Named Data Networking (NDN)

Introduction to NDN

Named Data Networking (NDN)

Northeastern University

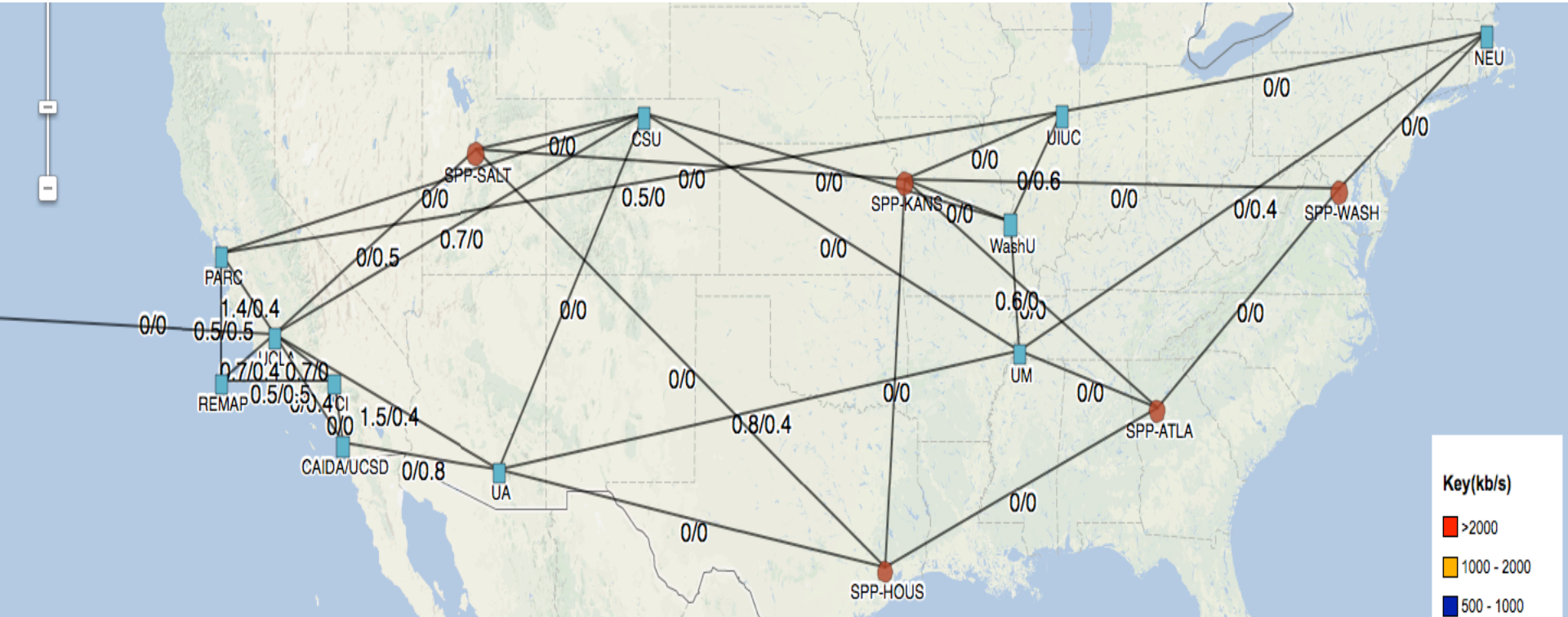
http://named-data.net • http://github.com/named-data

