A QoS Routing and Admission Control Scheme for Ad Hoc Networks

Lin Luo, Hang Liu, Marco Gruteser, Dipankar Raychaudhuri
WINLAB
Rutgers, The State University of New Jersey
Piscataway, NJ 08854

WINLAB
WIRELESS INFORMATION NETWORK LABORATORY

Outline

- Background
- QoS routing and admission control
  - Available bandwidth estimation
  - Bandwidth consumption computation
  - The working of the scheme
- Simulation Results
- Orbit Demo

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What is QoS and Admission Control?

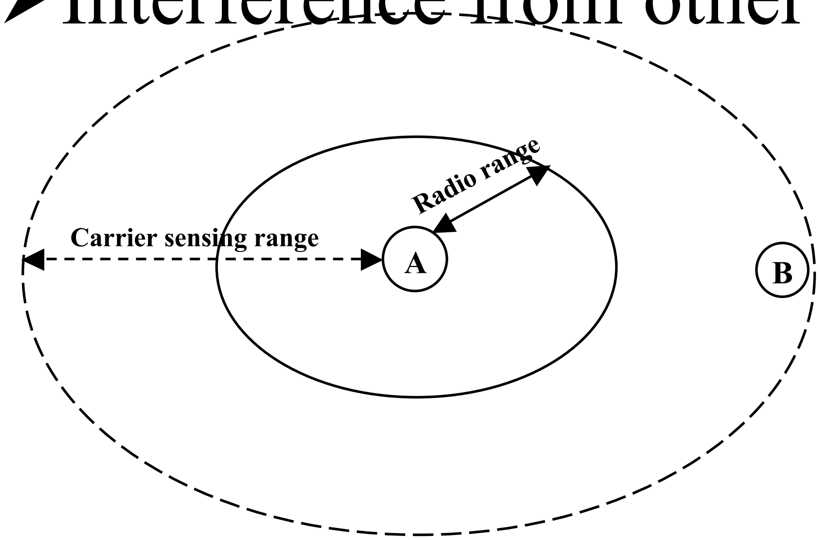
- QoS is the performance level of service offered by a network to the user.
- The goal of QoS is to provide applications with guarantees in terms of bandwidth, delay or jitter so that the information carried by the network can be better delivered and the resources can be better utilized.
- QoS routing is the process of providing end to end paths to ensure the necessary QoS parameters (bandwidth, delay, etc) are met.
- Admission control is the process of deciding if a new user request can be granted service or not; it guarantees that the admitted flows do not exceed network capacity.
- Admission control is a necessary component to support QoS.

Why integrate Admission Control with Routing ?

- For on-demand routing, performing admission control during routing process saves control messages and resources; no separate signaling process is needed.
- Route establishment must consider resources along the entire route of communication.
- With QoS awareness, routing would go around the would-be-congested spot in the first place

Challenges of Achieving QoS in Ad Hoc networks

- No centralized control => distributed algorithm
- Shared nature of wireless channel makes resource allocation complex
  - ➢A node can be affected by the nodes which it may not directly communicate with
  - ➢Interference from other nearby networks

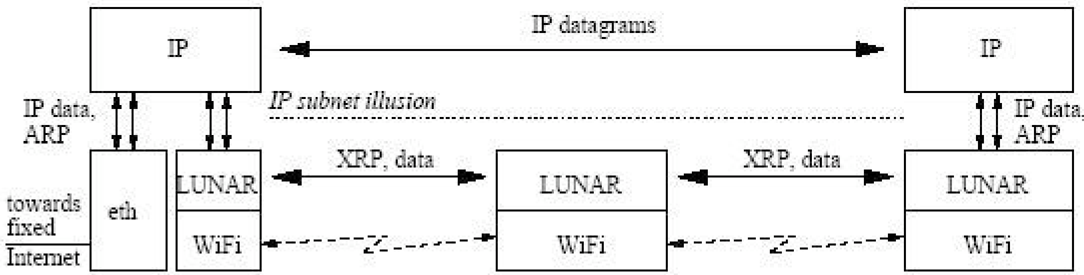


Carrier-sensing neighbor(CSN):

Nodes within A's carrier-sensing range

- Mobility may often break connections or resource reservations

Outline of LUNAR



- Route discovery is triggered by ARP requests
- Individual unicast delivery path is created for each source-destination pair.
- Periodic route refreshing

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Overview of Admission Control Scheme

- Estimate the available bandwidth (the amount of bandwidth not consumed by existing flows) B_{avail}
- Compute the amount of bandwidth the requesting flow would consume $B_{consume}$
- Make an admission decision (maintain the QoS of already admitted flows):

if ($B_{consume} < B_{avail}$), accept the flow

otherwise, reject the flow

Available Bandwidth Estimation

- Given the link rate B and channel utilization ρ , unconsumed bandwidth is measured as

$$B_{unconsumed} = (1-\rho).B$$

- ρ is measured by monitoring the amount of channel busy time,

T_{busy} during every period T_p

$$\rho = \frac{T_{busy}}{T_p}$$

- Using moving average,

$$B_{avail} = \alpha B_{avail} + (1-\alpha)(1-\rho)B - B_{resv}$$

- B_{resv} is the amount of bandwidth reserved by other flows

Available Bandwidth Estimation (cont')

