Mobility prediction and routing in ad hoc wireless networks

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Presented By

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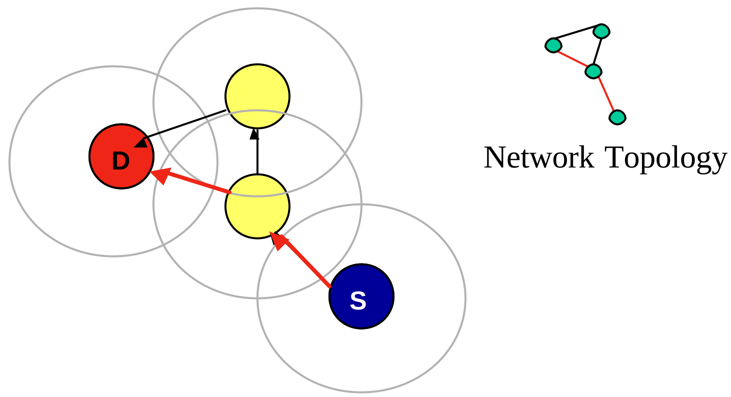
INTRODUCTION

Ad Hoc Networks Unlike Cellular Networks Are:

- infrastructure-less
- dynamic in nature
- formed by wireless hosts which may be mobile

INTRODUCTION

Hosts Participating In Ad-hoc Networks:



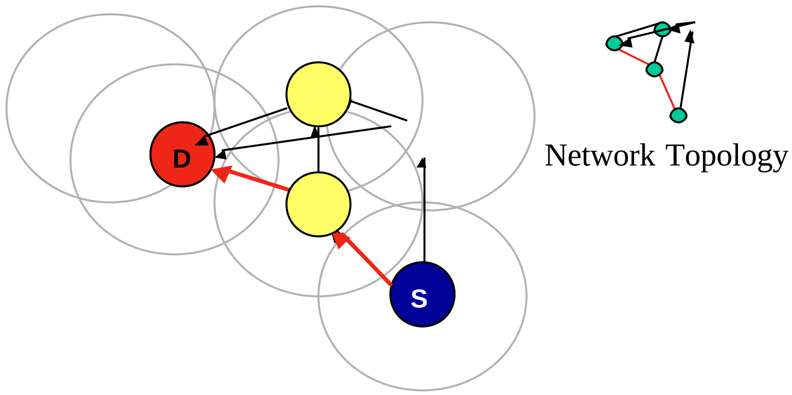
INTRODUCTION

Hosts Participating In Ad-hoc Networks:

- may need to traverse multiple links to reach a destination
- acts as routers
- moves arbitrarily

INTRODUCTION

Mobile Hosts Participating In Ad-hoc Networks:



INTRODUCTION

Hosts Mobility Causes:

- frequent route disconnections
- dynamic route changes
- network topology changes

Critical to route packages to destinations without excessive overheads

INTRODUCTION

Why Ad Hoc Networks

- Ease of deployment
- Speed of deployment
- Decreased dependence on infrastructure

INTRODUCTION

Applications of Ad Hoc Networking

Personal area networking
cell phone, laptop, ear phone, wrist watch

Military environments
soldiers, tanks, planes

Civilian environments
taxi cab network
meeting rooms
sports stadiums
boats, small aircraft

Emergency operations
search-and-rescue
policing and fire fighting

INTRODUCTION

Ad Hoc Network Issues & Primary Concerns

- Adapt to changing/unpredictable network topology changes
- High degree of mobility
- Intermittent connection
- Bandwidth Limitations
- Limited battery life
- Limited memory

INTRODUCTION

Observation

Mobile nature of hosts in an ad hoc network

Users move with certain degree of regular (and random) movements

Look for mobility patterns in user movement

INTRODUCTION

Variations of Mobility patterns

- Mobility patterns may be different
  - people sitting at an airport lounge
  - New York taxi cabs
  - kids playing
  - military movements
  - personal area network
- Mobility characteristics
  - speed
  - predictability
    - direction of movement
    - pattern of movement
  - uniformity (or lack thereof) of mobility characteristics among different nodes

INTRODUCTION

Users Mobility Patterns Can Be Studied To:

- predict the future state of network topology
- proactive route reconstruction
- eliminate transmission of control packets
- reduce overheads
- minimize disruptions and find routes in a timely manner
- improve routing protocol performance

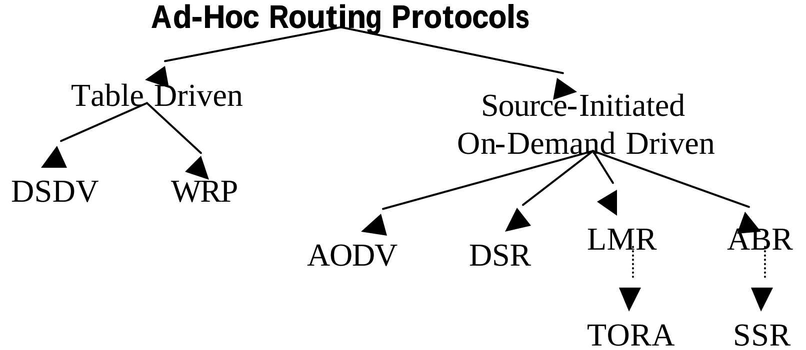
INTRODUCTION

Routing Protocols

- Many protocols have been proposed
- Some have been invented specifically for MANET
- Others are adapted from previously proposed protocols for wired networks
- No single protocol works well in all environments some attempts made to develop adaptive protocols

INTRODUCTION

Ad-Hoc Routing Protocols



INTRODUCTION

Routing Protocols - use Location Info

- LAR (Location Aided Routing)
- DREAM (Distance Routing Effect Algorithm for Mobility)
- Both use GPS information

INTRODUCTION

Solutions

- Critical to route packages to destinations without overheads
  Difficult to achieve because of changing environment and network topology
- Require the prediction of the location of the destination node even after a route is constructed.

INTRODUCTION

Idea

USE LINK EXPIRATION TIME

PREDICTION MECHANISMS

Estimation of Link Expiration Time

Predict time D_t that the two hosts will stay connected:

$$D_t = \frac{-(ab+cd)+\sqrt{(a^2+c^2)r^2-(ad-bc)^2}}{a^2+c^2}$$

where

$$a = v_i \cos\theta_i - v_j \cos\theta_j$$
$$b = x_i - x_j$$
$$c = v_i \sin\theta_i - v_j \sin\theta_j$$
$$d = y_i - y_j$$

Motion parameters of two nodes are known:

- speed
- direction
- radio propagation range

that two mobile hosts i and j in their respective co-ordinates (X_i, Y_i) and (X_j, Y_j) and within the transmission range r of each other

PREDICTION MECHANISMS

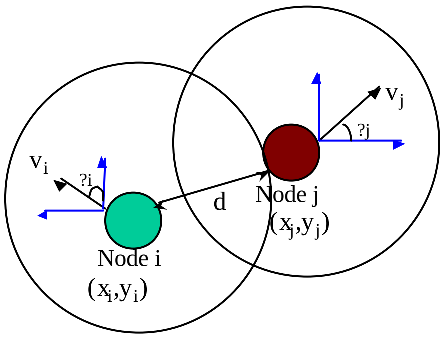
Estimation of Link Expiration Time

Range of Transmission = r

For Link to be active d < r

Distance between two nodes on X-axis after time 't' $D_x = [x_j - x_i] + [v_j \cos q_j - v_i \cos q_i]t$

