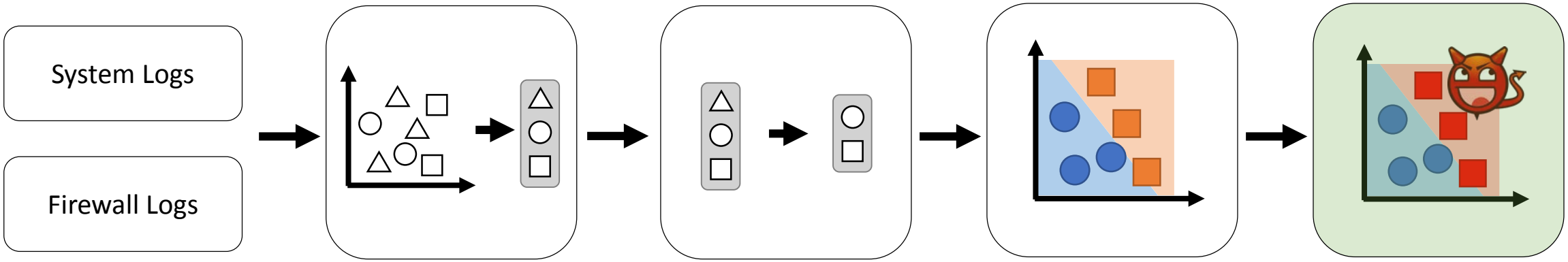
Intrusion Detection Using Monitor Information Fusion

Student: Atul Bohara

P.I.: William H. Sanders

Previous Work [1]

Intrusion detection by combining and clustering diverse monitor data



Host-level and network-level context

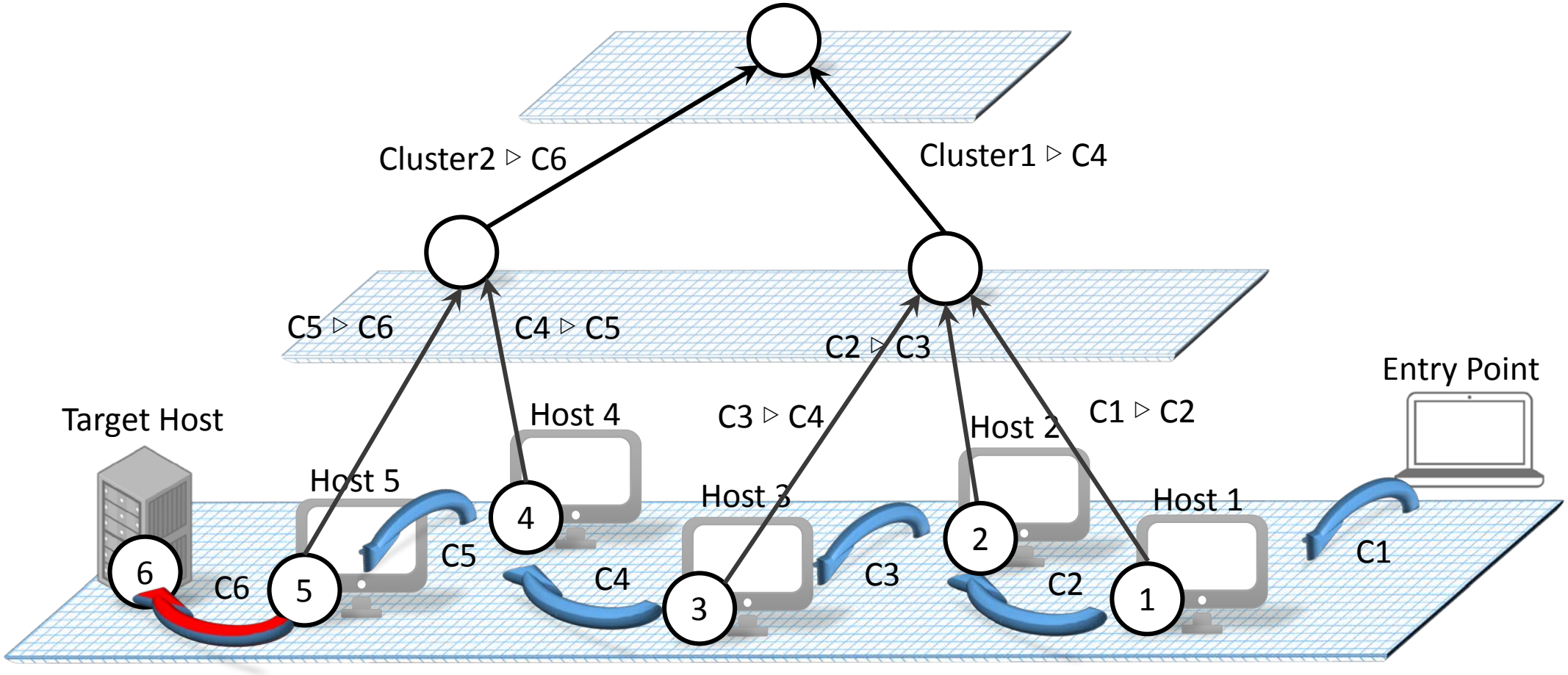
Feature extraction and selection

Cluster analysis and prioritization

Intrusion Detection in Enterprise Systems by Combining and Clustering Diverse Monitor Data. Atul Bohara, Uttam Thakore, William H. Sanders. In *Proceedings of the 2016 Symposium and Bootcamp on the Science of Security* (HotSoS '16)

Previous Work [2]

Lateral movement detection using distributed data fusion



Lateral Movement Detection Using Distributed Data Fusion. Ahmed Fawaz, Atul Bohara, Carmen Cheh, William H. Sanders. In *Proceedings of 35th Symposium on Reliable Distributed Systems* (SRDS 2016).

