

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

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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)

Row 0

Row 1

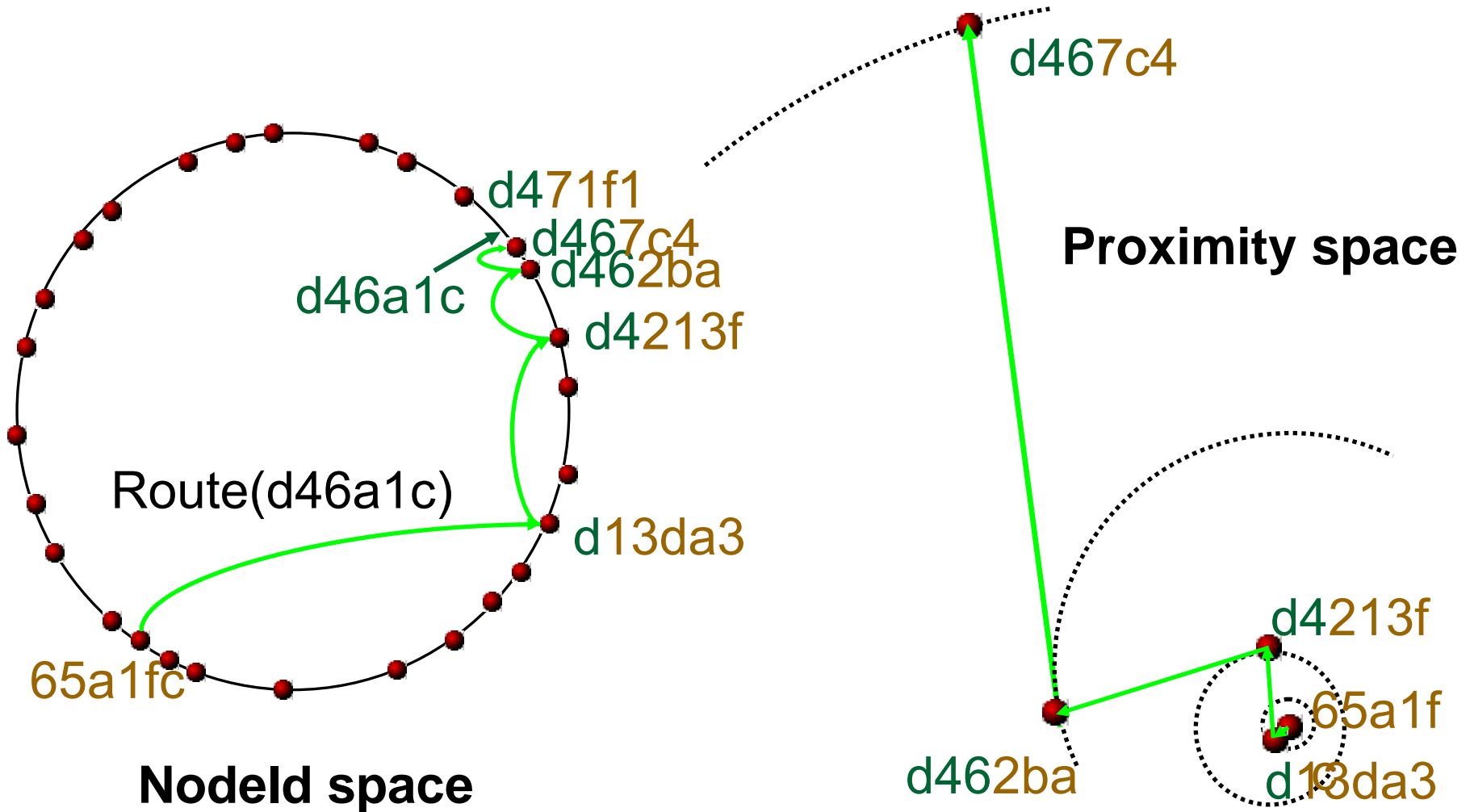
Row 2

Row 3

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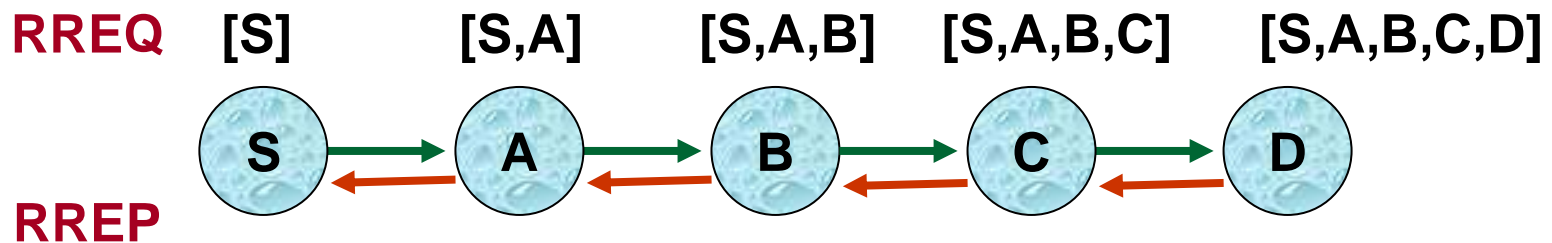
$\log_{16} N$
rows

