Location Aware Communication Protocols for Ad Hoc Networks

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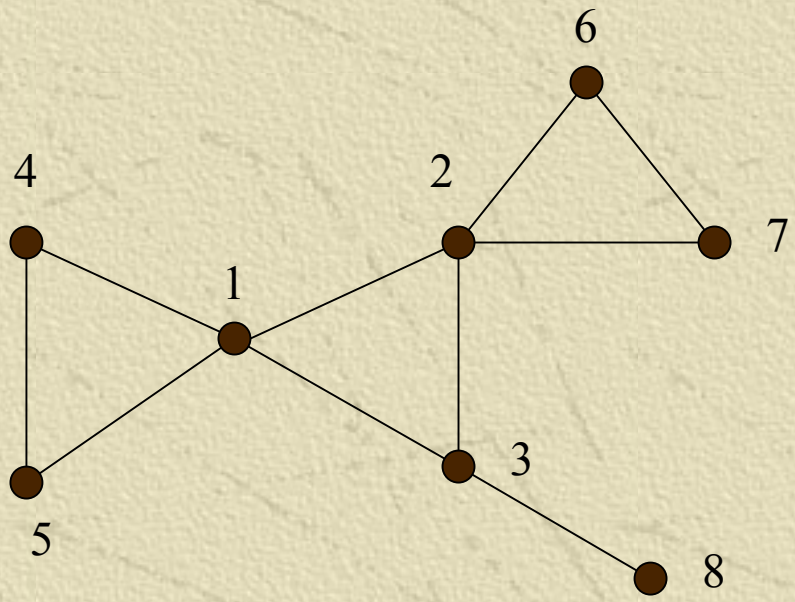
Ad Hoc Networks

- A “mobile ad hoc network’’ is an autonomous system of mobile routers (and associated hosts) connected by wireless links, the union of which forms an arbitrary graph
- The routers are free to move randomly and organize themselves arbitrarily
- The network’s wireless topology may change rapidly and unpredictably

A Simple Ad Hoc Network



Ad Hoc Routing

- Multi-hop point-to-point communication
- Internet kind of routing: every node is a switch (well, if it wants to be a switch)
- First attempts: adapting solutions for wired networks

Routing the Old Way: Link-State Protocols

- Based on broadcast
- Each node maintains information on the state of the links established between the other nodes
- Very expensive, especially in terms of bandwidth

Routing the Old Way: Table-Driven or Proactive Solutions

- Each node maintains one or more routing table
- Changes in the network topology are dealt with by propagating updates
- A consistent network view is maintained
- Existing protocols differ in the number of routing table maintained and in updates propagation methods

Proactive Solutions: Drawbacks

- Updates overhead, especially in presence of high mobility
- Overhead for enforcing loop freedom
- Large routing tables
- Low *scalability*

➢ Is it really necessary to maintain a consistent view of the network topology?

The Answer: Reactive Solution

- A route to a destination is sought for only when needed (on-demand routing)
- Route discovery process
  - A probe is sent (flooded) to discover a path to the destination
  - Upon receiving the probe the destination sends the probe back to the source
  - The probe “accumulates” the route

Reactive Protocols: Drawbacks

- The discovery phase introduces long delays
- Route discovery and maintenance is very sensitive to node mobility
- Route caching is memory greedy
- The size of the header of a data packet can become cumbersome (no scalability)
- ➢ Is the dependency on the network topology avoidable?

The Answer: Location Aware Ad Hoc Routing

- Nodes are equipped with positioning system devices (e.g., Global Positioning System receivers) that make them aware of their position
- This enabled “directional” routing
- Possible solutions differ on how the location information of the destination nodes is achieved

Location Aware Routing: Strengths

- No need to update big routing tables, no need to piggyback routes to the packet
- No need to know the nodes on the way to the destination: they can be moving while the packet travels

GPS-enabled Routing: DREAM

- Distance routing effect algorithm for mobility [Basagni+, 1998]
- A proactive, effective way to spread location information
- Directional routing

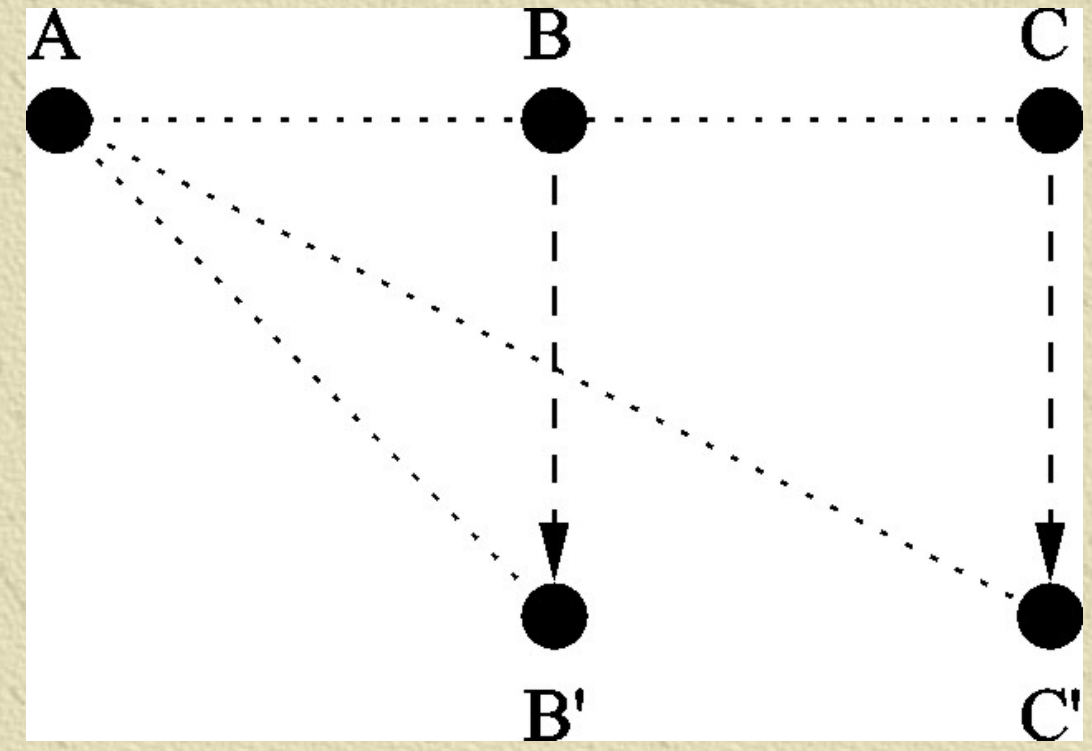
DREAM: Disseminating Location Information. Problems.