Ongoing Work

Proactive detection of advanced attacks through fusion

- Hypothesis: events observed in the system, as a result of a multi-stage attack, are correlated. By combining the evidences of different attack stages, we can increase the confidence in the detection of overall attack
- E.g., Fuse the evidence of *C&C* and lateral movement to detect and prevent a possible data exfiltration attack
- Data-driven modelling of attack and defense (system)

Air Force Research Laboratory

Chris Cai

PI: Professor Roy Campbell

Integrity ★ Service ★ Excellence

CRONets: Cloud-Routed Overlay Networks

- We aim to understand what level of performance improvement can a user expect to get from leveraging public cloud service to build overlay network, as opposed from other resource providers like ISPs.
- Performance metrics can include throughput, latency, loss rate, etc, corresponding to particular demands of different applications.
- Questions to answer:
  - **Can CRONets provide similar improvements compared to the previous experimental studies, but in a realistic-cloud-setting?**
  - **How can emerging technologies simplify the overlay path selection problem?**

Measurement Testbed

- We use PlanetLab nodes as clients and Eclipse mirros as servers. We use IBM Softlayer as cloud provider to provide overlay nodes.
- Blue labels indicate locations of PlanetLab nodes. Red labels indicate locations of overlay nodes.

Contributions

- Our work will help large companies as well as individual users to best leverage the available commercial cloud network resources to meet their specific network requirement.
- CRONets also has the potential to provide a robust fault-tolerant transmission layer to help application surviving network failures.
- Our work will help cloud provider to better design their inter-datacenter transmission mechanism to be “CRONets-friendly”.

U.S. AIR FORCE

Advisor: Professor Iyer, Professor Kalbarczyk

KEYWHAN CHUNG

Security as a Signaling Game

- Continued work w/ Dr. Kamhoua & Dr. Kwiat at AFRL
- An approach on modeling the **decision making process** for security under limited observation on the environment as a **signaling game**, and studying the effectiveness of the optimized decisions
- Simulation results had shown:
  - That the signaling game can reason the decisions of the attacker
  - Worst case scenarios for the defender
  - Promising evaluation results compared to the common approach
- Further steps:
  - Comparison with more advanced mitigation methods or other attack models
  - Deployment to a real system w/ real monitors and responses

Attack on Computing Infrastructures through Targeted Alteration of ICS

- A study on seeking the possibility of utilizing the relatively weak security of the ICS systems to attack a well hardened computing infrastructure that requires advanced environmental control
- Studied the cooling system for Blue Waters
  - Campus / Building / Cooling cabinet level
  - Interdependency between the systems
- Studied Blue Waters failures related to the cooling system
  - Three failure scenarios with possibility of the attacker replaying through alteration in the monitoring / control system
- Further steps:
  - Formulation of the attack model
  - Mitigation methods (Bro IDS, etc.)

Intel VT-x on QEMU

Lavin Devnani

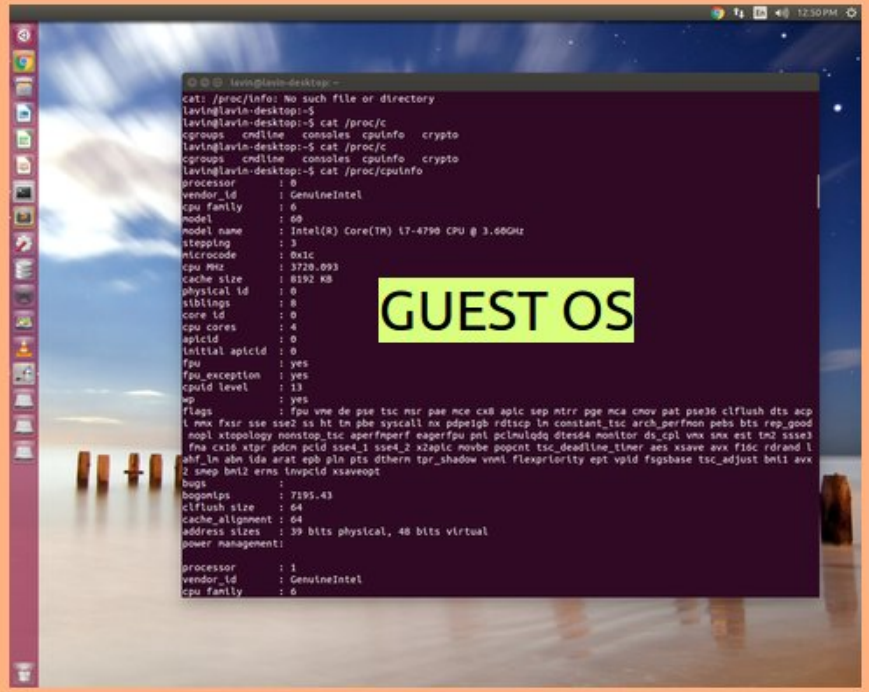
PROJECT GOALS

- Extend QEMU (Quick Emulator) to emulate Intel VT-x instruction set
- Run a hypervisor + guest OS in emulated operating system
- Support future security and reliability projects

QEMU + VT-x

HOST OS

KVM



Future Applications

- Taint analysis of VT-x
- Taint analysis + Symbolic execution
- Profiling existing hypervisors
- Prototyping new hypervisors
- Extension of VMX functionality

Cloud Security Certifications:
A Comparison to Improve Cloud Service Provider Security

Carlo Di Giulio (cdigiul2@illinos.edu)
Masooda Bashir (mn@illinois.edu)

09/21/2016

Previous Steps

Goals:

- Security & Privacy in Cloud Environments
- Evaluation of cloud vendors
- Market trends

