ArmoredSoftware: Trust in the cloud

Annual Demonstration

Dr. Perry Alexander, Dr. Andrew Gill, Dr. Prasad Kulkarni,
Adam Petz, Paul Kline, Justin Dawson, Jason Gevargizian,
Leon Searl, Edward Komp

Information and Telecommunication Technology Center
Electrical Engineering and Computer Science
The University of Kansas
palexand@ku.edu,andygill@ku.edu,prasadk@ku.edu

January 15, 2015

Outline

- Introduction and Project Goals
  - Big Picture
  - Implementation
- Prototype demonstration and discussion
  - Refine big picture to current demo
  - Protocol Execution
  - Attestation Protocol Execution
  - Appraisal
  - Measurement
  - Communication
- Short term goals and milestones
- Questions and guidance

Trust in the Cloud

Provide new capabilities that establish and maintain trustworthy cloud-based application deployment

- Establish trust among cloud components
  - trust among cohorts of processes
  - trust among processes and environment
- Promote informed decision making
  - data confidentiality can be confirmed
  - execution and data integrity can be confirmed
- Autonomous run-time response and reconfiguration
  - responds to attack, failure, reconfiguration, and repair
  - response varies based on measurement

Delivery Platform

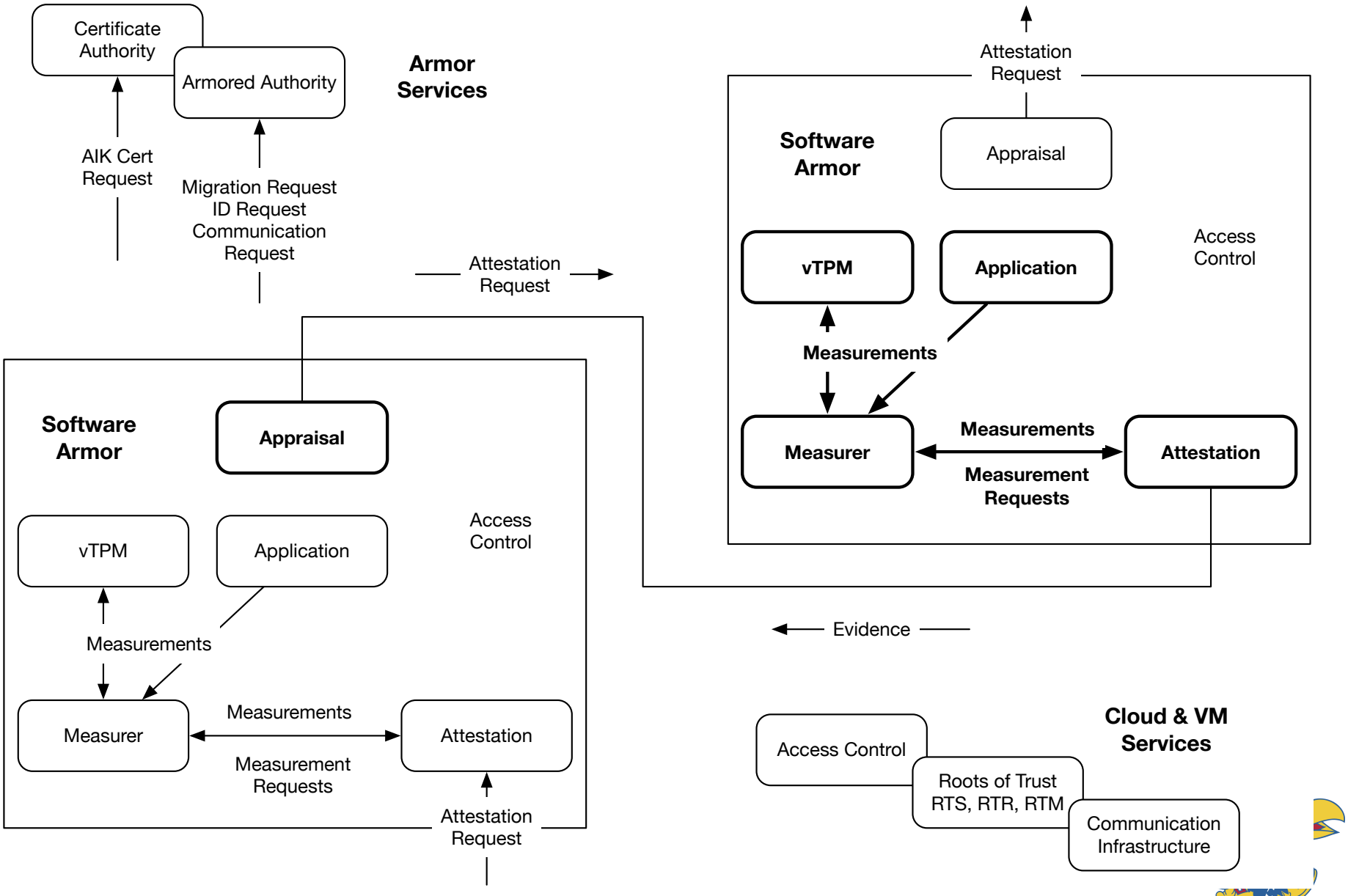
Open source, standards compliant

- Lightweight integration with existing cloud infrastructure
  - OpenStack cloud infrastructure
  - Xen+XSM VM infrastructure
  - Fedora, HotSpot JVM, GHC
- Trusted Computing Group standards compliant
  - Trusted Platform Module 1.2
  - TCG vTPM (in principle)
  - Trusted OS infrastructure
- Standard communication mechanisms
  - JSON structures for all exchanged data
  - *vchan* for on-platform communication
  - TCP/IP for off-platform communication

New Technologies

- Trustworthy protocol execution
  - executable protocol representation
  - protocol execution generates evidence of trustworthiness
  - highly focused protocols
  - strand space formal semantics
- Application specific measurement
  - managed and traditional execution environments
  - compile-time assistance for measurer synthesis
  - specialized measurement bundled with applications
- Attestation driven cloud application and data management
  - health monitoring
  - problem mitigation
  - application migration
  - access control

