Practical Routing for Delay Tolerant Networks

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The Problem: Routing in DTNs

Get data from the source to the destination without an end-to-end connection

Previous Work: Epidemic Routing

- Eventually, all buffers contain the same messages

Advantages:

- Very robust
- Zero knowledge

Disadvantages:

- Many messages exchanged
- Need large buffer

Previous Work: Shortest Paths

- Minimize metric to minimize resources consumed

Advantages:

- Few transmissions
- Low buffer requirements

Disadvantage:

- Requires predictable schedules

Design Goals

- Deployable
  - Self configuring
  - Robust to changes and failures
- Efficient use of buffer and network resources
- Reliable delivery

Optimization Criteria

- Maximize delivery ratio
- Minimize delay
- Minimize buffer consumption
- Minimize number of transmissions

Path Metrics: Expected Delay

- Minimum Expected Delay (MED)
  - Compute the expected delay for each hop
  - Minimize end-to-end expected delay
- Minimum Estimated Expected Delay (MEED)
  - Compute expected delay for the observed history

Topology Distribution: Link State

Natural match for epidemic protocol

- Link state: flood link state to all nodes
- Epidemic: propagate a message to all nodes

- Complete update after a single exchange

Routing Decision Time

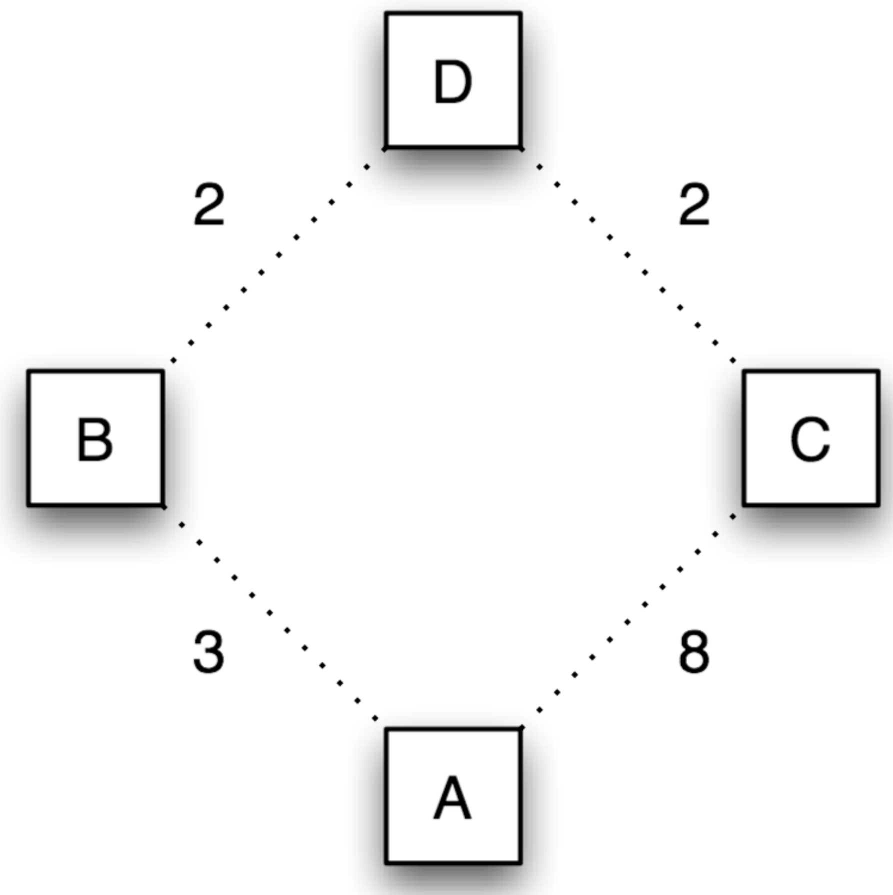
- Source routing
  - Cannot react to topology changes
- Per hop routing
  - If messages wait for a long time, same problem
- Per contact routing
  - Recompute routing for all messages on each connection
  - Takes advantage of opportunistic connectivity
  - Frequently recompute routing table

