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Improving Network Efficiency in Video Traffic Analysis using Wireless Sensor Network

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Abstract: Wireless Sensor Network plays an essential role in present time in various data-centric applications such as environmental monitoring, enemy detection, etc. Due to increased vehicle demands, there is a need for video traffic monitoring for the monitoring of traffic and WSN plays an essential role in the forecasting real-time traffic monitoring system. In this work, a data collection and routing protocol is proposed. The proposed protocol improved the network performance by reducing the Fist Node Dead, Half Node Dead, Last Node Dead, and number of alive nodes at different intervals, energy consumption in the network.

Keywords: *WSN, Fist Node Dead, Half Node Dead, Last Node Dead, environmental monitoring*

1. Introduction

In order to gather and transmit data from cameras and other sensors in a dispersed and dependable manner, Wireless Sensor Networks (WSNs) can play an important role in video traffic analysis [1]. WSNs can be used to collect data from sensors that are scattered throughout a large region, including video cameras, microphones, and others. After receiving the data wirelessly, a central processing unit may examine it [2], [3]. WSNs may be used to combine information from several sources, such video cameras and audio sensors, to give a more thorough picture of the scenario being watched. As a result, a more accurate image of the traffic flow may be provided, and abnormalities can be found, which can increase the precision of video traffic analysis [4]. Real-time monitoring of video traffic data by WSNs enables quick identification and remediation of security concerns or traffic infractions [5]. This can enhance public safety and help avoid accidents. According to the size of the region being monitored, WSNs are easily deployable and scalable up or down. As a result, they provide an affordable option for video traffic study in both urban and rural. WSNs can, in general, increase the effectiveness and accuracy of video traffic analysis, by offering a distributed and dependable platform for gathering, sending, and processing data from many sources [6].

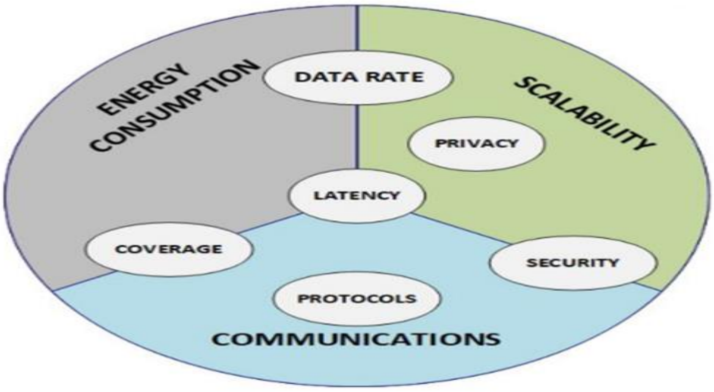

Fig.1. WSN Challenges domain.

Security and surveillance, traffic management, and business information are just a few of the uses for video traffic analysis [7]. By examining recorded or live security camera footage, video traffic analysis can assist uncover security concerns. It may identify odd behavior like loitering or vehicles parked in forbidden areas [8]. By comparing images to a predefined database of known suspects, it can also assist in spotting suspicious people or cars [9]. By identifying and examining vehicle

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movements at junctions and on highways, video traffic analysis can assist regulate traffic flow and lessen congestion [2]. It can identify traffic infractions including running red lights or making illegal turns, and it can send notifications to traffic management facilities or law police. Video traffic analysis may offer insightful data on customer behaviour and preferences, including dwell periods, foot traffic patterns, and demographic data [10]. Businesses may benefit from optimising their shop designs, product positioning, and marketing tactics. Overall, video traffic research may increase public safety, lessen traffic, and offer insightful information for businesses.

Even though adopting Wireless Sensor Networks (WSNs) for video traffic monitoring has numerous advantages, there are still a number of issues that need to be resolved [2], [11]. Sensors used by WSNs are powered by batteries, which have a finite lifespan. Energy-efficient solutions are therefore necessary to extend the sensors' lifespan and decrease their energy usage. The breadth and precision of video traffic analysis may suffer due to the constrained communication range of WSNs. WSNs must be built to handle multi-hop communication and relay nodes to increase the communication range in order to solve this difficulty. Security concerns against WSNs include data alteration, interception, and unauthorised access [12]. Therefore, to guarantee the security and integrity of video traffic data, powerful encryption and authentication procedures are required. Other wireless devices using the same frequency range as WSNs might interfere with their functioning. The reliability of video traffic analysis can be lowered by interference, which can result in packet loss. It becomes increasingly difficult to handle and analyse the data as a WSN's complexity rises along with the number of sensors and data sources. Scalable solutions are therefore required to guarantee the effective and efficient operation of WSNs. In conclusion, overcoming these difficulties is crucial to the effective deployment and operation of WSNs for video traffic analysis.

