Aspects of Networking in Multiplayer Computer Games

J. Smed, T. Kaukoranta and H. Hakonen

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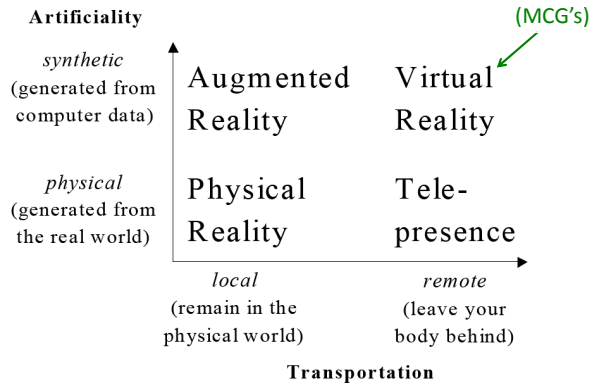
Introduction

- Network growth, especially wireless, making multiplayer computer games (MCGs) more popular
- Commercial computer games increasingly having mutiplayer option
- And not just PCs, but consoles, too (*PS4*, *Xbox One, Wii…*)
- Wireless-only devices, too (3d *DS, PS Vita, Smart phones*)

Shared Space Technologies



Other VR Research Efforts

- *Distributed Interactive Simulations* (DIS)
  - Protocol (IEEE), architectures …
  - Ex: flight simulation
  - Large scale, spread out, many users
- *Distributed Virtual Environments* (DVEs)
  - Immersive, technology oriented
  - Ex: "Caves"
  - Local, few users
- *Computer Supported Cooperative Work* (CSCW)
  - Focus on collaboration
  - Ex: 3D editors
- And MCGs are similar, yet not discussed in scientific literature
  → Hence, this paper seeks to rectify

Outline

- Introduction (done)
- Networking Resources (next)
- Distribution Concepts
- Scalability
- Security and Cheating
- Conclusions

Network Resources

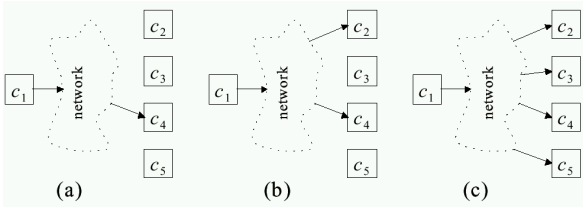
- Distributed simulations face three resource limitations
  - *Network bandwidth*
  - *Network latency*
  - *Host processing power* (to handle network aspects)
- Physical restrictions that system cannot overcome
  - Must be considered in design of application

(More on each, next)

Network Bandwidth (Capacities)

- Data sent/received per time
- LAN – 10 Mbps to 10 Gbps
  - Limited size (hosts) and scope (distance)
- WANs – 10s of kbps from modems, to 1-10 Mbps (broadband), to 55 Mbps (T3) and more
  - Potentially enormous (billions of hosts), Global in scope (across continents and world)
- Number of users, size and frequency of messages determines bitrate use
- As does transmission technique (next slide)

Network Bandwidth (Transmission Techniques)



- (a) Unicast: one send and one receive
  - Can waste bandwidth when path shared by several clients
- (c) Broadcast: one send and all receive
  - Perhaps ok for LAN
  - Can waste bandwidth when most nodes don't need
- (b) Multicast: one send and only subscribed receive
  - Current Internet does not support
  - Multicast *overlay* networks (e.g., MBone or application layer mcast)

Network Latency

- Delay when message sent until received
  - Variation in delay (delay jitter) also matters
- Cannot be totally eliminated
  - e.g., speed of light propagation yields 25-30 ms across Atlantic
  - And with routing and queuing, usually 80+ ms
- Application tolerances:
  - File download – minutes
  - Web page download – up to 10 seconds
  - Interactive audio – 100s of ms
- MCG latencies tolerance? → Depends upon game!
  - First-Person Shooters – about 100 ms
  - Third-Person Adventure – up to 500 ms
  - Real-Time Strategy – up to 1 second
  - And depends upon action *within* game! (topic for another paper)

