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A Review on Architecture of Wireless Communication Sensor Networks in Cooperative field

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Abstract— The study of wireless sensor networks is challenging in that it requires an enormous breadth of knowledge. A wireless sensor network (WSN) is a computer network consisting of spatially distributed autonomous devices using sensors to cooperatively monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion or pollutants at different locations. The development of wireless sensor networks was originally motivated by military applications such as battlefield surveillance. However, wireless sensor networks are now used in many civilian application areas, including environment and habitat monitoring, healthcare applications, home automation and traffic control.

Index Terms—Sensor, Wireless sensor network (WSN).

I. INTRODUCTION TO WIRELESS SENSOR NETWORK (WSN)

A Wireless Sensor Network is a special kind of wireless network consisting of small and spatially distributed autonomous devices (nodes) which can cooperatively sense physical phenomena around them [5].

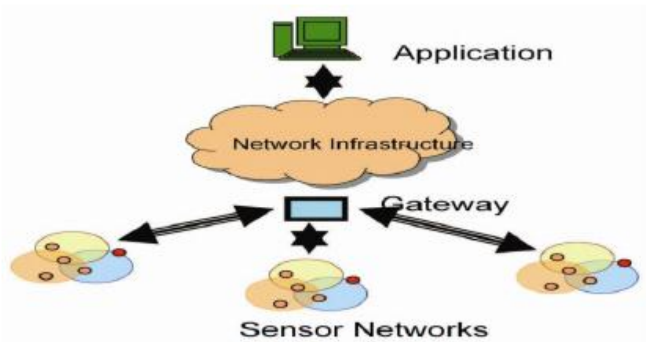

Figure 1.1 Wireless Sensor Network

It also processes the collected data and effectively route them to the nearest sinks or gateway node. It consists of a large number of densely deployed sensor nodes [1]. Each node in the sensor network may consist of one or more sensors, a low power radio, portable power supply, and possibly localization hardware, such as a GPS (Global Positioning System) unit or a ranging device. These nodes incorporate wireless transceivers so that communication and networking are enabled. Additionally, the network possesses self-organizing capability. Ideally, individual nodes should be battery powered with a long lifetime and should cost very little. A key feature of such networks is that their nodes are untethered and unattended. Consequently, they have limited and non-replenish able energy resources. Therefore, energy efficiency is an important design consideration for these networks.

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In addition to one or more sensors, each node in a wireless sensor network is typically equipped with a radio transceiver or other wireless communications device, a small microcontroller, and an energy source, usually a battery. The size a single sensor node can vary from shoebox-sized nodes down to devices the size of grain of dust. The cost of sensor nodes is similarly variable, ranging from hundreds of dollars to a few cents, depending on the size of the sensor network and the complexity required of individual sensor nodes. Size and cost constraints on sensor nodes result in corresponding constraints on resources such as energy, memory, computational speed and bandwidth.

1.1 Classification of Sensors

The sensors are classified into three categories.

1.1.1 Passive, Omni Directional Sensors: Passive sensors sense the data without actually manipulating the environment by active probing. They are self powered i.e. energy is needed only to amplify their analog signal. There is no notion of "direction" involved in these measurements.

1.1.2 Passive, narrow-beam sensors: These sensors are passive but they have well-defined notion of direction of measurement. Typical example is 'camera'.

1.1.3 Active Sensors: These groups of sensors actively probe the environment, for example, a solar or radar. Sensor or some type of seismic sensor, which generate shock waves by small explosions.

II. ARCHITECTURE OF SENSOR NODE

One of the most important features is the hardware, namely the node itself. A node is a resource-constrained device capable of radio communication, sensing and limited data-processing. It is optionally also capable of actuating the environment. It is low on processing power, energy as well as memory. A sensor node is usually composed of four components: a Processing Unit, a Power Unit, one or more Sensing Units and/or Actuating Units, and a Transceiver. The Processing Unit is typically an 8-16 bit, 1-24 MHz microcontroller with 1KB –4MB onboard memory. These figures vary within different families of microcontrollers, and with different vendors.

