Comparing Immersive and Non-Immersive Virtual Reality User Interfaces for Management of Telecommunication Networks

Mohsen Kahani, H. W. Peter Beadle

Department of Electrical and Computer Engineering, University of Wollongong
Northfield Avenue, Wollongong, NSW 2522, Australia
Phone: +61-42-21-3065, FAX: +61-42-21-3236
E-mail: moka@elec.uow.edu.au, beadle@elec.uow.edu.au

Abstract

Networks are becoming increasingly complex as a result of new technologies in hardware and software. Consequently, the traditional WIMP-based user interfaces are no longer suitable for management of large and high-speed broadband networks. In this paper we introduce two kinds of three-dimensional user interfaces: an immersive virtual reality user interface and a WWW-based flat screen 3D collaborative user interface. A comparison of the approaches is also made to show the merits and pitfalls of each.

1. INTRODUCTION

The Broadband Integrated Services Digital Network (B-ISDN) based on Asynchronous Transfer Mode (ATM) technology introduces bandwidth capabilities that allow the emergence of sophisticated multimedia applications. ATM networks include the concept of logical connectivity and virtual private network (VPN) [1]. A virtual private network is a set of network resources, such as user-network interfaces (UNIs), and (semi) permanent virtual connections (VPC) that link the different sites of a customer together. This logical connectivity, although providing higher management flexibility than physical connectivity, increases the complexity of network management task.

The virtual private network concept also implies that there are some dependencies between operation of different networks, because they may share the same physical link. Consequently, some kind of collaboration among network management systems of private networks and with that of the carrier is required to effectively manage the network in real time.

It is believed that the management of emerging networks requires greater visualisibility and interactivity than that provided by traditional user interfaces [2]. The manager in these environments has to deal with tens of thousands of virtual channels, and potentially hundreds of ATM switches [3].

To enhance the network management operating environment we have been investigating the use of Virtual Reality (VR) user interface technology for network management applications. In this paper, we introduce two kinds of 3D user interfaces. Firstly, we explain the design and implementation of an immersive virtual reality environment, consists of Head Mounted Display (HMD) and some 3D input devices [4]. Then, we discuss how the observation from this has led us to build a non-immersive, distributed, collaborative, 3D interface using WWW technologies, such as HTML, VRML (Virtual Reality Modeling Language) and Java [5].

Here, we initially introduce the architecture of both systems, followed by a qualitative comparison of merits and pitfalls of each. The conclusion discusses the lessons learned from these implementations.

2. IMMERSIVE VR USER INTERFACE

The architecture of the immersive VR system is illustrated in Figure 1. This system has the basic VR elements such as 3D image rendering and 3D navigation tools. It is coupled to an existing SNMP based network management system (Cabeltron SPECTRUM). Three kinds of information are retrieved from the network management system: network configuration, topology, and performance/fault data. The formers are nearly static and rarely need updating, but performance and fault data are quite dynamic, requiring a continuous update.
The network configuration and connectivity information are extracted, as network topology changes, from the NMS and a virtual network world database is constructed, automatically. This database is used by the VR system to build the virtual environment.

To provide a real-time user interface, performance and fault data must be collected directly from the NMS. This can be achieved by establishing a direct link between NMS and VR systems, in which the VR system sends its inquiries to the NMS to retrieve the required data. The VR system also sends the operator's manipulation of network elements the

NMS to be applied to their real counterparts. The physical interface between the systems is provided by the underlying network.

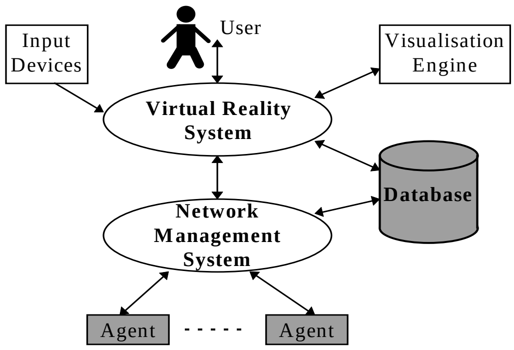

Figure 1- Immersive VR system architecture

After the construction of a virtual network world, the user can navigate it, by walking or flying around the network. The status of the icons in the world represents current network performance levels. For instance, the thickness of a link determines the amount of load being carried by the connection, its colour represents its operational status, and a disconnected link is represented by a broken line. Correlated alarm information could be presented using speech synthesis with clues to the location of the alarm provided by spatially locating the sounds in 3D. This is in contrast to topological maps and colour based roll-up procedures used in existing WIMP based systems.

