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Routing Messages Protocol in Wireless Sensor Network Grids (RMP)

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Abstract:

Wireless Sensor Network Grids (WSNG) is considered one of the main four categories of wireless grids based on the devices predominant in the grid and the relative mobility of the devices in the grid. One of the important challenges in WSNG is the routing of messages through the grid. This area is concerned with the reduction of power consumption but through efficient routing of messages. A second concern is the reduction of message latency. In this paper, we propose an applicable routing messages protocol (RMP) which uses a multi-hop forwarding scheme to achieve long-range communication. Our RMP has three phases: firstly, the initialization phase where each sensor node determines the best first hop toward the Sink among its neighbors. Secondly, sending the best route phase where each node sends an accumulative routing message (ARM) to the sink includes the hops list. Thirdly, in the maintenance phase, the out of reach node sends a maintenance message (MARM) to create the alternative route to the Sink. The proposed RMP provides a simple and applicable routing model for WSNG. It also makes the total energy consumed in data transmission more efficient in the sensor network and minimizes the node memory size and processing steps which reduces the total network cost.

Keywords:

Wireless sensor network Grids, Sink, Sensor node.

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1. Introduction

Grid Computing is increasingly capturing the attention of the computing community. It uses clusters of personal computers, servers or other machines. They link together to tackle complex calculations. In part, grid computing lets companies harness their unused computing power, or processing cycles, to create a type of supercomputers [1,2].
Wireless grid computing with its model of coordinated resource sharing may provide a way to utilize such resources that are normally distributed throughout a grid. We may have Grid net in the future as we have Internet today. Wireless grid computing supports sharing of these resources by mobile, and fixed wireless devices within the virtual organizations. It may include devices like laptops, mobiles, PDAs, sensors, etc., while the resources of these devices can be processor, memory, bandwidth, code repositories, software, etc. It may also incorporate some other devices such as cameras, microphones, bar code and RFID readers, GPS receivers and satellite receiver/ transmitters as well as a wide variety of special purpose sensors. Among the many types of sensors currently available are those that measure temperature, air pressure and humidity, those that detect movement, and those that measure radiation and particulate levels. Characteristics of wireless grid can be summarized as follows [2,3,4]:

- No centralized control.
- Consists of small, low powered devices.
- Includes heterogeneous resources, applications and interfaces.
- New types of resources like cameras, GPS trackers and sensors can be shared among grid devices.
- Dynamic and unstable users / resources.
- Geographically dispersed resources, with different management policies.
- Different security requirement and policies.

Adding the feature of wireless devices gives the wireless grid computing not only its advantages but also creates challenges. These challenges lustrated in the following listed:

- Resource status monitoring:
- Resource status updating and communication
- Authentication and Authorization of device/user:
- Resource description
- Resource discovery
- Resource allocation
- Routing of messages through the grid
- Power consumption

- Mobility
- Information Security
- Fault management
- Energy-efficient medium access:
- Communication Paradigms

Wireless grid architectures can be broadly classified into the following four categories based on the devices predominant in the grid and the relative mobility of the devices in the grid: Fixed Wireless Grids, Mobile or Dynamic Wireless Grids, Ad Hoc grids and Wireless Sensor Network Grids [5,6,7,8].

WSNG is composed of a large number of sensor nodes, which are densely deployed either inside or close to a phenomenon, distributed randomly, have self-organizing, cooperative capabilities, prone to failures, topology changes frequently [1, 2], mainly use broadcast communication, limited in power, computational memory capacities, and limited cost for each node [3, 4]. WSNG have attracted a lot of attention recently due to their broad applications in both military and civilian operations. The core function of a WSNG is to detect and report events which can only be meaningfully assimilated and responded to, if the accurate location of the event is known. The sensed data must be gathered and transmitted to a base station for further processing to meet the end-user queries. Since the network consists of low-cost nodes with limited battery power, it is a challenging task to design an efficient routing scheme that can collect massive data and offer good performance in energy efficiency, and long network lifetimes. We propose an applicable routing messages protocol (RMP) that uses a multi-hop forwarding scheme to achieve long-range communication.

This paper is organized as follows: Section 2 presents related work. The proposed routing message protocol (RMP) is presented in Section 3. The evaluation and analysis of the proposed scheme is presented in Section 4. The analytical comparison between RMP & related model is presented in section 5. Finally, Section 6 concludes the paper and presents our future work.

