A Hybrid Architecture for Massively Multiplayer Online Games

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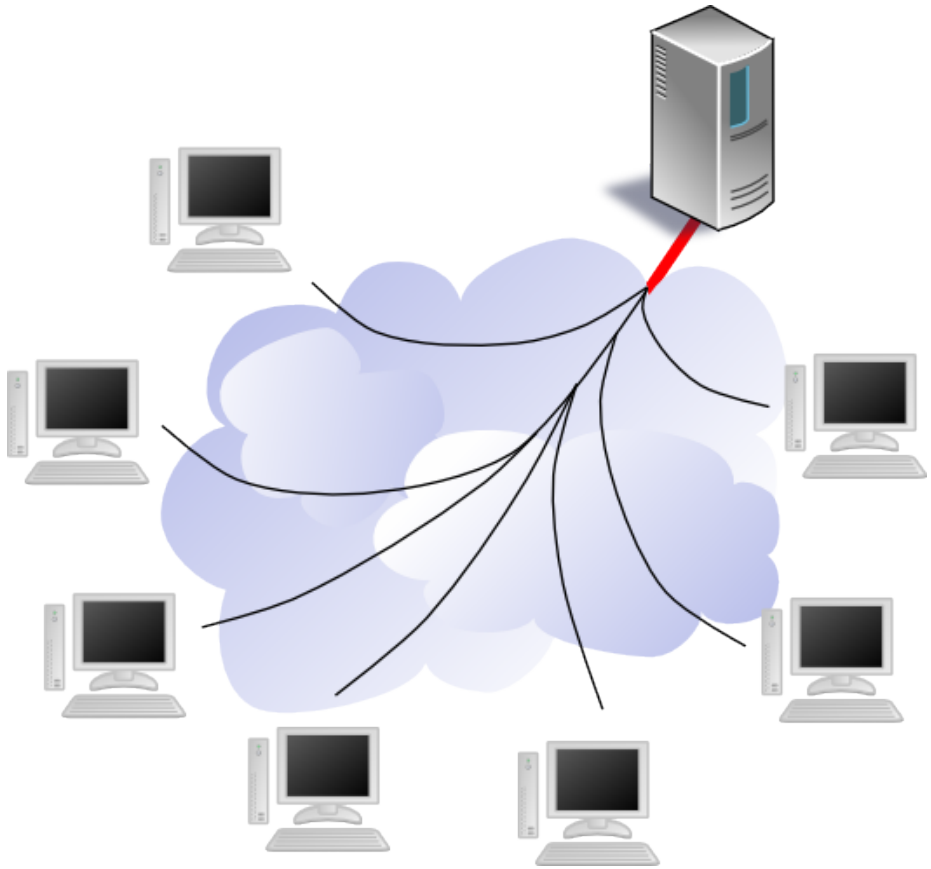
The Bandwidth Bottleneck

- bandwidth is a bottleneck for client-server game architectures
- peer-to-peer architectures
  - distribute bandwidth
  - lower latency
  - provide greater fault tolerance



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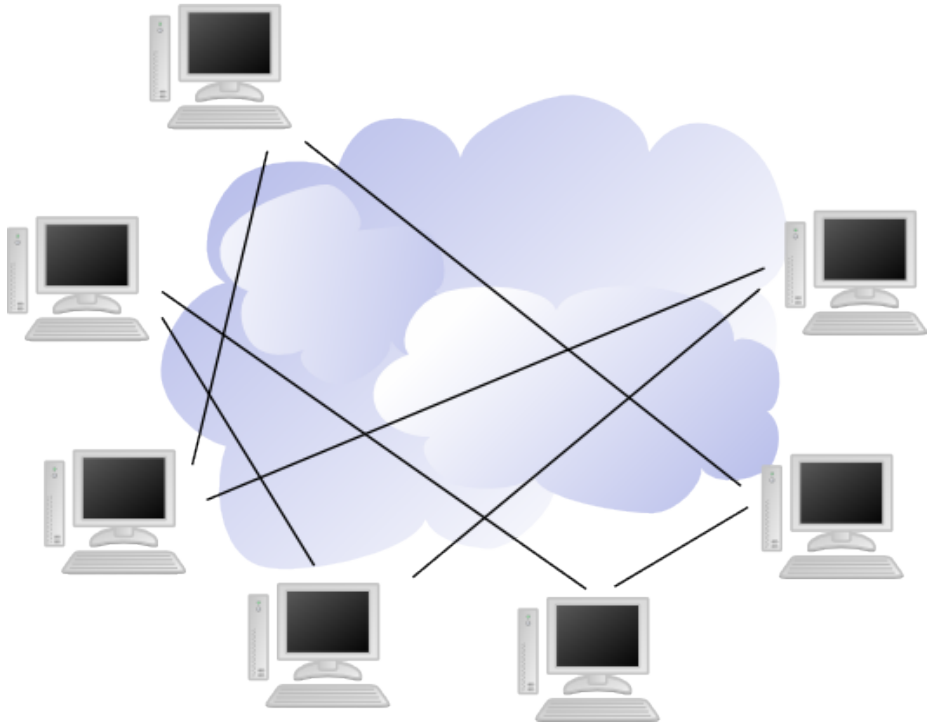


Advantages of a Client-Server Architecture

- server controls game state
  - simple to provide state consistency – a single source for state updates
  - simple to provide event ordering – order moves as they reach the server
  - (relatively) simple to prevent cheating – the server is a central authority for who did what when
- peer-to-peer architectures make all of this much harder
- any peer can be malicious

A Hybrid Architecture

- state-changing moves: any move that changes state, such as items, boundaries, attacks
- positional moves: any move that does not affect game state, such as walking
- hybrid of client-server and peer-to-peer
  - use server to distribute state-changing moves
  - use a hierarchy of peers to distribute positional moves
- goals
  - use centralized control to maintain consistency and prevent cheating
  - use peers to offload bandwidth from the central server
- challenges
  - ensuring peers are capable of distributing positional moves
  - detecting and removing malicious or poorly-performing peers

