On-Demand Routing Protocols

- Routes are established “on demand” as requested by the source
- Only the active routes are maintained by each node
- Channel/Memory overhead is minimized
- Two leading methods for route discovery: source routing and backward learning (similar to LAN interconnection routing)

On Demand Routing - Readings

- D. B. Johnson and D. A. Maltz, "Dynamic Source Routing in Ad-Hoc Wireless Networks," Mobile Computing, 1994.

  Charles E. Perkins and Elizabeth M. Royer. "Ad hoc On-Demand Distance Vector Routing." Proceedings of the 2nd IEEE Workshop on Mobile Computing Systems and Applications, New Orleans, LA, February 1999, pp. 90-100.

Existing On-Demand Protocols

- Dynamic Source Routing (DSR)
- Associativity-Based Routing (ABR)
- Ad-hoc On-demand Distance Vector (AODV)
- Temporarily Ordered Routing Algorithm (TORA)
- Zone Routing Protocol (ZRP)
- Signal Stability Based Adaptive Routing (SSA)
- On Demand Multicast Routing Protocol (ODMRP)

Dynamic Source Routing (DSR)

- **Forwarding: *source route* driven instead of hop-by-hop route table driven**
- **No periodic routing update message is sent**
- **The first path discovered is selected as the route**
- **Two main phases**
  - ***Route Discovery***
  - ***Route Maintenance***

DSR - Route Discovery

- **To establish a route, the source floods a *Route Request* message with a unique request ID**
- **The *Route Request* packet "picks up" the node ID numbers**
- ***Route Reply* message containing path information is sent back to the source either by**
  - the destination, or
  - intermediate nodes that have a route to the destination
- **Each node maintains a *Route Cache* which records routes it has learned and overheard over time**

DSR - Route Maintenance

- Route maintenance performed only while route is in use
- Monitors the validity of existing routes by *passively* listening to acknowledgments of data packets transmitted to neighboring nodes
- When problem detected, send *Route Error* packet to original sender to perform new route discovery

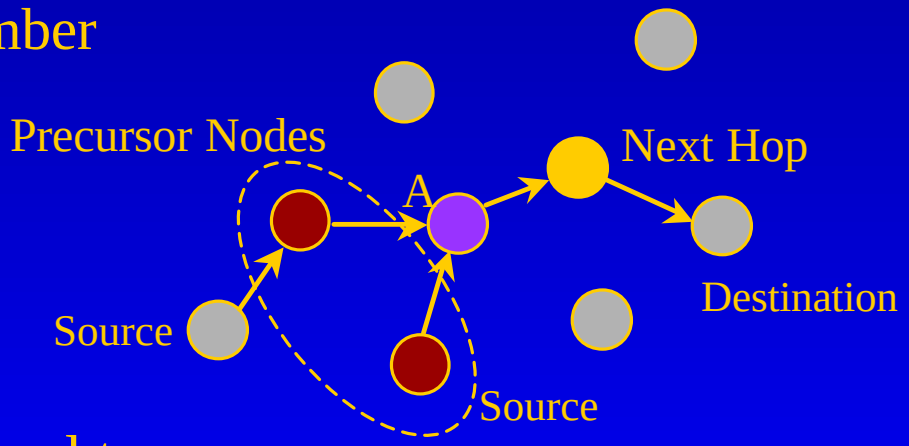
Ad hoc On-Demand Distance Vector Routing (AODV)

- **Primary Objectives**
  - Provide unicast, broadcast, and multicast capability
  - Initiate forward route discovery only on demand
  - Disseminate changes in local connectivity to those neighboring nodes likely to need the information
- **Characteristics**
  - *On-demand* route creation
    - Effect of topology changes is localized
    - Control traffic is minimized
  - Two dimensional routing metric: <*Seq#, HopCount*>
  - Storage of routes in Route Table

Route Table

- Fields:
  - Destination IP Address
  - Destination Sequence Number
  - HopCount
  - Next Hop IP Address
  - Precursor Nodes
  - Expiration Time
- Each time a route entry is used to transmit data, the expiration time is updated to

  current_time + **active_route_timeout**

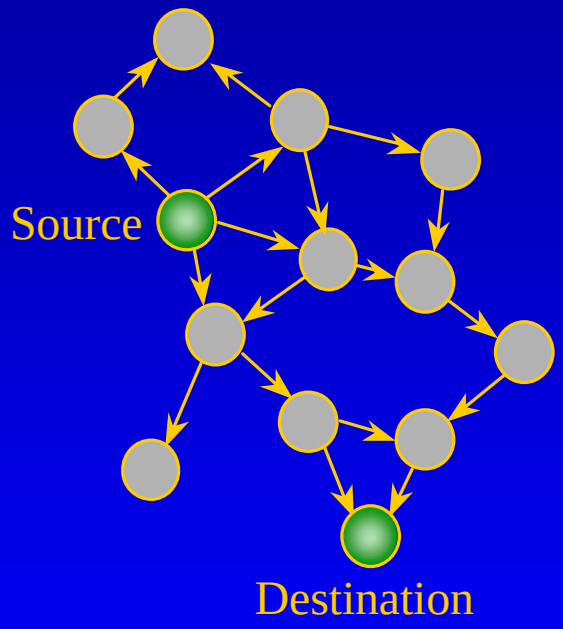


Unicast Route Discovery

- Source broadcasts *Route Request* (RREQ)

