ÉCOLE POLYTECHNIQUE
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Terminode Routing - A Scalable Routing Scheme for Large Mobile Ad Hoc Networks

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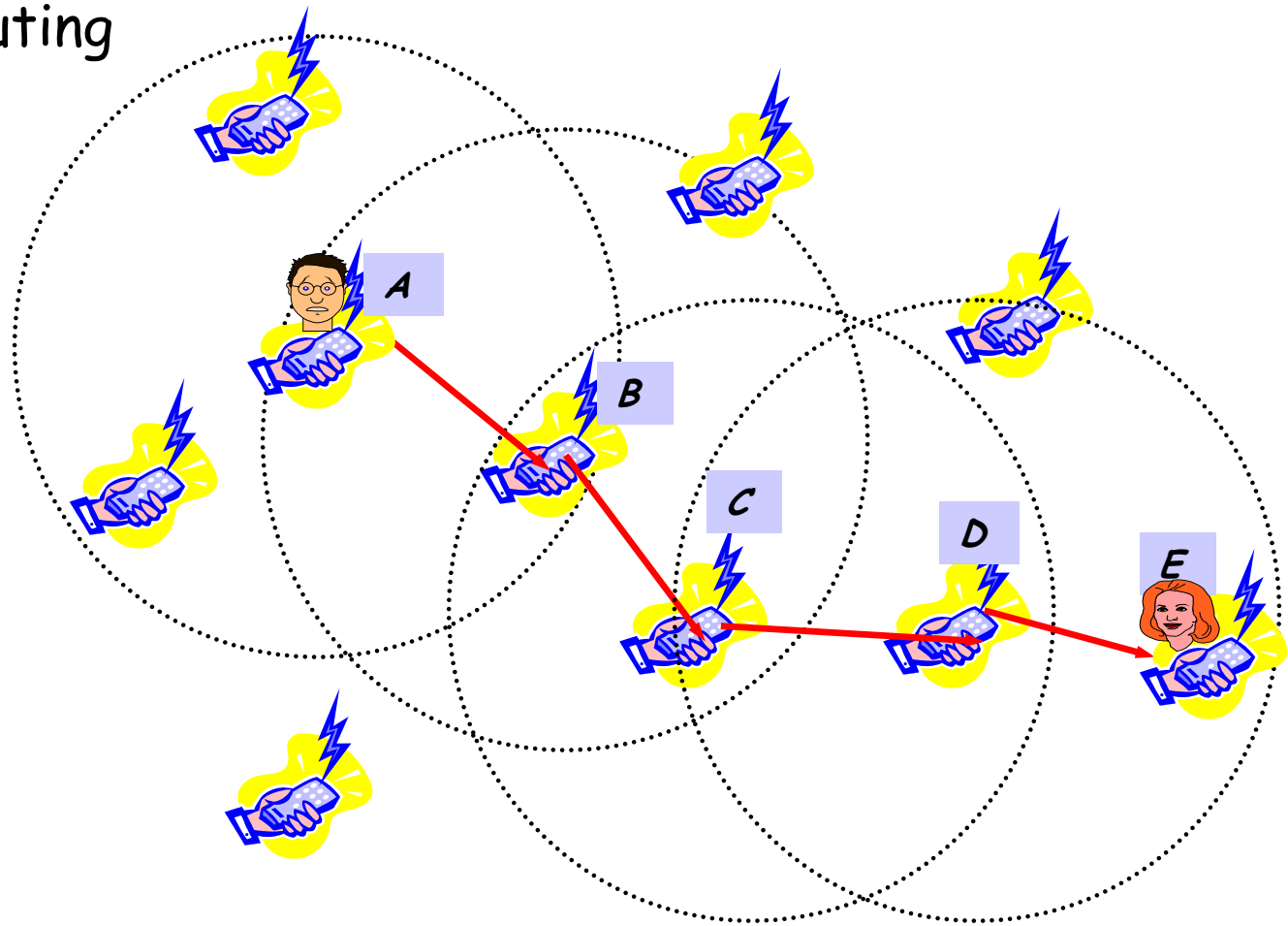
Mobile Ad Hoc Networks

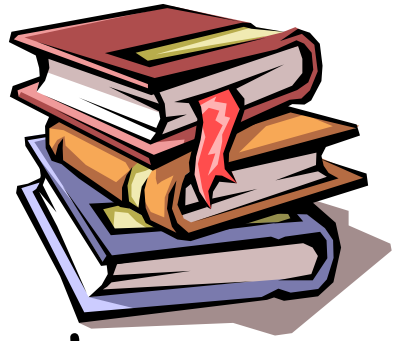
- Autonomous system of mobile routers, connected by wireless links
  - we call it terminode network
- Network covers area larger than transmission range, by use of routing



Goal: Design Routing Protocol for Terminode Network

- Requirements:
  - scalability (geography, number of terminodes)
  - support dynamicity of network
  - minimal intermediate system functions and overhead

Existing Routing Protocols



- **Topology-based (MANET) protocols use info. about links in network** (ex.DSR,AODV,ZRP, DSDV,OLSR)
  - difficult to maintain topological structure for more than 100 nodes
- **Scalability can be achieved through geography** (ex. LAR,GPSR, GRA, GFP)
  - reduction of control traffic, router state information
  - routes may not be optimal
  - location inaccuracy is not well supported
- **Terminode Routing combines both**
  - geography-based until close to destination; there on MANET-like

Terminode Routing

- Every terminode is identified by two addresses:
  - End-system Unique Identifier (EUI)
  - Location-Dependent Address (LDA): (longitude, latitude, height)
    - obtained with GPS or GPS-free positioning system
    - location management assumed to exist

- Source S knows EUI_D and approximate value of LDA_D. How can S reach D?

Terminode routing = TRR(location-based) + TLR(MANET-like)

- Elements of Terminode Routing:
  - Terminode Remote Routing (TRR): location-based, far from destination
  - Terminode Local Routing (TLR): non location-based, close to destination
  - Interworking between the two

