A Review of Cross-Layer Scheduling and Resource Allocation for Wireless Mesh Networks

Jason Ernst and Mieso Denko

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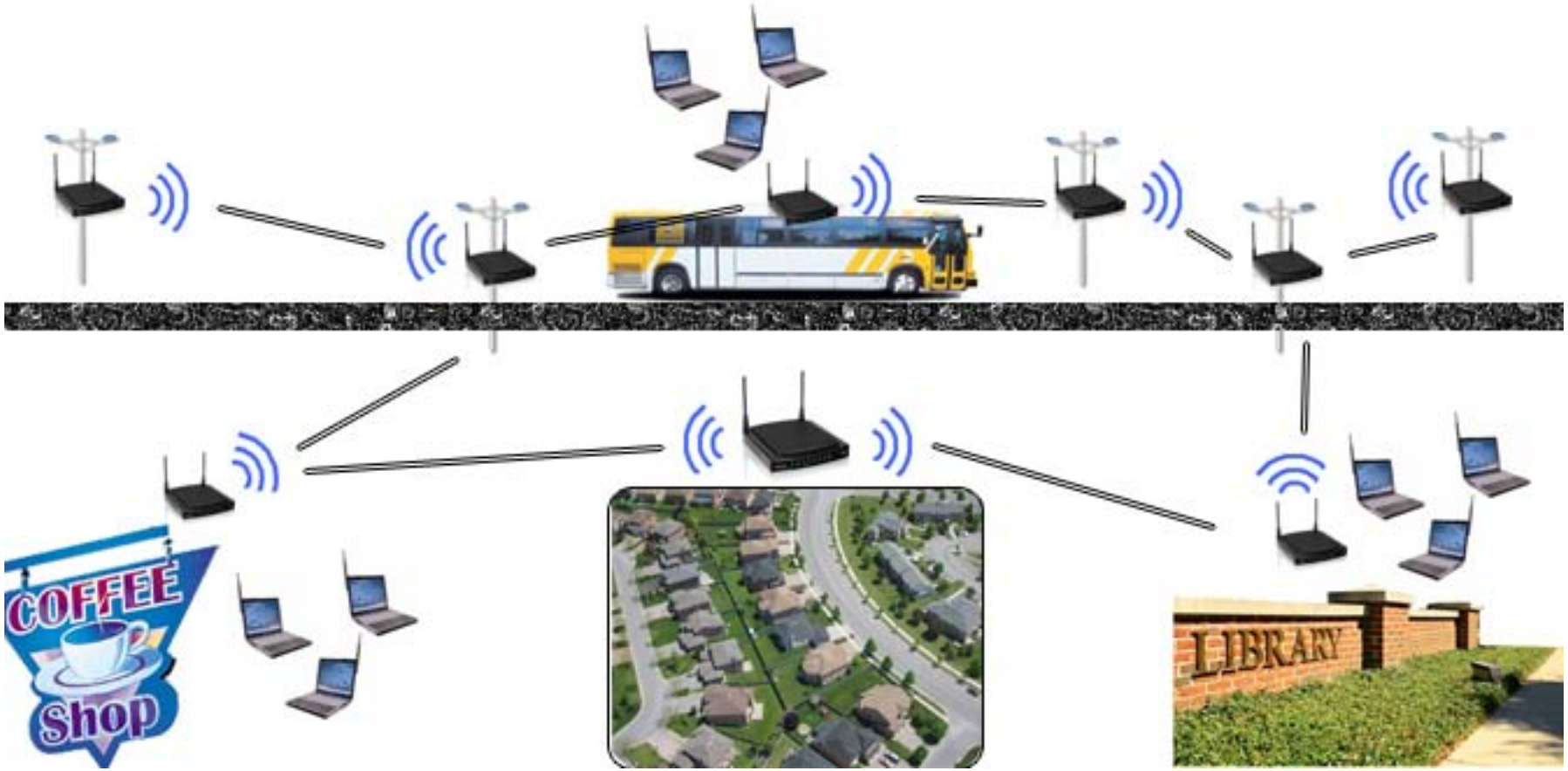
Introduction

- Wireless Mesh Networks
- OSI VS Cross-Layer Design
- Cross Layer Design Architectures
- Cross-Layer Design Techniques
- Our scheme
- Conclusions & Future Work

Wireless Mesh Networks

- Multi-hop wireless ad hoc network
  - Mesh Routers MR
  - Gateways GW
  - Mesh Clients MC
- Majority of traffic between MC and GW
  - Not MC to MC
- MR often assumed static, more resources
  - CPU, Memory, Power (battery life)

Wireless Mesh Networks



Wireless Mesh Networks

- Applications
  - Commercial internet access
  - Also applications in Military communication
  - Search and Rescue
  - Sensor applications where Mesh provides backbone
- Advantages
  - Cheap and easy to deploy compared with wired
  - Autonomous: self-configuration, self-optimization, self-healing network
  - Good for rural applications and sparsely populated areas