  <Flags, Bcast_ID, HopCnt, Src_Addr, Src_Seq#, Dst_Addr, Dst_Seq#>

- Node can reply to RREQ if
  - It is the destination, or
  - It has a "fresh enough" route to the destination
- Otherwise it rebroadcasts the request
- Nodes create *reverse route* entry
- Record Src IP Addr / Broadcast ID to prevent multiple rebroadcasts



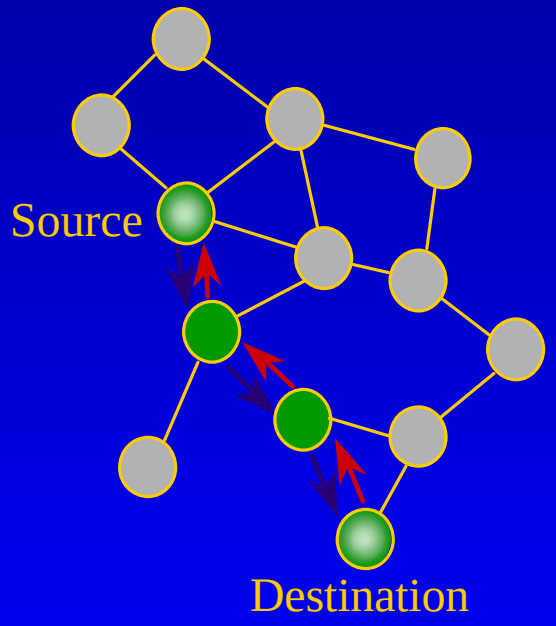
Route Request Propagation

Forward Path Setup

- Destination, or intermediate node with current route to destination, unicasts *Route Reply* (RREP) to source

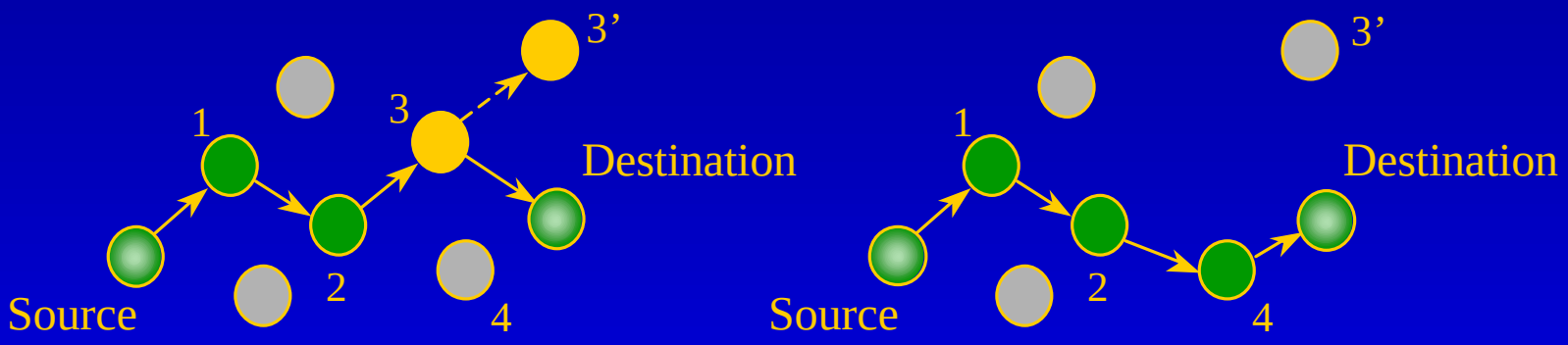
  <Flags, HopCnt, Dst_Addr, Dst_Seq#, Src_Addr, Lifetime>

- Nodes along path create *forward route*
- Source begins sending data when it receives first RREP



