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Network Routing Issues in Global Geographic Information System

Ibrahim Ahmed Alameri[1,2,*], and *Jitka Komarkova*[1]

[1]University of Pardubice, Faculty of Economics and Administration, Institute of System Engineering and Informatics, Studentská 84, 532 10 Pardubice, Czech Republic
[2]Jaber ibn Hayyan Medical University, Kufa, 54001 Najaf, Iraq

Abstract.

Research background: A geographic information system (GIS) is a computer-based information system that gathers, manages, and disseminates different geographic (related to earth) information to provide intelligent analytics necessary for prompt decisions and actions. A GIS can aggregate data from several different streams and turn it into a smart dashboard for different users to enhance productivity. The use of intelligent technologies, remote sensing, and ad-hoc wireless networks has significantly improved GIS. In GIS, utilization of sensed data from different sources depends upon the use of efficient sensing equipment, smart mobile nodes, and network gateways and relays that can efficiently route traffic towards the sink or base station. GIS achieve attention in emergency response scenarios for their capability to collect, analyze, and process spatial-referred.
Purpose of the article: Article is focused on studying and identifying suitable routing issues of wireless mobile nodes, which are the main transponders for smooth and errorless data transmission.
Methods: We performed a simulation-based comparative study of three different routing protocols used in ad-hoc wireless networks, namely is to identify suitable routing protocols that can aid the GIS to improve its overall performance. We calculated and compared our results with different routing protocols. We were able, with the Random mobility model, to estimate the performance of various network parameters.
Findings & Value added: We proposed a study in this work that includes geo-information services overall of routing protocols to support a team in stressful situations. The study shows that the AODV routing protocol performed better than the other two routing protocols (OLSR & TORA) under the given topology.

Keywords: *GIS; MANET; FSR; ICT; UAV*

JEL Classification: *L86; L63; L96*

* Corresponding author: ib.alameri@jmu.edu.iq

1 Introduction

Our world is dynamic in nature. There are myriad of processes or phenomena that change constantly [1]. Scientists try to study the behaviour of such dynamic processes to make predictions. They use different tools and apparatus to achieve this goal. Geographic Information System (GIS) is one such tool which transform geographic data, through analysis, into meaningful and useful information. This meaningful information is used to solve many real-world problems [2]. In Table 1 we presented different domains where geographic information system is applied to solve various challenges.

Information or data comes in many different forms or shapes, geographic information system deals with spatial or geographic data. Spatial data refers to positional data, it defines where an object is, or perhaps it was or will be in the future [3]. GIS is a tool which is applied by re-searchers and practitioners to make analytics, exploration or decisions [4]. GIS can be defined as a computer-based system that provides following four set of capabilities to handle geographic data numbers [5].

1. Data acquisition and transmission.
2. Data management (including storage & maintenance).
3. Data manipulation and analysis.
4. Data presentation.

Data acquisition and transmission is the first and foremost important step in building a good geographic information system. Advancements in remote sensing and Information Communication Technologies (ICT) tremendously increased the proliferation of GIS in industries, government organizations and research sectors. Sensor is a basically a transducer that converts some physical phenomenon into electrical signal like temperature or humidity sensor, Force Sensitive Resister (FSR), etc.

Generally, in remote sensing, sensors sense an object or environment by analysing the reflected or emitted radiations from satellites, Unmanned Aerial Vehicles (UAV) or flying drones, mobile nodes etc. Special cameras are mounted on mobile nodes (or UAVs) to collect data remotely and transfer sensed data to sink node (server or cloud). Safe transfer of sensed information is one big challenge in geographic information systems. In this regard, data routing plays a pivotal role for robust transmission of collected data to sink nodes. In geographic information system, sensor nodes create an adhoc network to successfully send collected data to sink or base station [6]. An adhoc network is a collection of mobile nodes created temporarily on the fly to achieve a particular goal. It lacks any physical infrastructure and central administration. In this context, the goal is to reliably transfer sensed information to sink nodes. In adhoc networks due to lack of central administration nodes can freely move due to which network topology may change unpredictably. Due to highly dynamic nature of adhoc networks, routing become a challenging problem. In literature there are different routing protocols are proposed for mobile adhoc networks. In this paper we will study and compare different routing protocols used in MANET.

