

PROPHET

Probabilistic **R**outing using **H**istory of **E**ncounters and **T**ransitivity

Primary Ref: Anders Lindgren, Avri Doria and Olov Schelén, Probabilistic routing in intermittently connected networks, In Proceedings of the The First International Workshop on Service Assurance with Partial and Intermittent Resources (SAPIR 2004), August 2004

Student Lecture

by

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Outline

- Introduction
- Background Scenarios
- Related Work
- PROPHET
 - Protocol
 - Metric Calculation
 - Forwarding Strategies
 - Transitivity Example
 - Simulations
 - Results
- Conclusions

Introduction

- Traditional routing protocols
 - Assume fairly connected paths
 - Fail to work on highly mobile networks
 - Includes some ad-hoc routing protocols as well
- Intermittently connected networks protocols
 - Need to provide reliable communication
 - Buffer messages
 - Exploit mobility
 - Non-randomness in node mobility
 - Optimize performance metric

Background Scenarios

- Saami population in North Sweeden
 - Reindeer Herders, camp life with no fixed infrastructure
- DakNet Project
 - Connectivity to rural villages in India, Cambodia
 - Store-and-forward based on buses and motorcycles
- Military war-time personal/vehicular networks
- Disaster response/recovery networks
- Mobile sensor networks
 - Oceanic temperature measurement through seals and whales
 - ZebraNet - monitoring movement patterns of wildlife
- Other Personal networks - Weather monitoring in national parks

Related Work

- Epidemic Routing
 - Nodes exchange Summary Vector and exchange messages
 - High delivery rates and high overhead/buffer space
 - Hop count determines the resource utilization
- Shared Wireless Infostation model (SWIM)
 - Selective exchange of messages based on probabilities
- Disconnected Transitive communication (DTC)
 - Send the message to one of the connected nodes in the cluster
 - Utility function to determine the node closest to the destination
 - Weights to tune the utility functions
 - Repeat the procedure at every node

PROPHET - Protocol

- Practical application characteristics
 - Predictable movement patterns
 - “If node visits a location several times, it is likely to visit it again”
 - Random way-point model not suitable
 - Bandwidth and buffer space are limited resources
- Each node ‘a’ maintains a delivery predictability metric $P_{(a,b)} \in [0, 1]$ for every other node ‘b’
- $P_{(a,b)}$ is likelihood of encounter between the two nodes
- When two nodes meet
 - Exchange the summary vector and delivery predictability vectors
 - Update the internal delivery predictabilities
 - Exchange messages based on the forwarding strategy

PROPHET – Metric Calculation

Factors that effect the delivery probability metric

1. Encounter of two nodes a, b
2. Aging effect: Time elapsed since the last encounter
3. Transitive Property

$$P_{(a,b)} = P_{(a,b)} + (1 - P_{(a,b)_{old}}) \times P_{init}$$

where $P_{init} \in (0,1]$ is an initialization factor

$$P_{(a,b)} = P_{(a,b)_{old}} \times \gamma^k$$

where $\gamma \in (0,1)$ is an aging constant and

k is the number of time units elapsed since last encounter

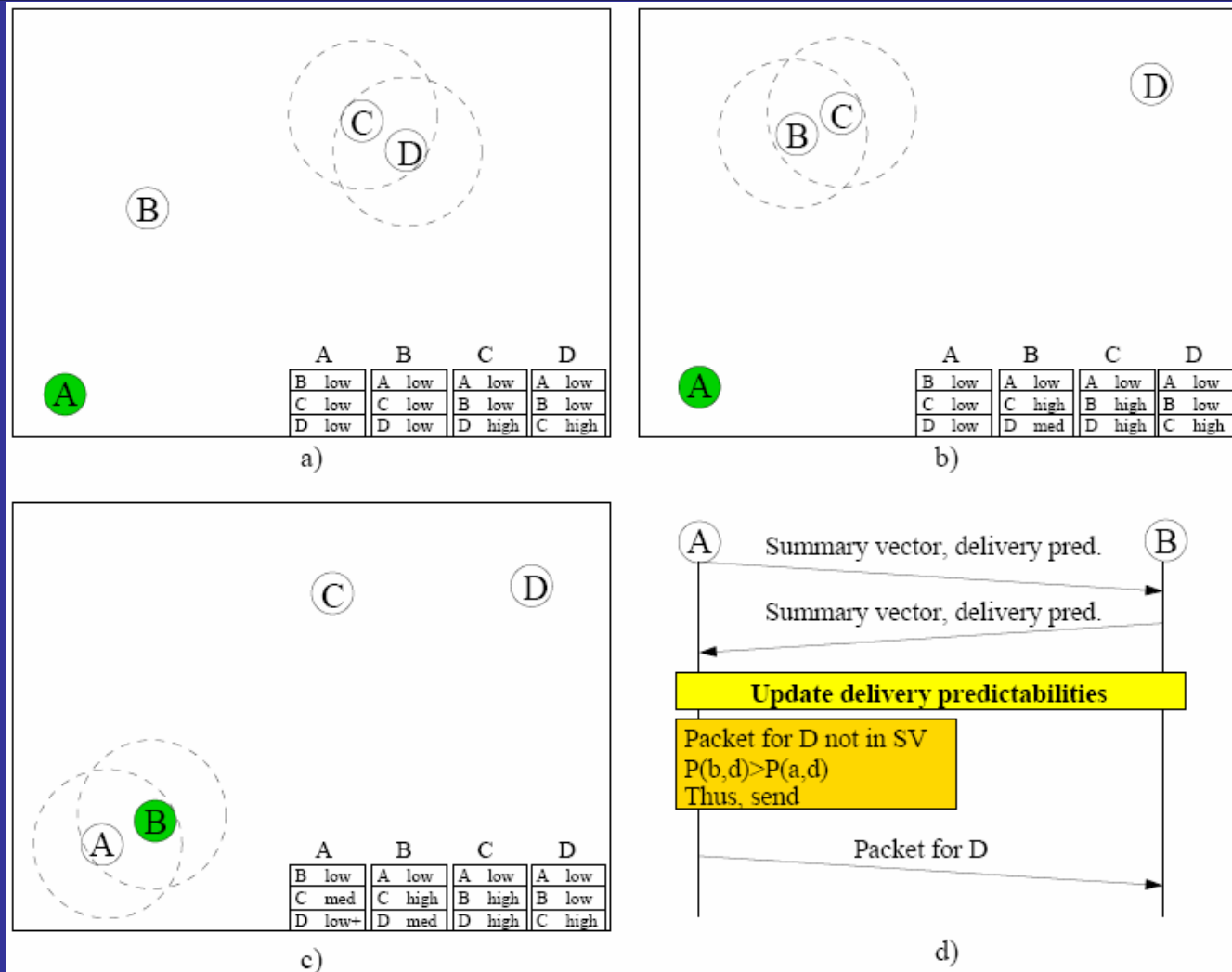
$$P_{(a,b)} = P_{(a,b)} + (1 - P_{(a,b)_{old}}) \times P_{(a,b)} \times P_{(b,c)} \times \beta$$

