Load Balancing Routing in Multi-Channel Hybrid Wireless Networks with Single Network Interface

QShine'05

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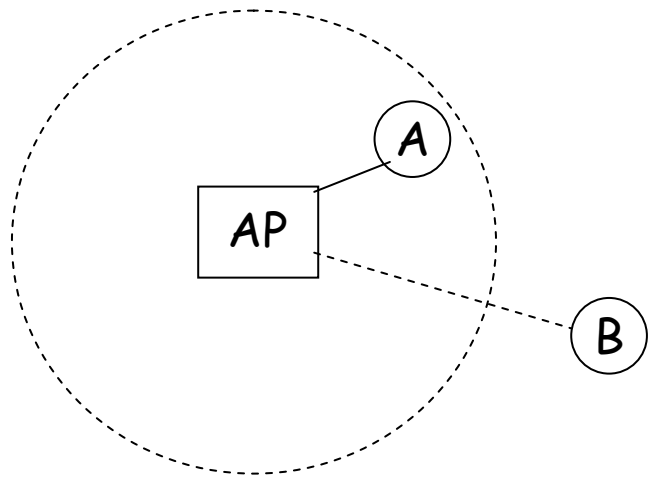
Outline

- Introduction
- Multi-Channel Hybrid Wireless Networks
- Proposed Routing Protocol
- Performance Evaluation
- Conclusions

Introduction

- Wireless networks are mostly single-hop infrastructure networks, today.
- To access the Internet, a mobile host must be directly within range of an access point.



Introduction (cont.)

- There are several limitations to the single-hop infrastructure network architecture:
  - It cannot handle unbalanced traffic load efficiently.
  - For a large area, it can be expensive to deploy a large number of wireline-connected APs to cover the entire region.
- Recently, researchers have proposed ideas to overcome these two limitations using multi-hop networking.

Multi-Channel Hybrid Wireless Networks with Single NIC

- A hybrid wireless network is an extension to an infrastructure network, where a mobile host may connect to an access point using multi-hop wireless routes, via other mobile hosts.
- The benefit of designing protocols that support nodes with a single network interface is that the protocol can be used for small, low-cost devices (e.g. cell phones, PDAs), where equipping multiple interfaces can be costly.

Example1

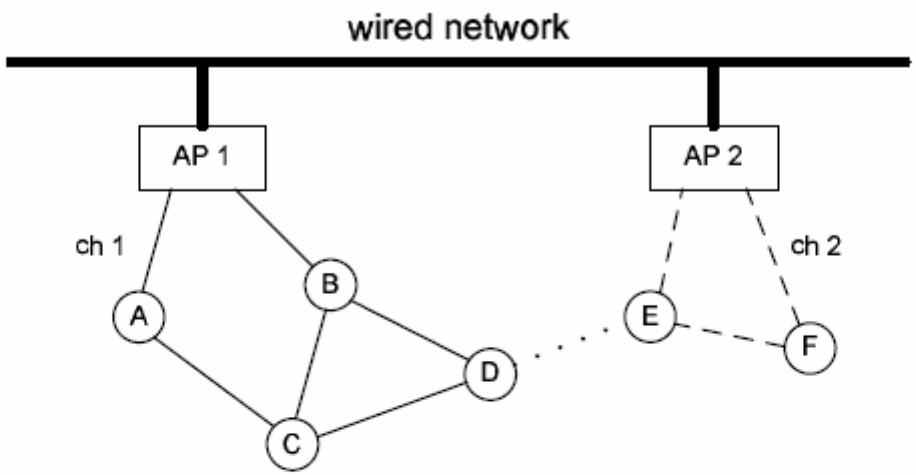
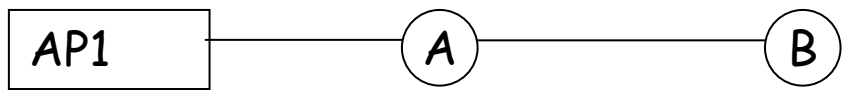


Figure 1. An example hybrid wireless network. Solid lines are links on channel 1, dashed lines are links on channel 2, and the dotted line indicates a potential link, if D and E were on the same channel.

