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CyLab

CONFIDENCE FOR A NETWORKED WORLD

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Future Internet Projects @ CMU

XIA & SCION

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eXpressive Internet Architecture
Security Architecture

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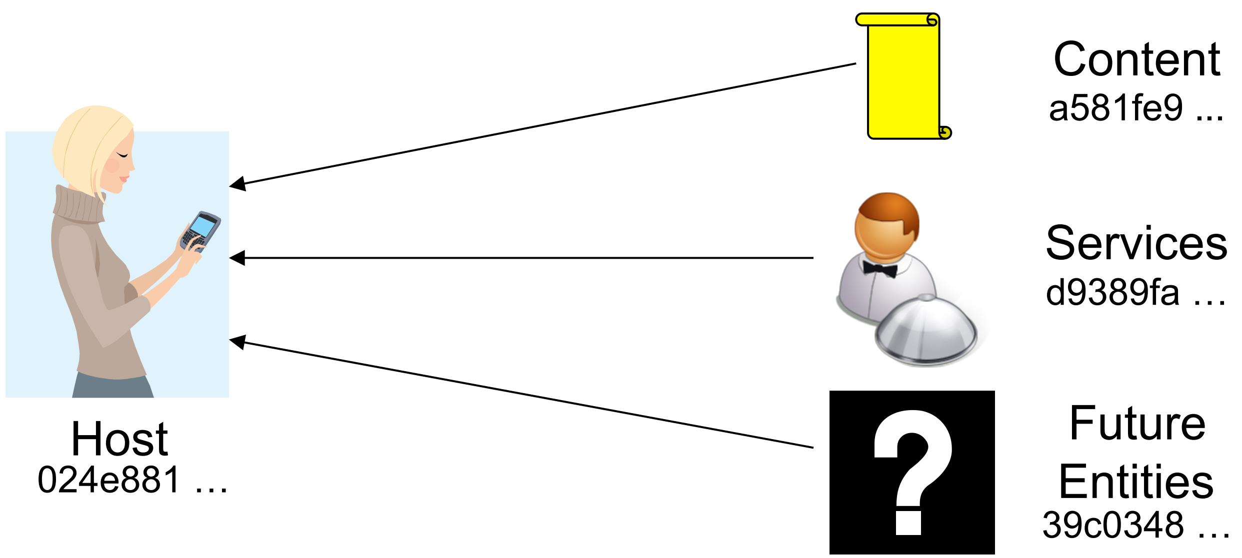
XIA Vision

