Query Control Mechanisms for the Zone Routing Protocol (ZRP)

Zygmunt J. Haas and Marc R. Pearlman
Wireless Networks Laboratory
Cornell University

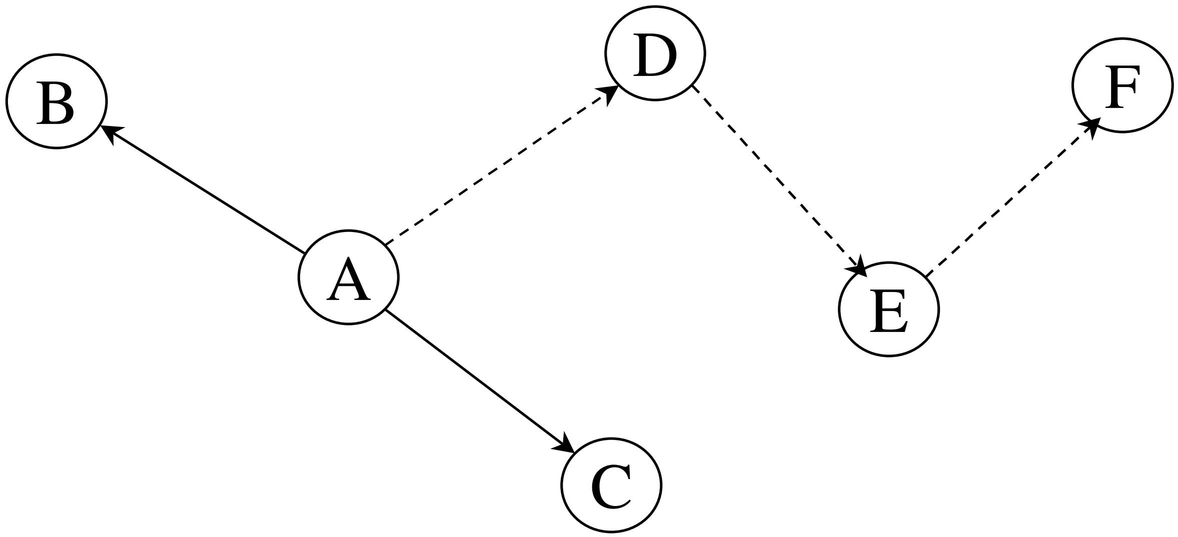
Agenda

- Introduction -
  Routing in Mobile Ad-Hoc Networks
- The Zone Routing Protocol (ZRP)
- Query Control Mechanisms
- Simulation Description
- Results
- Conclusions

Mobile Ad-Hoc Networking

- Rapidly deploy a regional (~ 100 m - 100 km) network of mobile hosts, anywhere.
- Why? Coordinate Efforts of Distributed Systems
  - military (battlefield communications)
  - law enforcement
  - construction
  - emergency response

Mobile Ad-Hoc Networking

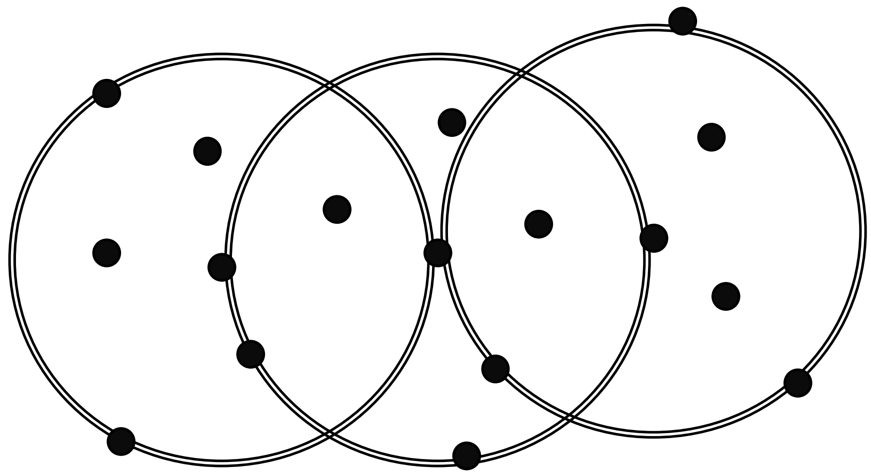


- no infrastructure !
- short range direct communication: A-B , A-C
- nodes act as relays: multihop routing: A-D-E-F

Traditional Routing Schemes

- Proactive (i.e. distance vector, link state)
  - maintain up-to-date view of network
  - extremely high traffic
  - most routes are not used
- Reactive (i.e. route query - response)
  - acquire routes on demand
  - high traffic
  - route query delays