Contributions

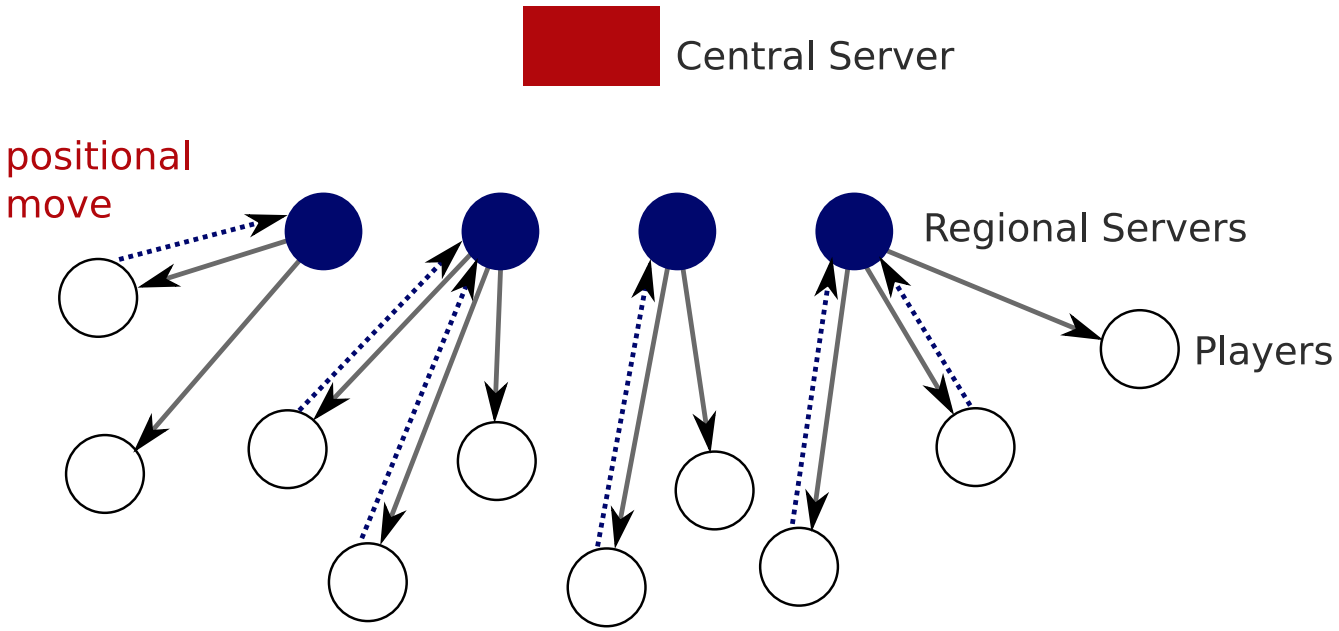
- experiments with 50 automated players on PlanetLab
- preliminary results show hybrid architecture scales better than client-server
- performance advantages depend on having enough capable players to participate in the distribution hierarchy

Related Work

- DHT Architectures
  - publish-subscribe for state changes
  - map game state to a node in the DHT
- hierarchical architectures
  - divide a game into regions
  - assign players as regional servers – manage state for the region
- both approaches susceptible to misbehaving or malicious users
  - allow players to store and manage game state
  - allow players to distribute updates
- hierarchy is more easily controlled

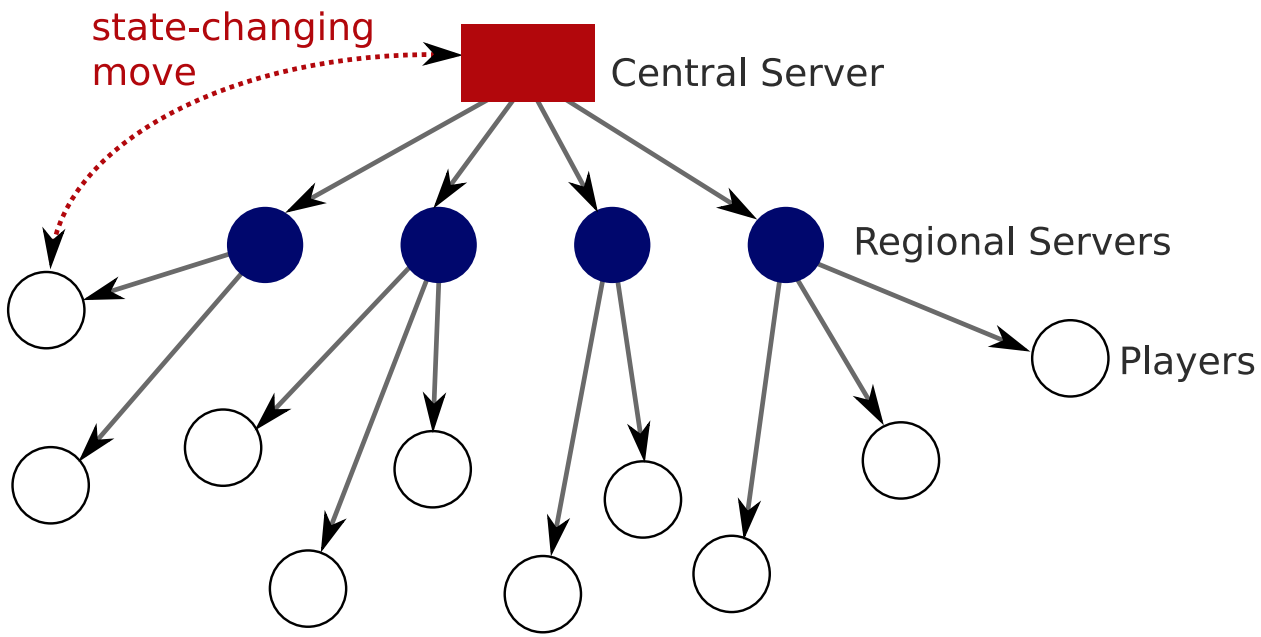
Hybrid Architecture

- divide the game into regions
- assign peers to act as regional servers
- players make positional moves through regional servers (e.g. walking across a room)



