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Load Dynamics of a Multiplayer Online Battle Arena and Simulative Assessment of Edge Server Placements

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Competitive Online Gaming

Gaming in Numbers 2015

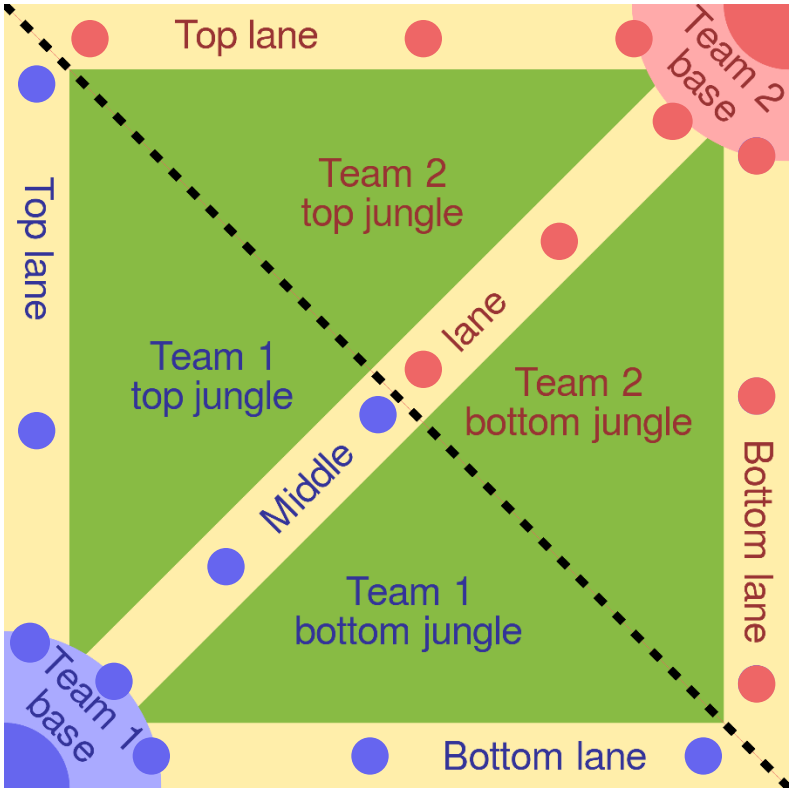
- *League of Legends* and *Dota 2* together have more than 80 million unique players every month

- Dota 2 makes $18 million each month, League of Legends makes the same amount each 5 days

- The price pool of the international Dota 2 championship 2015 was $18,429,613

- In 2015 Twitch.tv had 421.6 monthly minutes watched per viewer compared to 291.0 monthly minutes watched per YouTube viewer

Multiplayer Online Battle Arena



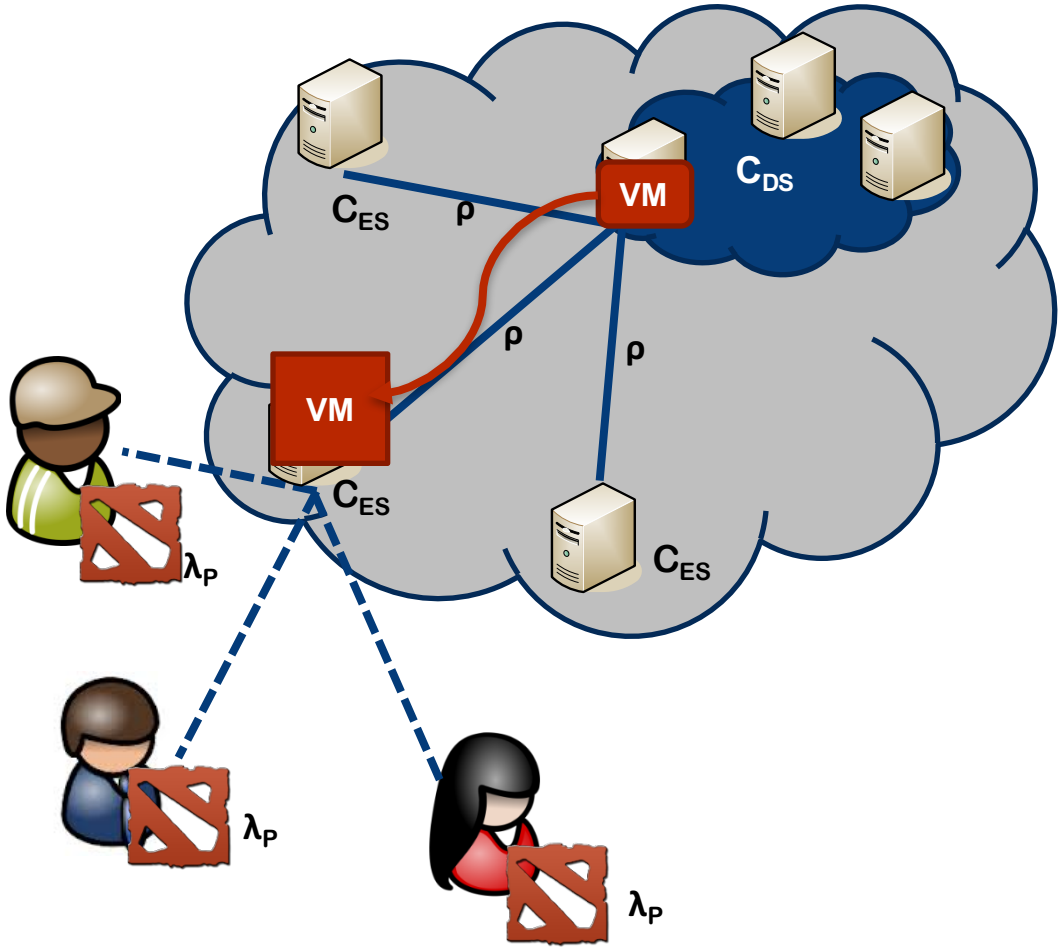
- Two teams of 5 players compete on map to destroy enemy base
- Team work and strategy are key to winning
- High importance of fast reaction times and corresponding network requirements