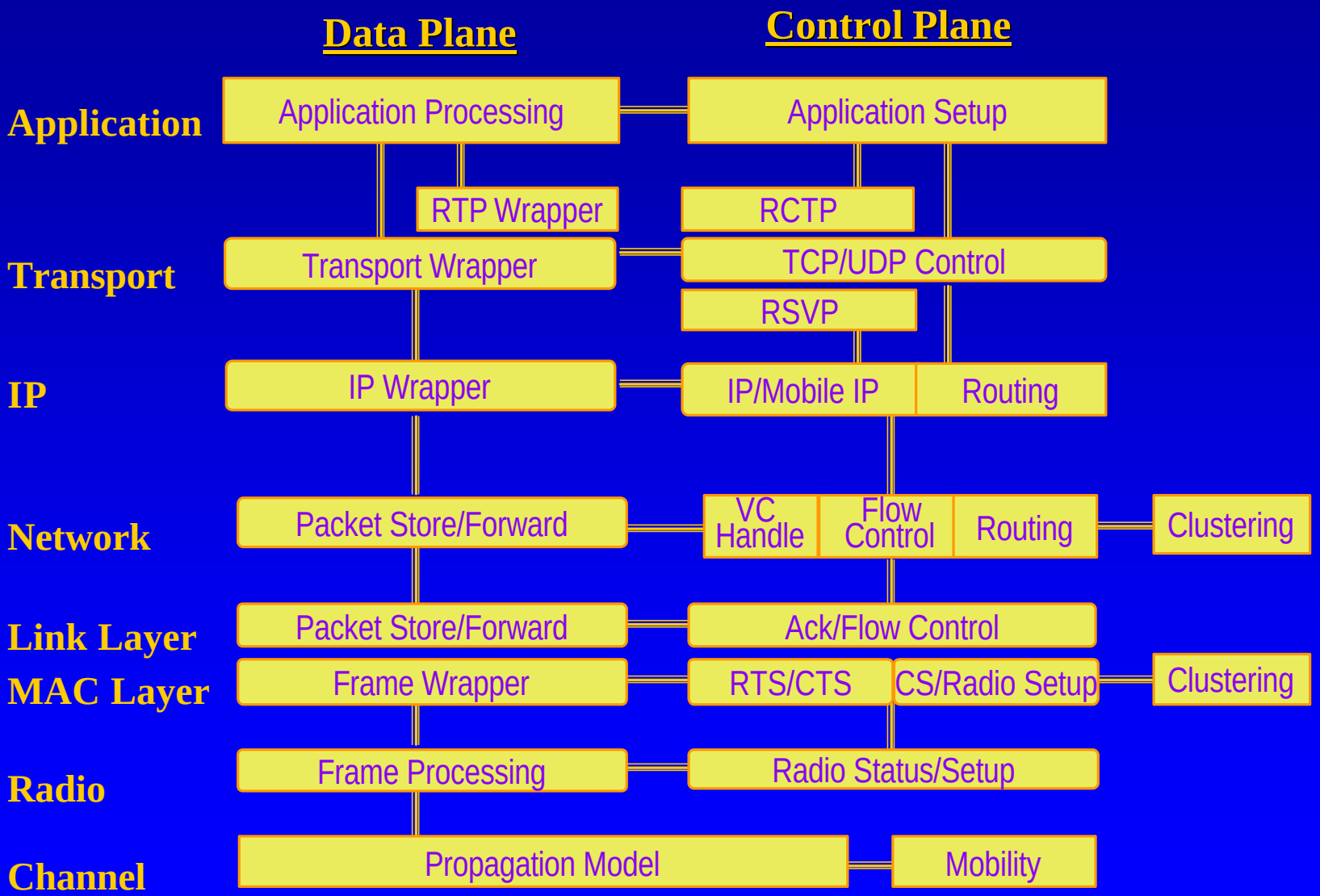
Forward Path Formation

Path Maintenance



- **Movement of nodes not along active path does not trigger protocol action**
- **If source node moves, it can reinitiate route discovery**
- **When destination or intermediate node moves, upstream node of break broadcasts *Route Error* (RERR) message**
- **RERR contains list of all destinations no longer reachable due to link break**
- **RERR propagated until node with no precursors for destination is reached**

