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Architecture and Algorithms for an IEEE 802.11-Based Multi-Channel Wireless Mesh Network

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- System Architecture
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- Evaluation
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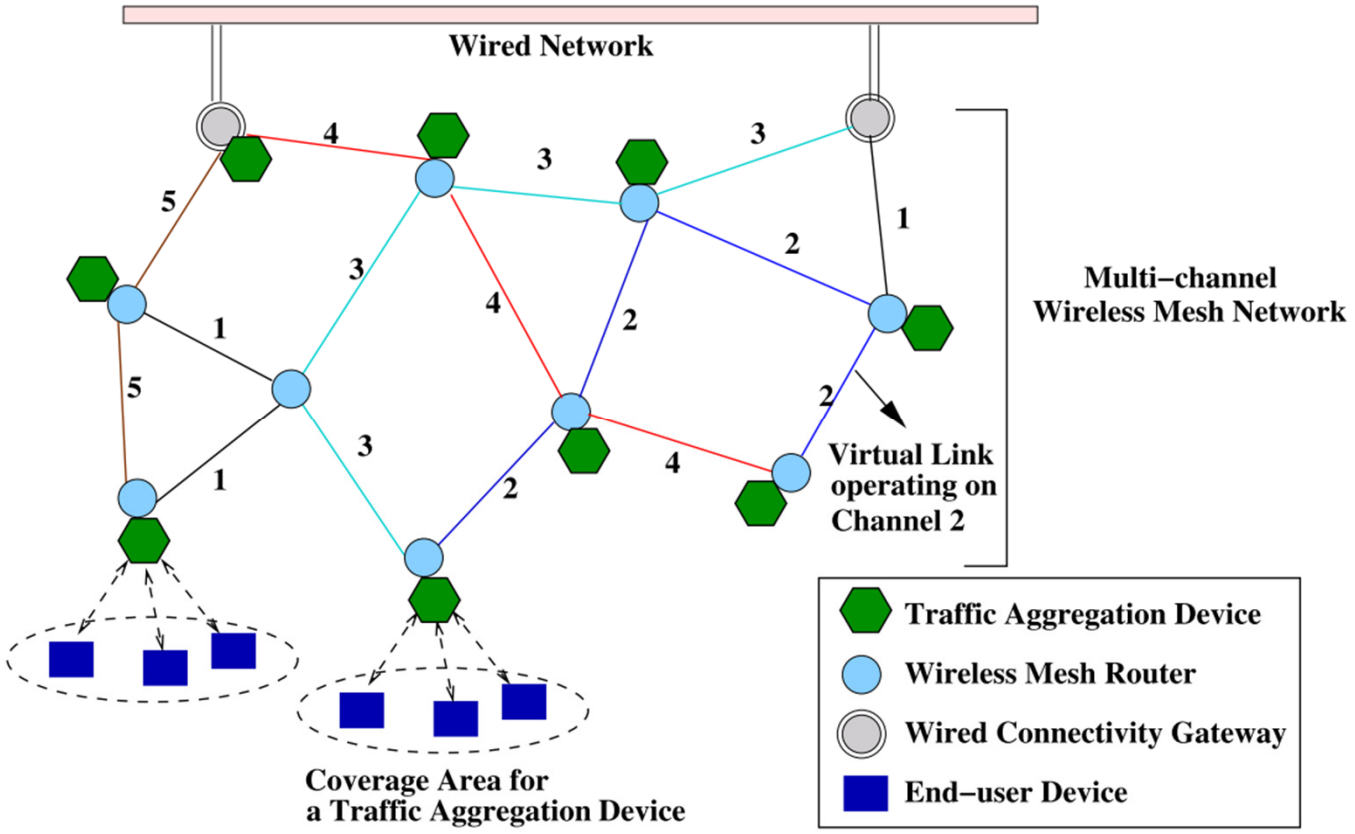
Introduction

- Most IEEE 802.11-based multi-hop ad hoc networks use only a single channel
  - Not used as wireless last-mile access network
  - Or wireless enterprise backbone network
- Hyacinth: WMN using multiple NICs on each node
- Central design issues: channel assignment and routing

Introduction

- Intelligent channel assignment is critical
  - Distributed algorithms
  - Centralized algorithms
- Even 2 NICs on each node lead to a throughput improvement of the factor 6 to 7

System Architecture



Channel Assignment Problem

- Bind each NIC to a channel
- Neighbor-to-interface binding
- Interface-to-channel binding
- 4 main constraints
  - Number of distinct channels → number of NICs
  - Two nodes communicating directly share one common channel
  - Raw capacity of channel is limited
  - Number of non-overlapped channels is fixed

Load-Balance Routing Problem

- Links should use radio channels that are not used so often
- Most WMN nodes communicate with wired network (internet, enterprise servers)
- Helps to avoid bottleneck links

