Implementation of Collaborative E-learning System for Unstable Environment

Implementation of Collaborative E-learning System for Unstable Environment

Kazuhiko Sato
College of Information and Systems
Muroran Institute of Technology
Mizumoto 27-1, Muroran 050-8585, Japan
Email: kazu@mmm.muroran-it.ac.jp

Suresh Shrestha
Graduate School of Engineering
Muroran Institute of Technology
Mizumoto 27-1, Muroran 050-8585, Japan
Email: 15043073@mmm.muroran-it.ac.jp

Pramesh Shrestha
Graduate School of Engineering
Muroran Institute of Technology
Mizumoto 27-1, Muroran 050-8585, Japan
Email: 15043072@mmm.muroran-it.ac.jp

Bishnu Prasad Gautam
Faculty of Integrated Media
Wakkanai Hokusei Gakuen University
Wakabadai 1-2290-8, Wakkanai 097-0013, Japan
Email: gautam@wakhok.ac.jp

***Abstract*—We design a collaborative e-learning system for stable operation in an unstable environment of developing countries. The proposed system is used for providing a collaborative learning among local schools of rural area in Nepal. The stable operation of the system is realized by the redundant robustness in three different levels: network arrangement, energy management, and replicative database. In this paper, we present an overall design of the system and its use case. Then, methods adopted for achieving the redundancy in each level are described.**

Keywords—collaborative e-learning; redundant robustness; developing countries; unstable environment

I. INTRODUCTION

Recently, e-learning has been spread widely in the world as one of the excellent educational engineering techniques [1]. Excellent educational materials are published in the world. Learners can utilize them by paying a fee or can use free of charge. The e-learning technology reduced the geographic educational inequality, and it was realized as fairness of the learning opportunity [2]. Teaching materials of e-learning are provided in a variety of media such as web document, audio file, movie file, and so on. Many learners around the world can utilize them with high-speed communication networks and large-scale information systems. With the development of ICT, the further development of e-learning technology is expected to evolve in the future.

E-learning is considered a comprehensive technique which assumes stable high-speed network environment for effective operation. Overtime, the quality of contents has been improved; and accordingly its capacity is also increased. Learners, who live in developed countries or in the metropolitan area, have a stable and high-speed communication environment. Therefore, they can obtain its benefits with no limit. On the other hand, the school environment of developing countries is still under poverty. In addition, the countries are underdeveloped in terms of ICT and its availability. In those countries, the basic infrastructure such as communication networks and power transmission lines has not been sufficiently established. Therefore, for learners who live in those kinds of countries, it is difficult to obtain excellent e-learning contents that have been published to the world. In their unstable environment, many other problems are also often noticed. For example, there are a lack of computers, narrow network bandwidth, and frequent power failure due to poor power supply. Learners of developing countries can't stably obtain the learning opportunities from e-learning. The above problems can be easily solved by the improvement and stabilization of the infrastructure. However, its cost is very enormous.

In this research, we discuss methods to provide the benefits of e-learning for learners in developing countries. We take a different approach than that of the developed countries in order to develop the educational infrastructure. We propose an e-learning system which operates stable in an unstable environment. The proposed system is for supporting a collaborative learning among several schools of rural areas in a developing country. We first discuss the requirements to develop the e-learning environment in those schools and explain about our proposed system. The power system for running the e-learning system is essential in order to use it in classroom. If there is a power control mechanism, the system can be operated stable in an environment where a power failure occurs frequently. Network can be operated stable by the usage of redundancy of load balancing and other needful nodes. Alternatively, if there are the replicated contents on school server, the external network is not needed for full time. The independence of each school can be realized by redundancy of the database of e-learning system. If any of these redundancies is available, the system becomes more stable. The system will be robust by each redundancy.

In this paper, we design an e-learning system which has that redundant robustness. Firstly, the overall service model provided by the system is shown. Secondly, experimented environment of Kaski district in Nepal is shown. For realizing stable operation under unstable environment, the mechanism that has a redundant robustness is described.

