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WSN Implementation to Prevent Train Track Collapse

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Abstract: In this research, it presents a Wireless Area Network (WSN) routing protocol with high throughput, dependability, and energy efficiency. It uses multi-hop topology to reduce energy consumption and increase network lifetime. It suggests utilizing a cost function to select a parent node or forwarder. The recommended cost function picks a parent node that is close to the sink and has a high residual energy. The residual energy parameter balances the energy consumption among the sensor nodes, while the distance parameter ensures successful packet delivery to the sink. The results of the simulations demonstrate that the suggested protocol maximizes network stability and node uptime. Higher packet delivery to sink is a result of longer stability periods, which is highly desirable for ongoing patient monitoring. This study describes a technical framework that includes sensor placement, base station and sensor node architecture, routing protocols, signal acquisition and transmission, and the establishment of an online monitoring system. The evaluation of linear network topologies based on routing algorithms for train monitoring has been studied using a realistic mesh sensing system. Results show that multi-hop topology outperforms the conventional in terms of end-to-end delay, throughput, and residual energy level. Our protocol approach maximizes network stability and node uptime, according to the simulation results. Longer stability durations lead to higher packet delivery to sink, which is extremely desirable for continual patient monitoring.

Keywords: Routing Scheme, Wireless Sensor Network (WSN), Multi Hop, sensor node, cost function, Residual Energy, LEACH Protocol.

1. Introduction

THE growing interest in Wireless Sensor Networks (WSNs) has successfully prompted extensive analyses of the new challenges that researchers and developers must overcome, including energy efficiency, limited processing and capacity resources, problematic correspondence, harsh conditions, and so on. Because of this, the bulk of SSDs now focus on solving these problems rather than providing in-depth utility in challenging real-world scenarios. As a result, many applications for sensor hubs follow a fairly static pattern of data collection, optional in-network processing, and output transmission to a centralized system. [1].

Recent projects aim to advance this vision by transferring more responsibility and knowledge to sensor hubs, which are common to the mark of activity. This paper have started researching the ways in which they can be beneficial and usable in intricate real-world applications in light of these considerations. Health and everlasting quality are deeply considered in all vehicle frameworks, particularly in light of rail routes. With the advancement of high-speed rail, train capacity and speed have been steadily growing, and traffic density has been rising over the past few years. As a result, there are more demands placed on the high-speed train operation in terms of reliability and safety. However, the surrounding environment has a significant impact on the safety of high-speed rail [2]. The number of railroad accidents involving collisions indicates an annual trend of growth. The ever-increasing operation speeds have increasingly serious effects on both the loss of human life and the train's and other railway equipment's structural integrity. Very few papers dealing with examinations into train collision processes to foretell the magnitude of forces and deformations experienced during unintentional accidents or crashes can be found in the technical literature [3]. The extremely hazy nature of train crash components can help to explain the dearth of literature. The research makes an effort to develop an iterative mathematical method for predicting the factors that may cause train impacts or crashes. [4] Is made possible by an effective rail communication system. Drivers and signalers can communicate at any moment from any location within the station. Through a broadcast channel, all drivers in a given area can communicate and receive information about any potential threat. In an emergency, the train's driver can communicate with signalers and the control room. Signalers should be illuminated near the training area on the track. Reduce the amount of instances where flagging problems and disappointments are identified. Providing passengers with up-to-date, reliable information about train schedules. Driver should be aware of the state of any attached wagons within the locomotive. Ensuring high levels of security and dependability across all communication sectors [5]. Track-side monitoring methods, such as infrared and acoustic monitoring, have been developed over the years to keep track of the rolling bearing in a freight train, but they were not well suited for use due to false positives and false alarms. On the other hand, since a freight train's cars are unattended, regularly put together, and do not have a consistent power source, onboard monitoring techniques cannot be applied to them.

2 System Model

2.1 Network Topology

The design of a WSN's routing protocols is directly impacted by the network architecture taken into account. In this research, a multi-hop network topology is described in order to investigate the impact of reducing the number of hops on the network's overall performance for train monitoring.

2.2 Multi-Hop Network Topology

In our test area, our model comprises of 8 nodes that are spread as shown in figure 1. Assume that each node along the train track is 130 meters apart (Trial and Error) and is situated in a straight line. The nodes were divided into 5 clusters, and each cluster serves a unique purpose. The nodes continually sense a selected parameter. Then, using a multi-hop protocol, it transmits data to the sink. In order to assure low cost and low energy consumption, the mesh network created by the 8 nodes sends data through gateways that adhere to IEEE 802.15.4 specifications for communication protocol. But it has a monitor for low data rates [6-7]. According to Equation 1, the sink node calculates the anticipated power needed for the network to broadcast to the base destination via free space at frequency 868MHz. employing a 6dBi directional antenna pointed at the sink.

$$\text{Transmitted power} = Q\left(\log_2(SF)E_b/(1.414N_o)\right) \tag{1}$$

No(dBi) = 10*log10(k*T*BW/1e-3) +NF+GN+GS.

