Various Approaches for Enhancing The Performance of Wireless Sensor Networks

Hasan Al Shalabi[1] & Ibrahiem M. M. El Emary[2]

[1]Computer Engineering Department, Al Hussein Bin Talal University
Ma'an, Jordan

[2]Information Technology Deanship, King Abdulaziz University
Jeddah, Saudi Arabia

Abstract

In the current time and next decades, Wireless Sensor Networks (WSNs) represents a new category of ad hoc networks consisting of small nodes with three functions: sensing, computation, and wireless communications capabilities. Many routing, power management, and data dissemination protocols have been designed for WSNs where energy awareness is an essential design issue to improve the overall performance of WSN. There are many approaches and techniques explored for the optimization of energy usage in wireless sensor networks. Routing represents one of these areas in which attempts for efficient utilization of energy have been made. In this paper, we report on the current state of the research on optimizing the performance of WSN using various advanced approaches. There are various directions to enhance and optimize the performance as: avoiding congestion and keep it within certain controlled value, selecting the optimum routing approach, reducing the level of power consumption to increase the life time of the sensor node and others. So, the major objective of this paper is to investigate the various techniques used in improving and enhancing the performance of WSN to let it be more reliable in various applications like: health care and biomedical treatment, environment monitoring, military survival lance , target tracking, greenhouse monitoring,…etc .

Keywords: *WSN, ad hoc, DAQ, TDMA, TRAMA, RETSINA, ACCP, Dijkstra algorithm*

1. Introduction

The wireless sensor network is some type of an ad-hoc network. Mainly it consists of small light weighted wireless nodes called sensor nodes, deployed in physical or environmental condition. It measure the physical parameters such as sound, pressure, temperature, and humidity. These sensor nodes deployed in large or thousand numbers and collaborate to form an ad hoc network capable of reporting to data collection sink (base station).

Wireless sensor network have various applications like habitat monitoring, building monitoring, health monitoring, military survival lance and target tracking. However wireless sensor network is a resource constraint if we talk about energy, computation, memory and limited communication capabilities.

A typical wireless sensor network is comprised of tens, hundreds, or even thousands of sensor nodes. Typically each sensor node is composed of a microcontroller, a radio transceiver, one or more micro sensors, power source and other components. The microcontroller samples the micro sensors, send the data, either with or without processing, through radio links to the locations where the information is needed. Due to the limited radio range and the relatively larger target areas, in many cases a multiple hop ad hoc wireless network is formed for the information transmission. The devices that gather the information from the wireless sensor networks are defined as base stations. There may be one or more base stations for a wireless sensor network. The base stations may be static or mobile. However, for many applications, the sensor nodes themselves are not moving, either due to the scenario requirements, or technical or economical hindrance.

All sensor nodes in the wireless sensor network are interacting with each other or by intermediate sensor nodes [1]. A sensor nodes that generates data, based on its sensing mechanisms observation and transmit sensed data packet to the base station (sink). This process basically direct transmission since the base station may locate very far away from sensor nodes needs (see Fig.1). More energy to transmit data over long distances so that a better technique is to have fewer nodes sends data to the base station. These nodes called aggregator nodes and processes called data aggregation in wireless sensor network.

