A QoS Routing and Admission Control for 802.11 Ad Hoc Networks

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Motivations and Challenges

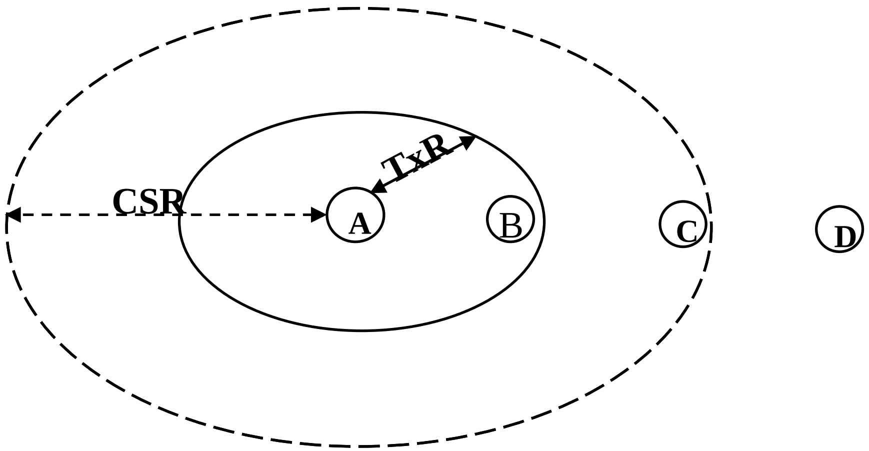
- Higher data rates supported by short-range wireless networking standards enable a variety of new media streaming and distribution applications
- Real-time media streams have specific service quality requirements, e.g.,
  - Stringent bandwidth requirement
  - Delay constraint
  - Packet loss requirement

Goal: to Provide Quality of Service to satisfy the requirements of the media streams

Challenges:

- The open and shared nature of single channel wireless communications
- Different view of channel utilization based on the position in space
- Contention from outside the direct communication range
- No centralized control

Challenges



- Transmission range (TxR) – Neighbors (N), e.g node B

  Carrier sensing range (CSR) -- Carrier-sensing neighbors (CSN), e.g node C

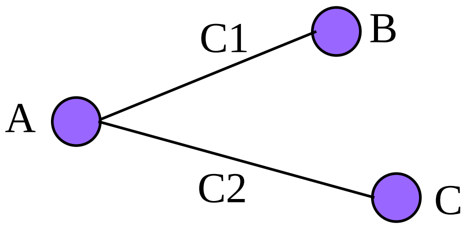
  - extended contention range (C interferes with A)
  - location based contention
  - Intra-flow contention
  - Parallel transmission (A and D do not interfere with each other)

Overview of Our Solutions

- An admission control mechanism integrated with ad hoc routing
  - Admission Control – prevents the network from reaching congestion by rejecting new media streams if insufficient bandwidth is available
  - QoS routing – find an end-to-end path between sender and receiver satisfying the QoS requirement; go around the heavily-loaded areas
- Highlights:
  - In multi-rate networks,

    channel utilization $\Leftarrow \rho = \frac{T_{busy}}{T_p}$: node-oriented

    available bandwidth $\Leftarrow W = (1-\rho)C$: link-oriented



Calculate available bandwidth per link

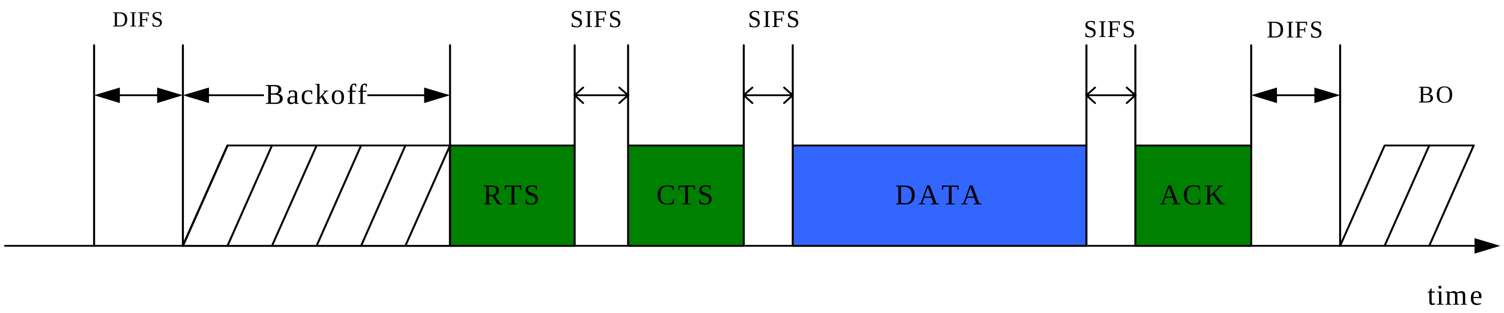
  - More accurate estimate of channel availability by considering channel reuse due to parallel transmission

