Using a Solar Powered Robotic Vehicle to Monitor and Manage Unstable Networks

Bishnu Prasad Gautam, Katsumi Wasaki, and Narayan Sharma

***Abstract*—This paper introduces the design and development of an autonomous path tracing robotic vehicle that can be utilized in the management of unstable network. Particularly, we have developed the path tracing module in terms of the software and hardware design which realizes the autonomous path tracing vehicle using the infrared reflective sensors. Furthermore, the concept of robotic vehicle in order to provide stable power system in TCP/IP network is presented. In order to accomplish this goal, this system utilizesa8 bit microcontroller in order to regulate the DC motor for motion and direction control and reach the server and supply the power. The path tracing mechanism is developed by using photoelectric sensors that receive the path tracing information and provides it to the microcontroller in real time. The mechanism of sensors units, role of microcontroller and the anatomy of our robotic vehicle and its utilization in terms of network management is discussed.**

***Index Terms*—Path tracing sensors, robotic vehicle, unstable network management.**

I. Introduction

Computer network technology consists of electronic computer and communication technology. The history of computer network is not so old; however, it has passed a number of phases to achieve the stage of today's Internet. ARPANET (Advanced Research Projects Agency Networks) had contributed to advance this technology as it had brought most of the concept of packet switching technology in 1969 [1], [2]. Network technology advancement of that time seemed to be a simple mini-step from a circuit switching to packet switching. However, this mini-step can be taken as a major milestone step in the history of computer networks. The closed and small ARPANET networks was later enhanced by ALOHAnet in 1970 and by the principle of Ethernet in 1973 and further enhanced by a DARPA project [3]. The latest architecture of TCP/IP was first deployed in January 1, 1983as the new standard host protocol for ARPAnet [4].

In this paper, we introduce the concept of robotic vehicle which is applied to monitor the unstable power supply of the computer networks. Unstable power supply refers to the interrupted power systems such that networks go unstable and unusable during such periods. We have developed a robotic vehicle which is an electro-mechanical device guided by an electronic circuit. Our final goal is to deploy robotic vehicle in order to monitor the network of outdoor. Before deploying in outdoor environment, we would like to do sufficient experiment in indoor network. In the following sections we briefly highlight how this approach of research emerged.

A. Literature Review

We have done research to utilize our robot in order to find out power offed-server due to different reasons and supply the power to that server so that network administrator need not visit the site. Network administrators can thus save their time and also be able to reduce the downtime of the networks. Networks are often interrupted and remain unstable due to power cut-off in most of the regions of developing countries. Some of the organizations in these regions are using back up power systems such as solar power so that they can supply the power to their networksuninterruptedly. However, this is not affordable to all kinds of organizations as it could be an expensive solution to afford and only financially capable organizations can afford. Power shortage situation also can arise during disaster time as power systems often go down. Our research aims to supply the power to the power-offed server, so that network can be re-established within very short time. Until date, there is not much research on using robotic vehicles in order to monitor and manage the network. This research is a first of its kind in this field particularly in academic societies. Though there is little research in using robotic vehicles to manage networks, we found a few path tracing algorithms andresearch which have been introduced in previous research. Path tracing algorithms are useful to mobilize the robotics vehicle to the position of power outage server. Some of the famous algorithms often cited in the research papers are the pure pursuit [5],[6] and the follow the carrot [7] algorithm. These algorithms are used to calculate the co-ordinates of the object or goal point and compute those points in order to assist the robot to follow a path as per the calculation. These algorithms however have shortcomings of accuracy to guide the robots to a destination. In contrast, we have used IR sensor that can identify the track and follow the path nearby the destination and supply the power to the power outage PC.

B. Unstable Network

The history of networks began from ARPAnet and reached today's Internet with a number of advancements. For example, the network media has changed from copper wire to fiber optics that can carry millions of bits of data in a second today. However, this kind of advancement of technology does not cover all parts of the world. There are still regions where it is very difficult to install networks and cost millions of dollars to deploy wired network. Many rural regions such as in Nepal, India, Bangladesh of South-Eastern Asian countries and mostAfrican countriesespecially in developing

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regions of those countries, do not have good connectivity solutions which are economically viable. In order to provide internet access in these regions, governmentsand INGOs are working to implement wireless service in these areas. In our previous studies [8], [9] we have built partial-mesh networks in Himalayan regions and this network is still working thereby providing community networking service in the remote villages of Nepal. However, these networks are not stable as compared to the networks built in urban areas. Lack of proper electricity and network infrastructure in rural areas and high installation costs as compared to urban areas are the two major hindrances in building stable wireless networks. Wireless networks in rural areas are not stable due to the power outage and link failures due to signal loss.