where $\beta \in (0,1)$ is the scaling factor

PROPHET – Forwarding

- Forwarding
 - Determines the performance as well as the resource overhead
 - Need a threshold to determine who to forward to
 - Number of nodes to forward the message to
 - Satisfy the minimum delay, delivery rate requirements
- PROPHET
 - Forward to any node that has higher delivery probability for dest.
 - If node 'a' has a message for destination 'd', it will forward it to ...
....any node 'b' if and only if $P_{(b,d)} > P_{(a,d)}$
 - Keep a copy of the forwarded message along as possible
 - Number of times the messages is forwarded : Hop Count
 - If buffer overflow, delete messages based on FIFO principle

PROPHET – Transitivity Example

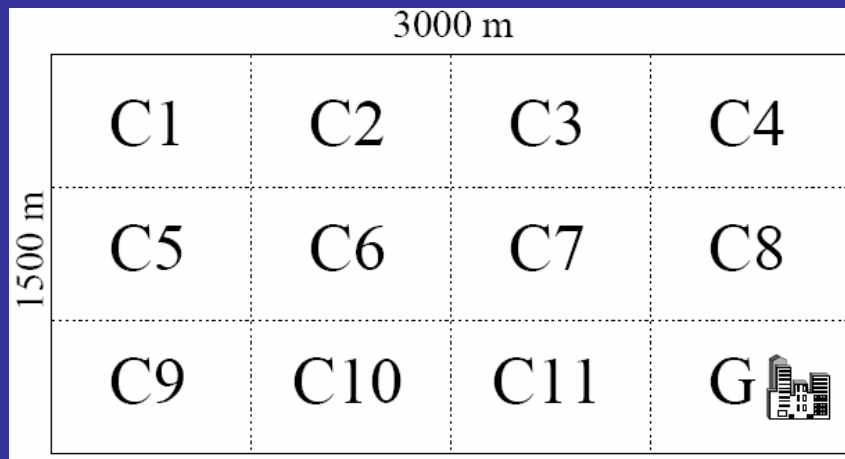


PROPHET - Simulations

- Random way-point model
 - 1500m x 300m area
 - 50 nodes
 - Speeds 0-20m/s
 - Subset of 45 nodes send a message every second
- Message Traffic
 - 45 nodes send a message to other 44 nodes = 1980 secs
 - Allow 2020 secs after the last transmission for message delivery
 - Warm up period of 500sec to initialize the delivery predictabilities

PROPHET - Simulations

- Community Model
 - 3000m x 1500m area divided into 12 subareas
 - 11 communities and 1 gathering place
 - Each node has one home community
 - Fixed node in each community & at gathering place
 - High probability of node movement between home and gathering place



From \ To	Home	Gathering place	Elsewhere
Home	-	0.8	0.2
Elsewhere	0.9	-	0.1

PROPHET - Simulations

- Community Model
 - 5 nodes per home community
 - Nodes move according to probabilities
 - Speed 10-30 m/s
- Message Traffic
 - Every tenth second
 - + two random comm. gateways generate a mess. for another comm..
.... gateway or to gathering place
 - Five sec after each such transmission
 - + Two random nodes generate message to random destinations
 - Message generation continues for 3000 sec
 - 8000 sec. to allow for message deliveries

