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Reliability in Cloud Computing: Issues and Challenges

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JEC-ECC 2015

E-JUST KYUSHU UNIVERSITY isee Information Science and Electrical Engineering Kyushu University

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About UWS

- One of the largest universities in Australia
- Largest undergraduate commonwealth funded university
- Over 42,000 students
- Culturally diverse student body
- ‘Bringing knowledge to life’
- Multi-campus structure


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Our Proud History
A young university with a long tradition of higher education
1891
1972
1989
2006
2014
Hawkesbury campus established
Former Australian Prime Minister Gough Whitlam announces a university in western Sydney
University of Western Sydney established
UWSCollege established
UWS celebrates 25 years
Bringing knowledge to life for over 200 years

UWS Campuses

Partner Institutions

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- Over 104 existing international partners in 31 countries
- Collaborative agreements
- Research
- Exchange – including students and staff
- Academic cooperation
- Guaranteed admissions and articulation
- Offshore delivery

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Partner Institutions

Research in School

Research Centre

- Centre for Research in Mathematics (CRM)

Three University Research Groups

- Artificial Intelligence Research Group (AI)
- Digital Humanities Research Group (DH)
- Solar Energy Technologies Research Group (SET)

School Groups

- *Networking, Security an Cloud Research Group (NSCR)*
- E-Health Research Group
- Computational Astrophysics

OUTLINE

- Introduction and Background
- Reliability in Cloud: Definition
- Failure Correlation
- Case Study: Failure-aware Hybrid Cloud Architecture
- Results
- Conclusions
- Issue, Challenges and Open Questions

CLOUD COMPUTING: OLD OR NEW?

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- In 1969, Leonard Kleinrock, one of the chief scientists of the original ARPA project which seeded the Internet, wrote:
  - "As of now, computer networks are still in their infancy, but as they grow up and become sophisticated, we will probably see the spread of "computer utilities", which, like present electric and telephone utilities, will service individual homes and offices across the country".

What is Cloud Computing

- Having a Car ?
  - Buying a Car
    - Pay the initial cost
    - Pay the insurance cost
    - Pay the maintenance cost
  - Renting a Car
    - Pay-as-you-go

Classical Computing

BUSINESS MODEL

Cloud Computing

WHAT IS CLOUD COMPUTING

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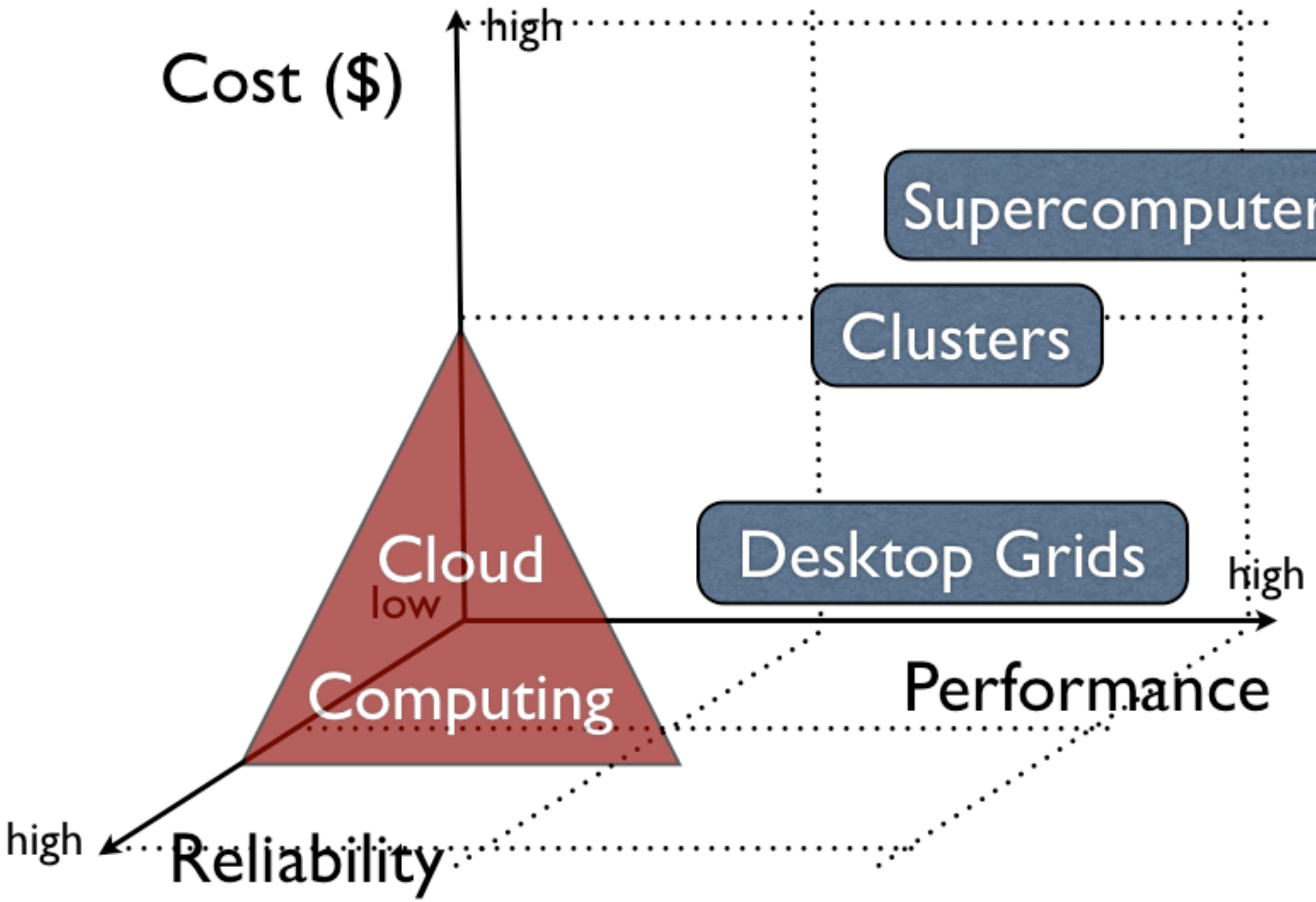
- New Technology ✗
- New Architecture ✗
- New Service ✓

- Cloud Computing: on-demand IT Service, anywhere, anytime with a pay-as-you-go model

