The effects of MAC protocols on localization in Wireless Sensor Network

Madeeha M. Alanazy [1] , Alaa E. S. Ahmed [2] and Mostafa E. A. Ibrahim [3]

[1,2,3] College of Computer and Information Sciences, Al Imam Mohammad Ibn Saud Islamic University (IMSIU)
Riyadh, Kingdom of Saudi Arabia
[2] Department of Electrical Engineering, Faculty of Engineering (Shoubra), Benha University, Egypt
[3] Communication and Computer Engineering Department, Benha Faculty of Engineering - Benha University - Egypt

Summary
As Wireless sensor network based solutions are getting more attention, more challenges are realized, in particular the efficiency of localization algorithms. In literature there has been much work employed simulation to measure the performance of Wireless Sensor Network localization under various constraints and environment circumstances. The choice of suitable MAC protocol has a direct impact on the performance of localization since it provides the nodes with ability of sharing limited channel bandwidth to maximize the localization scope and minimize communication cost. The question to be answered in this paper is how much MAC protocols affect the network energy consumption when applying localization. In This paper, the answer to this question is presented by simulating the performance of an efficient localization algorithm called ALWadHA when run over different MAC Protocols such as T-Mac and Tunable Mac. Simulation results show that MAC protocols affect the performance of localization in wireless sensor network.

Key words:
WSN; Localization techniques; MAC; Energy consumption; positioning

1. Introduction

Development in sensor technology and wireless communication has noticeably evolved in such a way that increased the Reliance on Wireless sensor network (WSN) for different applications such as tracking, monitoring and process control [1]. As WSN based applications begin to spread out into market, Sensor nodes locations awareness is a crucial issue in order to magnify the value of data collected by these nodes. Localization is the process of computing the sensor node coordinates in order to establish a spatial relationship between objects to facilitate a successful run of different WSN applications [2].
Achieving a precise knowledge of node location in WSN requires a reliable sharing of other nodes positions information throughout the communication medium of the WSN. Position information should be delivered to other nodes in a reliable and real time manner. For this reason MAC protocols would affect the performance of the localization process [3].
The main objective of MAC protocols is to emphasize the reliability of data transmitted by channels. Since in WSN the physical medium is shared by all sensor nodes, Mac protocol is also responsible for managing the criteria by which sensor nodes can access the communication channels. These criteria include the regulations that control the interval timing when data packets sent, listened or received. Energy efficiency is also an important consideration in WSN [4]. Generally speaking, energy is consumed by the sending, receiving and listening processes. Most sensor nodes are battery operated and have a limited lifetime.
The objective in this paper is to determine how the choice of MAC protocol would affect the performance of localization algorithms in WSN. ALWadHA [5] is the localization algorithm used in the paper. The performance measure would be calculated in terms of energy consumption. So, the question is to find out the effect on energy consumption level when the ALWadHA algorithm runs over different MAC protocols such as TMAC [6] and TunableMAC [7].
The remainder of this paper is organized as follows. Section 2 provides an overview of ALWadHA localization algorithm used in the paper. Section 3, describes each of the MAC protocols to be utilized. The simulation environment and results are presented in Section 4. Finally, Section 5 concludes the paper.

2. Localization Algorithms

Many localization algorithms have been developed in WSNs such as [8, 9, 10, and 5]. These algorithms adopt different methods to get the accurate position of sensor nodes. In these algorithms distance between two nods and nodes position estimation, are applied to obtain the nodes positions. Obtaining the distance between nodes is computed by utilizing a variety of techniques such as TOA (Time of Arrival) [11], TDOA (Time Difference of

Manuscript received August 5, 2016
Manuscript revised August 20, 2016

Arrival) [12], Received Signal Strength Indicator (RSSI) [13]. In these algorithms, Nodes are categorized into unknown and references or beacon nodes. The beacon nodes coordinates are known so that the other unknown nodes can compute its own coordinate using some techniques such as maximum likelihood estimation. In [5] algorithm, each node in the network start to search for their accurate position then sends it to the sink node. the algorithm woks in rounds, and at the end of each round nodes are categorized as either active or sleep in order to save the energy consumed by nodes used for either sending, receiving or processing data packets. In order to analyze the effect of MAC protocols, ALWadHA Localization algorithm [5] is selected for this study since it use a smart and accurate method for localization . The following section gives a brief overview over ALWadHA Algorithm.

