International Journal of
Wireless Security and Networks
ISSN: 2584-0703
Volume 3, Issue 2, 2025
July–December
DOI (Journal): 10.37591/IJWSN
https://journals.stmjournals.com/ijwsn
Research IJWSN

Classification and Comparison of Routing Protocols in Wireless Sensor Networks

Shallu Hassija[1,*], Sunil Sikka[2], Meenu Vijarania[3]

Abstract

Recent developments and the overlap of multiple technologies, including distributed signal processing, ad-hoc network routing protocols, embedded systems, integrated circuits, micro electro-mechanical systems, microprocessor hardware, and nanotechnology, have rendered the idea of Wireless Sensor Networks (WSNs) possible. Sensor network nodes are finite with regard to energy, processing capability, and communication bandwidth. Yet, since they can vary with respect to the application and network structure, the routing protocols have received the most emphasis. In order to prolong the lifespan of the sensor nodes, effective routing protocols need to be designed. While monitoring and reporting occurrences is the primary purpose of sensor networks, no single routing protocol can be used for all applications since sensor networks rely on their applications. In this research, we are dealing with the difficulties of sensor network design and proposing classification and comparison of routing protocols. This comparison highlights the significant features that must be considered when designing and comparing new routing protocols for sensor networks.

Keywords: Sensor networks, design issues, routing protocols, applications

INTRODUCTION

Wireless sensor networks that organize themselves using batteries have become a real tool for monitoring, and potentially changing, the physical world. The sensors can perceive, process, and communicate. Energy is a critical resource for sensor networks, but applications display only a limited set of properties. Consequently, it is both possible and imperative to optimize the network structure for the applications in a way that reduces resource utilization. Sensor networks' design and protocols differ from traditional Internet architecture because of their specific requirements and constraints.

A sensor network is an array of many small, disposable, low-power devices, or nodes, dispersed geographically to carry out an application-specific global function [1, 2]. The nodes are part of a network through direct or indirect communication with other nodes. Some or all of these nodes will be sinks, capable of communicating with the user directly or indirectly or through the wire-line networks that already exist. The central element of the network, the sensor needs to monitor a broad set of physical parameters of the real world, including motion, sound, temperature, humidity, intensity, vibration, pressure, and pollution. The low-power sensor nodes, consisting of sensing, onboard CPU for data processing, and communication elements, adopt the concept of sensor networks based on the cooperation of many nodes [3, 4]. Figure 1 illustrates the structural perspective of a sensor network, where sensor nodes are depicted as small circles. Each node normally has four elements:

***Author for Correspondence**
Shallu Hassija
E-mail: shchutani.2@gmail.com

[1]Research Scholar, Department of Computer Science and Engineering, Amity University, Gurugram, Haryana, India
[2]Professor, Department of Computer Science and Engineering, Amity University, Gurugram, Haryana, India
[3]Associate Professor, School of Engineering and Technology, Kr. Mangalam University, Gurugram, Haryana, India

Received Date: July 10, 2025
Accepted Date: August 25, 2025
Published Date: September 09, 2025

Citation: Shallu Hassija, Sunil Sikka, Meenu Vijarania. Classification and Comparison of Routing Protocols in Wireless Sensor Networks. International Journal of Wireless Security and Networks. 2025; 3(2): 35–44p.

CPU, communication unit, power unit, and sensor unit. They have been assigned a range of tasks. The sensor unit is composed of both the sensor itself and an Analog-to-Digital Converter (ADC).

The sensor unit gathers data at the request of the ADC. The ADC reports to the CPU the analog data it has detected. As a translator, the ADC gives instructions or information from the sensor unit to the CPU. The communication unit's job is to receive instructions or questions from the CPU and report the information back out into the world. The CPU is the most complicated unit. It decodes commands or queries directed to ADC, evaluates received data, selects the next hop toward the sink, tracks and manages power as needed, and so forth. The power unit provides power to the sensor, processing, and communication units. Location locating system and the mobilizer, the two optional units, can also be added to each node.