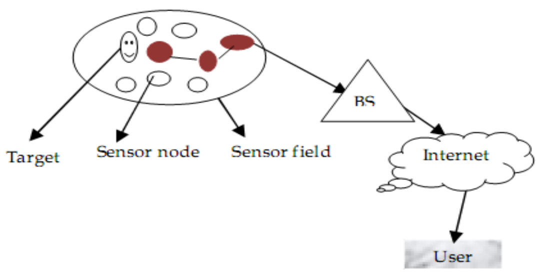

Fig. 1 Architecture of the Sensor network

In a wireless sensor network, sensing nodes with limited power, computation, communication and storage resources cooperate to fulfill monitoring and tracking functionalities. Compared with conventional sensors, wireless sensor networks have the following advantages: Since the relevant technologies have become technologically and economically feasible, people want to gather much more information from more places in the physical world, which was either impossible due to technological difficulties or formidable due to high cost, in terms of money and human power. Decreasing form factors and costs of micro sensors make deployment of hundreds even thousands of sensors much more feasible than conventional sensors that are too cumbersome and expensive [2].
Many conventional sensors send data to data acquisition (DAQ) modules in personal computers or workstations, and typically the sensors, personal computers and workstations are interconnected in a wired manner for data collection, aggregation and processing. When the number of sensors deployed in a certain area increases exponentially, this approach obsoletes. A more appropriate approach is to connect the sensors with low cost microcontrollers and to send and receive information through wireless links. This approach is made feasible by decrease in costs, form factors and power consumption of microcontrollers and radio transceivers. Based on the sensing ranges of quite a few commonly used types of sensors, a deployment density of one node per one hundred square meters is typical [2].
One of the design optimization strategies applied in WSN is to deterministically place the sensor nodes in order to meet the desired performance goals. In such case, the coverage of the monitored region can be ensured through careful planning of node densities and fields of view and thus the network topology can be established at setup time. However, in many WSNs applications sensors deployment is random and little control can be exerted in order to ensure coverage and yield uniform node density while achieving strongly connected network topology. Therefore, controlled placement is often pursued for only a selected subset of the employed nodes with the goal of structuring the network topology in a way that achieves the desired application requirements. In addition to coverage, the nodes' positions affect numerous network performance metrics such as energy consumption, delay and throughput. For example, large distances between nodes weaken the communication links, lower the throughput and increase energy consumption.

2. Literature Review

This section review the prior work on improving the congestion control over wireless sensor networks as one approach for enhancing the performance of WSN. In [3], a cross-layer TDMA-based protocol that guarantees collision-free communication by scheduling slots for each node and results in significant energy savings was presented. This technique has the capability of determining the collision-free slots that are to be assigned to wireless nodes in a multiple-hop network. In [4], another approach was proposed in which TRAMA that organizes time into frames and uses a distributed election scheme based on traffic information at each node to determine which node can transmit at a particular slot. TRAMA uses a distributed hash function to determine a collision-free slot assignment and builds a scheduling scheme when a node has data to send. This random scheduling scheme increases the queuing delays.
Another technique called Queue based Congestion Control Protocol with priority support, using the queue length as an indication of congestion degree was presented in [5]. In this approach, the rate assignment to each traffic source is based on its priority index as well as its current congestion degree. A node priority-based congestion control protocol for wireless sensor networks was proposed in [6]. In this technique, the node priority index is introduced to reflect the importance of each node and uses packet inter-arrival time along with packet service time to measure a parameter defined as congestion degree and imposes hop-by-hop control based measurement as well as node priority index.
In [7], it was proposed an energy efficient congestion control scheme for sensor networks called Enhanced Congestion Detection and Avoidance which comprises of three mechanisms. First, the approach uses buffer and weighted buffer

difference for congestion detection. Secondly, proposed a bottleneck-node-based source data sending rate control scheme and finally uses a flexible queue scheduler for packets transfer. A new and more recent approach was proposed in [8] called a cluster head method to allow parallel transmission of data packets to form a schedule by arranging data transfer at each round. The cluster head accepts request for data transfer and assigns a slot for each node wishing to transmit. Each node of data transfer is divided into contention, data transmission and idle period. In WSN the single point of failure is eliminated by providing a decentralized control and nodes that have no data to send waste time slots in the contention period where idle listening and overhearing occurs.

In [9] a suggested approach called an adaptive rate control for congestion avoidance in WBANs was presented. The scheme performs rate control dynamically each node based on a predication model which uses rate function including congestion risk degree and valuation function, without requiring congestion detection and congestion notification steps. There is another advanced approach presented in [10] based on a distributed and scalable algorithm that eliminates congestion within a sensor network, and ensures the fair delivery of packets to a central node or a base station. This routing structures often results in the sensors closer to the base station experiencing congestion, which inevitably cause packets originating from sensors to have a higher probability of being dropped. The problem of single-path upstream congestion control in wireless sensor networks through the traffic control was investigated in [11], where authors of this work proposed a multi-agent system based approach to control the traffic in the upstream congestion. The traffic generated in a wireless sensor node is of two types named, source traffic and transit traffic. The source traffic is generated from each wireless sensor node and the transit traffic is generated from other wireless sensor nodes.

A Reusable Task-based System of Intelligent Networked Agents (RETSINA) is a cooperative multi-agent system that consists of three classes of agents: interface agents, task agents and information agents. RETSINA provides a domain-independent, componentized, and reusable substratum to (a) allow heterogeneous agents to coordinate in a variety of ways and (b) enable a single agent to be part of a multi-agent infrastructure. RETSINA [12] provides facilities for reuse and a combination of different existing low-level infrastructure components, and it also defines and implements higher level agent services and components that are reconfigurable and reusable. Paper [11] proposed an upstream congestion control model by using RETSINA multi-agent named Agent-based Congestion Control Protocol (ACCP). ACCP reduce the packet loss by its intelligent scheduling schemes. Fig.2 illustrates the proposed congestion control model in a wireless sensor node. ACCP consists of four components: Execution Monitor, Communicator, Planner, and Scheduler [13].