3 Pillars:

- Laws and Regulations
- Cloud services
- Privacy and security policies

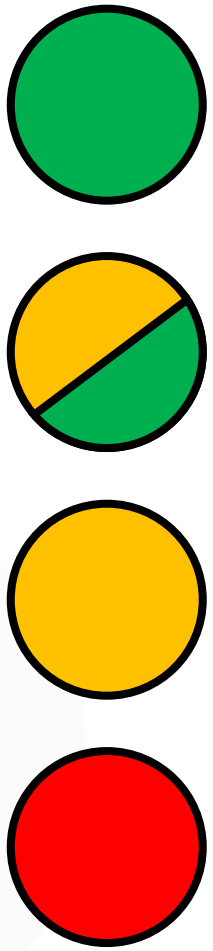
- Focus on the first and third pillar
- Security and privacy certifications and standards
- FedRAMP, ISO27001

Contribution

- Evaluation of the impact and relevance of Privacy and Security certifications for Cloud Services
- Deeper understanding of vendors' commitment in promoting information assurance
- Suggestion of improvements to current standards and guidelines

Current Status, Accomplishments

- ISO27001:2005 and 2013
- FedRAMP Moderate and High baseline (DoD Lev 2-4)
- AICPA SOC2 (TSPC 2014 and 2016)
- BSI Cloud Computing Compliance Control Criteria (C5)



Secure Containers

Konstantin Evchenko, Read Sprabery, Abhilash Raj*, Sibin Mohan, Rakesh Bobba*, Roy H. Campbell

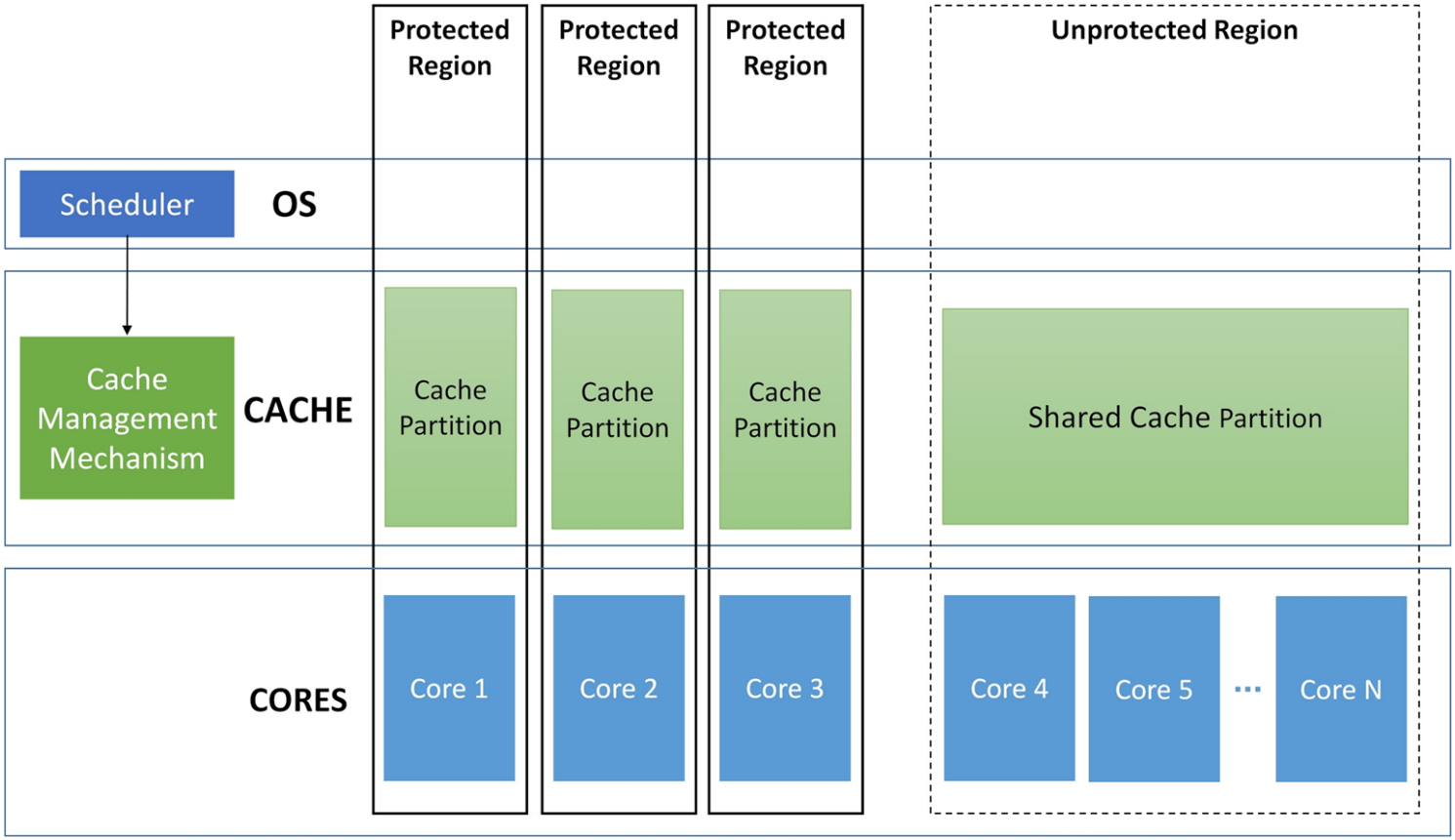
University of Illinois at Urbana-Champaign

