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Tensai Gothalo: A Solar Powered Robotic Vehicle for Real Time Network Monitoring and Management using Raspberry Pi

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Abstract

In this paper, we describe the architecture of *Tensai Gothalo*, a network monitoring robotic vehicle developed in our previous research. Tensai Gothalo uses Wi-Fi modules to communicate with its slave node and also uses IR sensor modules that detects the path agent called the *passage* and assists an autonomous robotic vehicle called the *Master Tensai Gothalo* in capturing the powered off server. In order to properly manipulate *Master Tensai Gothalo,* it should be enhanced with the functionalities of routing, image recognition, network aggregation, and remotely controllable module. Instead of using general purpose distributed system solutions for these services, we employ whole lab grown technology integrating some of those functionalities with Raspberry Pi to implement simple and efficient mechanisms of robotic vehicle. We believe that such approach of integrating robotic vehicle with Raspberry Pi further enhances the network management and monitoring, yielding pragmatic solutions that leverage future network.

Keywords: Enhancing Network Survivability, Robotics Vehicle, Redundant Wi-Fi Network, Tensai Gothalo

1. Introduction

The technology of computer networks is still evolving as new computing solution such as new kinds of social networks or cloud computing products are introduced monthly, weekly and in sometimes daily basis into the market. Realizing the benefits and importance of new computing resources, products and the data that can be shared among many organizations, implementation of management or monitoring tools that can govern the entire collection is growing further. Monitoring and management of globally distributed resources of networks across organizational, geographical and political boundaries is highly required to securely manage their resources before harmful event occurs in the networks. We observed that there is a continuous growth in networking technology and this trend will continue on its rapid curve for coming day too. This will certainly may lead a current Networks to a more complex networks [1], [2], [3] in the very near future. Regardless of its complexity, network technology of today have evolved into an integral and necessary part of any kinds of organization. As their resources in the form of digital artifacts are increased, the necessity of management and monitoring of those resources are also need to be improved. This requirement contributed to evolve both of the management and monitoring technology of computer networks. As the resources of computer networks increased, new challenges are also associated and arising all the time. These challenges are giving high pressure to the network management team to maintain the quality of network services. In order to increase the quality assurance of network services, network engineer, researchers

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or administrators are in continuous research of network management and monitoring tools so that they can manage their network more efficiently and effectively.

The concept of Tensai Gothalo is to enhance network quality by ensuring network availability and to reduce the administration time of network administrator by fabricating various technologies of computer networks, robotics, electronics and cloud computing. In our previous research [4], [5] we started to employ the concept of network administration by using robotic vehicle. We are emphasizing of utilizing robotic vehicle for network administration in order to reduce the administrative cost of the organization as cost is a critical factor of any organization to sustain or to grow. Furthermore, we are proposing to introduce robotic vehicle to enable the redundant network during disaster thereby reducing the down time of network and thus assist the rescue team for disaster management. Robotic vehicle that can join rescue team to enable redundant network is named Tensai Gothalo which can perform a few important tasks such as network monitoring, management and administration. Our main contributions in this research are:

- We describe the design and implementation of Smart Gothalo, a network monitoring robotic vehicle attached with IR sensor nodes that detects and aids a Slave Gothalo in identifying and troubleshooting the power offed server.
- We are able to design efficient and simple mechanism of cost effective robotic vehicle.
- We demonstrate one of the first prototypes of its kind that can monitor the network and can assist network administrator to trouble shooting.