Distance between two nodes on Y-axis after time 't' $D_y = [y_j - y_i] + [v_j \sin q_j - v_i \sin q_i]t$



$v_j\cos?_j - v_i\cos?_j$ = **a**, $x_j - x_i$ = **b**

$v_j\sin?_j - v_i\sin?_j$ = **c**, $y_j - y_i$ = **d**

$$d = \sqrt{(x_j - x_i)^2 + (y_j - y_i)^2}$$

PREDICTION MECHANISMS

Estimation of Link Expiration Time

- For nodes to be in contact, the distance should be less than 'r' (transmission range)
- Distance between nodes (in transmission range) after time 't'

$$d = \sqrt{D_x^{\,2} + D_y^{\,2}} < r$$

$$\sqrt{(b + at)^2 + (d + ct)^2} < r$$

$$(a^2 + c^2)t^2 + 2(ab + cd)t + (b^2 + d^2 - r^2) <= 0$$

$$t <= \frac{-(ab + cd) \pm \sqrt{(a^2 + c^2)r^2 - (ad - bc)^2}}{(a^2 + c^2)}$$

PREDICTION MECHANISMS

Estimation of Link Expiration Time

- $t = D_t$ (Link Expiration time)

- **When $v_i = v_j$, & $?_i = ?_j$, $D_t = 8$**

INTRODUCTION

Paper uses Link Expiration Time to :

- predict route breakage
- schemes to improve routing protocol performance
- enhancements to unicast and multicast routing protocols
- evaluate the effectiveness of prediction using GLOMOSIM simulation environment

PREDICTION MECHANISMS

METHODS & ASSUMPTIONS

Methods

- Use GPS
- Estimate the link expiration time
- Use expiration time to predict route breakages

Assumptions

- Free space propagation model: *assumes the ideal propagation condition that there is only one clear line-of-sight between the transmitter and the receiver.*

Nodes have synchronized clocks (NTP/GPS)

PREDICTION MECHANISMS

WHAT IF GPS IS NOT AVAILABLE

PREDICTION MECHANISMS

ALTERNATIVE METHODS TO PREDICT D_t

- Measure Transmission power samples periodically from a mobile's neighbor
  - Compute rate of change
  - Time that the transmission level drops below the threshold value

APPLICATION OF PREDICTION

ROUTING PROTOCOLS

- UNICAST

  Unicast: One Source – one Destinations

  Uses Flooding For Data Delivery

  - FORP (Flow Oriented Routing Protocol)
  - DSDV (Distance Sequence Distance Vector)

- MULTICAST

  ONE Or MORE Sources To A GROUP Of Destinations

  - ODMRP (On-Demand Multicast Routing Protocol

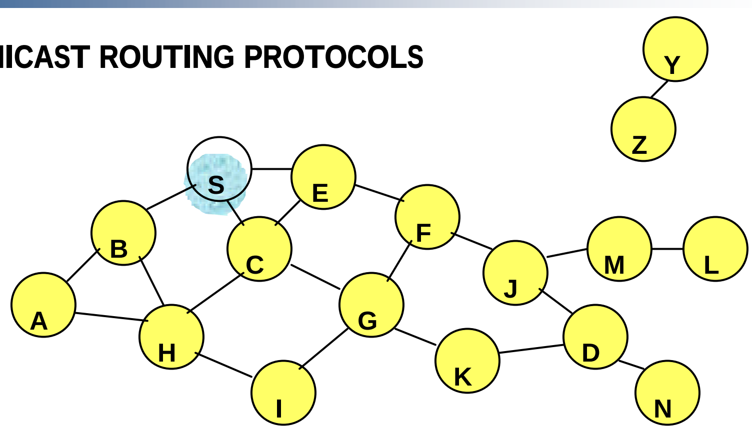
APPLICATION OF PREDICTION

UNICAST ROUTING PROTOCOLS

- Sender S trying to reach D will broadcasts data packet P to all its neighbors
- Each node receiving P forwards P to its neighbors
- Sequence numbers used to avoid the possibility of forwarding the same packet more than once
- Packet P reaches destination D provided that D is reachable from sender S
- Node D does not forward the packet

APPLICATION OF PREDICTION

UNICAST ROUTING PROTOCOLS



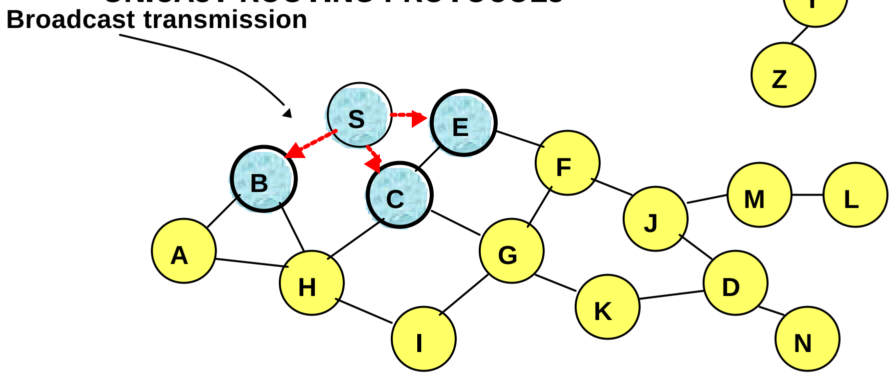
Represents a node that has received packet P

Represents that connected nodes are within each other's transmission range

Courtesy : Nitin Vaidya

APPLICATION OF PREDICTION

UNICAST ROUTING PROTOCOLS



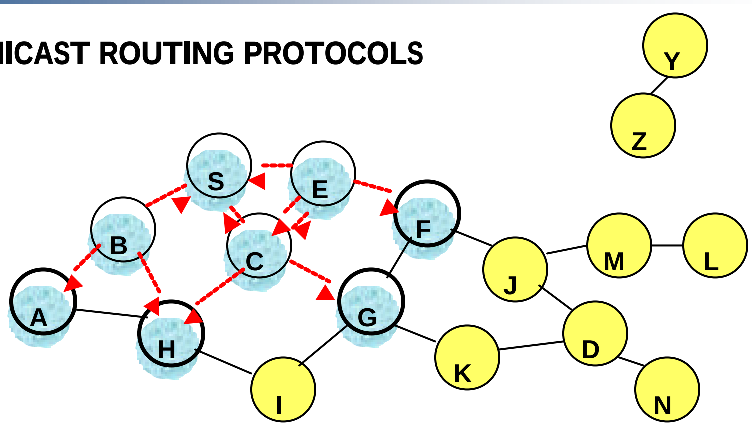
Represents a node that receives packet P for the first time

