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# Energy and Security Aware WSN Routing Protocol for Landslide Monitoring with Efficient Data Gathering and Handling System

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## Abstract

In WSN, it is difficult to transmit the sensed data efficiently during heavy rainfall, soil pore water pressure, moisture content, and soil movement. In this paper, we present an Enhanced Landslide Monitoring system based on Energy efficient and Secure WSNs routing protocol for avoiding link failure or connectivity in the network (ELM-ES). For efficient routing, we present cluster based routing in this paper. We form the cluster using particle swarm optimization algorithm. Start a new organization on the parametric quantity like remainder energy, distance to the neighbor, density, maximum distance and angle, we select cluster head in each cluster. The sensed data are evaluated using fuzzy, at the main sensor node and is sent to the base station. Fuzzy evaluation at each sensor node is evaluated during sleep mode and only if the fuzzy output is 'true', the aggregated data is compressed and sent to the base station during an active period. Simulation results shows that, our proposed approach improves the energy efficiency and network lifetime than, that of existing work.

**Key Words:**WSN, landslide monitoring system, particle swarm optimization, cluster head, cluster based routing.

# 1. Introduction

Wireless sensors are pulling due to its dynamical features, since more type of applications. As there is quick advance in the innovation in miniaturized scale electro mechanical frameworks, integrated circuit (IC), and radio frequency (RF), the wireless sensor systems have been broadly string out in an assortment of reconnaissance the act of using something for a purpose [1]. A regular sensing element system is a gathering of detector nodes with a base station all associated in remote for correspondence, and comprises of triad units a chip, a sensor unit and a power control unit [2]. Microchip gives knowledge support to sensor nodes which is in charge of control of sensors, execution of correspondence convention and flag preparing calculations on the accumulated sensor information [3]. A sensor network consists of high number of nodes. Separately, each node is independent and has less range, and they operate together and effective over a large area. Function of each node is to collect the raw information while running in a particular application and convey it to the base station [4].

Landslide is a kind of serious geological hazard caused when masses of rock, earth, and debris flow down a steep slope during periods of intense rainfall [5]. Such debacles are generally flighty and happen inside limited capacities to focus time, so it is critical to catch pertinent signs with least checking delay. Right now, the observing innovations for avalanches for the most part incorporate groundwater level checking, precipitation checking, ground twisting estimations, programmed retractable meter surface dislodging estimation, TDR profound avalanche disfigurement estimation and programmed remote control monitoring[6]. In arrangement of landslide hazard monitoring utilizing WSNs innovation, expansive sorts of sensors gather data and after that transmit these data to the control focus through remote means, which can unravel the troubles of surrounding link observing framework. Avalanche checking in light of WSNs is generally related to the localization of sensor nodes, routing protocols, fault tolerance, monitoring algorithm and so on. WSN consists of number of nodes that are equipped with processing, communicating and sensing capabilities. Such network consists of large number of distributed sensor nodes that organize themselves into a multi-hop Ad hoc network [7].

The present observing strategies are delegated into three sorts: manual checking, self-loader checking and auto-checking. The manual observing requires experts conveying testing hardware to the checking site; it is difficult to identify the little relative distortion and can't finish ceaseless obtaining. Semi-automatic monitoring necessities staffs are work with the network and gather the information from the monitoring equipment [8].

Landslides lay a serious hazard in many regions of the world [9]. Recent literature refers to several locations of landslide hazard-monitoring systems such as the Canelles Reservoir, Spain [10]; the Slano Blato landslide and the

Rebrnice landslide, both in Slovenia [11]; NW Bohemia [12]; the Åknes rockslide, Norway [13]; the Basilicata Region, Italy [14]; the Jiweishan Hill area, Chongqing, China [15]; and Turtle Mountain, Canada [16]. This monitoring systems have wireless data transmission, but none of them are wireless sensor network (WSN) based. There are some studies on the use of WSNs for landslide monitoring.

The SENSLIDE consist of filter gauges deployed at low depths (Twenty five – Thirty cm) and carried out this design on a lab test bed [17]. The use of a power system of sensor columns used to find the establishment of a slip surface that introduces a landslide natural event [18]. They tested their ideas using computer simulations. A wireless sensor network of slope inclination and soil temperature sensors to monitor slope stability [19]. A wireless sensor node containing a soil moisture and tilt sensor and measure the inclination angle and acceleration of a hill slope. The nodes were tested on a small slope equipped with an artificial rainfall simulator. It was found that these sensor nodes can detect ground motion once the slope begins to move.

Section 2 consists of relates our proposed work with the previous works. Problem definition and system model of our proposed approach has been discovered in section 3. Section 4 presents of proposed approach Enhanced Landslide Monitoring system based on Energy efficient and Secure WSNs routing protocol. Simulation results of our proposed approach were discussed in section 5. This paper has terminated with section 6.

# 2. Related Works

Ramesh *et al.* [20] have presented deep earth probes (DEPs) based WSNs that used deployed to monitor an active landslide in the Western Ghats mountain range of South India. There have been a few earlier landslide monitoring WSNs using accelerometers in Emilia Romagna Apennines, Italy; global navigation satellite system (GNSS) sensors to monitor the Hornbergl landslide, Austria; and vibrating wire stress sensors to monitor a slope in China.

Al-Turjman *et al.* [21] have proposed powerful and cost-efficient solution for unattended outdoor environment monitoring (OEM) applications. These applications impose certain challenges on WSN deployment, including 3-Dimensional (3-D) settings, harsh operational conditions, and limited energy resources.

Chen *et al.* [22] have proposed an approach upon WSN for early warning on geohazards. Setup of sensors of the WSN is a priory issue. Various types of sensors may apply, e.g., interior displacement sensors, apparent displacement sensors, solid settle sensors, rainfall sensors, and water pressure sensors. Information collected by these sensors is first transferred to the base station via wireless multi hop transmission then the monitoring center via wireless wide area network. The field monitoring level is responsible for data transmission and data reliability test for the WSN. The remote networks transfer field information to the monitoring center. The monitoring center performs data analysis and visualization to support geohazard monitoring and management.

Bae *et al.* [23] have proposed bridge health monitoring system. WSN signal obstruction from various bridge components, including girders, bracings and connectors, can affect the performance and reliability of wireless communication. Although the placement of sensor nodes is essential for forming a mesh or ad-hoc network, there are no quantitative approaches related to the optimal separation distance of each node and the corresponding signal quality.

Wu *et al.* [24] have proposed framework with committed combination of data anticipation, concretion, and retrieval to concurrently achieve accuracy and efficiency of the data processing in clustered Wireless sensor networks. It is reduce the communicating cost while assuring the data processing and data prediction accuracy. The data prediction is achieved by implementing the least mean square (LMS) dual prediction algorithm with optimal step size by minimizing the mean-square derivation (MSD), in a way that the cluster heads (CHs) can obtain a good approximation of the real data from the sensor nodes.

