Revisiting Ethernet: Plug-and-play made scalable and efficient

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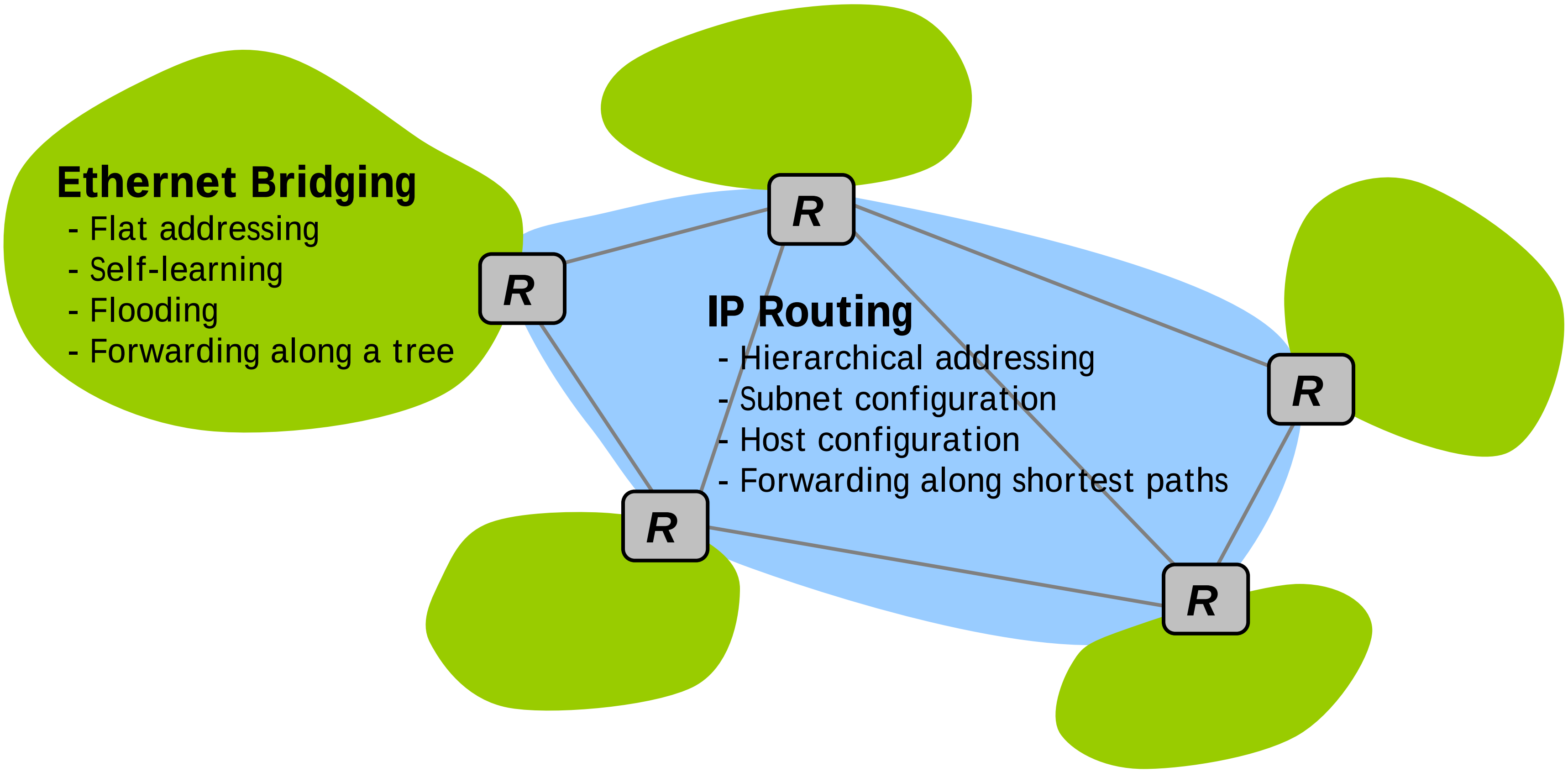
An *"All Ethernet"* Enterprise Network?

