International Journal of Computer Engineering & Technology (IJCET)
Volume 7, Issue 3, May-June 2016, pp. 07–16, Article ID: IJCET_07_03_002
Available online at
http://www.iaeme.com/IJCET/issues.asp?JType=IJCET&VType=7&IType=3
Journal Impact Factor (2016): 9.3590 (Calculated by GISI) www.jifactor.com
ISSN Print: 0976-6367 and ISSN Online: 0976–6375

A SURVEY OF ENERGY-EFFICIENT COMMUNICATION PROTOCOLS IN WSN$_S$

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ABSTRACT

Wireless sensor networks are harshly restricted by storage capacity, energy and computing power. Wireless Sensor Networks have acquired a lot of attention by research community, manufacturer as well as actual users for monitoring remote trades and how to gather data in different environment. The wireless sensor nodes are especially battery powered devices having life can be extended for some times while long lasting and reliable for maintaining consumption of energy and network lifetime while designs applications and protocols. So it is essential to design effective and energy efficient protocol in order to enhance the network lifetime. In this paper we present the study of different energy efficient communication protocols of Wireless Sensor Networks (WSNs).Then some of the communication protocols which are widely used in WSNs to improve network performance are also discussed advantages and disadvantages of each protocols.

Keywords: Wireless Sensor Networks, Energy Efficient, Communication Protocols

Cite this Article: Roshan Singh Sachan, Raghav Yadav and Ajeet Kumar Rai. A Survey of Energy-Efficient Communication Protocols in WSNs, *International Journal of Computer Engineering and Technology*, 7(3), 2016, pp. 07–16.
http://www.iaeme.com/IJCET/issues.asp?JType=IJCET&VType=7&IType=3

1. INTRODUCTION

Wireless sensor nodes are low power electronic devices, deployed in remote areas, where power resources are limited. The demand of wireless sensor networks (WSN) has extended many real world applications such as environment monitoring, military applications and monitoring etc. There are some issues in WSN like limited battery power, security etc. There are different layers in this network like as: network layer, data link layer, transport layer, physical layer etc. Many different protocols used for data transmission in the Wireless sensor networks. The energy-efficient communication protocols of Wireless Sensor Networks have attracted high attention in recent years. Many published research work has addressed all kind of issues to relate them. We can find different research work related to energy-efficient protocols. They tend to focus on layer wise communication protocols. In this section we will see some works and we will provide some of conclusions presented in these papers.

Sarika Yadav et al. [1] examined current state of approaches for energy conservation, with various issues on three activities: data collection, routing and clustering. They give a review of new applications and review the literature on various aspects of Wireless Sensor Networks [2]. Tifenn Rault et al. [3] classified the problems in three categories: internal platform, protocol stack and network services. The author presents a top down survey of energy efficiency and classification of energy conservation schemes. It reviewed advance in the development of energy efficient solutions in WSNs. Daquan Feng et al.[5] outlined the technical schemes of major projects for energy efficient sensor networks and discuss the research an energy conservation techniques in WSNs. Co-operative communication, energy efficient metric, network strategies, MIMO and OFDM technologies and optimizations for developing energy-efficient WSNs were introduced. S. Gowrishanker et al. [6] have presented the cause of energy loss in sensor nodes. It discussed the energy wastage given the e-circuit and compares several MAC protocols that have been designed to reduce the power consumption. Y. G. Lyer et al. [7] presented requirement for a transport protocol and proposed STCP. STCP is a scalable and reliable at transport layer. This protocol allows controlled variable congestion, avoidance and support many applications in the network. Design, implementation and evaluate the STCP with different network. Y. Zhou et al. [8] proposed Price-oriented Reliable Transport (PORT) protocol to facilitate the Base Station (sink). This is energy conservation protocol it uses two schemes: sink application-based optimization scheme and optimal routing scheme. According to simulation result PORT is effectiveness. In [9] S. J. Park et al. considered the problem of data transmission from sink-to-sensor. It proposed a scalable frame work for downstream data transmission. The author evaluates the proposed framework through NS2 simulator. C. Gungor et al. [10] presented Delay Sensitive Transport protocol for WSNs. DST is to timely, reliability event features from sensor field to sink with reduce energy consumption. Simulation shows the DST protocol occurs high performance in terms of real-time communication.

