A Routing Infrastructure for XIA

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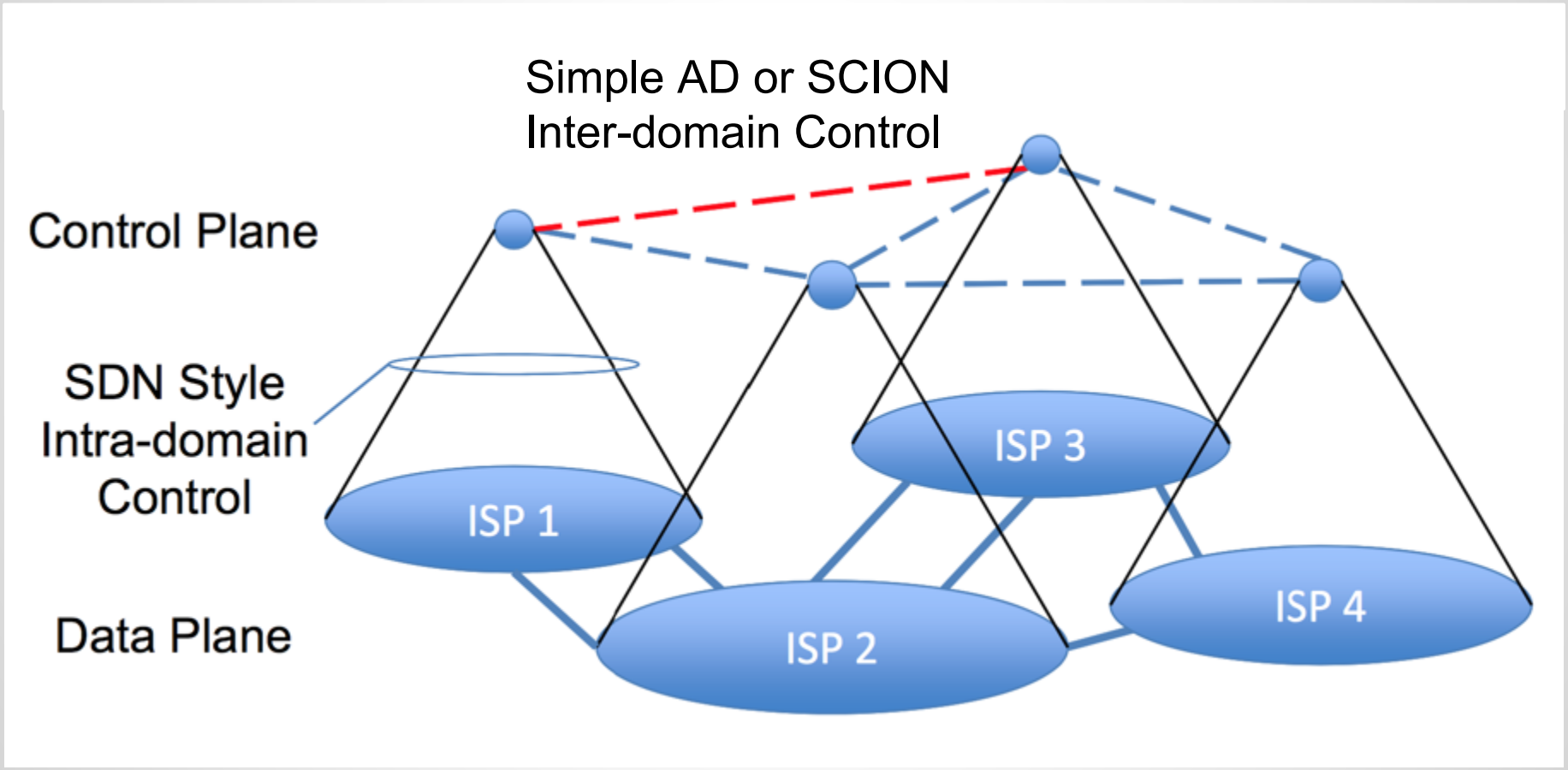
Overview

