

Simulation, Emulation and Performance Analysis of Dhital-Kaski CWN Networks

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●要約

本論は、ネパールの Dhital-カスキ村に、設立された CWN ネットワークについてである。Dhital-カスキ CWN ネットワークはネパールの遠隔地域のコミュニティにインターネットサービスを提供するため、2010年以来、ゴータムラボラトリーによって開発された。Dhital-カスキの CWN は、接続性と堅牢性の面で多数の問題を持っている。本研究では、これらの問題を解決するため、CWNs のシミュレーション、エミュレーションを行った後、現地による実装を試みた。この地域の CWN の不安定な背後にある主な理由は、頻繁な電源遮断と雷及び稲妻のような多数の自然災害である。本研究では、既存の CWN ネットワークの堅牢性を高めることに焦点を当てている。

本研究では、CWN のサイトを訪問する前に、ネットワークシミュレーションとエミュレーションのテストを確実に成功させた。CWN のネットワークトポロジの性能を分析するためにいくつかのシミュレーションツールおよびハードウェアデバイによる実験を行った。最終的には、現地を訪問し、Asthm 村で避雷針の設立の上、新しいノードを構築することによって、Dhital 村の学校と正常にインターネット接続に成功した。

●キーワード

Network Simulation, Emulation, Community Wireless Networks (CWN), and Earthing System.

1 . Introduction

1.1 Introduction

Recently there has been an emphasis on developing wireless mesh networks specifically for rural areas in order to connect other regions of the world. The flexibility and scalability nature of wireless mesh networks provide the solution to bridging the digital divide and connecting remote communities to the world.

There are very limited number of researches that have been done in the case of Himalayan regions of Nepal. This research was occurred in comparatively low land hilly areas ranging from 700 meter to 1800 meter of altitude. Implementation of network infrastructure and developing Internet enabled services are regarded as challenging task in such regions. There are still lacks of appropriate research to connect affordable wireless networks in the rural areas of Himalayan region like Nepal. The motive of doing this research is to provide sustainable internet access in deprived Himalayan regions of Nepal by deploying relatively cheaper CWN technology. This research emphasis is to enhance the robustness of the existing Community Wireless Networks (CWN) after experimenting network simulation, emulation and their performance analysis.

1.2 Overview of Dhital-Kaski CWN in Nepal

For our research works, we have built a CWN in Kaski district of Nepal. Kaski is one of the 75 districts on Nepal which is about 200km away from Kathmandu, the capital of Nepal. Kaski district has a second biggest town named Pokhara . Two remote villages Dhital and Kaskikot are located near Pokhara. Our CWN in Kaski district aims to connect two remote villages, having few primary, secondary and high schools in Dhital and Kaskikot VDC with internet from Pokhara. Our main server is located at Simpani, Pokhara. The CWN was created in year 2011 and has been upgraded every year since its establishment. Recent upgrade was done in 2013 when the solar panels and backup power batteries were installed at the main server in Simpani, Pokhara. In Simpani, Pokhara we have server room which consists of main server devices.

There are schools in both of the villages Kaskikot and Dhital. These schools are now connected to internet through CWN. The school in Dhital is also installed with solar and backup batteries. We planned to install solar panels and backup batteries in school at Kaskikot this year but due to social and budget issues we could not achieve this target. The network was also upgraded to partial mesh wireless network last year which means when a node fails; the network will sustain its life by picking another route. It was successfully tested for making it partial mesh Network. However, this year we performed our experiment only on CWN network because of financial constraint and time limit.



Figure 1 : Geographical view of CWN, Dhital-Kaski Nepal

1.3 Research Issues

The CWN (Community Wireless Networks) implemented by the previous researchers (Joint Research between Wakkanai Hokusei Gakuen University and Muroran Institute of Technology) [1],[2],[3] in the Himalayan region of Dhital-Kaski Nepal has lots of tasks to do. The network implemented in that region is not stable due to many reasons such as lightning (the towers were not equipped with lightning and thunder free technology due to the lack of budget), low bandwidth (256 kbps resulting low quality in voice and video communication as per the increment of the internet users) and lack of hardware equipment (antennas, towers, proper power backup system). This research is carried out after doing substantial literature reviews and few simulation works in Gautam-Asami Laboratory.

The purpose of this research work is not only to know about the fundamental shortcomings of existing networks, but also to seamlessly solve the exiting routing, and other problems with proper solution methodology. Furthermore, in order to deepen the understanding of routing, switching and simulation technology, a number of intensive practical works have been rendered followed by implementation of the network in the field [4].

This research is intended to investigate, analysis and to make robust wireless mesh network. Due to growing demand of Wi-Fi and Wi-MAX, many operators are looking for new way to provide a technology. The basic scenario of Kaski Wireless Network infrastructure which has been designed and developed by respected senior students and professors is shown in the figure below.

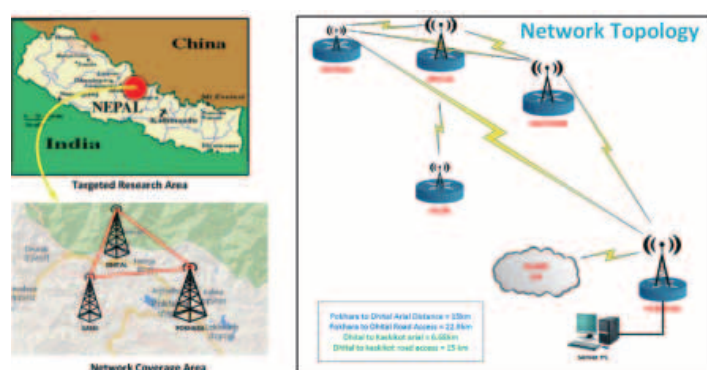


Figure 2 : Dhital-Kaski Wireless Network (Existing)



Figure 3 : Geographical Location

1.4 Objective of the Research

The main objective of this research work is to enhance the robustness of Dhital-Kaski CWN network infrastructure in order to enhance the local community, students and many other stakeholders by using e-learning system and other applications in education sectors, tourism and many other sectors directly or indirectly.

Beside this, few other objectives of this study are listed below:

- 1 . To find out the problems of existing network infrastructure.
- 2 . To Simulate and analyze the performance of network topology of CWN in Dhital-Kaski.
- 3 . Addition of redundant network in order to provide sustainable and highly available network infrastructure.

2. Simulation and Emulation Experiment

2.1 Simulation

A network simulation is a method to imitate the behaviors of the networking devices without implementing the real devices by using software tools. Simulation is the cheapest way to design, testing, and analyzing the network topology before implementation. Researchers, developers, and engineers of industry and educational institutions used simulation for designing, testing, analyzing and enhance knowledge. Simulations include designing a model of a system to carry out experiments on it as it progresses over time.

In this research work, we are going to simulate the existing network topology which has been implemented few years ago by senior students and professors [1],[2],[3] in order to understand, analyze, testing and enhance the network performance.

2.2 Network Simulation

Our main target of doing this simulation is to understand the behavior of the existing network topology in order to enhance the robustness of the network. To accomplish this task, we simply simulated the network topology with a simulating tool. We used same four nodes and connect few clients' computers and servers to create the network scenario. We have tested both wired and wireless technology to test and analyze the simulation [20].

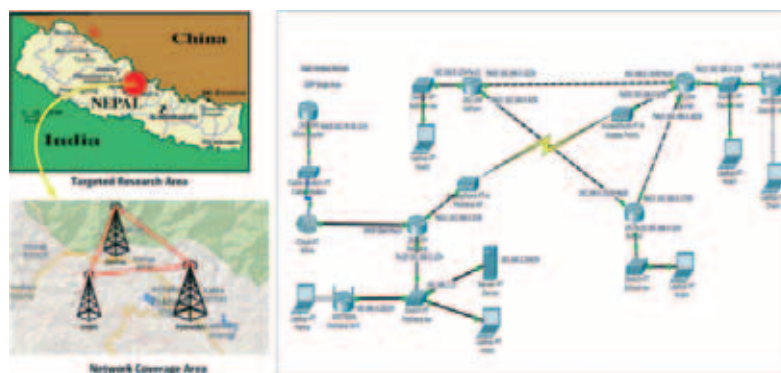


Figure 4 : Existing Network Topology

We can easily create and test any network simulation in our lab but there might be some factors that can affect the performance of network in the real field. Few of them are listed below:

- Disturbance in communication media
- Mismatch in protocol
- Power failure
- Server failure
- Virus attacks, etc.

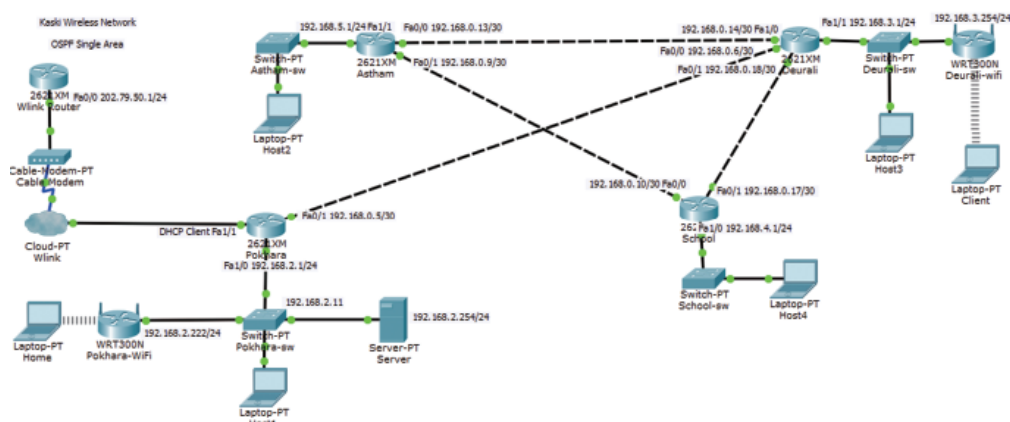


Figure 5 : Simulation Test Wired

2.3 Emulation

Emulation is the process of combining both hardware and software in order to imitate the functions of any real system. In this research, we emulated community wireless network (CWN) of Dhital-Kaski Nepal to study and understand the behaviors of that network before visiting the real test-bed. The network topology that we have emulated and practical works are shown in the figure 5&6 respectively. The main objective of doing this emulation work is to sharpen the knowledge about the wireless devices, to grasp the overall topology of Dhital-Kaski Networks and steps to set up these devices.

