Networked Virtual Environments

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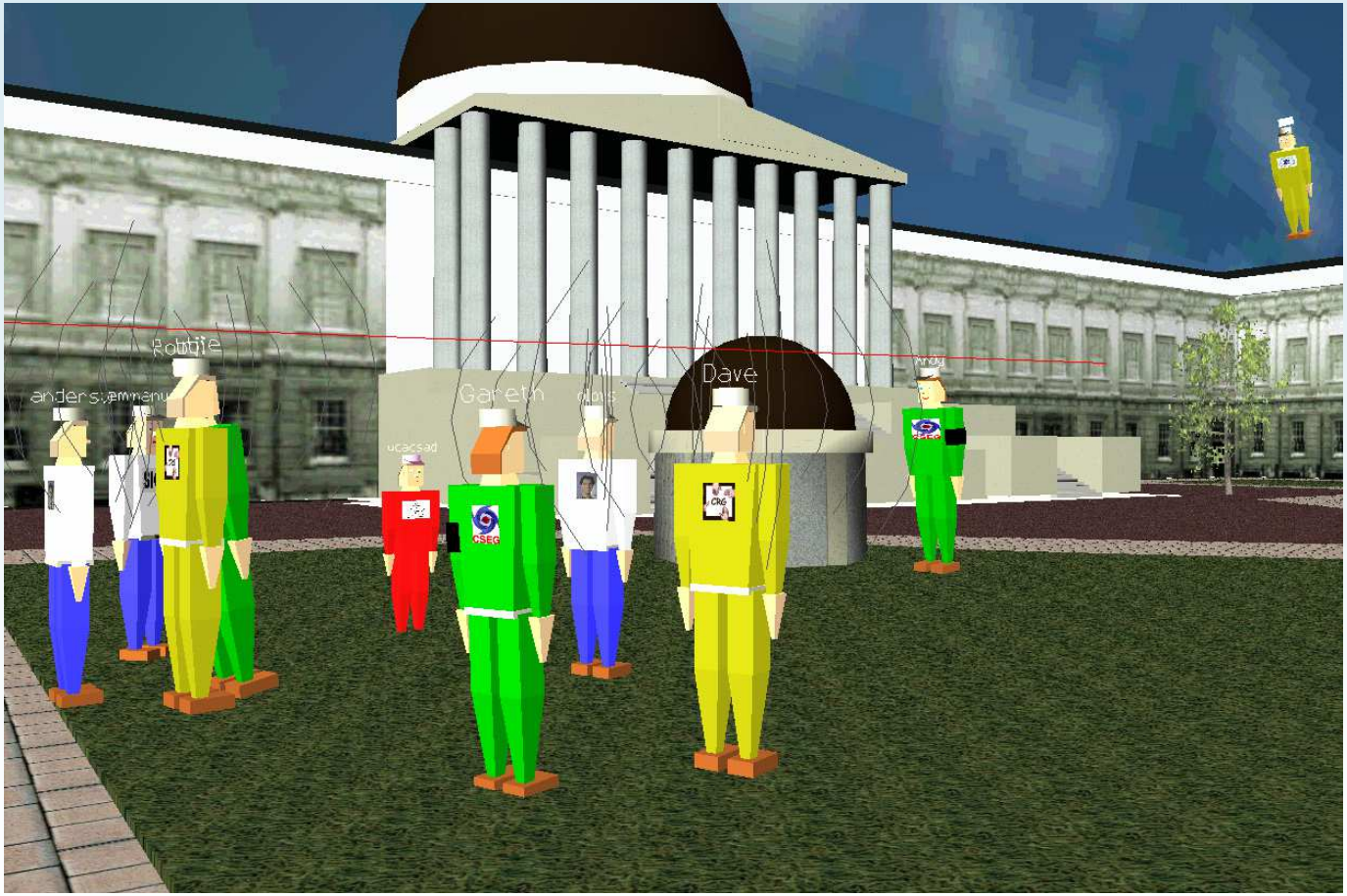
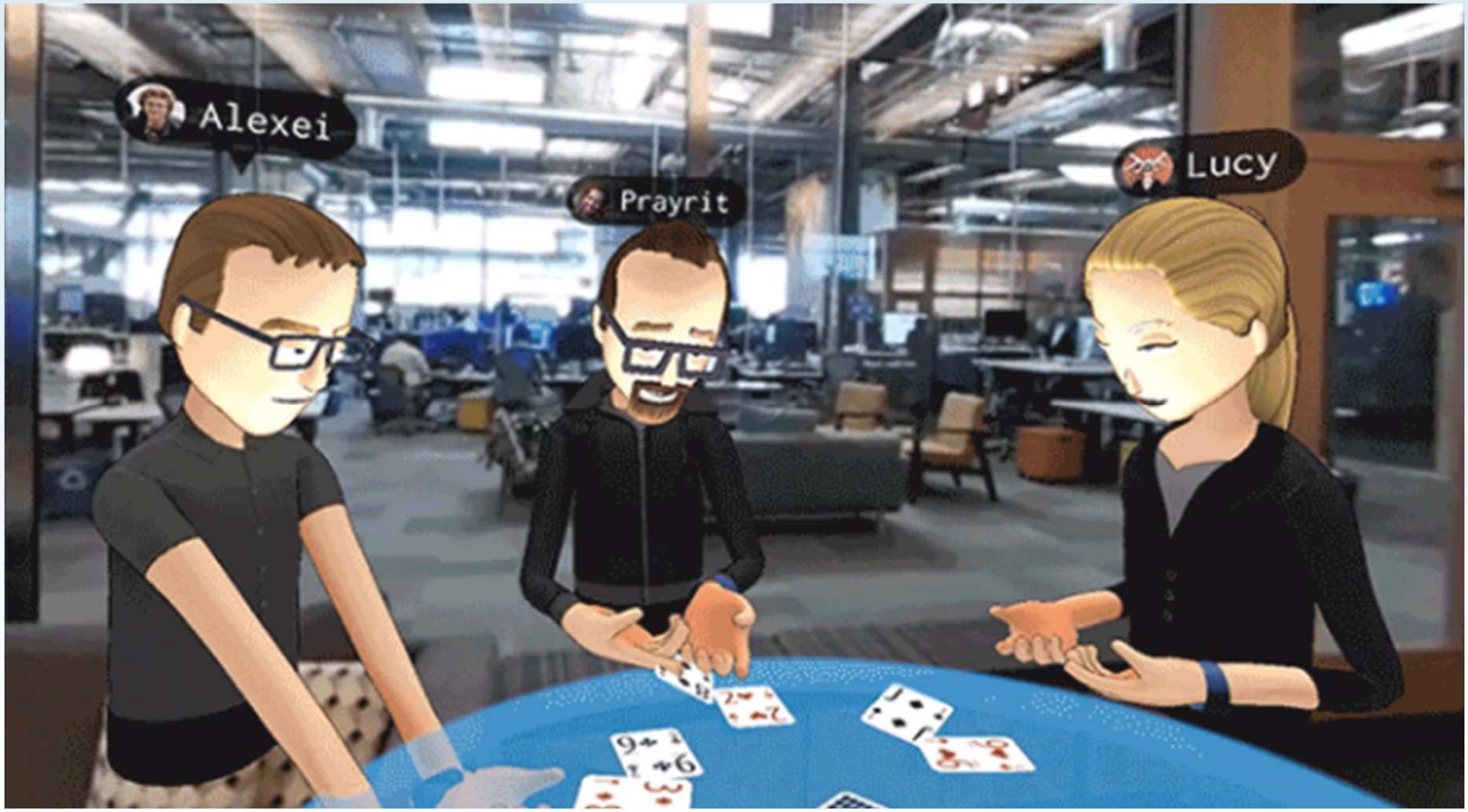
With material from Sebastian Friston

