Volume 3, Issue 4, April 2013 ISSN: 2277 128X
International Journal of Advanced Research in Computer Science and Software Engineering
Research Paper
Available online at: www.ijarcsse.com

# Routing Issues in Wireless Sensor Networks: A Survey

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***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 specifically 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 a survey of the routing protocols in WSNs. The routing techniques are classified into three categories based on the underlying network structure: flat, hierarchical, and location-based routing. Furthermore, these protocols can be classified into multi path- based, query- based, negotiation-based, QoS-based, and coherent-based depending on the protocol operation. In this proposed work the advantages and performance issues of each routing protocols also were highlighted.***

***Keywords:***

## 1. Introduction

Due torecent technological advances, the manufacturing of small and low cost sensors became technically and economically feasible. The sensing electronics measure ambient conditions related to the environment surrounding the sensor and transforms them into an electric signal. Processing such a signal reveals some properties about objects located and/or events happening in the vicinity of the sensor. A large number of these disposable sensors can be networked in many applications that require unattended operations. A Wireless Sensor Network (WSN) contains hundreds or thousands of these sensor nodes. These sensors have the ability to communicate either among each other or directly to an external base-station (BS). A greater number of sensors allows for sensing over larger geographical regions with greater accuracy [1]. Basically, each sensor node comprises sensing, processing, transmission, mobilize, position finding system, and power units. Sensor nodes are usually scattered in a sensor field, which is an area where the sensor nodes are deployed. Sensor nodes coordinate among themselves to produce high-quality information about the physical environment. Each sensor node bases its decisions on its mission, the information it currently has, and its knowledge of its computing, communication, and energy resources. Each of these scattered sensor nodes has the capability to collect and route data either to other sensors or back to an external base station. A base- station may be a fixed node or a mobile node capable of connecting the sensor network to an existing communications infrastructure or to the Internet where a user can have access to the reported data [2].

## 2. Routing Protocols in WSNs

In general, routing in WSNs can be divided into flat-based routing, hierarchical- based routing, and location-based routing depending on the network structure. In flat- based routing, all nodes are typically assigned equal roles or functionality. In hierarchical-based routing, however, nodes will play different roles in the network. In location-based routing, sensor nodes' positions are exploited to route data in the network. Furthermore, these protocols can be classified into multipath-based, query- based, negotiation-based, QoS-based, or coherent-based routing techniques depending on the protocol operation. In addition to the above, routing protocols can be classified into three categories, namely, proactive, reactive, and hybrid protocols depending on how the source finds a route to the destination. In proactive protocols, all routes are computed before they are really needed, while in reactive protocols, routes are computed on demand. Hybrid protocols use a combination of these two ideas. Another class of routing protocols is called the cooperative routing protocols. In cooperative routing, nodes send data to a central node where data can be aggregated and may be subject to further processing, hence reducing route cost in terms of energy use. Many other protocols rely on timing and position information [3].

 

**2.1 Network Structure Based Protocols**

The underlying network structure can play significant role in the operation of the routing protocol in WSNs.

**2.1.1 Flat Routing**

In flat networks, each node typically plays the same role and sensor nodes collaborate together to perform the sensing task. Due to the large number of such nodes, it is not feasible to assign a global identifier to each node[4].

**2.1.1.1 Sensor Protocols for Information via Negotiation (SPIN)**

SPIN that disseminate all the information at each node to every node in the network assuming that all nodes in the network are potential base-stations. This enables a user to query any node and get the required information immediately. These protocols make use of the property that nodes in close proximity have similar data, and hence there is a need to only distribute the data that other nodes do not posses. The SPIN family of protocols uses data negotiation and resource-adaptive algorithms. Nodes running SPIN assign a high-level name to completely describe their collected data (called meta-data) and perform meta-data negotiations before any data is transmitted. This assures that there is no redundant data sent throughout the network. These protocols work in a time- driven fashion and distribute the information all over the network, even when a user does not request any data.