Pastry: Routing Example



DSR

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



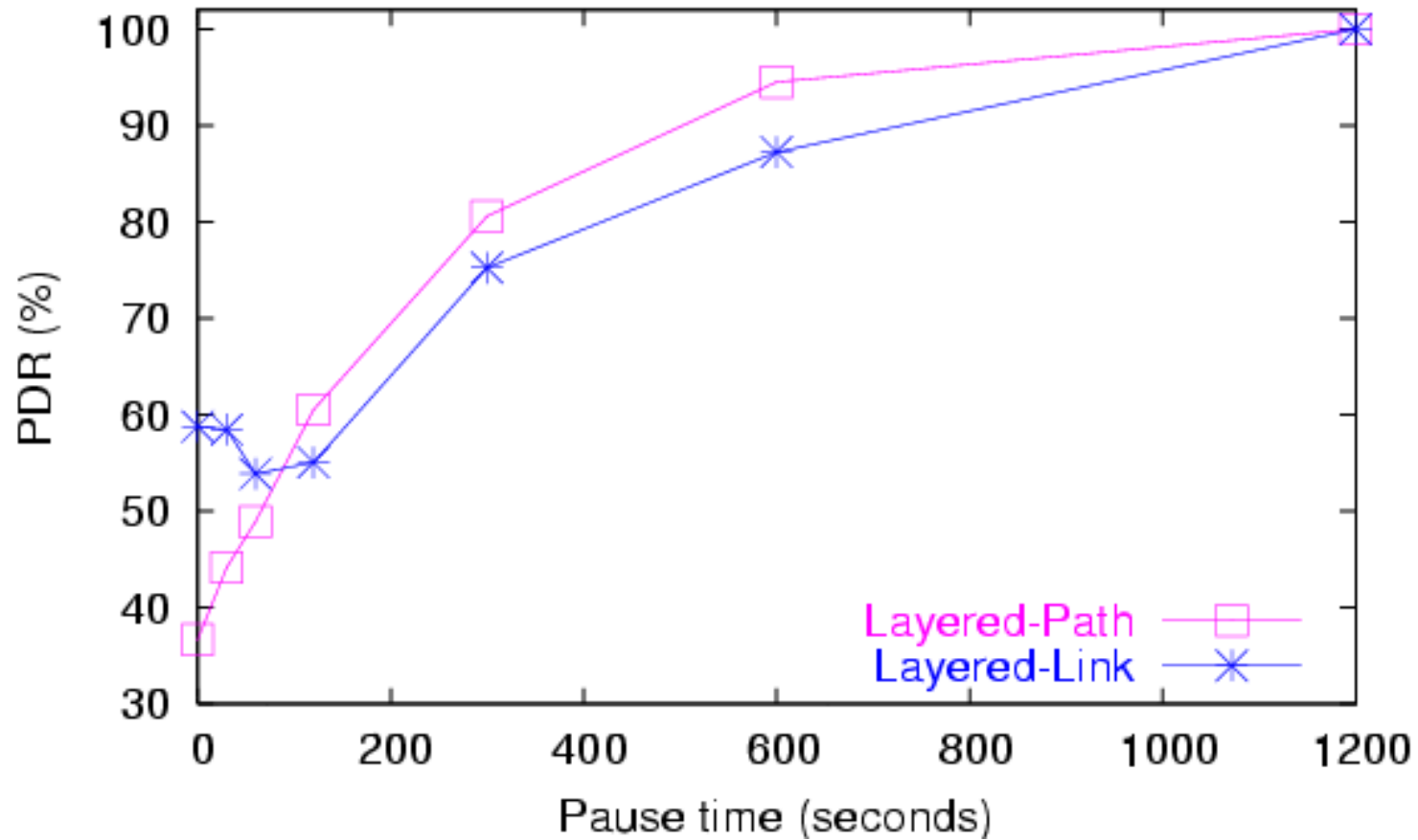
Layered approach

- 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



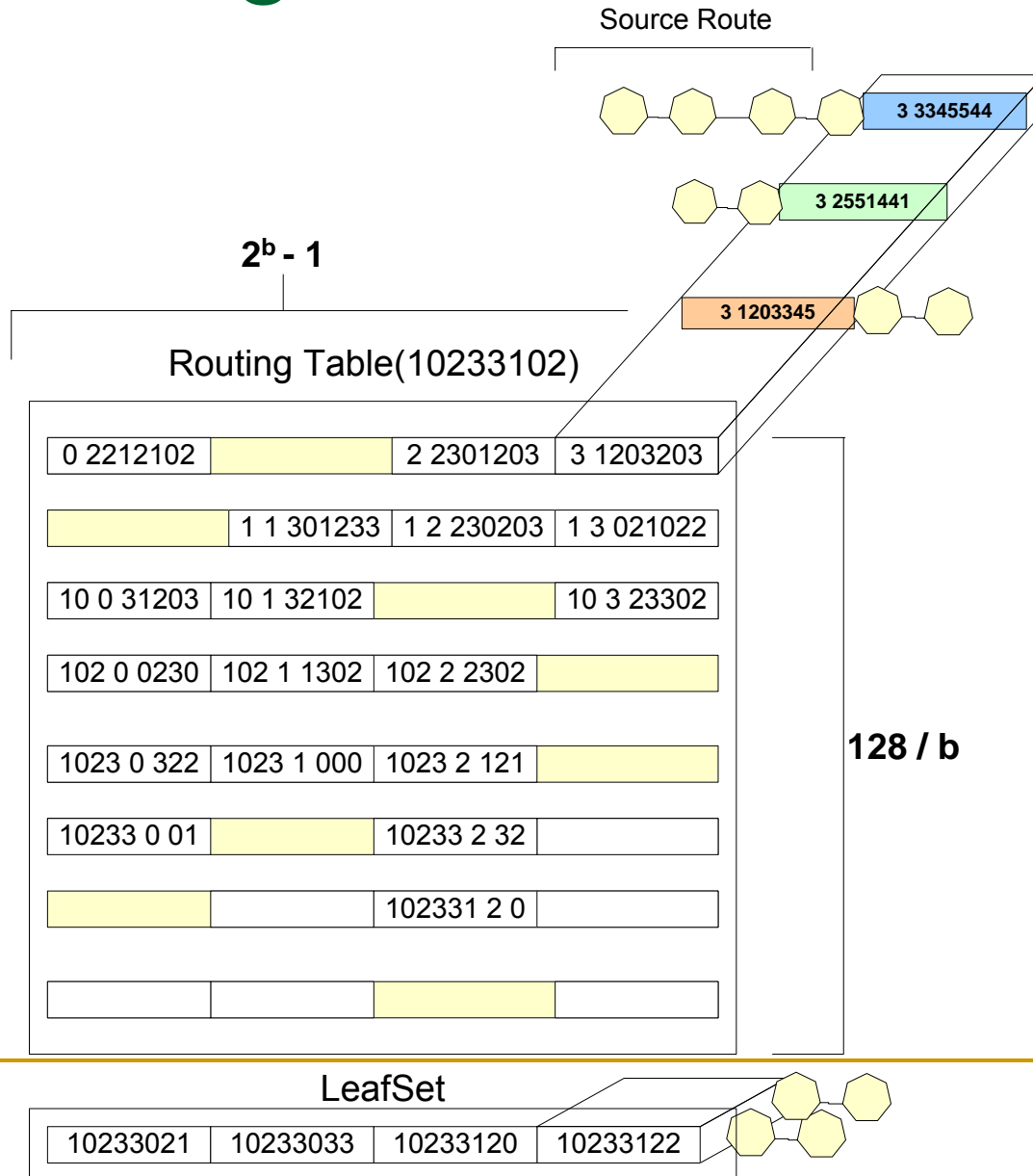
