A Survey on Application Specific Energy-Efficient Routing Protocols and Recent Developments in Wireless Sensor Network

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***Abstract*—Many researchers, industrial manufacturers and users have attracted toward wireless sensor networks (WSNs) and Internet fo things (IoT) devices for remotely observation tasks and impressive data collection of various environmental conditions like humidity, temperature, light, radiation, sound, pressure, vibration etc. The wireless sensor nodes are generally small battery powered devices with limited lifetime, so for enhanced and reliable network lifetime, the primary concern is reducing energy consumption while creating algorithms and applications. In this survey, we present and discuss wireless sensor network (WSN) design issues, clustering mechanism and routing process to conserve energy conservation and enhance network lifetime. A theoretical model is presented in this survey for energy efficiency of WSN. A comprehensive survey of several way under structured and unstructured wireless sensor networks for clustering, routing, data collection and aggregation is presented with primary issues.**

***Keywords*— Wireless Sensor Networks, Clustering, Network Lifetime, Energy Efficiency, Stable Election, EEDRR.**

I. Introduction

A WSN is defined as a network of small devices, called sensor nodes, which are spatially dispersed and work cooperatively to transmit information collected from the environment through wireless links [1][2]. The data collected by the different sensor nodes is sent to a base station which is either used locally or is connected to Internet. In recent years, Wireless Sensor Networks (WSNs) and Internet of Thing (IoT) devices have become widely applied research interest [3][4]. WSN is well developed and established for economic devices which brings IoT applications to be richer sensing, efficient and actuation capabilities [5]. With several industrial applications and commercial opportunities springing up every day, the WSN and IoT market is forecast to grow exponentially from 2010 to 2017 [6][7]. Figure 1 presents the predicted growth in financial gain from the WSN and IoT market for the period of 2010-2017.

A regular wireless sensor network (WSN) is considered as an particular variety of wireless ad hoc networks with reduced or no mobility. In WSN, sensor gather information about environmental phenomenon or the occurrence of events such as rise or drop in temperature [8][9]. Sensor networks are usually composed of "nodes", it has a specific name that is "Sensor" because these nodes are furnished with automatic sensors. A sensor node is a type of electro-mechanical device which converts a sensed attribute like temperature, humidity, pressure, vibrations into a data pattern readout by the users [10]. In WSN, nodes are not mobile however, it is a category

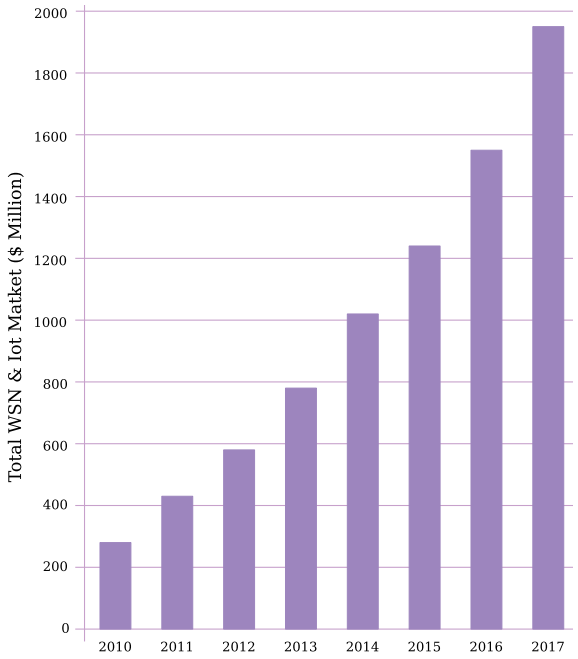

Fig. 1. WSN market 2010−2017 ($ Millions)

of adhoc networks. So in case of ad-hoc network, the mobility characteristic is more. Data are inquired depending on bounded physical quantity in wireless sensor network. A sensor node have transducer, an embedded processor with small memory unit and a wireless transceiver, all these devices run on the power supplied by an attached battery [11, 12]. The modern wireless sensors nodes are electromechanical and they have been used today they are widely used in industry process control, healthcare applications, traffic control, home automation, environmental monitoring and battle field surveillance [13].

