Improving Online Gaming Quality using Detour Paths

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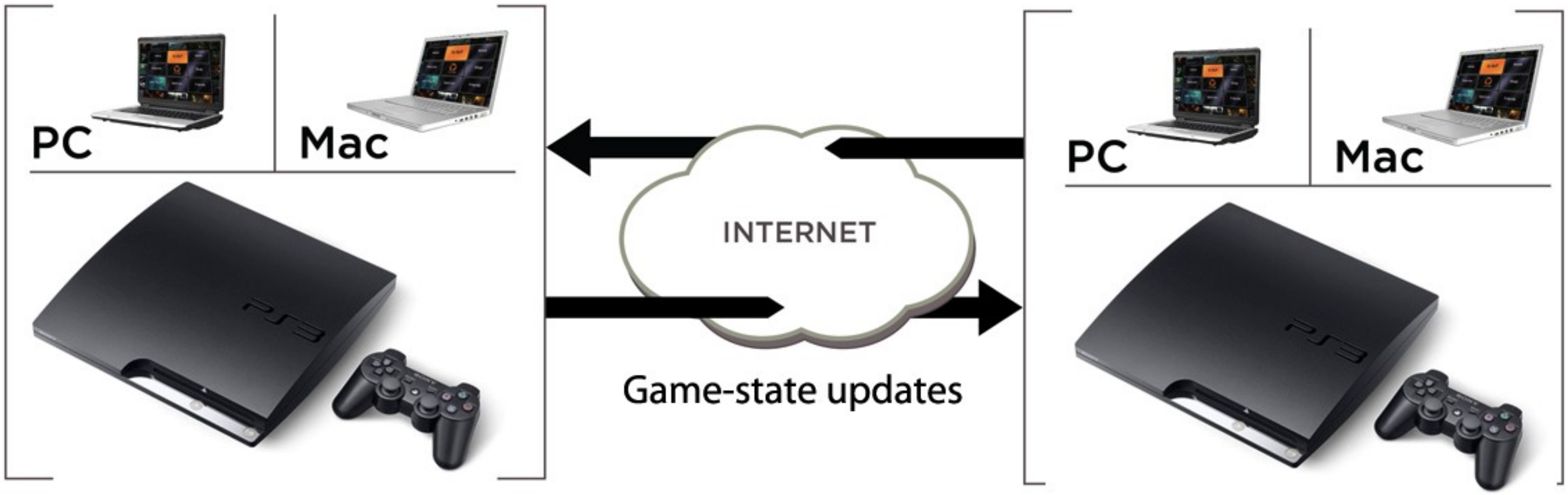
Online Multiplayer Games



- 37% of the US population played online games in 2009 [Nielsen]
- World of Warcraft (WoW) has 11.5 million subscribers [Blizzard]
- Market research forecasts [NPD]
  - $48.9 billion revenue by 2011

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Online Gaming over the Internet

- Gaming traffic
  - Highly periodic
  - Low bit rates (25 – 100 bytes/packet) [Feng]
  - Less sensitive to bandwidth and packet loss
  - Sensitive to high latency
- Network latency in the Internet
  - Geographical locations
  - Link congestion (failure)
  - Types of network technology, e.g., 3G data networks

Network Latency

Game Type	Example Genre	Latency Threshold
Avatar	First-person shooter (FPS), Racing	100 msec
	Sports, Role-playing games (RPG)	500 msec
Omnipresent	Real-time strategy (RTS), Simulations	1,000 msec

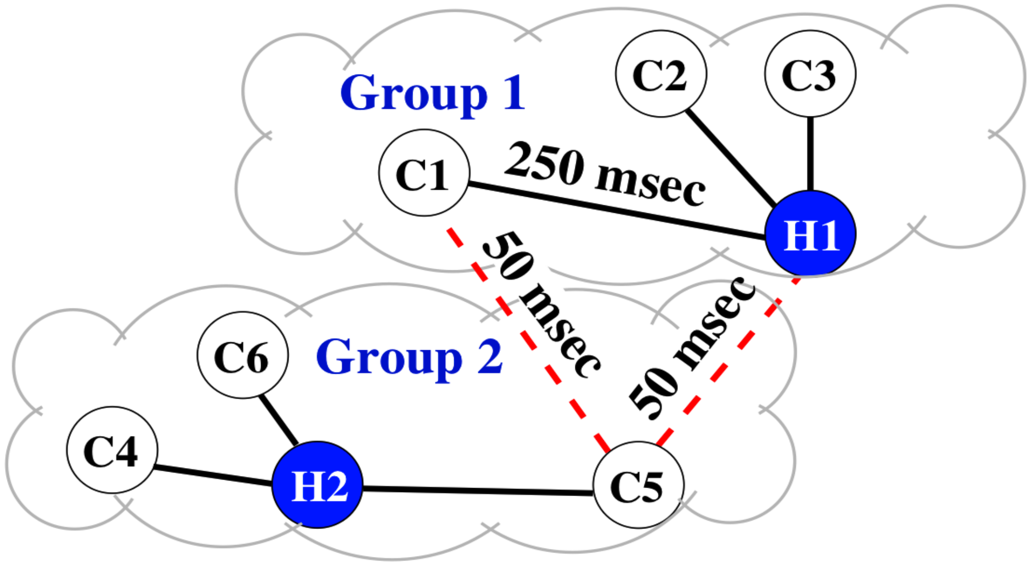
- Different types of games can tolerate different amount of quality degradation caused by network latency [Claypool]
- Higher than these thresholds would lead to significant drops in gaming quality
  - Players will leave the game

More efficient routing is needed for game traffic!

