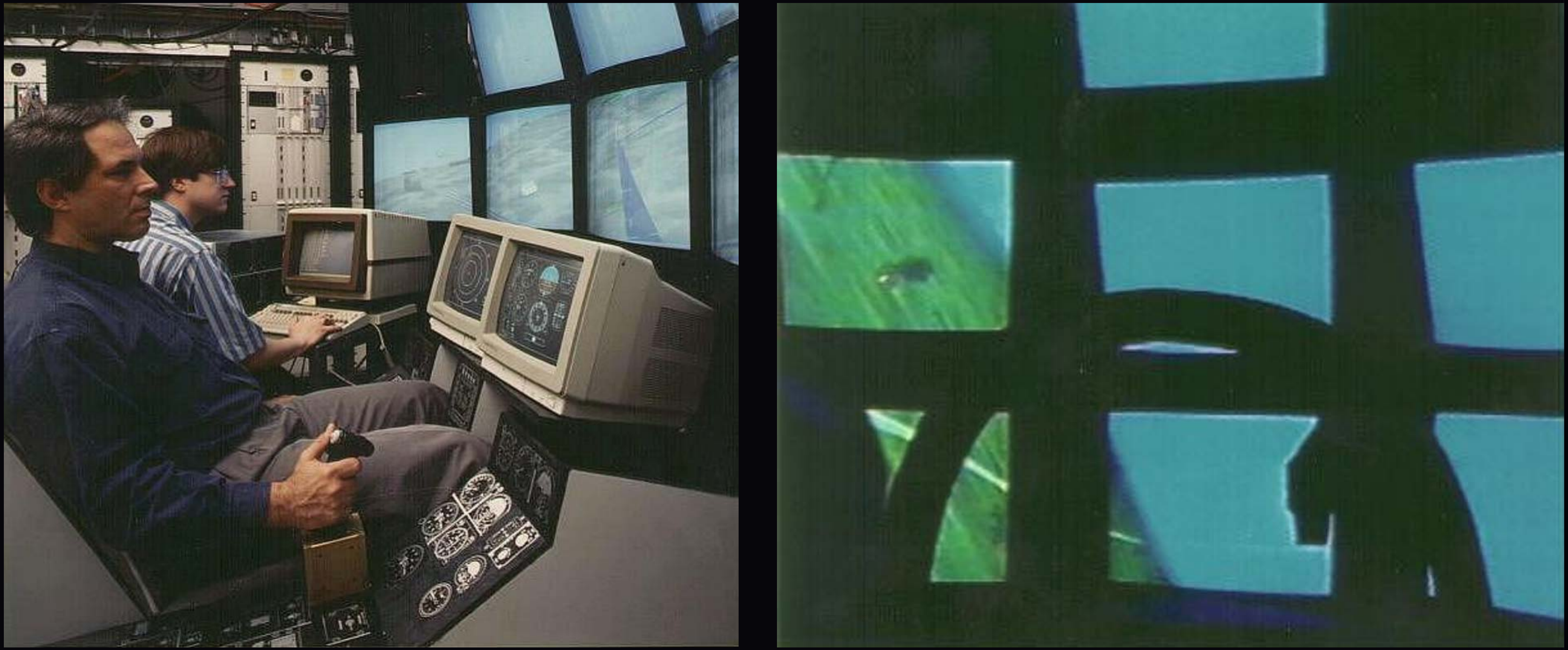
Introduction to Networked Graphics

- Part 1 of 5: Introduction

Overview

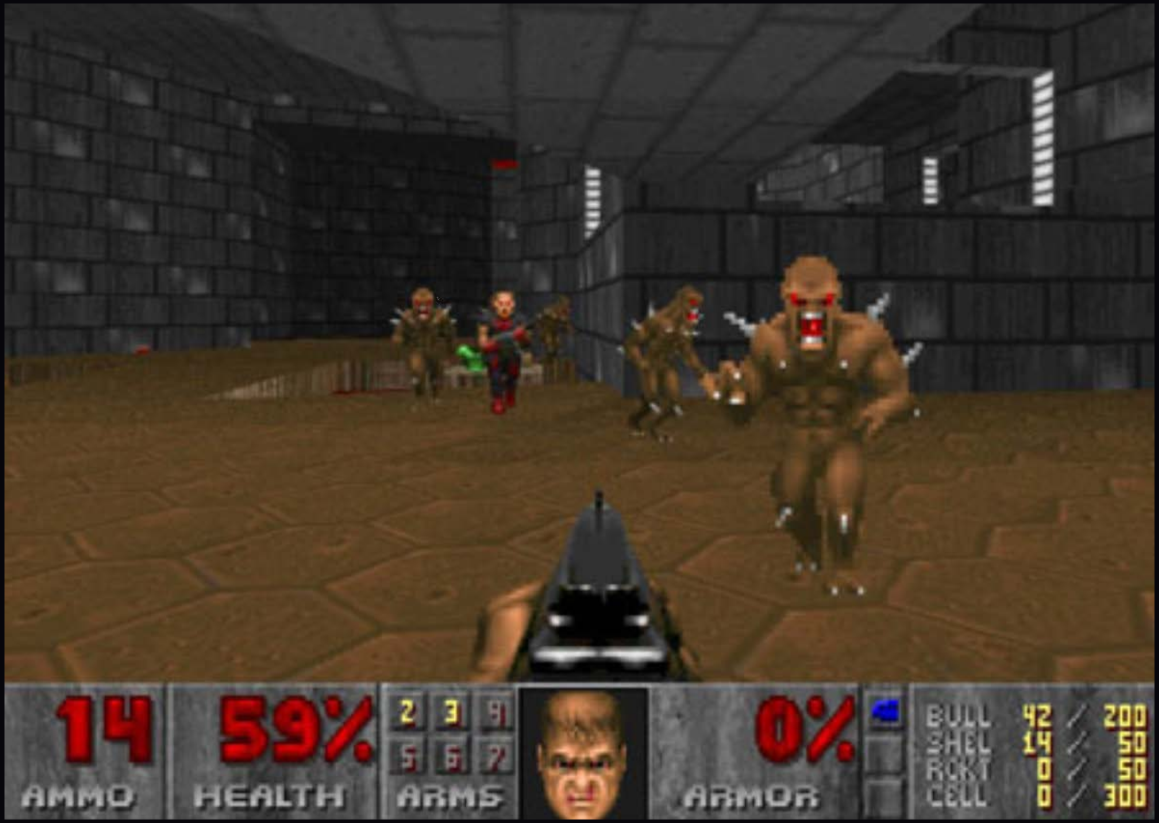
- Goal:
  - To give an overview of the networked graphics and the Internet
- Topics:
  - A very short history of networked graphics
  - Requirements for networked graphics
  - The Internet and TCP/IP stack
  - Basic protocol and architecture choices

