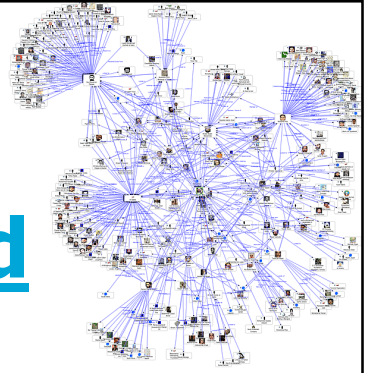
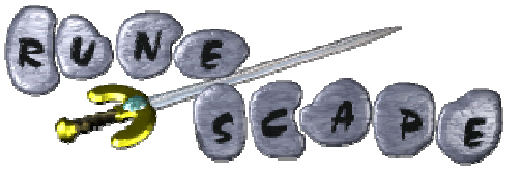
Massivizing Online Games:
Distributed Computing Challenges and High Quality Time





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Our team: **Undergrad** Adrian Lascateu, Alexandru Dimitriu (UPB, Romania), …, **Grad** Siqi Shen, Yong Guo, Ruud vd Bovenkamp (TU Delft, the Netherlands), … **Staff** Otto Visser, Dick Epema, Henk Sips, Fernando Kuipers (TU Delft), Thomas Fahringer, Radu Prodan (U. Innsbruck), Nicolae Tapus, Vlad Posea, Alexandru Olteanu (UPB), …

Lectures at the Technion Computer Engineering Center (TCE), Haifa, IL

IaaS Cloud Benchmarking	May 7	**10am Taub 337**
Massivizing Online Social Games	**May 9**	
Scheduling in IaaS Clouds	May 27	
Gamification in Higher Education	June 5 (HUJI)	
A TU Delft perspective on Big Data Processing and Preservation	June 6	

Grateful to Orna Agmon Ben-Yehuda, Assaf Schuster, Isaac Keslassy.

Also thankful to Bella Rotman and Ruth Boneh.

The Parallel and Distributed Systems Group at TU Delft

VENI

Alexandru Iosup

Grids/Clouds
P2P systems
Big Data
Online gaming

Dick Epema

Grids/Clouds
P2P systems
Video-on-demand
e-Science

VENI

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HPC systems
Multi-cores
Big Data
e-Science

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HPC systems
Multi-cores
P2P systems

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Video-on-demand

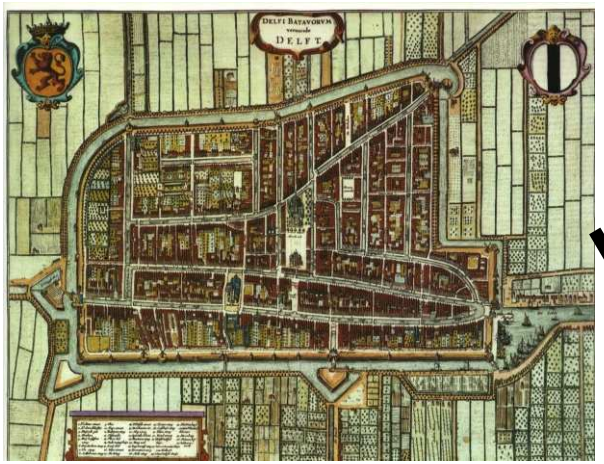
Home page

- www.pds.ewi.tudelft.nl

Publications

- see PDS publication database at publications.st.ewi.tudelft.nl

(TU) Delft – the Netherlands – Europe



founded 13th century
pop: 100,000

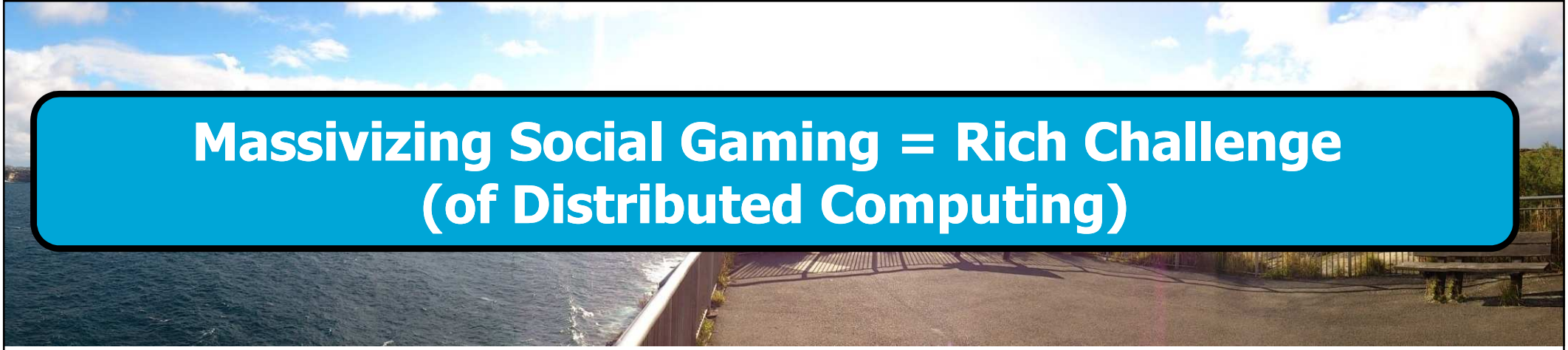
founded 1842
pop: 13,000

pop: 16.5 M

(We are here) אנחנו כאן

Why Social Gaming?

What is This Talk About?



Massivizing Social Gaming = Rich Challenge (of Distributed Computing)

Online Gaming used to be art, may now be computing

Online Gaming used to be multimedia, is now DC

Online Gaming used to be networking, is now *all* DC

Online Gaming used to be v-worlds, is now *many apps*

What's in a name? MSG, MMOG, MMO, …

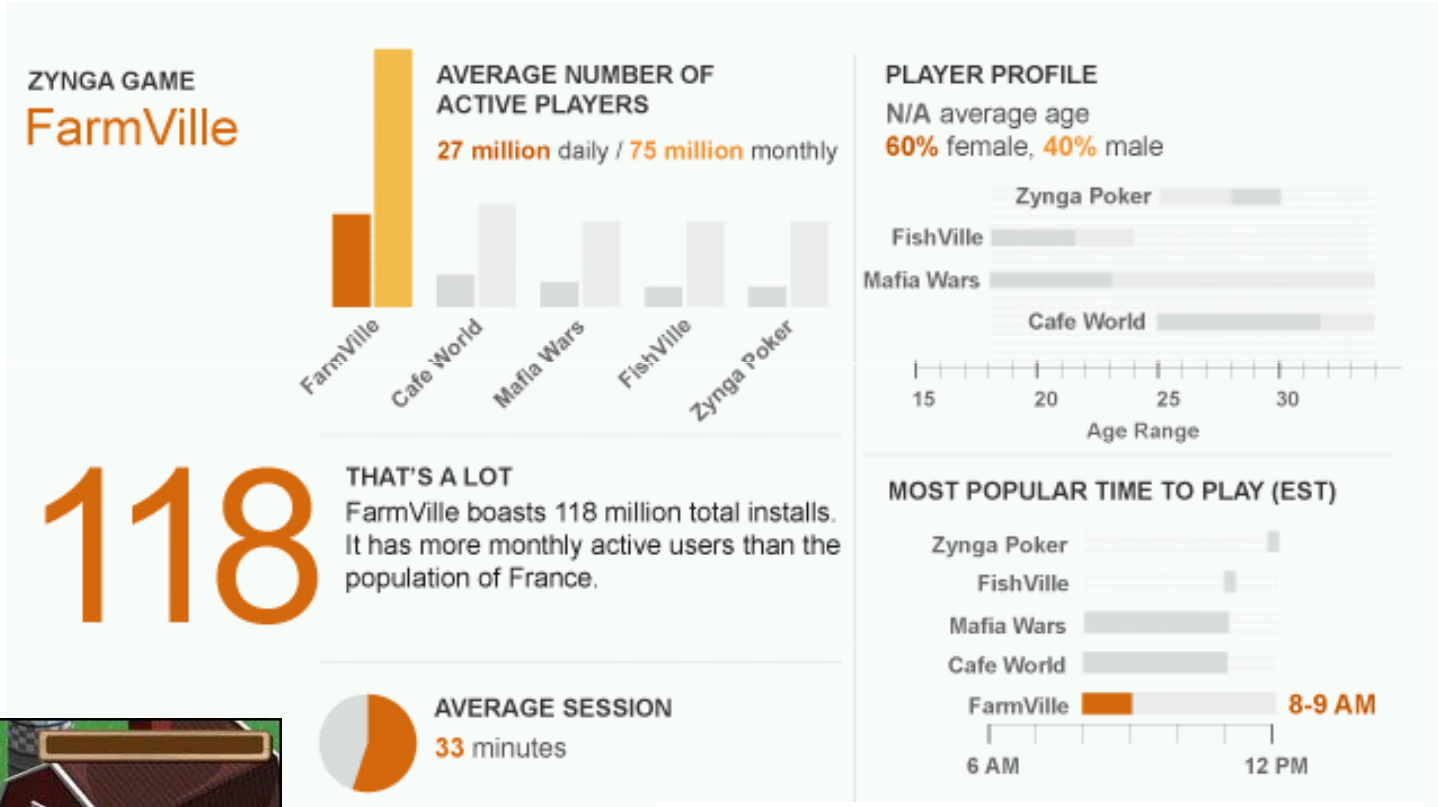
Over 250,000,000 active players

Massively Social Gaming =

(online) games with massive numbers of players (100K+), for which social interaction helps the gaming experience

1. **Virtual World Sim**
   Explore, do, learn, socialize, compete
   +
2. **Game Data**
   Player stats and relationships, others
   +
3. **Game Content**
   Graphics, maps, puzzles, quests, culture

Zynga, an Amazon WS User



Source: InsideSocialGames.com

Selling in-game virtual goods: Sources: CNN, Zynga.

"Zynga made est. $270M in 2009 from."
http://techcrunch.com/2010/05/03/zynga-revenue/

"Zynga made more than $600M in 2010 from selling in-game virtual goods."
S. Greengard, CACM, Apr 2011

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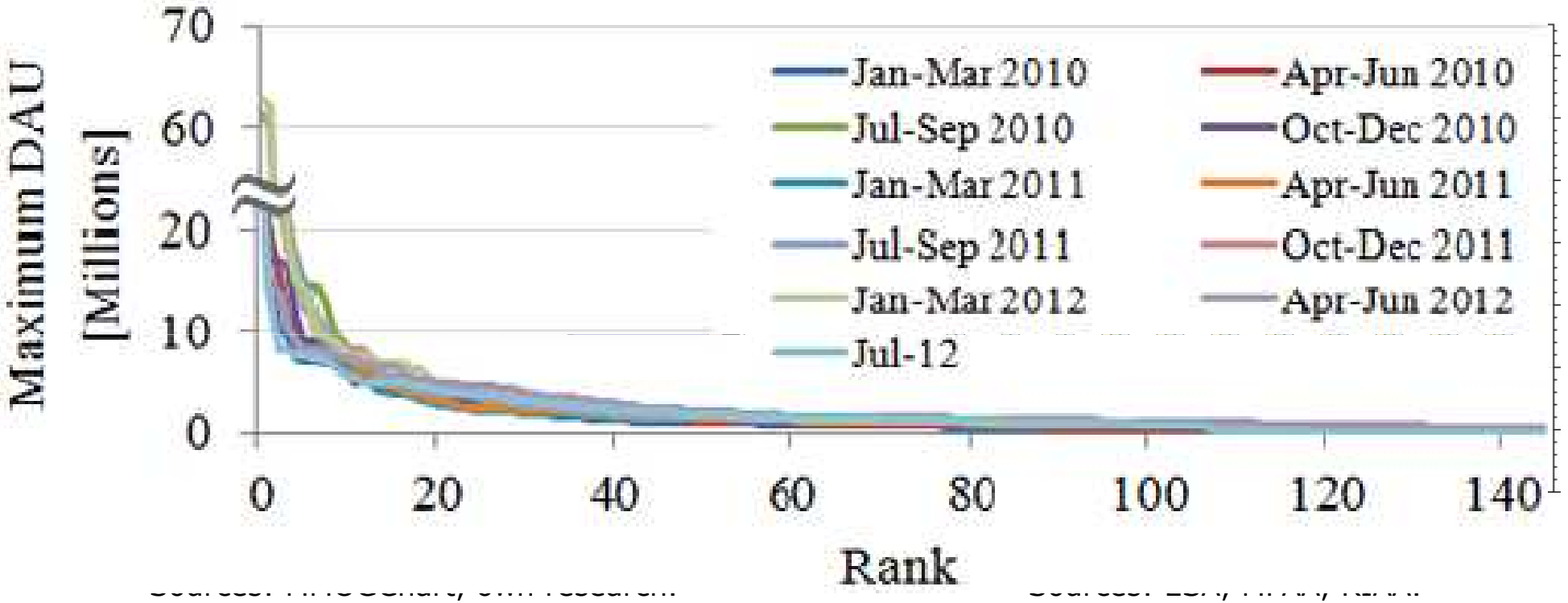
MSGs are a Popular, Growing Market

- 25,000,000+ subscribed players (from 250,000,000+ active)
- Over 10,000 MSGs in operation
- Subscription market size $7.5B+/year, Zynga $600M+/year



A.C. Olteanu, A. Iosup, and N. Tapus, Towards a workload model for online social applications. Proc. ICPE 2013 http://bit.ly/VzTei2

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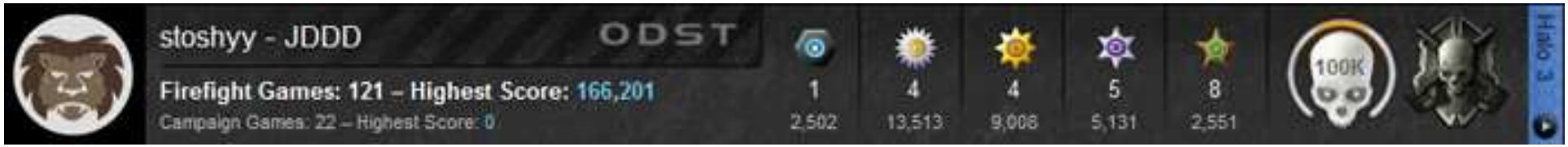
World of Warcraft, a Traditional HPC User (since 2003)

- 10 data centers
- 13,250 server blades, 75,000+ cores
- 1.3PB storage
- 68 sysadmins (1/1,000 cores)

http://www.datacenterknowledge.com/archives/2009/11/25/wows-back-end-10-data-centers-75000-cores/

Bungie, Computing then Serving 1.4PB/yr.



- Halo 3 is one of the many successful games
- Halo 3 players get, in 1.4PB
  - Detailed player profiles
  - Detailed usage stats
  - Ranking

- CERN produces ~15PB/year (10x larger)
  - (Not) faster than the speed of light, the Higgs boson (?)

Agenda

1. What's in a Name?
2. **Three Current Challenges**
    1. Platform Scalability Challenge
    2. Gaming Analytics Challenge
    3. Content Generation Challenge
3. The Next Five Years
4. Conclusion

Cloudification: PaaS for MSGs

(Platform Challenge)

Build MSG platform that uses (mostly) cloud resources

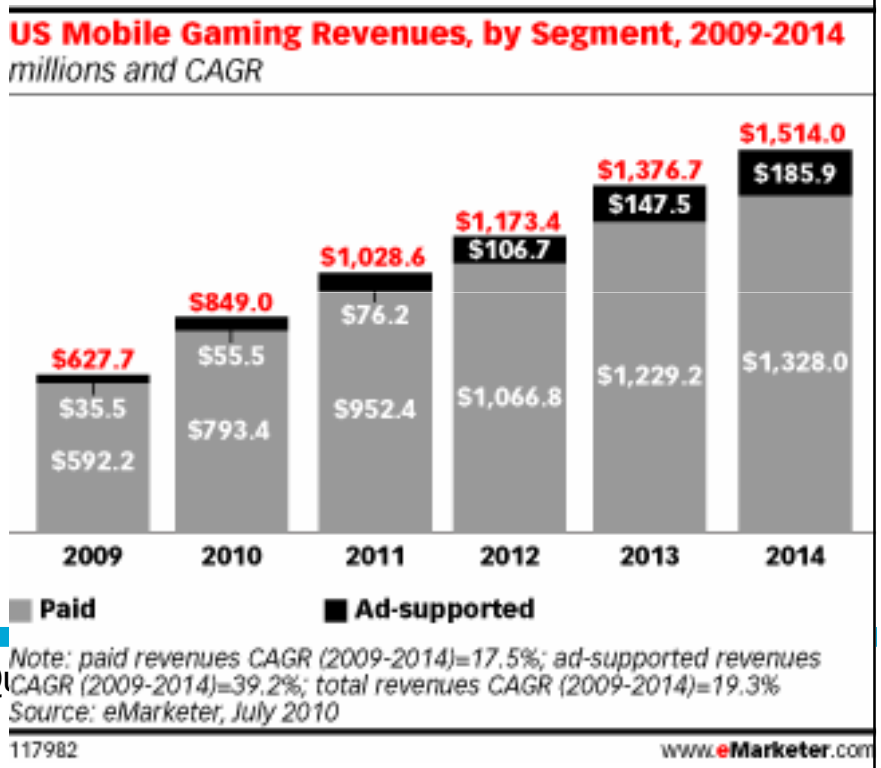
- Close to players
- No upfront costs, no maintenance
- Compute platforms: multi-cores, GPUs, clusters, all-in-one!
- Performance guarantees
- Hybrid deployment model
- Code for various compute platforms—platform profiling
- Load prediction miscalculation costs real money
- What are the services?
- Vendor lock-in?
- *My* data

Mobile Social Gaming and the SuperServer

(Platform Challenge)

Support MSGs on mobile devices

- Mobiles everywhere (2bn+ users)
- Gaming industry for mobiles is new Growing Market
- SuperServer to generate content for low-capability devices?
- Battery for 3D/Networked games?
- Where is my server? (Ad-hoc mobile gaming networks?)
- Security, cheat-prevention



Social Everything! So Analytics

- **Social Network**=undirected graph, **relationship**=edge
- **Community**=sub-graph, density of edges between its nodes higher than density of edges outside sub-graph

(Analytics Challenge)

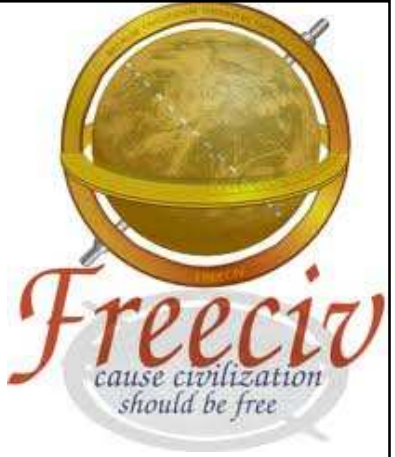
Improve gaming experience

- Ranking / Rating
- Matchmaking / Recommendations
- Play Style/Tutoring

Self-Organizing Gaming Communities

- Player Behavior

Content, Content, Content



(Content Challenge)

Produce and distribute content for 1BN people

- Game Analytics → Game statistic
- Crowdsourcing
- Storification
- Auto-generated game content
- Adaptive game content
- Content distribution/ Streaming content

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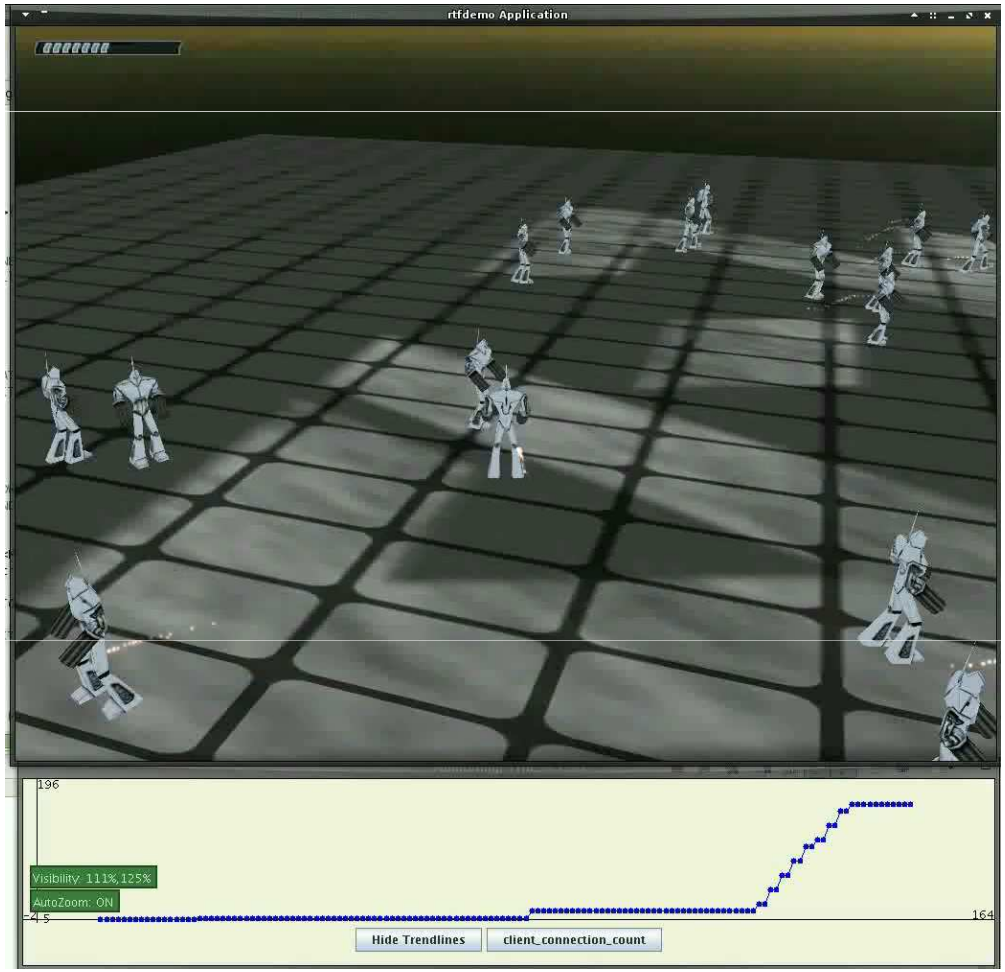
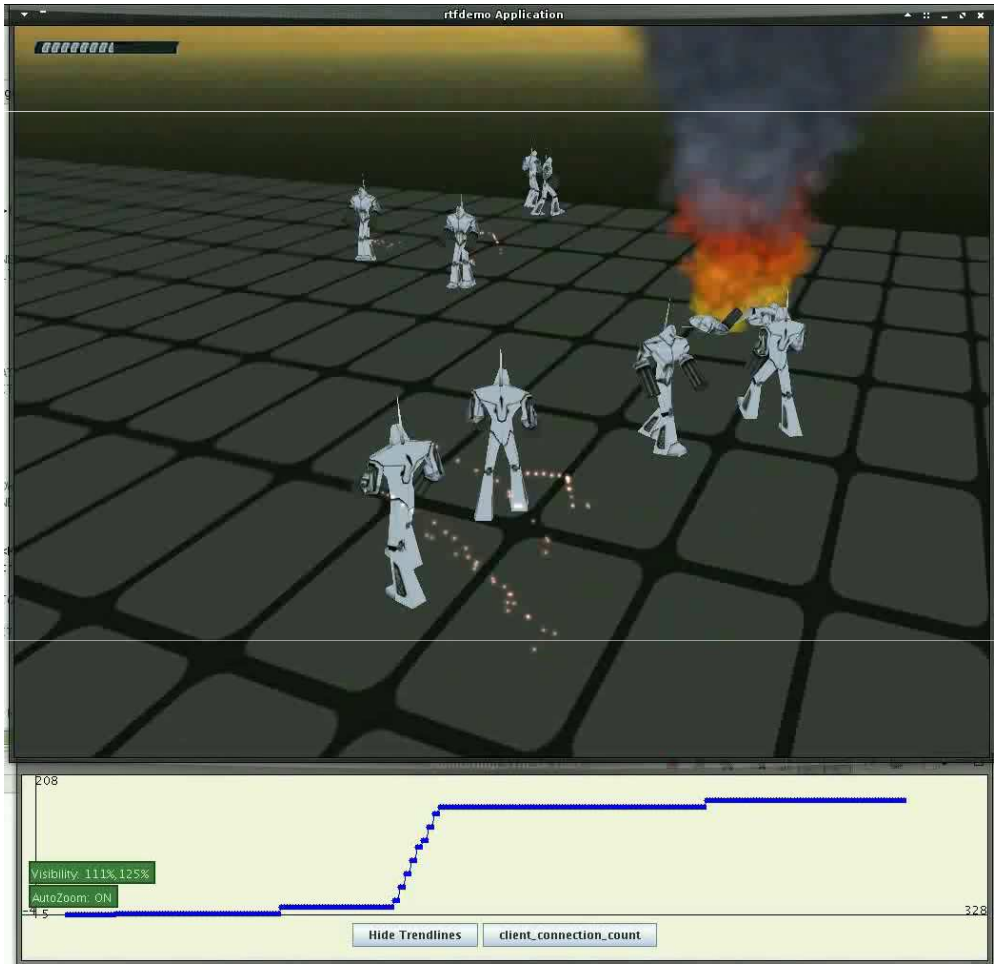
Impact of Platform on Game-Play

Responsive game-play



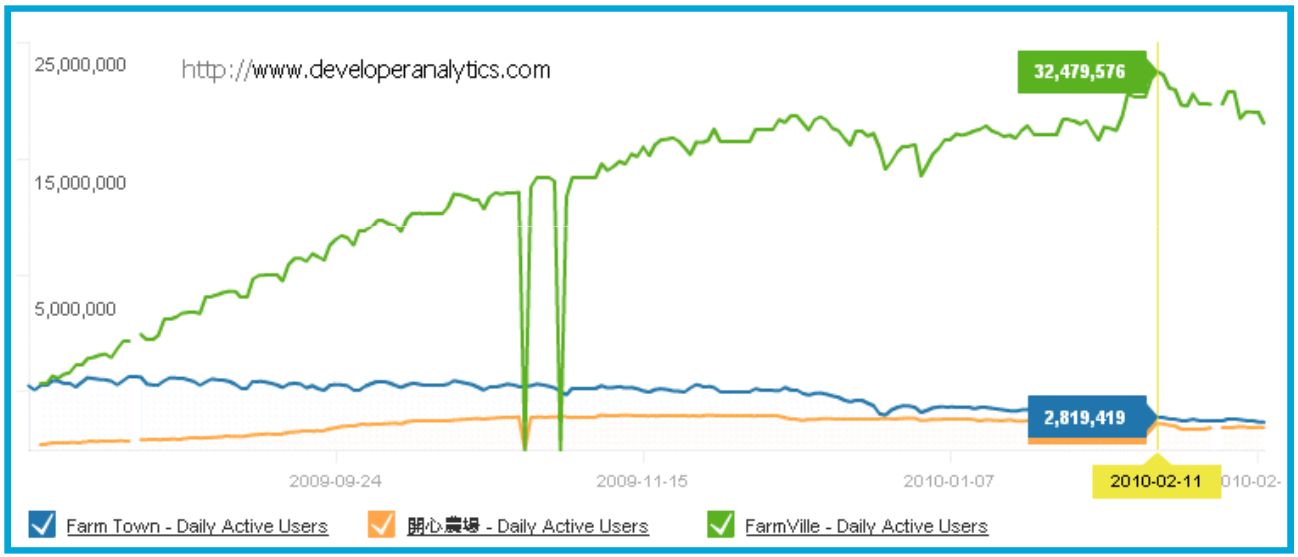
Unresponsive game-play



@large Research Challenge: V-World Platform for MMOGs

Scaling quickly to millions of players

- 1M in 4 days, 10M in 2 months
- Up-front and operational costs
- Performance, Scalability, & Cost



Rich Research Opportunities: How to Build the Core?

- Application models
- Deployment/Hosting models
- Scheduling
- Performance engineering
- Reliability engineering
- Scalability and Elasticity
- Offloading
- Etc. (including Usability, Security, Utility Models, and Programming Models)

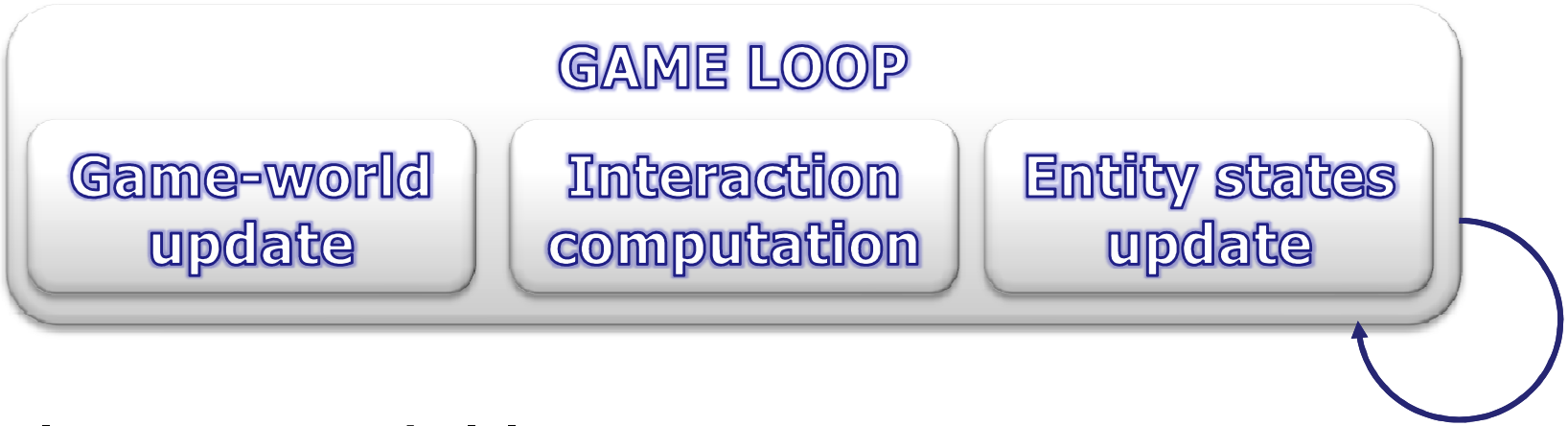
Platform Scalability Challenge

1. **Introduction**
    1. **Online Game Types**
    2. **Game Models**
2. (Scheduling) Hosting Models
    1. Cluster + Parallelization
    2. Multi-cluster + Sharding
    3. Cloud-based + Sharding
    4. The SuperServer (video)
3. (Naming) Locating Servers
    1. Central directory
    2. Peer-to-Peer
4. Consistency
    1. (Eventual) Dead-reckoning
    2. (Continuous) Simultaneous Sim
    3. (Continuous) + Pipelining
    4. (Continuous) + Dynamic Tick
    5. (Continuous/Eventual) Area of Simulation vs Interest
5. Other issues

Online Game Types

- MMO Role Playing Games (MMORPG)
  - Adventure: Runscape, World of Warcraft
  - Thousands of players sharing one persistent game session in a huge game world
  - Latency <1s acceptable
- First Person Shooter (FPS)
  - Action games
  - Counter Strike Source, Call of Duty, …
  - Max. 64 players in one session (minutes or hours)
  - Latency <100ms needed
- Real-Time Strategy (RTS)
  - Economic and battle strategy games
  - DotA 2, Starcraft
  - Latency <350ms needed

Computational Model for the Server



- Single sequential loop
- 3 steps in each loop:
  1. Game-world state update
  2. Entity interaction computation (dominant for MSGs)
  3. Entity state updates
- Load generated by (2) non-deterministic ← human factor

[Source: Nae, Iosup, and Prodan, ACM SC 2008]

Model for Entity Interaction Computation

- Player to Player/Player to Environment interaction
  - **Low** interaction: **O(n)**, e.g. RTS
  - **Medium** interaction: **O(n·log(n))** – RPG quest maps
  - **High** interaction: **O(n^2)** – RPG war maps, FPS
  - **Very High** interaction: **O($n^2 \cdot \log(n)$)/O(n^3)**, unit-target matching, team path-finding, maxflow alg., …

Platform Scalability Challenge

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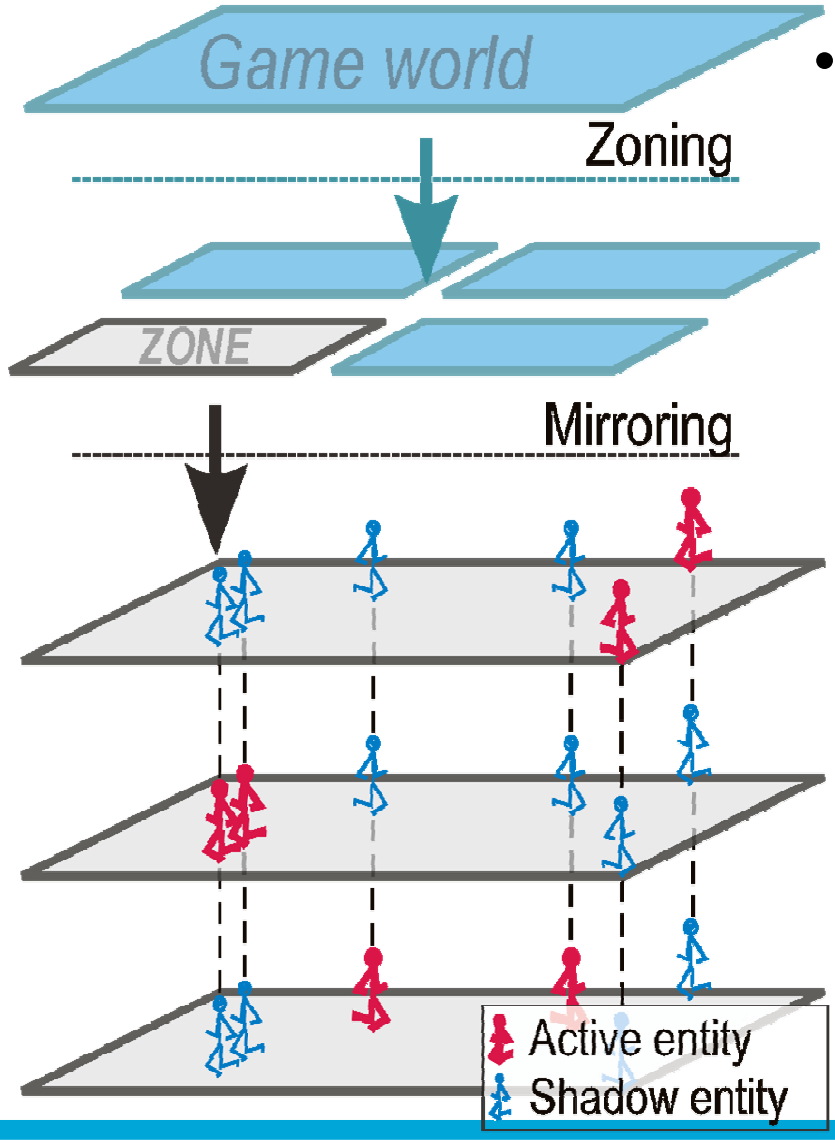
5. Other issues

Online games hosting model

- Generic Online Games (non-MM)
  - **Static:** dedicated isolated single servers
- MMOGs
  - **Static:** dedicated clusters - using parallelization techniques
- Problems with these approaches
  1. Large amount of over-provisioning
  2. Non-efficient coverage of the world for the provided service

[Source: Nae, Iosup, and Prodan, ACM SC 2008]

Game parallelization models



- Models:
  - Zoning: huge game-world division into geographical sub-zones – each zone is handled by different machines
  - Mirroring: the same game-world handled by different machines, each one handling a subset of the contained entities (synchronized states)
  - **Instancing/sharding**: multiple instances of the same zone with independent states. (World of Warcraft, Runescape,..)

