Adaptive Mixed Bias Resource Allocation for Wireless Mesh Networks

Jason Ernst, Thabo Nkwe

School of Computer Science – University of Guelph
Presented at BWCCA - Thursday November 4th, 2010
Fukuoka, Japan
Overview

- Introduction
- Allocation Schemes
- Mixed Bias
- Adaptive Mixed Bias
- Performance Evaluation
- Results
- Conclusions & Future Work
Introduction

• Resource allocation
  – Focus on access to the medium
  – Could also be applied to other resources such as queues, CPU, frequency

• Wireless Mesh Network
  – Traffic to and from Gateway (GW) via Mesh Routers (MR)
Existing Allocation Schemes

• Proportional:
  – Resources assigned proportionally to some characteristic
  – Danger of starvation with strong proportionality (bias)

• Max-min:
  – Allocate resources such that we maximize the minimum of some characteristic of the network

• Round-robin / Fair:
  – Resource split evenly
# Existing Allocation Schemes

<table>
<thead>
<tr>
<th>Reference</th>
<th>Technique</th>
<th>Layers</th>
<th>Goal</th>
</tr>
</thead>
<tbody>
<tr>
<td>[1] Ernst, Denko</td>
<td>Combined Mixed Bias</td>
<td>MAC, PHY, NET</td>
<td>Scheduling</td>
</tr>
<tr>
<td>[2] Singh et al</td>
<td>Mixed Bias</td>
<td>MAC, NET</td>
<td>Scheduling</td>
</tr>
<tr>
<td>[3] José-Revuelta</td>
<td>Genetic Algorithm</td>
<td>PHY</td>
<td>Channel Assignment</td>
</tr>
<tr>
<td>[5] Choi and Choi</td>
<td>Heuristic, Utility based</td>
<td>PHY, MAC</td>
<td>Scheduling with Service Differentiation</td>
</tr>
<tr>
<td>[7] Mandal et al</td>
<td>Constraint based heuristic</td>
<td>PHY</td>
<td>Channel Assignment</td>
</tr>
<tr>
<td>[8] Beljadid et al</td>
<td>Genetic Algorithm, Tabu Search</td>
<td>PHY</td>
<td>Channel Assignment</td>
</tr>
<tr>
<td>[10] Zhang et al</td>
<td>Diversity weight adaptive</td>
<td>PHY, MAC, NET</td>
<td>Scheduling, Queue Management</td>
</tr>
</tbody>
</table>

See the paper for more details
Mixed Bias

- Resource assigned by:

\[ R = \frac{\alpha}{c\beta_1} + \frac{1 - \alpha}{c\beta_2} \quad \alpha < 1, \beta_1, \beta_2 > 0 \]

- \( \alpha \) – weight of competing biases
- \( \beta_1, \beta_2 \) – strength of bias
- \( c \) – characteristic to bias against
- \( R \) – probability a MR will transmit

(Ernst, Denko), (Singh, et al)
Mixed Bias

• With $c =$ distance from GW $\alpha,\beta_1,\beta_2$ determined analytically (for static topology)

• With $c =$ link quality or other characteristics, analysis becomes difficult, dependant on a model
The Case for Adaptive Resource Allocation

• Resource allocation often rigid
  – Wireless network conditions change rapidly
  – Decisions made from limited information and assumptions
  – Often disregard:
    • Interference, Mobility, Congestion, Distance …
Motivation

• Difficult to determine objective function for complicated multi-hop heterogeneous networks
• Avoid long delays in making decisions
• Introduces autonomous aspect to WMN
• Capitalize on MR abundant abilities
Motivation

• Goals:
  – Maximize packet delivery ratio
  – Minimize end-to-end delay

  – Utility function, combination of two
Related Work

• Scheduling & Resource allocation with defined service levels (Choi et al)
  – Focus is on maximizing profit, not network performance in many solution
  – Service level weak point

• Genetic algorithms applied to channel assignment (José-Revuelta)

• Constraint-based routing (Mahjoub et al)
  – (Heuristic optimization approaches used in wireless often)
Tabu Search

• Explore the parameter space of the mixed bias algorithm

• Real time changes to the mixed bias parameters (Tabu Move)

• Change in performance used to make next parameter change

• Moves restricted temporarily so that the same space is not searched repeatedly
Tabu Search

• Chosen because other techniques may require “offline” simulation time (PSO, Genetic …)
  – While offline simulation occurs the conditions in network may change
  – Only tabu search can react quickly to changing conditions
Tabu Search

