Capacity of Ad Hoc Wireless Networks

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Motivations

- Is Manet scalable?
  - Control plane (RTS-CTS, Ack, routing overhead)
  - Data plane (data forwarding)
- Is it possible to make large Manets?
  - Single node capacity (2Mbps, 10Mbps, 50Mbps)
  - Achievable end-to-end bandwidth?
  - Is a global channel scheduling possible?

Single Cell Capacity

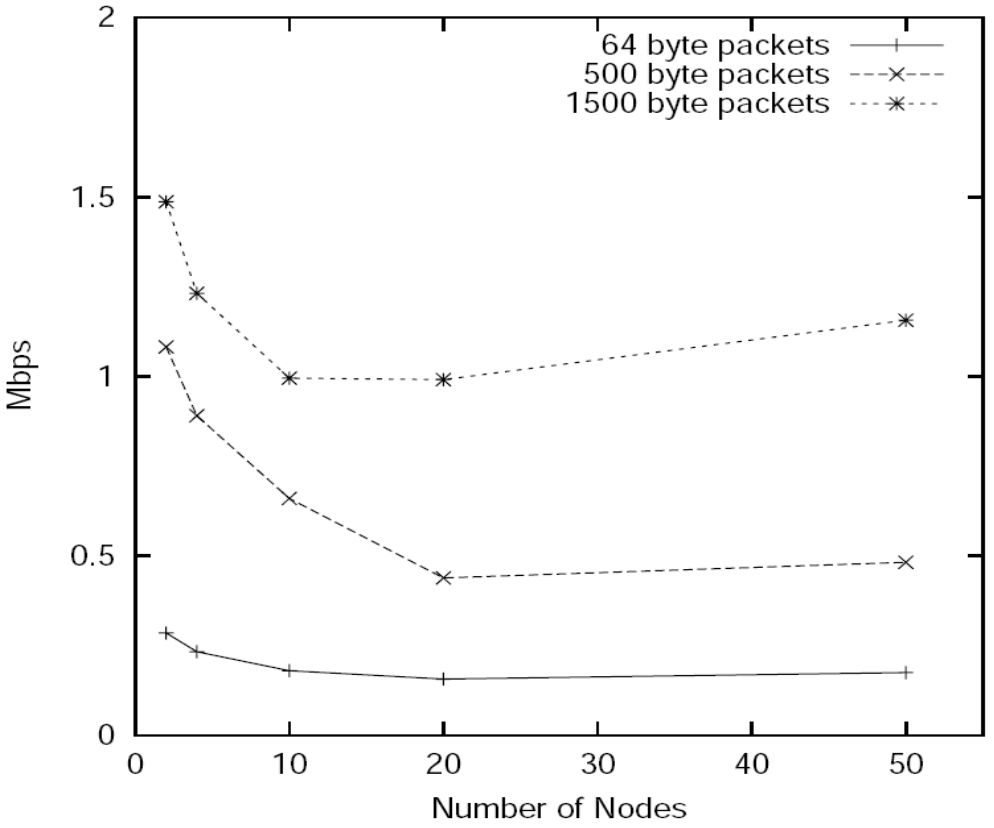


Figure 1: Total network throughput achieved as a function of the number of competing nodes. All nodes are within each others' radio ranges, and all nodes send as fast as 802.11 allows.

Logics for the single cell experiment

- RTS: 40 bytes
- CTS: 39 bytes
- ACK: 39 bytes
- MAC header: 47 bytes
- Possible data throughput:
  - 1500 / (1500 + 40 + 39 + 47) = 1.8 Mbps (vs 2Mbps)