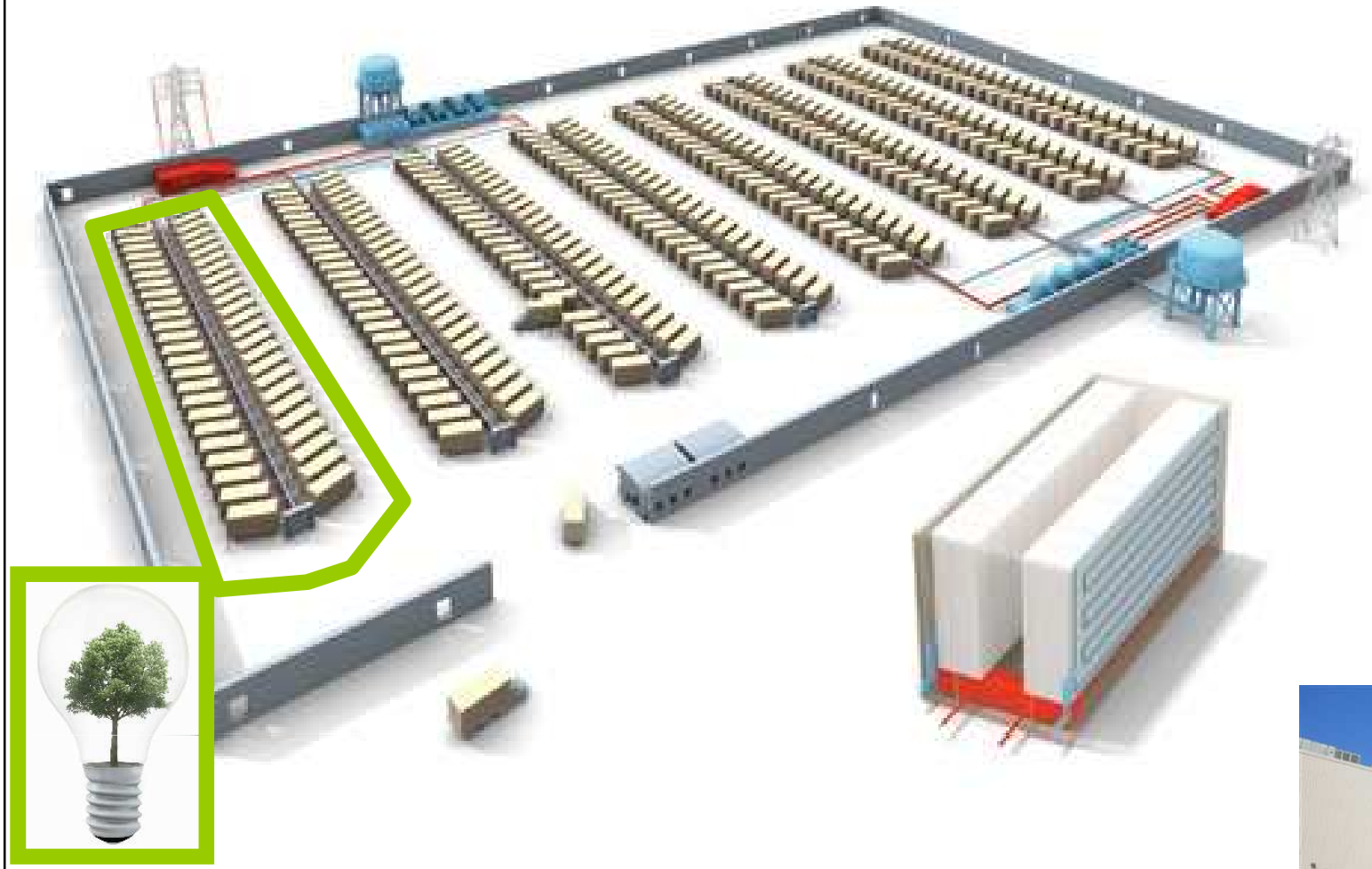
Proposed hosting model: dynamic

- Using data centers for dynamic resource allocation

- Main advantages:
  1. Significantly lower over-provisioning
  2. Efficient coverage of the world is possible

[Source: Nae, Iosup, and Prodan, ACM SC 2008]

Cloud Computing



Dynamic MSG Ecosystem: Model

- **Game operators**
  - Past player activity/business model → **Predicted load → requests**
- **Data centers**
  - **Local** time-space **renting policy → offers**
  - Time-Space renting policy, e.g., 1 node-hour
- Resource allocation: central request-offer matching
- Rules for ranking request-offer match:

  The offer size and type vs. the request, The geographical proximity offer-request, etc.

[Source: Nae, Iosup, and Prodan, ACM SC 2008]

Experimental Setup [1/3]
Discrete-Event Simulator

- Input
  - Traces from RuneScape, a real top-5 MMOG
    - 7 countries, 3 continents
    - More than 130 game worlds
  - Consisting of
    - Geographical location
    - Number of clients
    - Over 10,000 samples at 2 min. interval, 2 weeks
- Output (for every time-step)
  - Resource allocation decisions
  - Resource allocation
  - Performance metrics

[Source: Nae, Iosup, and Prodan, ACM SC 2008]

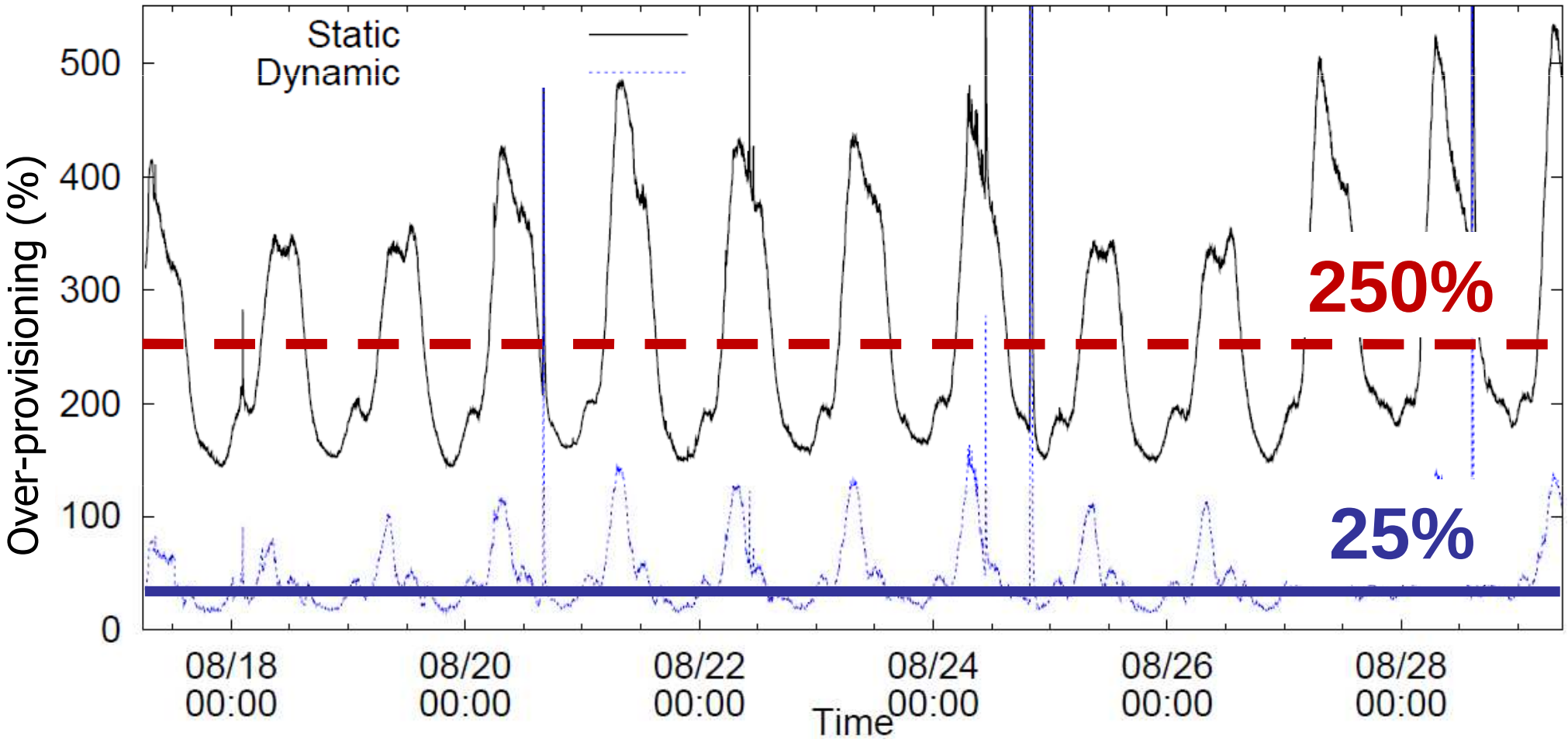
Experimental Setup [3/3]
Performance Metrics

- Resource over-provisioning [%]
  - The wasted resources vs. optimal provisioning at each simulation time step for all utilized machines (cumulative)
- Resource under-provisioning [%]
  - The amount of resources needed but not allocated, for all machines (computed individually)
- Significant under-provisioning events (count)
  - Count of events: resource under-provisioning is >1%, for a period of 2 minutes → **people leave**

[Source: Nae, Iosup, and Prodan, ACM SC 2008]

Resource Provisioning and Allocation

Static vs. Dynamic Provisioning



[Source: Nae, Iosup, and Prodan, ACM SC 2008]

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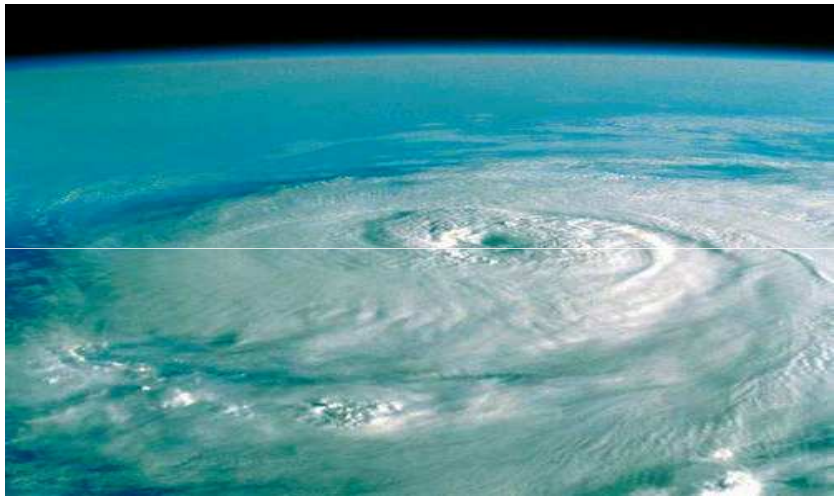
Also Studied

- Via real game measurements
  - Interactivity model (short-term msmt.)
  - Effects of underperforming platform (long-term msmt.)
- Via prototype implementation
  - Match model-reality [TPDS'11]
- Via simulation
  - Impact of virtualization [NetGames'11][IJAMC'11]
  - Economic models [CAC'13]

Remaining Challenge in Perf. Eng.: To the Real IaaS Cloud

http://www.flickr.com/photos/dimitrisotiropoulos/4204766418/

VS



Tropical Cyclone Nargis (NASA, ISSS, 04/29/08)

- "The path to abundance"
- On-demand capacity
- Cheap for short-term tasks
- Great for web apps (EIP, web crawl, DB ops, I/O)

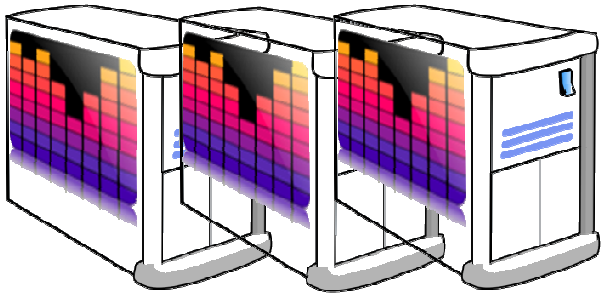
- "The killer cyclone"
- (1) Not so great performance for scientific applications (compute- or data-intensive)
- (2) Unstable performance

1- Iosup et al., Performance Analysis of Cloud Computing Services for Many Tasks Scientific Computing, IEEE TPDS, 2011,
http://www.st.ewi.tudelft.nl/~iosup/cloud-perf10tpds_in-print.pdf

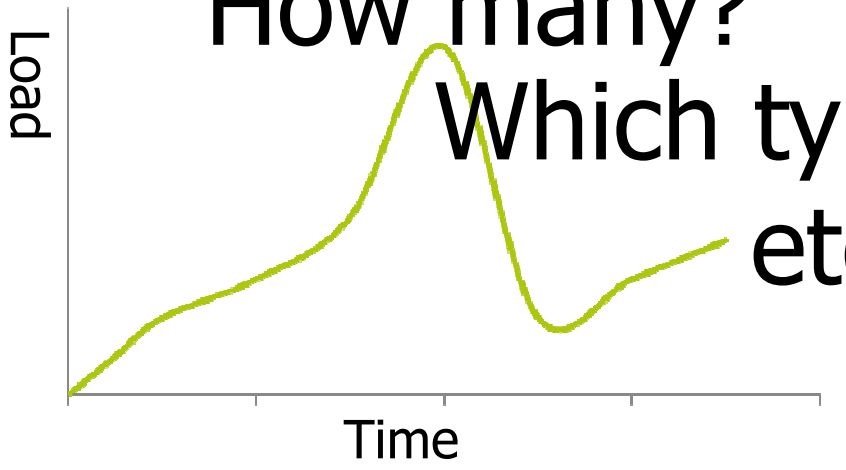
2- Iosup et al., On the Performance Variability of Production Cloud Services, CCGrid 2011, pds.twi.tudelft.nl/reports/2010/PDS-2010-002.pdf

Remaining Challenge in Scheduling: Provisioning and Allocation *Policies*

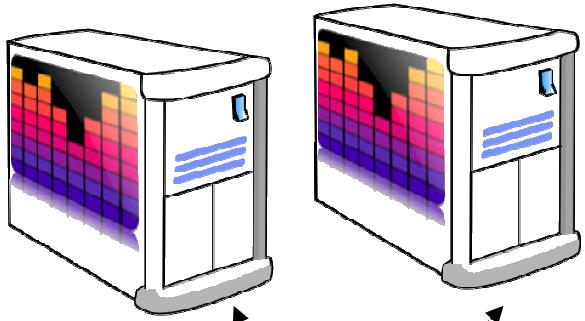
Provisioning



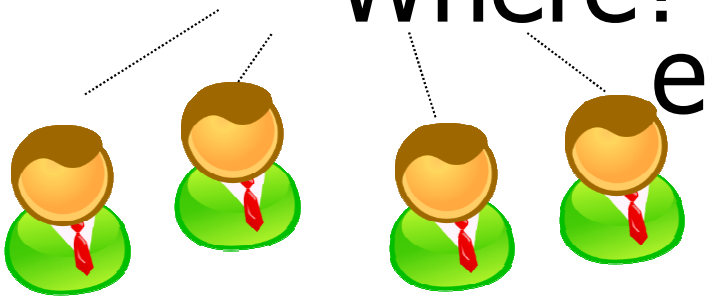
When? How many? Which type? etc.



Allocation



When? Where? etc.



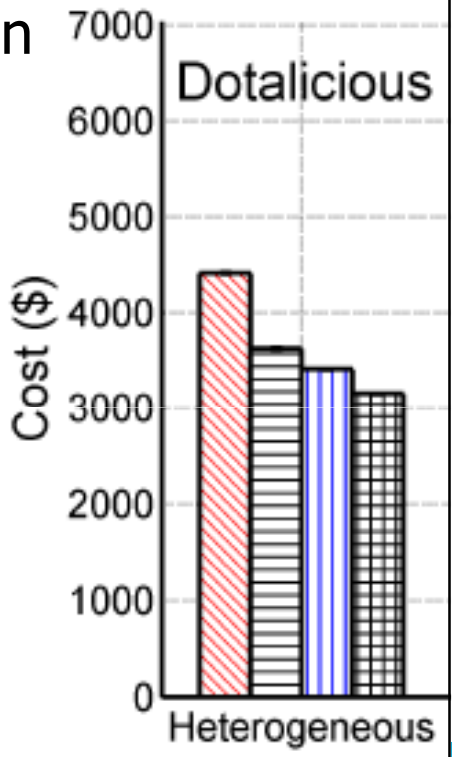
(Source: A. Antoniou, MSc Defense, TU Delft, 2012.)

An Example: Portfolio Scheduling for Online Gaming (also for Scientific Workloads)

- **CoH =** Cloud-based, online, Hybrid scheduling
  - Intuition: keep rental cost low by finding good mix of machine configurations and billing options
  - Main idea: **portfolio scheduler** = run *both* solver of an Integer Programming Problem and various heuristics, then pick best schedule at deadline
  - Additional feature: Can use **reserved cloud instances**
- Promising early results, for

  Gaming (and scientific) workloads

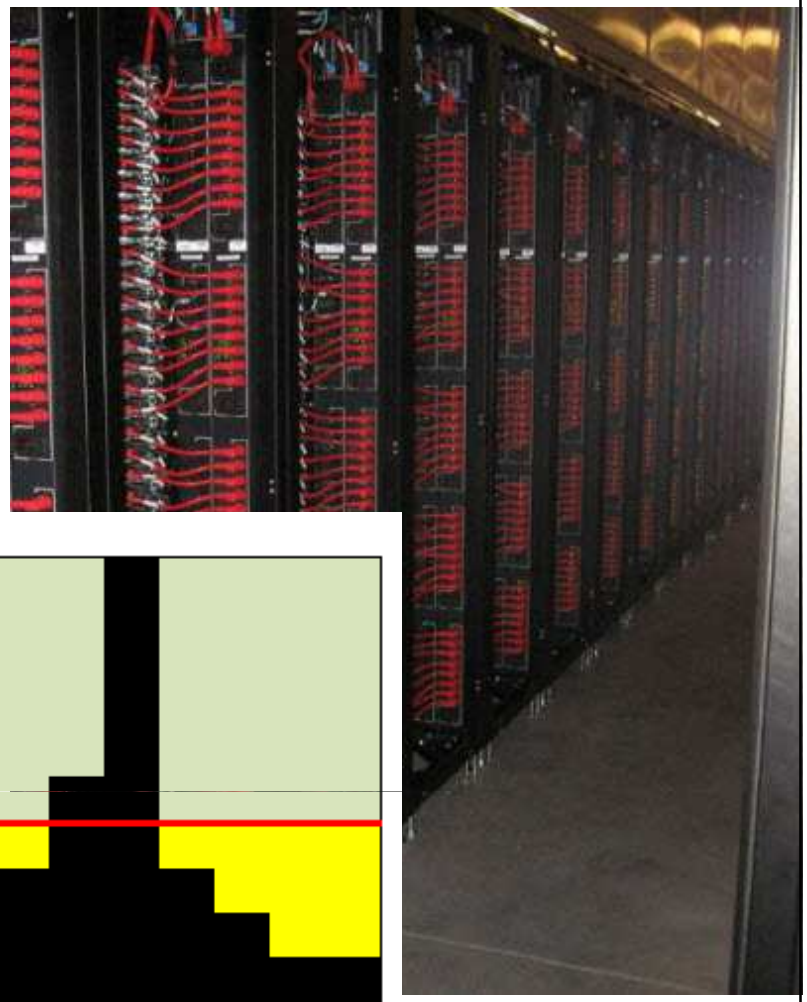
Trace	#jobs	average runtime [s]
Grid5000	200,450	2728
LCG	188,041	8971
DotaLicious	109,251	2231



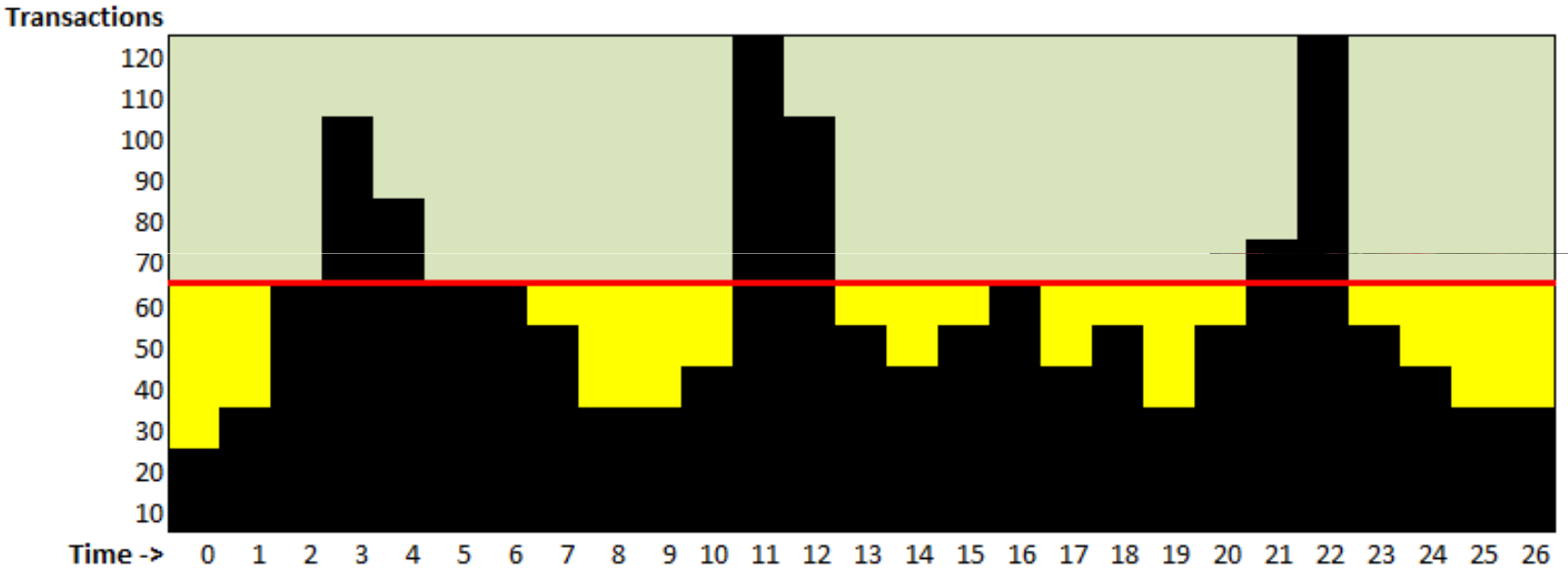
Shen, Deng, Iosup, Epema, Scheduling Jobs in the Cloud Using On-demand and Reserved Instances, EuroPar'13 (sub)

Remaining Challenge in Deployment: Zynga zCloud: Hybrid Self-Hosted/EC2

- After Zynga had large scale



- More efficient self-hosted servers
  - Run at high utilization
- Use EC2 for unexpected demand



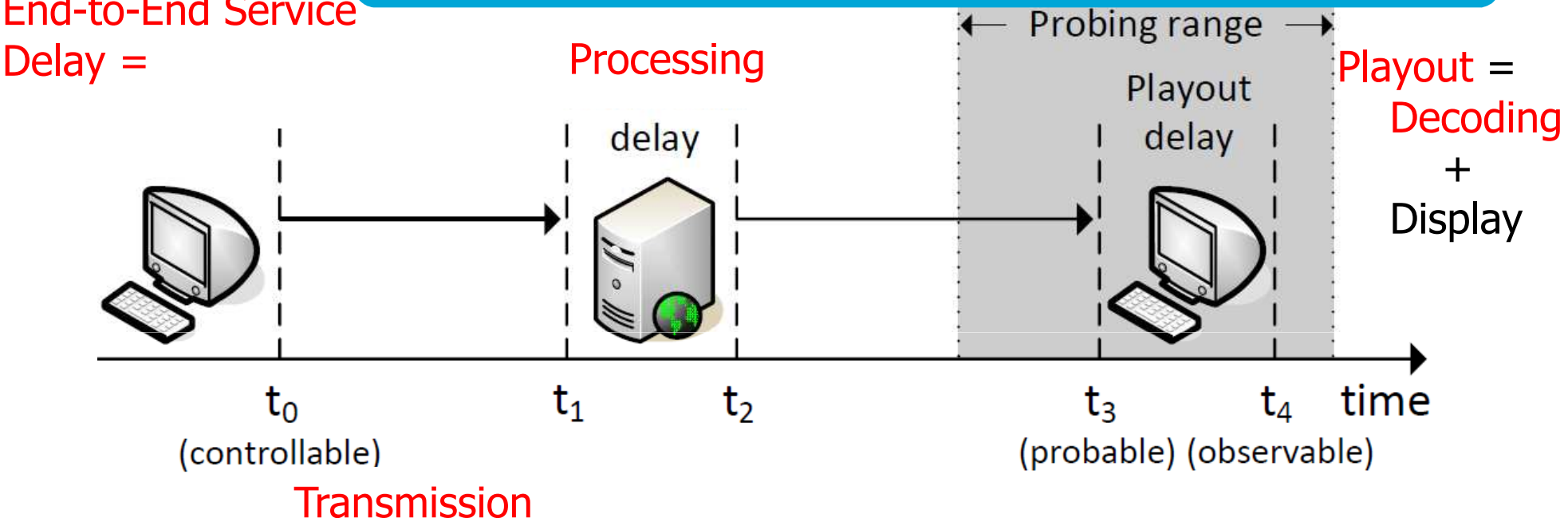
May 9, 2013

(Sources: http://seekingalpha.com/article/609141-how-amazon-s-aws-can-attract-ugly-economics and http://www.undertheradarblog.com/blog/3-reasons-zynga-is-moving-to-a-private-cloud/)

"Cloud Gaming" = Interactive Gaming Videos from the Cloud

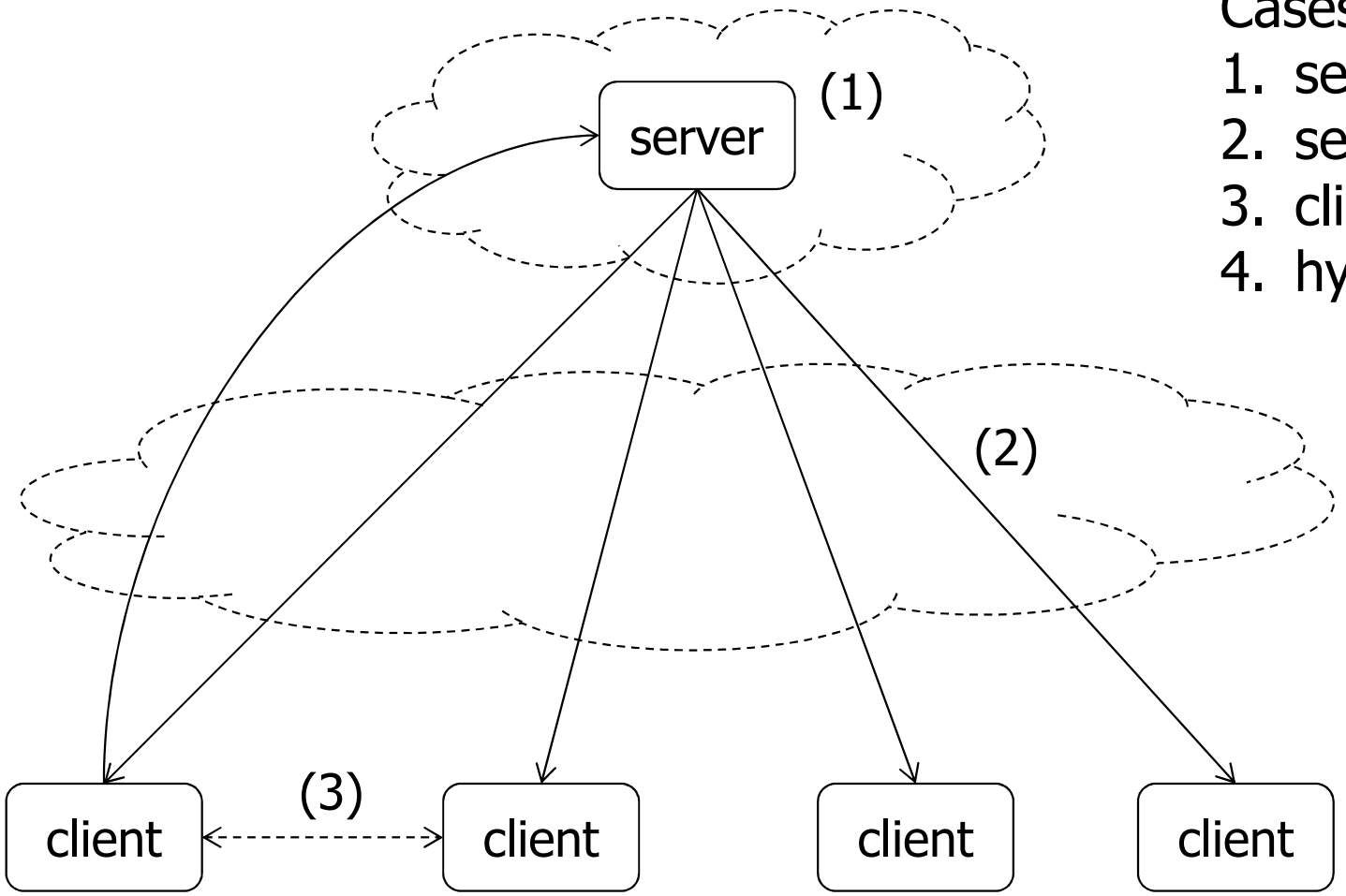
- Gaikai, OnLive—servers in own data centers, HDTV 720p

This is only one type of cloud offloading



Kuan-Ta Chen et al., Measuring the latency of cloud gaming systems. ACM Multimedia 2011: 1269-1272.

Remaining Challenges: Many Cloud Offloading Alternatives

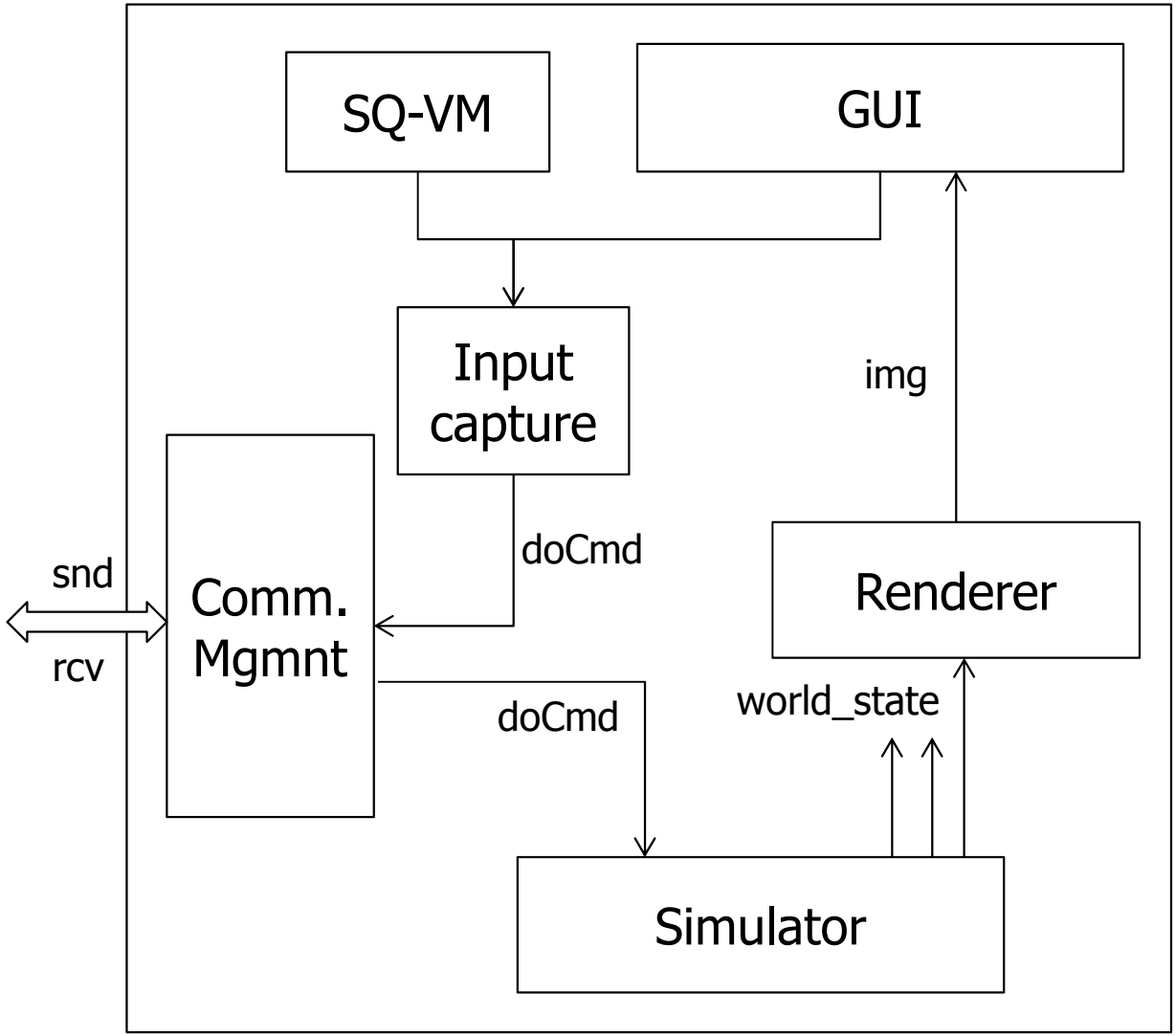


Cases to investigate:

1. server in cloud
2. server behind cloud
3. clients in same LAN
4. hybrid

Work in Progress. With Alexandru Olteanu.

