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Journal

Selecting a routing strategy for your ad hoc network

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Outline

- Overview
- Routing protocols categories
- Simulation Model
- Simulation Results
- Conclusion
- Comment

OVERVIEW

❖Overview

Main Goal

- To investigate the performance of routing strategies in ad hoc networks.

Detailed problem

- Ad hoc networks Ξ {Highly mobile hosts}
- Routs tend to be multihop
- Routing protocols constrained by
  - mobility… random
  - bandwidth… limited
  - power… limited
- Various routing protocols have been introduced

OVERVIEW

Scenarios

- Utlising PARSEC, model simulation environment to evaluate routing protocols …
  - relative strengths
  - weaknesses
  - applicability to different situations
  - Effectiveness
- Two mobility patterns used…
  - random waypoint model; node movements are not correlated
  - group mobility model; nodes in the same group move in a similar direction with similar speed

Node speed = 0 … 72 km/h in both models

ROUTING CATAGORIES

❖Routing protocols categories

- Traditional table-driven protocols
  - distance vector based; WRP
  - link state based; FSR
  - ✓ based on permanent tables
- Reactive on-demand protocols
  - DSR
  - ✓ No permanent table only source on demand
- Location-based protocols
  - LAR+DREAM
  - ✓ utilize GPS *(Global Positioning System)* in determining location info to establish routs

ROUTING CATAGORIES

Protocols	WRP	FSR	DSR	LAR	DREAM
Routing strategy	Distance vector	Link state	On-demand	Location based (reactive)	Location based (proactive)
Route selection metric	Shortest path	Shortest path	Shortest path	Shortest path, location	Shortest path, location
Loop-free	No (temporary)	Yes	Yes	Yes	Yes
Periodic messages	HELLOS	HELLOS, ROUTE entries	None	None	Location Packets
Updates triggered by	Event, time	Time	Event	Event	Time
Flooding packets	None	None	RREQs	RREQs	Location packets, data (Partial)
Routes in data	No	No	Source route	Source route	Next hop nodes
Promiscuous mode	No	No	Yes	No	No
Need for GPS	No	No	No	Yes	Yes

Wireless routing protocol (WRP)

W
R
P

- **WRP *(Wireless routing protocol)***
- Distance vector based protocol.
- WRP modifies and enhances distance vector routing through

4. First…
   - If no link changes, WRP periodically exchanges HELLO packet rather whole route table.
   - If topology changes are perceived, only the 'path-vector tuples' that reflect the updates are sent.
   - path-vector tuples contain = destination, distance, and the predecessor (second-to-last hop) node
5. Second… to improve reliability in delivering update messages,
   - every neighbor sends acknowledgments for update packets received.
   - retransmissions if no positive acknowledgments within the timeout.
6. Third… the predecessor node ID allows to recursively calculate the entire path
   - WRP reduces looping situations, speeds up the convergence, and lowers the 'count-to-infinity' problem.
   - temporary loops exist and update messages triggered frequently in networks with highly mobile hosts.

W

R

P

WRP parameters

Periodic HELLO interval	1s
Max allowed HELLO miss	4
Update acknowledgment timeout interval	1s
Retransmission counter	4
Retransmission timer	1s

Criterion

Send >more frequent updates and less retransmissions;

highly mobile hosts

>less retransmission; reduce MAC buffer flood

F
S
R

FSR *(Fisheye state routing)*

- link state type protocol
- maintains a topology map at each node.

- Overhead, incurred by control packets, reduced in FSR through

6. First, link state packets are not flooded; only neighboring nodes exchange the link state information.
7. Second, link state exchange is only time-triggered, not event-triggered.
8. Third, FSR uses different exchange intervals for different entries in the table, instead of transmitting the entire link state information at each iteration,

- So FSR reduces the control packet size and the frequency of transmissions.
- As a result, FSR scales well to large network size since link state exchange overhead is kept low.
- As mobility increases, however, routes to remote destinations may become less accurate.

F S R

- FSR parameters

Scope		1hop
Periodic HELLO interval	Speed ≤ 3.5 km/h Speed > 3.5 km/h	5s 1s
Max allowed HELLO miss		3
Periodic INTRASCOPE UPDATE interval	Speed ≤ 3.5 km/h Speed > 3.5 km/h	5s 1s
Periodic INTERSCOPE UPDATE interval	Speed ≤ 3.5 km/h Speed > 3.5 km/h	15s 3s

D
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R

DSR *(Dynamic source routing)*

- on-demand routing protocol.

- A source floods a ROUTE REQUEST if data to send exist, but no route to its destination is known.
- The ROUTE REQUEST packet records in its header the IDs of the traversed nodes.
- Route Reply is sent to the source via the recorded route, when the ROUTE REQUEST is received by the destination or a node that knows a route to the destination,
- Each node in the network maintains a route cache storing routes it has learned over time.
- Aggressive caching helps minimizing the cost incurred by the route discovery process.
- DSR uses source routing instead of hop-by-hop routing; the source node appends the list of node IDs that comprise the route in the data header.
- When a node learns the route is obsolete due to topology changes, it builds and sends a Route Error to the source. The source then invokes a route discovery process to construct a new route.

- No periodic message of any kind are required in DSR.

D
S
R

- DSR parameters

Time between retransmitted ROUTE REQUESTS (exponentially backed off)	500ms
Max time where the same requests can be sent	10s
Non-propagating ROUTE REQUEST timeout	30ms

L A R

LAR *(Location-aided routing)*

- on-demand routing protocol
- LAR exploits location information.
- LAR operates similar to DSR.
- LAR differs by using GPS to restrict the flooded area of ROUTE REQUEST packets.
- Two schemes to determine which nodes propagate ROUTE REQUESTs.

7. Scheme 1…
   - the source defines a circular area in which the destination may be located.
   - position and size of the circle is decided through:
     a) the destination location known to the source
     b) the time instant when the destination was located at that position
     c) the average moving speed of the destination.
   - The smallest rectangular area that includes this circle and the source is the request zone.
   - This information is attached to a ROUTE REQUEST by the source and only nodes inside the request zone propagate the packet.

L
A
R

1. Scheme 2 …
   - the source calculates the distance between the destination and itself. This distance, along with
   - the destination location known to the source, is included in a ROUTE REQUEST and sent to neighbors. nodes receive this packet, they compute their distance to the destination, and continue to relay the packet only if their distance to destination is less than or equal to the distance indicated by the packet.
   - When forwarding the packet, the node updates the distance field with its distance to the destination.

- In both schemes, if no Route Reply is received within the timeout period, the source retransmits a ROUTE REQUEST via pure flooding.

L
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- LAR parameters

Timeout to send ordinary flooding request when no reply is received	2s

DREAM

DREAM (*Distance routing effect algorithm for mobility*)

- proactive location based routing protocol; it maintains permanent routing tables
- The scheme partially floods data to nodes in the direction of the destination.
- In the route table, coordinates of each node are recorded instead of route vectors.
- Each node in the network periodically exchanges control messages to tell its location to other nodes
- Achieve distance effect by assigning 'TTL (Time-To-Live)' value to location control messages.
- Location updates with low TTL value (short-lived updates) are sent more frequently to packets with high TTL value (long-lived updates).
- DREAM adjusts to network dynamics by controlling update frequency based on movement speed.
- When sending data, if the source has 'fresh enough' location information of the destination, it selects a set of one hop neighbors that are located in the direction from source to destination.
    - If no such nodes found, the data is flooded to the entire network.
    - If such nodes exist, the list is enclosed in the data header and transmitted.
- Only nodes specified in the header are qualified to receive and process the packet. These nodes in turn select their own list of possible next hops and forward the packet with such updated list.
- If no neighbors are located in the direction of the destination, the packet is dropped.
- destination on receiving data sends ACKs back to the source.
- No ACKs transmitted when data received via flooding.
- When the source sends data with designated next hops (not by pure flooding), it starts a timer.
- If no ACK is received before the timer expires, the data is retransmitted by ordinary flooding.

