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An Overview of Wireless Sensor Networks

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Abstract. Wireless sensor networks (WSN) are becoming very attractive for both telecommunication and network industry. These sensors can influence the understanding of the physical world around us by transmitting signals by sensing the physical around the field of influence of such devices. Such devices can then transmit electrical signals from sensor to sensor through the network until the signal reaches the sink stage. This survey explores the design issues, network services and mechanisms in this field. It provides an understanding for WSN technology.

Keywords. Wireless sensor networks, WSN design, WSN technology

1. Introduction

Wireless sensor networks have seen extensive proliferation of applications and interest in research and industry. Such networks can be densely deployed over a diverse geographic area ranging from 10s of meters to several hundreds of kilometres through deploying small, low cost devices that can observe and influence the physical world around them by gathering status information and then transforming this into radio signals. Such signals are then transmitted to a local sink which may be connected to a gateway to send the data to external network such as internet. The data thus received may be analysed and appropriate decision/action taken depending on the type of application. Unfortunately, these sensors suffer from resources constraint and power limitation as these sensors are usually deployed in remote places that are not easy to reach. Inevitably, there is a finite life time duration for such devices and new sensors have to be deployed to replace the old ones. It is some of these limitations that has shown an increasing interest from the scientific community to research in such devises that would enhance the longevity and coverage of the devices by using various new technology developments in this field. The main emphasis is on maximizing the life time of sensors and to use the limited resources efficiently by adopting mechanisms, algorithms and protocols that consider these limited resources as main priorities and challenges to produce efficient and reliable networks.

Wireless sensor networks utilize an efficient form of technology that has no structures or rules or adhering to a specific standard. This makes it an interesting area for research and thus significant resources are being placed on its study by research scholars and manufacturer's alike. There are a number of applications for such devices and networks such as; military, health monitoring, indoor and outdoor fire fighting applications, security applications, environmental, agricultural, climate changes and studying animal behaviour.

2. WSN design issues

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A WSN can be defined as: 'a network of devices, denoted as nodes, which can sense the environment and communicate the information gathered from the monitored field (e.g., an area or volume) through wireless links. The data is forwarded, possibly via multiple hops, to a sink (sometimes denoted as controller or monitor) that can use it locally or is connected to other networks (e.g., the Internet) through a gateway. The nodes can be stationary or moving. They can be aware of their location or not. They can be homogeneous or not'[1].

Sensor networks are a distributed small sensing devices provided with short-range wireless communications, memory and processors. This kind of network differs from conventional ad-hoc networks in the following way:

- number of nodes deployed in WSN is higher
- sensor nodes are densely deployed and usually in harsh environment
- sensor nodes have finite and limited life span
- topology of the network may change frequently
- WSN work in a broadcast fashion, while ad-hoc is point to point
- WSN has limited power and range resources
- may not have a global ID

To build a WSN some factors will influence the design [1, 2]:

1. Fault tolerance (reliability): is the ability to adapt node failures without affecting the network function. Fault tolerance could be calculated through the following equation:

   $$R_k(t)=\exp(-\lambda_k t) \quad (1)$$

   Where: R_k is the reliability (fault tolerance), λ_k is the fault rate for node k, t is the time period.
2. Scalability: network ability to increase the size of the network or add new number of nodes is very important, but scalability or increasing number of nodes has to consider network density as a factor to determine the required number of sensors to cover a certain area, which depends on the nature of application as well. The density can be calculated by [2]:

   $$\mu(R) = (N\pi R2)/A \quad (2)$$

   Where: N is the number of sensors; R is the sensor range. $\mu(R)$ is the density function to find the number of sensors within sensor range, N is the number of sensors, A is the area.
3. Product cost.
4. Hardware constraints: basically, sensors consist of; sensing unit (sensor, ADC), processing unit (simple micro-controller, small memory), transceiver unit with short range communication capability and power unit(usually it is two AA batteries). Some applications have extra components such as; location finding system (e.g., GPS device), power generator(e.g. solar panels) and mobilizer. See Fig. 1.
5. Power consumption: WSNs consume power in three parts:
   i) Sensing: This is almost fixed power.
   ii) Data communication: major power is used in this part. A sensor transceiver comprises of:
      - Transmitter and receiver which is consum approximately the same power.
      - Mixer, frequency synthesizer, voltage control oscillator.
      - PLL, power amplifier.

