SSCH: Slotted Seeded Channel Hopping for Capacity Improvement in IEEE 802.11 Wireless Networks

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Introduction

- Try to increases the capacity of an IEEE 802.11 network by utilizing frequency diversity
- Proposed method: Slotted Seeded Channel Hopping (SSCH)

Introduction

- New ideas
  - Optimistic synchronization:
    - Allow control traffic to be distributed across all channels
  - Partial Synchronization:
    - Allow the load for a single multi-hop flow to be distributed across multiple channels

Introduction

- Constraints:
  - SSCH should require only a single radio per node
  - SSCH use an unmodified IEEE 802.11 protocol (including RTS/CTS) when not switching channels
  - SSCH should not cause a logical partition
- Main Method:
  - Scheduling
    - Packet scheduling, channel scheduling
  - Addition modulo a prime numbers

SSCH

- SSCH defines a slot to be the time spent on a single channel
- The channel schedule is the list of channels that the node plans to switch to in subsequent slots and the time at which it plans to switch to in subsequent slots, and the time at which it plans to make each switch
- SSCH switches each radio across multiple channels so that multiple flows within interfering range of each other can simultaneously occur on orthogonal channels

Packet Scheduling

- Maintain packets in per-neighbor FIFO queues
- Packet transmissions are attempted in a round-robin manner among all flows
- Handles the broadcast problem through repeated link-layer retransmission of broadcast packets en-queued by higher layer

Channel Scheduling(1/7)

- We represent the channel schedule as a current channel and a rule for updating the channel.

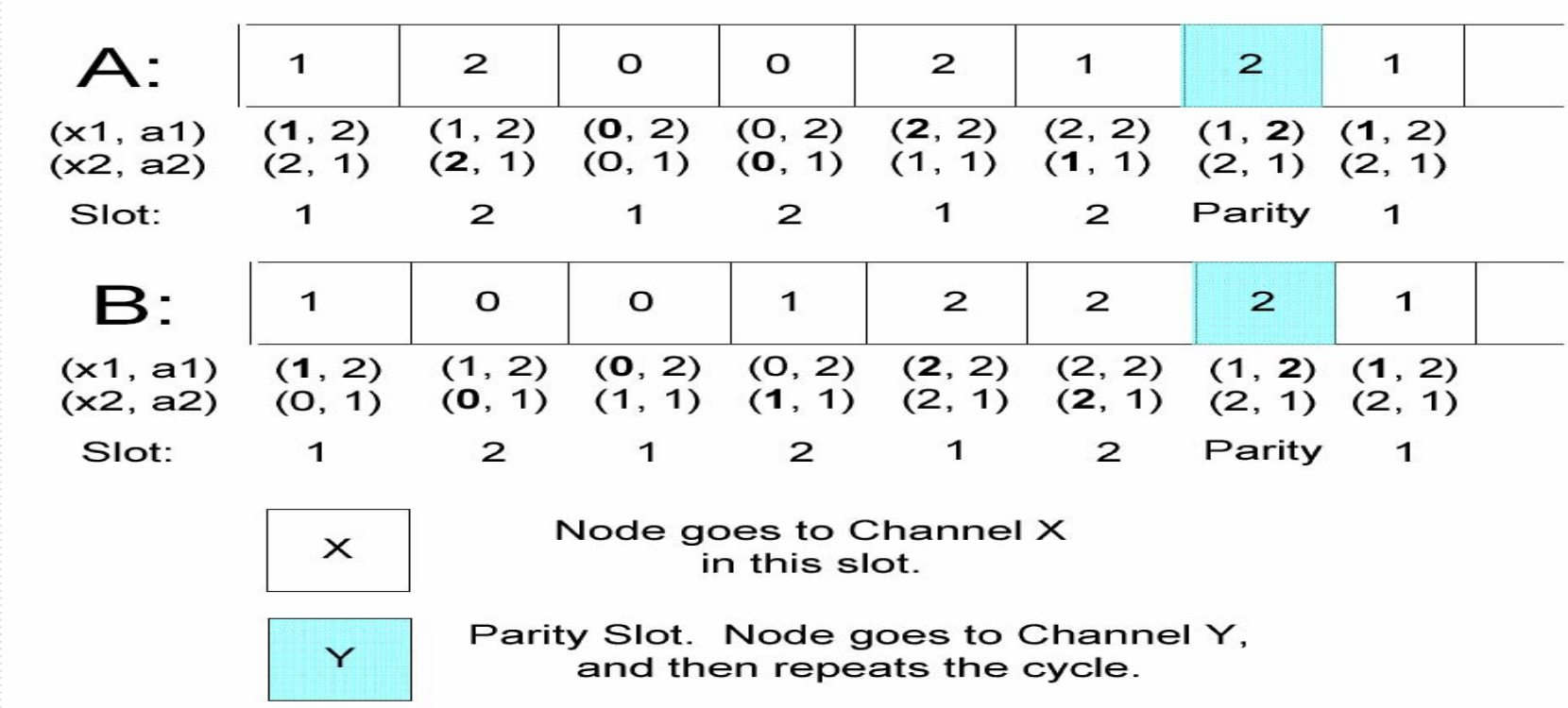
  (channel, seed), and our experimental results show that 4 pairs suffice to give good performance
- The pair of (channel, seed) is randomly chosen at the beginning.
- Nodes learn each other's schedules by periodically broadcasting their seeds and the offset within this cycle through the channel schedule
- (channel, seed)= (x_i, a_i)

Channel Scheduling(2/7)

- Each node iterates through all of the channels in the current schedule, switching to the channel designated in the schedule in each new slot. The node then increments each of the channel in its schedule using the seed $x_i \leftarrow (x_i + a_i) \bmod 13$ and repeat the process.
- After the node has iterated through every channel on each of its 4 slot, it switches to a parity slot whose channel assignment is given by $x_{parity} = a_1$

Channel Scheduling(3/7)

- 2 slots and 3 channels



Channel Scheduling(4/7)

