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

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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

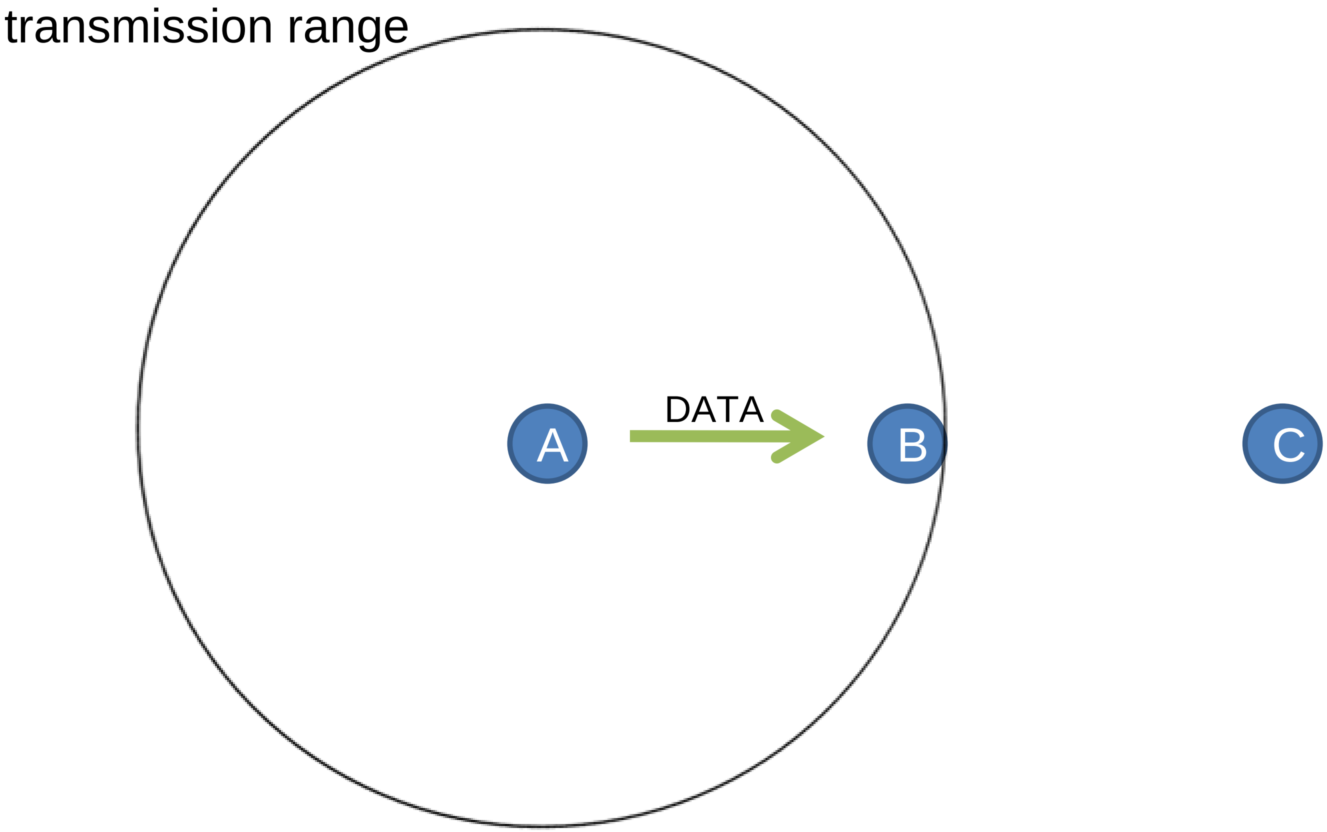
- IEEE 802.11 MAC does not fit for multi-channel
  - Communication cannot take place in the desired channel
  - Using k channels does not translate into throughput improvement by a factor of k
- Related work does not consider traffic congestion
- Goal: Modify the traditional 802.11 MAC that utilizes multiple channels to improve overall performance
  - Support multi-channel transmission simultaneously
  - Capacity of resolving traffic congestion

