MASSIVIZING COMPUTER SYSTEMS

= MAKING COMPUTER SYSTEMS SCALABLE, RELIABLE, PERFORMANT, ETC., YET ABLE TO FORM AN EFFICIENT ECOSYSTEM

Co-sponsored by:

Netherlands Organisation for Scientific Research

STW connecting innovators

@Large Research

Massivizing Computer Systems

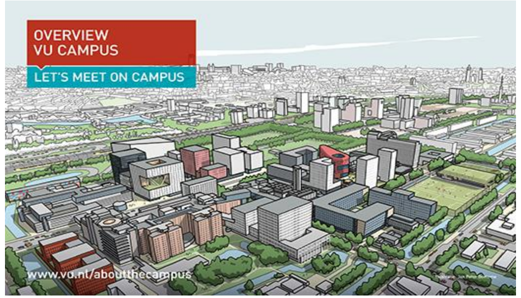
http://atlarge.science

VU VRIJE UNIVERSITEIT AMSTERDAM

@AIosup

Prof. dr. ir. Alexandru Iosup

VU AMSTERDAM < SCHIPHOL < THE NETHERLANDS < EUROPE



Amsterdam
founded 10th century
pop: 850,000

VU
founded 1880
pop: 23,500

The Netherlands

pop: 16.5 M

Europe

WHO AM I?
PROF. DR. IR. ALEXANDRU IOSUP

- Education, my courses:
  - > Systems Architecture (BSc)
  - > Distributed Systems, Cloud Computing (MSc)
- Research, 15 years in DistribSys:
  - > Massivizing Computer Systems

- About me:
  - > Worked in 7 countries, NL since 2004
  - > I like to help… I train people in need
  - > VU University Research Chair
  - > NL ICT Researcher of the Year
  - > NL Higher-Education Teacher of the Year
  - > NL Royal Young Academy of Arts & Sciences

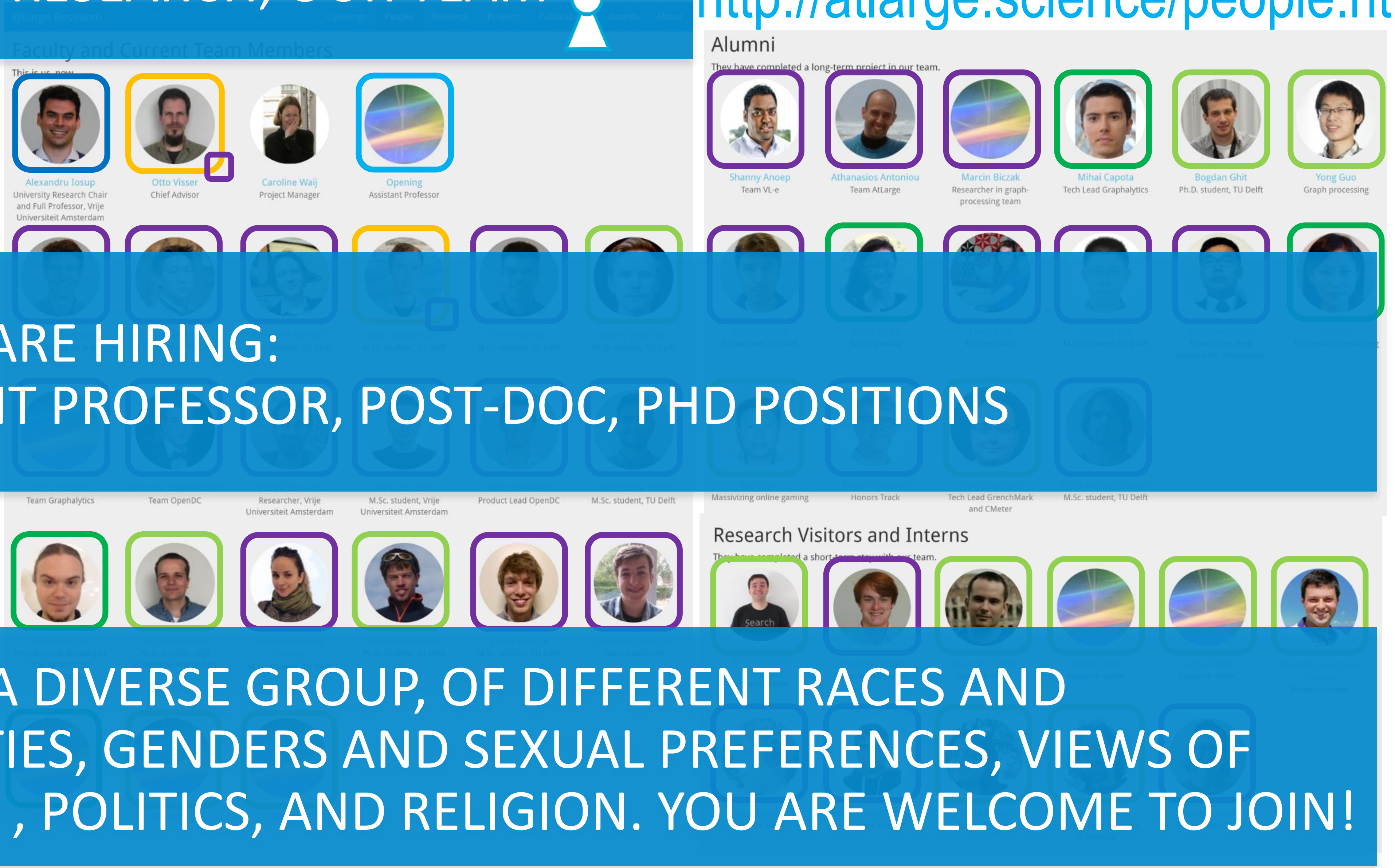
VU

ATLARGE RESEARCH, OUR TEAM

VU VRIJE UNIVERSITEIT AMSTERDAM
TU Delft

http://atlarge.science/people.html

- Professor
- Assistant Prof.
- Ph.D. student
- Scientist



Opening

WE ARE HIRING:
ASSISTANT PROFESSOR, POST-DOC, PHD POSITIONS

WE ARE A DIVERSE GROUP, OF DIFFERENT RACES AND ETHNICITIES, GENDERS AND SEXUAL PREFERENCES, VIEWS OF CULTURE , POLITICS, AND RELIGION. YOU ARE WELCOME TO JOIN!

MASSIVIZING COMPUTER SYSTEMS: OUR MISSION

1. Improve the lives of millions through impactful research.

2. Educate the new generation of top-quality, socially responsible professionals.

3. Make innovation available to society and industry.

Solvinity This is IT
Nerdalize
spec Research
LDBC
salesforce
netherlands eScience center
Amsterdam Data Science
databricks
Delft Data Science
intel
ORACLE
IBM
SAP

http://atlarge.science/about.html

Massivizing Computer Systems
A Structured Discussion

~40’

~3’ — About Our Team

~10’ — The Golden Age of Massive Systems …Yet We Are in a Crisis

- The main challenges
- How we address them

~5’ — Massivizing Computer Systems: Examples

1. The Ecosystem Navigation Challenge
2. The New World Challenge
3. The Scheduling Challenge

Vote for what you want to hear about

~2’ — Take-Home Message

VISION: WHAT DOES OUR SOCIETY NEED?

ISN'T THIS ALREADY HAPPENING?

prosperous society

blooming economy

inventive academia

wise governance

Iosup et al., Massivizing Computer Systems, ICDCS 2018. [Online]

THIS IS THE GOLDEN AGE OF DISTRIBUTED ECOSYSTEMS

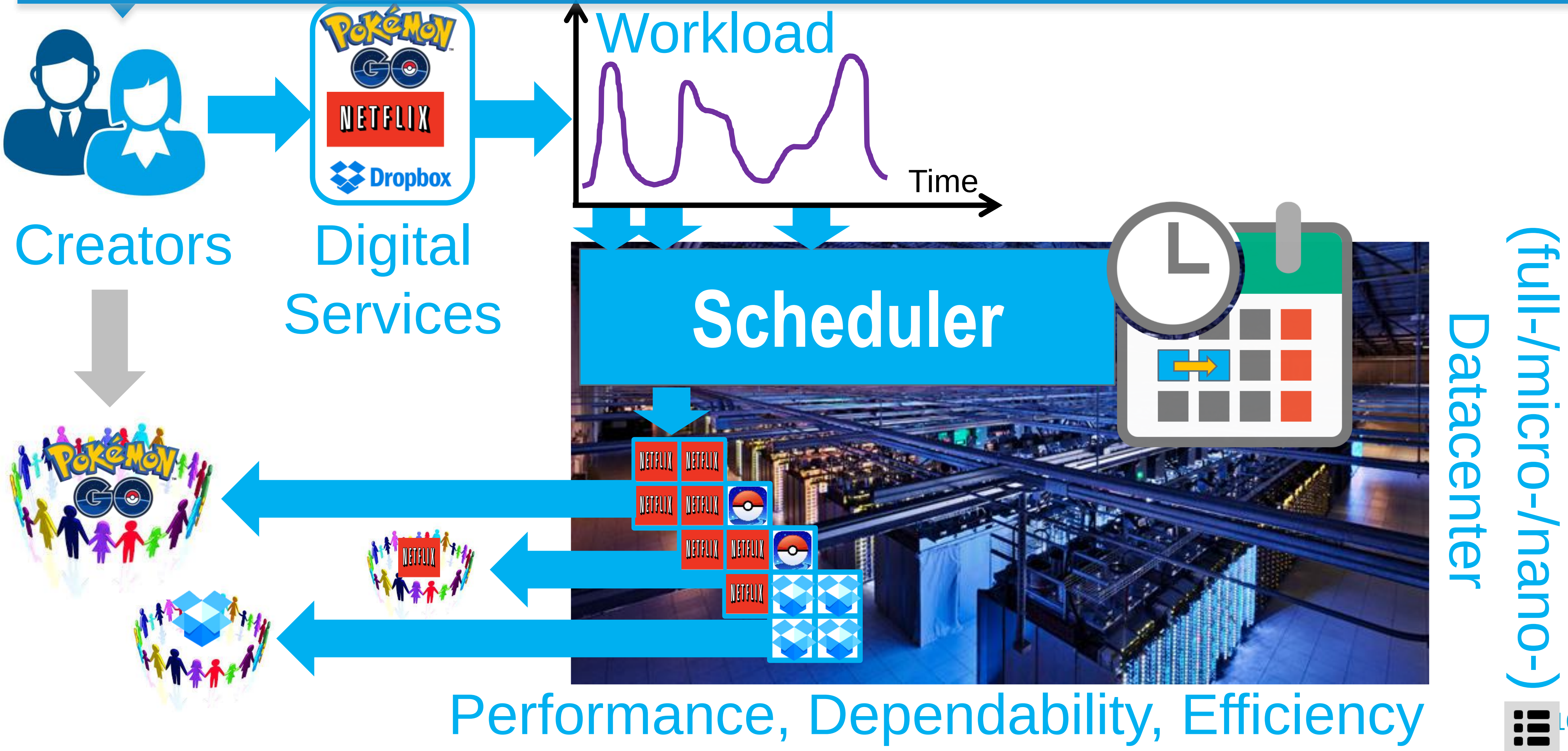
THIS IS THE GOLDEN AGE OF DISTRIBUTED COMPUTER SYSTEMS

Do you recognize this App?

Daily Life

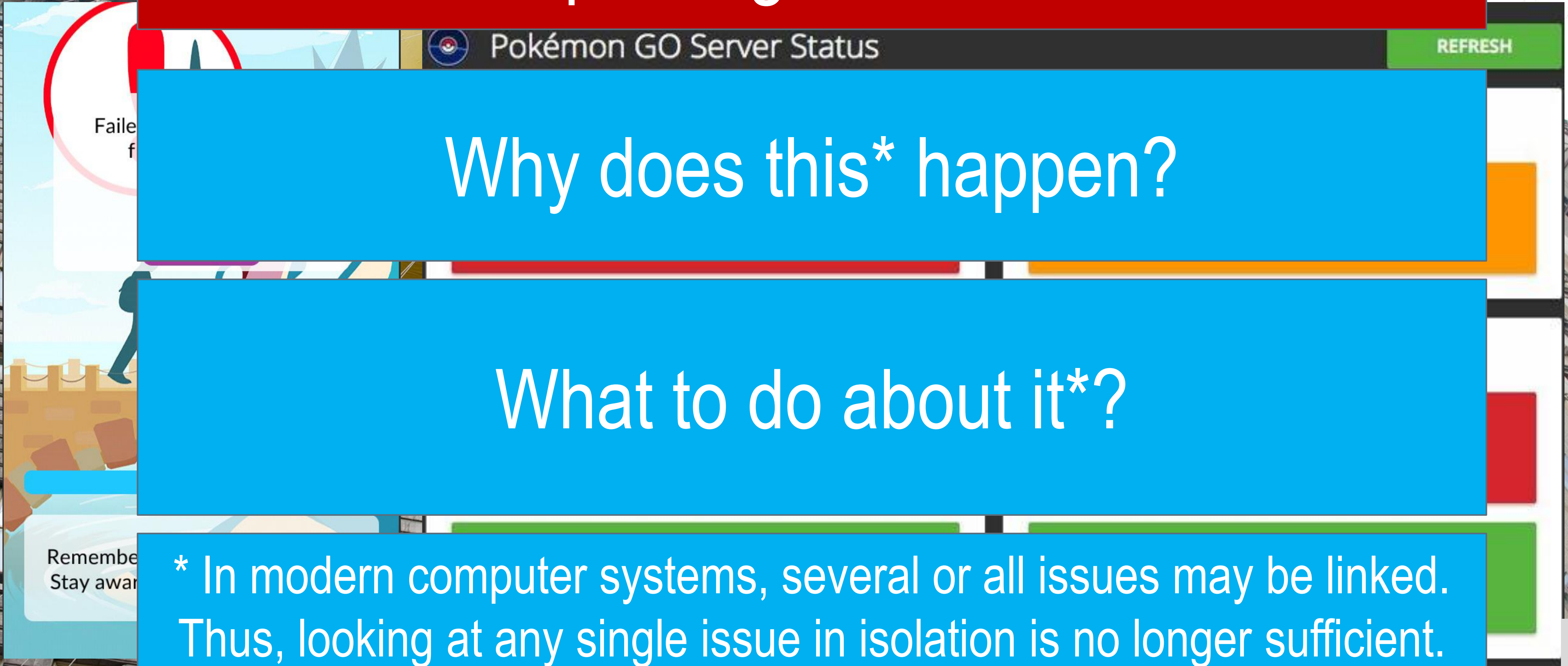
Here is how it operates…

THE CURRENT TECHNOLOGY STACK: DATACENTER, SCHEDULER



My Research: Massivizing Computer Systems

Is 56% uptime good? 66%? 96%?



Why does this* happen?

What to do about it*?

* In modern computer systems, several or all issues may be linked. Thus, looking at any single issue in isolation is no longer sufficient.

THIS IS THE GOLDEN AGE OF DISTRIBUTED COMPUTER SYSTEMS

YET WE ARE IN A CRISIS – 5 CORE PROBLEMS

1. The Current Laws and Theories Are Built and Tested for Isolated Computer Systems (or Silos, or Narrow Stacks)

TRADITIONAL DISTRIBUTED SYSTEMS COURSES TEACH YOU ALL ABOUT THIS

2. Need to Understand How to Maintain Ecosystems

3. Need to Understand How to Make Ecosystems Automated, Efficient (Smarter)

4. Beyond Tech: Need to Also Be Ethical

5. Need to Address the Peopleware Problems

THIS IS THE GOLDEN AGE OF DISTRIBUTED COMPUTER SYSTEMS

YET WE ARE IN A CRISIS

WHICH WE & YOU CAN HELP SOLVE!