Example2

Using single-hop wireless networks

Using multi-hop wireless networks



Differences in Multi-Hop Wireless Networks

- In the multi-hop architecture, a node may potentially find multiple routes to different access points, possibly operating on different channels.
- Thus, each node should select the "best" route where it can achieve the best service quality.

Differences in Multi-Hop Wireless Networks (cont.)

- Once the primary route has been established, each node collects load information for its own route tree and other route trees. Based on this information, the node switches to the route tree with minimum load so that it can obtain the highest quality of service possible.

Example

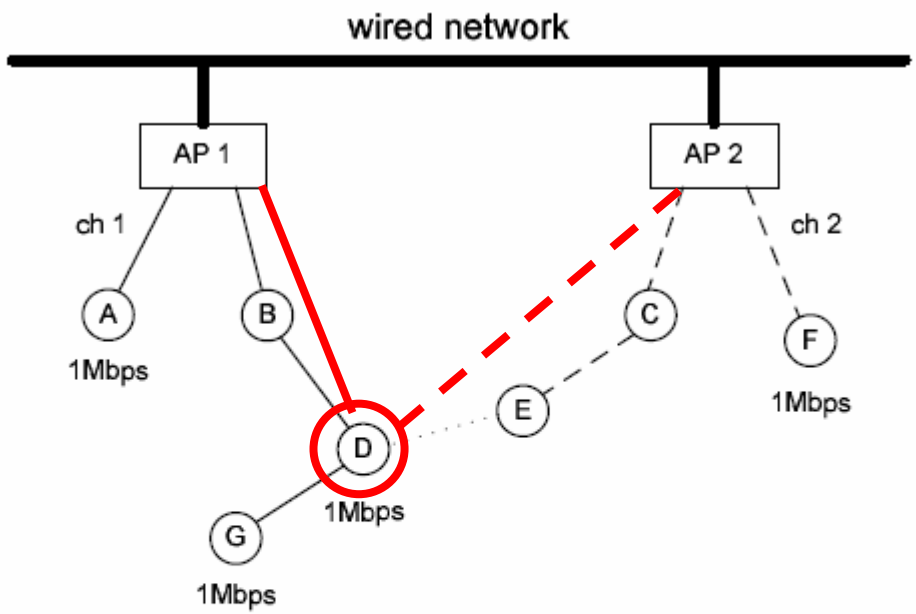


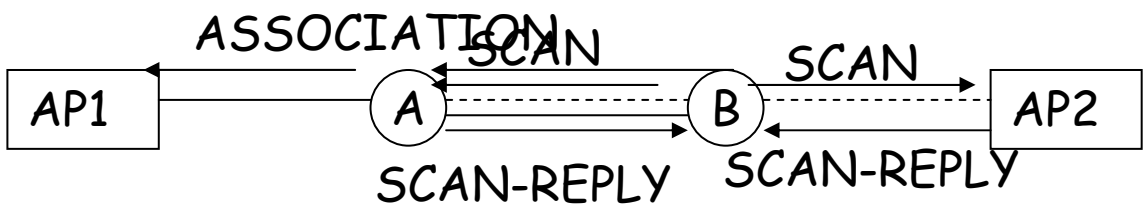
Figure 2. An example network scenario. This example indicates that subtree load must be considered when selecting the best route.

Proposed Routing Protocol

- The routing protocol must answer the following questions:
  - How are the routes established?
  - How are the routes maintained and updated?

Route Establishment

- When a node is turned on, it must first discover a route to an access point. For this purpose, the node performs an "*active scanning*" on all channels.



