# Ekta: An Efficient DHT Substrate for Distributed Applications in Mobile Ad Hoc Networks

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WMCSA 2004
6th IEEE Workshop on Mobile Computing Systems & Applications

PURDUE UNIVERSITY

# Mobile ad hoc networks (MANETs)

- Wireless networks in which wireless hosts act as forwarding nodes as well as end systems
- No base station or routing infrastructure
- Network topology changes frequently and unpredictably
- Challenge lies in routing packets with changing topology while minimizing overhead
  - Specialized routing protocols: DSR, AODV

# Structured peer-to-peer routing protocols in the Internet

- Operate in an overlay p2p network in which nodes act as clients as well as servers
- Rely on underlying Internet infrastructure to route packets between overlay hops
- Implement a DHT in a scalable, robust manner
- Challenge lies in routing packets in a network with changing membership while limiting state at each node
  - Specialized protocols: Pastry, Tapestry, Chord, CAN

# Motivation

- DHTs provide a useful platform for building scalable and robust distributed applications in the Internet
- DHTs can potentially provide an efficient way to construct distributed applications and services in MANETs
  - Applications such as file sharing, resource discovery could benefit from the insert/lookup convergence
- Main Challenge
  - Provide an efficient DHT abstraction in a MANET and demonstrate its usability

# Outline

- How to support an efficient DHT abstraction in an ad hoc environment?
  - Can off-the-shelf protocols be used?
  - If not, what is an efficient architecture to provide the DHT abstraction?
- How should the DHT abstraction be used in an ad hoc environment ?
  - Can a MANET application benefit from the DHT?

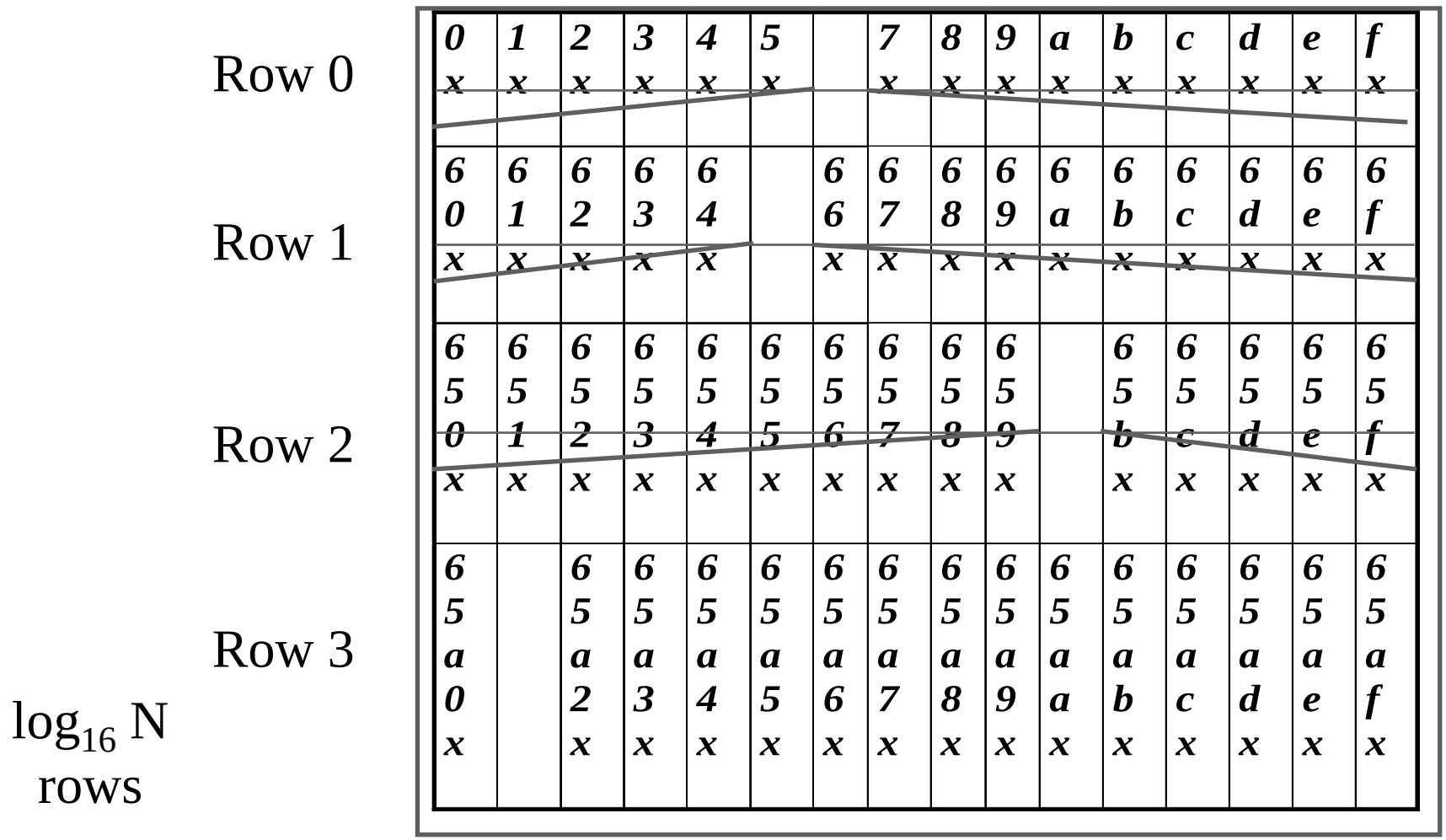
# Implementing DHT: Layered Approach

- Layer Pastry (structured p2p protocol) on top of DSR (MANET routing protocol)
- Pastry operates in the application layer similar to the Internet
- DSR used as underlying routing protocol