Pushing Intelligence to the Edge

- Latency considerably influences the game play and the users' gaming experience
- Huge amount of concurrent players puts high load on network resources
- Migrate game server virtual machines to edge nodes and push intelligence to the edge of the network
  - Save network resources in the core network
  - Reduce latency of players and improve quality of gaming experience
- Where to allocate how much capacity for edge nodes and when?
- What is the potential to reduce latency and network resources?

Simulation Model

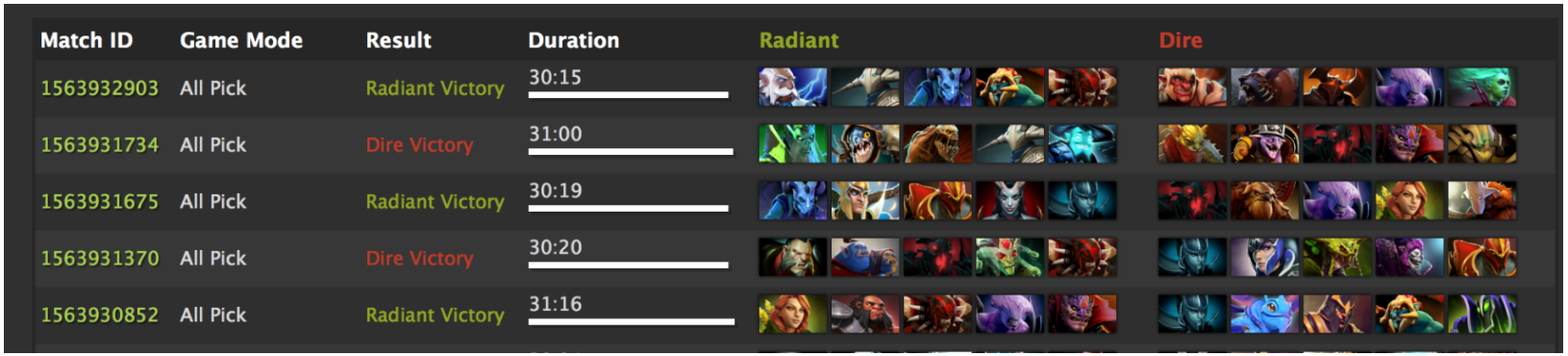
- Set of server resources (DS) with capacity C_{DS}
- Set of edge resources (ES) with capacity C_{ES}
- Links connecting server resources and edge resources with capacity ρ
- Party and single player arrival rates λ_P/λ_s
- Location ξ_i of request i



Model Requirements

- Location of game servers
- Arrival rate of game requests
- Player Locations
- Duration of matches

