Routing in Multi-Channel Multi-interface Ad Hoc Wireless Networks

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Outline

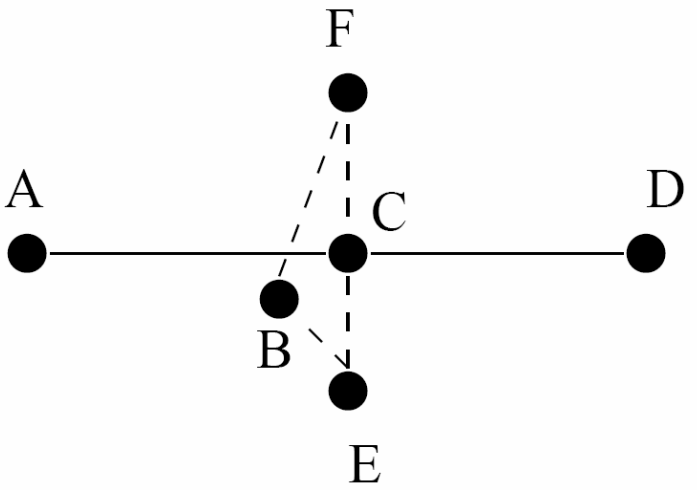
- Motivation
- Related work
- Proposed protocol
  - Interface assignment
  - Routing protocol
- Evaluation
- Discussion and conclusion

Motivation

- Multi-channel
  - Meeting the ever-increasing throughput demands of applications
- Benefits of using multiple interfaces
  - Decreasing the end-to-end latency
  - Increasing the maximum capacity
  - Receiving and transmitting data in parallel

Motivation

- Need for specialized routing protocols
  - Interface switching costs



Related work

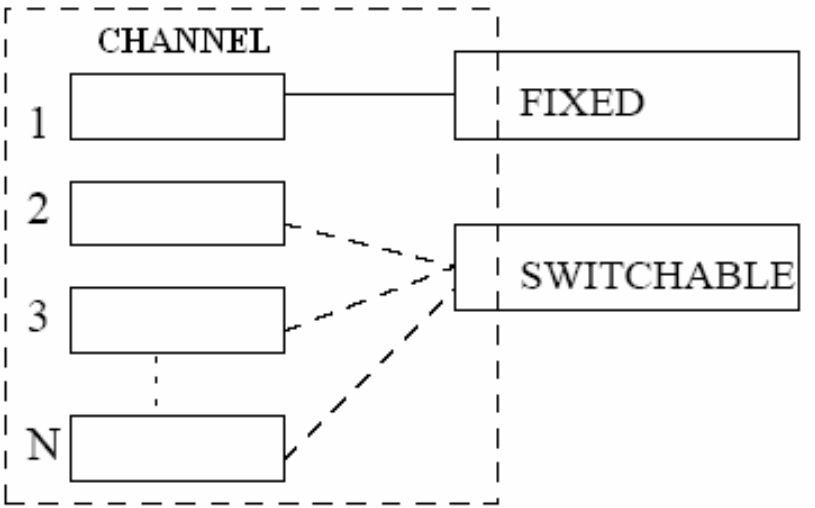
- Multi-channel MAC and link layer protocols
  - All nodes have an interface on each channel.
  - Two interface, one for control channel, and one for data channel.
  - Single interface
- Multi-channel routing protocol
  - AODV,DSR
  - Raniwala ’s protocol
  - LQSR

Proposed protocol

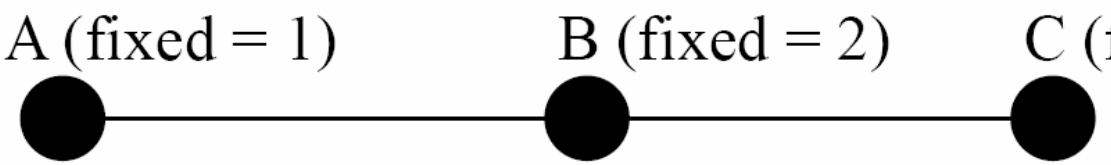
- Targets:
  1. Improve network capacity by utilizing all the available channels, even if the number of interfaces is smaller than the number of available channels
  2. Ensure that a network which is connected when using a single common channel, continues to be connected when multiple channels are being used
  3. Allow implementation using existing IEEE 802.11 hardware.
- Switching Protocol
- MCR :Multi-channel Routing Protocol

Switching protocol

- Classify available interfaces
  - Fixed interfaces(receiving data)
  - Switchable interfaces (transmitting data)



