eXpressive Internet Architecture: Overview and Next Phase

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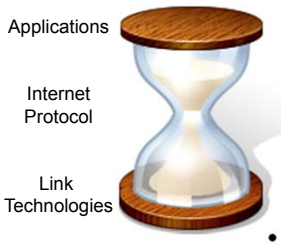
Outline

- XIA overview
  - Architecture review
  - Prototype
  - Research activities
- Research nuggets
- Next phase direction

"Narrow Waist" of the Internet Key to its Success

- Has allowed Internet to evolve dramatically
- But now an obstacle to addressing challenges:
  - No built-in security
  - New usage models a challenge – content and services, not hosts
  - Hard to leverage advances in technology in network
  - Limited interactions between network edge and core
- But where do we get started?



Three Simple Ideas

- Support multiple types of destinations
  - Not only hosts, but also content, services, etc.
  - Network can adapt over time - reduces complexity and overhead at higher layers
- Flexible addressing gives the network multiple options for completing a communication operation
  - Includes both an "intent" and "fallback" address
  - Supports evolvability, in-network error recovery, network diversity, mobility, …
- Intrinsic security guarantees security properties as a direct result of the design of the system
  - Do not rely on external configurations, data bases, ..
  - Network level management of addresses

Multiple Principal Types

- Hosts XIDs support host-based communication similar to IP – *who?*
- Service XIDs allow the network to route to possibly replicated services – *what does it do?*
  - LAN services access, WAN replication, …
- Content XIDs allow network to retrieve content from "anywhere" – *what is it?*
  - Opportunistic caches, CDNs, …
- Autonomous domains allow scoping, hierarchy
- Set of principal types can evolve over time

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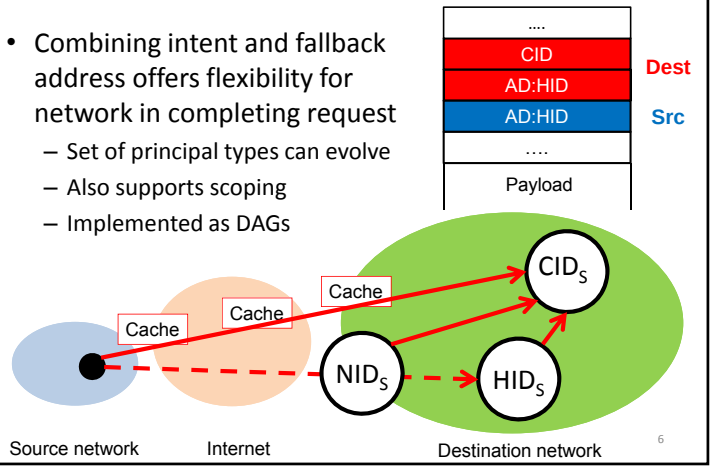
Flexible Addressing

- Combining intent and fallback address offers flexibility for network in completing request
  - Set of principal types can evolve
  - Also supports scoping
  - Implemented as DAGs



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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
- Useful for bootstrapping e-e security solutions
- Intrinsic security is specific to the principal type:
  - Content XID: content is correct
  - Service XID: the right service provided content
  - Host XID: content was delivered from right host

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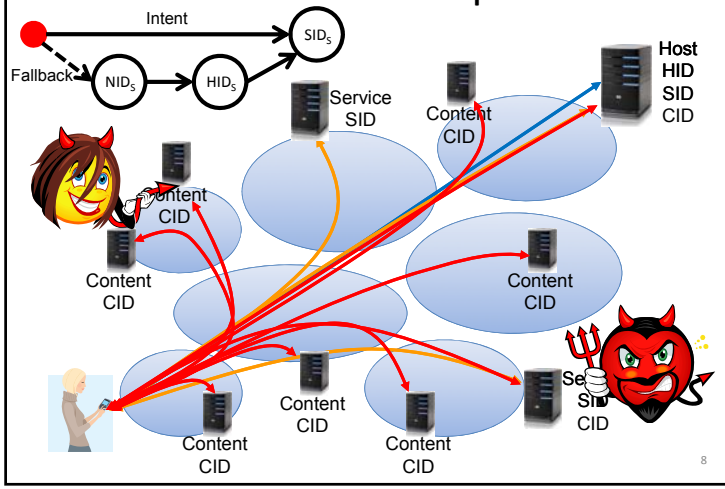
XIA: An Example