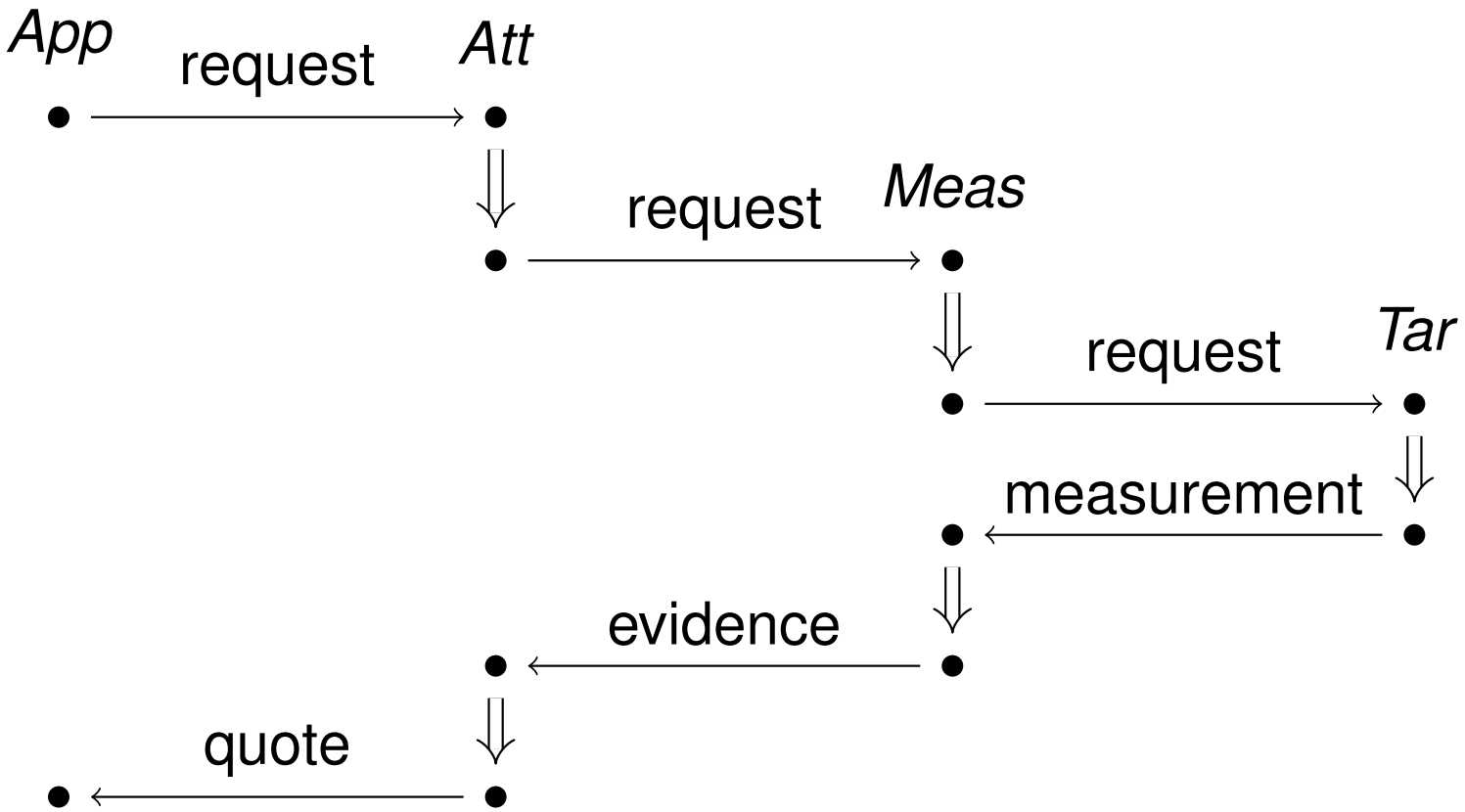
High-Level Architecture



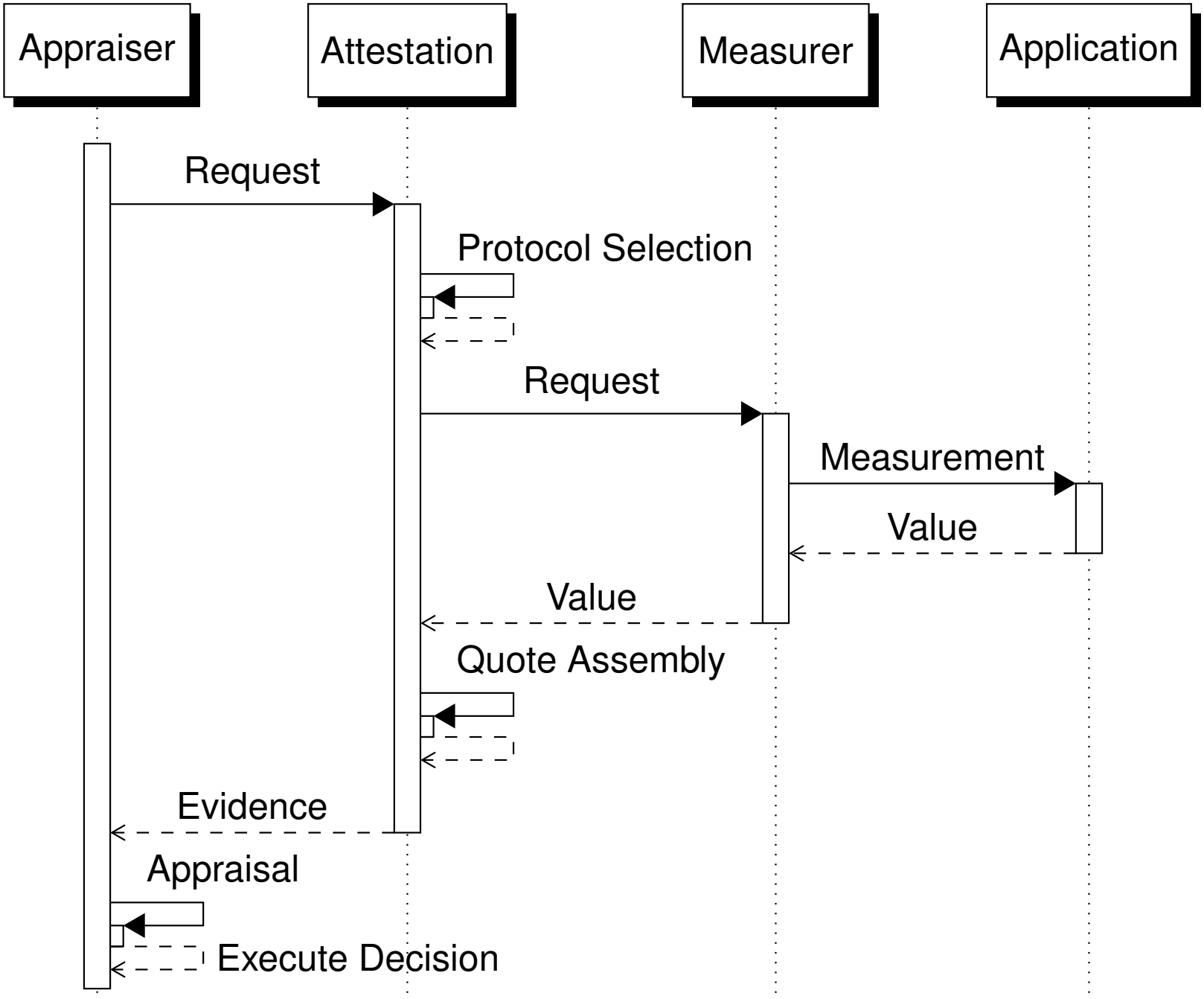
What We Are Demonstrating

- Execution of a CA-based Attestation Protocol
  - Attestation request
  - Protocol execution
  - Evidence appraisal
- Major architectural subsystems
  - Appraiser
  - Attestation Manager
  - Measurer
  - Instrumented JVM
  - vTPM and Certificate Authority
- Anomaly Detection
  - Bad signatures and PCRs
  - Bad CA certificates
  - Bad quotes and AIKs
  - Bad measurements

Abstract CA-Based Attestation Protocol



Abstract CA-Based Attestation Protocol



Message List Representation

$App \rightarrow Att : d, N_{\text{App}}, PCR_{\text{m}}$ on C_{AppAtt}

$Att \rightarrow TPM : make\_and\_load\_identity$ on C_{AttTPM}

$TPM \rightarrow Att : AIK^{+}, AIK_h$ on C_{TPMAtt}

$Att \rightarrow CA : Att, AIK^{+}$ on C_{AttCA}

$CA \rightarrow Att : \{K, |AIK|\}_{EK^{+}}, \{[AIK^{+}]_{CA^{-}}\}_{K^{+}}$ on C_{CAAtt}

