eXpressive Internet Architecture
Security Architecture

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Outline

- Brief XIA overview
- Security architecture
  - Requirements
  - XIA principles and concepts
  - Supporting basic security properties
- Security research overview

XIA Vision

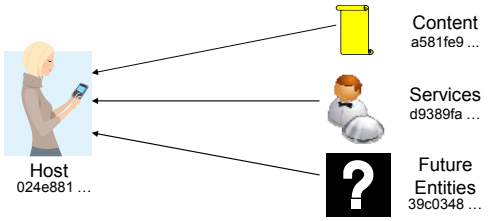
We envision a future Internet that:

- 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

Security central to all four aspects!

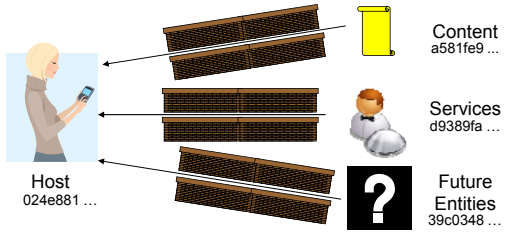
P1: Evolvable Set of Principals

- Specifying intent allows future network support to optimize performance, efficiency
  - 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



5

Other XIA Principles

- Narrow waist for trust management
  - Intrinsically secure identifiers must match the user's trust assumptions and intensions
  - Narrow waist allows leveraging diverse mechanisms for trust management: CAs, reputation, personal, …
- Narrow waist for all principals
  - Defines the API between principals and 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

6

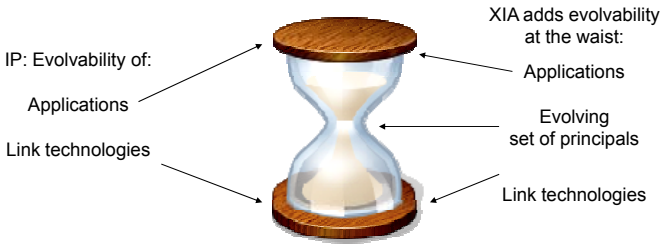
XIA: eXpressive Internet Architecture

- Each communication operation expresses intent of operations
  - 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

7

What Do We Mean by Evolvability?

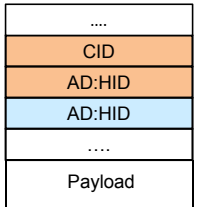
- Narrow waist of the Internet has allowed the network to evolve significantly
- But need to evolve the waist as well!
  - Can make the waist smarter



8

Evolvability

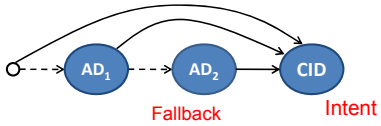
- Introduction of a new principal type must be incremental – no "flag day"!
  - Not all routers and ISPs will provide support from day one
  - No universal connectivity
  - Some ISPs may never support certain principal types
- Solution is to provide an *intent* and *fallback* address
  - Intent address allows in-network optimizations based on user intent
  - Fallback address is guaranteed to be reachable



9

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, ..
  - Common case: small dag, most routers look at one XID

10

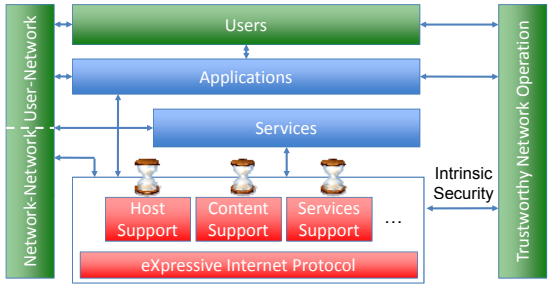
XIA Security in the Real World?

- Relationship among providers
  - Impact of multiple principals, new routing paradigms, etc. on economic incentives
  - Net neutrality, audit trails for billing purposes, …
- Interfaces for applications and users
  - User's trust in "the network" affects what tasks they are willing to use it for:

    What makes people trust information they obtain?
    Why would they make data available?
    What about privacy?