SIMNET



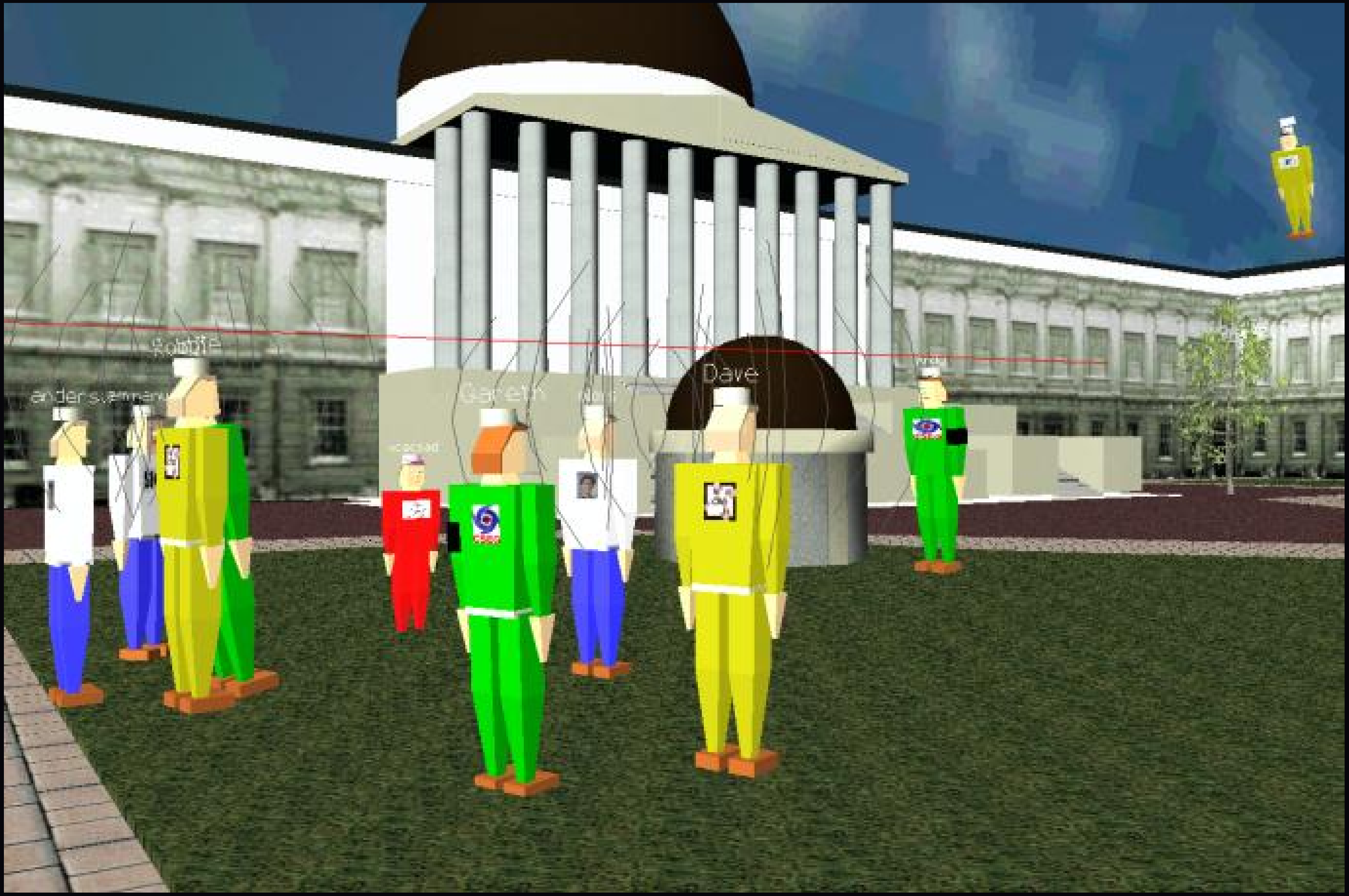
SIMNET aircraft simulation. Left: A view of the simulator control. Right: a view from the cockpit of an aircraft simulator. Images from (Harris, 1994)

