Journal on Recent Technologies in Mechanical and Electrical Engineering
Volume: 5 Issue: 12
ISSN: 2349-7947
01 - 04

IOT Enabled Energy Efficient Wireless Sensor Network & Services – A Pathway towards Green Engineering - Part 4 (Energy Efficient WSN with Suitable Protocol)

Prof K K Vyas, Director SIET Sikar
Amita Pareek, Scholar, MTech, SIET Sikar

*****

Network connected devices, including the Internet of Things, are growing rapidly and offer enormous opportunities for improved energy management. At the same time, there is a responsibility to ensure that these devices use a minimal amount of energy to stay connected. 4E's Electronic Devices and Networks Annex (EDNA) works to align government policies in this area and keep participating countries (Current members of 4E[2] are: Australia, Austria, Canada, Denmark, France, Japan, Korea, Netherlands, Switzerland, Sweden, UK and USA) informed as markets for network connected devices develop. In this part Energy relevance, Energy efficiency like important issues explored. This part further reveled the standby power of novel mains connected IoT devices and their estimated impact on the worldwide standby energy consumption.

Wireless Sensor Network (WSN) requirements –

There are a few requirements that apply to most sensor network applications [8]

Lifetime: it is desirable to prolong the lifetime of the network because sensors are not accessible after deployment.

Network size: in most applications a larger network is of interest as it covers more area and therefore monitors more events.

Minimise faults: a faulty network uses resources to generate incomplete data. At the sensor level, it means the monitoring of the environment is broken and many events may be missed. In transmission to the sink, it means packet loss is high; in both cases, the knowledge of the environment is incomplete and therefore the gathered data is not reliable. In other words, a reliable collective event-to-sink is vital in WSNs (8).These requirements dictate the following criteria in communication protocols,

Lower energy consumption: as a direct consequence of the requirement for longer sensor lifetimes, the communication between these sensors (and sink) must slowly consume the available energy, as the majority of a sensor‟s energy is consumed in communication.

Compatible with multi-hop communication: typically, sensors avoid direct communication with the sink (as energy usage is proportional to the square of distance); instead, it is preferred that sensors use other sensors as hops to communicate.

Scalability: the communication protocol must be reliable in terms of establishing and keeping connectivity among sensors. This protocol must perform as normal when the size of the network becomes larger.

Reliability: reliable data transmission in term of packet loss is one of the main concerns to provide a high degree of efficiency in monitoring and control systems. Therefore, employing energy-efficient communication techniques, taking into account multi-hop ability, scalability and reliability, is highly desired. As a direct result, the lifetime of the network will be improved.

Most current energy minimisation approaches consider WSNs in terms of network layers: (1) the operating system, (2) the physical layer, (3) the MAC layer, (4) the network layer, (5) the application layer, and (6) the power harvesting layer. In this section we review related efforts in the minimisation of energy consumption at each layer.

At the network layer, several approaches may be adopted to increase the network lifetime. Topology control and related routing mechanism scan be optimised for the purpose. Determining the best topology among nodes in order to provide a connected network to route packets to the destination is a significant operation in WSNs. The challenges in selecting a suitable topology include duty cycle control of redundant nodes, connectivity maintenance, self-configuration and redundancy identification in a localised and distributed fashion (Xuet al., 2003).Two significant methods for tackling these challenges are the Geographic Fidelity (GAF) and Cluster-based Energy Conservation (CEC) protocols. GAF uses the node‟s location information (as determined by a GPS) to configure redundant nodes and cluster them into small groups using localised and distributed algorithms. CEC has the same fundamental operation but it does not depend on location information. In (Xuet al., 2003), the two methods were compared by simulation. They found that CEC consumes much less energy than GAF (about half) if the nodes are stationary. However, GAF is more efficient than CEC in high mobility environments. In (8), the reference authors suggested a new approach for reducing protocol overhead created by the CEC protocol and the energy consumption of GPS connected to sensors. In this approach, a base station informs the sensors about their cluster ID and cluster area by sending a sweeping beacon. If a node hears the beacon it can locate its cluster without the need for a GPS receiver. Various kinds of topology such as tree, mesh, clustered, ad-hoc and others can be employed. Referenced Authors in (8), examine the influence of different types of mesh topologies on the power dissipated. Routing is a significant and costly task in WSNs as it plays a major role in determining the network lifetime. Al-Karaki and Kamal (Al-Karakiand Kamal, 2004) discussed types of networks, topologies and protocols and their influences on the energy cost. SPIN (Sensor Protocols for Information via Negotiation) (Heinzelmanet al., 1999a)is a routing technique based on node advertisements where nodes only need to know their one-hop neighbours; however,it is not suitable for applications thatneed reliable data delivery. LEACH (Low-Energy Adaptive Clustering Hierarchy) (Heinzelmanet al., 2000)is a clustered routing algorithm. In this method, the clusterheads are responsible forrelayingdataand controlling the cluster. Although LEACH is an effective technique for achieving prolonged network lifetime, scalability, and information security, LEACH does not guarantee an optimal route. Directed Diffusion technique is a data centric, localised repair, multi-path delivery for multiple sources, sinks and queries (Intanagonwiwatet al., 2000). Also, this method is able to find the optimal route. While efforts to reduce energy consumption have covered different aspects of WSNs, many important issues remain untouched:

●There is no a general approach for determining and optimising the energy consuming constituents of WSNs.

