Lightweight Context Aware Routing in Wireless Sensor Networks for Real Environments

SAMIA AIJAZ*, SANA HOOR JOKHIO**, AND JAVED ALI BALOCH**

RECEIVED ON 06.06.2014 ACCEPTED ON 17.03.2015

ABSTRACT

Design and implementation of a WSN (Wireless Sensor Network) that can efficiently work for a longer time period must include identification of the deployment environment context and to conform to the behavior of the sensor nodes. The context information when treated with evaluation factor becomes a process of context awareness and the evaluation factor is called the context attribute. In this paper, we consider the context factor of energy. The paper identifies analyses and evaluates efficiency of two when used in a context aware environment. Furthermore, the study also highlights the strengths and weaknesses of sensor SPIN (Sensor Protocol for Information via Negotiation) and LEACH (Low Energy Adaptive Clustering Hierarchy) protocols with respect to the support for WSN with heavy network traffic conditions. The performance has been evaluated in terms of energy efficiency, data packet transmission, network status, data management, reliability, etc.

Key Words: WSN, Context Aware, Real Environments, Routing.

1. INTRODUCTION

Over the decade, commercial, industrial and research interests in WSNs have escalated as WSNs span a very wide range of real-time application domain including object tracking and monitoring, control of nuclear reactors, the detection of seismic activity, surveillance systems, fire monitoring, medical and health diagnosis system, etc. [1]. These applications may require physical position and robust data transmission to BS (Base Station) so that timely action may be taken. Hence, the WSN protocols should minimize the latency/delay and support real-time communication. The sensor nodes in a WSN usually face resource deficiencies where energy is the most critical resource constraints of all. Therefore, by efficiently managing the usage of energy resources in a sensor node may increase the overall WSN's life time.

WSN applications can be classified according to their nature that is monitoring areas, things and complex interactions. Comparatively large-scale WSNs are required for these application areas [2]. A sensor node comprises of three basic parts or units including battery, sensing device and an antenna. However, WSN application's main constraint is limited energy (small battery unit). The only source of life in a WSN node is battery and vast amount of energy is consumed during communication between

* Assistant Professor, Department of Computer Engineering, Sir Syed University of Engineering & Technology, Karachi.
** Associate Professor, Department of Computer Systems Engineering, Mehran University of Engineering & Technology, Jamshoro.

sensor nodes and during sensing activities. A number of solutions have been proposed globally addressing this problem [3]. Efforts have been made to design power-aware protocols for WSNs and to overcome issues such as:

- Transmission range
- Efficient routing and data collection methods
- Scheduling of sensor nodes states (i.e. receiving, transmitting, idle or sleep)
- In case of overhearing, handling of unwanted data.

Hence a major concern is the energy dissipation in the sensor node, as in many WSN applications sensors nodes are deployed in harsh environments with limited and/or irreplaceable energy source [4]. Hence, designing energy efficient protocol for WSN applications operating under harsh environments is a challenging task. WSN for real environments should not only consider the timeliness constraints but should also solve challenging tasks such as energy-efficient routing and relaying of data between sensor nodes and sink to maximize the network lifetime. In this paper we analyze the context aware routing protocols and verify the efficiency for real-time applications of WSN. Nevertheless, we classify the globally proposed routing protocols according to their operations and structures to highlight the strength and weaknesses of each with respect to the application environment of a WSN application.

Real-time environments impose a number of challenges for efficient routing of data from one part of the WSN to the other. It is hence important to know which of the said "light-weight" protocols perform better in such conditions. A number of comparisons may have been carried out using SPIN and LEACH in past but we focus on the issues and challenges faced with respect to the real-environments WSN application scenarios. The change of perspective allows us to look into the problems that may arise while choosing a routing protocol for such environments without first analyzing them for the same. Hence, a thorough analysis with respect to node status, data transmission ability and energy consumption has been carried out along with highlighting the real WSN environment challenges.

Rest of the paper has been organized as follows. Related work, challenges and issues addressed by researchers over the globe with respect to energy dissipation in WSN applications, have been focused in section 2. A thorough discussion regarding energy efficient routing protocols such as LEACH and SPIN is provided in Section 3 Features of LEACH and SPIN have been outlined to provide a brief understanding of the protocols to the users. Section 4, discuses experimental results and highlights working of the two protocols in context aware environment. Finally, we conclude our findings and outline our future research issues in Section 5.

2. WSN ROUTING PROTOCOLS TAXONOMY

WSNs face a number of challenges with respect to communication due to energy constraint. Lifetime of WSN may be increased by decreasing the communication overhead or possibly balancing it. In other words, light weight energy efficient protocols should be used for WSNs applications [5]. Careful resource management is needed. A number of solutions have been proposed addressing this problem. Some energy-aware protocols are also proposed. In this section, via a thorough literature review, we present a survey of state-of-art WSN routing protocols. Routing plays an important part in WSN communication. Although a number of factors are considered for classification of these state-of-art routing protocols, network structure may be considered one of the main parameters for this. Moreover, some routing protocols have fixed routing criteria. These may include energy efficiency, load balancing, route cost, delay, etc. Focusing on these two vital characteristics, we categorize the state-of-art routing solutions as structure based and operation based routing techniques. Fig. 1 illustrates the proposed taxonomy.

The categories are briefly discussed below.

