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EARTHQUAKE EARLY WARNING SYSTEM IN THE WESTERN HIMALAYAN REGION OF INDIA: AN ARCHITECTURAL DESIGN USING THE BotRf SIMULATION TOOL

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Abstract **:** We present a Long distance Wi-Fi based architectural design for an early earthquake warning system using the BotRf Telegram simulation tool for wireless links design. In this paper, a dedicated bidirectional communication ring connecting three locations within Himachal Pradesh state with a ring topology is proposed. This topology allows for redundancy to transport the signal to the earthquake monitoring centres by two independent routes, a direct one and another using an intermediate site as a repeater point. Being a dedicated ring, not part of the commercial Internet, it is not affected by commercial traffic during and after an earthquake. Even in case of disrupted service of the existing commercial communications networks, as often happens after a seismic event, the proposed network would still operate since it will be autonomously powered by means of solar panels and batteries. Therefore, the seismic data will be delivered to the emergency offices that can effectively react with the proper measures. The functional architectural design testbed for early earthquake warning (EEW) system would be available in the western Himalayan Region of India constituting a major step to improve earthquake monitoring alertness in this region.

Keywords: Early Earthquake Warning System (EEWS), Long distance WiFi, BotRf, Radio link simulation, Line of Sight (LOS)

1. INTRODUCTION

In the era of advancement in Science and Technology, it is still a big challenge to have a forewarning about the earthquake.Natural Disaster due to earthquake is a major concern of all human beings around the globe. A few geographic locations in Himachal in the western Himalayan region of India are under Seismic zone V, considerably vulnerable to earthquakes.

It was a harsh truth to witness 25th **April 2015 Nepal earthquake** (also known as the **Gorkha earthquake**) with a magnitude of 7.8M at about a distance of 80 km to the northwest of Kathmandu, the capital of Nepal, in the Himalayan Region, which killed more than 9,000 people and injured more than 25,000 [1]. Its epicentre was east of the district of Lamjung and its hypocentre was at a depth of approximately 15 km. This earthquake created great panic and people were hesitant to stay in their homes. It was the worst natural disaster to strike Nepal since the 1934 Nepal-Bihar earthquake. Earlier, the western Himalayan Region of India faced another, still worse, earthquake in Kangra district in the state of Himachal Pradesh, on 4th April 1905, with a magnitude 7.8 M, which killed more than 20,000 people and caused terrible destruction of buildings in the cities of Kangra, Mcleodganj, Dharamshala and Palampur [2].The devastation caused is shown in Figure 1.

Figure 1. Market after earthquake in Palampur (Kangra Distt.), India.

The Nepal earthquake also triggered an avalanche on Mount Everest making April 25, 2015 the deadliest day killing at least 19 people. It further triggered another huge avalanche in the Langtang valley, where 250 people were reported missing. In the past, there had been many other instances of earthquakes in India, with many lives lost. These tremors were also felt throughout India, from north to down south in Kerala; Bhutan, Bangladesh and Pakistan [3], details given below:

MAJOR EARTHQUAKES IN INDIA

DATE	LOCATION	FATALITIES	MAGNITUDE
Sept 18, 1737	Kolkata	1,00,000	NA
June 16, 1819	Kutch District	>1,543	7.7-8.2
Dec 31, 1881	Andaman and Nicobar Islands	none	7.9
June 12, 1897	Shillong Plateau	1,500	8.1
April 4, 1905	Kangra (HP)	20,000	8.25
Jan 15, 1934	Bihar	8,100	8.7
Aug 15, 1950	Arunachal Pradesh China border	1,526	8.5
Jan 19, 1975	Himachal Pradesh	47	6.8
Oct 20, 1991	Uttarkashi	>2,000	7.0
Sep 30, 1993	Latur-Killari	9,748	6.2
Jan 26, 2001	Kutchh	20,000	7.6/7.7
Dec 26, 2004	Off west coast, northern Sumatra, India, Sri Lanka, Maldives	2,83,106	9.0 to 9.3
Oct 8, 2005	Kashmir, HP, Pakistan	>80,000	7.6
Sept 7, 2011	Delhi	To be determined	4.2
Sept 18, 2011	Sikkim	To be determined	6.9
March 5, 2012	New Delhi	To be determined	4.9