**2.1.1.2 Directed Diffusion**

Directed diffusion is a data-centric (DC) and application-aware paradigm in the sense that all data generated by sensor nodes is named by attribute-value pairs. The main idea of the DC paradigm is to combine the data coming from different sources en route (in-network aggregation) by eliminating redundancy, minimizing the number of transmissions; thus saving network energy and prolonging its lifetime. Unlike traditional end-to-end routing, DC routing finds routes from multiple sources to a single destination that allows in-network consolidation of redundant data. In directed diffusion, sensors measure events and create gradients of information in their respective neighbourhoods. The base station requests data by broadcasting interests. Interest describes a task required to be done by the network. Interest diffuses through the network hop-by-hop, and is broad-cast by each node to its neighbors. As the interest is propagated throughout the network, gradients are setup to draw data satisfying the query towards the requesting node, i.e., a BS may query for data by disseminating interests and intermediate nodes propagate these interests. Each sensor that receives the interest setup a gradient toward the sensor nodes from which it receives the interest. This process continues until gradients are setup from the sources back to the BS. More generally, a gradient specifies an attribute value and a direction. The strength of the gradient may be different towards different neighbors resulting in different amounts of information flow. At this stage, loops are not checked, but are removed at a later stage [5]. All sensor nodes in a directed diffusion-based network are application- aware, which enables diffusion to achieve energy savings by selecting empirically good paths and by caching and processing data in the network. Caching can increase the efficiency, robustness and scalability of coordination between sensor nodes which is the essence of the data diffusion paradigm. Other usage of directed diffusion is to spontaneously propagate an important event to some sections of the sensor network. Such type of information retrieval is well suited only for persistent queries where requesting nodes are not expecting data that satisfy a query for duration of time. This makes it unsuitable for one-time queries, as it is not worth setting up gradients for queries, which use the path only once.

The performance of data aggregation methods, used in the directed diffusion paradigm, are affected by a number of factors which includes the positions of the source nodes in the network, the number of sources, and the communication network topology.

**2.1.1.3 Rumour Routing**

In general, directed diffusion uses flooding to inject the query to the entire network when there is no geographic criterion to diffuse tasks. However, in some cases there is only a little amount of data requested from the nodes and thus the use of flooding is unnecessary. An alternative approach is to flood the events if the number of events is small and the number of queries is large. The key idea is to route the queries to the nodes that have observed a particular event rather than flooding the entire network to retrieve information about the occurring events. In order to flood events through the network, the rumour routing algorithm employs long-lived packets, called agents. When a node detects an event, it adds such event to its local table, called events table, and generates an agent. Agents travel the network in order to propagate information about local events to distant nodes. When a node generates a query for an event, the nodes that know the route, may respond to the query by inspecting its event table. Hence, there is no need to flood the whole network, which reduces the communication cost. On the other hand, rumour routing maintains only one path between source and destination as opposed to directed diffusion where data can be routed through multiple paths at low rates [6].

**2.1.1.4 Minimum Cost Forwarding Algorithm (MCFA)**

In MCFA, each node should know the least cost path estimate from itself to the base-station. This is obtained as follows. The base-station broadcasts a message with the cost set to zero while every node initially set its least cost to the base-station to infinity. Each node, upon receiving the broadcast message originated at the base- station, checks to see if the estimate in the message plus the link on which it is received is less than the current estimate. If yes, the current estimate and the estimate in the broadcast message are updated. If the received broadcast message is updated, then it is re-sent; otherwise, it is purged and nothing further is done.

**2.1.1.5 Gradient-Based Routing**

 

The key idea in GBR is to memorize the number of hops when the interest is diffused through the whole network. As such, each node can calculate a parameter called the height of the node, which is the minimum number of hops to reach the BS. The difference between a node's height and that of its neighbour is considered the gradient on that link. A packet is forwarded on a link with the largest gradient. GBR uses some auxiliary techniques such as data aggregation and traffic spreading in order to uniformly divide the traffic over the network. When multiple paths pass through a node, which acts as a relay node, that relay node may combine data according to a certain function. In GBR, three different data dissemination techniques have been discussed (1) Stochastic Scheme, where a node picks one gradient at random when there are two or more next hops that have the same gradient, (2) Energy-based scheme, where a node increases its height when its energy drops below a certain threshold, so that other sensors are discouraged from sending data to that node, and (3) Stream- based scheme, where new streams are not routed through nodes that are currently part of the path of other streams. The main objective of these schemes is to obtain a balanced distribution of the traffic in the network, thus increasing the network lifetime [7].

