Location-Based Routing Protocols GAF and its enhanced versions in Wireless Sensor Network a Survey

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Summary
Since the last two centuries, humanity has made scale steps in this attraction to innovation and technological progress. The emergence of global networks of computers corresponding to Wireless Sensor network WSN is one of those great steps that man could do. WSN is an advanced technology that occur in response to overcome user needs. It resolves many problem such as, controlling phenomena, monitoring places, and diagnostic. Nevertheless, this advanced technology still incomplete in order to different constraints such as energy consumption, routing, aggregated data and security, also routing information represents a critical issue in it. For that, great researches designed. In this paper, we present a survey of GAF and their enhanced versions as Location-Based routing protocols in WSN, which allows reducing the consumed energy in the network and prolonging the network lifetime.

Key words:
WSN, routing protocols, location-based, GAF.

1. Introduction

Due to latest technological progresses, WSN is widely considered as one of the most essential technologies.
In recent years, it has received specific attention from both industry and academia around the world. A WSN usually contains a huge vast number of nodes deployed, communicate over short distance using a wireless medium and cooperate to complete a collective job, for example, military surveillance, environmental monitoring, and industrial control.
When events arrived data collected by the sensors sent directly or through other sensors to base station called sink, which transfer aggregated data to treatment center, this process shown at figure 1.

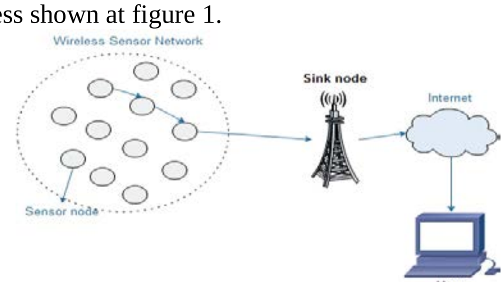

Fig. 1. WSN architecture.

WSNs applied in all areas as shown at Table 1 and in many of them; nodes are randomly scattered and organizing themselves using wireless communication.

These sensor nodes should work for a great length and powered by battery, but in the majority of cases, it is very difficult and also even impossible to recharge or change batteries. For that matter, to optimize energy constraints of vast deployed sensor nodes, it necessitates a set of routing protocols to implement various network management functions and control like synchronization of transmitting data, localization position, and aggregation also network security.

The traditional routing protocols consume several shortcomings when applied to WSNs, Nevertheless, several routing protocols are invented [1] [2] [3] [4] [5] and are in fact classified according to three families data-centric routing, hierarchical routing and location based routing protocols.
Data-centric (DC) routing [6]., in this family, the base station sends questions to certain areas of interest and waits for request data from sensors responsible for collecting data in the regions selected.

Specifying type and properties of data in this kind of routing protocols is necessary, in order to know which data is being sent by queries from one source to destination, the process of DC is based on the objective of eliminating repetitive data in network by using aggregation, so that reducing transmissions, saving energy and extending the network lifetime. As opposed to traditional routing protocol called end-to-end, DC routing catches routes from several sources to destination, which allows in-network integration of redundant arrived data, Figure 2 shows the principal process of DC routing.

Hierarchical: The key goal of hierarchical routing is based on the objective of efficiently conserve the energy consumption of nodes during transmitting data. This process is by dividing the network into clusters and in each one electing one manager, which called Cluster Head (CH) responsible for applying aggregation in data received from sensor nodes and transmit it to the BS. In order to

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diminution the number of transmitted messages to the sink. So that prolonging the network lifetime, Figure 3 shows the principal process of Hierarchical routing. Clustering can make available higher network performance due to the minimize number of sensor nodes which sends data to the BS directly in the other kind of routing protocols.

Location-based [ ]: in this architecture kind of network, sensor nodes are deployed in random way in area of interest, nodes are regularly known by the geographic position where they are scattered. They are located mostly by means of GPS (Global Positioning System), where the distance from node to another expected by the signal received from those nodes, coordinates data calculated by exchanging information between neighboring nodes. This approach optimize the energy consumption, which prolong the network lifetime due to uses of location.

Table 1. Classification of routing protocols

Classification	Protocol
Data-centric	DD, RR, SPIN, COUGAR, AQUIRE
Hierarchical	LEACH, PEGASIS, TEEN, APTEEN
Location based	MECN, SMECN, GAF, GEAR

Our paper is organized as two sections, the first one contains the related work especially GAF protocol and its improved versions, and the second one contains the comparative study of GAF and its enhanced versions.

