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A Survey on Active Mode Energy Consuming Factors of Sensor Nodes in WSN

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Abstract — **Wireless sensor networks play vital role in different emerging applications. As batteries of sensor nodes in wireless sensor networks cannot be either replaced or recharged in many critical situations like military border area monitoring, the sensor nodes have to survive on their own battery backup as maximum as possible to keep the entire network alive. Many tasks like sensing, routing, query processing, sensor location calculations, security algorithms in wireless sensor network applications consume sensor node's battery energy for their intended tasks. Unfortunately some tasks consume more energy and hence the importance of the lifetime of the sensor nodes is compromised. Any approach to wireless sensor networks needs to care about the energy consumption. In general, the battery energy is consumed in active mode, idle mode and sleep mode. Our survey focuses on various active mode energy consuming factors in detail to assist the researchers, engineers who develop the energy management and energy conservation techniques in wireless sensor networks.**

Keywords — **WSN Lifetime, Active Mode Energy Consumption, Sensing Energy Cost, Computation Energy Cost, Communication Energy Cost.**

I. Introduction about WSN

A wireless sensor network is a collection a large number of sensor nodes, which are densely deployed in the sensing area or close to the area to be monitored. Wireless sensor networks (WSNs) are useful in many different areas such as disaster management systems, ocean navigation, underwater monitoring, industrial automation and control, military surveillance, medical care, environmental monitoring, public service and home automation applications, etc. I. F. Akyildiz, W. Su, Y. Sankarasubramaniam, and E.Cayirci [1] explain the design, analysis and construction of WSNs in the computer and communication fields.

The participation of individual sensor node is very much important. Wireless sensor networks can be used to detect foreign chemical agents in air and water. In recent years, advances in micro-electro-mechanical systems technology, wireless communications, and digital electronics have enabled the development of low-cost, low-power, multifunctional sensor nodes that are small in size and are able to communicate in short distances. Sensor networks represent a significant improvement over traditional sensors. Sensors can be positioned far from the actual phenomenon, i.e., something known by sense perception. In this approach, large sensors that use complex approach, large sensors that use some complex techniques to distinguish the targets from environmental noise are required. Several sensors that perform only sensing can be deployed. The positions of the sensors and communications topology are carefully engineered. They transmit time series of the sensed phenomenon to the central nodes where computations are performed and data are fused. In this paper, we present a survey on energy consuming factors in wireless sensor networks. The survey deeply explains the communication cost, computational workload in the following sections.

II. Emerging Applications of WSNs

In many wireless sensor networks, area monitoring is an important task. In area monitoring, the WSN is deployed over a region where some phenomenon is to be monitored. A military example is the use of sensors to detect enemy intrusion; a civilian example is the geo-fencing of gas or oil pipelines. When the sensors detect the event being monitored (heat, pressure), the event is reported to one of the base stations, which then takes appropriate action (e.g., send a message on the internet or to a satellite). Similarly, wireless sensor networks can use a range of sensors to detect the presence of vehicles ranging from motorcycles to train cars. I.F.Akyildiz, W.Su, Y.Sankarasubramaniam, and E.Cayirci [1] and Jennifer Yick, Biswanath Mukherjee and Dipak Ghosal [8] gives the emerging applications of wireless sensor networks.

Sensor networks may consist of different 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 and the current characteristics such as speed, direction, and size of an object. In many military applications sensor motes are deployed in the border areas to monitor the intruders, terrorists, enemies and their vehicles. The sensor motes can also be used to sense the environment to collect the data like temperature, pressure, humidity, nuclear accidents, vibration, etc. Each sensor motes send the sensed data to the control station or base station for further action.

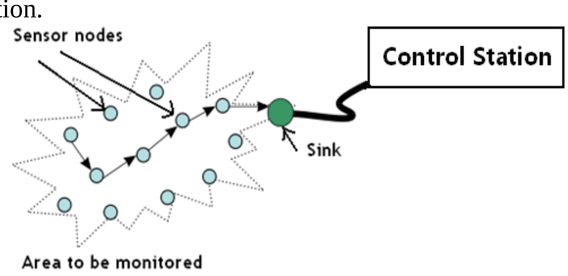

Fig.1. A typical wireless sensor network architecture

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III. Building Block of a Typical Wireless Sensor Network

Collection of senor nodes constitutes the sensor network. A general sensor network consists of sensor nodes, anchor nodes and controls stations as given in the figure 1. Sensor nodes are deployed in the area to be monitored to observe the environment. Depending upon the nature of application, different sensors are deployed to send the sensed information to control stations for further actions. The following sub sections explain the individual components of a general sensor network in detail.

A. Control Station

The sensor nodes senses the environment parameters like temperature, pressure, vibration, enemy troops, animals, forest fire, earth quake, etc. The sensed information immediately needs to be routed to control stations as soon as possible for further actions. For example, in border area monitoring, an army control can guide and command its troops according to their enemies' activities, which is sensed by the deployed sensors.

