
Routing in Delay Tolerant Networks (2)

Primary Reference: E. P. C. Jones, L. Li and P. A. S. Ward,
"Practical Routing in Delay-Tolerant Networks," SIGCOMM'05,
Workshop on DTN, August 22-26, 2005, Philadelphia, PA,
USA.

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Outline

- Background
- MEED, Per-hop routing and Per-contact routing
- Topology distribution using epidemic protocol
- Simulation Results
- Conclusion

Background

- MED, ED, EDLQ, EDAQ presented earlier
- ED, EDLQ, EDAQ require knowledge of contact schedules
- Minimum Expected Delay (MED) practically realizable, self configurable
 - Each node finds mean expected delay for each contact
 - Contacts summary oracle knows this information
 - Dijkstra's algorithm to find MED path at source (source routing)
 - Costs in Dijkstra's algorithm are mean expected delays
 - Minimum delay routing increases delivery probability
- This paper
 - Minimum Estimated Expected Delay (MEED)
 - Per-hop routing
 - Per-contact routing

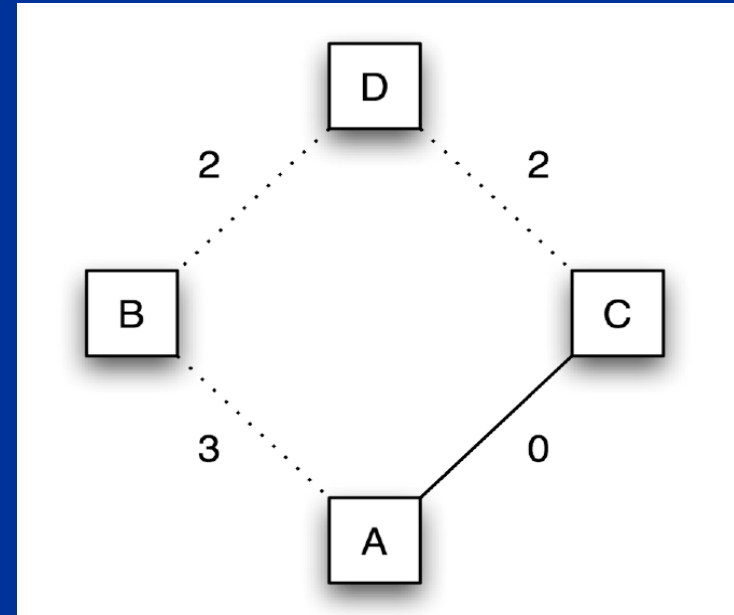
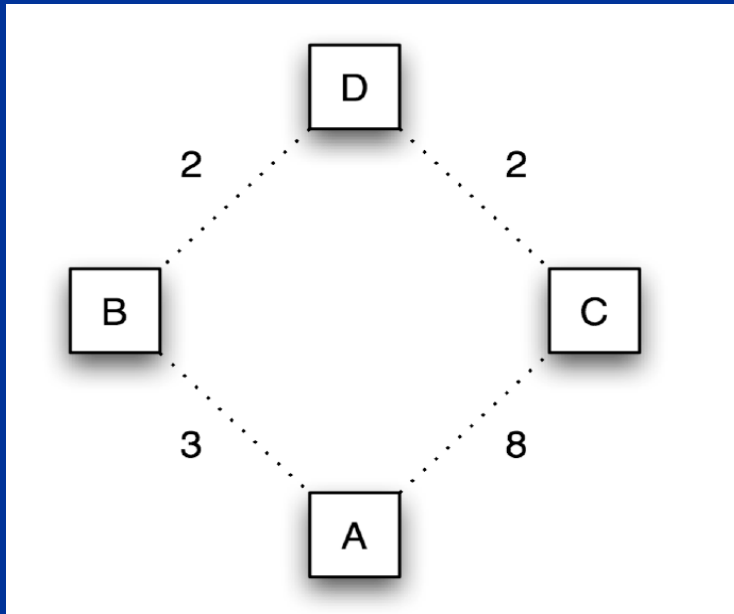
MEED and Per-hop routing

