Wireless Underground Sensor Networks: Packet Size Optimization Survey

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Abstract. In Wireless Sensor Networks (WSNs) Packet size optimization is a major issue and many performance indicators (e.g., latency, network lifecycle, reliability and throughput) can be improved by it. In WSN, due to channel conditions, long packages encounter high loss rates. On the other hand, small packages may be affected by an increase. Therefore, you have to choose the maximum packet size to improve the different WSN performance matrix. Here in WSN to determine the maximum packet size several methods have been proposed. Deployment environments or specific applications are the center of attraction of packet size optimization in the literature. However, to categorize these different methods there are no complete and recent survey files. In order to meet this demand, the recent research and optimization of the data size of the Underground Sensor Networks (WUSNs), the small package encouraged the scientific community to find out more about this promise field of research. To better understand the various packet size optimization techniques used in application networks and variant types of sensors, and in this field introducing new research issues is the main purpose of this research.

Keywords: Cross-layer Design, Energy Efficiency, Network Reliability, Packet Size Optimization, Wireless Sensor Networks.

1 Introduction

In many applications Wireless Sensor Networks (WSNs) are used such as logistics applications, military, space, commercial, precision agriculture and visual surveillance [1-6]. Generally, on the base of deployment environment WSNs can be categorized into four types: Body Area Sensor Networks (BASNs), Terrestrial WSNs (TWSNs), Underwater WSN (UWSN), and Wireless Underground Sensor Networks (WUSNs). Each environment has its exclusive capabilities because of the environment type used to transfer the data. It offers extra challenges due to its incredible changeable channel capabilities in a variety of promotional environments. [7].

The recent study shows that the size of the packet directly influences the contact performance of the nodes. It has come to know that due to difficulty conditions, Large Packets are more harmful, while Short packet data may cause overload [8]. In order to track service closure between network reliability and energy efficiency, a number of techniques have been analyzed to decide the maximum size of packet in the WSN.

In figure 1, define to improve the optimization of data, by the use of relay nodes in wireless underground sensor networks. For networks with limited energy resources WUSNs, it is expected that more data transmission will be processed on Relay node to Collection center (Sink node). In this network, we conclude that all sensor nodes (including relay nodes) are randomly placed in the environment [9].

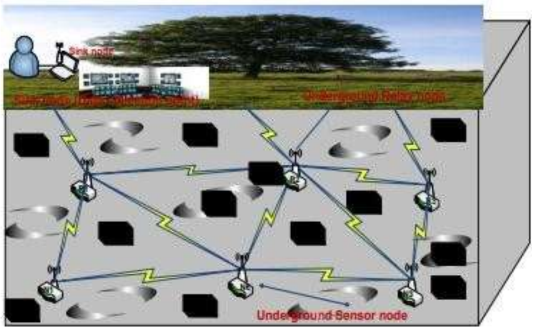

Fig. 1. Node Deployment in Underground Environment

In figure 2, we offer general link layer packets format in the sensor network [8]. Note that there are 3 major factors of a package (trailer, payload and header). The information contains in header field is about the present segment number, the station node, the overall number of segments and the source node. For checking error parity bits are contained in the trailer field. The information bits are included in payload field. The bits LH, LT and LPL are used to represent lengths of the header, trailer and payload respectively.

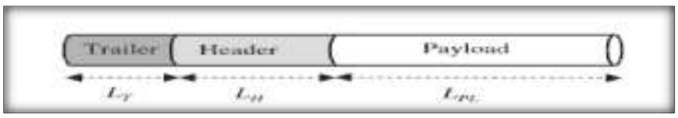

Fig. 2. In Sensor Networks Format of Typical Link-layer Packet

The Analysis of Dynamic Packet Length Control (DPLC) is shown in figure 3. The following are the principles of the work of the DPLC scheme. At the application level for transmission message is send by the application. The DPLC module sender's determines to use which one service if the length of the message is minimum the aggregation service (AS) is used or if the message length is greater than the highest packet length then the segmentation service (FS) is used CC2420 radio load (128 bytes). Link estimate in DPLC dynamically evaluates the length of the packet for communication. On this basis, the DPLC module of the sender determines how the messages should be distributed for the total (AS) or frames in which the message should be split (for FS). When the frame is ready to send (enough messages are grouped or AS's time has expired), the DPLC has to send through the Mac layer. [10], [12]. When the DPLC module obtains the Mac frame on receipt, later describes the frame or defragment the frame to get the original message. When the message is ready the Receiver DPLC module on the receipt informs the upper layer for further processing (Receiver has received all message frames or recipient's buffer is full in the FS).