Wang *et al.* [25] have provided the analytical results of the path loss of the four types of channels. Based on the path loss analysis, the transmission range of each channel is derived, which completely depends on the environmental conditions. Then, they provide the critical density for the WSNs under the impact of sandstorms. Accordingly, they demonstrate that when sensors are buried in shallow depth, the critical density of the single medium communication scheme, which only uses terrestrial air channels.

Goh *et al.* [26] have presented hetero-core spliced optical fiber surface Plasmon resonance sensor system for soil gravity water monitoring in environments. The system simultaneously provides data communications and sensing functions over the same optical fiber line. The sensor is covered with tantalum pent oxide, which allows data transmission distance to be extended with a wavelength of 1310 nm for wide-area monitoring. Sensor system can gather remotely observed environmental data from monitoring points and deliver them to users on a real-time basis.

# 3. Problem Definition and System Model

### Problem Identification and Solution

Nguyen et al. [27] have focused the development of a flexible and efficient WSN for detecting rainfall-induced landslides. A flexible switching between star and tree topologies is used to adapt to weather conditions in order to maximize the reliability of the transmission. Moreover, the power management is designed concurrently with the weather condition to improve both the operation reliability and the power efficiency. The performance of this system analyzed by simulation and by testing on a suitable outdoor experiment. A flexible switching between star and tree topologies is use to adapt to the weather condition in order to maximize the reliability of the transmission. The power management is designed concurrently with the weather condition to improve both the operational reliability and the power efficiency, but the network lifetime is not guaranteed in this design compare to existing techniques discussed in related works.

The paper deals with an Enhanced Landslide Monitoring system based on Energy efficient and Secure WSNs routing protocol for avoiding link failure or connectivity in the network (ELM-ES). The proposed system consists of two phases such as data gathering and data handling or aggregated system. WSNs, comprising of sensor nodes that are capable of wireless data transmission, data processing, data gathering and data storage, are quickly emerging as worthful tools for monitoring environmental phenomena and are especially suited for landslide monitoring. The sensor nodes are also capable of communicating with other nodes in the network and making decisions on the basis of these communications. Thus, a WSN provides a relatively inexpensive and reliable method to gather data on rainfall, moisture content, soil pore water pressure and soil movement.

In the data gathering phase, efficient clustering and cluster head selection algorithm used to improve the energy efficiency in transmission phase without connectivity losses. The clustering is first performed on all sensor nodes via the modified particle swarm optimization (PSO) algorithm. Then, the proper CHs are selected from the parameters like residual energy, distance to the neighbor, density, maximum distance and angle. Then the sensor nodes are capable of wireless data transmission, data storage, data acquisition, and data processing. The sensed data are evaluated using fuzzy, at the main sensor node and is sent to the base station. Fuzzy evaluation at each sensor node is evaluated during sleep mode and only if the fuzzy output is ‘true’, the aggregated data is compressed and sent to the base station during an active period. The gathered data can be submitted in real time and convert it into elementary working operations such as data collection, distributed analysis, data reduction, and consensus within the network itself. The processed data can then be transmitted quickly over long distances and inhospitable terrains. Data processing reduces the amount of transmitted data and thereby reduces the power consumption of the network and increases the lifetime of the network. Moreover, in a Wireless sensor network, the data collection rate can be changed remotely or by the network taking suitable decisions itself. Thus, in a landslide monitoring WSN, data collection and transmission can be minimized during dry seasons, while all relevant sensor data can be captured and transmitted during periods of heavy rainfall. WSNs also have other attractive features such as self-organizing and self-healing capabilities, high fault tolerance, and easy integration with web-based technologies.

## System Model

The data gathering phase is responsible for data collecting and data transmission for the Wireless sensor network. The sensor nodes are responsible for collecting environmental information, i.e. rainfall, moisture content, soil pore water pressure, and soil movement. The gathered information's are transferred from senor nodes to base station by proposed energy efficient routing protocol based on clustering techniques. Then the base station transfers all collected information in to data handling phase to analyze the possibility of landslide in the given area. The fuzzy based data mining technique is used to handle the different sensor values such as rainfall in terms of millimeter (mm) or inch, moisture sensor in terms percentage and pore pressure in terms of kilopascal (kPa). The predicted output is transfer to display panel of data handling phase. In two phase system, our contribution is in data gathering phase by achieving multipath routing in terms of enhanced cluster based technique. It is consist of two steps such as cluster formation and cluster head (CH) selection process. All sensor nodes in cluster are connected with in the CH of that cluster. Only CH sensor nodes are connected each other, and base station is connected nearby CH sensor node and the detailed structure is shown in fig. 1.

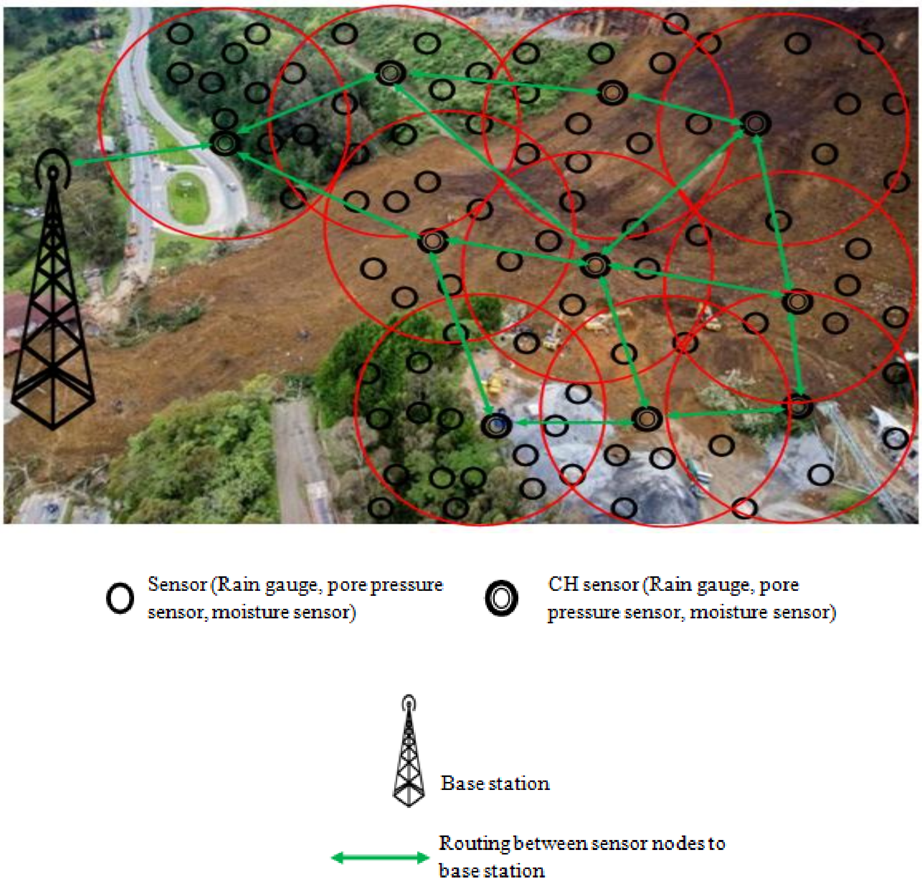



Figure 1: System Model for Proposed Work

# 4. Proposed ELM-ES System

## 1. Data Gathering Phase

In data gathering phase to collect environment factors such as rainfall, moisture content, soil pore water pressure, and soil movement using different sensor nodes such as rain gauge, pore pressure gauge moisture sensor, and different movement sensors (strain gauge, tilt meter, and geophone) respectively. Then the collected information's are transferred from sensor nodes to base station via proposed routing protocol.

