EntomoModel: Understanding and Avoiding Performance Anomaly Manifestations

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Internet Services Occasionally Perform Poorly

- Internet services are very complex
  - Depend on many third party components, e.g., Apache Web server, IBM WebSphere, MYSQL
  - Complicated business logic with millions of LOC
- Today Internet services perform well most of the time, *but not all of the time*
  - Keynote Systems, July--December 2008
  - Studied 11 retailers known to offer low response times most of the time
  - **Only 3 of 11** could meet an SLA that required responding to **98%** of user requests within 2 seconds

Performance Anomalies: One Cause of Poor Performance

- Sometimes poor performance stems from…
  - 1) subtle mis-configurations, 2) poor implementations, or 3) unexpected interactions between components
- *A **performance anomaly manifestation** occurs when these root causes degrade performance*
  - Real example:
    - System monitors miss a significant increase in resource needs **and** performance-critical components are co-located with less critical components. [Amazon S3]
  - Not examples:
    - 1) System-crash bugs, 2) Obvious under-provisioning

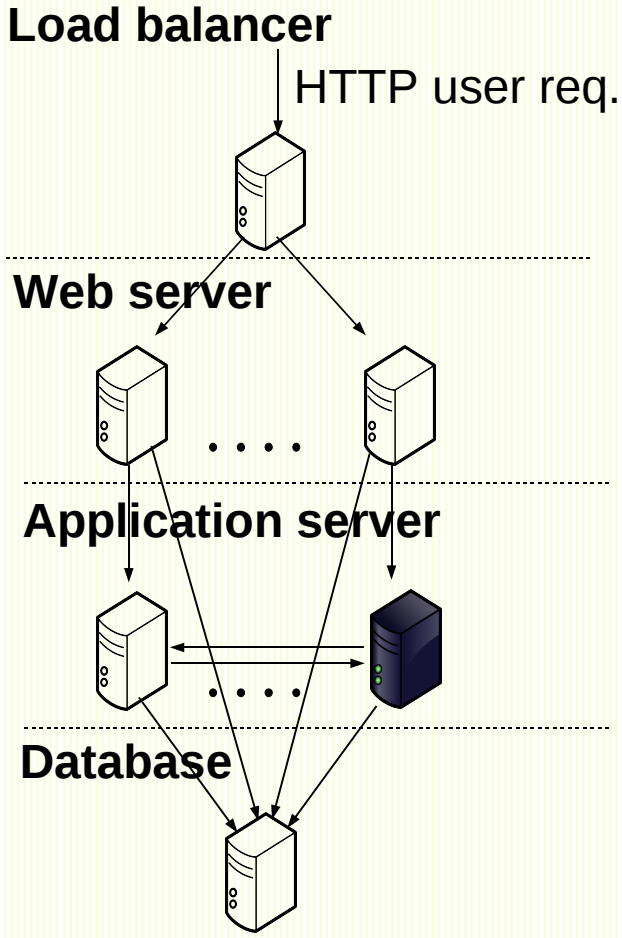
Outline

1. **A study of performance anomaly manifestations**
2. EntomoModel: Understanding the conditions where anomaly root causes are likely to manifest
3. Entomophobic management: Avoiding performance anomaly manifestations
4. Conclusion

A Study of Anomaly Manifestations

1. Setup
2. Anomaly Root Causes
3. Manifestation Patterns

- Internet services support a wide range of management policies and workloads, e.g.,
  - Application logic
  - Http protocol
  - Placement of application logic
  - Request arrival intensity
  - Number of web servers
- We chose 9 practical parameters with over 1M possible settings
- A full specification is called a ***workload-policy setting***



A Study of Anomaly Manifestations

1. Setup
2. Anomaly Root Causes
3. Manifestation Patterns

- Procedure for detecting anomaly manifestations
  1. Randomly select a workload-policy setting
  2. Measure performance under the setting
  3. Re-insert a known, well-documented anomaly cause
  4. Measure performance under the setting again, but with the root cause(s) reinserted

An anomaly manifestation occurred under the setting if performance fell after reinsertion