- Compute mean expected delay based on observed contact history
 - Don't use future contact schedule (MED does that)
- Record connection/disconnection times over a sliding window
 - Too large: reduces routing updates; slow reaction to permanent changes
 - Too small: sensitive to random fluctuations
- Implementation in this paper: propagate update if
 - At least one link weight changes by more than 5%
 - New contact has been added
 - Note that updates are flooded to all nodes (overhead)
- Use per-hop routing instead of source routing
 - As message travels closer to destination, nodes have more accurate and ...
...recent information
 - Can cause routing loops

Per-contact routing

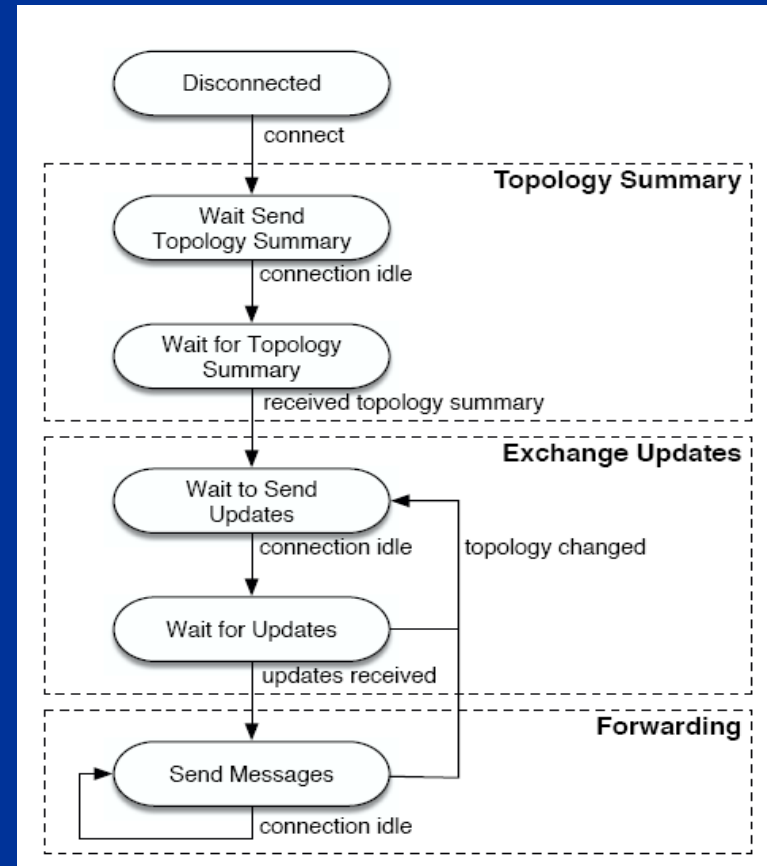
- Message arrives -> find next hop from forwarding table -> place in...
...queue until contact arrives
- But changes in topology can occur when message is waiting in queue
 - May lead to suboptimal routing
- Don't compute next hop in advance, compute when a contact arrives
- This way, routing decision is made with most recent information
- Disadvantages
 - Routing recomputed more often: more processing resources
 - Additional delay before a link can be used
 - Scaling problems for large networks
- Contacts that arrive infrequently have high mean expected delay
 - Shortest paths will not use these links
 - But these links may be very good when they are available
 - Assign a cost of zero when contact arrives

Per-contact routing (Example)



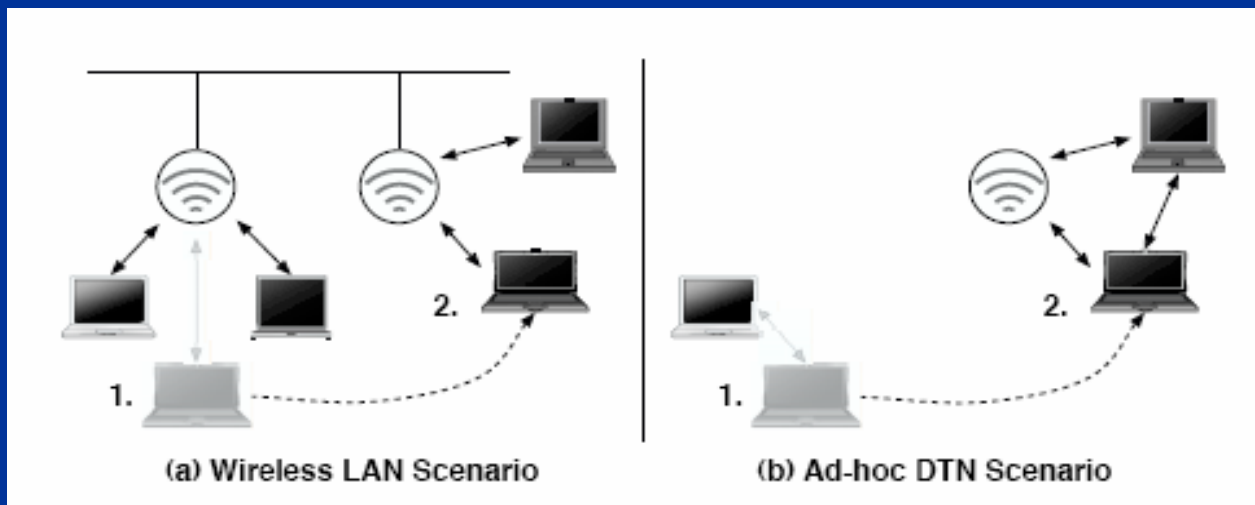
Topology distribution (Epidemic protocol)

