

Foundational and Systems Support for Quantitative Trust Management (QTM)

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Project Team

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Stream Algorithms, Run-time monitoring, Cryptography
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Real-time and cyber-physical systems, Run-time monitoring
- **Matt Blaze** (Ph.D. 93, Princeton)
Network security, Cryptography, Trust Management
- **Oleg Sokolsky** (Ph.D. 96, SUNY-SB)
Formal methods, Real-time and hybrid systems
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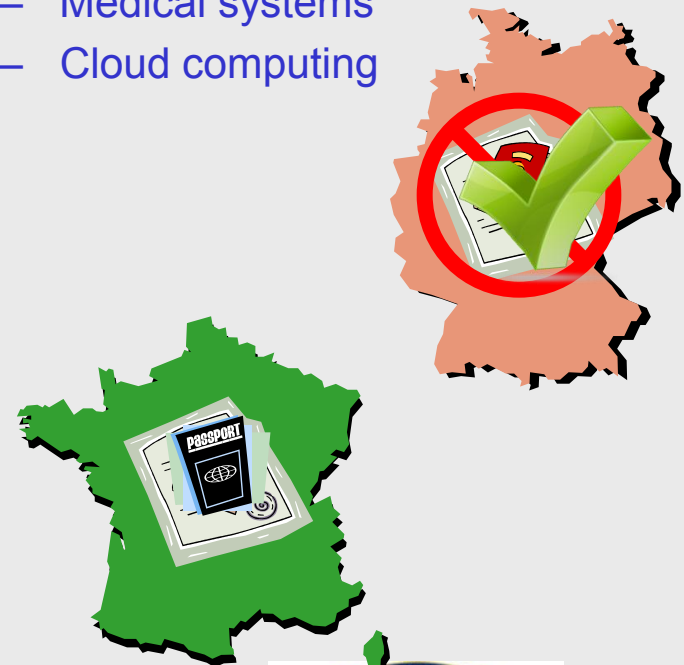