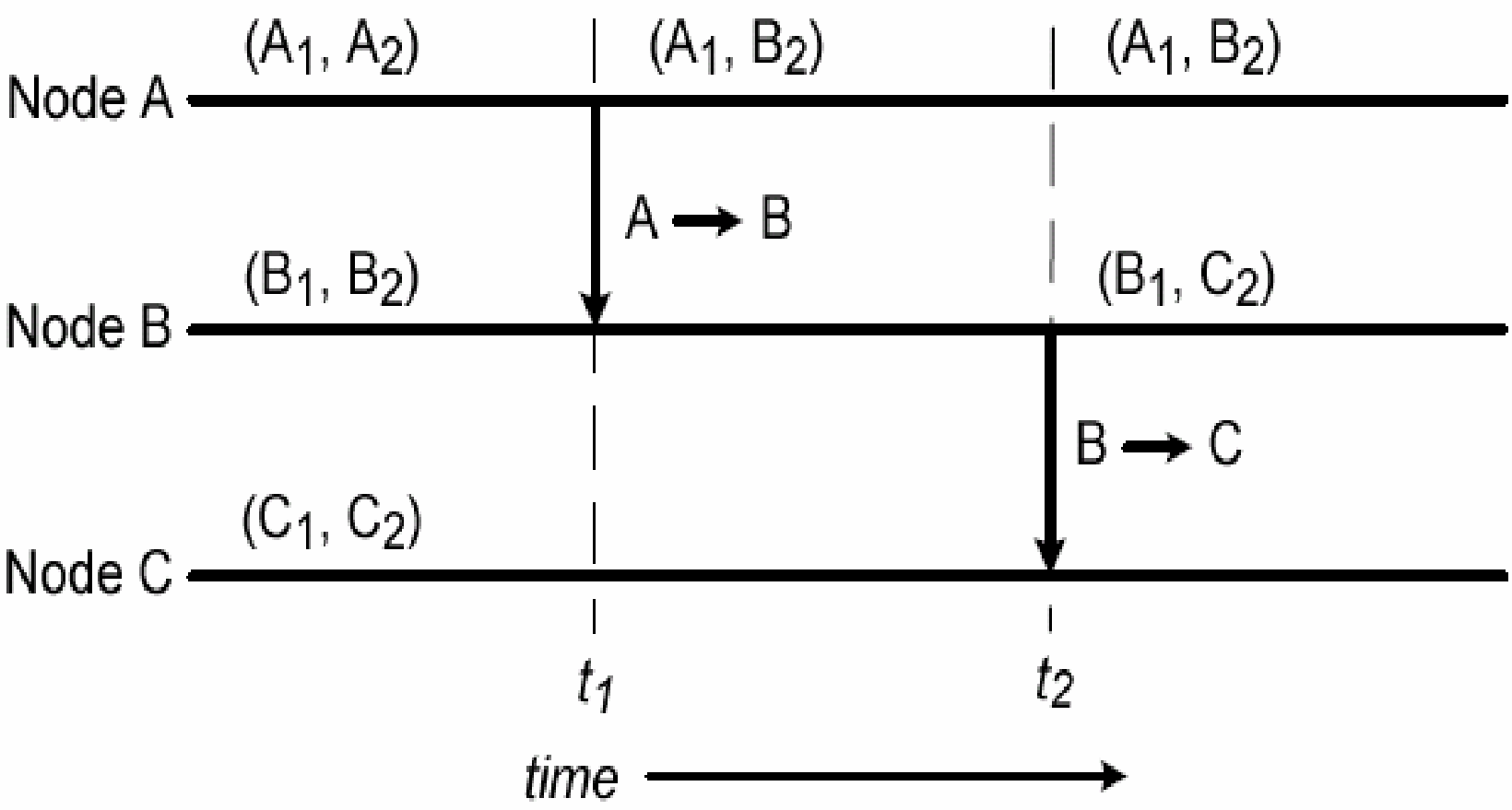
- How does a given node change its own schedule?
  1. Each node attempts to maintain its slots start and stop at roughly the same time as other nodes, and that
  2. It's channel schedule overlaps with nodes for which it has packets to send.

Channel Scheduling(5/7)

- Methods

1. Apply the method described in [15]
2. Change part of it's own schedule to match that of the other nodes
    1. Examine it's packet queue, and select the (channel, seed) pairs that lead to the best opportunity to send the largest number of packets

Channel Scheduling(6/7)



Channel Scheduling(7/7)

1. Consider the interest (receiving or sending) of the node.
2. Avoiding the congesting channels.
   - De-synchronous
3. Addition constraints:
   - Pace of change in schedule information
   - The (Channel, seed) pair for the first slot is only allowed to be updated during the parity slot

System Evaluation

- Measure the overhead of SSCH in several scenarios
- Overhead of Switching and synchronizing

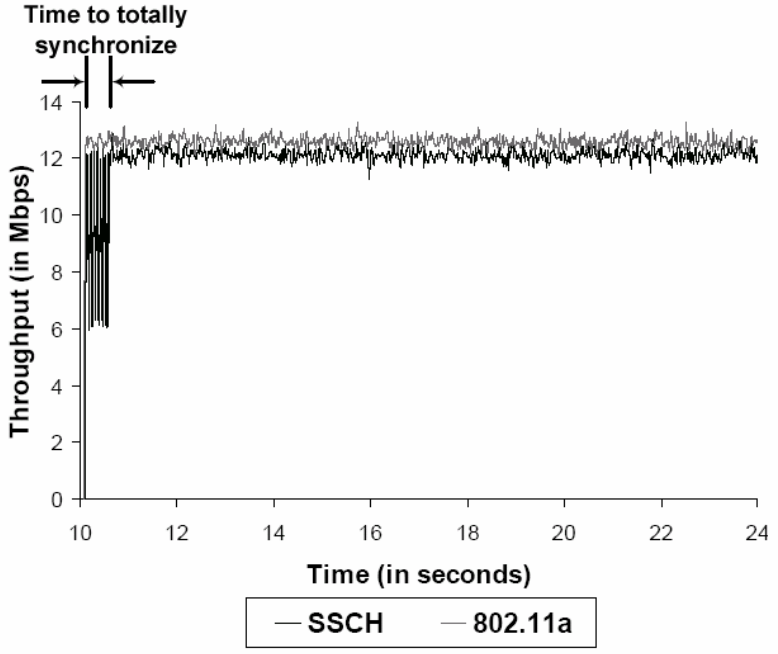


Figure 4: Switching and Synchronizing Overhead: Node 1 starts a maximum rate UDP flow to Node 2. We show the throughput for both SSCH and IEEE 802.11a.

