

# A Virtual World for Network Management

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## Abstract

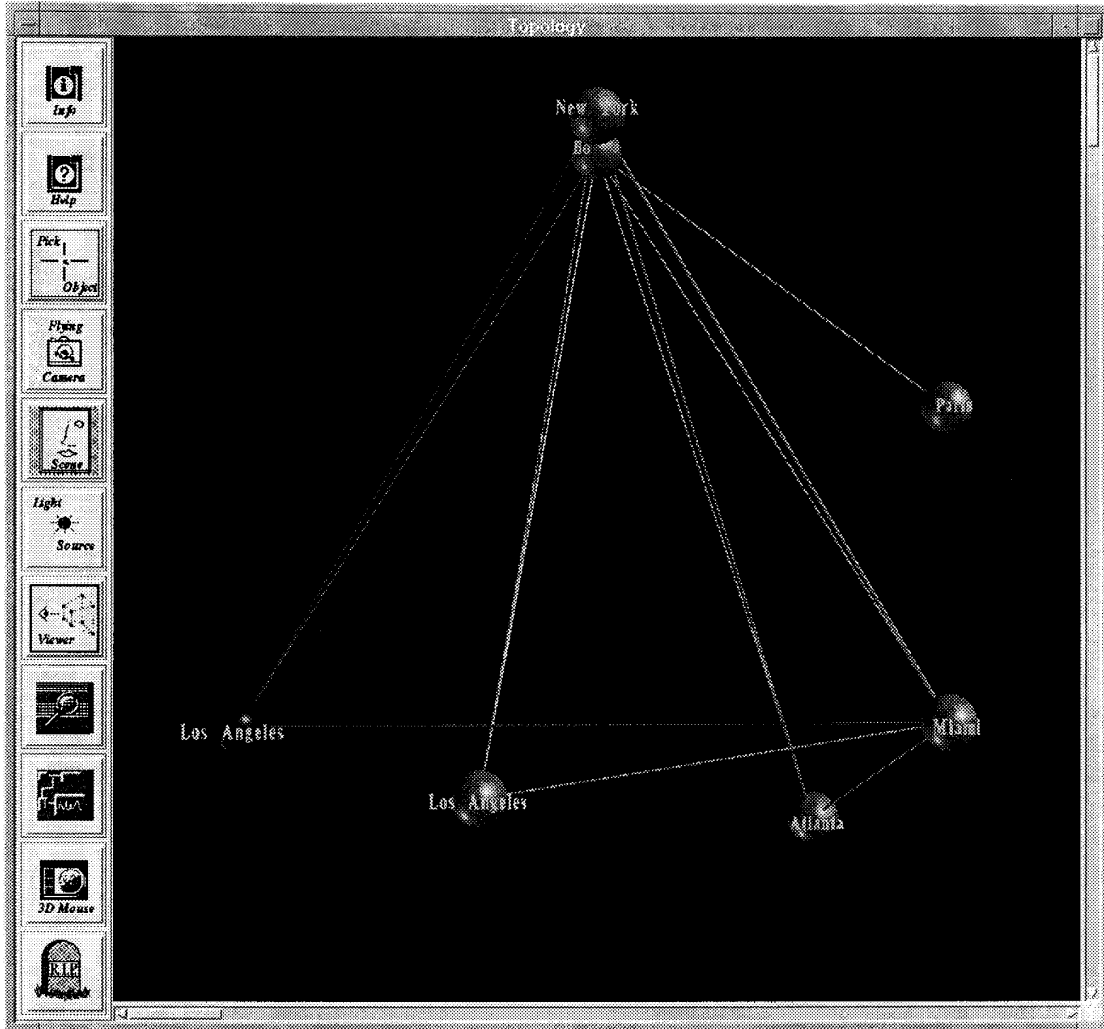
Existing network management systems typically use a combination of textual displays and 2D directed graph representations of network topology. We are designing a network management system that instead uses a virtual world presented through a 3D stereo display and manipulated with a 3D mouse. Our goal is to allow the user to better understand and control the structure and behavior of a large, complex network. In our current prototype, the user interacts with a 3D representation of a network whose topology and behavior is specified by a separate network emulator. The user can choose from among a set of different views of the network. For example, one view shows a selected virtual path as a series of logical links contained within a physical path. The system will ultimately serve as a testbed for the knowledge-based design of network visualizations.

## Introduction

Network management is a task in which users must rapidly process and act on large amounts of information, much of which is changing over time. As networks become larger and faster, they become harder to manage. Larger networks have a larger state space to understand and control. With link speeds moving up to gigabits per second and beyond, it becomes more difficult to follow network state changes. Changes in size and speed are reflected in the user interface, as the network manager has to deal with an increasing volume of information that changes at an increasing rate.