- Upon connection, nodes exchange summary vectors of link state tables
- Tables are tagged with sequence numbers
- Nodes exchange missing updates
- Then nodes re-compute routing tables
- Finally messages are forwarded
- Summary vector size: $O(N)$
- Topology updates: $O(DN)$ where D is degree of each node
- Overhead acceptable for small networks but may be a problem for large networks



Simulation scenario

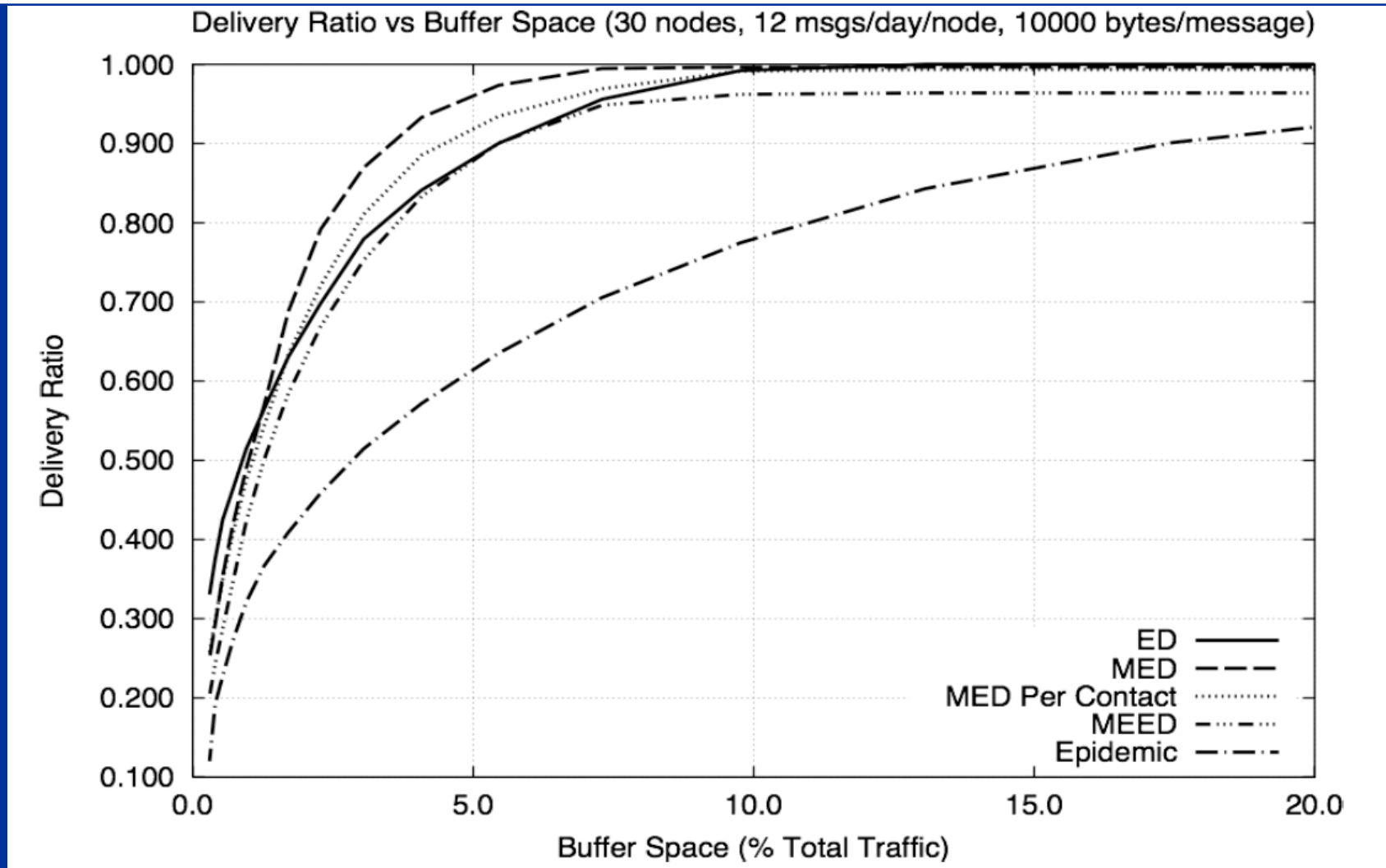
- Earliest Delivery (ED), MED, MED Per-contact, MEED and Epidemic
- Mobility trace derived from WLAN trace from Dartmouth College
 - 500 access points, 2000 users, 2 years
 - Derive ad-hoc DTN traces from WLAN trace
 - Two nodes are connected when they are in contact with same access point
 - Access points are also DTN routers
 - Number of nodes pruned to 30 for each simulation