Human Life is extremely precious, which demands an efficient & prompt Early Earthquake Warning Systems (EEWS) in each of the highly sensitive seismic zones with minimum delay. Thismotivated the present study aimed at building areliable early warning infrastructure at long distances. If high-intensity earthquake hits Himachal Pradesh state, it might disrupt the traditional communications lines and road, bridges and cables might be washed away. In this scenario, the only source of communications would be dedicated radio links, since mobile phone, internet and other cabled media may not work, according to [4].

Traditionally, Wireless Sensor Networks(WSN)have beensuccessful deployed indoor for distances upto 30 metres, and outdoors setting up to a couple of kilometres. Nevertheless, using high gain antennas and modified protocolos very long distances and high throughput can be achieved with modified WiFi low cost equipment.The longest WiFi link on recordwas established by Ermanno Pietrosemoli(one of the author of this paper) over a 382 km path in 2006 [5], [6].By cascading several links in a row the Rural Telecommunication Research Group of Pontificia Universidad Catolica del Peru (GTR PUCP) in collaboration with the Spanish EHAS Foundation,was able to span 445 km in the Amazonian jungle [7] to service rural communities along the Napo river. However, as far as we know, this kind of long distance communication has not been utilized for early earthquake warning and monitoring systems.

In this paper, an effort has been made to design an EEWS as a pilot project for the western Himalayan Region of Indiausing long distance WiFi links. This would be helpful for sending an early alert triggered by sensors when seismic waves are generated by an earthquake. Such an advance warning system could allow people to take appropriate actions to protect their lives.

A demonstration EEW System [8] called **ShakeAlert** began sending test notifications to selected users in California in January 2012. The system detects earthquakes using the California Integrated Seismic Network (CISN), an existing network of about 400 high-quality ground motion sensors. CISN is a partnership between the United States Geological Survey (USGS), State of California, Caltech, and University of California at Berkeley, and is one of the seven regional networks that make up the Advanced National Seismic System (ANSS).

ShakeAlert is transitioning from the current demonstration system to a production prototype for the West Coast. The USGS has published an Implementation Plan with the steps needed to complete the system and begin issuing public alerts. The basics are schematically presented in Fig.2.

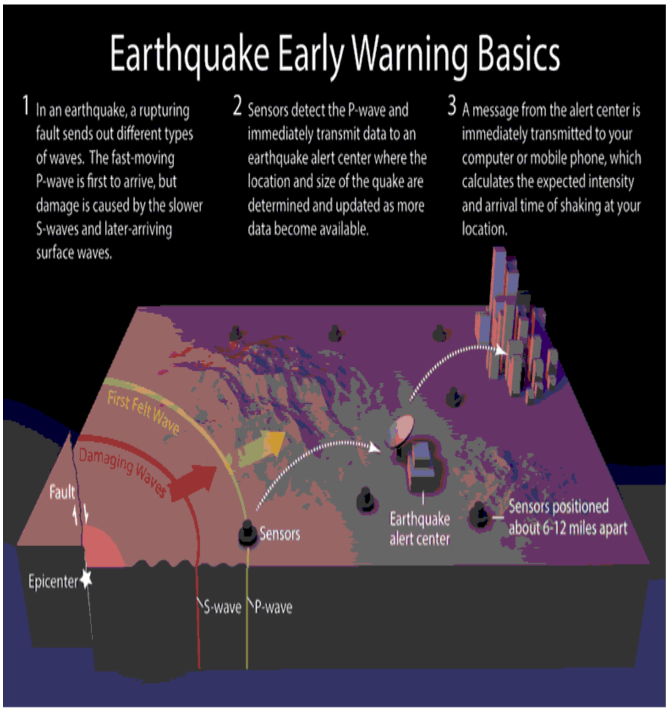


Figure 2.

In figure 2, the P is the longitudinal pressure wave quite deep inside the earth and the S wave is the transverse body wave responsible for destruction on the surface of the earth. Propagation velocity ratio of these two waves is roughly 2:1.