2. ISSUES IN WSN

The major issues that affect the design and performance of a wireless sensor network, some issues discussed [5] are:

2.1 Hardware and Operating System for WSN Wireless sensor networks are composed of hundreds of thousands of tiny devices called nodes. A sensor node is often abbreviated as a node. A Sensor is a device which senses the information and passes the same on to a mote. Sensors are used to measure the changes to physical environment like pressure, humidity, sound, vibration and changes to the health of person like blood pressure, stress and heartbeat. A Mote consists of processor, memory, battery, A/D converter for connecting to a sensor and a radio transmitter for forming an ad hoc network. A Mote and Sensor together form a Sensor Node. There can be different Sensors for different purposes mounted on a Mote. Motes are also sometimes referred to as Smart Dust. A Sensor Node forms a basic unit of the sensor network. The nodes used in sensor networks are small and have significant energy constraints. The hardware design issues of sensor nodes are quite different from other applications.

2.2. Wireless Radio Communication Characteristics - Performance of wireless sensor networks depends on the quality of wireless communication. But wireless communication in sensor networks is known for its unpredictable nature.

2.3 Deployment - Deployment means setting up an operational sensor network in a real world environment. Deployment of sensor network is a labor intensive and cumbersome activity as we do not have influence over the quality of wireless communication and also the real world puts strains on sensor nodes by interfering during communications. Sensor nodes can be deployed either by placing one after another in a sensor field or by dropping it from a plane.

2.4 Localization - Sensor localization is a fundamental and crucial issue for network management and operation. In many of the real world scenarios, the sensors are deployed without knowing their positions in advance and also there is no supporting infrastructure available to locate and manage them once they are deployed.

2.5 Synchronization - Clock synchronization is an important service in sensor networks. Time Synchronization in a sensor network aims to provide a common timescale for local clocks of nodes in the network. A global clock in a sensor system will help process and analyze the data correctly and predict future system behavior. Some applications that require global clock synchronization are environment monitoring, navigation guidance, vehicle tracking etc. A clock synchronization service for a sensor network has to meet challenges that are substantially different from those in infrastructure based networks.

2.6 Data Base Centric and Querying - Wireless sensor networks have the potential to span and monitor a large geographical area producing massive amount of data. So sensor networks should be able to accept the queries for data and respond with the results.

2.7 Architecture - According to the authors of lack of overall sensor network architecture is the main factor for currently limiting the progress in sensor networks. Architecture can be considered as a set of rules and regulation for implementing some functionality along with a set of interfaces, functional components, protocols and physical hardware. Software architecture is needed to bridge the gap between raw hardware capabilities and a complete system.

2.8 Quality of Service - Quality of service is the level of service provided by the sensor networks to its users. The authors of define Quality of Service (QoS) for sensor networks as the optimum number of sensors sending information towards information-collecting sinks or a base station. Since sensor networks are getting implemented in more and more number of applications which includes mission critical applications such as military applications and nuclear plant monitoring applications; QoS is being given considerable review as the events occurring in these situations are of utmost importance.

2.9 Security - Security in sensor networks is as much an important factor as performance and low energy consumption in many applications. Security in a sensor network is very challenging as WSN is not only being deployed in battlefield applications but also for surveillance, building monitoring, burglar alarms and in critical systems such as airports and hospitals. Since sensor networks are still a developing technology, researchers and developers agree that their efforts should be concentrated in developing and integrating security from the initial phases of sensor applications development; by doing so, they hope to provide a stronger and complete protection against illegal activities and maintain stability of the systems at the same time.

3. APPLICATIONS OF WSNS

Sensor networks applications can be classified into two categories: tracking and monitoring. Tracking applications have tracking objects, animal, human, bird and vehicles and the other is monitoring include indoor monitoring, outdoor monitoring, environmental monitoring, power monitoring, health monitoring etc.