    estimate and add the amount of possible parallel transmissions

Outline

- Challenges and Overview of Our Solution
- ➔ **QoS routing and admission control**
  - Prediction of link utilization of a flow
  - Estimation of channel availability
- Protocol Implementation
- Simulation Results
- Conclusions

Prediction of Link Utilization of A Flow



- For IEEE 802.11 MAC using RTS-CTS-DATA-ACK handshake, per-hop occupation time of a data packet

$$T_{occup} = T_{difs} + T_{rts} + T_{cts} + \frac{L}{B} + T_{ack} + 3T_{sifs} + \frac{CW_{\min}}{2}.SlotTime$$

$$= \frac{L}{B} + T_{oh}$$

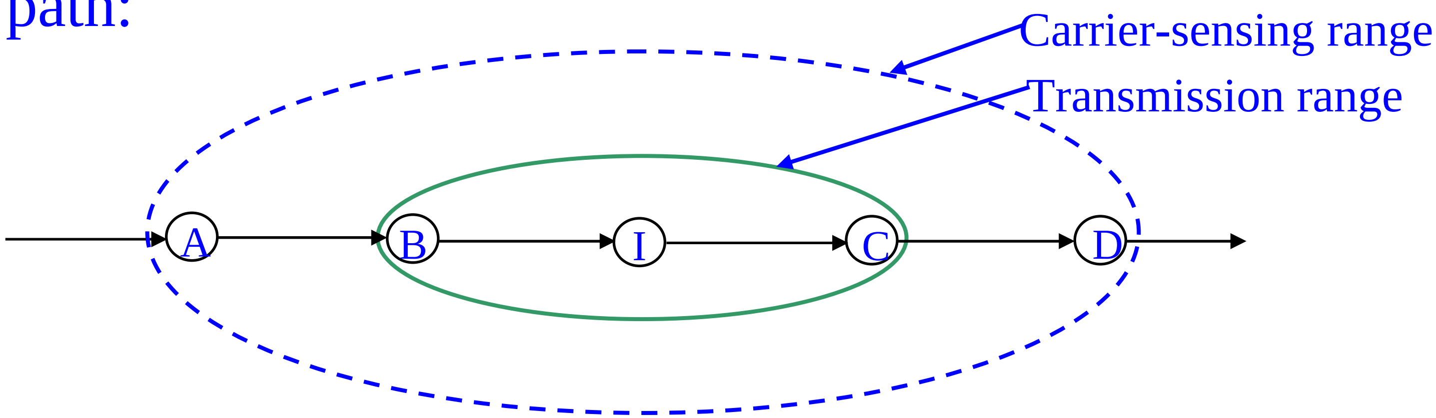
L – length of data packet; B – link rate

Assuming the application generates R packets per second, the link utilization requirement of the source

$$\rho_{req} = R \times (\frac{L}{B} + T_{oh})$$

Prediction of Link Utilization of A Flow

- Estimating flow self-interference -- on the same flow, transmission at each hop has to contend for the channel with upstream and downstream nodes
- Total link utilization of a flow depends on the link's position on the path:



$$\rho_{aggr} = \sum_{i=1}^{N_{cont}+1} R \cdot \left(\frac{L}{B_i} + T_{oh}\right)$$

N_{cont} -- number of contending nodes on the flow $N_{cont} \approx \left[\frac{CSR}{RxR}\right]$

