Peer-Server Systems

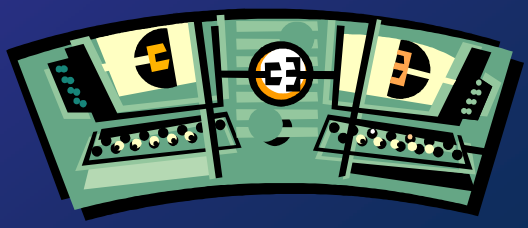
- Peer-to-peer: minimizes latency, consumes bandwidth
- Client-server: effective aggregation and filtering, increases latency
- Hybrid peer-server:
  - over short-haul, high-bandwidth links: peer-to-peer
  - over long-haul, low-bandwidth links: client-server
- Each entity has own multicast group
- Well-connected hosts subscribe directly to a multicast group (peer-to-peer)
- Poorly-connected hosts subscribe to a *forwarding server*
- Forwarding server subscribes to the entities' multicast groups
  - aggregation, filtering

Recapitulation: Resource Management Methods

1. Optimizing the communication protocol
   - packet compression and aggregation
2. Controlling the visibility of data
   - area-of-interest filtering
3. Exploiting perceptual limitations
   - altering visual and temporal perceptions
4. Enhancing the system architecture

§7 Other Issues

- Taxonomy of online cheating
- Analysis of denial-of-service activity
- Synchronized simulation in *Age of Empires*



Network Security

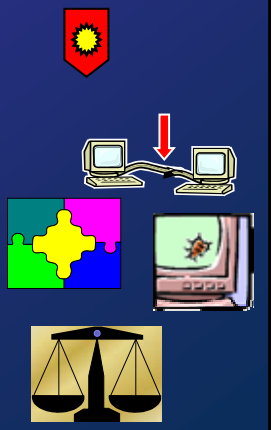
- Military
  - private networks → no problem

- Business, industry, e-commerce,…
  - 'traditional' security problems

- Entertainment industry
  - multiplayer computer games, online games
  - specialized problems

Security and Cheating in Multiplayer Computer Games

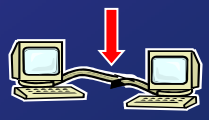
- Protect the sensitive information
  - cracking passwords and user accounts
  - pretending to be an administrator
- Provide a fair playing field
  - tampering with the network traffic
  - colluding with other players
- Uphold justice inside the game world
  - abusing beginners
  - ganging up



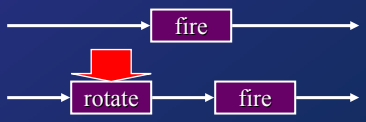
Taxonomy of Online Cheating 1 (4)

- Cheating by compromising passwords
  - dictionary attacks
- Cheating by social engineering
  - password scammers
- Cheating by denying service from peer players
  - denial-of-service (DoS) attack
  - clog the opponent's network connection

Taxonomy of Online Cheating 2 (4)



- Cheating by tampering with the network traffic
  - reflex augmentation
  - packet interception
  - look-ahead cheating
  - packet replay attack



- Cheating with authoritative clients
  - receivers accept commands blindly
    - requests instead of commands
    - checksums from the game state

Taxonomy of Online Cheating 3 (4)

- Cheating due to illicit information
  - access to replicated, hidden game data
  - compromised software or data
- Cheating related with internal misuse
  - privileges of system administrators
  - logging critical operations into CD-ROMs
- Cheating by exploiting a bug or design flaw
  - repair the observed defects with patches
  - limit the original functionality to avoid the defects
  - good software design in the first place!