Short Circuiting

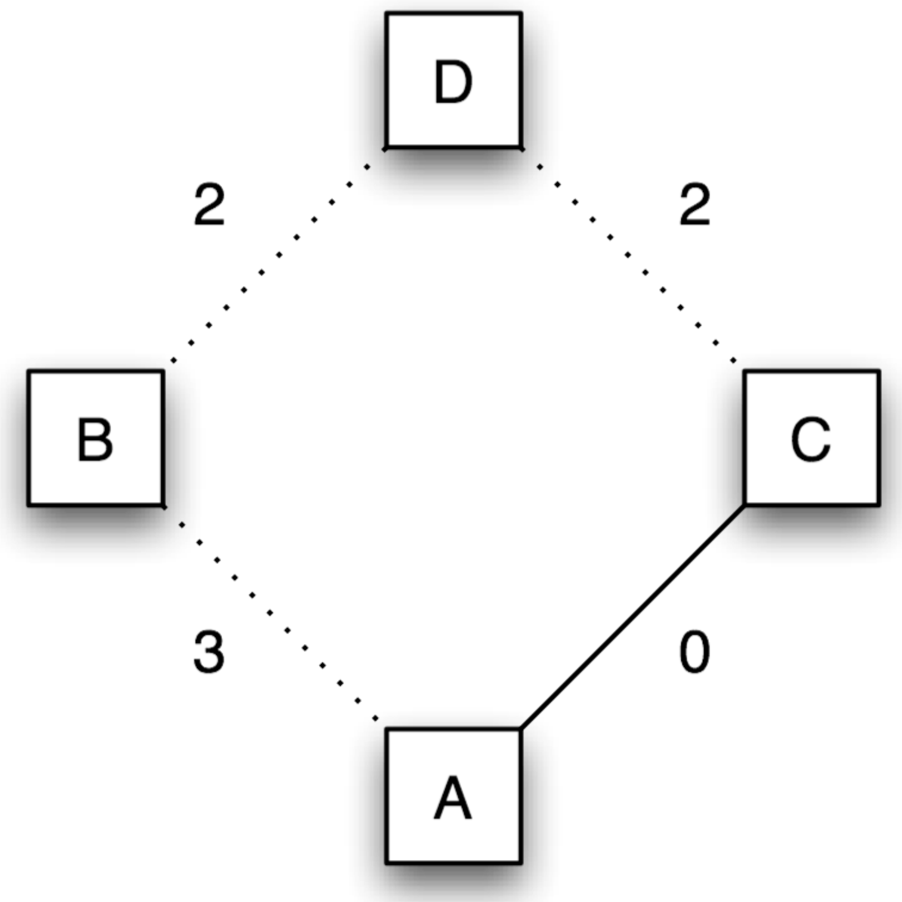
When link is up: link cost = link latency