System Evaluation

- Overhead of ad absent node

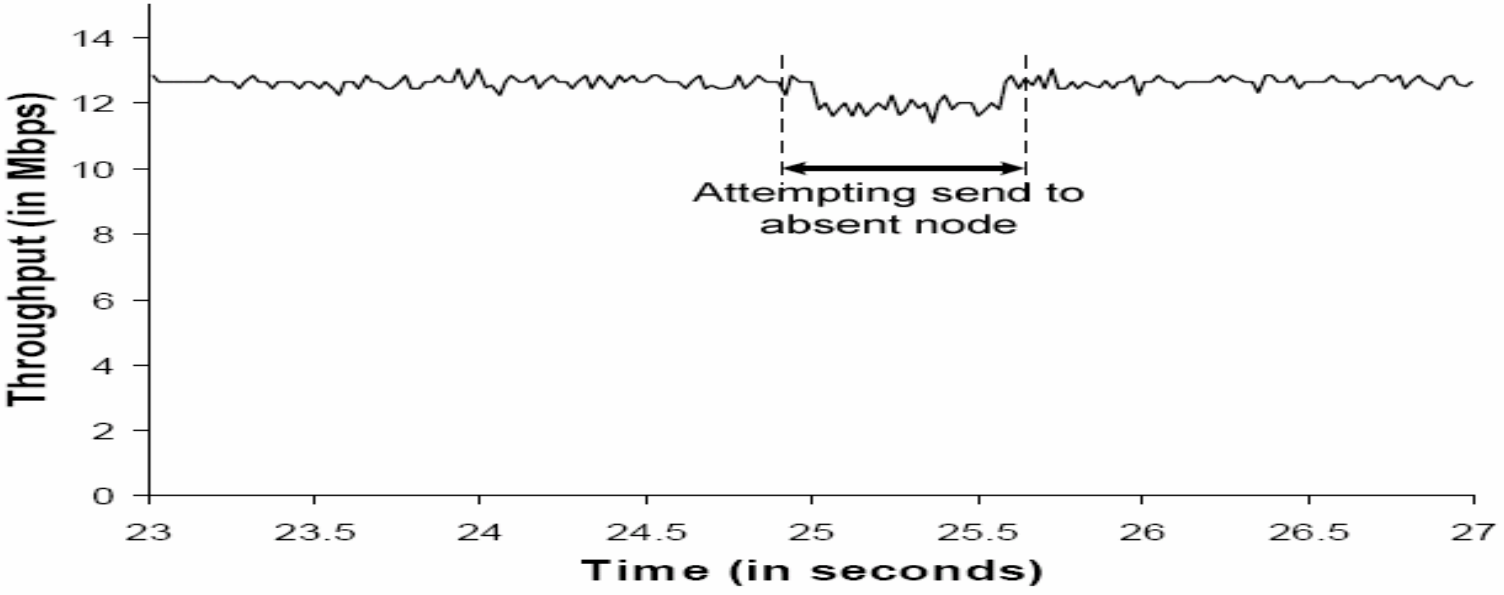


Figure 5: Overhead of an Absent Node: Node 1 is sending a maximum rate UDP flow to Node 2. Node 1 then attempts to send a packet to a non-existent node.

System Evaluation

- Overhead of a Parallel Session

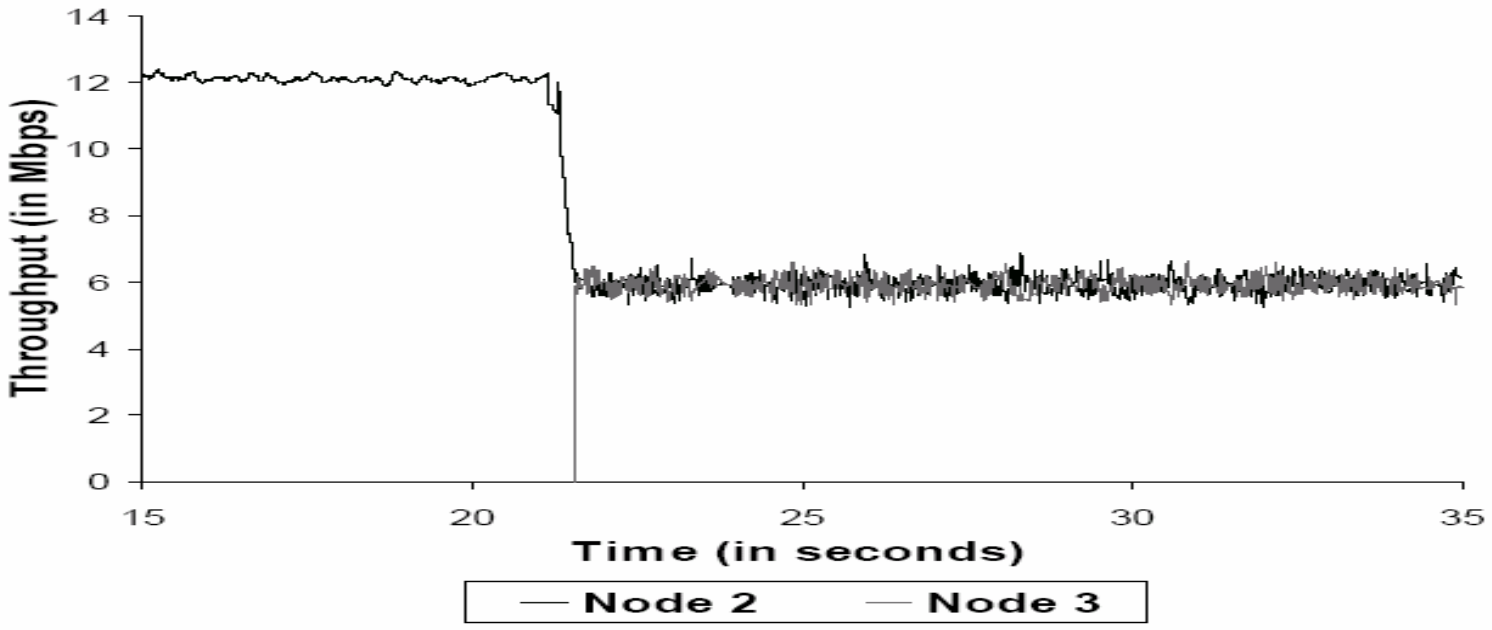


Figure 6: Overhead of a Parallel Session: Node 1 is sending a maximum rate UDP flow to Node 2. Node 1 then starts a second flow to Node 3.