Topics

1. **Goals**
2. The Internet
3. Strategies
4. Latency
5. Scalability



DIVE “London Demonstrator”, UCL & colleagues 1999



Facebook Social VR Demo, Oculus Connect 3, September 2016

Consistency and Plausibility

- Goal is the illusion of a consistent shared state
- Local plausibility is the appearance of consistency of only local actions (e.g. physics & collision detection appears to work)
- 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!

Technical Requirements

- Synchronise multiple scenes
  - E.G. copy a scene graph between different sites
- Support communication
  - Include voice, perhaps video
  - Track and show the users to each other (as icons/cars/full-body avatars)
- Allow different types of interaction
  - Individual interacting with a single object independently
  - Joint interaction
- Do all of this over the Internet

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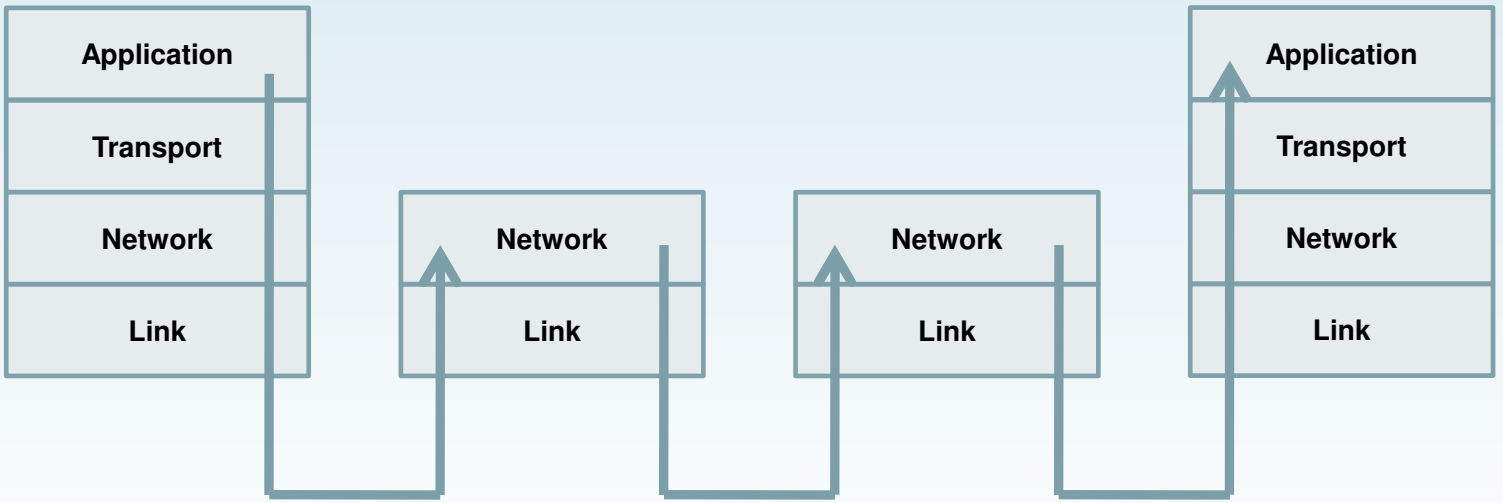
Internet Protocol - IP