- Due to the shared nature of wireless channels,

  Available bandwidth at a node is affected by its CSNs

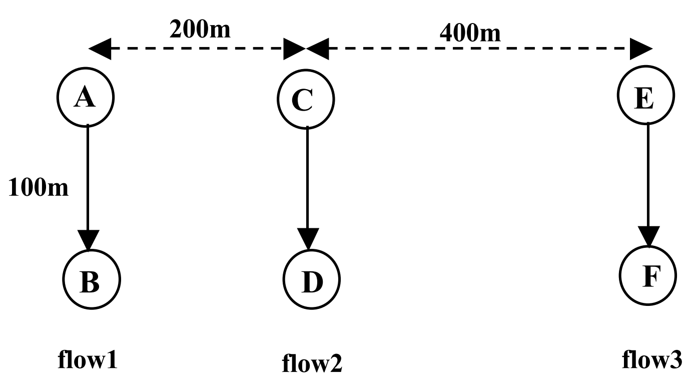
  Transmission from the node itself affects the available bandwidth at its CSNs

- To admit a new flow:

  Check local available bandwidth, B_{avail}^{local}

  Check available bandwidth at it CSNs, B_{avail}^{csn}

- Example:



Node	Local Avail BW
A	2
C	2
E	2

Node	Local Avail BW
A	1.07
C	1.07
E	2

Flow 1 starts

Node	Local Avail BW
A	0.14
C	0.14
E	1.07

Flow 2 starts

Node	Local Avail BW
A	0.34
C	congested
E	0.34

Flow 3 starts

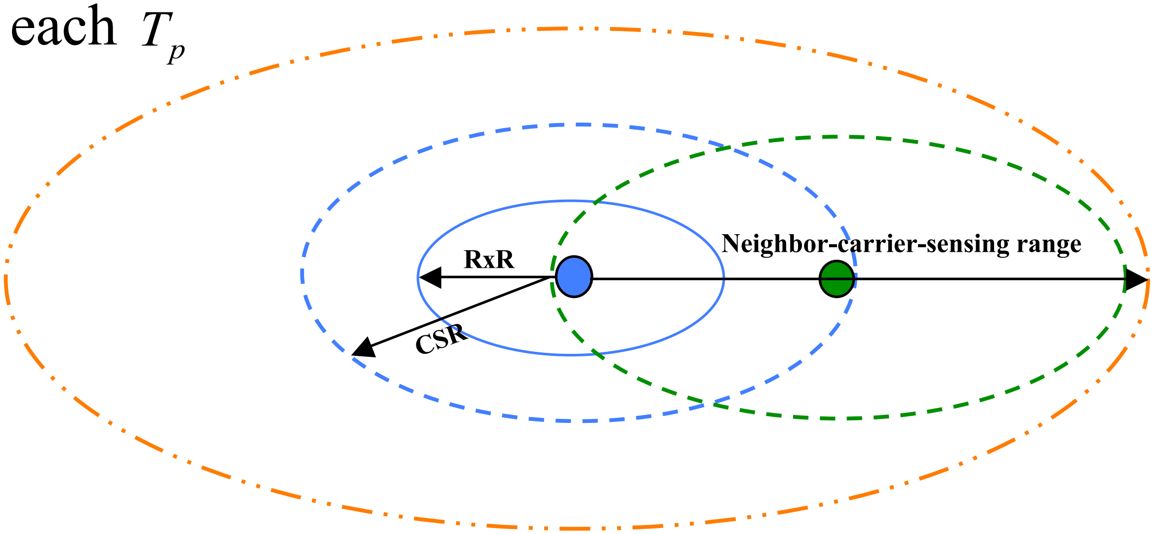
Available Bandwidth Estimation (cont')

- Two ranges of measurement

  B_{avail}^{local}:carrier-sensing range (carrier-sensing threshold)

  B_{avail}^{csn} :neighbor-carrier-sensing range (neighbor-carrier-sensing threshold)

- Neighbor-carrier-sensing range is twice as large as carrier-sensing range, so it covers the CSRs of all the sensing node's CSNs
- T_{busy}^{local} and T_{busy}^{csn} are measured using the above two ranges (thresholds) during each T_p



Prediction of Bandwidth Consumption

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

$$T_{data} = T_{difs} + T_{rts} + T_{cts} + \frac{L + H}{B} + T_{ack} + 3T_{sifs}$$

L – length of data packet

H – IP and MAC header length

- Assuming the application generates R packets every second, then the bandwidth requirement W of the source