*Oregon State University

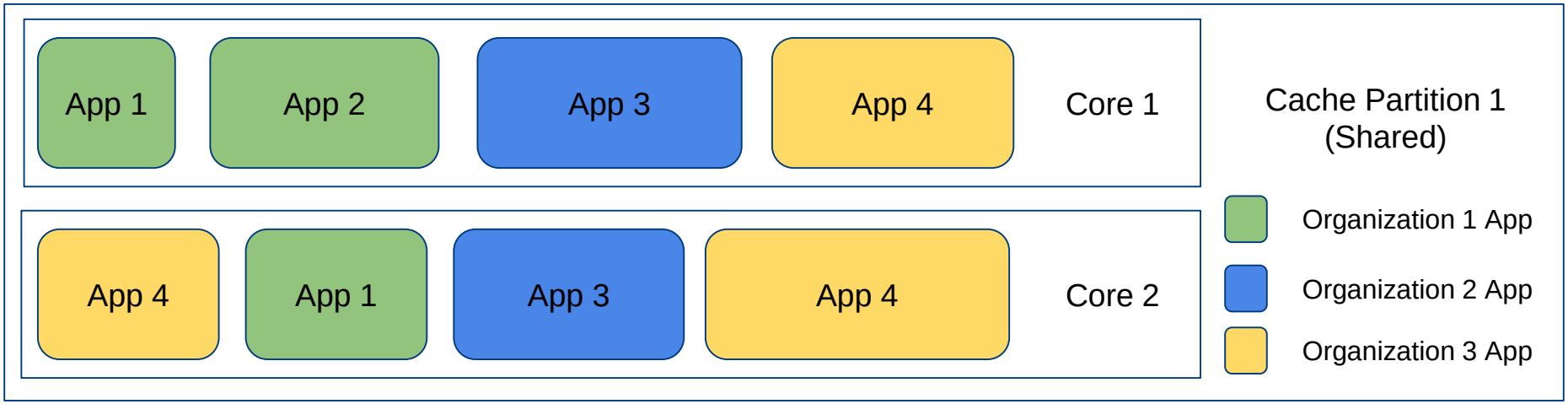
Motivation

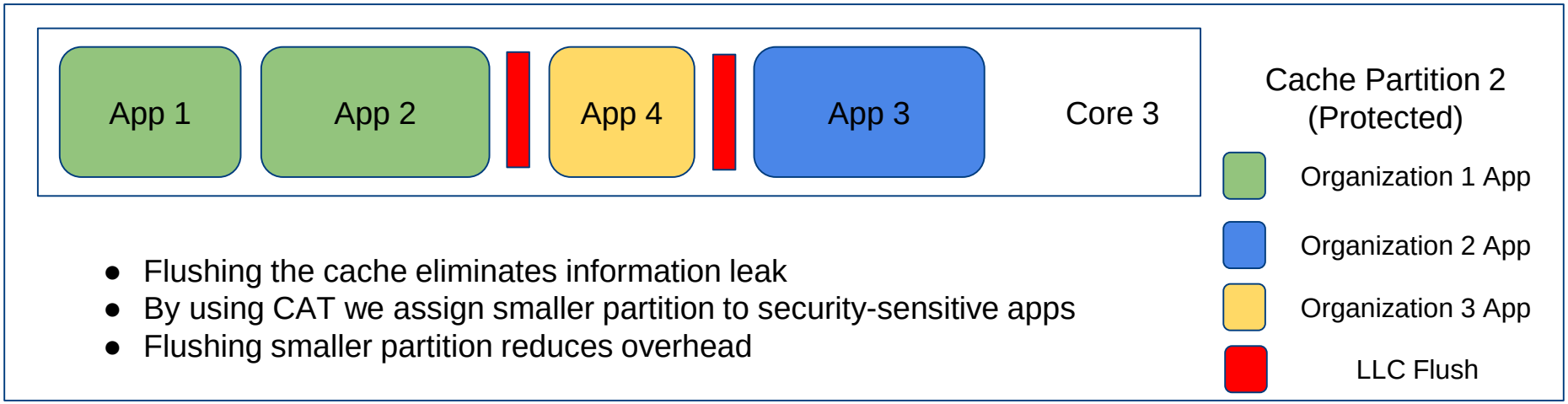
- Container-based products become ubiquitous in cloud infrastructure
- Several parties run their containerized applications in a shared environment
- Enables cache-based side-channel attacks (e.g. Prime+Probe and Flush+Reload)
- These attacks can be used to retrieve fine-grained sensitive information (e.g. cryptographic keys)
- Both attacks have been effectively carried in PaaS and IaaS infrastructures, both in a lab and real world environments