Capacity of a chain of nodes

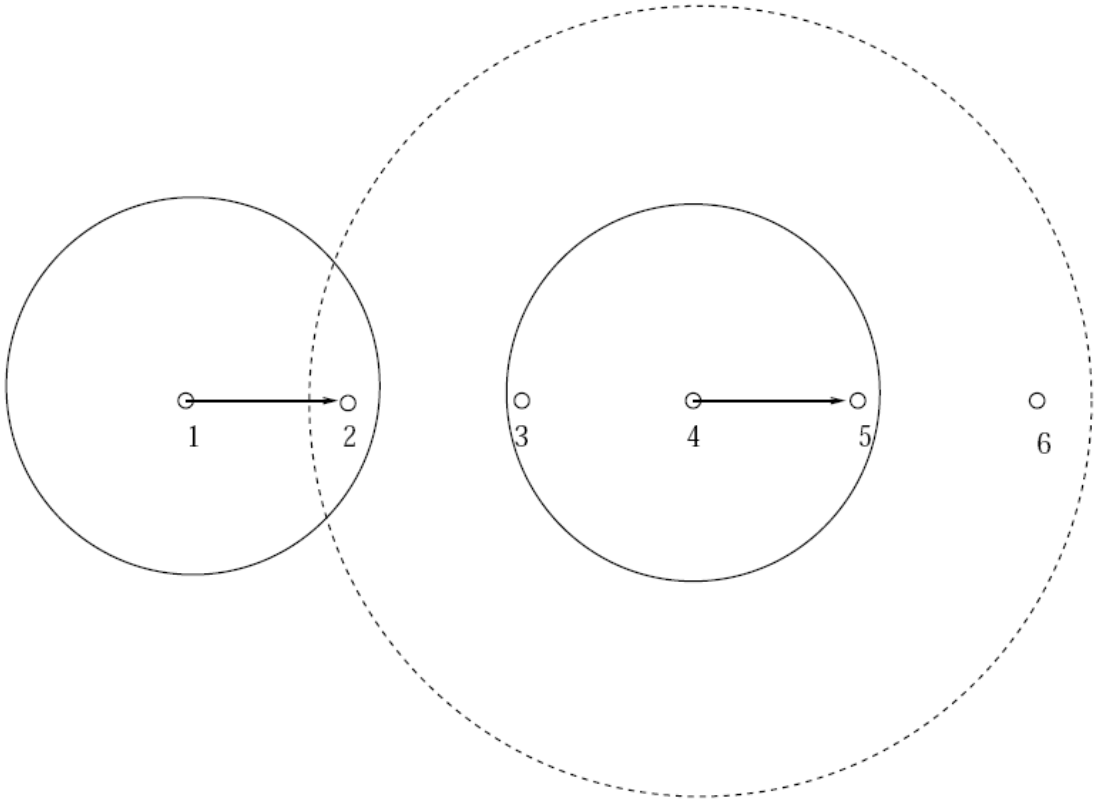


Figure 2: MAC interference among a chain of nodes. The solid-line circle denotes a node's valid transmission range. The dotted-line circle denotes a node's interference range. Node 4's transmission will corrupt node 1's transmissions at node 2.

Expected capacity of the chain

- About 1/4?

