



# CROSS LAYER ROUTING IN AD HOC NETWORKS

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# Outline

- Cross layer framework
  - Introduction
  - General cross layer architectures
  - A cautionary perspective
  - Architectures for routing protocols using cross layer information
- A specific example
  - Rerouting time with proactive routing protocols
  - The rerouting scenario
  - 802.11 MAC retransmission mechanism
  - The queueing problem
  - Analysis of rerouting time
  - Simulation results
  - Proposed solution and results
- Conclusion

# Cross layer framework

Introduction

General cross layer architectures

A cautionary perspective

Current cross layer routing protocols

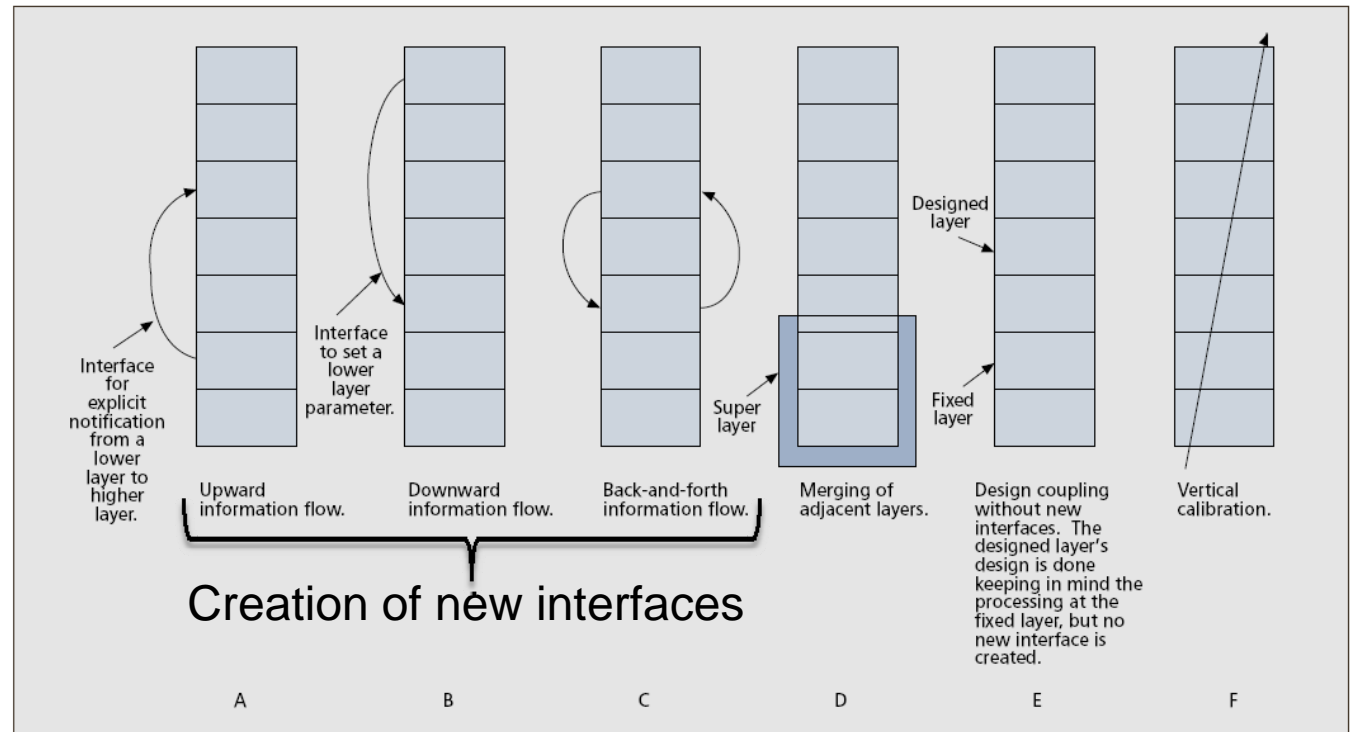
# Introduction

- A layered architecture simplifies development of different components in the network stack.
- The layered architecture is an origin of the wired networks world
- Wireless ad hoc networks introduce, or alters significantly, the perspective on:
  - Mobility
  - Bit error rate
  - Transmission rate
  - Transmission range
  - Energy
- Using a strictly layered architecture developed for wire-based communications results in sub-optimal performance in a wireless ad hoc environment.

# General cross layer architectures

Srivastava and Motani's four main classes of cross layering architectures.

A cross layer design proposal may belong to more than one class.



■ Figure 1. Illustrating the different kinds of cross-layer design proposals. The rectangular boxes represent the protocol layers.

# A cautionary perspective

Kawadia's presentation of the downside to cross layering, "A cautionary perspective on cross layer design."

- Warning
  - Isolated, a cross layer suggestion may enhance performance, but a cross layer implementation may rule out or be adversely affected by other cross layer interactions
- Advice
  - Cross layer interactions must be made holistically
  - Design re-examination, also in the unmodified parts of the protocol stack, must always be performed in order to reveal unintended side effects.
  - Time scale separation is one proposed solution for alleviating unintended cross layer interactions

# Current cross layer routing protocols

A short survey of 7 papers has been made.

Go to the reference page for listing.