Route Management and Updates

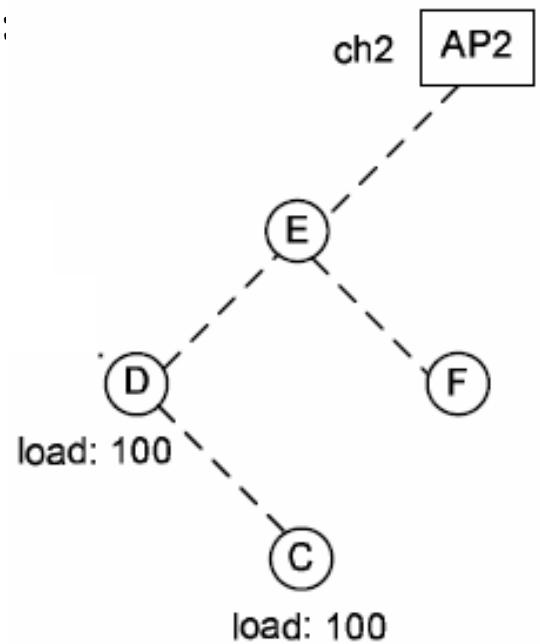
- Managing and updating routes is the most important part of our proposed protocol. We present the process of route update:
  - Step1: Measuring load
  - Step2: Distributing and collecting load information
  - Step3: Switching route trees for load balancing

Step1: Measuring load

- **"AP-measured weighted load" is used as measuring load in this paper.**

$$L_1 = \sum_i (h_i \times l_i)$$

Example:



Tree Load = 100*2 + 100*3 = 500

Step2: Distributing and collecting load information

- Periodically, each AP transmits a HELLO message, which includes the load information, on all channel. When the nodes receive the HELLO message, they update their route table according to the information given in the message.
- Only if the sender of the HELLO message is the *next hop* node in its primary route, the node forwards the HELLO message.

Hello Message

- The HELLO message is used for two purposes: update load information and discover backup routes to other APs on other channels.
- It includes the following information:
  - The address of AP that the node is currently associated with
  - Number of hops to the AP
  - Load of the node's route tree

Step3: Switching route trees for load balancing

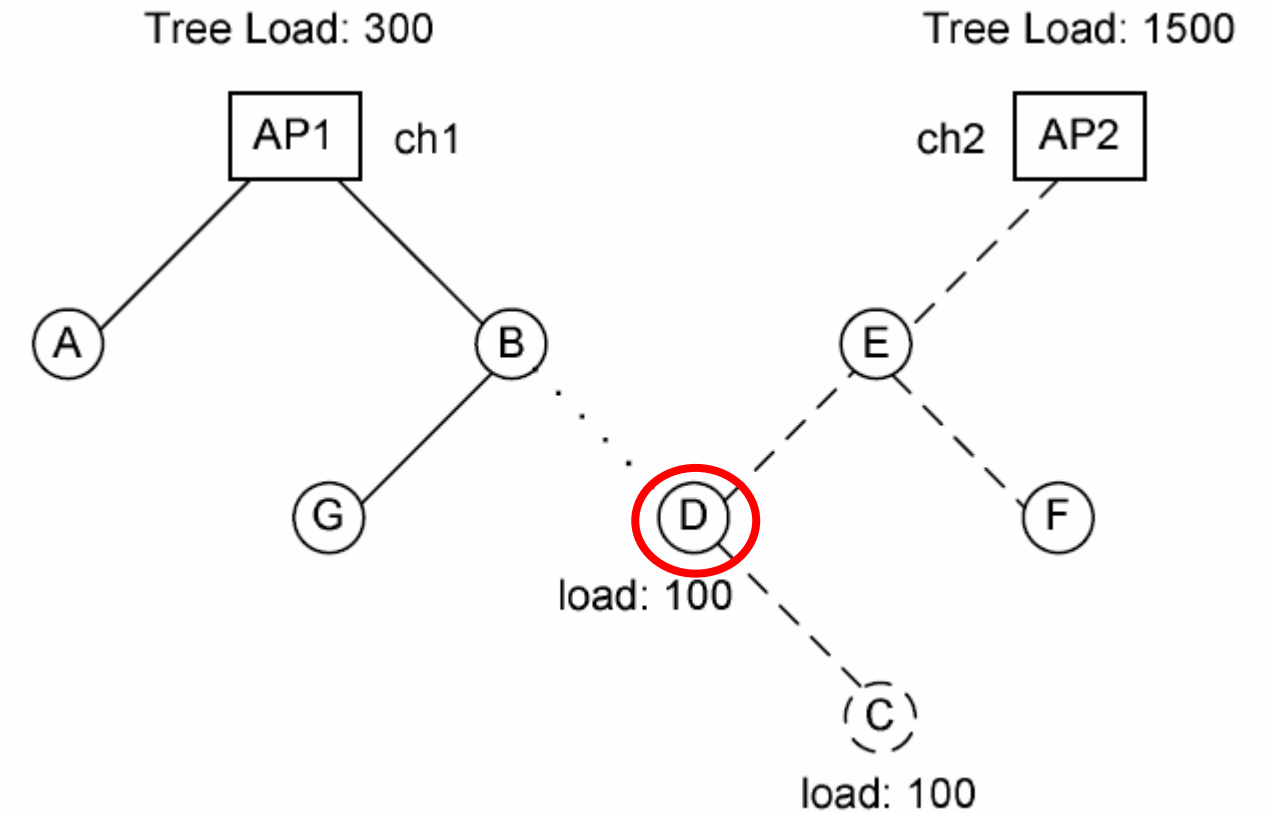
- Once the necessary load information is obtained, nodes can decide whether to switch to other route trees.
- When making the decision, the node compares the current load of its route tree and the load of the other tree *when the node joins the tree*.

