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A Survey on Energy Proficient Techniques in WSN

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Abstract

This paper focuses on different techniques to decrease the consumption of the limited energy resources of sensor nodes. After having recognized the reasons of energy waste in WSNs, we classify energy efficient techniques into five classes, namely data reduction, control reduction, energy efficient routing, duty cycling and topology control. We then detail each of them, presenting subdivisions and giving many examples. We conclude by a recapitulative chart.

Keywords: *data reduction, Control reduction, duty cycle, topology control.*

1. Introduction

Wireless sensor networks (WSNs) consist of a possibly large amount of wireless networked sensors required to operate in a possibly hostile environment for a maximum duration without human involvement. Typically, a sensor node is a miniature device that includes four main components: a sensing unit for data acquirement, a microcontroller for local data processing and some memory operations, a message unit to allow the transmission/reception of data to/from other connected devices and finally a power source which is usually a small battery. WSNs support a broad range of applications such as target tracking, environmental monitoring, system control, health monitoring or exploration in hostile environment. For data congregation applications, which represent the main use of WSN applications, the goal is to sense any event occurring in the area of interest and to report it to the sink. [1], [2] are the earliest papers proving that if the communication range is at least twice the sensing range, a full coverage implies connectivity among active nodes inside the area of concern.

Application scenarios for WSNs often involve battery powered nodes being full of life for a long period, without external human control after initial deployment. In the nonexistence of energy efficient techniques, a node would drain its battery within a couple of days. This need has led researchers to design protocols able to reduce energy consumption. In [3], authors present a classification of energy conservation schemes. Their very interesting classification, however, does not include energy efficient routing, protocol overhead reduction, data collection and cross-layering mechanisms. In this survey, we cope with this drawback by providing a new classification integrating more techniques.

2. Network Lifetime Definition

The most challenging concern in WSN design is how to save node energy while maintaining the desirable network performance. Any WSN can only fulfill its mission as long as it is considered alive, but not after that. As a result, the goal of any energy efficient technique is to maximize network lifetime. This latter depends considerably on the lifetime of any single node. However, in the literature, there is no agreement for the definition of network lifetime. The greater part of authors uses a definition suitable for the context of their work. This situation has driven toward an overabundance of coexisting definitions. Based on the previous works on WSNs [4], [5], we give an overview of the most common definitions.

1) *Network lifetime based on the number of alive nodes*
The definition found most frequently in the text is the time during which all sensors are alive (also called n out of n in [5], where n is the total number of sensors). The sink nodes are barred from the set of nodes to reflect the assumption that sink nodes are more sophisticated and powerful devices. This lifetime is easy to calculate since it does not take into account the topology changes. However, in intense networks where redundancy is present, this metric does not represent actually the lifetime evaluation. Therefore, the only case in which this metric can be sensibly used is if all nodes are of equal of importance and critical to network application. A variant defines the network lifetime as the time until the part of alive nodes falls below a predefined threshold _ [6]. While this definition takes redundancy into relation unlike the former, it does not accurately define the correct running of data gathering applications where the failure of at most _ % of

sensors near the sink can prevent the sink to receive collected data. In the idea of clustering [7], [8], authors define the network lifetime as the time to failure of the first cluster head. However, in most works, researchers modify cluster head dynamically to balance energy consumption.

2) *Network lifetime based on coverage*
It shows how well the network can detect an event in the monitored area. Therefore some works describes the lifetime as the time during which the area of interest is covered by sensor nodes. However, 100% coverage is not sufficient because it does not ensure that collected data are delivered to the sink.

3) *Network lifetime based on connectivity*
This definition is based on the capability of the network to transmit data to a sink. This definition is same as what has been proposed in context of ad hoc networks. In [9] authors define the lifetime as the minimum time when either the amount of alive nodes or the size of the largest connected component of the network drops below a specific threshold.

4) Network lifetime based on application requirements few authors consider that network is alive as long as application functionalities are ensured. Kumar et al. [10] state "we define the lifetime of a WSN to be the time period during which the network continually satisfies the application requirements". Tian and Georganas [6] suggest another definition: "It is the time until the network no longer provides an acceptable event detection ratio." However, if no connectivity is guaranteed to report the event, this definition becomes irrelevant.

As a conclusion, network lifetime must take into account connectivity and coverage if needed by the application supported by WSN. Information of the application requirements will enable WSN designers to refine the definition of network lifetime, leading to an evaluation more realistic and more relevant for the application users.

3. Taxonomy of Energy Efficient Techniques

We detail in this section the reasons of potential energy waste in a WSN. We then propose taxonomy of existing energy efficient solutions, keeping in mind the resource constraint nature of sensors.