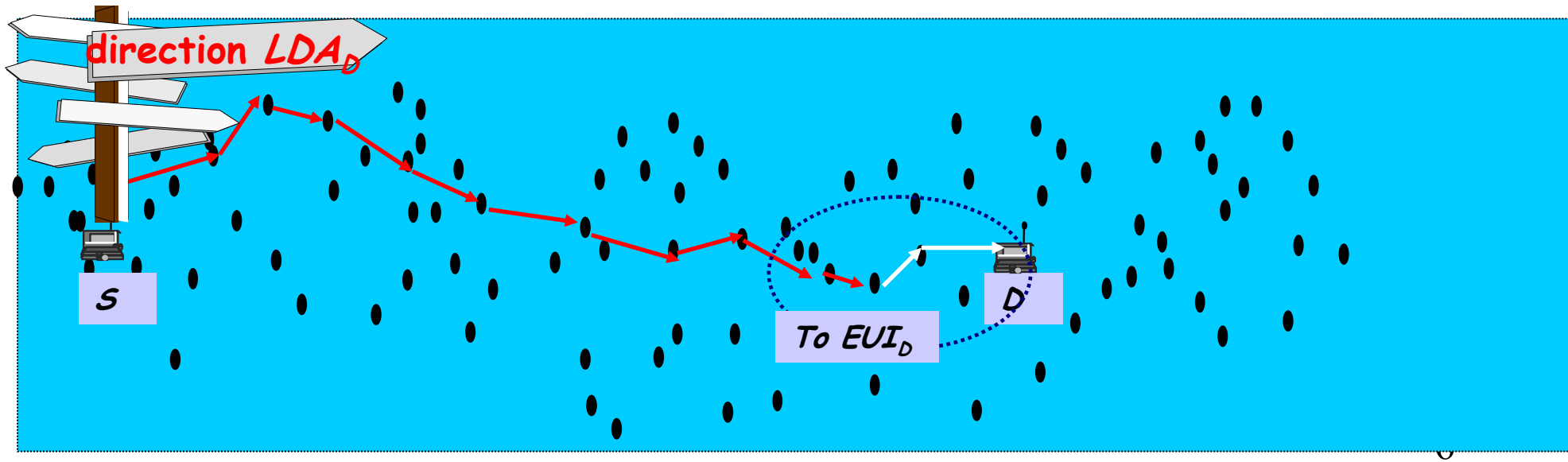
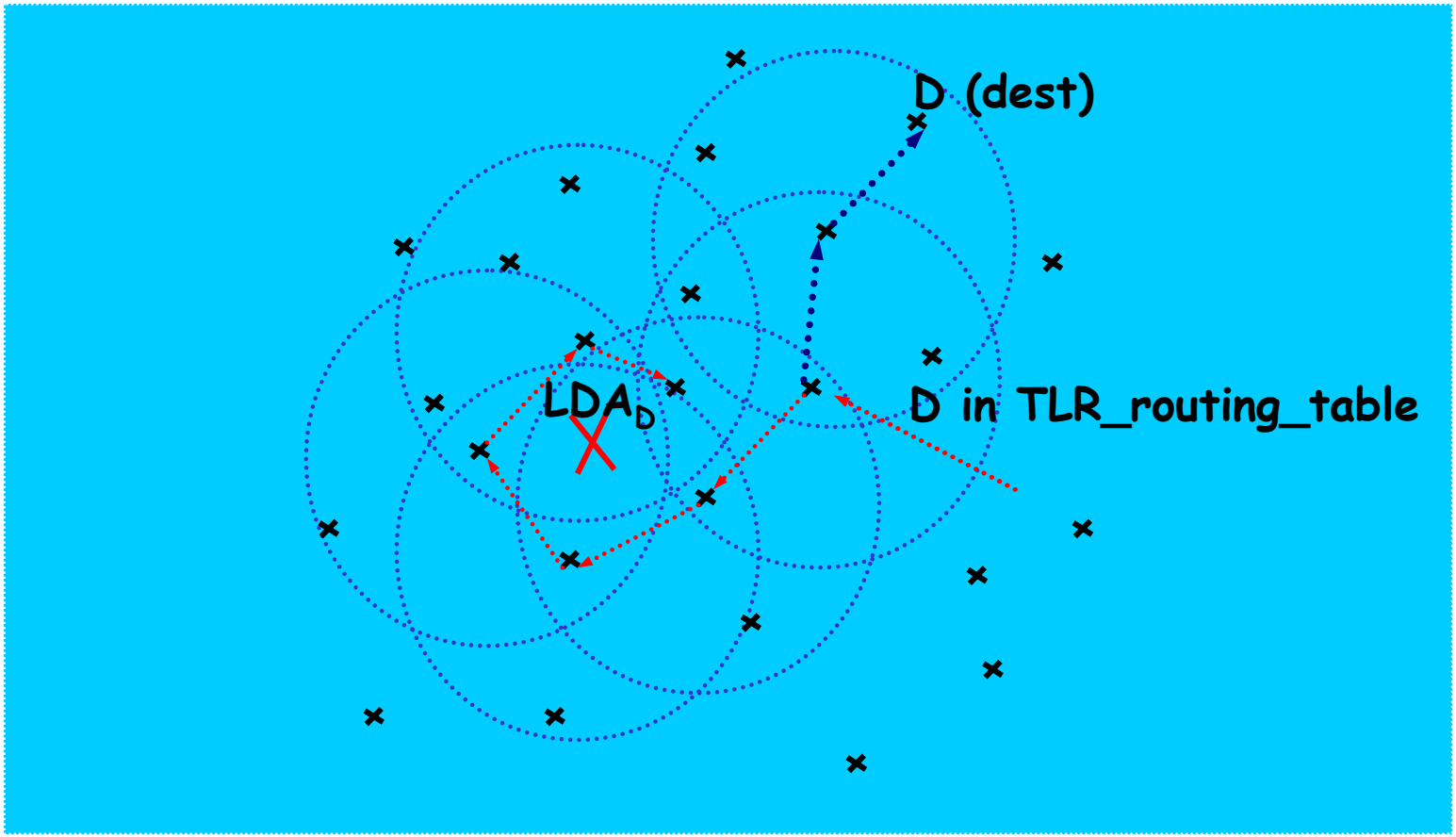


Illustration of advantages with TLR

- TLR helps when the destination has moved from its reference position more than scope of one transmission range