Cauldron Framework Design



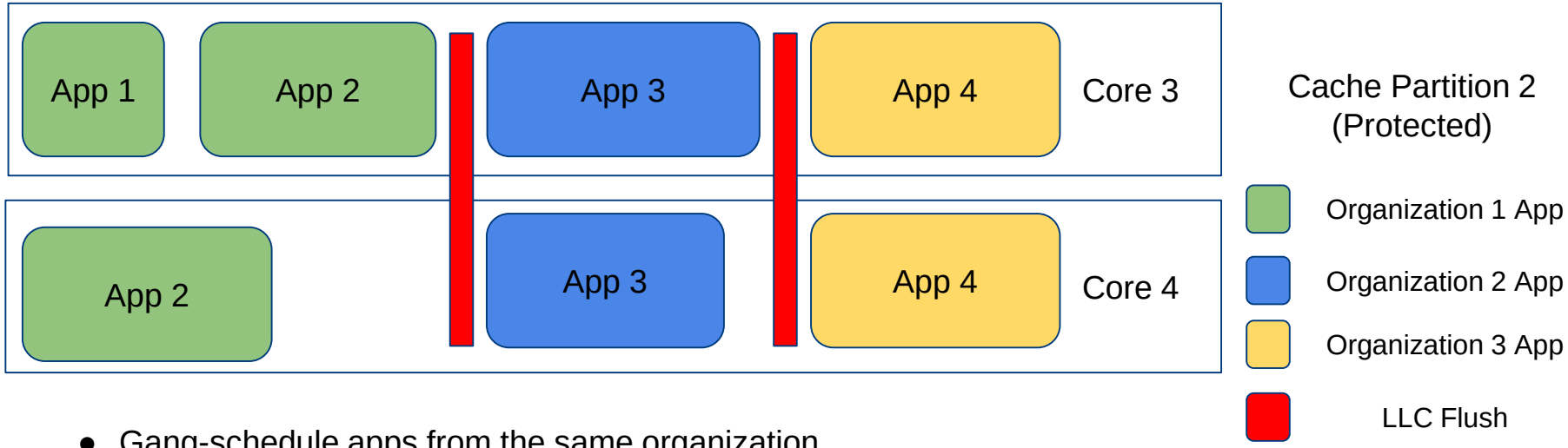
Workflow example





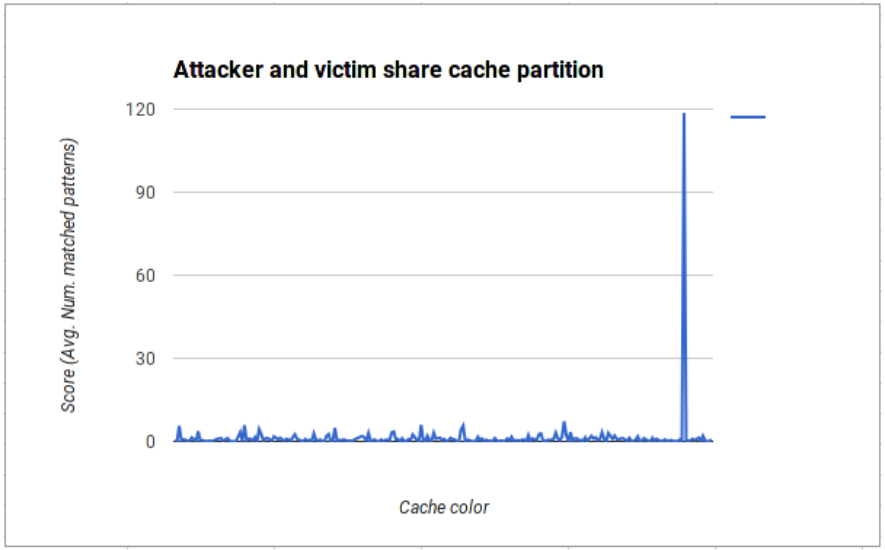
- Flushing the cache eliminates information leak
- By using CAT we assign smaller partition to security-sensitive apps
- Flushing smaller partition reduces overhead

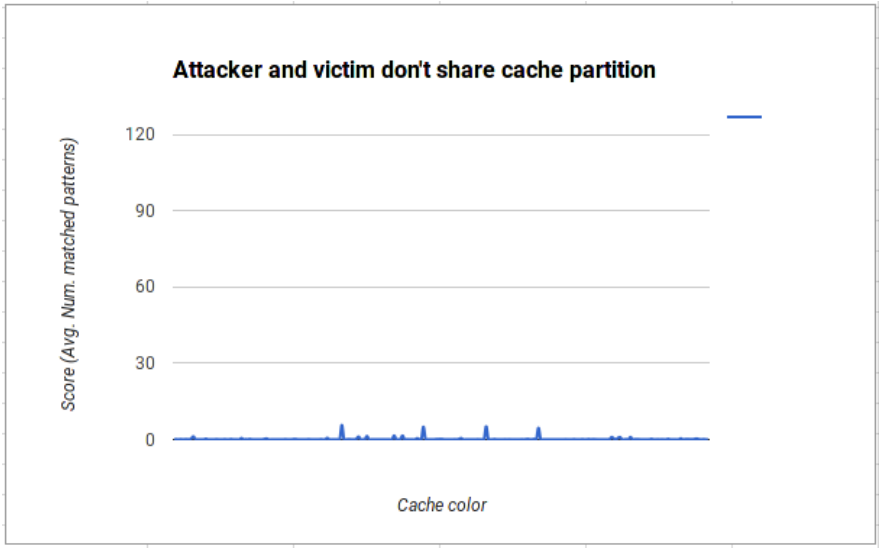
Improving performance with Gang Scheduling

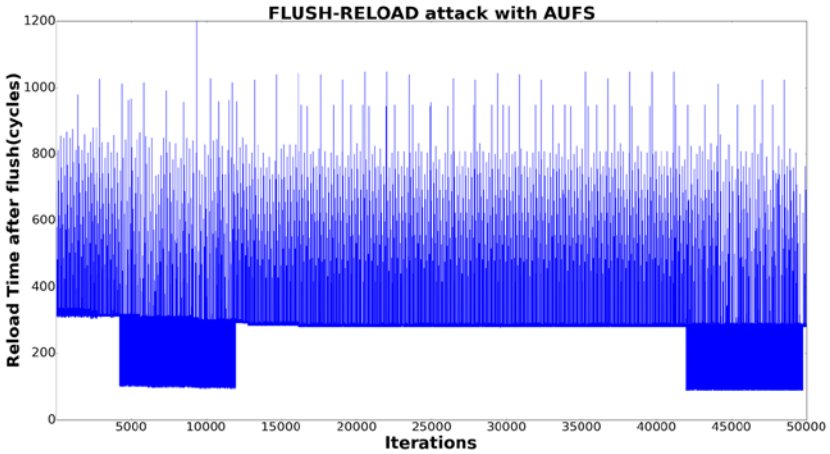


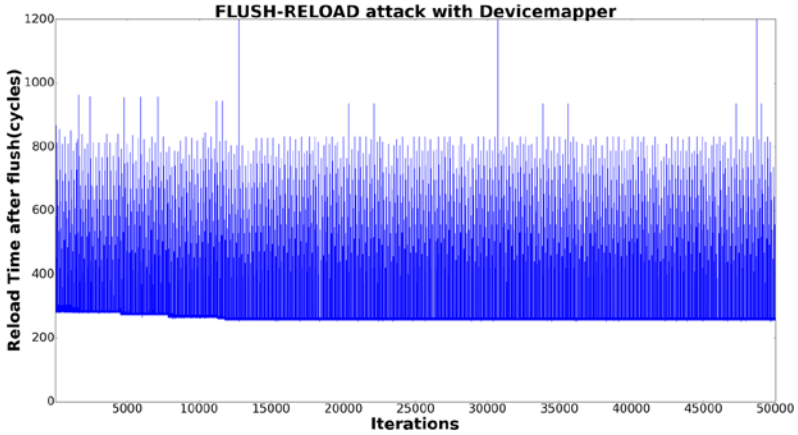
- Gang-schedule apps from the same organization
- Reduces the number of flushes
- Potentially increases idling
- Possible solution: soft gang scheduling
  - If no apps from the same org are available, schedule from other orgs
  - No flushing
  - Might leak some information, but not enough to enable the attack