II. Unstable Environment

A. Overview

In this section, we discuss the unstable network environment and the rapidly changing behavior of the system that are the causes of instability of those networks. There might be varieties of terms that define an unstable network environment. Any system is said to be an unstable if any factors related to that system stops to function properly, for instance (software, hardware, physical environment, etc.). Most of the network infrastructures of developing countries are unstable. However, we can define an unstable network under the basis of its surrounding environment like connection media, geographical situation, and hardware stability and so on. The network with very low availability due to frequent network outage can be defined as an unstable network.

The overall objectives of the research are to develop collaborative e-learning tools and its learning materials for improving education of rural schools. In order to conduct experiments, we have chosen the Community Wireless Networks (CWN) which is located in one of the Himalayan district in Nepal. This CWN test-bed has multi-dimensional research area where varieties of investigation have been carried out since the last few years [3]-[6]. The motivation of network implementation in this region is to provide an internet access to remote schools of the developing countries like Nepal. However, because the network has been affected by various serious problems, its performance is not stable.

According to the network quality and performance of CWN in Nepal, we have found some major reasons behind the instability of those networks. In this research, we can define an unstable environment if there exist any of the problems listed below:

- Lack of supporting infrastructure (teachers, local network administrators, etc.)
- Lack of redundant network hardware (servers and communications nodes, etc.)
- Slow Internet speed
- Single point of failure on network
- Proper safety measures against the natural disasters (like thunder, lightning)
- Frequent power failure problems

B. Current Situation of Schools in Nepal

Fig.1 shows a map of Kaski district of Nepal, where is a target area of our research. This area includes three primary schools. Geographically, those schools are located in a certain distance far from each other connecting two remote villages, called Dhital and Astam. The distance from those schools to Pokhara which is main city of this area, is about 14km in a straight line. However, those schools are situated in high altitude. It is very difficult for village people in order to move from village to town area.

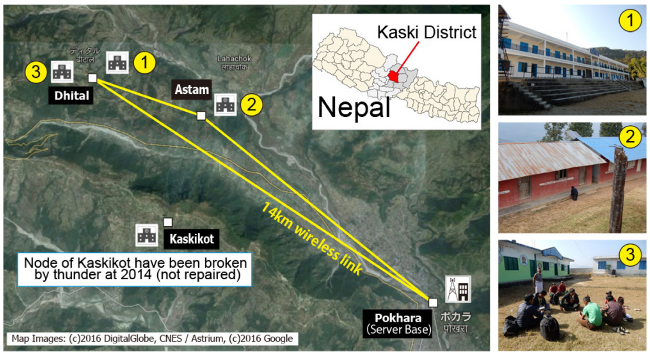

Fig. 1. Geographical Location of Targeted Schools

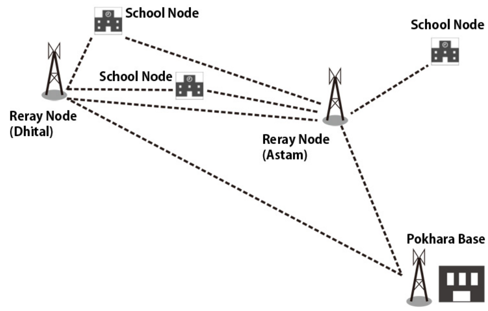

Fig. 2. Current Network Topology of Dhital-Kaski CWN (Active)

In village school, there are problems due to the lack of educational equipment and the lack of teachers who have enthusiasm and capabilities. In home of rural areas, children do not have an enough time for study. They have to help daily works in home. In addition, there is no lighting at night.

These schools are equipped with 10 or fewer computers by international support. Due to the lack of useful contents and application, students are obligate to depend upon only on analog (particularly textbooks) based education system for learning. These computers are used by certain authorized persons for official use only. For example sending and receiving email only. And, yet, they have to wait for network connectivity most of the time.

C. Current Situation of Network in Nepal

Network situation in Nepal has regional disparities. Urban area has relatively extensive equipment. Generally, users can use Internet service via optical line for home use. Many places such as stores and restaurants provide free Wi-Fi service. Many people have access to mobile phones or smart phones. Those communication networks are also available during a power failure.