1.1 Target Tracking and Server Identification

The prototypic vehicular movement mechanism of Tensai Gothalo is similar to unmanned ground vehicles often used in military and disastrous rescue assignments where it is difficult to send people to perform the task. For example, in bomb or mine disposal work, fire intervention, nuclear disaster areas and many kinds of scientific research. These days the increasing number of terrorist incidents around the world further contributed to boost the interest in unmanned robotic vehicle. Tensai Gothalo is a kind of unmanned robotic vehicle which can be applied to monitor the network of disastrous, military zones or any kind of networks. The major task of Tensai Gothalo is to discover server machine in the network that needs power supply to resume the tasks or to solve the problems facing by such nodes. First of all, discovering a node in a network that has trouble is a challenging task. Discovery of the nodes or services can be done by using different kinds of discovery protocols. For example, there are service discovery protocols [6], [7], link layer discovery protocols [8], [9] and neighbor discovery protocols [10], [11] and many others. The common scenario of these protocols is that the node that joins the networks sends multicast or broadcast packets. Other nodes in a network listens such packets and keep the records of its MAC address or IP address. In this way, the network nodes keep the records of its neighboring nodes and discover the adjacent nodes in a network that joins or leaves the network. These protocols are very useful to discover new node and troubled node but are not useful to track the path where the node physically is located. Identifying physical location of the node is inevitable in our solution. In our case, we are proposing to use IR sensor to detect the troubled node rather than relying upon discovery protocols. Tensai Gothalo, start to approach to the troubled node while something is gone wrong in that node. In the current design, Tensai Gothalo utilizes the IR sensors in order to track the path that leads to server room. Infrared sensors are often used in the identification of object detection, vehicle position control, collision avoidance and identification of obstacles. We have also investigated this method to recognize our target. Figure 1 showed the experimented tracking path and Tensai Gothalo which is attached by IR sensor. IR sensor receives the tracking information through Infrared

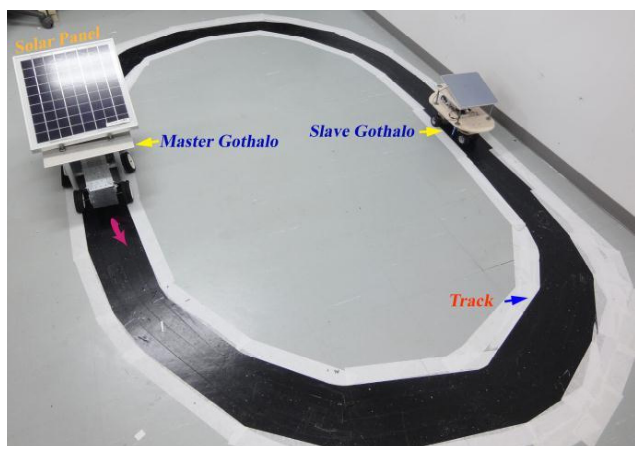

Figure 1. Experimented Tensai Gothalo and Tracking Path.

sensors used in object-detection module on the principle of a light emitting signal with a specific frequency, which is transmitted from a source, being reflected back by the object and being detected by the receiver.

2. Motivation

2.1 Issues and Objectives

We agree that network complexity is increasing day by day and thus organizations also require knowing how their monitoring technologies or activities are executed. Systematic and continuous monitoring is essential not only vulnerable situation but also in normal situation. Unfortunately, most of the times, monitoring and management issues are not taken as a high priority issues. Organizations often take this issue more cautiously when there is a direct negative casualty in their resources. Network troubles issues are more serious issues in the Himalayan regions and in the extreme climatic regions such as northern most parts of Hokkaido. Networks of these areas [12], [13], [14], [15] often affected due to power failures. We roughly categorize the major network issues of these areas as follows:

- Network Management and Monitoring Issue
- Network Survivability and Availability Issue

The concept of Tensai Gothalo arises while the authors face number of troubles during network administration at their place and at the experimented areas. Our experimented areas are located in northern most part of Hokkaido (Refer Figure 2) and the other one is located in remote hilly areas of Nepal.

Both of these places are vulnerable places in terms of Network survivability and availability. Specifically, during winter seasons, the networks of these area are often affected by sudden power failures. We have experienced numbers of power failures in these areas, the situation of which is more or less alike with disaster affected areas. Though the power failures due to unfavorable climatic situations such as heavy storm, wind etc might not physically damage the underlying network infrastructures, downtime situation of these networks are often similar to