Represents transmission of packet P

Courtesy : Nitin Vaidya

APPLICATION OF PREDICTION

UNICAST ROUTING PROTOCOLS

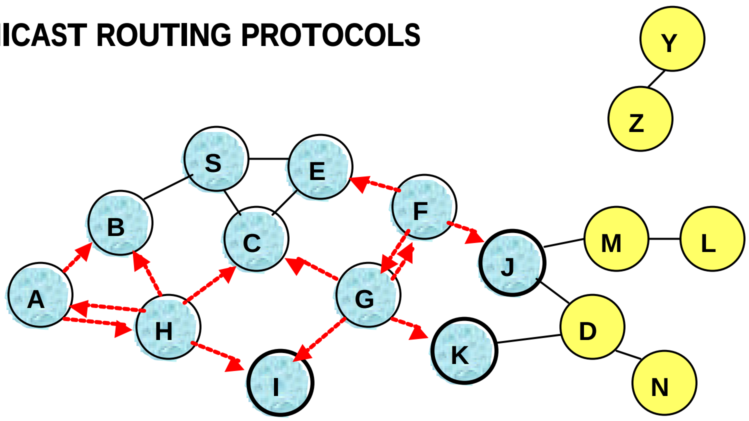


- Node H receives packet P from two neighbors: potential for collision/duplicate packets

Courtesy : Nitin Vaidya

APPLICATION OF PREDICTION

UNICAST ROUTING PROTOCOLS

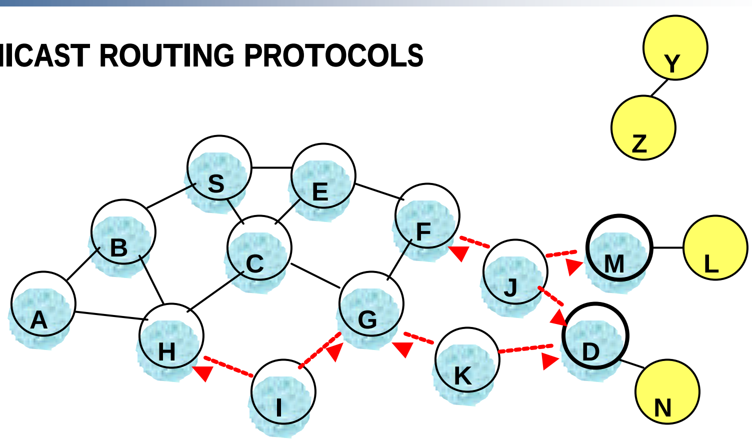


- Node C receives packet P from G and H, but does not forward it again, because node C has already forwarded packet P once

Courtesy : Nitin Vaidya

APPLICATION OF PREDICTION

UNICAST ROUTING PROTOCOLS



- Nodes J and K both broadcast packet P to node D
- Node D does not forward packet P, because node D is the intended destination of packet P

Courtesy : Nitin Vaidya

PREDICTION MECHANISMS

UNICAST ROUTING PROTOCOLS - Advantages

- Simplicity
- Efficient
  - When rate of information transmission is low enough that the overhead of explicit route discovery/maintenance incurred by other protocols is relatively higher
  - this scenario may occur, for instance, when nodes transmit small data packets relatively infrequently, and many topology changes occur between consecutive packet transmissions
- Reliable
  - Potentially higher reliability of data delivery
  - Because packets may be delivered to the destination on multiple paths

PREDICTION MECHANISMS

UNICAST ROUTING PROTOCOLS – Disadvantages

- Potentially, very high overhead
  - Data packets may be delivered to too many nodes who do not need to receive them
- Potentially lower reliability of data delivery
  - Flooding uses broadcasting -- hard to implement reliable broadcast delivery without significantly increasing overhead
    - Broadcasting in IEEE 802.11 MAC is unreliable
  - In our example, nodes J and K may transmit to node D simultaneously, resulting in loss of the packet
    - in this case, destination would not receive the packet at all

PREDICTION MECHANISMS

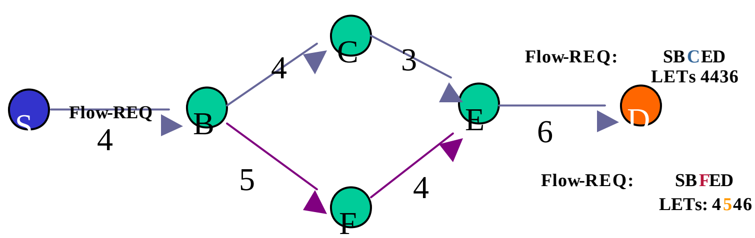
UNICAST ROUTING PROTOCOLS - FORP - How it works

When a source S needs to send data/flow to destination node D

- Checks its routing table for an unexpired route
- If it finds uses it or else
- Broadcast a Flow_REQ message to find a route to D

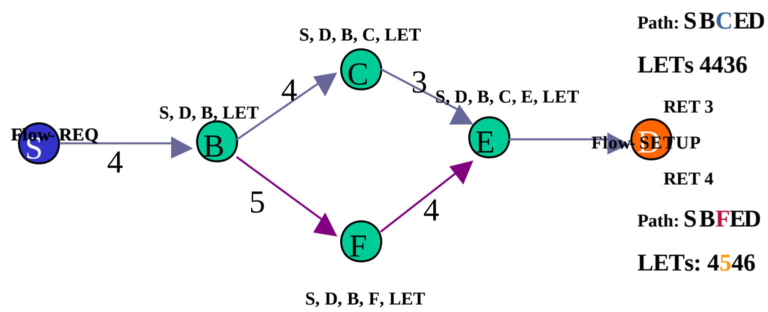
PREDICTION MECHANISMS

UNICAST PROTCOLS - FORP - USING LET's



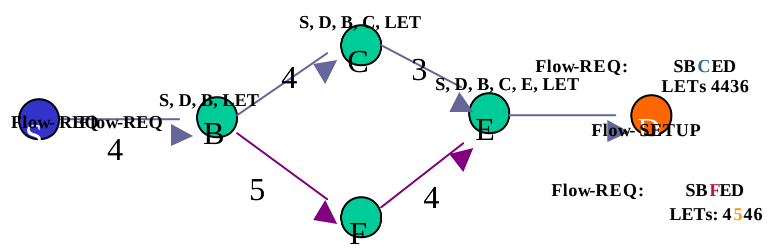
PREDICTION MECHANISMS

UNICAST ROUTING PROTOCOLS - FORP – How it works



PREDICTION MECHANISMS

UNICAST ROUTING PROTOCOLS - FORP – How it works



APPLICATION OF PREDICTION

FORP - How it works

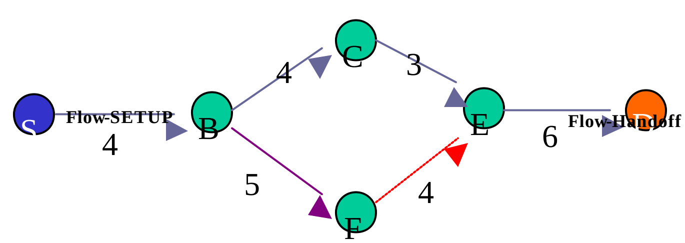
- Link Expiration Time (LET)
- Route Expiration Time (RET)
- Critical Time T_c: the time that the route is about to expire < RET $T_c = RET - T_d$

