High Level Anatomy for Energy Conversations schemes 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.

Index Terms- Sensor, energy conservation, Anatomy, Data driven, Mobility based.

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.

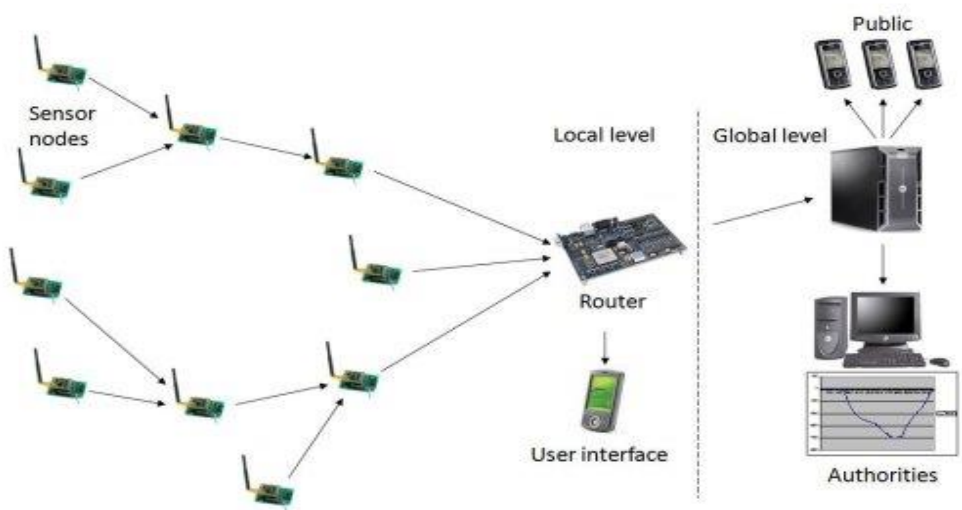

FIG. 1. Sensor network architecture.

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, while 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.

II. APPROACHES FOR ENERGY CONSERVATION

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

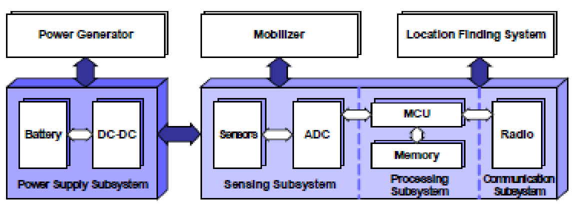

FIG. 2: Architecture of a typical wireless sensor node.

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.

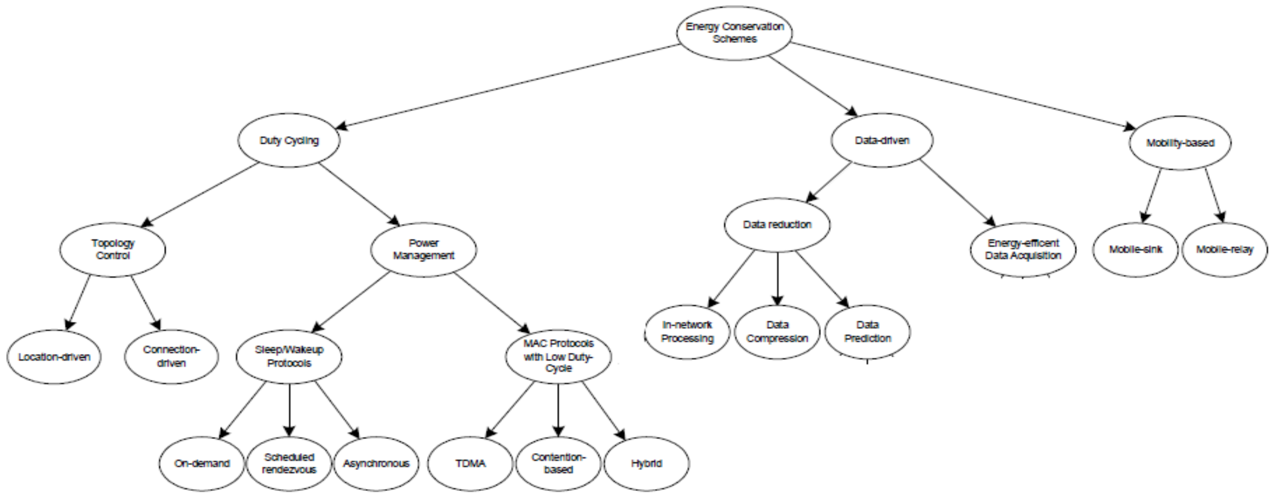

FIG. 3: Taxonomy of approaches to energy savings in sensor networks.

