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Immersive and Non-immersive Virtual Reality Techniques Applied to Telecommunication Network Management

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Abstract

In this paper, we will introduce two different three dimensional VR-based user interface for telecommunication network management. The first one is an immersive system, using HMD and other 3D input devices. The other is a WWW-based flat screen 3D collaborative user interface. The architecture of each system and our observation from it will be described. Then, a comparison will be made to show the merits and pitfalls of each.

Keywords

Telecommunication Network Management, Virtual Reality, Virtual Reality Modeling Language (VRML), User Interface.

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) (Kositpaiboon, 1993). A virtual private network is a set of network resources, such as user-network

A. A. Lazar et al. (eds.), *Integrated Network Management V*

interfaces (UNIs), and (semi) permanent virtual connections (VPC) that link the different sites of a customer together. However, 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.

Managing ATM networks requires a more decentralised approach, as well. Several organisations, from the network provider to customer site administration, may require hierarchical access to network management information. While distributing management, a centralised and integrated view of the whole system should also be provided.

The complexity of the networks and the new services that they provide has made network management more mission critical to a larger number of organisations. This has led to the development of integrated network management systems using Windows Icons Mouse Pointer (WIMP) based direct manipulation user interfaces. Despite advances in computer technology, these interfaces appear to be inadequate for visualising and manipulating the huge databases typical of modern network management systems (Lazar, 1992). One of the major drawbacks of WIMP based user interfaces is that, even for small networks, the user becomes lost among too many open windows, and in too much modeling hierarchy (see Figure 1). This means a high conceptual load for the operator and an inefficient use of human short-term memory, when the operator wants to find faulty devices, and/or observe the performance of network elements.

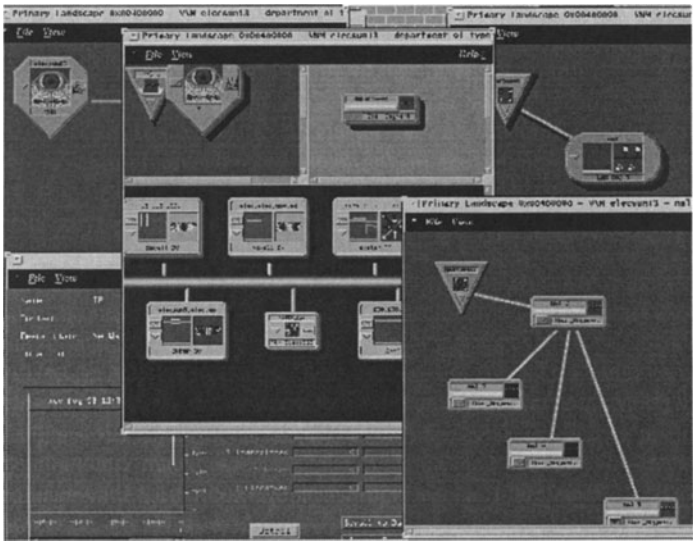

Figure 1- A typical view of WIMP user interfaces.

It is believed that the management of emerging networks requires greater visualisibility and interactivity than that provided by traditional user interfaces (Crutcher, 1993). The manager in these environments has to deal with tens of thousands of virtual channels, and potentially hundreds of ATM switches (Alexander 1995). To enhance the network management operating environment, we have been investigating the use of Virtual Reality (VR) user interface technology for network management applications. Two approaches have been used and some prototype systems have been implemented. In the first model (Kahani, 1995), we deployed an immersive virtual reality environment, consists of Head Mounted Display (HMD), pointing devices, joystick, and other input devices. The observation from the implementation of the system has led us to build a non-immersive, distributed, collaborative, 3D interface using WWW techniques (HTML, VRML, Java and JavaScript) (Kahani, 1996).

In this paper, firstly, the special requirements of a distributed and collaborative network management system are discussed. Then, we introduce the architecture of the immersive system and discuss our observations from it. This will be followed by the discussion of pitfalls and merits of this system that led us to implement the second prototype system. After explaining the structure of the second system, a comparison will be made between them. Finally, we conclude the paper with the discussion of the lessons learned from these implementations and explain further work.

2 SYSTEM REQUIREMENTS

The system proposed here is a Distributed Virtual Reality (DVR) system. DVR systems are mostly used for simulations, eg. SIMNET (Pope 1989), or computer games. However, in a network management environment, there are several issues that have to be treated differently. These issues are:

- **Bandwidth**: The amount of bandwidth used by a network management system should be as small as possible, compared to actual network traffic. Network management tasks (eg. device polling) consume a considerable amount of bandwidth by themselves, so the system should be so designed that the distributed VR user interface does not add much more traffic. Unlike some other systems in which the distributed system, itself, is the goal (eg. games or simulators), the total amount of bandwidth consumed by network management system (device polling and operators' collaborations) is considered waste, and reduces the network throughput.
- **Reliability**. Reliability is a major issue in network management. In a distributed VR game if some update messages are lost, the effect on the total system is not dramatic. In a network management environment, each individual message may carry important information, and may have a catastrophic effect on the network, if does not reach the destination. As a result, a best effort communication protocol is not suitable, and a reliable end-to-end protocol, such as TCP/IP should be considered.

