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Efficiency Methods for Energy in Wireless Sensor Networks: A Survey

[1]Gaudence Stanslaus Tesha; [2]Mohammad Amanul Islam

[1]School of Telecommunication Engineering, Xidian University, Xi'an,
Xi'an, 71007, China

[2]School of Computer Science and Technology, Xidian University, Xi'an,
Xi'an, 71007, China

Abstract-A wireless sensor network is a network which consisting of a large number of small sensors called node which has a low-power transceiver that used as a tool for gathering data in a variety of environments based on the network setup. The sensing data collected by each sensor within a network is communicating to a single processing center that uses all reported data to determine characteristics of the environment or detect an incident. The communication or message passing process designed to conserve the limited energy resources of the sensors for the data processing. This article discusses the various methods and operational challenges for batteries used on sensor nodes deployed in various environment with different sensor networks. The article proposed the implementation of the photolytic solar system for wireless sensor network. The proposed system is for in a case study Tanzania that is located Eastern of Africa due to low national grid power but with high energy available from the sunlight throughout a year.

Keywords: *Energy Efficient, Sensor Network, Energy Harvesting, Sensor Node, Network Lifetime;*

1. Introduction

The wireless sensor network (WSN) are spatially distributed network sovereign sensor to monitor physical or environmental condition. Typically, a WSN is a network of nodes that work in a cooperative way to sense and control the environment surrounding them [1]. The network built of sensor nodes and each node connected to one another. The sensor nodes contain communication components that include radio receiver, a micro-controller and an energy source, which together enable the processing of the data information. The sensor nodes communicate over the short distance via a wireless communication medium as presented by [2], [3].

Nowadays, WSN is broadly applying in most application after the expansion of the Internet of Things (IoT) over the Information communication technology (ICT). The efficiency energy is a major issue in WSN due to the nature of the sensor node based on the operation for collecting and sending data according to the network setup. The manuscript focuses the energy lifetime of the batteries that used to power the sensor nodes.

The batteries are the main source of power for sensor node that connect the network and ensure communication of the network is active. Both rechargeable and non-rechargeable batteries characterized to lifespan, which requires the changing or recharging to ensure the energy available.

Some of the WSNs topology network, their batteries are easily changed, charging or recharging while others topology setup is difficult due to nature of network environmental. The difficult setup for energy are those Network topologies like underwater network or those deployed in embedded situation such as mining, undersoil, forest or other dangerous places for human.

Furthermore, the sensor network has many challenges in deployment compared to tradition network like local area network (LAN) or wireless local area network (WLAN). The traditional network has some physical nodes, transmission media, switches, routers and other network devices, which make easily for setup compared with WSNs, which looks like Ad-hoc network. The WSNs architecture for data processing and network environmental of the WSN including the provenance as indicated on figure (1).

Not only that, but apart from the batteries there are some other parameters, which affect the WSN performance like nature of transmission media, network topology setup and bandwidth issue as depicted by [4], [5].

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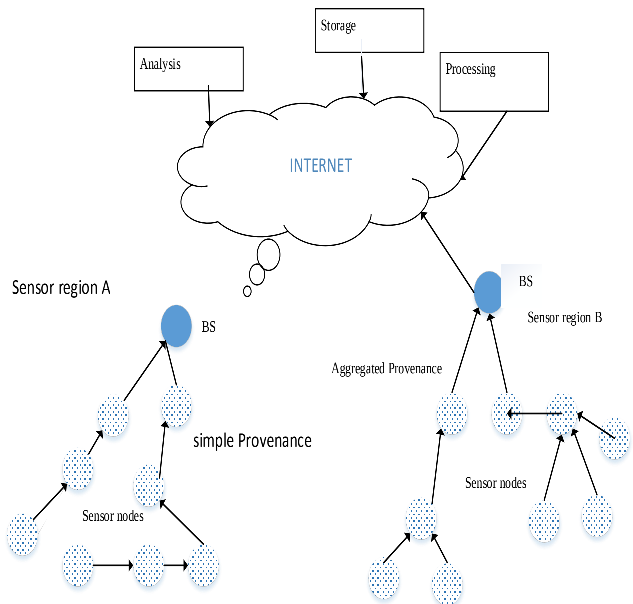

Fig. 1: WSN both simple and aggregates provenance architecture

Based on this survey the sensor nodes are major network constrained based on the energy that is required by the network. The energy ensures network-processing, memory functional and supply [4], [6]. Some of nature for WSNs ensure by itself energy suitability like when the sink node is static mode that a few paths can be more added than others did this depending on the network topology and packet generation rates at sources. Researchers [7] and [8] point out that sink node utilizing more energy than other node within the network due to the data traffic.