The Power Unit usually consists of one or more batteries, providing 3V - 4.5V, generally with a capacity ranging between 1700mAh – 2700mAh. The node can be fitted with various sensors for acoustic, photo, temperature, pressure etc based applications. Each node may also optionally be fitted with an interface for plugging-in an actuator for performing any mechanical actions on a application-specific basis. Figure 1.2 shows the structure of a sensor node.

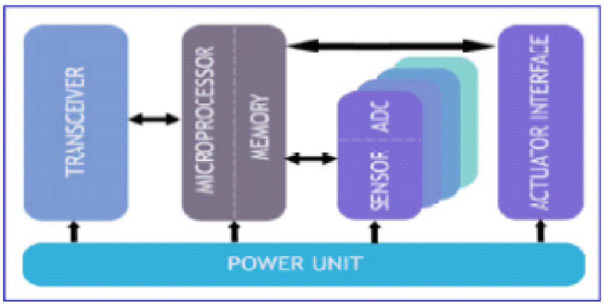

Figure 1.2 Architecture of Sensor Node

III. COMPONENTS OF A SENSOR NODE

The main components of a sensor node are microcontroller, transceiver, external memory, power source and one or more sensors ref[1].

3.1 Microcontroller

Microcontroller performs tasks, processes data and controls the functionality of other components

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in the sensor node. Other alternatives that can be used as a controller are: General purpose desktop microprocessor, Digital signal processors, Field Programmable Gate Array and Application-specific integrated circuit. Microcontrollers are most suitable choice for sensor node. Each of the four choices has their own advantages and disadvantages. Microcontrollers are the best choices for embedded systems. Because of their flexibility to connect to other devices, programmable, power consumption is less, as these devices can go to sleep state and part of controller can be active. In general purpose microprocessor the power consumption is more than the microcontroller; therefore it is not a suitable choice for sensor node. Digital Signal Processors are appropriate for broadband wireless communication. But in Wireless Sensor Networks, the wireless communication should be modest i.e. simpler, easier to process modulation and signal processing tasks of actual sensing of data is less complicated.

3.2 Transceiver

Sensor nodes make use of ISM (Industrial Science and Medical) band which gives free radio, huge spectrum allocation and global availability. The various choices of wireless transmission media are Radio frequency,Optical communication (Laser) and Infrared. Laser requires less energy, but needs line-of-sight for communication and also sensitive to atmospheric conditions. Infrared like laser, needs no antenna but is limited in its broadcasting capacity. Radio Frequency (RF) based communication is the most relevant that fits to most of the WSN applications. WSN's use the communication frequencies between about 433 MHz and 2.4 GHz. The functionality of both transmitter and receiver are combined into a single device know as transceivers are used in sensor nodes. Transceivers lack unique identifier. The operational states are Transmit, Receive, Idle and Sleep.

Current generation radios have built-in state machines that perform this operation automatically. Radios used in transceivers operate in four different modes: Transmit Receive, Idle, and Sleep. Radios operating in Idle mode results in power consumption, almost equal to power consumed in Receive mode. Thus it is better to completely shut down the radios rather than in the Idle mode when it is not Transmitting or Receiving. And also significant amount of power is consumed when switching from Sleep mode to Transmit mode to transmit a packet.

3.3 Sensing Unit

It senses the environment through transceiver.

3.4 External Memory

From an energy perspective, the most relevant kinds of memory are on-chip memory of a microcontroller and FLASH memory - off-chip RAM is rarely if ever used. Flash memories are used due to its cost and storage capacity. Memory requirements are very much application dependent. Two categories of memory based on the purpose of storage

a. User memory used for storing application related or personal data.
b. Program memory used for programming the device.