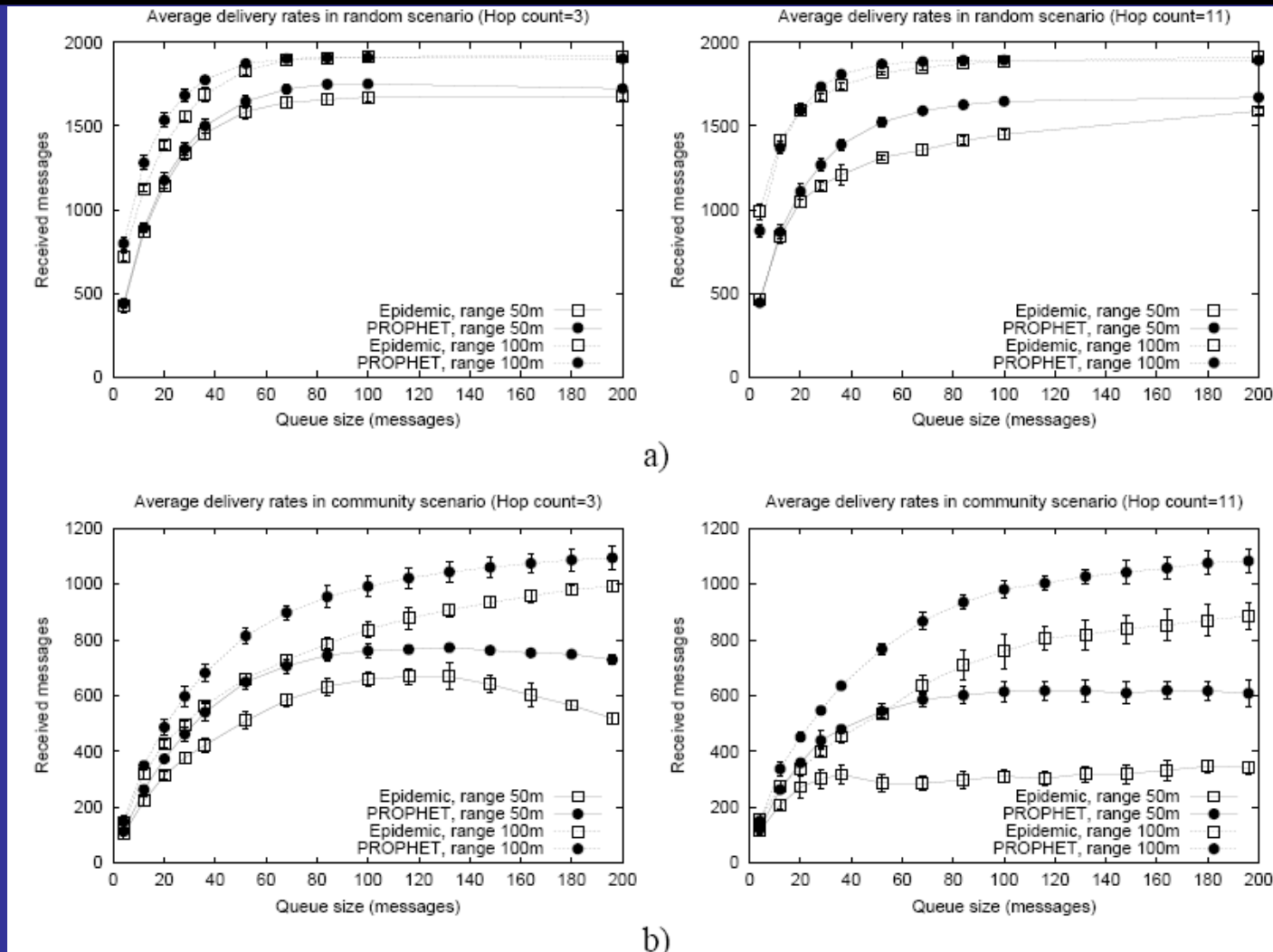
PROPHET - Simulations

- Protocol Parameters

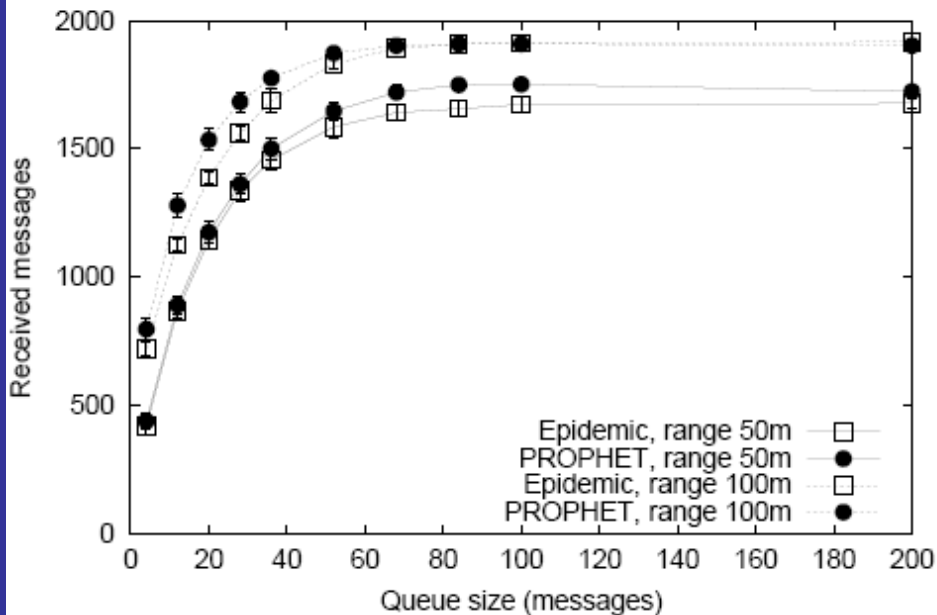
Parameter	Value
P_{init}	0.75
β	0.25
γ	0.98

- Performance Metrics
 - Message delivery ability
 - Message delivery delay
 - Number of message exchanges
- Simulations repeated 5 times

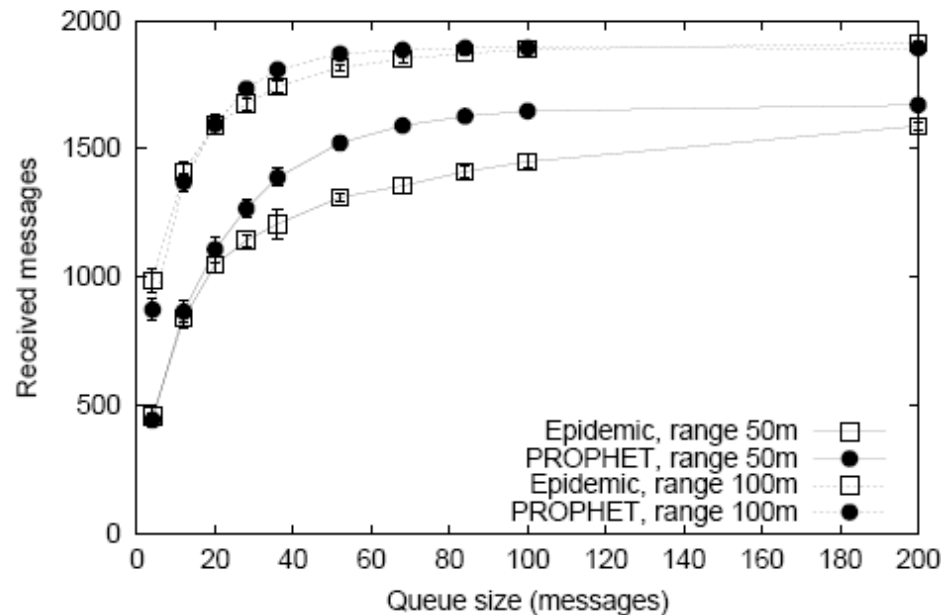
PROPHET – Results: Message delivery



Average delivery rates in random scenario (Hop count=3)