- Need to periodically update the location of a moving node.
  - Efficient broadcast of location information
  - Determining how far each location packet should travel
  - Determining how often a location packet should be sent

DREAM: Disseminating Location Information. Solutions.

- Mobility-adaptive, deterministic broadcast
- Distance effect
- Rate of updates is bound to the mobility of the node

The Distance Effect



The Distance Effect

- “Closer nodes look like they are moving faster”
- Need to receive more location updates from closer node
- Each packet is associated with an age that determines how far that packet must travel

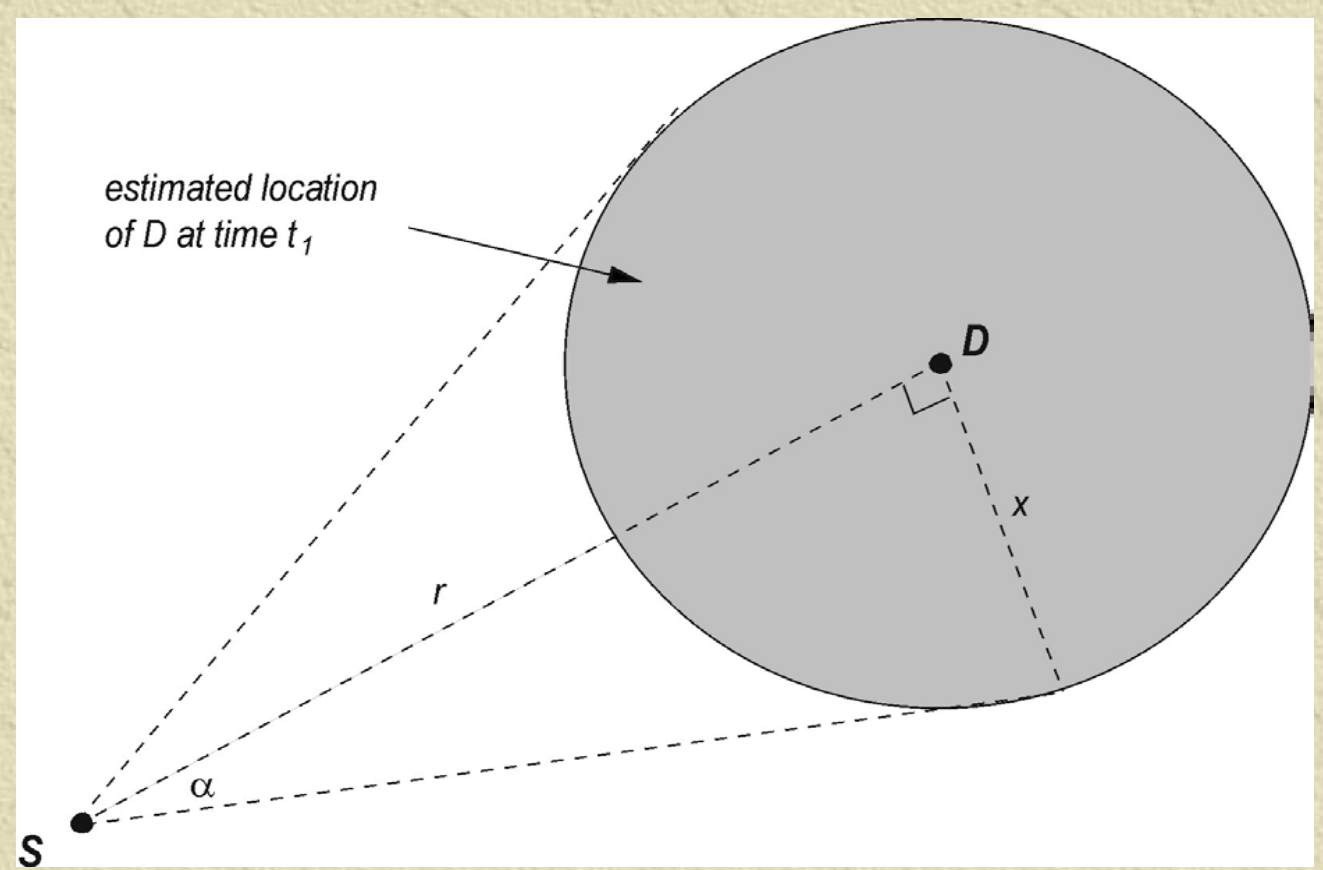
DREAM: Rate of updates

- Triggered by the mobility of the nodes
- The faster the node the more updates it sends
- A plus: slow moving nodes impose little overhead