Trust

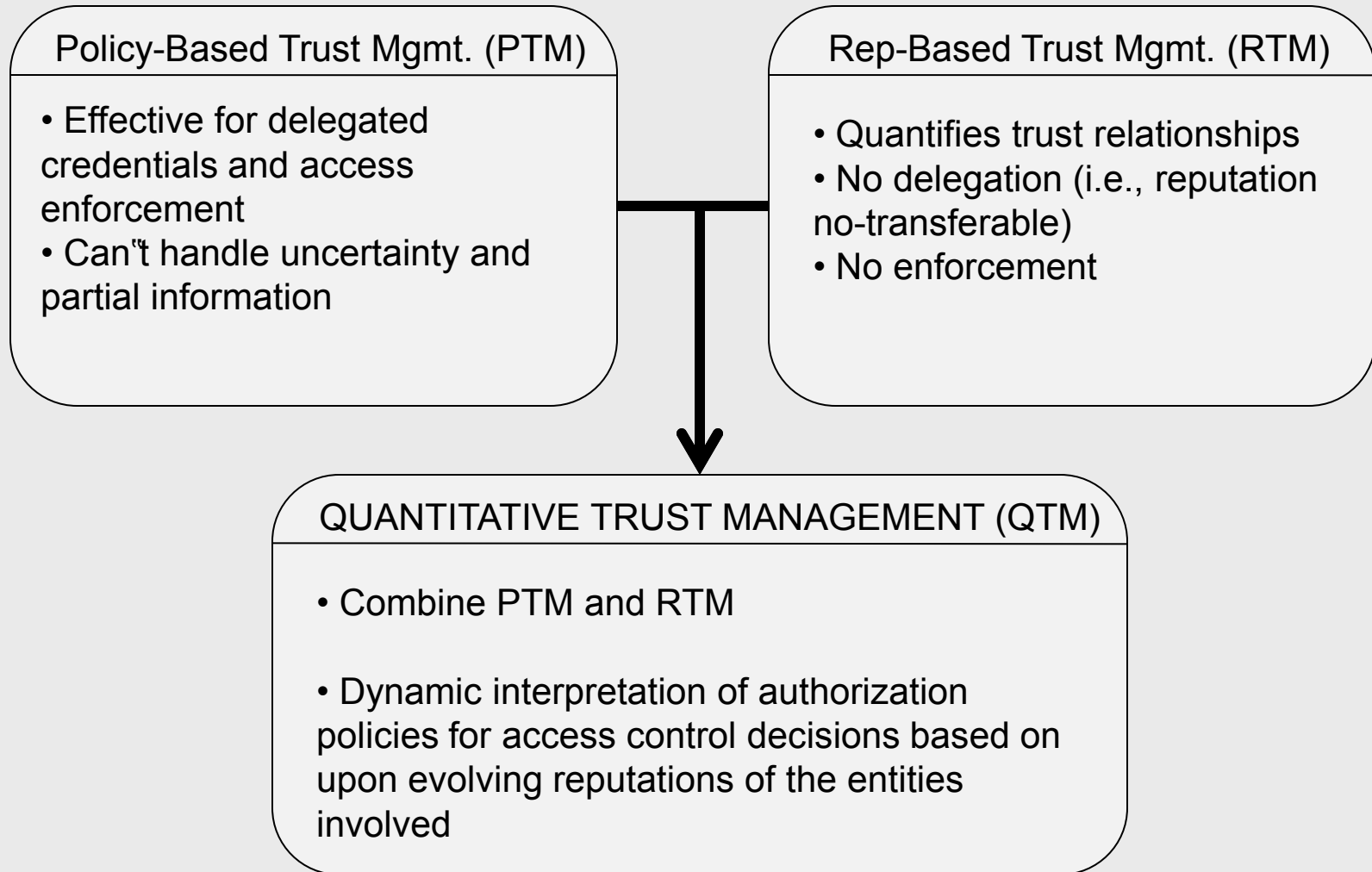
- Webster's Dictionary: TRUST, -noun:
 - (1) Assured reliance on the character, ability, strength, or truth of someone or something.
 - (2) One in which confidence is placed.
- Our Definition:
 - Trust is the expectation of a **trustor** with respect to certain properties of a **trustee** or her actions under a specified **context** and **time**, considering the **risks**, **incentives**, and **historical information**.

The Problem of Trust

- *Quantitative Trust* for federated networked systems
 - Decentralized policies
 - Dynamic environment, partial trust
 - Complex “trust” models (logic + reputation), in reality
- Applications
 - E-commerce systems
 - Service compositions in GIG
 - Reusing components/subsystem in complex DoD systems
 - Social Networks
 - Medical systems
 - Cloud computing



