



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

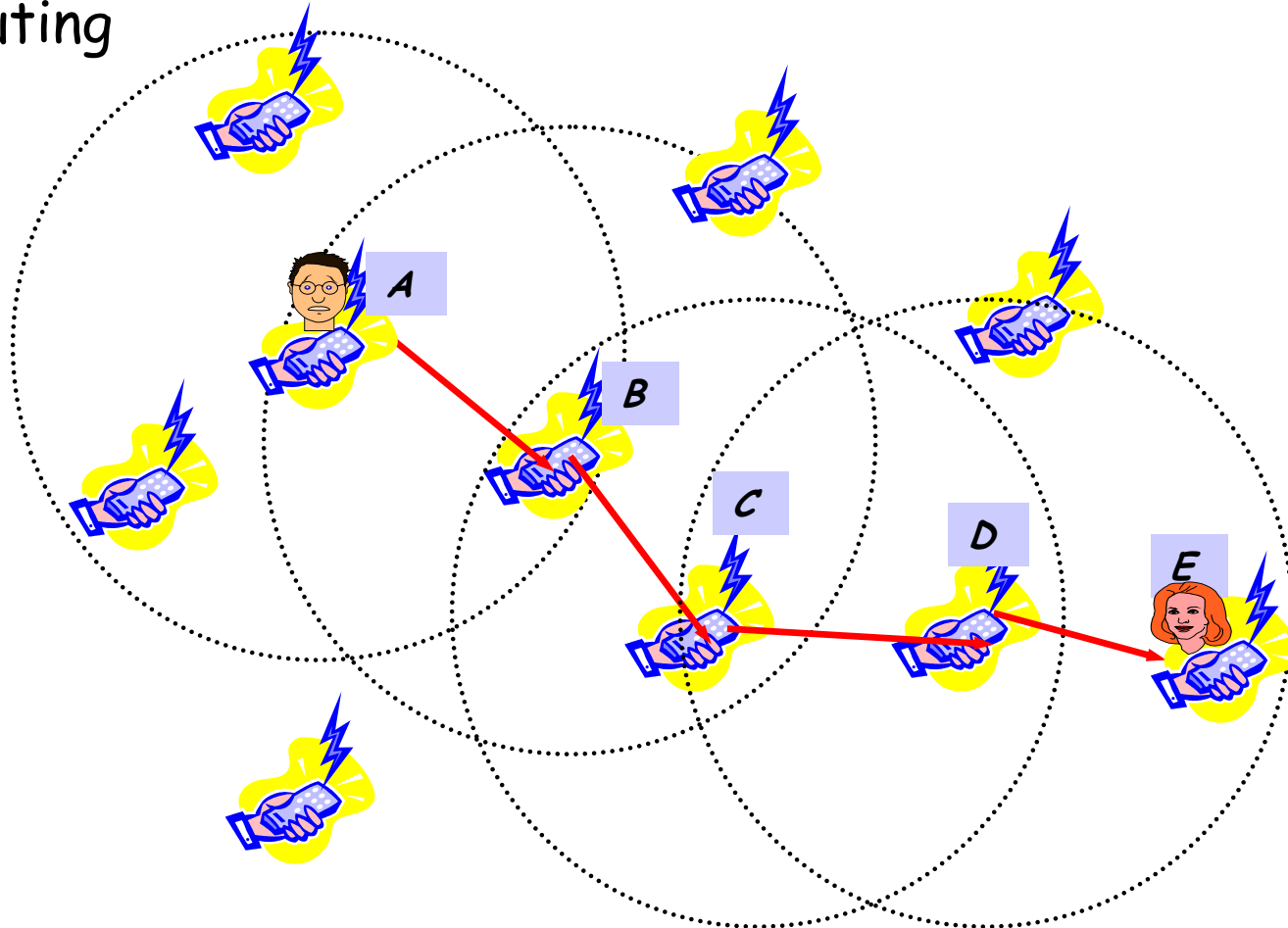
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Mobile Ad Hoc Networks

