Requirements of Routing Algorithms for Sensor Networks

∗ Prof. Prashant J Bagga, ∗∗ Prof. Nagendra P Gajjar

* Assistant Professor, Institute of Diploma Studies, Nirma University, Ahmedabad, India
** Associate Professor, Institute of Technology, Nirma University, Ahmedabad, India

ABSTRACT

Wireless Sensor Networks (WSNs) consist of small nodes with sensing, computation, and wireless communications capabilities. Many routing, power management, and data dissemination protocols have been specially designed for WSNs where energy awareness is an essential design issue. The focus, however, has been given to the routing protocols which might differ depending on the application and network architecture. In this paper, we present design challenges that are required to be fulfilled for routing techniques in WSNs. We first outline the differences in the approach required for designing routing algorithms for WSNs as compared to other Wireless networks followed by a design issues in routing algorithms for WSNs. The paper concludes with possible future research areas.

Keywords: *Wireless networks, communication, routing, data aggregation, QoS and sensor nodes.*

1. INTRODUCTION

Sensor networks have potential applications in many areas. The application areas are classified into environment, military and civil. Military Applications includes surveillance, battlefield assessment etc. Structure monitoring systems detect, localize, and estimate the extent of damage. Pollution and Toxic Level Monitoring sensors collect data from industrial areas and areas where toxic spills occur. These are useful in sensing nuclear, biological, and chemical phenomena in environment and transmitting it to remote stations for analysis. Rainfall and Flood Monitoring networks have water level, wind and temperature sensors and the data is transmitted to a central database for analyzing and forecasting weather. Other Applications involves Habitat monitoring for determining biocomplexity. Health applications involve tracking patients, monitoring drug administrations in hospitals, etc. Great commercial opportunities exist in the household electronics and in realizing the smart home and office environments.

2. DIFFERENCES IN THE ROUTING CHARACTERISTICS COMPARED TO OTHER NETWORKS

Routing in WSNs is very challenging due to the inherent characteristics that distinguish these networks from other wireless networks like mobile ad hoc networks or cellular networks.

First, due to the relatively large number of sensor nodes, it is not possible to build a global addressing scheme for the deployment of a large number of sensor nodes as the overhead of ID maintenance is high. Thus, traditional IP-based protocols may not be applied to WSNs. Furthermore, sensor nodes that are deployed in an ad hoc manner need to be self-organizing as the ad hoc deployment of these nodes requires the system to form connections and cope with the resultant nodal distribution especially that the operation of the sensor networks is un-attended. In WSNs, sometimes getting the data is more important than knowing the IDs of which nodes sent the data.

Second, in contrast to typical communication networks, almost all applications of sensor networks require the flow of sensed data from multiple sources to a particular Base Station (BS).

Third, sensor nodes are tightly constrained in terms of energy, processing, and storage capacities. Thus, they require careful resource management.

Fourth, in most application scenarios, nodes in WSNs are generally stationary after deployment except for, may be, a few mobile nodes. Nodes in other traditional wireless networks are free to move, which results in unpredictable and frequent topological changes. However, in some applications, some sensor nodes may be allowed to move and change their location (although with very low mobility).

Fifth, sensor networks are application specific, i.e., design requirements of a sensor network change with application. For example, the challenging problem of low-latency precision tactical surveillance is different from that required for a periodic weather-monitoring task.

Sixth, position awareness of sensor nodes is important since data collection is normally based on the location. Currently, it is not feasible to use Global Positioning System (GPS) hardware for this purpose. Methods based on triangulation [4], for example, allow sensor nodes to approximate their position using radio strength from a few known points. It is found in [4] that algorithms based on triangulation or multilateration can work quite well under conditions where only very few nodes know their positions apriori, e.g., using GPS hardware. Still, it is favorable to have GPS-free solutions [5] for the location problem in WSNs.

Finally, data collected by many sensors in WSNs is typically based on common phenomena; hence there is a high probability that this data has some redundancy. Such redundancy needs to be exploited by the routing protocols to improve energy and bandwidth utilization. Usually, WSNs are data-centric networks in the sense that data is requested based on certain attributes, i.e., attribute-based

addressing. An attribute-based address is composed of a set of attribute-value pair query. For example, if the query is something like [temperature > 60F], then sensor nodes that sense temperature > 60F only need to respond and report their readings.

Due to such differences, many new algorithms have been proposed for the routing problem in WSNs. These routing mechanisms have taken into consideration the inherent features of WSNs along with the application and architecture requirements. The task of finding and maintaining routes in WSNs is nontrivial since energy restrictions and sudden changes in node status (e.g., failure) cause frequent and unpredictable topological changes. To minimize energy consumption, routing techniques proposed in the literature for WSNs employ some well-known routing tactics as well as tactics special to WSNs, e.g., data aggregation and in-network processing, clustering, different node role assignment, and data-centric methods were employed.