2.1 Structure-Based WSN Routing Protocols

Operations of some of the proposed protocols depend on the structure of the network with respect to the type of WSN application. We classify these protocols as "structure-based" [6]. This category includes flat, location based, hierarchical routing protocols. Network design is one of the constraints of this category of protocols. The "structure" may be considered as the assigned roles a node play in a network, node's physical position utilization for data routes, etc. In other words, network structure may play a significant part in the routing protocol's operation in a WSN. Hence the routing protocols exploit the network physical arrangement parameters. Below, we briefly discuss the type of routing techniques that fall under this category.

2.1.1 Flat

In this type of routing protocol all sensor nodes have similar type of roles. The nodes may be able to communicate with the sink or the BS independently. The nodes may also be responsible for data collection here. However, the collected information may repeat. In other words, multiple information copies might be sent to the sink due to sensor nodes exercising similar responsibilities in the network [7].

2.1.2 Hierarchical

Cluster based structure is used for sensor nodes arrangement in the network here. A cluster head responsible for gathering, aggregation and verification of information is present in each cluster. The cluster

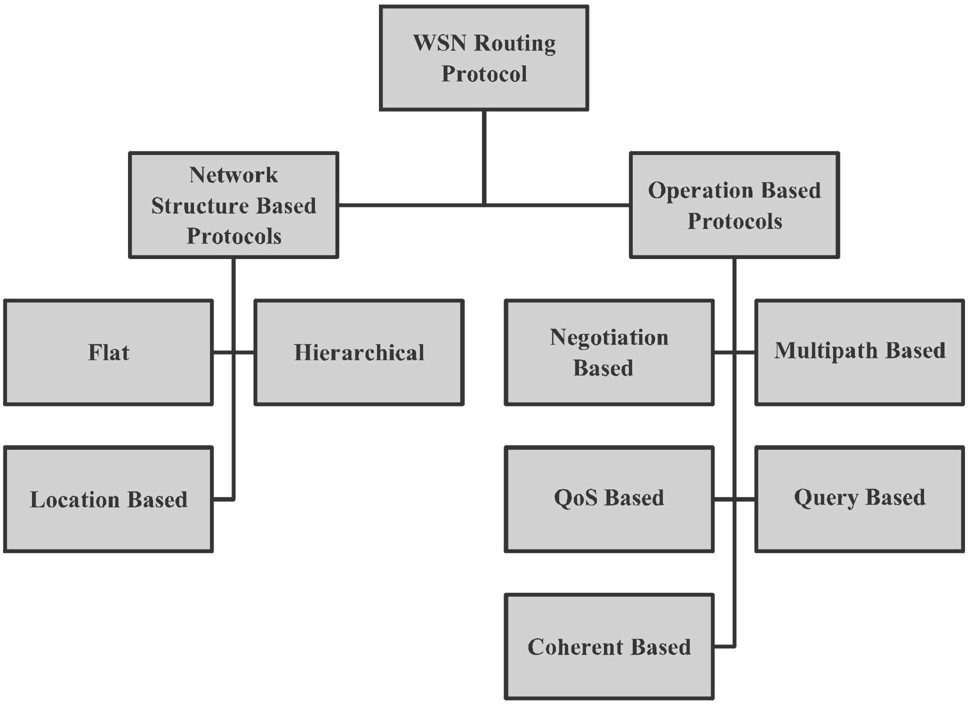

FIG. 1. WSN ROUTING PROTOCOL TAXONOMY

head then forwards the information to the receiver [8]. This type of routing favors energy aware routing and also reduces the communication overhead on sensor nodes.

2.1.3 Location-Based

In location based routing, every senor node is addressed according to its physical location. The nearest neighbor distance is estimated with the help of signal power. However, due to a number of reasons the signal power often weakens and hurdles the proper nearest neighbor estimation. Energy consumption in sensor node is a major concern in routing information from source to destination in a WSN [9]. Hence the node status must be changed frequently from active to idle in order to save energy when no operation is being carried out.

Although, the structure of network plays a vital role in routing data from one part of the WSN to another and a number of solutions have been proposed to overcome the limitations and challenges for efficient routing, the nature of network operation of the scenario under consideration cannot be ignored. We discuss the routing techniques that rely on network operation next.

2.2 Operation Based WSN Routing Protocols

In this category we describe the protocols that are purely depending on the operations which include negotiation, path based, QoS (Quality of Service), query and coherence [10]. Adaptive routing protocols help adapt network conditions via controlling specific system parameters especially the energy levels. In such type of protocols a number of techniques are used such as on demand route computation, advance route computation, or a combination of both. For a static WSN advance route computations may be useful considering the energy constraint. Whereas for mobile WSN or one with a dynamic topology, routes may be computed on demand or periodically. We discuss such routing techniques next.

2.2.1 Multi-Path

These protocols enable sensor nodes to use multiple channels to send/transmit data instead of using a single path. As a result tolerance and reliability may be increased as an alternative path is provided in case the straight or main path fails. These protocols may be used to overcome multipath effects on communication [11].

2.2.2 Query Based

In order to get information from sensor nodes in these types of protocols, the base station transmits query signals. The sensor nodes are responsible for detecting a phenomenon and collection of data. The nodes send data to the base station for further processing. Base station sends data of interest over the network this process is known as direct diffusion. While the messages propagate through the network sensor nodes a path is also generated. The nodes match the requested data and if appropriate requested data is available, the sensor node transmits it to the base station along with the message of interest [12]. This may be used as a solution to consume less energy during communication over the network.

2.2.3 Negotiation Based

High level descriptors are used by this type of protocols for removing transmission of abundant information/data. Flooding is used for information distribution. Flooding may cause overlapping and collision issues/problems and the nodes may get multiple copies of the information transmitted over the network. Energy consumption is high. SPIN protocols may provide a better solution to all these problems as it resolves the duplication issue and eliminates the possibility of transmitting multiple copies of the information [13]. Actual information may be sent by using a number of negotiation messages along with the actual data.