Problems with layered approach

- 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



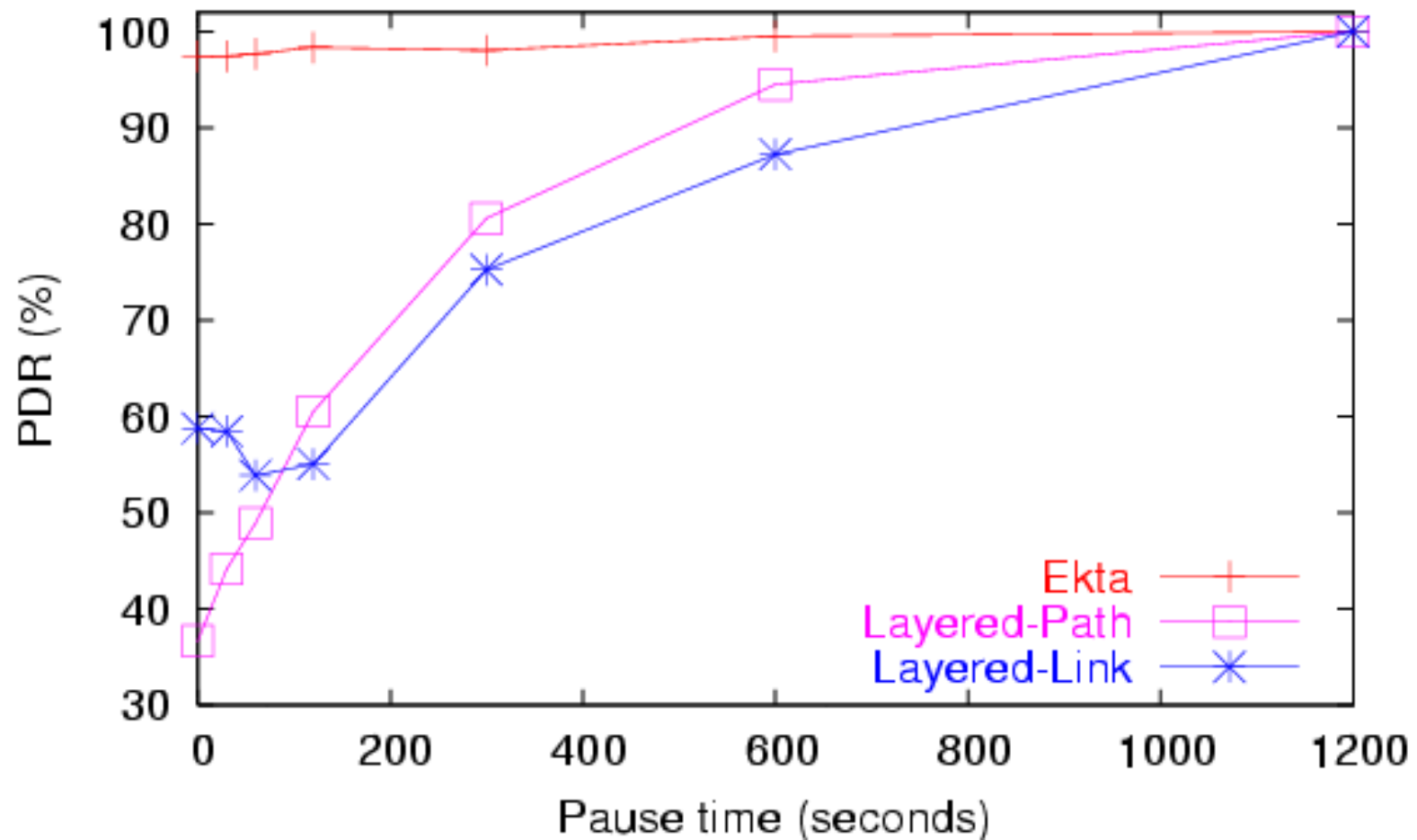
Ekta: Join and leave

- 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”