Simulation results of the chain

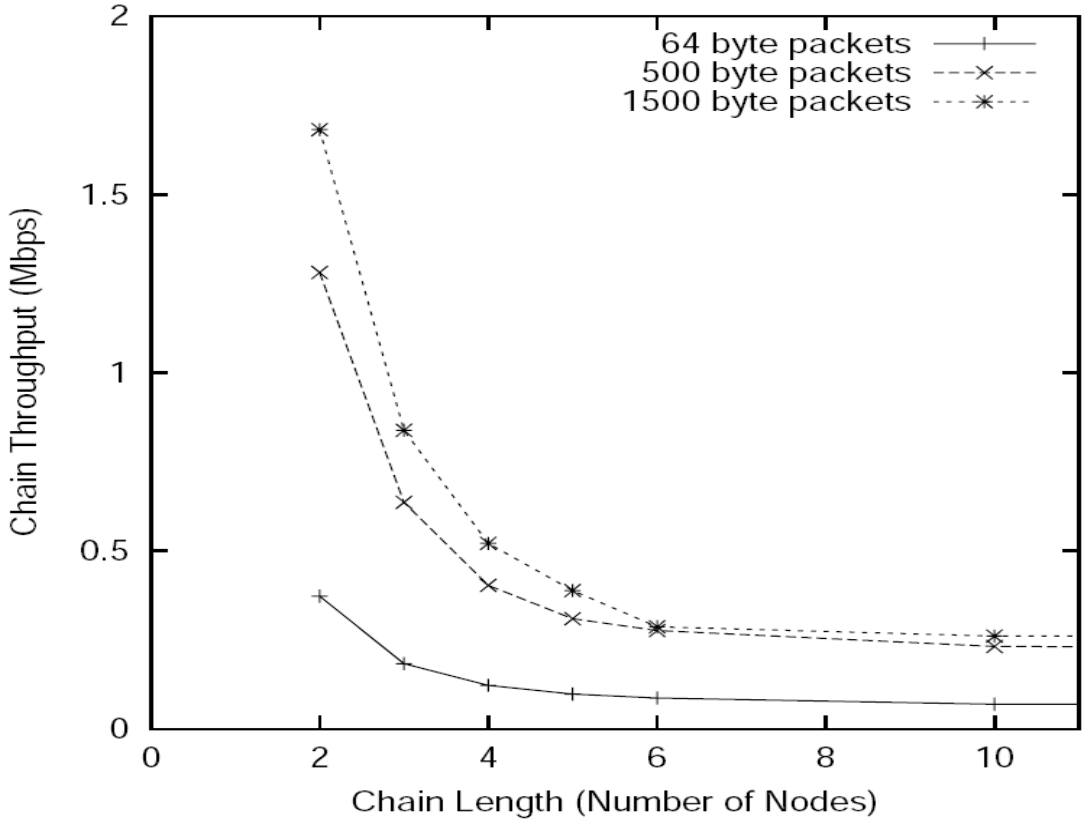


Figure 3: Throughput achieved along a chain of nodes, as a function of the chain length. The nodes are 200 meters apart. The first node originates packets as fast as 802.11 allows, to be forwarded along the chain to the last node. The throughputs for chains of 20 and 50 nodes are the same as for 10 nodes.

Analysis

- 1/7 vs 1/4!
  - What should be the reasons?
- Is the back-off timer the bad guy?
-

	Node					
	1	**2**	**3**	**4**	**5**	**6**
Send rate	0.48	0.35	0.27	0.26	0.26	0.26
Wasted time (%)	5.4	3.3	3.1	1.5	0	0

Figure 5: Individual node send rates in Mbps, and percent of total time spent in wasted backoff for a 7-node chain, with 1500-byte packets. Note that the 802.11 MAC allows node 1 to send much faster than nodes 2 or 3 can forward, resulting in lost packets.