- Measure multiple times for confidence
- Performance metric= % of requests with response time within 2 seconds

A Study of Anomaly Manifestations

- We pulled 6 anomaly root causes from bug repos of open source components, e.g., JBoss, MYSQL, etc.
- Recreated from published fixes and comments

Load balancer: An earlier version of our load balancer implemented round-robin load balancing poorly. The last server IP address in the setup file did not receive requests [Sourceforge project page]

DNS system: A DNS server did not have some IP address to a domain name mappings. Network messages to unmapped machines were delayed. [MYSQL Forums]

A Study of Anomaly Manifestations

1. Setup
2. Anomaly Root Causes
3. **Manifestation Patterns**

- *How frequently do performance anomalies manifest?*
- *What is their impact on performance?*
- *Are manifestations more likely under certain settings?*

	Load balancer	DNS system	Median in study
Manifestation frequency	**11%**	**7%**	**7.5%**
Avg. performance degradation	**65%**	**21%**	**38%**
Parameter with highest info gain	**Replica (43%)**	**HTTP (20%)**	

A Study of Anomaly Manifestations

1. Setup
2. Anomaly Root Causes
3. **Manifestation Patterns**

- Do root causes manifest differently in combination than in isolation?
  - For each setting, we measured performance when multiple root causes were reinserted. We compared the anomaly classification to the in isolation tests.

DNS + LB root causes	Normal in combination	Manifest in combination
Normal in isolation *(i.e., neither cause manifested by itself)*	**81%**	**2%**
Manifest in isolation (i.e., either LB or DNS manifested by iteself)	**7%**	**10%**

A Study of Anomaly Manifestations

1. Setup
2. Anomaly Root Causes
3. **Manifestation Patterns**

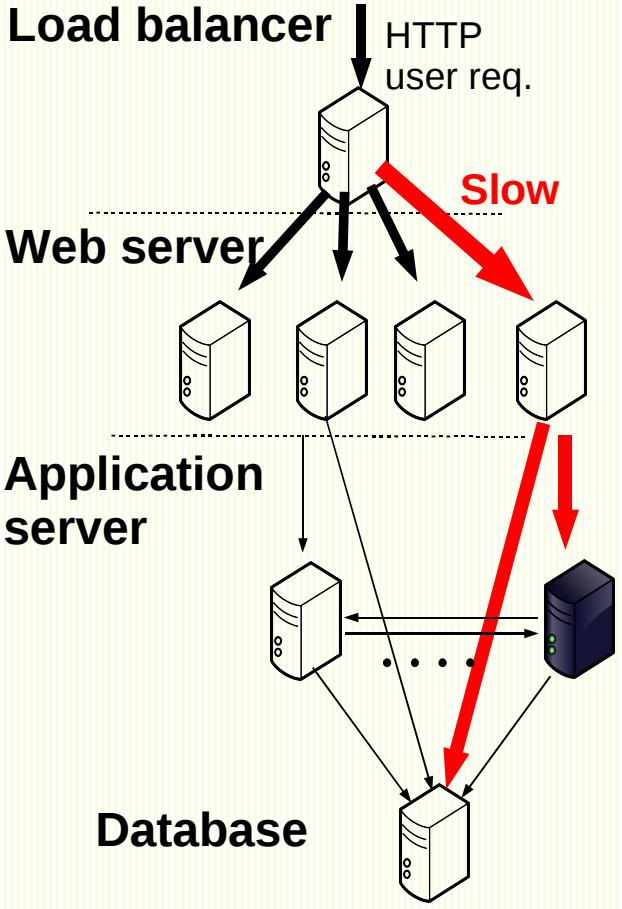
	Normal in combination	Manifest in combination
Normal in isolation	**81%**	**2%**
Manifest in isolation	**7%**	**10%**

- Under some settings, root causes would manifest if they were reinserted in isolation but not in combination

- **Emergent "good" behavior: *How does combining two performance degrading anomalies help?***