Estimation of Channel availability

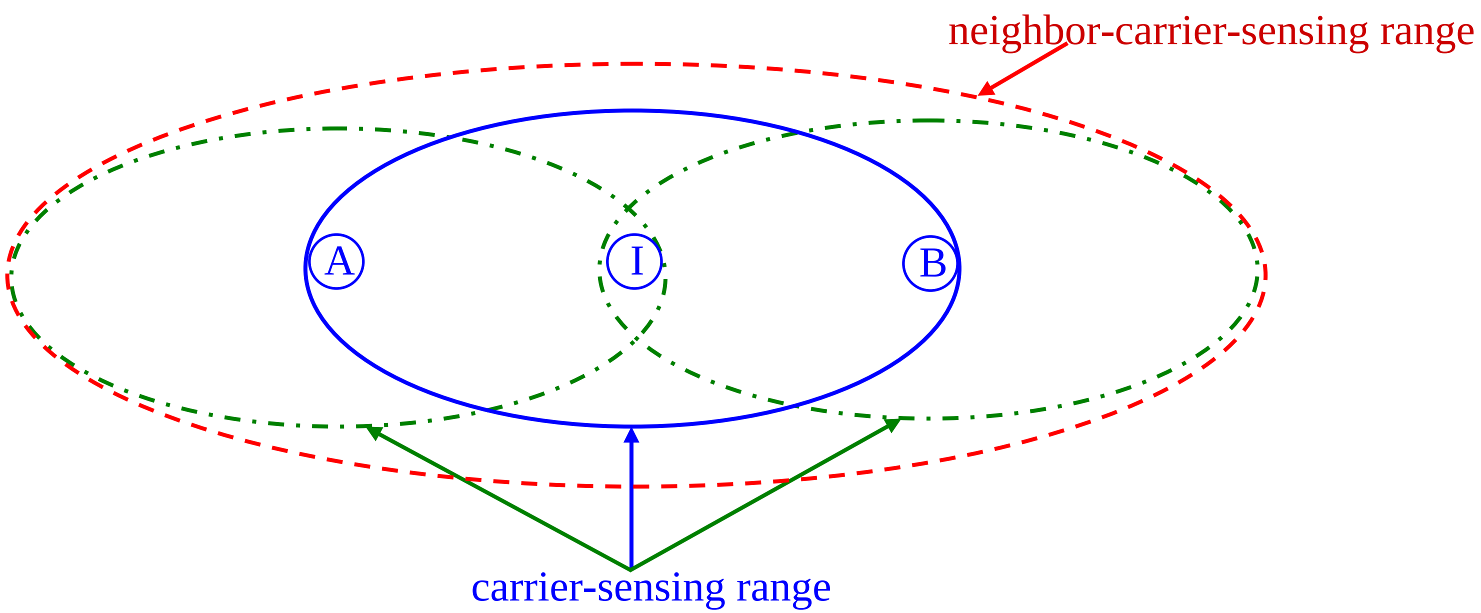
- Channel availability is estimated through passive monitoring at each node

carrier-sensing threshold: $T_{busy}^{local} \Rightarrow \rho_{local} = \frac{T_{busy}^{local}}{T_p}$

Channel availability at a node is affected by its CSNs

neighbor-carrier-sensing threshold: $T_{busy}^{csn} \Rightarrow \rho_{csn} = \frac{T_{busy}^{csn}}{T_p}$

Transmission from the node itself affects channel availability at its CSNs



Estimation of Channel availability(cont')

- Parallel transmission part

$$\rho_{overlap} = \frac{T_{busy}^{csn} - T_{busy}^{local}}{T_p} \times R \cdot (T_{oh} + \frac{L}{B_I})$$