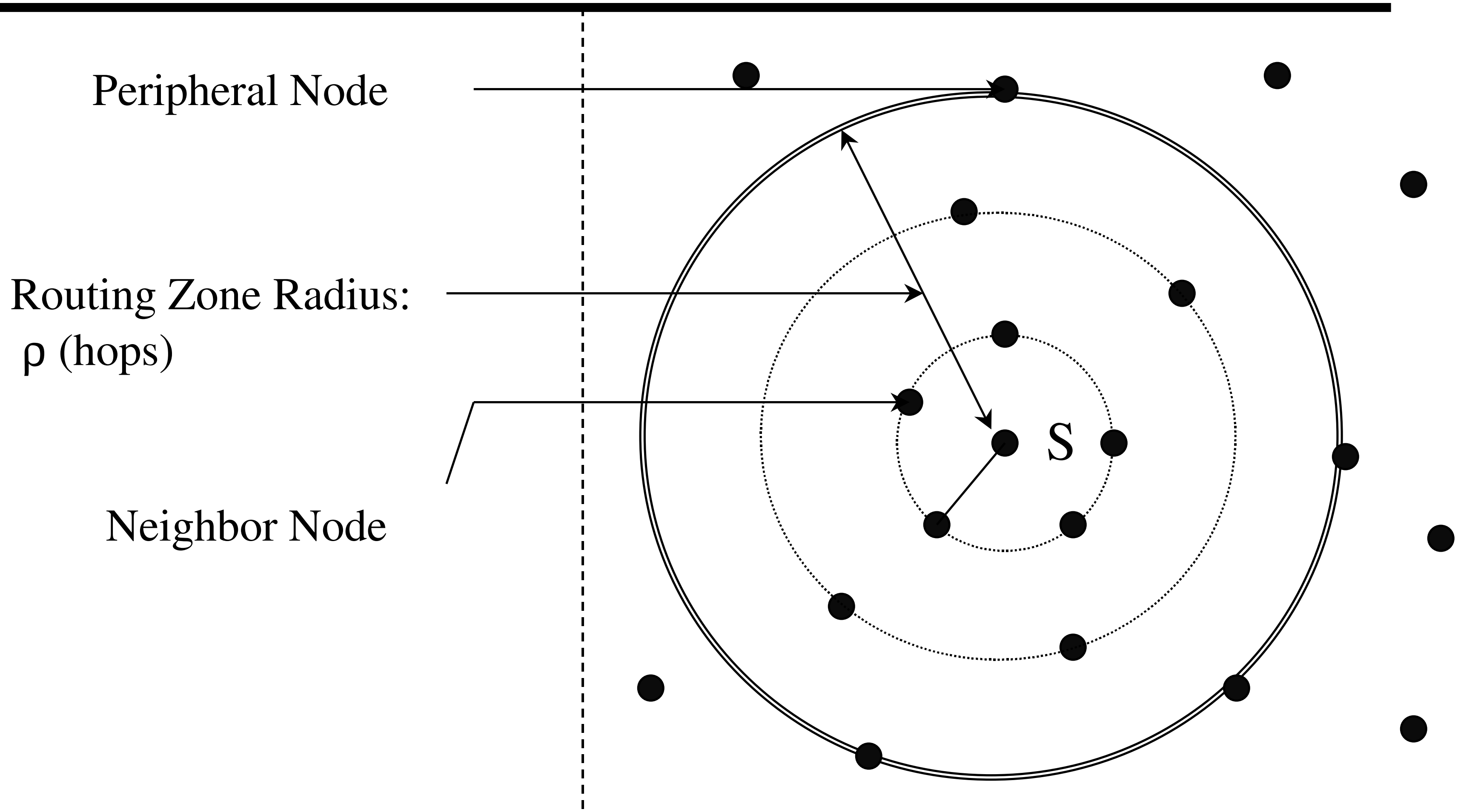
A Hybrid Approach: Introducing the Routing Zone



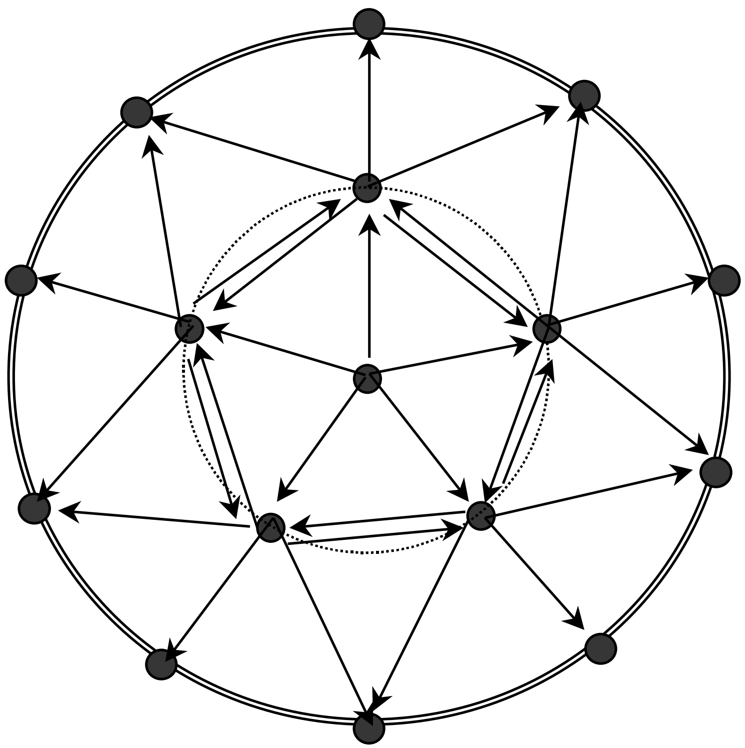
Each node:

- **Proactively** tracks topology within its own routing zone
- **Reactively** acquires routes to nodes beyond routing zone by querying between overlapping zones