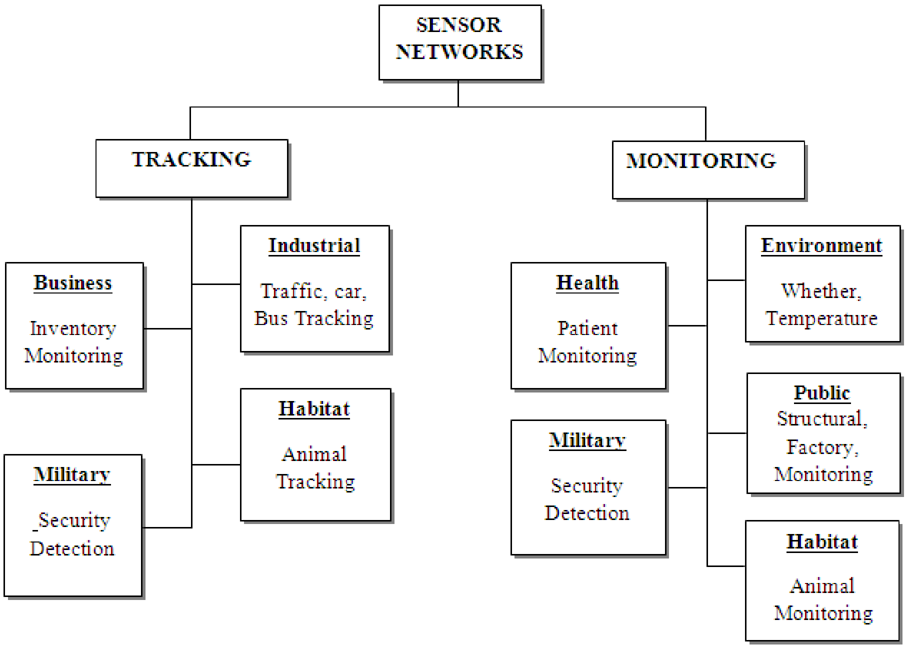

Figure 1 Applications of sensor networks

3.1 Environmental monitoring - Habitat monitoring is an important tool for assessing the threat and conservation status of species and protected areas. This can be used to get the information about the breeding pattern of birds where human cannot go because it can disturb them. This can be done at global and regional scales, where data are available.

3.2 Military surveillance - In the battle field some sensor nodes are doing surveillance, monitoring and guiding systems of intelligent missiles. The detection of weapons of mass destruction is also performed.

3.3 Area monitoring - It is a common application of WSNs in which WSN is deployed over a region where some physical phenomenon has to be monitored i.e. large number of sensors are deployed over a battlefield to detect enemy instead of using landmines. When the sensors detect the event being monitored (heat, pressure, sound, light etc), these events needs to be reported to the base.

3.4 Agriculture - By the help of WSN irrigation automation system is developed which enables efficient water use and reduces waste. Gravity fed water systems can be monitored by pressure transmitters to monitor water tank levels and pumps are controlled by wireless devices and water use can be measured and wirelessly transmitted back to a central control center for billing.

3.5 Greenhouse Monitoring - WSNs are used to control the temperature and humidity levels inside commercial greenhouses. The threshold value is set if temperature and humidity drops below specific levels then the greenhouse manager must be notified via e-mail, text message on a cell phone. Host systems can trigger misting systems, open vents, turn on fans etc.

3.6 Health monitoring – Health monitoring is the main application of the wireless sensor networks. The help of this monitoring Wireless Sensor Network can improve the health care and patient monitoring. There are five prototype designs have been developed for applications such as infant monitoring, alerting the deaf, blood pressure monitoring and tracking, and fire-fighter vital sign monitoring.

4. ENERGY-EFFICIENT COMMUNICATION PROTOCOLS

Energy-efficient communication protocols are an important and supporting for WSNs [2]. This protocol stacks must energy efficient in terms of data transmission, communication and be able to work efficiently across multiple nodes. We review the different communication protocols proposed for transport layer, network layer and link layer.

