

The eXpressive Internet Architecture: from Architecture to Network

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NSF Future Internet Architecture

- The Internet has been unbelievably successful
 - Has sustained tremendous growth
 - Supports very diverse set of applications and services
 - Integral part of our society and economy
- Lots of exciting research on how to improve Internet
 - Security, routing, wireless/mobile, management, ...
 - But Internet architecture constrains what can be modified
- Future Internet Architecture frees researchers to go beyond today's IP architecture and infrastructure
 - Five teams funded by NSF, including XIA

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Outline

- XIA architecture concepts
 - Motivating example
- Building an XIA network
- Research directions

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Predicting the Future is Hard!

- A lot of really smart people don't agree:
 - Named Data Networking, content centric networking
 - data is a first class entity
 - Mobility First, mobility as the norm rather than the exception – generalizes delay tolerant networking
 - Nebula: Internet centered around cloud computing data centers that are well connected

We love all of them!

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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!

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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:
hash(content) = content id
- How does source know it is talking to the right client?
 - Intrinsic security! Self-certifying host identifiers

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A Bit More Detail ...

Flexible Trust Management

Diverse Communicating Entities

Intrinsic Security

Hash() = CID?

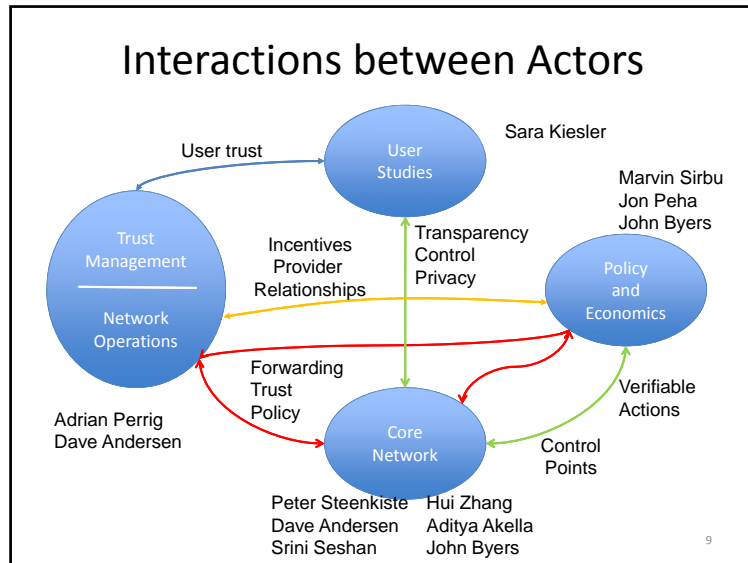
Also keep many good features of Internet!

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XIA: eXpressive Internet Architecture

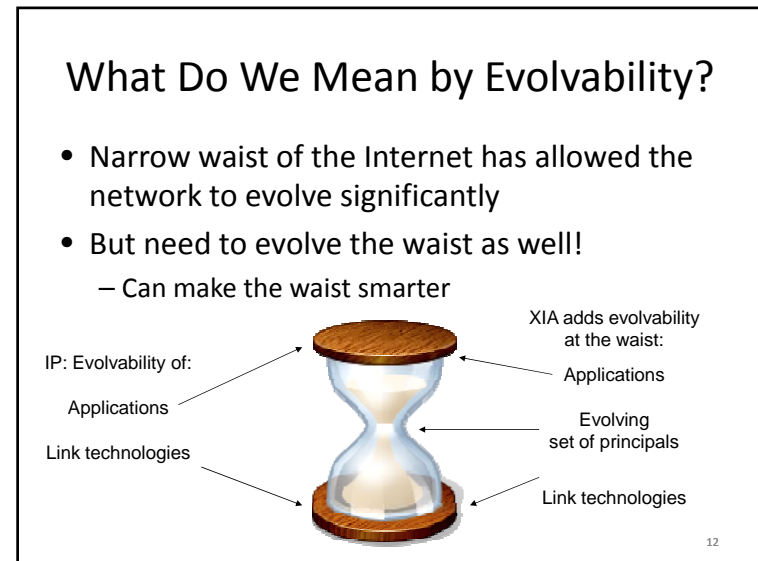
- Each communication operation expresses the intent of the operation
 - Also: explicit trust management, APIs among actors
- XIA is a single inter-network in which all principals are connected
 - Not a collection of architectures implemented through, e.g., virtualization or overlays
 - Not based on a “preferred” principal (host or content), that has to support all communication