A. *Reasons of energy waste*
In WSNs, sensors disperse energy while sensing, processing, transmitting or receiving data to fulfill the mission required by the application. The sensing subsystem is devoted to data acquirement. It is obvious that minimizing data extracted from transducer will save energy of very constrained sensors. Redundancy inherent to WSNs will produce huge similar reporting that the network is in charge of routing to the sink. Experimental results confirm that communication subsystem is a greedy source of energy dissipation.

With regard to communication, there is also a great amount of energy wasted in states that are useless from the application point of view, such as [4].

Collision: when a node receives more than one packet at the same time, these packets collide. All packets that cause the collision have to be discarded and the retransmission of these packets is required.

Overhearing: when a sender transmits a packet, all nodes in its transmission range receive this packet even if they are not the intended destination. Thus, energy is wasted when a node receives packets that are destined to other nodes.

Control packet overhead: a minimal number of control packets should be used to enable data transmissions.

Idle listening: is one of the major sources of energy dissipation. It happens when a node is listening to an idle channel in order to receive possible traffic.

Interference: each node located between transmission range and interference range receives a packet but cannot decode it.

As network lifetime has become the key characteristic for evaluating WSN, panoply of techniques aimed at minimizing energy consumption and improving network lifetime, are proposed. We now give taxonomy of these techniques.

4. Classification of energy efficient techniques

We can identify five main classes of energy efficient techniques, namely, data reduction, protocol overhead reduction, energy efficient routing, duty cycling and topology control.

1) Data reduction: focuses on reducing the amount of data produced, processed and transmitted. For instance, data compression and data aggregation are examples of such techniques.

2) Protocol overhead reduction: the aim of this technique is to increase protocol efficiency by reducing the overhead.

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Different techniques exist. Transmission periods of messages are adapted depending on the stability of the network, or on the distance to the source of the transmitted information. More generally, a cross-layering approach will enable an optimization of the communication protocols taking into account the application requirements. Another technique, optimized flooding can significantly contribute to reduce the overhead.

3) Energy efficient routing: routing protocols should be designed with the target of maximizing network lifetime by minimizing the energy consumed by the end-to-end transmission and avoiding nodes with low residual energy. Some protocols are opportunistic, taking advantage of node mobility or the broadcast nature of wireless communications to reduce the energy consumed by a transmission to the sink. Others use geographical coordinates of nodes to build a route toward the destination.

4) Duty cycling: duty cycling means the fraction of time nodes are active during their lifetime. Nodes sleep/active schedules should be coordinated and accommodated to specific applications requirements. These techniques can be further subdivided. High granularity techniques focus on selecting active nodes among all sensors deployed in the network. Low granularity techniques deal with switching off (respectively on) the radio of active nodes when no communication is required (respectively when a communication involving this node may occur). They are highly related to the medium access protocol.

5) Topology control: it focuses on reducing energy consumption by adjusting transmission power while maintaining network connectivity. A new reduced topology is created based on local information.

5. Energy Efficient Routing Protocols

The energy constraints of sensor nodes raise challenging issues on the design of routing protocols for WSNs. Proposed protocols aim at load balancing, minimizing the energy consumed by the end-to-end transmission of a packet and avoiding nodes with low residual of energy. In this section, we give a classification rather than an exhaustive list of energy efficient routing protocols. Our classification of energy efficient routing protocols generalizes the one given in [20]: data centric protocols, hierarchical protocols, geographical and opportunistic protocols. Each category will be discussed in details in next subsections.

A. Data centric protocols

These protocols target energy saving by querying sensors based on their data attributes or interest. They make the assumptions that data delivery is described by a query driven model. Nodes route any data packet by looking at its content. Mainly, two approaches were proposed for interest dissemination. The first is SPIN [38] where any node advertises the availability of data and waits for requests from interested nodes. The second is Directed Diffusion (DD) [20] in which sinks broadcast an interest message to sensors, only interested nodes reply with a incline message. Hence, both interest and gradients establish paths between sink and interested sensors. Many other proposals have being made such as rumor routing, gradient based routing, COUGAR, CADR. See [20] for a complete summary.

B. Hierarchical protocols

Recently, clustering protocols have been developed in order to improve scalability and reduce the network traffic towards the sink. Cluster based protocols have shown lower energy consumption than flat networks despite the overhead introduced by cluster construction and maintenance. One of the revolutionary hierarchical routing protocols is LEACH [20]. In this protocol, sensors organize themselves in local clusters with one node acting as a cluster head. To balance energy consumption, a randomized rotation of cluster head is used.

