Australian Journal of Basic and Applied Sciences, 5(8): 1496-1503, 2011
ISSN 1991-8178

A Survey of Wireless Sensor Networks

Jalil Jabari Lotf, Seyed Hossein Hosseini Nazhad ghazani

Department of Computer Engineering, Ahar Branch,Islamic Azad University, Ahar, Iran.

Abstract: Wireless sensor network is a special kind of Ad hoc networks and includes a set of small nodes which are able to sense their surroundings with a definite goal, information processing, storage, data exchange with other nodes and also the adjustability in response to the changes. Typically all the nodes are homogeneous and practically work together to achieve the overall goal of the network. The main goal in wireless sensor networks is to supervise and control the weather conditions and changes, physically or chemically, in an environment with a known limitation.

Key words: Wireless sensor networks; Ad hoc networks; Routing protocol.

INTRODUCTION

The first samples of sensor networks were designed and executed for military applications in order to let the militants communicate with each other in a new region without first settling of special equipments related to the base for a network construction. The dynamic and changingnature of militaries' activities makes the use of fixed networks' equipments useless. On the other hand, other wireless communications can only work in frequencies higher than 100 MHz Thus, there is a connection only in case of direct view. These difficulties will be removed easily by using sensor networks. Because the connection in these networks is multi-hop, i.e. there is no need for the direct view between the sender and the destination or even there is no need to put them in waves dominated by each other. But rather by using some medium nodes, the connection between the sender and the receiver is achieved. Note that the forming components of sensor networks are only those nodes and there is no need for other pre-defined equipments.

The history of using sensor networks dates back to cold war era (mid-1950s decade) and Sound Surveillance System (SOSUS). This system was devised by United States to recognize and track Soviet Union submarines in the bed of northern Atlas Ocean. This network was a broad net of hydrophones which were connected to each other by a cable and covered the ocean environment. This system is currently used in controlling the current phenomena in ocean's bed by National Oceanographic and Atmospheric Administration (NOAA).

Sensor network using trend continued in late 1980s and early 1990s by US ministry of Defense, Defense Advanced Research Projects Agency (DARPA), and some other countries and some innovations were done by research groups in universities. In mid-1990s, some standards such as IEEE1999 technologies were created because the standards were determined and several active research groups in wireless communications entered the potential civilian (non-military) market. In fact those samples which are currently considered as commercial brands have resulted from the research environments in the earlier years.

The rest of the article is organized as follows. In part 2 each sensor node's structure will be explained. Connection architecture and protocol stack of sensor networks description will appear in part 3 and 4, respectively. In part 5 the advantages and applications of sensor networks will be explained. The state of the art problems in sensor networks will be presented in part 6. Part 7 is the conclusion.

The Structure of Each Sensor Node:

Since sensor nodesare known as the smallest independent components in a sensor network, we need to know the components and the equipments of a node and its hardware limitations in order to design the algorithms and suitable protocols for these networks. In this part we will define the characteristics of a real sample node, after talking about the components of a sensor node.

Corresponding Author: Jalil Jabari Lotf, Department of Computer Engineering, Ahar Branch, Islamic Azad University, Ahar, Iran.
E-mail: j-jabbari@iau-ahar.ac.ir,

The Internal Components of a Sensor Node:

Each sensor node is equipped with a set of internal equipments which are required to be included according to the tasks and probable conditions of a node. The relation types of internal components in a sensor node are defined in figure 1. The duties of each of these components are as follows (Akyildiz, 2002):

