# What's Next for Networked Games?

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*W. Feng, "What's Next for Networked Games", NetGames 2007 keynote talk, Sept. 19-20, 2007.*

# Networked Games

- A smashing success


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# Networked Games

- $3.8 billion in 2006, $11.8 billion by 2011
  - Source: Strategy Analytics (9/11/2007)

Warcraft/Starcraft

Half-Life/Counter-Strike


World of Warcraft

Age of Empires

Battlefield

Lineage

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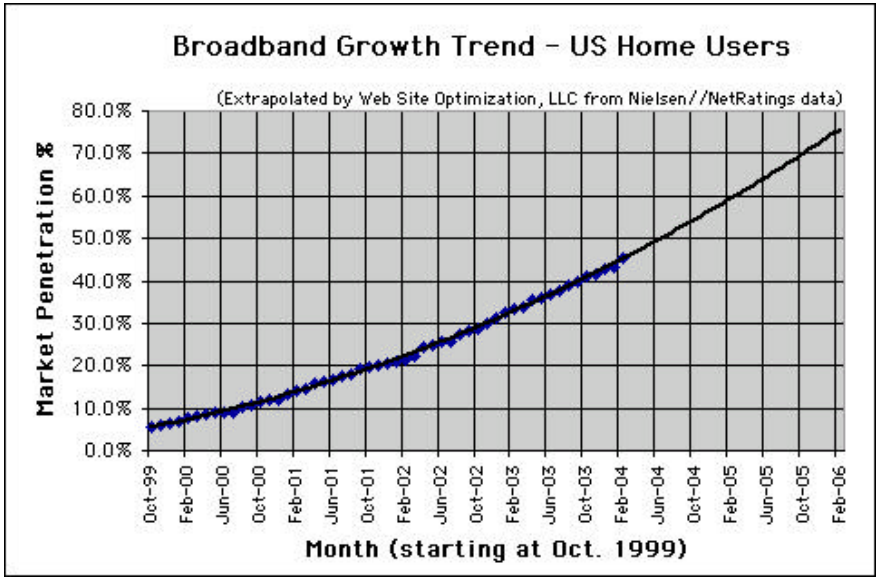
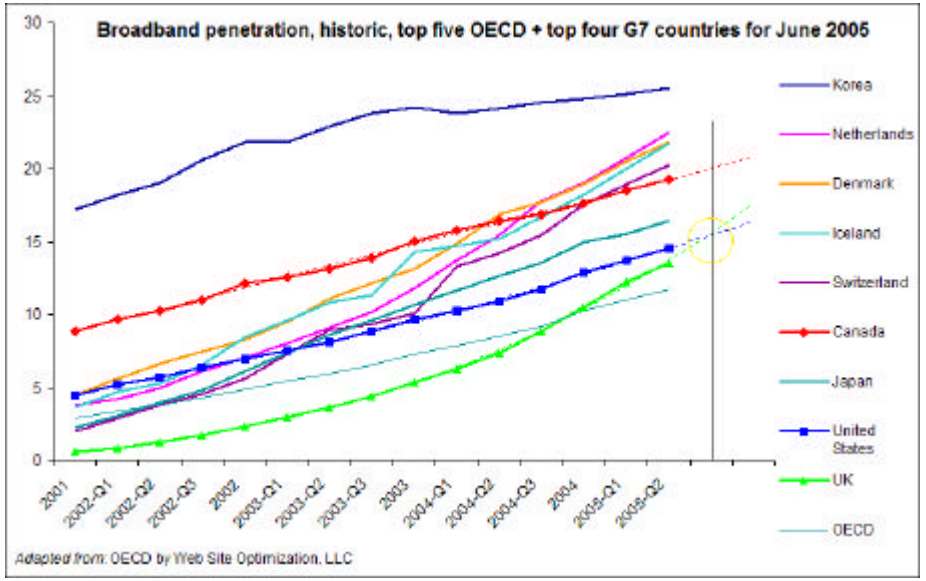
# Is it the network?

- Sure…
  - Pat yourselves on the back mates!
  - Success coincides with broadband rollout
    - 80% of Internet users
    - 20% of population

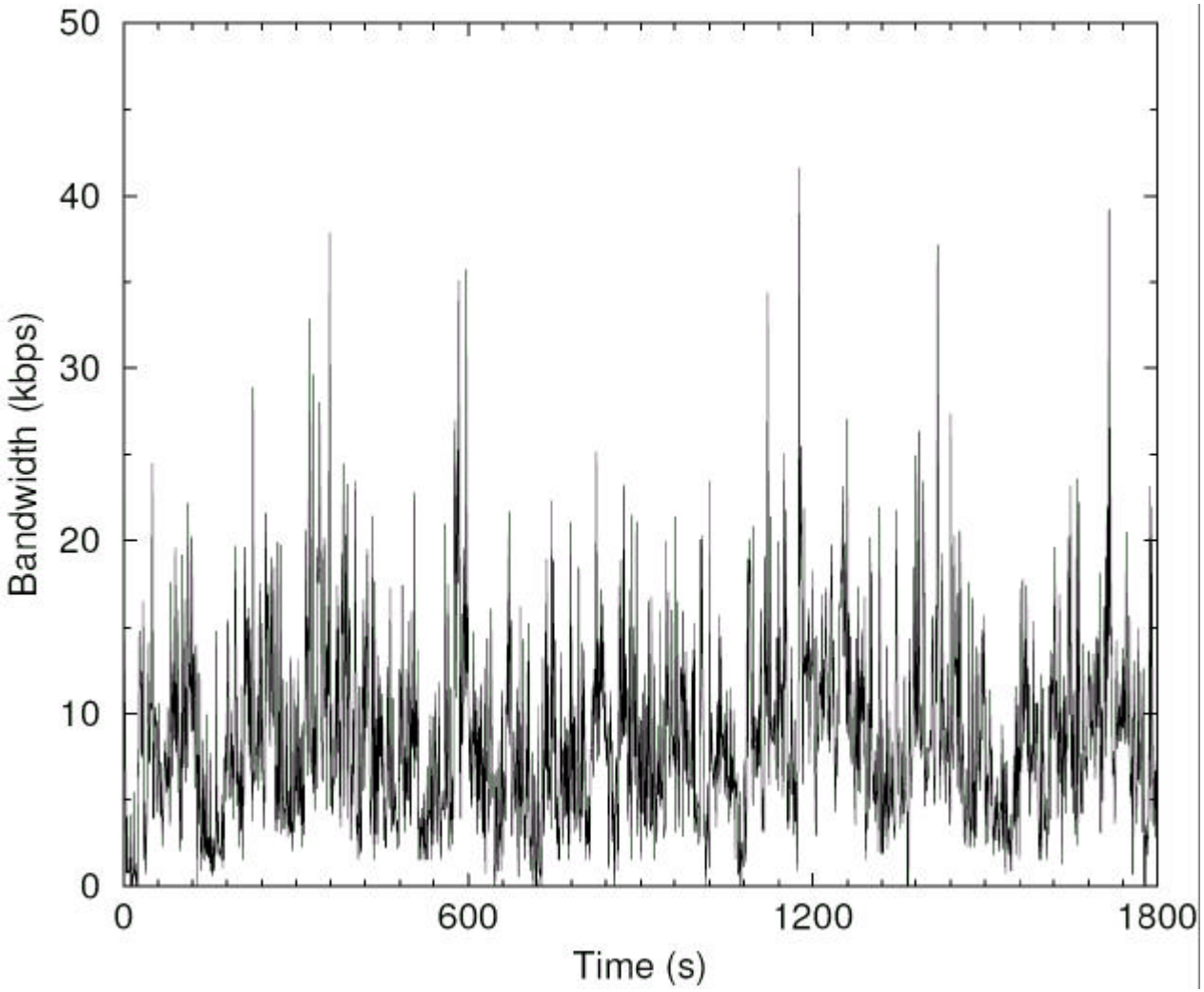



Source: Website Optimization, LLC and Nielsen/NetRatings

# Or not…

- World of Warcraft

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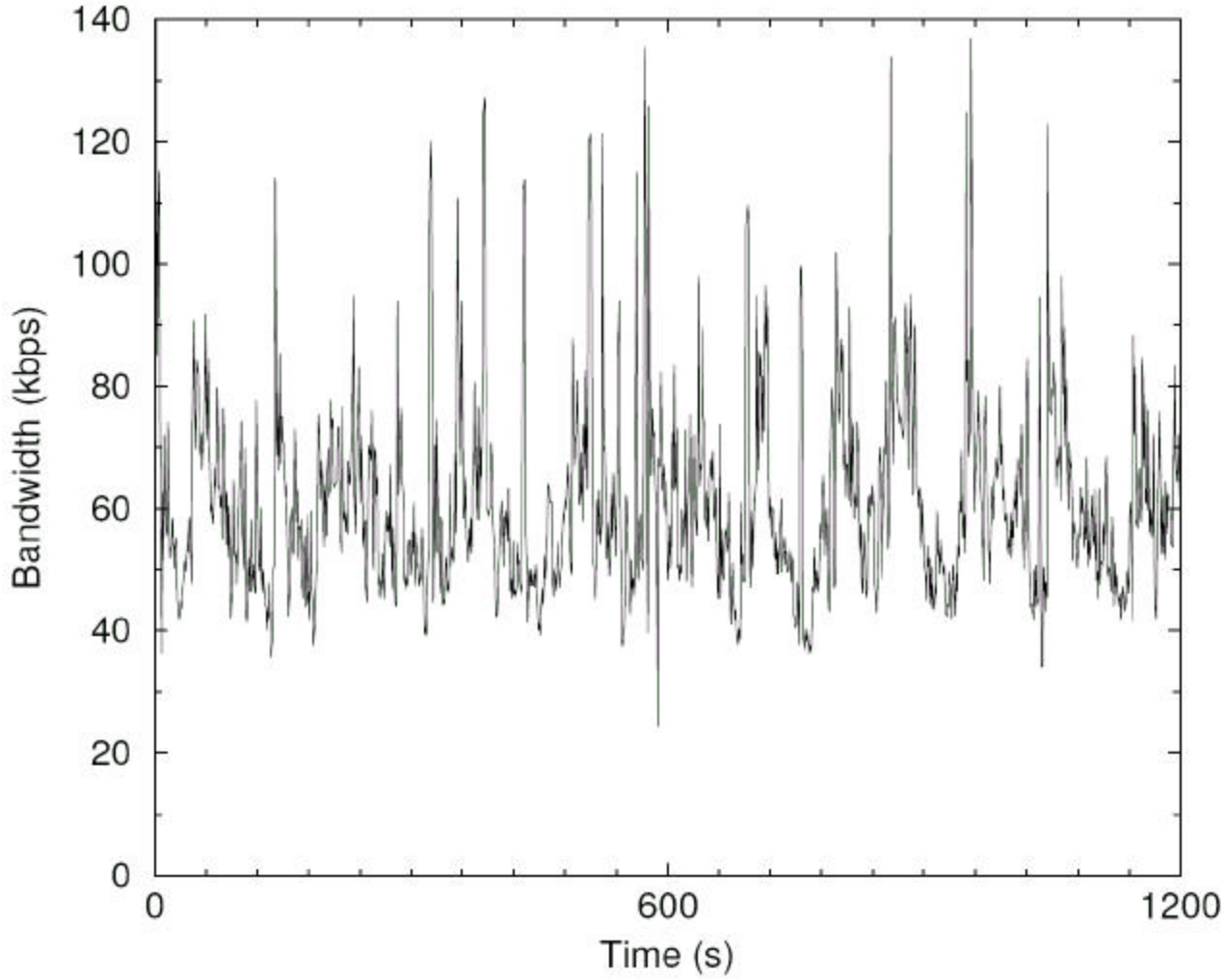
# Or not…