$Att \rightarrow TPM : activate\_identity(AIK_h, |AIK|)$ on C_{AttTPM}

$TPM \rightarrow Att : K$ on C_{TPMAtt}

$Att \rightarrow Meas : d$ on $C_{AttMeas}$

$Meas \rightarrow Att : e$ on $C_{MeasAtt}$

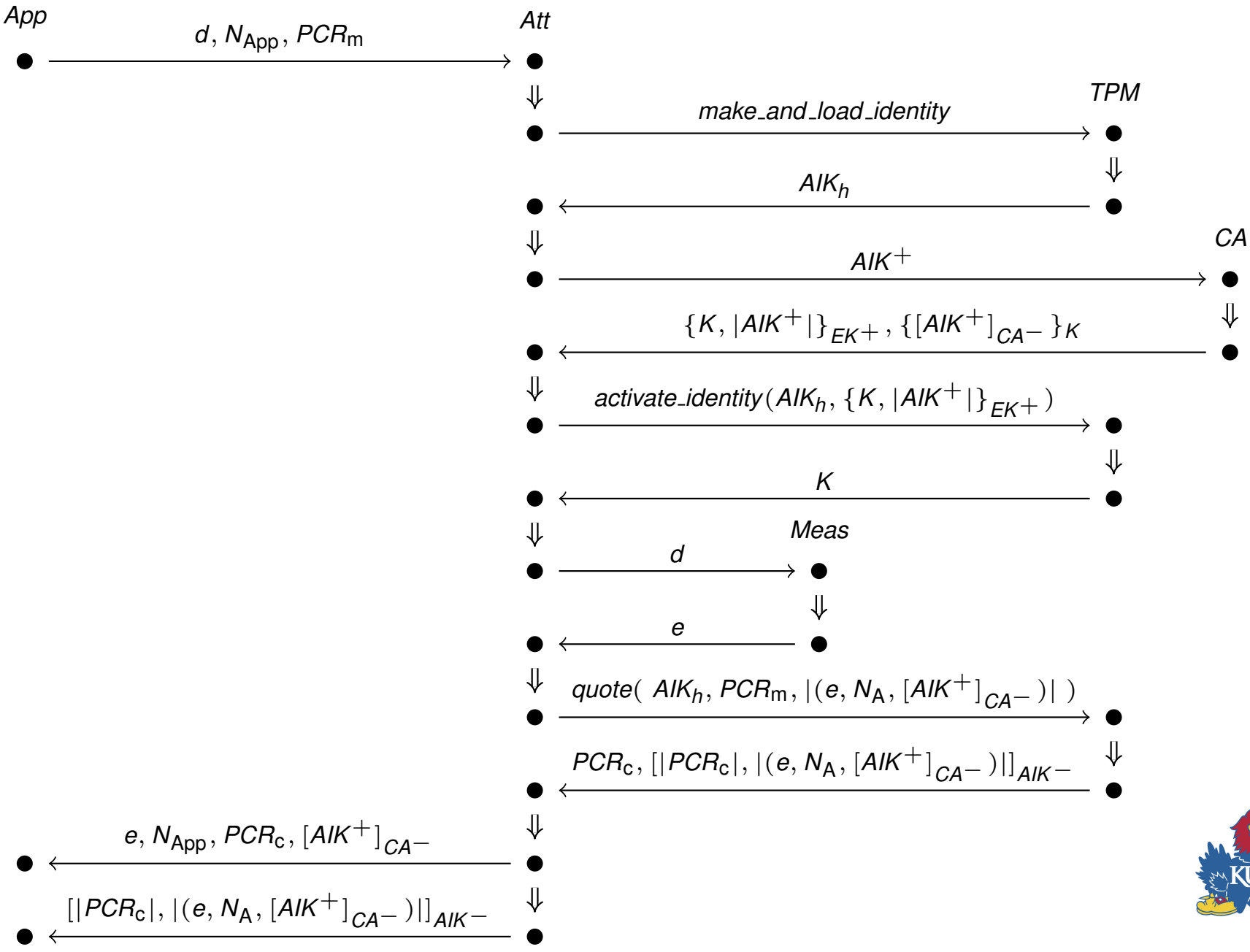
$Att \rightarrow TPM : quote(\ AIK_{\text{h}}, PCR_{\text{m}}, |(e, N_{\text{A}}, [AIK^{+}]_{CA^{-}})|\ )$ on C_{AttTPM}

$TPM \rightarrow Att : PCR_{\text{c}}, [|PCR_{\text{c}}|, |(e, N_{\text{A}}, [AIK^{+}]_{CA^{-}})|]_{AIK^{-}}$ on C_{TPMAtt}

$Att \rightarrow App : e, N_{\text{App}}, PCR_{\text{c}}, [AIK^{+}]_{CA^{-}}$ on C_{AttApp}

$Att \rightarrow App : [|PCR_{\text{c}}|, |(e, N_{\text{A}}, [AIK^{+}]_{CA^{-}})|]_{AIK^{-}}$ on C_{AttApp}