• Utility Function:
  – $U = \frac{1}{\text{delay}} + \text{PDR}$
  – Simple to start, more factors taken into account later: ex) fairness index, congestion level etc

• Utility computed periodically
• Goal is for long term maximization of utility
• Adapt to changing network conditions
Tabu Search

- Neighbourhood defined by adjusted one or more parameters (alpha or beta1, beta2)

- Tabu moves restrict the entire solution (alpha, beta1, beta2)

- Tabu tenures (set to expire after 0.5 seconds of simulation time)
Tabu Search

- Neighbourhood
  - Equal probability of changing each value
  - Value changes are restricted within a set range
    - \( 0.1 < \alpha < 1, \)
    - \( 0.5 \leq b_1, b_2 \leq 10 \)
    - \( b_1 < b_2 \)
  - Small probability of a random value assignment within the range
Tabu Search

• Aspiration Criteria
  – After a set number of optimization steps, we reset back to the best known solution, and search again from here
    – (do not know if a given tabu move will have a higher objective value than current so we can’t use that)

• Tabu moves have set tenure
Tabu Search

• Every 10 requests
  – Tabu Iteration

• Everyone 100 tabu iterations
  – Potentially reset back to best known solution

• Initial Condition
  – Alpha = 0.5, Beta1 = 2, Beta2 = 5
    (from original work by Singh et al)
  – Alpha -> 1, Beta1 -> 0.5, Beta2 -> 0.5
Performance Evaluation

- HWMP Routing Algorithm used in this topology
- Each MR running the AMB algorithm
Performance Evaluation

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interarrival rate</td>
<td>0.01</td>
</tr>
<tr>
<td>Packet Size</td>
<td>1024 bytes</td>
</tr>
<tr>
<td>MRs</td>
<td>10-30</td>
</tr>
<tr>
<td>Distance between MRs</td>
<td>100m</td>
</tr>
<tr>
<td>Source MRs</td>
<td>3</td>
</tr>
<tr>
<td>Simulation time</td>
<td>100s</td>
</tr>
<tr>
<td>Tabu tenure</td>
<td>0.5s</td>
</tr>
<tr>
<td>Packets between tabu move</td>
<td>15</td>
</tr>
<tr>
<td>Packets between tabu reset</td>
<td>300</td>
</tr>
<tr>
<td>Initial $\alpha$</td>
<td>0.5</td>
</tr>
<tr>
<td>Initial $\beta_1$</td>
<td>2</td>
</tr>
<tr>
<td>Initial $\beta_2$</td>
<td>5</td>
</tr>
</tbody>
</table>

Implemented in ns3 simulation tool
Performance Evaluation

• Important to note:
  – Every 300 packets, tabu resets to best known solution
  – Every 15 packets, tabu move
  – When a move is declared tabu, this lasts for 0.5 seconds
  – These numbers were determined empirically
  – $\alpha, \beta_1, \beta_2$ taken from original work
Results

Effect of Network Size on PDR

Packet Delivery Ratio

Mesh Routers

802.11
MB
AMB
Results

Effect of Network Size on Delay

Average End-to-end Delay

Mesh Routers

- 802.11
- MB
- AMB
Results

• As network size grows
  – Adaptive Mixed Bias delivers more packets
  – Delay increases, likely due to packet drops in other solutions yielding an artificially lower delay
  – Mostly the delay is equivalent in all cases (Between 0.08 and 0.1s)
Results

- Improvement in delay results may be seen with more emphasis on delay in utility (but may come at the cost of PDR)
Future Work

• Adjust utility function
  – Include fairness measure, congestion measure

• Adjust tabu search parameters
  – Neighbourhood function
    • Explore different rules for adjusting parameters
  – Tabu tenures
    • How long to keep a set of parameters tabu
  – Aspiration Criteria
    • More complex than return to best known
Future Work

• Experiment with other heuristic approaches:
  – Simulated annealing, temperature could be related to how congested the network
  – Fuzzy approach (rules translate well)

• Use an offline approach (GA, PSO) in order to determine a parameter set that “performs well” under many network conditions
Summary

• Overview of the Adaptive Mixed Bias (AMB) technique

• Comparison of AMB to IEEE 802.11 and MB

• Performs well, good starting point for further refinement

• Lots of opportunity for future research
Questions?

• Thanks for listening!

• Contact: Jason Ernst
  jernst@uoguelph.ca