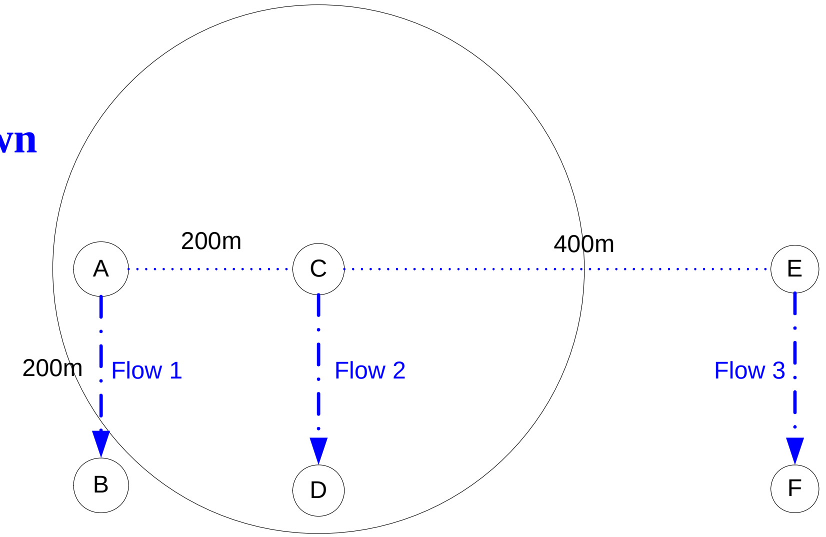
Transmission outside I's CSR

Admitting node's own transmission

- To admit the requesting flow,

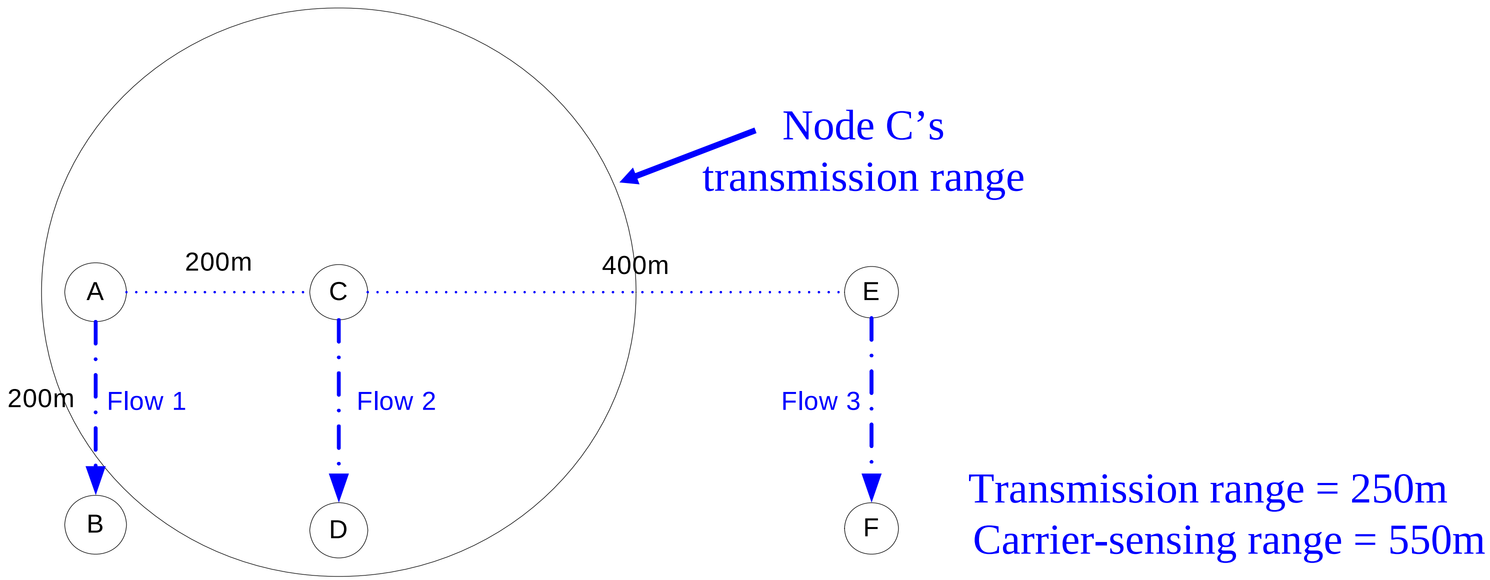
$$\rho'_{local} = \rho_{local} + \rho_{aggr} \leq 1$$

$$\rho'_{csn} = \rho_{csn} + \rho_{aggr} - \rho_{overlap} \leq 1$$



Since the second condition is more stringent, it is enough for admission decision making