This paper provides a comprehensive survey and issues regarding energy efficiency and network lifetime of wireless sensor network. An exploratory analysis is presented on energy efficient protocols and methods used in wireless sensor networks.

II. WSN Architecture

For monitoring and information gaining about environment, hundreds or thousands of sensor nodes make the sensor network. The functionalities like sensing, data processing, storing, location finding, data packet transmission, power consumption etc. are available in each of the nodes [14, 15].
The main components of WSN are:

Sensor Node: It is the primary component of a WSN. It carry multiple tasks in a network, such as sensing, data processing, storing, searching, routing and transmission.

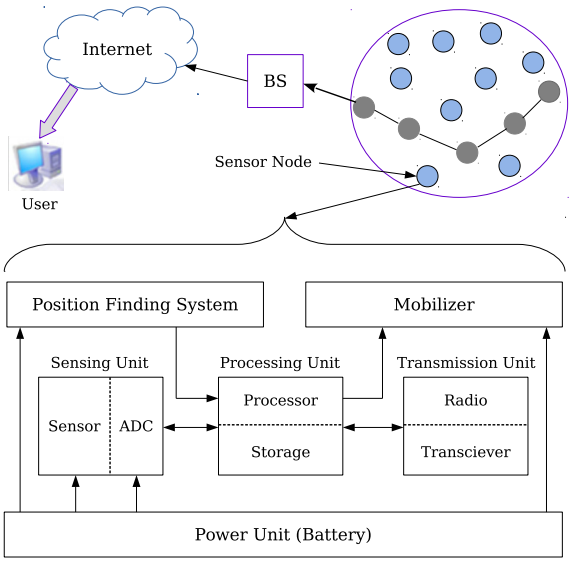

Fig. 2. Architecture of Wireless Sensor Network

Clusters: It is a group of sensor nodes. Normally sensor nodes are collected into clusters. Clusters are the organizational unit for WSNs. The cluster simplify the task of communication by dividing the dense network into groups.

Cluster Head: Cluster heads (CHs) are the group leader of a cluster. All sensor node send their data to the cluster head within a cluster. CHs are required to organize activities in the cluster. These tasks include data-aggregation and organizing the communication schedule of a cluster. Cluster head directly communicates with the base station.

Base Station: Base station (BS) provides the communication link between the sensor network and its end-user. It is at the higher level of the hierarchical in WSN. Base station receives data from the cluster heads.

End User: It is the user or observer of the WSN. The sensed data in a wireless sensor network can be used for various applications. Therefore, a general application may make use of the network data over the internet, using a Laptop, PDA, a desktop computer. In a basic queried sensor network where the required data is collected from a query sent through the network which is produced by the end user.

The structural model of sensor network is shown in figure 2. Transmission unit, sensing unit, processing unit, and power unit (battery) are the four major ingredients of sensor nodes