- *"All Ethernet"* makes network management easier
  - Zero-configuration of end-hosts and network due to
    - Flat addressing
    - Self-learning
  - Location independent and permanent addresses also simplify
    - Host mobility
    - Troubleshooting
    - Access control
- But, Ethernet has problems
  - Poor scalability
  - Poor efficiency

Today: Hybrid Architecture For Scalability

Enterprise networks comprised of Ethernet-based IP subnets interconnected by routers



Motivation

Neither bridging nor routing is satisfactory.

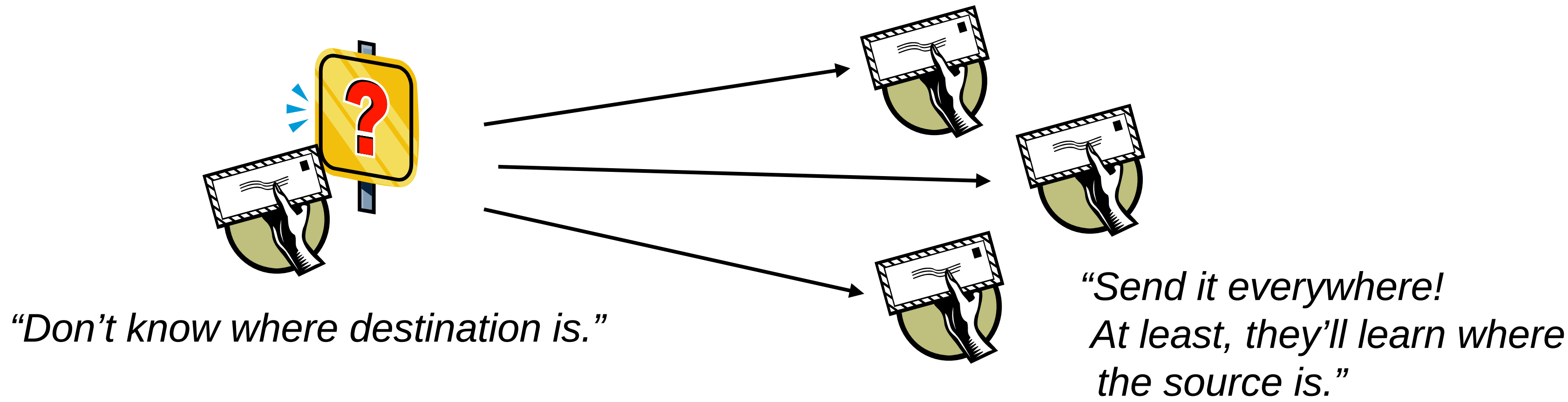
Can't we take only the best of each?

Features \ Architectures	Ethernet Bridging	IP Routi	SEIZE
Ease of configuration	👍	👎	👍
Optimality in addressing	👍	👎	👍
Mobility support	👍	👎	👍
Path efficiency	👎	👍	👍
Load distribution	👎	👍	👍
Convergence speed	👎	👍	👍
Tolerance to loop	👎	👍	👍

SEIZE (Scalable and Efficient Zero-config Enterprise)

Avoiding Flooding

- Bridging uses flooding as a routing scheme
  - Unicast frames to unknown destinations are flooded



  - Does not scale to a large network

- Objective #1: Unicast unicast traffic
  - Need a control-plane mechanism to discover and disseminate hosts’ location information

Restraining Broadcasting

- Liberal use of broadcasting for bootstrapping (DHCP and ARP)
  - Broadcasting is a vestige of shared-medium Ethernet
  - Very serious overhead in switched networks

- Objective #2: Support unicast-based bootstrapping
  - Need a directory service
- Sub-objective #2.1: Support general broadcast
  - However, handling broadcast should be more scalable

Keeping Forwarding Tables Small

- Flooding and self-learning lead to unnecessarily large forwarding tables
  - Large tables are not only inefficient, but also dangerous
- Objective #3: Install hosts' location information only when and where it is needed
  - Need a reactive resolution scheme
  - Enterprise traffic patterns are better-suited to reactive resolution