System Evaluation

- Overhead of Mobility

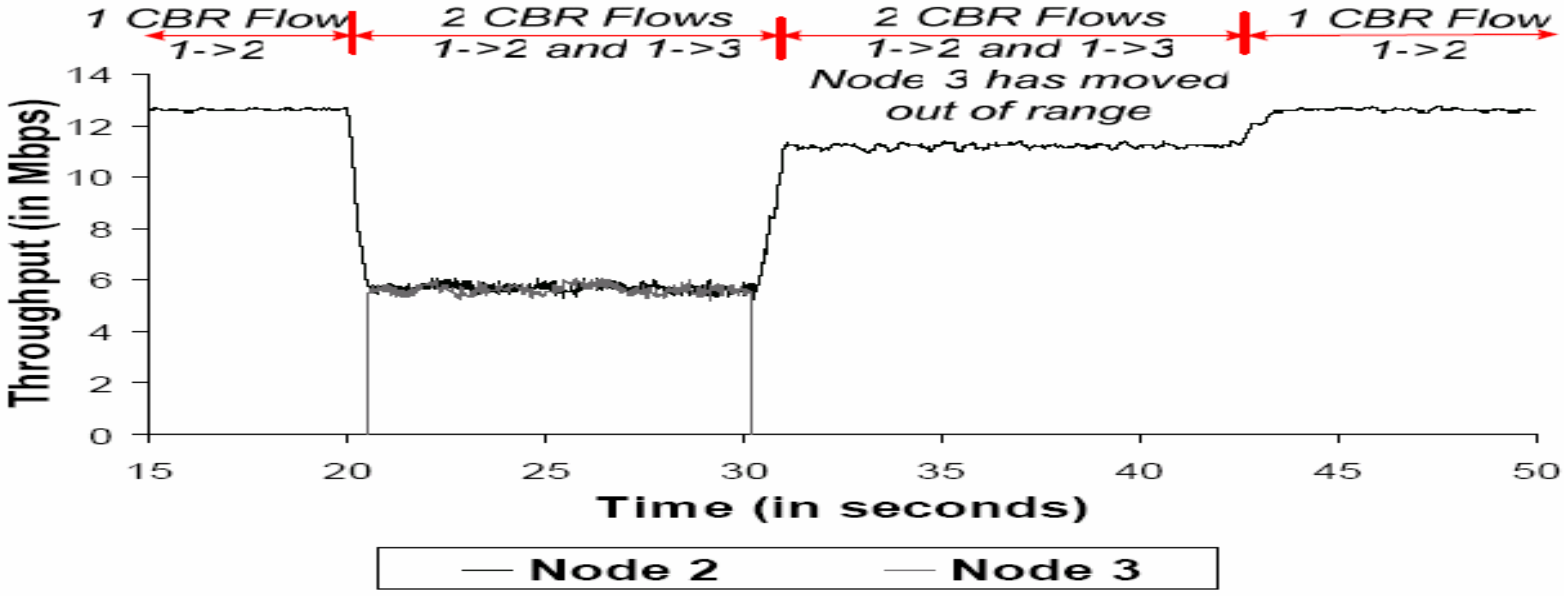


Figure 7: Overhead of Mobility: Node 1 is sending a maximum rate UDP flow to Node 2. Node 1 starts another maximum rate UDP flow to Node 3. Node 3 moves out of range at 30 seconds, while Node 1 continues to attempt to send until 43 seconds.

System Evaluation

- Overhead of Clock Drift

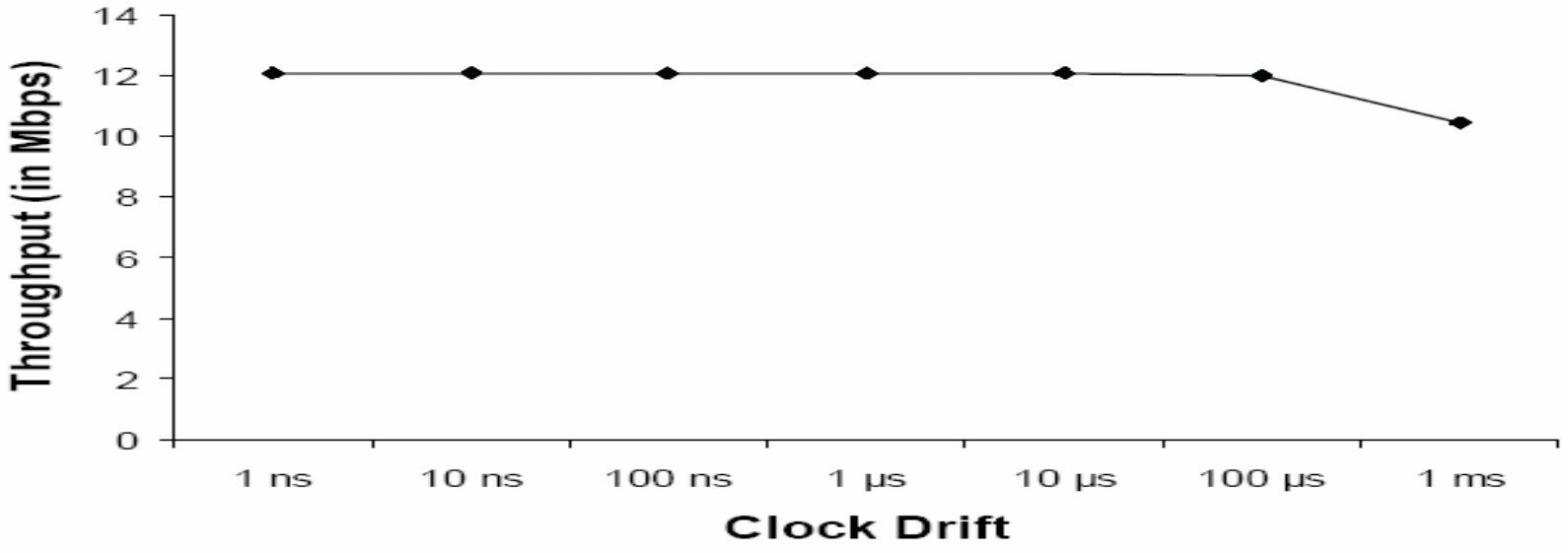


Figure 8: Overhead of Clock Skew: Throughput between two nodes using SSCH as a function of clock skew.