One would require a mobilizer to relocate sensor nodes when necessary to complete the tasks in question, and the node ought to be equipped with a location discovery system if the user requires knowing the exact location (Figure 1).

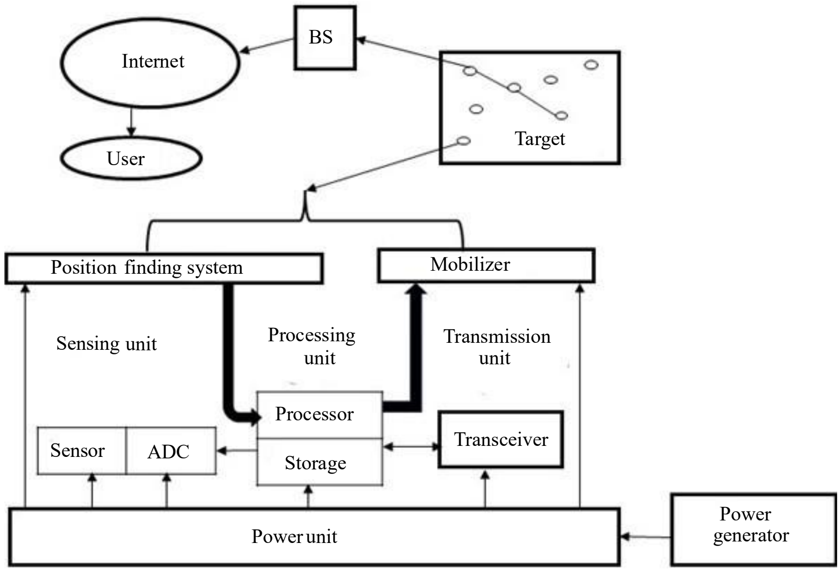

Figure 1. Structural view of sensor network.

Rather than forwarding the raw data to the nodes that are responsible for the fusion, sensor nodes take advantage of their processing capabilities in doing minor computations locally and send only the necessary and partially computed data. Besides acquiring informative data like sound, temperature, light, etc., the sensor nodes also act as the router by exchanging information through wireless channels and being battery-powered [1]. All of the energy supply, computational power, and communication bandwidth available in sensor network nodes are limited. Fault tolerant, networked, scalable, intelligent, programmable via software, efficient, fast data capture ability, long-term accuracy and reliability, cheap to buy, low maintenance are all desirable attributes of the perfect wireless sensor.

The principal objectives of a WSN are to:

i. Measure the values of physical variables at a given point,
ii. Discover events of interest and identify the parameters of the observed event or events,
iii. Track an object, and
iv. Classify a discovered object.

Hence, the following are paramount WSN requirements:

a. Use of sensors in great amounts,

b. Sensor fixation,
c. Cooperative signal processing,
d. Self-organization,
e. Low energy usage, and
f. Querying capabilities.

The following sections compare MANETs and sensor networks; describe sensor network applications; address routing protocol classification; address design issues with routing protocols; address comparisons among routing protocols; and a conclusion is provided in the last section.

COMPARISON OF MANETS AND SENSOR NETWORKS

Sensor networks and MANETS (Mobile Ad-hoc NETworkS) are two types of wireless ad hoc networks with resource limitations. MANETs are normally made up of highly capable, mobile devices cooperating together. Sensor networks are normally placed in fixed geographic locations for tracking, monitoring, and sensing applications [5]. These wireless networks are defined by their ad hoc environment and absence of pre-existing computation and communication infrastructure. They are similar in the sense that the nodes of the network are linked using wireless communication links, the network topology is dynamic, and power is a costly resource.

WSNs and MANETs are different in the following respects.

- Sensor networks are primarily employed for information gathering, while MANETS are employed for distributed computing.
- Sensor nodes employ the broadcast communications paradigm to a large extent, while most MANETS use point-to-point communications.
- Sensor networks may contain orders of magnitude higher numbers of nodes compared to MANETs.
- Sensor nodes might not possess global ID because of the high number of sensors and high overheads.
- Sensor nodes are significantly more cost-effective than MANET nodes and are usually deployed in large quantities, often numbering in the thousands.
- Sensor nodes are power, memory, and computing constrained, although nodes within a MANET may be recharged somehow.
- In comparison with their MANET counterparts, sensor nodes are far less powerful in terms of computation and communication because they are low-cost; sensors typically get deployed only once in their lifespan, whereas MANET nodes move on a need basis.

