IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

RAIL TRAFFIC AMBIENCE ANOMALIES DETECTION USING WIRELESS SENSOR NETWORKS FOR OPTIMIZATION OF RAILWAY TRAFFIC MONITORING AND CONTROL.

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Abstract: Failure of the rail infrastructures and abnormal environmental are main key factors of the major rail accidents other than the human errors causes loss of human life's and economic loss of rail systems. The Indian railway faces major challenge due its second largest network and is expanding rigorously. Safety and the punctuality are the key factors of efficient Rail Transport system to compete with the Surface Transport. The Wireless Sensor Network Technology is low cost, compact and requires less energy to detect the anomalies in rail ambience which can avoid unwanted event thus protecting passenger's safety and saves economic loss. This paper discusses aspects of factors affecting the root causes of Rail accidents and efficient methodology to counter measure it using state of the art new Wireless Sensor Networks Technology.

Index Terms **- Rail ambience Anomalies, Real Time environmental parameters detection, WSN, Railway Traffic system.**

I. INTRODUCTION

Rail Transport is the fastest and most economical way to connect the major economic hubs across India .The Indian Railway is more than One Sixty years now can not cater todays population explosion in metro cities. The room for new development is very limited due to the congestion and other issues. The only way is to increase the speed of the traffic by powerful traffic detection systems in the rail field. For that Wireless Sensor Network plays a key role in most of the parts in the world. Wireless Sensor Network is the second largest network other than internet network. It is an *adhoc* Network which is developing at much faster rate .It is the promising technology of collecting ,processing environmental parameters in rail field and distributing information from various nodes to the application layer of Rail monitoring system. Small ,smart and very economical sensors can detect the unwanted event, thus WSN turns to be the most productive , easily deployable , very useful and very powerful technology for real time rail traffic monitoring systems in metropolitan as well as in off grid areas .[1]For last ten years the Indian Government is focusing on the

economic development of undeveloped parts of India other than metro cities by investing huge amount in surface transport networks and rail transport networks. Areas where roads were not existed like in Uttarakhand and in Kashmir valley ,today Indian railway is developing high speed rail networks. The major challenge is of unstable geologies and highly volatile environmental conditions which will hamper the rail passengers ,rail infrastructure safety other than the economic losses. The rail ambience also in other parts of the country is extremely harsh and so far was monitored by the human surveillance which was the main cause of major rail accidents in recent years. The rail ambience information from harsh environment conditions from remote location on real time basis can be handled by introducing a temporary *ad hoc* network using Wireless Sensor Networks [2]

II. Factors causing Rail accidents.

Rail accidents are unwanted event which should be averted at any given cost. Safety procedures are to be practiced stringently in order to avoid rail accidents. The Major cause of Rail accidents is derailment all over the world apart from Human errors and environmental conditions.

One of the significant cause of rail accidents in India is the derailment. There may be many reasons for the derailment one of which is cracks developed in the rail road. Also the overruling of the speed at curvature rail sites and sabotage are major causes of rail derailment. However the recent study shows that the number of derailment cases in 2001 was 350 and in 2017 it has drastically reduced it to 70 which is still a significant number. The powerful track and infrastructure surveillance can still reduce the derailment numbers in near future.

Another major factor of the rail accidents are collision.. In 2001 the number of collision cases was 20 and the numbers are drastically reduced to 4 in 20017. However by deploying state of the art radar based “Kavach System” can totally avert such incidences .

Since Indian rail road network passes through variety of harsh environments across extreme geographic areas one particular solution or methodology can not be implemented on overall networks. To optimize the smooth functioning of rail traffic different solutions to be adopted in different geographical areas.

Some of the environmental related factors which can be effectively handled by Wireless Sensor Networks deployed at various sensitive locations are .

