Lecture Notes

Managing and Mining Multiplayer Online Games

Summer Term 2019

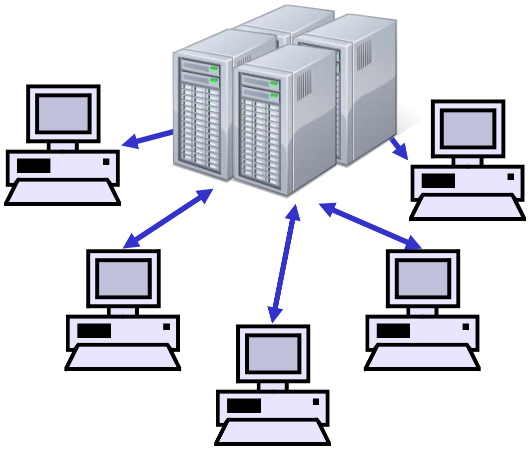
Chapter 3: Distributed Game Architectures

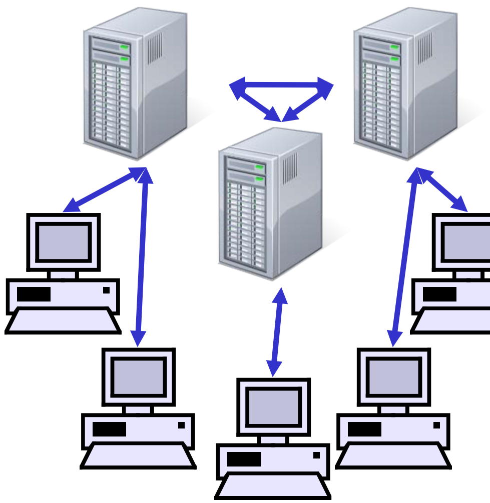
http://www.dbs.ifi.lmu.de/cms/VO_Managing_Massive_Multiplayer_Online_Games

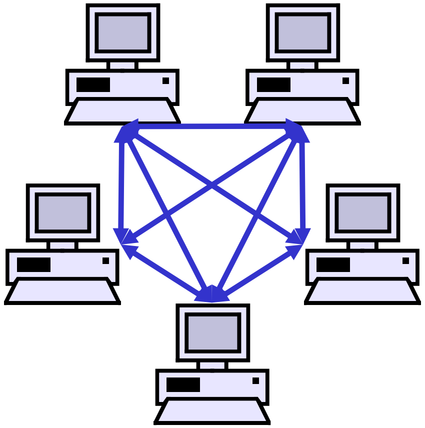
Overview

- architectures for distributed games
- distributed action handling
  - Fat-Client vs. Thin-Client
  - problems of centralized and decentralized computation
  - problems with local time stamps
- spatial movement and dead reckoning
  - update strategies
  - movement models
  - error correction
- network protocols and games
  - typical network load of games
  - TCP and games
  - UDP and games

MMOG Architectures







Client-Server:
- provider hosts game in a computing center
- game client and server run different software
- centralized solution for:
  - account-management
  - partitioning of the game world
  - monitoring
  - persistence

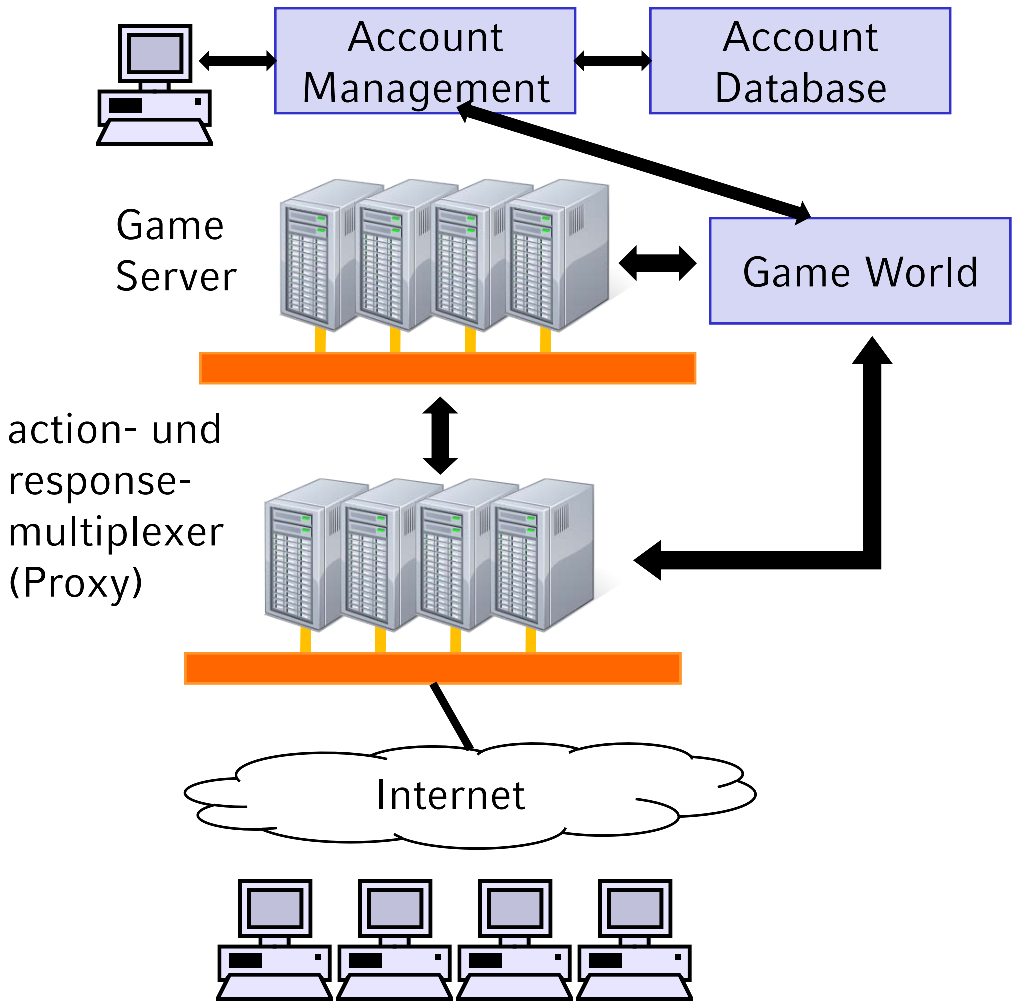
Multi-Server:
- several servers
- redundant data storage
- network distance between client and server is generally shorter
- dynamic solutions:
  - replication
  - proxy-Server