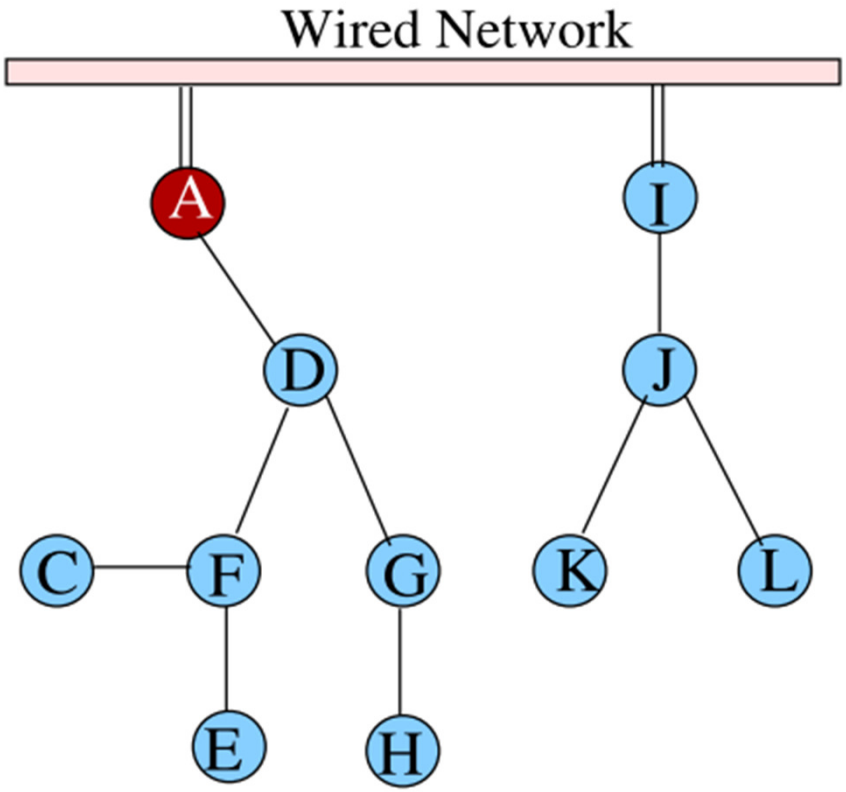
Evaluation Metric

- Maximize overall network goodput
- $X = \sum_a \min(\sum_i C(a, g_i), B(a))$
  - Device a
  - Gateway node g_i

