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# A Review on Cross-Layer Optimization for Energy and Security in loT-MANET WSNs

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## ABSTRACT

Nowadays, the minimization of energy consumption in terms of cost and lifetime is the main preoccupation in the recent research studies. This work deals with the proposition of a Power Consumption Protocol-Physical, Mac and Network (PCP-PMN) based on cross-layer for wireless sensor networks which uses three layers (Physical, Mac and Network). Our PCP-PMN algorithm presents the minimum transmission power between nodes at the physical layer. It uses this minimum transmission power as a metric at the network layer for the proposed routing based on LEACH protocol and performs scheduling at the mac layer for the proposed hybrid spread spectrum. The evaluation results mark that the implementation of our proposed approach preserves more energy and leads to a better performance system.

**Keywords:** Cross layer, Energy management, Wireless Sensor Networks, LEACH, PCP-PMN.

## I. INTRODUCTION

Wireless sensor networks (WSNs) are one of the most important elements in the internet of things (IoT) paradigm, as they are a sensor nodes battery powered devices. Accordingly, energy efficiency is one of the determining factor for lifetime and a major research topic of WSNs. The limitation of energy in the sensor nodes which demanded every functionality of WSNs to be energy efficient. In fact, we must face concern how to reduce the energy consumption to extended the network lifetime. So, optimization of energy consumption in Wireless Sensor Network nodes has become a critical challenges to researchers. In this context, an increasing number of research works has been conducted in order to propose a wide solutions to the energy-saving problem. Thus, all layers of protocol architecture influence the energy consumption. Thus, using interaction between these layers by a cross layer design will result in an efficient energy and improve the overall network performance. Indeed, recent papers on WSN reported in (1), (2) based on cross layer result progress in term of energy preservation. This work makes the following key contributions. First, at the level of physical layer, the minimum transmission power between nodes is obtained and gives this node where it is obtained a higher priority. Second, at the network layer, we used the parameter obtained previously as a metric to make elect cluster-head and make improvement of proposed routing algorithm based on LEACH protocol. Third, at the level of Mac Layer, PCPPMN treats the scheduling by using proposed hybrid spread spectrum. To evaluate the performance of our approach, we simulated our WSN on NS-3 Simulator. PCP-PMN economizes energy and prolongs the life cycle of the entire network.

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## II. LAYERED ARCHITECTURE

The protocol stack in wireless sensor network is an hybrid model between OSI and TCP/IP model as shown in Figure1. We are interested to present the layers that will be used in our work. The physical layer is responsible for frequency generation, modulation, and data encryption. The two sub layers of Data link layer are DLC (Data Link Control) which is responsible of multiplexing and error control, and MAC (Medium Access Control) which is responsible for Channel access and scheduling. The primary function of network layer is routing. More detailed description can be found in (6).