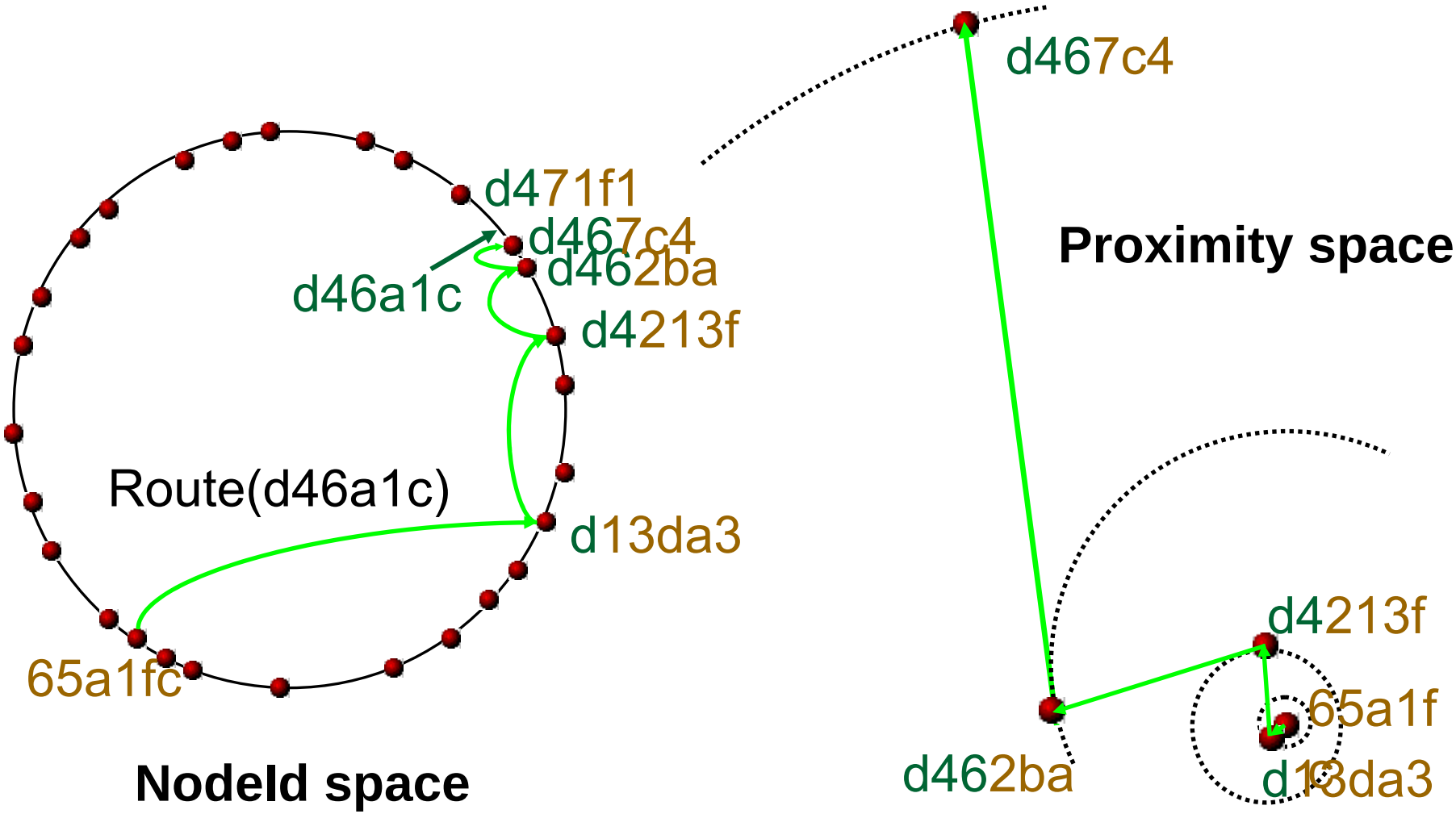
# Pastry : Features

- Nodes have unique Id, messages have keys
  - Typically 128 bits long
- Primitive: **`Route(msg, key)`**
  - Delivers **`msg`** to the currently alive node whose Id is numerically closest to **`key`**
- Scalable, efficient
  - Per node routing table contains O(log(N)) entries
  - Routes in O(log(N)) steps
- Fault tolerant
  - Self-fixes routing tables when nodes are added, deleted or fail

# Pastry : Routing table (# 65a1fcx)

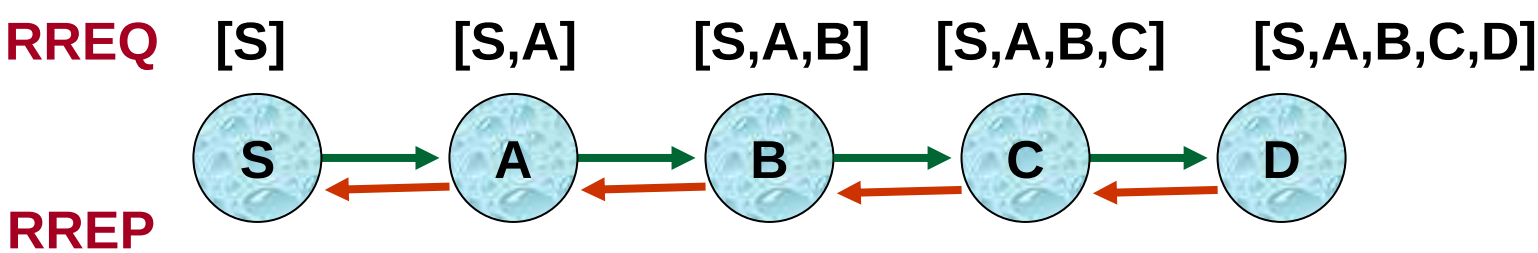


# Pastry: Routing Example



# DSR

- Reactive routing protocol based on source routing
- Operation: route discovery and maintenance
- Route caching: path and link cache