Outline

- Motivation
- Problem Statement
- Related Work
- Design and Implementation
- Real Deployments and Experimental Results
- Simulation Results
- Conclusions

Problem Statement



- Players form game sessions
- Problem: design an efficient system to reduce the network latency among players in each game session

Related Work

- Latency compensation mechanisms
  - Lockstep and event-locking, controls consistency [Baughman ‘01]
  - Dead reckoning (DR), extrapolate the behavior [Bernierr ‘01]
  - Matchmaking, prevents high latency peers from playing together [Agarwal ‘09]
  - Hide network latency
- Detour routing for latency reduction
  - RON (resilient overlay network) [Andersen ‘01]
  - OverQoS uses overlay routing for QoS enhancements [Subramanian ‘04]
  - PeerWise searches for faster detour paths [Lumezanu ’07]
  - Not for online multiplayer games
- We use detour paths in online gaming networks to directly reduce end-to-end network latency

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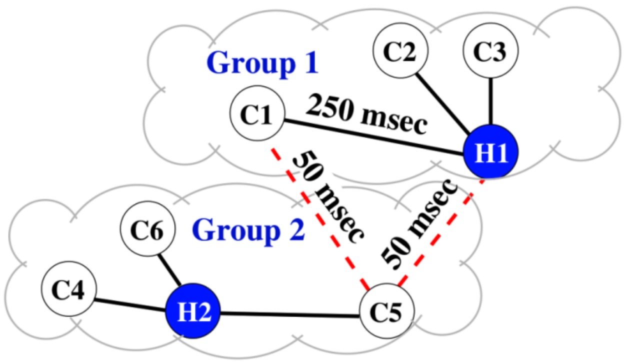
Detour Paths

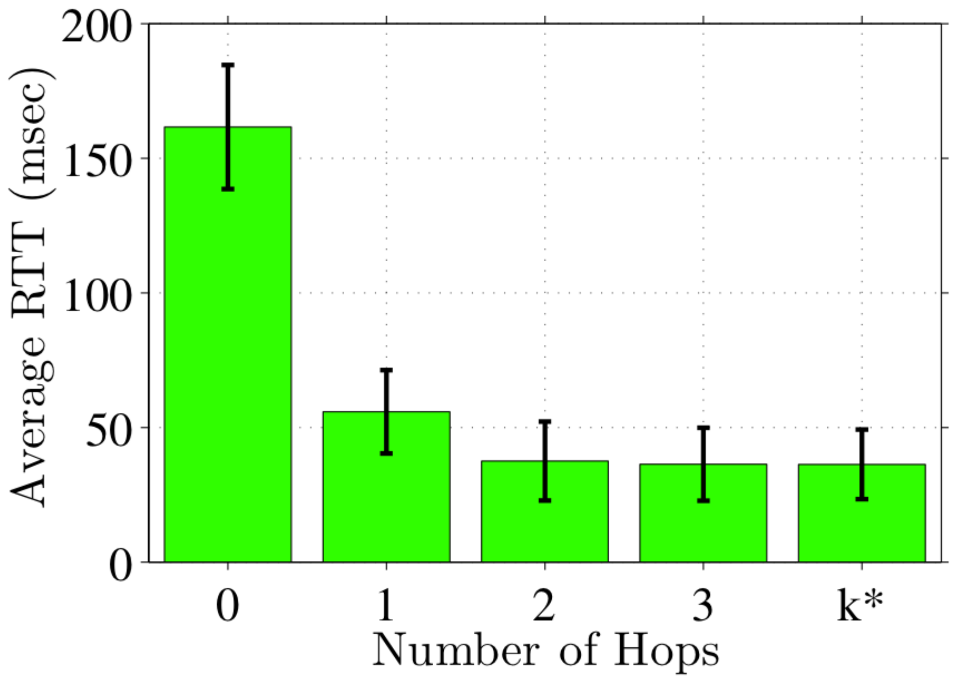
- Detour paths: indirect paths that lead to smaller RTTs
- Exist because of triangle inequality violations (TIVs) in Internet [Savage 99']
  - Inter-domain policy routing
- By routing game-state updates over detour paths, we can reduce end-to-end RTTs



- How many hops should we consider when identifying detour paths?

Number of Hops

- We conducted RTT measurements among more than 28,000 IPs from online game players
- We quantify the potential of detour routing in online games
- Average RTT of detour paths
  - Reduced from 156 msec to 53 msec with just 1-hop
  - Optimal k*-hop is 46 msec



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Indirect Relay System (IRS)

- We propose the Indirect Relay System (IRS) to identify 1-hop detour paths
- Straightforward approach: construct a graph
  - May take prohibitively long time to measure RTTs
- A better solution: evaluate the likelihood for a client *r* to be the best relay client based on estimation errors of network coordinates
  - Higher estimation error results in higher likelihood of detour paths [Lumezanu '09]
  - Actual relay node evaluations are distributed to the clients

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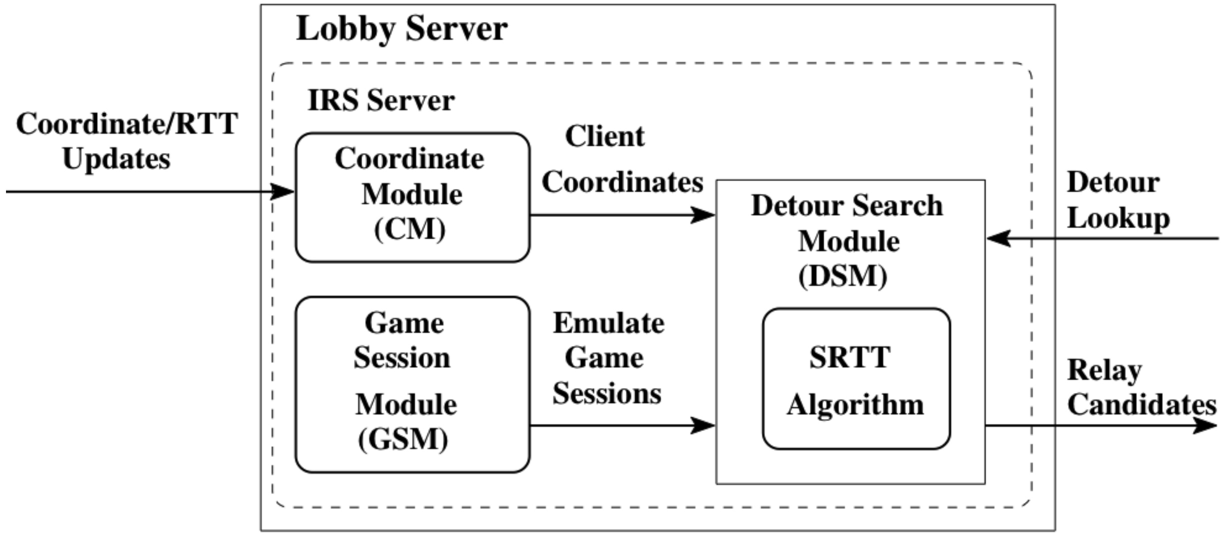
IRS Server Design



