



# Location Aware Communication Protocols for Ad Hoc Networks

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Notes for ECE 3656 (Winter 03)

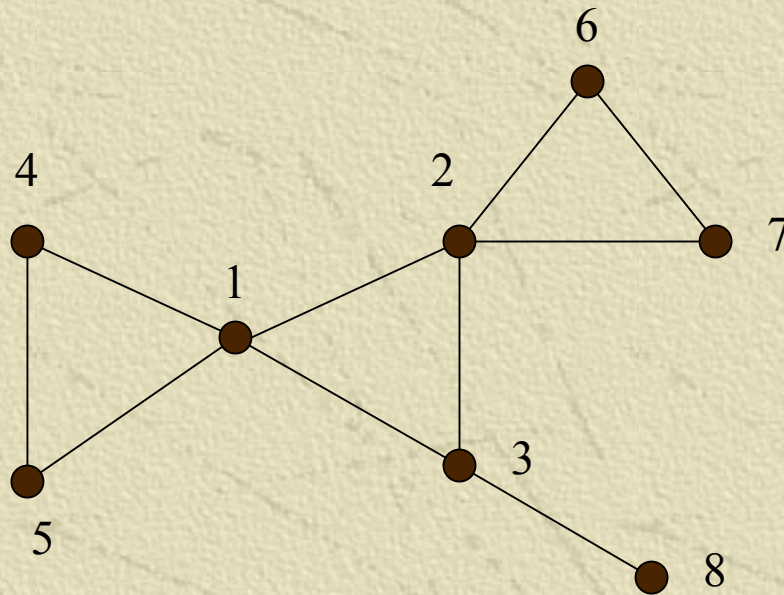
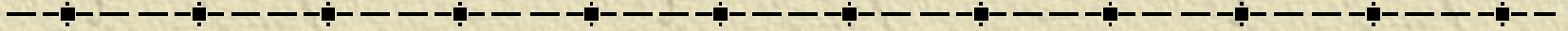
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# Ad Hoc Networks

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- ✦ 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

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- ✦ 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

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- ✦ 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

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- ✦ 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

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- ✦ 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

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- ✦ 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

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- ✦ 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

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- ✦ 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

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- ✦ 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

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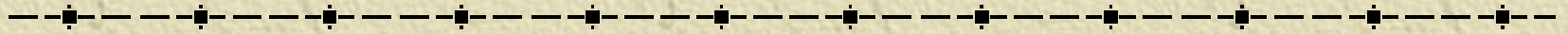
- ✦ Distance routing effect algorithm for mobility [Basagni+, 1998]
- ✦ A proactive, effective way to spread location information
- ✦ Directional routing

# DREAM: Disseminating Location Information. Problems.

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- ✦ 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.

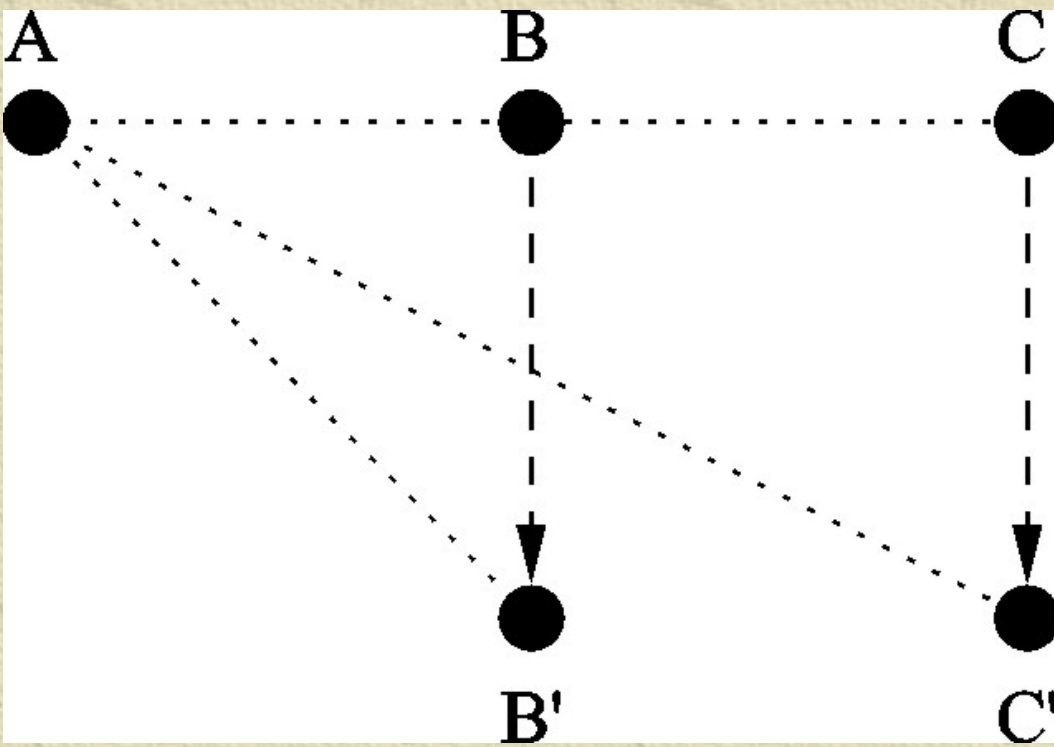
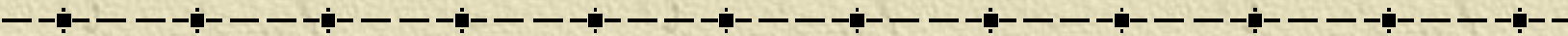