On the other hand, current situation in rural areas is more serious. Villages in rural area are located in the hillside of the steep gradient. From the beginning of our research, there was the communication network of the mobile phone in those villages. However, there was no communication network for connecting Internet. It is difficult to connect the wired network from the town at the foot of the hill to the village. The wireless network also suffers from limitation of the communication strength by the terrain.

Since 2011AD, we have continued to implement the communication wireless networks (CWN). During the 5 year period (2011AD-2015AD), our CWN have been evolving every year since its establishment. Fig.2 represents latest network topology of CWN which has been last upgraded in the year 2014. There are five active nodes. The server base in Pokhara is connected to local ISP and it further distributes internet services to the remaining nodes via wireless medium.

D. Physical Limitations and Our Preferences

Beyond the adverse effects of geographical localities, there is a big challenge to provide highly available and sustainable communication platforms. Most of the communication networks in developing countries suffer from severe instability. It is still a challenging task to reach and solve the problems in the rural areas instantly during network disaster due to lack of proper roadways and transportation.

The connection between nodes is established using either wired or wireless technology. The rate of packet loss in wired media is less than in the wireless media, but due to the geographical constraints, we preferred wireless media for this research.

III. APPROACHES OF REDUNDANT ROBUSTNESS

In an unstable environment, to stably operate the support system for the collaborative learning between schools, we considered three mechanisms which have a redundant robustness. Each mechanism is implemented at different levels, network arrangement, energy management, and database replication. In this section, overview of each mechanism and its current situations are shown.

A. Redundant Communication Wireless Network

As an approach to stabilize the network communication, the development of redundant networks has conducted [7]. Since 2012 AD, we have been continuing to construct the CWN for connecting local schools in Kaski district of Nepal [8]. First, we constructed a server base (see Fig.3) at Pokhara city. Then, we connected the base and three villages, Dhital, Astam, and Kaskikot by wireless communication networks. The longest distance is 14km between Pokhara and Dhital village. The distance between each village is about 1km-3km. In each village, an access node of village and a node of school were connected. By arranging several relay nodes in the middle point between villages, redundancy for the load balancing or the fault avoidance was achieved. A solar panel, a battery device and grounding unit were installed at three access nodes (Pokhara base, Dhital school, and Astam school). Those access nodes can maintain its operation by avoiding weather and power failure problems.

Fig.2 shows a current network topology. According to the redundant CWN, a resistance against cutting of partial communication node was improved. However, many nodes of the network do not have the power backup device and

Fig. 3. Server Base (Left) and Main Antenna (Right) in Pokhara City

grounding unit. In addition, there are some bottlenecks. Only a node of the server base can access Internet via ISP. Moreover, some of the nodes do not have the redundant path. These bottlenecks have to be improved.

B. Sustainable Power Supply

In Nepal, rolling blackouts are occasionally carried out, particularly in the dry season. In the period of rolling blackouts, a power is cut off during the day time, and it is supplied during the night. Service time is also changed frequently, without providing proper scheduling. Thus, this leads to unstable communication.

In the context of education system that use e-learning system, long-term power outage in the day is fatal. To achieve a cooperative learning between schools, it is necessary to maintain communication path. Thus, all nodes which are on the network path between schools must have survived. Redundancy of the network can enhance its viability. But the period in which the network is maintained is not depicted explicitly.

To visualize a viable time, we adopt an energy management system (EMS) that can monitor the status of each node. Each node has own EMS. All EMS share the status of each other. Such kind of Collaborative EMS (CEMS) has been developed [9][10]. It can visualize the viable time of collaborative learning between schools.

C. Replicative Database

Replicative database is a core mechanism of our collaborative e-learning system [11][12]. To maintain the collaborative learning, the network must be alive. To maintain the system by limited power under the environment which has frequent power failure during the day, the sent data also must be restricted to a minimum size. If each school has all teaching materials on their server, even when the network is disconnected, the system can use the materials independently. To achieve this environment, we implement a replicative database. This database has a redundancy to satisfy the following requirements:

- Each school has its own database. Each database can be operated independently. It does not depend on the state of the network and other databases.
- Always, the database sharing is performed between the nodes when connection is alive.
- Database to adopt MySQL in order to enable the cooperation with the existing e-Learning system, such as Moodle.

