Characteristic Issues for Routing Protocols in Wireless Sensor Networks based on Categorization

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***Abstract*—Wireless Sensor Networks (WSNs) plays a vital role in many real world day to day applications. The sensor nodes are placed in different locations to sense the desired data and the consolidated data will be sent back to desired users. To complete this job we need an efficient and stable routing protocol that can select the best and optimal route between the sensor nodes and users. The environment of the sensors with low powered batteries and memory to full fill this goal. It is almost impossible to change the battery of the sensor node and it becomes big challenge to maintain the good battery life. To extend the lifetime of a wireless sensor network it need energy efficient routing protocol. I reviewed recent energy-efficient wireless sensor routing protocols. In this paper I am presenting the importance of rooting in wireless sensor networks and its environment characteristics.**

Keywords: Wireless Sensor Networks (WSNs), routing protocols, Design Issues, Applications, Optimization Techniques.

Algorithm Paradigms for Wireless Sensor Networks[26]

Routing technique is needed for sending the data between the sensor nodes and the base stations

The wireless sensor applications require procedures or algorithms for its execution to communicate with nodes. [26]There are three kinds of algorithms can be executed on wireless sensor networks [4]:

- ***Centralized Algorithms*:** They are executed in a node that posses the knowledge of the whole network. These algorithms are quite rare because of the cost of transmitting the data to make the node know the status of the complete network.
- ***Distributed Algorithms*:** message passing supports this type of communication.
- ***Local based Algorithms[26]*:** The nodes use restricted data acquired from a close area. With this local information, the algorithm is executed in one node.

To determine the routing protocol in the network these algorithm paradigm is an important factor. If localized algorithms are used, the routing protocol should reinforce and optimize the communication between neighbors. On the other hand, for centralized algorithms, combining the messages that simultaneously go the central node (even when they are generated by different sources) could be an advantage. The distributed algorithms should efficiently support the communication between any two pairs of nodes. Finally, local based algorithms depend on some solution that provides geographic coordinates, like GPS, making the solution more expensive[26].

APPLICATIONS OF SENSOR NETWORKS:

The sensor networks can be used in Disaster Relief, Emergency Rescue operation, Military, Habitat Monitoring, Health Care, Environmental monitoring, Home networks, detecting chemical, biological, radiological, nuclear, and explosive material etc.

Military[25]: Military situation awareness [6], Sensing intruders on basis Detection of enemy unit movements an land and sea[8]

Emergency situations: Disaster management. Fire/water detectors Hazardous chemical level and fires[8]

Physical world :Environmental monitoring of water and soil [2] ,Habitual monitoring [2] ,Observation of biological and artificial systems [2]

Medical and health :Sensors for blood flow, respiratory rate, ECG(electrocardiogram), pulse oxy-meter, blood pressure and oxygen measurement [9]. Monitoring people's location and health condition

Industrial :Factory process control and industrial automation [1] Monitoring and control of industrial equipment

Home networks: Home appliances, location awareness (Bluetooth) Person locator

Automotive: Tire pressure monitoring Active mobility Coordinated vehicle tracking [1]

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, limited memory and limited bandwidth of the wireless links connecting sensor nodes. The main design goal of WSN 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. The design of routing protocols in WSNs is influenced by many challenging factors. In the following section, 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. The deployment is either deterministic (manual) or self-organizing (random). In deterministic situations, the sensors are manually placed and data is routed through pre-determined paths. Whereas in self-organizing systems, the sensor nodes are scattered randomly creating an infrastructure in an ad hoc manner.
- **Energy Conservation:** During the creation of an infrastructure, the process of setting up the routes is greatly influenced by energy considerations. Since the transmission power of a wireless radio is proportional to distance squared or even higher order in the presence of obstacles, multi-hop routing will consume less energy than direct communication.
- **Fault Tolerance:** If sensor nodes fail, MAC and routing protocols must accommodate formation of new links so that sensor node failure should not affect the overall task of the 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. In addition, sensor network routing protocols should be scalable enough to respond to events in the environment.
- **Network dynamics:** Most of the network architectures assume that sensor nodes are stationary, because there are very few setups that utilize mobile sensors. It is sometimes necessary to support the mobility of sinks or cluster- heads (gateways).
- **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. Hence, area coverage is also an important design parameter in WSNs.
- **Connectivity:** High node density in sensor networks precludes them from being completely isolated from each other. Therefore, sensor nodes are expected to be highly connected.
- **Sensor network topology:** It must be maintained even with very high node density.
- **Environment:** Nodes should be operating in inaccessible location because of hostile environment.
- **Production Costs:** The cost of a single node must be low.
- **Hardware Constraint:** All Subunits of sensor node (e.g. sensing, processing, communication, power, location finding system and mobilizer) must consume extremely low power and be contained within an extremely small volume.
- **Transmission Media:** Generally, Transmission Media is wireless (RF or Infrared), which is affected by fading and high error rate and affect the operation of WSNs.

