Adaptive Mixed Bias Resource Allocation for Wireless Mesh Networks

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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

Reference	Technique	Layers	Goal
[1] Ernst, Denko	Combined Mixed Bias	MAC, PHY, NET	Scheduling
[2] Singh et al	Mixed Bias	MAC, NET	Scheduling
[3] José-Revuelta	Genetic Algorithm	PHY	Channel Assignment
[4] Mahjoub et al	Real-time Search Algorithm	NET	Routing
[5] Choi and Choi	Heuristic, Utility based	PHY, MAC	Scheduling with Service Differentiation
[7] Mandal et al	Constraint based heuristic	PHY	Channel Assignment
[8] Beljadid et al	Genetic Algorithm, Tabu Search	PHY	Channel Assignment
[10] Zhang et al	Diversity weight adaptive scheduling	PHY, MAC, NET	Scheduling, Queue Management
[11] Hedayati et al	Mixed-integer linear programming	PHY, MAC	Power, Rate Adaption
[12] Prashanth et al	Traffic Prediction	PHY, MAC, NET	Joint Scheduling and Routing

See the paper for more details

Mixed Bias

- Resource assigned by:

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

- α – weight of competing biases
- β_1, β_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 α,β_1,β_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 = 1 / delay + 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 <= b1, b2 <= 10
    - b1 < b2
  - 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

