Portable Tensai Gothalo: Leveraging Network Availability, Survivability, and Manageability Through Movable Redundant Device

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This paper introduces a novel approach of managing disaster survival network through deployment of Tensai Gothalo, a master-slave architecture for network monitoring, management and automation. Technology like Tensai-Gothalo is a mechanism that enhances the automation, monitoring and management process of network without compromising the existing architecture which is able to execute prescribed device and functions ensuring scalability of the network to meet changing demand. It also investigates the fault node in the network and start recovery process of the fault node on the basis of Master-Slave monitoring architecture thereby providing survivability, high availability and manageability. Furthermore, we have expanded our previous architecture by adding HA cluster so that Tensai Gothalo can act as proxy server while needed.

1. Introduction

Tensai Gothalo [1] is a network device that can participate in the network as a movable router device. This device is equipped with movable unit supported by DC motors along with controlling circuit attached with the device. A path tracing module has been implemented in order to lead the device to the place of troubled node in a network. While it finds the trouble node, it will attempt to trouble shoot the node and try to recover the failed network. However, while it cannot recover trouble node, it will act as a proxy node which can deliver the network services during trouble time thereby providing the internet services to the users. We designed a path and tested the movability on which Tensai Gothalo operates and traces over it in order to identify the troubled node. Initially our research have begun by simply designing black topped path that can be sensed by IR sensor; though it can varies from as simple as black line on the floor to as complex as embedded lines, magnetic lines or others. In order to detect or trace the path, different kind of navigation schemes or vision schemes can be employed. These navigation schemes may vary from as simple and cheap as IR sensors circuits to as complex and expensive as vision circuits [2]. Though the decision of which kind of path tracing schemes is to be employed depends on the various factors such as requirements of users, cost, localities, we have employed IR sensors circuits to detect the path as this can be developed in a low budget. Applying simple and cheap technology has good advantage for the areas where rails or conveyor belts are not possible to be created. A simple black path can be traced by using simple IR sensors however when it leaves the path accidently than it is difficult for the device to get back to the track.

Our previous researches have already finished the development of movable module. We further enhance Tensai Gothalo by extending its architecture with highly available cluster (HA cluster) supported by portability feature. In this paper we will focus on design and development of HA cluster highlighting its feature of portability.

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2. Problem Identification

Many a times, a large enterprises requires a highly available, survivable and secure network infrastructure in order to support their day to day business. In order to meet their business demand, a highly available network is necessary to design and implement. Most of the time, this requirement is fulfilled by providing hierarchical approach leveraging a high-speed routed core network layer to which are attached multiple independent distribution blocks. This architecture may work however due to lack of consideration in portability feature into their design and implementation, problem may arises while the networks need to be physically migrate from one place to another. Similarly, a network may not be re-usable while it has been damaged by natural disaster. We agree that network availability, survivability and manageability can be achieved by applying traditional approach however they are lacking the portability of the system which requires a new approach of architecture implemented in a comprehensive strategy. Previous studies and implementation have paid little attention to portability of artifacts other than the main module of hardware or software. For example there is no generally-accepted portability metrics to measure the entire system both the hardware and software. In this study, we apply portability measure that can enhance QoS of the entire system.

3. Design Requirement of Portable Tensai Gothalo

One of the major goals of Tensai Gothalo is to develop movable and portable network device that can deliver routing services. Besides, doing routing service, it aims to deliver other sercvices such as monitoring and the management of the network along with cluster nodes that it can carry over while required. Furthermore, this device aims to serve network services during disaster situation and also in the remote areas where the network administrator are not available. Thus, it has multiple objectives. We witnessed that during a disaster, network devices are prone to damage and we need backup portable devices that can operate in a dynamic way.

Portability in terms of routing is the ability of serving network with the capability of movement from one place to another. However, portable also should not ignore the feature of likelihood of carrying devices by human or any other machine. This factor is very important as we cannot carry heavy equipment effectively in the disastrous environment.