- Purpose of cross layering: improve the end-to-end performance and the routing service.
- Common characteristics:
  - Most cross layer interactions are among the three lower layers of the stack (PHY, MAC, NET)
  - Routing with other parameters than shortest path
  - Moving part of the routing service to layer 2 (MAC)
- Examples of shared information include:
  - energy levels
  - signal-to-noise ratio
  - transmission delay
  - queuing delay
  - antenna element

# A specific example

Rerouting time with proactive routing protocols

The rerouting scenario

802.11 MAC retransmission mechanism

The queueing problem

Analysis of rerouting time

Simulation results

Proposed solution and results

# Rerouting time with proactive routing protocols

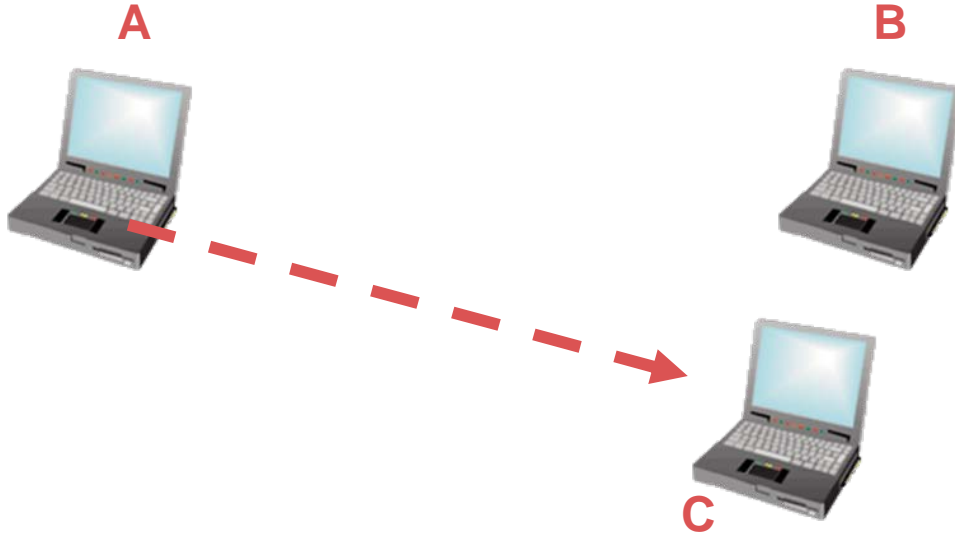
Pham, Larsen,  
Øvsthus,  
Engelstad and  
Kure,  
"Rerouting  
Time and  
Queueing in  
Proactive Ad  
Hoc  
Networks"

- Rerouting time could be more than 10 times higher than network layer link timeout
- Rerouting time is affected by:
  - ▣ UDP traffic load
  - ▣ MAC layer queue size
  - ▣ MAC layer retries