DOOM



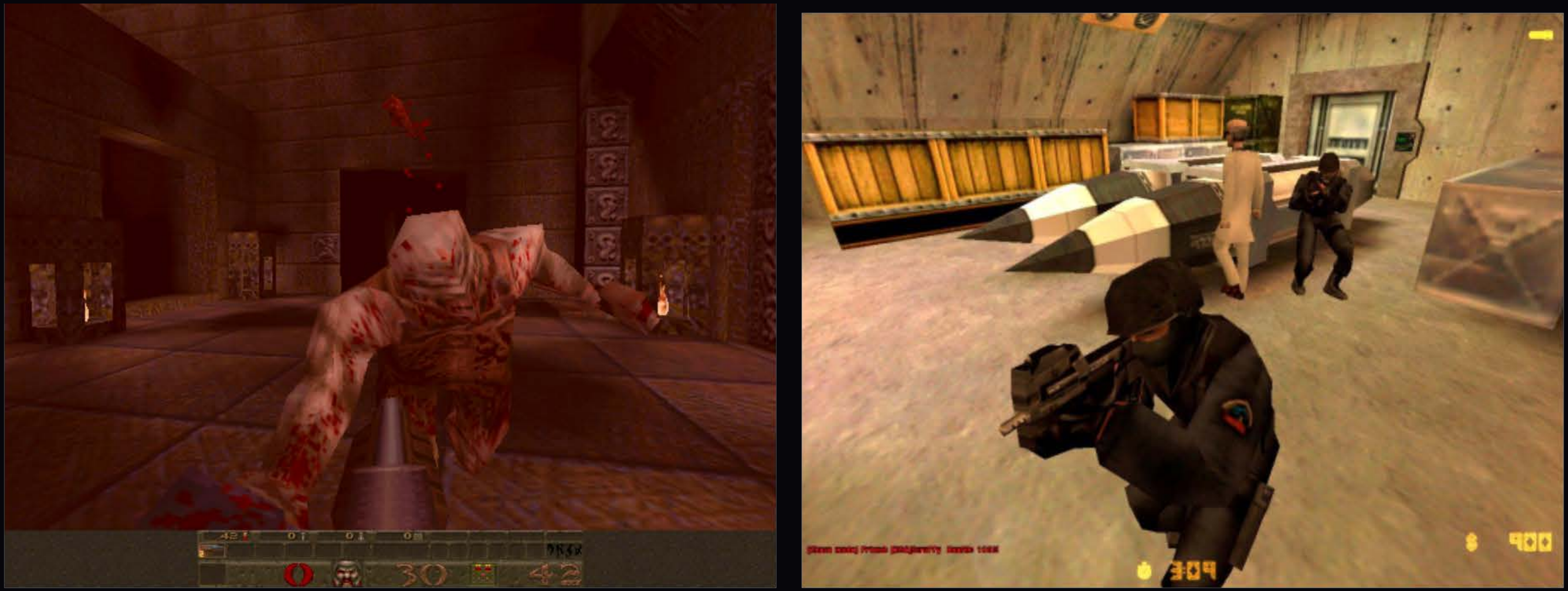
DOOM™ (iD Software) was the first multi-player first-person shooter to reach wide-spread public attention

DIVE



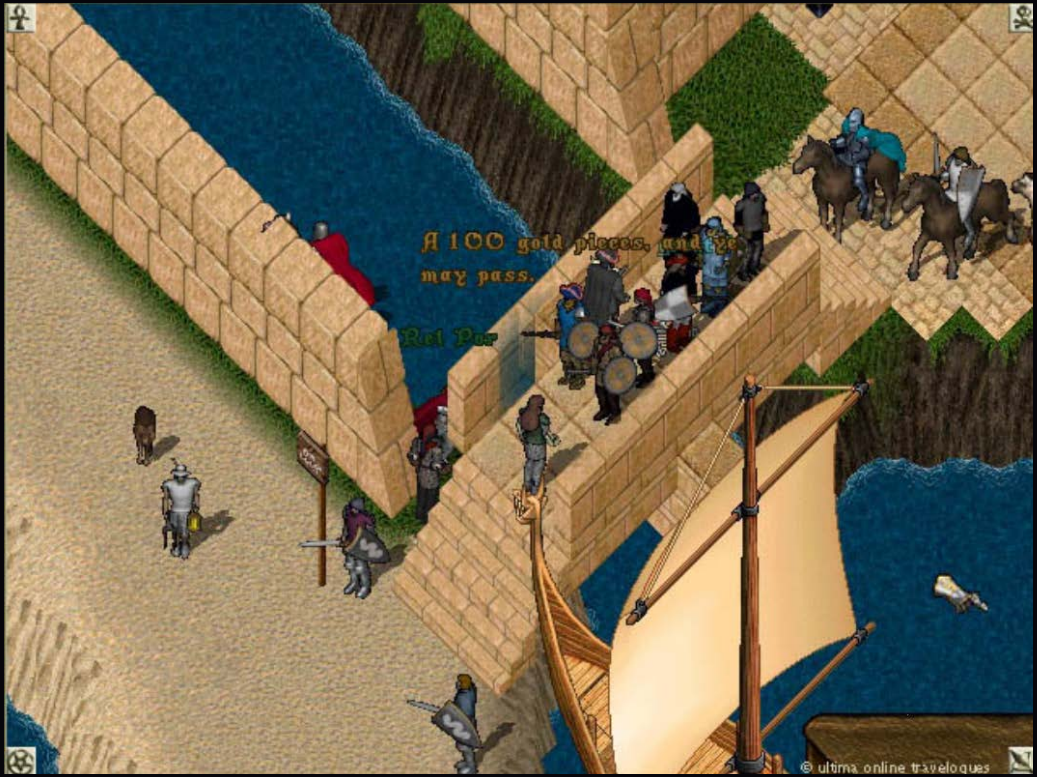
DIVE system from Swedish Institute of Computer Science. UCL scene in 1999 with spatialised audio amongst 16 participants.

Quake



Quake (id Software) brought true 3D and was the basis for several licensed games. Left: the original Quake game. Right: Counter-Strike (Valve Software), originally a modification of the game Half-Life which was based on Quake engine.

