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Coupling of Geographic Location-based Service and Routing for Wireless Sensor Networks

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Abstract: *Geographic Routing Protocols use location information when they need to route packets. Obviously, location information is maintained by Location-based Services provided by network nodes in a distributed way. Routing and location services are very related but are used separately. Therefore, the overhead of the location-based service is not considered when we evaluate the geographic routing overhead. Our aim is to combine routing protocols with location-based services in order to reduce communication establishment latency and routing overhead. To reduce the location overhead, we propose a combination of GPSR (Greedy Perimeter Stateless Routing) and Location-based Services (Grid and Hierarchical Location Services (GLS/HLS)). GPSR takes care of routing packets and GLS or HLS are called to get destination position when the target's node position is unknown or is not fresh enough. In order to implement this concept, we have proposed a patch over the NS-2 simulator which mixes GPSR, GLS and HLS according to our proposal. We have undertaken a set of experimentations and we have considered two performance criteria, the location overhead (number of sent location requests and the consumed location bandwidth) and the network performances (i.e., the packet delivery ratio and the average latency).*

Keywords: *WSN, Geographic Routing Protocols, Location-based services.*

1. Introduction

WSNs (Wireless Sensor Networks) are a special case of MANETs (Mobile Ad-hoc Networks). Usual topology based routing protocols have limited performances in such networks due to the high network dynamics. Geographic routing protocols were designed to provide better performances for such networks. Each node has to care about its actual geographic position and the position of the targeted node to reach. The paradigm position-to-position is used. The Location-based Services is required to catch the destination position. The combination of this service with routing is quite natural in order to ensure better performances. When a sender needs to send a packet to a destination, the sender looks for the destination position in its records. If it is fresh enough, the packet is then sent immediately. If not, the sender sends an HLS or GLS request in order to get the actual destination position. When this later is received, the packet is then sent.

For this purpose, we have proposed a patch over the NS-2 simulator which mixes GPRS, GLS and HLS according to our proposal. We have undertaken a set of experimentations and we have considered two performance criteria, the location overhead (number of sent location requests and the consumed location bandwidth) and the network performances (i.e., the packet delivery ratio and the average latency)..

The paper is organized as follows. Section II is dedicated to related works. Section III details our combination algorithm about GPRS, GLS and HLS. Section IV talks about our experimentations and the obtained results. Finally, section V concludes the study.

2. Related Works

2.1. Geographic Routing Protocols

Routing protocols algorithms must choose some criteria to make routing decisions, for instance the number of hops, latency, transmission power, bandwidth, etc. The Topology-based Routing Protocols suffer from heavy discovery and maintenance phases, which lead to scalability problems. This is due to the high mobility, which generates frequent topology changes and short links. This is why Geographic Routing Protocols are suitable for large scale wireless sensor networks.

The first routing protocol using the geographic information is the Location-Aided Routing (LAR) [1].The LAR [1] is a reactive routing protocol that uses the geographic information in the route discovery, to limit the propagation of route request packets RREQs to the geographic region where it is most probable the destination is located. The route discovery is initiated in a Request Zone. If the request doesn't succeed, it initiates another request with a larger Request Zone and the decision is made on a routing table.

The first real geographic routing protocol is the Greedy Perimeter Stateless Routing (GPSR) [2]. It is a reactive and efficient routing protocol designed and adapted for mobile ad hoc networks and sensor networks. It forwards the packet to the target's nearest neighbor (Greedy Forwarding approach) until reaching the destination. Therefore, it scales better than the topology based protocols, because it uses the geographical position of the nodes for routing packets.

Another geographic routing protocol is the Distance Routing Effect Algorithm for Mobility (DREAM) [3].DREAM is a proactive routing protocol where each node maintains a location table that contains the geographical coordinates of all the destinations obtained by a positioning system such as GPS[4]. The use of this location information allows calculating the direction of each destination and the distance to each. Each node broadcast packets containing its current position within the network, the frequency of the broadcast is determined by considering:

- *Distance effect:* More important is the distance between two nodes, slower they move relative to each other. Therefore, remote nodes share their location information with each other less frequently than close nodes.
- *Node mobility rate:* A node with a high mobility must frequently inform the other nodes of its location and vice versa [5].

To forward a packet, a node looks up the location of the destination in its local location table, and forwards the packet to all its neighbors in the direction of the destination. DREAM can deliver exponentially many copies of a packet to the destination, which ensures better reliability.

We have used the Greedy Perimeter Stateless Routing (GPSR) as the geographic routing protocol for the combination.