1. Lanslides: Landslides is another major area of the rail accidents other than derailment. This unwanted event can be early detected by the use of WSN
2. Heavy Rainfall : Heavy rain fall decreases visibility of the loco pilot and may cause collision.
3. Water Logging :One of the major cause of disruption in the rail traffic, is water logging especially in heavy monsoon nearby coastal areas. Many rail tracks are laid by the early British Government 160 Years back in metro cities and still in used which are below the sea level at the high tides in heavy monsoon. In recent years the entire Train was stuck at Badlapur area in Mumbai Central Division due to heavy water logging on rail track, which could have been avoided if the emergency response system would have been employed in near by rail field.
4. Earthquakes: Most unpredictable and catastrophic event on the planet earth is earthquakes. It has a very deep impact on infrastructure and on human lifes. It can not be fully predicted. However the vibration sensors can be used to detect the vibrations near by rail field which can stop immediately rail traffic to avoid loss of lives and rail infrastructures at a great extent.
5. Temperature: Temperature has a significant impact on development on the rail road cracks. Extremely Hot and Extremely cold temperatures may develop the cracks on the rail road and on Rail bridges and other vital infrastructures, which may lead to the catastrophic events.
6. Wind : Since the ambitious rail infrastructure projects in Northen Himalya and in the far east are the areas are on very very high altitudes, wind is major challenge on the rail transportation to be reported before the safe traffic movement.
7. Physical Interference on the rail road: One of the major cause of rail accidents is unwanted interference on the rail road. In recent years hundreds of human lost their lives in Punjab on rail road because they were standing on the rail road without any notice to the loco pilot of the upcoming train.

There might be many unknown factors other than the mentioned in this research paper. But some of them can be tackled effectively with low cost highly reliable real time system using Wireless Sensor Networks. Wired networks are expensive, difficult to maintain and requires more energy to operate.Where as WSNs are deployed at minimum costs. They can dynamically adapted to changes in environment they are deployed in. They are very flexible and can be deployed at the exact location from where the information is to be collected. They are extremely compact.

III.WSN STRUCTURE

The structure of the WSN node consists of

1 Power Module
2 Sensor Module
3 Processor Module
4 Trans Receiver

The general block diagram of WSN node [4] is represented in Fig.1.

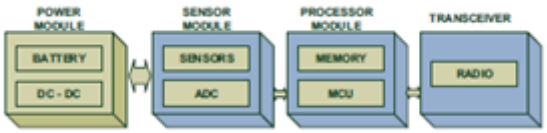


Fig 1.WSN structure

1.Power Module:

In rail field ambience sensing environments the WSNs are located in remote areas which are not easily accessible to the rail maintain ace staff on daily basis. Also these locations are in Off Grid areas where local power is not accessible to power up the WSNs .Hence the only source to the WSN is the battery. Ideally the WSN nodes are deployed for no human intervention from the security perspective reasons and are mostly deployed in the hidden or inaccessible locations to avoid sabotage attempts. Hence the battery used in WSNs has to operate for a longer time. Once the battery is discharged the WSNs node becomes dead and is practically useless unless other wise new battery or WSN replaces the previous ones. Energy management plays a crucial role in WSNs effective operation. Energy saving techniques such as Data Reduction, sleep or Wake up methods, Radio Optimization and energy efficient protocols plays significant role in extending the WSN active life time. Different energy harvesting techniques can also be deployed for boosting the life of the WSN network [5]

2.Sensor Module:

Vital physical parameters such as vibrations, Temperature, wind velocities, soil moistures and soil movements, Rain falls are detected by various compact low power operated sensors directly from the rail field. This information is gathered from sensor nodes [6]and is the area of interest and is then computed and forward through the Radio transmission module.

3. The Processor Module:

Although several wireless sensor node platforms based on the MCU have been proposed, they generally have the same basic architecture. They differ with regard to processing and memory specifications, communication capabilities, power supply and consumption, sensor support, applications and so on.The most popular Microcontroller, is Arduino Uno in low power applications.

4..Transreceiver

Large portion of energy in a WSN still get depleted through data transmission. low power sensor networks is the key requirement of WSNs to be deployed in the rail field parameter detection .The range of the sensor node to the base station is typically only few meters. The modulation scheme is a crucial element in transceivers that are based on energy harvesting from the RF signal. Most of the WSN transceiver covers ISM band (902 − 926 MHz) channels with output power − 6 dbm. The CMOS technology now dominates the Transreceiver modules since it operates on very low power and is extremely compact. [7] .