- 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

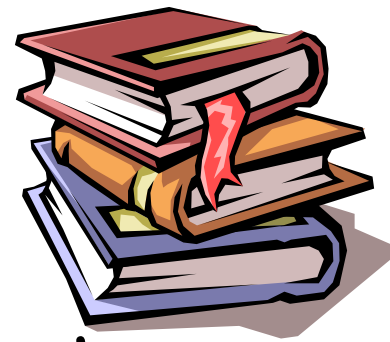


Goal: Design Routing Protocol for Terminode Network

- 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

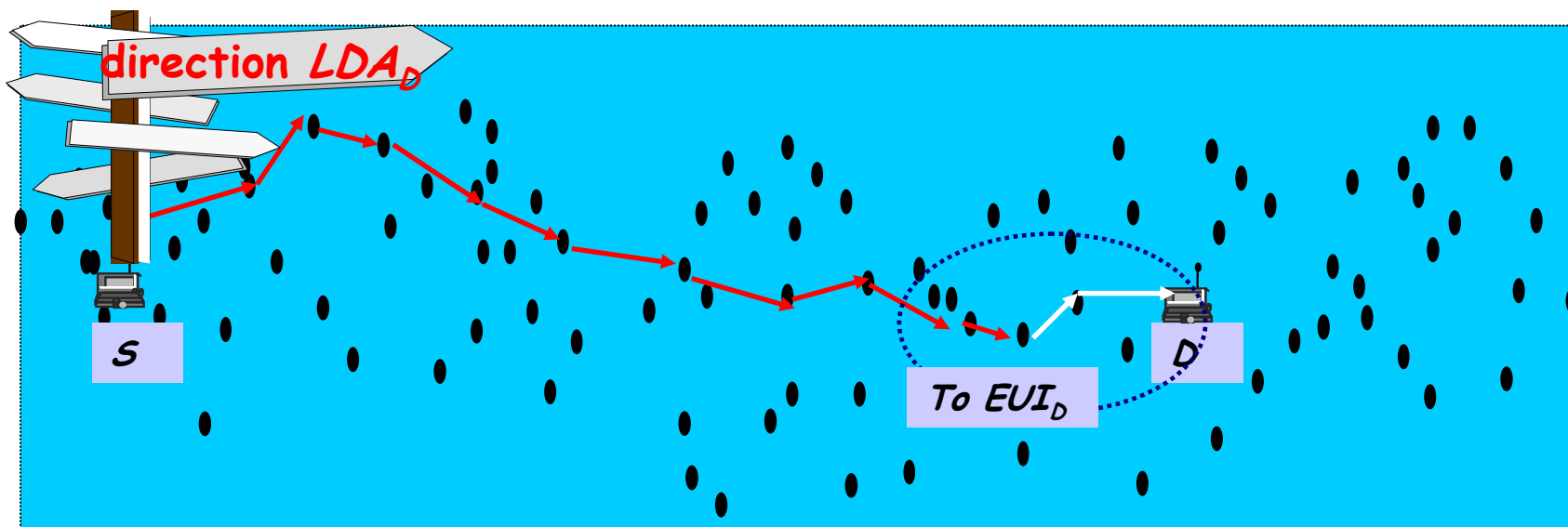
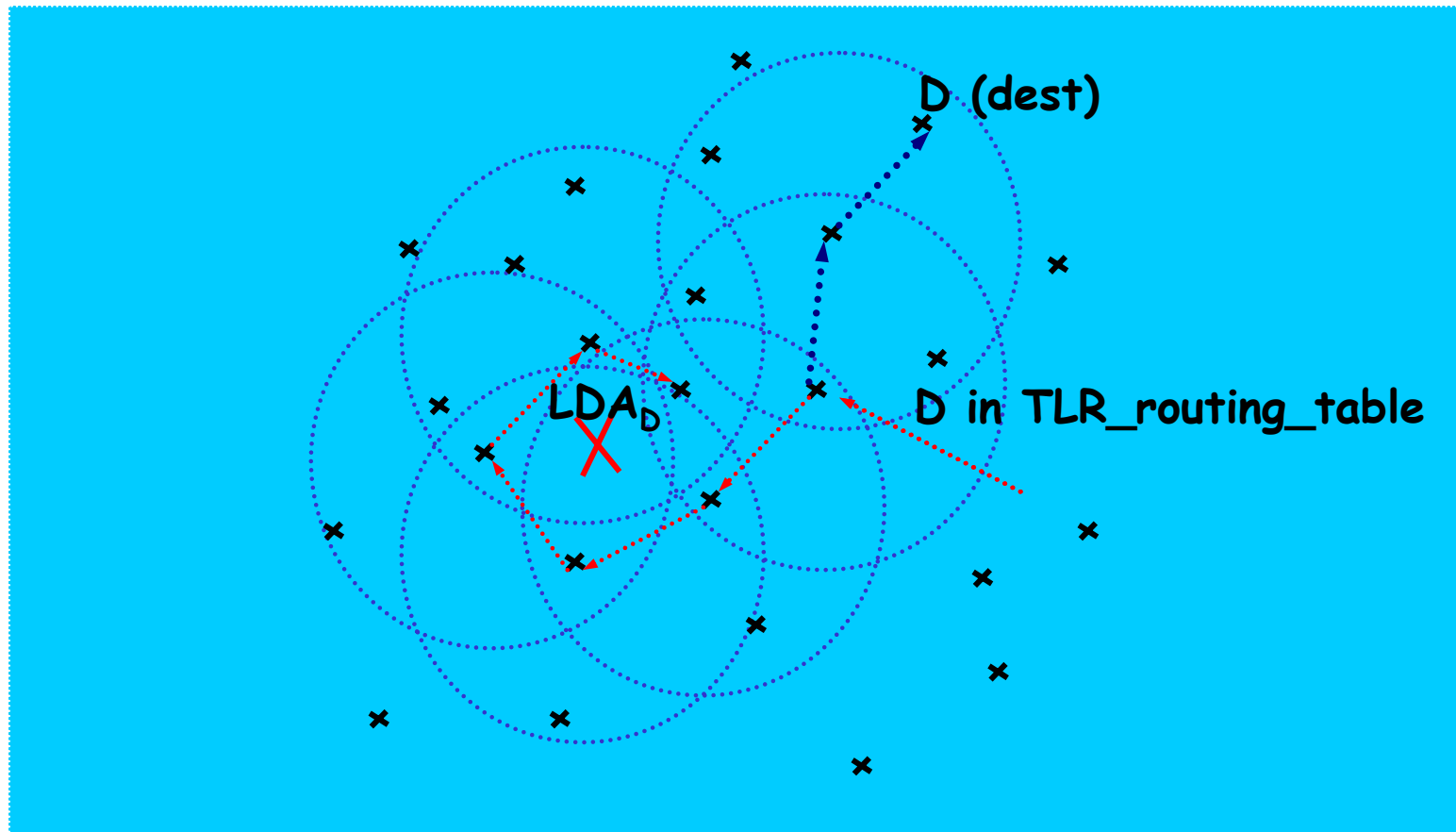