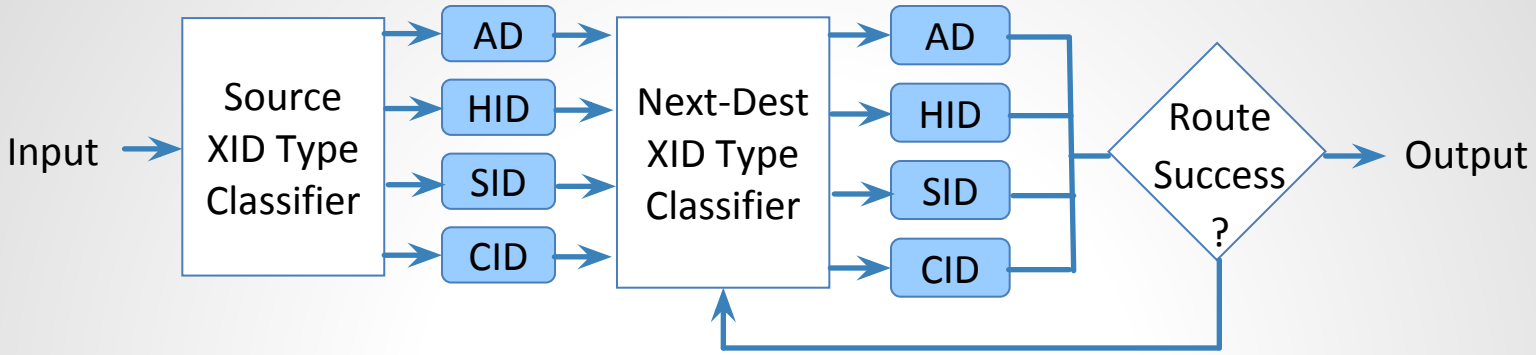
- Intra-domain routing
  - Use centralized SDN-style protocol

- Inter-domain routing
  - Simple AD routing protocol similar to intra-domain routing protocol for common case usage
  - SCION protocol for explicit end-to-end trusted paths

Architecture



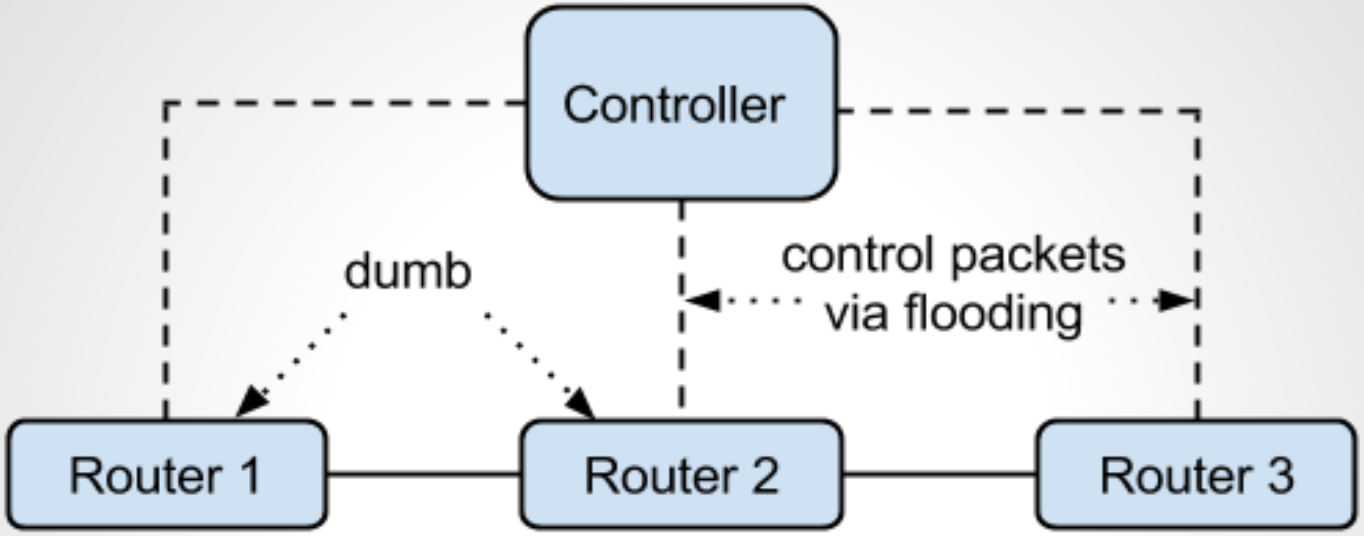
Forwarding Engine



- Principal-independent processing defines how to interpret the DAG
- Principal-dependent processing realizes forwarding semantics for each XID type

Note: We introduce a new XID type called XION for integrating SCION as an inter-domain routing protocol. This will require new processing capabilities to be added to the illustrated forwarding engine.

