MAC Considerations in (Vehicular) Ad Hoc Networors

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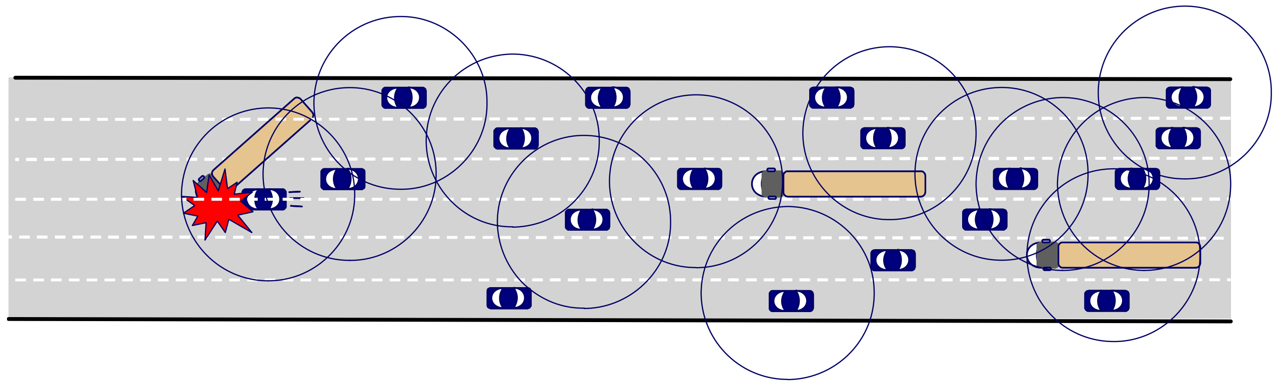
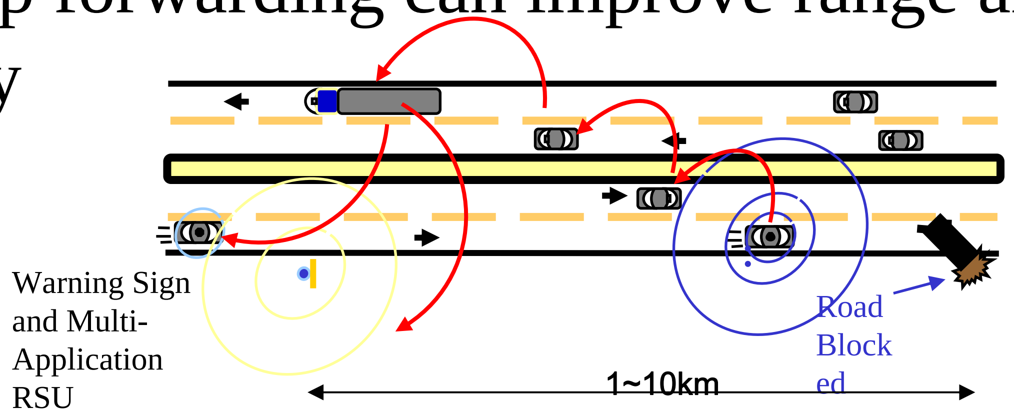
WIRELESS INFORMATION NETWORK LABORATORY

Automotive Safety Applications

- Extended Electronic Brake Light (EEBL)



- Multi-hop forwarding can improve range and reliability



Compelling Intelligent Transportation System Applications

- Vehicular networks likely driver for deployment of wireless ad hoc and sensor systems
  - Compelling application scenarios: Vehicular accidents account for ~40,000 fatalities/yr (in US)
  - FCC approved spectrum for Dedicated Short Range Communications
  - IEEE 802.11p will standardize MAC for vehicular environment
  - Challenging requirements: high velocity, low-latency environment, privacy, security, reliability

Key Applications:

- Automotive safety
  - Obstacle/slow-traffic-ahead warning
  - Red-light warning
  - Active Collision Avoidance
- Congestion Management
  - Real-time traffic information
  - Navigation traffic-aware travel time optimization
  - Improved information for traffic engineering

Add-on Applications:

- Entertainment
  - Video, Web, Gaming
- Efficient Pricing and Payment
  - "Pay-as-you-drive" insurance
  - Highway tolls
  - Gas station paymetns
- Point-of-Interest Queries
  - Finding nearby hotels, gas stations; travel guides, local entertainment
- Fleet management
  - Tracking fleet of company vehicles

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Challenge 1: Association procedure changes in 802.11p draft standard

- Change in association procedure
  - Beacons are replaced by WAVE announcement messages
  - Supports more transient associations
- Multichannel MAC
  - Channel 178 reserved as control channel, only 6Mbps is used.
- Provides QoS control through EDCA parameters (from 802.11e QoS)
  - Also available on the Atheros cards used in testbed