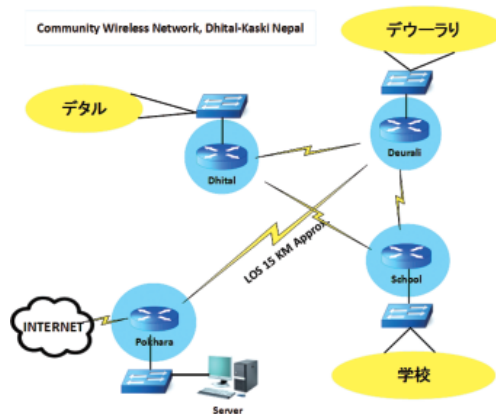


Figure 6 : Existing Network Topology

The figure 6 shows the existing network topology of Dhital-Kaski Nepal. It consists of four main nodes. The main node is located at Simpani Pokhara which receives the internet from local ISP. Then it transmits the signal to the second main node Deurali which is approximately 12 km in air distance. Then the remaining two nodes of Dhital and School are connected to Deurali node resulting the mesh connection.



Figure 7 : Settings for Experiment

We had setup lab at the sports Hall of Wakkanai Hokusei Gakurn University to conduct our experiment during Open Campus 2014. We have setup real Cisco routers, Mikrotik routers, switches, computer servers, TP Link devices, and reflectors in order to construct an infrastructure which imitates the network topology of Dhital-Kaski CWN networks. After completing installation, we tested link between all nodes and internet access was established using OSPF as a routing protocol [7],[9],[10].



Figure 8 : Setting of devices for emulation

2.4 Setting of Devices

After connecting hardware devices physically, we started setting of routers, switches and other wireless devices in order to accomplish our task. Some snap shots taken during the setting up of devices are attached in the figures below (Please refer figures from figure no 9-12). After completing this practical work, we came to know that emulation is pretty exciting and difficult task than simulation. In simulation, we can easily plug and play the devices. But emulation is just opposite of it. Emulation helps us to understand and obtain the practical knowledge of networking which is not possible in simulation.

| 4 items | | | | |
|---------|---|-----------------|--------------|-----------------|
| | | ▲ Address | Network | Interface |
| - | D | 10.96.10.59/24 | 10.96.10.0 | Eth1-Wlink |
| - | D | 192.168.0.5/30 | 192.168.0.4 | Eth2-Deurali-AP |
| - | D | 192.168.2.1/24 | 192.168.2.0 | Eth4-LAN-Switch |
| - | D | 192.168.11.1/24 | 192.168.11.0 | Eth2-Deurali-AP |

Figure 9 (a) : IP Setting of Pokhara Router

Figure 9 (a) displays the IP setting of Pokhara router. It has 5 Ethernet ports. The port Eth1 is a WAN port which is connected to local ISP, Eth2 is connected to Deurali AP and Eth3 is connected to Astham AP.

| Neighbor | Router ID | Address | Interface | State | Changes |
|----------|-----------|--------------|---------------------|-------|---------|
| Default | 4.4.4.4 | 192.168.0.17 | Eth3-School | Full | 0 |
| Default | 1.1.1.1 | 192.168.11.1 | Eth1-Pokhara-TPLink | Full | 0 |
| Default | 1.1.1.1 | 192.168.0.8 | Eth1-Pokhara-TPLink | Full | 0 |
| Default | 3.3.3.3 | 192.168.0.13 | Eth2-Astham | Full | 0 |

Figure 9 (b) : Neighbors database of Deurali router

| Address | Network | Interface |
|-----------------|--------------|---------------------|
| 192.168.0.6/30 | 192.168.0.4 | Eth1-Pokhara-TPLink |
| 192.168.0.14/30 | 192.168.0.12 | Eth2-Astham |
| 192.168.0.18/30 | 192.168.0.16 | Eth3-School |
| 192.168.3.1/24 | 192.168.3.0 | Eth4-LAN-Switch |
| 192.168.11.2/24 | 192.168.11.0 | Eth1-Pokhara-TPLink |

Figure 10 : IP Setting of Deurali

Figure 9 (b) displays neighbors database and figure 10 shows the IP configuration of Deurali router. The figure 10 shows that Eth1 is connected to Pokhara as WAN port, Eth2 is connecting to Astham and Eth3 is connecting to school. The ports Eth4 and Eth5 are bridges which are connected to LAN switch.

Figure 11 and 12 shows the neighbor IP addresses of Astham and Dhital respectively. In this practical work, we have used Cisco 2600 series routers to set up these two nodes. When we execute the command “*show ip ospf neighbor*”, we are able to view the log from routers as shown in the following figures.

Finally, we have successfully implemented partial mesh network with OSPF routing protocol and tested the performances of this emulation.

| Neighbor ID | Pri | State | Dead Time | Address | Interface |
|-------------|-----|---------|-----------|--------------|-------------|
| 2.2.2.2 | 1 | FULL/DR | 00:00:34 | 192.168.0.14 | Ethernet0/0 |
| 4.4.4.4 | 1 | FULL/DR | 00:00:39 | 192.168.0.10 | Ethernet0/1 |

Figure 11 : Neighbors database of Astham router

| Neighbor ID | Pri | State | Dead Time | Address | Interface |
|-------------|-----|----------|-----------|--------------|-----------------|
| 2.2.2.2 | 1 | FULL/BDR | 00:00:38 | 192.168.0.18 | FastEthernet0/1 |
| 3.3.3.3 | 1 | FULL/BDR | 00:00:39 | 192.168.0.9 | FastEthernet0/0 |

Figure 12 : Neighbors database of Dhital router

3. Routing and Switching Experiments

3.1 Routing

Routing is the process of selecting a network path in order to send the packets from source to destination. It plays important role in communication. In a network, there are lots of nodes connected to each other. While a source host A sends its packets to destination host B, where host B is connected with multiple paths, then there needs a selection of optimum path, which is done by routing. To accomplish this process, there is a device called router which stores routing information in a table format known as routing table. There are lots of routing protocols exist, among them we have tested dynamic routing protocols, RIP (Routing Information Protocol) and OSPF (Open Shortest Path First) [5] [6] [8].

3.2 Routing Information Protocol (RIP)

Routing Information Protocol is a distance vector dynamic routing protocol, specially designed for small networks. It uses Bellman-Ford Distance-Vector algorithm to determine the best path to a particular destination. It uses hop count as it's metric. 15 is the maximum hop count. The network that contains 16 hops is considered infinitive or unreachable network. A metric of 16 hops in RIP is considered a poison reverse. It has two versions, RIPv1 and RIPv2 and there is RIPv6 that supports IPv6. It sends out full routing updates periodically in every 30 seconds. Although, it has some limitations, we can still use RIP in small size networks with higher functionalities due to its simplicity to understand and deploy [16].

The real and simple network topology using RIP v2 is shown in the diagram below. This is a real network scenario deployed in the Dhital-Kaski, Pokhara Nepal.

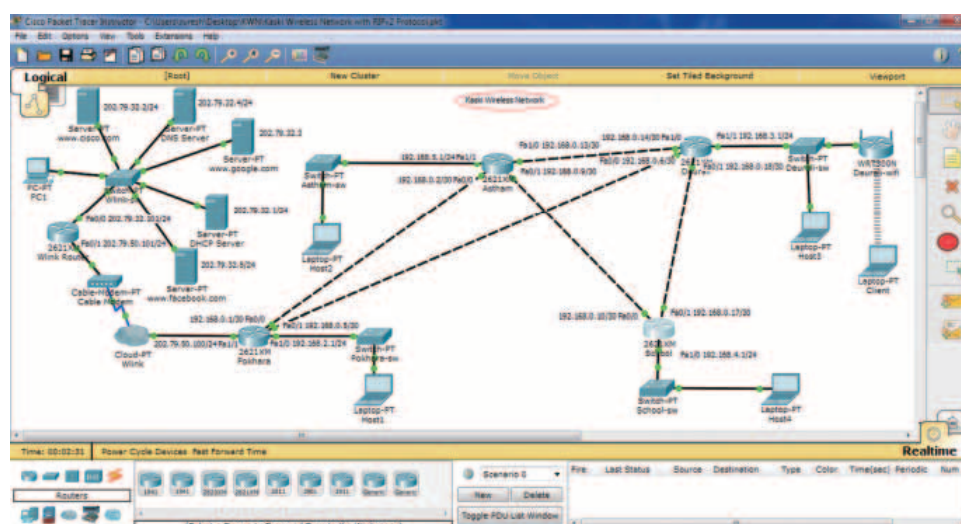


Figure 13 : Simulation Scenario 1

In this scenario, we use same network topology with some servers. The main aim of doing this work is to practice and making clear understanding before implementing the real infrastructure using RIP routing protocol. We have successfully installed web server and ping test was done which is shown in the figure below:

```
PC>ping www.google.com

Pinging 202.79.32.3 with 32 bytes of data:

Reply from 202.79.32.3: bytes=32 time=13ms TTL=124
Reply from 202.79.32.3: bytes=32 time=19ms TTL=124
Reply from 202.79.32.3: bytes=32 time=19ms TTL=124
Reply from 202.79.32.3: bytes=32 time=20ms TTL=124

Ping statistics for 202.79.32.3:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
    Approximate round trip times in milli-seconds:
        Minimum = 13ms, Maximum = 20ms, Average = 17ms
```