- Counter-Strike: Source (32 players)

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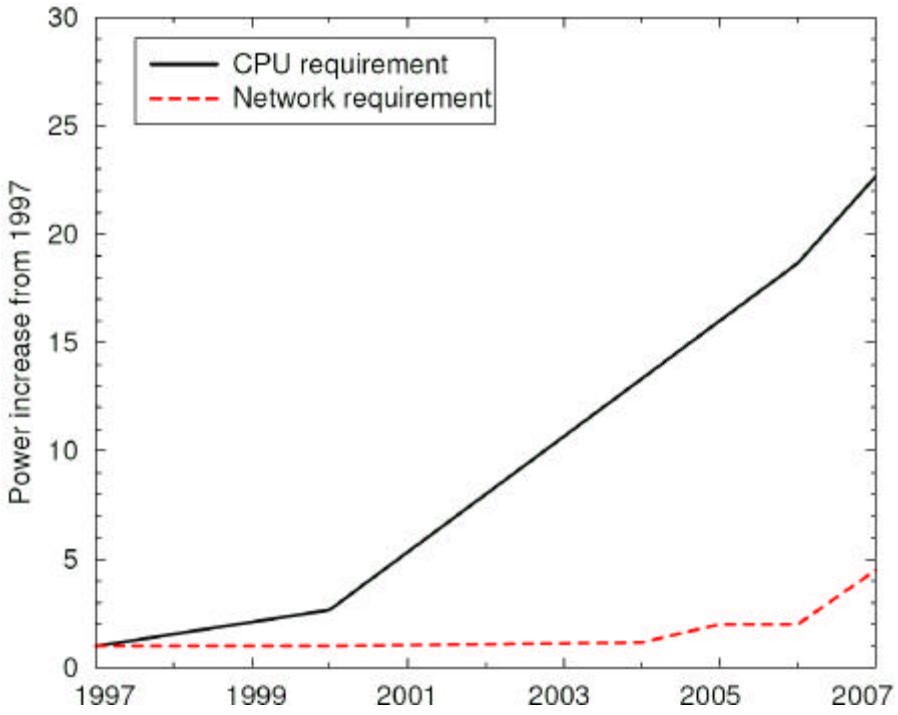
# Digging deeper

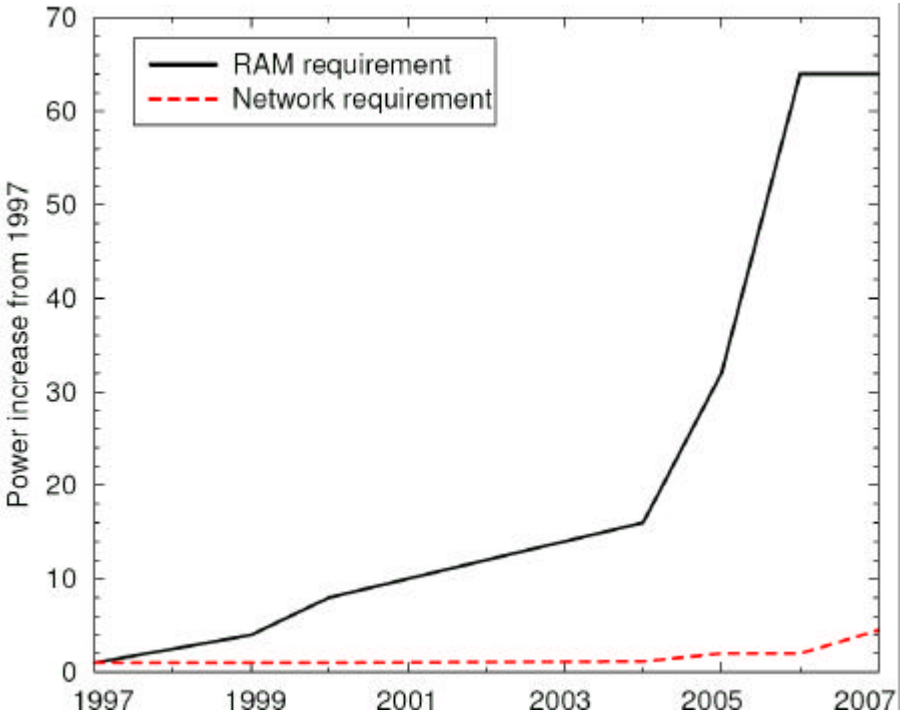
- Minimum system requirements for FPS games

| Game | Year | CPU (MHz) | RAM (MB) | Network (kbps) | Graphics |
|---|---|---|---|---|---|
| Quake | 1997 | 75 | 8 | 28.8 | None |
| Unreal Tournament | 1999 | 200 | 32 | 28.8 | None |
| Quake 3 | 2000 | 233 | 64 | 28.8 | OpenGL 3D |
| Unreal Tournament 2003 | 2003 | 1000 | 128 | 33.6 | DX 7 |
| Counter-Strike: Source | 2004 | 1200 | 256 | 56.6 | DX 7 |
| Call of Duty 2 | 2005 | 1400 | 512 | 56.6 | DX 9 |
| Battlefield 2142 | 2006 | 1700 | 512 | 128 | DX 9 |

# Downright depressing

- Minimum requirements to play popular FPS games over time compared to 1997

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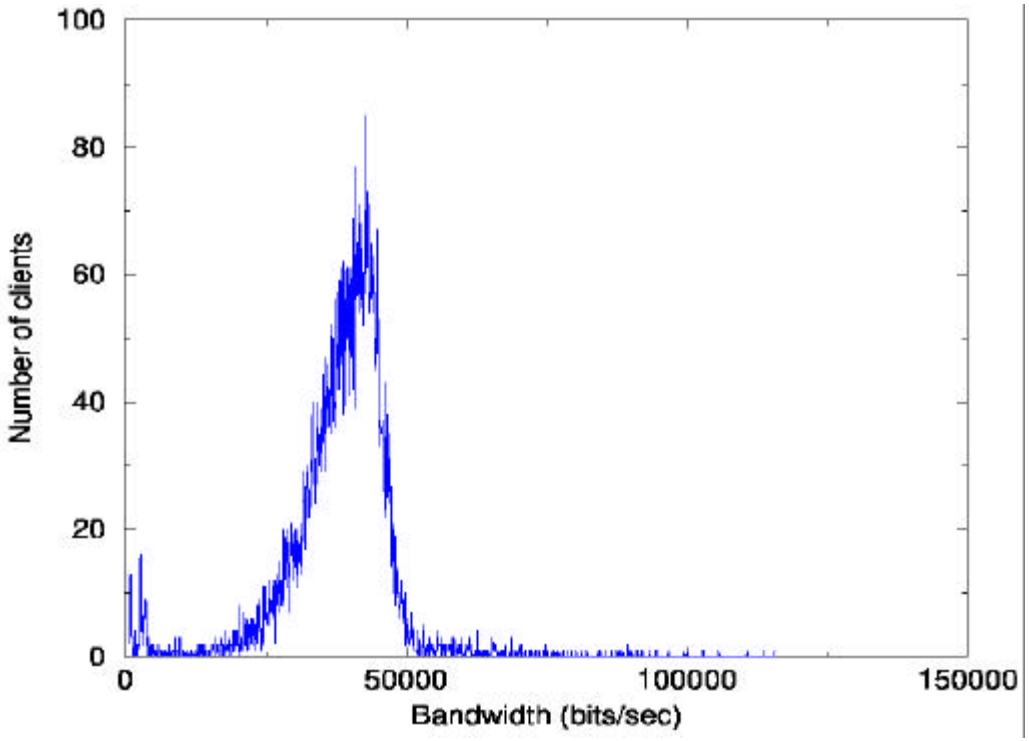
# Who to blame?

- Suspect #1: Those last broadband hold-outs
  - You 20% know who you are!
    - Slow e-mail and web = still usable
    - Slow on-line games = unusable (unless you are a masochist)
  - Game companies must target narrowest last-mile link
    - cs.mshmro.com client bandwidth histogram

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# Who to blame?

- Suspect #2: Those traffic shaping, rate-limiting, anti-net-neutrality ISPs
  - "Pay, but don't play"
    - We'll give you unlimited broadband, just don't use it
  - Putting tolls on the information superhighway
    - My "unlimited" hotel Internet: 3 days, $40 AUD, 400 MB limit

**Shutting Down Big Downloaders**

Comcast Cuts Internet Service to Bandwidth Hogs

*By Kim Hart*
Washington Post Staff Writer
Friday, September 7, 2007; Page A01

The rapid growth of online videos, music and games has created a new Internet sin: using it too much.

Comcast has punished some transgressors by cutting off their Internet service, arguing that excessive downloaders hog Internet capacity and slow down the network for other customers. The company declines to reveal its download limits.

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# Who to blame?

- Suspect #3: Those stingy game publishers
  - One MMORPG has 33% of subscription fee go to networking and data center operations
    - No one wants to pay the server traffic bill
  - Consider the bandwidth costs
    - Lower-bound on WoW usage
      - Courtesy of Xfire (http://xfire.com)
      - Taken Sept 12, 2007 at 12:10am
      - 18,866,594 minutes/day
    - What if players were pegged at 300kbps?
      - (18,866,594*60*300000)/8 = 38.6TB/day
      - Or 3.66 Gbps!