2. Related Work:

In [13], the authors have focuses on the real-time communication limitations of the current service delivery architectures. Priorities are assigned using an effective queuing method that takes queue length and input data type into account. Real-time traffic and low capacity networks are both protected by this queuing method. The over-provisioning of resources, latency, and packet loss ratio are all decreased by the model.

In [14], the authors have proposed a solution for stochastic optimisation issue the reduction of the time required to finish the distributed visual based analysis for a video series subject to a mean average accuracy criterion. The authors have suggest a fix based on two different composite predictors that recover randomly missing piece of data, linear approximations of the feature distribution based on quantiles, and time series analytic techniques.

In [15], the authors have proposed a solution an Integrated WSN Solution for high yield agriculture. The sole cost-cutting approach deployed, IEEE 802.15.4, successfully integrates operations for crop data collection, data communication to the end user, and video monitoring. Their model evaluated for the specific situation of video data based surveillance of distributed crops using computer modeling and crop data analysis. The ideal data communication metrics include energy consumption, frame collision probability, and end-to-end delay since they have been thoroughly examined to give the optimal wireless network working.

In [16], the authors have proposed an investigation of video sensor-based wireless sensor network transmission performance. The suggested routing method is based on LAR, Direct Diffusion, and Flooding. It has been modified to support constant video data transmission. Unless the original methods, it takes into account the requirements of video streams for transmission quality. Simulation evaluation displays the predicted performance overall and places special attention on a few delicate areas.

In [17], the authors have proposed a method for avoiding the burning of motes is one of the biggest concerns when using a WSN to follow a fire front. In order to detect a fire's progress through vegetative fuels on a field size, this research illustrates the efficacy of wireless sensor networks using thermally insulated motes.

In [18], the authors have proposed a method to enhance video streaming in WSNs' energy, distortion, and encryption performance. This work makes two contributions. In order to reduce the additional encryption dependence burden at the application layer, a channel-aware selective encryption technique is first presented. Second, a network resource allocation plan based on uneven error protection (UEP) is suggested to increase the effectiveness of communication at the lower tiers.

In [19], Levelling, sectoring, and adaptive clustering for video traffic will all be reconsidered in the proposed strategy. Using multi-hop communication, the network might be divided into clusters to handle the video traffic needed for data distribution to the base station. The core concept of this routing system is to make the cluster head selection and cluster size dynamic.

In [10], the authors described a unique system that provides drivers with cutting-edge services. With the help of these services, drivers may remotely obtain data on the volume of traffic and the number of parking spots at their destination. An Android smartphone application is used to implement this capability. This system's main objective is to assist drivers in avoiding traffic congestion by giving real-time traffic rate updates that enable them to choose alternate routes as needed. The technology also seeks to make it easier to locate available parking spaces, which will cut down on pointless excursions.

In [20], This study's objective is to evaluate a traffic volume measurement-based algorithm that dynamically activates and deactivates various cameras depending on the real need to keep an eye on a given area. This approach was developed to address both network topology and workload situations by using a fuzzy logic controller for flexible QoS management.

In [21], the authors introduced and thoroughly analyzed a number of error-control techniques in the context of Wireless Multimedia Sensor Networks (WMSNs), including Forward Error Correction (FEC), Erasure Coding, Automatic Repeat Request (ARQ), link-layer hybrid ARQ/ FEC, and cross-layer based hybrid strategies. This research concentrates on a number of performance metrics, including energy economy, frame loss rate, frame Peak Signal-to-Noise Ratio (PSNR), cumulative jitter, and delay oriented constrained based PSNR. The assessment offers a full comprehension of the performance traits of various strategies in WSN.

In [22], the authors wanted to accomplish the following goals: create a wireless video sensor node that can process video on-board that is low-power, economical, and power-aware. This is accomplished by integrating energy collecting technologies, low-power hardware design, power management strategies, and local processing capabilities. Make a smart camera that uses less energy and has high-precision abandoned/removed item detecting technologies [23]. The article includes experimental findings that show how their strategy performs well in terms of power use, video processing precision, and long-term operating viability.

3. Proposed Model

WSN typically comprises of sensor nodes with limited power supply, radio communication channels, and base stations (BS). Therefore, creating a novel routing protocol with the best chance of choosing CHs is really vital. Designing an energy-efficient routing approach with appropriate CH selection and cluster formation, however, remains a challenging challenge for many researchers. The LEACH protocol has undergone several improvements in order to handle cluster choices. In order to attain signal strength, LEACH relies on cluster node development, and the nearest CHs serve as a switch to convey the data to the sink. In this study, we introduced a novel algorithm combination that combines the micro genetic algorithm with the LEACH protocol to provide superior CHs selection for each cluster while taking into consideration enhanced network performance due to an extended sensor network lifespan in the application of video traffic monitoring.