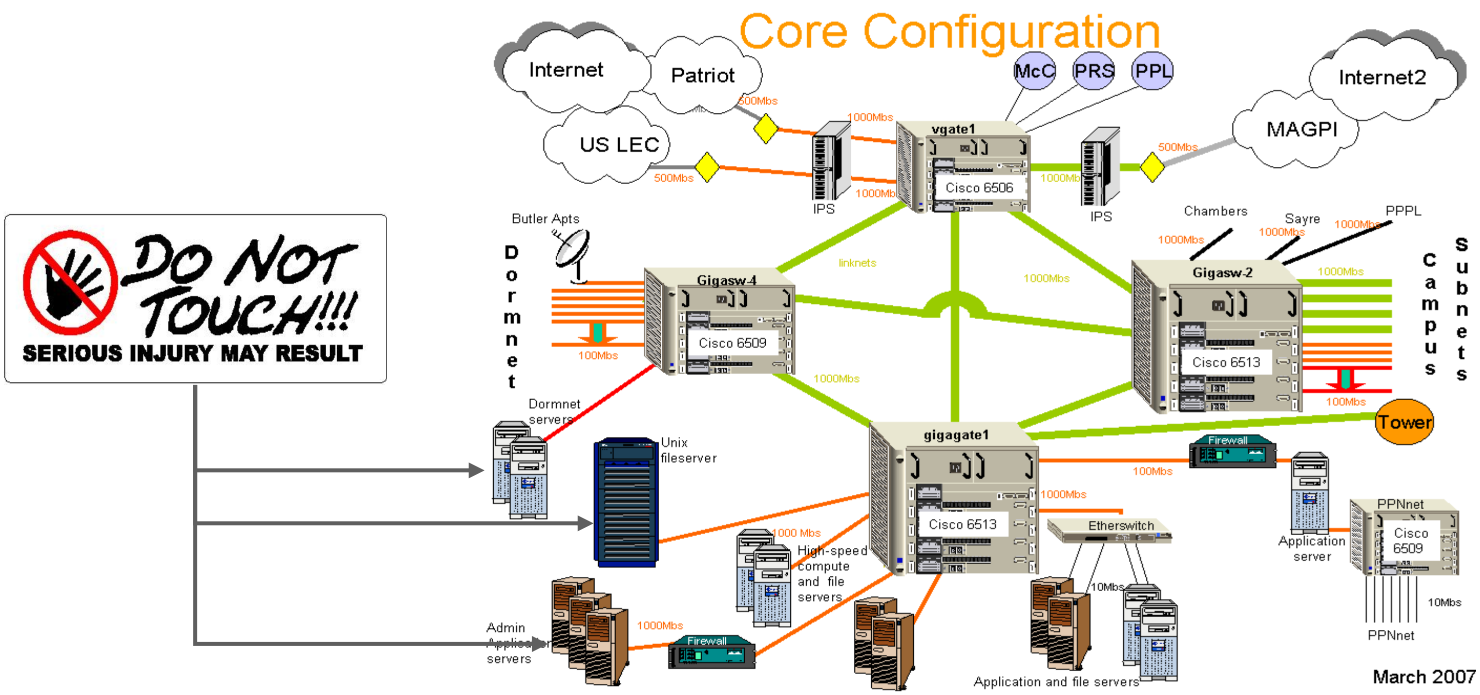
Ensuring Optimal Forwarding Paths

- Spanning tree avoids broadcast storms.
  But, forwarding along a single tree is inefficient.
  - Poor load balancing and longer paths
  - Multiple spanning trees are insufficient and expensive

- Objective #4: Utilize shortest paths
  - Need a routing protocol
- Sub-objective #4.1: Prevent broadcast storms
  - Need an alternative measure to prevent broadcast storms

Backwards Compatibility

- Objective #5: Do not modify end-hosts
  - From end-hosts' view, network must work the same way