A Study of Anomaly Manifestations

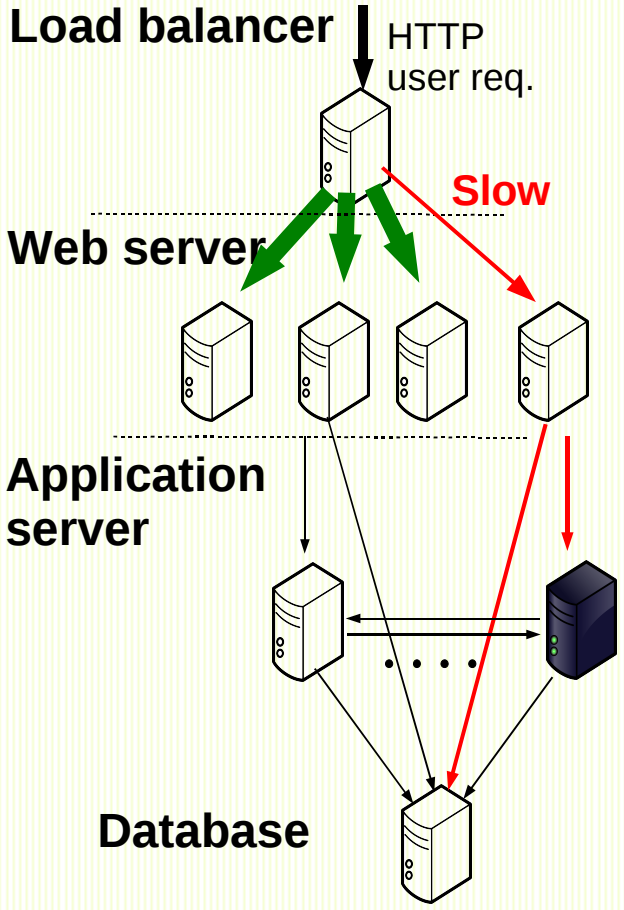
1. The DNS root cause increases the communication delay between components
   - When the root cause afflicts a web server, communication between the load balancer and web server are affected
   - By itself, the increased communication delay can slow down the response time for a large portion of requests



A Study of Anomaly Manifestations

1. Setup
2. Anomaly Root Causes
3. **Manifestation Patterns**

1. The DNS root cause increases the communication delay between components
2. If the load-balancer root cause afflicts the same web server, it will reduce the number of round trip communications
   - Reducing the relative impact of the DNS delay
   - But also, increasing the workload of other web servers in the system