Multi-Channel Hidden Terminal Problem

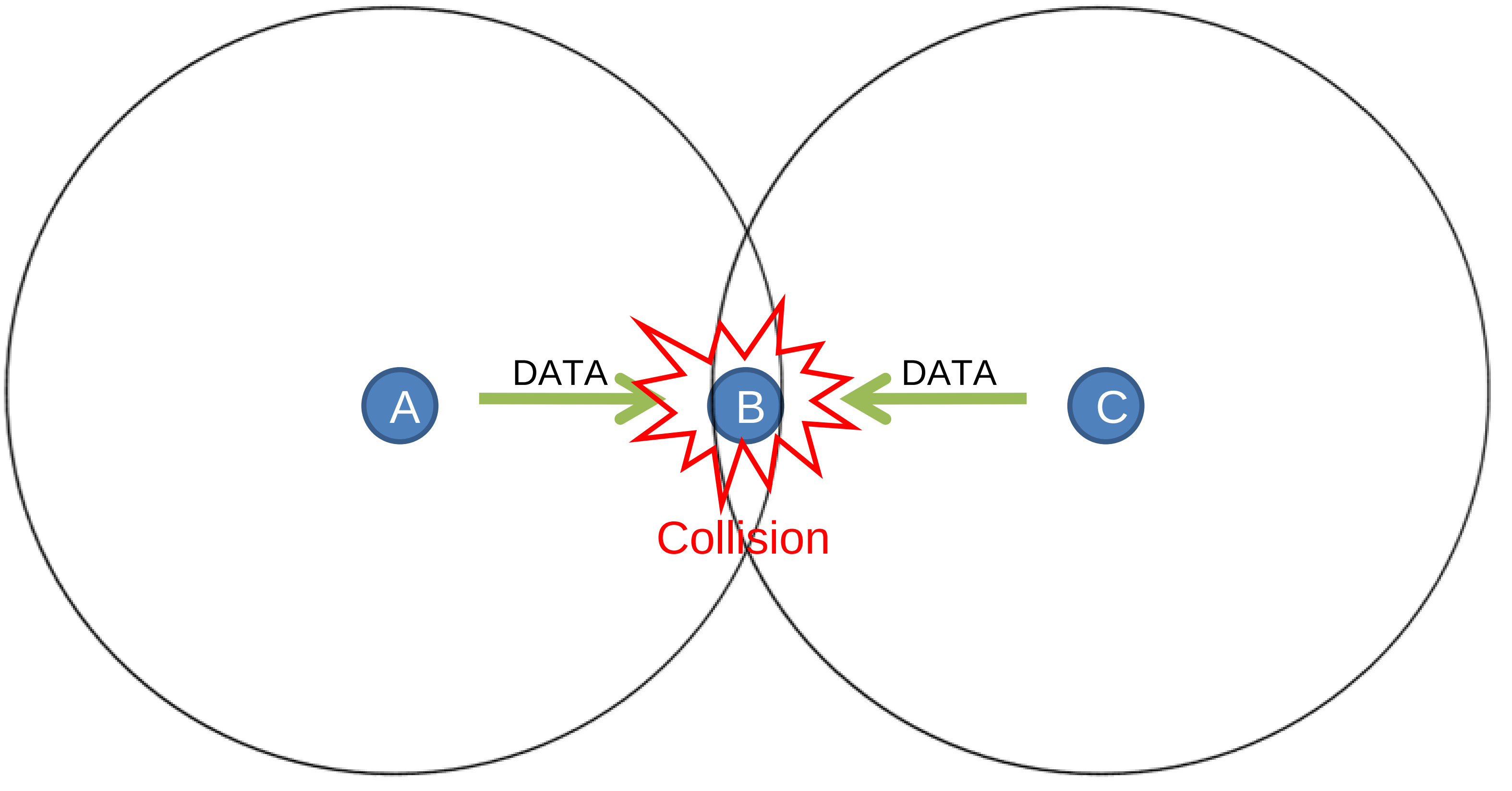
Congestion

ISSUES IN MULTI-CHANNEL ENVIRONMENT

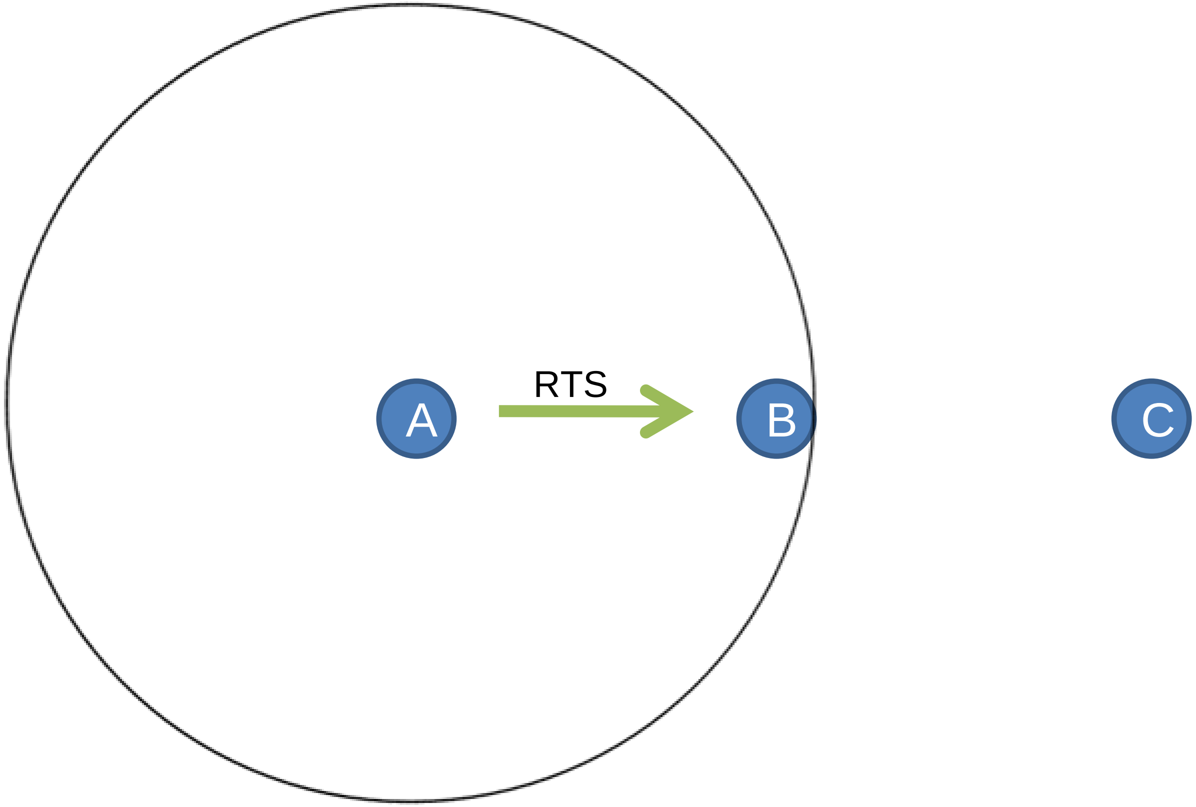
Hidden Terminal Problem



Hidden Terminal Problem



Solution: Virtual Carrier Sensing



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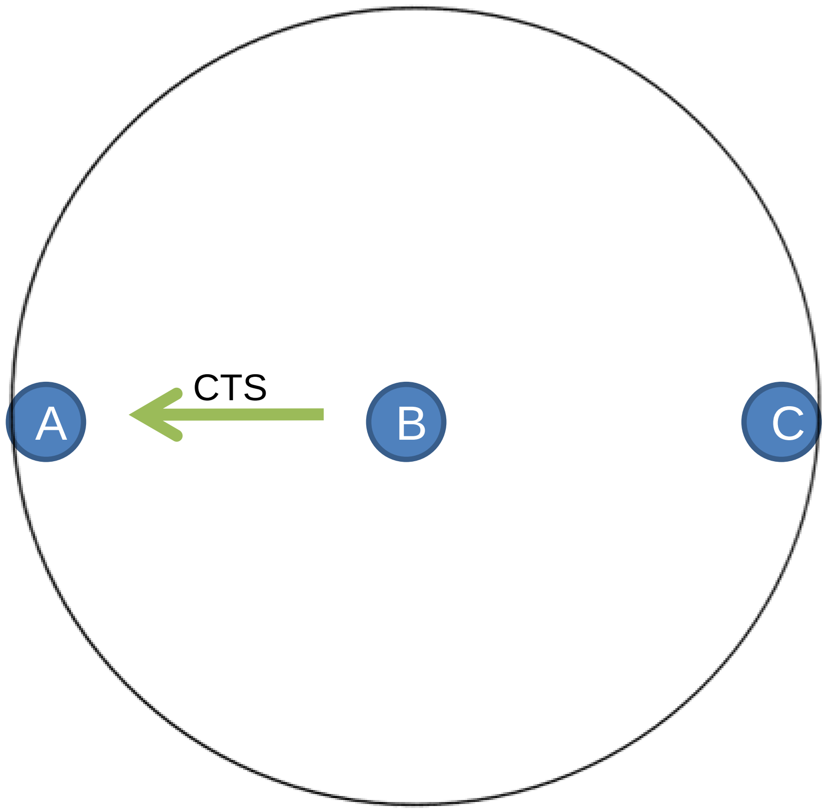