Strand Space Diagram Representation

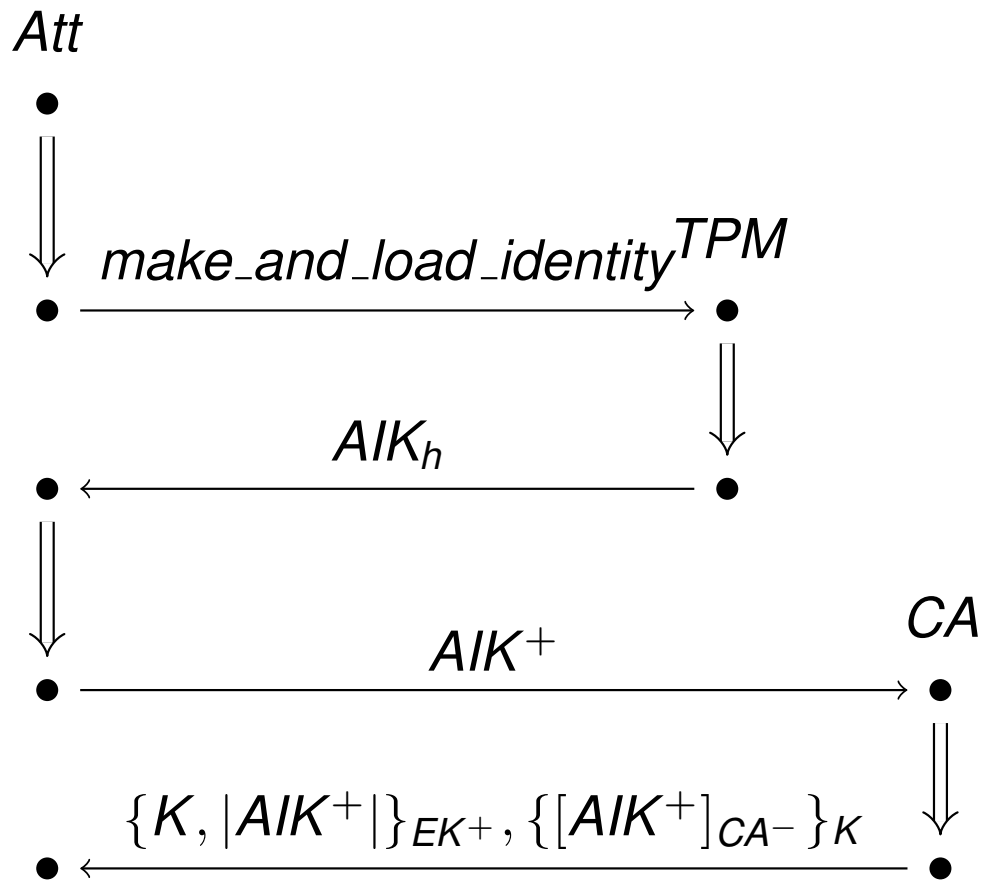


Attestation Request

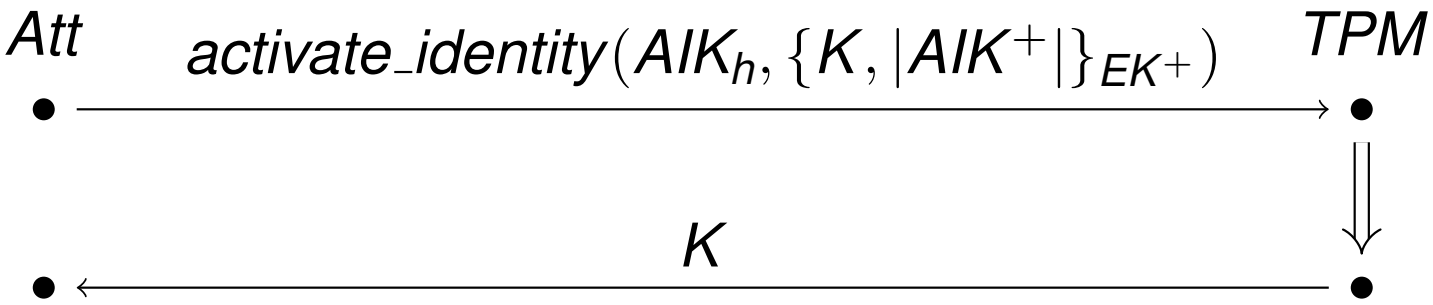
- Initiate with an attestation request
  - d abstractly defines desired evidence
  - N_{App} is the appraiser's nonce
  - PCR_{m} selects PCRs
- Attestation agent selects and executes protocol based on request