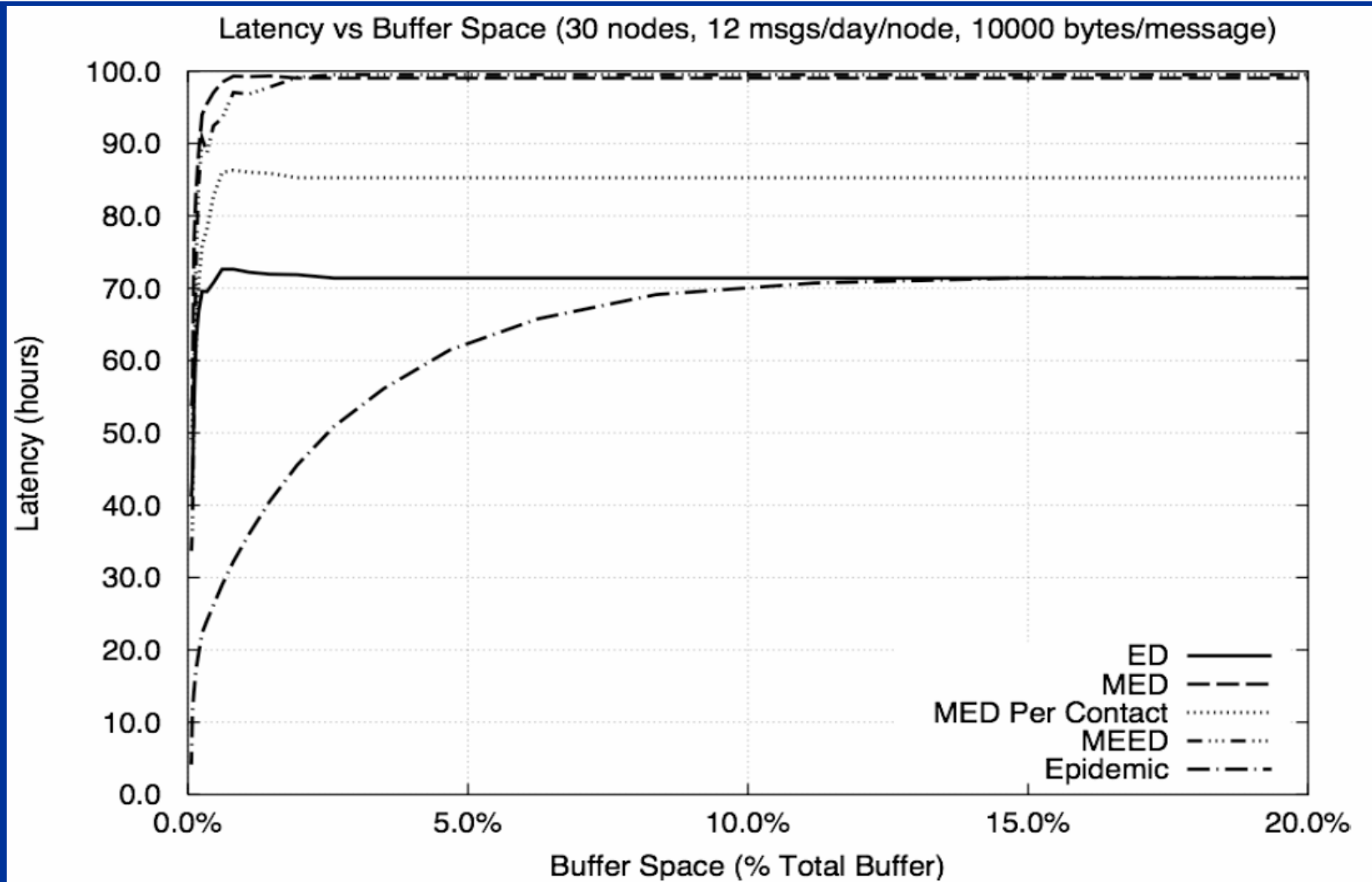
Simulation parameters

- Include only nodes that connect to other nodes at least 10 times per...
...month
- Random node pairs selected, bidirectional traffic
 - 6 messages every 12 hrs
 - Each message 10,000 Bytes
- Simulation run for one month
 - Statistics reported only for second week of simulation run
- Each test performed with 10 different network topologies