- Sensor: the sensor presents the amount of specific parameter changes in its sense limitation of the environment in the form of an electrical signal, by sensing the environment. This part can contain a combination of several types of sensors which protects changes of several different parameters in an environment.
- Analog-to-Digital Converter (ADC): the received signal from sensor part may have analog nature. Thus, this part converts the related signal into digital in order to be used easily in the following processing parts.
- Processor: the central processor is the node. All procedures done by the node and also the computation and processing on node information are done in this part.
- Memory: memory is used to store the information needed for processing or temporarily received data and the list of needed programs.
- Transceiver: it is used to make connection with other nodes.
- Power Unit: it is used to supply and allocate the needed energy for consumption for each of these components. Surely in each node a battery is used which can be charged by solar energy, regarding the conditions, but mostly this is not the case. Also the interior part of a node needs certain consumption energy. Thus the consumed energy on the whole should be divided and controlled properly to be used on time.
- Location finding system: this has been provided in some of the nodes. And it is not present in most nodes. It is used to do location finding operations in nodes.
- Mobilize: it is provided in some of the nodes. And it is not present in most nodes. It is used to make nodes move for a specific reason such as swirling or partial movement of the node.

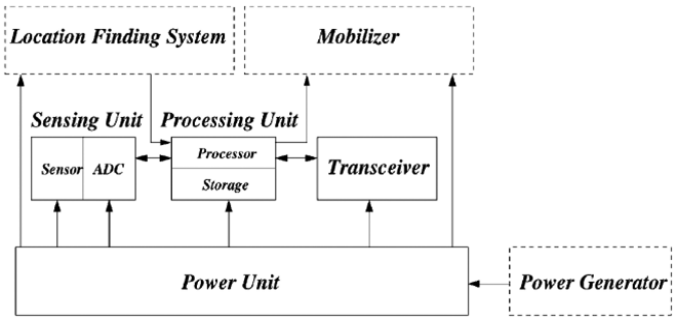

Fig. 1: The components of a sensor nods.

Hardware Limitations in a Sensor Network:

Factors such as having economical system, the expected abilities, the vast number of the nodes and realizing the ideas in a real environment have forced each node to face hardware limitations (Ilyas, 2005). These limitations are as follows:

- Low-cost:the final system should be economical. Since the number of nodes in a network is a lot, by reducing the costs in each node there would be a lot of save in the network. We will try to keep the costs in each node less than one dollar.
- Small size: regarding the whole area, the nodes allocated some part for themselves. The less area filled by nodes, the network will have a better performance. Mostly the nodes should be very small in size not to be considered bulky and to be placed in some areas.
- Low energy consumption: the energy source of nodes is limited and practically it is impossible to change or charge the battery. Thus the present energy should be used ideally.
- Low rate bit: because of some limitations, transferring and processing of information in one sensor node is low.
- Autonomy: each node should be independent of other nodes and perform its tasks according to its own characterizations and conditions.
- Adjustability: while controlling the environment, the conditions may change any time. For example, some of nodes may become demolished. So each node should be able to adjust itself with the new condition.

Connection Architecture in Wireless Sensor Networks:

We can see connection architecture of wireless sensor networks in figure 2 (Akyildiz, 2002). In wireless sensor networks, there are many nodes with communication equipments, processing, environment sensing,etc and they are distributed in an environment with a definite frame. The event happened or the questions asked by sink and the task defined for each node creates connections between nodes. The data exchanged can be a report of the area conditions which are controlled by sensor nodes to the sink or a request by sink sent towards sensor nodes. Sink works as the connection port of sensor network with other systems and communication networks, and in fact it is the end receiver of reports from sensor nodes. And after a set of processing, it sends the processed data to the user (using a communication media such as internet, satellite). On the other hand, the requests of the user are transferred to the network by this node.

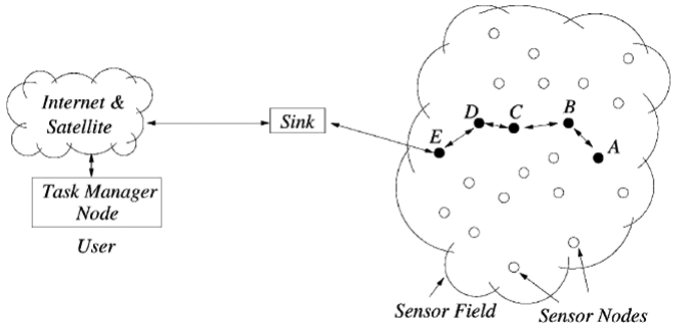

Fig. 2: connection architecture of wireless sensor networks.