2.2. Location-based Services

Geographic Routing Protocols use location information when they need to route packets. Obviously, location information is maintained by Location-based Services provided by network nodes in a distributed way. Routing and location services are very related but are considered separately in the literature. The Location-based Services (in the context of WSNs) is a distributed service without infrastructure in general. It has to answer to a location query such as: "Where is the node X?".

There are mainly two types of Location services according to Fig. 1: Flooding-based and Rendez-vous-based location services. An example of flooding-based location services is Reactive Location Service (RLS) [6].

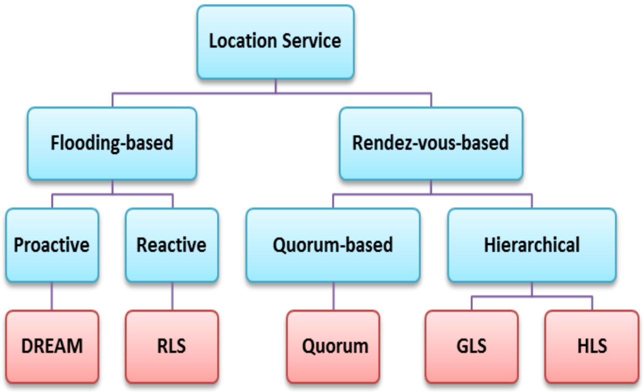

Figure 1. Location based-service Taxonomy

In this service, every node foods its location request through the whole network. Once this request has reached a node with information, it responds directly. The location response is sent after receiving a location request.

The two major Hierarchical Rendez-vous-based location services are, the Grid Location Service (GLS) [7] and the hierarchical location services (HLS) [8]. The network is divided into several levels. At each level, a node recruits location servers. The location query is forwarded up and down in the hierarchy. This limits the number of forwarded packets and avoids flooding.

Nodes in Hierarchical Location Services must elect location servers in different levels to keep updating their positions with those servers. When another node needs this position, it sends a request to those servers which reply with a location response packet indicating location information received from the last update.

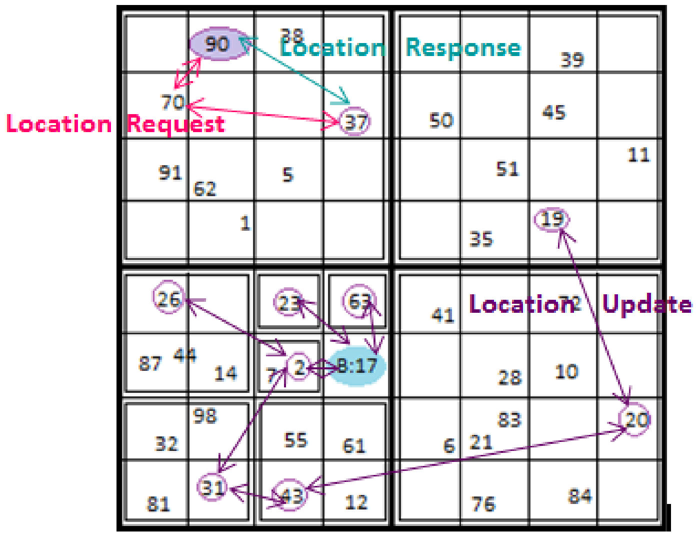

Figure 2. GLS Network Partition

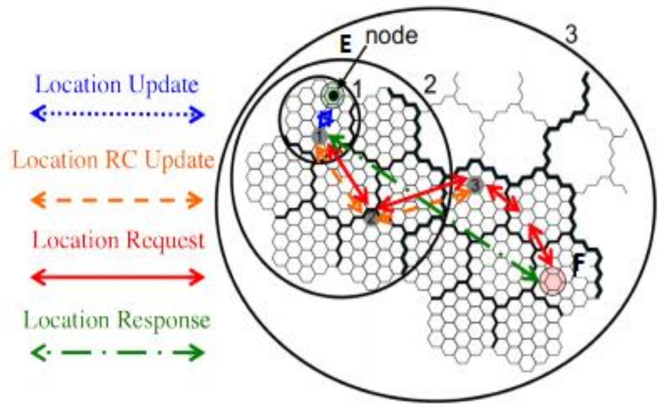

Figure 3. HLS Network Partition

In GLS "Fig. 2", each node sends a periodic update of its position to all location servers at all levels. While in HLS "Fig. 3", to update its location information, a node frequently sends packets to the responsible cell (the cell where a node must select its location servers) at the first level and only the level i responsible cell's location is sent to the level i+1 region.