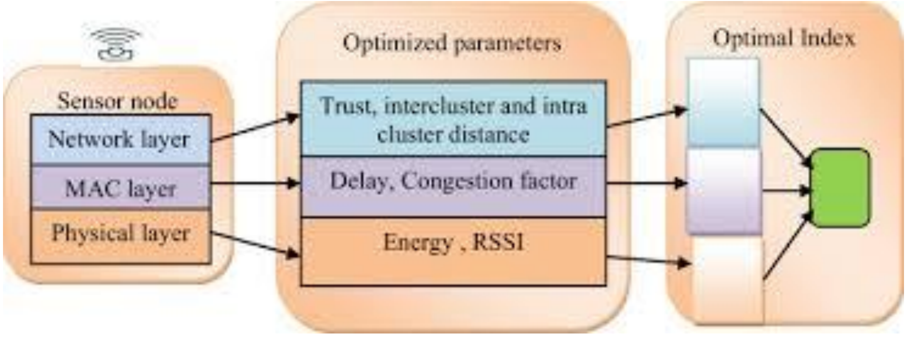


Fig.1. OSI and TCP/IP model

IoT is defined as the technology that strives to interconnect and join all the devices within the same network. This is made possible by using Wireless Sensor Networks (WSN) which plays a major role in implementing this technique [1]. It is a technique which is normally utilized for identifying the system containing unique objects that can be identified which are naturally independent and hence will have the ability to get connected to the internet for presenting and exchanging real time data in a digital format. IoT has lots of similarities to Networked control System on the basis of Industrial WSN. This persists the WSN technology to be implemented in industries [2]. These devices usually contain sensors, processors, transceivers, energy sources, etc. for monitoring their environment and transferring the necessary data. It is used in a various fields like home automation, transportation, surveillance, healthcare, etc. [3]. The design of the devices depends upon its usage in the available equipment for Wireless Sensor Network. Conventional protocols follow strict rules for the communication between the layers. This is done for ensuring faster deployment and efficient implementation.

However, there is no coordination between the different layers and this hinders the performance of the architectures due to the problems in transmission. In order to overcome this limitation, cross layered design is proposed as an alternative. This will keep the functionalities of the original layers, but allows to coordinate and interact the functionalities linked with the available layers and joint optimisation of protocols using different layers.

## III. LAYERS OF IOT FRAMEWORK

There are five layers in the IoT frameworks. These are built on already available TCP and IP structures. The layers are Perception Layer, Data Processing Layer, Transport layer, Network layer and Application Layer as shown in Figure1.

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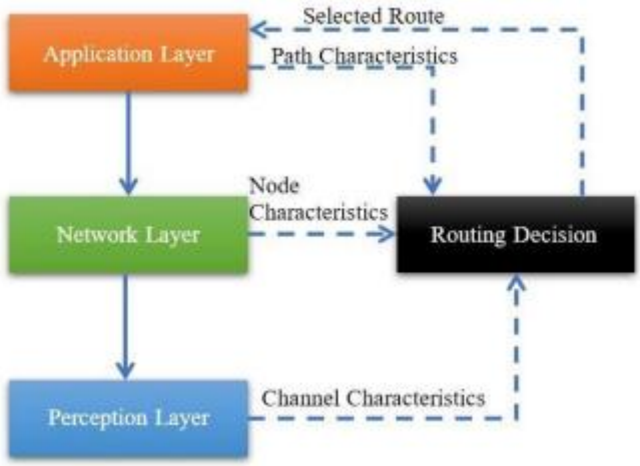


Fig.2. Layers in the IoT frameworks.

Perception Layer

The bottom most layer in the model is the perception layer that is also called as the physical layer, which assigns various features like electrical, optical and radio of the channel. This layer selects the required modulation technique and the bandwidth. Its quality is calculated using Peak Error Rate (PER). At the same time, the data link layer controls the flow of data. It creates frames from packets and contains two sub layers, each for controlling the media access and the logical link. The logical link control contains common interfacing, flow control and reliability, whereas the media access control has the physical addresses for framing them. Hence, these two layers may be used for cross layered applications and give techniques like Adaptive modulation and Coding, scheduling, etc. The information from the physical objects is present in different networks like RFID, GPS and sensor networks. The interaction between these nodes have physical objects that collect the data periodically, coordinates the nodes that transmit the raw data through the network, frame the control instructions sent to the actuations in the network, execute these instructions in these actuation nodes [4].

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Network layer

The next layer is the architecture is the Network layer. Connections are established through common network devices and then IP addresses are assigned individually. The network layer uses Internet Protocol security for providing the confidentiality, integrity and authentication of data. The functionalities like Data addressing, data routing, and translation of logical addresses to physical addresses are provided.

