

Adaptive Mixed Bias Resource Allocation for Wireless Mesh Networks

Jason Ernst, Thabo Nkwe

School of Computer Science – University of Guelph
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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

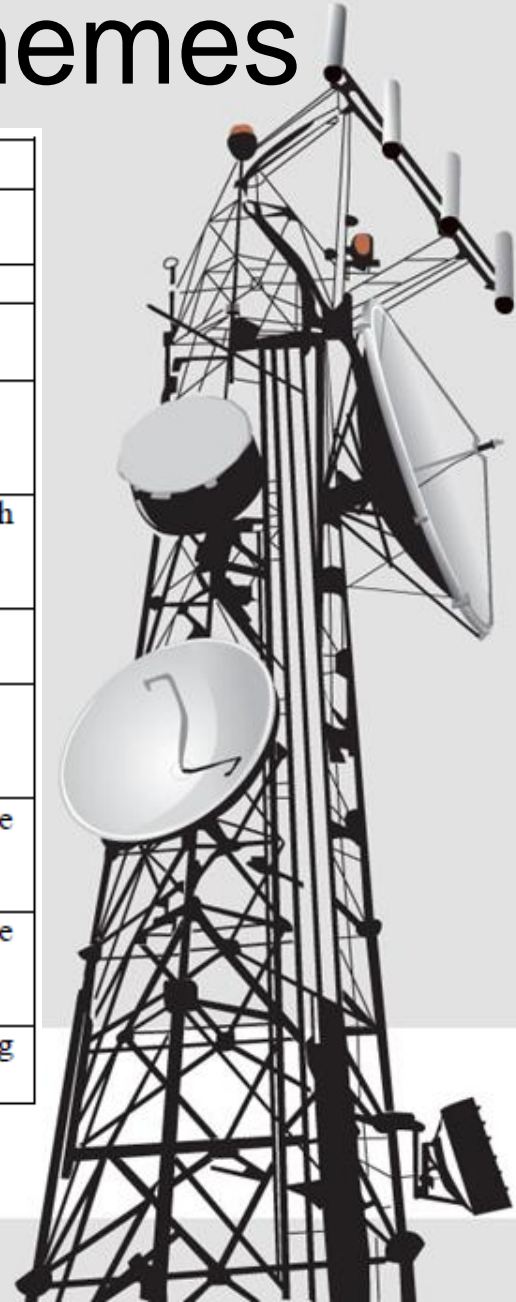
- Proportional:
 - Resources assigned proportionally to some characteristic
 - Danger of starvation with strong proportionality (bias)
- Max-min:
 - Allocate resources such that we maximize the minimum of some characteristic of the network
- Round-robin / Fair:
 - Resource split evenly



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:
 - $U = 1 / \text{delay} + \text{PDR}$
 - 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
 - $0.1 < \alpha < 1$,
 - $0.5 \leq b1, b2 \leq 10$
 - $b1 < b2$
 - 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
 - $\text{Alpha} = 0.5$, $\text{Beta1} = 2$, $\text{Beta2} = 5$
(from original work by Singh et al)
 - $\text{Alpha} \rightarrow 1$, $\text{Beta1} \rightarrow 0.5$, $\text{Beta2} \rightarrow 0.5$