Massivizing Computer Systems Tackles The Challenges of Distributed Systems and Ecosystems…

… and Is Relevant, Impactful, and Inspiring for Many Young Scientists and Engineers

OUR DISTRIBUTED SYSTEMS COURSE

THIS IS THE MODERN SCIENCE OF DISTRIBUTED ECOSYSTEMS

MASSIVIZING COMPUTER SYSTEMS IN A NUTSHELL

WHO?	SCIENTISTS, ENGINEERS, DESIGNERS, MANAGERS, ETC.
WHAT? MAIN GOAL	UNDERSTAND AND CONTROL DISTRIBUTED ECOSYSTEMS, TO TURN THEM INTO EFFICIENT, AUTOMATED UTILITIES
HOW? CENTRAL PARADIGM	ECOSYSTEM OPERATION AND CHARACTERISTICS DERIVE NON-TRIVIALLY FROM ITS SYSTEMS AND USERS (RECURSIVELY)
WHICH APPROACH?	MODERN DISTRIBUTED SYSTEMS AND PROBLEM-SOLVING

Iosup et al., Massivizing Computer Systems, ICDCS 2018. [Online]

MASSIVIZING COMPUTER SYSTEMS: MEANINGFUL DISCOVERY

Scheduling
Workflows
Domain-Specific/Agnostic
Portfolio, Auto-scaling*

Dependability
Performance & Failure Analysis*
Space-/Time-Correlation
Availability-On-Demand

New World
Workload Modeling
Serverless
Reference Architectures

Ecosystem Navigator
Performance Variability
Grid*, Cloud, Big Data
Benchmarking*
Longitudinal Studies

Scalability/Elasticity
Delegated Matchmaking*
BTWorld*, POGGI*, AoS
Auto-Scalers*
Heterogeneous Systems

Socially Aware
Collaborative Downloads*
Groups in Online Gaming
Toxicity Detection*
Interaction Graphs

Education
Social Gamification*

Software Artifacts
Graphalytics, OpenDC

Data Artifacts
Distributed Systems Memex*

Fundamental Problems/Research Lines
Our Contribution So Far

* Award-level work
Competitive personal grants

MEANINGFUL DISCOVERY

science + engineering + design

[Iosup et al. ICDCS'18]

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- Choose your own path:
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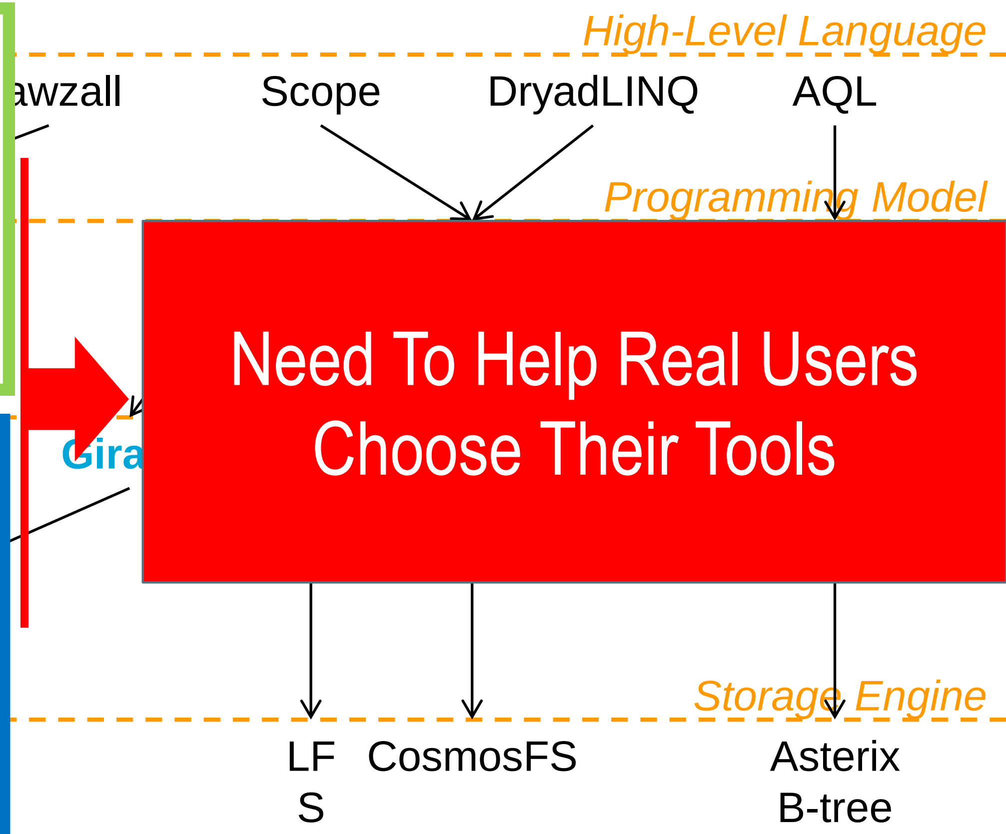
  - > The New World Challenge (Abstraction + Design)
  - > The Scheduling Challenge (Design + Operation)

The Ecosystem Navigation Challenge

Ecosystem operators: how to prove capabilities? How to tune the tool? In which technology to invest? Which tech to DevOp in-house?

Ecosystem customers: how to choose the right tool? For batch, workflows, stream, transactions, etc. (No one size fits all!)



Batch data processing ecosystem in 2011. Our latest update covers ecosystems until 2018.

Alexandru Iosup
Chair

Nikolas Herbst
Vice-Chair

The SPEC RG Cloud Group

Methodology, Benchmarking, and Performance Analysis of Cloud Systems and Applications

"A broad approach, **relevant for both academia and industry**, to cloud benchmarking, quantitative evaluation, and experimental analysis."
"To develop new **methodological elements** for gaining deeper understanding not only of **cloud performance**, but also of **cloud operation and behavior"**
"… through diverse quantitative evaluation tools"

http://research.spec.org/working-groups/rg-cloud-working-group.html

Sales team: "$200/year for research teams"

A General Approach for Ecosystem Benchmarking (Works for Cloud and Big Data Benchmarking)

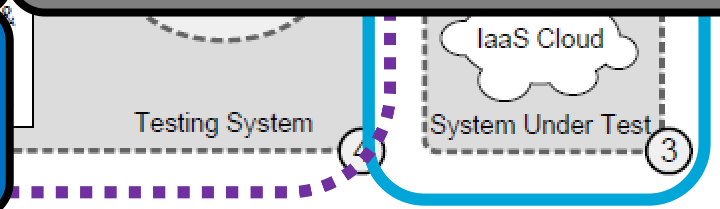
Q1: What is the performance of production IaaS cloud services?

Q2: How variable is the performance of widely used production cloud services?

Q3: What is the performance of IaaS-cloud auto-scalers?

Q4: What is the performance of graph-processing systems?

+ many other questions…



Iosup, Prodan, Epema. IaaS Cloud Benchmarking: Approaches, Challenges, and Experience. Cloud Computing for Data-Intensive Applications 2014: 83-104

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EXPERIMENTAL METHOD OF DISCOVERY

UNIQUE OPPORTUNITY TO VALIDATE: WE DRINK OUR OWN CHAMPAGNE (*IN VIVO*)!

Our Prototypes (*in phyisico/in vitro*)

+ amazon web services™

We also use clouds

+ OpenDC

And simulators (*in silico*)

300+ scientists as users

We won IEEE Scale Challenge 2014

VU

Our Method

Q1

- General performance technique, adapted to clouds: model performance of individual components; system performance is performance of workload + model [Saavedra and Smith, ACM TOCS'96]

Iosup et al., Performance Analysis of Cloud Computing Services for Many Tasks Scientific Computing, IEEE TPDS 2011.
Highest cited article in the best journal of the field (2009-2015).

Q2

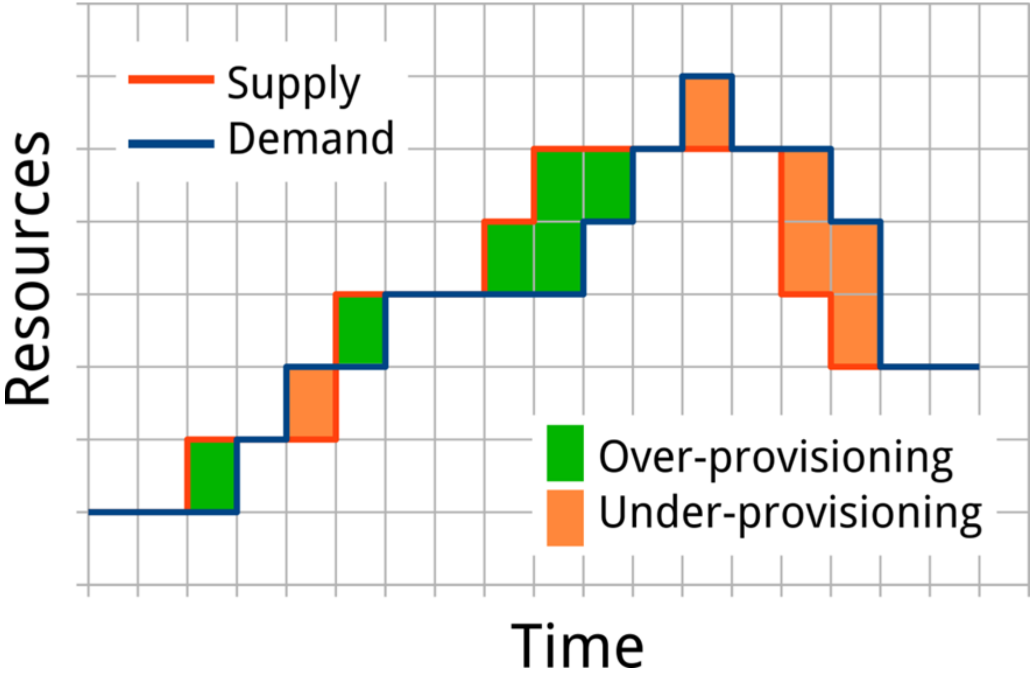
- Performance traces from CloudStatus, to understand variability
  - All Amazon AWS and Google GAE services
  - Periodic performance probes, sampling rate under 2 minutes
- Simulations to assess impact of performance variability
  - Based on traces collected from other applications

Iosup, Yigitbasi, Epema. On the Performance Variability of Production Cloud Services, IEEE CCgrid 2011.
Highest cited study on performance variability in clouds.

Our Method

Q3

Ilyushkin et al. An Experimental Performance Evaluation of Autoscaling Policies for Complex Workflows. ICPE 2017. Nominated for Best Paper Award.



- Real-world experiments (1 workload)
- Later: simulations (more parameters)

Q4

- Many classes of algorithms used in practice
- Diverse real and synthetic datasets
  - Recently, Broido and Clauset found that power-laws are rare in graphs
- Diverse set of experiments representative for practice

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Iosup et al. LDBC Graphalytics: A Benchmark for Large-Scale Graph Analysis on Parallel and Distributed Platforms. PVLDB 9(13): 1317-1328 (2016) Collaboration academia-industry.

Main Findings

Q1
- Lower performance than theoretical peak in IaaS services
  - Especially CPU (GFLOPS)
  - Not explained by traditional models, not covered by SLA

Q2
- Performance variability in IaaS and PaaS services
  - Explored in longitudinal study of Amazon Web Services and Google App Engine
  - Not captured in traditional models

- Compared performance of IaaS clouds with many commercial alternatives, such as supercomputers and clusters

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Main Findings

Q3

- Explored impact of auto-scaler (+ ecosystem of schedulers) on over 10 facets of elasticity
  - Findings not explained by traditional models

Q4

- The HPAD model for the performance of graph-processing systems ~ replaces previous theories
  - Performance is function of Platform, but also Dataset and Algorithm
  - With configurable many-/multi-cores, the Hardware also is also crucial for performance

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MASSIVIZING COMPUTER SYSTEMS

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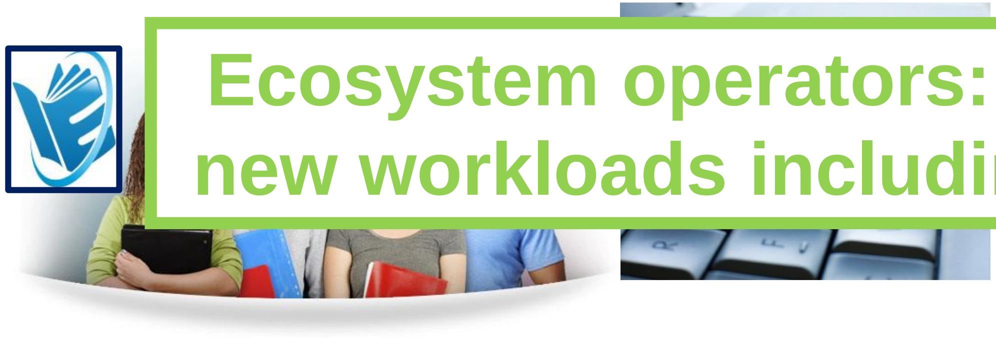
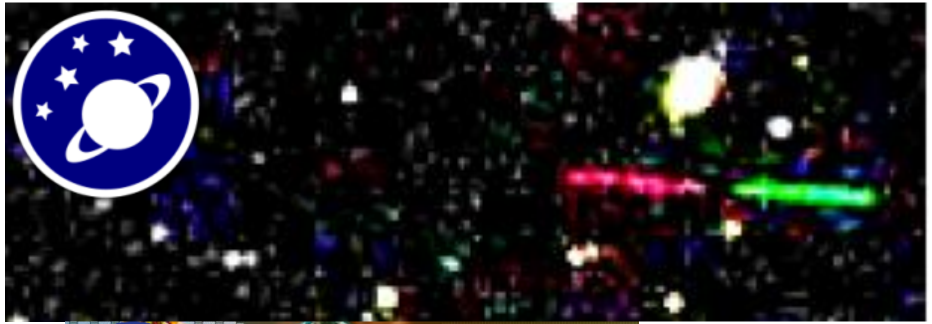
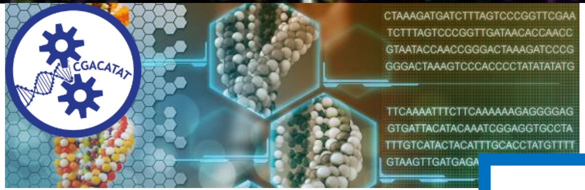
The New World Challenge



Ecosystem operators: new value-adding services, new workloads including FaaS, DevOps workloads



Need Operational Models



Ecosystem customers: new apps, new services, micro-services, customers can become operators (recursive value-chain)

