Pinpoint: Problem Determination in Large, Dynamic Internet Services

Mike Y. Chen, Emre Kiciman, Eugene Fratkin,
Armando Fox, Eric Brewer

Univ of CA, Berkeley

Stanford Univ

Presented by

Ophelia Chesley

Motivation

- Requests for internet services very often travel through many components:
  - front-end load balancers
  - web servers
  - Frameworks
  - Databases
  - Everything else in between
- Hard to determine the cause of unanticipated faults among components
- Need to develop dynamic analysis methodology to detect problems and isolate root causes

Goals of the Methodology

- To dynamically trace internet requests through a multi-layered system without human intervention.
- To record the outcome (success or failure) and the components that service them
- Use data clustering and statistical techniques to correlate failure to components

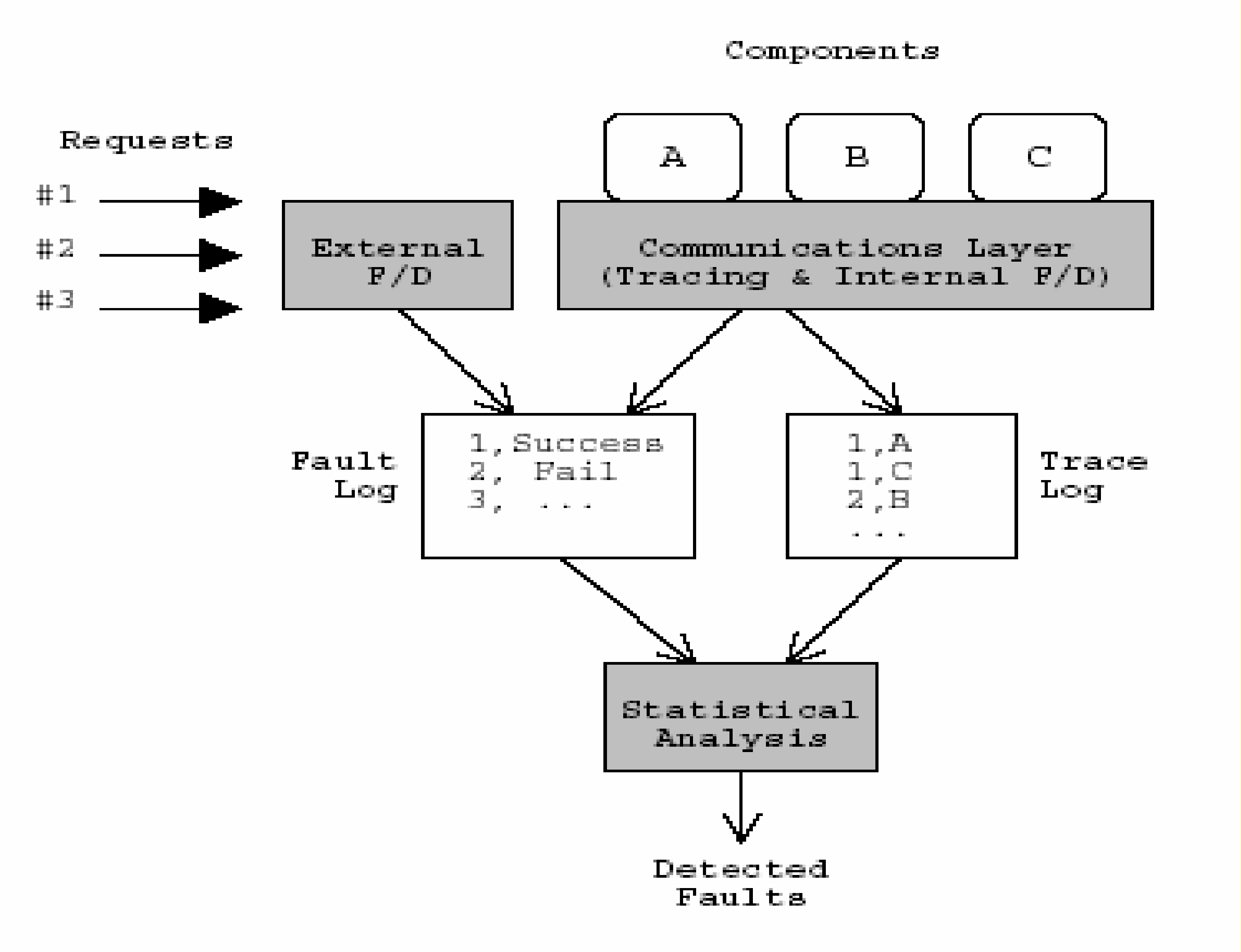
Overview

- Assumptions
- Pinpoint Framework
  - Client request tracing
  - Failure Detection
  - Analysis
- Implementation
- Experiments
- Limitations of Pinpoint
- Conclusion