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

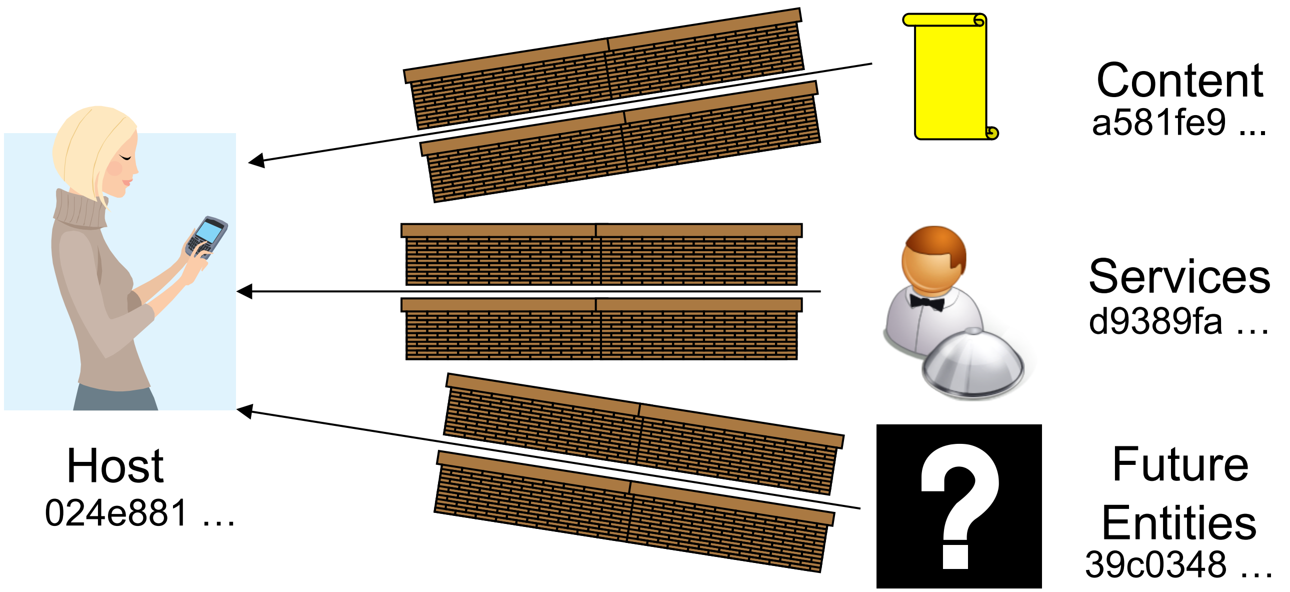
P1: Evolvable Set of Principals

- 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



Other XIA Principles

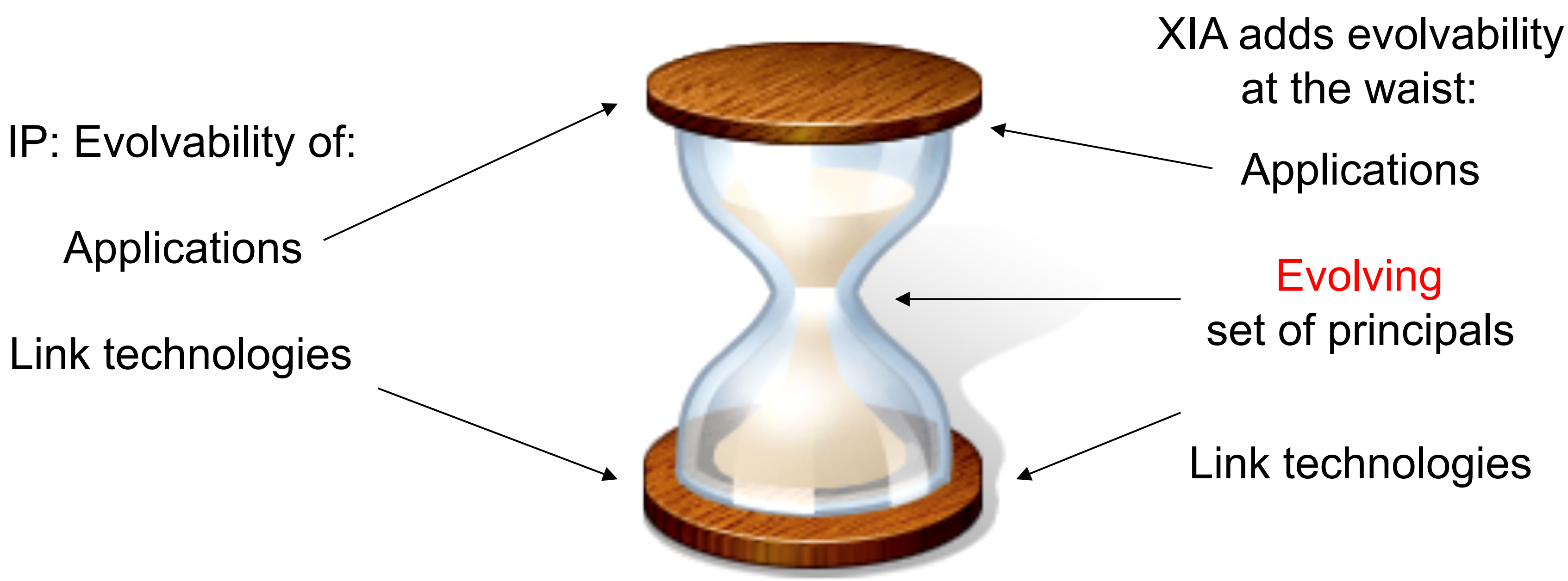
- Narrow waist for trust management
  - Intrinsically secure identifiers must match the user's trust assumptions and intensions
  - Narrow waist allows leveraging diverse mechanisms for trust management: CAs, reputation, personal, …
- Narrow waist for all principals
  - Defines the API between principals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