✦ Mobility-adaptive, deterministic broadcast

✦ Distance effect

✦ Rate of updates is bound to the mobility of the node

# The Distance Effect



# The Distance Effect

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- ✦ “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

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✦ Triggered by the mobility of the nodes

✦ The faster the node the more updates it sends

✦ A plus: slow moving nodes impose little overhead

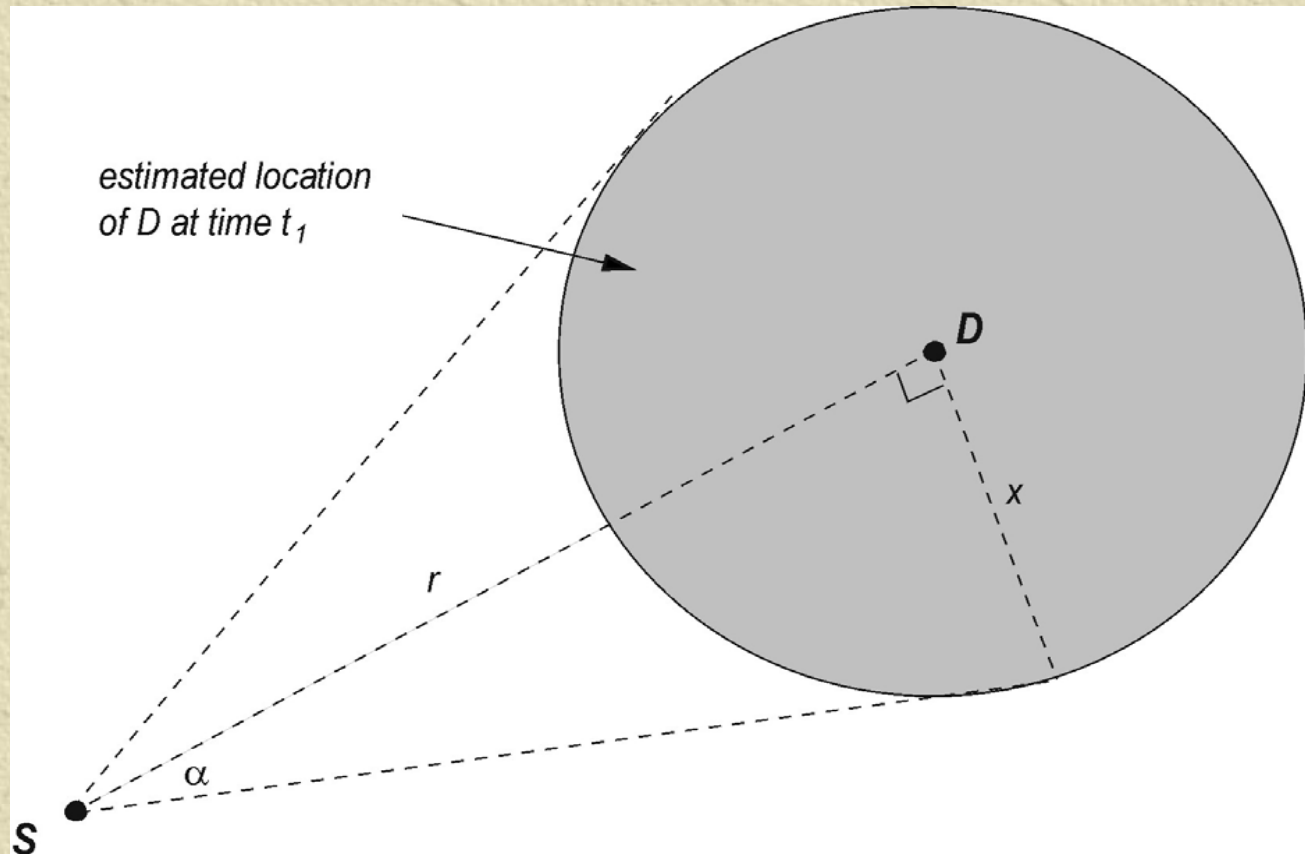