OSI VS Cross-Layer Design

- Cross-Layer
  - Provides feedback from multiple layers
  - More intelligent decisions made at routing, MAC layers
  - Must be designed carefully to allow for extensions

- OSI
  - Good design from software engineering point of view
  - Provides good separation and abstraction compared with a “flat” model

Cross-Layer Design

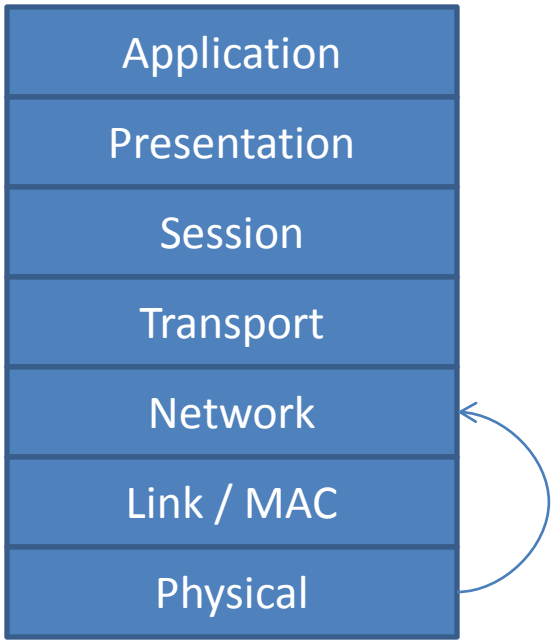
- Cross-Layer Design an Emerging Technology?
  - It has been around for about 5 years now
    - Last major survey covered only the beginning of cross-layer design
    - Many developments in the last 5 years
  - Somewhat controversial technique

  - Many different ideas are being applied to cross-layering
    - Cognitive radio techniques
    - Adaptive control
    - Network coding

Cross-Layer Design Architectures

OSI 7 Layer Stack

Cross-Layer Design Architectures

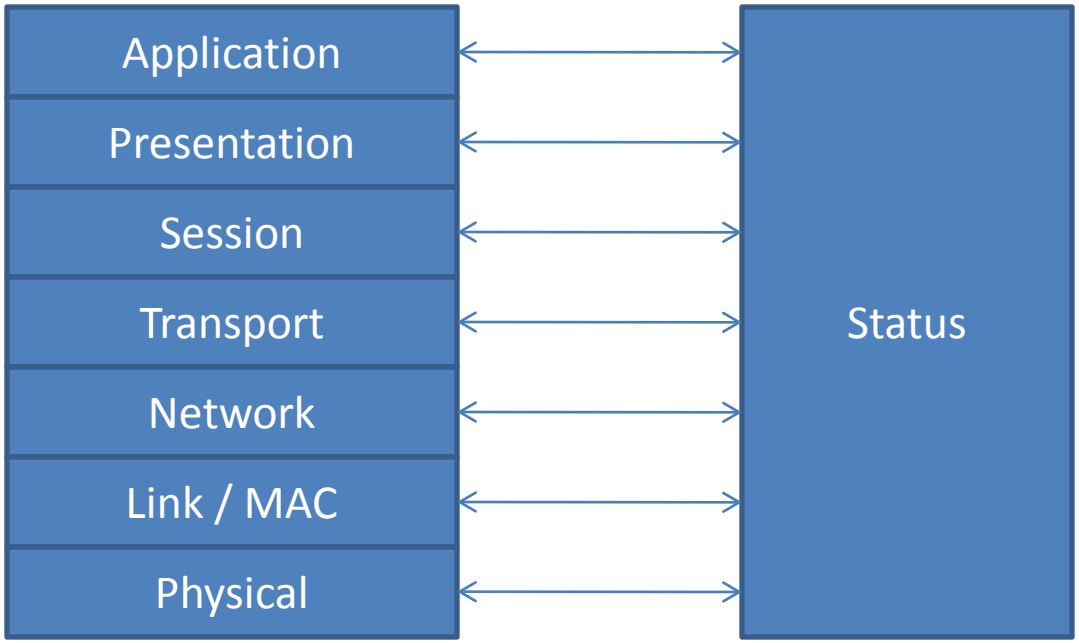


OSI 7 Layer Stack

Direct Communication:

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

Cross-Layer Design Architectures



OSI 7 Layer Stack

Status:

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

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

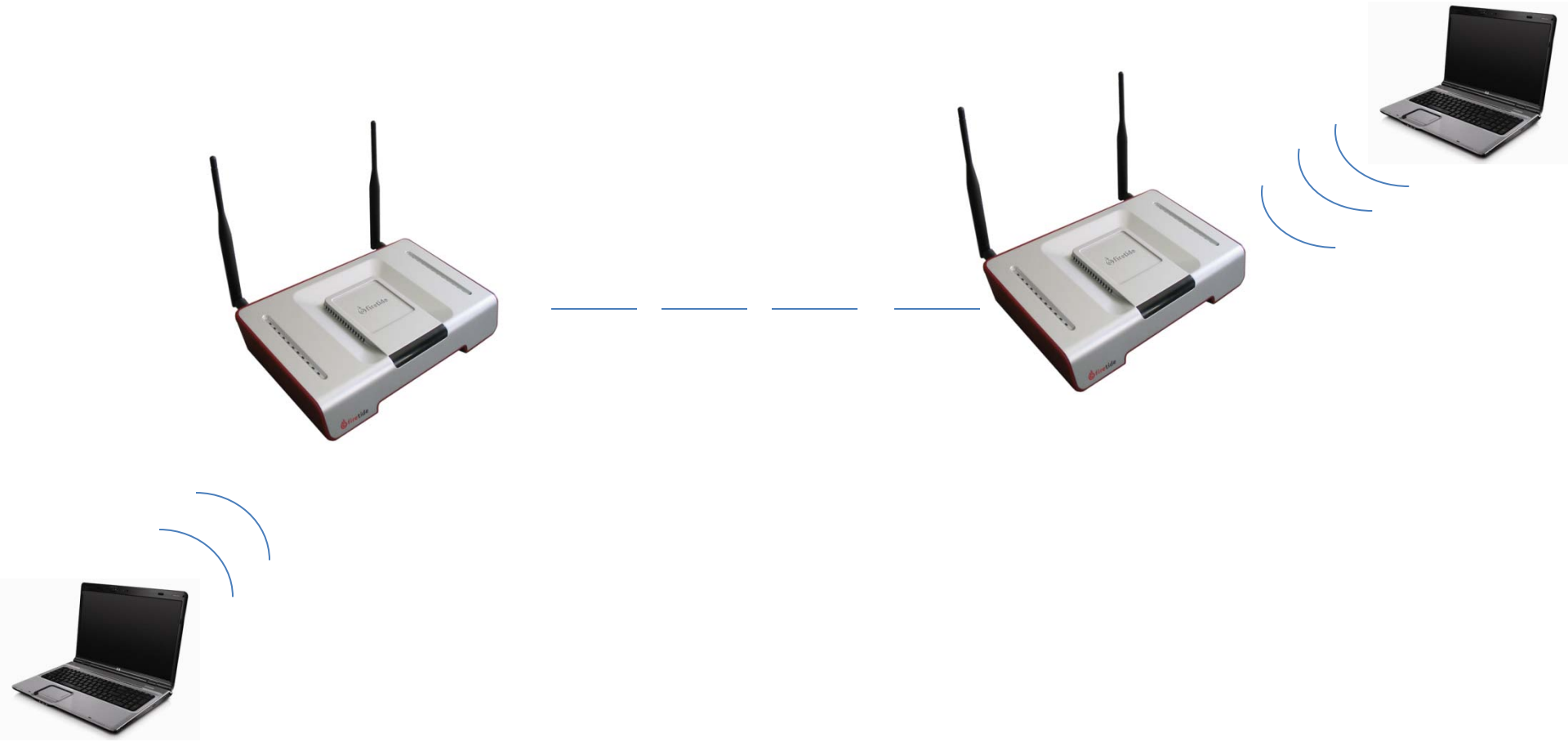
Cross-Layer Design Techniques

- Power Control
- Rate Control
- Route Control
- Network Coding
- Mixed-Bias

Power Control

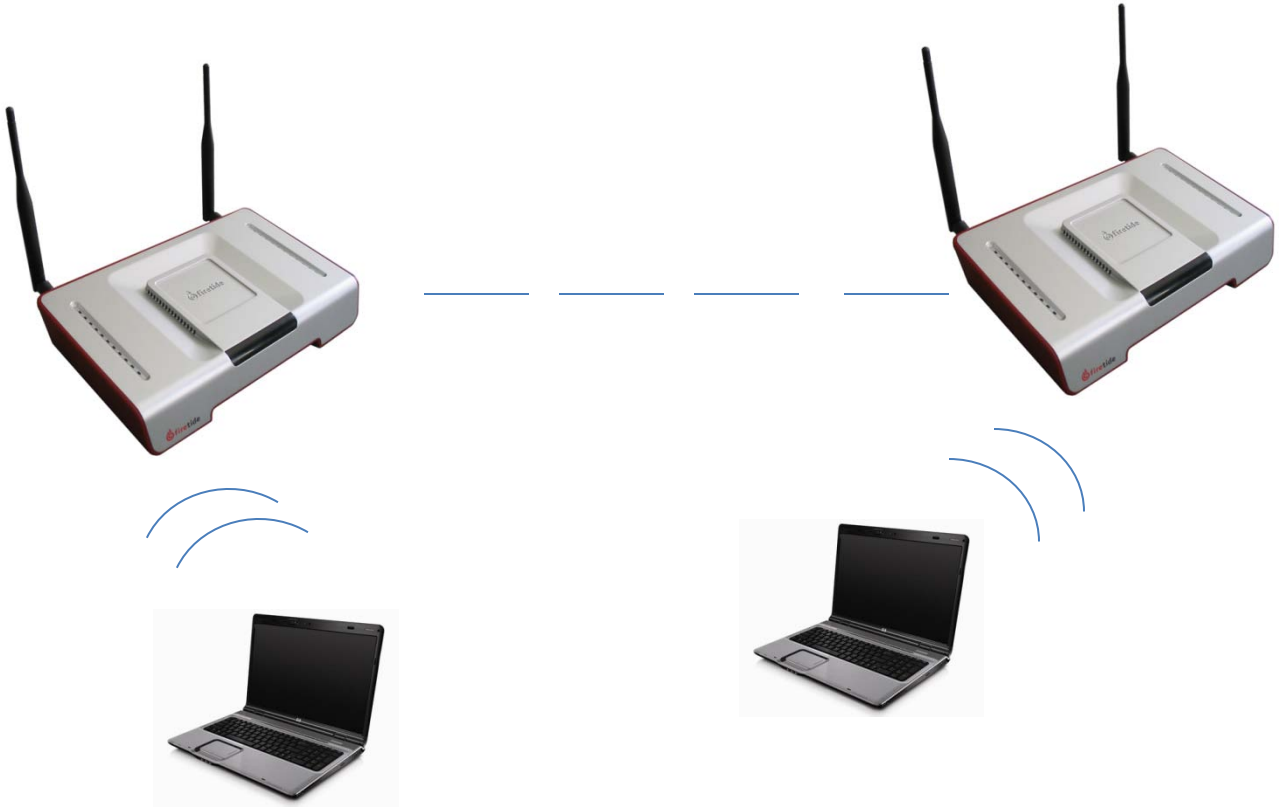
- Power levels of competing nodes are adapted to ensure less contention and interference
- Often combined with Rate Control, Route Control
- Makes use of Physical, MAC and Network layers