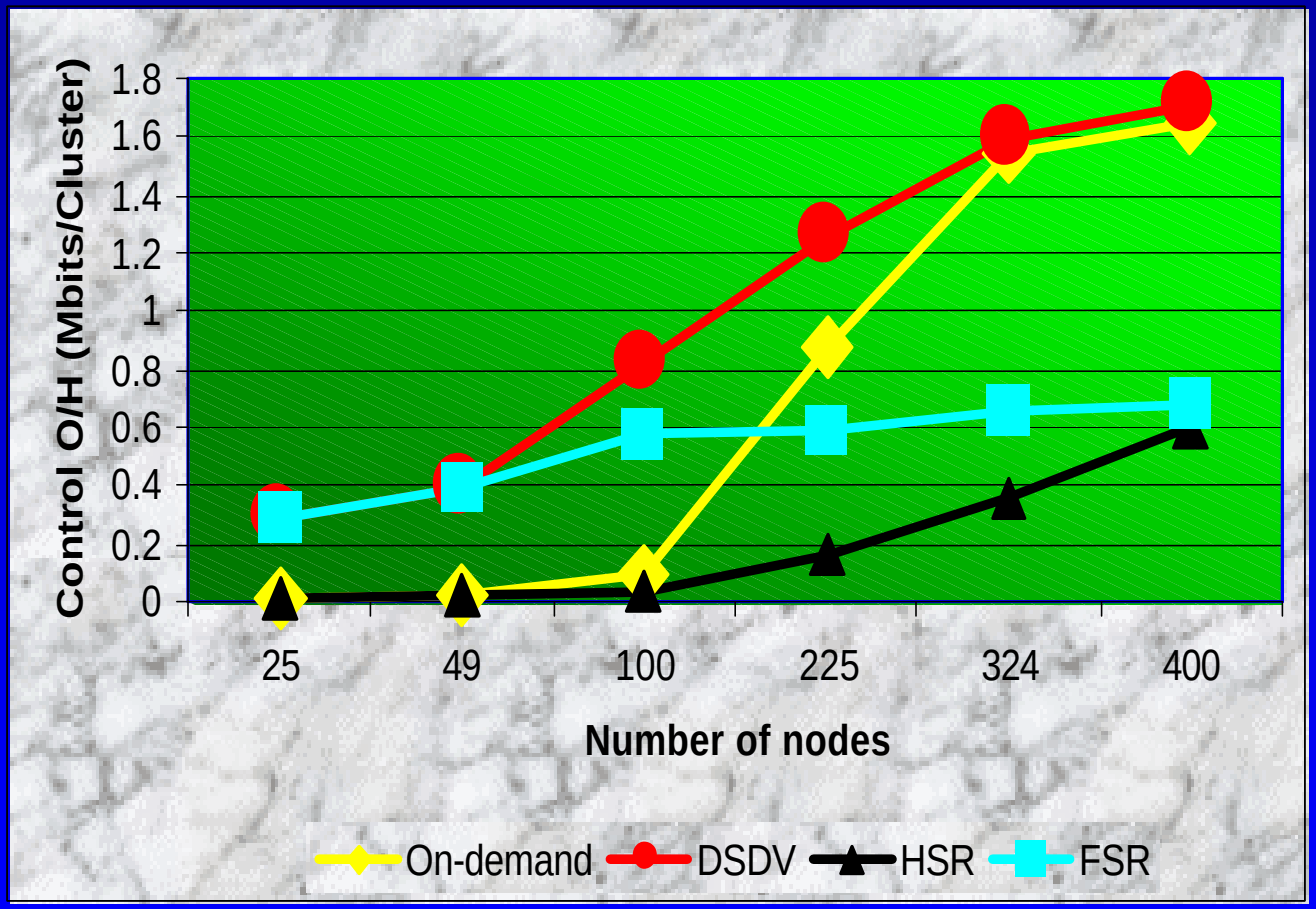
GloMoSim/Qualnet Simulation Layers



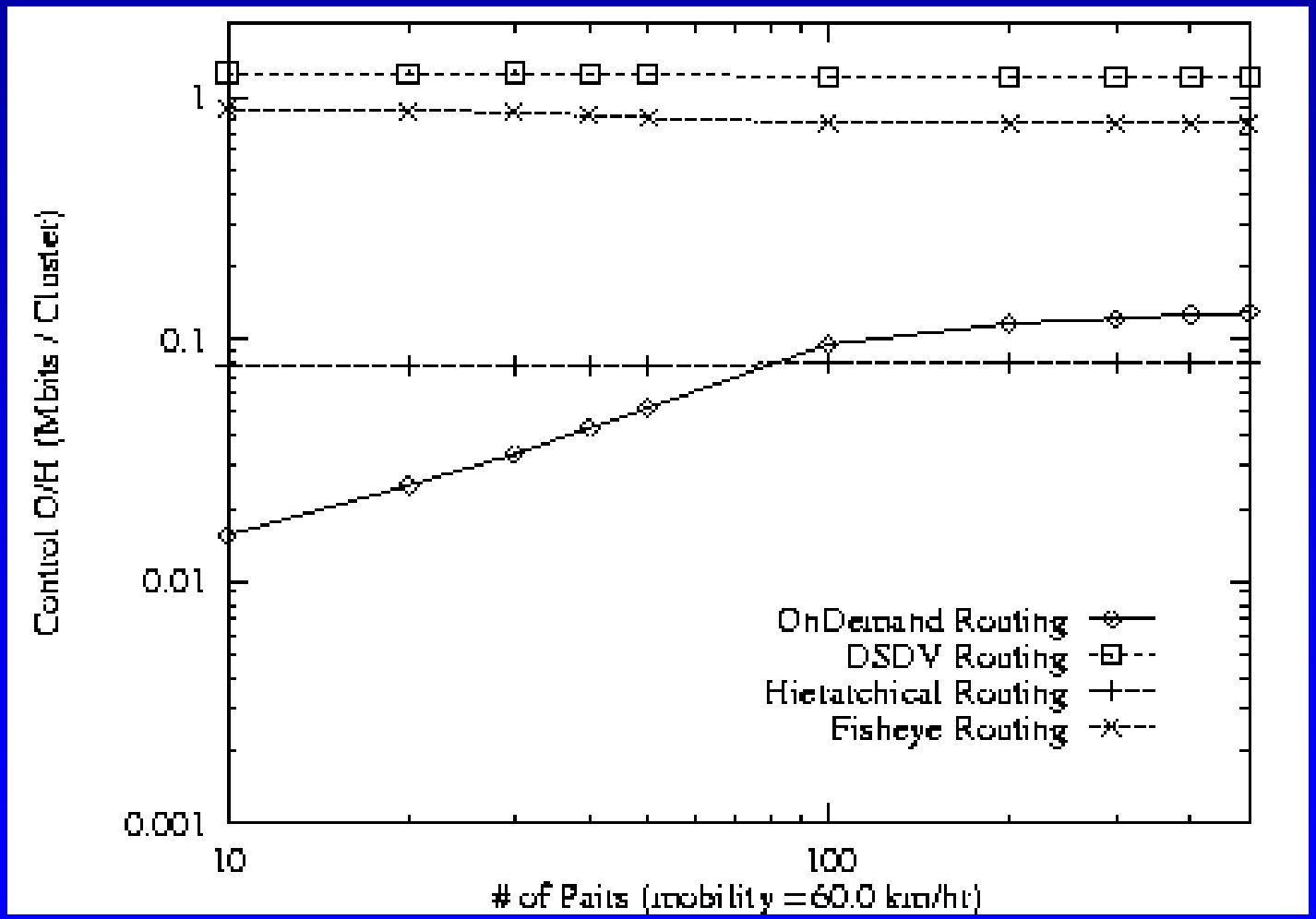
Performance Evaluation Enviroment

- **PARSEC simulation enviroment**
  - 100 nodes
  - 1000mx1000m square area
  - transmission range: 100m
  - channel data rate: 2 Mbps
  - random mobility model
  - UDP traffic between randomly selected node pairs
  - cluster-token MAC layer protocol
- **HSR**
  - 2 level physical partition
  - 1 level logical groupings, number of logical subnets varies with network size
- **FSR**
  - 2 level fisheye scoping
  - fisheye radius is 2 hops