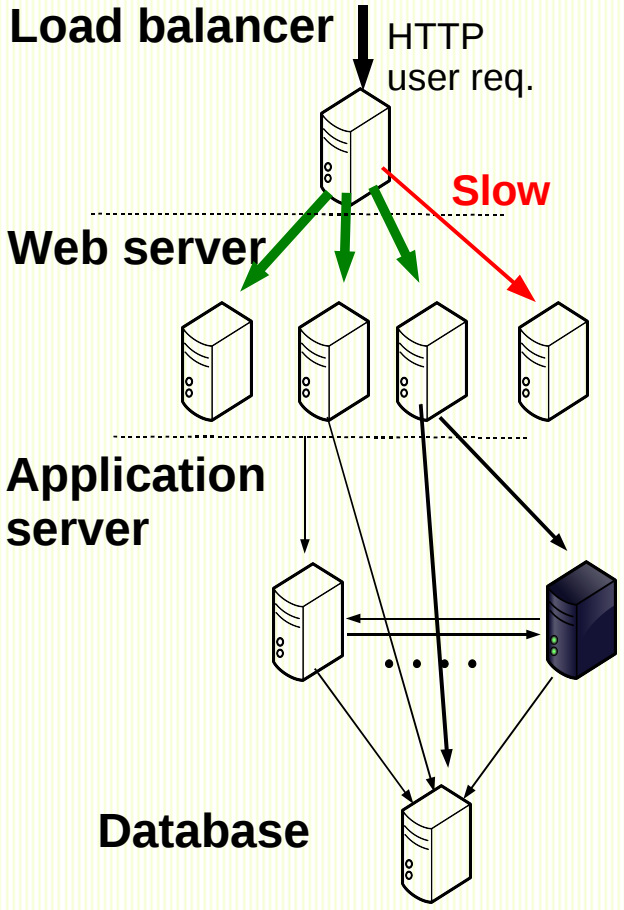
A Study of Anomaly Manifestations

1. Setup
2. Anomaly Root Causes
3. **Manifestation Patterns**

1. The DNS root cause increases the communication delay between components

2. If the load-balancer root cause afflicts the same web server, it will reduce the number of round trip communications

3. Well-balanced systems are often robust to single-node failures/slowdowns



Outline

1. A study of performance anomaly manifestations

2. **EntomoModel: Understanding the conditions where anomaly root causes are likely to manifest**

3. Entomophobic management: Avoiding performance anomaly manifestations

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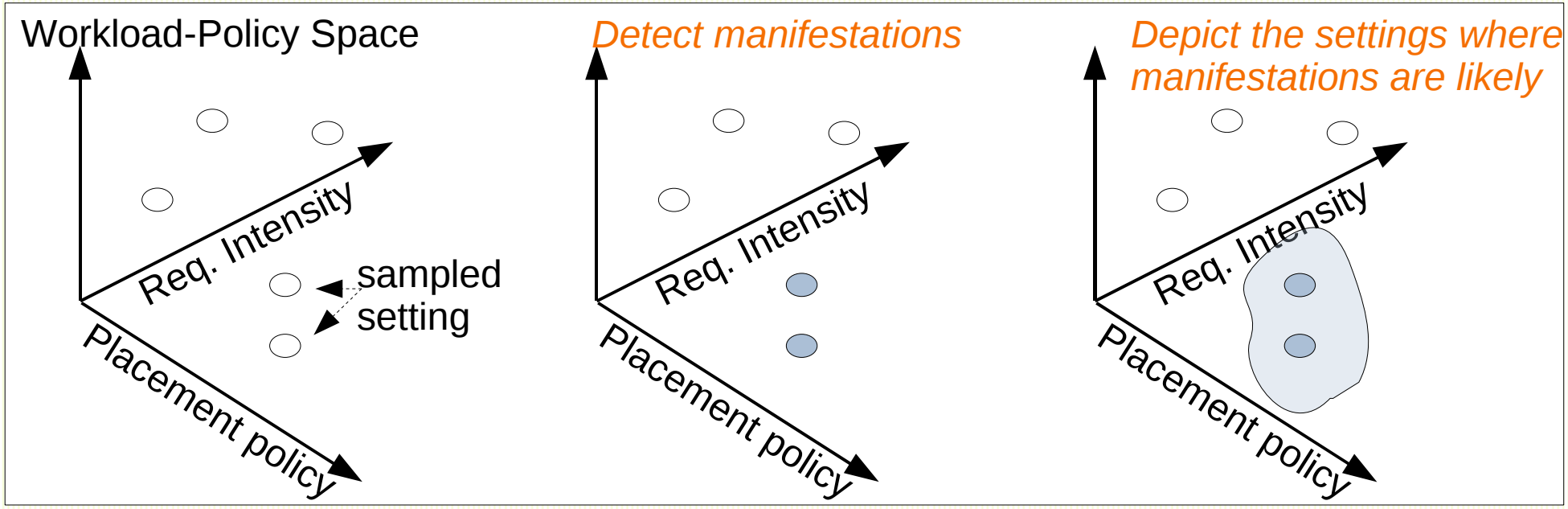
Understanding When Anomalies Manifest

1. Approach
2. Evaluation
3. Unknown Root Causes

- Intuition: Anomaly root causes are more likely to manifest under certain settings. *Which settings?*