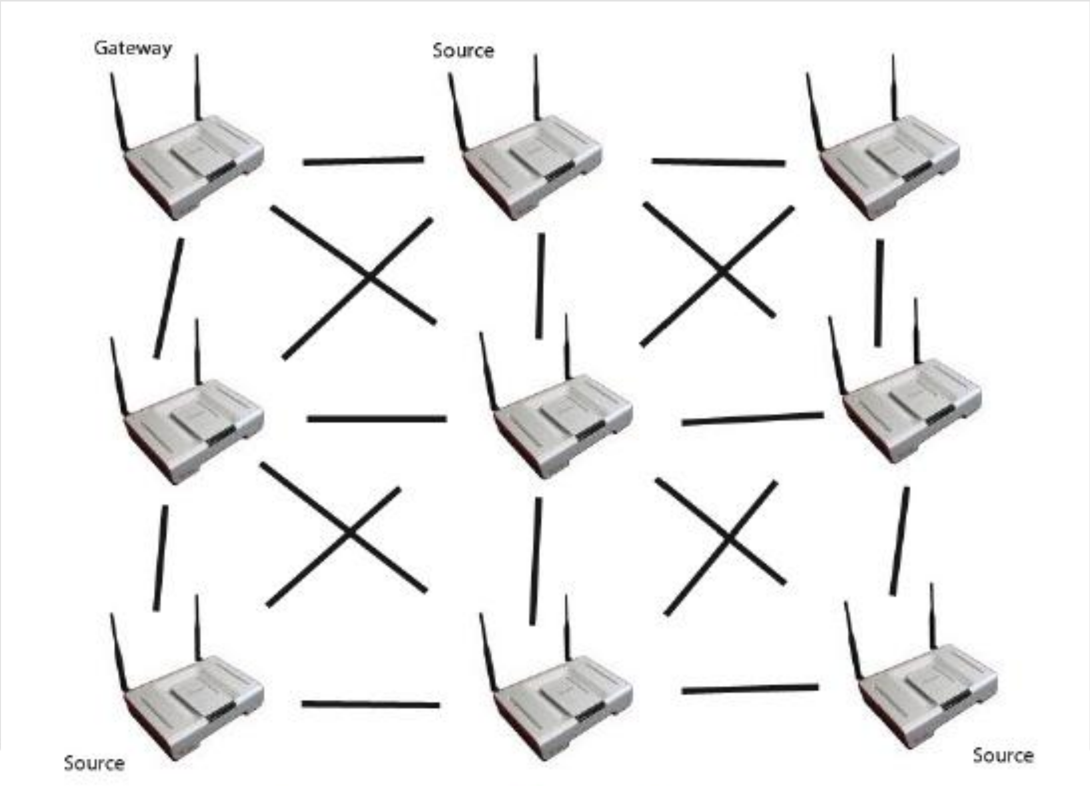


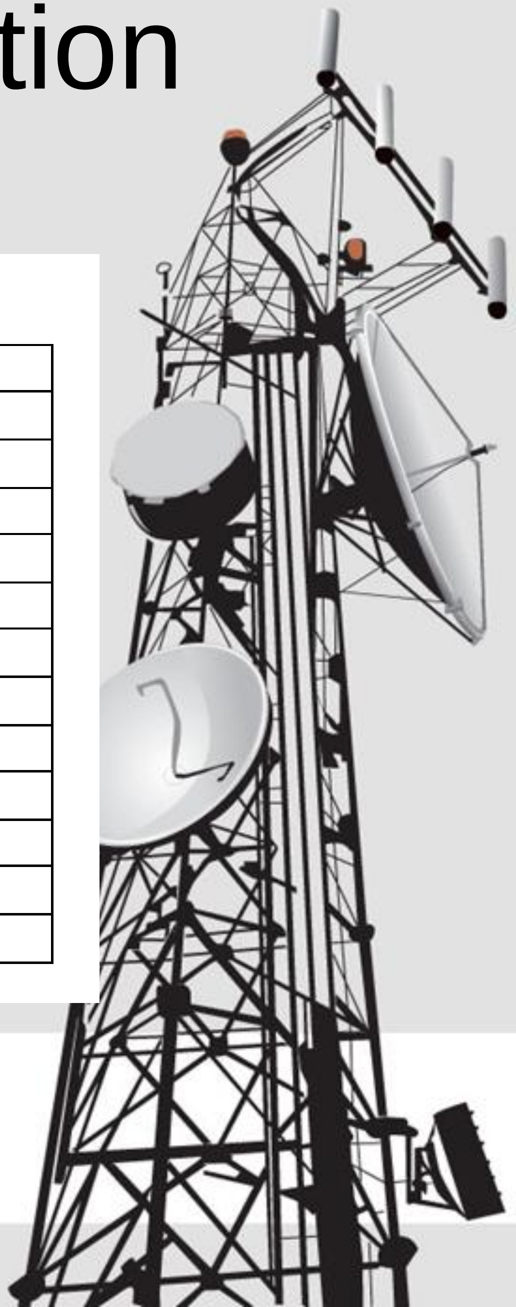
Figure 1. Example Network Topology

Performance Evaluation

TABLE II. SIMULATION PARAMETERS

Parameter	Value
Interarrival rate	0.01
Packet Size	1024 bytes
MRs	10-30
Distance between MRs	100m
Source MRs	3
Simulation time	100s
Tabu tenure	0.5s
Packets between tabu move	15
Packets between tabu reset	300
Initial α	0.5
Initial β_1	2
Intiali β_2	5