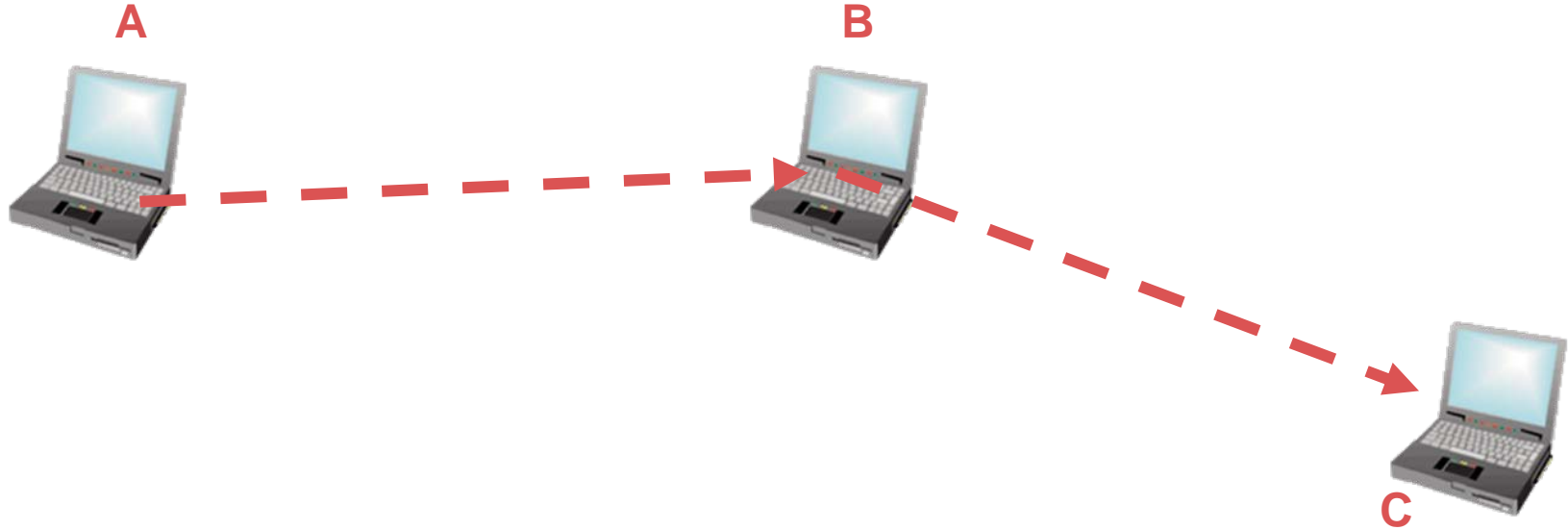
# The rerouting scenario



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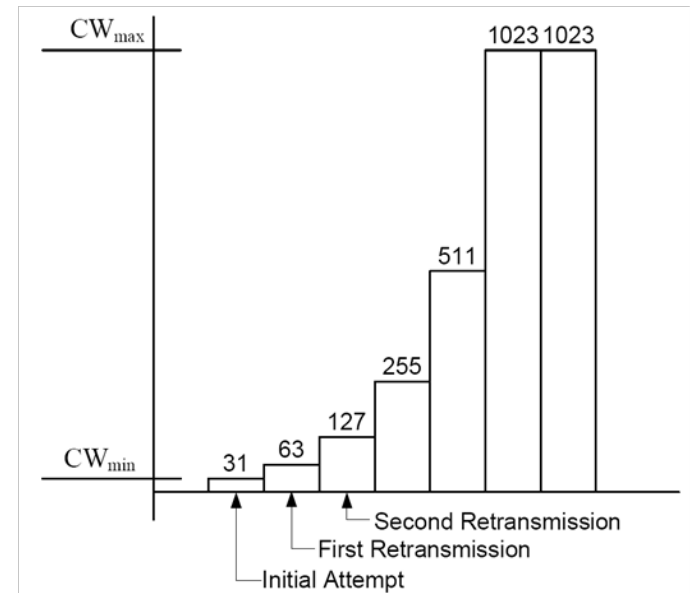
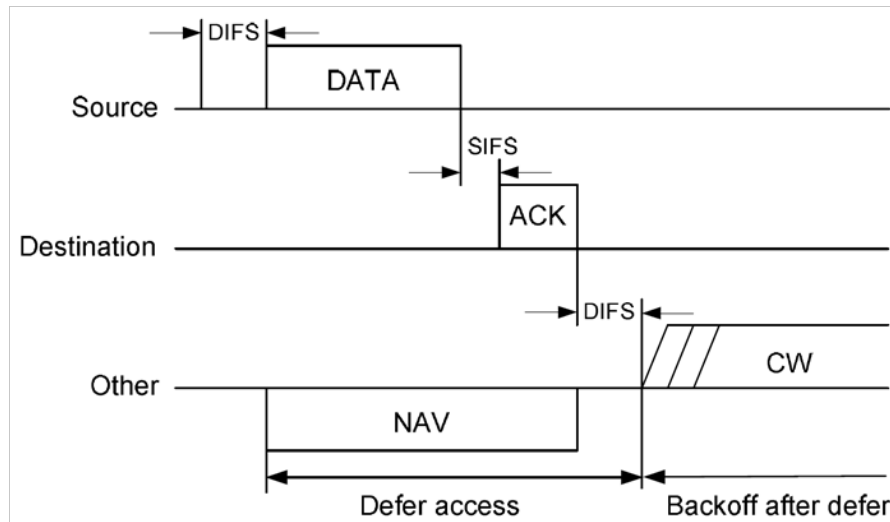


# The rerouting scenario



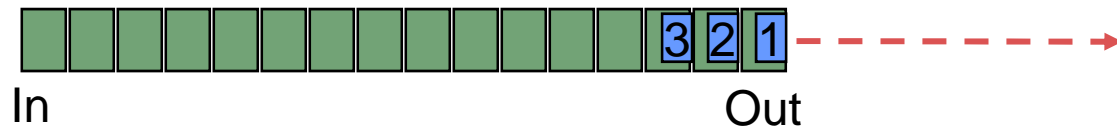
# 802.11 MAC retransmission mechanism

- 802.11 MAC selects a backoff counter from a contention window that increases exponentially for each retransmission.
- The number of MAC-retries increases the transmission time for each packet to a lost destination.