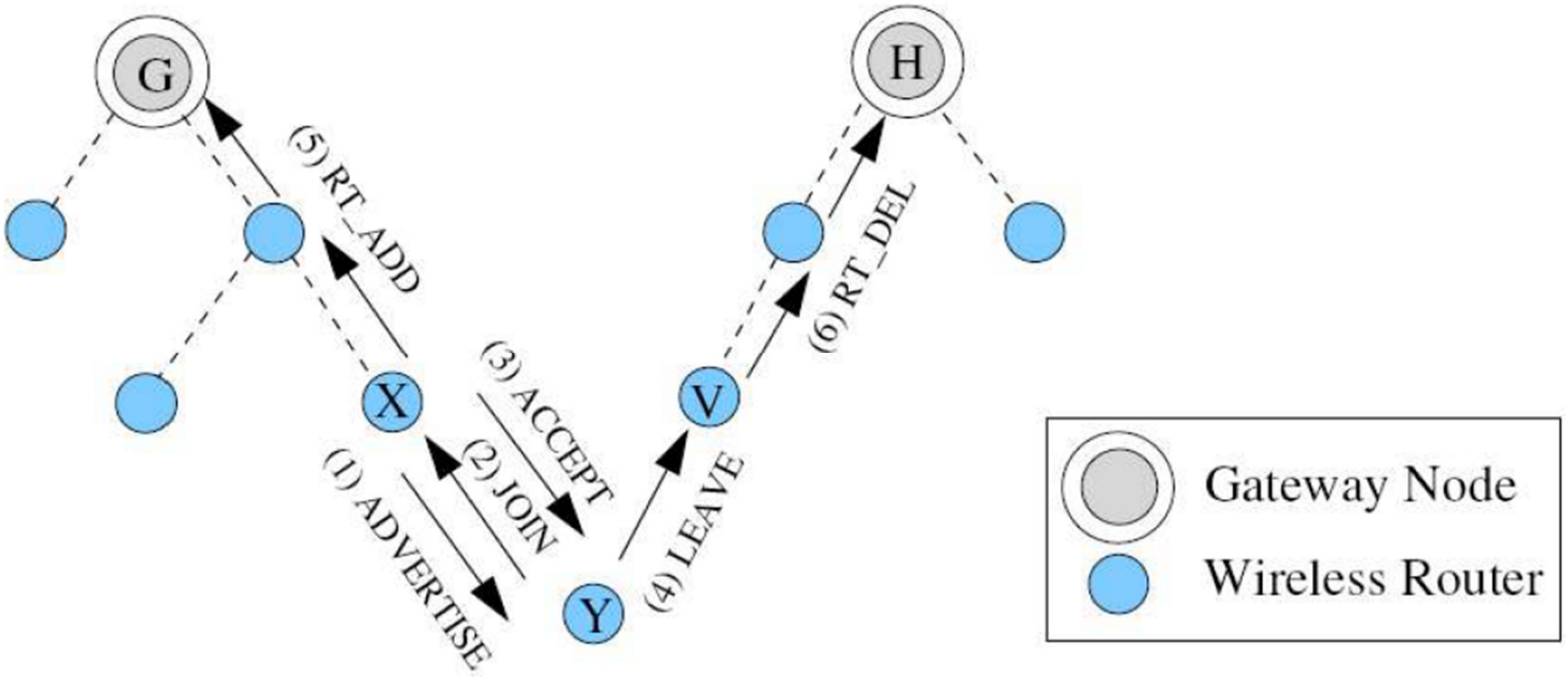
Load-Balancing Routing Algorithm

- Each wired gateway is the root of a spanning tree
- The spanning trees are connected through the wired network
- Each node is associated with only one tree