# DREAM: Directional Routing

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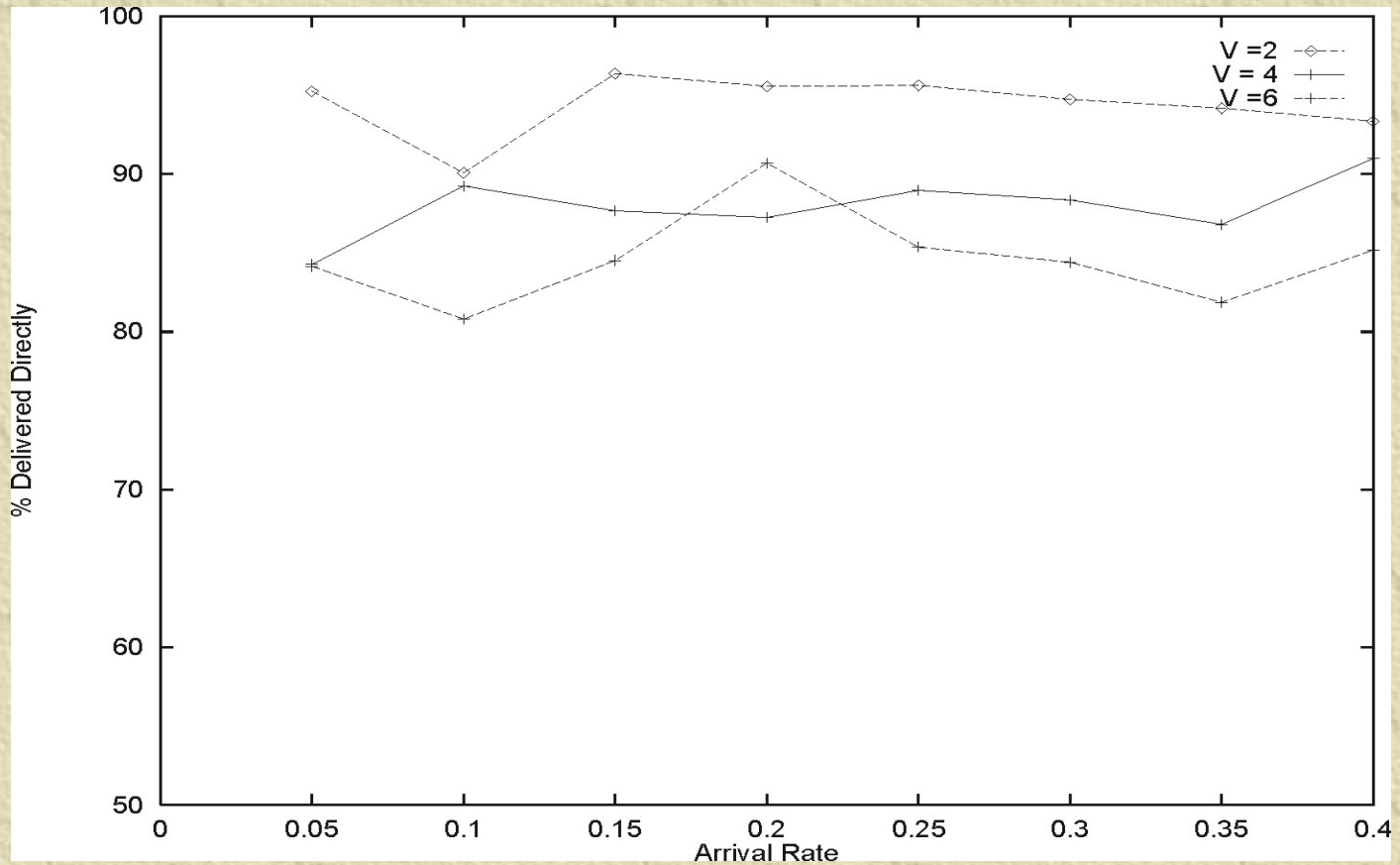
- ✦ Source S determines the location of destination D at time  $t_0$  based on its location table
- ✦ Based on the current time  $t_1$  and  $t_0$  S determine the area in which D can be find (hence, D's direction)
- ✦ S transmit the data packet to all its neighbors in D's direction
- ✦ Each neighbor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