- Integration
  - Lobby server or Standalone
- Shortest RTT (SRTT) Algorithm
  - Compute estimate errors
  - Select *K* potential relay clients

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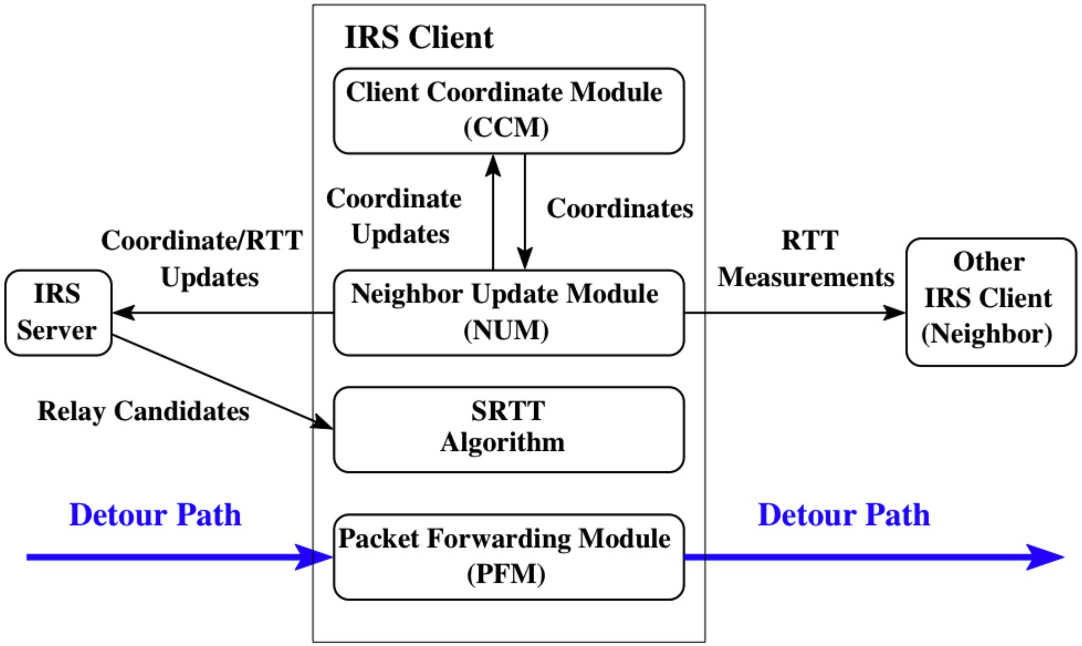
IRS Client Design



- Integration
  - Game client
- Shortest RTT (SRTT) Algorithm
  - Conduct actual RTT measurements to the *K* potential relay clients

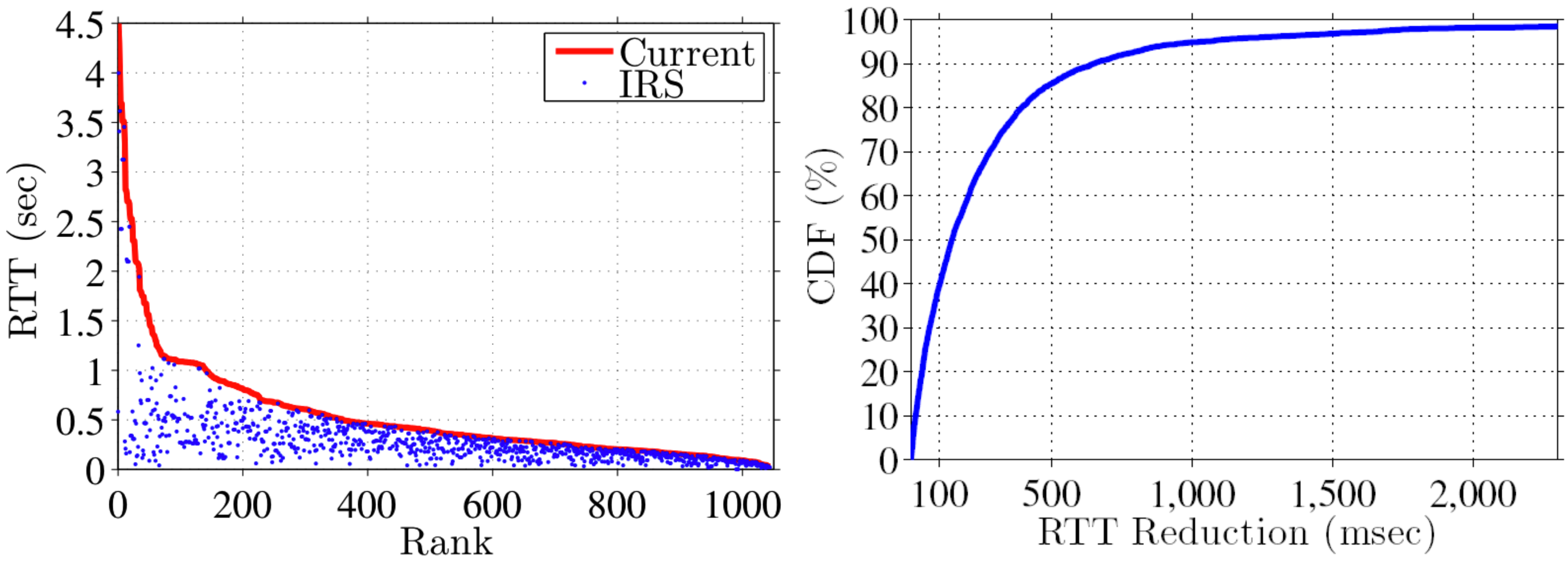
Implementation

- About 3,700 lines of Java code.
  - Client & Server components
- Network coordinates system
  - Uses Vivaldi, a decentralized network coordinate system
  - Based on open source Pyxida project [Ledlie]
- Simulate real gaming traffic
  - Randomly send packets between 25-100 bytes
  - Relay overhead are embedded in the Proxy-Ping

