LIFETIME MAXIMIZATION STRATEGIES IN WIRELESS SENSOR NETWORK

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ABSTRACT

Wireless sensor networks consist of small nodes with sensing, computation, and wireless communications capabilities. Goal of the network is to sense the environment and report what occurs in the region it is deployed in. Wireless sensor networks can be used for various applications like Environmental Applications health applications, military applications, Home Applications. Each node has a limited energy supply and in many applications it is not easy to replace the batteries or sometimes not even recharge the batteries. Therefore how to optimize the network lifetime becomes an important problem. According to the research fruit many researchers have contributed. In the paper we give out the survey lifetime maximization strategies in wireless sensor network. In this article we also points out the open research concerns and intends to inspiration innovative interests and developments in this field.

Keywords: Wireless Sensor Networks, Network Lifetime, Energy efficient routing, MAC Protocols, Sleep scheduling, Aggregation, Topology control.

I INTRODUCTION

A Wireless Sensor Networks (WSNs) contains hundreds or thousands of sensor nodes. These sensors have the ability to communicate either among each other or directly to an external
Base-station (BS). A greater number of sensors allows for sensing over larger geographical regions with greater accuracy. Sensor nodes coordinate among themselves to produce high-
quality information about the physical environment. Each sensor node bases its decisions on its mission, the information it currently has, and its knowledge of its computing, communication, and energy resources. Each of these scattered sensor nodes has the capability to collect and route data either to other sensors or back to an external base station(s)[1]. Traditionally sensor networks have been employed for monitoring environmental conditions such as temperature, pressure, moisture contents etc. But with technological advances sophisticated sensor nodes are being produced capable of transmitting real-time data (video/images) and critical data (outages/leaks).

A base station may be a fixed node or a mobile node capable of connecting the sensor network to an existing communications infrastructure or to the Internet where a user can have access to the reported data. Figure 1 shows a schematic diagram of sensor node components. Basically, each sensor node comprises sensing, processing, transmission, mobilizer, position finding system, and power units (some of these components are optional, like the mobilizer). The same figure shows the communication architecture of a WSN. Sensor nodes are usually scattered in a sensor field, which is an area where the sensor nodes are deployed. Sensor nodes coordinate among themselves to produce high-quality information about the physical environment.

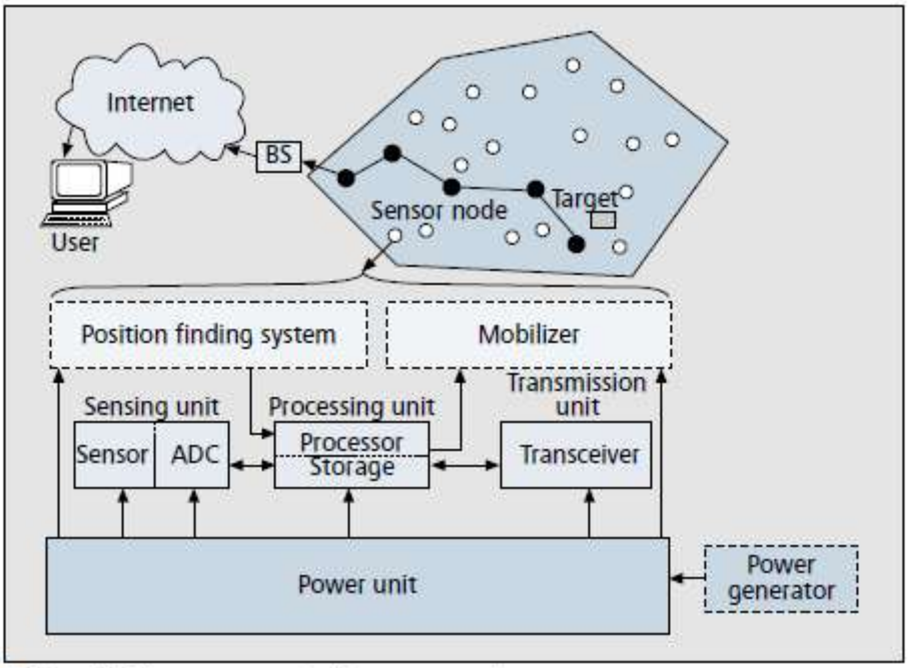

Figure 1. *The components of a sensor node.*

The applications of sensor networks in various fields vary from environment monitoring, military applications to monitoring patients in hospitals [2]. Basically nodes are driven by batteries and in many applications it is not easy to replace the batteries or sometimes not even recharge the batteries so each node has a limited energy supply. Lifetime is very important factor in wireless sensor network.