Switching protocol



Initially: switchable = 3 switchable = 1 switchable = 2

Step 1: switchable = 2

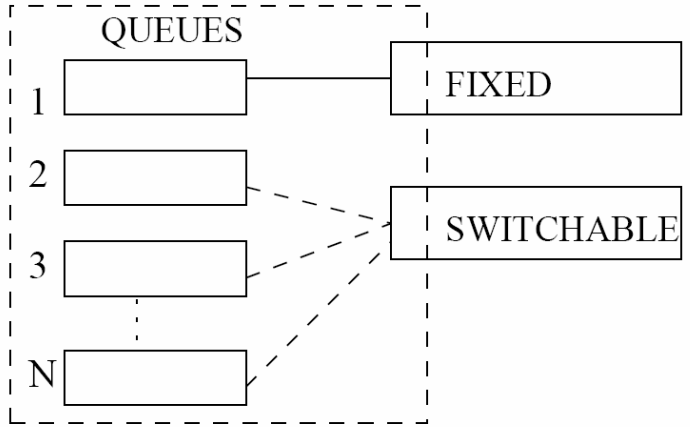
Step 2: switchable = 3

Switching protocol

- Fixed interface assignment
  - Choosing the channel to be assigned to the fixed interface and
    - Initially a node chooses a random channel for its fixed interface, and
    - Periodically consults its ChannelUsageList (with probability p change its fixed channel).
    - Maintain **Neighbor Table** and **ChannelUsageList**
  - Informing neighbors about the channel being used by the fixed interface
    - Broadcast **Hello** message(Routing protocol can utilized this message)

Switching protocol

- Managing switchable interface
  - When to switch an interface ?
  - what channel to switch the interface to ?



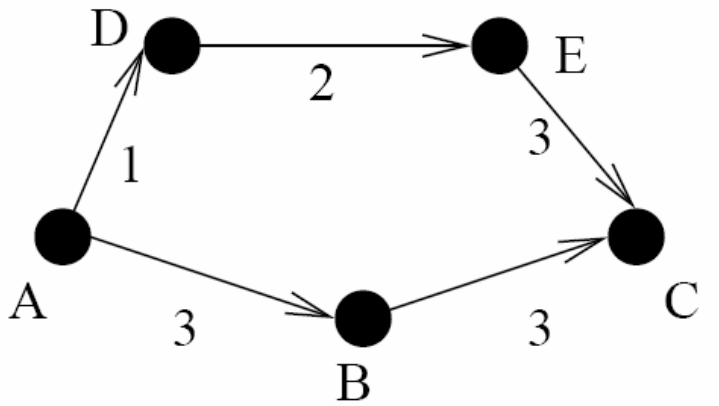
  - BurstLength:
    - maximum number of queued packets can be transmitted on one channel.
  - MaxSwitchTime:
    - The upper bound a switchable interface can stay on a channel

MCR :Multi-channel Routing Protocol

- Multi-channel routing protocol
  - Channel diversity cost
    - A link I in a route is interfered by other links in the route that use the same channel, and are in its interference range
  - Interface switching cost
  - Route discovery and maintenance

MCR :Multi-channel Routing Protocol

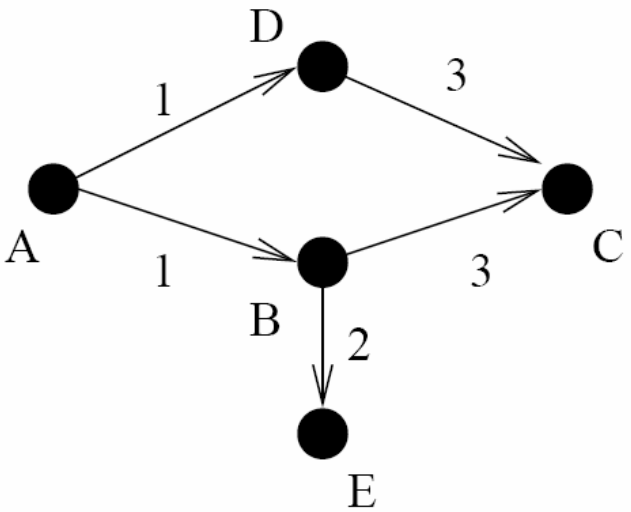
- Channel diversity cost



- Metric
  - $DC = \sum_{i=0}^{n-1} \sum_{j=i+1}^{\max(i+Interferenclength,n)} I(C(i) == C(j))$
    - Maximum diversity cost of any link along the route