**TODAY'S TOP GAMES**

| GAME | MINUTES PLAYED |
|---|---|
| World of Warcraft | 18,866,594 |
| Call of Duty 2 Multiplayer | 8,160,949 |
| Counter-Strike: Source | 6,773,867 |
| Battlefield 2 | 3,014,673 |
| Guild Wars | 2,507,360 |
| Warcraft III - The Frozen Throne | 1,641,263 |
| Wolfenstein: Enemy Territory | 1,555,348 |
| Counter-Strike 1.6 | 1,293,343 |
| Silkroad Online | 1,282,702 |
| Enemy Territory - QUAKE Wars Demo | 1,214,957 |

# Who to blame?

- Suspect #4: Those unimaginative game developers
  - No one knows what to do with the bandwidth
  - What's there to send?
    - Positions of other players
    - Positions of NPCs
    - Not exactly a high-bandwidth proposition
  - How about multimedia?
    - Who watches a video while playing a game?
    - Watching video = passive
    - Playing game = active
    - What would be a compelling example of multimedia facilitating gameplay?

# What are NetGames researchers to do?

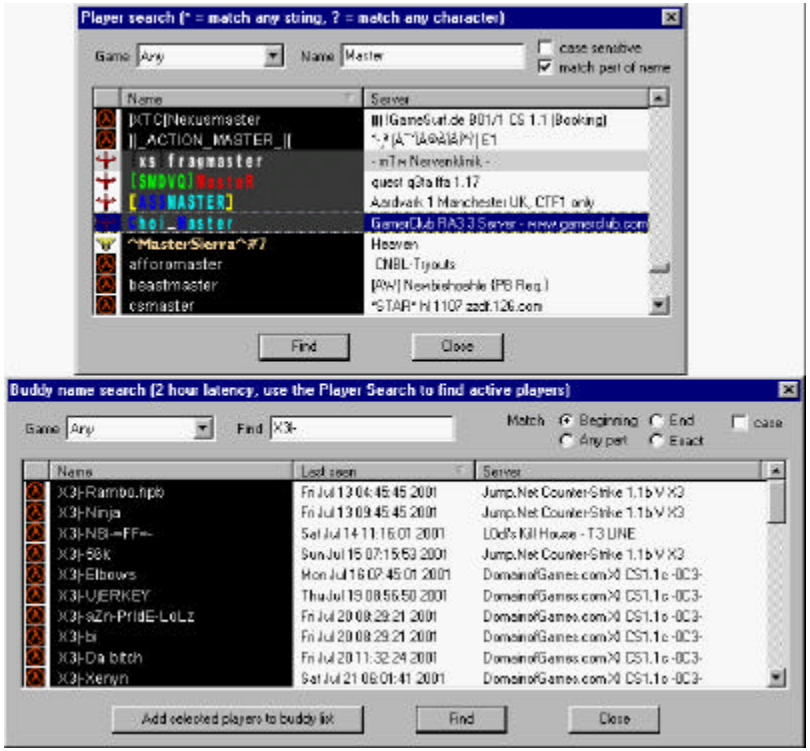
- Doing more with less (the pessimist)
- Doing more with more (the optimist)
- Expanding the definition of “network” (the opportunist)

# What are NetGames researchers to do?

- Doing more with less (the pessimist)
  - Going outside of the game
  - Procedural content
- Doing more with more (the optimist)
- Expanding the definition of “network” (the opportunist)

# Going outside of the game

- Use the network to build communities
  - Social networking within games common
    - Many developed for Half-Life
    - Server browsers that added player tracking/chat
      - UDPSoft All-seeing-eye
      - Qtracker, HLSW

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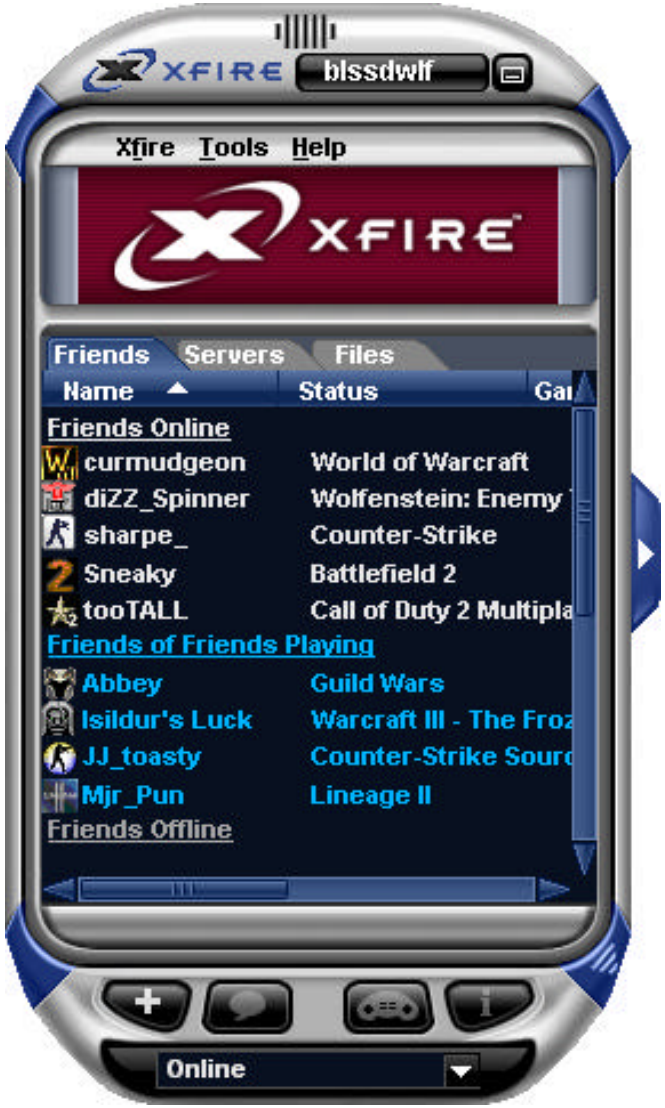
# Going outside of the game

- Use the network to build communities
  - Now, social networking across games
    - Ladders, rankings, tournaments
    - Voice/text chat
    - Player tracking
    - Game and game server tracking
  - Examples
    - Xfire
    - Gamespy Arcade/Arena/Comrade
    - UDPSoft/Yahoo! All-seeing-eye

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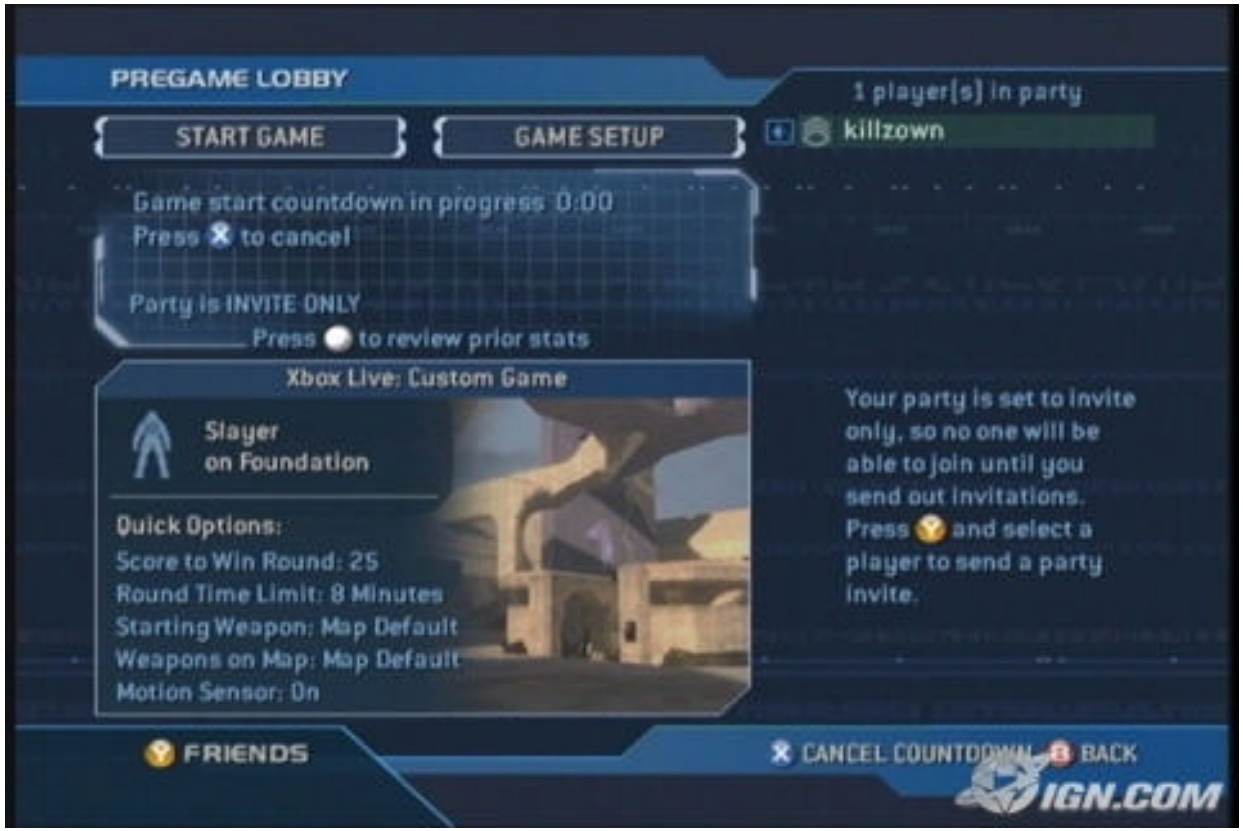
# Going outside of the game

- Use the network to build communities
  - Even for consoles and casual games!
    - Xbox Live
    - BigFish games, Xuqa



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# Going outside of the game

- Use the network to deliver game
  - Casual PC games




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# Going outside of the game

- Use the network to deliver game
  - Console games
    - Xbox Live Marketplace
    - Playstation Store
    - Wii Shop Channel