Illustration of advantages with TLR

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

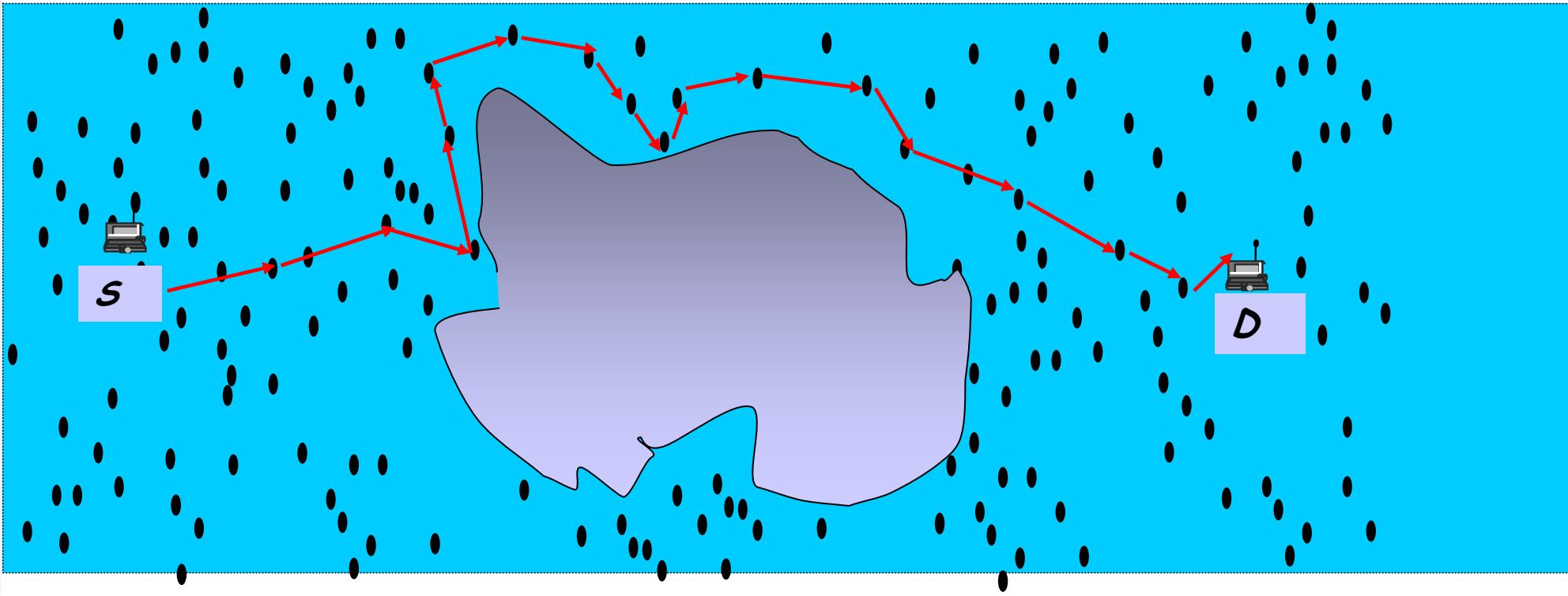


Terminode Remote Routing (TRR)

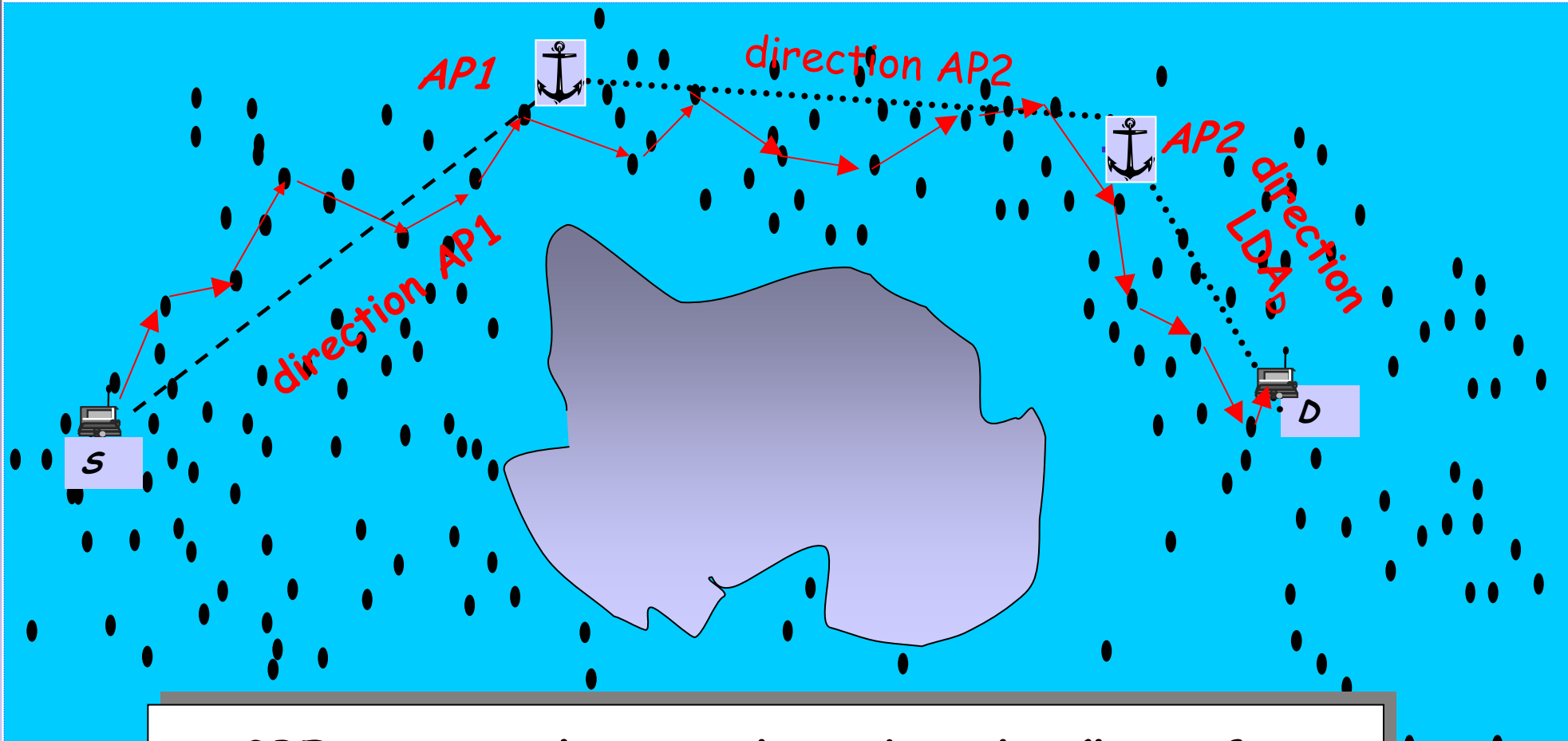
- Default method: *Geodesic Packet Forwarding (GPF)*
 - packet is sent to a neighbour geographically closest to D's location
- *Anchored Geodesic Packet Forwarding (AGPF)* helps in case of obstacles and voids