The main energy efficiency methods for WSNs are on various algorithms methods such as:

- clustering algorithm
- energy harvesting
- data processing
- powering device
- transmission adaption
- energy reducing
- routing renewable energy

The contributions of the manuscript involve the following;

- Introduce energy lifetime conservation
- Introduce energy challenges to WSN
- Techniques of energy implementation
- Introduce the photolytic solar panel alterative based on environment for WSN

2. Related Works and Motivation

Energy conservation is obviously a main issue when designing WSN. Therefore, sensor nodes designed to operate using battery powered and others to a source like from the national grid power system. Researchers in the field [9], [10], heavily investigate the point of shutting down power consumption, whether acting at battery, hardware or protocol stack levels. There have been several network routing protocols proposed for wireless networks that examined in the context of WSNs based on the energy efficiency to ensure the network is active all the time. Felicia [11] propose to prolonging the sensor nodes alive making the network more operational and efficient. The idea of Felicia [11] can help but have some challenges of the batteries lifespan.

Lee at el [12] introduce challenge in the real time communication for WSNs. Computing power and narrow bandwidth provide the constraints, which are not suitable to provide real-time communication. Thus, the issues and research challenges have to be addressing to provide real-time communication in WSNs.

Kapalta at el [13] proposed the clustering approach that increase the lifetime of the network. The process executed in periodical manner. Every round divided into two phases: Cluster building phase and stable data communication phase [14]. However, Rezaei and Mobininejad [15] identify two main enabling techniques namely: duty cycling and data driven approaches for ensure the energy not wasted. Not all the proposed techniques can ensure the permanent solution because all have lifetime duration based on the chemistry of the sensor nodes batteries.

Pubill at el [16] propose the energy harvesting using the artificial lights. The proposed solution consists of an energy-harvesting module that powers a WSN source node that is transmitting data to a WSN sink node. The energy-harvesting module consists of a photovoltaic (PV) cell that harvests artificial light from a nearby lamp using the PV, a boost converter that transforms the gathered energy into the proper electrical features of the WSN node and a 3*V* rechargeable coin battery that stores the electrical energy.

This proposed algorithm for Pubill at el [16] is working for small sensor networks such as home security system where there is national grid power available all time. According to this proposed article with strategic for larger network and installation environmental, the idea is difficult for implementing. The article intention is for difficult location where after deployment is impossible for human to visit for batteries change, charging or recharge for certain period. The target for proposed are like great forest, National parks for monitoring animals, and all hazard places but there is sunlight available.

The case study that Tanzania is in era of Eastern Africa have a shortage of power. Tanzania have four seasons as autumn, winter, spring and summer. Overall annual range of temperature for Tanzania all seasons lies between 28^oC and 31^oC $(82-88^oF)$ with occasional maximum and minimum extremum.

The national grid power is not enough based on the required power. Thus, there is a power scheduler distribution through the region. During the power scheduler or power cut off, network security system like closed circuit television, (CCTV) systems that required about $12vDC$ and WSN $(3.3to5V)$ shut down for that particular era. Thus, if there are no power backup or uninterruptible power supply (UPS) for those systems then the whole network will be down. Therefore, when no power it's difficult for security system or WSN to perform its operation like traffic monitoring, police monitoring, security guard monitoring, patients monitoring, animal monitoring, etc.

The data source from the reference of World Bank indicates that the average electricity consumption per capital in Tanzania is $99kWh$ per year, compared to Sub Saharan Africa average consumption is $550kWh$ per year, while $2,500kWh$ is the average for World Bank consumption per year [17].
However, consider BRICS Nationals, like Brazil $2601kWh$, Russia $6603kWh$, India $806kWh$, China $3927kWh$ and South Africa $4198kWh$ respectively from the World Bank records[17].

However, the proposed can be implementing in India because is located below the World Bank range average for energy consumption capital per year. The most part in India range of day time maximum and night-time minimum temperature for Indian is more that 15^oC and maximum exceeding 45^oC [18]. The current report of the World Bank for electricity consumption per capital released on 2014.