Data Collection



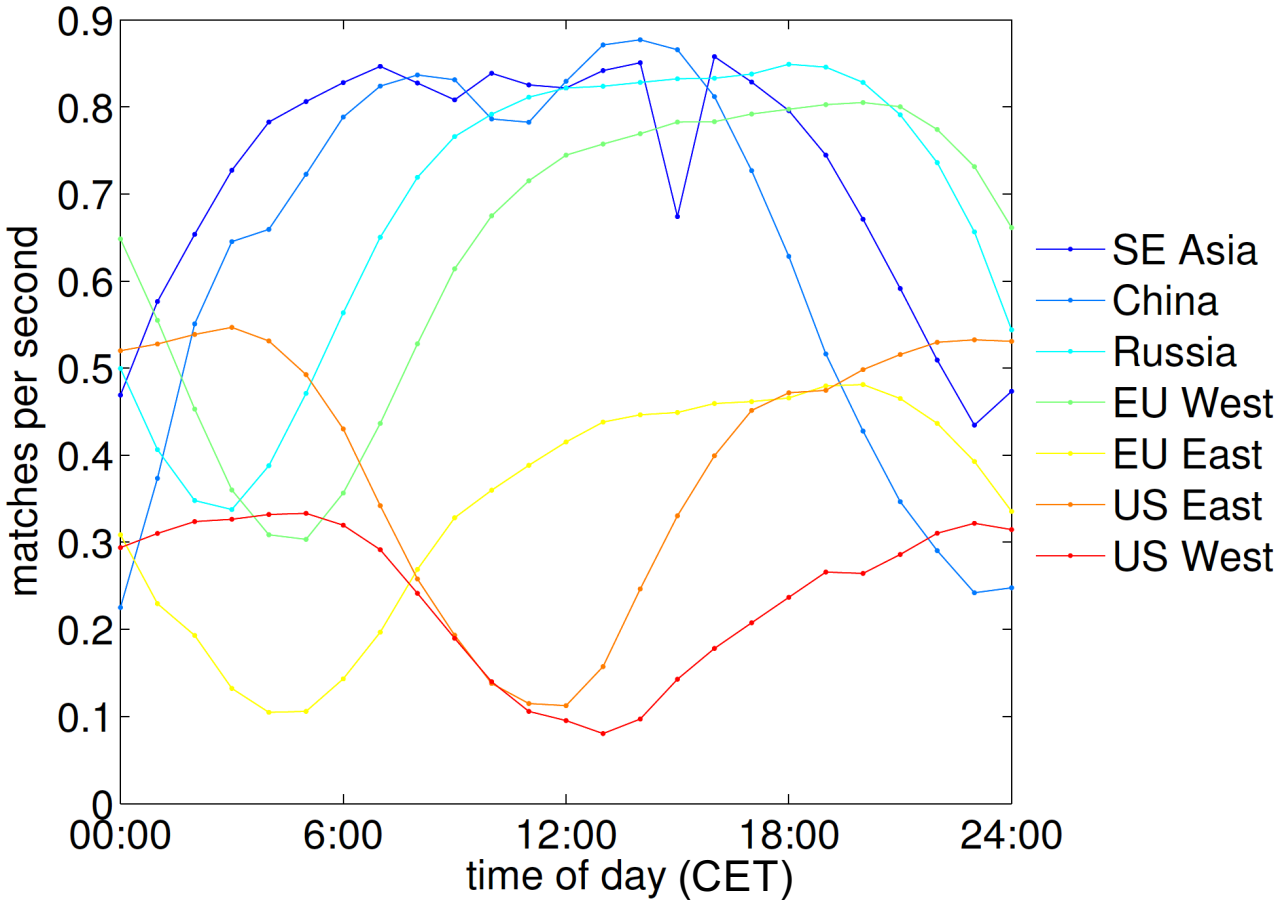
Match ID	Game Mode	Result	Duration	Radiant	Dire
1563932903	All Pick	Radiant Victory	30:15		
1563931734	All Pick	Dire Victory	31:00		
1563931675	All Pick	Radiant Victory	30:19		
1563931370	All Pick	Dire Victory	30:20		
1563930852	All Pick	Radiant Victory	31:16		

- Dota 2 match histories derived from API calls
  - Game start time and date
  - Game duration
  - Server location (region)
- Measurement period was from March 18th to March 25th, 2015
- More than 1 million games per day
- 8,470,933 public Dota 2 matches and 1,786,148 unique public player profiles crawled in total

Dota 2 Regions and Server Locations

- **US West** Seattle, WA, USA
- **US East** Sterling, VA, USA
- **Europe West** Luxembourg
- **Europe East** Vienna, Austria
- **SE Asia** Singapore
- **China** Shanghai
- **South America** São Paulo, Brazil
- **Russia** Stockholm, Sweden
- **Australia** Sydney, Australia