2. Related work

Routing messages in WSNG attracts a lot of researcher in last few years. F.Ye, H.Luo et al [9] presents the design of Two-Tier Data Dissemination (TTDD) routing protocol. This scheme creates a virtual grid structure on which data is delivered to any of the interested sinks. The grid is rooted at a single data source from which the grid is constructed during a data advertisement phase. The data source becomes the first dissemination node and other dissemination nodes are selected at grid cross-points throughout the sensor field. Following the advertisement phase, sinks may query the dissemination nodes for the advertised data. A query received at a dissemination node is forwarding along the reverse grid path of the advertisement to the data source, then the requested data is returned along the same path to the requesting node. Simple geographic forwarding is used to move messages between dissemination nodes on the grid. The grid structure used by TTDD efficiently overcomes the problem encountered by geographic routing when irregularly-shaped holes exist in the sensor field caused by sensor failure or the random deployment.

J. Homsberger and G. C. Shoja [10] have addressed a different grid structure routing protocol with TTDD. Their proposed scheme is called the Geographic Grid Routing (GGR) protocol. The GGR protocol is a hierarchical protocol for disseminating tasks in a sensor network and retrieving the corresponding data. The effort is broken into three stages; task dissemination, data forwarding and maintenance stage. The routing path of a message from the source to the sink after detecting an event by the source is shown in Figure 1.

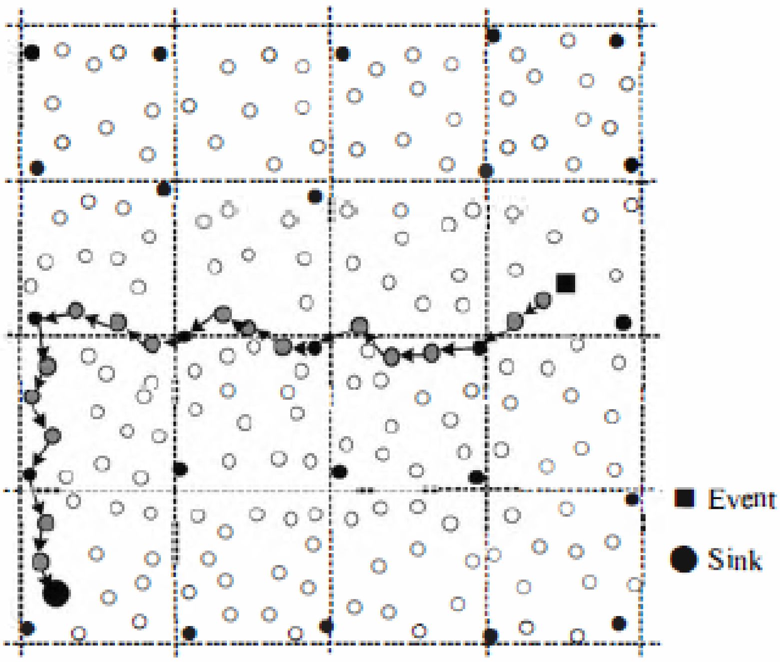

Figure (1): *The routing path in GGR.*

Chiu-Kuo Liang et al [11] present Steiner Trees Grid Routing STGR Protocol in order to reduce the total energy consumption for data transmission between the source node and the sink node. They construct a different virtual grid structure instead of the virtual grid introduced in GGR. Their idea is to construct the virtual grid structure based on the square Steiner trees as shown in Figure 2.