Ultima Online

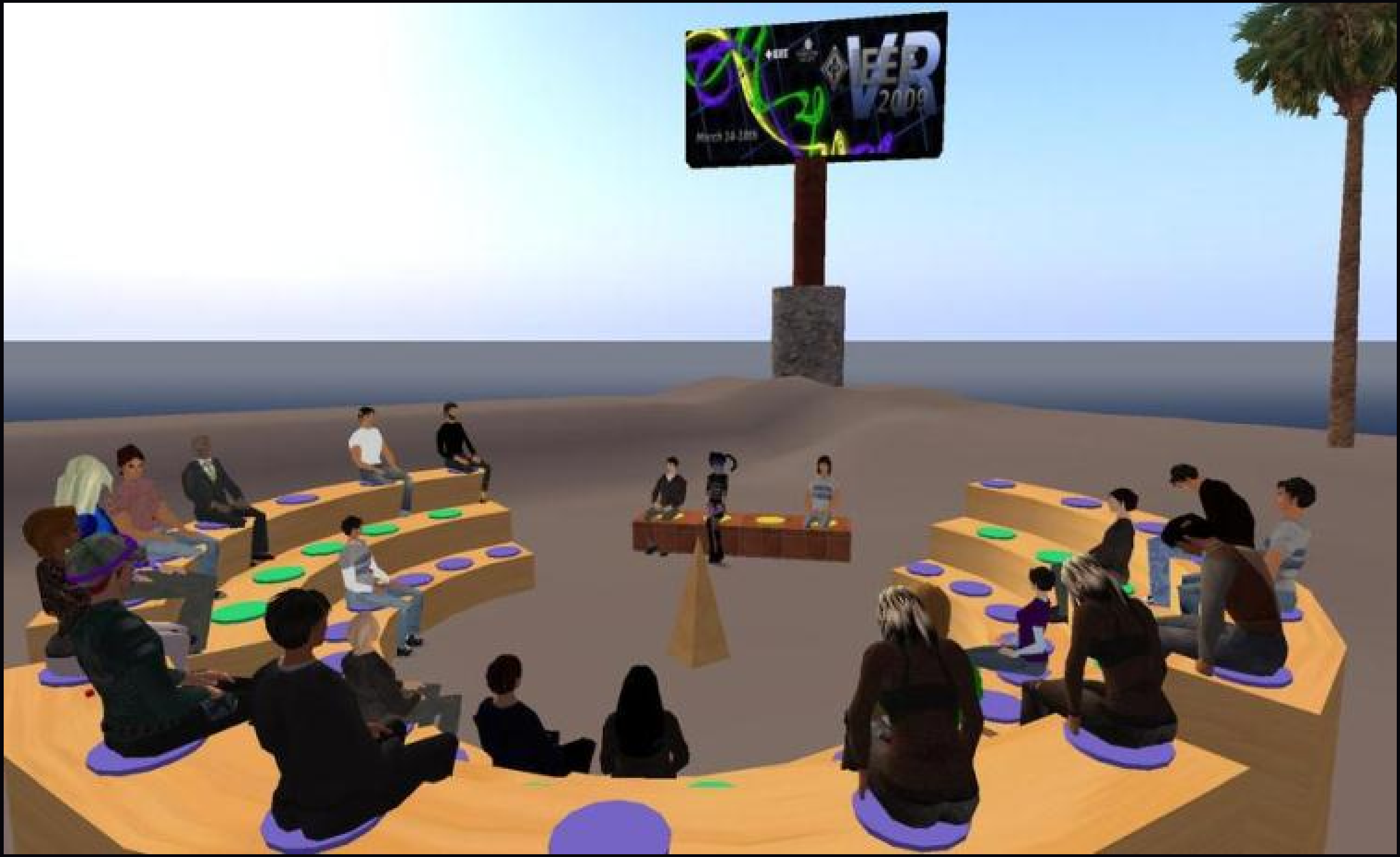


A 100 gold pieces, and ye may pass.

Rel Por

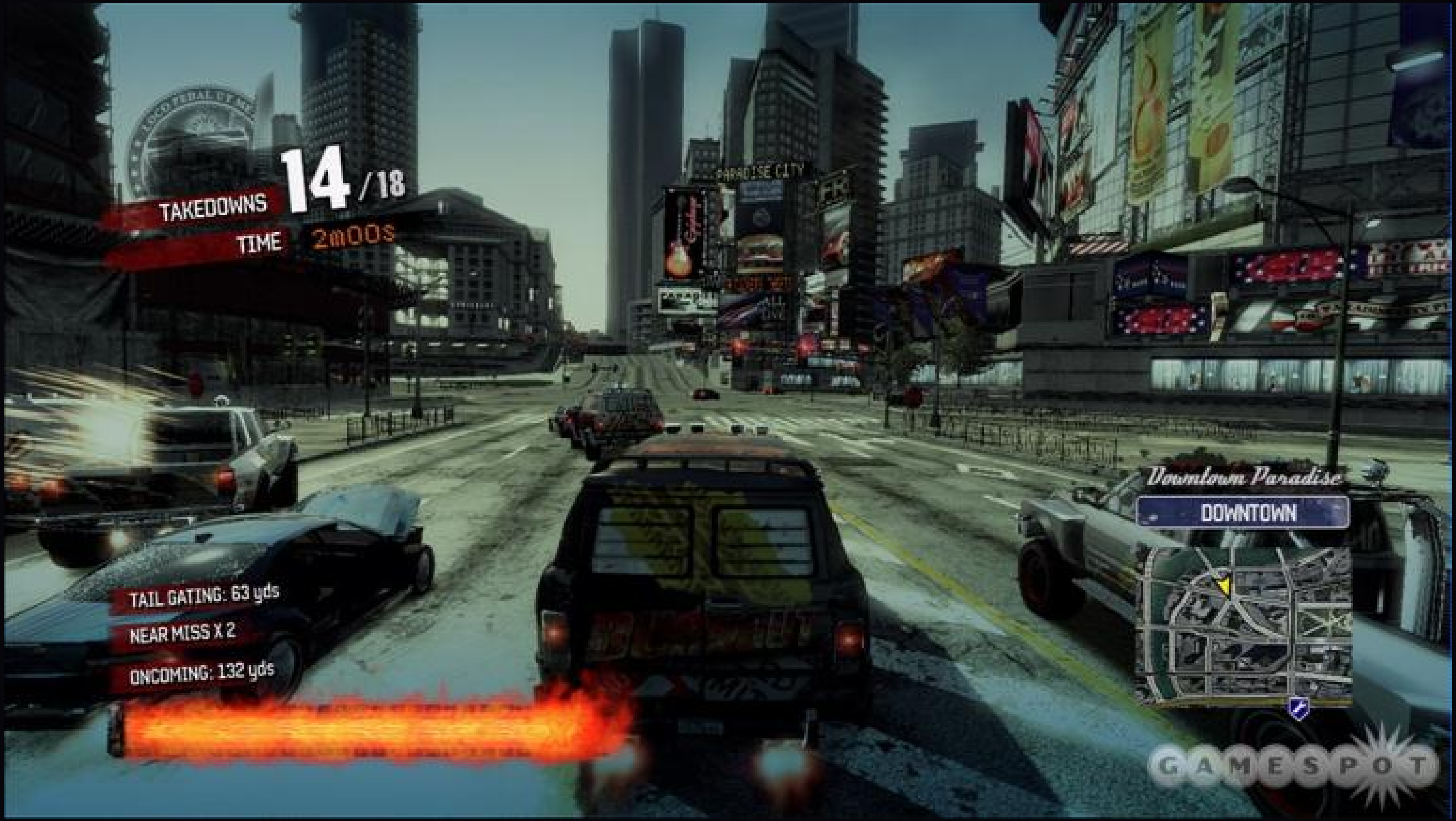
Pirates demanding tribute (Schultz, A., 2009)