Power Control



No Interference between MCs

Power Control

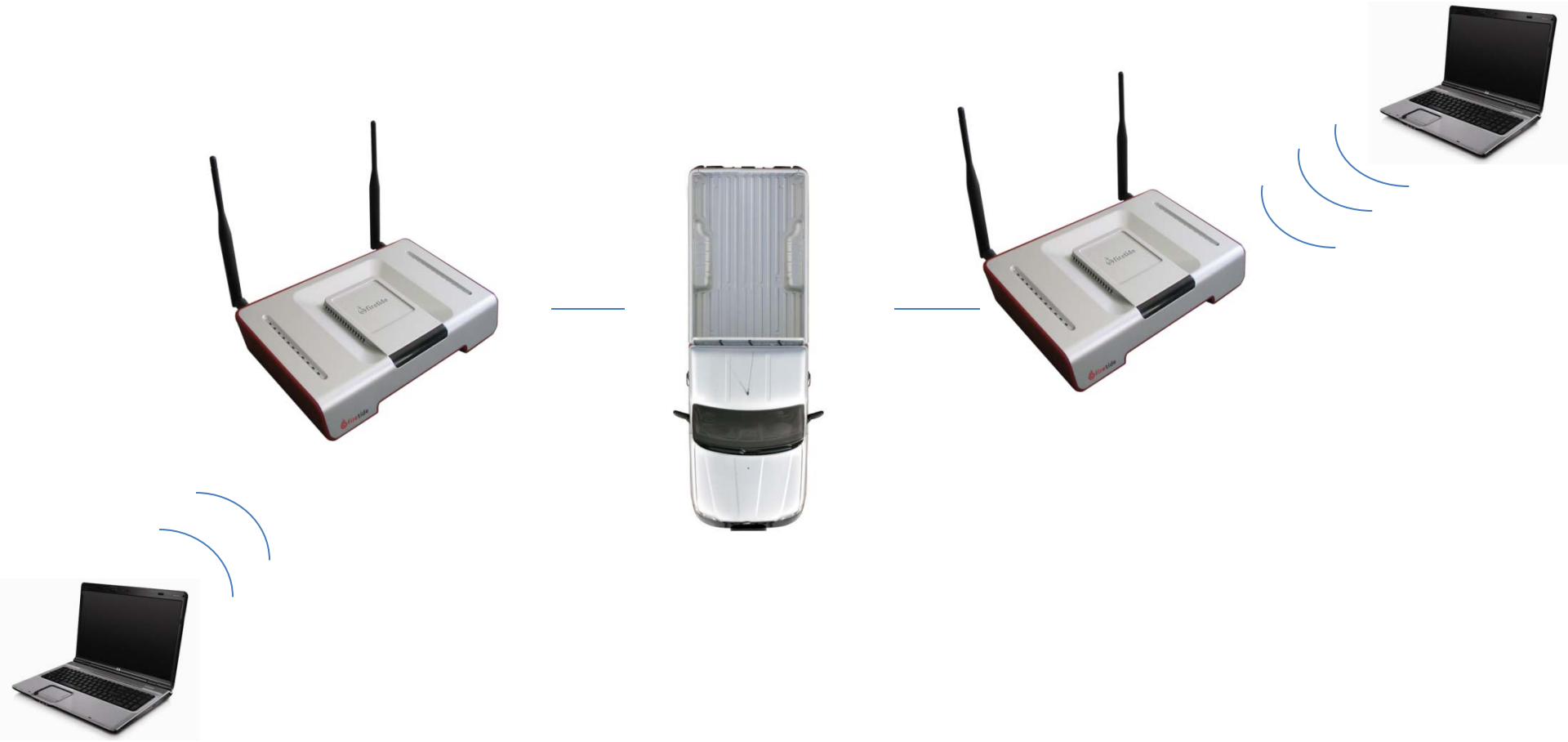


Interference between MCs

Rate Control

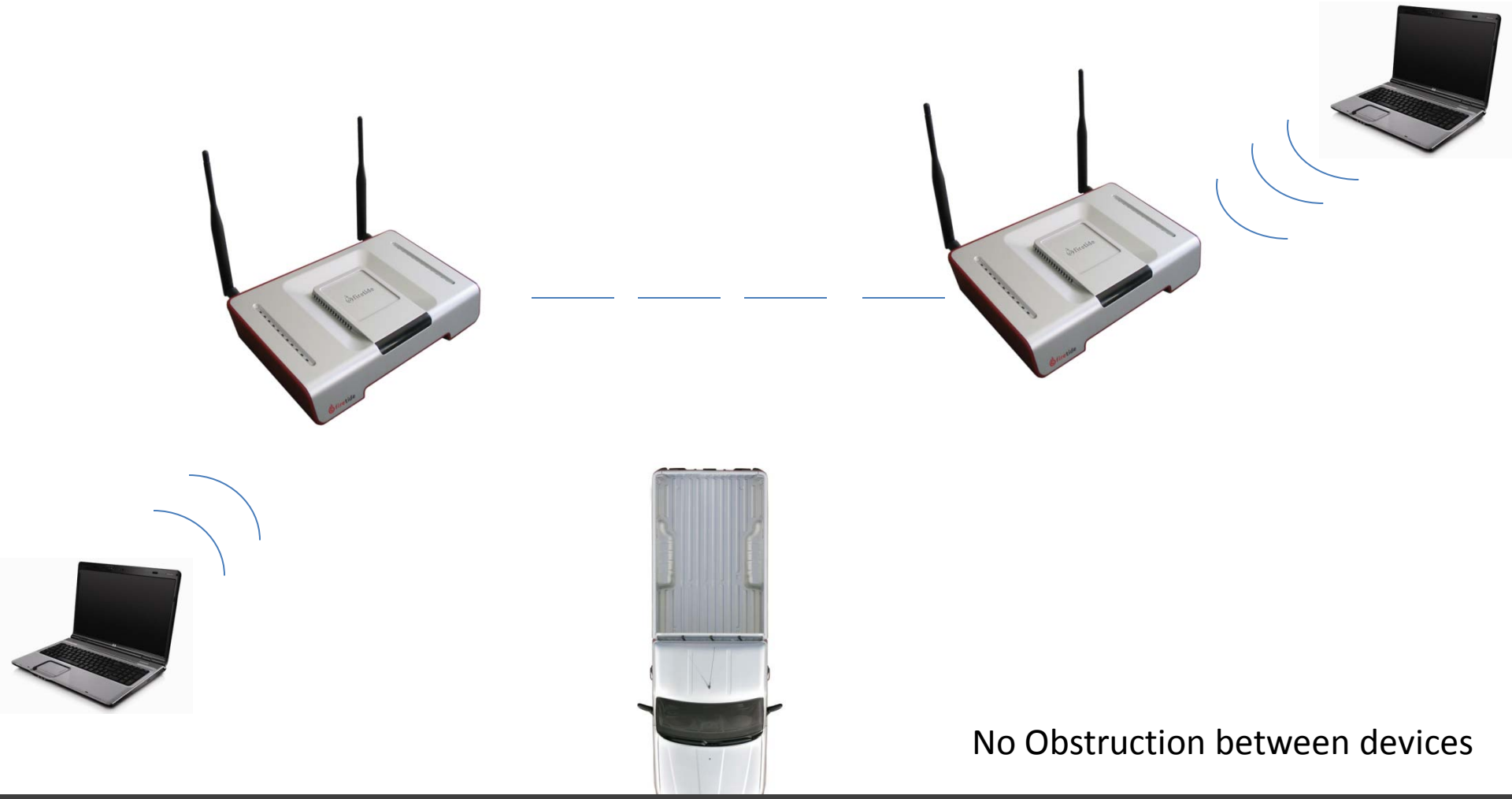
- Allows MRs to control the transfer rates of associated MCs
- Rates are raised for a given link when the quality is higher
  - Thresholds to ensure other MCs are not affected
- Solutions make use a wide range of layers
  - Some take parameters from application layer (multimedia applications)
  - Generally Physical, MAC, Network layers are used