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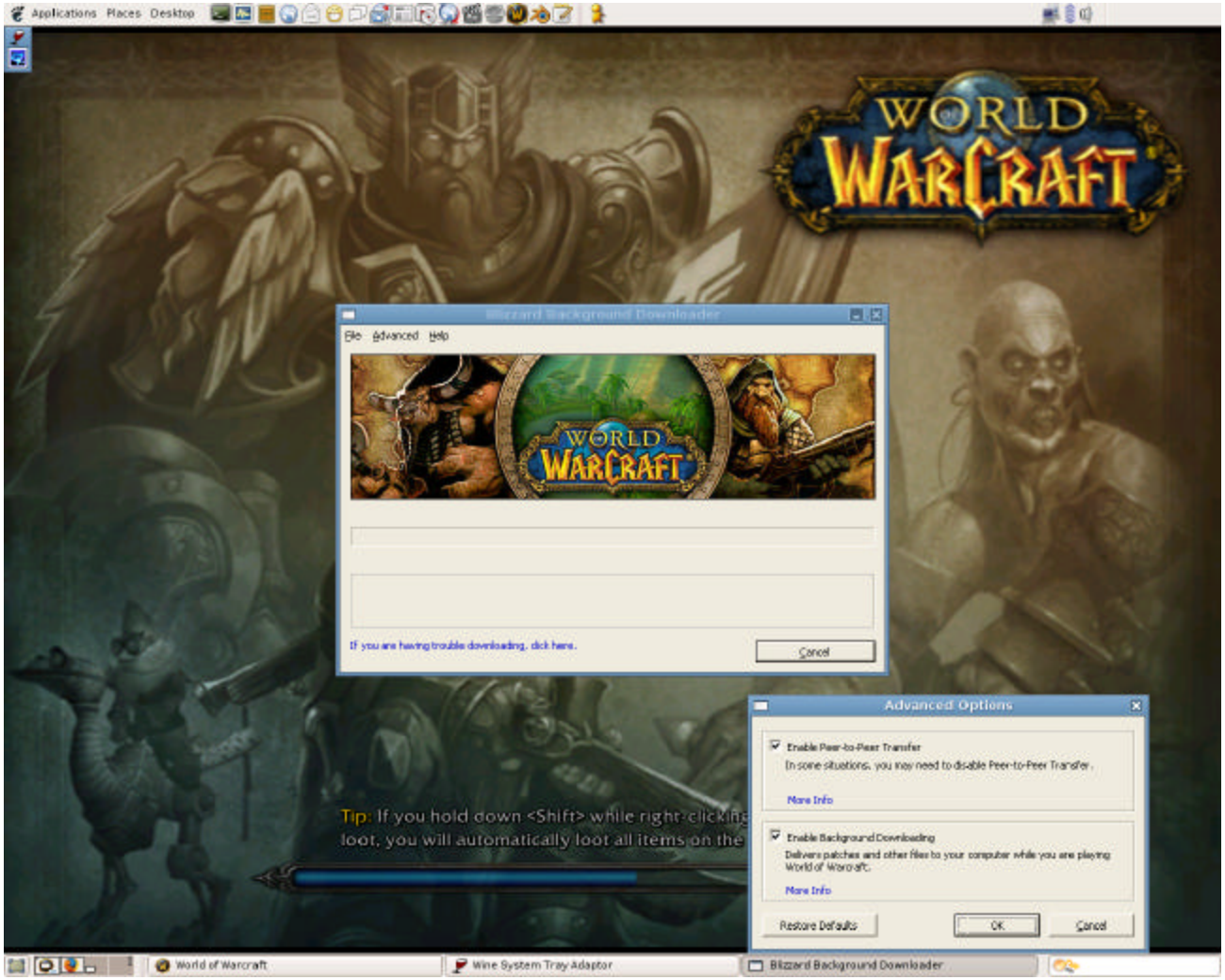
# Going outside of the game

- Use the network to deliver game
  - Full PC game updates (WoW)

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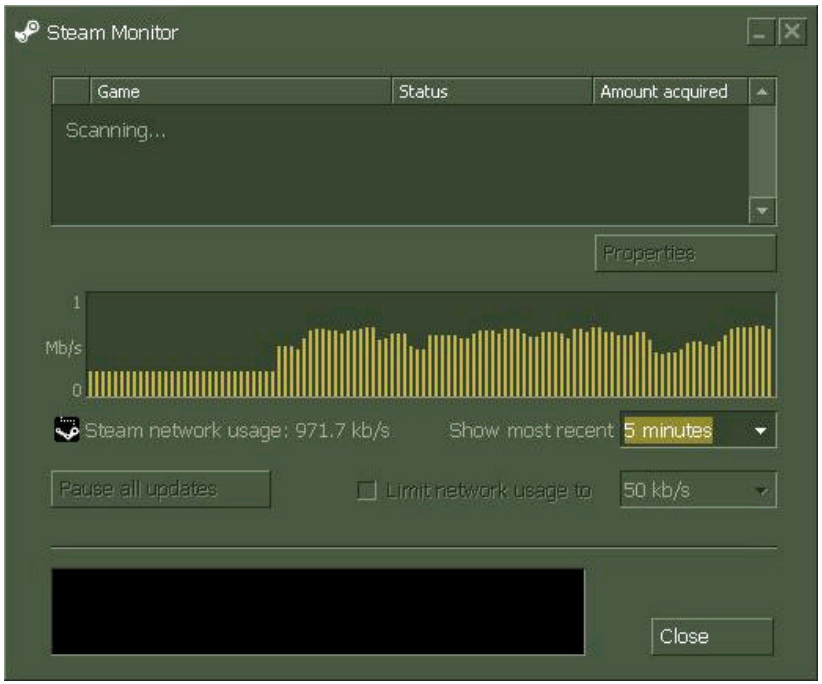
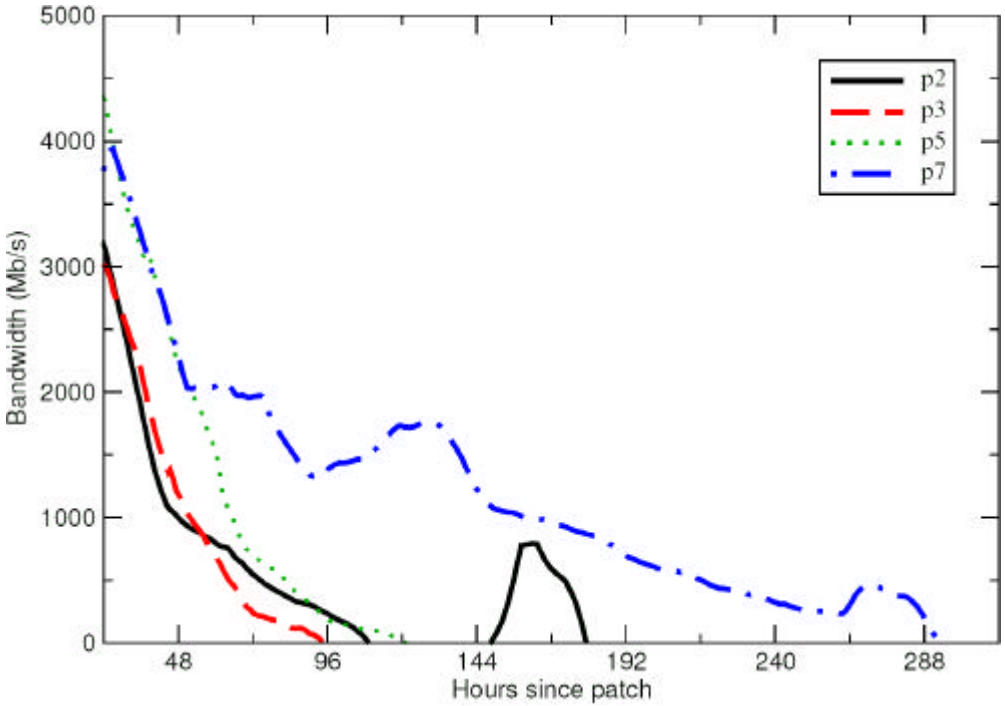
# Going outside of the game

- Use the network to deliver game
  - Full PC games and game updates

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# What are NetGames researchers to do?

- Doing more with less (the pessimist)
  - Going outside of the game
  - Procedural content
- Doing more with more (the optimist)
- Expanding the definition of “network” (the opportunist)

# Procedural content

- All that content being downloaded
  - Who pays for the network and servers to deliver it?
    - Game publisher usually
    - Sometimes helped by donated resources (Steam)
  - Problem
    - Higher resolutions and richer media increase costs significantly
    - The need for procedural content…

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# Procedural content

- Run-time generation of audio and visual effects
  - Costs for distributing a game via network rising
    - Everquest 2 on 10 CDs, WoW > 3GB
    - Mostly due to artwork and audio
  - Take advantage of CPU/RAM speed versus network
    - Don’t send new content across the wire
    - Send algorithms for producing it instead
    - Send new “tree generation algorithm” vs. new trees
      - Procedurally generate all objects, textures, and sound
      - Demo coders can generate a 3D game in 64KB

# Generate character animation

- Versus manually generating static animations
  - Example: The Sims 2 with 22,000 different animations
- Procedural animation based on player's character design
  - Will Wright's Spore
  - GDC 2005 talk

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# Procedural content

- Generate lighting and textures
  - Versus fixed levels of lighting in FPS games
    - Shadows and lighting pre-rendered in textures and shipped to client
    - Counter-Strike with two pre-rendered versions of a tunnel in cs_militia
  - Have client generate textures vs. sending them with map

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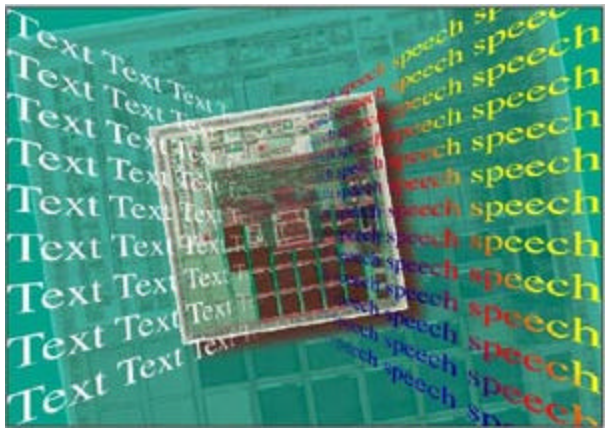
# Procedural content

- Generate character voices
  - Versus static pre-recorded dialogue
  - Example: Call of Duty 2 battle chatter system (10/2005)
    - 20,000 lines with static levels of hoarseness and tones
    - Takes up more space than original CoD!
    - 8% of $14.5 million budget on audio
- Send text and perform run-time speech synthesis
  - Epson/Fonix 5 language TTS chip (11/2005)
  - http://www.tmaa.com/tts/engine_listing.htm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# What are NetGames researchers to do?