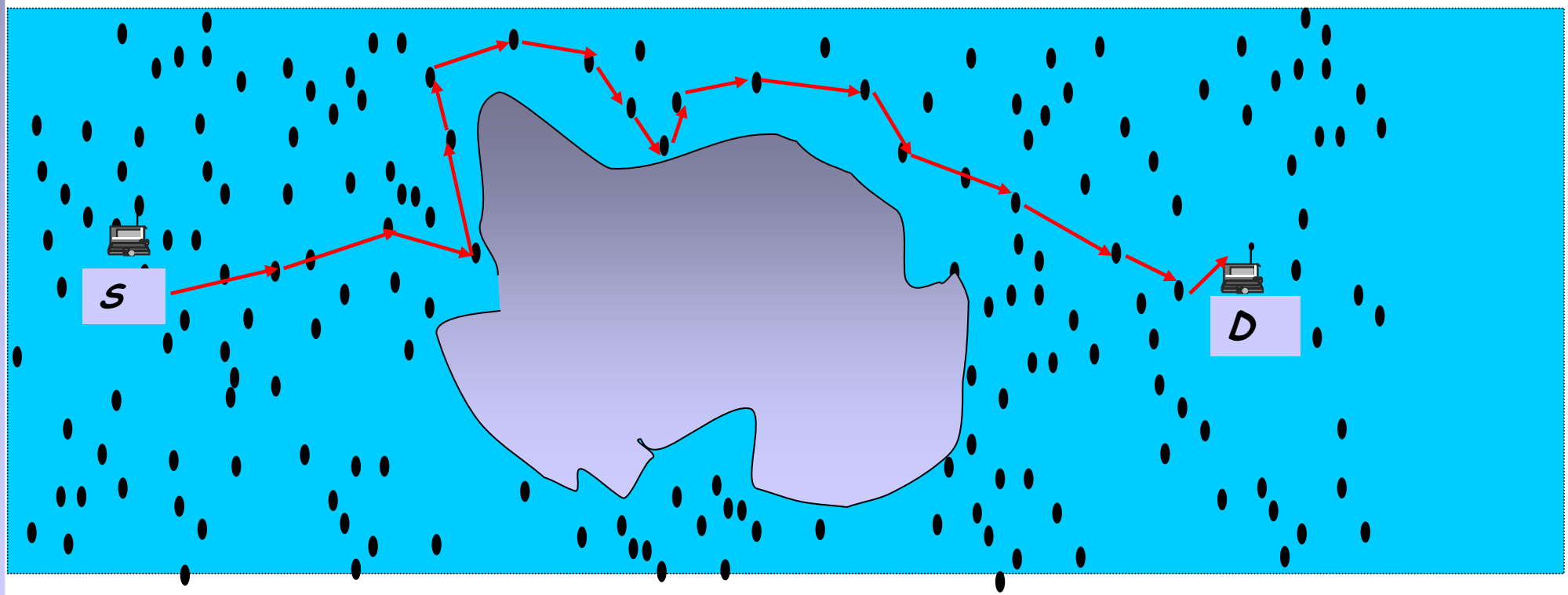


Terminode Remote Routing (TRR)

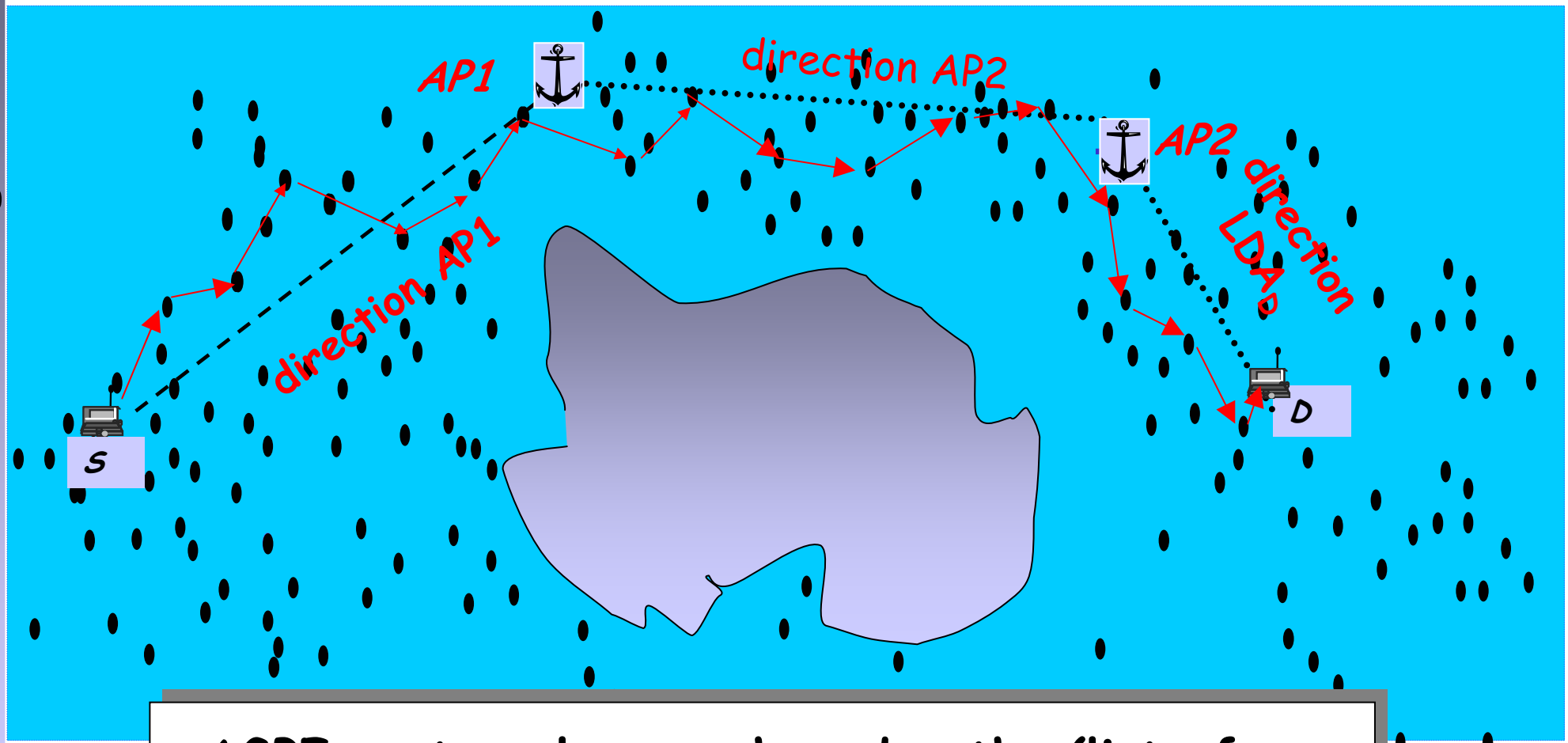
- Default method: Geodesic Packet Forwarding (GPF)
  - packet is sent to a neighbour geographically closest to D's location
- *Anchored Geodesic* Packet Forwarding (AGPF) helps in case of obstacles and voids

GPF - Problems

- Greedy mode: packet can be "stuck" in local minimum
- Perimeter mode is used in that case:
  - uses planar subgraph of wireless network graph to route around perimeter of a void
  - problem: may loop due to mobility