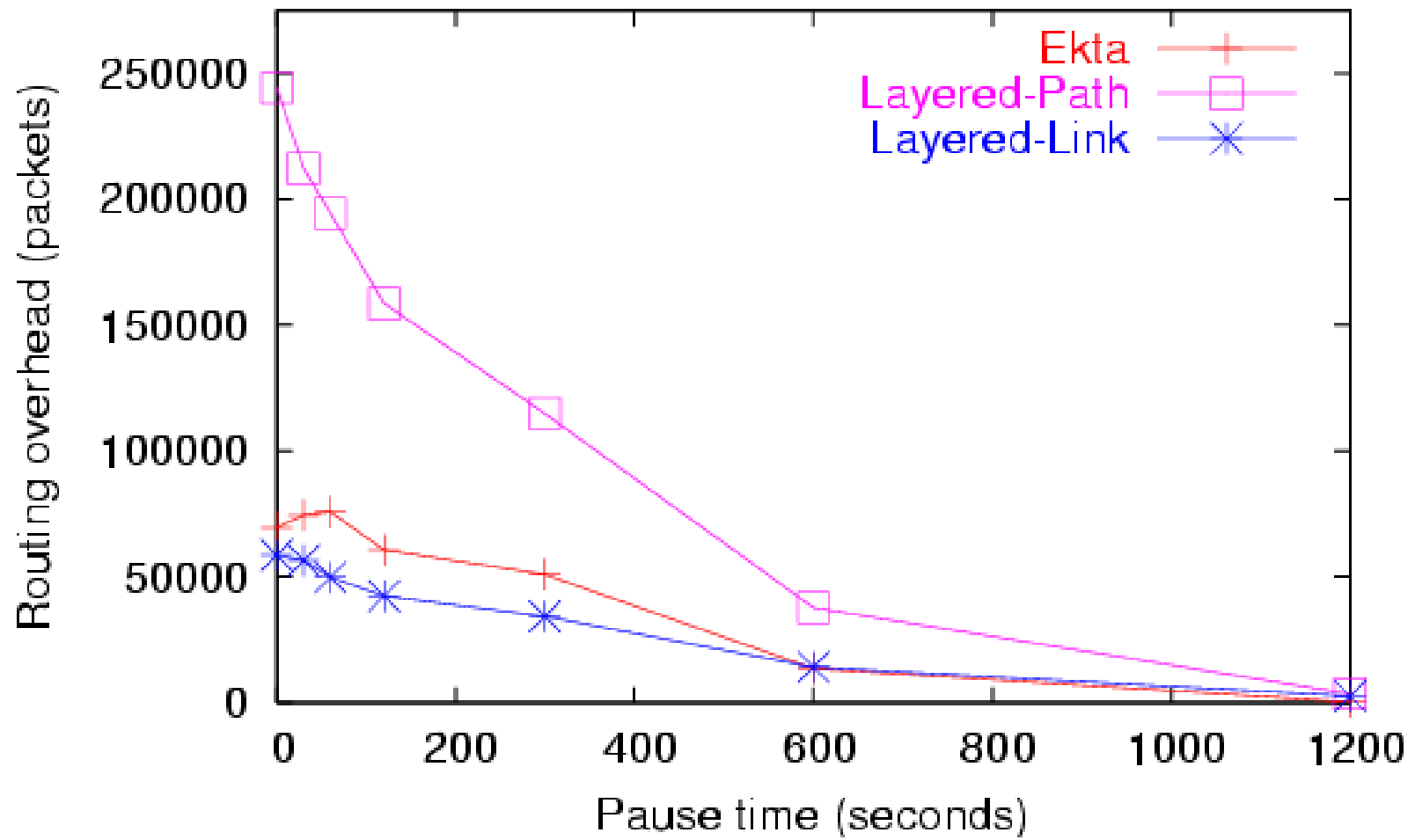
Ekta: Optimizations

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

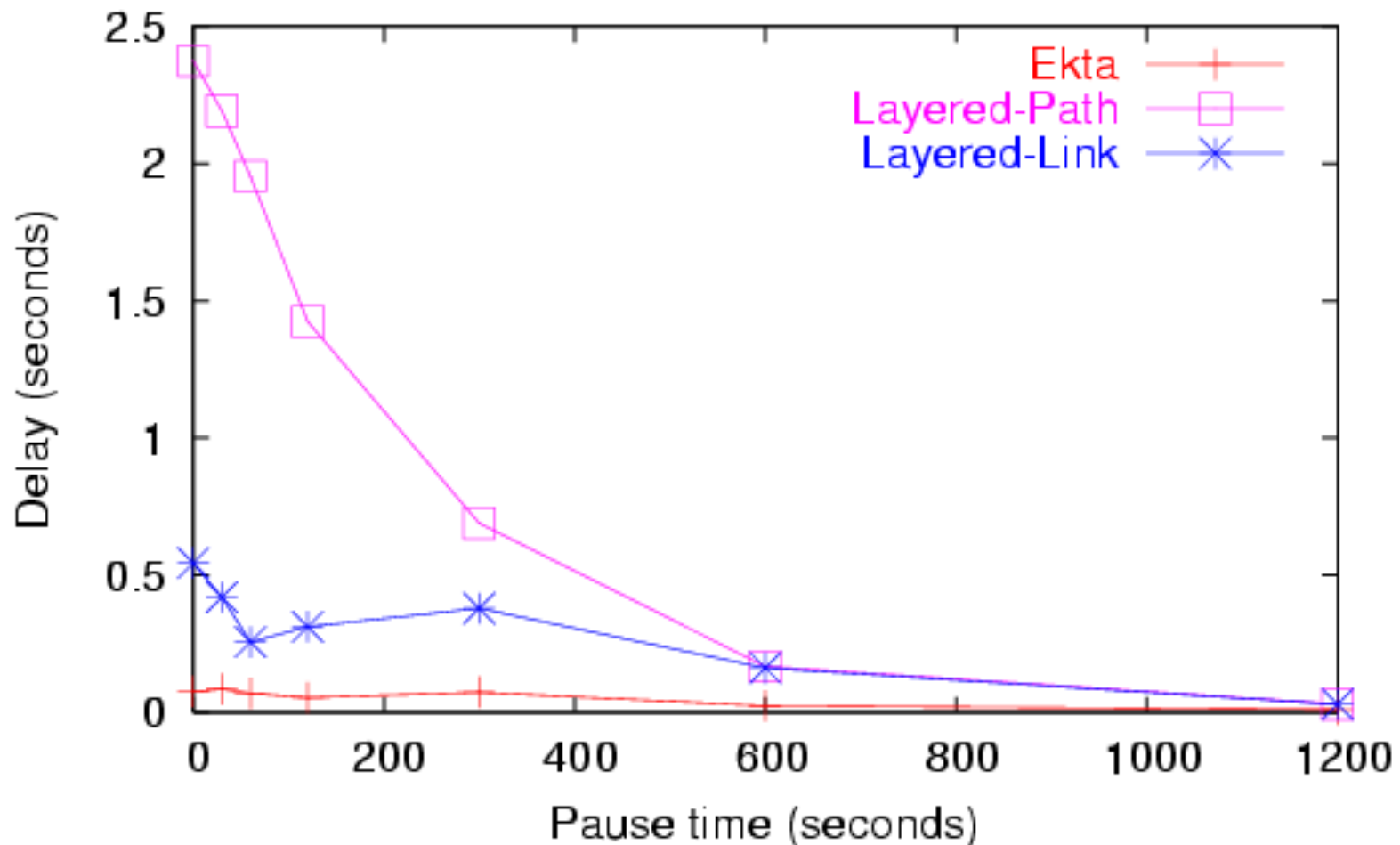
PDR



Overhead



Delay



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

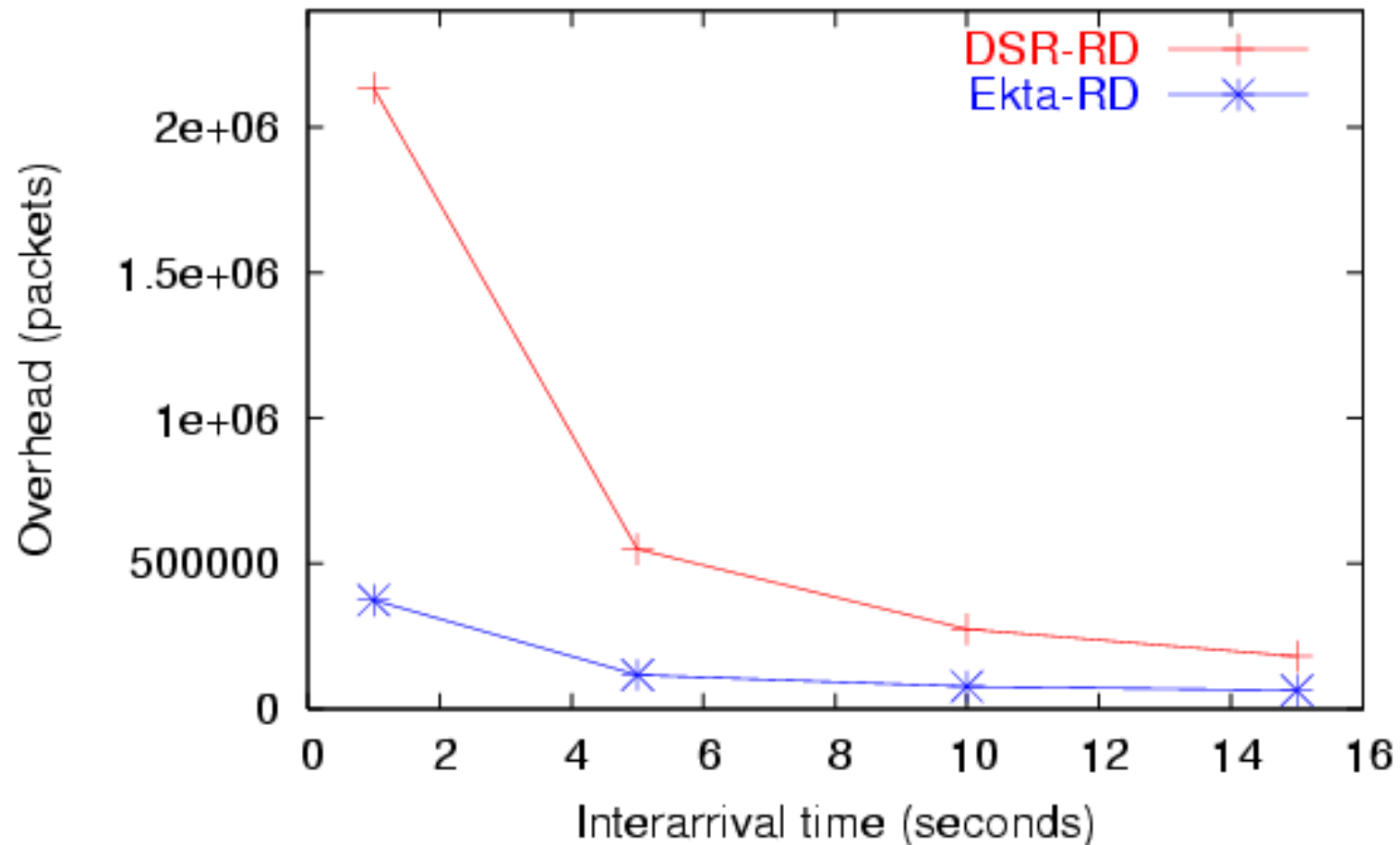
Ekta-RD vs. DSR-RD

- 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