MAC Challenges

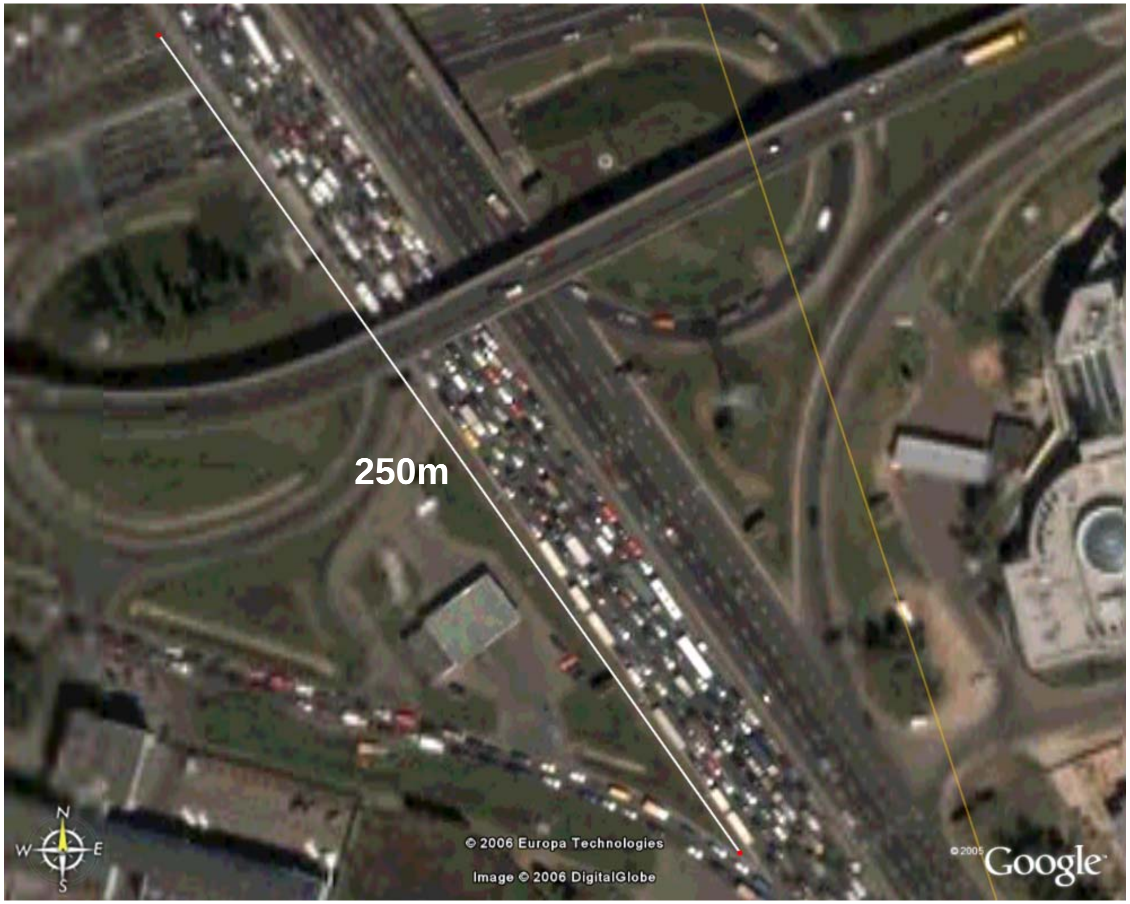
- High relative speeds ~150mph
  - Discovery: Short association times
- Large numbers of nodes ~100 million
  - Highly localized communication
  - 1-3 hops
- Group communication rather than unicast
  - Efficient geocast primitives
- Scalability: High and highly variable node densities

802.11p Background

- PHY and MAC for WAVE (Wireless Access in Vehicular Environments)
  - Outdoor environments
  - High mobility with closing speeds up to 280 km/h.
  - Low latency (emergency / safety applications)
- MAC / PHY Features
  - OFDM PHY and MAC adopted with slight modifications from 802.11a PHY
- Higher available transmission power
  - Max allowed amplifier power output is 750 mW.
  - Nominally EIRP of 33 dbm (omni-directional)
  - EIRP of 44.8 dbm (directional antennae) for public safety applications.
  - Power used depends on the distance the message is to be transmitted and the speed of the transmitter.

Challenge: High node densities

- Warning messages must be reliably delivered in both low and high density scenarios
- High density scenario:
  - 100 vehicles broadcasting EEBL messages



Analytical model

- Predicts goodput of <50 packets/s for >50 nodes due to collisions
- 802.11 saturation throughput model from "Performance Analysis of the IEEE 802.11 Distributed Coordination Function", G. Bianchi, IEEE Journal On Selected Areas in Communications (JSAC), vol. 18, No. 3, March 2000
  - Modified for broadcast transmissions
    - no SIFS, ACKs, retransmissions and exponential backoff
    - All frames use 6Mbps
  - 66-byte payload (128-byte MAC frame)
  - Saturated channel, RTS/CTS off, CWmin = 16