OPTIMIZATION TECHNIQUES FOR ROUTING IN WSN[26]

The particular characteristics of wireless sensor networks and their constraints have prompted the need for specific requirements to routing protocols. When compared to mobile *ad hoc* networks routing protocols, the algorithms in wireless sensor networks usually realize the following specifications[26]:

Attribute-based

In these algorithms, the sink sends queries to certain regions and waits for the response from the sensors located in this area. Following an attribute-value scheme, the queries inform about the required data[26]. The selection of the attributes depends on the application. An important characteristic of these schemes is that the content of the data messages is analyzed in each hop to make decisions about routing.

Energy Efficiency

Multiple routes can communicate a node and the sink. The aim of energy-aware algorithms is to select those routes that are expected to maximize the network lifetime[25]. To do so, the routes composed of nodes with higher energy resources are preferred[26].

Data Aggregation

Data collected in sensors are derived from common phenomena so nodes in a close area usually share similar information. A way to reduce energy consumption is data aggregation. Aggregation consists of suppressing redundancy in different data messages. When the suppression is achieved by some signal processing techniques, this operation is called data fusion[26].

Addressing Scheme

Wireless sensor networks are formed by a significant number of nodes so the manual assignation of unique identifiers is infeasible. The use of the MAC address or the GPS coordinates is not recommended as it introduces a significant payload. However, network-wide unique addresses are not needed to identify the destination node of a specific packet in wireless sensor networks. In fact, attribute-based addressing fits better with the specificities of wireless sensor networks. In this case, an attribute such as node location and sensor type is used to identify the final destination[26].

Location-based

When this technique is used, a node decides the transmission route according to the localization of the final destination and the positions of some other nodes in the network[26].

Multipath Communication[26]

With this technique, nodes use multiple paths from an origin to a destination in the network. As multipath communications are intended to increase the reliability and the performance of the network, these paths should not share any link. Multipath communications can be accomplished in two ways. Firstly, one path is established as the active communication routing while the other paths are stored for future need, i.e. when the current active path is broken. On the other hand, it is also possible to distribute the traffic among the multiple paths[26].

Quality of Service[26]

The network application business and its functionalities prompt the need for ensuring a QoS (Quality of Service) in the data exchange. In particular, effective sample rate, delay

bounded and temporary precision are often required. Satisfying them is not possible for all the routing protocols as the demands may be opposite to the protocol principles. For instance, a routing protocol could be designed to extend the network lifetime while an application may demand an effective sample rate which forces periodic transmissions and, in turn, periodic energy consumptions[26].

ROUTING PROTOCOLS IN WSN

a. Data Centric Protocols[25]

i. **Sensor Protocols for Information via Negotiation (SPIN):** SPIN[18] protocol was designed to improve classic flooding protocols and overcome the problems they may cause, for example, implosion and overlap. The SPIN protocols are resource aware and resource adaptive. The SPIN protocols are based on two key mechanisms namely negotiation and resource adaptation. There are three messages defined in SPIN to exchange data between nodes. These are:

ADV message to allow a sensor to advertise a particular meta-data,

REQ message to request the specific data and

DATA message that carry the actual data.

ii. **Directed Diffusion[25]:** Directed diffusion[15][19] is a data-centric routing protocol for sensor query dissemination and processing. It meets the main requirements of WSNs such as energy efficiency, scalability, and robustness. Directed diffusion has several key elements namely data naming, interests and gradients, data propagation, and reinforcement. At the beginning of the directed diffusion process, the sink specifies a low data rate for incoming events. After that, the sink can reinforce one particular sensor to send events with a higher data rate by resending the original interest message with a smaller interval. Likewise, if a neighboring sensor receives this interest message and finds that the sender's interest has a higher data rate than before, and this data rate is higher than that of any existing gradient, it will reinforce one or more of its neighbors.