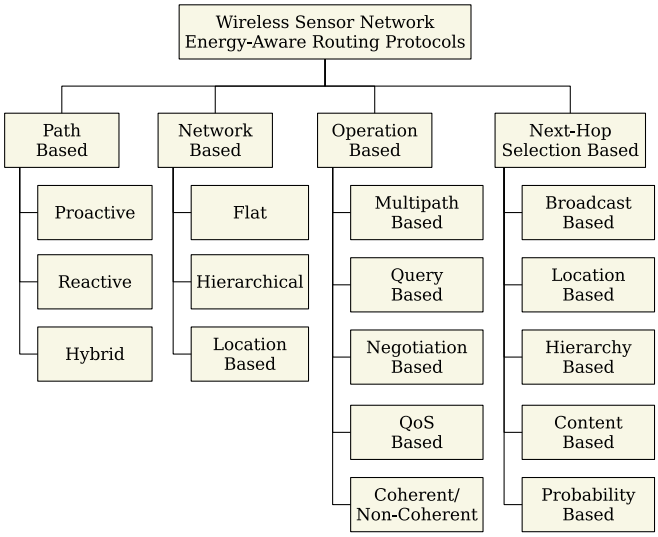

Fig. 3. Classification of Routing Protocols in WSN

assigned with dissimilar jobs. To detect the physical environment, sensing unit is used and reports the CPU to compute or process and store the sensed data. Transmission unit is tasked to accept the information from CPU and convey it to the cluster head or base station. Power unit regulate battery power to sensor node [16].

Due to various characteristics that distinguish WSNs from other kind of wireless networks like mobile ad hoc networks (MANET) or cellular networks, routing in WSN is major challenging task [17]. These include very dense deployment of sensor nodes, significant redundancy of data, limited bandwidth and limited power of transmission.

III. Classification Survey of Energy-Aware Routing Protocols in WSN

For designing network routing, energy efficiency is a fundamental issue as sensor nodes have limited power supply, low memory and limited processing power in structured as well as unstructured wireless sensor networks.

In wireless sensor networks, high sensor node density eliminates them from being totally isolated from each other therefore, sensor nodes are expected to be highly connected. This characteristic combines multi-hop in wireless sensor networks where each sensor node reveal a double role as data sender as well as data router [18]. Rerouting of packets and reconfiguration of the wireless sensor network may be required due to the malfunctioning of some sensor nodes by energy drain out which can cause topological changes. This occurs as instability in network topology and decrement in network coverage region [19][20].

As presented in Figure 3, most of the routing protocols are categorized according to the path based routing as proactive, reactive or hybrid, network structure based as flat, hierarchical, or location-based, protocol operation based as multi-path, query, negotiation, Quality of Service (QoS) or coherent/non-

coherent and next hop selection based as broadcast, location, probabilistic, content or hierarchical [21].

Route establishment can be accomplished by proactive, reactive or hybrid protocols. Proactive protocols continuously transmit data by maintaining recent lists of destinations and their paths by periodically distributing routing tables throughout the wireless sensor network. Network based routing protocols depend on the network arrangement strategy and this type of protocols are under three categories: flat, hierarchical and location based. Flat based routing is applied when enormous sensor nodes are required to impart same responsibility [22].

In hierarchical-based routing, for cluster head selection, processing and transmitting data, high energy sensor nodes are selected. Whereas, low energy nodes are selected for sensing and sending sensed data to the cluster heads. Location-based routing protocols carry out routing based on the geographical location of sensor nodes by using their position information instead of their links information for routing and located mostly by means of GPS [23].

Routing protocols are basically categorized according to their characteristics affected by these functionalities such as: multipath, query-based, QoS-based, negotiation-based, coherent and non-coherent routing protocols. Multiple path selection is followed by a message to reach destination in case of multipath routing protocols so that delay is reduced to improve the network performance. Next-hop selection based routing protocols can be categorized under following: broadcast based, location based, hierarchy based, content-based and probability based. Each node in the network decides individually whether to forward a message or not in broadcast-based routing protocols [24].

IV. Proposed Approach

Due to battery power limitations, researchers are now working on the structures and methods of energy aware protocols for wireless sensor network. Because, generally, the battery of sensor node in WSNs are equipped as one time limited power source. There are some limitations in each specific routing protocol, and they use their own strategies for efficient routing to overcome limitations.

For improvement and enhancement of the network lifetime, clustering provides an efficient and effective way [25]. The clustering protocols discussed as path, network, operation and next-hop selection based protocols usually apply two techniques, selection of cluster heads with more residual energy and rotation of cluster heads (CHs). These works on the probability basis periodically, for fairly even distribution of energy consumption among sensor nodes in each cluster and enhance the network lifetime. When cluster heads cooperate with other cluster heads for forwarding their data packets to the base station, then the cluster heads nearer to the base station are loaded with high data packet transmission traffic and it tend to die early, leaving areas of the network uncovered and produce network partition.