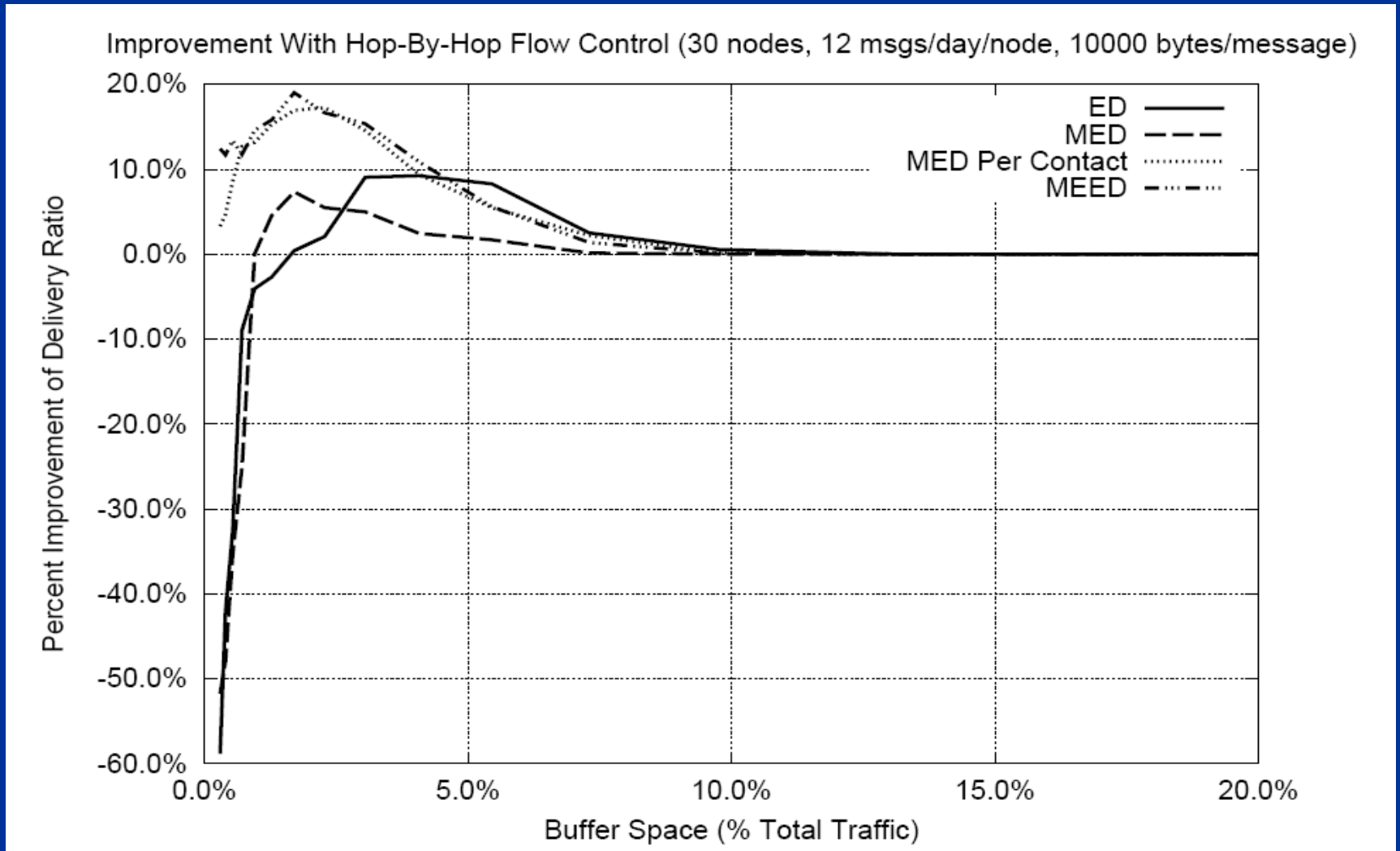
Impact of buffer size



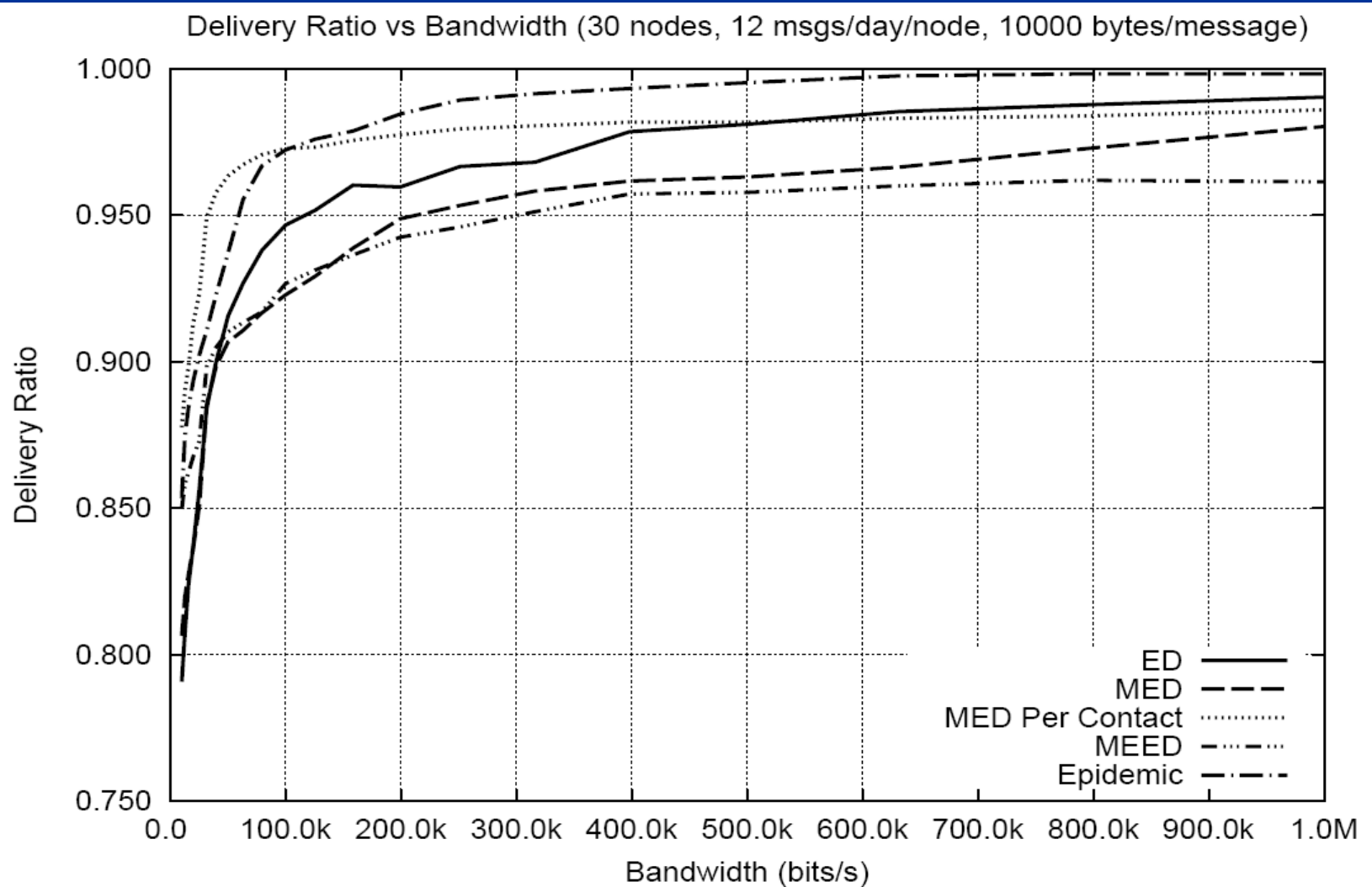
Latency with varying buffer size



