XIA: An Architecture for a Trustworthy and Evolvable Future Internet

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Outline

• Vision

• Getting real

• The real world
Vision

We envision a future Internet that:

• Is trustworthy
  – Security broadly defined is the biggest challenge

• Supports long-term evolution of usage models
  – Including host-host, content retrieval, services, ...

• Supports long term technology evolution
  – Not just for link technologies, but also for storage and computing capabilities in the network and end-points

• Allows all actors to operate effectively
  – Despite differences in roles, goals and incentives

Today’s Internet

• Client retrieves document from a specific web server
  – But client mostly cares about correctness of content, timeliness
  – Specific server, file name, etc. are not of interest

• Transfer is between wrong principals
  – What if the server fails?
  – Optimizing transfer using local caches is hard
    • Need to use application-specific overlay or transparent proxy – bad!
eXpressive Internet Architecture

- Client expresses communication intent for content explicitly
  - Network uses content identifier to retrieve content from appropriate location
- How does client know the content is correct?
  - Intrinsic security! Verify content using self-certifying id: 
    \[ \text{hash(content)} = \text{content id} \]
- How does source know it is talking to the right client?
  - Intrinsic security! Self-certifying host identifiers

A Bit More Detail ...

- Dest: Service ID
- Content Name?
- Dest: Client ID
- Content ID
- Dest: Content ID
- Hash(\( \_ \_ \_ \) = CID?

Flexible Trust Management
Diverse Communicating Entities
Intrinsic Security
P1: Evolvable Set of Principals

- Identifying the intended communicating entities reduces complexity and overhead
  - No need to force all communication at a lower level (hosts), as in today’s Internet
- Allows the network to evolve

P2: Security as Intrinsic as Possible

- Security properties are a direct result of the design of the system
  - Do not rely on correctness of external configurations, actions, data bases
  - Malicious actions can be easily identified
Other XIA Principles

• Narrow waist for trust management
  – Ensure that the inputs to the intrinsically secure system match the trust assumptions and intensions of the user
  – Narrow waist allows leveraging diverse mechanisms for trust management: CAs, reputation, personal, ...

• Narrow waist for all principals
  – Defines the API between the principals and the network protocol mechanisms

• All other network functions are explicit services
  – XIA provides a principal type for services (visible)
  – Keeps the architecture simple and easy to reason about

XIA: eXpressive Internet Architecture

• Each communication operation expresses the intent of the operation
  – Also: explicit trust management, APIs among actors

• XIA is a single inter-network in which all principals are connected
  – Not a collection of architectures implemented through, e.g., virtualization or overlays
  – Not based on a “preferred” principal (host or content), that has to support all communication
What Do We Mean by Evolvability?

• Narrow waist of the Internet has allowed the network to evolve significantly
• But need to evolve the waist as well!
  – Can make the waist smarter

Developing XIA v0.1

• Principles do not make a network!
• Meet the core XIA team:

  Fahad Dogar  Dongsu Han  Hyeontaek Lim  Ashok Anand

  Michel Machadoy  Boyan Li  Wenfei Wu

• Next: quick look at multiple principals, intrinsic security, and evolvability
Multiple Principal Types

Choice involves tradeoffs:
- Control
- Trust
- Efficiency
- Privacy
- Intrinsic security

Intrinsic Security in XIA

- XIA uses self-certifying identifiers that guarantee security properties for communication operation
  - Host ID is a hash of its public key – accountability (AIP)
  - Content ID is a hash of the content – correctness
  - Does not rely on external configurations

- Intrinsic security is specific to the principal type
  - Important – guarantees depend on principal type

- Example: retrieve content using ...
  - Content XID: content is correct
  - Service XID: the right service provided content
  - Host XID: content was delivered from right host
Evolvability

- Introduction of a new principal type will be incremental – no “flag day”!
  - Not all routers and ISPs will provide support from day one
  - No universal connectivity
  - Some ISPs may never support certain principal types

- Solution is to provide an *intent* and *fallback* address
  - Intent address allows in-network optimizations based on user intent
  - Fallback address is guaranteed to be reachable

Generalizing Evolvable Address Format

- Use a directed acyclic graph to represent address
  - Router traverses the DAG
  - Priority among edges

- DAG format supports many addressing styles
  - Shortcut routing, binding, source routing, infrastructure evolution, ..

- Packet processing combines basic and principal specific processing
Prototype Implementation

- Click implementation of XIA router
- Python API for sending/receiving packets
- Implemented a web service using XIA
- Ran simple tests over ProtoGeni

It Is Not Just About Architecture!

- End-to-end transport over heterogeneous networks and for multiple principals
  - Error control, congestion control, ...
  - How to better support wireless mobile users, insertion of services, vehicular, DTNs, ...
- Trustworthy network operations
  - Improve “security” broadly defined by leveraging the intrinsic security properties of XIA
  - Focus on availability and systematic approaches to trust management
What About the Real World?

• Policy and economic viability
  – Impact of multiple principals on economic incentives
  – Net neutrality, audit trails for billing purposes, ...

• Interfaces for applications and users
  – Value of network depends on whether users are willing to use all its capabilities - User trust is key
  – User studies to evaluate impact on user’s attitude

• Rich interactions with core network, security

Conclusion

• XIA supports evolution, expressiveness, and trustworthy operation.
  – Multiple principal types and intrinsic security

• But research has just started!
  – Protocols that take advantage of in-network caches and services
  – Trustworthy protocols that fully utilize intrinsic security of XIA

• More information on
  http://www.cs.cmu.edu/~xia