# Wireless Sensor Networks: A Survey

**Neeti Pathak, Priyanka Agrawal, Ritesh gupta**

***Abstract*— This paper describes the concept of sensor networks which has been made viable by the convergence of micro-electro-mechanical systems technology, wireless communications and digital electronics. First, the sensing tasks and the potential sensor networks applications are explored, and a review of factors influencing the design of sensor networks is provided. Then, the communication architecture for sensor networks is outlined, and the algorithms and protocols developed for each layer in the literature are explored. Open research issues for the realization of sensor networks are also discussed © 2002 Published by Elsevier Science B.V.**

***Index Terms*— micro- electro-mechanical, wireless communications, protocols developed.**

## I. Introduction

Networked micro sensors technology is a key technology for the future. In September 1999, Business Week heralded it as one of the 21 most important technologies for the 21st century. Cheap, smart devices with multiple onboard sensors, networked through wireless links and the Internet and deployed in large numbers, provide unprecedented opportunities for instrument and controlling homes, cities, and the environment. In addition, networked micro sensors provide the technology for a broad spectrum of systems in the defense arena, generating new capabilities for reconnaissance and surveillance as well as other tactical applications.

Smart disposable micro sensors can be deployed on the ground, in the air, under water, on bodies, in vehicles, and inside buildings. A system of networked sensors can detect and track threats (e.g., winged and wheeled vehicles, personnel, chemical and biological agents) and be used for weapon targeting and area denial. Each sensor node will have embedded processing capability, and will potentially have multiple onboard sensors, operating in the acoustic, seismic, infrared (IR), and magnetic modes, as well as imagers and micro radars. Also onboard will be storage, wireless links to neighboring nodes, and location and positioning knowledge through the global positioning system (GPS) or local positioning algorithms. Networked micro sensors belong to the general family of sensor networks that use multiple distributed sensors to collect information on entities of interest. Table 1 summarizes the range of possible attributes in general sensor networks. Current and potential applications of sensor networks include: military sensing, physical security, air traffic control, traffic surveillance, video surveillance, industrial and manufacturing automation, distributed robotics, environment monitoring, and building and structures monitoring. The sensors in these applications may be small or large, and the networks may be wired or wireless. However, ubiquitous wireless networks of micro sensors probably offer the most potential in changing the world of sensing. While sensor networks for various applications may be quite different, they share common technical issues.

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## II. SENSOR NETWORKS COMMUNICATION ARCHITECTURE:

The sensor nodes are usually scattered in a sensor field as shown in Fig. 1. Each of these scattered sensor nodes has the capabilities to collect data and route data back to the sink. Data are routed back to the sink by a multi hop infrastructure less architecture through the sink as shown in Fig. 1. The sink may communicate with the task manager node via Internet or satellite. The design of the sensor network as described by Fig. 1 is influenced by many factors, including fault tolerance, scalability, production costs, operating environment, sensor network topology, hardware constraints, transmission media, and power consumption.

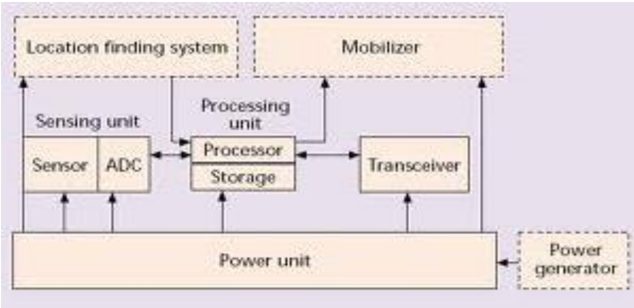


FIG1.

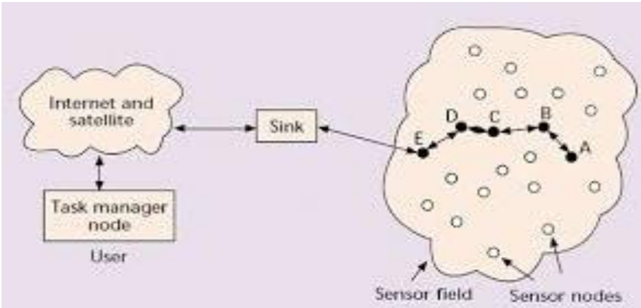


FIG.2

## III. DESIGN FACTORS:

The design factors are addressed by many researchers as surveyed in this article. However, none of these studies has a fully integrated view of all the factors driving the design of sensor networks and sensor nodes. These factors are important because they serve as a guideline to design a protocol or an algorithm for sensor net- works. In addition, these influencing factors can be used to compare different schemes.