Throughput by 8 nodes of chain

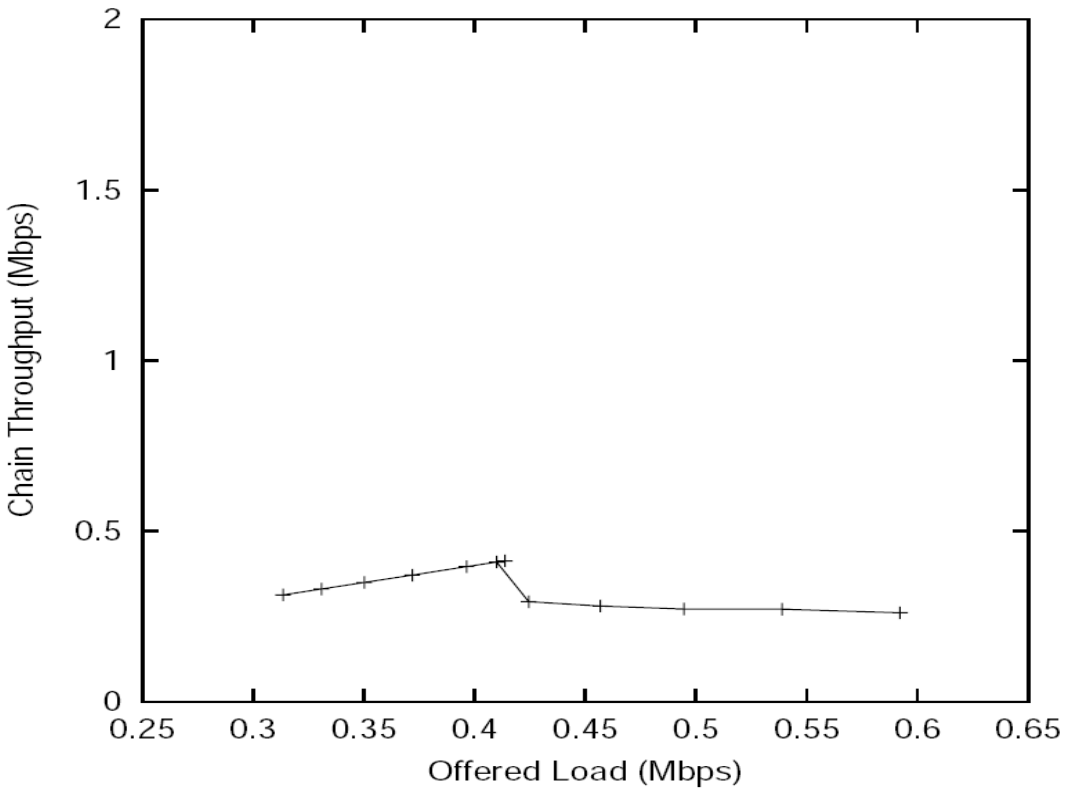


Figure 4: Throughput delivered by an 8-node chain with different send rates, using 1500-byte packets. The fact the peak rate of 0.41 Mbps is not maintained shows