APPLICATIONS OF SENSOR NETWORKS

The past few years have witnessed the embedding of wireless sensor networks in a broad range of systems and applications with hugely varying requirements and nature [6, 7].

Disaster relief, rescue operations under emergency, military uses, monitoring of habitats, health care, environmental monitoring, home networks, and the detection of chemical, biological, radioactive, nuclear, and explosive substances are some examples of the numerous applications of sensor networks that are listed in Table 1.

WSNs' flexibility enables them to be used for everything from critical military operations to household convenience. They offer a degree of data gathering and surveillance in every region that was unaffordable or impossible before.

Military and Emergency Services: WSNs are essential for military battlefield surveillance because they provide information on enemy movements and guard against intruders. Because they can be used in hazardous situations, they are ideal for enhancing situational awareness without putting troops in danger. In a similar vein, sensor networks can be rapidly deployed to support disaster management operations by identifying survivors, detecting hazardous chemical levels, and verifying the integrity of structures during emergencies such as fires or natural disasters.

Monitoring of the Environment and Habitat: Environmental science has advanced significantly as a result of WSNs. They are used for extensive environmental monitoring of soil, water, and air quality as well as for tracking animal populations in habitat monitoring programs. This continuous, long-term data collection helps scientists gain new understanding of delicate ecosystems.

Healthcare and Home Automation: WSNs are used in the healthcare sector to create body-sensor networks that are capable of continuously monitoring vital signs such as heart rate, blood pressure, and oxygen levels. This makes proactive and remote medical intervention possible. Smart automation, appliance control, increased security, and resident location awareness are all made possible by sensor networks in the home.

CLASSIFICATION OF ROUTING PROTOCOLS

The design space for such algorithms is quite broad, and we can categorize the routing methods for WSNs in several ways [14]. Routing protocols may be node-centric, data-centric, geo-centric (location-aware), or QoS-based. Node-centric routing is the predominant protocol used in ad hoc networks, where destinations are specified through the numerical IDs or addresses assigned to individual nodes. Node-centric communication is hardly anticipated in WSNs. Consequently, routing protocols in WSNs are more data-centric or geocentric. In the usage of data-centric routing, the sink issues queries to the desired areas and then waits for data from the sensors in those areas.

We can group WSN routing strategies into a number of different ways, and the algorithms' design space is quite large [14]. Routing protocols are either location-aware (geo-centric), data-centric, node-centric, or QoS-based. Most routing protocols used in ad hoc networks follow a node-centric approach, where destinations are identified using nodes' numerical addresses or unique identifiers. However, in Wireless Sensor Networks (WSNs), direct node-to-node communication is rarely expected. As a result, routing protocols in WSNs are typically designed to be either data-centric or geocentric.

In data-centric routing, the sink node issues queries targeting specific regions, and it passively waits to receive relevant data from sensors located in those areas. Routing protocols can also be classified based on their operational mode, either proactive or reactive. Proactive protocols establish and maintain routing paths in advance, regardless of whether there is ongoing data transmission. In contrast, reactive protocols initiate the route discovery process only when data needs to be transmitted, building the necessary paths dynamically as queries arise.

Table 1. Some applications for different areas.

Area	Applications
Military	Military situation awareness [6]. Sensing intruders on basis. Detection of enemy unit movements on land and sea [2]. Battle field surveillances [8].
Emergency situations	Disaster management [9]. Fire/water detectors [10]. Hazardous chemical level and fires [2].
Physical world	Environmental monitoring of water and soil [11]. Habitual monitoring [11]. Observation of biological and artificial systems [11].
Medical and health	Sensors for blood flow, respiratory rate, ECG (electrocardiogram), pulse oxymeter, blood pressure and oxygen measurement [12]. Monitoring people's location and health condition [8].
Industrial	Factory process control and industrial automation [6]. Monitoring and control of industrial equipment [10].
Home networks	Home appliances, location awareness (blue tooth [10]). Person locator [13].
Automotive	Tire pressure monitoring [10, 5]. Active mobility [7]. Coordinated vehicle tracking [6].