Definitions of network Lifetime of wireless sensor network can be defined as:

• Definition 1: the period to the first node failure due to battery outage;

• Definition 2: the period to the unapproachability of application functionality.

• Definition 3: the period to the first network partitioning. As soon as the network is no longer connected, vital information can no longer be transferred to its destination.

Due to the energy constrained nature of wireless nodes requires the use of energy efficient strategies to maximize network lifetime. We can classify these strategies in following categories:

1) Energy efficient routing
2) MAC Protocols with Low Duty Cycle
3) Sleep scheduling
4) Mobility based schemes
5) Reducing the amount of information
6) Topology control

This paper is organized as follows. In Section II, we focus on energy efficient routing. In Section III, we present MAC Protocols with low duty cycle. In Section IV, we present solutions allowing nodes to sleep while maintaining network connectivity. In Section V, we present mobility based schemes. In Section VI, we present different strategies whose common goal is to reduce the amount of information transferred. Section VII present topology control scheme that allowing nodes to decrease their transmission power as long as the network remains connected. Section VIII presents the conclusion of the paper.

II. ENERGY EFFICIENT ROUTING

With the help of energy efficient routing we can minimize the energy consumed by the end-to-end transmission of a packet, to avoid nodes with a low residual energy and reduce the number of unsuccessful transmissions.

2.1 Multipath routing

In [3], a multipath routing, energy aware, is proposed to maximize network lifetime. It is a reactive routing protocol triggered by the data sink. It consists in finding all paths between source and destination according to a metric which takes into account 1) the energy consumed by the transmission and reception of the packet and 2) the residual energy of nodes. Paths that have a cost higher than a given threshold are discarded.

2.2 Hop-By-Hop Routing Protocols

The second category of energy efficient routing protocols corresponds to adaptive hop-by-hop routing protocols. We can distinguish the families of energy efficient routing protocols:

- the protocols selecting the path consuming the minimum energy. The advantage is that each transmission of a packet from its source to its destination minimizes the energy consumed. We can cite for example [4] and a more sophisticated protocol [5]. This routing protocol computes the additional energy dissipated by one flow when routed on a given path, taking into account the SINR and the energy lost by radio interferences. Then, it uses the Dijkstra algorithm to find the path which minimizes this additional energy.
- the protocols selecting the path visiting the nodes with the highest residual energy. In the paper [6] use the concept of potential in physics to design an energy efficient routing protocol in WSN. They use virtual potential field in terms of depth, energy density, and residual energy and residual energy and develop a scheme that forces packets towards sink through the dense energy area. This helps in conservation of energy of low residual energy nodes.

III MAC PROTOCOLS WITH LOW DUTY CYLCLE

In the following discussion we will focus mainly on power management issues rather than on channel access methods. Most of them implement a low duty cycle scheme for power management.

3.1 TDMA (Time Division Multiple Access)

These schemes naturally enable a duty cycle on sensor nodes as channel access is done on a slot-by-slot basis. As nodes need to turn on their radio only during their own slots, the energy consumption is ideally reduced to the minimum required for transmitting/receiving data. In TDMA-based MAC protocols [7], [8] time is divided in (periodic) frames and each frame consists of a certain number of time slots. Every node is assigned to one or more slots per frame, according to a certain scheduling algorithm, and uses such slots for transmitting/receiving packets to/from other nodes.

3.2 Contention-based protocols

They achieve duty cycling by tightly integrating channel access functionalities with a sleep/wakeup scheme. The only difference is that in this case the sleep/wakeup algorithm is not a protocol independent of the MAC protocol, but is tightly coupled with it. One of the most popular contention-based MAC protocols is B-MAC (Berkeley MAC) [9], a low complexity and low power MAC protocol which is shipped with the TinyOS operating system. The goal of B-MAC is to provide a few core functionalities and an energy efficient mechanism for channel access. A well-known MAC protocol for multi-hop sensor networks is S-MAC (Sensor-MAC) [10], which adopts a scheduled rendezvous communication scheme. Nodes exchange sync packets to coordinate their sleep/wakeup periods.