Figure 14 : Ping test of web server

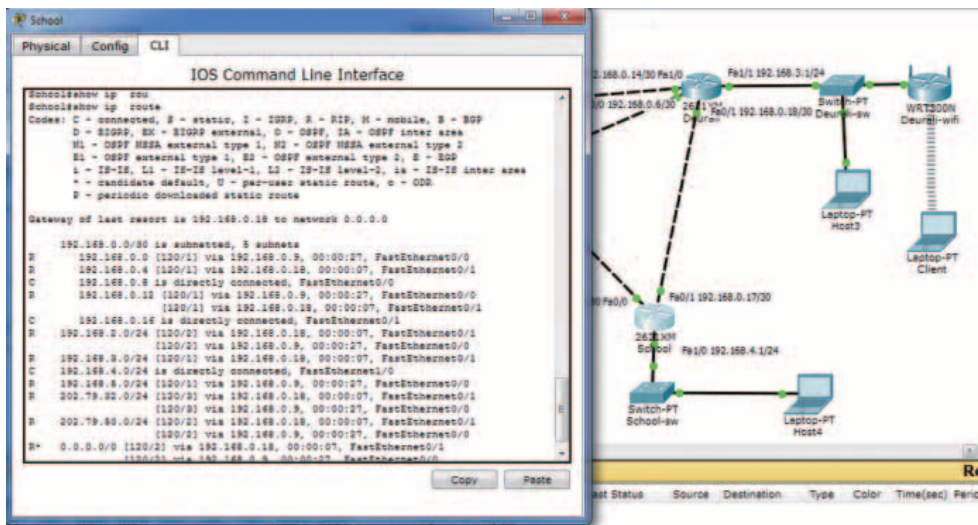


Figure 15 : Routing table of School router

3.2.1 Basic commands in RIP

3.2.2 To view the IP routing table

```
School#show ip route
Codes: C - connected, S - static, I - IGRP, R - RIP, M - mobile, B - BGP
        D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
        N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
        E1 - OSPF external type 1, E2 - OSPF external type 2, E - EGP
        i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, ia - IS-IS inter area
        * - candidate default, U - per-user static route, o - ODR
        P - periodic downloaded static route

Gateway of last resort is 192.168.0.18 to network 0.0.0.0

    192.168.0.0/30 is subnetted, 5 subnets
R       192.168.0.0 [120/1] via 192.168.0.9, 00:00:10, FastEthernet0/0
R       192.168.0.4 [120/1] via 192.168.0.18, 00:00:13, FastEthernet0/1
C       192.168.0.8 is directly connected, FastEthernet0/0
R       192.168.0.12 [120/1] via 192.168.0.9, 00:00:10, FastEthernet0/0
        [120/1] via 192.168.0.18, 00:00:13, FastEthernet0/1
C       192.168.0.16 is directly connected, FastEthernet0/1
R       192.168.2.0/24 [120/2] via 192.168.0.18, 00:00:13, FastEthernet0/1
        [120/2] via 192.168.0.9, 00:00:10, FastEthernet0/0
R       192.168.3.0/24 [120/1] via 192.168.0.18, 00:00:13, FastEthernet0/1
C       192.168.4.0/24 is directly connected, FastEthernet1/0
R       192.168.5.0/24 [120/1] via 192.168.0.9, 00:00:10, FastEthernet0/0
--More-- RIP: received v2 update from 192.168.0.18 on FastEthernet0/1
        0.0.0.0/0 via 0.0.0.0 in 2 hops
        192.168.0.0/30 via 0.0.0.0 in 2 hops
        192.168.0.4/30 via 0.0.0.0 in 1 hops
        192.168.0.12/30 via 0.0.0.0 in 1 hops
        192.168.2.0/24 via 0.0.0.0 in 2 hops
        192.168.3.0/24 via 0.0.0.0 in 1 hops
        192.168.5.0/24 via 0.0.0.0 in 2 hops
        202.79.32.0/24 via 0.0.0.0 in 3 hops
        202.79.50.0/24 via 0.0.0.0 in 2 hops
RIP: sending v2 update to 224.0.0.9 via FastEthernet0/1 (192.168.0.17)
RIP: build update entries
        192.168.0.0/30 via 0.0.0.0, metric 2, tag 0
        192.168.0.8/30 via 0.0.0.0, metric 1, tag 0
        192.168.4.0/24 via 0.0.0.0, metric 1, tag 0
        192.168.5.0/24 via 0.0.0.0, metric 2, tag 0
-----
```

3.2.3 To view information to the RIP

```
School#show ip protocols
Routing Protocol is "rip"
Sending updates every 30 seconds, next due in 23 seconds
Invalid after 180 seconds, hold down 180, flushed after 240
Outgoing update filter list for all interfaces is not set
Incoming update filter list for all interfaces is not set
Redistributing: rip
Default version control: send version 2, receive 2
  Interface          Send Recv Triggered RIP Key-chain
  FastEthernet0/1      2     2
  FastEthernet1/0      2     2
  FastEthernet0/0      2     2
Automatic network summarization is in effect
Maximum path: 4
Routing for Networks:
    192.168.0.0
    192.168.4.0
Passive Interface(s):
Routing Information Sources:
    Gateway         Distance      Last Update
    192.168.0.18      120          00:00:05
    192.168.0.9       120          00:00:08
Distance: (default is 120)
```

3.2.4 To view RIP database

```
School#show ip rip database
0.0.0.0/0      auto-summary
0.0.0.0/0
    [2] via 192.168.0.18, 00:00:18, FastEthernet0/1    [2] via 192.168.0.9,
00:00:20, FastEthernet0/0
192.168.0.0/30  auto-summary
192.168.0.0/30
    [1] via 192.168.0.9, 00:00:20, FastEthernet0/0
192.168.0.4/30  auto-summary
192.168.0.4/30
    [1] via 192.168.0.18, 00:00:18, FastEthernet0/1
192.168.0.8/30  auto-summary
192.168.0.8/30  directly connected, FastEthernet0/0
192.168.0.12/30 auto-summary
192.168.0.12/30
    [1] via 192.168.0.9, 00:00:20, FastEthernet0/0    [1] via 192.168.0.18,
00:00:18, FastEthernet0/1
192.168.0.16/30 auto-summary
192.168.0.16/30 directly connected, FastEthernet0/1
192.168.2.0/24  auto-summary
192.168.2.0/24
    [2] via 192.168.0.18, 00:00:18, FastEthernet0/1    [2] via 192.168.0.9,
00:00:20, FastEthernet0/0
192.168.3.0/24  auto-summary
192.168.3.0/24
    [1] via 192.168.0.18, 00:00:18, FastEthernet0/1
```

3.3 Limitation of RIP



Figure 16 : Limitation of RIP

RIP is also feasible protocol to implement in our CWN networks although it has some limitations. RIP is feasible because the size of CWNs that we have deployed is relatively small. But while our CWN network increases its number of nodes in the future, RIP is not workable because it has limitation of 15 hops only. In this scenario we use 16 hops with RIP routing protocol. While we ping 16th hop, the ping statistics reply “request time out”. Slow convergence, Routing loops, counting to infinity, no load balancing and small infinities are some drawbacks of RIP [11]. That’s why we decided to use OSPF as a routing protocol in out CWN networks.