- Doing more with less (the pessimist)
- Doing more with more (the optimist)
  - Streaming worlds
  - Security schemes to thwart cheating
  - New game architectures
- Expanding the definition of “network” (the opportunist)

# Streaming worlds

- State-of-the-art in games
  - Worlds (maps) are pre-delivered
    - On CD-ROM or DVD-ROM
      - Almost all games
    - Over the network as part of on-line updates
      - WoW
    - When needed
      - Counter-Strike, Sims On-line
  - Must have entire map on client before playing
- Why?
  - Not enough bandwidth to deliver 3D geometry in real-time
  - But, something happened in the world outside of games…

# Streaming worlds

- Second Life (http://secondlife.com/)
  - 3D virtual world delivered dynamically to client
  - Requires broadband to support (more later)
  - Changes the content delivery paradigm
    - Content not delivered a-priori via sneakernet or download
    - Content streamed on-demand to dumb client (33MB SL client install)


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# Streaming worlds

- Second Life statistics (1/2007)
  - 7000 servers simulating 16 acres each (440 $km^2$)
  - 35 TB user content
  - 1 Petabyte of total traffic per month
  - 10 Gbps peak bandwidth
  - Source: Cory Ondrejka, Microsoft Academic Days Game Conference 2007.
- Currently
  - Over 9 million residents
  - http://secondlife.com/whatis/economy-graphs.php

# Streaming worlds

- 3D geometry typically large
- What's the magic?
  - SL requires low polygon counts and compression to stream
  - Each simulation can support 15k prims
    - Simple geometric shapes glued together to form objects
      - Boxes, spheres, pyramids, etc.
    - Compressed when sent to clients
  - Textures also compressed and streamed
    - Creative texturing allows one to deal with prim limit
- Clients stream information based on frustrum
  - Predictive loading of content
  - Streamed over multiple UDP connections

# Streaming worlds

- Other content
  - Audio
    - Music is SL's "killer app" (128kbps = mp3)
    - Immersive voice used for language teaching
  - Video
    - Reuters island


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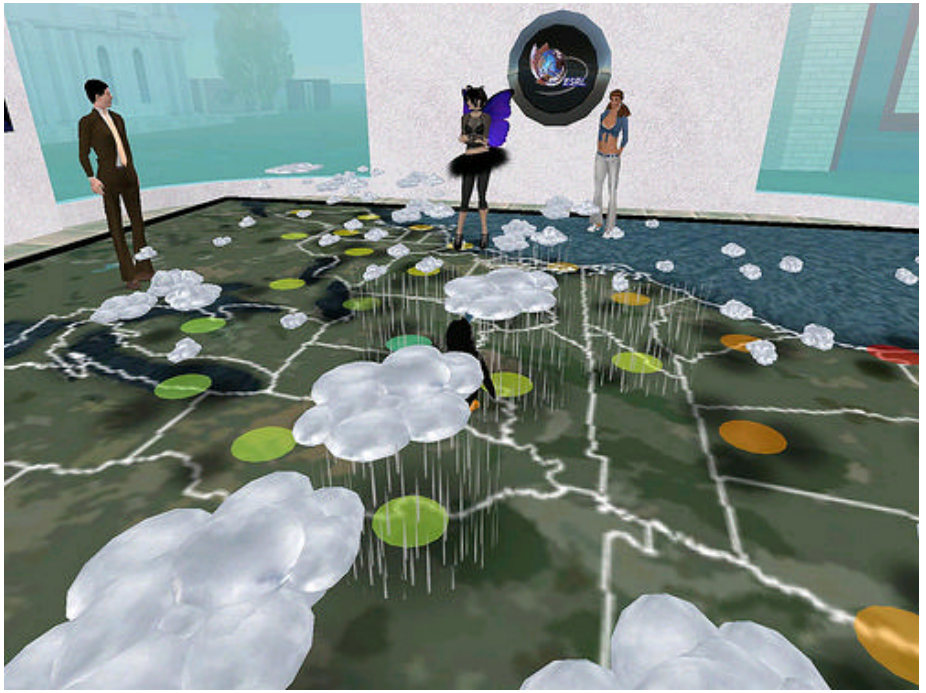
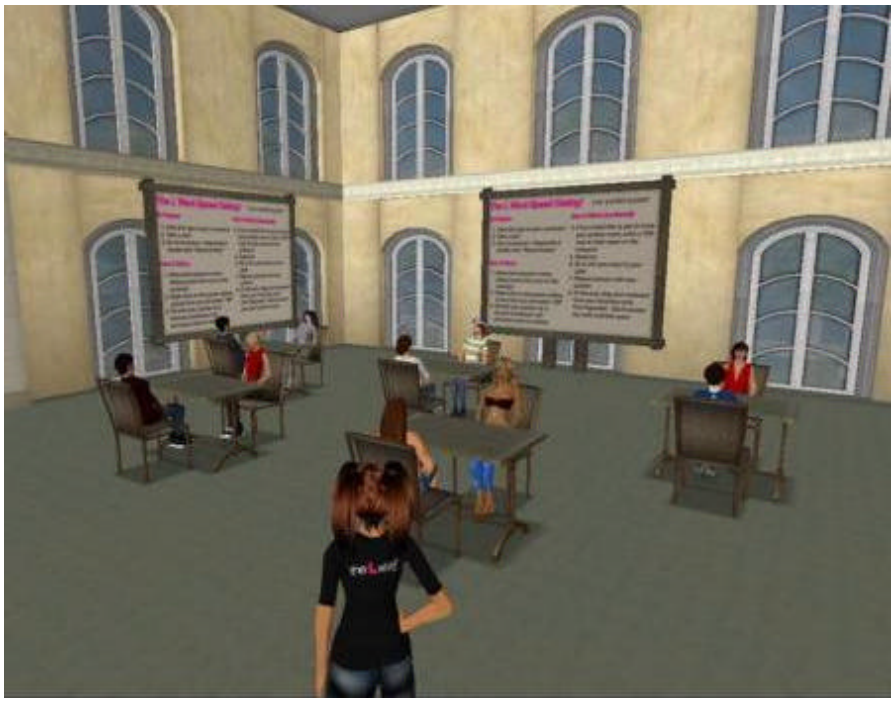
# Streaming worlds

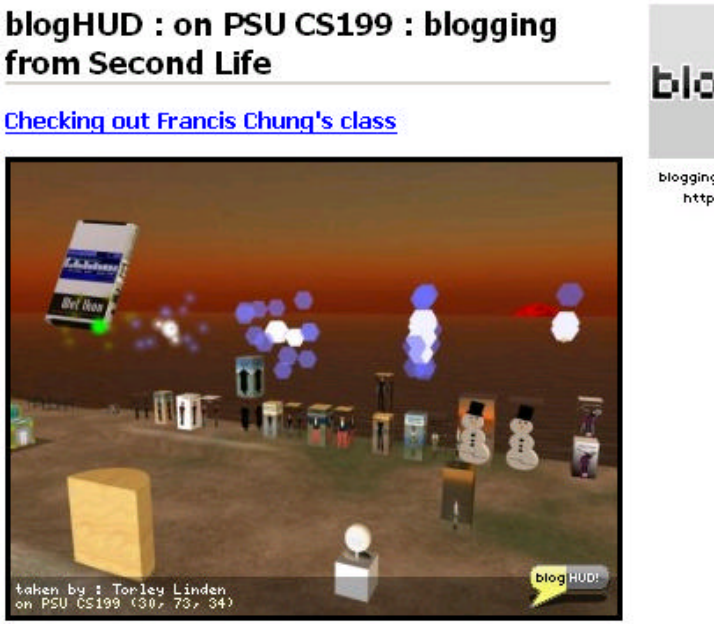
- Other content
  - Scientific data
    - NOAA’s collaborative 3D visualizations

# Streaming worlds

- Other content
  - Presentations
    - SL PowerPoint viewer used to teach courses in a virtual classroom (e.g. Harvard Law courses)
    - PSU CS 199 course



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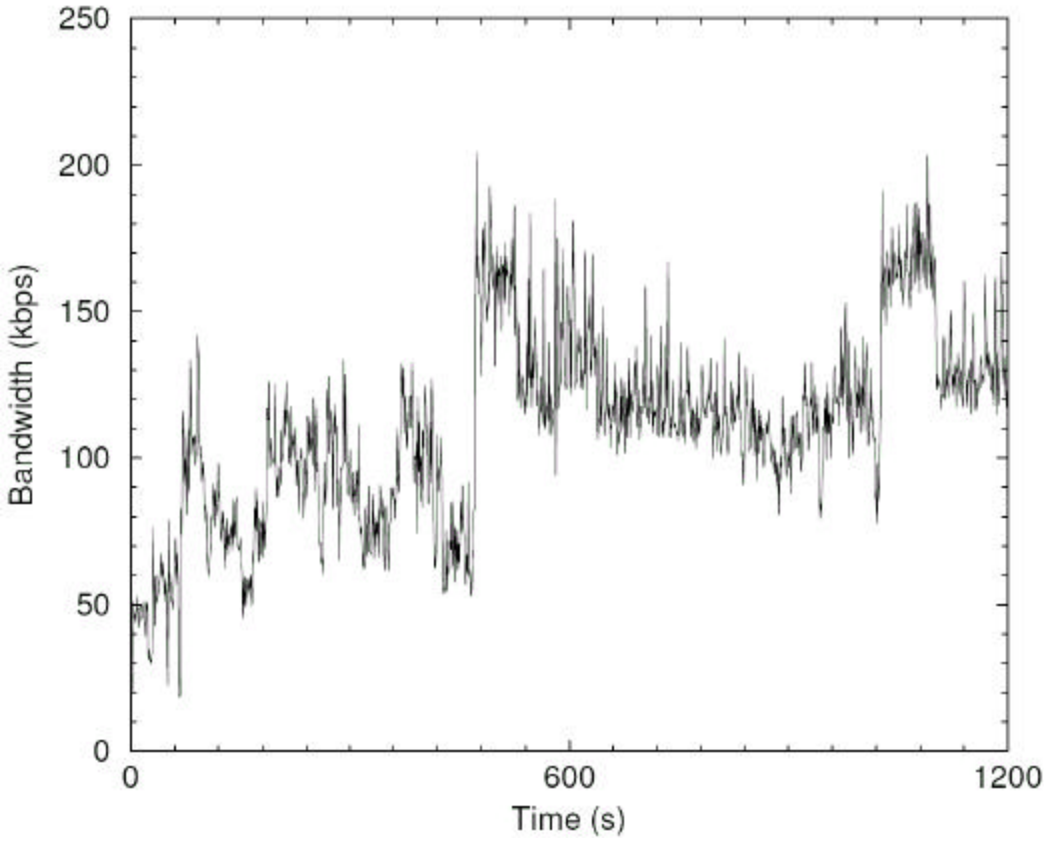
# Streaming worlds

- Traffic trace of Second Life
  - Clearly a broadband application
  - Navigating one of Intel's island (3D geometry only)

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# Streaming worlds

- Modern game engines equipped to do the same if network catches up
- Example: Unreal Engine 3
  - Supports streaming 3D geometry from disk
  - Allows for almost infinitely sized maps/worlds (HDD-limited)
  - Load world on-demand into main memory
  - Could be adapted to do so over the network, but high resolution streaming needs a lot of bandwidth
    - Source: Mark Rein, Microsoft Academic Days Game Conference 2005

# What are NetGames researchers to do?

- Doing more with less (the pessimist)
- Doing more with more (the optimist)
  - Streaming worlds
  - Security schemes to thwart cheating
  - New game architectures
- Expanding the definition of “network” (the opportunist)