C. Fundamental Idea

Our fundamental idea of keeping network stable relies in two methods. One of which is to monitor the network by using network management protocol such as SNMP. SNMP constantly monitor the status of Network and while things go unexpected, it notifies to the administrator about abnormalities or changing state of networks. SNMP is very useful to monitor and reduce downtime of network by troubleshooting of the networks after receiving proper notification. SNMP requires that each device understand SNMP protocol. However, we found that most of the devices used in unstable networks in the developing regions are not utilizing the features of SNMP due to less literacy of network knowledge. There are also various kinds of network management and monitoring tools such as Nagios, MRTG, PRTG, Dude and many others by which network administrator can monitor their networks and keep their network under control. Nonetheless, in the remote areas that we mentioned above, networks are managed simply by the beginners who have very less skill of network management. We agree that SNMP and other network management tools are very useful to monitor and manage the networks however in order to properly utilized these tools; network administrator must have proper knowledge of these tools. This is possible in general scenario, however, this situation is not applicable in the remote areas of developing countries at which this research has been carried out. Most of the available tools are usable while the networks are alive.

We still think that it is necessary to create some kind of tools or application so that network can be maintained more stable.

The other method of monitoring network is to deploy an agent which can notify the administrator about the status ofthe network and also can troubleshoot it in some circumstances. This agent in our case is assumed to be a robotic vehicle. Therefore, we realized that in this research, our focus should be on robotic vehicle at which the robot can sensed the down state of the network and proceed to the server to provide the electric power to the node without using SNMP.

II. Flow Diagram

As shown in the Fig. 1, let us explain about how our robotic vehicle application can contribute to manage the unstable network in WAN, LAN or PAN area networks. Our robotic vehicle is equipped with sensor application attached on its body. While power goes down, this sensor automatically can sense about it and proceed to server room in order to supply the power of the redundant node. The detailed steps are described in the Fig. 1.

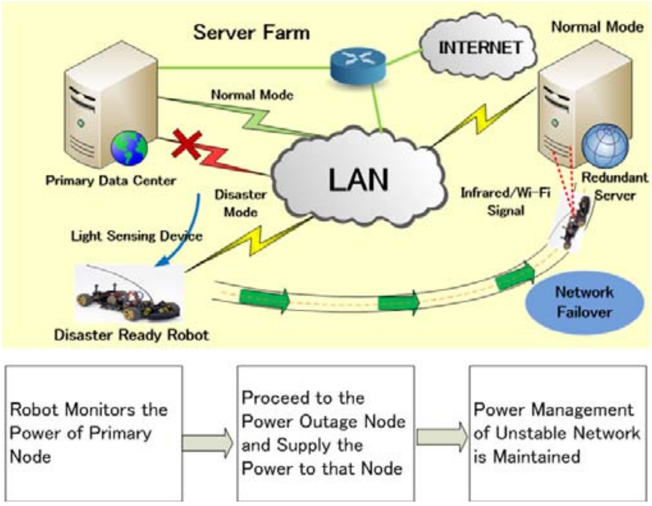

Fig. 1. Conceptual diagram.

This figure is modeled on the basis of our test-bed network built in Nepal during our previous research [8], [9]. Though we are modeling our network that is deployed in outdoor, we are not assuming that we can deploy our robotics vehicle in the outdoor network. Until we are able to develop a robotic vehicle that can walk in the outdoor field, we will use master-slave method to control our slave nodes that walks indoor. This master-slave model is described in subsection D of Section III. The departure of our research as the first step would start from a development of power monitoring module between the servers. We are focusing to this problem that can be occurred due to an unstable power source. We recognized that unstable network trouble can arise due to other related networks problem such as signal loss, routing problems and many others. In this paper, we limit our research scope only in power monitoring module.

III. System Requirements and Architecture

A. Microcontroller and It's Functionalities

A microcontroller is an electronic device that can either be programmed in already prepared device or can be embed the program into it. This device is a compactly designed to govern the operation of embedded systems such as motor vehicles, robots, computer systems and many other appliances. A typical microcontroller includes a CPU, RAM, ROM, I/O ports, and timers like a standard computer, but because they are designed to execute only a single or a few specific tasks to control a single system, they are much smaller and simplified so that they can include all the functions required on a single chip. The microcontroller used in this research is the AT89S51 microcontroller. This device is used to control the motors of our robotic vehicle. This controlling device has two different kinds of functionalities. One of which is to regulate the motor as per the signal received by sensor units that is attached in it. The other of which is to pursue the vehicle motion either in forward direction or in backward direction. Depending upon the synchronize signals between these two units; the program embedded in the controller will be executed by which the robotic vehicle has to move accordingly. The whole programis written and burnt into the microcontroller itself as per our design decision.

