CS 268: Lecture 25 Internet Indirection Infrastructure

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Motivations

- Today's Internet is built around a unicast point-to-point communication abstraction:
  - Send packet "p" from host "A" to host "B"
- This abstraction allows Internet to be highly scalable and efficient, but…
- … not appropriate for applications that require other communications primitives:
  - Multicast
  - Anycast
  - Mobility
  - …

Why?

- Point-to-point communication → implicitly assumes there is one sender and one receiver, and that they are placed at fixed and well-known locations
  - E.g., a host identified by the IP address 128.32.xxx.xxx is located in Berkeley

IP Solutions

- Extend IP to support new communication primitives, e.g.,
  - Mobile IP
  - IP multicast
  - IP anycast
- Disadvantages:
  - Difficult to implement while maintaining Internet's scalability (e.g., multicast)
  - Require community wide consensus -- hard to achieve in practice

Application Level Solutions

- Implement the required functionality at the application level, e.g.,
  - Application level multicast (e.g., Narada, Overcast, Scattercast…)
  - Application level mobility
- Disadvantages:
  - Efficiency hard to achieve
  - Redundancy: each application implements the same functionality over and over again
  - No synergy: each application implements usually only one service; services hard to combine

Key Observation

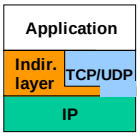
- Virtually all previous proposals use indirection, e.g.,
  - Physical indirection point → mobile IP
  - Logical indirection point → IP multicast

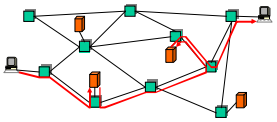
"Any problem in computer science can be solved by adding a layer of indirection"

Our Solution

Build an efficient indirection layer on top of IP

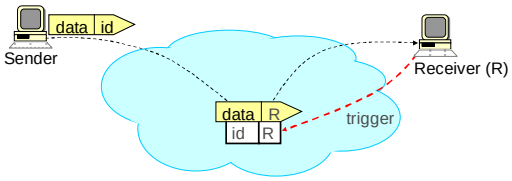
- Use an overlay network to implement this layer
  - Incrementally deployable; don't need to change IP





Internet Indirection Infrastructure (i3)

- Each packet is associated an identifier ***id***
- To receive a packet with identifier ***id***, receiver R maintains a trigger (***id***, R) into the overlay network

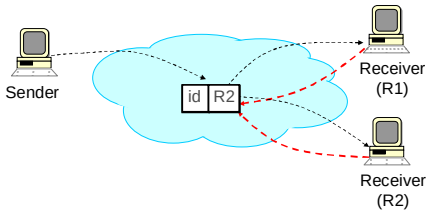


Service Model

- API
  - sendPacket(p);
  - insertTrigger(t);
  - removeTrigger(t) // ***optional***
- Best-effort service model (like IP)
- Triggers periodically refreshed by end-hosts
- ID length: 256 bits

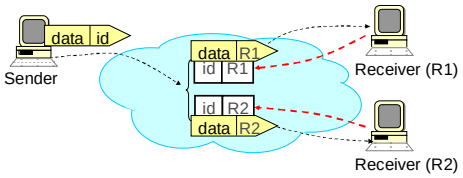
Mobility

- Host just needs to update its trigger as it moves from one subnet to another



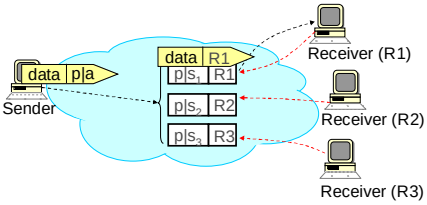
Multicast

- Receivers insert triggers with same identifier
- Can dynamically switch between multicast and unicast



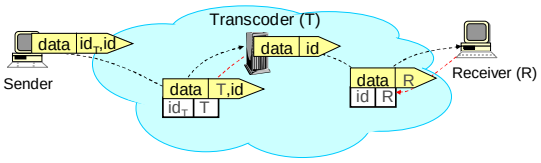
Anycast

- Use longest prefix matching instead of exact matching
  - Prefix p: anycast group identifier
  - Suffix s_i: encode application semantics, e.g., location



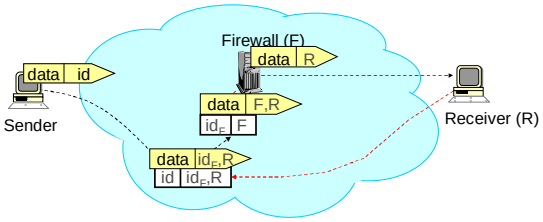
Service Composition: Sender Initiated

- Use a stack of IDs to encode sequence of operations to be performed on data path
- Advantages
  - Don't need to configure path
  - Load balancing and robustness easy to achieve