3.3 Hybrid Protocols

They behave 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. In wireless sensor networks, one of the most interesting hybrid protocols is Z-MAC [11]. In order to define the main transmission control scheme, Z-MAC starts a preliminary setup phase. By means of the neighbor discovery process each node builds a list of two-hop neighbors. Then a distributed slot assignment algorithm is applied to ensure that any two nodes in the two-hop neighborhood are not assigned to the same slot. As a result, it is guaranteed that no transmission from a node to any of its one-hop neighbor interferes with any transmission from its two-hop neighbors. The local frame exchange is aimed at deciding the time frame procedure.

IV. SLEEP SCHEDULING

They allow nodes to sleep in order to spare energy, provided that the network and application functionalities are still ensured, A wireless node's radio can be in one of the following states:

- Transmit: node is transmitting a frame with transmission power Ptransmit;
- Receive: node is receiving a frame with reception power Preceive.
- Idle (listening): even when no messages are being transmitted over the medium, the nodes stay idle and keep listening the medium with power Pidle;
- Sleep: when the radio is turned off and the node is not capable of detecting radio signals: no communication is possible.

As it is wasteful to send a message to a sleeping receiver, it is then needed to coordinate neighbour nodes states. Moreover, sleeping nodes must not inhibit the application functionalities. That is why scheduling node activity is required.

4.1 On-demand

The basic idea is that a node should wakeup only when another node wants to communicate with it. STEM (Sparse Topology and Energy Management) [12] uses two different radios for wakeup signal and data packet transmissions, respectively. To achieve a tradeoff between energy saving and wakeup latency, [13] proposes a

Pipelined Tone Wakeup (PTW) scheme. Like STEM, PTW relies on two different channels for transmitting wakeup signals and packet data, and uses a wakeup tone to awake neighboring nodes. Hence, any node in the neighborhood of the source node will be awakened.

4.2 Scheduled Rendezvous

The basic idea behind scheduled rendezvous schemes is that each node should wake up at the same time as its neighbors. Typically, nodes wake up according to a wakeup schedule, and remain active for a short time interval to communicate with their neighbors. Then, they go to sleep until the next rendezvous time. The simplest way is using a Fully Synchronized Pattern [14]. In this case all nodes in the network wake up at the same time according to a periodic pattern. More precisely, all nodes wake up periodically every Twakeup, and remain active for a fixed time Tactive. Then, they return to sleep until the next wakeup instant.

4.3 Asynchronous Schemes

Asynchronous schemes allow each node to wake up independently of the others by guaranteeing that neighbors always have overlapped active periods within a specified number of cycles. Asynchronous wakeup was first introduced with reference to IEEE 802.11 ad hoc networks. Zheng et al. [15] took a systematic approach to design asynchronous wakeup mechanisms for ad hoc networks. Their scheme applies to wireless sensor networks, as well.

V. MOBILITY BASED SCHEMES

5.1 Mobile-Sink-based Approaches

Many approaches proposed in the literature about sensor networks with mobile sinks (MSs) which is exploited in order to optimize parameters such the network lifetime and so on. For example, in [16] the authors propose a model consisting of a MS which can move to a limited number of locations (sink sites) to visit a given sensor and communicate with it (sensors are supposed to be arranged in a square grid within the sensing area. Two-Tier Data Dissemination (TTDD) [17] is a low-power protocol for efficient data delivery to multiple MSs. Instead of passively waiting for queries coming from sinks, sensor nodes can proactively build a structure to set up forwarding.

5.2 Mobile-Relay-based Approaches

One of the most well-known approaches is given by the message ferrying scheme [18]. Message ferries are special mobile nodes which are introduced into a sparse network to offer the service of message relaying. Message ferries move around in the network area and collect data from source nodes. They carry stored data and forward them towards the destination node. Thus, message ferries can be seen as a moving communication infrastructure which accommodates data transfer in sparse wireless networks.

VI. REDUCE THE AMOUNT OF INFORMATION TRANSFERRED

This energy efficient strategy consists in aggregating information by reducing wasteful transmissions or tuning the refreshment period of control messages (e.g.; neighbourhood discovery, topology dissemination, data gathering tree structure).

