Fair Scheduling for Wireless Mesh Networks with Multiple GWs

Jason B. Ernst and Mieso Denko

Pervasive & Wireless Networking Research Lab (PERWIN)
Computing & Information Science Department
University of Guelph, Guelph, Ontario, N1G 2W1, Canada

Presented at AINA 2009

UNIVERSITY of GUELPH

Outline of Presentation

- Introduction
- Background & Related Work
- Limitations of Existing Work
- Proposed Approach
- Detailed Description of Fair Scheduling
- Performance Evaluation
- Conclusions & Future Work

UNIVERSITY of GUELPH

Introduction

- Wireless Mesh Network (WMN):
  - Mesh Routers (MR)s: Often fixed, more resources (CPU, Memory) than traditional ad hoc nodes
  - Gateways (GW)s: Source and Destination of all Internet Traffic
  - Mesh Clients (MC)s: User devices such as laptops, PDAs, mobile phones etc.

UNIVERSITY of GUELPH

Introduction: WMN

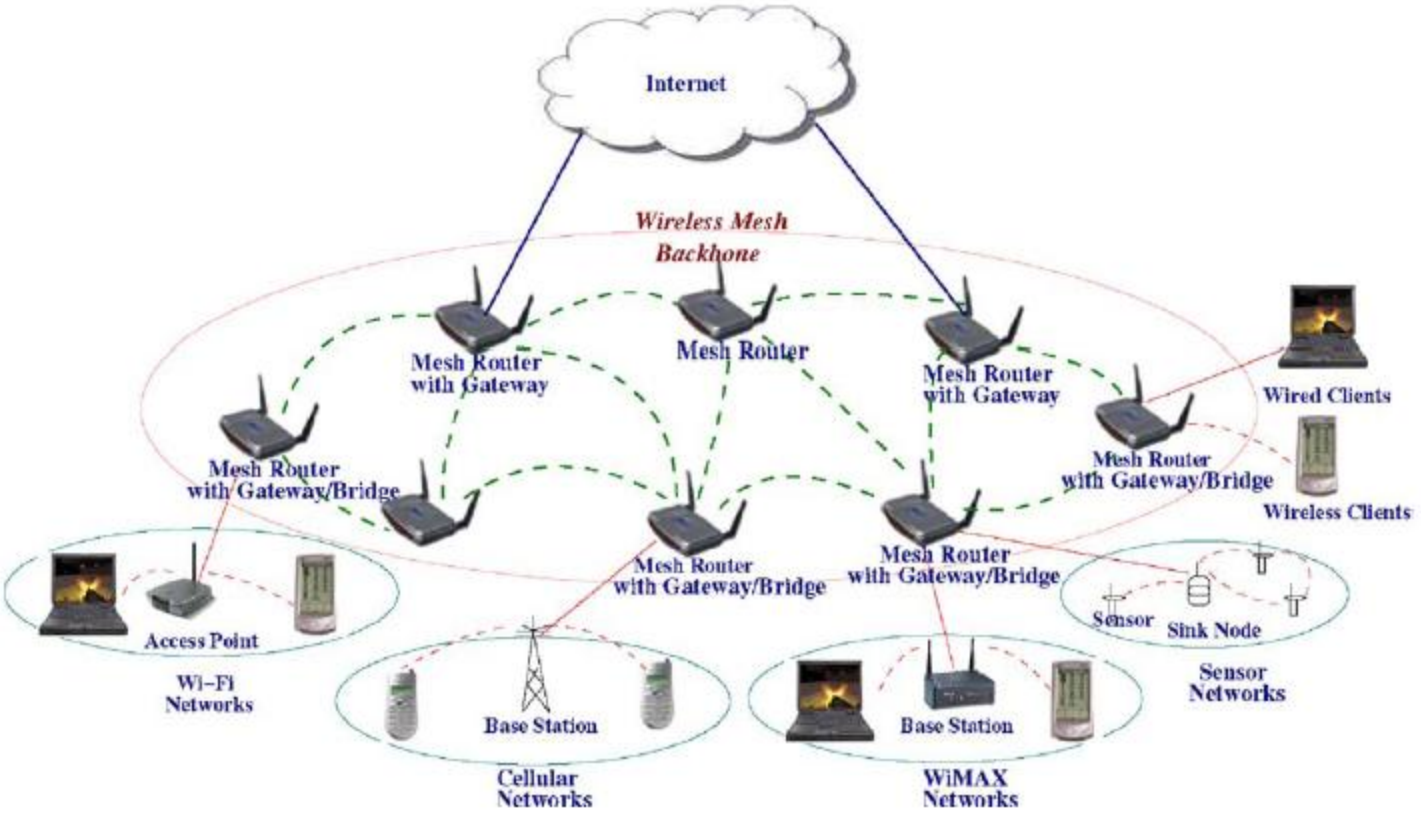
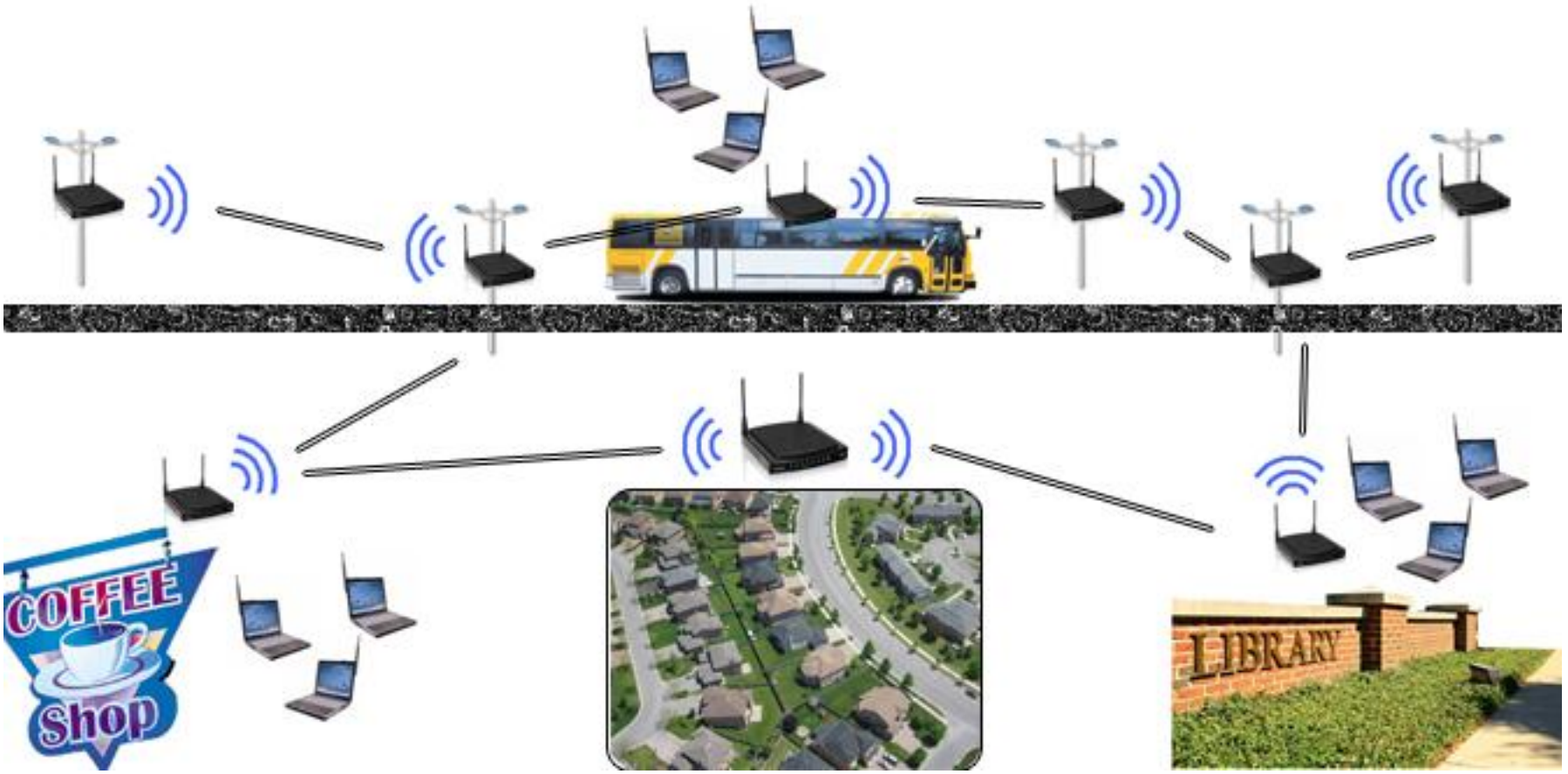