Erwin
van Eyk

Alexandru
Iosup

Serverless / FaaS Execution

Vision and Architecture for Serverless Execution in Cloud Environments

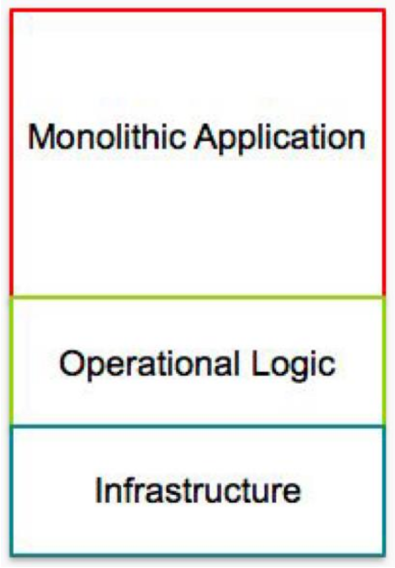
SPEC Research Serverless

van Eyk, Toader, Talluri, Versluis, Uta, Iosup: Serverless is More: From PaaS to Present Cloud Computing. IEEE Internet Computing Sep/Oct 2018. [Online]

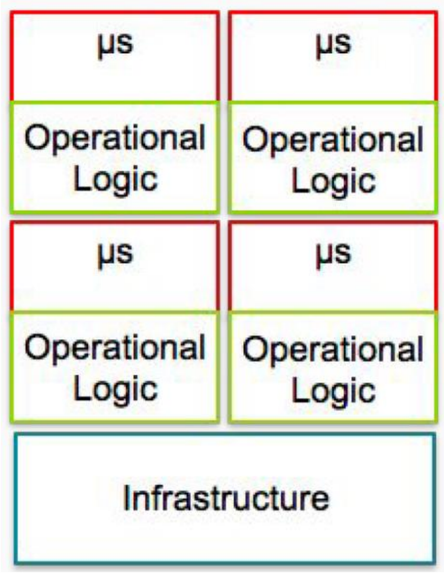
Erwin Van Eyk, Alexandru Iosup, Cristina L. Abad, Johannes Grohmann, Simon Eismann:
A SPEC RG Cloud Group's Vision on the Performance Challenges of FaaS Cloud Architectures. ICPE 2018. [Online]

Erwin van Eyk, Simon Seif (SAP), Markus Thoemmes (IBM Germany), Alexandru Iosup. The SPEC Cloud Group's Research Vision on FaaS and Serverless Architectures. Workshop on Serverless Computing (WoSC'17), held in conjunction with Middleware'17. [Online]

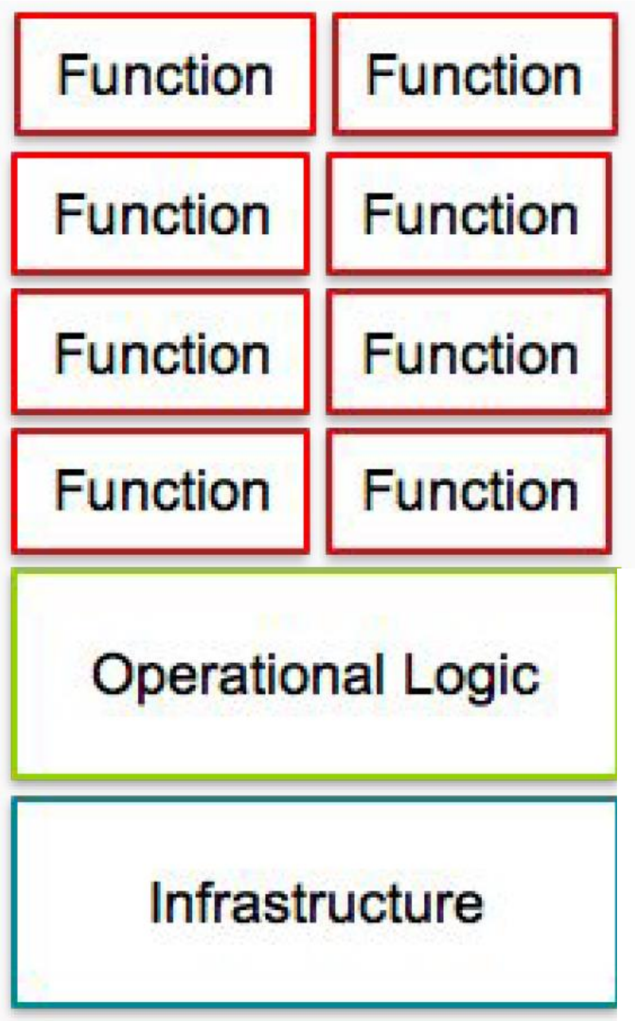
From Monoliths to Microservices to FaaS



- Difficult to Scale
- Infrequent
- Inflexible
- Complex deployment
- Tightly coupled stack

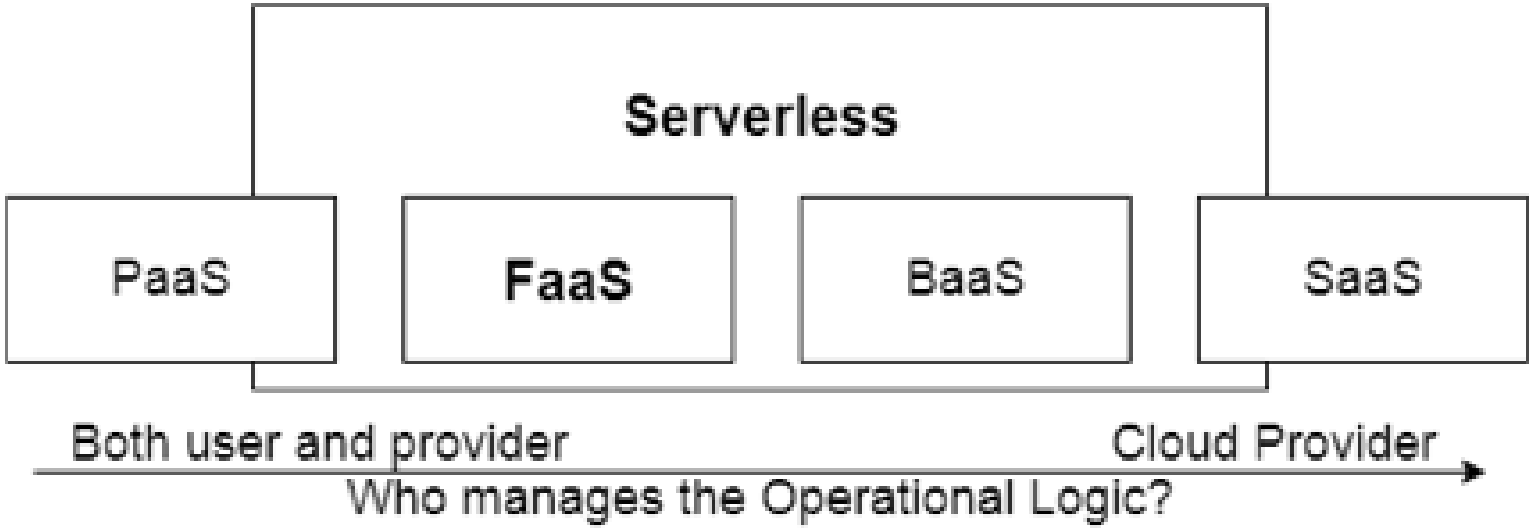


- Scalable
- Frequent
- Flexible
- Complexity: from application logic to operational logic.
- Need for DevOps



- Scalable
- Frequent
- Flexible
- Explicit separation of Business Logic vs. Operational Logic.
- Minimal layer coupling, unit of deployment

Serverless and FaaS



- **Serverless**
  - (Almost) no operational logic
  - Event-Driven
  - Granular billing
- **FaaS**
  - A form of *serverless computing*
  - User provides a function
  - Function deployed and managed by cloud provider

van Eyk et al. [Online]

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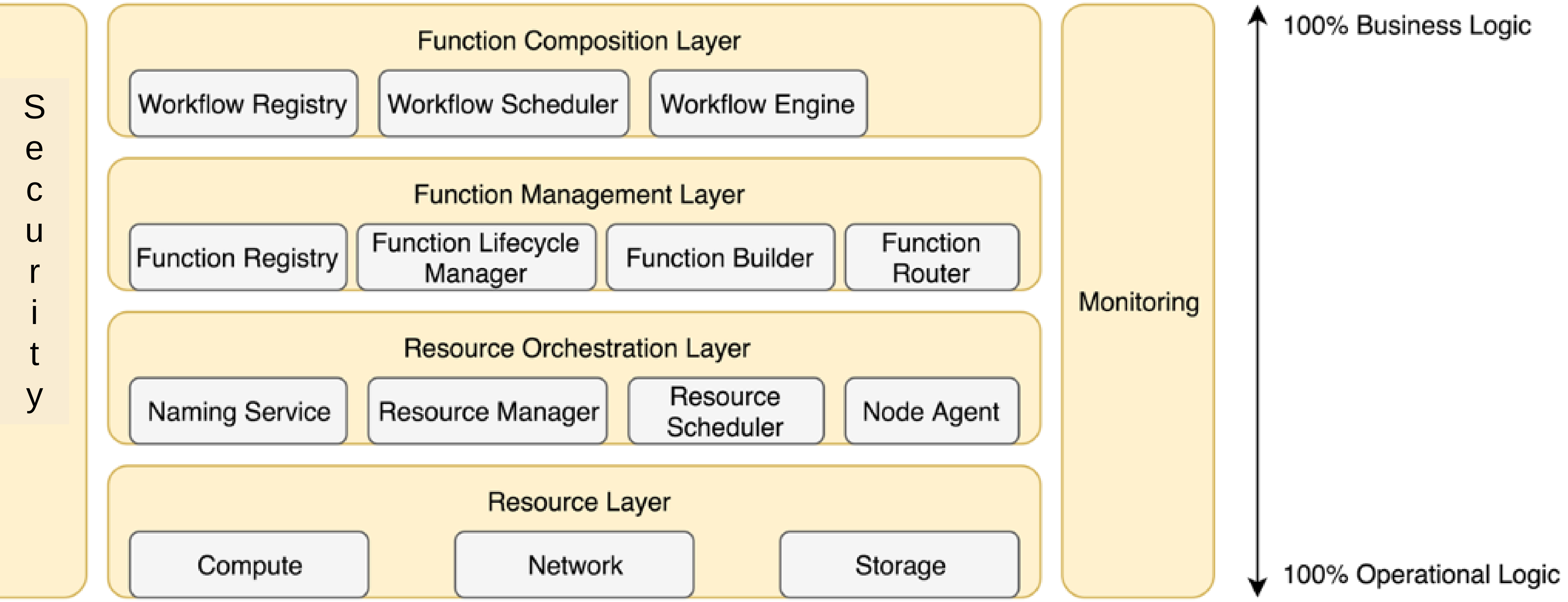
Reference Architecture for FaaS Management



spec Research Serverless

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Van Eyk et al., A SPEC RG Cloud Group's Vision on the Performance Challenges of FaaS Cloud Architectures. ICPE 2018. [Online]

Workflow Management Architecture in Fission.io

Designed by Erwin van Eyk during internship at Platform9, in collaboration w/ Platform9 team and Alexandru Iosup.

1 Core Function / 2 API Server

- Exposes all actions through API

3 Event Store / 4 Projector

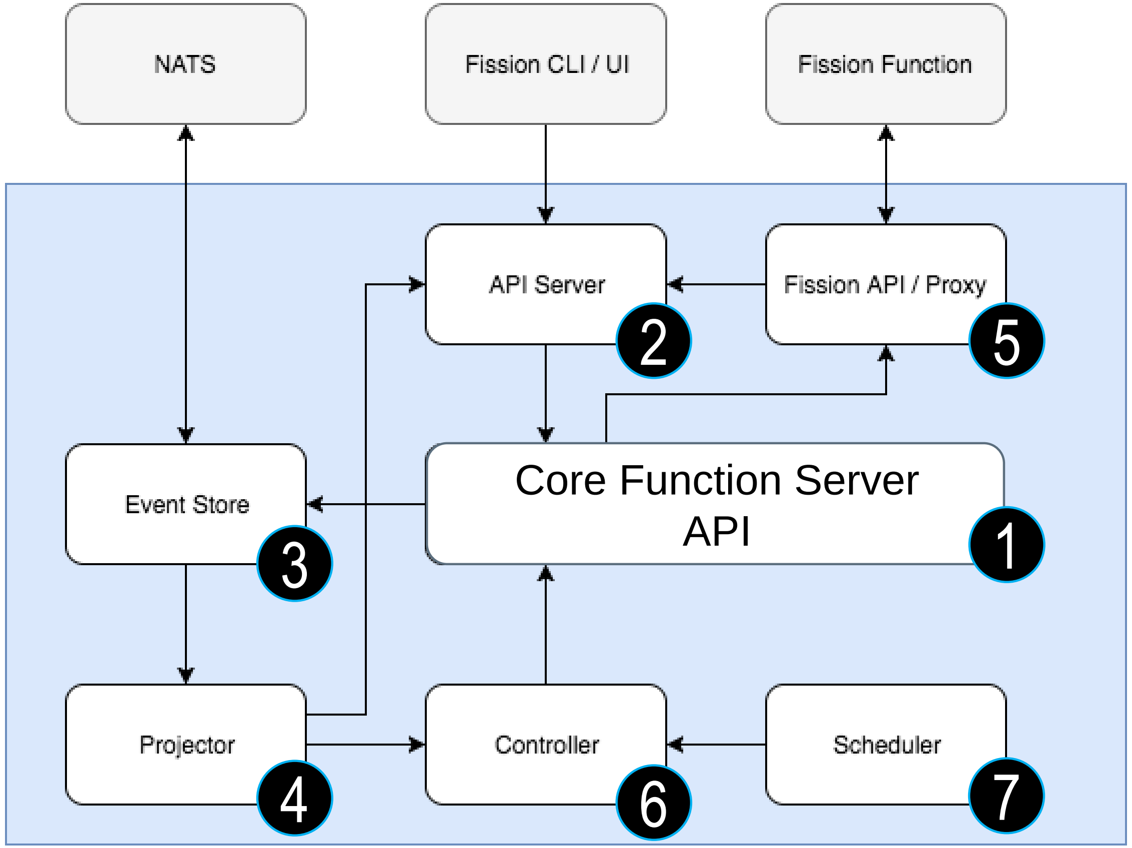
- Events update the workflow
- Store has Pub/Sub functionality
- Projector builds current state