Generating and Certifying an AIK

- Request a new *AIK* from TPM (optional)
- Receive *AIK* handle
- Request AIK^+ signed by CA (*AIK* cert)
- Receive *AIK* cert encrypted with session key *K*
- Receive *K* encrypted with public *EK*

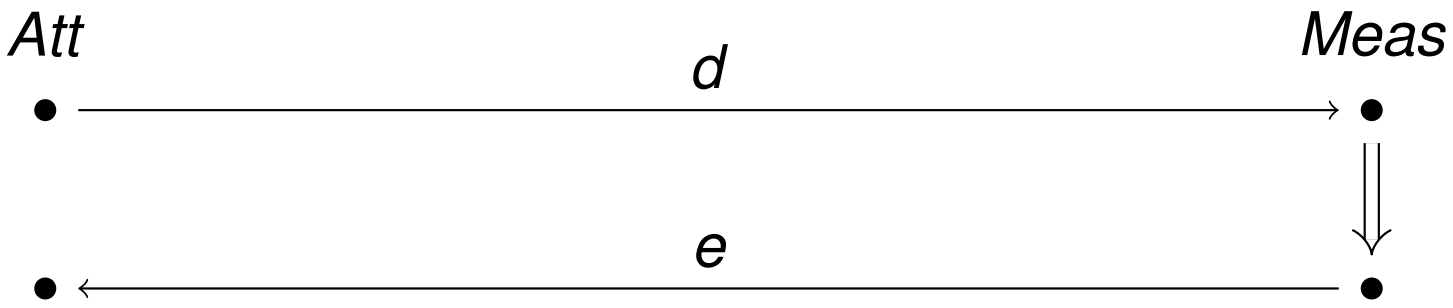


Activating the AIK



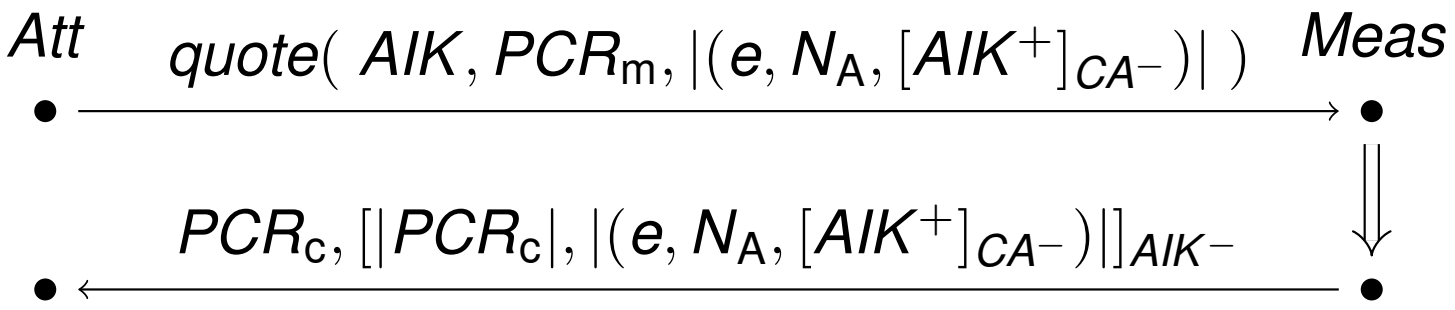
- Request TPM decryption of the *AIK* cert
- Receive K used to decrypt signed public *AIK*
- Only TPM can gain access to K
- Only TPM can obtain signed, public *AIK*
- Oddly, No manipulation of the *AIK* in this “activation” process