DREAM

DREAM parameters

Periodic ‘short-lived’ control update interval	
Speed <10 km/h	45 s
10 km/h ≤ speed <30 km/h	35s
Speed ≥ 30 km/h	25s
TTL of short-lived control updates	200
Ratio of short-lived and long-lived control updates sent	10:1
Min flooding angle towards the direction of destination	40º

Criterion: remove the ACK procedure of DREAM; data packets reached destinations but ACKs for those packets failed to get back to sources, thus invoking unnecessary flooding. Also, transmission of ACKs congested the network to a great degree, so poor performance.

SIMULATION MODEL

❖Simulation Model

- The simulator implemented within the GloMoSim library.
- GloMoSim library = scalable simulation environment for wireless network systems using the parallel discrete event simulation capability provided by PARSEC.
- PARSEC (*Parallel Simulation Environment for Complex systems*) = C-based simulation language, developed by the Parallel Computing Laboratory at UCLA, for sequential and parallel execution of discrete-event simulation models. It can also be used as a parallel programming language.

SIMULATION MODEL

Network model:

- 50 mobile hosts randomly placed
- 750m X 750m area
- Radio propagation range for each node = 200m
- Channel capacity = 2 Mbit/s.
- no network partitions
- Each simulation executed for 600 s of simulation time.
- Multiple runs for each scenario; so take averaged collected data

SIMULATION MODEL

Channel radio model

- A free space propagation model with threshold cutoff
- signal power attenuates as **$1/d^2$**, where d is the distance between radios.
- Implement SIRCIM (Simulation of Indoor Radio Channel Impulse-Response Models); considers multipath fading, shadowing, barriers, foliages...
- SIRCIM is more accurate than the free space model, but:
    - complexity of SIRCIM increases simulation time by two orders of magnitude
    - the accuracy of the channel model does not affect the relative ranking of the routing protocols
    - SIRCIM must be 'tuned' to the characteristics of the physical environment
- assume radio to lock onto a sufficiently strong signal in the presence of interfering signals, i.e. radio capture.
- capture ratio= minimum ratio of an arriving packet's signal strength relative to those of other colliding packets
- If the capture ratio is greater than the predefined threshold, the arriving packet is received while other interfering packets are dropped.

SIMULATION MODEL

MAC (Medium Access Control) protocol

- The IEEE 802.11 MAC protocol with DCF (Distributed Coordination Function) as MAC layer
- DCF is basic access method used by mobiles to share the wireless channel under independent ad hoc configuration.
- Carrier Sense multiple access/collision avoidance (CSMA/CA) access with acknowledgments.
- Optionally, the nodes can make use of Request To Send/Clear To Send (RTS/CTS) channel reservation control frames for unicast, virtual carrier sense, and fragmentation of packets larger than a given threshold.
- By setting timers based upon the reservations in RTS/CTS packets, the virtual carrier sense augments the physical carrier sense in determining when mobile nodes perceive that the medium is busy.
- Fragmentation is useful in the presence of high bit error and loss rates, as it reduces the size of the data units that need to be retransmitted.
- Here, employ RTS/CTS and virtual carrier sense; to minimize the frequency and deleterious effects of collisions over the wireless medium.
- Do not employ fragmentation; because data packets are small enough that the additional overhead would reduce overall network throughput.

SIMULATION MODEL

Traffic pattern

- Develop traffic generator to simulate constant bit rate sources.
- The size of data payload is 512 bytes; because smaller payload sizes penalize protocols that append source routes to each data packet.
- Ten data sessions with randomly selected sources and destinations were simulated.
- Each source transmits data packets at a rate between 0.5 and 4 packet/s.
- Vary traffic load by changing the number of data sessions and examine its effect on routing protocols

SIMULATION MODEL

Mobility models

- Random waypoint model
  - A node selects a destination randomly within the terrain range and moves towards that destination at a predefined speed.
  - Once the node arrives at the destination, it stays at its current position for a pause time of 10 s.
  - After being stationary for the pause time, it selects another destination randomly and migrates towards it, staying there for 10 s, and so forth.
  - Mobility speed varies from 0 to 72 km/h
  - Note that the stationary period is not considered in computing node speed.

SIMULATION MODEL

✓ Group mobility model

- Nodes within a group move in a similar direction and speed
- Each group may move differently from the others.
- Movement of each group and each node in a group can be characterized as Exponentially correlated random mobility (ECRM)
- The model can be best described by

$$b(t+1) = b(t)e^{1/\tau} + s\sigma\sqrt{1 - e^{2/\tau}}\,r,$$

  - b(t) = position (r, θ) of a group or a node at time t,
  - τ = time constant that regulates the rate of change,
  - σ = variance that regulates the variance of change,
  - s = speed of the node,
  - r =Gaussian random variable.
- Variables τ & σ control the movement.
- Here, use same values for nodes within the group but different value for each group.
- There are five groups here, each with 10 nodes.
- One group is stationary and other four groups move in different directions.
- If nodes hit the boundary of our simulation terrain range, they are bounced back in the reverse pause time.
- The average node degree
  - = 10:52 group mobility model
  - = 10:24 random waypoint model

SIMULATION MODEL

Metrics

- Packet delivery ratio
  - = The ratio of data packets delivered to the destinations and data packets originated by the sources.
  - represents the routing protocol effectiveness
- Hop count
  - =Average number of hops traveled by data packets that reached their destinations.
  - low hop count indicates effectiveness of route selection, but same packet delivery ratio protocols.
  - the higher the delivery rate, the higher the hop-count; only data packets that survive all the way to destinations are reflected,
  - low hop count means that most of the data packets delivered are destined for nearby nodes, and packets sent to remote hosts are likely dropped.
  - Thus, the hop count measure provides us with information about the survivability of the protocols.

