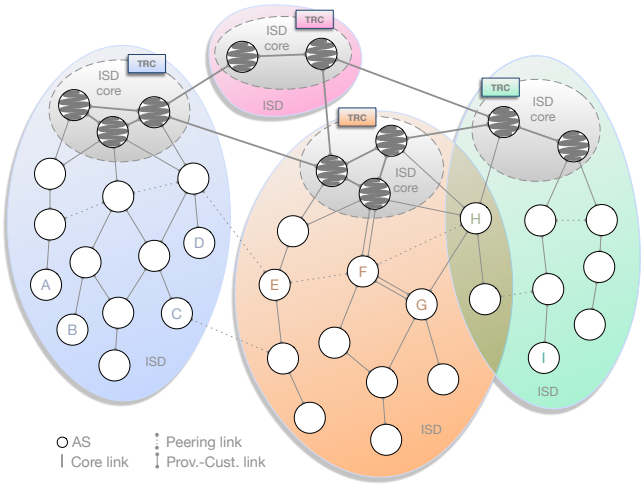

Figure 1: Four SCION ISDs with ISD Cores and ASes. The ISD Core ASes are connected via Core paths. Non-Core ASes are connected via customer-to-provider or peering links. AS H is contained in two ISDs.

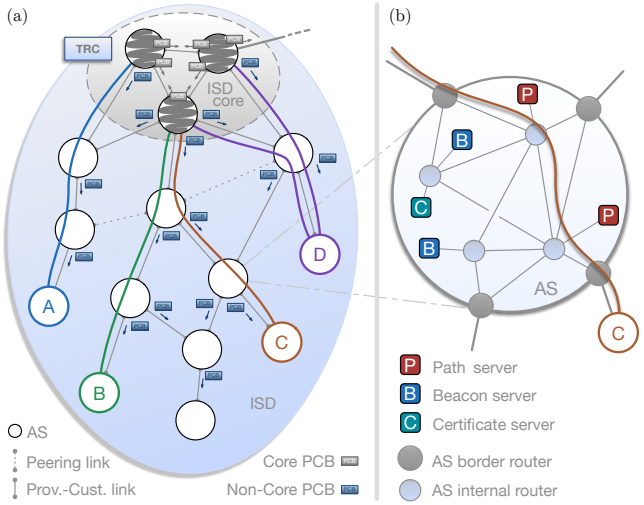

Figure 2: (a) SCION ISD with path construction beacons (PCBs) that are propagated from the ISD Core down to customer ASes, and path segments for ASes A, B, C, and D to the ISD Core. (b) Magnified view of an AS with its routers and servers. The path from AS C to the ISD Core traverses two internal routers.

Trust Root Configuration (TRC), which is negotiated by the ISD Core. The TRC defines a cohesive set of trust roots that are used to validate routing paths, domain names, and end entities. As part of the TRC, every ISD has an associated globally-consistent, human-understandable name space.

ASes join an ISD by purchasing service from another AS in the ISD; joining an ISD thus constitutes acceptance of the ISD's TRC. Typically, 2 to 10 current large-scale ISPs would comprise the ISD's Core ASes, and their associated customers would participate in the ISD. We envision that ISDs will span areas with uniform legal environments that provide enforceable contracts (e.g., countries or federations of countries). All ASes within an ISD agree on the entities that operate the trust roots and determine the ISD policies. ISDs are flexible; they support sub-ISDs, allowing a hierarchical structure; and they can overlap in the sense that an AS may be part of several ISDs. Although the primary goal of SCION's ISDs is to provide control-plane isolation, an additional benefit of ISDs is coarse-grained path transparency and the support of heterogeneous trust environments.

Control Plane: Beaconing for Route Discovery

SCION uses two levels of routing, intra-ISD and inter-ISD. Both levels utilize *Path Construction Beacons (PCBs)* to discover and establish routing paths (see Figure 2a).

An ISD Core AS announces a PCB and disseminates it as a policy-constrained multi-path flood either *within* an ISD (to discover intra-ISD paths) or *among* ISD Core ASes (to discover inter-ISD paths). PCBs accumulate cryptographically-protected AS-level path information as they traverse the network. These cryptographically protected contents within received PCBs are chained together by sources to create a path segment that enables packets to traverse a sequence of ASes. Packets thus contain AS-level path information avoiding the need for border routers to maintain inter-domain routing tables. We refer to this concept as *Packet-Carried Forwarding State (PCFS)*.

Through the inter-domain PCB transmission process, Core ASes learn paths to every other Core AS. Through the intra-domain PCB dissemination, ASes learn path segments on how to reach ISD Core ASes, which enable an AS to communicate with the ISD Core. Figure 2a shows some path segments from the ASes A, B, C, and D to the ISD Core.

We emphasize that PCFS in SCION is *different* from source routing since a source node does not search a network topology graph to construct its path. Instead, a source node combines any segment from its AS to the core, any segment connecting two ISDs, and any segment from the remote ISD to the destination's AS. These segments result in a valid end-to-end path.

The control plane is responsible for discovering paths and making those paths available to end hosts. Figure 2b shows the main components that perform these operations in SCION: *beacon servers* discover path information; *path servers* disseminate such path information; and *certificate servers* manage and distribute cryptographic key material. Border routers provide connectivity between ASes.

- *Beacon servers* are responsible for disseminating PCBs (see Figure 2a). Beacon servers in a Core AS generate intra-ISD PCBs that are sent to all non-Core ASes of the ISD. Non-Core AS beacon servers receive such PCBs and resend them to their customer ASes, which results in policy-compliant AS-level paths. Figure 3 shows PCBs that are propagated from the ISD Core down to customer ASes. At every AS, information about the AS's interfaces is added to the PCB. The beacon servers run a fault-tolerant protocol to ensure state consistency across all local servers. Periodically, a master beacon server generates a set of PCBs that it forwards to its customer ASes. In the case of inter-ISD communication, the beaconing process is similar to BGP's route advertising process, although the process is periodic and PCBs are flooded multi-path over policy-compliant paths to discover multiple paths between any pair of core ASes. SCION's beacon servers can be configured to express current