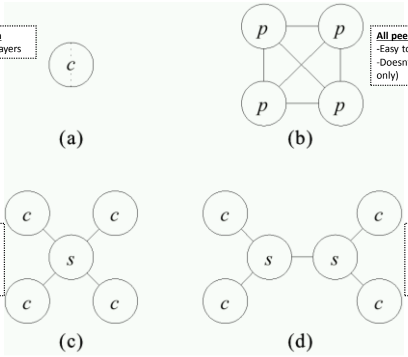
Distributed Computing Systems

(Slides for Final Class)

Outline

- Network Games
  - Architectures
  - Compensation techniques
  - Cheating
  - Cloud games
- Peer-to-Peer Systems
  - Overview
  - P2P file sharing

Communication Architectures



Split-screen
- Limited players

All peers equal
-Easy to extend
-Doesn't scale (LAN only)

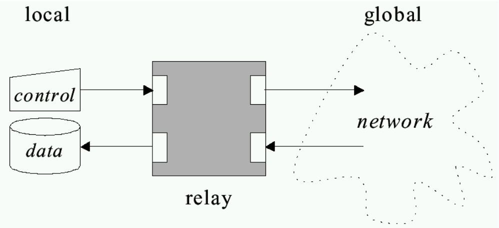
Central server
- Clients only to server
-Server may be bottleneck

Server pool
-Improved scalability
-More complex

Data and Control Architectures

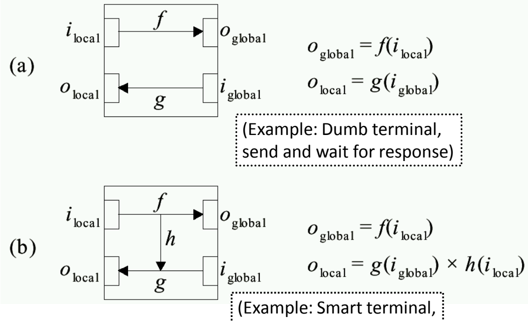
- Want *consistency*
  - Same state on each node
  - Needs tightly coupled, low latency, small nodes
- Want *responsiveness*
  - More computation locally to reduce network
  - Loosely coupled (asynchronous)
- In general, cannot do both → *Tradeoffs*

"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



(a) $o_{global} = f(i_{local})$

$o_{local} = g(i_{global})$

(Example: Dumb terminal, send and wait for response)

(b) $o_{global} = f(i_{local})$

$o_{local} = g(i_{global}) \times h(i_{local})$

(Example: Smart terminal, send and echo)

Network Game 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, provides responsiveness
  - What about consistency? → Make design decisions
    - 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)

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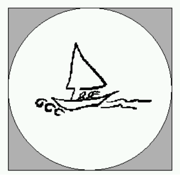
Interest Management – Auras

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

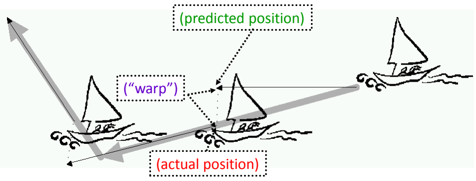


- Only world information in circle/sent sent even if world is larger

- Side benefit → can prevent cheating (later)

Dead Reckoning

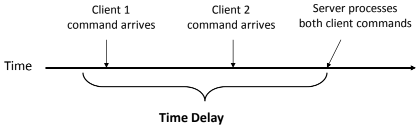
- Based on ocean navigation techniques ("dead" == "deduced (ded.)")
- Predict position based on last known position plus direction
  - Only send updates when deviates past threshold



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

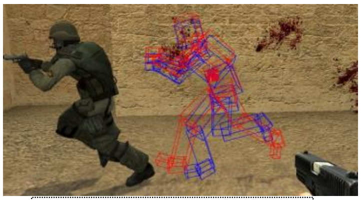
Time Delay

- Server delays processing of events
  - Wait until all messages from clients arrive
  - (Note, game plays at highest round-trip time)
- Server sends messages to more distant client first, delays messages to closer
  - Needs accurate estimate of round-trip time



Time Warp

- With network latency, must lead opponent to hit (even with "instant" weapon!)
- Instead, knowing latency roll-back (warp) to *when* action took place
  - Usually, estimate latency as ½ round-trip time