The execution monitor identifies the congestion based on the packet arrival time (ta) and packet service time (ts) at the Medium Access Control (MAC) layer. The packet arrival time (ta) is the time interval between two subsequent packets arrived from any source and the packet service time (ts) is the time interval between arrival of packets at the MAC and its successful transmission. These two parameters are monitored at each node by the execution monitor on a packet-by packet manner.

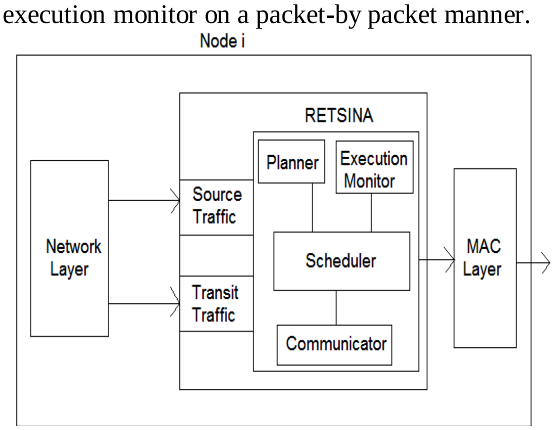

Fig.2 Congestion control model [11]

From this, a congestion index (Cx) is calculated and it is defined as the ratio of average packet service time over average packet arrival time at each wireless sensor node. The congestion index at node i is given [11] by:-

$$Cx(i) = ts / ta \qquad (1)$$

The execution monitor also takes the agent's next intended action and prepares, monitors, and completes its execution. The communicator module communicates all the notifications at each wireless sensor node in the packet header to be forwarded. From the congestion index the communicator module computes a global congestion priority index by summating source congestion priority index and the global congestion priority index of the lower level wireless senor nodes. The planner receives goals through communication message packets and finds alternative ways to fulfill them. The planning component is reusable and capable of accepting

different planning algorithms in an intelligent way. The scheduler has two queues for the source traffic and the transit traffic. By adjusting the scheduling rate the congestion can be reduced. The scheduling algorithm uses the earliest deadline-first heuristic. A list of all actions is scheduled and the action with the earliest deadline is chosen for execution. When a periodic action is chosen for execution, it is reinstated into the schedule with a deadline equal to the current time plus the action's period.
The four modules of RETSINA multi-agent are implemented for the upstream congestion control as autonomous threads of control to allow concurrent planning and scheduling actions, and execution in an efficient way. Furthermore, all modules are executed as separate threads and are able to execute concurrently. So almost all the packets are forwarded to the next wireless sensor node without any loses.

3. WSN Architecture Parameters and Design Requirements

A typical sensor network operates in five phases: the planning phase, deployment phase, post-deployment phase, operation phase and post-operation phase. In the planning phase, a site survey is conducted to evaluate deployment environment and conditions, and then to select a suitable deployment mechanism. In the deployment phase, sensors are randomly deployed over a target region. In the post deployment phase, the sensor networks operators need to identify or estimate the location of sensors and to access coverage. The operation phase involves the normal operation of monitoring tasks where sensors observe the environment and generate data. The post-operation phase involves shutting down and preserving the sensors by settings the sensors to sleep mode for future operations or destroying the sensor network. In a WSN setup, the nodes may be deployed in an ad-hoc manner with no predefined topology. The nodes automatically setup a network by communicating with one another in a multihop fashion. New nodes can malfunction, be added or removed from the network at any time. Newly added nodes must integrate into the network seamlessly and the network must detect and react quickly when nodes are removed to avoid affecting the reliability of message delivery services. The timely detection, processing, and delivery of information are indispensable requirements in a real-time WSN application. In SPEED there are two types of communication associated with data delivery

- **unicast** (a specific node will receive the packet) area-multicast (where a copy of the packet is send to every node inside the specified area)
- **area-unicast** (copy of the packet is sent to at least one node inside the specified area)

For efficient communication both the route discovery cost and resulting route length are important. Unlike wired networks, where the delay is independent of the route length, in multihop wireless sensor networks, the end-to-end delay depends on not only single hop delay, but also on the distance a packet travels.
Any real time protocol should satisfy three design objectives: stateless nodes, load balanced routes and congestion control mechanism. The architectures of WSNs emerged from the experience gained from devising architectures for self-organizing, mobile, ad hoc networks . The latter show emphasis on the need for decentralized, distributed form of organization and this is a shared characteristic with WSNs. They benefit from the evolutions in real-time computing, peer-to-peer computing, active networks and mobile agents/swarm intelligence. Besides the networking and computing concepts just mentioned, many other factors play a significant role when devising architectures for a WSN.
The critical factors that distinguished between different WSNs architectures are listed as follows:-