- Permits messages to take advantage of good timing

Short Circuiting



Short Circuiting



Loop Free Routing

- Must make decisions with the same state

Traditional networks

- State does not change while data is in transit

Delay tolerant networks

- Want to be able to adapt while data is in transit

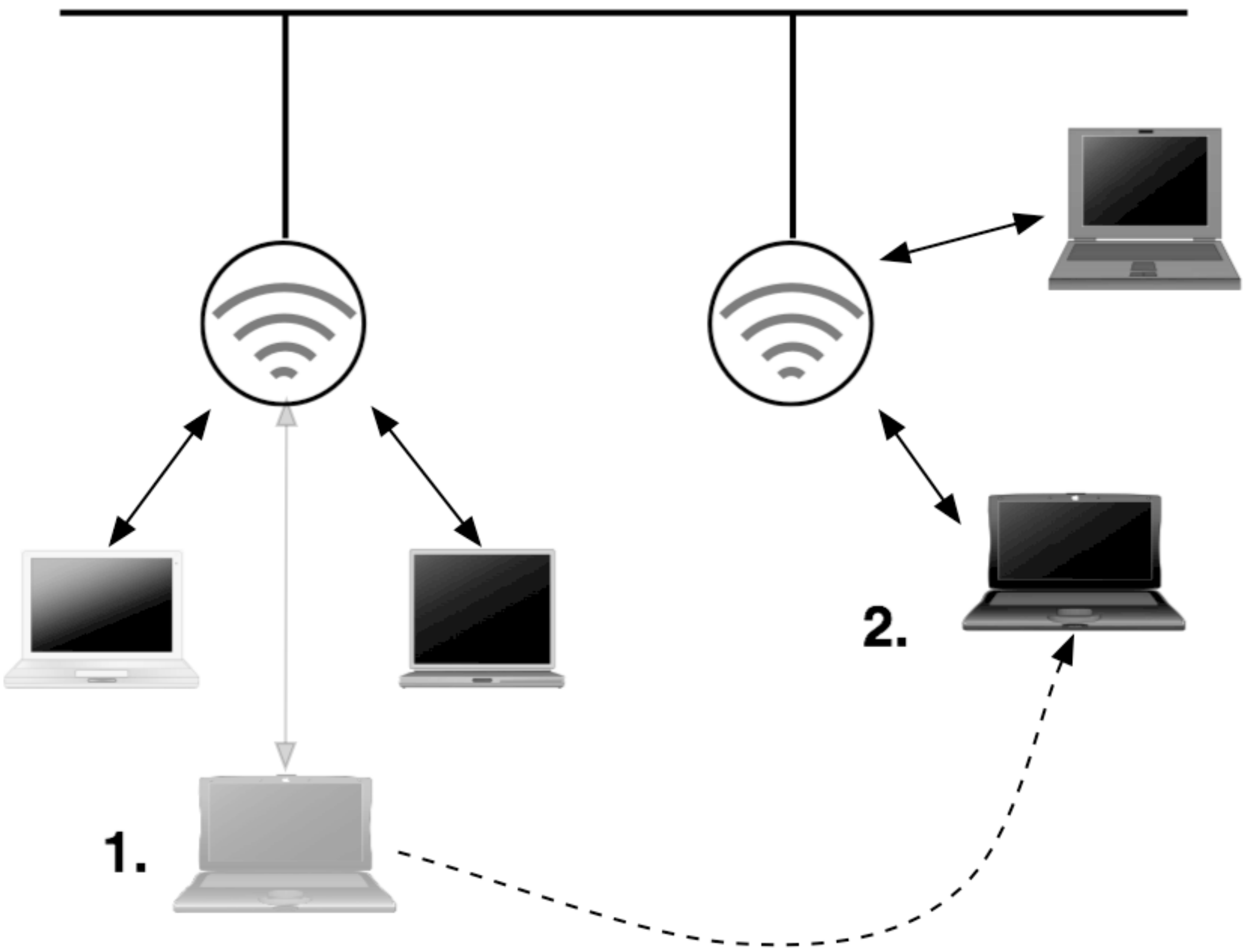
Performance Evaluation

- Compare five protocols:
  - Earliest Delivery (ED)
  - Minimum Expected Delay (MED)
  - MED Per Contact
  - Epidemic
  - Minimum Estimated Expected Delay (MEED)
- Network layer simulator