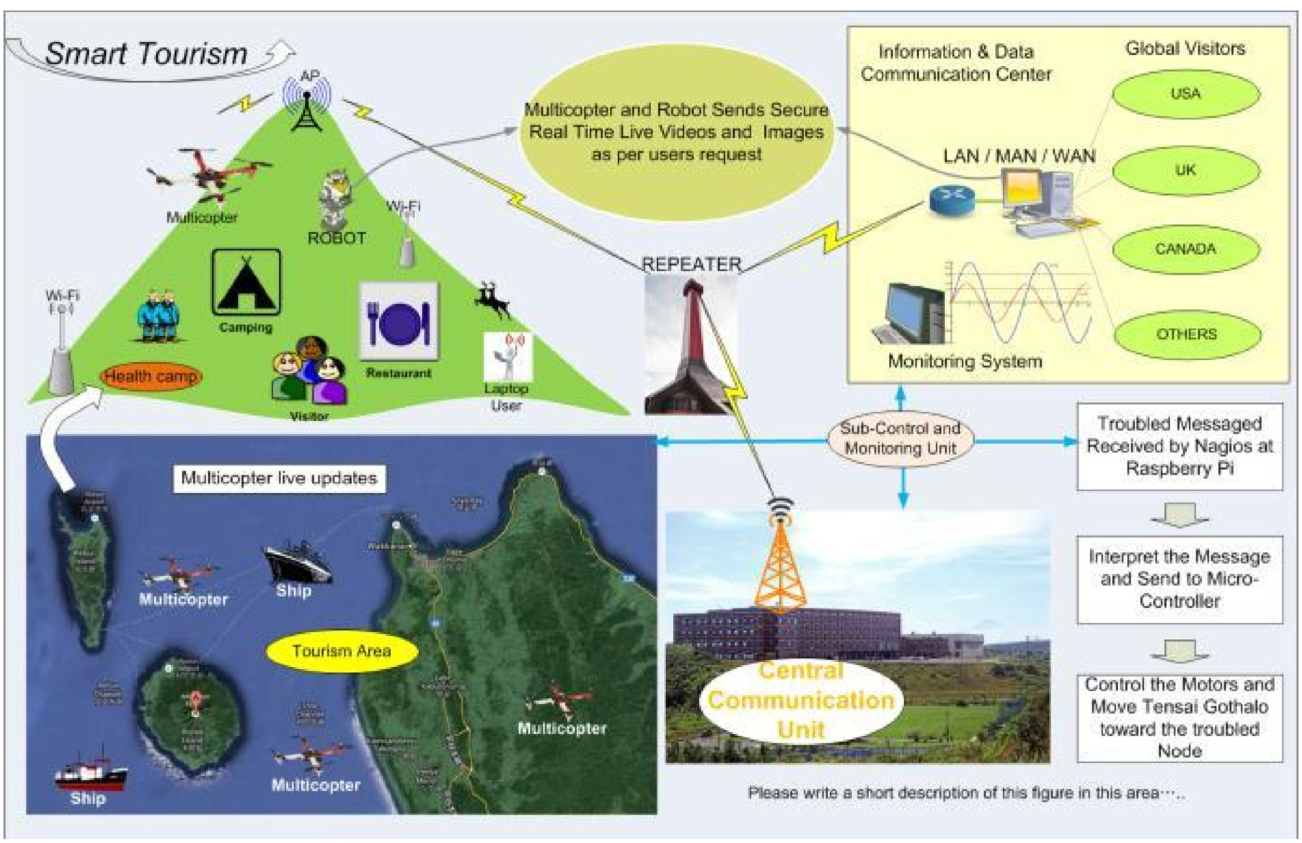

Figure 2. Network Monitoring Field Scenario.

the disastrous areas in terms of network availability. From the past experience, we know that disasters, by their very nature, destroy existing network infrastructure. Disasters can also lead to data overloading and saturation, which also destroy networks. The use of mobile ad hoc networks and the distribution of antennas in disaster areas can often address these problems. Although networks can be re-established in disaster areas, doing so may not be feasible in large-scale emergencies. Some authors [16] even suggest the use of a wireless opportunistic network based on mobile devices carried by emergency personnel to forward the data created and collected in disaster areas to coordination points [16], [17], [18]. These approaches are all post-disaster measures.