An Offloading Use Case: the OpenTTD Client (Early Work)

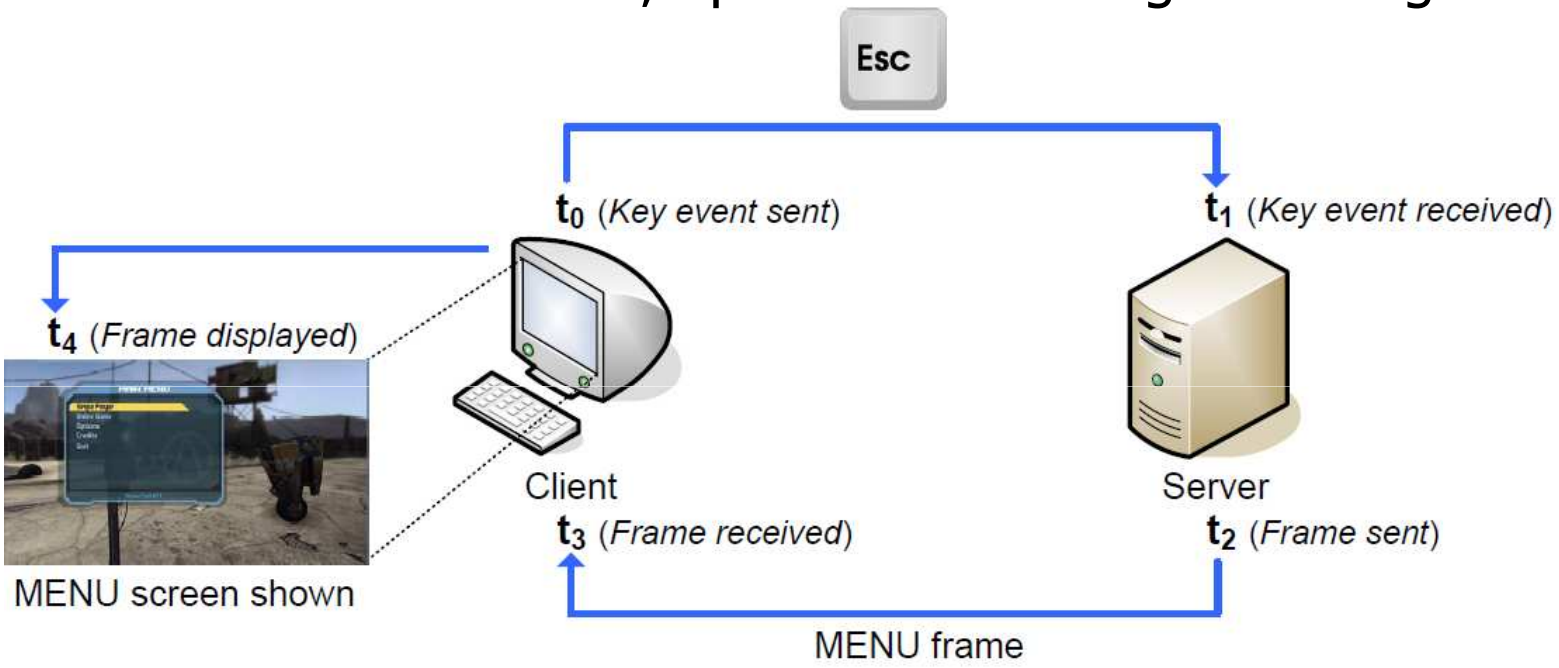


Game Parameters:

- map size
- number of players
- number of cities
- number of resources
- animations on/off

"Cloud Gaming" = Interactive Gaming Videos from the Cloud [2/3]

- Measurement approach
  - Reverse engineer calls
  - Inject measurement probes into library calls
  - Smart detection of t3, up to and including Decoding

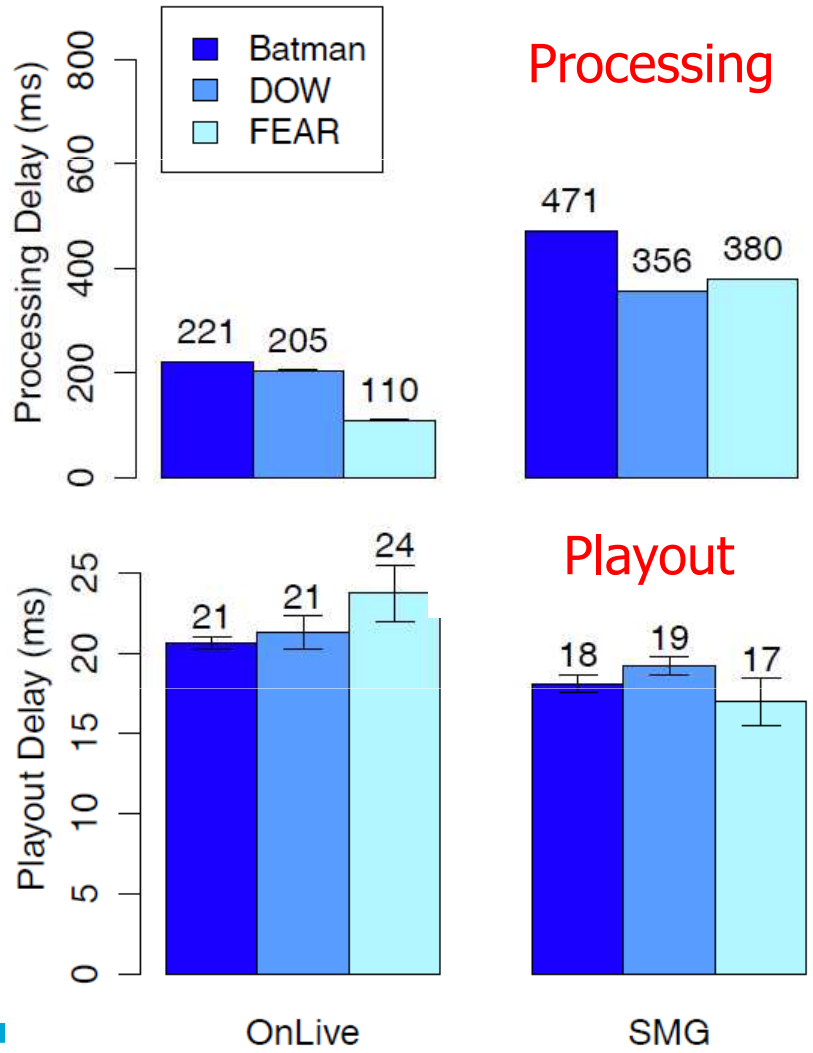


Kuan-Ta Chen et al., Measuring the latency of cloud gaming systems. ACM Multimedia 2011: 1269-1272.

"Cloud Gaming" = Interactive Gaming Videos from the Cloud [3/3]

- Games used in experiments
  - Batman (action-adventure)
  - Warhammer 40k: DOW (RTS)
  - FEAR (FPS)

- Measurement results
  - OnLive better processing delay
  - FPS FEAR supported very well by OnLive
  - OnLive supports well Batman&DOW
  - StreamMyGame: 400-500ms delay
  - Similar playout delays



Kuan-Ta Chen et al., Measuring the latency of cloud gaming systems. ACM Multimedia 2011: 1269-1272.

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Platform Scalability Challenge

1. Introduction
   1. Online Game Types
   2. Game Models
2. (Scheduling) Hosting Models
   1. Cluster + Parallelization
   2. Multi-cluster + Sharding
   3. Cloud-based + Sharding
   4. The SuperServer (video)
3. (Naming) Locating Servers
   1. Central directory
   2. Peer-to-Peer
4. **Consistency**
   1. **(Eventual) Dead-reckoning**
   2. **(Continuous) Simultaneous Sim**
   3. **(Continuous) + Pipelining**
   4. **(Continuous) + Dynamic Tick**
   5. **(Continuous/Eventual) Area of Simulation vs Interest**
5. Other issues

Other Distributed Systems Issues

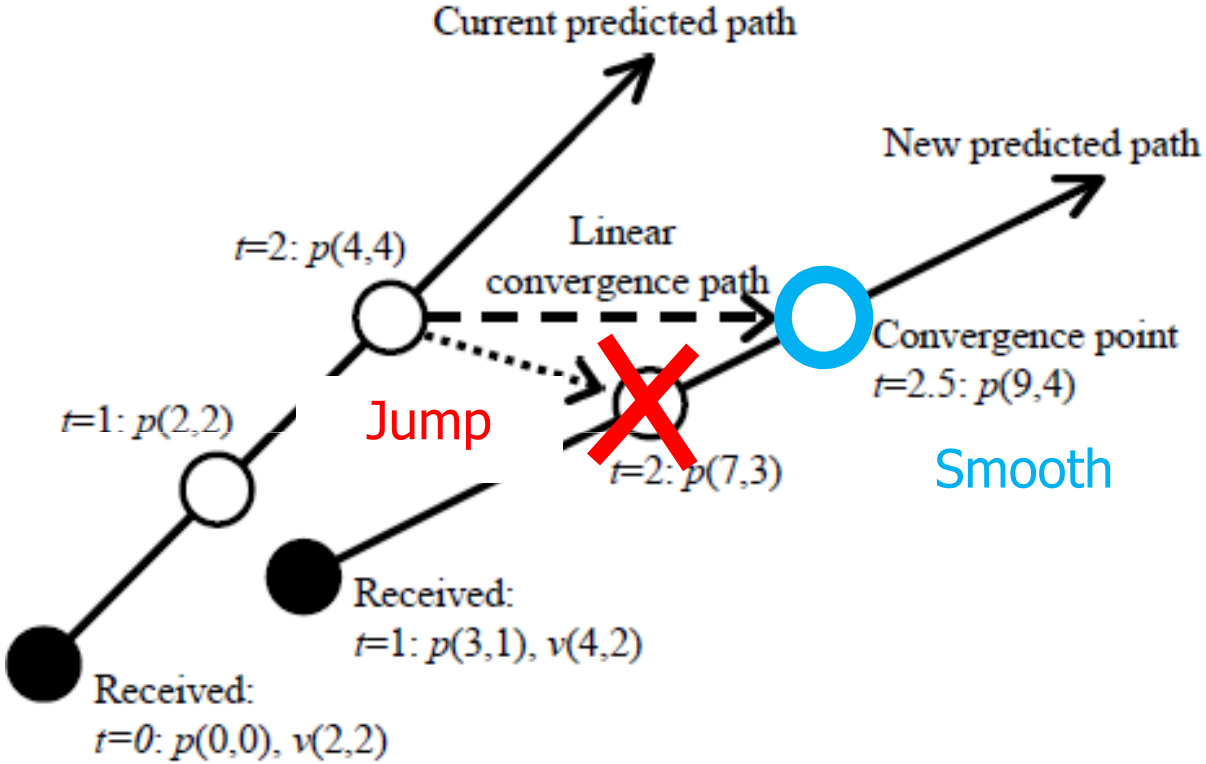
Consistency

- Eventual Consistency or Inconsistency
  - Dead-reckoning: eventual consistency with low message overhead
  - Smarter extensions

t = time

p = position

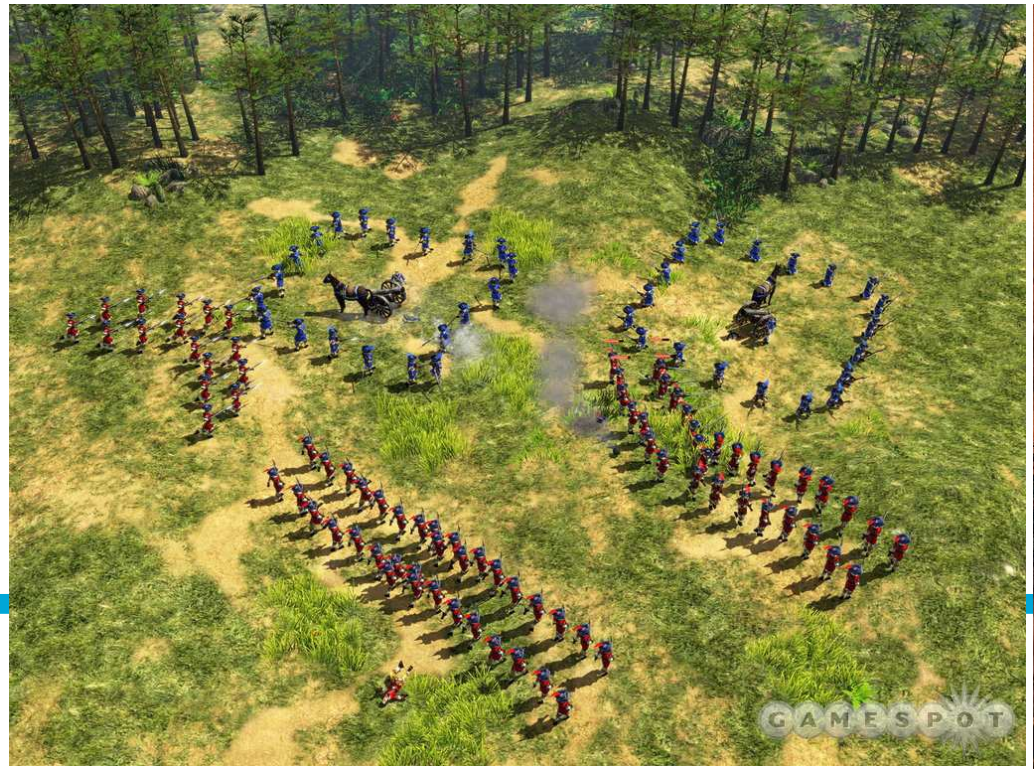
v = velocity



Smed et al., A Review of Networking and Multiplayer Computer Games. TR454, 2002.
http://staff.cs.utu.fi/~jounsmed/papers/TR454.pdf

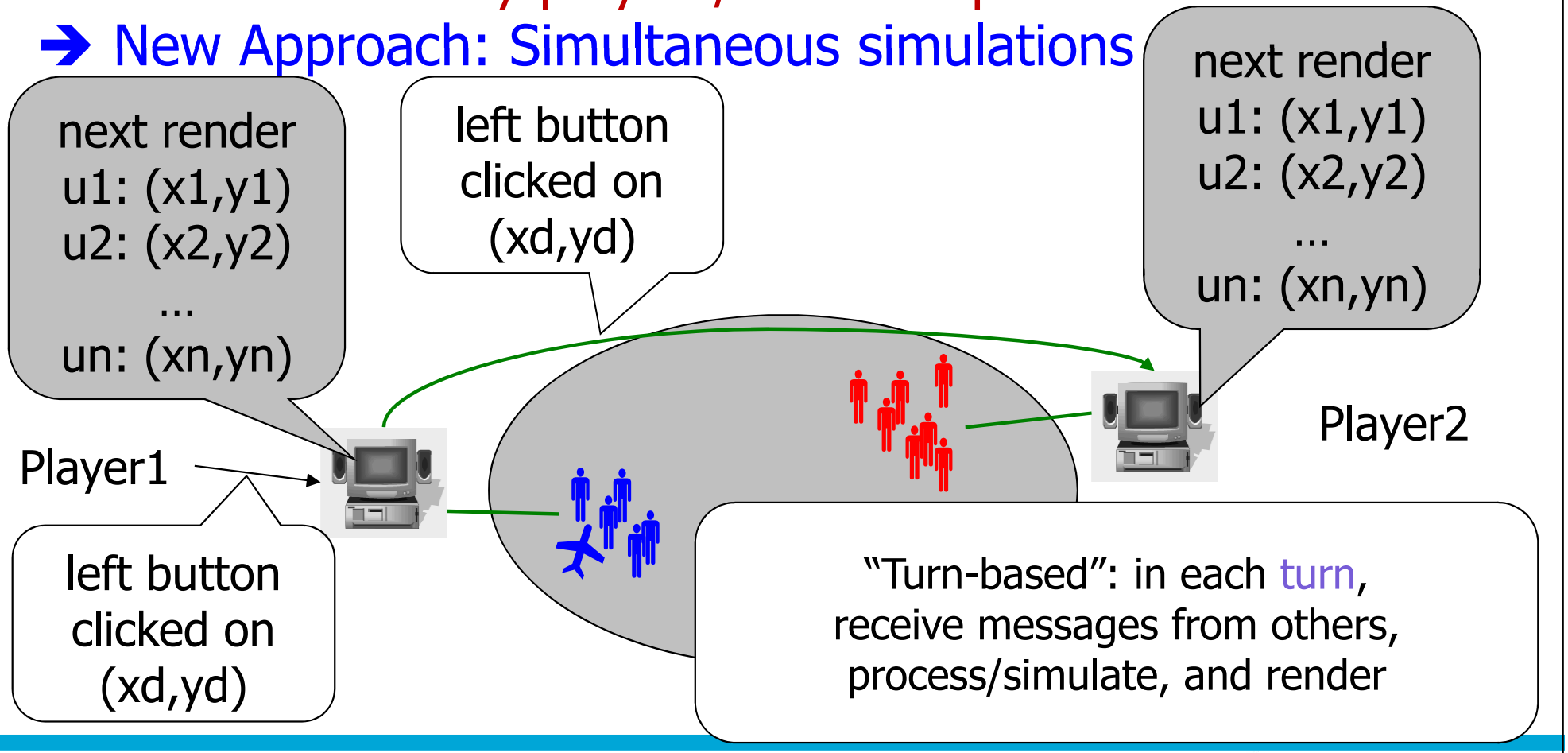
Remember RTS Games?

- Players control tens up to hundreds of units.
- Players need to take decisions in real-time.



Other Distributed Systems Issues Consistency: 1.5k Archers on 28.8k Line [1/3]

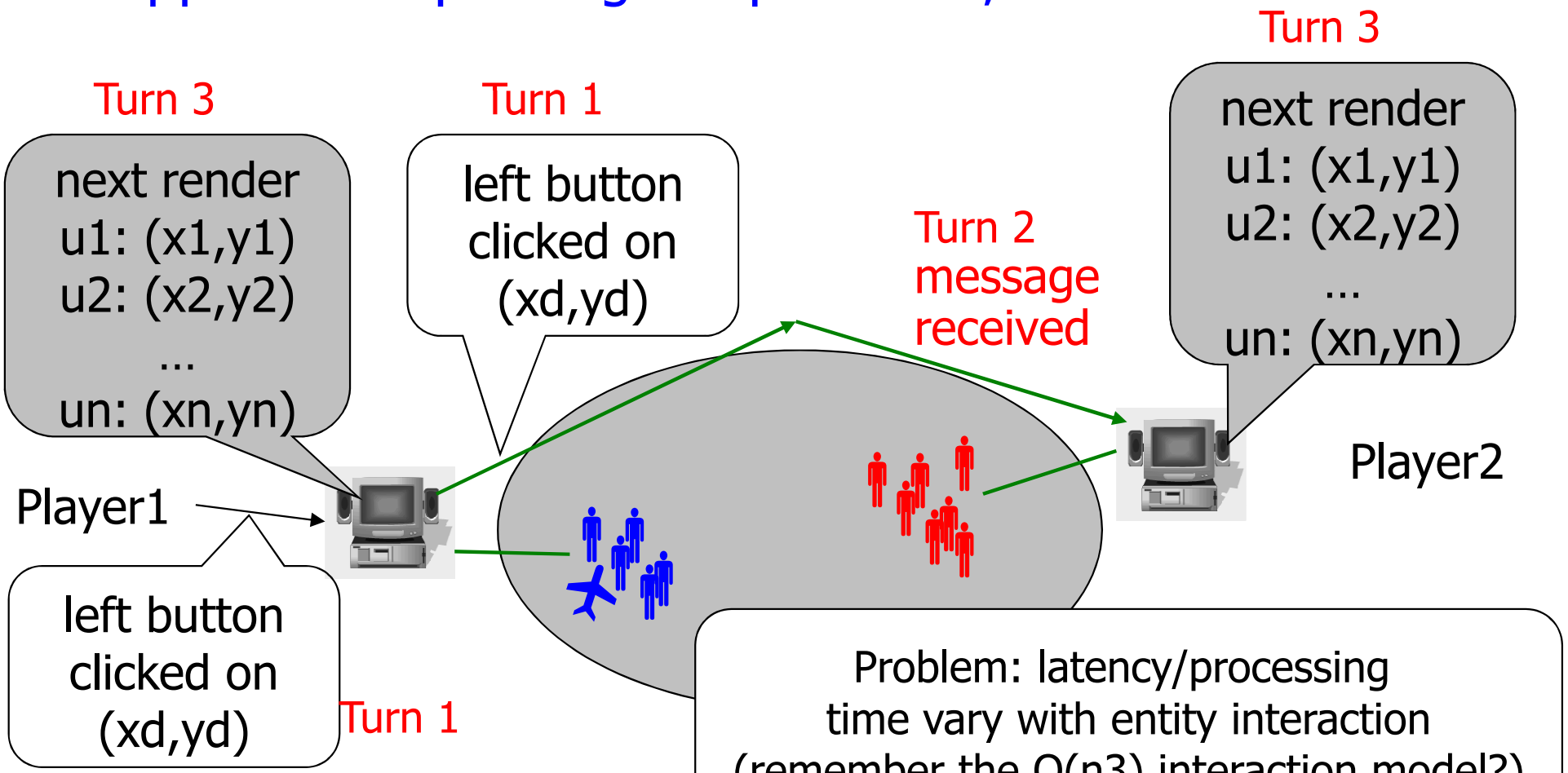
- Age of Empires [Bettner & Terrano GDC01]
- Problem: Too many players/units to update at each click
  - ➔ New Approach: Simultaneous simulations



Source: http://www.gamasutra.com/view/feature/131503/1500_archers_on_a_288_network_.php?print=1.
Slides source: http://www.cs.duke.edu/courses/spring08/cps214/lectures/lecture18.ppt

Other Distributed Systems Issues Consistency: 1.5k Archers on 28.8k Line [2/3]

- Problem: need very long turn to finish everything!
  - ➔ Approach: Pipelining of operations, have multi-turn tick

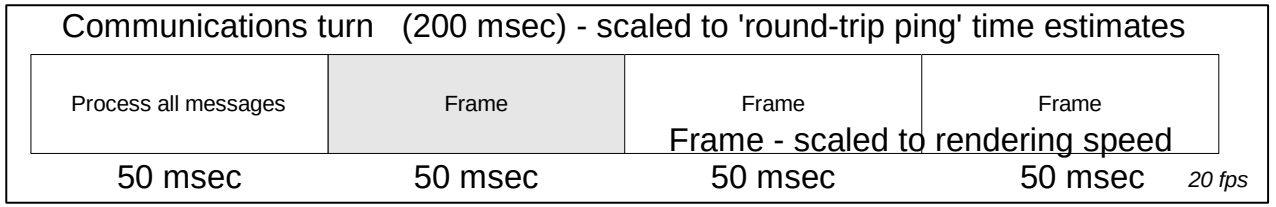


Source: http://www.gamasutra.com/view/feature/131503/1500_archers_on_a_288_network_.php?print=1.
Slides source: http://www.cs.duke.edu/courses/spring08/cps214/lectures/lecture18.ppt

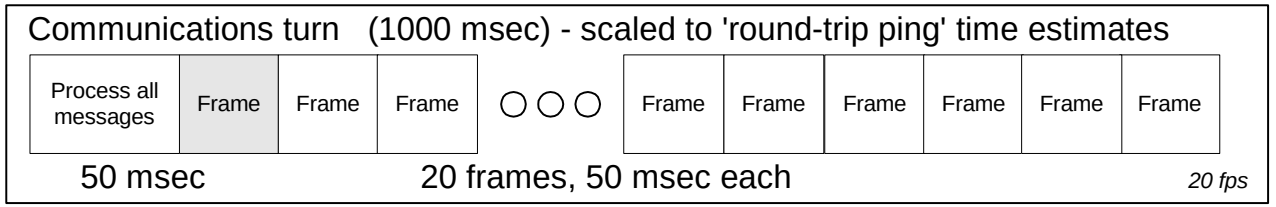
Other Distributed Systems Issues Consistency: 1.5k Archers on 28.8k Line [3/3]

- Approach: dynamic turn length
  - Adjusts to real delays experienced by real players

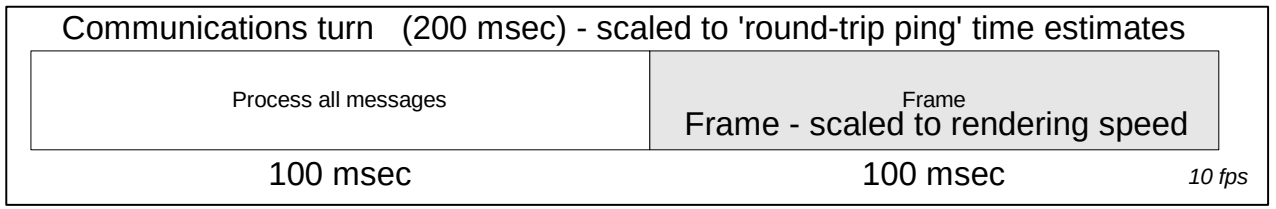
Regular Net/CPU
200 ms latency
50 ms proc/render



Slow Net/Reg. CPU
1000 ms latency
50 ms proc/render



Reg. Net/Slow CPU
200 ms latency
100 ms proc/render

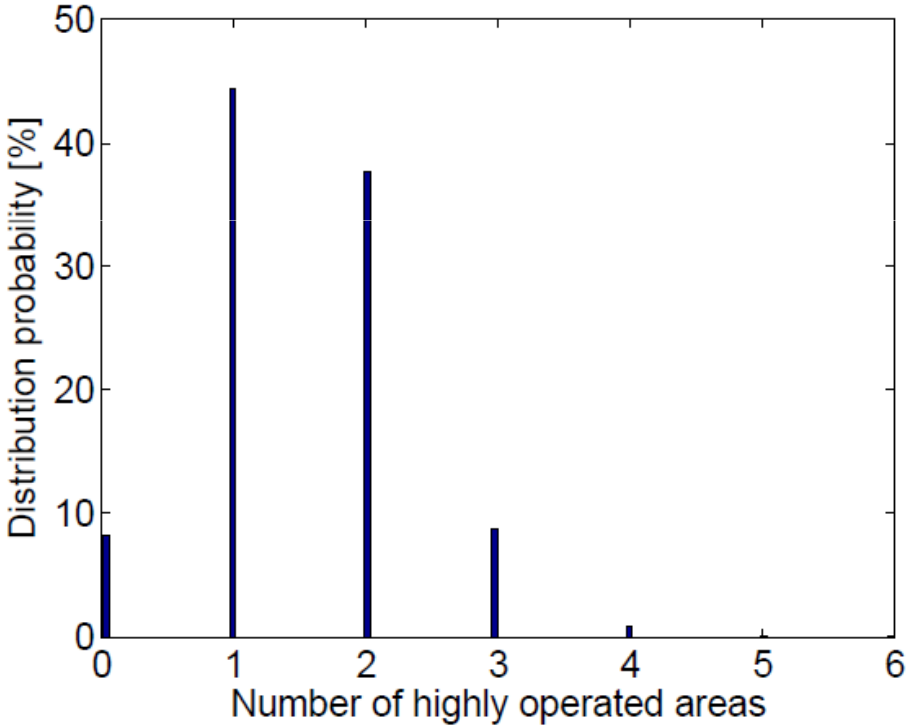


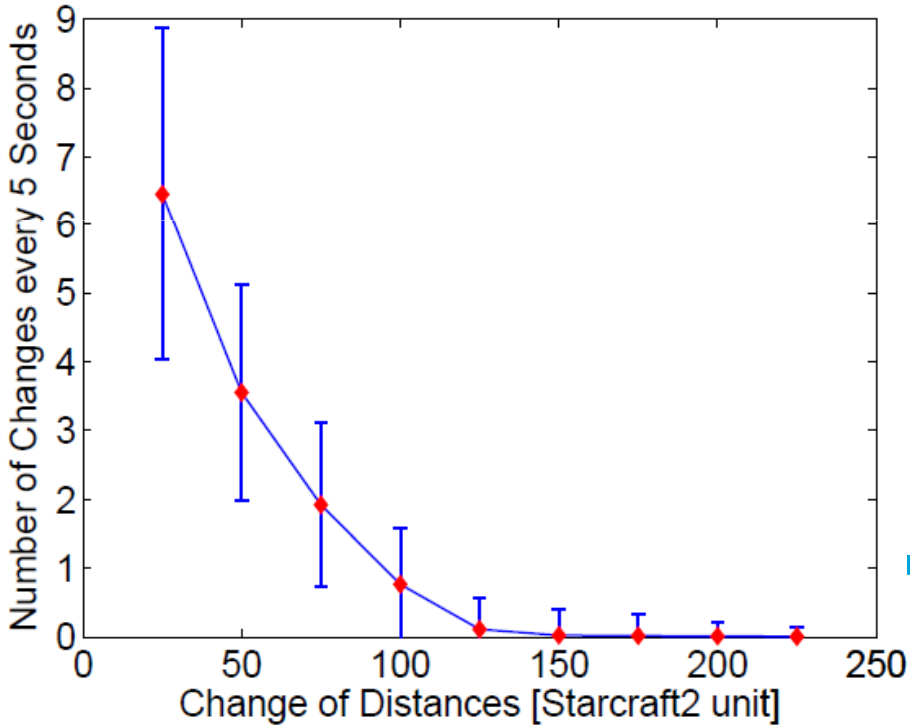
- Problem: slow turns. Could we use only Area of Interest?