# Security schemes to thwart cheating

- Cheating
  - Achilles heel of networked games
  - Causes legitimate players to quit
  - Creates bad word-of-mouth to discourage new players
  - Wrecks virtual economies

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# Security schemes to thwart cheating


Wallhack (CoD 2)

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# Security schemes to thwart cheating


Aimbots (Counter-Strike)

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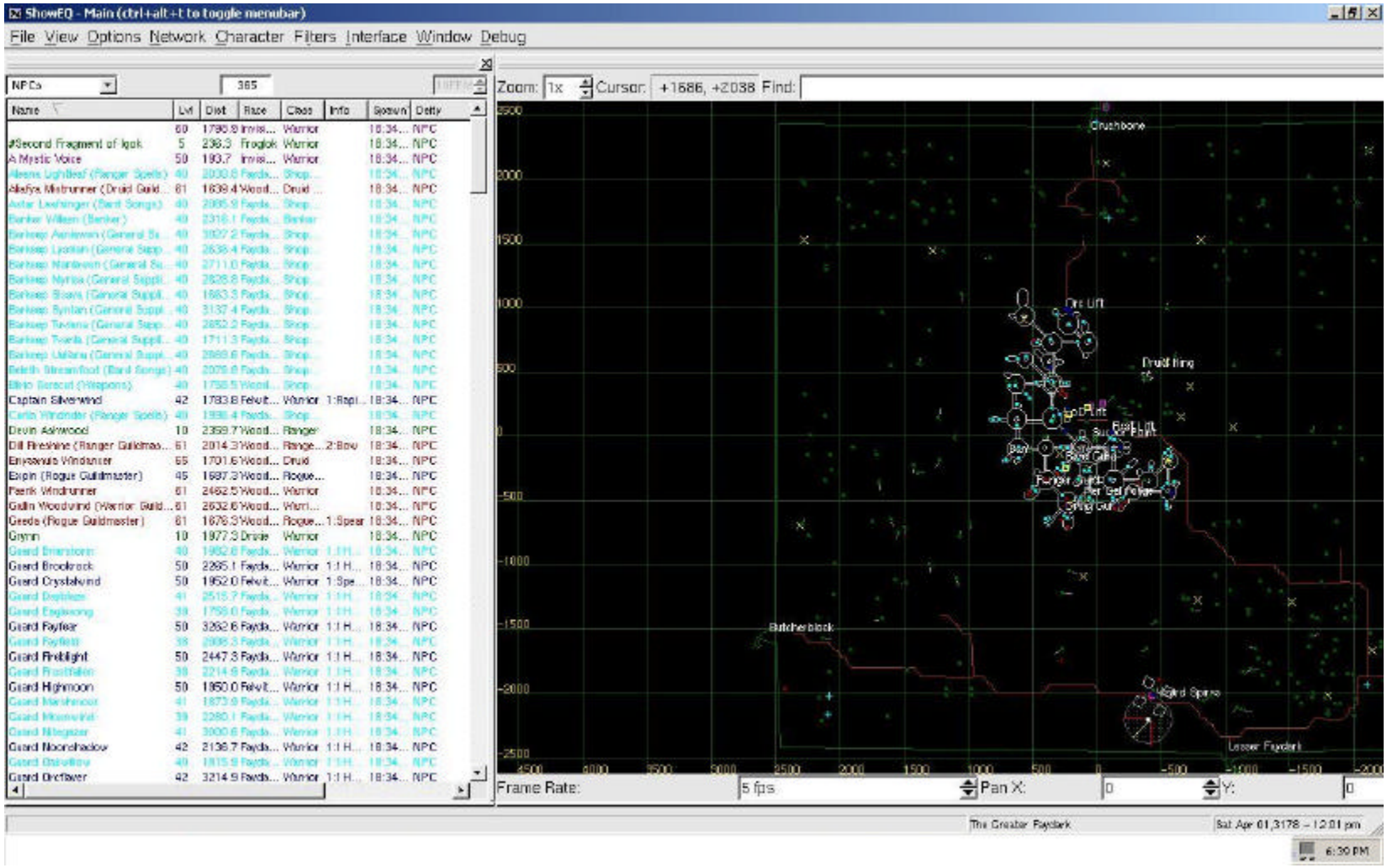
# Security schemes to thwart cheating




Maphack/Chesthack (EQ)

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# Security schemes to thwart cheating


Bots (WoW)

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# Security schemes to thwart cheating

- Example: Maphack in RTS games
  - Warcraft3


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# Security schemes to thwart cheating

- Example: Maphack in RTS games
  - Warcraft3 with Maphack
  - Reveal map and enemy units


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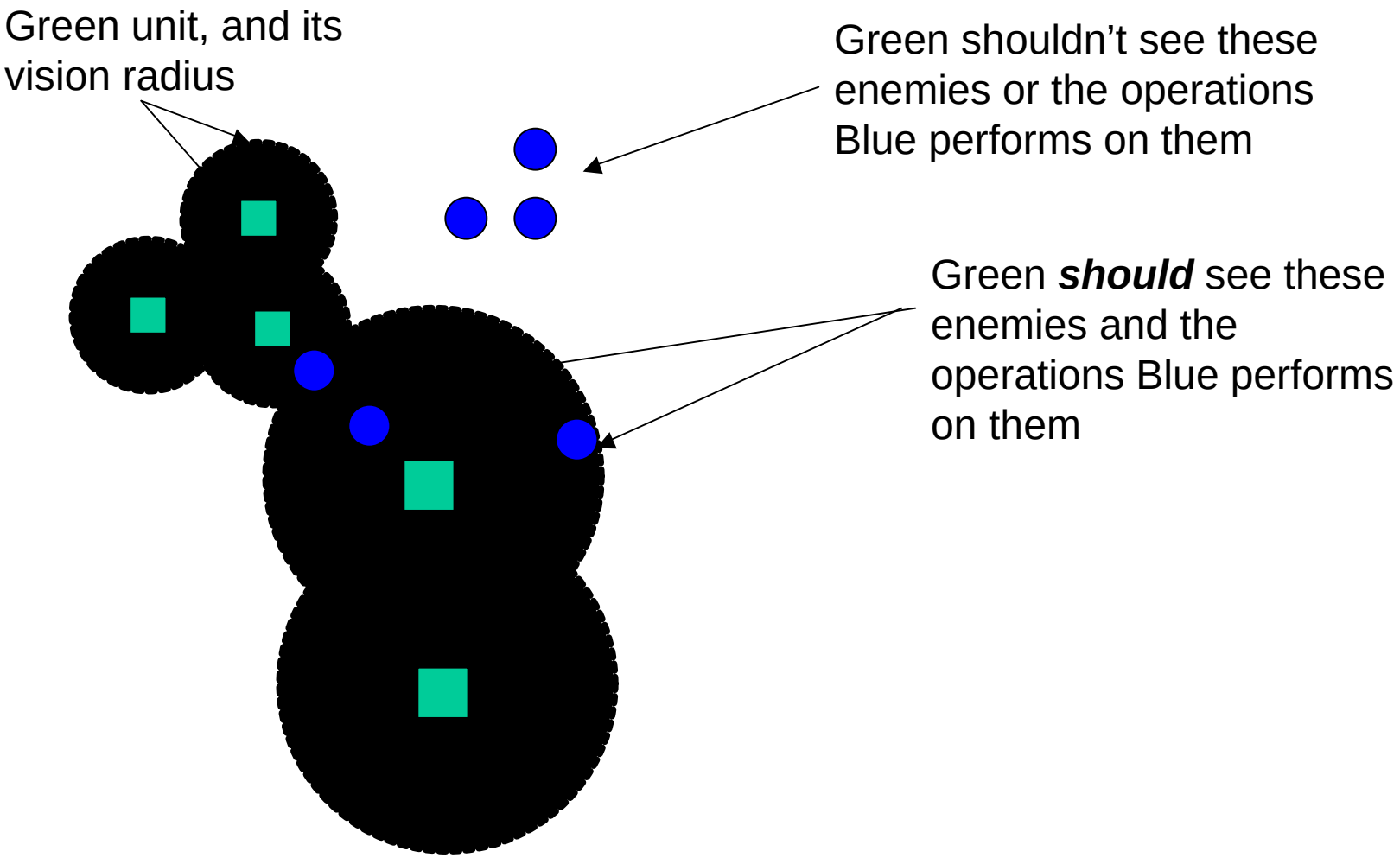
# Security schemes to thwart cheating

- Goal: Modify or create network game protocols that resist cheats
- RTS network game protocol
  - Exchange initial game state and all subsequent mouse clicks
  - Each player simulates identical copies of game
    - PRO: no one can lie about what units they have
    - CON: each player knows state of the entire game

# Security schemes to thwart cheating

- How it should work

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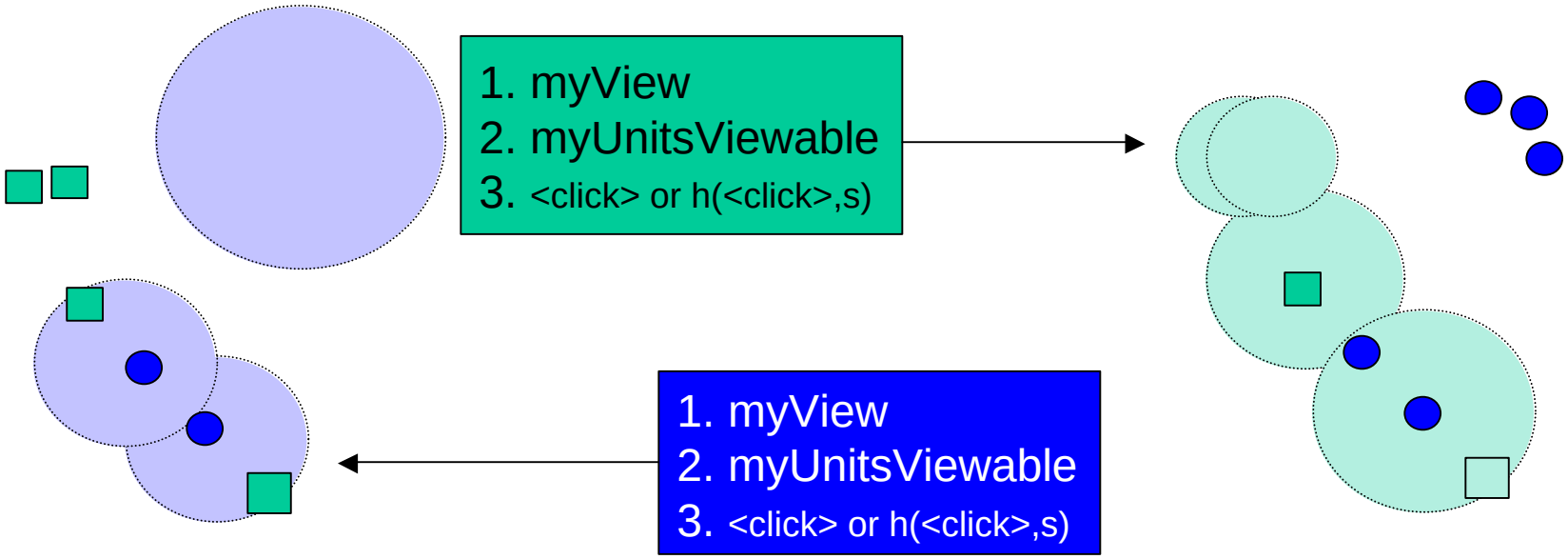
# Security schemes to thwart cheating