# The Queueing Problem (1)

Each packet is transmitted without failure/few retransmissions

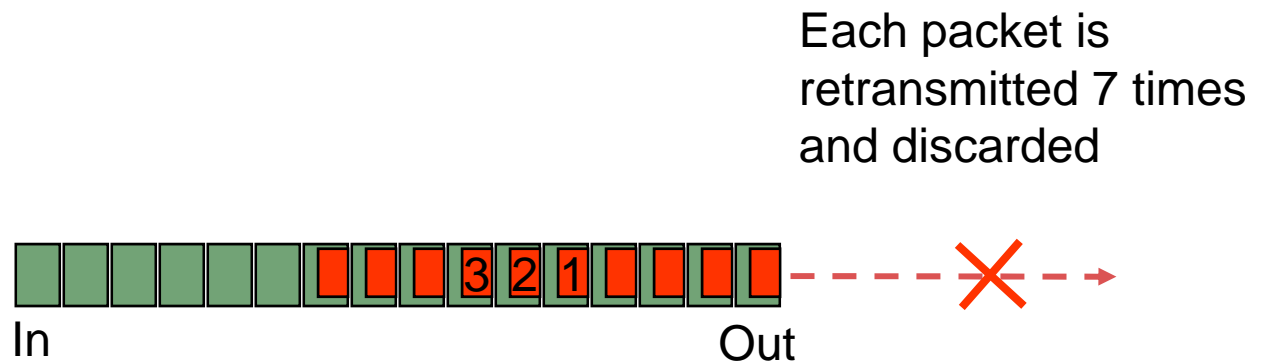


All packets are successfully transmitted

$$R_{\text{out}} = R_{\text{in}}$$

No accumulation of packets in the queue

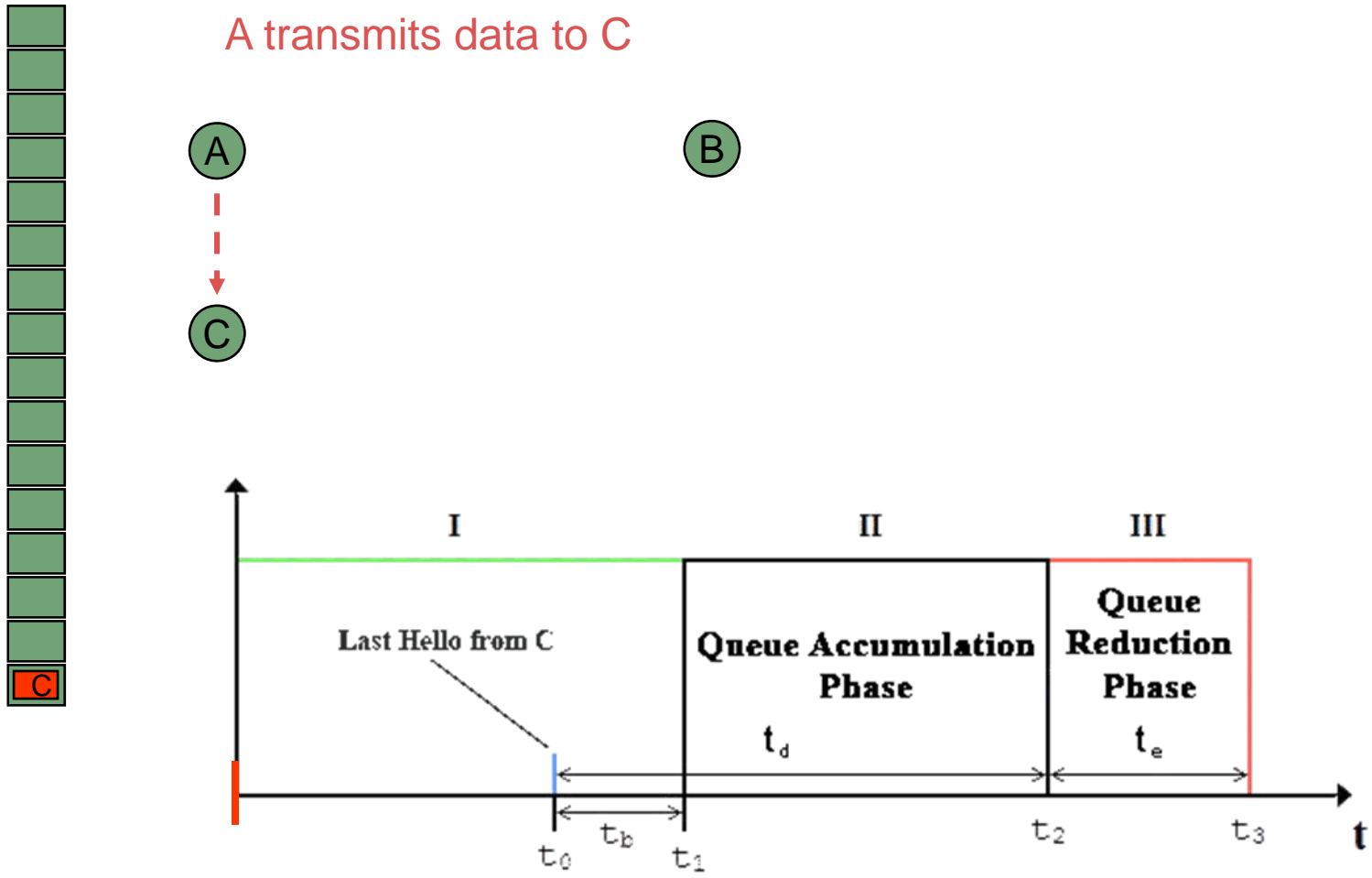
# The Queueing Problem (2)