Source: http://www.gamasutra.com/view/feature/131503/1500_archers_on_a_288_network_.php?print=1.
Slides source: http://www.cs.duke.edu/courses/spring08/cps214/lectures/lecture18.ppt

Traditional AoI does **not** work

- Area of Interest (AoI) = traditional mechanism for RPG: only receive information around avatar, but…
- …In RTS, each player has tens of units under control, so much more data to be transferred
- … In RTS, players change focus (interest) more often than in RPG and FPS, so higher management overhead





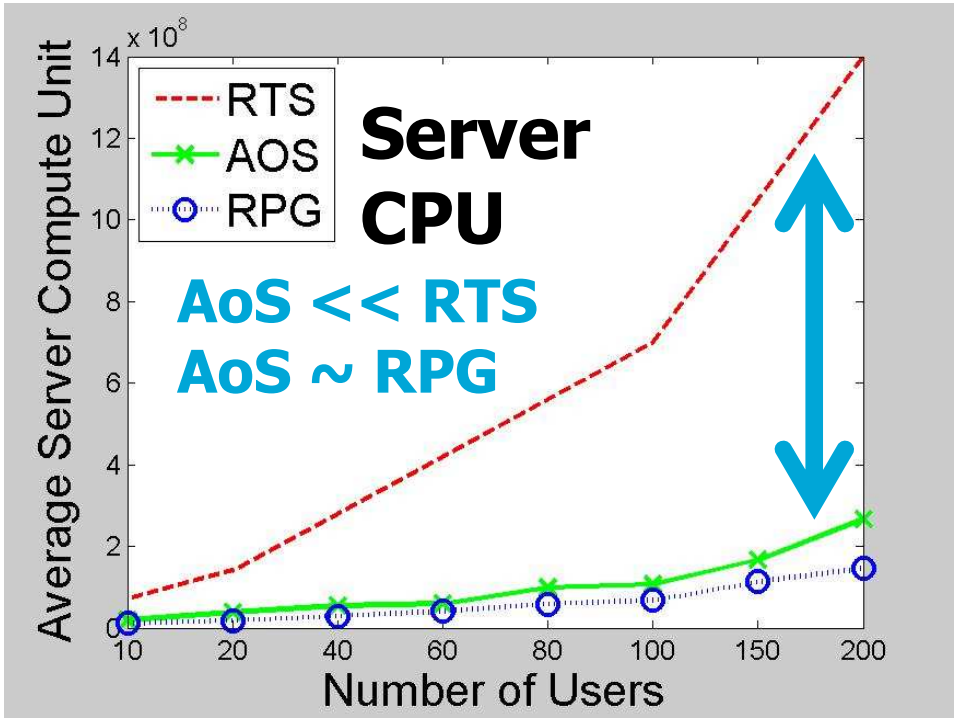
Core Idea

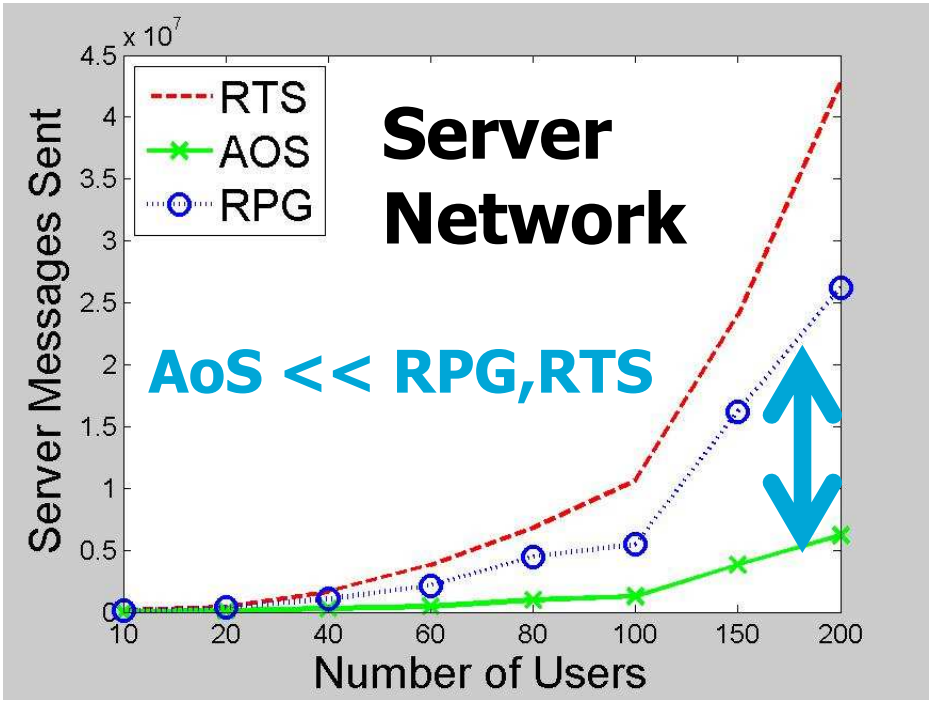
- Partition the game into multiple areas (rectangular)
- Each player pays attention to different areas + attention level
- Depending on attention level and machine performance, the player will receive different types of information (**commands** or **state**) about the game world
  - AoS: Area of Simulation = high-attention area, full simulation based on input commands (CPU-intensive)
  - AoU: Area of Update = low-attention area, receives state (Net)
  - NUA: No update area
- Each player can have multiple AoS and AoU

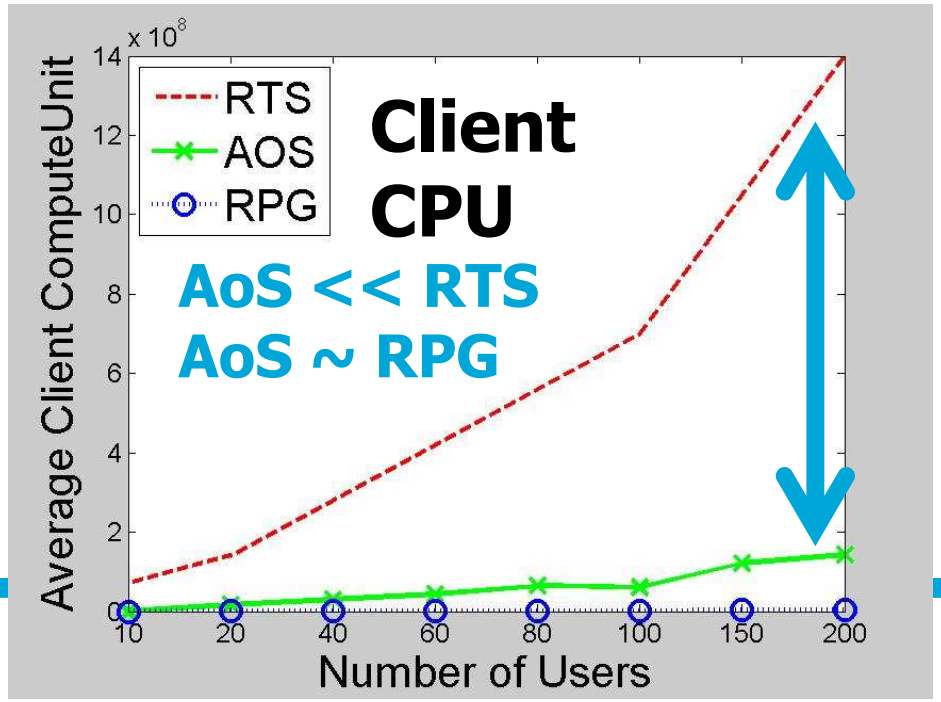
Experimental results

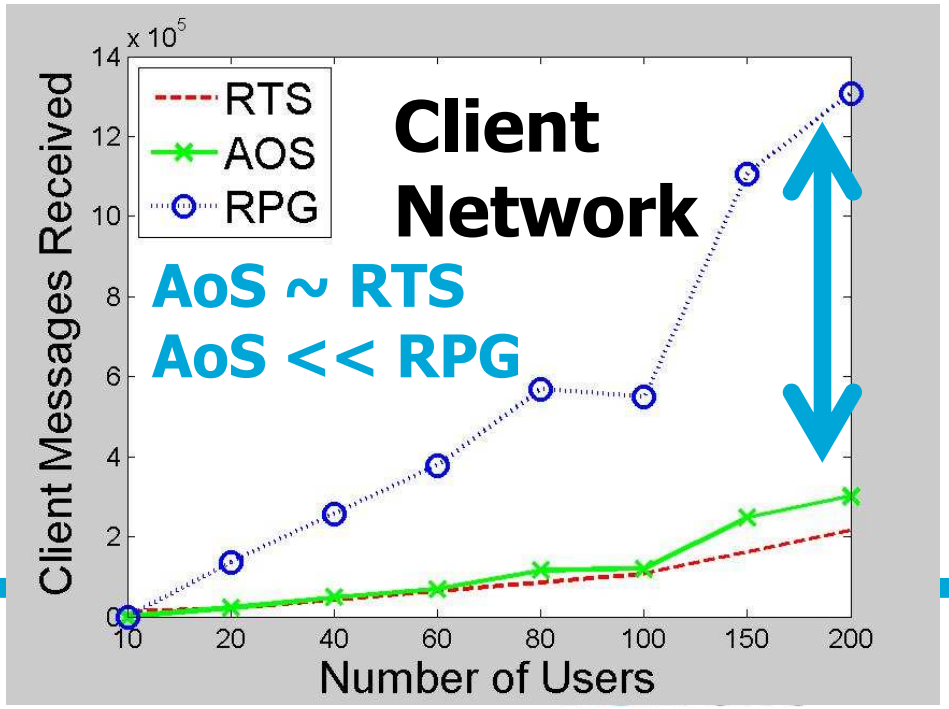
- Simulator and prototype RTS game
- Evaluate in two Cloud platforms: EC2 and Azure
- Prototype about 20k lines of C++ code
  - Based on an open source game (~6k lines)
- Up to 200 players and **10,000 battle units**
  - **State-of-the-art unplayable at 1-2,000**
  - **Crashes not uncommon due to CPU and Network bottlenecks**

- ➔ Using our AoS-based method can lead to **lower CPU** consumption than pure event-based method (RTS) and **lower network consumption** than pure update-based method (RPG)









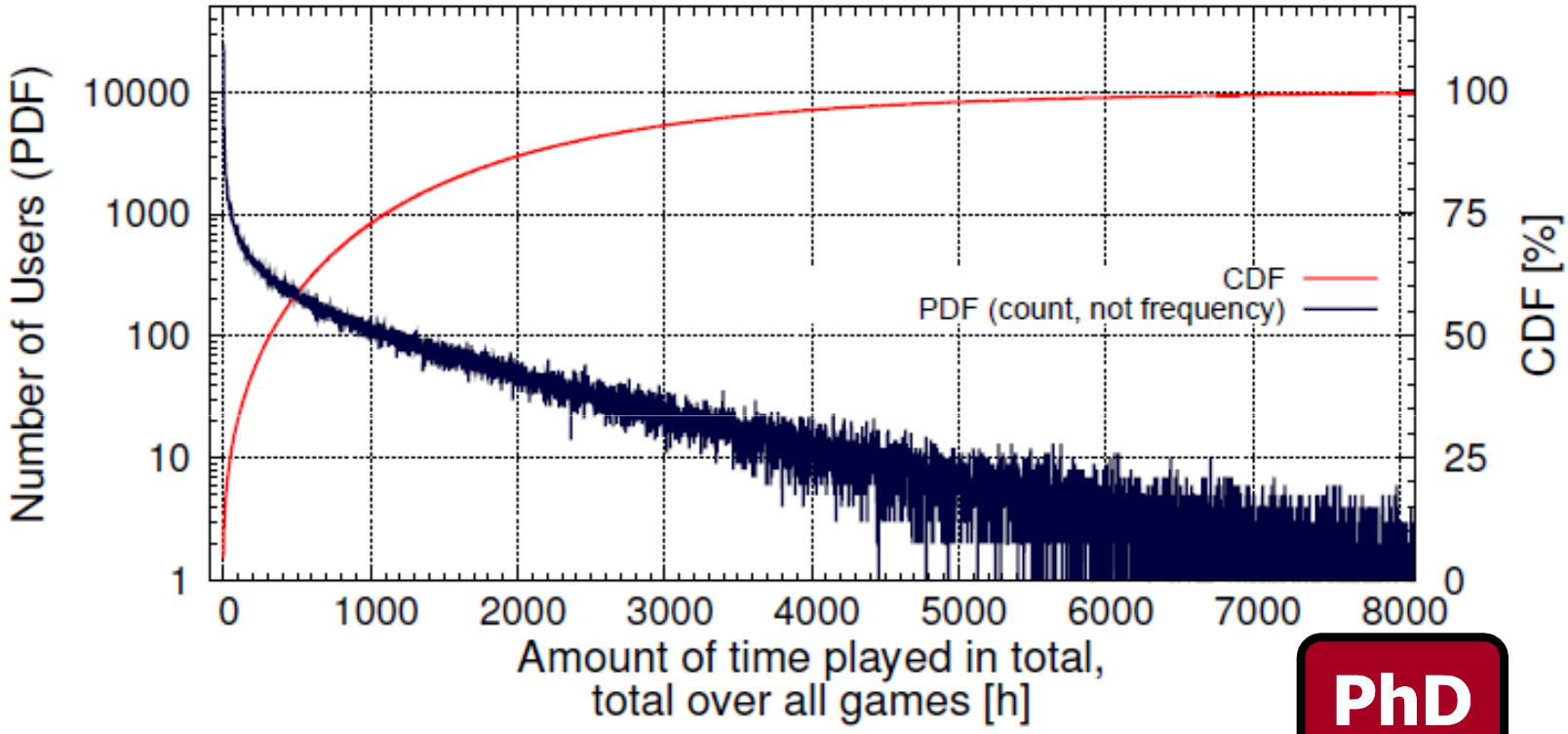
Work in Progress

Agenda

1. What's in a Name?
2. **Three Current Challenges**
   1. Platform Scalability Challenge
   2. **Gaming Analytics Challenge**
   3. Content Generation Challenge
3. The Next Five Years
4. Conclusion

@large: Sample Analytics Results
Analysis of Meta-Gaming Network

- "When you play a number of games, not as ends unto themselves but as parts of a larger game, you are participating in a metagame." (Dr. Richard Garfield, 2000)
- XFire: since 2008 (3+ years), 500K of 20M players



PhD

S. Shen, and A. Iosup, The XFire Online Meta-Gaming Network: Observation and High-Level Analysis, MMVE 2011

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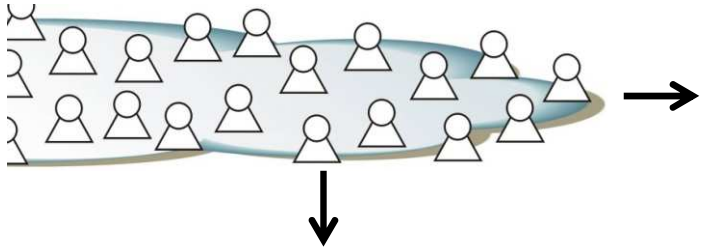
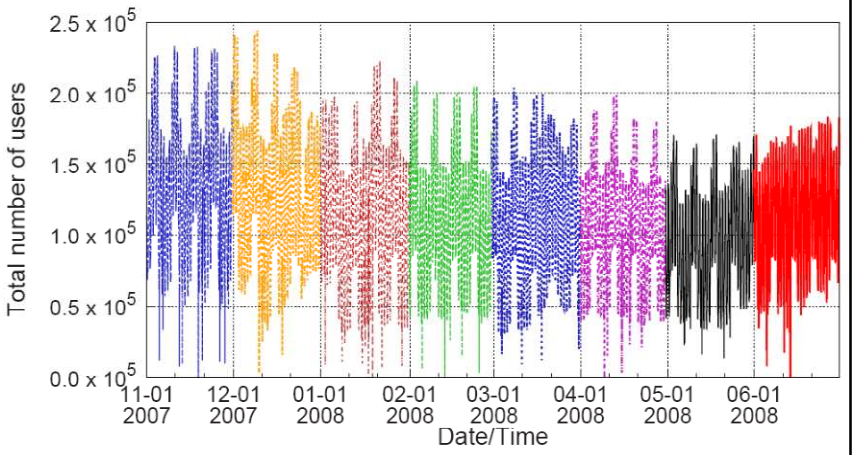
@large Research Challenge: Continuous Analytics for MMOGs

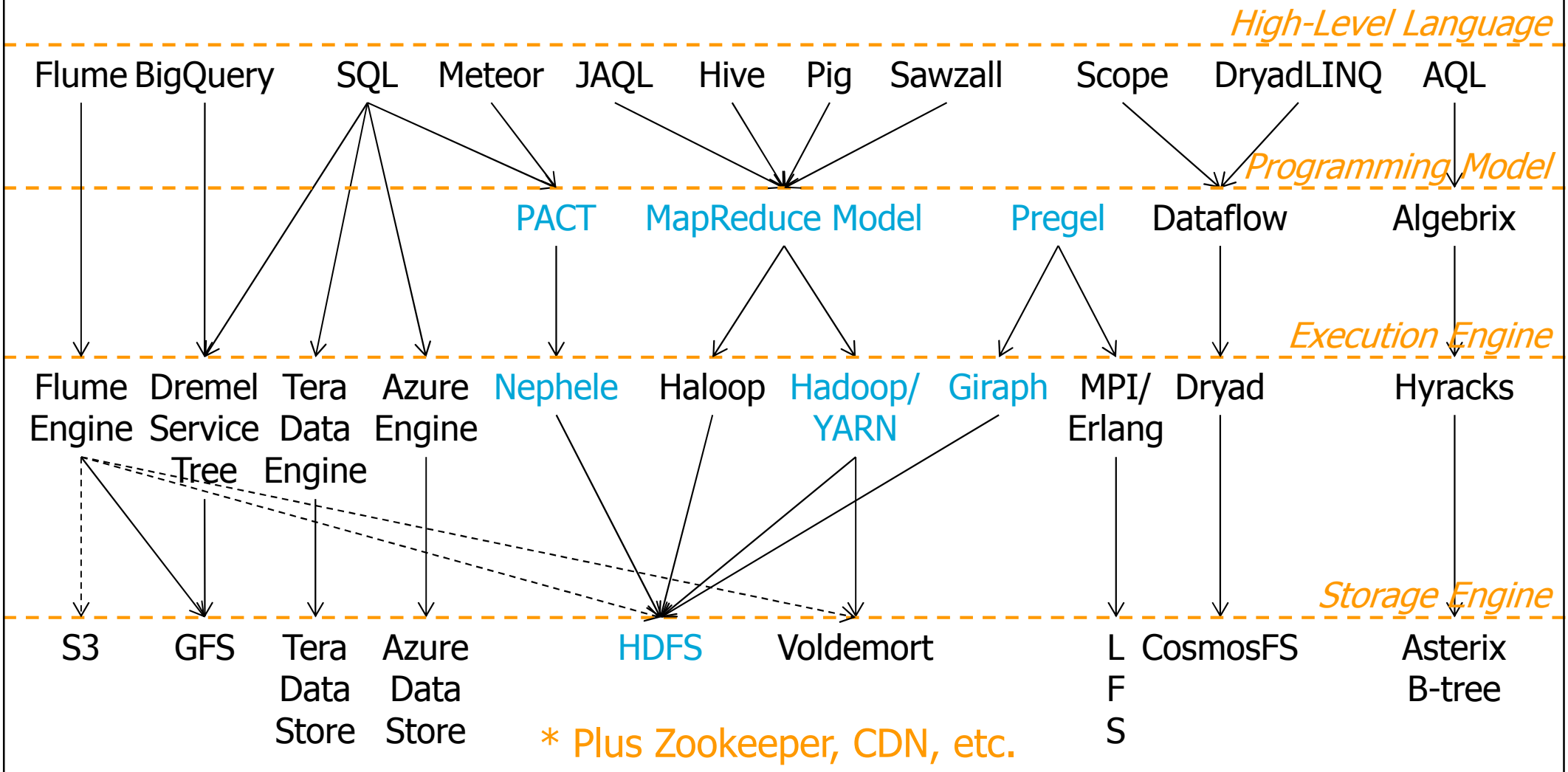
Analyzing the behavior of millions of players, on-time

- **Data mining**, data access rights, cost v. accuracy, …
- Reduce upfront costs
- Low response time & Scalable
- Large-scale Graph Processing





How to Analyze? Ecosystems of Big-Data Programming Models



Adapted from: Dagstuhl Seminar on Information Management in the Cloud, http://www.dagstuhl.de/program/calendar/partlist/?semnr=11321&SUOG

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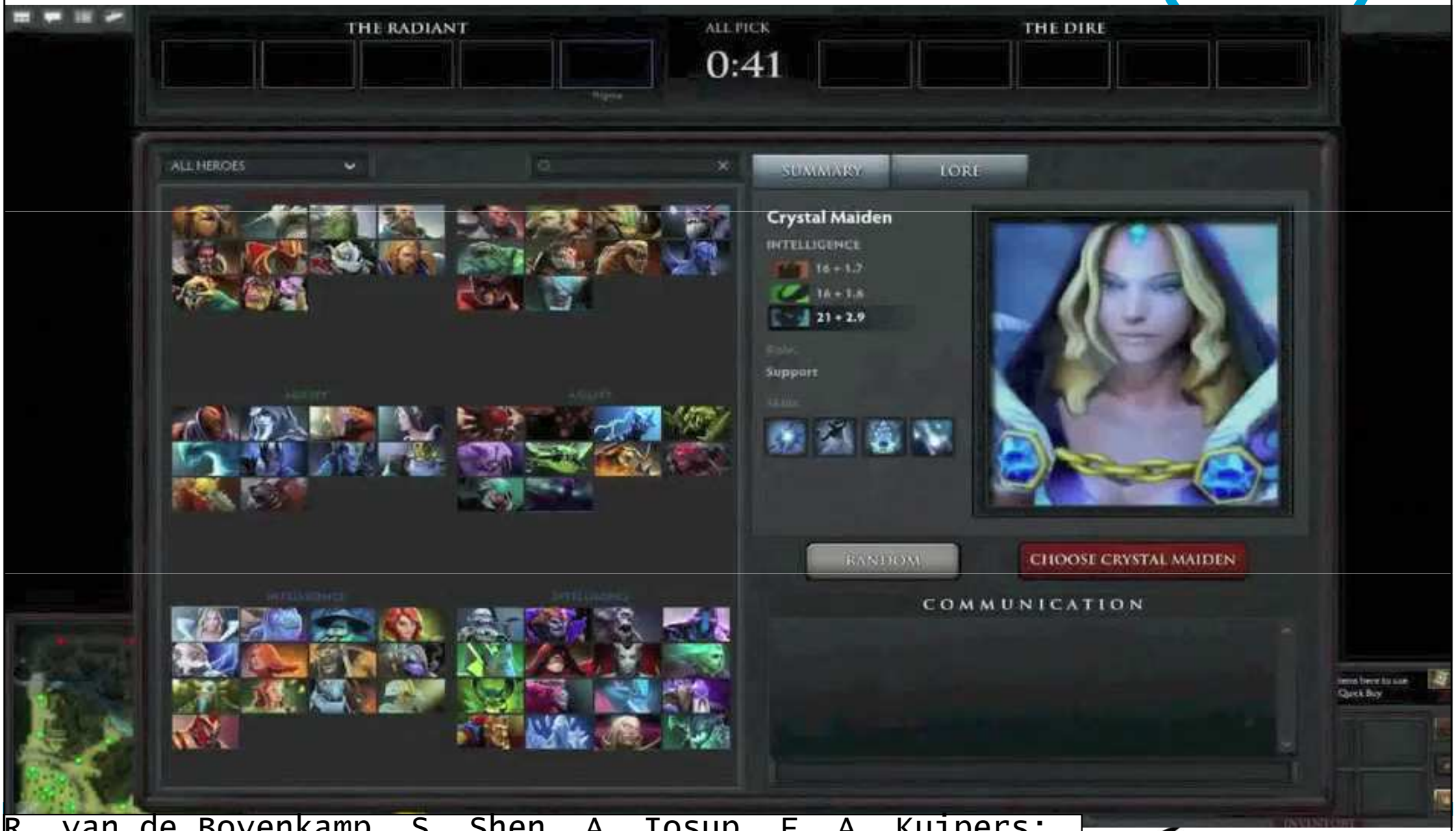
A Use-Case in Gaming Analytics, based on Defence of the Ancients (DotA)



R. van de Bovenkamp, S. Shen, A. Iosup, F. A. Kuipers: Understanding and recommending play relationships in online social gaming. COMSNETS 2013: 1-10

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DotA communities

- Players are loosely organised in communities
  - Operate game servers
  - Maintain lists of tournaments and results
  - Publish statistics and rankings on websites

- Dota-League: players join a queue and matchmaking forms teams
- DotAlicious: players can choose which match/team to join

R. van de Bovenkamp, S. Shen, A. Iosup, F. A. Kuipers: Understanding and recommending play relationships in online social gaming. COMSNETS 2013: 1-10

Our Datasets

- We have crawled all matches played and per match have:
  - Names of the players for each team
  - Active, start and end time
  - Game-play statistics per team
  - The team that has won

- Dota-League:
  - ~1.5M matches played between Nov'08 and Jul'11, 61K players

- DotAlicious:
  - ~0.6M matches played between Apr'10 to Feb'12, 62K players

R. van de Bovenkamp, S. Shen, A. Iosup, F. A. Kuipers: Understanding and recommending play relationships in online social gaming. COMSNETS 2013: 1-10

From game instances to social ties

- We need to define how to map the relationships found in real-world matches to a **gaming graph** (nodes and links)

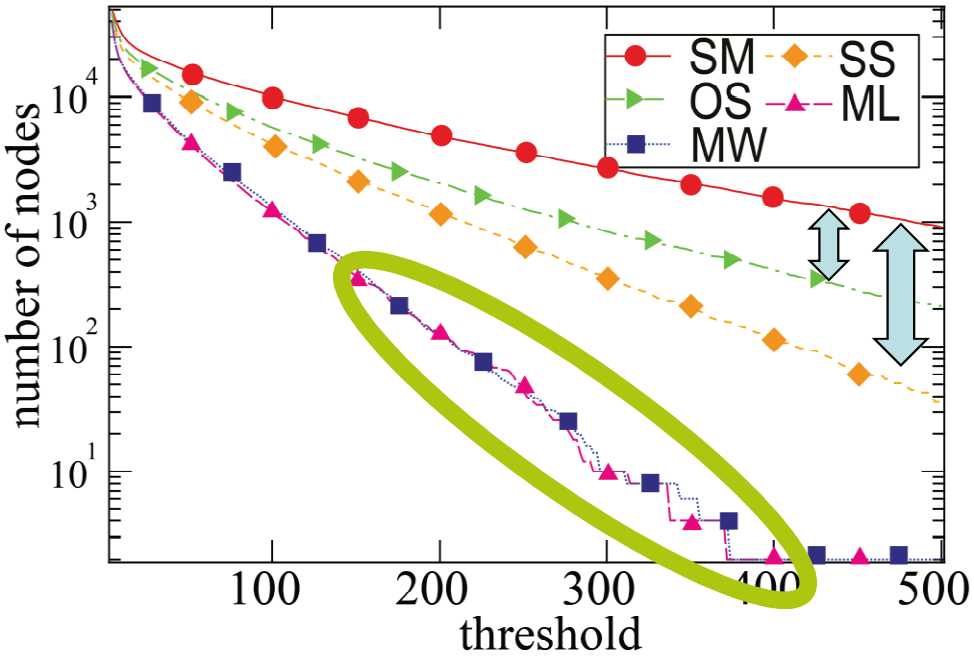
- We use six different mappings and various thresholds:
  - **SM:** two players occur more than *n* times in the **same match**
  - **SS:** two players occur more than *n* times on the **same side**
  - **OS:** two players occur more than *n* times on **opposing sides**
  - **ML:** two players have **lost** more than *n* **matches together**
  - **MW:** two players have **won** more than *n* **matches together**

  - **PP:** a directed version of the mappings above. A link exists if a player has played more than n percent of his matches together

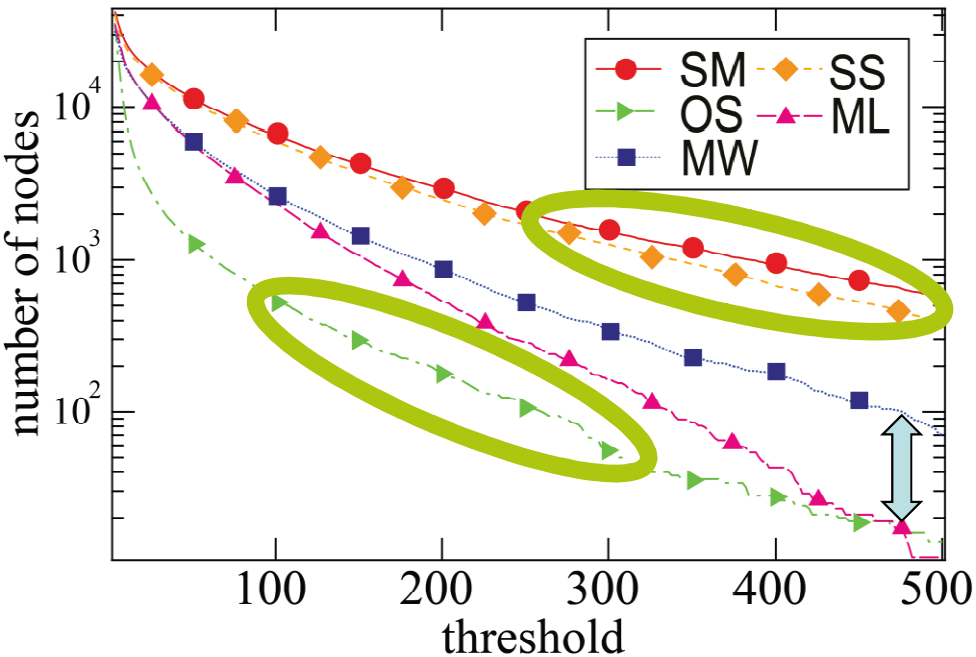
R. van de Bovenkamp, S. Shen, A. Iosup, F. A. Kuipers: Understanding and recommending play relationships in online social gaming. COMSNETS 2013: 1-10

Network sizes (w/o isolated nodes) in the Gaming Graph

Dota-League



DotAlicious



Number of nodes in the network as a function of the threshold

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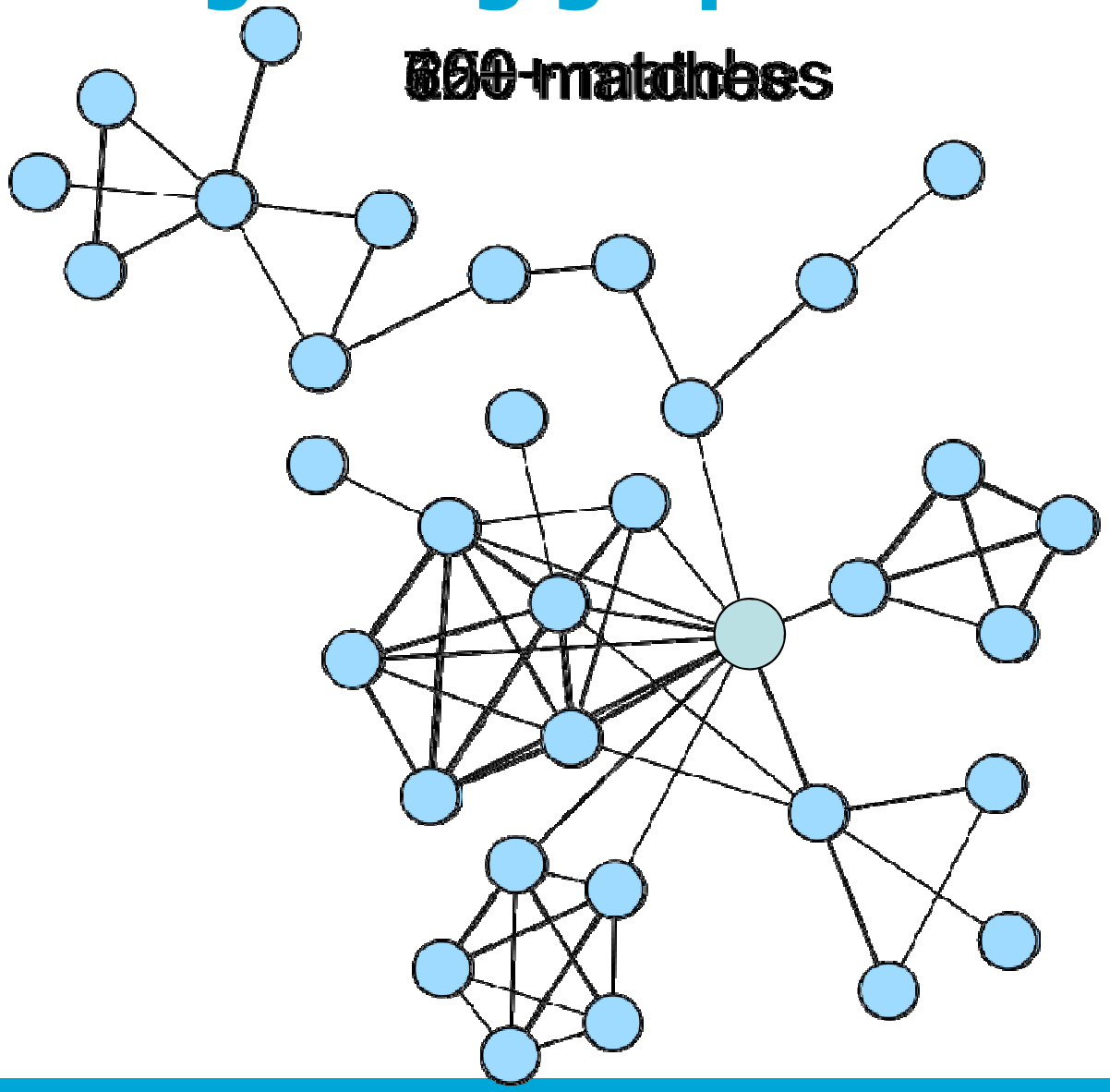
Small clusters show strong ties in the gaming graph



R. van de Bovenkamp, S. Shen, A. Iosup, F. A. Kuipers: Understanding and recommending play relationships in online social gaming. COMSNETS 2013: 1-10

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Relationships in the gaming graph

- Players who regularly play together in DotAlicious do so in more diverse combinations than in Dota-League
- Contrary to Dota-League, DotAlicious players tend to play on the same side: playing together intensifies the social bond
- Winning together increases friendship relationships, while loosing together weakens friendship relationships
- Small clusters of friends with very strong social ties exist

R. van de Bovenkamp, S. Shen, A. Iosup, F. A. Kuipers: Understanding and recommending play relationships in online social gaming. COMSNETS 2013: 1-10

Matchmaking application

- Replay match list, but also consider clusters in gaming graph
- Scoring methodology:
  - Points per cluster: Number of players in the match that are part of the same cluster
  - Excluding largest cluster of the network and clusters of size 1

Player	Cluster
a	1
b	2
c	1
d	3
e	4

Team 1

Player	Cluster
f	2
g	5
h	3
i	6
j	3

Team 2

Cluster	Points
1	2
2	2
3	3
4	0
5	0

Total of 7 points for this match

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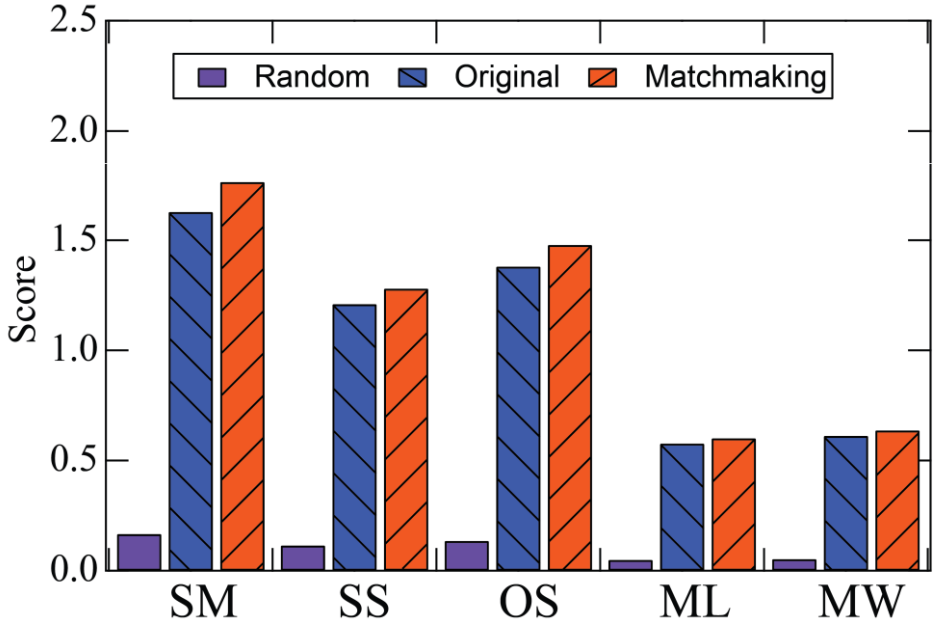
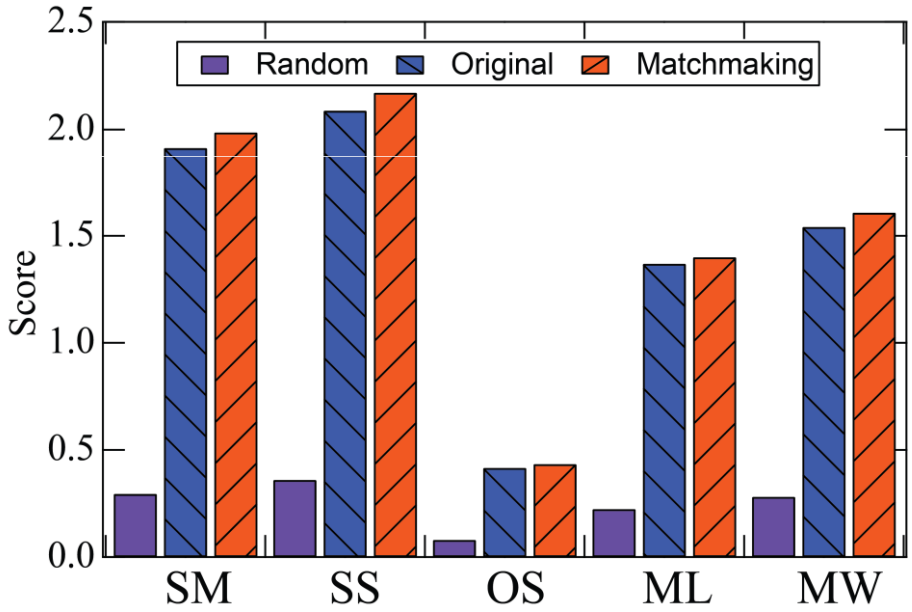
Results matchmaking

Dota-League



DotAlicious



Can do much better than random matchmaking

Can already improve original matchmaking algorithm for all gaming graphs!