5 Fission Proxy

- API access to Fission FaaS

6 Controller / 7 Scheduler

- Workflow manager



https://github.com/fission/fission-workflows/blob/master/Docs/architecture.md

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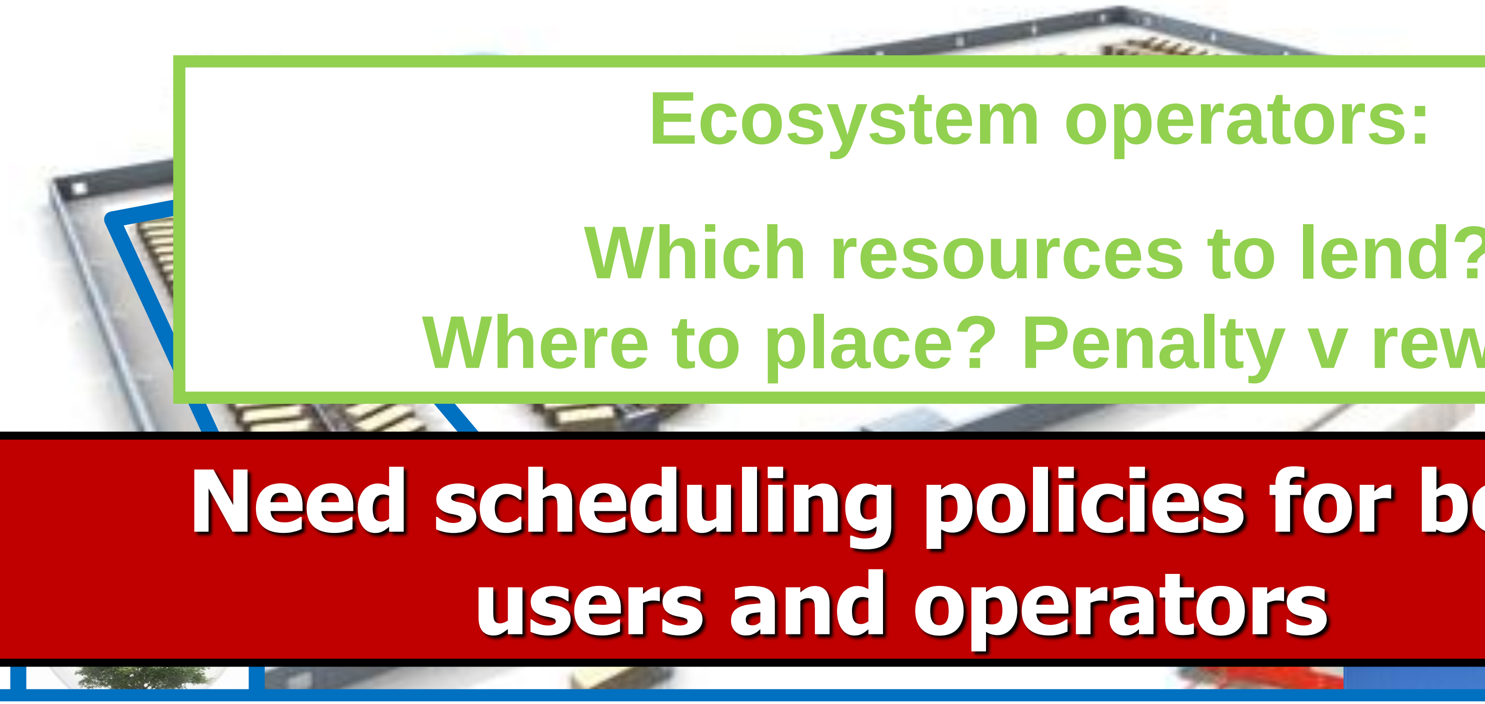
The Scheduling Challenge



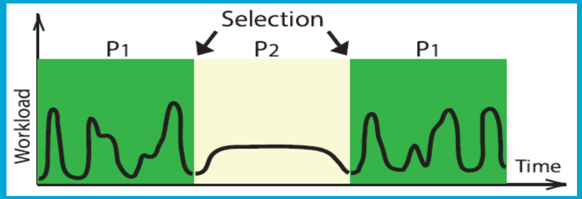
Ecosystem operators:

Which resources to lend?
Where to place? Penalty v reward?

Need scheduling policies for both users and operators

Ecosystem customers:

Which resources to lease?
When? How many? When stop?
Utility functions?



Vincent van Beek

Tim Hegeman

Jesse Donkervliet

Alexandru Iosup

Portfolio Scheduling for DCs

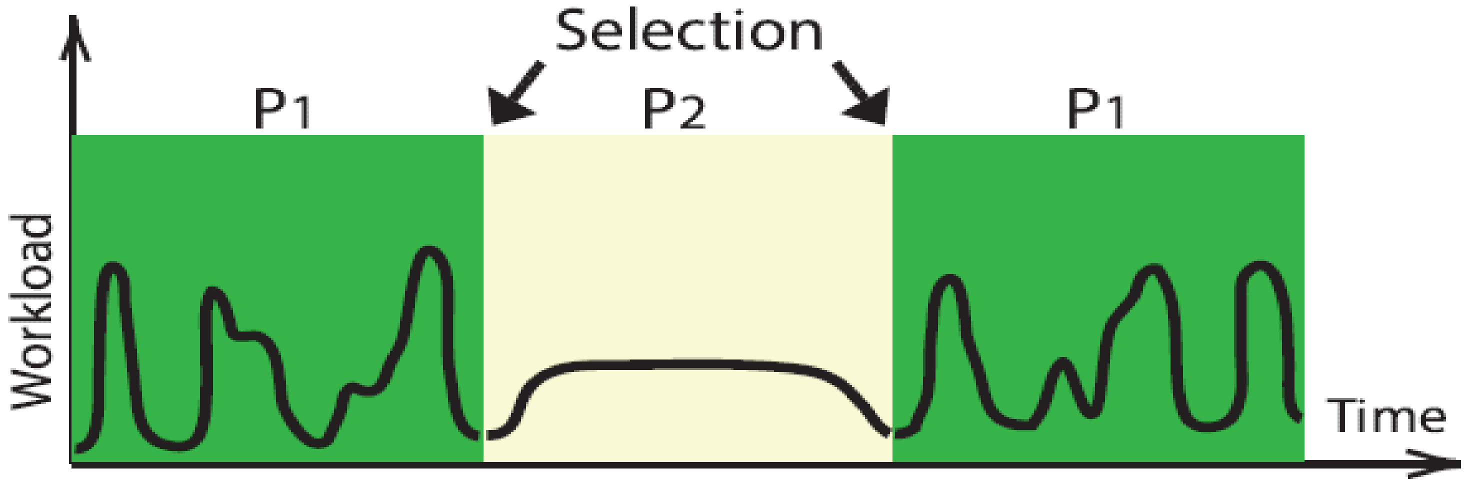
Self-Expressive Management of Business-Critical Workloads in Virtualized Datacenters

van Beek, Donkervliet, Hegeman, Hugtenburg, Iosup. Self-Expressive Management of Business-Critical Workloads in Virtualized Datacenters. IEEE Computer 48(7): 46-54 (2015)

Deng, Song, Ren, Iosup. Exploring portfolio scheduling for long-term execution of scientific workloads in IaaS clouds. SC 2013: 55:1-55:12

Portfolio Scheduling, In A Nutshell

- Datacenters cannot work without one or even several schedulers
- Instead of ephemeral, risky schedulers, we propose to



1. Create a set of schedulers (resource provisioning and allocation policies)
2. Select active scheduler online, apply for the next period, analyze results

(Repeat)

K. Deng et al. Exploring portfolio scheduling for long-term execution of scientific workloads in IaaS clouds. SC|13

Portfolio Scheduling

Portfolio Scheduling for Computer Systems

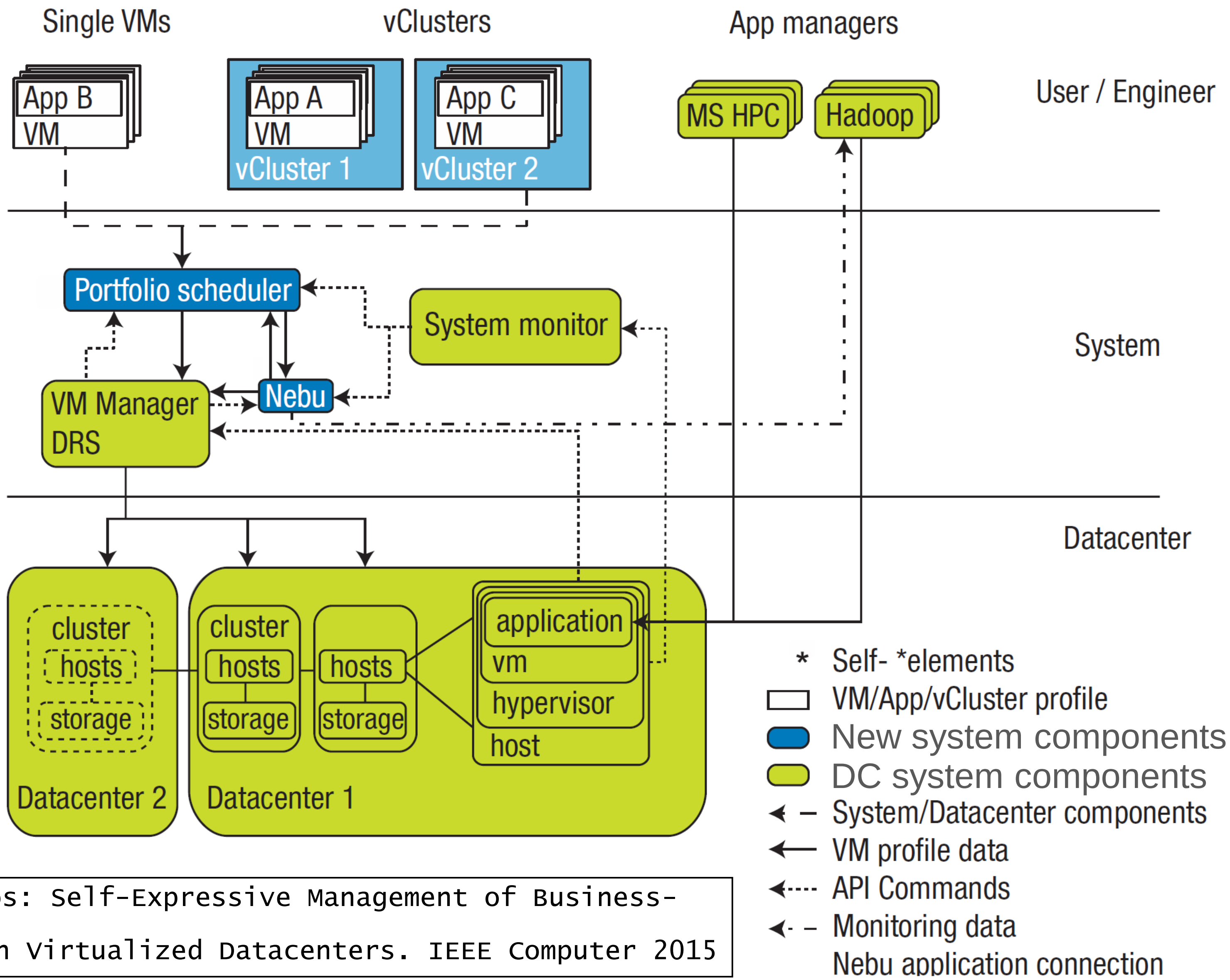
Portfolio Creation
- Configure schedulers
- 10s-100s+ schedulers

Scheduler Selection + Explanation
- Define new metrics, risk
- Consider data in the process

Application of Selected Scheduler
- Monitor system for issues

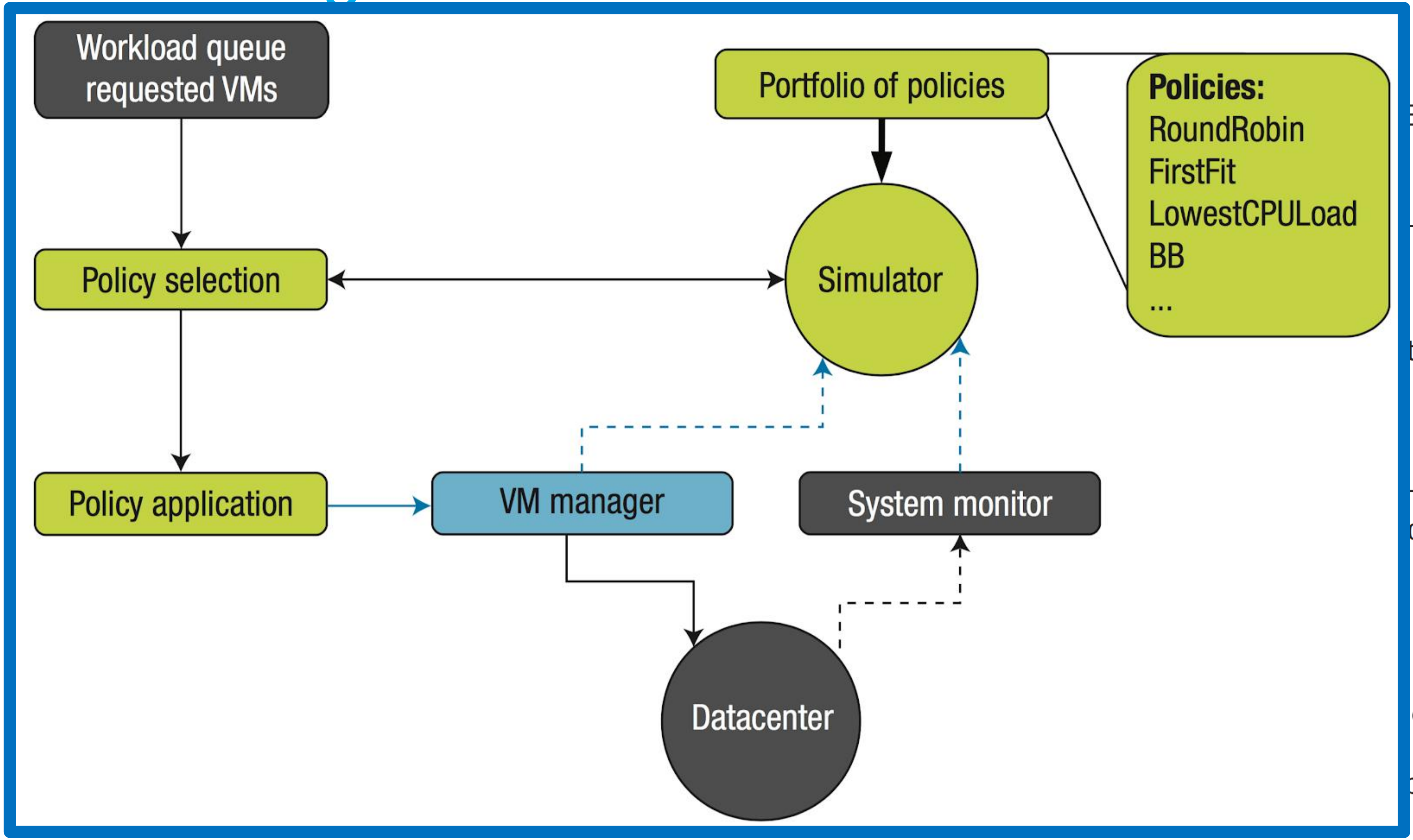
Self-Reflection on Portfolio + Scheduler
- Reflect and Adapt portfolio

Portfolio Scheduling in Datacenters



V. van Beek et al. Mnemos: Self-Expressive Management of Business-Critical Workloads in Virtualized Datacenters. IEEE Computer 2015

Portfolio Scheduling in Datacenters



V. van Beek et al. Mnemos: Self-Expressive Management of Business-Critical Workloads in Virtualized Datacenters. IEEE Computer 2015