When Tc reached:

- Destination sends a *Flow-HANDOFF* to Source
- The Source then sends a *Flow-SETUP* to Destination

PREDICTION MECHANISMS

UNICAST PROTOCOLS - FORP



PREDICTION MECHANISMS

FORP - How it works

Criteria for Route Selection

- **LET**
- **QoS**
- **Bandwidth**

Consider weighted average of the criteria for Route Selection

PREDICTION MECHANISMS

Distance Vector Approach

- Each node *i* maintains, for each destination x, a set of distances $\{d_{ij}(x)\}$ for each node j that is a neighbor of *i*.
- Node *i* treats neighbor *k* as the next hop for a packet destined for x if $d_{ik}(x)$ equals min $\{d_{ij}(x)\}$
- The succession of next hops chosen leads to x along the shortest path
- To keep the distance estimates up to date, each node monitors the cost of its outgoing links and periodically broadcasts, to all its neighbors, its current estimates of the shortest distance to every node in the network
- In Short nodes exchange routing tables with its neighbors

PREDICTION MECHANISMS

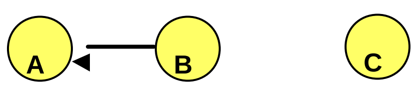
Distance Vector Approach DSDV

- Each node maintains a routing table which stores
  - next hop towards each destination
  - a cost metric for the path to each destination
  - a destination sequence number that is created by the destination itself
  - Sequence numbers used to avoid formation of loops
- Each node periodically forwards the routing table to its neighbors
  - Each node increments and appends its sequence number when sending its local routing table
  - This sequence number will be attached to route entries created for this node

PREDICTION MECHANISMS

DSDV

- Assume that node A receives routing information from B about a route to C

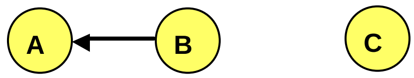


- Let S(A) and S(B) denote the destination sequence number for node C as stored at node A, and as sent by node B with its routing table to node A, respectively

PREDICTION MECHANISMS

DSDV

- Node A takes the following steps:



  - If S(A) > S(B), then A ignores the routing information received from B
  - If S(A) = S(B), and cost of going through B is smaller than the route known to A, then A sets B as the next hop to C
  - If S(A) < S(B), then A sets B as the next hop to C, and S(A) is updated to equal S(B)

PREDICTION MECHANISMS

DSDV

Routing Tables

DEST	NEXT HOP	METRIC	SEQNUM
MH	MH	Hop-Count	Integer
B	B	3	2

PREDICTION MECHANISMS

DSDV

Routing Tables Update

- Triggered
- Periodic

PREDICTION MECHANISMS

DSDV

Routing Tables Update

- **Triggered**
  - When a MH moves out of range, neighbor triggers update with higher seqnum advertising infinite cost
  - Routes propogate to all mobiles serving all links with MH
  - MH hears route update and responds with new routing update
  - Routing overhead constant regardless of number of senders
  - Flooding of route discovery packets increase with senders, leads to performance degradation
  - Leads to network congestion when network dynamic

PREDICTION MECHANISMS

DSDV

Routing Tables Update

- Periodic
  - Periodic update of tables
  - Immediate updates when significant information
  - In high mobility

    routes need to updated often, update interval shortened to increase performance, Short update interval increases routing overhead
  - In slow mobility

    Routes do not change often, Often updates, excessive overheads,

PREDICTION MECHANISMS

DSDV with Prediction

Uses Route Expiration Time (RET's) as route selection metric

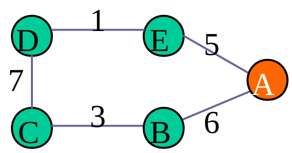
Leads to:

- Stable routes
- Relaxed updates interval time
- Relaxed update frequency
- Routing protocol - mobility robust
- Bandwidth efficient

DEST	NEXT HOP	METRIC	SEQNUM
MH	MH	RET	Integer
B	B	6	2

PREDICTION MECHANISMS

DSDV with Prediction - How it works



Route Table for A			
Dest	**Next Hop**	**RET**	**Seqnum**
A	n/a	n/a	3
B	B	6	3
C	B	3	2
D	E	1	2
E	E	5	2

Updated Route Table for A			
Dest	**Next Hop**	**RET**	**Seqnum**
A	n/a	n/a	3
B	B	6	3
C	B	3	3
D	B	3	3
E	E	5	2

Route Table Received from B			
Dest	**Next Hop**	**RET**	**Seqnum**
A	A	6	2
B	n/a	n/a	3
C	C	3	3
D	C	3	3
E	A	5	2

PREDICTION MECHANISMS

DSDV with Prediction

Uses Route Expiration Time (RET's) as route selection metric

Leads to:

- Stable routes
- Relaxed updates interval time
- Relaxed update frequency
- Routing protocol mobility robust
- Bandwidth efficient

CautioN

a stable route may not necessarily be a optimal route

PREDICTION MECHANISMS

SIMULATION ENVIRONMENT

- GloMoSim
- 50 Mobile Host
- 1000m x 1000m
- Radio Propagation Range 250m
- Channel Capacity 2Mbits/sec
- Simulation Time 600 secs
- Free Space Propagation Model
- Power of Signal Attenuation $1/d^{2}$, d is the distance between radios

PREDICTION MECHANISMS

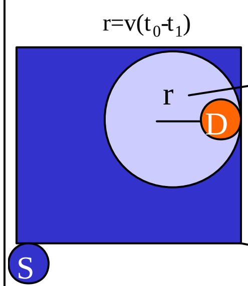
SIMULATION SCENARIOS

- Unicast
  - *FORP*
  - *LAR*
  - *DV-MP*
  - *WRP*
- Multicast
- Prediction Error Effects

PREDICTION MECHANISMS

SIMULATION SCENARIOS

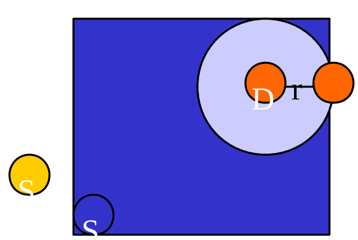
- Unicast
  - *LAR Concepts*
    - *Exploits location information to limit the scope of route request flood (loc. Info obtained by GPS)*
    - *Expected Zone is determined as a region that is expected to hold current location of the destination*
      - *Expected region determined based on potentially old location information, and knowledge of the destination's speed*



- *Route Request limited to a Request Zone that contains the Expected Zone and location of the sender node*

PREDICTION MECHANISMS

SIMULATION SCENARIOS



PREDICTION MECHANISMS

SIMULATION SCENARIOS

LAR

- Advantages
  – reduces the scope of route request flood
  – reduces overhead of route discovery

- Disadvantages
  – Nodes need to know their physical locations
  – Does not take into account possible existence of obstructions for radio transmissions

PREDICTION MECHANISMS

SIMULATION SCENARIOS

Wireless Routing Protocol - WRP

- Is a table based protocol
- Each node maintain four tables
  – distance, routing, link-cost, message transmission list table(MRL)