Hybrid Architecture

- divide the game into regions
- assign peers to act as regional servers
- players make state-changing moves through central server (e.g. picking up a coin off the floor)



Bandwidth Savings

- positional moves
  - central server uses no bandwidth
  - savings proportional to the percentage of positional versus state-changing moves
  - in role-playing games, a significant percentage of moves are positional
- state-changing moves
  - central server sends updates to regional servers instead of all players
  - savings proportional to the average density of a region

Measuring Capable Players

- regional servers need
  - enough bandwidth capacity
  - low latency to central server
- measurements
  - pathrate: estimate the capacity of the path between central server and regional server
  - ping: measure the lateny between central server and regional server
- requirements
  - minimum bandwidth, latency
  - no NAT
  - group players into bins, with bandwidth preferred over latency
- monitoring
  - regional servers send periodic positional updates
  - replace regional server if it misses 3 consecutive updates

Security Concerns I

- ability to cheat significantly limited compared to peer-to-peer architectures
  - state changes handled by central
  - security concerns limited to regional servers
  - reduced subscription fees to well-behaved servers to provide incentive to avoid cheating

1. denial of service: drop or delay state updates
   - players monitor regional server performance
   - report complaints to central server
   - central server may replace regional server

Security Concerns II

2. inside information: join own region, see how other players move before making its own move; join multiple regions
   - changing regions is considered a state-changing move
   - prevent regional server from moving into its own region
   - prevent players from joining more than one region
3. collusion: give advantages to some players in its region
   - central server conduct audits of state-changing moves
   - verify the player had enough time to move into area where state-changing move is made
   - remove offending servers from game

Treasure Hunt Game

- two opposing teams of players
- a player from each team assigned a particular treasure to find and return to home base
  - given region where treasure is located
  - must travel to region and search for treasure there
  - given updates of what they can see as they move
  - move 1/2 speed when carrying treasure
- players that meet fight for treasure
  - winner determined by previous victories, team score, random factor
  - winner keeps treasure, loser returns to base

Experimental Setup

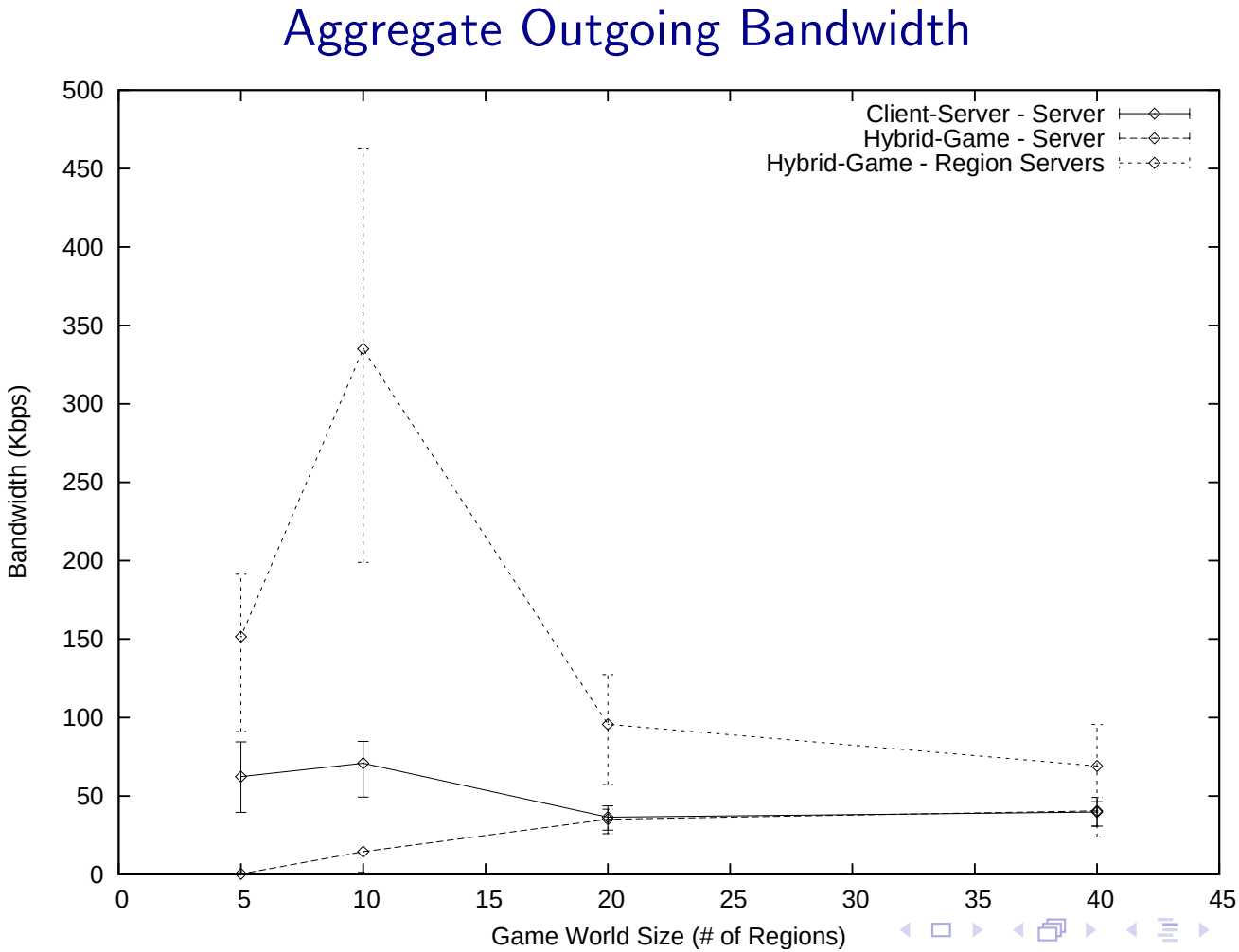
- PlanetLab experiments
  - 50 automated players, 10 minute game
  - rate limit players to 10 Mbps, 1 Mbps, 56 Kbps
  - 5 repetitions of each experiment
- workload
  - 5 moves per second maximum
  - player updates: 20 bytes
  - state updates: 320 bytes (sizes based on recent study)
- compare client-server and hybrid architectures