Where, SF "Spreading Factor used in signals"=11.

K"Boltzmann Constant "= 1.38e-23 J. K^-1.

Node Gain = 6dBi.

Sink Gain = 10dBi.

T "Temperature" = 308Kelvin.

BW "Bandwidth" = 125KHz.

No "Minimum detectable signal for each node in dBi".

GN"Gain Node = 6dBi".

GS"Sink Node = 10dBi".

NF "Noise Figure".

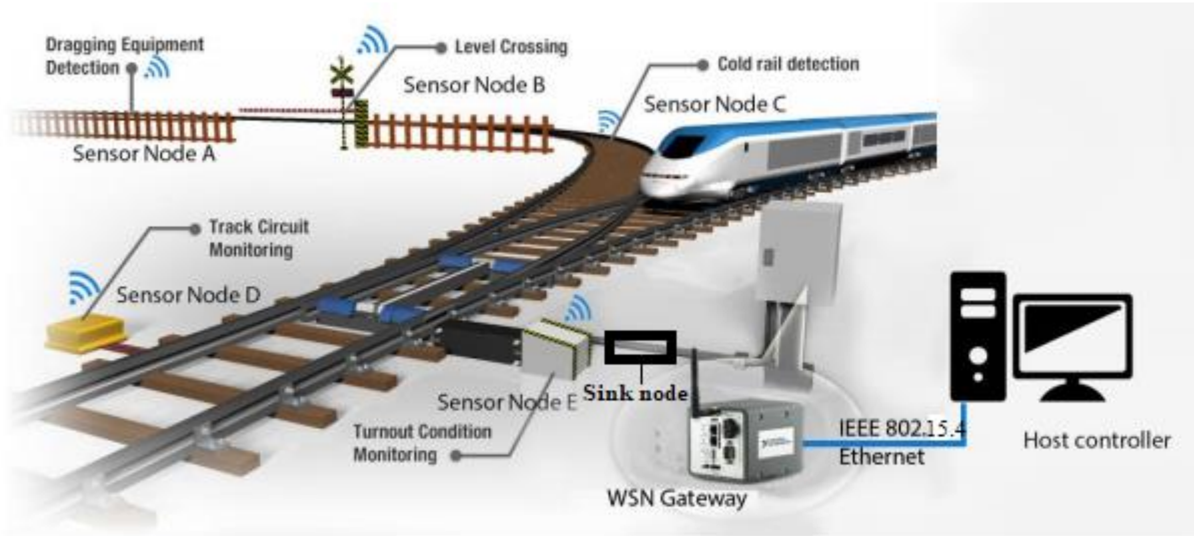

Figure.1: remote condition monitoring of the rail system [9].

2.2.1. Selection of next hop

In order to save energy and increase network throughput, this work proposed a multi hop approach for railway track. This section list the requirements for a node to be chosen as a parent node or forwarder. To balance energy use across sensor nodes and lower network energy consumption, a recommended protocol elects a new forwarder in each cycle. The sink node is aware of the ID, location, and state of the nodes' remaining energy. Each node's cost function is determined by Sink, who then sends it to each node. Based on this cost function, each node chooses whether or not to become a forwarder node. Equation 2 computes the cost function of the i nodes as follows if i is the number of nodes:

$$C.F\ (i)=d(i)/(R.\ E(i)) \tag{2}$$

Where d_i is the separation between node i and sink R. According to Figure 2, by subtracting the node's current energy from its initial total energy, the residual energy of node i, or Ei, is calculated. A node having a low-cost function is preferred as a forwarder. Each of the neighbor nodes continues to communicate with the forwarder node and sends data to it. The forwarder node gathers data, which it then sends to the sink. Data is transferred to the sink using the least amount of energy possible because the forwarder node has the closest destination and the most remaining energy.

Any procedure that gathers data and expresses it in a summarized manner is considered data aggregation. The rows of atomic data that are routinely collected from several sources are replaced with totals or summary statistics when data is aggregated. Summary statistics created from those observations are used in place of groups of observed aggregates. Ata aggregation can make it possible for analysts to quickly access and analyze enormous amounts of data. One or more atomic data records may be represented by one or more rows of aggregate data. Instead of consuming all the processing cycles to access each atomic data row when the data is queried or accessed, it can be queried rapidly once it has been aggregated.

