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A Survey on the Energy Conservation in Wireless Sensor Networks

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Abstract: In the past years, wireless sensor networks (WSNs) have gained increasing attention from both the research community and actual users. Wireless Sensor Networks (WSN) are used in variety of fields which includes environmental, healthcare, military, biological and other commercial applications. The critical aspects to face concern "how to reduce the energy consumption of nodes" and sensor nodes are generally battery-powered devices so that the network lifetime can be extended to reasonable times. However, we conducted that first break down the energy consumption for the components of a typical sensor node i.e. discussion of the main directions to energy conservation in WSNs. We present a systematic and comprehensive taxonomy of the energy conservation schemes that are subsequently discussed in depth. A technique for energy efficient data acquisition special attention has been devoted to promising solutions that have not yet obtained a wide attention in the literature.

I. INTRODUCTION

A wireless sensor network consists of sensor nodes deployed over a geographical area for monitoring physical phenomena like humidity, temperature, seismic events, vibrations, and so on [2]. Wireless sensor networks (WSNs) are distributed measurement systems consisting of a large number of measurement units deployed over a geographical area; each unit is a low-power device that integrates processing, sensing and wireless communication abilities [3].A sensor node is a tiny device that includes three basic components:

a. A sensing subsystem for data acquisition from the physical surrounding environment
b. A processing subsystem for local data processing and storage
c. A wireless communication subsystem for data transmission

A power source supplies the energy needed by the device to perform the programmed task. However, the power source consists of limited energy resource. It could be impossible or inconvenient to recharge the battery, because nodes may be deployed in a hostile or unpractical environment. Among the set of potential scenarios, monitoring applications can particularly benefit from this technology as WSNs allow a long-term data collection at scales and resolutions that are difficult to achieve with traditional techniques. The sensor network should have a lifetime long enough to fulfill the application requirements. The crucial question is "how to prolong the network lifetime to such a long time?" External power supply sources often exhibit a non-continuous behavior so that an energy buffer is needed as well. Therefore, energy conservation is a key issue in the design of systems based on wireless sensor networks.

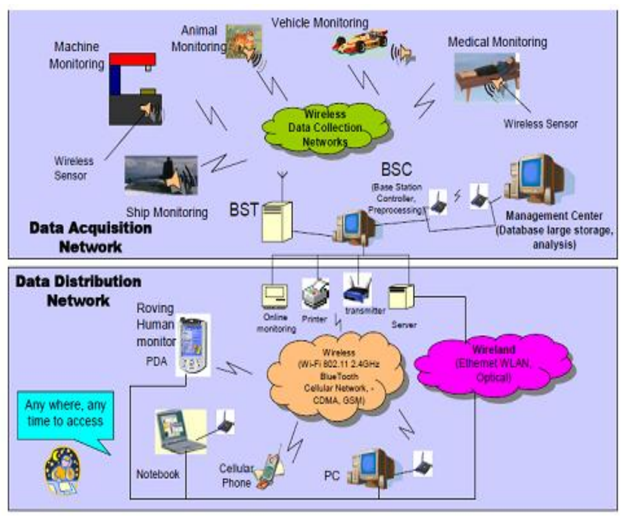

FIG. 1. Sensor network architecture.

As shown in the fig.1 we consider the sensor network consisting of base station and number of sensor nodes deployed over a large geographic area [4]. Data are transferred from sensor nodes to the sink through a multi-hop communication paradigm. Experimental measurements have shown that generally data transmission is very expensive in terms of energy consumption that the data processing consumes significantly less [5]. 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. Energy consumption remains the major obstacle for the full diffusion and exploitation when batteries can be recharged. In general energy-saving techniques focus on two subsystems:

- The networking subsystem:
  The energy management is taken into account in the operations of each single node, as well as in the design of networking protocols.
- The sensing subsystem
  The techniques are used to reduce the amount or frequency of energy-expensive samples.

Energy efficient protocols are aimed at minimizing the energy consumption during network activities. Power management schemes are thus used for switching off node components that are not temporarily needed. We will survey the main enabling techniques used for energy conservation in wireless sensor networks. We will also survey the main techniques suitable to reduce the energy consumption of sensors when the energy cost for data acquisition cannot be neglected. These techniques are the basis for any networking protocol and solution optimized from an energy-saving point of view.

I. SOURCES OF ENERGY DISSIPATION

Some of the energy dissipations are idle listening, Overhearing, Collision, reduction of protocol overhead etc.