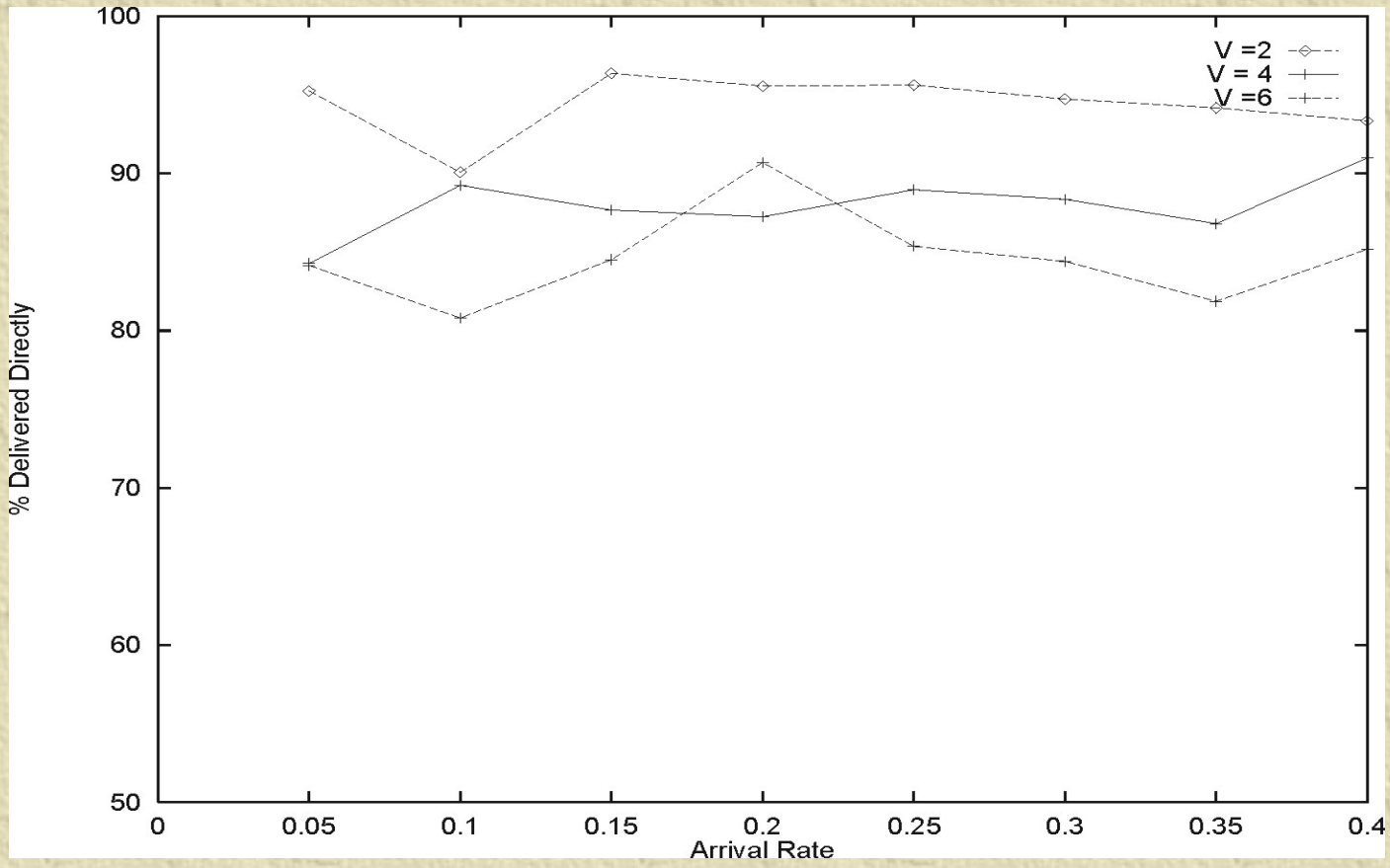
DREAM: Directional Routing

- Source S determines the location of destination D at time t_0 based on its location table
- Based on the current time t_1 and t_0 S determine the area in which D can be find (hence, D's direction)
- S transmit the data packet to all its neighbors in D's direction
- Each neighbor does the same till D is reached