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. HIGH LEVEL ANOTOMY

Duty cycling

It can be achieved through two different and complementary approaches as shown in the fig.3. From one side it is possible to exploit node redundancy that is typical in sensor networks and adaptively select only a minimum subset of nodes to remain active for maintaining connectivity [8]. Finding the optimal subset of nodes that guarantee connectivity is referred to as topology control. The basic idea behind topology control is to exploit the network redundancy to prolong the network longevity. On the other hand, active nodes do not need to maintain their radio continuously on.

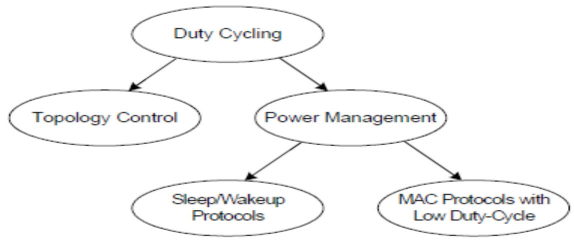

FIG. 4: Anatomy of duty cycling schemes.

Throughout we will refer to duty cycling operated on active nodes as power management. Topology control and power management are complementary techniques that implement duty cycling with different granularity. Power management protocols can be implemented either as independent sleep/wakeup protocols running on top of a MAC protocol [9][10]. Topology control protocols can be broadly classified in the following two categories:

- Location driven protocols: It define which node to turn on and when based on the location of sensor nodes that are assumed to be known
- Connectivity driven protocols: dynamically activate/deactivate sensor nodes so that network connectivity, or complete sensing coverage are fulfilled

Sleep/wakeup schemes can be defined for a given component of the sensor node, without relying on topology or connectivity aspects [14]. Independent sleep/wakeup protocols can be further subdivided into three main categories:

- *on-demand*

It takes the most intuitive approach to power management. The main problem associated with on-demand schemes is how to inform the sleeping node that some other node is willing to communicate with it. A low-rate and low-power radio for signaling, and a high rate but more power hungry radio for data communication is typically using multiple radios.

- *scheduled rendezvous*

  The basic idea behind scheduled rendezvous schemes is that each node should wake up at the same time as its neighbors. Nodes wake up according to a wakeup schedule and remain active for a short time interval to communicate with their neighbors.

- *asynchronous*

A node can wake up with asynchronous protocols when it wants and still be able to communicate with its neighbors. The goal is achieved by properties implied in the sleep/wakeup scheme, thus no explicit information exchange is needed among nodes.

We will focus mainly on power management issues rather than on channel access methods. We will survey below the most common MAC protocols by classifying them according to the taxonomy.

TDMA (Time Division Multiple Accesses): The schemes naturally enable a duty cycle on sensor nodes as channel access is done on a slot-by-slot basis.

Contention-based protocols: These are the most popular class of MAC protocols for wireless sensor networks. It achieves duty cycling by tightly integrating channel access functionalities with a sleep/wakeup scheme.

Hybrid protocols: It adapts the protocol behavior to the level of contention in the network. It behaves as a contention-based protocol when the level of contention is low and switch to a TDMA scheme when the level of contention is high.

Data-driven approaches

It can be divided according to the problem they address as shown in the fig.4. Data-reduction schemes address the case of unneeded samples that the energy-efficient data acquisition schemes are mainly aimed at reducing the energy spent by the sensing subsystem. All these techniques aim at reducing the amount of data to be delivered to the sink node. In-network processing consists in performing data aggregation at intermediate nodes between the sources and the sink. Hence, we can reduce the amount of data reduction while traversing the data in network.