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

Routing


Application
Transport
Network
Link
Network
Link
Network
Link
Application
Transport
Network
Link

Network properties

- Latency (Round Trip Time)
  - Devices take time to send data (e.g. Modems)
  - Data takes time to transmit (speed of light)
- Jitter
  - Routers insert buffering
- Bandwidth (Capacity)
  - Bandwidth costs money
  - 100Mbps is fairly standard @£30/month
- Loss (Congestion, Reliability)
  - Routers drop packets, links do go down, routes do fluctuate

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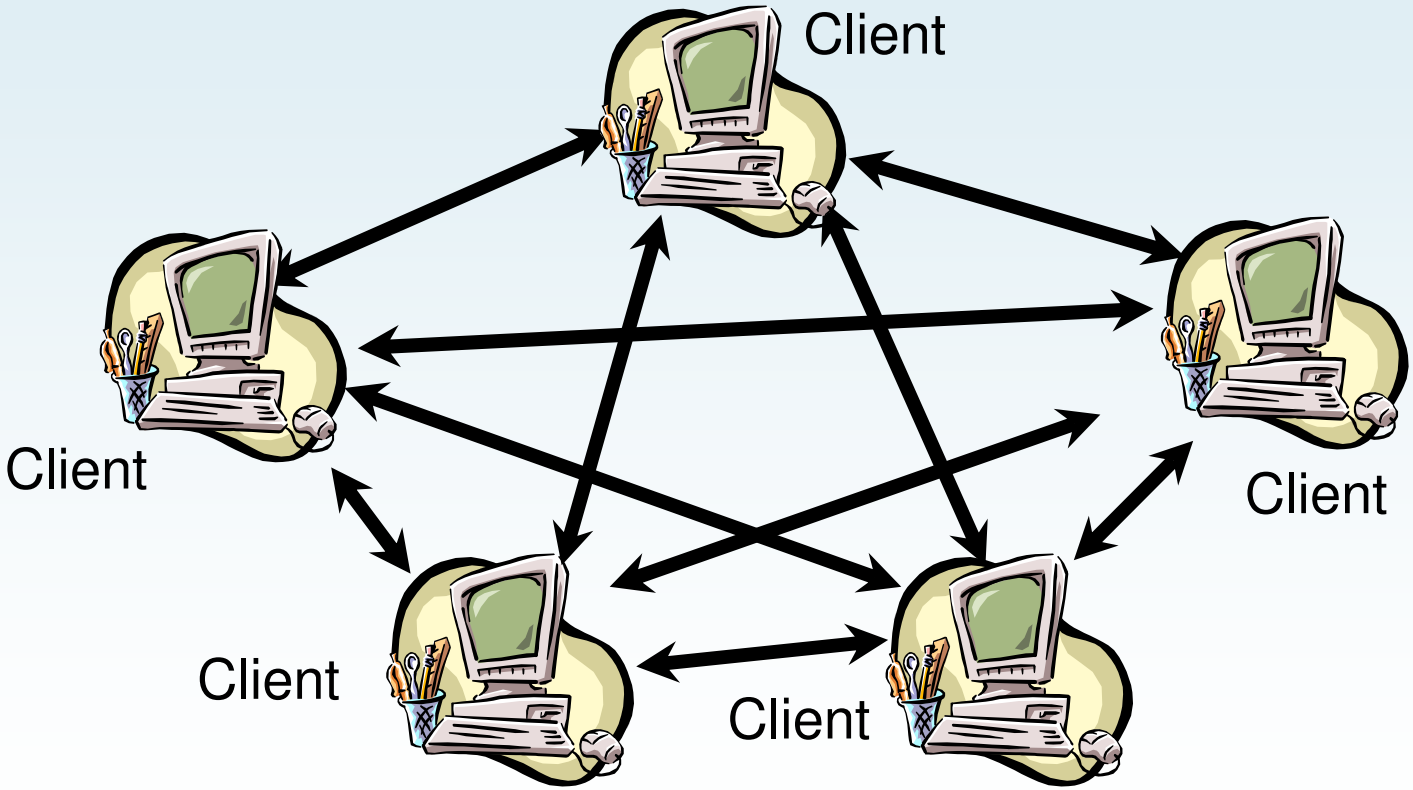
What Do You Share?