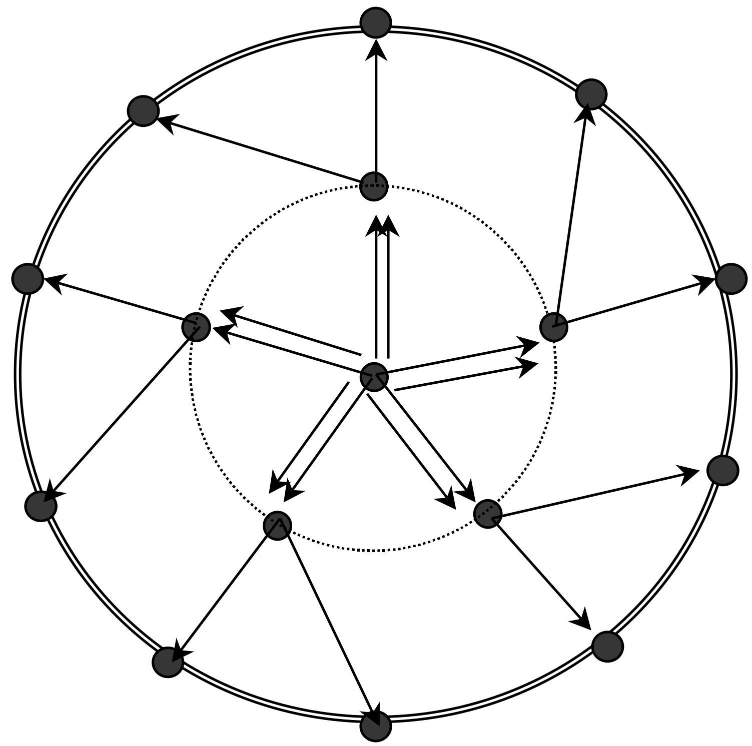
Anatomy of a Routing Zone



Bordercasting

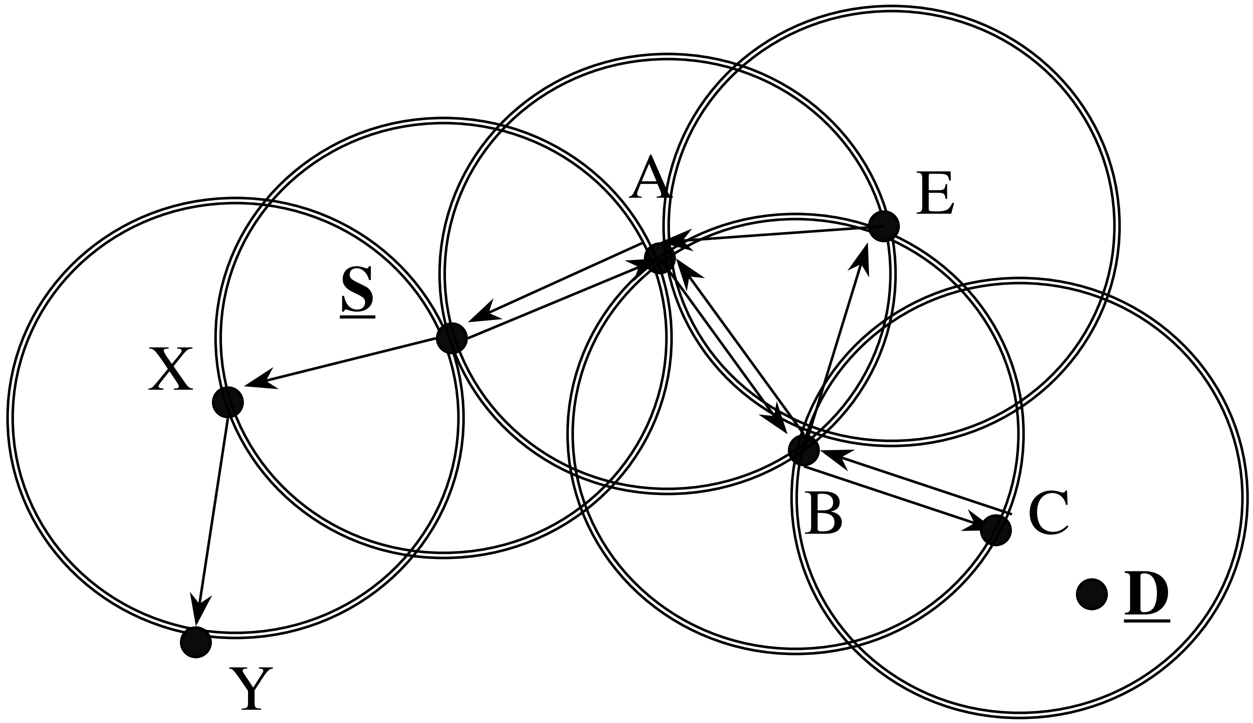


flooding: 30 transmissions



<u>bordercasting</u>: 20 transmissions

Route Discovery Example



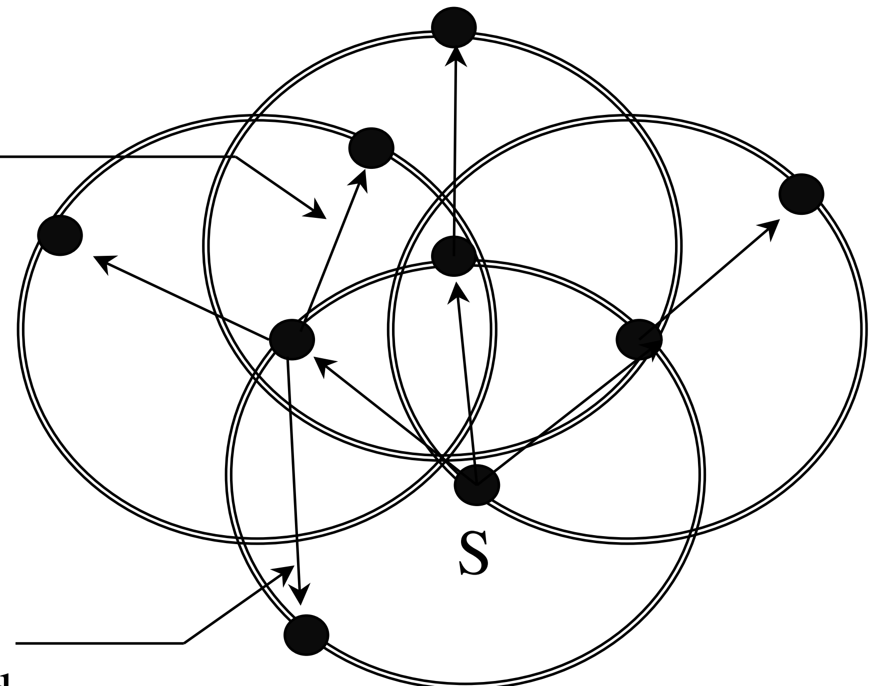
1) S-X-Y: terminates because Y has no peripheral nodes
2) S-A-B-E-A: terminates because thread returned to A
3) S-A-B-C: successful discovery !