### Clustering using modified PSO

The modified PSO is employed for efficient clustering of nodes with least redundant (un-clustered) node in the network. PSO, devised by Eberhart and Kennedy in 1995, is a random optimization technique based on population. PSO is a involving computation technique that optimizes a problem (situation) using a series of looping to increase the possible solution for a given quality evaluate a solution to the problem of complex non-linear optimization has been proposed using PSO by means of simulating the bird flocks behavior.

Particle Swarm Optimization simulates the behavior of clustering birds, where a group of birds randomly search food in a given area. Consider there is only one piece of food in the area of search and no birds know the where the food is. But they know how far the food is in each iteration. Hence, the best strategy is to follow the bird which is nearest to the food. PSO similarly utilizes strategy where each "bird" represent the solution in the given environment (for the proposed environment) i.e. "particle". Particles are considered using the two parameters – position and velocity. Each particle have velocity and position values, which represent and direct their flying. In every one considered individually looping, velocity of each particle is modified using the current velocity, the previous *local best (pbest)* and *global best (gBest)* position. Established on them the *new velocity* and *new position* values are updated. The first best maximum value is known as the previous *local best* .Then the second best value is evaluated keeping the best value so far obtained in the whole swarm population as the global best. As shown in Fig. 2, with the help of PSO algorithm during cluster formation, some of the nodes, which were left out without being a member of any cluster which results in residual node formation, clustering is carried out until all the nodes become member of any of the present clusters. Hence the rate of individual node formation which reduces the lifetime of the network is eliminated.

Initially, when all the nodes are spread in the network, the base station (sink) broadcasts an INITIATE MSG followed by an INFO COLLECT message to all the sensor nodes in the network. The sensor nodes after receiving the INITIATE MSG and the INFO COLLECT message from the base station (sink), starts to communicate with every other sensor node in the given sensing region, by broadcasting an HELLO message, in their sensing region.

| INFO COLLECT Message | | | |
|---|---|---|---|
| Node's ID | Position $(u,w)$ | Velocity $(v_1, v_2)$ | Energy ($E$) |

Figure 2: Hello Message Format

After the broadcast of the HELLO message, every sensor node sends an INFO COLLECT reply message to the base station HELLO message contains information about the nodes ID and its residual energy, bandwidth and connectivity. INFO COLLECT reply message sent from the nth sensors to the sink node (base station) contains the following information: Position $(u_n,w_n)$ of the sensor node. Velocity $(v_{1n}, v_{2n})$ of the sensor nodes. (Where $v_{1n}$is the current velocity of node $n$, $v_2$is the average velocity of node $n$) Energy ($E_n$) of the $n$th sensor node. Hence for each sensor node the value of position, velocity and energy are maintained and updated at the base station (sink node).

| Hello Message | | | |
|---|---|---|---|
| Node's ID | Residual energy | Band width | Connectivity |

Figure 3: Info Collect Message Format

In this proposed algorithm, each WSN sensor node is considered as the particle. Here the base station (sink node) makes the sensor nodes to perform cluster formation, which is carried out using PSO.

Using PSO, the fitness of each particle is calculated to choose the cluster particles (cluster member selection). Fitness value in our proposed approach depends on:

- The energy of the sensor node (particle) $E_m$.
- Connectivity ($C_{mn}$).
- Distance of sensor node/particle (n) within the radio range 'a' from node m.
- Energy of the sensor node/particle (n) within the radio range 'a' from node m.

Based on the fitness value clustering is carried out considering all the sensor node and hence eliminating the presence of residual nodes in the network. The nodes with maximum number of connectivity and residual energy are considered as the cluster particle (member).

$$Fitness\ value = \left(\kappa_1 * \left(\frac{D_{nm}}{C_{mn}}\right)\right) + \left(\kappa_2 * \left(\frac{E_{Avg_{c_{mn}}}}{E_m}\right)\right) + \left(\kappa_3 * \left(\frac{1}{C_{mn}}\right)\right) \quad (1)$$

Where, $D_{nm} = \sqrt{(u_m - u_n)^2 + (w_m - w_n)^2}$ i.e. the length between m and $n$ nodes, n= $\{1,2,3.....l\}$ be the count of nodes (particles) reachable by the given node $p$ in the given sample space $0 < \kappa_1 < 1$, $0 < \kappa_2 < 1$ and $\kappa_3 = 1 - \kappa_1 - \kappa_2$.

Fitness value of each node is calculated during every iteration and the maximum fitness value obtained is taken as the local best. The maximum value among all the fitness values obtained is taken as global best position and velocity updation is carried out in PSO for every particle as follows:

$$V\_update_p = W_{velocity\ p} + W_1\ (Pervious\ position\ of\ node\ p - current\ position\ of\ node\ p)$$

$$+ W_2\ (precious\ position\ of\ node\ p * current\ position\ of\ node\ p) \quad (2)$$

$$P\_update_p = Previous\ position\ of\ node\ p + V\_update_p \quad (3)$$

Where, $W_{velocity\ p}$ =weight of nodes velocity, $W_1$ and $W_2$= weight of nodes location. As shown in fig.4, *(X-axis, Y-axis)* be the assumed workspace (detecting region) and '$a$' be the coverage of each sensor nodes. The total number of cluster formed in the considered sensing area was calculated as:

$$N = \frac{total\ network\ area}{individual\ cluster\ area} = \frac{(X*Y)}{(x*y)} \quad (4)$$

Where, *(x, y)* be the co-ordinates of the cluster in the detecting region,*(X, Y)* be the coordinates of the sensing region, from the fig.4, using Pythagoras theorem the value was written as:

$$a = \sqrt{\frac{x^2}{4} + \frac{y^2}{4}} \quad (5)$$

Let us assume, $x = y = u$ and $X=Y$. Equation (1) and (2) becomes:

$$a = \frac{u}{\sqrt{2}} \quad (6)$$

$$N = \frac{(X*Y)}{u^2} = \frac{(X*Y)}{2a^2} \quad (7)$$

The upper bound of the number of clusters formed in a network can be:

$$N = \left\{ \left(\frac{X*Y}{x*y}\right) + \left(\frac{X}{x}\right) + \left(\frac{Y}{y}\right) \right\} \quad (8)$$

Substituting, $x = y = u$ and $X=Y$ in Eqn. (5)

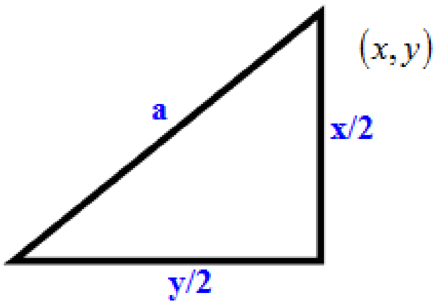



Figure 4: Cluster Formation using PSO

$$N = \frac{(X^2) + (2\sqrt{2} * x * a))}{2a^2} \quad (9)$$

## Cluster Head Selection

The modified energy efficient and secure CH selection technique is based on parameters like residual energy, distance to the neighbor, density, maximum distance and angle.