●Current approaches focus on one aspect and may load energy consumption in other aspects.

●Existing approaches miss quantitative measures of energy consumption of the entire network.

●Most of the current approaches are applicable for specific sensor networks with special properties.

One research work [8] introduces a new energy-driven architecture by splitting the whole WSN system into a few main constituents. Then, energy-related parameters in each constituent are extracted. After reducing the number of parameters using the concept of machine learning, a new routing algorithm is designed. The result is an application-independent and constituent-based network model, such that existing approaches can be adapted to energy constituents of this architecture.

This exploratory paper part focuses on minimising and optimising energy consumption based on the energy consuming constituents as a general model for WSN deployment and development. The model deals with all common aspects of energy consumption in all types of WSNs. It is fact that designing wireless sensor networks with their energy constituents in mind will enable designers to balance the energy dissipation and optimise the energy consumption among all network constituents and sustain the network lifetime for the intended application.

Fig: Energy consuming Constitutents[8]

This research work [8] further reveled that comprehensively model components having five energy constituents of the architecture. The achievement of aim is possible by accurate account of all functional aspects of a constituent and their salient energy-related parameters. These parameters will allow us to evaluate the performance of WSNs, optimise their operation, and design more energy-efficient applications.

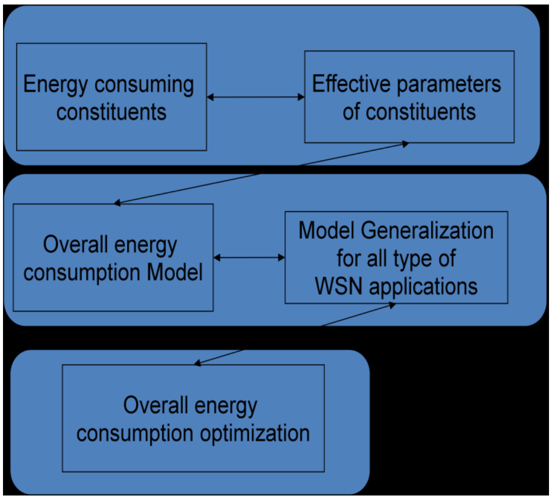

Fig : Typical approach by a research work [8]

The steps that will be followed in above referenced [8] thesis -

- Determine the effect of energy consuming constituents and their prevalent parameters on overall energy consumption in WSNs.
- Obtain a quantitative measurement and modelling of the overall energy consumption based on prevalent parameters.
- Propose a model which is applicable for all types of sensor network applications.
- Optimise overall energy consumption by optimising the model.
- The model should cover the challenging problems: scalability, reliability, and collaboration

ISSN: 2349-7947
01 - 04

- The overall model will offer the best approach to minimise the energy consumption by involving the prevalent parameters

CodeBlue , one of the well known WSN health care projects, uses a large number of mica2 motes sensors ; after collecting data from the patient's body, these medical sensors transmit data to PDAs, mobiles, laptops and personal computers for further investigation. The general architecture of the CodeBlue is shown in Figure below –

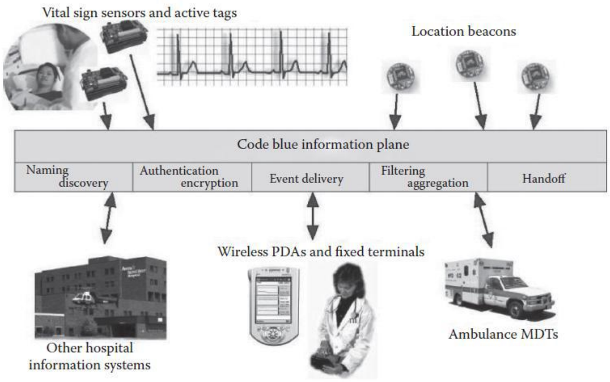

Fig : CodeBlue Architecture [8]

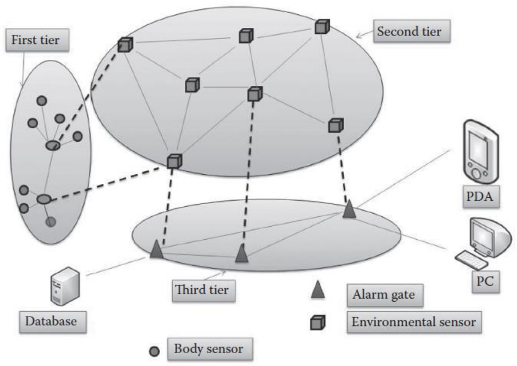

Fig : ALARMNET Architecture [8]