SIMULATION MODEL

- Number of data packets transmitted per data packet delivered
  - 'Data packets transmitted' is the count of every transmission of data by each node.
  - This count includes transmissions of packets dropped and retransmitted by intermediate nodes
  - Since we divide this figure by the number of packets delivered to the destinations, this measure can be viewed as the efficiency of delivering data

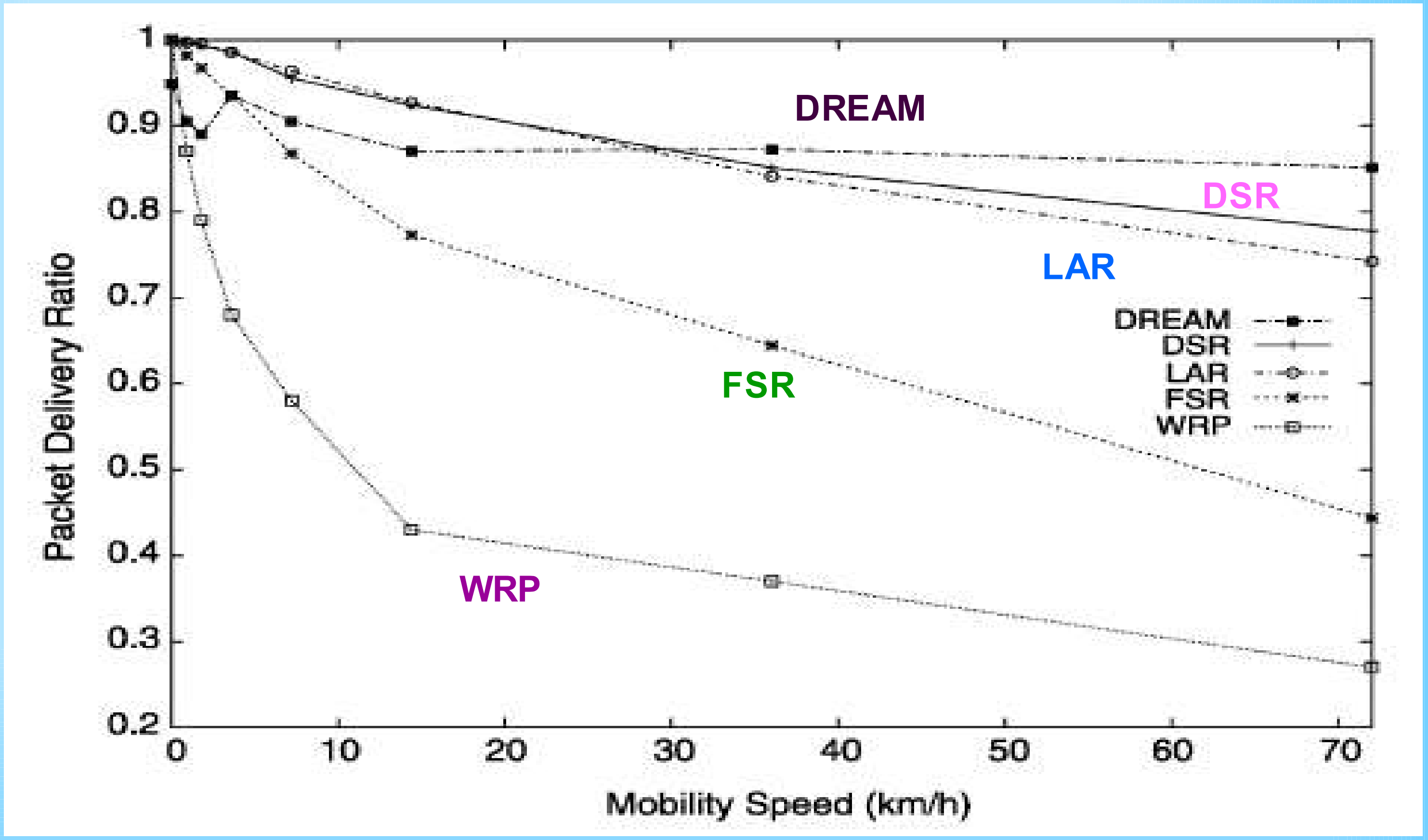
SIMULATION MODEL

- Number of control bytes transmitted per data byte delivered
  - In place of using a pure control overhead, we chose to use a ratio of control bytes transmitted to data byte delivered to investigate how efficiently control packets are utilized in delivering data.
  - Not only bytes of control packets (route tables, route update vectors, hellos, location updates, etc.), but also bytes of data packet headers (including source routes) are included in the number of control bytes transmitted.
  - Only bytes of the data payload contribute to the data bytes delivered.
- Number of control and data packets transmitted per data packet delivered
  - This measure shows the efficiency in terms of channel access
  - This efficiency is important since link layer protocols are typically contention-based.

SIMULATION RESULTS

❖Simulation Results

Packet delivery ratio

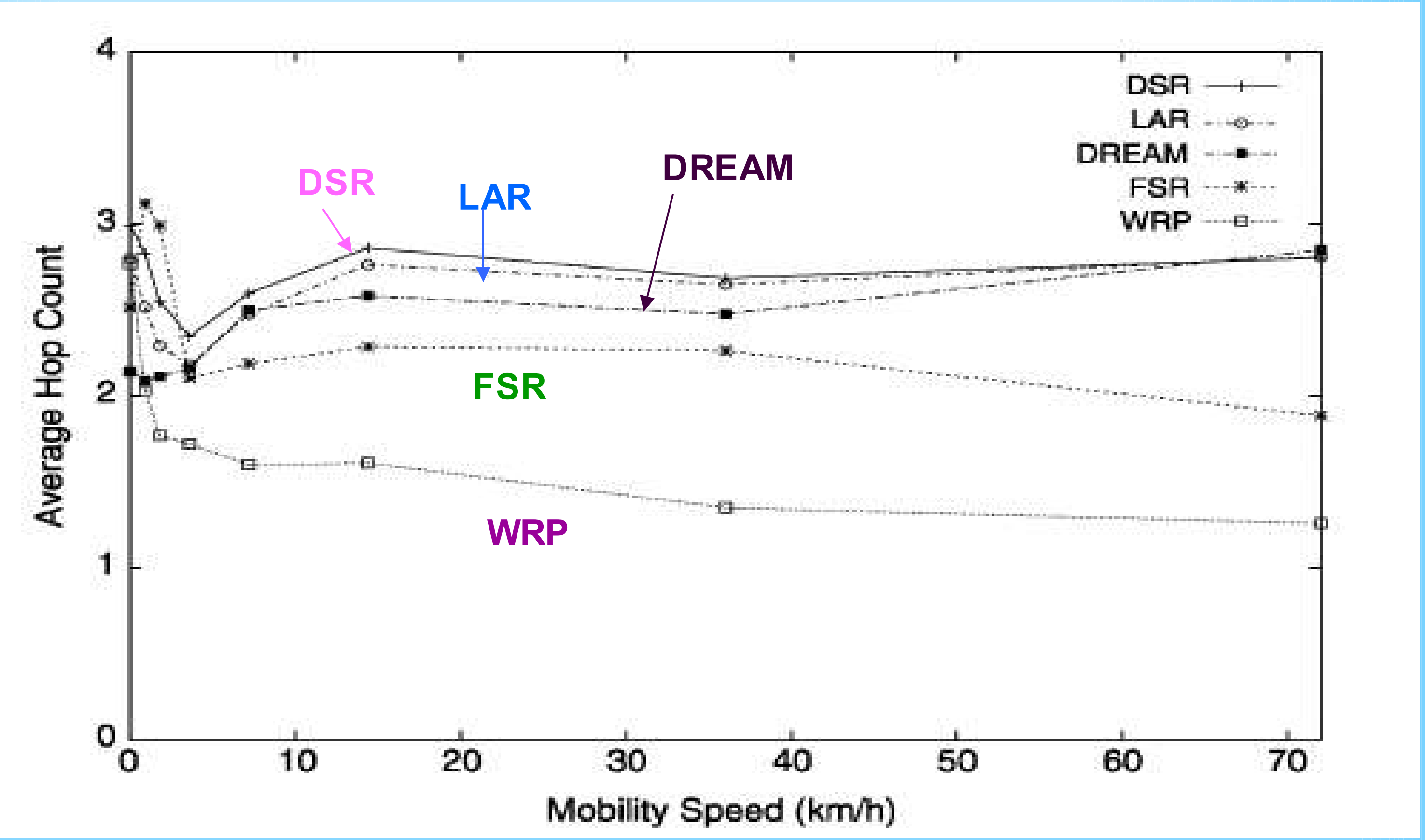


SIMULATION RESULTS

- All protocols perform well under low mobility rates, but they become less effective as the mobility speed increases.
- DREAM is the most robust to mobility; due to the partial flooding of data
- On-demand routing protocols (DSR and LAR) have very high packet delivery ratios overall, especially in relatively low mobility
- LAR is an improvement of DSR, so why LAR does not perform better than DSR
  - DSR has several optimization features that are not implemented in LAR.
  - the location information used by LAR may be out-of-date when nodes move at high speeds.
- FSR is sensitive to mobility; Update messages in FSR are time-triggered only, and routes to remote destinations become less accurate as mobility increases.
- WRP showes less effectiveness when compared to other protocols, especially at high mobility rates; changes need message update so neighboring nodes are required to send back an acknowledgment, temporary loops and thus further collisions, congestion, contention, and packet drops.