Example



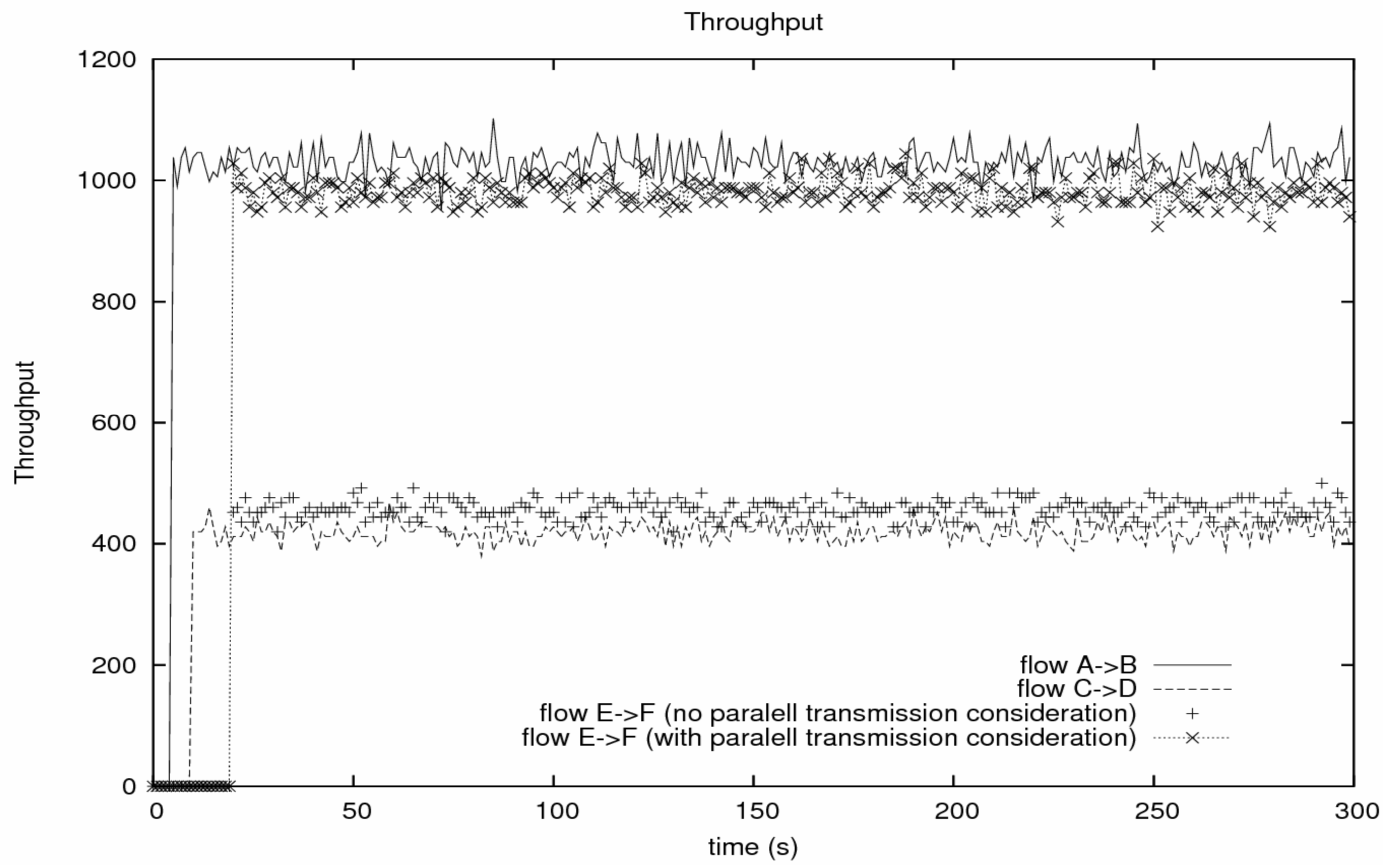
- A and E can transmit at the same time
- Whether E admits flow 3 depends on:

$$\rho_{CD} + \rho_{EF} < 1$$

$$\rho_{AB} + \rho_{CD} + \rho_{EF} - \rho_{overlap} < 1$$

$\rho_{overlap}$ - represents the fraction of A and E transmitting simultaneously

Simulation


Throughput
1200
1000
800
600
400
200
0
Throughput
0
50
100
150
200
250
300
time (s)
flow A->B
flow C->D
flow E->F (no paralell transmission consideration)
flow E->F (with paralell transmission consideration)