Service Composition: Receiver Initiated

- Receiver can also specify the operations to be performed on data



Outline

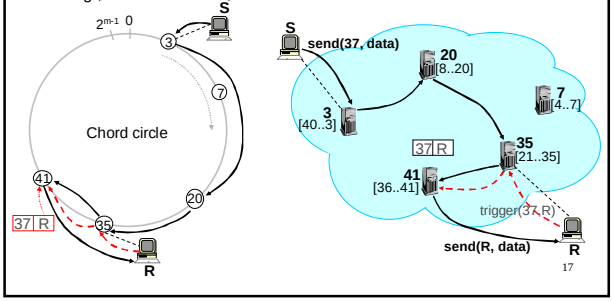
- Implementation
- Examples
- Security
- Applications

Quick Implementation Overview

- i3 is implemented on top of Chord
  - But can easily use CAN, Pastry, Tapestry, etc
- Each trigger t = **(*id*, *R*)** is stored on the node responsible for ***id***
- Use Chord recursive routing to find best matching trigger for packet p = **(*id*, *data*)**

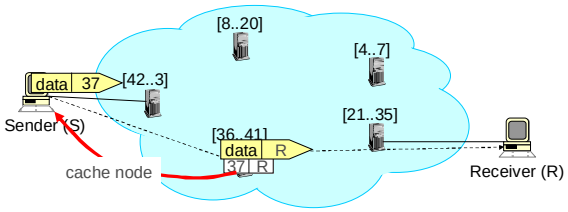
Routing Example

- R inserts trigger t = **(*37*, *R*)**; S sends packet p = **(*37*, *data*)**
- An end-host needs to know only one i3 node to use i3
  - E.g., S knows node 3, R knows node 35



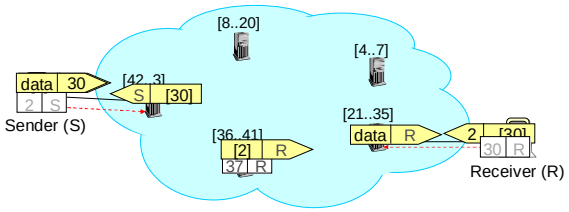
Optimization #1: Path Length

- Sender/receiver caches i3 node mapping a specific ID
- Subsequent packets are sent via one i3 node



Optimization #2: Triangular Routing

- Use well-known trigger for initial rendezvous
- Exchange a pair of (private) triggers well-located
- Use private triggers to send data traffic

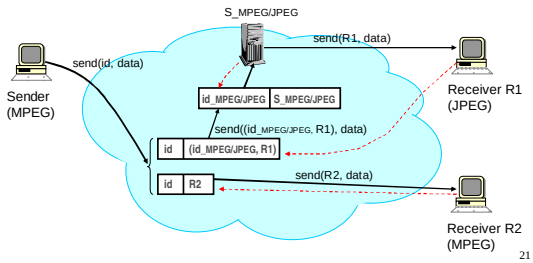


Outline

- Implementation
- Examples
  - Heterogeneous multicast
  - Scalable Multicast
  - Load balancing
  - Proximity
- Security
- Applications

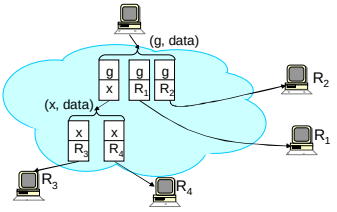
Example 1: Heterogeneous Multicast

- Sender not aware of transformations



Example 2: Scalable Multicast

- i3 doesn't provide direct support for scalable multicast
  - Triggers with same identifier are mapped onto the same i3 node
- Solution: have end-hosts build an hierarchy of trigger of bounded degree



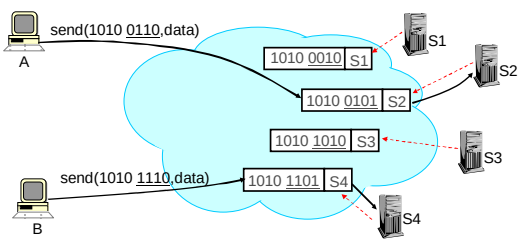
Example 2: Scalable Multicast (Discussion)