DREAM: Routing a Data Packet



DREAM: Experiments



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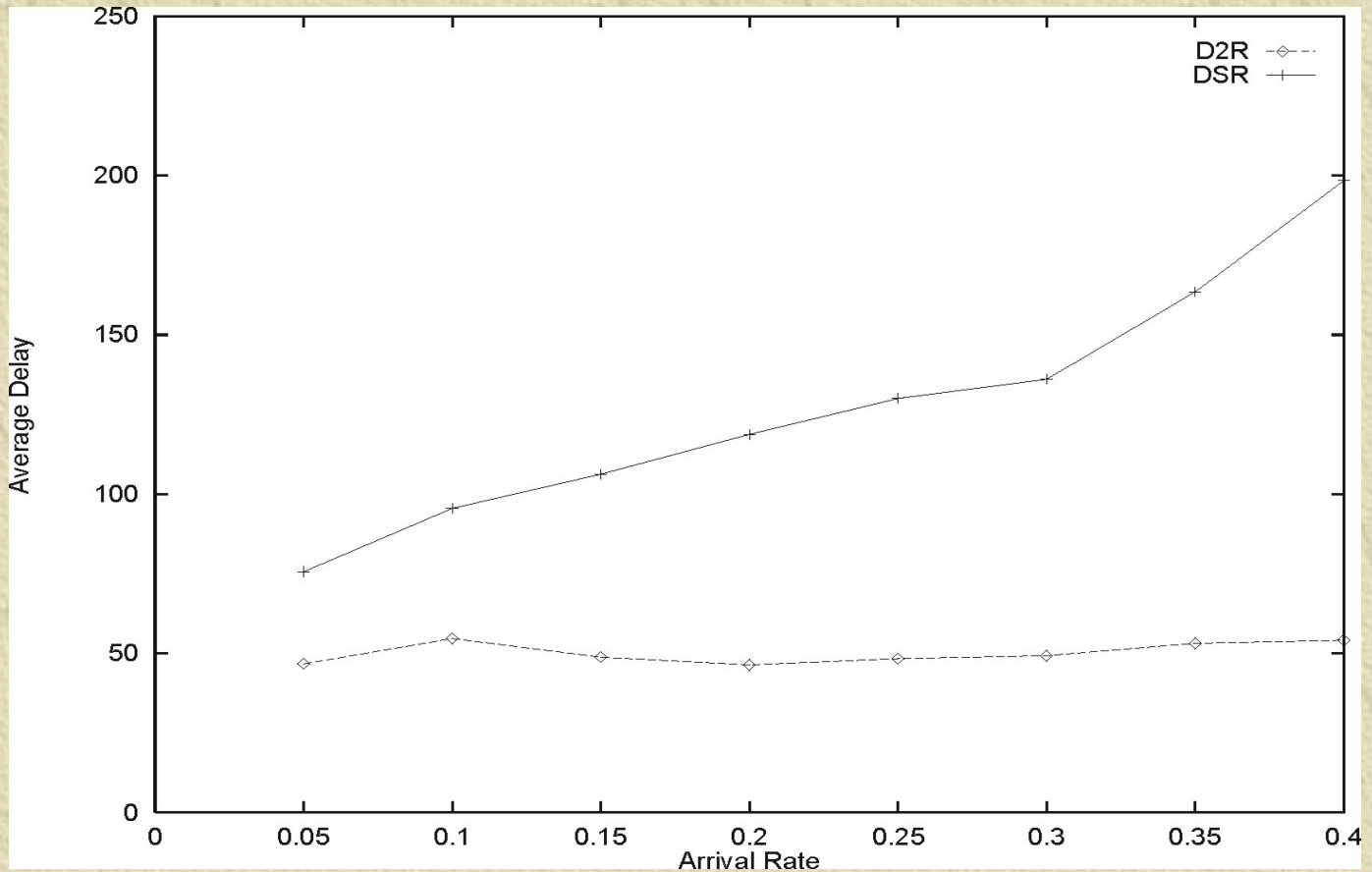