**2.1.2.1 LEACH Protocol**

LEACH is a cluster-based protocol, which includes distributed cluster formation. LEACH randomly selects a few sensor nodes as cluster heads (CHs) and rotates this role to evenly distribute the energy load among the sensors in the network. In LEACH, the cluster head (CH) nodes compress data arriving from nodes that belong to the respective cluster, and send an aggregated packet to the base station in order to reduce the amount of information that must be transmitted to the base station. LEACH uses a TDMA/CDMA MAC to reduce inter-cluster and intra-cluster collisions. However, data collection is centralized and is performed periodically. Therefore, this protocol is most appropriate when there is a need for constant monitoring by the sensor network. A user may not need all the data immediately. Hence, periodic data transmissions are unnecessary which may drain the limited energy of the sensor nodes. After a given interval of time, a randomized rotation of the role of the CH is conducted so that uniform energy dissipation in the sensor network is obtained [11].

The operation of LEACH is separated into two phases, the setup phase and the steady state phase. In the setup phase, the clusters are organized and CHs are selected. In the steady state phase, the actual data transfer to the base station takes place. The duration of the steady state phase is longer than the duration of the setup phase in order to minimize overhead.

**2.1.2.2 Power-Efficient Gathering in Sensor Information Systems (PEGASIS)**

The protocol, called Power-Efficient Gathering in Sensor Information Systems (PEGASIS), is a near optimal chain-based protocol. The basic idea of the protocol is that in order to extend network lifetime, nodes need only communicate with their closest neighbors and they take turns in communicating with the base-station. When the round of all nodes communicating with the base-station ends, a new round will start and so on. This reduces the power required to transmit data per round as the power draining is spread uniformly over all nodes. Hence, PEGASIS has two main objectives. First, increase the lifetime of each node by using collaborative techniques and as a result the network lifetime will be increased. Second, allow only local coordination between nodes that are close together so that the bandwidth consumed in communication is reduced.

**2.1.2.3 Threshold-sensitive Energy Efficient Protocols (TEEN and APTEEN)**

These protocols were proposed for time-critical applications. In TEEN, sensor nodes sense the medium continuously, but the data transmission is done less frequently. A cluster head sensor sends its members a hard threshold, which is the threshold value of the sensed attribute and a soft threshold, which is a small change in the value of the sensed attribute that triggers the node to switch on its transmitter and transmit. Thus the hard threshold tries to reduce the number of transmissions by allowing the nodes to transmit only when the sensed attribute is in the range of interest. The soft threshold further reduces the number of transmissions that might have otherwise occurred when there is little or no change in the sensed attribute. A smaller value of the soft threshold gives a more accurate picture of the network, at the expense of increased energy consumption. Thus, the user can control the trade-off between energy efficiency and data accuracy. The main drawback of this scheme is that, if the thresholds are not received, the nodes will never communicate, and the user will not get any data from the network at all.

APTEEN, on the other hand, is a hybrid protocol that changes the periodicity or threshold values used in the TEEN protocol according to the user needs and the type of the application.

**2.1.2.4 Small Minimum Energy Communication Network (MECN)**

MECN identifies a relay region for every node. The relay region consists of nodes in a surrounding area where transmitting through those nodes is more energy efficient than direct transmission. The main idea of MECN is to find a sub- network, which will have less number of nodes and require less power for transmission between any two particular nodes. In this way, global minimum power paths are found without considering all the nodes in the network. This is performed using a localized search for each node considering its relay region. 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. The sub network constructed by SMECN for minimum energy relaying is provably smaller (in terms of number of edges) than the one constructed in MECN. Hence, the sub network constructed by SMECN is smaller than the one constructed by MECN if the broadcast region is circular around the broadcasting node for a given power setting.

**2.1.2.5 Hierarchical Power-aware Routing (HPAR)**

The protocol divides the network into groups of sensors. Each group of sensors in geo-graphic proximity are clustered together as a zone and each zone is treated as an entity. To perform routing, each zone is allowed to decide how it will route a message hierarchically across the other zones such that the battery lives of the nodes in the system are maximized. Messages are routed along the path which has the maximum over all the minimum of the remaining power, called the max-min path. The motivation is that using nodes with high residual power may be expensive as compared to the path with the minimal power consumption.

**2.1.3 Location Based Routing Protocols**

In this kind of routing, sensor nodes are addressed by means of their locations. The distance between neighbouring nodes can be estimated on the basis of incoming signal strengths. Relative coordinates of neighbouring nodes can be obtained by exchanging such information between neighbors.