- There are many strategies
- Share inputs to the “simulation”
  - Works for deterministic simulations (usually simple games, e.g. Doom)
- Share outputs of the “simulation”
  - Generally more work because the output can be complex (e.g. lots of objects moving)
- A common strategy is to share *changes to a scene graph*
  - This is exactly what we will do in the coursework

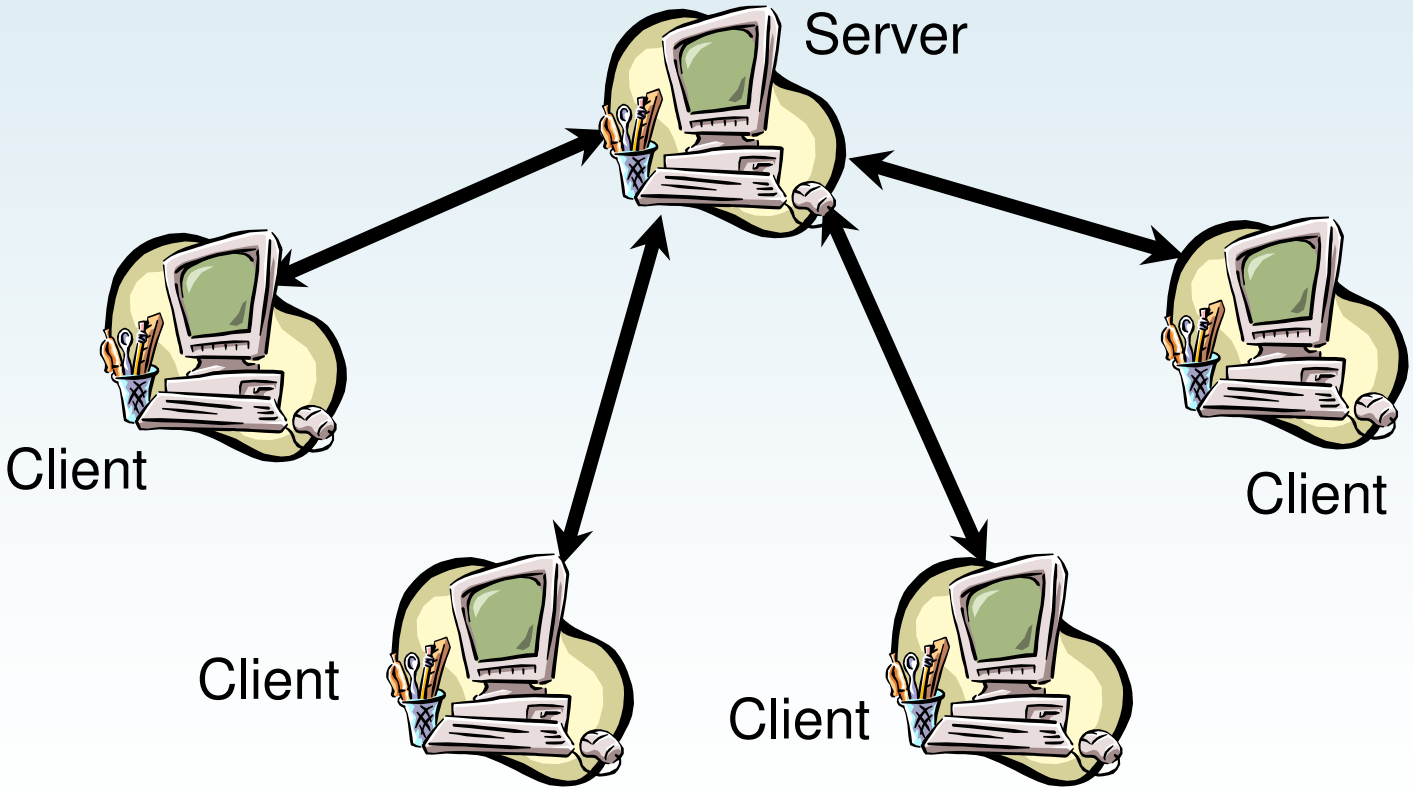
Basic Architectures and Protocols

- Two basic models are possible
  - Peer to Peer
  - Client/Server
- There are various hybrids that use multiple servers (see later)

Peer to Peer Architecture



Client-Server Architecture



Implications

- Peer to Peer
  - –Data need to be sent multiple times on the network links might vary in bandwidth & latency
  - –Clients need to manage multiple connections
- Client Server
  - –The Server is a bottleneck
  - –Clients manage one connection
  - –Server can have privileged data, and can probably be trusted
  - –Latency is higher
  - –Synchronization is easy

Missing Details

- Authority problems:
  - Certain objects should only be changed by one person (E.G. the user's own avatar)
  - Sometimes users want to own objects (E.G. because they are holding them)
- Scalability problems:
  - We might not want to send absolutely everything because the world is large or detailed (E.G. far members of a crowd, birds in a flock)