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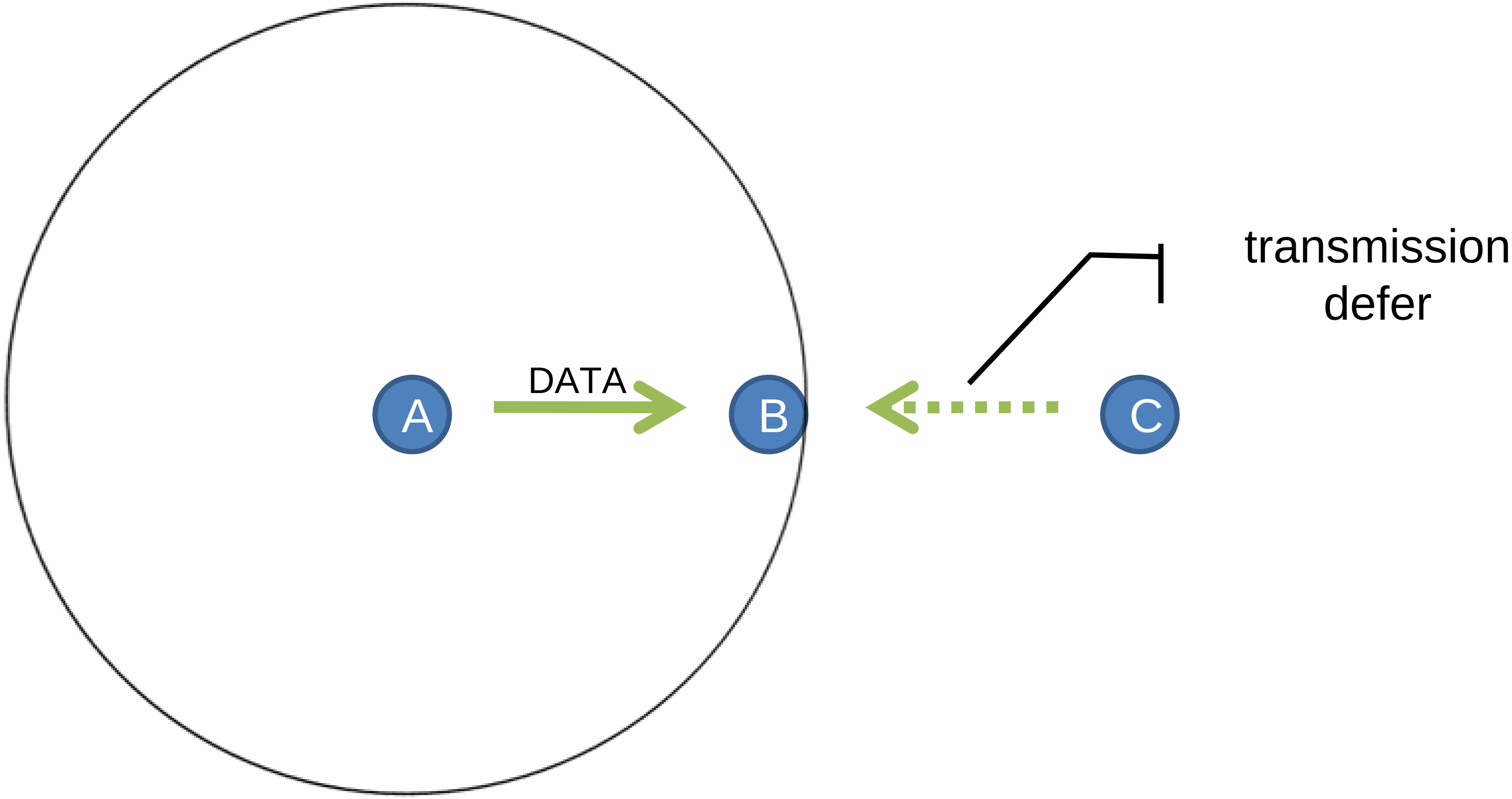
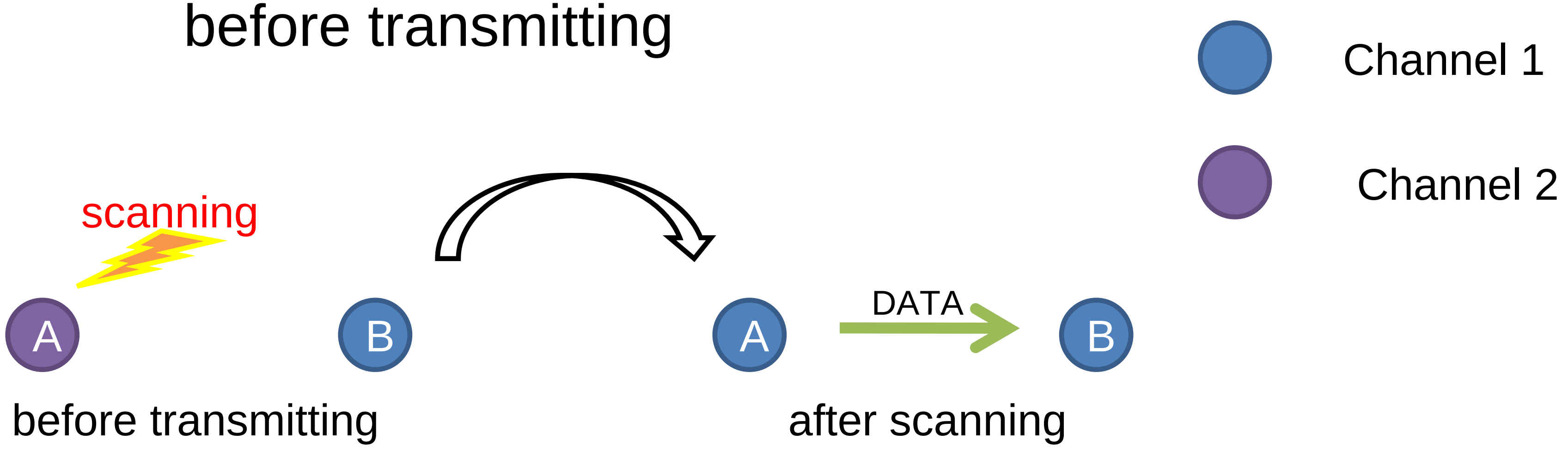
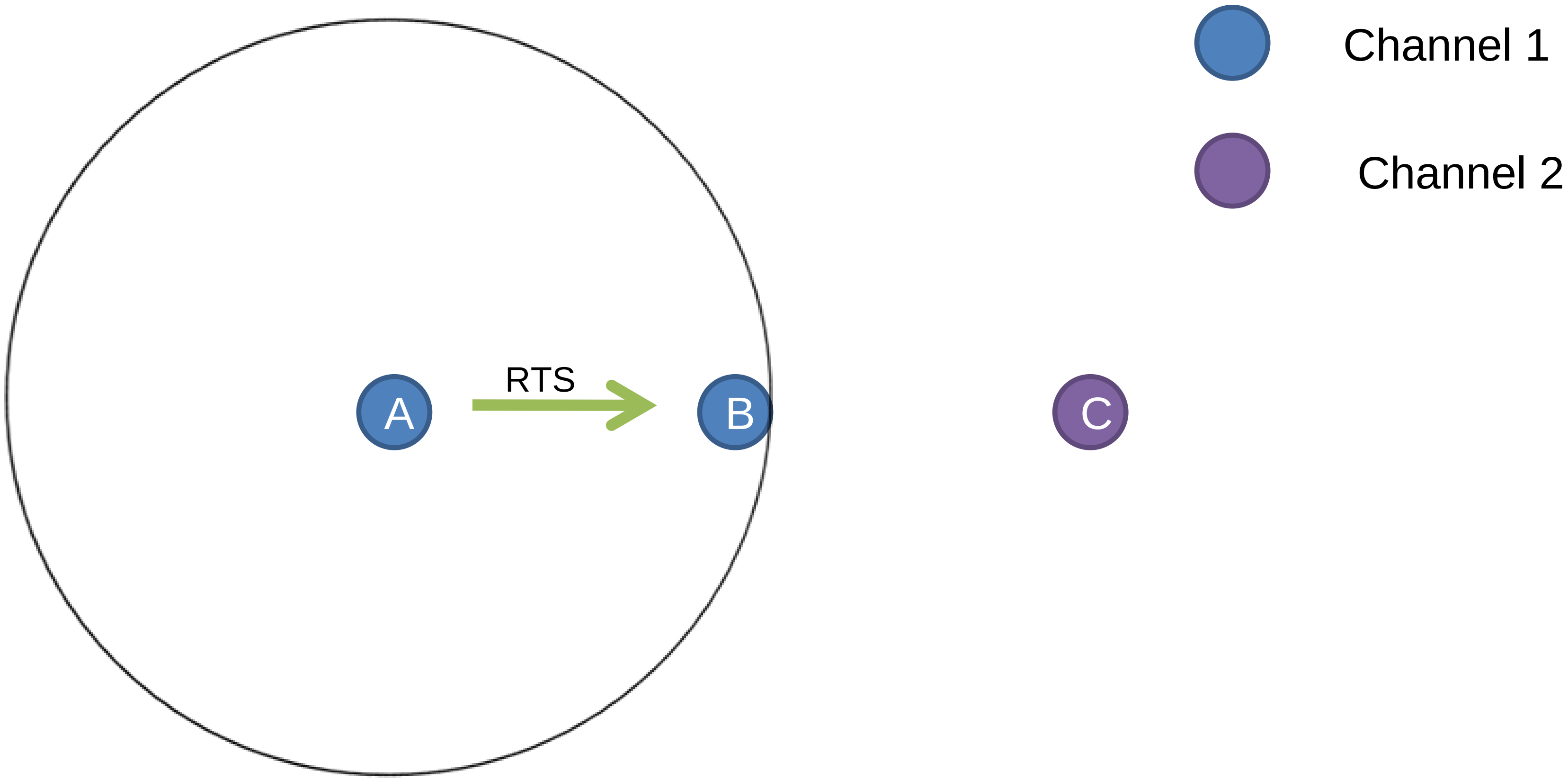


Multi-Channel Hidden Terminals

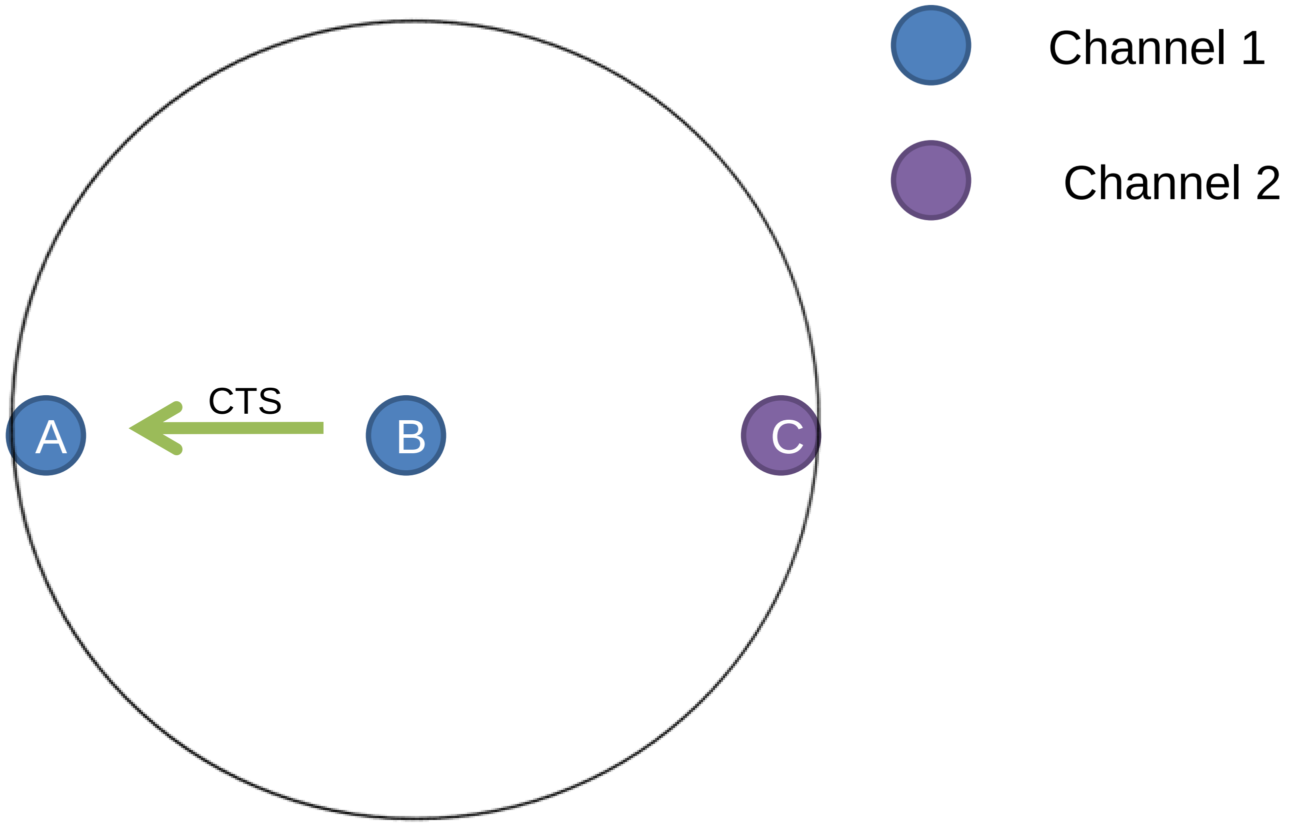
- Multi-channel transmission by DCF
  - Static channel assignment
  - Transmission on receiver’s channel
    - Sender switches its channel to receiver’s channel before transmitting