Applying bit commitment to RTS protocol

Key idea: You and your opponent only know each others "view area" not each others units

```
if (<click> is in oppView)
  send <click>
else
  send hash(<click>,secret)
```

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# Security schemes to thwart cheating

- Modified RTS network protocol
  - Pre-game
    - Create your secret s
    - Generate initial game state igs, send h(s,igs)
  - In-game
    - Each time slice, send (and receive)
      - Your viewable area
      - Either your move m, or, if it's invisible to him, h(s,m)
      - If one of your units just entered his area, send that unit
  - Post-game
    - Exchange your secret, initial conditions, and all hidden moves throughout the game
    - Verify opponent's integrity by simulating the game rapidly with the (now known) hidden moves

# Security schemes to thwart cheating

- Increased network requirements
  - Old way: bandwidth = number of clicks
  - New way: bandwidth = clicks or hash of clicks, viewable areas

C. Chambers, W. Feng, W. Feng, D. Saha, “Mitigating Information Exposure to Cheaters in Real-Time Strategy Games”, NOSSDAV 2005.

# Security schemes to thwart cheating

- Remote measurement
  - Keyboard, mouse activity
  - Screenshots



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# Security schemes to thwart cheating

- Game protocol integrity via message signatures
  - Proxy cheating
    - Send messages to “man-in-the-middle” proxy
    - Have proxy adjust your aim/movements automatically
    - Completely avoids host integrity checking being done by game itself (i.e. Warden)
  - Sign messages to prevent tampering within network
    - Signing key must be secured (i.e. kept away from player/game) for this to work
      - Intel AMT?
      - NIC?

# What are NetGames researchers to do?

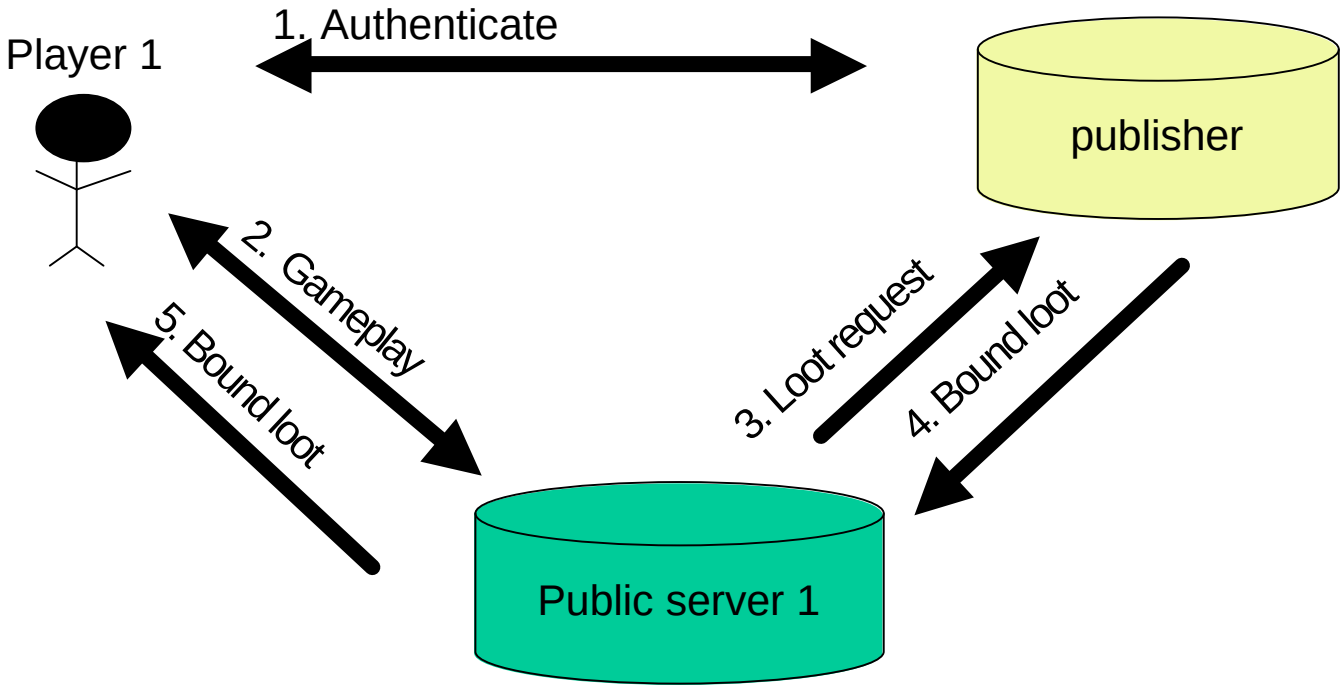
- Doing more with less (the pessimist)
- Doing more with more (the optimist)
  - Streaming worlds
  - Security schemes to thwart cheating
  - New game architectures
- Expanding the definition of “network” (the opportunist)

# New architectures

- P2P MMORPG
  - Each peer responsible for a region of MMO
  - Players handed off between adjacent peers as they move through virtual world
  - Network issues
    - Splitting world amongst active peers
    - Dealing with churn in P2P networks
    - Handing off players from peer to peer
  - See current and previous NetGames workshops

# New architectures

- Public-server MMORPG
  - Security protocols to prevent cheating
    - Game-based captchas to protect incentives based on authenticated player minutes
    - Loot authentication to prevent fabrication cheats
    - NetGames 2006



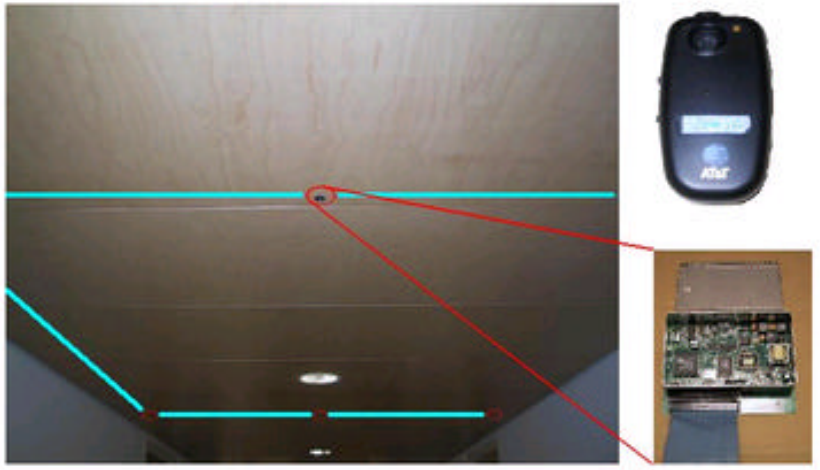

*W. Feng, "What's Next for Networked Games", NetGames 2007 keynote talk, Sept. 19-20, 2007.*

# What are NetGames researchers to do?

- Doing more with less (the pessimist)
- Doing more with more (the optimist)
- Expanding the definition of “network” (the opportunist)
  - Network at the client
  - Network at the server

# Network at the client

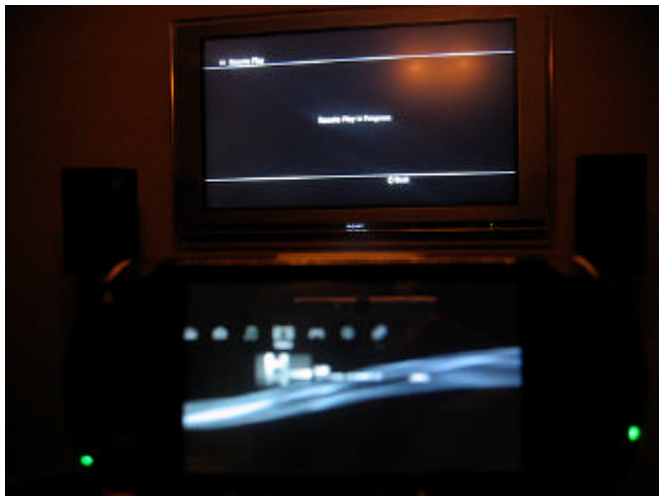
- Game controller
  - Nintendo Wii
  - ActiveBat (NetGames 2004)
    - Sensor localization
  - Real Tournament (NetGames 2003)
    - GPRS, 802.11 combination

*W. Feng, "What's Next for Networked Games", NetGames 2007 keynote talk, Sept. 19-20, 2007.*

# Network at the client

- Remote rendering
  - Example: PSP to PS3 RemotePlay
    - Now over ad-hoc WiFi
    - Soon over the Internet
  - Eliminate information exposure cheats





*W. Feng, "What's Next for Networked Games", NetGames 2007 keynote talk, Sept. 19-20, 2007.*

# Network at the server

- Holy grail of MMOs
  - A single virtual world with everyone in it
- Current games
  - Entire game application replicated into separate instances
    - Socket, thread, memory limitations
  - FPS
    - Single server with 32-64 players
    - Run 20,000 – 50,000 independent servers to support large numbers of users
  - MMORPG
    - Single server and DB with 5,000-10,000 players
    - Run hundreds of independent instances to support large numbers of users