The core aim of this technique is to minimize the large data traffic and high energy consumption in the network. The development technique fixes each Cluster head near to the sink and sensing event while the remaining set of the CHs are appointed in the middle of each cluster to achieve the highest level of energy efficiency in a deployed dense network.

**Residual energy ($RE_n$)**: A CHs should enough energy to perform packet transmission; witness data flow and process the data.

$$CH_{RE} > Threshold \quad (10)$$

**Maximum distance**: Is the maximum distance between node *m* and node *n* i.e. $D_{nm\ max}$

**Angle**: Angle of the sensor node *m* to its neighboring node *n*,

**Density ($\rho$)**: Density ($\rho$) represents the number of nodes (sensors/particles) in a given region. $\rho$ =1 for thick region and $\rho$ =2 for thin region.

**Distance to Neighbor** ($D_{nm}$): A CH must have smallest transmission distance to all its member nodes in the given densely deployed cluster. Hence, the CH must efficiently cover the given sensing region with least amount of energy consumption. Active nodes in a region '*a*' around a node to select itself as the CH can be calculated using:

$$Active\ nodes = \frac{RE_n}{\left(\sum_{i=1}^{n} D_{nm} / D_{nm(\max)}\right)^2 + \left(\rho - \left(\frac{D_i}{100}\right)\right)^2} \forall sensor\ \ nodes \quad (11)$$

## Data Aggregated using Fuzzy Logic

The small sensor nodes are using low power battery which not easy to replace the power battery in the limited periods. The energy consumption of sensor nodes are defines the life time of sensors as well as whole sensor networks. The energy attributes are consider as critical factor in multi path routing protocol other than delay, data loss and delivery ratios. Most of the energy wastages are occurred only in idle sensing stage. The problem is reduced by modify the design to make energy efficient by the condition, sensor nodes are don't wake up all the time rather choose energy conservation by going to sleep mode. The energy consumption of the sensor nodes are depends on the different stages such as energy consumption due to transmitting, receiving, overhearing and idle stages. Energy consumption of sensor nodes are very less in the sleep mode compare to the active or idle mode. The total simulation time $(Sim_t)$ of routing protocol process is as follows.

$$Sim_t = Tx_t + Rx_t + OH_t + Idle_t + Sleep_t + Tra_{SA_t} \tag{12}$$

where $Tx_t$, $Rx_t$, $OH_t$, $Idle_t$, $Sleep_t$ and $Tra_{SA_t}$ is time spent for sensor nodes performed data transmitting, receiving, overhearing, idle, sleep, and transmission from sleep to idle alive mode. The energy consumption of total simulation time $(Sim_t)$ is representing as follows:

$$E_{sim_t} = Tx_t \times E_t(n,d) + Rx_t \times E_r(n) + OH_t \times E_{OH}(n) + Idle_t \times E_{idle}(n) + Sleep_t \times E_{sleep}(n) + Trans_t + E_{trans}(n) \tag{13}$$

The sensed data are evaluated using fuzzy, at the main sensor node and is sent to the base station. Fuzzy evaluation at each sensor node is evaluated during sleep mode and only if the fuzzy output is 'true', the aggregated data is compressed and sent to the base station during an active mode. The Mamdani's fuzzy approach is used for data evaluating process and the system block is shown in fig. 5.

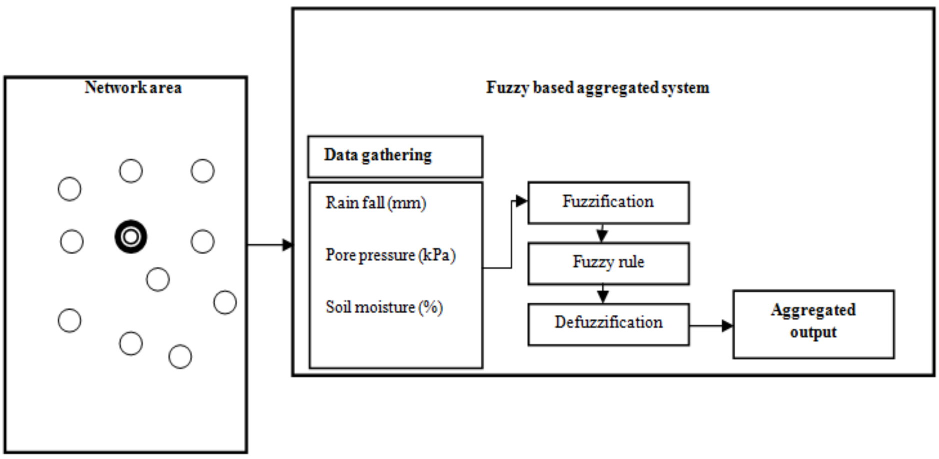
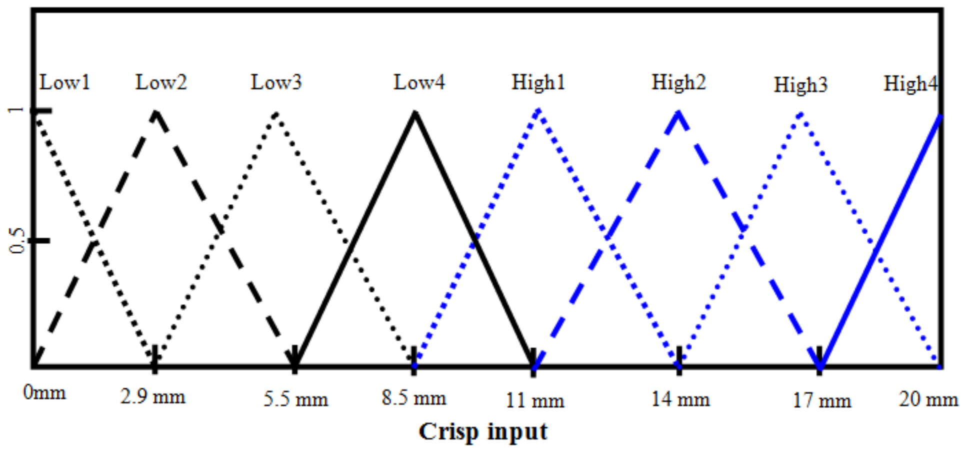