IP

NDN

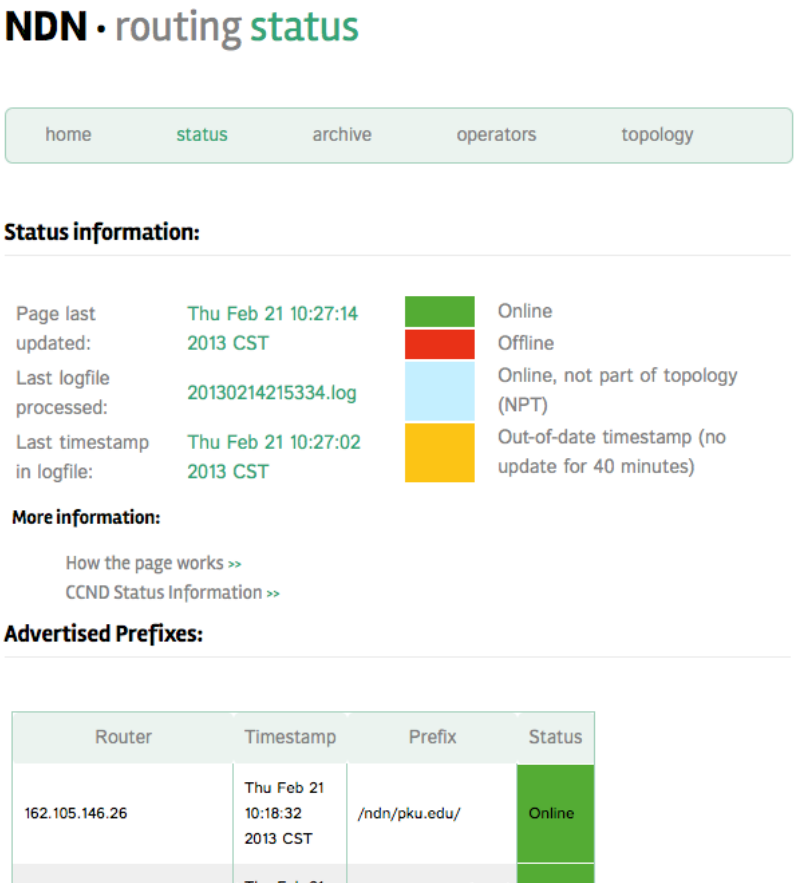
Is It Deployed?

- Deployable now as an overlay (TCP, UDP) or on Layer 2 transport
- C, Java, Python, Javascript libraries
- `http://github.com/named-data`
- Testbed of 15 routers, including 5 on Internet2 / GENI
- http://ndnmap.arl.wustl.edu/