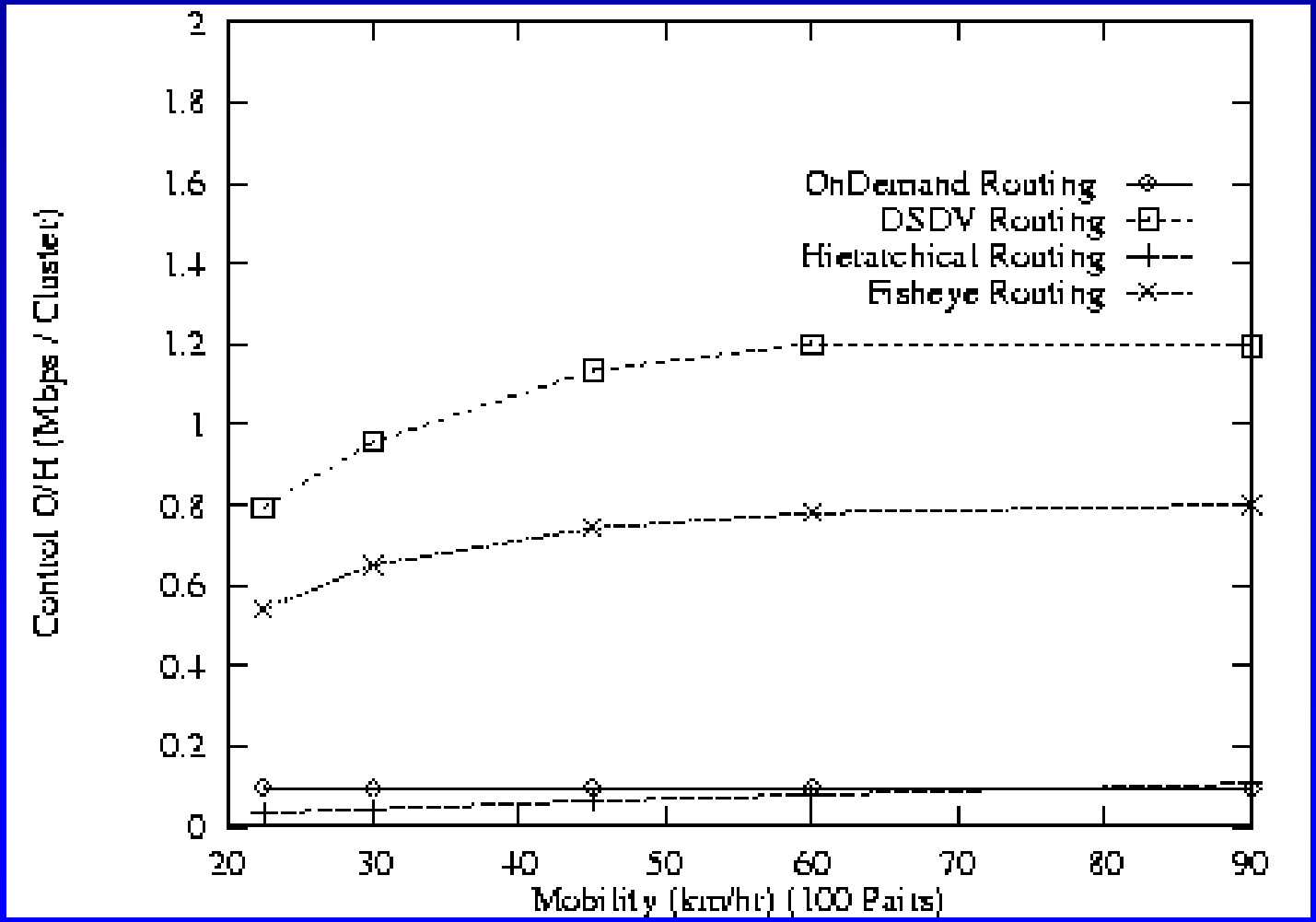
Control O/H vs. number of nodes



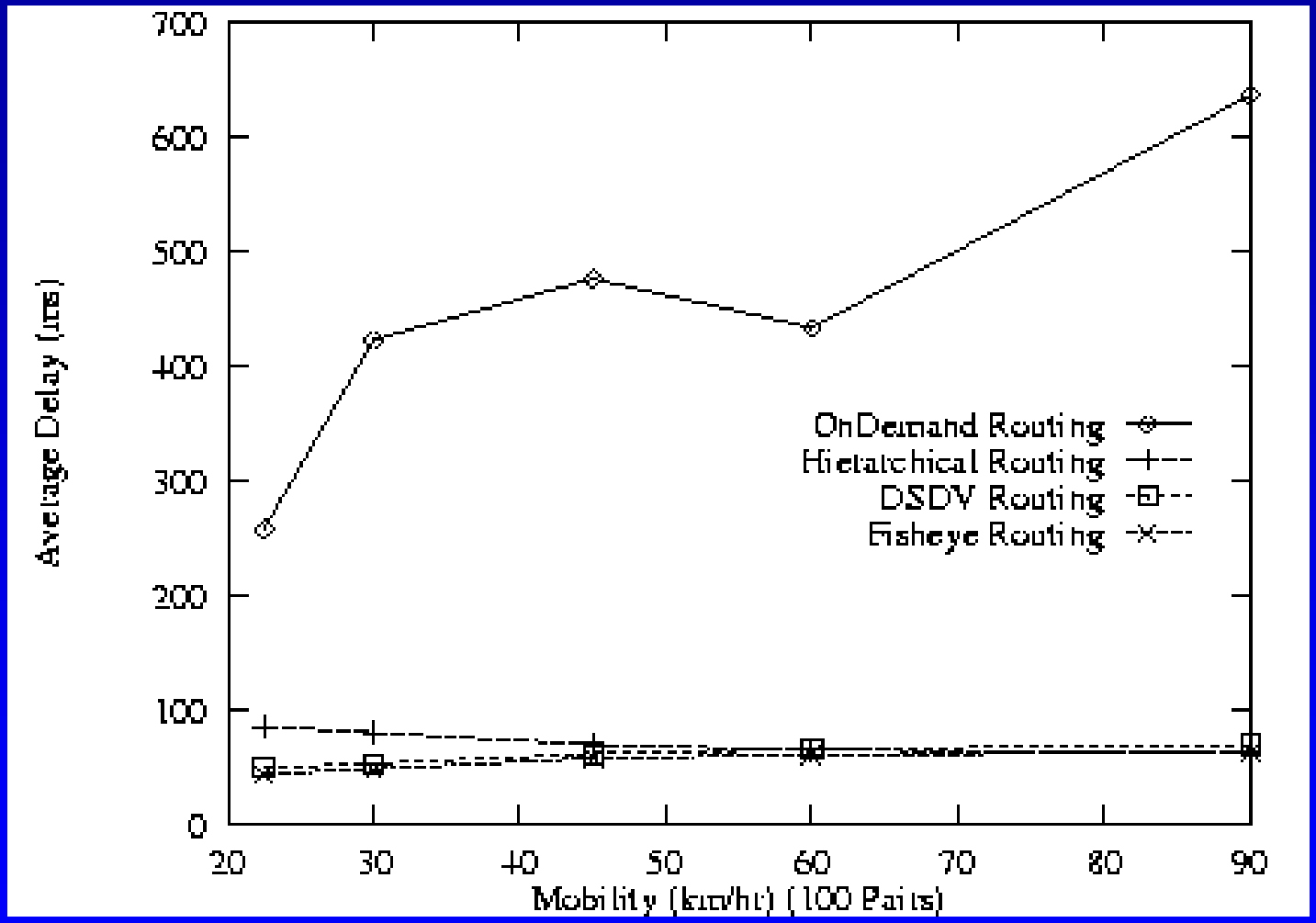
Control O/H vs. Traffic Pairs



Control O/H vs. Mobility (100 pairs)



Average Delay (ms)



Location-Aided Routing (LAR)

- Ko and Vaidya (Texas A & M)
- Location assisted (requires GPS)
- On-demand
- No periodic messages
- LAR works like DSR except it limits the flooded area of *Route Requests* using location information

LAR (cont'd)

- **Scheme 1**
  - The source specifies a *request zone* which includes the source and the area where the destination may reside
  - Nodes within the request zone propagate *Route Requests*
- **Scheme 2**
  - The source specifies the distance between itself and the destination
  - Nodes forward *Route Requests* if their distances to the destination is less than or equal to the distance indicated by the packet

DREAM

- Besagni, *et al.* (U of Texas, Dallas)
- Location assisted (requires GPS)
- Node coordinates (instead of routes) are recorded in the route table
- *Distance Effect*: Send location updates to nearby nodes more frequently
- Location update frequencies are adjusted to mobility rate

DREAM (cont'd)