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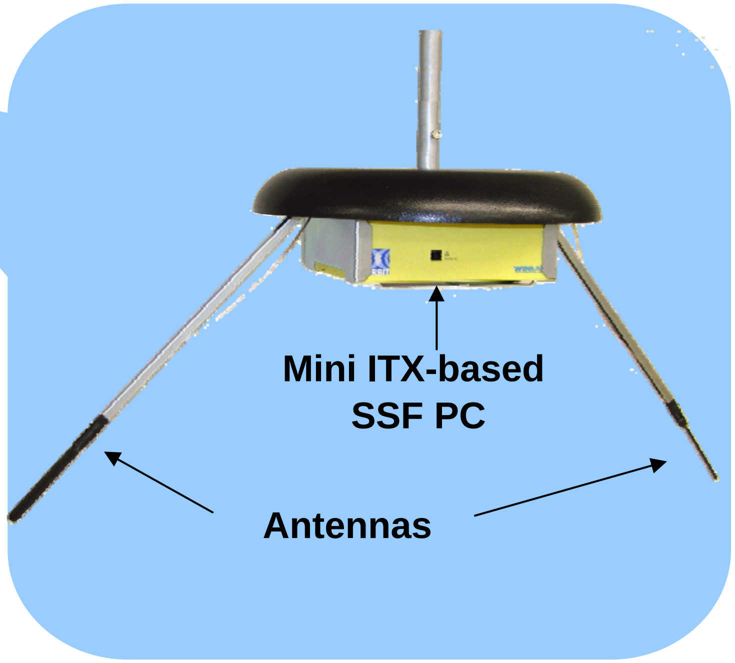
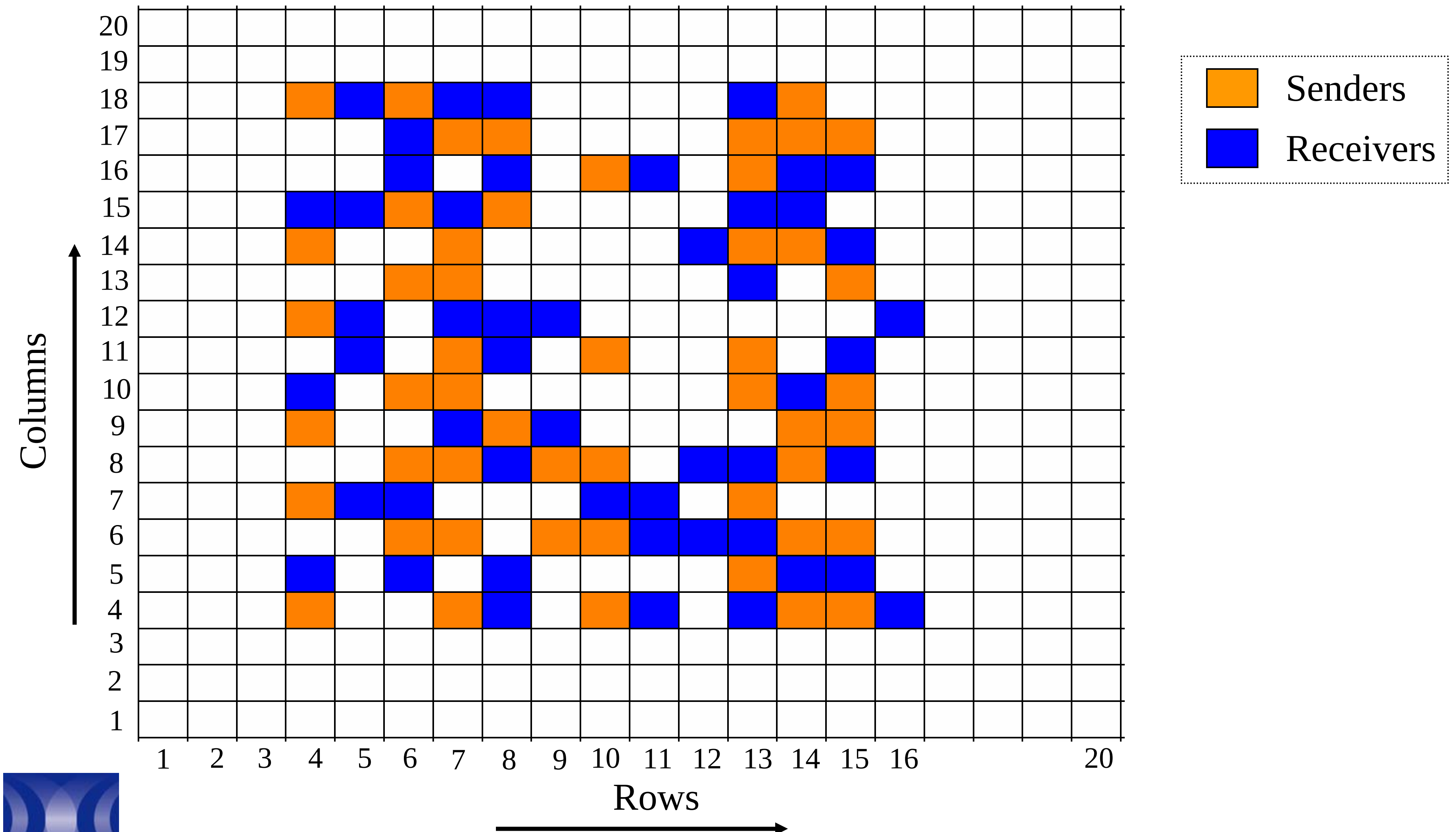
**Thanks to Haris Kremo (WINLAB) for the MATLAB implementation*

