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A temporal framework for timely completion of cloud workflows

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SUCCESS

Swinburne University of Technology

Melbourne, Australia

SUCCESS – A Brief Introduction

Swinburne University Centre for Computing and Engineering Software Systems

- Swinburne is one of top 500 universities in the world
  - 2nd smallest one (less faculties than MIT CS Lab)
- SUCCESS has the strongest SE group in Australia
  - five full professors
- 2011 figures on two top SE journals:
  - TSE – IEEE Trans. on Software Engineering
    4 (2+2) (world total: 48)
  - ToSEM – ACM Trans. on Software Engineering and Methodology
    2 (1+1) (world total: 18)

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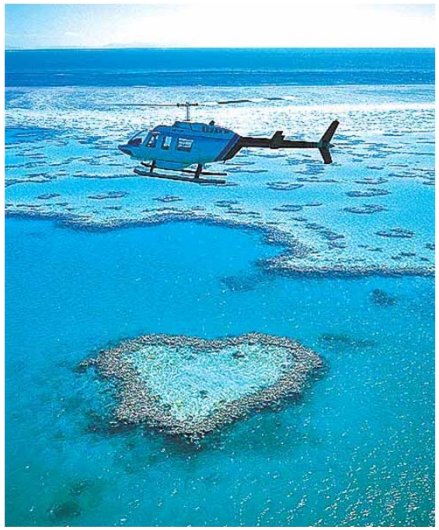
Melbourne – Capital City of Victoria

- a very dynamic city
- population just over 4 million
- Australia's cultural capital
- famous for parks and gardens
- "The Most Liveable City in the World"
- Welcome for (joint) PhD program etc.



Outline

- Related Publications (and Acknowledgement)
- Background
- Motivating Example and Problem Analysis
- A Probabilistic Temporal Framework
- Evaluation
- Conclusion

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Related Publications for This Talk

Acknowledgement: Assoc. Prof. Jinjun Chen; Dr Xiao Liu (two former PhD graduates)

- X. Liu, Y. Yang, Y. Jiang and J. Chen, *Preventing Temporal Violations in Scientific Workflows: Where and How*. IEEE Transactions on Software Engineering, 37(6):805-825, Nov./Dec. 2011

- J. Chen and Y. Yang, *Temporal Dependency based Checkpoint Selection for Dynamic Verification of Temporal Constraints in Scientific Workflow Systems*. ACM Transactions on Software Engineering and Methodology, 20(3):Article 9, Aug. 2011.

- J. Chen and Y. Yang, *Adaptive Selection of Necessary and Sufficient Checkpoints for Dynamic Verification of Temporal Constraints in Grid Workflow Systems*. ACM Transactions on Autonomous and Adaptive Systems, 2(2):Article 6, June 2007

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Background: Workflow QoS

- QoS dimensions
  - time, cost, fidelity, reliability, security …
- QoS of Cloud Services
- Workflow QoS
  - the overall QoS for a collection of cloud services
  - but not simply add up!

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Temporal QoS

- System performance
  - Response time
  - Throughput
- Temporal constraints
  - Global constraints: deadlines
  - Local constraints: milestones, individual activity durations
- Satisfactory temporal QoS
  - High performance: fast response, high throughput
  - On-time completion: low temporal violation rate

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Motivating Example

- Astrophysics: pulsar searching
- Pulsars: the collapsed cores of stars that were once more massive than 6-10 times the mass of the Sun
- http://astronomy.swin.edu.au/cosmos/P/Pulsar
- Parkes Radio Telescope (http://www.parkes.atnf.csiro.au/)

- Swinburne Astrophysics group (http://astronomy.swinburne.edu.au/) has been conducting pulsar searching surveys (http://astronomy.swin.edu.au/pulsar/) based on the observation data from Parkes Radio Telescope.
- Typical scientific workflow which involves a large number of data and computation intensive activities. For a single searching process, the average data volume (not including the raw stream data from the telescope) is over 4 terabytes and the average execution time is about 23 hours on Swinburne high performance supercomputing facility (http://astronomy.swinburne.edu.au/supercomputing/).