- **Fault tolerance:** WSNs are mainly monitoring important phenomena. Therefore, it is essential for a WSN to sustain its functionality without disruptions, even if some nodes malfunction or die. Usually, WSNs are deployed in hostile environments where nodes may be damaged, due to environmental interference, or eventually die due to the impracticality of recharging or replacing their batteries. Nodes in a WSN are prone to failures and this may result in sever situations like partitioning the network. The design of a WSN should guarantee that its functionality and services are never degraded by these failures.
- **Scalability:** Sensor nodes are deployed densely to form a WSN. This huge number of nodes has a direct impact on the design of schemes and protocols at different layers. For example, a MAC protocol (data-link layer) should be able to grant, in a fair fashion, each node access to the medium while minimizing or preventing collisions, which is very difficult given the huge number of available nodes. Also, a routing protocol (network layer) that depends on exchanging routing tables among nodes may not be efficient since there will be excessive control traffic that underutilizes the bandwidth of the medium.

- **Production cost:** The cost of a single sensor node should be minimized since it determines the overall cost of the network under design.
- **Network topology:** The fact that Wireless Sensor Networks are constituted by a huge number of nodes raises the challenge of network topology maintenance and modification. The challenge occurs starting at the early stage of nodes deployment. Sensor nodes can be either thrown in a mass (e.g., from a plane) or manually placed one by one (e.g., by a human or a robot) in the field. Also, after nodes deployment, topology may change due to failures in some nodes, changes in nodes locations, lack of reachability (due to jamming for instance), and huge reductions in power resources at some nodes (which affect their transmission power levels to the limit that they vanish from the vicinity of neighboring nodes). The WSN should be able to adapt to these sudden changes to avoid any degradations in its functionality.
- **Security:** In the environment of deployment, sensor nodes are either deployed very close to the phenomenon of interest or directly inside it. As a result, we can see that WSNs are usually not supervised (especially in remote geographic areas). This means that WSNs may be targeted by intruders to exploit any security vulnerability.
- **QoS support:** Time-sensitive applications (especially in military) require support for real-time communication that provisions guarantees on maximum delay, minimum bandwidth, or other QoS parameters.
- **Power consumption:** this is a primary design factor for any WSN. Power consumption should be made minimal in order to prolong the lifetime of the network. In fact, "power conservation" is a distinguishing factor between designing a WSN and designing other classes of wireless networks. The latter may consider QoS parameters (like, delay, throughput, fairness, etc.) as key design requirements. Based on this observation, research activities target the development of power-aware protocols and algorithms for sensor networks. That is, power-awareness should be incorporated in every stage of designing a WSN. In fact, power-awareness imposes constraints on the size and complexity of a sensor node's platform. In this context, hardware of sensor nodes should be designed to be power-efficient.

1. 4. Various Methodologies Applied for Enhancing the WSN Performance

In this section, we list and report the important works achieved for improving the WSN performance in view point of different directions given as follows:-

- **Firstly regarding the congestion control problem:** [3] proposed a cross-layer TDMA-based protocol that guarantees collision-free communication by scheduling slots for each node and results in significant energy savings. This has the main challenge to determine the collision-free slots that are to be assigned to wireless nodes in a multiple-hop network. [4] proposed TRAMA that organizes time into frames and uses a distributed election scheme based on traffic information at each node to determine which node can transmit at a particular slot. TRAMA uses a distributed hash function to determine a collision-free slot assignment and builds a scheduling scheme when a node has data to send. This random scheduling scheme increases the queuing delays. [5] proposed a novel upstream congestion control protocol for WSNs named Priority based Congestion Control Protocol, which introduced node priority index to reflect the importance of each sensor node. This utilizes a cross-layer optimization and imposes a hop-by-hop approach to control congestion. [6] presented a new Queue based Congestion Control Protocol with priority support, using the queue length as an indication of congestion degree. In this approach, the rate assignment to each traffic source is based on its priority index as well as its current congestion degree. [5] proposed a node priority-based congestion control protocol for wireless sensor networks. In this, the node priority index is introduced to reflect the importance of each node and uses packet inter-arrival time along with packet service time to measure a parameter defined as congestion degree and imposes hop-by-hop control based measurement as well as node priority index. [9] proposed an energy efficient congestion control scheme for sensor networks called Enhanced Congestion Detection and Avoidance which comprises of three mechanisms. First, the approach uses buffer and weighted buffer difference for congestion detection. Secondly, proposed a bottleneck-node-based source data sending rate control scheme and finally uses a flexible queue scheduler for packets transfer.