2. GAF: Geographic Adaptive Fidelity Protocol

Different location based protocols are proposed in order to reduce the energy consumption in wireless sensors network [7] [8] [9].
GAF protocol is location-based protocol, which improves the energy consumed by sensors nodes.
(GAF) [10] Geographic Adaptive Fidelity, first proposed for MANETs; however, it also used for WSNs. It organizes sensors into equal groups based on their positions geographic using GPS, or other localization systems.
Despite of the location system used, it is impossible to find equivalents sensors in terms of transmission between the sensors.
The algorithm and the operating principle of GAF is based on the model of virtual grid, which allows to divide the network into virtual zones called square grids, in each grid sensors can talks with each sensor in the neighboring grid. In addition, each sensor node can be in three modes: Active, Discovery and sleeping as shown in figure 2. This concept resolve the problem of finding equivalents sensors for transmission. The dimension of the grid squares is taken based on the fact that any two farthermost sensors in whichever adjacent grids can be able to communicate with each other. As presented in Figure 3, it showed that in each grid only one sensor is full of life, which is responsible to transmit packets to a sensor located in the neighboring grid, while the others are in sleep state, which allows prolonging the network lifetime.

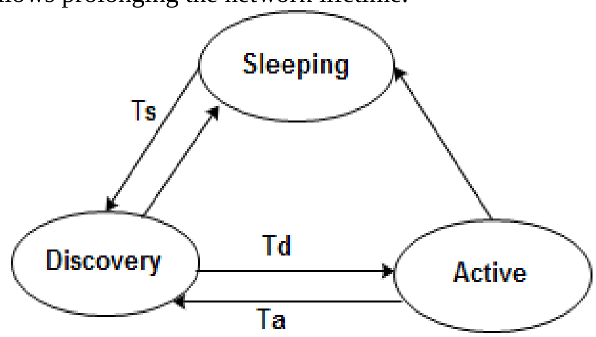

Fig. 2. Transition state in GAF.

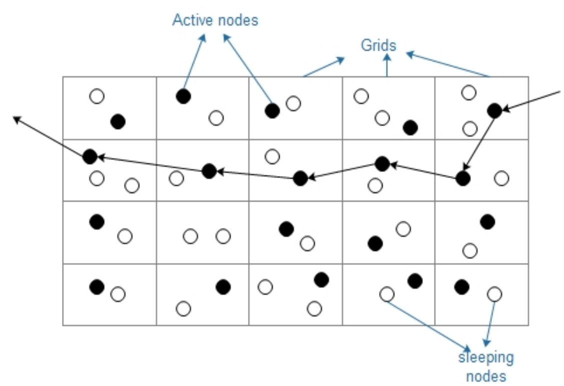

Fig. 3. Architecture of GAF protocol.

GAF is a totally distributed algorithm, which allows the apparition of many improved versions such as DGAF, T-GAF, B-GAF, H-GAF, HEX-GAF and optimized GAF….
The benefits of the GAF protocol are represented by the use of the transition states to allow prolonging the network lifetime.

GAF can significantly increase the lifetime of the network. Indeed, only one node in each grid remains in the active state by passing the other nodes of the grid to the sleep state for a certain period while ensuring the function of the routing.

However, this protocol has many drawbacks as follows:
Even though GAF protocol aimed to solve the critical problem of energy, it does not consider the remaining energy of nodes during the active node selection.

GAF protocol accepts only neighboring

communication between active nodes. Consequently, during routing data a high number of active nodes participate in this function, which consume more energy in the architecture of GAF.

Due to this, GAF consume more energy and. In fact, there is many signal propagation problems such as the presence of obstacles, which causes the direct unreachability of the BS from nodes. On the other hand, the active node have the same capabilities as regular sensor nodes. Consequently, GAF is not suitable for large networks.

In order to overcome these limitations of GAF protocol, new versions appeared:

3. Improved versions of GAF protocol

3.1 DGAF protocol:

DGAF: Diagonal GAF [11] it is an improved version of GAF that permits communication between two diagonal grids in a direct way. Moreover, that comes to avoid the drawback of basic GAF, where forwarding data take place only in two direction: horizontal and vertical. The size of the virtual grid hinge on transmission in order to allow to two farthest sensors in whichever adjacent grids to communicate with each other.