III. TYPICAL WSN RAIL AMBIENCE ARCHITECTURE

The parameters which are to be monitored are in the vicinity of the few meters from the rail roads. Railway engineers identifies the sensitive locations where the environmental parameters are to be detected and may play crucial role in the functioning of the smooth rail traffic movements. The general parameters discussed above can be represented in Wireless Sensor Network Architecture in Fig 2. One or many sensor networks can be clubbed together to transmit the data to local base station ,which then process this information and presents it to the rail application layer for event detection. WSN clustering is one of the proven models of efficient energy management .In clustering model mode of communication and data transmission rates playas important role .There are many more than thirty WSN clustering protocols.Self healing network is most suitable for rail field applications [8].

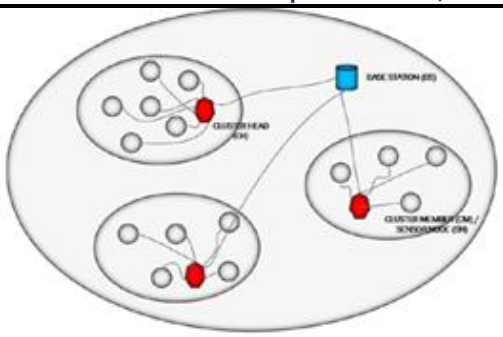


FIG 2; Rail field WSN architecture

IV PROPOSED SYSTEM

Wireless Sensor Networks are having limited coverage areas but clistering of many sensor nodes can offer a custom made solution for rail field ambience parameters detection. A typical geographical and environmental constraints detects the types of physical parameters to be monitored to avoid unwanted event.We have focused a typical Hilly region area like Konkan, Himalaya region where there is a sudden change in weather pattern disrupts the rail traffic movements.Too much of rain can cause the soil movements and is the root cause of the Landslides there by causing rail accidents and disrupts the rail traffic movements causing delay in travel time and economic loss.The soil moisture is the prime concerned because more the moisture in the soil it may cause the land mass movement and its an early sign of the Landslides.In himalyain Tunnels the landslides occurs internally which is due to water trapped in the mountain layers and very difficult to predict.

Landslides and slope failures are induced by heavy rain and earthquakes causes thousands of casualties and major economic loss [9]. Landslides and slope failures induced by heavy rain and earthquakes causes thousands of casualties and major economic loss [1]. In monsoon in the heavy rains , the soil is eroded and it flows with the downstream with high velocity causing a momentum and due the slope the rocks having bigger mass becomes start of the landslide. The elastic limit of the rocks and or soil is exceeded due to the percolating water causes development of hydraulic pressure and the strength of adhesiveness of the rocks and soil loosens and causing a landslide. For hostile and harsh environment WSN is the most proven methodology[2].

Landslides destroy railway infrastructure and disrupts the rail traffic may cause the loss of life and delay in traffic hence economic loss. This can be avoided using Sensor Nodes deploying near to the tracks and can give early warning system .A real time Landslide detection system using WSN Wireless sensor networks(WSN) is to be employed as early detection and traffic control [2] .However the major challenges of the deploying the Wireless Sensor Nodes are Lack of Memory in storage in the nodes, High Power consumption by the WSN nodes and if the power is consumed the WSN transmitter becomes dead hence performance of the monitoring system gets compromised. And the limited Bandwidth of the WSN nodes.

With the limited availability of bandwidth in the lower frequencies, wireless sensor network nodes are forced to perform at higher frequencies. Having this limitation, the sensor nodes of the network are not expected to transmit a large among of data. A delay in data transmission may occur, and the real-time update of this technology is jeopardized [3].

But the presence of WSN provides simplicities in the measurement of field data, and makes the landslide prediction system becomes more effective. Data density flexibility, improved accuracy due to optimizing the on field installation , much improved communication distance due to the advancement in semiconductor technology and optimization of battery backup and power management its possible to have a real time landslide detection as early warning system. The smart sensor when have wireless communication capability with the base nodes , and if the more than one sensor node it forms the a local wireless sensor node which is capable of monitoring and communicating with base station or in the network. Since they are wireless connected with readily available protocols ,the physical state of the rail field can be monitored on real time basis and can generate the digital signal which can aware the rail traffic monitoring control station as well as local rail signalling system as well as to a Loco pilot who can take immediate corrective action.