State-of-the-art network management systems rely on a combination of 2D network diagrams and textual displays to communicate this information to their users [3]. Because of the complexity of the information involved, and the fact that much of it is highly spatial, current 2D user interfaces act as a bottleneck, making it difficult for the user to understand and control the network's behavior. We believe that virtual worlds that combine high-performance interactive 3D graphics with 3D displays and interaction devices can make it possible to break the bottleneck.

Several projects have shown the utility of 3D visualizations of directed graphs in related applications, including displays of semantic nets [4] and representations of the structure of



**Figure 1:** Physical topology. The user is moving the Los Angeles node. The previous locations of the node and its links are rendered using transparency.

object-oriented programs [7]. Recent work has also begun to explore the use of virtual worlds for network management using a head-mounted display [9]. We are designing a testbed network management environment that uses a virtual world presented on a stereo CRT display, with interaction provided through a 3D mouse. By using a CRT display rather than a current head-mounted display, we take advantage of the significantly better resolution that the CRT offers, which can be vital for the effective display of quantitative information. By using a 3D mouse rather than an instrumented glove, we provide users with an interaction device with which they are already familiar.

## User interface

Our current prototype system consists of two parts: a virtual world user interface and an ATM (Asynchronous Transfer Mode) network emulator, each of which runs on a separate processor. The user can request that a network configuration be loaded into the emulator for processing. Our user interface combines a conventional 2D X Window System with a 3D virtual world. Thus, we can take advantage of existing window-system widgets when appropriate by treating the mouse as a 2D device.

In network management, as in many other applications, the quantity and kind of information with which the user must interact depend on the situation. In the following sections we describe the different views that our prototype currently supports and conclude with a description of our implementation environment and the research directions that we are taking.

### Physical topology view

The most fundamental view of a network is that of its physical topology, as shown in Figure 1. In the physical topology view, nodes are presented as spheres and links are presented as cylinders. The 3D mouse can be attached to either the network model or the camera to modify the user's view. An additional button on the mouse serves as a "clutch," making it possible to disengage the object being controlled to allow relative translation and rotation [11]. We also provide a conventional pop-up control panel to make precise adjustments.

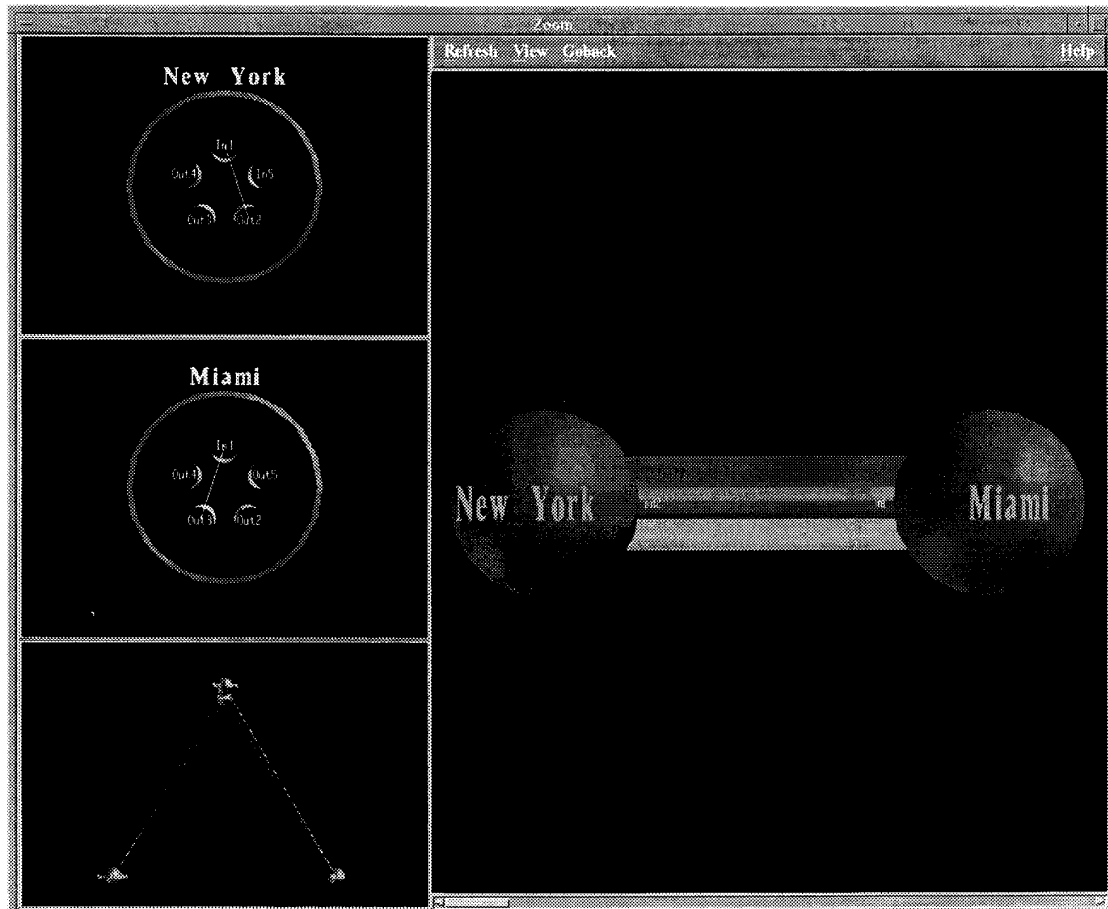
In Figure 1, the user is rearranging the network layout by moving a node that has been selected with the 3D mouse. Transparent versions of the node and its links are shown in their previous locations to provide context. The 3D mouse can also be used to select a node or link to be examined in more detail using the logical topology views.