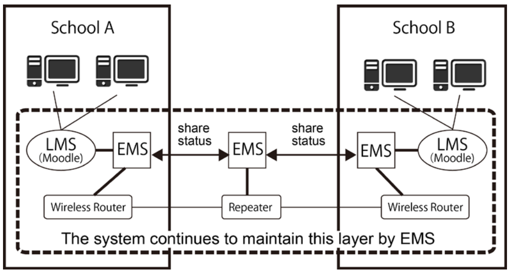

Fig. 4. Image of Proposed Collaborative E-learning System

IV. Proposed System

In this section, the collaborative e-learning system is described. It is designed based on approaches of a redundant robustness shown in previous section.

A. System Overview

Fig.4 shows an image model of proposed system. The system includes a standalone Learning Management System (LMS) to each school. In this research, we adopted Moodle as a tool of LMS. Basically, independent lecture was carried out by using this web-based e-learning environment. Teaching materials in LMS are created by teachers of each school. In addition, contents of other school's LMS are also able to share each other.

Each school and the server base have a solar panel and battery units (see Fig.5). Therefore, even when there is power failure, students can continue to use the computer within certain amount of time. Moreover, the system includes the energy management system (EMS) to each school. The EMS monitors a status of power supply. The EMS visualizes the power consumption of servers and network devices, and the charging rate of the battery. In addition, the EMS shares its status with other EMSs which is prepared for other school and the relay nodes. The system calculates the communicable time between schools based on this shared information. This time means the sustainable time of the collaborative learning.

The teaching materials of LMS are managed on a MySQL database server. In our system, an environment which the database can synchronize each other and can operate standalone, was implemented by layering the several database. In this environment, not only teaching materials, all information such as the network status and the power supply status, is shared.

B. Hierarchical Database for Redundant Data Replication

1) Overview

Fig.6 shows a hierarchical database of our e-learning system. Three schools are connected each other by CWN. Student in each school will use the e-learning system as the desktop application. The LMS will be used in the day time. In the dry season, the rolling blackout is conducted at most of the day time. In those time, computers of each school can sustain to use by own battery. To realize collaborative learning among schools, the learning materials of each school should be shared even if the system suffer power failure and network disconnection during the day. Therefore, the database server of each school, must obtain a replication of the learning materials, must be able to be used without depending on the state of the network.

Fig. 5. Solar Backup Units in Pokhara Base

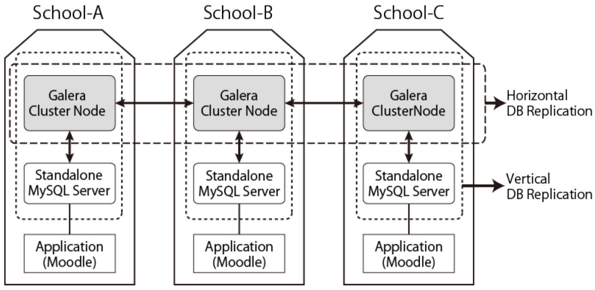

Fig. 6. Image of Database Replication of the System

To replicate the database, the data synchronization is a critical process for maintaining the consistency and uniformity of data instances across all consuming applications. It ensures that the same copy or same version of data is used in all devices from source to destination. When a single database is changed independently at two or more places, a post-processing for synchronizing all databases is a daunting task.

In our system, there are two database servers in each school. They are namely Standalone MySQL Server (SMS) and Galera Cluster Node (GCN). The SMS is a local MySQL database server and the GCN is one of nodes of cluster database. To keep the database stable, our system has two different methods for database replication. One is the horizontal replication, and another is vertical replication. The horizontal replication is for synchronizing database among schools. On the other hand, the vertical replication is for dividing the daily use and data synchronization from the database tasks. Such kind of replication of several databases is considered robustly redundant. However, such kind of redundancy can contribute to realize an independent management of the system under the unstable environment.