Additionally, routing protocols are categorized as source-initiated or destination-initiated. In source-initiated protocols, the routing process begins at the source node upon request, where the node initiates communication and announces the availability of data. Conversely, in destination-initiated protocols, the destination node initiates the route setup process.

Routing strategies are also influenced by the architecture of the sensor network. Some WSNs feature homogeneous nodes, while others are heterogeneous, with nodes of varying capabilities. This leads to a classification of protocols based on network topology: flat or hierarchical. In flat routing, all nodes are treated equally, and data may traverse multiple hops to reach the sink. Hierarchical routing is more suitable for heterogeneous networks, where certain nodes possess greater resources. In this approach, nodes are often organized into clusters, with cluster heads aggregating data from their members. The hierarchy may not necessarily be based on energy or computing power, but serves to streamline communication and enhance efficiency. Clustering protocols have many advantages, including manageability, scalability, and energy efficiency in route discovery.

DESIGN ISSUES OF ROUTING PROTOCOLS

At first, military applications were the main force behind WSNs. Since then, the civilian application domain of wireless sensor networks has been considered, encompassing environmental and species monitoring, smart homes, production and healthcare, and more. The network topology of these WSNs can be as simple as a star topology, and their sensor nodes can be mobile and diverse. The density and scale of the network are determined by the application. To align with the growing trend of diversification, several key factors must be taken into account when designing sensor networks.

Fault Tolerance

Some sensor nodes might fail or become jammed due to physical damage, environmental disturbance, or unavailability of electricity. Sensor node failure should not impact the overall functionability of the sensor network. This is the fault tolerance or reliability problem. Fault tolerance is the ability to continue sensor network processes even when there are sensor node failures.

Flexibility

The nodes of sensors placed within the sensing region could be hundreds, thousands, or thousands more, and routing systems need to be sufficiently scalable to react to incidents.

Production Costs

The cost of each sensor node must be kept low because the cost of a single node plays a significant role in determining the total cost of sensor networks, which have many sensor nodes.

Operational Environment

Sensor networks can be installed on large machinery, on the ocean floor, in a chemically or biologically contaminated field, outside enemy lines, in a house or large building, in a large warehouse, on animals, on fast-moving vehicles, in a forest area for monitoring habitat, etc.

Power Consumption

Because the transmission power of a wireless radio increases with the square of the distance, or even more in the presence of obstacles, using multi-hop routing is more energy-efficient than direct transmission. However, medium access control and topology management are significantly burdened by multi-hop routing. Direct routing would work well if all nodes were near the sink [15]. The power supply of sensor nodes is small (less than 0.5 Ah, 1.2 V). The lifespan of the node is significantly impacted by its battery life.

Data Delivery Models

Data delivery models dictate when the node's collected data needs to be sent. Based on the specific application of the sensor network, data can be transmitted to the sink using continuous, event-based, query-based, or a combination of these delivery methods [16]. Under the continuous delivery concept, each sensor regularly sends data. In event-driven models, data transmission begins when an event occurs. The sink creates the query that starts the data transfer in query-driven architectures. A hybrid strategy that blends query-driven, event-driven, and continuous data delivery is employed by certain networks.

Data Aggregation/Fusion

Sensor nodes often produce redundant information, so merging similar data packets from different nodes can help minimize transmission overhead. This process, known as data aggregation, involves consolidating data from various sources using operations like averaging, finding minimum or maximum values, or eliminating duplicates [17]. Since processing data requires significantly less energy than transmitting it, data aggregation can greatly reduce energy consumption. Many routing protocols have adopted this strategy to improve energy efficiency and optimize network traffic.

Quality of service, or QoS

The level of service that the application needs is referred to as "quality of service"; this could include features like location awareness, energy efficiency, data reliability, longevity, and collaborative processing. The routing protocols selected for a particular application will be influenced by these factors. The data must be provided within a certain amount of time after it is detected in certain applications, such as military applications.

