Networked Virtual Spaces and Clouds

Magda El Zarki

UC Irvine
Outline

• Introduction to Networked Virtual Environments (NVE)
• Networked Virtual Environment Architectures
• Quality of Experience
• Clouds and real time interactions in NVE
• NVE as a Service
• Design issues for NVEs in the Cloud
Networked Virtual Environments

• A shared *(space, time, presence)* 3D virtual environment
• All have **Real-time** changes
• **Collaboration** with other users
  – Representation of users in the world (typically as human-like avatars)
  – Objects that users interact with – cars, planes, etc.
  – Text and voice communication
Universal Campus
Immersive Exercising
Broad Definition of NVE

- By definition an online/network virtual space must involve a network.
- Multi-user virtual spaces are not necessarily networked.
- Not all networked virtual spaces are multi-user.
- In a nutshell: a networked multi-user virtual space is a software system that allows multiple users to interact with each other in real-time from different locations, usually remote, and preferably with immersive graphics.
NVE by Definition MUST

Have a Network and Involve Multiple users
Network Architectures
Peer to Peer
Network Architectures

Client-Server

Client

Server

Client

Client

Client

Client
Network Architectures

Hybrid

- Multiple servers serving different regions
- Multiple service types & service layers

Server pool
Most NVEs today run on the client-server (C-S) architecture:
  - the server handles the NVE logic
  - every request made by a user in the NVE is processed at the server

When a request is made by a user, it travels from the client to the server and back to client, and this transmission introduces possible unacceptable latency in the NVE.
Responsiveness, Consistency and Plausability

• The system needs to be **responsive (or locally plausible)** – react to a user’s input/local actions and give appearance of consistency

• The system needs to have a **consistent view** across all clients/users (**shared plausibility**):
  
  – **Network delay** means that all received information is **out-of-date**. Messages are delayed, incur different delays, arrive out of order, lost -> inconsistent views -> conflicts
  
  – **Conflicts** – An NVE must provide **accurate collision detection**, **agreement on actions/events**, and **resolution among participants** when states are out of sync
Categorizing User Actions

- Precision
- Deadline

The precision and deadline requirements for a user action determine the effects of latency on that action.
QoS vs QoE

- **QoS – Quality of Service:**
  - network characteristics/behavior
  - **Network performance guarantees** given by network provider based on measurements taken over time

- **QoE – Quality of Experience:**
  - impact of network performance on end user
    - some imperfections may go unnoticed
    - some imperfections may render application/service useless
  - impact not always captured by network measurements
    - a 5% packet loss could be invisible if it affects background
    - A late action due to a 100ms delay can affect the user interaction
Quality of Service (QoS) vs Quality of Experience (QoE)

User Interactions

QoE
1. View Inconsistency
2. Perception & Mapping
3. Properties of QoE
4. Aggregation & Tradeoffs

QoS
1. Compensation Algorithm
2. Loss Latency Jitter
3. Network Transmission
4. System Consistency

Responsiveness
Precision
Fairness

Player/Client
Client/Server
Player/Player
Precision – Deadline Requirements

- First Person Avatar
- Third Person Avatar
- Omnipresent
Performance vs Latency for different classes of online NVEs

- Omnipresent
- Third-Person Avatar
- First Person Avatar
Impact of Delay on User Performance

The graph shows the impact of delay on user performance, with different delay times represented by various lines. As delay increases from 0 ms to 100 ms, the user performance decreases, indicated by the curves moving towards the origin on the graph.
### Ball Park Numbers for Designers

<table>
<thead>
<tr>
<th>Model</th>
<th>Perspective</th>
<th>Sensitivity</th>
<th>Thresholds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avatar</td>
<td>First person</td>
<td>High</td>
<td>100msec</td>
</tr>
<tr>
<td></td>
<td>Third person</td>
<td>Medium</td>
<td>500msec</td>
</tr>
<tr>
<td>Omnipresent</td>
<td>Several</td>
<td>Low</td>
<td>1,000msec</td>
</tr>
</tbody>
</table>
• **Network as a Service – NaaS**
  - A framework that integrates current cloud computing offerings with **direct, secure, user access** to the network infrastructure - **SDN**

• **Software Defined Networking (SDN)**
  - Users can easily deploy custom routing and multicast protocols
  - Users can efficiently implement advanced network services (aggregation, duplication, redundancy) ->
  Users create their own private network that conforms to their desired specs.
Cloud NVE- Why?

• Elasticity property – ability to accommodate a very “variable” user population
  – Popularity of a NVE hard to gauge – users can increase overnight, population can go into the hundreds of thousands
  – Users not very loyal – new NVE released, lose users overnight

• User accessibility - global reach

• NVE Distribution – software and patches
Cloud NVEs

• **Classic NVE** - all the logic is executed at clients, and the servers are only responsible for maintaining consistent space states among multiple clients.

• **Cloud NVE** - run on cloud servers and users interact with virtual space over the Internet, via thin/thick clients, which run on commodity PCs, TVs with set-top boxes, and mobile devices.

• Usually implemented as IaaS
iXercise – Immersive Socially Inspired Exercising

Hardware

Web services

iXercise Application

Hardware interface

User specific data

Remote data access

Servers / cloud
iXercise: A Cloud Based NVE Project
Group Real-Time Exercising
Cloud NVE Models

- AAAS – NVE as an application service
  - Streaming – most popular model
  - Graphics – current online NVE model
  - Hybrid –
    - Streaming and Graphics – a blend of the two
    - Local and remote graphics processing
    - Layered graphics rendering

- Tiered Clouds
  - Remote public cloud, servers handle large number of users:
    - update state and create new view
    - sends graphics instructions to local cloud servers
  - Local regional cloud, servers render and stream view data to clients
Video Traffic vs Cloud NVE Traffic

• Answer Q1: The characteristics of NVE traffic are similar for all genres, but total bitrates for downstream and upstream traffic can vary by as much as 50%.
  – First and Third person avatar 50% > omnipresent

• Answer Q2: Downstream traffic is more similar to downstream live video, while upstream traffic is only somewhat similar to upstream traditional NVE traffic.
## Comparison of Bit Rates

<table>
<thead>
<tr>
<th>Application</th>
<th>Bitrate (Kbps)</th>
<th>Packet Size (bytes)</th>
<th>InterPkt Arr. (msec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trad. Game</td>
<td>67</td>
<td>75</td>
<td>45</td>
</tr>
<tr>
<td>Virtual Env.</td>
<td>775</td>
<td>1027</td>
<td>9</td>
</tr>
<tr>
<td>Live Video</td>
<td>2222</td>
<td>1314</td>
<td>0.1</td>
</tr>
<tr>
<td>Thin Client Cloud</td>
<td>6247</td>
<td>1203</td>
<td>0.7</td>
</tr>
<tr>
<td>Pre-recorded Video</td>
<td>43914</td>
<td>1514</td>
<td>0.1</td>
</tr>
</tbody>
</table>
Tiered Clouds

Tier 1: Public Cloud (Scalable and Elastic)

Tier 2: Local Cloud (Low Delay and Power)
Open Issues

• Cloud Model
• Application QoE
  – Latency
  – Interactivity
  – Bit rates
• Application/Edge (fog network/computing) processing to accommodate cloud infrastructures and meet QoE
Questions?

Questions?