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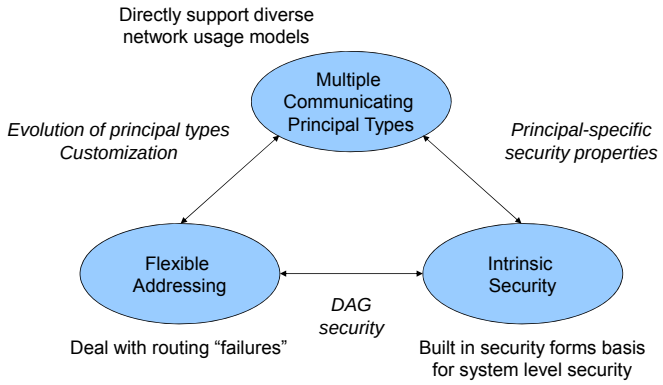
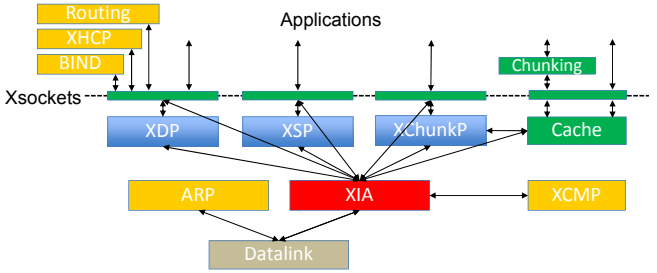
Ideas are Complementary



Open Source XIA Release

https://github.com/xia-project/



- XIA Prototype released in May 2012
  - Includes full XIA protocol stack and utilities
- Being used to support evaluation, applications, services
- New functionality is being added regularly

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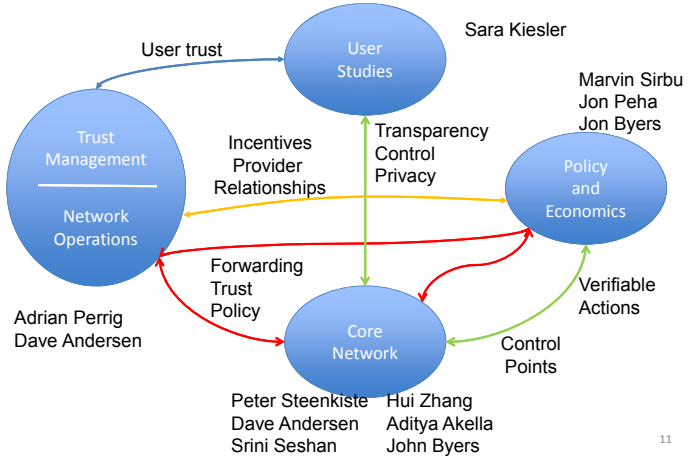
Broader XIA Research Agenda



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Ongoing Networking Research

- Transport protocols: congestion control, error recovery
- Intrinsic security and mobility, …
- Incremental deployment of network architectures (features)
- Verification of third party services using TPMs
- Very fast lookup of flat IDs in huge tables
- Optimize use of network features under user control
- Native Unix XIA implementation; extensibility
- Design of a network control plane
- Routing and forwarding for services, content
- Network diagnostics, centralized versus distributed control
- Video streaming as a use case for XIA
- Economic incentives and implications of cryptographic identifiers
- Balancing user accountability and privacy