2.1 ALWadHA Algorithm

This main objective of this algorithm is to improve the accuracy of the sensor nodes positions. Nodes are categorized as references, known and unknown nodes. Reference nodes are those with known coordinate while the known nodes are those converted from unknown after applying the position estimation module of the algorithm.

It is based on using a subgroup of references (and known nodes which were previously unknown) in order to estimate other unknown nodes positions. A smart method is used for creating this sub group. The references sub group is maintained by the requesting unknown nodes. Only sub group of references contribute in estimating the unknown nodes positions. In case there are references with better accuracy level, they replace references with lower value of accuracy level. ALWadHA algorithm consists of four phases as shown in table 1. In the first phase, unknown nodes search for reference nodes existed in the around area. In the second, a subgroup of the most relevant found references are created then MMSE method is applied in order to determine the unknown node initial position. In the third, the initially estimated position in the previous phase is improved by removing irrelevant references from the sub group increase the position accuracy level. In The final fourth phase, the unknown nodes check whether the acquired position is accepted or rejected.

Table 1: Alwadha Localization Algorithm

1-	Initialization: Search for reference nodes in the around area
2-	Initial position estimation - Create a subgroup of references - Measure its distance to the references. - Apply MMSE to determine the node initial node position
3-	Redefined position estimated: Improve the position estimated in step 2
4-	Position Update: Check the acquired position and decide whether it is final or irrelevant.

3. Mac Protocols

In Wireless Sensor Network, it is important to control the time of both sending and listening to packets. Choosing a suitable MAC protocol would facilitate the control of those times and consequently lead to important performance gains such as high throughput, low error rate and efficient energy consumption. TMAC and tunable MAC are two famous protocols that are used with WSN.

Timeout medium access control (TMAC) [6] allows the sensors to work on their radios at synchronized times, and to work off of them after a definite period during which no communication takes place. When sensors receive frame of data, it is woke up and transmit data to its neighbour then returns to the sleep mood until a new data frame came up. Sensor nodes communicate with each other using the acknowledge (ACK) , Request To Send (RTS), Clear To Send (CTS) , and data planner mechanisms to reduce and avoid frame collisions and achieve reliable transmission. A node will carry listening and transporting ability as long as it is in an active period. The active period ends when no activation event has occurred for a certain period of active time (TA). In TMAC, all messages are transported in a burst of changing lengths, and there is a gap between the bursts called sleep–sleep time, which decreases idle listening.

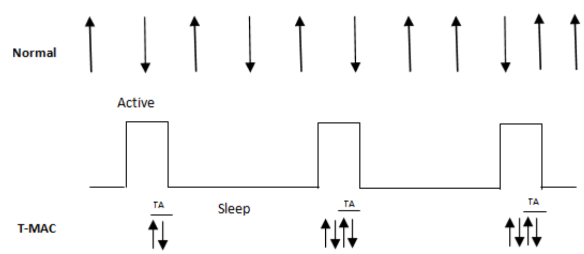

Fig. 1 Nodes with active time TA

In Figure 1, the TA finishes when there is no active event for a time period TA, and the node shifts to sleep mode. At the time of top load, the node communicates continuously without sleeping.

TunableMAC [7] is designed in such a way that allows the ability of simulating many other communal MAC protocols. It doesn’t support acknowledgment and it uses the CDMA method to overcome the packet collision problems. It is called tunable since its design includes

several parameters that determine its operation. These parameters may be summarized as follows:
-Duty Cycle: The time that the radio pauses and the node listens to the channel. It directly impacts node energy consumption.
-Listen Interval: how long, in milliseconds, the node listens to the channel through a single period. The listen interval, combined with the duty cycle, defines the length of a single period as the listen interval/duty cycle.
-Beacon Interval: Nodes send out a set of beacons to their sleeping neighbors to wake them. This parameter defines how long nodes must transmit their beacons.
-CSMA persistence: A value of 0 indicates a non-constant CSMA, so nodes back off when busy channel is busy.