In the proposed method, we have devised a novel approach for selecting Cluster Heads (CHs) based on the hybrid-genetic algorithm (HGA). This algorithm enables us to identify optimal CHs within the network, considering various factors such as energy efficiency, connectivity, and load balancing. By leveraging this intelligent selection process, our method enhances the overall performance of the system. To facilitate efficient communication between CHs located at larger distances and the sink, relay nodes are proposed. These relay nodes act as intermediaries, effectively bridging the gap and improving the reliability of data transmission. By strategically placing these nodes, we can overcome the challenges associated with long-distance communication, ensuring seamless connectivity and reducing signal degradation. To evaluate the effectiveness and performance of our proposed HGA-LEACH protocols, we have employed the first radio model [10]. This model provides a comprehensive analysis of our protocols, enabling us to assess their efficiency and reliability. By utilizing this model, we gain valuable insights into the transmitted and received energy over k-bits, which are vital metrics in evaluating the system's overall energy consumption and efficiency.

Equation 1 quantifies the transmitted energy over k-bits, capturing the energy expenditure involved in transmitting data packets within the network. This equation takes into account various factors, such as transmission power, distance, and network topology, providing a comprehensive measure of the energy consumed during data transmission.

$$E_{TX}(k,d) = E_{TX-\text{elec}}(k) + E_{TX-amp}(k,d) \qquad (1)$$

Equation 2 represents the received energy over k-bits, which reflects the energy received by the sink or destination node. This equation considers factors such as signal strength, channel conditions, and path loss, providing an estimate of the energy received by the sink after traversing through the network.

$$E_{TX}(k,d) = \begin{cases} k \times E_{\text{elec}} + k \times \varepsilon_{fs} \times d^2 & d < d_o \\ k \times E_{\text{elec}} + k \times \varepsilon_{\text{amp}} \times d^4 & d \geq d_o \end{cases} \qquad (2)$$

Equation 3 further expands on the received energy over k-bits, taking into account additional factors that influence energy reception. These factors may include interference, noise, and other environmental conditions that affect the overall energy reception at the sink.

$$E_{RX} = k \times E_{\text{elec}} \qquad (3)$$

By incorporating these equations into our evaluation framework, we can quantitatively analyze the energy dynamics and performance of the proposed HGA-LEACH protocols. This analysis aids in fine-tuning the system parameters, optimizing energy consumption, and ensuring efficient operation of the network

4. Proposed Algorithm

```
Step 1: Initialize the network and GA parameters
Step 2: Start the iteration with minimum number of generation
Step 3: Find best individual among the nodes using roulette wheel method
Step 4: Perform elitism to compute the best value among the best individual
Step 5: Evaluate the fitness function based on the elitism
Step 6: Preparation Phase:
                If r < T (n)
                If g(1,i) > min
                CH(s) ← TRUE          // CH(s) = CM(s)
                else
                Relay ← TRUE
                end if
Step 7: Setup phase:
        If CH(s) = TRUE then
                Broadcast (adv) →Cluster Members
                Join (ID_i)
                Cluster (c)
        else
                Go to  step 4
        end if
Step 8: Steady state phase:
        If CH(s) = CM(s) then
                R_x(ID_i ,Packets )          //Receive data from CM(s)
        end if
        If CH(s) = CM(s) then
                R_x(ID_i ,Packets )          //Receive data from CM(s)
                Aggregate (ID_i, Packets)          //Aggregate Received data
                T_xtoBS (ID_i, Packets)    //Transmit Received data
        end if
```

a. **H.264/AVC Video Codec :** H.264/AVC, also known as MPEG-4 part 10 Advanced Video Coding (AVC), is a widely used video coding standard that has been recommended by the ITU-T (International Telecommunication Union - Telecommunication Standardization Sector) as International Standard 14496-10 and by the ISO/IEC (International Organization for Standardization/International Electro technical Commission) [12][13].
b. **Video Encoder:** The creation of compressed bit streams using H.264/AVC, which requires prediction, DCT transform, and encoding for the input video, is demonstrated in Figure 2.
c. **Video Decoder:** In order to recreate the video sequence and recover the original input video, the H.264 decoder must execute decoding, inverse DCT transform, and reconstruction procedures.

5. Video Traffic Data Transmission Over Proposed Protocol

In wireless sensor networks (WSNs), video transmission across a hierarchical routing algorithm poses a significant problem. HGA-LEACH- (Hybrid Genetic Algorithm-Low-Energy Adaptive Clustering Hierarchy) is used in the context of WSNs to transmit video traffic data, specifically using H.264/AVC. The steps involved in this process are as follows:

Step 1: Establishing a WSN with 'N' nodes:

Establishing a wireless sensor network (WSN) with a predetermined number of nodes, designated as "N," is the initial step. To create an appropriate coverage, these nodes can be dispersed throughout the network region. Although the WSN may have a variety of nodes, in this instance, we concentrate on the video sensor nodes that are in charge of gathering video data. To carry out its assigned functions, each node is furnished with sensors, communication tools, and processing units.