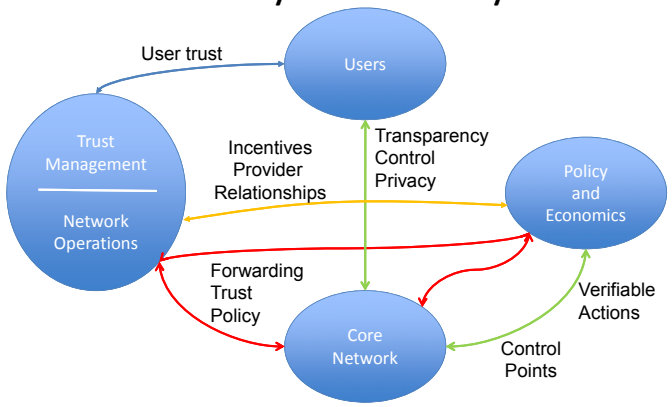
11

XIA Components and Interactions



12

Cross-Cutting Themes are Heavy on Security



13

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14

XIA Security

- A key feature of XIA is flexibility, thus, the architecture can be extended in ways we cannot anticipate
- XIA security depends on
  - Underlying architecture
  - XIA extension principals and mechanisms
  - Specific extensions future designers choose
- Consequently, detailed security analysis depends on specific principal types

15

XIA High-Level Security Goals

- Support today's Internet-style host-to-host communication with drastically improved security
- Provide improved security for two classes of communication we anticipate being important: content retrieval & accessing services
- Provide groundwork for future extensions to make good decisions w.r.t. security and availability

16

Main Security Properties

- Availability
  - Communication availability (hosts and services)
  - Finding nearby contents and services
  - Defenses against DoS attacks
- Authenticity / integrity
  - Authentication of user, host, domain, service, content
- Authentication and Accountability
  - Both authorization and deterrence, respectively
- Secrecy of identity, anonymity, privacy
  - Sender / receiver privacy if desired
- Trust management
  - How to set up trust relations, roots of trust

XIA Security Design Principles

- Well-foundedness: Identifiers, associations match user's intent
- Fault isolation: Good design reduces dependencies, insulates correct portions of network operation from incorrect/malicious
- Fine-grain control: Allow users to specify their intent
- Explicit chain of trust: Allow users to understand the basis for trust, underlying assumptions

18

Security-relevant XIA Mechanisms

- Multiple principal types
- Intrinsically secure identifiers
- Flexible trust management

19

Security-Relevant XIA Mechanisms

Multiple Principal Types

- Hosts XIDs support host-based communication (like IP)
  - W*ho is talking?*
- Service XIDs route to (possibly replicated) services
  - *Identify what the service does and who provides it*
- Content XIDs specify specific chunks of content
  - Identify what the content is
- Autonomous domains allow scoping, hierarchy

Intrinsically Secure Identifiers

Flexible Trust Management

20

Security-Relevant XIA Mechanisms

Multiple principal types

Intrinsically secure identifiers

- Self-certifying or self-verifiable identifiers
- Guarantee security properties *once you know the ID*
  - e.g., Host XID is hash(public key)
    - Knowing host ID, can validate public key, and bootstrap signatures & encryption
  - Content ID is a hash of the content – correctness
- Does not rely on external configuration
- Key question: Bridging from "human ID" to intrinsic ID ..

Flexible trust management

21

Security-Relevant XIA Mechanisms

Multiple principal types

Intrinsically secure identifiers

Flexible trust management

- Name resolution: Name -> secure XID
- Trust bootstrapping between communicating entities
- Should support many sources of trust: CAs, DNSSEC-like mechanisms, PGP model, "perspectives"-like trust models, physical interaction, etc.
  - Goal: Create a "Narrow waist" - minimal / flexible API for trust management
  - Needs to involve users; how to communicate relevant information and decisions?