Figure 5: Fuzzy Inference Model with Landslide Crisp Data

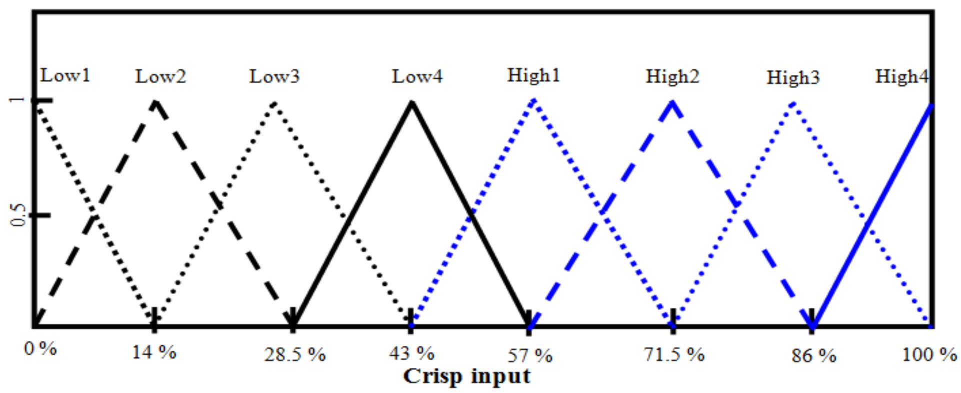
The fuzzy model consists of four processes such as (1) Fuzzification-the inputs are given with crisp value and changed into fuzzy sets (2) Rule Evaluation-the inputs are taken and applied to the antecedents of fuzzy rules and then it is applied to the consequent membership function (3) Aggregation of output rule-it is involves merging of output of all rules and (4) Defuzzification-it is transforms the fuzzy set into a crisp value. The linguistic variables for the fuzzy set are defined by the peak/threshold values by the format of [Rainfall, Moisture, and Pore pressure]. We define fuzzy rules by sensed values only informed to base station only at peak/threshold values such as [20mm, 0%, 0kPa], [17mm, 14%, 8.5kPa], [14mm, 28.5%, 17kPa], [11mm, 43%, 26kPa], [8.5mm, 57%, 34.5kPa], [5.5mm, 71.5%, 43kPa], [2.9mm, 86%, 51.5kPa] and [0mm, 100%, 60kPa]. The trapezoidal and triangular membership functions are employed for low1, low2, low3, low4, high1, high2, high3 and high4 variables and is shown in fig. 6a-c. Based on the crisp inputs the possible outcomes are described and it is tabulated in table 1.

**Membership function**



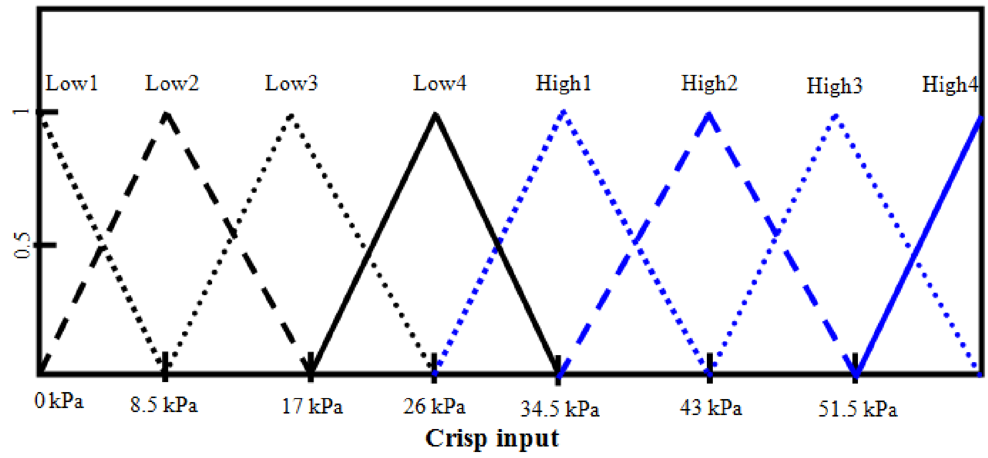

(a)

**Membership function**




**(b)**

**Membership function**




(c)

Figure 5: Membership Function for (a) Rainfall Values (b) Moisture Values (c) Pore Pressure Values

Table 1: Possible data combinations

| No | Rainfall | Moisture | Pore pressure | Aggregated data |
|---|---|---|---|---|
| 1 | Low1 | Low1 | Low1 | False |
| 2 | Low1 | Low1 | Low2 | False |
| 3 | Low1 | Low1 | Low3 | False |
| 4 | Low1 | Low1 | Low4 | False |
| 5 | Low1 | Low1 | High1 | False |
| 6 | Low1 | Low1 | High2 | False |
| … | | | | |
| 64 | Low1 | High4 | High4 | True |
| 65 | Low2 | Low1 | Low1 | False |
| 66 | Low2 | Low1 | Low2 | False |
| 67 | Low2 | Low1 | Low3 | False |
| 68 | Low2 | Low1 | Low4 | False |
| … | … | … | … | … |
| 510 | High4 | High4 | High2 | False |
| 511 | High4 | High4 | High3 | False |
| 512 | High4 | High4 | High4 | False |

# 5. Results and Discussions

Our proposed approach Enhanced Landslide Monitoring system based on Energy efficient and Secure WSNs routing protocol (ELM-ES) is simulated using the network simulator NS2. In this work, we have considered 125 sensor nodes. These sensor nodes are performed in the 1000×1000m region and were grouped as a cluster. Each node in a cluster has 250m transmission range. IEEE

802.11 wireless protocol is used in this simulation. Sensor nodes in the region are formed as a number of clusters using our presented Particle swarm optimization algorithm as shown in figure 6. After the cluster formation, cluster head is selected for each cluster based on parameters like residual energy, distance to the neighbor, density, maximum distance and angle as shown in figure 7. These selected CH monitors and gathers data from the non cluster head members. The sensed data are evaluated using fuzzy at each sensor node during sleep mode and only if the fuzzy output is 'true', the aggregated data is compressed and sent to the base station during an active period. As shown in figure 8, the node 115 and 36 send on the observed data to the corresponding cluster head. The sensed data are forwarded to the base station by selecting the neighbor CH of each cluster as shown in figure 9. Table: 1 shows the simulation parameters of our proposed approach.