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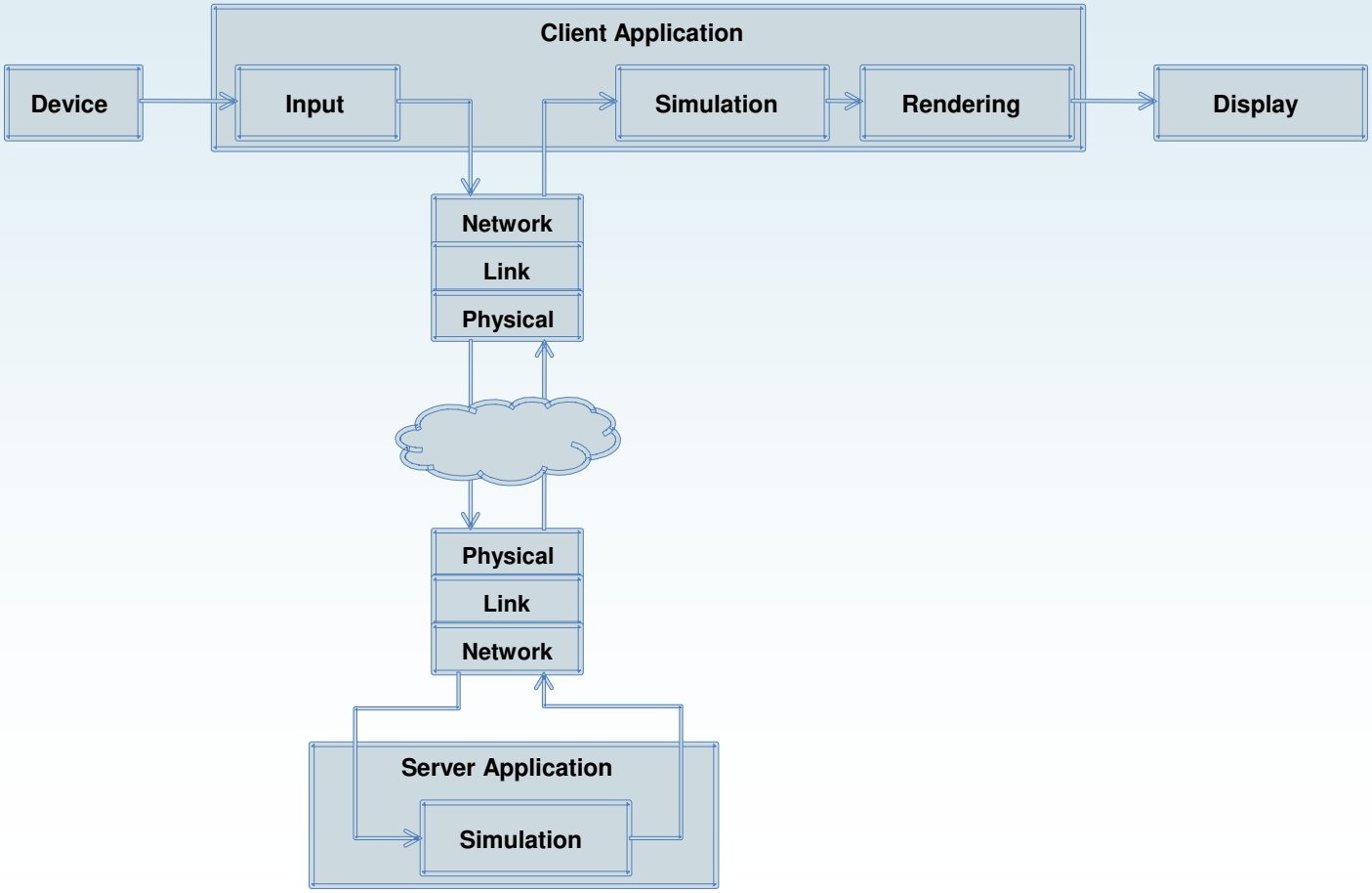
Latency

- Sources of latency
  - Speed of copying to link (e.g. modem)
  - Speed of transmission in link (e.g. speed of light)
  - Client scheduling (when packets arrive compared to the commitment to render the effect)
  - Server scheduling (e.g. server updates at a fixed frequency)
- Latency means that complete consistency is impossible between multiple sites