Second Life



Two day conference papers panel in SecondLife

Burnout™ Paradise



Electronic Arts, Burnout™ Paradise

Common Themes

- A shared 3D virtual environment
  - Networked virtual environment (NVE) or networked games (NG)
- Real-time changes
- Collaboration with other users
  - Representation of users in the world (typically as avatars, but also cars/tanks/etc.)
  - Text and occasionally voice communication

Common Themes

- One *client* is usually responsible for generating the view for one user
- A set of clients creates the *illusion* of a shared virtual environment
- "Illusion" because
  - Virtual environments can involve detailed *models*
  - Information about changes in models takes time to travel across communication links

Consistency and Plausibility

- *Local plausibility* is the appearance of consistency of only local actions
- *Shared plausibility* is the appearance of properties being the same as observed by users
  - *Objects that are in the background need not be consistent*
  - *Further: only things that might be the focus of joint attention can be discussed and be different*
- A local implausibility might be an obvious thing to talk about!

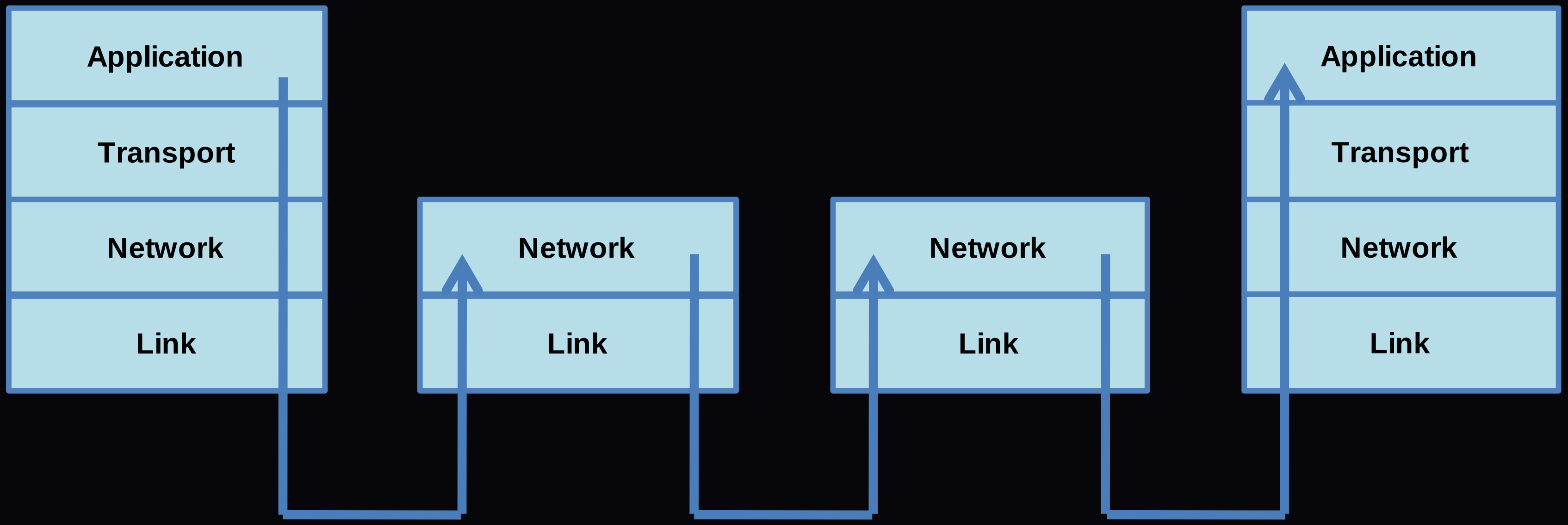
The Internet

- Networks at the heart of *networked* VR
- Many network protocols are out there
  - TCP, UDP, multicast, RTP, etc
  - Choice based on needs
- Properties of the Internet

IP Stack

Application	DHCP, DIS, DNS, FTP, HTTP, IMAP, RTP, SMTP, SSH, Telnet
Transport	TCP, UDP, RSVP
Network	IP, ICMP, IGMP
Link	Ethernet, 802.11, ADSL
Physical	copper wires, fibre-optic cable, radio waves

End to End Principle



- Only the end nodes know about the application. The network only sees IP packets. They don’t know about TCP or UDP, or HTTP, etc.

Application Layer Protocols

- Determine what *messages* are sent between applications
  - Messages defined by *syntax* and *semantics*
- Various standards for messages, typically set by RFCs (Requests for Comments) hosted by the IETF (Internet Engineering Task Force)

E.G. HTTP Request

- If you connect to *Host* www.cs.ucl.ac.uk at *Port* 80
- And then issue (type!) in ASCII the following message:

```
GET /staff/A.Steed/ HTTP/1.1
Host: www.cs.ucl.ac.uk
```

- And issues (type) two carriage returns
- You get …

...

```
HTTP/1.0 200 Document follows
MIME-Version: 1.0
Server: CERN/3.0
Date: Sun, 08 Feb 2009 15:25:18 GMT
Content-Type: text/html
Content-Length: 16150
Last-Modified: Wed, 21 Jan 2009 17:42:00 GMT

<?xml version="1.0" encoding="iso-8859-1"?>
<!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Transitional//EN" "http://www.w3.org/TR/xhtml1/DTD/xhtml1-transitional.dtd">
<html xmlns="http://www.w3.org/1999/xhtml" lang="en" dir="ltr">
<head>
<meta http-equiv="Content-Type" content="text/html; charset=iso-8859-1" />
<meta name="keywords" content="A. Steed, Anthony Steed, Department of Computer Science, University College London, virtual environments, virtual reality, computer graphics" />
```