3. ROUTING CHALLENGES AND DESIGN ISSUES IN WSNS

Despite the innumerable applications of WSNs, these networks have several restrictions, e.g., limited energy supply, limited computing power, and limited bandwidth of the wireless links connecting sensor nodes. One of the main design goals of WSNs is to carry out data communication while trying to prolong the lifetime of the network and prevent connectivity degradation by employing aggressive energy management techniques [6]. The design of routing protocols in WSNs is influenced by many challenging factors. In the following, we summarize some of the routing challenges and design issues that affect routing process in WSNs.

Node deployment: Node deployment in WSNs is application dependent and affects the performance of the routing protocol [7]. The deployment can be either deterministic or randomized.. If the resultant distribution of nodes is not uniform, optimal clustering becomes necessary to allow connectivity and enable energy efficient network operation.

Energy consumption: Sensor nodes can use up their limited supply of energy performing computations and transmitting information in a wireless environment. Sensor node lifetime shows a strong dependence on the battery lifetime [1]. In a multihop WSN, each node plays a dual role as data sender and data router. The malfunctioning of some sensor nodes due to power failure can cause significant topological changes and might require rerouting of packets and reorganization of the network.

Data Reporting: Data sensing and reporting in WSNs is dependent on the application and the time criticality of the data reporting. Data reporting can be categorized as either time-driven (continuous), event-driven, query-driven, and hybrid [2]. The time-driven delivery model is suitable for applications that require periodic data monitoring. In event-driven and query-driven models, sensor nodes react immediately to sudden and drastic changes in the value of a sensed attribute due to the occurrence of a certain event or a query is generated by the

BS. As such, these are well suited for time critical applications. A combination of the previous models is also possible. The routing protocol is highly influenced by the data reporting model with regard to energy consumption and route stability.

Fault Tolerance: Some sensor nodes may fail or be blocked due to lack of power, physical damage, or environmental interference. The failure of sensor nodes should not affect the overall task of the sensor network. If many nodes fail, MAC and routing protocols [8] must accommodate formation of new links and routes to the data collection BS. This may require actively adjusting transmit powers and signaling rates on the existing links to reduce energy consumption, or rerouting packets through regions of the network where more energy is available. Therefore, multiple levels of redundancy may be needed in a fault-tolerant sensor network.

Scalability: The number of sensor nodes deployed in the sensing area may be in the order of hundreds or thousands, or more. Any routing scheme must be able to work with this huge number of sensor nodes [9].

Network Dynamics: Most of the network architectures assume that sensor nodes are stationary. However, mobility of both BS and sensor nodes is sometimes necessary in many applications [3]. Routing messages from or to moving nodes is more challenging since route stability becomes an important issue, in addition to energy, bandwidth etc. Moreover, the sensed phenomenon can be either dynamic or static depending on the application, e.g., it is dynamic in a target detection/racking application, while it is static in forest monitoring for early fire prevention. Monitoring static events allows the network to work in a reactive mode, simply generating traffic when reporting. Dynamic events in most applications require periodic reporting and consequently generate significant traffic to be routed to the BS.

Coverage: In WSNs, each sensor node obtains a certain view of the environment. A given sensor's view of the environment is limited both in range and in accuracy; it can only cover a limited physical area of the environment [10]. Hence, area coverage is also an important design parameter in WSNs.

Data Aggregation: Since sensor nodes may generate significant redundant data, similar packets from multiple nodes can be aggregated so that the number of transmissions is reduced. Data aggregation is the combination of data from different sources according to a certain aggregation function, e.g., duplicate suppression, minima, maxima and average. This technique has been used to achieve energy efficiency and data transfer optimization in a number of routing protocols [11]. Signal processing methods can also be used for data aggregation. In this case, it is referred to as data fusion where a node is capable of producing a more accurate output signal by using some techniques such as beam forming to combine the incoming signals and reducing the noise in these signals.

Quality of Service: In some applications, data should be delivered within a certain period of time from the moment it is sensed; otherwise the data will be useless. Therefore bounded latency for data delivery is another condition for time-constrained applications. However, in

many applications, conservation of energy, which is directly related to network lifetime, is considered relatively more important than the quality of data sent [12]. As the energy gets depleted, the network may be required to reduce the quality of the results in order to reduce the energy dissipation in the nodes and hence lengthen the total network lifetime. Hence, energy-aware routing protocols are required to capture this requirement.

Comparison of routing protocols: Table 1 and 2 represents comparison of routing protocols proposed by different authors on the basis of above discussed properties. In this paper we compared the following routing protocols according to their design characteristics.
SPIN [15]: Sensor Protocols for Information via Negotiation.
DD [13]: Directed Diffusion
LEACH [1]: Low Energy Adaptive Clustering Hierarchy
PEGASIS [13]: Power-Efficient Gathering in Sensor Information Systems
TTDD [13]: Two-Tier Data Dissemination

Table 1: Comparison of routing protocols in WSNs

Protocol	Data Aggregation	Localization	Quality of Service	Scalability	Multi path	Query Based
SPIN	Yes	No	No	Limited	Yes	Yes
DD	Yes	Yes	No	Limited	Yes	Yes
LEACH	Yes	Yes	No	Good	No	No
PEGASIS	Yes	Yes	No	Good	No	No
TTDD	No	No	No	Low	Possible	Possible

Table 2: Comparison of routing protocols in WSNs

Protocol	Classification	Mobility	Energy consumption	Negotiation Based
SP--*IN	Flat	Possible	Limited	Yes
DD	Flat	Limited	Limited	Yes
LEACH	Hierarchical	Fixed BS	Maximum for CH	No
PEGASIS	Hierarchical	Fixed BS	Maximum for CH	No
TTDD	Hierarchical	Yes	Limited	No

4. CONCLUSION

In this paper, we presented a summary of issues related to design of routing algorithms in WSNs. The common objective is of trying to extend the lifetime of the sensor network, while not compromising data delivery. The crucial point in the development of wireless sensor protocols and hardware is to keep in mind the resource crunch faced by these devices. Energy conservation and parsimonious energy expenditure must be built in every aspect of design.