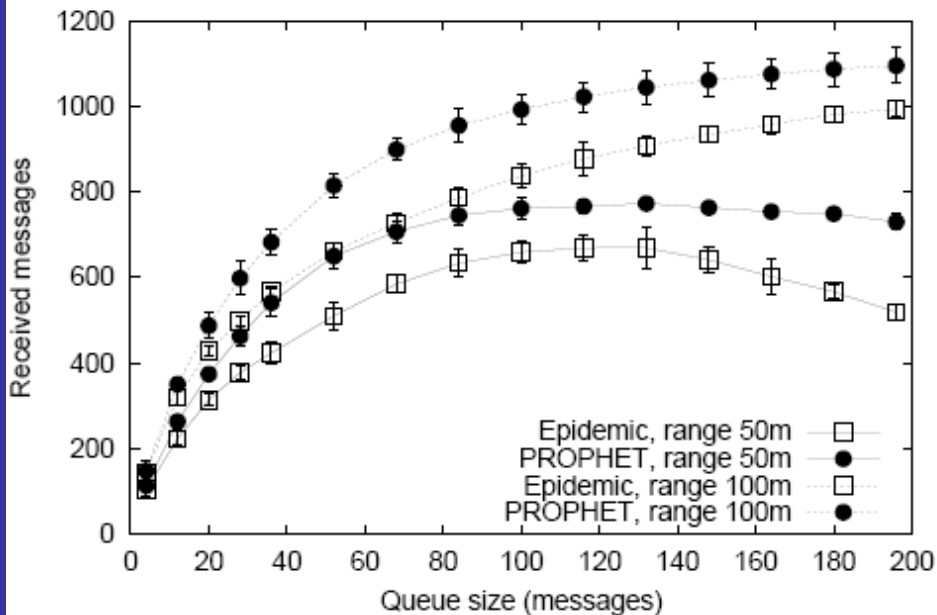


Average delivery rates in random scenario (Hop count=11)

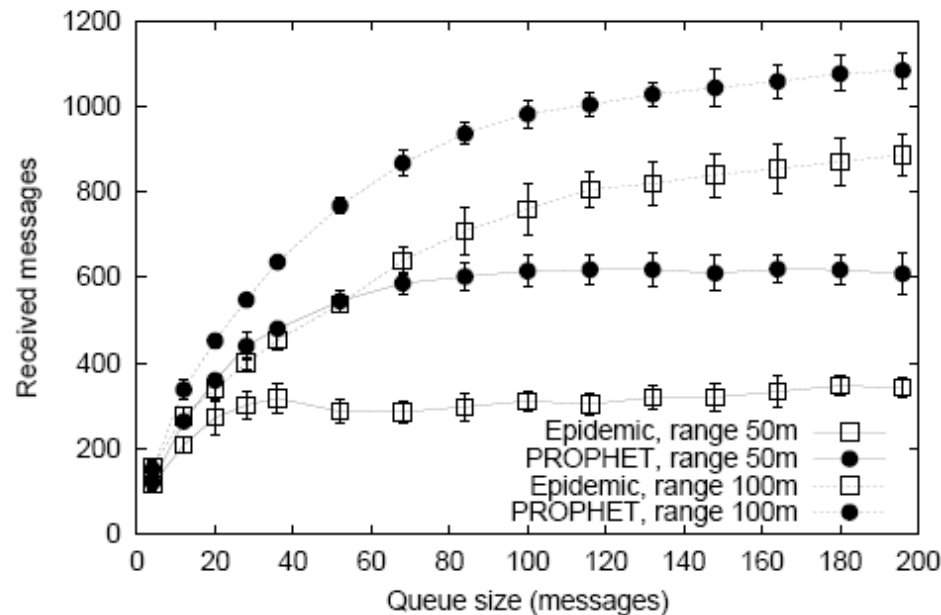


a)

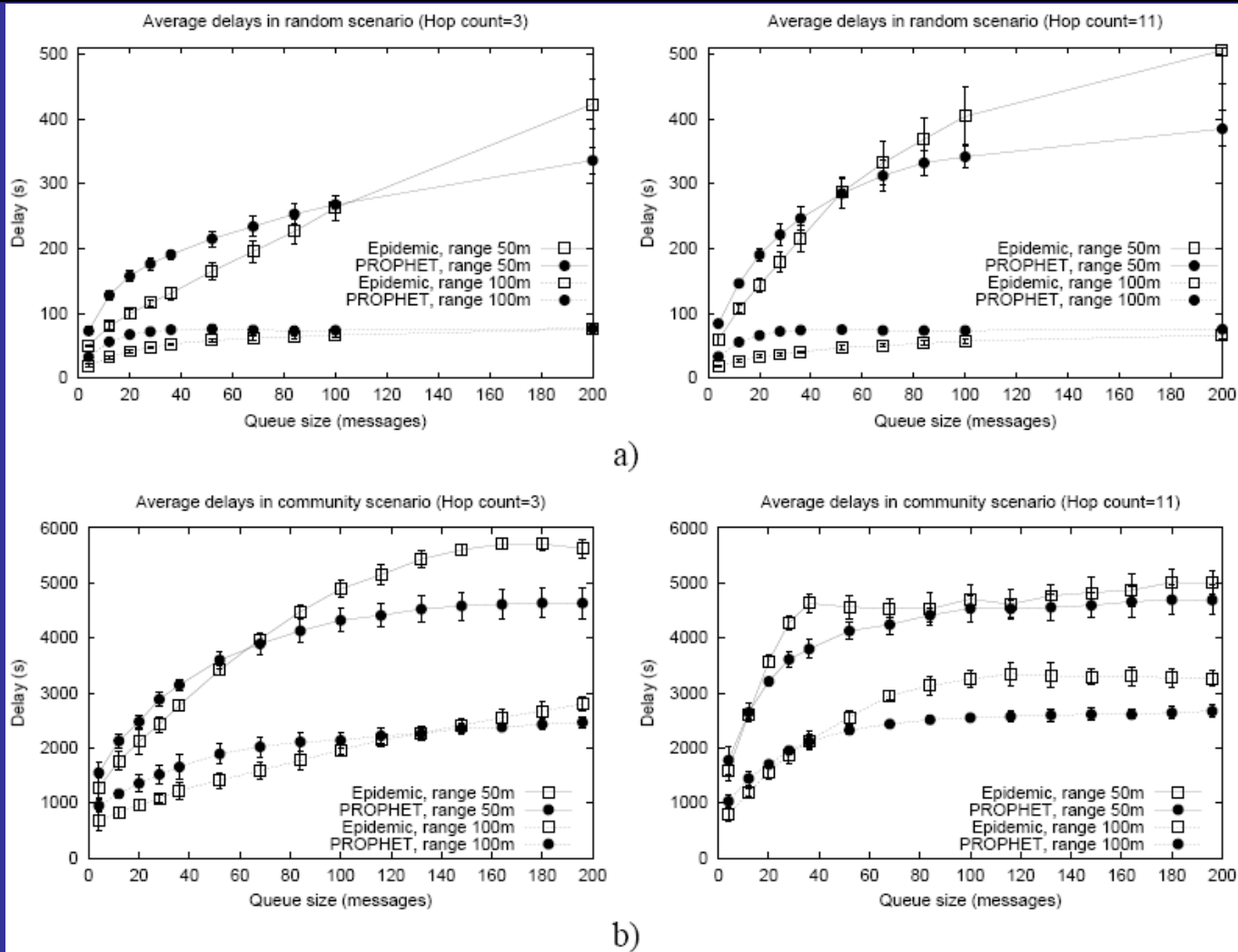
Average delivery rates in community scenario (Hop count=3)