3.5 Power Source

Power consumption in the sensor node is for Sensing, Communication and Data Processing. More energy is required for data communication in sensor node [3,4]. Energy expenditure is less for sensing and data processing. The energy cost of transmitting 1 Kb for distance of 100 m is approximately the same as that for the executing 3 million instructions by 100 million instructions per second/W processor. Power is stored either in Batteries or Capacitors. Batteries are the main source of power supply for sensor nodes. Namely two types of batteries used are chargeable and non-rechargeable. They are also classified according to electrochemical material used for electrode such as NiCd (nickel-cadmium), NiZn(nickel-zinc), Nimh (nickel metal hydride), and Lithium-Ion. Current sensors are developed which are able to renew their energy from solar, thermo generator, or

vibration energy. Two major power saving policies used are Dynamic Power Management (DPM) and Dynamic Voltage Scaling (DVS). DPM takes care of shutting down parts of sensor node which are not currently used or active.
DVS scheme varies the power levels depending on the non-deterministic workload. By varying the voltage along with the frequency, it is possible to obtain quadratic reduction in power consumption.

IV. STRUCTURE OF A WIRELESS SENSOR NETWORK

In the structure of a wireless sensor network from the logical point of view, the nodes can only be contacted through services of the middleware layers. They do not perform any individual tasks. The distributed middleware coordinates the cooperation of services within the network. It is logically located in the network layer but physically exists in the nodes. All layers together in conjunction with their configuration compose the sensor network application. The middleware architecture called as SINA (Sensor Information Networking Architecture).The SINA architecture proposes Sensor Query and Tasking Language (SQTL) as the programming interface between sensor applications and SINA middleware. Operating system acts as an interface between the hardware and the sensor network application. Tiny OS is the component based operating system that is specially designed for sensor network [1,2,5].
Sensor networks consist of a huge number of small sensor nodes, which communicate wirelessly. The following figure 1.4 shows the structure of a sensor node. The following factor influences the developments of sensor nodes.

- Increasing device complexity on microchips
- High performance, wireless networking technologies
- A combination of digital signal processing and sensor data acquisition
- Advances in the development of micro electromechanical systems (MEMS) and
- Availability of high performance development tools.

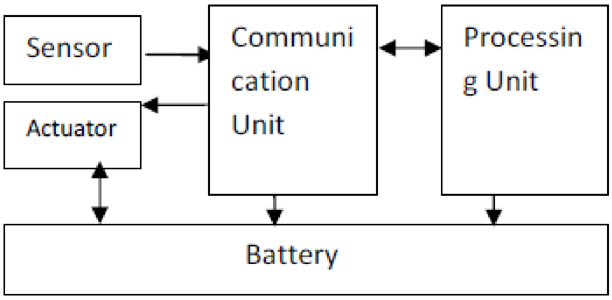

Figure 1.4 Structure of a sensor node

Sensor nodes can be imagined as small computers, extremely basic in terms of their interfaces and their components. They usually consist of a processing unit with limited computational power and limited memory, sensors (including specific conditioning circuitry), a communication device (usually radio transceivers or alternatively optical), and a power source usually in the form of a battery. The base stations are one or more distinguished components of the WSN with much more computational, energy and communication resources. They act as a gateway between sensor nodes and the end user.

V. WIRELESS SENSOR NETWORK ARCHITECTURE

In the figure 1.5 the wireless sensor network architecture consisting of one sink node (or base station) and a (large) number of sensor nodes deployed over a large geographic area (sensing field). Data are transferred from sensor nodes to the sink through a multi-hop communication paradigm [7].