Because of the MAC-layer retransmission,

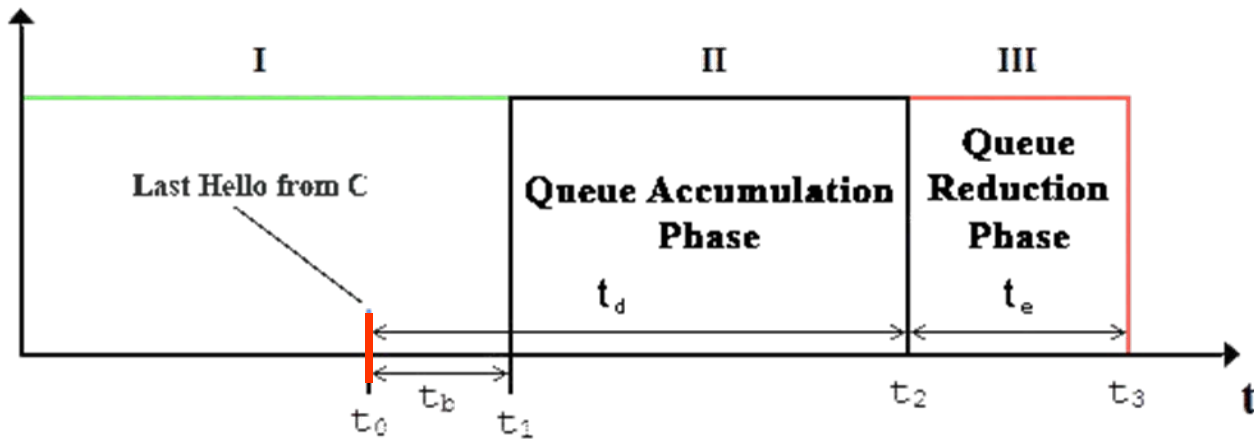
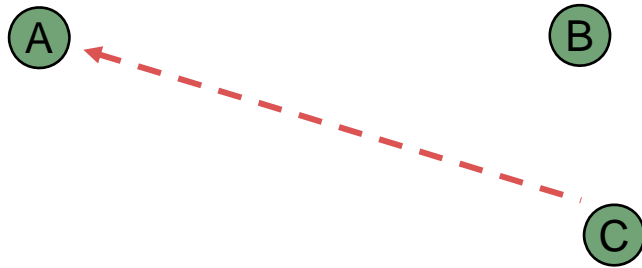
$R_{out} < R_{in}$ , this leads to rapid accumulation of packets in the queue

# Analysis of Rerouting Time



# Analysis of Rerouting Time

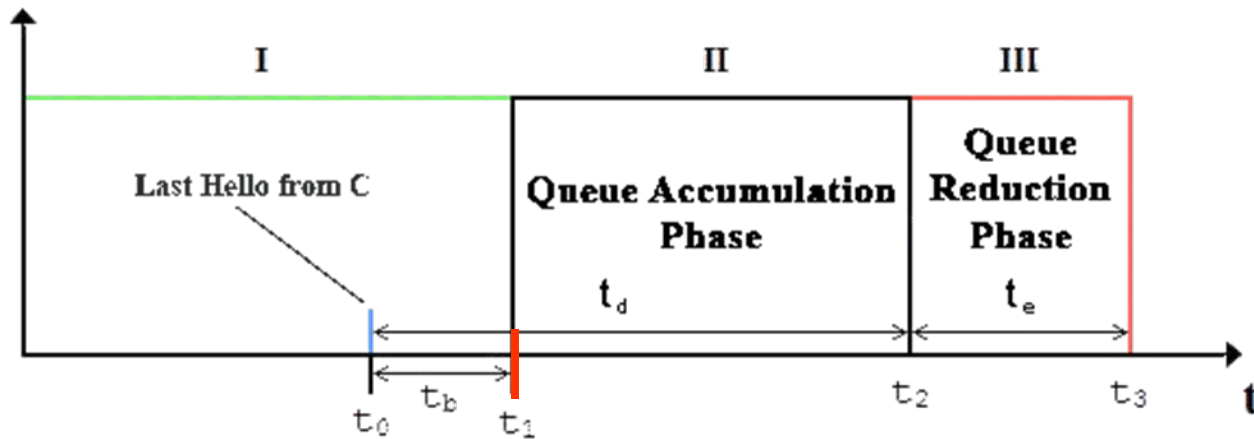
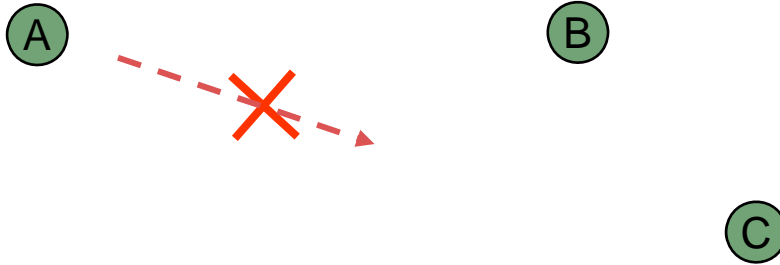
Last Hello from C received at A