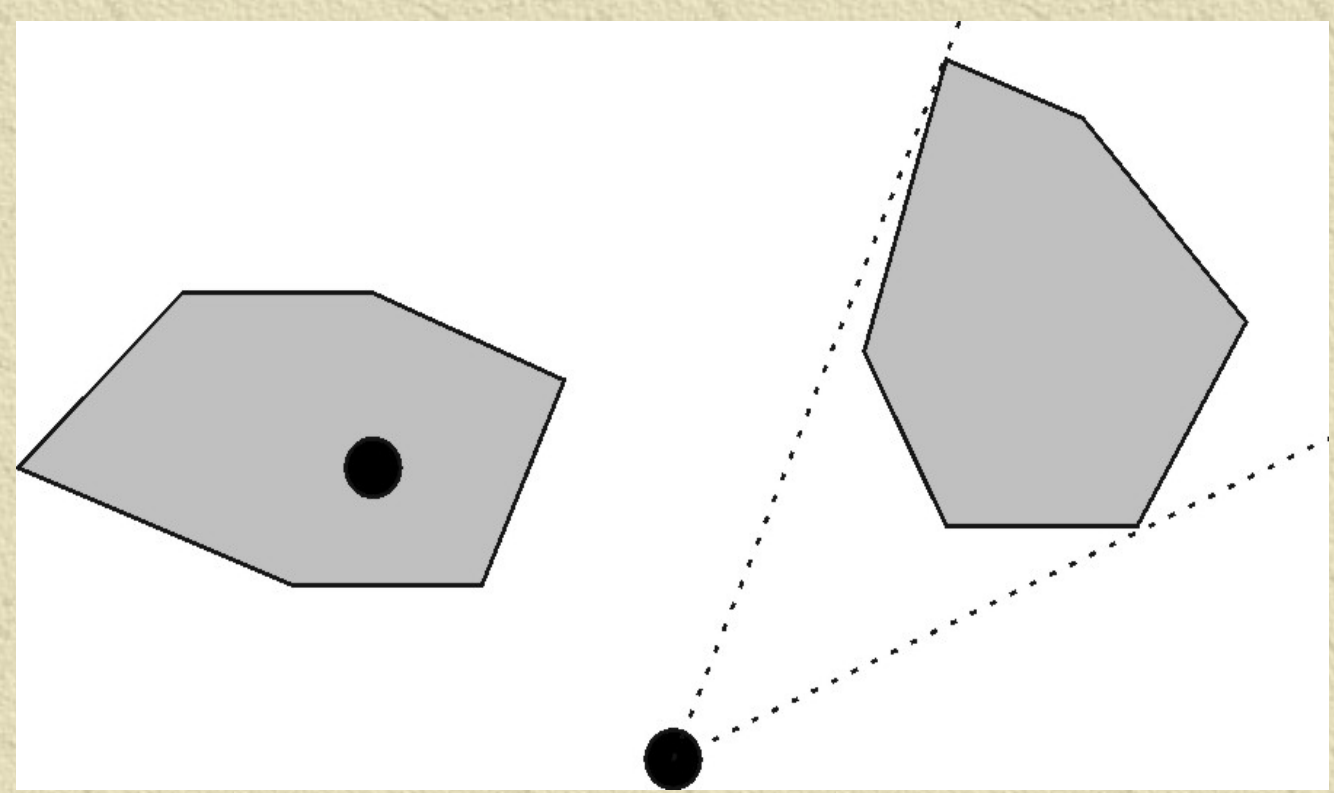
DREAM: Strengths

- First of its kind: after us, the deluge!
- Robustness: multiple routes to the destination
- Energy efficient management of control information

Geographic Messaging

- Messages from source S have to reach nodes in a given geographic area A
- Based on its current position S determines the direction of A
- Messages are sent in that direction
- Propagation of packets is naturally stopped when they reach A boundaries