### Logical topology views

We currently support two logical topology views: a view of the virtual paths on a single link or switch, and a view of the complete virtual path through the network. (A virtual path is a logical path through a physical network that uses some portion of the available bandwidth [2].)

In the logical link attachment view, we display all virtual paths associated with a given physical link, as shown in Figure 2. The thin cylindrical link representation of the physical topology view is replaced with a thick cylindrical link that is sliced open to reveal the virtual paths inside. The slicing is computed dynamically (using back-face culling of a cylinder with inward-facing surface normals) so that the virtual paths are always exposed relative to the user. The diameter of each virtual path is proportional to its capacity. Separate views of each node reveal the details of the port connections, while a small overview of the entire network provides context.

In the complete virtual path display, shown in Figure 3, all nodes on the path are displayed using the same representation at the top of the display. Statistics for the virtual path are displayed textually, while the inset at the right displays a graphical representation of capacity in terms of the three traffic classes (I–III), each of which is mapped to a different dimension. The plane shown within the cube is defined by the maximum number of calls of each class (e.g., video, voice, or data) that can be accommodated by the bandwidth of the virtual path. At any time, the number of calls that are set up through a virtual path should define a point that is beneath the plane in order for the network to satisfy the quality-of-service associated with each call.

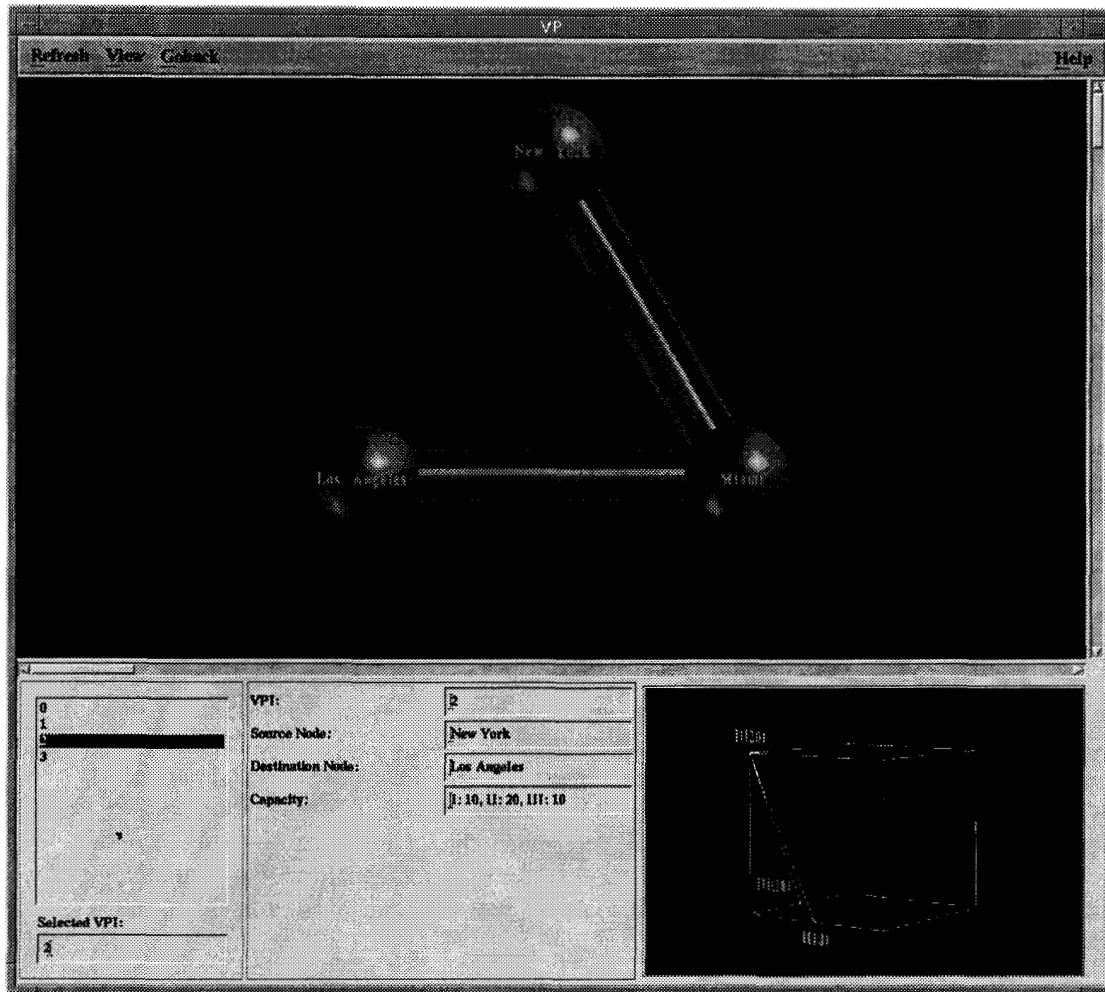


**Figure 2:** Logical link attachment. All virtual paths associated with a selected physical link are shown, along with details of port connections.

## Implementation

The user interface for our prototype is implemented on a HP 9000/735 with a CRX-48Z graphics accelerator using C++, Motif, and the Starbase graphics package. We use a StereoGraphics CrystalEyes liquid crystal stereo display system and a Logitech 6D ultrasonic mouse. The mouse has an additional button that we use to indicate whether it is active as a 3D device, effectively acting as a clutch for relative transformations. When its 3D position information indicates that the mouse is on the table top, we generate X pointer and button events, so that it can also be used as a 2D device.

The network emulator runs on a SUN SparcStation 10-30. RPC is used to communicate between the user interface and emulator. Messages allow the user interface to obtain the physical topology (node ids, link ids, node-link attachments, port ids and types, geographic data for nodes, and node capacities for different classes of calls) and logical topology (virtual path ids, the series of logical link attachments that form a virtual path, and virtual path capacities for different classes of calls). The emulator also makes it possible to instantiate and monitor call