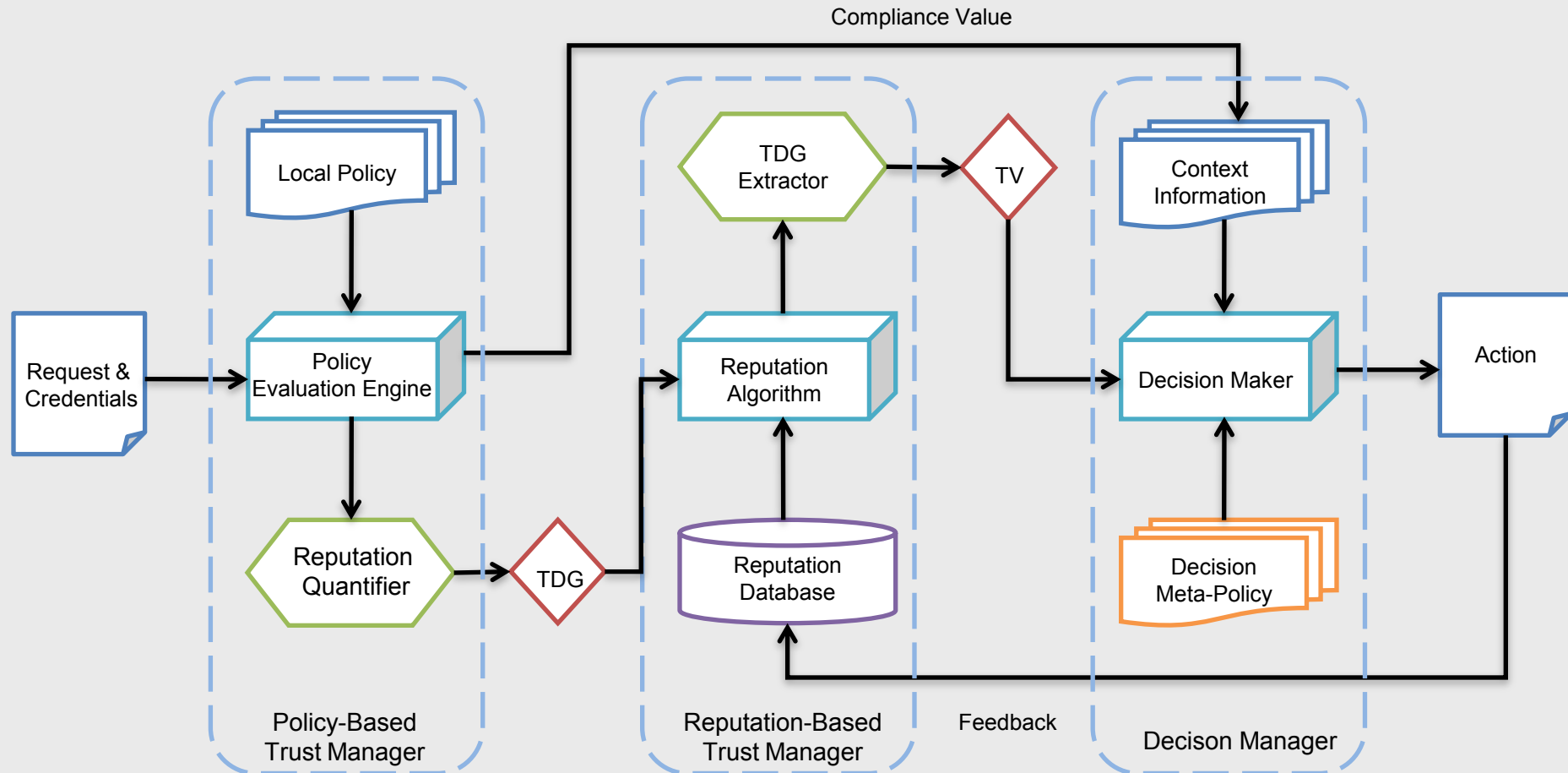
Trust Management



QTM Challenges

- What are some metrics for effectiveness of TM systems?
- How do we incorporate uncertainty in policy-based TM"s?
- How do we incorporate dynamism in policy-based TM"s?
- How can we model adversaries as **economic agents** and develop a **game-theoretic view** of trust management?
- Can we build new reputation management systems based on sound principles?
- What is the proper way to mathematically **combine reputations**?
 - Involves integration of logical/quantitative/probabilistic reasoning
 - Is there a means to build consensus from distributed observations?
- How do we **integrate** policy-based and reputation-based TMs?
- What are some important applications of TM systems?

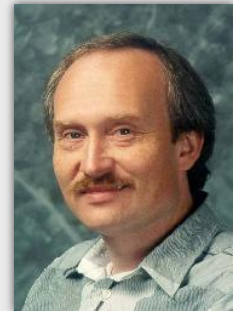
Quantitative Trust Management (QTM)



Collaboration



Policy-based Trust Management (PTM)



KeyNote PTM Systems

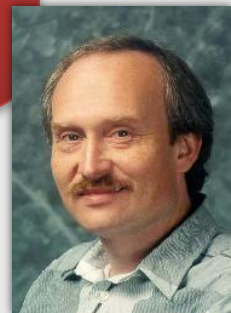
Permission-to-Speak

Dynamic Trust Management
Arachne

Collaboration



Reputation-based Trust Management (RTM)