Load-Balancing Routing Algorithm

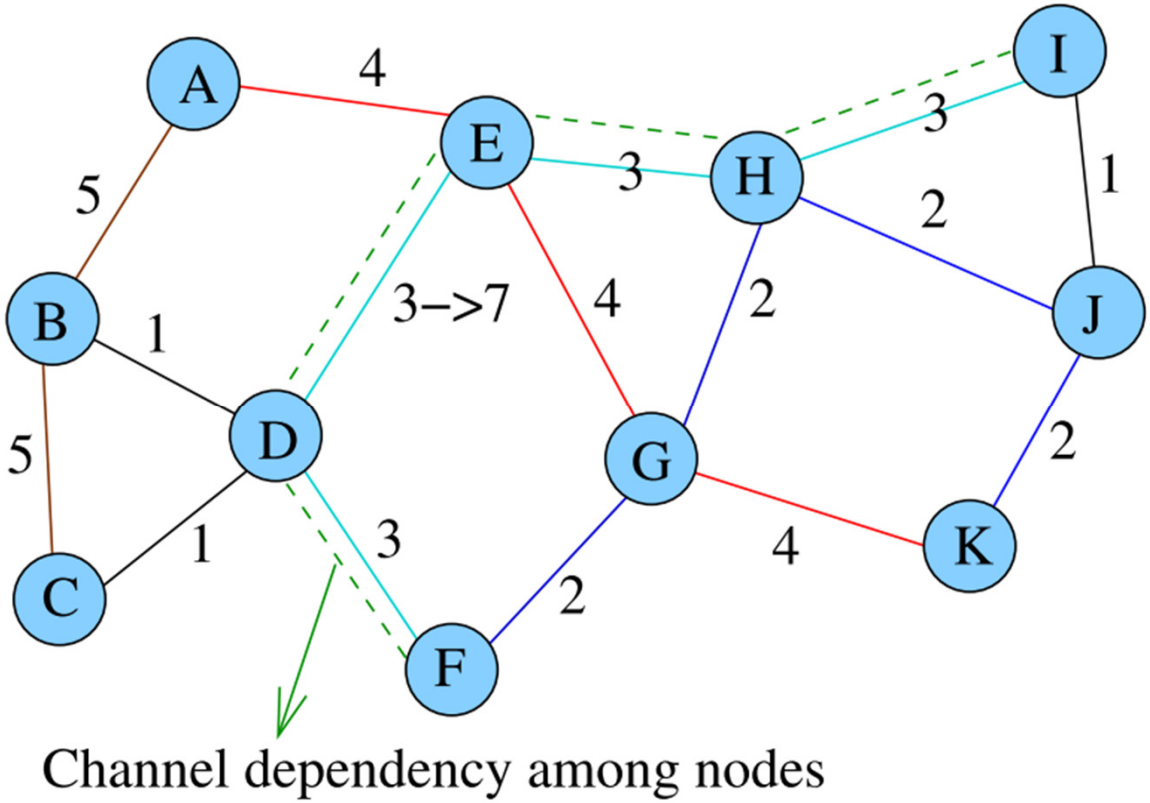


Routing Tree Construction

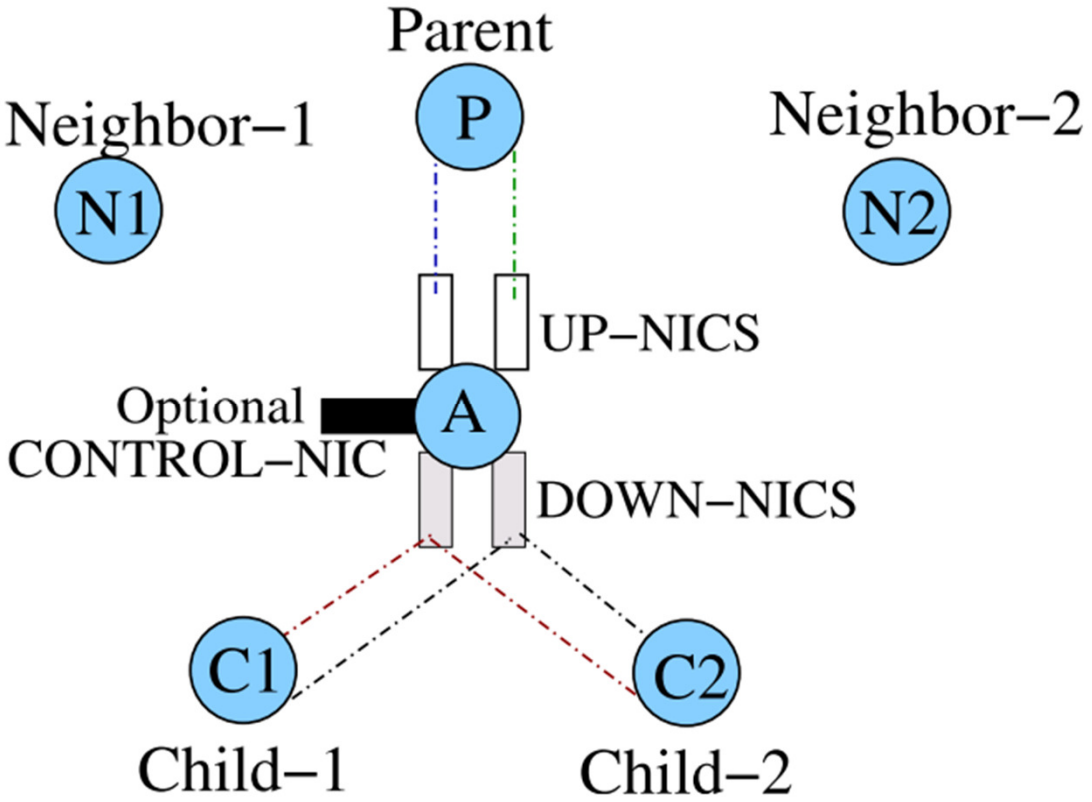


Routing Metrics

Neighbor-Interface Binding



Elimination of Channel Dependency Problem



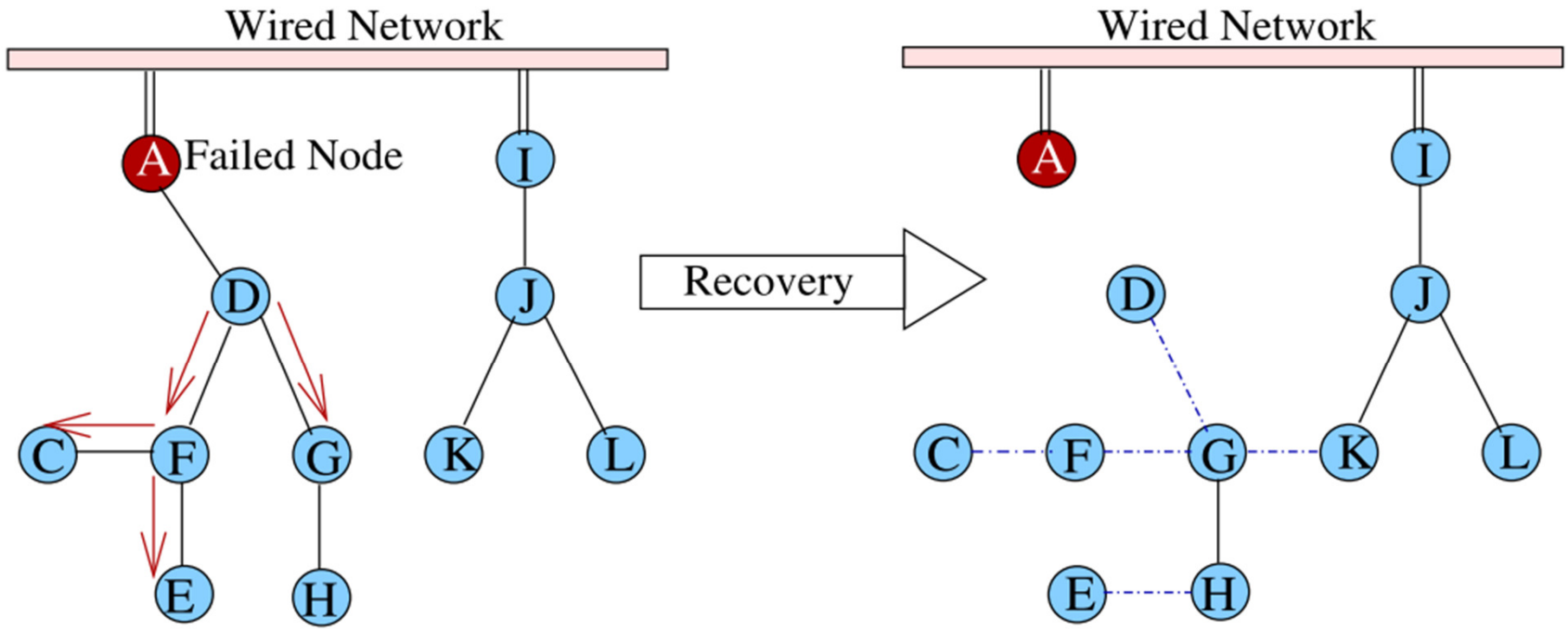
Channel Assignment Algorithm

- Estimate usage status to assign channels to the DOWN-NICs
  - Periodically exchange of channel usage information with each node in the interference range
- Nodes higher up in the tree need more bandwidth

Virtual Control Network

- Simple Option: Using a CONTROL-NIC
- To save the additional hardware interface: Use a virtual Control Network
  - Scan all channels for broadcasting HELLO messages during neighborhood discovery phase