3. GPSR and Location-based services combination

3.1. Description

GPSR takes care of routing packets and GLS or HLS are called to get destination position when the target node position is unknown or is not fresh enough. When a destination is quite far away from the sender, the exact position of the target is first calculated.

The GLS and HLS location algorithm is presented in the Fig. 4. In GLS and HLS if a node needs to send a packet to another node, it looks for its position. If it has a fresh location, it uses it to send data until reaching the destination. Otherwise, it sends a location request to catch the new position. After receiving the response, it begins sending data.

3.2. Algorithm

The function Location (Algo. 1) handles the destination position queries; it looks into the local cache memory of the current node and updates the packet information with the destination position.

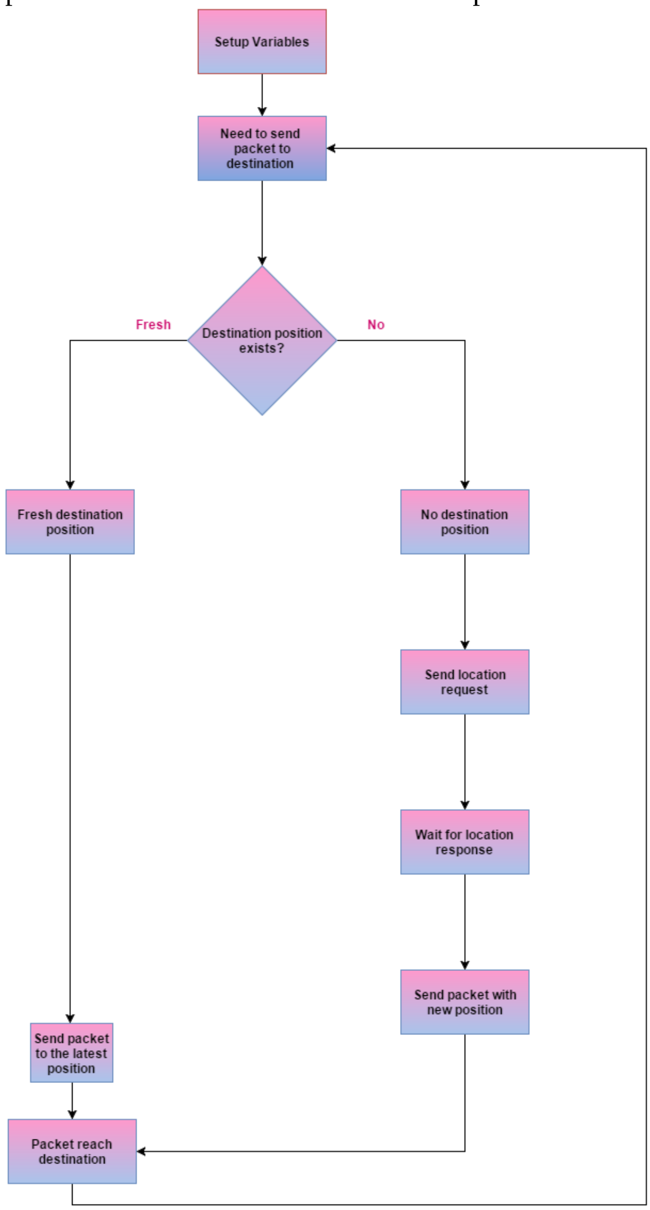

Figure 4. Schematic presentation of Routing and Grid/Hierarchical Location based Combination Algorithms

Algorithm 1 GLS or HLS :: Location

```
cacheThreshold ← LocationCacheMaxAge ;
procedure LOCATION(packetToSend)
if (Destination Location age < cacheThreshold) then
PreparePacket (packetToSend);
ChooseNextBestHop(packetToSend);
ForwardPacket(packetToSend);
else
LaunchPositionQuery(destination);
StickToBuffer(packetToSend);
end if
end procedure
```

4. Simulations

4.1. Working Environment for Experimentations

The simulations were performed using the NS-2 Simulator 2.35[8].The geographic routing protocol used is Greedy Perimeter Stateless Routing (GPSR)[2] .The selected area is a 2*2km2 The topology is shown on Fig. 5.The Media Access Control (MAC) layer used is the IEEE 802.11p.The simulation is run 10 times and the results are averaged for more accuracy. The parameters used in the simulations in NS-2 are summarized in Table 1.