WSN is a new generation of sensor systems, although still limited in data processing capability and bandwidth for communication [4]

Ideally, it's Difficult to monitor the all atmospheric conditions because landslides occurred in forest areas in the mountains ,hilly area's and there are many things that can cause landslides, so we need a reliable sensors to keep an eye on them. Our proposed system has various sensors that helps to monitor Atmospheric conditions and can give early detection as well as communicate with traffic monitoring and control system on real time as well as can indicate the warning signal on the rail track to avoid the accidents using local warning signal.

From the remotely located field landslide occurred message can't reach long distance because the event of the landslide message to be conveyed we need , internet or GPS network is required. But in Mountain region or in deep forest areas the network availability is not there, due to this, real time situation and communication it is not possible so message can't reach long distance. So we propose NRF module. NRF module will help to reach message to the WSN master node. The master node can be integrated with IoT based modules or Using GSM network .Currently we have employed Arduino UNO based receiver node which can alert the Railway Traffic Control Unit at located on the rail road section which is responsible for traffic control via SMS alert. We have proposed a Local Indicator in case the landslide occurs and the rail traffic is in very closed to the location of the landslide site the loco pilot can take immediate action and can avoid the accident.

IV KEY FEATURES OF PROPOSED SYSTEMS

we present a key features of the brief explanation about the proposed system.

The system uses Arduino Nano on the Data Acquisition System Side and Arduino Uno on the Receiver Side. NRF Module are used for sending data from Slave Node (transmitter side) and for receiving the data at the Master Node (Receiver side).

A rain sensor, humidity sensor, temperature sensor and soil moisture sensor are used for early detection and alert. A vibration sensor is used to detect the how much vibration takes place and accelerometer are used to detect the tilt angle of the mountains.

All the data collected at Slave Node (transmitter side) is sent using NRF Module to another NRF Module connected at Master Node (receiver end).

A local indicator is used to provide local alerts along with 16x2 LCD which displays the current status of the system at the receiver end for the local inspection personal as well as a Local Signal is placed at the distance of 500 meters to 1 Km distance to make aware the Loco Pilot about the early warning of the Landslide ahead on the Rail Track so that he can sttop the Train immediately. Also with the help of GSM Module the alert is sent to the registered mobile number of the Main Section Traffic Control Module which is primarily responsible to monitor and Control the particular rail section traffic and accordingly he can divert/stop the traffic on the particular stretch of rail line.Our system can be very effective which detects the Landlside event on real time and can prevent the traffic congestion on the rail line since the Main Traffic controller can divert the rail traffic from another rail section. In near future we are in process to develop the IOT based application.

V HARDWARE MODULES

A.Microcontroller Board**:**

We are using ATmega328 because it is cheapest processor , can be programmed easily and available in bread board –compatible package. It works on 16 MHz having 14 Input/Output. We can use 6 of them as PWM output. A USB connection and ICSP header and a power jack is available on board.

With locally available AC-to-DC adapter and a USB cable we have powered it. It works on 5 Volts and has a DC current per I/O is 40ma.32KB Flash Memory is available and in which only 0.5 KB used by boot loader

Fig.3 Microcontroller Board

V. B. Wireless Sensor Node :

We have used the Arduino Nano on the Wireless Sensor Node on the optimized location near to the Railway tracks where the Landslide is to be detected before any damage to the rail track occurs and early warning signal to be conveyed to the Loco Pilot and to the main Rail Traffic Control Unit.
ATmega168 is a small, complete, and breadboard-friendly.It also works on 5 Volts,having 14 Digital I/O Pins and out of which 6 of them provides PWM output.A 32 KB Flash Memory is available and it Boot Loader uses only 2 KB Flash Memory.
Flash Memory 16 KB (ATmega168) or 32 KB (ATmega328) of which 2 KB used by bootloader.* Analog input pins can read the data from surrounding of the railway tracks and can provide Digital outputs . DC current per I/O pin only 40 ma .and a clock speed is 16 MHz.