- **Number of users:** Most distributed simulators have a large number of participants, spreaded over several LAN segments. As a result, the communication of update messages among users is done via either broadcasting or multicasting. In a network management environment, however, the number of participants is relatively small, and it is less likely that too many users join the system from the same LAN. So, in the absence of widely deployed point-to-multipoint and multipoint-to-multipoint services, a point-to-point unicast communication model is used.
- **Security**. For most distributed simulation systems, security is not an issue. Some of those systems have a dedicated network, which physically maintains the security, for others, such as distributed games, the data is not sensitive. None of these are true for a network management environment. As a result, special security measures must be considered.

3 IMMERSIVE VR USER INTERFACE

3.1 System architecture

The architecture of the immersive VR system is illustrated in Figure 2. 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. While the formers are nearly static and rarely need updating, the performance and fault data are quite dynamic, requiring continuous update.

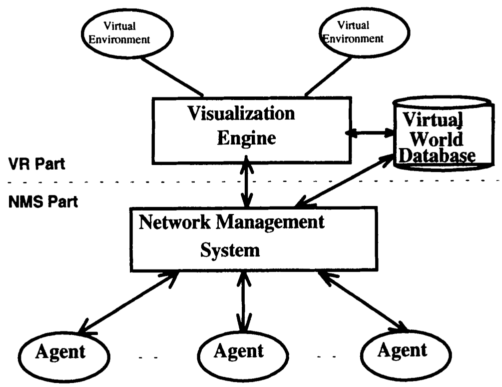

Figure 2- Immersive VR system architecture.

The network configuration and connectivity information are extracted, as network topology changes, from the NMS using its Command Line Interface (CLI), 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/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 part sends its inquiries to the NMS using CLI commands to retrieve the required data. The VR part also converts the operator's manipulation of the network to appropriate CLI commands and sends them to the NMS. The physical interface between the systems is provided by the underlying network.

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 is 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.

3.2 Observations

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 3.

The main advantage of a VR user interface is its additional spatial dimensions, since the network's hierarchical properties become explicit (Stanger, 1992). 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.

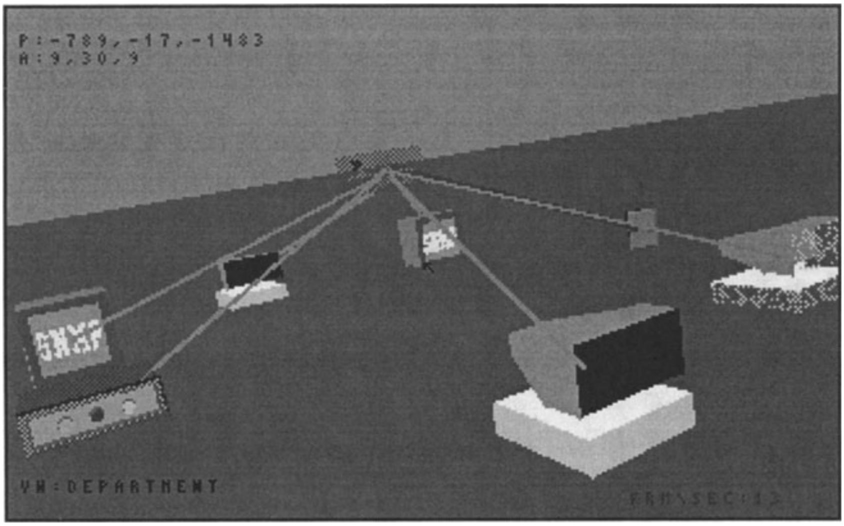

Figure 3- A view of immersive VR system that shows several network elements, such as router, pingable and generic SNMP devices. Colour coding has been used to show faulty devices and congested links.

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 distributed and 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

4.1 System architecture

The system uses a client/server architecture based on Telecommunication Network Management model (ITU-T M.3010, 1992). Each server 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 Virtual Reality Modelling Language (VRML) plugin, Java and JavaScript. VRML is a three dimensional modelling language for multi-participant simulation (Bell, 1995 and Bell 1996). Java is a platform independent object-oriented language that can run in the client's environment, rather than server machine.

