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A Cross-Layered Design of Routing Approach for Reliable Internet of Medical Applications

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Abstract

The Internet of Health Things (IoHT) comprises intelligent, low-power, tiny node sensors that monitor signals from the body and transmit them to submerged nodes over wireless connections. IoHTs possess many uses in e-health and private health monitoring. Due to the delicate nature of the data assessed by the devices and the power limitations of the sensor nodes, dependability and energy efficiency are paramount in communication within IoHTs. The reliability is compromised by the heightened loss of packets resulting from suboptimal MAC and routing algorithms, ambient interference, and body shadows. Ineffective node choice for routing concurrently leads to a shortage of energy reserves in crucial nodes. Recent developments in cross-layer protocol improvements have demonstrated their efficacy for packet-based Internet. The paper proposes a Routing-based cross-layer method for secure communication that conserves the energy resources of nodes that transmit sensors in the IoHT. The suggested methodology is expanded to encompass multiple sensor systems, wherein nearby sensors collaborate and coordinate for data transmission. The efficacy of the suggested technique is assessed using metrics such as Packet Loss, Delays, and energy consumption per data packet. The findings demonstrate that the proposed solution enhances the dependability and efficiency of energy relative to the Basic Opportunistic Routing method.

Keywords: Cross-layered Design, Routing Approach, Internet of Medical Things, Reliability.

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Introduction

The Internet of Health Things (IoHT) (Rodrigues et al., 2018) is a component of the Internet of Things (IoT) (Abdul-Qawy et al., 2015) focused on detecting biological signals from individuals and older people for e-health applications. The IoHT encompasses essential sensors for e-health services, facilitating remote and local monitoring of patients and older adults. In IoHTs, monitors detect electrical impulses from the human body and transmit them to a regional or distant server via numerous networks and terminals. These diminutive sensors are resource-limited nodes affixed to the human being in both intrusive and non-invasive ways to assess various physiological states for medical or eldercare applications. The significance of sensor-reported data is paramount in preserving lives and facilitating a good recovery, contingent upon the monitored situation. The signals detected by the sensors and the information sent are of paramount significance. The sensor nodes used in the IoHT are more minor in quantity than those in Wireless Sensor Networks (WSN) (Carlos-Mancilla et al., 2016), where sensor networks are plentiful; hence, the power supply of each IoHT sensor node is paramount.

Dependable and energy-efficient sensor connectivity is a crucial performance metric in low-power heterogeneous networks. The inconsistent and energy-ignorant transmission in IoHTs interferes with the data gathered by sensors on an individual, potentially leading to severe effects and life-threatening outcomes. Hospital personnel do not receive timely notification regarding the patient's critical condition, obstructing adequate surveillance. Users are directed to the given survey for further information on reliability concerns in IoHTs and critical variables. Implementing the IoHTs for healthcare and geriatric care necessitates stability and sustained power since vital and medical conditions require remote monitoring.

The cross-layer methodology achieves optimal Quality of Service characteristics (UR Rehman et al., 2017). This subsequently integrates multiple protocol communication layers, enabling the exchange of information in a non-hierarchical fashion. Routing algorithms are categorized into flat and hierarchical types based on the network's structure. According to flat routing standards, each sensor node must serve a similar function to minimize network cost.

The supplemental features include bandwidth for transmitting communication among the groups, energy-efficient routing system location between the groups, and preserving duplicate data transfer across the nodes (Nakas et al., 2020). Every head in the group assumes full responsibility for transmitting data. The procedure of selecting the best head is exceedingly absurd. The choice of Cluster Head (CHs) pertains not only to data transfer but to the intricacies of energy use during every connection (Jesudurai & Senthilkumar, 2019). Additional study is underway regarding the appropriate selection of head clusters. Optimizing techniques have experienced numerous revisions and advancements to address complicated issues.

Background

The study presented a routing system for diverse networks based on a cross-layer routing system that emphasizes energy conservation through dynamic threshold-sensitive dispersal. The weighted likelihood theory was utilized to select the cluster's CH. The simulation, evaluation, and comparison of the suggested method were conducted alongside traditional protocols for routing, demonstrating its efficacy in network longevity.