2) Horizontal Database Replication

The horizontal replication is achieved by using the Galera Cluster (GC) database (see Fig.7). The GC for MySQL is a true multi-master cluster based on synchronous replication. The GC is an easy-to-use, high-availability solution, which provides high system uptime, no data loss and scalability for future growth [13].

All the nodes are master as well as slave in the multi-master replication. So replication is possible from every node to every node. Hence read and write is possible from every database node at real time. The transaction in GC takes place at real time so there is no loss in transaction. Moreover, the GC controls its membership automatically. We can add and remove a node

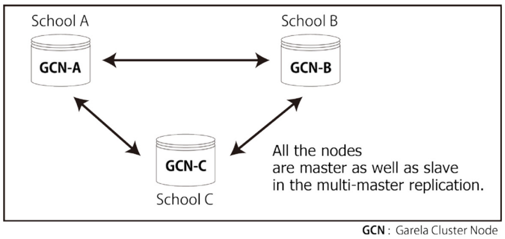

Fig. 7. Horizontal Replication

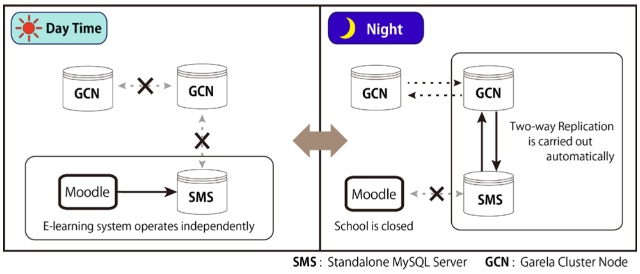

Fig. 8. Vertical Replication

easily and simply by adding the IP address of the node in the configuration files of all nodes. The member node becomes part of cluster automatically as soon as they are connected.

3) Vertical Database Replication

Fig.8 represents the vertical replication. During day time the e-learning system is used independently of network connection and hence students are capable of accessing the system. The system is capable of operating in an isolated and network disconnected condition. The updated data in the daytime is written to SMS, and the SMS synchronizes the database with GCN in the night. Same process is carried out in all the schools.

C. *Collaborative Energy Management System*

Fig.4 shows the architecture of CWN network with EMS installed at the every nodes of the network. This EMS monitors its own network devices, network connection and data flow from and to the node. Learning Management System (LMS) with Moodle database is available within computers of CWN. This LMS should be live and available every time in order to continue data sharing between schools. The stable EMS is required to support the LMS system.

We adopt the BeagleBone Black (BBB) [14] as a device of EMS. BBB is a low-cost development platform in which it is possible to install a Linux OS. The EMS is constructed as web-based application, which can monitor and control the power system of our e-Learning system. This system can decide whether it is required or not for the particular usage of device in a particular time. The system also calculates the power backup of the battery, energy consumed by the individual device in the wireless network. This system also can predict the remaining time that the battery can support all the devices connected to network.

The EMS has two batteries installed on it separately. When the EMS detects that the supply of first battery is going down, second battery comes into action to power up the devices. On critical condition of very low power in both batteries, EMS can

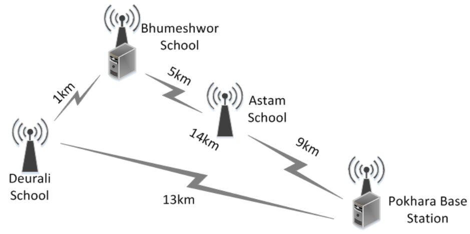

Fig. 9. Node Distribution in Dhital-Kaski, Nepal

hibernate the server and restart it safely when the power supply is restored. This prevents damage of the network devices due to sudden shutdown. Furthermore when the internet to the outer world is disconnected from the server due to natural calamities, the system will allow the internal network connections which allow people in the CWN network to communicate.

V. Prototyping and Experiments

Since the proposed system can withstand the poor network infrastructure, it can easily furnish e-learning services for schools and libraries located in remote areas. The system uses database replication approach to cater the all connected servers with the same database.