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

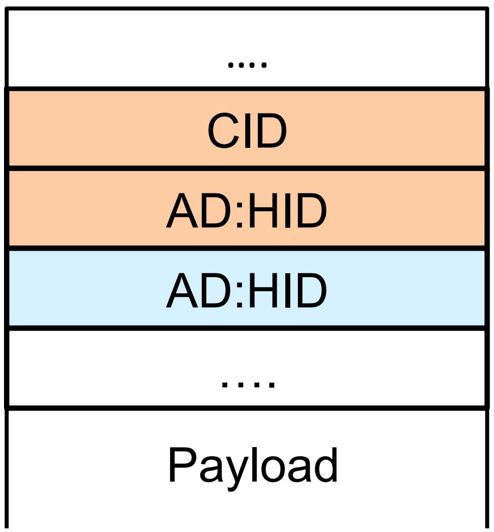
What Do We Mean by Evolvability?

- 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



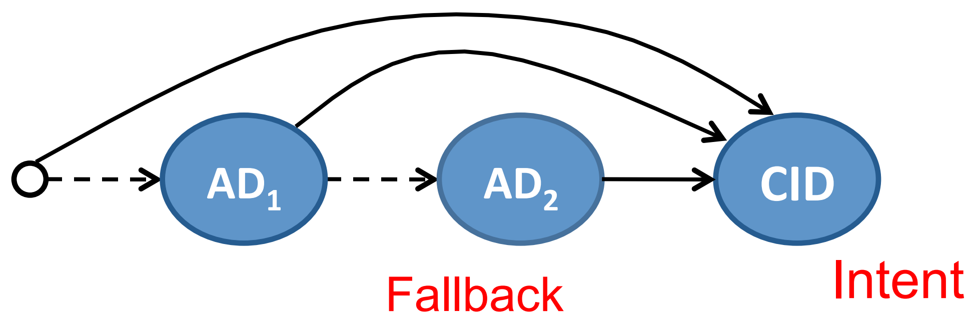
Evolvability

- 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



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

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

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

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-grained control: users can specify their intent
- Explicit chain of trust: Allow users to understand the basis for trust, underlying assumptions
- Intrinsically secure identifiers

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SCION:

Scalability, Control and Isolation On Next-Generation Networks

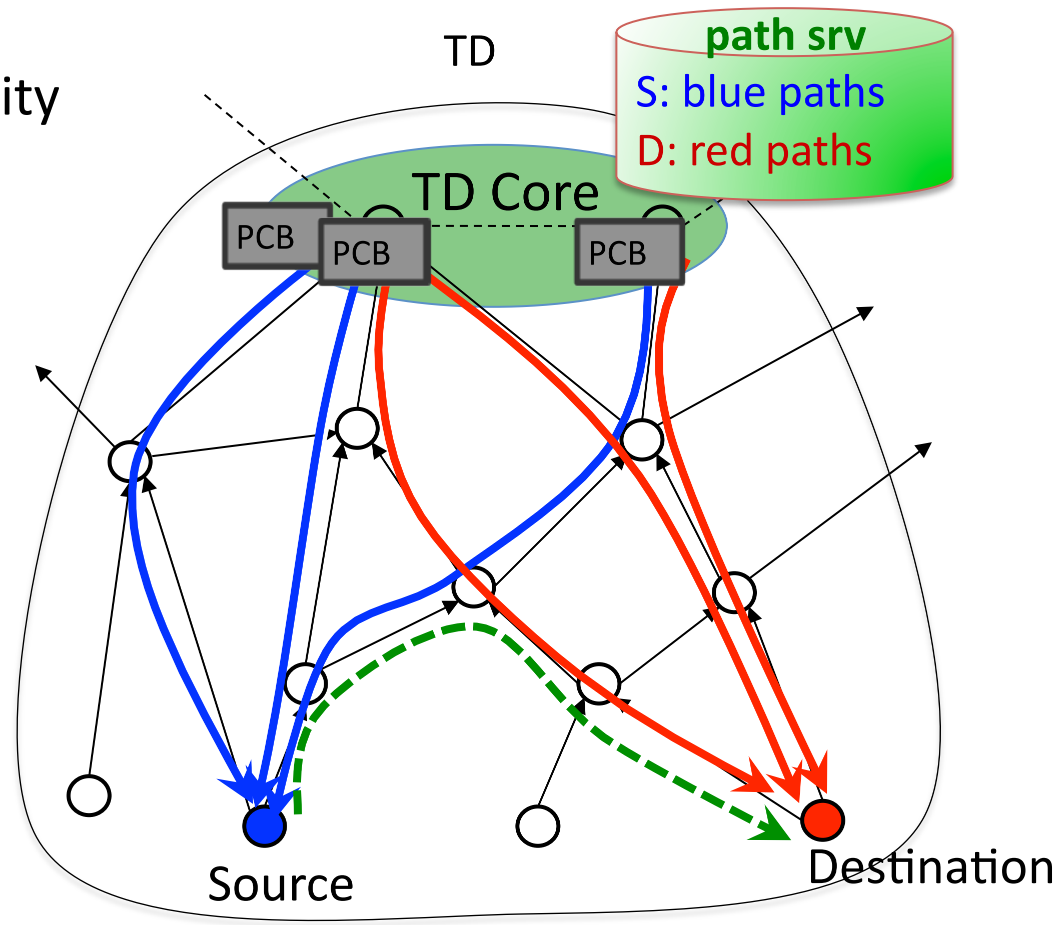
Xin Zhang, Hsu-Chun Hsiao, Geoff Hasker,
Haowen Chan, Adrian Perrig, David Andersen