Taxonomy of Online Cheating 4 (4)

- Cheating by collusion
  - two or more players play together without informing the other participants
  - one cheater participates as two or more players

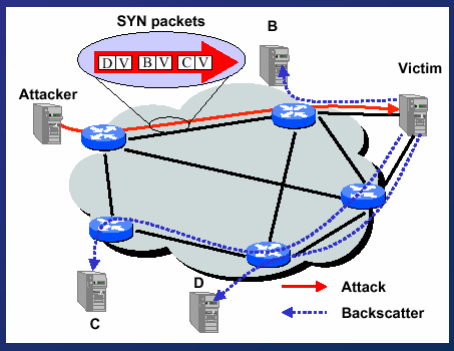
- Cheating related to virtual assets
  - demand ⇒ supply ⇒ market ⇒ money flow ⇒ cheating
- Cheating by offending other players
  - acting against the 'spirit' of the game
    - players handle the policing themselves → militia
    - systems records misconducts and brands offenders as criminals
    - players decide whether they can offend/be offended

Denial-of-Service (DoS) Attack

- Attack types:
  - logic attack: exploit flaws in the software
  - flooding attack: overwhelm the victim's resources by sending a large number of spurious requests
- Distributed DoS attack: attack simultaneously from multiple (possibly cracked) hosts
- IP spoofing: forge the source address of the outgoing packets
- Consequences:
  - wasted bandwidth, connection blockages
  - computational strain on the hosts

Analysing DoS Activity

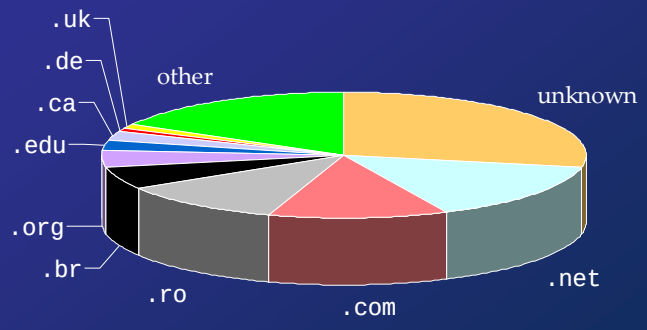
- Backscatter analysis
- Spoofing using random source address
- A host on the Internet receives unsolicited responses
- An attack of *m* packets, monitor *n* addresses
- Expectation of observing an attack: $E(X) = nm/2^{32}$



DoS: Selected Results

- Three week-long logging periods, February 2001
- >12,000 attacks, >5,000 distinct targets
- Significant number of attacks were directed against
  - home machines
  - users running Internet Relay Chat (IRC)
  - users with names that are sexually suggestive or incorporate themes of drug use
  - users supporting multiplayer games
- In addition to well-known Internet sites, a large range of small and medium sized businesses were targeted

DoS: Most Attacked Top-Level Domains

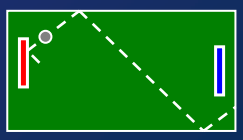


Synchronized Simulation in *Age of Empires*

- *Age of Empires* game series by Ensemble Studios
- Real-time strategy (RTS) game
- Max 8 players, each can have up to 200 moving units
  ⇒ 1600 moving units
  ⇒ large-scale simulation
- Rough breakdown of the processing tasks:
  - 30% graphic rendering
  - 30% AI and path-finding
  - 30% running the simulation and maintenance

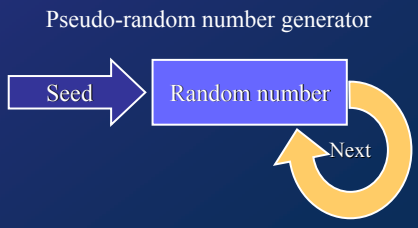
Synchronized (or Simultaneous) Simulation