- Client 100 ms behind
- Still hits (note blood)
- (Boxes are *bounding boxes*)

https://developer.valvesoftware.com/wiki/Source_Multiplayer_Networking

Time Warp Notes

- Inconsistency
  - Player target
  - Move around corner
  - Warp back → hit
  - Bullets seem to "bend" around corner!
    - → "Magic" bullets
- Fortunately, player often does not notice
  - Doesn't see opponent
  - May be just wounded

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Cheating

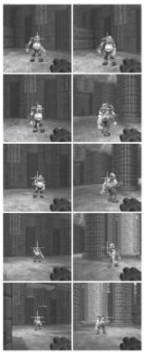
- Unique to games
  - Other multi-person applications don't have
  - e.g, Distributed Interactive Simulation (DIS), not public, "employees" so considered trustworthy
- Cheaters want:
  - *Vandalism* – create havoc (relatively few).
    - Mostly, game design to prevent (e.g., no friendly fire)
  - *Dominance* – gain advantage (more)
    - Next slides

Packet and Traffic Tampering

- *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
- Solutions:
  - MD5 Checksum or Encrypt packets
  - Authoritative host keeps within bounds

Packet Tampering

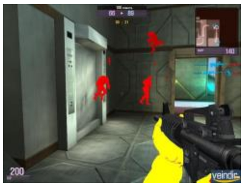
- *Reflex augmentation* - enhance cheater's reactions
  - e.g., aiming proxy monitors opponents movement packets, when cheater fires, improve aim
- Tough to detect
  - e.g., *PunkBuster* – scan for "known" hacks
  - False positives?



S. Yeung and J. Lui. "Dynamic Bayesian approach for detecting cheats in multi-player online games", Springer Multimedia Systems, Vol. 14, No. 4 Sep. 2008.

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)



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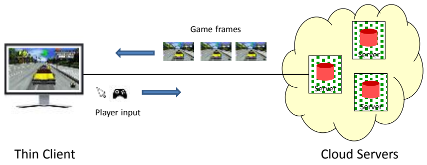
Cloud-based Games

- Connectivity and capacity of networks growing
- Opportunity for cloud-based games
  - Game processing on servers in cloud
  - Stream game video down to client
  - Client displays video, sends player input up to server

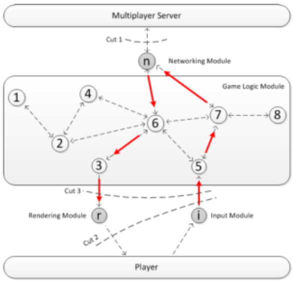


Why Cloud-based Games?

- Potential elastic scalability
  - Overcome processing and storage limitations of clients
  - Avoid potential upfront costs for servers, while supporting demand
- Ease of deployment
  - Client "thin", so inexpensive ($100 for OnLive console vs. $400 for Playstation 4 console)
  - Potentially less frequent client hardware upgrades
  - Games for different platforms (e.g., Xbox and Playstation) on one device
- Piracy prevention
  - Since game code is stored in cloud, server controls content and content cannot be copied
  - Unlike other solutions (e.g., DRM), still easy to distribute to players
- Click-to-play
  - Game can be run without installation

Cloud Game - Modules (1 of 2)

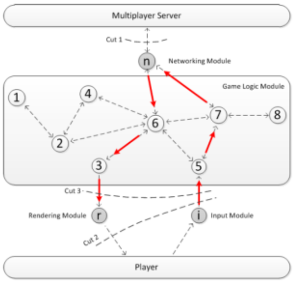
- Input (*i*) – receives control messages from players
- Game logic – manages game content
- Networking (*n*) – exchanges data with server
- Rendering (*r*) – renders game frames
- How to put in cloud?