Varying Region Density

- 50 players
- reduce size of game world: 40 to 5 regions
- 12/50 players capable of begin regional servers

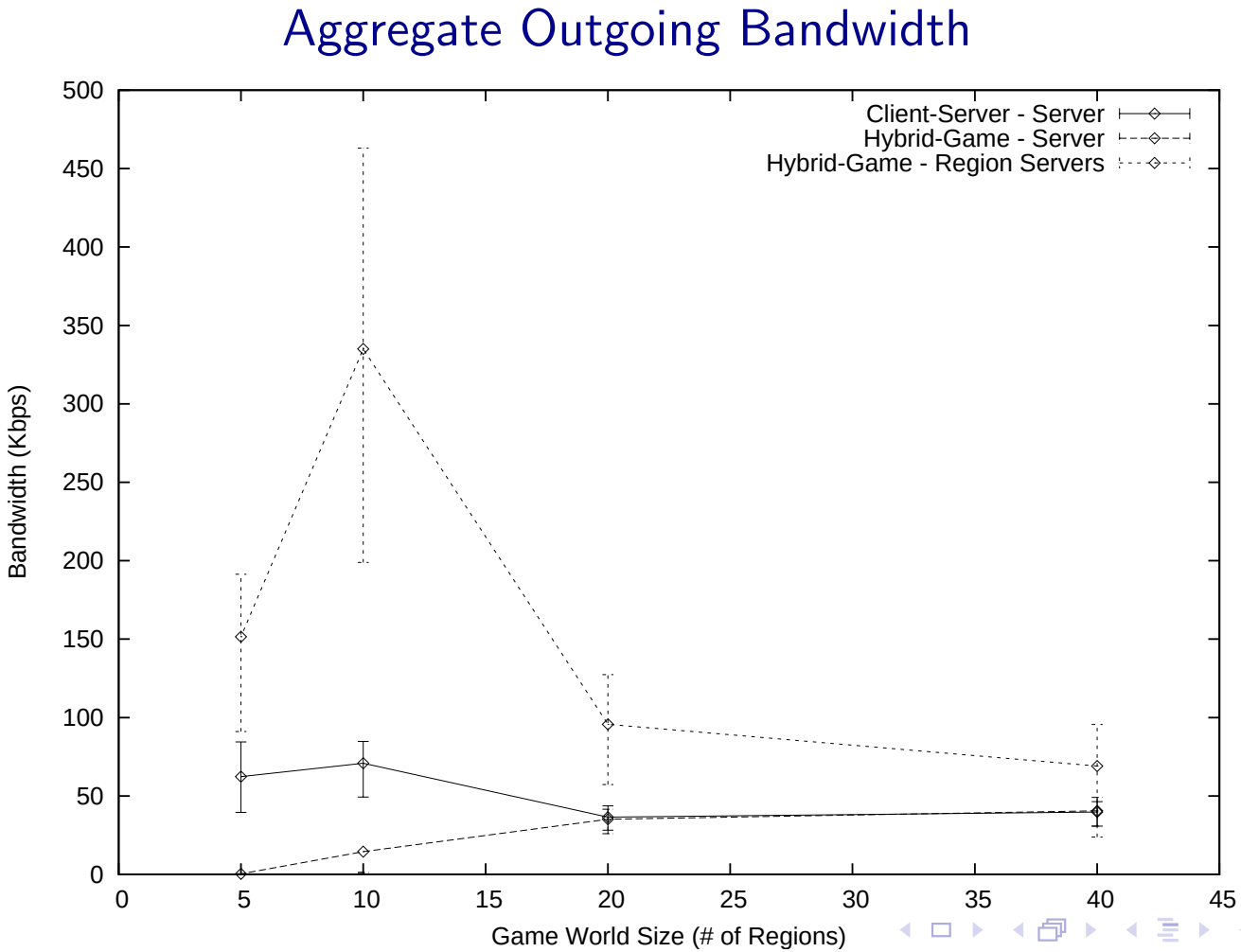
Varying Region Density

- reduces central server bandwidth once there are enough regional servers



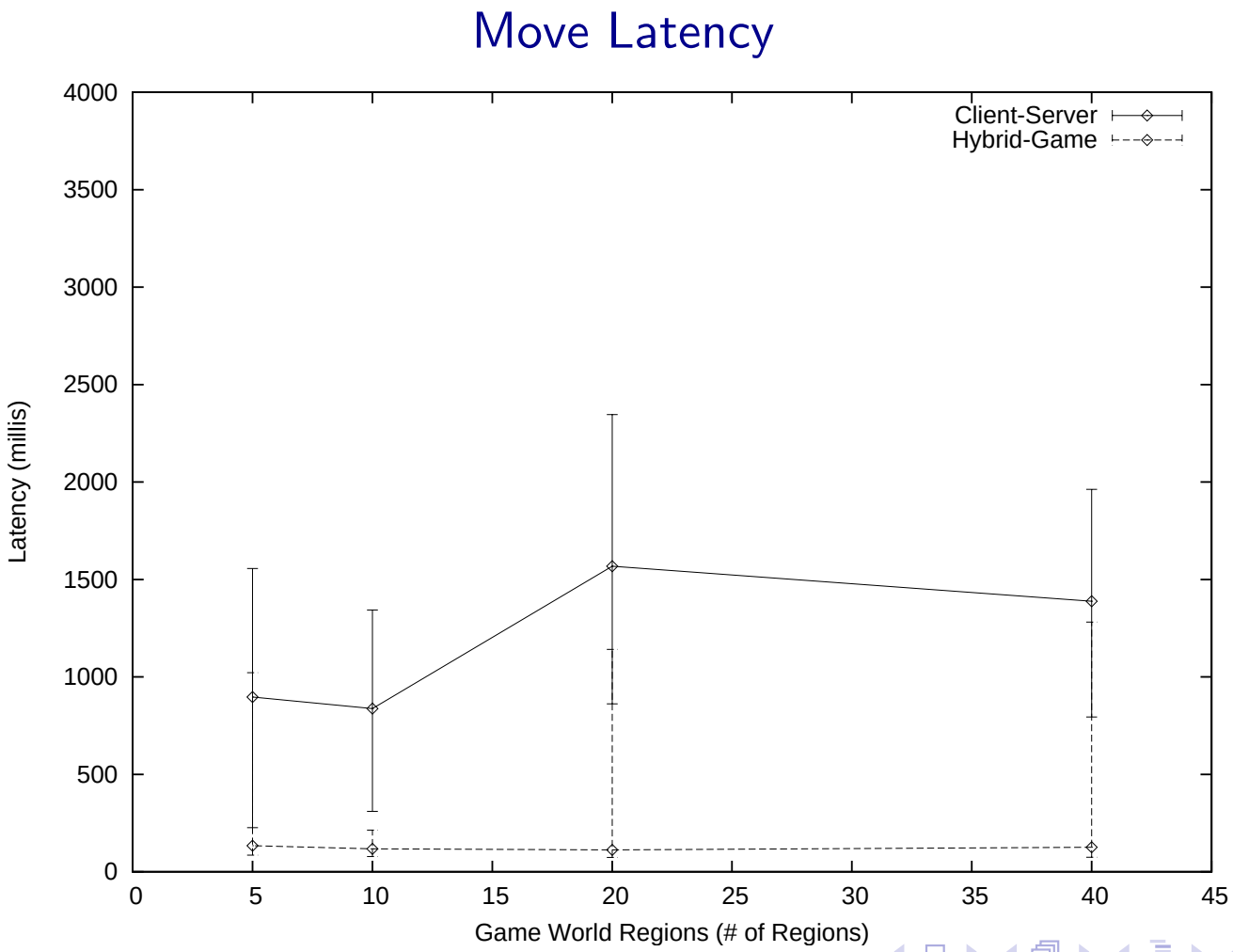
Varying Region Density

- high regional server bandwidth indicates handling more moves per second (2.5 versus 1)