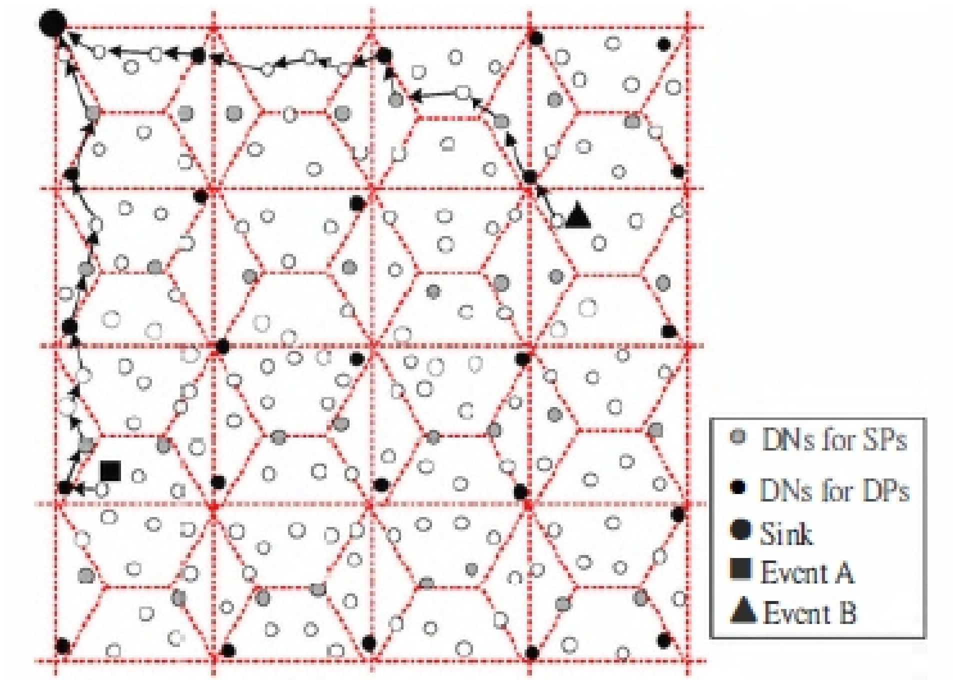

Figure (2): *The routing path in STGR*

It is to the best of our knowledge; this algorithm presented in [11] is the recent work that addresses the specific location based model with respect to the WSNGs.

3. The Proposed RMP

Before going further, let us first explain the network model in our work. As we have known that the main task of sink node is to disseminate the user queries into a sensor network and retrieve the corresponding data from the sensor network. For this purpose, a sensor network is assumed to have the following characteristics:

The sensor field is made up of hundreds or perhaps thousands of small, cheap sensing devices that are randomly deployed throughout a two dimensional area of interest. The power supply is restricted due to the size of sensor nodes. Short-range radios with static transmission power are used due to the energy constraint. Therefore, multi-hop forwarding schemes are used to achieve long-range communication. The sensing devices are assumed to have known location within the sensor field. An immobile data sink is deployed with the area of interest, and has location knowledge and an infinite power source. The routing algorithm will be accomplished in three phases:

A. Phase I: (Initialization Phase):

Once the sensor nodes (SN) are deployed randomly, each sensor node in the network should have the location and ID of the fixed sink. Each sensor node starts to send a message containing its id and its location to all its neighbors that lie in its radio range. Then each node starts to determine the best 1st hop node toward the sink by calculating two distances: D1 which is the distance between each neighboring node and the sink, D2 which is the distance between each neighboring node and itself. The value A which is equal to (d2-d1) determines the 1st hop node. Each node chooses the best 1st hop node which has the largest A, as shown in the example in Fig 3. The best 1st hop for Sn1 is Sn5; Fig 4 illustrates the selective algorithm of phase I in RMP, we can notice that the for loop enables the node to apply the selective condition on its neighbors and come out with the best 1st hop ID.

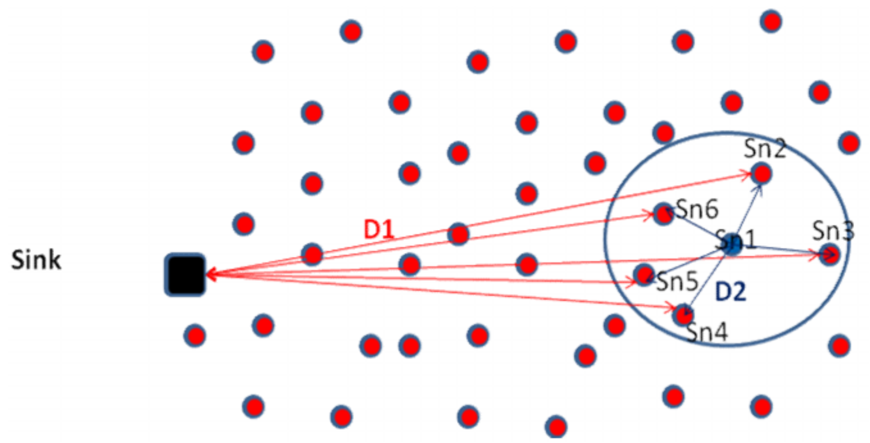

***Figure (3):** Example of applying the selective condition in RMP*

B. Phase II (ARM Phase):

By finishing phase I, each border node start to send accumulative route message (ARM) to the sink through the best node which has been determined in phase I. While the ARM travels hop by hop, it carries the ID of each intermediate node it passes through until it reaches the sink. When the ARM reaches the sink, the sink builds ARM table for each SN in the ARM. When the Sink needs to send any request to SN it uses the inverse of the ARM sequence that stored in ARM table as shown in Fig 5. Fig 6 illustrates the algorithm of phase II in RMP.