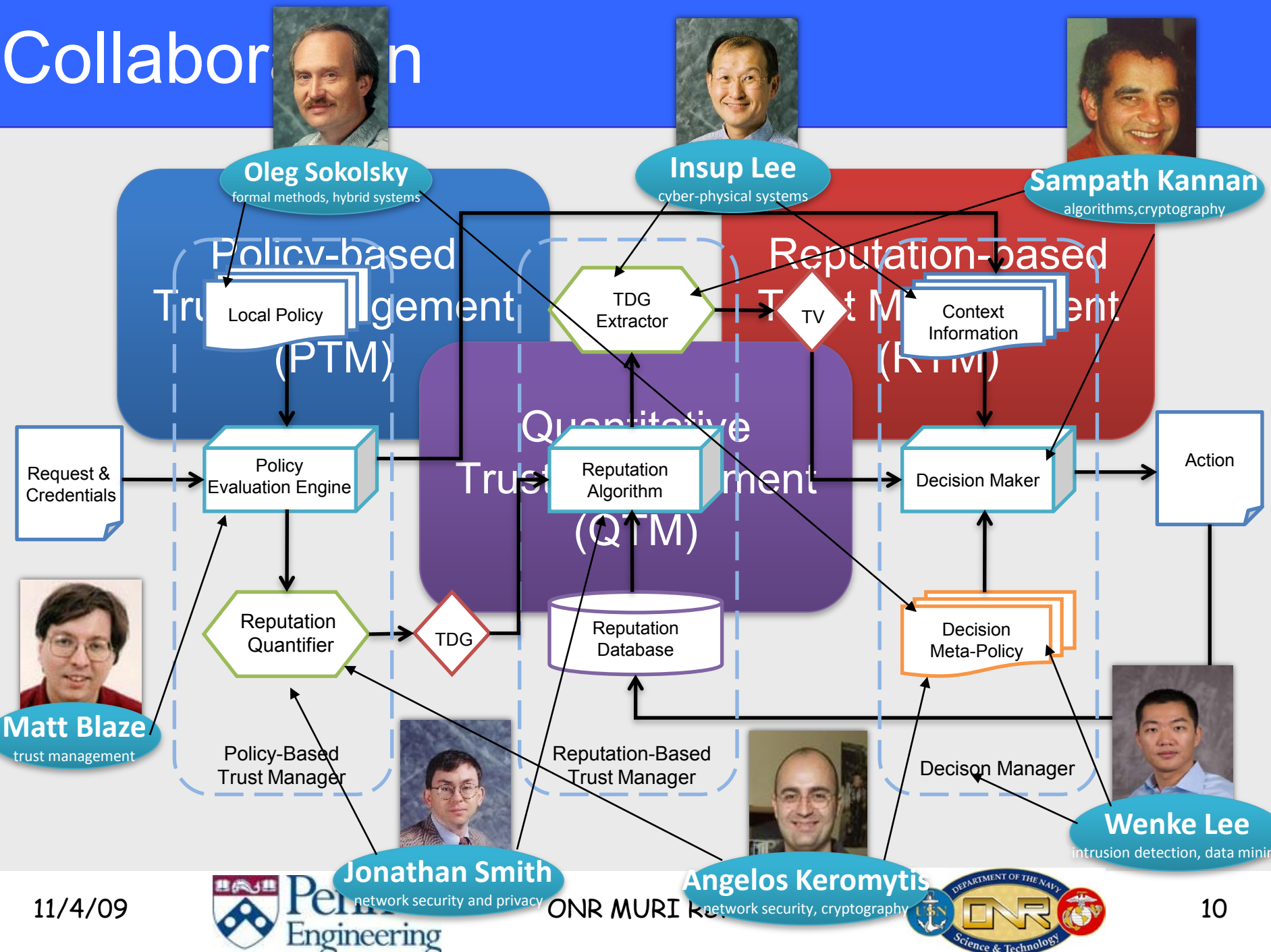


Evaluating RTM Systems

Blacklist as Feedback of
Reputation Management



Collaboration



Team Efforts

- Several Research Collaborations
 - Distributed TM, Dynamic TM, Spatio-Temporal Reputations, ...
 - Keynote-base QTM
- Annual meetings
 - 2007, 2008, 2009
- Many Tele-conferences and Student Visits
 - Penn -> GA Tech, Columbia -> Penn, GA Tech -> Penn
- Collaborative case studies
 - SPAM list and BGP security as QTM application
- PhD Dissertation Committees
 - Matt Burnside (Columbia)
 - David Dagon (GA Tech)
 - Andrew West (Penn)