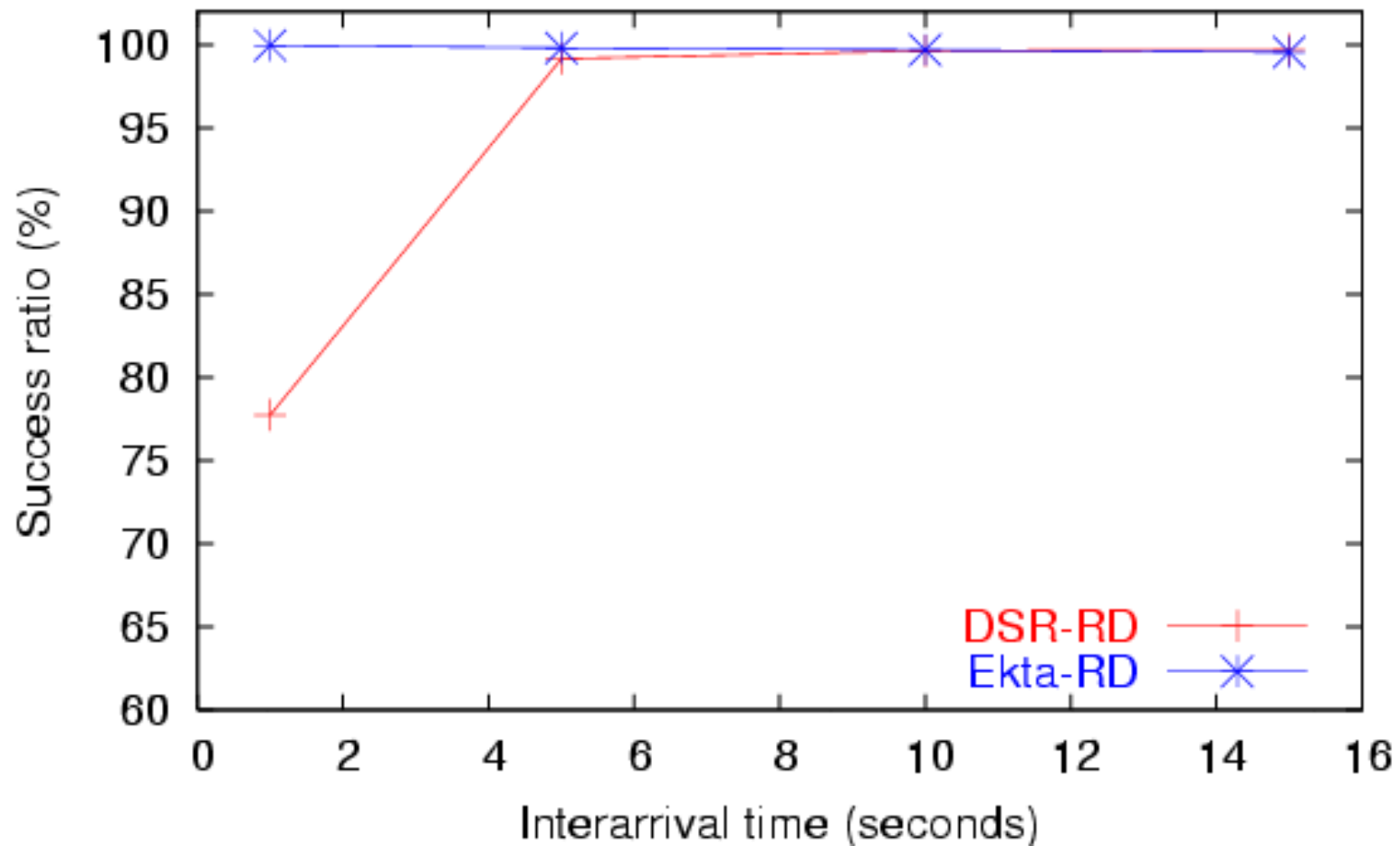
Overhead analysis

- N = network size
- λ = average num of resource requests/node
- q = average degree of replication of any resource
- P = average hops between 2 nodes
- P_b = probability a route is not cached or cached but stale
- Overhead (DSR-RD) = $\lambda \cdot N^2 + \lambda \cdot q \cdot N^2 \cdot P$
 - Independent of mobility
 - Grows as $O(N^2)$
 - Decreases with increasing λ
- Overhead (Ekta-RD) = $N (\lambda \cdot \log_2^b N \cdot P + \lambda \cdot P) + N^2 \cdot P_b \cdot \lambda (\log_2^b N + 1)$
 - Increases with mobility
 - Grows as $O(N \cdot \log_2^b N)$
 - Decreases with increasing λ