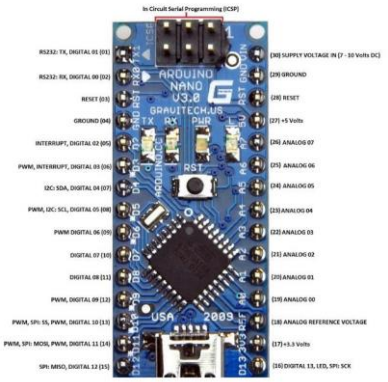


Fig.4 Wire;less Sensor Node

V.C RAIN FALL SENSORS
In Himalayin region the rain starts within no time and due to the steep slows water velocity causes the sudden landslide. The rain fall detection can create early warning signals to the Loco Pilots in highly sensitive areas. Our rain sensor module is having a size of 5cm x 4cm nickel plate on side.It can be used for a longer time since it has Anti-oxidation, anti-conductivity coatings.The control board is different from the Rain Fall detection sensor board.When the rain drops strikes on the sensor board it generates the analog output and LED becomes ON and the DO output becomes LOW.When Rain drops are not there the DO output is HIGH.The rain drop sensor board uses 5 Volts supply and consumes only 15 ma. LM393 comparator is used for simplicity.

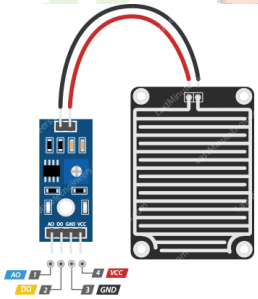


Fig.5 Rain Fall sensor.

PIN Configuration: -
1. AO: Analog output
2. DO: High/low output
3. GND: ground
4. VCC: 5V DC

V.D VIBRATION SENSOR

SW -420 vibration sensor is used to detect the vibration caused by surrounding moments of the soil and rocks or a potential landslide. Using LM393 comparator we generate the digital output. The surrounding vibrations are first studied and then the threshold limit is to be set by adjusting a threshold limit using on-board potentiometer.When the vibration is detected sensor provides Logic Low.

Fig 6 Vibration Sensor

PIN Connfiguration:-

1. VCC: The VCC pin powers the module, typically with +5V.
2. GND: Power supply ground
3. DO: Digital Out Pin for Digital Output.

V.E SOIL MOISTURE SENSOR:

The moisture in the soil is very critical parameter to start the moment of the soil as well as the rock mass. volumetric content of water inside the soil plays very important role.Our soil moisture sensor module works on 5 Volts DC having operating current 15 mA and has both Analog as well as Digital outputs.The threshold limits can be adjusted as per the soil data of the site location.It is suitable for harsh conditions

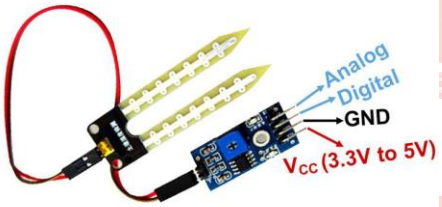


Fig.7 Soil Moisture Sensor

V.F ACCELEREOMETER SENSOR

Now a days many electronic devices ,smartphones and wearable devices uses accelerometer sensor since they are compact measures the acceleration of any body or object in its instantaneous rest frame.A low power ,3 axis accelerometer board is used detect static acceleration of gravity in tilt-sensing applications, as well as dynamic acceleration resulting from motion or shock. The ADXL345 Triple Axis Accelerometer Board is well suited for rail fields applications since it can have 10,000 g shock survival.

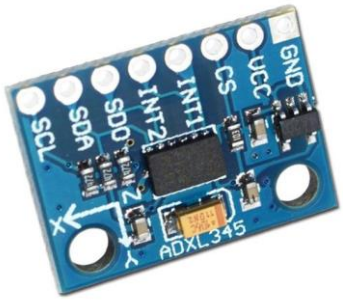


Fig.8 Accelerometer Sensor

PIN Configuration: -

1. VCC: The VCC pin powers the module, typically with +5V.
2. GND: Power supply ground
3. CS: Chip Select.
4. INT1: Interrupt 1 output.
5. INT2: Interrupt 2 output.
6. SDO: Serial Data Output / I2C Address Select.
7. SDA: Serial Data Output / I2C Serial.

