# IOT BASED ENERGY EFFICIENT EARLY LANDSLIDE DETECTION SYSTEM

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**Abstract:** A landslide, also called as landslip appear to be the most threatening disaster of all time especially in the hillside regions. It involves enormous surface movements including debris flows, slopes failure, rock fall etc. It mainly occurs when the land slopes become unstable. Other measures that also lead to landslides are Ground water changes, Earthquakes, Floods, Volcano eruptions and Heavy rainfalls. People among these hill areas doesn't know about the disaster that's about to happen massively. The perfect way to avoid such hazards is by predicting it at initial phase with maximum accuracy. There are many wired and wireless supervising systems available to detect landslides which require higher cost and maintenance. But we have a suitable solution for this with IOT (Internet of Things) based approach. It improves objects control and detection remotely between various networks thereby creating possibilities for direct communication between physical and computer-based world. By this approach Landslides can be predicted at the initial phase. If there is a higher chance of Landslide then an alert will be sent to disaster management sector immediately to take necessary precautions so that enormous precious lives can be protected. This paper proposes a model for IoT based Landslide detection mechanisms in detail.

***Keywords:*** *Internet of Things (IoT), Energy Efficient, Landslide detection, Wireless sensor network*

## 1. Introduction

The Internet of Things (IoT) is a network that consists a collection of objects or devices connected with other electronic devices or sensors with a network connection that allows these objects to accumulate useful data and to transfer autonomous flow of data with the help of current technologies. It is also used to do monitoring, analysis, detection and in rescue operations. In our case we have to use IoT based approach to detect landslide in prior with accurate data and to send the corresponding data to the disaster management sector. A landslide in general is an unexpected phenomenon that costs many lives. It is a common phenomenon in all the hill areas but with no solution so far to safeguard people from such disaster. In India, mainly in the Hill region, landslides occur very frequently compared to any other geographic phenomenon thereby causing lots of deaths. Since many deaths are occurring and also major infrastructural damage there is a greater need to design a device to detect the disaster at an early stage. We have to monitor landslides regularly and also to alert the public in prior. Several methodologies have been proposed for landslide detection mechanism but not as feasible as IoT based landslide detection system. It provides an alternative approach to detect landslides well in advance. In this paper, complete development and design of IoT based landslide detection system is discussed. This methodology also discusses about the use of sensors such as Rainfall sensor and Vibration sensor. We have proposed an alert mechanism where we will be alerting the nearby traffic control room so that they will take necessary precautions to evacuate the public in the affected zones.

Many of the high probability landslide regions are complicated to reach by the electrical power sources. Therefore, the sensor devices are designed to operate with a built-in-battery. Continuous monitoring and communication among the devices cause high consumption of power which is not suitable for battery operated devices. Intermediate or periodical monitoring may cause accuracy issues which depends the situation. Thus, the proposed procedure uses an innovative way to save power without compromising the regular operational performance of the entire sensor network.

## 2. Related works

There are many proposed mechanisms regarding monitoring and early detection of landslides with the help of various technologies. Various methodologies have been used to predict the landslides in an effective way. Some of the related works we have referred are mentioned here. Aibek Musaev [4], proposed a prototype tool to examine and implement research concepts and ideas related to disaster detection. He also proposes about the current system of identification of 137 landslide locations during the year 2014. In real-time, a live demonstration of landslide detection system and its corresponding results display in a web map is also discussed here. This proposal named as LITMUS – a multiple service approach to landslide detection and a multiple hazard representation. In [5], radar polarimetry is used for disaster detection and monitoring (LDCSPC). They have proposed a POLSAR data for the detection of various disasters including landslides, debris flows etc. Their main approach is to compare the scattering images or data acquired from POLSAR before and after the disaster. Based on polarimetric analysis the upcoming landslide detected area will be avoided by the public and therefore evacuating the people based on the need. In [6], with the help of heterogeneous wireless network, monitoring of landslide detection is taken place (LDMWSN). A greater advantage of this proposal is the usage of transmitter and receiver nodes which gives the advantage of receiving low cost optimum results. With wireless sensor network, landslides in Asian countries are greatly monitored and our livelihood is protected. In [1], landslide monitoring is done with the help of CAD and CAE which tends to increase the life time by six times more compared to CDC model. In [2], landslide monitoring module is done with the help of camera sensor and geological sensor and a simulation platform is developed to check the module's feasibility and effectiveness. In [3], risk analysis of landslide is done with the help of WSN. The proposed model is very adaptive and fault tolerant and they have a self-organized network too.