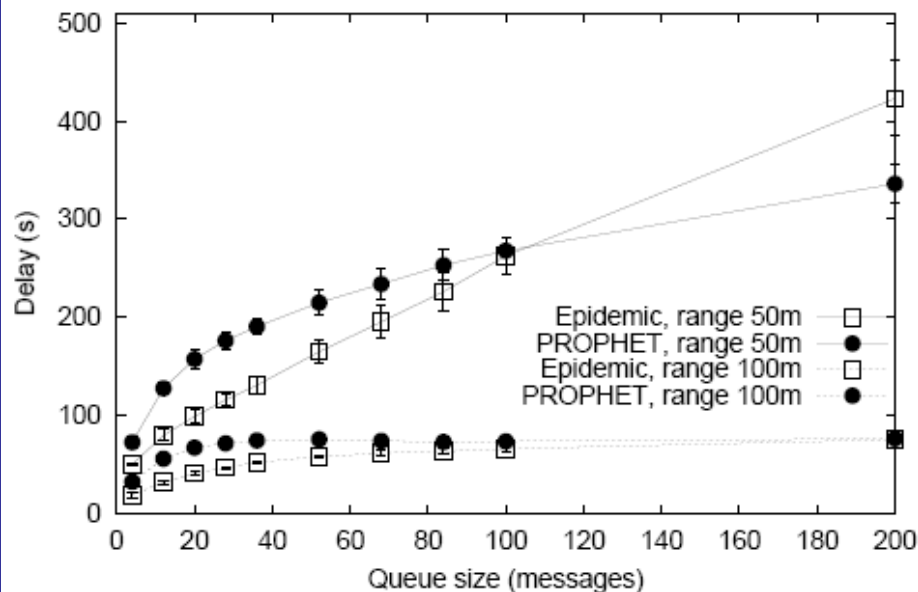
Average delivery rates in community scenario (Hop count=11)



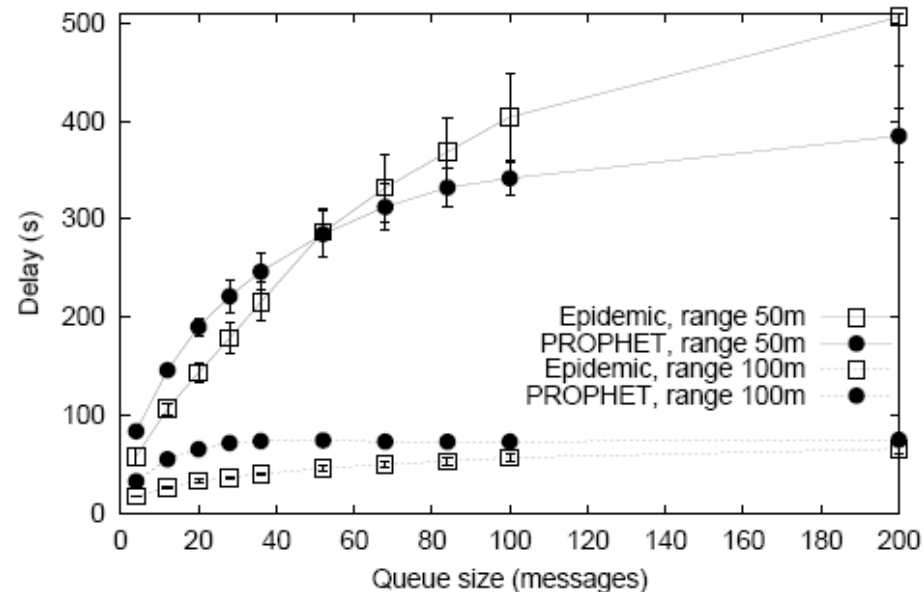
PROPHET – Results: Delivery delay



Average delays in random scenario (Hop count=3)

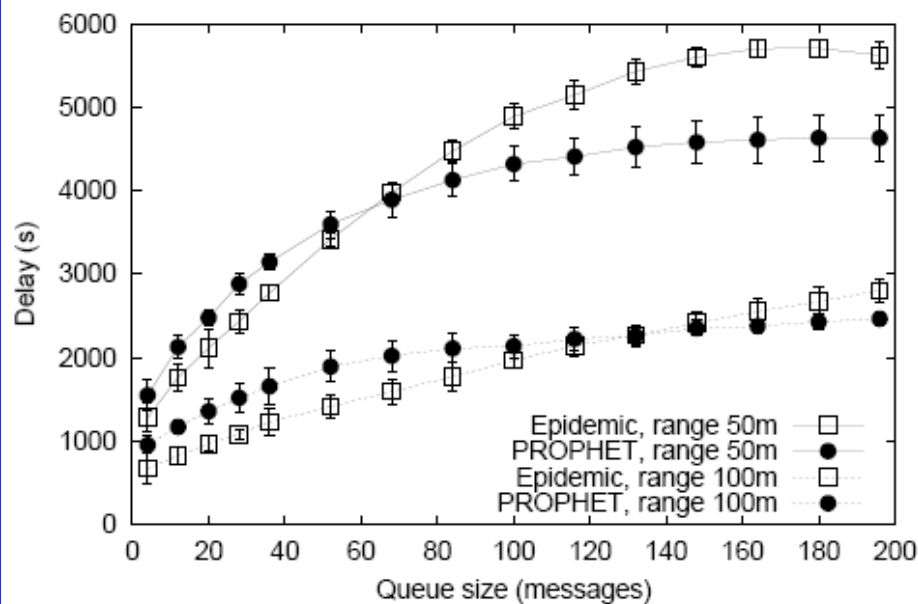


Average delays in random scenario (Hop count=11)