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- XIA overview
- Research nuggets
  - Architecture
  - Controlling paths
  - Evolvability everywhere
  - Users and providers
- Next phase directions

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Architecture Nuggets

Examples of how XIA features can help address various network challenges

- Evolvability
- Mobility
- Incremental deployment
- Accountability versus privacy
- eXtreme evolvability

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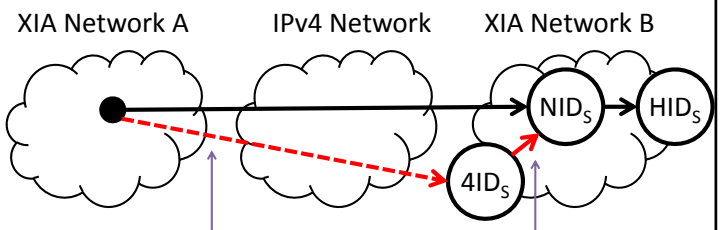
4ID in Action: Dealing with Legacy Networks



Entering IPv4 network: Encapsulate XIA packet with IP header

Entering XIA network: Remove IP header for native XIA packet processing

Works for arbitrary pairs of XIA networks

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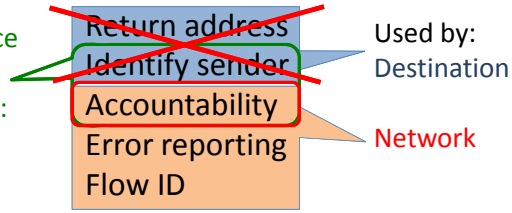
Source Addresses, or Balancing Privacy and Accountability

- Source address are assumed to be essential but you can build a network without them
- What are source addresses used for?

Hard to balance Privacy and Accountability: Tor versus AIP



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Accountability and Privacy

- View source addresses as accountability addresses
  - "Service" that takes responsibility for packet
    - Accountability can be delegated
  - Return address can be inside packet
  - Uses AIP style accountability
- Many "details": nature of delegate, faith sharing, …

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XIA as a Platform of Architectural Exploration

- Evolvability is hard to quantify
- Our approach: port alien designs
  - Push evolvability to the extreme
  - Realize pluralism through inclusiveness
- Recurrent porting questions
  - How to best map Y's identifiers to XIDs?
  - When can we reuse XID types?
  - How to break Y into principals?
  - Are there interesting alternative interpretations?

How Alien Designs Pushed XIA

- Serval: service-centric architecture
  - multiple classes of identifiers
- NDN: content-centric architecture
  - evolution stress test

- IP: migration/deployment plan
- ANTS: active network
  - Proof/demonstration of generality

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SCION Architectural Goals

- High availability, even in presence of 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

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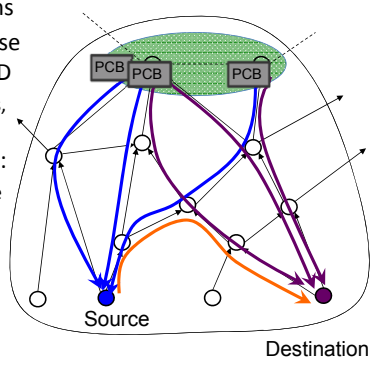
Path Selection in SCION Architecture Overview

- Split network in trust domains
- Source/destination can choose from up/down hill paths in TD
  - Path control shared between ISPs, receivers, senders
- Desirable security properties:
  - High availability, even in presence of malicious parties
  - Explicit trust for operations
  - Minimal TCB: limit number of entities that must be trusted
  - No single root of trust
  - Simplicity, efficiency, flexibility, and scalability



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Richer Interfaces - Tussle

- How do we control relationship between users, service providers, ISP, etc. – "choice points":
- Choice of XID type, i.e. how is communication operation performed involving different tradeoffs
  - Choices for both end-points and providers: XIDs to use or support
- DAGs add flexibility: fallback, services, …
  - Input from destination, sources, and providers
  - Different options for supporting binding, mobility, …
- Scion offers some control over path selection
  - Can balance control between end-points and providers
  - Opens doors for service differentiation