Earthquake early warning systems, like **ShakeAlert**, work because the warning message can be transmitted almost instantaneously, whereas the shaking waves from the earthquake travel through the shallow layers of the Earth at speeds of about one to a few kilometers per second (0.5 to 3 miles per second) [10]. This diagram shows how the system would function. When an earthquake occurs, both compressional (P) waves and transverse (S) waves radiate outward from the epicenter. The P wave, which travels fastest, trips sensors placed in the landscape, causing alert signals to be sent ahead, giving people and automated electronic systems some time (seconds to minutes) to take precautionary actions before damage can begin with the arrival of the slower but stronger S waves and later-arriving surface waves. Computers and mobile phones receiving the alert message would be able to calculate the expected arrival time and intensity of shaking at your location if time permits. Main idea behind is to provide an early alarm system so that people can go out of buildings and save their life.

2. METHODOLOGY:

2.1. The methodology consists of the following steps:

- **Identification of sites in the highly sensitive seismic zone (V):** For this pilot, three sites weretargeted namely Dharamshala (H.P.), Kufri (Shimla) and Kasuali. These sites fall within the province of Himachal Pradesh, India. It is pertinent to the mention that Shimla (capital of Himachal Pradesh) and Dharamshala (second winter capital of the state of Himachal Pradesh) have been identified as Smart Cities by the Government of India. Therefore, it is expected that funds would be available for innovative ideas/projects in them. The coordinates of the sites are given in table I.

Table-1: Sites for Radio Links

Site Name	Latitude Longitude	Antenna Height	Altitude
Dharamshala (DS)	32.287100 76.393886	3 m	4531m
Kufri	31.096454 77.262646	3 m	2675m
Kasauli	30.901792 76.961881	3 m	1841m

- **Setting up of Earthquake Monitoring Station (EMS)**: Seismic sensors installed in vulnerable areas will convey data by means of a dedicated wireless sensor network (WSN). Earthquake Monitoring Station would be installed at Dharamshala and Shimla. Kasauli will act as a relay centre for redundancy thus providing added reliability.

- **Communication of earthquake event**: As soon as the P wave is detected by the seismic sensor this information is transferred to the earthquake monitoring station (EMS)in less than 1 ms, the time it takes for the radio waveto travel 300 km. When the servers at EMS receive the warning, they set up an alarm system without human intervention. This alarm will be spread by different media to all interested parties.
- **Warning Signal**: A high volume siren will also be actuated. (During the mock drill the purpose of the siren will be explained). Efforts will be made to sign a memorandum of understanding (MOU) with all operators and the Government of Himachal Pradesh, to make it possible that every mobile phone in the area will receive an earthquake alert.The purpose of using a long distance modified WiFi is to have an independent, low latency transmission system which is reliable, robust and remotely managed. This allows to launch an early warning system that can contribute to the safety human lives.

2.2. Radio Links planning using the BotRfTelegramtool.

The first condition for a successful radio link at microwave frequencies is that there should be a clear line of sight (LOS) without any obstructions that could penetrate in the Fresnel zone, the volume around the LOS occupied by the radio wave. The second condition is that the received signal power should be strong enough for correct recodification. The establishment of the first condition requires a complete knowledge of the topography of the intervening terrain and the propagation path of the wave. This information is used to calculate the power expected at the receiver station. BotRf isa free, open source and user friendly bot based on the Telegram messaging application that can be used for the simulation and design of wireless links [8]. Telegram [9] is a cloud-based instant messaging service, similar to Whatsapp. Itcan beused in smartphones (Android, iOS, Windows Phone, Ubuntu Touch) or run as an operating system independent web browser application.Telegram can be used without a phone once the account is established. The client is free and has no limits on the size of media that can be exchanged. Servers are distributed in many locations around the world.