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

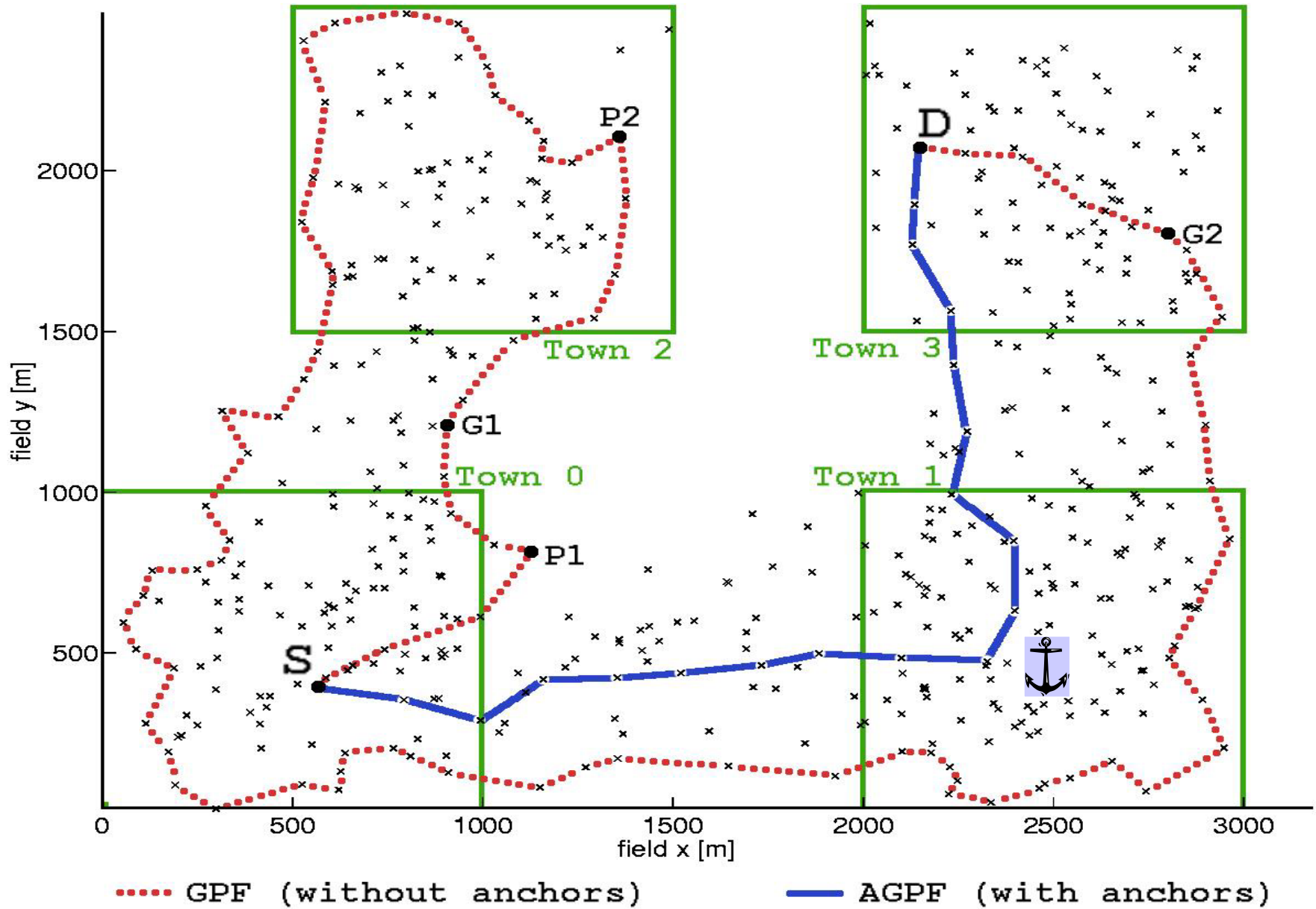


AGPF routes along anchored paths (list of geographic points - **anchors**)
AGPF = source routing with anchors