Step 2: Locating the base station and locating the video sensor nodes

A particular number of nodes, denoted as "M," are assigned as video sensor nodes solely responsible for video sensing tasks among the "N" sensor nodes in the WSN. These video sensor nodes are positioned carefully to record footage from the surroundings. In order to facilitate communication and data aggregation from the sensor nodes, a base station (BS) is also positioned in the network's core. The base station acts as a hub for processing video data after it is collected from the video sensor nodes for transmission and storage.

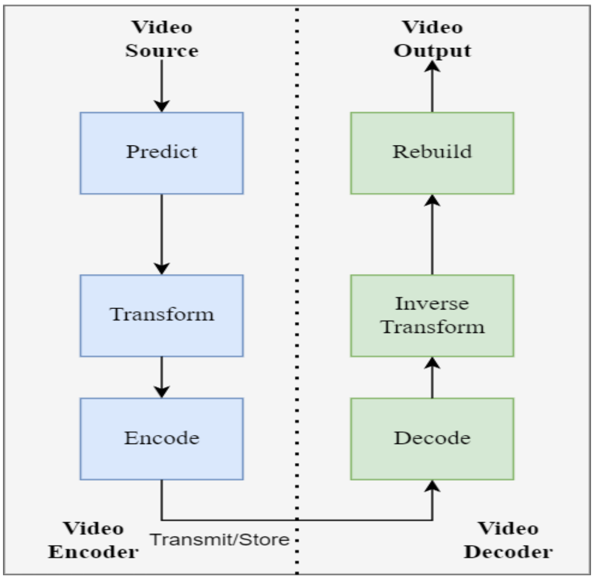

Fig.2. Video traffic data encoding/decoding

Step 3: Use HGA-LEACH to determine the shortest path:

The proposed HGA-LEACH protocol used to get the optimal path between Cluster Heads (CHs) and BS to connect the source and destination sensor nodes.

Step 4: Delivery of video traffic data:

Video traffic data is delivered via the network using the H.264/AVC encoding mechanism after determining the optimal path.

Step 5: Receive of video traffic data:

The transmitted video is rebuilt using the H.264/AVC decoding technique at the receiver end node.

Step 6: Performance evaluation:

The performance evaluation of the proposed approach is evaluated using various parameters such as Jitter value, average peak signal to noise ratio, average node dead, number of alive nodes, energy consumption in the network