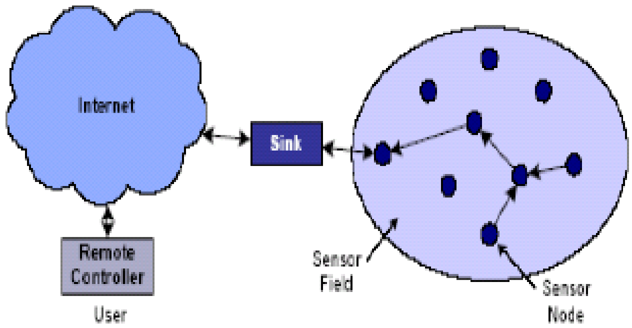

Figure 1.5 Wireless sensor network architecture

The energy consumption for transmission of data is more compared to data processing [4]. The energy cost of transmitting a single bit of information is approximately the same as that needed for processing a thousand operations in a typical sensor node. The energy consumption of the sensing subsystem depends on the specific sensor type. In general, energy-saving techniques focus on two subsystems: the networking subsystem (i.e., energy management is taken into account in the operations of each single node, as well as in the design of networking protocols), and the sensing subsystem (i.e., techniques are used to reduce the amount or frequency of energy-expensive samples). The lifetime of a sensor network can be extended by jointly applying different techniques. For example, energy efficient protocols are aimed at minimizing the energy consumption during network activities. However, a large amount of energy is consumed by node components (CPU, radio, etc.) even if they are idle. Power management schemes are thus used for switching off node components that are not temporarily needed. Specifically, it focuses primarily on the networking subsystem by considering duty cycling. Furthermore, the main techniques suitable to reduce the energy consumption of sensors when the energy cost for data acquisition i.e. sampling) cannot be neglected. Finally, introduce mobility as a new energy conservation paradigm with the purpose of prolonging the network lifetime. These techniques are the basis for any networking protocol and solution optimized from an energy-saving point of view.

VI. CHARACTERISTICS OF WSN

6.1 Node mobility

Mobility of the nodes creates a dynamic network topology. Links will be dynamically formed when two nodes come into the transmission range of each other and are torn down when they move out of range [1,5].

6.2 Unattended operation

In most cases, once deployed, sensor networks have no human intervention. Hence the nodes themselves are responsible for reconfiguration in case of any changes [6].

6.3 Dynamic Network Topology

It is an important aspect of the sensor networks. The lifecycle of a sensor network may be represented in three phases with respect to the topology and its maintenance. During the deployment phase, the nodes are dropped into their positions in an ad hoc manner. The nodes need to self-organize into a communicating network. The Post-deployment phase topology maintenance consists of topology changes induced due to the failure of the nodes, failure of radio links, or arrival of some mobile obstacles. The Re-deployment phase deals with the deployment of nodes to replace failed nodes. In each of the three phases, a sensor network should be capable of seamlessly organizing itself to stream data to the base-station [7].

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6.4 Limited power

Sensor Networks are highly sensitive to energy usage [3,4]. They may, probably, be deployed in inhospitable or hostile environments, where it may not be possible to refresh energy sources. Hence, energy consumption is a major issue, and energy-aware protocols / applications are desirable. Energy consumption is observed at three stages, node communication, sensing and processing. Optimizing the three processes will lead to a reduction in the energy consumed.

6.5 Large scale of deployment

Establishing communication within large networks, consisting of hundreds or thousands of nodes flung far apart, is not possible [6]. Furthermore, many parameters like interference, noise, dispersion, available bandwidth, asymmetry of links and constantly changing signal strength, may make complete connectivity unachievable even in tiny networks.

VII. FEATURES OF WIRELESS SENSOR NETWORK

The following are the unique features of the wireless sensor network [2]

- Large scale of deployment
- Unattended operation
- Small-scale sensor nodes
- Limited power they can harvest or store
- Harsh environmental conditions
- Mobility of nodes.
- Network topology is dynamic
- Heterogeneity of nodes.