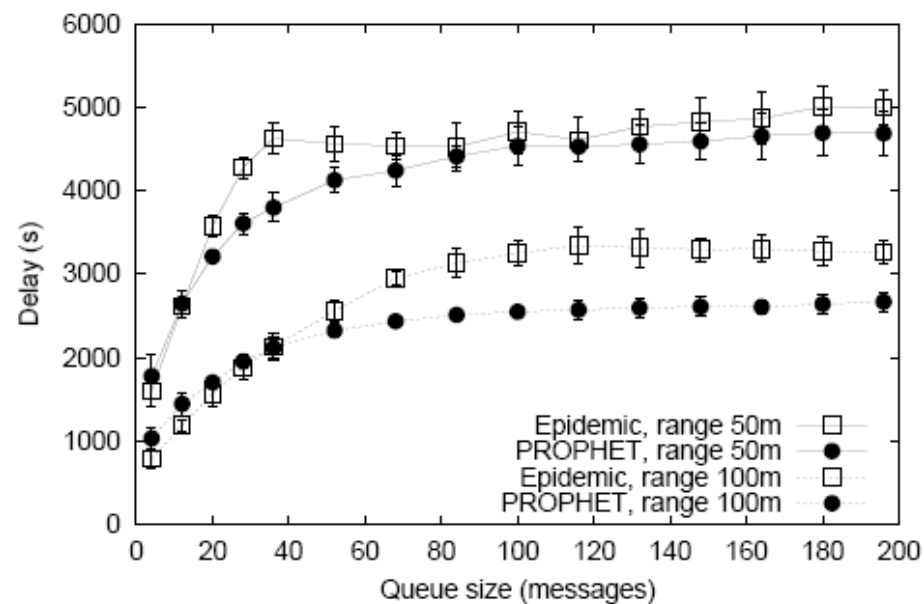


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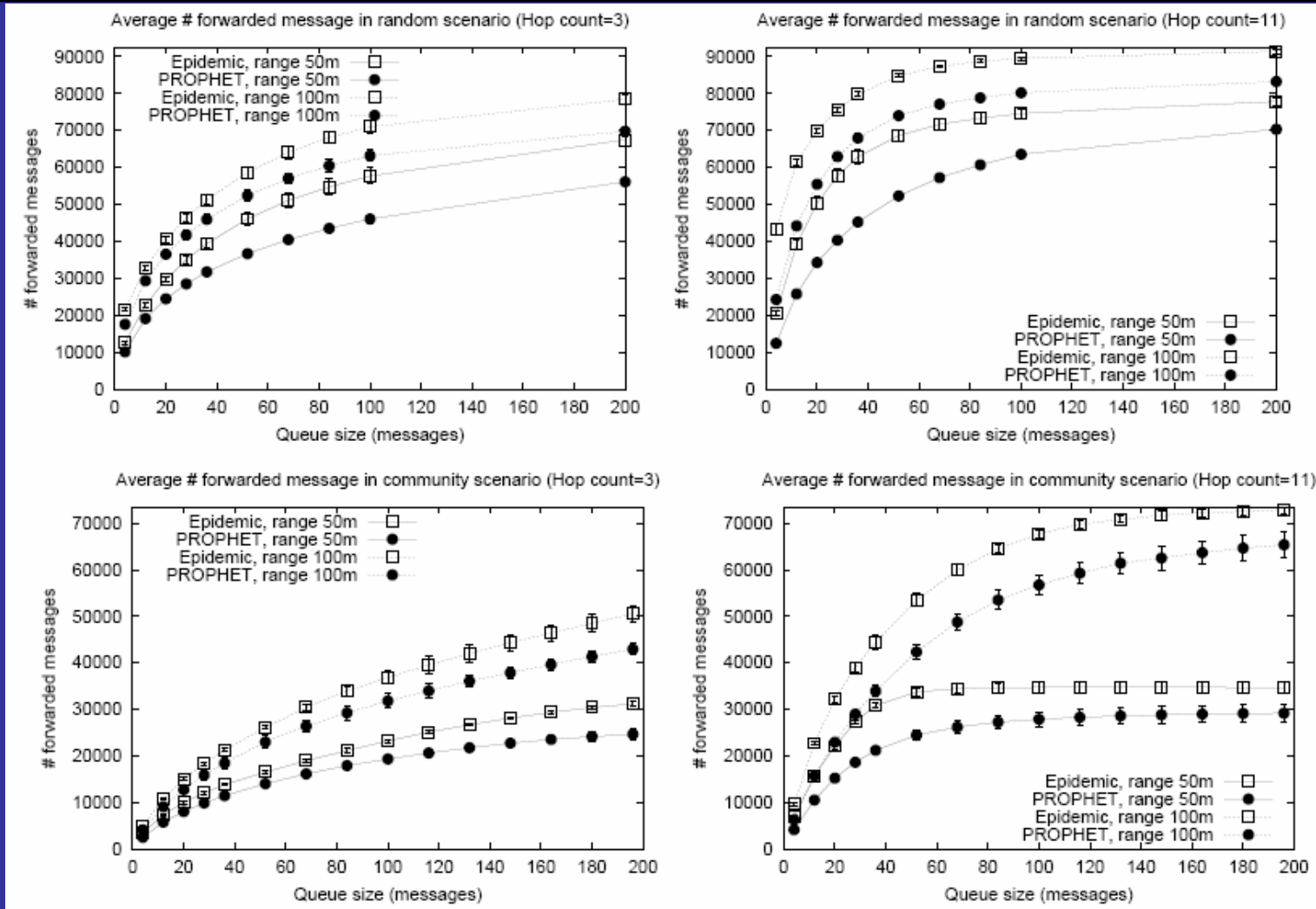
Average delays in community scenario (Hop count=3)