$$W = R \times T_{data} \times B$$

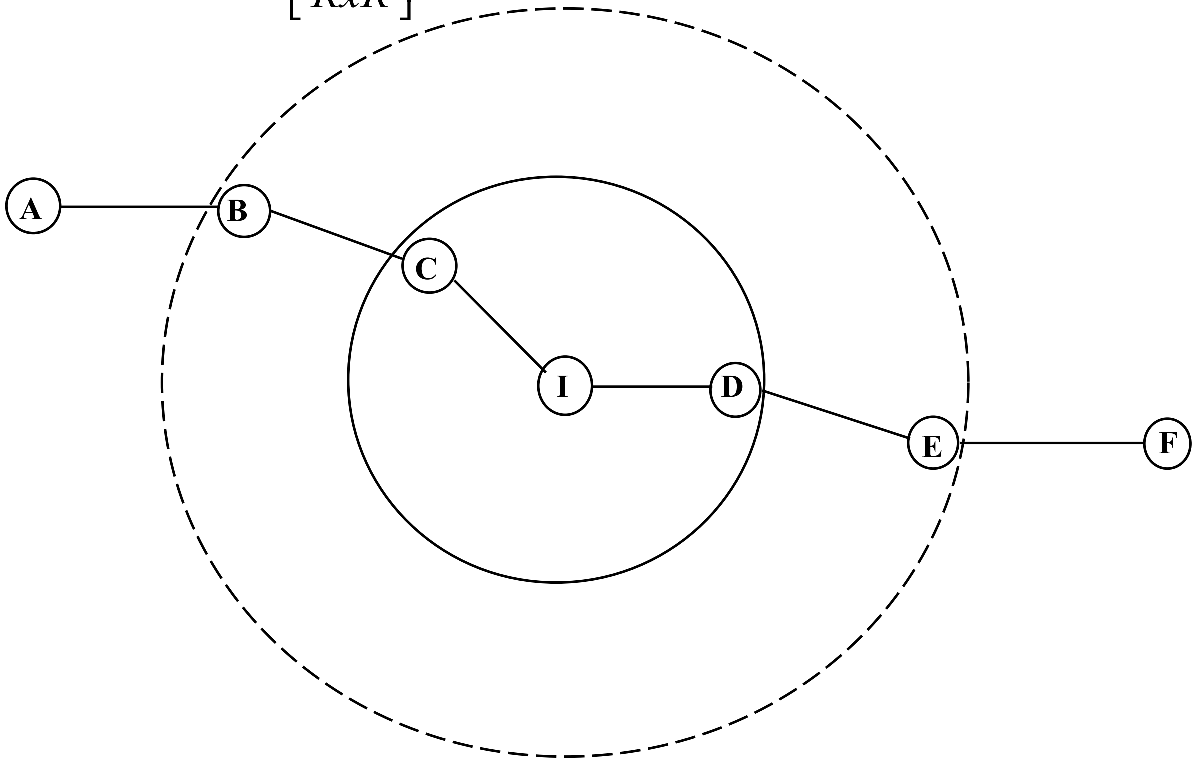
- Since nodes on the same path may contend for bandwidth with each other, actual bandwidth consumption at a node depends on its position: $B_{consumed} = (N_{cont} + 1) \times W$

N_{cont} -- the number of contending nodes

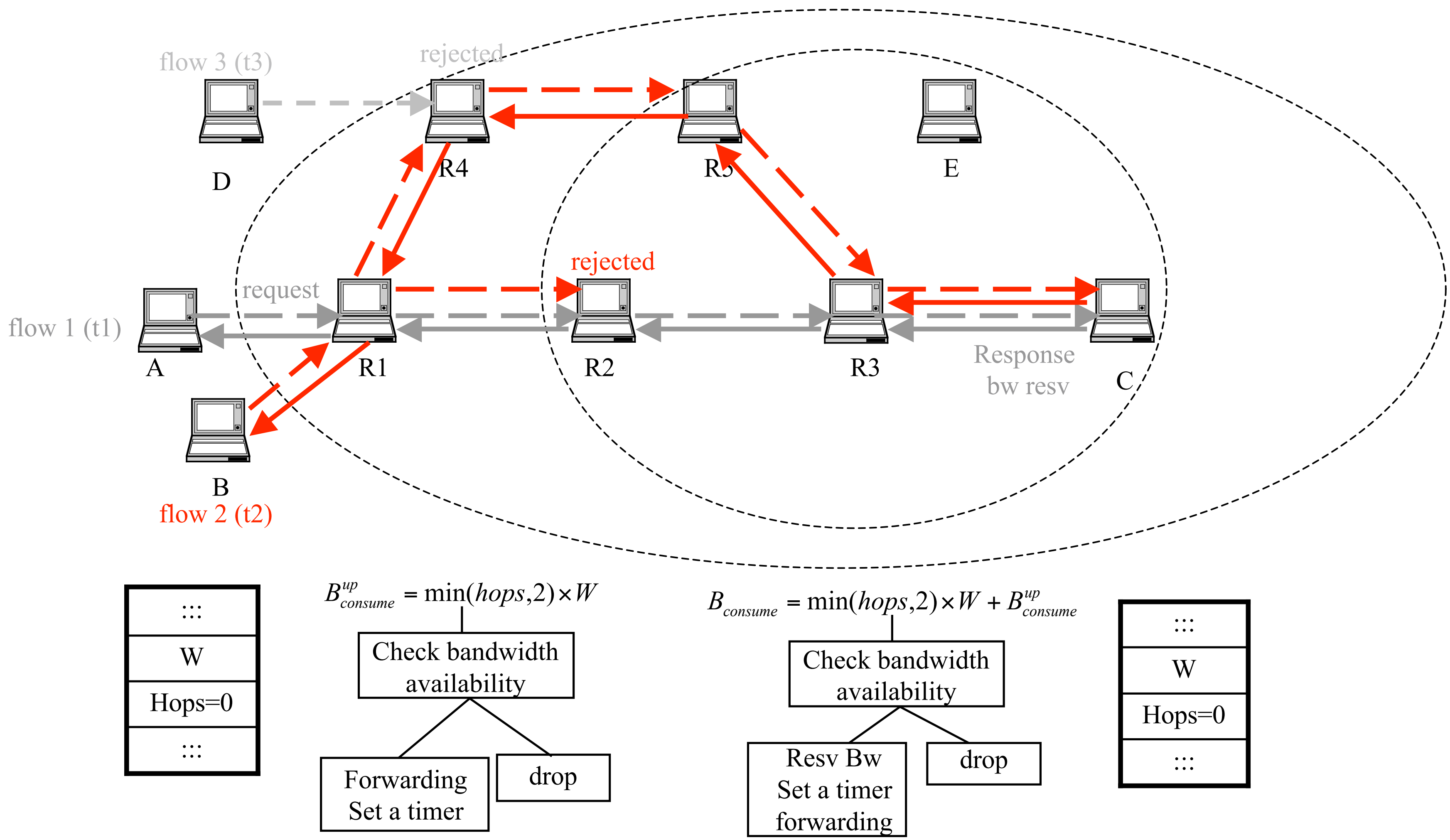
N_{cont} Computation

N_{cont} is hard to achieve due to dynamic topology, unstable channel conditions, etc