Bu-Chin Wang [7], proposed a landslide monitoring technique by the usage of transmitter array and dual -receiver system which tracks the independent signals coherently and based on the proportionate phase difference changes landslide movement is detected in prior. A complete illustration of 3-D landslide detection technique is explained. In [8], they have proposed a landslide detection technique with the help of VHF pulse radar so that the detection happens at an early stage by comparing the radar images of a normal weather and storm weather and thereby aftermath from the disaster can be met with precautions. In [9], landslide monitoring is done with the help of PSI and synthetic aperture radar to provide a wide range of characterization of deformation of land at local scale. In [10], SAR is used here to detect the landslides triggered by the earthquakes. It also monitors the prone areas at an early phase to manage all the risks. The merits and disadvantages summary of existing methods is given below in Table 1.

Table 1: Merits and Disadvantages of existing methods

| **Author** | **Work** | **Method** | **Advantages** | **Disadvantages** |
|---|---|---|---|---|
| Aibek Musaev et.al. | LITMUS: a multi-service composition system for landslide detection | Multi-service Composition method | Real-time implementation model | Network metrics not measured |
| T.Shibayama et.al. | A landslide detection based on the change of scattering power components between multi-temporal PolSAR data | radar polarimetry disaster detection and monitoring | Operates by POLSAR Image data | Lateral landslide detection |
| G.Teja et.al. | Land Slide detection and monitoring system using wireless sensor networks | Heterogeneous Wireless Sensor Network | Low cost effective communication | Limited Scalability |
| R.Prabha et.al. | Energy Efficient Data Acquisition Techniques using Context Aware Sensing for Landslide Monitoring Systems | Context Aware Data and Energy Management | Improved Energy handling & Network life time | Limited Scalability |
| Y.Wang et.al. | Anomaly detection and visual perception for landslide monitoring based on a heterogeneous sensor network | Camera and Geological sensor based Visual Perception | Supports Heterogeneous network nodes | Lateral landslide detection |
| A.Giorgetti et.al. | A robust wireless sensor network for landslide risk analysis: system design, deployment, and field testing | clinometer based landslide detection WSN | Better falut tallerence self organized network | Limited Scalability |
| B.C.Wang et.al. | A landslide monitoring technique based on dual-receiver and phase difference measurements | Independent signals coherently tracking | Earlier landslide detection | High cost limited scalability |
| Y.Jin et.al. | Monitoring and early warning the debris flow and landslides using VHF radar pulse echoes from layering land media | VHF Pulse Radar based landslide detection | Earlier landslide detection | High cost limited scalability |
| S.Bianchini et.al. | Detecting and monitoring landslide phenomena with TerraSAR-X persistent scatterers data | PSI and synthetic aperture radar based detection | Accurate deformation detection | Limited Scalability |
| M.Liao et.al. | Post-earthquake landslide detection and early detection of landslide prone areas using SAR | High-resolution synthetic aperture radar | More accurate early landslide detection | High cost limited scalability |

## 3. Proposed approach

The proposed design named as IoT based Energy Efficient Early Landslide Detection (EEELDS) model detects the landslide way prior to its occurrence and saves the livelihood. We have used various objects such as, Vibration sensor – there will be a movement of bedrocks during earthquakes which causes a vibration in the surface area and that can be sensed and detected using this vibration sensor, Rainfall sensor – this sensor will be activated immediately when a heavy rainfall occurs in that region. The rainfall sensor changes its resistance based on the droplets on the surface. The nodes equipped with the rainfall sensor connect with the network and transmit the information to the other nodes. The central network IoT hub connects with several nodes to collect the data and to broadcast messages. It also sends emergency signals to the alert node which is responsible to raise the alarms and to alert the traffic signals.