Anchors help to go around Connectivity Voids

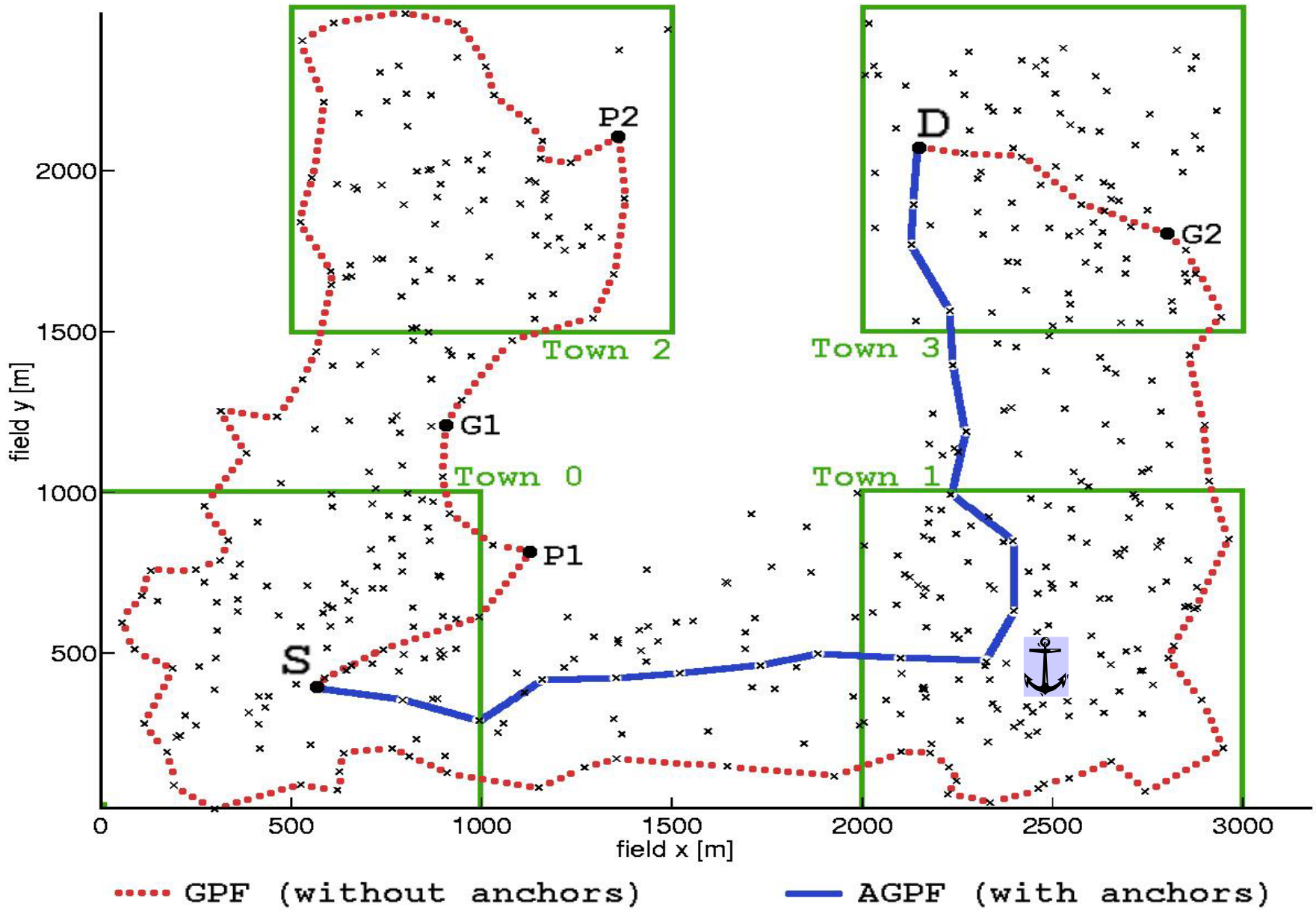


AGPF routes along anchored paths (list of geographic points - anchors)
AGPF = source routing with anchors

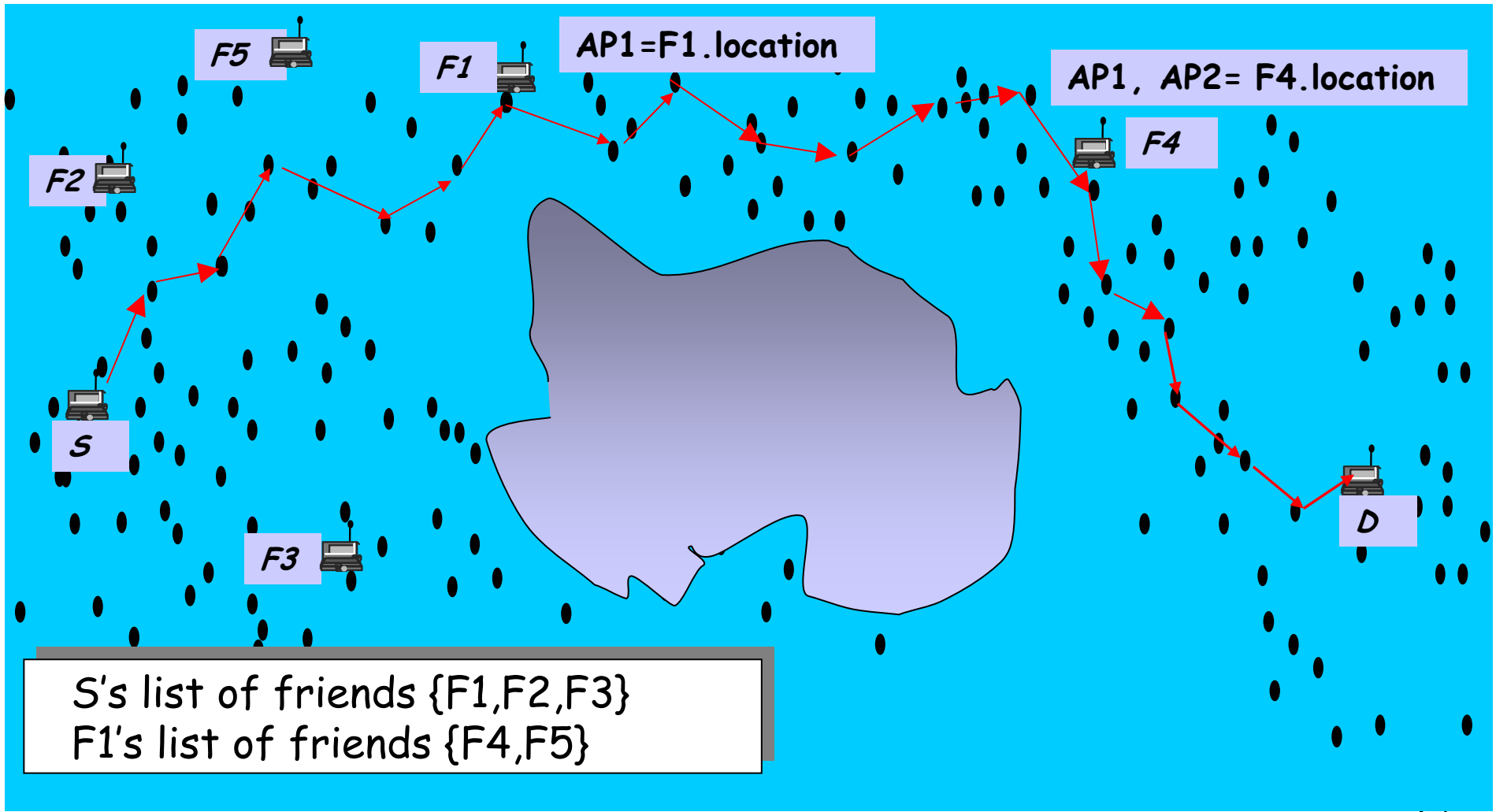
Anchored Path Discovery

- List of anchors found by GMPD or FAPD
- Geographical Map-Based Path Dicovery (GMPD)
  - map identifies areas with higher node density (towns and highways)
  - anchored paths found with help of map
- Friend Assisted Path Discovery (FAPD)
  - a terminode can ask its friends to help in finding a path
    terminode has a good path to a friend