22

Integrity	Availability	Secrecy	Accountability

Design Principles

- Allow verification of integrity at *the highest semantic level possible*
- Make integrity *intrinsic* so that it's easy for any component in the system to verify

Integrity	Availability	Secrecy	Accountability

XIA Mechanisms

- Multiple principal types
  - Allow users to express highest-level intent
- Intrinsically secure principals
  - Verify that your intent was actually met
- Flexible trust management
  - Allow many ways to bootstrap trust from human-level ID to intrinsically secure ID

Integrity	Availability	Secrecy	Accountability

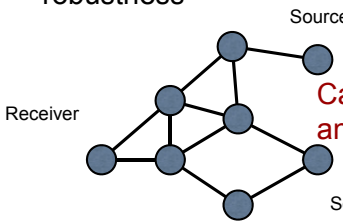
Per-principal integrity

- IP expresses: Packet P from host A to B
- IPSec can sign contents of packet
- XIA expresses:
  - Content! ID = hash(content)
    Integrity: Verify hash
  - Services & hosts! ID = hash(service public key)
    Integrity: Verify signature
  - Future types! ID = <your idea here>

Integrity	Availability	Secrecy	Accountability

Design Principle

Choice of path, source + replication provide robustness



Can survive failure/DoS of any one link or server

(More on resource isolation later in talk)

Integrity	Availability	Secrecy	Accountability

XIA Mechanisms

- Multiple principal types
  - Any source that has the capability to satisfy your intent *can* do so.
- Intrinsically secure principals
  - Satisfy intent even from untrusted sources
- Flexible trust management
  - Fallback mechanisms for trust establishment, e.g., out-of-band via cellphone, etc.

Integrity	Availability	Secrecy	Accountability

Content Example

- Express intent: Content ID *CID*
- Retrieve from any cache, Akamai replica, origin server, or your neighbor
  - Your intent is content, not a particular source...
- Use of replication require integrity: Detect fake source by checking the hash
  - Need mechanism to then avoid that source for the next request is valid

Integrity	**Availability**	Secrecy	Accountability

Next few years question: Service Replication

- Hash(service public key)
  - Any replica that knows private key can provide service
- Easy step: Accessing already-replicated services
  - Future: Combine with trusted computing to create a TrustedCDN for wide-area, mutually isolated service replication?

Integrity	Availability	**Secrecy**	Accountability

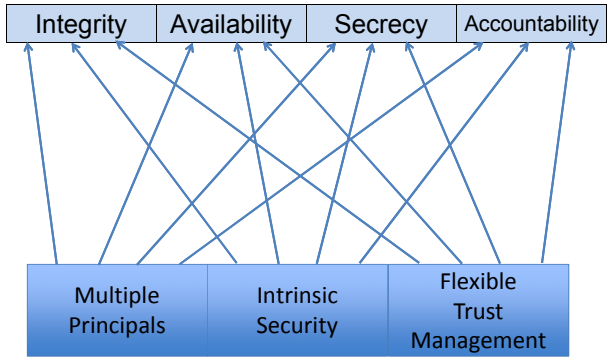
XIA Mechanisms

- Multiple principal types
  - Expresses user's intent
  - Expressiveness versus revealing intent
- Intrinsically secure principals
  - If you know the sender/receiver ID, you know a key to use for encryption
- Flexible trust management
  - Provide many ways to reliably *obtain* that ID