The purpose of this paper is to come up to know which more routing protocols are suitable with GIS. The remaining paper is organized accordingly:

- In Section 2 and 3 we will present overview and introduction to GIS and MANET respectively.
- Section 4 outlines and describes the techniques for different types of routing protocols and shows why our research is driven.
- Section 5 presents the simulation methodology and parameters are that are used in our simulation for the network.
- Results and Discussion are illustrated in section 6, while the rest of the paper is concluded in section 7.

2 Overview of geographic information systems and their components

Geographic information always remains prime important to humans for exploration, discovery, navigation, planning etc. Literature shows us it has also contributed to the survivability of mankind [7]. Traditionally geographic information is used in routine tasks such as route discovery and navigation. However, it gives us more insights when combined with computer-based analysis tools. Rest of this section we will present component level details of geographic information system.

2.1 Components of GIS

A geographic information system consists of several components. Few core elements are shown in the Figure 1. In this section, we will discuss these components sequentially.

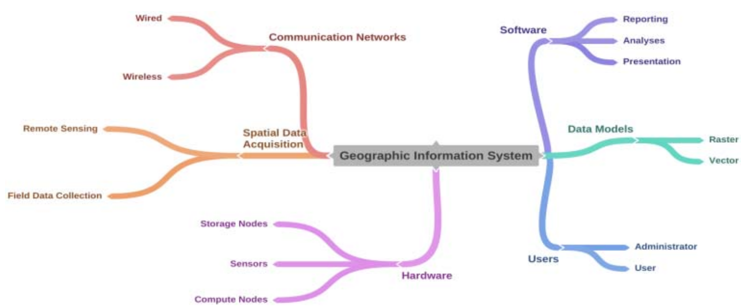

Fig. 1. Components of a GIS.

2.1.1 Spatial data acquisition

Spatial data acquisition techniques include remote sensing and field data collection. Primarily remote sensing techniques are used to gather data from deferent sources, however in some situations field data gathering technique is also practiced where remote sensing is not possible. Remote sensing techniques usually use Unmanned Aerial Vehicles (UAVs) or drones, satellite imaging, Wireless Mobile Networks etc to gather spatial data.

2.1.2 Hardware components

GIS hardware encompasses around data acquisition technologies, data processing and storage devices. Data acquisition technologies are briefly presented in the Section 2.1.1. Data processing equipment or ’compute nodes’ includes hardware that process spatial data and also execute GIS software. Storage nodes consists of different storage technologies that provide reliable and secure storage options. Compute nodes and storage nodes both can be deployed within premises or setup on the cloud [8].

2.1.3 Communication networks

Communication networks is basically the backbone of geographic information system. Without a reliable, efficient and secure communication facility GIS cannot operate as expected [9]. In GIS communication takes place in different phases as discussed below.

1. Data acquisition devices like UAVs, drones, mobile nodes capture / sense spatial data.

2. The capture or acquired data is transmitted to base station or sink nodes.
3. Base station or sink forward received data from deferent sources to next hop sink or central server. In some case sink is also responsible for data aggregation.
4. Central server processes raw data and store it into storage cluster.
5. Processed meaningful information is furnished to GIS users over the web via Internet or intranet.