Planetlab Deployment

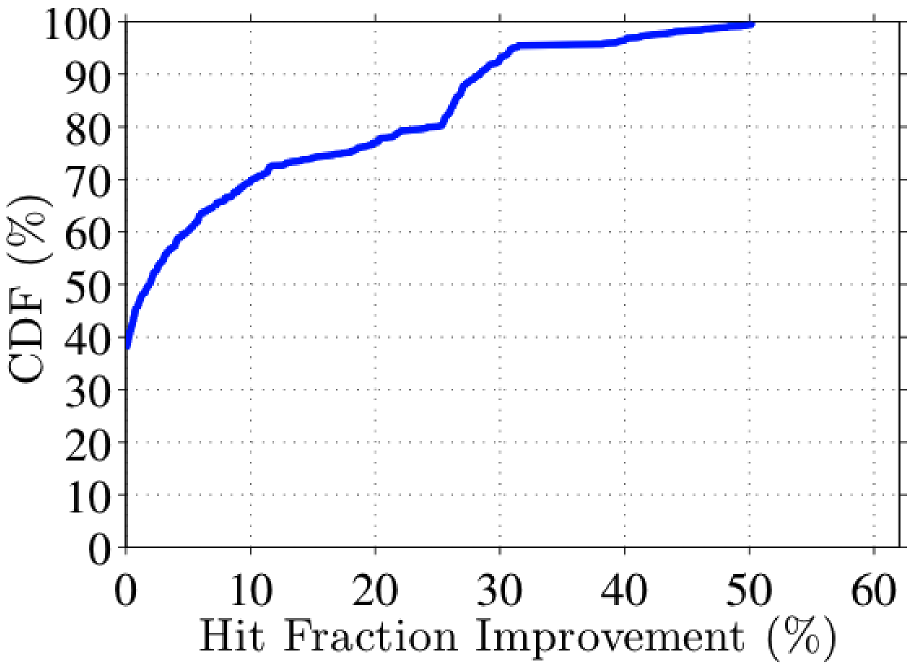
- On 500+ nodes
- *K* potential relay clients and *N* neighbors are set to 32
- More than 3,000 game sessions with length between 3 and 10 mins
- Five experiments to rule out the time-of-day variations
- 9+ hours each run
- Results from the experiments are consistent, and we report the results from the experiment conducted on Jan 07, 2010

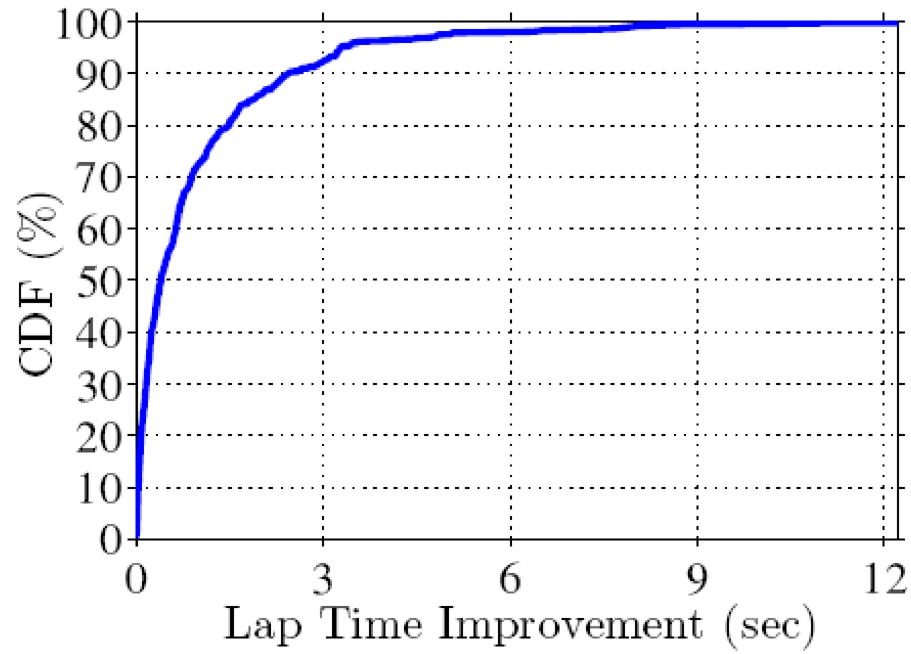
RTT Reduction



- Some sessions are reduced from > 3 sec to < 0.3 sec
- More than 60% player pairs achieve more than 100 msec reduction