Varying Region Density

- reduces latency relative to client-server

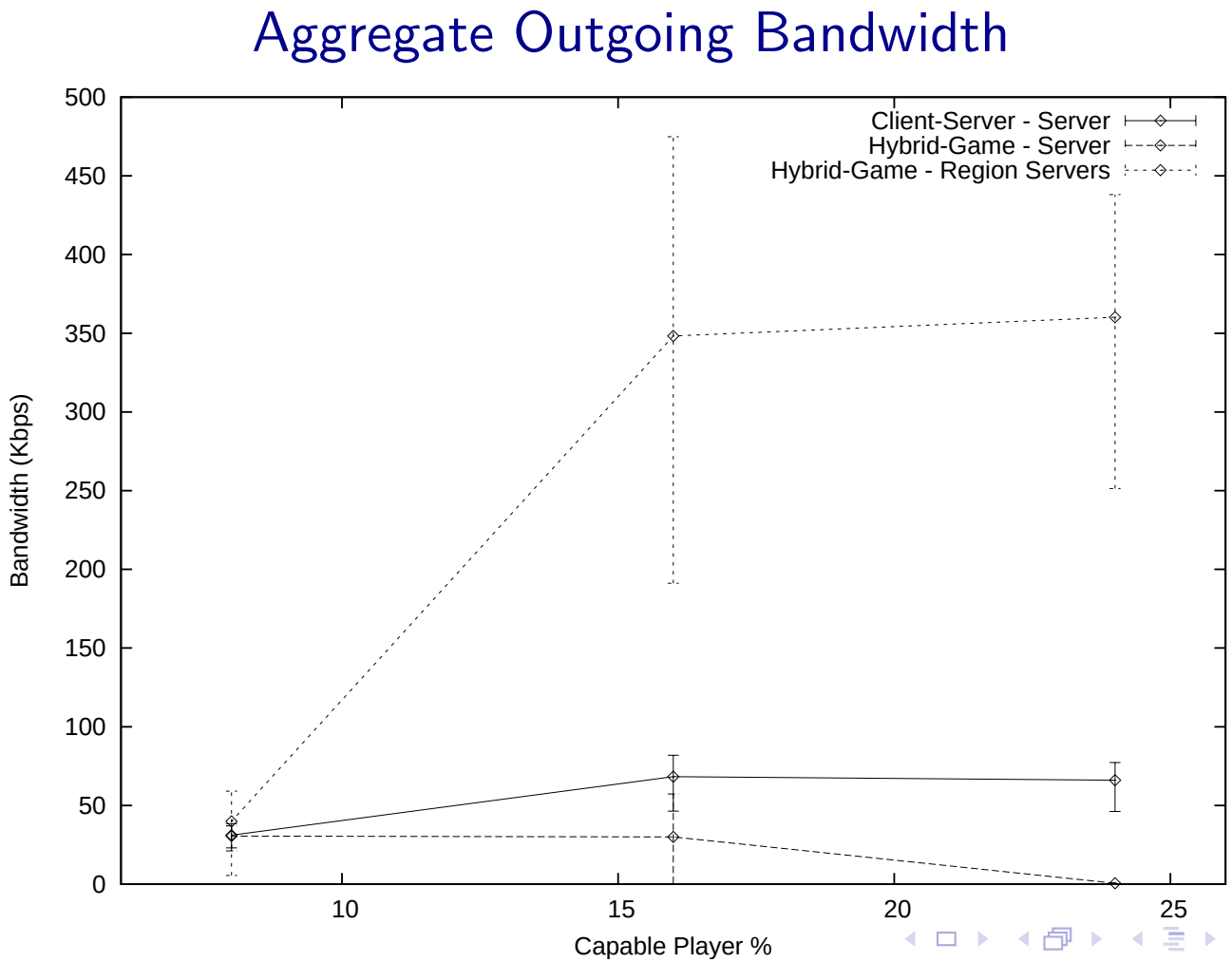


Varying Player Capability

- 50 players, 8 regions
- vary capable players: 4 to 12

Varying Player Capability