Assumptions

- Different combinations of components are used for different requests
  - Granularity at the component level
- Failure of a request is independent of the activities of other requests
  - Highly replicated internet services clusters
  - Minimized single-point of failure

Pinpoint Framework



Client Request Tracing

- Each request is assigned a requestID
- Instrument the middleware and communication layers to record <requestID, component_ID> pairs
- Request ID is passed from component to component by the middleware along with the call data
- Collect machine, cluster, component, component version, database table, configuration file information
- Depends on inter-component communication protocol
- Generates the trace log

Failure Detection

- Internal Failure Detection
  - Report failures that might be masked
  - Options to track assertions and exceptions generated by the application components
- External Failure Detection
  - Failures that are visible to users
  - Include infrastructure and application failures
- Generates the failure/success log

Data Analysis

- Use data clustering algorithm
  - Groups similar data points together
  - Correlates failure with a set of components cluster

Implementation of Pinpoint

- J2EE instrumentation
- Layer 7 Packet Sniffer
- Data Analyzer

J2EE Instrumentation

- Pinpoint sits on top of J2EE middleware
- No modifications at application level
- Instruments three types of components:
  - Enterprise JavaBeans (business/application logic)
  - Java Scripting Pages (dynamic HTML)
  - JSP tags that extends JSP
- Can be extended for any J2EE applications

J2EE Instrumentation

- Request ID stores in a thread-specific local variable
  - Assume components do not create threads
  - Does not support clustering
- Internal fault detector logs exceptions that pass component boundaries
- Request ID is passed to the external fault detector using the HTTP header

Layer 7 packet Sniffer

- Snifflet is the external fault detector
  - Built to capture TCP packets
  - Monitor TCP and HTTP failures (timeouts, resets, 404 not found, 500 Internet server error, etc.)
  - Can be programmed for customized failure detection

Data Clustering Analyzer

- Use hierarchical clustering method
  - Unweighted pair-group method using arithmetic averages (UPGMA)
    - Distance between clusters = average distance among all pairs of points within the clusters
  - Jaccard similarity coefficient
    - Distance between 2 points = number of requests they appear in together/all the requests the 2 points appear in total

Experiments

- System setup
- Metrics: accuracy versus precision
- Results

Experiments - Setup

- One machine with J2EE server
- One machine with a client browser emulator
- Use the PetStore demo application
- Executed 133 tests
  - Application server restarted after each test
  - 1 transaction active at any time
  - Each transaction exercise different sets of components

Experiments - Setup

- Each test is injected with faults:
  - Declared exceptions (masked by application)
  - Undeclared exceptions (often caught by middleware)
  - Infinite loops (TCP timeouts)
  - Null calls (detectable through other faults)
- Fault is always injected to the last component used in a request

