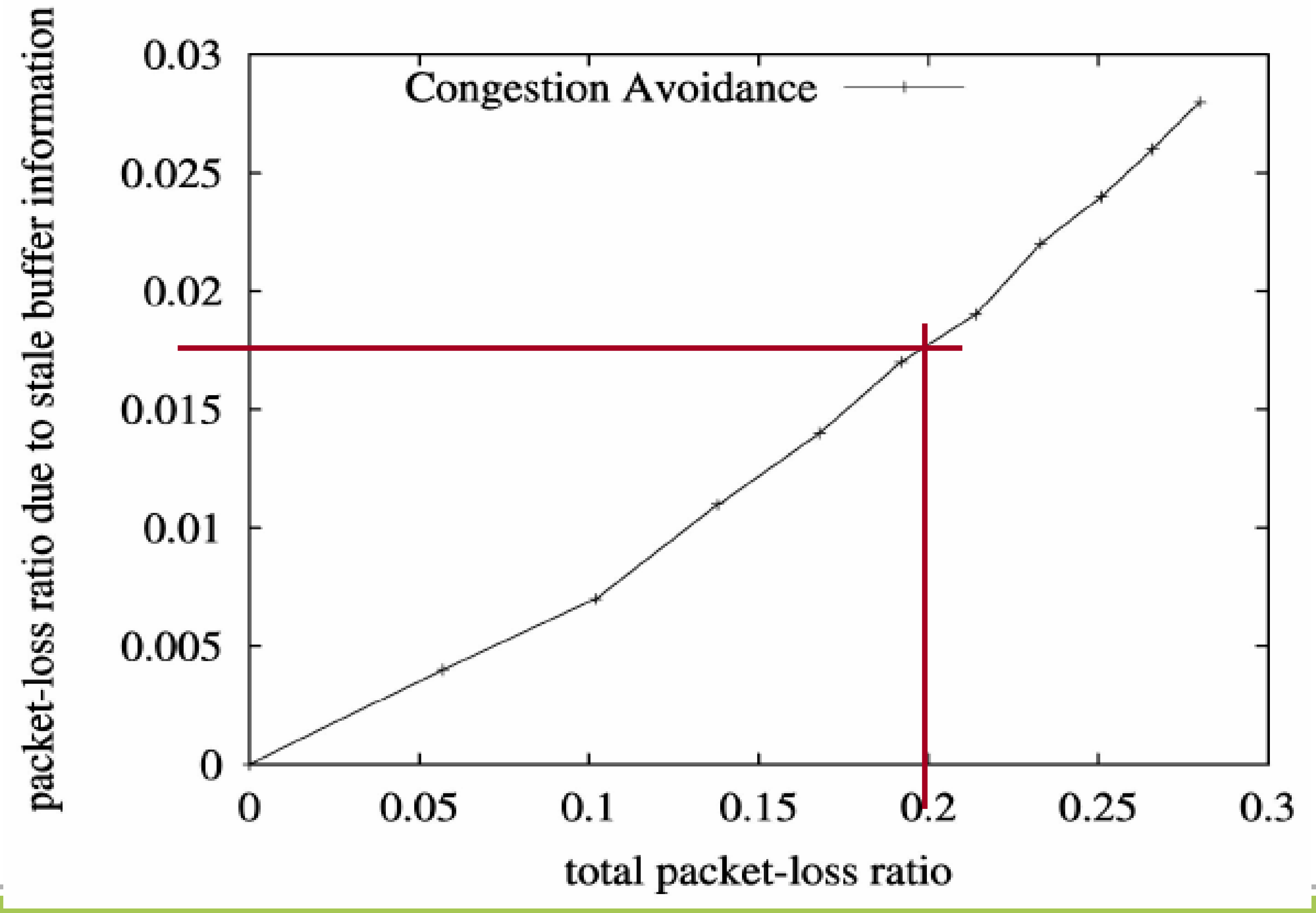
Global Rate Control
Backpressure (50%)
Backpressure (25%)
Congestion Avoidance
20000
15000
10000
5000
0
0
1
2
3
4
5
6
7
8
number of dropped packets
initial source rate (packets per second)


Global Rate Control
Backpressure (50%)
Backpressure (25%)
Congestion Avoidance
No Congestion Control
total source rate (packets per second)
time (seconds)
0
100
200
300
400
500
600
0
50
100
150
200



buffer size = 12
buffer size = 18
buffer size = 24
buffer size = 30
buffer size = 36
400
350
300
250
200
total source rate (packets per second)
0
50
100
150
200
time (seconds)

Impact of Failed Overhearing



Conclusion

- This paper proposes a buffer-based congestion avoidance scheme.
- It shows how to implement such a scheme with various MAC protocol.
- For CSMA with implicit ACK, the 1/k-buffer solution for the hidden-terminal problem is proposed.

References

- [1] Y. Sankarasubramaniam, O. Akan, and I. Akyildiz, “ESRT: Eventto-Sink Reliable Transport in Wireless Sensor Networks,” Proc.Fourth ACM Symp. Mobile Ad Hoc Networking and Computing(MobiHoc ’03), June 2003.

- [2] C.-Y. Wan, S.B. Eisenman, and A.T. Campbell, “CODA: Congestion Detection and Avoidance in Sensor Networks,” Proc. ACMSenSys ’03, Nov. 2003.

Thank You !