Table: 2 Simulation Parameters

| **Parameters** | **Values** |
|---|---|
| No. of nodes | 125 |
| Wireless protocol | 802.11 |
| Area | 1000×1000 |
| Simulation time | 50s |
| Packet size | 500 |
| Routing protocol | AODV |
| Transmit power | 0.660W |
| Receiving power | 0.395W |
| Initial energy | 40J |
| Transmission range | 250m |
| Constant bit rate | 500kbps |

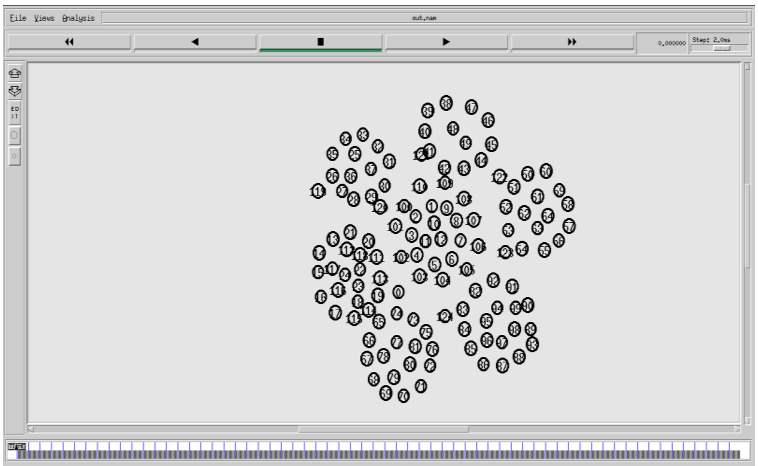


Figure 6: Cluster Formation

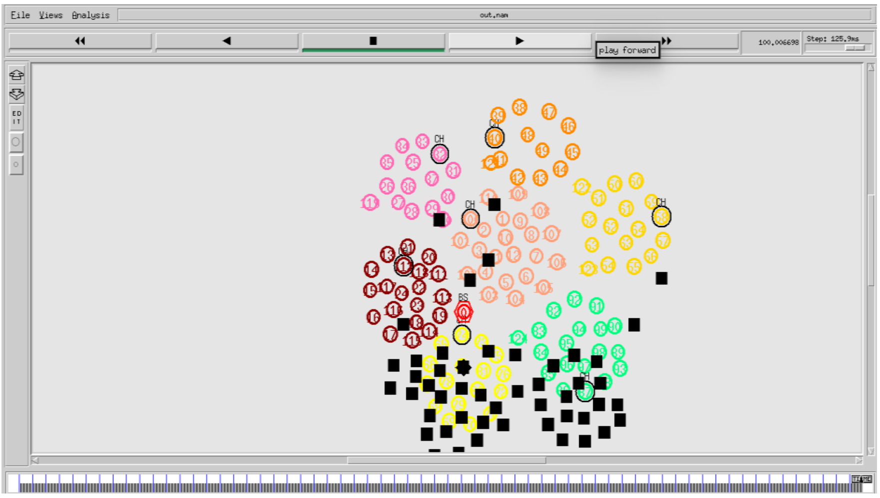



Figure 7: Cluster Head Selection

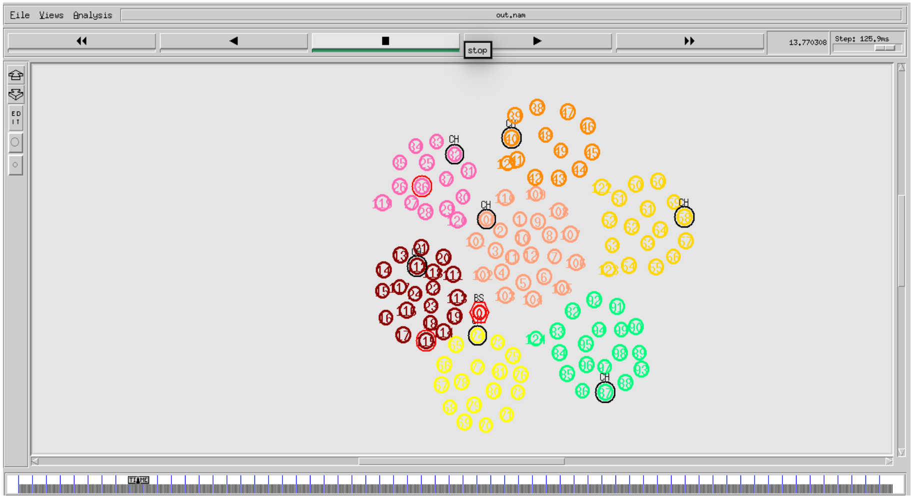



Figure 8: Sensed Data Are Evaluated using Fuzzy Based Aggregated System

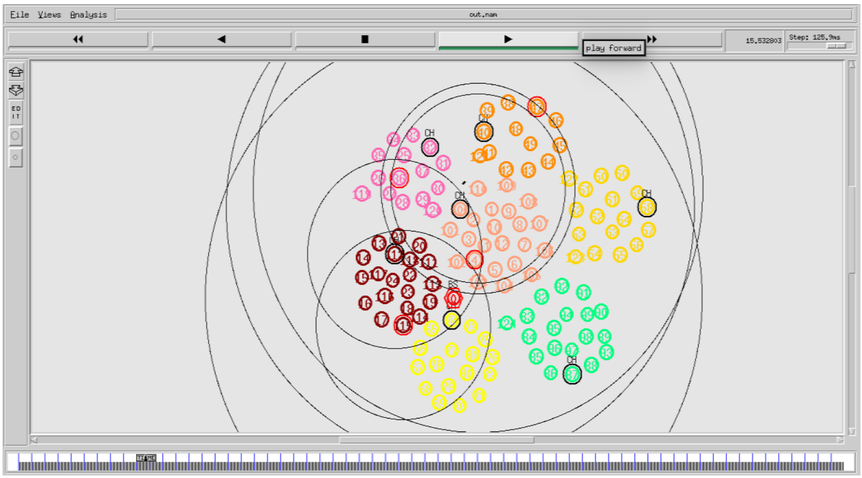



Figure 9: Cluster Based Routing

### Performance based on Nodes

In this section, performance metrics of our proposed approach is estimated for varying nodes 25, 50, 75, 100 and 125. Figure 9-13 and table 3-8 show that packet delay, delivery ratio, energy consumption, throughput and overhead for varying nodes. Our proposed Enhanced Landslide Monitoring system based on Energy efficient and Secure WSNs routing protocol (ELM-ES) is compared with the existing EWSN-RIL [27] and OSSLMS [24]. Figure 10 and table 3 show the packet delay of our proposed approach. For the set of 125 nodes, our proposed approach has less packet delay. Packet delay of our proposed approach is reduced to 42% and 54% than that of EWSN-RIL and OSSLMS respectively. The cluster head in a cluster gathers data from the non-CH members and transmits the received data to the destination through the neighbor cluster heads. So the packet delay of our proposed approach is reduced.