Objects in the virtual world are active, so more information about their status can be obtained by walking into them for a detailed internal view. If the object is a link, walking into it will show the virtual paths within the link. If the object is a network element, walking in will show the interfaces contained in the element. If the object is a sub-network, walking in will show the layout and status of the sub-network elements. The walk in metaphor captures the hierarchically structure of the network and constrains the information presented on the screen to a comfortable level for network operators.

Navigation in the world is by using mouse, joystick, Logitech Cyberman 3D mouse or Data Gloves. Currently, we are examining how the operator can interact with the interface in a more natural way. For example, to grab a network element, for moving, disconnecting, etc..., the most natural way is to grab it with a virtual hand, using VR gloves.

The other important issue, is the representation of network element in the virtual world. Using special rendering techniques, such as texture mapping and smooth shading, the scene should be designed in such a way that it can immerse the operator, so that they can forget the interface, and act as though they are in the real world.

3. Observations From the Immersive VR User Interface

The prototype system is basic and does not incorporate texture mapping. It employs a head mounted 3D stereo display, and a Cyberman or joystick, as input device. Using this prototype system, the user can observe the hierarchy of the network and its spatial relationships. The network can freely and quickly be navigated to observe the primitive information for network elements such as faulty devices and overloaded links. We achieve this without becoming lost in a screen full of windows, the typical problem with existing WIMP based systems. A typical view of the prototype system is shown in Figure 2.

The main advantage of a VR user interface is its additional spatial dimensions, since the network's

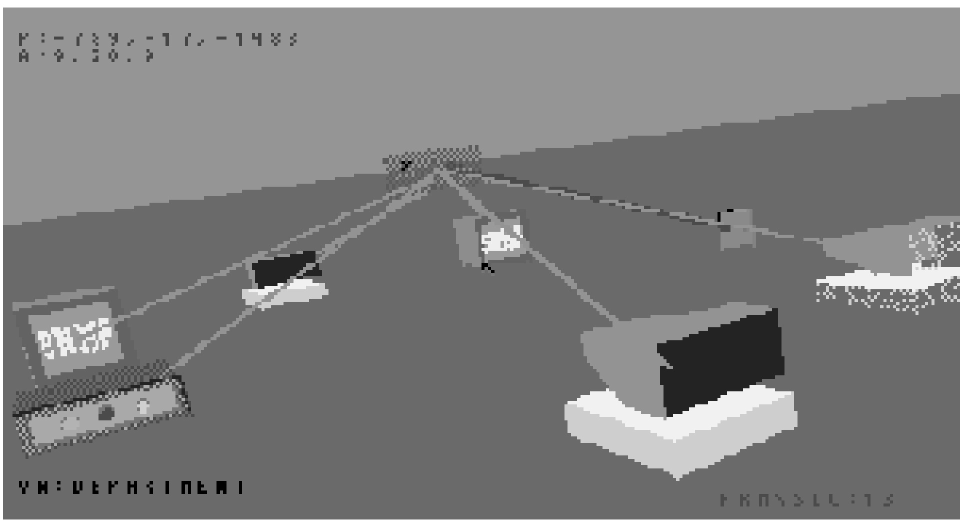

Figure 2- A view of immersive VR system

hierarchical properties become explicit [6]. A HMD while creating a more immersive environment, acts as an input device as well. By rotating the head, the user easily and quickly navigates into the system. A joystick or Cyberman gives more sense of moving in the virtual world than the traditional mouse. A virtual glove provides yet another powerful input device, which increases interactivity.

The other major advantage of VR user interfaces for network management is their short learning time. As user's interaction with the system is designed to be as natural as possible, there is not much need to teach operators how to use the system. That is, if operators learn the basic principles of the interface, they can easily and quickly decide, when facing with more complicated situations, how to do the task. For instance, there is no need to teach operators how to move an object, because everybody knows how to move objects with his hands. This is in contrast to WIMP user interface, in which all actions must be taught to the operator.

The other important factor is the user's cognitive load during operation. As in WIMP user interfaces, the interaction between user and computer is not natural, the user has not only to think about 'what to do', but also 'how to do' it. For instance, if the alarms associated with an object are needed, the object has to first be selected, by clicking the mouse button on it. Then, from a menu the appropriate action must be selected. This simple task seems quite easy and straight forward. However, working with many objects in a window and with several other windows in this manner, causes confusion, because of limitations of human short term memory. While in an immersive virtual reality user interface, these kinds of tasks could be done by using a speech based interface with speech and visual acknowledgment, reducing the operator's cognitive load.