Overhearing:

In high density sensor networks the short distances between sensor nodes lead to interferences with non-participant neighbor nodes during data conveyance, is known as the Overhearing. As the signal moves from the sensor node to the transmitted node, as the transmitted moves circularly idealized to its surrounding nodes, which are at the active mode. The not involved sensor nodes within reach burn up energy resources owing to receiving and processing useless information. Connectivity requirements have to be weighed up with the arising disadvantages regarding energy dissipation and latency caused by generously keeping nodes in active mode.

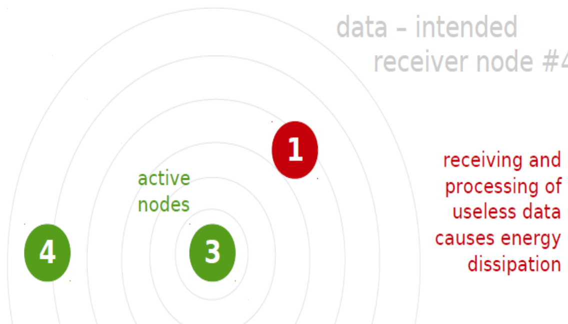

Figure 2: Overhearing

Idle listening:

Generally, the nodes are the active mode in the network, which consume more energy (i.e. crucially more amount of the energy is wasted) than the energy expenditure for the node detection, information receiving, sending and the waiting stage of the data transmission. Usually the individual sensor node is not at any time involved in a data transmission process and thereby not every component of the node especially the Transceiver does implicitly have to be in an active state. Idle listening refers to the receiving or sending the data when it is in the awaiting ready state. There are different approaches to find out when the particular components are not needed or to just reduce the overall active time without further examination. After receiving of the wake-up signal the sleeping node switch back to the active mode.

Collision:

In some cases transmitter/ sender sends the same data multiple times that are not useful. While in the transmission time, i.e. in the transmission process, the energy is more dissipated. Since the energy dissipation is more if the no. of node between the source and the receiver is more in count. Hence, re-transmission consumes lot of energy.

Reduction of protocol overhead:

Consider in the transmission the node follows a protocol that have header information, control information etc. Techniques for the reduction of the protocol overhead are for instance adaptive transmission periods, cross-layering approaches. A short transmission period leads to less energy consumption and helps therefore saving resources at the same time latency to changes is increased. In consequence a favorable value for the transmission period depends on the frequency of change.

II. GENERAL APPROACHES FOR ENERGY CONSERVATION

We mainly consider the most widely adopted model in the literature, which is depicted in the fig.1.

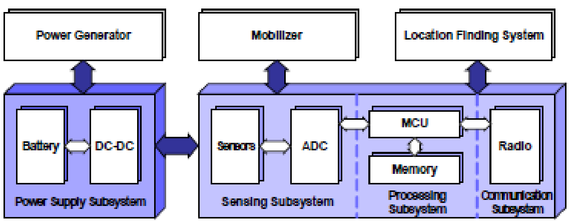

FIG. 3: Architecture of a typical wireless sensor node.

As shown in the fig.2 typical wireless sensor node as usually assumed in the literature. It mainly consists of the four components:

- ✓ A sensing subsystem including one or more sensors for data acquisition
- ✓ A processing subsystem including a micro-controller and memory for local data processing
- ✓ A radio subsystem for wireless data communication
- ✓ A power supply unit

Sensor nodes may also include additional components such as a location finding system to determine their position. As the latter components are optional and only occasionally used. We identify three main enabling techniques namely:

i. Duty cycling

It is mainly focused on the networking subsystem. The most effective energy-conserving operation is putting the radio transceiver in the (low-power) sleep mode whenever communication is not required [8]. The radio should be switched off as soon as there is no more data to send/receive and should be resumed as soon as a new data packet becomes ready. However, in this way nodes alternate between active and sleep periods depending on network activity.

ii. Data-driven approaches

It can be used to improve the energy efficiency even more. Data sensing impacts on sensor nodes' energy consumption in two ways:

- ✓ *Unneeded samples:* Sampled data generally has strong spatial and/or temporal correlation. Therefore, there is no need to communicate the redundant information to the sink [6].
- ✓ *Power consumption of the sensing subsystem:* Reducing communication is not enough when the sensor itself is power hungry.

iii. Mobility

It can finally be used as a tool for reducing energy consumption. In a static sensor network packets coming from sensor nodes follow a multi-hop path towards the sink(s). A few paths can be more loaded than others can and nodes closer to the sink have to relay more packets so that they are more subject to premature energy depletion [7]. The traffic flow can be altered if mobile devices are responsible for data collection directly from static nodes.