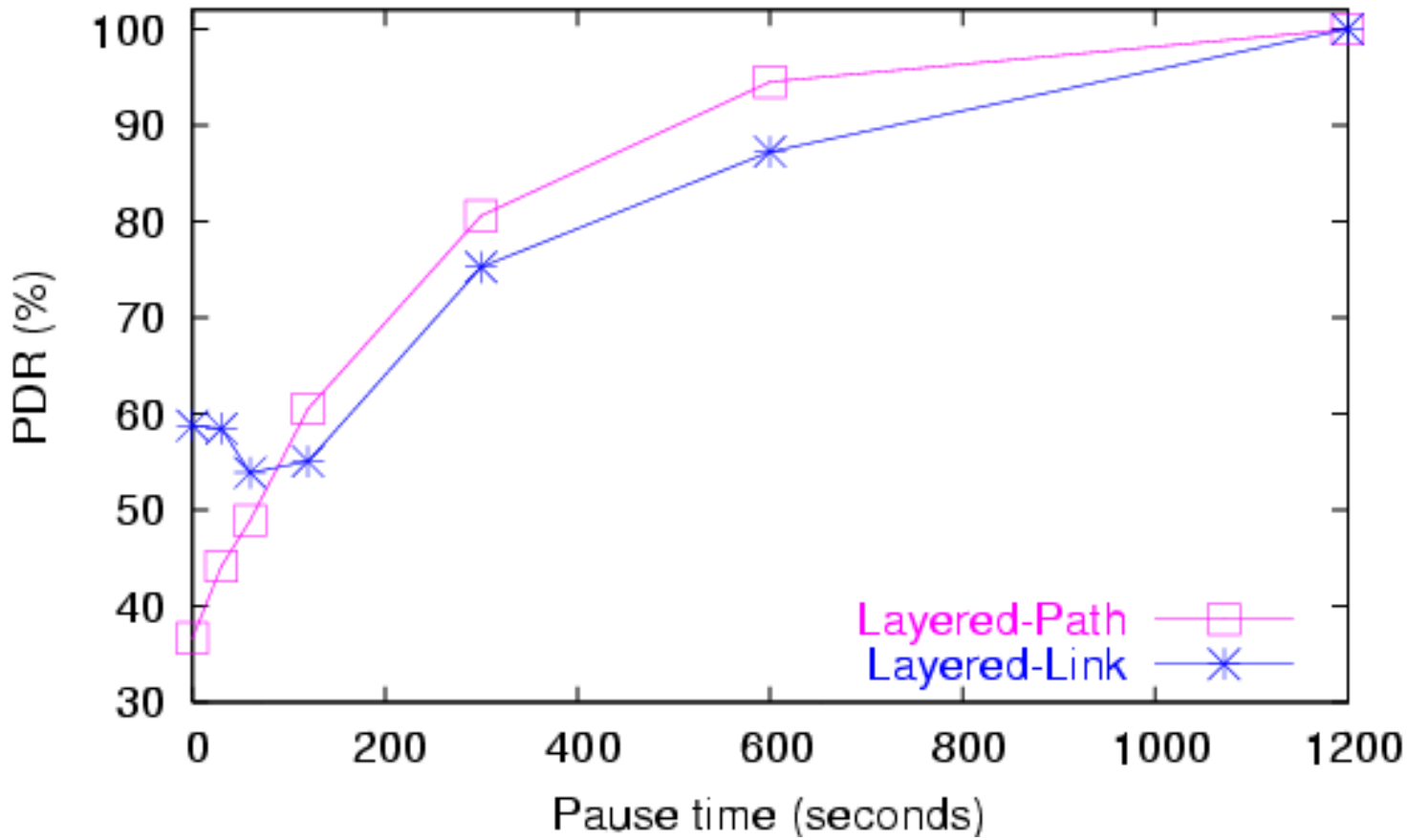
# Layered approach

- Direct layering is not practical
- Pastry uses ‘ping’ to measure delay for proximity
  - Proximity of Pastry routing tables uses hop count instead of delay from ‘ping’
  - DSR exports API to answer proximity probes from Pastry using its route cache
- Expanding ring search for bootstrap node

# Simulation setup

- Pastry implemented in ns-2 on top of DSR
- Parameters: 50 nodes, 1500mx300m, 2Mbps, 250m, 1-19m/s
- Traffic: 40 sources, 3 pkts/sec, random keys generated
- Metrics
  - Packet delivery ratio (PDR): ratio of successfully and correctly delivered packets to packets sent
  - Overhead
  - Delay

# Layered approach performance



# Problems with layered approach

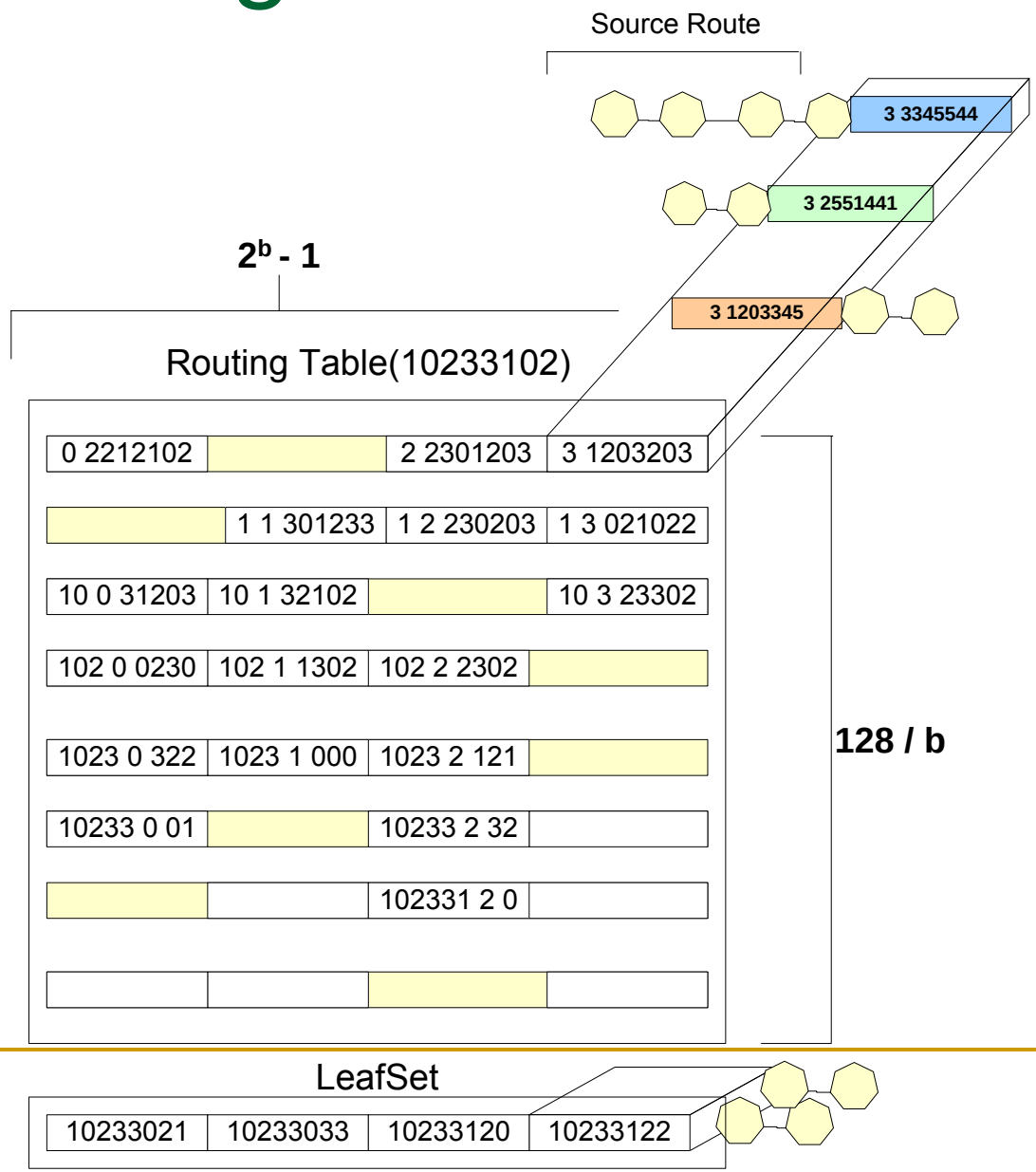
- High overhead
  - Periodic maintenance, proximity probing
- Choice of next logical hop independent of DSR
- Stale proximity information with Pastry

