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A Network Troubleshooting System Using Augmented Reality Technology

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We envision that in the future, the users will be more involved in the management aspect of the network. This is due to the users are becoming more dependent on the network either for personal or business matters. However network management is a complicated task and still a closed domain affair by the network service providers. In this paper, we propose TIARA, a network troubleshooting system that utilizes the Augmented Reality technology. TIARA allows user to perform network troubleshooting seamlessly by using visualization of management information of network devices. TIARA architecture reduces the technology gap between the users and the complexity of network management. We measure the performance of TIARA and the results show that TIARA performs reasonably well in terms of the time taken to visualize the information.

1. Introduction

One of the most important and most common tasks in network management is to troubleshoot network problems. In order to diagnose the root cause of the problems, there are many steps to be taken and they can be time consuming. It is not easy to troubleshoot network problems due to many reasons; the problems can be intermittent, originated from outside network domain and due to software bugs. In addition, network troubleshooting is a closed domain affair. Only qualified technical staff of the network service providers are given this responsibility.

However, we envision that this scenario is to be changed in the future. Since the users are becoming more dependable on the network for their personal and business purposes, the users' stakes in the network are increasing. The users would like to be more involved in the process of ensuring that the network is available at all times. They may want to know how the network is operated and managed in order to take proactive action that can either prevent network problem from occurring, assist network service providers in finding solutions, or even solve the problems on their own.

This scenario can be realized with the advent of Augmented Reality (AR) technology. AR is a method of using computer-generated images to visualize important information onto the real-world environment, in an interactive manner. Though AR is mainly used in the entertainment applications (such as computer games), adapting AR into network management could yield tremendous benefits especially in the area of network troubleshooting. However, a proper framework and architecture are necessary before AR benefits can be harvested. Moreover, the organization of responsibility between network service providers and the users should also be clearly defined.

In this paper we propose TIARA (Tracking Information using Augmented Reality), a system to troubleshoot network problems using AR technology. Though we anticipate that TIARA is more appealing to the common users, using TIARA by the network service providers may value-add their existing troubleshooting procedure. Thus, this paper is organized as follows; Section 2 highlights some related work; Section 3 describes the design of TIARA; Section 4 is about performance evaluation; Future works are outlined in Section 5 and this paper is concluded in Section 6.

2. Related Work

Existing related research works can be divided into two categories; solutions for effective network troubleshooting and utilizing AR in various aspects of life.

In the area of effective network troubleshoot (or similar to network diagnose and fault management), Kandula et al [1] had stressed that in order to diagnose network problem accurately, it is important for the diagnostic system to also analyze application-specific faults (i.e. error codes) in addition to analyzing generic faults (typically performance related). Mahimkar et al [2] had proposed NICE (Network-wide Information Correlation and Exploration) infrastructure that analyze statistical correlations across multiple data sources in troubleshooting chronic network conditions. In addition, Ballani et al [3] had proposed an architecture for fault management using the CONMan (Complexity

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Oblivious Network Management) abstraction. These researches however mainly aim at network service providers and still rely on traditional management tools.

In relation to researches to AR, 'uMegane' [4] is one of the most interesting projects that leverages AR to visualize a context by using illumination icon and colors. Liarokapis et al [5] uses AR to present geographical information in both indoor and outdoor environments. Midieum et al [6] applies AR in an interactive storyboard authoring tool. Nevertheless, these researches are not suitable for troubleshooting network problem since their main focus are mainly on visualization of information in various applications.

3. Design & Implementations of TIARA

3.1 Design requirements

There are a few requirements that are important to be considered when adapting AR technology into a new network management tool.

(1) **Flexible visualization of objects**

The key feature of an AR technology is using computer graphics to visualize relevant information to the users. TIARA should have the flexibility to visualize various types of information in various formats (such as charts and texts). In addition, to make it more appealing to the users, the colors and fonts can be customized according to the users' preferences.

(2) **Simple descriptions of visualization objects**

TIARA should have an easy method to describe the visualization objects. Since there can be a huge number of network entities, it should also be easily readable and scalable.

(3) **Accommodate heterogeneity of protocols**

As the network may contain different type of network devices (such as routers, switches, wireless sensors etc), there can be various management protocols (SNMP, NETCONF, Wireless Sensor Network) used in the network. Therefore it is crucial for TIARA to be able to accommodate all types of protocols in order for the user to use TIARA in a seamless manner.

(4) **Seamless troubleshooting capability**

Since the main objective of using TIARA is to troubleshoot network problems, this capability should be embedded as part of its integral design. The users should not be burdened with additional settings in order to implement comprehensive troubleshooting process.

3.2 Implementations of TIARA

To implement TIARA, we need to understand at what scope TIARA is used, what suitable architecture it should be and what management functions that need to be clearly defined.