Application Protocol Descriptions

- Often ASCII preamble with binary assets inserted at known or marked positions
- Some messages are designed to be carried over a reliable stream and are of unknown length (likely to be over TCP)
- Some messages are small and it is not important if they get lost (likely to be over UDP)

Common Application Protocols

Service Full Name	Short Name	Port	Transport
File Transfer Protocol	ftp	21	tcp
Simple Mail Transfer	smtp	25	tcp
Domain Name System	dns	53	udp
Finger	finger	79	tcp
HyperText Transfer Protocol	http	80	tcp
Post Office Protocol (Version 3)	pop3	110	tcp
Internet Message Access Protocol	imap	143	tcp
Hypertext Transfer Protocol Secure	https	443	tcp
File Transfer Protocol Secure	ftps	990	tcp
Distributed Interactive Simulation	dis	3000	udp
BZFlag Game Server	bzflag	5154	tcp
Quake Game Server	quake	26000	udp

Domain Name Service (DNS)

- Maps fully qualified domain names (narok.cs.ucl.ac.uk) to their IP addresses (128.16.5.123)
- Is a network service, thus takes time
- Time is variable because it's a hierarchical search
- Local DNS caches query responses for a time (e.g. 24 hours)
- Otherwise needs to query a canonical domain

Transport Layer Protocols

- User Datagram Protocol (UDP)
  - Send a message (datagram) and forget about it
  - No guaranteed delivery
  - No guaranteed ordering
- Transmission Control Protocol (TCP)
  - Guaranteed, in-order stream of data from one host to another

UDP

- All hosts on the Internet have an IP address
- How does the network know which program wants it?
- You additionally need (for UDP and TCP) a port number
  - These are 16 bits numbers, so must lie in the range 0-65535
  - Some are reserved, see later
- Processes listen for incoming UDP packets
- Need to check the packet for consistency

TCP

- In comparison to UDP, TCP offers:
  - A connection-oriented services with bi-directional (full-duplex) communication
  - Reliable transmission of messages
  - Congestion avoidance, using variable rate transmission
  - In order, and non-duplicate delivery of information
- Applications add messages to an outgoing buffer
- The buffer is streamed in packets to the receiver
- The receiver reconstructs the buffer and extract packets

TCP is Bi-Directional

- Even if, logically, data only flows one way, in order to ensure reliability, we need return data which tells us which data has been successfully received (ACK)
- The sender must maintain the buffered data until it receives an ACK
- ACKs can waste space if the traffic is mostly one way!

TCP Fairness

- How does TCP decide when to send packets
  - With UDP you call “send”!
- It sends packets within increasing frequency but when they start going missing, it halves its rate
- There are LOTS of variants of TCP
- Protocols are often tested to see if there are TCP-fair, i.e. if N streams share a network link they get 1/N of the bandwidth
- UDP protocols are often NOT TCP-fair, you need to add that functionality yourself

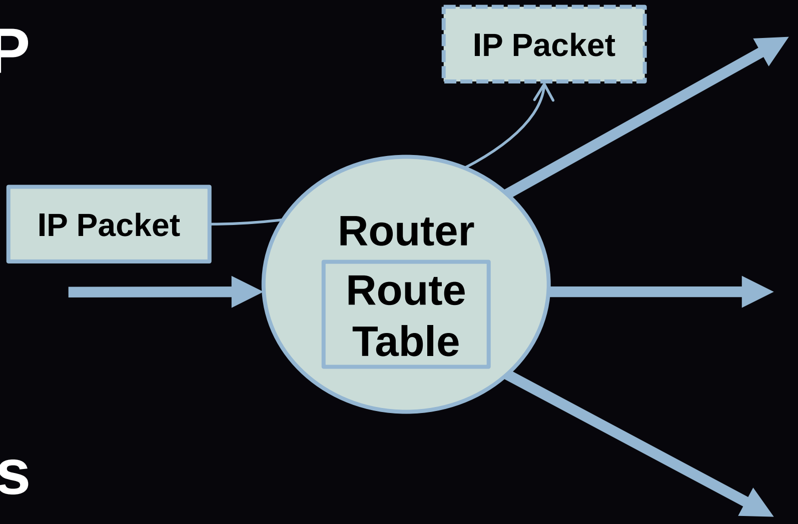
Observations

- If there is lots of data to send TCP can fill up IP packets, UDP might waste network capacity
- There are potentially lots of ACK packets in TCP
- TCP is slow to start, UDP is rapid start
- UDP protocols need to play fair when there is congestion

- Specifically for NVEs & NGs, TCP repair is probably redundant a lot of the time because more up to date data has already been generated by the simulation

Network Layer

- The Internet is a collection of machines that understand IP packets
- A network routes packets from one host to another through routers
- In IPv4 addresses are 32 bits in the form 128.16.13.118
- They are running out and IPv6 is ready to be deployed



IP Packets

- Key problem is what happens if links support frames of different size
  - E.G. Ethernet is 1500bytes
- The solution is that IP supports packet fragmentation, where a large packet is broken in to smaller ones: the end point must then reassemble them
- Obviously try to pick a *maximum transmission unit (MTU)* that avoids this

IP Packet Format

Bits	0		15	16	31
0-31	Version	Header Length	Type of Service	Total Length	
32-63	Identification			Flags	Fragment Offset
64-95	Time to Live		Protocol	Header Checksum	
96-127	Source Address				
128-159	Destination Address				
160-191	Options (Optional)				
160+ 192+, 224+, etc.	Data				

Link and Physical Layer

- The one we all have experience with is Ethernet, either wired or wireless
- Our experience is that for a specific Ethernet interface, we either need to:
  - Set IP address manually
  - Get an address automatically using DHCP
- DHCP is actually an application-layer protocol
- In both cases, we are making a mapping between the MAC address of the Ethernet adapter and the IP address