- Mismatch between routing state of Pastry and DSR

# Implementing DHT: Integrated Approach

- Integrates Pastry and DSR
- A unified DHT substrate at the network layer
- Referred to as *Ekta* (unity)

# Ekta: Routing



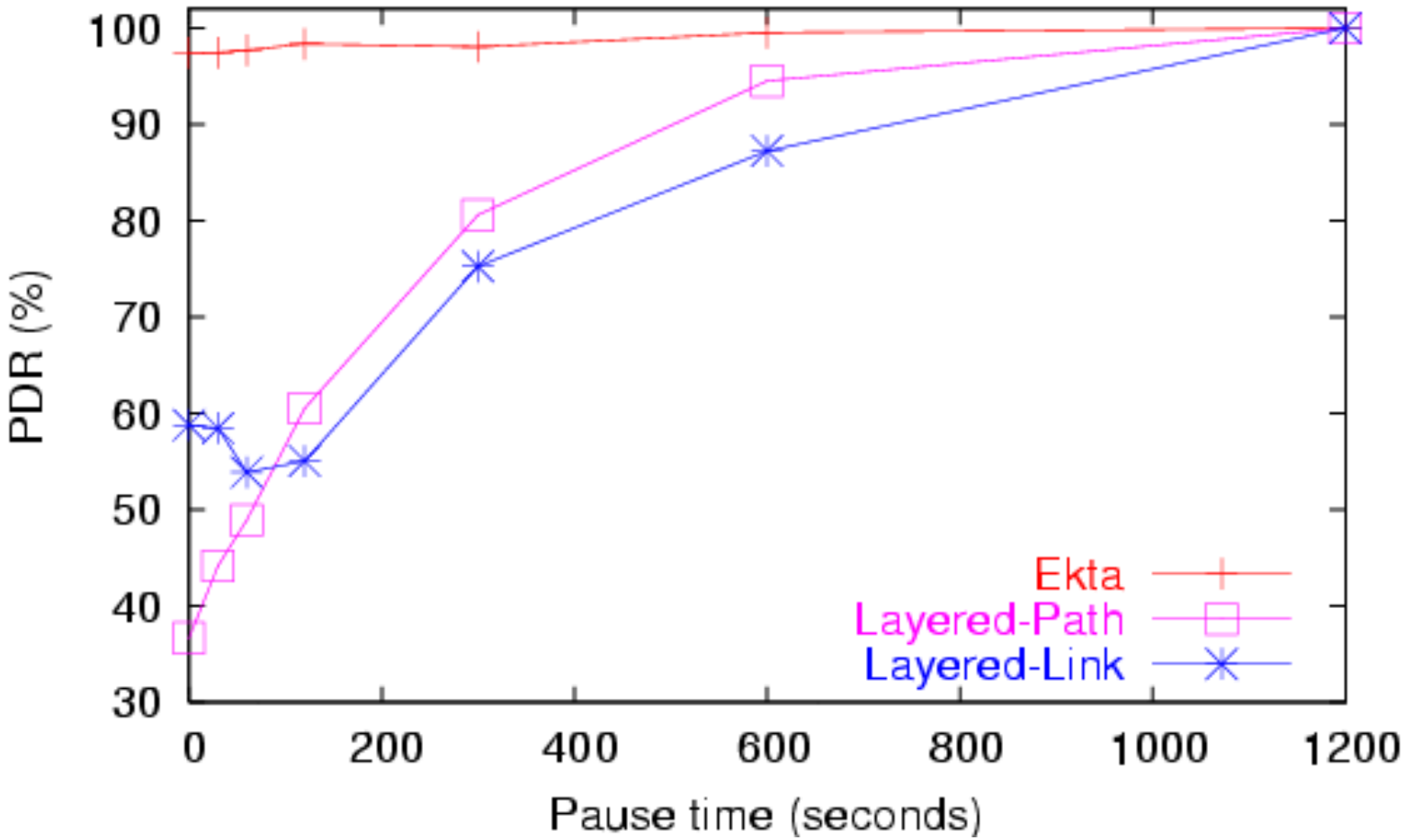
# Ekta: Join and leave

- Join
  - Flood “JOIN REQUEST”
  - Potential leafset members send “JOIN ACK”
  - Node closest sends “JOIN COMPLETE”
- Graceful leave
  - Flood “LEAVE”
  - Leafset members send “LEAVE ACK”
  - Exchange leafsets
- Node failure
  - Reactive failure handling
  - Node sends “proxy leave”