Fig. 3. Infrastructure/backbone WMNs.

[Akyildiz et al]

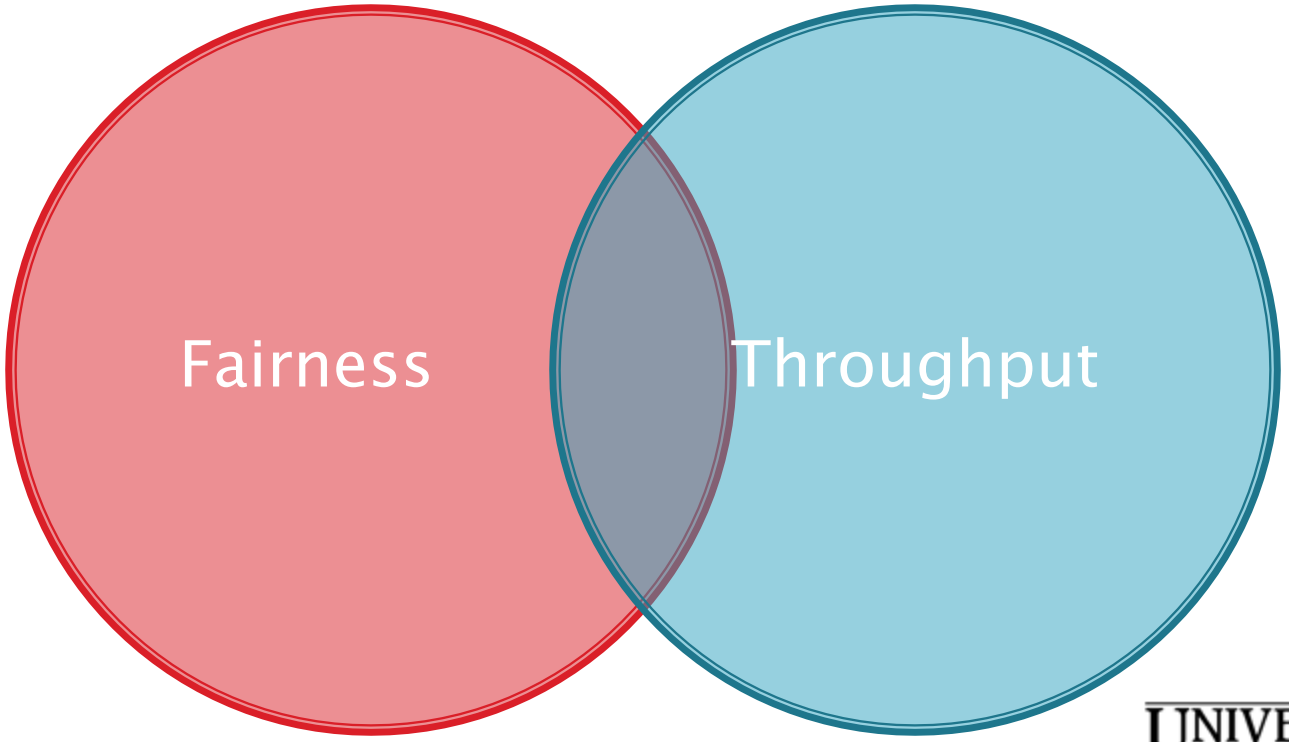
UNIVERSITY of GUELPH

Introduction: Mobile WMN



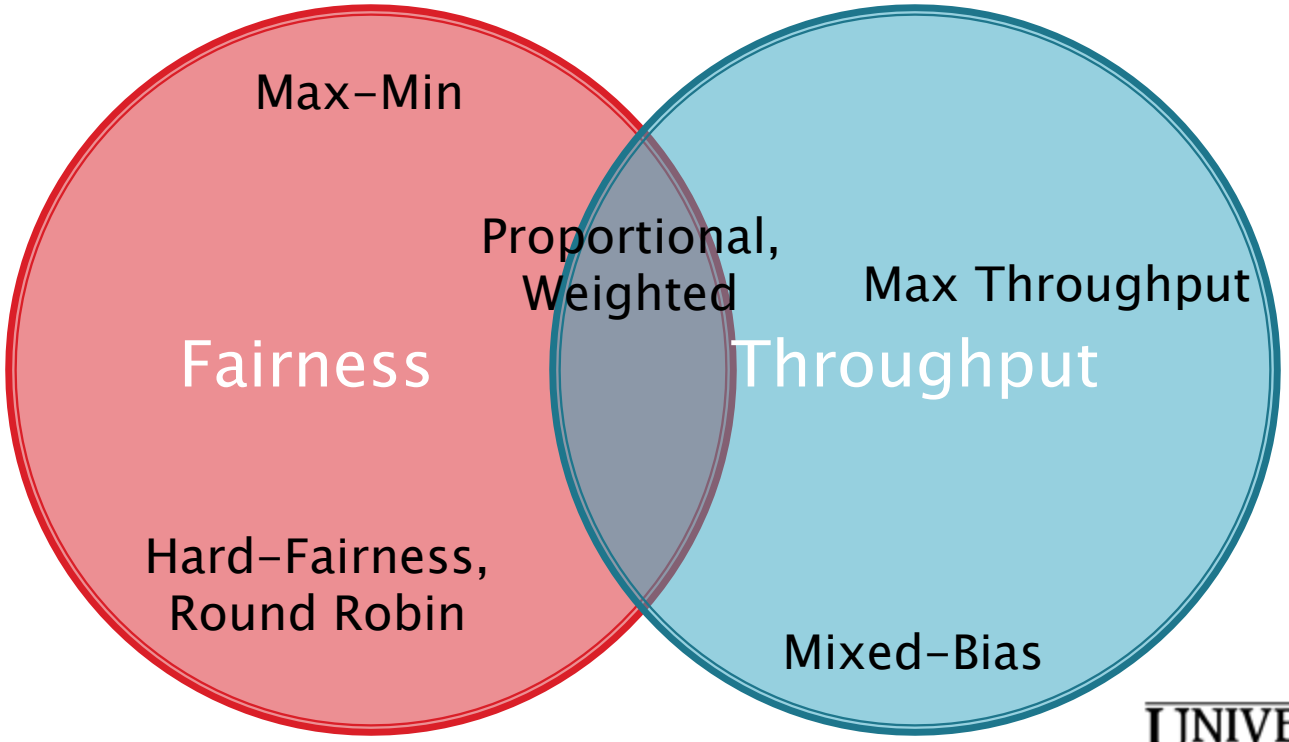
UNIVERSITY of GUELPH

Introduction: Definition of Fairness



UNIVERSITY of GUELPH

Introduction: Definition of Fairness



UNIVERSITY of GUELPH

Introduction: Motivation for Scheduling

- Equal Price, Equal Quality of Service (QoS)
- Avoid node starvation
- Wasted Resources

UNIVERSITY of GUELPH

Background & Related Work

- Operating Systems
  - User and process scheduling in interactive OS's started in the 1960s and 1970s (multics, unix)
- Wired Networks, Wireless LAN (single hop)
- Ad hoc networks
- Other distributed computing
  - SHARCNET, World Community Grid

UNIVERSITY of GUELPH

Background & Related Work

- Hard Fairness [Cao et al, Nelson et al]

$$\text{Re}\,sources\ assigned\ (R) = \frac{1}{\#\ flows\ through\ the\ node}$$

- Equal resources assigned to every node, flow, mesh router etc.
- Does not work well if some nodes do not require resources

UNIVERSITY of GUELPH

Background & Related Work

- Max-min [Bejerano et al]
- Maximize the minimum amount of resources assigned to each node, or revert to an equal split
- Does not work well if there are large differences in requirements from node to node