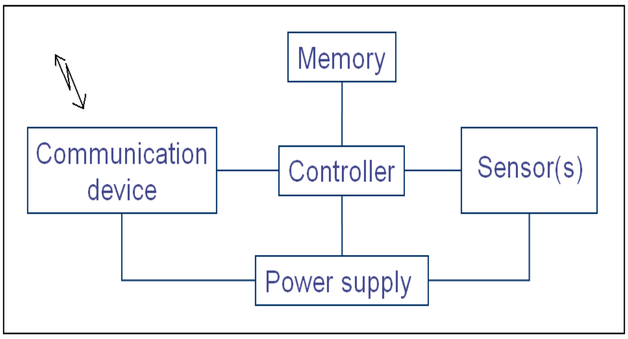

Fig.2. A typical sensor node's architecture

B. Sensor node

A typical sensor node consists of control unit or processing unit, memory, communicating units, sensors units and optionally actuators as shown in figure 2. Sensor units sense the environment parameters which are analog in nature. Hence the analog-to-digital convertor is used to convert the observed signal into digital signal. The sensor nodes receive control information from base stations or anchor nodes using receivers. Similarly sensors send the observed data to control stations using their transmitters. Based on the nature of the sensor node, various types and sizes of memory can be used. Some sensor nodes have actuators for automation tasks.

C. Anchor Node

The main task of anchor nodes is to help the ordinary sensor nodes to compute their own locations. Anchor-free localization is also possible. Gustav J. Jordt, Rusty O. Baldwin, John F. Raquet and Barry E. Mullins [6] proposed anchor-free localization schemes in wireless sensor networks. Mobile anchor based localization scheme is proposed by W.H.Liao, Y.C.Lee and S.P.Kedia [9]. It is not an optimistic solution to equip GPS receivers to all sensor nodes. An alternative solution is to determine the physical coordinates of the individual sensor nodes by utilizing the localization algorithms, where only a few anchor nodes are aware of their own location information by means of their own GPS receivers or by receiving the location messages from the other location aware units. All the other sensor nodes use the radio communication techniques to receive the location information from the location ware anchor nodes and use the received information to determine their own locations as given in figure 3.

IV. Life Time of the Sensor Nodes and Sensor Networks

In many applications the uninterrupted power supply to the sensor nodes is not possible. The life time of each sensor node mainly runs on their battery power. These batteries cannot be either replaced or recharged after deployment of the sensor nodes. So it is very important to save the battery life in all aspects to extend the lifetime of individual sensor nodes and thereby the WSN lifetime.

The wireless sensor network is nothing but the collection of deployed sensor nodes. Hence the life time of individual sensor nodes must be carefully extended as maximum as possible to keep the entire sensor network alive. Even the failure of a single sensor node can cause severe impacts to the entire sensor network like path break, topology changes, etc, and hence the intended objective may not be achieved successfully. As the battery power of a sensor mote reduces, its transmission range will shrink and hence that mote will be isolated from the wireless sensor network. This can lead to several impacts like topology changes, path break, and hence the overall lifetime reduction of the sensor network. The following section explains the various active mode energy consuming factors in detail.

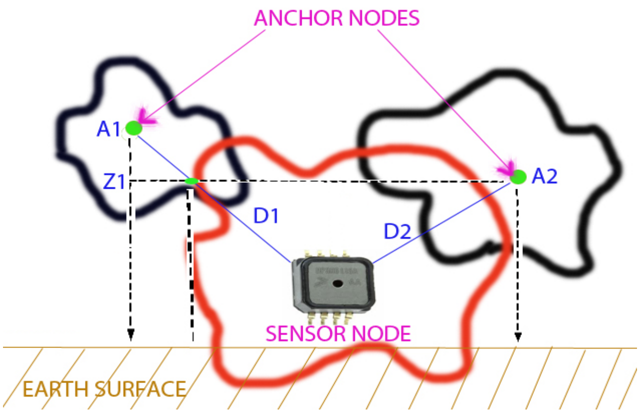

Fig.3. Anchor nodes in localization of sensor nodes

V. Energy Consuming Factors in Wireless Sensor Networks

Sensor nodes may consume their battery energy for sensing, actuating, routing, executing the security procedures, sensing the medium, etc. These energy consuming activities can be generalized as active mode, sleep mode and idle mode energy consumption as given in figure 4 and equation (1).

$$P_{total} = P_{active} + P_{idle} + P_{sleep} \quad (1)$$

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Sensor node's battery energy is conserved even in the idle mode and sleep mode because of the device characteristics. But we focus our survey only on the active mode energy consuming factors.

A. Energy consumption in active mode of sensor nodes

Routing tasks, localization process, security procedures, query processing, data aggregation are the common intended tasks of sensor nodes in a sensor network. These tasks are referred as active mode tasks. Generally the active mode tasks can be classified as communication task, sensing task and computation task as given in equation (2).

$$P_{active} = P_{comm} + P_{comp} + P_{sensing} \quad (2)$$

Sensing cost

A sensor network may be deployed to monitor the enemies' troops, detecting forest fire, observing the movement of earth plates, watching tsunami waves, etc. Various types of sensors may be attached with the sensor nodes depends on the application. Considerable amount of battery energy may be consumed to trigger the cameras, vibrators, pressure sensors to sense the environment. So good sensing techniques must care about the energy consumption issues to keep the sensor nodes alive as maximum as possible.