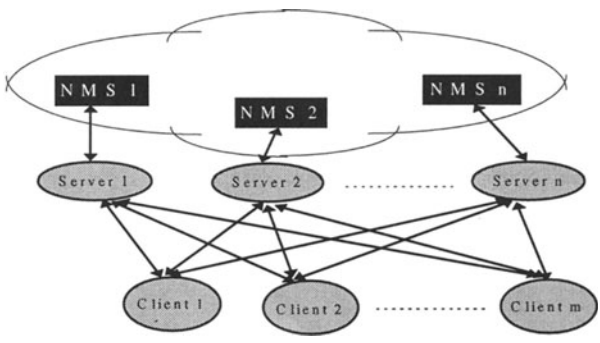

Figure 4- The architecture WWW-based system.

Within the virtual world, each 3D object can have a link to other objects and 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 4 illustrates this architecture.

Each server consists of four parts: NMS interface, Collaborative Manager (CM), object-oriented database (OODB), and HTTP server, as shown in Figure 5. 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.

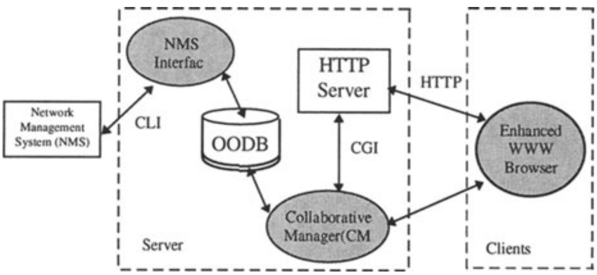

Figure 5-Details of client/server communication.

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.

4.2 Observations

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 mobile computers with them 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.

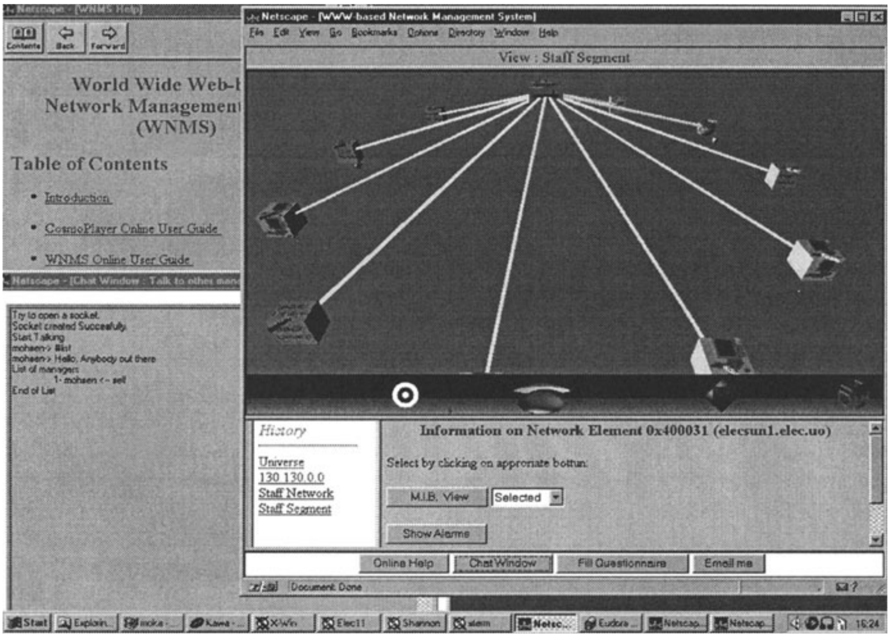

Figure 6- A typical view of the system.

The user initially connects to the system by requesting an HTML document from the specified HTTP server. This document asks for user ID and password, and sends them to the server, which actually calls the CM via CGI protocol. If the user is accepted, an entry in the database is created for it, and a document consisting of text and graphics frames is forwarded to it. The client then navigates into the systems, and does its management job. A typical view is also shown in Figure 6.

The impressions of people seeing the system is that, despite its preliminary implementation, its 3D view and mixture of text and graphics give the manger more flexibility than available two-dimensional commercial network management systems. Incorporating voice communication between participants and using more realistic and complex scene will improve further the system's efficiency.

Whoever has ever repaired networks acknowledges that there are some situations where one needs to be in at least two places at once. The collaboration feature of this system, addresses this problem very efficiently.

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.

5 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 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 is 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 platform 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 beyond current systems.

With the trend of network management moving towards using HTTP and Web technology instead of or in corporation with SNMP for device polling and status notification (Wellens, 1996), 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"* (Bruins, 1996).

6 CONCLUSION

We are investigating the application of virtual reality user interface paradigm for managing telecommunication networks. In order to focus on user interface problem, we have used one of better network management software as the network management back-end. Then, 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.

Finally, Although we used this system for network management purposes, the generic structure can be used in any application that require data visualisation.

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.

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8 BIOGRAPHY

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