We developed a prototype system. For evaluating its performance, we had tested it on three primary schools which are geographically located at different locations and are connected with our Dhital-Kaski CWN in Nepal. All three nodes including Bhumeshwor School, Deurali School, and the server base of Pokhara ware experimented for synchronization. Fig.9 represents overall distribution scenario and approximate air distance between the nodes. The approximate air distance between Deurali School and Bhumeshwor School is 1 km. Deurali School and Bhumeshwor School are located 13 km and 14 km away from base station of Pokhara. Meanwhile, Astam is the newly added relay node in the year 2014 that is located approximately 9 km LOS from the base station. Astam also has a primary school where we intent to conduct an experiment on replication in the coming future.

For the experiments, we had prepared three types of the movie file, 5.2 Mbyte, 56.8 Mbyte and 104 Mbyte, in order to compare the effect due to the difference of the data size. We measured the time until complete synchronizing all nodes, after uploading one data to one node.

First, we tested the synchronization on the stable network in which each server is connected to a switching hub by short cable. Each cable used 10 meter of CAT.6. TABLE I represents the result of the experiment carried out on stable wired network. The experiment was carried out 10 times. In the table, the file size and average time taken during every data transaction are shown. All sizes of data had been passed with quick synchronization without any significant trouble.

Next, TABLE II shows the result of the experiment carried out in Kaski-Dhital CWN environment. The experiment also carried out 10 times. In the table, the file size and average time taken during each data transaction are shown. In this experiment we measured the three different lines. Test-1 is the test between Deurali and Bhumeshwor. Test-2 is the test

TABLE I. CONTENT SYNC. IN STABLE WIRED NETWORK

Test No./ Time(s)	Content Synchronization in Stable Wired Network				
	File Size (MB)			Approx. Distance (km)	Avg. Ping Speed (ms)
	5.2	*56.8*	*104*		
1	0.5	5.22	10.022	0.01	0.58
2	0.51	5.21	10.21	0.01	
3	0.5	5.21	10.21	0.01	
4	0.49	5.21	10.22	0.01	

TABLE II. CONTENT SYNC. IN UNSTABLE WIRELESS NETWORK

Test No./ Avg. Time(s)	Content Synchronization in Unstable Network				
	File Size (MB)			Approx. Distance (km)	Avg. Ping Speed (ms)
	5.2	*56.8*	*104*		
1 (Deurali - Bhumeshwor)	2.62	27.88	51.37	1	2.547
2 (Pokhara - Deurali)	12.99	129.91	238.91	13	4.78
3 (Pokhara - Bhumeshwor)	45.13	533.33	928.41	14	6.838

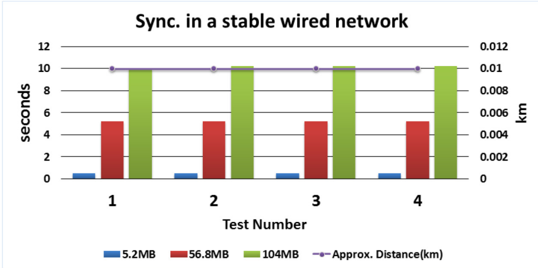

Fig. 10. Content Sync. in a stable wired network

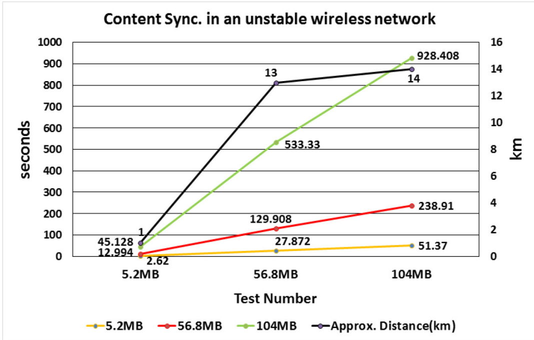

Fig. 11. Content Sync. in an unstable wireless network

between the base and Deurali, and Test-3 is the test between the base and Bhumeshwor. Fig.10 and Fig.11 represents graphical results of these experiments. In the graph, the packet size, and the time taken for synchronization over certain distance were reported. From the figure, the time increasing as per the increment of the file size was noticed.