SIMULATION RESULTS

Hop count

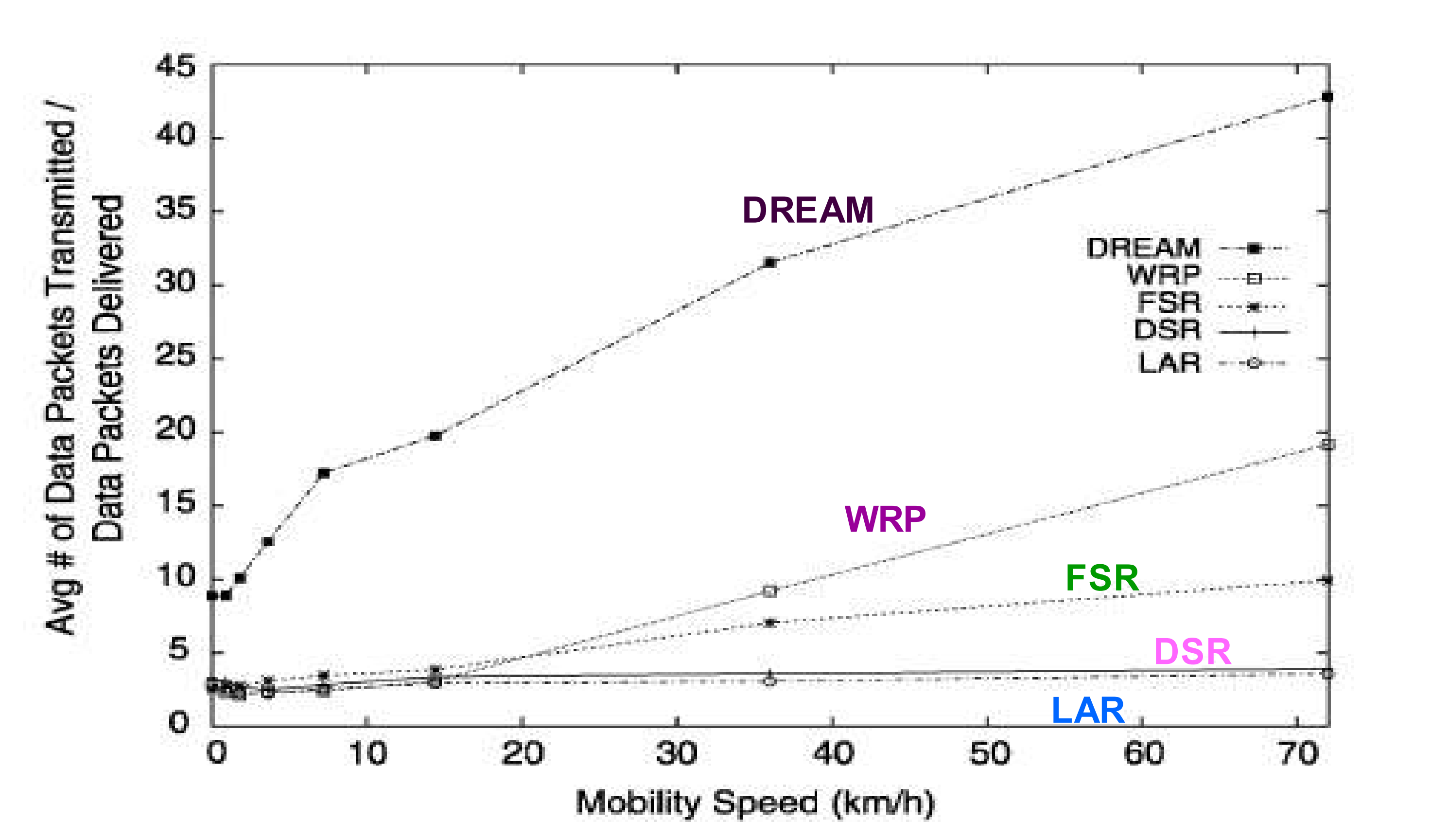


SIMULATION RESULTS

- average hop count only accounts for data packets that ‘survive’ to destinations.
- protocols that delivered more data packets have higher average hop count.
- If the distance between source and destination is greater, the number of intermediate nodes that data packets need to visit increases.
- The likelihood of a packet being dropped becomes greater as packets are required to traverse many links, particularly if network topology changes often.
- If a routing protocol cannot handle connectivity changes rapidly, more data packets get dropped.