4. Simulation Environment and Results

The performed simulation is executed using Castalia-3.2/OMNET 3++ simulator [12][13]. This simulator includes realistic model for both the wireless channel and the sensor nodes behavior. The simulator is also highly parametric and can simulate different platforms. Node deployment, Node density and network size are three parameters that are used in evaluating the effect of the MAC protocols selection on energy consumption level when run under ALWADHA localization algorithm. The results are measured in terms of the power consumption due to applying both Tunable Mac and TMac protocols. Nodes are deployed in a working area of 200x200 m on the form of either random or grid deployment. Table 2 shows the simulation parameter of first experiment.

Table 2: Node Deployment Environment

Parameter	***Deploy.***	***Field Area***	***# Beacons***	***# unknowns***
Node Deployment	Random	200x200 m	12	52
	Grid	200x200 m	12	52

The results of this experiment are shown in figures 2, 3, 4 and 5. The first two figures indicate the effect of using Tunable MAC and TMac protocols when used in Random deployment while the later shows their effect when using grid deployment. The trend line when using random deployment indicate that different MAC protocols doesn't affect the level of power consumed by nodes when applying ALWADAH algorithm. The average power consumption in case of using TMAC is 0.22 J and it is 0.221 J in case of using Tunable MAC.

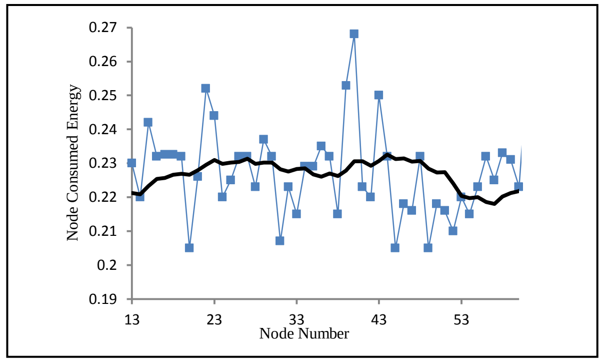

Fig. 2 Random Deployment – Tunable Mac protocol Effect

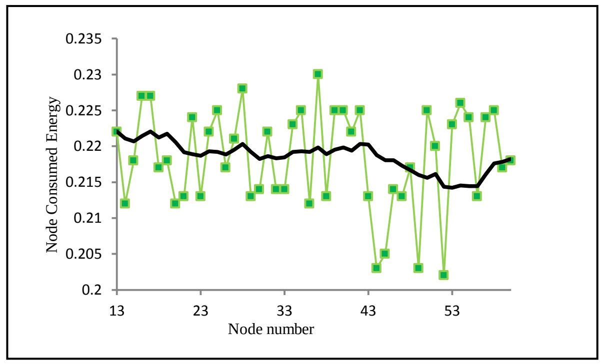

Fig. 3 Random Deployment – TMac protocol Effect

The trend line in figures 4 and 5 indicate that, using TunableMAC saves energy consumption more than the case of using TMAC model. Also, For the TunableMAC the results when using grid deployment are better than the case of using random deployment. This is because in grid deployment most of the nodes have the same number of neighbors while in random deployment nodes could have a different number of neighbors. Fixed number of neighbors led to lower and stabilize energy consumption. Other factor that may help in saving the nodes energy consumption is the fixed duty cycle. In this experiment, the average power consumption when using TMAC is 0.188 J and when using Tunable MAC is 0.185.