Approximation: $N_{cont} \approx \left[\frac{CSR}{RxR} \right]$



QoS routing and Admission Control



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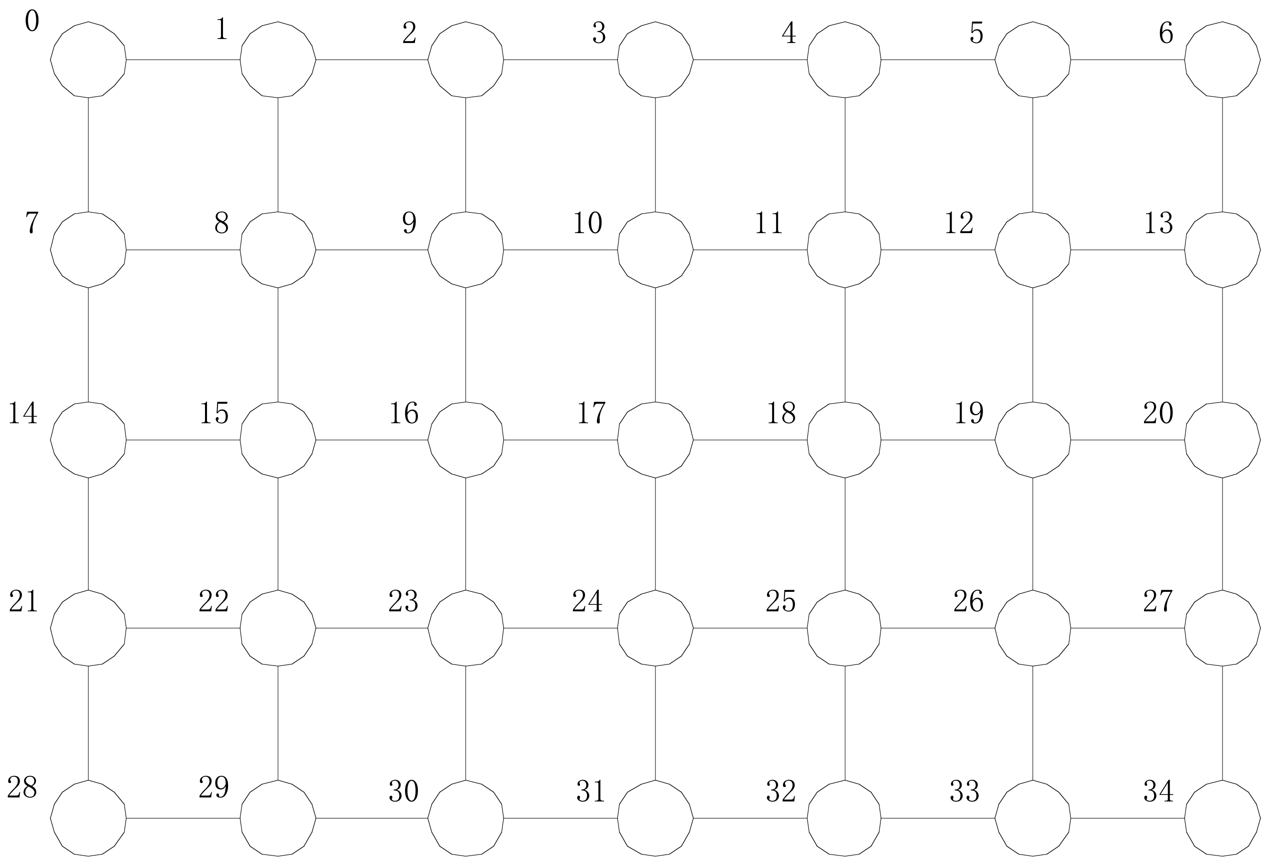
Simulation Settings

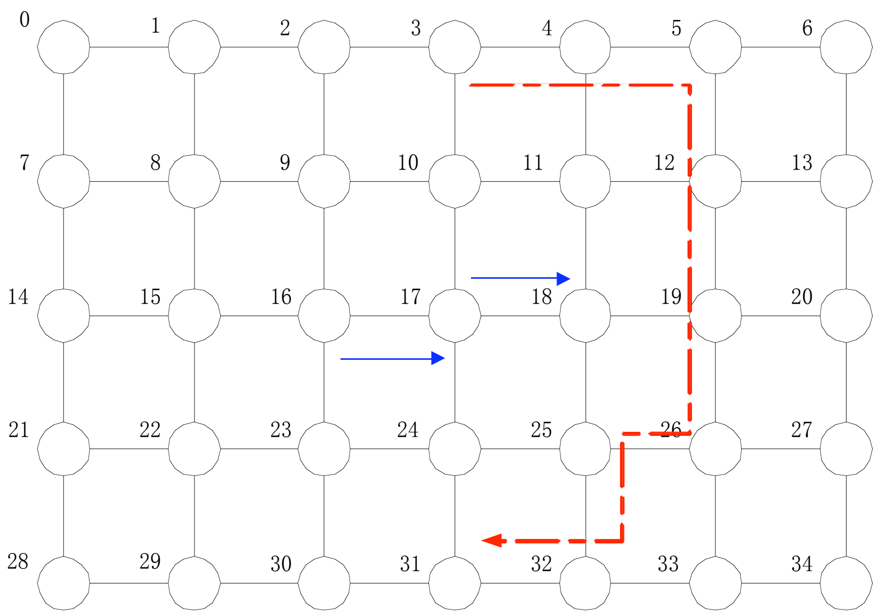
- MAC settings: IEEE 802.11 DCF
  - radio model (Lucent WaveLAN):
  - bit-rate: 2Mb/sec
  - radio range: 250m
  - carrier sense range: 550m
- Sending buffer: 64 packets with timeout 30s
- Interface queue:
  - capacity: 50 packets
  - two priorities: routing and data