Basic Architectures and Protocols

- A single connection might be established, but how should a set of clients be connected
- Two basic models are possible
  - Peer to Peer
  - Client/Server
- There are various hybrids that use multiple servers

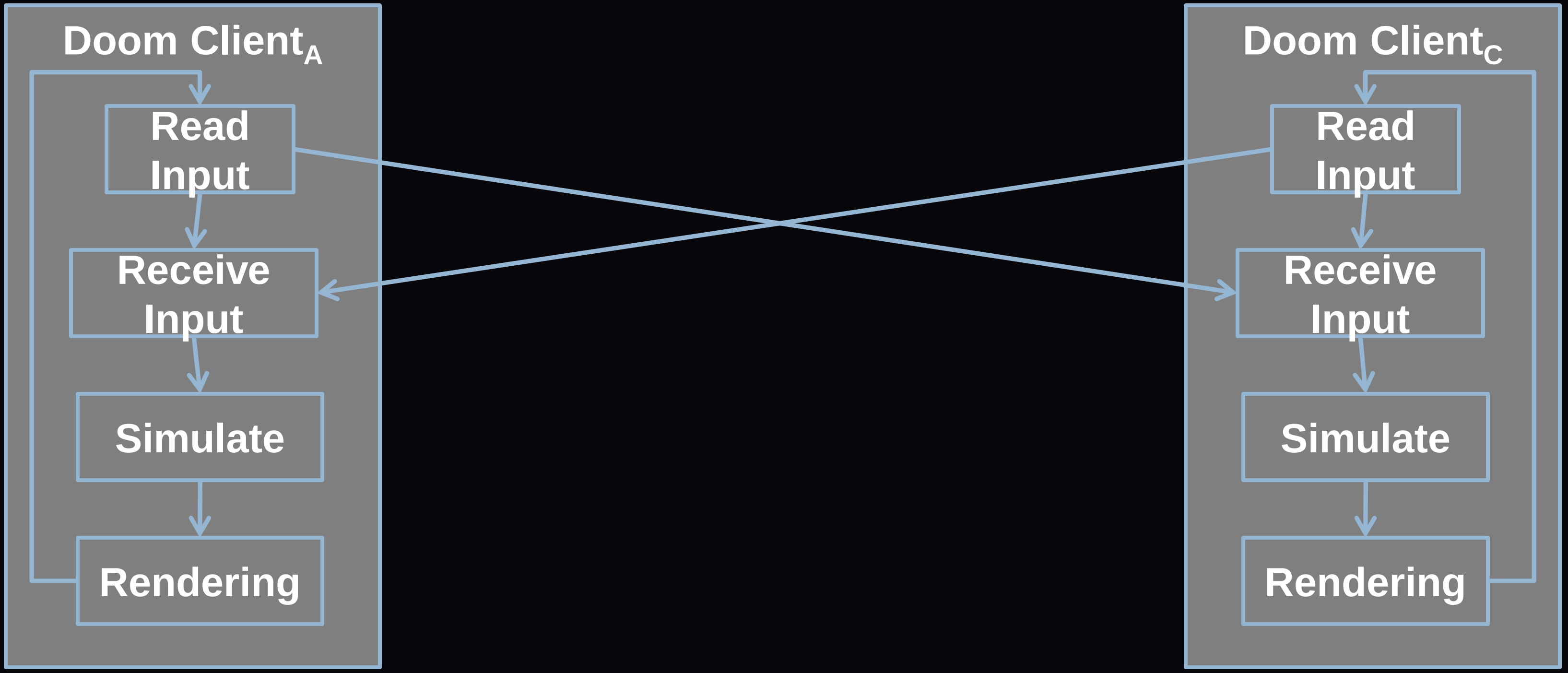
Consider Just Two Machines

- What is the relationship between them?
- Peers?
- Master/slave? Client/server?
- Does one have data the other one does not?

Peer to Peer with Two Clients

- Need to decide separation of responsibilities
  - E.G. Each client simulates one player’s actions
- Need to communicate sufficient information to the other that they can get both get the same state
- Assumes that they have the same information other than real-time input
- Can be achieved simply with sending input to each other