5. FUTURE DIRECTIONS

Although the performance of current routing protocols is promising in terms of energy efficiency, further research would be needed to address issues such as Quality of Service (QoS) posed by video and imaging sensors and real-time applications. Another interesting issue for routing protocols is the consideration of node mobility. Most of the current protocols assume that the sensor nodes and the BS are stationary. However, there might be situations such as battle environments where the BS and possibly the sensors need to be mobile. In such cases, the frequent update of the position of the command node and the sensor nodes and the propagation of that information through the network may excessively drain the energy of nodes. New routing algorithms are needed in order to handle the overhead of mobility and topology changes in such energy constrained environment.

REFERENCES

[1] [1] W. Heinzelman, A. Chandrakasan and H. Balakrishnan, "Energy-Efficient Communication Protocol for Wireless Microsensor Networks," Proceedings of the 33rd Hawaii International Conference on System Sciences, January 2000.

[2] [2] Y. Yao and J. Gehrke, "The cougar approach to in-network query processing in sensor networks", in SIGMOD Record, September 2002.

[3] [3] F. Ye, H. Luo, J. Cheng, S. Lu, L. Zhang, "A Two-tier data dissemination model for large-scale wireless sensor networks", proceedings of ACM/IEEE MOBICOM, 2002.

[4] [4] N. Bulusu, J. Heidemann, D. Estrin, "GPS-less low cost outdoor localization for very small devices", Technical report 00-729, Computer science department, University of Southern California, Apr. 2000.

[5] [5] A. Savvides, C-C Han, and M. Srivastava, "Dynamic Fine-grained localization in Ad-Hoc networks of sensors," Proceedings of the Seventh ACM Annual International Conference on Mobile Computing and Networking (MobiCom), July 2001. pp.166-179

[6] [6] Jamal N. Al-Karaki Ahmed E. Kamal "Routing Techniques in Wireless Sensor Networks: A Survey" Dept. of Electrical and Computer Engineering Iowa State University, Ames, Iowa.

[7] [7] S. Tilak, N. Abu-Ghazaleh, W. Heinzelman,\A taxonomy of wireless micro-sensor network models", ACM SIGMOBILE Mobile Computing and Communications Review, Volume 6, Issue 2 (April 2002), pp 28-36.

[8] [8] John Heidemann, Fabio Silva, Chalermek Intanagonwiwat, Ramesh Govindan, Deborah Estrin, and Deepak Ganesan, "Building efficient wireless sensor networks with low-level naming," in

Proceedings of the Symposium on Operating Systems Principles, Lake Louise, Banff, Canada, Oct. 2001.

[9]   [9] Chalermek Intanagonwiwat, Ramesh Govindan, and Deborah Estrin, "Directed diffusion: A scalable and robust communication paradigm for sensor networks," in Proceedings of the ACM/IEEE International Conference on Mobile Computing and Networking, Boston, MA, USA, Aug. 2000, pp.56–67, ACM.

[10]   [10] X. Wang, G. Xing, Y. Zhang, C. Lu, R. Pless, C. D. Gill, "Integrated Coverage and Connectivity Configuration in Wireless Sensor Networks. Proc. of 1st ACM Conference on Embedded Networked Sensor Systems, 2003.

[11]   [11] C. Intanagonwiwat, R. Govindan, and D. Estrin, "Directed Diffusion: a Scalable and Robust communication Paradigm for Sensor Networks,

Proc. ACM Mobi- Com 2000, Boston, MA, pp. 56–67, 2000.

[12]   [12]] I. F. Akyildiz et al., "Wireless Sensor Networks: a survey" Computer Networks, Vol. 38, pp. 393-422, March 2002.

[13]   [13] F. Ye, H. Luo, J. Cheng, S. Lu, L. Zhang, "A Two-tier data dissemination model for large-scale wireless sensor networks", proceedings of ACM/IEEE MOBICOM, 2002.

[14]   [14] S. Lindsey, C. Raghavendra, "PEGASIS: Power-Efficient Gathering in Sensor Information Systems", IEEE Aerospace Conference Proceedings, 2002, Vol. 3, 9-16 pp. 1125-1130.

[15]   [15] J. Kulik, W. R. Heinzelman, and H. Balakrishnan, "Negotiation-based protocols for disseminating information in wireless senssor networks," Wireless Networks, Volume: 8, pp. 169-185, 2002.