Transport Layer

The next upper layer is the transportation layer and its main work is to ensure that there is a good amount of communication. It is known that the transmitting and receiving the data consumes more energy when compared to the energy consumed while processing the data, hence is necessary for the sensor objects to show the different phases while transmitting the data packets. It utilizes UDP and TCP protocols to perform appropriate communication. It also allows compressing the header, fragmenting the packet, reassembling and routing the edges. The major function of the transportation layer is to address the objects in the IoT which is mapped to only one address, integrating the network using different heterogeneous terminals, managing the resources by efficiently by utilizing the resources efficiently.

Data Processing layer

This layer focuses on formatting the data and giving a schematic understanding of the data that is gathered. The functions of this layer involve analysing, storing, querying and mining the data. The layer utilises a combination of computing strategies, database storage and intelligent processing for handling large volume of data.

Application Layer

This layer wants to converge between the social needs of the IoT and the industrial technology. It is structured at the upper part of the framework and provides different IoT applications like status monitoring, operational control, public enquiry and other value added services for using in collaboration services and interconnections between the things. When this data is analysed and processed, the data is used by this layer for providing the users. The business strategies of the IoT applications like management and charges are defined. The services based on the data obtained through security protocols, analytics, processing models and management devices are also rendered.

Cross Layer Design Overview:

In layered architecture each layer has its own functionality and can use only the services provided by the layer below it. So, the communication is permitted only between adjacent layers. On the other side, in the cross layer approach, each layer can use services provided by any other layer. The interactions between all layers of the network protocol stack improve performance of WSN.

Different cross-layer designs have been classified into six approaches in terms of possible interactions between physical (PHY), medium access control (MAC), Routing (NET), and application layers (APP).

## IV. LEACH PROTOCOL OVERVIEW: LEACH

Low Energy Adaptive Clustering Hierarchy: As shown in Figure 1, LEACH Protocol is an hierarchical clustering-based routing protocol. It is self-organizing and adaptive clustering. LEACH utilizes randomized rotation of local cluster base stations (cluster-heads) to evenly distribute the energy load among the sensors in the network, operations are broken into rounds, each round is made on two phases: Setup Phase and Steady Phase.

## PROBLEM IDENTIFICATION

Cross-layer optimization in IoT-enabled MANET-based Wireless Sensor Networks (WSNs) faces significant challenges due to the conflicting requirements of energy efficiency and network security. Traditional layered network architectures treat routing, MAC, and physical layers independently, leading to redundant control overhead, inefficient energy utilization, and delayed security responses in highly dynamic MANET environments. Resource-constrained sensor nodes further struggle to support strong security mechanisms without compromising network lifetime. Additionally, frequent topology changes, mobility, and heterogeneous IoT traffic increase vulnerability to attacks such as packet dropping, spoofing, and energy exhaustion. These limitations highlight the need for an integrated cross-layer approach that jointly optimizes energy consumption and security performance to ensure reliable, secure, and long-lasting IoT-MANET-WSN operations.

**RESEARCH SIGNIFICANCE**

The research on cross-layer optimization for energy and security in IoT-MANET-based Wireless Sensor Networks is significant as it addresses two critical and interdependent challenges: limited energy resources and increasing security threats in dynamic network environments. By enabling coordinated interaction among the physical, MAC, network, and application layers, the proposed approach reduces redundant processing, improves energy efficiency, and enhances real-time threat detection without introducing excessive overhead. This research contributes to the development of resilient and long-lasting IoT-MANET-WSNs capable of supporting mission-critical applications such as disaster management, military communication, smart transportation, and healthcare monitoring. Furthermore, the findings provide a scalable framework for designing secure and energy-aware protocols, advancing the practical deployment of intelligent and sustainable wireless sensor networks.

