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NPSNET: A Multi-Player 3D Virtual Environment Over the Internet

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NPSNET: A MULTI-PLAYER 3D VIRTUAL ENVIRONMENT OVER THE INTERNET

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Networked Virtual Worlds

The development of multi-user networked virtual worlds has become a major area of interest to the graphics community. The realization of high bandwidth wide area communications, the success of World Wide Web applications such as the National Center for Supercomputing Application's Mosaic browser, and government funding of Distributed Interactive Simulation (DIS) has fueled the desire to expand networked virtual worlds beyond local area networks. However, the Internet has proved a challenging environment for real-time applications such as interactive virtual worlds and multimedia.

Our group has been motivated to expand the capabilities of simulations and virtual environments (VEs) by exploiting multicast networks to serve medium to large numbers (more than 1,000) of simultaneous users. To understand and meet these challenges we have developed the Naval Postgraduate School Networked Vehicle Simulator IV (NPSNET-IV) -- a 3D virtual environment suitable for multi-player participation over the Internet.

Key Technologies

NPSNET-IV is used for the following research areas:

- Dynamic IP Multicast for network group communication to support large scale distributed simulation over the Internet.
- Wireless (mobile) and remote (Integrated Services Digital Network, ISDN, and low-rate analog) communications technology for VEs.
- Human, instrumented figures in VEs for medical and emergency training applications.
- Distributed Interactive Simulation protocol development for application level communication among independently developed simulators (e.g. legacy aircraft simulators, constructive models, and real field instrumented vehicles).
- Networked real-time hypermedia within 3D VEs such as video and audio.
- Autonomous players or entities for populating virtual worlds.
- Low-cost 3D sound.
- Simulation-based design.

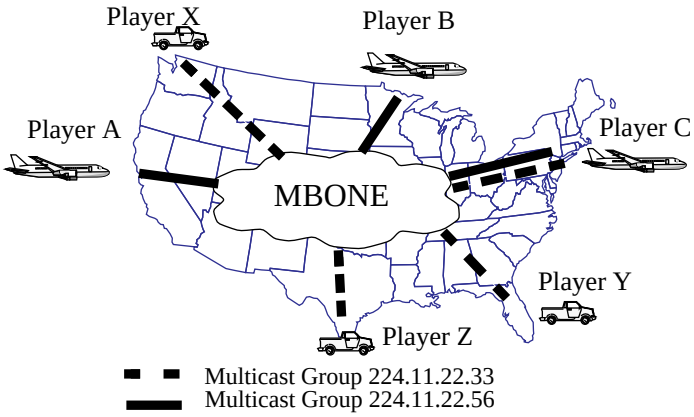

Figure 1. The MBONE allows different large-scale networked virtual environments to exist simultaneously over the Internet.

NPSNET

NPSNET-IV runs on commercial, off-the-shelf Silicon Graphics workstations and employs the Performer graphics library[8]. Developed at the Naval Postgraduate School's (NPS) Department of Computer Science in the Graphics and Video Laboratory, the simulator uses Simulation Network (SIMNET) databases. NPSNET-IV participants communicate with other virtual environment "players" located across the United States via IP multicast network protocols, the IEEE 1278 Distributed Interactive Simulation application protocol and the Internet Multicast Backbone (MBONE)[4,6].

NPSNET-IV is the first DIS application to use the IP Multicast protocol. IP Multicast, developed by Steve Deering, is an Internet standard (RFC 1112), and is supported by a variety of operating systems including SGI's Irix and Sun's Solaris [3].

Multicast provides one-to-many and many-to-many delivery services for applications such as teleconferencing and distributed simulation in which there is a need to communicate with several other hosts simultaneously. For example, a multicast teleconference allows a host to send voice and video simultaneously to a set of (but not necessarily all) locations. With broadcast, data is sent to all hosts while unicast or point-to-point routes communication between only two hosts.

Most distributed VEs have employed some form of broadcast (hardware-based or IP) or point-to-point communications. However, these schemes are bandwidth inefficient and broadcast, which is used in SIMNET and most DIS implementations, is not suitable for

internetworks.

IP broadcast, which is commonly used in DIS environments, cannot be used over the Internet unless it is encapsulated. It also adds an additional burden because it requires that all nodes examine a packet even if the information is not intended for that receiving host, incurring a major performance penalty for that host because it must interrupt operations in order to perform this task at the operating system level.

Point-to-point communication requires the establishment of a connection or path from each node to every other node in the network for a total of N*(N-1) virtual connections in a group. For example, with a 1000 member group each individual host would have to separately address and send 999 identical packets. If a client-server model is used, such as that typically found in networked games and multi-user domains (MUDs), the server manages all the connections and rapidly becomes an input/output bottleneck.

Dead-reckoning

The networking technique used in NPSNET-IV, evolved from SIMNET, and embodied in DIS follows the *players and ghosts* paradigm presented in [1][7]. In this paradigm, each object is controlled on its own host workstation by a software object called a Player. On every other workstation in the network, a version of the Player is dynamically modeled as an object called a Ghost.

The Ghost objects on each workstation update their own position each time through the simulation loop, using a dead-reckoning algorithm. The Player tracks both its actual position and the predicted position calculated with dead-reckoning. An updated Entity State Protocol Data Unit is sent out on the network when the two postures differ by a predetermined error threshold, or when a fixed amount or time has passed since the last update (nominally 5 seconds). When the updated posture (location and orientation) and velocity vectors are received by the Ghost object, the Ghost's is corrected to the updated values, and resumes dead-reckoning from this new posture.

This dead-reckoning technique helps in overcoming a major problem found in a number of networked simulations -- excessive network utilization. For example, each networked participant playing the popular game DOOM generates a packet on every graphics frame. On an SGI, this translates into 30 packets per second, even when an entity is inactive. This not only wastes bandwidth, it also overloads the ability of network devices to process packets. On the other hand, a high performance aircraft in a DIS environment typically produces about 8 packets per second --a dramatic difference.

MBONE

MBONE is a virtual network that originated from an effort to multicast audio and video from the Internet Engineering Task Force (IETF) meetings [2]. MBONE today is used by several hundred researchers for developing protocols and applications for group communication.

We have used MBONE to demonstrate the feasibility of IP Multicast for distributed simulations over a wide area network. In the past, participation with other sites required prior coordination for reserving bandwidth on the Defense Simulations Internet (DSI). DSI, funded by ARPA, is a private line network composed of T-1 (1.5 Mbps) links, BBN switches and gateways using the ST-II network protocol. It had been necessary to use DSI because ARPA sponsored DIS simulations use IP broadcast - requiring a unique wide-area bridged network.

With the inclusion of IP Multicast in NPSNET-IV, sites connected via the MBONE can immediately participate in a simulation. MBONE uses a tool developed by Van Jacobson and Steven McCanne called the Session Directory (*SD*) to display the advertisements by multicast groups. SD is also used for launching multicast applications like NPSNET-IV and for automatically selecting an unused address for a new group session. Furthermore, we can integrate other multicast services such as video with NPSNET-IV. For example, participants are able to view each other's simulation with a video tool, NV, developed by Ron Fredrickson at Xerox Parc [5].

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Resources

Many of the references noted below are available via the NPSNET Research Group's WWW home page:

file://taurus.cs.nps.navy.mil/pub/NPSNET_MOSAIC/npsnet_mosaic.html

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