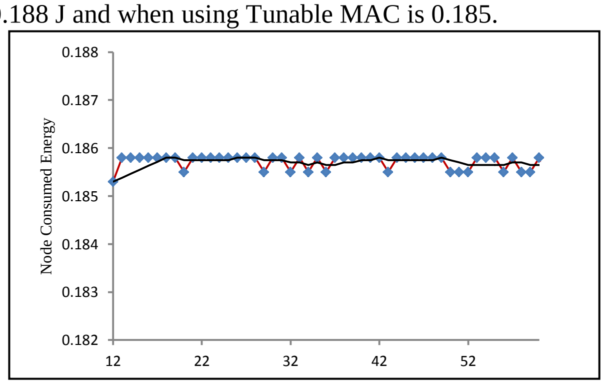

Fig. 4 Grid Deployment – Tunable Mac protocol Effect

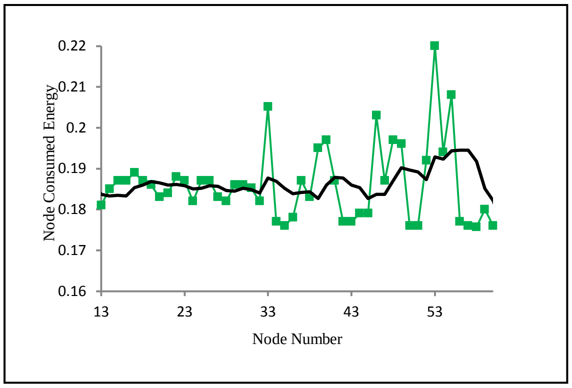

Fig. 5 Grid Deployment – TMac protocol Effect

Since the nodes in the network are classified as beacons and unknown nodes. The following part of experiments checks the effect of changing the number of these two kinds of nodes on the performance of ALWADHA algorithms when using T-Mac and Tunable Mac protocols. First, a fixed number of beacons were used while changing the number of unknown nodes, and then the number of unknown nodes was fixed while changing the number of beacons. In all the experiments done in this section, nodes were deployment randomly in a 200 m×200 m field as shown in table 3.

Table: Node Density Environment

Deployment	***Field Area***	***# Beacons***	***# unknowns***
First Experiment			
Random	200x200 m	9	35
Random	200x200 m	9	51
Second Experiment			
Random	200x200 m	23	21
Random	200x200 m	39	21

To check the effect of node density, two experiments are run in two different deployments. In first, the nodes are deployed randomly with fixed number of bacons equal to 9. Each experiment use different unknown node density levels, medium and large densities. The number of unknown nodes density varied as 35 and 51 unknown nodes. From The results in the trend line, the average values of power consumption when changing the unknown density from medium to large can be listed as in the following:

TMAC (Midium)	***Tunable Mac (Midium)***
0.197 J	.198 J
TMAC (Midium)	***Tunable Mac (Midium)***
.199 J	.204 J

As shown in figures 6, 7,8 and 9, The energy consumption when using TunableMac is increasing because as the unknown nodes number increases, there will be a frequent listening even though there is no events is occurring. While when using T Mac protocol, as the unknown nodes density increases, the energy consumption increase slowly because TMAC use the FRTS (future request to send) property that prohibit some nodes from using the communication medium for a while which consequently save some energy.