Unlike IP multicast, i3

1. Implement only small scale replication → allow infrastructure to remain simple, robust, and scalable
2. Gives end-hosts control on routing → enable end-hosts to
   - Achieve scalability, and
   - Optimize tree construction to match their needs, e.g., delay, bandwidth

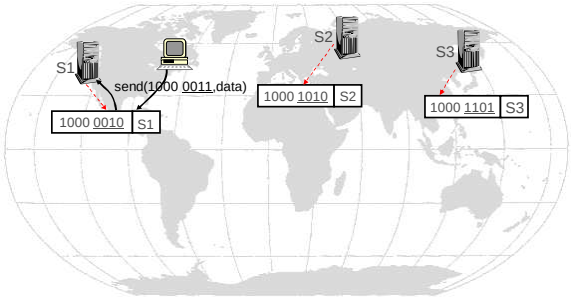
Example 3: Load Balancing

- Servers insert triggers with IDs that have random suffixes
- Clients send packets with IDs that have random suffixes



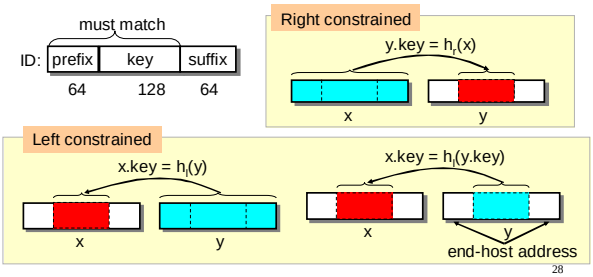
Example 4: Proximity

- Suffixes of trigger and packet IDs encode the server and client locations



Constrained Triggers

- $h_l()$, $h_r()$: well-known one-way hash functions
- Use $h_l()$, $h_r()$ to constrain trigger (x, y)



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Attacks & Defenses

Attack / Defense	Trigger constraints	Pushback	Trigger challenges	Public ID constraints
Eavesdropping& Impersonation	✓			✓
Loops & Confluences	✓			
Dead-ends		✓		
Reflection & Malicious trigger-removal	✓		✓	
Confluences on i3 public nodes				✓

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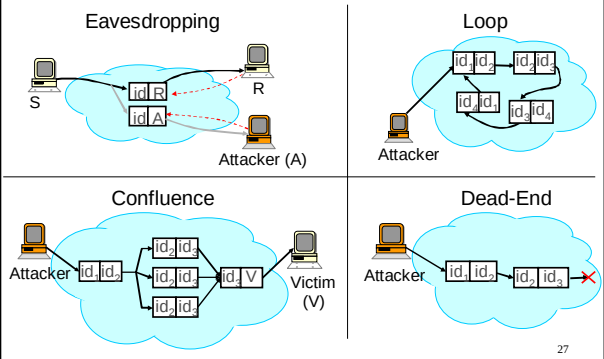
Some Attacks



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  - Protection against DoS attacks
    - Routing as a service
    - Service composition platform

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In a Nutshell

- Problem scenario: attacker floods the incoming link of the victim
- Solution: stop attacking traffic before it arrives at the incoming link
  - Today: call the ISP to stop the traffic, and hope for the best!
- Our approach: give end-host control on what packets to receive
  - Enable end-hosts to stop the attacks in the network

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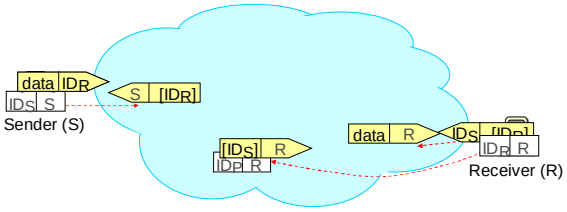
1. White-listing

- Packets not addressed to open ports are dropped in the network
  - Create a public trigger for each port in the white list
  - Allocate a private trigger for each new connection



IDP – public trigger IDS, IDR – private triggers

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Why End-Hosts (and not Network)?