# DREAM: Routing a Data Packet

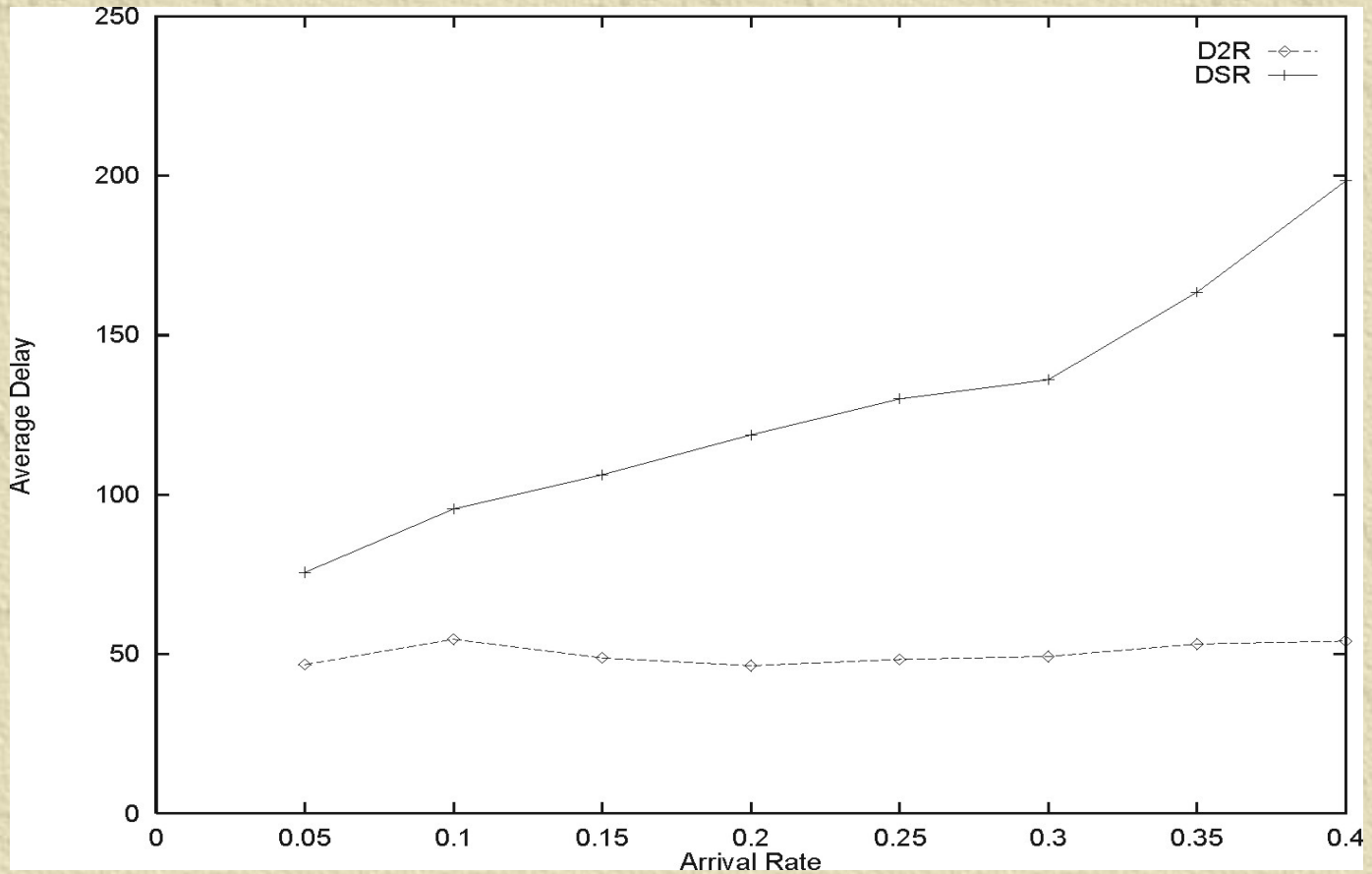
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# DREAM: Experiments