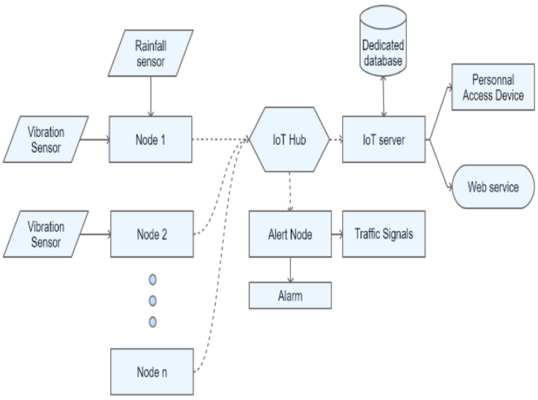


Figure 1: Proposed Block Diagram

In Figure 1, based on the weather conditions rainfall sensor will be activated and in case of an earthquake, vibration sensor will be activated. This sensor information will be acquired by node 1 and it is sent frequently to IoT Hub. There will be many sensors and many nodes based on the area range and all information will be received by IoT Hub which is used in broadcasting all the gathered information to the respective nodes. Now buzzer will be triggered in a traffic control room when node 3 sends information regarding the landslide monitor report. Accordingly, traffic control signal system is triggered and altered to avoid the traffic in that region and all these data is now passed on to IoT server which keeps tracking all the gathered information and when needed it sends an alert to the government via SMS with the help of personal access device. A web service is also essential to store and send the information in the web to alert other areas and also to save information in the cloud. With the help of this proposed model we can able to detect the landslides at an early stage and also to send the alert messages to the disaster management sector of our government to take necessary precautions and to completely save our livelihood. We have also made our proposed model energy efficient by the use of solar batteries since it is a major renewable energy source and the required maintenance is also less.

In our model, for a certain sensor node, let $\varepsilon_i$ and $\varepsilon_r$ are its initial energy and remaining energy in order. The duty cycle $\Delta$ can be defined in (1) as,

$$\Delta = \Delta_{max}\left(1 - \frac{Ta}{Tx}\right) \times \left(1 - \frac{\varepsilon_i}{\varepsilon_\gamma}\right) \qquad (1)$$

Here $\Delta_{max}$ represents the maximum duty cycle and $Ta$ is incorporated to reduce the response delay. The duty cycle decreases with the increase in anomaly probability, which means the greater the likelihood of landslide occurrence, the shorter the wakeup interval. $\varepsilon_r$ contributes to balancing the energy consumption among sensor nodes. The sensor node will increase the duty cycle as its remaining energy constantly decreases. Suppose we have a cell '$a$' and '$v$' is the class associated with '$a$', either being true or false. Then, assuming a hidden variable $X$ for an event to select one sensor, a probability for a class

$v$ given $a$: $P(v|a)$, can be expressed as a marginal probability of a joint probability of $X$ and $v$ in (2) as,

$$P(v|a) = \Sigma_i^n\left(P(v, X_i|a)\right) \quad (2)$$

We use external knowledge $P(X_i|a)$ to express each sensor's confidence given '$a$'. For instance, if a certain sensor becomes unavailable, the corresponding $P(X_i|a)$ will be zero. We can also assign a large probability for the corresponding $P(X_i|a)$ if one sensor dominates over other sensors. Taking all the criteria into account, the formula will be further improved into the following format in (3) as,

$$P(v|a) = \sum_i^n Q_i\left(\sum_j^n K_{ij} - \Sigma_j^n L_{ij} - \frac{\sum_j^n U_{ij}}{\Sigma_i^n N_i}\right) \quad (3)$$

Here, $Q_i$ denotes the normalized prior F-measure of sensor $i$ from historic data, $K_{ij}$ denotes positively classified items from sensor i in cell a, $L_{ij}$ denotes negatively classified items from sensor $i$ in cell $a$, $U_{ij}$ denotes the items from sensor $i$ in cell a that have been filtered out using stop words and stop phrases and $N_i$ is a total number of items from sensor $i$ in cell $a$.

Since we have used seasonal algorithm in our proposed model, the system works regularly during rainy season and in other seasons it works as

per the requirement to save the energy consumption level.