System Evaluation

- Single-hop case
- Disjoint Flows

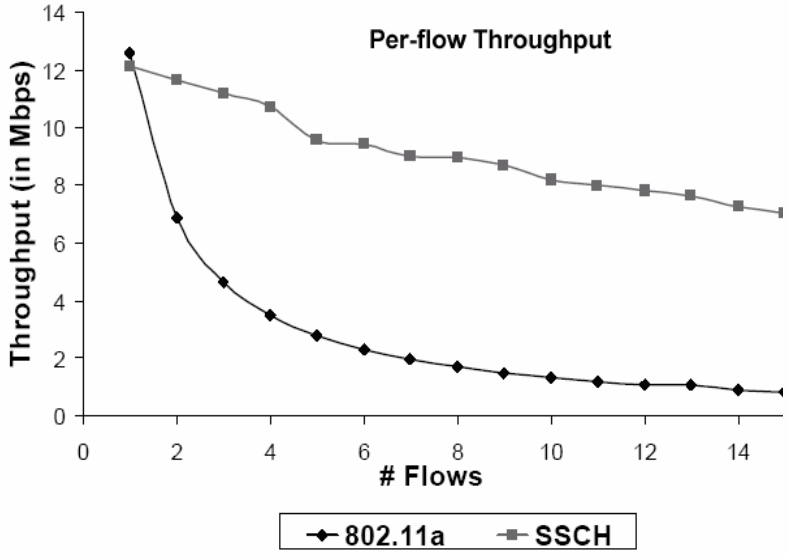


Figure 9: Disjoint Flows: The per-flow throughp on increasing the number of flows.

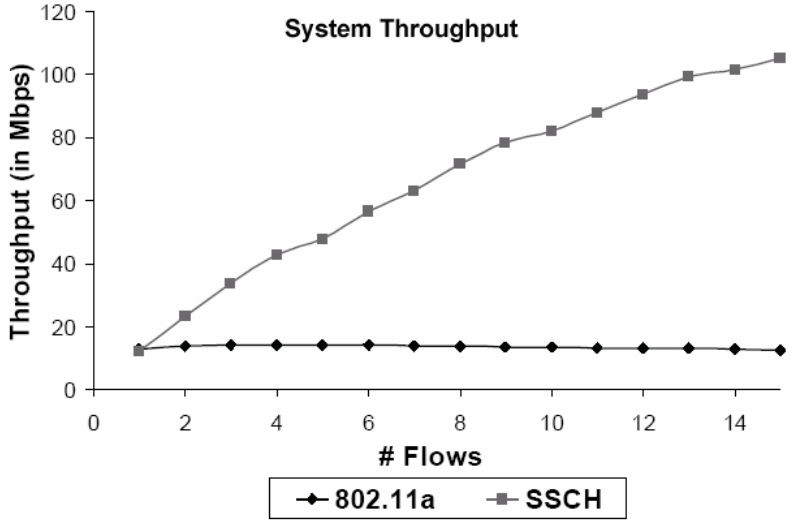


Figure 10: Disjoint Flows: The system throughput on increasing the number of flows.

System Evaluation

- Non-Disjoint Flows

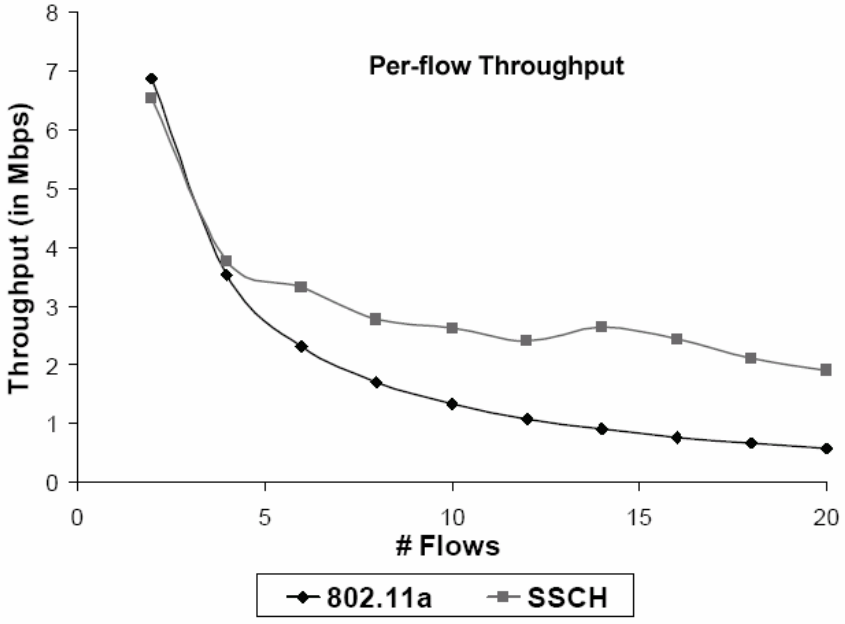


Figure 11: Non-disjoint Flows: The per-flow throughput on increasing the number of flows.

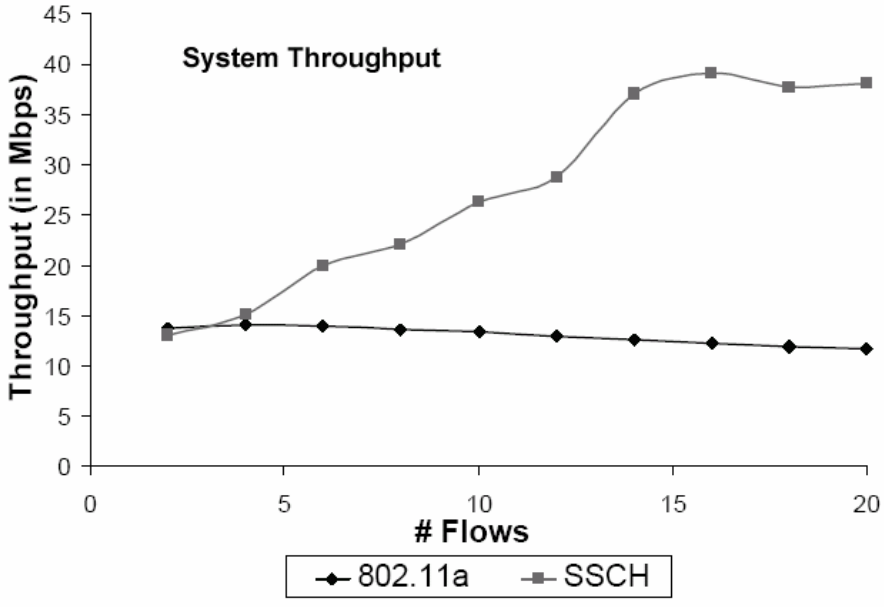


Figure 12: Non-disjoint Flows: The system throughput on increasing the number of flows.