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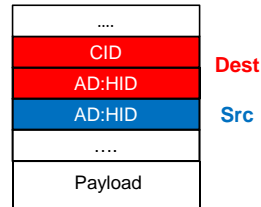
- ### Outline
- XIA architecture concepts
 - Building an XIA network
 - Making it work
 - Research directions

- ### 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
 - Associated with different forwarding semantics
 - Set of principal types can evolve over time



Supporting Evolvability

- Introduction of a new principal type will be incremental – no “flag day”!
 - Not all routers and ISPs will provide support from day one
- Creates chicken and egg problem - what comes first: network support or use in applications
- Solution is to provide an *intent* and *fallback* address
 - Intent address informs network of user intent
 - Fallback address is guaranteed to be reachable



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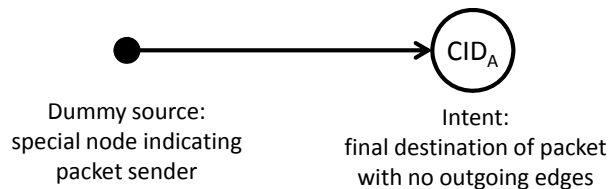
Addressing Requirements

- Fallback: intent that may not be globally understood must include a backwards compatible address
 - Incremental introduction of new XID types
- Scoping: support reachability for non-globally routable XID types or XIDs
 - Needed for scalability
 - Generalize scoping based on network identifiers
 - But we do not want to give up leveraging intent
- Support for mobility, in-path services, ...
- Want to combine the above requirements

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Our Solution: DAG-Based Addressing

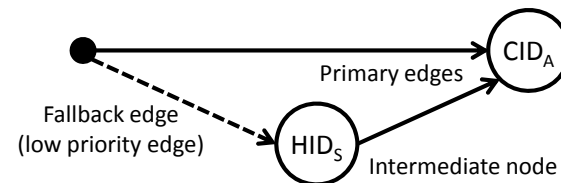
- Uses direct acyclic graph (DAG)
 - Nodes: typed IDs (XID; expressive identifier)
 - Outgoing edges: possible routing choices
- Simple example: Sending a packet to CID_S



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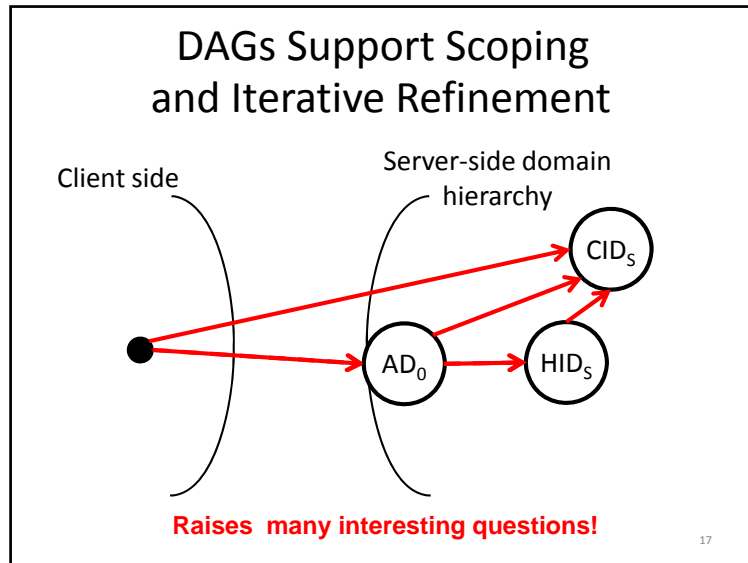
Support for Fallbacks with DAG