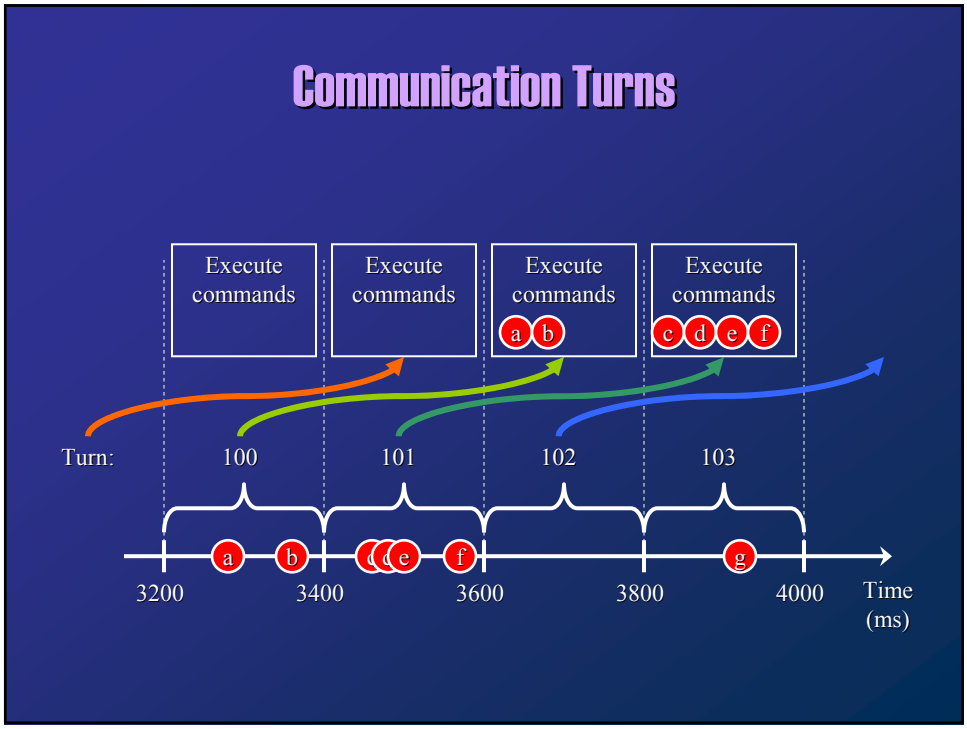
- Large simulation ⇒ a lot of data to be transmitted
- Trade-off: computation vs. communication
  - 'If you have more updating data than you can move on the network, the only real option is to generate the data on each client'
- Run the *exact* same simulation in each client