System Evaluation

- Effect of Flow Duration

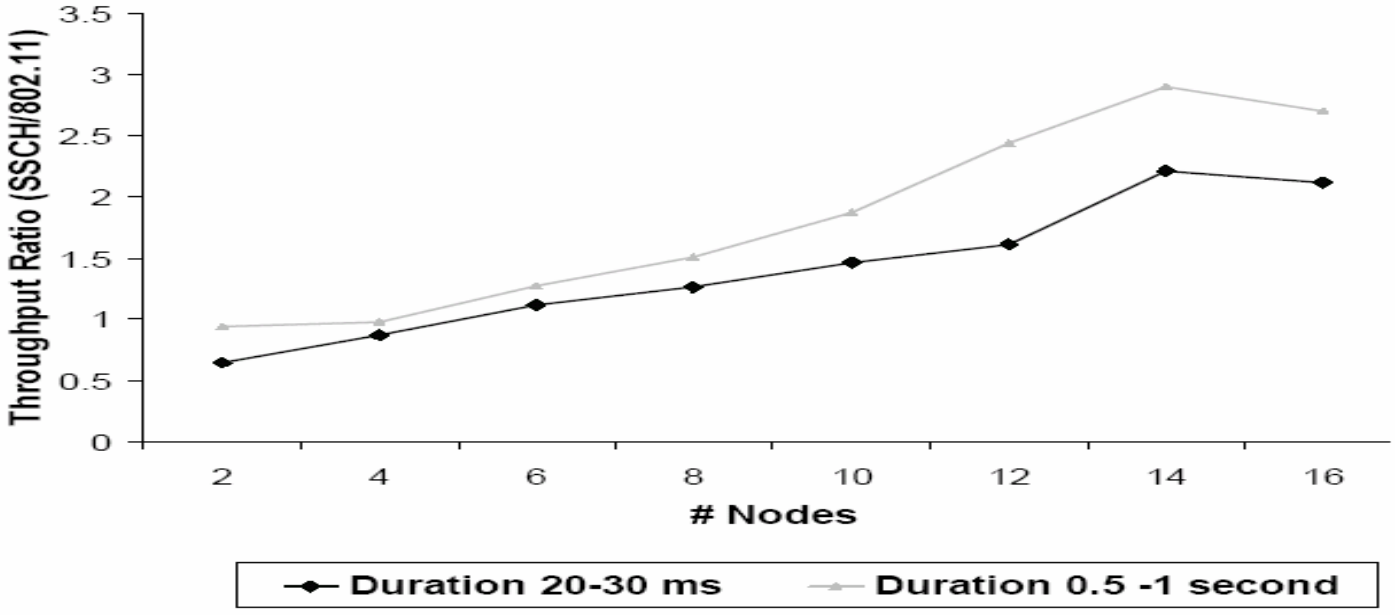


Figure 13: Effect of Flow Duration: Ratio of SSCH throughput to IEEE 802.11a throughput for flows having different durations.

System Evaluation

- TCP Performance over SSCH

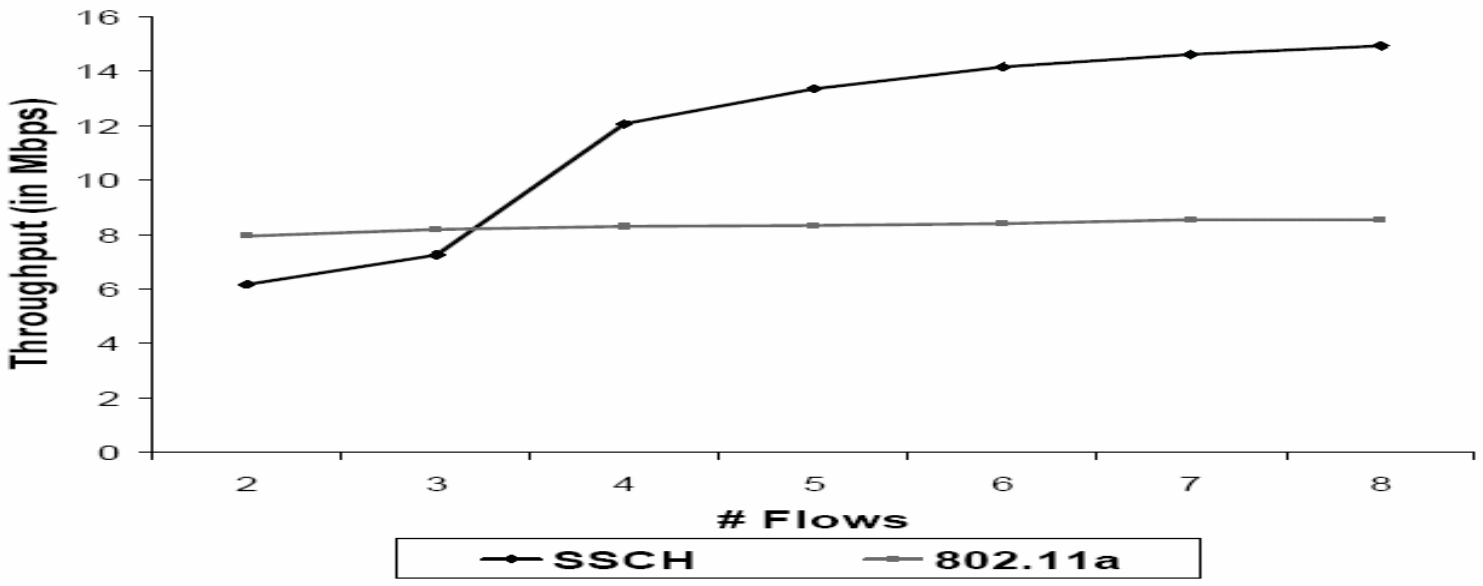


Figure 14: TCP over SSCH: Steady-state TCP throughput when varying the number of non-disjoint flows.