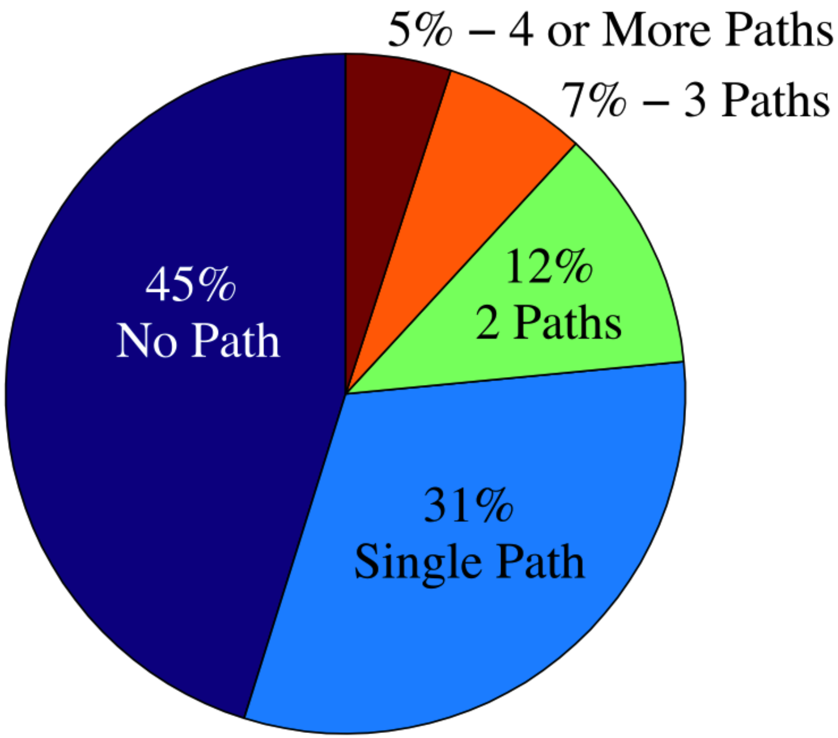
Gaming Performance Improvement





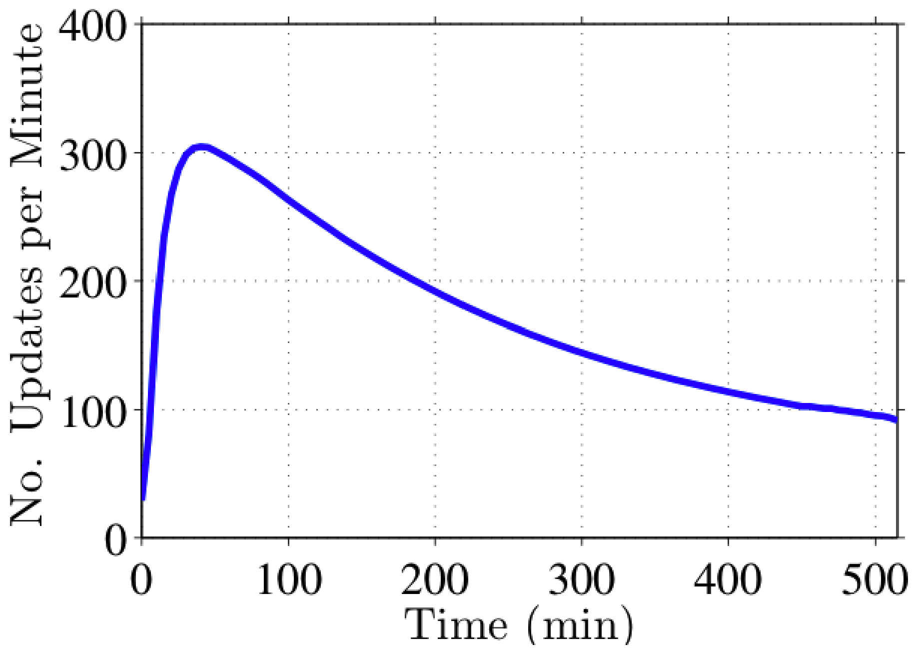
- Better QoE → better gaming performance
  - 30% of players can increase their hit fractions by more than 10%

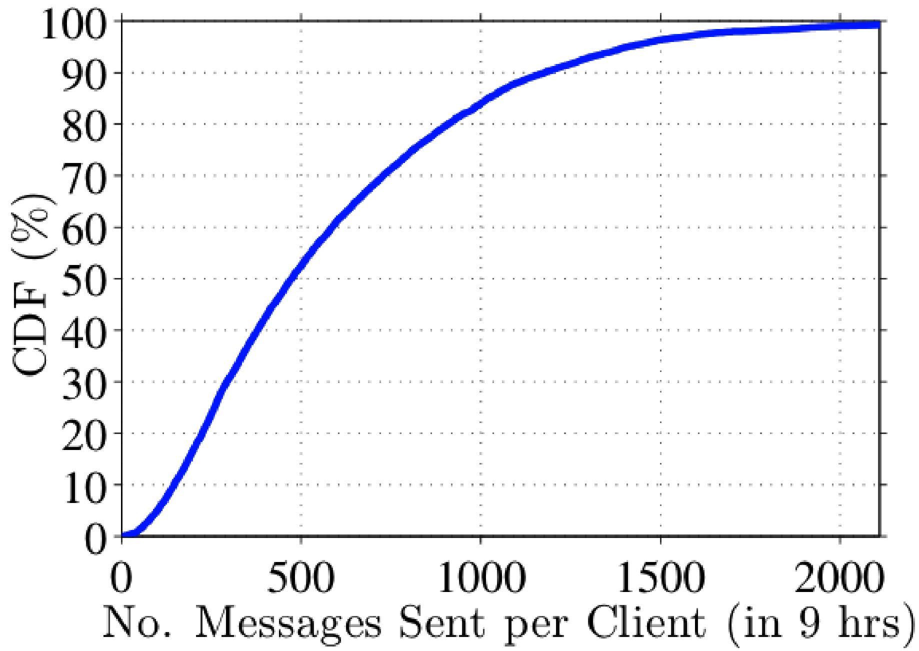
Existence of Backup Detour Paths



- Number of detour paths found by IRS
  - 55% of the clients have at least one detour path
  - 24% of the clients have two or more

Network Overhead





- Server: up to 307 updates per minute for 500+ nodes
- Client: sends one packet every 16 sec

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Residential Deployment

- Home computers with DSL and cable modem access links
- 17 nodes, 7 cities around the world
- Experiment ran for 1 week
- *K* potential relay clients and *N* neighbors are set to 8
- Users are allowed to join and leave the experiment at any time