$$L_{AP1'} = L_{AP1} + \sum_{i} (h_{iAP1} \times l_i)$$

Step3: Switching route trees for load balancing (cont.)

- If node has children in the route tree, it cannot just switch channels to join other trees, because the child nodes will lose connections with the AP.
- Instead, if node decides to switch channels, it should tell all its children to switch channels as well.

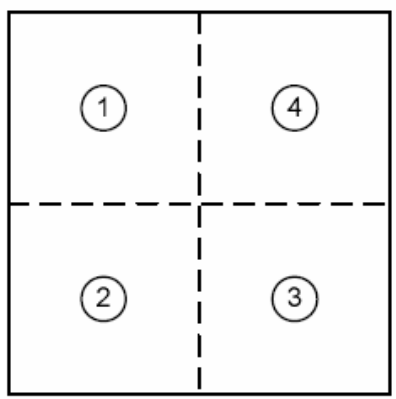
Example



$$L_{AP1'} = 300 + (100 \times 2 + 100 \times 3) = 800$$

Simulation Setup

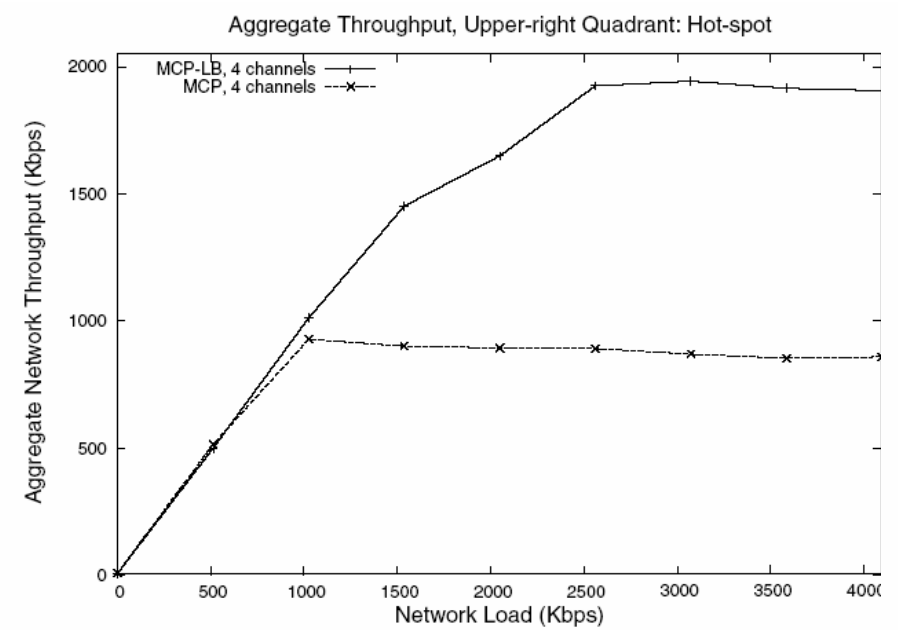
- A simulation area of 1000m × 1000m is divided into 4 quadrants, and APs are placed at the center of each quadrant.
- All AP are assigned different channels.
- 16 nodes were randomly placed in each quadrant, making a total of 64 nodes.