In contrast, our approach is a pre-disaster measure. Our measures covers, establishment of redundant networks and robust network management and monitoring system. These measures are considered to reduce the risk of damages to the Network. In our previous research [4], [5], [19], [20] we investigated about unstable network and deployed a model of redundant network. The other pre-disaster measure is to equip the network with robust monitoring system so that in disastrous circumstances, network administration can handle the situation quickly. The tasks of network administrator such as service monitoring and identification of power failure nodes can be done by Tensai Gothalo.

3. Vehicle Architecture

Tensai Gothalo is composed of a number of separable sections called units. Each unit has its own purpose and control systems. At its simplest, Tensai Gothalo uses an electric motor powered by solar panel on its roof usually backed up by a power unit supported with battery. Figure 3 shows the the completed Tensai Gothalo in our lab. To make it go along, it has gear units and the wheels. At each unit unnecessary parts are discarded and thus the total vehicle mass is reduced, in order to increase the efficiency and increase the amount of energy required to move the vehicle along the path. A pure electric vehicle can work with such kinds of components. However, as Tensai Gothalo is more than a pure electric vehicle, it needs more intelligent system that can control its motor and gears. We can see the body (Figure 3), solar power and its working mechanism (Figures 3 and 4) gear mechanism (Refer Figure 5).

Figure 3. Tensai Gothalo.

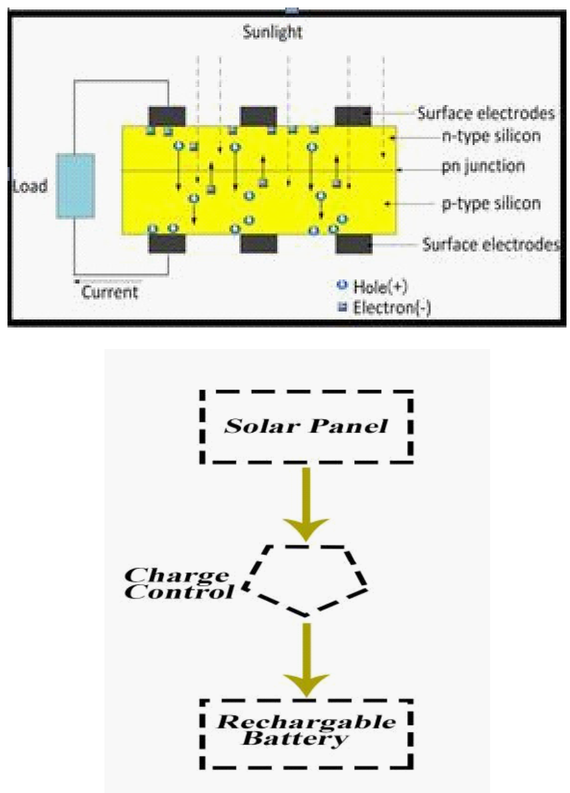

Figure 4. a) Solar Cell Physics b) Solar Panel Attached in Tensai Gothal.

3.1 Solar Power System and its Control

Solar energy is important renewable resource that can be used to generate electricity in our Tensai Gothalo. Solar electricity is produced from sunlight shining on photovoltaic

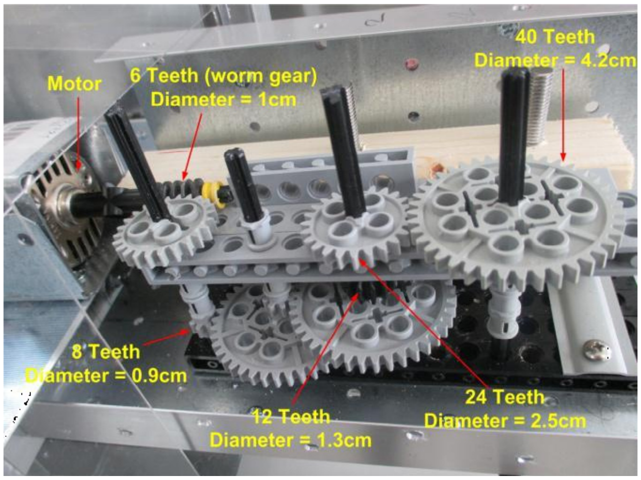

Figure 5. Gear Mechanism.

solar panels. A solar panel generates electricity from using the photovoltaic effect. It was discovered in early 19th century after observing that certain materials produced an electric current when exposed to light [5].