Despite these advantages, the system has some drawbacks, as well. As network management is nearly a continuous task, which takes several hours a day, the use of HMD causes some problems. Even the best available HMDs cause dizziness and eye strain if worn for a long period. Also, as it obscures the user's view, it significantly reduces the interaction and communication of the user in the real world.

The other problem is textual information. Although, a VR user interface minimises the amount of textual data, by converting them to symbols in the virtual world, in a network management environment there is a significant amount of information that has to be presented to the operator as text. However, in a graphics-based user interface, proper provision of text is difficult. The situation is even worse when HMD is used.

Based on these and other limitations we decided to move toward a non-immersive approach, while maintaining the three-dimensional semantics of the view. Because of the need for a collaborative environment for effective management of forthcoming networks, a World Wide Web (WWW) based approach was chosen. The main reasons for this selection are that WWW browsers are reasonably uniform and ubiquitous, platform independent, and have low prices.

4. WWW-Based User Interface System Architecture

The system uses a client/server architecture based on Telecommunication Network Management model [7]. Each server host communicates with a network management system and uses its services to get the management information. This information is sent to the clients, which are WWW browsers enhanced with VRML, Java and JavaScript. Each VRML object can have a link to other views that may be within the domain of another network management system (NMS). This allows an integrated view of distributed networks in which each subnet is managed by an independent NMS. Moreover, managers can collaborate with each other, in real-time, to solve the problems that involve more than one domain.

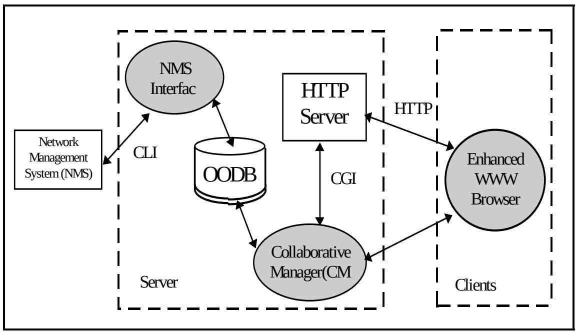

Figure 3-WWW-based system architecture.

Each server consists of four parts: NMS interface, Collaborative Manager (CM), object-oriented database (OODB), and HTTP server, as shown in Figure 3. The NMS interface communicates with network management system via its command line interface (CLI). NMS can be any system capable of gathering information from network elements (NEs), and again in our case is Cabeltron Spectrum. The interface queries the NMS to get management information about the status of NEs, and stores them in the OODB. It also gets update information from the database and sends them to the NMS.

The collaborative manager (CM) is the core of the system. It communicates with the clients directly, or via HTTP server, through a Common Gateway Interface (CGI) script. It also coordinates the collaboration between clients, by collecting the updating information from each client, broadcasting them to the other clients, and storing them in the OODB.

The scenario is as follows: The manager uses an enhanced WWW browser to connect to the HTTP server. After authentication, HTTP server asks the appropriate view from the CM via CGI protocol. The CM responds with the information in VRML format. The VRML script has several Java applets that firstly establish a TCP/IP connection between the client and the server, and secondly, control the behaviour of NEs in the client’s environment. User, then, navigates into the 3D virtual world, interacts with NEs and manipulates the world scene. The position of the navigator and its manipulations' data are continually sent to the CM via the established connection. The Java applets also listen to the connection and update the world scene based on the received data.

The CM receives two kinds of data from clients. The first kind of data is only related to the virtual environment, such as notification of the changes of objects’ position in the virtual world. This data is sent to all concerning participants. The other type of data concerns the real counterparts of the objects, as well, such as change of the status of a link. In this case, the NMS has to be notified of the change as well. This task is achieved through the NMS interface.

5. OBSERVATIONS FROM WWW-BASED SYSTEM

The system is currently being implemented. Here, we present some initial observation and results from it. The main feature of the implementation is its platform-independency. The manager can connect to the network, from any computer at any point, either remotely or locally, from his/her notebook or desktop computer, and uses the full capabilities of the system. The managers can take handy notebook computers with themselves to the fault locations, and collaborate with the managers at the central station to fix the fault quickly, and with great confidence.

As with previous system, the three-dimensional view of the network hierarchy and additional navigational facilities increase the visualisability of the network management information. The greater visualisibility means the lower probability of error and miscalculation of the manager, which directly increases the network survivability and reduces down time.

The user connects to the system by pointing her browser to a specific URL address. After authentication process, she receives a combination of text and graphics in a framed window, as shown in Figure 4. The graphical window shows the structure of the network in a three-dimensional environment. Network elements are represented by 3D objects. These symbols are chosen so that they can be recognised by the user as true-representations of their real counterparts. Each object can have two kinds of links: graphical and textual.