3. Energy Wastage and Challenges in Wireless Sensor Network

By categorizing, the different behaviors that caused energy wastage in WSNs it is an opportunity for the energy safeguarding for prolong lifetime of the network in general. The sensor nodes dissolved energy when sensing in event action, signal processing after sensing, data transmitting or receiving. Regarding the communication within the network, there is a great amount of energy wasted in states that are useless from the application point of view, such as power transmission methods, idle node listening, range between the one sensor node to another, data collision and data retransmission. Schurgers at el [19] and Mansouri at el [20] elaborate factors caused the energy wastage in WSN as follows;

- Transmission power: radio communication known to be the main source of power consumption in WSN. Thus, higher is the transmission, shorter is the sensor node lifetime
- Physical deployment of the WSN: The deployment can have caused the interferences, thus each node located between transmission range and interference range receives a packet but cannot decode it.
- Idle listening mode: This happens when a node is listening to an idle channel based on the type of topology in order to receive packets that may come through that channel medium for another node.
- Distance: Energy wasted, if the path from source to destination chosen for communication is not the shortest one according to the topology.
- Overhearing: When a node transmits a packet, all nodes in its transmission range receive this packet even if they are not the intended destination. Thus, energy wasted when a node receives packets that sent to other nodes as nodes listening the network.
- Collision: When a node receives more than one packet at the same time, there is a possibility of collision among these packets. Collision requires the sender to retransmit the packet which is energy wastage
- Control packet overhead: The control information used during transmission of data. Using more number of control packets will cause energy wastage.
- over emitting: which is caused by node to transmit a message when the destination node is not ready to receive that message

3.1 Challenges to Ensure Energy Efficient

There are many factors considered when designing energy efficient protocols in WSNs. Those factors ensured before efficient communication achieved in WSNs. Some key factors to consider for energy efficient to WSNs are;

- Type of Transmission media: In larger WSNs above 1000 nodes, sensor nodes connected using the wireless medium. The network arrangement of nodes is a big challenge for configuration when consider time consuming for provenance communication based distance and security system.
- Network Data aggregation: Different data from different source considered for communication.
- Fault tolerance: Ensure the operation of the network are active all the time without failed.
- Nature of node deployment: Routing protocols affecting network performance due to sensor node setup.
- Quality of services: Data transported within a network according to the network architecture.

3.2 Algorithm Minimize Energy Consumption

Regarding literature from researchers about the energy, they introduced algorithms, which reduce amount of energy consumption in WSNs. The low-latency, overcome the limited factors of every sensor node in sensor networks. From those algorithms, few are well suitable solution for reducing the energy in the WSNs. Those algorithms are Low-Energy Adaptive Clustering Algorithm (LEACH), Power Efficient Gathering in Sensor Information System (PEGASIS), Multi-hop clustering [21]. The researchers do not indicate the amount of energy saving through their implementation so that we can know how we can sustain a network like 1000 nodes.

Together with those algorithms aforementioned which reduce the energy consumptions but they cannot ensure the long lifetime for the batteries, which installed to a sensor node. Therefore, the network at the end shut down the network operation. The article suggests the permanent methods to ensure the network never cut down because of the energy and the methods suggesting is the energy harvesting from the source of sunshine for the place where sunlight available throughout a day of a year. The available daytime sunlight can be harvesting their energy and recharging batteries during the nighttime for the sensor node. Batteries lifetime taken into consideration.

3.3. Sensor Network Lifetime Definition

According to this article, the sensor network lifetime is the lifetime span for the sensor nodes batteries, which used to power on the sensors. The WSN fulfill its service for communication as long as it is active at all the time.

4. Proposed Energy Lifetime

The aforementioned problem can utilized the energy source available in Tanzania based on the weather forecasts. Together with freely availability of good weather forecasting some few researchers utilized the benefit of harvesting the energy for the temperature availability from the sun and use it to overcome the WSN energy constrain. Some countries utilized but in a scenario case as in Tanzania not yet if not fully implemented based on the sunlight availability.

The proposed method is to deploying the photolytic solar system to all WSNs and security systems. Tanzania experiences an equatorial climate changes with two annual rainy seasons. The short rains starting October to December and the long rains from March to May. During the rainy seasons still the temperature maximum is $26^{o}C$ and minimum is $16^{o}C$ [44]. Jones at el [44] was researching about the epidemic malaria and rainy seasons in Tanzania and through his data indicates the maximum and minimum temperature which helps for this study on deploying the photolytic solar to our WSN and harvesting energy through a year as indicates on figure (2) [44].