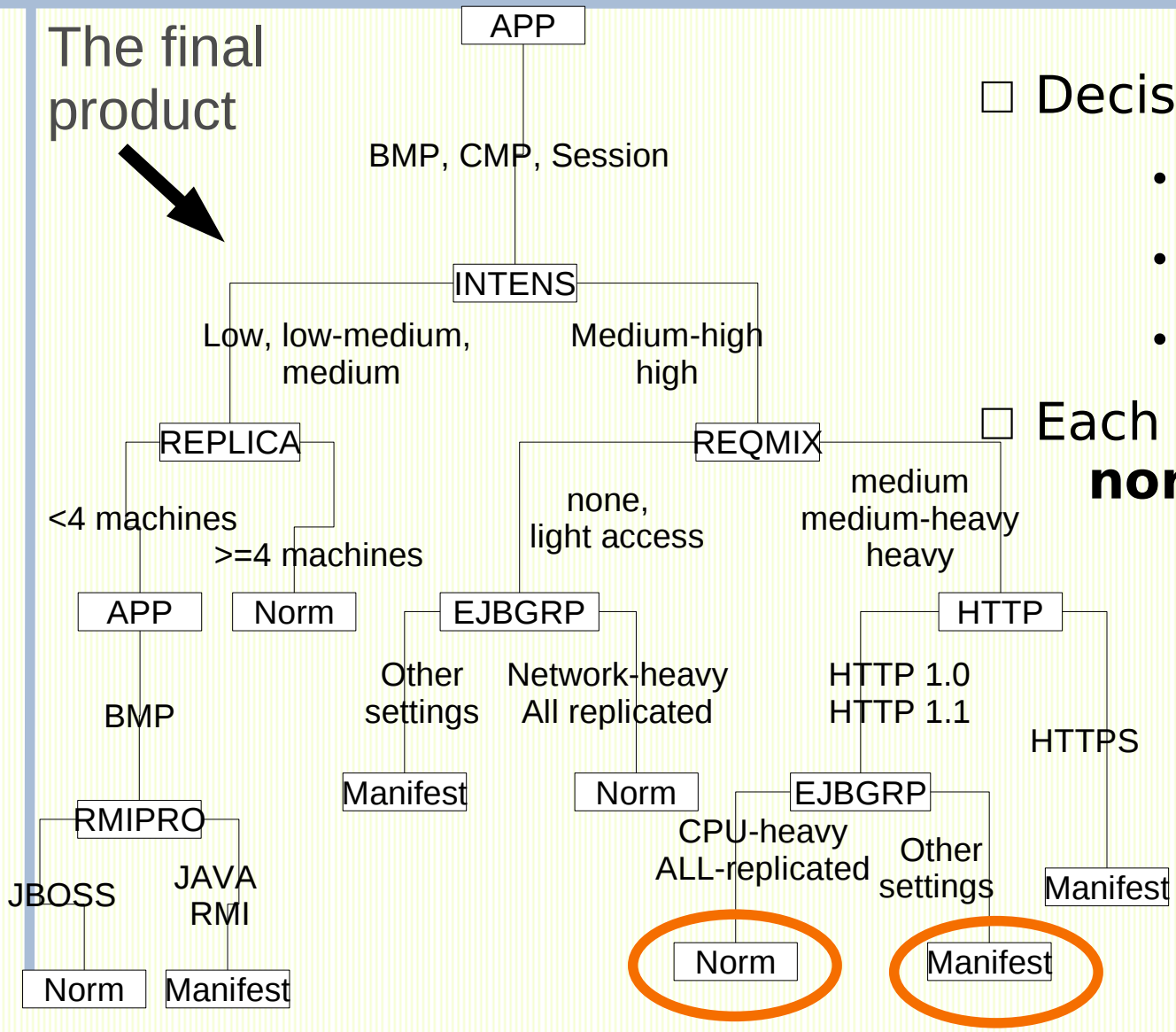
- EntomoModel uses 1) the ability to detect anomaly manifestations and 2) machine learning



Understanding When Anomalies Manifest

1. **Approach**
2. Evaluation
3. Unknown Root Causes

The final product



- Decision tree classifiers
  - No a-priori knowledge
  - Used in previous studies
  - Interpretable
- Each workload setting is **normal or manifest**

Understanding When Anomalies Manifest

- First, we used the approach in our study to detect the manifestation of known anomalies
  - 885 samples to build decision trees, 445 to evaluate

LB Root Cause	Predicted normal	Predicted manifest
Actual normal	86%	3%
Actual manifest	1%	10%

- Impact of emergent "good" behavior
  - For DNS+LB were reinserted in combination, *emergent "good" behavior reduced misclassification by 25%*
  - Across many combinations: 1) Never hurt and 2) Up to 50% reduction in misclassification

Understanding When Anomalies Manifest

1. Approach
2. Evaluation
3. **Unknown Root Causes**

- Unknown, active root causes will probably manifest under different settings than past, fixed anomalies

  Challenge: How can we detect the manifestations of root causes that we can't reinsert?

