CS514: Intermediate Course in Computer Systems

Lecture 32: April 9, 2003

"Internet Indirection Infrastructure (i3 and Secure-i3)"

Remember this?

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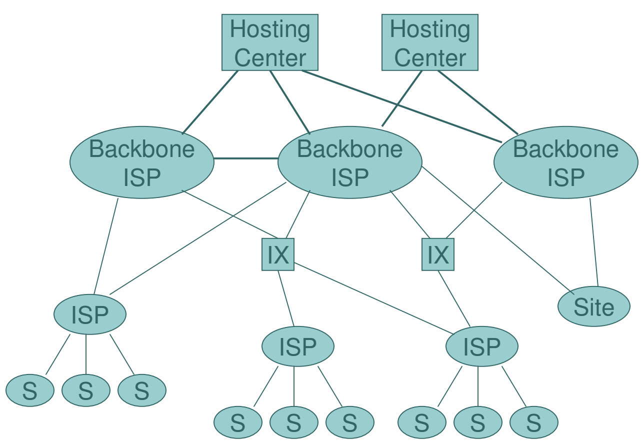

Internet has a somewhat hierarchical structure.

IP address assignment

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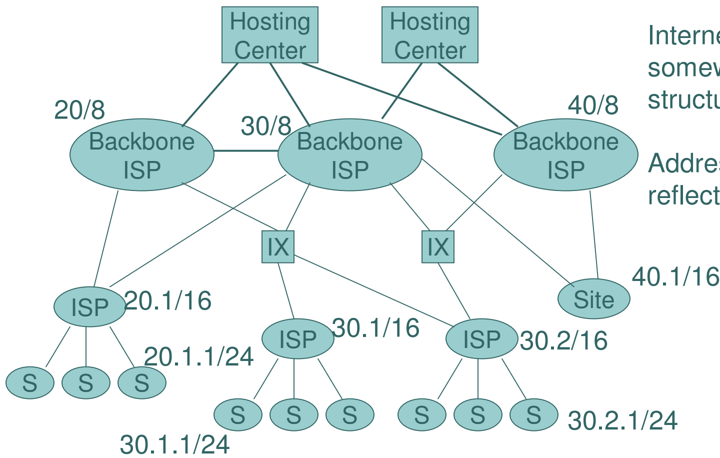

Internet has a somewhat hierarchical structure.

Address assignment reflects this hierarchy

IP address are “overloaded”

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- Two roles:
  - Acts as a host identifier
    - Used to determine which host sends or receives a packet
  - Acts as a hierarchical address
    - Used to route packet to a host across the Internet

Overloading is important for security

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- "Reverse routability"
- A host can spoof its identify in transmitted packets
  - Spoofed source address
- But return packets won't go back to it
  - The routing infrastructure prevents it
- Therefore, a host cannot easily pretend to be another host

But overloading limits mobility

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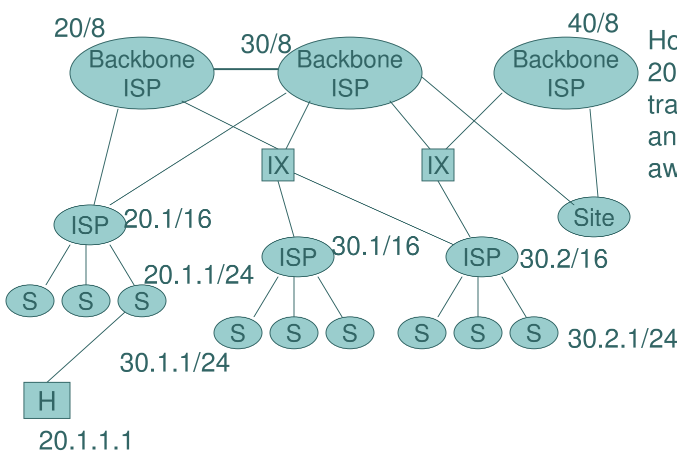

Host with address 20.1.1.1 cannot transparently move to another location far away