Giving the *calc* command with the names and coordinates of the extreme to BotRfwill result in a profile of the intervening terrain and a graph of of the radio wave propagating above it at the chosen frequency. The program will warn of any obstacle that intrudes in the Fresnel zone.To calculate the received power strength the radio and antenna parameters must also be entered. For our design we chose the following values:

Operating frequency: 5.8 GHz

Transmision Power: 20 dBm

Receiver Sensitivity: -80 dBm

Antenna Gain: 34 dBi (same antenna used for transmission and reception)

For example, to simulate the link from Dharamshala to Kufri using BotRf we entered:

calc ds kufri

Results

Free space path loss: 151.59 dB

No obstructions to LOS path due to terrain were detected.

Then figure 3(a) was displayed. In it one can see the apparent trajectory of the radio wave and the first Fresnel zone in magenta, the profile of the terrain in green and the apparent earth curvature in brown. We say apparent because the radio wave in reality follows a curve, but by modifying the radio of curvature of the earth according with the atmospheric refraction index we can depict the radio trajectory as a straight line. Its apparent that no obstacle intrude in the Fresnel zone over this 156 km path.

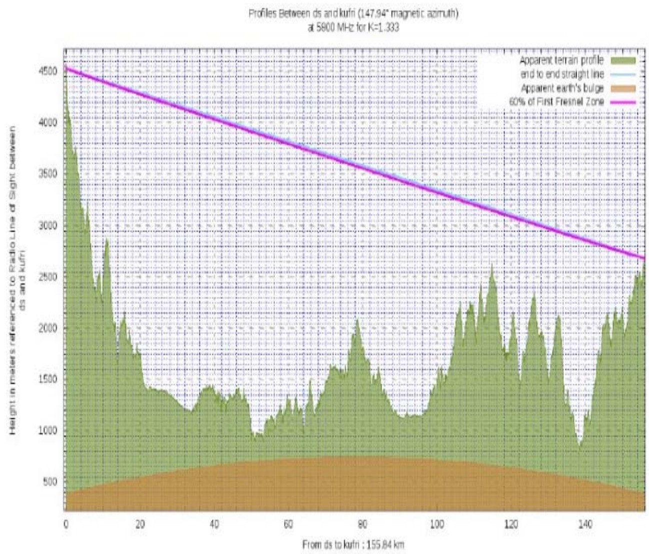


Figure 3 (a)Dharamshala (DS) to Kufri

To calculate the margin of the received signal above the receiver sensitivity we use the command:

pow Site1 Site2 TxPw TxCl TxAg RxAg RxCl RxSe

where:

TxPw: transmitter power (dBm)

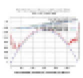
TxCl: transmitter cable loss (dB)

TxAg: transmitter Antenna gain (dBi)

RxAg: receiver Antenna gain (dBi)

RxCl: receiver cable loss (dB)

RxSe: Receiver sensitivity



BotRf

pow ds kufri 20 0.0 34.0 34.0 0.0 -80.0

Obtaining Figure 3 (b):

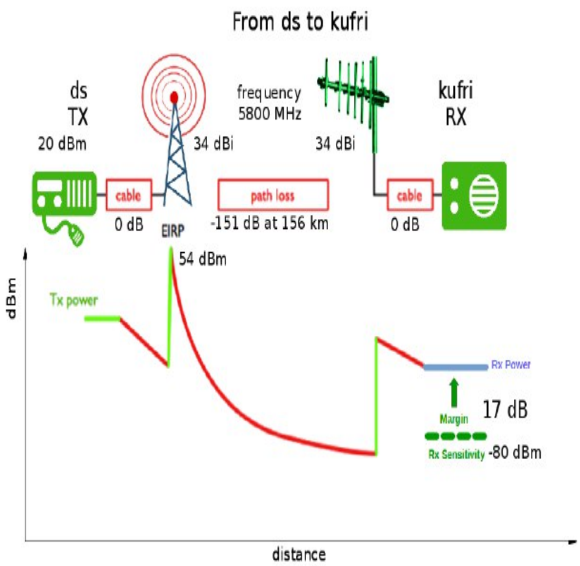
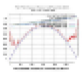


Figure 3 (b) Power vs distance on the Ds-Kufri link

In this diagram we can see that at the frequency of 5800 MHz the received signal will have a margin of 17 dB above the receiver sensitivity of -80 dBm.This means that the received signal has a value of -63 dBm after traversing the 156 km that separate Dharamsala from Kufri.