Initial results









Future Work

- Design a Secure Containers framework with support from multiple layers of the stack including hardware, hypervisor, kernel, compiler and application layer.
  - Hardware supported isolation and sandboxes
  - Novel scheduling techniques for increased isolation and performance
  - Monitoring techniques to detect compromises and protect containers from both co-tenants and host

Getafix: Workload-aware Data Management in Lookback Processing Systems

Presenter: Mainak Ghosh

Collaborators: Le Xu, Thomas Kao, Xiaoyao Qian, Indranil Gupta

Problem

- Lookback Processing Systems -- Warehouse for time series data
- Current systems like Druid, Pinot make workload assumptions in design replication, caching and load balancing strategies
  - Recent segments assigned to “hot tier” -- larger replication
  - LRU used for cache eviction
- Under a different workload, this causes, poor memory utilization, large network overhead
- Our solution, Getafix, proposes a general solution which looks at segment popularity to define replication, caching and load balancing strategies.

Progress

- Finished so far …
  - Proposed an optimal algorithm which can minimize the replication while improving throughput
  - Compare different replication strategies using a simulator
  - Implemented Getafix inside Druid
- Moving on …
  - Evaluate the improvements in memory usage, effect on query throughput while using our adaptive replication scheme
  - Implement popularity aware caching and load balancing strategies and measure their effect
  - Publish this work in a top conference.

Energy-Aware Dynamic Code Offloading in Mobile Cloud Applications

Kirill Mechitov, Atul Sandur, and Gul Agha

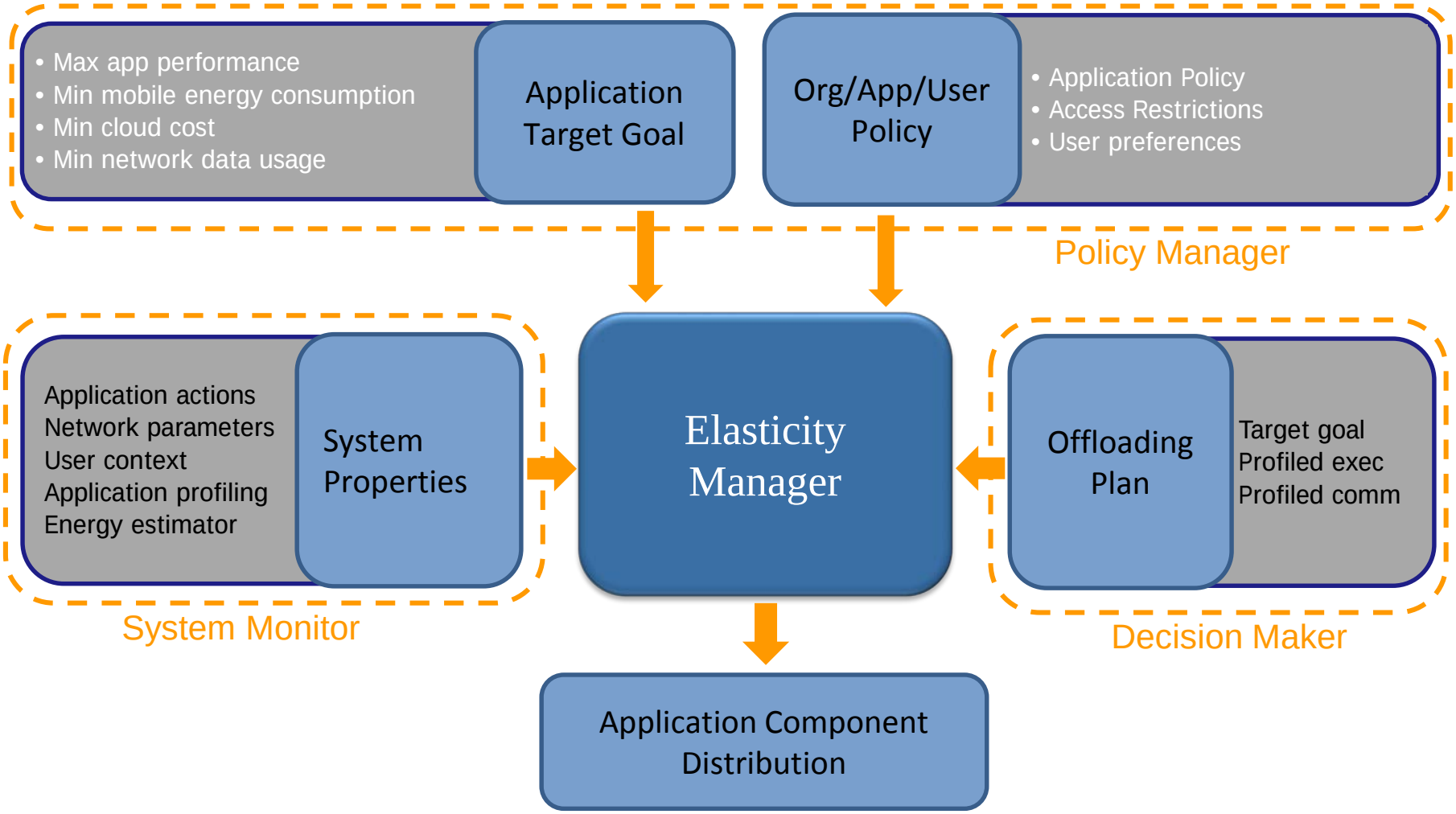
IMCM: Illinois Mobile Cloud Manager

- Code offloading:
  - Automatic
  - Dynamic
  - Fine-grained
  - Parallel
- Supports:
  - Hybrid cloud with multiple cloud spaces
- Provides:
  - Policy-based control by cloud provider, app developer, user

