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 \( \leq \rho = \frac{T_{\text{busy}}}{T_p} \): node-oriented
    - available bandwidth \( \leq W = (1 - \rho)C \): link-oriented

- 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

\[ T_{occu} = T_{difs} + T_{rts} + T_{cts} + \frac{L}{B} + T_{ack} + 3T_{sifs} + \frac{CW_{\text{min}}}{2}.\text{SlotTime} \]

= \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

\[ \rho_{req} = R \times \left( \frac{L}{B} + T_{oh} \right) \]
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:

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

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

- Channel availability is estimated through passive monitoring at each node.

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

  Channel availability at a node is affected by its CSNs

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

  Transmission from the node itself affects channel availability at its CSNs
Estimation of Channel availability (cont’)

- Parallel transmission part

\[
\rho_{\text{overlap}} = \frac{T_{\text{busy}}^\text{csn} - T_{\text{busy}}^\text{local}}{T_p} \times R \cdot (T_{oh} + \frac{L}{B_t})
\]

Transmission outside I’s CSR

Admitting node’s own transmission

- To admit the requesting flow,

\[
\rho_{\text{local}}' = \rho_{\text{local}} + \rho_{\text{aggr}} \leq 1
\]

\[
\rho_{\text{csn}}' = \rho_{\text{csn}} + \rho_{\text{aggr}} - \rho_{\text{overlap}} \leq 1
\]

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

Node C’s transmission range

Transmission range = 250m
Carrier-sensing range = 550m

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Simulation

Throughput

- flow A->B
- flow C->D
- flow E->F (no parallel transmission consideration)
- flow E->F (with parallel transmission consideration)
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Protocol Implementation

flow 1 (t1)

flow 2 (t2)

flow 3 (t3)

request

rejected

Response
resource resvd

R.L
Hops=0

...
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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

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**Number of admitted flows**

**Aggregate throughput**
Throughput Improvement vs. Packet Delivery Ratio

- Throughput Improvement vs. Packet Delivery Ratio

Diagram showing the relationship between aggregate throughput improvement and packet delivery ratio with and without parallel transmission consideration.
Case Studies

- Case Study 1:

- Case Study 2:

  no parallel transmission consideration  with parallel transmission consideration
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  ➢ Estimation of Channel utilization
  ➢ Prediction of Link Utilization of a Flow
• Protocol Implementation
• Simulation Results

➢ Conclusions
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