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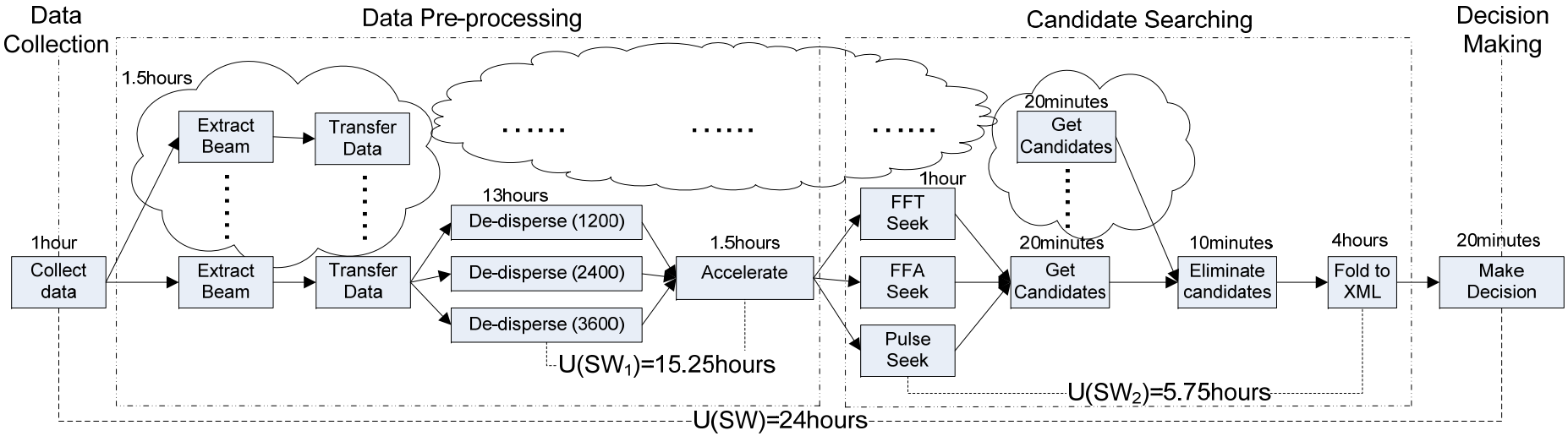
Pulsar Searching



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Problem Analysis

- Setting temporal constraints
  - Coarse-grained and fine-grained temporal constraints
  - Prerequisite: effective forecasting of activity durations
- Monitoring temporal consistency state
  - Monitor workflow execution state
  - Detect potential temporal violations
- Temporal violation handling
  - Where to conduct violation handling
  - What strategies to be used

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Ultimate Goal

- Achieving on-time completion
- Measurements:
  - Temporal correctness
  - Cost effectiveness

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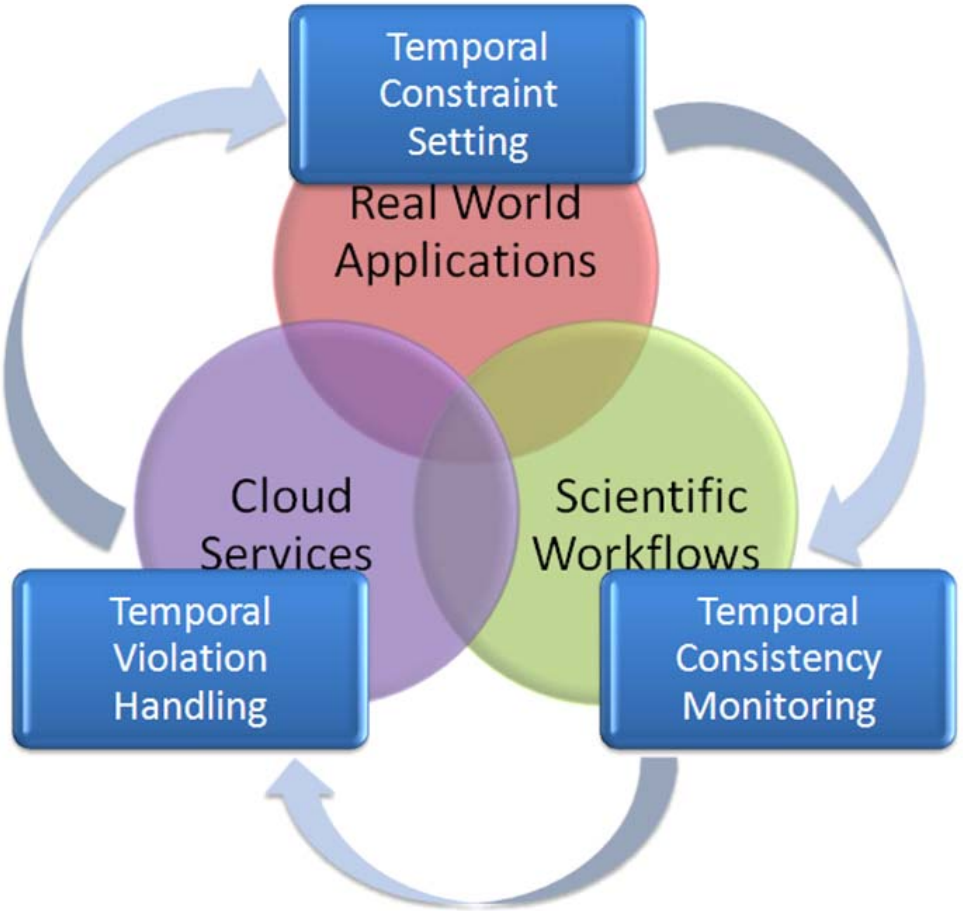
Temporal Framework