Multi-Channel Hidden Terminals

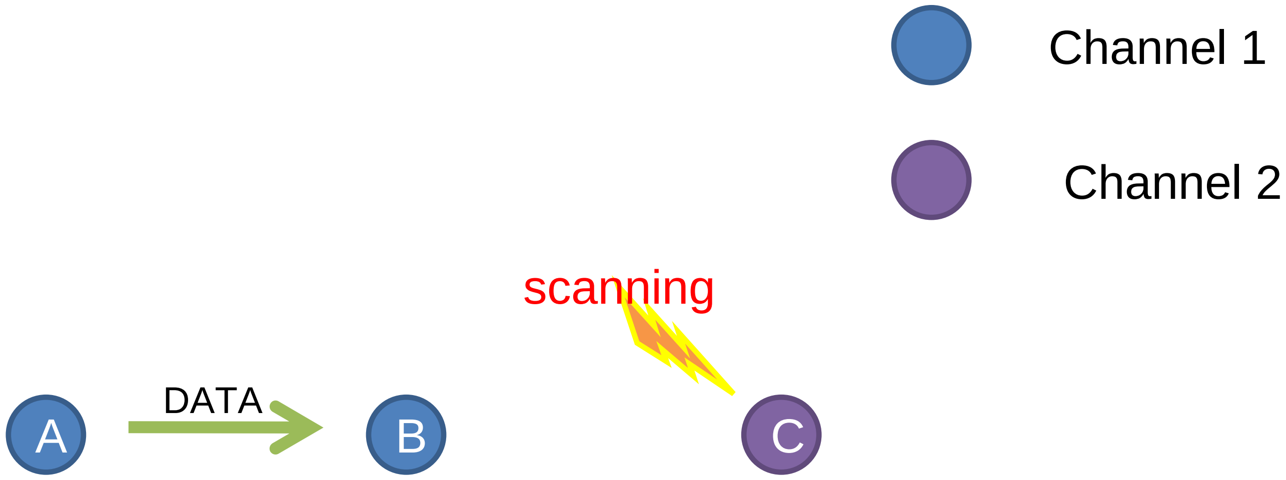


Multi-Channel Hidden Terminals

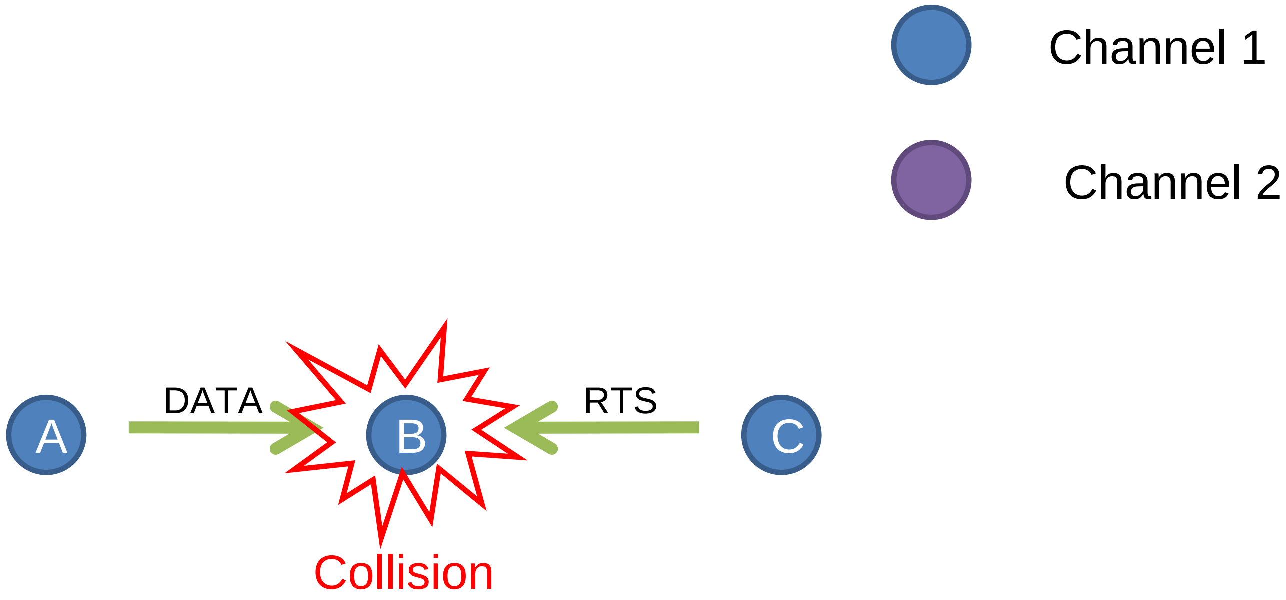


Multi-Channel Hidden Terminals

Multi-Channel Hidden Terminals

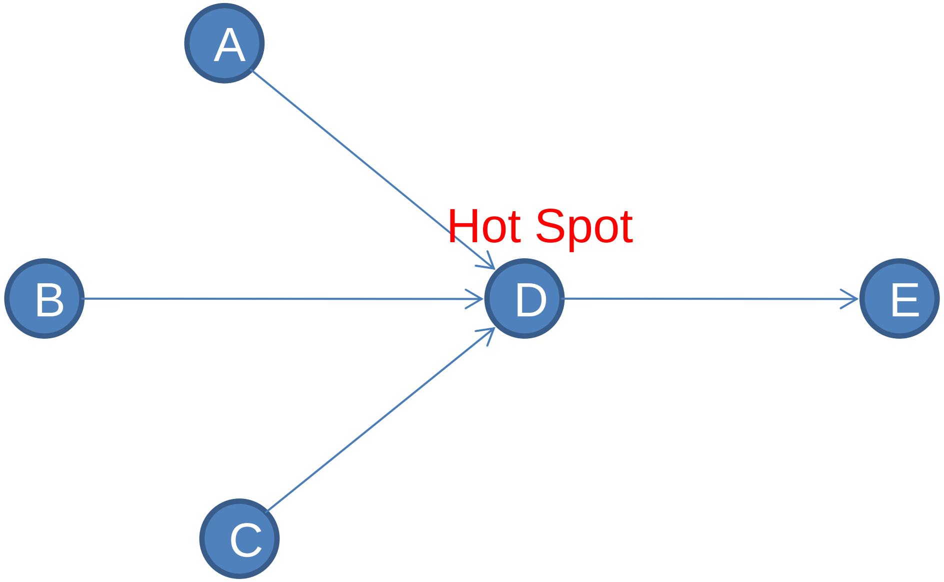


Multi-Channel Hidden Terminals



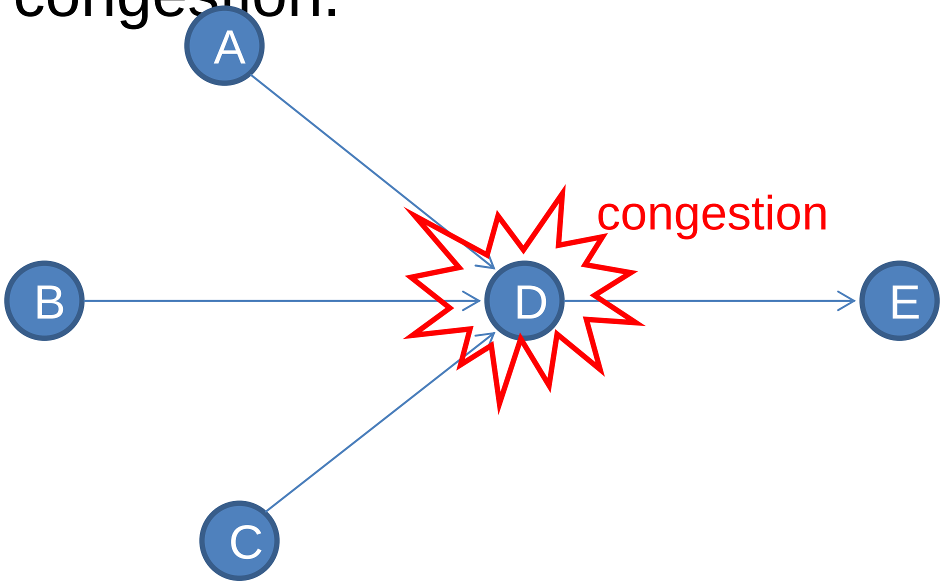
Congestion

- In mutihop MANET, hot spot may suffer congestion.
  – Because of fair policy of IEEE 802.11 DCF



