Scalable Routing Protocols for Mobile Ad Hoc Networks

Dealing with mobility and scalability

Main problems:

1. moving nodes
2. large number of nodes
3. limited communication resources

Main topics:

1. Flat routing protocols
2. Hierarchical routing protocols
3. Geographic position assisted routing protocols

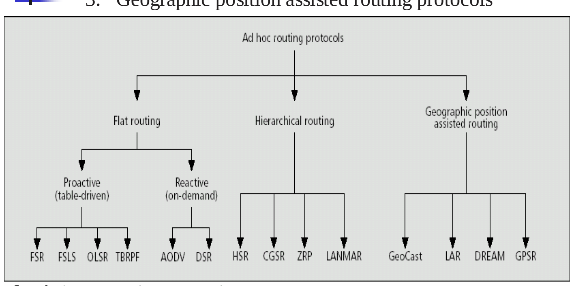


Figure 1. *Classification of ad hoc routing protocols.*

Flat routing protocols

Two basic categories

- Proactive (table-driven)
- Reactive (on-demand)

Proactive protocols

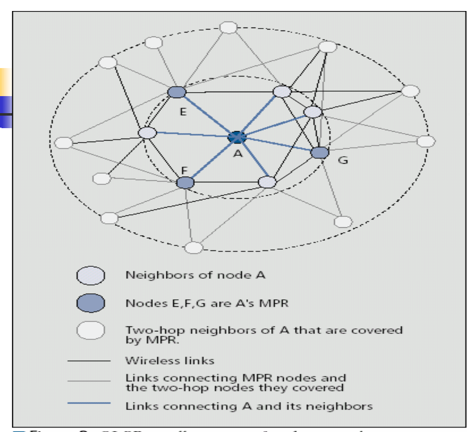
- FSR (Fisheye State Routing)
- FSLS* (Fuzzy Sighted Link State)
- OLSR (Optimized Link State Routing)
- TBRPF (Topology Broadcast Based on Reverse Path Forwarding)

FSR

- A simple, efficient LS type routing protocol
- FSR exchanges the entire link state information only with neighbors
- Link state exchange is periodical
- Periodical broadcasts of LS info are conducted in different frequencies depending on the hop distances

OLSR

- OLSR uses *multipoint relays* to reduce superfluous broadcast packet retransmission and also the size of the LS packets
- OLSR thus leads to efficient flooding of control messages in the network



■ Figure 2. *OLSR: an illustration of multipoint relays.*

OLSR (cont'd)

- Only the *multipoint relays* nodes (MPRs) need to forward LS updates
- OLSR is particularly suited for dense networks
- In sparse networks, every neighbor becomes a multipoint relay, then OLSR reduces to pure LS protocol

TBRPF

- Consists of two modules: the neighbor discovery module (TND) and the routing module
- TND send differential HELLO messages that reports *only* the changes of neighbors.
- The routing module operates based on partial topology information

TBRPF (cont'd)

- TBRPF only propagates LS updates in the *reverse direction* on the *spanning tree* formed by the minimum-hop paths.
- Only the links that will result in changes to the source tree are included in the updates

On-demand Routing Protocols

- AODV (Ad Hoc On-demand Distance Vector routing)
- DSR (Dynamic Source Routing)

AODV

- Using *backward learning* : On receiving a query, the transit nodes “learn” the path to the source and enter the route in the forwarding table
- The query packet is dropped if it encounters a node which already has a route to the destination

AODV (cont’d)

- A link failure will trigger a query-response procedure in order to find a new route

DSR

- *Source routing* : A source indicates in a data packet’s header the sequence of intermediate nodes on the routing path
- DSR also takes advantage of existing route information at immediate nodes to save route search overhead

Comparisons of Flat Routing Protocol

	FSR	OLSR	TBRPF	AODV	DSR
Routing philosophy	Proactive	Proactive	Proactive	On-demand	On-demand
Routing metric	Shortest path	Shortest path	Shortest path	Shortest path	Shortest path
Frequency of updates	Periodically	Periodically	Periodically, as needed (link changes)	As needed (data traffic)	As needed (data traffic)
Use sequence numbers	Yes	Yes	Yes (HELLO)	Yes	No
Loop-free	Yes	Yes	Yes	Yes	Yes
Worst case exists	No	Yes (pure LS)	No	Yes (full flooding)	Yes (full flooding)
Multiple paths	Yes	No	No	No	Yes
Storage complexity	$O(N)$	$O(N)$	$O(N)$	$O(e)$	$O(e)$
Comm. complexity	$O(N)$	$O(N)$	$O(N)$	$O(2N)$	$O(2N)$

Table 1. *Characteristics of flat routing protocols.*

Main topics:

1. Flat routing protocols
2. Hierarchical routing protocols
3. Geographic position assisted routing protocols

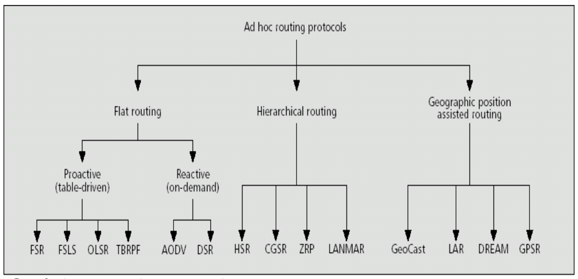


Figure 1. *Classification of ad hoc routing protocols.*

Hierarchical Routing Protocols

- When the network size increases, the "flat" routing schemes become infeasible
- Hierarchical routing is based on "organizing nodes in groups and assigning nodes different functionalities inside and outside a group"

Hierarchical Routing Protocols

- CGSR (Clusterhead-Gateway Switch Routing)
- HSR (Hierarchical State Routing)
- ZRP (Zone Routing Protocol)
- LANMAR (Landmark Ad Hoc Routing Protocol)

CGSR

- Partition the whole network into clusters
- A *clusterhead* is elected in each cluster
- A node belonging to two clusters is a called a *gateway*

CGSR (cont'd)

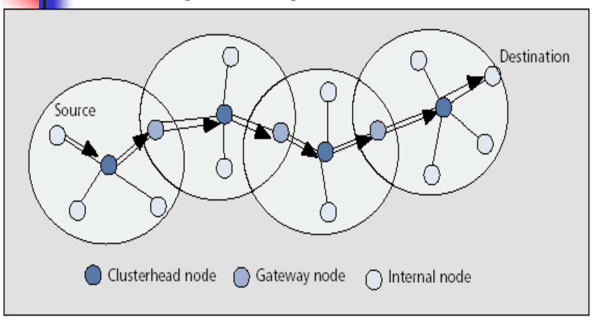


Figure 3. *CGSR routing: showing a data path from source to destination.*

CGSR (cont'd)

- It uses the distance vector routing algorithm
- At each node two tables are maintained: a cluster member table and a DV routing table
- The cluster member table records the clusterhead for each node and is broadcast periodically

CGSR (cont'd)

- The routing table only maintains one entry for each cluster recording the path to its cluster head
- CGSR can significantly reduce the routing table size compared to DV protocols

HSR

- It is a multilevel clustering-based LS routing protocol
- Same as CGSR, there are three kinds of nodes: clusterheads, gateways, and internal nodes
- As it is multilevel, new cluster heads are elected at each level and become members of the higher-level cluster

HSR

- HSR uses hierarchical addresses
- Think of identifying a soldier in the army: <division #, battalion #, company #, platoon #, squad #, name>

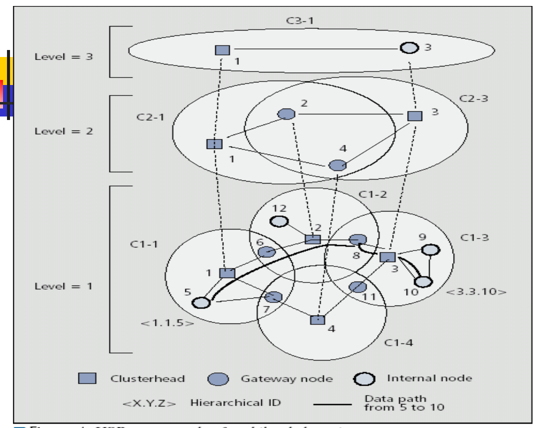


Figure 4. *HSR: an example of multilevel clustering.*

ZRP

- A hybrid routing protocol that combines both proactive and on-demand routing strategies
- Each node has a predefined zone
- Inside zones: proactive routing
- Outside zones: on-demand routing
- ZRP provides more flexibility

LANMAR

- Similar to ZRP, the whole network is partitioned into groups
- Each group has a predetermined *landmark* which keeps track of the group
- It is very suitable for the situation that nodes are likely to move in groups

Comparisons of Hierarchical Routing Protocols

	CGSR	HSR	ZRP	LANMAR
Hierarchy	Explicit two levels	Explicit multiple levels	Implicit two levels	Implicit two levels
Routing philosophy	Proactive, distance vector	Proactive, link state	Hybrid, DV and LS	Proactive, DV and LS
Loop-free	Yes	Yes	Yes	Yes
Routing metric	Via critical nodes	Via critical nodes	Local shortest path	Local shortest path
Critical nodes	Yes (clusterhead)	Yes (clusterhead)	No	Yes (landmark)
Storage complexity	$O(N/M)$	$O(M*H)$	$O(L) + O(e)$	$O(L) + O(G)$
Comm. complexity	$O(N)$	$O(M*H)$	$O(N)$	$O(N)$