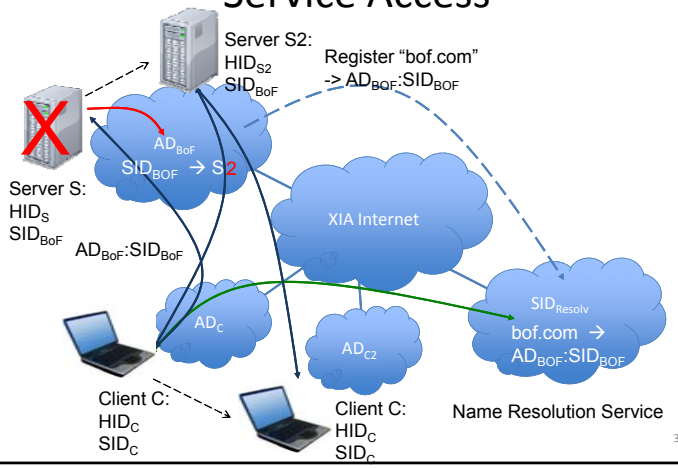
Integrity	Availability	Secrecy	**Accountability**

XIA Mechanisms

- Multiple principal types
  - Higher semantic level may provide stronger level of accounting
- Intrinsically secure principals
  - Authentication per principal type
  - Provides a basis for irrefutable, verifiable statements, e.g., audit trails
- Flexible trust management
  - Scope which IDs we trust and how



Example of Secure Mobile Service Access



33

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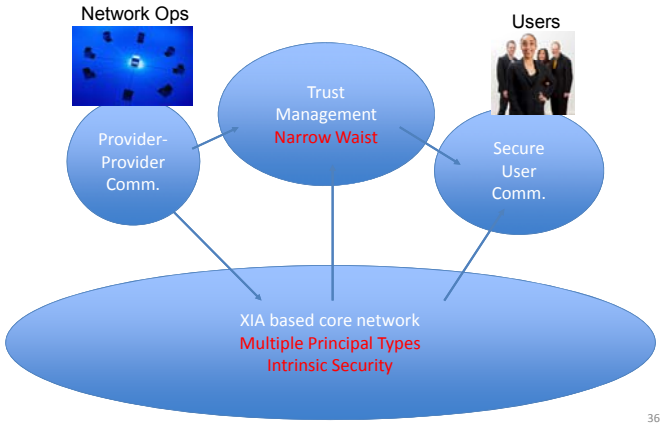
34

Security Focus for XIA

- Important network security aspects
  - Core network security properties
  - Trust management
  - Trustworthy network operations, provider-provider relations, public policy
  - User trust in the network
- Deemphasized areas: host security, DRM
  - Hope to learn from teams working on these topics

35

XIA Security-related Research



36

Initial Results
XIA Security in the Real World

- Trust management
- User trust in the network
- Enable content delivery
- SCION: network level resource isolation and path selection

37

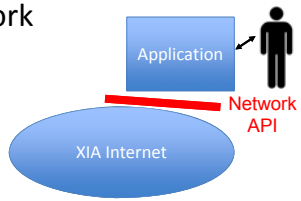
Flexible Trust Management

- How can users establish trust in Internet entities and resources?
  - Service, data, content provider
  - Individuals (email address, Twitter data, etc.)
- Flexible approaches
  - Leverage existing PKI mechanism
  - Perspectives: age-based trust
  - Usage-based trust: social network-based trust
  - Local trust establishment between users

38

Who is the User?

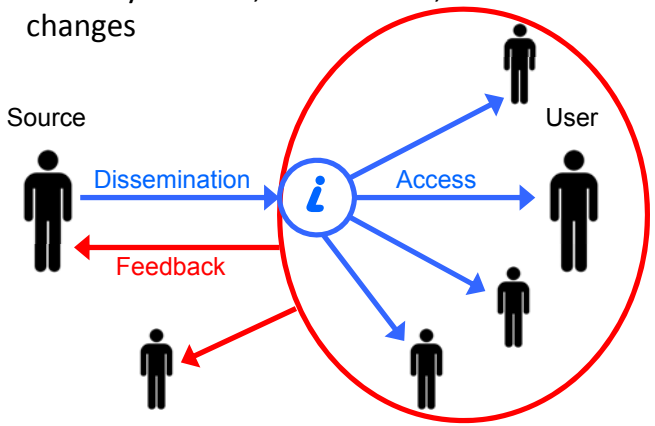
- Traditional focus of network API is to support robust application development
- Users do not directly interact with network
  - Separate user view from application API
- A broader perspective on what people know about Internet behavior at different levels
  - Network, other users, third parties, etc.