2.1.4 Data models

Data model comprises of finite set of rules that govern, characterize and identify features of real objects [10]. These rules transform physical real objects into logical objects, where each spatial object is completely recognized by deferent attributes and geometric data. Geometric data is encoded by two modelling techniques, which are known as raster and vector models [11]. Raster models are made up of set of points also known as pixels (picture elements). These cells or pixels are defined on x,y grid which specify the value of the data. Raster models comprise of collection of points (also known as pixels) on a grid organized into rows and columns, where each cell represents some specific information about the object. Raster models are easier to build and process as compared to vector models. Collection of deferent cells constitute corresponding object. On the other hand, vectors models require more computational resources as compared to raster model. However, vector models generally have high resolution as compared to raster models and generate more smooth object boundaries [12]. It also takes less storage.

2.1.5 Software

A working GIS requires a software that convert raw spatial data into meaningful insights. GIS software should able to make maps and other graphical information that can help in analysis, making presentations, extract intelligence and decision making. It should provide a consistent interface for deferent users to collaborate and analyse data. Generally, web-based interface is provide for online collaboration for end users.

3 Introduction to mobile adhoc networks (MANET): features and challenges

As discussed in Section 2, the first step of geographic information system is data acquisition and transmission which is performed with the help of different sensors, cameras etc. These devices are mounted on mobile nodes which moves in deferent directions to collect GIS data. Mobile nodes transmit collected information wirelessly. This type of network which is formed with the help of mobile nodes is known as Mobile Adhoc Networks (MANET) [13, 14]. There are two fundamental categories of wireless networks which are infrastructure-based wireless networks and infrastructure-less or adhoc wireless networks. Adhoc networks is a type of networks which is constructed on the fly or dynamically with the help of mobile nodes. It does not require any planning and infrastructure setup requirements [15].

4 Routing protocols of mobile adhoc networks

MANET routing protocols are classified into three main categories i.e. reactive, proactive and hybrid [16]. These protocols make use of topology information from the nearby nodes to establish routing path that is why they are also known as topology-based routing protocols. Figure 2, shows different type of topology-based routing protocols.

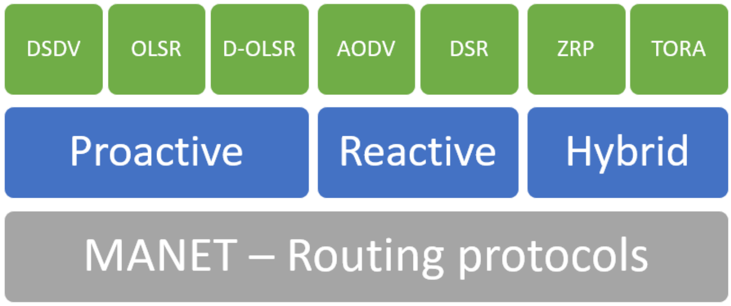

Fig. 2. MANET - Topology-based Routing Protocols.

4.1 Proactive routing protocols

Proactive routing protocols stores complete information about all fresh routes links in routing table, due to this they are called table driven routing protocols. These tables are exchanged among neighbouring nodes at each topology change and updated accordingly. Since every node has full ”map” of the network therefore route to any node in the network is readily available and shortest route can be found easily, reducing delivery delays. In order to keep routing paths up to date, nodes exchange a lot of routing messages that significantly adds network overhead and congestion. Therefore, it is not suitable to use proactive routing protocols if network topology changes frequently.

4.1.1 Optimized link state routing (OLSR) protocol

OLSR uses link state strategy to build routing table [17]. It uses hello and topology change packets periodically to keep routing tables up to date. OLSR has introduced the concept of MultiPoint Relay (MPR) node. MPR nodes cover up to two hop neighbours to create link state information and forward data packets to other MPR nodes. This technique reduces network overhead.

4.2 Reactive routing protocols

Reactive routing protocols are also known as ’on-demand’ routing protocols because they discover route as needed. These routing protocols do not build routing table in advance. Instead when a node request to transmit a packet to a particular destination, it starts route discovery process [18]. Since there is no pre-route discovery nor routing tables are populated in advance, this scheme mainly suffers due to high end-to-end delay, latency, etc., however reactive routing protocols does not add extra routing overheads.