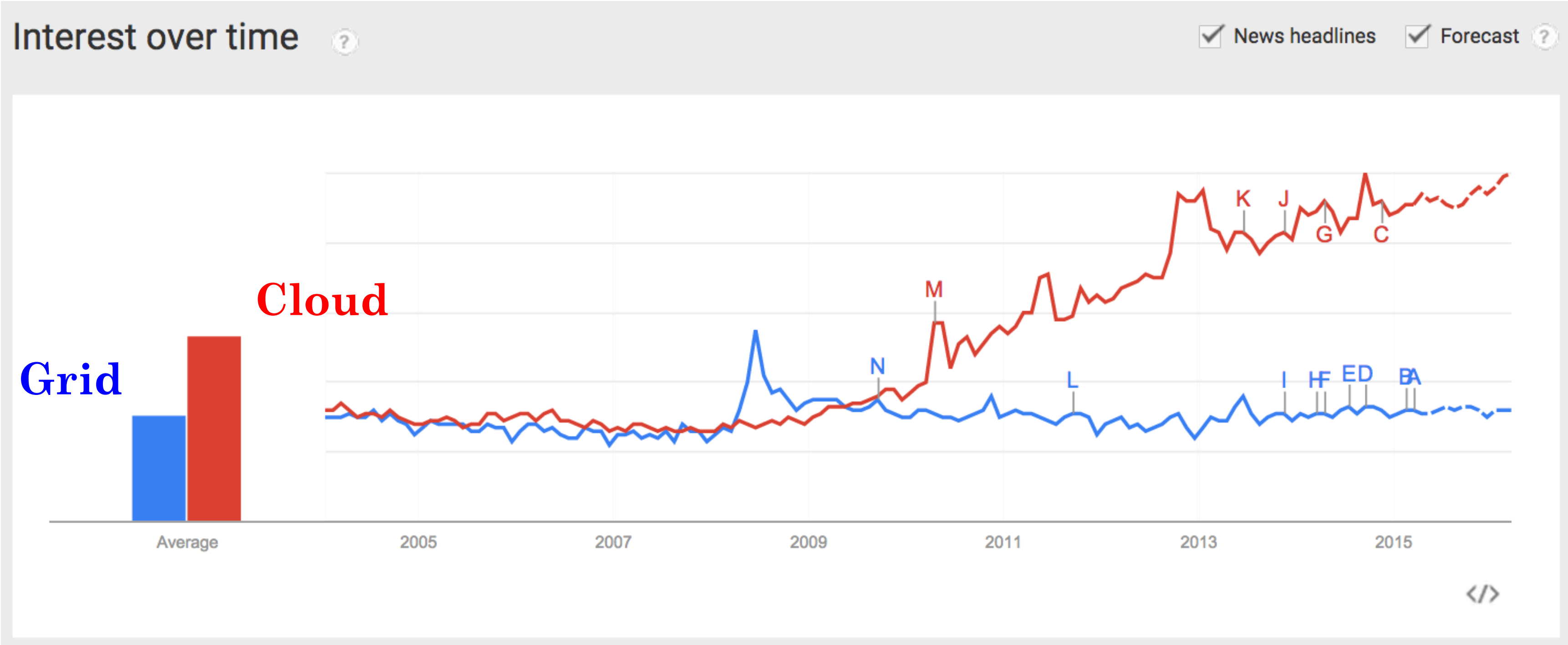
- The name comes from the use of a <u>cloud-shaped symbol</u> as an abstraction for the complex infrastructure it contains in system diagrams.

Trade-offs



high
Cost ($)
Supercomputers
Clusters
Desktop Grids
Cloud
low
Computing
high
Performance
high
Reliability