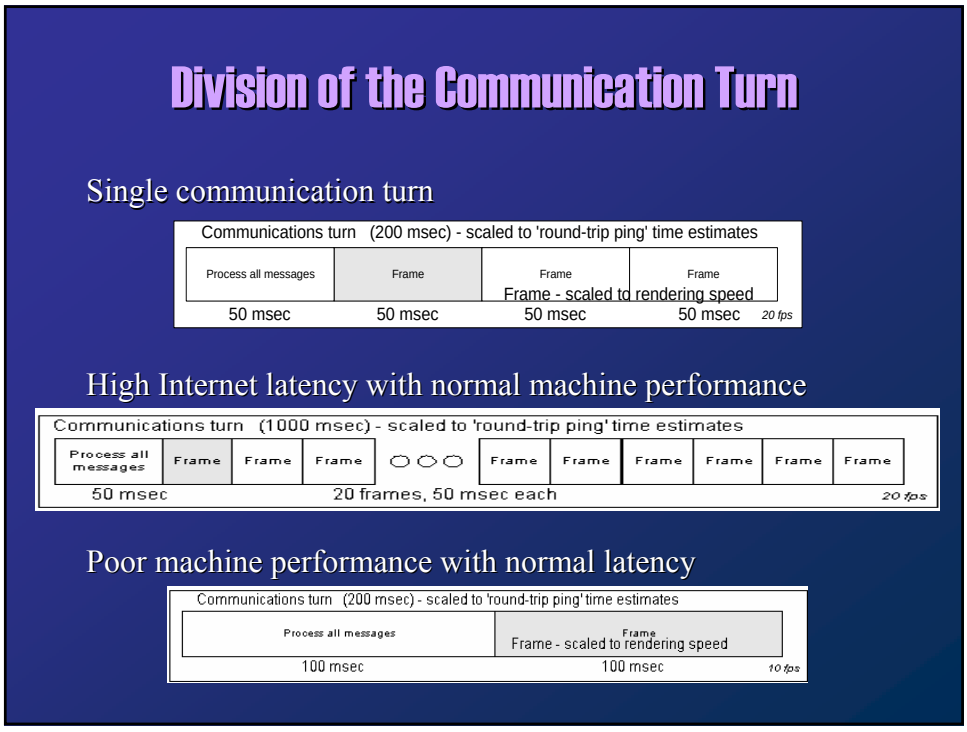


Handling Indeterminism

- 'Indeterministic' events are either
  - predictable (computers) or
  - unpredictable (humans)
- Only the unpredictable events have to be transmitted ⇒ communication
  - apply an identical set of commands that were issued at the same time
- The predictable events can be calculated locally on each client ⇒ computation
- Pseudo-random numbers are deterministic
- All clients use the same seed for their random number generator
  - disseminate the seed




Communication Turns
Execute commands
Execute commands
Execute commands
Execute commands
a b
c d e f
Turn:
100
101
102
103
a
b
c
d
e
f
g
3200
3400
3600
3800
4000
Time (ms)


Division of the Communication Turn
Single communication turn
Communications turn (200 msec) - scaled to 'round-trip ping' time estimates
Process all messages
Frame
Frame
Frame
Frame - scaled to rendering speed
50 msec
50 msec
50 msec
50 msec
20 fps
High Internet latency with normal machine performance
Communications turn (1000 msec) - scaled to 'round-trip ping' time estimates
Process all messages
Frame
Frame
Frame
Frame
Frame
Frame
Frame
Frame
Frame
50 msec
20 frames, 50 msec each
20 fps
Poor machine performance with normal latency
Communications turn (200 msec) - scaled to 'round-trip ping' time estimates
Process all messages
Frame
Frame - scaled to rendering speed
100 msec
100 msec
10 fps

Features

- Guaranteed delivery using UDP
  - message packet:
    - execution turn
    - sequence number
  - if messages are received out of order, send immediately a resend request
  - if acknowledgement arrives late, resend the message
- Hidden benefits
  - clients are hard to hack
  - any simulation running differently is out-of-sync
- Hidden problems
  - programming is demanding
  - out-of-sync errors
  - checksums for everything
    - 50 Gb message logs

Lessons Learned

- Players can tolerate a high latency as long as it remains constant
  - for an RTS game, even 250–500 ms latencies are still playable
- Jitter (the variance of the latency) is a bigger problem
  - consistent slow response is better than alternating between fast and slow
- Studying player behaviour helps to identify problematic situations
  - hectic situations (like battles) cause spikes in the network traffic
- Measuring the communication system early on helps the development
  - identify bottlenecks and slowdowns
- Educating programmers to work on multiplayer environments

§8 Final Remarks

Outline of the Course (Revisited)

1. Introduction
2. Background
   - history
   - past projects and applications
3. Networking
   - data transfer and protocols
   - communication architectures
4. Managing dynamic shared state
   - consistency-throughput trade-off
   - centralized information repositories
   - frequent state regeneration
   - dead reckoning
5. System design
   - threads
   - polygon culling and level-of-detail
6. Resource management
   - packet compression and aggregation
   - area-of-interest filtering
   - exploiting perceptual limitations
7. Other issues
   - security
   - case examples

Examinations 1 (2)

- examination dates
  1. March 15, 2004
  2. April 5, 2004
  3. May 10, 2004
- check the exact times and places at `http://www.it.utu.fi/opetus/tentit/`
- if you are *not* a student of University of Turku, you must register to receive the credits
  - further instructions are available at `http://www.tucs.fi/Education/Information/regcredits.php`

Examinations 2 (2)

- questions
  - based on the lectures and additional literature (3 articles)
  - four questions à 8 points
  - to pass the examination, at least 16 points (50%) are required
  - questions are in English, but you can answer in English or in Finnish
- remember to enrol in time!