Data Latency and Overhead

These are believed to be the main factors affecting routing protocol design. Data aggregation and multi-hop relays are the sources of data latency. Additionally, some routing protocols are not appropriate for networks with high energy constraints because they produce massive overheads to implement their algorithms.

Node Deployment

Node deployment affects the routing protocol's performance and varies depending on the application. The deployment may be deterministic or self-organizing. In deterministic scenarios, the sensors are manually positioned, and the data is routed along predetermined paths. In contrast, the sensor nodes in self-organizing systems are randomly distributed, creating an infrastructure as it is needed. The placement of the cluster head or sink in that infrastructure is also crucial for performance and energy efficiency. When the node distribution is irregular, the optimal location of the cluster head becomes essential to guarantee energy-efficient network operation.

COMPARISON OF ROUTING ROTOCOLS

In this study we compared the following routing protocols according to their design characteristics.

- *SPIN [18, 15]:* Sensor Protocols for Information via Negotiation.
- *DD [19]:* Directed Diffusion.
- *RR [20]:* Rumor Routing.
- *GBR [21]:* Gradient Based Routing.
- *CADR [22]:* Constrained Anisotropic Diffusion Routing.
- *COUGAR [13].*
- *ACQUIRE [23]:* ACtive QUery forwarding In sensoR nEtworks.
- *LEACH [24]:* Low Energy Adaptive Clustering Hierarchy.
- *TEEN and APTEEN [25]:* (Adaptive) Threshold sensitive Energy Efficient sensor Network.
- *PEGASIS [26]:* The Power-Efficient GAthering in Sensor Information Systems [27].
- *VGA [11]:* Virtual Grid Architecture Routing.
- *SOP [3]:* Self Organizing Protocol.
- *GAF [27]:* Geographic Adaptive Fidelity.
- *SPAN [28].*

- *GEAR [29]:* Geographical and Energy Aware Routing.
- *SAR [30]:* Sequential Assignment Routing.
- *SPEED [31]:* A real time routing protocol.

Table 2 represents classification and comparison of routing protocols in WSNs. Table 3 represents routing protocols selection for particular applications in WSNs. These tables are based on the survey by Akyildiz *et al.* [1], and modified according to application requirements.

Selecting the appropriate routing protocol is essential and depends only on the specific needs of the WSN application. Long-term habitat monitoring may not benefit from a technique that is effective for military surveillance. Therefore, a comparison study based on significant performance and design indicators is essential for network architects. Table 2 compares protocols based on several fundamental characteristics.

Classification and Power Use: First, protocols are divided into groups based on their architecture (Flat, Hierarchical, Location-based) and initiation mode (Source-initiated, Destination-initiated). Power usage is crucial since it has a direct impact on how long a network can operate. Some protocols, like LEACH, are made for high energy efficiency through clustering, while others, like SPIN, aim for low power consumption through negotiation.

Scalability and Data Aggregation: By combining data from multiple sensors, data aggregation is a technique that minimizes redundant transmissions and conserves energy. Some protocols, like DD and COUGAR, use data aggregation, while others do not. A protocol is said to be scalable if it can continue to operate effectively as the number of nodes in the network increases. Large-scale deployments require strong scalability, which hierarchical protocols like PEGASIS and TEEN generally possess.

Table 2. Classification and comparison of routing protocols in WSNs.