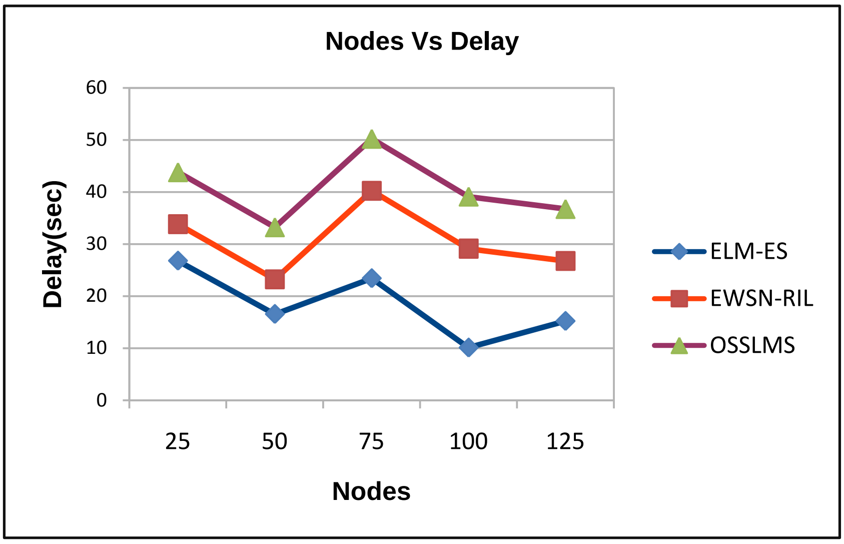



Figure 10: Node Vs Delay

Table 3: Comparison of Delay

| Nodes | Delay (Seconds) | | |
|---|---|---|---|
| | ELM-ES | EWSN-RIL | OSSLMS |
| **25** | 26.7 | 33.8 | 43.7 |
| **50** | 16.5 | 23.2 | 33.2 |
| **75** | 23.4 | 40.2 | 50.2 |
| **100** | 10 | 29.1 | 39.1 |
| **125** | 15.2 | 26.7 | 36.7 |

Figure 11 and table 4 show the delivery ratio of our proposed approach. Because of the cluster based routing, delivery ratio of our proposed approach is increased to 17% and 97% than that of EWSN-RIL and OSSLMS respectively.

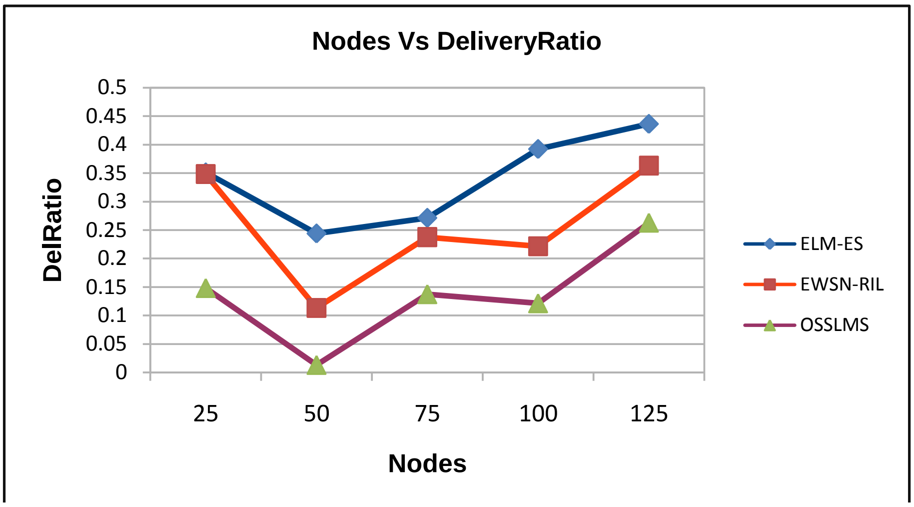



Figure 11: Node Vs Delivery Ratio

Table 4: Comparison of Delivery ratio

| **Nodes** | **Delivery Ratio** | | |
|---|---|---|---|
| | **ELM-ES** | **EWSN-RIL** | **OSSLMS** |
| **25** | 0.35 | 0.34 | 0.14 |
| **50** | 0.24 | 0.11 | 0.01 |
| **75** | 0.27 | 0.23 | 0.13 |
| **100** | 0.39 | 0.22 | 0.12 |
| **125** | 0.43 | 0.36 | 0.26 |

Energy consumption of our proposed approach is shown in figure 12 and table 5. Because of the cluster based transmission, energy consumption of our proposed approach is reduced to 55% and 67% than that of EWSN-RIL and OSSLMS respectively.

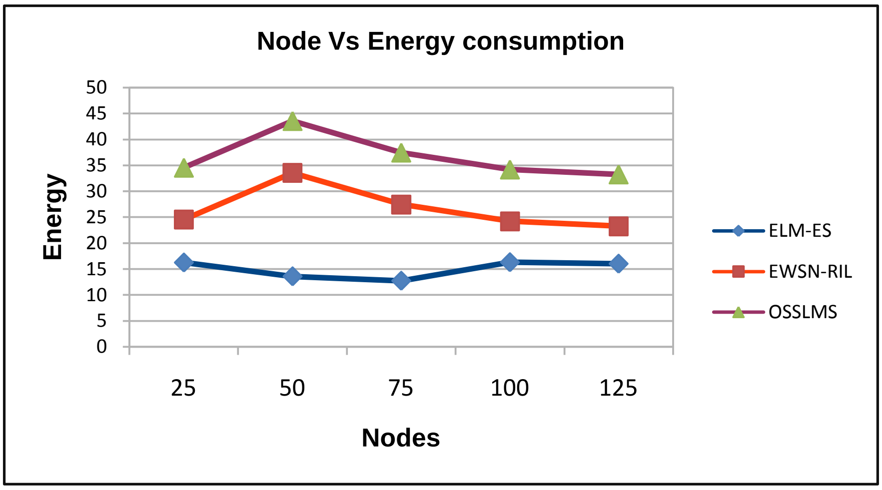



Figure 12: Node Vs Energy Consumption

Table 5: Comparison of Energy consumption

| Nodes | Energy consumption (J) | | |
|---|---|---|---|
| | ELM-ES | EWSN-RIL | OSSLMS |
| 25 | 16.2 | 24.5 | 34.5 |
| 50 | 13.5 | 33.5 | 43.5 |
| 75 | 12.7 | 27.4 | 37.4 |
| 100 | 16.3 | 24.2 | 34.2 |
| 125 | 16 | 23.2 | 33.2 |

Figure 13 and table 6 show the throughput of our proposed approach. Compared to the EWSN-RIL and OSSLMS, the throughput of our proposed approach is increased to 42% and 96%.