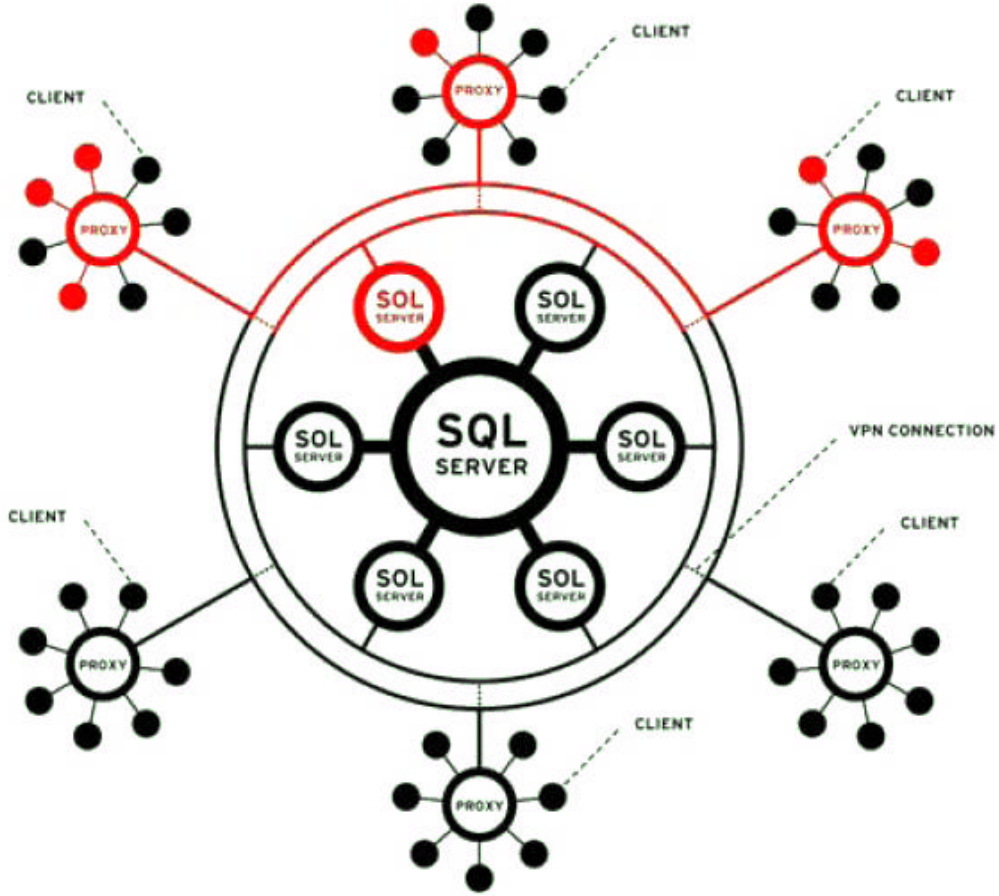
*W. Feng, "What's Next for Networked Games", NetGames 2007 keynote talk, Sept. 19-20, 2007.*

# Network at the server

- Parallel and clustered FPS server implementations
  - Parallel Quake II (Glenn Deen, OptimalGrid, IBM Research)
  - Clustered implementation with 70ms transition between nodes
  - ICPP keynote
    http://www2.dnd.no/icpp2005/keynote_icpp2005.pdf

# Network at the server

- EVE Online
  - Single shard MMORPG
  - 35,000+ simultaneous players

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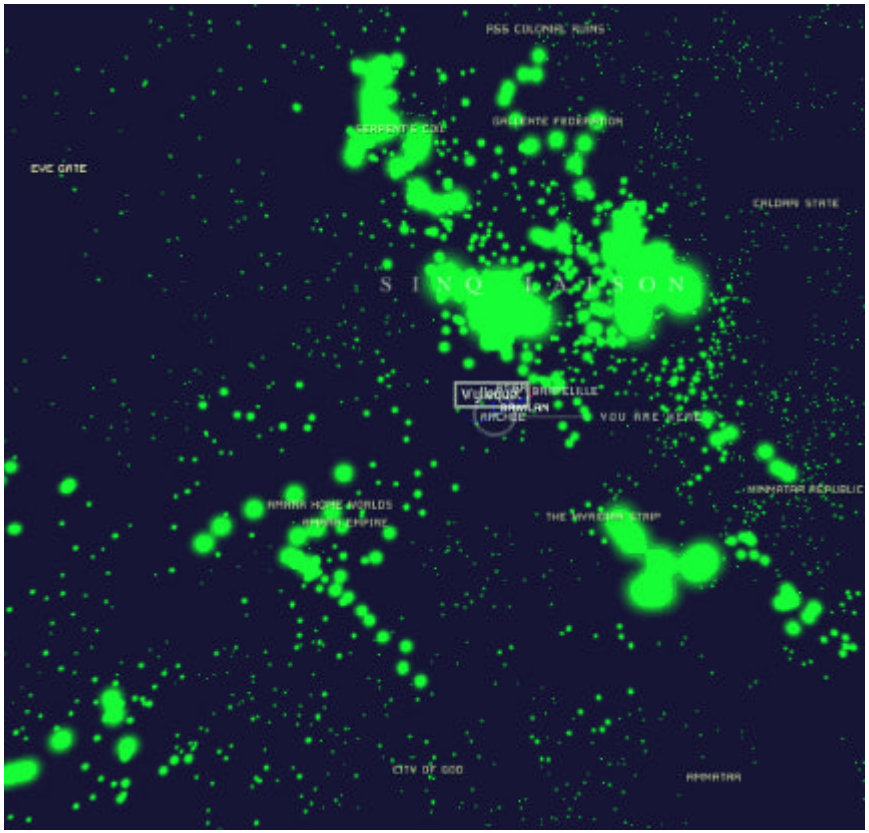
# Network at the server

- EVE Online requirements
  - Flexible scripting language
    - Interpreted languages for rapid prototyping and debugging
  - Massive per-entity multithreading (> 20,000)
    - Event-driven programming too difficult
    - Efficient threading, scheduling, synchronization
  - Transparent thread migration between processors
    - Serialization and migration of entity objects
    - Load is unpredictable across universe



# Network at the server

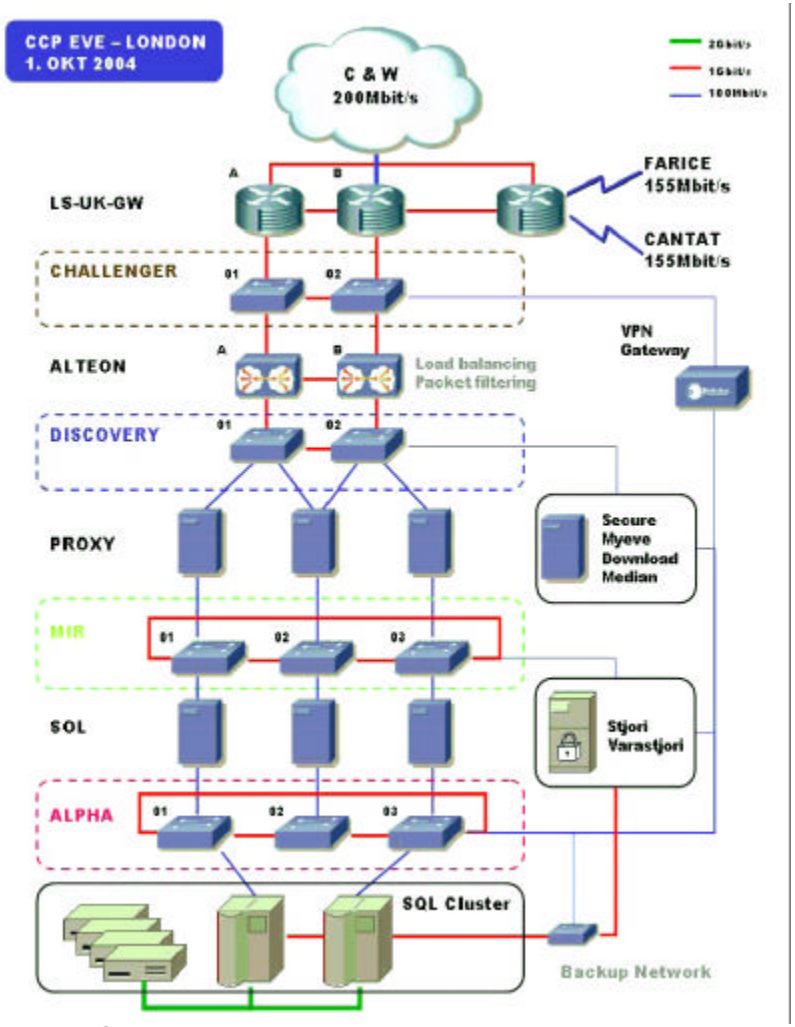
- Example scripting languages and engines for MMORPGs
  - Python (Eve Online, Civilization, Kaneva engine, BigWorld)
  - Lua (WoW)
  - UnrealScript (Unreal Engine games: e.g. Lineage II, America's Army, Deus Ex)
  - Torque (Torque game engine)

# Network at the server

- EVE Online
- Stackless Python http://www.stackless.com/
  - Cooperative user-level multithreading (minimize synchronization)
    - “Tasklets” and “microthreads” (think user-level threads and co-routines)
  - Heap-based stacks (vs. 1MB per pthread for OS threads)
    - Massive threads with slight heap overhead
  - O(1) RR scheduler (minimize scheduling)
  - “Pickling” (think Java serialization) to swap to disk and to migrate to other processors
  - Other known users
    - BigWorld game engine http://www.bigworldtech.com/
    - Butterfly.net

# Network at the server

- EVE Online architecture
  - Dynamic transparent load balancing on the back-end




*W. Feng, "What's Next for Networked Games", NetGames 2007 keynote talk, Sept. 19-20, 2007.*

# Summary

- An optimistic view
  - Networks are still relevant in networked games
  - Many interesting problems still to be solved
  - Might need to expand what we consider “NetGames” research to keep these workshops interesting!

# And finally, what I learned yesterday

- How to say “I was drunk” in Australia

  I got rotten

  I was quite ‘full’

  I was off my face

  I was stonkered

  I had the wobbly boot on

  I was a gutful of piss

# Questions?

# Extra

# NOSSDAV 2008

18th International workshop on
Network and Operating Systems Support for Digital Audio and Video
Braunschweig, Germany May 28-30, 2008

http://www.nossdav.org/2008/

Keep our track record of having the coolest session at NOSSDAV!

# Speed limits

- Dynamically limit what world data is sent
  - Data culling to conserve network bandwidth
    - Based on player movement (dead reckoning)
    - Based on viewable area
- Limiting size of world and its population
  - Battlefield 2142
    - 64 kbps connection = 16 players
    - 128-768 kbps connection = 32 players
    - > 1.5 Mbps connection = 64 players

*W. Feng, "What's Next for Networked Games", NetGames 2007 keynote talk, Sept. 19-20, 2007.*

# Going outside of the game

- Use the network to build communities
  - More examples
    - Gamespy Arcade/Arena/Comrade
    - UDPSoft/Yahoo! All-seeing-eye



*note talk, Sept. 19-20, 2007.*

# Streaming worlds

- Copycats coming
  - Playstation Home



*W. Feng, "What's Next for Networked Games", NetGames 2007 keynote talk, Sept. 19-20, 2007.*

# VoIP

- Voice communication within game common
  - Done in-band for most networked games
    - Audio is a low-bandwidth feature
  - Done out-of-band (e.g. Ventrilo, TeamSpeak)
    - Mandatory for going on raids with some guilds in WoW
    - In lieu of WoW voicechat