Cloud Game - Modules (2 of 2)

"Cuts"

1. All game logic on player, cloud only relay information (traditional network game)
2. Player only gets input and displays frames (remote rendering)
3. Player gets input and renders frames (local rendering)



Application Streams vs. Game Streams

- Traditional thin client applications (e.g., x-term, remote login shell):
  - Relatively casual interaction
    - e.g., typing or mouse clicking
  - Infrequent display updates
    - e.g., character updates or scrolling text
- Computer games:
  - Intense interaction
    - e.g., avatar movement and shooting
  - Frequently changing displays
    - e.g., 360 degree panning

- Approximate traffic analysis
  - 70 kb/s traditional network game
  - 700 kb/s virtual world
  - 2000-7000 kb/s live video (HD)
  - 1000-7000 kb/s pre-recorded video
- Cloud-based games?
  - 7000 kb/s (HD)

Challenge: *Latency* since player input requires round-trip to server before player sees effects

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Definition of Peer-to-Peer (P2P)

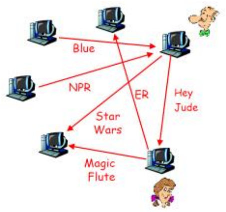
- Significant autonomy from central servers
- Exploits resources at edges of Internet
  - Storage and content
  - Multicast routing
  - CPU cycles
  - Human knowledge (e.g., recommendations, classification)
- Resources at edge may have intermittent connectivity

P2P Includes

- P2P communication
  - Instant messaging
  - Voice-over-IP (e.g., Skype)
- P2P multicast routing
  - e.g., Mbone, Yoid, Scattercast
- P2P computation
  - e.g., seti@home, folding@home
- P2P systems built on overlays
  - e.g., PlanetLab
- P2P file sharing
  - e.g., Napster, gnutella, KaZaA, eDonkey, BitTorrent …

P2P File Sharing – General

- Alice runs P2P client on her laptop
- Registers her content in P2P system

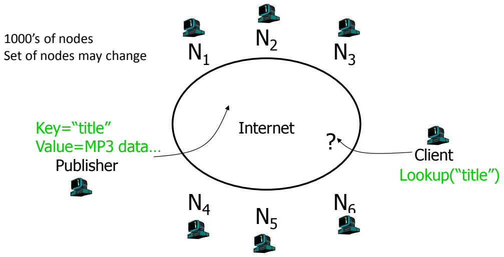


- Asks for "Hey Jude"
- Application displays other peers with copy
- Alice choses one, Bob
- File is copied from Bob's computer to Alice's
  → P2P
- While Alice downloads, others upload

P2P File Sharing Capabilities

- Allows Alice to show directory in her file system
  - Anyone can retrieve file from it
  - Like Web server
- Allows Alice to copy files from other's
  - Like Web client
- Allows users to search nodes for content based on keyword matches
  - Like search engine (e.g., Google)

Example: Searching



1000's of nodes
Set of nodes may change

N_1 N_2 N_3

Internet

Key="title"
Value=MP3 data…
Publisher

?

Client
Lookup("title")

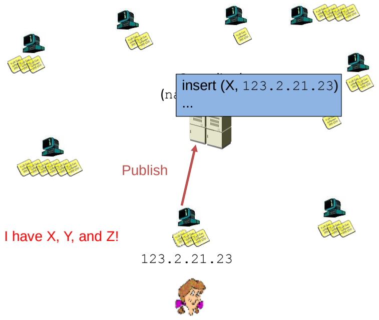
N_4 N_5 N_6

- Needles versus Haystacks
  Searching for top 40 pop song? Or obscure punk track '81 nobody's heard of?
- Search expressiveness
  Whole word? Regular expressions? File names? Attributes? Whole-text search?

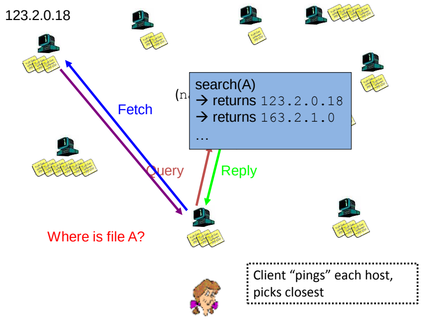
P2P File Sharing Systems

	Central	Flood	Super-node flood	Route
Whole File	Napster	Gnutella		Freenet
Chunk Based	BitTorrent (swarm)		KaZaA (bytes)	(DHTs) eDonkey2k New BT

Napster: Publish



Napster: Search

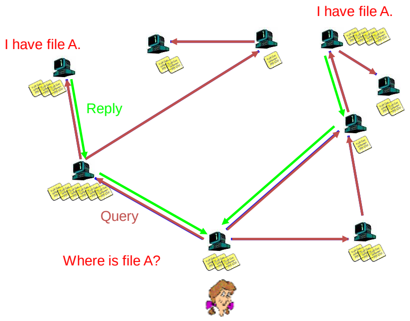


Client "pings" each host, picks closest

Napster: Discussion

- Pros
  - Simple
  - Search scope is O(1)
  - Controllable (pro or con?)
- Cons
  - Single point of failure
  - Server maintains O(N) state
  - Server does all processing
  - (Napster's server farm had difficult time keeping up with traffic)