Research topics

- Monitoring
  - Real-time fine-grained monitoring of energy use, performance, security of mobile actor-based applications
  - Real-time monitoring of actor energy use and access patterns to identify malicious code
- Optimization
  - Refined model for actor deployment and dynamic reconfiguration in hybrid mobile-cloud spaces with security-aware priority management
- Model-checking
  - Use model-checking tool for creating valid and sensible initial deployment configurations
- Policy-based control
  - Composable per-site, per-actor, per-user policies

IMCM framework



Future work

- Full IMCM Framework proof-of-concept implementation
  - Based on Salsa for Android mobile actor platform
- Model-checking tool for actor deployment
  - Timed Rebeca model of mobile-cloud hybrid applications
- Optimization algorithm for actor deployment and reconfiguration
  - Performance & energy goals
  - Policy-based access restrictions
  - Assurance of performance guarantees/SLAs

A Digital Forensic Analysis Framework

Imani Palmer
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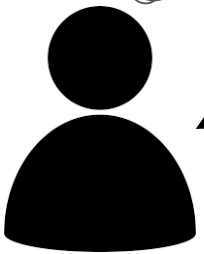
Motivation

Cloud is composed of a large number of components vulnerable to attacks
Systems generate an enormous amount of digital evidence
Incident responders/examiners determine the cause of the intrusion
Analysis of digital evidence remains highly subjective to the forensic practitioner

The Problem

The digital forensic investigative process is marred by its lack of knowledge, accreditation, and human bias.

Analysis



Analysis Toolkit

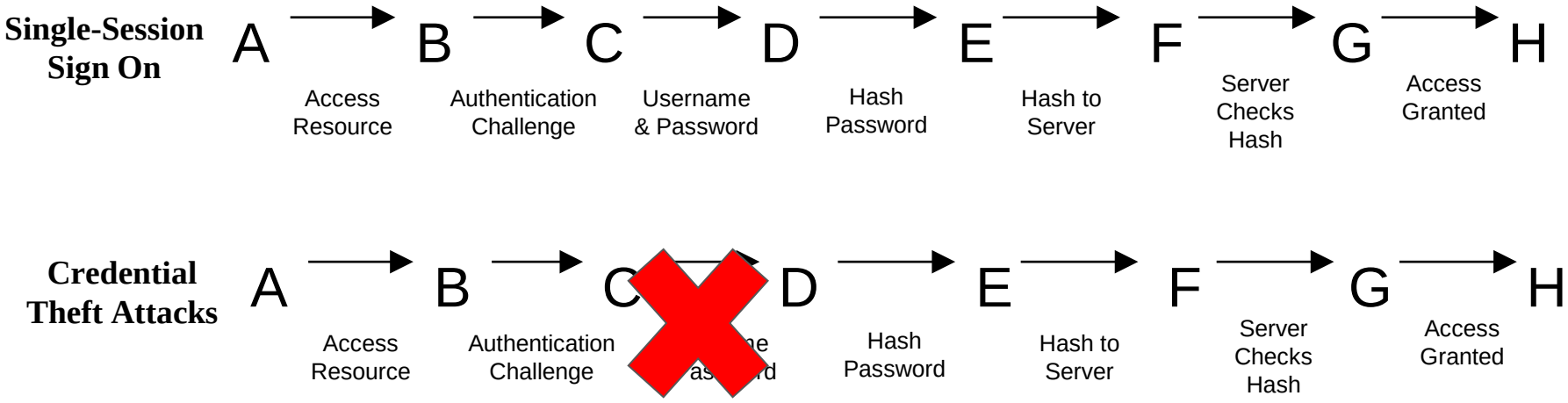
- Google Search History
- Chat logs
- Email
- Photos
- Internet Activity Logs
- Executable Programs
- Internet Protocols Address
- Financial Asset Records
- Address Books
- Telephone Records
- Maps
- Movie Files
- Images
- Configuration Files