UNIVERSITY of GUELPH

Background & Related Work

- Proportional Fairness [Erwu et al, Gupta et al]

$$R = \frac{1}{c^{\beta}}$$

Where:
R is the resources allocated to the node
c is the characteristic which priority is given to, $c > 0$
β is the proportionality factor, $\beta > 0$

- Works well, but what if we would like to bias more strongly against certain characteristics while still retaining a minimum service level

UNIVERSITY of GUELPH

Background & Related Work

- Mixed-Bias [Singh et al]

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

Where:

R is the resources allocated to the node

c is the characteristic which priority is given to, $c > 0$

β_1, β_2 are the proportionality factors, $\beta_1, \beta_2 > 0$

- Allows multiple strong and weak biasing against one characteristic

UNIVERSITY of GUELPH

Limitations of Existing Work

- Fair Scheduling
  - In [Salem et al] only scheduling proposed
    - No mechanism for maintaining and collecting the requirements
    - Performance evaluation based on length of schedule, not other metrics such as PDR or delay
    - Single GW

UNIVERSITY of GUELPH

Proposed Approach

- Fair Scheduling for WMNs with Multiple Gateways
  - Distributed Requirement / Routing Tables
  - Requirement Propagation
  - Clique Generation / Compatibility Matrix
  - Implementation of Schedule Generation

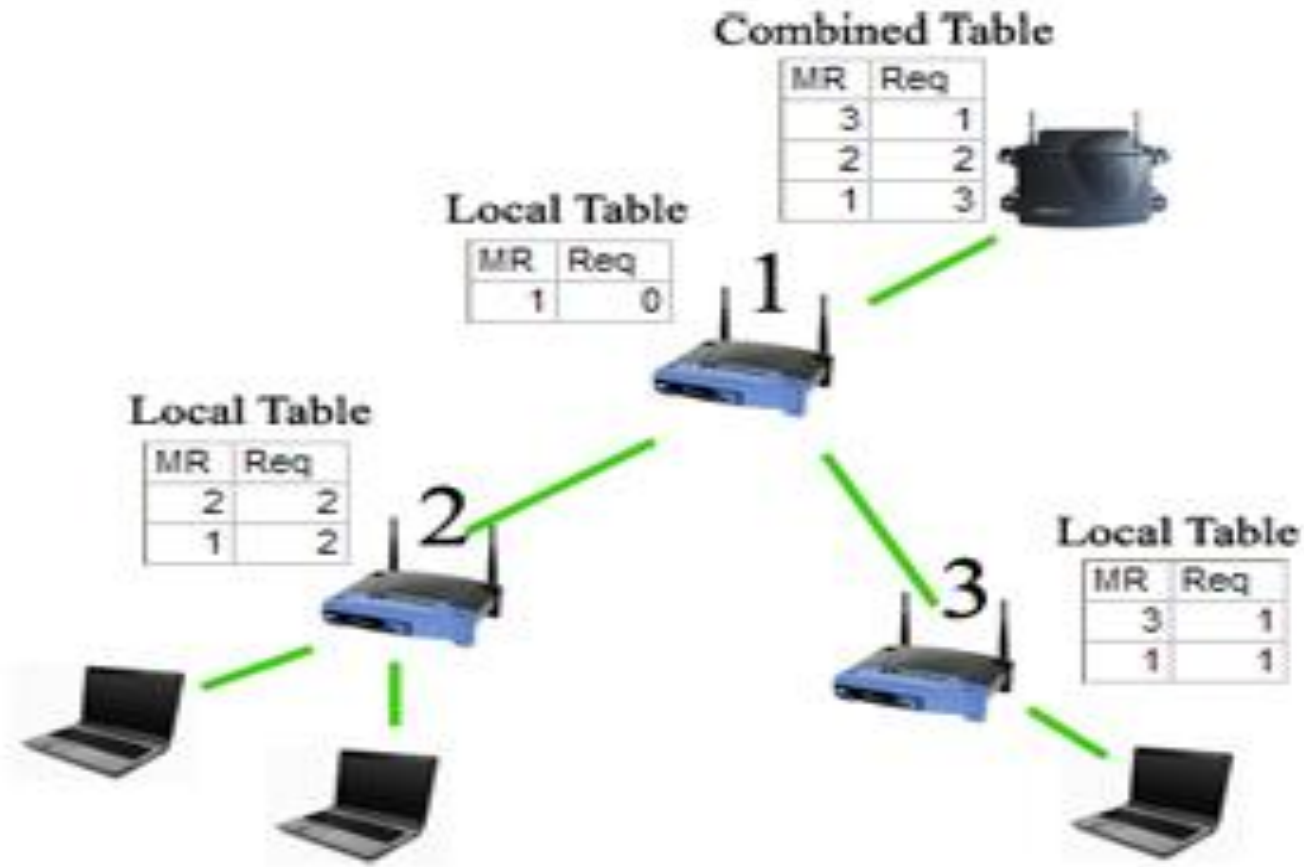
UNIVERSITY of GUELPH

Fair Scheduling for WMNs with Multiple Gateways

- Based on [Salem et al]
  - Our approach gives a mechanism for collecting the requirements and distributed the scheduling
  - We also relax the assumption of a single gateway
  - We evaluate the solution with a network simulation. The original authors evaluate based solely on scheduling lengths