Experimental MAC Scalability Analysis

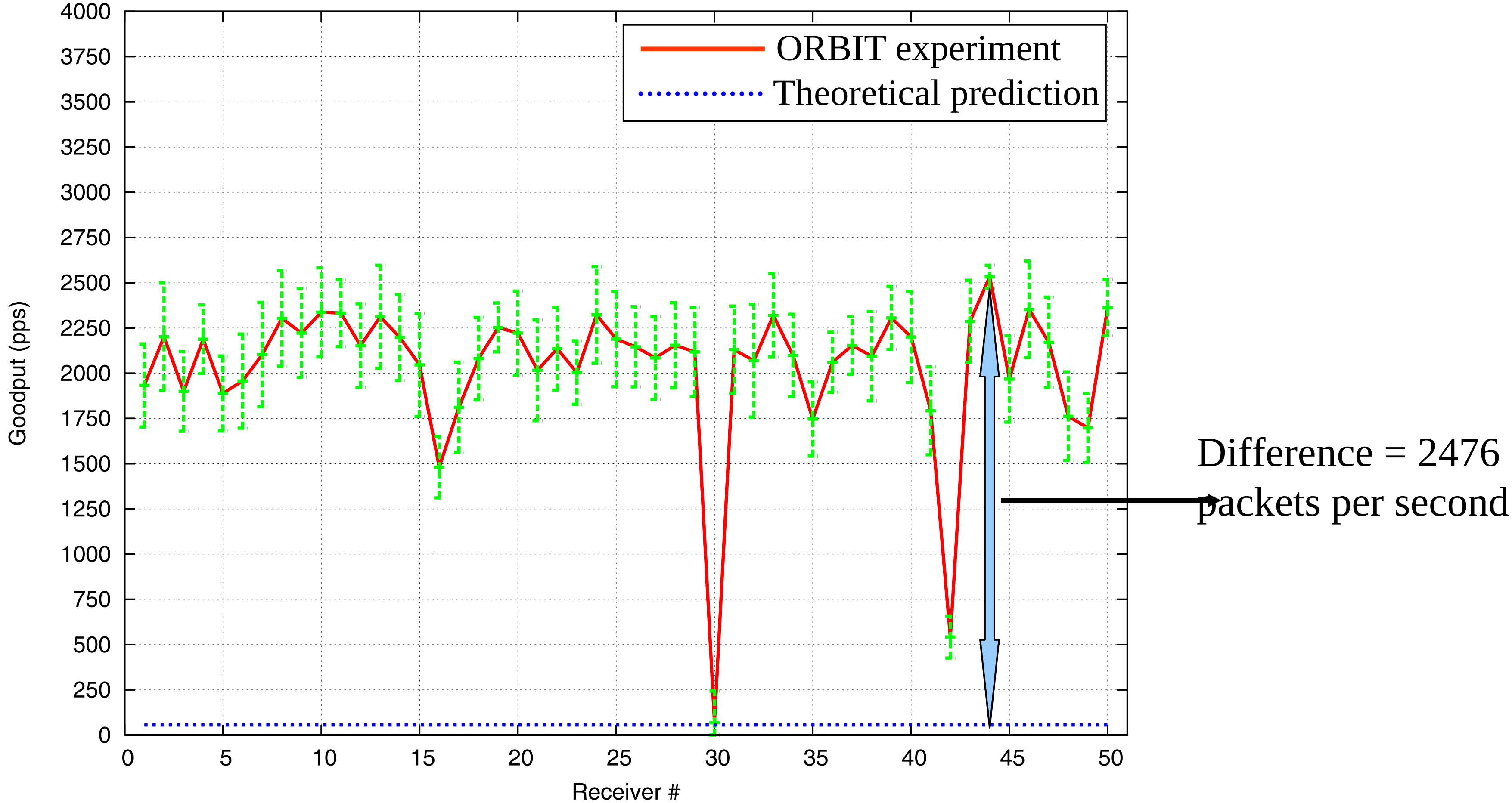


- ORBIT: 400 nodes in 20m x 20m– two 802.11 radios each (atheros and intel-based)
- Experiment: Measure per node goodput in saturation for different numbers of senders

50 senders, 50 receivers (node positions)