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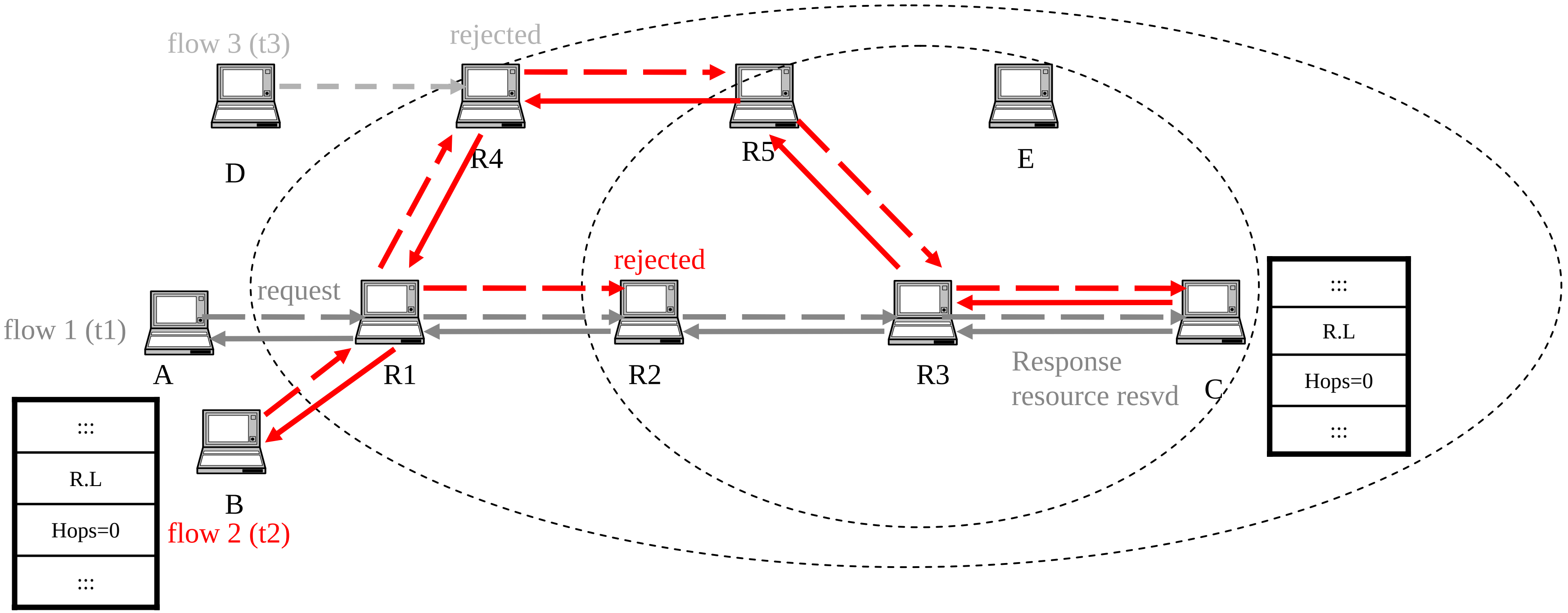
- Simulation Results
- Conclusions

Protocol Implementation



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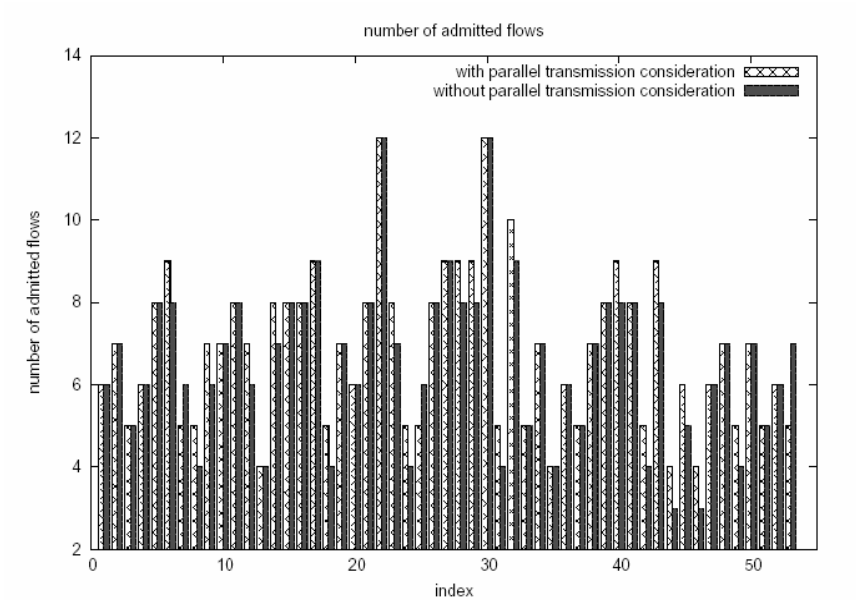
Simulation Settings