2.2.4 QoS Based

Here energy and quality should be maintained in the network under consideration. Whenever a node requests for data the transmission and communication must meet the QoS parameters. These parameters normally include bounded latency (data should be sent immediately) and bandwidth consumption. SR (Sequential Routing) protocol uses this approach [14]. The routing decision depends upon three factors such as energy consumption by BS and the sensor node, QoS level for every single path, and the packet priority for every transmitted packet.

2.2.5 Coherent Based

The information collected by the network is sent to sink or the closest neighbor when these protocols are used. In this process, information collection is a vital task. The collected information can then be processed using coherent or non-coherent methods. In the non-coherent method the sensor nodes collect information and process it prior to sending it to the closest neighbor for more manipulation. These neighbors that further process the received information are known as aggregators [15]. On the other hand, aggregators perform the processing of information and are directly referred by the sensor nodes after nominal manipulation is carried out. The nominal processing may include manipulation of time and date, or elimination of duplication of information. Hence the coherent method may be used to save more energy as the processing overhead on the nodes is reduced resulting in less energy consumption in sensor nodes.

A wireless sensor network is often deployed in harsh environments where frequent maintenance cannot be carried out. Hence, network life time plays an important role in the performance of the WSN. Therefore getting environment context and sensor node behavior conforming is an important requirement for the WSN. This may help in development of efficient routing. We discuss the context aware routing protocols and their importance in the next section.

3. CONTEXT AWARE ROUTING PROTOCOLS

Keeping energy consumption minimum during routing information between source and the destination is a challenging task in a WSN. Efficient routing may be a vital factor which may help in reducing communication overhead on the sensor nodes hence increasing WSN's lifetime. This may be achieved by acquiring the context information regarding the application environment of the WSN under consideration and sensor node's behavior adaptation. A number of constraints are associated with the routing algorithms proposed globally, such as [16]:

- Sensor node deployment
- Energy consumption at sensor node
- Fault tolerance
- Mobility
- Quality of Service
- Data reporting methods

"Context awareness" is a process in which the context information is treated with the "context attribute" which is an evaluation factor [17]. Context can be categorized into:

- Information
- Energy
- Mobility
- Privacy
- QoS, etc.

Any information that can be used to describe the state of an entity is known as context. Here, in a WSN, it is referred to sensor nodes that interact with each other and/or the base station. In this paper, LEACH and SPIN have been considered and evaluated under context aware environment. These protocols are briefly discussed below.

3.1 Low Energy Adaptive Clustering Hierarchy

It is the WSN's first hierarchical protocols and has also been considered as a benchmark for other globally proposed protocols. It has some unique characteristics such as communication range adjustment according to distance, self-reconfiguration, scheduling individual node data transmission, etc. LEACH is most commonly used protocol in WSNs. This routing algorithm has five phases [15]:

Advertisement: In the initial round all sensor nodes should independently decide if it wants to be a CH (Cluster Head).

Cluster Setup: All the remaining sensor nodes should find an appropriate cluster for them and should inform the CH that they have joined as a member of that cluster.

Schedule Creation: TDMA (Time Division Multiple Access) is used for scheduling and is maintained by the CH of every cluster. This schedule helps in information transmission.

Data Transmission: CHs should be in active state all the time as it is responsible for collection of information from every node in that cluster. The CH the processes the information and compresses it so that a composite signal carrying collective information may be sent to the base station.

Multiple Clusters: CDMA (Code Division Multiple Access) technique is used and every cluster is assigned unique codes for communication to reduce interference among clusters during communication.

LEACH uses multi-hop and cluster based approaches for routing information in a WSN. Multi-hop technique is used for inter-group interaction among CHs and/or the BS. The five phases of the algorithm are repeated as soon as the collected information reaches sink this brings completion to the communication process and phase-1 starts with formation of new cluster heads for each cluster. This self-organized way of choosing CHs in a particular region reduces energy consumption [18]. As sensor nodes in a cluster may either be deployed very close to the CH or far away, the dynamic process of choosing new cluster heads every time information reaches sink may reduce the communication delays and the amount of energy consumed by those located further away in the region. Hence, load is divided among the sensor nodes in the network as they can either be a member or a CH at a specific time. The cluster heads collect information from the cluster members (sensor nodes) and send it collectively in a form of a table to the base station. It is most likely that the clusters may be distributed over large geographical region from where the BS is not directly reachable. Hence by sending their information to CHs that are near a BS they form a multi-hop routing network. Selection CHs is done randomly to reduce communication overhead on the CHs and the network.

3.2 Sensor Protocol for Information via Negotiation

Communication in the SPIN protocol depends on negotiation among the sensor nodes prior to transmitting information. This is done to overcome flooding and network overlapping effects. The SPIN protocol guarantees determination and transmission of only useful information [19]. Using metadata information directed and transmitted to the next neighbor. SPIN uses message types to accomplish the data transfer. SPIN uses three types of messages also known as "meta data". For transmitting information, the interested nodes on the network first transmit the meta-data to find out if any other node wants to share information too. This metadata allows nodes to receive selected information from other nodes hence reducing communication overhead on the nodes to help save energy. Metadata also describes certain attributes for the information that is to be shared. The types of SPIN messages are described below:

ADV: Advertises the information and/or an update on the network for neighboring nodes.

REQ: Interested uses this message to request to the advertising node for the information or an update.