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Temporal Framework

- Component 1: Temporal Constraint Setting (JSS, CCPE)
  - Forecasting workflow activity durations
  - Setting coarse-grained temporal constraints
  - Setting fine-grained temporal constraints
- Component 2: Temporal Consistency Monitoring (TSE, ToSEM)
  - Temporal checkpoint selection
  - Temporal verification
- Component 3: Temporal Violation Handling (TSE, JSS)
  - Temporal violation handling point selection
  - Temporal violation handling

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Temporal Checkpoint Selection - Requirements / Objectives

- Checkpoint: the point (e.g. activity point, time point) for conducting temporal verification
- The measurements for temporal checkpoint selection
  - Necessity: only those activity points where real temporal inconsistency states take place are selected
  - Sufficiency: there are no any omitted activity points
- Efficiency
- Effectiveness

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Temporal Checkpoint Selection - Existing Work

- Representative Checkpoint Selection Strategy (CSS)
  - Every activity as a checkpoint
  - The start activity, and add a new checkpoint after each decision activity is executed
  - User defined static activity points
  - The activity duration exceeds its maximum duration
  - The activity duration exceeds its mean duration
- Problems: necessary? Sufficient?

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Temporal Checkpoint Selection - Our Strategy

Necessary and Sufficient Checkpoint Selection Strategy

- Probability Time Redundancy
- Minimum Probability Time Redundancy
- DOMTR: Dynamically Obtaining Minimum Time Redundancy
- Theorem of Checkpoint Selection
- Proof of Necessity and Sufficiency