Peer-to-Peer:
- no explicit Servers
- data exchange between adjacent peers
- every peer is hosting part of the game world
- dynamic partition of the game world

Detailed Client Server Architecture

- hosted in a computing center
- several game servers share game state
  - zones shards/realms, instances
  - strict division of zones
  - seamless distribution (communication between servers)
- authentication / account management service
- action- and response-multiplexer

  (proxy) may ease the load on game servers by taking over particular functionalities



Distributing the Game Core

design choices:

- What kind of peers do exist?
- What are the peers exchanging?
  (actions, object states, user input, …)
- Who is authorized to read which part of the game state and who is also entitled to write?
- How is the load redistributed among existing peers?
- How is time between peers synchronized?

Protocol Content

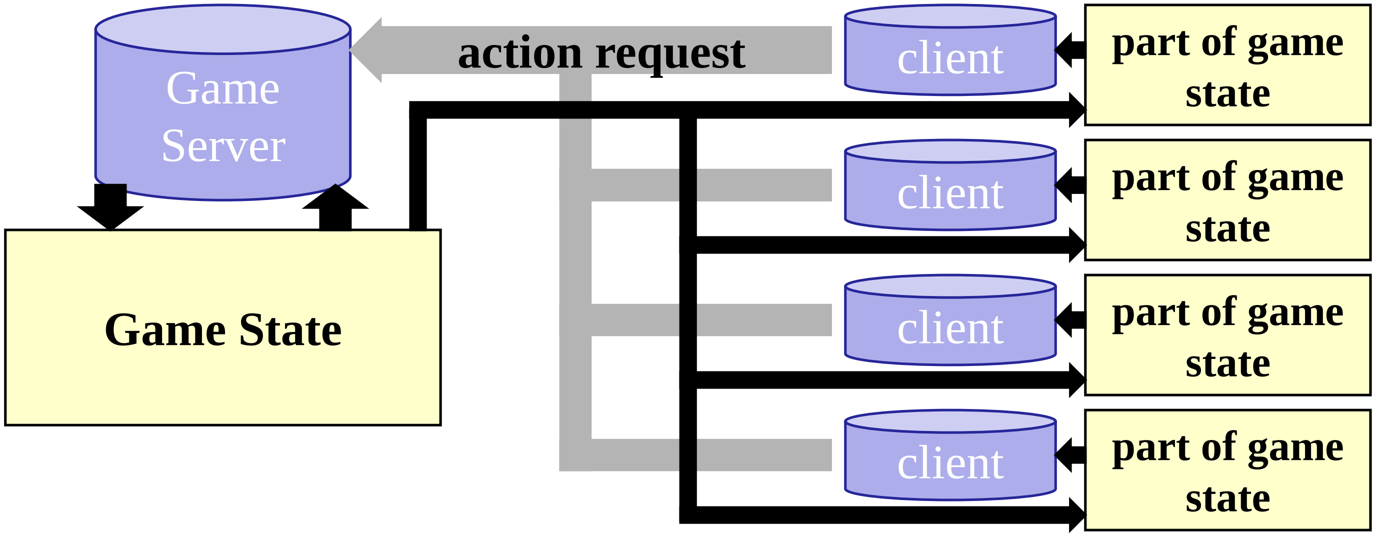
- Object attributes: (Action Result Protocol)
  - protocol sets the current parameter value of a game entity
    (set player „ FacemeIt0r“ HP to 96)