Experiments - Metrics

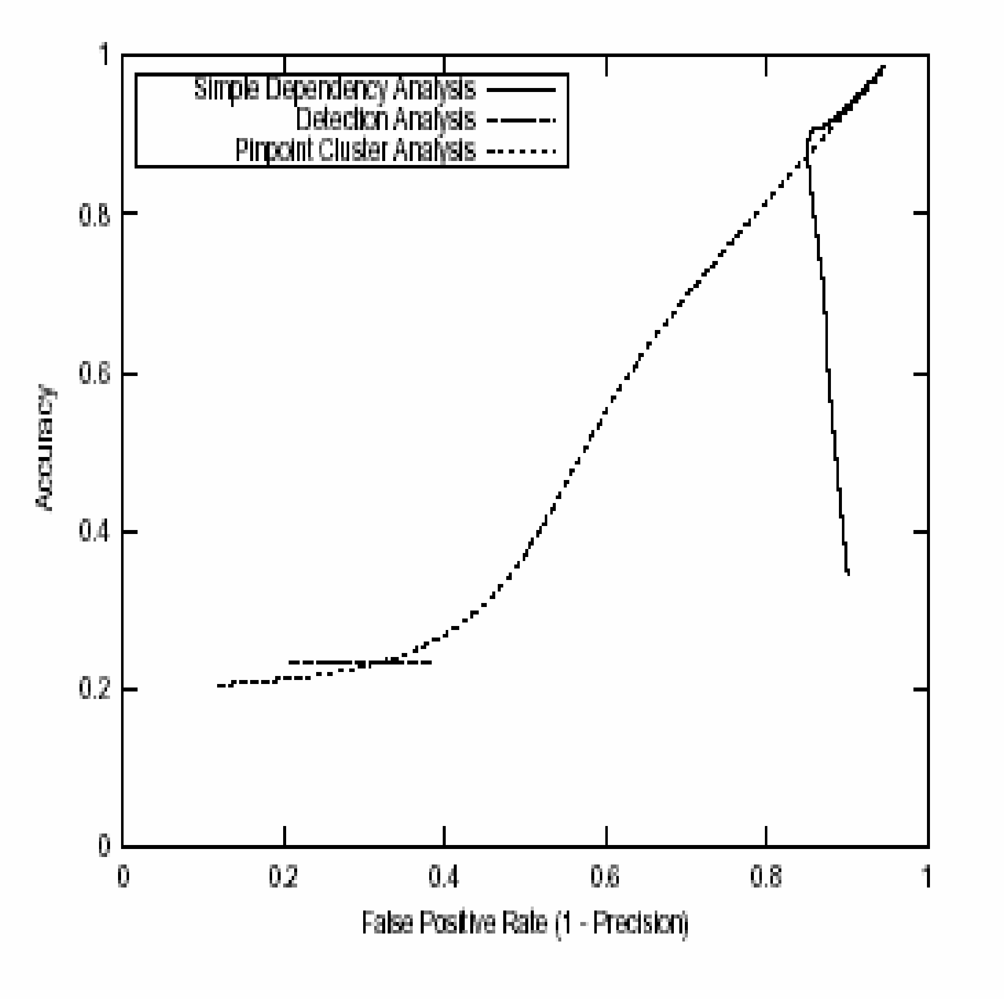
- Accuracy
  - How often all components causing a fault are correctly identified
- Precision
  - Ratio between correctly identified faults and predicted faults
- Increasing accuracy can result in many false positives

Experiments - Results

- Compare Pinpoint to 2 other techniques (detection and dependency checking) in terms of accuracy and precision
- Detection:
  - Similar to Pinpoint's internal fault detector
  - Return component where a failure is manifesting
- Dependency Checking:
  - Returns components that the failed requests used
  - Ignore successful requests