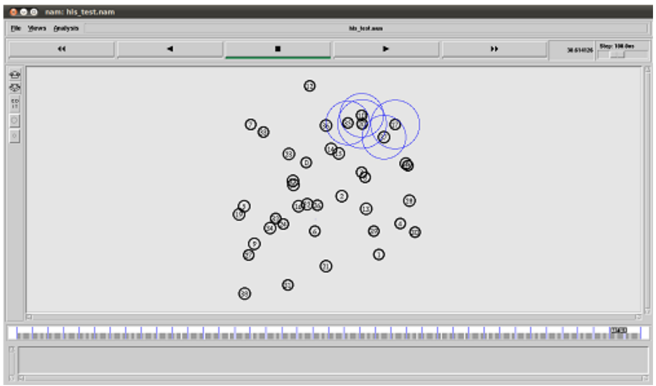

Figure 5. Network Topology

4.2. Experimentation results

Our experimentations have provided the following figures. On each figure, we show the network behavior with HLS and GLS.

Four criteria have been considered during the simulation process:

- Location statistics: This includes all the statistics we were able to extract from the simulations concerning the location such as the location cache access, the cache average age, the number of sent requests and sent updates (Figures 6–9).
- Location and routing overhead: The overhead is represented as the location bandwidth consumed within the MAC layer in order to send location updates, forward the location requests and replies by location responses (Figure 10). Besides, we represent the routing overhead such as the bandwidth consumed for routing (Figure 11).
- Routing efficiency: The routing efficiency is evaluated by the Packet Delivery Ratio (PDR) depicted by Figure 12, which is defined as the ratio between the CBR packets received from all the CBR packets sent, and the average CBR packets latency represented by Figure 13. The CBR packets Latency is evaluated as the difference between the arrival time of the CBR packet to the destination and the time when the packet is sent from the source.

Table 1. Simulation Parameters.

Parameters	Value
Channel type	Channel/WirelessChannel
Propagation model	Propagation/TwoRayGround
Network interface	Phy/WirelessPhyExt
MAC layer	802.11p
Interface queue type	Queue/DropTail/PriQueue
Link layer	LL
Antenna model	Antenna/OmniAntenna
Interface queue length	512 packets
Ad-hoc routing protocol	GPSR
Location-based service	GLS or HLS
Location cache maximum age	4,8,12,16 and 22s
Number of nodes	100
Area	2*2 km2
Simulation time	150s
GPSR beacon interval	0.5s
CBR traffic	4*20 packets/node
CBR packet size	128 B
CBR send interval	1 s

4.2.1. Location statistics results

Fig. 6 shows the number of access operations to the location cache memory. It confirms that the HLS approach uses aggressive location cache policy compared to the GLS. HLS uses more of cache lookups than GLS in average. As a direct consequence, the average age of the location cache entries used increases greatly while comparing the GLS to the HLS scheme, which is depicted by Figure 7. From all simulation results, we have noticed that the average age increases from 0.17 s in GLS to 1.4 s in HLS.

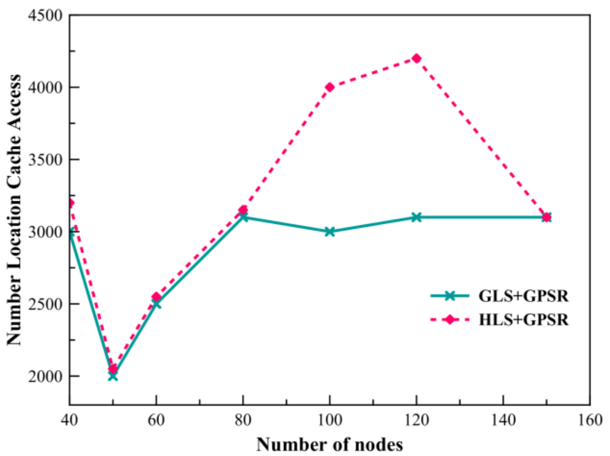

Figure 6. Location statistics results: location cache lookups access

In addition to the cache entries used, GLS decreases heavily the number of the sent requests as shown in Figure 8. In average, there are less than a half of location requests in GLS than in HLS. Therefore, there are less requests launched and forwarded.

Another result, less predictable, is the decline of the location updates number in HLS compared to the GLS Figure 9. In fact, the HLS scheme focuses on reducing requests launched before routing packets. However, Figure 9 reveals that this mechanism also reduces sent location updates particularly when the number of nodes increases.