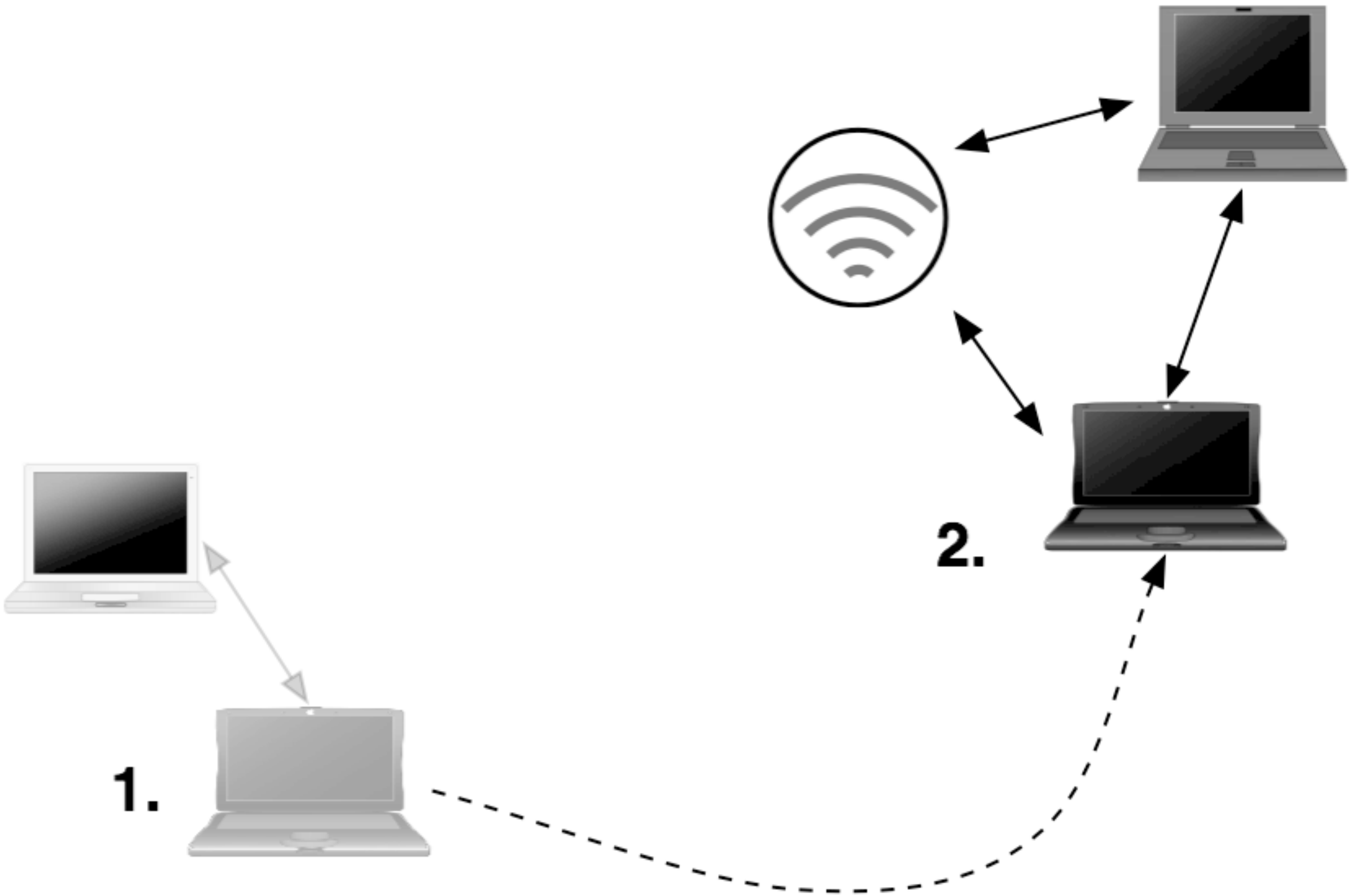
Scenario

- Based on wireless LAN usage traces from Dartmouth College
  - More than 2000 users
  - More than 500 access points
  - 2 years
- Represents mobile users forming an ad-hoc DTN
- "Random" mobility with statistical regularity

Dartmouth Data



Dartmouth Data



Scenario Generation

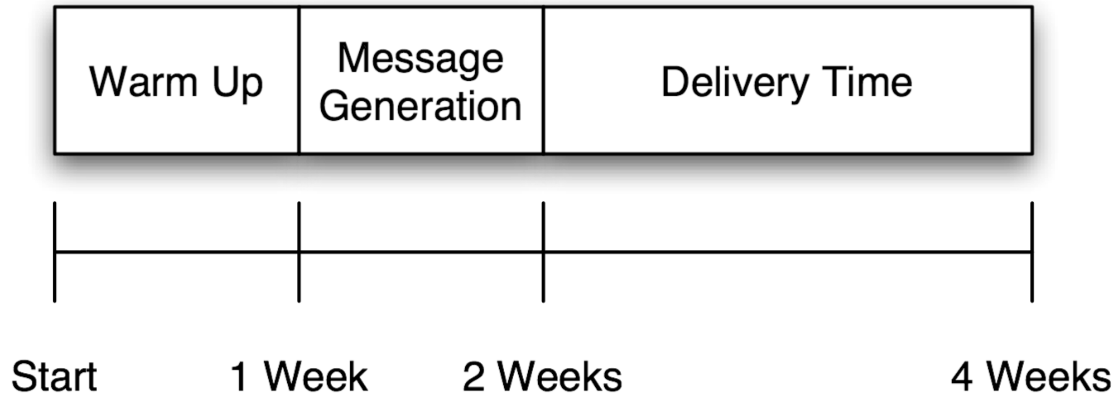
Too much data!