  - protocol sends relative changes
    (reduce player „FacemeIt0r“ HP by 100)

- Actions: (Action Request Protocol)
  - contains only player input without direct impact on game state
  - protocol only transfers user input
    => results must be calculated on the server
    (try to hit Player „FacemeIt0r“ with „Uppercut“)

Thin Client Solution

- server holds the complete game state and is solely authorized to change it
- clients receive a part of the game state upon login
- server transmits game state changes to clients
- client transmits actions it wants to execute to the server (Action Requests)
- server collects all incoming action requests
- actions are handled in order of arrival and results are transmitted to the affected clients



Thin Client Solution

Advantages:

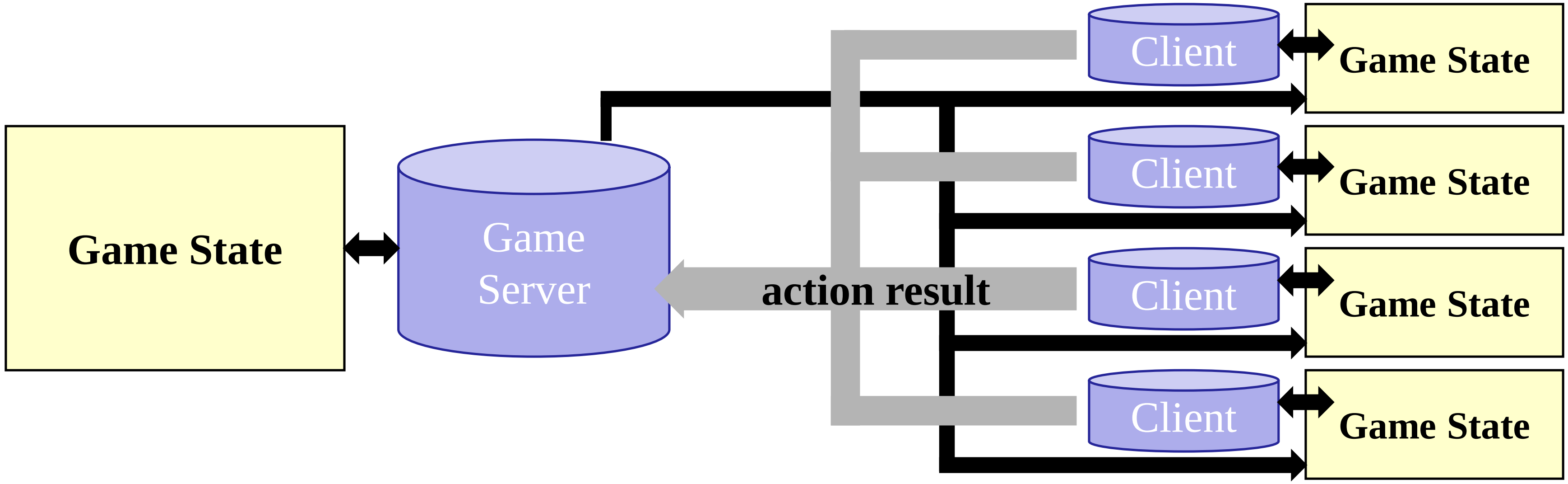
- game state is centrally managed
  - consistent game state for calculating action results
  - no conflicts from several contradictory game states
  - persistence system is able to save consistent game states
- low potential for cheating/ action handling only on the server

Disadvantages:

- maximum server load because all action handling is done on the server
- potential for high latencies due to round trip times
  (actions need to be transmitted to the server and back to take effect)
- processing power at client side is largely unused
  (clients only display the game state and
  transmit user inputs to the server)

Fat Client Solutions

- every client has its own objects which only can be edited by itself
- server manages chronological sequence with time stamps and transmits changes to the other clients
- local game states may vary, due to transmission delay
- chronological sequence may be inconsistent because local changes may be applied before global changes with an earlier time stamp arrive