R. van de Bovenkamp, S. Shen, A. Iosup, F. A. Kuipers: Understanding and recommending play relationships in online social gaming. COMSNETS 2013: 1-10

Agenda

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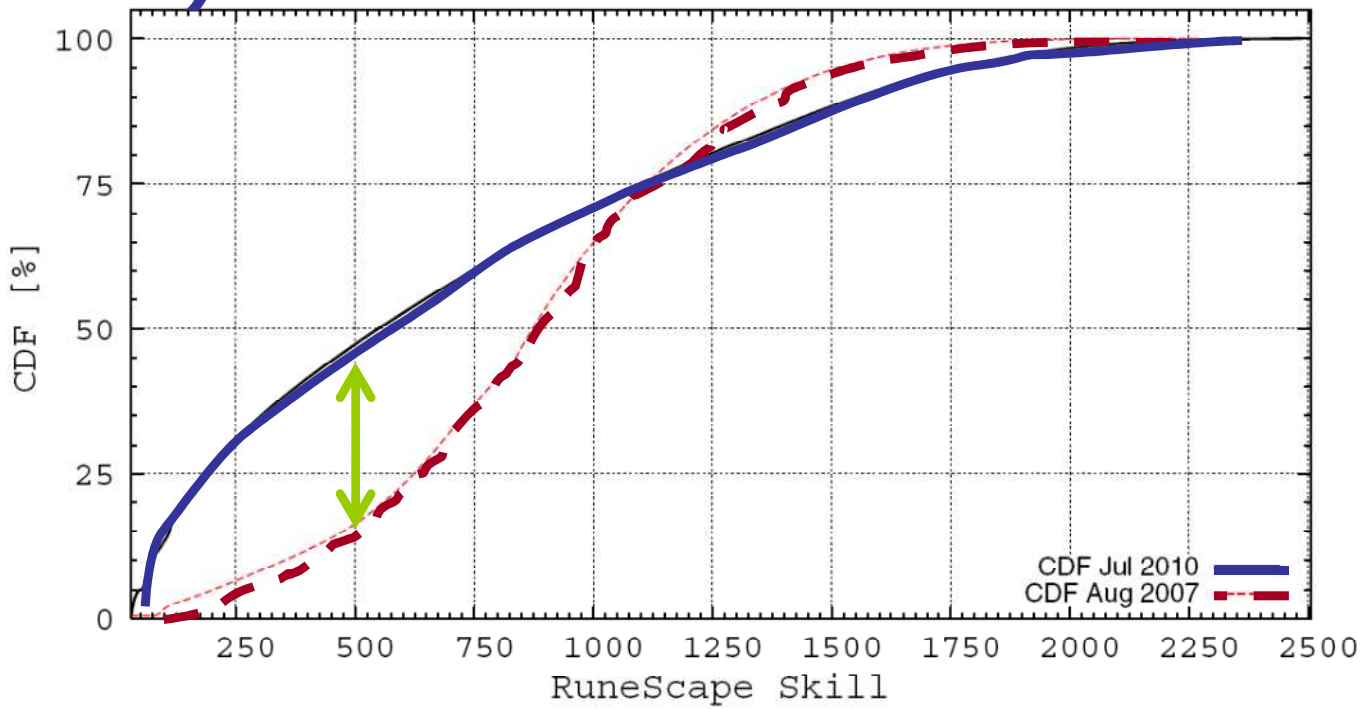
   1. Platform Scalability Challenge
   2. Gaming Analytics Challenge
   3. **Content Generation Challenge**
3. The Next Five Years
4. Conclusion

@large: Sample Analytics Results
Skill Level Distribution in RuneScape

- Runescape: 135M active accounts, 7M active (2008)
- High-scoring players: 1.8M (2007) / 3.5M (2010)
- **(largest MMOG msmt.)**

- **Player skill: distribution changes over time**

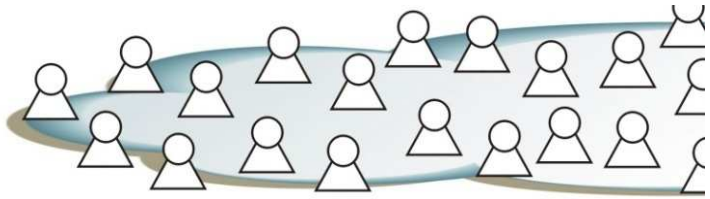


A. Iosup, A. Lascateu, N. Tapus, CAMEO: Enabling Social Networks for Massively Multiplayer Online Games through Continuous Analytics and Cloud Computing, ACM NetGames 2010.

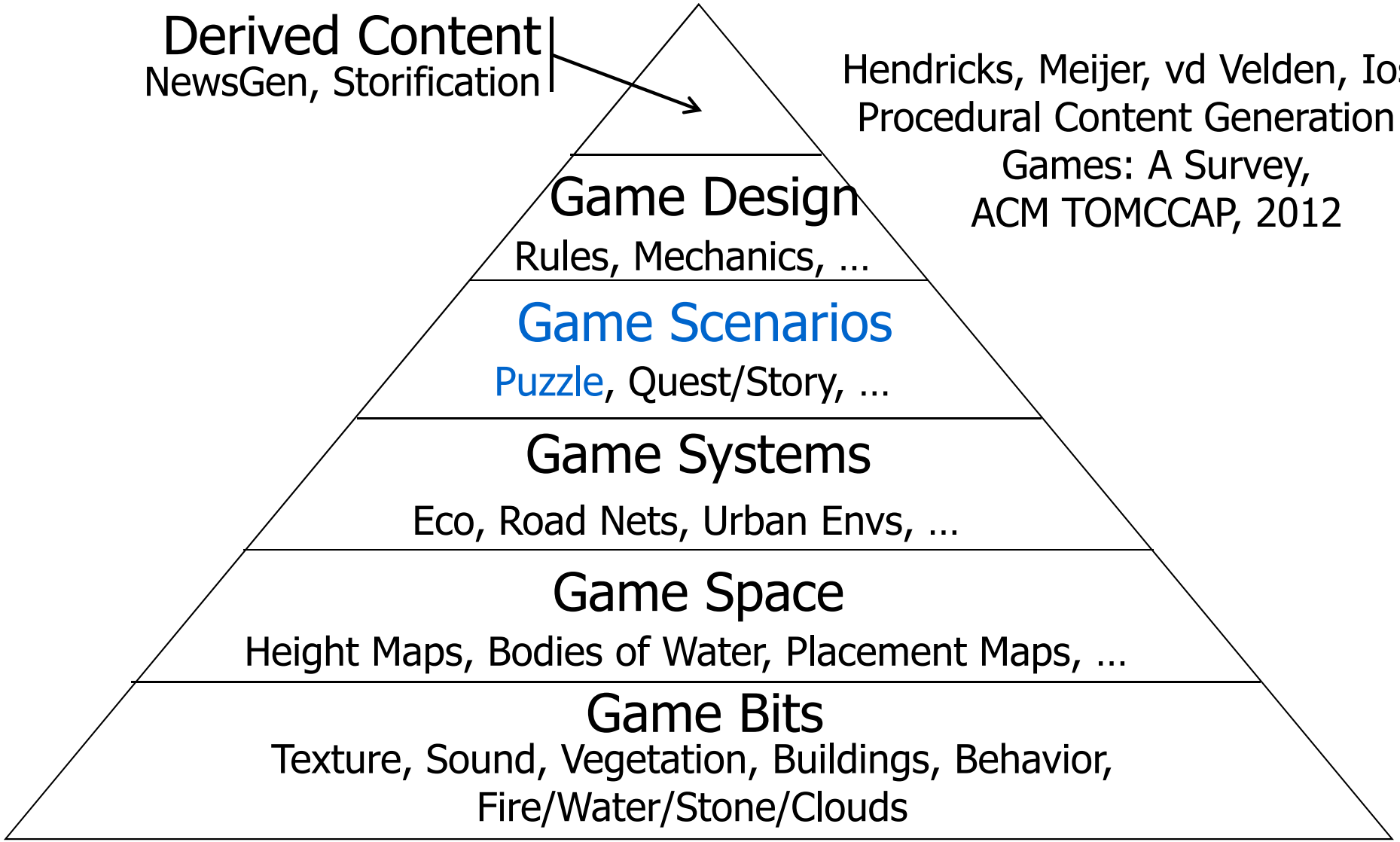
@large Research Challenge: Content Generation for MMOGs

Generating content on time for millions of players

- Player-customized: Balanced, Diverse, Fresh
- Up-front and operational costs
- Response time, Scalability, & Cost



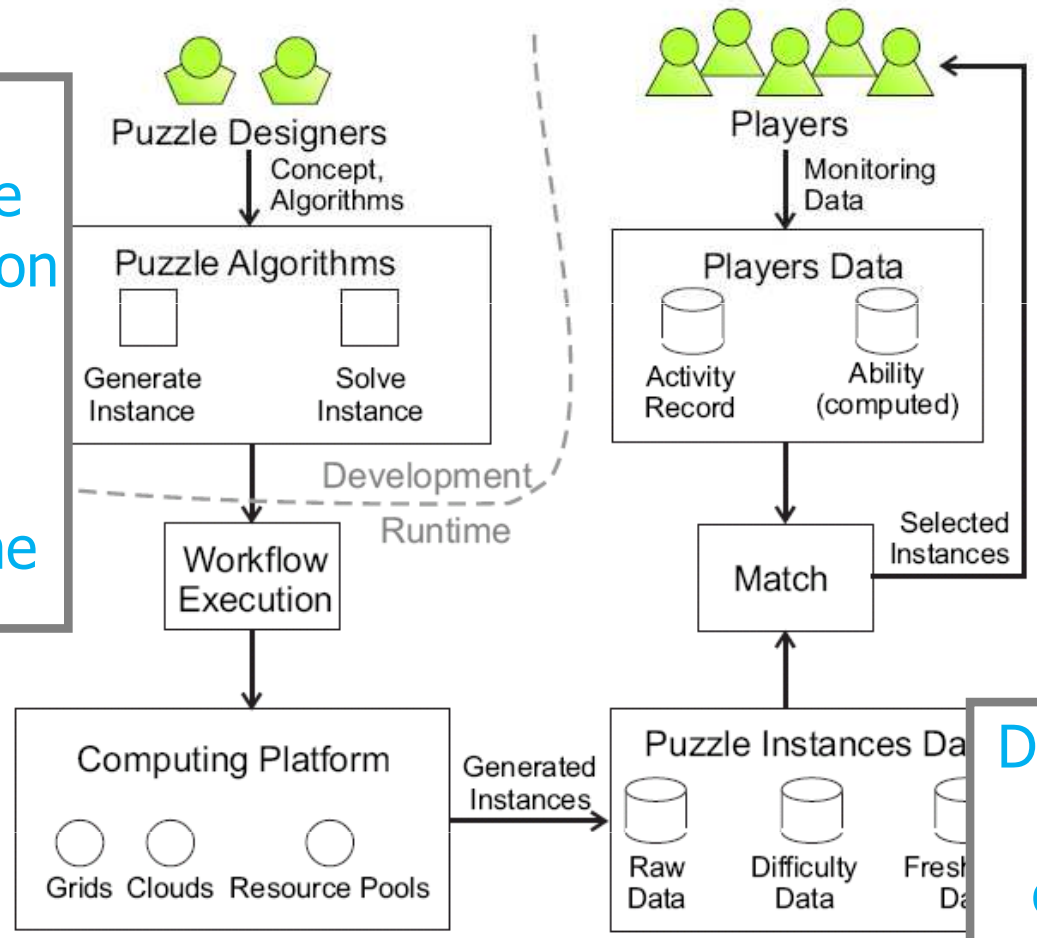
(Procedural) Game Content (Generation)



Hendricks, Meijer, vd Velden, Iosup, Procedural Content Generation for Games: A Survey, ACM TOMCCAP, 2012

The POGGI Content Generation Framework

Only the puzzle concept, and the instance generation and solving algorithms, are produced at development time



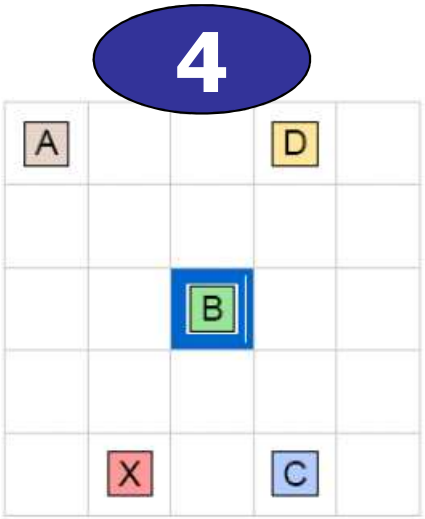
Distributed system to generate instances on-demand, reliably, efficiently, and with performance guarantees

* A. Iosup, POGGI: Puzzle-Based Online Games on Grid Infrastructures, EuroPar 2009 (Best Paper Award)

Puzzle-Specific Considerations Generating Player-Customized Content

Puzzle difficulty

- Solution size
- Solution alternatives
- Variation of moves
- Skill moves



X:Right A:Right B:Up X:Up
(Best solution: 4 moves)

B:Up X:Up B:Left C:Down C:Left
B:Down B:Right B:Down E:Right E:Down
E:Right B:Up A:Up B:Left C:Down
C:Right E:Down X:Left E:Left X:Down
X:Left
(Best solution: 21 moves)

Player ability

- Keep population statistics and generate enough content for most likely cases
- Match player ability with puzzle difficulty
- Take into account puzzle freshness

Agenda

1. What's in a Name?
2. Three Current Challenges
3. **The Next Five Years**
    1. **Cloudification**
    2. Mobile Social Gaming
    3. Social Everything!
    4. Content, Content, Content
4. Conclusion

Cloudification: PaaS for MSGs

(Platform Challenge)

Build MSG platform that uses (mostly) cloud resources

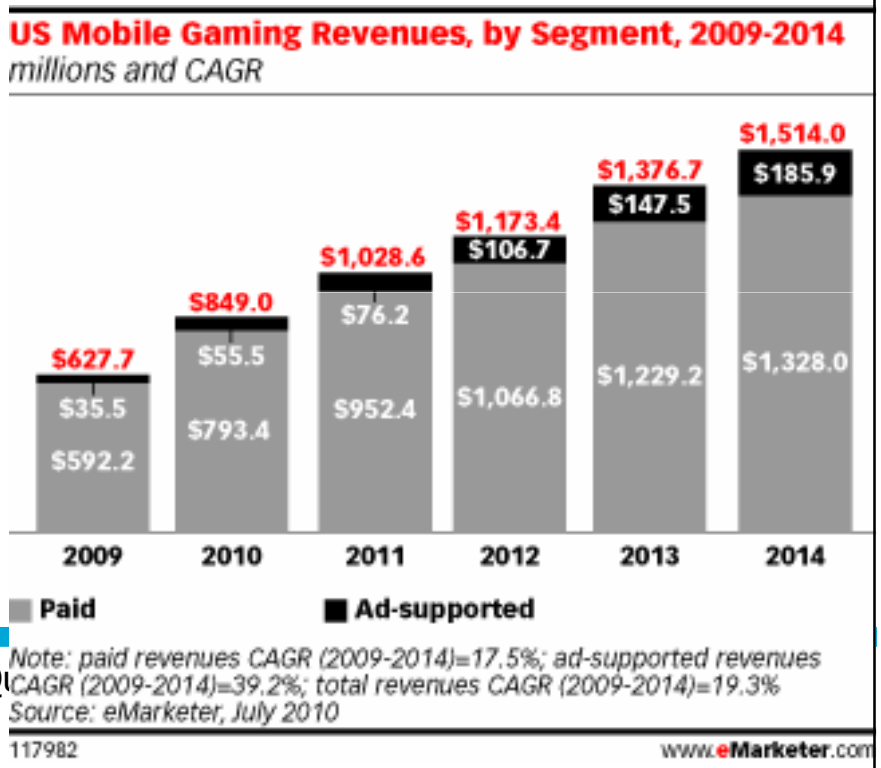
- Close to players
- No upfront costs, no maintenance
- Compute platforms: multi-cores, GPUs, clusters, all-in-one!
- Performance guarantees
- Hybrid deployment model
- Code for various compute platforms—platform profiling
- Load prediction miscalculation costs real money
- What are the services?
- Vendor lock-in?
- *My* data

Mobile Social Gaming and the SuperServer

(Platform Challenge)

Support MSGs on mobile devices

- Mobiles everywhere (2bn+ users)
- Gaming industry for mobiles is new Growing Market
- SuperServer to generate content for low-capability devices?
- Battery for 3D/Networked games?
- Where is my server? (Ad-hoc mobile gaming networks?)
- Security, cheat-prevention



Social Everything!

- **Social Network**=undirected graph, **relationship**=edge
- **Community**=sub-graph, density of edges between its nodes higher than density of edges outside sub-graph

(Analytics Challenge)

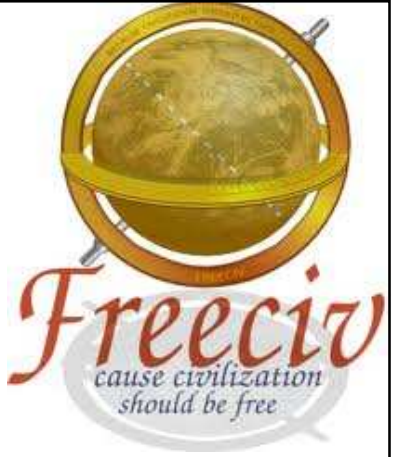
Improve gaming experience

- Ranking / Rating
- Matchmaking / Recommendations
- Play Style/Tutoring

Self-Organizing Gaming Communities

- Player Behavior

Content, Content, Content



(Content Challenge)

Produce and distribute content for 1BN people

- Game Analytics → Game statistic
- Crowdsourcing
- Storification
- Auto-generated game content
- Adaptive game content
- Content distribution/ Streaming content

Summary

Massivizing Online Gaming

- Million-user, multi-bn market
- V-World, Content, Analytics

Current Technology

- Upfront payment
- Cost and scalability problems
- Makes players unhappy

Publications Gaming and Clouds
- 2008: ACM SC
- 2009: ROIA, CCGrid, NetGames, EuroPar (Best Paper Award), …
- 2010: IEEE TPDS, Elsevier CCPE
- 2011: Book Chapter CAMEO, IEEE TPDS, IJAMC
- 2012: IPDPS, CCGrid, …

Graduation (Forecast)
- 2012–14: 3PhD, 6Msc, 6BSc

@large: Our Vision

- DC/Cloud has to help
- Economy of scale with clouds

@large: Ongoing Work

- Content: POGGI Framework
- Platform: edutain@grid
- Analytics: CAMEO Framework

@large: The Future

- **Happy players**
- **Happy cloud operators**

Thank you for your attention! Questions? Suggestions? Observations?

More Info:

- http://www.st.ewi.tudelft.nl/~iosup/research.html
- http://www.st.ewi.tudelft.nl/~iosup/research_gaming.html
- http://www.st.ewi.tudelft.nl/~iosup/research_cloud.html

Alexandru Iosup

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Parallel and Distributed Systems Group
Delft University of Technology

Platform Scalability Challenge

1. Introduction
   1. Online Game Types
   2. Game Models
2. (Scheduling) Hosting Models
   1. Cluster + Parallelization
   2. Multi-cluster + Sharding
   3. Cloud-based + Sharding
   4. The SuperServer (video)
3. **(Naming) Locating Servers**
   1. **Central directory**
   2. **Peer-to-Peer**
4. Consistency
   1. (Eventual) Dead-reckoning
   2. (Continuous) Simultaneous Sim
   3. (Continuous) + Pipelining
   4. (Continuous) + Dynamic Tick
   5. (Continuous/Eventual) Area of Simulation vs Interest
5. Other issues

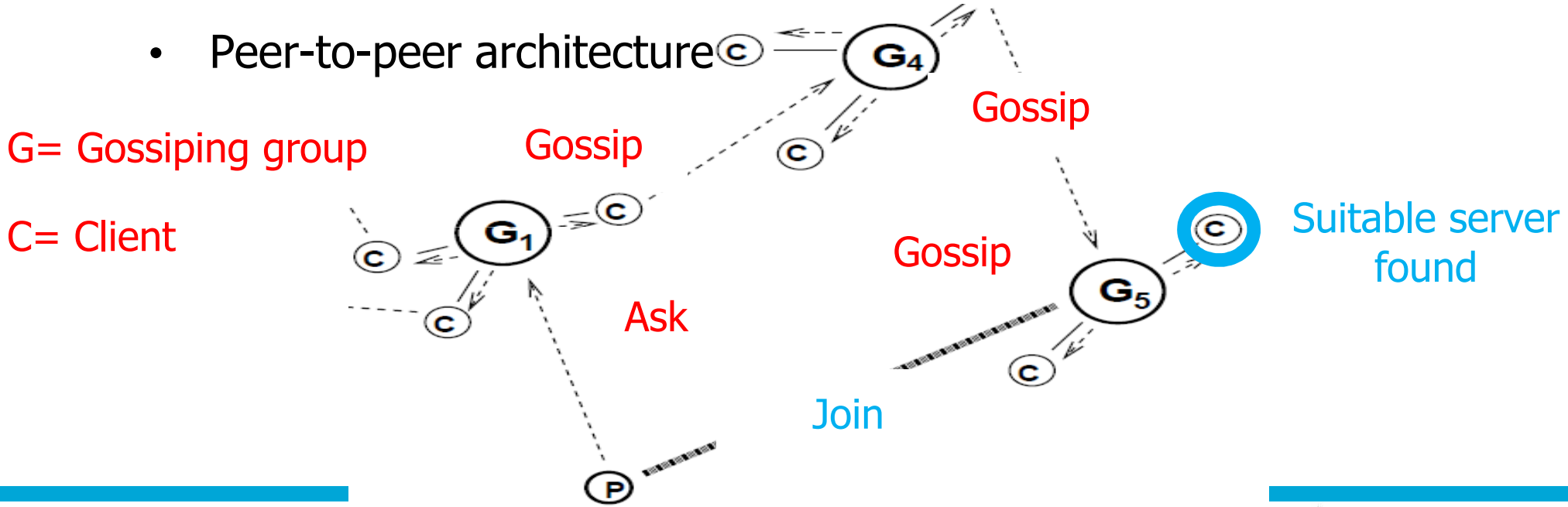
Other Distributed Systems Issues

Naming (Locating Servers)

- Master directory
  - Web page with hundreds of servers (Minecraft)
  - TCP/IP-based protocol to get information from master server
-

	Min	*Max*	*Mean*	*Median*
Number of advertised servers	7984	20930	18891.10	18789
Number of active servers	2458	7588	5659.08	5804
Active servers (as % of advertised)	16.32	72.19	30.21	30.71
Time taken for query (seconds)	310	676	656.45	670

- Peer-to-peer architecture



Tristan Henderson: Observations on game server discovery mechanisms. ACM/IEEE NETGAMES 2002.

Platform Scalability Challenge

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    4. (Continuous) + Dynamic Tick
5. **Other issues**

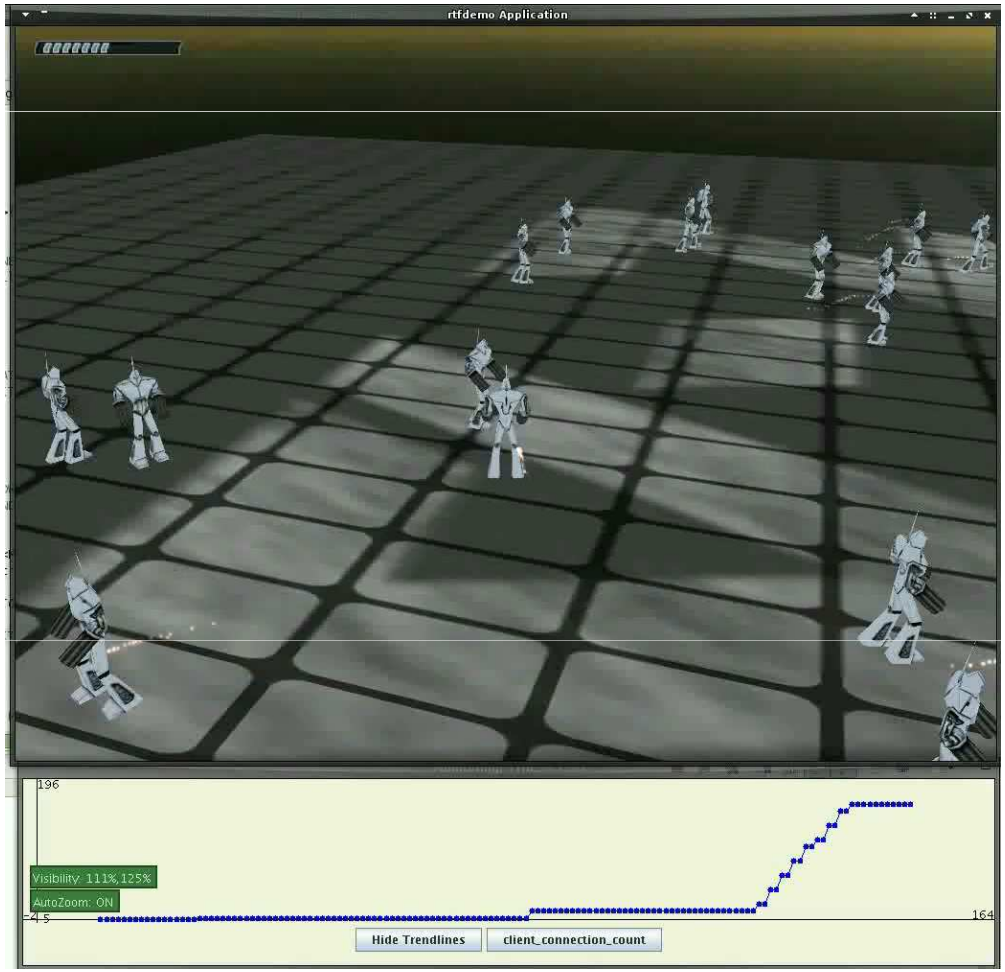
Other Distributed Systems Issues

- Operation of replicated servers: performance guarantees
- Operation with slow user clients/networks
- Persistent worlds
- Content distribution
- The whole CAP spectrum
  - Consistency
  - Availability
  - Partition-tolerance

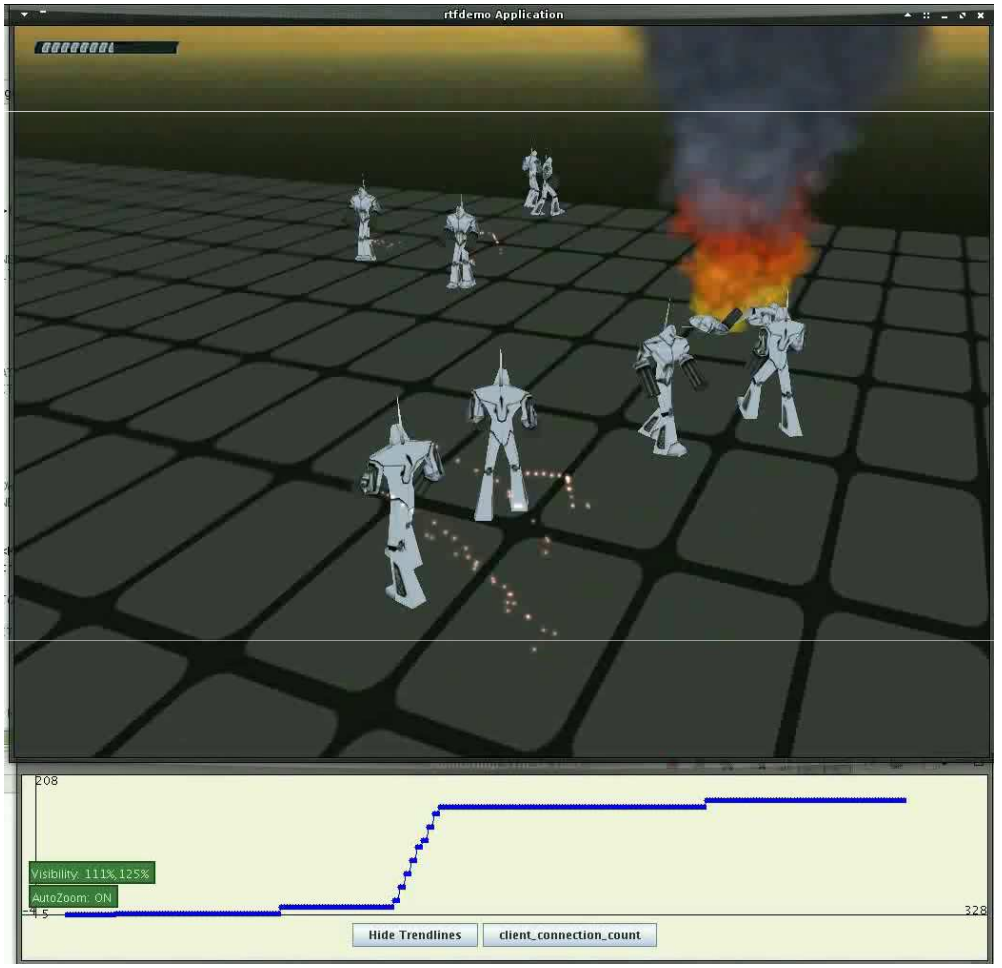
http://www.popscreen.com/v/6wEHS/Minecraft-Epic-Fail-Creeper

Impact on Game Experience

Responsive game



Unresponsive game



[Source: Nae, Iosup, and Prodan, ACM SC 2008 and IEEE TPDS 2011]

Experimental Setup [2/3] Environment

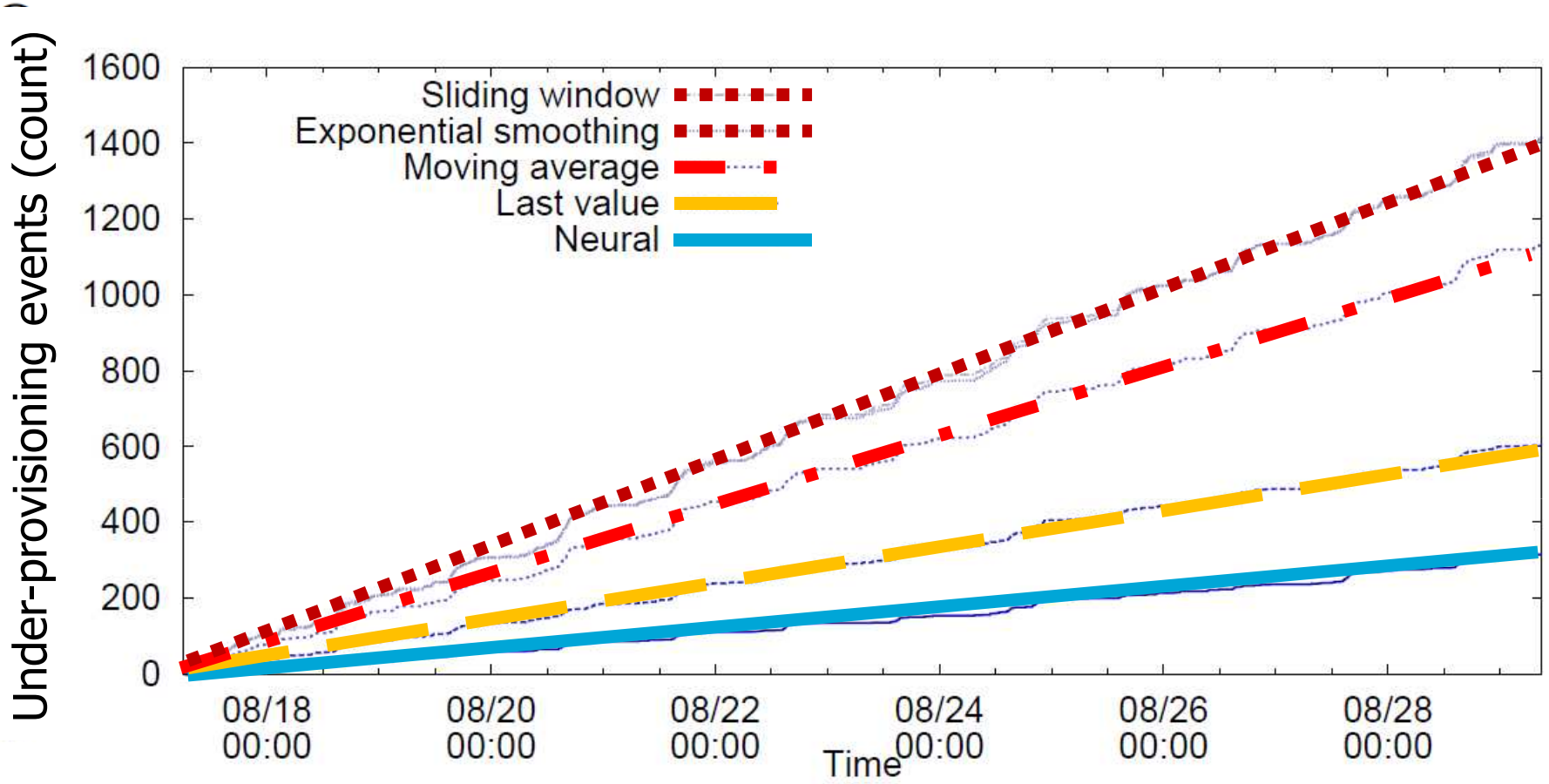
- 1 game operator
- 17 data centers
- 11 data center time-space renting policies

Location		Data Centers	Machines (total)
Continent	Country		
Europe	Finland	2	8 machines
	Sweden	2	8 machines
	U.K.	2	20 machines
	Netherlands	2	15 machines
North America	U.S. (West)	2	35 machines
	Canada (West)	1	15 machines
	U.S. (Central)	1	15 machines
	U.S. (East)	2	32 machines
	Canada (East)	1	10 machines
Australia	Australia	2	8 machines

[Source: Nae, Iosup, and Prodan, ACM SC 2008]

Impact of Load Prediction Accuracy

Q: How does the prediction accuracy impact resource provisioning? A: Good prediction matters.