A study has developed a strategy for loss-and-delay sensitivity WSNs to reduce delay and enhance communication connection dependability (Liu et al., 2018). The efficiency of the entire network was further boosted using optimization limitations: Even with increased transmission distance, fewer hops are required for packet delivery. This diminished the time, and reliability was improved due to the dependability products of each router path run. The count decreased when each dependability hop resembled traditional models.

The study has deployed an altered algorithm to enhance and optimize the network's efficiency. This paper primarily focused on the system's Media Access Control (MAC) (Sotenga et al., 2020) and physical levels of sensed routing data. It was directed to the nodes with the highest power nearest to the sink via an innovative method and the material layer data. The protocol utilized the MAC level to ascertain the node's operation cycle and prolong the sleep mode duration.

Research has identified several challenges in WSNs, including developing innovative network protocols, creating novel communication techniques, and evaluating solutions in practical scenarios. This study offered various cross-layer design methodologies in Wireless Multimedia Sensor Networks (WMSNs). Various conventional cross-layer optimization methods were analyzed based on these fundamental architecture principles. The forthcoming studies delineate the promising difficulties and issues.

Proposed Cross-layered Design of Routing Approach

This structure presents a narrative methodology that utilizes a cross-layer process across various layers, as illustrated in Fig. 1. The mechanism guarantees high efficiency in establishing WSNs for optimum energy use.

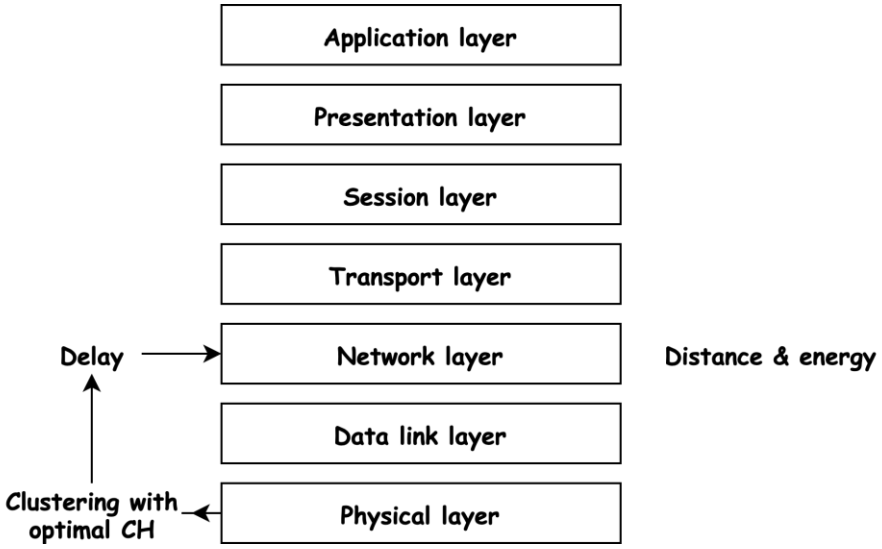


Fig. 1: Layered architecture

The cross-layer approach primarily aims to enhance Quality of Service (QoS). It depends on many communication method levels for sharing data non-hierarchically. A clustering-based routing system is proposed, wherein the ideal cluster head is determined by evaluating several constraints such as distance, tardiness, and energy consumption. The specified parameter assessment occurs inside the designated cross layers: the evaluation of distance and energy use for nodes defined as heads is conducted in the physical layer of the system. At the same time, delay is assessed in the entire network layer.

Encoding of Solutions

This research presents a cross-layer architecture within a cluster-based routing concept. The choice of an ideal cluster head is a challenging undertaking. The choice must consider specific parameters such as distance, latency, and energy. This is identified as the optimization issue, and a novel hybrid technique has been presented to address it.

Suggested Model

This work introduces an innovative hybrid method that integrates the concepts of optimization. The Whale Optimization Algorithm (WOA) emphasizes the necessity of remodeling the Grey Wolf Optimizer (GWO) idea. The benefits associated with this hybrid are outlined below:

Improvement in scalability facilitates the resolution of large-scale issues with manageable processing resources. Focus on acquiring a critical understanding regarding convergence speed and rate. Decreased time complexity.