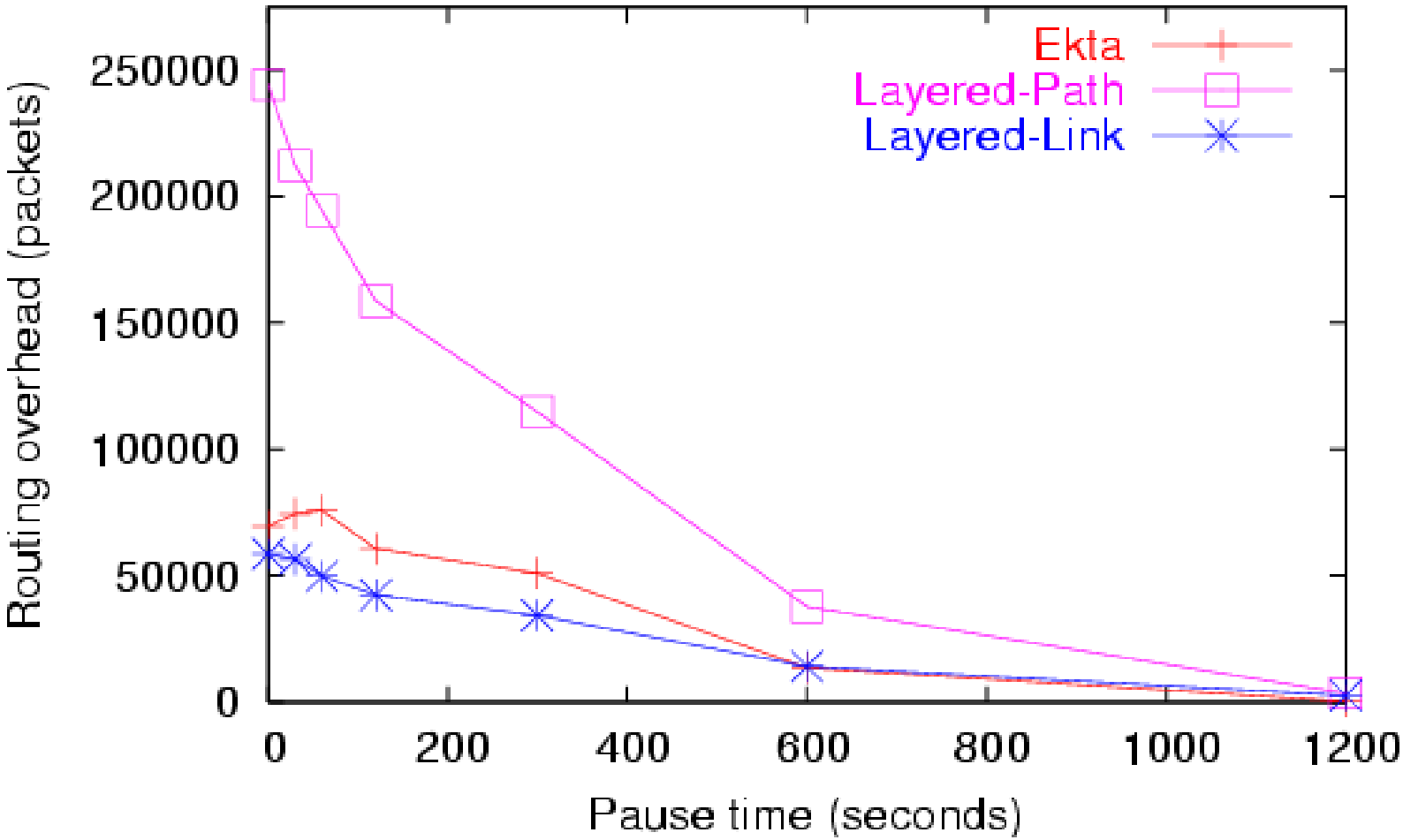
# Ekta: Optimizations

- Prefix based route requests
- Routes updated using snooping and overhearing

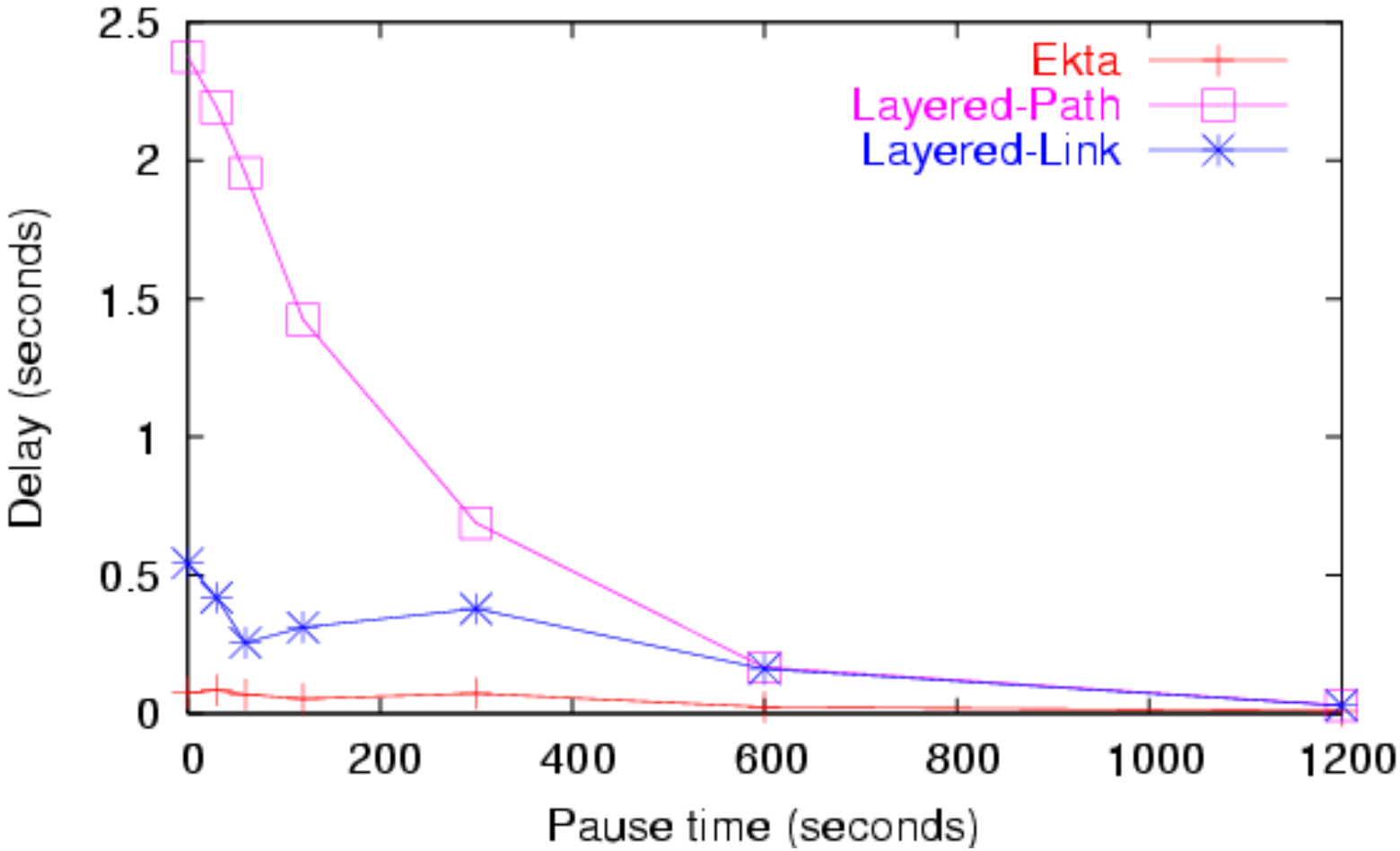
# PDR


100
90
80
70
60
50
40
30
PDR (%)
0
200
400
600
800
1000
1200
Pause time (seconds)
Ekta
Layered-Path
Layered-Link

# Overhead


Ekta
Layered-Path
Layered-Link
Routing overhead (packets)
250000
200000
150000
100000
50000
0
0
200
400
600
800
1000
1200
Pause time (seconds)

# Delay


Ekta
Layered-Path
Layered-Link
Delay (seconds)
Pause time (seconds)
2.5
2
1.5
1
0.5
0
0
200
400
600
800
1000
1200

# Summary

- Integrated approach is an efficient architecture for implementing a DHT in MANETs
- Ekta is superior
  - No proximity probing and periodic maintenance
  - Better coordination between routes available in routing table and choice of logical hops
  - Prefix route requests
  - Fresher proximity information from snooping and overhearing