Benefits of Routing Zones

- Proactive: maintain routing zone
  - routing traffic significantly reduced
  - routes used more often
- Reactive: query only peripheral nodes
  - fewer query packets
  - shorter query packets *
  - reduced delay
  - routes more robust

Routing Zones Overlap

thread enters a zone previously
queried by another thread



thread loops back onto a
zone which it already queried.

Overlapping Zones May Lead to Excess Control Traffic

Encourage Outward Propagation of Queries

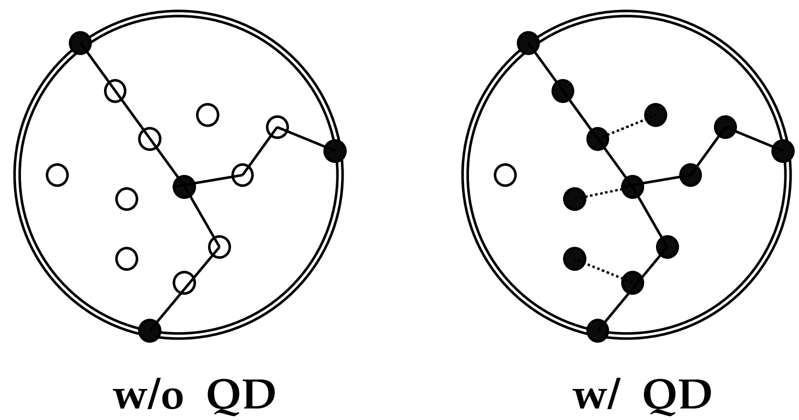
- Terminate threads that return to a queried node (not strong enough)
- Terminate threads that return to a queried zone
  - threads that loopback on themselves
  - threads that overlap with other threads
- Prevent overlap

Query Control Mechanisms

Terminate threads when they appear in previously queried <u>zones</u>

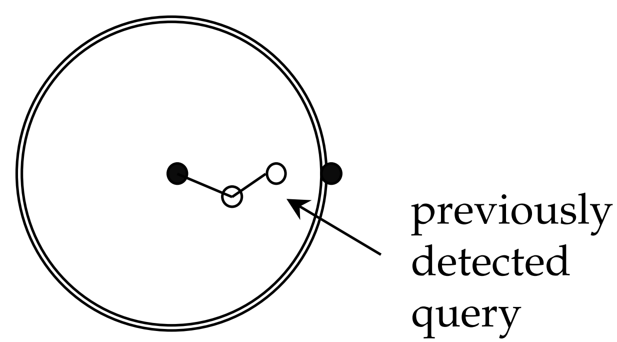
– Query Detection (QD)

intermediate nodes can detect passing threads



– Early Termination (ET)

intermediate nodes can terminate previously detected threads

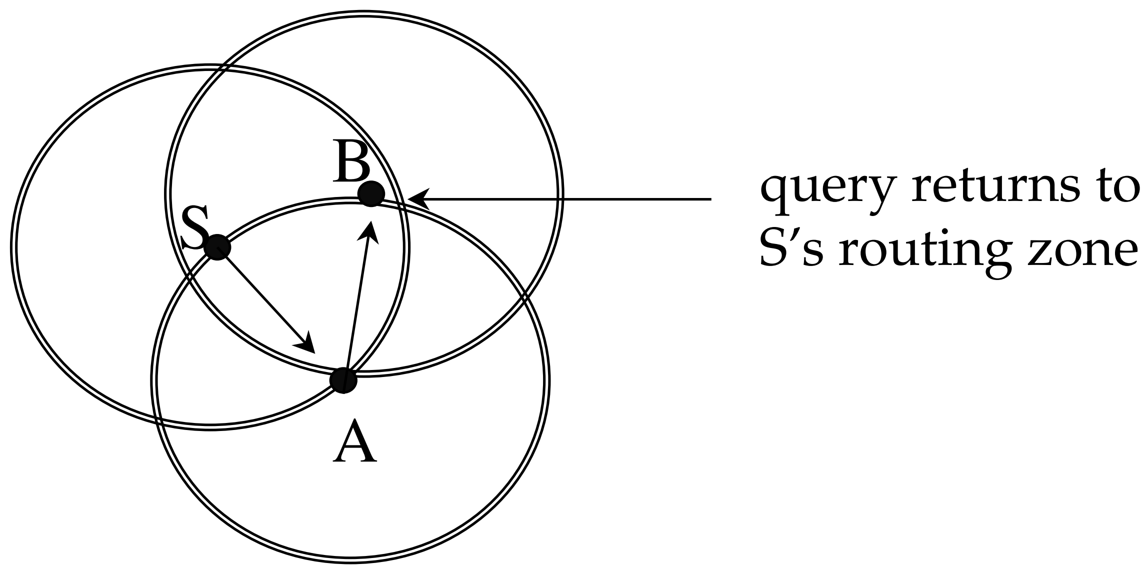


Query Control Mechanisms (cont'd)

