Multi Channel, Multi Radio
• What is multi channel, multi radio
• Why use multi channel, multi radio?
• Design Issues in using multi channel, multi radio.
• Examples of protocols
• MMAC
• HMCP
  – Link Layer Protocol
  – Routing Protocol
• Evaluation of HMCP
What is Multi Channel, Multi Radio?

- Use multiple frequencies to transmit on.
  - 802.11a has 12 non overlapping channels in the 5GHz range.
  - each channel is 20MHz wide
    - 5.200 GHz, 5.180 GHz, 5.220 GHz, 5.240 GHz, 5.260 GHz, 5.280 GHz, 5.300 GHz, 5.320 GHz, 5.745 GHz, 5.765 GHz, 5.785 GHz, 5.805 GHz

- Use multiple antennas to transmit/receive at the same time
  - wireless routers
Why use Multi channel, multi radio?

- Increased Throughput
- Decreased chance of collision/interference
- Hardware cost is low enough to allow multiple radios(interfaces)
Design Issues?

- Distribution of load across channels
  - Divide the traffic across all the available channels
    - decreases chance of collision
    - Increases throughput
Design Issues?

- Channel coordination
  - ensure connectivity
  - prevent virtual network partitions
Design Issues?

- Broadcast support
  - routing protocol information
Examples

- MAC protocols
  - Multichannel CSMA - Nasipuri and Zhuang[2]
- Link Layer protocols
  - MUP - Adya et al.[3]
  - SSCH - Bahl et al.[4]
  - MMAC - So and Vaidya.[5]
  - HMCP - Kyasanur and Vaidya.[7]
- Routing protocols
  - WCETT - Draves et al.[1]
  - MCR(HMCP)[7]
Summary

- Multiple channels and multiple antennas will increase throughput
- Any solution should support:
  - distribution of load across channels
  - maintaining node connectivity
  - broadcast abilities
MMAC

- Link Layer protocol
- only 1 interface
- ATIM window when all nodes are on the same channel
  - negotiate channel to use
- Control Messages:
  - ATIM
  - ATIM-ACK
  - ATIM-RES
Simulation Environment

- 64 Nodes
- 32 Flows
- 3 orthogonal channels each running at 2Mbps
- DCA
  - 1 control channel, n data channels
  - each node has 2 interfaces
Simulation Results

Aggregate Throughput, 32 Flows

Packet Arrival Rate per flow (packets/sec)

Aggregate Throughput (Kbps)

- 802.11
- DCA
- MMAC
Summary of MMAC

Pros:
- Single interface
- Load is distributed across all available channels
- Broadcast supported during ATIM window

Cons:
- Tight node synchronization
Hybrid Multi-channel Protocol (HMCP)

- Used when there are 2 or more interfaces
- Synchronization is not required
- Link Layer Protocol
  - coordinates distribution of load across channels
- Routing Protocol
  - selects channel diverse paths
  - uses a new routing metric MCR
HMCP Link Layer

- at least 2 interfaces
  - divided into “fixed” and switchable interfaces
- different nodes can use different fixed and switched channels.
- broadcast “Hello” message notified neighbors of which channels are fixed
- *NeighborTable* is used to track fixed channels for neighbors
HMCP Link Layer - Setup

- Each node divides its available interfaces into the groups “fixed” and switchable.
- Broadcasts “Hello” messages to notify neighbors of which channel they are on.
- Neighbors will add an entry into their NeighborTable for use when sending messages.
HMCP Link Layer - Sending

- Look up which channel is being used by receiver.
  - Switch to channel if needed.
  - Wait a maximum sized transfer
- Send packet
- Broadcasts are achieved by duplicating the message on all channels
HMCP Link Layer - “fixed” doesn't mean fixed

- Fixed channels may be “clogged” if too many nodes are using it.
  - “fixed” = longer term
- change channel if there are too many (probabilistic)
- broadcast “Hello” message
“Clogged” is determined by 2 hops

- ChannelUsageList
  - created from neighbors NeighborTables
  - transmitted in Hello message
HMCP Routing (MCR)

- Multi-channel Routing Metric
  - based on WCETT
- Incorporates switching cost
- Used in source initiated on demand protocols
Motivation

- Even if Link Layer ensures diversity in neighborhoods, routing protocol may not take advantage of links on different routes.
MCR

- weights for each link
  - based on the expected transmission time (ETT)
  - based on an Expected transmission attempts (ETX), the average packet size (S) and the data rate (B)
    - ETX is based on the probability of a loss

\[ X_j = \sum_{\forall i, \text{such that } c_i = j} ETT_i \]

\[ \text{MCR} = (1 - \beta) \sum_{i=1}^{n} (ETT_i + SC(c_i)) + \beta \max_{1 \leq j \leq c} X_j \]
Routing Protocol

- Similar to DSR
- Broadcast RREQ
  - sequence number
  - ETT, switching cost, channels for all previous hops
  - Forwarded by intermediate nodes if:
    - new sequence number
    - lower cost if discovered
- RREP from destination
- RERR from DSR
Simulation Environment

- Simulated for 100 seconds
- Interface switching delay of 1ms
- Compared to one channel DSR

Single Flow performance:
- Stationary nodes with communication only between adjacent nodes
- 40m between adjacent nodes

Network performance:
- Random topologies of 50 nodes
- No mobility
- 500m x 500m area
Evaluation - Multiple channels improves Throughput

![Graph showing throughput vs chain length for different channel configurations.]

- One Channel
- MCR - 2
- MCR - 5
- MCR - 12
Evaluation - MCR is resistant to high congestion
Evaluation - More channels = More overhead

![Graph showing the relationship between the number of flows and total overhead per node for different MCR settings (2, 5, and 12). The graph illustrates that as the number of flows increases, the total overhead per node also increases.](image)
Evaluation - Shortest Path can be better for many hops
Summary of HMCP/MCR

Pros:
- Easily scalable to more channels
- Supports broadcast
- Distributes load across all available channels
- Maintains connectivity

Cons:
- Increased overhead for broadcasts
Lecture Summary

- Using multiple channels with multiple interfaces can improve throughput
- HMCP provides support for broadcasts, maintains connectivity in the network, and utilizes all available channels
- MCR selects channel diverse paths
Resources


4) P. Bahl, R. Chandra, and J. Dunagan, “SSCH: Slotted Seeded Channel Hopping for Capacity Improvement in IEEE 802.11 Ad-Hoc Wireless Networks”


6) S.-L. Wu, C.-Y. Lin, Y.-C. Tseng, and J.-P. Sheu, “A New Multi-Channel MAC Protocol with On-Demand Channel Assignment for Multi-Hop Mobile Ad Hoc Networks”

7) P. Kyasanur and N. H. Vaidya, “Routing and Link-layer Protocols for Multi-Channel Multi-Interface Ad hoc Wireless Networks”


9) Y. Yang, J. Wang, R. Kravets, “Designing Routing Metrics for Mesh Networks”