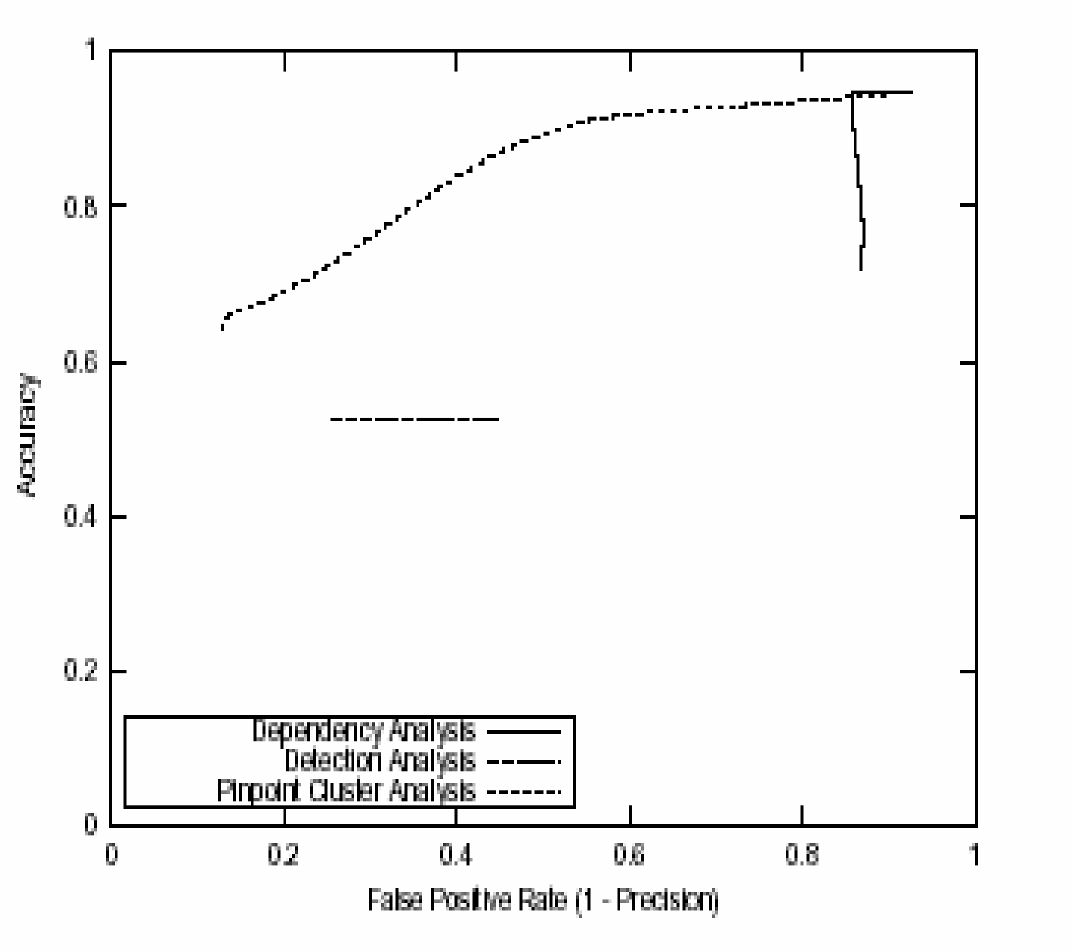
Experiments - Results

- Online overhead is about 8.4%
- Pinpoint has higher accuracy and precision than the other techniques