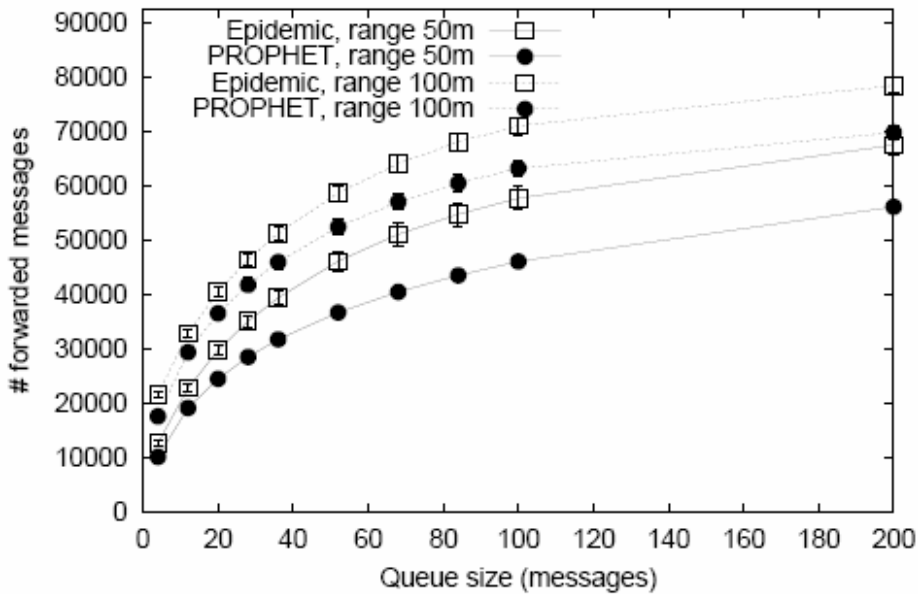
Average delays in community scenario (Hop count=11)



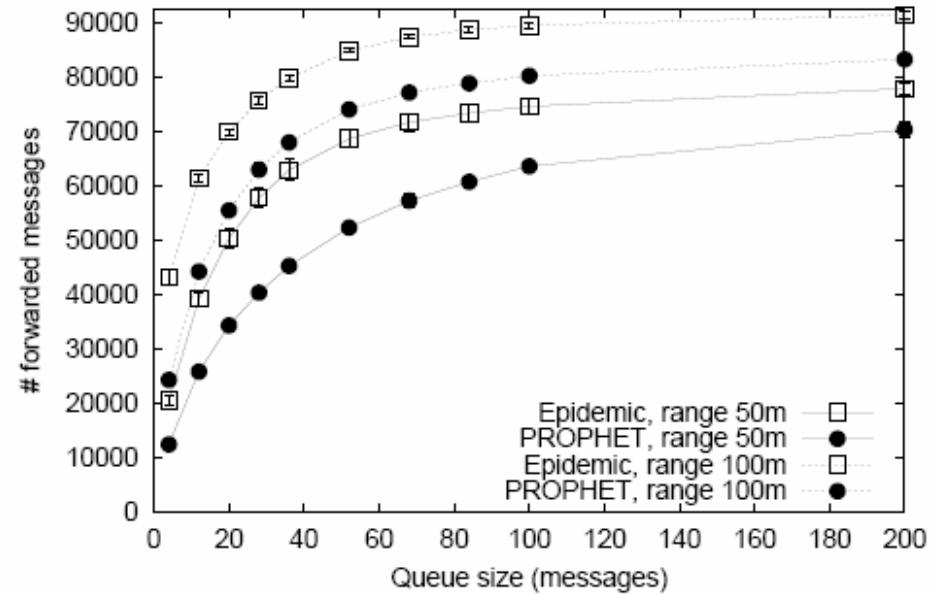
PROPHET – Results: Message overhead



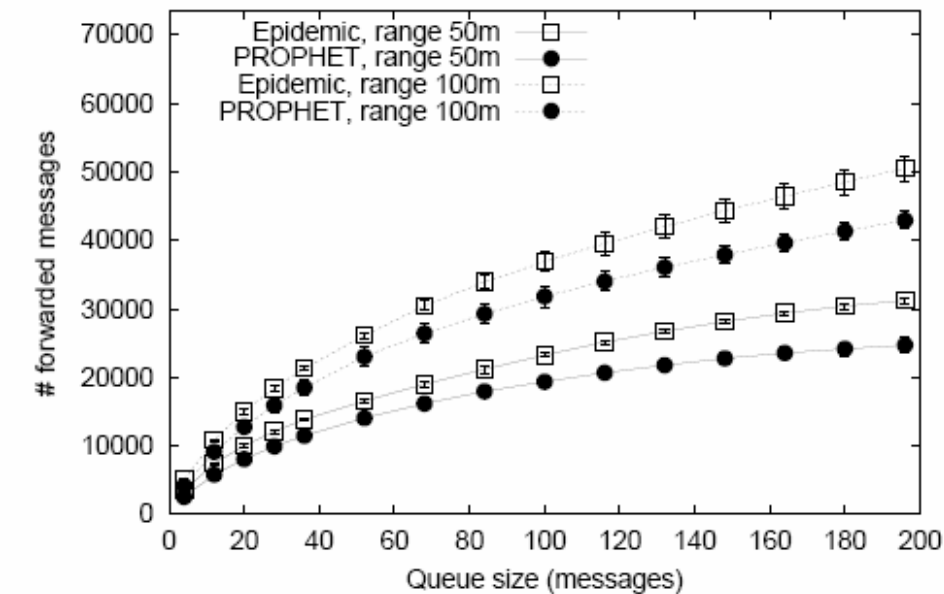
Average # forwarded message in random scenario (Hop count=3)