Landslide detection module pseudo code is as follows

```
INITIALIZE
    IF vib >100
    Power ON and send alert msg
ELSE_IF hum < 28°C and vib > 100
Power ON and send alert msg
    ELSE
    Power OFF
END
```

As per the algorithm given above, if the vibration value exceeds 100 it sends the alert messages accordingly and also if the humidity value is less than $28°C$, alert messages are sent. When the sensor nodes are regularly awoken to sample acceleration data then the monitoring will be more accurate but it weighs heavily on sensor nodes. Maintaining balanced energy consumption between nodes should also be considered to prolong the network lifetime. In Table 2, geophone calibration constants are compared with damping ratio values, in Table 3, each byte value is represented with hexadecimal and character notations and Table 4 denotes the model parameter configuration for landslide.

| Geophone calibration constants | No Damping ratio | With damping ratio |
|---|---|---|
| **Vstep** | 0.998 | 2.961 |
| **Frequency f** | 0.6276 | 1.1462hz |

Table 2: Frequency and Damping Ratio

| Byte | Hex | Char | Details |
|---|---|---|---|
| **1** | 0A | \n | New line character |
| **2** | 48 | H | Fixed character H |
| **3** | 3A | : | Fixed character |
| **4** | 30 | 0 | Humidity char hundreds |
| **5** | 35 | 5 | Humidity char Tens |
| **6** | 38 | 8 | Humidity char ones |
| **7** | 20 | " | Space |
| **8** | 54 | T | Fixed character T |
| **9** | 3A | : | Fixed character |
| **10** | 30 | 0 | Temperature char Hundreds |
| **11** | 32 | 2 | Temperature char Tens |
| **12** | 34 | 4 | Temperature char ones |
| **13** | OD | " | space |

Table 3: Byte, Hexadecimal and Character representation

| **Frequency 100 MHz** | | | |
|---|---|---|---|
| | Normal case | Warning case 1 | Warning case 2 |
| **Water strip depth** | 0m | 0.5m | 0m |
| **Layer 2** $\varepsilon_1$ | 3.5+i0.05 | (1-r)(3.5+i0.05)+r(84+i0.6) where r=0.1 | (1-r)(3.5+i0.05)+r(84+i0.6) where r=0.1 |
| **Scatterer** $\varepsilon_s$ | Stone 6+i0.1 | Stone 6+i0.1 | Water bodies (1-r)(3.5+i0.05)+r(84+i0.6) where r=0.5 |
| **Scatter diameter** | 10x10x5cm | 10x10x5cm | 20x20x10cm |
| **Scatter orientation** | Uniformly in all direction | | |
| **Layer 3** $\varepsilon_3$ | Bedrock 6+i0.1 | Water strip 84+i0.6 | Bedrock 6+i0.1 |
| **Interface between layers 1 and 2** | Guass spectrum with rms height 4cm and correlation length 20cm | | |
| **Interface between layers 2 and 3** | Gauss spectrum with rms height 2cm and correlation length 40cm | | |

Table 4: Model parameter configuration for landslide

## 4. Experimental Setup

Accurate evaluation has been done in our proposed model to measure the communication speed and the accuracy level separately. We have also used various modules that contribute to our landslide detection mechanism. The modules such as, Registration module – this module is mainly used to add or manage the number of users involved, Landslide detection module – the major purpose of this module is to get the corresponding threshold value and to monitor along with sensor values and buzzer value, Device test module – this is mainly used to check all the devices connected in the module to work properly without any malfunctions, Sensor management module – the main purpose of this module is to manage all the sensors used in our design model to check their on and off status constraint, Short message service module (SMS) – whenever the detected landslide is about to cross the threshold value an SMS is sent to the governing authority immediately. The hardware setup consists of an Arduino mainboard with Zigbee and FM modules. Sensors are connected with the mainboard and an LCD display is also associated for onboard display.

The implementation of EEELDS is performed in four different configurations for different purposes. The first configuration consists of Arduino mainboard [11], Humidity and Vibration Sensor, Zigbee module [12] and LCD screen. This is used take readings of humidity and vibration directly for observation – given in Figure 2.