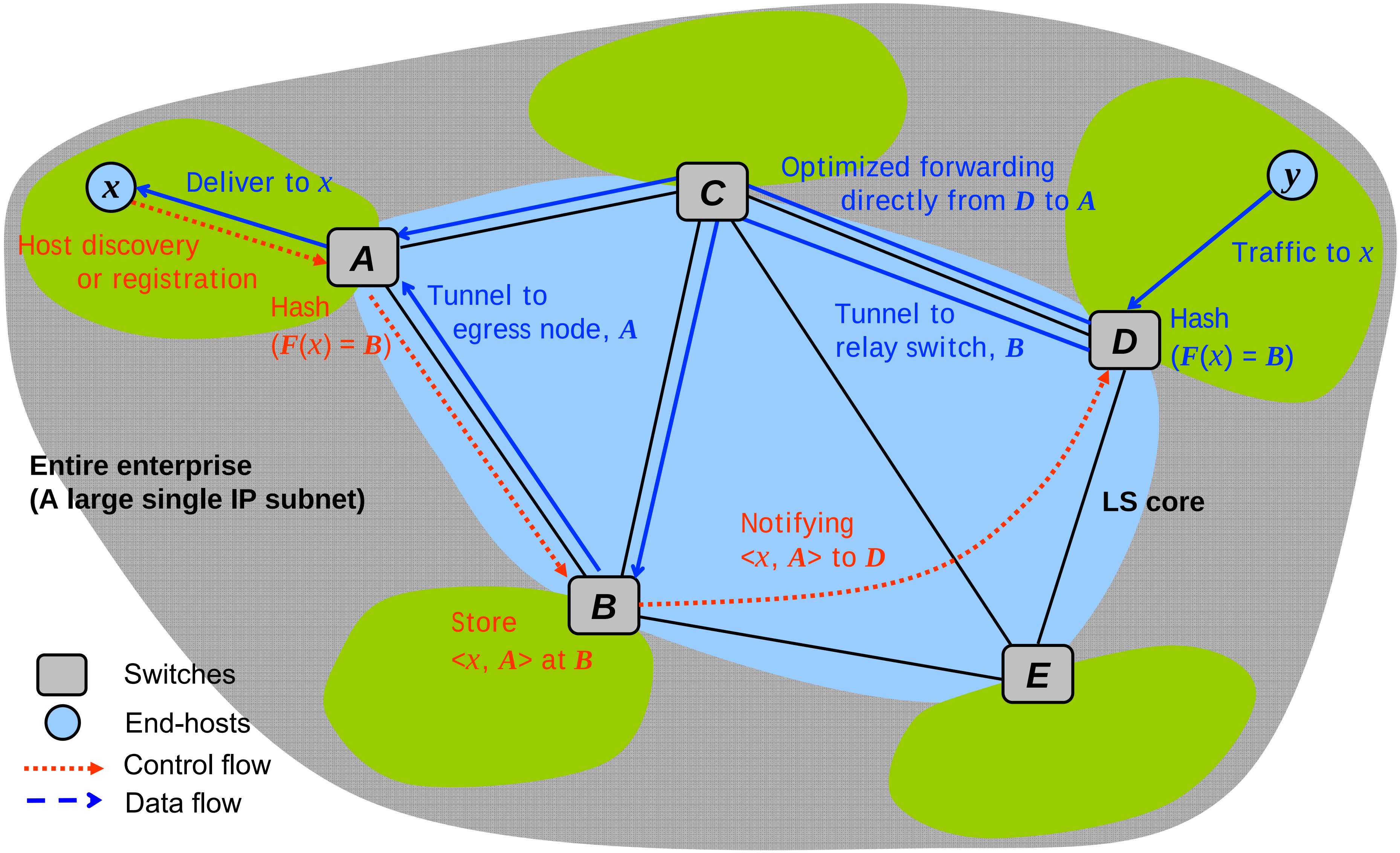


- End hosts should
  - Use the same protocol stacks and applications
  - Not be forced to run an additional protocol