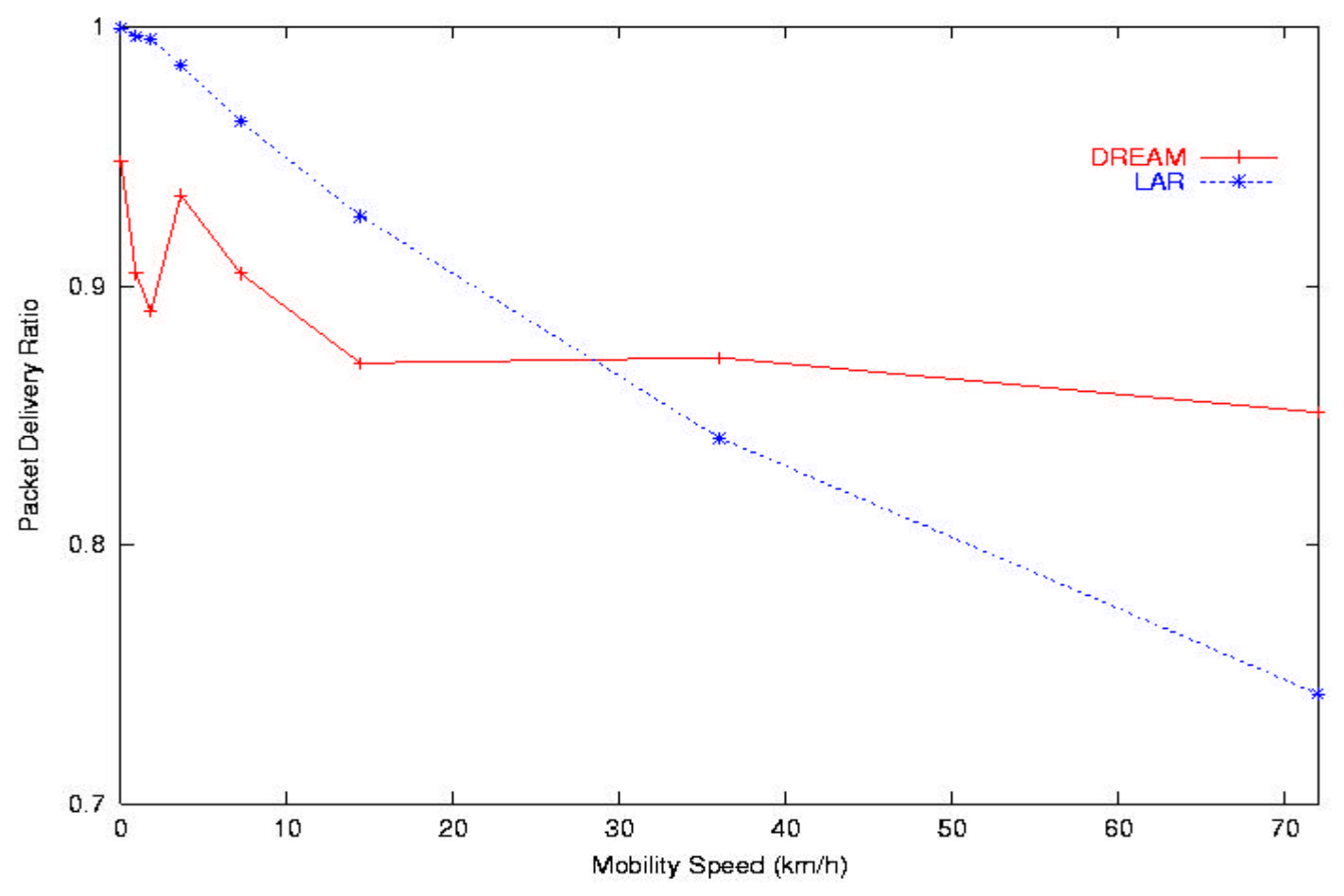
- The source partially floods data to nodes that are in the direction of the destination
- The source specifies possible next hops in the data header using location information
- Next hop nodes select their own list of next hops and include the list into data header
- If the source finds no neighbors in the direction of the destination or has no fresh location information of the destination, data is flooded to the entire network

Location Based Routing Simulation (LAR and DREAM)

- 50 nodes; 750m X 750 m space
- Free space channel propagation model
- Radio with capture ability
- MAC: IEEE 802.11 DCF
- 10 UDP data sessions with constant bit rate

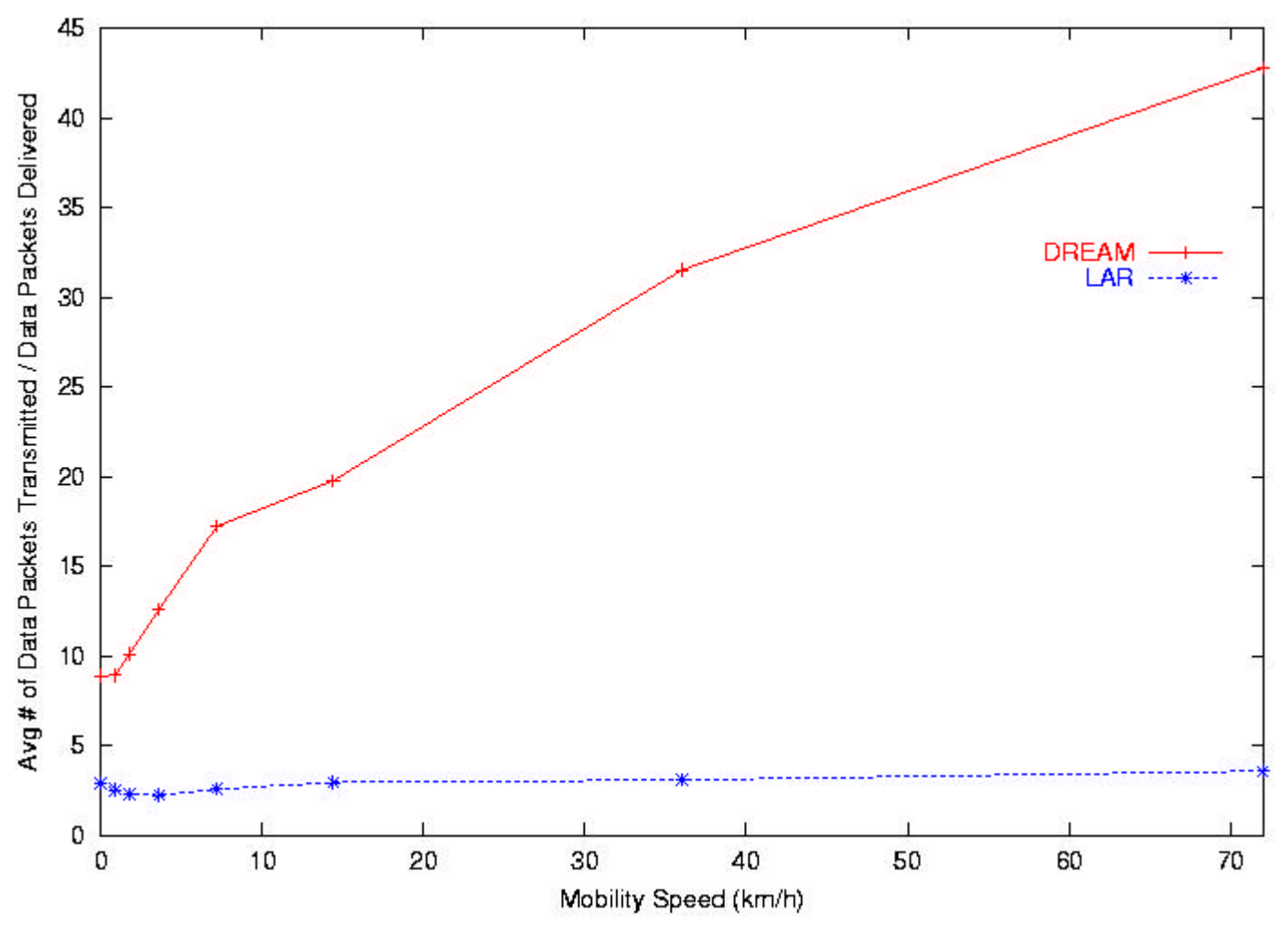
Simulation Results (cont'd)