Performance Evaluation

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

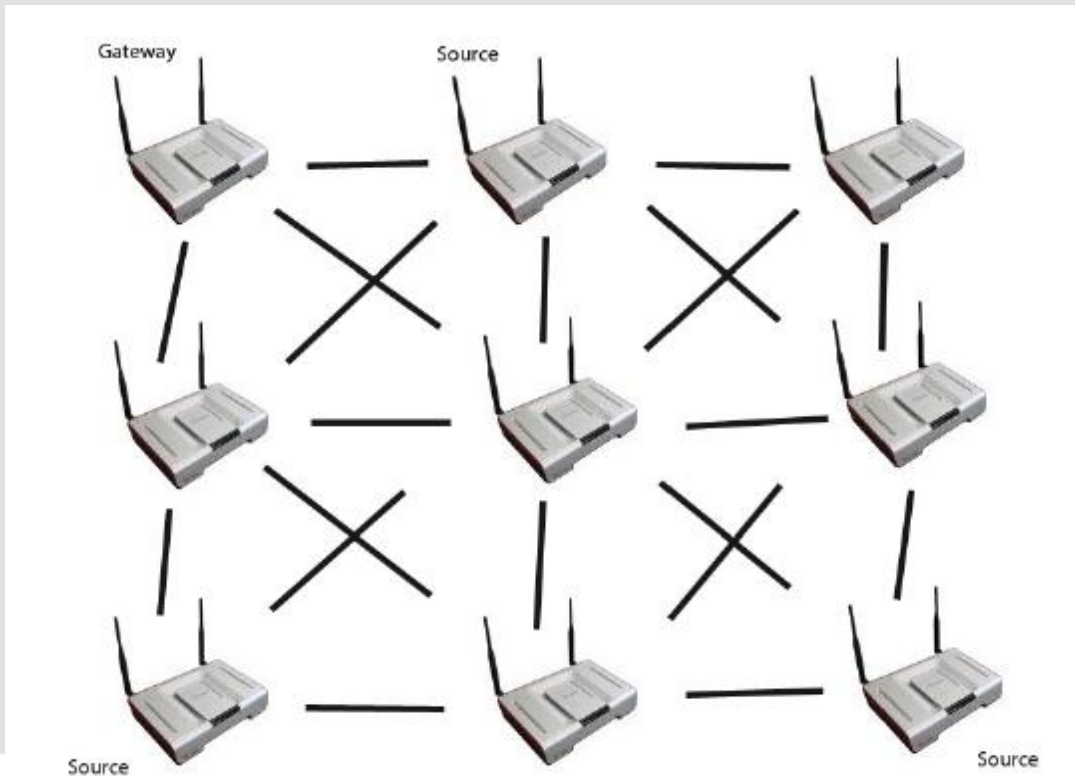


Figure 1. Example Network Topology

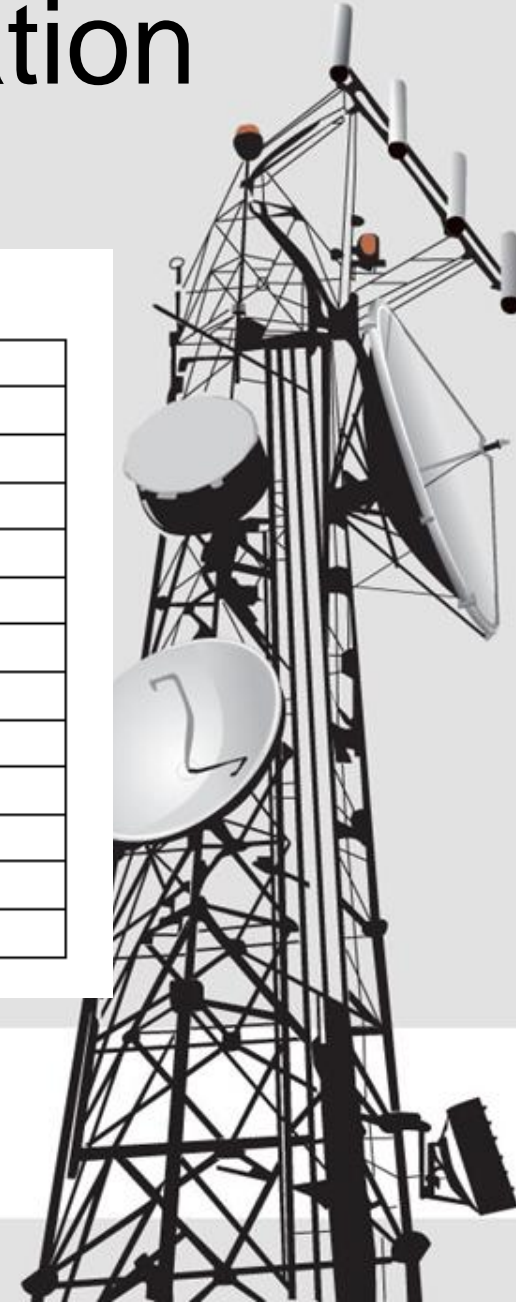


Performance Evaluation

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