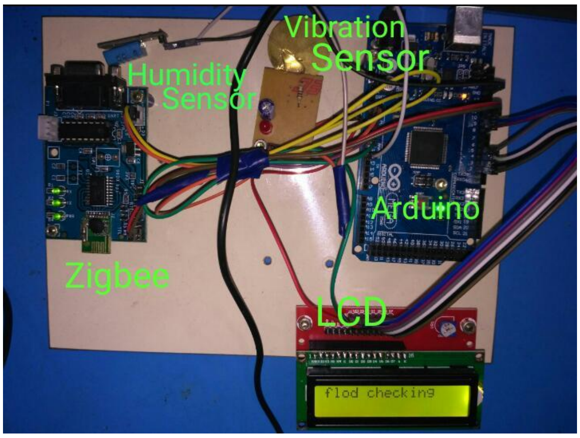


Figure 2: Proposed model with humidity and vibration sensor

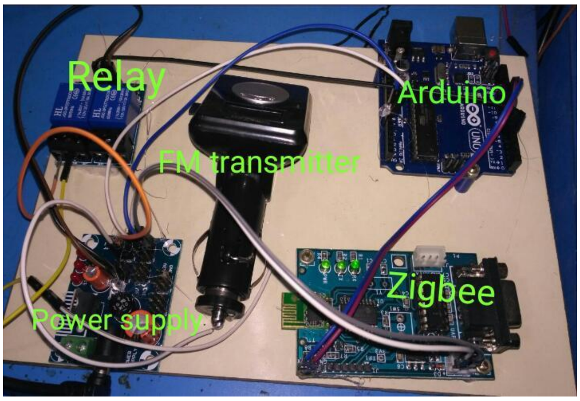


Figure 3: Proposed model with FM transmitter and Relay

The second model consists of Arduino board, Zigbee module and a FM transmitter which is used to broadcast the information to other listening nodes. Recipients get the data of humidity and vibration of a remote place. The implementation photo is given as Figure 3.

The third model consists of Arduino board, Zigbee module and a Buzzer. This module receives the information about the landslide and raise an alarm to warn the local inhabitants about the upcoming natural disaster. The implementation model photo is given in Figure 4.

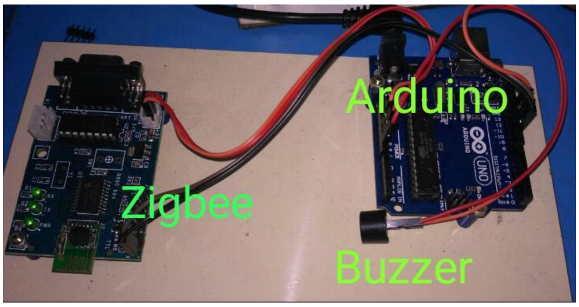


Figure 4: Proposed model with buzzer

The fourth one is the simulation model performed with the help of a Network simulation Tool OPNET [13]. OPNET is capable of measuring various network metrics such as Throughput, Latency, End-to-End Delay and Power consumptions[14]. Simulations are performed for one hour of real world time and the results are logged every 10 minutes time interval. The simulation is performed repeatedly for LITMUS, LDCSPC, LDMWSN and EEELDS methods. The node placement in OPNET is given in Figure 5.

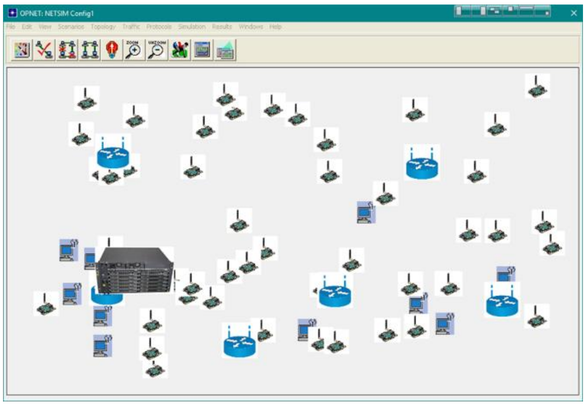

Figure 5: Node Placements in OPNET

## 5. Results and Analysis

Standard network metrics such as Throughput, Latency, End-to-End delay and Power consumption of existing and proposed methods are measured and given in this section. The landslide accuracy is also measured for the existing LDMWSN method and for proposed EEELDS. The landslide simulation is performed using a dedicated trajectory simulation evaluation setup.

### 5.1. Throughput

The throughput refers the communication quality in a network. Higher throughput means the higher quality of the network schema whereas the lower throughput refers the disadvantage of the network. Based on the observed results, proposed EEELDS achieved higher value throughputs. The observed values are given in Table 5 and comparison graph is provided as Figure 6.

| Throughput (kbps) | | | | |
|---|---|---|---|---|
| Time stamp | LITMUS | LDCSPC | LDMWSN | EEELDS |
| 1 | 1355 | 1565 | 1888 | 1921 |
| 2 | 1396 | 1471 | 1816 | 1993 |
| 3 | 1266 | 1568 | 1829 | 2091 |
| 4 | 1360 | 1465 | 1843 | 2044 |
| 5 | 1303 | 1473 | 1792 | 1971 |
| 6 | 1339 | 1631 | 1853 | 1986 |