(1) **Scope of TIARA troubleshooting capability**

In troubleshooting network problems, TIARA is mainly aimed at investigating layer 1 and layer 2 of the TCP/IP model (i.e. Link layer and Internet layer). At the moment, TIARA has limited capability of troubleshooting at the higher layers. In addition, TIARA is used to visualize the management information of network devices where, in most cases, these network devices are belonged to the network service providers that are deployed at the users' premises. As such, the users are only authorized to view the management information. Changes to the configuration of network devices are only permissible to the network service providers.

(2) **TIARA architecture**

TIARA consists of three main components as shown in Fig. 1. Besides these components, all network devices are tagged with the 2D marker that is unique from one device to the other. There are two types of 2D marker used; the main marker (to display general information) and the function marker (that has its associated troubleshoot function such as 'ping').

Client agent. This component resides with the user (such as in the user's Laptop/PC). It requires an image input device (typically a web camera) in order to view the management configuration of a particular network device. Once it views a 2D marker attached to the network device, it recognizes the code and it will then communicate with the TIARA Server component (described later) to obtain the real-time information about the device. It will then visualize the information on the users' screen using a drawing module on top of the 2D marker. An example of information visualization is as shown in Fig. 2.

TIARA Server. This component resides with the network service provider. It receives request from the Client Agent for information on specific device, collects the information using variety of tools and protocols, and returns the data. It hides

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the complexity of protocol-specific commands to the user by having a single HTTP interface to the user.

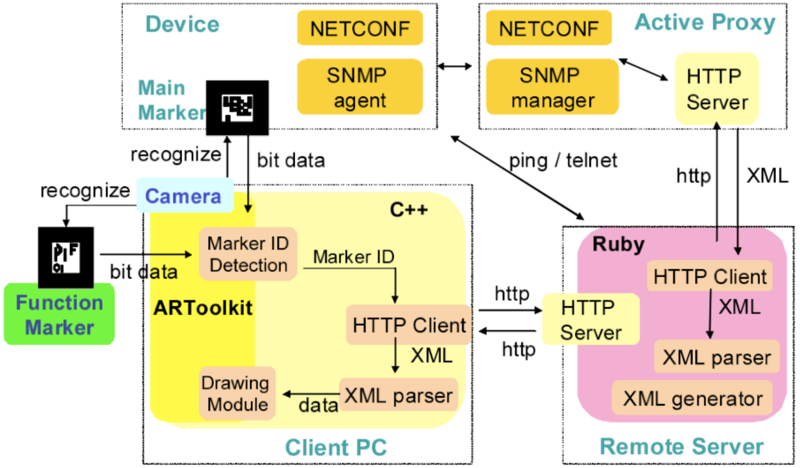

Fig. 1 TIARA architecture that contains 3 main components: Client, Server and Active Proxy

Active Proxy. This component also resides with the network service provider that acts as the intermediary between the TIARA server and the network devices. The active proxy translates HTTP requests from the server into appropriate management protocols (typically SNMP) in order to obtain management information of network devices. However, when TIARA server executes Telnet or ping, the active proxy is bypassed.

(3) TIARA management functions

Once the components of TIARA are developed, it is necessary to define the management functions for a structured implementation of TIARA to the users and the network service providers. These management functions are as described in detail in Table 1.

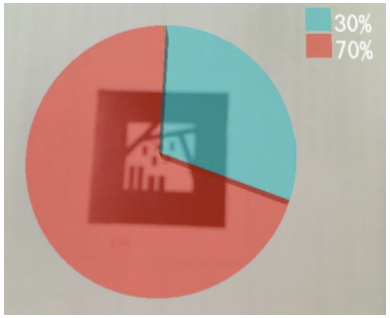

Fig. 2 Example of visualization of management information on top of the 2D marker. Here, 30% and 70% normally represents the battery life of a wireless sensor.

Table 1 Management functions in TIARA

Management functions	Descriptions	Network service provider's responsibility	User's responsibility
2D marker creation and registration, network device registration	This function is to allow TIARA to monitor new network devices where new 2D marker is required to be associated with each device.	To inform the user about new devices are added into the network and provide the user with its associate 2D marker.	To attach the new 2D marker to the network device.
Dynamic description of network topology	To be used in TIARA when the network topology changes. At the moment, TIARA is using a static description of network topology.	To update the descriptions when topology changes.	None.

3.3 Example of troubleshooting scenario

In order to comprehend the process to troubleshoot network problem using TIARA, Fig. 3 depicts a scenario where a user faces a typical and simple network problem.