4.2.1 Adhoc on demand distance vector (AODV) protocol

It is a combination routing protocol based on DSR and DSDV protocols [19]. It mimics hop by hop behaviour of DSR and periodic updates of DSDV protocol [20]. It first starts discovery process to draw routing path with least number of hops. This can minimize significantly the overhead and avoid network congestion. To keep built links updated, it sends updates with expiry timer.

4.3 Hybrid routing protocols

Hybrid routing protocols attempt to combine best features of proactive and reactive routing protocols. These protocols try to overcome the overhead limitation of proactive and high delay problems of reactive routing protocols. Hybrid routing protocols introduce the concepts of ’zones. Routing within same zone is achieved with the help of proactive routing protocols and inter-zone routing is performed with the help of reactive routing protocols.

4.3.1 Temporally ordered routing algorithm (TORA) protocol

TORA is a hybrid distributed routing protocol which is based on Directed Acyclic Graph (DAG). It is suitable for highly dynamic topology where frequent changes in the topology takes place. The goal of TORA is to reduce routing overhead that generally consumes too much load.

5 Simulation methodology

Simulation results will be presented in this section. However, before proceeding to simulation results, we will discuss simulation configuration and topology layout in this section. We used NS2, to perform simulation of GIS topology. We created 1000 m by 1000 m simulation space (also knows topology size). We placed 30 nodes which are mobile and can move in different directions to perform data acquisition. Mobile nodes communicate with base station which is planted at the centre. We selected one protocol from each protocol category discussed in Section 4. We studied OLSR (proactive), AODV (reactive) and TORA (hybrid) routing protocols. Some important simulation related parameters are discussed in Table 1.

Table 1. Simulation Parameters.

Simulation Parameter	Value
Area	1km x 1km
Duration	180 seconds
Traffic Generator	Constant Bit Rate (CBR)
Payload Size	512 bytes
Mobile nodes (n)	30
Movement Pattern	Random Way Point (RWP)

5.1 Studied parameters

Following parameters are considered to study and their impact and results are presented in this section.

5.1.1 Packet drop count (PDC)

Packet drop rate describes how many packets are dropped during the simulation. This studied parameter is very important to analyse the performance of a routing protocol. High packet drop count effects the Quality of Service (QoS) of the network. Packets are mainly dropped due to high congestion in the network. Due to high packet drop count, throughput of the network is also impacted. Figure 3, shows packet drop count of different routing protocols.

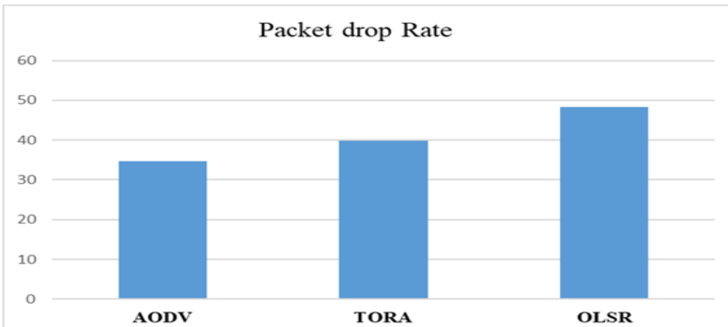

Fig. 3. Packet Drop Count.

5.1.2 Throughput

Throughput is one key parameter that can be measured with the help of Eq. 1. Throughput of the network shows the behaviour of the routing protocol. High throughput means good performance of the routing protocol. Throughput can be measured as" successfully packet delivery rate in terms of packets per seconds or bits transferred per seconds). Figure 4, shows throughput of the network under different routing protocols.