Objects that act as links between different views have a graphical link (shown as small spheres in Figure 4). By clicking on the link, another graphical view is presented. So, the user can navigate the whole network by clicking on link-objects within each view.

Each objects has a textual link. The link is represented by a text line under the object showing the object’s name (As the current beta version of VRML plugin does not support text, these links are represented by rectangular boxes). By clicking on this link, textual information is presented in the text frame.

Whoever has ever repaired networks acknowledges that there are some situations that one need to in at least two places at once. The collaboration feature of this system, addresses this problem very efficiently. For the moment, only a textual communication between managers has been provided. Using this facility, managers can talk to each other, and solve the problem collaboratively. We plan to examine other kinds of communication including telephone-like conversation.

Compared to other commercial network management systems, this system is cheap, and allows the managers to use their existing computers to connect to this system for a real-time network management.

6. COMPARISON

In this section we will compare the systems, qualitatively. As the second system is more comprehensive and has more components, we focus our comparison mostly on the components that both systems have. In this sense, we justify why we did not build collaboration and distribution modules on top of the immersive system.

The major point in the first system is the immersion. If built properly, the users feel they are in a similar environment to the real world, with similar level of interaction. Whenever a failure occurs, the user only needs to think of 'what to do' rather than 'how to do'. This means that quicker and higher quality actions can be chosen in the times of stress. However, with current technology, the level of immersion and interaction is still inadequate. Moreover, ergonomic considerations mean that existing head mounted displays are not appropriate for lengthy applications, such as network management.

The second system lacks these facilities. Instead, it benefits from some of the advantages of WIMP interfaces. Multiple frames consisting of 3D graphics and text, carry more information than a pure graphical one. Also, as mentioned earlier, in a network management environment, there are plenty of useful textual information that cannot be translated efficiently into graphical symbols. The second system can easily show them in the text frame, while proper display of text in graphical environment is more difficult, and yet to be investigated.

The level of interaction in an immersive system is much higher. Utilising VR gloves and other 3D input devices such as Cyberman and 3D mouse, navigation in the 3D world is quite easy. On the other hand, most WWW browsers only use mouse for interaction. This cause some confusion as user has to switch between different modes of movement, eg. walk vs. fly. However, it seems that forthcoming browsers will support more input devices.

Platform dependency is another important issue. Immersive systems are mostly platform dependent. Developing a system for a special platform requires a special set of libraries and utilities that usually are not available for other platforms. Even, some types of input devices, such as HMDs and gloves, are available for only few platforms. For the second system, however, the situation is different. Some WWW browser, such as Netscape, are available for most platforms. Moreover, the browser from different vendors are quite compatible, as they use the same set of standards.

The higher mobility of WWW-based approach is another advantage. The immersive system has a lot of bulky components, such as HMD, glove, and other input devices, which makes it difficult to move the system around the network. While, in the other approach, a highly mobile notebook computer can be used as the network management workstation.

The other advantage of the non-immersive system is the higher accessibility to the network management system. The prices of browsers are so low that most computers have a copy of them installed. So, the managers can virtually use any computer in the network to connect to the system, and benefit from the graphical user interface to manage the network remotely. With collaboration added to the system, the scope and level of management will go far behind currently existing systems.

With the trend of network management moving towards using HTTP and Web technology instead of,