Fault Tolerance - Some sensor nodes may fail or be blocked due to lack of power, or have physical damage or environmental interference. The failure of sensor nodes should not affect the overall task of the sensor network. This is the reliability or fault tolerance issue. Fault tolerance is the ability to sustain sensor network functionalities without any interruption due to sensor node failures. The reliability Rk(t) or fault tolerance of a sensor node is modeled in using the Poisson distribution to capture the probability of not having a failure within the time interval (0,t): Rk(t) = e–λkt, (1) where λk is the failure rate of sensor node k and t is the time period.

Scalability - The number of sensor nodes deployed in studying a phenomenon may be on the order of hundreds or thousands. Depending on the application, the number may reach an extreme value of millions. New schemes must be able to work with this number of nodes. They must also utilize the high density of the sensor networks. The density can range from few sensor nodes to few hundred sensor nodes in a region, which can be less than 10 m in diameter. The density μ can be calculated according to [3] as μ(R) = (N · πR2)/A, (2) where N is the number of scattered sensor nodes in region A, and R is the radio transmission range. Basically, μ(R) gives the number of nodes within the transmission radius of each node in region A.

Production Costs - Since sensor networks consist of a large number of sensor nodes, the cost of a single node is very important to justify the overall cost of the network. If the cost of the network is more expensive than deploying traditional sensors, the sensor network is not cost-justified. As a result, the cost of each sensor node has to be kept low. The state-of-the-art technology allows a Bluetooth radio system to be less than US$10 [4]. Also, the price of a pico node is targeted to be less than US$1. The cost of a sensor node should be much less than US$1 in order for the sensor network to be feasible. The cost of a Bluetooth radio, which is known to be a low-cost device, is even 10 times more expensive than the targeted price for a sensor node.

## IV. HARDWARE CONSTRAINTS :

A sensor node is made up of four basic components, as shown in Fig. 2: a sensing unit, a processing unit, a transceiver unit, and a power unit. They may also have additional application-dependent components such as a location finding system, power generator, and mobilizer. Sensing units are usually composed of two subunits: sensors and analog-to-digital converters (ADCs). The analog signals produced by the sensors based on the observed phenomenon are converted to digital signals by the ADC, and then fed into the processing unit. The processing unit, which is generally associated with a small storage unit, manages the procedures that make the sensor node collaborate with the other nodes to carry out the assigned sensing tasks. A transceiver unit connects the node to the network. One of the most important components of a sensor node is the power unit. Power units may be supported by power scavenging units such as solar cells. There are also other subunits that are application-dependent. Most of the sensor network routing techniques and sensing tasks require knowledge of location with high accuracy. Thus, it is common that a sensor node has a location finding system. A mobilizer may some - times be needed to move sensor nodes when it is required to carry out the assigned tasks. All of these subunits may need to fit into a matchbox-sized module. The required size may be smaller than even a cubic centimeter, which is light enough to remain suspended in the air. Apart from size, there are some other stringent constraints for sensor nodes. These nodes must consume extremely low power, operate in high volumetric densities have low production cost, be dispensable and autonomous, operate unattended, and be adaptive to the environment.

## V. PLATFORMS:

***Hardware***- One major challenge in a sensor network is to produce low cost and tiny sensor nodes. There are an increasing number of small companies producing Sensor Network hardware and the commercial situation can be compared to home computing in the 1970s. Many of the nodes are still in the research and development stage, particularly their software. Also inherent to sensor network adoption is the use of very low power methods for data acquisition.

In many applications, a Sensor Network communicates with a Local Area Network or Wide Area Network through a gateway. The Gateway acts as a bridge between the Sensor Network and the other network. This enables data to be stored and processed by device with more resources, for example, in a remotely located server.