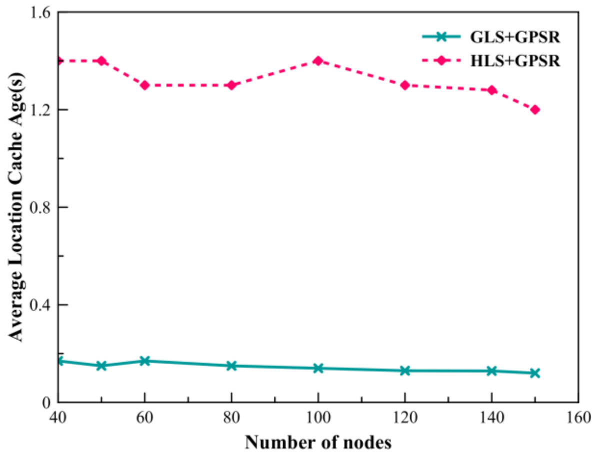

Figure 7. Location statistics results: location cache average age.

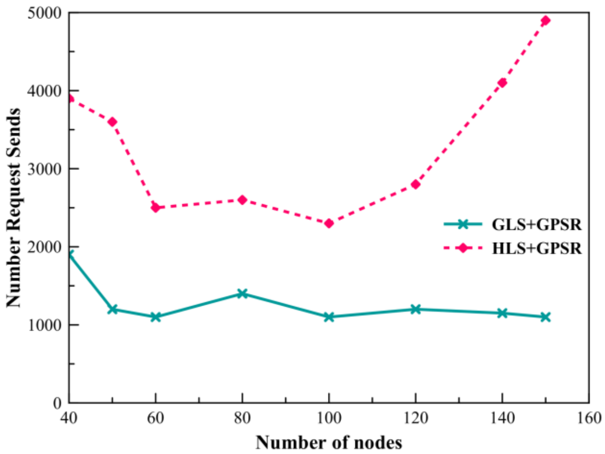

Figure 8. Location statistics results: number of sent location requests.

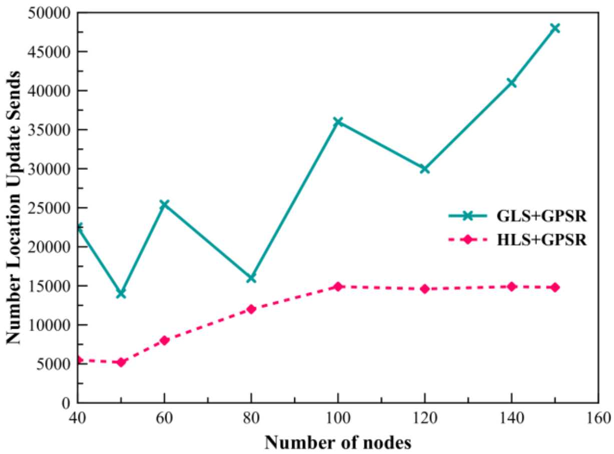

Figure 9. Location statistics results: number of sent location updates.

4.2.2. Location and routing overhead results

As location requests and location updates decrease, the location bandwidth consumed in the MAC and routing layers is reduced in the HLS scheme compared to the GLS one. Figures 10 and 11 show that the location-based service that consumes more bandwidth is GLS, followed by HLS in average.

4.2.3. Routing Efficiency Results

The location-based service is considered as a support to the geographic routing protocol (GPSR here). Making routing decisions depends directly on location information maintained by the location-based service. Therefore, monitoring routing performances is as important as localization performances. Figure 12 illustrates the PDR of CBR packets. The PDR in HLS is higher compared to GLS. It increased by about 15% in HLS against GLS. These increases are highly significant given that the PDR is generally above the 80%. The only exception is when the number of nodes raises due to the network congestion.

The second routing parameter depicted by Figure 13 is the average latency. The average latency is minimal for HLS. Although, it is maximal for GLS. On average, the latency decreases by a factor higher than two times from 3.2 s in GLS to 1.88 s in HLS.

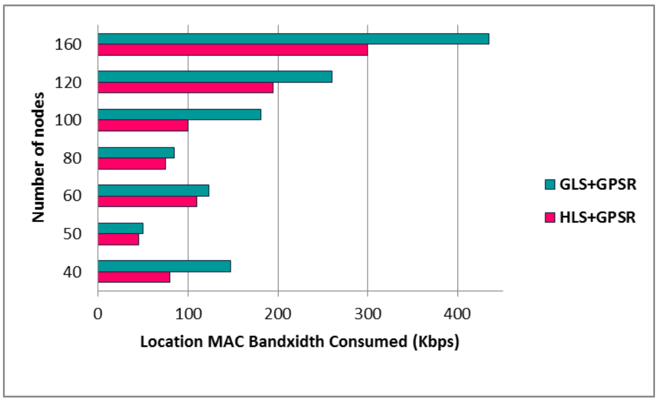

Figure 10. Location overhead results: Location MAC Bandwidth Consumed.