Measurement



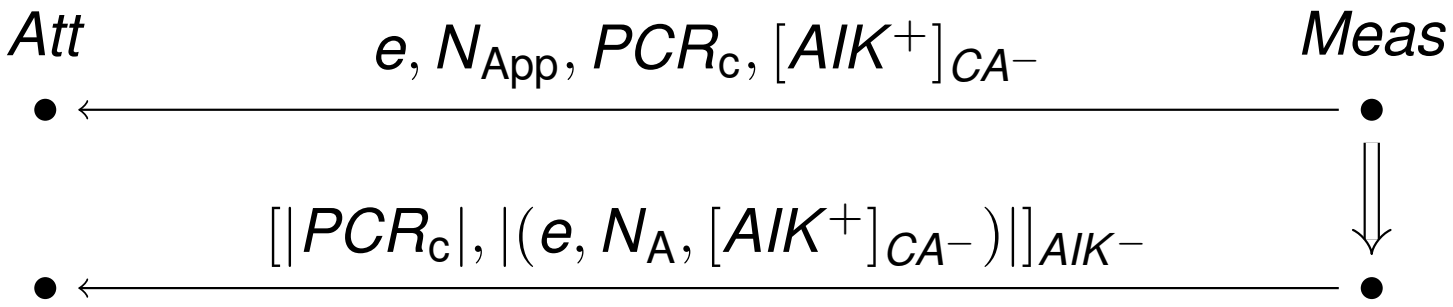
- Request information from measurer
- Receive evidence *e* from measurer
- *d* is abstract allowing protocol reuse
- Most protocols make many requests of the measurer

Generating a Quote



- Request a quote from the TPM
  - *AIK* identifies the signing *AIK*
  - PCR_m identifies desired PCRs
  - $|(e, N_A, [AIK^+]_{CA^-})|$ guarantees integrity of returned evidence
- Receive quote from TPM
  - PCR_c is PCR composite built from requested PCRs
  - $[|PCR_c|, |(e, N_A, [AIK^+]_{CA^-})|]_{AIK^-}$ is the signed quote

Appraisal



- Receive quote from the attestation manager
- Receive evidence from the attestation manager
- Evaluate evidence and quote

3-4 Slides on Attestation Protocol Execution

1-2 Slides on Appraisal

3-4 Slides on Measurement

2-3 Slides on Communication Mechanisms

CA communication

Shared notion of AIKCertRequest, AIKCert, and CAResponse JSON structures.

Attester

- creates an AIKCertRequest (containing attester ID, AIK) and converts to JSON
- JSON sent as POST request to CA running as web server

Certificate Authority

- POST body bytes $\rightarrow$ UTF8 $\rightarrow$ JSON $\rightarrow$ AIKCertRequest
- looks up TPM_PUBKEY associated with ID in sql database
- AIKCert $\approx$ AIK signed with CA_{-1}
- generates key K and encrypts with TPM_PUBKEY
- AIKCert encrypted with K
- both wrapped in a CAResponse, converted to JSON and sent as response.

CA communication continued

Properties

- CA only responds to receiving an $AIKCertRequest_{JSON}$
- The CACert can *only* be decrypted by knowing K (and therefore TPM_PRIVATEKEY)

Appraiser Knowledge after receiving Cert:

- signature on AIK ensures it was CA who generated signature
  +
- only an entity knowing TPM_PRIVATEKEY could decrypt and send me the CACert
  =
- Attester is using a registered TPM

Goals and Milestones for 2015

- Push to the cloud
- Establish roots of trust and trust argument
- Executable protocol representation and protocol semantics
- Operational, integrated vTPM prototype
- Name Server / Certificate Authority prototype
- More capable measurement
- Downloadable demonstration

Questions and Guidance

- What problems are interesting?
- What problem would be a nice attention grabber?
- What should we be watching and integrating with?

References

- G. Coker, J. Guttman, P. Loscocco, A. Herzog, J. Millen, B. O'Hanlon, J. Ramsdell, A. Segall, J. Sheehy, and B. Sniffen. Principles of remote attestation. *International Journal of Information Security*, 10(2):63–81, June 2011.
- F. J. T. Fábrega, J. C. Herzog, and J. D. Guttman. Strand spaces: Proving security protocols correct. *Journal of computer security*, 7(2):191–230, 1999.
- V. Haldar, D. Chandra, and M. Franz. Semantic remote attestation – a virtual machine directed approach to trusted computing. In *Proceedings of the Third Virtual Machine Research and Technology Symposium*, San Jose, CA, May 2004.