Further details of the link can be obtained using the r command:



BotRf
r ds kufri

Results

Path Analysis from ds to kufri

Distance between ds and kufri: 155.84 km
Transmitter site: ds
Site location: (+32.2871,+76.3939) (+32 17'13"/+76 23'37")
Elevation: 4531 m above sea level
Antenna height: 3 m above ground / 4534 m above sea level
Azimuth to kufri: 147.94 degrees
Depression angle to kufri: -1.2049 degrees
Receiver site: kufri
Site location: (+31.0965,+77.2626) (+31 5'47"/+77 15'45")
Elevation: 2675 m above sea level
Antenna height: 3 m above ground / 2678 m above sea level
Azimuth to ds: 328.39 degrees
Elevation angle to ds: +0.1543 degrees
Elevation angle to the first obstruction: +0.1548 degrees
Analysis model: Longley-Rice
Parameters used in this analysis:
Earth's Dielectric Constant: 15.000
Earth's Conductivity: 0.005 Siemens/meter
Atmospheric Bending Constant (N-units): 301.000 ppm
Frequency: 5800 MHz
Radio Climate: 5 (Continental Temperate)
Polarization: 0 (Horizontal)
Fraction of Situations: 50.0%
Fraction of Time: 50.0%
Summary for the link between ds and kufri:
Free space path loss: 151.59 dB
Longley-Rice path loss: 151.41 dB
Attenuation due to terrain shielding: -0.18 dB
Mode of propagation: Line-Of-Sight Mode
Longley-Rice model error code: 0
ErrorMessage[0]:
"No error"
No obstructions to LOS path due to terrain were detected.

Following the same procedure we obtained Figure 3(c) for the link from Dharamsala to Kasauli:

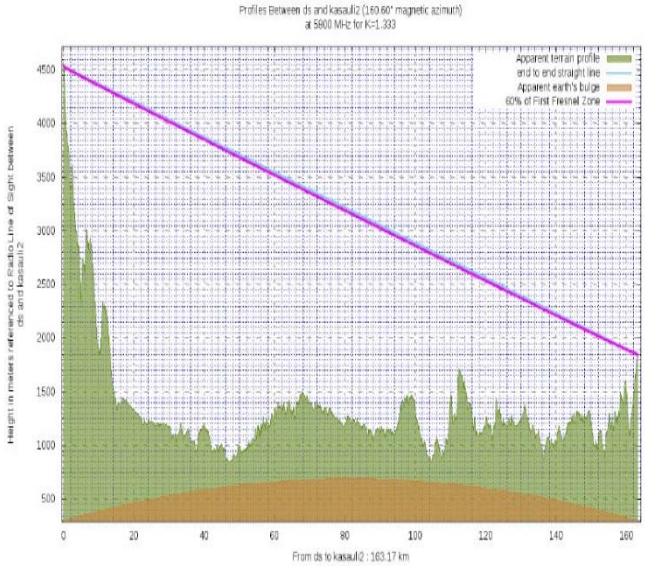


Figure 3 (c)Link 2- Dharamshala to Kasauli

Again, there are no obstales in this trajectory.

Using the *pow* command we get Figure 3 (d):

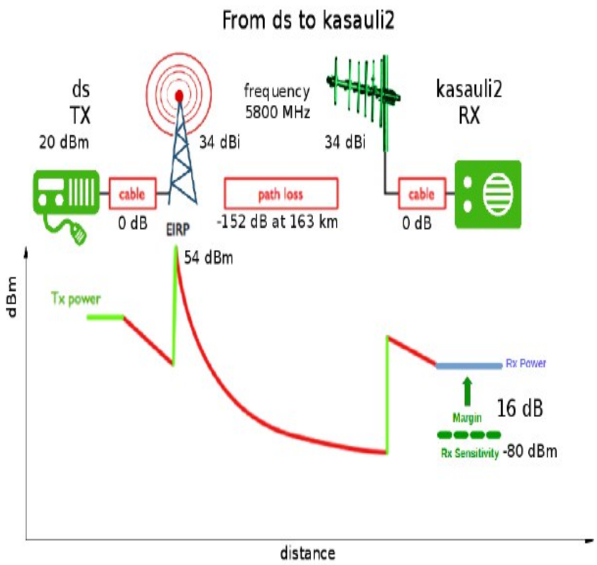


Figure 3 (d)Power vs distance on the DS and Kasauli link.