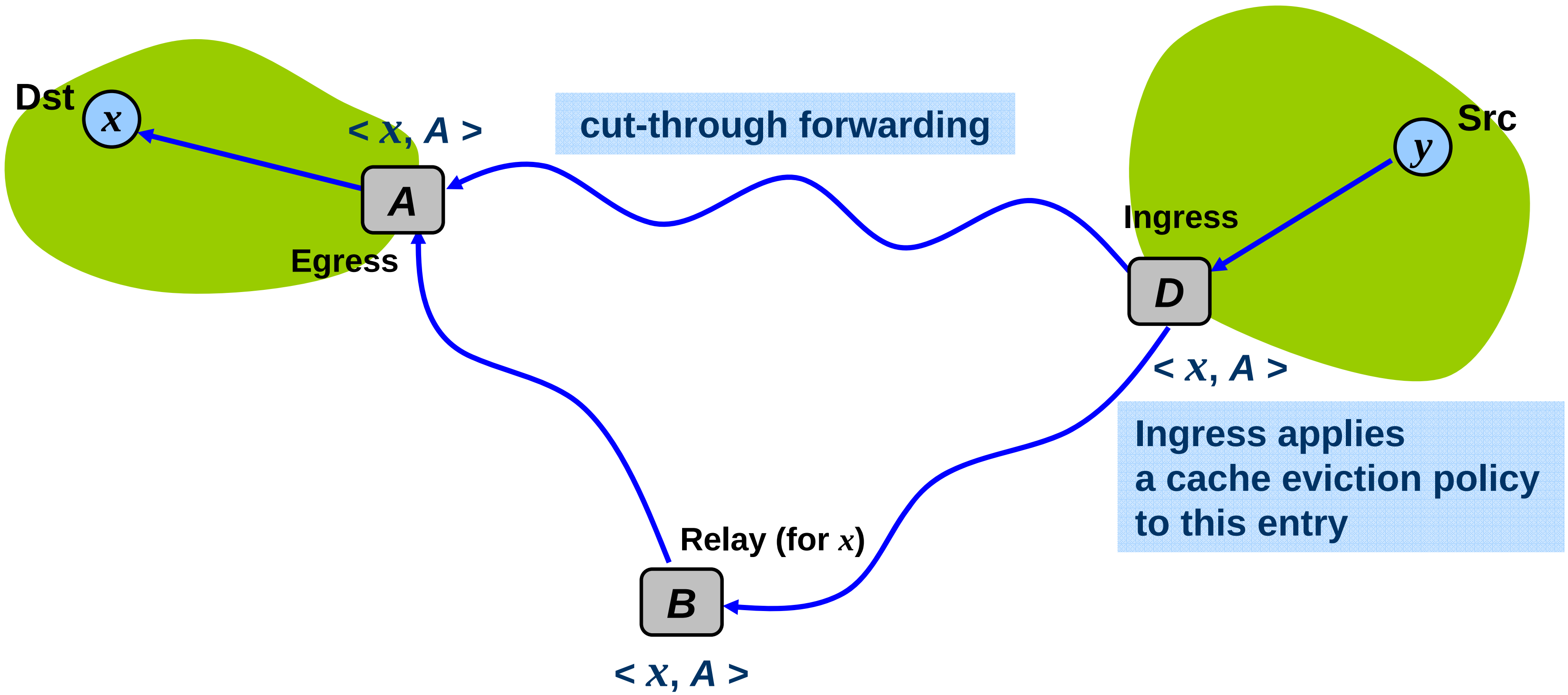
SEIZE in a Slide

- Flat addressing of end-hosts
  - Switches use hosts' MAC addresses for routing
  - Ensures zero-configuration and backwards-compatibility (Obj # 5)
- Automated host discovery at the edge
  - Switches detect the arrival/departure of hosts
  - Obviates flooding and ensures scalability (Obj #1, 5)
- Hash-based on-demand resolution
  - Hash deterministically maps a host to a switch
  - Switches resolve end-hosts' location and address via hashing
  - Ensures scalability (Obj #1, 2, 3)
- Shortest-path forwarding between switches
  - Switches run link-state routing with only their own connectivity info
  - Ensures data-plane efficiency (Obj #4)

How does it work?