- **Secondly regarding the avoidance of routing problems:** The limited energy supply of sensor nodes necessitates energy-awareness at most layers of networking protocol stack including the network layer. In addition, many applications of sensor networks require the deployment of a large number of sensor nodes making it impractical to build a global addressing scheme. Moreover, in contrary to contemporary communication networks almost all applications of sensor networks require the flow of sensed data from multiple sources to a particular sink. These unique characteristics of sensor networks have made efficient routing of sensor data one of the technical challenges in wireless sensor networks [15]. While a number of routing protocols pursued a data centric methodology by naming the data, some considered clustering the sensor nodes in order to decrease the number of transmitted messages to the sink node and have a more scalable setup. Other protocols either adopted a location-based routes setup or strived to achieve energy saving through activation of a limited subset of nodes. In addition, with the increasing interest in the applications that require certain end-to-end performance guarantees, a few routing protocols have been proposed for providing energy-efficient relaying of delay-constrained data [16, 17]. While the goals of most published techniques are increasing network lifetime and on-time delivery of data through clever architecture and management of the network, none of the work considered the possibility of relocating the sink (gateway) node for enhanced network performance.

Gateway positioning has been also investigated in the context of wireless local area network and cellular infrastructure [18, 19]. The gateways, also called base stations, in these systems are stationary in nature and are placed in order to achieve coverage of an area or a building using the minimal number of gateway units. The considered model was using the gateway node as a direct router for a group of mobile nodes that would be otherwise unreachable due to topological reasons such as blockages. The problem addressed was to find the optimal place for the gateway node to best serve the group in terms of latency and throughput. The pursed approach was to move the gateway to the weighted geographic centroid of the group by considering the location and traffic generated by nodes regardless the established routes.

Determining the gateway position was formulated as an optimization problem. The gateway applies the repositioning algorithm at each sampling instant to gradually get closer to the nodes that generate the highest traffic and to respond to changes in the node locations. The work in [14] is path-based and does not just consider nodes. They argue that it is not possible to optimally place the gateway without considering the network topology and inter-node links. They observe that frequent changes to the network topology can impose overhead that can surpass the value of the relocation from a system's point of view.

- **Thirdly regarding the problem of power saving**: Ideally, we would like the sensor network to perform its functionality as long as possible. Optimal routing in energy constrained networks is not practically feasible (because it requires future knowledge). However, we can soften our requirements towards a statistically optimal scheme, which maximizes the network functionality considered over all possible future activity. A scheme is energy efficient (in contrast to 'energy optimal') when it is statistically optimal and causal (i.e. takes only past and present into account).

In most practical surveillance or monitoring applications, we do not want any coverage gaps to develop. We therefore define the lifetime we want to maximize as the worst case time until a node breaks down, instead of the average time over all scenarios. However, taking into account all possible future scenarios is too computationally intensive, even for simulations. It is therefore certainly unworkable as a guideline to base practical schemes on. Many routing and data transfer protocols have been specifically designed for WSNs [21-24]. Most sensor network routing protocols are, however, quite simple and for this reason are sometimes insecure. In what follow, we present a discussion of major attacks against them. Most network layer attacks against sensor networks fall into one of the following categories [25].

1- Sinkhole attacks: to make the compromised node look attractive to surrounding nodes with respect to the routing choice.

2- Spoofed, altered routing attack: to replay routing information, create routing loops, and to extend or shorten source routes.

3- Selective forwarding: refuse to forward certain messages, to simply drop them, and to attract or repel network traffic

4- Sybil attacks: a single node presents multiple identities to other nodes in the network.

5- Wormholes: adversary tunnels messages received in one part of the network over a low latency link and replays them in a different part.

6- HELLO flood attacks: broadcast HELLO packets to announce themselves to their neighbors and define new node.

7- Acknowledgement spoofing: spoof link layer acknowledgments for "overheard packets" addressed to neighboring nodes.

As in [26], a centralized approach which allows using a source routing methodology (see fig.3) was adopted. Before realizing the route discovery, a first phase consists in providing each link in the network a specific weight. This weight depends on the energy of the destination node, in order to relay the information by the nodes having the higher remaining energy, and the distance between nodes, in order to prefer short distance transmissions.