Figure 3 depicts the flow chart of the proposed HGA-LEACH protocol

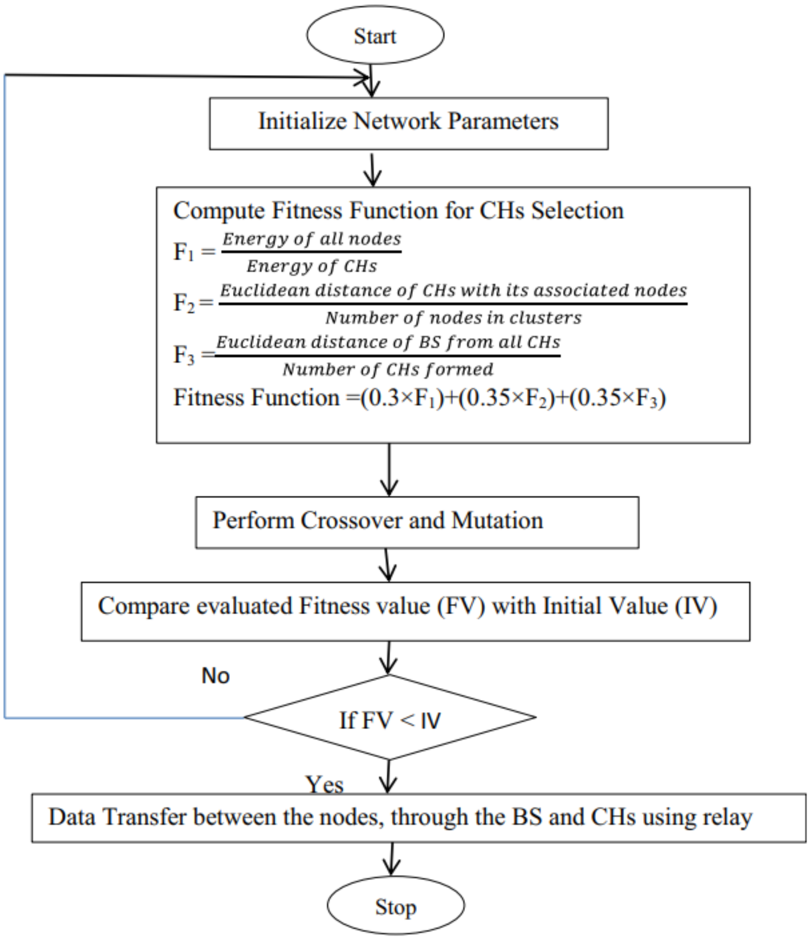

Fig.3. Flow chart of the proposed protocol

6. Simulation Results

In this section, we focus on evaluating the performance of the proposed HGA-LEACH technique through simulation in MATLAB. We have chosen MATLAB as the simulation platform due to its versatility and wide adoption in the field of wireless communication and networking. The network diagram in Figure 4 shows the transmission of video traffic data using conventional H.264 encoding and decoding techniques over a Wireless Sensor Network (WSN).Using the HGA-LEACH technique, we have conducted a comparative analysis of various routing techniques, allowing us to assess the respective strengths of the proposed approach. The different parameters used in the simulation is shown in table 1.

Table 1: WSN parameters for simulation

S.N	Network-parameters	Value
1.	Network size	200 X 200 m^2
2.	Deployed nodes	200
3.	Packet data size	2000 and 4000 bits
4.	Initial energy of nodes	Eo 0.2 and 0.3 J/node
5.	Energy for transmission	ETX 50 nJ/bit
6.	Energy at receiver end	ERX 50 nJ/bit
7.	Energy amplification of short distance nodes	Efs 10 pJ/bit/m2

8.	Energy amplification for long distance nodes	Emp 0.0013 pJ/bit/m2
9.	Aggregation in data energy	Eda 5 nJ/bit
10.	Probability of node for CH	p 0.15
11.	Max no. of rounds	5000

We have considered a monitoring area measuring 200 x 200 m ^{2} and deploy 200 sensor nodes within this region. These sensor nodes are strategically placed or randomly scattered, simulating real-world deployment scenarios. The network topology formed by these SNs serves as the foundation for evaluating the performance and effectiveness of the HGA-LEACH technique.

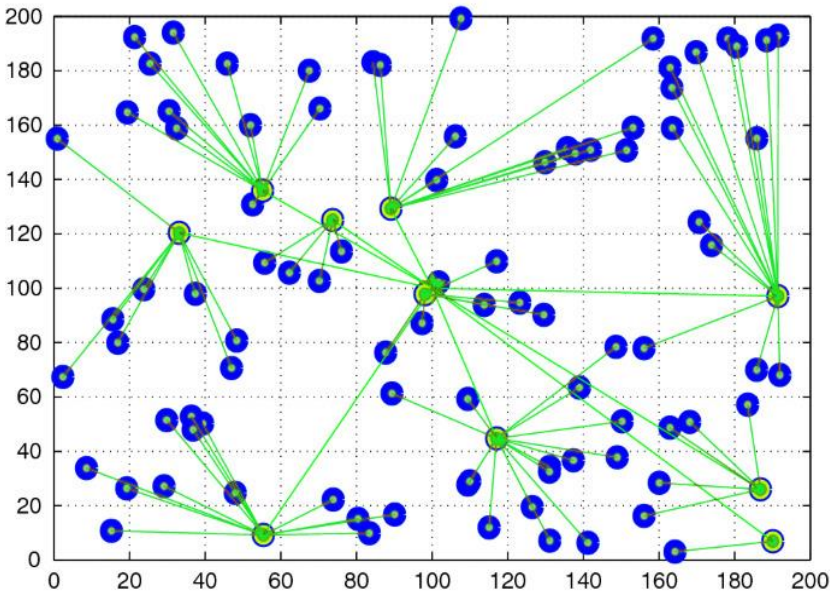

Fig.4. Nodes deployed in 200 x 200 m^2 area

Two short video traffic data used in the simulation are transmitter over the network using the proposed protocol. The different parameters used is shown in table 2.

Table 2: Video traffic data parameters

Parameters	**Video Traffic Data 1**	**Video Traffic Data 2**
Frame Height	180	240
Frame Width	320	320
Frame rate	30	20
Bits per pixel	32	32
No. of frames	16	16
Format of video	RGB24	RGB24

The PSNR (Peak Signal-to-Noise Ratio) and Jitter measurements are used to assess how well the received video performed. These measurements make it possible to analyze the squared mean error between the transmitted and received videos. PSNR and Mean Square Error (MSE) characteristics can be used to get the squared mean error value.