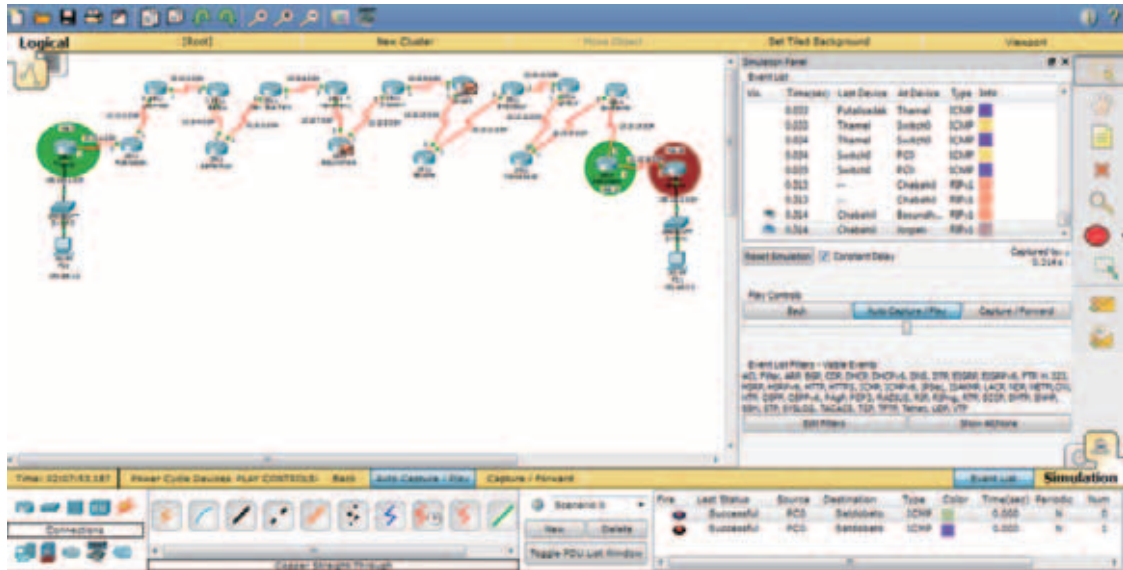


Figure 17 : Simulating RIP

```

PC>ping 10.10.15.1

Pinging 10.10.15.1 with 32 bytes of data:

Reply from 10.10.15.1: bytes=32 time=53ms TTL=241
Reply from 10.10.15.1: bytes=32 time=47ms TTL=241
Reply from 10.10.15.1: bytes=32 time=16ms TTL=241
Reply from 10.10.15.1: bytes=32 time=31ms TTL=241

Ping statistics for 10.10.15.1:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
    Approximate round trip times in milli-seconds:
        Minimum = 16ms, Maximum = 53ms, Average = 36ms

PC>ping 10.10.16.1

Pinging 10.10.16.1 with 32 bytes of data:

Reply from 10.10.16.1: bytes=32 time=35ms TTL=240
Reply from 10.10.16.1: bytes=32 time=15ms TTL=240
Reply from 10.10.16.1: bytes=32 time=16ms TTL=240
Reply from 10.10.16.1: bytes=32 time=15ms TTL=240

Ping statistics for 10.10.16.1:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
    Approximate round trip times in milli-seconds:
        Minimum = 15ms, Maximum = 35ms, Average = 20ms

PC>ping 10.10.16.2

Pinging 10.10.16.2 with 32 bytes of data:

Request timed out.
Request timed out.
Request timed out.
Request timed out.

Ping statistics for 10.10.16.2:
    Packets: Sent = 4, Received = 0, Lost = 4 (100% loss),
  
```

15th HOP

16th HOP

Figure 18 : Illustration of unreachable of 16th hop

3.4 Open Shortest Path First (OSPF)

Open Shortest Path First (OSPF) is a link state routing protocol. It is a dynamic protocol that performs real time calculations. OSPF uses the Dijkstra Shortest Path First algorithm to determine the optimum path. This is a classless protocol that supports VLSM. OSPF is the most popular interior gateway protocol and specially designed to support large networks. OSPF routing protocol generates routing updates only when a change occurs in the network topology. The updated information is send to other routers in the format of Link State Advertisement (LSA). Once the router gets the LSA, it updates its database and forwards LSA to other neighboring routers. LSAs are refreshed every 30 minutes. OSPF employs a hierarchical network design using Areas and will form neighbor relationships with adjacent routers in the same Areas.

OSPF has no hop count limit and supports only IP routing. It uses cost as it's metric to determine the best path which is based on the bandwidth of the link.

The OSPF process builds and maintains following three separate tables.

- 1 . A Neighbor Table: This table contains a list of all neighboring routers.
- 2 . A Topology Table: This table contains a list of all possible routes to all known networks within an area.
- 3 . A Routing Table: This table contains the optimum route for each known network [12].

Types of Routers in OSPF

There are different types of routers in OSPF networks. We will describe each type of routers in the section below.

- 1 . Internal Router (IR)
- 2 . Backbone Router (BR)
- 3 . Area Border Router (ABR)
- 4 . AS Boundary Routers (ASBR)

OSPF offers a number of benefits, which is described below [13].

- 1 . Multipath routing
- 2 . Hierarchical routing
- 3 . High level of security
- 4 . Traffic engineering
- 5 . Fast reroute
- 6 . Cost based routing metrics

3.4.1 Scenario 3

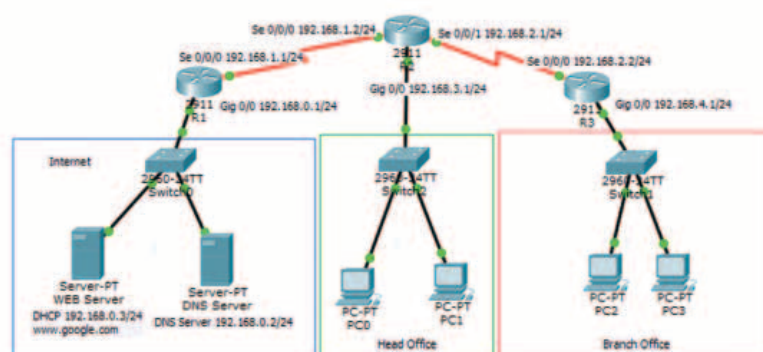


Figure 19 : Simulating OSPF

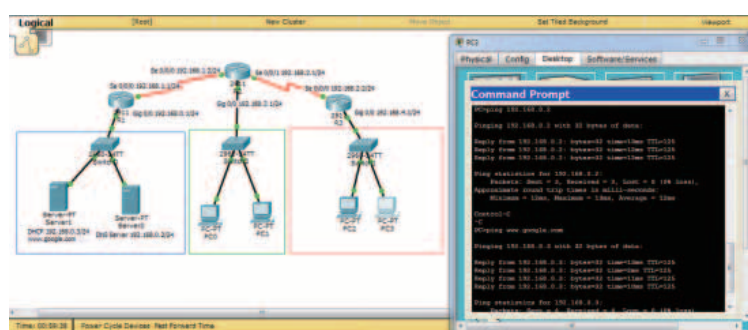


Figure 20 : Verifying OSPF

4.3.2 Scenario 4

The network topology using OSPF protocol is shown in the figure 21. We have used two different areas, Area 0 and Area 1. In order to simulate in the different areas, we decided to design 2 areas rather than keeping in the same area. Our decision was helpful because this design was applied during the real implementation in Nepal. The diagram below represents the real network topology which is deployed in the Himalayan region Kaski, Pokhara of Nepal.

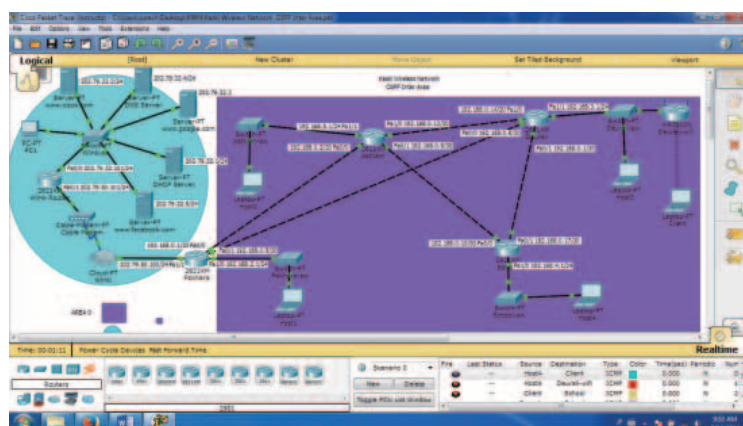


Figure 21 : Simulating Dhital-Kaski CWNs

In this simulation test, we have tested different parameters. The wireless internet of bandwidth 256 kbps is provided by Worlklink, the Internet Service Provider (ISP). There are four main nodes. Pokhara node is the main node and is referred as main server station which is connected to ISP. The remaining three nodes Aastham, Deurali and Dhital are meshed to each other.

The IP setting of four nodes Pokhara, Aastham, Deurali and School are as follows.

| Pokhara#show ip interface brief | | | | |
|---------------------------------|---------------|-----|-----------------------------|----------|
| Interface | IP-Address | OK? | Method Status | Protocol |
| FastEthernet0/0 | 192.168.0.1 | YES | manual up | up |
| FastEthernet0/1 | 192.168.0.5 | YES | manual up | up |
| FastEthernet1/0 | 192.168.2.1 | YES | manual up | up |
| FastEthernet1/1 | 202.79.50.100 | YES | manual up | up |
| Loopback0 | 1.1.1.1 | YES | manual up | up |
| Aastham#show ip interface brief | | | | |
| Interface | IP-Address | OK? | Method Status | Protocol |
| FastEthernet0/0 | 192.168.0.2 | YES | manual up | up |
| FastEthernet0/1 | 192.168.0.9 | YES | manual up | up |
| FastEthernet1/0 | 192.168.0.13 | YES | manual up | up |
| FastEthernet1/1 | 192.168.5.1 | YES | manual up | up |
| Loopback0 | 3.3.3.3 | YES | manual up | up |
| Deurali#show ip interface brief | | | | |
| Interface | IP-Address | OK? | Method Status | Protocol |
| FastEthernet0/0 | 192.168.0.6 | YES | manual up | up |
| FastEthernet0/1 | 192.168.0.18 | YES | manual up | up |
| FastEthernet1/0 | 192.168.0.14 | YES | manual up | up |
| FastEthernet1/1 | 192.168.3.1 | YES | manual up | up |
| Loopback0 | 2.2.2.2 | YES | manual up | up |
| School#show ip interface brief | | | | |
| Interface | IP-Address | OK? | Method Status | Protocol |
| FastEthernet0/0 | 192.168.0.10 | YES | manual up | up |
| FastEthernet0/1 | 192.168.0.17 | YES | manual up | up |
| FastEthernet1/0 | 192.168.4.1 | YES | manual up | up |
| FastEthernet1/1 | unassigned | YES | unset administratively down | down |
| Loopback0 | 4.4.4.4 | YES | manual up | up |

The geographical view of network scenario is shown in the figure 22.