Table 5: Throughput

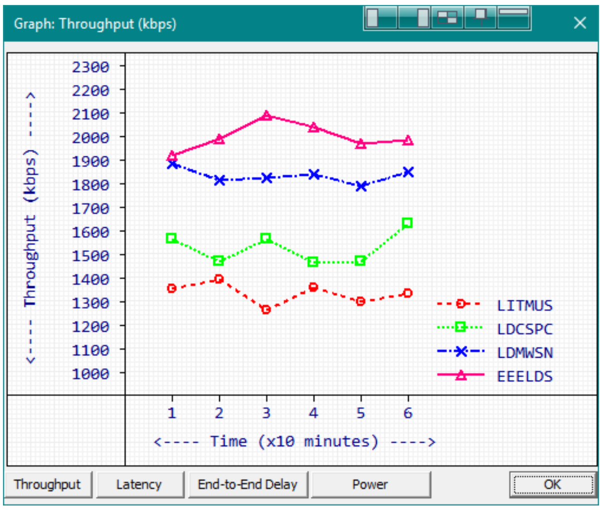


Figure 6: Throughput

### 5.2. Latency

Latency is one of the communication delays which causes performance degradation. The lower value of latency refers the higher efficiency of the network. The measured latency values are given in Table 6 and comparison graph is given in Figure 7.

| Latency (mS) | | | | |
|---|---|---|---|---|
| Time stamp | LITMUS | LDCSPC | LDMWSN | EEELDS |
| 1 | 93 | 83 | 87 | 65 |
| 2 | 96 | 80 | 87 | 65 |
| 3 | 102 | 88 | 84 | 66 |
| 4 | 93 | 91 | 78 | 68 |
| 5 | 104 | 89 | 78 | 69 |
| 6 | 101 | 85 | 82 | 69 |

Table 6: Latency

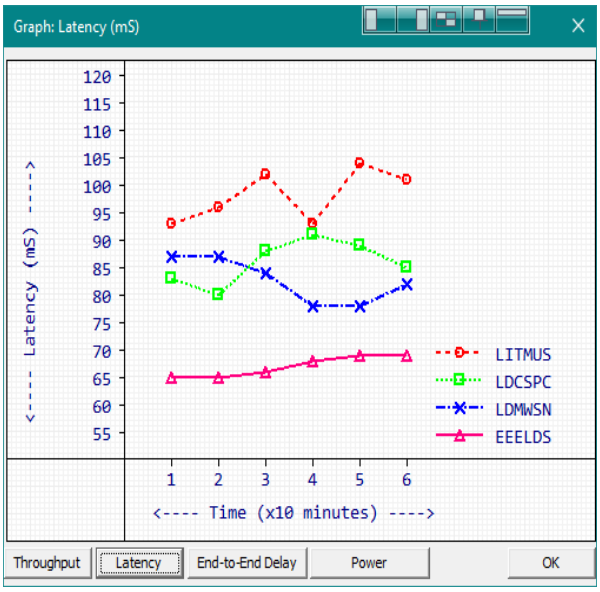


Figure 7: Latency

### 5.3. End-to-End Delay

The complete travelling time of a data packet is referred as End-to-End delay which is the accumulated values of all communication delays.

| End-to-End Delay (mS) | | | | |
|---|---|---|---|---|
| Time stamp | LITMUS | LDCSPC | LDMWSN | EEELDS |
| 1 | 327 | 285 | 218 | 181 |
| 2 | 313 | 286 | 205 | 183 |
| 3 | 327 | 265 | 217 | 181 |
| 4 | 322 | 254 | 211 | 187 |
| 5 | 327 | 281 | 207 | 187 |
| 6 | 320 | 288 | 219 | 181 |