Overhead: Varying λ

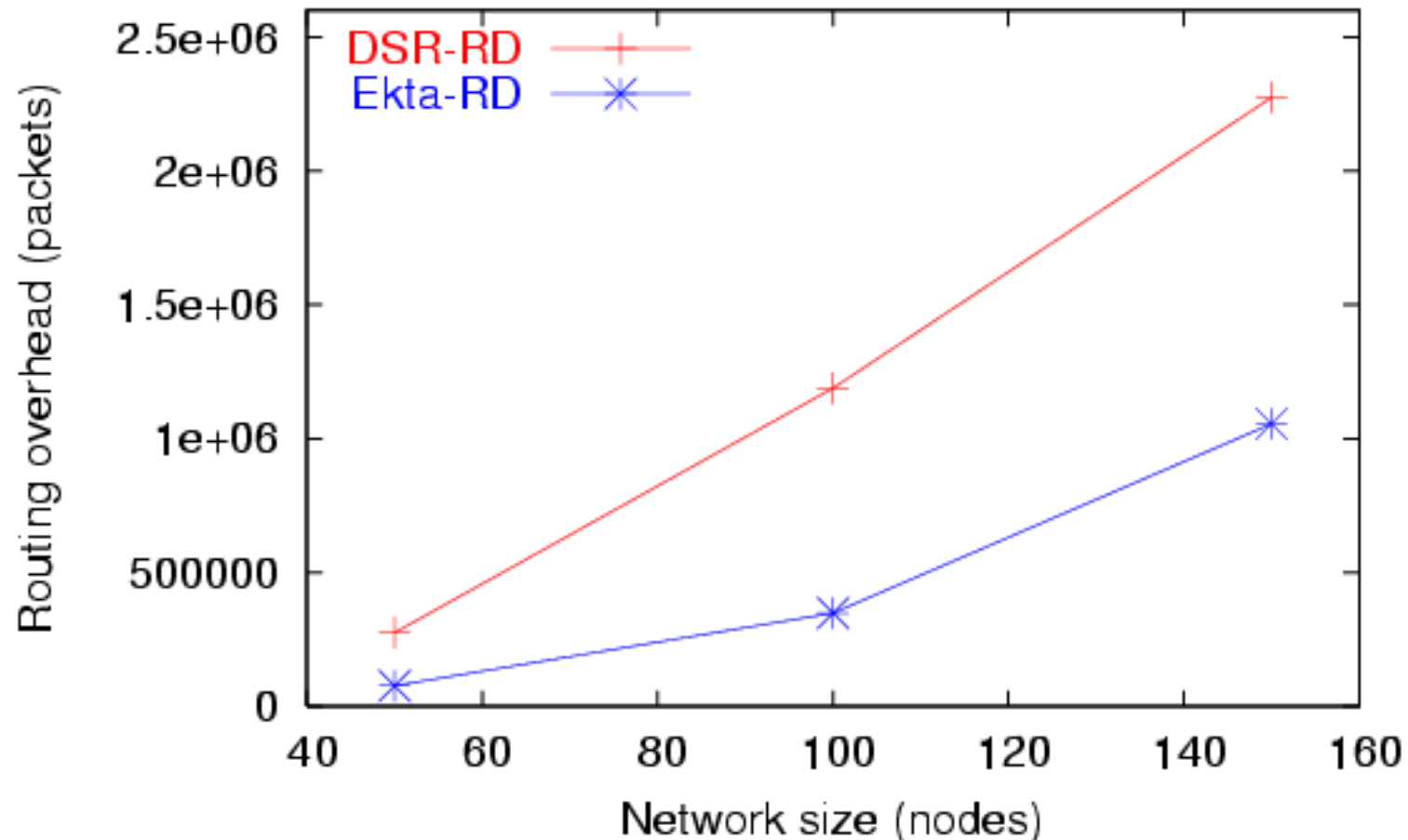


Success ratio: Varying λ

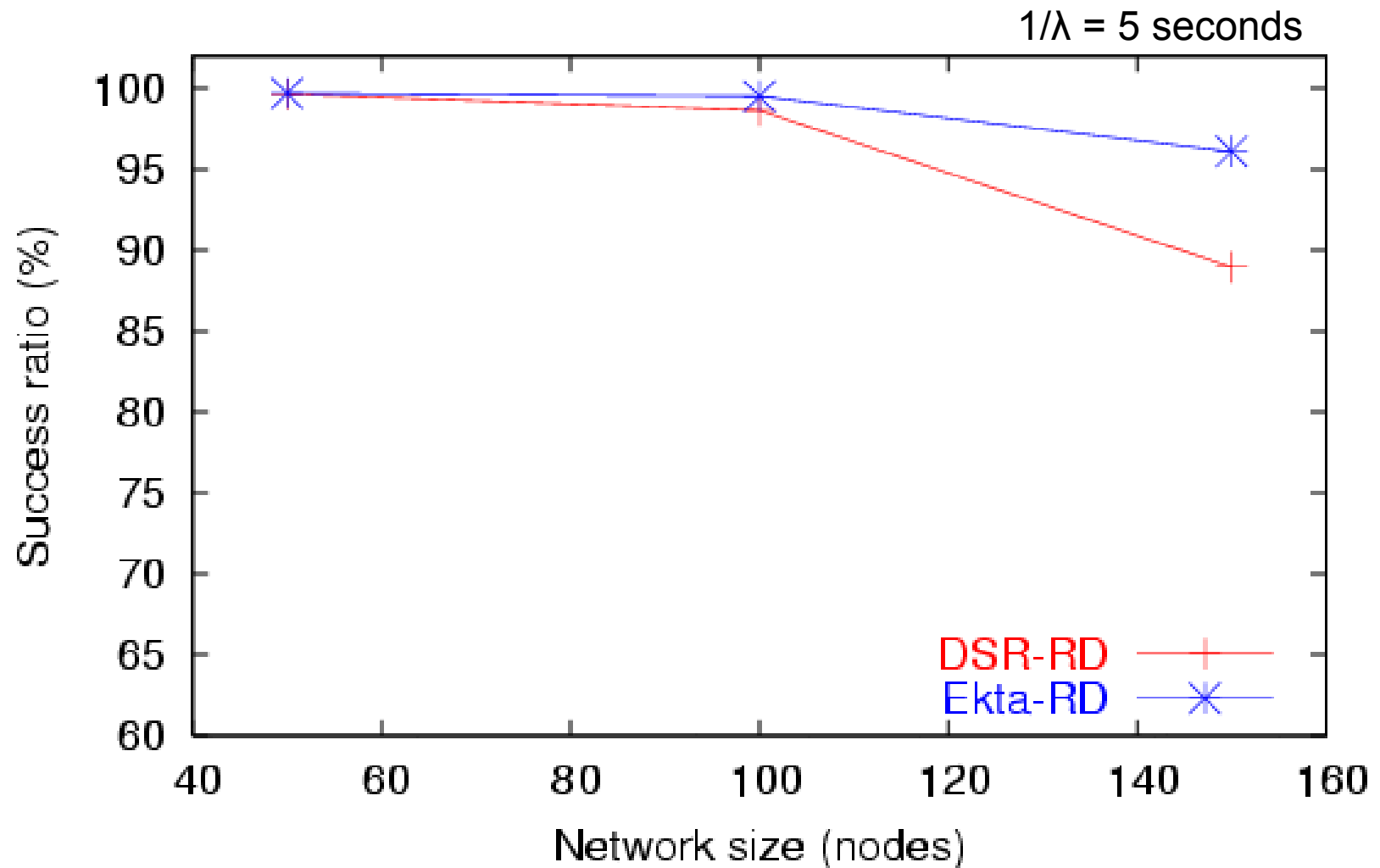


Overhead: Varying N

$1/\lambda = 5$ seconds



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