A sensor node can take the role of either a data producer or relay the data produced by other nodes. Generally in sensor networks, the nodes often perform both tasks together. The establishment and designing the structure and the architecture of the connections between the nodes of a network needs observing many different factors such as error endurance, scale adaption, production cost, operation environment, sensor network topology, hardware limitations, the tools and connection media, energy consumption and etc.

Protocol Stack:

According to figure 3, sensor networks' protocol Stack consists of five layers of physical, bond and MAC (Medium Access Control), network, transfer and application from one hand and three management phases of energy, motion and task on the other hand (Akyildiz, 2002). The physical layer's duty is the modulation operation and sending and receiving in low level. The accessibility to media control layer should be able to connect to the adjacent nodes by using general distribution method with least collision. The network layer should perform locating route. The transfer layer has the duty of managing the flow of transferring the packages when the user needs it. Various kinds of different application software can be used on application layer and offer different services, depending on the task the network has been designed to perform.

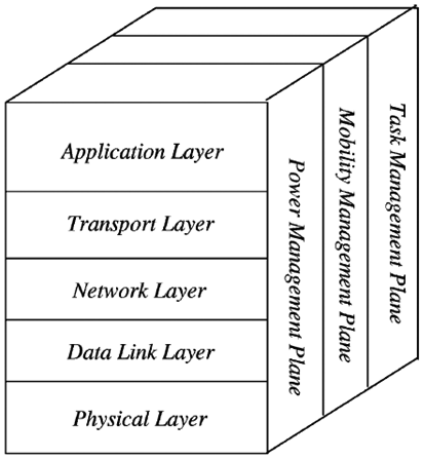

Fig. 3: The sensor networks protocol stack.

Energy management phase defines how to consume energy for the node by intervening in all layers. In fact we need algorithms and energy-aware protocols in order to decrease energy consumption. For example, a node turns off the receiver after it receives a message from one of its adjacent and avoids the message being received again and thus energy consumption decreases. Another idea which can be used simultaneously is that a node which has reached to low level of energy announces to its neighbors that its energy is being finished and it can not take part in routing of the messages. Then the neighboring nodes will route the messages by using other nodes. Motion management phase, which is due to the use of location aware methods, recognizes the removal of the node and records it. Thus the trail of the moving node will be followed and it will be managed if needed. Duty management phase will time the duties of the nodes and equilibrates them. For example, if the sense duty is defined for an area all sensor nodes there are not forced to do the sense operation simultaneously. But this duty can be put on some of the nodes which are more reliable or have fewer tasks to do or have more energy. However, the nodes in a sensor network can work together with energy aware methods and route the data in a moving sensor network and commonly use the sources among the nodes.

In reference (Goldsmith, 2002) another protocol Stack called cross-layer Stack protocol for sensor networks has been proposed [figure 4]. In this Stack protocol, the border between the different layers is so vague and the layers are developed in a hierarchical and unified framework. This vagueness of the borders between the layers is due to the limitations and special applications of sensor networks and it creates the guidelines and optimal and adjustable protocols for sensor networks.