Communication technologies

In the domain of WSNs, there are two main communication protocols: 6LowPAN and ZigBee. 6LowPAN, released in 2007 by IEFT, is an open standard communication protocol on how to use IPv6 on top of low power, low data rate, low cost personal area networks; it works on top of physical and MAC layers, defining how IPv6 datagrams are transmitted using 802.15.4 frames by implementing compression/decompression of IPv6 headers. It also deals with the time varying link relationship among the nodes comprising the WSN. In addition, it supports implementation of routing protocols at either the link layer (mesh under routing) or network layer (route over routing) (J.N.M.Valdez, 2011). ZigBee (April 28, 2013), arguably as popular for a low-cost, low-power advanced communication protocol for small devices, builds on top of the physical layer and MAC defined in IEEE standard 802.15.4 for low-rate wireless personal area networks (LR-WPANs). It is widely used in Body Sensor Networks (BSNs). BSNs comprise a sensor or group of sensors attached to a patient and a coordinator for collecting raw data from the sensors. This data will be sent, analysed, and processed by control devices through the network. The ZigBee coordinator as a controlling device works with interrupt to reduce power consumption in the network – one of the key factors of healthcare monitoring – and gathers raw data. In addition, ZigBee is applied in a mesh network of routers to relay data from different patients to the Access Point (AP). The AP is connected to the internet to allow collaboration of the doctors, medical centre, and other data centres that gather patient records, so that decisions can be made. It is worth noting that the main difference between ZigBee and 6LowPAN is the IP interoperability of the latter. A ZigBee device requires an open 802.15.4/IP gateway to interact with an IP network while a 6LowPAN device communicates with other IP-enabled devices; which one is chosen highly depends on the application. Most sensor applications need to connect to internet, so ZigBee has to provide this feature. Authors in (Sveda and Trchalik, 2007) focused on designing software architecture between ZigBee and Internet by IEEE 1451. IEEE 1451 is a standard-base networking framework that includes a transducer information model called the Network Capable Application Processor (NCAP). NCAP is an object-oriented model that uses block classes, physical blocks, transducer blocks, function blocks, and network blocks. ZigBee Gateway and ZigBee Bridge are proposed to provide connectivity between ZigBee and the internet. Zigbee Gateway translates both addresses and commands between ZigBee and IP. ZigBee Bridge works over Ethernet or WiFi devices and is used to communicate with IP devices.

WSN sensors, usually deployed in non-accessible environment, are powered using small batteries along with techniques for power harvesting; replacing batteries is not an option. Relying on a battery not only limits the sensor's lifetime but also makes efficient design and management. Energy Driven Architecture (EDA) is proposed as a robust architecture taking into account all principal energy constituents of wireless sensor network applications [8]. By building a single overall model, a feasible formulation is then proposed to express the overall energy consumption of a generic wireless sensor network application in terms of its energy constituents.

Energy Consumption Formulation [8]

We suppose a continuous time between t1 and t2 for the energy consumption measurement. Residual energy in time t is defined by omitting consumed energy in Δt from the initial battery power in t-Δt. Thus, the energy consumption will be determined in Δt as -

ISSN: 2349-7947
01 - 04

$$\begin{cases} E_{residual,i}(t_2) = E_{residual,i}(t_1) - E_{consumed,i}(\Delta t) \\ E_{consumed,i}(\Delta t) = \frac{\partial E_{residual,i}(t)}{\partial t}\Delta t \\ \Delta t = t_2 - t_1 \end{cases}$$

One typical algorithm, called Parametric Dijkstra-based Topology Management Algorithm (PDTM), is compared with a distance-based method based on Dijkstra. The the experiments showed PDTM outperforms the other method in terms of increasing lifetime and performance. This algorithm dynamically manage the network topology and associated routing paths from each sensor to its sink, taking into account identified parameters to minimise the energy consumption of the global constituent and hence the overall energy consumption of the whole network. The key idea of PDTM is to find the best paths among nodes, subject to distributing energy consumption across all nodes in the network, and consequently minimise energy consumption of the entire network.

References :

[1]. Energy efficient network architecture for IoT applications, Sarwesh P ; N.Shekar V. Shet ; Chandrasekaran K
[2]. Energy efficiency of IOT, Technology & Energy Efficiency report, April 2016.
[3]. https://www.elprocus.com/architecture-of-wireless-sensor-network-and-applications/
[4]. https://www.scnsoft.com/blog/iot-architecture-in-a-nutshell-and-how-it-works
[5]. Energy Efficiency of IOT, EDNA,
[6]. Design & Analysis of Energy Efficient Routing protocol – R D Deokar
[7]. Energy Efficiency in WSN N K Pour, Dec 2015,
[8]. https://arxiv.org/ftp/arxiv/papers/1605/1605.02393.pdf
[9]. https://www.analyticsvidhya.com/blog/2016/08/10-youtube-videos-explaining-the-real-world-applications-of-internet-of-things-iot/