But overloading limits mobility

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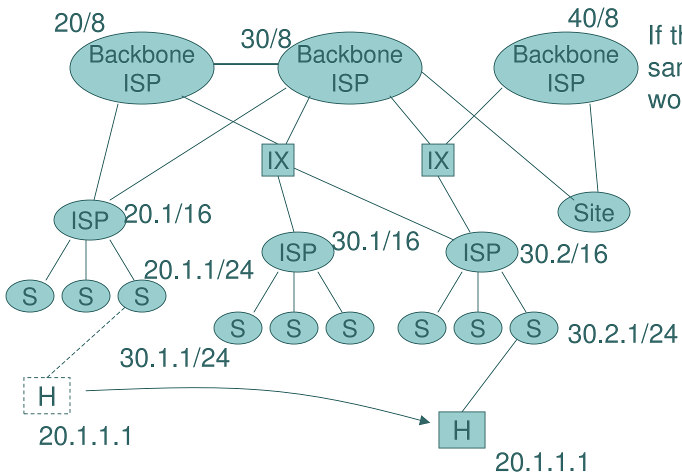

If the address stays the same, routing won't work anymore

But overloading limits mobility

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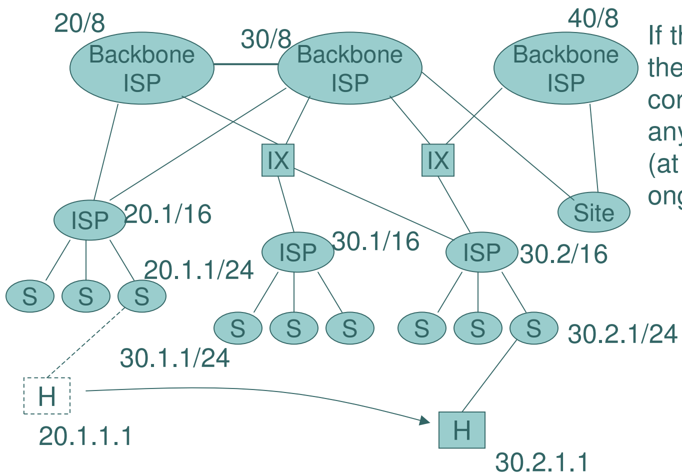

If the address changes, the host won't be correctly identified anymore
(at least not for ongoing connections)

IP multicast/unicast addresses are not overloaded

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- They are pure identifiers, not hierarchical addresses
- But as a result, multi/anycast don't scale well
  - Routers must keep per-group state
- Multi/anycast also have security issues
  - In the absence of higher-level security mechanisms, any host can join a group

Overlay multicast

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- Poor IP multicast scaling has led to the use of overlay multicast
- IP hosts form multicast tree
  - Tunnel over IP
- Typically application specific
  - Streaming (Real Networks, etc.)

Question for today

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- Is there another *simple model* for an *infrastructure service* that has scalable unicast, multicast, and anycast services?
- Internet Indirection Service (i3) is an interesting answer
  - Ion Stoica (Berkeley) et. al.

i3: a DHT application

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- Hosts use flat identifiers
- Hosts can make them up anytime, as many as they want
- A DHT is used to map identifier to IP address
  - Unicast, anycast, or multicast
  - Also composable services
- But this DHT built from high-end, stable infrastructure boxes
  - Not "P2P"
- Best explained by example…

Drawings and some slides care of Ion Stoica

i3 model

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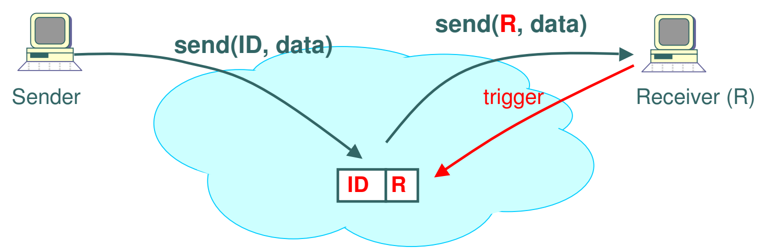
- Receiver maintains a mapping between ID and R (address) in the DHT
  - Using soft-state "trigger"
- Sender sends to ID, DHT forwards to R



Service Model

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- API
  - sendPacket(*p*);
  - insertTrigger(*t*);
  - removeTrigger(*t*); ***// optional***
- Best-effort service model (like IP)
- Triggers are periodically refreshed by end-hosts
- Reliability, congestion control, and flow-control implemented at end-hosts