CLOUD INTERESTS OVER TIME



Ref: Google Trends

Cloud Services

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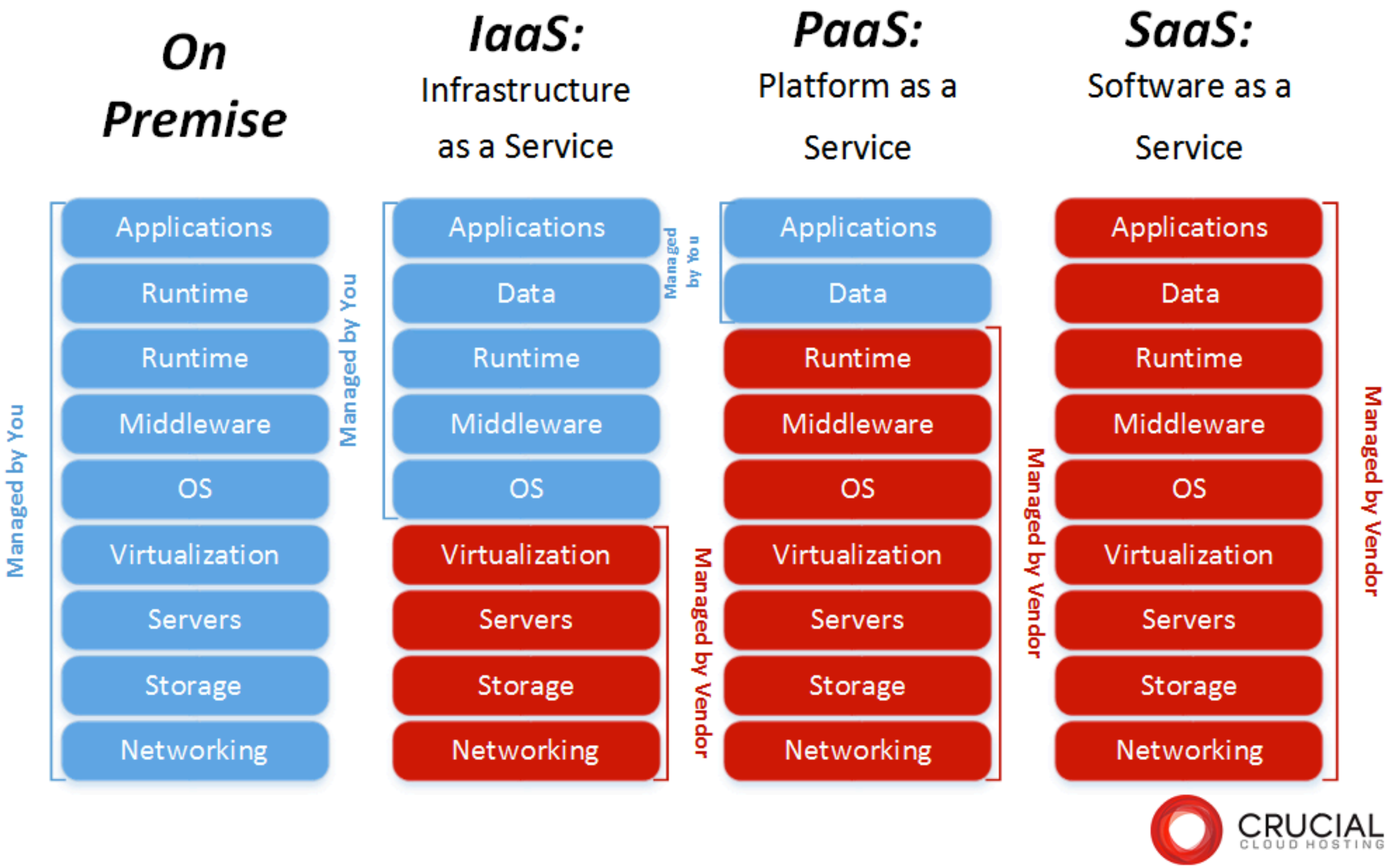
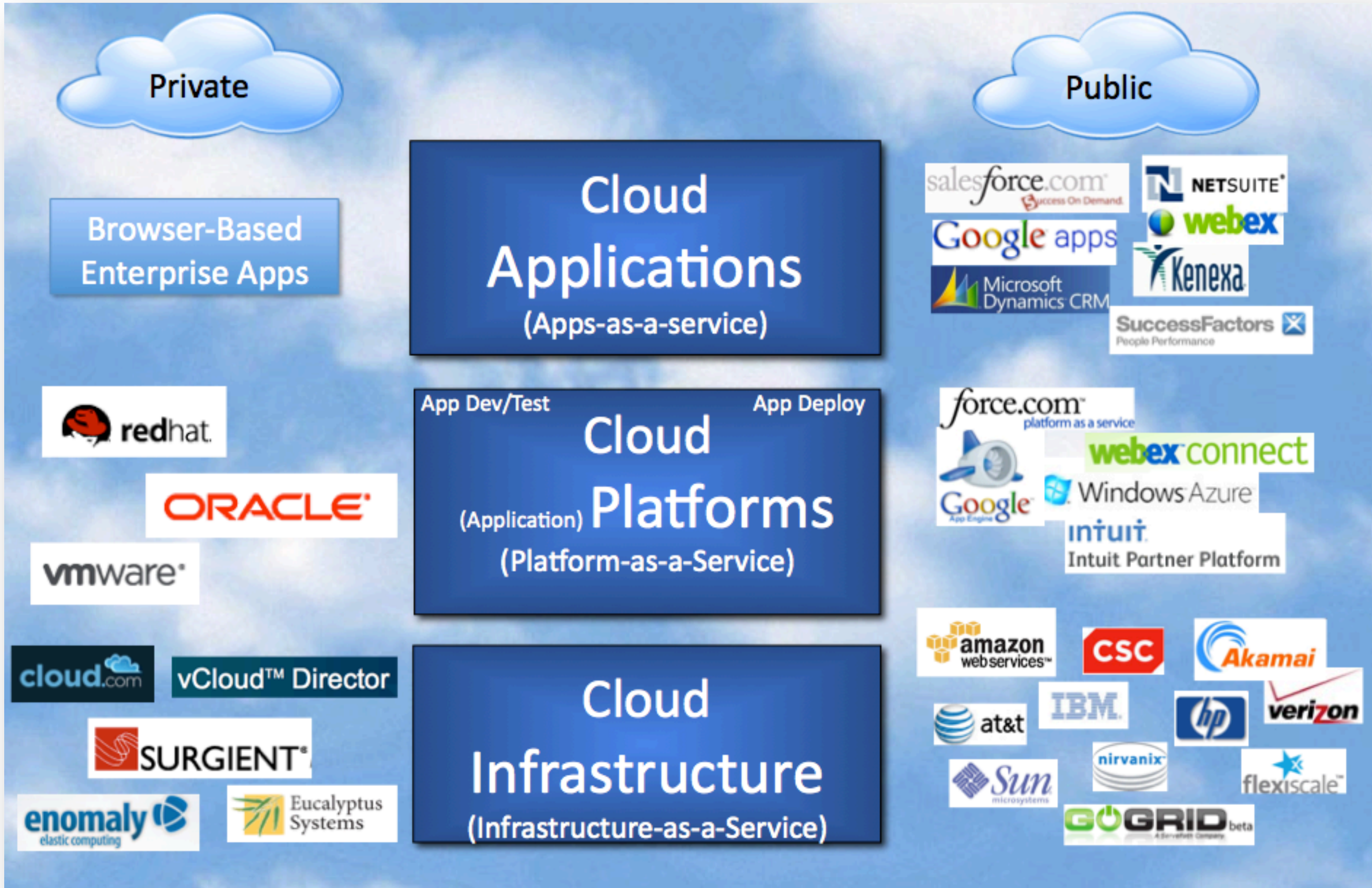
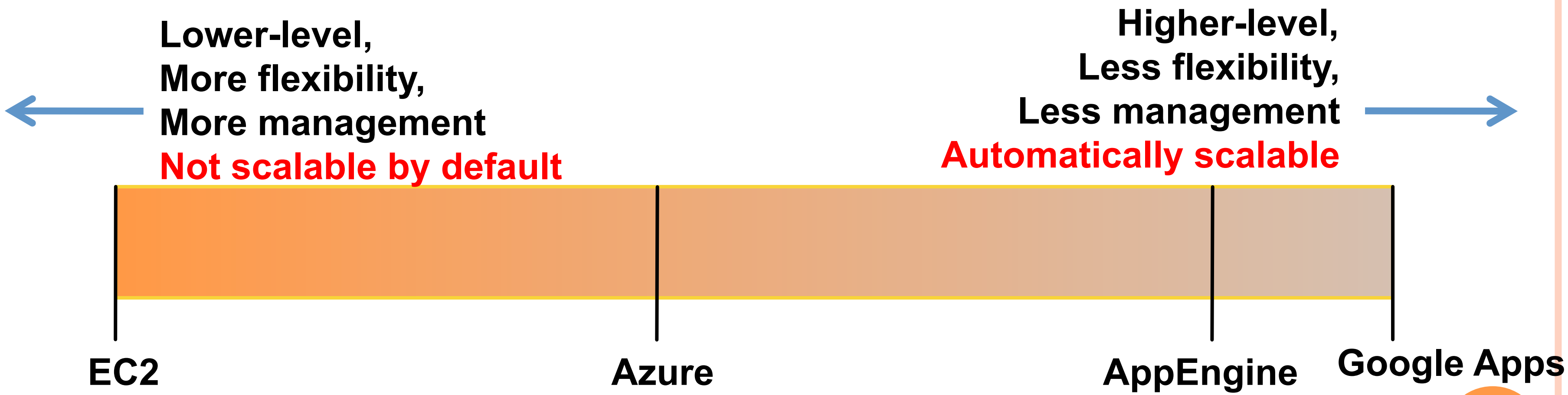


Cloud Service Providers



Spectrum of Abstractions

- Different levels of abstraction
  - Instruction Set VM: Amazon EC2
  - Framework VM: Google App Engine
- Similar to languages
  - Higher level abstractions can be built on top of lower ones



Cloud Computing: Pros and Cons

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- Pros
  - Elasticity
  - Cost-effective
  - Quick deployment
  - Unlimited storage
- Cons
  - Security and Privacy
  - Vendor Lock-in
  - Lack of Control

