An Efficient Flow Control and Medium Access in Multihop Ad Hoc Networks with Multi-Channels

Presented by Chun-Chieh Chang
The MNet Lab, NTHU-CS.
INTRODUCTION

Motivation
Problem Statement

INTRODUCTION
Motivation

- IEEE 802.11 provides multiple channels for use
  - 802.11b/g: 14 available channels, 3 non-overlap channels

- Utilizing multiple channels can improve throughput
  - Allow simultaneous transmissions

- Advantages of utilizing multiple channels
  - Decreasing the end-to-end delay
  - Increasing the total throughput
  - Receiving and transmitting data in parallel (equip multiple transceivers)
Problem Statement

• IEEE 802.11 MAC does not fit for multi-channel
  – Communication cannot take place in the desired channel
  – Using k channels does not translate into throughput improvement by a factor of k

• Related work does not consider traffic congestion

• Goal: Modify the traditional 802.11 MAC that utilizes multiple channels to improve overall performance
  – Support multi-channel transmission simultaneously
  – Capacity of resolving traffic congestion
ISSUES IN MULTI-CHANNEL ENVIRONMENT

Multi-Channel Hidden Terminal Problem
Congestion
Hidden Terminal Problem

transmission range

A — DATA — B

C
Hidden Terminal Problem
Solution: Virtual Carrier Sensing
Solution: Virtual Carrier Sensing

A

CTS

B

C
Solution: Virtual Carrier Sensing

DATA transmission defer
Multi-Channel Hidden Terminals

- Multi-channel transmission by DCF
  - Static channel assignment
  
  - Transmission on receiver’s channel
  
  - Sender switches its channel to receiver’s channel before transmitting
Multi-Channel Hidden Terminals

A
RTS
B

Channel 1

Channel 2

C
Multi-Channel Hidden Terminals

Diagram showing three terminals (A, B, C) within range of two channels (Channel 1, Channel 2), with an indication of a CTS signal from Terminal A.
Multi-Channel Hidden Terminals
Multi-Channel Hidden Terminals

Channel 1

Channel 2

A → B → C

scanning

DATA
Multi-Channel Hidden Terminals
Congestion

- In multi-hop MANET, hot spot may suffer congestion.
  - Because of fair policy of IEEE 802.11 DCF
Congestion In Multi-Channel Environment

- In order to utilize multiple channels, a node may equip multiple transceivers.
- If node D has two/three transceivers, it may suffer more serious congestion.
Congestion In Multi-Channel Environment

• The following is the worst case, and result in the high ratio of packet loss.

• Solution: Each node equips only one transceiver.
  – Decrease the channel utilization
Previous work on multi-channel MAC
Nasipuri’s Protocol [VTC 2000]

• Assumptions:
  – N channels available
  – Each node equips N transceivers

• Each node listens to all channels simultaneously
• Sender must listen for an idle channel before transmitting

• Disadvantage: high cost of transceivers

• Solution: every node equips few transceivers with the idea of dynamic channel allocation (DCA)
Tseng’s Protocol [ICDCS 2001]

• Assumptions:
  – Each node equips two transceivers.
  – Channels are classify into control channel and several data channels

• One transceiver at each node always listen on control channel

• Nodes contend the right of the data channel usage on control channel before transmitting on data channel

• Disadvantage: waste the bandwidth of the control channel when it is idle
So’s Protocol [MobiHoc 2004]

• Assumptions:
  – Each node equips one transceiver
  – Clock synchronization is required

• Idea similar to IEEE 802.11 PSM
  – Divide time into beacon intervals
  – At the beginning of each beacon interval, all nodes negotiate channels on a predefined fixed duration of time
  – Nodes switch to selected channels for the rest of the beacon interval

• Disadvantage: no policy of resolving congestion
Zhai’s Protocol

- A node would send feedback about the size of buffer to the upstream node

- **Drawback:**
  - The maximum throughput only reach \( \frac{1}{4} \) of the channel bandwidth of the chain topology with single channel
Efficient Flow Control With Multi-Channels (EFCM)

PROPOSED METHOD
DESCRIPTION
Proposed Method

• Capacity
  – Support multi-channel transmission simultaneously
  – Resolve multi-channel hidden terminal problem
  – Resolve traffic congestion

• Assumption:
  – Each node equips two transceivers
  – Multi-hop synchronization is achieved by other means
  – Contention is classified into Intraflow/interflow contention
Intraflow contention

• From the transmission itself
  – Because the transmission at each hop has to contend for the channel with the upstream and downstream nodes
Intraflow contention

- From other flows with pass by the neighborhood

Interflow contention with flow_a and flow_b
EFCM

- Modify the 802.11 MAC to carry multi-channel and flow information

- Insert new fields in RTS/CTS header (named RTSM/CTSM)
  - Source address
  - Flow id
  - Multichannel message
    - Current usage information
    - NAV ch1
    - NAV ch2
    - NAV ch3
Channel negotiation

• Progress:
  – Divide time into beacon intervals
  – Divide beacon interval into contention period and data transmission period
  – Nodes contend the right of the channel usage in the contention period
  – Nodes switch to selected channels in the data transmission period
Congestion control (1/3)

- We impute the rise of congestion to the occurrence of the intraflow and interflow contention

- We proposed a hop-by-hop congestion control algorithm to solve the intraflow and interflow contention problem

- To solve the intraflow contention problem:
  - We set the intermediate node a higher channel access priority than the source
  - Based on the number of packets of the flow buffered in an intermediate node, each node has different initial value of the backoff window size to transmit packets of the flow.
Congestion control (2/3)

Optimum packet scheduling for chain topology
Congestion control (3/3)

• To solve the interflow contention problem:
  – Each node maintains a table to record the packet number and
    the status of each flow

• We add two control message, including CTSM-Block and CTSM-
  Resume

• If the packet number exceeds a threshold, the node would refuse to
  receive the packets of this flow by sending CTSM-Block

• Until the packet number less than the threshold, the flow would be
  started again by sending CTSM-Resume to the preceding node
Congestion happened
Congestion happened

Contention Period

Data Transmission Period

Data in channel 1

Data in channel 2

RTSM

CTSM

CTSM-Blocking

CTS-Resume
Congestion happened
PERFORMANCE EVALUATION

Simulation Model
Simulation Results
Simulation Model

- ns-2 simulator
- Transmission rate: 2Mbps
- Interfering range: 550m
- Transmission range: 250m
- Traffic type: Constant Bit Rate (CBR)
- Beacon interval: 100ms
- Packet size: 1000 bytes
- ATIM window size: 20ms
- Default number of channels: 3 channels

- Compared protocols
  - 802.11: IEEE 802.11 single channel protocol
  - OPET: Zhai’s Protocol
Throughput

![Graph showing throughput vs. total offered load for different configurations.](image-url)

- Vertical axis: Aggregate throughput (Gbps)
- Horizontal axis: Total offered load (Mbps)
- Legend includes different configurations such as Basic-oneway, EFET-oneway, etc.
Delay
CONCLUSION
Conclusion

• Our method resolves not only multi-channel hidden terminal problem and congestion problem

• In our method, the intermediate node has higher priority than the source and each node maintains a table to monitor the status of each flow.

• EFCM increases the end-to-end throughput and decreases the end-to-end delay
Thank you!