PREDICTION MECHANISMS

SIMULATION SCENARIOS

- All schemes evaluated as function of speed and No of data UNICAST data sessions
- Assumes no reliable transport protocols
- Two cases
  - Fixed # of data sessions (5) , Mobility speed varies (0 km/h to 72 km/h)
  - No of data sessions varies (5 – 30) , speed set constant (36 km/h)

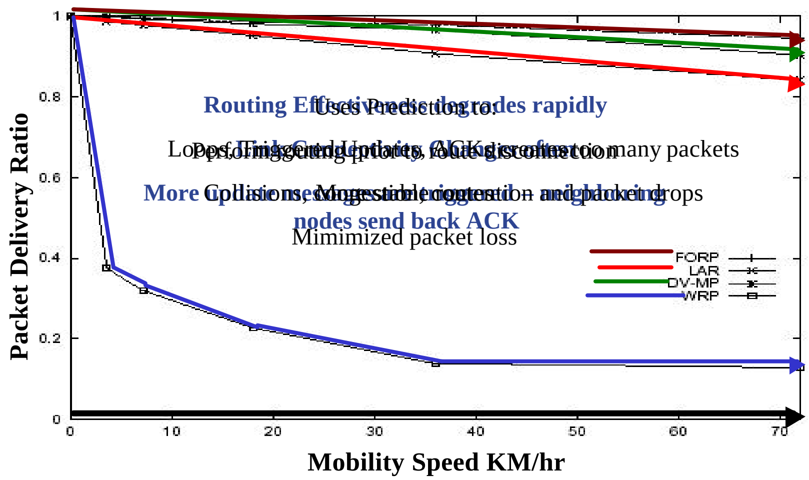
PREDICTION MECHANISMS

SIMULATION METRICS

- Packet Delivery Ratio
  - # of data packets received by D / # of data packets expected by D
- Number of Control Bytes transmitted per data byte delivered
  - Control byte transmitted / data byte delivered
  - Measures how efficiently control packets are used in delivering data
- Number of Total Packets transmitted per data packet delivered
  - # of control packet + # of data packet transmitted / # of data packet delivered
  - Measures efficiency in terms of channel access

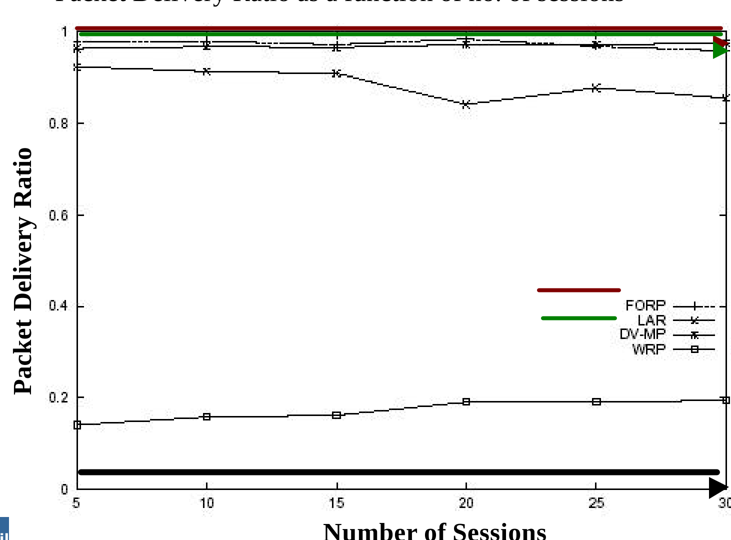
Simulation Results (Unicast)

- Packet Delivery Ratio as a function of speed



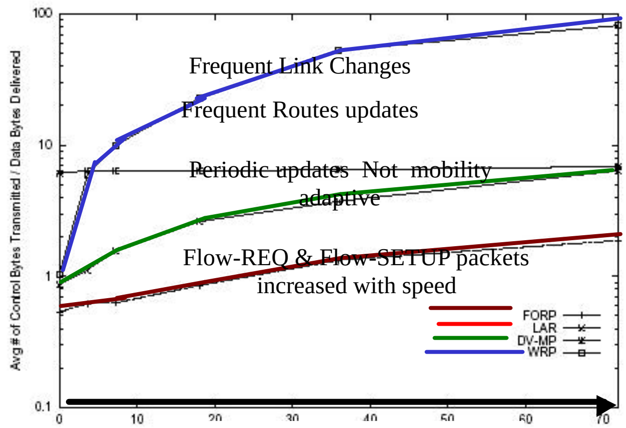
Simulation Results (Unicast)

- Packet Delivery Ratio as a function of no. of sessions



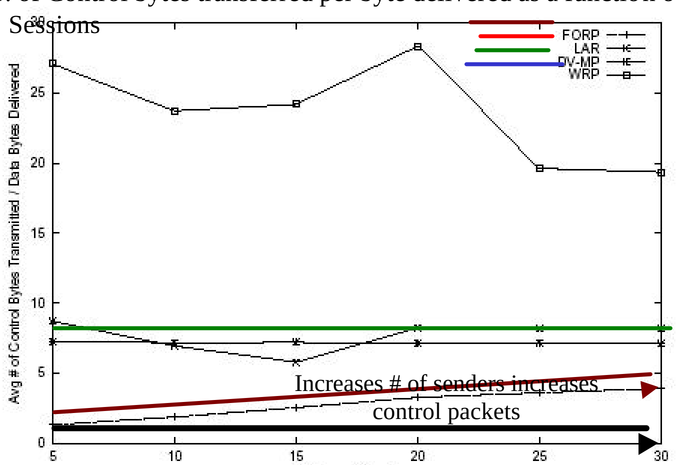
Simulation Results (Unicast)

No. of Control bytes transferred per byte delivered as a function of speed



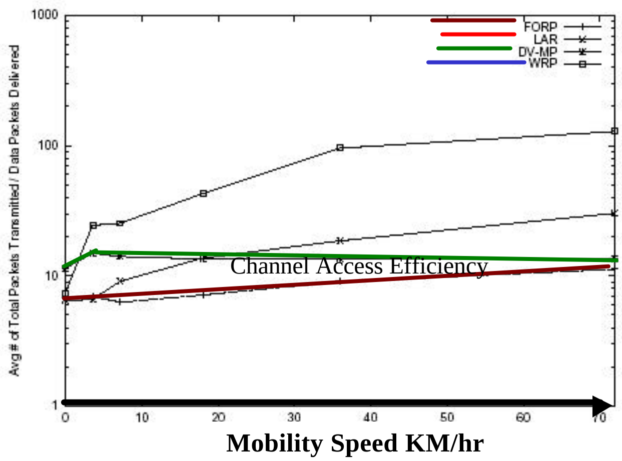
Simulation Results (Unicast)

No. of Control bytes transferred per byte delivered as a function of # of Sessions