Query Flooding (e.g., Gnutella)

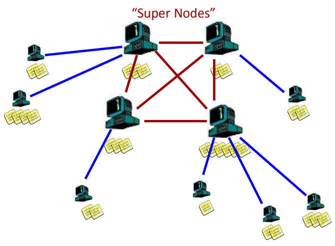


Flooding Discussion

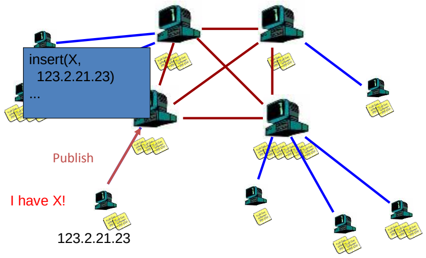
- Pros
  - Fully de-centralized
  - Search cost distributed
  - Processing @ each node permits powerful search semantics
- Cons
  - Search scope is O(*N*)
  - Search time is O(???) – depends upon "height" of tree
  - Nodes leave often, network unstable
- Hop-limited search works well for haystacks
  - For scalability, does NOT search every node. May have to re-issue query later

Flooding with Supernodes (e.g., KaZaA)

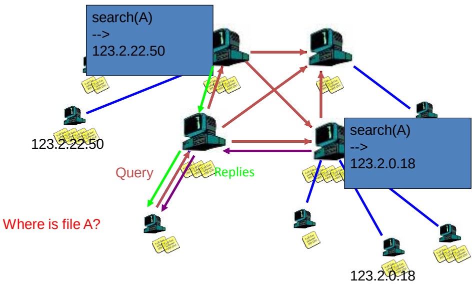
- Architecture
  - Hierarchical
  - Cross between Napster and Gnutella
- Some nodes better connected, longer connected than others
  - Use them more heavily
  - Super Nodes
- "Smart" query flooding
  - Only flood through Super Nodes
  - Only one Super Node replies



Supernodes: Publish



Supernodes: Search



Supernode Flooding Discussion

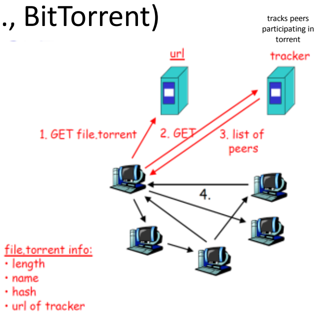
- Pros
  - Take into account node heterogeneity
    - Bandwidth
    - Host computational resources
    - Host aavailability
  - May take into account network locality
  - Scales better
- Cons
  - Still no real guarantees on search scope or search time
- Similar behavior to plain flooding, but better

Fetching in Parallel and Swarming (e.g., BitTorrent)

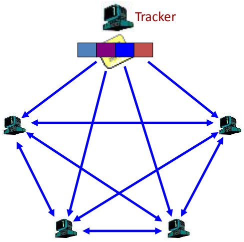
- When have file ID, get list of peers with ID
- Download in parallel from multiple peers
- "Swarming"
  - Download from others downloading same object at same time (tit-for-tat)

Fetching in Parallel and Swarming (e.g., BitTorrent)

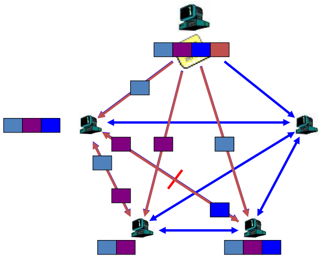
- When have file ID, get list of peers with ID
- Download in parallel from multiple peers
  - Use "rarest first" algorithm to increase availability
- "Swarming"
  - Download from others downloading same object at same time



BitTorrent: Publish/Join



BitTorrent: Fetch



BitTorrent: Summary

- Pros
  - Works reasonably well in practice
  - Gives peers incentive to share resources; avoids freeloaders
- Cons
  - Central tracker server needed to bootstrap swarm
  - Tracker is a design choice, not a requirement
    - Newer variants use a “distributed tracker” - a Distributed Hash Table (DHT)