V.G TEMPERATURE SENSOR

Before the rain fall starts the temperature of the surrounding drops and the humidity in the surrounding increases hence we use DHT11which is a commonly used Temperature and humidity sensor. Humidity from 20 to 90 percentage with an accuracy of ±1°C and ±1 with a Temperature range from 0°C to 50°C.The Himalyan region never exceeds the temperature range of 50°C hence we have used the above sensor.Its Operating current: 0.3mA (measuring) and 60uA (standby) and works on 3.5V to 5.5V.

Fig.9 Temperature Sensor

PIN Configuration: -

1. VCC: - Power supply 3.5V to 5.5V.
2. Data: - Outputs both Temperature and Humidity through serial Data
3. GND: - Connected to the ground of the circuit

V.H TRANSMISSION MODULE

nRF24L01 Module: Since we are using Ardino this module is a popular choice.It operates on 2.4GHz transceiver with an embedded baseband protocol engine. Very few external passive components are needed to design a radio system with the nRF24L01.

It has Ultra low power operation, 1.9 to 3.6V supply range with on board Voltage regulator , 11.3mA TX at 0dBm output power, 12.3mA RX at 2Mbps air data rate and a 900nA current in power down.

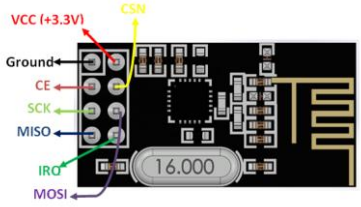


Fig 10 Transmission Module

V I GSM MODULE

We required ultra compact as well as reliable technology hence GSM/GPRS based SIM900A module is employed.

A dual-band GSM/GPRS engine that works on frequencies EGSM 900MHz and DCS 1800MHz. SIM900A features GPRS multi-slot class 10/ class 8 (optional) and supports the GPRS coding schemes CS-1, CS-2, CS-3 and CS-4.It has power saving mode in which typical power consumption is only 1.5mA.

Its operating range is -30ºC to +80ºC. It has operating voltage 3.4V – 4.5V with transmitting power: Class 4 (2W) at EGSM 900, Class 1 (1W) at DCS 1800 with

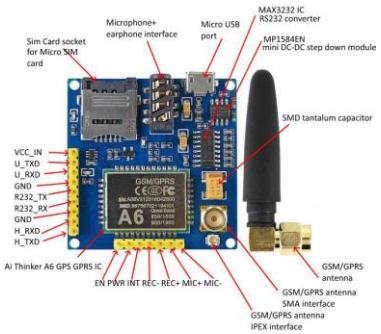
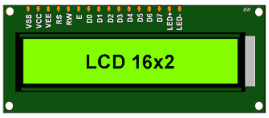


Fig 11 GSM Module

VJ LCD DISPLAY MODULE

16x2 LCD Display: A local LCD display facility is provided to local railway monitoring staff for early warning system and immediate corrective action for smooth functioning of Railway Traffic.

16x2 LCD is an easy-to-use display module; it can make display easier. The Arduino library for 16x2 LCD, user just need a few lines of the code can achieve complex graphics and text display features.The main advantage is that it can also display any custom generated characters.Custom generated characters also can be displayed. Green and Blue Backlight are available for display.



No.	PIN	Function
1	VSS	Ground
2	VCC	+5 Volt
3	VEE	Contrast control 0 Volt: High contrast.

No.	PIN	Function
4	RS	Register Select 0: Commannd Reg. 1: Data Reg.
5	RW	Read / write 0: Write 1: Read
6	E	Enable H-L pulse
7-14	D0 - D7	Data Pins D7: Busy Flag Pin
15	LED+	+5 Volt
16	LED-	Ground

Fig. 12 16x2 LCD Display

VI SOFTWARE USED.

Arduino IDE: -

Using Java a cross platform application for WINDOWS ,Linux and MAC OS IDE that is Integrated Development Environment is used here.

GNU public License of IDE source codes are used. The Arduino IDE supports the languages C and C++ using special rules of code structuring. Many common input and output procedures are used from Arduino software libraries.

The Arduino IDE employs the program argued to convert the executable code into a text file in hexadecimal encoding that is loaded into the Arduino board by a loader program in the board's firmware. In our project, it is used for uploading code to Arduino UNO and Arduino NANO Board.