In the past it was not considered to deliver such kind of router or network device as there was never a requirement for the system to operate dynamically, but it is required to provide a network during the disaster as the main route of the network is not workable during disastrous situation. In some cases, such as in tunnel construction, some scenarios necessitated a communications range which can varies as the length of tunnel can increased during construction.

The other design requirement is to provide highly available network. In our previous research, we were able to develop portable device but availability was not properly considered. Problem might arises while the service of Tensai Gothalo might interrupted or the device of Tensai Gothalo goes down. In order to address this kind of situation, redundant node should be considered. We assume that by adding redundant node, we can increase availability and survivability..

4. Portability in Tensai Gothalo

This research proposes an architecture for incorporating portability considerations into the hardware implementation process. Maximizing portability, nonetheless is a demanding process which requires phase wise evaluation of each cycle of hardware implementation. Furthermore, our architecture demands further enhancement of portability into the software implementation lifecycle also. In this particular research, we identify certain issues and propose development guideline in order to increase portability.

Tensai Gothalo is equipped with moving module so that it can enhanced its portability. Portability can be enhanced by providing movable and flying capacity in the device. We have paid sufficient attention to increase portability of Tensai Gothalo than our previous versions.

In order to evaluate portability properly, we need to apply a certain kind of metric. We applied a standard method studied by [4] in our design implementation. We utilize hardware unit to indicate our hardware module that participate in our entire system. Thus, we define a network system implementation process is a combined implementation process of hardware and software units. In this paper we use the term Tensai Gothalo having both of these units.

4.1 How to achieve portability

While the system achieve mobility, modularity or replaceability, compatibility, cost effectiveness, extensibility and adaptability, we value the system as portable. The narrow concept of portability in hardware may refer to the feature of handiness and compactness. Generally, we say a device is portable while it is carried able, however, this line of thought has narrow meaning. In our design principle, we employ the concept of degree of portability measure by applying the following portability metrics introduced by [4] with further clarification.

DoPM=1-(cost to port/cost to redevelop)

The system is portable if the value of the above equation is more than 0. First of all, let's clarify the meaning of cost here. The cost means the total value of portability parameters. Portability parameters are mobility, modularity, compatibility, extensibility and adaptability. If all of these parameters are addressed, we assign 0 and only count the cost to port. If any of these parameters are not addressed properly, that means there is some cost of port which will be divided by the cost of redevelopment and the output is calculated for the value of degree of portability metrics (DoPM). Theoretically, the value of portability will be 1 when there is perfect portability, however, such a situation can hardly be achieved.

5. Redundancy and HA Cluster

5.1 Overview of HA Cluster

As per our portability principle, we need to develop the hardware module in modular basis. Considering modularity and portability, we have developed HA (Highly Available) cluster module. Figure 1 shows the general conceptual architecture of HA cluster to be implemented in Tensai Gothalo. In this architecture, we have setup 6 nodes. Each node is consisted of Raspberry Pi with Debian Wheezy. A summarized specification is provided in table 1. Among six nodes, two of them are proxy servers which balance the load between the servers. Our design principle indicates that in order to increase portability, we have to include physical mobility in the device also. This feature has been accomplished in our previous studies [1],[2],[3]. In our previous research, we have implemented the movable feature in our device. In order to test this feature, we did number of demonstrations which can be seen in figure 2 annotation 1. In this research, we further extend our functionality and thus added the feature of availability of servers. In order to achieve this quality of high availability, we decoupled the architecture and design HA cluster