MCR :Multi-channel Routing Protocol

- Interface switching cost



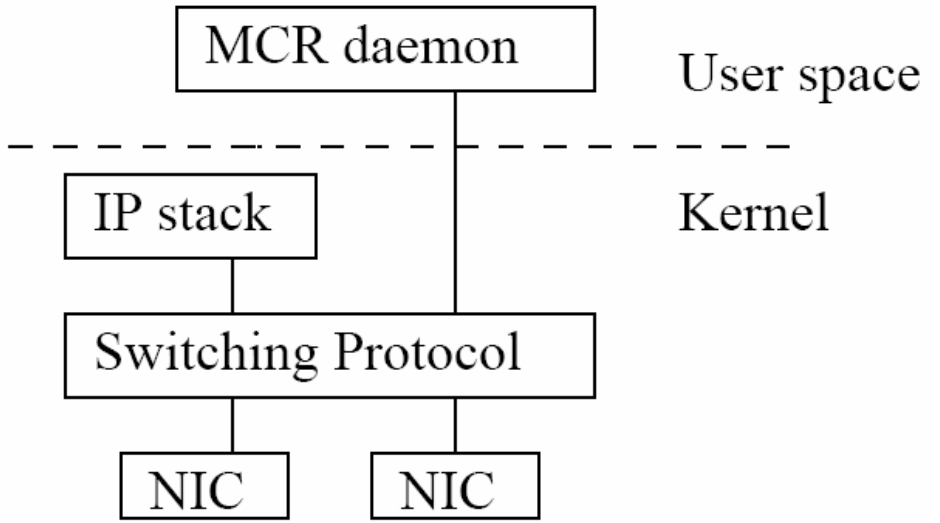
- Metric
  - Number of “interface bottlenecked link along the route, or
  - Total switching cost along each link in the route (*switchingDelay / estimatedPacketTransmissionTime*)

MCR :Multi-channel Routing Protocol

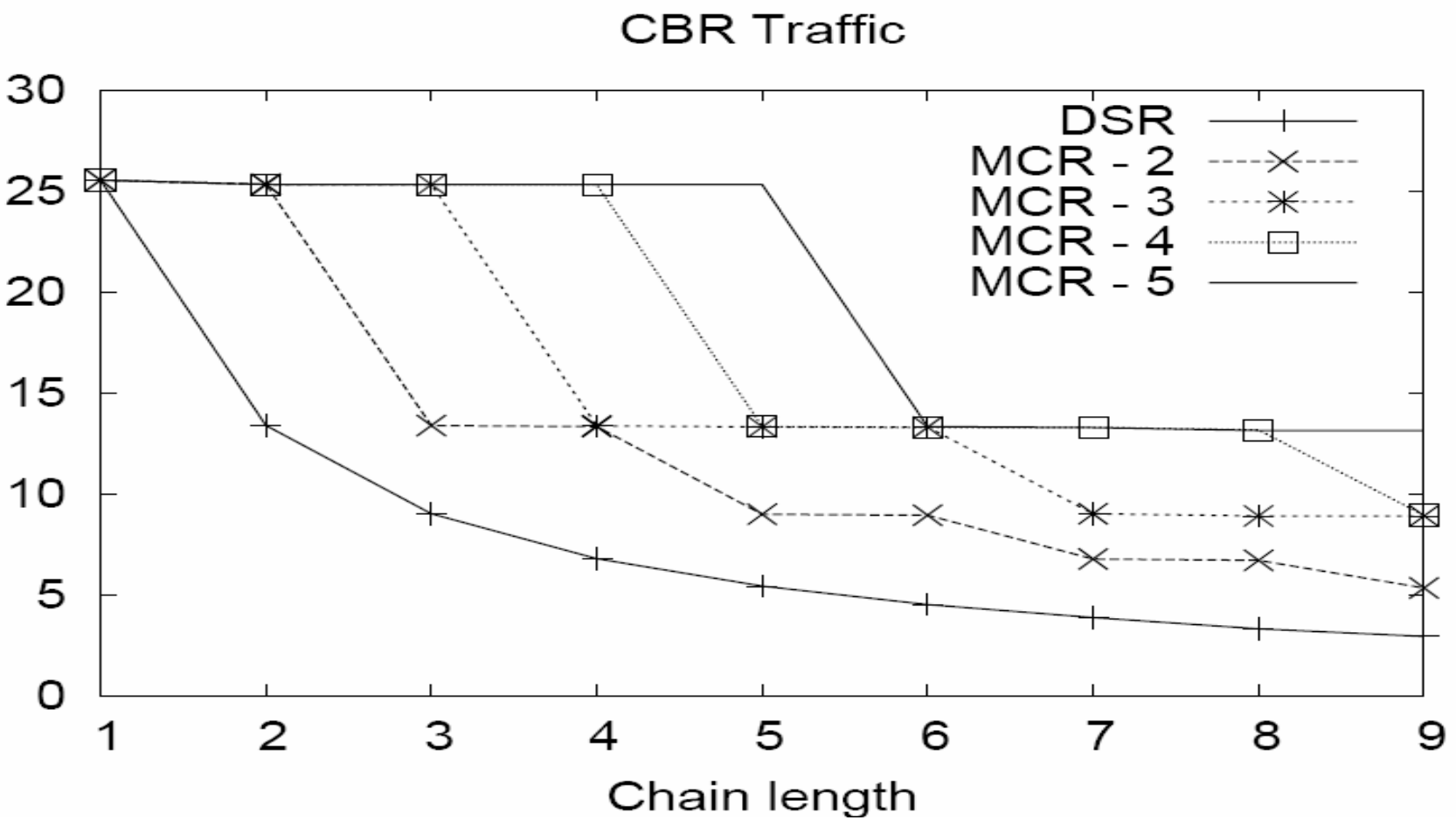
- Routing metric:
  - A weighted linear combination of total hop count, total diversity cost, and total switching cost.
- Route discovery and route maintenance
  - Source-initiated on-demand routing, similar to DSR