6.1 Information aggregation

Information aggregation is frequently used in data gathering applications, where it enables high benefits. It can use clustering. 1) With clustering: LEACH (Low-Energy Adaptive Clustering Hierarchy) [19] organizes nodes into clusters with one acting as cluster head which is used as router to the base station Hence, all members of cluster transmit their data to the cluster head. Then the cluster head aggregates and compresses all the data received and sent it to the base station. The energy consumption of nodes is balanced by means of a randomized rotation of the cluster heads over time. Performance evaluation results show that LEACH reduces communication energy by as much as 8 times compared to direct transmission. Another improved and very popular energy-efficient protocol is HEED (Hybrid Energy- Efficient Distributed Clustering [20]). HEED is a hierarchical, distributed, clustering scheme in which a single-hop communication pattern is retained within each cluster, whereas multi-hop communication is allowed among CHs and the BS. The CH nodes are chosen based on two basic parameters, residual energy and intra cluster communication cost. Residual energy of each node is used to probabilistically choose the initial set of CHs. On the other hand, intra cluster communication cost reflects the node degree or node’s proximity to the neighbor and is used by the nodes in deciding to join a cluster or not.

6.2 Without clustering

In [21], the MLDA (Maximum Life- time Data Aggregation) problem is to find a data gathering schedule with a maximum lifetime (duration after which a node has exhausted its energy) for the sensor network which allows data aggregation. In each round, an aggregation tree is created, whose root is the data sink. This tree specifies how data will be collected, aggregated and transmitted to the base station (i.e.; the data sink). To resolve this problem, an integer program is presented with a linear relaxation. This centralized protocol improves network lifetime.

VII . TOPOLOGY CONTROL

These strategies find the optimum node transmission power that minimizes energy consumption, while keeping network connectivity, power, and each node adjusts its power transmission. Thus, energy dissipated in transmission is reduced and a new network topology is created. In [22], the idea is to reduce the transmission range d of every node to minimize the energy dissipated in transmission, $E(d) = d\alpha + c$, where α and c are physical parameters, while keeping a connected topology. It is shown that there exists an optimal transmission range which minimizes energy consumption. In [23], the TCH (Topology Control with Hitch-hiking) problem is addressed. Hitch-hiking takes advantage of a physical layer that allows combining partial messages containing the same information to decode a complete message. The goal of TCH is to obtain a strongly connected topology minimizing the energy dissipated in transmission. An Adaptive Transmission Power Control (ATPC) is proposed in [24]. The goal of ATPC is to achieve energy efficiency and guarantee link quality between neighbors. ATPC allows each node to know the optimal transmission power level to use for each neighbor while maintaining a good link quality. This power is adjusted adapting to spatial and temporal factors by collecting the link quality history.

VII. CONCLUSION

In this paper we have surveyed the main approaches to enhance lifetime in wireless sensor networks. Clearly, the highest benefits will be obtained by a solution combining these strategies. Along with the current research projects, we encourage more insight into the problems and intend to motivate a search for solutions to the open research issues described in this article.

REFERENCES

[1] I.F. Akyildiz, W. Su, Y.Sankarasubramaniam, and E. Cayirci,"Wireless Sensor Networks: A Survey,"IEEE Trans on Computer Networks, vol.38, no. 4, pp. 393-422, 2002.

[2] J. N. AL-Karaki and A. E. Kamal, **"**Routing Techniques in Wireless SensorNetworks: A Survey", IEEE Trans onWireless Communications, vol. 11, no. 6, pp.6-28, Dec. 2004.

[3] R.C. Shah, J.M. Rabaey, Energy Aware Routing for Low Energy Ad Hoc Sensor Networks, IEEE WCNC, Volume 1, pp. 17-21, March 2002.

[4] S.-M. Senouci, G. Pujolle, Energy efficient routing in wireless ad hoc networks, IEEE International Conference on Communications (ICC 2004), volume 7, pp. 4057-4061, June 2004.

[5] S. Kwon, Ness B. Shroff, Energy-Efficient Interference-Based Routing for Multi-hop Wireless Networks, IEEE INFOCOM'2006, Barcelona, Spain, April 2006.

[6] Fengyuan Ren; Jiao Zhang; Tao He; Chuang Lin; Ren, S.K.D. "EBRP: Energy-Balanced Routing Protocol for Data Gathering in Wireless Sensor Networks" Parallel and Distributed Systems, IEEE Transactions onVol.22,2011.

[7] K. Arisha, M. Youssef, M. Younis "Energy-aware TDMA-based MAC for Sensor Networks", Proc. IEEE Workshop on Integrated Management of Power Aware Communications, Computing and Networking (IMPACCT 2002), New York City (USA), May 2002.