the 802.11 MAC does not schedule greedy senders optimally for ad hoc forwarding.

Real hardware througput

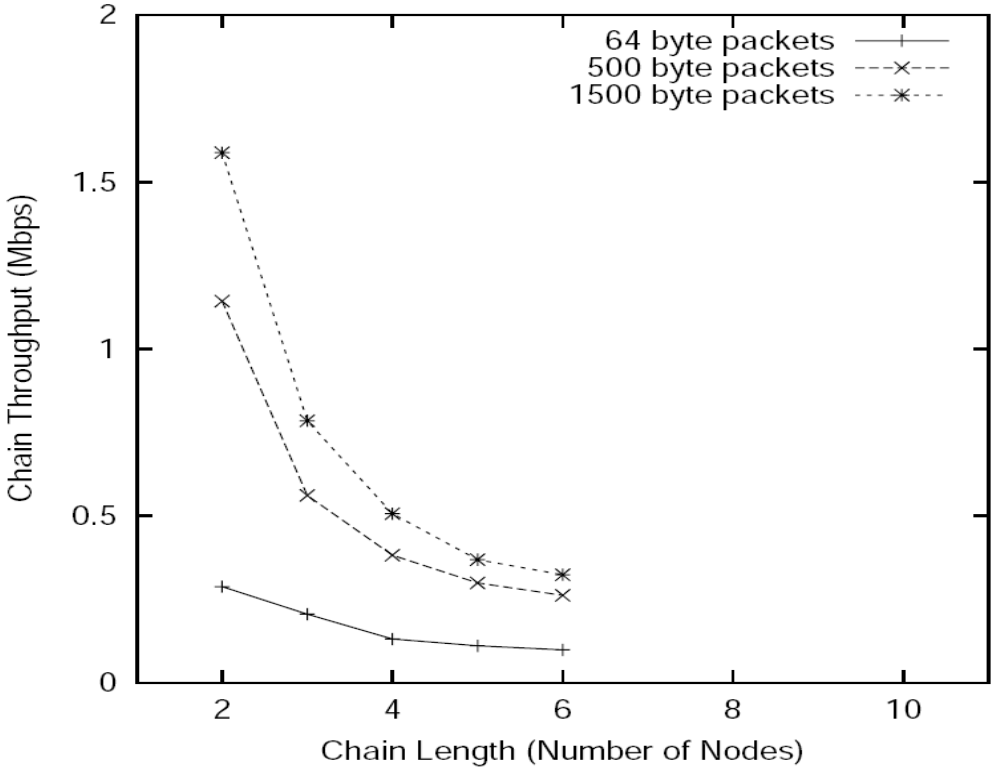
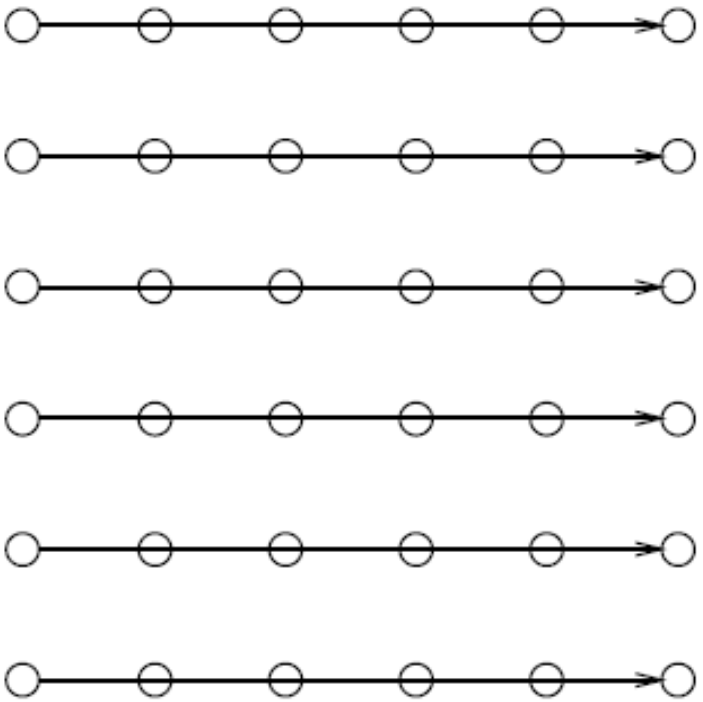
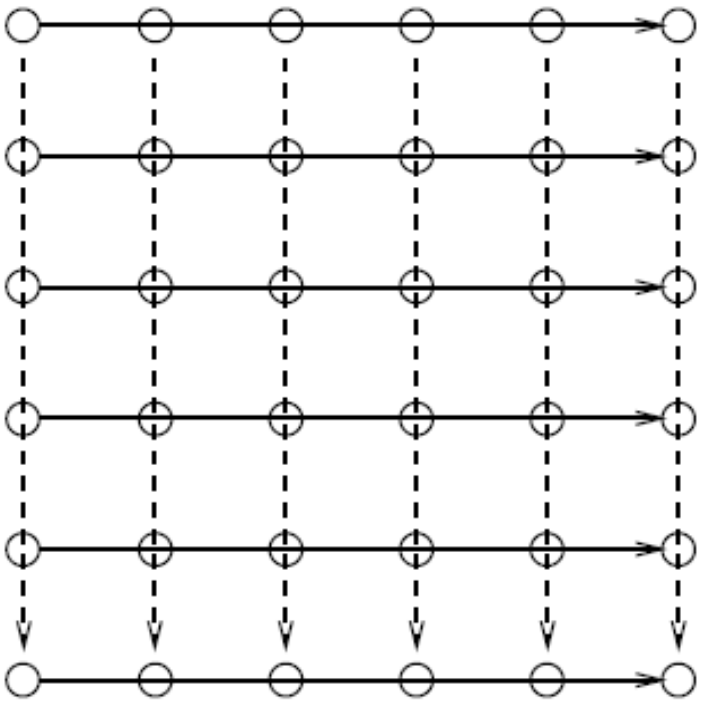