For solving limitations, soft computing techniques and unequal clustering mechanism can be proposed for periodical gathering of data packets in wireless sensor networks. It groups the sensor nodes into the clusters of unequal size, and clusters closer to the base station (sink) have smaller in size than those farther away from the base station. Thus cluster heads nearer to the base station can preserve some energy for the inter-cluster data packet forwarding. Soft computing techniques are helpful for efficient cluster head selection and routing.

V. Conclusion

This survey presents categories as path, network, operation and next-hop selection based routing protocols in wireless sensor network. The general and comprehensive analysis of these energy efficient methods in WSN have been presented, by which network lifetime can be enhanced. Researchers mainly focused on hierarchical routing protocols which provide energy efficiency and enhanced the network lifetime. The soft computing techniques and unequal clustering mechanism is presented as an improvement over existing hierarchical routing protocols. Hierarchical routing protocols are effective, but still major future challenging issues are needed to be developed in the sensor networks.

References

[1] A. Forster, *What are Wireless Sensor Networks?* IEEE, 2016.

[2] A. A. Ahmed, H. Shi, and Y. Shang, "A survey on network protocols for wireless sensor networks," in *Information Technology: Research and Education, 2003. Proceedings. ITRE2003. International Conference on*, Aug 2003, pp. 301–305.

[3] Q. Chi, H. Yan, C. Zhang, Z. Pang, and L. D. Xu, "A reconfigurable smart sensor interface for industrial wsn in iot environment," *IEEE Transactions on Industrial Informatics*, vol. 10, no. 2, pp. 1417–1425, May 2014.

[4] E. Fitzgerald, M. Pióro, and A. Tomaszewski, "Energy-optimal data aggregation and dissemination for the internet of things," *IEEE Internet of Things Journal*, vol. 5, no. 2, pp. 955–969, April 2018.

[5] S.-H. Yang, *Principle of Wireless Sensor Networks*. London: Springer London, 2014, pp. 7–47. [Online]. Available: https://doi.org/10.1007/978-1-4471-5505-8_2

[6] J. Lambrechts and S. Sinha, *Population Growth in Developing Countries and Smart City Fundamentals. The Internet-of-Things and Wireless Sensor Networks*. Cham: Springer International Publishing, 2016, pp. 29–62. [Online]. Available: https://doi.org/10.1007/978-3-319-28358-6_2

[7] N. C. Luong, D. T. Hoang, P. Wang, D. Niyato, D. I. Kim, and Z. Han, "Data collection and wireless communication in internet of things (iot) using economic analysis and pricing models: A survey," *IEEE Communications Surveys Tutorials*, vol. 18, no. 4, pp. 2546–2590, Fourthquarter 2016.

[8] T. Y. Chen, H. W. Wei, Y. C. Cheng, W. K. Shih, and H. Y. Chen, "An efficient routing algorithm to optimize the lifetime of sensor network using wireless charging vehicle," in *2014 IEEE 11th International Conference on Mobile Ad Hoc and Sensor Systems*. IEEE, Oct 2014, pp. 501–502.

[9] T. Fujii, S. Takegi, T. Nakayama, M. Ohta, and O. Takyu, "Highly efficient environment aware wireless sensor network," in *2016 13th IEEE Annual Consumer Communications Networking Conference (CCNC)*, Jan 2016, pp. 256–257.

[10] M. Kuorilehto, M. Hännikäinen, and T. D. Hämäläinen, "A survey of application distribution in wireless sensor networks," *EURASIP Journal on Wireless Communications and Networking*, vol. 2005, no. 5, pp. 1–15, 2005.