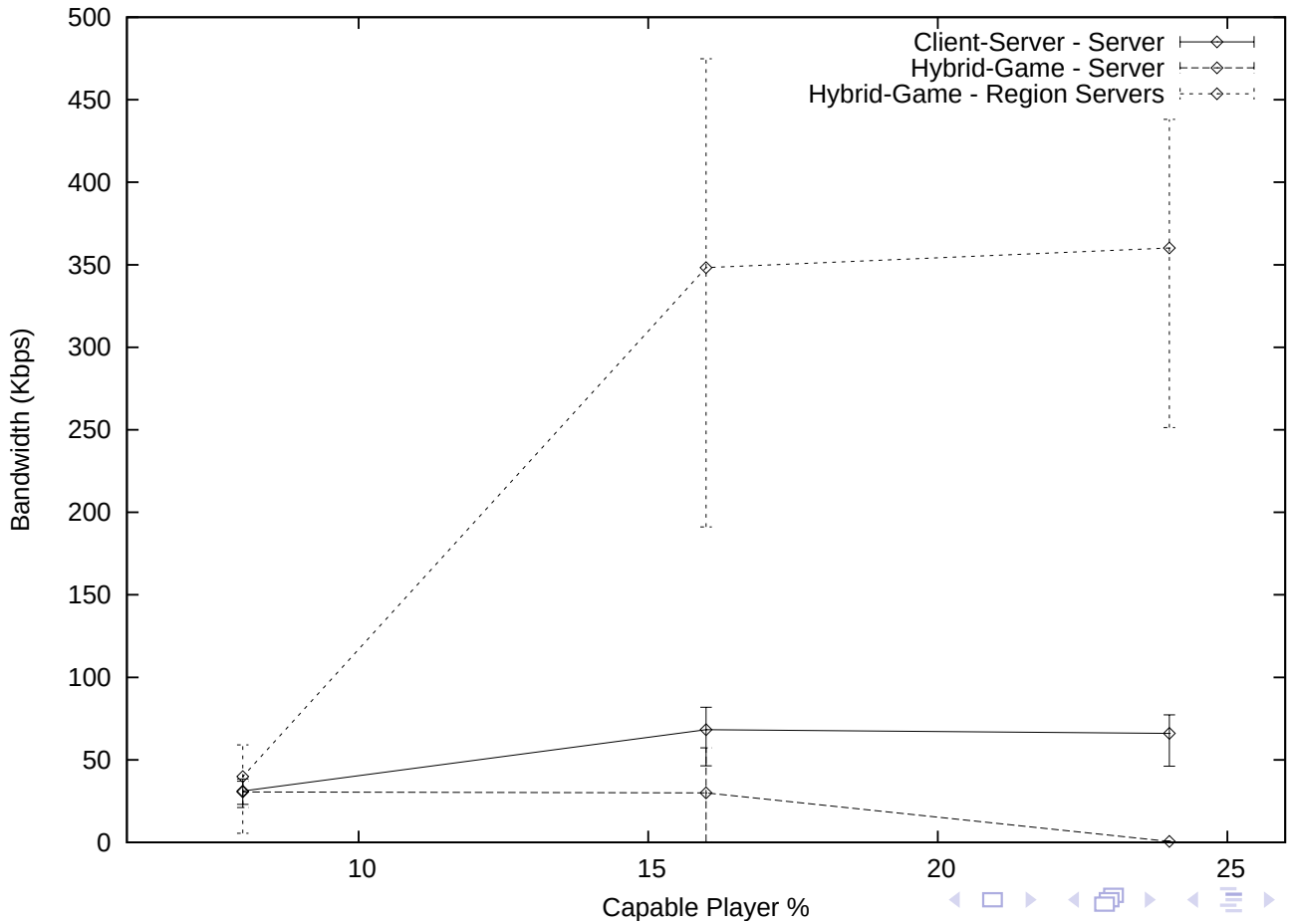
- more capable players means reduced bandwidth on central server



Varying Player Capability

- high regional server bandwidth indicates handling more moves per second (2 versus < 1)