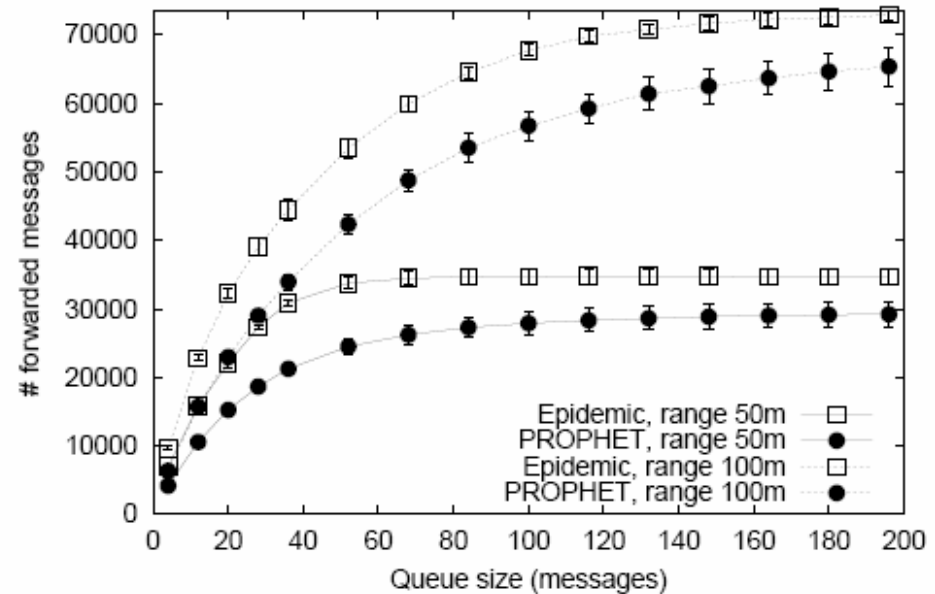
Average # forwarded message in random scenario (Hop count=11)



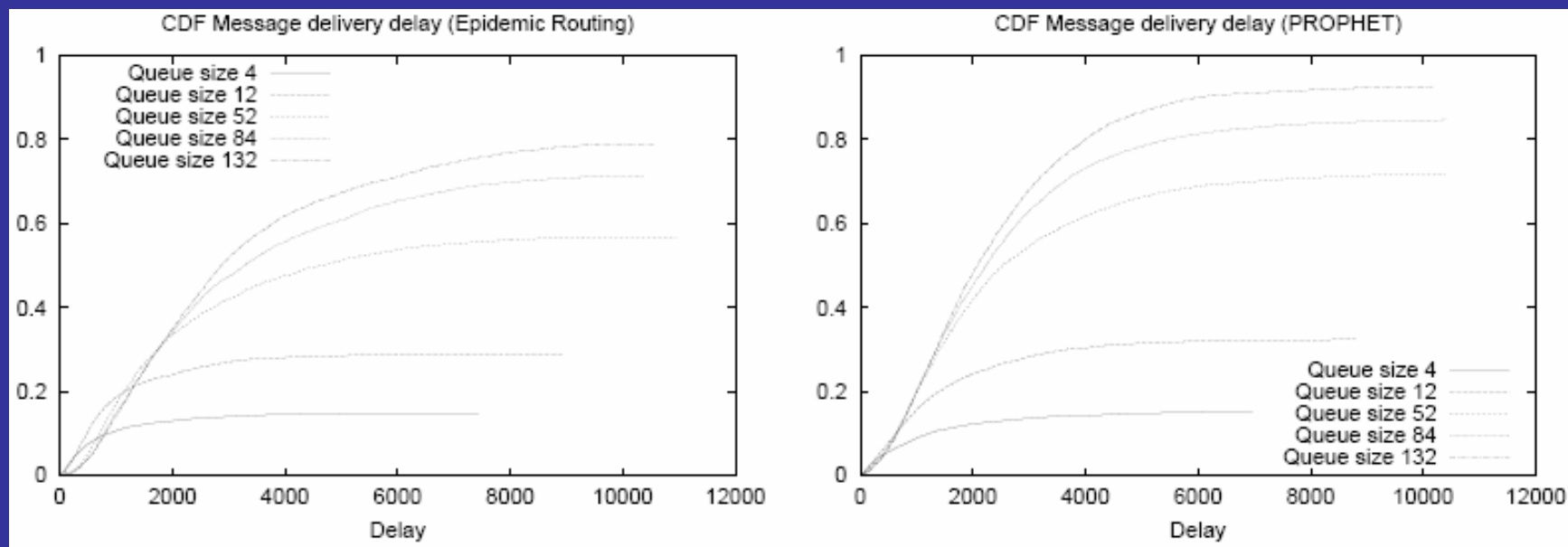
Average # forwarded message in community scenario (Hop count=3)



Average # forwarded message in community scenario (Hop count=11)



PROPHET – Results: Delay CDF



Conclusion

- Message Delivery rate
 - Similar to Epidemic protocol in random mobility scenario
 - Twice as much as epidemic protocol in community model
- Message Delay
 - Increases with queue size
 - Epidemic performs better in random mobility and community ...
... model with low hop count
 - PROPHET performs better in high hop count community model
 - Avg. increase in delay with queue size attributed to increased ...
... delivery rate
- Message Overhead
 - Outperforms epidemic in all cases
 - Increases with transmission range

PROPHET - Problems

- Performance degradation w.r.t
 - Speed of the node above 30 m/s
 - Density of the network
 - Transmission and propagation delay
 - Traffic load
- Maximizes delivery rates with reduced overhead
 - Increased delay
- ?????

References

1. Anders Lindgren, Avri Doria and Olov Schelén, Probabilistic routing in intermittently connected networks, In *Proceedings of the The First International Workshop on Service Assurance with Partial and Intermittent Resources (SAPIR 2004)*, August 2004, Fortaleza, Brazil.
2. Anders Lindgren, Avri Doria and Olov Schelén, Probabilistic routing in intermittently connected networks, *Presented at the Forth ACM International Symposium on Mobile Ad Hoc Networking and Computing (MobiHoc 2003)*, June 1-3, 2003, Annapolis, Maryland, USA.
3. Anders Lindgren, Avri Doria, and Olov Schelén. Probabilistic routing in intermittently connected networks. In *Proceedings of IEEE 6th International Symposium on a World of Wireless, Mobile and Multimedia Networks (WOWMOM'05)*, 2005.