- Only use one month of data
- Select 30 connected users

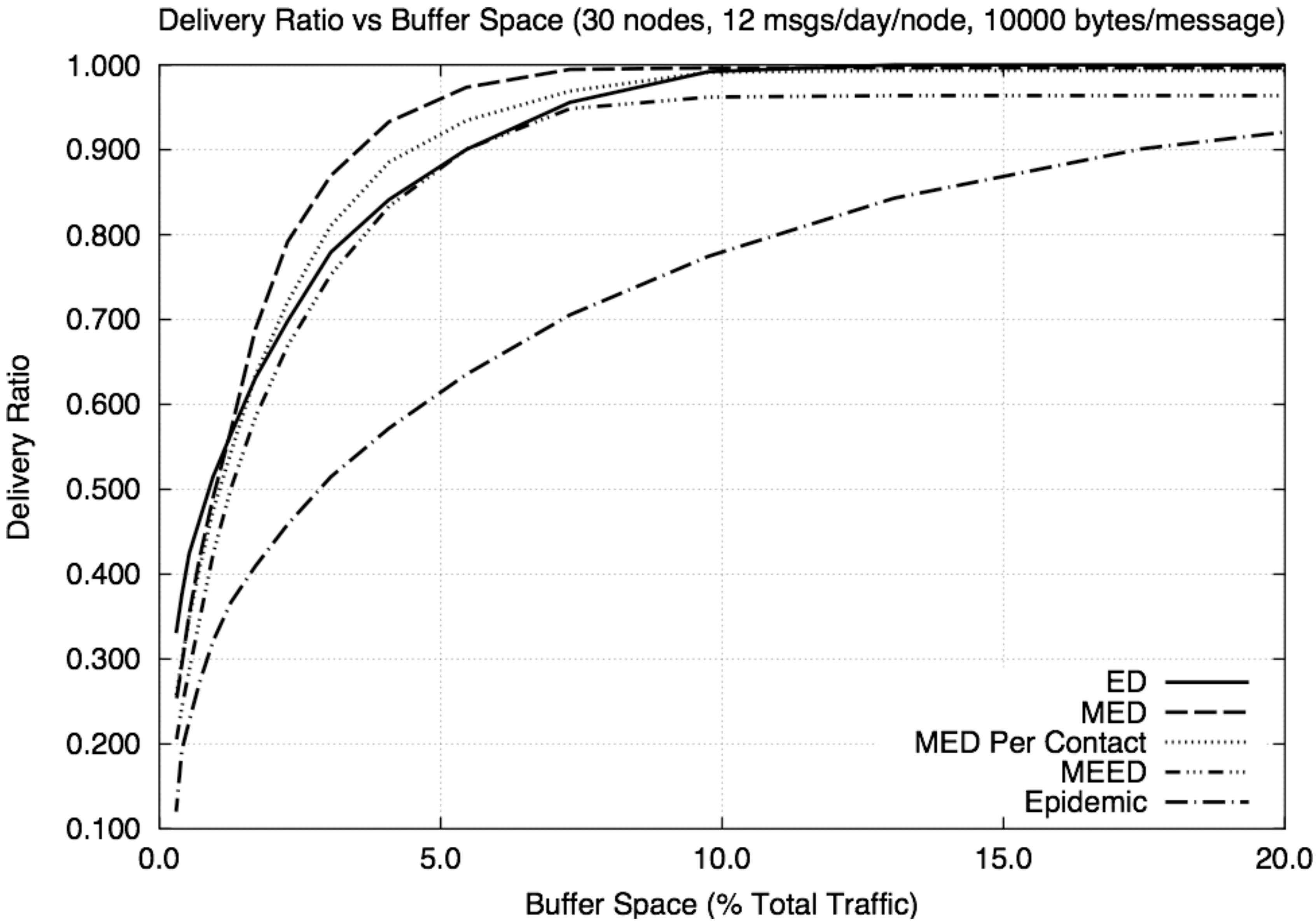
1. Pick a node at random
2. Put its "good" neighbours in a set
3. Select node at random from the set
4. Repeat 2 until you have N nodes