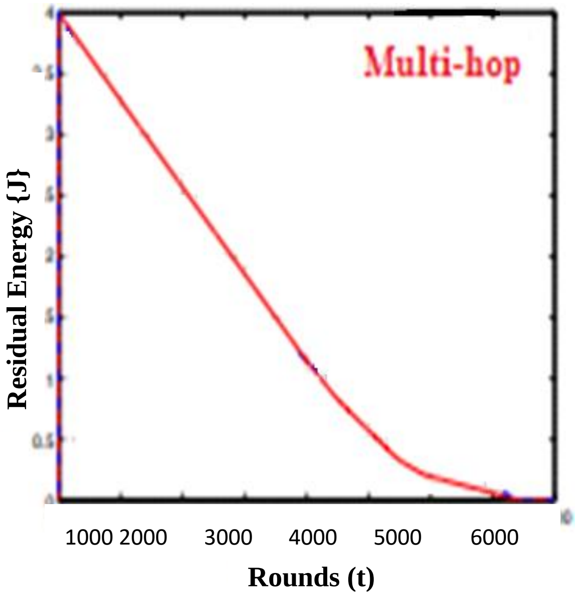

Figure.2: Analysis of residual energy.

2.2.2 Routing Protocol

Energy consumption constraints have an impact on the routing techniques used in WSN. Energy from the sensors is used for data processing and transmission. A sensor's battery has a major impact on how long it lasts. Failure of a sensor node might dramatically alter the topology of the network and force an expensive reorganization of it. LEACH Protocol and AODV Protocol were the two protocols used in this study.

• LEACH Multi-hop Protocol is an extension of the single hop approach that allows the maximum number of Cluster Heads (CHs) to transfer data to the Back-end Server (BS). A single CH in this approach also exchanges data with the other CHs. Energy conservation is this protocol's key feature. Energy conservation is a crucial component of sensor networks. As a result, numerous routing algorithms, including the LEACH protocol, have been developed with an eye toward efficient energy use. The hierarchical Low-Energy Adaptive Clustering Hierarchy (LEACH) protocol [8] is designed to reduce power consumption and extend network lifetime. The nodes in LEACH are grouped into clusters, with one node serving as the cluster head. The cluster head must receive data from all cluster members, do data processing (data aggregation), and transmit data to the base station. All non-leader nodes should communicate their data to the cluster head. There are rounds in the LEACH. Leader nodes are switched during each round to spread the network's energy usage. The rounds are made up of two phases: the grouping of clusters and the communication phase. During the clustering phase, a distributed algorithm is used to select the leaders, and the source nodes decide to join the closest cluster-head. Data transfer to the base station is made during the communication stage, including data fusion and aggregation by the leaders.

• The routing protocol AODV (Adhoc on Demand Distance Vector) is taken into account. A distance vector protocol is called AODV [10]. Sequence numbers are used to indicate the new paths to the destination node and to prevent routing loops. A routing table entry essentially includes the destination's address, the next node's address, the number of hops between the destination and the entry's location, and the destination sequence number. When a node delivers an RREQ message (Route request message) to the AODV protocol, it sends an RREP message with the optimal destination, starting the path discovery process. Following each retransmission of the RREQ and RREP messages, nodes update their routing tables [11].

Path loss, which is measured in decibels (dB) and indicates the signal attenuation, must be taken into account in our computation. Additionally, Additive White Gaussian Noise (AWGN) reduces signal power [12]. The difference between sent and received power is known as path loss, although antenna gain may or may not be taken into account. Path loss happens as a result of the wave front's propagating surface area expanding. Any object between the transmitter and receiver will interfere with the signal transmission since the transmitting antenna distributes power outward. Different obstructions on railroad tracks alter the signal that is transmitted. Equation3 demonstrates the relationship between path loss and frequency and distance [13].

$$P_{LFree}\text{-space (dB)} = 20\log(f) + 20\log(d) + 32.44 - GN - GS. \quad (3)$$

Where d: Distance

F frequency

GN Gaussian Noise

-The Path Costs are based on the BEP "Power needed to obtain total low BEP/BER" determined by Equation 4 [14] (a more accurate method uses Linear CHIRP Time Division Modulation [15]).

$$Pe,css=Q(\log12(SF)Eb/1.414\ NO) \quad (4)$$

Where, $E_b = Pt*TB - PL$

T_B: Bit Duration.

P_t: Transmitted Power.

P_L: Path Loss.

Eb/No energy per bit to noise power spectral density ratio

3. Results:

To simulate the behavior of the suggested routing protocol using MATLAB. The sink node is positioned at the head of the network, and eight nodes are randomly positioned around the track. We looked at the high throughput routing protocol, reliability, and performance of the multi-hop protocol.