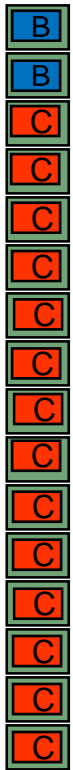
# Analysis of Rerouting Time

Last successful data transmission from A directly to C

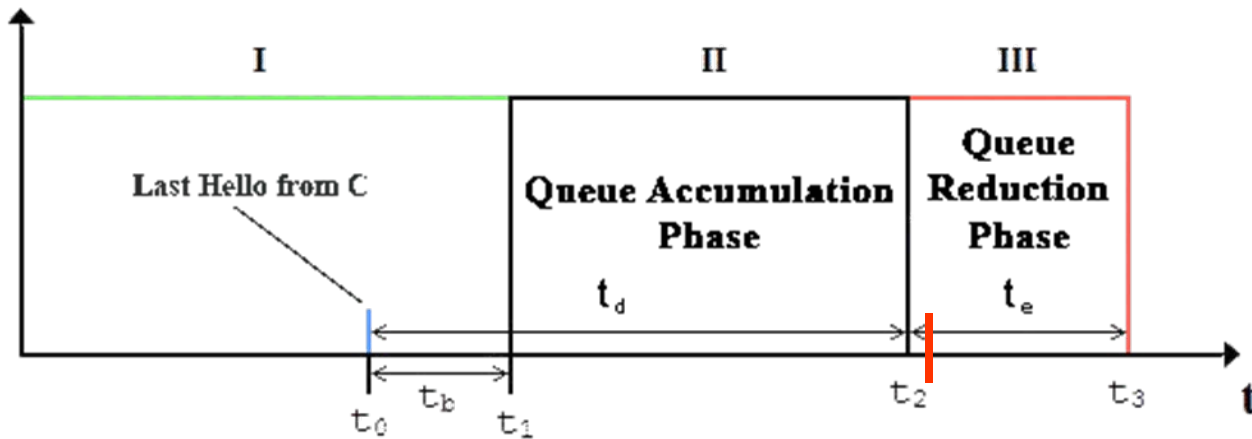
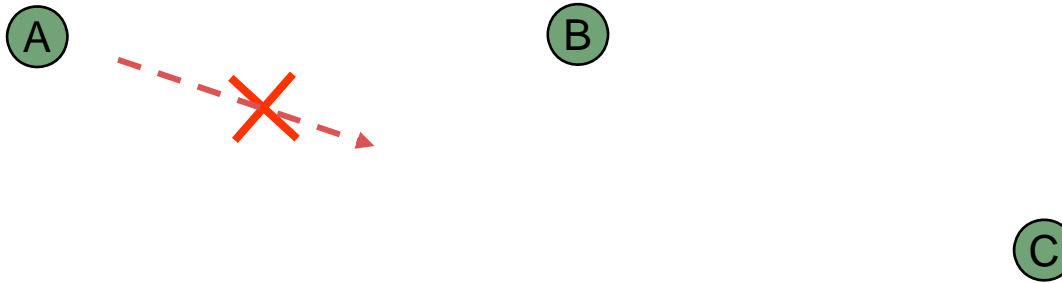
Link is broken between A and C. A's queue fills up.



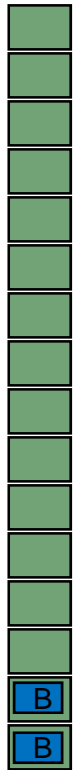
# Analysis of Rerouting Time



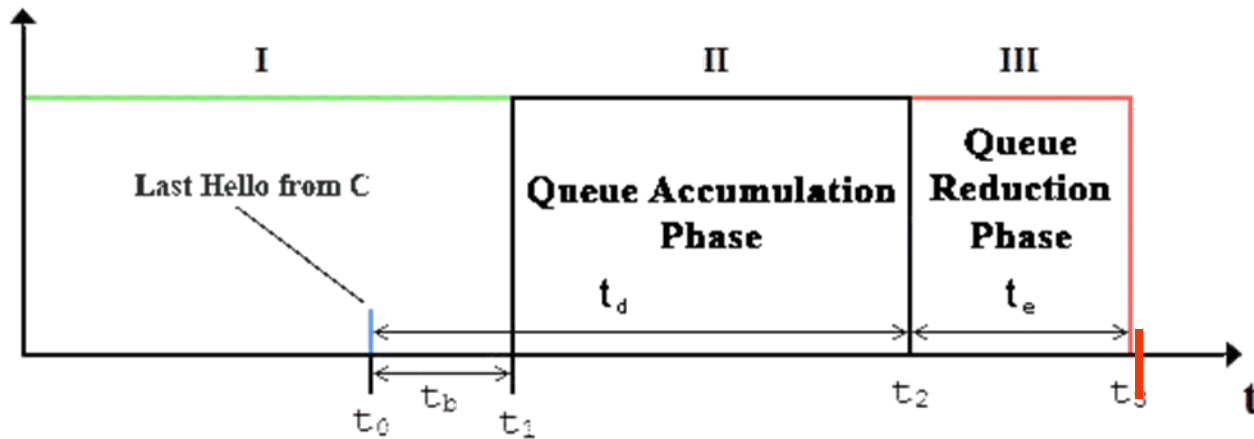
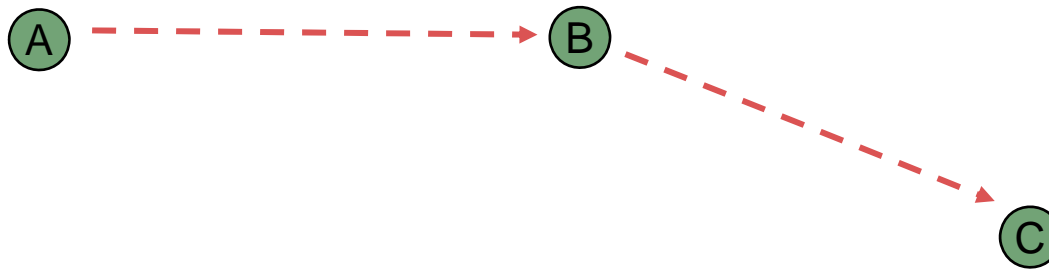
Packets to C are discarded from A's queue