4.1 Sensor Transmission Control Protocol (STCP) - STCP [7] is a unicast protocol and this protocol support data exchange between two end points. STCP is a transport layer protocol that provides reliability and congestion detection and support of application in the same network. STCP functionalities are executed at the Base Station (BS) and BS having high processing capability and power communicate with the nodes in the network. Before the sending data a source node must transmit a single session initiation data packet to the base station. This packet contains information about the no. of flows from the node. Before transmitting data packet the node must wait for an acceptance from the BS. The base station estimates the time of arrival of each data packet from each source for continuous data flow. In a given period of time, the BS is not receiving a data packet, the BS determine the present required reliability is met.

Congestion control is being present in STCP. Direction of reliability is sending to sink. There are two approaches for data packet recovery: hop-by-hop and end-to-end. STCP used end-to-end approach for data transmission. STCP have packet recovery. In STCP energy conservation is better because time reliability is high.

4.2 Price-oriented Reliable Transport Protocol (PORT) – PORT [8] Protocol provides event reliability with minimum energy consumption. PORT follows end-to-end communication mechanism in the network. Direction of data delivery is source to the sink. This protocol provides two types of mechanism that insure this reliability. The first mechanism provides the base station (sink) to adjust the reporting rate of each information source. The base station adjusts the reporting rate of every source. The second mechanism to allow to the BS with end-to-end communication cost information from the source to the BS. This communication cost is reduced congestion, when congestion occurs in the network. Communication cost increases with respect to data packet loss. For the reliability must be maintained, the base station uses the communication cost information to slow-up reporting rate of the suitable source and increase the reporting rate of other sources that have lower communication cost. PORT is not providing the data packet recovery and this protocol is a energy conservative protocol.

4.3 GARUDA – GARUDA [9] is a downstream reliability communication protocol which uses hop-by-hop recovery mechanism in sensor networks. GARUDA's using the first data packet delivery method. In this protocol the first data packet delivery using Wait-for-First-Packet (WFP) pulse. This pulse is short duration pulse send periodically by the base station (sink). It's protocol design a loss recovery core infrastructure and two stages negativeACK based recovery process. This infrastructure use is constructed using the first data packet delivery method. In this process the receiver notifies the sender that some packets are missing or send the negative ACK (NACK) about the lost packet in the sensor networks. It uses NACK based arrangement and contains no congestion control mechanism (CCM). Solution of the problem is NACK based schemes for receiving at least one packet of the block by detecting loss of other packets. In the event of packet losses, this protocol uses an out-of-order forwarding strategy to overcome problem of under utilization. This strategy allows subsequent data packet to be forwarded even when a data packet is lost. For recovery of the data packet losses it usages two stages: the first one is core recovering phase and second non-core recovering phase. In this protocol, the direction of the data transmission is sink to sensor, while other transport protocol have data transmission is sensor to sink.

4.4 Delay Sensitive Transport (DST) – Delay Sensitive Transport [10] is an upgrade version of event-to-sink reliable transport protocol. DST has two different components: a reliable event transport mechanism and real time event transport mechanism. The first one mechanism observed delay constrained event reliability while the second mechanism uses event to sink delay. The event to sink delay is a measure of the event transport and event process delay.

This protocol measures buffer overflow at each sensor node and calculate the average sensor node delay. According to the simulation results occur that DST protocol acquires reliability and timely event detection with reduce energy consumption and latency.

4.5 Pump slowly, fetch quickly (PSFQ) – PSFQ [11] is a downstream scalable, robust and reliable protocol. The purpose of this protocol is to guarantee data packet transmission and reduce the number of transmission for lost detection and data packet recovery operation. This protocol requires 100% reliability in downstream direction. For the data delivery to the sink it uses hop-by-hop transmission. To reduce the cost of loss recovery it uses NACK based loss detection, notification and transmission in this protocol. PSFQ consists of three basic primitives: pump operation (data transmission), seek or fetch operation (local loss recovery) and operation report (feedback mechanism). Node injects data packets into the network for the help of pump operation. This operation based on simple scheduling scheme. The seek operation requests a retransmission of the lost data packet from near nodes in the network. Finally, the operation report provides a feedback status to the users. According to this report data packets sends from the farthest target node in the network.