Analysis Toolkit

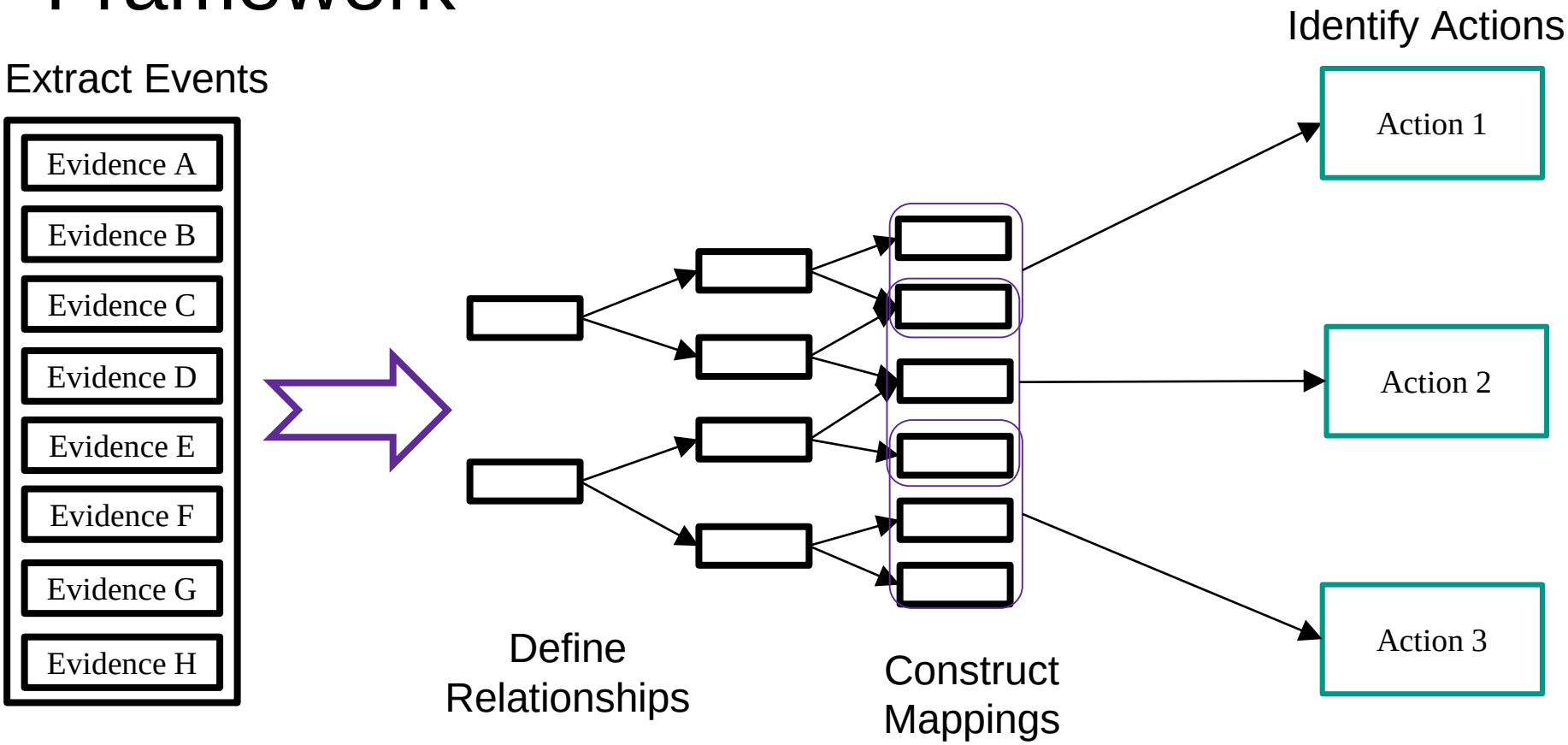
This actor took action X is supported by facts with strength and quantity

Objective Analysis

Provide quantitative assessments to detect user actions



Framework


Extract Events
Evidence A
Evidence B
Evidence C
Evidence D
Evidence E
Evidence F
Evidence G
Evidence H
Define Relationships
Construct Mappings
Identify Actions
Action 1
Action 2
Action 3

Continued Work

Implement Framework

Run case study evaluations

Provide a tool for digital forensic investigators

Verification of Distributed Key-Value Stores Using Reachability Logic

Stephen Skeirik
PI: José Meseguer

Introduction

- Knowing that a distributed system design satisfies certain
  - Consistency
  - Latency
  - Security

  requirements *before* being fully built saves time and money

- Model checking and deductive theorem proving-based techniques can both be used to verify distributed systems meet such requirements

Project Status

- We have successfully used model-checking techniques to explore the behavior of key-value stores, e.g. Cassandra
- To provide even greater assurance, we plan to develop and verify models of key-value stores in reachability logic
- *Reachability logic* naturally models behaviors of *complex, concurrent* systems with *recursive* behavior (as a generalization of both Hoare and Separation logic)
- We have already performed simple experiments modeling and verifying mutual exclusion algorithms

Future Outlook

- Our work will proceed in two directions:
  - Modeling and verifying a selection of distributed key-value stores (e.g. Cassandra and G-DUR are potential targets)
  - Using the ACC case studies to improve the effectiveness of our reachability logic analysis tools for distributed systems (esp. heuristics and techniques for handling undecidable theories)

Project Topic: Dynamic security monitor selection and data analysis for intrusion detection

Student: Uttam Thakore

P.I.: William H. Sanders

Previous work

- A Quantitative Methodology for Security Monitor Deployment
  - A methodology for monitor deployment to **meet intrusion detection goals** and **minimize monitoring cost**
    - Uses quantitative metrics to capture monitor utility and cost
    - Uses integer programming to determine optimal monitor deployment based on intrusion detection goals and cost requirements
  - **Best Paper Award** at DSN 2016
- Intrusion Detection in Enterprise Systems by Combining and Clustering Diverse Monitor Data
  - Applied unsupervised clustering to **fused** network- and host-level security logs to identify potentially malicious behavior **without administrator labeling**
  - Presented at HotSoS 2016

Current work: Data-driven monitor selection in enterprise clouds

- Using **statistical correlation techniques** to identify data that would promote **earlier investigation and detection of incidents**
  - Intuition: Data sources with high correlation to incident-specific alerts with temporal lag are likely useful for detection
- Prioritize monitor deployment/alert investigation based on strength of correlation and administrator security requirements
- Plans for this year:
  - Refine approach and evaluate on NCSA historical security data
  - Will submit paper (potentially to DSN 2017)

Contribution: Can be used to more effectively monitor clouds for security, reliability, and performance incidents

Planned work: Host behavior analysis across heterogeneous logs using unsupervised learning

- Extension of HotSoS 2016 work
- Using unsupervised learning over heterogeneous logs to **classify and track behavior of hosts** over time and identify likely malicious behavior in early stages
- Plans for this year:
  - Identify unsupervised learning techniques and features that strongly separate behavior classes in heterogeneous logs
  - Evaluate on NCSA historical security data

Contribution: Can be used to more effectively detect advanced intrusions in clouds