PEGASIS is another example of hierarchical protocol [20]. It enhances LEACH by organizing all nodes in a chain and letting nodes to alternate the head of the chain. TEEN is both data centric and hierarchical. It builds clusters of different levels until reaching the sink. The data centric aspect is outlined by using two thresholds for sensed attributes: Hard threshold and soft threshold. The former will trigger the sensor node to transmit to its cluster head. Another transmission is only permitted when the attribute value becomes higher than the soft threshold. This mechanism can drastically reduce the number of transmission and thus energy consumption. Since TEEN is not adaptive to periodic sensor data reporting, an extension called APTEEN [20] has been proposed.

C. Geographical protocols

Non geographical routing protocols suffer from scalability and efficiency limitations because they depend on flooding for route discovery and updates. Geographical protocols take advantage of nodes location information to compute routes. In [20], authors propose an energy aware protocol called GEAR consisting of two phases. In the first phase, the message is forwarded to the target region. In the

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second phase, the message is forwarded to the destination within the region. The basic idea behind GEAR is to enhance DD by sending the interests only to a certain region rather than the whole network. GAF [20] ensures energy efficiency by building virtual grids based on location information of nodes. Only a single node needs to be turned on in each cell, other nodes are kept in sleeping state. SPEED [18] ensures load balancing among multiple routes with its non deterministic forwarding module.

D. Opportunistic protocols

The vital idea of opportunistic routing is to exploit 1) the broadcast nature and space diversity provided by the wireless medium or 2) node mobility. We distinguish two subclasses of opportunistic routing:

1) Medium broadcast nature and space diversity based protocols: These techniques maintain multiple forwarding candidates and sensibly decide which sets of nodes are good and prioritized to form the forwarding candidate set. In [39], authors highlight how these protocols achieve better energy efficiency.

2) Mobility based protocols: By introducing mobility in WSN, network lifetime can be extended. Indeed, mobile nodes can move to isolated parts of the network and hence connectivity is again reached. Several works merging routing and mobility have demonstrated that this class of routing protocol exhibits smaller energy expenditure when compared to classical techniques.

- Mobile sink based protocols: the authors of propose a structure where mobility of the sink and routing are combined. Their proposed routing strategy offers 500 % improvement of network lifetime by using combination of sink route and short paths. In a learning based approach is proposed to efficiently and reliably route data to a mobile sink. Sensors in the neighborhood of the sink learn its movement pattern over time and statistically characterize it as a probability distribution function. authors demonstrate that maximum lifetime can be achieved by solving optimally two joint problems: a scheduling problem that determines the break times of the sink at different locations, and a routing problem in order to deliver the collected data to the sink in an energy efficient way.

- Mobile relay based protocols: these techniques have been introduced in the context of opportunistic networks where the existence of an end-to-end routing path is

not usually ensured. Thus, any node can be used as an intermediate hop for forwarding data closer to the destination. Authors assume the existence of mobile entities (called MULES) present in the monitored area. MULEs pick up data from the sensors when in close range, buffer it, and drop off the data to wired access points. Their model integrates a random walk for mobility pattern and incorporates system variables such as number of MULEs, sensors and access points. Data mules accommodate their trajectories for data delivery based on only local information.

6. Topology Control

The fundamental idea behind topology control is to build and maintain a reduced topology that will save the small energy budget of sensors while preserving network connectivity and coverage. This can be achieved by reducing the transmission power of sensors. Authors prove that there is an optimal transmission range that minimizes energy expense while keeping a connected topology. Since in most applications, devices in WSNs are mixed, we present three topology control algorithms for heterogeneous WSN: Directed LMST (DLMST), Directed RNG (DRNG), and the Residual Energy Aware Dynamic (READ) topology construction algorithm. Both DLMST and DRNG build the reduced topology based on locally collected information. If the original network is strongly connected and symmetric, the reduced topologies computed by these protocols preserve these properties.

On the other side, READ takes benefit from the heterogeneity of nodes where more powerful devices plays a more leading role in the network connectivity to extend network lifetime. Instead of using the euclidian distance between two communicating nodes to define the link cost, READ introduces a weighted cost for each pair of nodes that considers both the energy for sending and receiving data and the current residual energy at each node.

7. Conclusions

The availability of sensor devices allows a wide variety of applications to emerge. However, the resource constrained nature of sensors raises the problem of energy: how to maximize network lifetime despite a very limited energy budget. In this paper, we have summarized different techniques that tackle the energy efficiency challenge in WSNs and classified them in five main classes as shown in Figure 1 that summarizes this survey. For each class of techniques, we have pointed out which source of energy waste it improves.