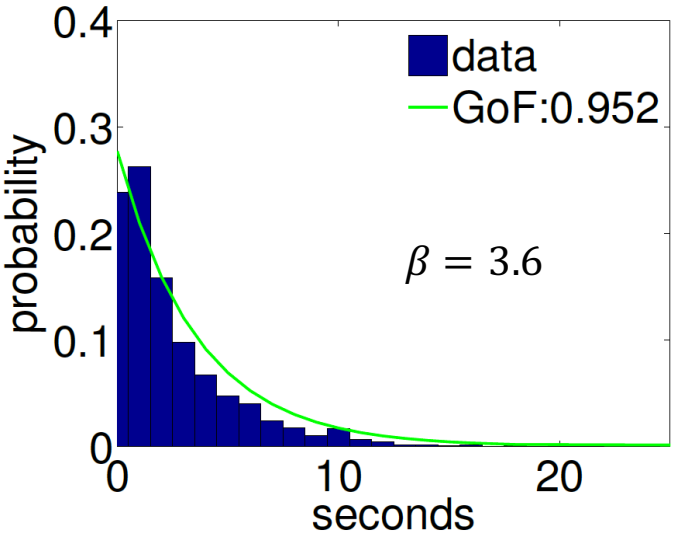
Daily Dynamics of Game Requests



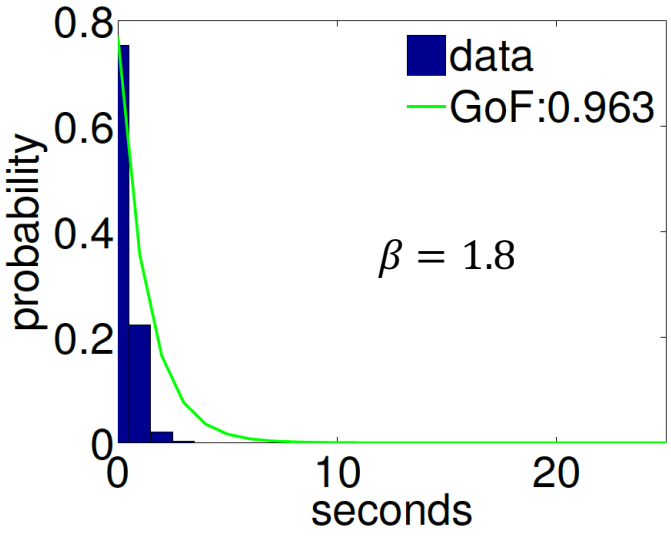
- Arrival rate of matches λ dependent on time and region
- Time shift and different load / peak load per region

Game Request Arrival Process

- Approximate empirical distribution of inter-arrival time of requests with exponential distribution $f(x, \beta) = \frac{1}{\beta} \exp(\frac{-x}{\beta})$
- Mean inter-arrival time β is set according to hourly arrival rate λ

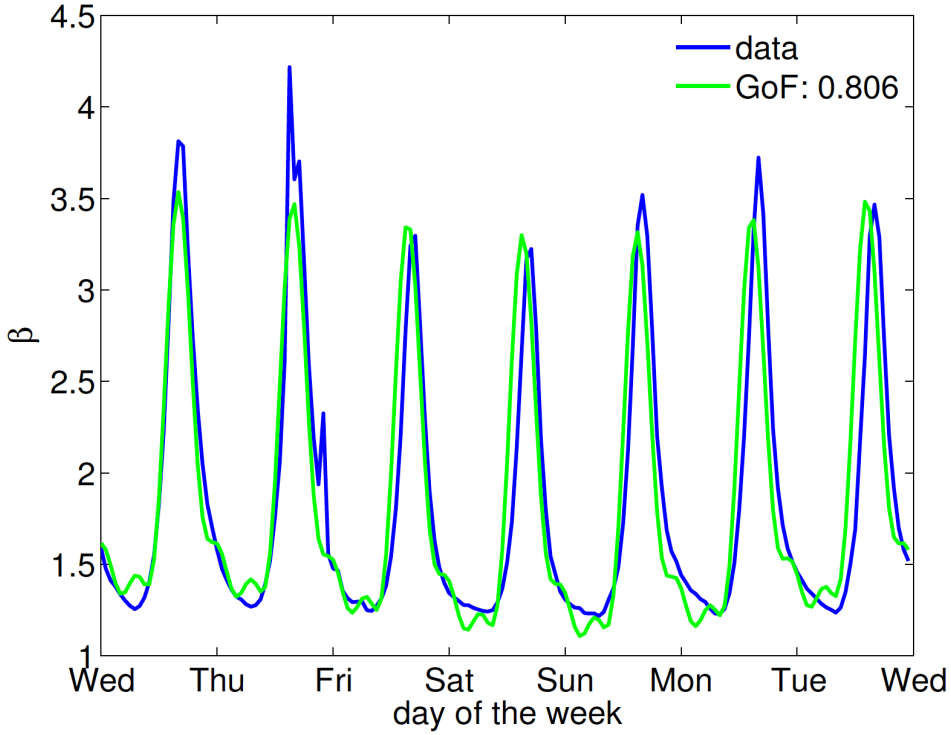


Non busy hour (4:00 AM)