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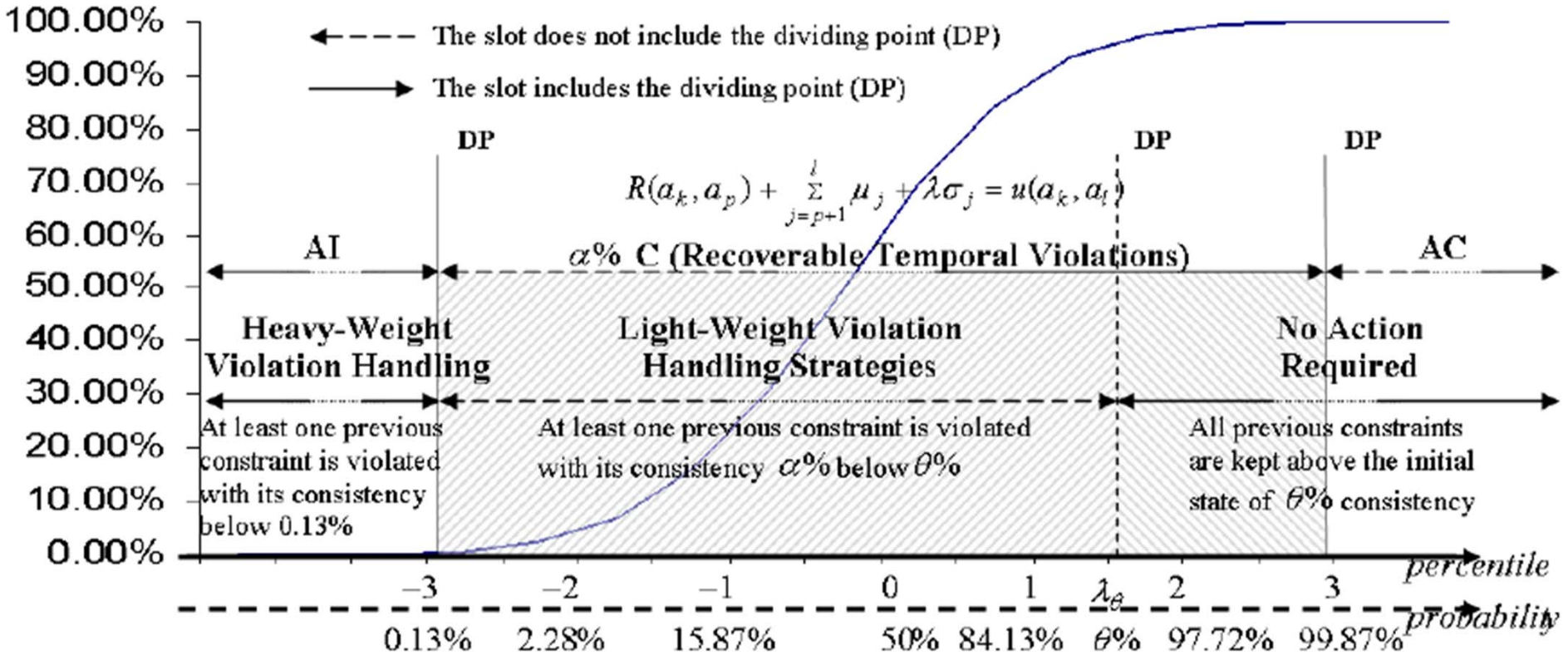
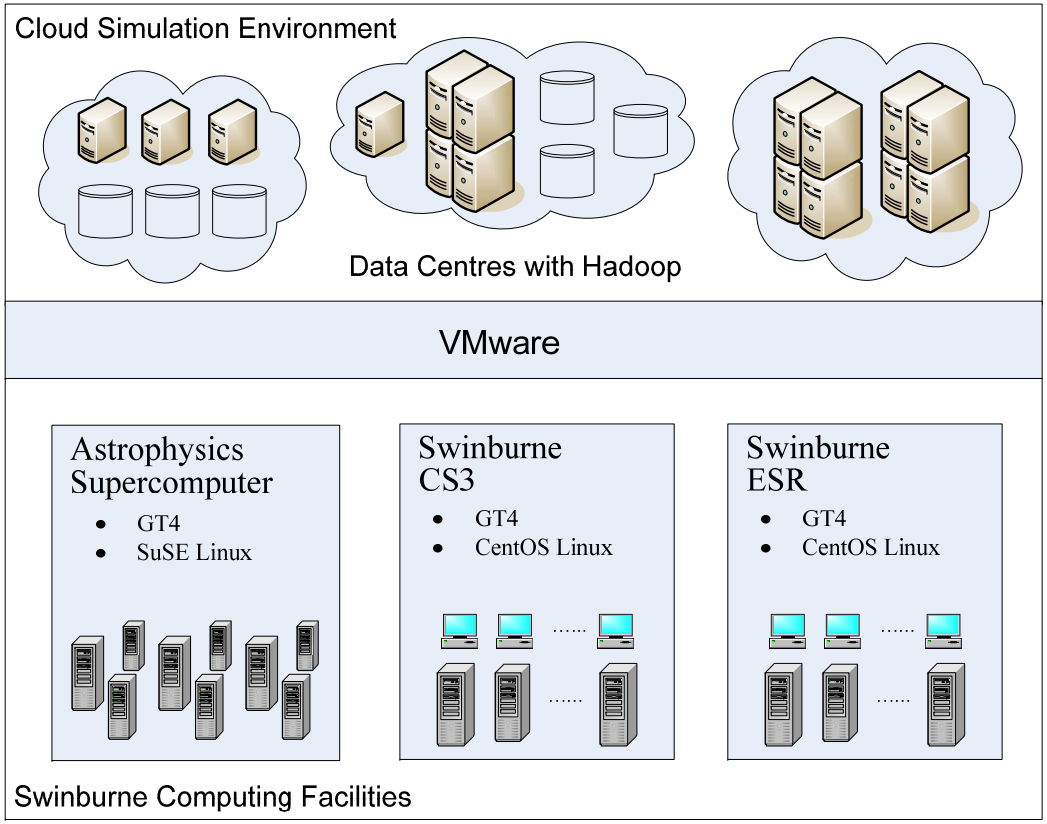
Temporal Verification