As showed in Figure 4, n0 and n1 are two farthest sensors in two adjacent grids. The size of the square grids is r units and the transmission range is R units. In order to meet the definition of virtual grid, distance between any two sensors in adjacent grids must not be larger than transmission range R. Thus for traditional GAF:

$$r^2 + (2r)^2 \le R^2 \Leftrightarrow r \le \frac{R}{\sqrt{5}}$$

Diagonal GAF (DGAF):

$$(2r)^2 + (2r)^2 \le R^2 \Leftrightarrow r \le \frac{R}{2\sqrt{2}}$$

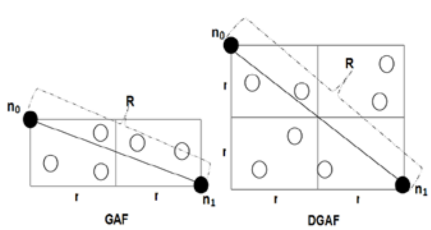

Fig. 4. Virtual grid in GAF and DGAF.

3.2 TGAF protocol:

T-GAF: Authors in [12] propose an improved version of GAF protocol called T-GAF. This new version aims to optimize the hop count of the traditional GAF. T-GAF reduces the number of sensors participating in routing significant information from the sender to the desired destination. This protocol represents a new optimized scheme for WSNs, which allow the communication between a sensor nodes and neighbors localized in the adjacent grids in their transmission range like the original GAF. Moreover, this novel scheme permits the direct communication to neighbors of adjacent grids, which mean that it uses two levels for routing data: member nodes of the adjacent grids of the source and the neighbors of the adjacent grids. Hence, this enhanced version minimizes the hop count comparatively to GAF. This efficient scheme improves the selection of grids coordinators, which are chosen, based on their residual energy. The sensors with the highest residual energy are the most preferred for the coordinator selection. The same idea is also applied in D-GAF protocol, as shown at Fig 5.

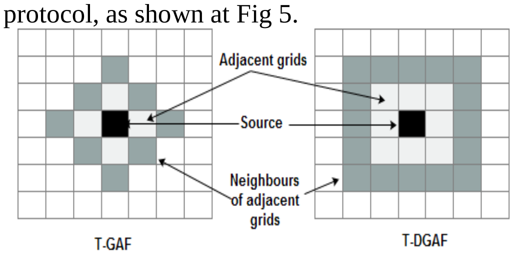

Fig. 5. Example of two-level neighbor sharing scheme

3.3 B-GAF:

B-GAF: Authors in [13] design a new improved protocol of GAF named as B-GAF for sensor networks. The new protocol is based on three-dimensional structure by dividing the network into different number of cubes having the same volume. The formed cubes represent the clusters, each cluster defines its cluster Head, which is selected, based on the highest residual energy and the distance separates it from the sink.

The probability for selecting the CHs combines both energy and distance parameters. It is calculated by :

Wi = w1 Ci +w2 /di

w1 +w2 = 1

the preferred values correspond to the highest values of Ci and the smaller values of di

In this new scheme, only Cluster Heads are active and responsible for routing data while the remaining nodes are in sleep mode. To avoid the excessive energy consumed by the CHs, B-GAF defines a node with maximal residual energy which play the role of an intermediate between CHs and the sink.

3.4 HEX-GAF protocol:

HEX-GAF: Authors in [14] proposed a new version of GAF called Hexagonal GAF.

The operating principle of this version aims at dividing the network on hexagonal grid [15]. Therefore, the hexagon structure replace the square grid in basic GAF.

The conception model of HEX-GAF in figure 6 showed that cell **O** has six cells as neighbors, covering destinations from all directions.

A Hexagon cell in GAF-HEX is defined as, for two adjacent cell O and B, all nodes in cell A can communicate with all nodes in cell B and vice versa. The hexagon mesh has the nice property that for a cell O, all of its six adjacent cells are at next hop. They have the same maximum distance to cell O. In the square grid architecture there are eight neighboring cells (four diagonal, two vertical and two horizontal cells) but only four (vertical and horizontal two each) are at next hop distance while the hexagon cell covers all six possible next hop cells with a single maximum distance due to its symmetry property. Therefore, all of the next hop cells for cell O are equally reachable by definition.