Routing Protocols	**Classification**	**Power Usage**	**Data Aggregation**	**Scalability**	**Query Based**	**Over head**	**Data delivery model**	***QoS***
SPIN	Flat/SRC-initiated/Data-centric	Ltd.	Yes	Ltd	Yes	Low	Event driven	*No*
DD	Flat/Data-centric/DST-initiated	Ltd	Yes	Ltd	Yes	Low	Demand driven	*No*
RR	Flat	Low	Yes	Good	Yes	Low	Demand driven	*No*
GBR	Flat	Low	Yes	Ltd	Yes	Low	Hybrid	*No*
CADR	Flat	Ltd		Ltd	Yes	Low	Continuously	*No*
COUGAR	Flat	Ltd	Yes	Ltd	Yes	High	Query driven	*No*
ACQUIRE	Flat/Data-centric	Low	Yes	Ltd	Yes	Low	Complex query	*No*
LEACH	Hierarchical/DST-initiated/Node-centric	High	Yes	Good	No	High	Cluster-head	*No*
TEEN and APTEEN	Hierarchical	High	Yes	Good	No	High	Active threshold	*No*
PEGASIS	Hierarchical	Max	No	Good	No	Low	Chains based	*No*
VGA	Hierarchical	Low	Yes	Good	No	High	Good	*No*
SOP	Hierarchical	Low	No	Good	No	High	Continuously	*No*
GAF	Hierarchical/Location	Ltd	No	Good	No	Mod	Virtual grid	*No*
SPAN	Hierarchical/Location	Ltd	Yes	Ltd	No	High	Continuously	*No*
GEAR	Location	Ltd	No	Ltd	No	Mod	Demand driven	*No*
SAR	Data centric	High	Yes	Ltd	Yes	High	Continuously	*Yes*
SPEED	*Location/Data centric*	*Low*	*No*	*Ltd*	*Yes*	*Less*	*Geographic*	*Yes*

Table 3. Routing protocols selection for particular applications in WSNs.

Application type	Project	Node deployment	Topology	Size	Routing protocol
Habitat monitoring	Great Duck [32]	Manual one time	Cluster Head	10–100	*SPAN, GAF*
Environment monitoring	PODS Hawaii [33]	Manual one time	Multi-hop Multi-path	30–50	*DD*
	Food Detection [34]	Manual	Multi-hop	200	*COUGAR, ACQUIRE*
Health	Artificial Retina [35]	Manual one time	Cluster Head	100	*LEACH*
	Vital Sign [36]	Manual	Star	10–20	*GBR, SAR, SPEED*
Military	Object Tracking [37]	Random	Multi-hop	200	*GAF*
Home/Office	Aware Home [38]	Manual Iterative	Three Tiered	20–100	*APTEEN, GEAR*
Production/Commercial	*Cold Chain [24]*	*Manual, Iterative*	*Three Tiered*	*55*	*SAR*

QoS and Data Delivery Model: The data delivery model decides whether data is sent to the sink continuously, in response to a query, or upon detection of an event. The application has a big influence on this choice. Finally, Quality of Service (QoS) indicates how well a protocol can ensure energy consumption, latency, and data delivery. In contrast to many early protocols, more recent ones, such as SPEED and SAR, incorporate QoS to support time-sensitive applications.

CONCLUSION

Sensor networks are quite promising for applications that need to collect sensing data in faraway areas. There is a lot of room for research because it is a developing field. Furthermore, sensor networks are typically created for particular applications, in contrast to MANETS. Therefore, it is critical to create effective routing protocols for sensor networks that work with sensor networks that serve a range of applications. In this research, we examined and contrasted the current routing protocols and identified some of the key design difficulties of sensor network routing protocols. Our research shows that it is impossible to create a routing algorithm that will work well in every situation and for every application. Despite the fact that numerous routing protocols have been put out for sensor networks, many issues still remain to be addressed.

More advanced and adaptable routing systems will be required as WSN development progresses. Future research should focus on developing hybrid protocols that can dynamically switch between different routing schemes in order to balance the trade-offs between energy conservation, data delay, and Quality of Service (QoS). Protocols that combine artificial intelligence and machine learning may be able to learn network behavior and predict traffic bottlenecks or node failures, resulting in more robust and self-organizing networks. Furthermore, as WSNs and the Internet of Things (IoT) grow more interconnected, maintaining security and interoperability will become a top priority. This necessitates creative routing designs that are secure from external threats and are efficient.