A greater PSNR value (>20dB) denotes a higher-quality image. Typically, PSNR is expressed in decibels (dB). For video files, the PSNR is computed by adding the squared error values for each every frame. Figure 5 shows the average transmission times for video traffic data 1 and 2 are 133 and 210 seconds, respectively.

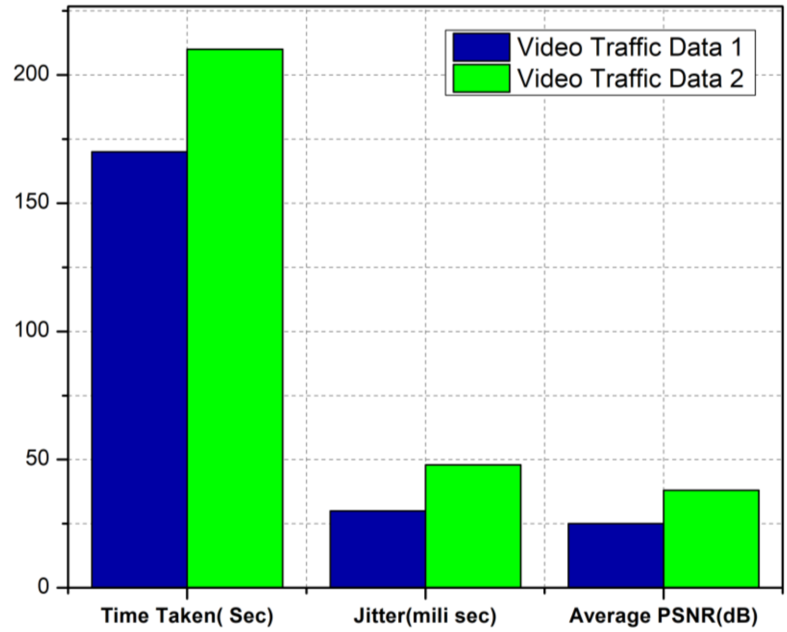

Fig.5. Comparative analysis of video traffic data 1 and data 2

In the simulation of the proposed work, the proposed protocol performed well in the data collection and transmission process and achieved more number of rounds at various time intervals i.e. First Node Dead (FND), Half Node Dead (HND) , and Last Node Dead (LND) , as shown in figure 6.

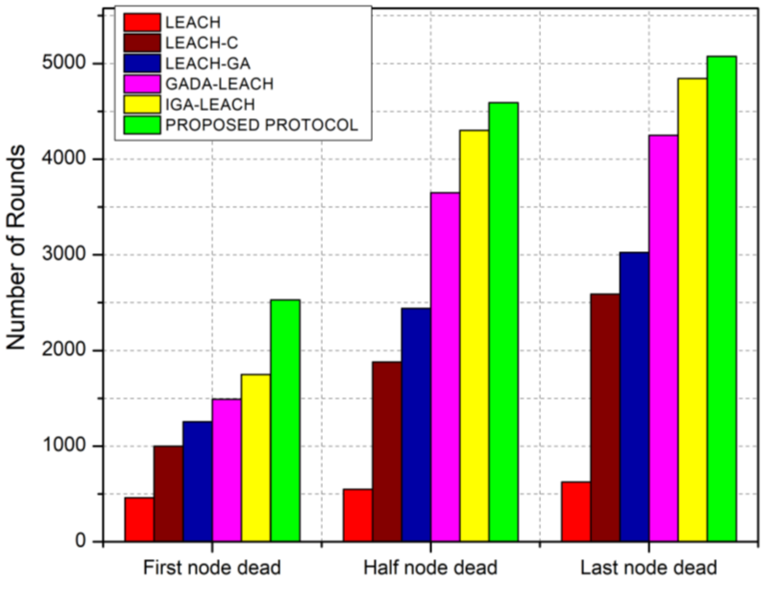

Fig.6. Consumption of **e**nergy at various rounds

Figure 7 depicts the Average Node Dead(AND) in the proposed protocol compared with other protocols.