Latency Sources



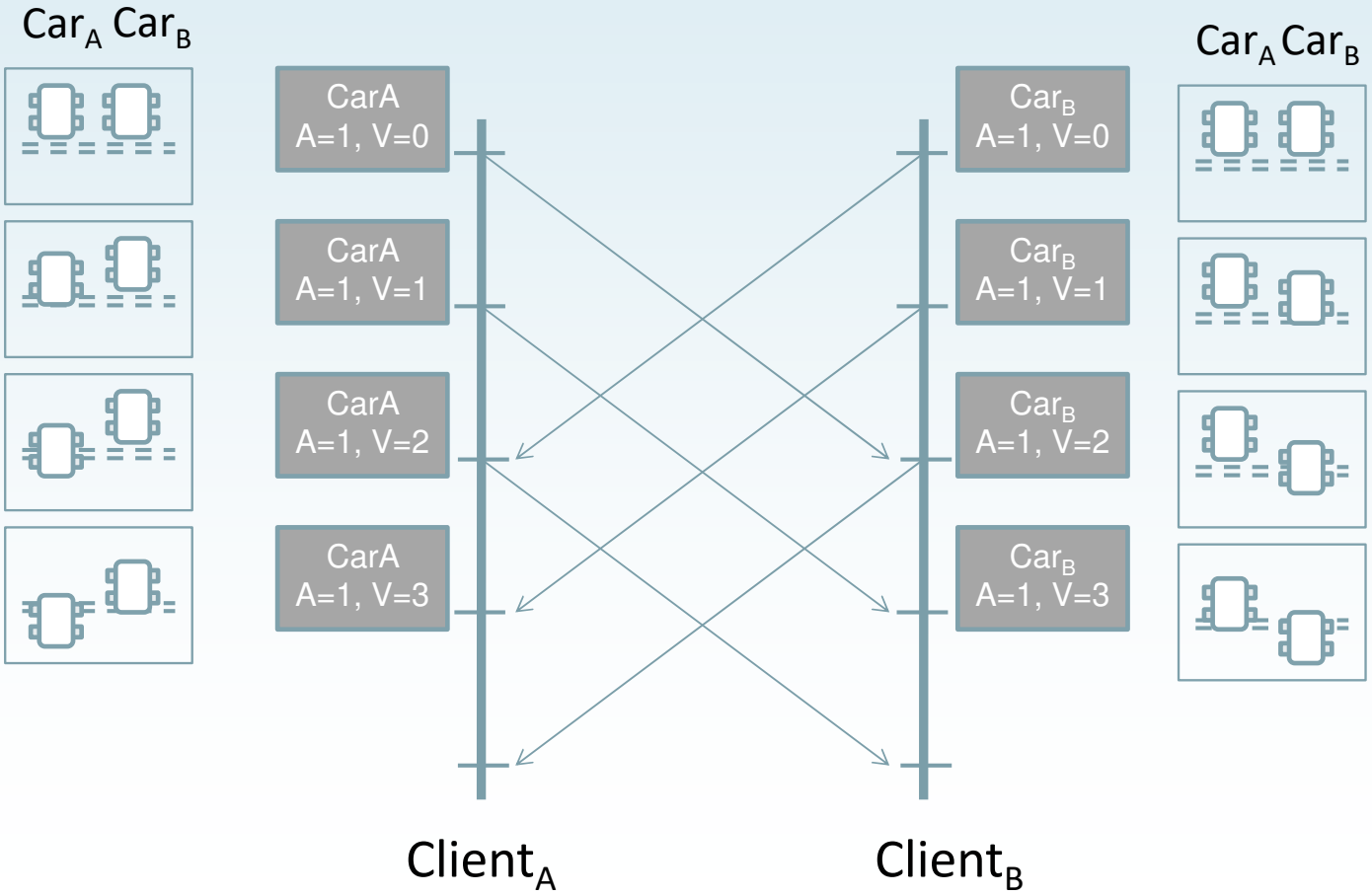
Consistency : System Perspective

- C1 : Local changes replicated at each site
- C2 : Simulation should not diverge over time
- C3 : Casual order of events should be preserved
- C4 : Temporal and motion characteristics of events should be preserved