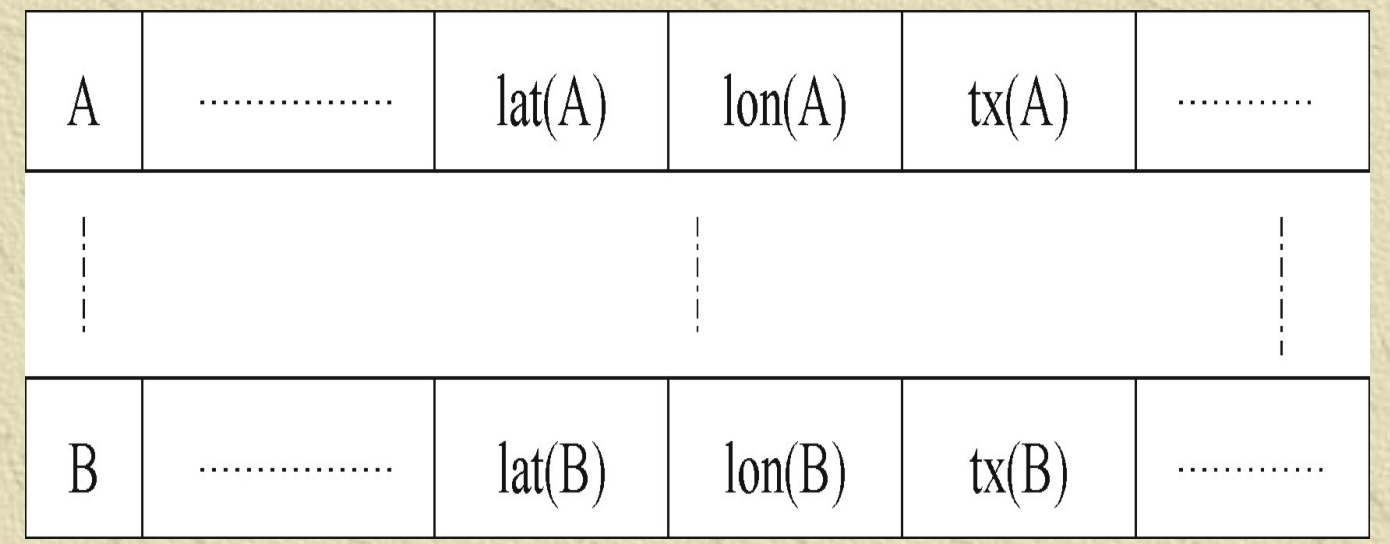
Geographic Messaging



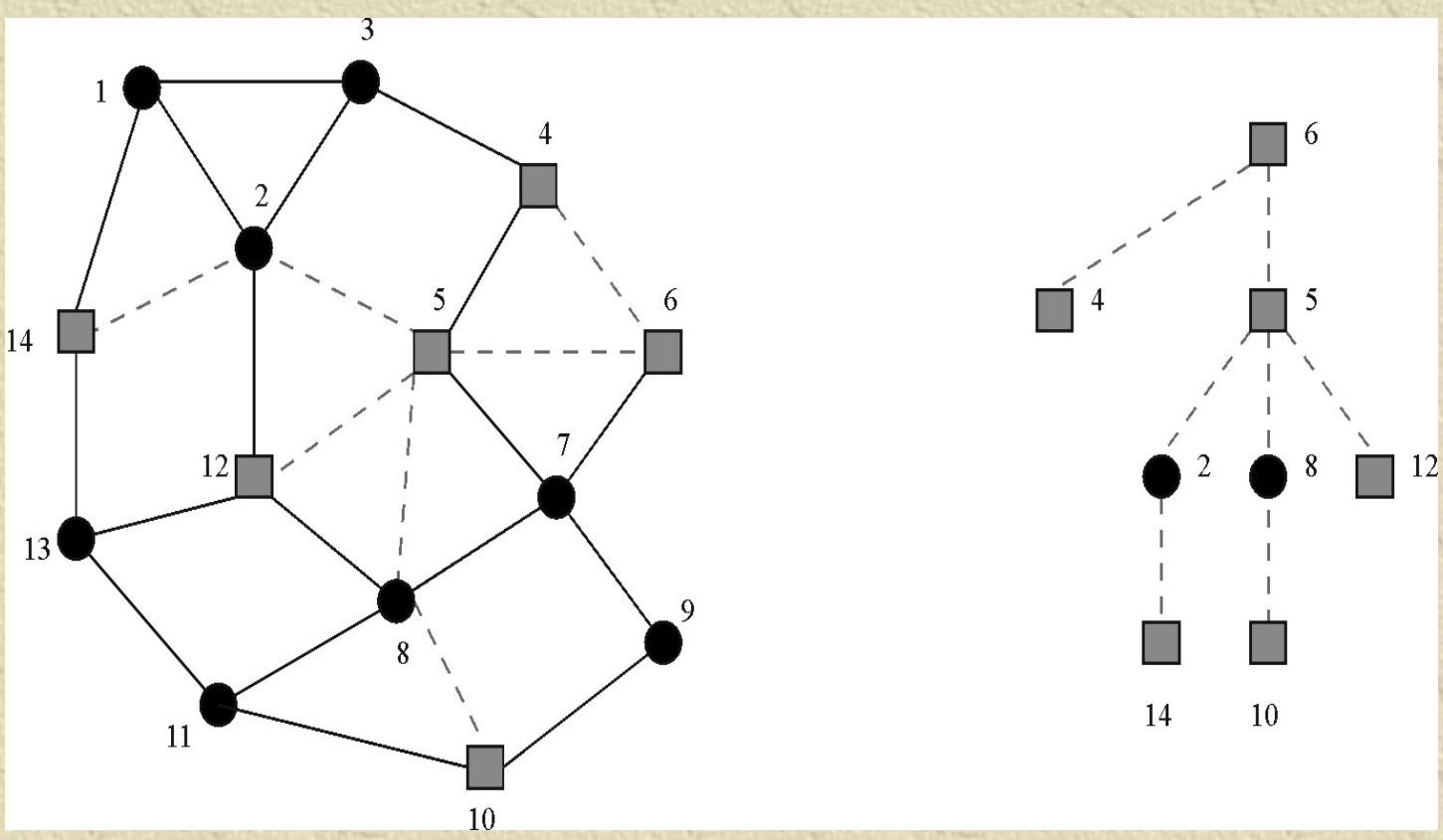
Source Multipoint Communication

- Location packets carry a node transmission range (plus something else, maybe)
- Based on its location table, source S construct (maintain) a snapshot of the network topology graph (NTG)
- On the NTG routes (simple routes or trees) are computed (locally!)
- Routes are (efficiently) piggybacked to the packets

Source Multipoint Communication: Location Packets



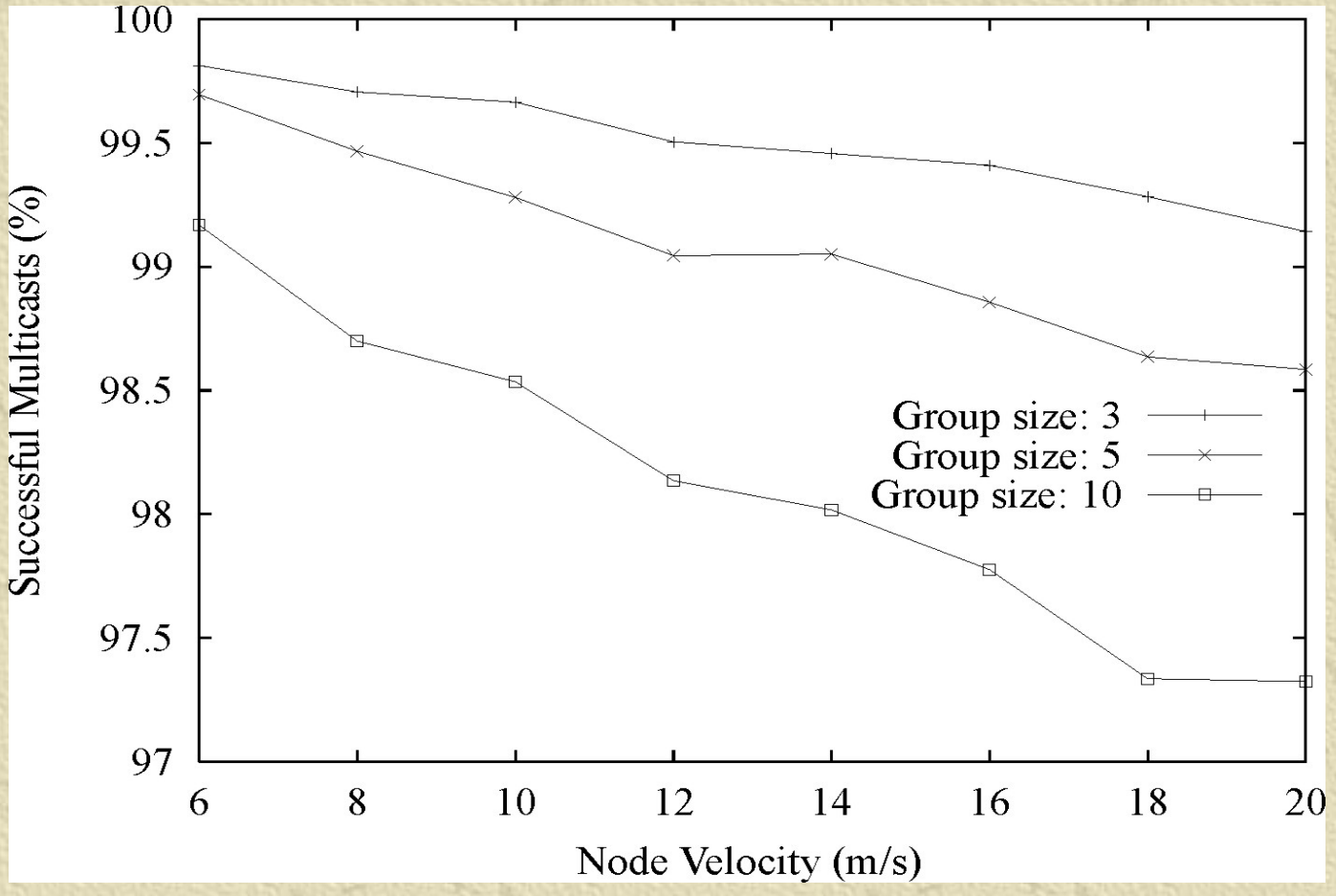
Dynamic Source Multicast (DSM)