- Multi-states temporal violations
- Statistical recoverable and non-recoverable temporal violations



Simulation Environment

- SwinCloud



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CSS Types

- CSS_1: every activity as a checkpoint.
- CSS_2: start time and end time of each activity.
- CSS_3: start activity, after each decision activity.
- CSS_4: user-defined static checkpoints.
- CSS_5: a_i as a checkpoint if $R(a_i) > D(a_i)$.
- CSS_6: a_i as a checkpoint if $R(a_i) > M(a_i)$.
- CSS_7: a_i as a checkpoint if $R(a_i) > M(a_i)$ + a minimum proportional time redundancy at a_i.
- CSS_8: a_i as a checkpoint if $R(a_i) > M(a_i)$ + a minimum time redundancy at a_i.

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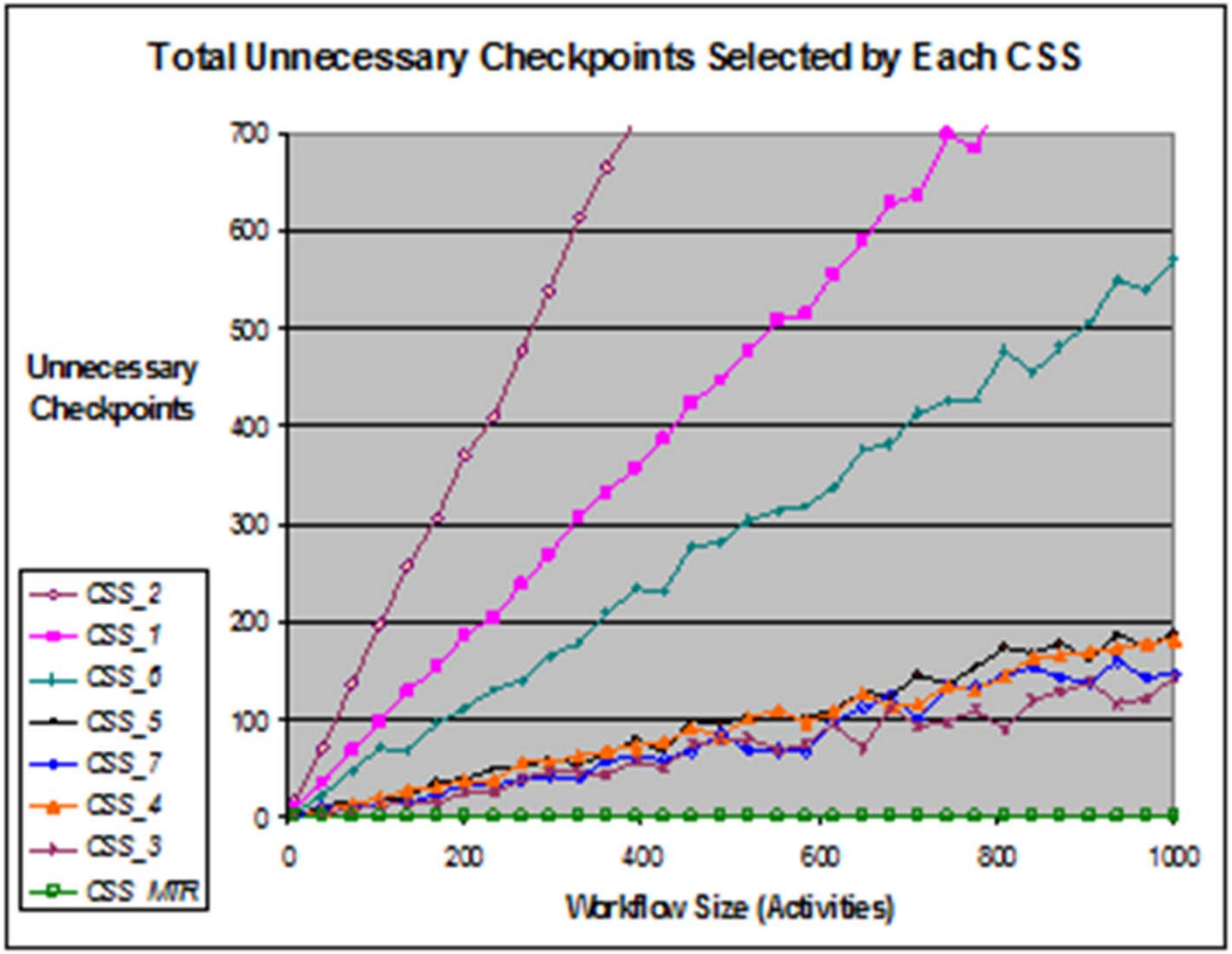
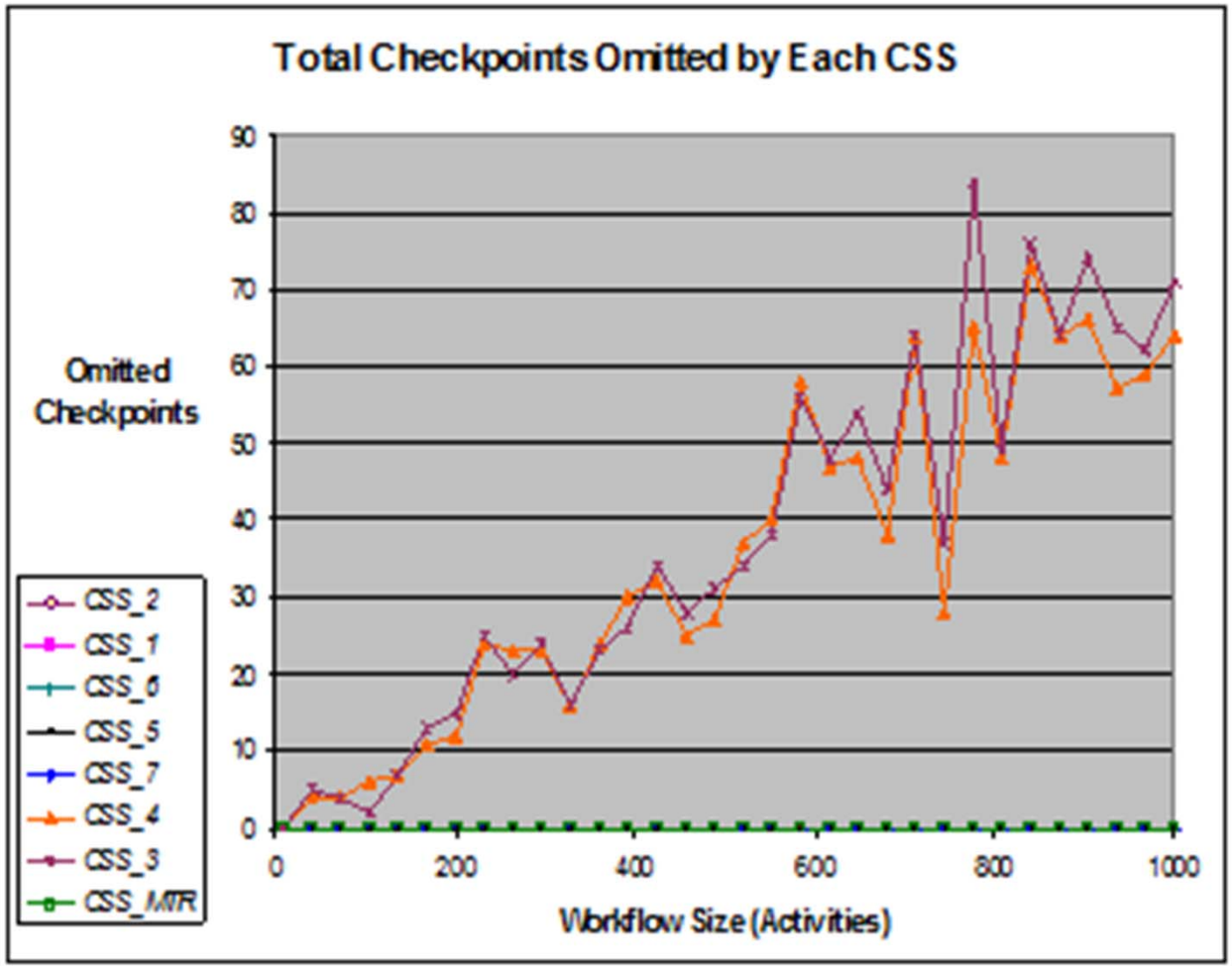
Evaluation