Mobility (invisible to sender)

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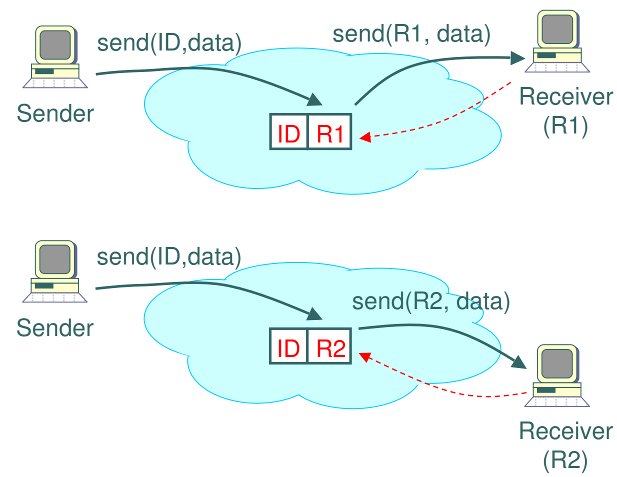

Multicast

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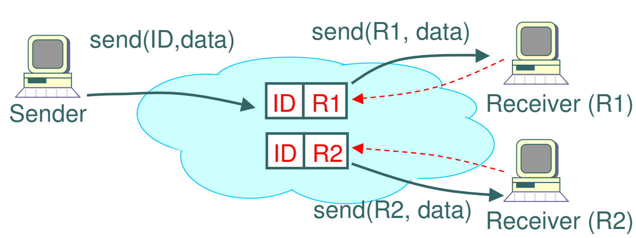

Anycast

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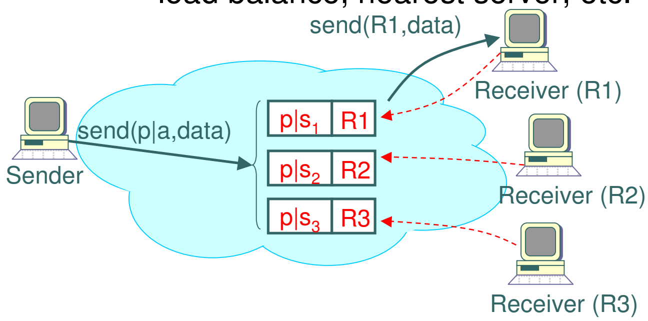
- i3 matching rule is actually longest prefix match
  - This allows various forms of anycast
    - load balance, nearest server, etc.



IDs are stackable

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- Instead of *send(ID, data)*
  - Can have *send(ID-stack data)*
- Instead of *trigger(ID, R)*
  - Can have *trigger(ID, ID-stack)*
- Behavior at i3 node:
  - Pop stack until match found

Service composition

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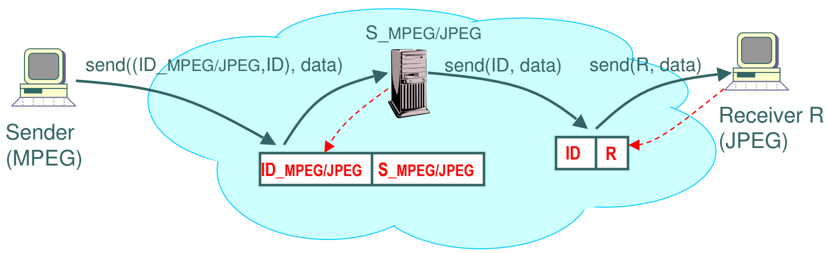
- Sender specified



Service composition

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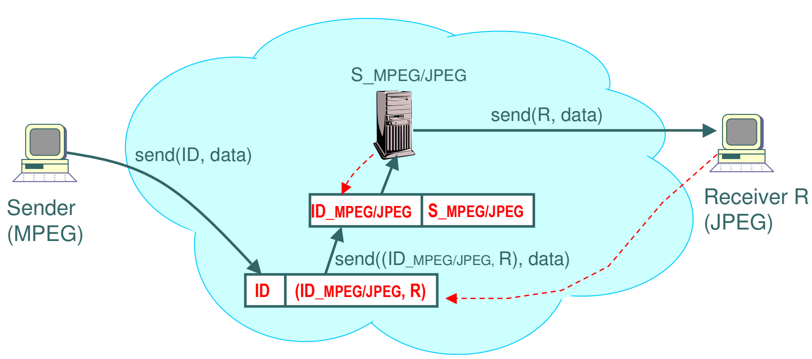
- Receiver specified