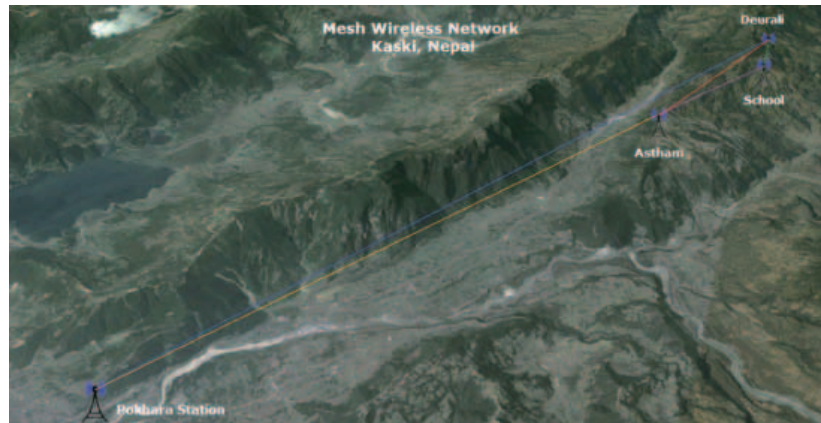


Figure 22 : Geographical view of CWN

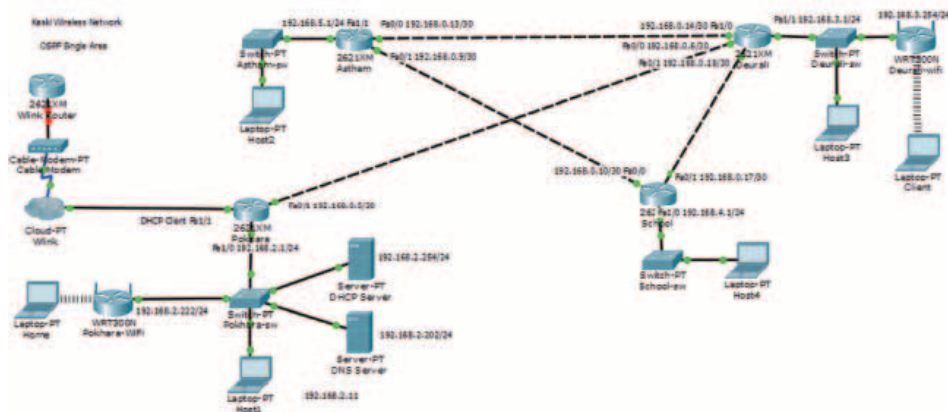


Figure 23 : Network Simulation using Wired Technology

4.3.3 Network Simulation using Wireless Technology

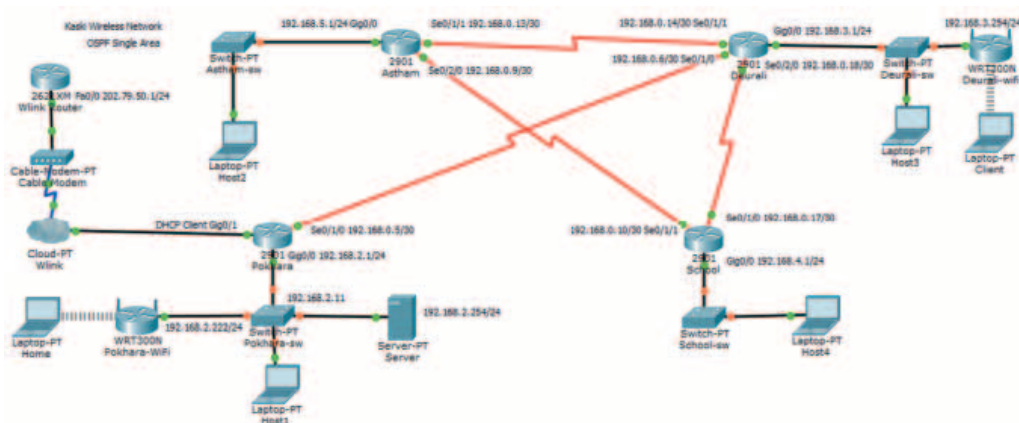


Figure 24 : Network Simulation using Wireless Technology

The working principle of Open Shortest Path First (OSPF) depends upon the following packet [14].

- Hello: The process of establishing and maintaining neighbor relationships.
- Database Description: It displays the information of topology infrastructure and the messages are exchanged whenever there is a change in neighbors.
- Link-state Request: This is the process of sending pieces of topological database from neighbor routers whether the topological database is still working or out of date.
- Link-state Update: Update is done in order to response to a link-state request packet. This process is done by Link State Acknowledgements (LSA).
- Link-state Acknowledgment: Acknowledges link-state update packets.

4.4.4 Enhanced Interior Gateway Routing Protocol (EIGRP)

In this section, we are going to discuss about EIGRP and its configuration. As the name represents, it is enhanced version of Interior Gateway Routing Protocol abbreviated as IGRP. This is the combined version of link state protocols and distance vector protocols. EIGRP is designed for large networks although it is a proprietary protocol.

A simple network topology and its specification that we use on our experiment is shown in the following figure.

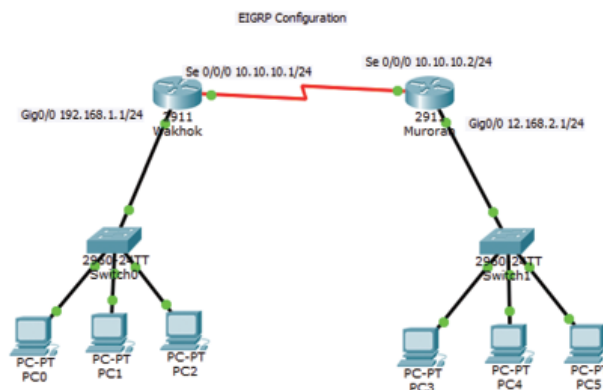


Figure 25 : Simulating EIGRP

The working principle of Enhanced Interior Gateway Routing Protocol (EIGRP) is depends upon the following five parameters.

- Hello
Hello packets are sent as periodic multicast and are not acknowledged. The main purpose of sending hello packets is to identify neighbors whether it is alive or not.
- Update
An updates are sent as multicast only when there is a change in a network topology. An updates advertise the neighbor routers.
- Acknowledgement (ACK)

This is the receipt of an update.

- Query

When update indicates that there is a problem in a link or network path, multicast queries are used to ask other neighbors if they still have a path or not. If the querier does not receive a reply from each of its neighbors, it repeats the query as a unicast to each unresponsive neighbor until it either gets a reply till sixteen tries.

- Reply

Each neighbor router responds to the query and reply indicating an alternative path or the fact that it does not have a path by using unicast reply [15][17].

5. Field Visit and Implementation

5.1 Site Survey and LOS checking



Figure 26 : Line of Sight

Firstly, we have verified the link between Simpani, Pokhara to newly proposed area: Astham whether it is clear or not, using online tools named ligowave.com. Then we input the latitude and longitude of transmitter and receiver site taken from GPS. The path between Pokhara to Astham is clear as shown in the figure 26.

5.2 Existing Network Topology

5.3 Newly Constructed Tower

The figure 29 represents the newly constructed tower at Astham. We have installed 20 feet tower with proper compound pipe type grounding technology. The tower was equipped with lightning arrester, AP, CP, search protectors, and the fiber box which consists of routers and switches. The air distance of this site form base station is approximately 9 Km.



Figure 29 : Newly installed tower with proper Earthing system

5.4 Difference between previous and current network topology

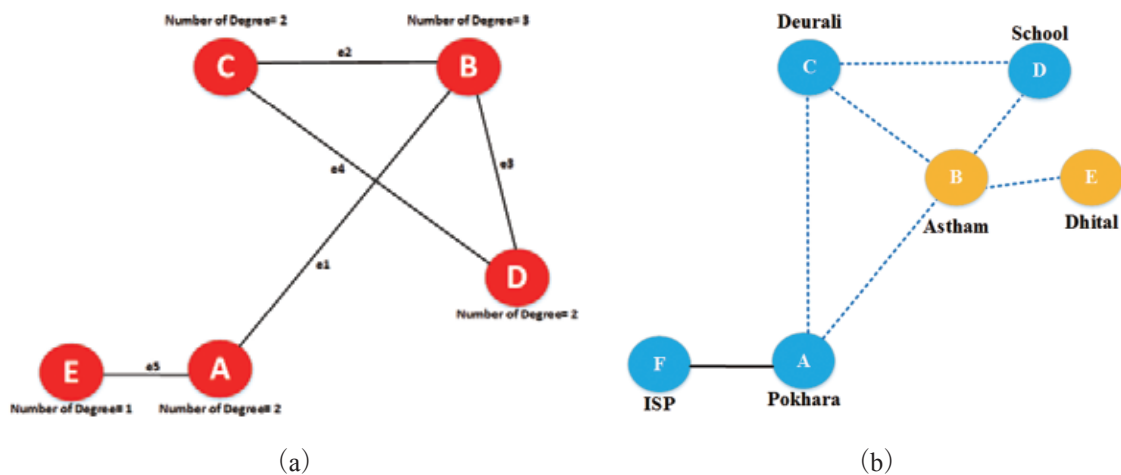


Figure 30 : Old vs. New Network Topology

The figure 30 shows the difference between previous network topology and newly implemented network topology. Topology (a) represents the previous network topology and (b) represents the newly implemented network topology. The yellow colors in figure (b) are newly constructed nodes. Astham is a second main node after Pokhara. There is also one more alternative link “AC” from Pokhara to Deurali. This is a partial mesh network of CWN in Dhital-Kaski networks.

5.5 Thunder and Lightning

Lightening is an electrostatic discharge during an electric storm between electrically charged regions of cloud with another cloud. It produces sound and is known as thunder [19].