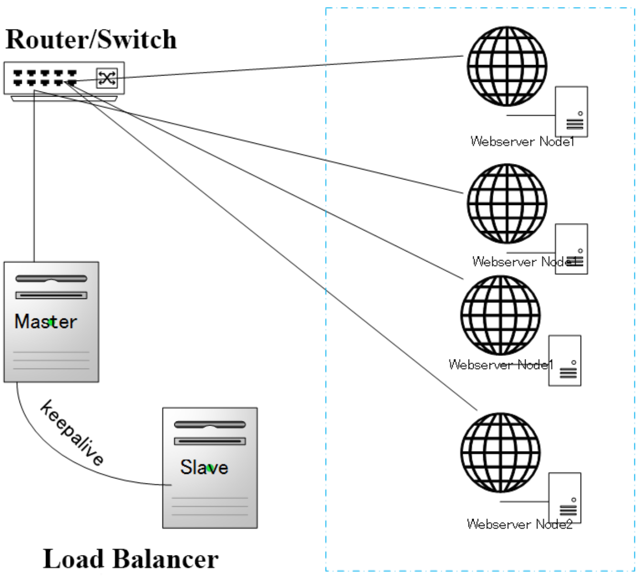

Figure 1: Topology of HA Cluster

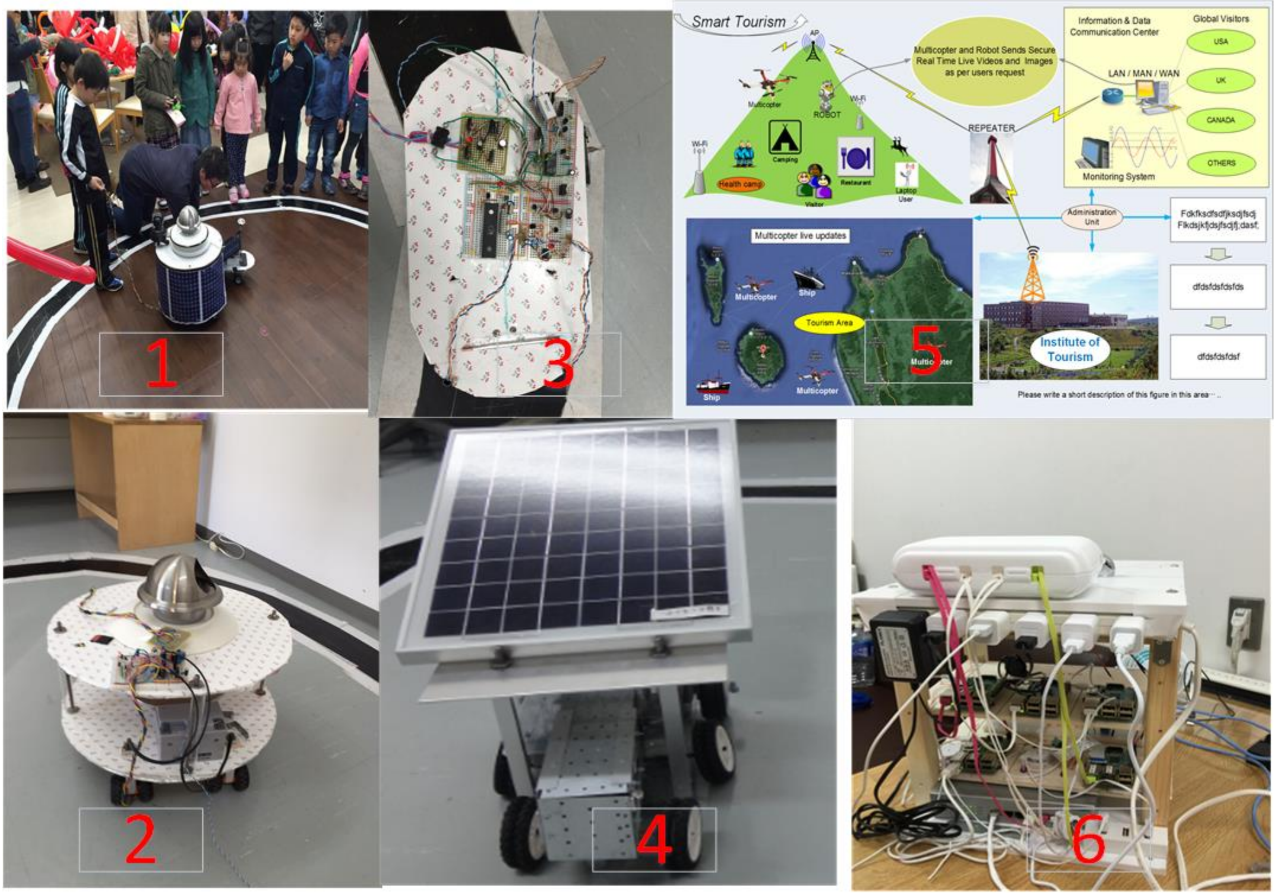

Figure 2: Concept and Experimented Scenario

separately. Our description about hardware architecture will focus only with this pluggable portion. Furthermore, let us describe about the annotation in figure 2 more properly. Annotation 1 indicates the demonstration of movable Tensai Gothalo the testing of movability was done during the spcial event of Wakkanai city. Annotation 2 and annotation 4 are the nodes of master Tensai Gothalo. These master nodes have higher computing capacity that can observe entire network. While network gets trouble (for example in the network of annotation 5), it will inform the slave Tensai Gothalo which will proceed to the troubled node and try to solve the problem. Annotation 3 indicates the slave Tensai Gothalo which can proceed along the path. Furthermore, annotation 5 shows the potential network environment at which Tansai Gothalo can operate in the future.

For the experiment, we have installed web and ssh servers and the experiment has been done. Testing was performed by sending multiple requests to the web servers. Details of testing is discussed in section 6.1

6. System Development Process and Evaluation

On the basis of our design principle, we require to implement HA cluster. As shown in figure 1, this cluster has 7 nodes. There is a root node from which all other 6 nodes are connected. This node is also resided inside the cluster delivering connectivity to the entire nodes. Among these, two of which are ported with master slave architecture. Master and slave nodes are necessary to acknowledge each other by sending keep alive message. In real scenario, Master Tensai Gothalo will carry this node and the slave Tensai Gothalo will carry the slave node.