CLOUD COMPUTING IN JAPAN

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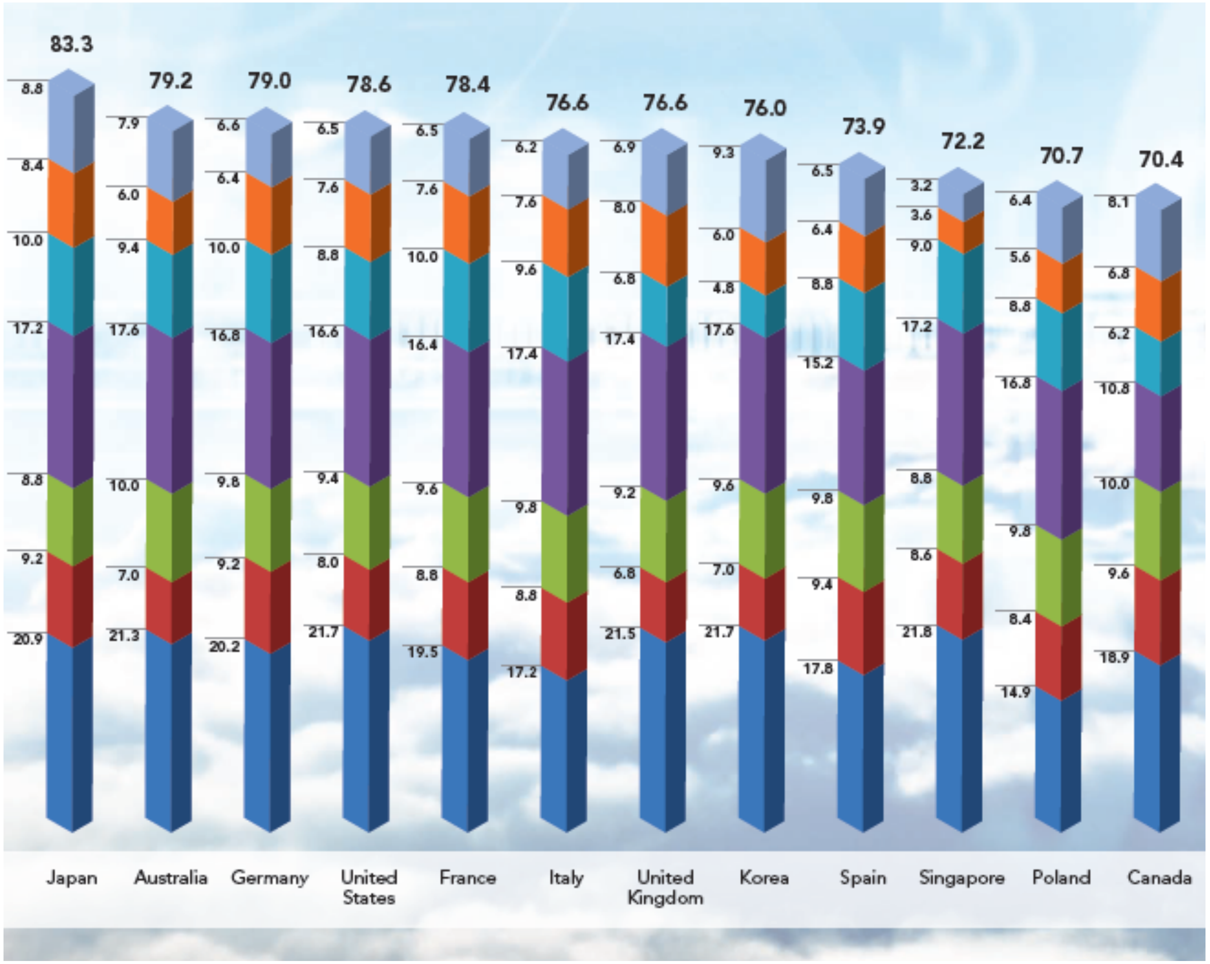

- The preparedness to support the growth of cloud computing
- These 24 countries account for 80 percent of the global ICT market.

BSA
BUSINESS SOFTWARE ALLIANCE

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CLOUD RELIABILITY

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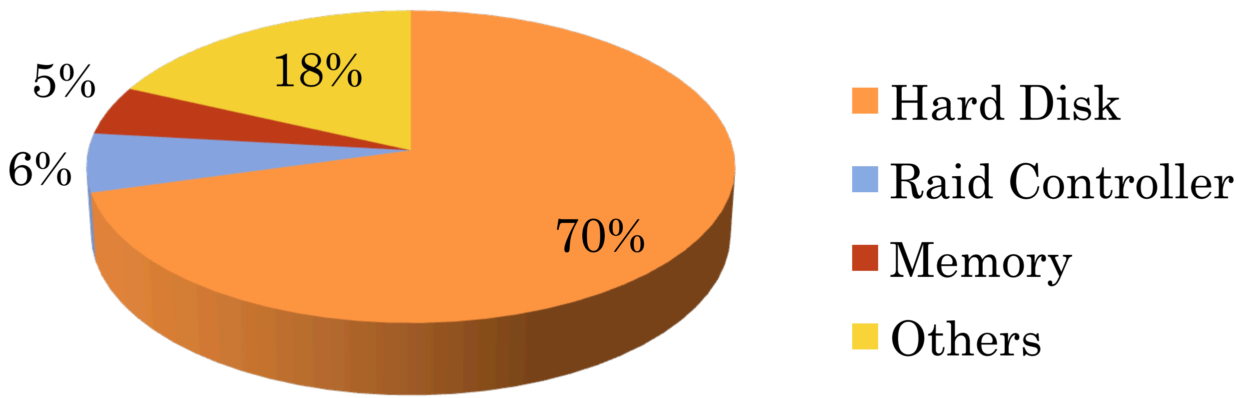
- A **failure** is an event that makes a system fail to operate according to its specifications.

- Resource failure is inevitable where failure is the norm rather than exception.

- Highly Reliable Service
  - Public Clouds
    - Redundant components to provide reliable services
  - Private Clouds
    - Frequent service failures

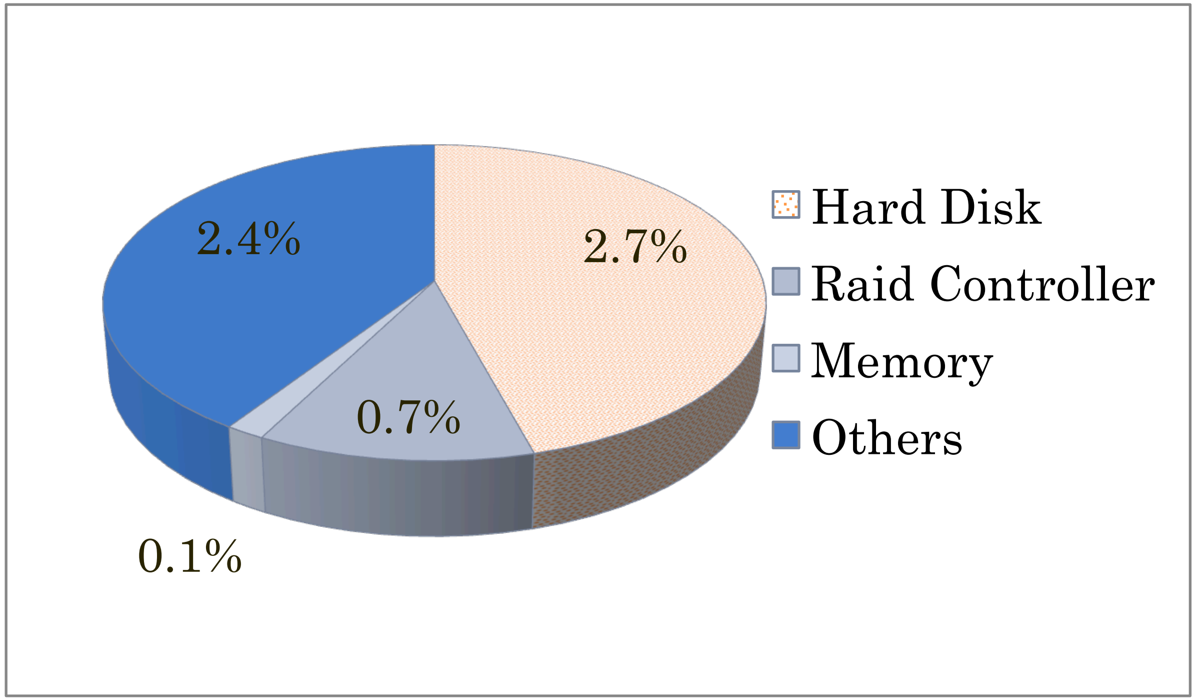
Classifying Failures of Server



Hard disks are the not only the most replaced component, they are also the most dominant reason behind server failure!!