The month of June, July, August, September and October weather temperatures are normally between $20^{o}C/68^{o}F$ and $30^{o}C/86^{o}F$ and vary greatly according to altitude and location based on region. In Tanzania, the most of days through out a year have a fine, clear sky and sunny weather. Tanzania has promising levels of solar energy, ranging between 2,800 and 3,500 hours of sunshine per year and a global horizontal radiation of 4 to 7kwh per $1m^2$ per day [45], [45]. Solar radiation is particularly high in the central region of the country.

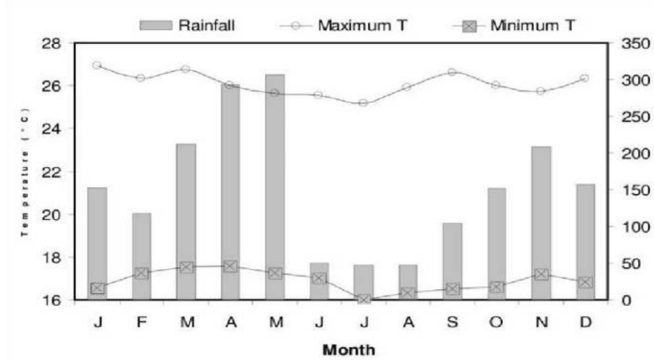

Fig. 2: Mean monthly climate data in Tanzania from 1991 to 1999

4.1. Solar Radiation per Month in Tanzania

The power generated per day has analyzed based on data from [45] as shown Eq. (1)

$$W\,(work) = F\,(force) * D\,(distance) \qquad (1)$$

Therefore, minimum per one day is 48Kilojoules and maximum per day is approximately 84kilojoules, which means the energy falling on an area of 1m2 over the period of one day. Therefore, total for one month is about energy from 1.440megajoules to 2.52megajoules in $1m^2$ as refer Eq. (1). Thus, indicates a lot of energy which we can utilizing them for many purposes rather than only for WSN or security system.

In Tanzania, the electricity supply is from Tanzania electric Supply Company limited (TANESCO). The solar power system most found in rural area but people using for individual purposes only. The TANESCO depend on hydropower, Biomass, Oil, gas and import from nearby country [46]. Thus, there is a need to utilizing the power that are freely available from the sunlight throughout a year for our WSNs and security system.

4.2. Sensor Node Energy Required

The energy consumption for the sensor nodes depending on many factors. Those factors including the message broadcasting, receiving or sensing and even the idle or sleeping mode. The maximum for sensor node from different data sheets is approximately $3.3 - 5v$.The energy consumption for sensor nodes is different from one WSN network topology to another as described by [47], [48], and [49]. The energy consumption is differ from one sensor node to another sensor node even in a same network setup based on its sensor node functionalities within the network. The intention is to recharging the batteries during the sunlight and utilizing them during the nighttime. There are many rechargeable batteries like Acid-Nic cad, Nickel-Metal Hydride and Li-loc as refers table (3). Thus, for economical reason of WSN installation, the higher the batteries storage capability the higher the cost for the WSN setup. Due to energy, power available based on the case study scenario the longer life batteries types with normal storage capability the better for the cost reasons.

4.3. Sensor Node Batteries Clarification

All batteries have three distinct measures of lifespan and each type of battery chemistry has a different measurement of lifespan as indicated below:

- Battery runtime; this refers to how long a battery or battery pack will run on a single use from manufacturer and each device or sensor node draws different amount of energy based on it is operational
- Battery shelf life; For the case of rechargeable batteries, it refers to how long the battery pack can sit on the shelf without going bad or before you charge it. Shelf life times affected by humidity and temperature. The more humid, and warmer the storage environment, the shorter the shelf life.
- Battery cycle life; this refers to how many complete charges and discharges a rechargeable battery can be used before it no longer holds a charge. All rechargeable batteries have a fixed number of cycles as refers table (1)

Table 1: Sensor Node Batteries Clarifications

S/n	Type of battery	shelf life Years	Cycle life	For WSN
1	Alkaline Non-Rechargeable	5 to 10	None	None
2	Carbon Zinc Non-Rechargeable	5 to 5	None	None
3	Lithium Non-Rechargeable	10 to 12	None	Yes
4	Nickel Cadmium	1.5 to 3	1000+	Yes
5	Nickel Metal Hydride	3 to 5	700 to 1000	Yes
6	Lithium Rechargeable	2 to 4	600 to 1000	Yes
7	Lead Acid	6 Month	Varies++	Yes