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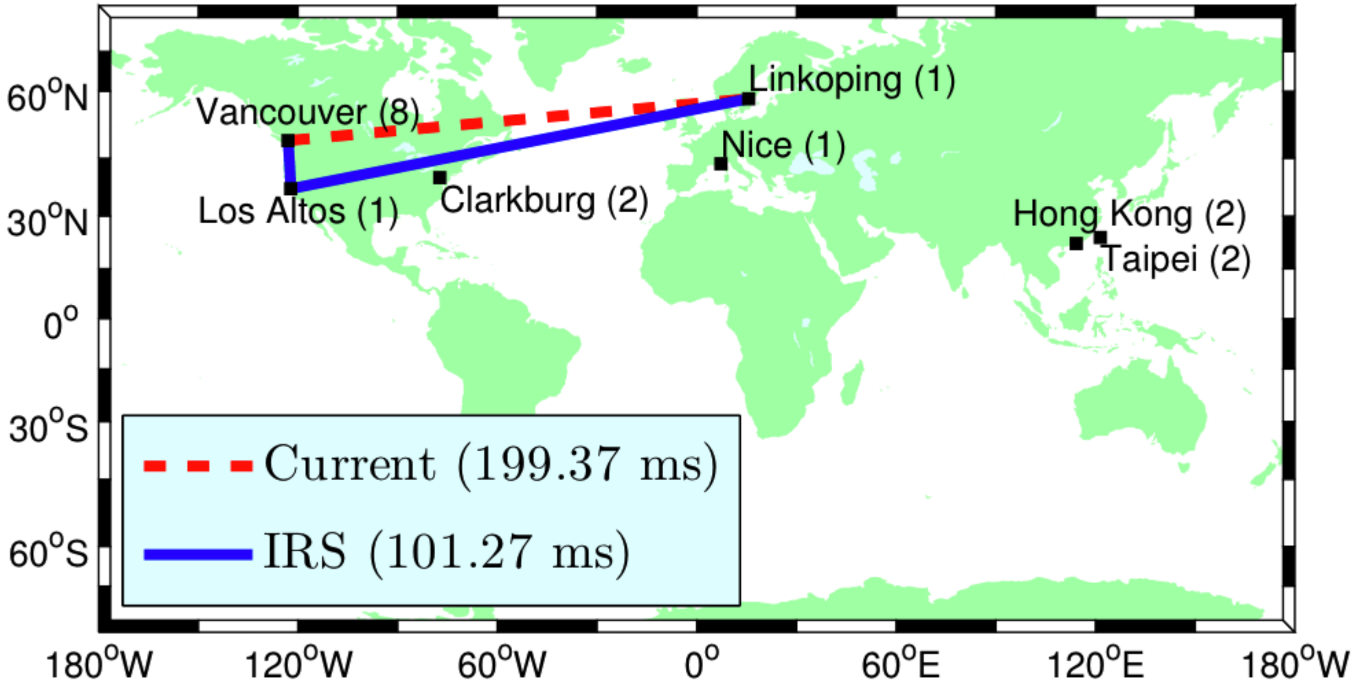
Latency Reduction



- Despite with only 17 nodes, IRS identified 8 detour paths
  - 50% reduction for Vancouver to Linkoping (199 msec to 101 msec)
  - A backup detour path through another Vancouver node leads to 162 msec

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Simulation Setups

- Evaluate the IRS system with wider ranges of parameters
  - Results are in the papers
- Study the matchability improvement of different RTT threshold
  - Compute the number of other players each player can connect to while maintaining acceptable gaming quality
  - Calculate the difference with and without the ISR system

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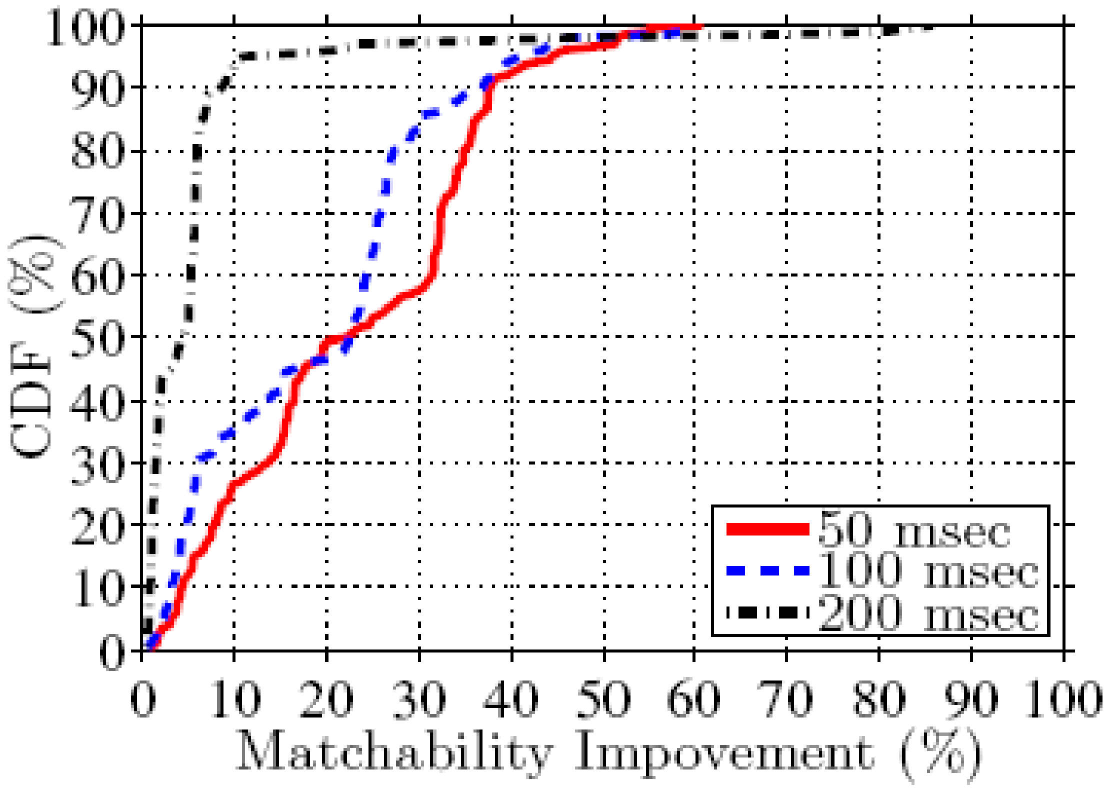
Matchability Improvement