Initial β_2	5

Implemented in ns3 simulation tool

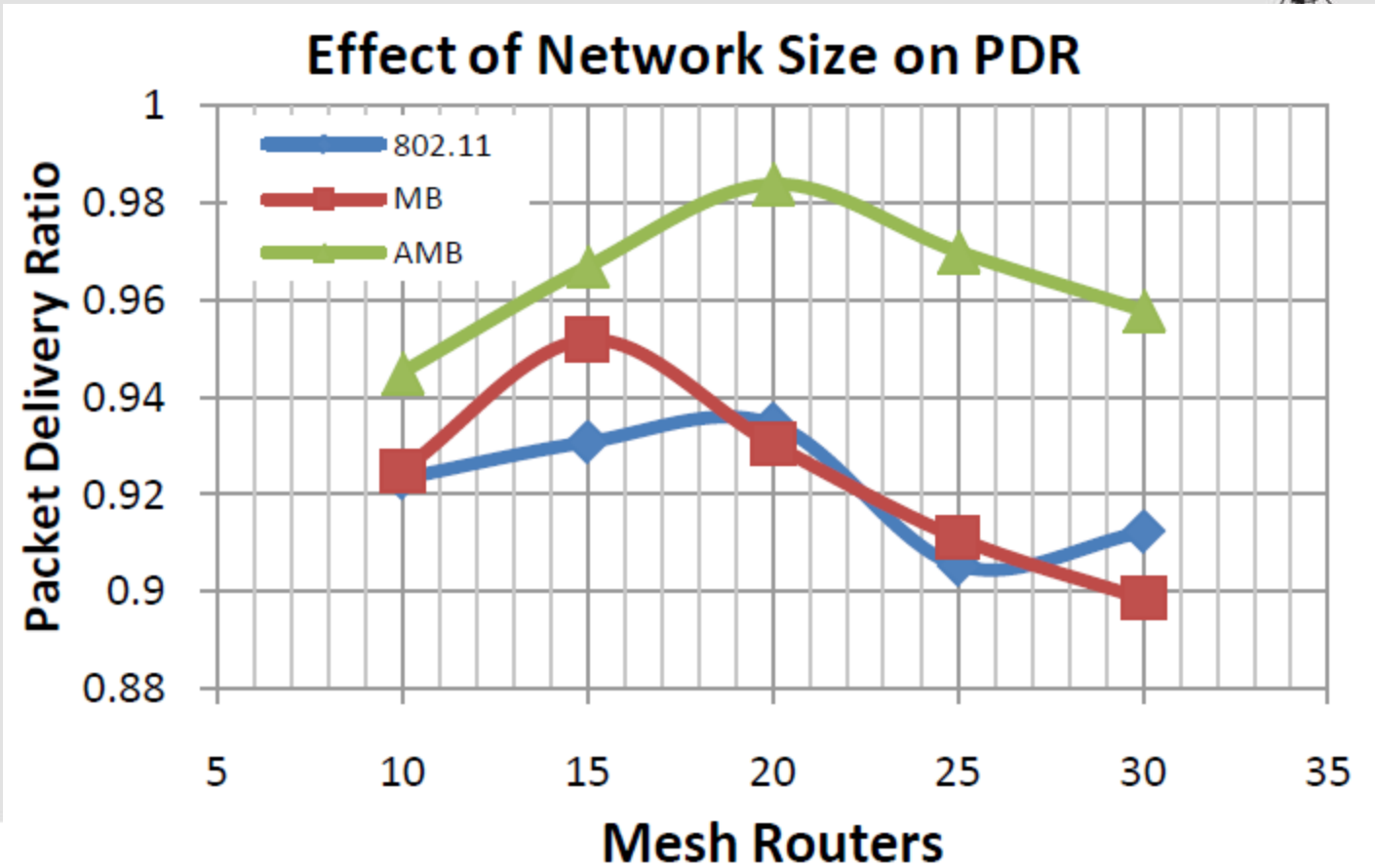


Performance Evaluation

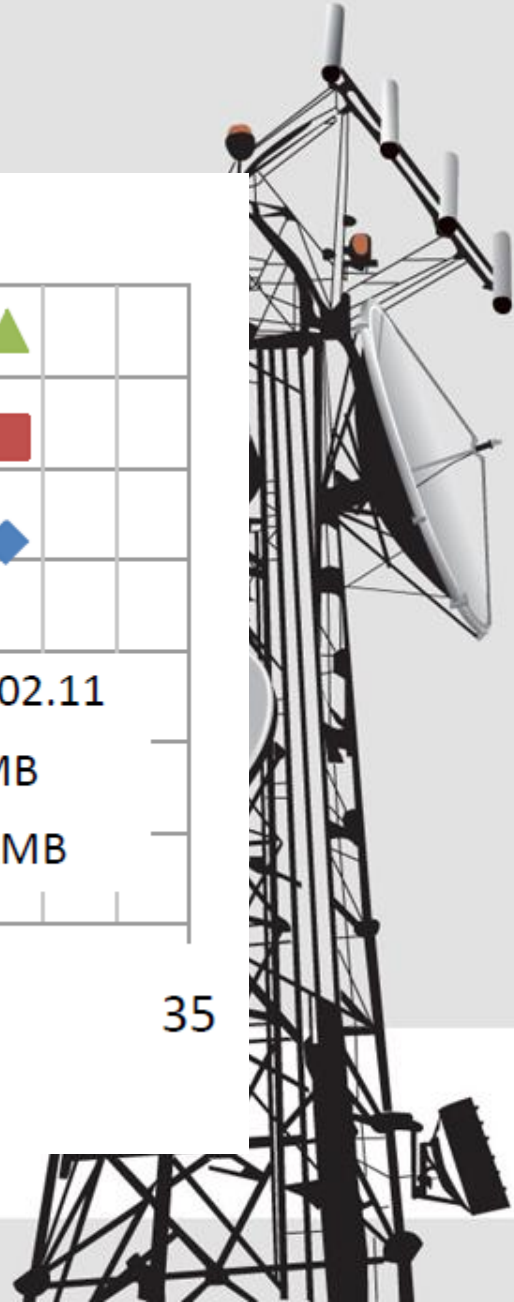
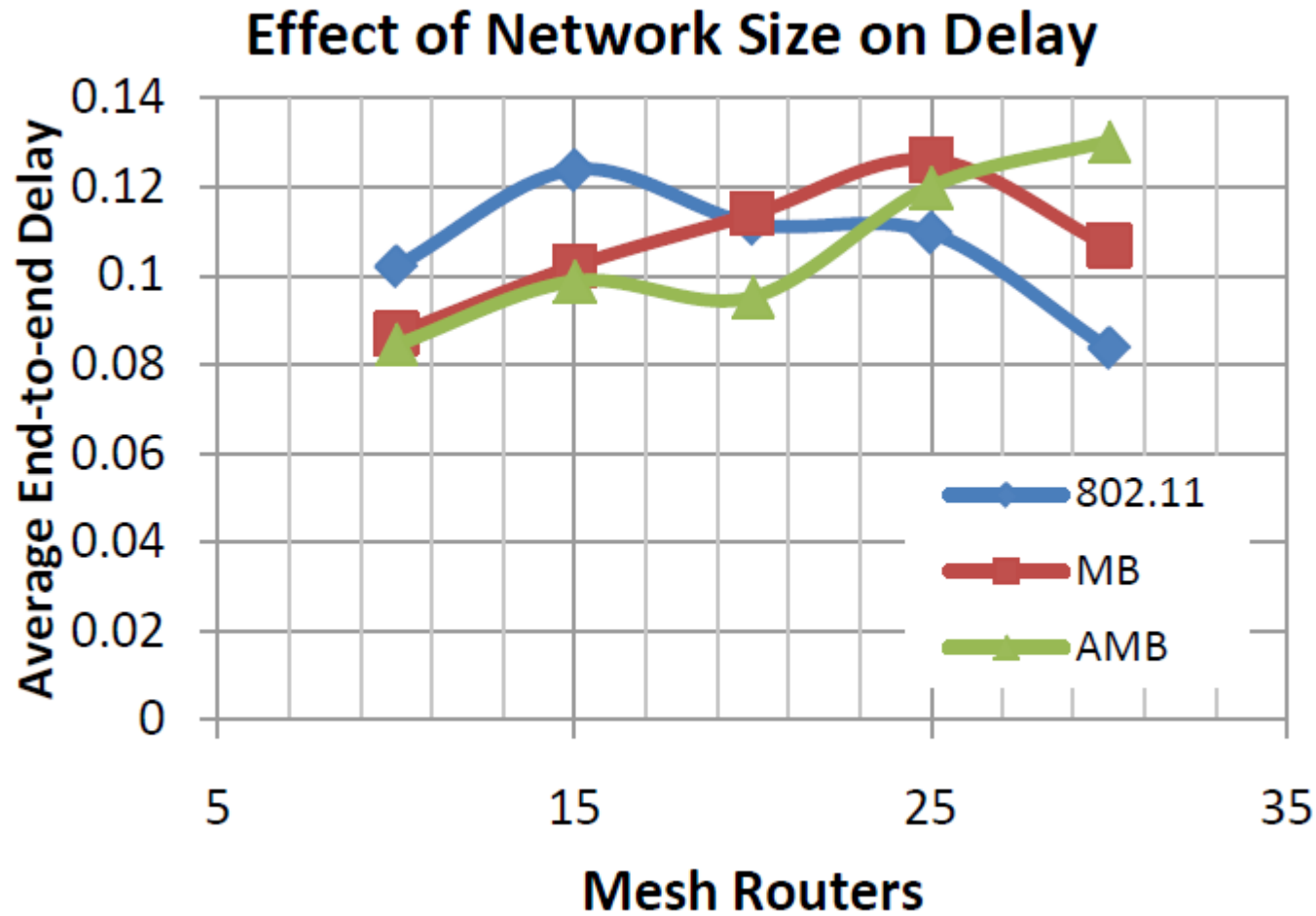
- Important to note:
 - Every 300 packets, tabu resets to best known solution
 - Every 15 packets, tabu move
 - When a move is declared tabu, this lasts for 0.5 seconds
 - These numbers were determined empirically
 - α, β_1, β_2 taken from original work



Results



Results



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