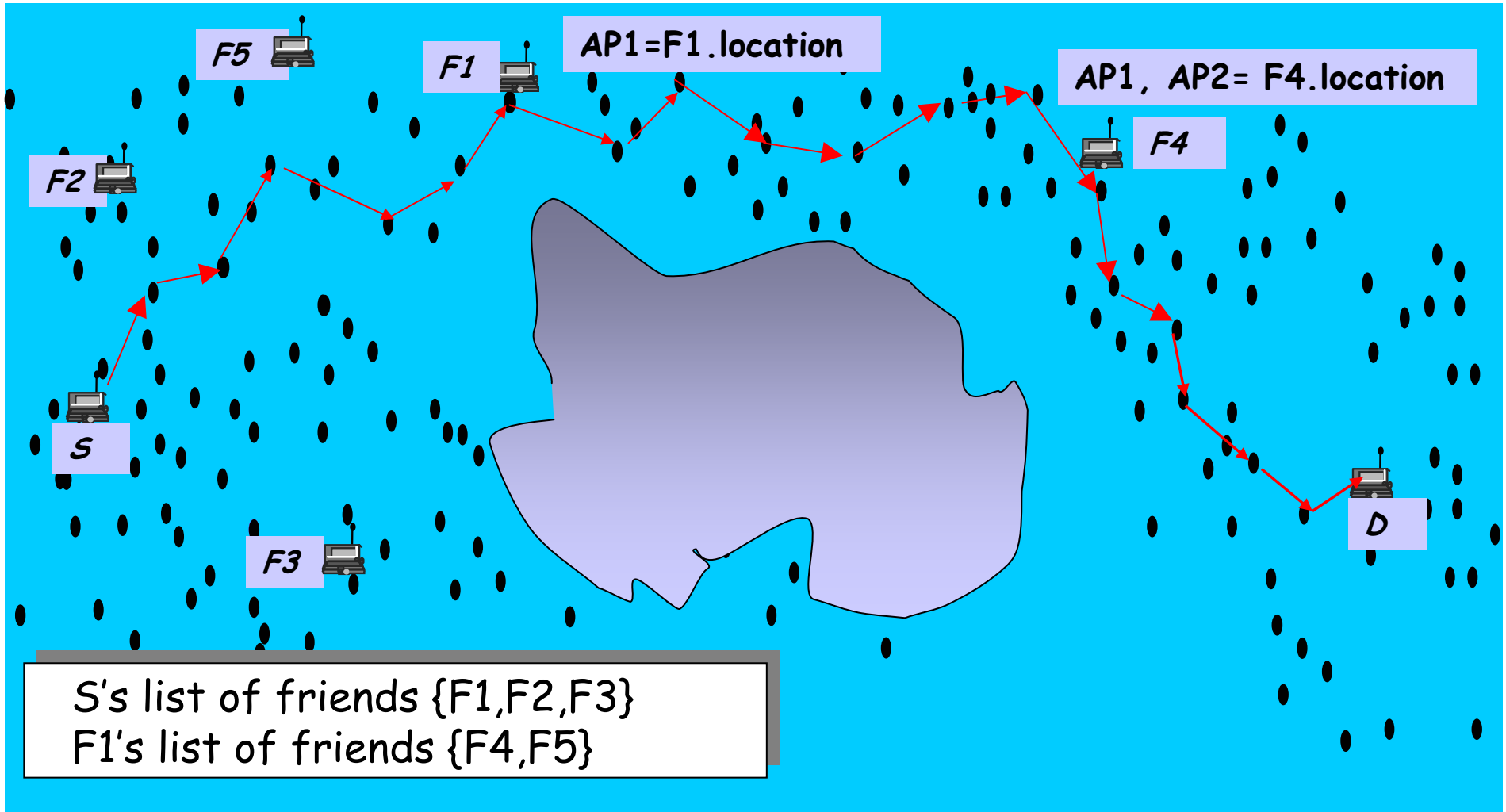
Anchored Path Discovery

- List of anchors found by GMPD or FAPD
- Geographical Map-Based Path Discovery (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