Education

- Courses
 - Integrated material into COMS W4180 course (Columbia)
 - CIS 125 new course on understanding of existing and emerging technologies, along with the political, societal and economic impacts of those technologies (Penn)
 - Integrated material into CIS 551 (Penn)
 - Material on botnet detection added to Network Security classes: undergraduate cs4237, and graduate cs6262 (GA Tech)
 - 3 senior design projects (Penn)
- Workforce training
 - 3 post-docs
 - 10 Ph.D. students
 - 1 Masters and 1 undergraduate

Publication

- Publications
 - 7 journal articles
 - 2 book chapter
 - 33 conference papers
- Selected papers
 - M. Blaze, S. Kannan, I. Lee, O. Sokolsky, J.M. Smith, A.D. Keromytis, and W. Lee. Dynamic Trust Management, In IEEE Computer Magazine, vol. 42, no. 2, pp. 44 - 52, February 2009.
 - A.G. West, A.J. Aviv, J. Chang, V. Prabhu, M. Blaze, S. Kannan, I. Lee, J.M. Smith, and O. Sokolsky. QuanTM: A Quantitative Trust Management System. EUROSEC 2009, pp. 28-35.
 - A.G. West, I. Lee, S. Kannan, and O. Sokolsky. An Evaluation Framework for Reputation Management Systems. In *Trust Modeling and Management in Digital Environments: From Social Concept to System Development* (Zheng Yan, ed.), 2009.

Dissemination & Tech transfer

- Beyond conference talks
 - 7 invited and 2 keynote talks, 6 panels
- Working with Symantec to determine modus operandi of rogue Antivirus sites (and why users trust them)
 - Interim Symantec Threat Report (ISTR), Oct 09
- Working with Damballa to deliver botnet detection and mitigation technologies to government and enterprise customers
 - Botnet detection system such BotMiner malware analysis technologies, and the DNS-based monitoring technologies
 - Several Ph.D. students did summer internship
 - Several Damballa researchers were former students at Georgia Tech, and still participate in some of the research meetings at Georgia Tech
- Matt Burnside now working for NSA
- QTM ideas used in ONR-supported "Networks Opposing Botnets" (NoBot) project, with Penn, Harvard and Princeton