DATA: This message contains the actual data to be shared with the neighboring/requesting nodes.

Information is collected from every single node on the network as a process of diffusion. SPIN protocol provides a way to collect information from various nodes to form a picture of the surroundings of a specific region and to strengthen the WSN. Resource blindness, overlap and implosion are the factors that have led to SPIN development [20]. These are briefly discussed below.

Implosion: Data implosion is a process in which a single node receives multiple copies of the information communicated over the network. In such case energy consumption is high due to using traditional flooding methods to transmit information to all the nodes in the network whether interested or not. Therefore, energy consumption during communication process increase that may lead to shortening WSN's lifetime. Fig. 2 shows the process in which node A is sending information "a" to node D.

Overlapping: In a WSN application it is possible that multiple sensor nodes may collect information from a specific region. In other words, the nodes overlap the geographical area. Hence, the sensed information by these overlapping nodes may also overlap. Nevertheless, multiple copies of same information may be transmitted as a result leading to wastage of energy and other sensor resources. The diagram illustrates the scenario, where nodes A and B collect information from two different Regions-I and II with some overlapped area and transmit the data to node C as shown in Fig. 3.

Resource Blindness: Use of flooding methods for information transmission in traditional protocols allows these to overlook the WSN's resource constraints. SPIN uses two key aspects to solve this issue [21]:

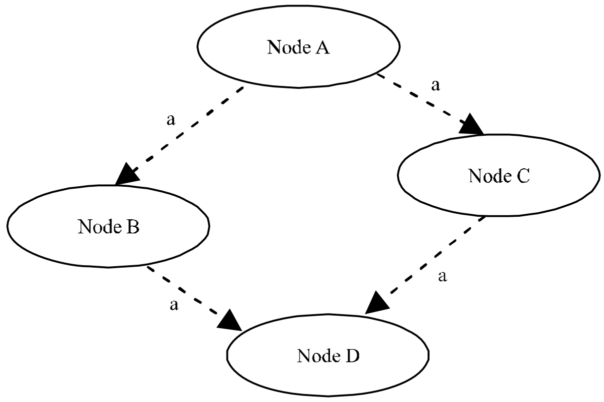

FIG. 2. IMPLOSION DUE TO FLOODING

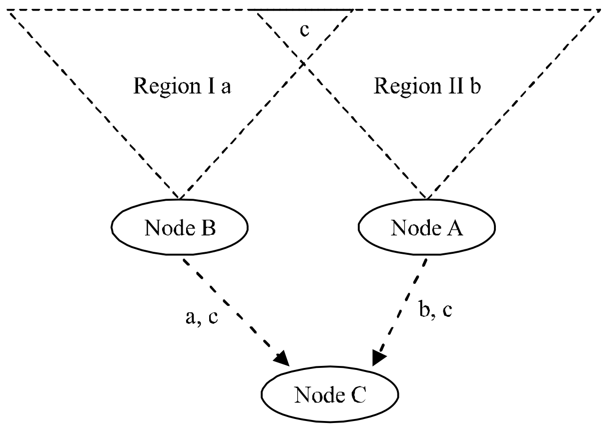

FIG. 3. INFORMATION OVERLAPPING

(i) ***Negotiation:*** The nodes must negotiate with each other prior to information communication to overcome issues like implosion and overlapping of data. SPIN makes sure that only requested and useful information is transmitted or communicated among the nodes in the network with the help of metadata.

(ii) ***Resource Adaptation:*** Resource manager is used by sensor node in the network that helps each node in resource management and controlling various sensor activities according to energy consumption and/or amount of available energy of the sensor node.

A routing protocol may behave differently with respect to the type of WSN application environment [22]. Certain factors affect the performance of WSNs and may play a vital role in design of routing protocols. These include latency, scalability, energy awareness, processing time, transmission plan, network power usage, etc. We discuss the simulation setup and the experimental results in the next section.

4. EXPERIMENTAL RESULT

A number of real-time applications have been rapidly developed for WNS in recent years thanks to research interest and advances in the technologies. We highlight the strength and weaknesses of SPIN and LEACH protocols with respect to being used in real-time WSN applications where guaranteeing real-time is an essential issue.

A number of WSN applications for real-environments have been considered while simulating WSN using NS2 (Network Simulator-2). Factors such as processing, communication and information gathering are considered for large-scale WSN applications operating in large traffic environments. WSN's nodes are considered to be battery powered. Sensor nodes are responsible for collecting data and transmitting it to the sink for further processing. A number of routing solutions have been proposed focusing specific WSN applications. We highlight the WSN for real-environments that deal with heavy communication traffic due to large-scale applications. Simulation details are given below:

- Sensor nodes are randomly deployed over a large geographical area.
- Base station collects data from the sensor nodes.
- The sensor nodes are static and mobile with respect to type of application environment.
- The data is retrieved by the sink from a real environment or a specific region.

It is important to know which protocol performs better with respect to WSN's real-time application environment. A thorough study has been carried out and simulations of SPIN and LEACH have been developed to carry out assessments based on data transmission ability, topological challenges and energy consumption. Figs. 4-5 show SPIN and LEACH protocol setup.

A number of challenges are faced while implementing a routing scheme in a WSN for real environments based on a number of issues to increase lifetime of WSN under consideration. Some of the challenges faced while dealing with real WSN environments include:

- Balancing energy efficiency in the sensor nodes with respect to the real time requirements of the application.
- Considering requirements regarding reliability and QoS to support different WSN applications.
- The WSN environment may contain highly mobile sensor nodes (normally lots of applications assume low mobility) hence a dynamic network establishment and control.