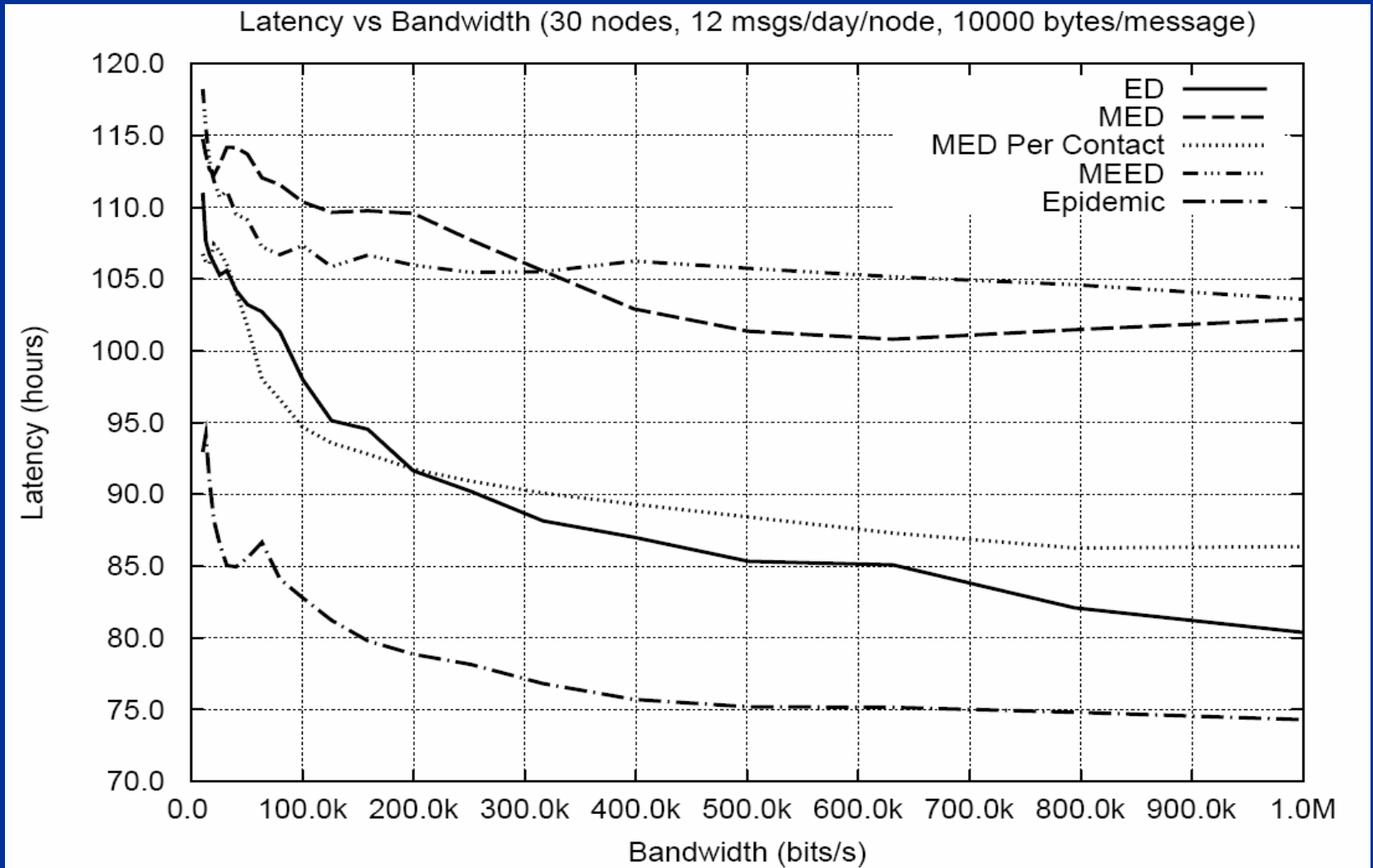
Hop-by-hop flow control



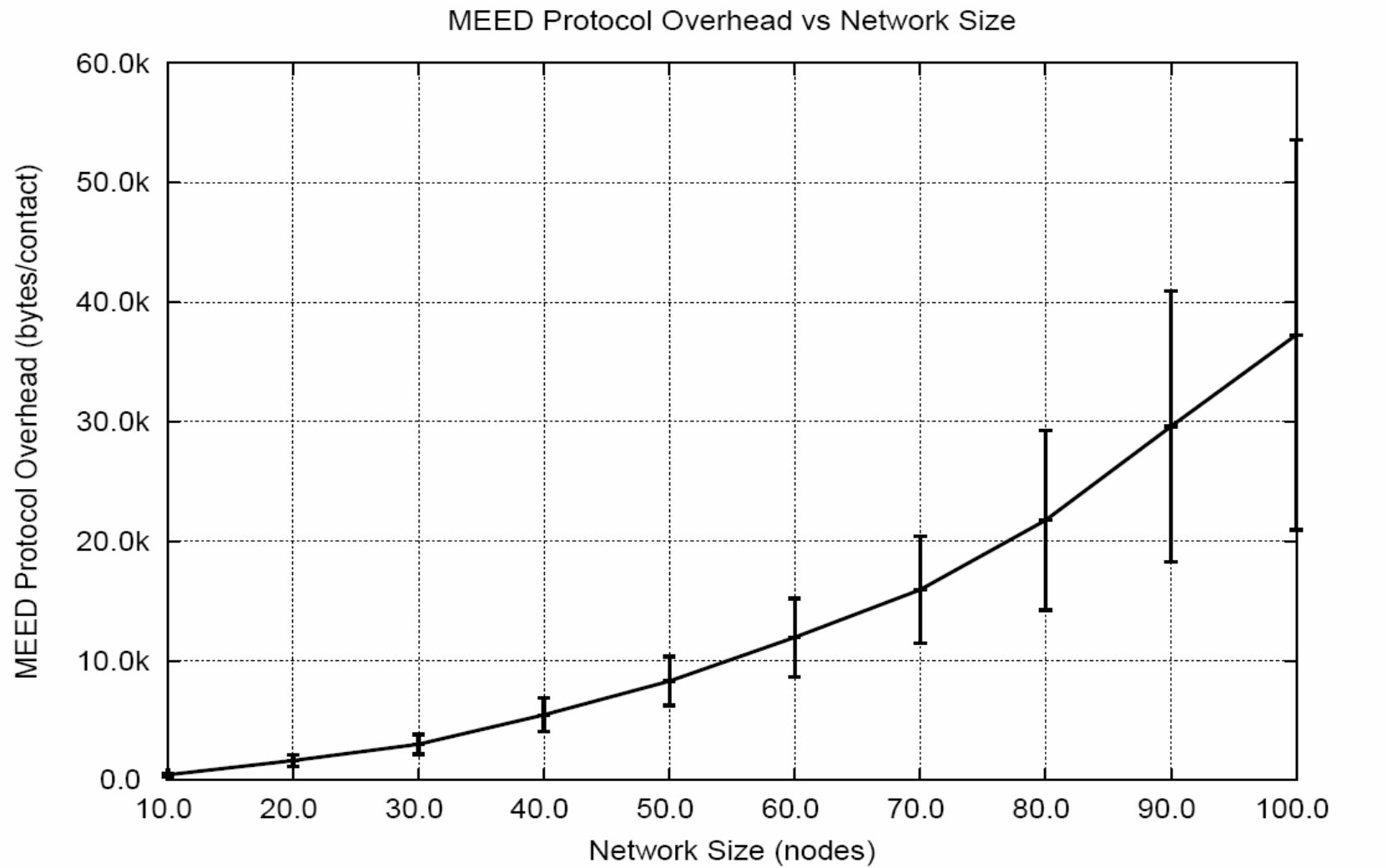
Delivery ratio vs bandwidth



Latency vs bandwidth



Protocol overhead



Conclusion

- Introduced
 - MEED
 - epidemic protocol for routing updates
 - per-contact routing
- Improves latency and delivery ratio
- Hop-by-hop flow control can improve delivery ratio