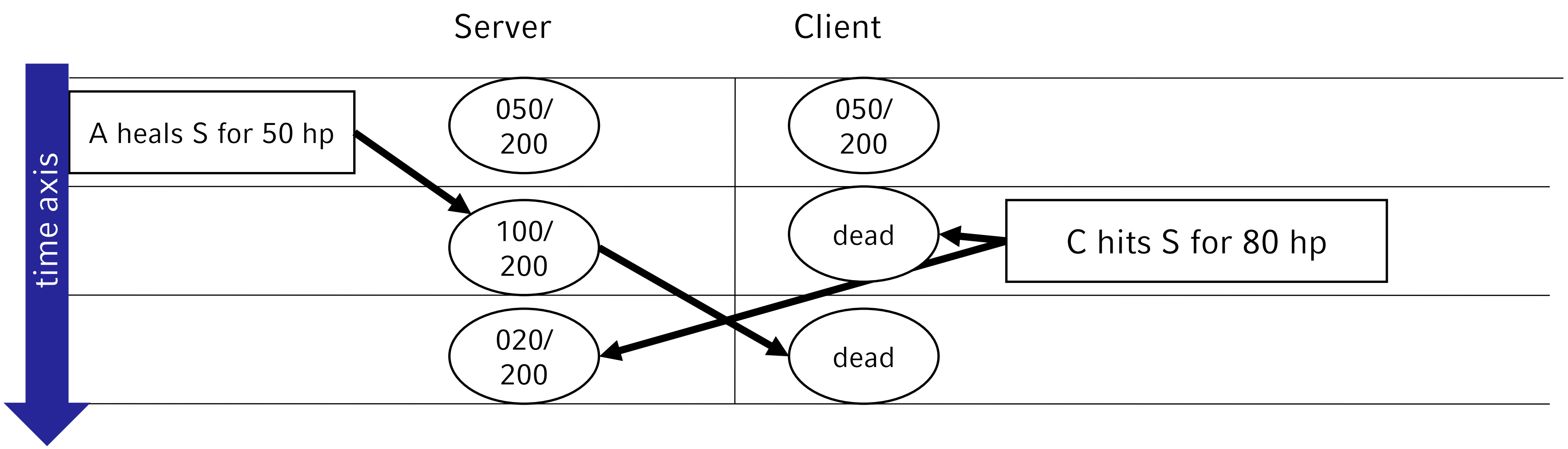


Conflicts during decentralized computing

- local changes need time to be transmitted within the network
- actions are calculated for and executed on local game states

  => changes that predate the action may not be taken into account
- simple solutions:
  - client is not allowed to change local data without server acknowledgment
  - using object protocols the server may send an update of the current game entity state.

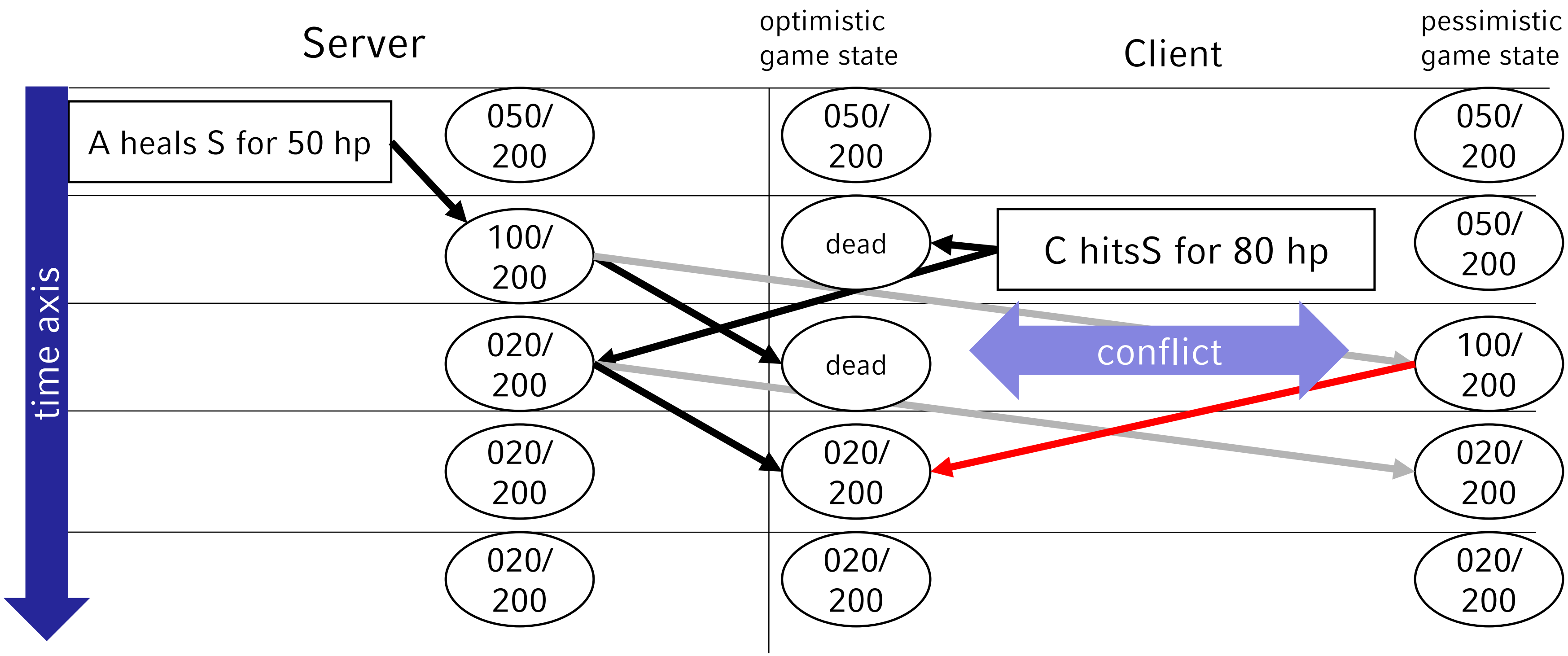
example for network effects on the game state:



Solution Approach

reset local actions

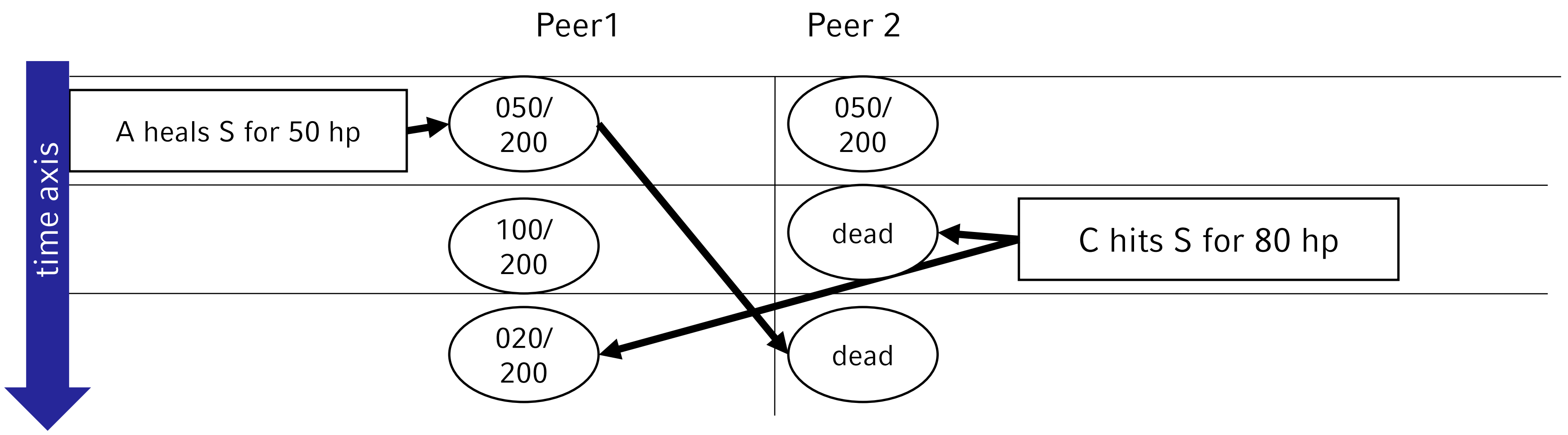
- client has 2 game states:
  - optimistic GS (contains local changes)
  - pessimistic GS (contains actions transmitted by the server)
- on mismatch: reset the optimistic GS to the state of the pessimistic GS



Local Time

up until now: one server handles processing sequence

- impossible for P2P games and multi server architecture
  => sequence is inconclusive after arrival at server
  => organization by local time stamps on creation
- during processing both, own and foreign changes may appear in incorrect sequence
- in case of inconsistencies game entities must be synchronized