- Faster information delivery may be allowed by considering data aggregation as routing and data aggregation may be strongly related to each other in real environments.

- Other parameters (of different layers) may also be taken into account to improve the communication performance in the WSN (cross-layer design) .

- Special application environment criteria such as WMSNs (Wireless Multimedia Sensor Networks) and UMSNs (Underwater Wireless Sensor Networks) may need special routing protocols to fulfill special requirements, etc.

We discuss the simulation details below.

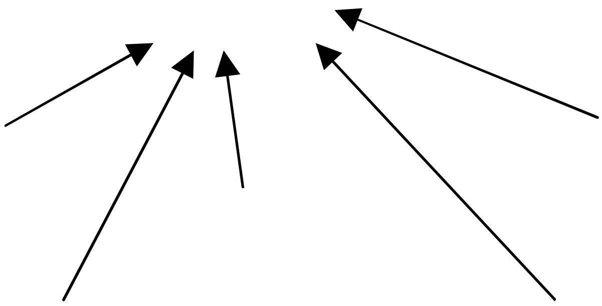

FIG. 4. WSN SETUP FOR LEACH PROTOCOL

NS2 has been used to simulate various WSN real-time environments and to carry out analysis and assessment of SPIN and LEACH. We mainly focus on the energy consumption, transmission of data packets over the WSN and node status. Tables 1-2 provide parameter details used for simulation setup regarding the two protocols.

In order to find out which protocol is more energy efficient among SPIN and LEACH protocol certain results have been acquired based on different parameters of energy consumption, rate of data packet transfer and the status of nodes alive at different time intervals. Fig. 6 highlights the comparison.

Energy efficiency is one of the primary and major concerns in a WSN. But in emerging applications low latency

TABLE 1. LEACH PROTOCOL SIMULATION SETUP PARAMETERS

Number of Nodes	100
X (Network Size)	1000
Y (Network Size)	1000
Base Station	(50,175)
Simulation Duration	3600s
Initial Energy	2 Jules
Number of Clusters	5
Cluster Reset After	20s
Packet Length	4000

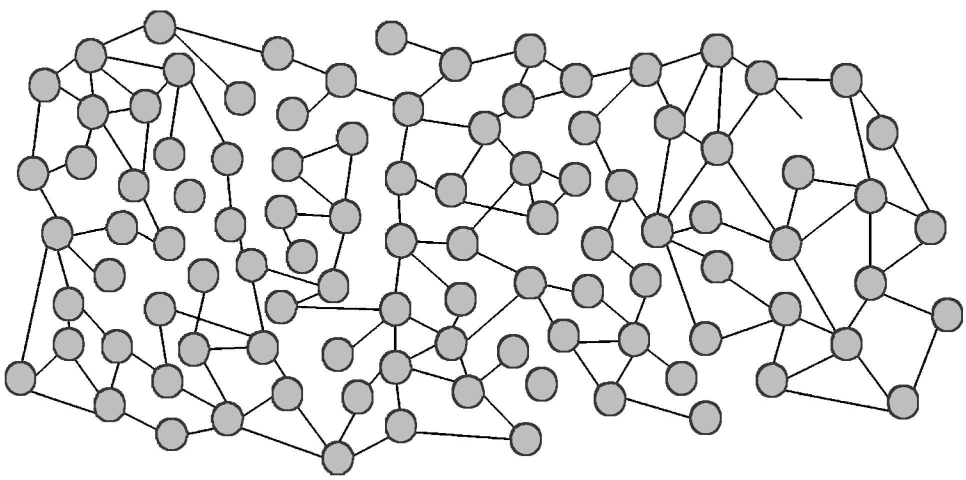

FIG. 5. WSN SETUP FOR SPIN PROTOCOL

communication is also becoming more important. For system monitoring and control it is important not to use out-of-date information as it is irrelevant and may lead to severe negative effects. Fig. 6 depicts a clear picture for the energy consumption of SPIN and Leach Protocols. It can be seen that the amount of energy consumption of SPIN protocol at time 500 seconds is 400 joules where as at the same time LEACH protocol consumes around 320 joules. Hence, LEACH protocol may be considered light-weight with respect to being adapted in real-time application environment of WSNs.

TABLE 2. SPIN PROTOCOL SIMULATION SETUP PARAMETERS

Nodes	100
X (Network Size)	1000
Y (Network Size)	1000
Edges	205
Simulation Duration	3600 s
Average Degree	3.6 neighbors
Data Size	4000 B
Diameter	10 hops
Meta-Data Size	20 B

Timely data delivery also plays a vital role in network performance. A Comparison of data packets transmitted over the wireless sensor network had also been carried out for SPIN and LEACH.

Fig. 7 shows the amount of data packets carried by SPIN and LEACH protocols. It can clearly be seen that the rate of data packets transferred by LEACH protocol is more than SPIN protocol. Hence as far as the communication overhead is considered, SPIN protocol's performance may be considered satisfactory if the focus of WSN application is on the optimization of network performance by decreasing processing and communication overhead.

Nevertheless, it is important to find status of each node in WSN under consideration as different applications are based on different architectures, goals and even constraints. Hence, how many nodes are in what status and for how long may play a vital role in overall WSN performance. Figs. 8-9 show status of sensor nodes using SPIN and LEACH protocols in a WSN real-time environment.