S I M U L A T I O N R E S U L T S

Number of data packets transmitted per data packet delivered

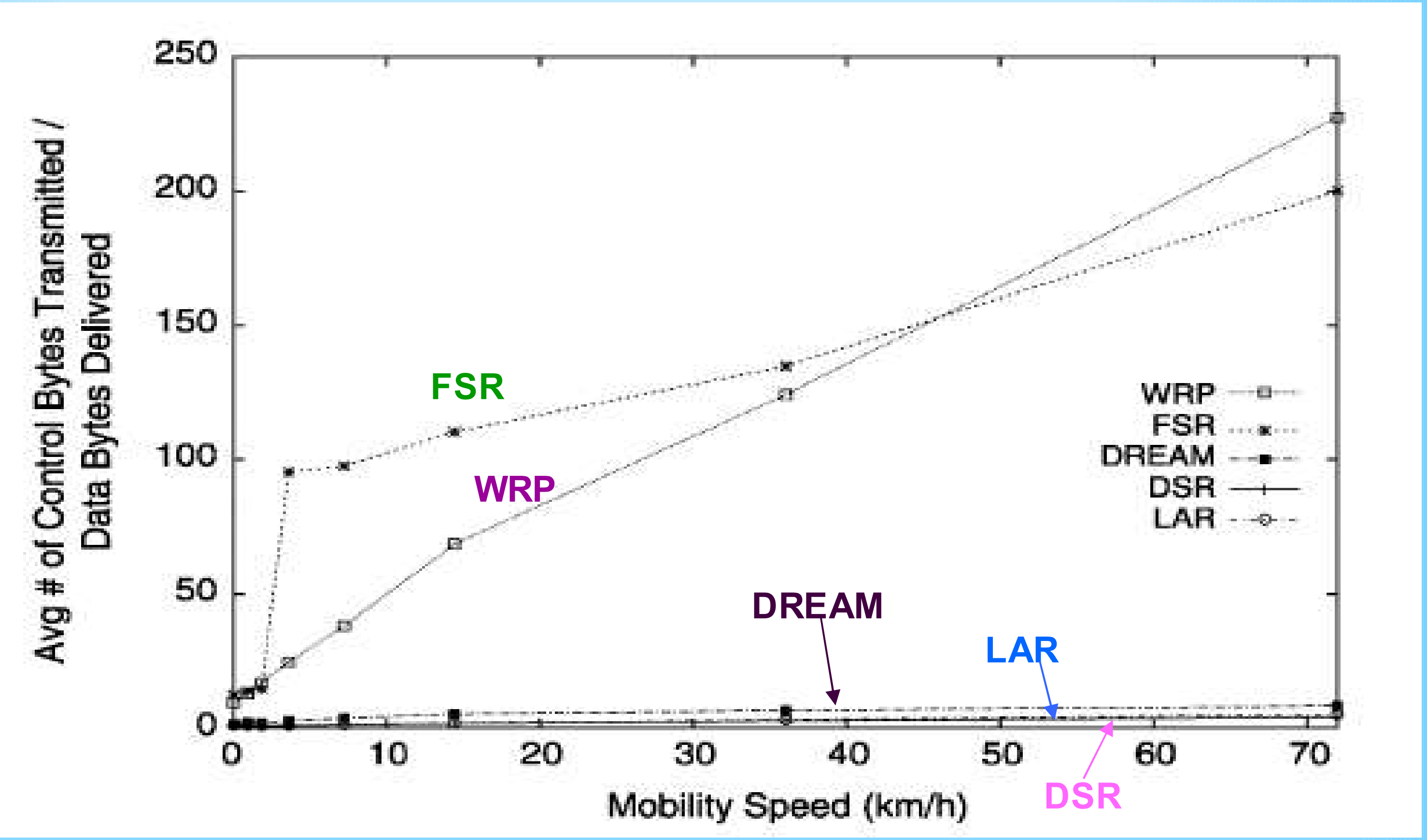


SIMULATION RESULTS

- DREAM has the highest measure since it partially floods data while other protocols unicast data.
- The values of WRP and FSR increase with mobility and these increases stem from packet drops by intermediate nodes.
- On-demand protocols are able to deliver data packets without much wasted data transmissions.
- DSR has an optimization salvaging feature, where the node detecting a route break salvages the data by sending it through another route to the destination, via a path it already knows (stored in route cache). Hence, data packets are dropped much less frequently when compared to proactive schemes.
- Proactive schemes (WRP and FSR) suffer from a large difference that grows with mobility speed.
- WRP and FSR have numerous packet drops in highly dynamic networks

SIMULATION RESULTS

Number of control bytes transmitted per data byte delivered

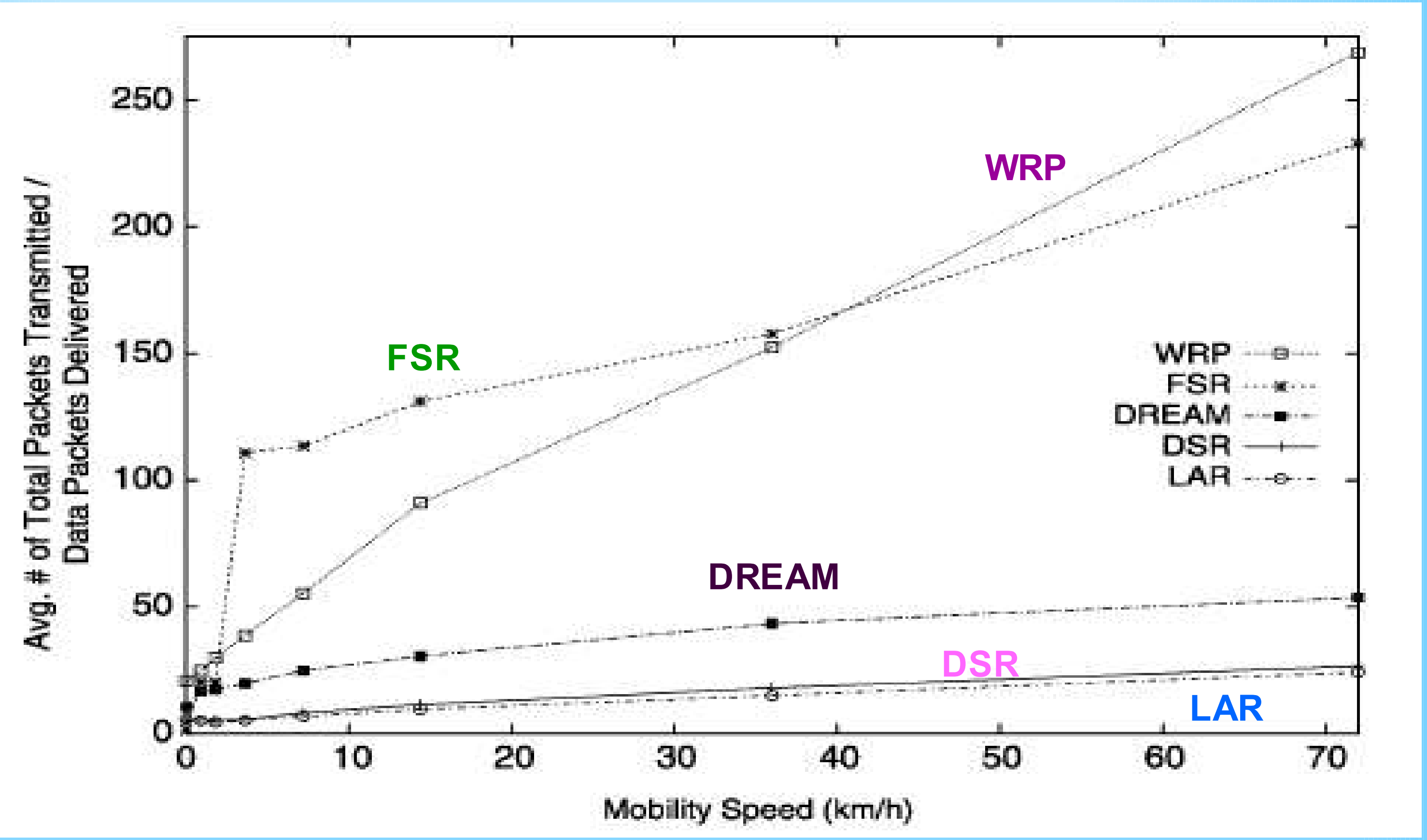


SIMULATION RESULTS

- Proactive protocols with periodic messages (HELLOS) have high comparative overhead.
- In WRP, each node sends acknowledgments for each HELLO it receives, and route update entries are produced more frequently in high mobility, where there are many link changes. As the WRP path vector has an extra field (next-tolast-hop node), control byte overhead actually becomes larger than that of a basic distance vector algorithm when the mobility rate is high.
- In FSR, route update messages are sent periodically only, thus the pure control overhead value does not increase.
- FSR delivered less data in high mobility cases.
- In FSR plot, the point of sharp increase represents the point when the update interval is adjusted to node movement speed.
- DREAM shows a very low control overhead in the figure because the size of location information packets is small.
- DSR and LAR have the least control traffic because they have no periodic messages and send control packets only when necessary, but proactive protocols still send this information
- Control packets in on-demand protocols are used efficiently.