iii. **Rumor routing[25]:** Rumor routing is another variation of Directed Diffusion and is mainly intended for contexts in which geographic routing criteria are not applicable. Rumor routing is a logical compromise between query flooding and event flooding application schemes . Rumor routing is an efficient protocol if the number of queries is between the two intersection points of the curve of rumor routing with those of query flooding and event flooding. Rumor routing is based on the concept of agent, which is a long-lived packet that traverses a network and informs each sensor it encounters about the events that it has learned during its network traverse.

iv. **COUGAR[25]:** COUGAR is an example of a data-centric approach which treats the whole network as a huge distributed database system and use declarative queries in order to abstract query processing from the network layer functions such as selection of relevant sensors. COUGAR includes architecture for the sensor database system where sensor nodes select a leader node among themselves to perform aggregation and transmit the data to the BS. The BS is responsible for generating a query plan, which specifies the necessary information about the data flow and in-network computation for the incoming query and send it to the relevant nodes. The query plan also describes how to select a leader for the query. The architecture provides in-network computation ability that can provide energy efficiency in situations when the generated data is huge independent methods for data query.

v. **ACQUIRE[25] (Active Query Forwarding in Sensor Networks):** ACQUIRE[20] is another data centric querying mechanism used for querying named data.. It provides superior query optimization to answer specific types of queries, called one-shot complex queries for replicated data. In this scheme, a node injects an active query packet into the network. Neighboring nodes that detects that the packet contains obsolete information, emits an update message to the node. Then, the node randomly selects a neighbor to propagate the query which needs to resolve it. As the active query progress through network, it is progressively resolved into smaller and smaller components until it is completely solved. Then, the query is returned back to the querying node as a completed response.

vi. **Energy-Aware Data-Centric Routing (EAD)[25]:** EAD is a novel distributed routing protocol, which builds a virtual backbone composed of active sensors that are responsible for in-network data processing and traffic relaying[21]. In this protocol, a network is represented by a broadcast tree spanning all sensors in the network and rooted at the gateway, in which all leaf nodes radios are turned off while all other nodes correspond to active sensors forming the backbone and thus their radios are turned on.

b. Hierarchical Protocols

i. **Low-energy adaptive clustering hierarchy (LEACH)[25]:** LEACH[22-23] is the first and most popular energy- efficient hierarchical clustering algorithm for WSNs that was proposed for reducing power consumption. The idea is to form clusters of the sensor nodes based on the received signal strength and use local cluster heads as routers to the sink. This will save energy since the transmissions will only be done by such cluster heads rather than all sensor nodes. The three important features of LEACH are:

- Localized co-ordination and control for cluster setup.
- Randomized cluster head rotation.
- Local compression to reduce global data communication.

Power-Efficient Gathering in Sensor Information Systems (PEGASIS): PEGASIS[24] is an extension of the LEACH protocol, Rather than forming multiple clusters, PEGASIS forms chains from sensor nodes so that each node transmits and receives from a neighbor and only one node is selected from that chain to transmit to the base station (sink). Gathered data moves from node to node, aggregated and eventually sent to the base station. The chain construction is performed in a greedy way.

ii. **Threshold Sensitive Energy Efficient Sensor Network**

Protocol (TEEN): TEEN) [10] is a hierarchical protocol designed to be responsive to sudden changes in the sensed attributes such as temperature. Responsiveness is important for time-critical applications, in which the network operated in a reactive mode. TEEN pursues a hierarchical approach along with the use of a data-centric mechanism. The sensor network architecture is based on a hierarchical grouping where closer nodes form clusters and this process goes on the second level until base station (sink) is reached[25].

iii. **Adaptive Periodic Threshold Sensitive Energy Efficient Sensor Network Protocol (APTEEN):** APTEEN[25]

[11] is an improvement to TEEN to overcome its shortcomings and aims at both capturing periodic data collections (LEACH) and reacting to time-critical events (TEEN). Thus, APTEEN is a hybrid clustering-based routing protocol that allows the sensor to send their sensed data periodically and react to any sudden change in the value of the sensed attribute by reporting the corresponding values to their CHs. The architecture of APTEEN is same as in TEEN[25].

iv. **Hybrid Energy-Efficient Distributed Clustering (HEED):** HEED extends the basic scheme of LEACH by using residual energy and node degree or density as a metrics for cluster selection to achieve power balancing [12]. It operates in multi-hop networks, using an adaptive transmission power in the inter-clustering communication[25]. HEED was proposed with four primary goals namely.