- With a 100 msec threshold, more than half of the player can connect to 20% more players with the ISR system

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Conclusions

- We proposed to reduce latency by leveraging on detour paths
- We designed and implemented IRS system to locate detour paths
- We deployed this actual implementation on PlanetLab and home computers, and conducted experiments
- We used simulations to exercise the IRS system with wider ranges of parameters
- Evaluation results indicate that our system
  - (i) reduces RTT, (ii) increases matchability, (iii) incurs low network overhead, and (iv) improves gaming quality (performance)

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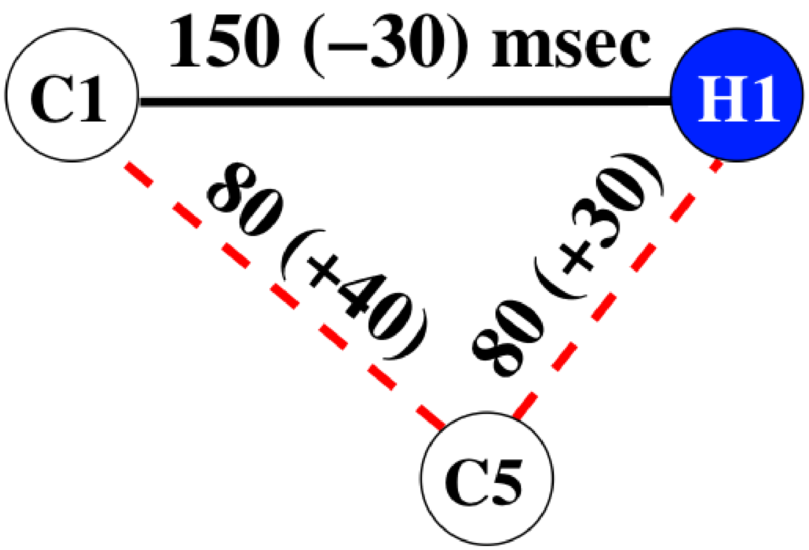
Questions and Comments

Thank you!

Embedding Errors

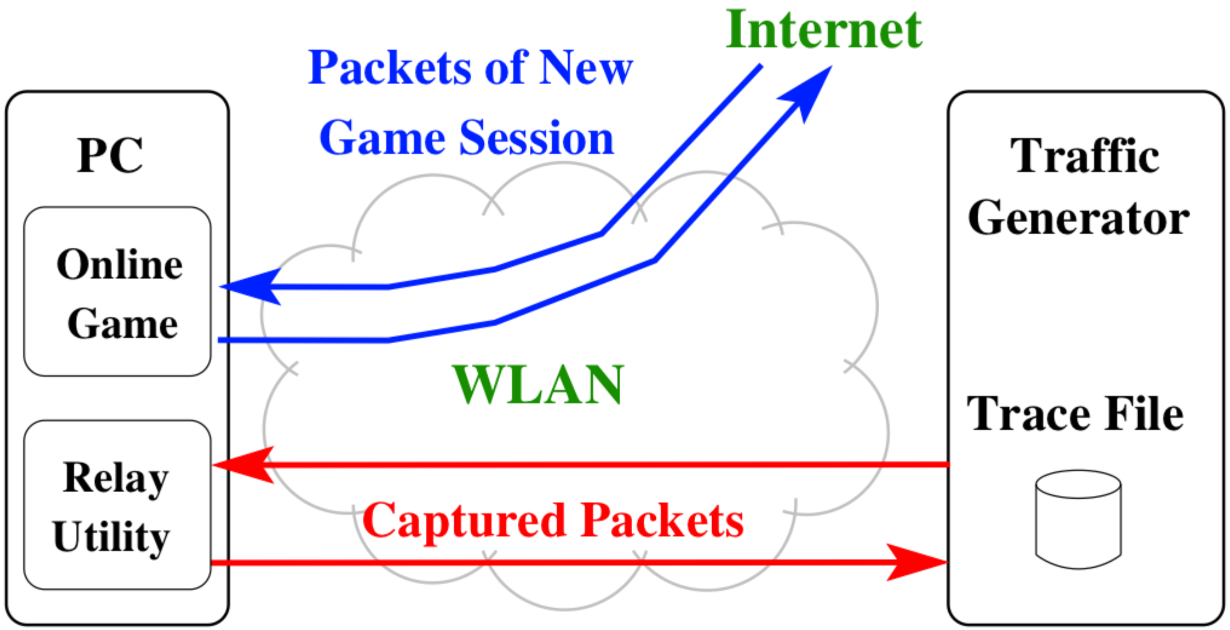


- **Identifying TIV**
  - Network coordinates are in Euclidian space
  - Calculated as “Estimates – Measured”
  - +40 and +30 indicate “excess” estimates. -30 under estimated

Likelihood Function

$$\hat{E}(r) = \begin{cases} E(s,r) = D'(x_s, x_r) - D(s,r) & \text{if D(s,r) is known;} \\ E(r,t) = D'(x_r, x_t) - D(r,t) & \text{if D(r,t) is known;} \\ \dfrac{E(s,r) + E(r,t)}{2} & \text{if D(s,r) and D(r,t) are known} \end{cases}$$

Measuring Relay Overhead



- **Relay Overhead**
  - Commodity PC with 2.8Ghz Intel CPU
  - 6.2 msec with Starcraft 2, real-time strategy game
  - 6.5 msec with Counter Strike: Source, first-person shooter

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Expected Impact

Latency (msec)	Hit Ratio	Kill Count	Death Count
50	49%	41.00	10.75
75	54%	39.75	14.00
100	42%	38.25	16.25
200	29%	35.75	16.75
250	29%	27.75	17
300	19%		

- **First-person shooter game**
  - Significant drop in hit ratio when latency is greater than 200 msec.