B. Electronic Circuit and It's Analysis

Flow diagram, and Electronic circuits used in our robotic vehicle is shown in the Fig. 2 and Fig. 3.

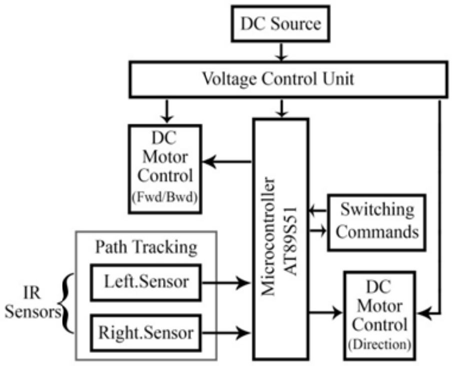

Fig. 2. Flow diagram.

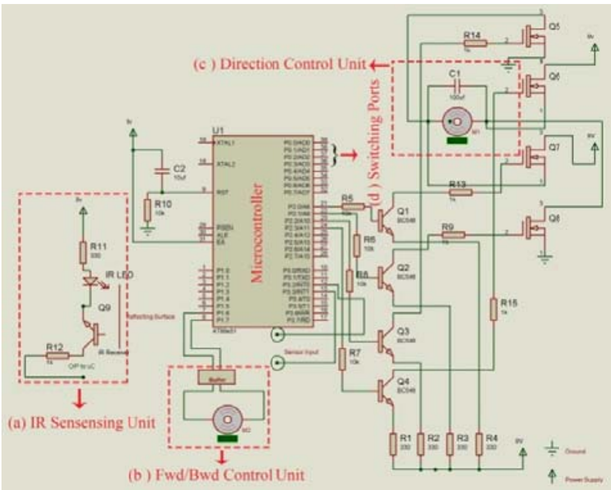

Fig. 3. Circuit diagram.

This circuit is built on the basis of path tracing and motor control objective. Path tracing is responsible for tracking the black and white colored path. Since infrared signals are absorbed by the black surface these signals could not reach the microcontroller via sensors. However, when the sensor steps into white surface then microcontroller gets the signal and it gives control signal for motor to change the current direction that its following and vice versa. This feature is designed in IR sensing unit.Similarly, voltage control unit VCU is responsible for providing a controlled and uninterrupted voltage to devices used for smooth operation of the circuit. Accordingly, DC motor control unit is responsible for direction and forward-backward movement. We have installed 2 DC motors in our vehicle. One of which is used for forward-backward motion and the other is for direction control. In order to regulate these motions, we have also designed the circuit accordingly so that it can control the motion. These circuit sections responses according to the signal changes in input IR sensors. For example, if left sensor attached on left wheel transmits the signal after sensing the white portion of the path, microcontroller will immediately execute corresponding command and this will result the motor to change the direction to right. This will lead left wheel goes to black track and follow the path. Similarly if right sensor gets signal then microcontroller understands that vehicle is required to turn into left direction and it immediately sends command for motor to change its direction to the left. In this way, our circuit with the help of sensors keeps the right path and move to the target. Forward-backward motor is responsible for forward-backward movement of vehicle. Movement occurs once the sensor of our robotic vehicle sense about the down state of the server. As soon as microcontroller receives the notification regarding the server in our network is off then microcontroller will immediately sends control command to the attached motor. This will results vehicle move forward to the server room and do necessary works. Both of the forward-backward control and direction control units are designed as shown in the Fig. 3.During our experiment we developed two sensors that can be used to sense whether the vehicle is off from the track or not.

TABLE I: TRACE TABLE

Left Sensor (LS)	Right Sensor (RS)	Motor (Direction Control)
0	0	No Change
0	1	Turn Left
1	0	Turn Right
1	1	Path Finder Step

C. Algorithm

In order to control the vehicle, we have implemented as per the following algorithm, the basis of which is derived from the Table I. In our algorithm leftmost sensor is denoted by LS, and right most sensorsis denoted by RS. The values of both sensors areassumed as per trace Table I.