When sunlight strikes the combination of two different silicon semiconductor (p-type and n-type), the light energy is absorbed in the solar cell. The semiconductor material used to build a solar cell is mostly silicon which is cut into very thin wafers. The light energy is absorbed in the solar cell. Some of these wafers are then doped to contaminate them, creating electron imbalance in the wafers. These wafers are aligned together to make a solar cell. The anatomy of solar cell is provided in the Figure 4. Tensai Gothalo utilizes the solar energy via solar panel and also stores the energy in battery (Refer Figure 4b). Battery power will be utilized during the power down period.

3.2 Raspberry Pi and Integration

The Raspberry Pi is a very handy and portable sized computer hardware which is almost alike with the size of your name card. This device can be taken as mini-computer and it is capable of little computer which can be used in electronics projects, and for many of the computation that modern desktop PC does, like spreadsheets, word-processing and games. The main task of Raspberry Pi in Tensai Gothalo is to integrate all application that manages the system control, network monitoring and notification to the administrator. Furthermore, this entire process can be done by a single access and with efficient power supply. The integration process can be done by installing Raspberry Pi into the embedded controlling program of Tensai Gothalo.

3.3 Working Principle

Out research project consists of Raspberry pi (Model-B) device and At89s52 microcontroller. Raspberry Pi is used to control the operation of microcontroller and the programming used in Pi. Pi refers to python programming language.

Microcontroller that we used in Tensai Gothalo is programmed using c language to control the movement and direction of robotic vehicle. As soon as raspberry pi informs that the state of pc in server room is off, it moves and waits for the power supply. If power supply is available in server room then it sent the command to switch on the server. For the detection of power in the server room we are using the light detecting resistance device in our vehicle. Raspberry Pi is responsible for receiving the state (ie on/off) of PC (server) through infrared receiver.

3.4 Sensing Mechanism

Our IR transmitter in server pc transmits the IR signal to robotic vehicle (receiver section) informing that power has gone and server is off. As soon as microcontroller gets the information about server off through Raspberry Pi. It immediately takes response and sends command to motor driver circuit and vehicle moves to the room and waits for the power to come. If there is already power in the room before vehicle reach, it immediately sends the command to switch the server and return back to its original location.

Sensor 1 receives the signal from server pc and gives to the receiver attached in Raspberry Pi so that it sends command to microcontroller that Tensai Gothalo heads toward the location of PC server. IR sensor attached with Tensai Gothalo is responsible for the path detection. IR sensor and encoded program will control the direction and will be able to drag the vehicle to the target. Figure 6 shows the overall controlling architecture and Figure 7 is the detailed circuit design.

3.5 Purpose of using Raspberry Pi

We are using raspberry pi to monitor and manage overall network operation. Currently, our infrastructure is monitored through Nagios installed in different server. We propose to integrate Nagios in our Tensai Gothalo.

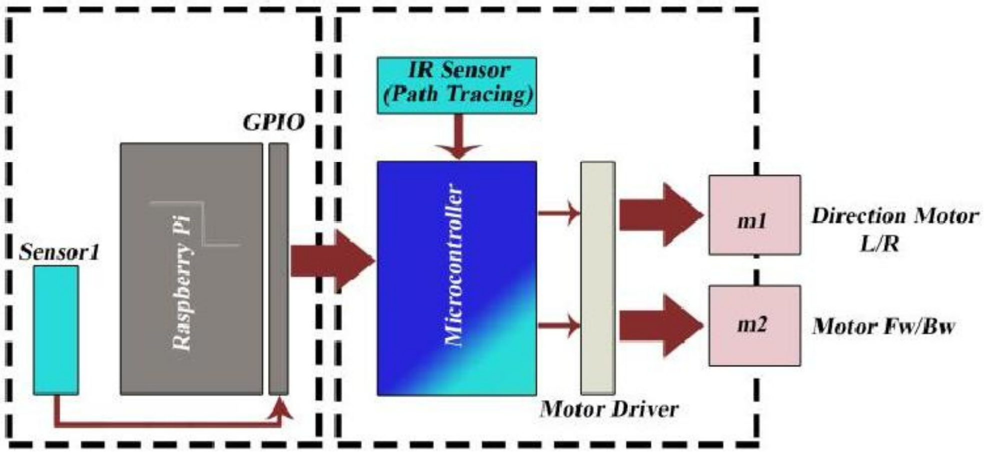

Figure 6. Controlling Diagram.