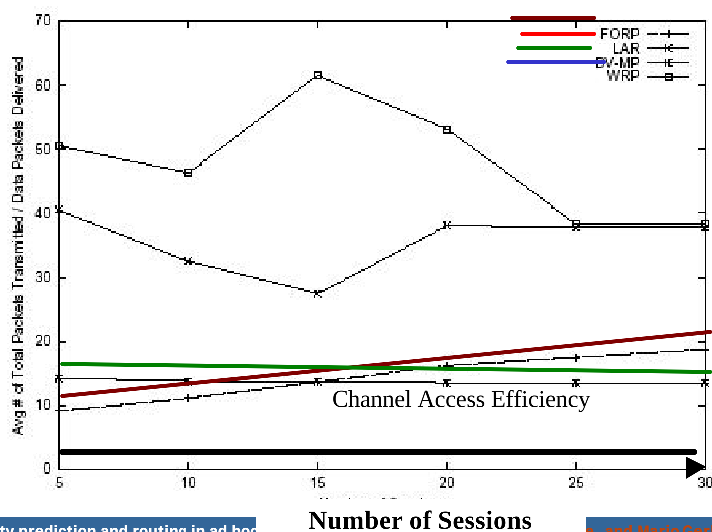
Simulation Results (Unicast)

- No. of Total Packets transmitted per data packet delivered as a function of speed and no. of sessions



Simulation Results (Unicast)

No. of Total Packets transmitted per data packet delivered as a function of number of sessions



PREDICTION MECHANISMS

Multicasting

- Unicast: One Source – one Destinations
- Multicast: ONE or MORE sources to a GROUP of destinations

PREDICTION MECHANISMS

Multicasting

- A multicast group is defined with a unique ***group identifier***
- Nodes may **join** or **leave** the multicast group anytime
- In traditional networks, the physical network topology does not change often
- In MANET, the physical topology can change often

PREDICTION MECHANISMS

Multicasting in MANET

- Need to take topology change into account when designing a multicast protocol

- Several new protocols have been proposed for multicasting in MANET
  - ODMRP
  - AODV

PREDICTION MECHANISMS

On-Demand Multicasting Routing Protocol (ODMRP)

- ODMRP requires cooperation of nodes wishing to send data to the multicast group
  - ➢ *To construct the multicast **mesh***

- A sender node wishing to send multicast packets *periodically* floods a ***Join Data*** packet throughput the network
  - ➢ ***Periodic transmissions are used:***
    - ❑ *to refresh group node membership and*
    - ❑ *route update information*

PREDICTION MECHANISMS

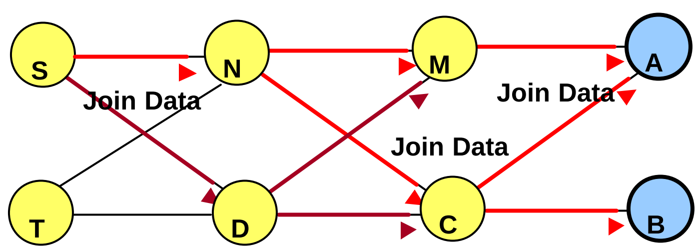
ODMRP

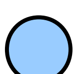
- When Join Data packet reaches multicast receiver, the member broadcasts a Join Table to all its neighbors
- Join Table contains (sender S, next node N) pairs, next node N denotes the next node on the path from the group member to the multicast sender S
- When node N receives the above broadcast, N becomes member of the forwarding group
- When node N becomes a forwarding group member, it transmits Join Table containing the entry (S,M) where M is the next hop towards node S