5.5.1 Earthing and its Type

Safety and security is the main reason of doing Earthing of electrical networks. Earthing is done in order to prevent human life and electric equipment' s by passing the unwanted electric power to the earth by creating the short circuited path to the ground, though eliminating any chance of electric shocks.

5.5.2 Types of Earthing:

There are several types of Earthing system. Few of them are listed below. This time we will explain only the system that we implemented in our newly installed site.

- 1 . Plate type Earthing
- 2 . Pipe type Earthing (Compound Earthing)
- 3 . TT System
- 4 . IT System
- 5 . TN-S System
- 6 . TN-C-S
- 7 . TN-C System [18]

5.6 Current status of Deurali node

Currently, the AP of Deurali station has been damaged by lightning. This area is very suitable in consist of Line of Sight (LOS) but has drawback of highly lightning resulting damages of AP and other electronic and networking devices. Earthing is only the solution which is done in order to safeguarding the electronic devices during the lightning and fluctuation of currents. Here we want to present some pictures that have been taken after thunder in that area.



Figure 31 : Deurali before Thunder fall



Figure 32 : Damages caused by Lightning at Deurali

We have visited the field and took photographs of existing situation which is shown in the figure 32. After visiting this place, we came to know that this is one of the prone areas of Nepal where the chances of lightening are very high.

Due to security regions we have decided to shift this site to new location called Astham which is approximately 3 km away (Air Distance) from the existing site. In this new site, we installed and mount 20 feet tower and radio devices with proper Earthing system. The photographs and all technical details is explained below.

Earthing: In this section, we describe about the survey that was conducted in order to find the better location of Earthing. Few photographs taken during installation of Earthing system is attached below. This type of Earthing is known as Chemical or Compound Earthing.



Figure 33 : Field survey for new node



Figure 34 : Backfill Compound

Backfill compound maintains moisture within the sphere of influence of the electrode, resulting in lower earth resistance. Backfill compound enhances the surrounding soil conductivity thereby making the Earthing reliable and effective. The earth resistance value depends on soil conditions and its resistivity value.



Figure 35 : Crystalline Conductive Mixture

It contains natural elements, which are highly conductive as well as anti-corrosive. The Crystalline Conductive Mixture does not disintegrate or collapse when the outer electrode corrodes.



Figure 36 : Earth Electrode

Table 1 : Specifications

| Model | Length (mm) | Outer Pipe Diameter (mm) | Inner Pipe Diameter (mm) | Pipe | Galvanization (In micron) | Quantity Used |
|-------|-------------|--------------------------|--------------------------|------|---------------------------|---------------|
| T-19 | 1000 | 48 | 27 | Cu | 80-100 | 2 |



Figure 37 : Lightning Arrester

The Lightning Arrester system which provides a more reliable system for the protection of transmission equipment on telecommunication towers from direct lightning strikes.

The Lightning Arrester captures the lightning energy at a preferred point. The energy is conveyed to ground via a down conductor. When the energy enters the dedicated lightning earth, it is safely dissipated without risk to personnel and equipment.

5.6.1 Installation Procedure

- Bore a hole at the place where Earthing is to be done to a suitable depth of electrode length (1.5 meter in this case)
- Place the Earthing electrode inside the pit.
- Mix the backfill compound nicely with the soil which has been dug out.
- Re-fill the empty space around the Earthing electrode with this compound mix soil.
- While re-filling the space pour adequate water in the PIT intermittently.
- Pack the soil around the electrode tightly and nicely.



Figure 37 : Lightning Arrester



Figure 38 : Installation of Lightning Arrestor

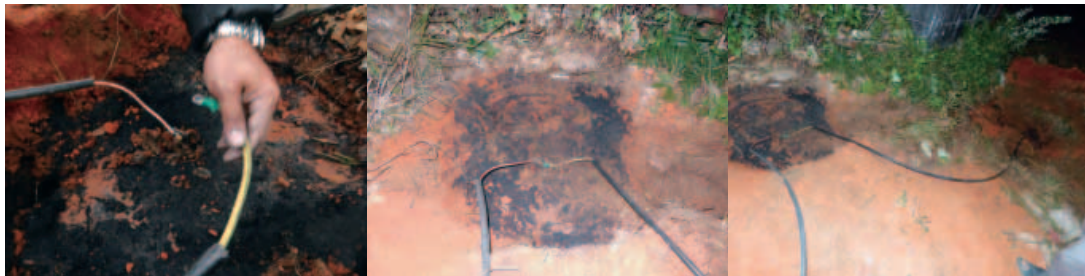


Figure 39 : Establishing connection between Lightning Arrestor and ground

The lightning arrestor mounted at the top of the tower shown in the figure 38 is connected to the earth electrode as shown in the figure 39 via zero gauge copper wire. And the connection between two holes are also established in order to robust the Earthing system.



Figure 40 : Measuring Earth Resistance

We have drilled two holes in order to enhance the performance of Earthing. We have taken data from each of them as follows. These data have been taken instantly after we finished the installation of Earthing. If we had taken data after a week of installation, it would have further decreased. Resistivity below than 7 is referred to as better conductivity.

Table 2 : Measurement of Earth Resistance

| Measuring Earth Resistivity (Ohm) | |
|-----------------------------------|-------------|
| Hole 1 | Hole 2 |
| 13.35 (Normal) | 6.47 (Good) |



Figure 41 : After completion of Earthing

It feels so good when we successfully completed installation of tower with proper Earthing system at newly proposed site Astham. These photographs were taken while we finish our work at the field at Astham and Dhital School.

6. Result and Data Analysis

6.1 Outputs of Simulation, Emulation and Practical Implementation

| Interface List | | | | | | | | | | | |
|------------------|----------|-------------|------------|------------|-----------|-----------|----------|----------|-----------|-----------|--|
| Interface | Ethernet | EoIP Tunnel | IP Tunnel | GRE Tunnel | VLAN | VRRP | Bonding | LTE | | | |
| Name | Type | L2 MTU | Tx | Rx | Tx Pac... | Rx Pac... | Tx Drops | Rx Drops | Tx Errors | Rx Errors | |
| R New_LAN_eth... | Ethernet | 1598 | 0 bps | 0 bps | 0 | 0 | 0 | 0 | 0 | 0 | |
| R To_Astham | Ethernet | 1598 | 0 bps | 768 bps | 0 | 1 | 0 | 0 | 0 | 0 | |
| R To_Ishwor | Ethernet | 1598 | 0 bps | 0 bps | 0 | 0 | 0 | 0 | 0 | 0 | |
| R WAN_ether1 | Ethernet | 1600 | 14.8 kbps | 434.3 kbps | 23 | 282 | 0 | 0 | 0 | 0 | |
| R WIFI_eth5 | Ethernet | 1598 | 290.3 kbps | 15.6 kbps | 35 | 26 | 0 | 0 | 0 | 0 | |

Figure 42 : Interface Details

There are collectively five nodes in CWNs Nepal. The main node situated at Simpani Pokhara is connected directly with local ISP. We can remotely access and control these routers. The interface lists and their specifications we configured while implementing the infrastructure is shown in the figure 42. The snap shot below represents the access of device remotely and successfully connected internet.