REFERENCES

1. Akyildiz IF, Su W, Sankarasubramaniam Y, Cayirci E. A survey on sensor networks. IEEE Commun Mag. 2002 Aug 31; 40(8): 102–14.
2. Doumit SS, Agrawal DP. Self-organizing and energy-efficient network of sensors. In IEEE MILCOM 2002. Proceedings. 2002 Oct 7; 2: 1245–1250.
3. Subramanian L, Katz RH. An architecture for building self-configurable systems. 2000 First Annual Workshop on Mobile and Ad Hoc Networking and Computing. MobiHOC (Cat. No.00EX444), Boston, MA, USA. 2000. pp. 63-73. doi: 10.1109/MOBHOC.2000.869214.
4. Pan J, Hou YT, Cai L, Shi Y, Shen SX. Topology control for wireless sensor networks. In Proceedings of the 9th annual international conference on Mobile computing and networking. 2003 Sep 14; 286–299.

5. Callaway E, Gorday P, Hester L, Gutierrez JA, Naeve M, Heile B, Bahl V. Home networking with IEEE 802.15. 4: a developing standard for low-rate wireless personal area networks. IEEE Commun Mag. 2002 Aug 31; 40(8): 70–7.
6. Shen CC, Srisathapornphat C, Jaikaeo C. Sensor information networking architecture and applications. IEEE Pers Commun. 2001 Aug 31; 8(4): 52–9.
7. Romer K, Mattern F. The design space of wireless sensor networks. IEEE Wirel Commun. 2004 Dec 20; 11(6): 54–61.
8. Shi E, Perrig A. Designing secure sensor networks. IEEE Wirel Commun. 2004 Dec 20; 11(6): 38–43.
9. Akyildiz IF, Su W, Sankarasubramaniam Y, Cayirci E. A survey on sensor networks. IEEE Commun Mag. 2002 Aug 31; 40(8): 102–14.
10. Gutierrez JA, Naeve M, Callaway E, Bourgeois M, Mitter V, Heile B. IEEE 802.15. 4: a developing standard for low-power low-cost wireless personal area networks. IEEE Netw. 2001 Oct 31; 15(5): 12–9.
11. Al-Karaki JN, Al-Mashaqbeh GA. Energy-centric routing in wireless sensor networks. Microprocess Microsyst. 2007 Jun 1; 31(4): 252–62.
12. Heinzelman WB, Murphy AL, Carvalho HS, Perillo MA. Middleware to support sensor network applications. IEEE Netw. 2004 Jun 28; 18(1): 6–14.
13. Yao Y, Gehrke J. The cougar approach to in-network query processing in sensor networks. ACM Sigmod Rec. 2002 Sep 1; 31(3): 9–18.
14. Al–Karaki JN, Kamal AE. Routing techniques in wireless sensor networks: a survey. IEEE Wirel Commun. 2004 Dec 20; 11(6): 6–28.
15. Kulik J, Heinzelman W, Balakrishnan H. Negotiation-based protocols for disseminating information in wireless sensor networks. Wirel Netw. 2002 Mar; 8(2): 169–85.
16. Tilak S, Abu-Ghazaleh NB, Heinzelman W. A taxonomy of wireless micro-sensor network models. ACM SIGMOBILE Mob Comput Commun Rev. 2002 Apr 1; 6(2): 28–36.
17. Krishnamachari B, Estrin D, Wicker S. Modelling data-centric routing in wireless sensor networks. In IEEE infocom. 2002 Jun; 2: 39–44.
18. Heinzelman WR, Kulik J, Balakrishnan H. Adaptive protocols for information dissemination in wireless sensor networks. In Proceedings of the 5th annual ACM/IEEE international conference on Mobile computing and networking. 1999 Aug 1; 174–185.
19. Intanagonwiwat C, Govindan R, Estrin D. Directed diffusion: A scalable and robust communication paradigm for sensor networks. In Proceedings of the 6th annual international conference on Mobile computing and networking. 2000 Aug 1; 56–67.
20. Braginsky D, Estrin D. Rumor routing algorthim for sensor networks. In Proceedings of the 1st ACM international workshop on Wireless sensor networks and applications. 2002 Sep 28; 22–31.
21. Schurgers C, Srivastava MB. Energy efficient routing in wireless sensor networks. In 2001 IEEE MILCOM proceedings communications for network-centric operations: creating the information force (Cat. No. 01CH37277). 2001 Oct 28; 1: 357–361.
22. Chu M, Haussecker H, Zhao F. Scalable information-driven sensor querying and routing for ad hoc heterogeneous sensor networks. Int J High Perform Comput Appl. 2002 Aug; 16(3): 293–313.
23. Sadagopan N, Krishnamachari B, Helmy A. The ACQUIRE mechanism for efficient querying in sensor networks. In Proceedings of the First IEEE International Workshop on Sensor Network Protocols and Applications, 2003. 2003 May 11; 149–155.
24. Heinzelman WR, Chandrakasan A, Balakrishnan H. Energy–efficient communication protocol for wireless microsensor networks. In IEEE Proceedings of the 33rd annual Hawaii international conference on system sciences. 2000 Jan 7; 10p.
25. Manjeshwar A, Agrawal DP. APTEEN: A hybrid protocol for efficient routing and comprehensive information retrieval in wireless sensor networks. In Parallel and distributed processing symposium, international; IEEE Computer Society. 2002 Apr 1; 3: 0195b–0195b.
26. Lindsey S, Raghavendra CS. PEGASIS: Power-efficient gathering in sensor information systems. In Proceedings, IEEE aerospace conference. 2002 Mar 9; 3: 3–3.