Our aim of designing HA cluster in this research is to increase availability of network and other services even in the disaster situation. Various researches [5],[6],[7],[8] show that network connections, disruptions and base station blackouts occurred in the previous natural disastrous. The authors well witnessed that about “great east Japan earthquake” on March11, 2011 in which

Table 1: Experimental Setup

Particulars	Details/Quantity	Remarks
Virtual Interface		10.X.X.251
Operating System	Raspbian	Model B+
Master Load Balancer	1	Eth0: 10.X.X.250
Slave Load Balancer	1	Eth0: 10.X.X.249
Server Nodes	4	10.X.X.248 10.X.X.247 10.X.X.246 10.X.X.245
CPU Model	Hardware: BCM2708	ARMv6-compatible processor rev 7 (v6l)

Table 2: Load Testing and Benchmarking

Number of Users	Transactions	Availability	Elapsed time	Data Transferred	Response Time	Transaction Rate	Throughput	Concurrency	Failure Transaction
10	8806	100%	59.71s	1.23MB	0.05s	147.48t/s	0.02MB/s	6.95	0
20	8331	100%	59.26s	1.16MB	0.08s	140.58t/s	0.02MB/s	11.25	0
30	9316	100%	59.29s	1.30MB	0.19s	157.13t/s	0.02MB/s	29.73	0
40	9452	100%	59.90s	1.32MB	0.25s	157.8t/s	0.02MB/s	39.55	0
50	9222	100%	59.21s	1.28MB	0.32s	155.75t/s	0.02MB/s	49.28	0
60	9253	100%	59.65s	1.29MB	0.38s	155.12t/s	0.02MB/s	58.93	0
90	9200	100%	60.08s	1.28MB	0.57s	153.13t/s	0.02MB/s	87.28	0
120	9118	100%	60.01s	1.27MB	0.75s	151.94t/s	0.02MB/s	114.31	0
150	9028	100%	60.36s	1.26MB	0.93s	149.57t/s	0.02MB/s	139.00	0
180	8399	99.98%	60.02s	1.17MB	1.13s	139.94t/s	0.02MB/s	158.32	6
210	8824	99.95%	60.34s	1.23MB	1.17s	146.24t/s	0.02MB/s	171.21	4
240	8510	99.93%	59.96s	1.18MB	1.32s	141.93t/s	0.02MB/s	186.96	6
270	8252	99.77%	59.90s	1.15MB	1.39s	137.76t/s	0.02MB/s	192.17	19
300	8239	90.90%	60.33s	1.15MB	1.39s	136.57t/s	0.02MB	189.62	8