- A node can have **multiple outgoing edges**

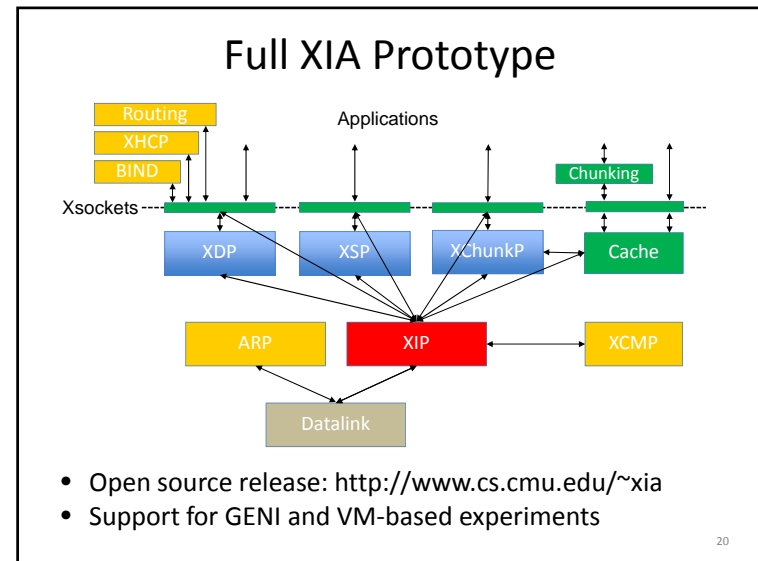
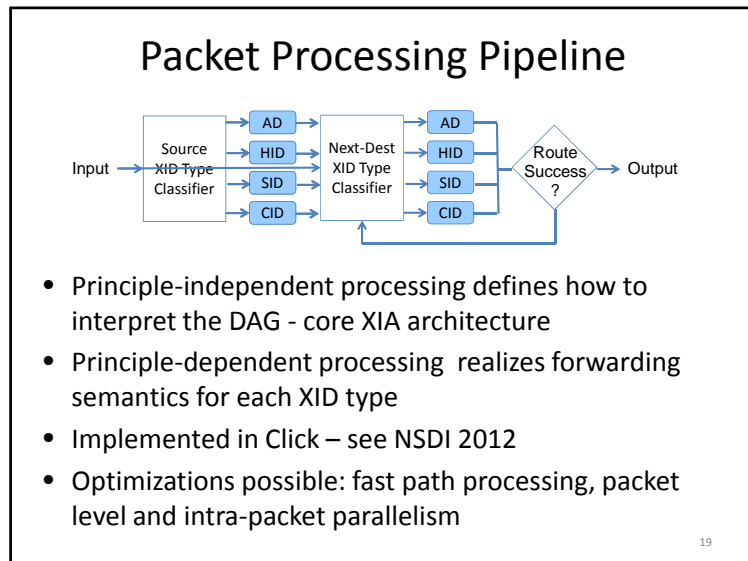


- Outgoing edges have **priority** among them
 - Forwarding to HID_S is attempted if forwarding to CID_A is not possible – Realization of fallbacks
 - Helps routers deal with routing failures

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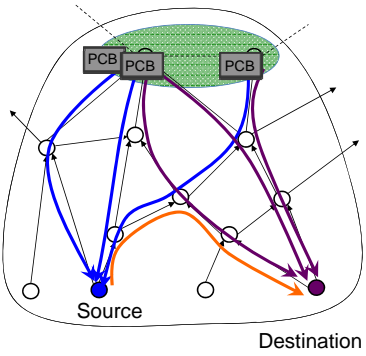


- ### Intrinsic Security in XIA
- XIA uses self-certifying identifiers that guarantee security properties for communication operation
 - Host ID is a hash of its public key – accountability (AIP)
 - Content ID is a hash of the content – correctness
 - Does not rely on external configurations
 - Intrinsic security is specific to the 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
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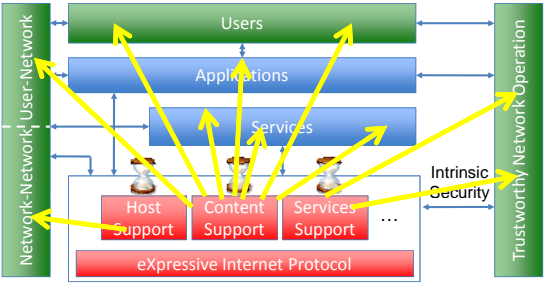
Path Selection in SCION Architecture Overview

- Source/destination can choose among up/down hill paths
- 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
- Porting to XIA DP this summer



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XIA Components and Interactions