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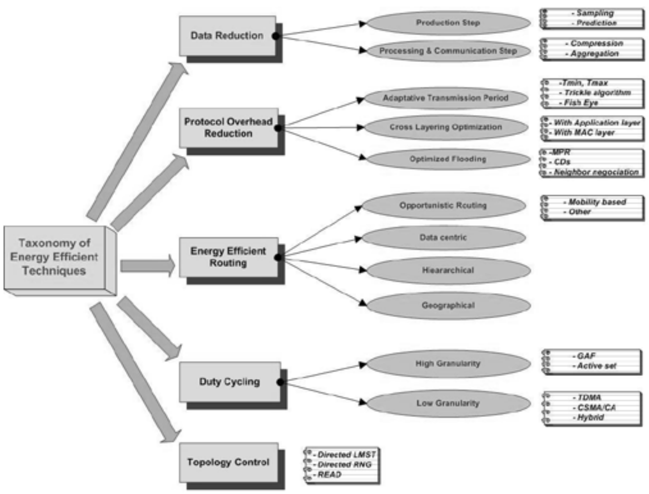

Fig 1: Taxonomy of energy efficient techniques

References

[1] Y. S. Han, W. B. Heinzelman, P. K. Varshney, “Scheduling sleeping nodes in high density cluster-based sensor networks”. Journal of Mobile Networks and Applications, Vol.10, December 2005.

[2] X. Wang, G. Xing, Y. Zhang, C. Lu, R. Pless, C. D. Gill, “Integrated coverage and connectivity configuration in wireless sensor networks”, in Proc. First ACM Conference on Embedded Networked Sensor Systems (SenSys 2003), Los Angeles, November 2003.

[3] G. Anastasi, M. Conti, L. M. Di Franchesco, A. Passarella, “Energy conservation in wireless sensor networks: A survey”. Ad Hoc Networks, vol. 7, pp 537-568, 2009.

[4] P. Minet, “Energy efficient routing”, in Ad Hoc and Sensor Wireless Networks: Architectures: Algorithms and Protocols. Bentham Science, 2009.

[5] I. Dietrich, F. Dressler, “On the lifetime of Wireless Sensor Networks”. ACM Transactions on Sensor Networks, Vol.5, 2009.

[6] D. Tian, N. D. Georganas, “A coverage-preserving node scheduling scheme for large wireless sensor networks”, in Proc. the 1st ACM International Workshop on Wireless Sensor Networks and Applications(WSNA), 32-41, 2002.

[7] S. Soro, W. B. Heinzeiman, “Prolonging the lifetime of wireless sensor networks via unequal clustering”, in Proc. the 19th IEEE Inetrnational Parallel and distributed Processing Symposium (IPDPS), 2005.

[8] D. M. Blough, P. Santi, “Investigating upper bounds on network lifetime extension for cell-based energy conservation techniques in stationary ad hoc networks”, in Proc. the 8th ACM International Conference on Mobile Computing and Networking(mobiCom), 183-192.

[9] C. F. Chiasserini, I. Chlamtac, A. Nucci, “Energy efficient design of wireless ad hoc networks”, in Proc. the 2nd IFIP networking. Vol. LNCS 2345, 367-386. 2002.

[10] S. Kumar, A. Arora, T. H. Lai. “On the lifetime analysis of alwayson warless sensor network applications”, in Proc. the IEE International Conference on Mobile Ad-hoc and sensor systems (MASS), Washington, November 2005.

[11] S. Goel, T. Imielinski, “Prediction-based Monitoring in Sensor Networks: Taking Lessons from MPEG”. Jal of ACM Computer Communication Review, Vol. 31, 2001.

[12] L. Liu, P. S. Yu, “ASAP: An Adaptive Sampling Approach to Data Collection in Sensor Networks”. IEEE Transactions on Parallel and Distributed Systems, 2007.

[13] S. Goel, A. Passarella, T. Imielinski, “Using buddies to live longer in a boring world”, in Proc. the Fourth Annual IEEE International Conference on Pervasive Computing and Communications Workshops, 2004.

[14] R. Willett, A. Martin, R. Nowak, “Backcasting: adaptive sampling for sensor networks“, in Proc. the 3rd international symposium on Information processing in sensor networks (IPSN’04), 2004.

[15] A Djafari Marbini, L. E. Sacks, “Adaptive Sampling Mechanisms in Sensor Networks”, in Proc. LCS, 2003.

[16] A. Jain, E. Y. Chang, “Adaptive sampling for sensor networks“, in Proc. the 1st international workshop on Data management for sensor networks: in conjunction with VLDB, 2004.