Engineer
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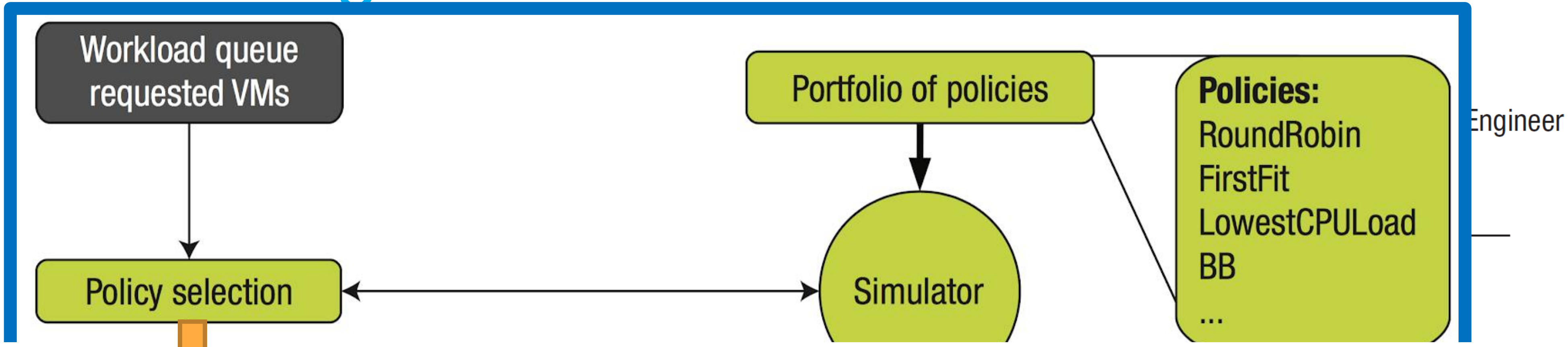
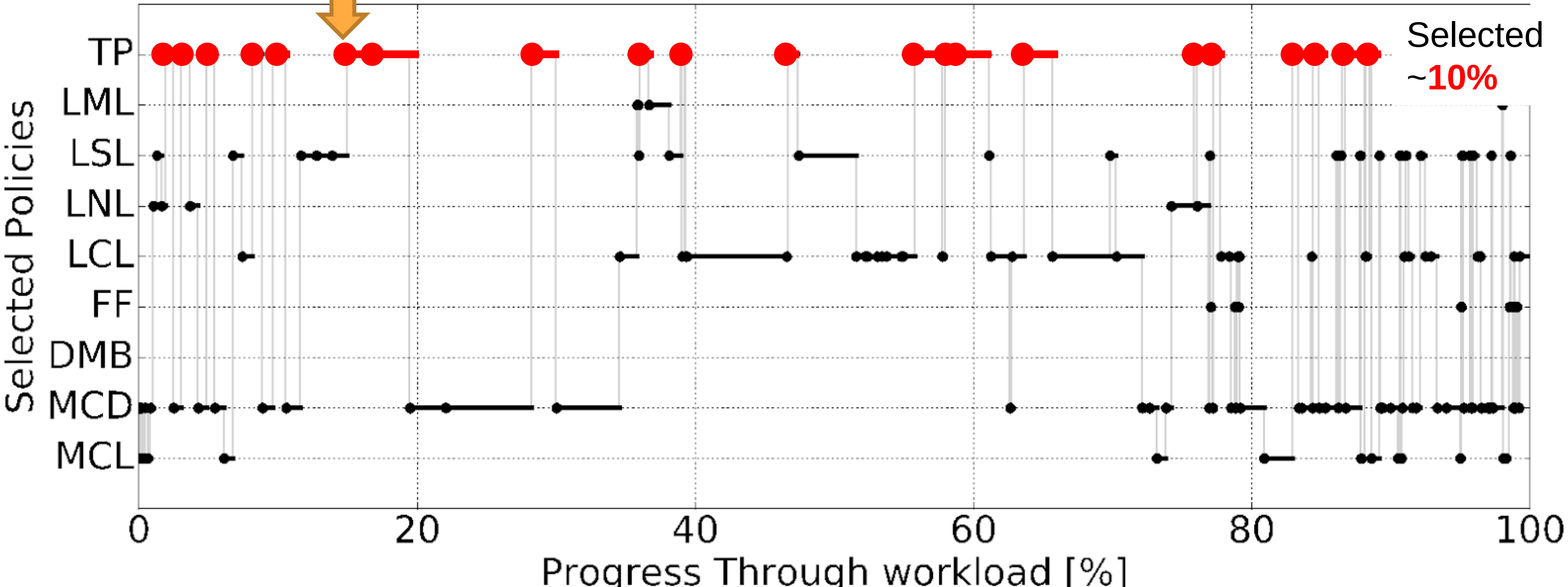
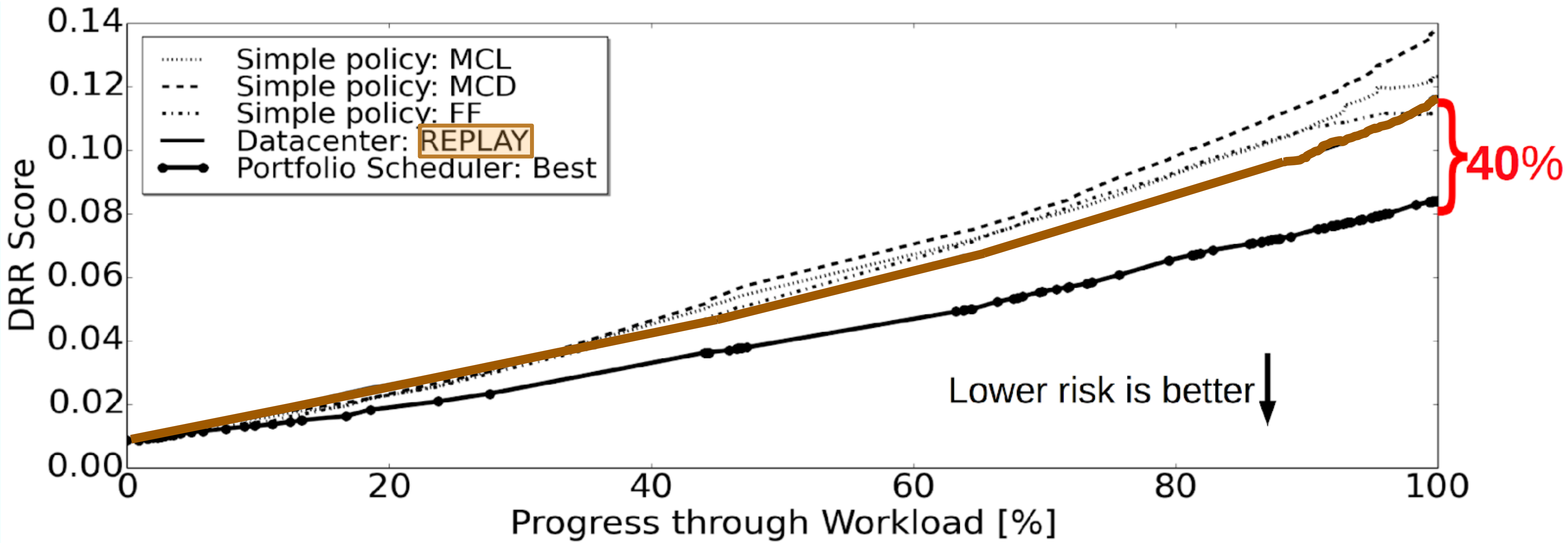
API Commands
Monitoring data
Nebu application connection

Portfolio Scheduling in Datacenters





Portfolio Scheduling in Datacenters



1. Portfolio scheduler achieves the lowest risk of all scenarios.
2. Portfolio scheduler achieves at least **35%** lower DRR compared to individual policies.
3. **40%** lower DRR than commercial production system (REPLAY).

21

Portfolio Scheduling in Datacenters

Not performance-related, but: A portfolio scheduler can explain each decision by presenting its decision data.

Q: Can our sysadmin do this? Can we? (Rhetorical)

Policy selected,
fraction of decisions

Scenario

ıents

DC

Unknown: Fundamental limitations? Use in ecosystem? User studies?

V. van Beek et al. Mnemos: Self-Expressive Management of Business-Critical Workloads in Virtualized Datacenters. IEEE Computer 2015

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- Golden Age of Distirbuted Ecosystems ... Yet a crisis Is looming
- Massivizing Computer Systems means modern distributed systems
  - Think Ecosystems
  - Methods to address key challenges in science, design, and engineering
  - Teaching facilitated by award-winning method
- Much left to do, as we are merely beginning ...
  - You can help! You can make a career, in science / industry.

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@Large Research
Massivizing Computer Systems

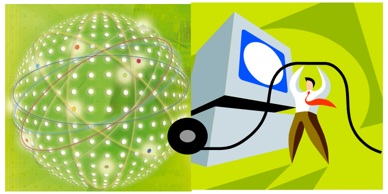
http://atlarge.science

MASSIVIZING COMPUTER SYSTEMS

FURTHER READING

1. Iosup et al. Massivizing Computer Systems. ICDCS 2018 (in print)
2. Andreadis et al. A Reference Architecture for Datacenter Scheduling: Design, Validation, and Experiments, SC18 (in print)
3. Van Eyk et al. Serverless is More: From PaaS to Present Cloud Computing, IEEE IC Sep/Oct 2018 (in print)
4. Jiang et al. Mirror: A computation-offloading framework for sophisticated mobile games, CCPE 2018 (in print)
5. Ilyushkin et al. An Experimental Performance Evaluation of Autoscaling Policies for Complex Workflows. TOMPECS 2018.
6. Iosup et al. The OpenDC Vision: Towards Collaborative Datacenter Simulation and Exploration for Everybody. ISPDC'17.
7. Iosup et al. Self-Awareness of Cloud Applications. Self-Aware Computing Systems book, 2017.
8. Iosup et al. LDBC Graphalytics: A Benchmark for Large-Scale Graph Analysis on Parallel and Distributed Platforms. PVLDB 2016.
9. Guo et al.: Design and Experimental Evaluation of Distributed Heterogeneous Graph-Processing Systems. CCGrid 2016.
10. van Beek et al.: Self-Expressive Management of Business-Critical Workloads in Virtualized Datacenters. IEEE Computer 2015.
11. Jia et al.: Socializing by Gaming: Revealing Social Relationships in Multiplayer Online Games. TKDD 2015.
12. Ghit et al. Balanced resource allocations across multiple dynamic MapReduce clusters. SIGMETRICS 2014.
13. Iosup and Epema: Grid Computing Workloads. IEEE Internet Computing 2011.
14. Iosup et al.: On the Performance Variability of Production Cloud Services. CCGRID 2011.
15. Iosup et al.: Performance Analysis of Cloud Computing Services for Many-Tasks Scientific Computing. IEEE TPDS 2011.

Contact Me or Our Team



Collaboration or discussion about Massivizing Computer Systems:

Understanding, designing, deploying, tuning, analyzing, benchmarking distributed systems and ecosystems, including cloud computing and big data systems. Other topics in large-scale distributed systems and performance engineering are welcome.

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The Netherlands

VU VRIJE UNIVERSITEIT AMSTERDAM

VISION: WHAT DOES OUR SOCIETY NEED?

ISN'T THIS ALREADY HAPPENING?

"A world where individuals and human-centered organizations are augmented by an automated, sustainable layer of technology. At the core of this technology is ICT, and at the core of ICT are computer ecosystems, interoperating and performing as utilities and services, under human guidance and control."

- People, good orgs = **ICT clients**:
  - Fundamental right to ICT
  - Understanding
- **ICT professionals**:
  - Understand and Create
  - Experiment and Operate
- **ICT = ecosystems**:
  - Utilities and services
  - Automated
  - Efficient
  - Controlled
  - Ecosystems
  - Human-guided

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Iosup et al., Massivizing Computer Systems, ICDCS 2018. [Online]

THE CRISIS: IN THIS DIGITAL ECONOMY, FEW CAN BE SUCCESSFUL!

THE COMPLEXITY CHALLENGE

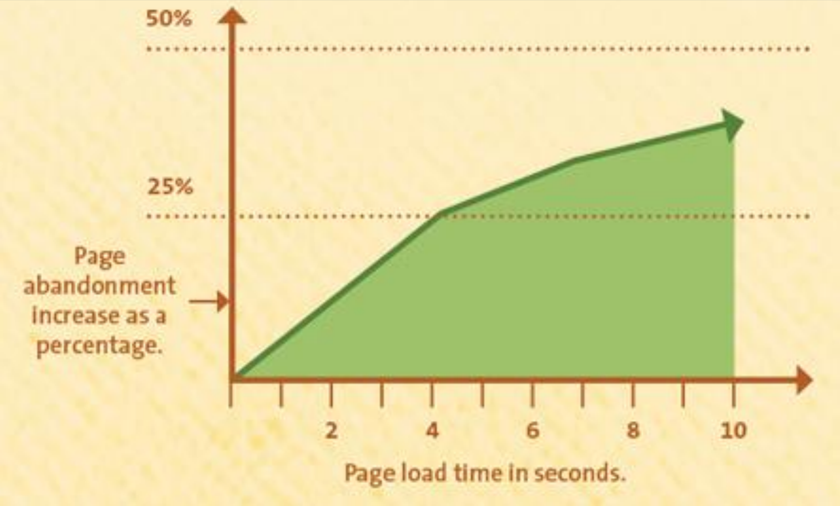
1. We Build and Test
Isolated Computer Systems
(or Silos, or Narrow Stacks), Yet
Everything Works in Ecosystems

<<1% OF BIG DATA
BY MATT TURK (2017)

THE CRISIS: IN THIS DIGITAL ECONOMY, FEW CAN BE SUCCESSFUL!

PERFORMANCE, DEPENDABILITY, AND OTHER NON-FUNCTIONAL CHALLENGES

2. We Cannot Even Maintain the Ecosystems we Have Built (and Tested, and Validated)



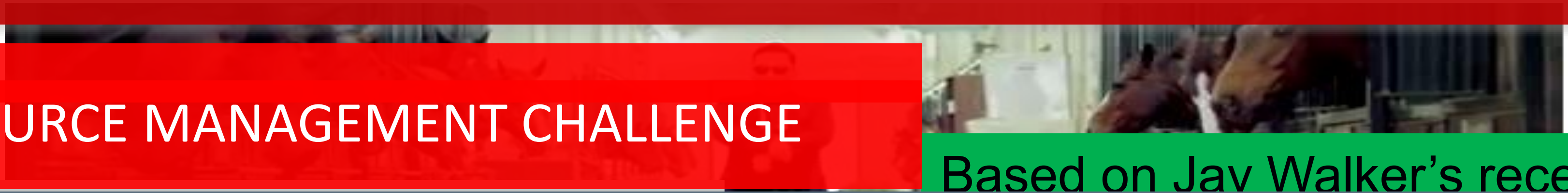
Google goes dark for 2 minutes, kills 40% of world's net traffic www.theregister.co.uk/2013/08/17/google_outage/

Systemwide outage knocks every service offline

Sources: https://www.fastcompany.com/1825005/how-one-second-could-cost-amazon-16-billion-sales

THE CRISIS: IN THIS DIGITAL ECONOMY, FEW CAN BE SUCCESSFUL!

THE RESOURCE MANAGEMENT CHALLENGE



Based on Jay Walker's recent TED talk.