Step 1: Set the solution parameters.

Step 2: Assess the fitness of every search agent, where F* represents the optimal search agent.

Step 3: If the current iteration p is smaller than the highest repetition, change the vector values J L to reflect the likelihood of each circumferential path pr for each search agent.

Step 4: If the likelihood is below 0.5 and |J| is less than a specified threshold, the location updating is assessed by the encircling device updating, where the location vector is denoted as F, and F* represents the element-wise multiplying.

$$\vec{F}(p+1) = \vec{F}^{*}(p) - \vec{J}\vec{V} \quad (1)$$

Step 5: If $|J| \geq 1$, select the random searching agents from the randomly chosen value of whale in the latest test run (Frand) and adjust the current search agents' location.

$$\vec{F}(p+1) = \vec{F}_{rand} - \vec{J}\vec{V} \quad (2)$$

Step 6: When the likelihood is greater than or equal to 0.5, the location update is executed via a new spiral revision, wherein $\vec{F}_1$ $\vec{F}_2$, and $\vec{F}_3$ They are assessed according to the pertinent alpha, beta, and delta formulations in the GWO method.

$$\vec{F}(p+1) = \frac{\vec{F}_1+\vec{F}_2+\vec{F}_3}{3} \quad (3)$$

Step 7: Assess the fitness of each searching agent and revise F∗ according to the optimal answer.

Results and Findings

This work primarily addresses geriatric residential healthcare environments. The use of this domain is crucial and strategic, as it allows patients greater autonomy while ensuring they remain under medical supervision. These bright medical rooms are equipped with WiFi to gather various forms of data on patients. The research examines a standard, sophisticated terminal environment measuring 1500 m × 1500 m, where 100 patients are monitored by a Wireless Body Area Network (WBAN). This region is serviced by eight WiFi Access Points (AP) with a connecting range of 100 meters. Each WBAN exhibits a star structure, with an administrator C positioned at the center and six sensor devices surrounding it.

Table 1: Result Analysis

Method	PDR (%)	Latency (ms)
EM-PCLRP	43.37	253.42
DS-PCLRP	29.43	184.31
GM-PCLRP	31.24	194.23
WASP	38.04	164.85
EM-DMQoS	25.94	208.43
DS-DMQoS	36.01	143.21
GM-DMQoS	41.28	109.36

Table 1 displays the Packet Delivery Ratio (PDR) and latency measured during different periods. The optimal results for the PDR are seen during the CFP time. This is attributable to the elevated probability of collisions and interference in the CAP period, exacerbating packet losses. As anticipated, the PDR diminishes with a rise in package rate, with a more pronounced decline observed for GM packets compared to DS and EM data packets due to the prioritization in packet servicing. PCLRP surpasses DMQoS (across all traffic categories) and WASP at every evaluated rate, as it guarantees node synchronization and fewer transmission delays compared to DMQoS and WASP. The scenario assesses the efficacy of PCLRP concerning executed backoff and latencies. The backoff latency is evaluated for PCLRP and WASP, as DMQoS does not address the network access problem. EM transmissions exhibit minimal delay, whereas GM packets demonstrate the most latency. This outcome is anticipated, as PCLRP nodes with the most significant priority possess the smallest backoff, delays, and assured slots.

Conclusion

This research proposes a cross-layer MAC and routing method to enhance the dependability of sensor connection in the IoHT. The proposed study's primary aim is to improve communications' reliability in IoHT while conserving the energy resources of node sensors. The model employs a timer-based relay selection method reliant on residual power. The node nearest to the sink with the most significant remaining energy will be chosen as the relay node. The efficacy concerning diverse payload sizes, node quantities, and packet interarrival intervals has been assessed and examined in the simulation outcomes designed for WBANs and multi-WBAN configurations. The suggested model enhances dependability, network longevity, end-to-end delay, and energy savings for the IoHT. The network lifetime is enhanced by roughly 12% for WBANs and 8% for multi-WBANs, while the delay is reduced by 2.8 ms for WBANs and 1.4 ms for multi-WBANs. The research intends to enhance the interface to increase its reliability further. The aim is to examine alternative channel designs and integrate node portability into the modeling process.

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