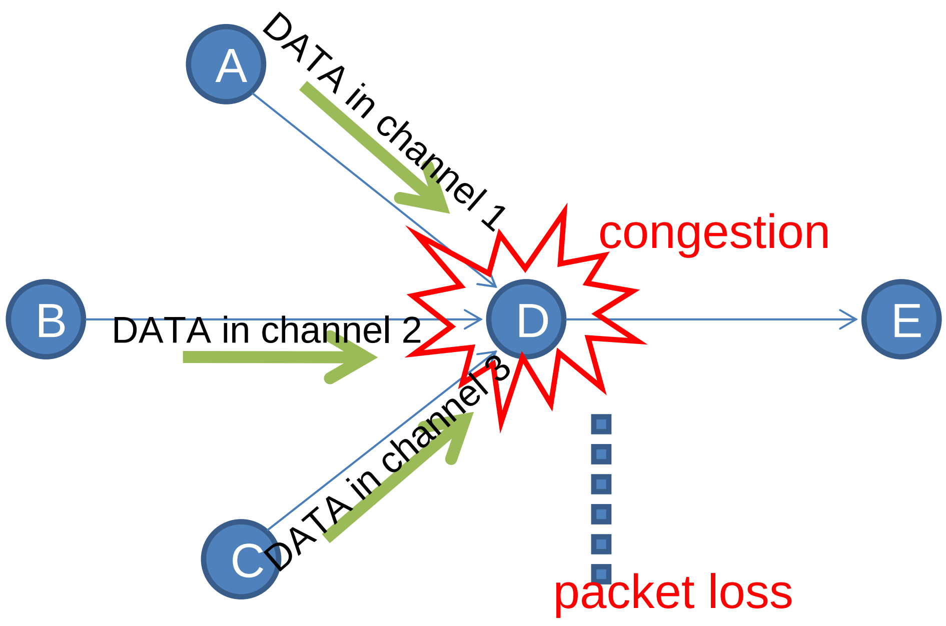
Congestion In Multi-Channel Environment

- 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

RELATED WORK

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

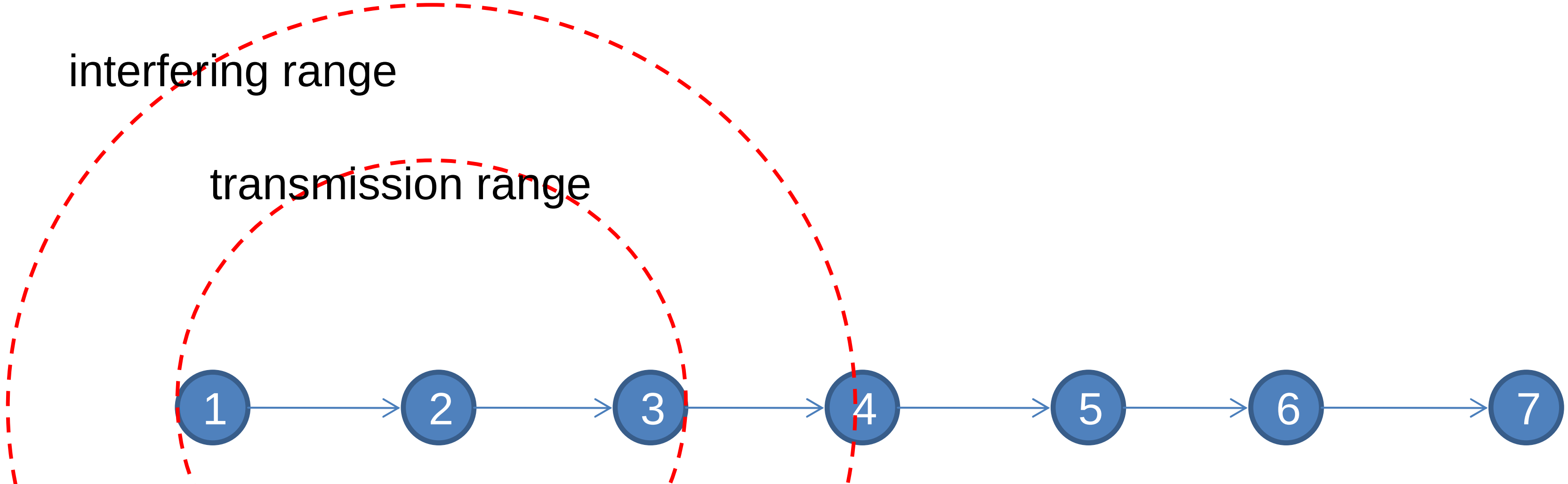
So’s Protocol [MobiHoc 2004]

- 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 ¼ of the channel bandwidth of the chain topology with single channel



Efficient Flow Control With Multi-Channels (EFCM)