Network Topology

7 x 5 grid: neighboring nodes are 250m away



Scenario 1:



a) flow 17->18 started at 0.0s, the bandwidth requirement is 480Kbps
b) flow 16->17 started at 2.5s, requiring bandwidth 480Kbps
c) at 4.8s, node 3 attempted to find a route to node 31, requiring bandwidth of 130Kbps

- *the route from 3 to 31 is multihop, so the actual bandwidth consumption is more than 130Kbps, which depends on the node's position on the route*
- *if the path goes through node 17, which is on the shortest path, the bandwidth consumption will be large enough to congest 17*
- *with admission control, a longer path is discovered from 3 to 31 (3 -> 4 -> 5 -> 12 -> 19 -> 26 -> 25 -> 32 -> 31) instead of the shortest one*

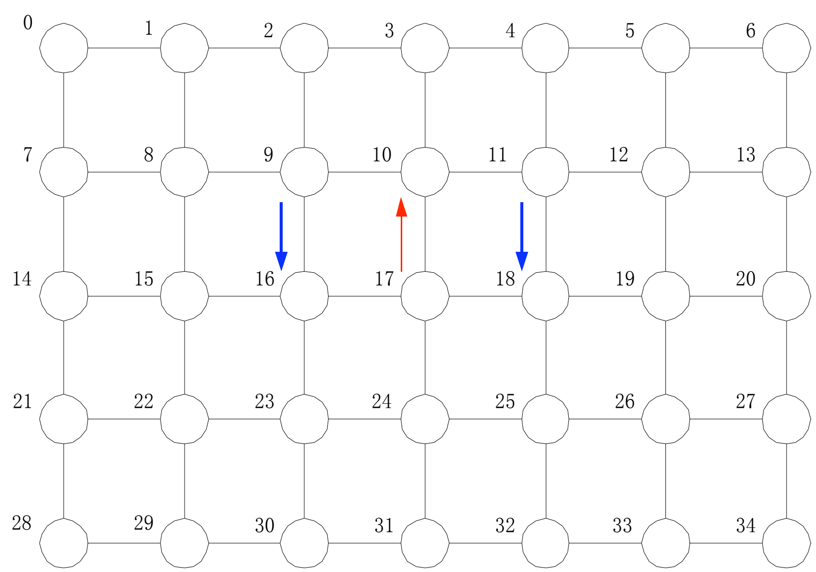
Scenario 2

- Settings:
  - Flow 9 -> 16 started at 10.0s, the bandwidth requirement is 380Kbps
  - Flow 11 -> 18 started at 20.0s, requiring bandwidth 380Kbps
  - At 30.0s, node 17 attempted to find a route to node 10, requiring bandwidth of 450Kbps
- Metrics: we looked at the following 3 metrics varying with time