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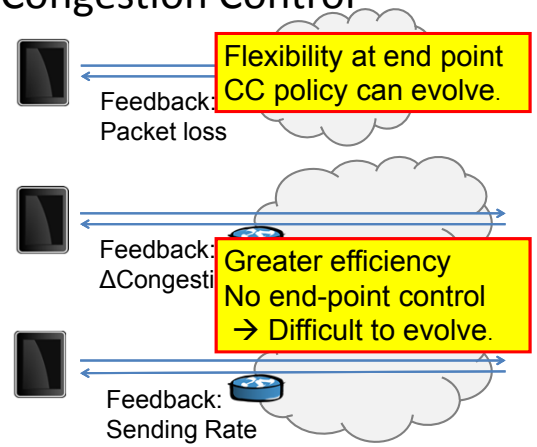
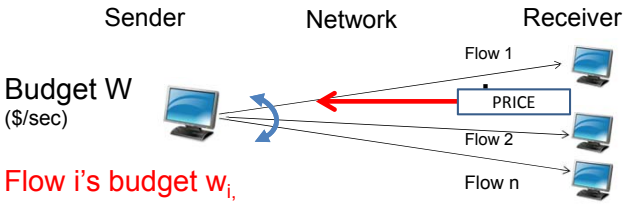
Evolvability Everywhere Congestion Control

- TCP and friends
- XCP
- RCP



Can we achieve both?



Flow i's budget w_i, subject to $W \geq \Sigma w_i$

Flow i's price: P_i ($/Byte)

Flow i's rate: R_i = budget/price = w_i / P_i (Byte/sec)

Questions/Challenges
- Can we achieve high efficiency?
- Can we implement different CC policies?
- How to deal with feedback errors due to delay?

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User Perspective

- Research questions
  - What do people know about the Internet?
  - Does informing them change their behavior?
- User study on user perspective on anonymity and privacy online (Ruogu Kang)
  - Users care about privacy for some sessions
  - User concerns are very diverse (really)
  - Users do not have clear picture of who gets access to what information as a result of specific actions
    - E.g., network versus application level threat

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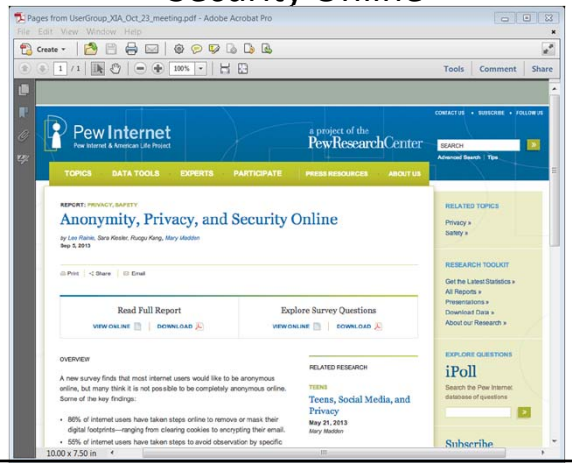
Pew Study on Anonymity, Privacy and Security Online



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Must "Empower" Users

- Having network-level mechanisms to deal with various threats is not sufficient
- How do users know what information is visible to observers inside the network?
  - Tell them!
  - Course project in HCI defined sample interface
- How do users control privacy for individual sessions?
  - Need to have model of what the threat is: source, destination, different points in the end-to-end path

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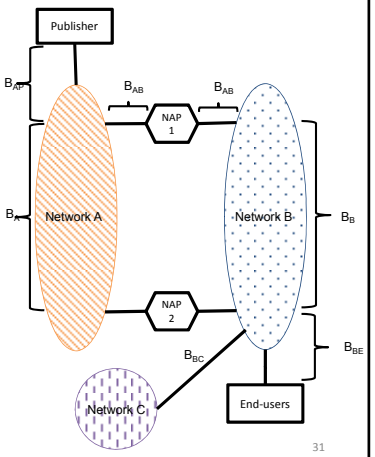
When Should ISPs Cache?