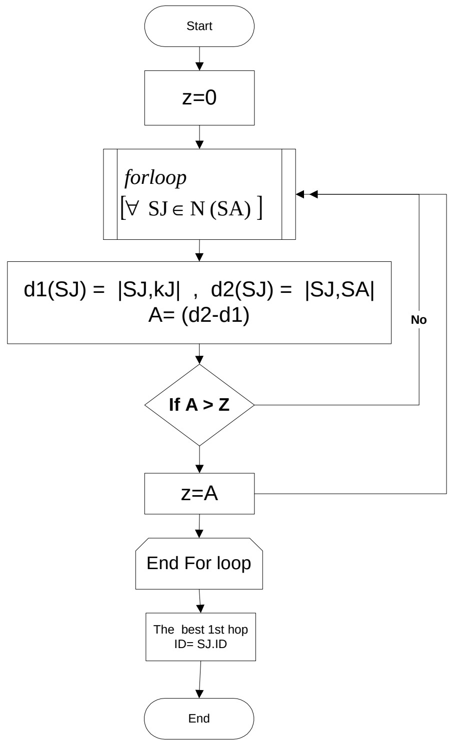

Figure (4): *The selective algorithm of phase I in RMP*

Sn ID	Inverse ARM
SN1	Sn109,Sn61,Sn54,Sn32,Sn7
SN7	Sn109,Sn61,Sn54,Sn32
SN32	Sn109,Sn61,Sn54
SN54	Sn109,Sn61
SN61	Sn109

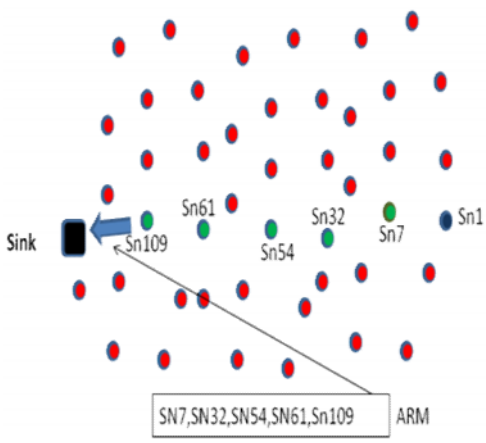

Figure (5): *Example to illustrate the ARM message and the inverse ARM table*

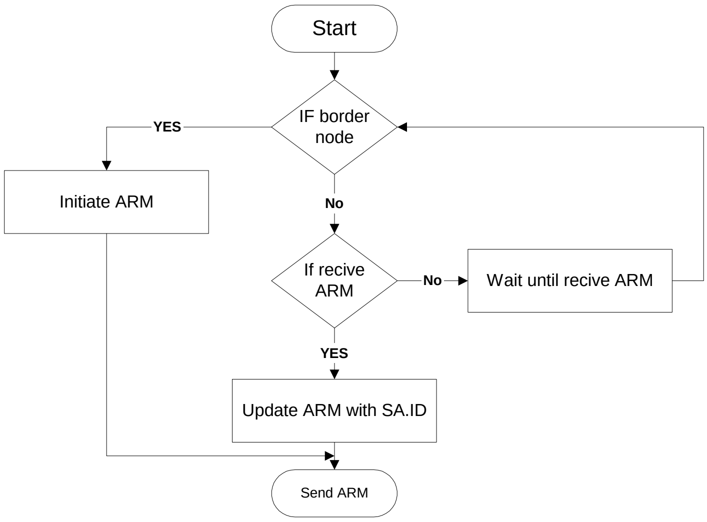

Figure (6): *Algorithm of phase II in RMP*

A. Phase III (Maintaining the ARM table):

Each SN will count the number of successive sessions, if it is smaller than certain thresholds it starts to send Maintenance ARM (MARM) to recover the failure nodes that may defect the path. In the way of the MARM, each node receives MARM choses again the 1st best hop from all its neighboring nodes except the node it received MARM from or the node that has an ID included in the MARM unless it is the only choice. In the only choice case, the node flags it's ID in the MARM and sends the MARM back to the last unflagged node in MARM. When the MARM reaches the sink, the sink updates the ARM table using the inverse of the MARM, as shown in Figures 7, 8.