Busy hour (6:00 PM)

Weekly Dynamics of EU West Server



- Decomposition by Fourier analysis (DFT)
- Approximation by the five most significant Fourier terms (sines)
  - Daily periodic pattern
  - Transition of decreasing rates from the weekdays to the week-end

Player Location

- Determine player counts per country from public Steam profiles to estimate the country probabilities
- 757,172 public-profiled accounts with a unique player ID in total that had set their locations
- 324,511 of these played on the EU West server

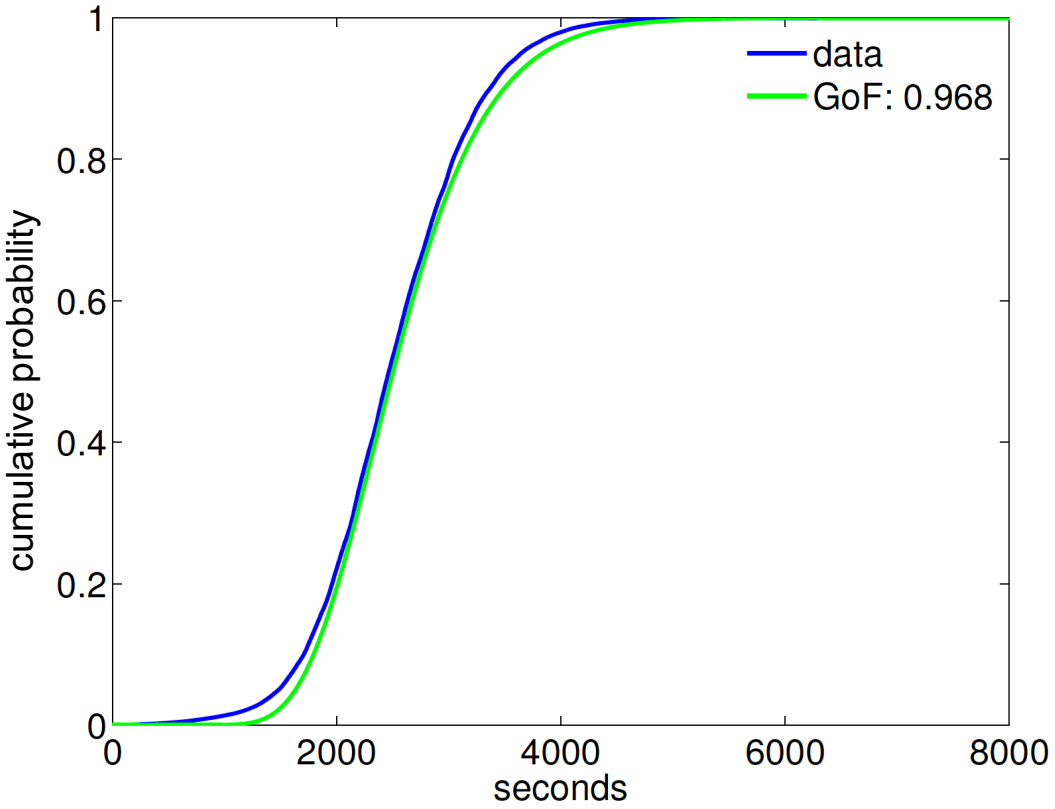
Rank	Country	Players	Probability
1	Russia	115210	0.355
2	Ukraine	39605	0.122
3	Great Britain	15078	0.046
4	Germany	12565	0.039
5	Belarus	12322	0.038

Player Distribution on Cities

- Empirical probability f_x of a player being in country x is determined by player count per country
- Given country x the probability f^y of a player playing in city y is determined by the population distribution f_x^y of cities in country x

- Player locations ξ_i are generated according to two schemes
  - **Random:** Single player looks for other random players (solo queuing)
    - City y is determined according to f^y
    - Exponentially distributed distance with parameter d_{rnd} added in a uniformly distributed angle to coordinates of center of city y
  - **Party:** Friends playing together (party queuing)
    - Relies on assumption that probability of friendship decreases exponentially with distance
    - Determine location of first player according to random scheme
    - Exponentially distributed distance of remaining k−1 players from first player with parameter d_{party}