Overall Architecture

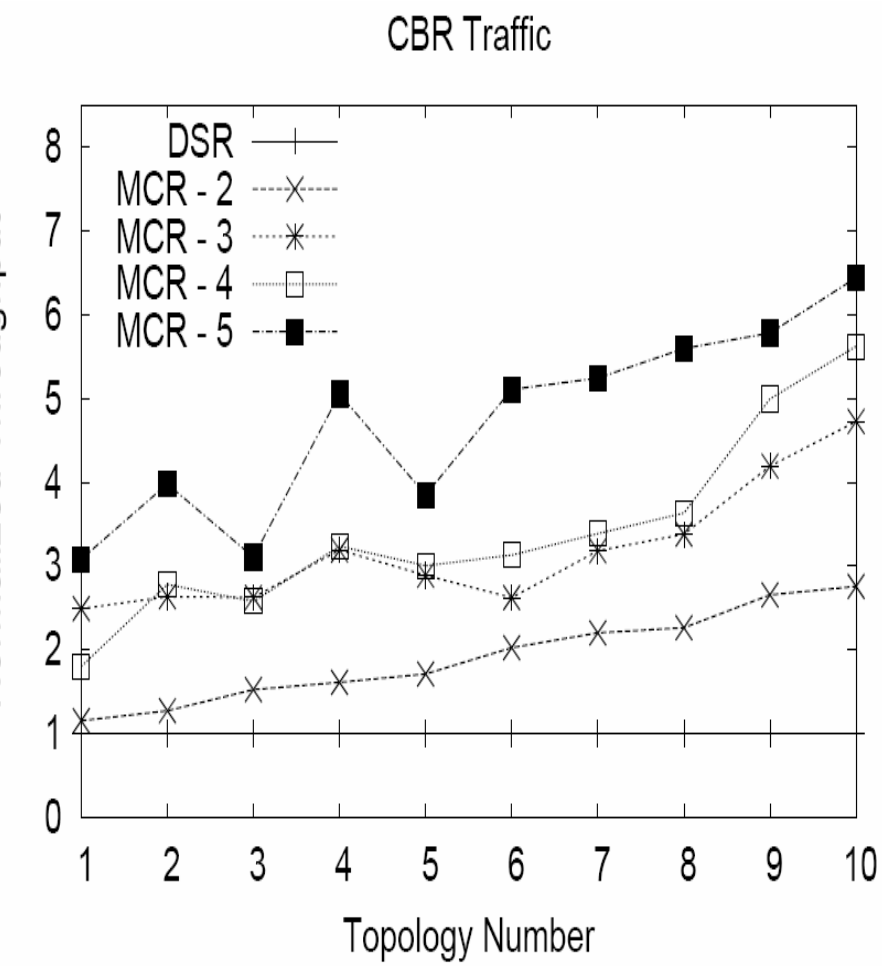
- **Switching protocol** can be implemented at **link layer** and communicate with network interface cards through the appropriate device driver
- **MCR routing protocol** can be implemented as a daemon in the **user space**