System Evaluation

- Multi-hop Case and mobility
- Multi-hop Chain Network

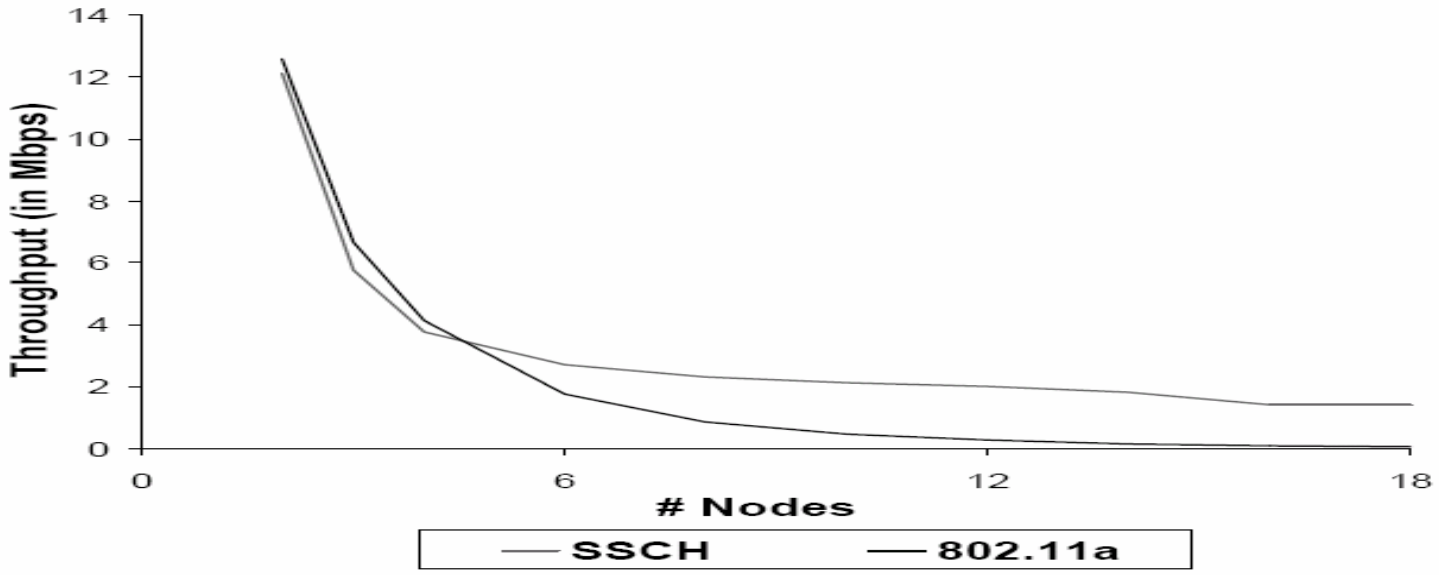


Figure 15: Multi-hop Chain Network: Variation in throughput as chain length increases.

System Evaluation

- Multi-hop Mesh Network

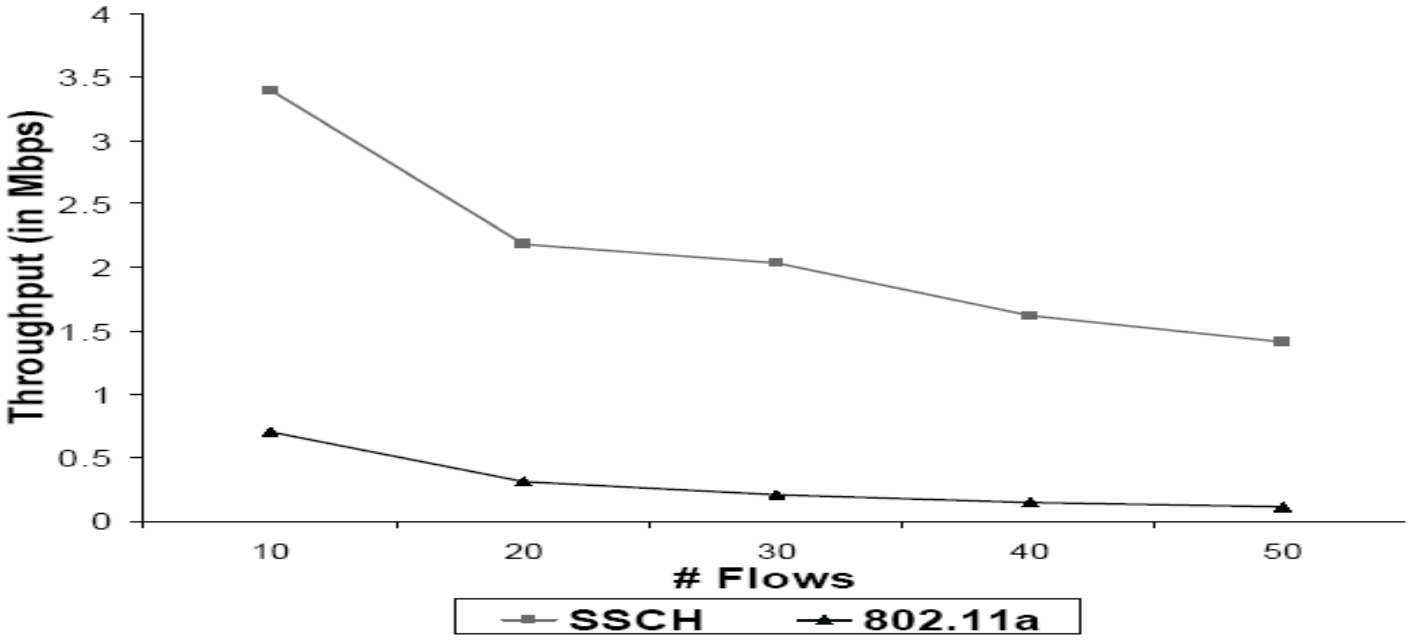


Figure 16: Mulithop Mesh Network of 100 Nodes: The per-flow throughput on varying the number of flows in the network.