**Figure 3:** Virtual path. All nodes on the same path are displayed, along with a representation of the virtual path's capacity for different traffic classes. dynamics.

### Conclusions and Future Work

We have described the early stages in the design and implementation of a prototype virtual world for network management. At this point, we can display and manipulate basic physical and logical topology, and have begun to work on visualizing full network dynamics. In addition to expanding our system to accommodate a number of basic network management capabilities (such as pulling components in and out of the network topology), and natural 3D extensions (such as “grabbing” information flows to be redirected), there are a number of other research directions that we will be exploring.

In the figures included in this paper, different views are displayed separately. We are currently integrating the views so that one view can change smoothly into another to avoid the

potentially confusing discontinuous change in view that our user currently experiences [10]. For example, the fatter cutaway links shown in the logical topology views can be smoothly grown in place from the thinner links of the physical topology view.

Because of the massive amounts of data involved and the speed with which the emulation will proceed, facilities for viewing and reviewing emulated behavior will be extremely important. We will need the ability to journal significant stretches of network activity, and to run journaled activity at varying speeds, both forward and backward. Given the richness of even a single emulation run, one important issue will be developing ways to present summary visual representations to users that will allow them to get a high-level feel for what happened during a given period of time or in some selected part of the network. Here we will use the notion of an “editable graphical history,” originally developed for static 2D user interfaces, which allow users to explore a graphical representation of previous activities [8].

We have recently acquired a sound processing system that allows sound sources to be positioned in 3D relative to the user [12] and are incorporating this into our system. Such spatially localized sound could help direct the user’s attention to relevant parts of the virtual world. For example, even if the network model surrounds the user, only that part projected on the display is visible. If localized sound were used to encode selected aspects of network activity, the user could be quickly made aware of interesting phenomena that occur outside of their field of view. The idea here is to use visual and audio media together to present a consistent spatial model of network activity.

Finally, one of the major thrusts of this project will be the design of a knowledge-based presentation component, building on our ongoing work on the automated design of virtual worlds to explain both abstract [1] and concrete [6] data. Our approach will involve categorizing the visualization techniques with regard to their applicability for expressing and controlling different kinds of network behavior. The idea is to build up a set of visualization policies that can be used by a rule-based system that will determine which interaction and visualization techniques to apply when to best meet the needs of the user and situation. For example, automatically generated cutaway views [5] could display topological detail in situ without changing the layout of a complex network.

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