# DREAM: Experiments



# DREAM: Strengths

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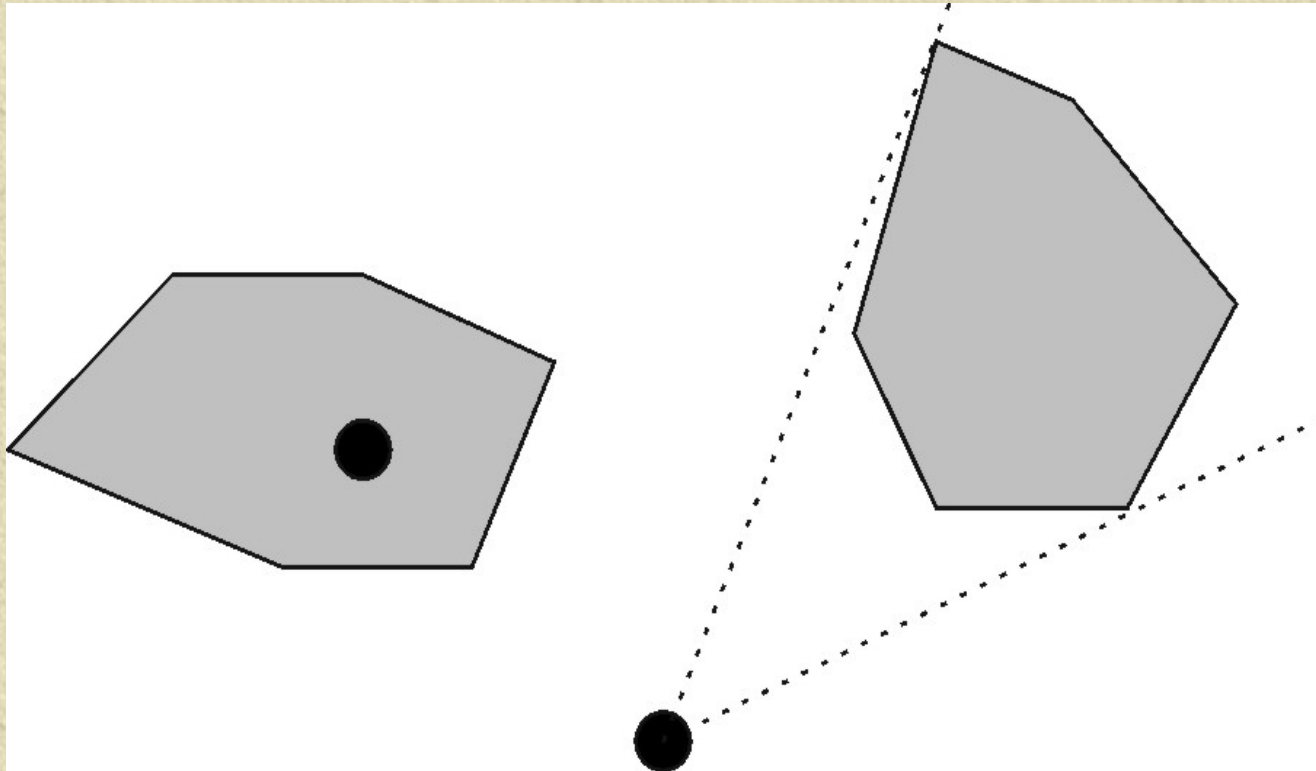
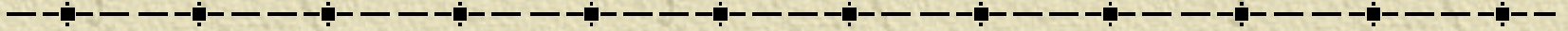
- ✦ First of its kind: after us, the deluge!
- ✦ Robustness: multiple routes to the destination
- ✦ Energy efficient management of control information