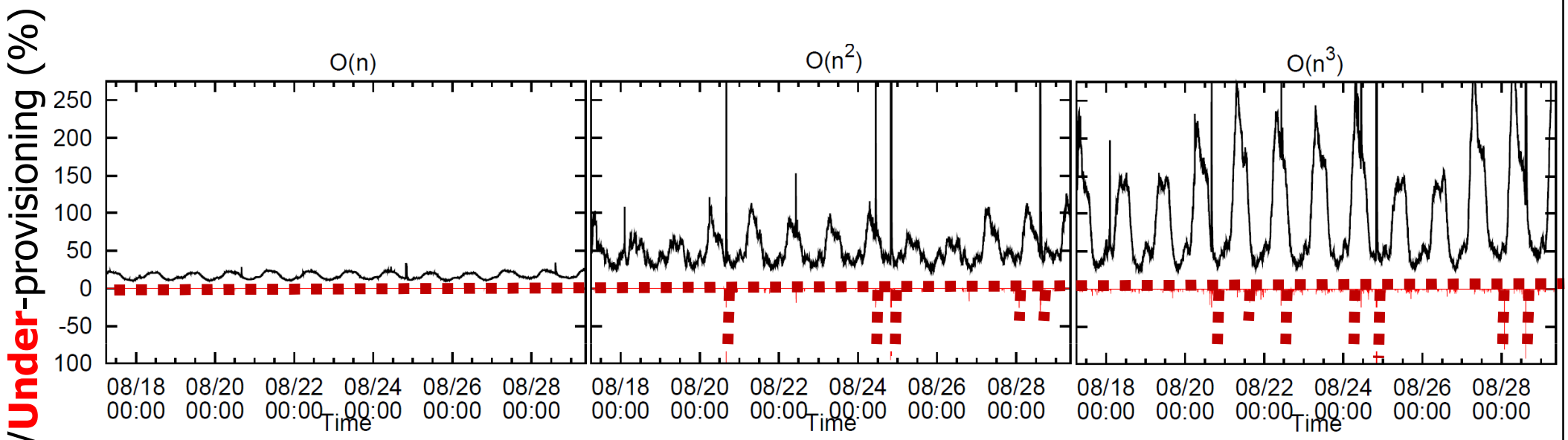


[Source: Nae, Iosup, and Prodan, ACM SC 2008]

Impact of Interaction Compute-Intensiveness

Q: How are different MMOG types handled under dynamic resource provisioning?

(Interaction models Low ~ O(n), Medium, High, Very High ~ O(n^3))

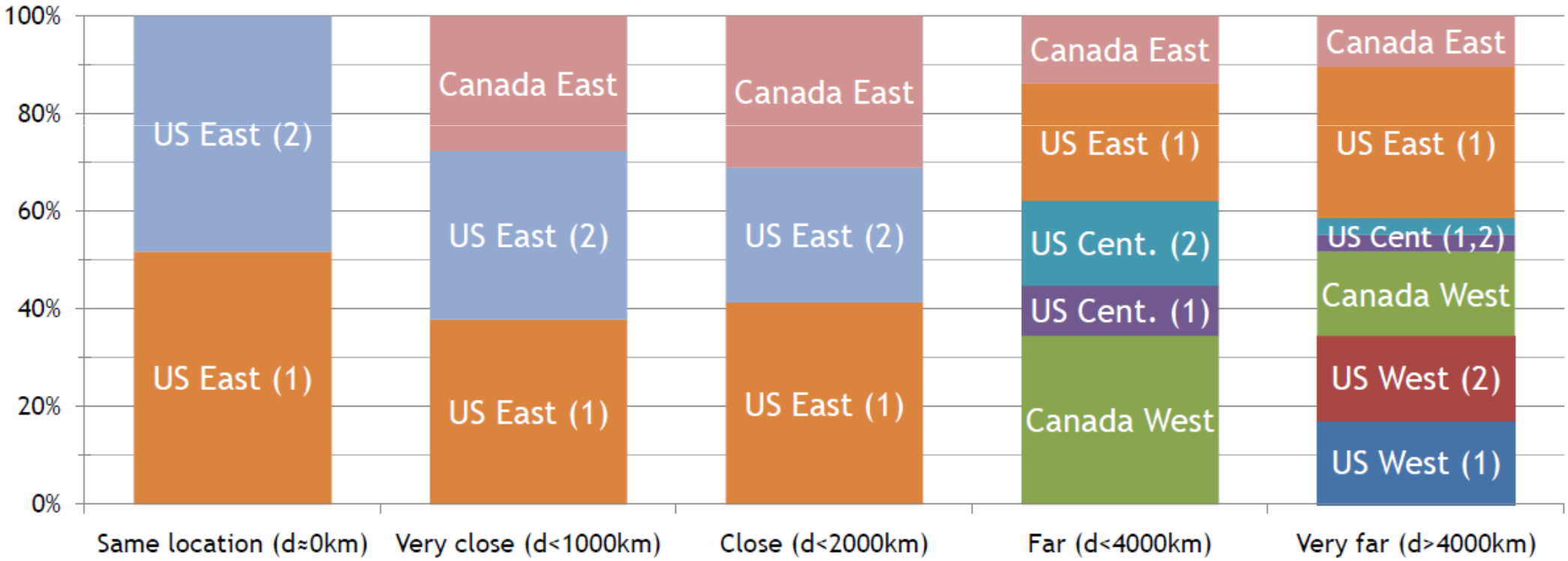


A: Over-provisioning, Under-provisioning worse with increase in interaction compute-intensiveness

[Source: Nae, Iosup, and Prodan, ACM SC 2008]

Latency Tolerance: From None to High

Q: What is the impact of latency tolerance on hosting?



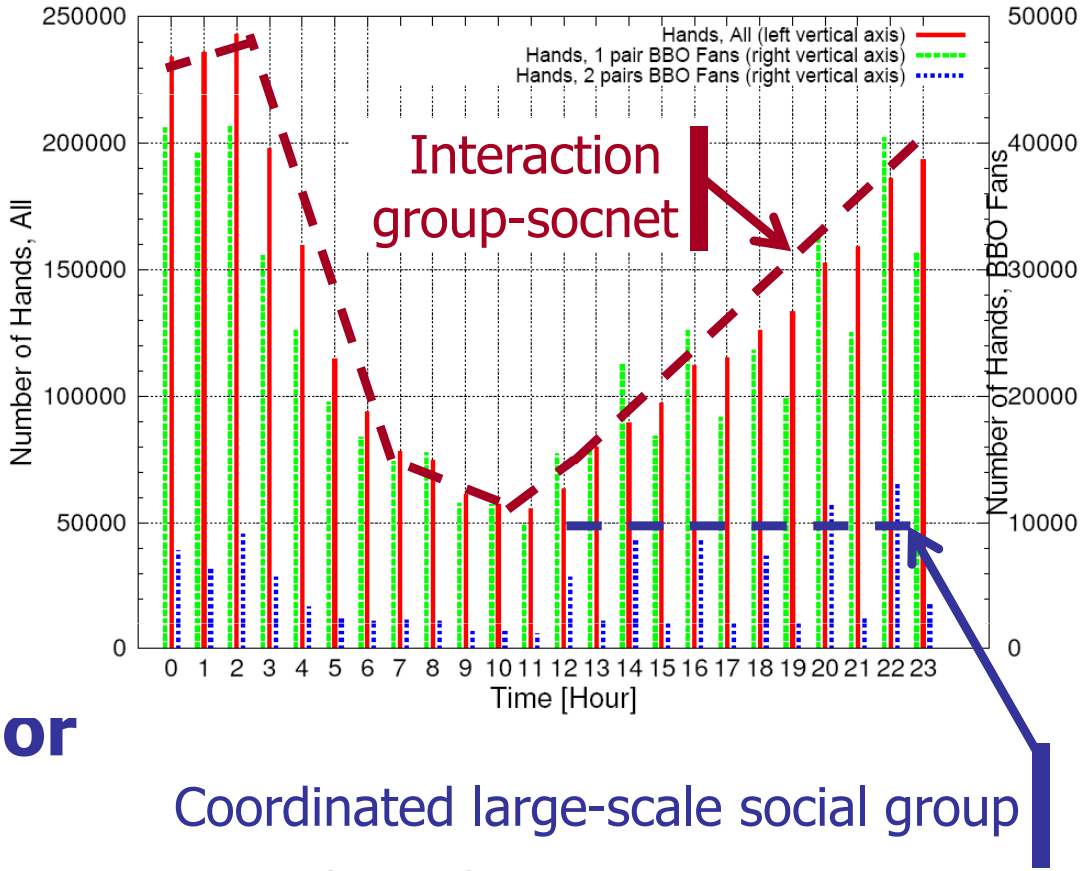
A: (left) very sensitive very costly

(mid) sensitive costly

(right) non-sensitive cheap

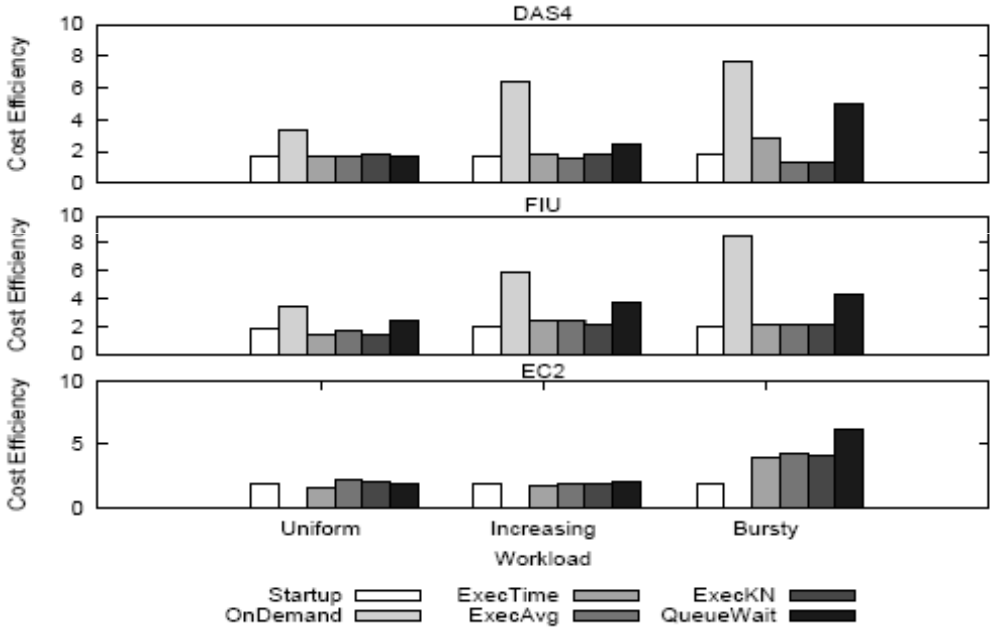
@large: Sample Analytics Results
Activity and Social Network

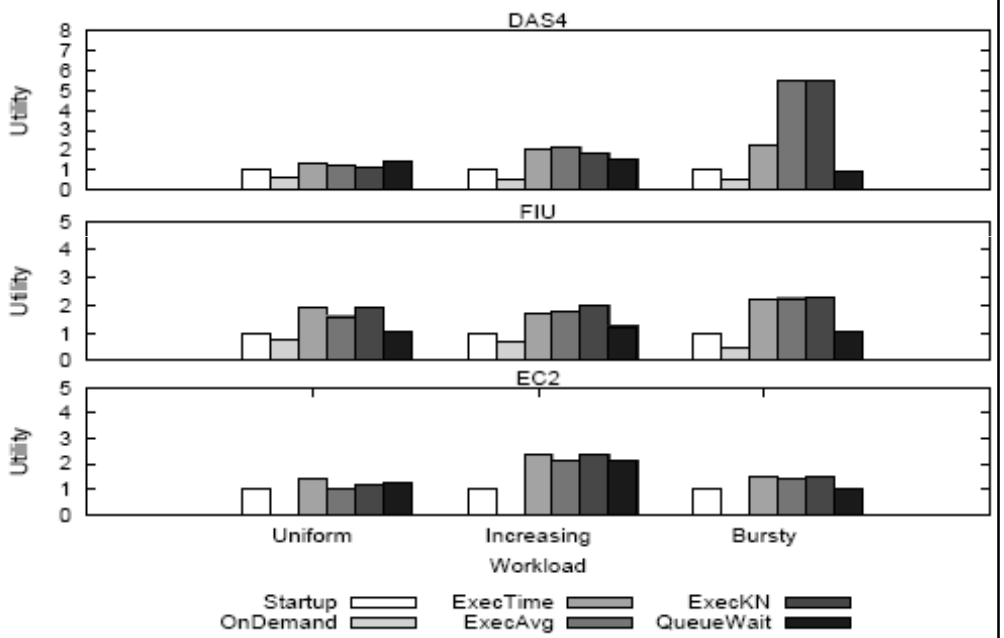
- **Bridge Base Online (BBO)**: 1M+ players, top free site
- Dataset: **100K players**
  - 9K group
  - Social relationships from bridge pairing
- **Large (~10K) online social groups can coordinate**
- **Identified player behavior**
  community builder,
  community member, random player, faithful player



M. Balint, V. Posea, A. Dimitriu, and A. Iosup, An Analysis of Social Gaming Networks in Online and Face to Face Bridge Communities, LSAP 2011.

Resource Provisioning and Allocation
Compound Metrics



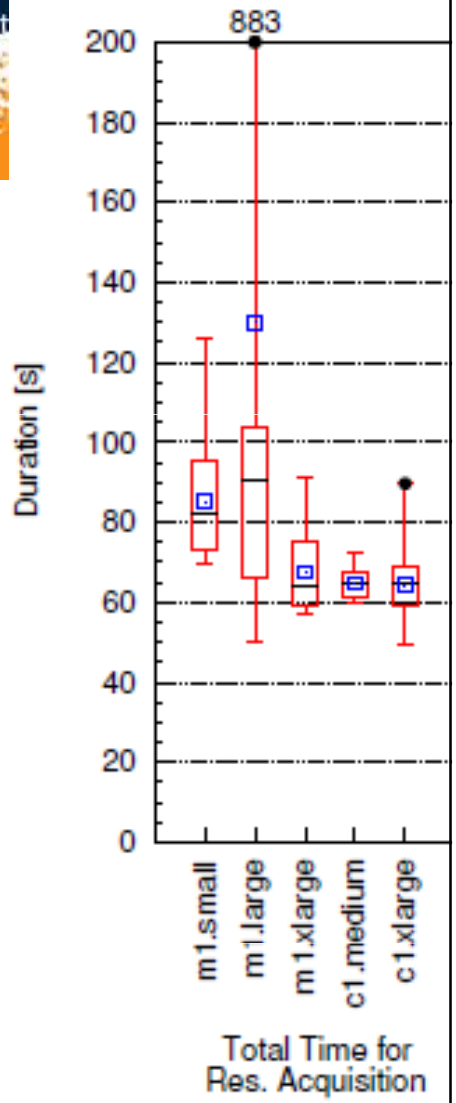


- Trade-off Utility-Cost still needs investigation
- Performance and Cost are not both improved by the policies we have studied

Villegas, Antoniou, Sadjadi, Iosup. An Analysis of Provisioning and Allocation Policies for Infrastructure-as-a-Service Clouds, CCGrid, 2012.

(Variable) Blackbox Performance Engineering

- **Performance Evaluation of Four Commercial Clouds**
  - Amazon EC2, GoGrid, Elastic Hosts, Mosso
  - Resource acquisition
  - Single- and Multi-Instance benchmarking
- **Low compute and networking performance[1]**
- **Performance variability over time[2]**

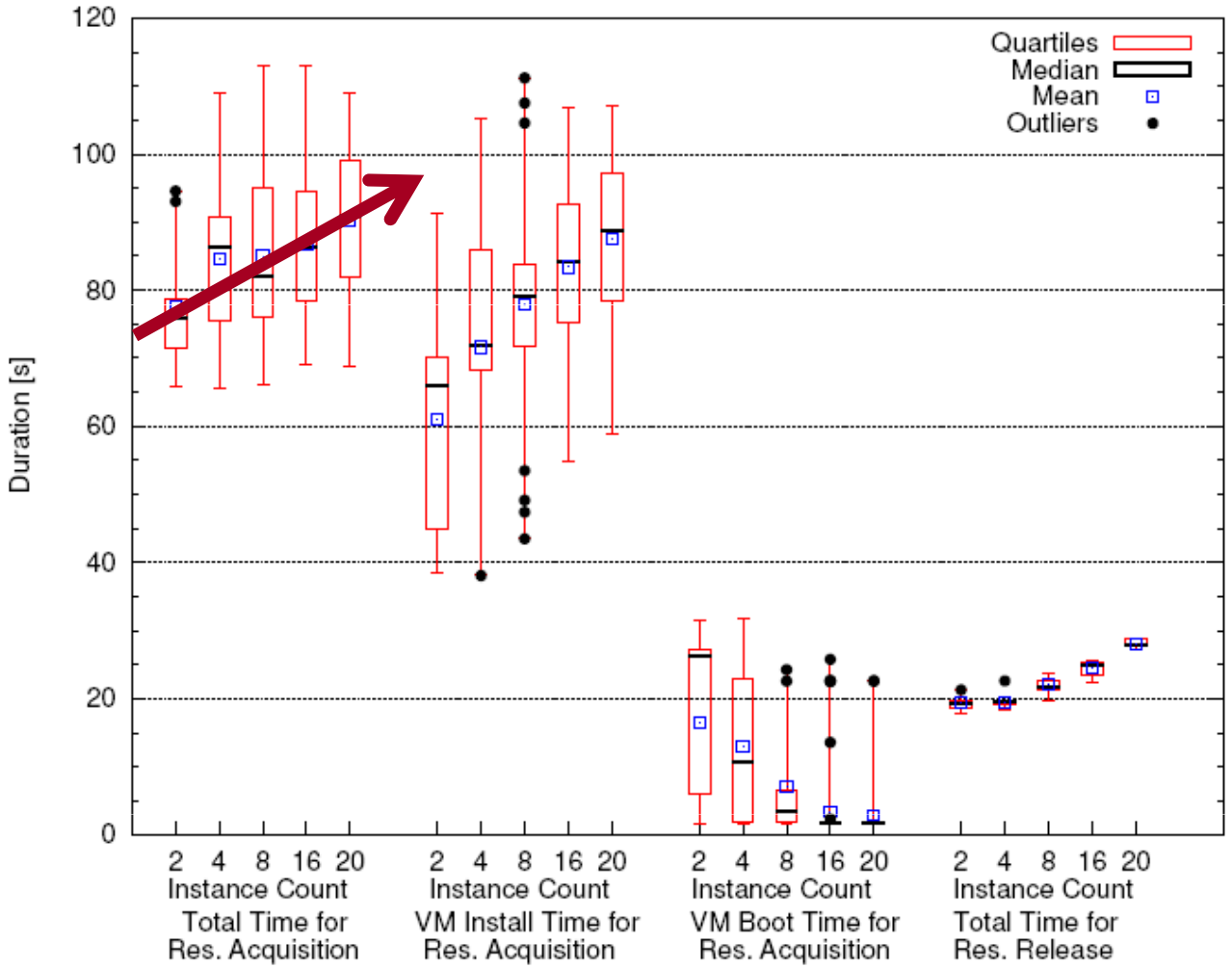


1- Iosup et al., Performance Analysis of Cloud Computing Services for Many Tasks Scientific Computing, IEEE TPDS, 2011, http://www.st.ewi.tudelft.nl/~iosup/cloud-perf10tpds_in-print.pdf

2- Iosup et al., On the Performance Variability of Production Cloud Services, CCGrid 2011, pds.twi.tudelft.nl/reports/2010/PDS-2010-002.pdf

*Multi-*Resource Provisioning/Release

Q1

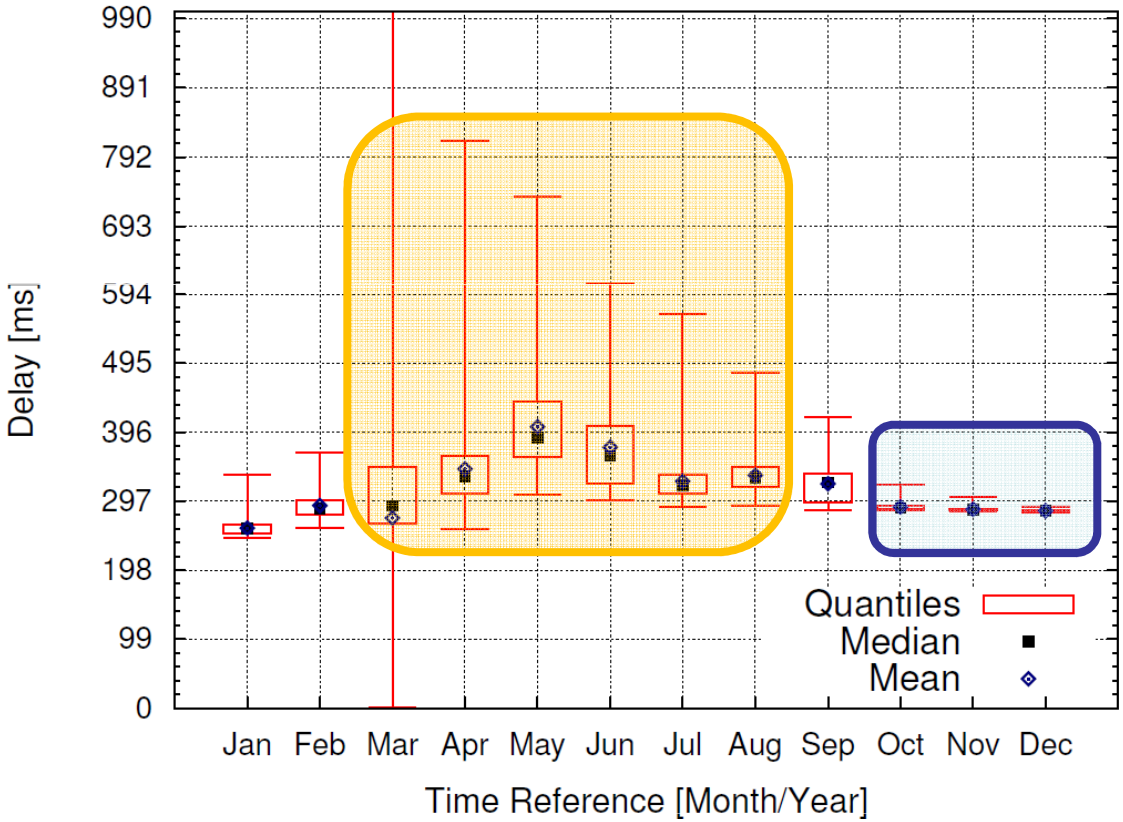


- Time for ***multi-***resource increases with number of resources

Iosup et al., Performance Analysis of Cloud Computing Services for Many Tasks Scientific Computing, (IEEE TPDS 2011).

GAE Dataset: Run Service

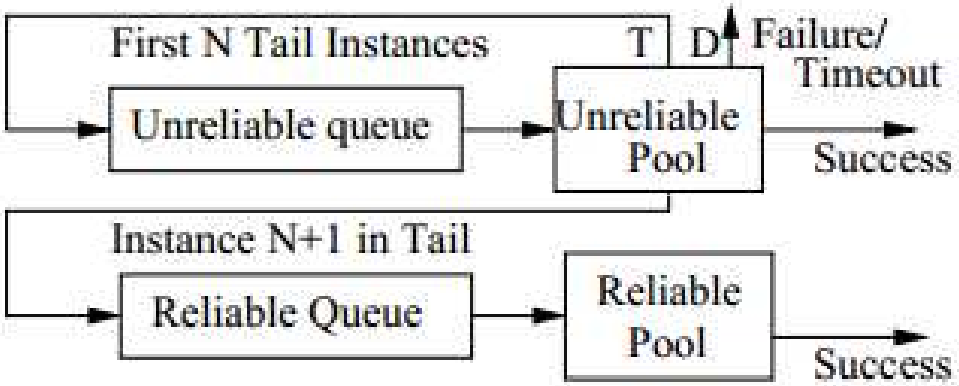
Q2

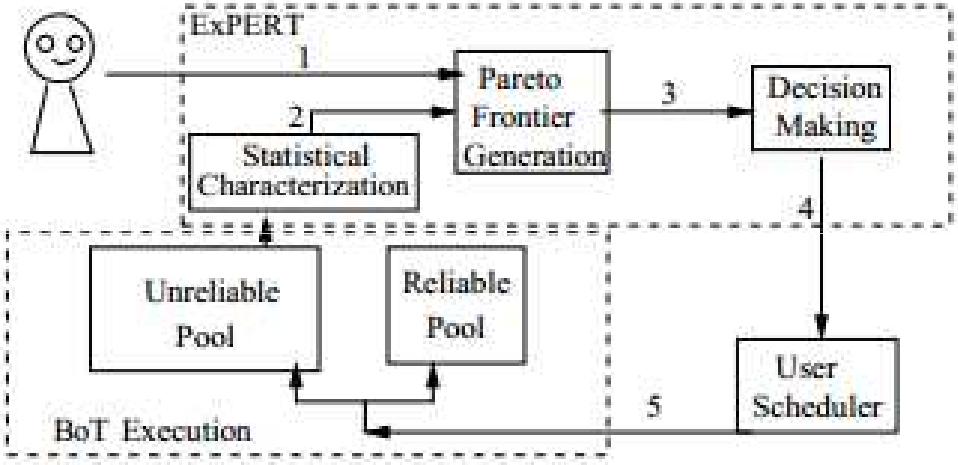


- **Fibonacci [ms]:** Time it takes to calculate the 27th Fibonacci number
- Highly variable performance until September
- Last three months have stable performance (low IQR and range)

Iosup, Yigitbasi, Epema. On the Performance Variability of Production Cloud Services, (IEEE CCgrid 2011).

Online Scheduling + Optimization
ExPERT



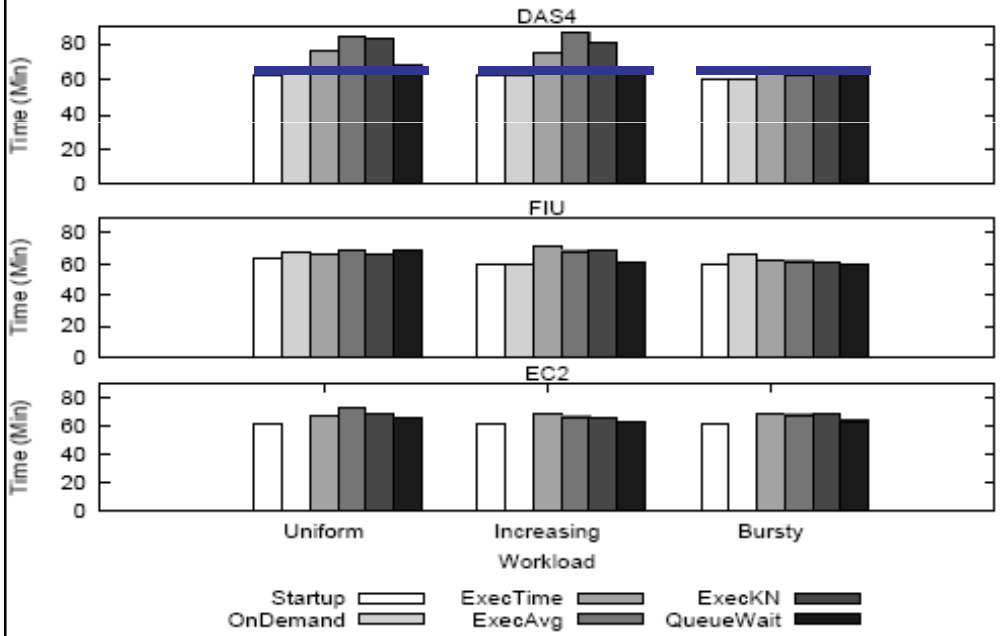


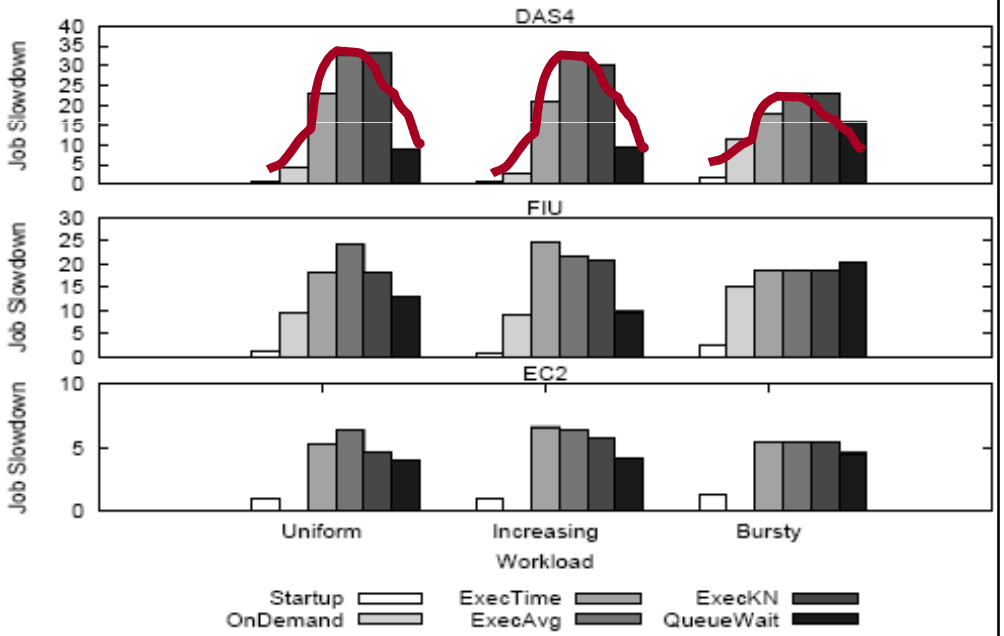
ExPERT recommended≡
$(N = 3, T = T_{ur}, D = 2T_{ur}, M_r = 0.02)$, in words: Send $N = 3$ instances to the unreliable pool during the tail phase, each timed out after twice the average task time ($D = 2T_{ur}$). Send the next instance after the average task time passes ($T = T_{ur}$). Use only one ($\sharp ur = 50$, $50 \times M_r = 1$) reliable machine at a time.

O. Agmon Ben-Yehuda, A. Schuster, A. Sharov, M. Silberstein, and A. Iosup, ExPERT: Pareto-Efficient Task Replication on Grids and a Cloud, IPDPS'12.