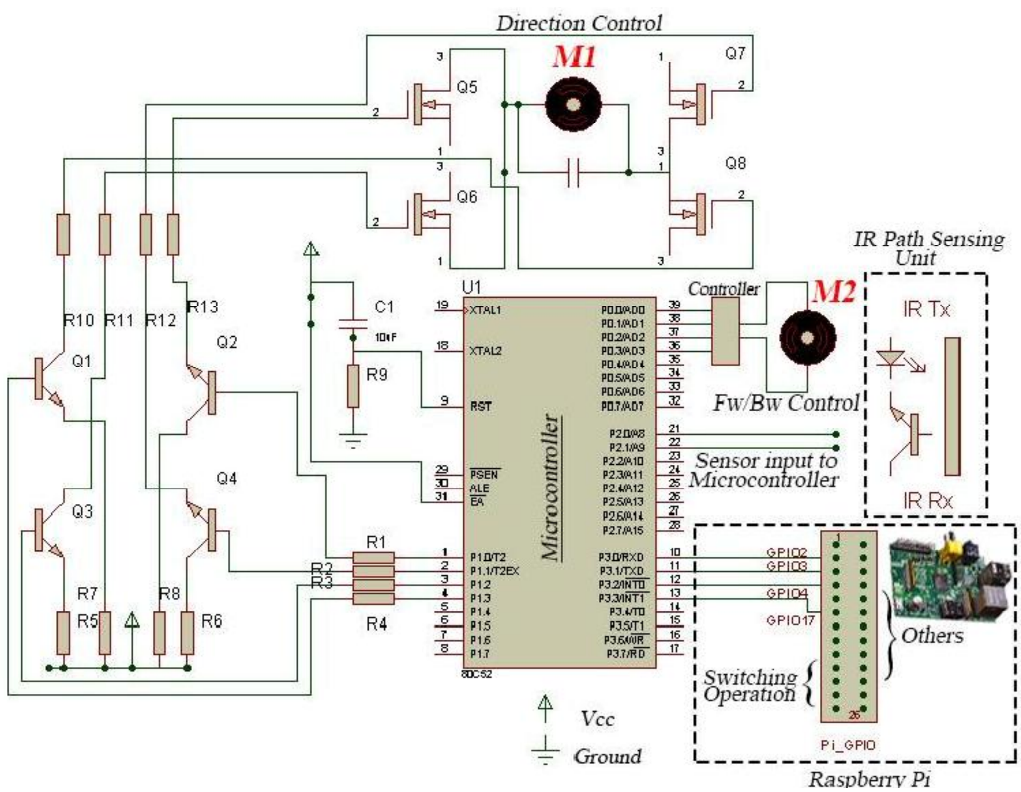

Figure 7. Circuit Diagram.

In order to do that we require the UNIX or Linux based operating system that can operate in minimal computing environment. As Raspberry Pi is completely Linux based mini-computer, it meets our requirement. Furthermore, we have plugged in Wi-fi module in Raspberry Pi device that can be connected with TCP/IP network. We also can use camera integrated with raspberry Pi so that monitoring of the server room can be further enhanced.