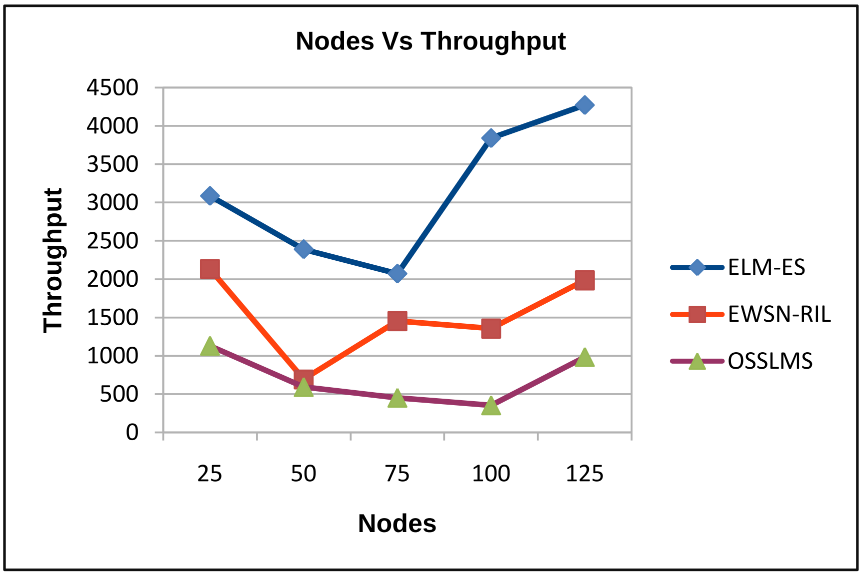



Figure 13: Node Vs Throughput

Table 6: Comparison of Throughput

| Nodes | Throughput | | |
|---|---|---|---|
| | ELM-ES | EWSN-RIL | OSSLMS |
| 25 | 3087 | 2131 | 1131 |
| 50 | 2390 | 693 | 593 |
| 75 | 2071 | 1453 | 453 |
| 100 | 3842 | 1355 | 355 |
| 125 | 4274 | 1984 | 984 |

Figure 14 and table 7 show the network lifetime of our proposed approach. Because of our presented data gathering and handling system, network lifetime is increased to 29% and 95% than that of EWSN-RIL and OSSLMS respectively.

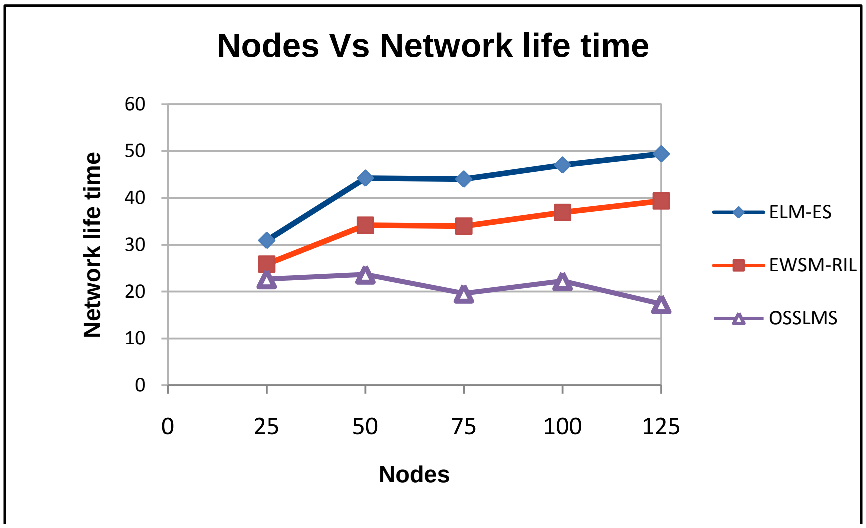



Figure 14: Node Vs Network lifetime

Table 7: Comparison of Network lifetime

| **Nodes** | **Network lifetime** | | |
|---|---|---|---|
| | **ELM-ES** | **EWSN-RIL** | **OSSLMS** |
| **25** | 30.9 | 25.9 | 22.7 |
| **50** | 44.2 | 34.2 | 23.7 |
| **75** | 44 | 34 | 19.6 |
| **100** | 47 | 36.9 | 22.3 |
| **125** | 49.4 | 39.4 | 17.4 |

Overhead of our proposed approach is shown in figure 15 and table 8. Compared to EWSN-RIL and OSSLMS, Overhead of our proposed approach is reduced to 51% and 66% respectively.

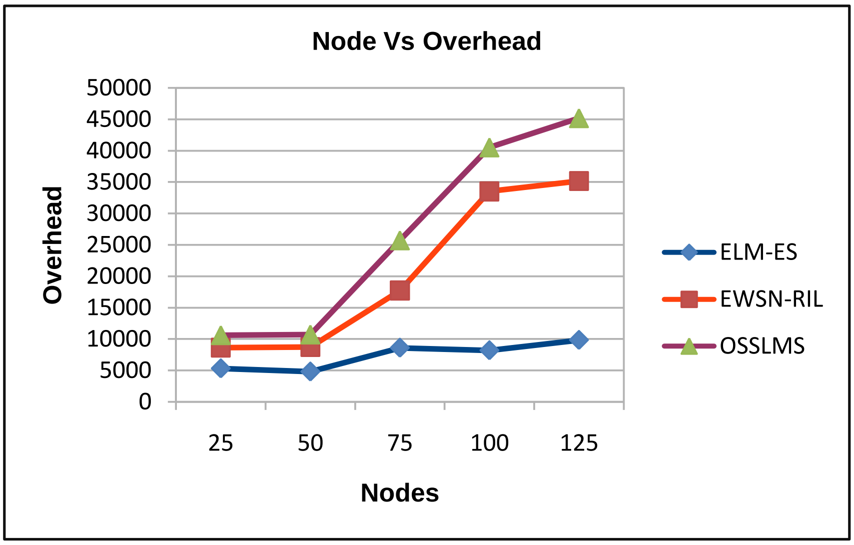



Figure 15: Node Vs Overhead

Table 8: Comparison of Overhead

| Nodes | Overhead | | |
|---|---|---|---|
| | **ELM-ES** | **EWSN-RIL** | **OSSLMS** |
| **25** | 5329 | 8641 | 10641 |
| **50** | 4823 | 8746 | 10746 |
| **75** | 8612 | 17740 | 25740 |
| **100** | 8206 | 33540 | 40540 |
| **125** | 9848 | 35193 | 45193 |

# 6. Conclusion

In this paper, our proposed approach Enhanced Landslide Monitoring system based on Energy efficient and Secure WSNs routing protocol (ELM-ES) has been presented and has been simulated using the network simulator NS2. Using our proposed approach, we have done efficient transmission during landslide in WSN. For efficient routing, we have presented cluster based routing. For cluster formation we have presented particle swarm optimization algorithm and also we have selected cluster head for each cluster based parameters like residual energy, distance to the neighbor, density, maximum distance and angle. Based on the fuzzy aggregated system, the sensed data are evaluated and are transmitted to the base station. Simulation results of our proposed approach showed that it improved the energy efficiency and network lifetime than that of existing work.

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