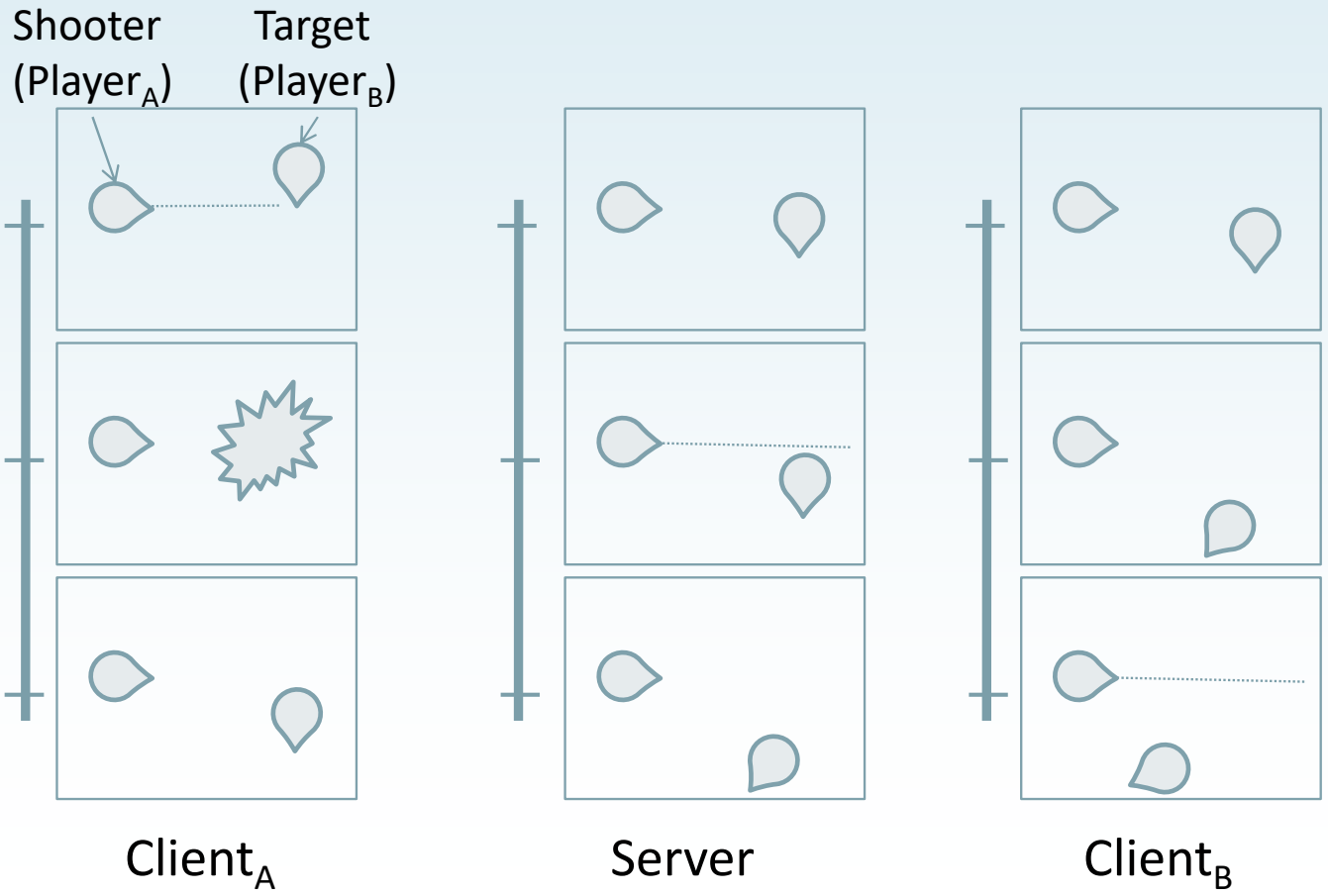
Consistency : User Perspective

- C5 : The joint perception of events should be plausible
- C6 : The outcome of the events should be fair
- C7 : The system should preserve the users' intentions