***Software***- Energy is the scarcest resource of Sensor Network nodes, and it determines the lifetime of Sensor Networks. Sensor Networks are meant to be deployed in large numbers in various environments, including remote and hostile regions, where ad hoc communications are a key component. For this reason, algorithms and protocols need to address the following issues:

- Lifetime maximization
- Robustness and fault tolerance
- Self-configuration

Lifetime maximization: Energy/Power Consumption of the sensing device should be minimized and sensor nodes should be energy efficient since their limited energy resource determines their lifetime. To conserve power the node should shut off the radio power supply when not in use.

Some of the important topics in Sensor Networks software research are:

- Operating systems
- Security
- Mobility

Operating systems- Operating systems for Sensor Network nodes are typically less complex than general-purpose operating systems. They more strongly resemble embedded systems, for two reasons. First, wireless sensor networks are typically deployed with a particular application in mind, rather than as a general platform. Second, a need for low costs and low power leads most Sensor nodes to have low-power microcontrollers ensuring that mechanisms such as virtual memory are either unnecessary or too expensive to implement .It is therefore possible to use embedded operating systems such as eCos or uC/OS for Sensor Networks. However, such operating systems are often designed with real-time properties.

## VI. SENSOR NETWORK APPLICATIONS:

Sensor networks may consist of many different types of sensors such as seismic, low sampling rate magnetic, thermal, visual, infrared, acoustic and radar, which are able to monitor a wide variety of ambient conditions that include the following:

- Temperature
- Humidity
- Vehicular movement
- Lightning condition
- Pressure
- Soil makeup
- Noise levels
- The presence or absence of certain kinds of objects
- Mechanical stress levels on attached objects
- The current characteristics such as speed, direction, and size of an object.

Sensor nodes can be used for continuous sensing, event detection, event ID, location sensing, and local control of actuators. The concepts of micro-sensing and wireless connection of these nodes promise many new application areas. We categorize the applications into military, environment, health, home and other commercial areas. It is possible to expand this classification with more categories such as space exploration, chemical processing and disaster relief.

### Military applications

Wireless sensor networks can be an integral part of military command, control, communications, computing, intelligence, surveillance, reconnaissance and targeting (C4ISRT) systems. The rapid deployment, self-organization and fault tolerance characteristics of sensor networks make them a very promising sensing technique for military C4ISRT. Since sensor networks are based on the dense deployment of disposable and low-cost sensor nodes, destruction of some nodes by hostile actions does not affect a military operation as much as the destruction of a traditional sensor, which makes sensor networks concept a better approach for battle fields. Some of the military applications of sensor networks are monitoring friendly forces, equipment and ammunition; battle field surveillance; reconnaissance of opposing forces and terrain; targeting; battle damage assessment; and nuclear, biological and chemical (NBC) attack detection and reconnaissance. Monitoring friendly forces, equipment and ammunition: Leaders and commanders can constantly monitor the status of friendly troops, the condition and the availability of the equipment and the ammunition in a battle field by the use of sensor networks. Every troop, vehicle, equipment and critical ammunition can be attached with small sensors that report the status. These reports are gathered in sink nodes and sent to the troop leaders. The data can also be forwarded to the upper levels of the command hierarchy while being aggregated with the data from other units at each level. Battle field surveillance: Critical terrains, approach routes, paths and straits can be rapidly covered with sensor networks and closely watched for the activities of the opposing forces. As the operations evolve and new operational plans are prepared, new sensor networks can be deployed anytime for battle field surveillance. Reconnaissance of opposing forces and terrain: Sensor networks can be deployed in critical terrains, and some valuable, detailed, and timely intelligence about the opposing forces and terrain can be gathered within minutes before the opposing forces can intercept them. Targeting: Sensor networks can be incorporated into guidance systems of the intelligent ammunition. Battle damage assessment: Just before or after attacks, sensor networks can be deployed in the target area to gather the battle damage assessment data. Nuclear, biological and chemical attack detection and reconnaissance: In chemical and biological warfare, being close to ground zero is important for timely and accurate detection of the agents. Sensor networks deployed in the friendly region and used as a chemical or biological warning sys- tem can provide the friendly forces with critical reaction time, which drops casualties drastically. We can also use sensor networks for detailed reconnaissance after an NBC attack is detected. For instance, we can make a nuclear reconnaissance without exposing a recce team to nuclear radiation.