# Can a MANET application benefit from the DHT?

Resource discovery using Ekta

# Problem

- Nodes in a MANET possess heterogeneous capabilities and resources
- Cooperative resource sharing is useful in MANETs
  - Requires resource discovery
- Two schemes
  - Ekta-RD
  - DSR-RD

# Ekta-RD vs. DSR-RD

- Simulations in ns-2 of both protocols
- Number of unique resources = number of nodes
- Each resource replicated on average on 10% of nodes
- Traffic: Poisson arrival of resource requests at each node, each request chooses random resource, varying λ
- Metrics
  - Success ratio: resource requests successfully satisfied
  - Overhead: control overhead for routing

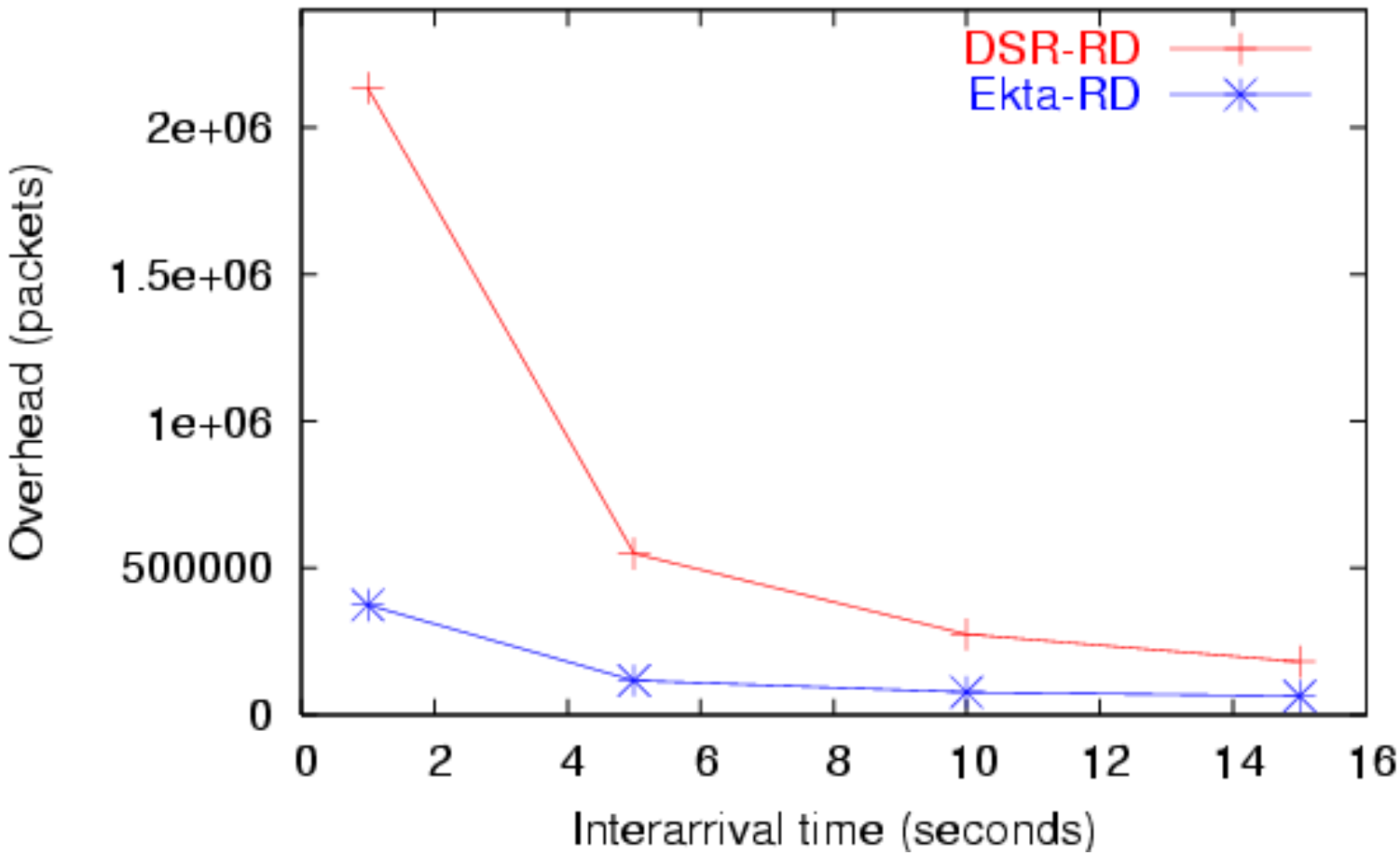
# Overhead analysis

- N = network size
- λ = average num of resource requests/node
- q = average degree of replication of any resource
- P = average hops between 2 nodes
- Pb = probability a route is not cached or cached but stale