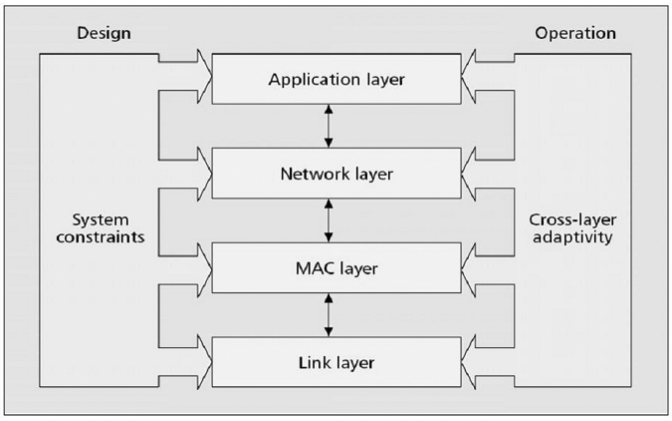

Fig. 4: Adaptive cross-layer design and operation.

The Advantages and Applications of Wireless Sensor Networks:

Every designed system requires a set of conditions and special situations regarding its instinctive characteristics and in using it in different conditions and situations it has a set of advantages and disadvantages in comparison with similar systems. We should choose the system with optimal efficiency due to the cost, by implied estimating and regarding all the present conditions. Below, we will list the advantages of wireless sensor networks first and then some applications of these networks will be explained.

Advantages:

Based on network and nodes' structure and the connection architecture method which we observed in the previous sections, we can identify a set of advantages for wireless sensor networks compared with other systems for doing similar tasks, which are listed below (Akyildiz, 2002; Ilyas M., 2005Al-Karaki, 2004).

Rapid Instalment in Emergencie:

In some cases such as natural disasters or other emergencies which we need the rapid and short time equipment installment, we can use wireless sensor network systems. Because in such a system we do not need to install equipments with a large volume and time-consuming and only the distribution of some nodes in the area which are ready beforehand and are small in volume and also in network installment we don't need much time-consuming operations and the nodes themselves can form their network topology architecture is enough.

It Is Appropriate for Environments Without Noise and Interference:

Using any kind of sysytem in the environment mentioned has some negative effects on the environment

depending on the working condition. And the less effect on our criterion will cause more popularity for the system. For example, suppose the animals' ecosystem. The wave radiation effects of communication networks in big masts is a lot more and it can have negative effect on environment's health or in order to make the installment we need direct presence of human resources in the area and they should use different machines which can ruin the view of the nature or it may cause the goal animals run away or to put it in other way this may lessen the delicacy of the action. While in wireless sensor networks, the nodes are so tiny that other creatures even can not sense it. And since they are small in volume, the nodes can be placed in every corner without having any harmful effect on the view of the environment. Besides the nodes are close to each other and surely the communication span distance is short and thus a lower level of energy is used and there would be no harmful radiation on the ecosystem and there would be no special noise on the other systems.

Avoid to Be Placed in Dangerous and Unreasonable Environments for Frequent Studies:

Using wireless sensor networks for studying contaminated environments, where human beings are not able to work, is very appropriate. Nodes distribution and sensor network installment in these environments can be done by an airplane. The nodes can form certain network topology outomatically, after being installed on the ground and based on their own abilities. They can study the contamination of the environment and report the observed data from the nvironment to the sink.

It Is an Economical Method for Long-term Data Collection:

The estimated cost for data collection is a criterion in choosing a certain system. The cost itself consists of several parts such as the costs due to the equipments, system installment cost, maintanance cost and … . In cost estimation the time span used should be taken into consideration. Compared with other similar systems, in sensor networks a large number of costs are related to the nodes and system installment and there is not much maintenance costs. In other words, using such a system in one week in comparison with some months has the same amount of costs. Thus, to collect data from the environment for a long period of time, the costs of using sensor networks is considerably less than other methods.

Application:

One of the suitable characteristcs of a technique or a system, is that it is able to be used in different scenes and it has various and different applications. Especially if a system is able to do the tasks completely and independantly and benefits from exchanging the data with other systems through using standard protocols. Sensor networks are considered for observing and checking the statistics and also tracking one or more aim/s in the environmrnt. Regarding the inherent characteristics of sensor networks we can use them in different applications. We are going to metion some of these applications below (Akyildiz, 2002; Estrin, 2001; Janakiram, 2005).