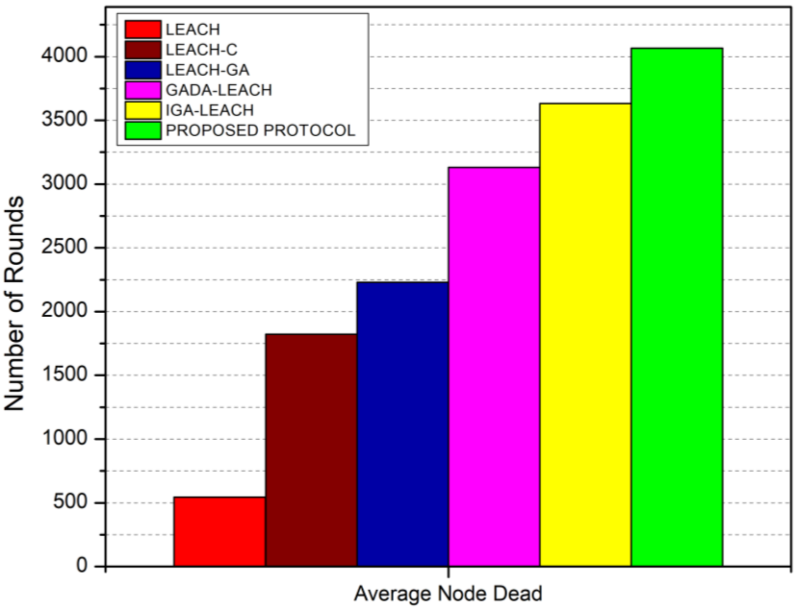

Fig.7. Dissipation of energy for AND

The average node dead(AND) rate is improved in the proposed protocol compared to LEACH, LEACH-C, LEACH-GA, GADA-LEACH and IGA-LEACH protocol. The simulation showed decreased dead node in the network. The total amount of alive nodes Vs the total number of rounds is depicted in Figure 8, which shows the comparative analysis using number of alive nodes in each round in the proposed protocol compared with aforesaid protocols

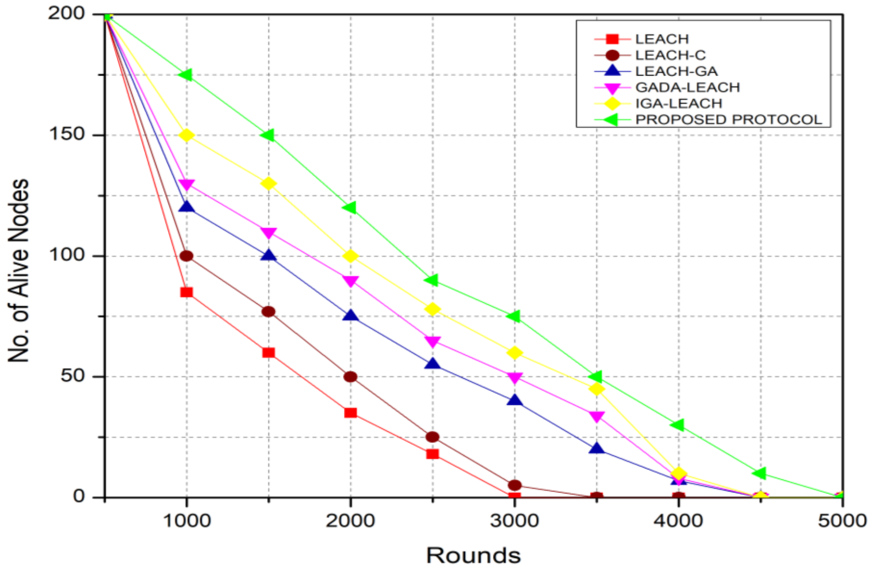

Fig.8. Number of alive nodes

The findings presented in Figure 8 provide compelling evidence that the proposed protocol outperforms existing protocols in terms of preserving the number of alive nodes in various rounds. This remarkable performance shows the efficiency of the proposed protocol in improving the overall lifetime of the network. The proposed protocol optimizes critical aspects such as CH selection and routing process. This holistic approach ensures effective resource utilization within the network while minimizing energy consumption. Consequently, the proposed protocol significantly increases the number of active nodes throughout the simulation. The superior performance of the proposed protocol can be attributed to its ability to maintain a balance between energy efficiency and network longevity. By optimizing cluster head selection, the protocol ensures that the most suitable and capable nodes are assigned as cluster heads, thereby reducing energy wastage and maximizing network stability.

Additionally, the proposed protocol's optimized routing and data transmission processes facilitate efficient and reliable communication among nodes, reducing the chances of packet loss and increasing the network's overall throughput. This further contributes to the sustained activity of a greater number of nodes throughout the simulation. Figure 9 shows the number of alive nodes compared to existing protocols.