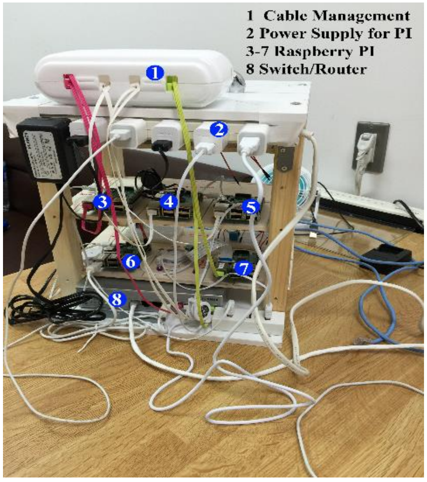

Figure 3: Prototype Implementation of HA cluster

a lot of information and communications technology (ICT) were disrupted. Suggino [7] presented the summary of the damages of the great east Japan earthquake and tsunami in March 2011. The damages to the telecommunication network in terms of service disruption, network traffic congestion, and base station blackouts were discussed in his paper [7].

Further elaboration can be found in the paper [8]. This revealed that 1.9 million fixed telephone lines and 29 thousand cellular base stations had been damaged. High availability in the past has been addressed just by providing only a redundant node without considering portability in the architecture [8]. These nodes were provided either in active/passive or active/active mode without considering the factor of portability.

This research proposes that in order to build high availability infrastructure, we can employ a better approach to support and promote greater system adaptability and flexibility.

The reason network infrastructure in the past has been so inflexible is largely due to limitations of physical portability.

We generated varieties of packets and send the packets in different times and situation. In our architecture, we build upon the entire system in modular design basis. Our movable parts are already implemented during our previous researches [1], [2], [3]. So, we do not go into details of our movable portion. Rather we would like to describe our system of HA cluster. Table 1 shows IP planning of this cluster. There are 2 nodes which are built upon master slave architecture. Master node will be carried out by our Master Tensai Gothalo and the Slave node will be carried out by our slave Tensai Gothalo. These two nodes are configured with HA (High Available) proxy. The objective of desiging HA cluster in this research is to test Tensai Gothalo whether it can provide services while the primary data center is unable to provide services. In such a case, Tensai Gothalo has just a few options. Either it should be able to troubleshoot the server and recover the service in a short downtime period or delivers the services by itself thereby providing service availability. Priority is given whether the HA cluster will fulfill the service demand considering outage of service in primary data center. Performance of the cluster has been tested by measuring different types of parameters which are shown in the table 2 and the discussion is given in the next section.

6.1 Load testing and benchmarking

Load testing was carried out in order to measure the performance of HA cluster at any load level by simply increasing the number of requests until the desired load is achieved. We setup a simple web page having an index file and would like to test the cluster whether it can handle the multiple requests at the same time. Sending large number of requests to the servers would require proper way of methodology. our testing by using 10 concurrent users and increases 10 users per test. As data shows we have gain 100% availability till the numbers of users are 150. However, as we increased users with additional 30 users, availability has been decreased to 99.98%. We continued our portability increases high availability by sensing network problem in the infrastructure thereby providing redundant node dynamically.