PROPOSED METHOD DESCRIPTION

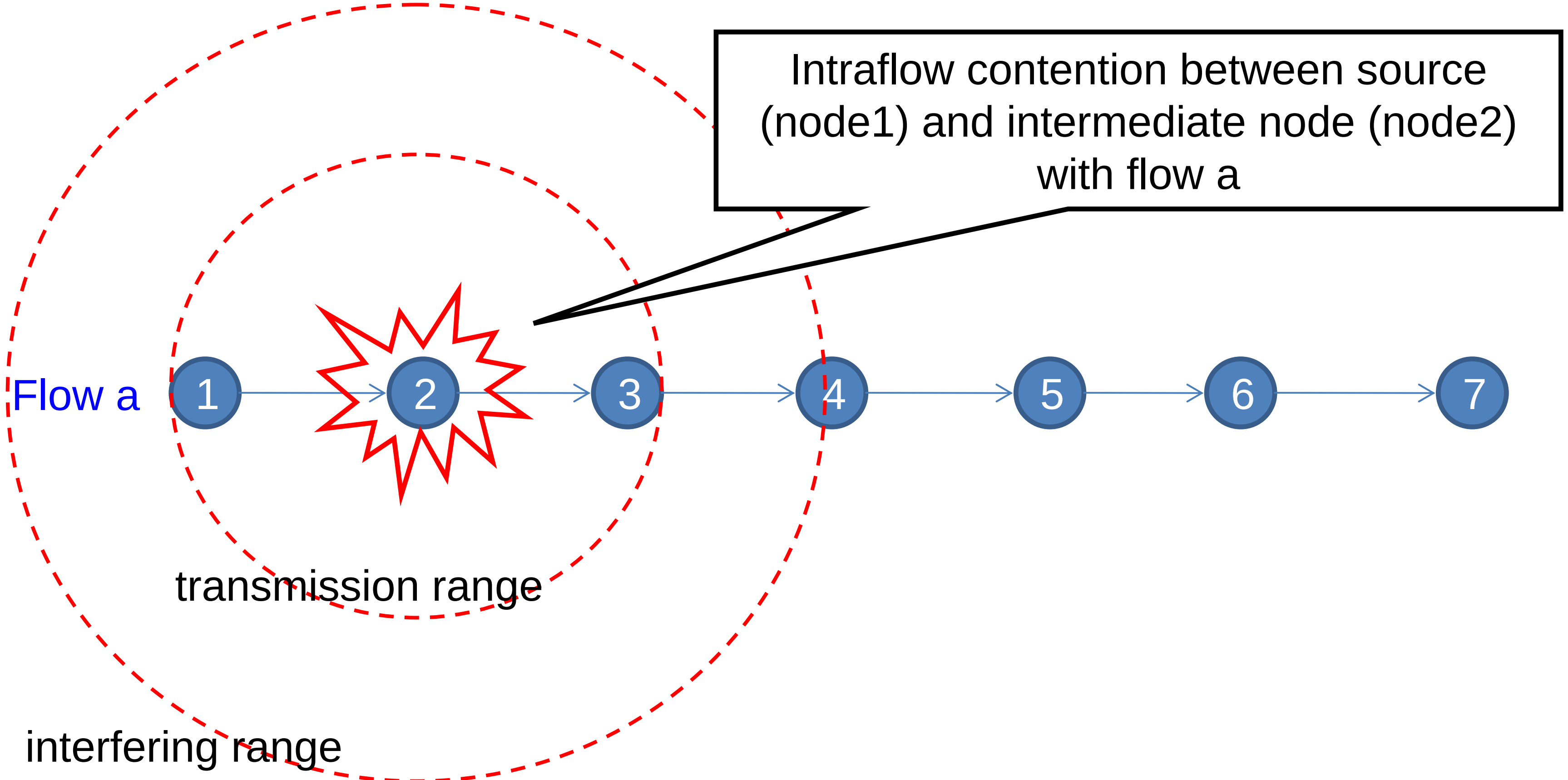
Proposed Method

- 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

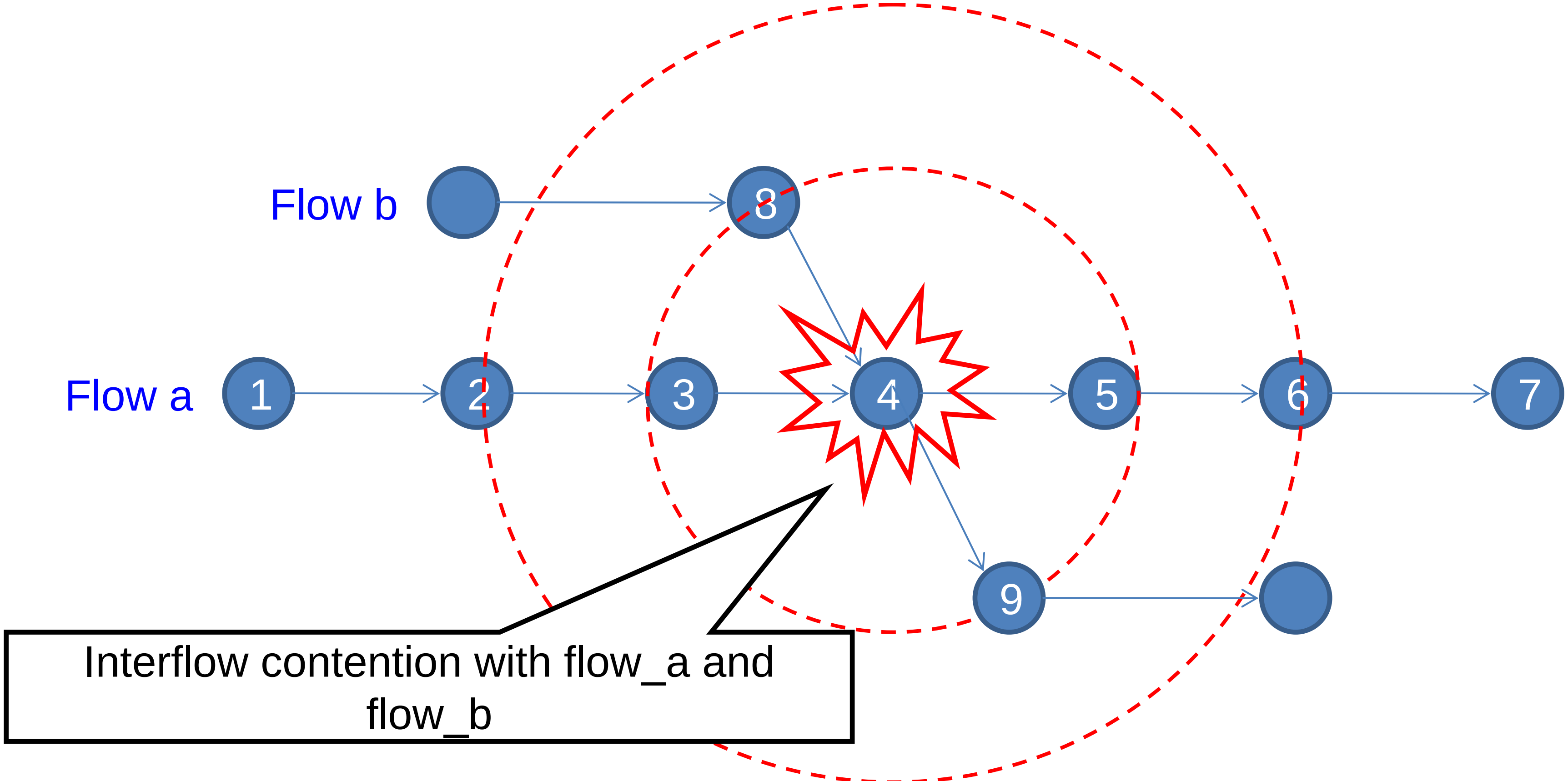
Intraflow contention

- 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



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

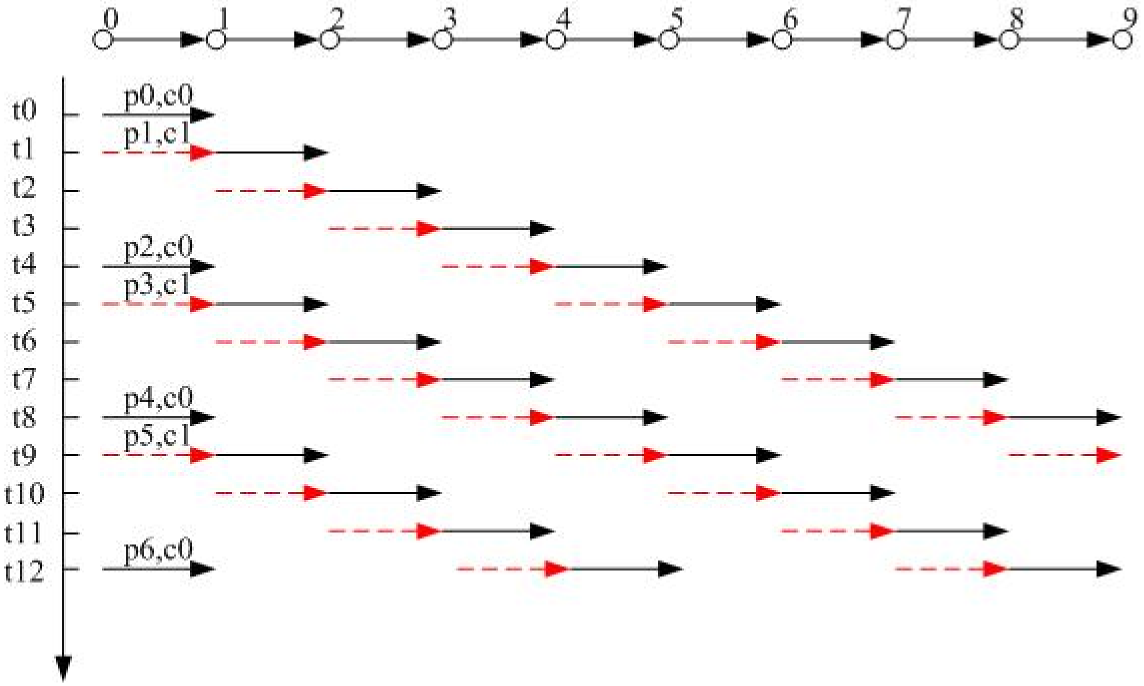
Channel negotiation

- 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)