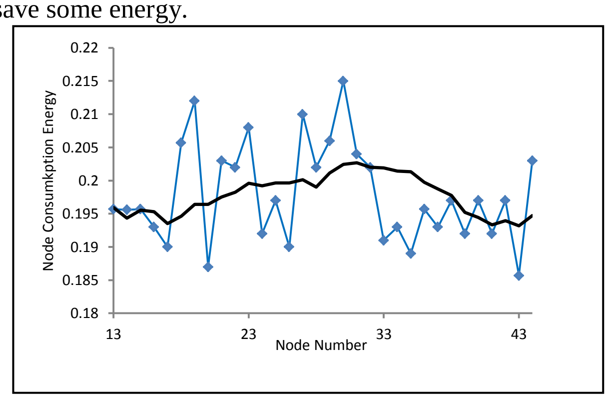

Fig. 6 Tamable MAC – Medium Unknown nodes effect

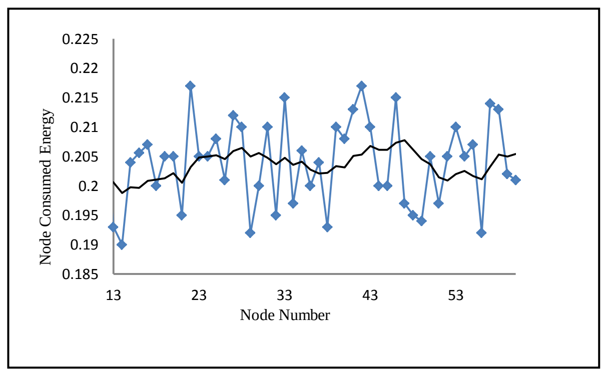

Fig. 7 Tamable MAC – Large Unknown nodes effect

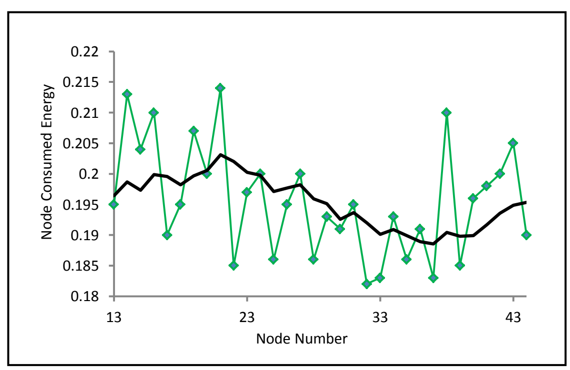

Fig. 8 TMAC – Medium Unknown nodes effect

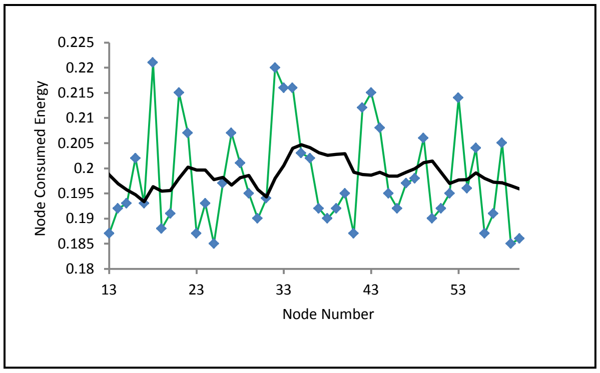

Fig. 9 TMAC – Large Unknown nodes effect

In second experiment, everything will be repeated but in this case the number unknown nodes are fixed while the number of known nodes varies from medium to large. More specifically, the known numbers changes from 23 to 39 while the number of unknown nodes is fixed and equal to 21.

As the number of known nodes increases, there is no need to consume energy by those nodes in order to estimate their location and the nodes energy consumptions are reduced. This would leads to the result shown in the trend lines in figures 10, 11,12 and 13. The average energy consumption in both TMAC and Tunable MAC are almost the same. The following table indicates the average consumed energy in different environment setting

TMAC (Midium)	***Tunable Mac (Midium)***
0.194 J	.194 J
TMAC (Midium)	***Tunable Mac (Midium)***
.19 J	.191 J