VI. CONCLUTION

In this paper, we designed a collaborative e-learning system for stable operation in an unstable environment in developing countries. Proposed system is used for providing a collaborative learning among local schools of Kaski district in Nepal. Target place is very unstable environment because it has many problems including physical limitations. To solve the problems, the stable operation of the system was realized by the redundant robustness of three different levels: network arrangement, energy management, and replicative database. The mechanism of the redundant replicative database can be applied for many other services. In the future we will consider downsizing of the cluster to achieve cost reduction in our proposed system followed by using of low cost controlling devices such as micro-controller in our EMS. Furthermore, the effectiveness of our system to upgrade education system of the village schools in Himalayan district of Nepal will be assessed.

REFERENCES

[1] Ministry of Economy, Trade and Industry's Commercial Affairs Information Policy Department Sectiuon of Japan, "E-learning White Paper 2007/2008," Tokyo Denki University Press, 2008.

[2] N. Islam, M. Beer, and F. Slack, "E-Learning Challenges Faced by Academics in Higher Education: A Literature Review," Journal of Edu. and Training Studies, Vol.3, No.5, pp.102-112, 2015.

[3] D. R. Paudel, K. Sato, B. P. Gautam, D. Shrestha, "Design and Implemantation of Partial Mesh Community Wireless Network in Himalayan Region," Proc. of Third Asian Himalayas International Conference on Internet (AH-IHI2012), pp.1-6, Nepal, Nov 2012.

[4] S. Shrestha, B. P. Gautam, H. Asami, T. Saga, and D. Pun, "Simulation, Emulation and Performance Analysis of Dhital-Kaski CWN Networks," WAKHOK University Journal, vol.15, pp.61-94, 2015

[5] B.P. Gautam, N. Sharma, S. Shrestha, R. Gautam, "Monitoring and Management of Unstable Network through Solar Powered Vehicle," WAKHOK University Journal, vol.14, pp.19-30, 2014.

[6] B. P. Gautam, N. Sharma, and K. Wasaki. "Tensai Gothalo: A Solar Powered Robotic Vehicle for Real Time Network Monitoring and Management Using Raspberry Pi," ScieXplore: International Journal of Research in Science [Online], Vol.1, No.1, pp.42-50, 2014.

[7] K. Sato, Y. Suzuki, D. Shrestha, D. R. Paudel and B. P. Gautam, "A Proposal of E-learning System for Unstable Networks," Proc. of 2014 CIEC conference, vol.5, pp.58-61, Tokyo, Japan, Mar 2014.

[8] D. Shrestha, and K. Sato, "Design and Implementation of Sustainable e-learning System in an Unstable Community Wiress Mesh Network," IEICE Technical Report, vol.114, No.121, pp.7-12, Jul 2014.

[9] P. Shrestha, S. Shrestha, and K. Sato, "Energy Management for Supporting E-learning System in Unstable Networks," Proc. of the 2016 IEICE General Conference, DVD-ROM, Fukuoka, Japan, Mar 2016.

[10] P. Shrestha, S. Shrestha, and K. Sato, "A Development of Web-based Energy Management System for Unstable Community Wireless Network," Proc. of JSED2016, pp.42-44, Mar 2016.

[11] S. Shrestha, B. P. Gautam, P. Shrestha, and K. Sato, "Cluster-based Replication of an E-Learning System on Unstable Networks," Proc. of the 2016 IEICE General Conference, DVD-ROM, Japan, Mar 2016.

[12] B. P. Gautam, A. Batajoo, K. Wasaki, S. Shrestha, and K. Sato, "Multi-master Replication of Enhanced Learning Assistant System in IoT Cluster," Proc. of the 30th IEEE International Conference on Advanced Information Networking and Applications (AINA-2016), pp.1006-1012, Crans-Montana, Switzerland, Mar 2016.

[13] Galera cluster for MySQL Documentation: http://galeracluster.com/documentation-webpages/weightedquorum.html (Last Access: 04 May 2016)

[14] BeagleBone Black Documentation: https://beagleboard.org/black (Last Access: 04 May 2016)