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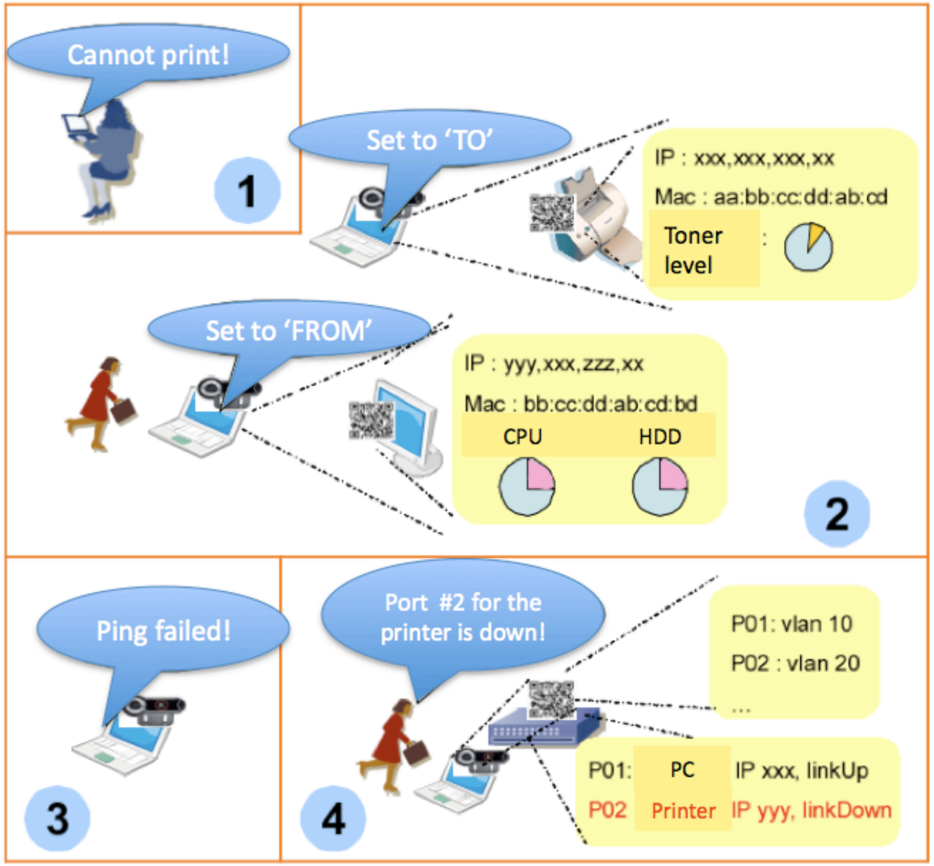

Fig. 3 An example of a scenario of which TIARA is used to troubleshoot printing problem

At stage 1, the user detects that she has a problem to print. Then, at stage 2, using TIARA, the user selects the computer as 'FROM' and the printer as 'TO' (while doing so, she can views some management information pertaining to the computer and the printer). Next, at stage 3, TIARA shows that the ping command has failed for 'FROM' to 'TO' devices (i.e. ping from the computer to the printer). Finally, the user detects the cause of the problem at stage 4 by monitoring the status of ports at the switch which connects both the computer and the printer. In this scenario, the port connecting to the printer is 'down' causing the printing problem. Thus, she can immediately relay this status to the network service provider (or her network admin) for corrective action to be taken on the related problem.

4. TIARA Performance Evaluation

We conduct some experiments in order to evaluate the performance of TIARA.

4.1 Configuration settings

Table 2 provides the list of the resources used in our experiment.

Table 2 Resources used in the experiment

Components	TIARA server	User's client	Active proxy
Processor	Intel(R) Core(TM)2 Duo CPU T7300 (2.00GHz)	Intel(R) Core(TM)2 Duo CPU L9400 (1.86GHz)	Intel(R) Pentium(R) 4 CPU (2.80GHz)
OS	Ubuntu 8.10	Ubuntu 8.10	Ubuntu 8.04 (VMware server)
Memory	2048MB	3070MB	1024MB

4.2 Experiment methodology

We conduct two different types of experiments.

(1) Time taken for information visualization

Using the webcam at a distance of 18cm from the 2D marker (as depicted in Fig. 4), we measure the time taken for TIARA to visualize the information. We varies two parameters; the number of object for visualization (from 1 to 22) and type of display (either in plain text or with specific texture).

(2) Time taken for executing protocol-specific commands

We measure the time for TIARA to conduct a few protocol-specific commands in

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order to obtain management information from network devices. Here, we limit to some simple commands related to NETCONF and SNMP.

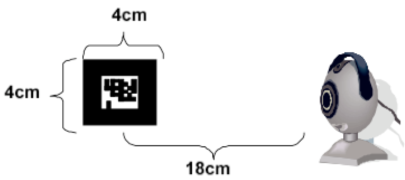

Fig. 4 Experiment setting used of which the webcam is located at 18cm from the 2D marker

4.3 Performance Results

Table 3 and Table 4 list the result for experiment (1), without and with texture respectively, and Table 5 and Fig. 5 show the results for experiment (2).