Vishwanath, Kashi Venkatesh, and Nachiappan Nagappan. "Characterizing cloud computing hardware reliability." Proceedings of the 1st ACM symposium on Cloud computing. ACM, 2010.

FAILURE RATE FOR COMPONENTS



The cost of per server repair (which includes downtime; IT ticketing system to send a technician; hardware repairs) is $300. This amounts close to 2.5 million dollars for 100,000 servers.

Vishwanath, Kashi Venkatesh, and Nachiappan Nagappan. "Characterizing cloud computing hardware reliability." Proceedings of the 1st ACM symposium on Cloud computing. ACM, 2010.

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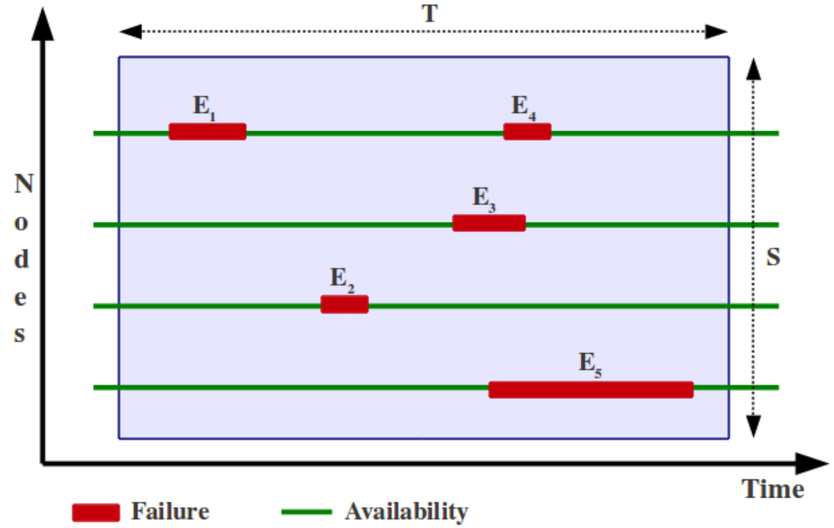
FAILURE CORRELATION

- Correlation in Failures → *overlapped failures*
  - Spatial
  - Temporal
- Spatial correlation means multiple failures occur on different nodes within a short time interval.

- Temporal correlation is the skewness of the failure distribution over which means failure events exhibit considerable **autocorrelation** at small time lags, so the failure rate changes over time.

FAILURES IN SERVICE



- The sequence of overlapped failures

$$H = \{F_i \mid F_i = (E_1, ..., E_n), T_s(E_{i+1}) \leq T_e(E_i)\}$$

- Downtime of the service

$$D = \sum_{\forall F_i \in H} (max\{T_e(F_i)\} - min\{T_s(F_i)\})$$

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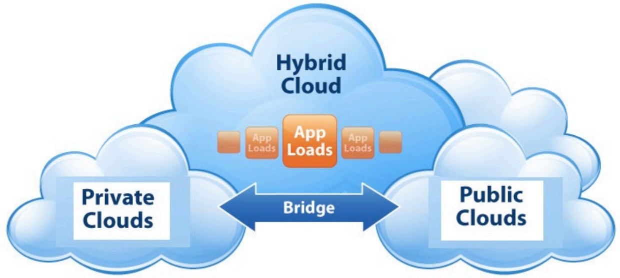
Case Study

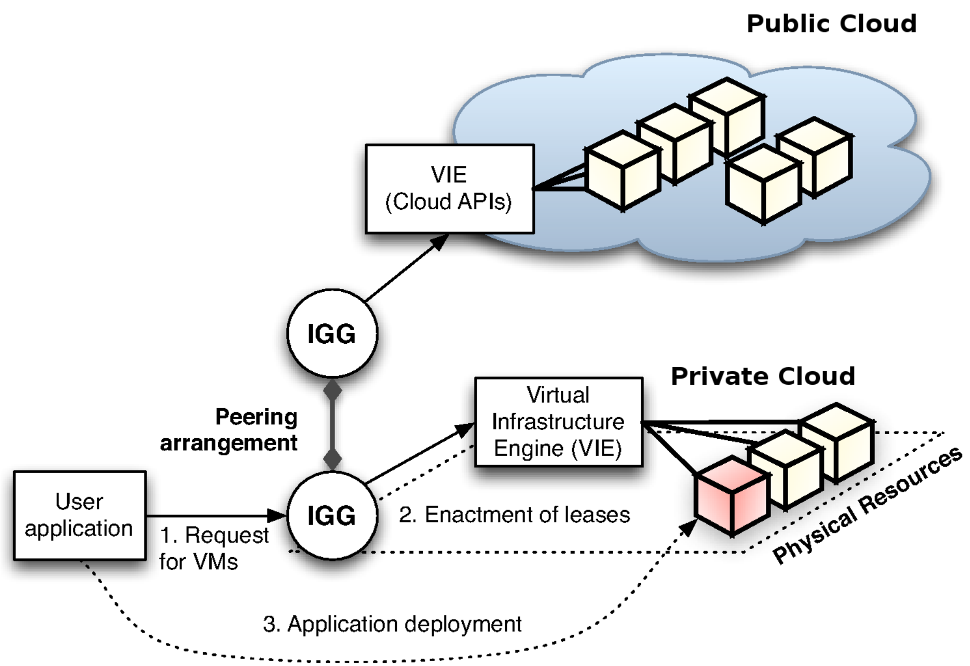
- Hybrid Cloud Systems
  - Public Clouds
  - Private Clouds

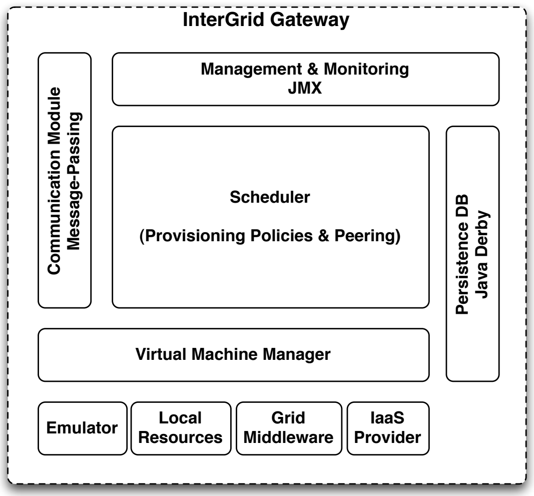


- Resource Provisioning in Hybrid Cloud
  - Users' QoS (i.e., deadline)
  - Resource failures
- Taking into account
  - Workload model
  - Failure characteristics
    - Failure correlations
    - Failure model

HYBRID CLOUD ARCHITECTURE

- Based on InterGrid components
- Using a Gateway (IGG) as the broker





IGG

WORKLOAD MODEL

- Scientific Applications
  - Potentially large number of resources over a short period of time.
  - Several tasks that are sensitive to communication networks and resource failures (*tightly coupled*)
- User Requests
  - Type of virtual machine;
  - Number of virtual machines;
  - Estimated duration of the request;
  - Deadline for the request (optional).