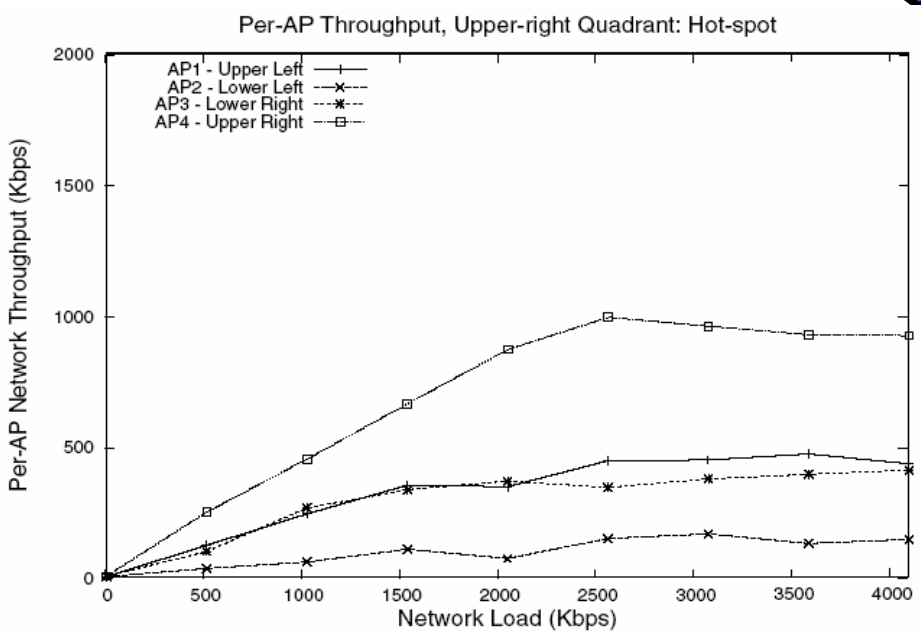
Simulation Setup (cont.)

- To create an unbalanced traffic pattern, the 16 nodes in the northeast quadrant were selected as destinations that receive traffic from the AP.
- Under this scenario, we have compared two protocols. The first one which we call “MCP” assigns channels randomly and selects routes based on number of hops, without any consideration of traffic load. The second one is “MCP-LB”, which is the proposed protocol.