UNIVERSITY of GUELPH

Fair Scheduling



Distributed Routing & Requirement Tables

UNIVERSITY of GUELPH

Fair Scheduling

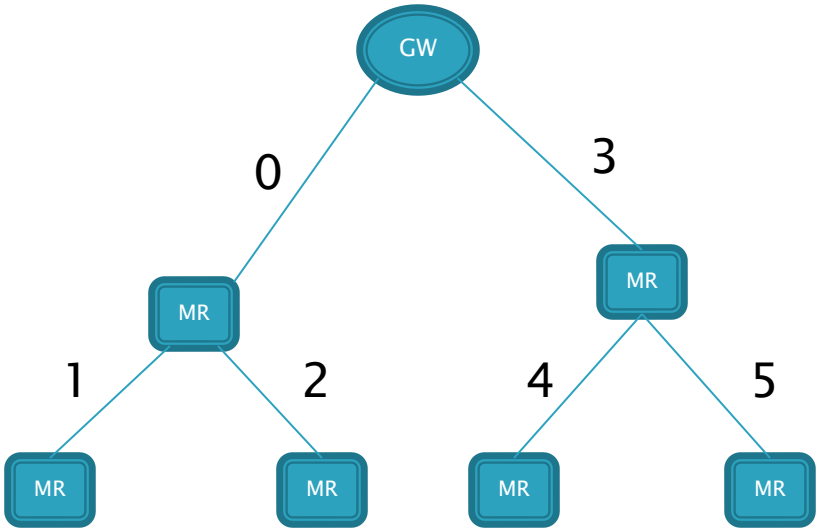
Requirement Propagation Algorithm Pseudocode

1. *Associate MC with MR*
2. *Generate a Client Requirement at MR for the MC*
3. *For each link between MR and GW*
   - *Requirement(current-link) ++*
4. *For each Hop*
   - *Requirement(current-link) --*
5. *On Drop: For each link between MR and GW*
   - *Requirement(current-link) --*

Algorithm 1 Requirement Propagation

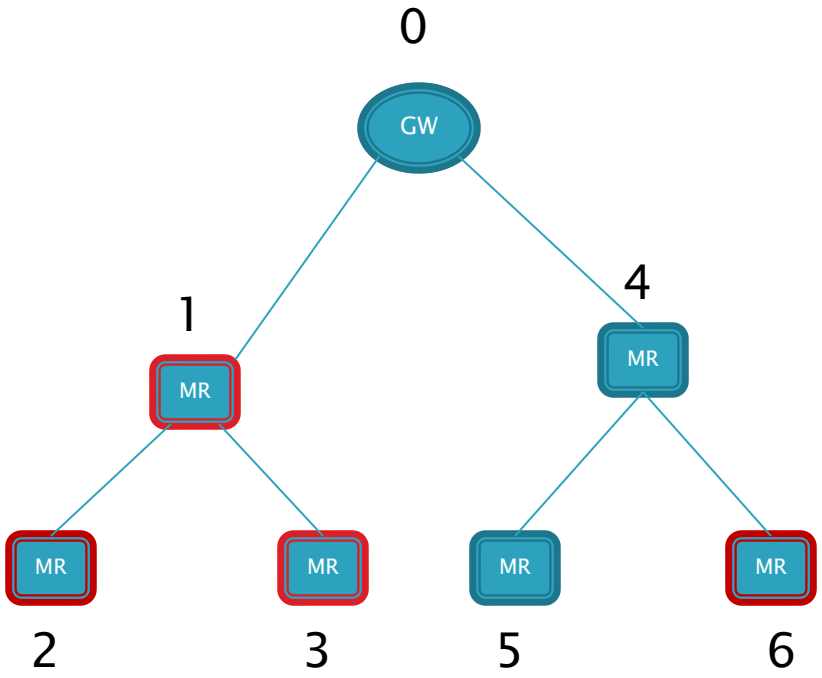
UNIVERSITY of GUELPH

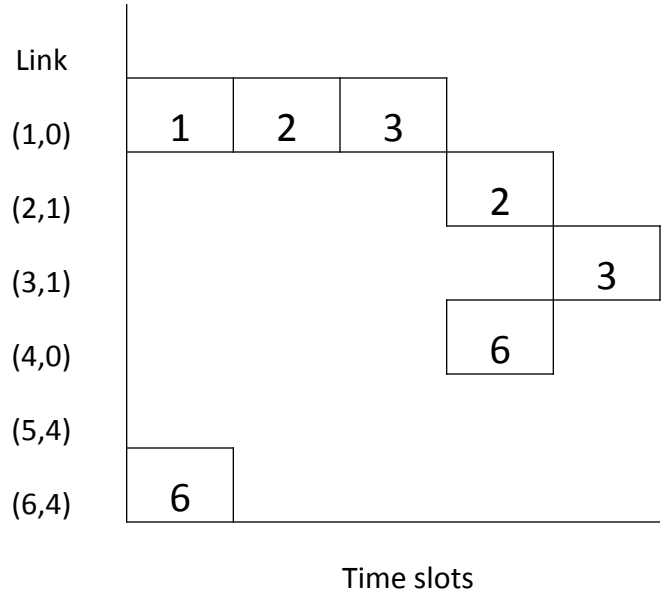
Fair Scheduling:
Clique Generation / Compatibility Matrix



	0	1	2	3	4	5
0	1	0	0	0	1	1
1	0	1	0	1	1	1
2	0	0	1	1	1	1
3	0	1	1	1	0	0
4	1	1	1	0	1	0
5	1	1	1	0	0	1

Fair Scheduling: Schedule Generation





- Red outline denotes requirements at these MRs

Example STDMA Scheduling

UNIVERSITY of GUELPH

Performance Evaluation

- Fair Scheduling for WMNs with Multiple GWs
  - Compared against single GW case
  - Compared against no fair scheduling case