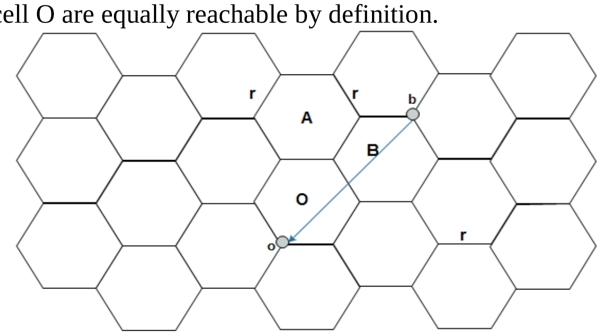

Fig. 6. Hexagon Architecture

1.5. HGAF protocol

HGAF: Hierarchical GAF [16] protocol represents an enhanced version of GAF protocol. It improves the traditional GAF using a layered structure for the selection of active nodes in the preformed cells. The main improvement of this new approach is keeping the connectivity between coordinators of the grids. This is done by limiting the active nodes positions in cells and synchronize these positions using a sub-cells distribution. Selecting the active nodes hierarchically (cells and sub-cells) as shown in figure 7 and that guaranties the communication between the adjacent cells.

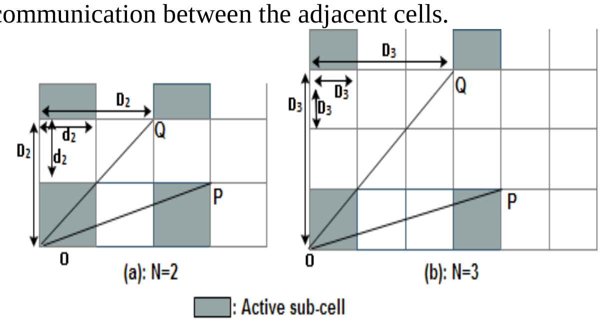

Fig. 7. A cell divided into N2 sub-cells

1.6. GAF&CO protocol:

Authors in [17] proposed a new version of GAF, called GAF&Co: GAF with COnnectivity-awareness, based on GAF protocol, where the network is separated into hierarchical and hexagonal cells as an alternative of rectangular cells in basic GAF. The essential objective of this management architecture shown in figure 8 is that, one node is kept as active node in every single hexagonal cell, in order to transfer information and sensing activities during time of routing which helps on saving energy consumed comparatively to basic GAF.

Due to this architecture, this protocol can be deployed as algorithm in several strategies, such as sleeping approaches and clustering.

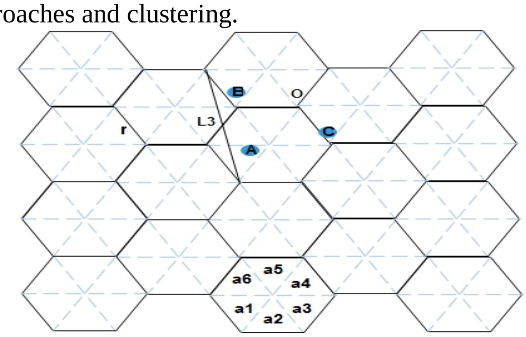

Fig. 8. GAF&CO Architecture

1.7. OPTIMIZED GAF:

Authors in [18] proposed a new version of basic GAF, based on improving the discovery phase of states of transition as shown at Figure 6. Optimized GAF also based on three states of transition Discovery, Active and sleep, same as the basic version, however its process is different.

- Discovery phase: Where a sequence of nodes are selected to become active nodes assigned to the nodes having maximum remaining energy. This phase will be executed once time just for finding the sequence of actives nodes.
- Active Phase: After Ta Node will become active without entering in discovery phase.
- Sleep Phase: After Ts, next node will become active node.

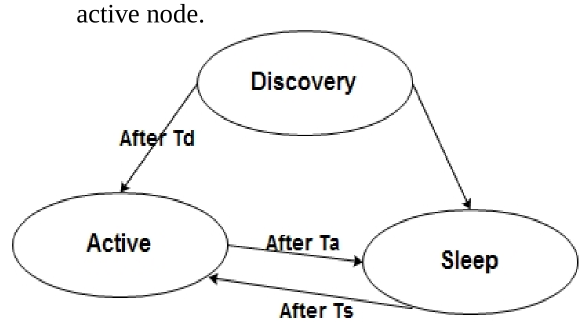

Fig. 9. Transition state in Optimized GAF

4. Comparison and discussion of the GAF based protocols

Respectively to various parameters of GAF and all enhanced versions based on it, Table2 and Table3 below provide a comparison of all of them. The different parameters selected for discussion are hop count, energy efficiency, and active node selection. In addition, the advantages and the disadvantages of all the GAF based protocols are listed in Table3.