Which shows that the margin is very similar since there are no obstructions and the path loss is similar. The third link between Kufri and Shimla is shown in Figure 3 (e), again no obstructions encountered, but the margin, depicted in Figure 3(f) is now 29 dB since the distance is only 36 km.

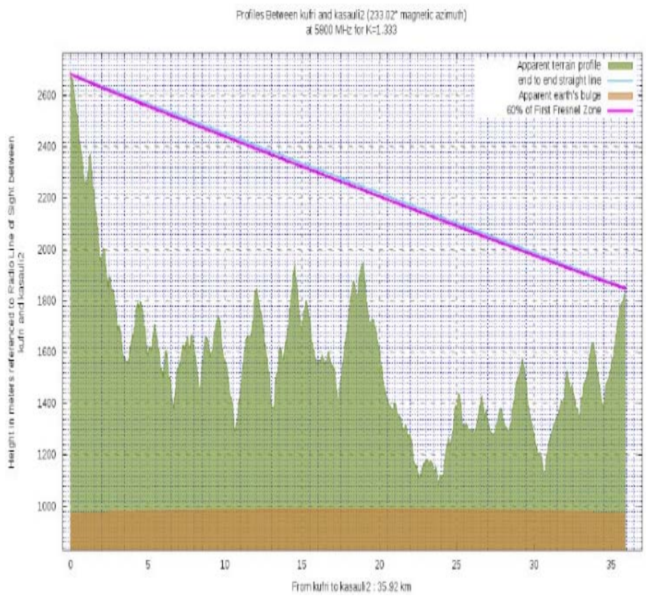


Figure 3 (e)Link 3. Kufri Shimla to Kasauli

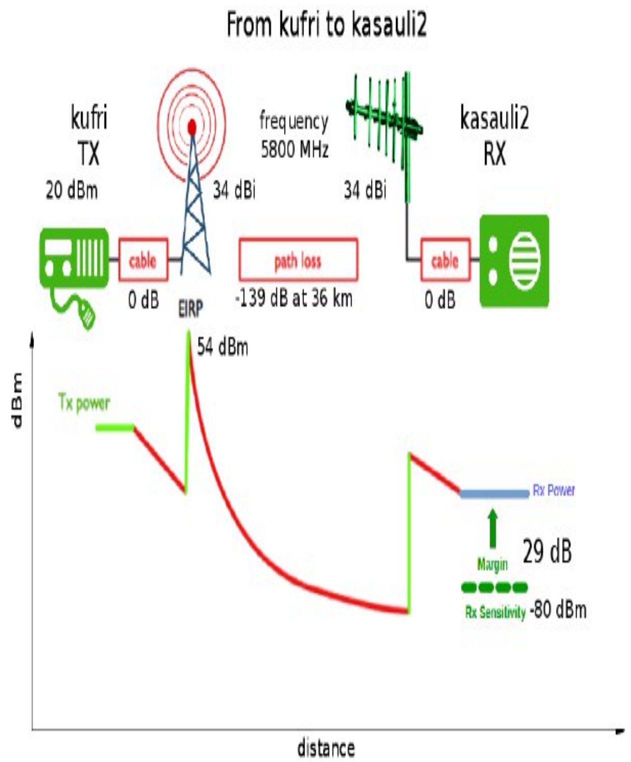


Figure 3 (f)Power vs distance on the Kufri- Kasauli link

These margins of 17,16 and 29 dB provide a quite reliable signal that will supportthe highest modulation schemes, affording transmission speeds in the megabit per second range.

Robustness

Because of the geographic locations of major earthquake (faults) in Himachal, falling under zone V, the area of interest is vulnerable to seismic activity. For this reason we have envisioned a ring topology, which provides an alternate path to reach the destination in case of failure of one link. This is shown inFigure 4.