SIMULATION RESULTS

Number of total packets transmitted per data packet delivered

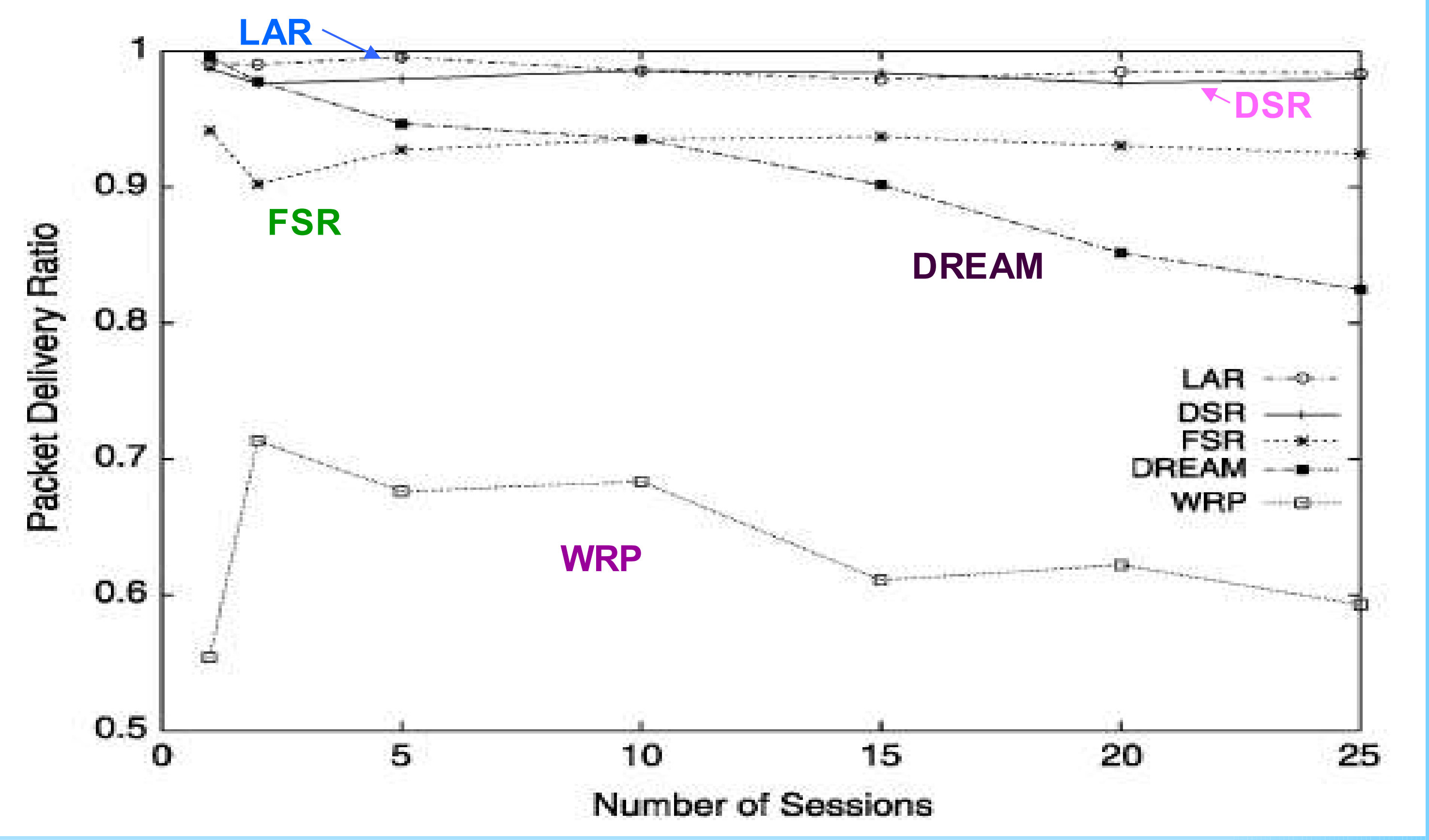


SIMULATION RESULTS

- this measure is particularly significant in ad hoc networks since most link layer protocols are contention based.
- data flooding accounts for higher values of DREAM.
- on-demand routing protocols show much lower values compared to those of other protocols.
- LAR has less packets transmitted than DSR; since ROUTE REQUESTs propagate using location information

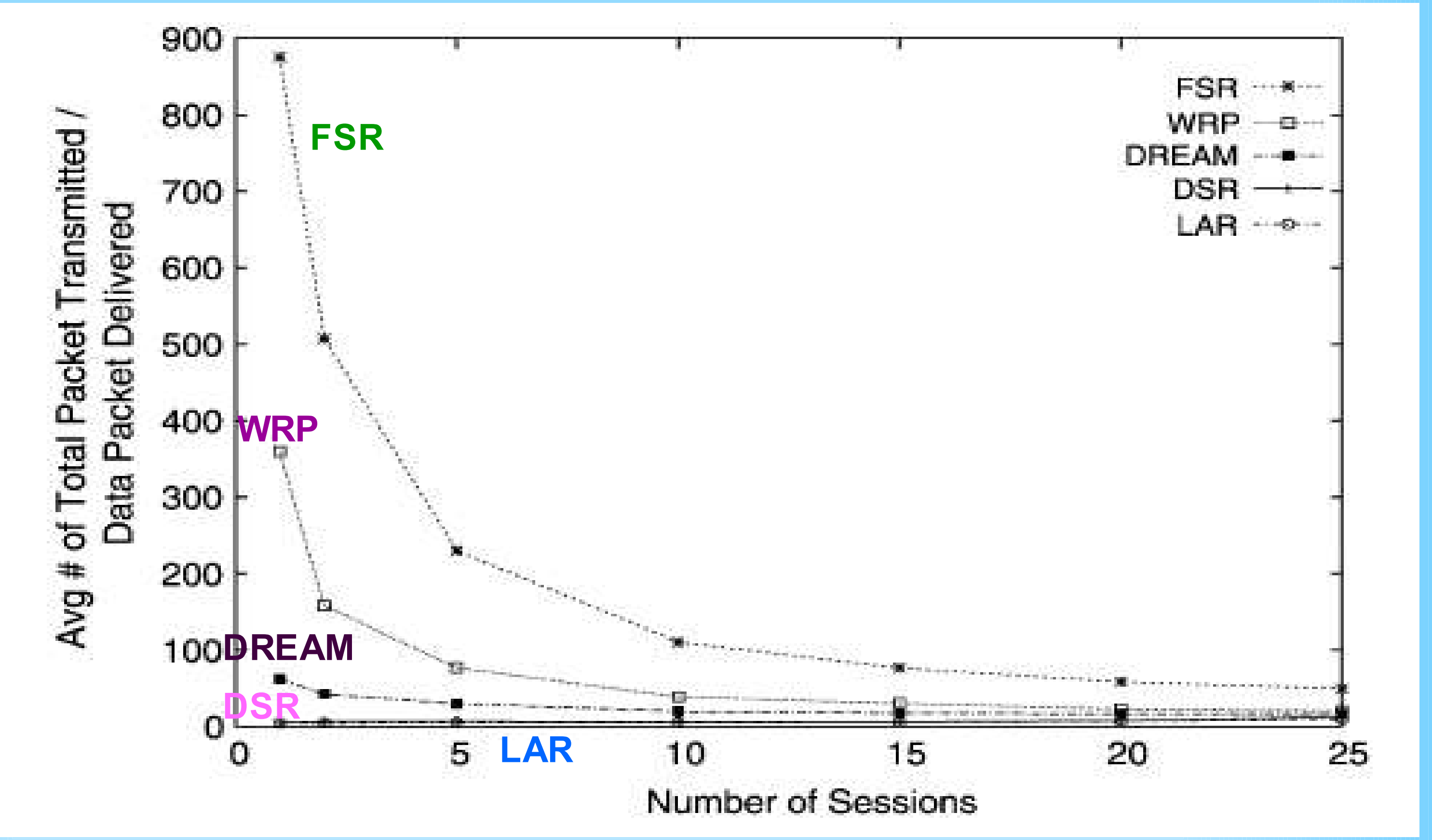
SIMULATION RESULTS

Effect of traffic load



Average packet delivered ratio as a function of number of sessions.