Table 3 Time taken for information visualization (without texture)

No. of objects	1	4	7	10	13	16	19	22
Filesize (byte)	403	1375	2350	3326	4304	5285	6266	7247
Avg. time taken (sec)	0.008	0.015	0.025	0.029	0.035	0.040	0.041	0.044
Variance	2.29E-05	4.96E-05	1.24E-04	9.53E-05	1.74E-04	1.34E-04	1.31E-04	1.95E-04

From Table 3 and Table 4, the time to visualize is small irrespective of using texture as its output. However, the time is slightly increased as the number of objects to be visualized increases, but still less than 0.1 seconds (which is a small amount of time).

Based on Table 5 and Fig. 5, though NETCONF requires the most time to be executed, it provides rich information about configuration settings on network devices. For executing commands related to SNMP, the time taken ranges from 1.61 seconds to 5.15 seconds. Though these times may be slightly larger as compared to executing them via a typical management console, TIARA has trade-offs in terms of simplicity and convenience.

Table 4 Time taken for information visualization (with texture)

No. of objects	1	4	7	10	13	16
Filesize (byte)	520	1843	3169	4496	5825	7157
Avg. time taken (sec)	0.009	0.020	0.023	0.031	0.038	0.041
Variance	3.76E-05	8.92E-05	9.38E-04	3.87E-04	1.55E-04	2.75E-04

Table 5 Time taken for executing protocol-specific commands

Type of marker	Marker functions	Protocol	Related OID / NETCONF commands	OID / NETCONF information	Time taken (sec)	Marker processing time (sec)
Function	VLAN setting	NETCONF	IVlan getConfig()	VLAN information	10.16	9.98
Function	ARP table	SNMP walk	1.3.6.1.2.1.4.22.1.2	ARP table	2.04	1.86
Function	Display port info	SNMP walk	1.3.6.1.2.1.2.2.1.8	Link up/down	3.36	3.18
Main	Switch	SNMP get	1.3.6.1.2.1.1.3.0	System uptime	1.61	1.34
Main	PC	SNMP get	1.3.6.1.2.1.25.3.3.1.2, 1.3.6.1.2.1.25.2.3.1.5.1, 1.3.6.1.2.1.25.2.3.1.6.1	CPU usage Total HDD Free HDD	5.14	4.82

5. Future works

While TIARA shows promise to be adapted in the real world, it is still at an early

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stage. There are a few features that are important to be embedded in TIARA. As a starting point, though TIARA has limited capability for troubleshooting the application layer, TIARA should also be able to troubleshoot at the transport layer and increase its capability to diagnose in more detail at the application layer. This shall allow TIARA to troubleshoot more complex network problems effectively as proposed in [1]. In addition, TIARA should also be able to allow dynamic configuration of network topology and its associated troubleshooting process flow. This enables TIARA to be used in variety of network sizes that include enterprise networks.

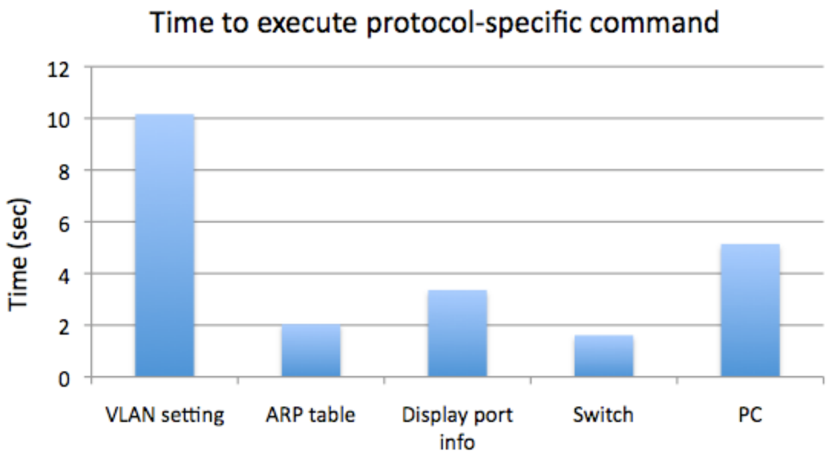

Fig. 6 Performance results for executing protocol-specific commands

6. Conclusion

In this paper we propose TIARA, a system that based on Augmented Reality (AR) technology, which acts as a new tool in network management. TIARA eases the troubleshooting process of network problems through visualization of management information and executing protocol-specific commands in order to diagnose the network conditions. Since we anticipate that, in the future, the users will be more involved in the management aspect of the network, TIARA will be one of the key management tools to the users. Finally, we demonstrated how TIARA is useful in troubleshooting a simple network problem.

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