  Throughput

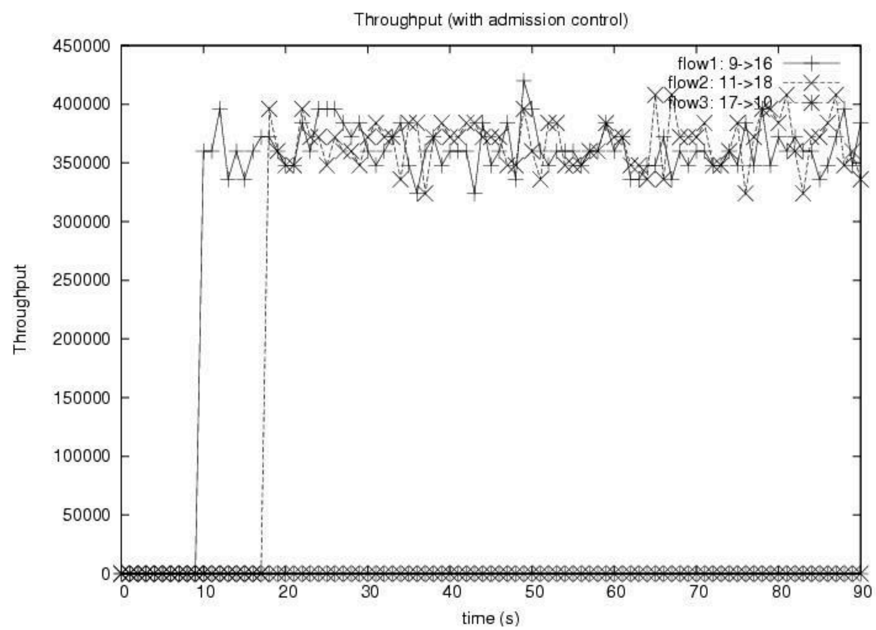
  Average packet delay

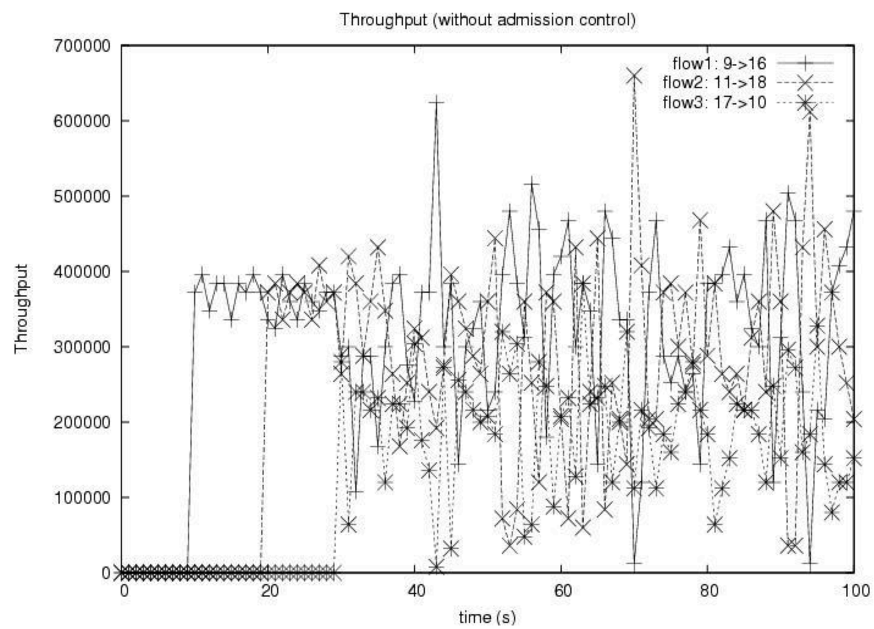
  Packet delivery fraction



Simulation results

Throughput with time

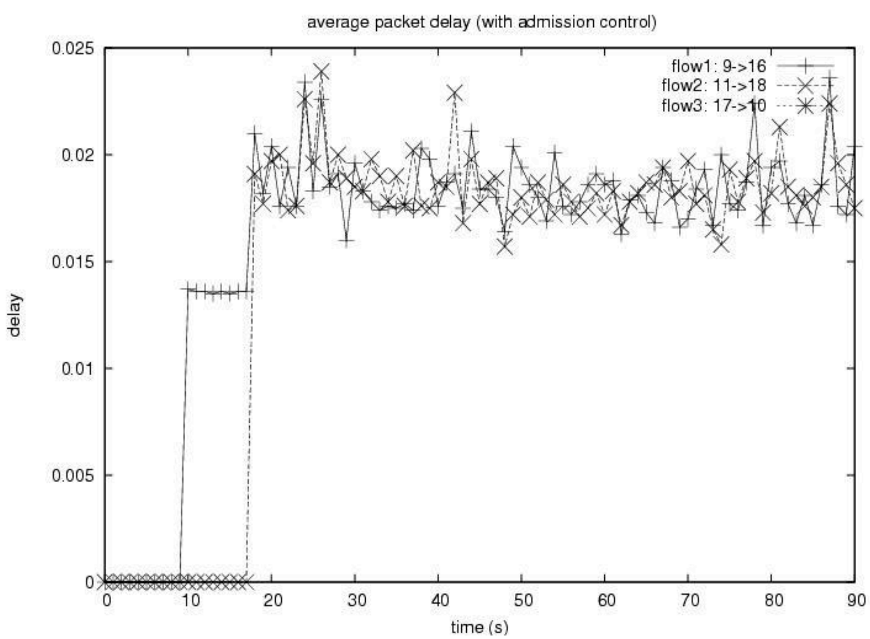


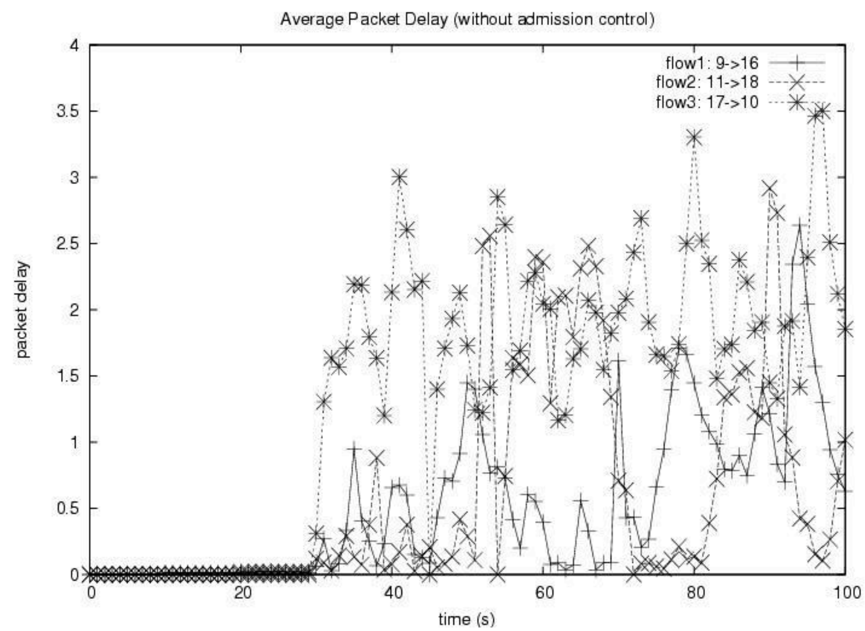


With admission control **Without admission control**

Simulation result (cont.)