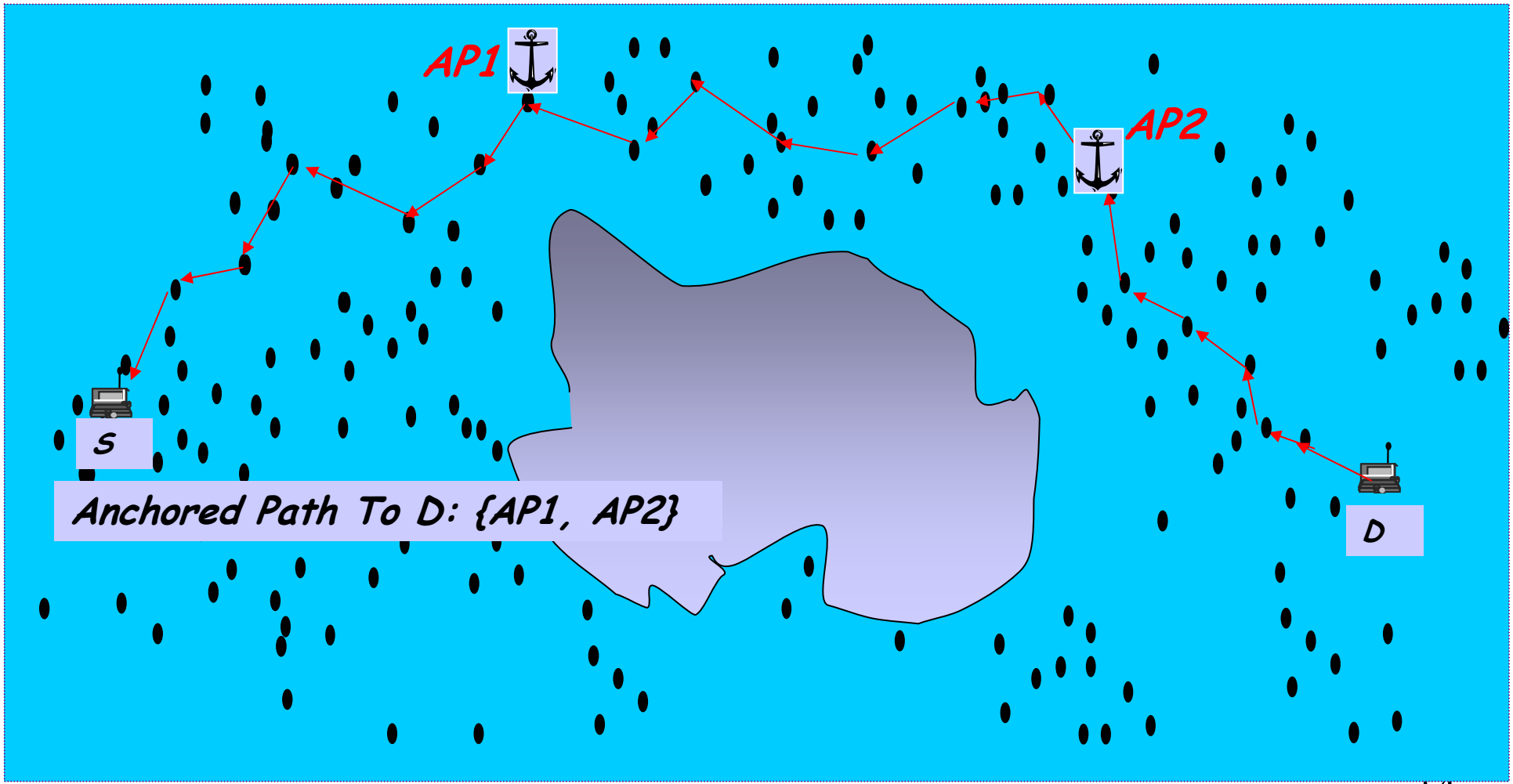
GMPD Illustrated



(a). FAPD Illustrated



(b). FAPD Illustrated



Terminode Local Routing (TLR)

- Inspired by existing MANET protocols
- Desirable characteristics of TLR:
  - low overhead
  - handles well problems due to location management inaccuracy
  - loop-free at all times

TLR Operation

- TLR consists of two methods:
  1. building of TLR routing tables
  2. TLR packet forwarding

1 All nodes keep link states for nodes in the 2-hop area

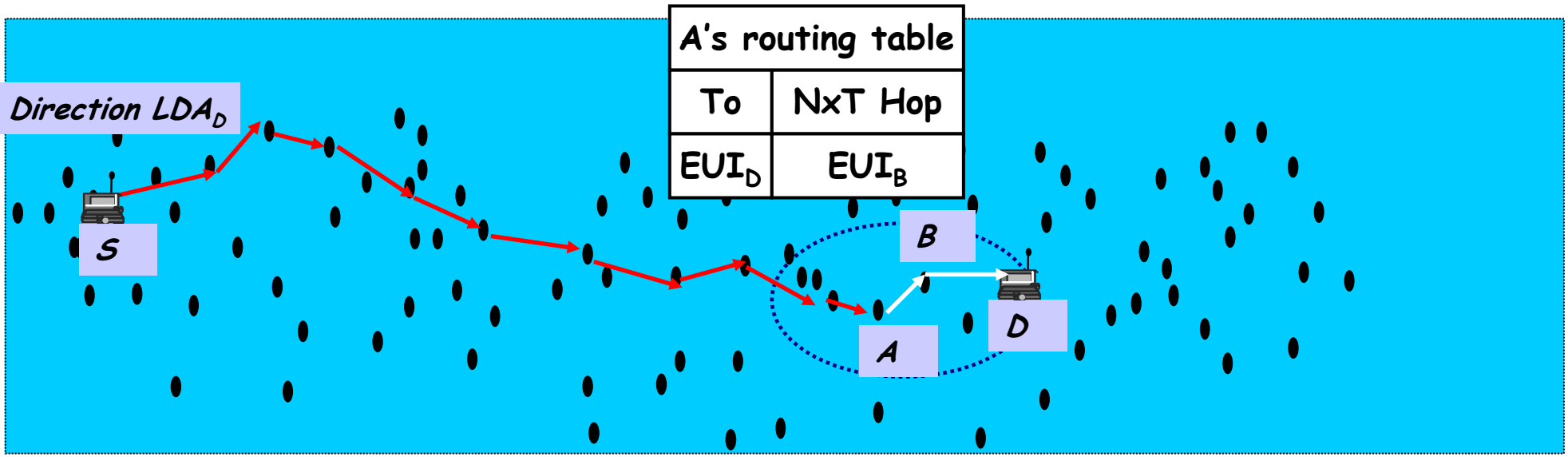
- *X* sends in a HELLO message: {EUI_X, LDA_X, *EUIs* of its immediate neighbours };
- HELLO messages are periodically broadcasted at the MAC layer
- X's routing table:
  - immediate neighbours' EUI and LDA (used for TRR)
  - 2-hop nodes: EUI and next hop node
- all entries are associated with a timeout