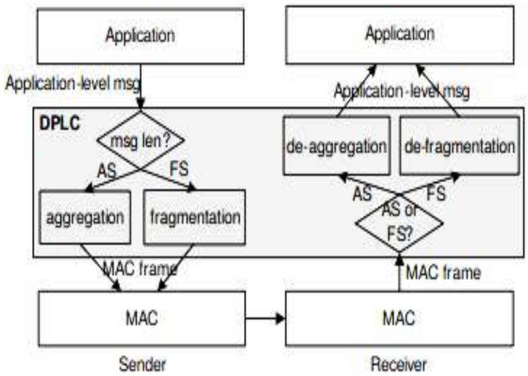

Fig. 3. DPLC Overview

According to standards of various wireless communications Packet size optimization can be accomplished [8-19]. Various optimization measures, such as energy efficiency and flow efficiency are used as accomplishment standards for optimization of packet size. For example, Authors use energy as well as improving to determine maximum fixed length of packet to improve energy efficiency [8]. In addition, to improve energy efficiency they discovered the effects of failure prevention about improving packet size. On the other hand, the authors of [18] used flow efficiency as an assessment measure. The authors propose the conclusion of selecting the best packet size in multi-hop WUSNs.

The fundamental target of this paper is to give a superior comprehension of packet size optimization ways utilized in WUSNs to present open research issues and difficulties in this research area.

Table 1: Maximum Packet Size Based on the Application of WSN

WSN application	Requirements	Optimum Packet Size
Military & Health care applications	Error-free transmission & High-energy efficiency	640 bits
Battlefield monitoring and Environmental & security and industrial	High-energy efficiency	50 bits

Therefore, before determining the optimal packet size application prerequisites (for example, low end-to-end latency, high energy efficiency, or high throughput) must be examined. In summary, maximum packet size according to the needs of a particular WSN application are listed in Table 1.

2 Literature Review on Packet Size Optimization For WUSNs

In the paper [20], work is developed by the authors and the reported that savings of energy can range up to 50% with a 6d advantage. In addition, to determine the best bit rate gain with low computational complexity and the best energy savings a two-stage decision game was developed. WUSNs aims to provide real-time monitoring of difficult underground environments, including soils, oil reservoirs, and underground mines and tunnels [21].

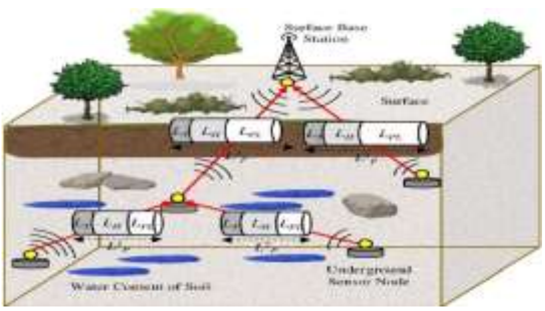

Fig. 4. Packet size optimization for a typical WUSNs

In paper [22], the author builds an Intel layer fixture framework to improve WSN, WUSN and UWSN packet size. All of the following are taken into account while designing this solution, cross-layer effects of multi-hop routing; the broadcast function of the wireless channel, underwater and underground and error control techniques. The relationship between routing decisions and packet size and the fundamentals of various types of applications is also examined in this study. The proposed customization solution order three different lens functions, such as input, bit rate energy and resources. Relaying on the essentials of the application each of these features can be utilized. In addition, the reliability effects and delay have also been studied.

From the perspective of WUSNs, the underpass is modeled according to the results reported in the paper study [23], to determine the optimal size of the packet. They exhibit a path loss function as a function of soil properties, soil water volume content, error rate based on error function and signal to noise ratio. The soil's volatile water content is based on BR and SNR error function. Automatic re-application and BHC (128, 78, 7), error control methods are examined for imitation conclusions. The author shows a meaningful correlation among quantitative water content and package size. When the volumetric water content increased from 5% - 20%, the additional energy utilization increased by 60%, and the packaging rate decreased by 37%. In addition, it can be seen that as water content increases in the amount of water, the size of the maximum package is reduced, so communication protocol must be associated with the changes in soil water content and correspondingly change the size of the package to improve Performance of Underground surveillance programs.