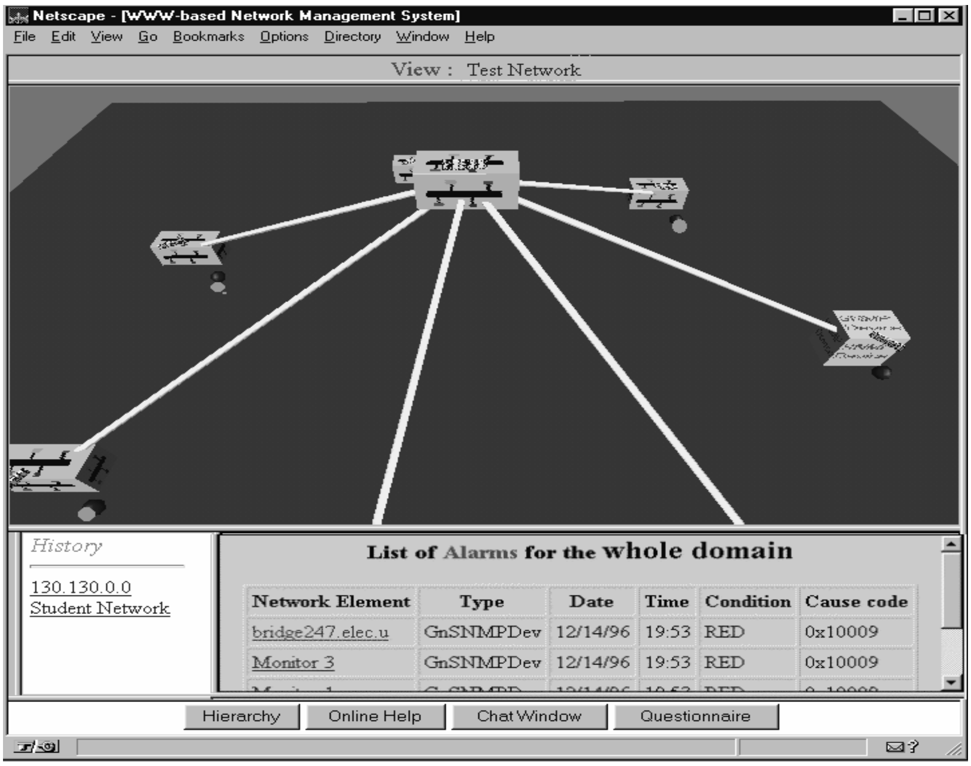

Figure 4- A typical view of the WWW-based system

or in corporation with, SNMP for device polling and status notification [8], the second method can be seemlessly expanded to even directly contact with the network elements. In fact, the trend towards Web-based network management is so high that some experts believe that 'the network management platform of the future may only have Web-based user interface' [9].

7. CONCLUSION

We have been investigating the application of virtual reality user interface paradigm for managing telecommunication networks. We started our research by design and implementation of an immersive 3D virtual reality system, incorporating head mounted display and 3D input devices. The experience from this system, led us to implement a WWW-based collaborative, distributed 3D user interface, using enhanced Web browser.

In this paper, we briefly, discussed the architecture of both systems and our observation from their prototype implementations. Then we compared them in terms of their suitability for a network management environment. Each system has some advantages and drawbacks, but it seems that, for now, the performance of WWW-based system is superior to that of immersive VR system.

The prototype WWW-based system implemented here, though yet to be completed, depicts some useful features. Most commercial management systems use graphical workstations which are relatively expensive. The communication with the system using other platform is only through text-based command line interface, which is not useful for management of complex networks. On the other hand, in our implementation, the managers can connect to the system and do full network operation from any location in the network using virtually any computer. A more powerful computer can deliver a very realistic view featuring texture mapping and smooth shading, while in less powerful machines a rather primitive view, with a reasonable speed, can be shown.

The three dimensional and collaborative environment created by this system, firstly, give a greater visualisation to the system, and secondly, allow real-time communication between managers, which is necessary for management of complicated and flexible broadband networks based on ATM technology.

As a future work, we plan to do object and subjective evaluation of our 3D user interfaces to measure their efficiency and effectiveness compared to traditional 2D user interfaces for network management.

Acknowledgments. This work is supported by a postgraduate scholarship from ministry of culture and higher education of I.R. Iran granted to M. Kahani. The financial support of The Institute for Telecommunication Research (TITR) of the University of Wollongong is also hereby acknowledged.

REFERENCES

[1] Kositpaiboon, R., Smith, B., "Customer Network Management for B-ISDN/ATM Services", ICC'93 Conference, Vol. 1, pp. 1-7.

[2] Crutcher, L; Lazar, A; Feiner, S; Zhou, M, "Management of Broadband Networks using a 3D Virtual World", 2nd Intl. Symp. on High Perf.. Distributed Computing, 1993, pp. 306-15.

[3] Alexander, P., Carpenter, K., "ATM Net Management: A Status report", Data Communication Magazine, September 1995.

[4] Kahani, M., Beadle, P., "Using Virtual Reality to Manage Broadband Telecommunication Networks", ATNAC'95 Conference, pp. 517-522

[5] Kahani, M., Beadle, P., "WWW-based 3D Distributed, Collaborative Virtual Environment for Telecommunication Network Management", Proceeding of ATNAC'96, pp. 483-488.

[6] Stanger, J., "Telecommunication Applications of Virtual Reality", IEE Colloquium on Using Virtual World, pp. 6/1-3, 1992.

[7] ITU-T Recommendation M.3010, "Principle and Architecture for the TMN", Geneva, 1992.

[8] Wellens, C., Auerbach, K., "Towards Useful Management", The Simple Times, Vol. 4, No. 3, July 1996.

[9] Bruins, Barry, "Some Experiences with Emerging Management Technologies", The Simple Times, Vol. 4, No. 3, July 1996.