### Environmental applications

Some environmental applications of sensor networks include tracking the movements of birds, small animals, and insects; monitoring environ- mental conditions that affect crops and livestock; irrigation; macro instruments for large-scale Earth monitoring and planetary exploration; chemical/ biological detection; precision agriculture; biological, Earth, and environmental monitoring in marine, soil, and atmospheric contexts; forest fire detection; meteorological or geophysical research; flood detection; bio-complexity mapping of the environment; and pollution study. Forest fire detection: Since sensor nodes may be strategically, randomly, and densely deployed in a forest, sensor nodes can relay the exact origin of the fire to the end users before the fire is spread uncontrollable. Millions of sensor nodes can be deployed and integrated using radio frequencies/ optical systems. Also, they may be equipped with effective power scavenging method, such as solar cells, because the sensors may be left unattended for months and even years. The sensor nodes will collaborate with each other to perform distributed sensing and overcome obstacles, such as trees and rocks that block wired sensors' line of sight. A bio complexity mapping of the environment re- quires sophisticated approaches to integrate information across temporal and spatial scales. The advances of technology in the remote sensing and automated data collection have enabled higher spatial, spectral, and temporal resolution at a geometrically declining cost per unit area. Along with these advances, the sensor nodes also have the ability to connect with the Internet, which allows remote users to control, monitor and observe the bio complexity of the environment.

Although satellite and airborne sensors are useful in observing large biodiversity, e.g., spatial complexity of dominant plant species, they are not fine grain enough to observe small size biodiversity, which makes up most of the biodiversity in an ecosystem. As a result, there is a need for ground level deployment of wireless sensor nodes to observe the bio complexity. One example of bio complexity mapping of the environment is done at the James Reserve in Southern California. Three monitoring grids with each having 25– 100 sensor nodes will be implemented for fixed view multimedia and environmental sensor data loggers. Flood detection : An example of a flood detection is the ALERT system [90] deployed in the US. Several types of sensors deployed in the ALERT system are rainfall, water level and weather sensors. These sensors supply information to the centralized database system in a pre defined way. Research projects, such as the COUGAR Device Database Project at Cornell University and the Data Space project at Rutgers, are investigating distributed approaches in interacting with sensor nodes in the sensor field to provide snapshot and long-running queries. Precision Agriculture: Some of the benefits is the ability to monitor the pesticides level in the drinking water, the level of soil erosion, and the level of air pollution in real time.

### Health applications

Some of the health applications for sensor net- works are providing interfaces for the disabled; integrated patient monitoring; diagnostics; drug administration in hospitals; monitoring the movements and internal processes of insects or other small animals; Tele monitoring of human physiological data; and tracking and monitoring doctors and patients inside a hospital. Tele monitoring of human physiological data: The physiological data collected by the sensor networks can be stored for a long period of time, and can be used for medical exploration. The installed sensor networks can also monitor and detect elderly people's behavior, e.g., a fall. These small sensor nodes allow the subject a greater freedom of movement and allow doctors to identify pre defined symptoms earlier. Also, they facilitate a higher quality of life for the subjects compared to the treatment centers. A ''Health Smart Home'' is designed in the Faculty of Medicine in Grenoble—France to validate the feasibility of such system. Tracking and monitoring doctors and patients inside a hospital: Each patient has small and light weight sensor nodes attached to them. Each sensor node has its specific task. For example, one sensor node may be detecting the heart rate while another is detecting the blood pressure. Doctors may also carry a sensor node, which allows other doctors to locate them within the hospital. Drug administration in hospitals: If sensor nodes can be attached to medications, the chance of getting and prescribing the wrong medication to patients can be minimized. Computerized systems as described in have shown that they can help minimize adverse drug events.