# Analysis of Rerouting Time

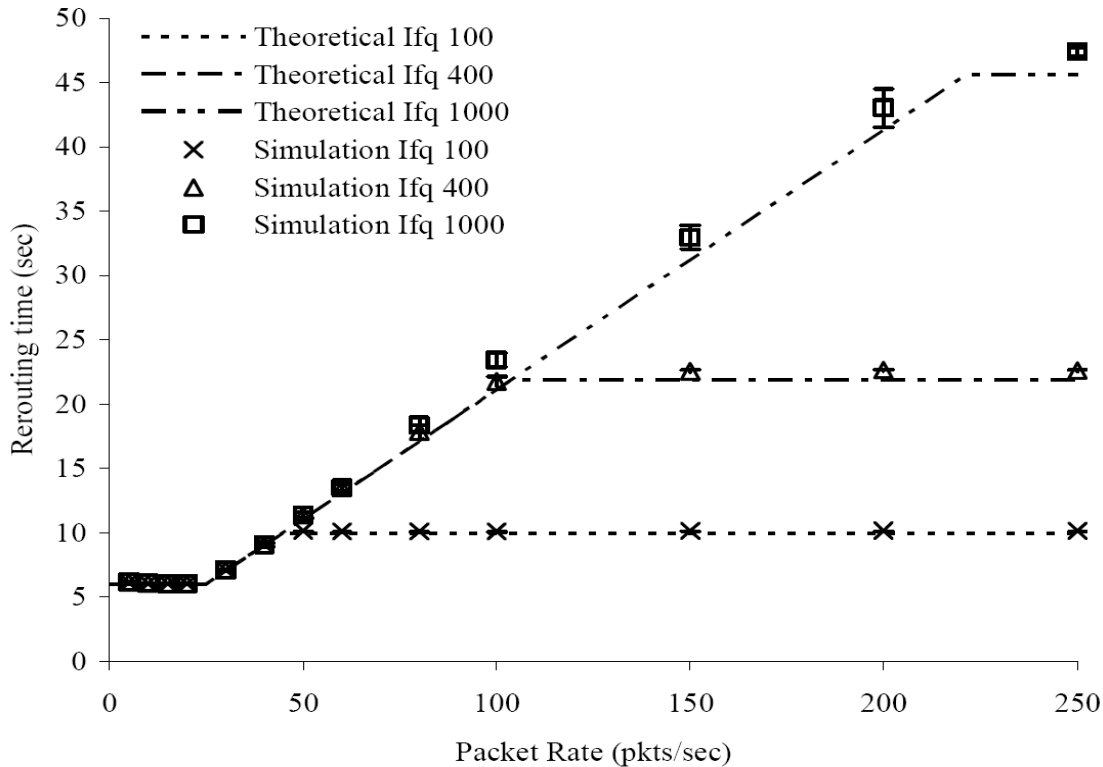


New route established via B



## Simulation Results:

# Rerouting Time vs Packet Rate



Variable packet rate

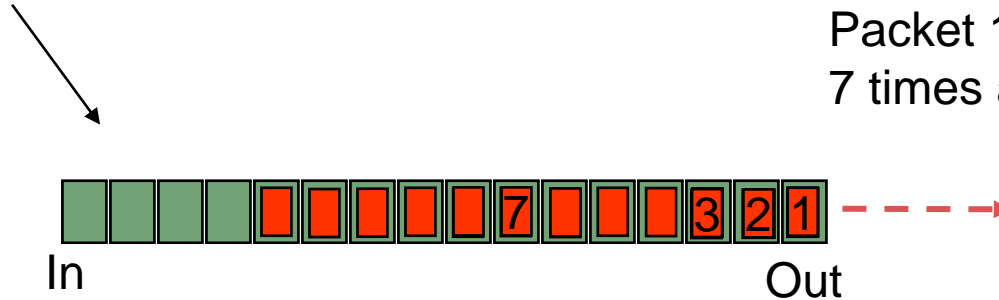
Queue sizes  
100, 400 and  
1000

Retry limit = 7

Proposed Solution:

# Adaptive Retry Limit

Node A's Interface Queue



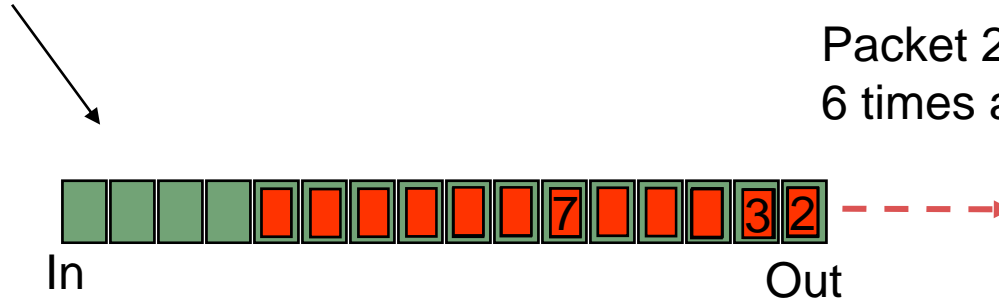
Assumes:

- Retry limit = 7
- All packets to the same destination

Proposed Solution:

# Adaptive Retry Limit

Node A's Interface Queue



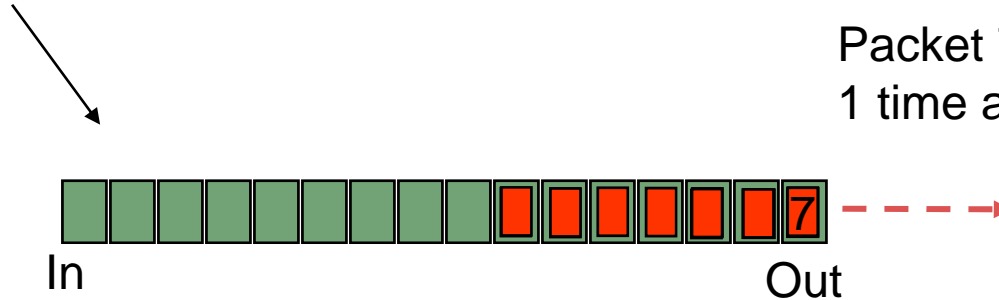
Assumes:

- Retry limit = 7
- All packets to the same destination

Proposed Solution:

# Adaptive Retry Limit

Node A's Interface Queue

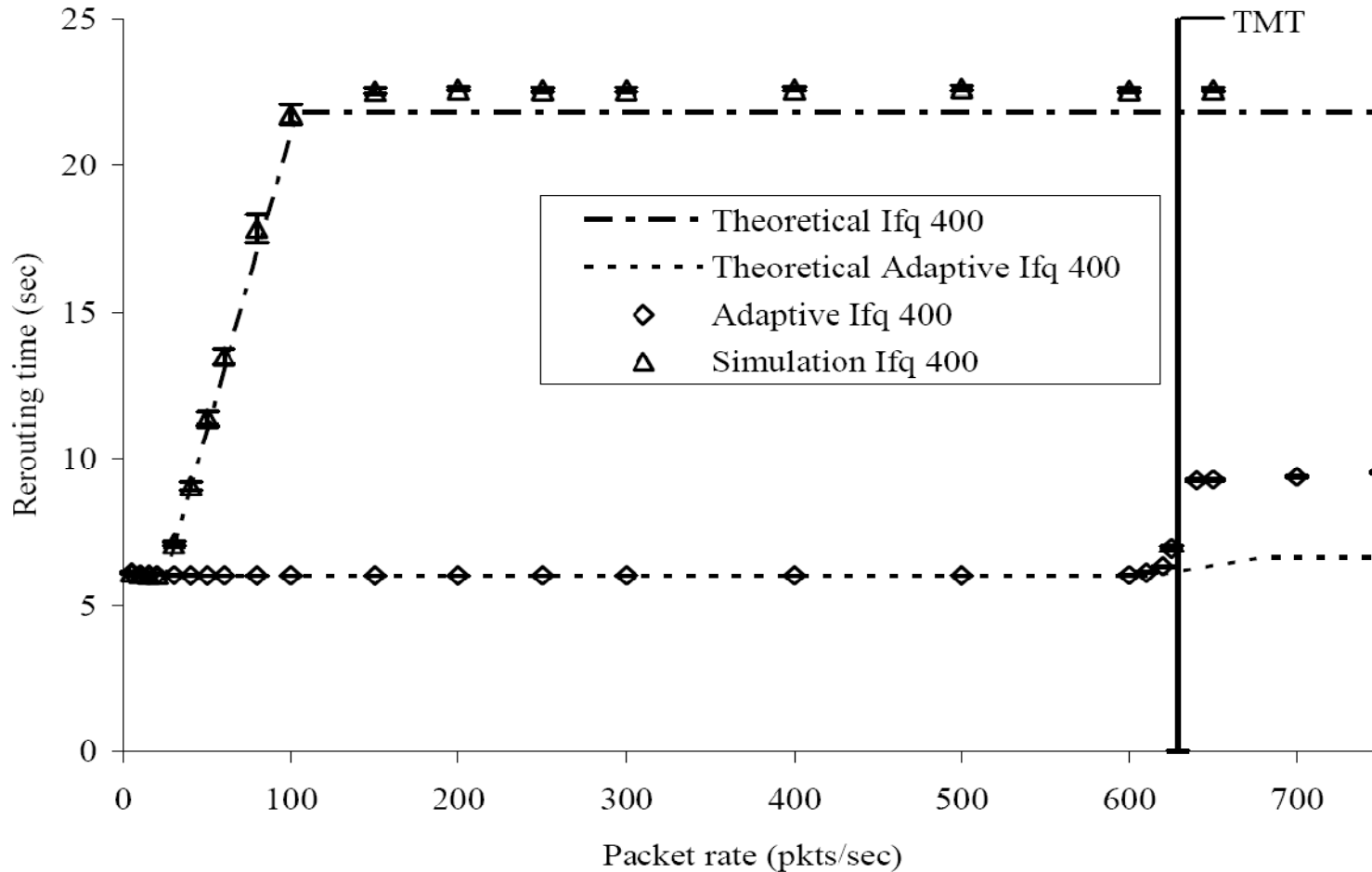


Packet 7 is transmitted  
1 time and discarded

Assumes:

- Retry limit = 7
- All packets to the same destination

# Results of Proposed Solution



# Conclusion

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- ❑ Wireless ad hoc networks have different dynamics than wired networks, making room for optimizations of the traditional layered architecture.
- ❑ Cross layering should be used with caution, as it is easy to lose track of the implications to the overall performance when employing several cross layer mechanisms.
- ❑ Changes to already defined standards can be avoided by allowing more information to flow between the layers.

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# Questions?

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