Rate Control



Obstruction between devices

Rate Control



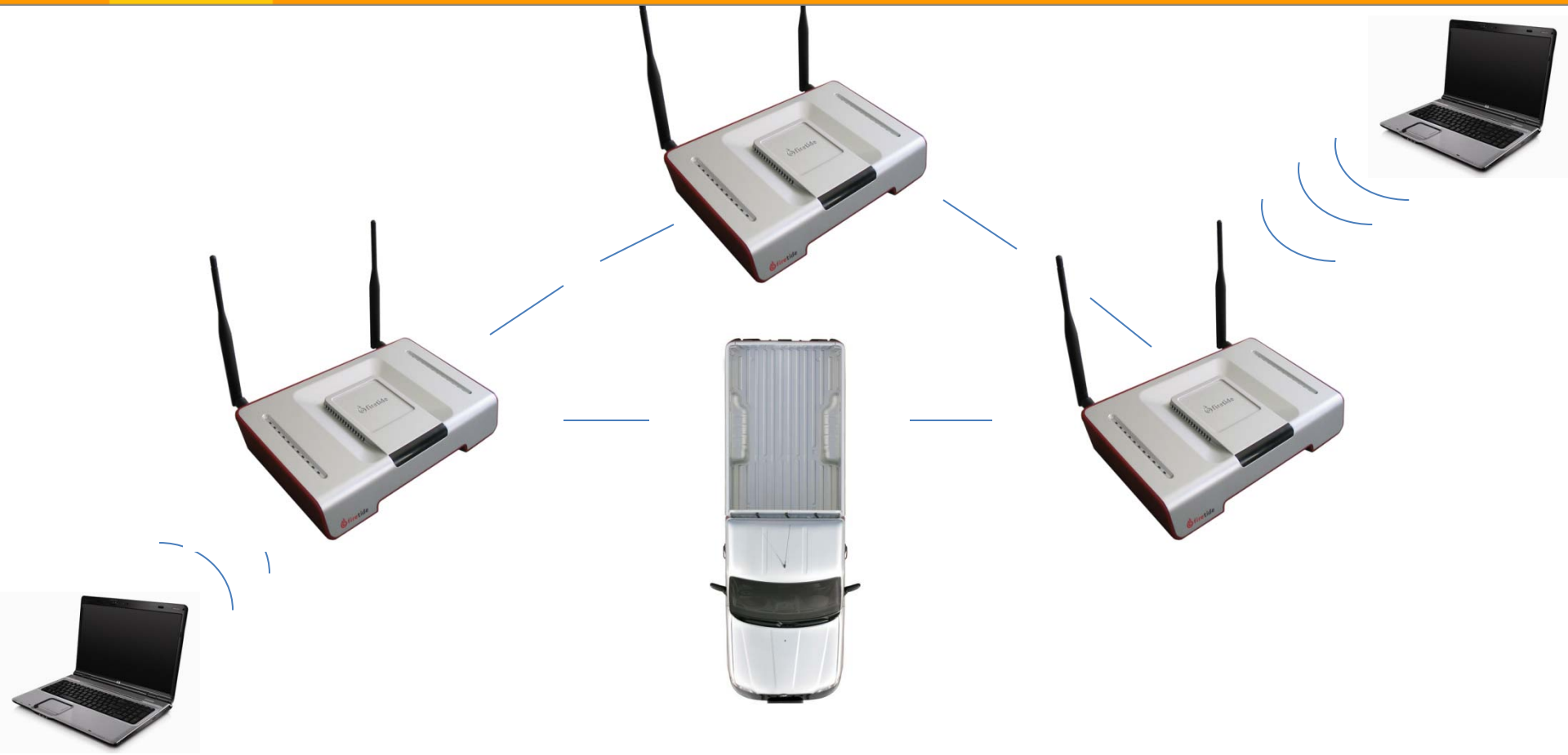
No Obstruction between devices

Route Control

- Avoid congested links, links with poor quality
- Use SINR, queue sizes to determine which links to avoid

- Existing solutions make use of Network, Transport and Link (MAC) layers

Route Control



Obstruction or Congestion on one link

Network Coding

- Allow multiple unicast transmissions simultaneously
  - Assign a unique code for each link
  - The correct information is decoded and separated from other simultaneous transmissions
  - SINR measure taken from physical layer to determine which links may cause conflict
- Often combined with other previous techniques
- Usually uses the MAC / Physical layer

Summary of Techniques

Reference	Technique	Layers
[12] J. Tang et. al	Power Control	MAC, Physical
[15] J. Thomas	Power Control	Network, MAC, Physical
[28] X. Wang et. al	Rate Control	Transport, MAC
[13] J. Tang et. al	Rate Control	Transport, Network, Link
[16] K. Karakayali et. al	Power / Rate	MAC, Physical
[1] C.E. Huang et. al	Power / Rate	Application, MAC, Physical
[7] H-Y. Wei	Route Control	Physical, Link, Network
[22] M.J. Neely et. al	Route Control	Transport, Network
[21] M.S. Kuran et. al	Route Control	Network, Link
[17] K. Li et. Al	Network Coding	MAC, Physical