To overcome the problem of neighbour communication in basic GAF, DGAF invented with a diagonal communication, which allows communication between two diagonal grids and permits for two farthest sensor node to communicate.

For controlling distance in WSN, T-GAF optimize the hop count, which reduce the number of node participating in routing.

To minimize energy consumption Optimized GAF, is invented to reduce more energy comparatively to GAF using a selection of active nodes based on maximum remaining energy.

Several parameters and methods are included for the improvement of GAF protocol such as the way of dividing the network and the delay of receiving messages.

In addition, researchers should take into account aggregation of data and security to guarantee that all data received. In order to design more protocols that are efficient, which will be used in different wireless sensor network applications.

Table 2: Comparative study of GAF and its enhanced versions

	Protocols	GAF	DGAF	TGAF	TDGAF	BGAF	HGAF	HEX-GAF	Optimized GAF	Co&GAF
Active nodes Selection	Randomly	+						+		+
	Residual energy		+	+	+				+	
	Distance to BS and residual energy					+				
	Distance parameter						+			
Transition	Return to discovery state	+	+	+	+	+	+	+		+
	Execution of Discovery state one time								+	

Table 3: Advantages, Inconvenient of GAF, and its enhanced versions

Protocol	Advantages	inconvenient
GAF	- location-based protocol - aimed to solve the critical problem of energy - sensor node can be in three modes: Active, Discovery and sleeping	- does not consider the remaining energy of nodes during the active node selection. - accepts only neighboring communication (horizontal and vertical). - high number of active nodes participate in this function - the active node have the same capabilities as regular sensor nodes
DGAF	-permits communication between two diagonal grids in a direct way sensor node can be in three modes: Active, Discovery and sleeping less overhead of coordinator election based on the residual energy of sensors	- does not optimize the hop count - does not consider distance parameter.
T-GAF	-optimize the hop count of the traditional GAF - reduces the number of sensors participating in routing significant information from the sender to the desired destination - Active nodes selected based on their highest residual energy	- does not consider distance parameter for selecting the active nodes.
B-GAF	- based on three-dimensional structure - active node selected based on highest residual energy and the distance separates it from the sink - B-GAF defines a node with maximal residual energy which play the role of an intermediate between CHs and the sink	- does not reduce the number of nodes participating in the network communication.
HEX-GAF	-the hexagon structure replace the square grid in basic GAF - covering destinations from all directions	- does not optimize the number of nodes participating in routing packets.
HGAF	-keeping the connectivity between coordinators of the grids -sub-cells distribution. Selecting the active nodes hierarchically (saves power by increasing the size of GAF cell) - guaranties the communication between the adjacent cells	- inefficient selection of the active nodes
GAF&CO protocol	- network is separated into hierarchical and hexagonal cells - one node is kept as active node in every single hexagonal cell - saving energy consumed comparatively to basic GAF	- does not optimize the number of hops.
OPTIMIZED GAF	improving the discovery phase of states of transition a sequence of nodes are selected to become active nodes assigned to the nodes having maximum remaining energy. This phase will be executed once time just for finding the sequence of actives nodes -helps saving energy comparatively to GAF	- does not consider distance parameter for selecting the active nodes - does not optimize the number of hops.

5. Conclusion

The Wireless technology attracts the majority of researches, As a result, it is exploited in different fields such as social and military fields. The main challenge of this developed technology is the consumption of the energy resources efficiently because the sensor energy is very limited. The energy of sensors is more consumed by the operations of data transmission and reception. The main objective of routing protocol design is extending the network's lifetime by keeping the individual sensors operating for a long time. Consequently the network's lifetime will be increased. GAF protocol is designed first for Magnet, consume less energy by using three state of sensor node, this approach improves the network lifetime but it has many drawbacks which offer the opportunity to several protocols to be emerged in order to solve these serious problems. In this paper, we have presented different extended versions of GAF protocol in WSNs. We have also discussed the improvement of each GAF version. Furthermore, we have deeply compared these different approaches based on various metrics. Finally, A detailed table summarizes the advantages, disadvantages, assumptions and active nodes selection criteria for each protocol. Several versions of GAF are appeared for improving the original GAF. However, It is necessary to integrate the node mobility and study the node security in GAF. Additionally, more work should be done for optimizing the number of nodes which participate in routing packets. Also, it is necessary to handle the various QOS requirements in order to design more efficient routing protocols.

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