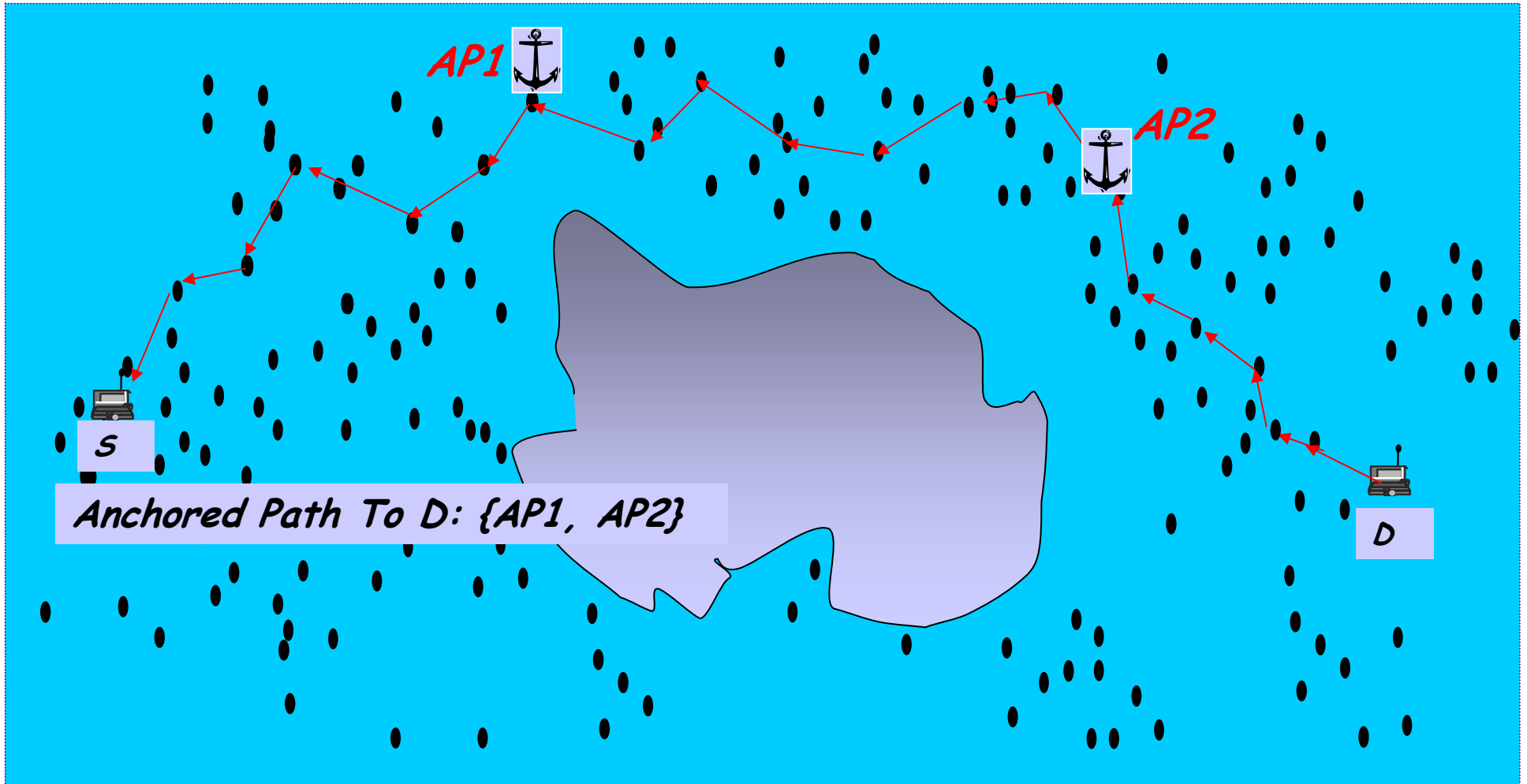
GMPD Illustrated



(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

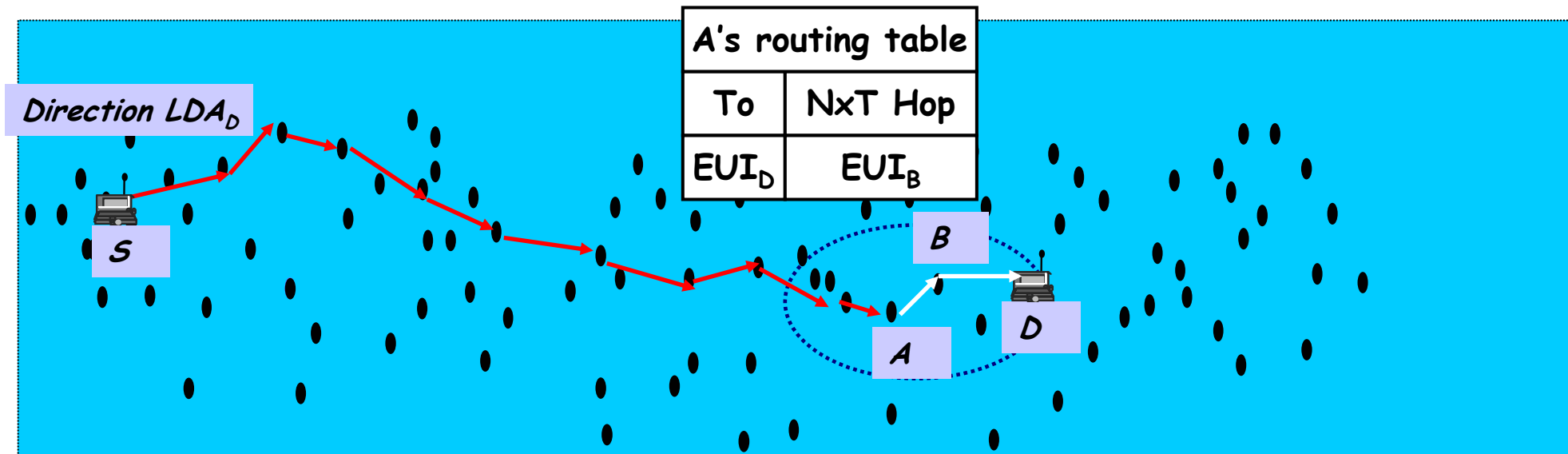
TLR Operation

- 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: $\{EUI_X, LDA_X, EUIs \text{ of its immediate neighbours}\}$;
 - 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 TTL expiration)
- Our goal: detect packet circulation problem and react

Expedite termination of TRR if:

$\text{dist}(LDA_D, LDA_X) < X.\text{transmission_range}$ && D not in $X.\text{TLR_routing_table}$

- One solution is **limiting lifetime of packets:**
 $X\text{sets: } p.\text{ttl} = \min(3, p.\text{ttl})$

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

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

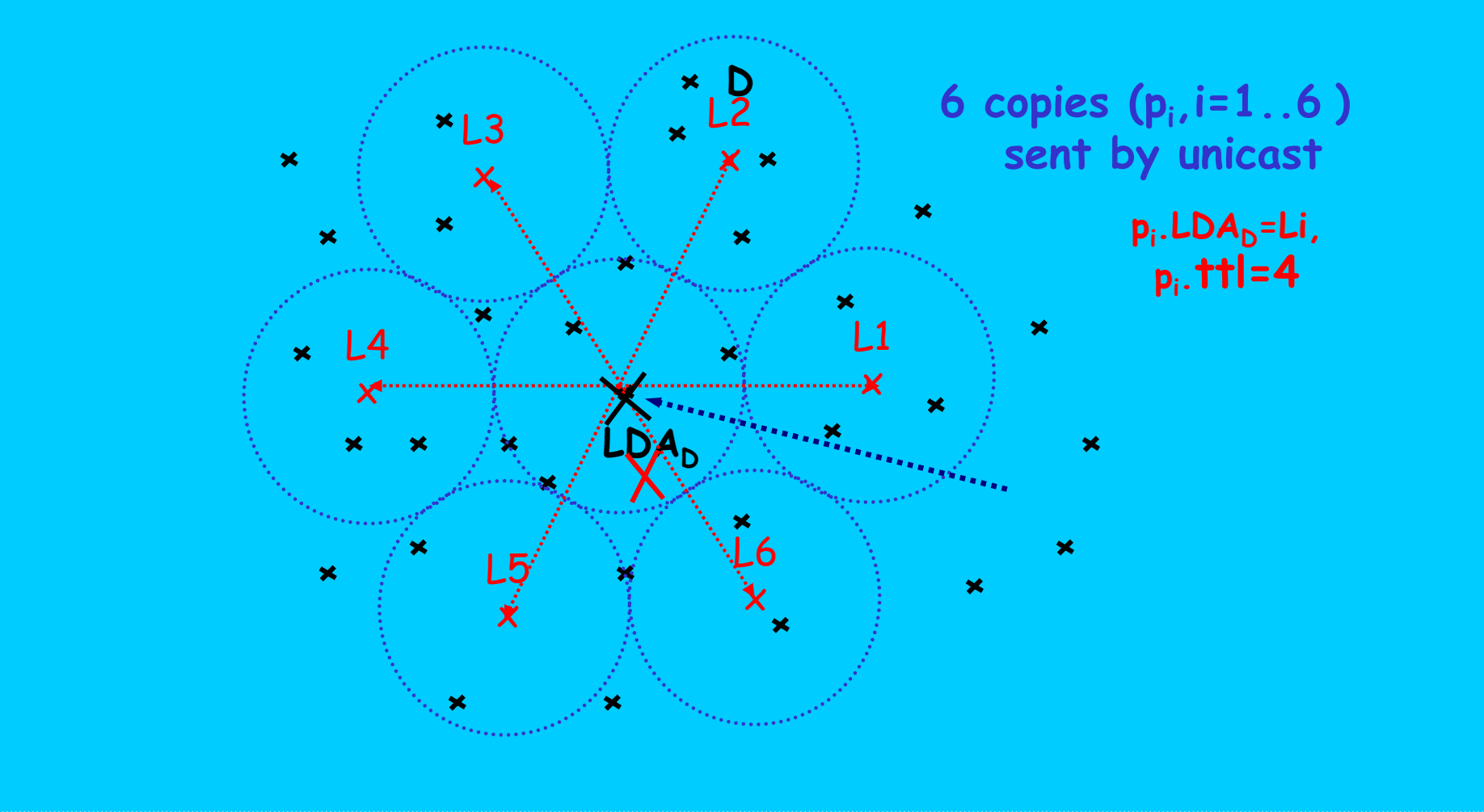
RLF is activated at X :