Proposed Approaches

- Knowledge-free Approach
  - *No Failure Model*
  - Using failure correlation
  - Three brokering policies
- Knowledge-based Approach
  - *Failure Model*
  - Generic resource provisioning model
  - Two brokering policies (cost-aware)
- Workload model
  - Request size
  - Request duration

Proposed Policies

- Size-based Strategy
  - Spatial correlation : multiple failures occur on different nodes within a short time interval
  - *Strategy*: sends wider requests to more reliable public Cloud systems
  - Mean number of VMs per request
    - P_1: probability of one VM
    - P_2: probability of power of two VMs

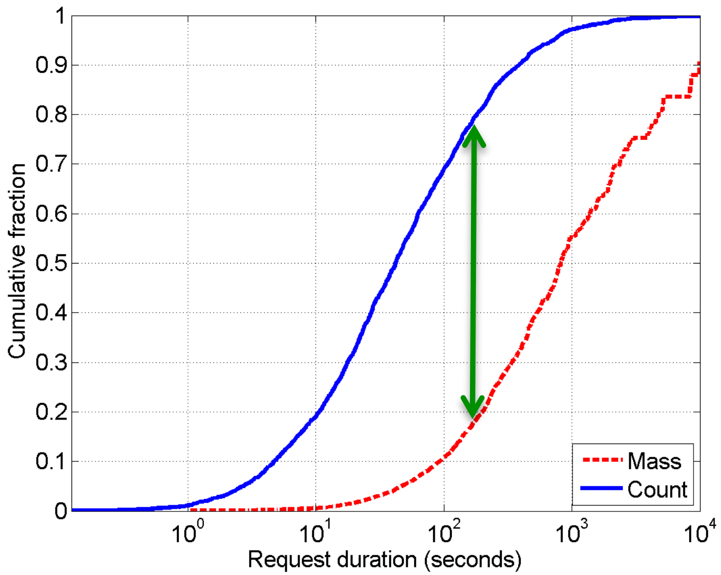
$$\overline{S} = P_1 + 2^{\lceil k \rceil}(P_2) + 2^k\left(1 - (P_1 + P_2)\right)$$

    - Request size: two-stage uniform distribution (l,m,h,q)

$$k = \frac{ql + m + (1-q)h}{2}$$

Proposed Policies (cont.)

- Time-based strategy
  - Temporal correlation: the failure rate is time-dependent and some periodic failure patterns can be observed in different time-scales
  - Request duration: are *long tailed*.



- The mean request duration
  - Lognormal distribution in a parallel production system

$$\overline{T} = e^{\mu + \frac{\sigma^2}{2}}$$

Proposed Policies (cont.)

- Area-based strategy
  - Making a compromise between the size-based and time-based strategy
  - The mean area of the requests

$$\overline{A} = \overline{T} \cdot \overline{S}$$

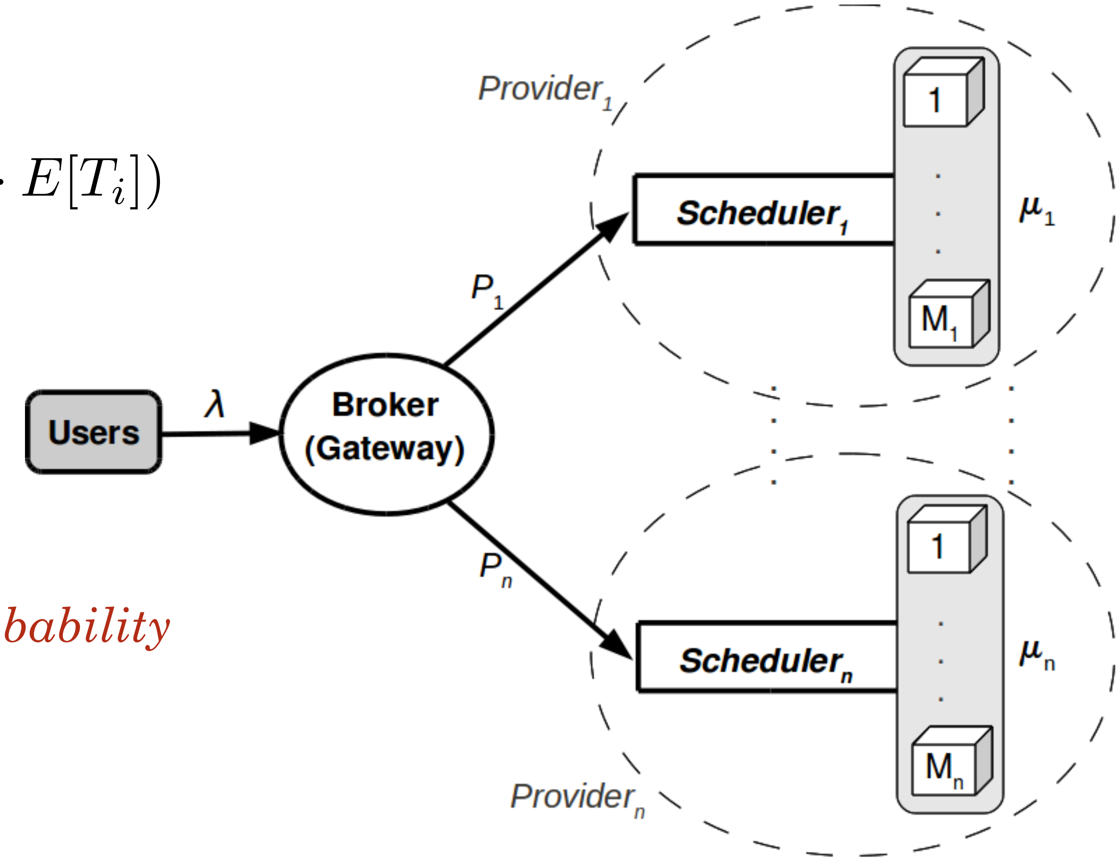
  - This strategy sends long *and* wide requests to the public Cloud,
  - It would be more conservative than a *size-based* strategy and less conservative than a *time-based* strategy.

Knowledge-based Approach: Generic resource provisioning model

- Model based on routing in distributed parallel queue

$$min \sum_{i=1}^{n} (K_i \cdot E[T_i])$$

Pi: routing probability



Ki: price of provider *i*

Model Parameters

- Using Lagrange multipliers methods, we obtained the routing probability as follows:

$$P_i = \frac{\mu_i}{\lambda} - \frac{\sum_{i=1}^{n} \mu_i - \lambda}{\lambda} \cdot \frac{\sqrt{K_i \eta_i}}{\sum_{i=1}^{n} \sqrt{K_i \eta_i}}$$

- Private Cloud service rate

$$\mu_s = \left(\frac{\overline{W}}{M_s \cdot \tau_s} \frac{t_a + t_u}{t_a} + L_s \right)^{-1}$$

- Public Cloud service rate

$$\mu_c = \left(\frac{\overline{W}}{M_c \cdot \tau_c} + L_c \right)^{-1}$$

Adaptive Policies

- Adaptive with Random Sequence (ARS)
  - Routing probabilities (*Pi*)
  - Dispatch using *Bernoulli* distribution
- Adaptive with Deterministic Sequence (ADS)
  - Routing probabilities (*Pi*)
  - Dispatch using *Billiard* sequence

$$i_b = \min_{\forall i} \left\{ \frac{X_i + Y_i}{P_i} \right\}$$

Scheduling Algorithms

- Scheduling the request across private and public Cloud resources
- Two well-know algorithms where requests are allowed to leap forward in the queue
  - Conservative backfilling
  - Selective backfilling

$$XFactor = \frac{W_i + T_i}{T_i}$$

- VM Checkpointing
  - VM stops working for the unavailability period
  - The request is started from where it left off when the node becomes available again