Cross-Layer Mixed Biasing

- Mixed bias technique [Singh et al]
- Studied using different levels of bias
  - A comparison against proportionally fair and max-min algorithms
  - Strong bias, weak bias
  - Mixed bias combines a strong and a weak bias together
- Only bias against one characteristics
  - Distance between GW and MR

Our Scheme

- Our Mixed-Bias technique

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

$$R = \gamma_1 R_1 + \gamma_2 R_2 + \gamma_3 R_3 \quad (2)$$

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

  - Combined Technique
    - Biases against multiple characteristics at once

Our Scheme

- Scheduling / Resource assigned according to a cost function at the gateways

- Multiple gateways are supported
  - Each GW is responsible for scheduling / allocation for MRs associated with it

- At each schedule a measure of the parameters is taken and applied to the cost function

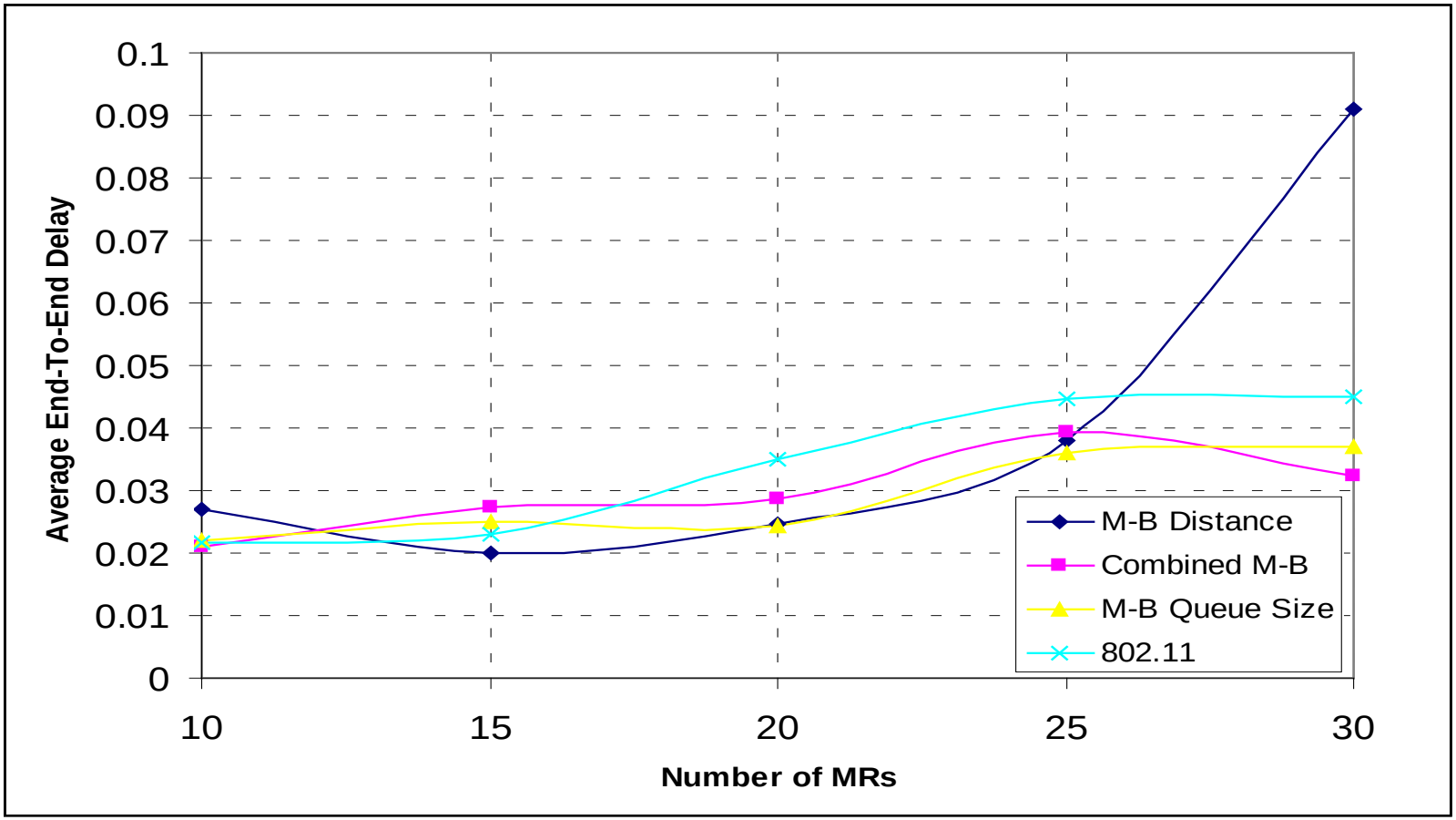
Initial Results

Simulation Parameters

Parameter	Value
MRs	10 to 30
GWs	1 to 5
MCs	250
Flows	2 to 5
Environment Dimensions	1000 x 1000 m
Node Range	150 m