Table 2: Showing Literature Overview of Packet Size Optimization Techniques BANs

Technique	Purpose	Performance metrics
Optimal packet size Selection [24]	Energy consumption, Improving the throughput efficiency, and latency in WUSNs	Latency, Throughput efficiency, and energy consumption
Measuring impact of packet size selection on the DACAP and CSMA protocols [25]	Determining the optimum packet size according to the BER value	Latency, Throughput efficiency, and energy consumption
Finding the optimal packet size with using a lookup table [24]	Increasing the energy efficiency by finding the optimal packet size	Energy efficiency
A cross-layer optimization framework [22]	Finding the optimal packet size in TWSNs	Resource Utilization and Packet throughput, energy per useful bit
Developing data link protocols for UWA system [26]	Developing an efficient data link layer protocol with formatting the data packets.	Throughput efficiency
An optimum packet size algorithm with 2H-ACK [25]	Increasing the energy efficiency and throughput by reducing channel impairments	Energy efficiency, throughput

As a result of the analysis in the article [19], the authors show that the optimal packet size of the type WUSNs needs to be determined according to the requirements of the application.

Based on these existing studies, summaries and comparisons from WUSNs are presented in Table 1, respectively, and it has been noticed that the size of the maximum packet significantly varies according to the needs of WSN application, and is also in the topology and method.

3 Research Issues in WUSNs

Maximum research used to determine maximum packet size in WSN is for high energy efficiency, high throughput and small size. Anyhow, this study is facing many challenges due to the specific requirements of the application and the features of the installed environment. Here, we will focus on these free research questions and challenge for deciding a best pack size in WSN.

3.1 Service Provisioning

QoS prerequisite of each WUSNs application alters as application changes. Subsequently, the packet size development strategy accommodates the particular application necessities (e.g. energy effectiveness and low end to end delay). Pointing to the ideal packet size, it is important to understand the remote channel conditions to properly adjust. Besides, the ideal packet size can be balanced by the type of traffic; it can be a real, real time or best effort. Real-time packages require fewer dimensions, and with lines, small packet sizes can be used. Then again, for real time and best effort packets, a long packet size can be preferred.

3.2 Transmission Power

The use of electricity is an important issue due to the limited battery consumption plan of sensor hub. Numerous investigations outline space to decide ideal packet size to expand the energy effectiveness. Most work packets use in writing to reduce the transmission control. In any case, If the communication control is controlled by the conditions of channel, the ideal packet size can be found more accurately.

3.3 Cross-layer Design

The overall cross layer is close to the applied layer of physical layer because in USN, it has not been mentioned in literature for various USN applications for packet size reform. For instance, different models of antenna e.g. Omni-directional or directional radio wires at physical layer or diverse MAC conventions (e.g. CSMA, TDMA, and half) at the connection layer can be acknowledge to decide the ideal size of packet.

3.4 Reliable Communication

Fault prevention is another basic issue in WUSNs, since the quantity of re-transmission diminishes when the communication free of error is accomplished. In the writing, some fault preventing components, for example, ARQ, FEC, and half and half strategies, are applied to get the ideal packet size. But, the performance measurement of these systems hasn’t been fully compared for various WUSN applications to get the comparing ideal packet size.

3.5 Cognitive Spectrum

Recently, CRSNs has been subjected to solve the problem of lack of wireless sensor networks spectrum. However, current packet size solution prepared for WSN is not directly applied to CRSN [18]. A spectrum warning is resolved to maximize network performance and energy efficiency while the ratio of ratio is maintained, which interferes with the acceptable level for licensed users.

3.6 Cognitive Spectrum

The WUSNs execution can be improved by Energy Harvesting (EH) with charging capacity of itself. In the environment accessible energy, for example, energy from magnetic, sun and thermal can be managed to control remote sensor. However, the current packet measure optimization methods for WUSNs can't be straight forwardly applied to EH- USNs. This is on account of the present energy changes on time, rather than constantly diminishing in energy-harvesting WUSNs. As a result, energy shortage requires an ideal packet size management to adjust the energy closure between energy usage and QoS.

In this section, we define four aspects for the necessary WUSN design for this unique environment: antennas design, Power savings, extreme environments and topology design.

3.7 Power Conservation

Depending on the application required, the lifetime of the WUSN equipment should be at least a few years in order to increase its deployment costs. Damage of underground channels complicates the challenge, which requires Wi-Fi equipment that is far higher than thermal association devices for the highest radio transmission power. Therefore, energy- saving is mainly the main concern in the WUSN design of the wireless sensor network. WUSN's life is limited by each device's free power supply. Unfortunately, maximum deployment is more difficult to reach groundwater WSN devices to access WUSN devices; it is less likely to charge devices for charging or replacement of their power supply. Although the use of information technology can be used to recharge the devices posted near the device, it is difficult, if not possible to charge deeper devices. It is also difficult to determine a new device to change the failure device. In addition, Terrestrial Wireless Sensor Network Equipment can be equipped with solar cells [14], [27] or to convert conventional power supply, which is not clearly the choice of WUSN equipment. WUSN equipment, such as bass vibration or thermal gradients, have to be converted into energy [25], [28], [29], but it has been found that these methods provide sufficient energy to run devices without traditional equipment can do. In [24], the state of the art in more unconventional techniques for energy scavenging is surveyed. For generating energy from, thermoelectric conversion, vibration excitation and background radio signals technologies are described by the authors.