Aggregate Outgoing Bandwidth



Varying Player Capability

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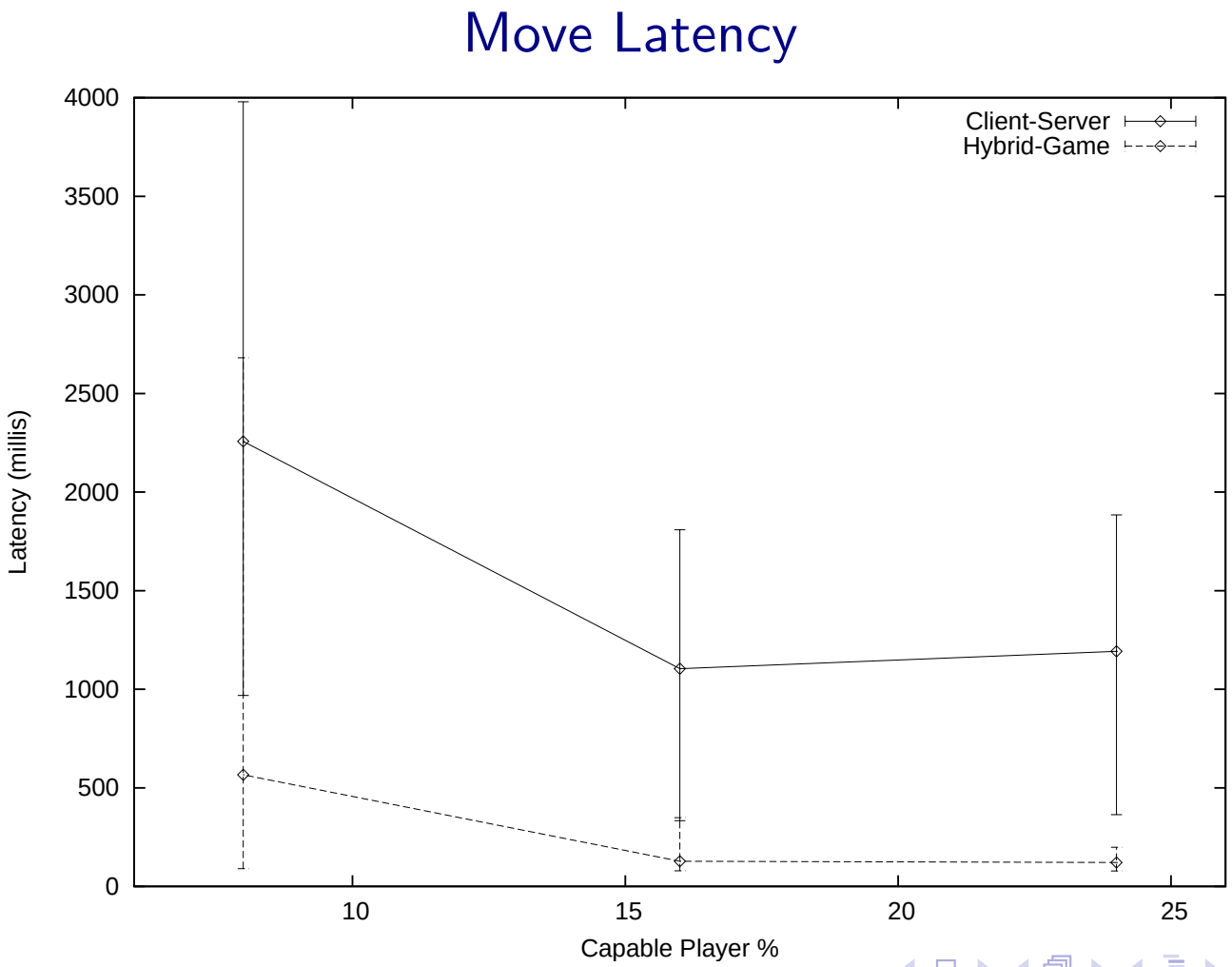
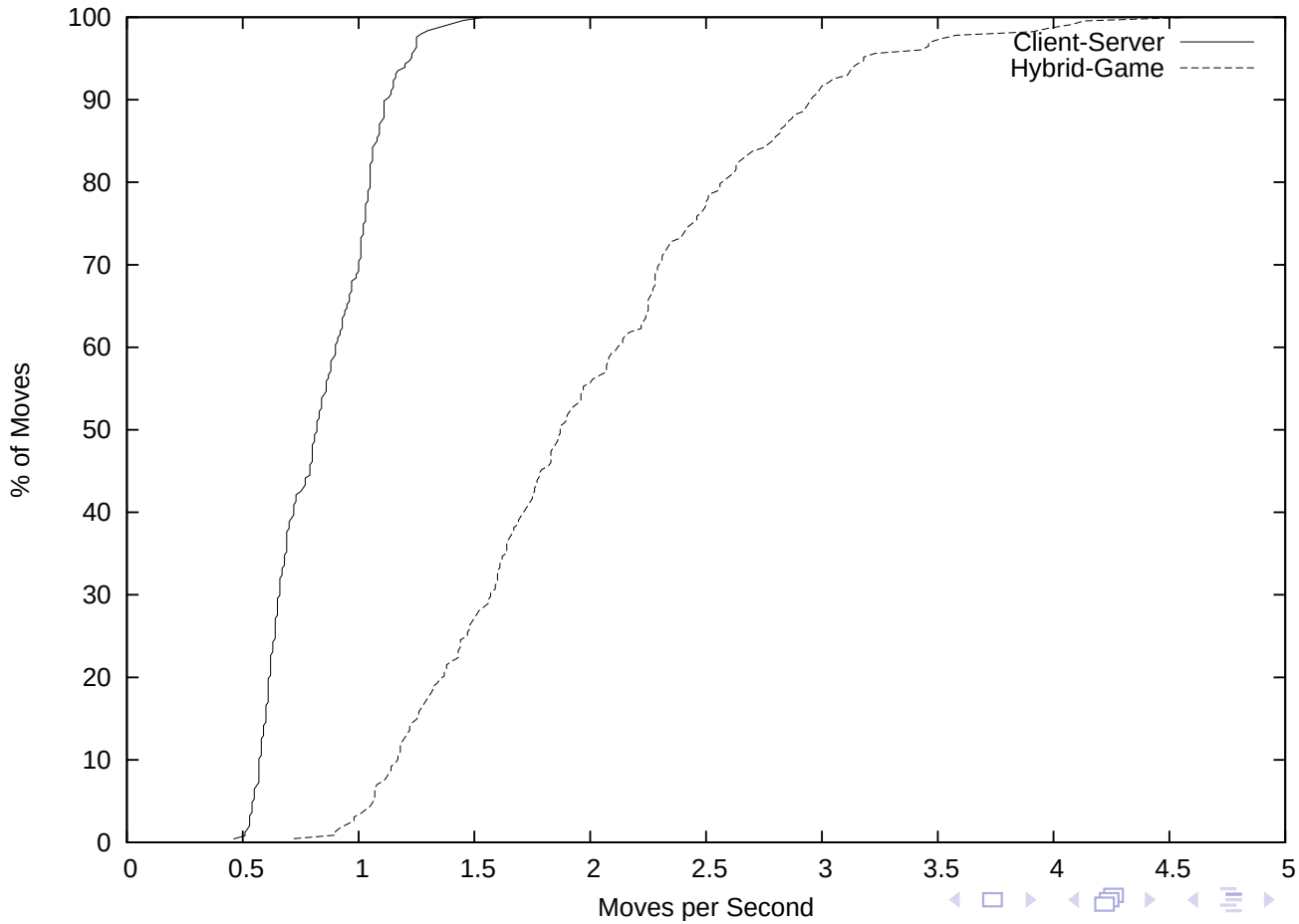