# Geographic Messaging

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- ✦ 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

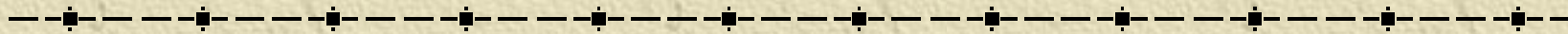




# Source Multipoint Communication

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- ✦ 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



A	.....	lat(A)	lon(A)	tx(A)	.....
⋮					⋮
B	.....	lat(B)	lon(B)	tx(B)	.....

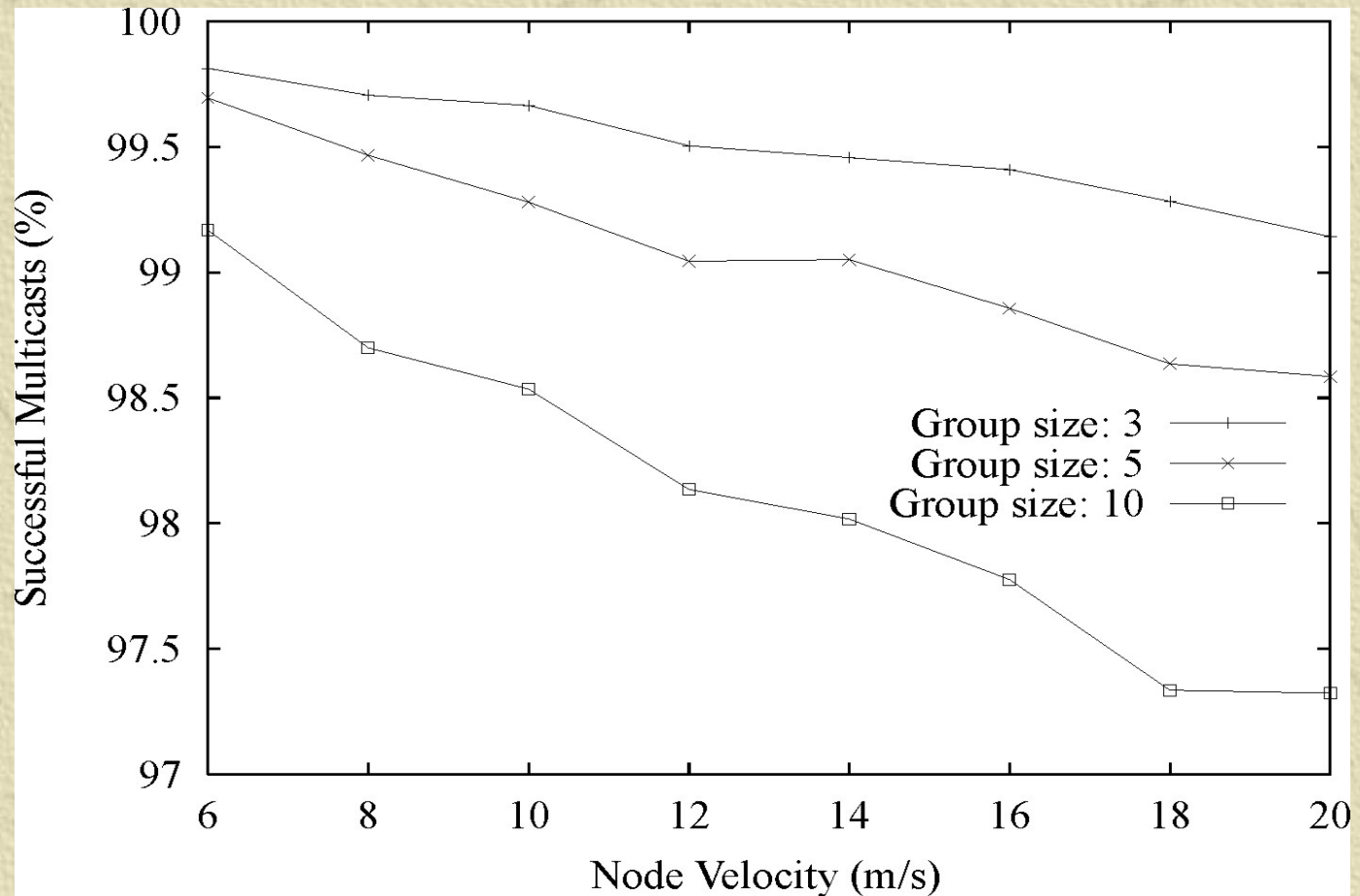