3. Need To Be Much More Efficient,

4. Need to Also Be Ethical, and to Also Educate Our Customers

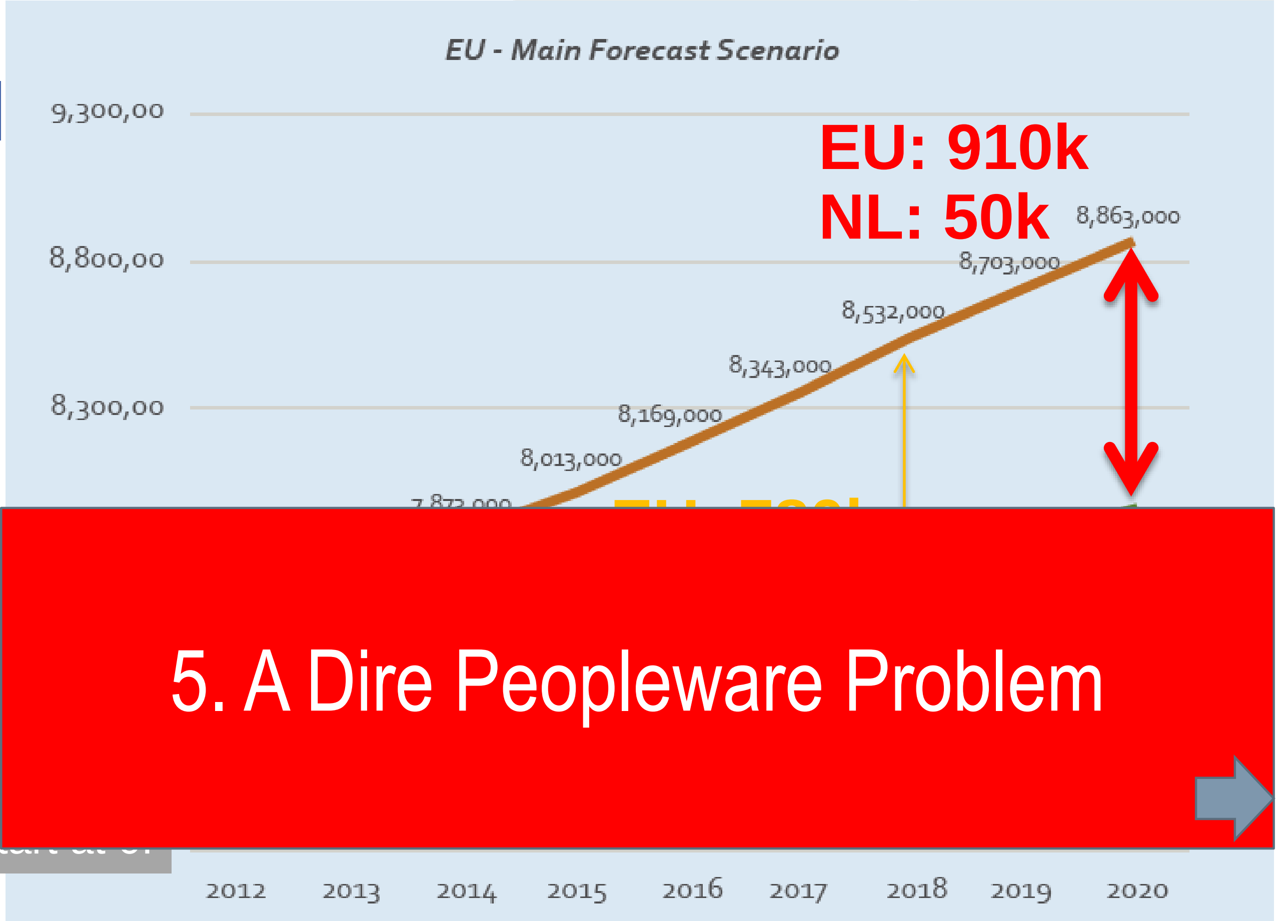
PSY Gangnam consumed ~500GWh

= more than entire countries* in a year (*41 countries),
= over 50MW of 24/7/365 diesel, 135M liters of oil,
= 100,000 cars running for a year, ...

Source: Ian Bitterlin and Jon Summers, UoL, UK, Jul 2013.
Note: Psy has >3.5 billion views (last update, May 2018).

THE CRISIS: IN THIS DIGITAL ECONOMY, FEW CAN BE SUCCESSFUL!

THE WORKFORCE GAP, IN THE NETHERLANDS & IN EUROPE



Source: e-Skills for Jobs in Europe, 2014

5. A Dire Peopleware Problem

MEANINGFUL DISCOVERY

UNCOVERING THE MYSTERIES OF OUR UNIVERSE

GALILEO GALILEI, 1608-9, 3-8X TELESCOPE

MERELY AN INSTRUMENT?

FUNDAMENTAL SCIENCE?

Garney. The Inquisition's Semicolon: Punctuation, Translation, and Science in the 1616 Condemnation of the Copernican System, ArXiv document 1402.6168. [Online]

Phil Diamond and Rosie Bolton, Life, the Universe & Computing: The story of the SKA Telescope, SC17 Keynote. [Online]

MEANINGFUL DISCOVERY

UNCOVERING THE MYSTERIES OF OUR UNIVERSE

400 YEARS LATER, SYSTEMATIC SURVEY

Radio Microwave Infrared Visible Ultraviolet X-Ray Gamma Ray

Phil Diamond and Rosie Bolton, Life, the Universe & Computing: The story of the SKA Telescope, SC17 Keynote. [Online]

MEANINGFUL DISCOVERY

UNCOVERING THE MYSTERIES OF OUR UNIVERSE

GEORGE SMOOT
NOBEL PRIZE 2006

SKA FUNDING: 500+ FTE, EUR 1.5B

James Cordes, The Square Kilometer Array, Project Description, 2009 [Online]
The Square Kilometer Array Factsheet, How much will it cost?, 2012 [Online]
Phil Diamond and Rosie Bolton, Life, the Universe & Computing: The story of the SKA Telescope, SC17 Keynote. [Online]

MEANINGFUL DISCOVERY

UNCOVERING THE MYSTERIES OF OUR UNIVERSE, PHYSICAL AND DIGITAL

Radio	Microwave	Infrared	Visible	Ultraviolet	X-Ray	Gamma Ray
Cloud, Grid, Edge, Fog, etc.	Big Data	Sci.&Eng. Apps	Consumer Apps	Enterprise Apps	Systems, Ecosystems	Performance, Security, etc.

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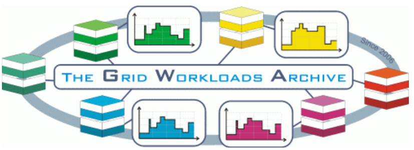
MEANINGFUL DISCOVERY

UNCOVERING THE MYSTERIES OF OUR UNIVERSE, PHYSICAL AND DIGITAL

Radio	Microwave	Infrared	Visible	Ultraviolet	X-Ray	Gamma Ray
Cloud, Grid, Edge, Fog, etc.	One aspect: BigData, P2P	Sci.&Eng. Apps+Sys.	Consumer Apps+Sys.	Enterprise Sys.	Systems, Ecosystems	Performance, Availability, etc.



[Iosup et al. FGCS'08]

P2P T.A.

[Zhang et al. CoNext'10]

BoTs, Groups, Workflows

[Iosup et al. IEEE IC'11]

Game Trace Archive

[Guo et al. NETGAMES'12]

Business-Critical

[Shen et al. CCGRID'15]

[Ghiț et al. CCGRID'14]

[Iosup et al. CCGRID'10]

MEANINGFUL DISCOVERY

UNCOVERING THE MYSTERIES OF OUR UNIVERSE, PHYSICAL AND DIGITAL

BUT … WHY WOULD YOU NEED TO UNCOVER AN ARTIFICIAL UNIVERSE?! YOU BUILT IT!

Cloud, Grid, Edge, Fog, etc.

[Iosup et al. FGCS'08]

One aspect: BigData, P2P

P2P T.A.

[Zhang et al. CoNext'10]

Sci.&Eng. Apps+Sys.

BoTs, Groups, Workflows

[Iosup et al. IEEE IC'11]

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Enterprise Sys.

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[Ghiț et al. CCGRID'14]

Performance, Availability, etc.

[Iosup et al. CCGRID'10]

MEANINGFUL DISCOVERY

UNCOVERING THE MYSTERIES OF OUR UNIVERSE, PHYSICAL AND DIGITAL

FOUND MANY UNFORESEEN PHENOMENA: INTERACTION, ADAPTATION, EXAPTATION, …

…

…

…

…

…

BOTS, NOT PARALLEL JOBS

Cloud, Grid, Edge, Fog, etc.

[Iosup et al. FGCS'08]

GROUPS NOT RARE, DOMINANT

One aspect: BigData, P2P

P2P T.A.

[Zhang et al. CoNext'10]

Sci.&Eng. Apps+Sys.

BoTs, Groups, Workflows

[Iosup et al. IEEE IC'11]

COMMUNITY FORMATION

Consumer Apps+Sys.

Game Trace Archive

[Guo et al. NETGAMES'12]

SYSTEMIC VARIABILITY

Enterprise Sys.

Business -Critical

[Shen et al. CCGRID'15]

Systems, Ecosystems

[Ghiț et al. CCGRID'14]

CORRELATED, NOT IID FAILURES

Performance, Availability, etc.

[Iosup et al. CCGRID'10]

MEANINGFUL DISCOVERY

UNCOVERING THE MYSTERIES OF OUR UNIVERSE, PHYSICAL AND DIGITAL

FOUND MANY UNFORESEEN PHENOMENA: INTERACTION, ADAPTATION, EXAPTATION, …

BUT … IS THERE A SYSTEMATIC WAY TO APPROACH THESE PHENOMENA?

BOTS, NOT PARALLEL JOBS	GROUPS NOT RARE, DOMINANT	COMMUNITY FORMATION	SYSTEMIC VARIABILITY	CORRELATED, NOT IID FAILURES

Cloud, Grid, Edge, Fog, etc. | One aspect: BigData, P2P | Sci.&Eng. Apps+Sys. | Consumer Apps+Sys. | Enterprise Sys. | Systems, Ecosystems | Performance, Availability, etc.

[Iosup et al. FGCS’08]

P2P T.A.

[Zhang et al. CoNext’10]

BoTs, Groups, Workflows

[Iosup et al. IEEE IC’11]

Game Trace Archive

[Guo et al. NETGAMES’12]

Business -Critical

[Shen et al. CCGRID’15]

[Ghiț et al. CCGRID’14]

[Iosup et al. CCGRID’10]

MEANINGFUL DISCOVERY

BUT … IS THERE A SYSTEMATIC WAY TO APPROACH THESE PHENOMENA?

FUNDING: > 3B USD

- The Human Genome Project:
  - > Physical map covering >90% human genome
  - > Sequence data made available open-access
- Big Science:
  - > Took >10 years to complete
  - > Led by US, work by 20 groups in CN, DE, FR, JP, UK, US
- Big impact:
  - > Decrease cost of sequencing
  - > Facilitate biomedical research

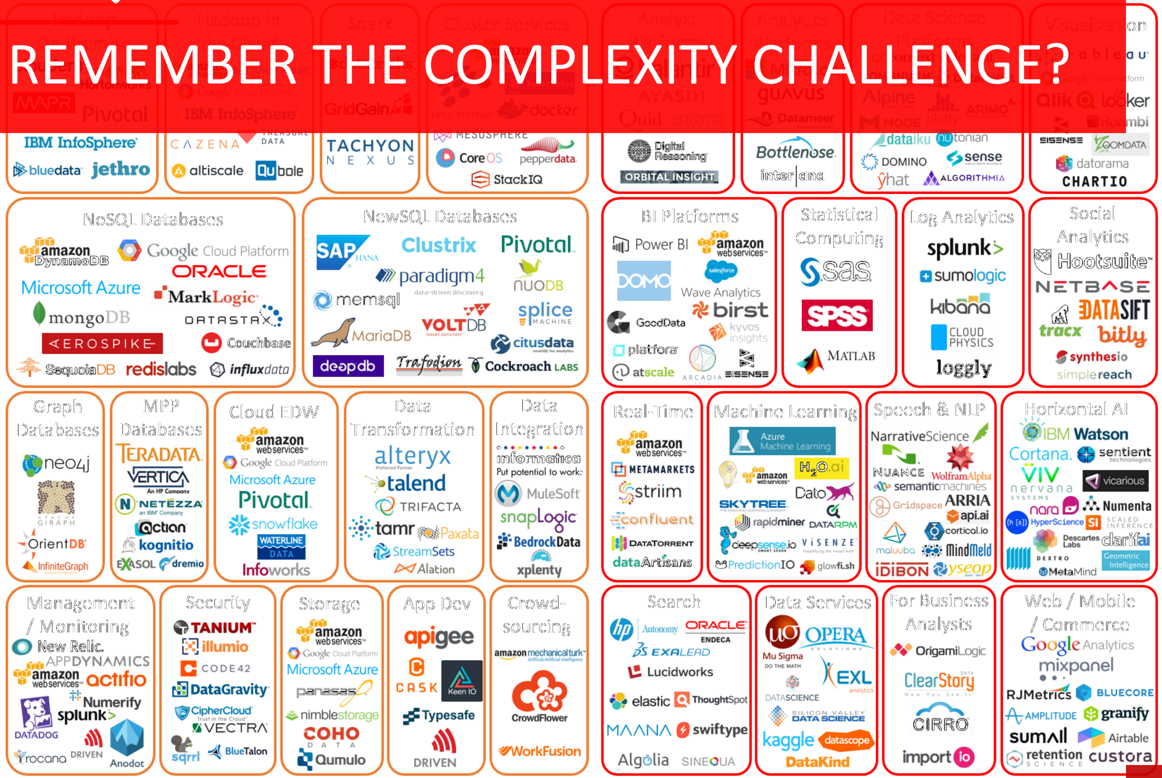
International Human Genome Sequencing Consortium, Initial sequencing and analysis of the human genome, Nature 409, Feb 2011. [Online]

Julie Gould, The Impact of the Human Genome Project, Naturejobs blog, 2015. [Online]

MEANINGFUL DISCOVERY

BUT … IS THERE A SYSTEMATIC WAY TO APPROACH THESE PHENOMENA?

REMEMBER THE COMPLEXITY CHALLENGE?