SCION Architectural Goals

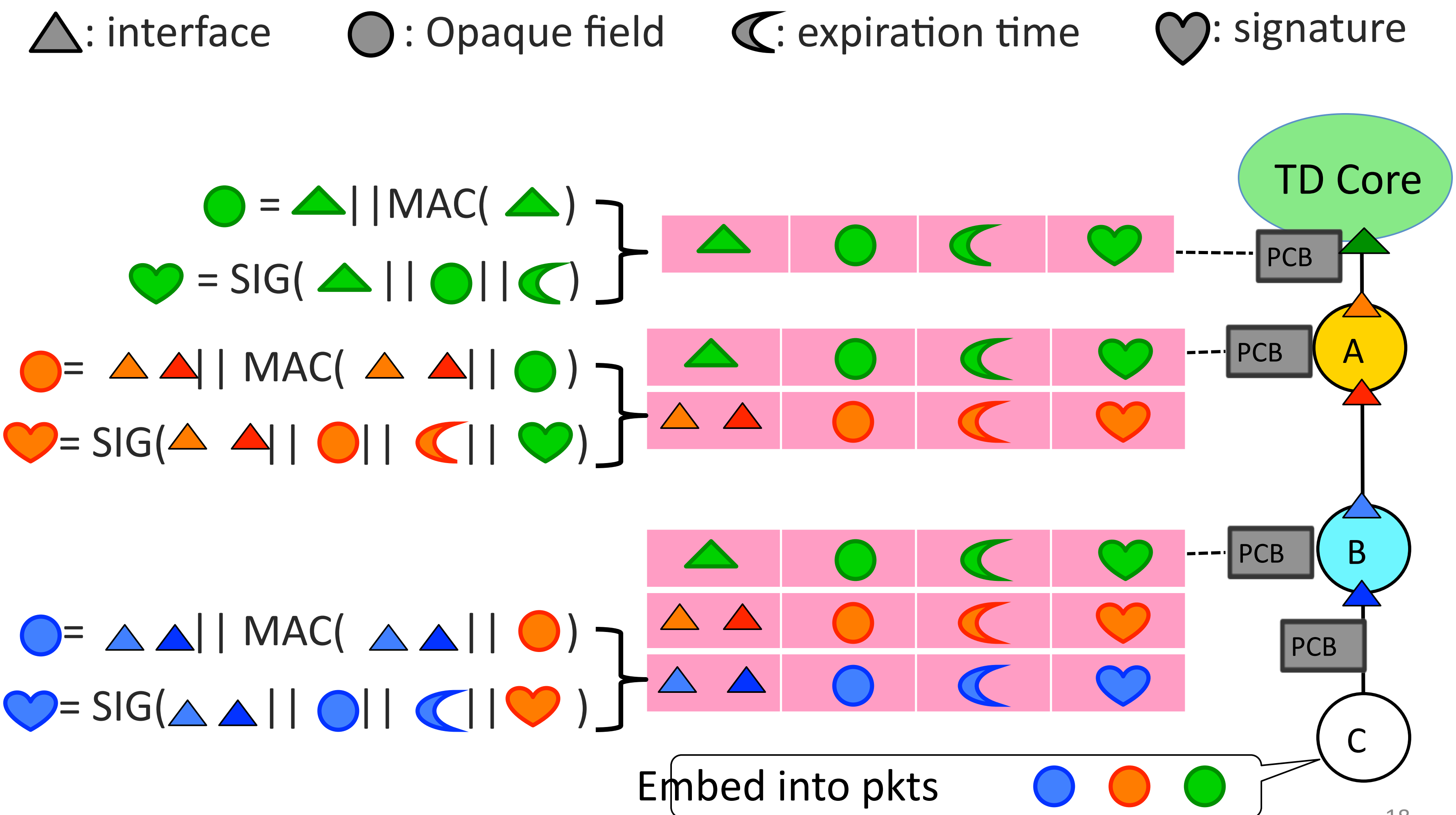
- High availability, even for networks with malicious parties
- Explicit trust for network operations
- Minimal TCB: limit number of entities that need to be trusted for any operation
  - Strong isolation from untrusted parties
- Operate with mutually distrusting entities
  - No single root of trust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

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



Path Construction



Discussion

- Incremental Deployment
  - ✓ Current ISP topologies are consistent with the TDs in SCION
  - ✓ ISPs use MPLS to forward traffic within their networks
  - ✓ Only edge routers need to deploy SCION
  - ✓ Can use IP tunnels to connect SCION edge routers in different ADs

- Limitations
  - ✗ ADs need to keep updating down-paths on path server
  - ✗ Increased packet size
  - ✗ Static path binding, which may hamper dynamic re-routing

BGP / Control Plane Issues

- Lack of fault isolation
  - Error propagation, potentially to entire Internet, disruption of flows outside domain
  - Can attract flows outside domain
  - Black art to keep BGP stable, manual rule sets, unanticipated consequences
- Instability propagates, when link/router goes down, remainder of the network has much more work to find new routes
  - Increased number of routing updates during DDoS attacks
  - Path changes need to be sent to entire Internet
  - Much more work required during times of instability
- Lack of scalability, amount of work by BGP is O(N), where N is number of destinations
- S-BGP requires single root of trust for AS and address certificates
- Lack of freshness for BGP update messages
- Slow route convergence
  - Convergence attack
  - Network may require minutes if not tens of minutes for convergence
- Other specific attacks
  - Blackhole attacks
  - Wormhole attack

IP / Data Plane Issues

- Complex route table lookup for each packet
- Lack of predictability for path availability
- Lack of route choice/control by senders and receivers
- Bursting routing tables