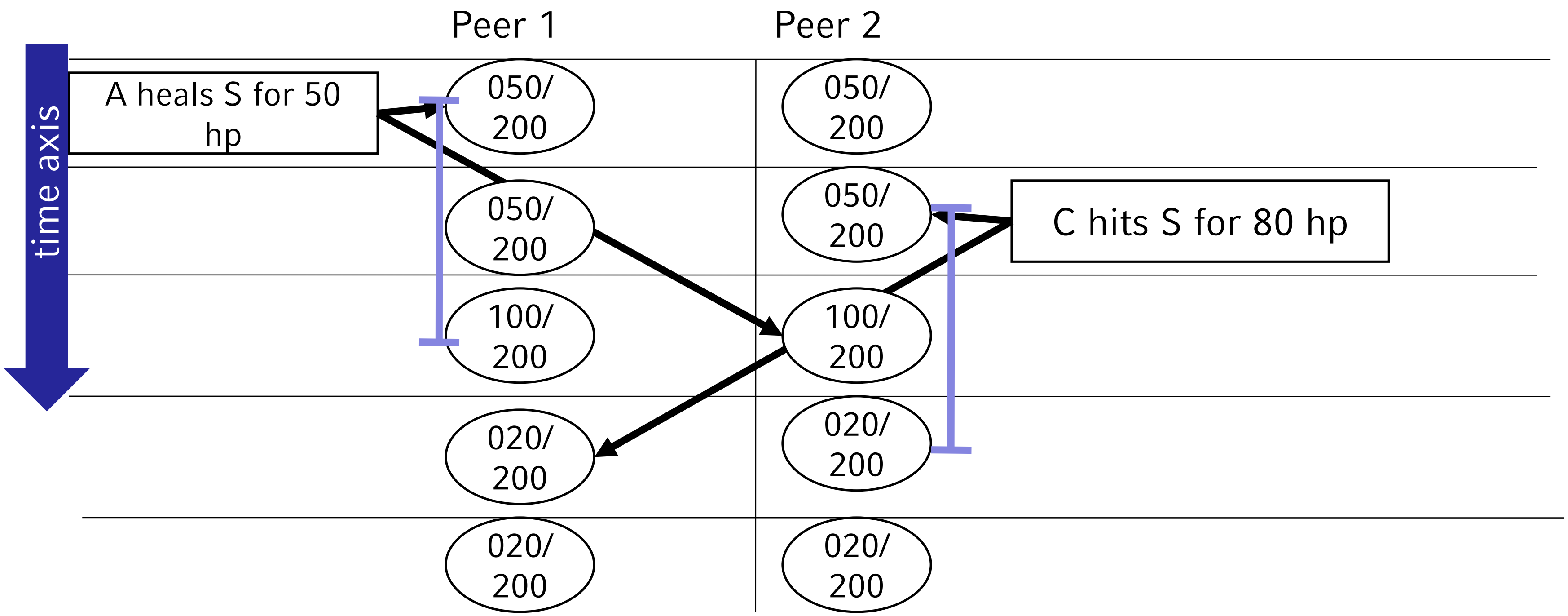


Solutions by Local Lag Mechanism

problem is caused by the lack of knowledge about previous actions

solution: local lag mechanism

- processing updates is delayed to allow for other actions to arrive in time
- if this time frame is exceeded, conflict detection and reset are necessary



Application in Games

Games can combine several approaches by processing actions differently.

Server side processing	Client side processing
• accuracy is important • response time less important • chronological order is important	• response time is crucial • synchronization and sequence are less important
• damage and healing • item pick up	• object positions and movement • animations and other display effects

Conclusion:

- generally speaking, there is a trade off between latency (here: response time) and consistency of the game world. (c.f. CAP theorem)
- another issue is reducing remote updates to reduce the needed bandwidth.

Movement Information

movement-updates play a special role in distributed virtual environments

- fluid movement
  - ⇒ positions may change several times per second (24-60 FPS)
  - ⇒ calculation should be closely tied to rendering
  - ⇒ handling movement and other actions in the same way might disturb fluid rendering of the gaming world
- precise positions are mostly irrelevant for game play:
  - ⇒ due to the fast update rates, the loss of several position updates is often negligible

Consequences:

- movement for real-time games is predominantly calculated locally on the client
- parts of objects trajectories are not transferred to other peers to save bandwidth
- Movement is extrapolated locally and positions are synchronized only at certain points times

=> **Dead Reckoning**: simulating movement between two updates to allow for fluid movement with limited bandwidth

Dead Reckoning

*dead reckoning components for **games**:*

- **Update-Strategy** on the server side (owner of changed) game entity:
  controls when is position information transmitted to other peers
  and with what frequency (influences bandwidth and error rate on the client)

- **Movement model** on remote peer:
  Comprises all methods to extrapolate fluid movement based on the transmitted positions (influences error rate and perception of movement on the client)

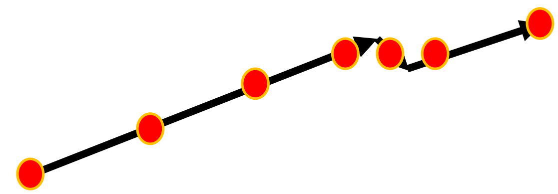
- **Error correction** on remote peer:
  Allows for converging extrapolated local position and exact positions received from the owner of the game entity (influences perception on the client)

=> **There is a trade-off between**

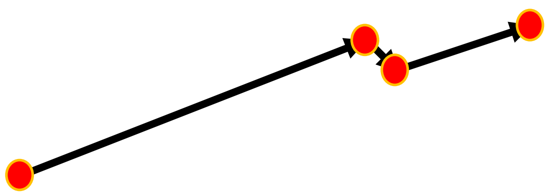
  - bandwidth and error rate
  - perception quality and processing time