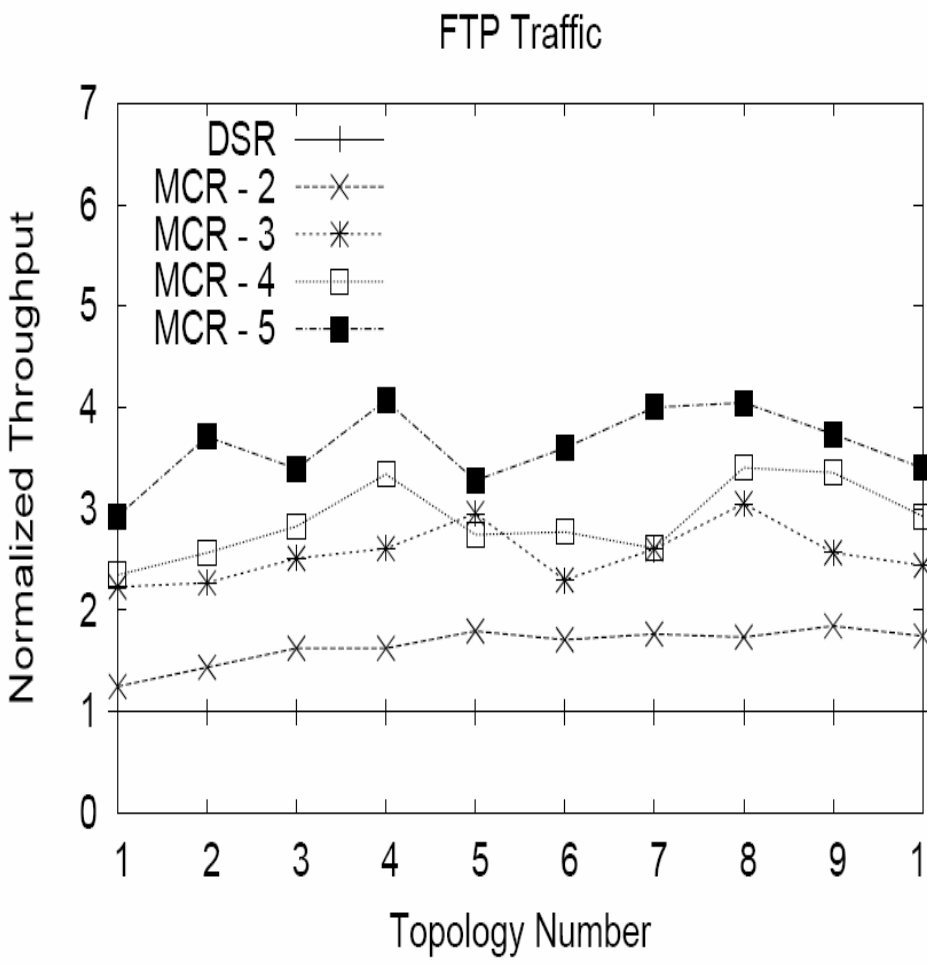


Evaluation

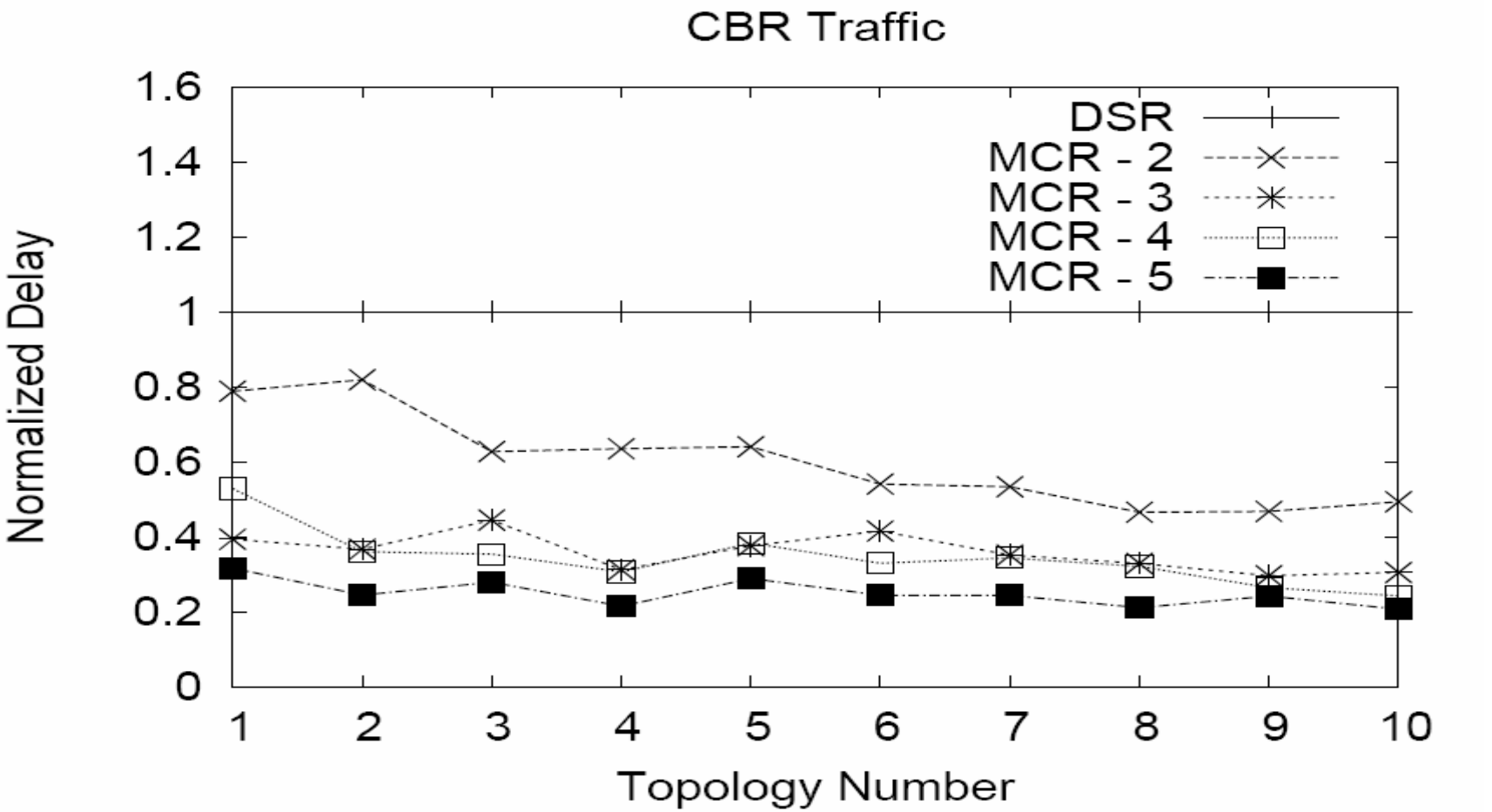

CBR Traffic
30
25
20
15
10
5
0
1
2
3
4
5
6
7
8
9
Chain length
DSR
MCR - 2
MCR - 3
MCR - 4
MCR - 5