<<1% OF BIG DATA
BY MATT TURK (2017)

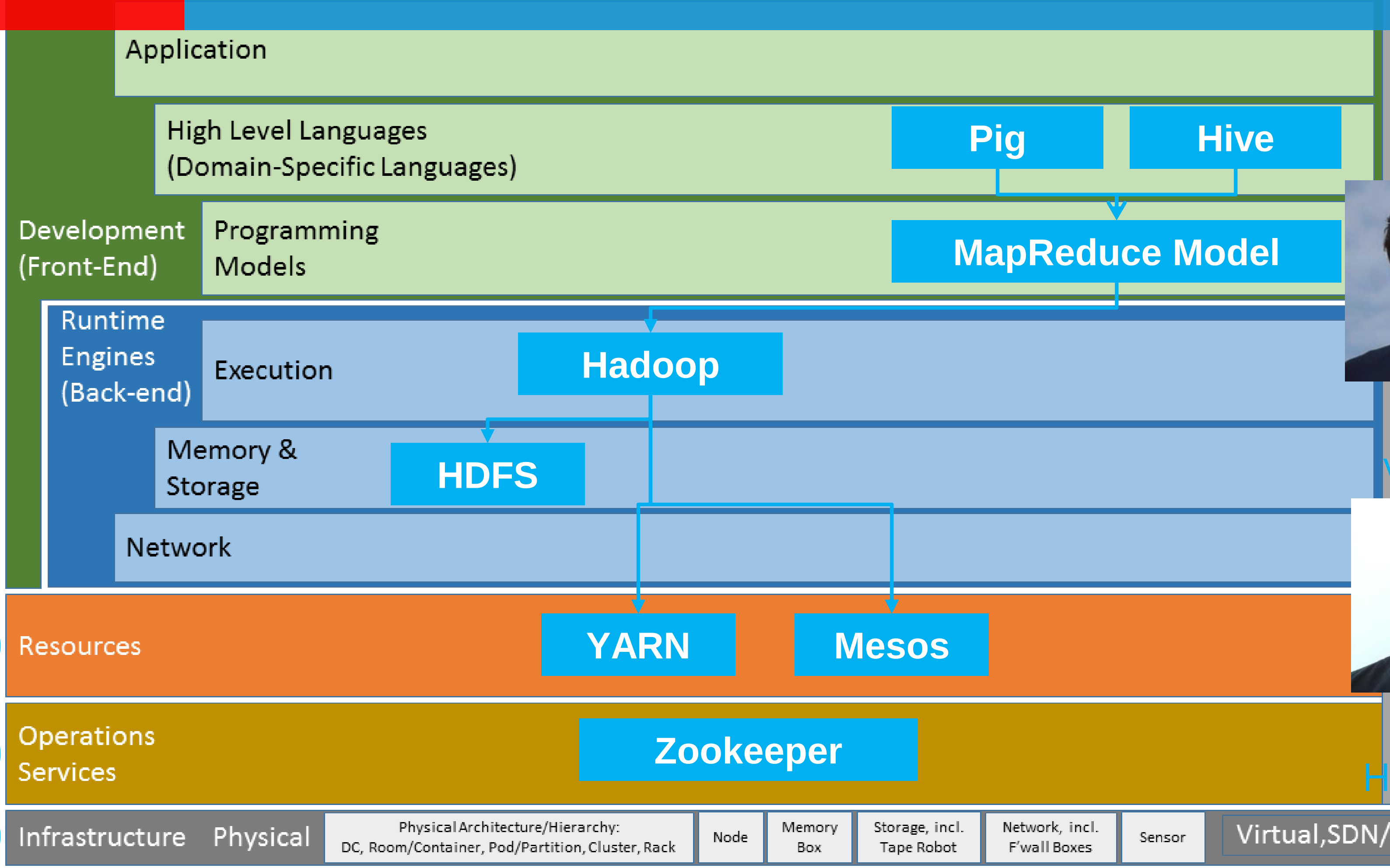
MEANINGFUL DISCOVERY

THE COMPLEXITY CHALLENGE

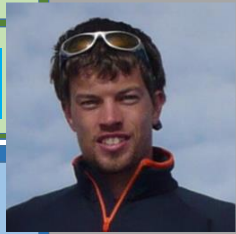
IOSUP ET AL. REFERENCE ARCHITECTURE FOR DCS

Focus on Applications,
5 Core Layers:

5. Development (Front-end)
4. Runtime Engines (Back-end)
3. Resources
2. Operations Services
1. Infrastructure



2-5'



Vincent van Beek

Tim Hegeman

[Iosup et al. ICDCS'18]

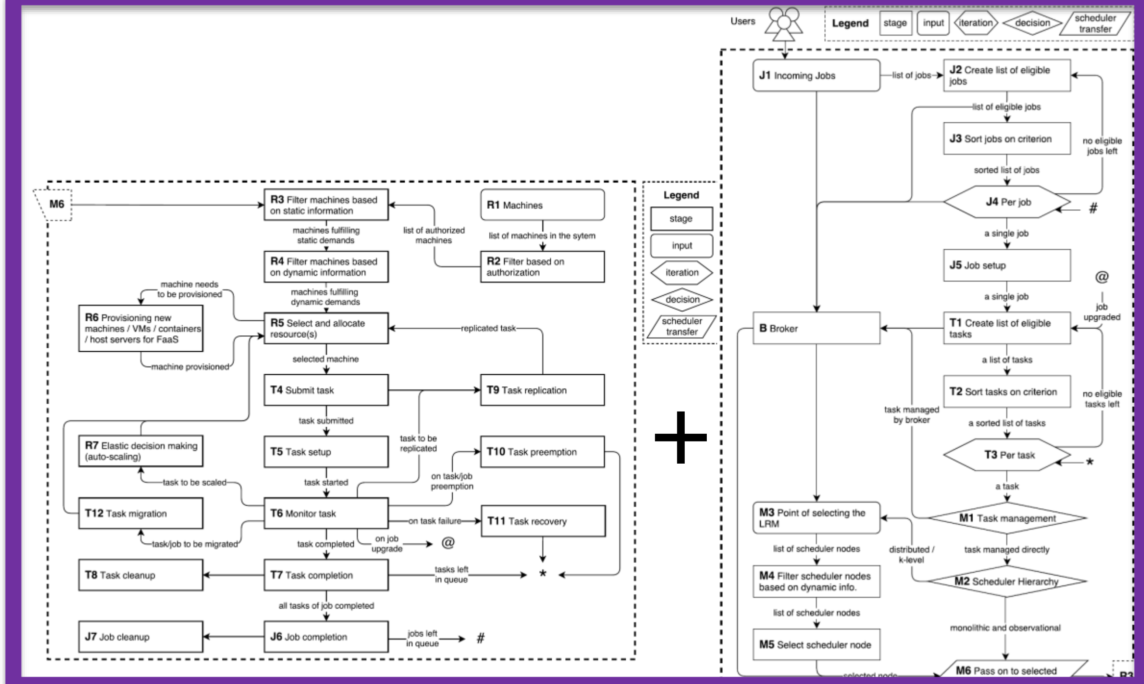
MEANINGFUL DISCOVERY

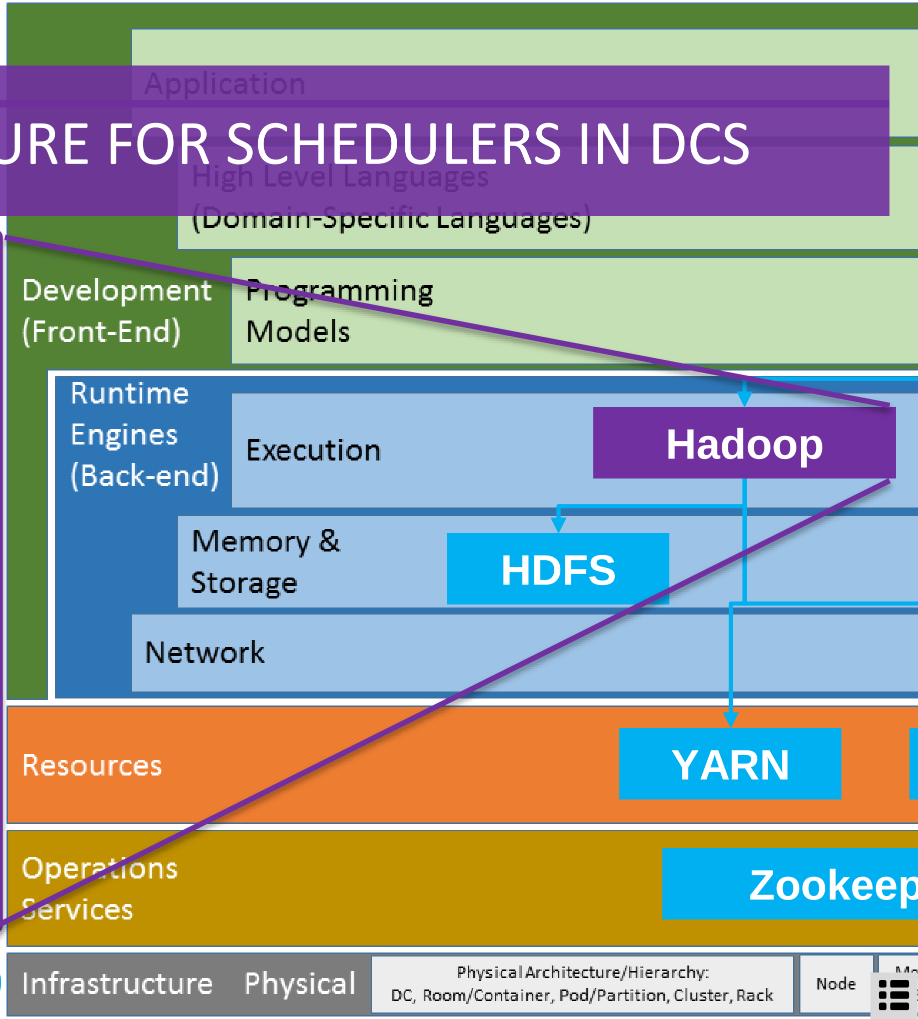
THE COMPLEXITY CHALLENGE

IOSUP ET AL. REFERENCE ARCHITECTURE FOR DCS

ANDREADIS ET AL. REFERENCE ARCHITECTURE FOR SCHEDULERS IN DCS

Georgios Andreadis

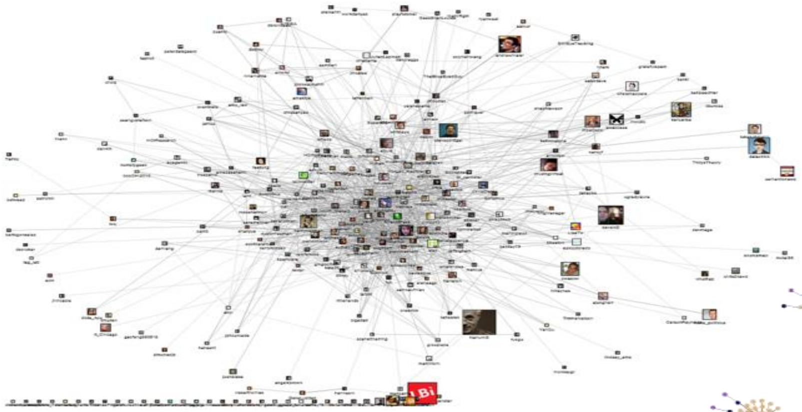




[Andreadis et al. SC'18]

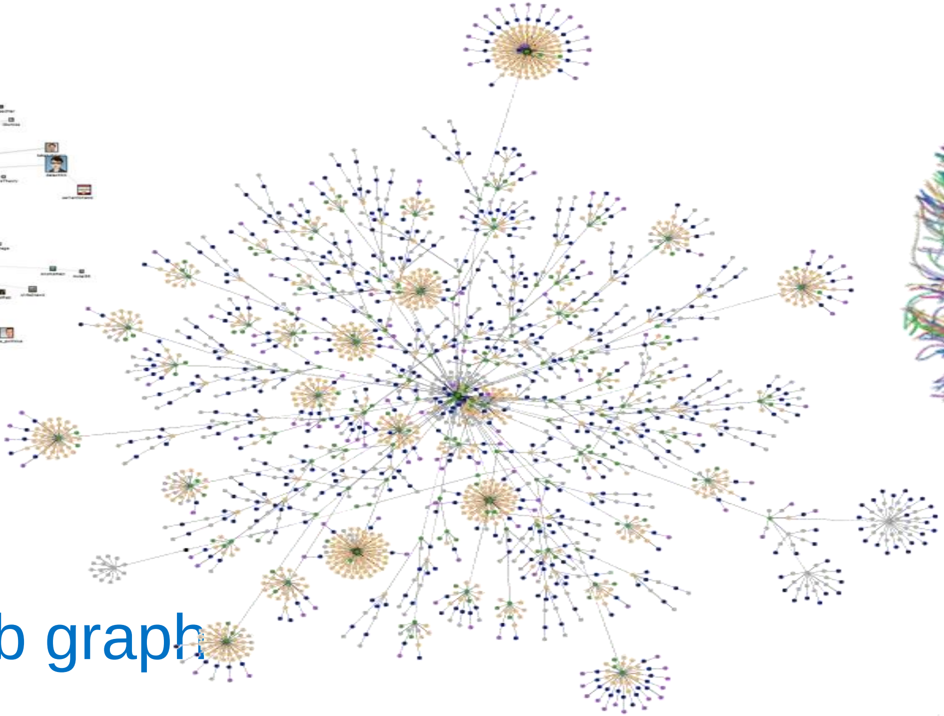
MEANINGFUL DISCOVERY

ENGINEERING LDBC GRAPHALYTICS: THE NEED FOR SPEED … & GRAPHS!



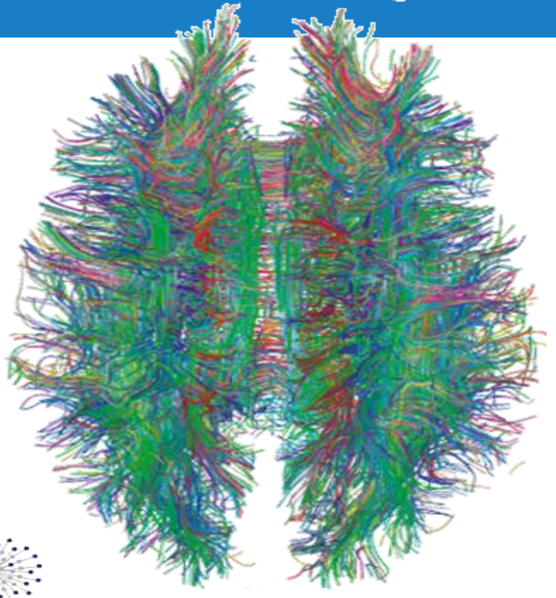
Social network

~1 billion vertices
~100 billion connections



Web graph

~50 billion pages
~1 trillion hyperlinks



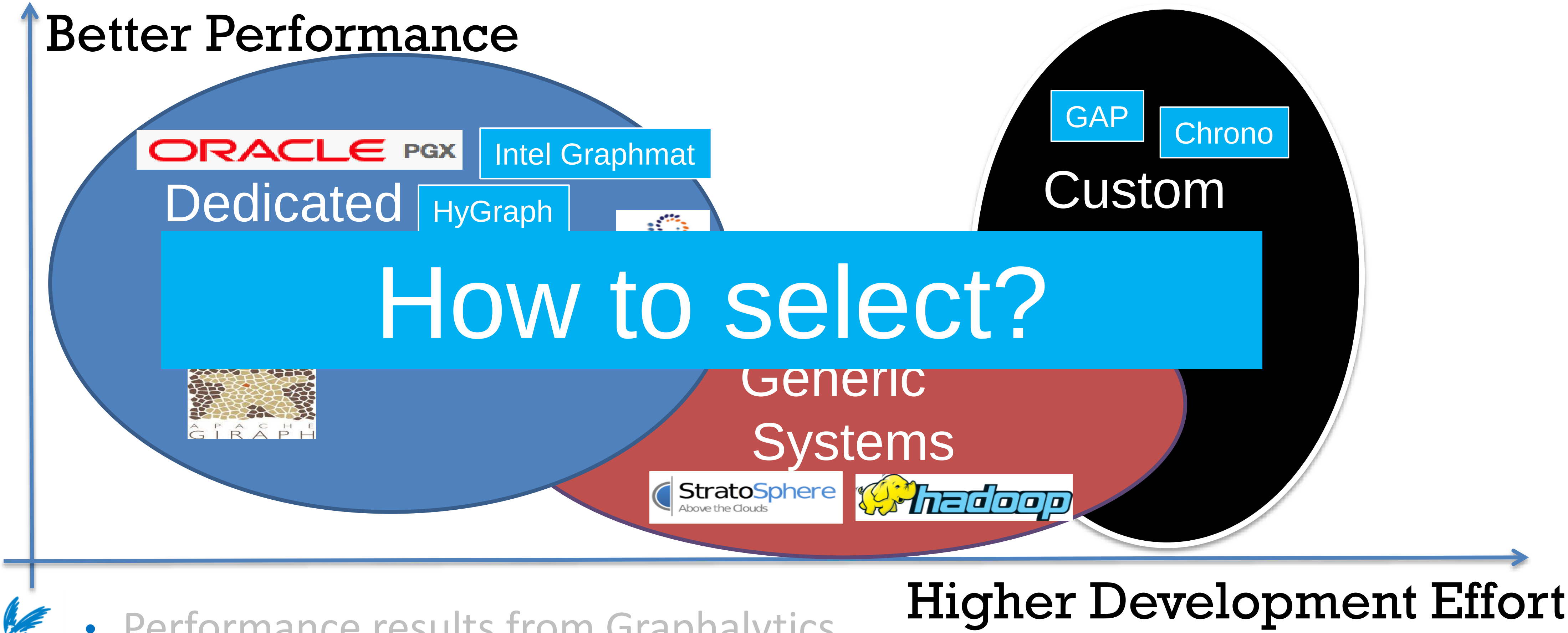
Brain network

~100 billion neurons
~100 trillion connections

Sources: Smith, CHI’10; Blog webpage; Gigandet et al., PLoS ONE 3(12)]