Update-Strategies for Dead Reckoning

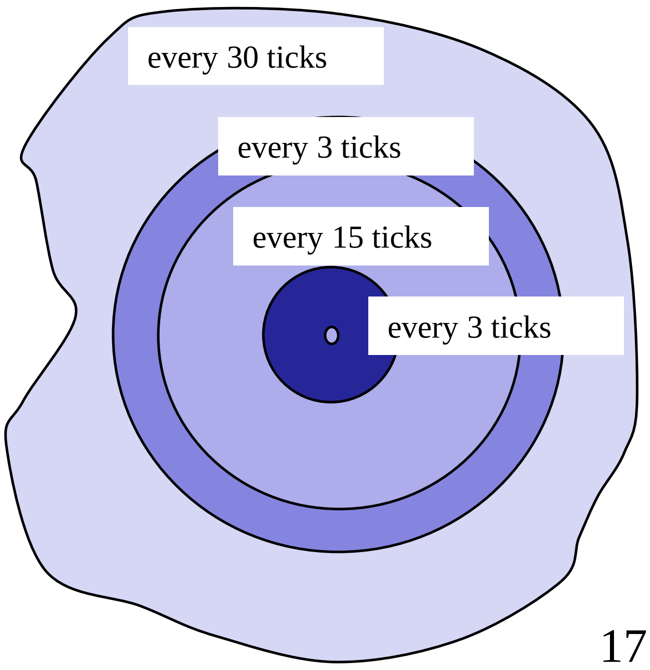
- regular updates:
  - send updates in regular intervals



- event based updates:
  - send updates on changing direction or movement type



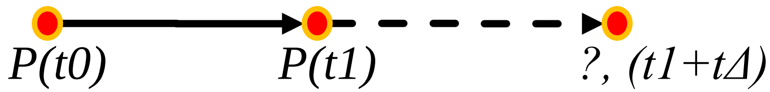
- distance-based-updates:
  - precise positions are more important the closer an object is
  - the closer an object is to a critical range (e.g., weapon range)
  - transmits regular updates, but with different rates, depending on distance.



Movement model for Dead Reckoning

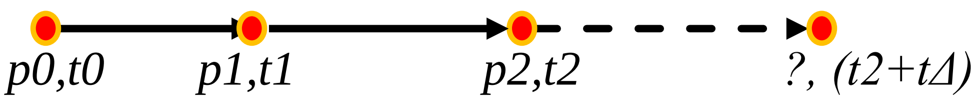
Point in time: t_i *Position:* $p(t_i)=(x_i,y_i)$ *Average speed:* $v(t_i)$ *acceleration:* $a(t_i)$

Linear movement with constant speed:



$$p(t_1+t_\Delta) = p(t_1) + \underbrace{\frac{p(t_1)-p(t_0)}{\|p(t_1)-p(t_0)\|}}_{\text{direction}} \cdot t_\Delta \cdot \underbrace{\frac{\|p(t_1)-p(t_0)\|}{(t_1-t_0)}}_{\text{speed}} = \boxed{p(t_1) + t_\Delta \cdot \frac{p(t_1)-p(t_0)}{(t_1-t_0)}}$$

Linear movement with constant acceleration:



$$p(t_i + t_\Delta) = \frac{1}{2} a(t_i) t_\Delta^2 + v(t_i) t_\Delta + p(t_i)$$

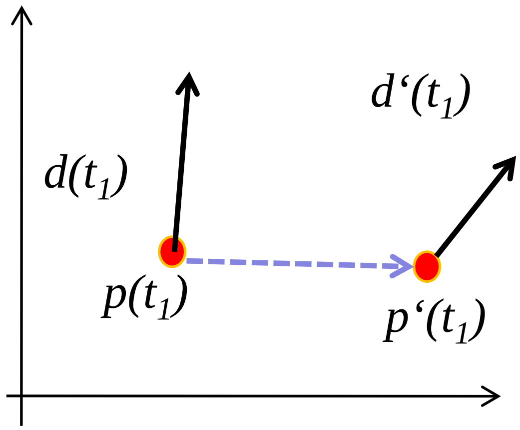
$$a(t_i) = \frac{\Delta v}{\Delta t} \approx \frac{v(t_i) - v(t_{i-1})}{t_i - t_{i-1}}$$

$$v(t_i) = \frac{\Delta p}{\Delta t} \approx \frac{p(t_i) - p(t_{i-1})}{t_i - t_{i-1}}$$

Error Correction for Dead Reckoning

problem: prediction and update do not correspond.

- object on a remote peer is overwritten by an update
  for high error rates:
  - objects jump
  - objects disappear and reappear elsewhere

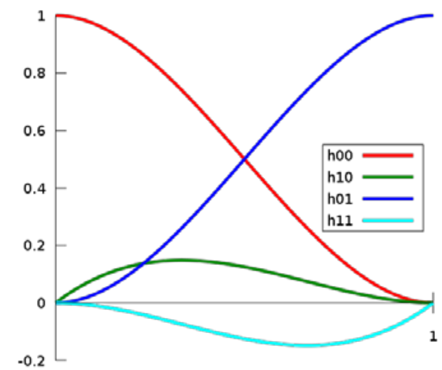


- both positions are merged with an accelerated fluid movement:
  - e.g. cubic polynomials: Bezier, B-Splines, Hermite
  - must allow for a certain correction time Δt

Hermite graphs for polynomial smoothing

four base polynomials:

- $h1(x) = 2x^3 - 3x^2 + 1$
- $h2(x) = -2x^3 + 3x^2$
- $h3(x) = x^3 - 2x^2 + x$
- $h4(x) = x^3 - x^2$

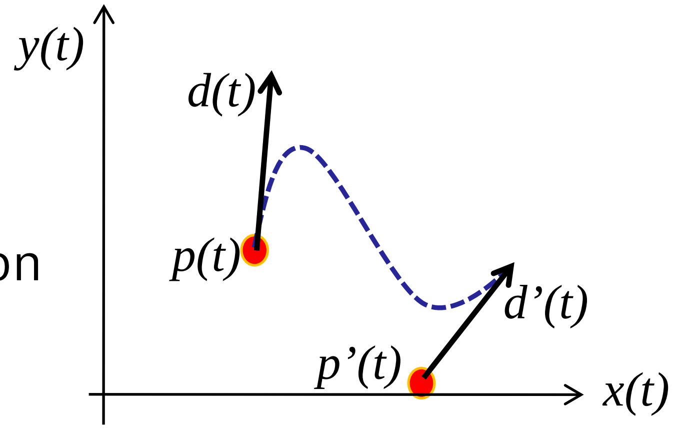


connecting points p and p′ + d′ using the following linear combination

$p(x) = p(t)\, h1(x) + p'(t+\Delta t) h2(x) + d(t)\, h3(x) + d'(t)\, h4(x)$ $(0 \le x \le 1)$

- position: $p(t)$ via Dead Reckoning
- movement direction: $d(t)$ via Dead Reckoning
- target: $p'(t) + d'(t)$ via server-update

  where $p'(t+\Delta t) = p'(t) + d'(t)$ is the position at the point $t+\Delta t$ in time
- Δt: Time for corrections (compensation by faster speed)



Thoughts on Client-Server Communication

important factors influencing the communication

- **Latency**: time until the system reacts
  - round trip time (RTT)
  - package size
  - system load aside from the network
- **Bandwidth**: How large is the transferred volume?
- **Burstiness**: How is the data volume distributed over time?
- **Connection-oriented/package oriented protocols**
  - connection oriented: Routing happens once
  - package oriented: Routing happens for every package
- **Security**: Is loss of data possible?

Requirements of computer games

application/platform	payload size (bytes) avg.	min	max	avg. bandwidth requirement pps	bps
Anarchy Online(PC)‡	98	8	1333	1.582	2168
World of Warcraft (PC)	26	6	1228	3.185	2046
Counter Strike (PC)	36	25	1342	8.064	19604
Halo 3	247	32	1264	27.778	60223
Gears of War (XBOX 360)	66	32	705	2.188	10264
Tony Hawk's Project 8 (XBOX 360)	90	32	576	3.247	5812
Test Unlimited (XBOX 360)	80	34	104	25	22912

from: Harcsik, Petlund, Griwodz, Halvorsen: Latency Evaluation of Networking Mechanisms for Game Traffic, NetGames'07, 2007

- small package sizes
- little bandwidth is used
- latency by genres:
  - RTS-games: <1000 ms
  - RPG: < 500 ms
  - FPS: < 100 ms

  (Estimated latency for observing a serious impairment of the gaming experience.)

Protocols and Communication solutions

TCP/IP:

- safe protocol: by re-transmission
- flow control and congestion control
- optimized for bandwidth usage and data transfer
  (sending big packages to reduce the transmitted TCP-Headers)

Disadvantages:

- packages may arrive with significant delay (re-transmission)
  => increased latency
  => package may not be needed anymore since newer information has already been transmitted
- optimizing bandwidth artificially increases latency
  - waiting for payload for underfilled packages
  - confirmation packages confirm several packages or are embedded within returning traffic
- optimization by tuning and turning features off.

Protocols and Communication solutions

UDP

- minimal datagram service
- no explicit connection to the remote station
- unsafe transmission, correct sequence is not guaranteed
- no congestion control mechanisms

Advantages:

- no retransmission of lost packages

  => outdated information will not be resend
- less header overhead

Use:

- middle ware solutions which implement missing service features in the higher layer protocols:
  - maintain update sequence
  - security for certain update operations (e.g. picking up items, …)

Conclusion network protocols

- TCP/IP is still the most used protocol since routers and infrastructure are usually designed for TCP/IP
- UDP offers a light weight solution for just-in-time services (voice, movement, …)
- secure services are still mandatory for most games and must be implemented in the application layer of the protocol
- studies on other protocols (e.g. SCTP), show no significant increase in performance
- majority of games uses TCP for communication

Learning Goal

- Client-Server and P2P architecture in games
- distribution of action handling:
  - global processing
  - local processing with centralized chronology
  - local processing with local chronology

- Dead Reckoning
  - update-strategies
  - movement models
  - error correction

- requirements for network protocols for games
  - TCP and games
  - UDP, middle ware and games

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