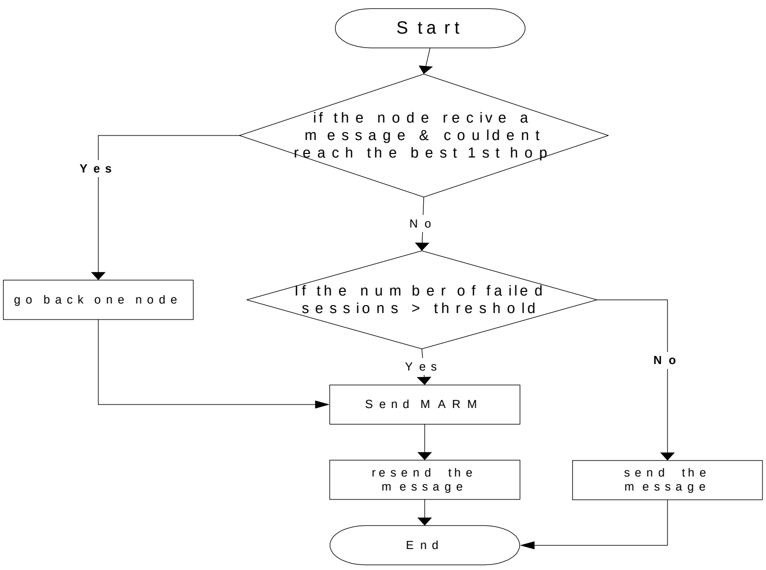

Figure (7): *1st algorithm of phase III in RMP*

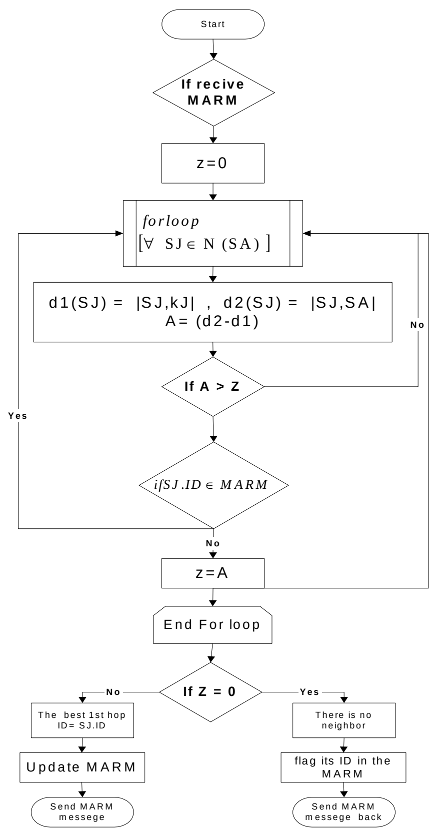

Figure (8): *2nd algorithm of phase III in RMP*

B. ARM & MARM communication overhead:

ARM message will have the following attributes; source *ID*, *next hop ID*, *Sink ID*, *ARM sequence*, *reported message* as shown in Figure 9.a. MARM message will have the following attributes; *source ID*, *next hop ID*, *Sink ID*, *MARM sequence*, *Flagged IDs*, *reported message* as shown in Figure 9.b. Notice that the length of the *ARM sequence* and *MARM sequence* will be 2*n* bytes where *n* is the maximum number of hops toward the sink, while the length of flagged IDs will be 2*m* where $m < n$, *m* and *n* will be calculated in setup process depending on the following factors; the radios of the network area, the node communication range and the nodes distribution density.

	Source ID	Next hop ID	Sink ID	Reported message	ARM sequence
Used memory	2 bytes	2 bytes	2 bytes	8bytes	2n bytes

Figure (9a): *ARM overhead structure*

	Source ID	Next hop ID	Sink ID	Reported message	MARM sequence	Flagged IDs
Used memory	2 bytes	2 bytes	2 bytes	8bytes	2n bytes	2m bytes

Figure (9b): *MARM overhead structure*

C. The proposed node memory structure:

The node memory will have the following attributes; *node ID, source ID, Sink ID, 1st hop ID , checked neighbor ID, distance D1, distance D2, calculated A, compared A, reported message, Sink location, node location , selected neighbor location, ARM sequence, MARM sequence and flagged IDs* as shown in Figure 10. Notice that we will use Global Positioning System Fix Data (GGA) location format which is one of the National Marine Electronics Association (NMEA) Global positioning system (GPS) standard format, which provide essential fix data for 3D location and accuracy data [12].