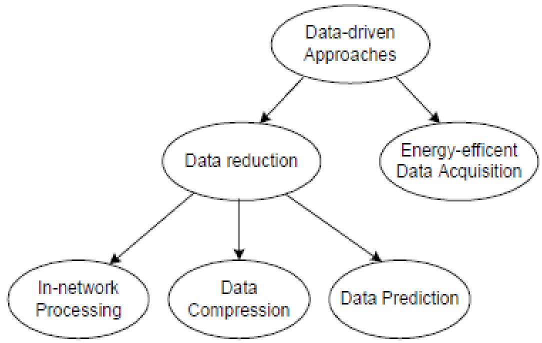

FIG. 5: Anatomy of data-driven approaches to energy conservation.

Data compression can be applied to reduce the amount of information sent by source nodes [11] [12]. It involves encoding information at nodes that generate data and decoding it at the sink. As compression techniques are general we will omit a detailed discussion of them to focus on other approaches specifically tailored to WSNs. Data prediction consists in building an abstraction of a sensed phenomenon [13]. The model can predict the values sensed by sensor nodes within certain error bounds and reside both at the sensors and at the sink. Data prediction techniques build a model describing the sensed phenomenon. Hence, the queries can be answered using the model instead of the actually sensed data.

Two instances reside in the model; they are one at sink and the other at source end. The model at the sink can be used to answer queries without requiring any communication, thus reducing the energy consumption. Techniques to a stochastic characterization of the phenomenon. Two main approaches of this kind are the following:

a) It is possible to map data into a random process described in terms of a probability density function
b) A state space representation of the phenomenon can be derived and forthcoming samples can be guessed by filtering out a non-predictable component modeled as noise.

Data prediction techniques are time series forecasting that a set of historical values obtained by periodical samplings are used to predict a future value in the same series. A time series can be represented as a combination of a pattern and a random error. Thus it is characterized by its trend and its seasonality.

Mobility-based

It schemes can be classified as mobile-sink and mobile-relay schemes as shown in the fig.5. Nodes are assumed static here and their density is expected to be large enough to allow communication between any two nodes, eventually by using a multi-hop path[7]. Mobility has been considered as an alternative solution for energy-efficient data collection in wireless sensor networks. We complete the survey by introducing the last energy conservation scheme as shown in the fig.5.

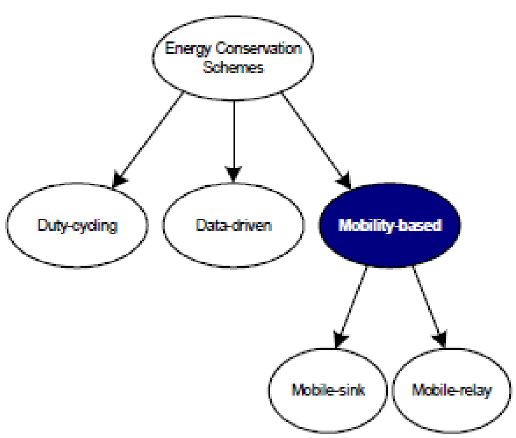

FIG. 6: Classification of data reduction techniques to energy conservation.

Energy consumption is reduced by the mobility. Packets coming from sensor nodes traverse the network towards the sink by following a multi-hop path. Depending on the network topology and packet generation rates at sources a few paths can be more loaded than

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others. Nodes closer to the sink also have to relay more packets so that they are subject to premature energy depletion. Ordinary nodes wait for the passage of the mobile device and route messages towards it. So that the communication with mobile data collector takes place in proximity. As mobilizers are generally quite expensive from the energy consumption standpoint, adding mobility to sensor nodes may be not convenient. The resulting energy consumption may be greater than the energy gain due to mobility itself, instead of making each sensor node mobile.

Mobility can be limited to special nodes, which are less energy constrained than the ordinary ones[15][16]. When the mobile elements visit the same node more than once at different distances, from an energy consumption standpoint it may be convenient for static sensors to defer transmissions at the instant in which the mobile element is closer to the source node. The energy consumption has to be better characterized with reference to Quality of Service parameters such as the fraction of reported data or the maximum latency. Most of these proposals give a little attention to the energy spent per transferred message, but focus on the way the mobile element should move to visit nodes in a timely fashion.

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. 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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