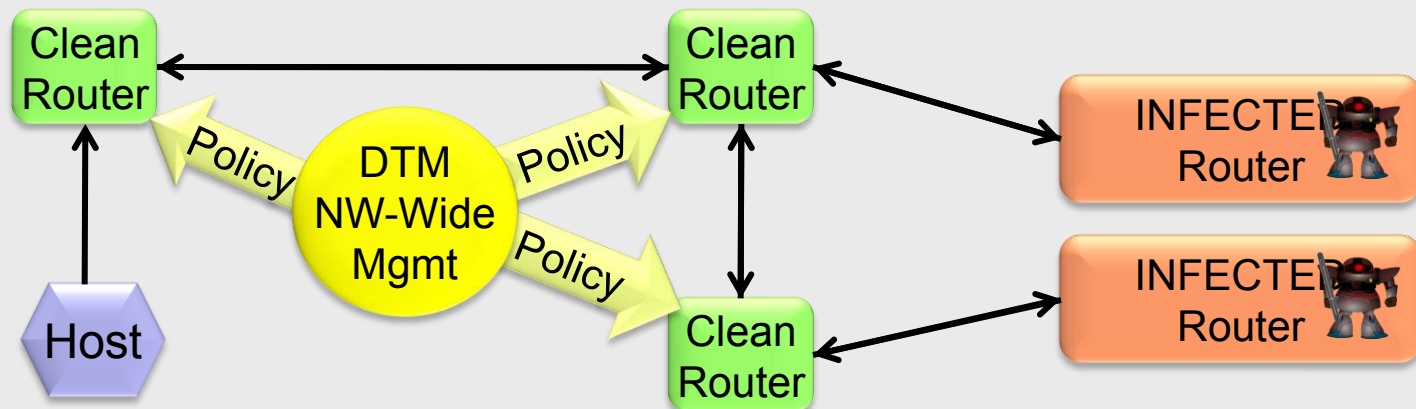
Research highlights

- Project Overview, Insup Lee (PI)
- Trust Management, Matt Blaze
- Dynamic Trust Management, Jonathan M. Smith
- Exposing Trust Assumptions in Distributed Policy Enforcement, Angelos Keromytis
- Permission to Speak: A Novel Formal Foundation for Access Control, Oleg Sokolsky
- Dynamic IP Reputation from DNS, Wenke Lee
- Using Spatiotemporal Reputation to Predict Malicious Behaviors, Andrew West
- Reputations and Games, Sampath Kannan
- Future Work and Discussion, Insup Lee

Dynamic Trust Management

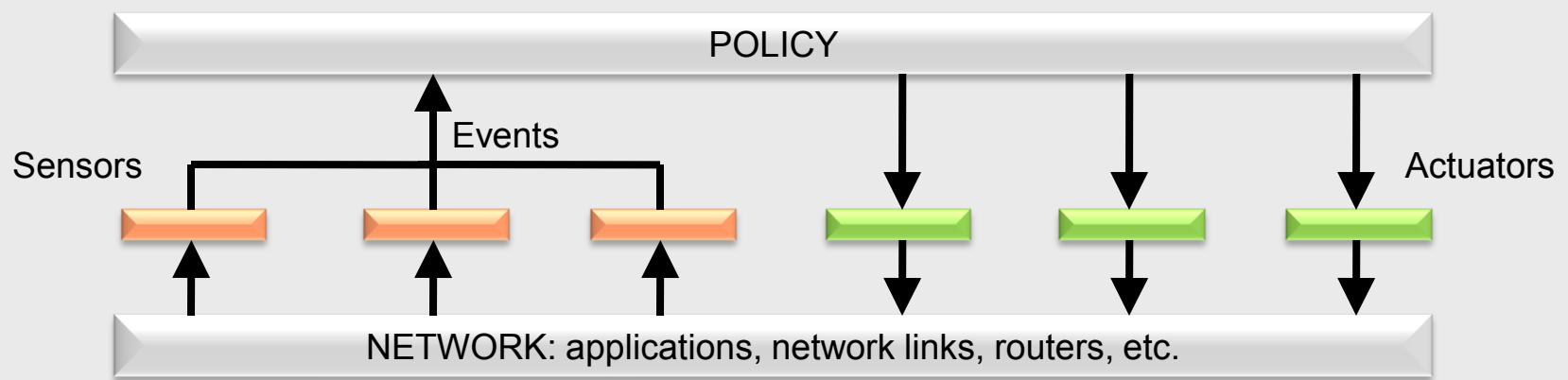
(Penn + Columbia + Georgia Tech)

- A **COOPERATIVE** and **DYNAMIC** policy evaluation infrastructure that will enable such critical capabilities as:
 - Adaptation to dynamic service availability
 - Complex situational dynamics (e.g., differentiating between bot-net and physical attacks on infrastructure).
- **BENEFITS** of a Dynamic Trust Management approach
 - Flexible and robust control of authorizations in complex distributed systems such as the DoD/IC GIG
 - The ability to define policies for scalable decentralized defense against emergent cyber-threats by rapid adaptation of resource access limits.



Arachne: Coordinated Policy Enforcement

(Columbia)



- **ARACHNE** is a system for the coordinated distribution and evaluation of a system-wide policy on different nodes
 - Several prototype systems for enterprise-level security have been developed
- **GOAL:** Integrate a variety of different, diverse security mechanisms and policy expression methods
 - Achieve enhanced protection over any individual method
 - Allow exchange of information between different mechanisms (Eliminate the possibility of “locally correct” but globally wrong decisions)
 - Capture trade-offs between amount of global context, scalability, etc.