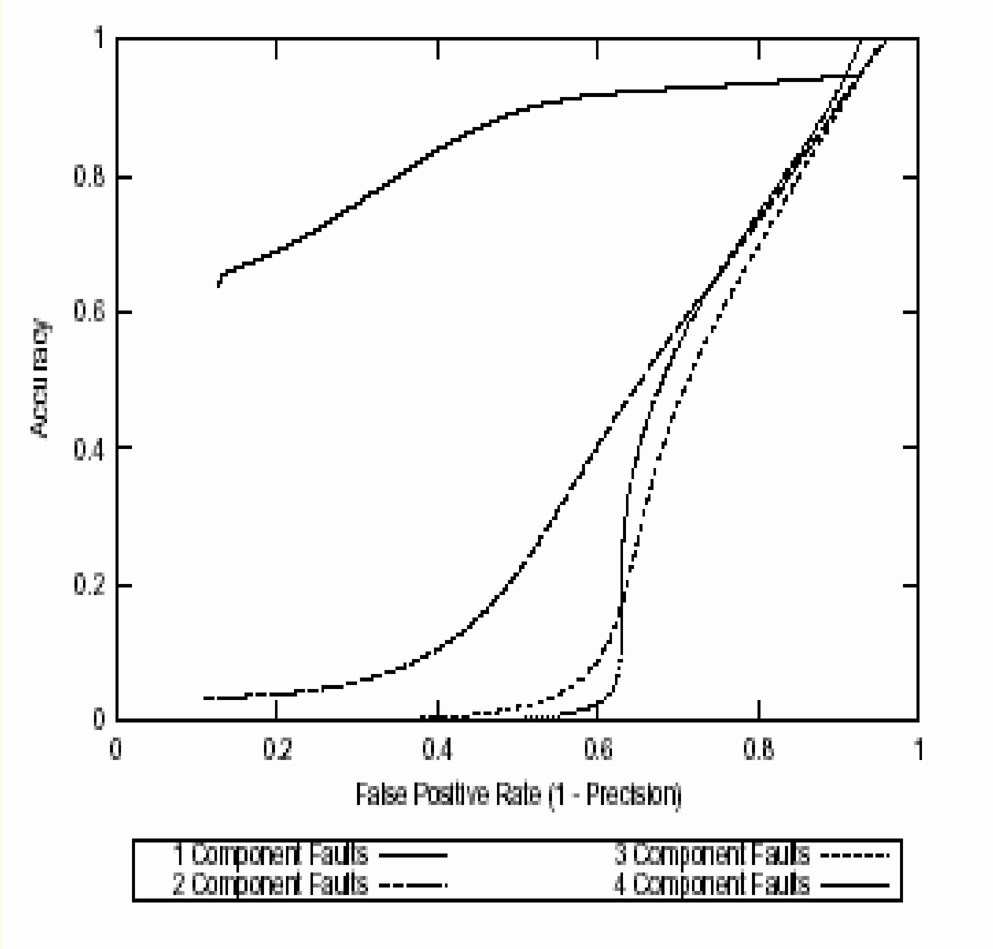
Experiments - Results

- Pinpoint does well for single-component failures



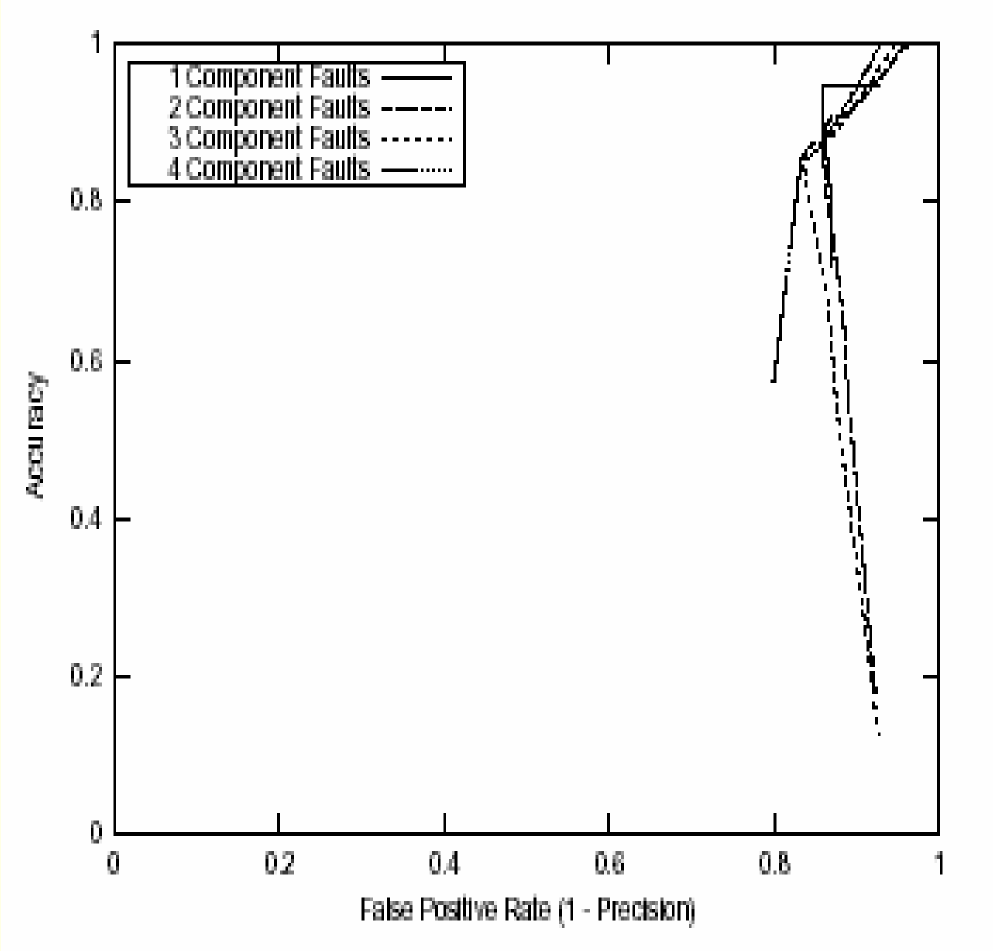
Experiments - Results

- Effectiveness of Pinpoint decreases as fault length increases
- Fault length is the number of interacting components that causes a failure