PREDICTION MECHANISMS

ODMRP

- Assume that S is a sender node

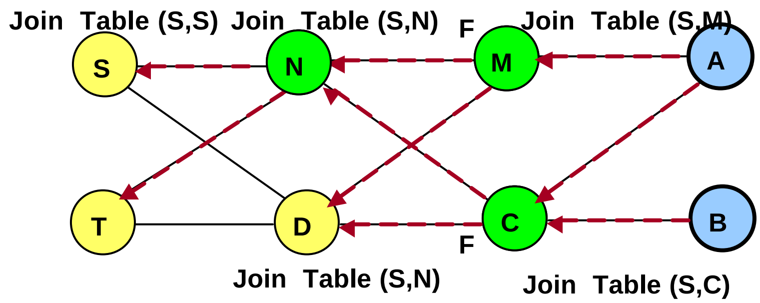




Multicast receiver

PREDICTION MECHANISMS

ODMRP

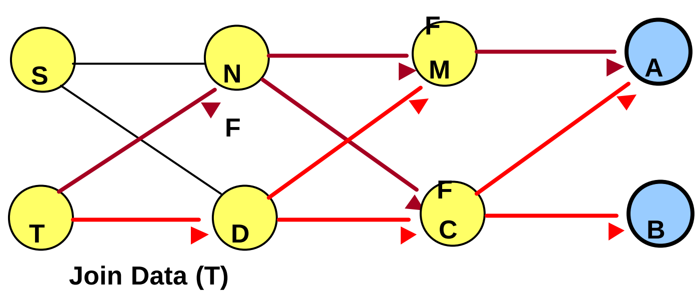


F marks a forwarding group member

Multicast receiver

PREDICTION MECHANISMS

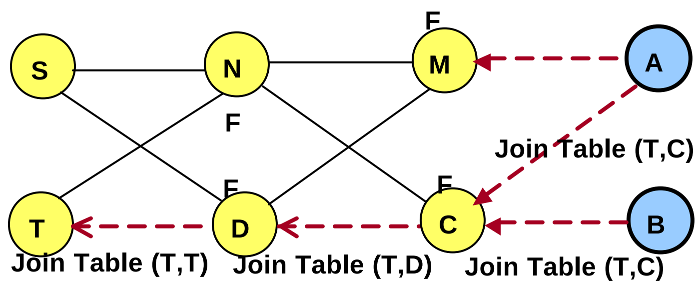
ODMRP



Multicast receiver

PREDICTION MECHANISMS

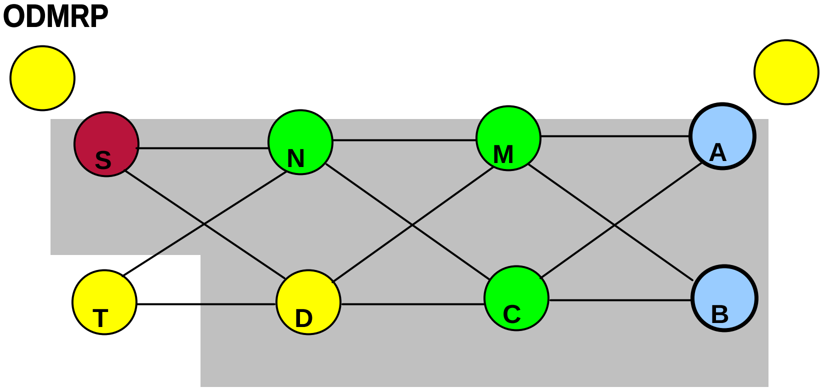
ODMRP



Multicast receiver

PREDICTION MECHANISMS

ODMRP



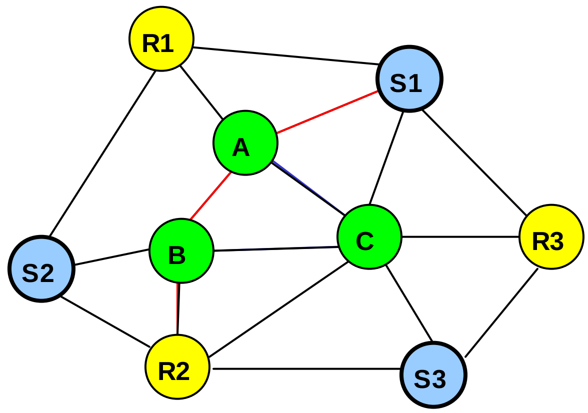
Forwarding Group Nodes

Regular Nodes

Multicast receiver

PREDICTION MECHANISMS

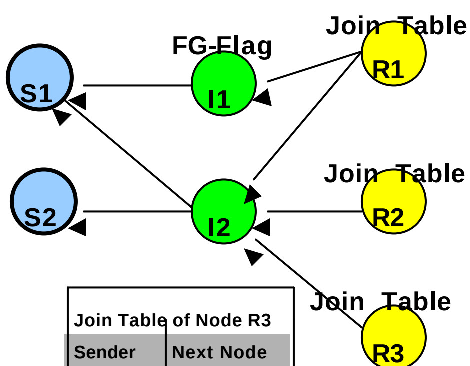
ODMRP



Sources: S1, S2, S3 **Recievers**: R1, R2, R3 **Forwarding Nodes:** A, B, C

PREDICTION MECHANISMS

ODMRP



Join Table of Node R1

Sender	Next Node
S1	I1
S2	I2

Join Table of Node I1

Sender	Next Node
S1	S1

Join Table of Node I2

Sender	Next Node
S1	S1
S2	S2

Join Table of Node R3

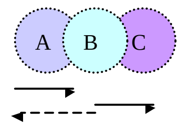
Sender	Next Node
S1	I2
S2	I2

Sources: S1, S2, S3 **Recievers**: R1, R2, R3 **Intermediate Nodes:** I1, I2

PREDICTION MECHANISMS

ODMRP

- Reliability
  Reliable transmission of JOIN-TABLE .



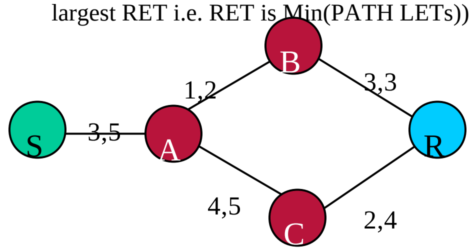
- Data Forwarding
  Through Intermediate Nodes.
  Forwarding until FG-Flag expires.

- Soft State
  No explicit control packets needed to join or leave the group.
  Join or Leave at will.
  Forwarding nodes demoted to non-forwarding nodes once the JOIN TABLEs are timed out.

PREDICTION MECHANISMS

Applying Mobility Prediction in ODMRP

- In basic ODMRP, routes chosen based on Delay
- In ODMRP (with Mobility Prediction), routes chosen on Stability. (Route with largest RET i.e. RET is Min(PATH LETs))



	Route 1	Route 2
Path	S-A-B-R	S-A-C-R
Delay	7	9
RET	2	4

i, j

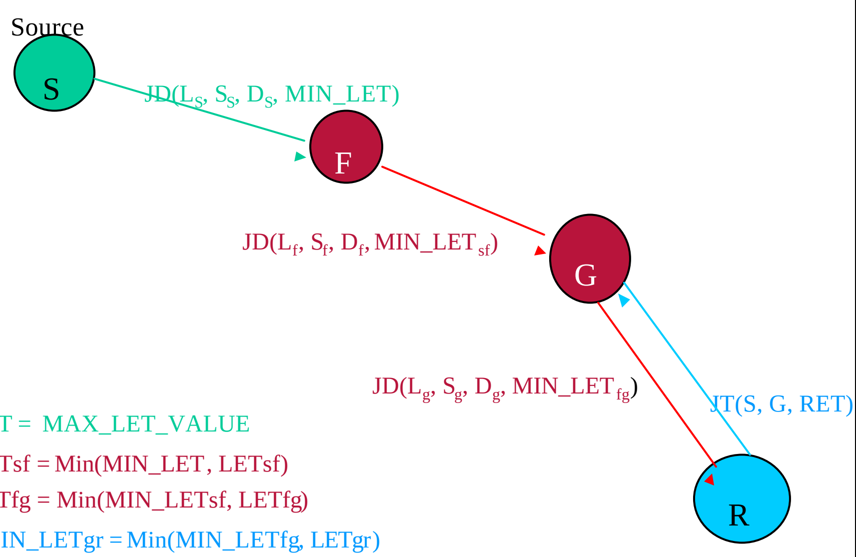
Link with delay 'i' and LET 'j'

PREDICTION MECHANISMS

Mobility Prediction in ODMRP

- ODMRP scheme floods JOIN DATA to build & refresh routes.
- Optimal flooding interval is critical for performance.
- Extra fields added into JOIN DATA and JOIN TABLE for enhancements.
- The Multicast Source sends a JOIN DATA packet and appends its Location, Speed and Direction to the packet. The MIN_LET is set to MAX_LET_VALUE as it does not have any previous hop node.
- The next node calculates the LET between itself and previous hop. (In this case the source)
- Min. between MAX_LET_VALUE and calculated LET is chosen.
- The node appends its own Location, Speed and Direction before forwarding the JOIN DATA.
- The receiver on getting JOIN DATA, calculates LET between itself and previous hop and the min. between calculated LET and MIN_LET specified in JOIN DATA is chosen as RET.
- This RET is value is then included in the JOIN TABLE packets.

PREDICTION MECHANISMS



MIN_LET = MAX_LET_VALUE

MIN_LETsf = Min(MIN_LET, LETsf)

MIN_LETfg = Min(MIN_LETsf, LETfg)

RET = MIN_LETgr = Min(MIN_LETfg, LETgr)

PREDICTION MECHANISMS

Mobility Prediction in ODMRP

- Flooding interval chosen based on estimated RET, mobility rate and topology changes.
- **Case 1: High Mobility**
  - Fast Topology changes, JOIN DATA propagation increases
  - Network congestion results
  - Hence MIN_REFRESH_INTERVAL enforced
- **Case 2: Low Mobility**
  - Hardly any topology changes, hence source sends no JOIN DATA
  - RET becomes obsolete, if a node suddenly changes direction
  - Also, a new node willing to join group has to wait for JOIN DATA
  - Hence, a need for MAX_REFRESH_INTERVAL