Therefore, energy conservation should be the main purpose of WUSN design. While increasing the device life through the means of large storage power, it is not necessary that this sensor increases the cost and size of the device. By using communication protocols and power-efficient hardware and protection can be achieved.

3.8 Topology Design

Designing right topology for WUSN is critical for network reliability and power saving. WUSN topologies can be very different from their land counterparts. For example, in order to perform excavation mining for deployment, the WUSN device is usually carefully planned. In addition, the 3D topologies in WUSN are also common, depending on the sensing application; the devices are deployed at different depths. The application of WUSN will play an important role in determining its topology, but also reducing power consumption and deployment costs should also be considered in design. In order to create the best topology, these ideas should have a careful balance. Here, we provide concerns associated with each of these considerations as well as suggest new WUSN topologies.

3.8.1 Intended Application

Sensor devices must be close to the phenomenon they are deployed to perceive; this determines the depth of their deployment. Some applications may require a very deep deployment of sensor in small physical areas, while other applications may probably be interested in sensing with low density but in large area. For example, security applications require deployment of underground pressure sensor, whereas soil-proof applications require fewer devices because differences in very little distance are not visible in soil properties.

3.8.2 Power Usage Minimization

Intelligent topology design helps save power in WUSN. Since the ratio between the transmitter and the receiver is relatively proportional to the control, the power consumption by designing a topology is designed with a large number of short-range hops instead of minimized range hops can be reduced.

3.8.3 Cost

Unlike free sensors, free sensors only require physical distribution equipment, critical personnel, and such costs, and are included in the mining required to deploy WUSN. Deep sensor device, the price is high – Unlike ground sensor devices, earth sensor devices only require physical distribution of goods, so there is a significant amount and value involved in the mining need to be deployed. The deeper the sensor device, the more mining it needs to deploy it and the higher the cost of deploying the device. Additional charges occur when the power of each device is over and the device needs to be replaced or recharge and must be unearthed for it. Therefore, when the price is a factor, deployment of deep equipment can be avoided as much as possible, and should minimize the number of devices. Minimizing deployment conflicts with the proposed dense deployment strategy of power considerations and must establish appropriate trade-offs.

Consider the above factors; we suggest that two possible WUSN topologies should be used to address maximum underground sensing applications. These are hybrid and underground topologies.

3.8.4 Underground Topology

It includes all sensor inland deployments, except for the sink, which can be positioned in the ground or above, as shown in Figure 5. Like the Territorial Wireless Sensor Networks, the WUSN receiver node receives all data from sensor networks. Underground land can be single- dimensional, i.e. all sensor devices are in multi depth or single deep, i.e. sensor devices are in different depths. Communication protocols and sensor device hardware for multi-depth networks require special consideration to ensure that data can be efficiently routed to surface receivers. Depth of the deployment of goods depends on the network application. For example, pressure sensor is to be kept near the ground, and soil water should be located near the root of the sensor plant. It reduces (or removes) top-level equipment (if it is a groundwater tank) providing maximum concealment of the network. The equipment posted on the hollow depths can be able to take advantage of the channel's groundwater air-landing route, resulting in a low-way loss of ground-based groundwater channels.

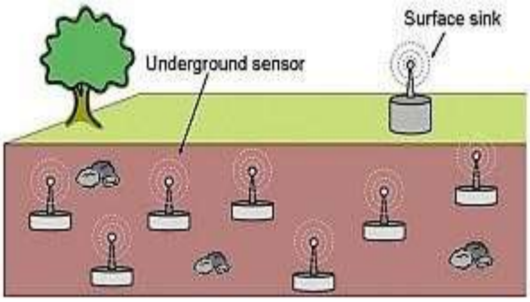

Fig. 5. Underground Topology

3.8.5 Hybrid Topology

This form consists of a mixture of underground and above ground sensor devices as illustrated in Figure 6. Since wireless signals are capable to travel freely in the air and the loss rate is less while when wireless signals are propagated through soil loss rate is high, to transmit over a given distance the underground sensor devices require more power output than the aboveground sensor devices. In fewer hops movement of data out of underground is allowed in hybrid topology, highland underground hop trading for less expensive hops in a casting network. In addition, ground equipment is more accessible when the power supply needs to be replaced or charged. Therefore, if selected, electricity expenditure should be completed by ground equipment instead of underground equipment. The loss of hybrid topology is that the network is not completely hidden as underground topology.

