Cross-Layer Mixed Bias Scheduling for Wireless Mesh Networks

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Outline

• Introduction
• Background & related work
• Proposed cross-layer technique
• Simulation environment
• Results & discussion
• Conclusions & future work
Introduction

• Consider Wireless Mesh Network (WMN)
  – Mesh Routers (MR)
  – Mesh Clients (MC)
  – Multiple Gateways (GW)

• Most traffic to and from Internet via GW
Introduction

[Ernst, Denko, 2010]
Why Wireless Mesh Networks?

• Many Applications

• Commercial & rural internet access
  • Cheap and easy to deploy compared with wired

• Military communication, Search & Rescue
  • Few infrastructure required

• Heterogeneous networks with WMN backbone
  • Autonomous: self-configuration, self-optimization, self-healing network
Why Scheduling?

- Fairness
- Throughput
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Background & Related Work

• Existing scheduling approaches:
  – Completely Fair (TDMA, FDMA etc)

\[ R = \frac{1}{n} \]

• Where \( n \) is number of nodes

– Wasted resources when a node has nothing to transmit
Background & Related Work

- Existing scheduling approaches:
  - Proportional Fairness
    - i.e. proportional bias against undesirable nodes
      - (often based on distance)

\[ R = \frac{1}{c^\beta} \]

- Good performance, but can be improved if we introduce multiple levels of bias (see mixed-bias)
Background & Related Work

• Existing scheduling approaches:
  – Max-min
    • Maximize the minimum flow

  – Mixed-Bias (Singh et al)
    • Allows multiple biases to be applied (strong + weak)

\[ R = \frac{\alpha}{d^{\beta_1}} + \frac{1-\alpha}{d^{\beta_2}} \]
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Cross-Layer Mixed Bias Scheduling

• Based on work by S. Singh et al “Beyond Proportional Fairness…”

• Main contributions:
  1. Extended to apply to characteristics other than just distance
  2. Combined mixed-bias technique
Cross-Layer Mixed Bias Scheduling

• Layers used in the approach:
  – MAC Layer
    • Queue of packets ready to be transmitted into the medium
  – Network Layer
    • TTL / Number of Hops examined and reported to MAC
  – Physical Layer
    • SINR measure reported to MAC
Cross-Layer Mixed Bias Scheduling

- Our mixed bias technique:

\[ R = \frac{\alpha}{c^{\beta_1}} + \frac{1-\alpha}{c^{\beta_2}} \]

- Additional characteristics
  - Distance between GW and MR
  - Queue Size
  - Link Quality

- Combined Technique
  - Biases against multiple characteristics at once
Combined Mixed Bias Scheduling

- Bias against multiple characteristics at once:

\[ R = \gamma_1 R_1 + \gamma_2 R_2 + \gamma_3 R_3 \]

- Where:

\[ R_1 = \frac{\alpha_1}{c^{\beta_{11}}} + \frac{1 - \alpha_1}{c^{\beta_{12}}} \]
\[ R_2 = \frac{\alpha_2}{c^{\beta_{21}}} + \frac{1 - \alpha_2}{c^{\beta_{22}}} \]

... 

\[ R_n = \frac{\alpha_n}{c^{\beta_{n1}}} + \frac{1 - \alpha_n}{c^{\beta_{n2}}} \]
Combined Mixed Bias Scheduling

• 802.11 MAC Solution:
  - At each MR modify MAC queue:
    • Change ordering depending on bias
    • Allow a given packet to be bumped a fixed number of times -> avoid starvation

• TDMA Solution:
  - Assign time based on the bias, the stronger the bias, the less time a given node is given
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Simulation Environment

• NS3 simulation environment
  – OLSR Routing
  – Modified 802.11 MAC layer

• Metrics:
  – PDR, end-to-end delay
Simulation Environment

- Parameters:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>Mesh Routers</td>
<td>10 – 30</td>
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<tr>
<td>Mesh Clients</td>
<td>250</td>
</tr>
<tr>
<td>Gateways</td>
<td>1 – 5</td>
</tr>
<tr>
<td>$\alpha$</td>
<td>0.5</td>
</tr>
<tr>
<td>$\beta_1$</td>
<td>2</td>
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<tr>
<td>$\beta_2$</td>
<td>5</td>
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<tr>
<td>Environment Dimensions</td>
<td>1000 x 1000m</td>
</tr>
<tr>
<td>Node Range</td>
<td>150m</td>
</tr>
</tbody>
</table>
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Results & Discussion

• Evaluation against two different schemes
  – 802.11 Modified MAC
  – TDMA Based on previous work
Results & Discussion

- Combined M-B generally lower delay compared with 802.11
- Performance improvement with larger sized networks
- Improvement against M-B distance approach

![Average End-To-End Delay](image)

*Figure 1 Average End-To-End Delay, Two Flows*
Results & Discussion

• As network becomes more congested (more flows) the combined approach performs well

• M-B distance alone does not work as well in congested networks, since farther nodes have low priority

• M-B combined takes into account growing queues at far nodes
Results & Discussion

- Shows that M-B approach is scalable with increasing number of gateways
- Improvement on original multiple gateway TDMA approach

![Figure 3 Average Packet Delivery Ratio, 250 Clients, 50 MR](image)
Results & Discussion

• Delay is lower with M-B except in case with a single GW, due to GW bottleneck

• (in the TDMA approach, the GW is the co-ordinator of the schedule)

Figure 4 Average End-To-End Delay, 250 Clients, 50 MR
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Conclusions & Future Work

• Extension of existing mixed bias approach by applying cross-layering

• Proposed new combined mixed bias approach

• Initial results are promising for further investigation

• Investigate adapting parameters to network conditions
Combined Mixed Bias Scheduling

- Bias against multiple characteristics at once:
  \[ R = \gamma_1 R_1 + \gamma_2 R_2 + \gamma_3 R_3 \]

- Where:
  \[
  R_1 = \frac{\alpha_1}{c^{\beta_{11}}} + \frac{1 - \alpha_1}{c^{\beta_{12}}}
  \]
  \[
  R_2 = \frac{\alpha_2}{c^{\beta_{21}}} + \frac{1 - \alpha_2}{c^{\beta_{22}}}
  \]
  ...
  \[
  R_n = \frac{\alpha_n}{c^{\beta_{n1}}} + \frac{1 - \alpha_n}{c^{\beta_{n2}}}
  \]
Thanks for Listening!

Questions?

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Cross Layering

OSI 7 Layer Stack
Cross Layering

Direct Communication:

- Layers which do not normally interact exchange information
- Difficult to maintain
- Poor extensibility

OSI 7 Layer Stack:
- Application
- Presentation
- Session
- Transport
- Network
- Link / MAC
- Physical
Cross Layering

OSI 7 Layer Stack

<table>
<thead>
<tr>
<th>Application</th>
<th>Status</th>
<th>Physical</th>
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</thead>
<tbody>
<tr>
<td>Presentation</td>
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</table>

Status:
- Link quality
- Queue sizes
- Application requirements
- Distance between nodes

- Easily enable cross-layer interactions by querying the status stack