Intra-domain routing architecture



- Controller makes all routing decisions
- Controller and routers exchange control messages via flooding
- Advantages:
  - All decision-making centralized in controller so routers are very simple
  - Communication via flooding is simple to implement
- Disadvantages:
  - Loss of routing updates if controller fails
  - Flooding results in extra overhead

Intra-domain routing protocol

Intra-domain routing currently populates forwarding tables only for HIDs.

1. Routers send HELLO messages in all ports to identify one-hop neighbors (link-state information)
   a. End-hosts also automatically register themselves with their gateway routers using XHCP
2. Routers flood LSA (link-state advertisement) messages throughout the AD
3. Central controller receives all flooded LSAs
4. Controller computes: LSAs → internal domain topology → shortest paths → individual routing tables
5. Controller disseminates (via flooding) routing tables throughout domain to the routers

Note: HELLO and LSA message are never sent outside the domain. External ports on edge routers are statically configured as such beforehand.

Transit forwarding within an AD

Packets will be forwarded as-is inside a domain when transiting through that domain. The interior routers will possess forwarding entries for each AD, and packets are forwarded by exact matching of each node in the DAG, including AD.

Advantages

- No need for encapsulation that would require extra logic in processing packets at the boundary routers

Disadvantages

- Every router needs to know how to forward based on next-hop AD, so forwarding tables will be larger
- The controller needs to compute and disseminate AD forwarding tables for all of the interior routers, which requires more computation and control messages

Simple inter-domain routing

1. Statically configure edge routers to be aware of adjacent ADs on external ports beforehand
2. Include neighboring AD information in LSAs sent to domain controller
3. Controller sets up routes to adjacent ADs as well as intra-domain routes
4. Controllers from neighboring ADs can communicate with each other through logical connections
   a. Destination DAG: $AD_{neighbor} \rightarrow$ SID(controller)
5. Controllers run an AD-level link-state routing protocol over these logical connections
6. Each domain's controller then disseminates the resulting AD routes to its internal routers

Simple inter-domain routing protocol

Protocol populates routing tables for ADs in a similar fashion to the intra-domain link-state protocol which populates routing tables for HIDs.

1. Using established logical connections, controllers flood adjacent domain information to all other AD controllers
2. Each controller receives all flooded advertisements
3. Controller computes neighboring domain messages -> domain-level topology -> shortest paths -> individual routing tables
4. Controller disseminates (via flooding) AD routing table entries throughout its domain to the routers

XIA + SCION Integration

- Also use allow the use of SCION for inter-domain routing, when explicit end-to-end trusted paths are desired
- Protocol must be chosen before or when an end-host's packet reaches its gateway router, so that it can be forwarded to the proper domain egress if SCION is chosen
- Possibilities for who chooses the inter-domain routing protocol:
  - End-host can choose SCION:
    - On a per-packet basis but does not choose the SCION path
    - On a per-packet basis and chooses the SCION path
  - Transparent to end-host, domain controller can choose SCION:
    - On a per-packet basis
    - On a per-host basis
    - **On a domain-wide basis***

* We will implement this first for the sake of faster development.

Bootstrapping SCION

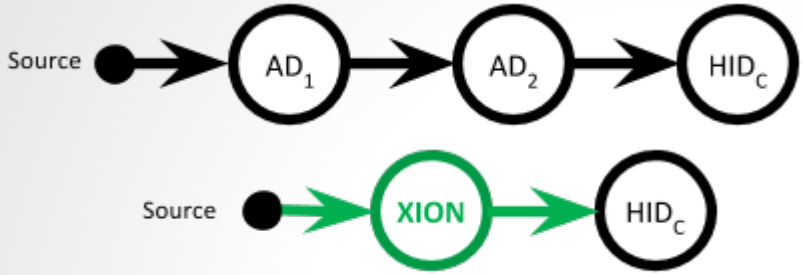
1. Each domain's controller populates intra-domain forwarding entries
   a. This includes entries for SCION Certificate, Beacon, and Path Server SIDs
2. Each domain's controller sets up forwarding entries for reaching adjacent ADs
3. As defined by SCION, TD Core Beacon Server generates PCBs and all downstream Beacon Servers propagate PCBs to further downstream ADs
   a. Note: this process never stops; it's not just for bootstrapping
4. When a border router receives a PCB, it forwards it to the domain's Beacon Server
   a. The routes to the Beacon Server were setup in step 1
5. As defined by SCION, receiving Beacon Servers use PCBs to construct and register paths with Path Servers

Using SCION

We introduce a new XID type called XION for packets that should use SCION for inter-domain routing. XION packets will make use of XIA's Extension Header feature.