2 *X* has packet *p* to forward to *D* with TLR

```
if (p.use_tlr_bit=0) p.use_tlr_bit:=1
if (EUI_D in X.TLR_routing_table)
      transmit(p, X.TLR_routing_table.next_hop(EUI_D))
else drop p
```

Interworking of TRR and TLR

- TRR is performed until some node finds destination to be within 2 hops
  - from there on, only TLR is used



- This simple way may not work ; then use more complex method to expedite termination of TRR

TRR termination

- If *D* has moved considerably from LDA_D (known at the source), normal termination not possible
  - packet may circulate around LDA_D and eventually die (after TLL expiration)
- Our goal: detect packet circulation problem and react

Expedite termination of TRR if:
dist(LDA_D, LDA_X)<X.transmission_range && D not in X.TLR_routing_table

- One solution is limiting lifetime of packets:

X sets: *p*.ttl=min(3, *p*.ttl)

A variant of how TRR termination is expedited- Restricted Local Flooding (RLF)

- RLF expands search area of *D* and improves probability of finding *D*

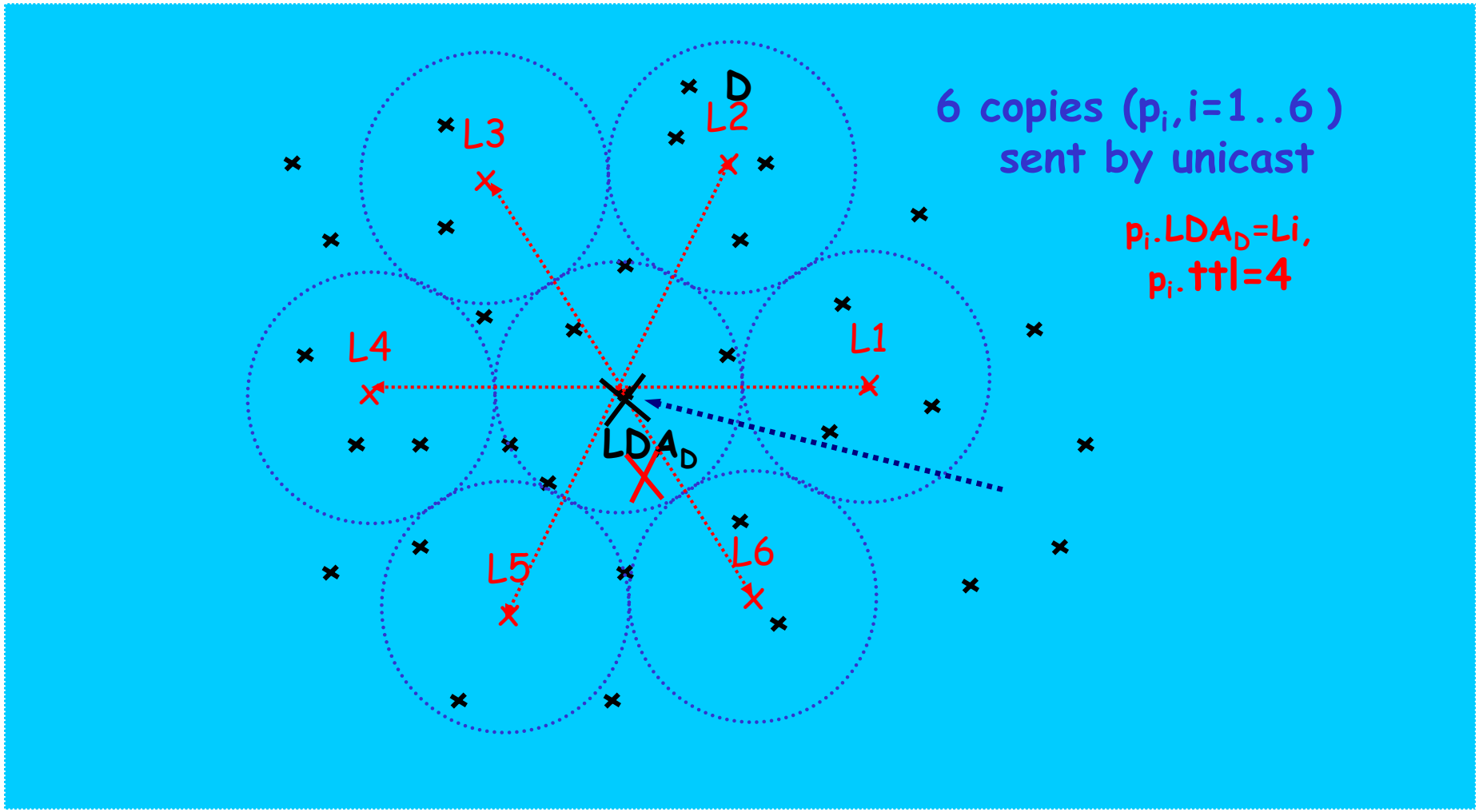
RLF is activated at *X*:

X creates several copies of packet (p_i) and selects different locations around itself (L_i) :

$p_i.LDA_D := L_i$
X sends p_i by GPF

- *Restricted* Local Flooding: 6 duplicates, 4 hops
- RLF never results in network-wide flooding

RLF operation



Terminode Routing Performance Evaluation

- Simulations were performed in GloMoSim:
  - IEEE 802.11 MAC protocol is used; nominal radio range is 250 meters and 2Mbs data rate (model of the Lucent WaveLAN card)
  - Piggypacking implemented (promiscuous use of network interface)
  - HELLO messages sent every 1 s (if no data is to be sent); TLR routing entries expire after 2s (if not updated)

- Simulation parameters:
  - size of the network
  - node distributions (uniform and non-uniform)
  - mobility level