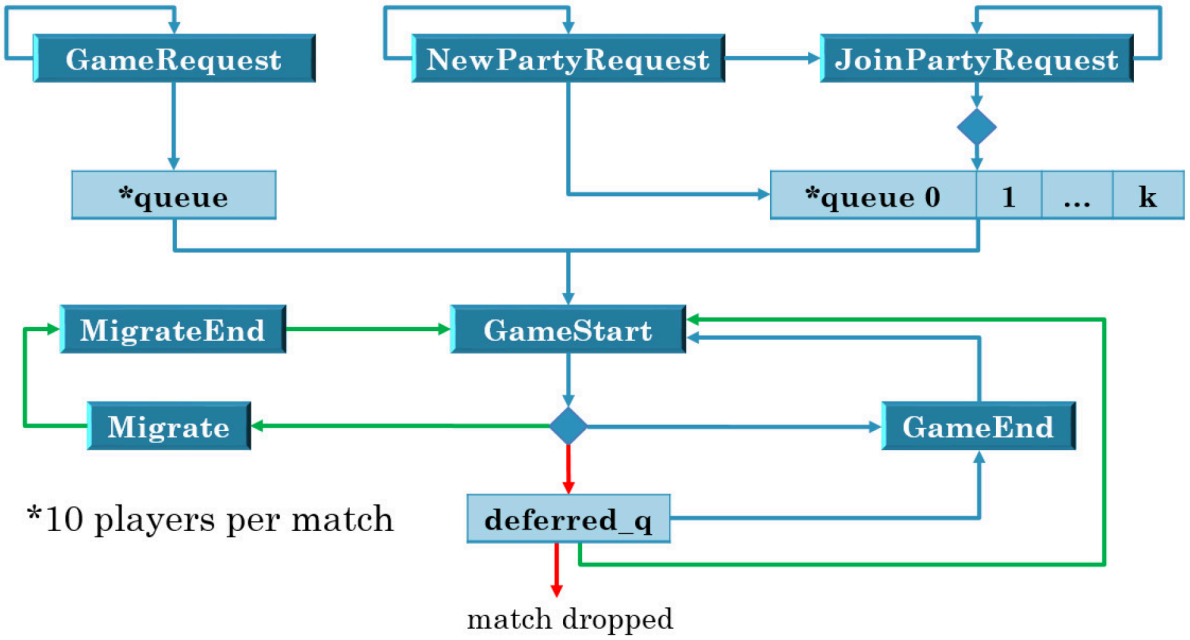
Match Durations on EU West Server



- 1,368,703 regular matches played from March 18th to March 25th
- Average match duration of 2590 seconds (ca. 43 minutes), standard deviation of 685 seconds
- Match duration modeled with log-normal distribution

Simulation Description

- Simulation implemented in Java using the JSimLib (DES) library
- ESs are distributed by ranking the cities according to f^y
- Migration Policy
  - Servers are sorted by increasing mean distance of the players
  - Match is hosted on first server with enough capacity in the list