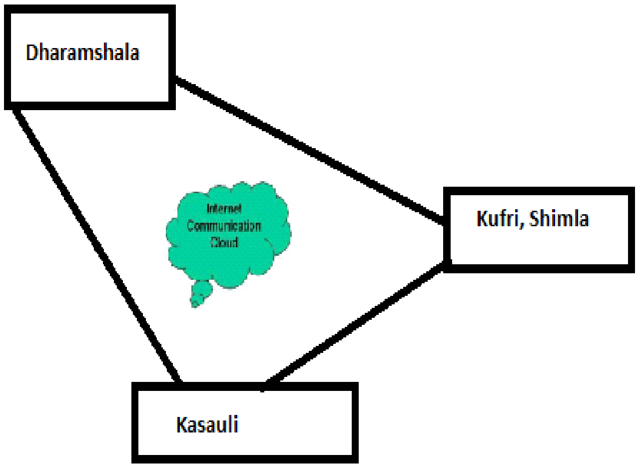


Figure 4: Ring Topology between selected sites

Seismic Sensors and its connectivity with Radio

Seismic Sensors would be placed in the seismic Zone V i.e Kangra/ Dharamshala. These would be connected as per the layout of EEW system given in figure 5:

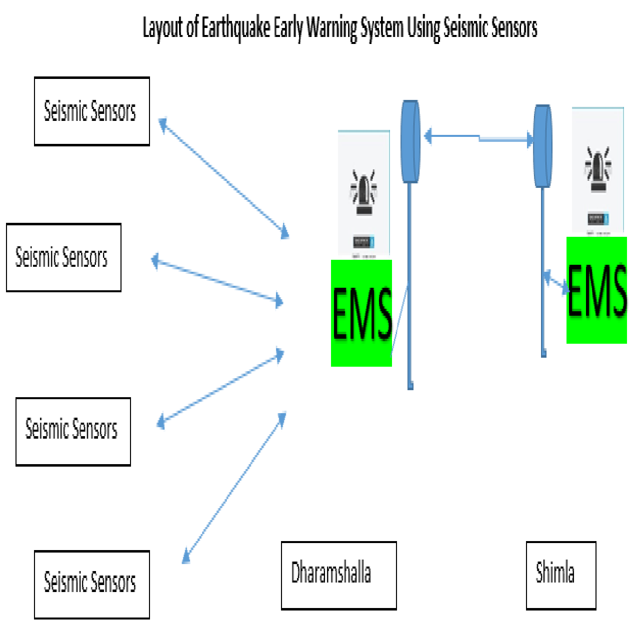


Figure 5 Layout of EEWS Using Seismic Sensors

Earthquake Monitoring System (EMS) will first sense P wave received from more than three seismic sensors and only then an alarm would be raised and an EEW signal would be sent to next station through radio based architecture for early warning system.

5. CONCLUSION

In the present paper, authors have presented an architecturaldesign set up for early earthquake monitoring and have assessed the effectiveness of using BotRf Telegramsimulation for establishing long distance Wi-Fi link. A dedicated communication ring connecting three locations within the state of Himachal Pradesh is presented in the ring topology having the advantage that can also be used to exchange other data besides the one pertaining to the earthquake, since the links will support a much higher data traffic and still offer very low latency, of the order of a few ms. Being a dedicated ring (not part of the commercial Internet), it remains unaffected by commercial traffic during and after an earthquake. emergency offices throughout the country.

On the basis of simulation results, it may be concluded that:

- Seismic Sensors/WSN may be integrated with these long distance Wi- Fi links. A functional architectural design to set up testbed in the remote location of western Himalayan Region of India, for early earthquake monitoring would be quite effective.
- The simulation for such long distancelinks prove its usefulness in monitoring the Early Earthquake Warning system and save lives in sensitive seismic zones of western Himalayan Region of India.
- To set up Long distance Wi-Fi network will be a major steps to improve the robustness of earthquake monitoring systems in this region as already mentioned that internet, cables may not work during earthquake. Only source of communications would be the radio link.
- A plan to include a study the feasibility of establishing a link with Nepal (seismic zone V) would be highly useful for early earth quakewarning system.

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