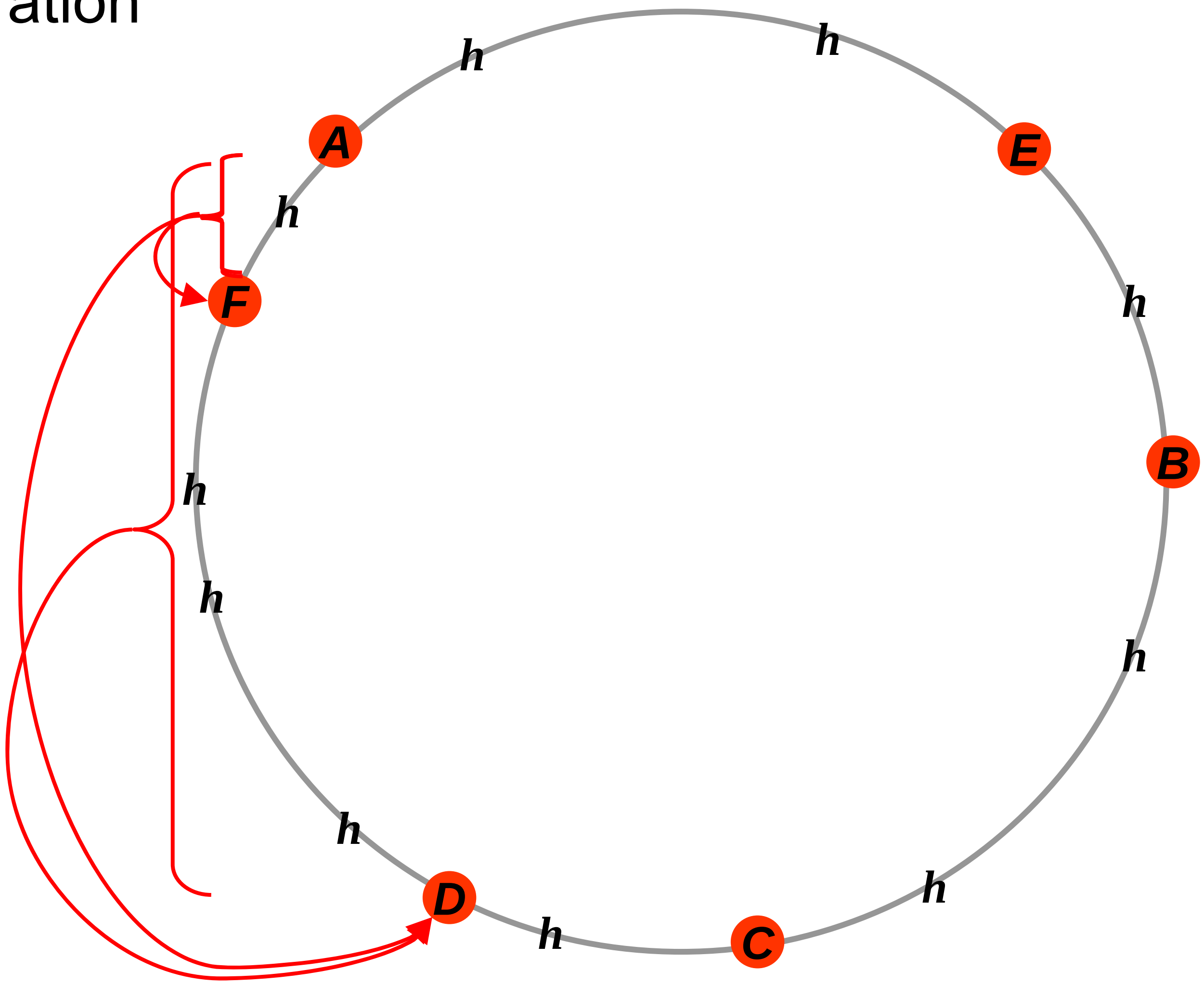


Terminology



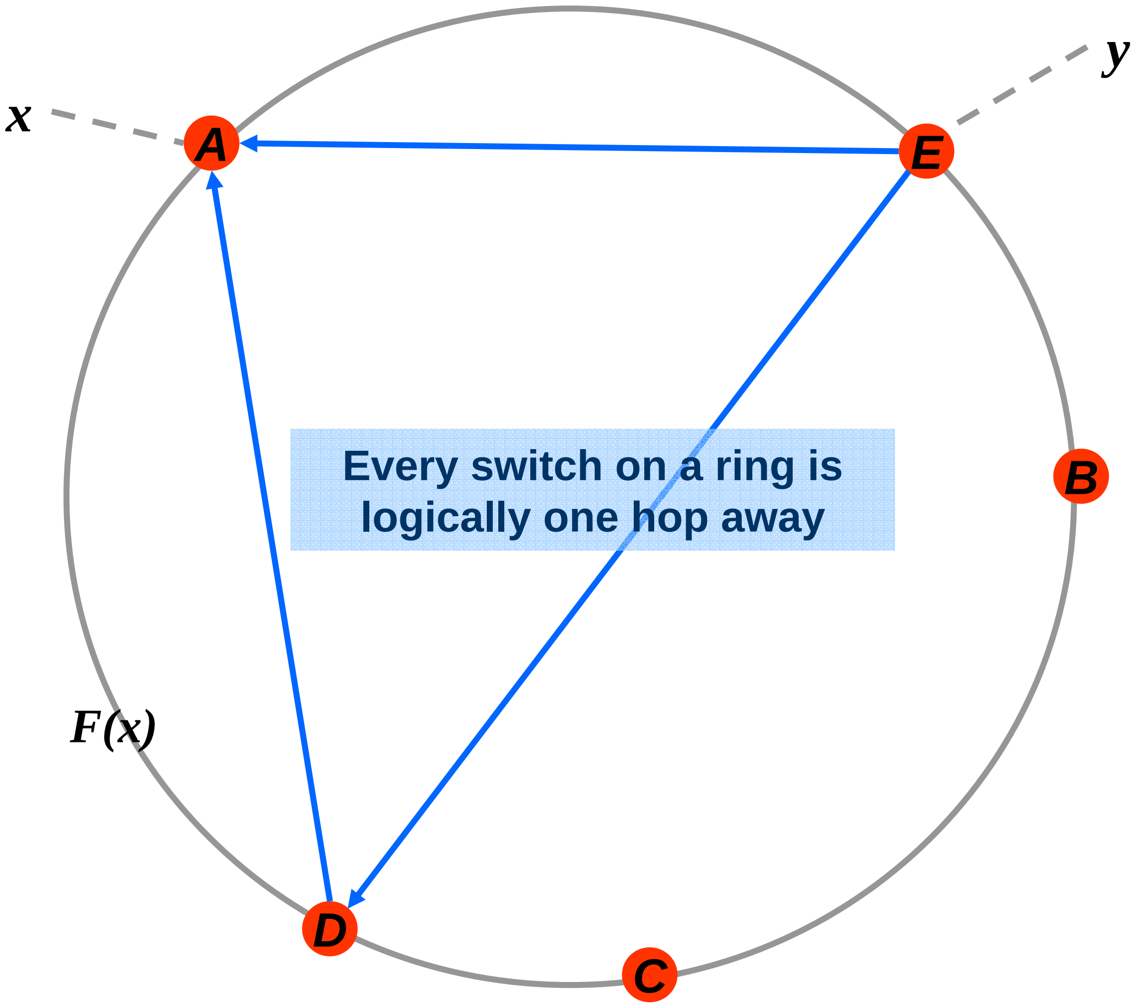
Responding to Topology Changes

- Consistent Hash [*Karger et al.,STOC'97*] minimizes re-registration

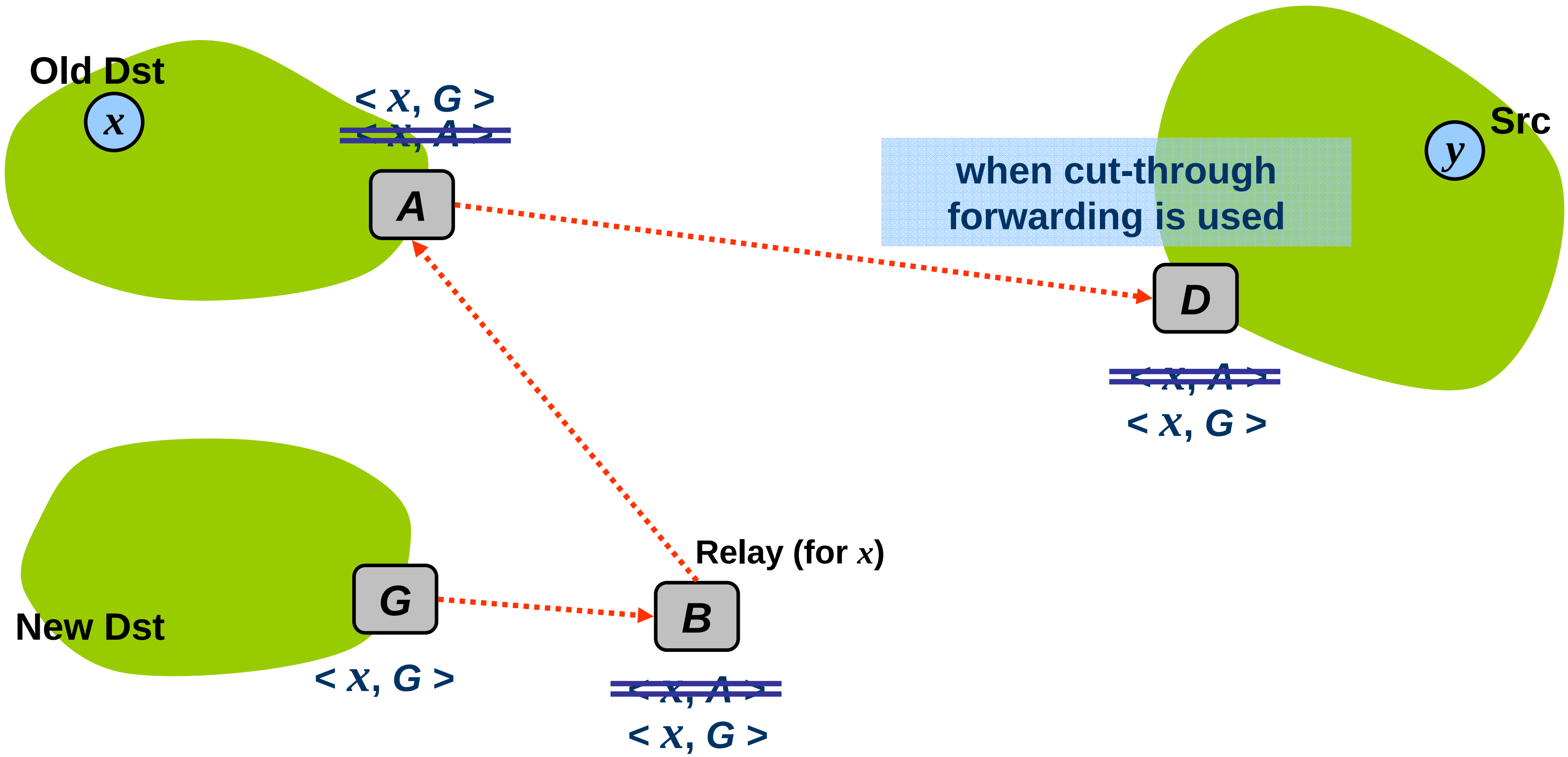


Single Hop Look-up

y sends traffic to *x*



Responding to Host Mobility



Unicast-based Bootstrapping

- ARP
  - Ethernet: Broadcast requests
  - SEIZE: Hash-based on-demand address resolution
    - Exactly the same mechanism as location resolution
    - Proxy resolution by ingress switches via unicasting
- DHCP
  - Ethernet: Broadcast requests and replies
  - SEIZE: Utilize DHCP relay agent (RFC 2131)
    - Proxy resolution by ingress switches via unicasting

Control-Plane Scalability When Using Relays

- Minimal overhead for disseminating host-location information
  - Each host's location is advertised to only two switches
- Small forwarding tables
  - The number of host information entries over all switches leads to $O(H)$, not $O(SH)$
- Simple and robust mobility support
  - When a host moves, updating only its relay suffices
  - No forwarding loop created since update is atomic

Data-Plane Efficiency w/o Compromise

- Price for path optimization
  - Additional control messages for on-demand resolution
  - Larger forwarding tables
  - Control overhead for updating stale info of mobile hosts

- The gain is much bigger than the cost
  - Because most hosts maintain a small, static communities of interest (COIs) [*Aiello et al., PAM'05*]
  - Classical analogy: COI ↔ Working Set (WS); Caching is effective when a WS is small and static

Conclusions

- SEIZE is a plug-and-playable enterprise architecture ensuring both scalability and efficiency
- Enabling design choices
  - Hash-based location management
  - Reactive location resolution and caching
  - Shortest-path forwarding
- Ongoing work
  - Analysis of enterprise traffic measurements
  - Evaluation of a SEIZE prototype in Emulab
  - Exploring ways to incrementally deploy SEIZE