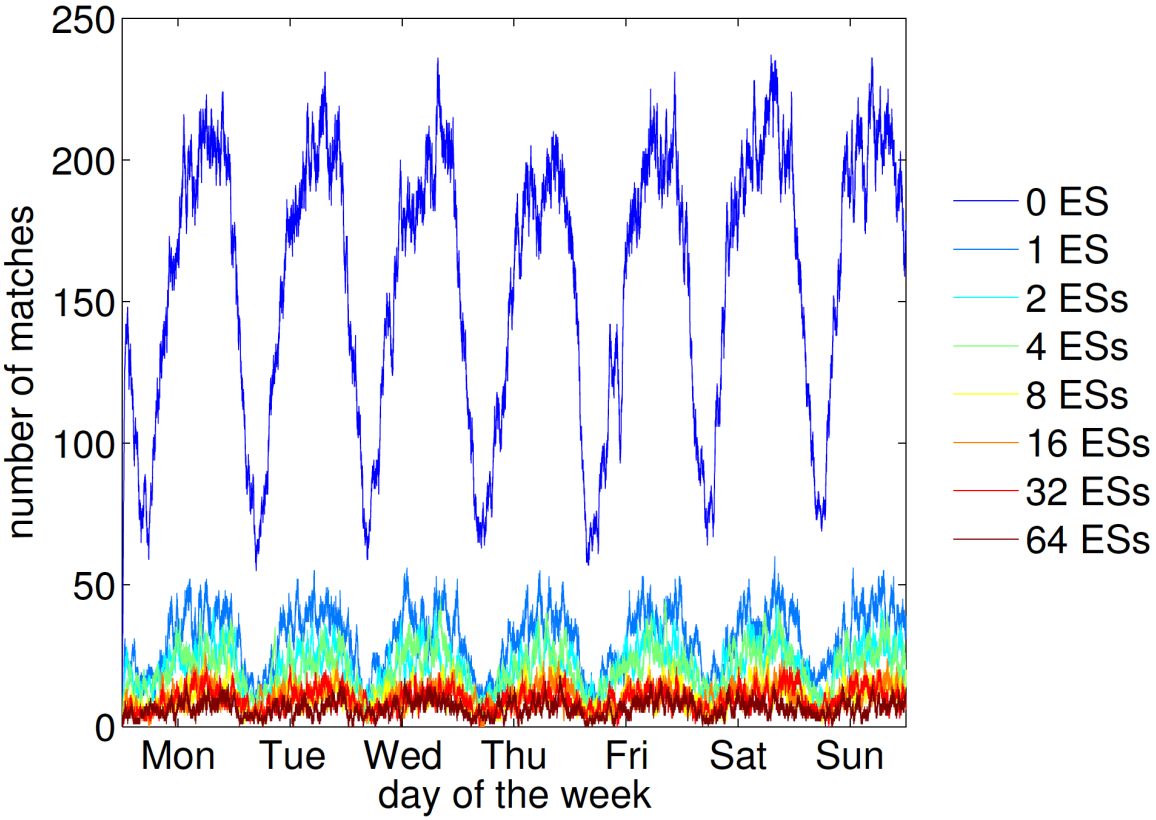
Parameters and Metrics

Parameter	Description	Default
C_{DS}	Dedicated server capacity	3000
n_{ES}	Number of edge servers	0
C_{ES}	Edge server capacity	1000
λ	Arrival rate of requests	
k	Number of players per match	10
μ	Match service rate	
ρ	Throughput of edge link	
σ	Memory footprint	
d_{rnd}	Distance from city center	5 km
d_{party}	Distance from party leader	100 km

Performance Metrics

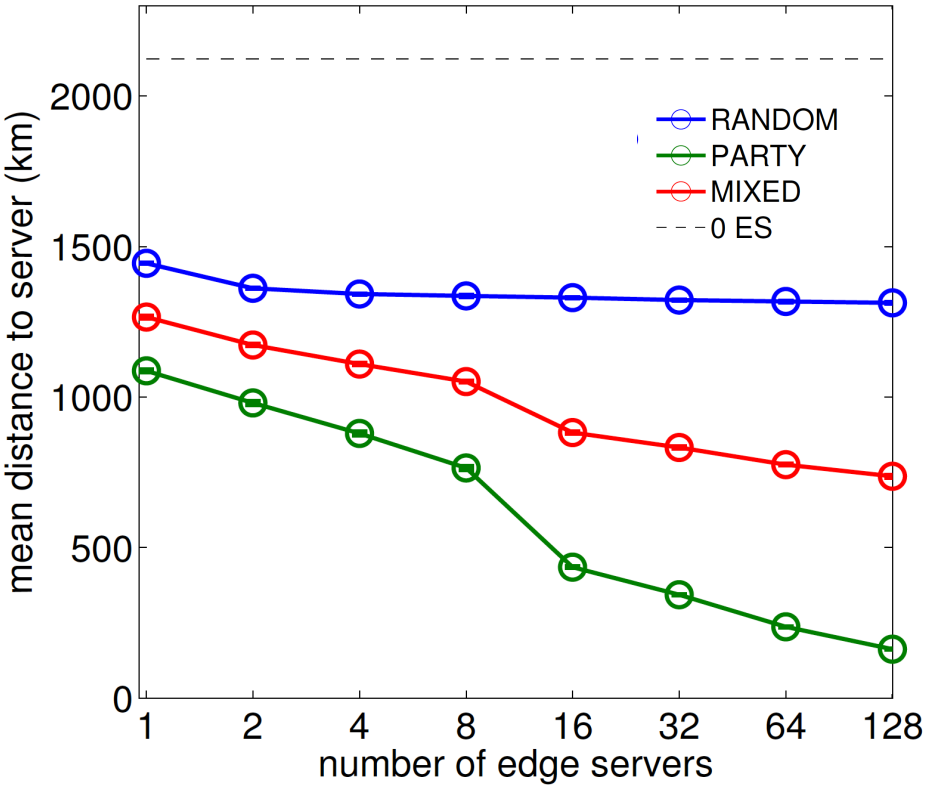
- Load on dedicated server: number of matches
- Game play experience: mean distance to server

Load on Dedicated Server



- Daily dynamics of server load
- Load on server decreases with the number of edge servers
- Deploying 1 ES with decent capacity already reduces the peak load on the DS by around 75%