**V. LITERATURE REVIEW**

**Namita K. Shinde et al. [1]** There are two main design issues in Wireless Sensor Network (WSN) routing including energy optimization and security provision. Due to the energy limitations of wireless sensor devices, the problem of high usage of energy must be properly addressed to enhance the network efficiency. Several research works have been addressed to solve the routing issue in WSN with security concerns and network life time enhancement. However, the network overhead and routing traffic are some of the obstacles still not tackled by the existing models. Hence, to enhance the routing performance, a new cluster-based routing model is introduced in this work that includes two phases like Cluster Head (CH) selection and Routing. In the first phase, the hybrid optimization model, Tasmanian Integrated Coot Optimization Algorithm (TICOA) is proposed for selecting the optimal CH under the consideration of constraints like security, Energy, Trust, Delay and Distance.

**G.R. Rama Devi et al. [2]** MANET (Mobile ad-hoc networks) is typically a no-infrastructure multi-hop network where every node interacts with other network nodes either indirectly or directly via intermediate nodes. A lot of research is being undertaken to save the energy of mobile nodes at different levels. Power-relevant issues can have an effect on every layer of the stack, making the traditional layered approach ineffective. In this work, cross layered routing protocol based on PSO (Particle swarm optimization) with adapted contention window technique is proposed. To form consistent and energy efficient routing paths, PSO algorithm uses Traffic index, Average energy load, data success rate & trust value parameters that are computed from network layer. After establishing routing paths, network's contentions are measured MAC layers for communications and contention with measured contentions and average energy loads.

**S. Harihara Gopalan et al. [3]** Internet of things (IoT) is an inventive technology which

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permit the association of physical things by means of the digital world throughout the use of heterogeneous networks and communication technologies. Ad-hoc routing protocols may be dispersed and involve every node in route discovery process by making routing data more reliable. Mobile-Adhoc-Networks (MANETs) consist of many portable nodes that can commune directly with each other or through intermediate nodes. Repeatedly, nodes in a MANETs operate with batteries and can roam freely, and thus, a node may exhaust its energy or move away without providing any notice to its cooperative nodes. IoT system using a combination of MANET, a route consists of numerous links in sequence, and so, its lifetime is based on the lifetime of every node and also the wireless links among adjacent nodes.

**Sherril Sophie Maria Vincent et al. [4]** WSN (Wireless Sensor Network) is considered as one of the promising technologies which are utilized in various fields for various applications. Along with it, MANET (Mobile Ad Hoc Network) has attracted a distinct attention, as they serve communication means across innumerable domain. In recent years, due to the development of both wired and wireless technologies, attacks are becoming more frequent and these attacks can be in various form such as worm hole, black hole, grey-hole, sinkhole and others. These attacks can cause loss of security, increase the number of drop packets, decrease packet delivery ratio which result in poor routing performance. In order to overcome these issues, the proposed study employs PBCS (Particle Bee Colony Swarm) algorithm for finding the shortest path between the nodes, which helps in reducing the routing cost and makes the model more efficient and effective. In addition to this, Hybrid AdaBoost-Random forest algorithm is utilized in proposed model. This model helps in reducing the training time which makes the model more reliable and efficient than existing models.

**Sabir Ali Changazi et al. [5]** Internet of Things (IoT) has emerged as one of the most promising technologies of the modern era, enabling connectivity between devices and systems for efficient data exchange and enhanced user experience. However, the optimization of IoT networks remains a significant challenge due to the complexity of the interconnected devices and systems. To overcome this challenge, various techniques to optimize networks and algorithms for enhancing the robustness of the network topology have been proposed. Artificial intelligence is also used to achieve the robustness of network topologies in IoT through AI-driven predictive analytic. This article reviews the state-of-the-art optimization techniques and algorithms for topology robustness in IoT networks, highlighting the open issues and challenges in this field. The article begins by providing an overview of IoT network optimization and the need for topology robustness.

**A. Chandra et al. [6]** Mobile ad hoc wireless networks (MANETs) are decentralized, lacking fixed infrastructure, which enables dynamic and flexible communication between mobile nodes. However, these networks face challenges such as limited energy resources, frequent topology changes, and performance degradation caused by node misbehavior. Existing protocols like AODV have significant limitations, including a lack of energy awareness, an inability to detect malicious behavior, and the absence of secure transmission mechanisms. These weaknesses lead to rapid energy depletion and increased vulnerability to attacks. To address these issues, this paper proposes a novel energy-aware unobservable routing protocol.