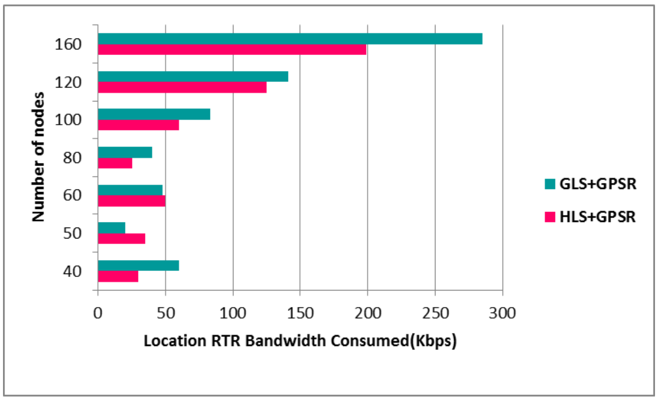

Figure 11. Location overhead results: location RTR Bandwidth Consumed

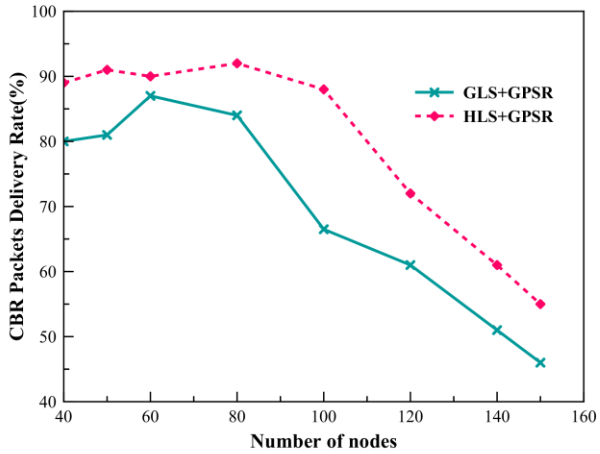

Figure 12. Routing efficiency results: CBR packet delivery ratio.

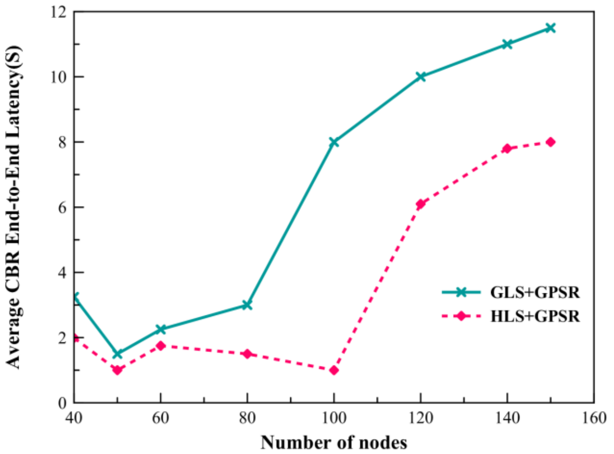

Figure 13. Routing efficiency results: average CBR packets latency.

As a conclusion about these results, we can notice that the HLS scheme reduces the location overhead (requests, updates, bandwidths, etc.) and increase the routing performances (PDR and Latency).

5. Conclusion

In this paper, we have investigated the combination between location based services with geographic routing. This combination reduces the location overhead while improving the routing performance. The hierarchical mechanisms are more suitable for WSNs with high mobility and frequent topology changes as this mobility has to be monitored in order to guarantee high performance. So, we have decided to base our solution on these mechanisms namely GLS and HLS.

In the proposed combined approach, when a packet needs to be sent, the fresh position will be used to route the packets, so the number of location requests will be reduced before sending a packet.

We implemented this combined solution in the NS-2 framework within a patch. We have conducted many experimentations with this patch in order to observe network performances. We have shown in this paper that a smart combination of GPSR with Location-based services (GLS and HLS) could provide better results in terms of network performances in particular for the packet delivery rate, the latency and the overhead. Another interesting result of the simulation study is that the HLS scheme is by far the favorite against GLS one.

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