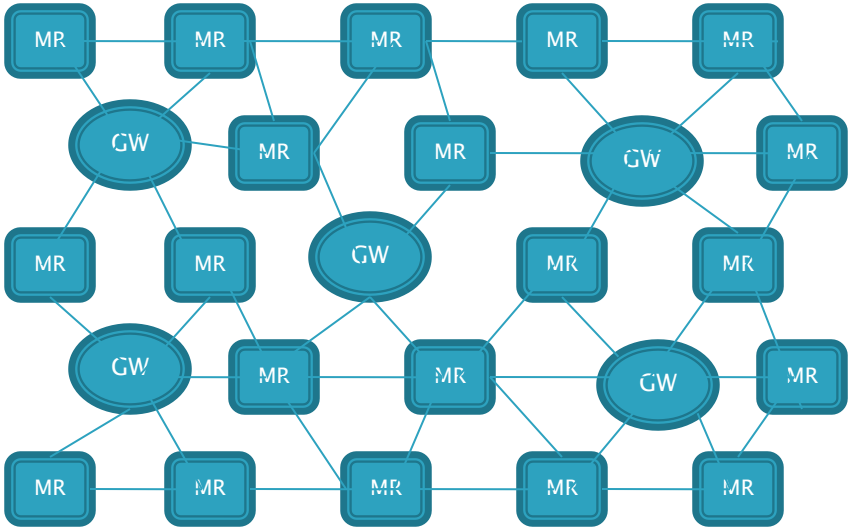
Parameter	Value
Environment Dimensions	1000m x 1000m
Node Range	250m
Number of Mesh Routers	10 to 50
Number of Mesh Clients	250
Number of Gateways	1 to 5
Mean Packet Arrival	0.01 s
Mean Hop Delay	0.01 s
Retry Threshold	0.01 s

  - Each run repeated 10 times for consistency

UNIVERSITY of GUELPH

Traffic Model and Node Placement

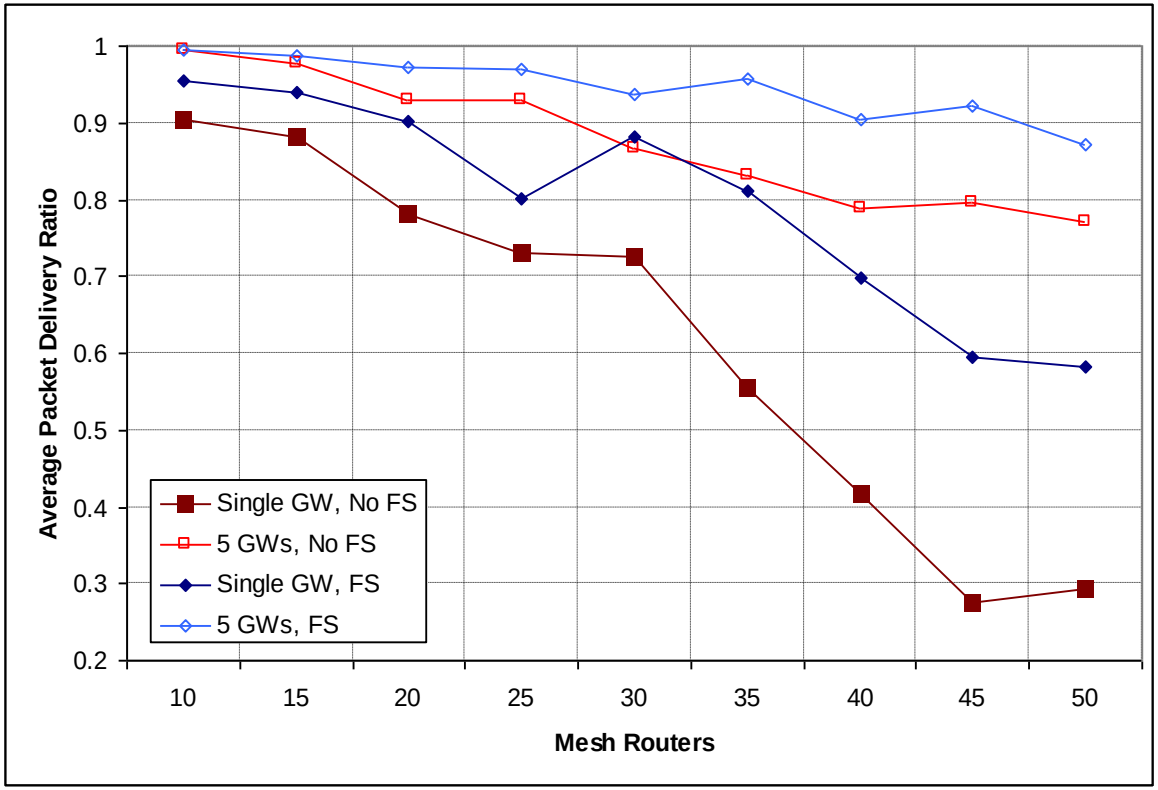
- MRs arranged in a staggered grid topology so that each node can have at max 6 neighbours
- GWs spread out as much as possible
- Traffic routes towards closest GW
- Packet arrivals modeled with a Poisson process