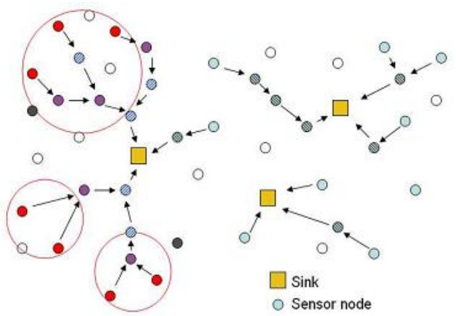

Fig. 3 Routing in a sensor network

Once this weight computed, we obtain a graph on which Dijkstra algorithm can be applied to find the shortest path between a sink and each node in the network. However, in our case the network contains more than one sink. So the aim now is to find the shortest path towards the nearest sink. We will proceed by exploring all the shortest paths towards all the sinks, and we will conserve for routing needs the one leading to the nearest sink. At this point, it is worth to notice that a more efficient searching method can be found, nevertheless our approach has the benefit to easily maintain, for each node, the n nearest sinks and their corresponding paths, which are necessary for the configuration evaluation. The algorithm complexity is acceptable since we achieve p Dijkstra in O(n).

One of the major and probably most important challenges in the design of WSNs is the fact that energy resources are significantly more limited than in wired networks [27,28]. Recharging or replacing the battery of the sensors in the network may be difficult or impossible, causing severe limitations in the communication and processing time between all sensors in the network. Note that failure of regular sensors may not harm the overall functioning of a WSN, since neighboring sensors can take over, provided that their density is high. Therefore, the key parameter to optimize for is network lifetime, or the time until the network gets partitioned [29].

Another issue in WSN design is the connectivity of the network according to the selected communication protocol [27]. The most common protocol follows the cluster-based architecture, where single-hop communication occurs between sensors of a cluster and a selected cluster head sensor that collects all information gathered by the other sensors in its cluster. Usually, connectivity issues include the number of sensors in each cluster, because a cluster head can handle up to a specific number of connected sensors, as well as coverage issues related to the ability of each sensor to reach some cluster head.

Finally, design issues that have been rather neglected in the research literature are those that depend on the particular application of WSNs. Energy and connectivity issues are certainly important in a WSN design, but one must not forget the purpose of the sensor network, which is the collection and possibly management of measured data for some particular application. This collection must meet specific requirements, depending on the type of data that are collected. These requirements are turned into specific design properties of the WSN, which in this work are called ''application specific parameters'' of the network.

Several analyses of energy efficiency of sensor networks have been realized [21–24] and several algorithms that lead to optimal connectivity topologies for power conservation have been proposed [30–34]. However, most of these approaches do not take into account the principles, characteristics and requirements of application-specific WSNs. When these factors are considered, then the problem of optimal design and management of WSNs becomes much more complex.

Fig. 4 shows the percentage of sensors (over the entire grid of 900 sensors) with battery capacities below certain percentage-levels after each measuring cycle, based on the assumption that all sensors had 100% battery capacity at the beginning of the first measuring cycle. It is clear that the percentage of sensors with battery capacity below 40% is kept very low during the 15 measuring cycles, even while at the end of the 15th measuring cycle there is no sensor with battery capacity below 20%. Corresponding results on the analysis of remaining sensors with battery capacities above certain percentage levels also showed high conservation of energy resources.

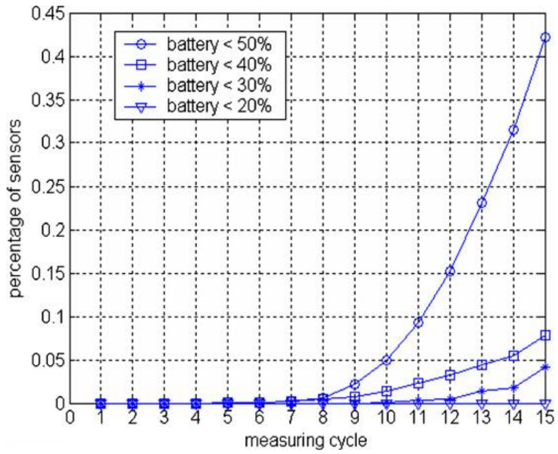

Fig. 4 Percentages of sensors with battery capacities below certain values (as percentages of full battery capacity) at the end of each measuring cycle of the adaptive WSN design.

5. Concluded Remarks

In the current time, there is a new era of ubiquitous computing . One type of such ubiquitous is wireless sensor technologies which is characterized with a great potential in opening a world of sensing applications. This paper provides the different approaches used in enhancing the performance of such WSN with great focus on three important factors: congestion control, optimal routing approaches and reducing the consumption power. However the consumption power was touched in deep since Wireless sensor networks are battery powered, therefore prolonging the network lifetime through a power aware node organization is highly desirable. An efficient method for energy saving is to schedule the sensor node activity such that every sensor alternates between sleep and active state. One solution is to organize the sensor nodes in disjoint covers, such that every cover completely monitors all the targets. These covers are activated in turn, in a round-robin fashion, such that at a specific time only one sensor set is responsible for sensing the targets, while all other sensors are in a low-energy, sleep state.