Failure Recovery

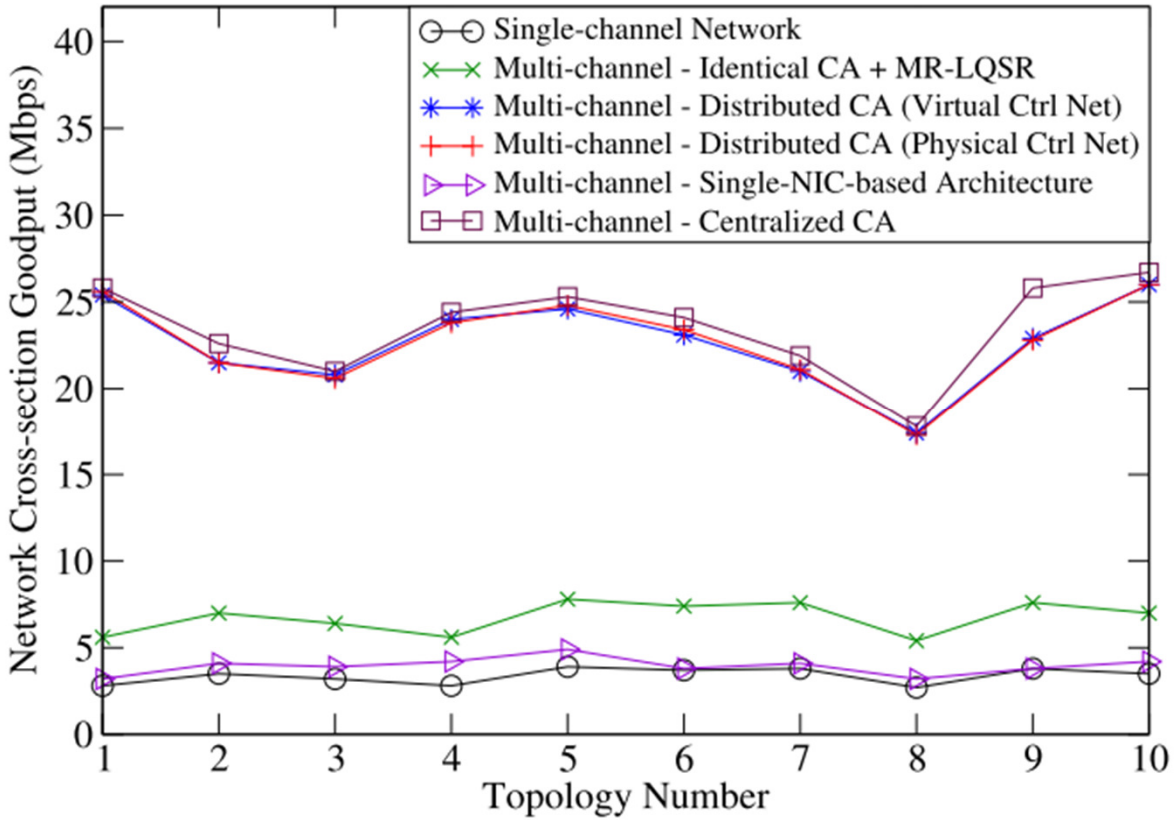


(a) Failure message after node A fails (b) New connectivity after recovery

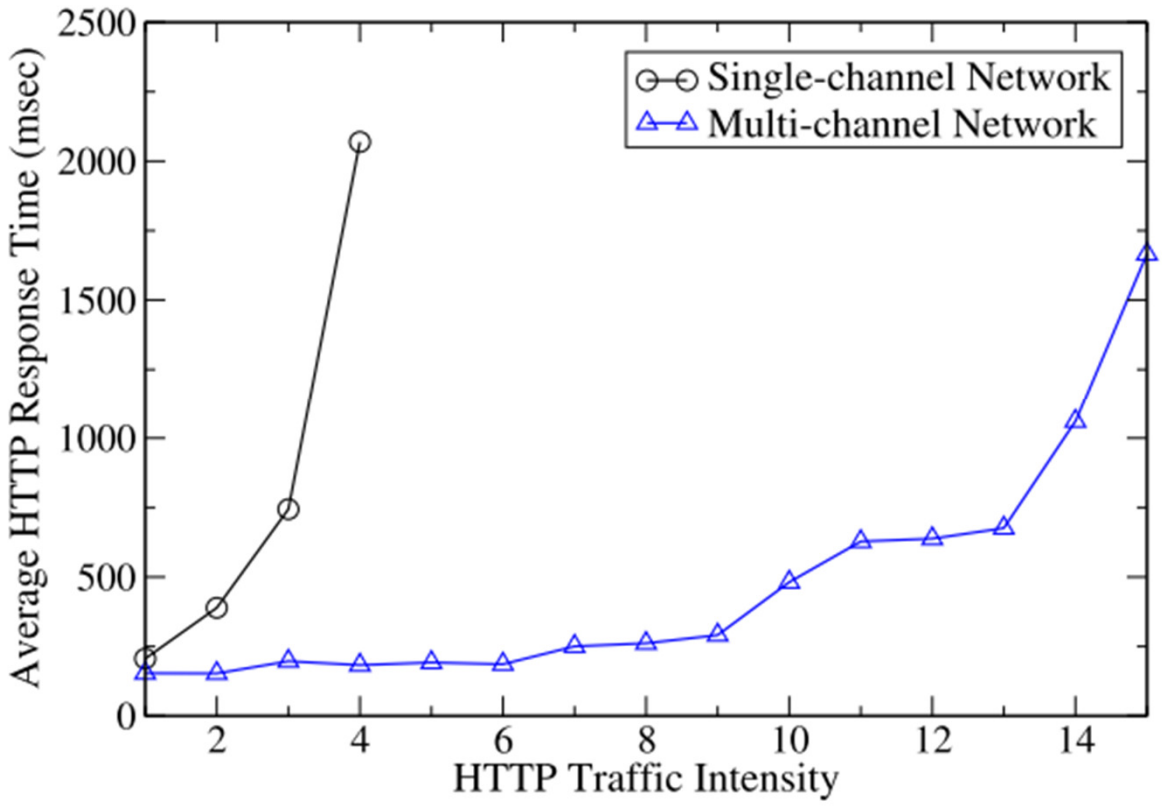
Evaluation

- 2 NICs per node
- 12 channels (IEEE 802.11a)
- Channel Load Balancing = 1 minute
- 10 scenarios with 60 nodes on 9x9 square grid network
- Random traffic = 0-3 Mbps