Average Packet Delay



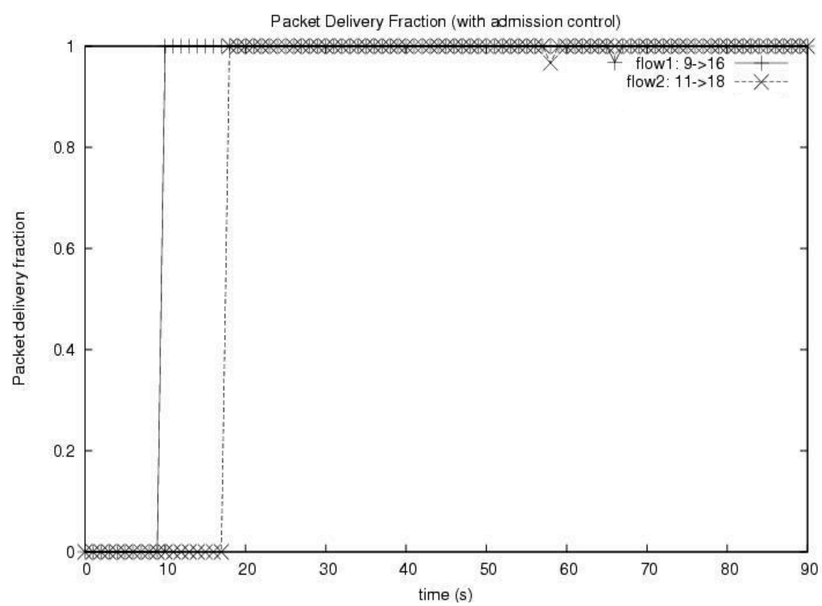


With admission control

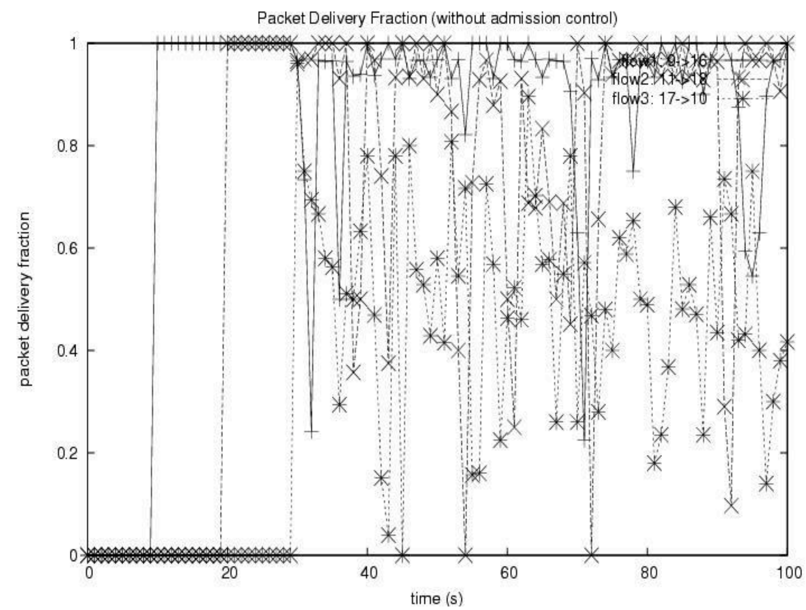
Without admission control

Simulation Results (cont.)

- Packet delivery fraction



With admission control



Without admission control

Simulation results (cont.)

- Admission control provides QoS commitment by not admitting too many flows into the network. So, it “protects” the already admitted flows.
- With admission control, the request of the third flow was rejected for last scenario, because nodes 10 and 17 have no enough bandwidth to accommodate it.
- With admission control, because no congestion occurred, the admitted flows (first two) did obtain their required resources, their throughput and packet delivery fraction being stable, delay very low and jitter small
- Without admission control, all the flows entered the network and contended for the resources, which leads to severe congestion. We can see that the throughput of each flow varies with time sharply, and delay and jitter are very high

Scenario 3

- 9 sessions try to enter the network. The sources of the 9 sessions are randomly chosen, but the destination is the same for them.
- Node 17 is the destination
- flow1: 1->17 starting at 5.0s