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Performance Evaluation

- CloudSim Simulator
- Performance Metrics
  - Deadline violation rate
  - Slowdown

$$Slowdown = \frac{1}{M} \sum_{i=1}^{M} \frac{W_i + max(T_i, bound)}{max(T_i, bound)}$$

  - Cloud Cost on EC2

$$Cost_{pl} = (H_{pl} + M_{pl} \cdot H_u)\, C_n + (M_{pl} \cdot B_{in})\, C_x$$

  - Workload Model
    - Parallel jobs model of a multi-cluster system (i.e., DAS-2)

Input Parameters	Distribution/Value
Inter-arrival time	Weibull ($\alpha = 23.375, 0.2 \leq \beta \leq 0.3$)
No. of VMs	Loguniform ($l = 0.8, m, h = log_2 N_s, q = 0.9$)
Request duration	Lognormal ($2.5 \leq \mu \leq 3.5, \sigma = 1.7$)
P_1	0.02
P_2	0.78

Performance Evaluation (cont.)

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- Failures from Failure Trace Archive (FTA)
  - http://fta.scem.uws.edu.au/
  - Grid'5000 traces
    - 18-month
    - 800 events/node

Parameters	Description	Value (hours)
t_a	Mean availability length	22.25
σ_a	Std of availability length	41.09
t_u	Mean unavailability length	10.22
σ_u	Std of unavailability length	40.75

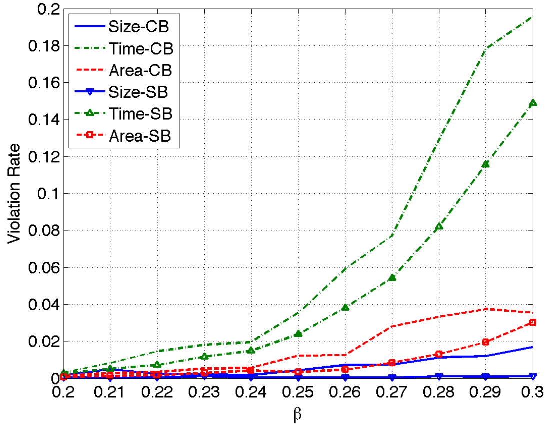
- Synthetic Deadline

$$d_i = \begin{cases} st_i + (f \cdot ta_i), & \text{if } [st_i + (f \cdot ta_i)] < ct_i \\ ct_i, & \text{otherwise} \end{cases}$$

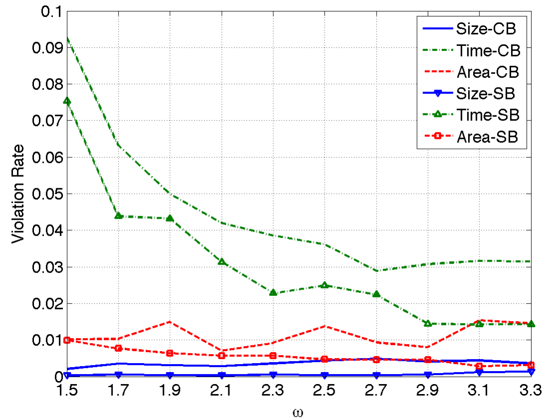
  - *f*: stringency factor
  - *f*>1 is normal deadline (e.g., *f*=1.3)
- $N_s = N_c = 64$

SIMULATION RESULTS

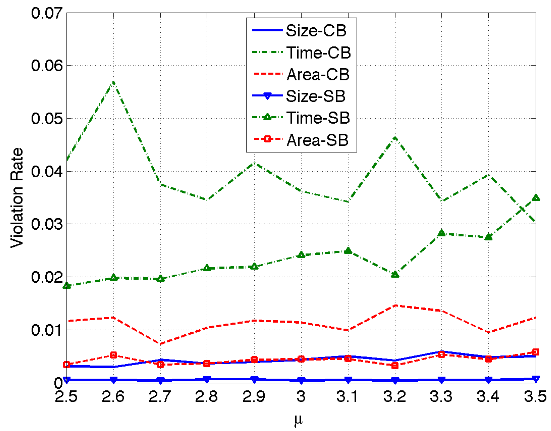
- Violation rate (knowledge-free policies)



Request arrival rate



Request size



Request duration

Simulation Results (cont.)

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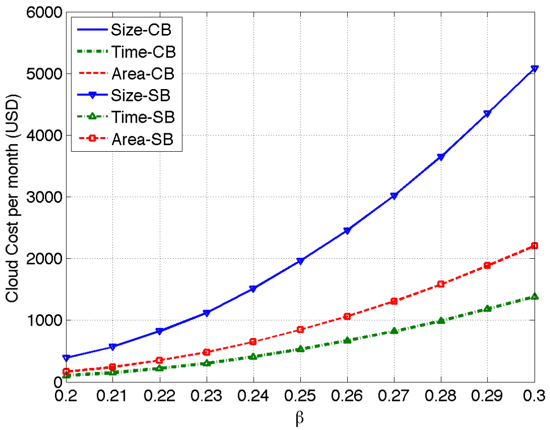
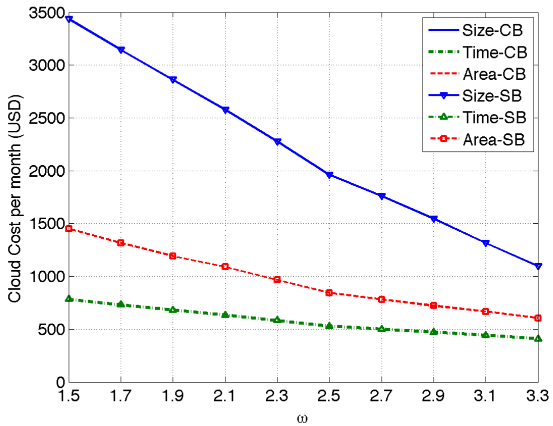
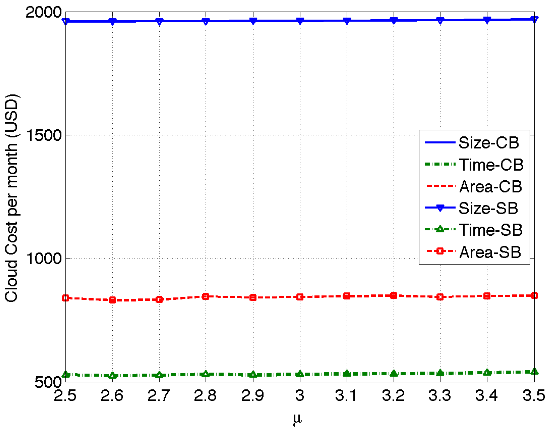
- Cloud Cost on EC2 (knowledge-free policies)