Step 1: If LS> RS Move right, If RS> L SMove left .
If LS=RS& LS=RS=0,move forward
If LS=RS& LS=RS=1 Goto Step 2 (Path Finder Step)
Goto step 3

Step 2: This step is named as path finder step. Move clockwise if the path was last seen on RS sensor and moveanti clockwise if path was last seen on LS sensor. Repeat Step 2 till path is found.

Step 3: Goto Step 1.

D. Traceable Path of Robotic Vehicle

Another degree of deploying robotic vehicle in the network is autonomy which describes how independent from humans or network administrator a robotic vehicle can operate. At one end we want a robotic vehicle that is fully controlled by a human operator,such as by the usage of remote control. At the other end, we want our robotic vehicle that istotallyautonomous. However, building a robotic vehicle totally autonomous that can manage a network is very far sighted dream. We have a master node and also a slave node that can actas an agent which, in real time, move towards the offline server accomplishing the assigned tasks. Master nodes are capable of sensing the power off state of the servers and then send the instructions to the slave nodes to take an action. In this way the master-slave operation will be executed.

To experiment ourrobotic vehicle, we designed a 6.5

moval shaped traceable path in our lab. The middle part of the path is black topped and the both edges are white topped which can be seen in Fig. 4. In order to move along the track line, the IR sensor detects the track line and signals from the sensor will execute corresponding command lines in the program embedded in the microcontroller.

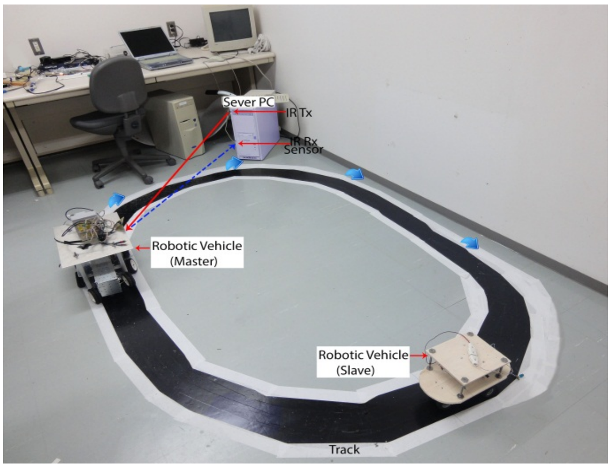

Fig. 4. Experimented Path

Accordingly, it regulates DC motor in order to control the motors' direction and speed. Presently developed track tracing system is able to control the vehicle in order to retain in the track and prevent from run out of the track-line.

This traceable path is designed in such a way that width of path is slightly greater than the width of wheel of the vehicle. Only one sensor (either left or right) has a chance of falling on white track at a certain time. Initially both will be on black track and when they change the path then they will reach to white track and microcontroller immediately response this and again sends signal so that both wheel always lies in black. Switching commands are responsible to control forward-backward motor and also responsible for switching on the server by sending the command to IR based remote control system attached on vehicle that sends command to the offline server and thus offline network is healed.

1) IR sensor

IR Sensors [10], [11] work by using a specific light sensor that detects the certain light wavelength in the Infra-Red spectrum. In our robotic vehicle, we are using 2 units of IR sensor as shown in Fig. 5. These IR sensor units are made of LED and photo transistor (IR Receiver). Led produces light at the same wavelength and strike it in the frontal object.

Our frontal object is a black labeled path. In our case, we are using the feature of IR sensor in order to sense the white object.

For example when our vehicle get off the black labeled track and the light hits other surface, the sensor start to sense the reflected light as the light emitted from LED reflects into the light sensor. This mechanism is shown in the Fig. 5 and Fig. 6 more clearly.

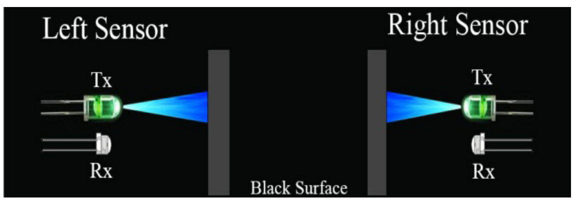

Fig. 5. IR Sensor (IR receiver is not getting reflected light).

E. Power System

Our power system used in this robotic vehicle is solar energy. Solar energy is regarded as one of the comprehensive renewable resource by which the solar cell made up of semiconducting materials such as silicon that allows the electron energy to flow freely while sun light struck its surface. In our robotic vehicle, our battery is charged by solar panel.