7. Results and Discussion

7.1 Availability Analysis

Table 2 shows the results of load testing and benchmarking of our HA cluster. We aimed to increase availability, serviceability and manageability by using redundant device. This redundant device referes to Tensai Gothalo. Many previous researches have emphasizes in redundancy and most of the practices have been involved with layered based redundancy. However, they lacked mobility and portability which can be expected from this research. Our prototyped HA cluster has produced high availability upto 150 concurrent users. We have not observed any failure in transaction until this level of concurrent users. Services have not been interrupted till we increase the number of concurrent users upto 300. However, the level of availability sharply decreased to 80%. We believe that availability could be increased more once we increase the number of nodes in the cluster. It can also be observed that when the response time crossed 1 second, after having 180 concurrent users, the percentage of availability is decreased.

7.2 Survivability Analysis

The term network survivability has been utilized since a long time ago. It has been studied and well defined as "the capability of a system to fulfill its mission in a timely manner, in the presence of attacks, failures, or accidents" [9]. It is also a capability to offer the service during the nodes failure. While one of our redundant node is offline, does our another node still can provide the service? We have tested that feature too. We got continuous connectivity during our entire experiment. This indicates that while any of the master and slave node of this cluster is offline, the other redundant node will continue offer the service.

However, we agree that survivability may suffer while installing the current prototype in the harsh geographical region. In order to increase the survivability, we need to secure the device by providing secure covering box to the cluster in order to protect it from harsh surrounding environment.

8. Future Work

We have started a consideration of portability not only in the process of software implementation but also in hardware implementation, however the complete implementation has not been achieved. Nonetheless, the concept of the portability has been considered and , a much expanded design based work has been started and HA cluster has been integrated in the lab. A prototype has been designed and the experiments were conducted to test the robustness of the implementations Research into capabilities of embedded systems and how they can be leveraged for the hardware architecture has also been accomplished. Since, portability is a concept that needs careful and phase wise implementation, it requires standard methodology and documentation in order to face with potential problems during its future implementation.

Our future works will emphasize to employ and document more concrete steps so that the more abstract portions of the design should be detailed and tested. For example, the complex design and integration between microcontroller and other OS should be formalized, detailed and tested. Furthermore, we would like to extend the survivability of networks during disaster by providing alternative energy or power backup. Survivability suffers critically in terms of power backup during disastrous situation. Similarly, manageability of the network will increase by integrating the management operation by Tensai Gothalo and other software tools. An intensive study will be done to enhance manageability of the networks too.

9. Conclusion

In this research, we designed the prototype and touched relatively broad concept of portability, high availability, survivability and manageability focusing mostly in hardware architecture which will guide further specifications and implementation in a relatively low cost. However, this is not the complete scenario of the discussion. We have initiated enough discussion into this areas in terms of portability so that the future research will bring deeper and standard concept into this area of computing. While most of the researchers are not focusing employing movable module for the network infrastructure, we have added enough light into this architecture. As per our architecture, we believe that movable mechanism is not a difficult portion of the implementation, the importance of this architecture requires that it should be considered deliberately.

Our study has crucial academic values also. For example due to the higher cost of network infrastructure, most of the academic intuitions are reluctant to allow their students to work with the hardware of the lab. This trend poses a challenge to the researcher which have to adjust their curriculum to fit with new challenges of computer science. Furthermore, instructors in the colleges or Universities need to abandon the lower level contents from their curricula in order to make the contents digestible to the students. This trend will definitely lead to a great loss in terms of hardware knowledge in the field of computer science. As an academicians and researcher, we must combat such situation by introducing relatively low cost infrastructure which has been possible by using raspberry pi as our core computing resource.

To conclude, this paper incorporate the issues of portability that should be considered as one of the principal activity of system implementation process in Tesnsai Gothalo. This study shows the guideline of portability implementation in Tensai Gothalo, however, this guideline can be taken into consideration for any other system implantation. The key point is to incorporate portability both in the hardware and software in order to maximize its effectiveness. We know that portability has been the subject of software development process however it has considered mostly in terms of handiness or compactness in hardware sector. To this fact, this paper has reviewed portability issues and shed light in the concept of portability which should also cover the mobility of the system and also incorporate portability metrics. These concepts will collectively enhance manageability, survivability and availability of network.

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