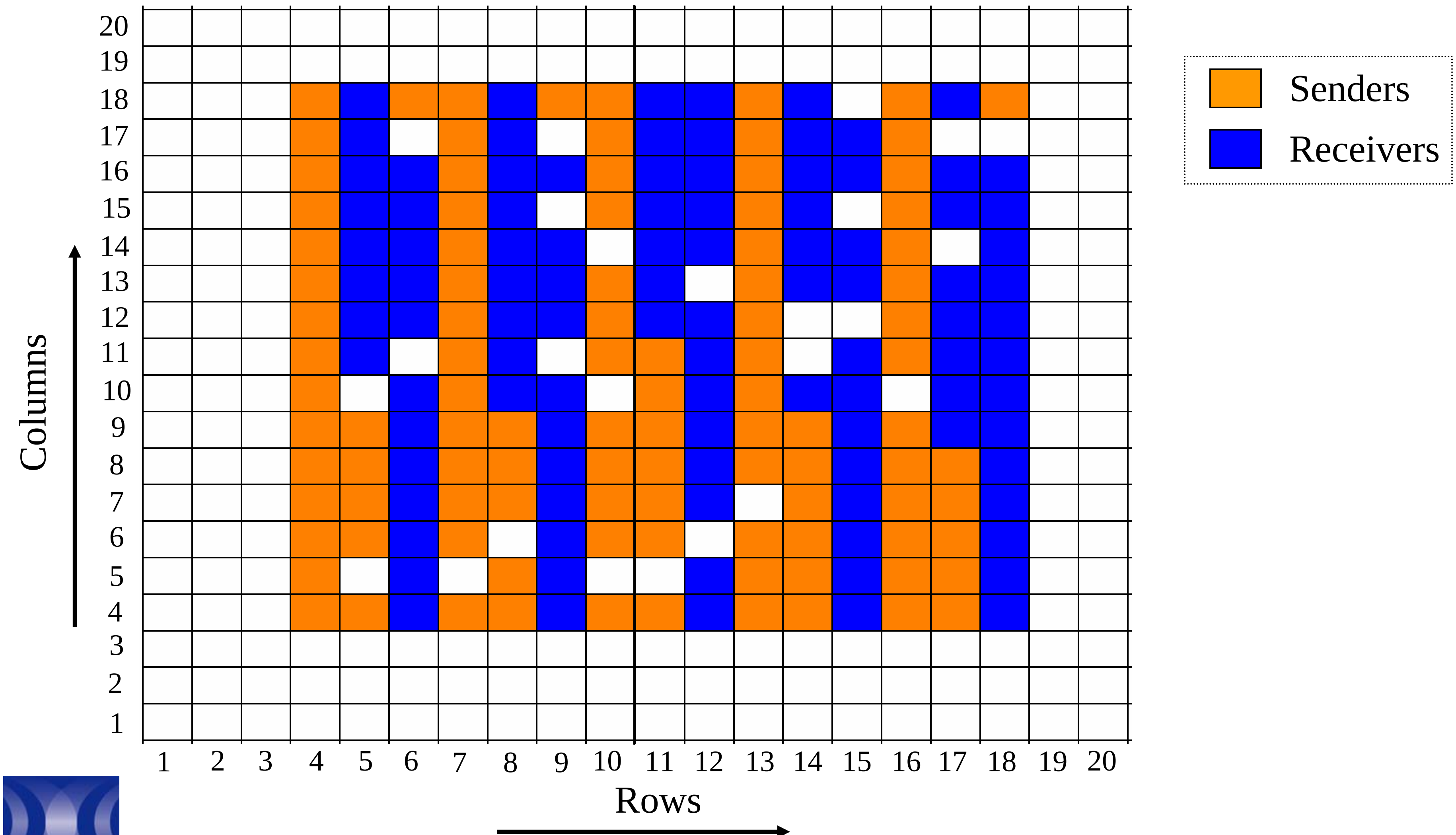


50 senders, 50 receivers (cumulative throughput)

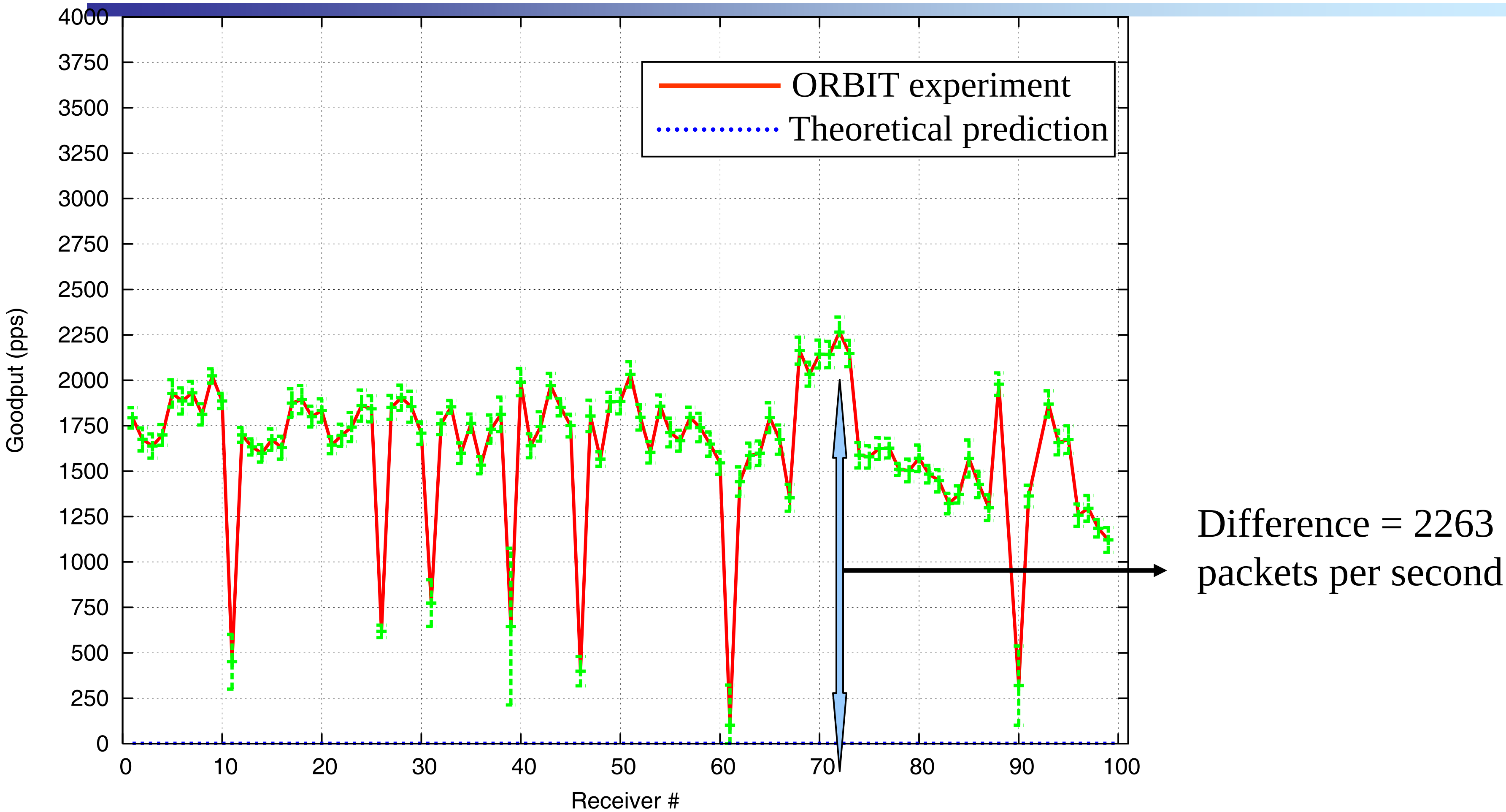


- Plot shows average and standard deviation in packets received per second at each receiver.