Figure 6: Real hardware throughput achieved along a chain of nodes, as a function of the chain length. Each node was placed at the maximum distance from the previous that allowed low-loss communications. Hardware parameters were set to mimic the simulation parameters as much as possible.

Lattice network topologies





Per flow throughout for horizontals

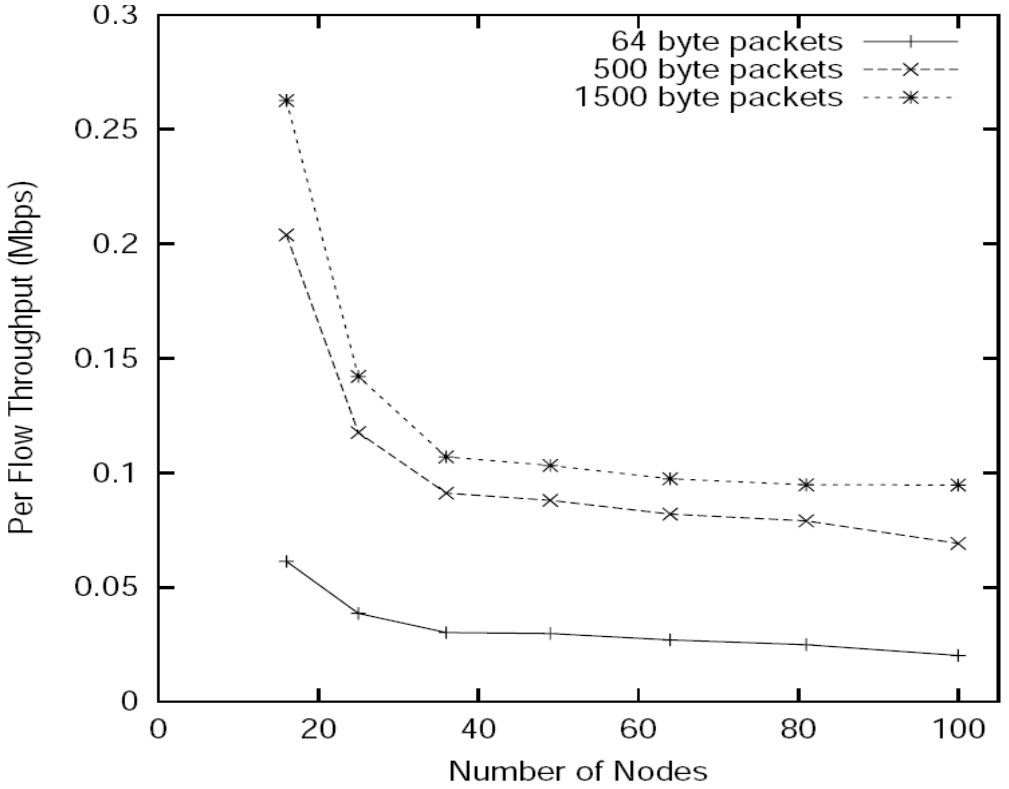


Figure 8: Average per flow throughput in square lattice networks with horizontal data streams only, as a function of network size. There are as many parallel chains as there are nodes per chain. The X axis value is the total number of nodes. Each node is separated from its four neighbors by 200 meters.

Per flow throughput for both

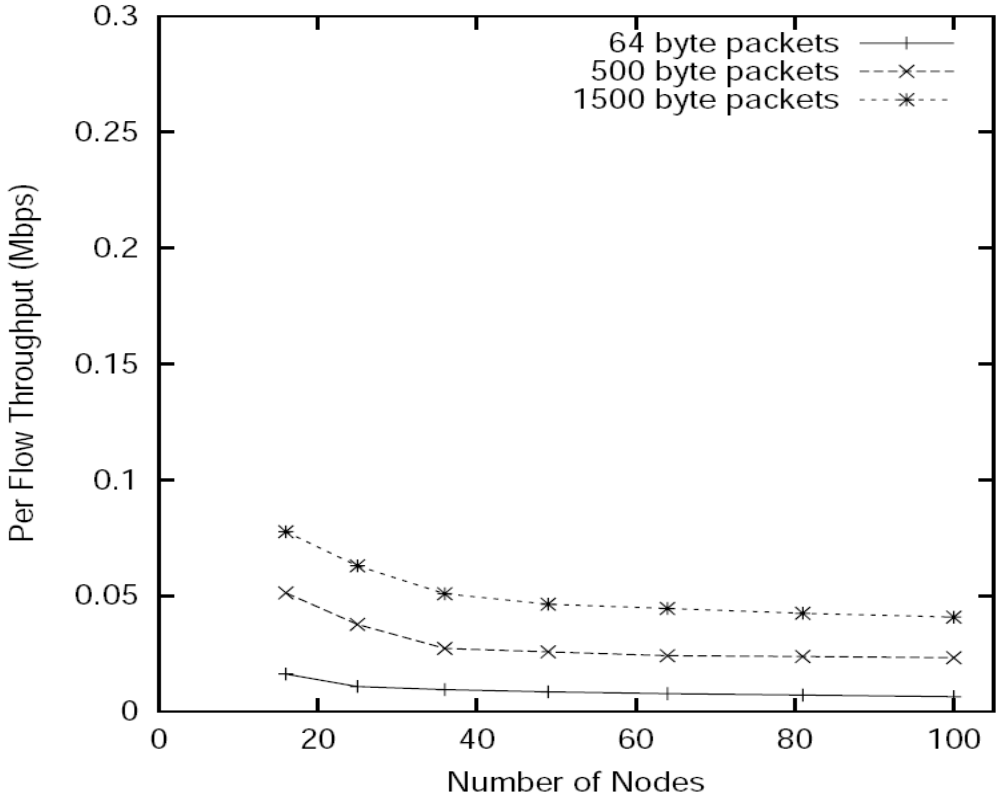


Figure 9: Average per flow throughput in square lattice networks with both horizontal and vertical data streams. This configuration has twice as many chains of traffic sharing the same network as Figure 8, which explains most of the difference between the two results.

Total one-hop throughput