  Observation: Performance anomaly manifestations cause unexpected and significant performance degradation

  Our approach: Build a performance model that captures the systems expected performance---*A manifestation occurs when actual performance falls below the model's expectations*

  - [Stewart-NSDI-2005, Urgaonkar-Sigmetrics-2005, Stewart-Usenix-2008, Thereska-Sigmetrics-2008]

Understanding When Anomalies Manifest

1. Approach
2. Evaluation
3. **Unknown Root Causes**

Our approach: Build a performance model that captures the systems expected performance---*A manifestation occurs when actual performance falls below the model's expectations*

- 885 samples (of performance) and model predictions to build decision tree; 445 to evaluate
- Decision tree shown earlier

No Known Root Causes Inserted	Predicted normal	Predicted manifest
Actual normal	82%	7%
Actual manifest	2%	9%

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1. A study of performance anomaly manifestations

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Avoiding Manifestations

1. Entomophobic Man.
2. Results

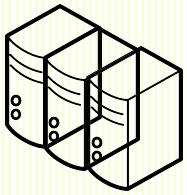
- Entomophobia is the fear of bugs
  - Option 1: Extermination---find and remove all anomaly root causes
  - Option 2: Avoidance [qin-sosp-2005]---operate under only the settings where anomalies don't manifest

Entomophobic management uses EntomoModel to identify workload and policy settings to avoid

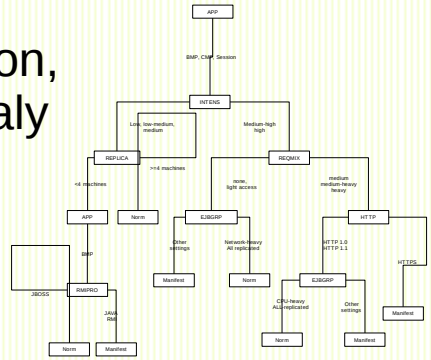
- Note, entomophobic management is intended to complement other online management techniques

Avoiding Manifestations

1. Entomophobic Man.
2. Results



Was this SLA violation, caused by an anomaly manifestation?