Performance Metrics

Q3





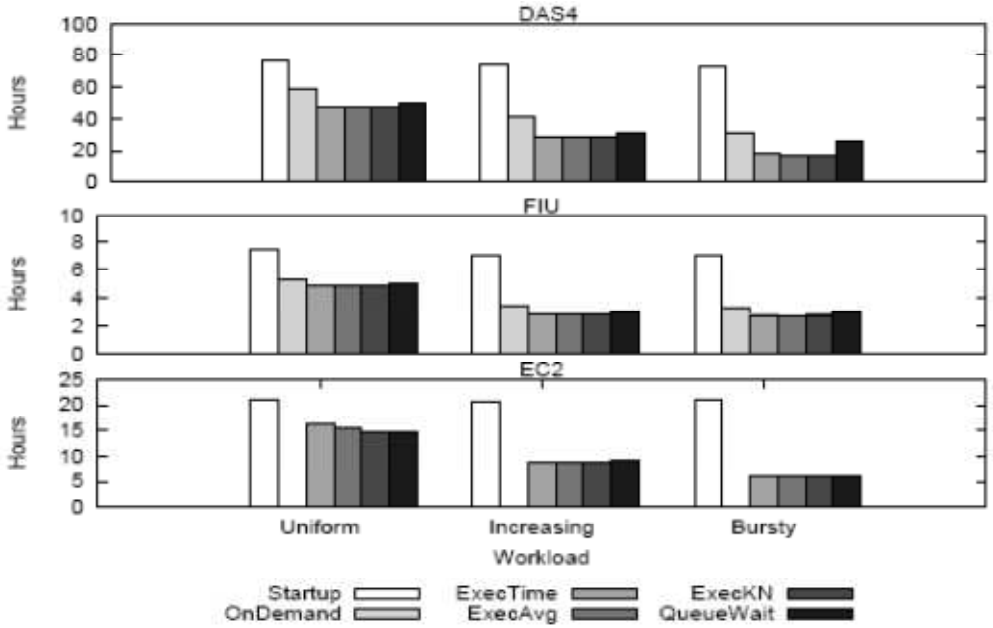
- Makespan very similar
- Very different job slowdown

Villegas, Antoniou, Sadjadi, Iosup. An Analysis of Provisioning and Allocation Policies for Infrastructure-as-a-Service Clouds, (submitted). PDS Tech.Rep.2011-009

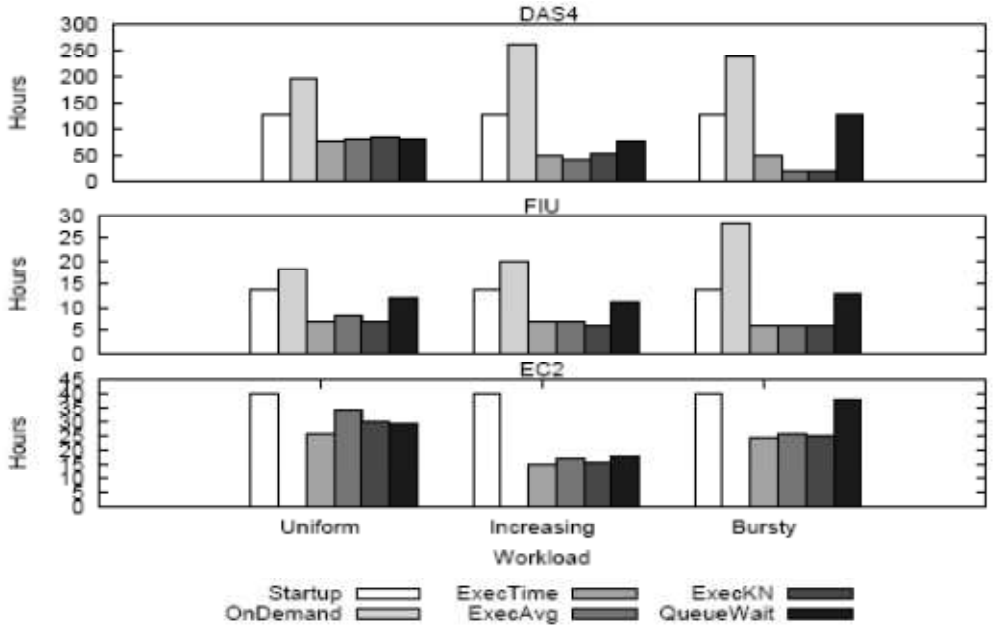
Cost Metrics

Q3

Actual Cost



Charged Cost

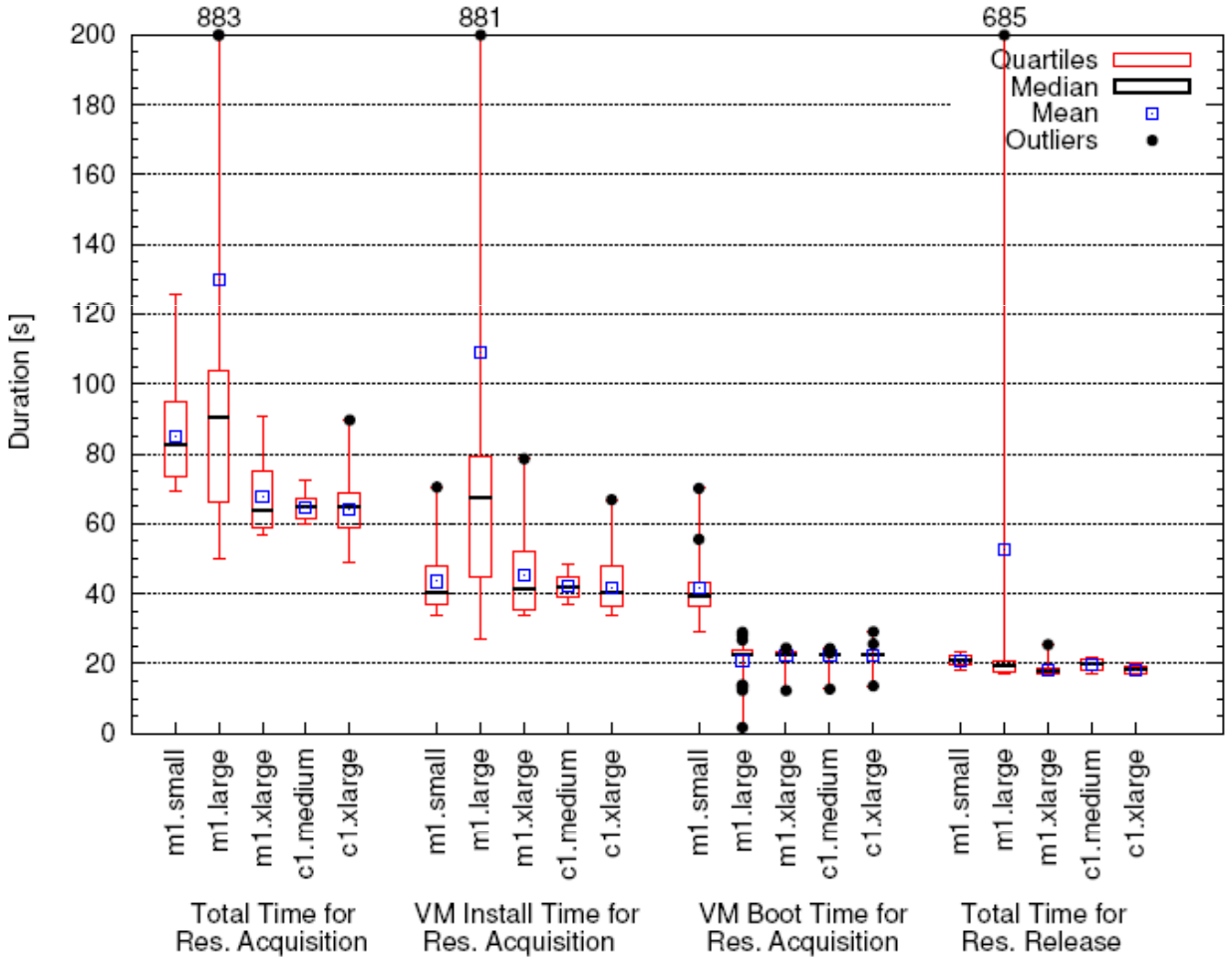


- Very different results between actual and charged
  - Cloud charging function an important selection criterion
- All policies better than Startup in actual cost
- Policies much better/worse than Startup in charged cost

Villegas, Antoniou, Sadjadi, Iosup. An Analysis of Provisioning and Allocation Policies for Infrastructure-as-a-Service Clouds, (submitted). PDS Tech.Rep.2011-009

Single Resource Provisioning/Release

Q1



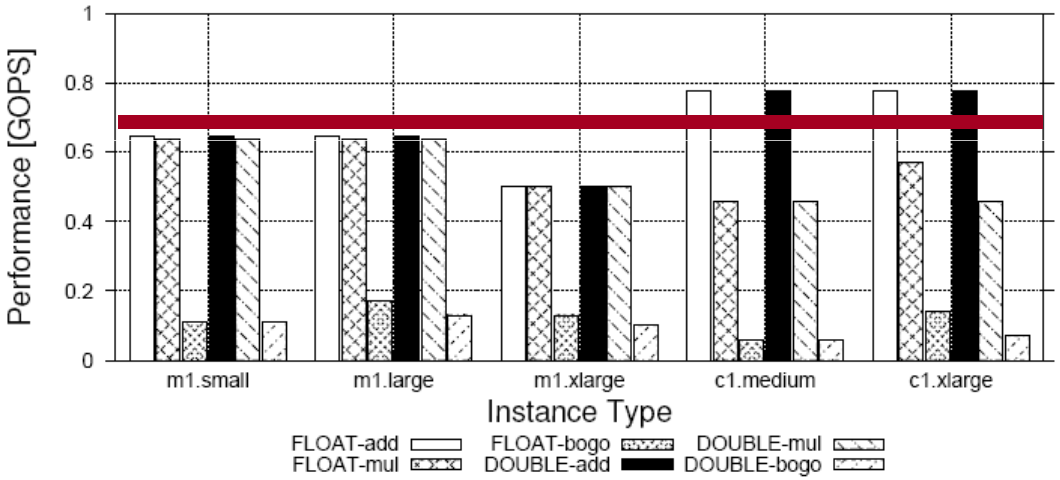
- Time depends on instance type
- Boot time non-negligible

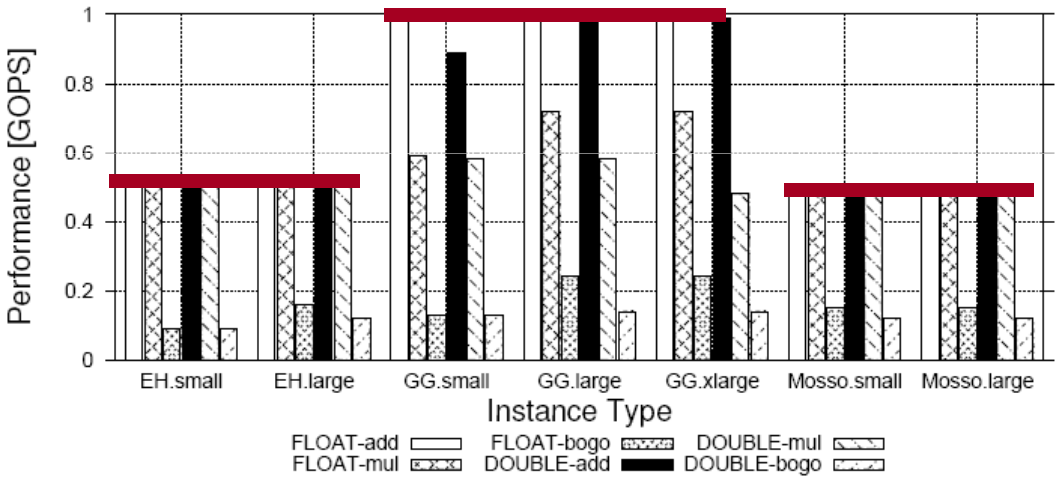
Iosup et al., Performance Analysis of Cloud Computing Services for Many Tasks Scientific Computing, (IEEE TPDS 2011).

CPU Performance of Single Resource

Q1

- ECU definition: "a 1.1 GHz 2007 Opteron" ~ 4 flops per cycle at full pipeline, which means at peak performance one ECU equals 4.4 gigaflops per second (GFLOPS)
- Real performance 0.6..0.1 GFLOPS = ~1/4..1/7 theoretical peak

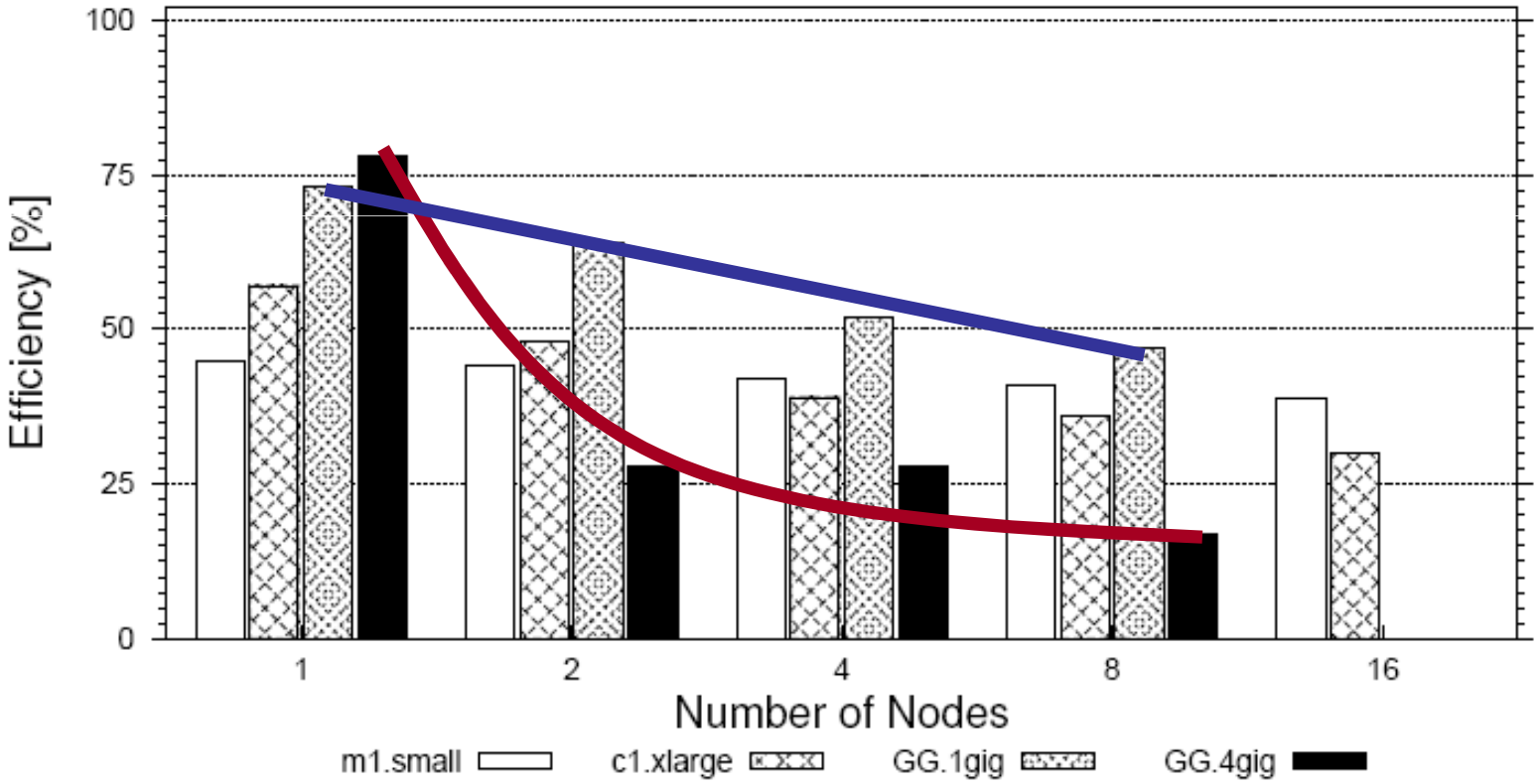




Iosup et al., Performance Analysis of Cloud Computing Services for Many Tasks Scientific Computing, (IEEE TPDS 2011).

HPLinpack Performance (Parallel)

Q1

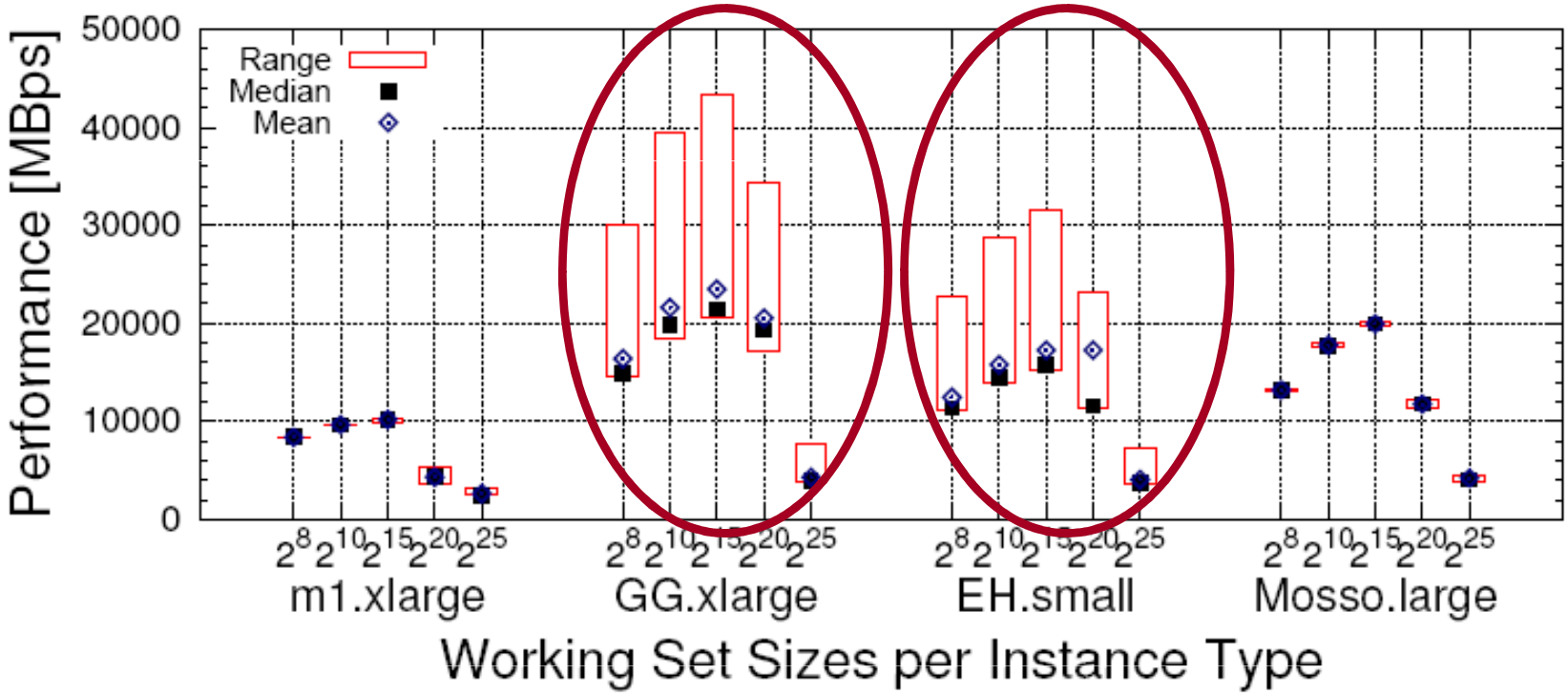


- Low efficiency for parallel compute-intensive applications
- Low performance vs cluster computing and supercomputing

Iosup et al., Performance Analysis of Cloud Computing Services for Many Tasks Scientific Computing, (IEEE TPDS 2011).

Performance Stability (Variability)

Q1



- High performance stability for the best-performing instances

Iosup et al., Performance Analysis of Cloud Computing Services for Many Tasks Scientific Computing, (IEEE TPDS 2011).

AWS Dataset (4/4): Summary

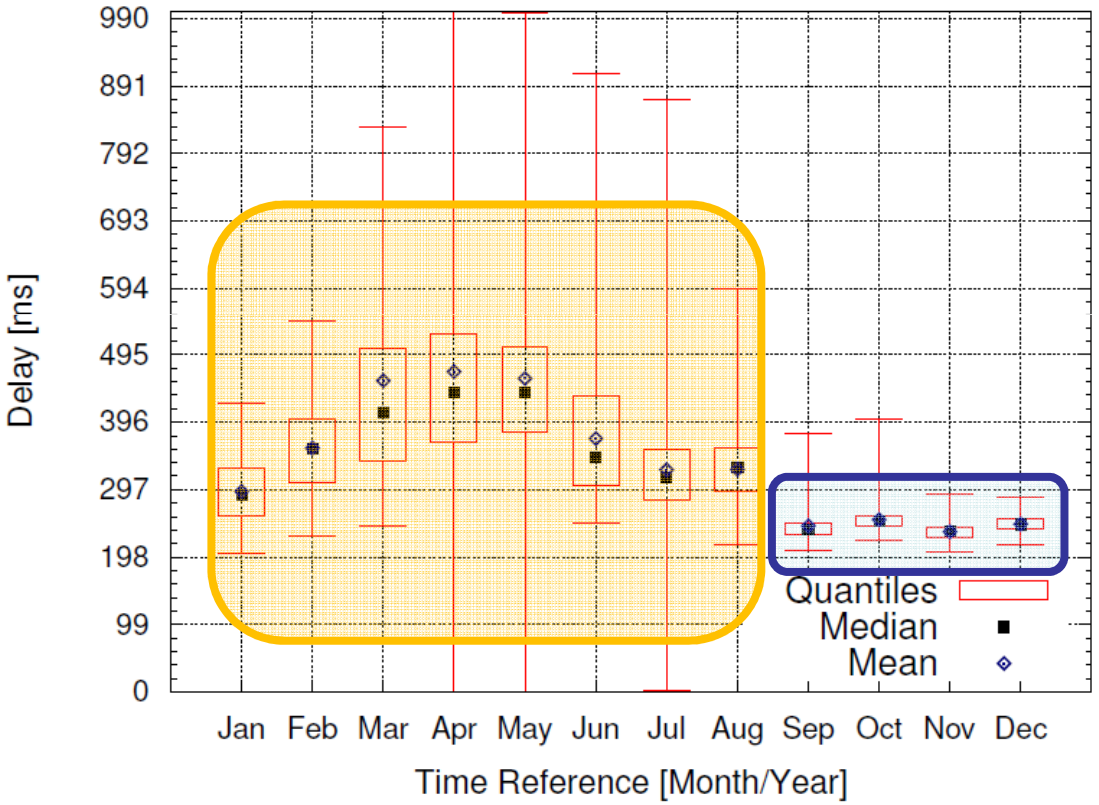
Q2

- **All services exhibit time patterns in performance**
- EC2: periods of special behavior
- SDB and S3: daily, monthly and yearly patterns
- SQS and FPS: periods of special behavior

Iosup, Yigitbasi, Epema. On the Performance Variability of Production Cloud Services, (IEEE CCgrid 2011).

GAE Dataset (2/4): Datastore

Q2

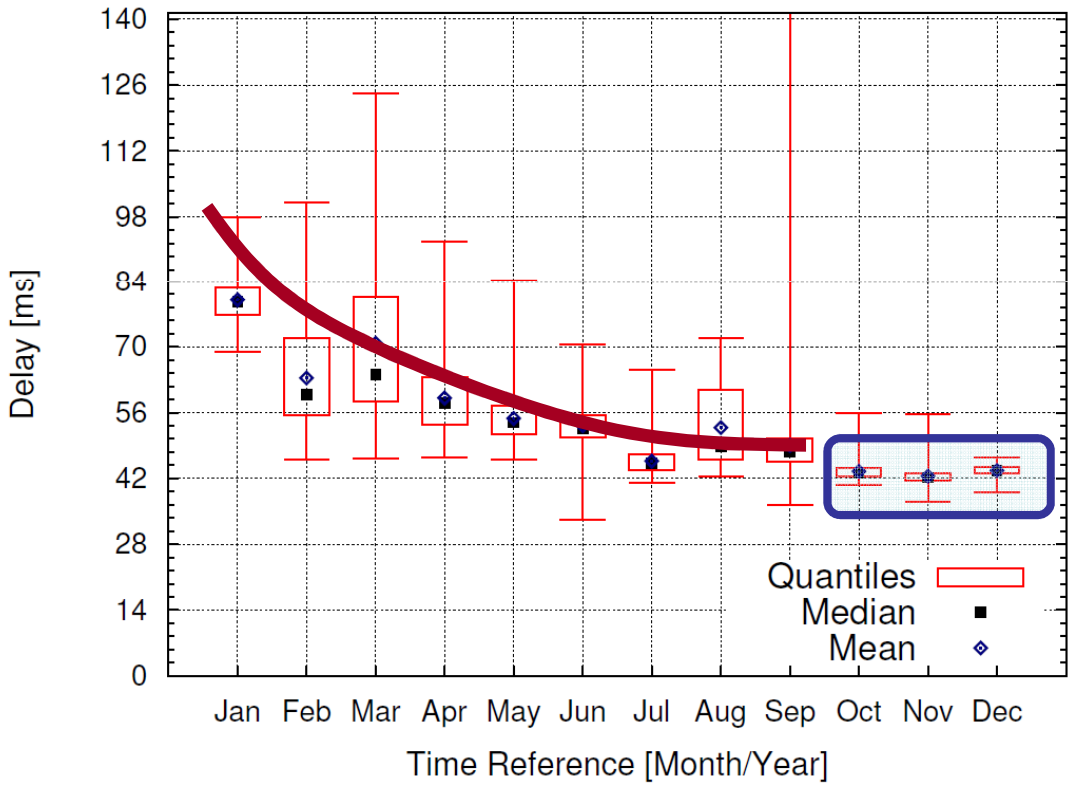


- **Read Latency [s]:** Time it takes to read a "User Group"
- Yearly pattern from January to August
- The last four months of the year exhibit much lower IQR and range
  - More stable performance for the last five months
  - Probably due to software/infrastructure upgrades

Iosup, Yigitbasi, Epema. On the Performance Variability of Production Cloud Services, (IEEE CCgrid 2011).

GAE Dataset (3/4): Memcache

Q2



- **PUT [ms]:** Time it takes to put 1 MB of data in memcache.
- Median performance per month has an increasing trend over the first 10 months
- The last three months of the year exhibit stable performance

Iosup, Yigitbasi, Epema. On the Performance Variability of Production Cloud Services, (IEEE CCgrid 2011).

GAE Dataset (4/4): Summary

Q2

- All services exhibit time patterns

- Run Service: daily patterns and periods of special behavior
- Datastore: yearly patterns and periods of special behavior
- Memcache: monthly patterns and periods of special behavior
- URL Fetch: daily and weekly patterns, and periods of special behavior

Iosup, Yigitbasi, Epema. On the Performance Variability of Production Cloud Services, (IEEE CCgrid 2011).

@large: Social Everything!

- **Social Network**=undirected graph, **relationship**=edge
- **Community**=sub-graph, density of edges between its nodes higher than density of edges outside sub-graph

(Analytics Challenge)

Improve gaming experience

- Ranking / Rating
- Matchmaking / Recommendations
- Play Style/Tutoring

Self-Organizing Gaming Communities

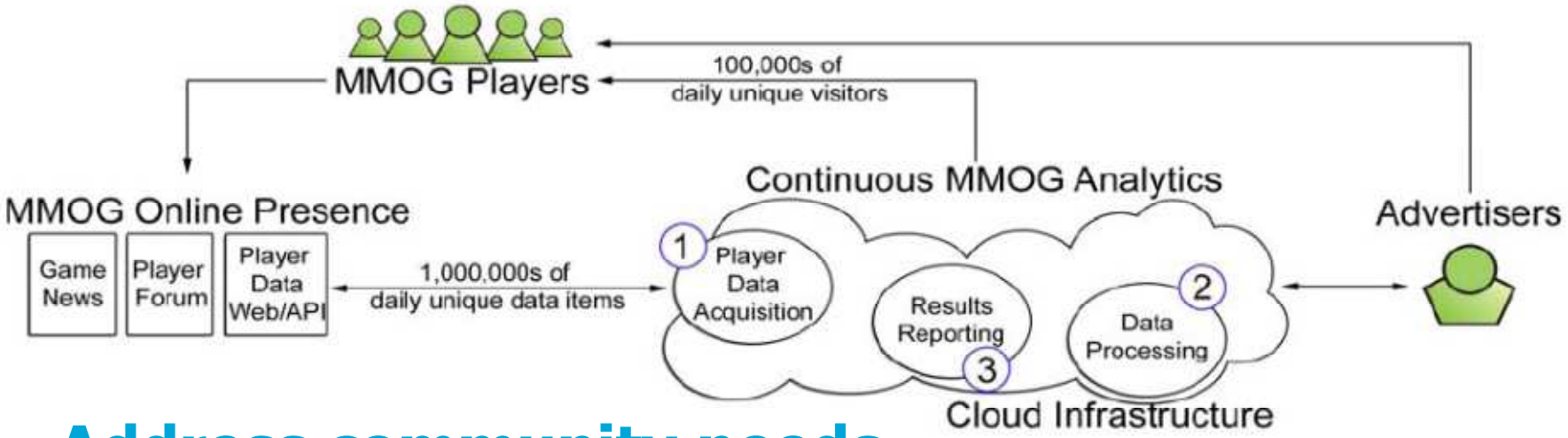
- Player Behavior

The Game Trace Archive (upcoming)

- Share gaming traces and best-practices on using them
- Support simulations and real-world experiments

Name	Period	Size (GB)	Node (M)	Edge (M)	Category
KGS	2002/02-2009/03	2	0.8	27.4	Chess Game
FICS	1997/11-2011/09	168	0.4	144.2	Chess Game
BBO	2009/11-2009/12	10	3.9	12.9	Card Game
XFire	2008/05-2011/12	58	7.7	34.7	OMGN
Dota League	2006/07-2011/03	23	0.1	3.0	RTS
DotaLicious	2010/04-2012/02	1	0.1	0.6	RTS
Dota Garena	2009/09-2010/05	1	0.3	0.1	RTS
WoWAH	2006/01-2009/10	3	0.1	N/A	MMORPG

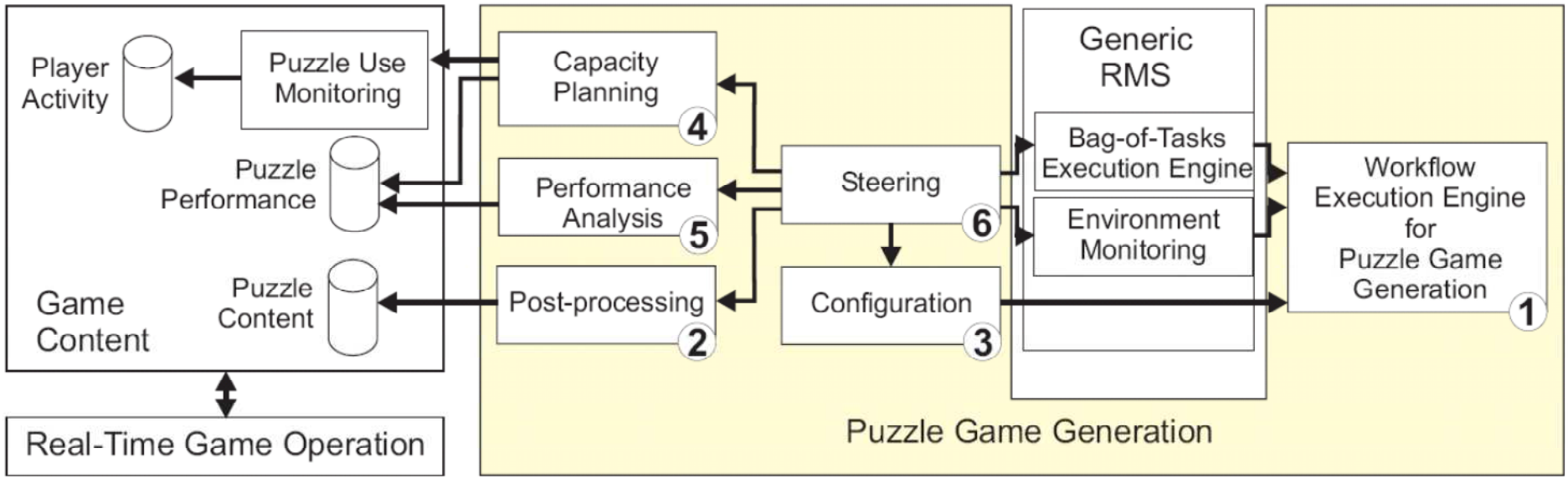
The CAMEO Framework



1. **Address community needs**
   - Can analyze skill level, experience points, rank
   - Can assess community size dynamically
2. **Using on-demand technology: Cloud Comp.**
   - Dynamic cloud resource allocation, Elastic IP
3. **Data management and storage: Cloud Comp.**
   - Crawl + Store data in the cloud (best performance)
4. **Performance, scalability, robustness: Cloud Comp.**

A. Iosup, CAMEO: Continuous Analytics for Massively Multiplayer Online Games on Cloud Resources. ROIA, Euro-Par 2009 Workshops, LNCS 6043, (2010)

The POGGI Framework



Focus on game content generation on grids

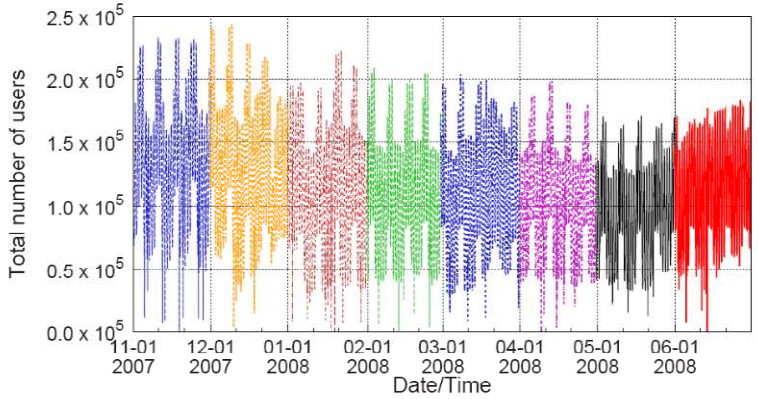
- Use existing middleware
- Control MMOG-specific workload demands and variability (soft guarantees for low response time by pre-generating content)

… but do not forget lessons on system design

- Add components for capacity planning and process monitoring

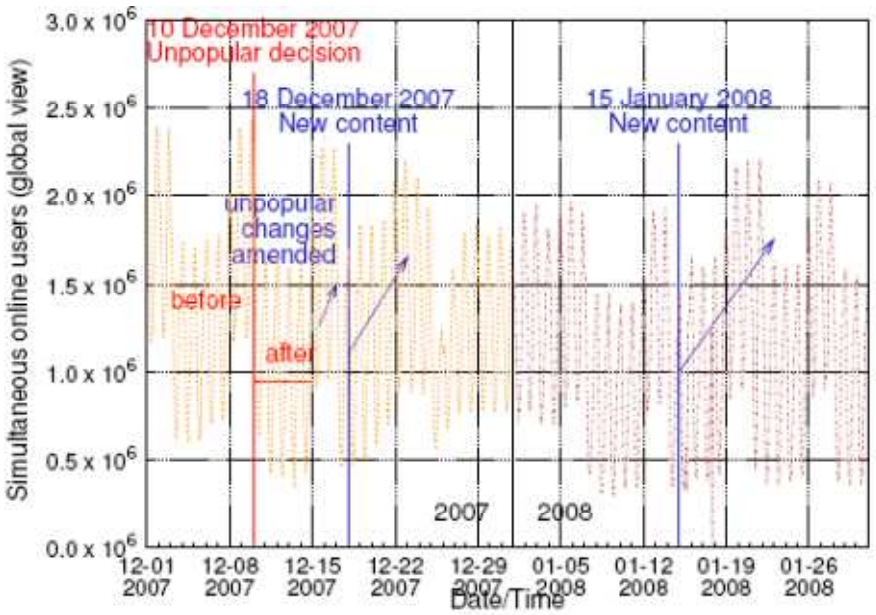
Continuous Analytics for MMOGs

MMOG Data =
raw and derivative information from the virtual world (millions of users)