Battle Grounds:

In battle grounds we can use sensor networks for recognizing and statistically analyzing the enemy's equipments, classification and tracking of the enmy troops' arrangement and the moving route of them or the own troops.

Recognizing Contaminated Environments:

In contaminated environments there may be several different kinds of contaminations. So by usingthese networks, we can check the presence of certaincontaminations in the environment and also study the thickness of contamination amount in different pats.

Controlling the Ecosystem:

From long ago haman being has been trying to discover the unknowns and the beauties of the world. Most of researches in ecosystems need frequent and concentrated studies and sending a lot of time to collect the data and human beings are not patient enough to experience it. Thus we can use observer, analyzer and results saving machines in this kind of researches. On the other hand, because of the conditions dominant in ecosystems, most research actions should be carried out in peace and quiet in order to avoid the negative effect of the instinctive and real operations of the creatures and the quality of the research not become less. Thus, all controlling systemsare usually able to remote control. Meanwhile, the systems are chosen in a way which is not sensible. Regarding all the above mentioned facts, we can observe that sensor networks benefit from a high amount of ability besides low consumption costs in controlling the ecosystem.

Studing and Analyzing Buidings' Conditions:

Most of research institutes and organizations in civil-engineering and building constructions need to use controlling equipments to get information about the conditions of intended monument buildings in the course of time or when earhquakes happen to gather data such as the pressure and endurance amount, crack presence, the amount of incurred damage, the exhaustion condition, the security and building maintenance and other datails related to the aim of the studies about buidings such as old buildings, bridges, dams, museums and etc. Regarding theabilities of sensor networks we can claim that this system is the best and optimal technique in these fields of study.

Different Applications in Medicine:

In medical studies about creatures or plants in order to get informed about the physical conditions we can use sensor nodes. This usage can be in different cases such as putting the nodes under the skin to do frequent studies in a relatively long period of time, medical equipments and specially in medical physics and etc.

Topical Issues:

Several factors influence the design of sensor networks and a lot of issues are topical in this field, which can not be discussed here completely, so the following is a brief account of some of these issues:

Routing:

The principal nature of sensor networks is that they do the tasks locally because each node can have connections only with its neighboring nodes and the overall and general information is not available for the nodes (collecting these data needs a lot of cost and time). The data gained by the nodes, should be sent to the sink by using routing techniques.

Hardware Limitations:

Not only each node should have all the needed components, but also it should be small enough, light and occupy less space. Meanwhile, each node should have low energy consumption and cost less and have adjustability with the environment. These are among the limitations which make the design and construction of sensor nodes challenging. Light and less volume hardware designs presentation regarding each node component especially wireless connection parts and the sensors are among research subjects which need more investigations. The advances made in integrated circuit with high intensity and low consumption level construction technology has had a crucial role in decreasing hardware limitations.

Error Endurance and Reliability:

Each node may be damaged or completely ruined by the environmental events such as collisions or explosion or it may be out of order because it has finished its energy source. By error endurance and reliability we mean that the nodes' damages should not affect the total performance of the network. In fact, by using unreliable components we want to make a reliable network.

Topology:

Network topology is one of basic concepts of sensor networks which include the identification of other components such as routing, etc. A lot of structures are includedin topology, which are preferred to one another based on different conditions. Some of the factors which affect choosing a structure are less energy consumption, shallowness of the structure, node's low degree, error endurance and interference.

Scalability:

A network should be scalable regarding both nodes number and nodes' distribution. In other words, a sensor network should be able to work with hundreds, thousands and even millions of nodes and also it should protect different distribution capacities of nodes. In most applications nodes are distributed randomly and even distribution with definite capacity is impossible or nodes may change their positionsby environmental factors. Thus, the capacity should differ from a few numbers to several hundred nodes. Also the scalability is related to methods. Some methods may not be scalable. That is it can work within a capacity with limited number of nodes. On the contrary there are some methods which are scalable.