Computational Power

- Processing to send/receive packets
- Most devices powerful enough for raw sending/receiving
  - Can saturate LAN
- Rather, *application* must process state in each packet (e.g., receive packet, update game world)
- Especially critical on resource-constrained devices
  - e.g., hand-held console, cell phone, PDA,

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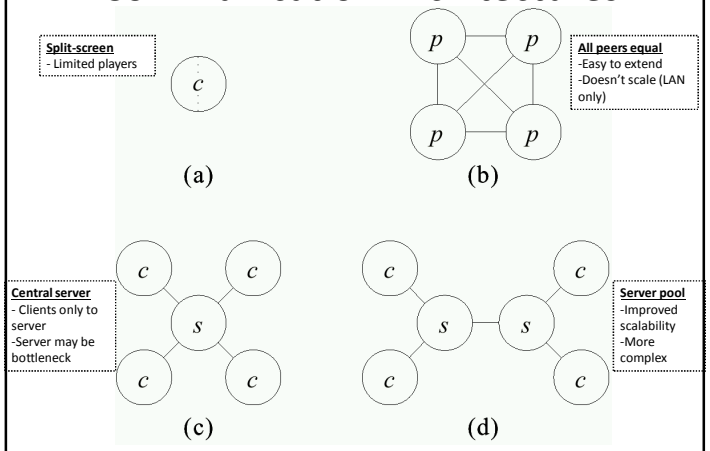
Distribution Concepts

- Cannot do much about above resource limitations
- Should tackle problems at higher level
- Choose architectures for
  - *Communication*
  - *Data*
  - *Control*
- Plus, *compensatory techniques* to relax requirements

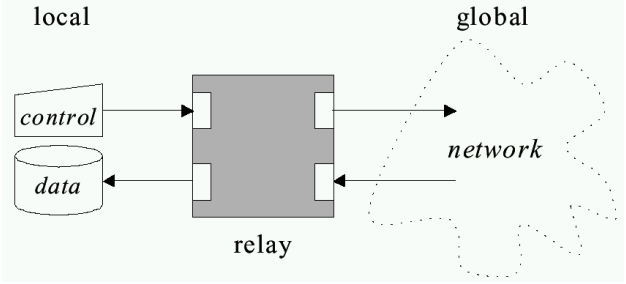
Communication Architectures



Data and Control Architectures

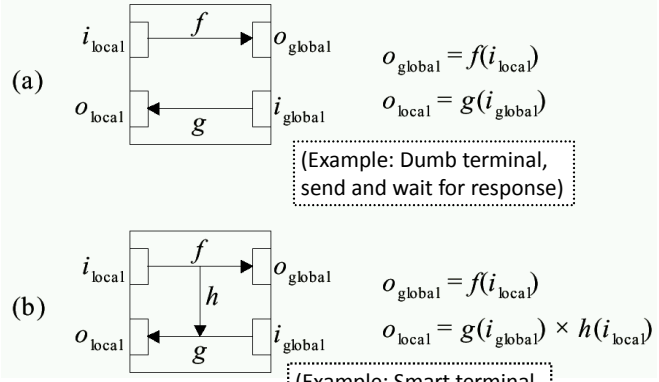
- Want *consistency*
  - Same state on each node
  - Needs tightly coupled, low latency, small nodes
- Want *responsiveness*
  - More computation locally to reduce network
  - Loosely coupled (asynchronous)
- In general, cannot do both → *Tradeoffs*

"Relay" Architecture Abstraction



- Want control to propagate quickly so can update data (*responsiveness*)
- Want to reflect same data on all nodes (*consistency*)