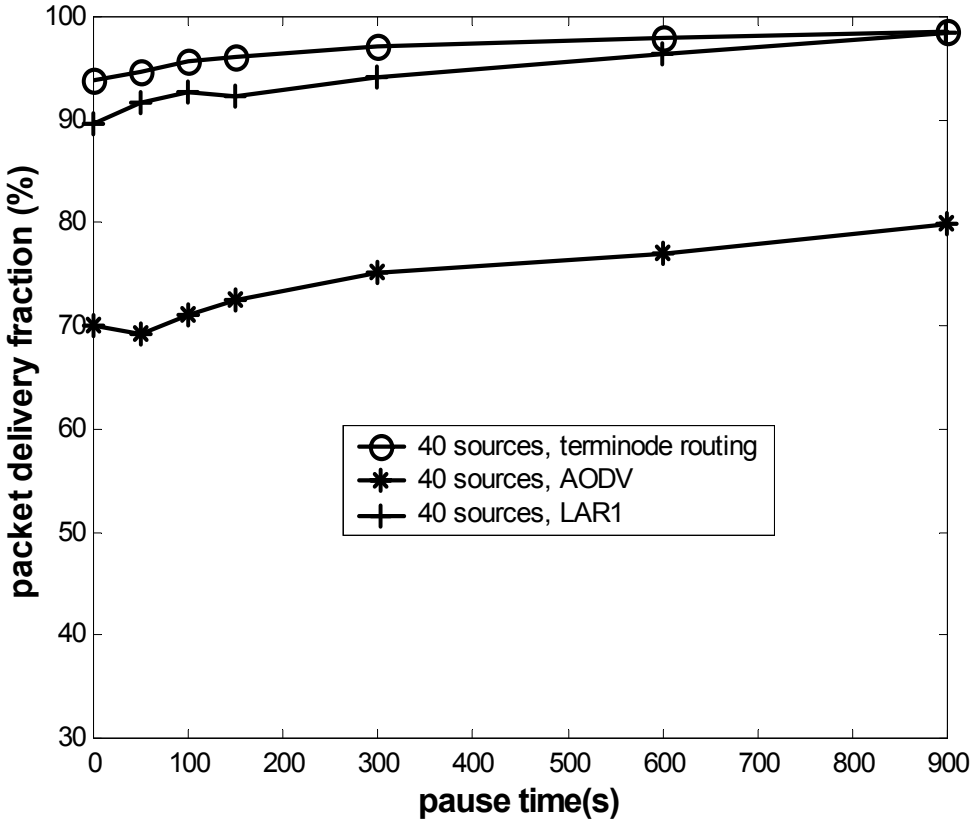
Location Management

- In SMALL nets (#nodes=100) our location management:
  - *location discovery* is on-demand: initiated by source, based on controlled flooding of network; destination sends its location back to source
  - *location tracking*: once two nodes begin communication, data packets periodically piggyback local sender's location

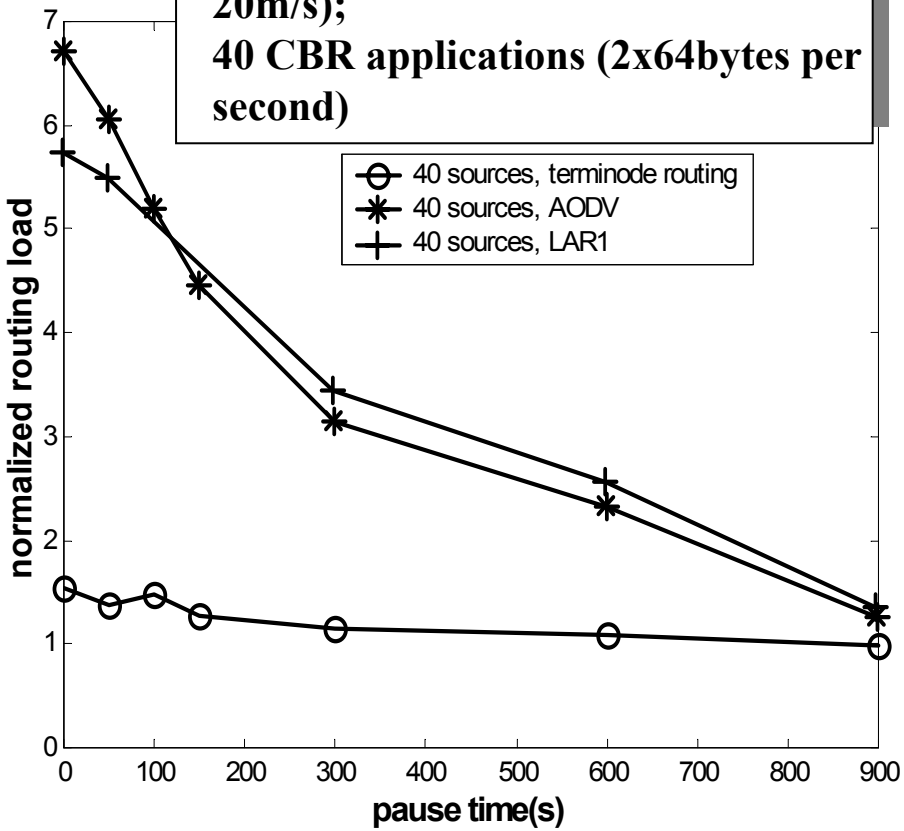
- In BIG nets (#nodes=600)
  - we assume idealized location management with no control overhead
  - however, we assume the location information can be stale
  - the *location information lifetime* parameter is the destination location update interval

In small networks TR better than MANET

- Terminode routing outperforms LAR1 and AODV in packet delivery success
- Terminode Routing has lowest routing load compared to LAR1 and AODV