Yes, avoid it by changing this policy

Yes, but you can't avoid it

No apply other techniques, e.g, add nodes

Experimental Setup

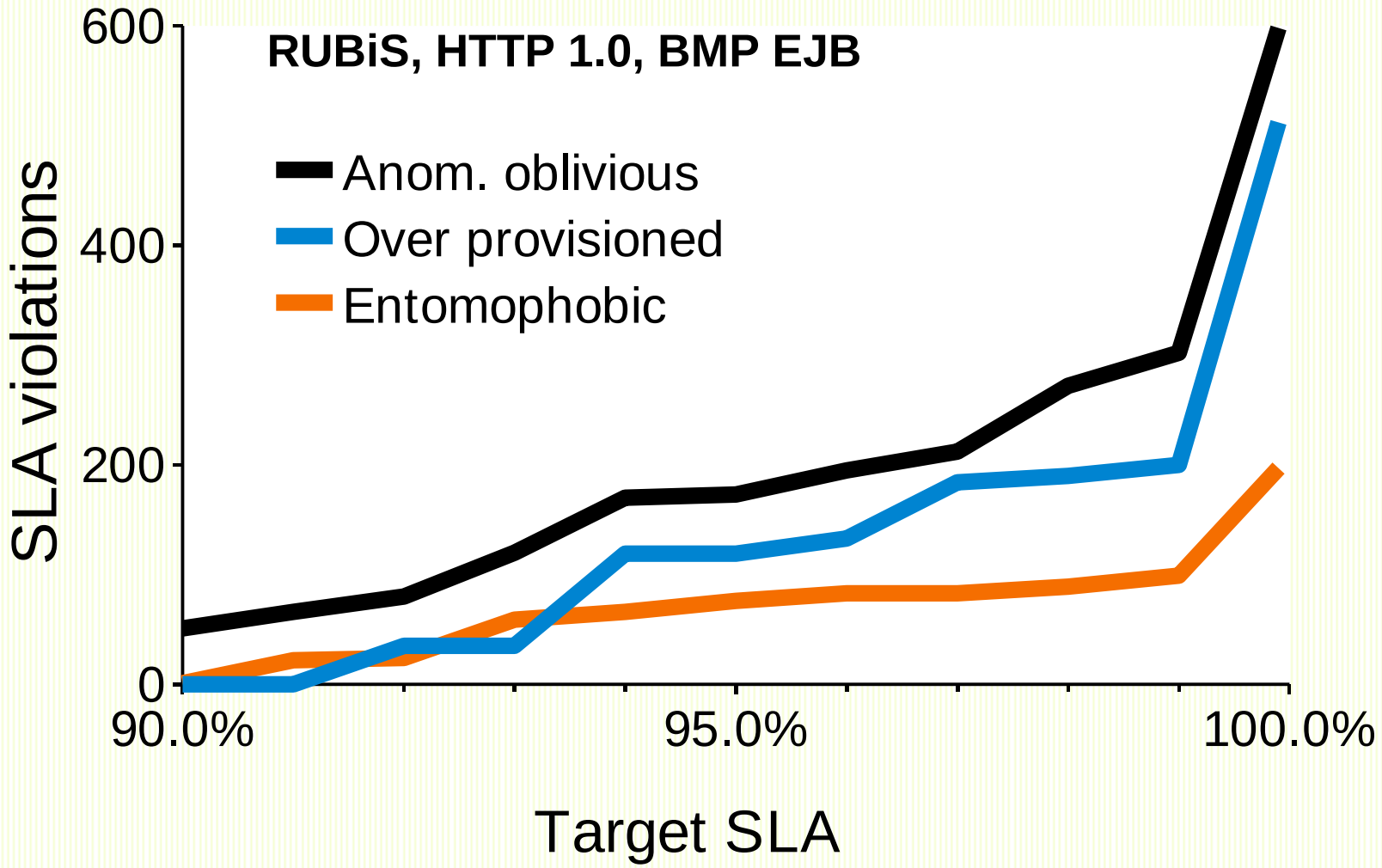
- Adapted a nonstationary request trace from a real enterprise application (stewart-eurosys-2007)
- Checked SLA status every 3 minutes

Compare 3 competing approaches

- Increase number of nodes on SLA violations
- Always use max nodes
- Entomophobic management uses EntomoModel

Avoiding Manifestations

1. Entomophobic Man.
2. Results



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Conclusion

- Jeff Mogul (mogul-eurosys-2006) warned about emergent behavior in complex computer systems, citing examples in networking and OS
- Eno Thereska et al. (thereska-sigmetrics-2008) created a hybrid human-crafted/machine-learned performance model.
- Kai Shen et al. (shen-sigmetrics-2009) proposed reference-driven anomaly detection---future direction
- Much work on online adaptive system management, e.g., padala-eurosys-2009

Conclusion

- How anomalous is your IAAS provider?
  - In this study, we learned that anomalies are more likely under certain management policies
  - *What is the role of the third-party infrastructure provider in avoiding anomaly manifestations?*
  - *Can an infrastructure provider trick monitoring components to inflate IAAS performance results?*

Approach: 1) Understand the effect of IAAS on performance dependability. 2) Create performance anomaly detection that can't be cheated.

Conclusion

1. Related Work
2. Future Work
3. **Take Aways**

- Performance anomalies manifest infrequently but their impact is significant
- Anomaly root causes manifest differently in combination than in isolation.
  - Under some settings, these interactions actually block manifestations (*emergent "good" behavior*)
- Anomaly manifestations are more likely under certain workload-policy settings, allowing machine-learned models (*EntomoModel*) to predict and avoid them.