Distance to Server



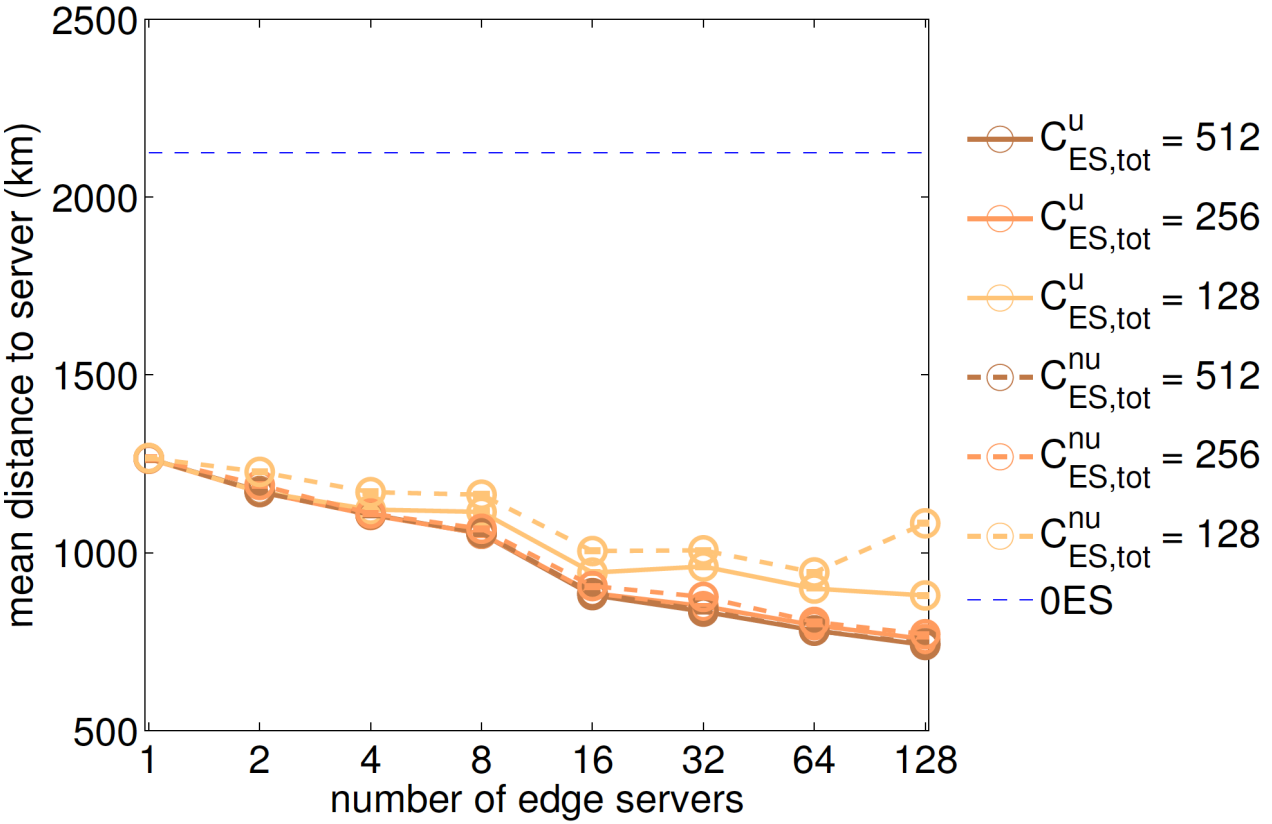
- Mean distance decreases with the number of edge servers
- Saturation effect for random players due to distance among them

Resources Allocation Schemes

- Investigate effect of resource allocation schemes on performance metrics
- Fix total capacity of edge servers to $C_{ES,tot}$={128,256,512}matches
- Compare uniform and non-uniform resource allocation
  - Uniform (u):
    $C_{ES,tot}$ is equally shared among the ESs

  - Non-uniform (nu):
    $C_{ES,tot}$ is allocated according to population in the ES locations

Resources Allocation Schemes



- High number of edge servers with smaller capacities is beneficial
- Non-uniform placement performs worse in cases where optimal location has no capacity (left)

Conclusion

- Multiplayer online battle arenas are rising online gaming services
- Performance of player and gaming service highly depend on the distance and latency to the game server
- We developed generic stochastic models for the load dynamics of the multiplayer online battle arena Dota 2 by evaluating match histories from the provided API
- The models are used to evaluate mechanisms aiming to improve the performance of the gaming service by pushing servers to the edge of the network
- Part of future work is to determine optimal resource allocations