Total Unnecessary Checkpoints Selected by Each CSS
Unnecessary Checkpoints
700
600
500
400
300
200
100
0
0
200
400
600
800
1000
Workflow Size (Activities)
CSS_2
CSS_1
CSS_6
CSS_5
CSS_7
CSS_4
CSS_3
CSS_MTR

Evaluation



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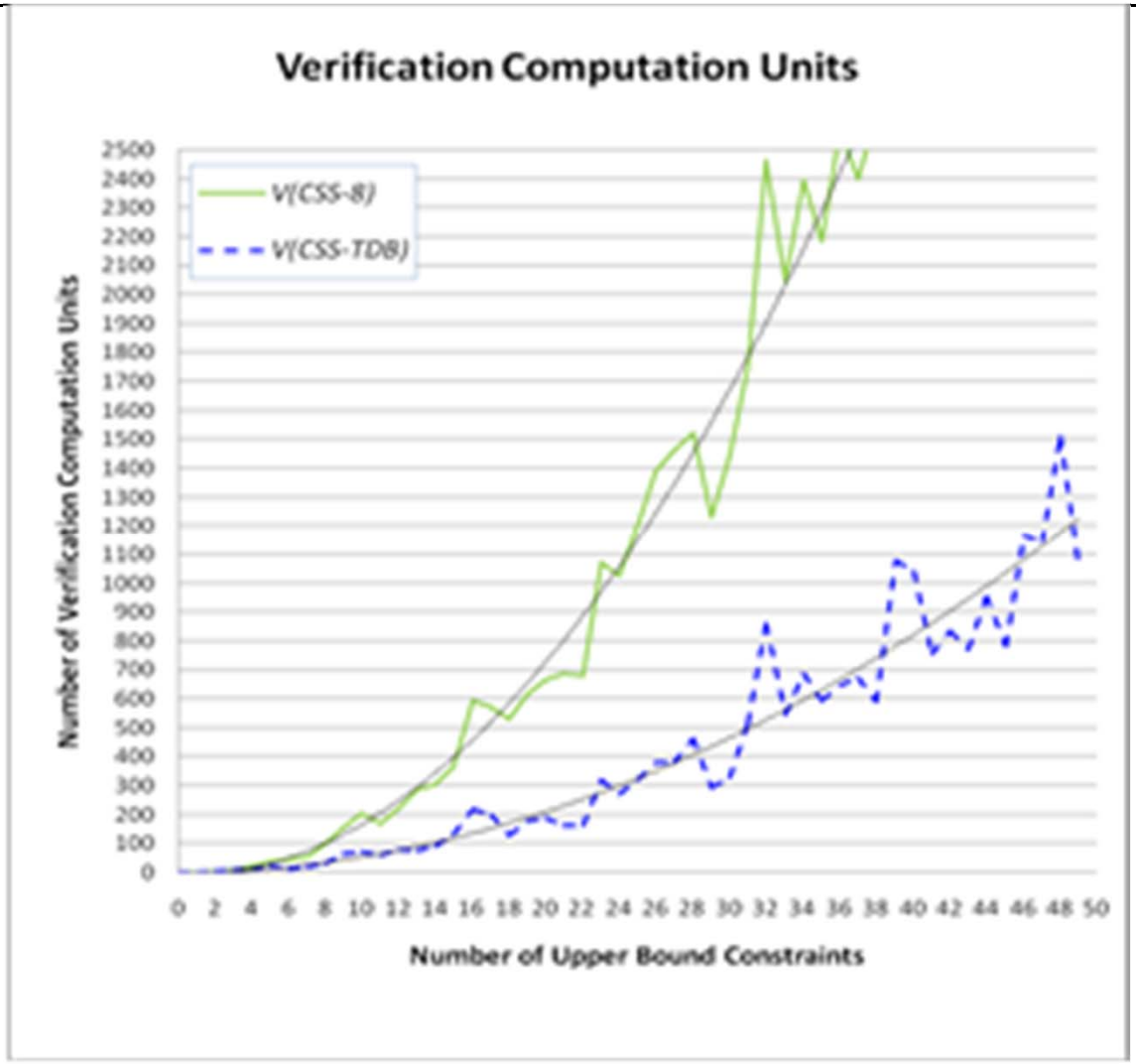