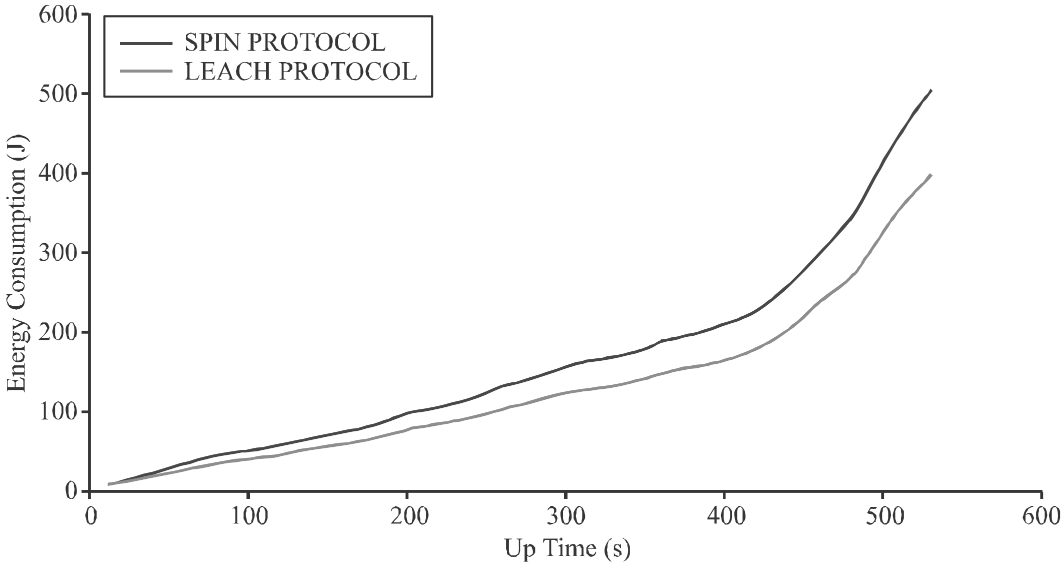

FIG. 6. ENERGY CONSUMPTION

The status of 100 nodes at different time intervals in LEACH and SPIN protocols has been illustrated. It can be observed that in Fig. 8 for SPIN protocol Nodes eventually start to die out after the interval of 300s where as in Fig. 9 for LEACH protocol the nodes start to die out after the interval of 400s. Nevertheless, the node's life time also depends upon the nature of the node and the processing and/or communication overhead on it. Although LEACH