39

How Users See Information Dissemination

- Visibility of users, transactions, and content changes



Trust Management Example

- Users are interested in common identities across sites, services, organization, etc.
  - However, anonymity important in some contexts
- Can improve trust in content
  - E.g., Wikipedia article authored by a NYT journalist
- Also of interest to service providers
  - Can simplify tracking interests, managing joint promotions, etc.
  - But may be perceived differently by users

41

Supporting Content Delivery

- Today's CDNs are based on contracts between CDN and a relatively small number of customers
  - Contract is basis for trust
- CIDs open the door for widespread use of caches, but …
- what are the economic incentives for deploying caches in different types of networks?
  - Reducing cost
  - Potentially new revenue streams: publisher payments
- What security protocols are needed to support economically viable deployment?
  - Tracking cache hits in verifiable way
  - How to scale contract establishment to XIA distribution model

42

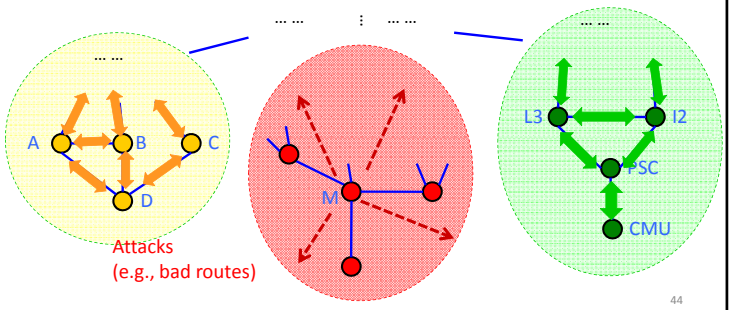
SCION Architectural Goals

- Scalability, Control, and Isolation on Next-generation networks (SCION)
- High availability, even for networks with malicious parties
- Explicit trust for network operations
- Minimal TCB: limit number of entities that need to be trusted for any operation
  - Strong isolation from untrusted parties
- Operate with mutually distrusting entities
  - No single root of trust
- Enable route control for ISPs, receivers, senders
- Simplicity, efficiency, flexibility, and scalability

43

Wish List (1): Isolation

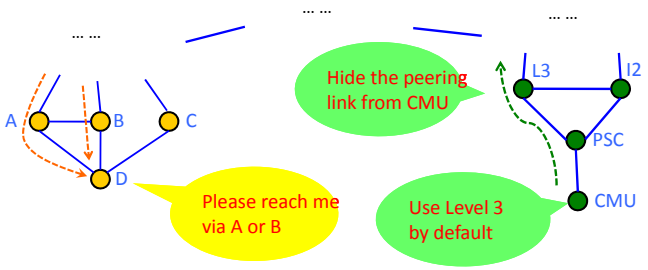
- Localization of attacks
- Scalable and reliable routing updates
- Operate with mutually distrusting entities without a global single root of trust



44

Wish List (2): Balanced Control

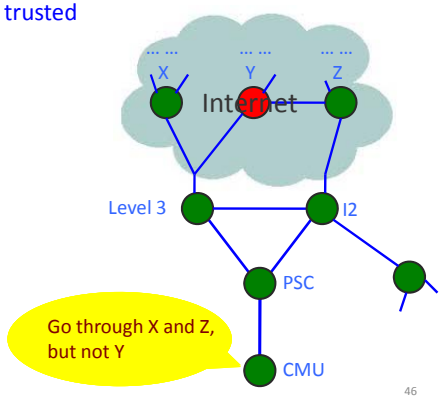
- Source: select paths to send packets
- Destination: select paths to receive packets
- Transit ISPs: select paths to support
- Support rich policies and DDoS defenses