Even heterogeneous service multicast

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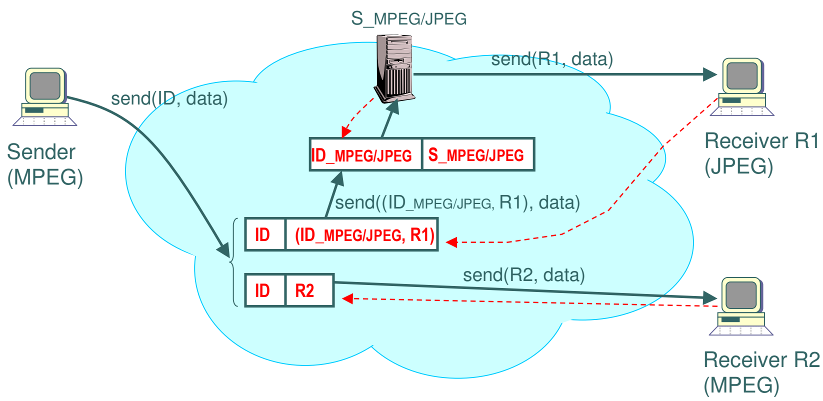

Trigger can map to another ID (as well to an address)

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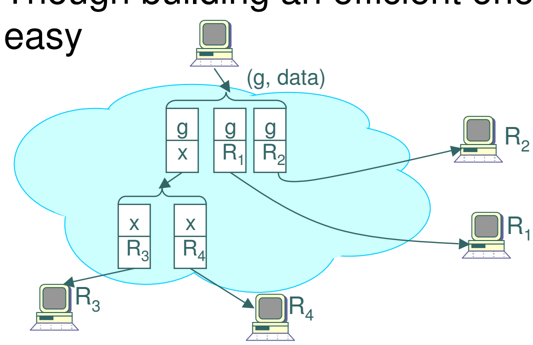
- Use to scale multicast, for instance
- End hosts can build this tree . . .
  - Though building an efficient one not easy



i3

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- Clever

i3

CS514

- Clever
- Very Clever

i3

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- Clever
- Very Clever
- But not without issues…

Eavesdropping problem

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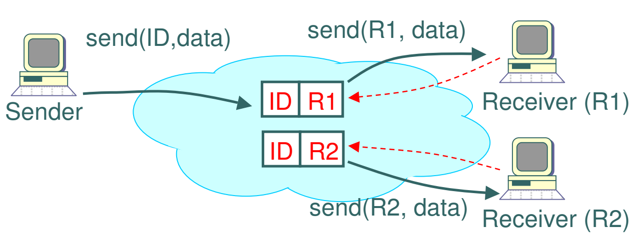
- R2 wishes to eavesdrop on R1's communications
  - Uses generalized multicast trigger



New work solves this

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- Initial paper (SIGCOMM '02) suggested the use of e2e public key encryption
  - To securely negotiate a second pair of "private" IDs that the eavesdropper cannot guess
- A subsequent unpublished paper solves this an other problems
  - An i3 redesign called Secure-i3
- As well as develops a whole DoS defense around i3

Secure-i3 identifier

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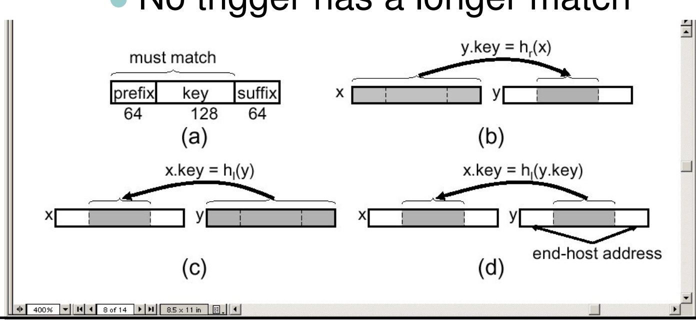
- ID composed of three parts
- Packet matches key iff:
  - Prefix and key match
  - No trigger has a longer match