Environmental Conditions:

A vast array of sensor networks' applications is related to environments where human beings are not able

to be present. For example, chemical, microbe and nuclear contaminated areas or studies done in ocean floors and in space or military environments because of enemy's presence or in jungle and animals' ecosystems where the presence of human beings makes them run away. In each case, the environmental conditions should be considered in node designing. For example, in seas and wet places the sensor node will be placed in a container which does not transfer the moisture.

Connection Media:

In sensor networks the connection between the nodes is made wirelessly and through radio, infrared or optical media. In radio media, which is used mostly, different industrial, scientific and medical bands which are free to be used in most countries, are used. Frequency identification in this media is done regarding some hardware limitations, antenna efficiency and energy consumption. Since direct view between the sender and the receiver is a necessity, infrared media is not used by sensor networks mostly, although their construction is easy and cheap. Recently, the optical media has been considered as a connection media. We can refer to its use in smart dust particle (Kahn J.M., 1999). Choosing a connection media from among these three media (radio, infrared, and optical) is a topical issue in sensor networks' designing, regarding the limitations and characteristics of the desired application.

Increasing Network Life Span:

Nodes life span is short because of the limitations of feeding source. Besides that, in some cases it intensifies the special condition of a node in the network. For example, a node which is located very close to the sink loses its energy very soon because of overloaded burden on it and also because being out of order cuts the connection between sink and the whole network and consequently it causes the network to be out of order. The early energy evacuation problem in case of less populated nodes' areas, also applies in unevenly distributed nodes' areas. In such cases, having an energy management within the nodes and offering energy-aware resolutions will be suitable in a way that the critical nodes will be used the least. Regarding the above-mentioned materials, all algorithms and techniques used in sensor networks consider energy as a serious limitation and try to act with awareness from the consumed energy to use the least consumption energy and thus it results in sensor network's increased life span.

Security and Interferences:

Security is a critical subject in some applications especially in military applications and due to some characteristics sensor networks are vulnerable against interference. The first characteristic is the network connections being wireless which facilitates the enemy's anti-security and interference activities. Another characteristic is using a single connection frequency for the whole network which makes the network vulnerable against overhearing. The next characteristic is the dynamic topology which facilitates the adoption of enemy's nodes. That the routing protocols, traffic control and network's availability control layer try to work with less cost and overhead causes security problems. One of the weak points of sensor network is lack of energy feeding source and the enemy can cause the nodes get out of sleeping mode without any reason by the neighboring nodes, by placing a troublesome node which produces wake-up messages generally to all the nodes and with a great amount of energy. The continuation of this trend causes the loss of nodes' energy and shortens their life span. Regarding the limitations we should trace simple and efficient resolutions based on sensor network's nature. Basically there are a lot of challenges in sensor network's security discussions and the research questions in this field are various and complex.

Unforseen Factors:

A sensor network suffers from a lot of uncertainties. We can name some of unpredictable natural factors such as flood, earthquake, problems due to wireless connections and radio interferences, each node's damaging, dynamic structure and network routing, increasing new nodes and omission of old nodes, controlled nodes' movement due to natural or unnatural factors as unforeseen factors. The question here is that in this condition how we can prepare a situation in which regarding the application layer, the network benefits a reliable presence in a large scale with recognized and reliable operation efficiency. Since sensor networks are not mostly controlled by sink and act automatically or at least semi-automatically they should overcome the problems by independent management. Thus they should have characteristics such as self-optimizing, self-organizing and self-healing. These are also issues which are research materials in sensor network.