Permission-to-Speak

- A new policy deontic logic developed under ONR-MURI
- Explicit representation of **PERMISSIONS** and **OBLIGATIONS** imposed by a policy, and the delegation of policies.
 - Captures notions such as „allow to require“ which are necessary for dynamic policy introduction.
- Explicit representation of policy **DEPENDENCIES**
 - Iterative algorithm for calculating the set of relevant policy statements
- Logic prog.-based evaluation allows efficient blame assignment

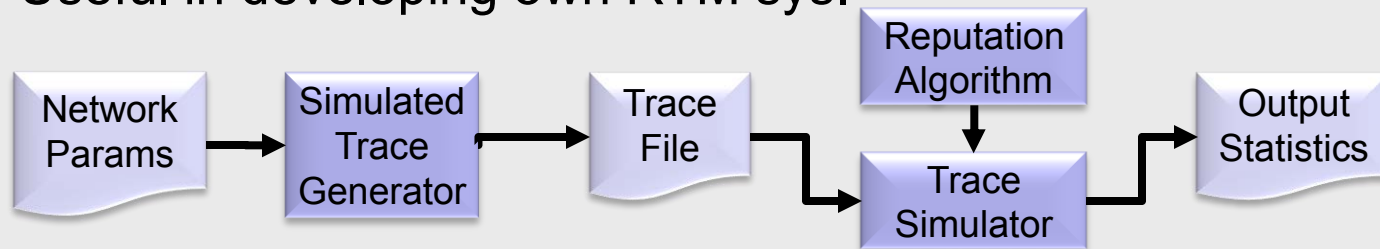
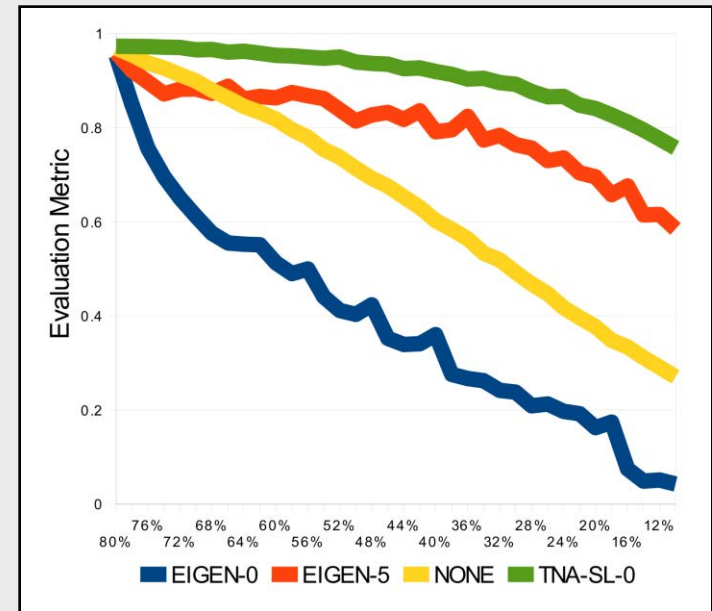
P_{pat} says_{pat} O_{hosp} says_{hosp} P_{pat} access(pat, record(pat))



Patients are allowed to ask a hospital for their medical records. In response, the hospital must permit access.

Evaluating RTM Systems

- Many reputation systems are available in the literature
 - EigenTrust, TNA-SL (Trusted Network Analysis with Subjective Logic), ...
 - Little or no comparison between them
- Designed and implemented a framework for comparative evaluation of reputation systems
 - Identified evaluation criteria
 - Generation of evaluation scenarios
 - Development of malicious strategies
 - Collection of statistics and analysis
- Useful in developing own RTM sys.



Dynamic IP Reputation from DNS

(Georgia Tech)

- Dynamic Domain Name reputation using passive DNS (pDNS)
 - Professional DNS hosting differs from non-professional
 - pDNS information is already present in our network
 - Static IP/DNS blacklists have limitations
 - Malicious Users tend to reuse their infrastructure
- Contributions:
 - Zone and network based clustering of pDNS
 - A new method of assigning reputation on new RRSETs using limited {White/Grey/Black}-listing
 - A dynamic Domain Name reputation rating system
 - Always maintain fresh reputation knowledge based on pDNS