100 senders, 100 receivers (node positions)

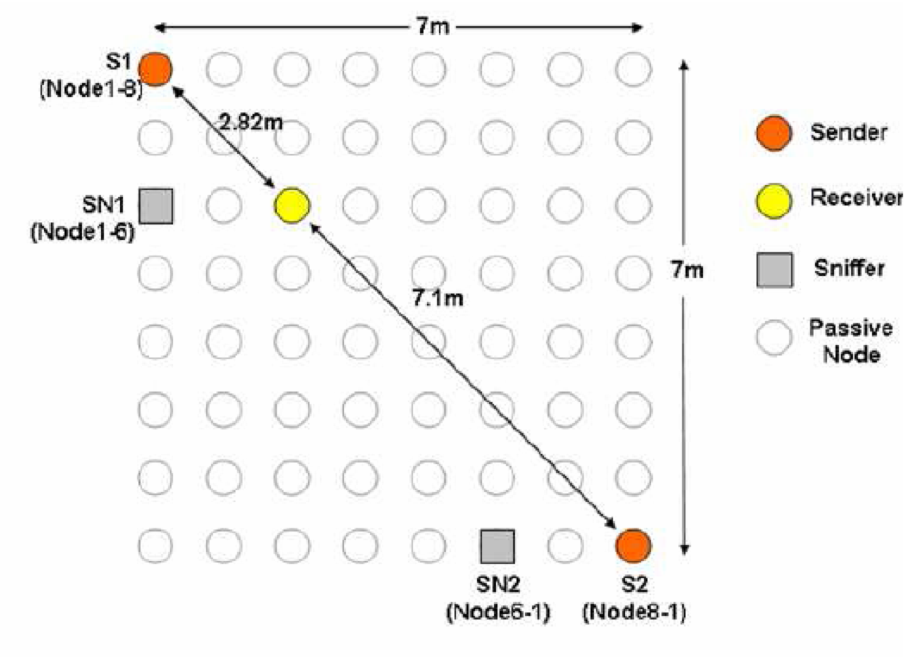


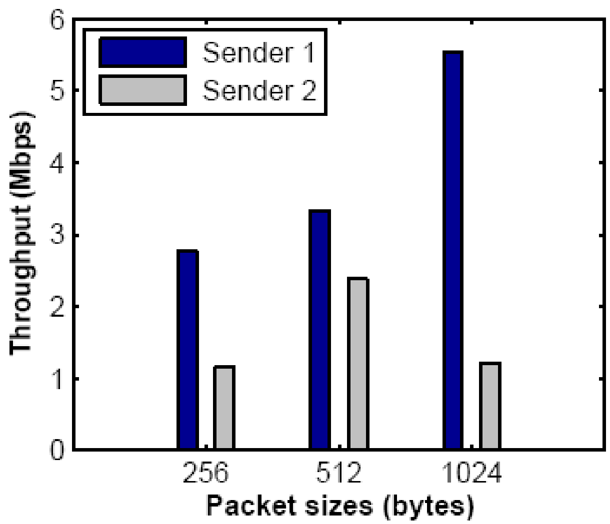
100 senders, 100 receivers (cumulative throughput)



- Plot shows average and standard deviation in packets received per second at each receiver.