References

[1] Kiran Maraiya, Kamal Kant, Nitin Gupta, “Wireless Sensor Network: A Review on Data Aggregation “, International Journal of Scientific & Engineering Research Volume 2, Issue 4, April - 2011

[2] Ting Yan, “Analysis Approaches for Predicting Performance of Wireless Sensor Networks” , Ph.D. Dissertation, August 2006

[3] Cheng Tien Ee, and Ruzena Bajcsy, “Congestion Control and Fairness for Many-to-One Routing in Sensor Networks”, Proceeding of the ACM Conference SenSys ’04, Baltimore, Maryland, USA, November 2004.

[4] Chonggang Wang, Kazem Sohraby, Victor Lawrence, Bo Li, and Yueming Hu, “Priority-based Congestion Control in Wireless Sensor Networks”, Proceedings of the IEEE International Conference on Sensor Networks, Ubiquitous, and Trustworthy Computing (SUTC ’06), IEEE Computer Society, 2006.

[5] Jain Liu, and Suresh Singh, “ATCP : TCP for Mobile Ad-hoc Networks”, IEEE journal on selected areas in Communications, Vol. 19, No. 7, pp 1300-1315, July 2001.

[6] Lazarou G. Y., Li J., and Picone J., “A Cluster-based Power-Efficient MAC Scheme for Event-Driven Sensing Applications”, Proceedings of the ACM Conference on Ad hoc Networks, Vol. 5, No. 7, pp. 1017-1030, Sep. 2007.

[7] Liqiang Tao and Fengqi Yu, “ECODA: Enhanced Congestion Detection and Avoidance for Multiple Class of Traffic in Sensor Networks”, Proceedings of the 15th Asia-Pacific Conference on Communications (APCC 2009), pp. 726-730, 2009.

[8] Mohammad Hossein Yaghmaee and Donald Adjeroh, “A New Priority Based Congestion Control Protocol for Wireless Multimedia Sensor Networks”, Proceeding of the IEEE, 2008.

[9] Paolucci M., D. Kalp, A. Pannu, O. Shehorg, and K. Sycara, “A planning Component for RETSINA Agents”, Internet Draft.

[10] Rajendran V., Obraczka K., and Garcia-Luna-Aceves J. J., “Energy Efficient Collision-Free Medium Access Control for Wireless Sensor Networks”, Proceedings of the First ACM International Conference on Embedded Networked Sensor Systems (SenSys ’03), March 2003.

[11] V. Vijaya Raja, R. Rani Hemamalini, A. Jose Anand, “Multi Agent System Based Upstream Congestion Control in Wireless Sensor Networks”, European Journal of Scientific Research, Vol.59 No.2 (2011), pp.241-248

[12] Sichitiu M. L., “Cross-Layer Scheduling for Power Efficiency in Wireless Sensor Networks”, Proceedings of the IEEE INFOCOM ’04, March 2004.

[13] Young-mi Baek, Byung-hwa Lee, Jilong Li, Qin Shu, Ji-hum Han, and Ki-ju Han, “An adaptive rate control for congestion avoidance in wireless body area networks”, Proceeding of the IEEE, 2009.

[15] K. Akkaya and M. Younis, “A survey on routing protocols for wireless sensor networks,” in Elsevier Journal of Ad Hoc Networks (to appear).