- End-hosts can better react to an attack
  - Aware of semantics of traffic they receive
  - Know what traffic they want to protect
- End-hosts may be in a better position to detect an attack
  - Flash-crowd vs. DoS

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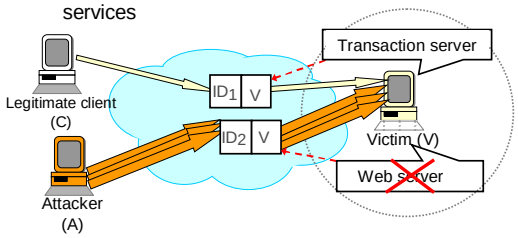
2. Traffic Isolation

- Drop triggers being flooded without affecting other triggers
  - Protect ongoing connections from new connection requests
  - Protect a service from an attack on another services



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Some Useful Defenses

1. White-listing: avoid receiving packets on arbitrary ports
2. Traffic isolation:
   - Contain the traffic of an application under attack
   - Protect the traffic of established connections
3. Throttling new connections: control the rate at which new connections are opened (per sender)

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2. Traffic Isolation

- Drop triggers being flooded without affecting other triggers
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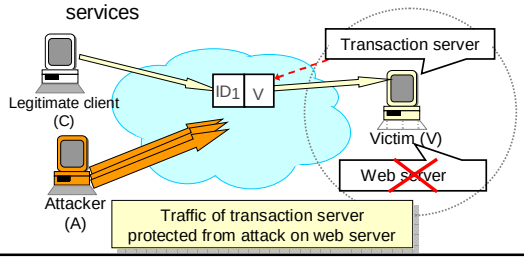

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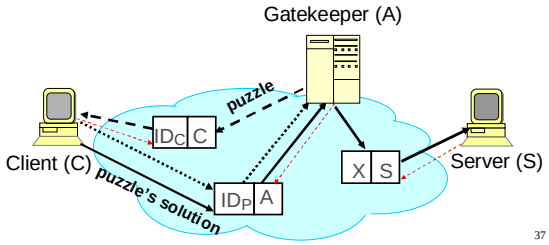
3. Throttling New Connections

- Redirect new connection requests to a gatekeeper
  - Gatekeeper has more resources than victim
  - Can be provided as a 3rd party service



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- Architecture Optimizations
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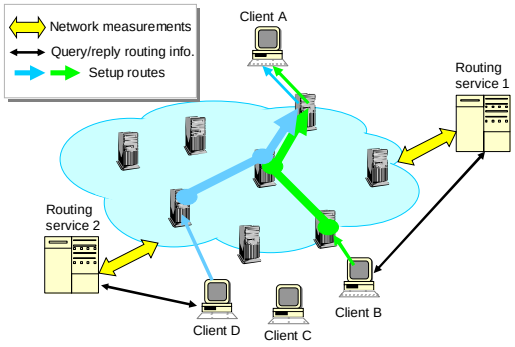
  - Protection against DoS attacks
  - Routing as a service
  - Service composition platform

Routing as a Service

- Goal: develop network architectures that
  - Allow end-hosts to pick their own routes
  - Allow third-parties to easily add new routing protocols
- Ideal model:
  - Oracles that have complete knowledge about network
  - Hosts query paths from oracles
    - Path query can replace today's DNS query
  - Hosts forward packets along these paths

Routing as a Service (cont'd)



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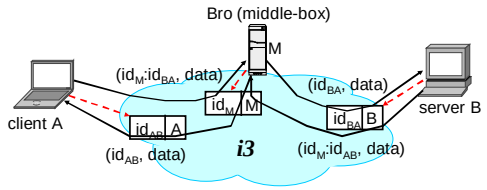
Service Composition Platform

- Goal: allow third-parties and end-hosts to easily insert new functionality on data path
  - E.g., firewalls, NATs, caching, transcoding, spam filtering, intrusion detection, etc..
- Why i3?
  - Make middle-boxes part of the architecture
  - Allow end-hosts/third-parties to explicitly route through middle-boxes

Example

- Use Bro system to provide intrusion detection for end-hosts that desire so



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Design Principles

1) Give hosts control on routing
   - A trigger is like an entry in a routing table!
   - Flexibility, customization
   - End-hosts can
     - Source route
     - Set-up acyclic communication graphs
     - Route packets through desired service points
     - Stop flows in infrastructure
     - …
2) Implement data forwarding in infrastructure
   - Efficiency, scalability

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Design Principles (cont'd)

	Host	Infrastructure
Internet & Infrastructure overlays		Data plane Control plane
p2p & End-host overlays	Data plane Control plane	
i3	Control plane	Data plane

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Conclusions

- Indirection – key technique to implement basic communication abstractions
  - Multicast, Anycast, Mobility, …
- This research
  - Advocates for building an efficient Indirection Layer on top of IP
  - Explore the implications of changing the communication abstraction; already done in other fields
    - Direct addressable vs. associative memories
    - Point-to-point communication vs. Tuple space (in Distributed systems)

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