Relay Architecture Choices



MCG Architectures

- *Centralized*
  - Use only two-way relay (no short-circuit)
  - One node holds data so view is consistent at all times
  - Lacks responsiveness
- *Distributed* and *Replicated*
  - Allow short-circuit relay
  - Replicated has copies, used when predictable (e.g., behavior of non-player characters)
  - Distributed has local node only, used when unpredictable (e.g., behavior of players)

Compensatory Techniques

- Architectures alone not enough
- Design to compensate for residual
- Techniques:
  - Message aggregation
  - Interest management
  - Dead reckoning

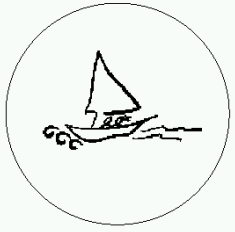
(next)

Message Aggregation

- Combine multiple messages in one packet to reduce network overhead
- Examples:
  - Multiple user commands to server (move *and* shoot)
  - Multiple users command to clients (player A's *and* player B's actions combined to player C)

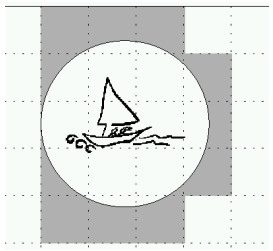
Interest Management – Auras (1 of 2)

- Nodes express area of interest to them
  - Do not get messages for outside areas

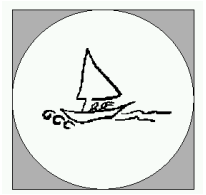


- Only circle sent even if world is larger
- But implementation complex (squares easier)

Interest Management- Auras (2 of 2)



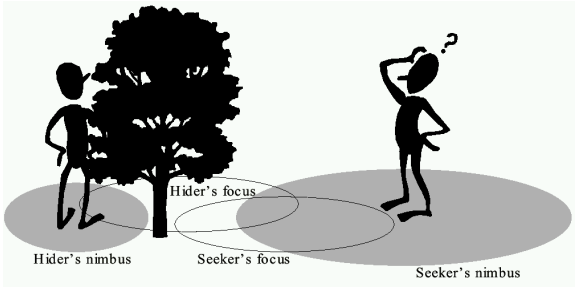
- Divide into cells (or hexes)
- Easier, but less discriminating



- Compute bounding box
- Relatively easy, precise

- Always symmetric – both receive
  - But can sub-divide – *focus* and *nimbus*

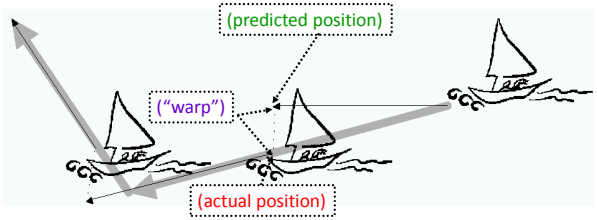
Interest Management- Focus and Nimbus



- *Nimbus* must intersect with *focus* to receive
- Example above: hider has smaller nimbus, so seeker cannot see, while hider can see seeker since seeker's nimbus intersects hider's focus

Dead Reckoning

- Based on ocean navigation techniques ("dead" == "deduced (ded.)")
- Predict position based on last known position plus direction
  - Only send updates when deviates past threshold



- When prediction differs and adjust, get "warping" or "rubber-banding" effect
  - Some techniques move to place over short time

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Scalability

- Ability to adapt to resource changes
- Example:
  - Expand to varying number of players
  - Allocate non-player computation among nodes
- Need hardware parallelism that supports software concurrency