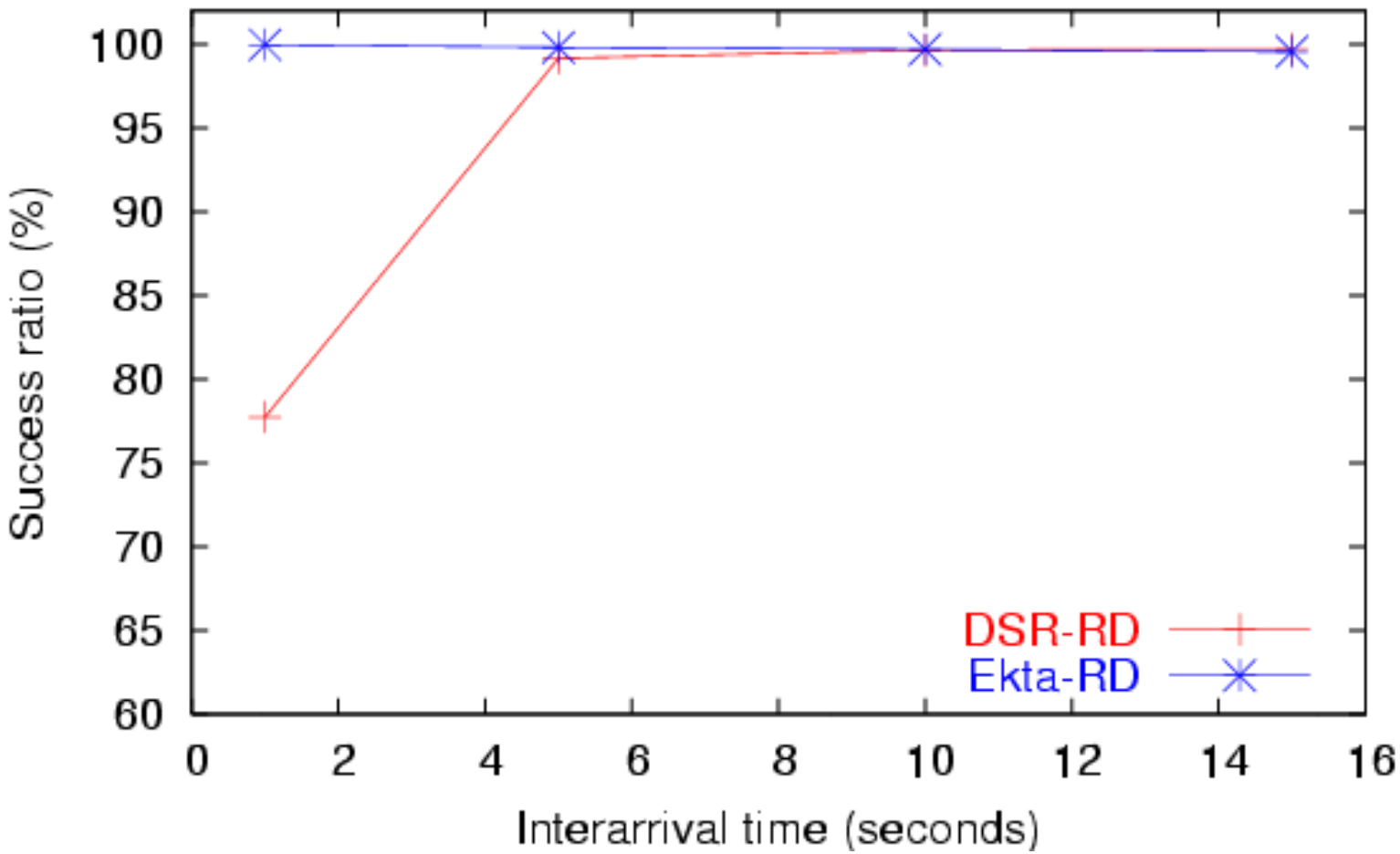
- Overhead (DSR-RD) = $\lambda . N^2 + \lambda . q. N^2 . P$
  - Independent of mobility
  - Grows as $O(N^2)$
  - Decreases with increasing λ

- Overhead (Ekta-RD) = $N ( \lambda . \log_{2^b} N . P + \lambda . P ) + N^2. Pb . \lambda (\log_{2^b} N + 1)$
  - Increases with mobility
  - Grows as $O(N . \log_{2^b} N )$
  - Decreases with increasing λ