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

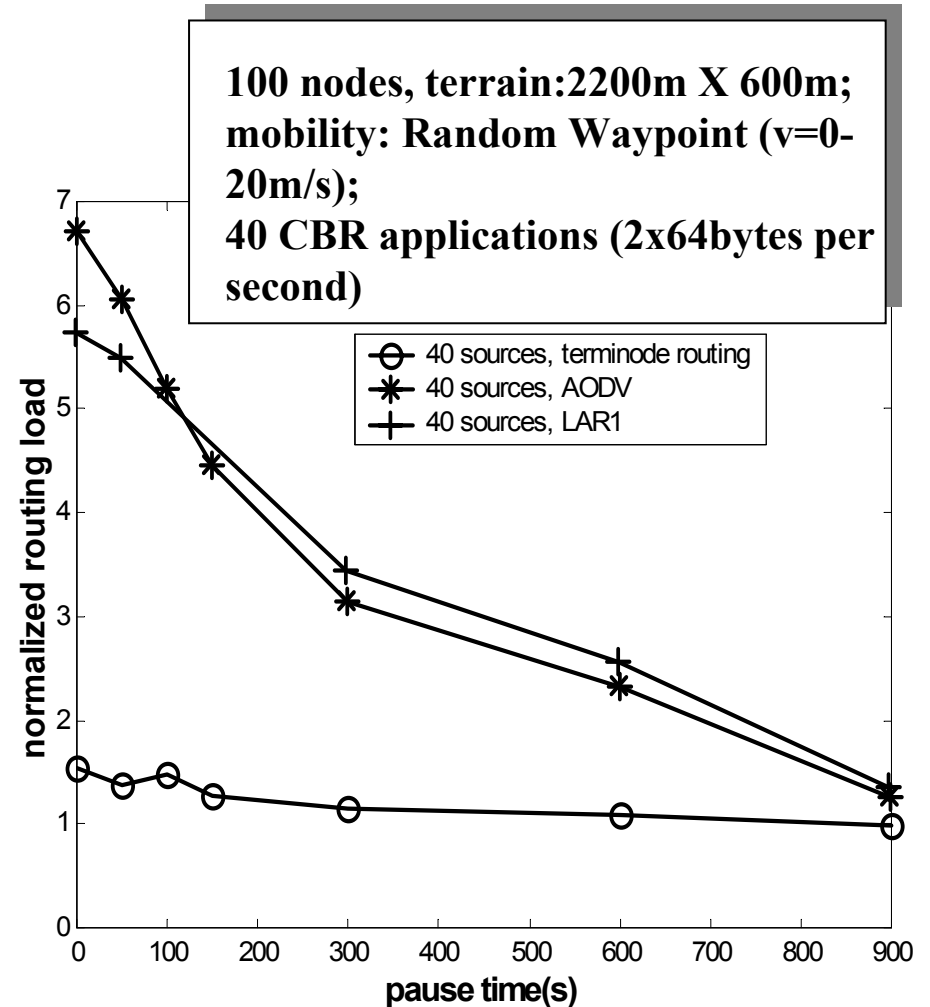
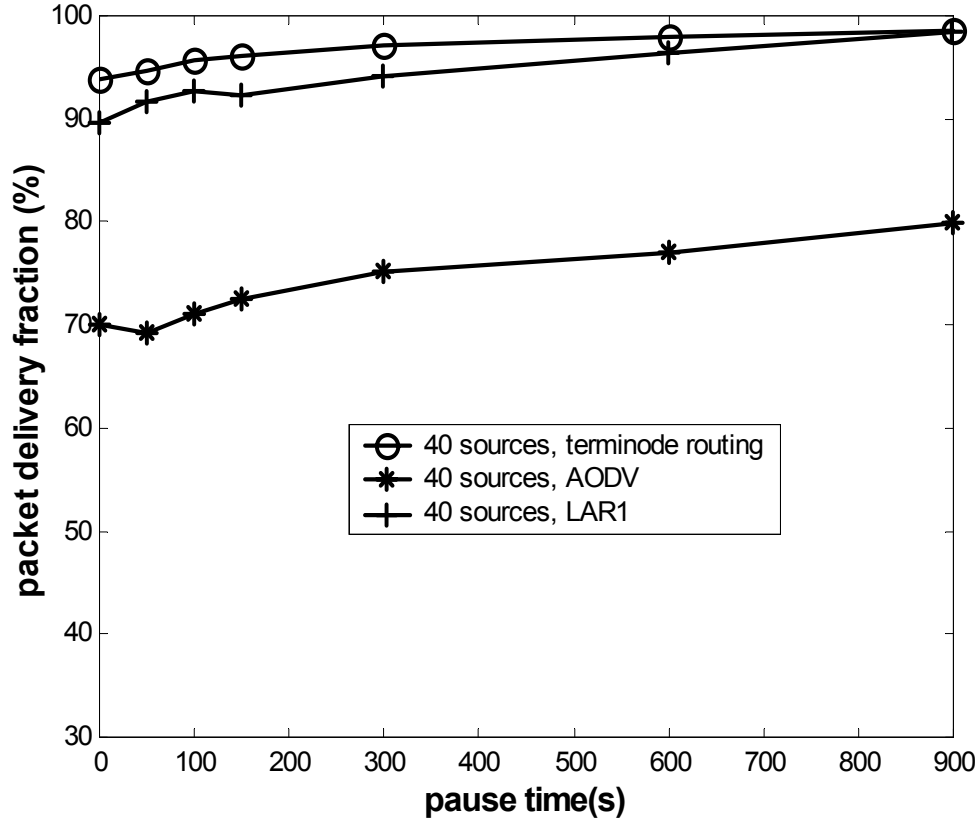
- Simulations were performed in GloMoSim:
 - IEEE 802.11 MAC protocol is used; nominal radio range is 250 meters and 2Mbps data rate (model of the Lucent WaveLAN card)
 - Piggypacking implemented (promiscuous use of network interface)
 - HELLO messages sent every 1 s (if no data is to be sent); TLR routing 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