Table 7: End-to-End Delay

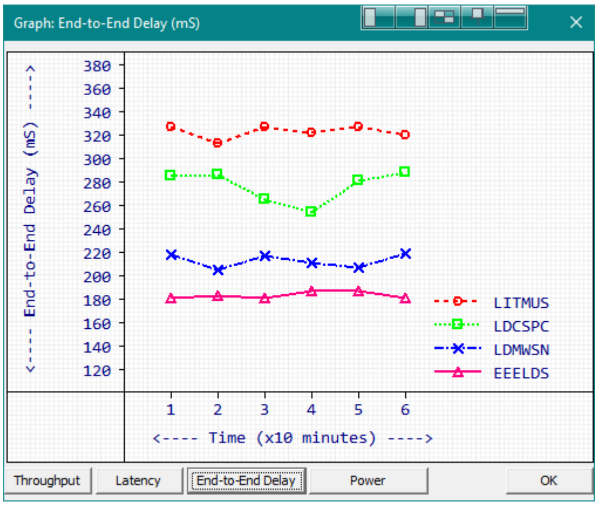


Figure 8: End-to-End Delay

A good network architecture should keep the End-to-End delay in control. Lesser End-to-End delay refers the higher quality of the network. The observed End-to-End values are given below in Table 7 and comparison chart is given in Figure 8.

### 5.4. Power Consumption

Power saving is the ultimate aim of this work. Since the sensor nodes are battery powered devices, the lower power consumption ensures the longer network node life times. The average power usage to perform a successful network communication is measured, tabulated in Table 8 and plotted as graph in Figure 9.

| Average Power (mW) | | | | |
|---|---|---|---|---|
| Time stamp | LITMUS | LDCSPC | LDMWSN | EEELDS |
| 1 | 1099 | 1023 | 1160 | 969 |
| 2 | 1058 | 1040 | 1111 | 967 |
| 3 | 1066 | 1039 | 1151 | 965 |
| 4 | 1084 | 1020 | 1145 | 956 |
| 5 | 1071 | 1041 | 1144 | 961 |
| 6 | 1094 | 999 | 1155 | 937 |

Table 8: Average Power Consumption

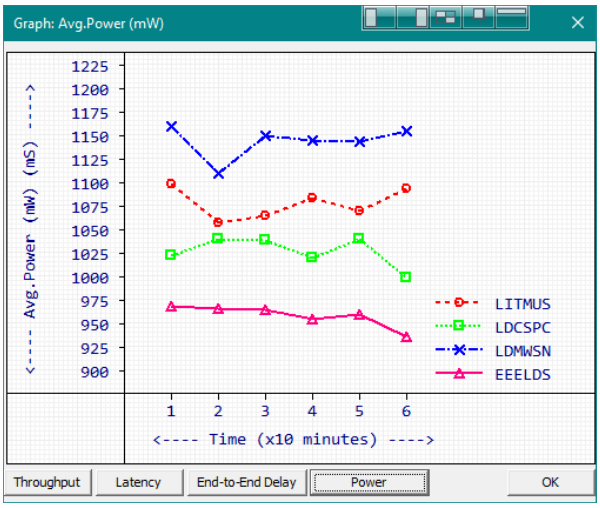


Figure 9: Average Power Consumption

### 5.5. Accuracy

Accuracy in one of the vital parameters in the task of landslide detection. The accuracy of existing and proposed methods is given as the comparison chart in Figure 10.

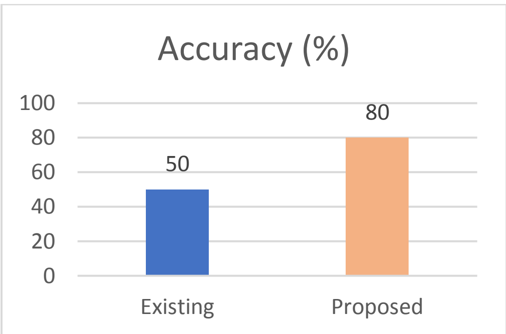


Figure 10: Accuracy level of proposed model

The experimental results regarding accuracy level of our proposed model are also magnificent. The information accuracy level is very much higher than that of our existing methodologies. Since the accuracy level is high, the information gathered from our model can be trusted and the upcoming precautions can take place without any ambiguity.

## 6. Conclusion

Landslides are the most common disasters happening in mountainous regions. It cannot be completely avoided but can be detected earlier to avoid the aftermath happening around to people living in those regions. An Energy efficient Landslide detection method with improved accuracy is proposed and tested by implementing as a real hardware device and by emulating multiple instances of the device in the network simulator. The proposed model has the higher accuracy in Landslide detection and it is energy efficient formulation improves the overall lifetime of the battery powered wireless sensor network nodes. Multiple disaster signaling alarms such as Local audible alarm, SMS indication and warning the Government disaster management department through priority channel of the proposed model make it as a boon for the people who are the residents of landslide prone area.

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