VIII. ADVANTAGES OF WIRELESS SENSOR NETWORK

The following are the list of advantages of wireless sensor networks [2,5], they are

- Advances in low-cost and low-power wireless communication, micro sensor, and microprocessor hardware, as well as progress in ad hoc networking routing and protocols, distributed signal and array processing, pervasive computing, and embedded systems have all made sensor networking a topic of active interest.
- Internet has been able to provide a large number of users with the ability to move diverse forms of information readily and thus revolutionized business, industry, defense, science, education, research, and human interactions.
- Sensor networking may, in the long run, be equally significant by providing measurement of the physical phenomena around us, leading to their understanding and ultimately the utilization of this information for a wide range of applications.
- Potential applications of sensor networking include environmental monitoring, health care monitoring, battlefield surveillance and reconnaissance, modern highway, modern manufacturing, condition-based maintenance of complex systems, and so forth.

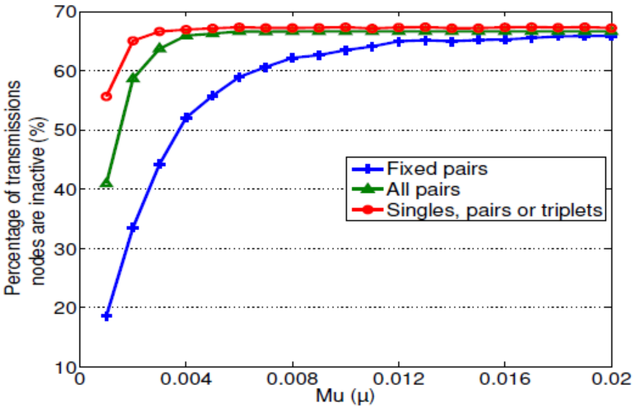

Fig.1.6 Node inactivity for varying channel quality

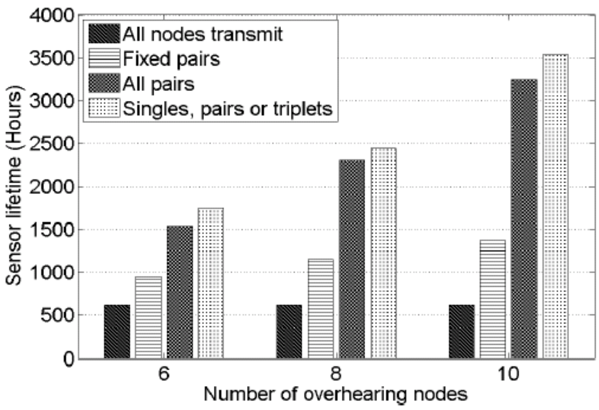

Fig. 1.7 Sensor Lifetime

The quality of source-node channels improves the nodes will be less active while still delivering complete messages.

IX. APPLICATIONS OF WIRELESS SENSOR NETWORK

The applications for wireless sensor network are many and varied [2]. They are used in commercial and industrial applications to monitor data that would be difficult or expensive to monitor using wired sensors. They could be deployed in wilderness areas, where they would remain for many years (monitoring some environmental variable) without the need to recharge/replace their power supplies. They could form a perimeter about a property and monitor the progression of intruders (passing information from one node to the next).Typical applications of wireless sensor network include monitoring, tracking, and controlling. Some of the specific applications are habitat monitoring, object tracking, nuclear reactor controlling, fire detection, traffic monitoring, etc. In a typical application, a WSN is scattered in a region where it is meant to collect data through its sensor nodes.

X. CONCLUSION

WSN are used to collect data from the environment. They consist of large number of sensor nodes and one or more Base Stations. The nodes in the network are connected via Wireless communication channels. Each node has capability to sense data, process the data and send it to rest of the nodes or to Base Station. These networks are limited by the node battery lifetime. The cost of sensor nodes is similarly variable, ranging from a few to hundreds of dollars, depending on the complexity of the individual sensor nodes. Size and cost constraints on sensor nodes result in corresponding constraints on resources such as energy, memory, computational speed and communications bandwidth. The topology of the WSNs can vary from a simple star network to an advanced multi-hop wireless mesh network.

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