Request arrival rate



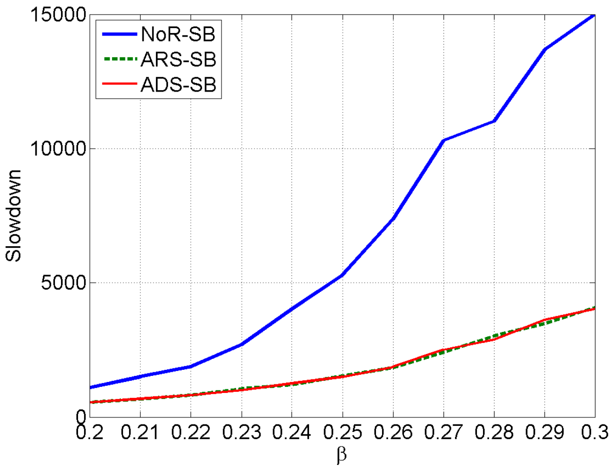
Request size



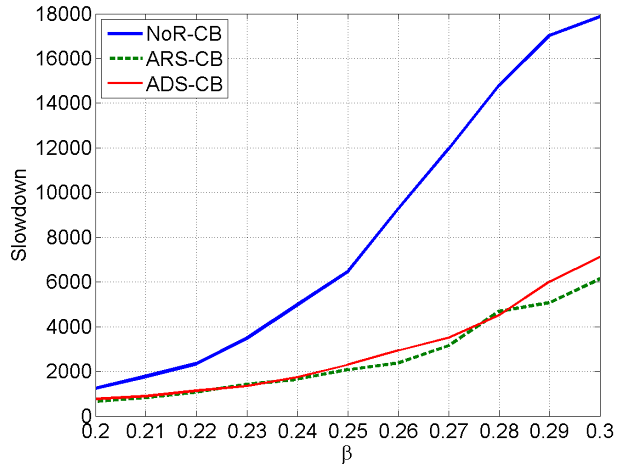
Request duration

Simulation Results (cont.)

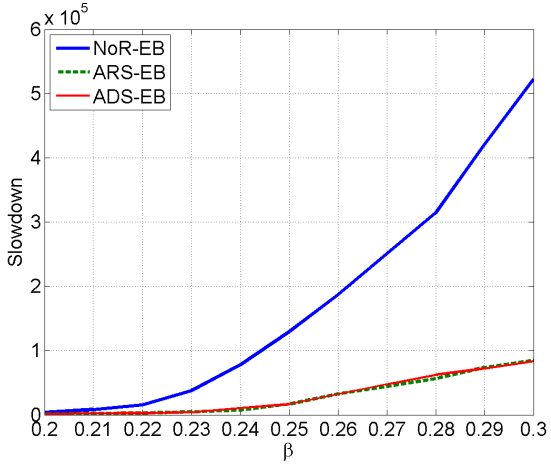
- Slowdown (Knowledge-based policies)



Request arrival rate (SB)



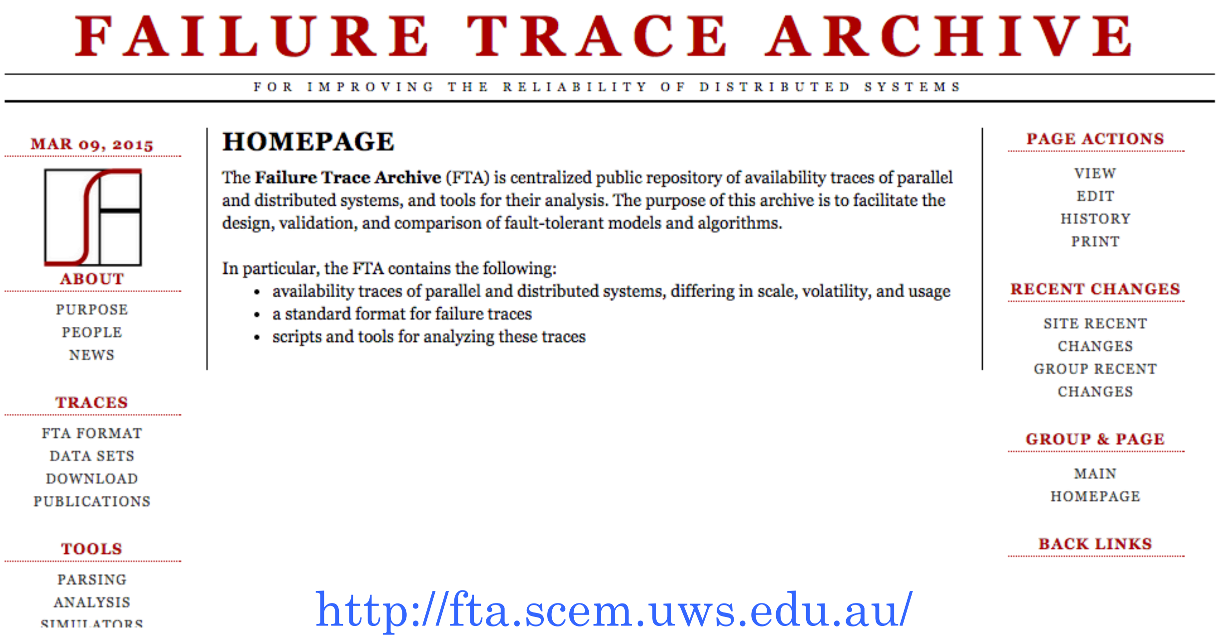
Request arrival rate (CB)



Request arrival rate (EB)

Failure Trace Archive (FTA)

- 27 Failure Traces
  - Supercomputers, HPC, Grid, P2P
- FTA Format
- Simulator and Scripts



http://fta.scem.uws.edu.au/

CONCLUSIONS

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- Adaptive resource provisioning in a failure-prone hybrid Cloud system
- *Flexible* brokering strategies based on failure correlation/model as well as workload model
- Improve performance of hybrid Cloud
  - Knowledge-free approach: 32% in terms of deadline violation and 57% in terms of slowdown while using 135$/month on EC2
  - Knowledge-based approach: 4.1 times in terms of response time while using 1200$/month on EC2

OPEN QUESTIONS

- Recourse Failures vs. Energy Consumption for Cloud Systems
  - How they are related?
- Reliability-as-a-Service (RaaS) in Cloud Computing
  - Providing reliability on demand based on the users' requirements (e.g., Amazon Spot Instances)
- Cost Model for Resource Failures in Cloud Systems
  - Repair …. Replacement

References

- Bahman Javadi, Parimala Thulasiraman, Rajkumar Buyya, "*Enhancing Performance of Failure-prone Clusters by Adaptive Provisioning of Cloud Resources*, Journal of Supercomputing", 63(2) (2013) 467-489.

- Bahman Javadi, Jemal Abawajy, and Rajkumar Buyya, "*Failure-aware Provisioning for Hybrid Cloud Infrastructure*", Journal of Parallel and Distributed Computing, 72 (10) (2012) 1381-1331.

- Bahman Javadi, Jemal Abawajy, and Richard O. Sinnott , "*Hybrid Cloud Resource Provisioning Policy in the Presence of Resource Failures*" 4th IEEE International Conference on Cloud Computing Technology and Science (CloudCom 2012), Taipei, Taiwan, December 2012, pp. 10-17. **Best Paper Finalist Award**.

- Bahman Javadi, Parimala Thulasiraman, Rajkumar Buyya, "*Cloud Resource Provisioning to Extend the Capacity of Local Resources in the Presence of Failures*", 14th IEEE International Conference on High Performance Computing and Communications (HPCC-2012), Bradford, UK, June 2012, pp. 311-319.

Thank You