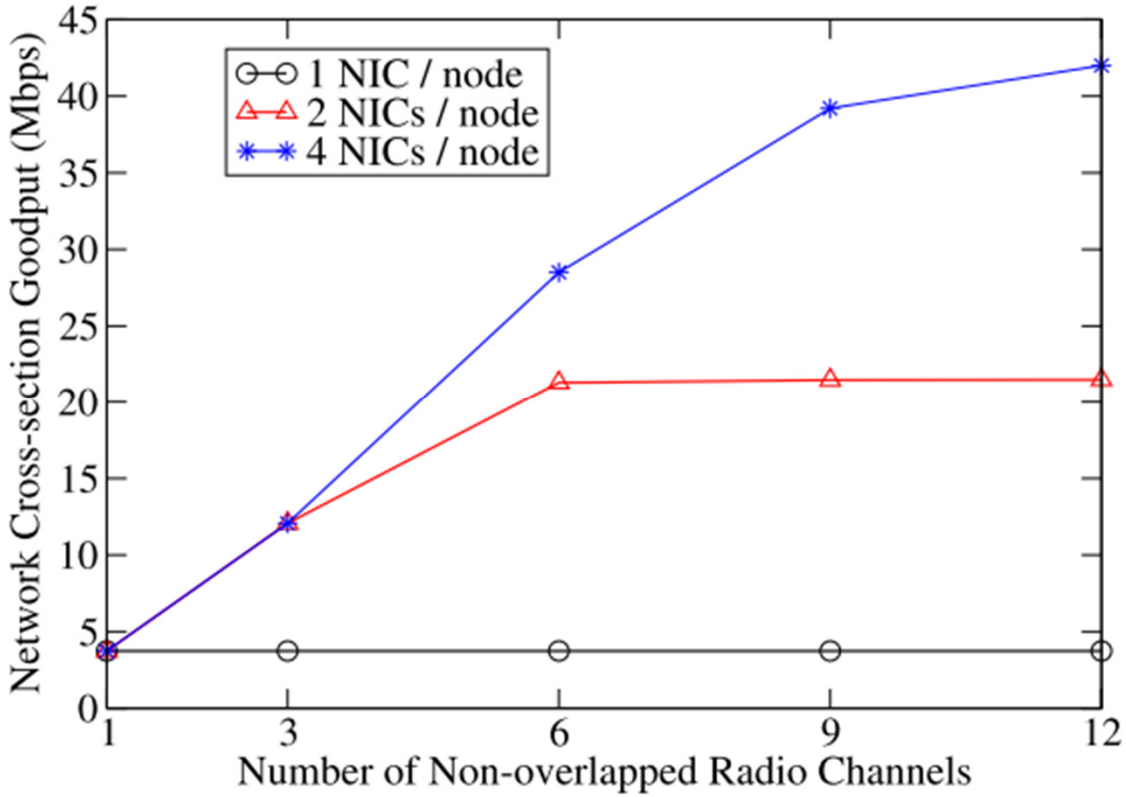
Goodput improvement



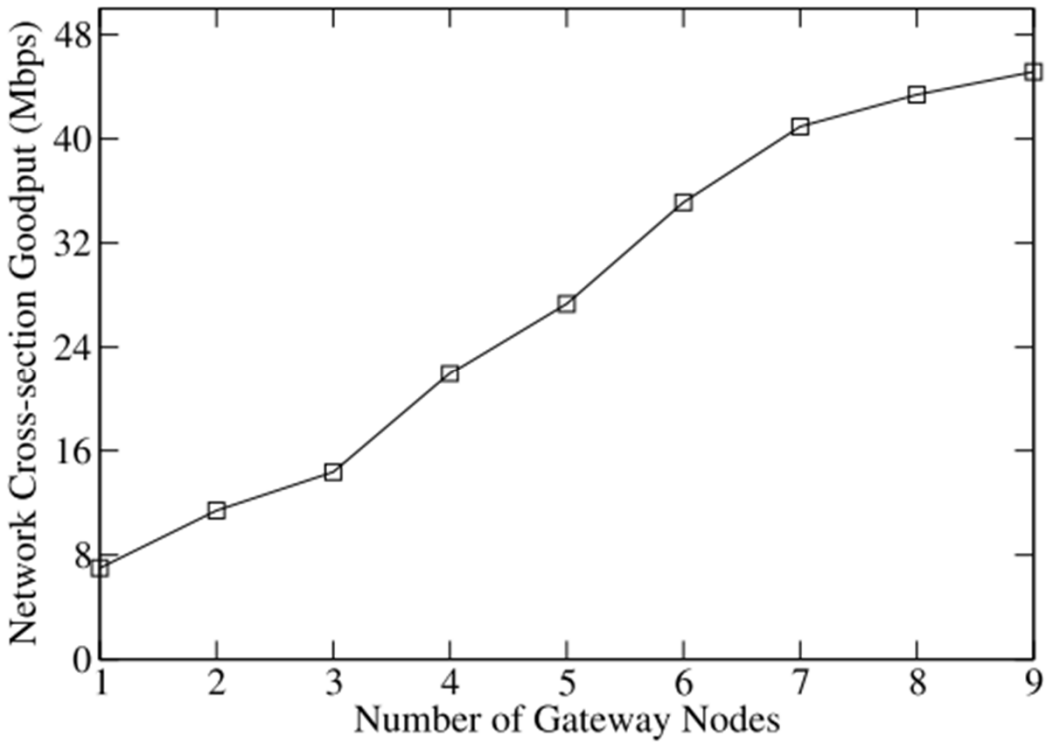
HTTP Response Time



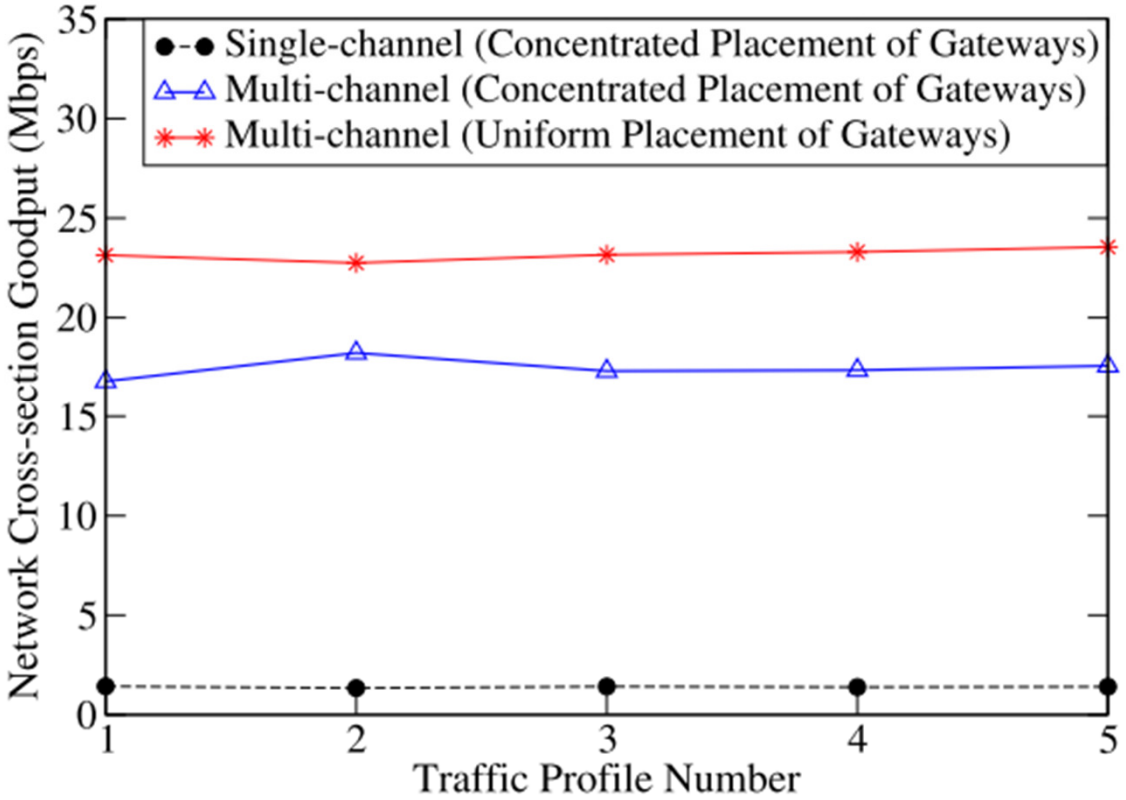
Different number of NICs per node



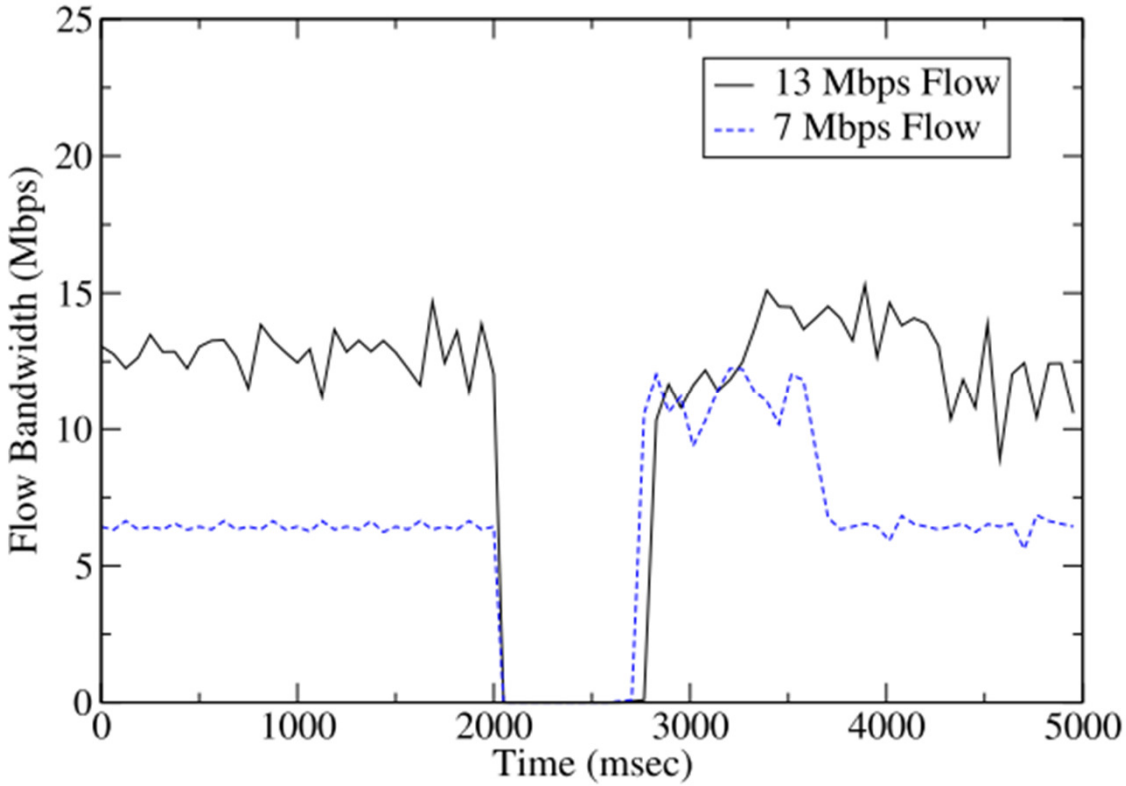
Number of gateway nodes



Placement of gateway nodes



Failure Recovery Time



Conclusion

- Bandwidth problem more serious for multi-hop WMNs
- Single-channel WMNs cannot adequately support the bandwidth
- Channel assignment
- Load balance routing

Future work

- Nodes in the trees are associated to more than one tree

Thank you!

QUESTIONS?