Table 2: Summary of Research Issues on Energy

s/n	Data Source	Research Issues	Paper Briefing	Year publication
1	[29], [30], [31], [32]	Adaptive transmission, energy harvesting, energy efficiency	Power control, improved harmony	2016
2	[33], [34] , [35]	prolong electron for heterogeneous	Routing algorithm	2017
3	[11], [36], [16]	Energy Efficiency	Routing algorithm	2017
4	[16], [37], [38],	Data rendezvous and routing	Data collection in UAV, delay	2018

	[39]	algorithm	minimization	
5	[40], [41], [42], [43],	Energy efficiency	MIMO, collection and clustering Data	2019

5. Energy Algorithm and Techniques Comparisons

Most of the researchers use the algorithms and energy mobility to ensure the lifespan for the batteries used in sensor node of WSN. The comparisons investigation for energy in WSN investigated as shown table (3). Furthermore, about 19 researchers for different year from 2016 to 2019 their investigation about the lifetime indicates various algorithms and methods to sustain the batteries lifetime or reduce processing time of the sensor nodes, which reduce energy consumptions as indicates summary of energy techniques as shown table (2). Those methods implemented but some places like in Eastern Africa they can use the energy from the sunlight that is available. By the present of the sunlight the method of energy harvesting using the solar panel can be main solution to ensure sensor node maintain the lifetime of the network. This energy harvesting method is for WSN that are implemented in heavily forest, police traffic monitoring, flight monitoring, patients monitoring and all those WSN where it's easily reached by human after implementation.

Table 3: Energy comparisons techniques

s/n	Data Source	Research Issues	Paper Briefing	Year publication
1	[22] [23]	Clustering Algorithm	Distributed, Randomized clustering algorithm	2015,2003
2	[11], [13], [16]	Energy harvesting	Using Solar, Batteries, Artificial light, Ultra low power, super capacitor	2017-2018
3	[6], [8], [20], [24] [25] [26]	On Powering system & energy conservation	Use alternative power such as solar, Batteries and wind	2000,2003,2009-2011,2017
4	[14] [19], [21] [27] [28]	Routing algorithm system	Renewable energy based routing protocols	2001,2009-2011,2015

6. Conclusion and Future Work

Regarding the WSN communication there is an important to consider the sensor nodes batteries lifetime. From review, investigation indicates that Lithium Rechargeable can have the shelf life for up to 4 years on its operation. The 4 years for operation for WSN is a huge numbers of years for various project using the WSN. The energy wastage and challenges for design the network has investigated to ensure the design of the network that considered difference factors to avoid unnecessary energy wastage and minimize challenges for the energy lifetime.

Furthermore, various methods and algorithm presented to ensure how to sustain the sensor node. The proposed energy lifetime for case study Tanzania, indicate that the climate temperature is between 20ºC/68oF and 30ºC/86oF. Thus, solar energy, ranging between 2,800 and 3,500 hours of sunshine per year. Therefore, the total for one month is about energy from 1.440megajoules to 2.52megajoules in $1m^2$.This energy is a lot which we can utilizing them for many purposes.

Further studies investigation for energy lifetime is needed for the WSN which are in a dangerous environmental like underwater, undersoil, mining sector and hazardous places.

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Authors biography

1. **Gaudence Stanslaus Tesha.** He received proficiency in certificate level in Multimedia for Music Production from SAE College Bangkok Thailand in 2013.Full Technician certificate in Computer Engineering (FTC) from Dar Es Salaam Institute of Technology, Dar Es Salaam, Tanzania East Africa in 2003. He received Bachelor of Engineering (BEng) in Electronics and Telecommunication from Dar Es Salaam Institute of Technology, Dar Es Salaam, Tanzania East Africa in 2007. Master in Engineering (MEng), Electronics and Communication from Chongqing University, Chongqing, China in 2011. He is working with the Dar Es Salaam Institute of Technology (DIT) in Tanzania as Assistant Lecturer. He is currently pursuing PhD with School of Telecommunications Engineering, Xidian University, Xi'an, China. His research interests include Communication Networks, Multimedia Security, Information Security and Wireless Sensor Network.

2. **Mohammad Amanul Islam (Aman)** is pursuing his PhD. degree with school of Computer Science and Technology from the Xidian University, Xi'an, China. His research interests include computer and network security, applied Cryptography. He is also interested to the application of secure computation technology, and machine learning techniques to enhance network security and data privacy.