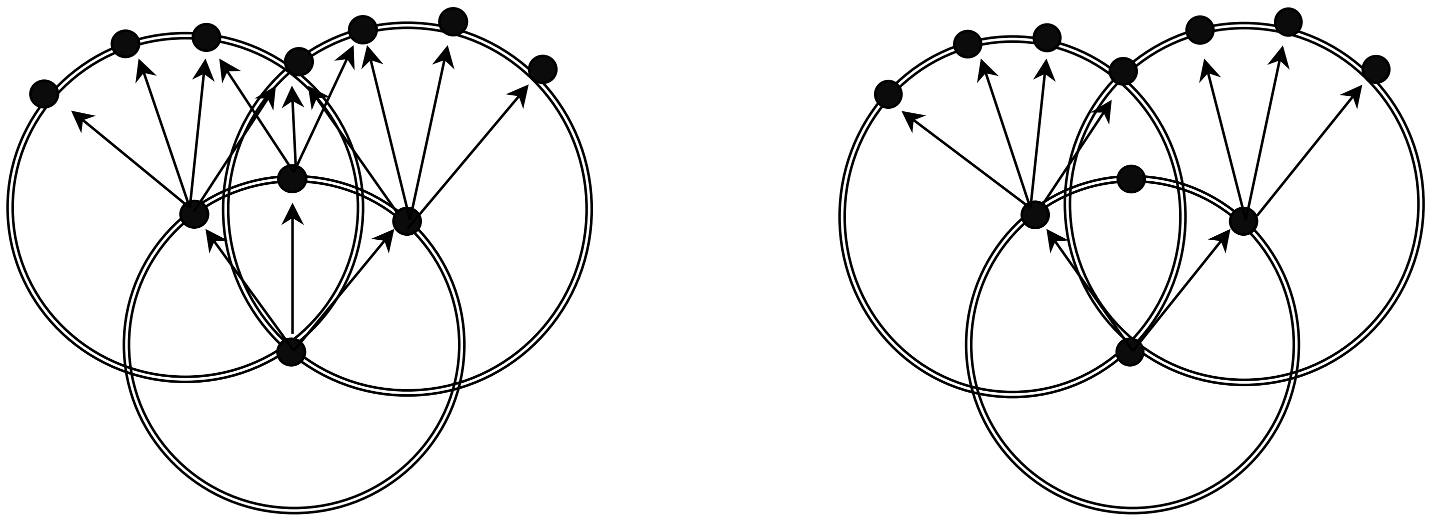
Special Case: thread loops back on itself

– Loopback Termination (LT) (100% effective)

use accumulated route to identify loopback condition



Query Overlap Prevention: Selective BorderCasting (SBC)



full bordercasting

selective bordercasting

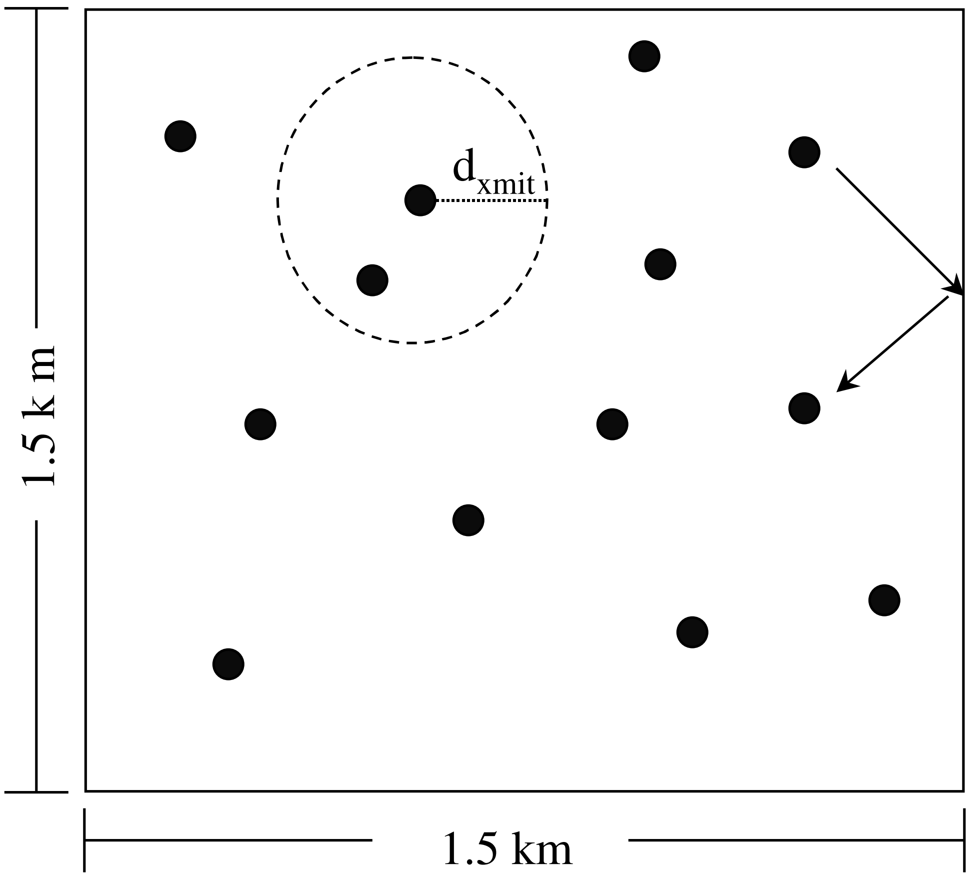
Cover a given set of “outer” peripheral nodes with the fewest “inner” peripheral nodes

Implementing Selective Bordercasting

- Extended Routing Zone (at least 2ρ hops):
- For each received query packet . . .
  - Compute "best" SBC assignment
  - Send SBC assignments

Do the benefits offset the cost?