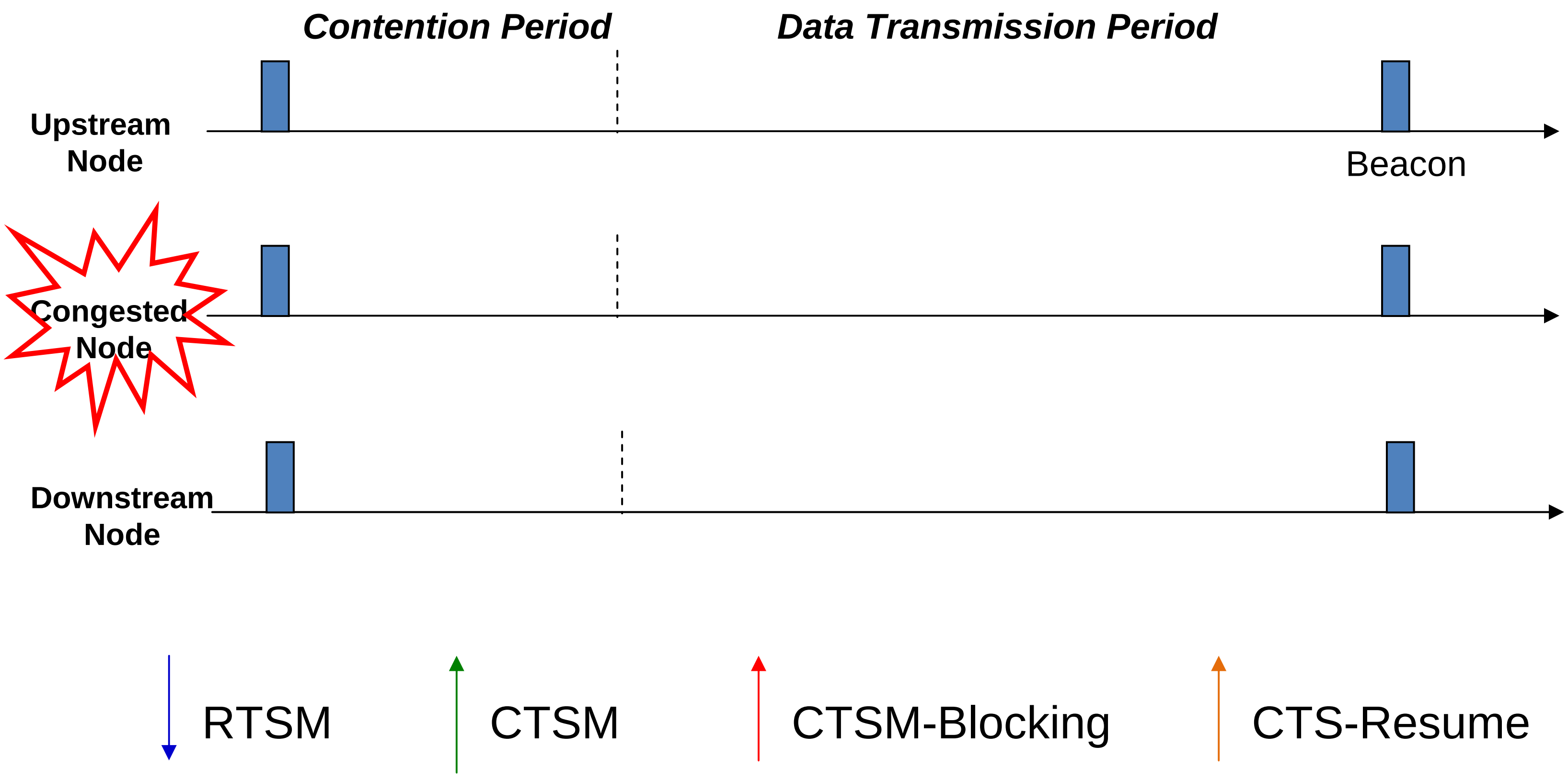


Optimum packet scheduling for chain topology

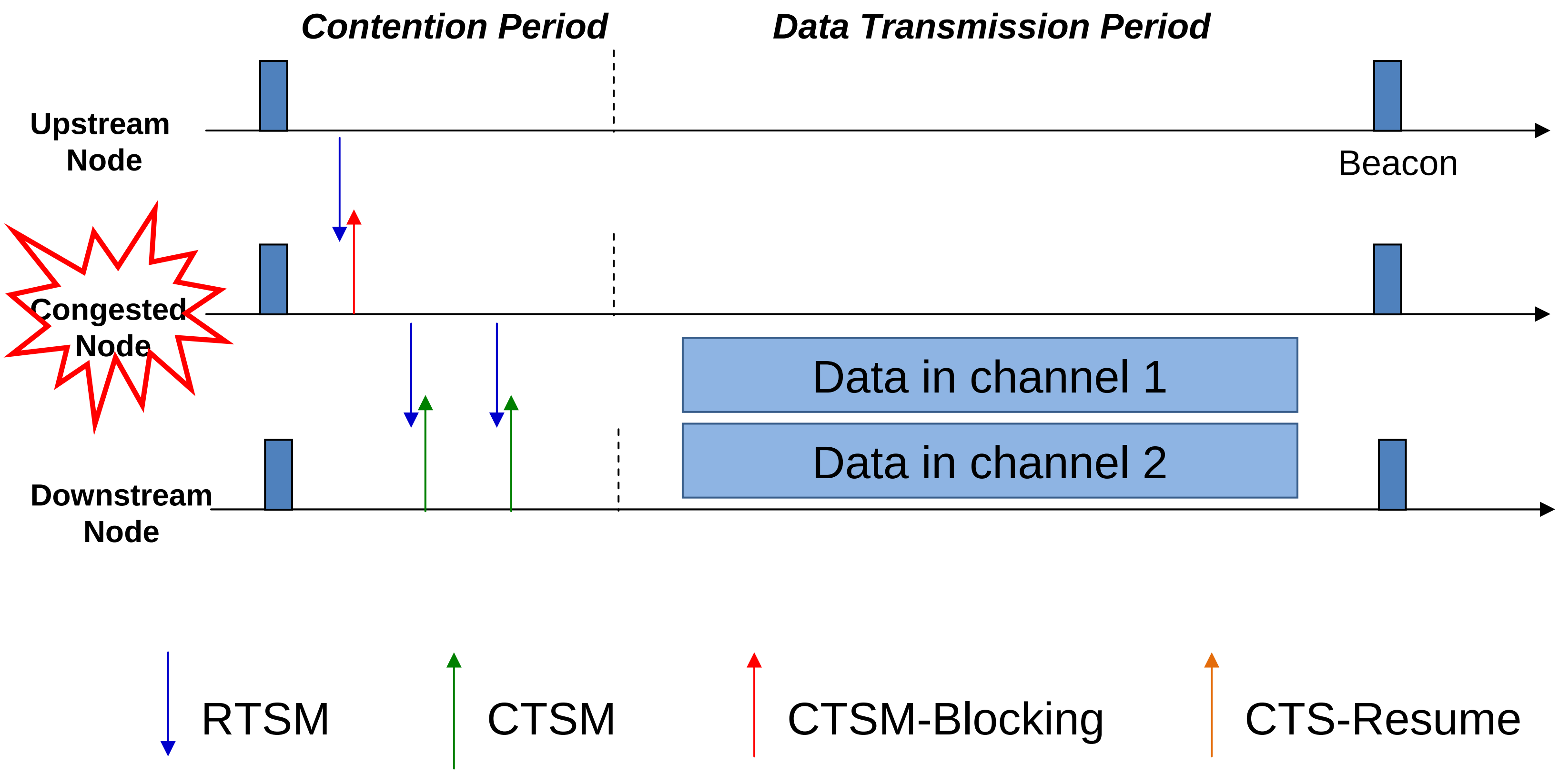
Congestion control (3/3)