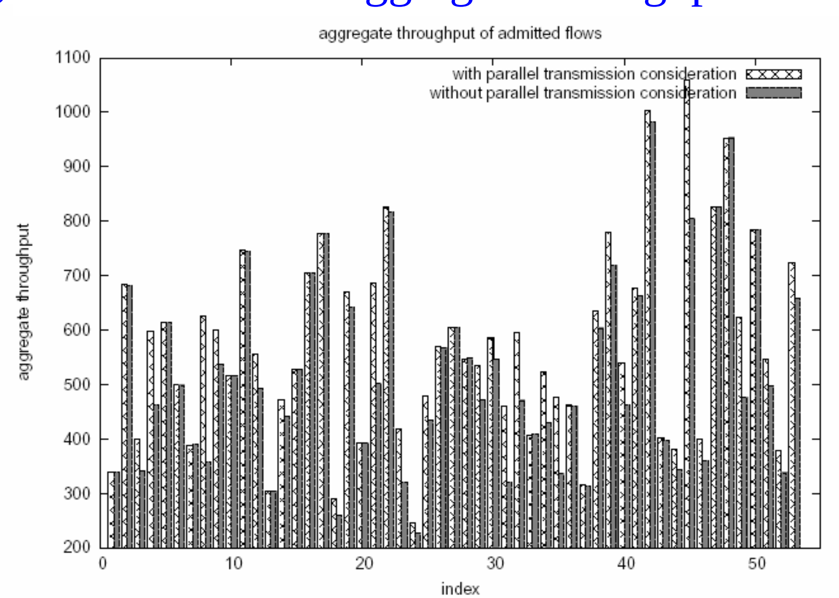
- MAC settings: IEEE 802.11 DCF
  - radio model (Lucent WaveLAN):
  - bit-rate: 1Mb/sec, 2Mb/sec
  - carrier sense range: 550m
- Sending buffer: 64 packets with timeout 30s
- Interface queue:
  - capacity: 50 packets
  - two priorities: routing and data

Benefit Brought by Parallel Transmission

- Settings:
  - 1000m X 1000m network
  - 20 randomly positioned nodes
  - Every node attempts to establish a CBR connection to a random destination
  - 50 repetitions of experiment
- Results: 19 times – more admitted flows; 31 times – more aggregate throughput