# Dynamic Source Multicast and Broadcast: Coding Trees

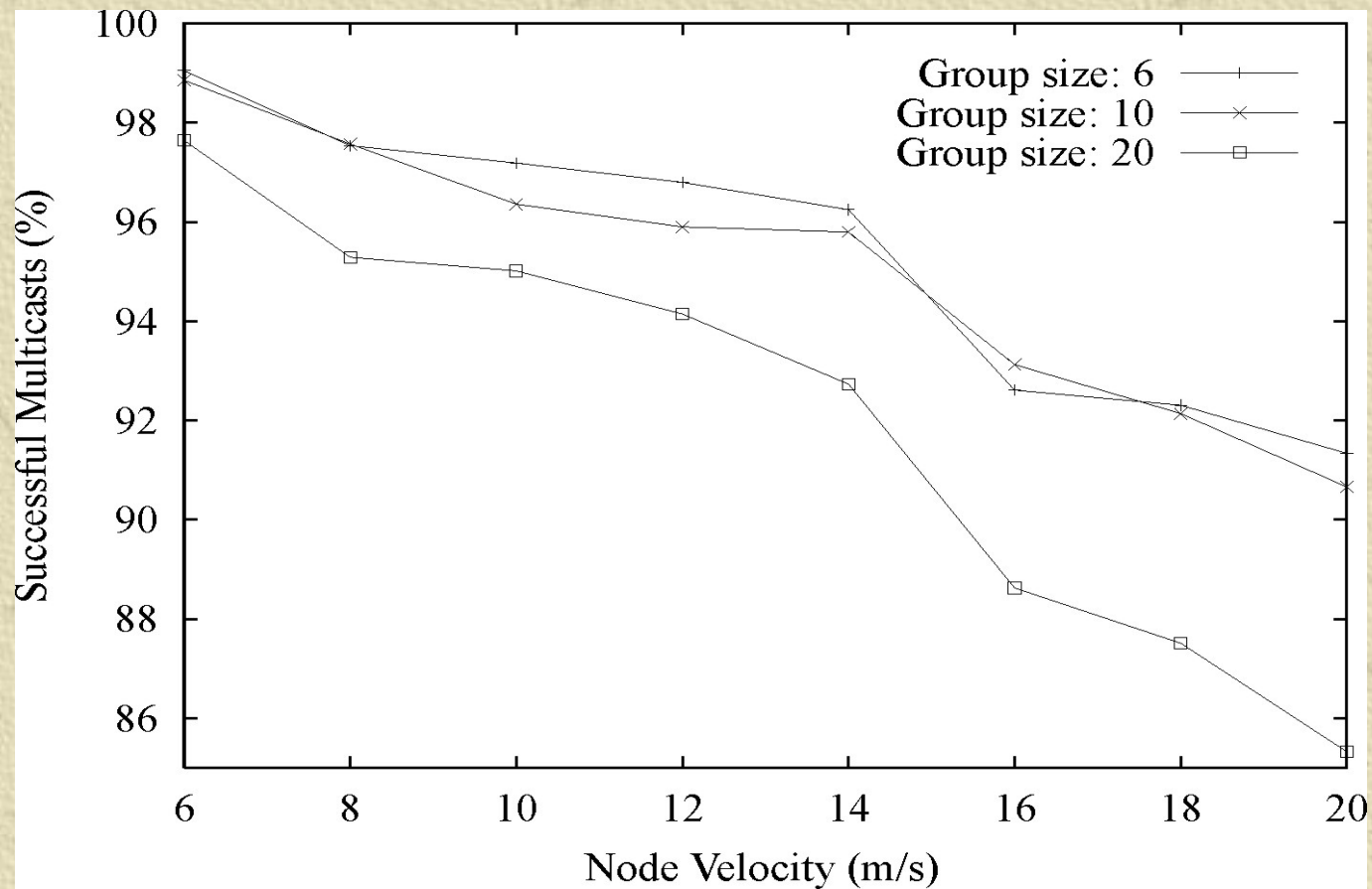
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- ✦ Unique method for coding trees locally computed: Prufer sequences
- ✦ A multicast tree with  $j < n$  nodes requires a Prufer sequence of  $j-2$  node identifiers
- ✦ No “space overhead” with respect to source routing
- ✦ Headers decrease as data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