      All these consume node power in addition to the START UP power.
      The start up power can be calculated by the equ. 3 [2]:

      $$Pc=N_T[P_T(T_{ON}+T_{ST})+P_{OUT}(T_{ON})]+N_R[P_R(R_{ON}+R_{ST})] \quad (3)$$

      Where: P_T/ P_R are the consumed power by transmitter and receiver respectively, P_{OUT} is the power at transmitted antenna, T_{ON}/R_{ON} is transmitter/receiver wake up time, T_{ST} /R_{ST} is transmitter/receiver start-up time and N_T/N_R is number of times transmitter or receiver is switched on per unit time, which depends on the task and medium access control (MAC) scheme.
   iii) Data processing: power consumption in data processing is much less than power consumption for Data communication. Due to the low cost and size requirements of sensor

manufacturing, CMOS technology is normally used for micro-processors and this limits the expended power thus giving greater efficiency.

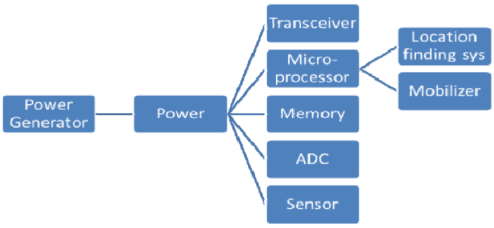

Figure 1: Sensor node

Other factors that influence the WAN design are; security, network type, Quality of service, self-organizing network, data rate and throughput, routing, modeling, size and applications.

3. Network services [3]

Some of the services carried out within the WSN networks are shown here.

i) WSN Storage Mechanisms [4]:For more information these are listed according to the reference source for each mechanism:

- GEM [5]: Graph Embedding Mechanism provides an infrastructure for routing and data centric storage, where each node has an identifier and label encoded with position and each node need to know the labels of its neighbour so the node chooses a label guest graph (receiver) then embeds that guest graph into the actual sensor topology.
- TSAR [6]: in this method the node sends the metadata to the nearest proxy and then this metadata moves from proxy to another where the actual data is stored in the sensor, through this we reduce the overhead through sending the queries to proxies.
- Multi-resolution storage [7]: Multi-resolution storage system provides a hierarchy distributed storage structure and long term query data in intensive data application. This storage method is divided into three stages; wavelet process to build a multi-resolution summary to compress the data, drill-down query is a process to reduce search cost done in the highest level of the hierarchy where this stage uses the summary as a pointer for the network part that contain the required data and finally, data aging scheme to discard summaries after a certain time and make a space for the new data.

ii) Localization: listed here are some localization algorithms used in WSN:

- Moore’s algorithm [8]: each node becomes a centre of cluster, then measure the distance of one hop neighbour then broadcast it for each cluster to use the overlap information to localize other sensors.
- RIPS [9]: it uses two radio transmissions to create interference, one transmission is set slightly different than others and by measuring the offset frequency the location can be obtained through the use of a given formula.
- Secure localization [10]: sensor relies on beacon information to compute their position and for security purposes sensor can only accept the information from authenticated beacon.

iii) Synchronization [3]: here are some synchronization protocols:

- Uncertainty-driven approach: based on long term clock drifts between all nodes for long time synchronization to minimize overhead. Where it measure the sync rate, obtain history of past sync beacon and compute the result of estimation scheme to use them in Rate Adaptive Time Synchronization protocol (RATS).

- Timing sync protocol for sensor network (TPSN): this protocol is carried out in two phases: Discovery phase to create a hierarchical topology for the network, where each node is classified into level and each node can at least communicate to one node from lower level. Synchronization phase where each node tries to synchronize with the nodes in level – 1.
- Clock-sampling mutual network sync (CSMNS): relies on IEEE 802.11, periodic beacon to exchange time information. Where each node has a different time drift coefficient and initial time so the nodes send their timing process periodically in the beacon and then the received node computes the difference and corrects its clock.

4. Bandwidth choices for Wireless sensor network [4]

These may be listed as:

- Narrow band that focus on bandwidth efficiency and use enough bandwidth for symbol rate transmission (data rate/ BW).
- Spread spectrum: the narrow band signal is spread into a wideband signal, this method has the ability to reduce the power and communicate effectively.
- Ultra Wide Band (UWB): employs larger BW than spread spectrum so the interference to other radios is negligible.

Spread spectrum and UWB are more suitable for WSN because of low power utilization and robustness for multipath fading, shadowing and interference.

5. Some test-beds to test WSN networks[4]

i) ORBIT: Open access research test-bed for next-generation wireless network, useful to test new applications, protocols and algorithms, indicate on system performance and run cross-layer experiments.

ii) MOTELAB: is a testbed of MicaZ wireless sensor networks based web. Used to test new developed protocols, analyse signal strength, and cluster performance.

iii) EMULAB: a mobile robot used to test wireless sensor networks. Analyse network topology, impact of mobility on protocols, test algorithms and applications.

6. Conclusion

This paper conducts an overview of the wireless sensor networks, their design issues, network services and developments that have recently taken place. The use of wireless sensor technology has seen proliferation in a large number of applications and this paper is towards that effort to develop a system for a specific application.

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