- **i.** Prolonging network lifetime by distributing energy consumption,
- **ii.** Terminating the clustering process within a constant number of iterations,
- **iii.** Minimizing control overhead, and
- **iv.** Producing well-distributed CHs and compact clusters.

c. Location-based protocols

i. **Geographic Adaptive Fidelity (GAF):** GAF [13] is an energy-aware routing protocol primarily proposed for MANETs, but can also be used for WSNs because it favors energy conservation. GAF conserves energy by turning off unnecessary nodes in the network without affecting the level of routing fidelity. It forms a virtual grid for the covered area. Each node uses its GPS-indicated location to associate itself with a point in the virtual grid[25].

ii. **Geographic and Energy-Aware Routing (GEAR):** GEAR [14] is an energy-efficient routing protocol proposed for routing queries to target regions in a sensor field, In GEAR, the sensors are supposed to have localization hardware equipped, for example, a GPS unit or a localization system [15] so that they know their current positions. Furthermore, the sensors are aware of their residual energy as well as the locations and residual energy of each of their neighbors. GEAR uses energy aware heuristics that are based on geographical information to select sensors to route a packet toward its destination region[25].

iii. **Minimum Energy Communication Network (MECN)** [16] sets up and maintains a minimum energy network for wireless networks by utilizing low power GPS. Although, the protocol assumes a mobile network, it is best applicable to sensor networks, which are not mobile[25]. A minimum power topology for stationary nodes including a master node is found. MECN assumes a master-site as the information sink, which is always the case for sensor networks[25].

iv. **The small minimum energy communication network (SMECN)** [17] is an extension to MECN. In MECN, it is assumed that every node can transmit to every other node, which is not possible every time. In SMECN possible obstacles between any pair of nodes are considered. However, the network is still assumed to be fully connected as in the case of MECN[25].

CONCLUSSION

Routing in sensor networks has attracted a lot of attention in the recent years and introduced unique challenges compared to traditional data routing in wired networks[25]. Routing protocols in WSNs is still an area of research as sensor nodes are finding newer and newer applications with time. One of the main challenges in the design of routing protocols for WSNs is energy efficiency due to the scarce energy resources of sensors[25]. The ultimate objective behind the routing protocol design is to keep the sensors operating for as long as possible, thus extending the network lifetime. The energy consumption of the sensors is dominated by data transmission and reception. Therefore, routing protocols designed for WSNs should be as energy efficient as possible to prolong the lifetime of individual sensors, and hence the network lifetime[25].

REFERENCES

[1] Romer, K., & Mattern, F. (2004). The design space of wireless sensor networks. IEEE wireless communications, 11(6), 54-61.
[2] Heinzelman, W. B., Murphy, A. L., Carvalho, H. S., & Perillo, M. A. (2004). Middleware to support sensor network applications. IEEE network, 18(1), 6-14.
[3] Lin, J., Liu, Y., & Ni, L. M. (2007, October). SIDA: self-organized ID assignment in wireless sensor networks. In 2007 IEEE International Conference on Mobile Adhoc and Sensor Systems (pp. 1-8). IEEE.
[4] Boukerche A., Nakamura E.F., Loureiro A.F. Algoritms for Wireless Sensor Networks. In: Boukerche A., editor. Algorithms and Protocols for Wireless Sensor Networks. John Wiley & Sons; Hoboken, NJ, USA: 2009.
[5] Akkaya, K., & Younis, M. (2005). A survey on routing protocols for wireless sensor networks. Ad hoc networks, 3(3), 325-349.
[6] Akyildiz, I. F., Pompili, D., & Melodia, T. (2005). Underwater acoustic sensor networks: research challenges. Ad hoc networks, 3(3), 257-279.
[7] Karl H., Willig A. Protocols and Architectures for Wireless Sensor Networks. John Wiley & Sons; Chichester, West Sussex, UK: 2005.
[8] Al-Karaki, J. N. (2006). Al-Mashagbeh: Energy-Centric Routing in Wireless Sensor Networks Computers and Communications, ISCC 06 Proceedings. In 11th IEEE Symposium.
[9] Kumar, P., Singh, M. P., & Triar, U. S. (2012). A review of routing protocols in wireless sensor network. International Journal of Engineering Research & Technology (IJERT), 1(4), 1-14.
[10] Manjeshwar, A., & Agrawal, D. P. (2001, April). TEEN: ARouting Protocol for Enhanced Efficiency in Wireless Sensor Networks. In ipdps (Vol. 1, p. 189).
[11] A. Manjeshwar and D. P. Agrawal, "APTEEN: A Hybrid Protocol for Efficient Routing and Comprehensive Information