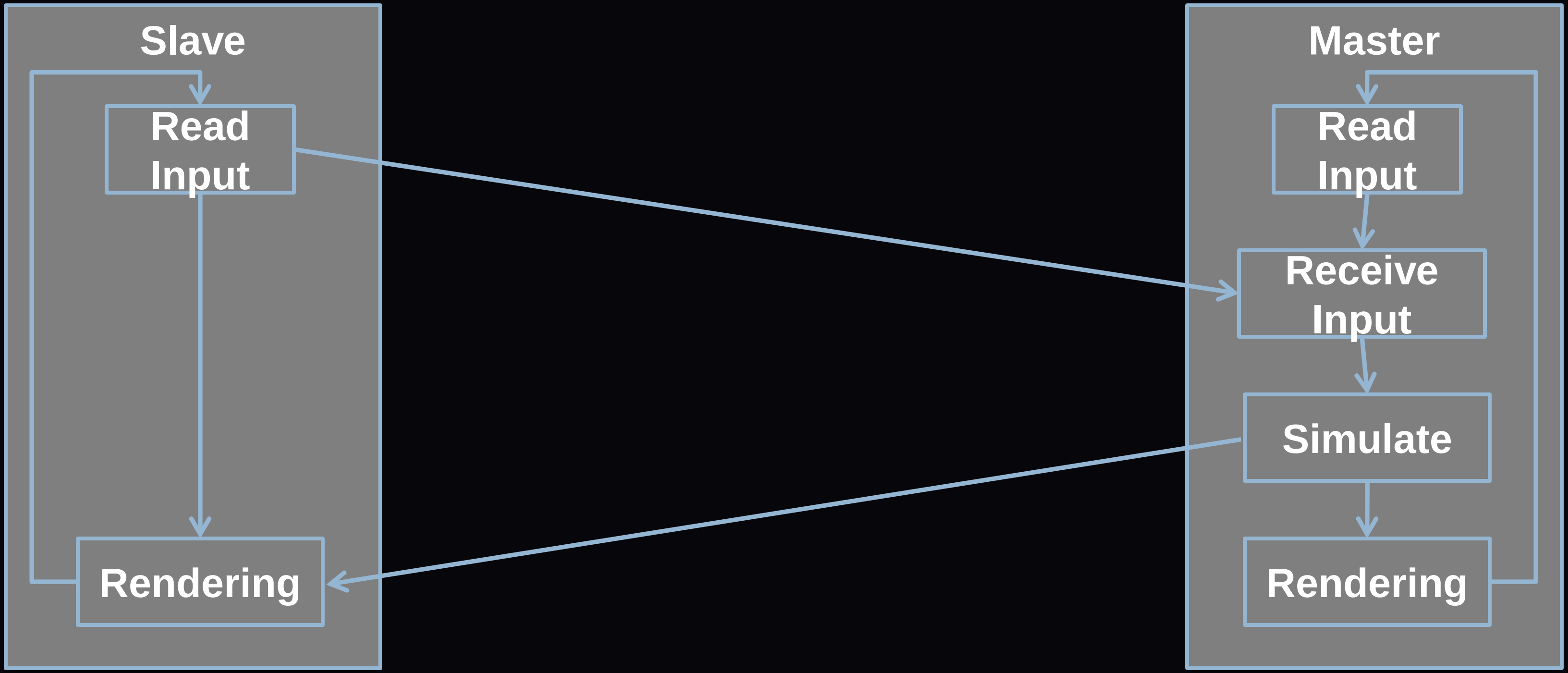
For Example DOOM



Master Slave with Two Clients

- One process calculates results of input and distributes it to the others
- Necessary if simulation is non-deterministic
- Many examples. E.G. Fable II from Lionhead/ Microsoft Games Studio

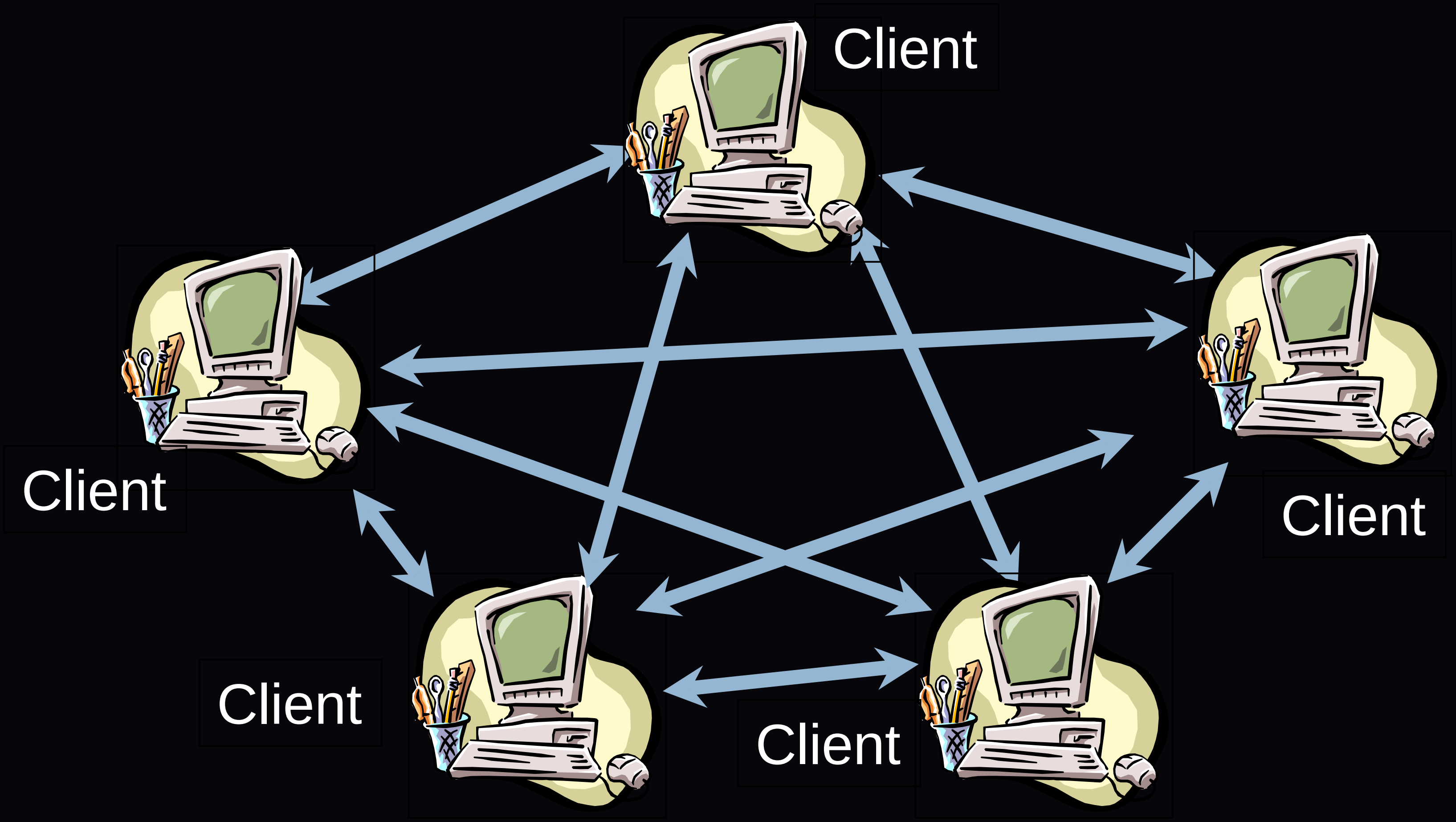
For Example


Slave
Read Input
Rendering
Master
Read Input
Receive Input
Simulate
Rendering

More Clients

- The same issues exist:
  - Who is responsible?
  - Who has the necessary data to evolve the state?
  - Who can be trusted to evolve the state?

Peer to Peer Architecture


Client
Client
Client
Client
Client