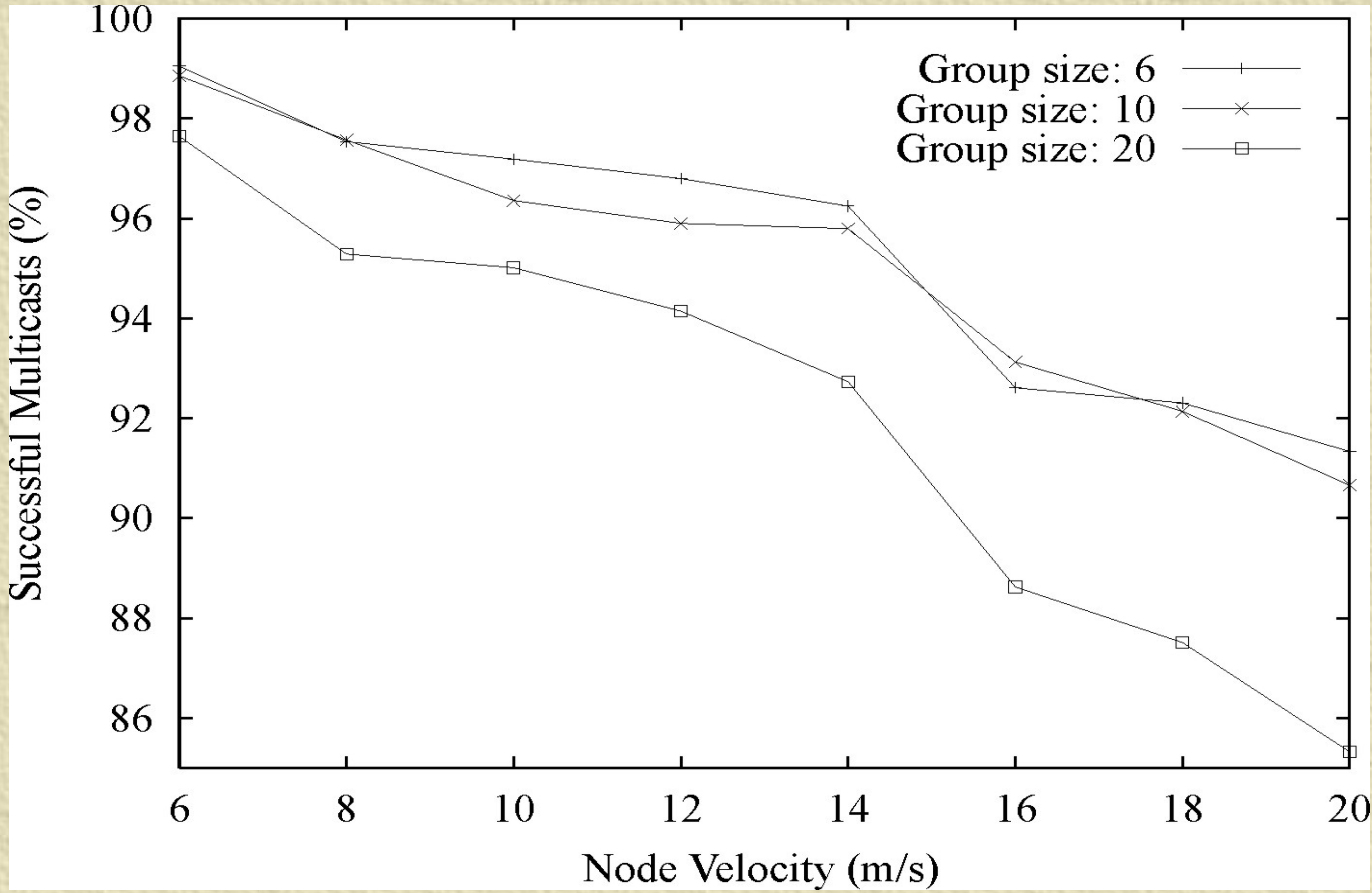
Dynamic Source Multicast and Broadcast: Coding Trees