4. Network Management and Monitoring

Network is often monitored and managed by using SNMP (Simple Network Management Protocol) protocol. SNMP can be used in most of the environment where constant monitoring of key devices is required and where SNMP is supported by the network devices. To monitor the network, administrator often set up management stations that can offer reporting capabilities by which an administrator can take an appropriate action so that he can save the network from the damage before problems can seriously affect users. The details of SNMP can further be enhanced with other tools such as Nagios, MRTG, Zabbix and Hyperic. While these tools provide excellent statistics, to monitor the health of network on the macro level, it does not provide the the way of trouble shooting. For example, these tools can easily indicate the traffic consumptions, status of host and services, however, these tools are not capable of network trouble shooting. In order to solve the problem, network administrator need to take an action by him selves. This leaves the administrator knowing what the problem is, but as these tools do not have functionalities of how to solve, network administrators are sometimes required to go to the trouble spot. This requirement is becoming a big issue for the administrator. For example, in some networks where there is a lack of redundant power supply and redundant server, network administrator need to go to the spot for probable solution. In our research, we would like to automate the network trouble shooting process. We also like to co-ordinate the management process of supplying power, restarting terminated services and other needful management tasks by utilizing our robotic vehicle. In our first attempt, we have successfully implemented the module of sensing power supply to the server. For example, when the server is down, our robotic vehicle begins to move to the location of the server. Then it starts to provide the power supply or start redundant server. In order to monitor and manage our network more accurately, this kind of server down information need to periodically examine and processes the data according to the set criteria. The results of the analysis are usually presented in the form of graphics and tables that enable easy identification of problems that emerge. In order to achieve such result in our Tensai Gothalo, we must be able to integrate it with Raspberry Pi. As Raspberry Pi can be programmed by more high level language such as C, Python, PHP and Java, we can interpret the information collected by SNMP protocol. This information contains the status of services, host or nodes of the networks. Our target is to identify the troubled service or nodes in the network at earliest possible. For example, if the information about host down is received, this information will be interpreted by our program and send message to microcontroller to control the motor. This will lead Tensai Gothalo to approach to the troubled host and do further trouble shooting activities after a while. In our lab experiment, we are able to move our Tensai Gothalo toward the troubled node, however, we are still in the development phase to solve the network troubles that can be done by Tensai Gothalo.

5. Future Works

There are some important features associated with the Raspberry Pi that can be integrated in our robotics vehicle, which can be implemented and improved in future. Firstly, for example, to operate high voltage motor, a suitable circuit and the program that can accurately read the voltage values should possibly require to switch off mosfet and transistor in case of high currents. This functionality will ensure the security of the devices. Secondly, as stated in our previous research, we have not integrated our hardware with Zigbee device. In our future work, we would like to integrate Raspberry Pi hardware with Zigbee device so that we can utilize our robotics vehicle to monitor the sensor networks. Thirdly, at this time we are relying upon sensor device in order to follow the path and reach to our target. In the future, we will implement target identifying module that can independently work without relying with the IR sensor devices. Furthermore, we would like to implement power aware routing mechanism [21], [22], [23] between the nodes of Tensai Gothalo. Similarly, we would like to test several nodes of Tensai Gothalo as a part of sensor networks thereby providing redundant network [23], [24], [25] for emergent situation. In our future work, we would like to integrate advanced features so that Tensai Gothalo can be deployed during disaster recovery [26], [27] and disaster management [28], [29] tasks too. The Raspberry Pi, providing newer and faster hardware that offers greater possibility of implementing the advanced functionalities of network monitoring and management.

6. Conclusion

In this paper, a network monitoring robotics vehicle equipped with micro-controller and raspberry pi OS has been architected and experimented. The major contributions of this paper are that we have started the new concept of introducing robotics vehicle to monitor and trouble shoots the network problems. Thought our initial efforts mainly has been focused in designing the vehicle and necessary electronic circuits, our future efforts will be employed into advanced network monitoring features. As far as we are successful to integrate the hardware of Rashpberry Pi with our micro-controller, we are able to mobilize our vehicle as per our instruction and direct it to the troubled server room. This will obviously reduce the administration time of administrator. We are also able to integrate Raspberry Pi OS and integrated this OS with our microcontroller in a layer based manner such that our low level instruction will be controlled by the microcontroller whereas high level monitoring functionalities cane be executed in raspberry pi system. The successful application of the master–slave scheme on an experimental set-up with sensor equipped devices can deal the troubled network more accurately in the future.

7. Acknowledgement

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