- **Packet delivery ratio**



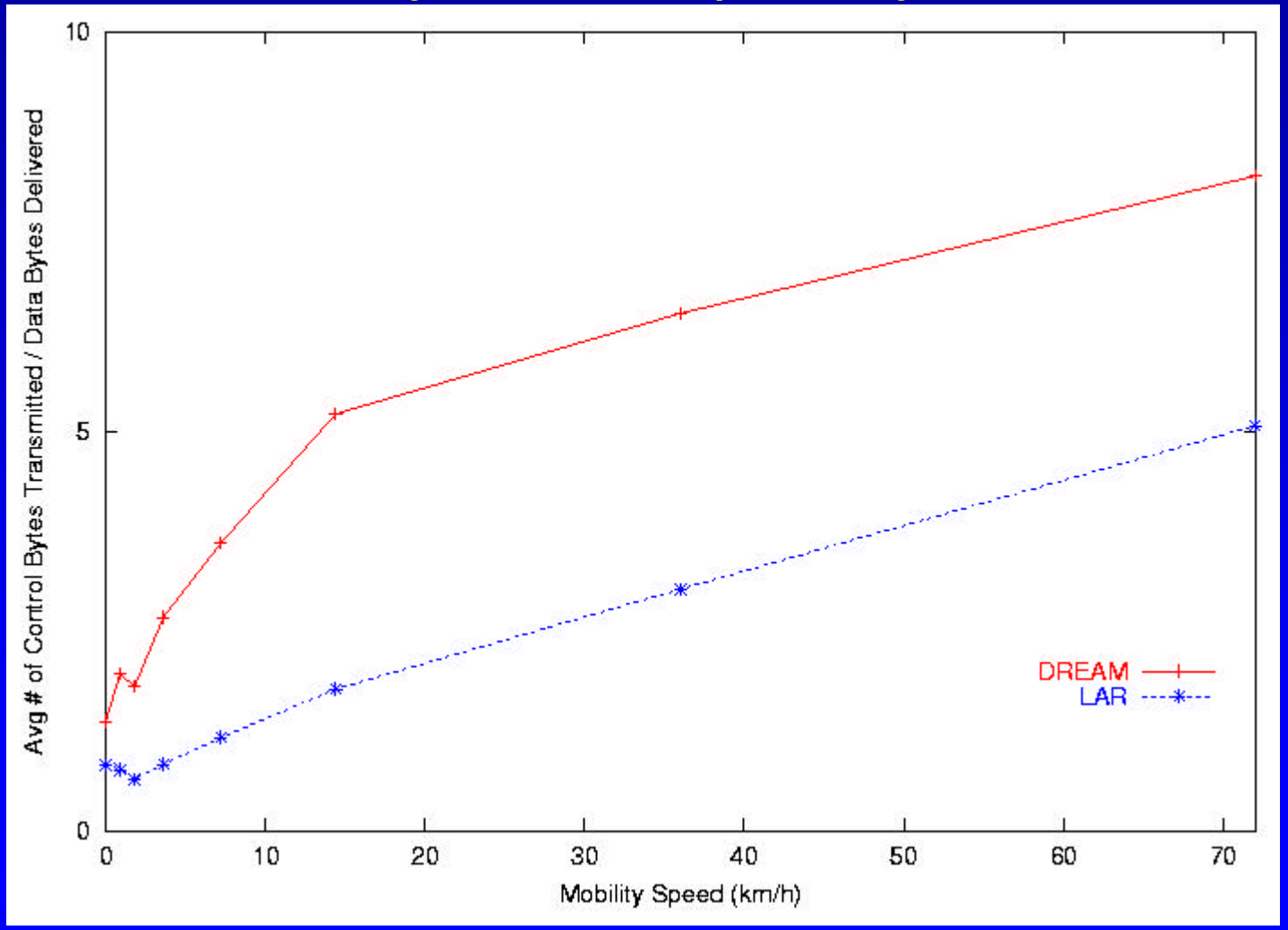
Simulation Results

- **Number of data packets transmitted per data packet delivered**



Simulation Results (cont'd)

- **Number of control bytes transmitted per data byte delivered**



Conclusions

- Conventional (wired net) routing schemes suffer of O/H, mobility and scalability limitations
- Hierarchical routing reduces O/H and improves scalability (at the expense of accuracy).
- On Demand routing eliminates background routing control O/H. It introduces latency; it does not well suited for QoS routing