The new protocol introduces custom packet types, such as PT_NID, PT_GID, and PT_CREV, to monitor the real-time behavior of neighboring nodes and to manage route revocation.

**Reham R. Mostafa et al. [7]** Unmanned Aerial Vehicle (UAV) technology has advanced rapidly, with broad use in both the military and commercial sectors. As a result, multi-UAV networks, also known as Flying Ad Hoc Networks (FANETs), have become a vital part of current communication systems. However, FANETs confront numerous challenges such as limited energy resources, high mobility, frequent topological changes, and inconsistent communication links. These difficulties influence network stability, limit data transmission efficiency, and shorten network longevity. Addressing these issues requires an adaptable routing strategy in FANETs. Cluster-based routing in UAVs is a great way to save energy, increase scalability, and improve network performance. This paper introduces a new clustering and routing framework for FANETs based on the Enhanced Genghis Khan Shark Optimizer (EGKSO).

**M.V.B. Murali Krishna M et al. [8]** A VANET is a kind of IMS, or intelligent transportation system, that connects moving vehicles. Guaranteeing timely and accurate information sharing between vehicles and infrastructure helps make roads safer and more efficient. Wireless connections are used for data transmission in VANET, making security a critical design challenge. At the same time, the energy constrained ability of the vehicles in VANET creates energy efficiency as a challenging problem. In this aspect, this study presents an effective invasive weed optimization algorithm based energy efficient clustering with deep wavelet neural network based intrusion detection (IWOEEC-DWNN) technique for VANET.

**Gajjala Savithri et al. [9]** In the world of wireless sensor networks (WSNs), optimizing performance and extending network lifetime are critical goals. In this paper, we propose a new model called DTLR-Net (Deep Temporal LSTM Regression Network) that employs long-short-term memory and is effective for long-term dependencies. Mobile sinks can move in arbitrary patterns, so the model employs long short-term memory (LSTM) networks to handle such movements.

**G. Vidhya Lakshmi et al. [10]** The TAM protocol is designed with a Two-Tier Security Mechanism (TTSM). In the first level of security, trustable nodes are selected based on their ability to process control messages. The recommended trust value of a node is determined by estimating the speed at which it processes control messages, with higher energy nodes being considered more trustable. In the second level of security, the original node identity is concealed, and data is transmitted through selected trusted nodes with duplicate identities generated using a factorial recursive function. This ensures secure transmission, as malicious observers are unable to identify participating nodes in the routing operation. The proposed TAM model is evaluated and compared with state-of-the-art schemes such as A Multi-attribute-based Trusted Routing for Embedded devices (EMBTR) and a cognitive energy-efficient-based trusted model (CEMT). Experimental evaluation demonstrates that the TAM model achieves better performance in terms of energy consumption, delay, packet delivery rate, and false node detection rate, thereby improving network optimality.

## VI. CONCLUSION

This synopsis work presents a Power Consumption Protocol Physical, Mac and Network (PCP-PMN) based on cross layer for Wireless Sensor Networks which uses three layers (Physical, Mac and Network) with the aim to study the energy consumption. Energy efficiency is the major factor that determines the lifetime of WSNs. The main contribution of our work, an energy optimization approach for wireless sensor networks is present, named PCP-PMN based on a Cross-layer approach between physical, MAC and Network layer. PCP-PMN obtains at the physical layer the minimum transmission power and gives this node a higher priority. Then used this parameter as a metric to make improvement of proposed routing algorithm based on LEACH protocol at the network layer and to perform scheduling by using proposed hybrid spread spectrum at the mac layer. Our algorithm improves reliability of communications, saves energy and uses bandwidth more efficiently

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