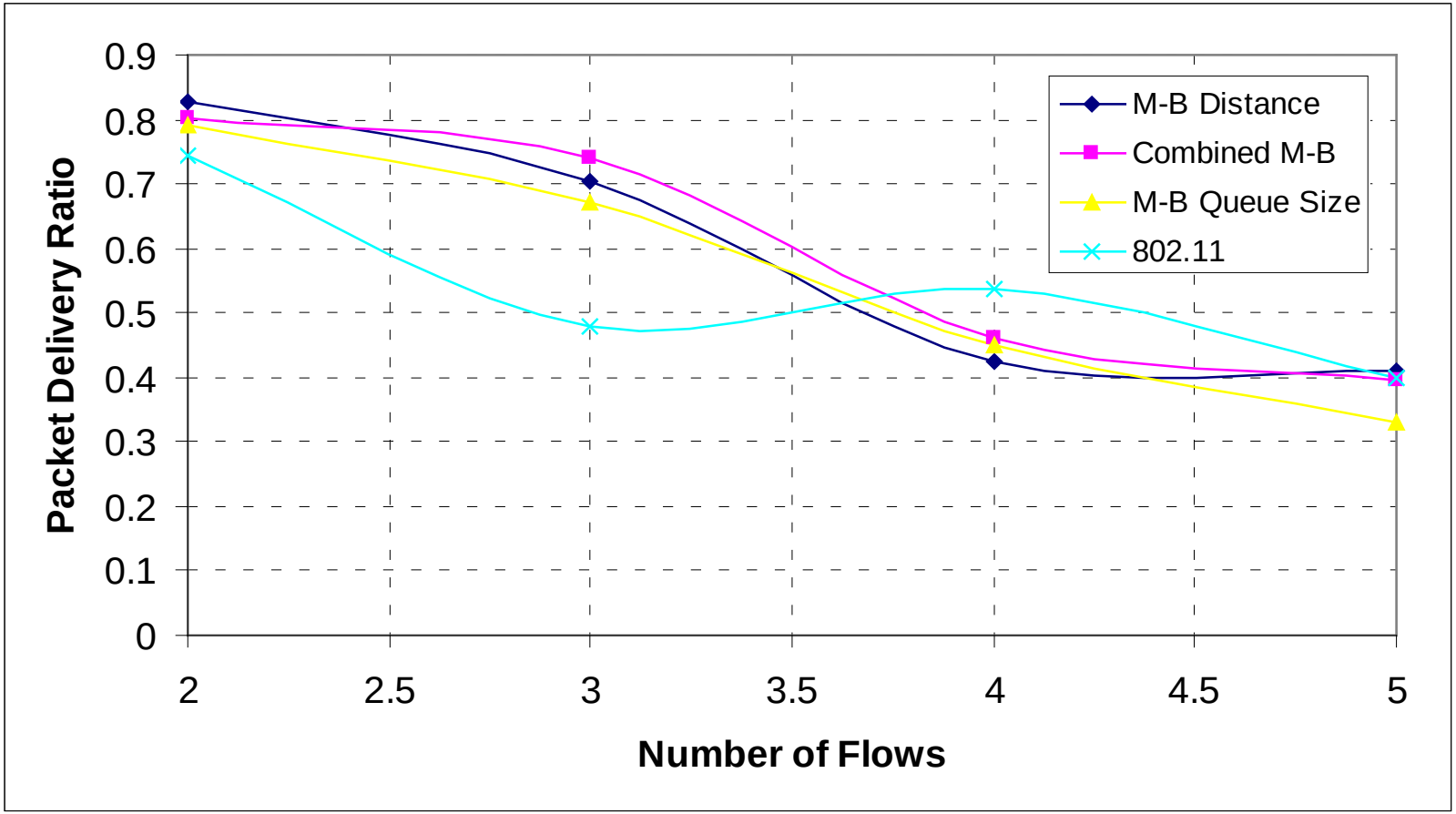
NS3 Simulation Tool

Initial Results



5 Flows – Effect of Varying MRs on End-to-End Delay

Initial Results



5 GWs - Effect of Varying Flows on Packet Delivery Ratio

Conclusions and Future Work

- Conclusions
  - Cross-Layering should be viewed as intimidating
  - Many existing approaches can apply cross-layer design
  - The results show that our cross-layered mixed bias approach is promising
- Future work
  - Experiment with tuning the weightings and bias factors in the mixed bias approaches
  - Implement the scheme in real equipment to compare
  - Many existing schemes make assumptions that limit the application (single GW, no mobility of MCs or MRs)

Questions?

Contact: Jason Ernst – jernst@uoguelph.ca

Thank you for listening!