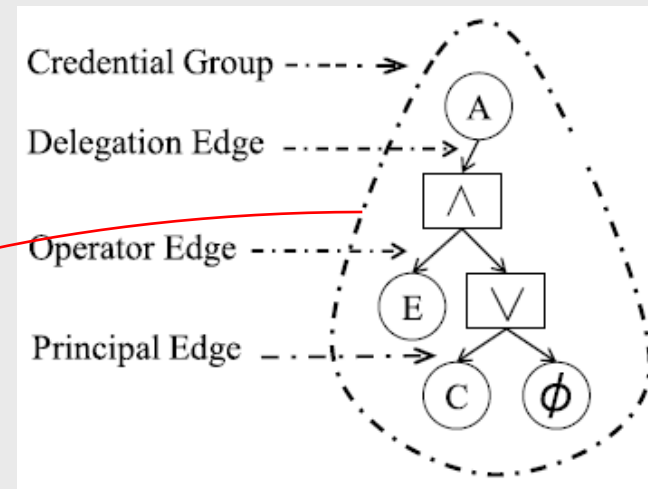
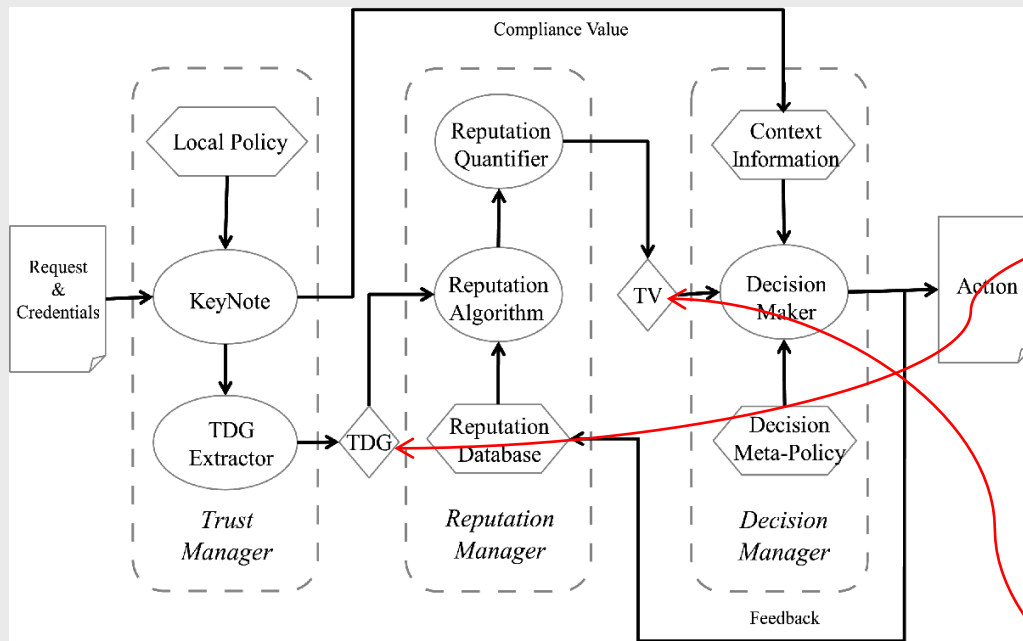
Spatio-Temporal Reputation

(Penn + Georgia Tech)

- As the RM part of QTM, we have developed reputation-bases trust management based on spatiotemporal reputation
- Approach
 - Assumptions
 - Bad guys are geographically clustered (spatio)
 - Bad guys are likely to repeat bad behaviors (temporal)
 - Given
 - A historical record of those principals known to be bad, and the time when this was noted (feedback)
 - Produce
 - An extended list of principals who are thought to be bad at the current time, based on their own past history, and the history of those around them
- Case studies: Spam filter based on IP blacklist, wikipedia

Quantitative Trust Management (QTM)

- QTM provides a dynamic interpretation of authorization policies for access control decisions using evolving reputations of parties
- *QuantM* is a QTM system that combines elements from PTM and RTM to create a novel method for trust evaluation



Trust Dependency Graph (TDG),
encoding PTM relationships
useful for RTM

Reputations of **PRINCIPALS**,
DELEGATIONS and
CREDENTIALS are
aggregated

The QuanTM Architecture