- 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

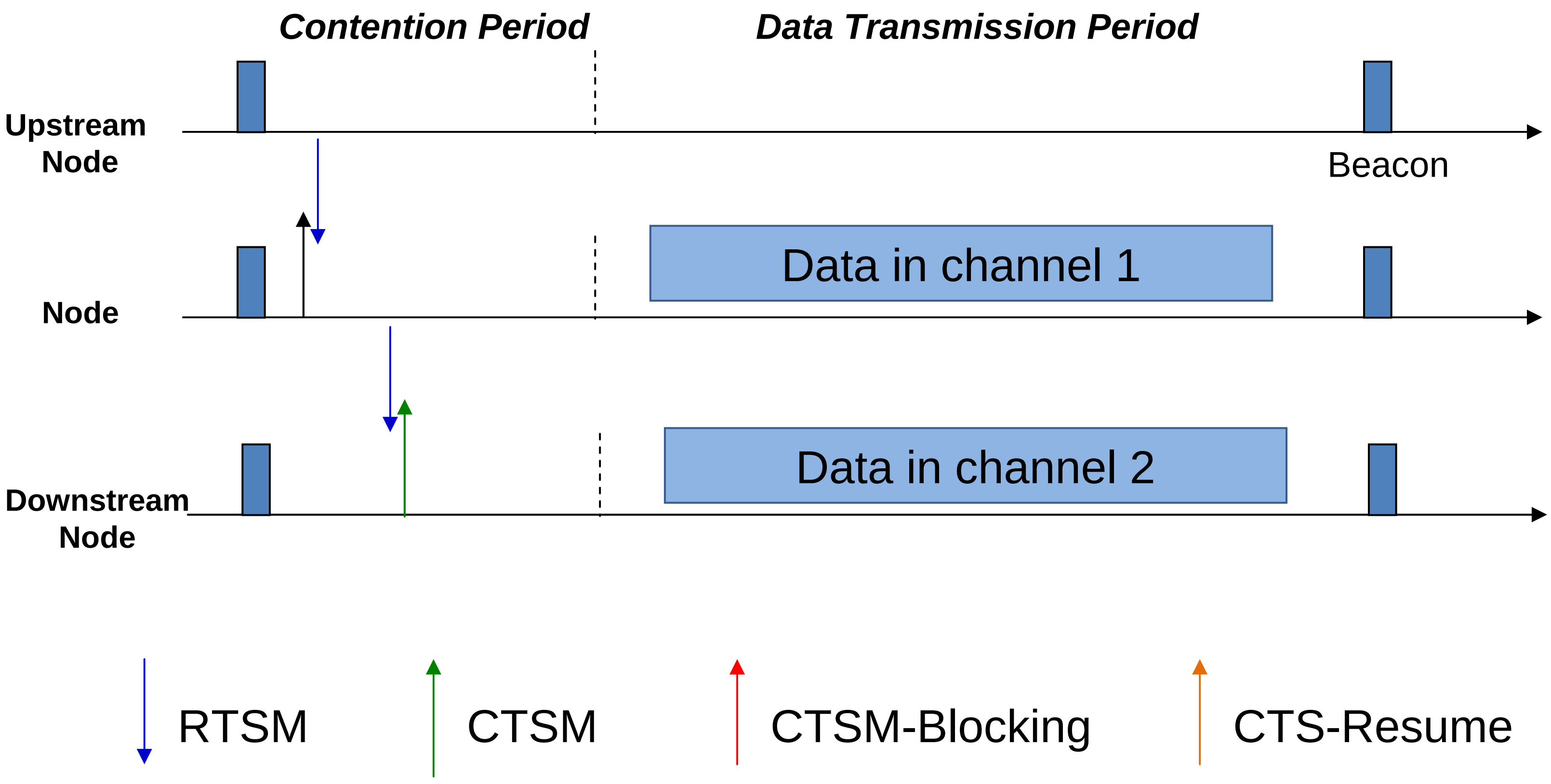
Congestion happened



Congestion happened



Congestion happened



Simulation Model

Simulation Results

PERFORMANCE EVALUATION

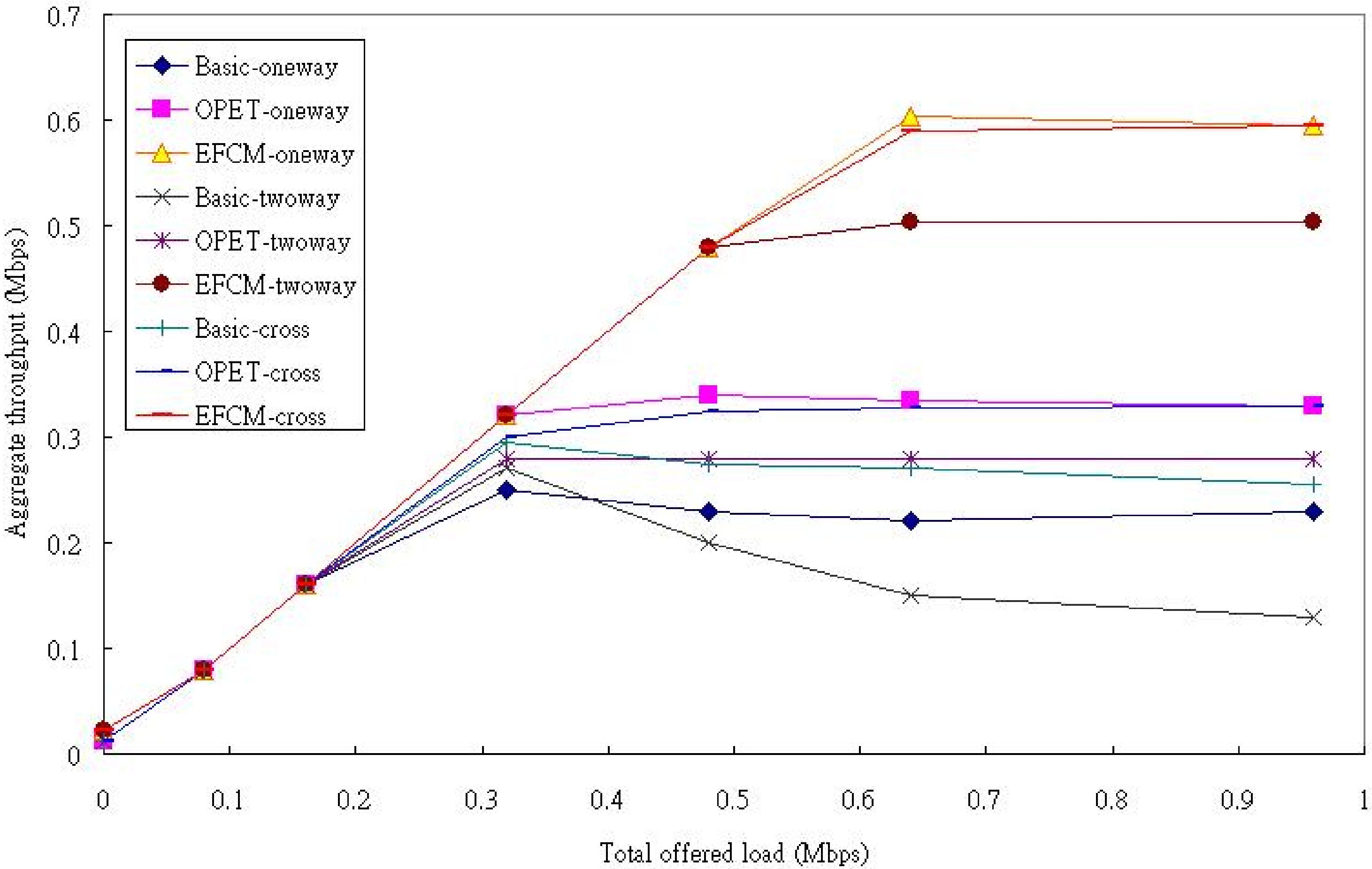
Simulation Model

- 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

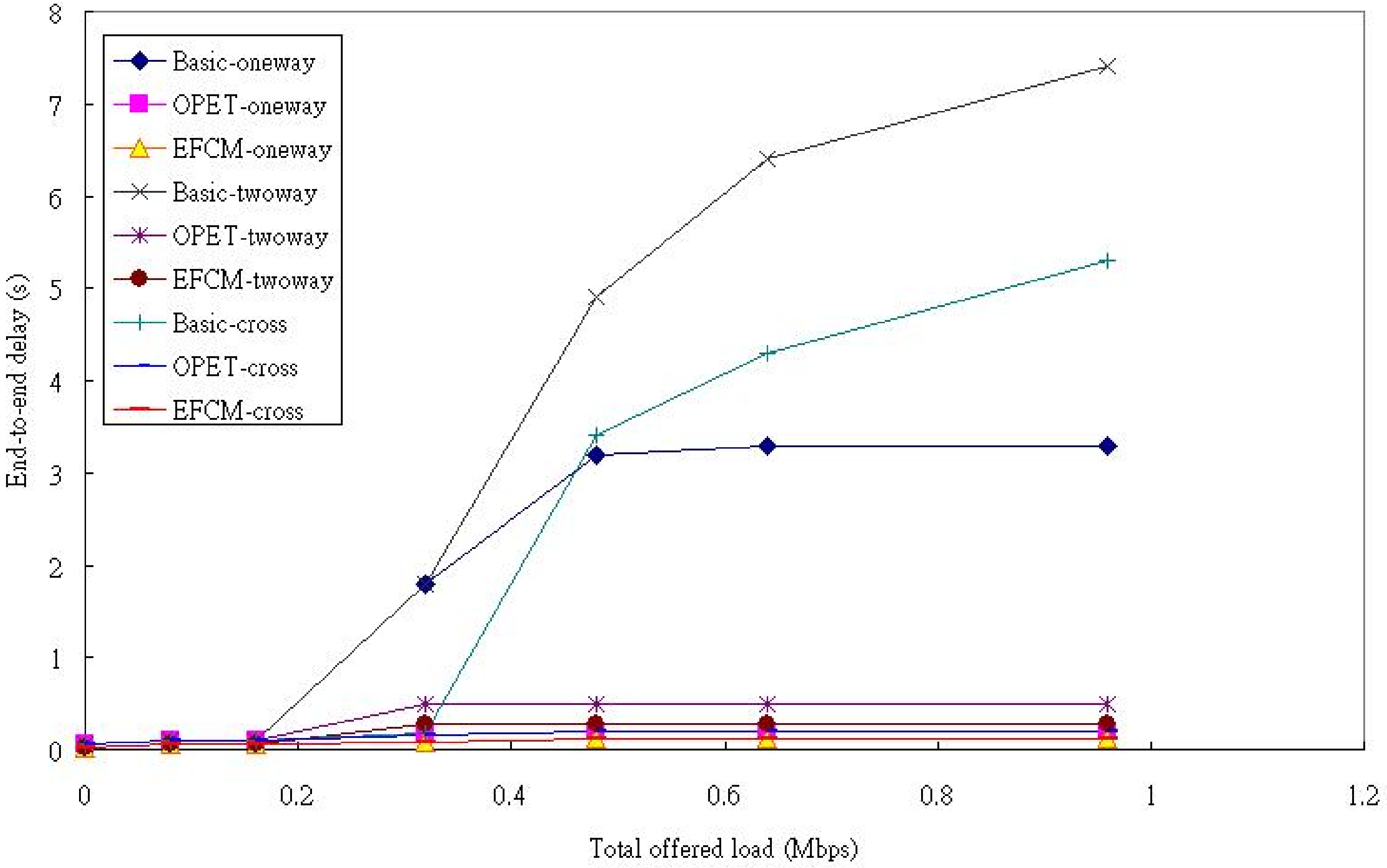
- Compared protocols
  - 802.11: IEEE 802.11 single channel protocol
  - OPET: Zhai's Protocol

Throughput



Basic-oneway
OPET-oneway
EFCM-oneway
Basic-twoway
OPET-twoway
EFCM-twoway
Basic-cross
OPET-cross
EFCM-cross
Aggregate throughput (Mbps)
Total offered load (Mbps)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

Delay



8
7
6
5
4
3
2
1
0
End-to-end delay (s)
Basic-oneway
OPET-oneway
EFCM-oneway
Basic-twoway
OPET-twoway
EFCM-twoway
Basic-cross
OPET-cross
EFCM-cross
0
0.2
0.4
0.6
0.8
1
1.2
Total offered load (Mbps)

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!