Aggregate and Per-AP Throughput for the Scenario with a Hot-Spot



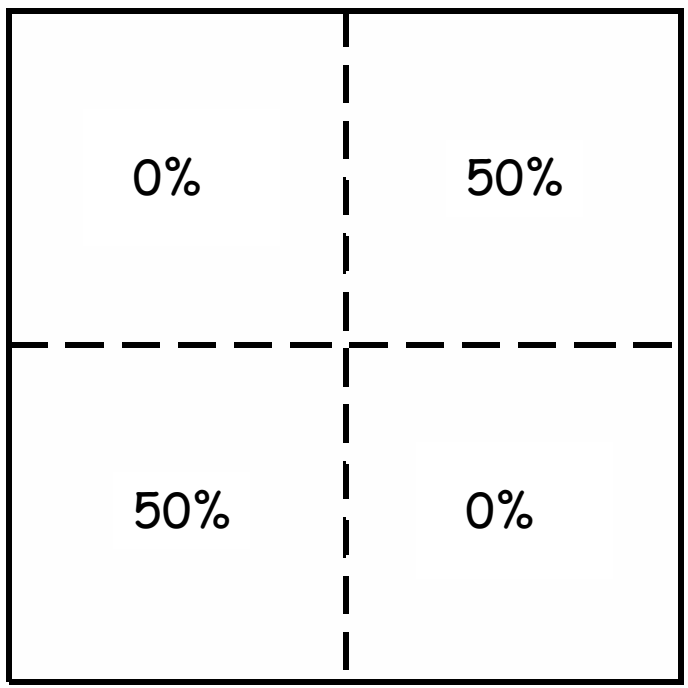
(a) Aggregate throughput



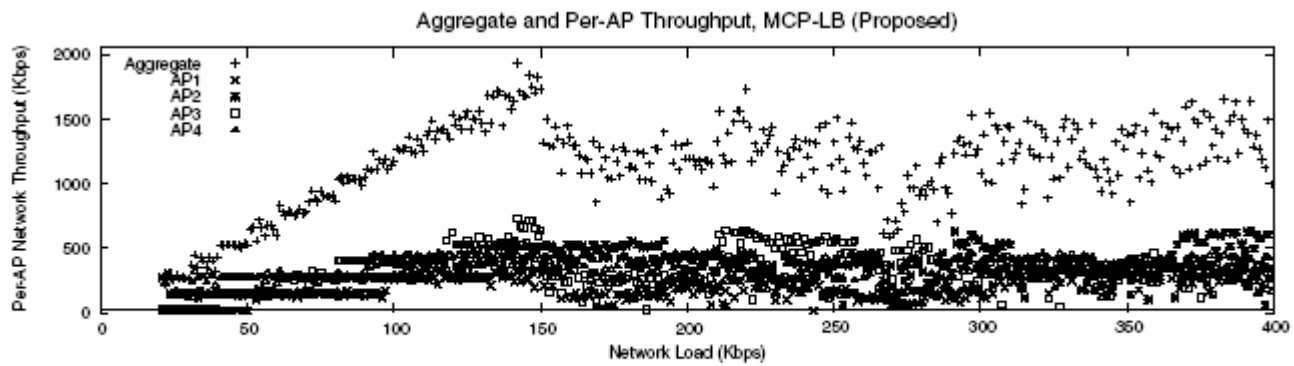
(b) Per-AP throughput

Simulation2

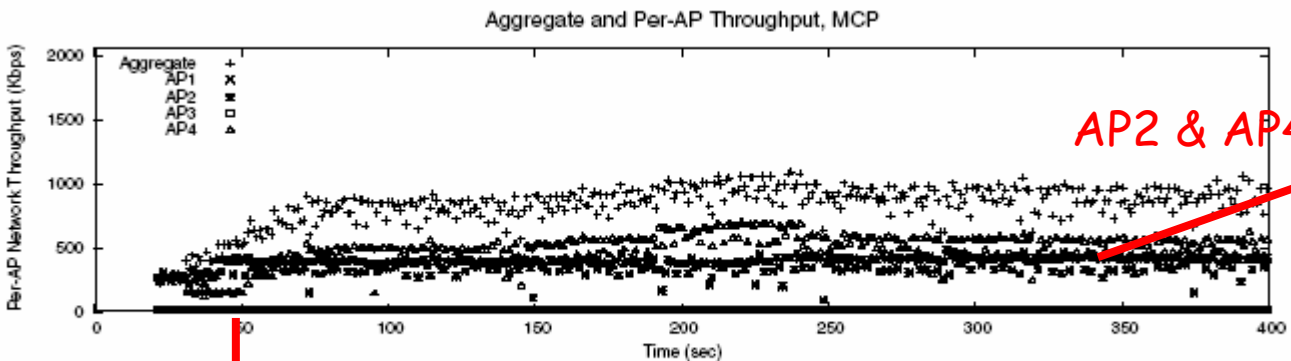
- The destination nodes were only selected from upper-right and lower-left quadrant.



Aggregate and Per-AP Throughput



(a) MCP-LB (Proposed), 4 channels



(b) MCP, 4 channels

AP2 & AP4 Throughput

AP1 & AP3 Throughput

Conclusions

- In multi-hop wireless networks, each node should select the “best” route where it can achieve the best service quality.
- The simulation results show that the proposed protocol can successfully reduce congestion in hot-spots and avoid wasting channel bandwidth due to unbalanced traffic load.

References

- J. So and N. H. Vaidya. Routing and channel assignment in multi-channel multi-hop wireless networks with single-nic devices. Technical report, UIUC, December 2004.
- J. SO and N. H. Vaidya. Load Balancing Routing in Multi-Channel Hybrid Wireless Networks with Single Network Interface.QShine'05.