$$Throughput=(\varepsilon\ received\ packets\ size)/\ Time \quad (1)$$

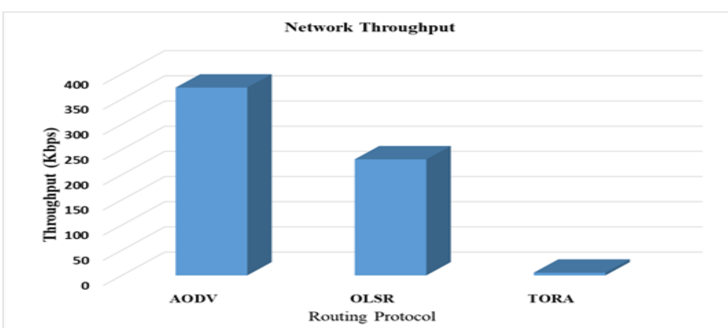

Fig. 4. Throughput.

5.1.3 Packet received ratio (PRR)

Packet received ratio shows how many packets are sent by the sender and out of which how many packets are received at the base station. It can be calculated by using Eq. 2. Table 2, shows packet received ratio for OLSR, AODV and TORA.

$$Packet\ Received\ Ratio = (No:\ of\ packets\ received)/(Total\ sent\ packets)*100 \quad (2)$$

Table 2: Packet Received Ratio in Percentage.

AODV	OLSR	TORA
32.14%	19.87%	0.47%

5.1.4 Average end to end delay

End-to-end delay is calculated by monitoring the initial time of the packet when it was sent by the sender till it reaches at the destination. Average end to end delay is calculated for all packets generated by the sender and received at the server or destination node. Average end to end delay is calculated for OLSR, AODV and TORA routing protocols and presented in the Figure 5.

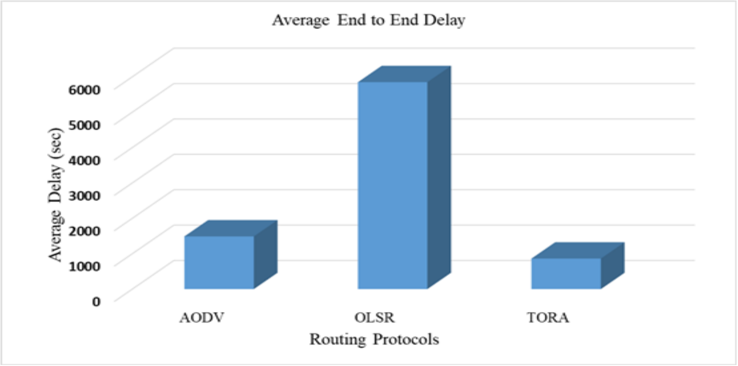

Fig. 5. End-End-delay.

6 Results and discussion

Simulation results show that the AODV routing protocol performed better than OLSR and TORA routing protocols. Therefore, the AODV routing protocol is more suitable to operate in mobile ad-hoc networks when used for geographic information systems. AODV routing protocol showed more excellent capability to reduce the packet drop rate, which is a critical parameter for the GIS network. Its impact becomes more significant when a mobile node acquires and transmits sensed data in real-time operation. Furthermore, reduced packet drop rate also improves network throughput and quality of service, which is evident from the results. Networks have good throughput and generally they scale better. Thus it can also improve the overall scalability of the network. AODV has a higher packet received ratio as well as compared to OLSR and TORA. High packet received rate also improves the Quality of Service (QoS) of the network. End to end delay is also an important parameter to gauge the QoS of the networks. TORA also showed pre-emptive nature, giving a very reasonable end to end delay.

7 Conclusion

A geographic information system (GIS) is a software tool that gathers, manages, and transform geographic information into intelligent presentations for informed decision making. It has several essential components that work together in harmony to achieve its goals. However, all of those components perform different processes on the sensed data. So data becomes the root of GIS. Selecting a proper routing protocol becomes a challenge when you need to optimize multiple parameters and have a variety of protocols in hand. In this paper, we tried to address this problem with the help of a simulation approach. We chose AODV, OLSR, and TORA protocols to be simulated in our simulation testbed. Results showed that the AODV routing protocol performed better in several areas as compared to OLSR and TORA.

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