Simulation Model



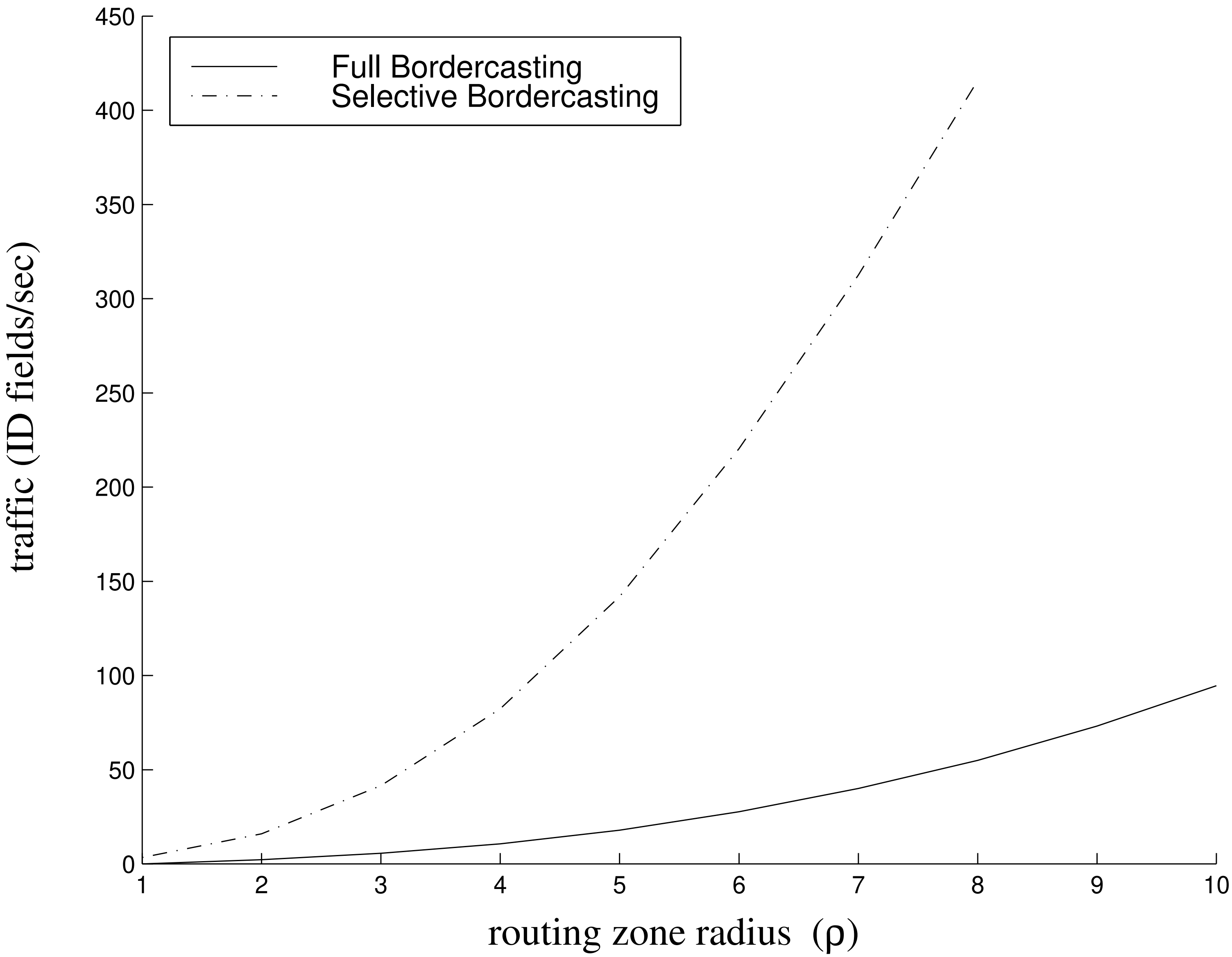
Static Simulation Parameters

d_{xmit} # nodes	100m 500

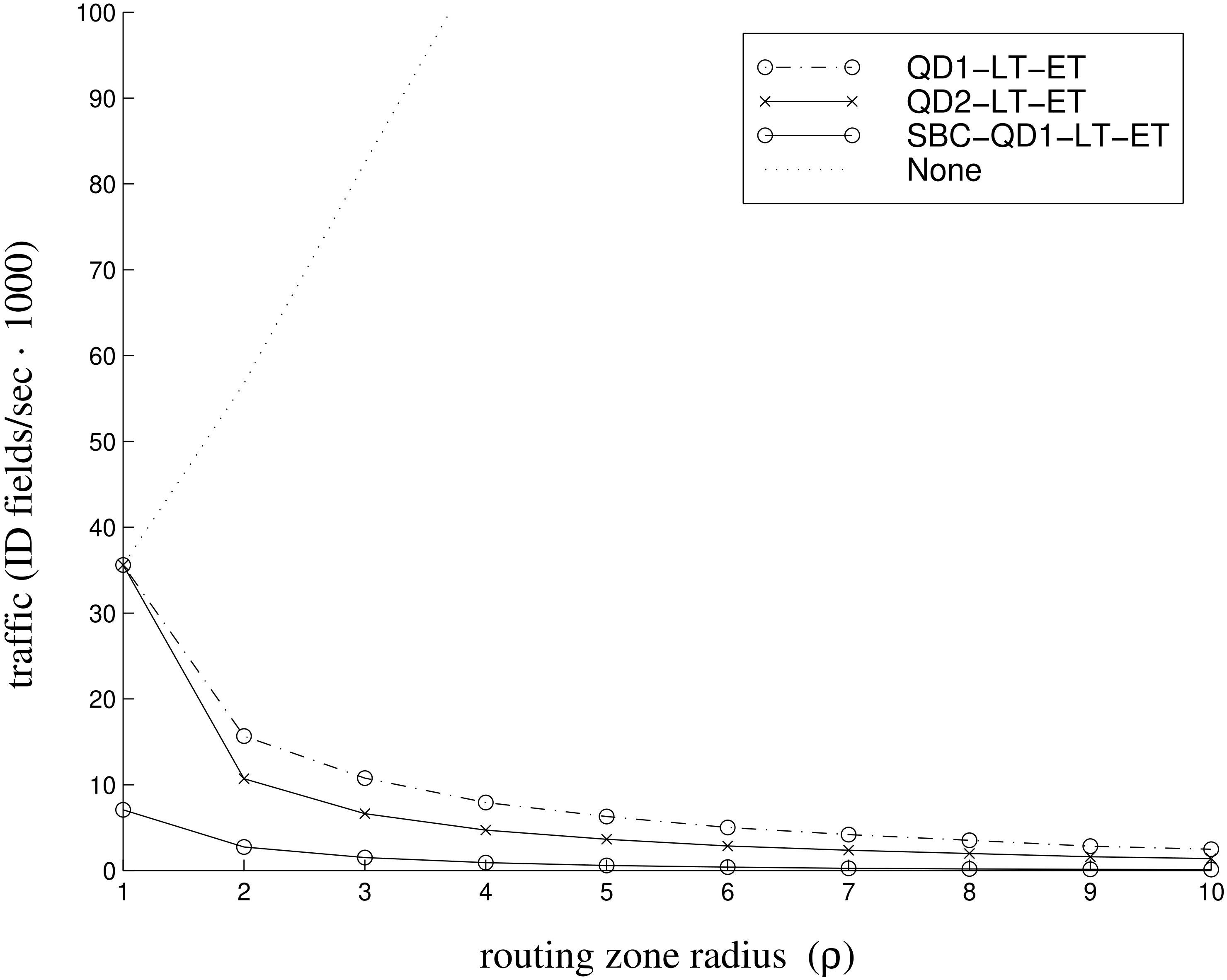
Variable Simulation Parameters

v ρ R_{query}	10 - 75 m/s 1-10 hops 0.1 - 10 queries/sec

IARP Traffic per m/s

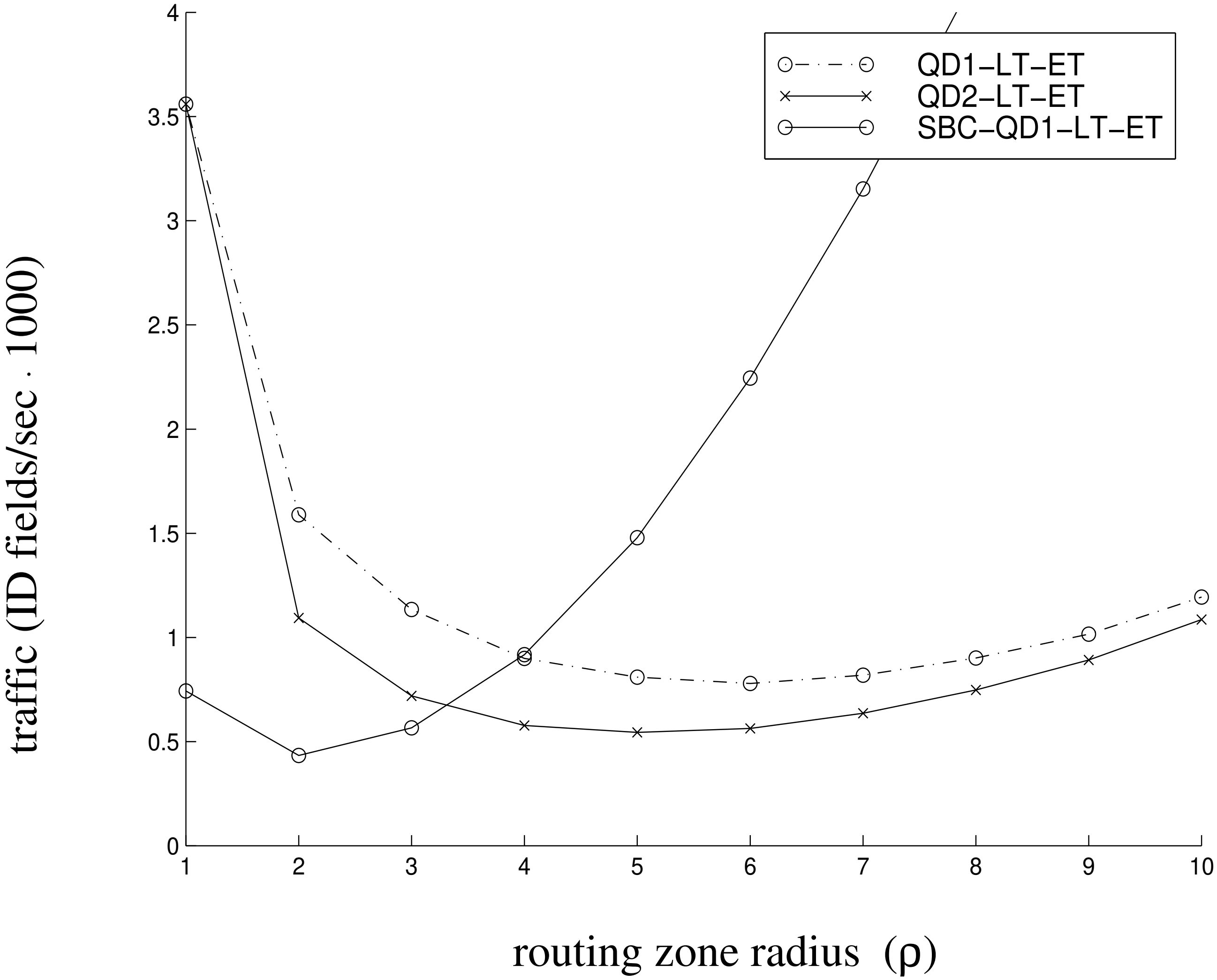