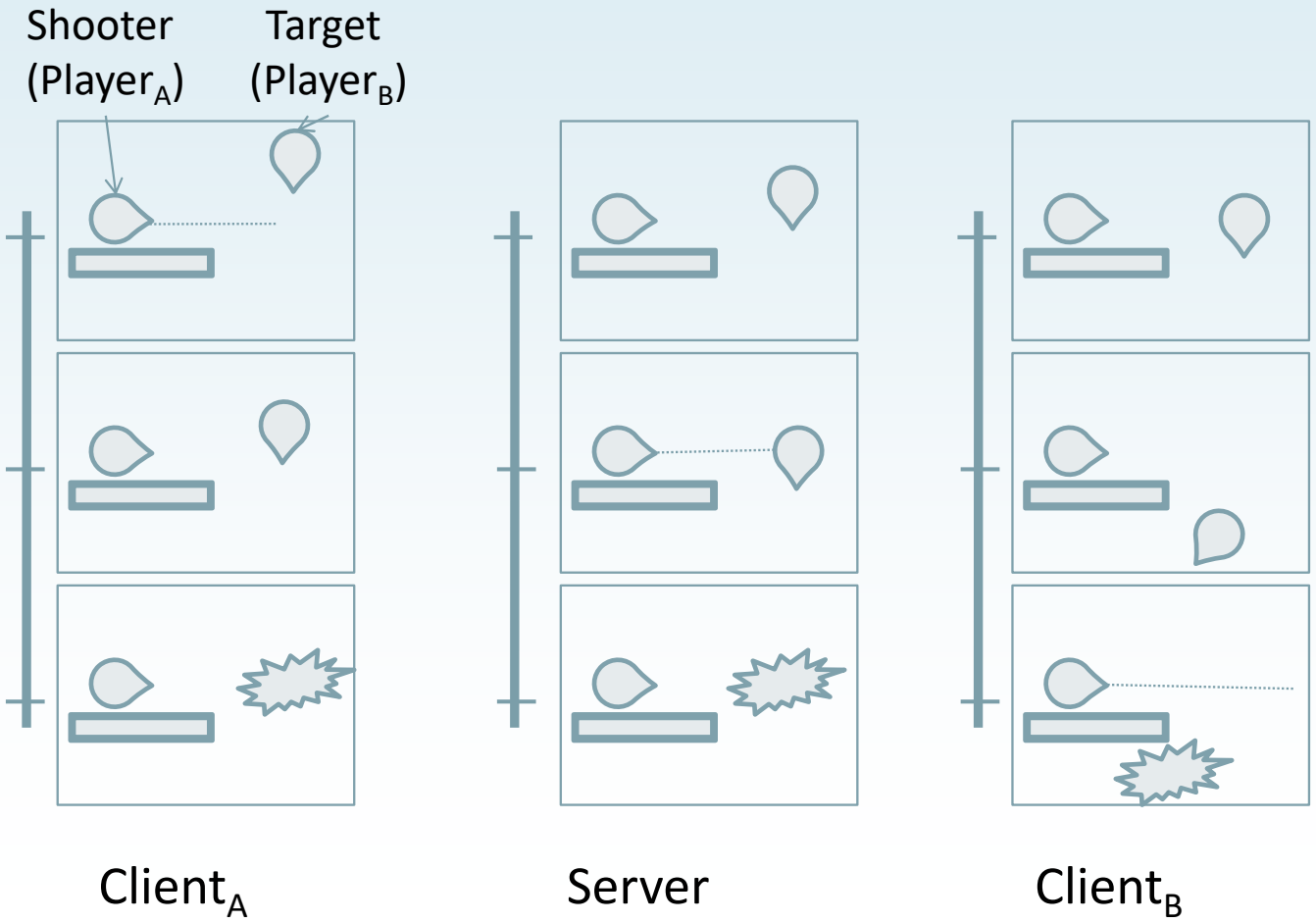
Peer to Peer Example



Impact: Fireproof Players



Impact: Shooting Around Corners



~~Dealing~~ Living with Inconsistency

- Have an authoritative server
  - –Estimate the most fair state
  - –Decisions might be unfair to one user, hopefully average to fair over time
- In peer to peer someone has to decide which version is “true”
  - –That person might cheat, so authority might move around
- In general this is the main issue with ensuring stability over time

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Goals

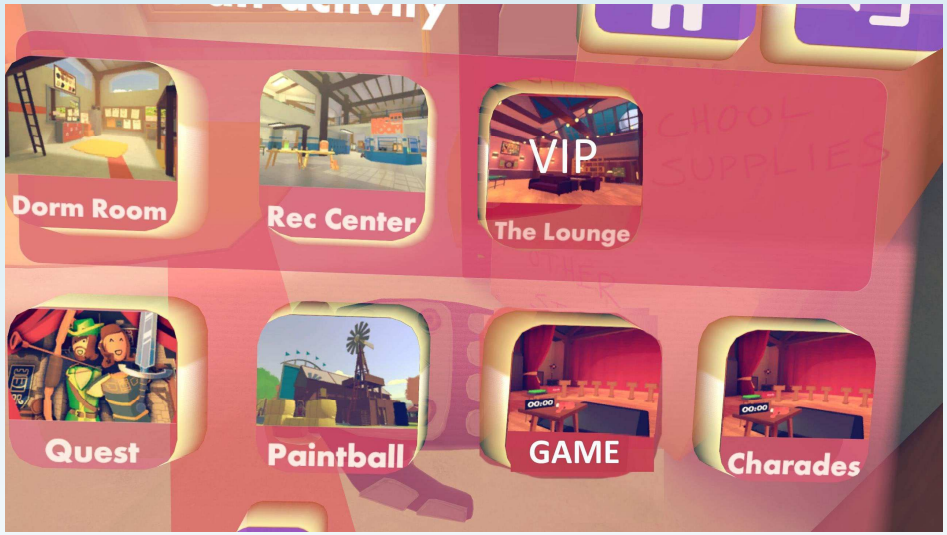
- Attempt to keep overall system utilization to a manageable level
  - client inbound & outbound bandwidth at a manageable level
  - server outbound bandwidth to a manageable level
- Do this by
  - Splitting clients into smaller sets
  - Manage the information that is sent

Partitioning

- Primary way of supporting scalability is to partition users in to different regions, each with <MAX number of connected players
  - Rooms (or shards)
  - Static Grid
  - Hierarchical or dynamic grid
  - Locales or Rooms

Rooms

- Server presents a list of rooms
  - –Sometimes a player count
- Player chooses a room
  - –Game engine reloads this room
  - –Selecting a room might change the server you connect to
- Very straight forward to implement
  - –Many games use this
  - –We will use in the coursework



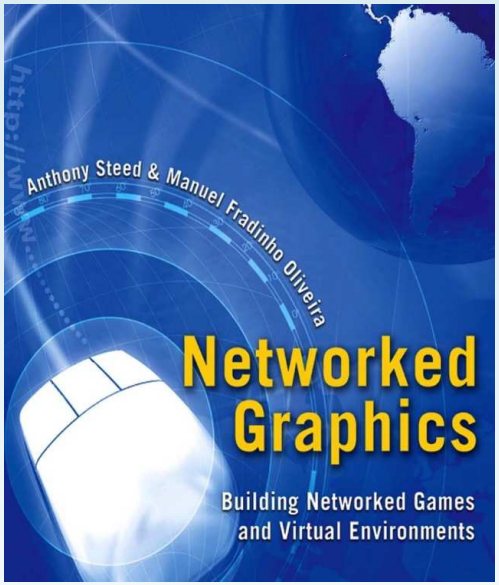
Continuous Worlds

- In very large environments you might have lots of “servers” each managing a region
- Then as you move around you connect to different servers
- Usually highly specific to the game
- Probably will underpin next-generation experiences (e.g. “metaverses”)

(improbable.io, 2018)

Conclusions

- Networked graphics is a huge area of research (see book!)
- Key issues:
  - Need to understand limitations of Internet
  - Virtual environments have high requirements
  - Many ways of building a networked virtual environment
  - Latency is a core issue as consistency is hard
  - Scalability manages bandwidth requirements



See http://www.networkedgraphics.org/