**2.1.3.1 Geographic and Energy Aware Routing (GEAR)**

The protocol, called Geographic and Energy Aware Routing (GEAR), uses energy aware and geographically-informed neighbour selection heuristics to route a packet towards the destination region. The key idea is to restrict the number of interests in directed diffusion by only considering a certain region rather than sending the interests to the whole network. By doing this, GEAR can conserve more energy than directed diffusion. Each node in GEAR keeps an estimated cost and a learning cost of reaching the destination through its neighbors. The estimated cost is a combination of residual energy and distance to destination. The learned cost is a refinement of the estimated cost that accounts for routing around holes in the network. A hole occurs when a node does not have any closer neighbour to the target region than itself. If there are no holes, the estimated cost is equal to the learned cost. The learned cost is propagated one hop back every time a packet reaches the destination so that route setup for next packet will be adjusted. There are two phases in the algorithm: (1) Forwarding packets towards the target region: Upon receiving a packet, a node checks its neighbors to see if there is one neighbour, which is closer to the target region than itself. If there is more than one, the nearest neighbour to the target region is selected as the next hop. If they are all further than the node itself, this means there is a hole. In this case, one of the neighbors is picked to forward the packet based on the learning cost function. This choice can then be updated according to the convergence of the learned cost during the delivery of packets and (2) Forwarding the packets within the region: If the packet has reached the region, it can be diffused in that region by either recursive geographic forwarding or restricted flooding. Restricted flooding is good when the sensors are not densely deployed [13].

**2.1.3.2 MFR, DIR, and GEDIR**

These protocols deal with basic distance, progress, and direction based methods. The key issues are forward direction and backward direction. A source node or any intermediate node will select one of its neighbors according to a certain criterion. The routing methods, which belong to this category, are MFR (Most Forward within Radius), GEDIR (The Geographic Distance Routing) that is a variant of greedy algorithms, 2-hop greedy method, alternate greedy method and DIR (compass routing method). GEDIR algorithm is a greedy algorithm that always moves the packet to the neighbour of the current vertex whose distance to the destination is minimized. The algorithm fails when the packet crosses the same edge twice in succession. In most cases, the MFR and Greedy methods have the same path to destination. In the DIR method, the best neighbor has the closest direction (that is, angle) toward the destination. That is, the neighbor with the minimum angular distance from the imaginary line joining the current node and the destination is selected [8].

**2.1.3.3 The Greedy Other Adaptive Face Routing (GOAFR)**

The greedy algorithm of GOAFR always picks the neighbour closest to a node to be next node for routing. However, it can be easily stuck at some local minimum, i.e. no neighbour is closer to a node than the current node.

**2.1.3.4 SPAN**

Another position based algorithm called SPAN selects some nodes as coordinators based on their positions. The coordinators form a network backbone that is used to forward messages. A node should become a coordinator if two neighbors of a non-coordinator node cannot reach each other directly or via one or two coordinators. New and existing coordinators are not necessarily neighbors.

**2.2 Routing Protocols based on Protocol Operation**

In this section, routing protocols are described based on their routing functionalities. It should be noted that some of these protocols may fall below one or more of the above routing categories.

**2.2.1 Multi Path Routing Protocols**

The fault tolerance (resilience) of a protocol is measured by the likelihood that an alternate path exists between a source and a destination when the primary path fails. This can be increased by maintaining multiple paths between the source and the destination at the expense of an increased energy consumption and traffic generation. These alternate paths are kept alive by sending periodic messages. Hence, network reliability can be increased at the expense of increased overhead of maintaining the alternate paths [9].

**2.2.2 Query Based Routing**

In this kind of routing, the destination nodes propagate a query for data (sensing task) from a node through the network and a node having this data sends the data which matches the query back to the node, which initiates the query.

### 2.2.3 Negotiation Based Routing Protocols

These protocols use high level data descriptors in order to eliminate redundant data transmissions through negotiation. Communication decisions are also taken based on the resources that are available to them.

### 2.2.4 QoS-based Routing

In QoS-based routing protocols, the network has to balance between energy consumption and data quality. In particular, the network has to satisfy certain QoS metrics, e.g., delay, energy, bandwidth, etc. when delivering data to the BS.