The solar powered robotic vehicle aims to operate and manage the networks is a totally new concept. By this concept, network administrator can save their time by reducing the number of field visits while there is power outage. The robotic vehicle has a capability to sense the power outage and also the capability to be operated through solar energy which is consumed by the robot itself. The main advantage of this method is that there is time savings for network administrator and also it can be operated without producing CO_2, so it is also an eco-friendly device.

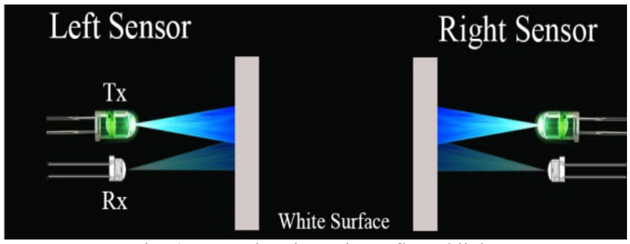

Fig. 6. IR receiver is getting reflected light

IV. Other Parts and Vehicle Anatomy

A. DC Motors

We have used dirt tuned motor manufactured by Tamiya Pvt Ltd. This motor is equipped with worn out brushes which can be replaced too. Heat sink type end bell allows effective heat dissipation.

This motor is 27 turn type motor that can works in the range of 6-12 V though the correct usable voltage is 7.2 V. The efficiency of RPM at no load produces 17,000 rotations per minute. Torque at best efficiency is 37.24 mN.m. Both of the torque and rpm works at the usable voltage of 7.2 V as described in Tamiya official website. The main function of this motor is to run as per the digital signals received from the microcontroller and produce the rotation and transfer this rotating energy into the gearbox.

Gears are special kinds of wheels with teeth. Robotic vehicle cannot properly move without gears.Gears in robotic vehicle is used to transfer motion or power from one moving part to another more efficiently.

Let's describe the gear principle of our robotic vehicle by using the Fig. 8.


Fig. 7. Dirt tuned motor.

Our robotic vehicle has numbers of gears which are used in order to increase the efficiency of torque received from motor indicated M in above. The total numbers of gears used for forward and backward motion is 9. Similarly we are also using gears in our direction control section too. The complete specification of the gears is mentioned in Table II and Table III below.

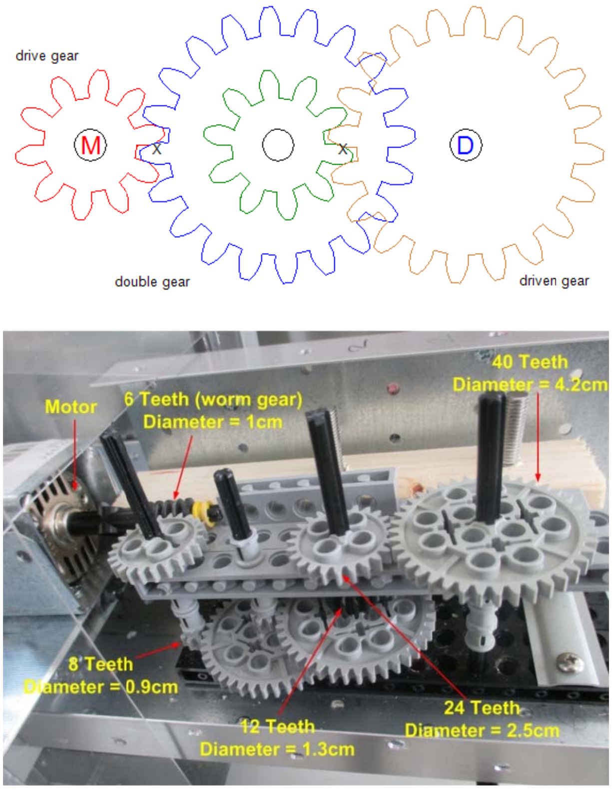

Fig. 8. Gear principle and snap shot of gears (Lego) used in robotic vehicle.

TABLE II: GEAR SPECIFICATION FOR DIRECTION CHANGE

Numbers of Teeth	Diameter (in cm)	Quantity Used	Remarks
6	1	1	Worm Gear
8	0.9	2	
12	1.3	1	
24	2.5	2	
40	4.2	3	

TABLE III: GEAR SPECIFICATION FOR FORWARD-BACKWARD MOVEMENT

Numbers of Teeth	Diameter(in cm)	Quantity Used	Remarks
8	0.9	3	
12	1.3	2	
24	2.5	2	
40	4.2	3	

When our motor receives the signal from microcontroller, it starts to rotate. First of all, it transfer the torque to driving gear and transmit to double gear and finally to the driven gear.