SIMULATION RESULTS



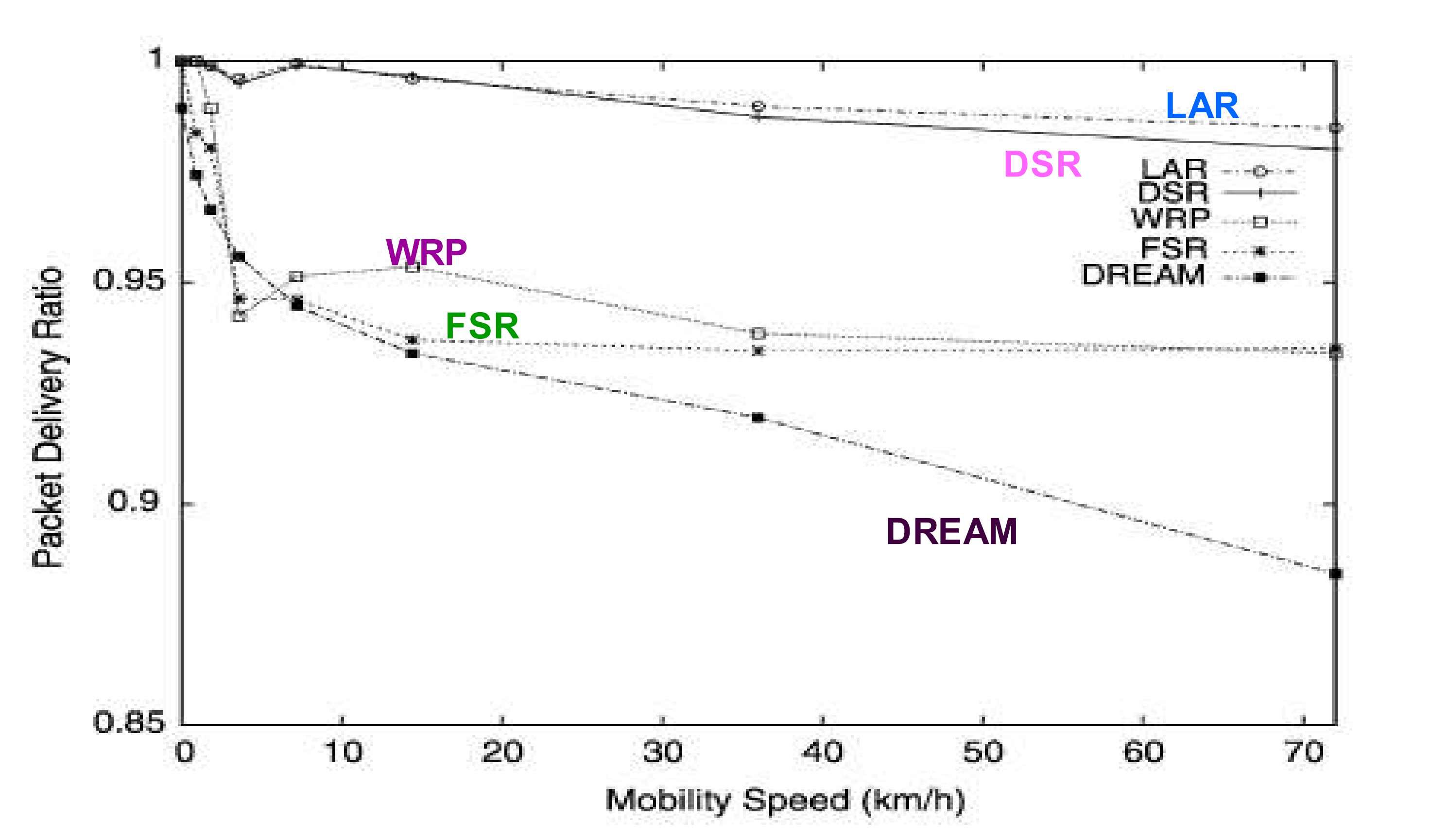
Average packet delivery ratio as a function of group mobility speed

SIMULATION RESULTS

- vary the number of data sessions while keeping the packet rate for each session constant.
- The mobility rate set constant at 1 m/s.
- Only DREAM and WRP suffer a packet delivery ratio drop with increase in the number of data sessions.
- Since data packets of DREAM are partially flooded, having many sessions increases the amount of flooded packets resulting in contention, collisions, and congestion.
- As for WRP, due to the random waypoint mobility, the routing algorithm is in a constant state of reconciling its tables to the perceived link changes, and propagating those changes across the network.
- Because of the method by which WRP reduces loops and invalid paths, there is a significant percentage of destinations that are temporarily unreachable from a given node while these link updates are being propagated.
- The effect of these temporarily unreachable destinations becomes increasingly noticeable with a larger number of sessions, as packets are dropped by the source or intermediate nodes with invalid routing table entries to a given destination.
- When increasing the number of sessions, the number of total packets transmitted per data packet delivered decreases for proactive schemes while they remain nearly constant for on-demand schemes.
- FSR and DREAM send periodic updates and the number of update transmissions remain the same regardless of number of data sessions.
- WRP sends event-triggered updates, but since the mobility rate is constant, having a different number of sessions does not affect the number of update transmissions.
- Meanwhile, the number of data packets received by destinations increases linearly with number of data sessions, resulting in the decrease of values.
- On-demand protocols, however, send more control packets when there are more data sessions.
- AS the number of sessions increase, more route discovery and route maintenance procedures are executed. The increase of these control packets