Move Latency

- 12/50 capable players, 8 regions
- hybrid: up to 4.5 moves per second

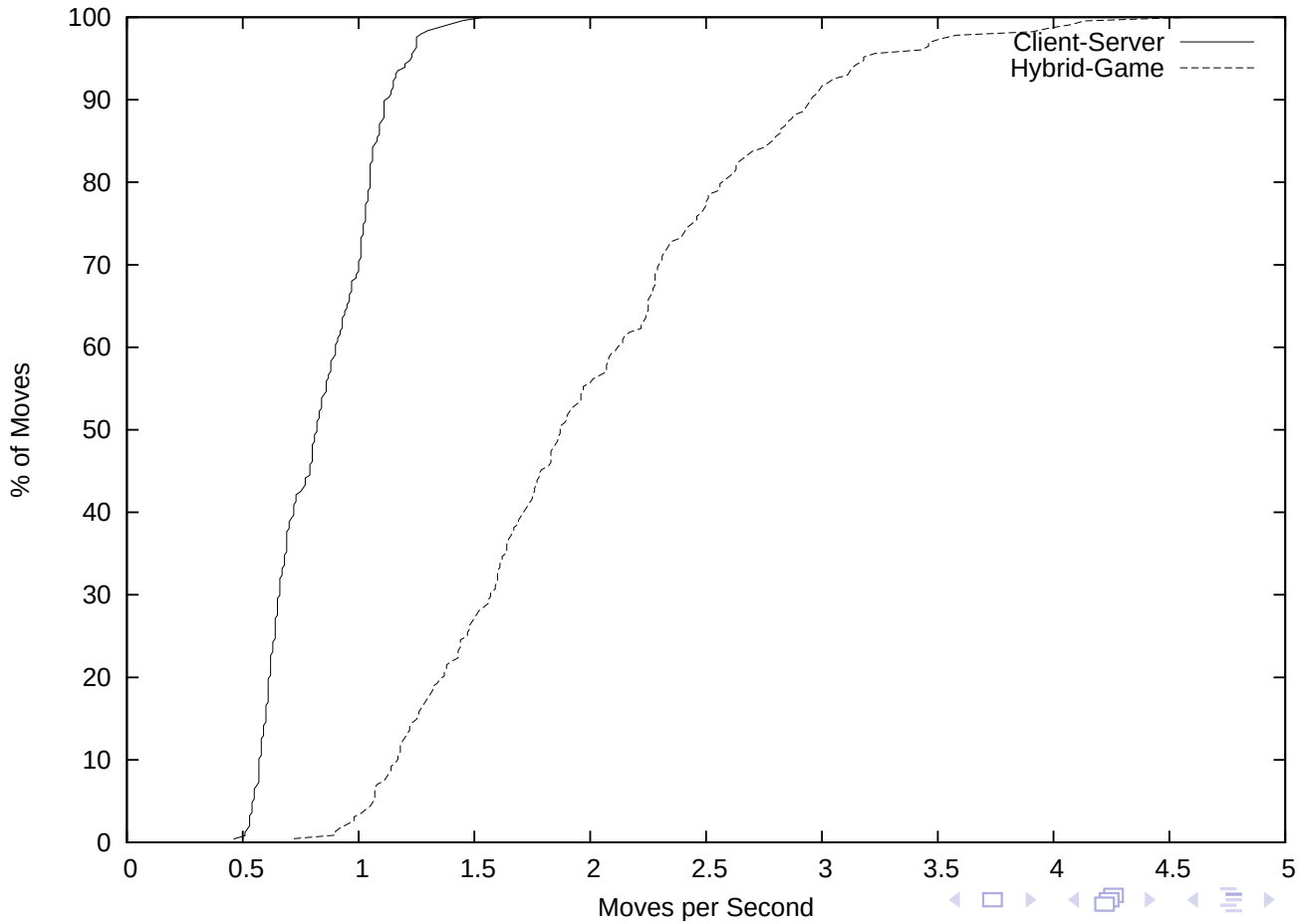
CDF of Move Latency



Move Latency

- 10th percentile for hybrid = 80th percentile for client-server
- some players may be stuck with high-latency paths

CDF of Move Latency



Future Work

- relatively poor performance in terms of moves per second
  - both architectures use same code base
  - improve implementation to make more realistic performance study
- try to decrease latency while coping with PlanetLab variance in capabilities and performance
- further examine
  - scalability
  - failure scenarios
  - cheating prevention
- integrate into an existing game