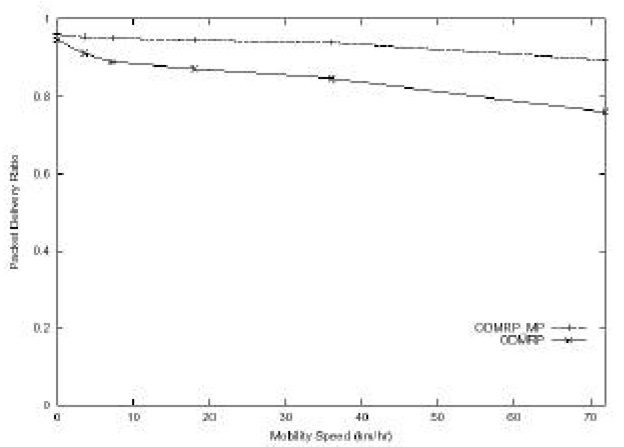
PREDICTION MECHANISMS

SIMULATION ENVIRONMENT

- GloMoSim
- 50 Mobile Host
- 1000m x 1000m
- Radio Propagation Range 250m
- Channel Capacity 2Mbits/sec
- Simulation Time 600 secs
- Free Space Propagation Model
- Power of Signal Attenuation $1/d^2$, d is the distance between radios

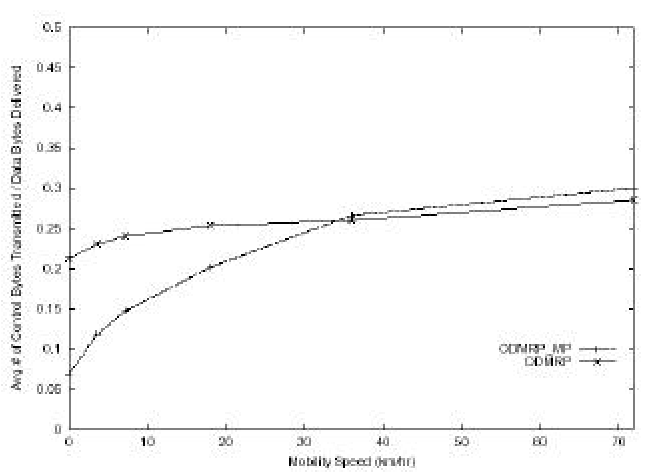
Simulation Results (Multicast)

• Packet Delivery Ratio as a function of speed



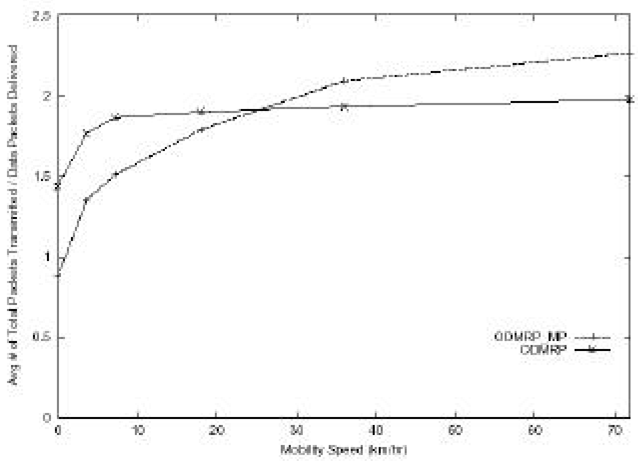
Simulation Results (Multicast)

• No. of Control bytes transferred per byte delivered as a function of speed



Simulation Results (Multicast)

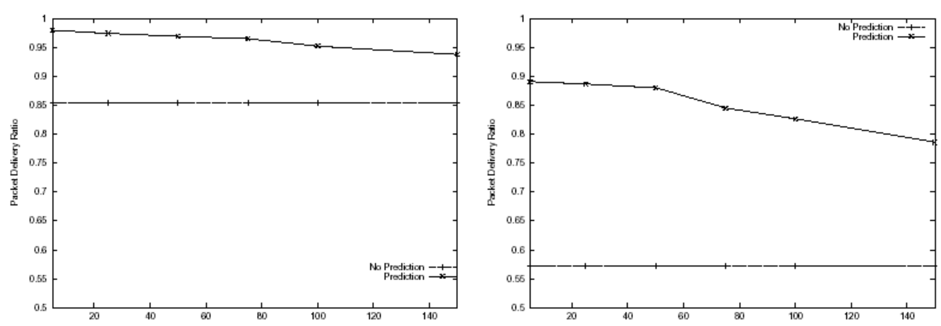
- No. of Total Packets transmitted per data packet delivered as a function of speed



Simulation Results

Prediction Error Effects

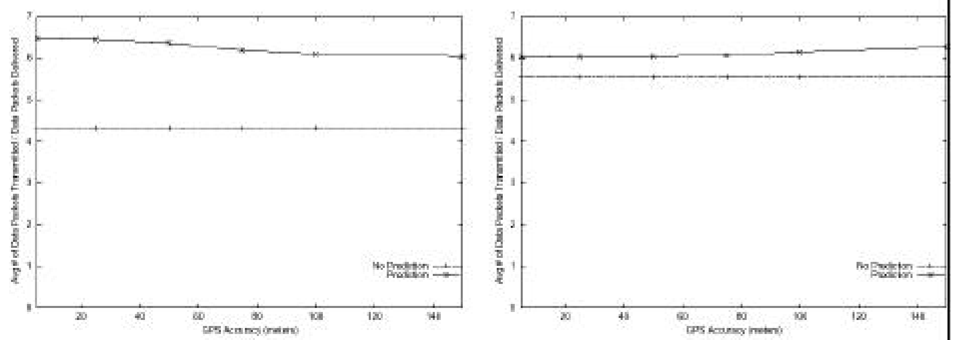
- Effect of GPS accuracy on performance



Simulation Results

Prediction Error Effects

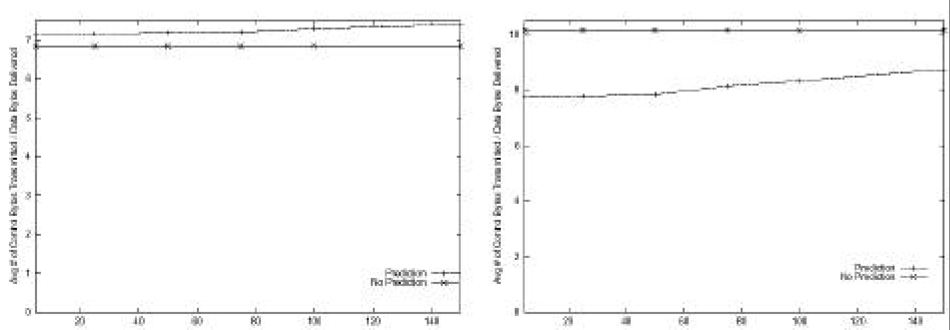
- Effect of GPS accuracy on avg. no. of packets transmitted per data packet delivered



Simulation Results

Prediction Error Effects

- Effect of GPS accuracy on no. of control bytes transmitted per data byte delivered



Conclusion

- More Effective Delivery of Data Packets, as interference due to link disruptions is minimized by building a new path before current route expires.
- Control packets utilized more effectively.

Critique

- Free Space Propagation model, a highly simplified view of real life scenario.
- Clock synchronization is done via GPS or NTP. GPS may not be a viable option indoors while to use NTP nodes have connect to Internet.
- Overhead in proposed prediction schemes is computationally demanding on resource poor mobile clients
- The concepts behind MAX_LET_VALUE, MIN_REFERSH_INTERVAL & MAX_REFRESH_INTERVAL not covered in detail.

Question / Commets

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