Ordinary nodes can save energy because path length, contention and forwarding overheads are reduced as well. The mobile device can visit the network in order to spread more uniformly the energy consumption due to communications.

III. MEASURES FOR ENERGY DISSIPATION

NODE ACTIVE MANAGEMENT:

Ready-to-receive mode consumes nearly as much energy of the sensor node's resources as receive mode. This is way to set the node to a sleeping mode and determine the right time to wake it again is necessary to effectively save energy in idle time spans.

On-demand Node Activity approaches the sleeping and transmission periods of the sensor nodes are not scheduled. The nodes are by default permanently in an inactive state with simple stand-by functionality. As the start-up signal usually does not have to be decoded, a very energy conserving design for the listening device is feasible.

DATA AGGREGATION, DATA FUSION, DATA PREPROCESSING, DATA REDUCTION:

The energy cost of transmitting data is higher than the effort on data processing it is beneficial to aggregate data within clusters. Appointed sensor nodes that act as cluster heads provide the connection between sensor nodes and the respective base station. *Clustering* can reduce the amount of data as the cluster head is in charge of monitoring and processing queries.

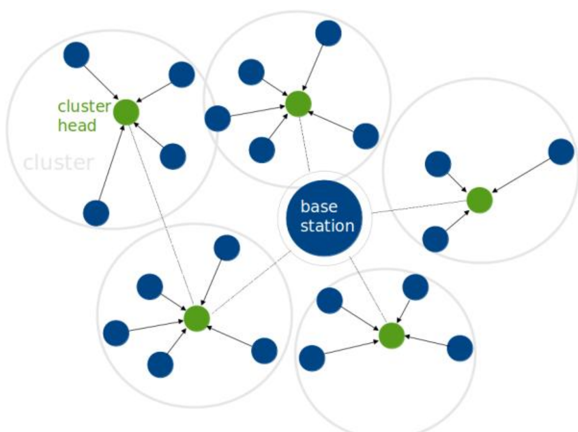

Figure 4: Clustering

Resepective algorithms check for instance density in certain areas volatility of the sensed data or the traffic level to avoid congestion by lowering the sampling rates. Data compression saves energy by relocating effort from communication to processing, which is either previously gathered at some point or directly compressed to lower the workload. The processing data customarily consumes much less energy than transmitting data in a wireless medium the implementation of data compression algorithms can lead to considerable energy savings.

ADAPTIVE TRANSMISSION RANGE

A reduction of the sensor node’s broadcasting range lowers energy expenditure, but all at once not unnecessarily extensive. The remaining energy in addition to inclusion of the node distances obtains especially in heterogeneous sensor networks good results.

LOAD BALANCING

The actual position of a sensor node within the set of deployed nodes determines which operations have to be conducted and how many established communication paths comprise the particular node. Regular sensor nodes appointed as cluster heads would have a much shorter lifetime as the nodes that are mere in charge of sensing data. There is no special more powerful hardware for the cluster heads in use, if clustering is applied. As energy expenses of the cluster heads for data transmission are dependent on the distance between sensor node and base station.

IV. CONCLUSION

We have surveyed the main approaches to energy conservation in wireless sensor networks. A systematic and comprehensive classification of the solutions has proposed in the literature. Energy conserving communication techniques become increasingly important and are in fact subject to many present research projects. The three prevalent boundary conditions of sensor nodes are communication consumes more energy than computation. Our discussion has no limitations to topics that have received wide interest in the past. However, we have also stressed the importance of different approaches such as data-driven and mobility-based schemes. As far as “traditional” techniques to energy saving, an important aspect, which has to be investigated more deeply, is the integration of the different approaches into a single off-the-shelf workable solution. The energy consumption of the radio is much higher than the energy consumption due to data sampling or data processing. We have shown the power consumption of the sensor is comparable to the power needed by the radio. We think that the field of energy conservation targeted to data acquisition has not been fully explored yet. We observe an increasing interest towards sparse sensor network architecture. A network can be very efficient and robust if communication protocols can appropriately exploit the mobility of collector nodes. We conclude the paper with insights for research directions about energy conservation in WSNs.

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