We are using 3:1 ratio in order to build a mesh gear as shown in the Fig. 8. We started to receive the torque from small gears and transfer this spin to larger gears. As the circumference of driven gear is larger than drive gear, the speed at the end decreased.

This sort of mesh design is intentional as we want more torque in our drive gear so that it can pull more loads. Most of the parts of our vehicle are steel made and thus making it heavier. In order to pull this vehicle, we require more torque rather than speed in our drive gear. In order to understand relation between force and torque, let see the equation below.

$$\tau = r \times F$$

where, torque is denoted by τ, moment arm by r and force by F. As the distance of r (Moment arm) is larger in drive gear, the amount of torque is increased. In this way, we are amplifying the torque at the output gear.

B. Conceptual Prototype of Robotic Vehicle

The complete conceptual prototype of robotic vehicle is shown in Fig. 9. The total length of robotic vehicle is 48 cm and the height is 24 cm. We have used 2 wheels at the rear part, 4 wheels in the middle and 4 wheels in the front. The rear wheels have diameter of 9.5 cm and can bear the load more than 50kg. As our motor for direction control does not have enough torque, we use very light wheel having 9.5 cm of diameter in the front. The complete figure is shown in Fig. 9.

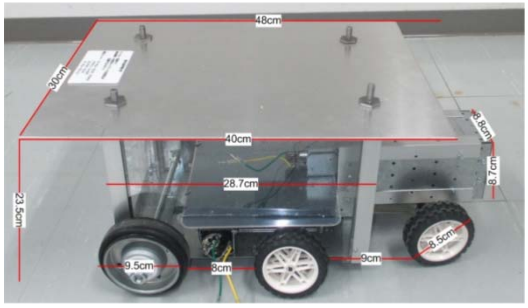

Fig. 9. Body of robotic vehicle.

V. FUTURE WORKS

We implementedan initial prototype of the robotic vehicle that can be used in order to manage the networks in the future. Our departure of research starts from stabilizing the power networks by providing and monitoring the redundant power supply. In our future work, we want to collaborate our robotic vehicle with other monitoring tools such as Nagios, SNMP, PRTG so that our robotic vehicle can be notified by those tools in order to rescue the networks from being offline for a longtime. The key component of this research includes microcontroller based control system, path tracing IR sensor devices and solar powered DC motors. Currently, we have not implemented the obstacle detections unit in its path, however, in our future work we will implement the IR sensor device that can detect the obstacle in its path and reflect back to the microcontroller so that it can regulate the motor to avoid the obstacle. Theoretically, it is possible to avoid the obstacle as infrared waves get reflected back to the robot and can be programmed accordingly. Our next future task is to facilitate this robot with wireless communication such as ZigBeeand utilize the robotic vehicle in the disaster area in order to assist the rescue team to support their management operation. In addition, further enhancements can be made with different perspective.For example, these robotic vehicles can be provided with cameras to send security information and the path information to the master node. These information will be interpreted and utilized in the future version that uses GPS, GIS based navigation. In the current prototype, we are applying master-slave model.

Master node will accordingly instruct to the slave node to operate properly during management of network.With the help of visualization, network administrator can send remote controlling instructions to the robotic vehicle and all control can be done through these cameras and enhancement on trouble shootings can be achieved. Specifically, our future endeavor will go on to implement the robotics vehicle that can autonomously move in the outdoor field in order to locate and accurately navigate the server position on the basis of GPS, GIS and GPRS information.After proper localization, our robotic vehicle will do the necessary possible management works of the network in order to materialize self-healing feature of the future networks.

VI. Conclusion

In this paper, a new concept of utilization of robotic vehicle in order to manage unstable networks is proposed, and the construction of a solar powered path tracing robotic vehicle that employs such mechanism is described. The power system of the robotic vehicle is equipped with solar unit. Moreover, DC motor supported with gear mechanism, IR sensor and electronic circuits are designed in order to control the movement of the vehicle as a means to locatethe target of the off-line node in the network.

To conclude, the main purpose of this research lies in the usage of robotic vehicle system in the management of network, based on renewable energy. On this basis, our research presents the concrete methods of a path tracing mechanism and solar powered mechanism in order to achieve the reliability and survivability of networks. On the other hand, it also proposes the new concept and un-experimented usage of robots in this field. We believe that this research has contributed a major milestone in the field of robotics thereby combining multi-discipline of network engineering, robotics and electronic vehicle in the common research platform.

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