Serial and Parallel Execution

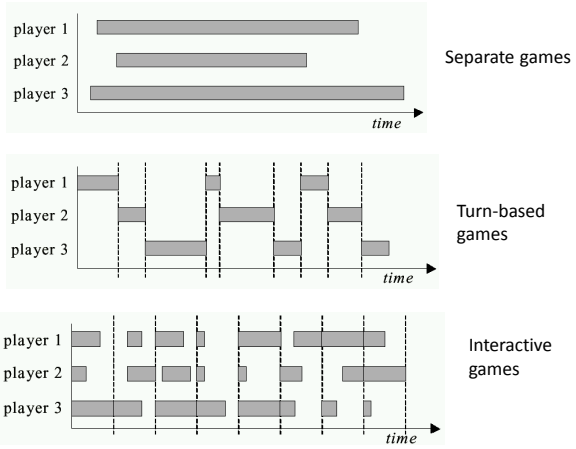
- Given time T(1), speedup with *n* nodes $S(n) = \frac{T(1)}{T(n)} \leq \frac{1}{n}$
- Part of T(1) must happen serially and part can be done in parallel
  $T_s + T_p = T(1)$ and $\alpha = T_s/(T_s + T_p)$
- If serialized optimally:

(Amdahls' law)

$$S(n) = \frac{T_s + T_p}{T_s + T_p/n} = \frac{1}{\alpha + (1-\alpha)/n} \leq \frac{1}{\alpha}.$$

- If $T_s = 0$, everything parallelizable but then no communication
  (ex: players at own console with no interaction)
- If $T_p = 0$, then turn based
- Between are MCGs which have some of both

Serial and Parallel MCGs



Communication Capacity

- Scalability limited by communication requirements of chosen architecture

Deployment architecture	Capacity requirement
Single node	0
Peer-to-peer	$\sim n \ldots n^2$
Client/server	$\sim n$
Peer-to-peer server-network	$\sim \frac{n}{m} + m \ldots \frac{n}{m} + m^2$
Hierarchical server-network	$\sim n$

(Multicasting)

- Can consider pool of *m* servers with *n* clients divided evenly amongst them
- Servers in hierarchy have root as bottleneck
- In order not to increase with *n*, must have clients not aware of other clients (interest management) and do message aggregation

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Security and Cheating

- Unique to games
  - Other multi-person applications don't have
  - In DIS, military not public and considered trustworthy
- Cheaters want:
  - *Vandalism* – create havoc (relatively few)
  - *Dominance* – gain advantage (more)

Packet and Traffic Tampering

- *Reflex augmentation* - enhance cheater's reactions
  - e.g., aiming proxy monitors opponents movement packets, when cheater fires, improve aim
- *Packet interception* – prevent some packets from reaching cheater
  - e.g., suppress damage packets, so cheater is invulnerable
- *Packet replay* – repeat event over for added advantage
  - e.g., multiple bullets or rockets if otherwise limited

Preventing Packet Tampering

- Cheaters figure out by changing bytes and observing effects
  - Prevent by MD5 checksums (fast, public)
- Still cheaters can:
  - Reverse engineer checksums
  - Attack with packet replay
- So:
  - Encrypt packets
  - Add sequence numbers (or encoded sequence numbers) to prevent replay

Information Exposure

- Allows cheater to gain access to replicated, hidden game data (e.g. status of other players)
  - Passive, since does not alter traffic
  - e.g., ignore “fog of war” in RTS, or “wall hack” to see through walls in FPS
- Cannot be defeated by network alone
- Instead:
  - Sensitive data should be encoded
  - Kept in hard-to-detect memory location
  - Centralized server may detect cheating (e.g., attack enemy could not have seen)
    - Harder in replicated system, but can still share

Design Defects

- If clients trust each other, then if client is replaced and exaggerates cheater effects, others will go along
  - Can have checksums on client binaries
  - Still, more secure to have trusted server that puts into play client actions (centralized server)
- Distribution may be source of unexpected behavior
  - Features only evident upon high load (say, latency compensation technique)
  - e.g., Madden Football

Conclusion

- Overview of problems with MCGs
- Connection to other distributed systems
  - Networking resources
  - Distribution architectures
  - Scalability
  - Security

Future Work

- Other distributed systems solutions
- Cryptography
- Practitioners should be encouraged to participate