IP / BGP / Misc. Issues

- No path predictability due to inconsistency between routing table and BGP updates
- No isolation between control and data planes (routing and forwarding)
    - By attacking routing, prevent forwarding to work correctly
- Huge TCB (entire Internet)
- Single root of trust for DNSsec

Performance Benefits

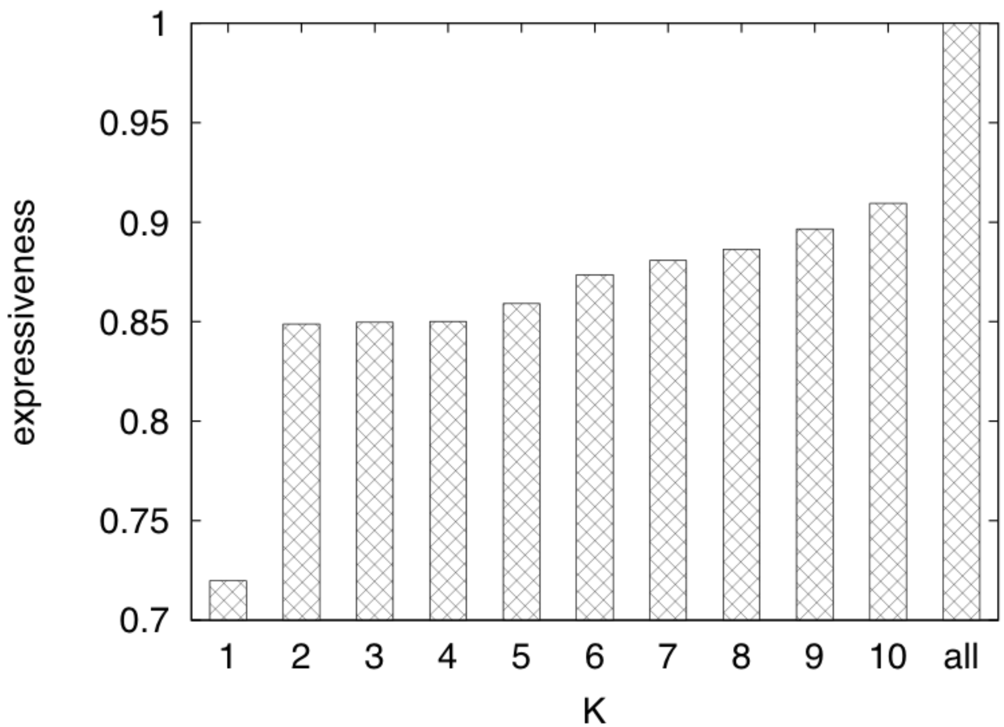
- Scalability
  - Routing updates are scoped within the local TD
- Flexibility
  - Transit ISPs can embed local routing policies in opaque fields
- Simplicity and efficiency
  - No interdomain forwarding table
    - Current network layer: routing table explosion
  - Symmetric verification during forwarding
  - Simple routers, energy efficient, and cost efficient

Evaluation

- Methodology
  - Use of CAIDA topology information
  - Assume 5 TDs (AfriNIC, ARIN, APNIC, LACNIC, RIPE)
  - We compare to S-BGP/BGP
- Metric 1: additional path length (AD hops) compared to BGP
  - *Without* shortcuts: 21% longer
  - *With* shortcuts:
    - 1 down/up- path: 6.7% longer
    - 2 down/up- path: 3.5% longer
    - 5 down/up- path: 2.5% longer

Evaluation (cont'd)

- Metric 2: Expressiveness
  - Fraction of BGP paths available under SCION



Summary

- Availability is fundamentally most important security property
- Core design mechanisms to provide maximum availability in XIA / SCION
  - XIA: Intrinsic security, user-specified intent, user-understandable trust, fault isolation, designed for extensibility
  - SCION: Isolation, explicit trust, control, no single root of trust

- Check us out at: http://www.cs.cmu.edu/~xia/