[11] C. Ma and Y. Yang, "Battery-aware routing for streaming data transmissions in wireless sensor networks," in *2nd International Conference on Broadband Networks, 2005.* IEEE, Oct 2005, pp. 464–473 Vol. 1.
[12] S. Emami, "Battery life time of coin cell operated wireless sensor networks," in *2014 IEEE 11th Consumer Communications and Networking Conference (CCNC)*, Jan 2014, pp. 7–10.
[13] N. M. Boers, P. Gburzyński, I. Nikolaidis, and W. Olesiński, "Developing wireless sensor network applications in a virtual environment," *Telecommunication Systems*, vol. 45, no. 2, pp. 165–176, 2010.
[14] W. R. Heinzelman, A. Chandrakasan, and H. Balakrishnan, "An application-specific protocol architecture for wireless microsensor networks," *IEEE Transactions on Wireless Communication*, vol. 1, no. 12, p. 660–670, Oct. 2002.
[15] L. Song and D. Hatzinakos, "Architecture of wireless sensor networks with mobile sinks: Sparsely deployed sensors," *IEEE Transactions on Vehicular Technology*, vol. 56, no. 4, pp. 1826–1836, July 2007.
[16] S. Emami, "Parallel battery configuration for coin cell operated wireless sensor networks," in *2013 IEEE 24th Annual International Symposium on Personal, Indoor, and Mobile Radio Communications (PIMRC)*, Sept 2013, pp. 2317–2320.
[17] J. N. Al-Karaki and A. E. Kamal, "Routing techniques in wireless sensor networks: a survey," *IEEE Wireless Communications*, vol. 11, no. 6, pp. 6–28, Dec 2004.
[18] C.-F. Cheng, T.-Y. Wu, and H.-C. Liao, "A density-barrier construction algorithm with minimum total movement in mobile wsns," *Computer Networks*, vol. 62, pp. 208 – 220, 2014. [Online]. Available: http://www.sciencedirect.com/science/article/pii/S1389128613004027
[19] H. S. Ramos, A. C. Frery, A. Boukerche, E. M. R. Oliveira, and A. A. F. Loureiro, "Topology-related metrics and applications for the design and operation of wireless sensor networks," *ACM Trans. Sen. Netw.*, vol. 10, no. 3, pp. 53:1–53:35, May 2014. [Online]. Available: http://doi.acm.org/10.1145/2512328
[20] L. Mottola, G. P. Picco, M. Ceriotti, c. Gună, and A. L. Murphy, "Not all wireless sensor networks are created equal: A comparative study on tunnels," *ACM Trans. Sen. Netw.*, vol. 7, no. 2, pp. 15:1–15:33, Sep. 2010. [Online]. Available: http://doi.acm.org/10.1145/1824766.1824771
[21] R. E. Mohamed, A. I. Saleh, M. Abdelrazzak, and A. S. Samra, "Survey on wireless sensor network applications and energy efficient routing protocols," *Wireless Personal Communications*, vol. 101, no. 2, pp. 1019–1055, Jul 2018. [Online]. Available: https://doi.org/10.1007/s11277-018-5747-9
[22] S. Yadav and R. S. Yadav, "A review on energy efficient protocols in wireless sensor networks," *Wireless Networks*, vol. 22, no. 1, pp. 335–350, Jan 2016. [Online]. Available: https://doi.org/10.1007/s11276-015-1025-x
[23] D. Koutsonikolas, S. M. Das, Y. C. Hu, and I. Stojmenovic, "Hierarchical geographic multicast routing for wireless sensor networks," *Wireless Networks*, vol. 16, no. 2, pp. 449–466, Feb 2010. [Online]. Available: https://doi.org/10.1007/s11276-008-0146-x
[24] D. Zhang, G. Li, K. Zheng, X. Ming, and Z. Pan, "An energy-balanced routing method based on forward-aware factor for wireless sensor networks," *IEEE Transactions on Industrial Informatics*, vol. 10, no. 1, pp. 766–773, Feb 2014.
[25] A. S. K. Mammu, U. Hernandez-Jayo, N. Sainz, and I. de la Iglesia, "Cross-layer cluster-based energy-efficient protocol for wireless sensor networks," *Sensors*, vol. 15, no. 4, p. 8314, 2015.