[17] N. Kimura, S. Latifi, ”A Survey on Data Compression in Wireless Sensor Networks“, in Proc. International Conference on Information Technology: Coding and Computing (ITCC’05), 2005, pp.8-13.

[18] W. R. Heinzelman, A. Ch , H. Balakrishnan, ”Energy-efficient communication protocol for wireless microsensor networks“, in Proc. the 33rd Hawaii International Conference on System Sciences (HICSS’00), 2000.

[19] W. B. Heinzelman, ”An application-specific protocol architecture for wireless networks“. IEEE TRANSACTIONS ON WIRELESS COMMUNICATIONS, Vol. 1, No. 4, October 2002.

[20] K. Akkaya, M. Younis, ”A survey on routing protocols for wireless sensor networks“. Ad Hoc Networks Volume: 3, Issue: 3, Pages: 325- 349, 2005.

[21] W. Zhang, G. Cao, ”Optimizing tree reconfiguration for mobile target tracking in sensor networks”, in Proc. INFOCOM 2004, 2004.

[22] W. Zhang, G. Cao, “DCTC: dynamic convoy tree-based collaboration for target tracking in sensor networks”. IEEE Transactions on Wireless Communications, 2004.

[23] A. Goel, D. Estrin, “Simultaneous optimization for concave costs: single sink aggregation or single source buy-at-bulk”, in Proc. SODA, 2003.

[24] R. C. Baltasar, R. Cristescu, B. B. Lozano, M. V, “On Network Correlated Data Gathering“, in Proc. INFOCOM 2004, 2004.

[25] Yujie Zhu, Sundaresan, K., Sivakumar, R, ”Practical limits on achievable energy improvements and useable delay tolerance in correlation aware data gathering in wireless sensor networks“, in Proc. IEEE SECON 2005,

[26] K. W. Fan, S. Liu, P. Sinha, ”On the potential of Structure-free Data Aggregation in Sensor Networks“, in Proc. INFOCOM 2006, April 2006.

[27] K. W. Fan, S. Liu, P. Sinha, ”Scalable data aggregation for dynamic events in sensor networks“, in Proc. the 4th international conference on Embedded networked sensor systems (SenSys’06), 2006.

[28] S. Mahfoudh, P. Minet, ”An energy efficient routing based on OLSR in wireless ad hoc and sensor networks“, in Proc. PAEWN08, Okinawa, Japan, March 2008.

[29] http://tools.ietf.org/html/rfc6206

[30] G. Pei, M. Gerla, T.-W. Chen, ”Fisheye state routing: a routing scheme for ad hoc wireless networks“, in Proc. IEEE ICC00, New Oreleans, LA June 2000.

[31] van Der Schaar, M. Sai Shankar N, ”Cross-layer wireless multimedia transmission: challenges, principles, and new paradigms“. IEEE Wireless Communications, vol. 12, 2005, pp. 50-58.

[32] M. Garey, D. Johnson, Computers and intractability: a guide to the theory of NP-completeness, Freeman, San Francisco, 1979.

[33] J. Wu, H. Li, ”On calculating connected dominating set for efficient routing in ad hoc wireless networks, in Proc. the 3rd international workshop on Discrete algorithms and methods for mobile computing and communications DIALM ’99, New York, August 1999.

[34] F. Dai, J. Wu, ”An extended localized algorithm for connected dominating set formation in ad hoc wireless networks“. IEEE Trans. on Parrallel and distributed systems, vol. 15(10), 2004.

[35] F. Ingelrest, D. Simplot-Ryl, I. Stojmenovic, ”Smaller Connected Dominating Sets in Ad Hoc and Sensor Networks based on Coverage by Two-Hop Neighbors“, in Proc. 2nd International Conference on Communication System Software and Middleware, Bangalore, India, 2007.

[36] K. Alzoubi, P.J.Wan, O. Fieder, ”Distributed heuristics for connected dominating sets in wireless ad hoc networks“. Jal of Communications and Networks, vol. 4(1), March 2002.

[37] B. Han, H.H. Fu, L. Li, W. Jia, ”Efficient construction of connected dominating set in wireless ad hoc networks“, in Proc. IEEE MASS 2004, Fort Lauderdale, Florida, October 2004.

[38] E.-O. Blass, J. Horneber, M. Zitterbart, ”Analyzing Data Prediction in Wireless Sensor Networks“, in Proc. IEEE Vehicular Technology Conference, VTC Spring 2008, 2008.

[39] K. Zeng, W. Lou, J. Yang, D. R. Brown III, ”On Geographic Collaborative Forwarding in Wireless Ad Hoc and Sensor Networks“, in Proc. International Conference on Wireless Algorithms, Systems and Applications (WASA), 2007.