### Home applications

Home automation: As technology advances, smart sensor nodes and actuators can be buried in appliances, such as vacuum cleaners, micro-wave ovens, refrigerators, and VCRs. These sensor nodes inside the domestic devices can interact with each other and with the external network via the Internet or Satellite. They allow end users to manage home devices locally and remotely more easily. Smart environment: The design of smart environment can have two different perspectives, i.e., human-centered and technology-centered. For human-centered, a smart environment has to adapt to the needs of the end users in terms of input/ output capabilities. For technology-centered, new hardware technologies, networking solutions, and middleware services have to be developed. A scenario of how sensor nodes can be used to create a smart environment is described in. The sensor nodes can be embedded into furniture and appliances, and they can communicate with each other and the room server. The room server can also communicate with other room servers to learn about the services they offered, e.g., printing, scanning, and faxing. These room servers and sensor nodes can be integrated with existing embedded devices to become self-organizing, self regulated , and adaptive systems based on control theory models as described in.

### Other commercial applications

Some of the commercial applications are monitoring material fatigue; building virtual key- boards; managing inventory; monitoring product quality; constructing smart office spaces; environ- mental control in office buildings; robot control and guidance in automatic manufacturing environments; interactive toys; interactive museums; factory process control and automation; monitoring disaster area; smart structures with sensor nodes embedded inside; machine diagnosis; transportation; factory instrumentation; local control of actuators; detecting and monitoring car thefts; vehicle tracking and detection; and instrumentation of semiconductor processing chambers, rotating machinery, wind tunnels, and anechoic chambers. Environmental control in office buildings: The air conditioning and heat of most buildings are centrally controlled. Therefore, the temperature inside a room can vary by few degrees; one side might be warmer than the other because there is only one control in the room and the air flow from the central system is not evenly distributed. A distributed wireless sensor network system can be installed to control the air room flow and temperature in different parts of the room. It is estimated that such distributed technology can reduce energy consumption by two quadrillion British Thermal Units (BTUs) in the US, which amounts to saving of $55 billion per year and reducing 35 million metric tons of carbon emissions. Interactive museums: In the future, children will be able to interact with objects in museums to learn more about them. These objects will be able to respond to their touch and speech. Also, children can participate in real time cause-and-effect experiments, which can teach them about science and environment. In addition, the wireless sensor networks can provide paging and localization in- side the museum. An example of such museums is the San Franciso Exploratorium that features a combination of data measurements and cause- and-effect experiments. Detecting and monitoring car thefts: Sensor nodes are being deployed to detect and identify threats within a geographic region and report these threats to remote end users by the Internet for analysis. Managing inventory control: Each item in a warehouse may have a sensor node attached. The end users can find out the exact location of the item and tally the number of items in the same category. If the end users want to insert new inventories, all the users need to do is to attach the appropriate sensor nodes to the inventories. The end users can track and locate where the inventories are at all times. Vehicle tracking and detection: There are two approaches as described into track and detect the vehicle: first, the line of bearing of the vehicle is determined locally within the clusters and then it is forwarded to the base station, and second, the raw data collected by the sensor nodes are forwarded to the base station to determine the location of the vehicle.

## REFERENCES

[1] G.D. Abowd, J.P.G. Sterbenz, Final report on the inter- agency workshop on research issues for smart environ- ments, IEEE Personal Communications (October 2000) 36–40.

[2] J. Agre, L. Clare, An integrated architecture for cooper- ative sensing networks, IEEE Computer Magazine (May 2000) 106–108.

[3] I.F. Akyildiz, W. Su, A power aware enhanced routing (PAER) protocol for sensor networks, Georgia Tech Technical Report, January 2002, submitted for publica- tion.

[4] A. Bakre, B.R. Badrinath, I-TCP: indirect TCP for mobile hosts, Proceedings of the 15th International Conference on Distributed Computing Systems, Vancouver, BC, May 1995, pp. 136–143.

[5] F. Zhao, J. Shin, and J. Reich, “Information-driven dynamic sensor collaboration for tracking applications,” IEEE Signal Processing Mag., vol. 19, pp. 61–72, Mar. 2002.

[6] J. Shin, L. J. Guibas, and F. Zhao, “A distributed algorithm for man- aging multi-target identities in wireless ad-hoc sensor networks,” presentedat the 2nd Int. Workshop Information Processing in Sensor Networks (IPSN’03), Palo Alto, CA, 2003.