3.1 Throughput

The throughput is the number of successful packages that are delivered to the sink. The Sink node contains crucial and critical train track data, hence it requires a protocol with a low packet drop rate and a high amount of properly received data. The multi-hop protocol offers tremendous throughput, as shown in Figure 3. How many packets are sent to the sink depends on how many live nodes are present. The throughput of the network increases as the number of active nodes sends more packets to the sink. As a result, the Leach Multi-Hop Protocol Network in the Chirp modulation Scheme [16, 17] can achieve high throughput over an extended stability period as shown in figure 3.

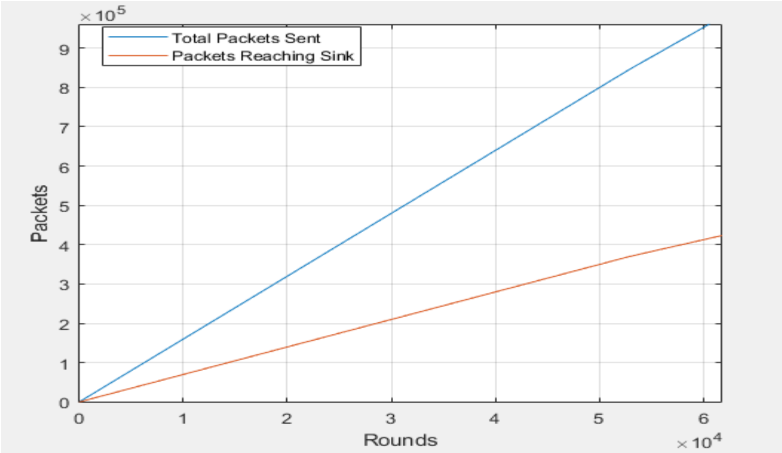

Fig.3: Analysis of Throughput.

3.2 Residual energy

The typical network power consumption for each cycle is shown in Figure 4. Each remote node provides data to the sink via a forwarder node in the multi-hop architecture used by the suggested paradigm. The sink node calculates the amount of electricity that the network must transport [18, 19]. A cost function is used to choose a forwarder node. Each round's choice of a suitable forwarder helps to conserve energy. In each round of packet transfers to sink, different forwarder nodes are used, which prevents overloading of a single node. The simulation findings show that up to 70% of the simulated time, the leach multi-hop protocol utilizes the least amount of energy. It signifies an unstable period when more nodes have the energy to send more data packets to the sink. The network's throughput is also improved. In Figure 4 the packets reaching sink in lower than total packets sent when power level increase that show the improvement in power consumption [20].

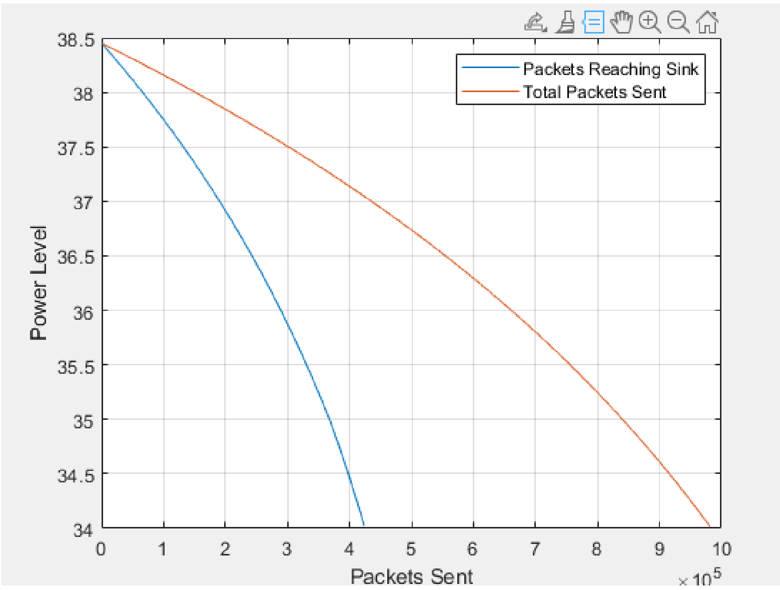

Figure.4: Total Power level over Total Packet sent.

4. Conclusion:

The mechanism for data routing in railroad lines is presented in this study. The suggested approach chooses a suitable sink route using a cost function. Based on the nodes' remaining energy and their distance from the sink, the cost function is computed. The parent nodes are chosen from the nodes having the lowest value of the cost function. As more nodes become its offspring, they send the parent node their data. Our simulation's results show that the recommended routing architecture enhances network stability and packet delivery to the sink. Path loss is another aspect of this technique. The results show that the proposed routing approach is more reliable in terms of packet delivery and consumes less energy. In the future, when there are mobile nodes in a mesh network, new routing protocol solutions will be investigated to enhance network longevity.

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