[16] T. He et al., "SPEED: A stateless protocol for real-time communication in sensor networks," in the Proceedings of International Conference on Distributed Computing Systems, Providence, RI, May 2003.
[17] K. Akkaya and M. Younis, "Energy-aware Routing of Delay-constrained Data in Wirel ess Sensor Networks," Journal of Communication Systems, special issue on QoS support and service differentiation in wireless networks, (to appear).
[18] R. Rodrigues et al., "Optimal Base Station Placement and Fixed Channel Assignment Applied to Wireless Local Area Network Projects, " in the Proceedings of IEEE International Conference on Networks, Australia, 1999.
[19] T. Fruhwirth and P. Brisset, "Optimal Placement of Base Stations in Wireless Indoor Telecommunication," in Lecture Notes in Computer Science, Volume 1520, 1998.
[20] Kemal Akkaya, Mohamed Younis and Meenakshi Bangad, "Sink Repositioning For Enhanced Performance in Wireless Sensor Networks"
www. www.cs.umbc.edu
[21] Jamal N. Al-Karaki, Ahmed E. Kamal, "Routing Techniques In Wireless Sensor Networks: A Survey", IEEE Wireless Communications December 2004
[22] Chris Karlof and David Wagner, Secure Routing in Wireless Sensor Networks: Attacks and Countermeasures", Sensor Network Protocols and Applications, 2003. Proceedings of the First IEEE. 2003 IEEE International Workshop on 11 May 2003 Page(s):113 - 127
[23] Brad Karp and H. T. Kung. "GPSR: Greedy Perimeter Stateless Routing for Wireless Networks". In Proceedings of the 6th Annual International Conference on Mobile Computing and Networking (MOBICOM'00), ACM Press, N. Y., 2000.
[24] M. Younis, M. Youssef and K. Arisha, "Energy-aware Routing in Cluster-Based Sensor Networks", in the Proceedings of the 10th IEEE/ACM International Symposium on Modeling, Analysis and Simulation of Computer and Telecommunication Systems, (MASCOTS2002), Fort Worth, Texas, October 2002. no. 5.408.237, April 1995
[25] B. Krishnamachari, F. Ordo ´ nez, Analysis of energy-efficient, fair routing in wireless sensor networks through non-linear optimization, in: Proc. IEEE Vehicular Technology Conference – Fall, Orlando, FL, 2003, pp. 2844–2848.
[26] S. Ghiasi, A. Srivastava, X. Yang, M. Sarrafzadeh, Optimal energy aware clustering in sensor networks, Sensors 2 (2002) 258–269.
[27] I.F. Akyildiz, W. Su, Y. Sankarasubramaniam, E. Cayirci, Wireless sensor networks: a survey, Computer Networks 38 (2002) 393–422.
[28] S. Slijepcevic, M. Potkonjak, Power efficient organization of wireless sensor networks, in: Proc. IEEE Int. Conf. on Communications, Helsinki, Finland, 2001, pp. 472–476.
[29] Konstantinos P. Ferentinos *, Theodore A. Tsiligiridis, "Adaptive design optimization of wireless sensor networks using genetic algorithms", Computer Networks 51 (2007) 1031–1051
[30] V. Rodoplu, T.H. Meng, Minimum energy mobile wireless networks, IEEE J. Select. Areas Commun. 17 (8) (1999) 1333–1344.
[31] W.R. Heinzelman, A. Chandrakasan, H. Balakrishnan, Energy-efficient communication protocol for wireless microsensor networks, in: Proc. 33rd Hawaii Int. Conf. on System Sciences, Maui, Hawaii, 2000.
[32] J.-H. Chang, L. Tassiulas, Energy conserving routing in wireless ad-hoc networks, in: Proc. IEEE INFOCOM'00, Tel Aviv, Israel, 2000, pp. 22–31.
[33] D.J. Chmielewski, T. Palmer, V. Manousiouthakis, On the theory of optimal sensor placement, AlChE J. 48 (5) (2002) 1001–1012.
[34] C. Zhou, B. Krishnamachari, Localized topology generation mechanisms for wireless sensor networks, in: IEEE GLOBECOM' 03, San Francisco, CA, December 2003.

First Author Biography:

Hasan Mohammad Al-Shalabi: He received his Ph.D. in Computer engineering in 1995. In the same year he joined Al-Isra' Private University then Princess Sumaya University for Technology. Currently he is the Dean of student's affairs at Al-Hussein Bin Talal University. His research interest includes computer networks, object-oriented programming, data security and e-learning.

Second Author Biography: Ibrahim M. M. El Emary received the Dr. Eng. Degree in 1998 from the Electronic and Communication Department, Faculty of Engineering, Ain shams University, Egypt. From 1998 to 2002, he was Assistant Professor of Computer sciences in different faculties and academic institutions in Egypt. From 2002 to 2010, he worked as visiting Assis. Professor and Assoc. Professor of computer science and engineering in two universities in Jordan. Currently, he is a Professor of computer science and engineering at King Abdulaziz University, Jeddah, Kingdom of Saudi Arabia. His research interests cover: various analytic and discrete event simulation techniques, performance evaluation of communication networks, application of intelligent techniques in managing computer communication network, and performing comparative studies between various policies and strategies of routing, congestion control, subnetting of computer communication networks. He published more than 150 articles in various refereed international journals and conferences covering: Computer Networks, Artificial Intelligent, Expert Systems, Software Agents, Information Retrieval, E-learning, Case Based Reasoning, Image Processing and Pattern Recognition, Wireless sensor networks, cloud computing and Robotic engineering. Also, he participates in publishing seven book chapters in three international books (Published by Springer Verlag, IGI publisher & NOVA Science Publisher) as well as Editor of two books edited by international publishers (LAP Lampert- Germany). He has been included in Marquis Who's Who in the World 2013 edition.