Evaluation

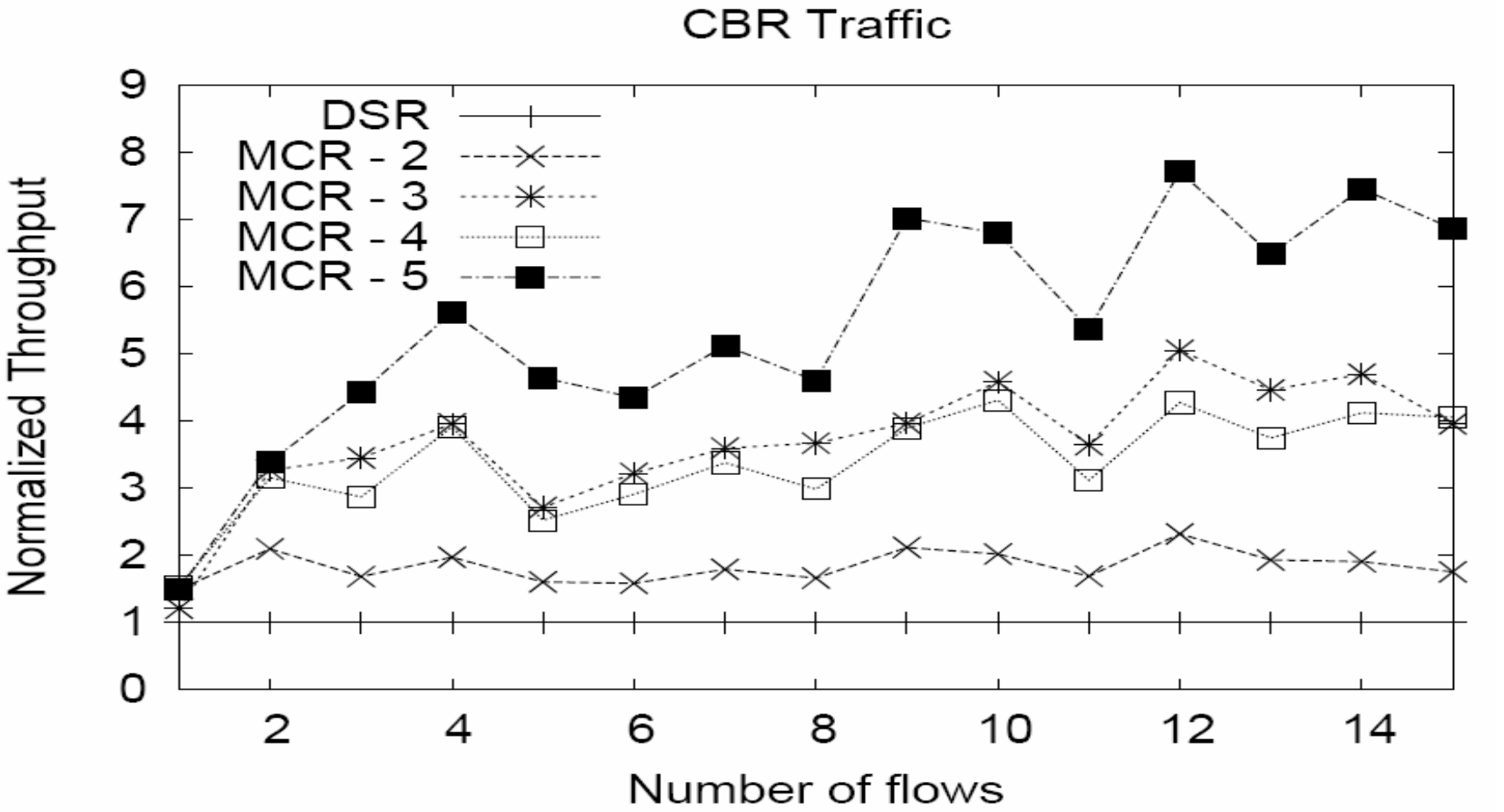

CBR Traffic
DSR
MCR - 2
MCR - 3
MCR - 4
MCR - 5
0
1
2
3
4
5
6
7
8
1
2
3
4
5
6
7
8
9
10
Topology Number


FTP Traffic
Normalized Throughput
DSR
MCR - 2
MCR - 3
MCR - 4
MCR - 5
0
1
2
3
4
5
6
7
1
2
3
4
5
6
7
8
9
Topology Number