Effect of capture on throughput fairness





- Multiple backoffs at weaker sender due to collisions
  - Throughput unfairness

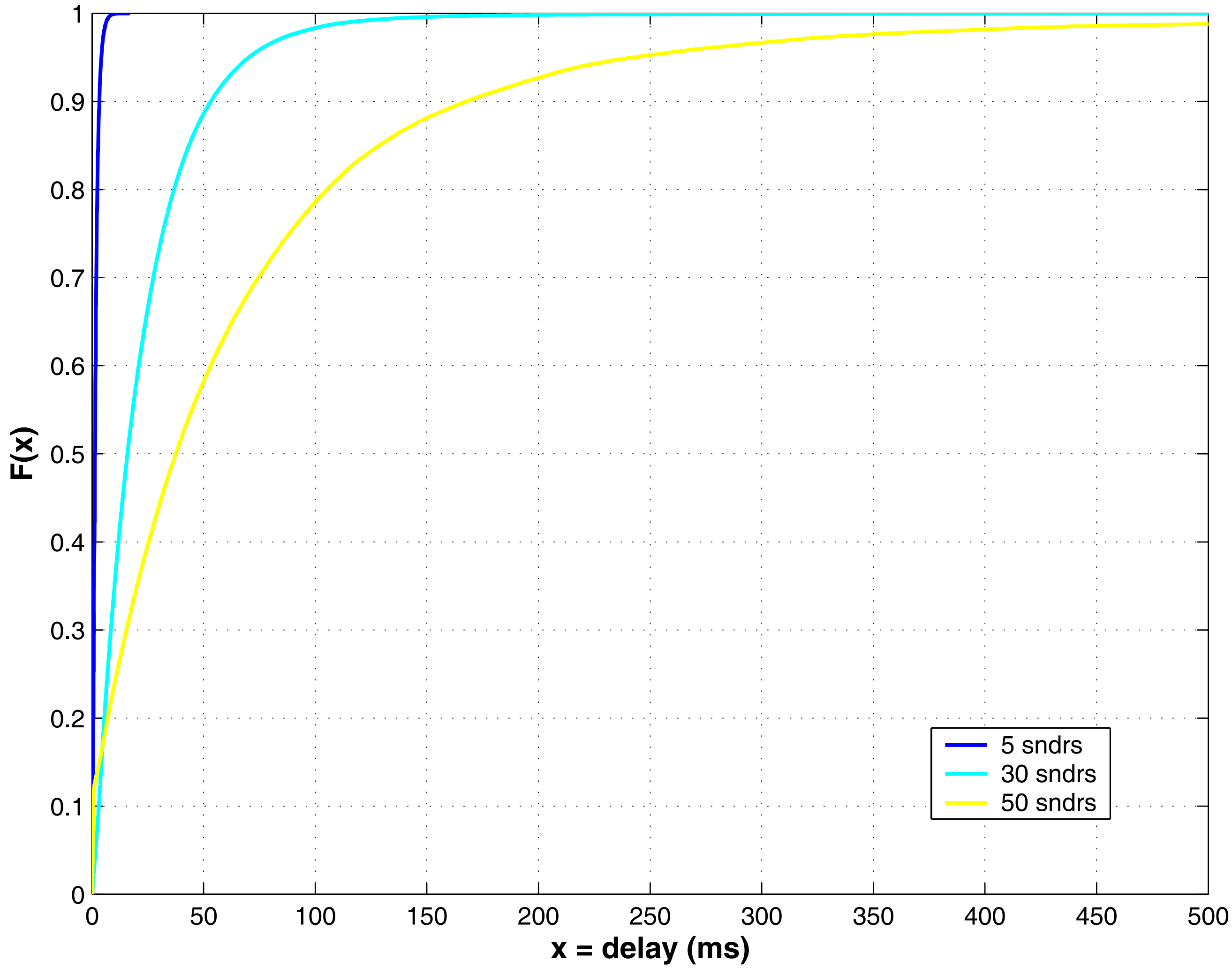
Constructing global timeline

Time	Frame Type	Frame Size	Source IP Address	Destination IP Address	Seq. No.
737856416	Data	1088	192.168.1.8	192.168.3.6	476
737856532	Ack	14		192.168.8.1	
737857611	Data	1088	192.168.8.1	192.168.3.6	726
737857612	Data	1088	192.168.1.8	192.168.3.6	477
737857729	Ack	14		192.168.1.8	
737858633	Data	1088	192.168.1.8	192.168.3.6	478
737858749	Ack	14		192.168.1.8	

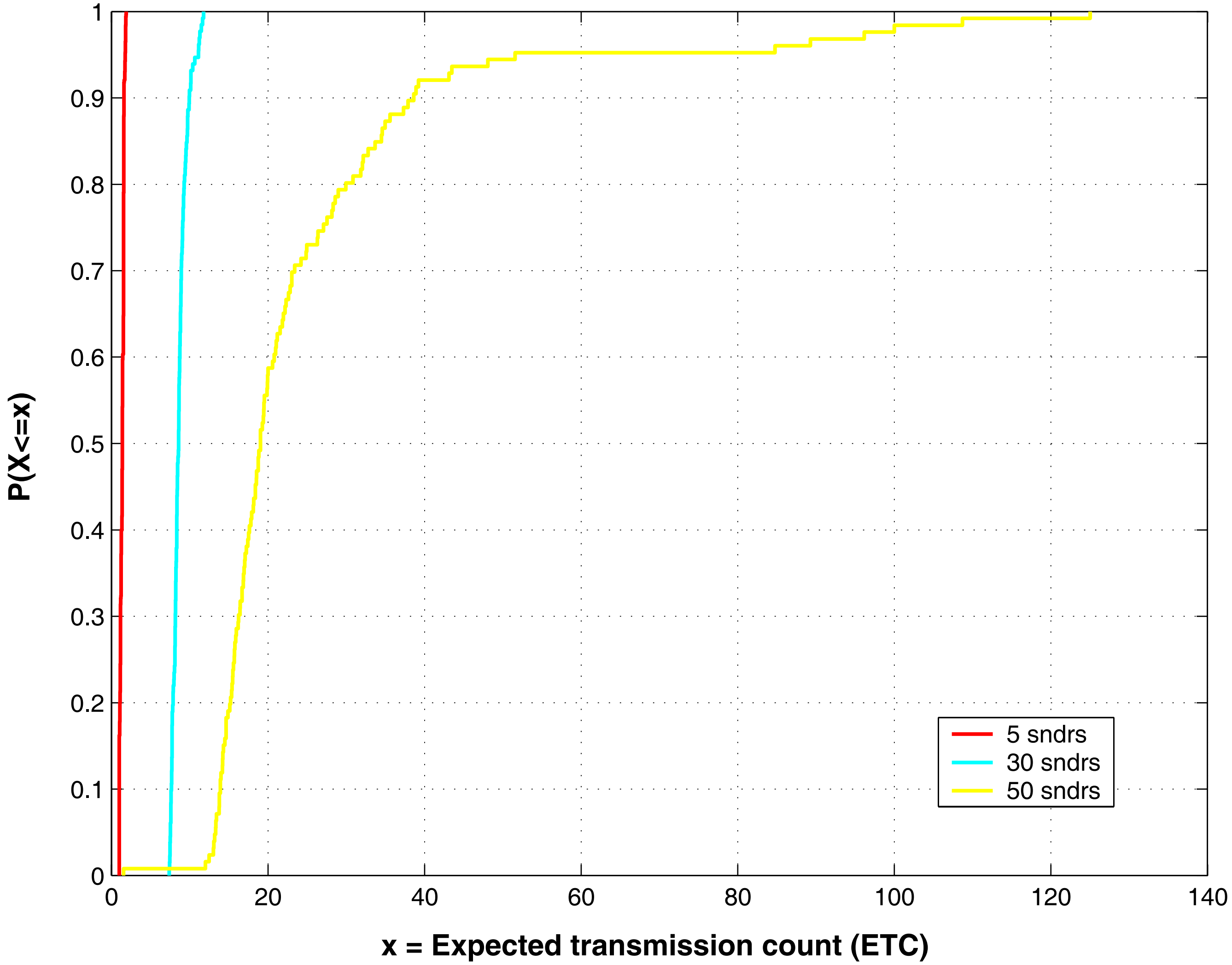
Two data frames seen at the sniffer, 1 µsec apart