[8] J. Li, G. Lazarou, "A Bit-map-assisted energy-efficient MAC Scheme for Wireless Sensor Networks", Proc.I nternational Symposium on Information Processing in Sensor Networks (IPSN 2004), pp. 56-60, Berkeley (USA),April 2004.

[9] J. Polastre, J. Hill and D. Culler, "Versatile Low Power Media Access for Sensor Networks", Proc. of the Second ACM Conference on Embedded Networked Sensor Systems , November 3-5, 2004.

[10] W. Ye, J. Heidemann and D. Estrin, "Medium Access Control With Coordinated Adaptive Sleeping for Wireless Sensor Networks", IEEE/ACM Transactions on Networking, Volume: 12, Issue: 3, Pages: 493-506, June 2004.

[11] I. Rhee, A. Warrier, M Aia, J. Min, "Z-MAC: a Hybrid MAC for Wireless Sensor Networks", Proc. ACM SenSys 2005, S Diego (USA), November 2005.

[12] C. Schurgers, V. Tsiatsis, M. B. Srivastava, "STEM: Topology Management for Energy Efficient Sensor Networks", IEEE Aerospace Conference '02, Big Sky, MT, March 10-15, 2002.

[13] X. Yang, N. Vaidya, "A Wakeup Scheme for Sensor Networks : Achieving Balance between Energy Saving and End-to-end Delay", Proc. of the IEEE Real-Time and Embedded Technology and Applications Symposium (RTAS 2004), pp. 19-26, 2004.

[14] A. Keshavarzian, H. Lee, L. Venkatraman, "Wakeup Scheduling in Wireless Sensor Networks", Proc. ACM MobiHoc 2006, pp. 322-333, Florence (Italy), May 2006.

[15] R. Zheng, J. Hou, L. Sha, "Asynchronous Wakeup for Ad Hoc Networks", Proc. ACM MobiHoc 2003, pp 35-45, Annapolis (USA), June 1-3, 2003.

[16] Z. M. Wang, S. Basagni, E. Melachrinoudis, C. Petrioli, "Exploiting Sink Mobility for Maximizing Sensor Networks Lifetime", Proc. of the 38th Annual Hawaii International Conference on System Sciences (HICSS '05), Hawaii, 03-06 Jan. 2005.

[17] H. Luo, F. Ye, J. Cheng, S. Lu, L. Zhang, "TTDD: Two-Tier Data Dissemination in Large-Scale Wireless Sensor Networks", Elsevier/ACM Wireless Networks, Vol. 11, No. 1-2, pp. 161-175, January 2005.

[18] H. Jun, W. Zhao, M. Ammar, E. Zegura, and C. Lee, "Trading Latency for Energy in Wireless Ad Hoc Networks using Message Ferrying", Proc. IEEE PerCom Workshops, International Workshop on Pervasive Wireless Networking (PWN 2005), March 2005.

[19] W. Heinzelman, A. Chandrakasan, H. Balakrishnan, Energy-efficient communication protocol for wireless microsensor networks, HICSS'00, Maui, Hawaii, USA, vol. 2, pp. 3005ˆa3014, January 2000.

[20] O. Younis and S. Fahmy, HEED: A hybrid, energy-efficient, distributed clustering approach for Ad Hoc sensor networks, IEEE Transactions on Mobile Computing, 3(4), 366–379, 2004.

[21] K. Kalpakis, K. Dasgupta, P. Namjoshi, Maximum Lifetime Data Gathering and Aggregation in Wireless Sensor Networks, IEEE Networks'02, Munich, Germany, August 2002.

[22] F. Ingelrest, D. Simplot-Ryl, I. Stojmenovic, Optimal Transmission Radius for Energy Efficient Broadcasting Protocols in Ad Hoc Networks, IEEE Transactions on Parallel and Distributed Systems, June 2006.

[23] M. Cardei, J. Wu, S. Yang, Topology Control in Ad hoc Wireless Networks with Hitch-hiking, First IEEE SECON04, October 2004.

[24] S. Lin, J. Zhang, G. Zhou, L. Gu, T. He, J. A. Stankovic, ATPC: Adaptive Transmission Power Control for Wireless Sensor Networks, SenSys'06, Colorado, November 2006.