	Node ID	Source ID	Next hop ID	Sink ID	checked neighbor ID	Reported message	ARM sequence	MARM sequence	Flagged IDs
Used memory	2 bytes	2 bytes	2 bytes	2 bytes	2 bytes	8 bytes	2n bytes	2n bytes	2m bytes

distance d1	distance d2	calculated A	compared A	Sink location	node location	selected neighbor location
4 bytes	4 bytes	4 bytes	4 bytes	NMEA GPS format 64 bytes	NMEA GPS format 64 bytes	NMEA GPS format 64 bytes

Figure (10): *The proposed node memory structure*

4. Mathematical Analysis of RMP

We consider a WSN consisting of *n SNs s1*, *s2*,..,*sn* and *m* sinks *k1*, *k2*,…., *km*. We model the network as an undirected graph *G* = (*V*, *E*), with the set of vertices *V* =

v1 ∪ *v2*, with *v1* being the set of *SNs* and *v2* being the set of sinks. *E* is the set of edges. An edge exists between any two nodes that are in each other's communication range. The set of vertices *V = v1 ∪ v2*. Here, *v1 = {s1, s2,…,sn}* and *v2 = {k1, k2,…., km}* where *n* and *m* are system dependant parameters and represent the number of *SNs* and sinks respectively.

The distance between each node and its sink will be *D1*, the distance between each node and its neighbor will be *D2*, where *N (SA)* represents the neighbor set of sensor (*SA*). In any event, each *SN* must have at least one neighbor represents the best 1st hop toward the corresponding sink, where this neighbor has the shortest *D1*. If we have two or more equal values represent shortest *D1* the best 1st hop will be the one of which has the longest *D2*. Therefore, the equations below give the necessary conditions for determining the best 1st hop:

$$\forall [\ SA \in v1,\ kJ \in v2,\ SJ \in N(SA)\ ] \text{ there is } D1(SJ) = |SJ, kJ|,\ D2(SJ) = |SJ, SA|$$

$$A = (D2(SJ) - D1(SJ)) \ \&\ A \text{ is the largest number } \forall (N(SA))$$

5. Analytical comparison between RMP & STGR

- *Power consumption of Network Setup*

  Due to using the border node only to establish the ARM messages; the power consumption of the interior Sensor nodes had been reduced that minimize the total power consumption of the set up process which make RMP initiation phase save more energy than STGR initiation phase.

- *Routing and Energy efficiency*
  If we compare between RMP and STGR based on two different criteria: the number of transmission hops in each session and the total energy consumption in each session,Due to the selective technique used in the RMP to determine the best 1st hop the pass become optimum while the STGR depend on the dissemination nodes which determined after creating the virtual grid will be longer, see Figure 2 and Figure 5.

- *Nodes range heterogeneity*
  STGR model depend on similar node ranges to create the virtual grid while RMP model will support different node ranges in the same WSNG.

6. Conclusion and Future Work

In this paper, we propose a routing message protocol (RMP) by using a new location based routing technique that provides a simple and applicable message routing model for WSNGs. RMP tries to make the source node to deliver the sensed data to the sink node more quickly. Also, our approach will make the total energy consumption in data transmission more efficient in a sensor network. Each node has one receiver, transmitter, power unit, sensing unit, processing unit, and a limited memory. This minimum specification reduces power consumption, hardware size, and WSN cost.

In future work, we aim to extend our model to evaluate the RMP Performance by comparing the energy-efficient feature and routing reliability between our proposed RMP and STGR protocols. By building our own RMP simulation to achieve the following stages: First, study area selection stage, which covers a subset of IKONOS satellite image with its real UTM, coordinates in Egypt, Cairo, with limits of 500 m × 500 m. Second, nodes distribution stage, to distribute the WSNG nodes randomly with predetermined number of nodes for each trial 2000 nodes to achieve density of 80 nodes / 100 X 100 meters^2. The range of the transmission and reception will be 40 meter, each sensor node will have initial power level with 6000 joules (J), each data transmission and reception will take 66 J and 39 J respectively. Third, ARM stage, by starting the ARM message and build the inverse ARM table in the sink.

7. References

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