Hybrid Topology can also include underground sensors and mobile floor sinks that pass the underground network deployment area and collect data from underground sensors or earth relays. In absence of ground trains, the deepest instruments can calculate the way to the nearest available device (able to communicate with the devices above ground and underground), which will store the data until the mobile receiver arrives. This topology should reduce the number of recipient hops to promote the energy savings in the network, because every morning device can work efficiently as a receiver. The loss of this topology is introduced by storing data as long as the mobile user is within that range. For mobile surveillance, mobile receivers have been successfully used in reverse WSNs [3].

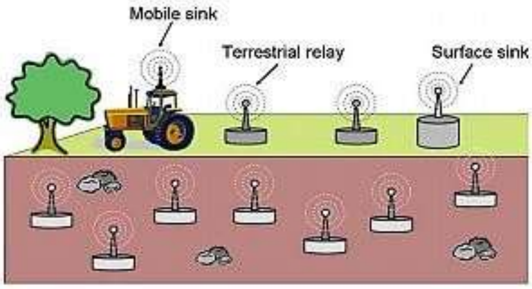

Fig. 6. Hybrid Topology

3.9 Antenna Design

Choosing the right antenna for the WUSN device is another challenge problem. In particular, the challenges are:

Variable Requirements
Various devices can be used for different communication purposes, so there may be antenna with different features. For example, devices posted within a few centimeters need to consider the ground-based interface especially due to EM radiation reflectivity. In addition, near- level devices can work as a rail between deep appliances and earth appliances. A deep device that works as a vertical refrigerator path works on the ground antenna that may be horizontally focused and vertically focused.

Size
In order to get the actual resolution distance of a few meters, frequency in MHz or low-level may require. It is known that antenna should be larger for low frequency, transfer and gain efficiently in this antenna. [19]. For example, in the frequency of 100MHz, quarter wave antenna will measure 0.75 meters. Obviously, this is a challenge for WUSN because we want to maintain compressor equipment compact.

Directionality
Future research essentially suggests that a set of council antenna or free directional antenna is suitable for best use. Communication challenge with single unidirectional antenna may be because the WUSN topology can be compatible with various different depth devices, and at the end of a radiation pattern, a commonly used antenna is experienced. This means a vertical directional antenna that will be communicated with the above and lower devices. [19] This problem can be resolved by providing the device with antenna for horizontal and vertical communication. Antenna design ideas vary depending on the physical layer technology used. We are here to focus on elec-

tromagnetic waves, but as a discussion in Section 4, it proves that other technologies are more suitable for the environment that it does not prove to be.

Environmental Extremes
For electronic devices the underground environment is not just the ideal location. Animals, extreme temperature, Water, excavation equipment and insects threaten WUSN equipment and must provide adequate protection. These factors have to be adjusted by power, radios, supply, processors and other components. In addition, the cost and time required for excavation of large equipment will increase therefore the physical size of WUSN equipment should be kept small. Environmental and physical size and capacity problems should be taken to balance the battery technology to adjust the temperature of the deployment during the balance. This device can also be emphasized on people or things that are moving towards the top, or deep deployment devices, which are subject to brain pressure on the above soil.

4 Conclusion

Packet size is a key parameter to improve the wireless sensor network performance. Researchers have suggested various methods of the optimization of packet size to improve network performance in terms of latency, throughput and energy efficiency. These methods are divided into different taxonomies, as some provide them for the use of default size of pack or changeable packet size, while other types provide different packet formats or for the use of the custom framework. Depending on the nature of the WSN, various kinds of WSNs should also be considered when packet size due to changes in specific channel properties explanation. Here, methods of the optimization of pack size for various types of WSNs are also modified. WSN types of each have different needs such as energy efficiency, low-dependent or maximum- output. We also developed the most advanced packet optimization studies to meet the needs of particular applications specifically to decide the size of packet. Finally, in order to facilitate future research approaches, we address key new research problems in the packet size optimization area. Since some of them provide a set of packages of length or dynamic packet size, others provide different packet settings or custom systems. Packet size optimization systems in terms of WUSNs are investigated. We reviewed the most advanced packet optimization techniques designed Complete the specific requirements of the application to determine the ideal packet size. Lastly, we offer large open research questions for future optimization of the data packet size optimization area.

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