### 2.2.5 Coherent and Non-coherent Processing

Data processing is a major component in the operation of wireless sensor networks. Hence, routing techniques employ different data processing techniques. In general, sensor nodes will cooperate with each other in processing different data flooded in the network area. Two examples of data processing techniques pro-posed in WSNs are coherent and non-coherent data processing-based routing. In non-coherent data processing routing, nodes will locally process the raw data before being sent to other nodes for further processing. The nodes that perform further processing are called the aggregators. In coherent routing, the data is forwarded to aggregators after minimum processing. The minimum processing typically includes tasks like time stamping, duplicate suppression, etc. To perform energy-efficient routing, coherent processing is normally selected [10]. Non-coherent functions have fairly low data traffic loading. On the other hand, since coherent processing generates long data streams, energy efficiency must be achieved by path optimality. In non-coherent processing, data processing incurs three phases: (1) Target detection, data collection, and pre-processing (2) Membership declaration, and (3) Central node election. During phase 1, a target is detected, its data collected and pre-processed. When a node decides to participate in a cooperative function, it will enter phase 2 and declare this intention to all neighbors. This should be done as soon as possible so that each sensor has a local understanding of the network topology. Phase 3 is the election of the central node. Since the central node is selected to perform more sophisticated information processing, it must have sufficient energy reserves and computational capability [12].

## 3 Conclusion

Routing in sensor networks is a new area of research, with a limited, but rapidly growing set of research results. In this paper, comprehensive surveys of routing techniques in wireless sensor networks which have been presented in the literature were described. They have the common objective of trying to extend the lifetime of the sensor network, while not compromising data delivery. Overall, the routing techniques are classified based on the network structure into three categories: flat, hierarchical, and location based routing protocols. Furthermore, these protocols are classified into multipath-based, query-based, negotiation-based, or QoS-based routing techniques depending on the protocol operation. We also highlighted the design tradeoffs between energy and communication overhead savings in some of the routing paradigm, as well as the advantages and disadvantages of each routing technique.

## References


[1]. W. Heinzelman, A. Chandrakasan and H. Balakrishnan, "Energy-Efficient Communication Protocol for Wireless Micro sensor Networks", Proceedings of the 33rd Hawaii International Conference on System Sciences (HICSS '00), January 2000.

[2]. C. Intanagonwiwat, R. Govindan, and D. Estrin, "Directed diffusion: a scalable and robust communication paradigm for sensor networks", Proceedings of ACM MobiCom '00, Boston, MA, 2000, pp.56-67.

[3]. W.Heinzelman, J. Kulik, and H.Balakrishnan, "Adaptive Protocols for Information Dissemination in Wireless Sensor Networks", Proc. 5th ACM/IEEE Mobicom Conference (MobiCom '99), Seattle, WA, August, 1999. pp. 174-85.

[4]. Perrig, R. Szewzyk, J.D. Tygar, V. Wen, and D. E. Culler, "SPINS: security protocols for sensor networks", Wireless Networks Volume: 8, pp. 521-534, 2000.

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

[6]. D. Braginsky and D. Estrin, "Rumour Routing Algorithm for Sensor Networks", Proceedings of the First Workshop on Sensor Networks and Applications (WSNA), Atlanta, GA, October 2002.

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

[8]. QLi and J. Aslam and D. Rus, "Hierarchical Power-aware Routing in Sensor Networks", Proceedings of the DIMACS Workshop on Pervasive Networking, May, 2001.

[9]. D. Braginsky and D. Estrin, "Rumour Routing Algorithm for Sensor Networks", International Conference on Distributed Computing Systems (ICDCS'01), November 2001.

[10]. N. Sadagopan et al., "The ACQUIRE mechanism for efficient querying in sensor networks", Proceedings of the First International Workshop on Sensor Network Protocol and Applications, Anchorage, Alaska, May 2003.

[11]. Jean-Lien C. Wu (IEEE Member) & Shan-Te Wang, "Comparison of Power Schemes for Sink Nodes in WSNs", IEEE International Conference on Advanced Information Networking and Applications, 2004, pp.011-013.

[12]. Giuseppe Anastasi, Marco Conti, Mario Di Francesco, Andrea Passarella, "Energy Conservation in Wireless Sensor Networks: A Survey", Science Direct, 2009, pp.535- 543.

[13]. Wu C.W. and Tay Y.C., "AMRIS: A Multicast Protocol for Ad Hoc Wireless Networks", Proc. IEEE Military Comm. Conf., vol.1, pp. 25-29, 1999.

 