- Many FIA proposals support app-independent caching, e.g., CIDs
  - ISP can subsume role of CDNs
- Consider transparent and "for pay" caching
  - Payment requires billing/ accountability services
- Eyeball networks have the most to gain



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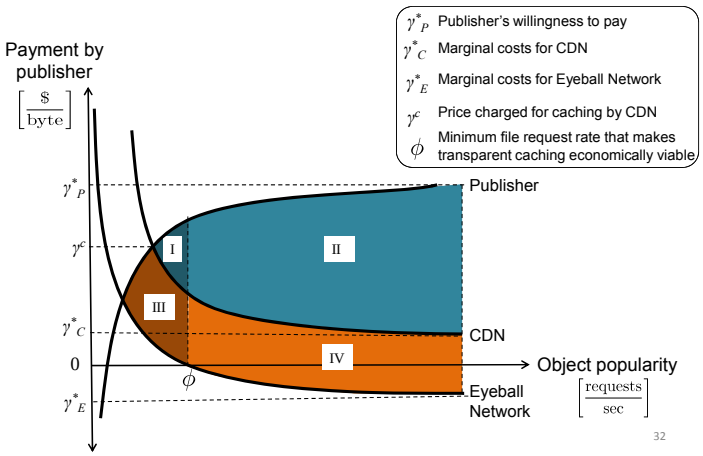
When is caching viable?



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- XIA overview
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- Next phase directions
  - Evaluation of network architectures
  - Network environments
  - Control plane architecture
  - Building and using XIA networks
  - Privacy, anonymity, and accountability

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Control Plane Architecture

- Today's internet does not have a real control plane
  - Ad hoc collection of independently developed control protocols, e.g., BGP, ICMP, …
- What would an architecture for a internet control plane look like?
  - What functions can be shared across protocols?
  - Can it evolve? Incremental protocol deployment?
  - How do we secure it?
- Use routing for our initial focus
  - More on this later

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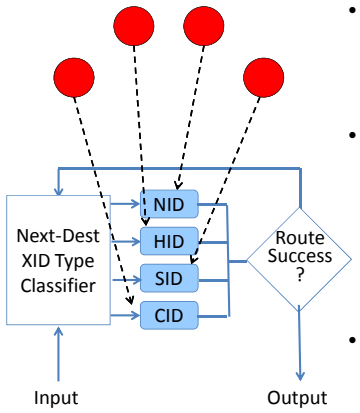
XIA Packet Processing Pipeline



- Principal-independent processing defines how to interpret the DAG
  - Core architecture
- Principal-dependent processing realizes forwarding semantics for each XID type
  - Logically: one forwarding table per XID type
  - Reality: anything goes, e.g., no forwarding table
- Control plane sets up forwarding for each principal type

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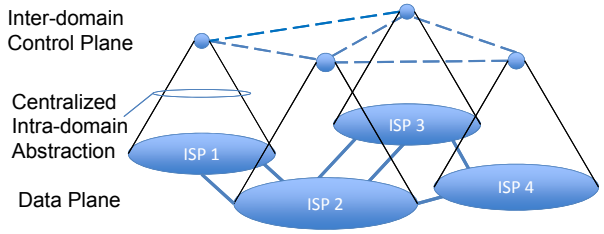
Control Plane
The 10K Mile View



- Domains present a single point of control at inter-domain level
- Matches logically centralized intra-domain control
  - But actual implementation can be anything

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Building and Using an XIA Network

- Looking at various network challenges and they can be addressed within XIA
  - Internet congestion control
  - Multicast and mobility
- Deploying and managing XIA networks
  - Multihoming, multipath
  - Service discovery, binding and routing
  - Fast XIA
  - Establishing and controlling session

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Questions?