ACK sent out by receiver to S1

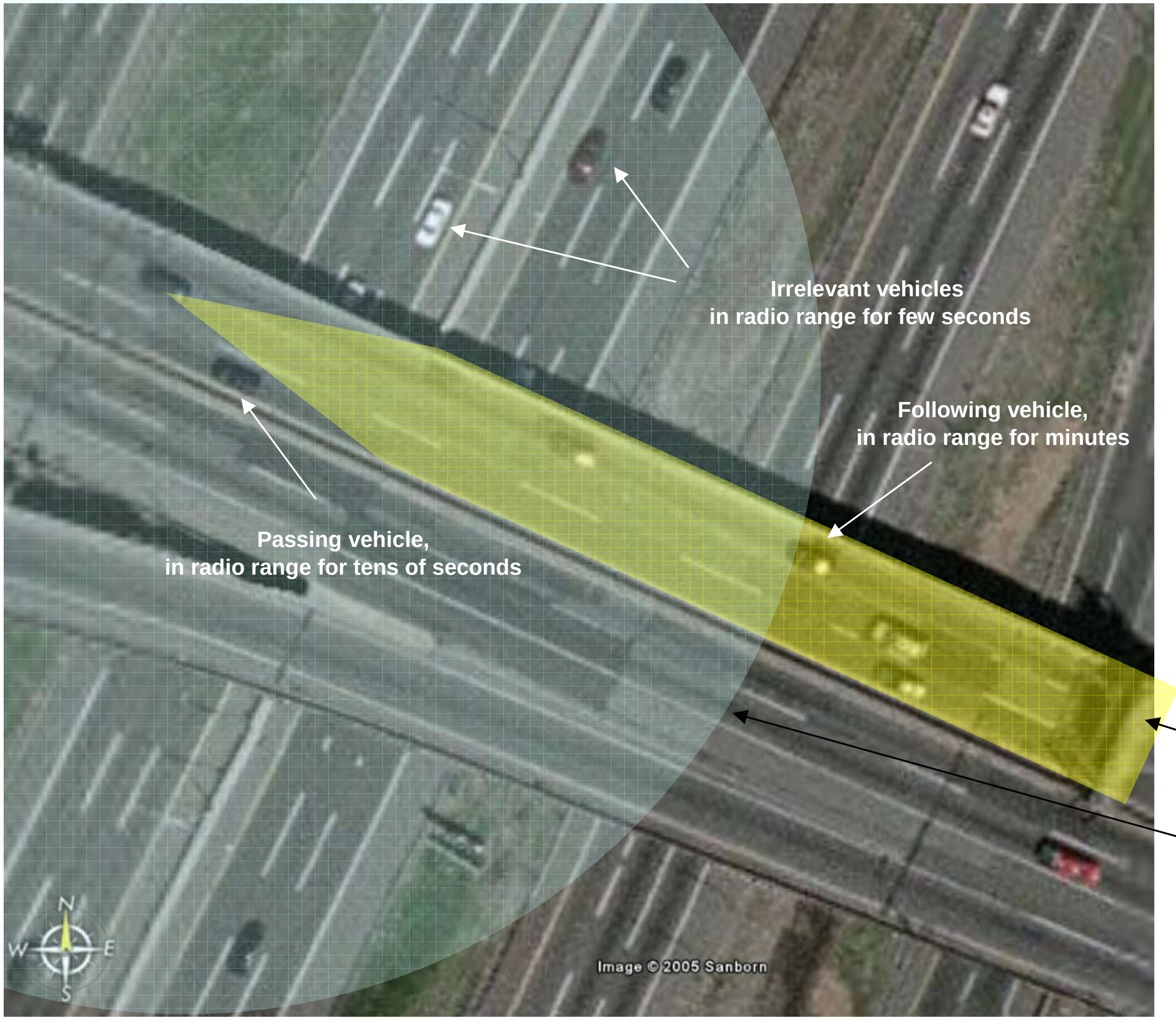
Delay to reach all receivers CDF



Expected transmission count (ETC) CDF



Reliability through collaborative MAC



- Opportunistic message forwarding within geographic perimeter
- Retransmissions from different vehicles
- Location information can help in selection forwarding nodes

Conclusions

- MAC protocols for vehicular ad hoc networks should support loose associations to reduce management frame overhead
- Mac protocols should exploit spatial reuse capture effect)
- MAC layer collaborative forwarding could improve reliability due to spatial diversity