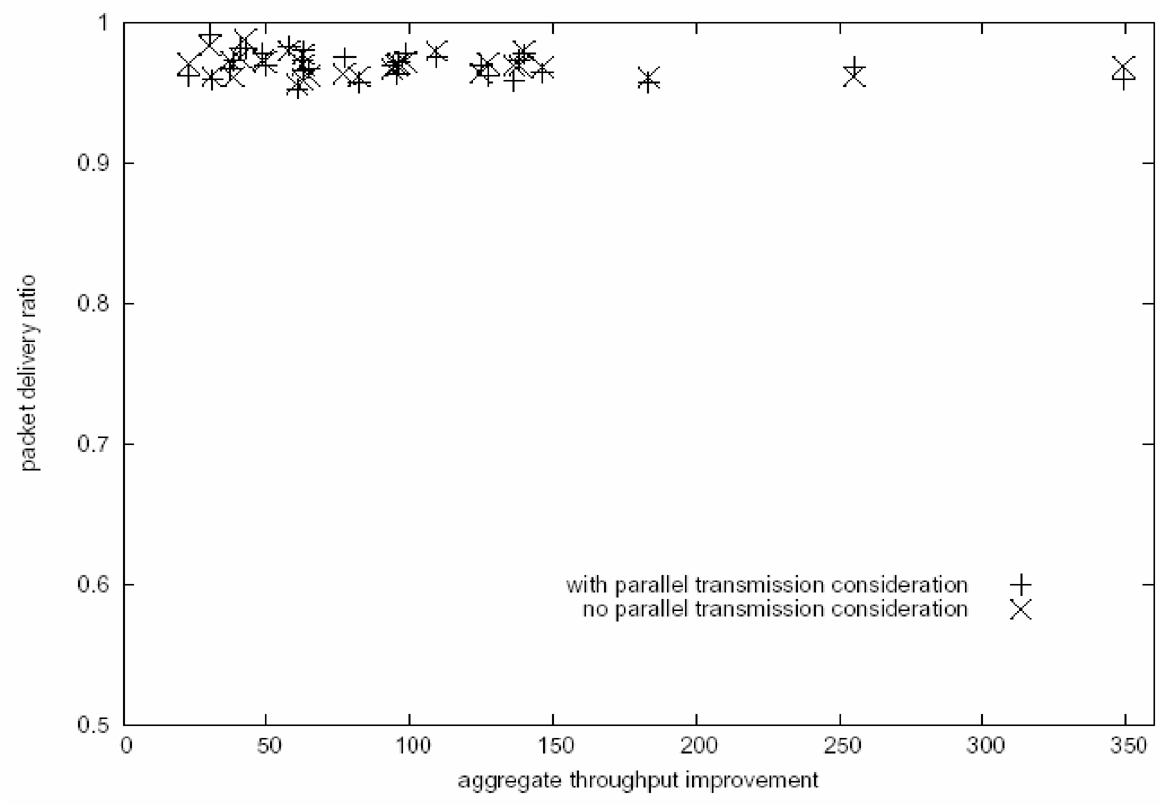


Number of admitted flows



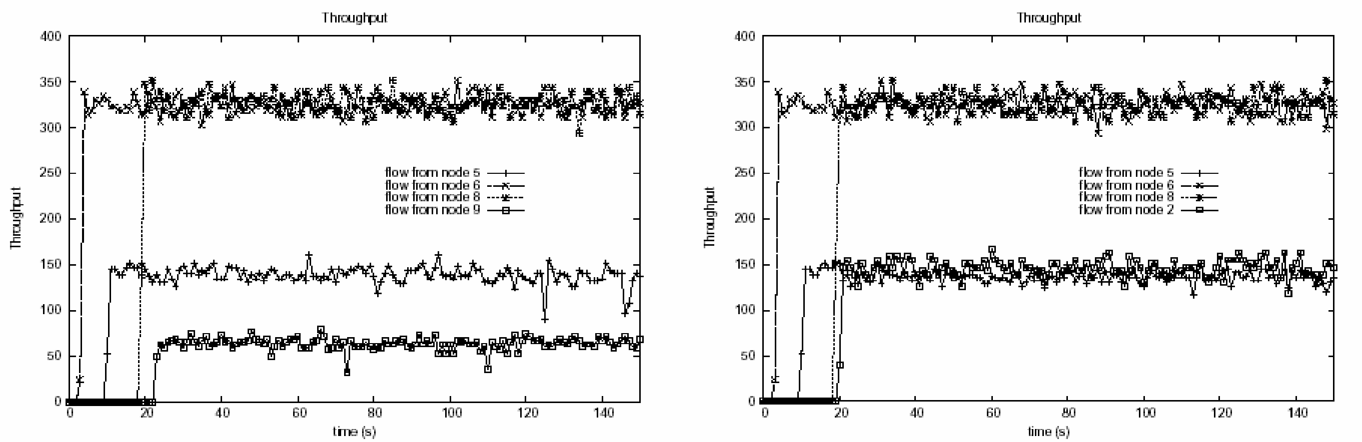
aggregate throughput

Throughput Improvement vs. Packet Delivery Ratio

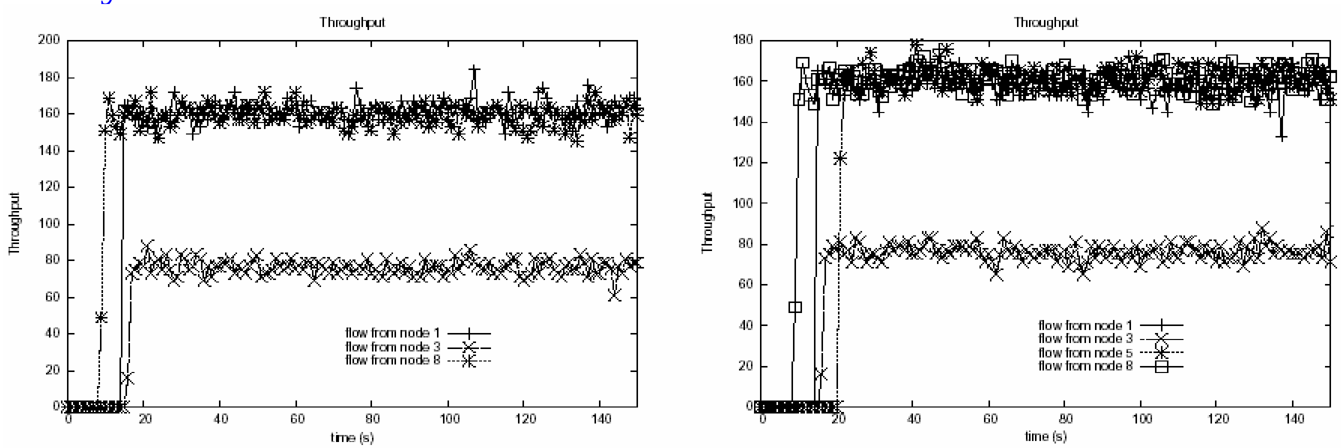


Case Studies

- Case Study 1:



- Case Study 2:



no parallel transmission consideration | with parallel transmission consideration

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Conclusions

- Proposed a QoS routing and admission control scheme for wireless ad hoc networks, considering:
  - shared nature of single-channel wireless communication
  - parallel transmission
- Showed the effectiveness of the proposed scheme via simulation
  - QoS routing
  - QoS guarantees to admitted flows
  - benefit of parallel transmission consideration

Questions ?

Thank You