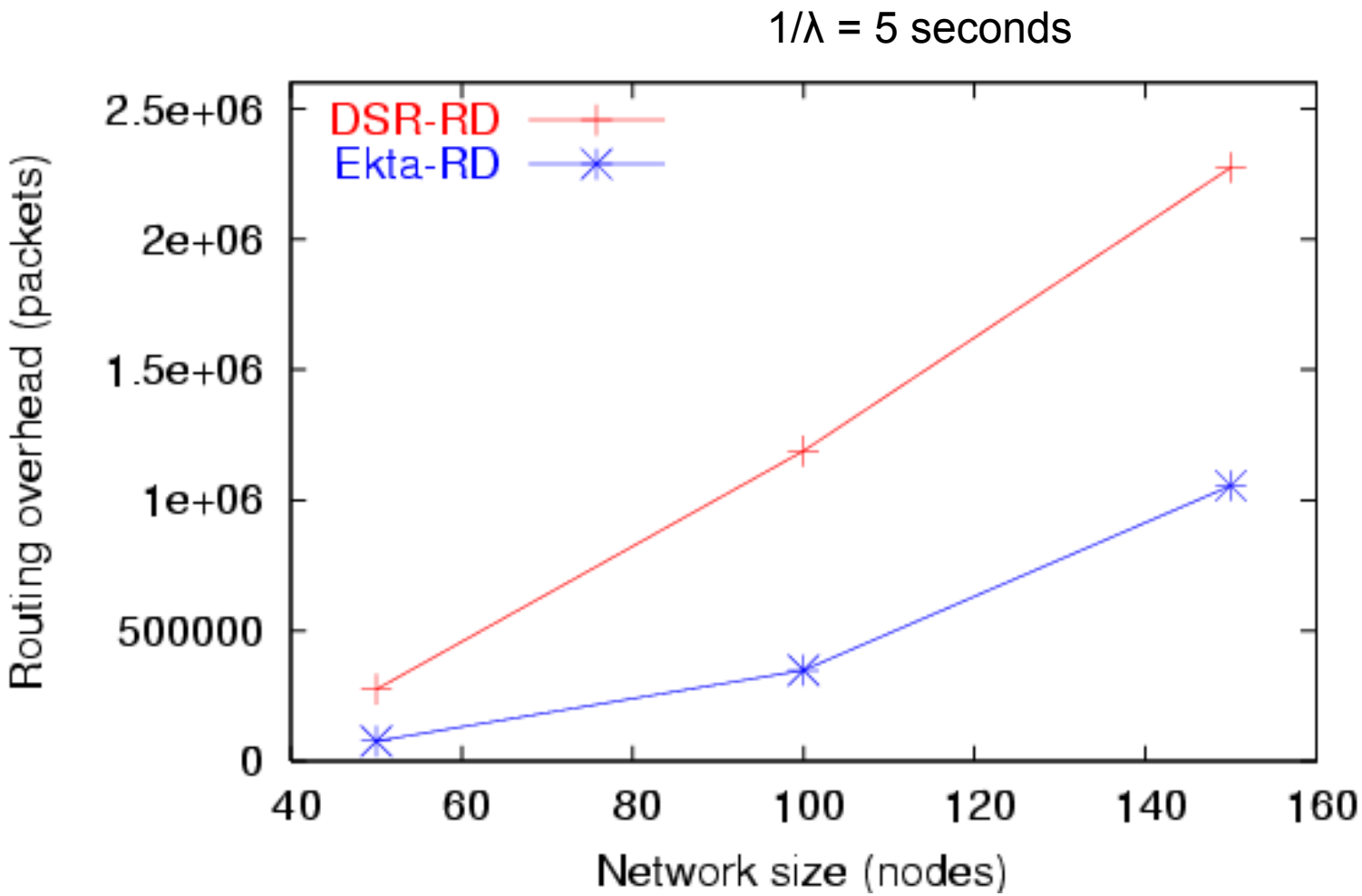
# Overhead: Varying λ



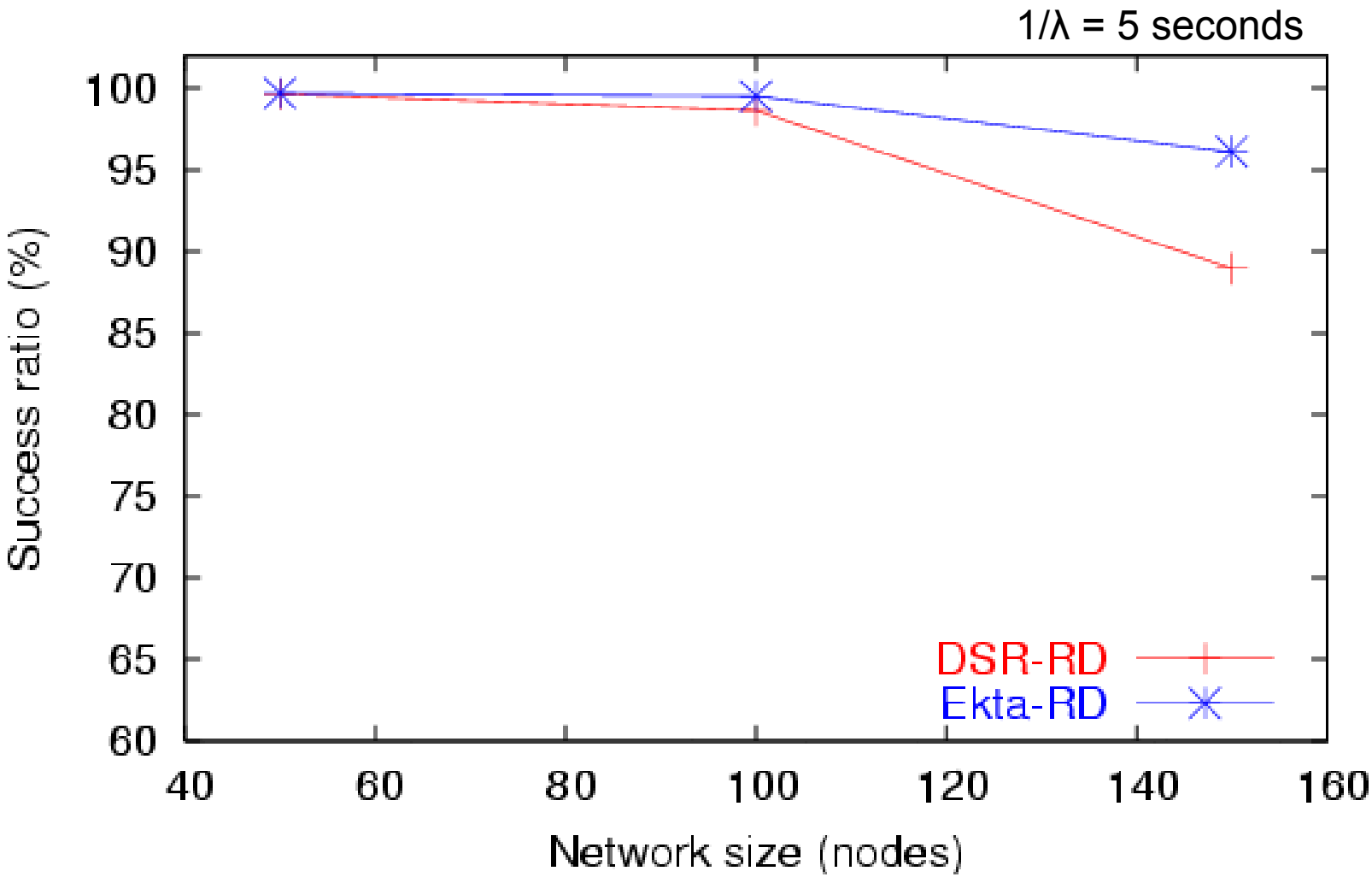
# Success ratio: Varying λ



# Overhead: Varying N



# Success ratio: Varying N



# Conclusions

- Integrated approach is an efficient architecture for implementing a DHT in MANETs
- MANET applications can benefit from DHTs as demonstrated by the resource discovery application
- Ekta can potentially be used as an efficient substrate for other applications

# Q & A