Computation cost

Generally the total computation power (P_{comp}) in each sensor mote includes the power for analog to digital conversions ($P_{a/d}$), power for routing operations ($P_{routing}$) (routing operations include shortest path calculations, routing table updates, routing table exchange, etc), power for general computations (P_{gp}) (general computations involve data aggregation, packet processing, local decision making tasks, etc), power for signal strength measurements (P_{ssm}) during localizations, and power consumption for executing complex localization algorithms ($P_{loc-alg}$).So the total computation power (P_{comp}) required at each sensor node can be expressed as in equation (3).

$$P_{comp} = P_{a/d} + P_{routing} + P_{gp} + P_{ssm} + P_{loc-alg} \quad (3)$$

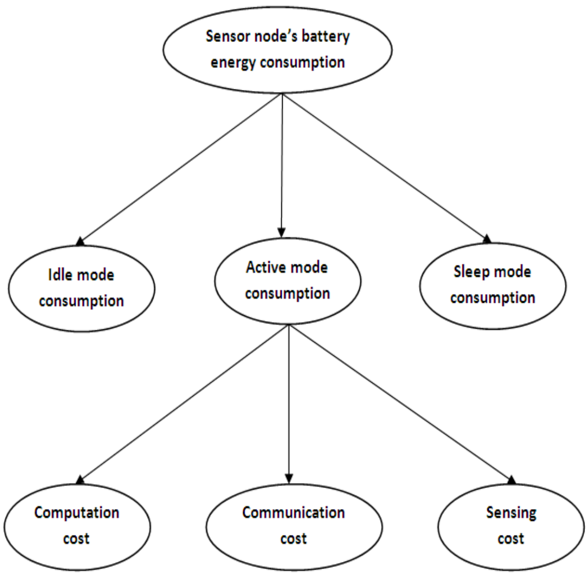

Fig.4. Energy consuming factors of sensor nodes in wireless sensor networks

Localization is an important task in wireless sensor networks. This technique is used to identify the position of all sensor nodes deployed in the field. At the same time, a localization algorithm must not consume more battery energy to compute the location of sensor nodes. In our survey, we focus only on the active mode energy conversation. Chia-Ho Ou, and Kuo-Feng Ssu [2] proposed a localization scheme, which need high beacon overhead and many geometrical calculations lead to more battery energy consumption. Chia-Ho Ou [3] explains the technique of using directional antennas in localization process. In this technique, many beacon messages are required to find the sensor location, which consumes more energy. A localization algorithm must care about the scarce energy sources. Binary Integer Linear Programming technique is proposed by Chompunut Jantarasorn and Chutima Prommak [4] to reduce the energy conservation. Target tracking mechanisms as proposed by Xue Wang, Junjie Ma, Sheng Wang and Daowei Bi [12] consumes considerable amount of the battery energy by observing the environment continuously. P.Shunmuga Perumal and V.Rhymend Uthariaraj [13] proposed a novel scheme to reduce the work load of individual sensor nodes to conserve the energy. Hanjiang Luo, Zhongwen Guo, Wei Dong, Feng Hong and Yiyang Zhao [7] proposed the beacon based localization in under water applications.

Communication cost

Most of the battery energy is consumed in the transmission and reception of location data with anchor nodes, location data with other sensor nodes (i.e) inter sensor communication, control message from control stations, sensed information with neighbor sensor node (relaying), routing information, queries with neighbor sensor nodes, etc. Generally the communication energy consumption can be given as the following equation (4).

$$P_{comm} = P_{Tx} + P_{Rx} \quad (4)$$

Giuseppe Anastasi, Marco Conti, Mario Di Francesco and Andrea Passarella [5] gave the detailed survey on energy conservation schemes. Communication cost for sensing tasks in static sensor network is explained by G.N.Purohit, Seema Verma and Megha Sharma [10]. Irregular communication rages cause severe effects in sensor applications. P.Shunmuga Perumal and V.Rhymend Uthariaraj [14], proposed a novel scheme to suppress the impacts of irregular radio ranges, and thereby high localization accuracy is achieved. The need of extending the lifetime of sensor networks is explained by Yunxia Chen and Qing Zhao [15]. Shigeng Zhang, Jiannong Cao, Lijun Chen and Daoxu Chen [11] proposed the scheme of energy efficient range free localization.

VI. Conclusion

Wireless sensor network is a collection of sensor nodes with limited energy resources. Even failure of a single senor node may cause severe impacts in sensing, actuating, relay tasks and hence the main objective of launching the wireless sensor network may not be reached successfully. So any approach like localization, routing, sensing, actuating, security procedures in wireless sensor networks must pay attention towards the battery energy consumption to extend the overall lifetime of the entire sensor network. The active mode energy consumption involves communication tasks, computational and sensing tasks. We focused our survey on active mode power consuming factors to assist the researchers, engineers who actively engaged in the design of energy conservation schemes to significantly extend the wireless sensor network lifetime.

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