UNIVERSITY of GUELPH

Performance Evaluation

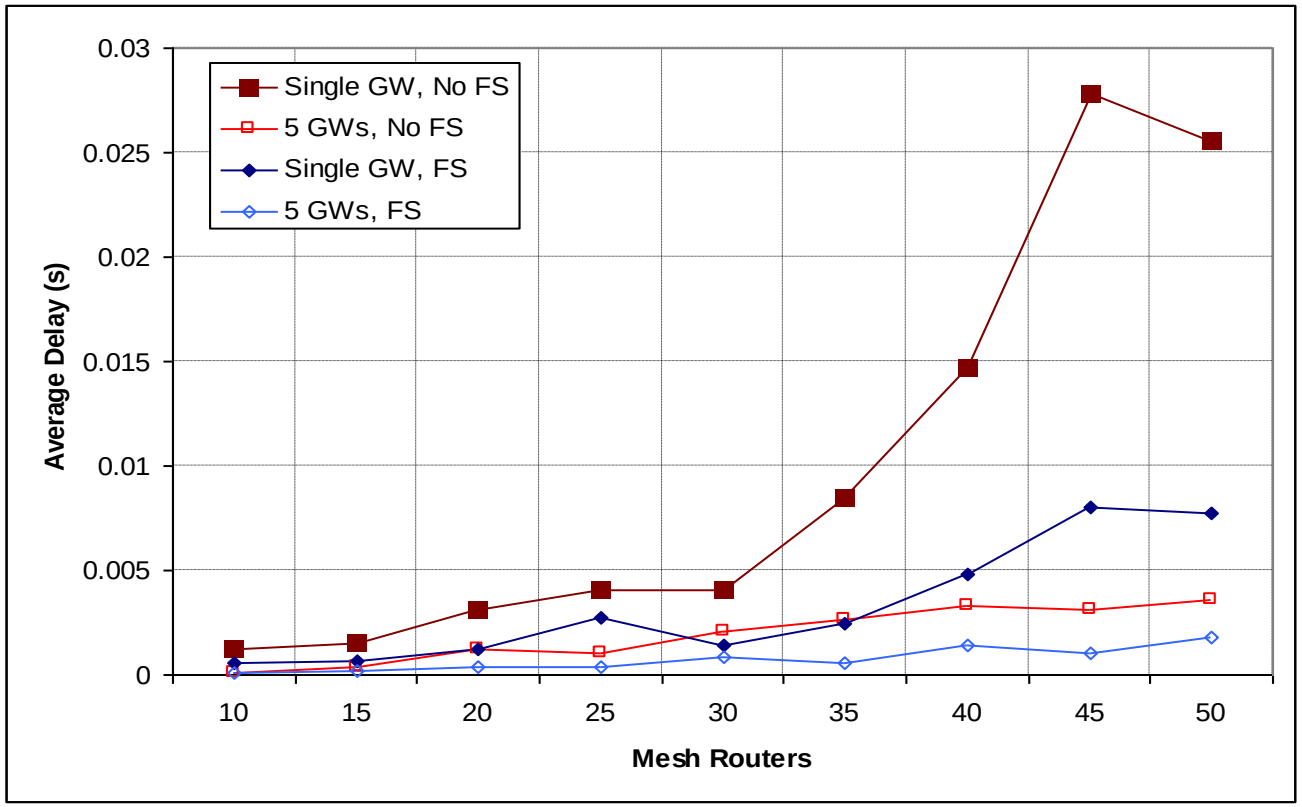
- Effect of Varying Mesh Routers on PDR



- Single GW performs poorly compared to Multi-GW

Performance Evaluation

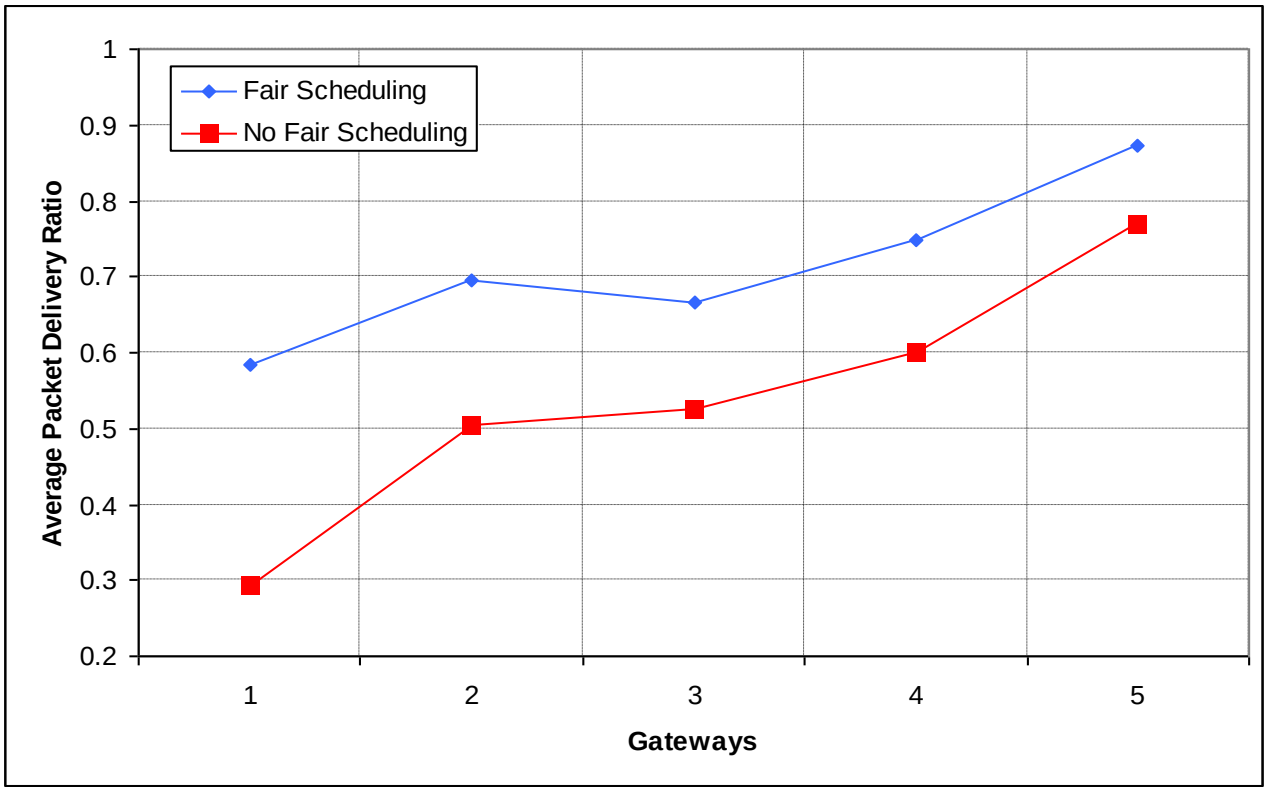
- Effect of Varying Mesh Routers on Delay