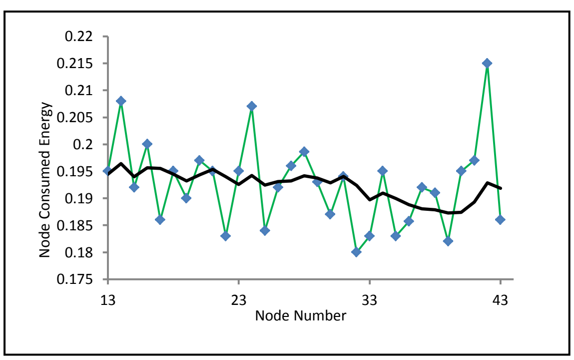

Fig. 10 TMac Medium known density effect

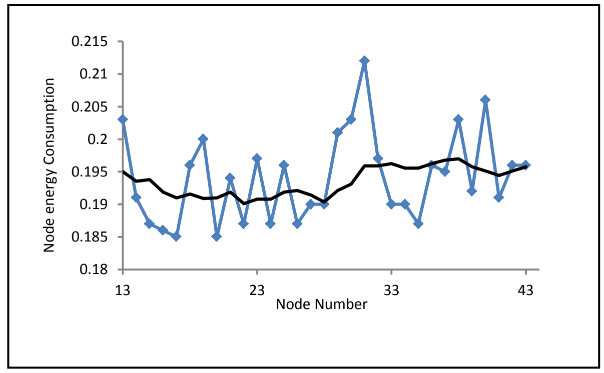

Fig. 11 TMac Medium known Density effect

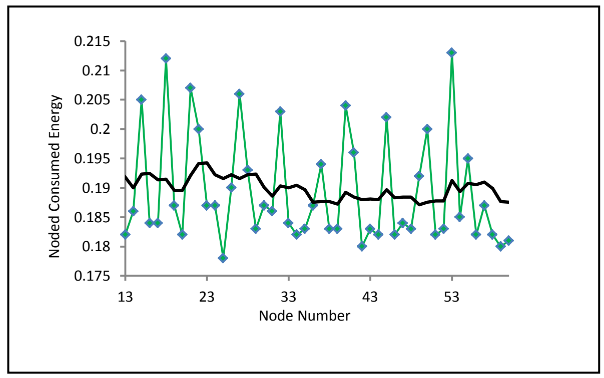

Fig. 12 Tunable MAC Large known density effect

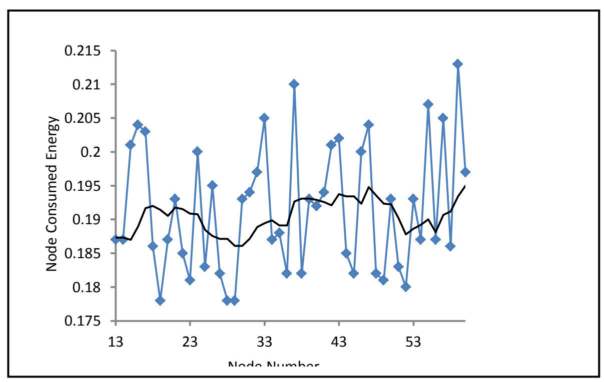

Fig. 13 Tunable MAC Large known density effect

4. Conclusion

This paper has presented a comparison between the effects of using TMAC and Tunable MAC protocols with ALWADHA localization algorithm. The comparison is done in terms of the level of energy consumed by sensor nodes involved in the network. The results of the experiments show that both TMAC and Tunable MAC have almost the same effect when sensor nodes are randomly deployed. In case of grid deployment environment, Tunable MAC and TMAC save more energy than case of random deployment due to the regular distribution of the neighbor nodes that will cause some sort of energy saving. When node density of both known and unknown nodes is changing, TMAC and Tunable MAC will have different effect on the energy consumption level. In case of fixed unknown and varied known nodes, as the number of known nodes increase the consumed energy slowly increases in case of TMAC since TMAC adopt the FRTS property . In case of Tunable MAC, as the number of known nodes increase the consumed energy increases in a noticeable way. In case of fixing the number of unknown nodes, increasing their density would not affect the energy consumption level since there is no need to consume energy to do localization. As a conclusion, MAC protocol is an important factor to be considered when comparing different localization algorithms.

References

[1] Asma Mesmoudi, Mohammed Feham, Nabila Labraoui , “Wireless sensor networks localization algorithms: a comprehensive survey”, International Journal of Computer Networks & Communications (IJCNC) vol.5, No.6, November 2013.

[2] Nabil Ali Alrajeh,1 Maryam Bashir,2 and Bilal Shams2, “Localization Techniques in Wireless Sensor Networks”, International Journal of Distributed Sensor Networks Volume, 2013,

[3] Moshaddique Al Ameen, S. M. Riazul Islam, and Kyungsup Kwak, “Energy Saving Mechanisms for MAC Protocols in Wireless Sensor Networks,” International Journal of Distributed Sensor Networks, vol. 2010, 16 pages, 2010.