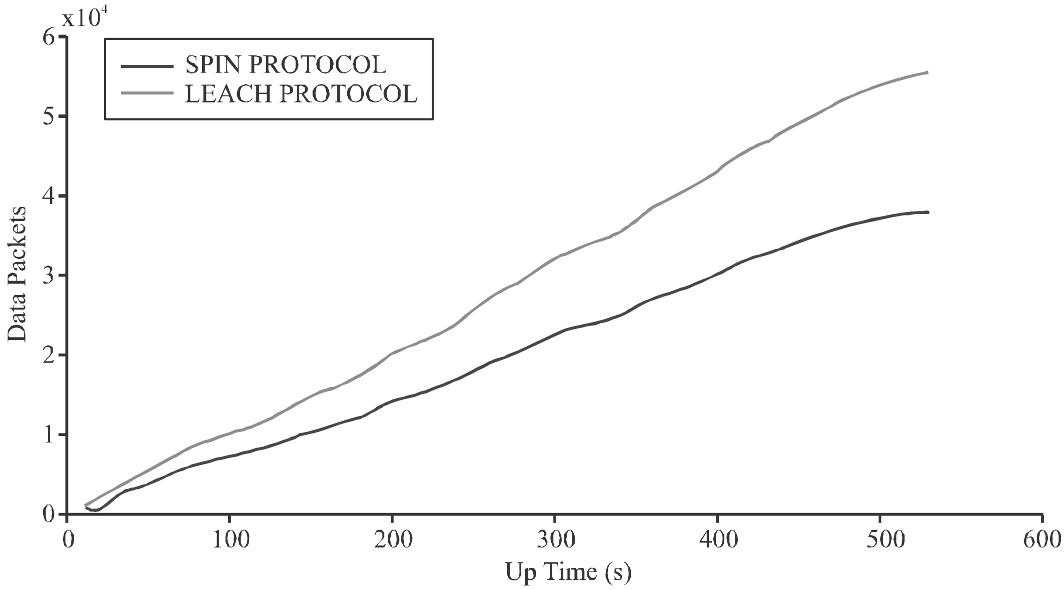

FIG. 7. DATA PACKETS TRANSMISSION

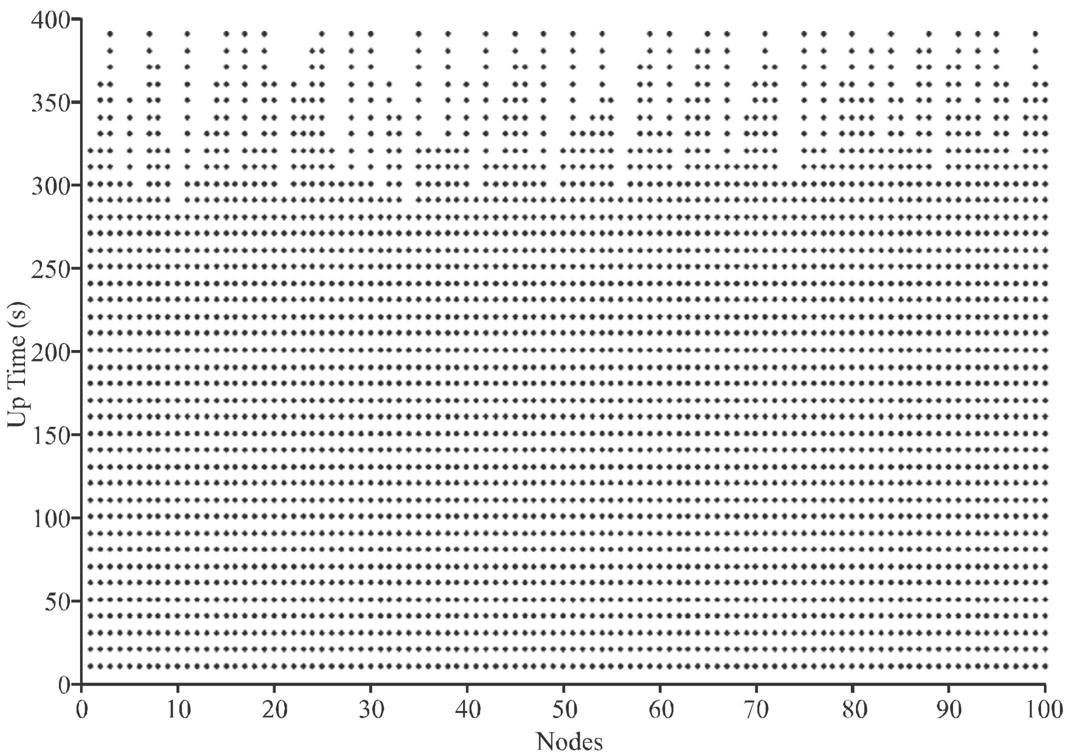

FIG. 8. SENSOR NODES STATUS FOR SPIN PROTOCOL

protocol may impose a communication overhead on the sensor nodes, it has been observed from the results that this routing technique provides a balance to overcome the limitations and optimize the overall node's life time. Considering WSN constraints for real application environments play a vital role in choosing a suitable routing protocol for a specific WSN application. It might also be possible that only being light-weight in terms of energy consumption a routing protocol's performance may not effectively help in optimizing overall life time of sensor nodes and as a result the network as a whole. We conclude our findings in the next section.

5. CONCLUSION

For a WSN working under harsh or real environments the primary objective is usually providing timeliness guarantee due to the resource constrained nature of WSNs. In our paper we carried out a survey of context aware protocols and presented a unique taxonomy of the WSN routing protocols by classifying them into operation based and network structure based groups. The unique categorization helped in highlighting the performance issues and working of each class of routing protocols. A thorough study of LEACH and SPIN protocols were carried out to analyze and assess the two for real-time application environment for WSN. The results showed LEACH worked more efficiently and routed significant data. Nevertheless, energy consumption was less as compared to SPIN hence may help increase network lifetime. By distributing the load among the sensor nodes in the WSN energy consumption was also decreased when using LEACH protocol. Furthermore, we highlighted some open research issues for the wireless sensor networks for real environments.

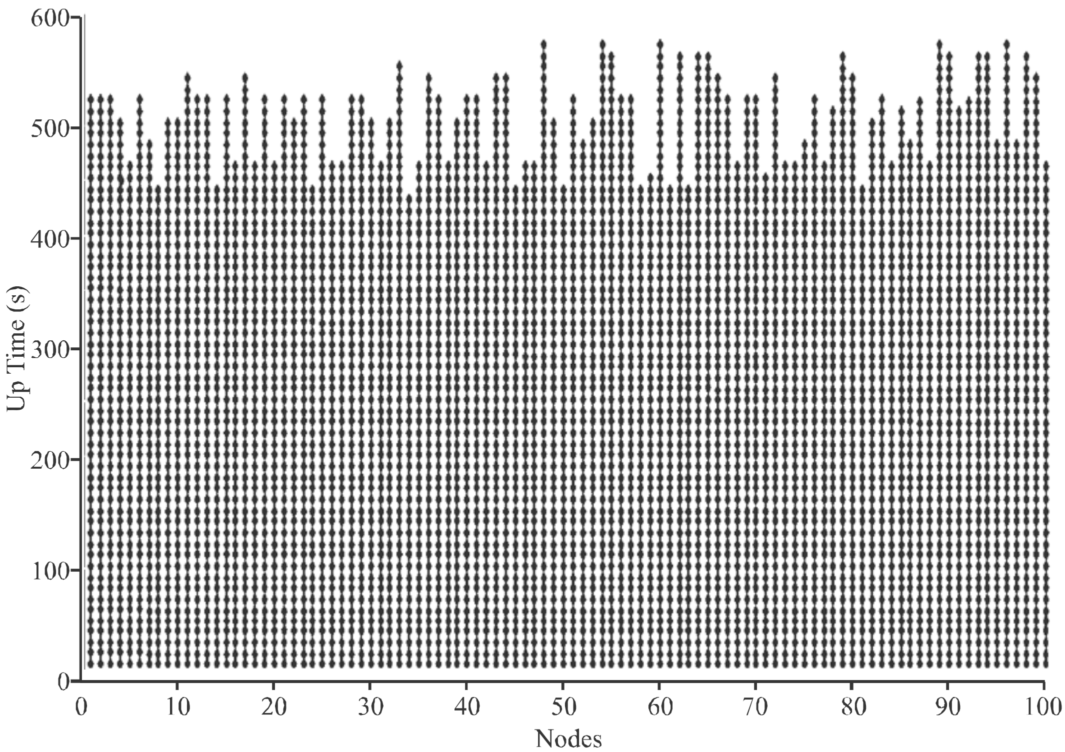

FIG. 9. SENSOR NODES STATUS FOR LEACH PROTOCOL

ACKNOWLEDGEMENT

This research has been conducted with the help and support from Mehran University of Engineering & Technology, Jamshoro, Pakistan. Authors would like to thank the authorities for their cooperation and facilities they provided.