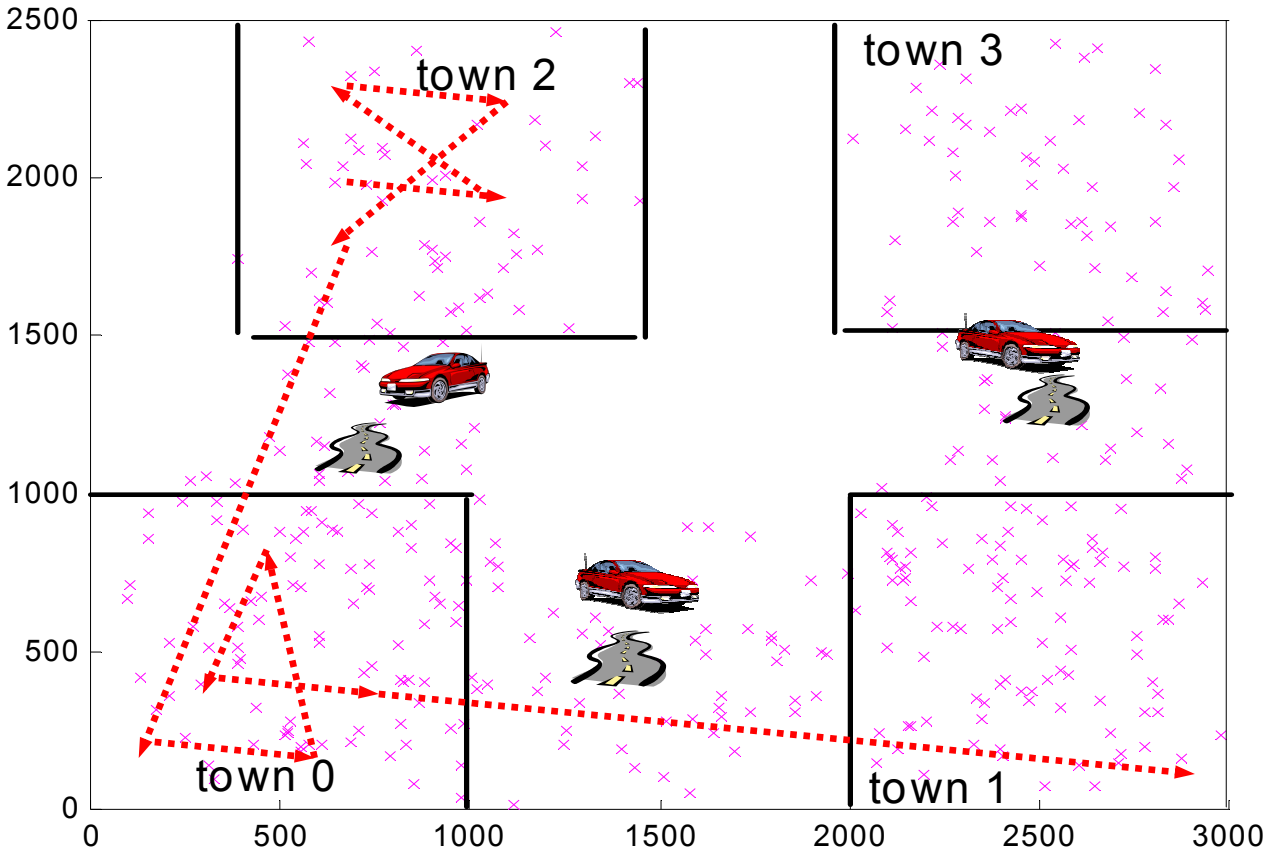


100 nodes, terrain:2200m X 600m; mobility: Random Waypoint (v=0-20m/s);
40 CBR applications (2x64bytes per second)

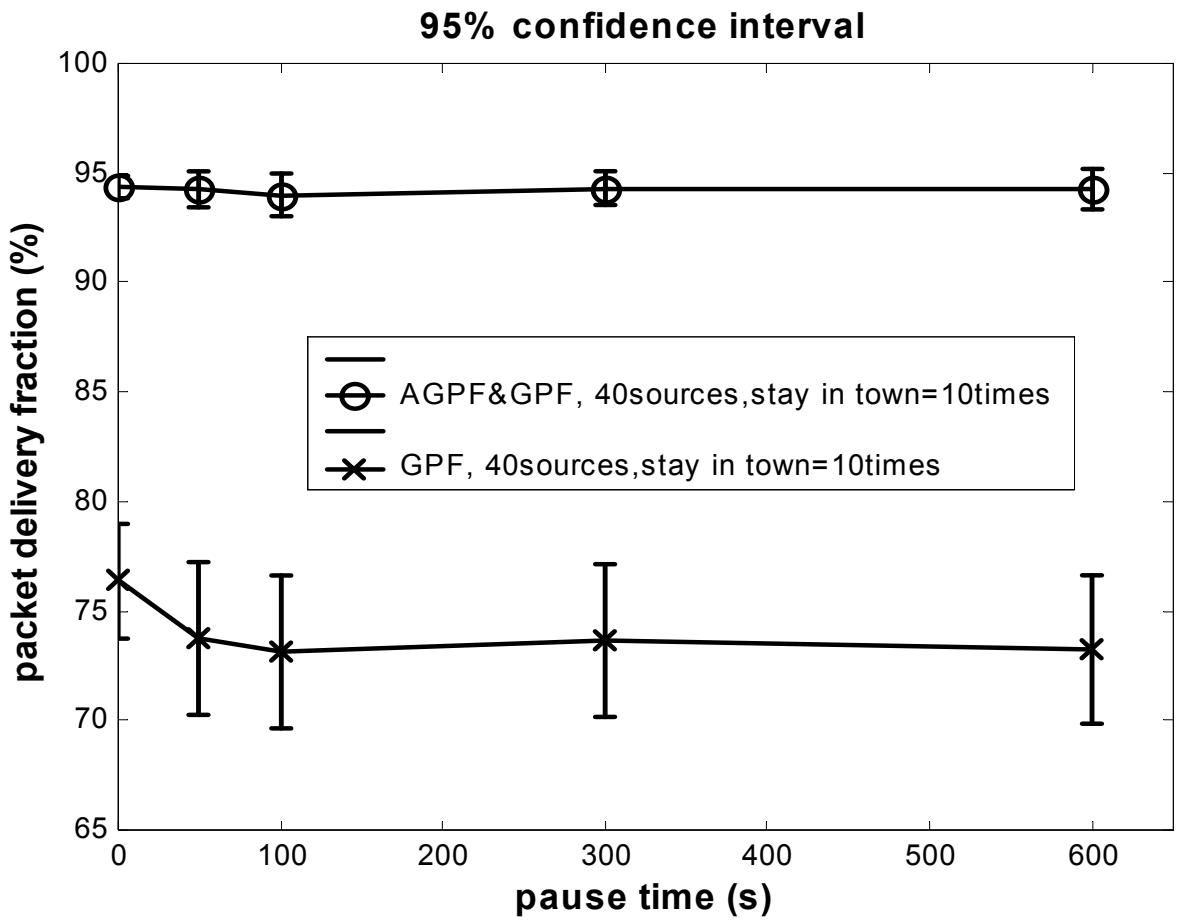


Large Network, Non-Uniform node distribution

- We designed new mobility model referred to as *restricted random waypoint* that is close to real life
- Nodes move in the same town area by random waypoint model, before moving to a different town
- *stay_in_town* parameter defines locality of movements within a town



Results for different levels of mobility while movements are localized *stay_in_town*=10



500 nodes,
mobility: Restricted Random Waypoint (v=0-20m/s)
40 CBR applications (2x64bytes per second)
location info. lifetime = 5 sec

AGPF improves GPF over 20%

Conclusions

- Designed terminode routing: scalable strategy for large mobile ad hoc networks
- Tested: TLR + TRR scales well under different simulation parameters

- Current work: Evaluation of FAPD algorithm