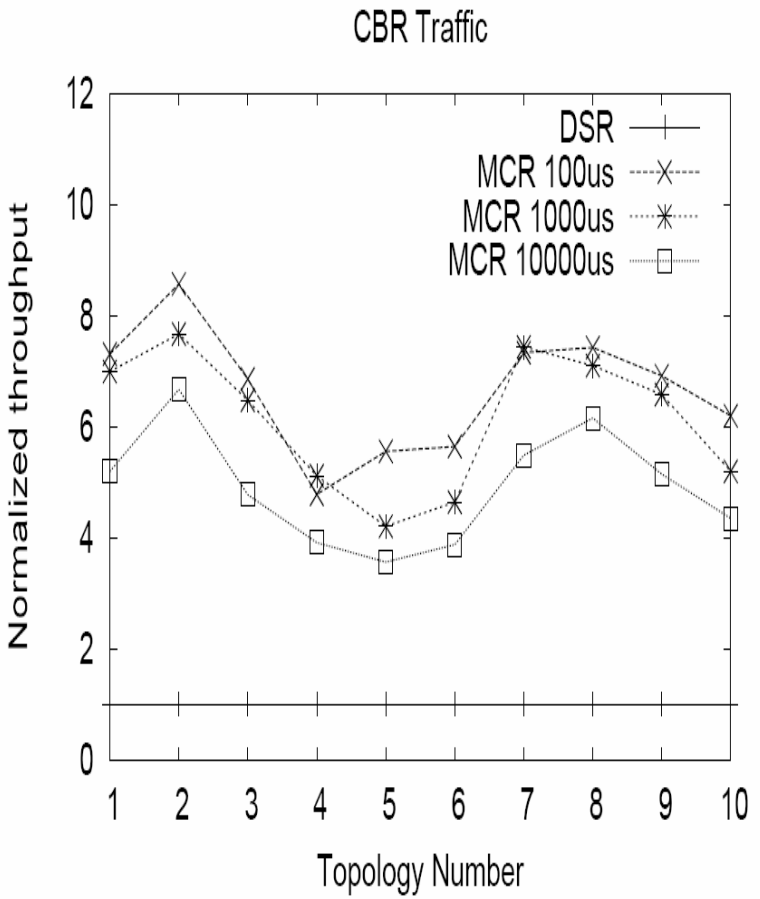
Evaluation

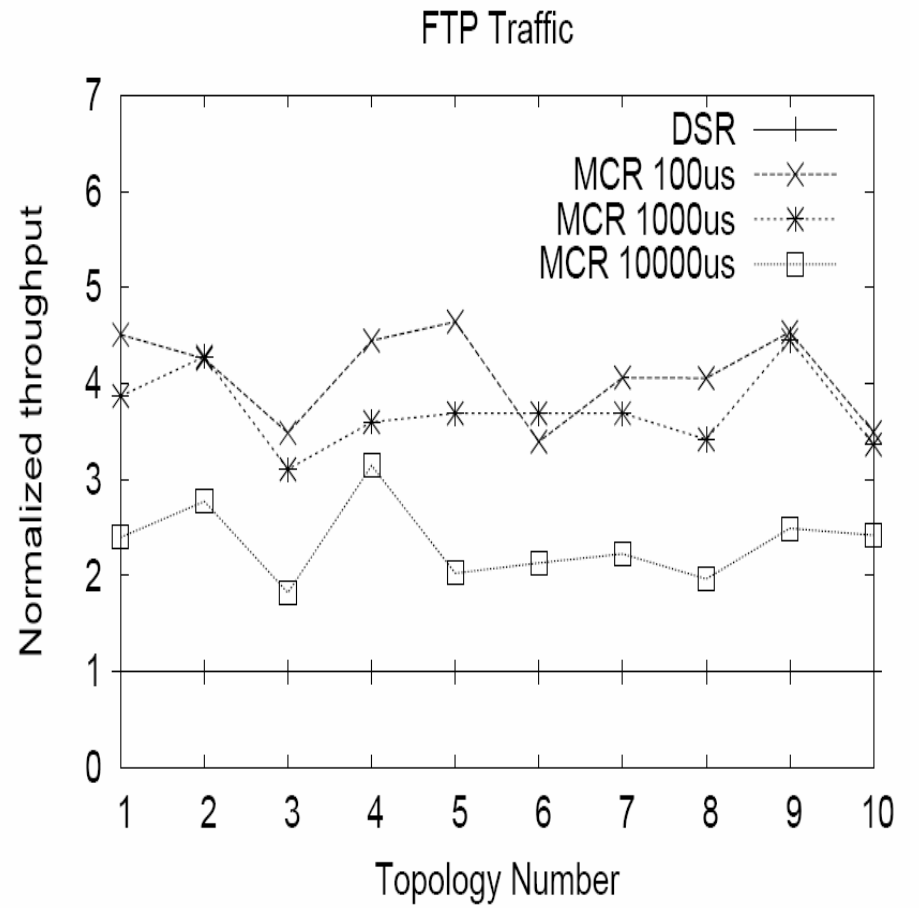

CBR Traffic
Normalized Delay
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1
2
3
4
5
6
7
8
9
10
Topology Number
DSR
MCR - 2
MCR - 3
MCR - 4
MCR - 5

Evaluation


CBR Traffic
DSR
MCR - 2
MCR - 3
MCR - 4
MCR - 5
Normalized Throughput
Number of flows
0
1
2
3
4
5
6
7
8
9
2
4
6
8
10
12
14

Evaluation


CBR Traffic
Normalized throughput
Topology Number
DSR
MCR 100us
MCR 1000us
MCR 10000us
0
2
4
6
8
10
12
1
2
3
4
5
6
7
8
9
10


FTP Traffic
Normalized throughput
Topology Number
DSR
MCR 100us
MCR 1000us
MCR 10000us
0
1
2
3
4
5
6
7
1
2
3
4
5
6
7
8
9
10

Discussion

- Future work
  - The relationship between the network capacity and the number of channel, and a given number of interfaces on each node
  - Dynamically changing the number of fixed interfaces at a node, based on the amount of data being transmitted and received by the node
  - Taking heterogeneous channels in to consideration.

Conclusion

- A multi-interface solution for exploiting multiple channels that can built with commodity IEEE 802.11 hardware
- An interface assignment strategy that simplifies coordination among nodes
- A routing protocol that selects high-throughput routes, which uses routing metrics that account for channel diversity and interface switching cost.