SIMULATION RESULTS

Result for Group mobility model



Average packet delivery ratio as a function of group mobility speed

SIMULATION RESULTS

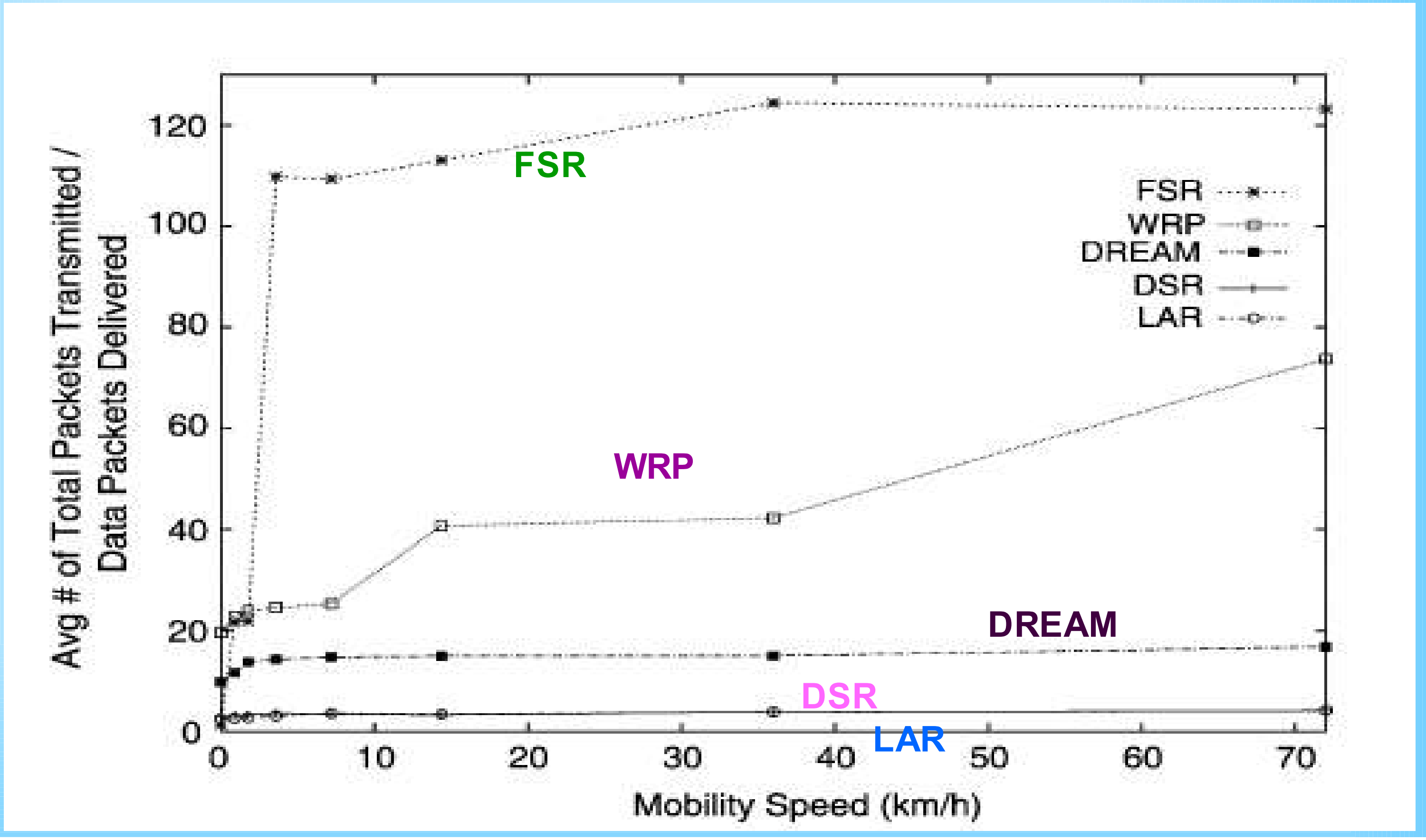
- In the group ECRM model.
- All protocols are able to deliver more data packets successfully than in the random waypoint model.
- WRP is the most improved protocol under the group mobility model.
- In the group ECRM model, nodes in the same group (i.e. immediate neighbors) move similarly and there are relatively few link changes. Even in highly mobile situations, route breaks occur much less frequently than in the random waypoint model. Few update packets are sent and the network view converges more quickly, thus improving WRP performance dramatically.

- Although the packet delivery ratio improved, DREAM is the protocol which benefited the least from this model.
- The number of link changes and route breaks does not affect the number of control packet transmissions in DREAM and it has no performance influence in delivering partially flooded data.

- DREAM is not only robust to mobility speed, it is also robust to movement pattern.

SIMULATION RESULTS

The measures also improved when compared with those in the random waypoint model. Because protocols delivered more data, the efficiencies are enhanced accordingly.



RESULT DISCUSSION

❖Result Discussion

- Distance vector protocols work well in static networks; since they maintain the full topology view all the time,
- distance vector type protocols are good choices when delivering real-time and heavy traffic.
- Distance vector type protocols they do not scale well to large and highly mobile networks because they suffer from the ‘count-to-infinity’ problem, slow convergence, and excessive control overhead.

- WRP, which improves the basic distance vector algorithm, do not perform well under dynamic situations,
- but performed very well when nodes form and move in groups.
- WRP enhances the pure distance vector protocol greatly
- WRP reduces control overhead by sending route entries instead of route tables and diminishes situations, where loops may occur by utilizing next-to-last-hop information.

- Link state algorithms are best suited for networks that require QoS (Quality of service) guarantees; because they provide link costs and capacities.
- link state protocols do not scale well to large networks and suffer from enormous amount of control overhead.
- A link state type protocol, FSR, do not show routing effectiveness in highly dynamic situations.

- Up-to-date routing information is not maintained when hosts moved quickly and randomly.
- Route update messages can be exchanged more frequently to obtain fresh information, but that will incur additional control traffic.

RESULT DISCUSSION

- Applying distance effect and adjusting update rates to movement speed reduces the amount of control overhead and allows prompt adaptation to network changes.
- Even though nodes may keep inaccurate routes to remote destinations as mobility increases, when a packet approaches its destination, it finds more precise routing instructions as it enters an area with a higher refresh rate.

- On-demand routing protocols produce less control traffic overhead than the proactive schemes since no route tables are periodically exchanged.
- Control packets are generated only as needed.
- Due to less overhead, they performed well in most of simulation scenarios, even in highly mobile situations.
- However, extra delay (route acquisition latency) is required to obtain a route
- DSR, a typical on-demand scheme, detects route breaks and link changes only after data packets fail to go through the broken link, thus yielding longer delays.

- With the knowledge of node position, routing can be more effective at the cost of overhead incurred by exchanging coordinates. In addition, location information recorded can be out-of-date.
- LAR, a reactive approach, further reduces control traffic of DSR by restricting the propagation of flood packets.

- DREAM is another location-based protocol, but a proactive scheme.
- The key characteristic of DREAM is its partial flooding of data packets to nodes that are in the direction of the destination. Because of this partial flooding, multiple packets travel to destinations via different paths. The probability of reaching destinations is higher than protocols that unicast the data.
- DREAM robust to mobility speed and mobility model.
- But, performance degrades when number of sessions in the network increased it increases the number of packets in the network as the number of sessions become larger Congestion, collisions, and channel contention occur.

Conclusion

CONCLUSION

- Overall protocols perform better in group mobility model than with the random way point model.
- WRP and FSR, especially, were the main beneficiaries of the group movement model.
- Each protocol's performance degraded as mobility rates
- increased, but DREAM was the most robust to the speed of network hosts.
- However, because of the data flooding, DREAM became less effective under heavy traffic scenarios.
- On-demand protocols were highly effective and efficient in most of scenarios.
- but Extra delay in acquiring routes, make them less attractive in delivering real-time traffic.
- LAR further improved an on-demand protocol by using location information, but produced more overhead to exchange location information.
- In summary, there is no single routing strategy that is best for all network situations.
- Every protocol has its advantages and disadvantages in different scenarios. aspect we provided in this paper (and possibly more).

C O M M E N T

❖Comment

- those scenarios cannot cover every possible situation.
- Moreover, there are other considerations which cannot be or are difficult to measure in simulation, that must be considered when selecting a routing strategy for specific applications and networks:
  - hosts are more prone to security invasions
  - Provision of network security
  - probability of detection/interception
  - Power usage of the protocol
  - storage overhead
  - protocol complexity
  - Computation overhead
- A very understandable paper but…
  - some items are not well defined, especially some protocols parameters

THANK YOU

Question?

End