4.6 Event-to-sink reliable transport (ESRT) – ESRT [12] is a novel recent transport solution that search to achieve reliable event detection with energy conservation and solving congestion problems. Its algorithm is run mainly at the sink. Sink calculate the accuracy factor and reporting frequency at each interval. This factor is a measure of the data received from the source node to the sink.

ESRT reduced the frequency of the source node then reliability is lower than desired reliability and increased the frequency of the source node then reliability to achieve the desire reliability. This protocol mechanism is based on monitoring the routing buffer of each node. According to simulation results, this protocol is able to attain the reliability level with reduce energy expenditure under different networks states with topology.

4.7 Congestion detection and avoidance (CODA) – CODA [13] is an energy efficient congestion control technique. That consists of three components for congestion detection: open-loop (congestion detection), hop-by-hop back pressure and closed-loop multi source regulation. CODA attempts to detect congestion by regular monitoring of the transmission channel. According to the results occur that protocol can improvement performance and reduce energy usage.

TABLE 1 Comparison of communication protocols in WSNs

Protocols	Congestion			Reliability		Approach for packet recovery	Data Packet Recovery	Category of ACK	Mechanism	Energy effectiveness
	Control	Detection	Reduction	Direction	Level					
STCP	Yes	Buffer size	Traffic redirection	-	Packet	End-to-end	Yes	ACK/ NACK	-	Fair
GARUDA	No	-	-	Down stream	Packet	Hop-by-hop	Yes	NACK	Hop-by-hop	Fair
CODA	Yes	Buffer size and Channel condition	Drop packets	-	-	-	-	ACK	-	Fair
ESRT	Yes	Buffer size	End-to-end rate adjustment	Up stream	Event	End-to-end	No	-	End-to-end	Fair
PSFQ	No	-	-	Down stream	Packet	Hop-by-hop	Yes	NACK	Hop-by-hop	-
PORT	Yes	Node price and link-loss rates	Traffic redirection	Up stream	Event	Hop-by-hop	No	-	Hop-by-hop	Fair
DST	Yes	Buffer size	End-to-end rate adjustment	Upstream	Event	End-to-end	No	-	End-to-end	Fair

4.8 Geographical routing – Geo-routing mainly proposed for Wireless Sensor Networks [14]. It uses greedy forwarding process. In this process data packet forwarded between source to destination. This mechanism forwards message by neighbors which are the closest to the destination. Different novel strategies are improved the performance of geo-routing. Data packet sending randomly to each node in a region is called geo-casting. These strategies can be divided into two parts: distance-based forwarding and reception based forwarding. In distance-based forwarding, which always try to send the data packets a shortest path with any constructing communication path previously. Reception based forwarding strategy, where the state of channel is also incorporate into route decision.

In comparison of both forwarding strategy, reception based forwarding is better than distance based forwarding strategy in terms of efficiency, delivery rate etc. Finally new geo-forwarding strategies are satisfying energy and minimization of route disconnection.

4.9 Anchor location service (ALS) – ALS [15] protocol is a grid based protocol that provide sink location service and support location based routing between source to destination. It avoids frequent and costly flooding procedures. ALS are evaluated with well knows protocols using analytical means and simulation. This protocol allows a scalable sink location service and minimizes the communication along the path. Residual Energy-Aware Dynamic (READ) algorithm increase energy efficiency, data packet delivery rate, maintaining the network and network lifetime.

4.10 Secure routing (Sec-ROUT) – In the presence of malicious nodes, this protocol is resilient SecROUT [16] protocol may launch selective packet dropping attack on the routing path. This process employs single-path routing and it is energy-efficient.