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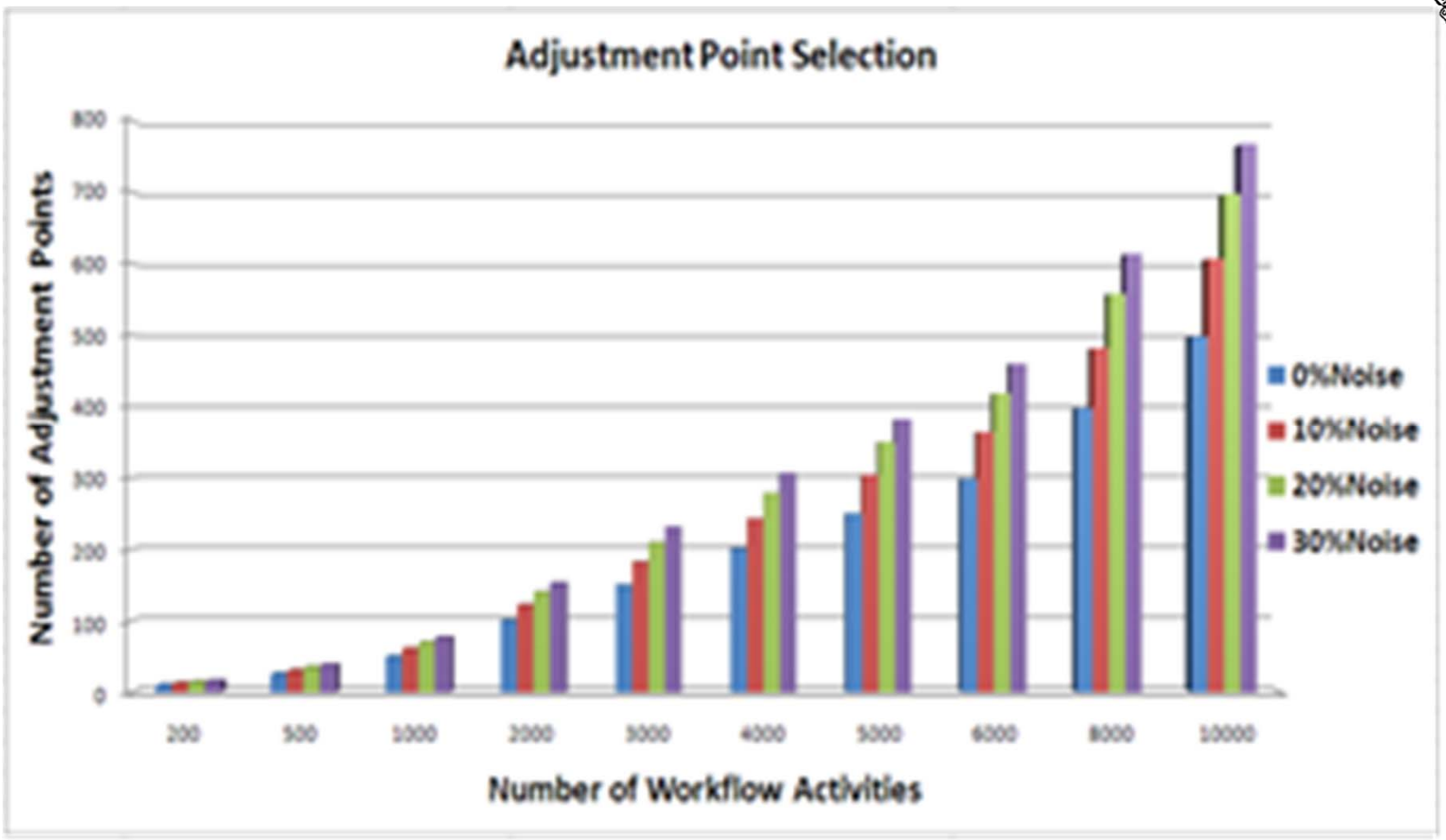
Evaluation



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Conclusion

- On-time completion of scientific workflows
- Lifecycle support of temporal QoS
- A probabilistic temporal framework
  - Setting temporal constraints
  - Monitoring temporal consistency
  - Handling temporal violation
- Necessary and sufficient checkpoint selection

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Future Work

- Instance intensive business workflows
- Fast response time vs. high system throughput
- Resource management in cloud computing environment
  - Service level agreement (SLA) management
  - Cloud resource reservation
  - Dynamic Scheduling

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End - Q&A

- Thanks for your attention!

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