REFERENCES

[1] Baranidharan, B., and Shanthi, B., "A Survey on Energy Efficient Protocols for Wireless Sensor Networks", International Journal of Computer Applications, Volume 3 11, No. 10, pp. 35-40, December, 2010.

[2] Taheri, H., Neamatollahi, P., Younis, O.M., Naghibzadeh, S., Yaghmaee, M.H., "An Energy-Aware Distributed Clustering Protocol in Wireless Sensor Networks using Fuzzy Logic", Ad Hoc Network, Volume 10, pp 1469-1481, 2012.

[3] Zhu, Y., Wu, W., Pan, J., and Tang, J., "An Energy Efficient Data Gathering Algorithm to Prolong Lifetime of Wireless Sensor Networks", Computer Communications, Volume 33, pp. 639-647, 2010.

[4] Wei, D., Jin, Y., Vural, S., Moessner, K., and Tafazolli, R., "An Energy-Efficient Clustering Solution for Wireless Sensor Networks", IEEE Transactions on Wireless Communication, Volume 10, pp. 3973-3983, 2011.

[5] Liu, M., Cao, J., Chen, G., and Wang, X., "An Energy-Aware Routing Protocol in Wireless Sensor Networks", Sensors, Volume 9, pp. 445-462, 2009.

[6] Foster, A., and Murphy, A.L.," FROMS: A Failure Tolerant and Mobility Enabled Multicast Routing Paradigm with Reinforcement Learning for WSNs", Ad Hoc Network, Volume 9, pp. 940-965, 2011.

[7] Villalba, L.J.G., Orozco, A.L.S., Cabrera, A.T., and Abbas, C.J.B., "Routing Protocol in Wireless Sensor Networks", Sensors, Volume 9, pp. 8399-8421, 2009.

[8] Enamul, H.M., Matsumoto, N., and Yoshida, N., "Context-Aware Multilayer Hierarchical Protocol for Wireless Sensor Network", 3rd International Conference on Sensor Technologies and Applications, [doi: 10.1109/ SENSORCOMM], pp. 277-283, 2009.

[9] Bummo, K., Junghea, W., Sungbum, P., and Hyeonsang, E., "PAAR: A Routing Protocol for Context-Aware Services in Wireless Sensor-Actuator Networks", IEEE, [ISSN: 978-1-4244-4570-7/09], 2009.

[10] Bajaber, F., and Awan, I., "Centralized Dynamic Clustering for Wireless Sensor Network", International Conference on Advanced Information Networking and Applications Workshops, pp. 193-198, 2009.

[11] Zhi, G.L., Xing, S.Z., Huai, F.Q., and Shining, L., "Model and Implementation of Context-Aware Sensor Networks", International Symposium on Information Science and Engineering, pp. 16-19, 2008.

[12] Zhang, M., Lu, Y., and Gong, C., "Energy-Efficient Routing Protocol based on Clustering and Least Spanning Tree in Wireless Sensor Networks", International Conference on Computer Science and Software Engineering, pp. 361-364, 2008.

[13] Wu, X., Wang, P., Wang, W., and Shi, B., "Data- Aware Clustering Hierarchy for Wireless Sensor Networks", Advances in Knowledge Discovery and Data Mining: Lecture Notes in Computer Science, Springer Berlin/ Heidelberg, Volume 5012, pp. 795-802, 2008.

[14] Hai-Ying, Z., and Kun-Mean, H., "CIVIC: A Power- and Context- Aware Routing Protocol for Wireless Sensor Networks", International Conference on Wireless Communications, Networking and Mobile Computing, pp. 2771-2774, 2007.

[15] Rathi, N., Saraswat, J., and Bhattacharaya, P.P., "A Review on Routing Protocols for Application in Wireless Sensor Networks", International Journal of Distributed and Parallel Systems, Volume 3, No. 5, pp. 39-58, 2012.

[16] Madheswaran, M., and Shanmugasundaram, R.N., "Enhancements of LEACH Algorithm for Wireless Networks: A Review", ICTACT Journal on Communication Technology, Volume 4, No. 4, December, 2013.

[17] Tan, R., Xu, Y., Chen, Z., Zha, M., and Tsou, T., "Improving Routing Protocols of WSN in WHSN", Proceedings of 14th International Conference on Communication Technology, pp. 56-60, 2012.

[18] Xu, D., and Gao, J., "Comparison Study to Hierarchical Routing Protocols in Wireless Sensor Networks", Procedia Environment Science, Volume 10, pp. 595-600, 2011.

[19] Wu, X., and Sheng, W., "Performance Comparison of LEACH and LEACH-C Protocols by NS-2", Proceedings of 9th International Symposium on Distributed Computing and Applications to Business, Engineering & Science, pp. 254-258, 2010.

[20] Al-Karaki, J., and Kamal, A.E., "Routing Techniques in Wireless Sensor Networks: A Survey", IEEE Communications Magazine, Volume 11, No. 6, pp. 6-28, December, 2004.

[21] Mattern, R.K., "The Design Space of Wireless Sensor Networks", IEEE Wireless Communications, Volume 11, No. 6, pp. 54-61, 2011.

[22] Geetu, J.S., "Performance Analysis of SPIN and LEACH Routing Protocol in WSN", International Journal of Computational Engineering Research, Volume 2, No. 5, pp. 1179-1185, September, 2012.