# DSM: Experiments



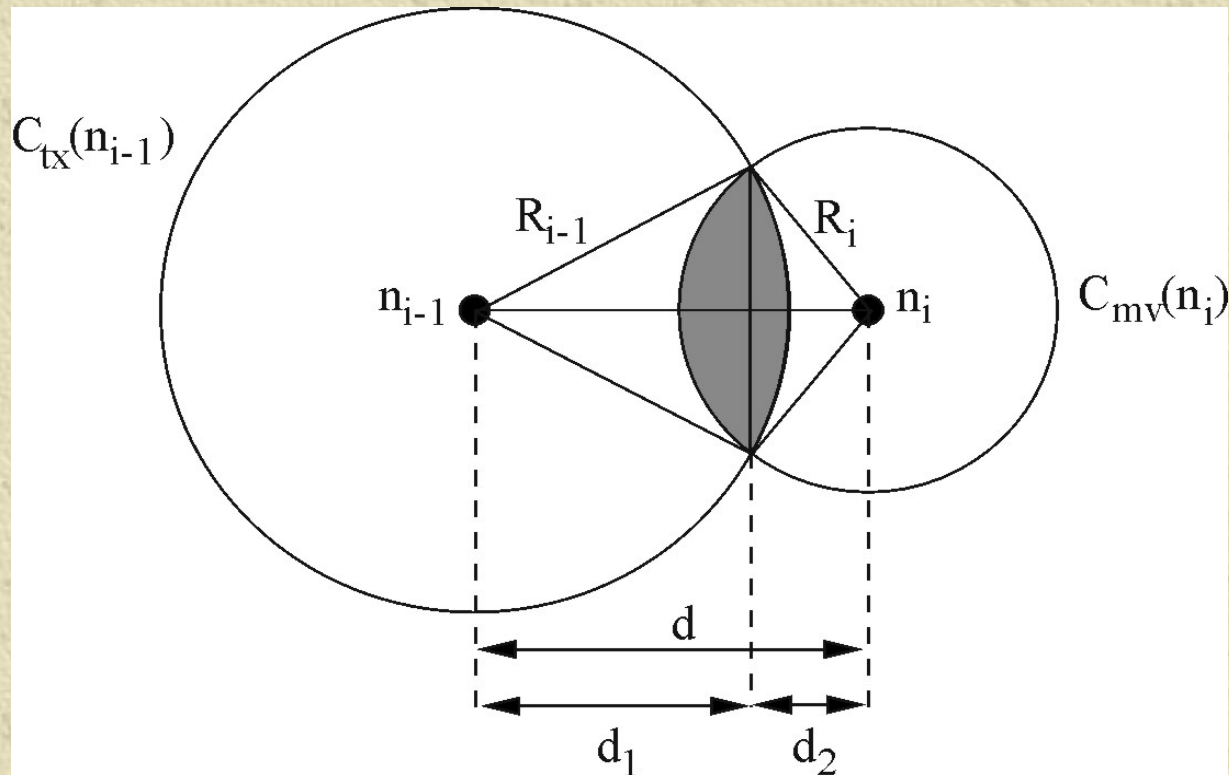
# DSM: Experiments



# Route Availability

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- ✦ 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

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- ✦ 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

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- ✦ 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

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## ✦ 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

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## ✦ Geographic messaging:

- ✦ Basagni, Chlamtac, Syrotiuk, 49<sup>th</sup> 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

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## ✦ (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.