Constraints on secure-i3 identifier

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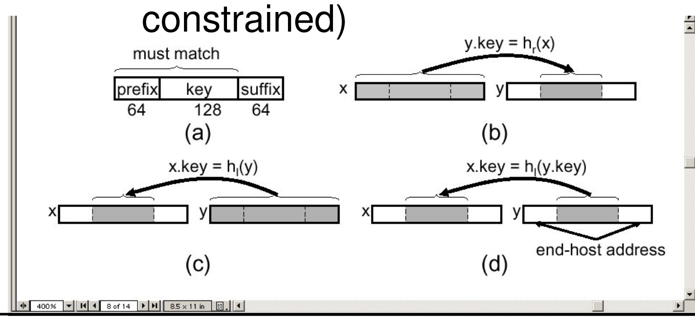
- Trigger(x,y) must satisfy one of three types of one-way hashes
  - (b) right constrained, (c) left constrained, (d) end-host (left constrained)



Constraints on secure-i3 identifier

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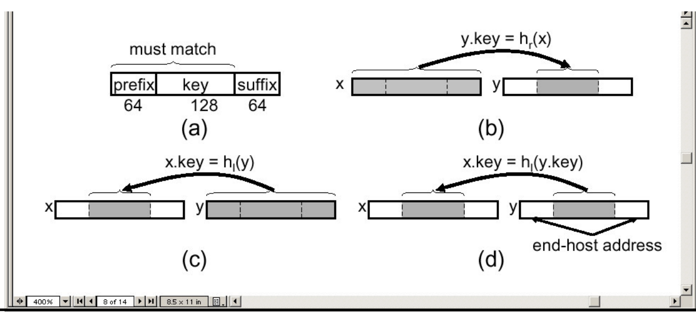
- Left constrained prevents eaves-dropping or impersonation
- Right constrained prevents a loop of triggers



Secure-i3 has defenses against DoS attacks

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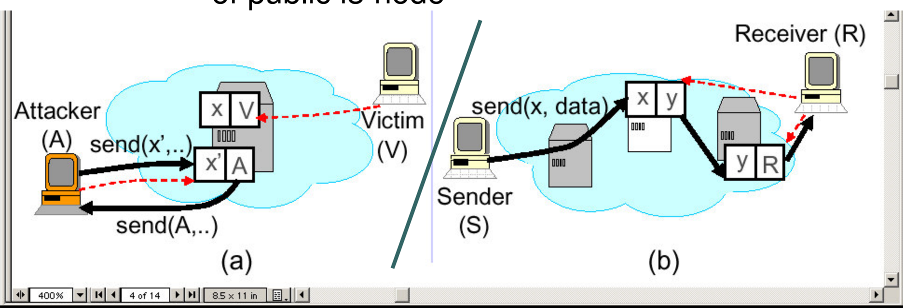
- Partition ID space into public and private
- Only allow public IDs to point to other IDs, not IP addresses
  - Makes it hard for attacker to learn IP address of public i3 node



Secure-i3 has defenses against DoS attacks

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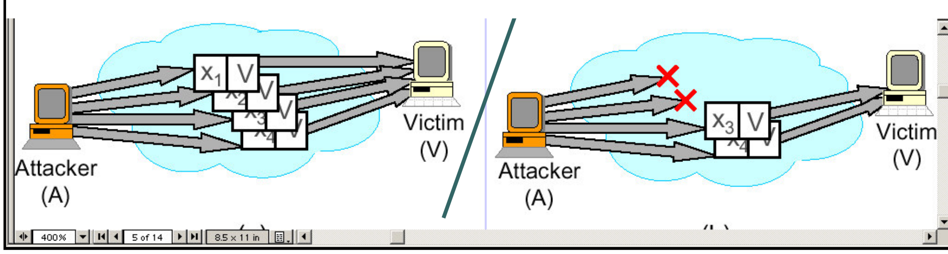
- Use multiple public IDs
  - Senders choose randomly among them
- Switch to private IDs to communicate
- Attacker has to attack all public IDs
- Remove some triggers to lessen attack