Market Demand and Potential

- 37% of the US population played online games in 2009 [Nielsen]
- World of Warcraft (WoW) have 11.5 million subscribers [Blizzard]
- 5 million players for the Halo franchise [Microsoft]
- Market research forecasts [NPD]
  - $48.9 billion revenue by 2011
- Internet gaming traffic forecasts [Cisco]
  - 239 PB/month world wide by 2013!

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Thesis Contributions

- Using RTT measurements, we quantify the potential of detour routing in online multiplayer games.
- We analyze the expected impact of 1,2,3 and k*-hop detour routing on player performance in different online games.
- We propose a **1-hop** overlay routing system called Indirect Relay System (**IRS**).
- Using results from Planetlab and residential deployments we show that IRS reduces RTT (round-trip time) among players in online games.

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Measurements Study

- We conducted measurements study
  - RTT measurements from more than 28,000 IPs from online game players.
  - 18.8 million pair-wise RTT measurements
- We quantify the potential of detour routing in online games.
  - Impact of detour routing in online games
  - Potential of 1, 2, 3, and k* relay clients

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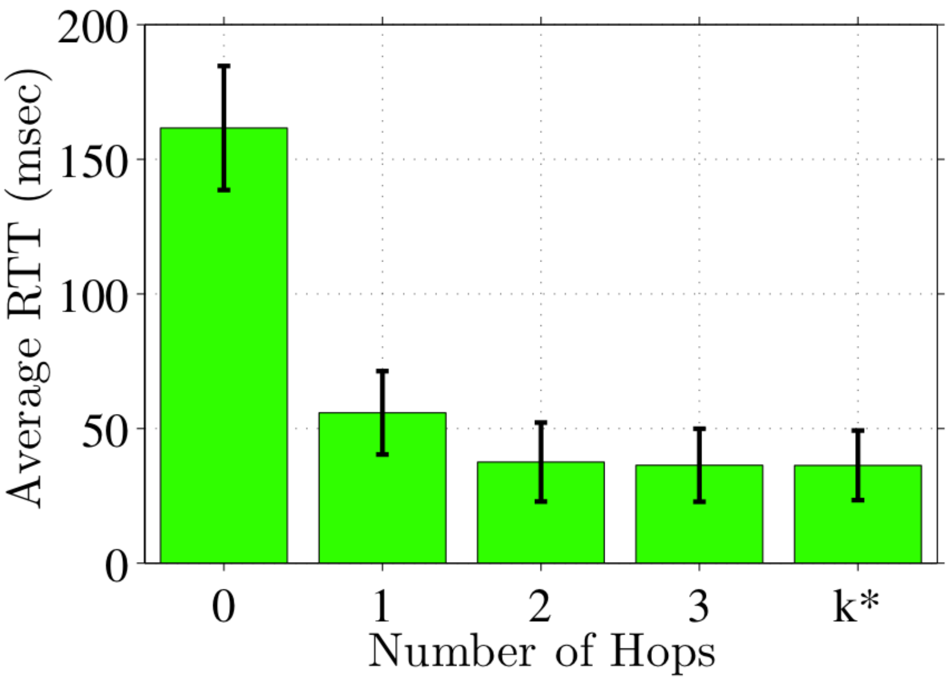
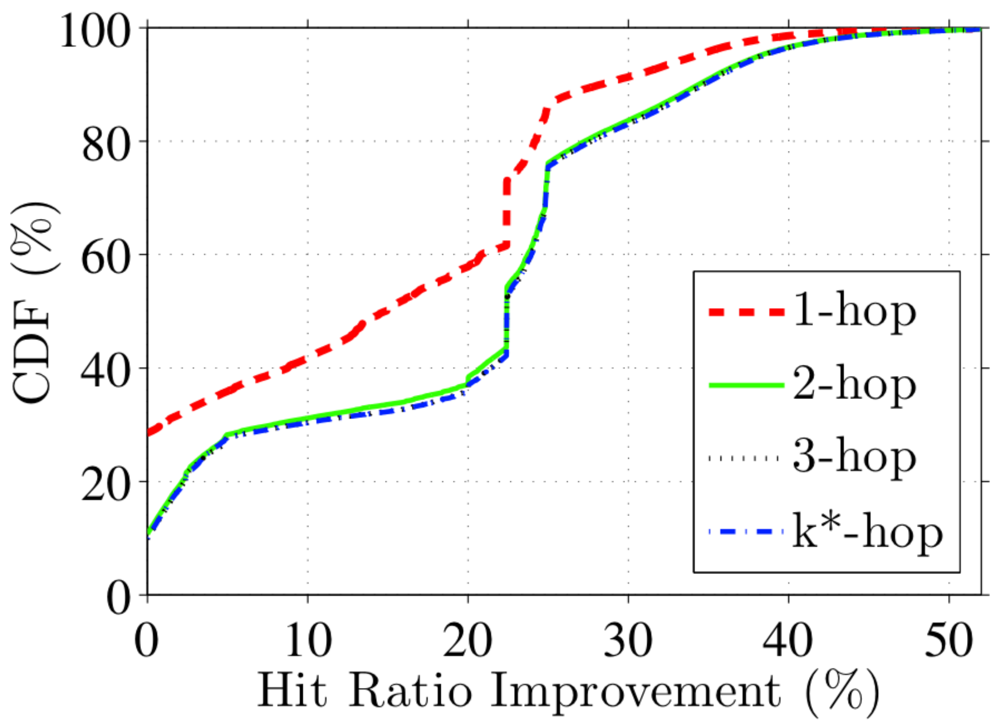
Average RTT



- Average RTT
  - Reduced from 156 msec to 53 msec with just 1-hop
  - Optimal k*-hop is 46 msec.

Impact On Actual Games



- Hit Ratio improvements
  - 60% of players gain at least 10% just 1-hop

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