Conclusion

In this article, the overall view of sensor network's hardware and software (needed for sensor networks' designing) was presented. Sensor networks have been noticed greatly during the recent years and are composed of a great number (which may reach thousands) of small sensor and low-cost nodes with high capabilities and low energy storages. These sensors can receive data (such as temperature, moisture, pressure …) from their surrounding environment and send them to the neighboring nodes. Sensor network has proposed a new control and observing model which has different applications in scientific and non-scientific fields such as environment observing, military, transportation, medicine and etc. Regarding the limitations of sensor networks, we need to propose new techniques for different issues. Some of the topical issues in sensor networks are routing, error endurance and topology control.

REFERENCES

Akyildiz, I.F., W. Su, Y. Sankarasubramaniam and E. Cayircl, 2002. “A survey on sensor networks”, in: Proceedings of the IEEE Communication Magazine, 40: 102-114.

Al-Karaki, J.N. and A.E. Kamal, 2004. ”Routing techniques in wireless sensor networks: a survey”. in: Proceedings of the IEEE Wireless Communications, 11: 6-28.

Akkaya, K. and M. Younis, 2005. "A survey on routing protocols for wireless sensor networks", in: Proceedings of the Elsevier Ad Hoc Network Journal, pp: 325-349.

Estrin, D., 2001. “Embedded Everywhere: A research agenda for network systems of embedded computers”, in: Proceedings of the National Academy Press, 2001, Computer Science and Telecommunication Board (CSTB) Report.

Goldsmith, A.J. and S.B. Wicker, 2002. “Design challenges for energy-constrained ad hoc wireless networks”, in: Proceedings of the IEEE Wireless Commun, pp: 8-27.

http://www.pmel.noaa.gov/vents/acoustics/sosus.html

Hill, J. and D. Culler, 2002. “Mica: A wireless platform for deeply embedded networks”, in: Proceedings of the IEEE Micro., 22(6): 12-24.

Hedetniemi, S. and A. Liestman, 1988. “A survey of gossiping and broadcasting in communication networks”, in: Proceedings of the Networks, 18(4): 319-349.

Heinzelman, W., J. Kulik and H. Balakrishnan, 1999. “Adaptive protocols for information dissemination in wireless sensor networks”, in: Proceedings of the 5th Annual ACM/IEEE International Conference on Mobile Computing and Networking (MobiCom_99), Seattle, WA.,

Heinzelman, W., A. Chandrakasan and H. Balakrishnan, 2000. "Energy-efficient communication protocol for wireless mi-crosensor network", in: Proceedings of the IEEE System Sciences, pp: 1-10.

Ilyas, M. and MahgoubI., 2005. "Handbook of Sensor Networks: Compact Wireless and Wired Sensing Systems", in: Proceedings of the CRC Press, London, Washington, D.C.

Janakiram, D., R. Venkateswarlu and S. Nitin, 2005. ”A survey on programming languages, middleware and applications in wireless sensor networks”, in: Proceedings of the IITM-CSE-DOS-2005-04.

Kahn, J.M., R.H. Katz and K.S.J. Pister, 1999. “Next centurychallenges: mobile networking for smart dust”, in: Proceedingsof the ACM Mobi Com 99, Washington, USA, pp: 271-278.

Kulkarni, S., A. Iyer and C. Rosenberg, 2006. "An Address-Light, Integrated MAC and Routing Protocol for Wireless Sensor Networks", in: Proceedings of the IEEE/ACM Transactions on Networking, 14(4): 793-806.

Nishimura, C.E. and D.M. Conlon, 1994. "IUSS Dual Use: Monitoring Whales and Earthquakes Using SOSUS", in: Proceedings of the Mar. Tech., Soc. Journal, 27(4): 13-21.

Shah, R. and J. Rabaey, 2002. ”Energy aware routing for low energy ad hoc sensor networks”, in: Proceedings of the IEEE Wireless Communications and Networking Conference (WCNC), Orlando, FL., pp: 350-355.

Younis, O. and S. Fahmy, 2004. "Distributed Clustering in Ad-hoc Sensor Networks: A Hybrid, Energy-Efficient Approach", in: Proceedings of the IEEE INFOCOM, 1: 629-640.