- Unique method for coding trees locally computed: Prufer sequences
- A multicast tree with $j < n$ nodes requires a Prufer sequence of $j-2$ node identifiers
- No “space overhead” with respect to source routing
- Headers decrease as data packets get closer to the destinations

DSM: Experiments



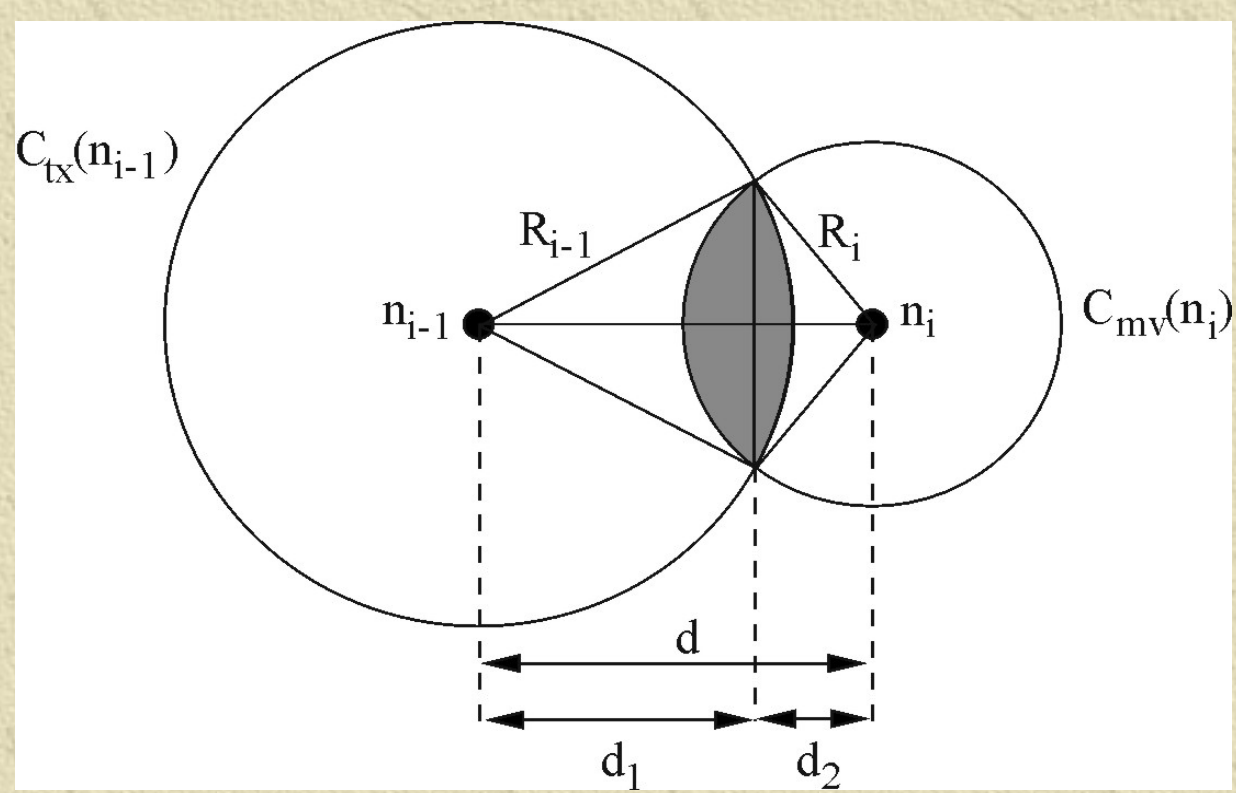
DSM: Experiments



Route Availability

- Based on local computation of the network topology graph
- Given the area of residence of the destination and intermediate nodes, for each route we define the probability of that route to be available for packet
- Multiple routes can be computed and the more convenient chosen

Route Availability



What now: Scalability and Security Issues for DREAM-like Protocols

- Location aware protocol offer potentially less problem for scalability, since only the location of the destination is needed, and not the identity or the location of intermediate nodes

- Efficient dissemination of TEKs (traffic encryption keys) can be implemented via location aware routing and “clustering”

Summary

- Location awareness for multipoint communication and route availability
- Efficient dissemination of location information
- Directional routing, geographic messaging, source multipoint communication protocols and protocols for route selection

Publications

- Efficient broadcast:
  - Basagni, Bruschi, Chlamtac, IEEE transaction on networking, 1999.
  - Basagni, Myers, Syrotiuk, IEEE symposium on emerging technologies, Richardson, TX, 1999.
- DREAM:
  - Basagni, Chlamtac, Syrotiuk, Woodward, ACM MobiCom'98, Dallas, TX 1998

Publications

- Geographic messaging:
  - Basagni, Chlamtac, Syrotiuk, 49th IEEE VTC, Houston, TX, 1999.
- Location aware multipoint communication:
  - Basagni, Chlamtac, Syrotiuk, Computer Networks, 2001.
  - Basagni, Chlamtac, Syrotiuk, IEEE WCNC 1999, New Orleans LA, 1999.

Publications

- (Location-aware multipoint comm., Cont.)
  - Basagni, Chlamtac, Syrotiuk, IEEE VTC spring 2000, Tokio, Japan, 2000.
  - Basagni, Chlamtac, Syrotiuk, Talebi, IEEE WCNC 2000, Chicago, IL, 2000.
- Route availability
  - Basagni, Chlamtac, Syrotiuk, Talebi, IEEE MoMuC 1999, San Diego, 1999.