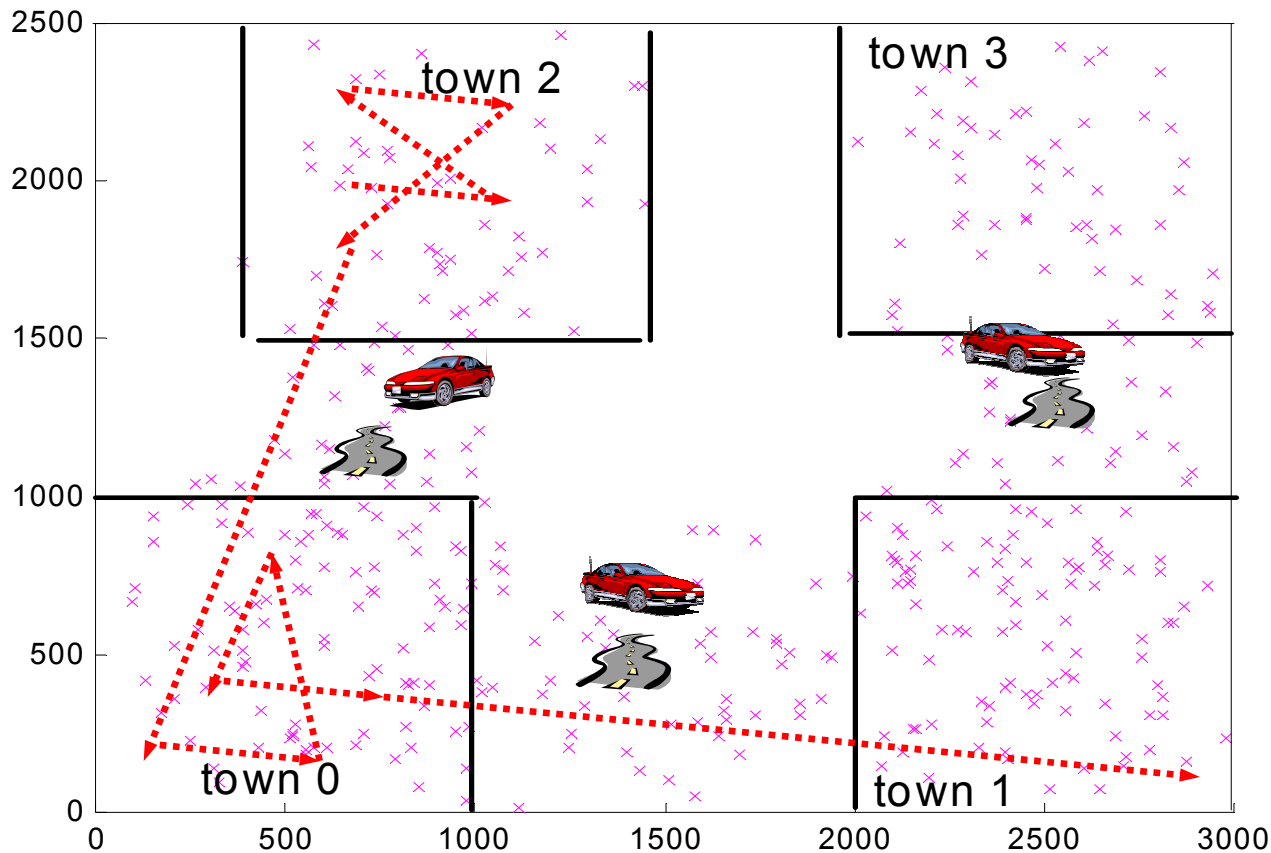
In small networks TR better than MANET

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



Large Network, Non-Uniform node distribution

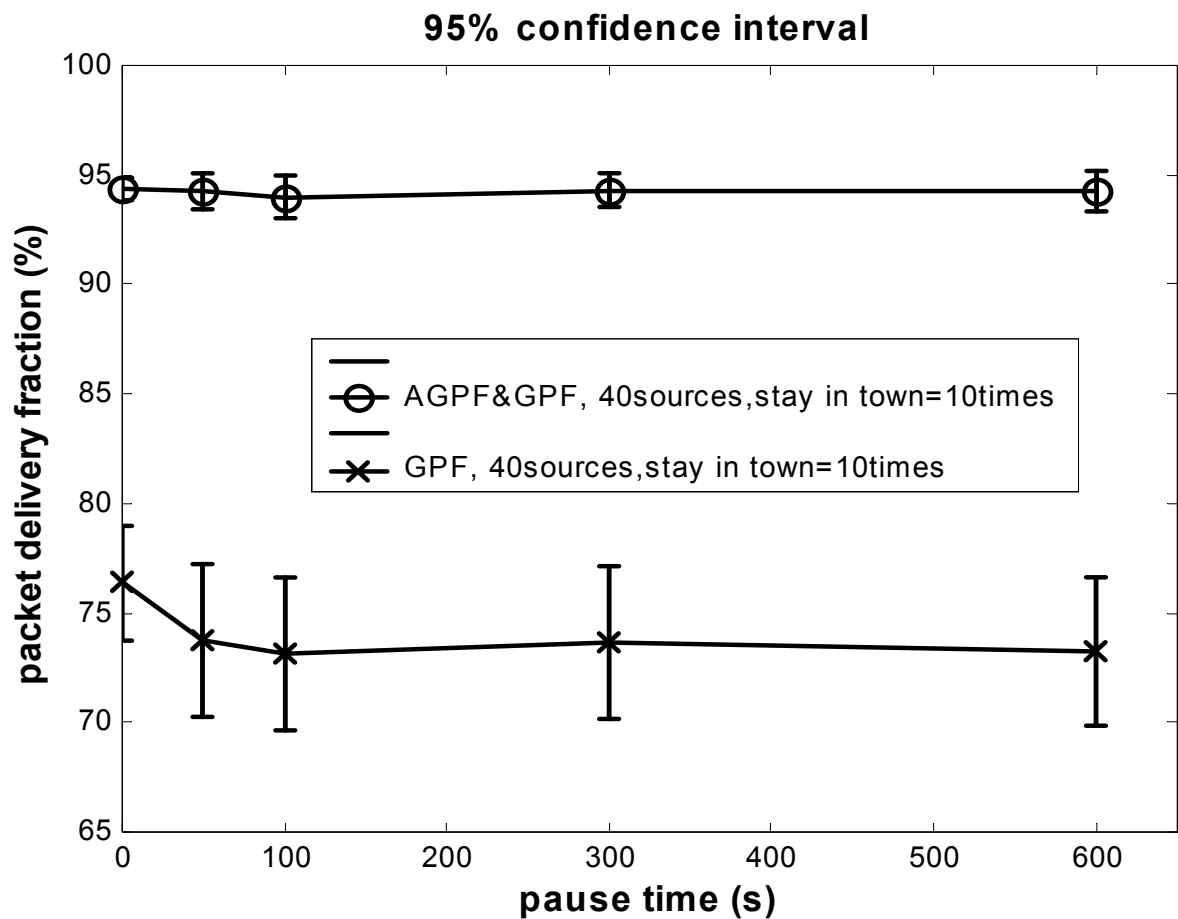
- We designed new mobility model referred to as *restricted random waypoint* that is close to real life
- Nodes move in the same town area by random waypoint model, before moving to a different town
- *stay_in_town* parameter defines locality of movements within a town



Results for different levels of mobility while movements are localized

stay_in_town=10

500 nodes,
mobility: Restricted Random
Waypoint ($v=0-20\text{m/s}$)
40 CBR applications
($2 \times 64\text{bytes per second}$)
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