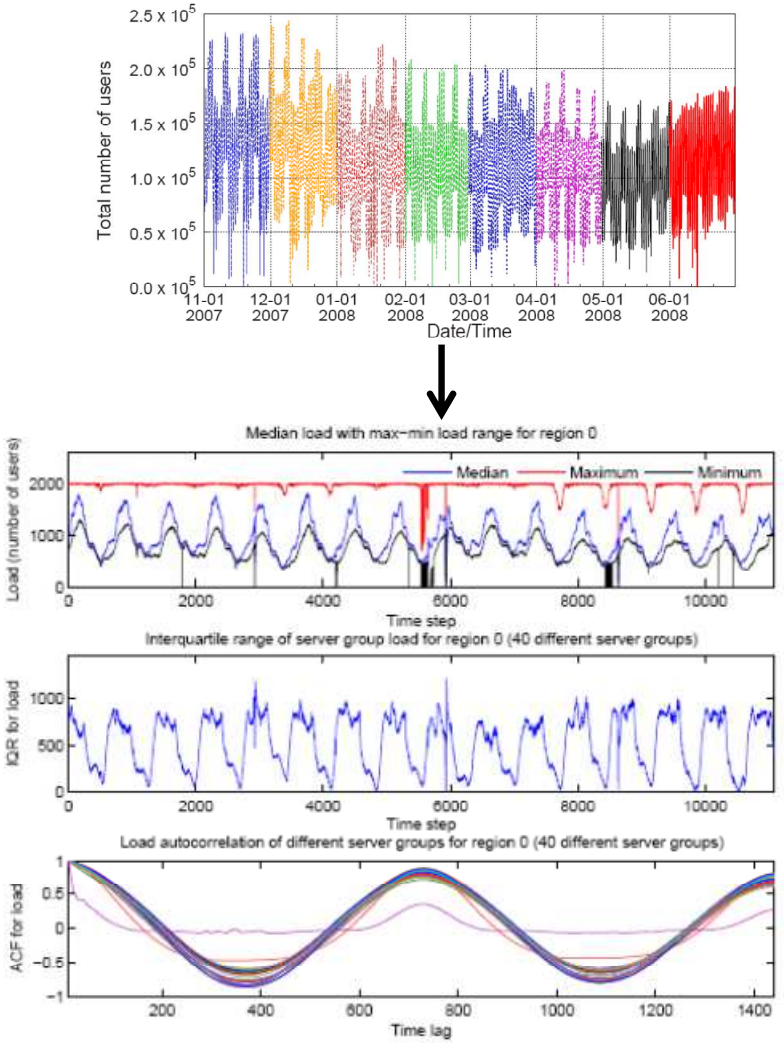
Continuous Analytics for MMOGs =
Analysis of MMOG data s.t. important events are not lost

- Data collection
- Data storage
- Data analysis
- Data presentation
- … at MMOG rate and scale



Continuous Analysis for MMOGs
Main Uses By and For Gamers

1. Support player communities
2. Understand play patterns
   (decide future investments)
3. Prevent and detect cheating or disastrous game exploits
   (think MMOG economy reset)
4. Broadcasting of gaming events
5. Data for advertisement companies
   (new revenue stream for MMOGs)



Other Uses for MMOG Data

Social Sciences

- The emergence and performance of ad hoc groups in contemporary society
- Emergent behavior in complex systems

Economy

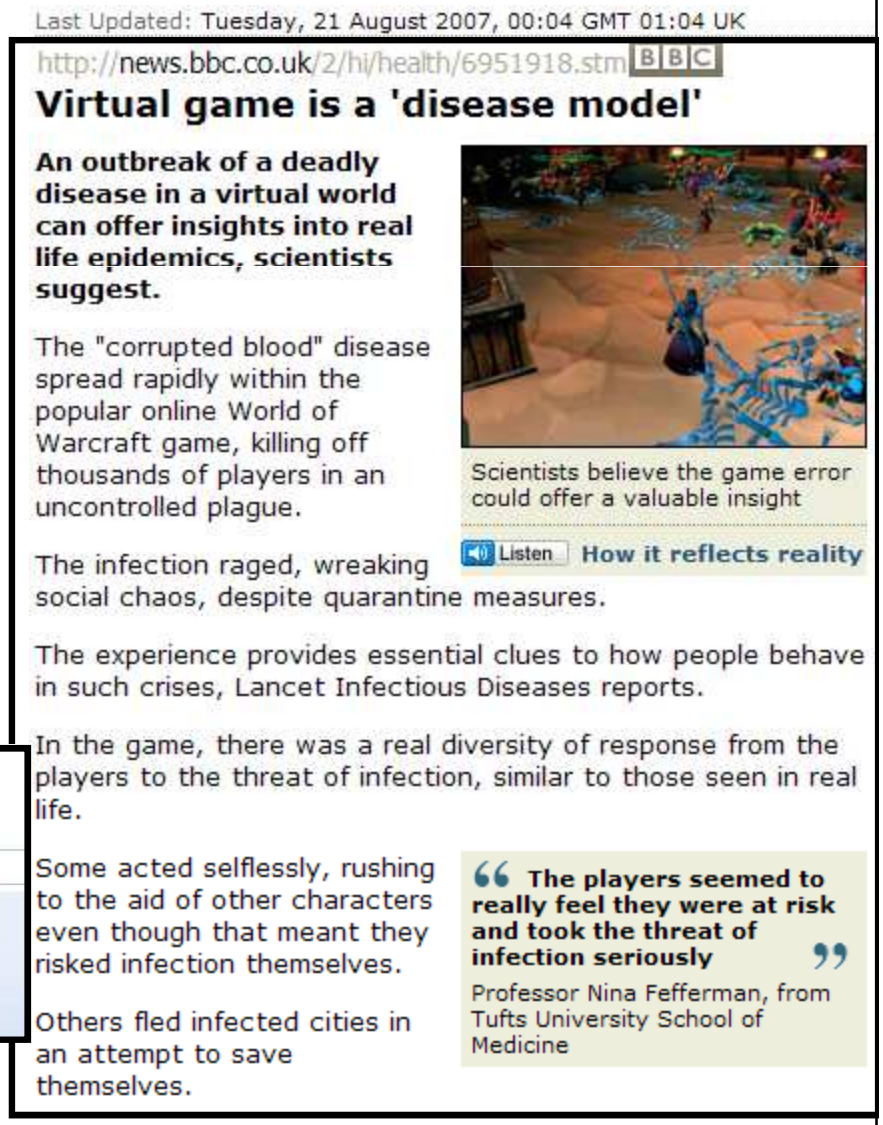
- Contemporary economic behavior

Psychology

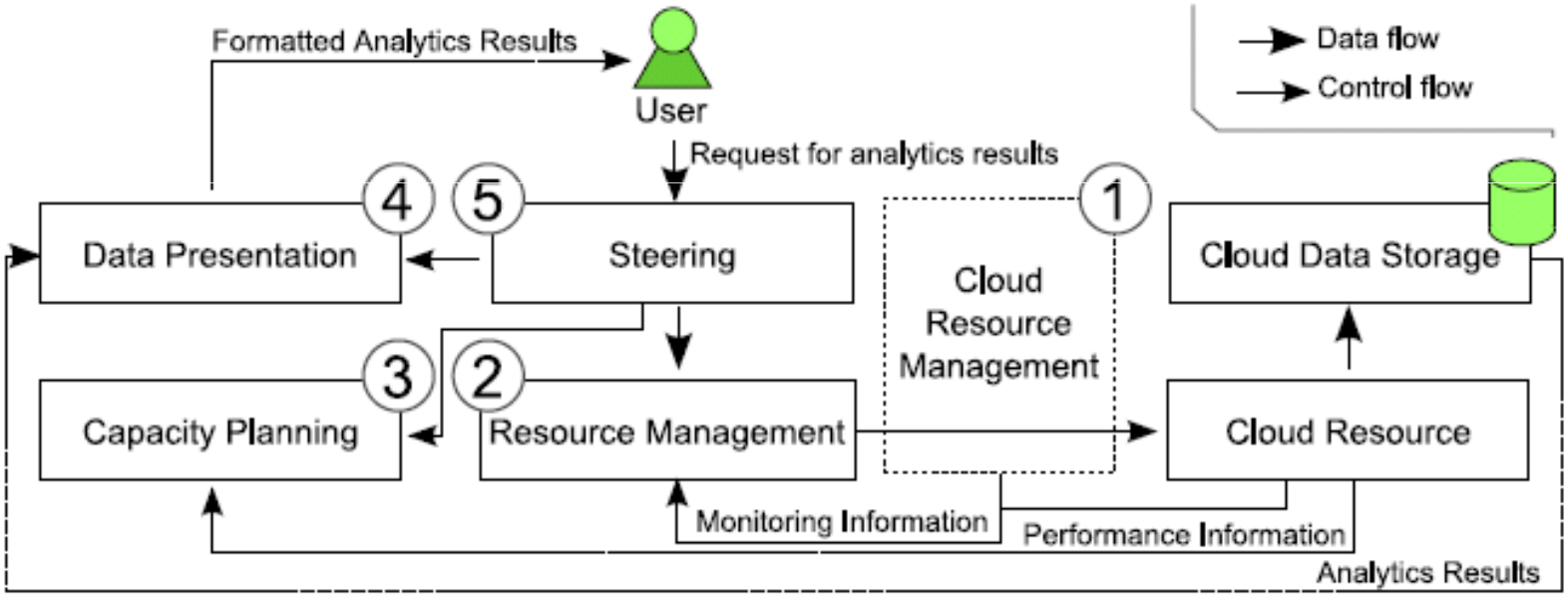
- Games as coping mechanism (minorities)
- Games as cure (agoraphobia)

Biology

- Disease spread models



The CAMEO Framework [ROIA09]
Continuous MSG Analytics on the Cloud



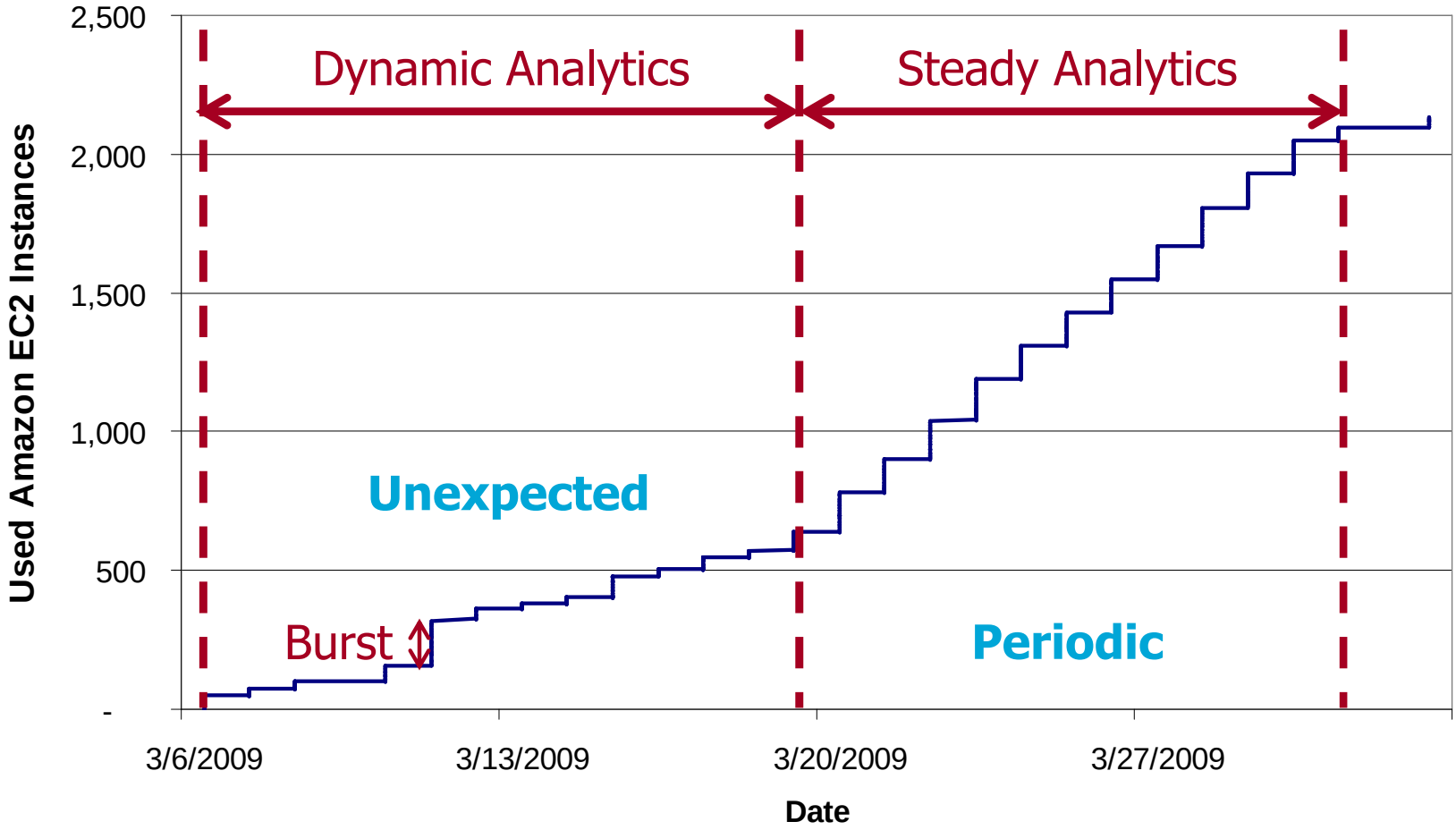
- Use own resources for continuous or predicted load
- **Use cloud (on-demand, paid-for, guaranteed) resources for sparse or excess load**
- Users (peers) may also provide service (future)

A. Iosup, CAMEO: Continuous Analytics for Massively Multiplayer Online Games on Cloud Resources. ROIA, Euro-Par 2009 Workshops, LNCS 6043, pp. 289--299. Springer, Heidelberg (2010)

CAMEO: Analytics Capabilities

1. **Various pieces of information**
   - Skill level, experience points, rank
2. **Single and Multi-snapshot analysis**
3. **Analysis functions already implemented**
   - Ranking by one or more pieces of information
   - Community statistical properties for a piece of information
   - Identification of Top-K players in single/multi-snapshot
   - Evolution of (Top-)K players
   - Evolution of average community skill
   - Identification of players with special skill combos

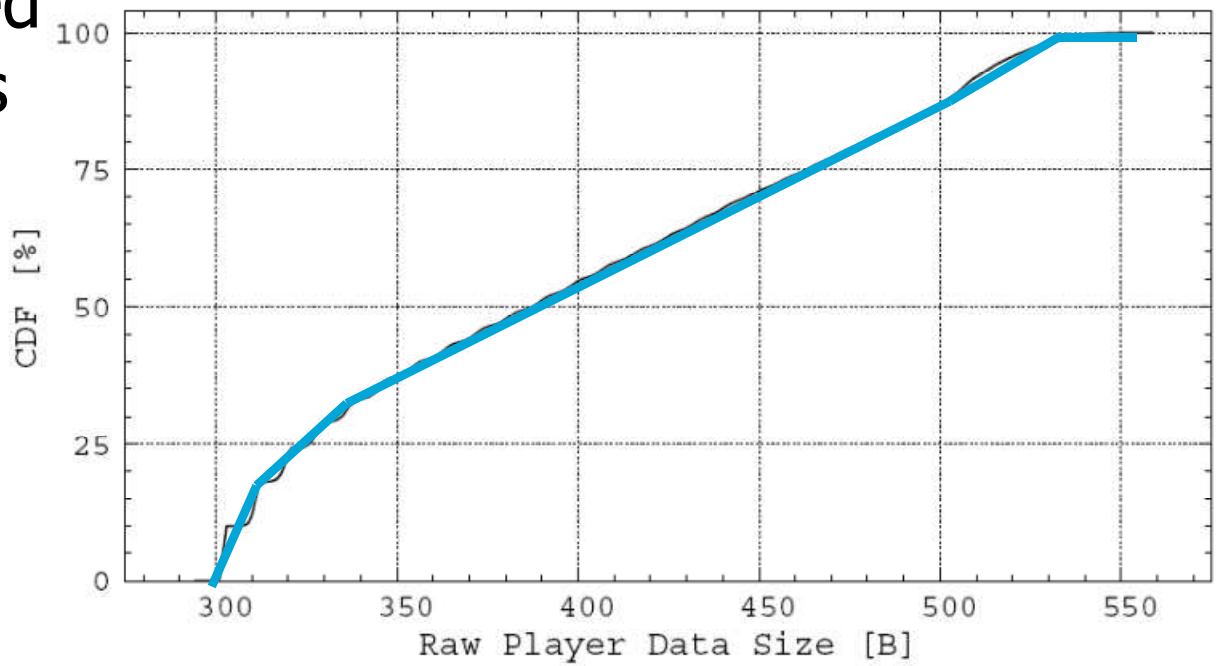
CAMEO: Cloud Resource Management



- Snapshot = dataset for a set of players
- More machines = more snapshots per time unit

CAMEO: Exploiting Cloud Features

- **Machines close(r) to server**
  - Traffic dominated by small packets (latency)



- **Elastic IP to avoid traffic bans**
  (legalese: acting on behalf of real people)

A. Iosup, A. Lascateu, N. Tapus, CAMEO: Enabling Social Networks for Massively Multiplayer Online Games through Continuous Analytics and Cloud Computing, ACM NetGames 2010.

Cost of Continuous RuneScape Analytics

Billing Statement: April 1, 2009

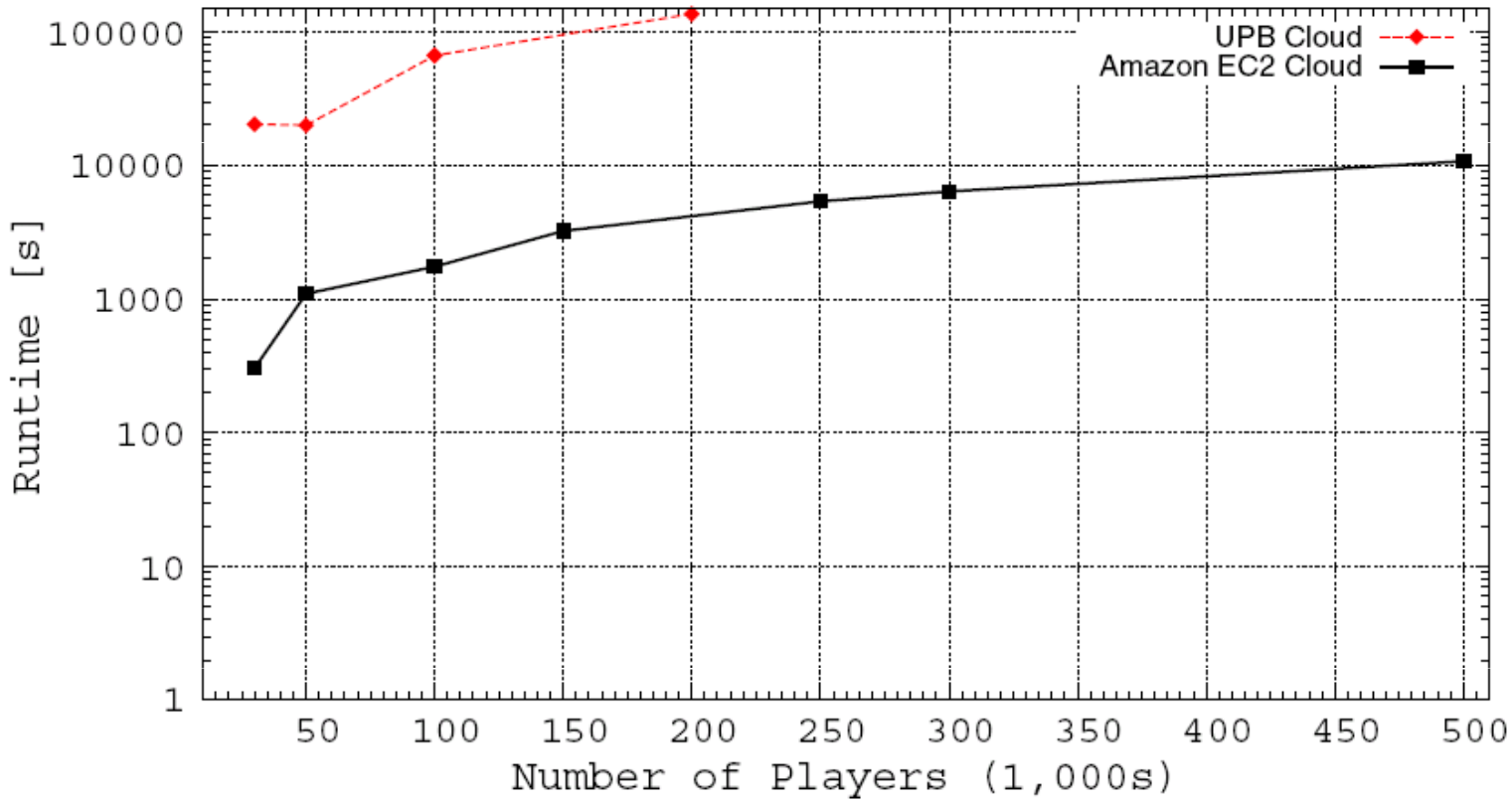
Billing Cycle for this Report: March 1 - March 31, 2009

Expand All | Collapse All

	Rate	Usage	Totals
Amazon Elastic Compute Cloud View/Edit Service			
Amazon EC2 running Linux/UNIX			
	$0.10 per Small Instance (m1.small) instance-hour (or partial hour)	2,097 Hrs	209.70
Amazon EC2 Bandwidth			
	$0.100 per GB Internet Data Transfer - all data transfer into Amazon EC2	611.005 GB	61.10
	$0.170 per GB Internet Data Transfer - first 10 TB / month data transfer out of Amazon EC2	507.121 GB	86.21
Taxes			**67.83**
Charges due on April 1, 2009†			**424.85**

- Put a price on MMOG analytics (here, **$425/month**, or less than **$0.00015/user/month**)
- Trade-off accuracy vs. cost, runtime is constant

Performance Results: Why Choosing the Cloud Matters



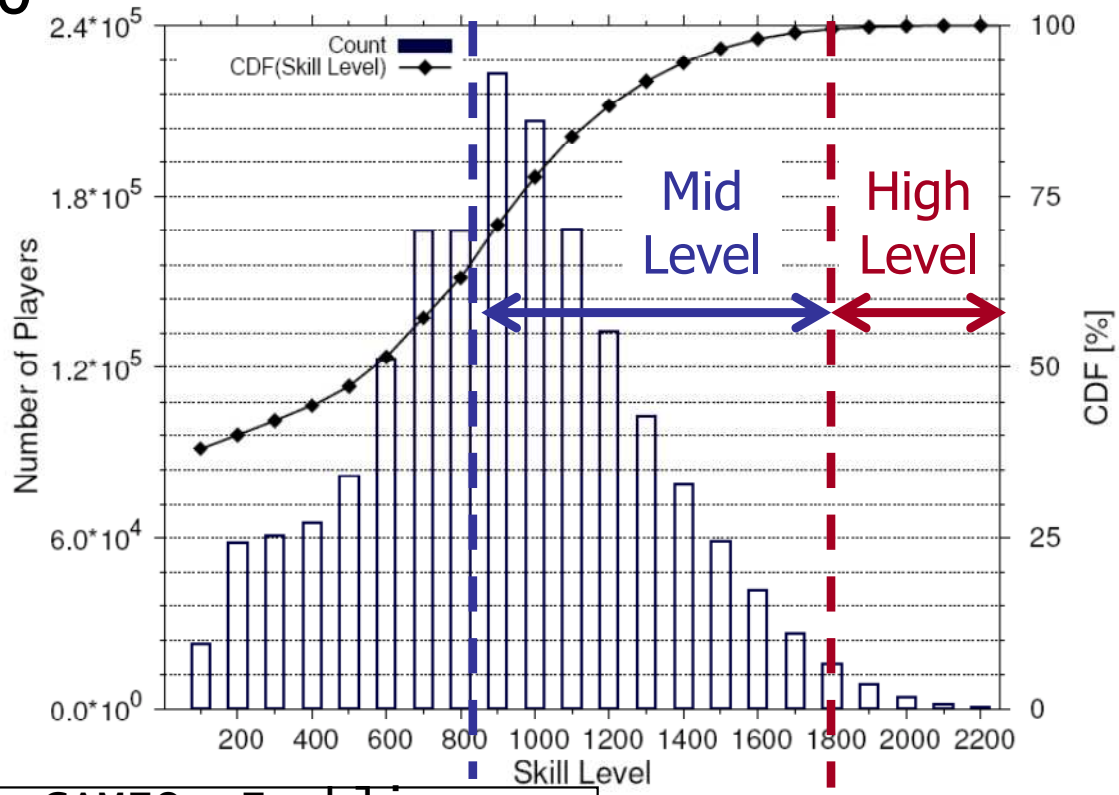
- Location of machines influences MMOG analytics performance (data acquisition)

Player-Customized Content
Skill Level Distribution in RuneScape

- **RuneScape**: 135M+ open accounts (world record)
- Dataset: **3M players (largest measurement, to date)**
  - 1,817,211 over level 100
  - Max skill 2,280

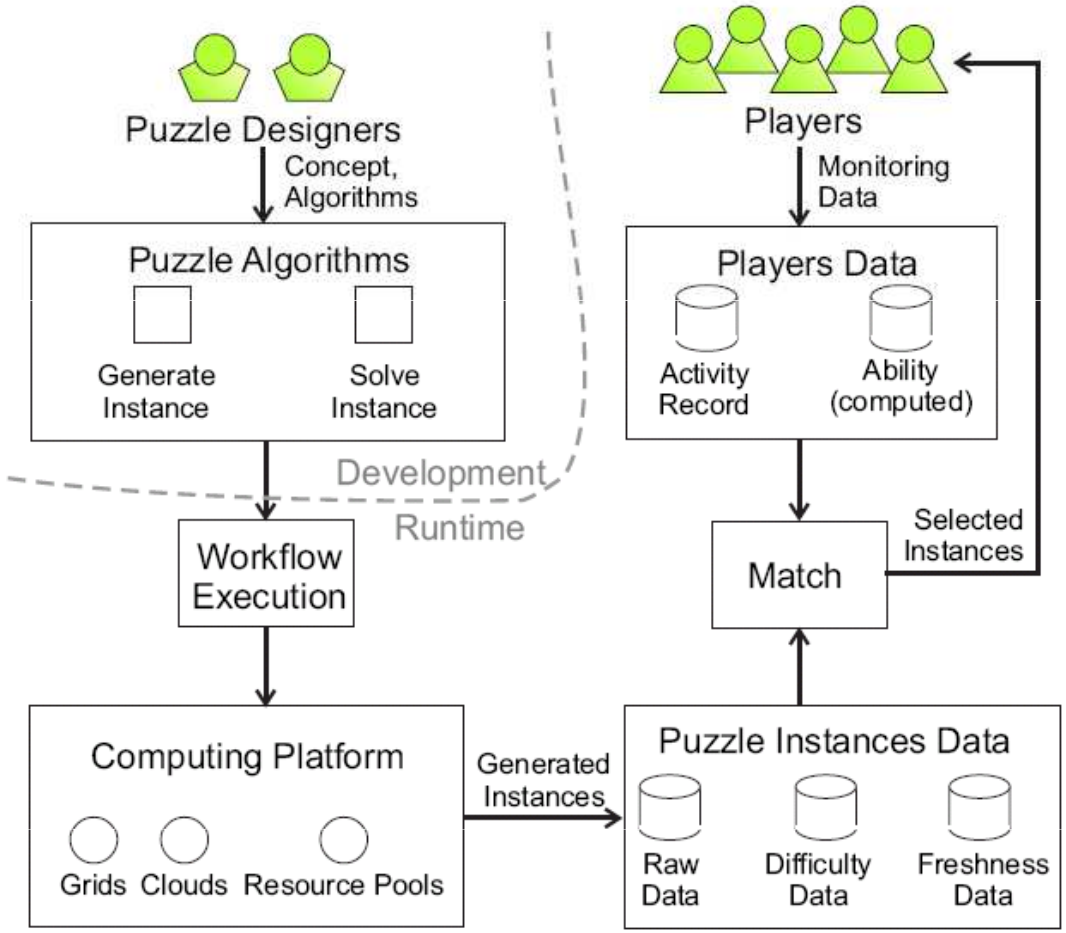
- **Number of mid- and high-level players is significant**

New Content Generation Challenge



A. Iosup, A. Lascateu, N. Tapus, CAMEO: Enabling Social Networks for Massively Multiplayer Online Games through Continuous Analytics and Cloud Computing, ACM NetGames 2010.

The POGGI Content Generation Framework

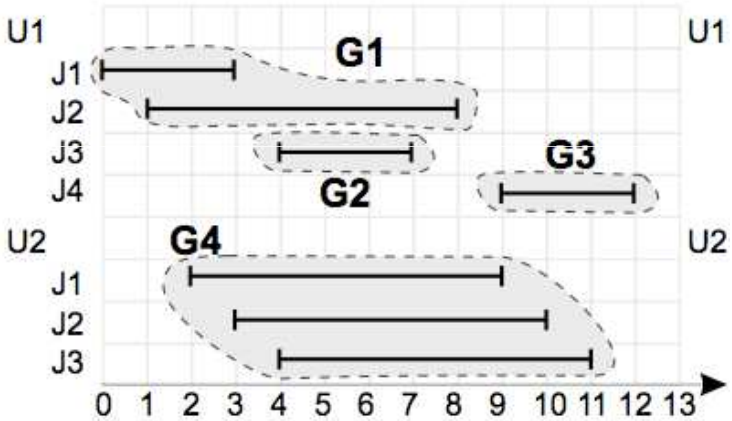


Only the puzzle concept, and the instance generation and solving algorithms, are produced at development time

* A. Iosup, POGGI: Puzzle-Based Online Games on Grid Infrastructures, EuroPar 2009 (Best Paper Award)

Grid Workload Components

Bags-of-Tasks (BoTs)



BoT = set of jobs…

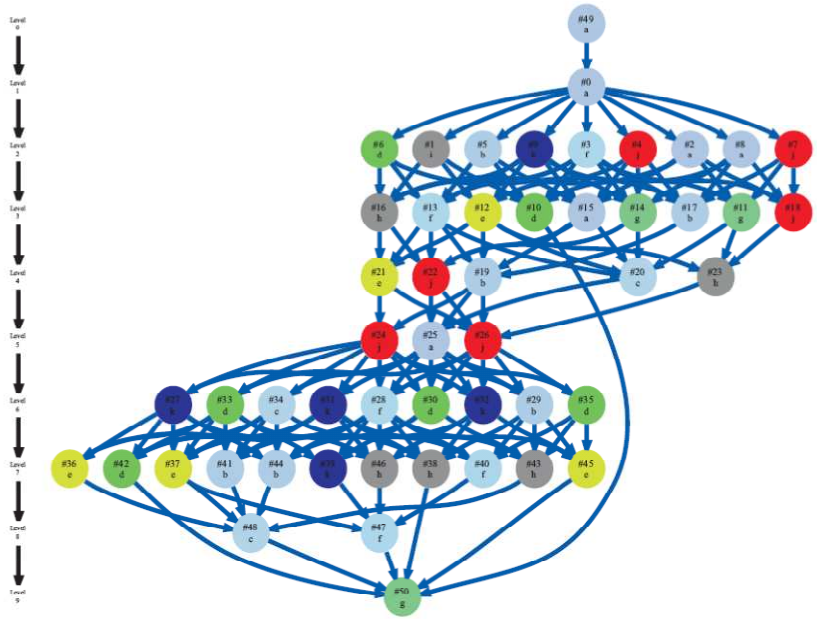
$$W_u = \{J_i | user(J_i) = u\}$$

…that start at most Δs after the first job

$$ST(J') \leq ST(J) + \Delta$$

Parameter Sweep App. =
BoT with same binary

Workflows (WFs)

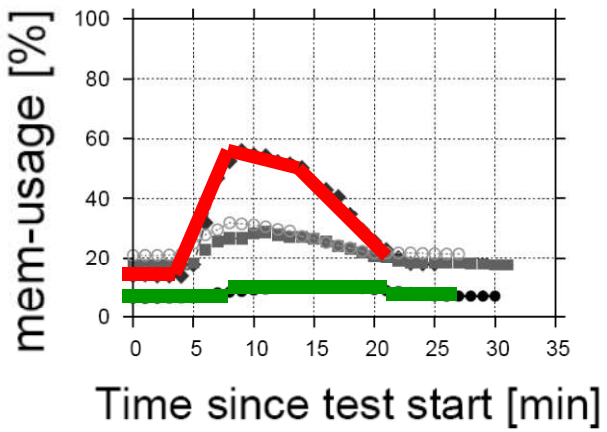


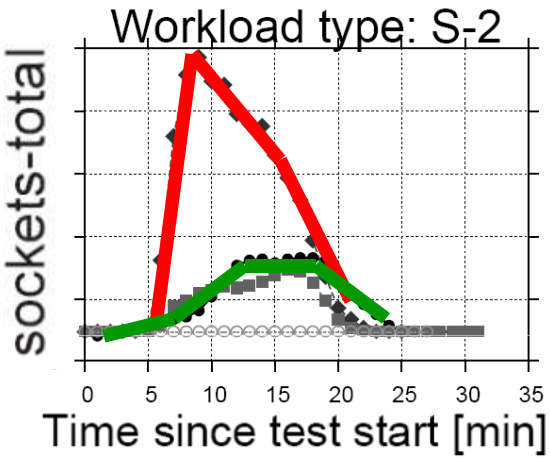
WF = set of jobs with precedence
(think Direct Acyclic Graph)

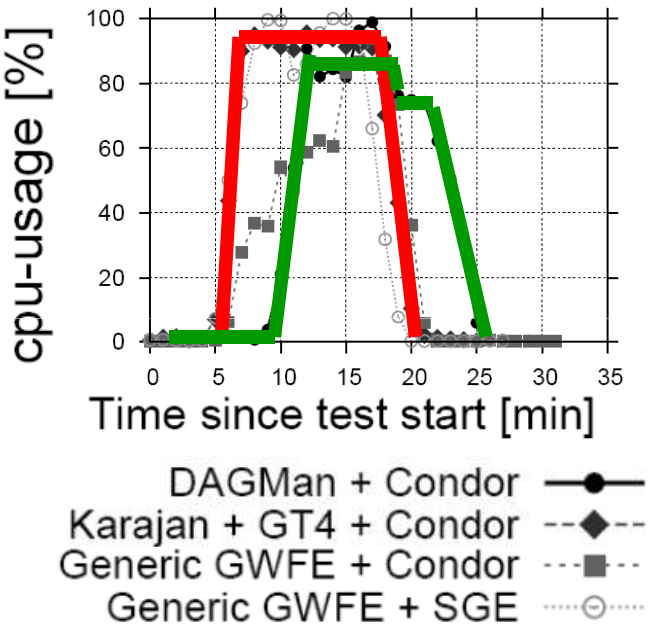
Workflow Engines: Performance vs. Resource Consumption

Middleware	MS [s]
DAGMan	1,327 ± 138
Karajan	1,111 ± 154

Karajan performs better than DAGMan, but runs quickly out of resources.







Karajan **DAGMan**

C. Stratan, A. Iosup, D. Epema: A performance study of grid workflow engines. GRID 2008: 25-32