Secure-i3 has defenses against DoS attacks

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- Other defenses as well
  - Slow down the attack
    - cryptographic puzzle
  - Evade the attack
    - Choose a different trigger
  - Multicast access control
    - Different IDs for senders and receivers
- Note that none of the DoS stuff works if the sender is not an i3 client!
  - IPv6-like deployment issues in this regard

i3 trust and service level agreement (SLA) issues

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- i3 runs over DHT
  - In theory, any i3 node anywhere may be your i3 node
- But, user wants i3 node in user's ISP
  - Perhaps assign blocks of IDs to ISPs?
  - ISP's i3 nodes have DHT IDs in its block
  - ISP's users assign own IDs from block
- i3 paper doesn't talk about this
- Also, what is the relationship between ISPs, for instance for DHT security?

Who would be motivated to deploy i3?

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- Elegant architecture, but what critical problem does it solve?
  - IP mobility not that important (yet), reasonably handled by existing standards
  - Anycast in a sense is handled by DNS
  - Multicast "style" very application dependent
    - App processing at each node, security, reliability, user tracking, acceptable latency, etc…
- Not sure I buy the argument that it is better to have a single (one-size-fits-all) solution to all problems

What about service composition?

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- This is something without a clean parallel in the current architecture
- How is service composition done today?
  - Transparent to end host:
    - Service in physical path, transparent to end host
      - Firewall, HTTP-style authentication
    - Smart DNS directs user to service
      - Akamai web caches
  - End host configured to go through service
    - Web proxy, WAP (Wireless Application Protocol) gateway

But more generally…

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- SIP provides a basis for service composition
  - For instance, to route call through VoIP/circuit gateway
- SIP routing can be service aware
  - Service is encoded in the SDP (Session Description Protocol) part of the message
  - SDP is richer service description language than i3 IDs
- SIP also has a redirect feature (URI level)
  - I wonder if i3 could benefit from a redirect feature . . .

MPEG/JPEG example in SIP (one of many)

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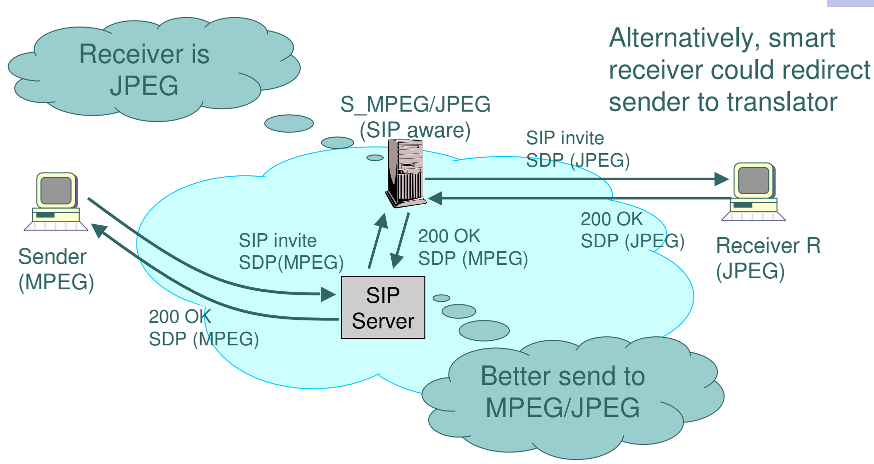

i3 versus SIP for service composition

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- My intuition is that SIP is better
- Richer service description (SDP)
- Separate control from data
  - Data can take direct path, not go through service point, though this has pros and cons both ways
- Can be controlled by source, destination, or the middle
  - Probably i3 could be controlled in the middle, though they don't give an example
- Note, SIP could be used for anycast too

i3 Summary

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- Very very interesting idea
- i3 creates an infinite number of new addresses, and allows hosts to create them at will and control routing to them!
- If we had i3 15 years go, we may not have DNS or SIP, would not have STUN, or IPv6 today
- But we do have those things, so hard to imagine that i3 will take off (doesn't fill a void)