System Evaluation

- Impact on Channel Switching on MANET Routing Protocols

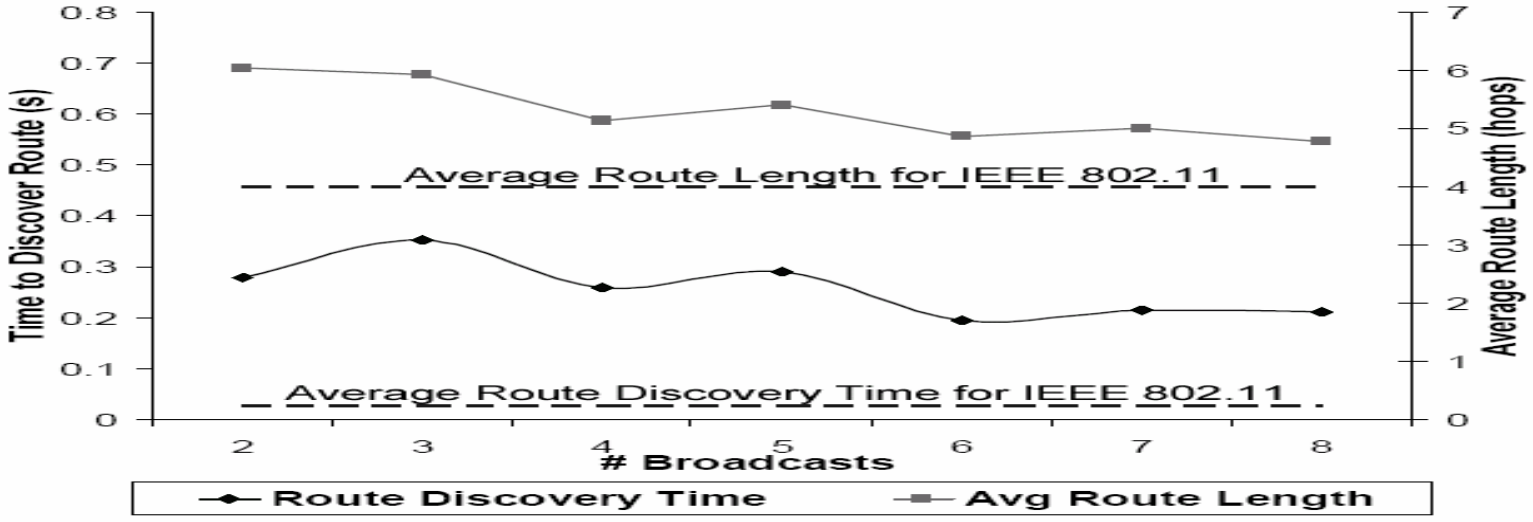


Figure 17: Impact of SSCH on Unmodified MANET Routing Protocols: The average time to discover a route and the average route length for 10 randomly chosen routes in a 100 node network using DSR over SSCH.

System Evaluation

- Multi-hop Mobile Network

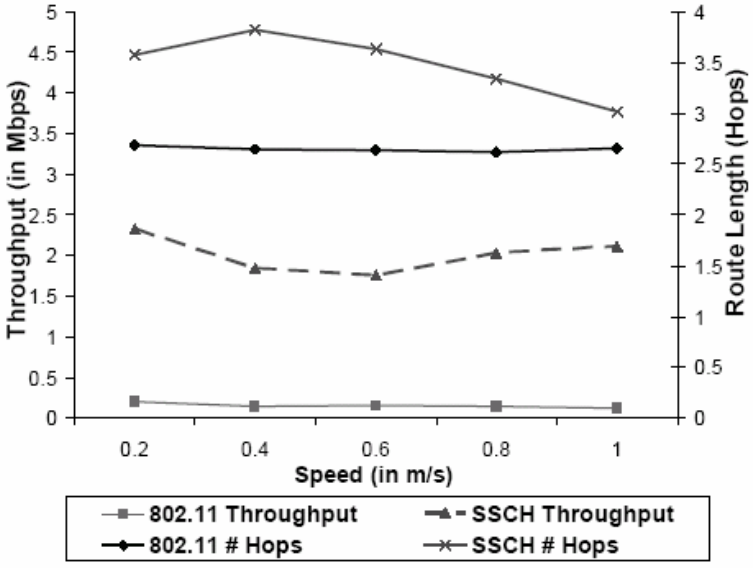


Figure 18: Dense Multi-hop Mobile Network: The per-flow throughput and the average route length for 10 flows in a 100 node network in a $200m \times 200m$ area, using DSR over both SSCH and IEEE 802.11a.

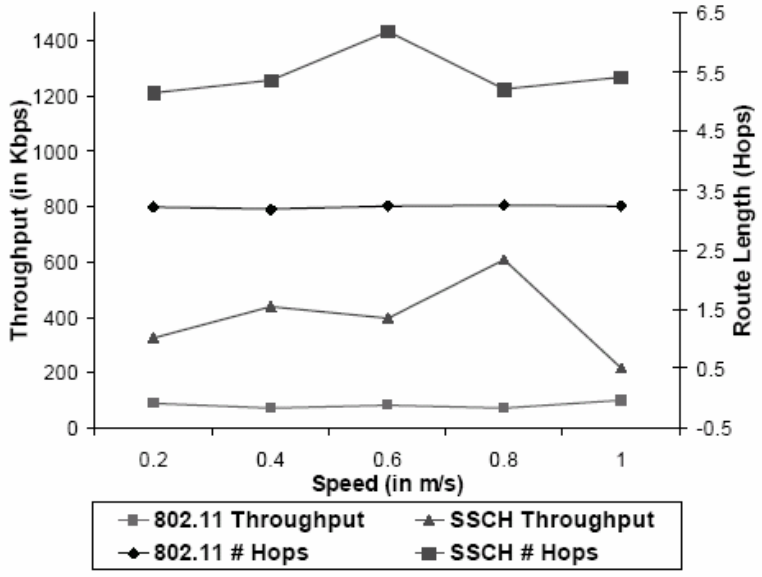


Figure 19: Sparse Multi-hop Mobile Network: The per-flow throughput and the average route length for 10 flows in a 100 node network in a $300m \times 300m$ area, using DSR over both SSCH and IEEE 802.11a.

Conclusion

- Traffic driven overlap
- Without control channel bottleneck
- Support broadcast
- Roughly synchronous