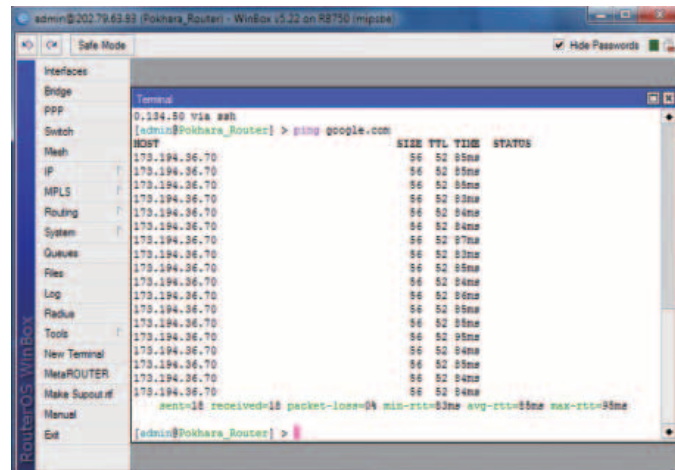


Figure 43 : Remote access of MikroTik Router

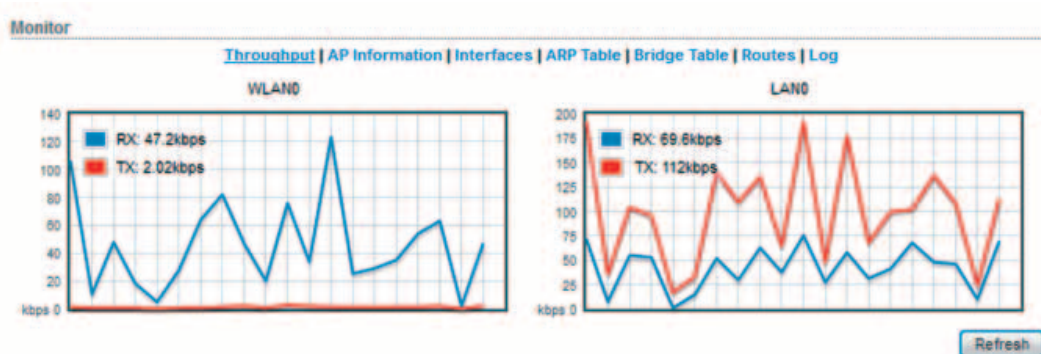


Figure 44 : Throughput check of LAN and WLAN

6.2 Executing Data Transfer in Simulation

```

Pinging 202.79.32.3 with 32 bytes of data:
Request timed out.
Reply from 202.79.32.3: bytes=32 time=25ms TTL=124
Reply from 202.79.32.3: bytes=32 time=20ms TTL=124
Reply from 202.79.32.3: bytes=32 time=23ms TTL=124

Ping statistics for 202.79.32.3:
    Packets: Sent = 4, Received = 3, Lost = 1 (25% loss),
    Approximate round trip times in milli-seconds:
        Minimum = 20ms, Maximum = 25ms, Average = 22ms

PC>ping www.google.com
Pinging 202.79.32.3 with 32 bytes of data:
Reply from 202.79.32.3: bytes=32 time=49ms TTL=124
Reply from 202.79.32.3: bytes=32 time=38ms TTL=124
Reply from 202.79.32.3: bytes=32 time=36ms TTL=124
Reply from 202.79.32.3: bytes=32 time=19ms TTL=124

Ping statistics for 202.79.32.3:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
    Approximate round trip times in milli-seconds:
        Minimum = 19ms, Maximum = 49ms, Average = 35ms

PC>ping www.google.com
Pinging 202.79.32.3 with 32 bytes of data:
Reply from 202.79.32.3: bytes=32 time=49ms TTL=124
Reply from 202.79.32.3: bytes=32 time=38ms TTL=124
Reply from 202.79.32.3: bytes=32 time=36ms TTL=124
Reply from 202.79.32.3: bytes=32 time=19ms TTL=124

Ping statistics for 202.79.32.3:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
    Approximate round trip times in milli-seconds:
        Minimum = 19ms, Maximum = 49ms, Average = 35ms

```

Figure 45 : Executing Simulation Data Transfer

6.3 Executing Data Transfer in Emulation

```
C:\Users\suresh>ping google.com -t
Pinging google.com [173.194.72.139] with 32 bytes of data:
Reply from 173.194.72.139: bytes=32 time=70ms TTL=43
Reply from 173.194.72.139: bytes=32 time=72ms TTL=43
Reply from 173.194.72.139: bytes=32 time=73ms TTL=43
Reply from 173.194.72.139: bytes=32 time=83ms TTL=43
Reply from 173.194.72.139: bytes=32 time=73ms TTL=43
Reply from 173.194.72.139: bytes=32 time=74ms TTL=43
Reply from 173.194.72.139: bytes=32 time=72ms TTL=43
Reply from 173.194.72.139: bytes=32 time=72ms TTL=43
Reply from 173.194.72.139: bytes=32 time=72ms TTL=43
Reply from 173.194.72.139: bytes=32 time=73ms TTL=43
Ping statistics for 173.194.72.139:
    Packets: Sent = 10, Received = 10, Lost = 0 (0% loss),
    Approximate round trip times in milli-seconds:
        Minimum = 70ms, Maximum = 83ms, Average = 73ms
Control-C
^C

C:\Users\suresh>ping google.com -t
Pinging google.com [173.194.72.139] with 32 bytes of data:
Reply from 173.194.72.139: bytes=32 time=76ms TTL=43
Reply from 173.194.72.139: bytes=32 time=74ms TTL=43
Reply from 173.194.72.139: bytes=32 time=71ms TTL=43
Reply from 173.194.72.139: bytes=32 time=74ms TTL=43
Reply from 173.194.72.139: bytes=32 time=71ms TTL=43
Reply from 173.194.72.139: bytes=32 time=80ms TTL=43
Reply from 173.194.72.139: bytes=32 time=71ms TTL=43
Reply from 173.194.72.139: bytes=32 time=71ms TTL=43
Reply from 173.194.72.139: bytes=32 time=71ms TTL=43
Reply from 173.194.72.139: bytes=32 time=71ms TTL=43
Ping statistics for 173.194.72.139:
    Packets: Sent = 10, Received = 10, Lost = 0 (0% loss),
    Approximate round trip times in milli-seconds:
        Minimum = 71ms, Maximum = 80ms, Average = 73ms
Control-C
^C

C:\Users\suresh>ping google.com -t
Pinging google.com [173.194.72.139] with 32 bytes of data:
Reply from 173.194.72.139: bytes=32 time=85ms TTL=43
Reply from 173.194.72.139: bytes=32 time=87ms TTL=43
Reply from 173.194.72.139: bytes=32 time=87ms TTL=43
Reply from 173.194.72.139: bytes=32 time=87ms TTL=43
Reply from 173.194.72.139: bytes=32 time=87ms TTL=43
Reply from 173.194.72.139: bytes=32 time=85ms TTL=43
Reply from 173.194.72.139: bytes=32 time=85ms TTL=43
Reply from 173.194.72.139: bytes=32 time=85ms TTL=43
Reply from 173.194.72.139: bytes=32 time=86ms TTL=43
Reply from 173.194.72.139: bytes=32 time=85ms TTL=43
Reply from 173.194.72.139: bytes=32 time=85ms TTL=43
Ping statistics for 173.194.72.139:
    Packets: Sent = 12, Received = 12, Lost = 0 (0% loss),
    Approximate round trip times in milli-seconds:
        Minimum = 85ms, Maximum = 87ms, Average = 85ms
Control-C
^C

C:\Users\suresh>ping google.com -t
Pinging google.com [173.194.72.139] with 32 bytes of data:
Reply from 173.194.72.139: bytes=32 time=72ms TTL=43
Reply from 173.194.72.139: bytes=32 time=78ms TTL=43
Reply from 173.194.72.139: bytes=32 time=78ms TTL=43
Reply from 173.194.72.139: bytes=32 time=76ms TTL=43
Reply from 173.194.72.139: bytes=32 time=76ms TTL=43
Reply from 173.194.72.139: bytes=32 time=76ms TTL=43
Reply from 173.194.72.139: bytes=32 time=72ms TTL=43
Reply from 173.194.72.139: bytes=32 time=72ms TTL=43
Reply from 173.194.72.139: bytes=32 time=75ms TTL=43
Ping statistics for 173.194.72.139:
    Packets: Sent = 10, Received = 10, Lost = 0 (0% loss),
    Approximate round trip times in milli-seconds:
        Minimum = 72ms, Maximum = 78ms, Average = 76ms
Control-C
^C
```

Figure 46 : Executing Emulation Data Transfer

6.4 Executing Data Transfer from Real Infrastructure

This ping result was taken while we received signal using TP Link 2.4 GHz that is transmitted by NanoStationM2, 2.4GHz wireless device. There was a maximum loss of signal and performance of internet was very slow although the air distance is approximately 3Km. Then we came to know that the main cause of loss of signal is due to the compatibility of two wireless devices.

```
C:\Users\suresh>ping google.com -t
Pinging google.com [202.166.193.167] with 32 bytes of data:
Request timed out.
Request timed out.
Request timed out.
Request timed out.
Request timed out.
Request timed out.
Request timed out.
Request timed out.
Request timed out.
Reply from 202.166.193.167: bytes=32 time=112ms TTL=59
Request timed out.
Request timed out.
Request timed out.
Request timed out.
Request timed out.
Request timed out.
Request timed out.
Reply from 202.166.193.167: bytes=32 time=18ms TTL=59
Request timed out.
Request timed out.
Request timed out.
Ping statistics for 202.166.193.167:
    Packets: Sent = 21, Received = 2, Lost = 19 (90% loss),
    Approximate round trip times in milli-seconds:
        Minimum = 18ms, Maximum = 112ms, Average = 65ms
Control-C
^C

C:\Users\suresh>ping google.com
Pinging google.com [173.194.36.72] with 32 bytes of data:
Request timed out.
Reply from 173.194.36.72: bytes=32 time=3466ms TTL=54
Reply from 173.194.36.72: bytes=32 time=166ms TTL=54
Request timed out.
Ping statistics for 173.194.36.72:
    Packets: Sent = 4, Received = 2, Lost = 2 (50% loss),
    Approximate round trip times in milli-seconds:
        Minimum = 166ms, Maximum = 3466ms, Average = 1816ms
C:\Users\suresh>
```

Figure 47 : Signal Loss

After we came to know the reasons of these problems, we replaced the TP Link from Dhital and installed NanostationM2 as a receiver. Then we again configured the devices. Then we tested the internet speed which is shown in the figure 48.

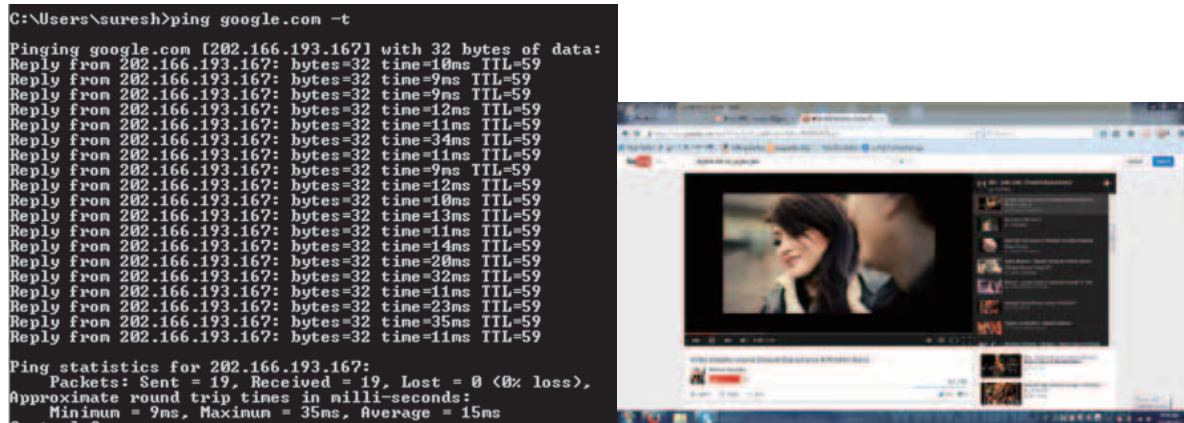


Figure 48 : Access of Internet after troubleshooting

6.5 Graphical Analysis of Data

The table 3 and figure 49 represents the time taken while testing of simulation, emulation and practically transmitted of radio signals in milliseconds. According to the graph, we can conclude that the time taken by emulation is higher than the simulation although the pattern of both simulation and emulation looks like same. This data was taken after executing the ping command from source to destination in both simulation and emulation. We can clearly see that there is a maximum delay or signal loss in the case of practical experiment which was held in the Dhital-Kaski of Nepal this year. After installing the proper devices in the right direction, we were able to connect the internet smoothly although it took more longer time than simulation and emulation because the signal have to travel over a long air distance.