  flow2: 3->17 starting at 10.0s

  flow3: 5->17 starting at 15.0s

  flow4: 15->17 starting at 20.0s

  flow5: 19->17 starting at 25.0s

  flow6: 29->17 starting at 30.0s

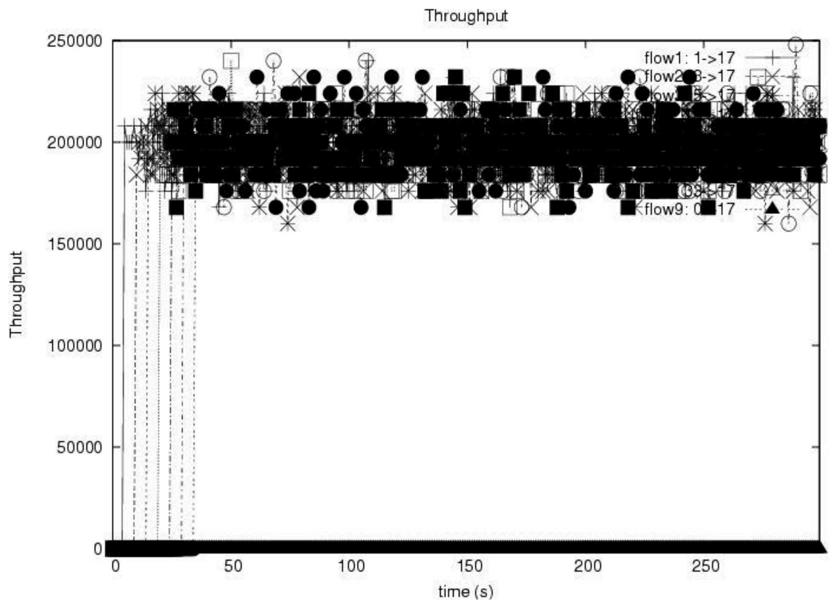
  flow7: 31->17 starting at 35.0s

  flow8: 33->17 starting at 40.0s

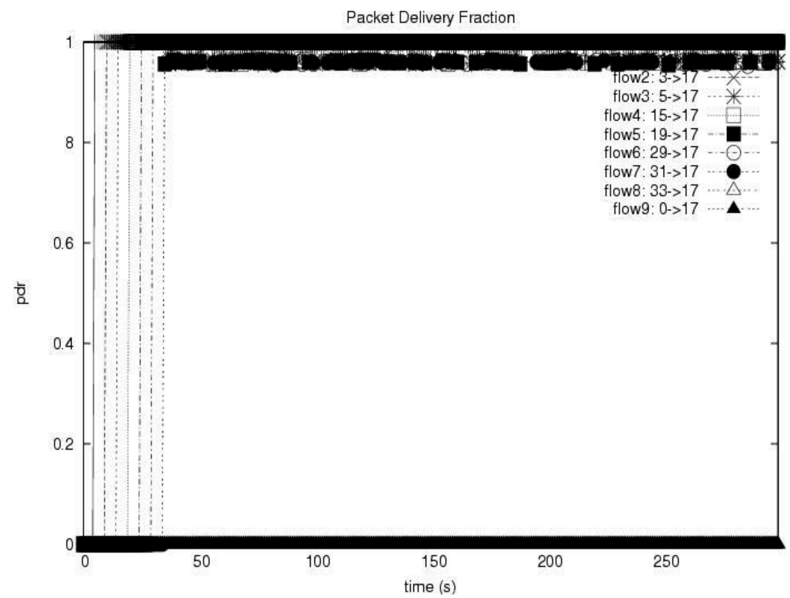
  flow9: 0->17 starting at 45.0s

  For all the flows, packet size is set to1000 bytes and rate set to 25 packets/s. The required bandwidth of each flow is thus about 258.4kbps

Simulation results

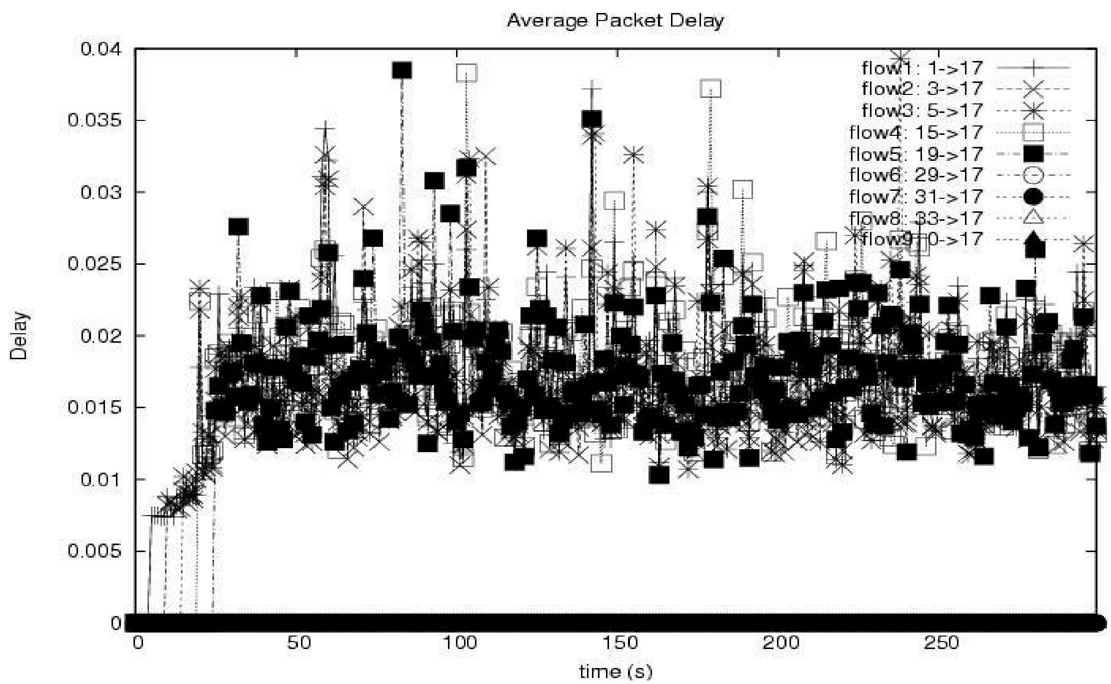


throughput



Packet delivery fraction

Simulation Results (cont.)



Average packet delay

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Orbit Experiment

- Current wireless cards don't support busy time measurement
- Simplified approach:

All nodes are set to promiscuous mode.

Available bandwidth is estimated based on counting the packets during T_p .

- Available bandwidth estimation (assume DATA-ACK):

$$B_{avail} = B - \left(\frac{8\sum_{i=1}^{N}(L_i + H_{PLCP})}{T} + \frac{N_{data}.(CW_{\min}.uSlot + DIFS).B + N_{ctl}.SIFS.B}{T} \right)$$

L_i – the length of *i*-th packet; B – link rate

$N = N_{data} + N_{ctl}$

- Experiment scenario: 6 nodes, 3 flows; all the nodes can hear each other