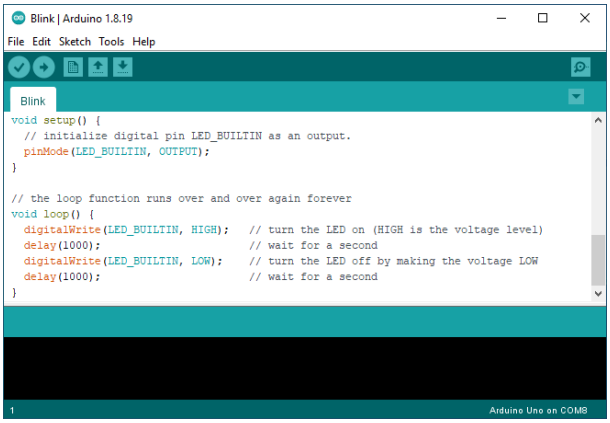


Fig.13 Arduino IDE

VII SIMULATION RESULTS

Proteus Software: -

For our WSN based landslide detection we have used The Proteus software since it is suitable for electronic design.

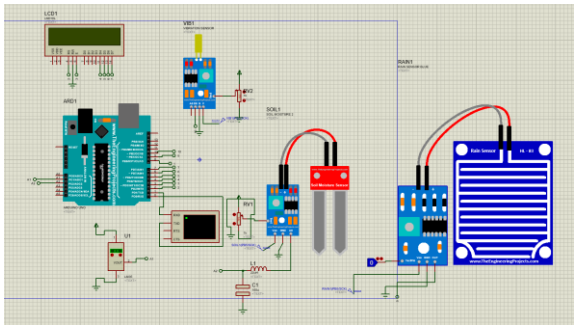


Fig.14 Proteus Simulation Circuit

When the rain falls on the rainfall circuit board it is detected by LED display

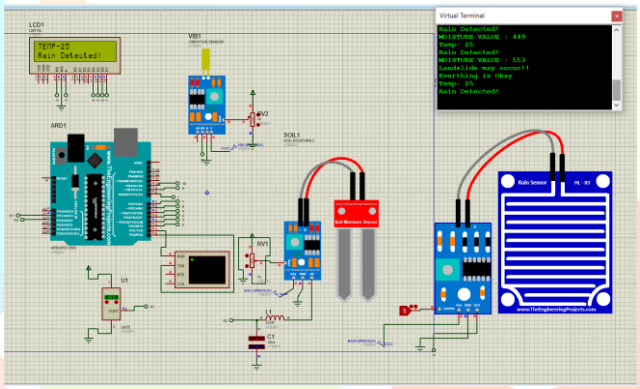


Fig 15 Rain detected

When the land mass moves the vibrational sensor detects the land mass movement above its threshold level and corresponding the local display gives the visual alarm is displayed for local rail surveillance staff and can take immediate corrective action. Also the NRF module and GSM module which transmits the Landslide and rain detection to the central server via SMS from the rail field

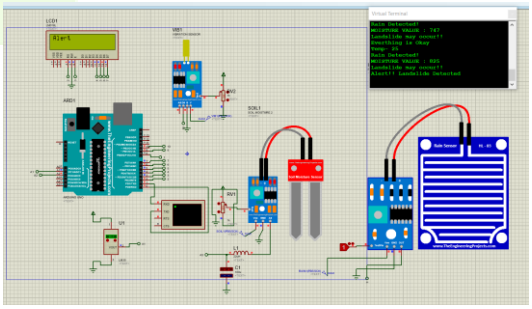


Fig.16 Landslide detected

If we detect the sudden fall in temperature we may predict the rain . The water contents in the soil near the railway track can give the early prediction of moment of soil as well as using accelerometer sensors an early landslide is detected. Hence using GSM module the warning signal is transmitted to the Centralizes Control room which is primarily responsible for traffic monitoring and control as well as to local railway woks station to take immediate necessary action. Similarly one of the output is used to display a warning signal for the Loco pilot to stop the train immediately there by we can save the loss of life as well as rail infrastructure. WSN network is a very fast and is inexpensive. Real Time WSN based Landslide early warning system for rail tracks and rail infrastructure is extremely suitable for Himalyan regions.

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