- High delay results in fewer successful packet arrivals

Performance Evaluation

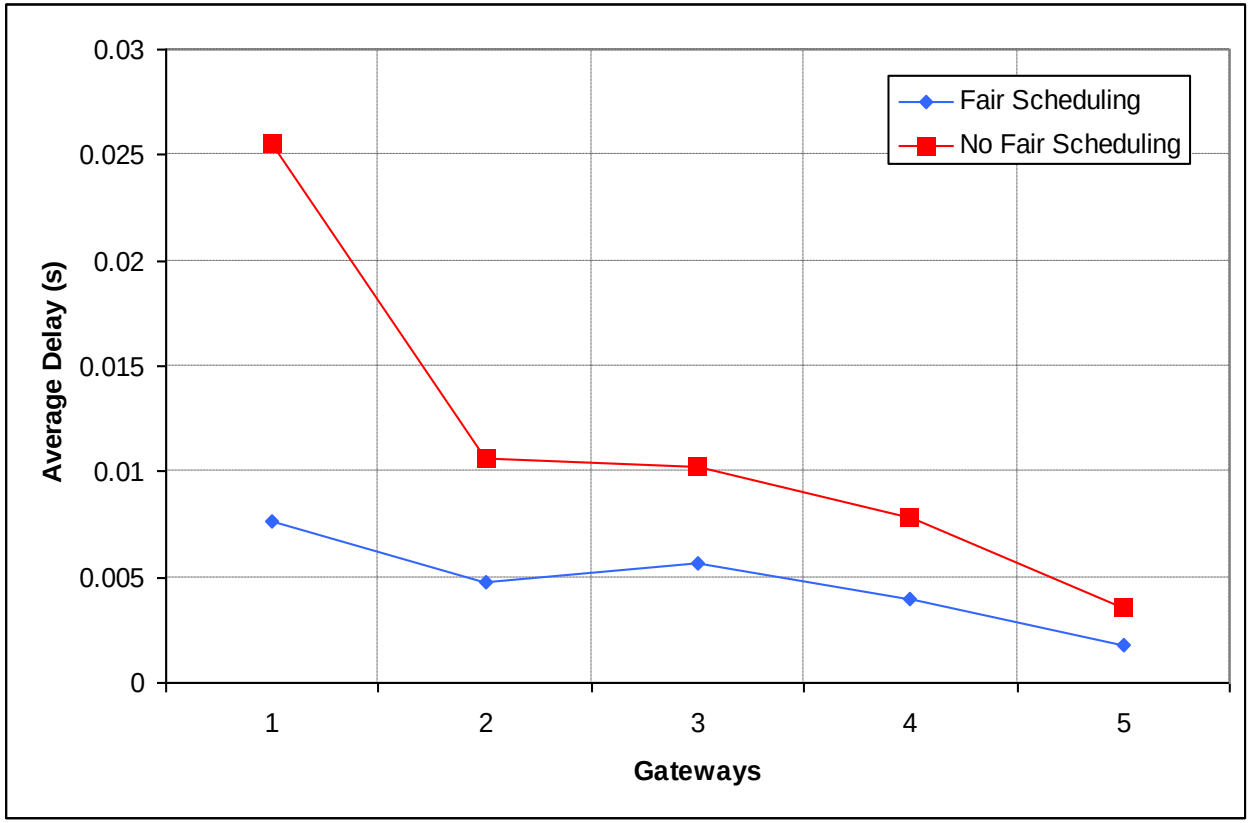
- Effect of Varying Gateways on PDR (50 MR)



- Multiple GWs allow increased performance most of the time
  - FS performs better than no FS

Performance Evaluation

- Effect of Varying Gateways on Delay (50 MR)



- Delay decreases significantly as more GWs are added since on average fewer hops are required

Conclusions & Future Work

- Fair Scheduling with for WMNs with multiple Gateways was proposed
- The main features of the proposed scheme are:
  - Distributed Requirement / Routing Tables
  - Requirement Propagation
  - Multiple GWs
- Simulation results with FS are improvement over no FS
- Multiple GWs are beneficial
- As a future work we will investigate:
  - The effect of mobility of mesh routers
  - Cross-layer design optimizations

UNIVERSITY of GUELPH

Thank you

Contact: Jason Ernst
jernst@uoguelph.ca

UNIVERSITY of GUELPH