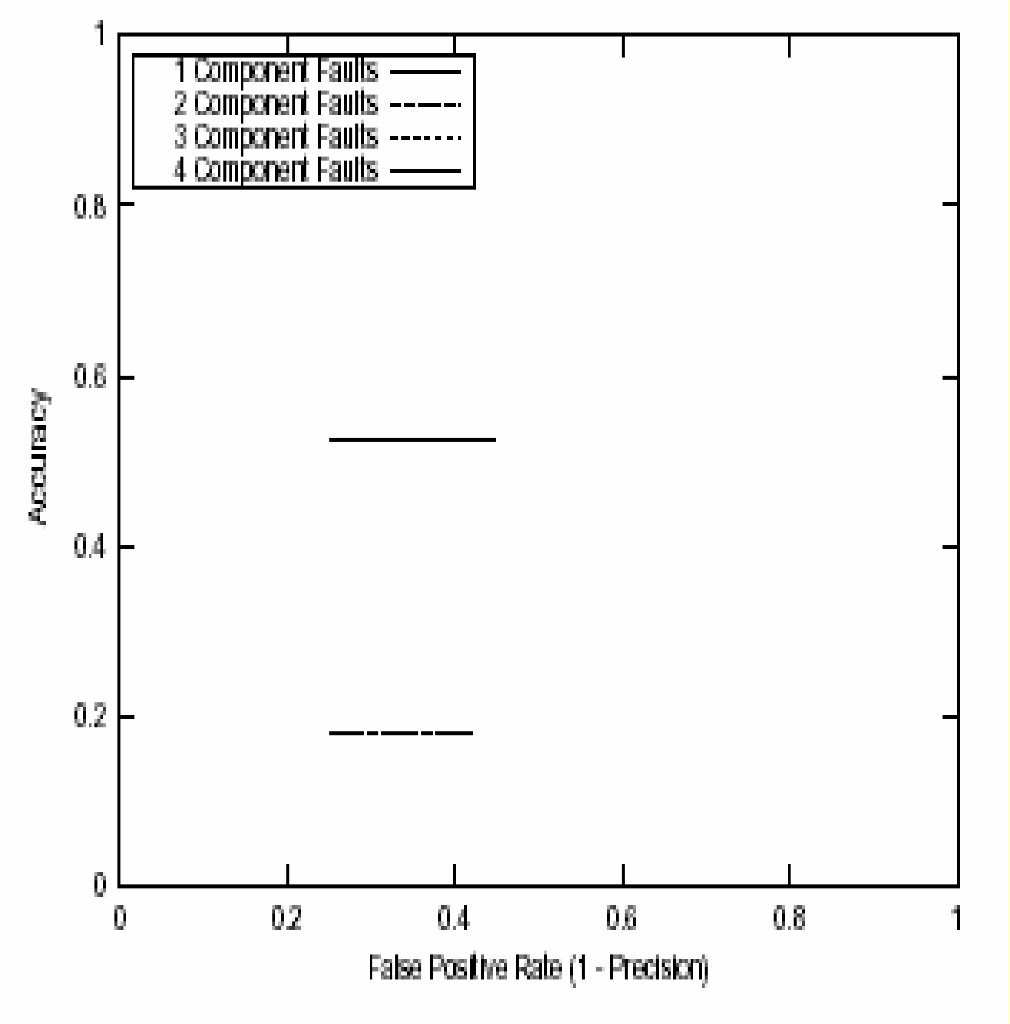
Experiments - Results

- Dependency always has low precision
- Not affected by fault length



Experiments - Results

- Detection is extremely sensitive to fault length
- Precision is about 30%
- Accuracy ranges from 50% to 0%



Limitations

- Pinpoint cannot distinguish tightly coupled components
- Pinpoint does not work for non-independent requests
- Pinpoint does not distinguish between bad inputs and failures
- Pinpoint does not capture masked faults that result in decrease in performance

Conclusion

- Presents a new problem determination framework for large, dynamic system
- Prototype Pinpoint has higher accuracy and precision that 2 other traditional techniques