IERP Traffic per Route Discovery

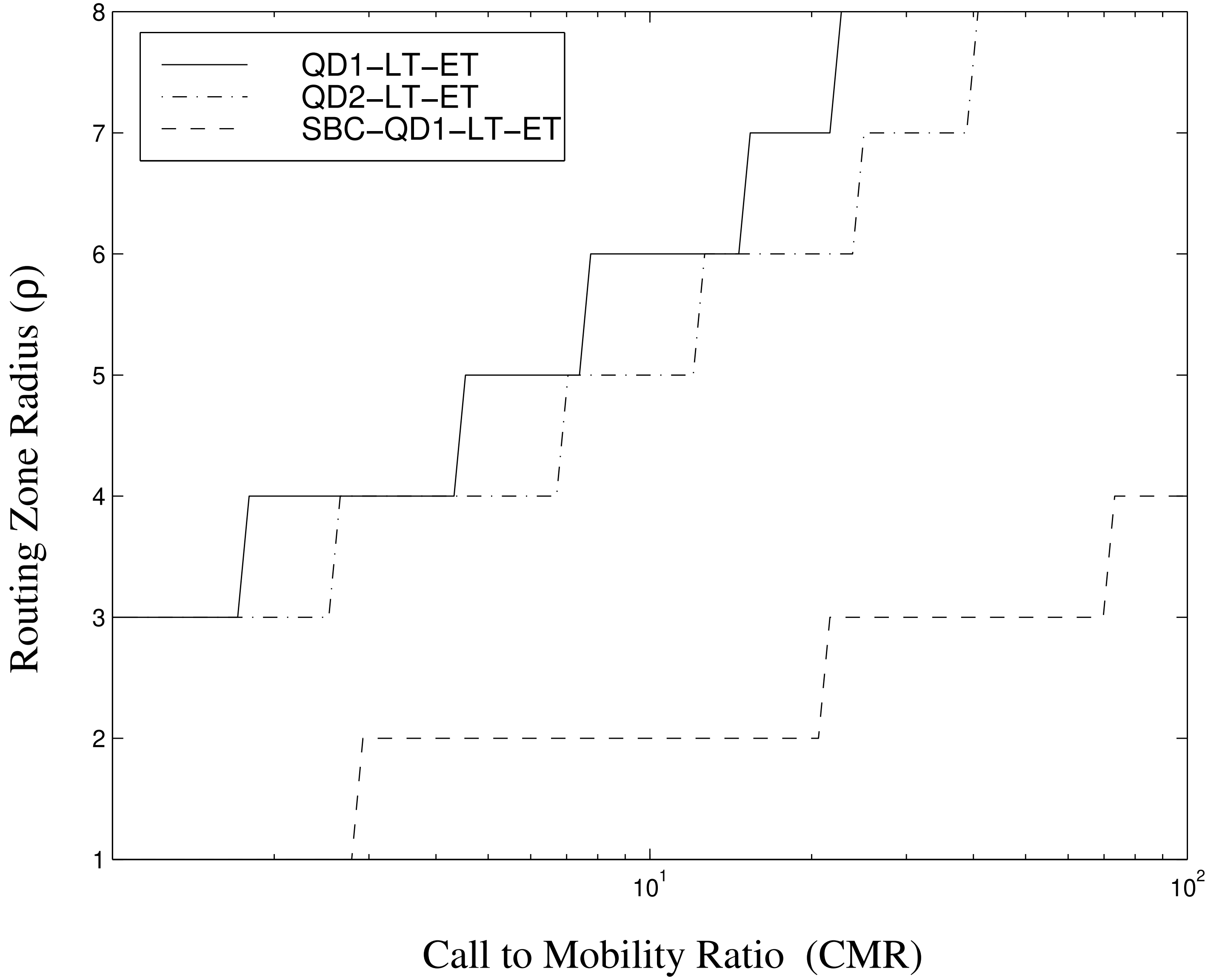


Total ZRP Control Traffic

v = 10 [m/sec] R_{query} *= 0.1 [query/sec]*



Optimal ZRP Configuration



Conclusions

- ZRP can perform worse than flooding <u>without</u> proper query control mechanisms.
- QD, ET and LT provide significant improvements compared with purely reactive ($\rho = 1$) and purely proactive schemes ($\rho \to \infty$).
- Optimal ZRP radius is an increasing function of the Call-to-Mobility Ratio (CMR).
- Use of SBC depends on delay and computational complexity considerations.