Table 2. *Characteristics of hierarchical routing protocols.*

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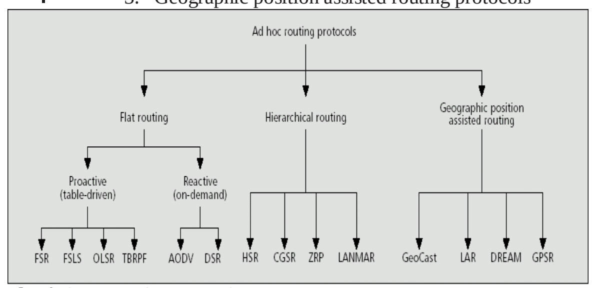

Figure 1. *Classification of ad hoc routing protocols.*

Geographic Position Information Assisted Routing

- LAR (Location-Aided Routing)
- DREAM (Distance Routing Effect Algorithm for Mobility)
- GPSR (Greedy Perimeter Stateless Routing)

GeoCast

- It uses specific geographic information to specify the destination, rather than logical node address
- A special computer host is in charge of receiving and sending geographic messages (GeoHost)
- GeoHost is responsible for forwarding the packets to local GeoRouter

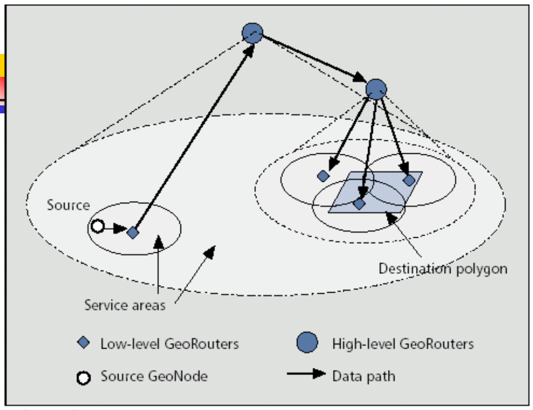

Figure 5. *An example of GeoCast.*

LAR

- LAR utilizes location information to limit the area for discovering a new route to a smaller *requested zone*
- The operation is similar to DSR : LAR performs the route discovery through *limited flooding*

LAR (cont'd)

Determine the requested zone

Scheme1

- estimate a circular area in which the destination is expected to be found
- During the route request flood, only nodes inside the request zone forward the request message

LAR (cont'd)

Scheme 2

- Calculate the distance to the destination
- The distance is included in a route request message
- A node relays a request message only if its distance to the destination is less than or equal to the distance included in the request message
- The distance field is updated before relaying the request

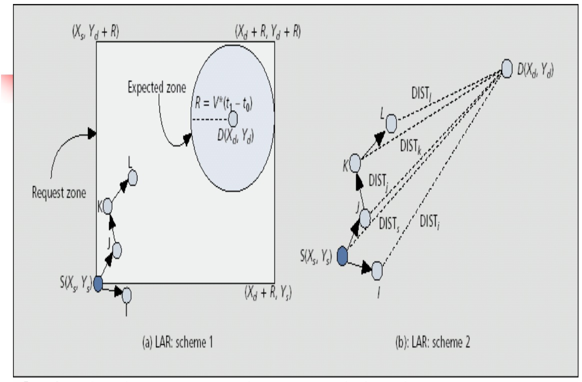

Figure 6. *LAR: limited flooding of route request: a) scheme 1: expected zone; b) scheme 2: closer distances.*

DREAM

- It is a proactive routing protocol using location information
- It minimizes the routing overhead by using two principles

DREAM (cont'd)

Two Principles

- distance effect : the greater the distance separating two nodes, the slower they appear to be moving w.r.t each other
- mobility rate : the faster a node moves, the more frequently it needs to advertise its new location

DREAM (cont'd)

- Each node maintains a location table, which records locations of all the nodes
- More frequently are the control packets sent to closer nodes
- The frequency of sending the control packets is adjusted based on its moving speed

GPSR

- It is a routing protocol that uses only neighbor location information in forwarding data packets
- It uses two data forwarding schemes : *greedy forwarding* and *perimeter forwarding*

	GeoCast	LAR	DREAM	GPSR
Support location propagation	Yes	Yes	Yes	No
Data forwarding by location	Yes	No	Yes	Yes
Routing philosophy	Proactive	On-demand	Proactive	Proactive (beacons only)
Sensitive to mobility	No	Yes	No	No
Routing metric	Shortest path	Shortest path	Shortest path	Closest distance
Loop-free	Yes	Yes	Yes	No
Worst case exists	No	Yes (full flooding)	No	Yes (loops and longer paths)
Multiple receivers	Yes	No	No	No
Storage complexity	$O(N)$	$O(N)$	$O(N)$	$O(M)$
Comm. complexity	$O(N)$	$O(e)$	$O(N)$	$O(M)$

Table 3. *Characteristics of GPS assisted routing.*