Table 3 : Data Implementation

| Time Calculation of Data Travel (ms) | | | |
|--------------------------------------|------------|-----------|-----------|
| S.N. | Simulation | Emulation | Practical |
| 1 | 25 | 78 | 112 |
| 2 | 20 | 72 | 18 |
| 3 | 23 | 83 | 180 |
| 4 | 19 | 73 | 166 |
| 5 | 19 | 74 | 34 |
| 6 | 20 | 80 | 10 |
| 7 | 36 | 87 | 18 |
| 8 | 38 | 85 | 11 |
| 9 | 49 | 85 | 23 |
| 10 | 19 | 77 | 35 |

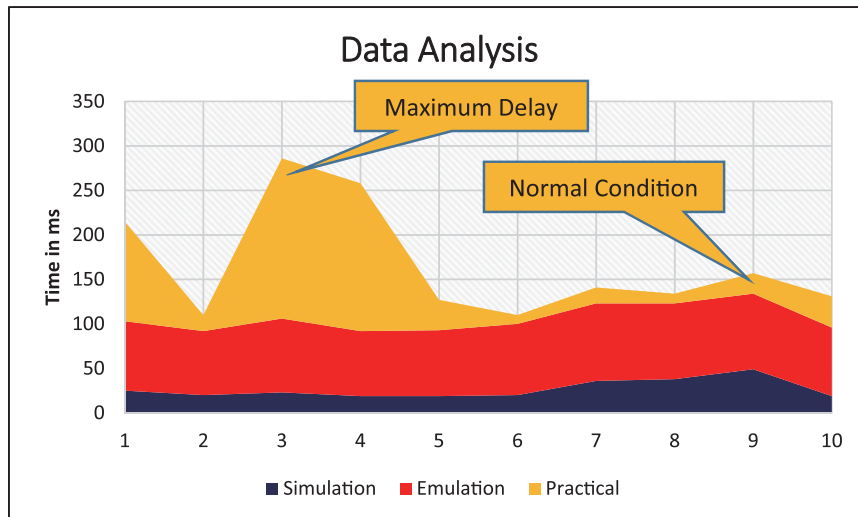


Figure 49 : Graphical Representation of Simulated, Emulated and Real data

7. Conclusion and Future Work

7.1 Conclusion

In this research, we have successfully completed our Network Simulation and Emulation work in Gautam-Asami laboratory before visiting the site in Kaski, Nepal. We tested various topologies by using some network simulators to understand the behaviors of network.

Secondly, we successfully constructed the simulated CWN network using some hardware devices such as routers, switches, wireless radios, reflectors and cables. This practical work is also known as emulation.

After we finished simulation and emulation, we came to know that there are significant differences between simulation and emulation in terms of data transfer. We can easily create a network simulation and analyze its performance with a basic knowledge of networking. But in contrast with simulation, emulation takes relatively longer time even in the same network topology. Additionally, emulation process is more costly.

Thirdly, during our site visit in December 2014, we met CWN users of the site and few other local people who will be benefited of these networks in the future. We were also reported that they were expecting more quality in our Networks, nonetheless, the networks at present could not meet their expectation. After network infrastructure was re-constructed and brought into operation, an Internet connection has been established between source point Simpani-Pokhara to destination (school at Dhital).

We conclude that we were able to provide more reliable network services to the local people than before. Reliability was improved by shifting the relay nodes in a more proper location. Additionally, we were also able to provide thunder safe measures. However, all the nodes are not thunder safe. In the future, the remaining nodes are recommended to also provide the thunder safe measure.

7.2 Future Work

There are still few tasks to be accomplished on the coming future for the sustainability of CWN. These are as follows:

- a. We could not able to manage power backup system at newly constructed site due to limited time and budget.
- b. There were no proper poles or towers; we have to replace all poles for fast recovery while troubleshooting.
- c. Security is another important issue in this research, proper grounding at every node is highly recommended for the security of human beings and other wireless devices.
- d. We will be carrying out experiments on Community Wireless Networks, Earthing system, routing protocols (BGP, MPLS), graph theory and complex networks and other related topics in future.

● References

1. Paudel D. R, "An Efficient Traffic Load Balancing and Optimization of Community Mesh Wireless Network", "Division of Information and Electronic Engineering, 2014."
2. Paudel D. R., Sato K., Gautam B.P., Shrestha D. "Design and Implementation of Partial Mesh Community Wireless Network in Himalayan Region" IEEE Third Asian Himalayas International Conference on Internet AH-ICI2012, Nov. 23,24&25, Kathmandu, Nepal
3. Gautam B.P, Paudel D. R., Shrestha S.K," A Study and Site Survey In Himalayan Region for Proper Utilization of Wireless Community Networks: An Assessment of Community Wireless Implementation in Heterogeneous Topography", WAKHOK University Journal, April 2011.
4. Ranjit Kumar, "Research Methodology", A step by step guide for beginners, Third Edition, Web: www.sagepublications.com
5. Redundancy, URL: <http://www.techterms.com/definition/redundancy>, Accessed Date: 2014/06/27
6. Network Redundancy, <http://www.amplicon.com/building/network-redundancy.cfm>, accessed Date: 2015-01-28
7. Bishnu Prasad Gautam, Narayan Sharma, Suresh Shrestha, Roshan Gautam, "Monitoring and Management of Unstable Network through Solar Powered Robotic Vehicle" /Wakhok Journal, Vol.14 / Page No. 19 – 30.
8. Safak DURUKAN ODABASI1, A. Halim ZAIM2 , "A Survey on Wireless Mesh Networks, Routing Metrics and Protocols" , International journal of electronics, mechanical and mechatronics engineering, Vol.2 Num.1 pp. (92-104)
9. Bishnu Prasad Gautam, Suresh Shrestha, Katsumi Wasaki "Enhancing Network Reliability by Establishing Redundant Network of Wi-Fi as Disaster Readiness in Soya Regions" / IPSJ SIG Technical Report / 2012
10. Bishnu Prasad Gautam, Suresh Shrestha, "Safeguarding Regional Network from Potential Natural Disaster by Establishing Redundant Network of Wi-Fi" / Wakhok Journal Vol.13 / Page No. 43 – 51
11. Simulation Models, URL: https://www.extendsim.com/sols_sim_def.html, accessed date: 2014/09/10
12. Open Shortest Path First (OSPF), Chapter 23, URL: http://www.alliedtelesis.com/media/fount/software_reference/271/ar400/ospf.pdf, Accessed Date: 2014-12-20
13. Configuring OSPF, URL: <https://perso.ens-lyon.fr/christophe.crespelle/enseignements/ASR/ospf-config.pdf>, Accessed Date: 2015/01/28
14. Open Shortest Path First Routing Protocol, URL: <http://www.firewall.cx/networking-topics/routing/routing-protocols/186-routing-protocol-ospf.html>, Accessed Date: 2014/11/05,
15. EIGRP Principles, URL: http://ptgmedia.pearsoncmg.com/images/9781587201479/samplechapter/158720147X_CH03.pdf, Accessed Date: 2014/11/05,
16. The TCP/IP Guide, RIP Protocol Limitations and Problems, URL: http://www.tcpipguide.com/free/t_RIPProtocolLimitationsandProblems.htm, Accessed Date: 2015-01-15
17. Border Gateway Protocol- BGP v2.01 – Aaron Balchunas, URL: <http://www.routeralley.com/guides/bgp.pdf>, Accessed Date: 2014-11-19
18. Types of Earthing System, Electrical Engineering, URL: <http://www.electricneutron.com/earthing-system/types-of-earthing->

systems/, accessed date: 2015-01-09

19. Lightning Protection International Pty. Ltd, Australia, URL: <http://lpi.com.au/>, Accessed Date: 2014-12-25

20. OMNet++, jesse Russell, Ronald Cohn, ISBN: 978-5-5124-7701-4, Published in 2012

● Abstract

This paper describes about the CWN networks established in Dhital-Kaski, Nepal. CWN networks in Dhital-Kaski has been developed by Gautam Seminar since 2010 in order to provide an internet service to communities in remote area of Nepal. CWN of Dhital-Kaski has numbers of problems in terms of connectivity and robustness. In this research, we have attempted to solve this issue by using simulation, emulation and real implementation of the network after having deepened ideas about CWNs in Nepal. The main reason behind unstable is frequent power cutoff and other natural disasters like thunder and lightning. Our study focuses on enhancing the robustness of the existing CWN networks.

In this research, Network simulation and emulation has been successfully tested before visiting the field in Nepal. We used some simulation tools and other hardware devices to study and analysis the performance of these network topologies. Finally, a practical field work has been done by constructing a new node at Astham with proper Earthing system and successfully established an internet connection to our main destination, the primary school of Dhital.