Retrieval in Wireless Sensor Networks", in the Proceedings of the 2nd International Workshop on Parallel and Distributed Computing Issues in Wireless Networks and Mobile computing, San Francisco CA, April 2001, pp. 2009-1015.

[12] Younis, O., & Fahmy, S. (2004). HEED: a hybrid, energy-efficient, distributed clustering approach for ad hoc sensor networks. IEEE Transactions on mobile computing, 3(4), 366-379.

[13] Xu, Y., Heidemann, J., & Estrin, D. (2001, July). Geography-informed energy conservation for ad hoc routing. In Proceedings of the 7th annual international conference on Mobile computing and networking (pp. 70-84).

[14] Yu, Y., Govindan, R., & Estrin, D. (2001). Geographical and energy aware routing: A recursive data dissemination protocol for wireless sensor networks.

[15] Intanagonwiwat, C., Govindan, R., Estrin, D., Heidemann, J., & Silva, F. (2003). Directed diffusion for wireless sensor networking. IEEE/ACM transactions on networking, 11(1), 2-16.

[16] Rodoplu, V., & Meng, T. H. (1999). Minimum energy mobile wireless networks. IEEE Journal on selected areas in communications, 17(8), 1333-1344.

[17] L. Li and J. Y Halpern, "Minimum energy mobile wireless networks revisited," in the Proceedings of IEEE International Conference on Communications (ICC'01), Helsinki, Finland, June 2001.

[18] Kulik, J., Heinzelman, W., & Balakrishnan, H. (2002). Negotiation-based protocols for disseminating information in wireless sensor networks. Wireless networks, 8(2-3), 169-185.

[19] Intanagonwiwat, C., Govindan, R., & Estrin, D. (2000, August). Directed diffusion: A scalable and robust communication paradigm for sensor networks. In Proceedings of the 6th annual international conference on Mobile computing and networking (pp. 56-67).

[20] Sadagopan, N., Krishnamachari, B., & Helmy, A. (2003, May). The ACQUIRE mechanism for efficient querying in sensor networks. In Proceedings of the First IEEE International Workshop on Sensor Network Protocols and Applications, 2003. (pp. 149-155). IEEE.

[21] W.R. Heinzelman, A. Chandrakasan, and H. Balakrishnan, "Energy-efficient Communication Protocol for Wireless Microsensor Networks", in IEEE Computer Society Proceedings of the Thirty Third Hawaii International Conference on System Sciences (HICSS '00), Washington, DC, USA, Jan. 2000, vol. 8, pp. 8020.

[22] Heinzelman, W. B., Chandrakasan, A. P., & Balakrishnan, H. (2002). An application-specific protocol architecture for wireless microsensor networks. IEEE Transactions on wireless communications, 1(4), 660-670.

[23] S. Lindsey and C.S. Raghavendra, "PEGASIS: Power-efficient Gathering in Sensor Information System",Proceedings IEEE Aerospace Conference, vol. 3, Big Sky, MT, Mar. 2002, pp. 1125-1130.

[24] Mehndiratta, N., & Bedi, H. (2013). Design Issues for Routing Protocols in WSNs Based on Classification. International Journal of Application or Innovation in Engineering & Management (IJAIEM), 20, 13.

[25] García Villalba, L. J., Sandoval Orozco, A. L., Trivino Cabrera, A., & Barenco Abbas, C. J. (2009). Routing protocols in wireless sensor networks. Sensors, 9(11), 8399-8421.