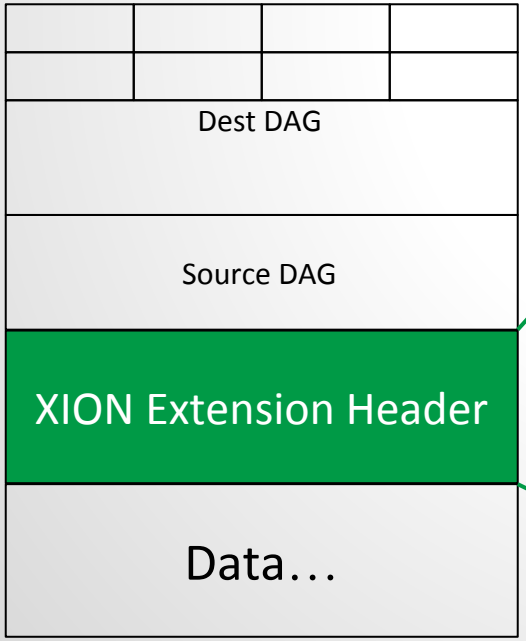
1. When sending a packet on a socket, end-host will specify a normal destination DAG of the form "AD: 123, HID: 456"
2. When a gateway router receives a packet, it will replace the destination DAG with one of the form "XION: 123, HID: 456" to identify it as requiring SCION for routing
3. It will also query the Path Servers and construct a SCION path to that domain
4. This path will then be added to the packet header as part of the XIA Extension Header
5. The gateway router and all subsequent routers in the domain forward packet to the first egress router
6. Egress router sends it to the next domain's ingress router
7. Repeat this until packet eventually reaches the final destination AD's ingress router
8. Routers within the final destination AD then forward packet to the final destination HID/SID

XION Principal Type

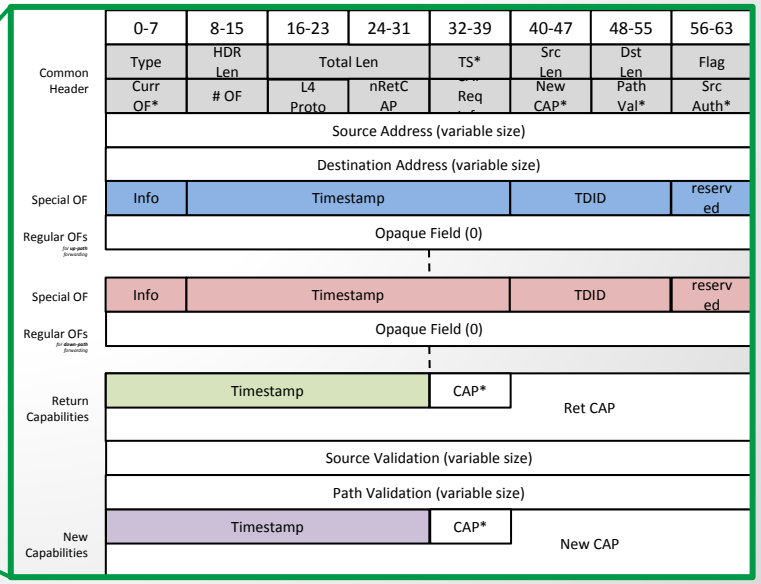


If Source needs ***Explicit Trust*** **on the Path (Network)** to HID

XIA Header



SCION Header



Current status

- Intra-domain routing
  - Implemented and functional
- Simple inter-domain routing
  - Controllers in adjacent ADs can communicate via controller SID
  - Next neighboring AD information needs to be flooded to controllers
  - Then AD-level topology and routes need to be calculated
- SCION inter-domain routing
  - Integrating bootstrapping of root-of-trust
  - Then PCB generation and propagation will be integrated