Simulation Parameters

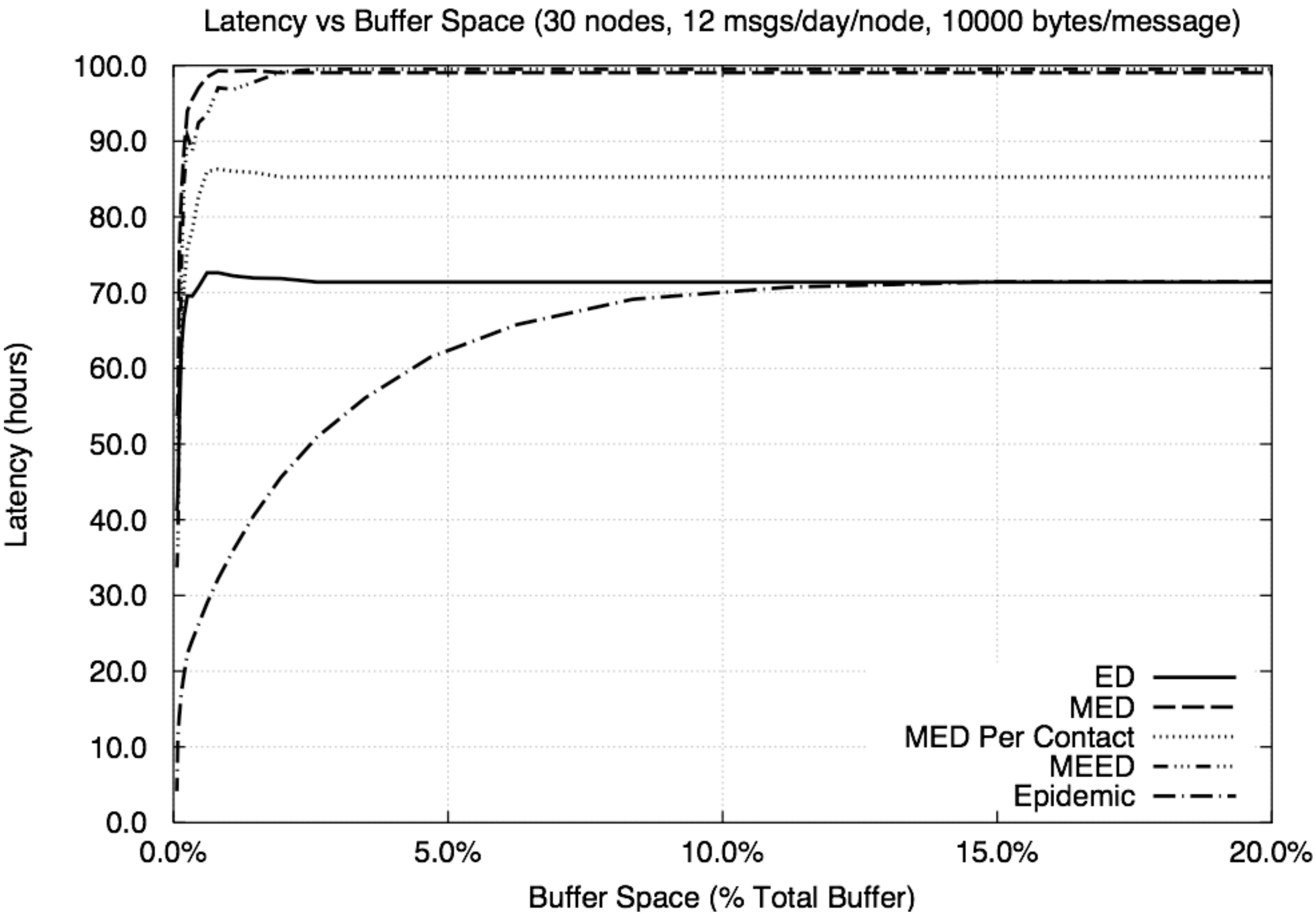
- 30 nodes
- 10 topologies
- Bidirectional traffic
- Each node sends 12 messages every 12 hours
- 10 000 bytes per message



Delivery Ratio Over Buffer Size



Latency Over Buffer



Conclusions

- Link state is an excellent fit with epidemic
- MEED: Reasonable performance without schedule
- Epidemic performance is buffer limited
  - Close to optimal with lots of resources
- Per-contact routing
  - Decreases delay

Future Work

- Different data sets
- Multiple copies

- Experimental deployments of DTNs
- Better metrics
- Use topology for directed multiple copy routing

Questions?