[4] Waltenegus Dargie, Christian Poellabauer “Fundamentals of Wireless Sensor Networks: Theory and Practice”, 2010, John Wiley & Sons Ltd

[5] A. M. Abu-Mahfouz and G. P. Hancke, “An Efficient Distributed Localisation Algorithm for Wireless Sensor Networks: Based on Smart Reference-selection Method,” Int. J. Sen. Netw., vol. 13, no. 2, pp. 94– 111, May 2013.

[6] Ghosh, S.; Veeraraghavan, P.; Singh, S.; Zhang, L.; “Performance of a Wireless Sensor Network MAC Protocol with a Global Sleep Schedule” International Journal of Multimedia and Ubiquitous Engineering, Vol. 4, No. 2, April, 2009, pp 99- 114.

[7] Ugo Colesanti, Silvia Santini “A Performance Evaluation Of The Collection Tree Protocol Based On Its Implementation For The Castalia Wireless Sensor Networks Simulator”, Technical Report Nr. 681 Department of Computer Science ETH Zurich August 31, 2010

[8] P. Motter, R. Allgayer, I. Müller, E. Freitas, Practical issues in wireless sensor network localization systems using received signal strength indication, in: IEEE Sensors Applications Symposium, IEEE, San Antonio, 2011, pp. 227–232.

[9] L. Cheng, C. D. Wu, Y. Z. Zhang, Y. Wang, Indoor robot localization based on wireless sensor networks 57 (3) (2011) 1099–1104.

[10] K. Lu, X. Xiang, D. Zhang, R. Mao, Y. Feng, Localization algorithm based on maximum a posteriori in wireless sensor networks 2012, pp 1099–1104.

[11] T.C. Karalar and J. Rabaey, “An RF ToF Based Ranging Implementation for Sensor Networks,” Communications, 2006.

[12] Xiuzhen Cheng and Thaeler A, “TPS: a time-based positioning scheme for outdoor wireless sensor networks,” Twenty-third AnnualJoint Conference of the IEEE Computer and Communications Societies, INFOCOM 2004.

[13] P. Kumar and L. Reddy, “Distance measurement and error estimation scheme for RSSI based localization in Wireless Sensor Networks,” Wireless Communication and Sensor Networks (WCSN), 2009.

[14] OMNeT++ Simulator. http://www.omnetpp.org/

[15] Castalia Simulator. https://castalia.forge.nicta.com.au

Madeeha M. Alanazi received his B.Sc. degree in Computer Science from Al – Imam Muhammad ibn Saud Islamic University, KSA, in 2009. Then she received his M.Sc. degree in Computer Science in Al – Imam Muhammad ibn Saud Islamic University, KSA, in 2016. Her research interests include hybrid cloud computing environment, wireless sensor network performance evaluation, artificial intelligence.

Alaa E. S. Ahmed received his B.Sc. degree in Communication Engineering from Zagazig University, Egypt in 1993. Then he received his M.Sc. degree in Computer Science in Cairo University, Cairo, in 1998. He earned his Ph.D degree in computer Science in 2005 from University of Connecticut, USA. His Ph.D was in fault tolerant Real time scheduling. He works as Assistant Professor in the college of computer and information sciences, Al – Imam Muhammad ibn Saud Islamic University. His research interests include Distributed systems support for harvesting unused resources in cloud computing environment, fault tolerant algorithm for mobile agents and wireless sensor network performance evaluation.

Mostafa Ibrahim received his BS degree in 1997, in computer engineering from High Institute of Technology - Benha University, Egypt. He received his MSc degree in 2004 from the same university. In November 2009, he received his PhD in electronics and comm. Eng. from Cairo University, Egypt in conjunction with Vienna University of Technology, Vienna, Austria under a channel supervision grant. He is now an assistant professor at Faculty of Engineering - Benha University, Egypt. His research interests include embedded code optimization from energy consumption perspective, Software Defined Radio, image and video processing, and Computer Architecture.