MEANINGFUL DISCOVERY

ENGINEERING LDBC GRAPHALYTICS: THE SYSTEMS LANDSCAPE



- Performance results from Graphalytics

MEANINGFUL DISCOVERY

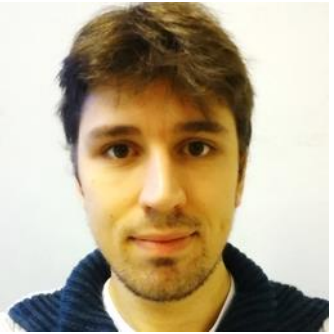
ENGINEERING LDBC GRAPHALYTICS: BENCHMARKING LEADING TO SCIENCE

LDBC *The graph & RDF benchmark reference*

- Graphalytics:
  - > Benchmark
  - > Many classes of algorithms used in practice
  - > Diverse real and synthetic datasets
  - > Diverse experiments, representative for practice
  - > Renewal process to keep the workload relevant
  - > Enables comparison of many platforms, community-driven and industrial
  - > Global Competition

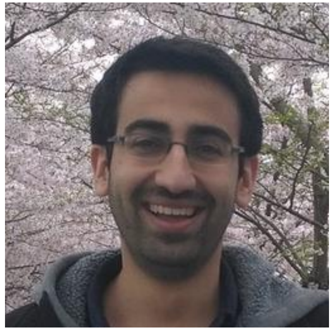
Wing Lung Ngai

Tim Hegeman

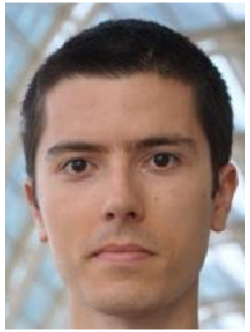


Stijn Heldens

Alex Uță



Ahmed Musaafir



Mihai Capotã

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[Iosup et al. PVLDB'16] [Guo et al. CCGRID'15] [Guo et al. IPDPS'14]

MEANINGFUL DISCOVERY

ENGINEERING LDBC GRAPHALYTICS: BENCHMARKING LEADING TO SCIENCE

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  - > Many classes of algorithms used in practice
  - > Diverse real and synthetic datasets
  - > Diverse experiments, representative for practice
  - > Renewal process to keep the workload relevant
  - > Enables comparison of many platforms, community-driven and industrial
  - > Global Competition

- Community endorsed:

graphalytics.org

- Surprising findings:

Performance: orders of magnitude difference due to each of platform, algorithm, dataset, and hardware

- Triggered new research

[Iosup et al. PVLDB'16] [Guo et al. CCGRID'15] [Guo et al. IPDPS'14]

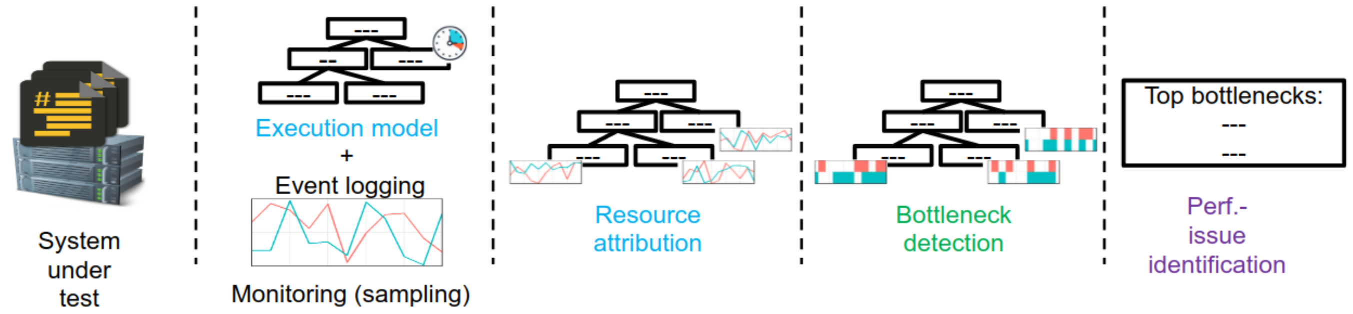
MEANINGFUL DISCOVERY

ENGINEERING LDBC GRAPHALYTICS: MODELING LEADS TO PERFORMANCE ANALYSIS

LDBC *The graph & RDF benchmark reference*

- Graphalytics Grade10:
  > Automated bottleneck detection
  > Automated identification of performance issues

Tim Hegeman



Multi-stage process, works in ecosystem

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MEANINGFUL DISCOVERY

ENGINEERING LDBC GRAPHALYTICS: MODELING LEADS TO PERFORMANCE ANALYSIS

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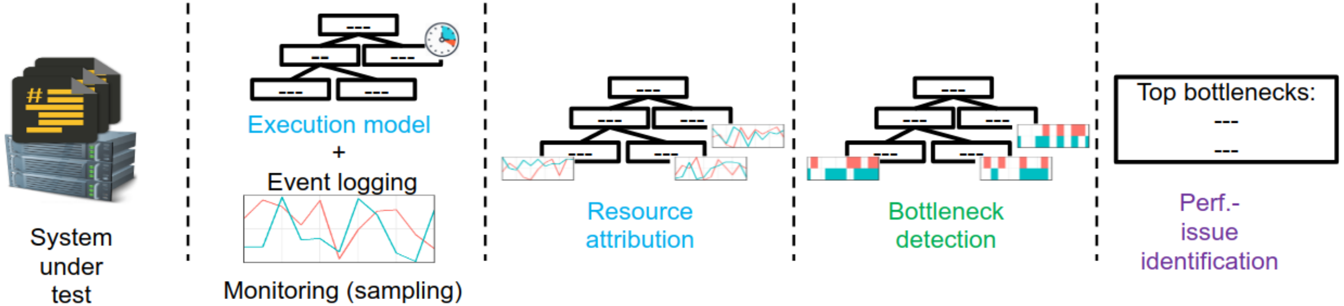


Multi-stage process, works in ecosystem

APACHE GIRAPH

- Without Grade10:

No bottleneck at all

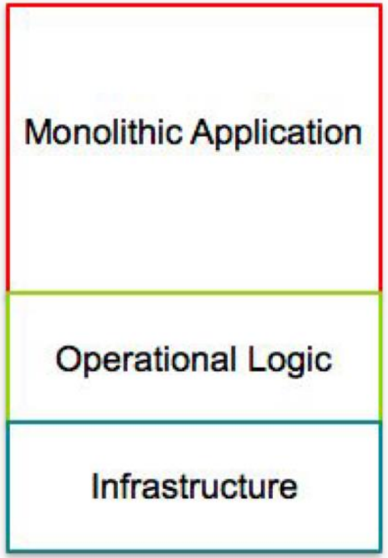
- With Grade10:

Always bottleneck
Cause:
+ Message queue full
+ Garbage collector
+ CPU
+ Others

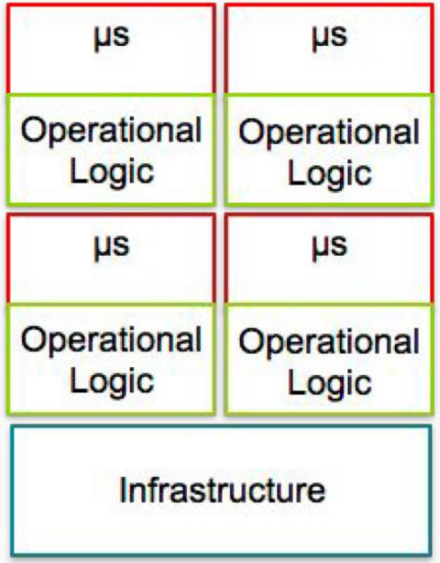
MEANINGFUL DISCOVERY

DESIGNING SERVERLESS ARCHITECTURES

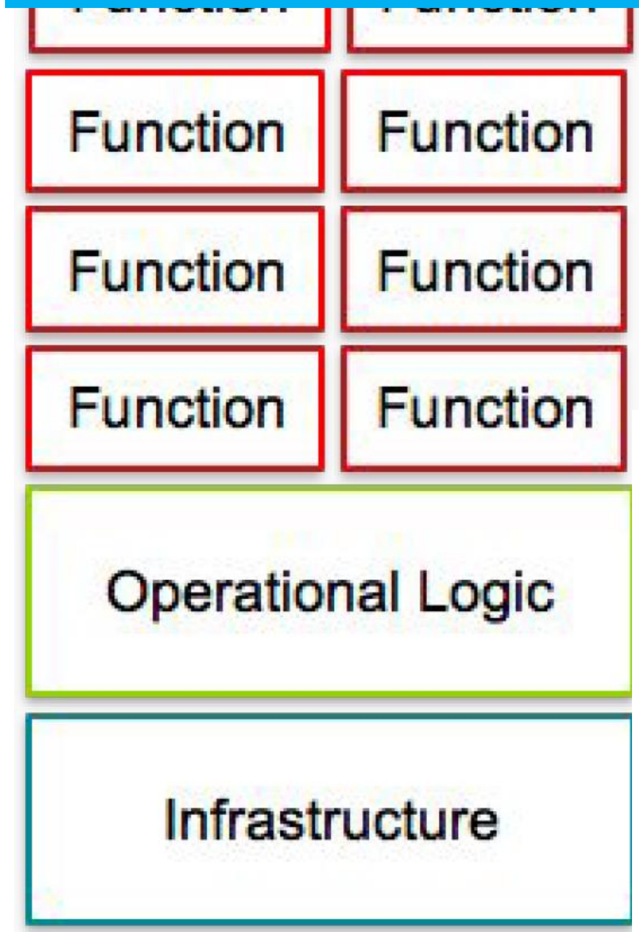
Abstraction: Serverless
Design: FaaS systems



Difficult to Scale
Infrequent, Inflexible
Complex deployment
Tightly coupled stack



- Scalable
- Frequent, Flexible
- Complexity: from application logic to operational logic



Erwin van Eyk

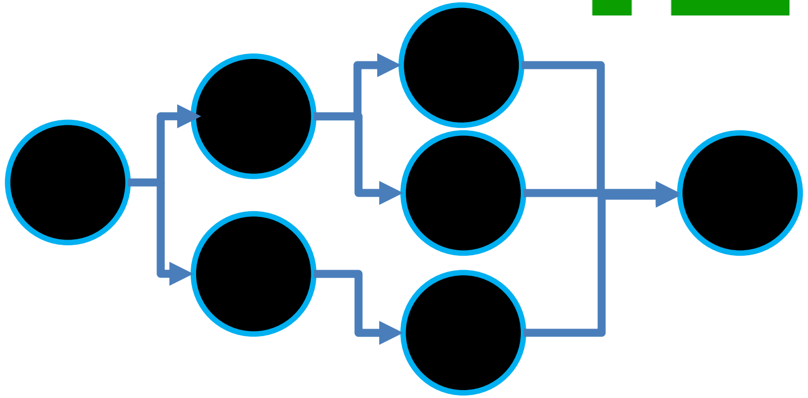
Lucian Toader

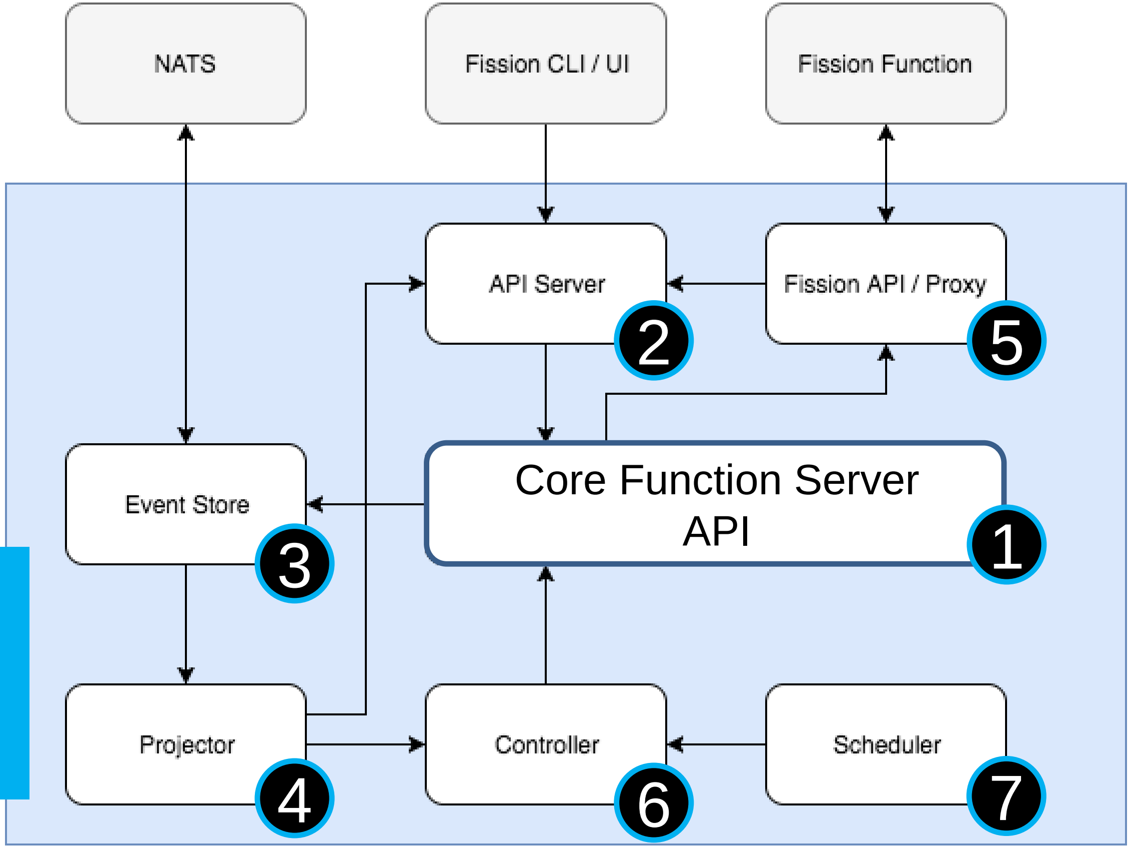
- Scalable
- Frequent, Flexible
- Explicit separation of Business Logic vs. Operational Logic.
- Minimal layer coupling, unit of deployment

MEANINGFUL DISCOVERY

DESIGNING SERVERLESS ARCHITECTURES

Erwin
van Eyk





The workflow management engine, part of the Serverless ecosystem at Fission.io

https://github.com/fission/fission-workflows/blob/master/Docs/architecture.md