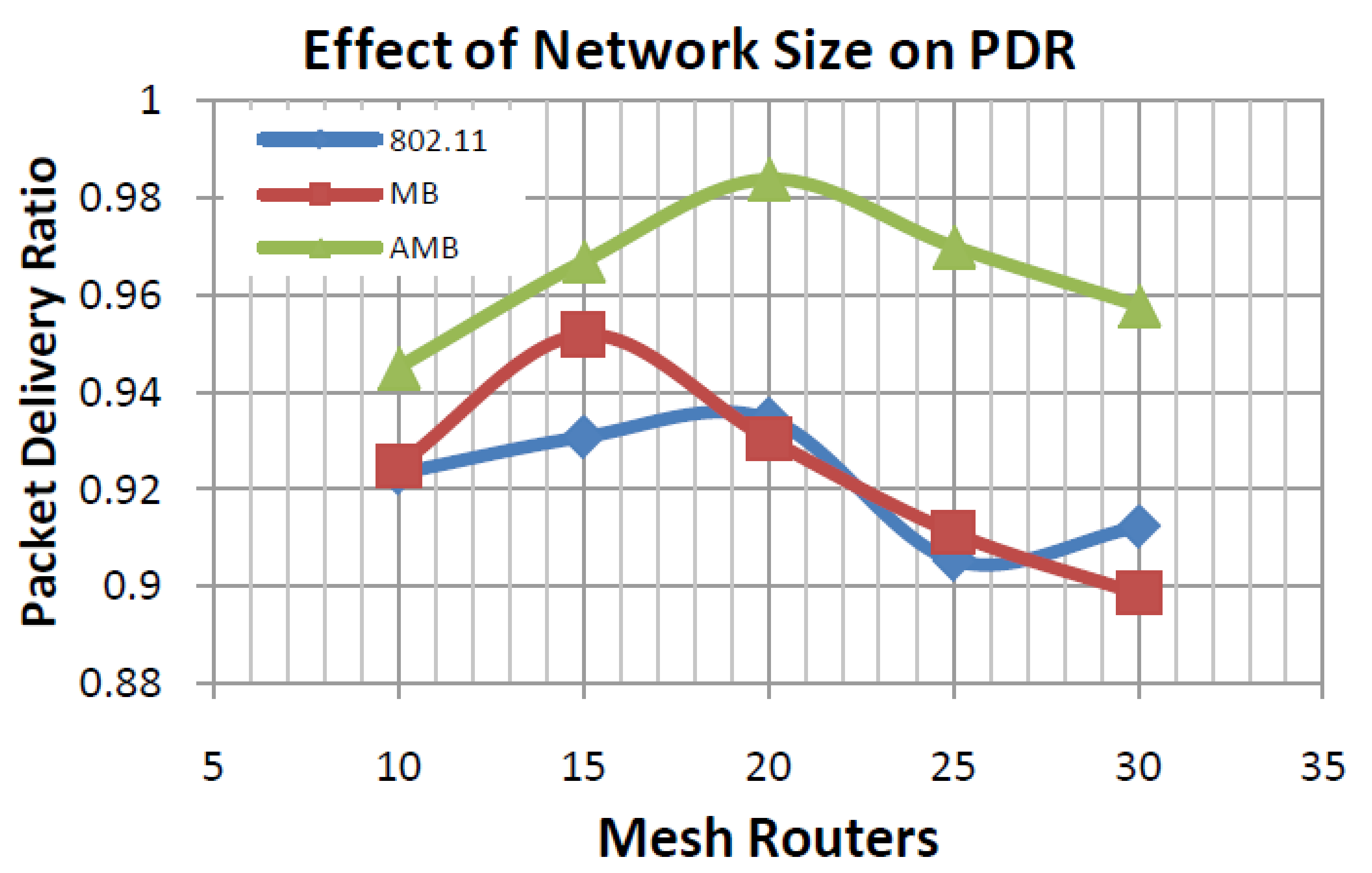
Implemented in ns3 simulation tool



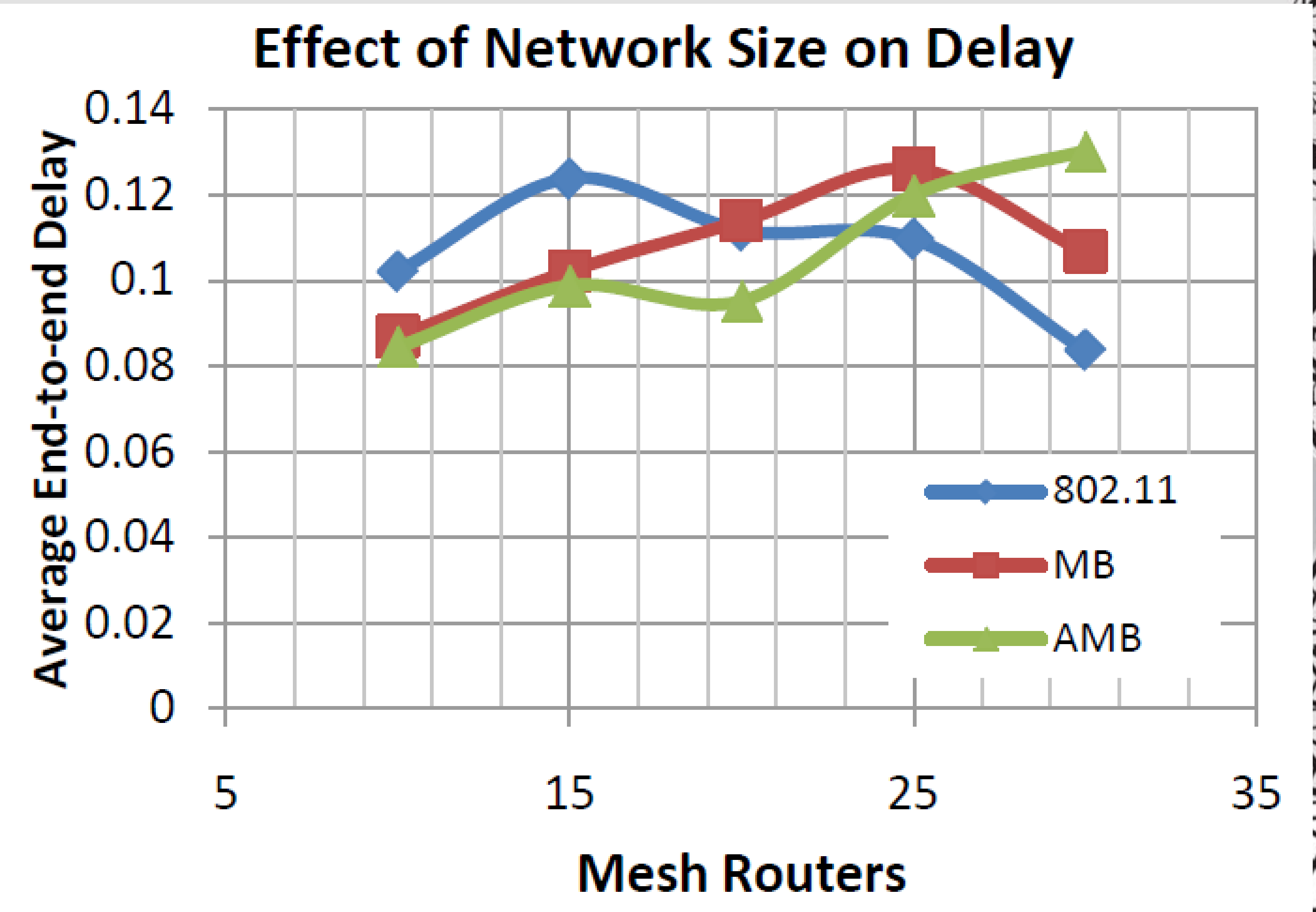
Performance Evaluation

- 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
  - α, β_1, β_2 taken from original work

Results


Effect of Network Size on PDR
Packet Delivery Ratio
1
0.98
0.96
0.94
0.92
0.9
0.88
802.11
MB
AMB
5
10
15
20
25
30
35
Mesh Routers

Results



Effect of Network Size on Delay
Average End-to-end Delay
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
5
15
25
35
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!

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