27. Xu Y, Heidemann J, Estrin D. Geography-informed energy conservation for ad hoc routing. In Proceedings of the 7th annual international conference on Mobile computing and networking. 2001 Jul 16; 70–84.
28. Chen B, Jamieson K, Balakrishnan H, Morris R. Span: An energy-efficient coordination algorithm for topology maintenance in ad hoc wireless networks. In Proceedings of the 7th annual international conference on Mobile computing and networking. 2001 Jul 16; 85–96.
29. Yu Y, Govindan R, Estrin D. Geographical and energy aware routing: a recursive data dissemination protocol for wireless sensor networks. UCLA Comput Sci Dep Tech Rep. 2001 May;UCLA/CSD-TR-01-0023:159-69.
30. Sohrabi K, Gao J, Ailawadhi V, Pottie GJ. Protocols for self-organization of a wireless sensor network. IEEE Pers Commun. 2000 Oct 31; 7(5): 16–27.
31. He T, Stankovic JA, Lu C, Abdelzaher T. SPEED: A stateless protocol for real–time communication in sensor networks. In 23rd IEEE International Conference on Distributed Computing Systems, 2003 Proceedings. 2003 May 19; 46–55.
32. Mainwaring A, Culler D, Polastre J, Szewczyk R, Anderson J. Wireless sensor networks for habitat monitoring. In Proceedings of the 1st ACM international workshop on Wireless sensor networks and applications. 2002 Sep 28; 88–97.
33. Biagioni E, Bridges K, Chee BJ. PODS: A remote ecological Micro sensor network. EURASIP J Wirel Commun Netw archive. 2005.
34. Bonnet P, Gehrke J, Seshadri P. Querying the physical world. IEEE Pers Commun. 2002 Aug 6; 7(5): 10–5.
35. Schwiebert L, Gupta SK, Weinmann J. Research challenges in wireless networks of biomedical sensors. In Proceedings of the 7th annual international conference on Mobile computing and networking. 2001 Jul 16; 151–165.
36. Baldus H, Klabunde K, Muesch G. Reliable set-up of medical body-sensor networks. In European Workshop on Wireless Sensor Networks. Berlin, Heidelberg: Springer Berlin Heidelberg; 2004 Jan 19; 353–363.
37. Römer K. Tracking real–world phenomena with smart dust. In European Workshop on Wireless Sensor Networks. Berlin, Heidelberg: Springer Berlin Heidelberg; 2004 Jan 19; 28–43.
38. Kidd CD, Orr R, Abowd GD, Atkeson CG, Essa IA, MacIntyre B, Mynatt E, Starner TE, News tetter W. The aware home: A living laboratory for ubiquitous computing research. In International workshop on cooperative buildings. Berlin, Heidelberg: Springer Berlin Heidelberg; 1999 Oct 1; 191–198.