45

Wish List (3): Explicit Trust

- Know who needs to be trusted
- Select whom to trust
- Confidence in selected paths
- Enforceable accountability



46

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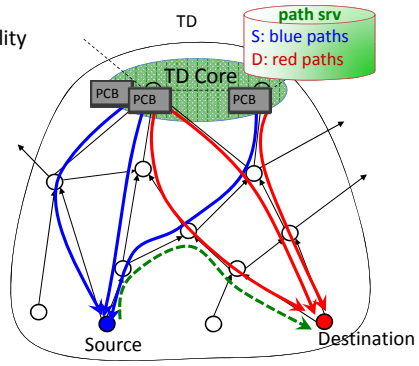
47

SCION Architecture Overview

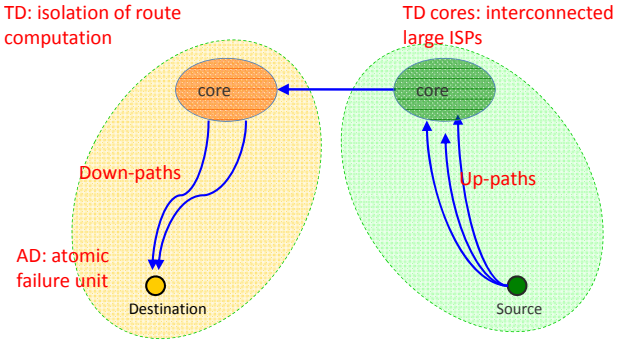
- Trust domain (TD)s
  - Isolation and scalability
- Path construction
  - Path construction beacons (PCBs)
- Path resolution
  - Control
  - Explicit trust
- Route joining (shortcuts)
  - Efficiency, flexibility



48

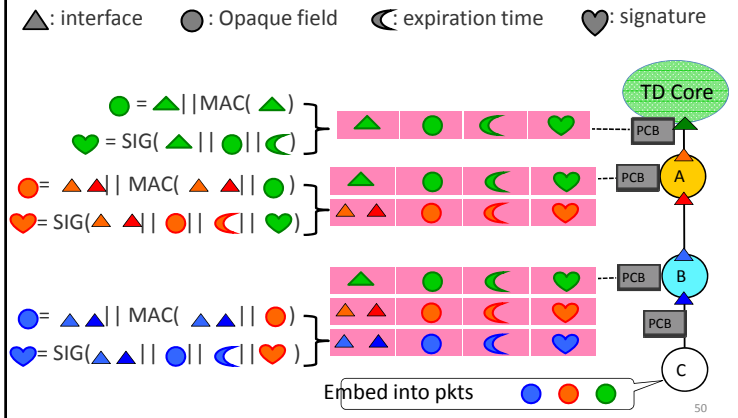
Hierarchical Decomposition

❖ Split the network into a set of trust domains (TD)



49

Path Construction



50

SCION Security Benefits

		S-BGP etc	SCION
Isolation	Scalability, freshness		
	Path replay attack	☹	☺
	Collusion attack		
	Single root of trust		
Trusted Computing Base		Whole Internet	TD Core and on-path ADs
Path Control	Source	End-to-end control	Only up-path
	Destination	No control	Inbound paths
	DDoS	Open attacks	Enable defenses

51

Ongoing and Future Work

- Study security interactions among principal types
- Availability for content and service types
- Accountability for content origin
- Mechanisms for trust management
- Support transparency for users
- Privacy / anonymity: in-network, overlay, …

52

Conclusions

- Core XIA security mechanisms …
  - Intrinsically secure identifiers
  - Multiple principal types
  - Flexible trust management
- … help support basic security properties
  - Integrity, secrecy, availability, accountability
- Used as the basis for security protocols supporting trustworthy network operations and to improve user trust
  - SCION, caching, improving user trust, …

53