4.11 Secure cell relay (SCR) – SCR [17] is provide the resistant to several kind of attacks on WSNs, including DoS attacks and security attacks like as spoofing, warm hole, sink hole, clone attack, hello flooding, misdirection attack, Sybil, selective forwarding attacks etc. SCR is a cluster-based algorithm, where sensor nodes from a cluster based in the network. This protocol is not used to cluster head election. The network is divided into equal-size square cells in this protocol. Whole network each sensor node aware of its own location

Each sensor and sink shares a common key before deployment. The key used for initial neighbor search and deployment. All sensor nodes and BS are synchronized. For data security it uses symmetric encryption. The help of key the BS encrypts its location information after deployment. In the neighbor node search phase, neighbor sensor node via a three protocol, which establishes the shared secret keys between neighbor sensor nodes. SCR is an energy efficient protocol. This protocol utilizes that in most networks are static and location aware. Its achieve security, high throughput and energy efficient.

4.12 Traffic-Adaptive Medium Access Protocol (TRAMA) – TRAMA increase the channel utilization in an efficient manner and this protocol attains energy efficiency by avoid collision and traffic congestion where there are no data transmission [18]. For data and signal transmission TRAMA assumes single, time slotted channel. TRAMA supports three types traffic: unicast traffic, multicast-cast traffic and broad cast traffic. This protocol has three components:

- Neighbor Protocol (NP)
- Schedule Exchange Protocol (SEP)
- Adaptive Election Algorithm (AEA)

4.13 Berkeley media access control (B-MAC) – B-MAC [19] is a reconfigurable CSMA protocol that attains collision avoidance, low power processing and high channel utilization. B-MAC protocol reforms system performance by employing an adaptive preamble sampling process. A set of adaptive bi-direction integrated to reconfigure the protocol depend on the network load.

This protocol holds the following functionality: clear channel assessment and packet back off, link layer acknowledgement and LPL. It promotes CCA to complete if the channel is clear for collision avoidance. CCA is an outlier occurs that the channel energy is extremely below the noise. An outlier is found, the channel is clear and the channel is busy during the channel sampling time. Packet back-off is used in case of busy channel. Back-off time is initially defined and randomly chosen.

4.14 Z-MAC – This protocol is a hybrid MAC protocol while offsetting their weakness that combines the strength of TDMA and CSMA. Z-MAC [20] gains high channel utilization and low latency under high contention. Z-MAC protocol reduces collisions between two hop neighbors at minimum cost. This protocol is patent to dynamic topology changes and time synchronization failures which ensures in the networks. Z-MAC protocol uses an efficient and scalable channel scheduling algorithm for channel reuse and slat assignment.

4.15 CC-MAC – This protocol [21] exploits the spatial correlation of the data at the MAC layer to regulate and redundant data transmissions. This protocol has two components: event based MAC (E-MAC) and network based MAC (N-MAC). Event MAC filters the correlated data packet while network MAC routing packets. This protocol is implemented to each node and shows significant savings in energy and packet drop rate etc.

4.16 Low Power reservation-based MAC Protocol – The low power reservation [22] based MAC protocol addresses the issue of energy conservation, this protocol uses a clustered hierarchical network and a TDMA like frame structure has contention based slot reservation schedule establishment and slotted data transmission. In this protocol the cluster head increases the frame size that the number of failure exceeds a predetermined value. The probability of packet transmission is increased by adapting the frame structure. By adapting frame size, this protocol shows significant energy conservation due to fewer collisions.

4.17 Low Power distributed MAC protocol – Low power distributed MAC protocol [23] is combines two types techniques: Multi-channel spread spectrum and CSMA/CA techniques. This protocol is divided the band into multiple channels, for a given frequency band. This protocol used two type radios: a low power wake-up radio and normal data radio. Low power radio monitors the network and normal radio monitors when there is data transmit or receive.

5. CONCLUSION

We have presented the main energy efficient communication protocols for wireless sensor networks in this work. The main characteristics required for this protocols and factors to be considered. We discussed key issues, applications and energy efficient communication protocols in wireless sensor networks. We show and compare several communication protocols. We have reviewed in this article issues on different categories: internal platform, protocol stack and network deployment issues. We have compared and summarized different communication protocols.

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