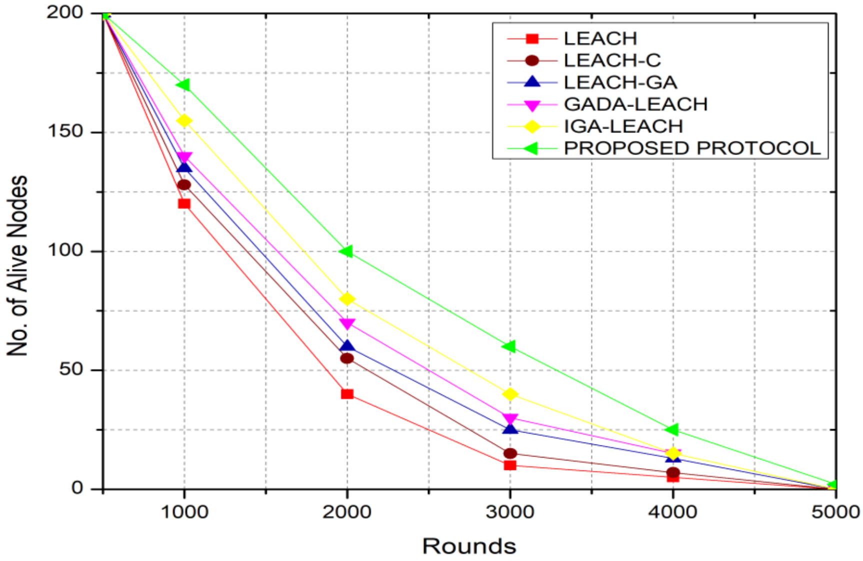

Fig.9. Number of alive nodes in the network at different intervals

In the simulation analysis, the proposed protocol achieved more number of alive nodes compared to existing protocol. Moreover, in the simulation the energy consumption in the network vs total number of rounds is shown in Figure 10.

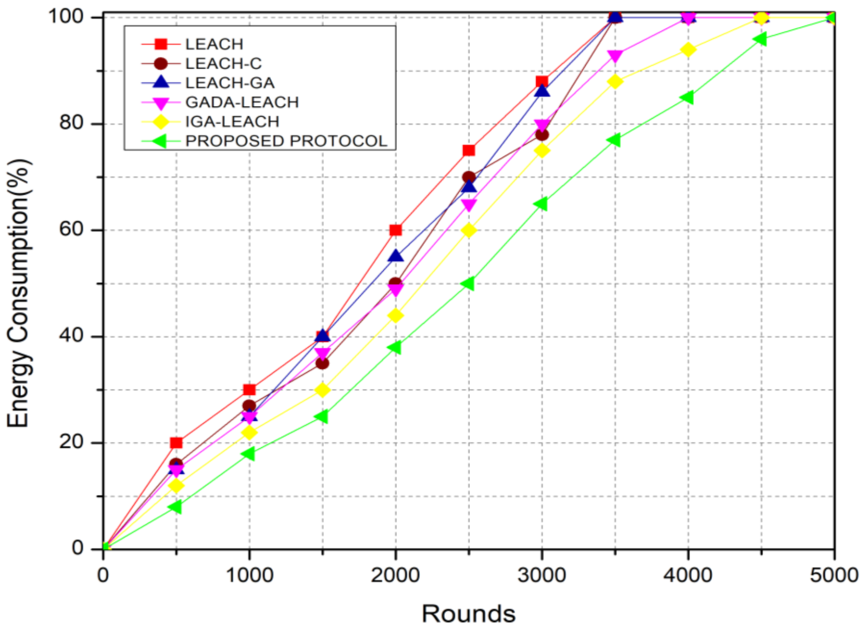

Fig.10. Energy consumption in the network

In the comparative analysis of the simulation, the proposed protocol outperformed other protocols in terms of energy utilization within the network. The proposed protocol achieved Notably, the LEACH, LEACH-C, and LEACH-GA protocols were able to sustain their operation for approximately 3500 rounds, while the GADA-LEACH and IGA-LEACH protocols showed a slightly longer survival time of around 4000 and 4500 rounds respectively. In contrast, the proposed protocol exhibited remarkable resilience by surviving up to 5000 rounds. This extended lifetime can be attributed to the protocol's optimization techniques, which effectively manage energy resources and minimize energy consumption throughout the simulation. By efficiently utilizing energy, the proposed protocol enables nodes to operate for a longer duration, thus increasing the overall network lifetime. The extended survival of the proposed protocol signifies its superiority with respect to energy efficiency and resource management. It showcases the protocol's ability to maintain node activity and sustain network operations for an extended period, thereby maximizing the utilization of available energy resources and enhancing the overall longevity of the network.

7. Conclusion

In conclusion, this paper emphasizes the significance of WSN in data-centric applications such as environmental monitoring and enemy detection. Specifically, the focus lies on utilizing WSNs for real-time traffic monitoring systems due to the increasing demands of vehicular traffic. The proposed data collection and routing protocol effectively improves network performance by reducing First Node Dead, Half Node Dead, and Last Node Dead occurrences, as well as increasing the number of alive nodes at different intervals. Furthermore, the protocol successfully addresses energy consumption concerns within the network. The traffic video data transmission time taken for the two sample data taken 170 and 210 seconds. The findings of this research contribute valuable insights to enhance WSN efficiency in real-time traffic monitoring, although further research is needed to validate its performance in diverse network conditions. Ultimately, this work lays a foundation for advancing WSNs in traffic monitoring and related fields.

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