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Outline

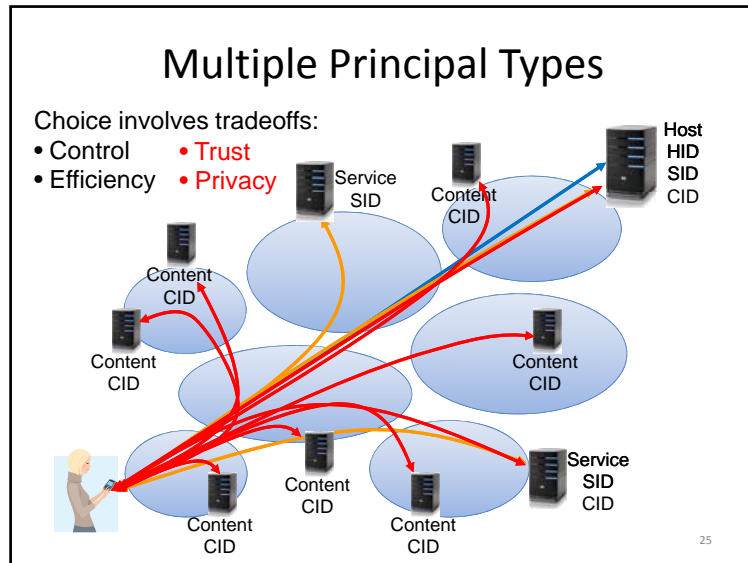
- XIA architecture concepts
- Building an XIA network
- Research directions
 - What is different?

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Balance of Control between Network Core and Edge

- Internet places most control in the network
- XIA provides more control to the edge
 - Choice of principal, DAGs, Scion path selection
 - Also offers flexibility to service providers: control path properties, new services, ...
- Many research opportunities
 - Other mechanisms + other functions/layers
 - Customizing roles depending on context
 - How to manage the tradeoff at runtime

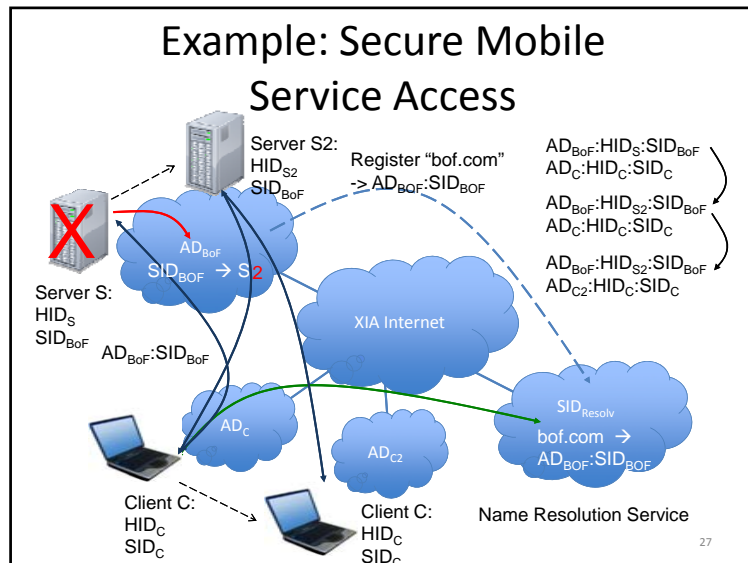
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Using DAGs

- DAG is “locator” that helps network reach “destination”
 - Provided by destination through a name service
 - Has the right incentive!
- DAG is created jointly by all parties involved
 - Source can modify destination DAG, pick from options, ..
 - DAG can be modified during session
 - Networks can limit what DAGs they accept
- Many other options exist
 - Path based options, locator services, different headers, ..

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Functionality in Network versus Edge

- Internet had notion that higher level functions were implemented at the edge
 - Currently lots of functionality in the network
- XIA addressing flexibility simplifies adding functions to the network
 - Services, new principal types
 - Does not require universal agreement (DAGs)
 - Example: supporting diversity at edge (Tapa)
- Many alternative solutions
 - Service-oriented architectures, active nets, ...

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How Much and What Security in the Network

- XIA uses “intrinsic security” to guarantee some properties of communication operation
 - XIA: cryptographic identifiers, Scion paths
 - Several other projects are using cryptographic ids.
- Many alternatives to explore
 - Different types of cryptographic identifiers
 - Alternative approaches, evolving the mechanisms
 - Verifiability of network functions

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What About the Users?

- Who are the users?
 - Human end-users, applications, or edge networks
- Trust management, naming
 - Hosts – DNS – nice and hierarchical
 - Services and content – different
 - Important: want to skip hosts
- User trust in network
 - Visibility + control
 - “Privacy button”



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Conclusion

- XIA supports evolution, expressiveness, and trustworthy operation.
 - Multiple principal types, flexible addressing, and intrinsic security
 - More information (including on release)
 - <http://www.cs.cmu.edu/~xia>
- Broad research agenda on key tradeoffs in network
 - Edge versus core, security in network, evolvability, ...
 - Affects all aspects of the network: transport protocols, trust management, applications, services, ...

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