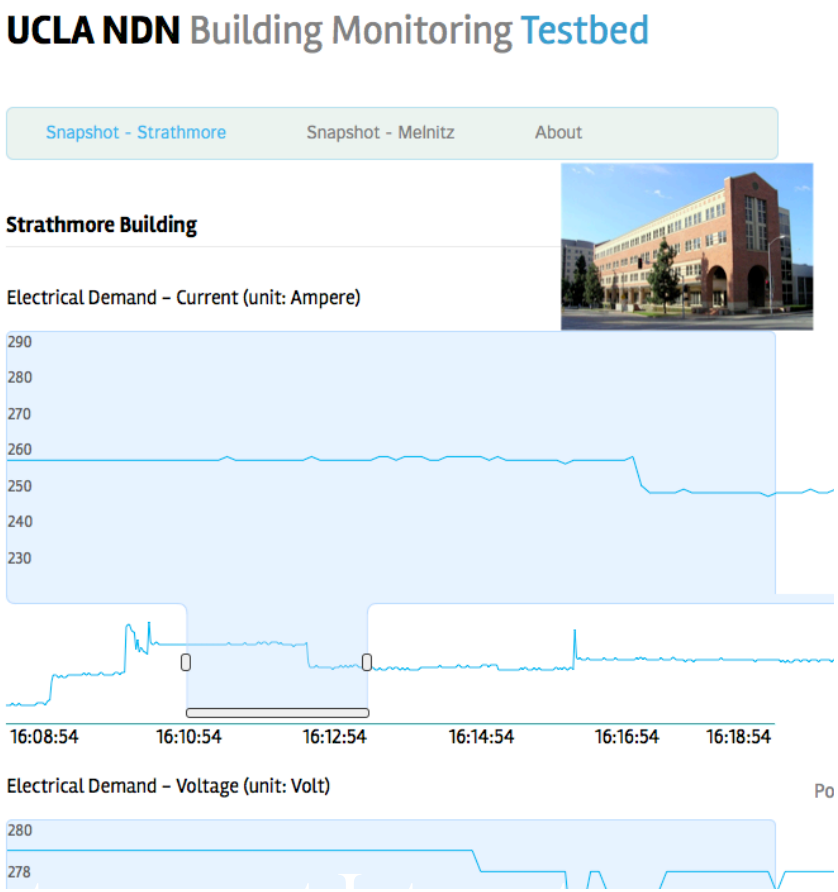


Run a Bit of NDN in your Browser Now

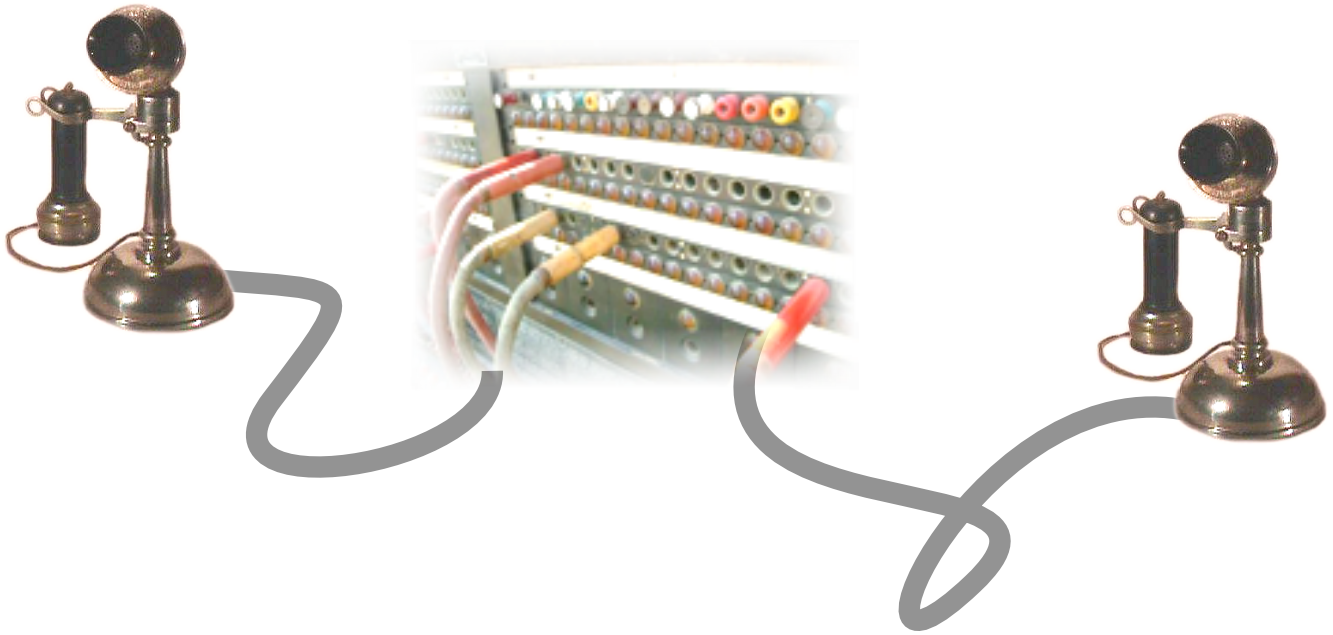
tinyurl.com/ndnrouting



tinyurl.com/ndnsensor

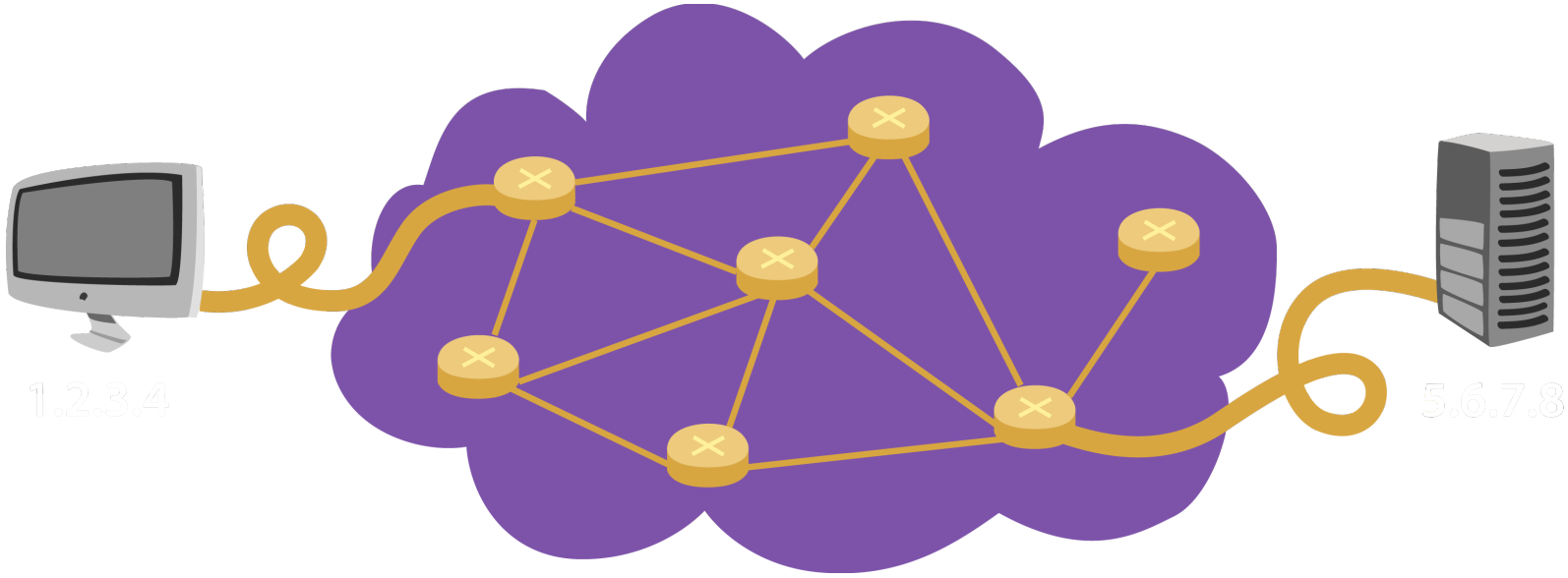


Telephone Network was the 1st Communication System



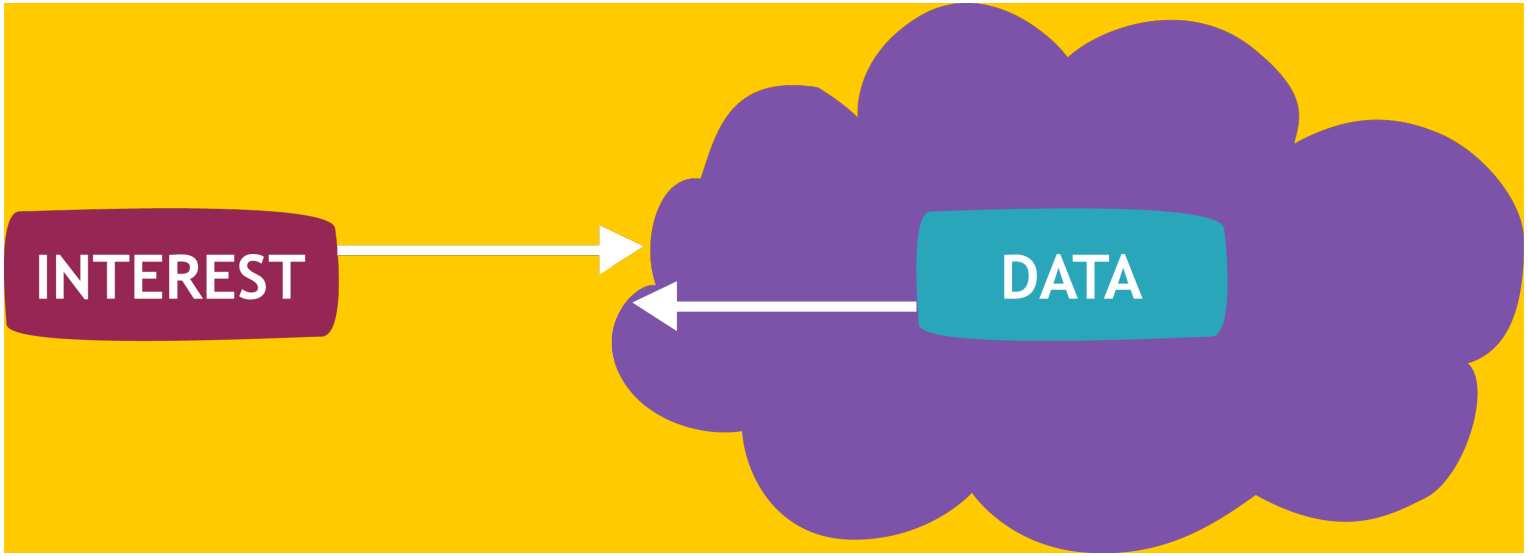
Focus on building and connecting the wires

IP Revolutionized the Communication System



Internet Protocol (RFC791): Focused on delivering packets to destination *host*

NDN: Focus on Data



Abstracting away the notion of “host”

Superset of host-to-host communication model

Two Problems with Current Internet

- Focus is on end-point communication
  - Artifact of original thinking: share resources, not content
  - Login to fast machine, access to the tape drive, the printer, etc.
- Security
  - To get data, you build a secure path
  - Once you authenticated with the server, you trust the content

New Communication Paradigm

- Users today care about *content*, not the servers
- Accessing the server is a by-product of the need to retrieve the desired content
  - If the server is down, no access to the content
- But what if the content was available from other places (e.g., my neighbor)?
- We do a lot of this already with HTTP
  - URLs, CDNs, caches, etc.

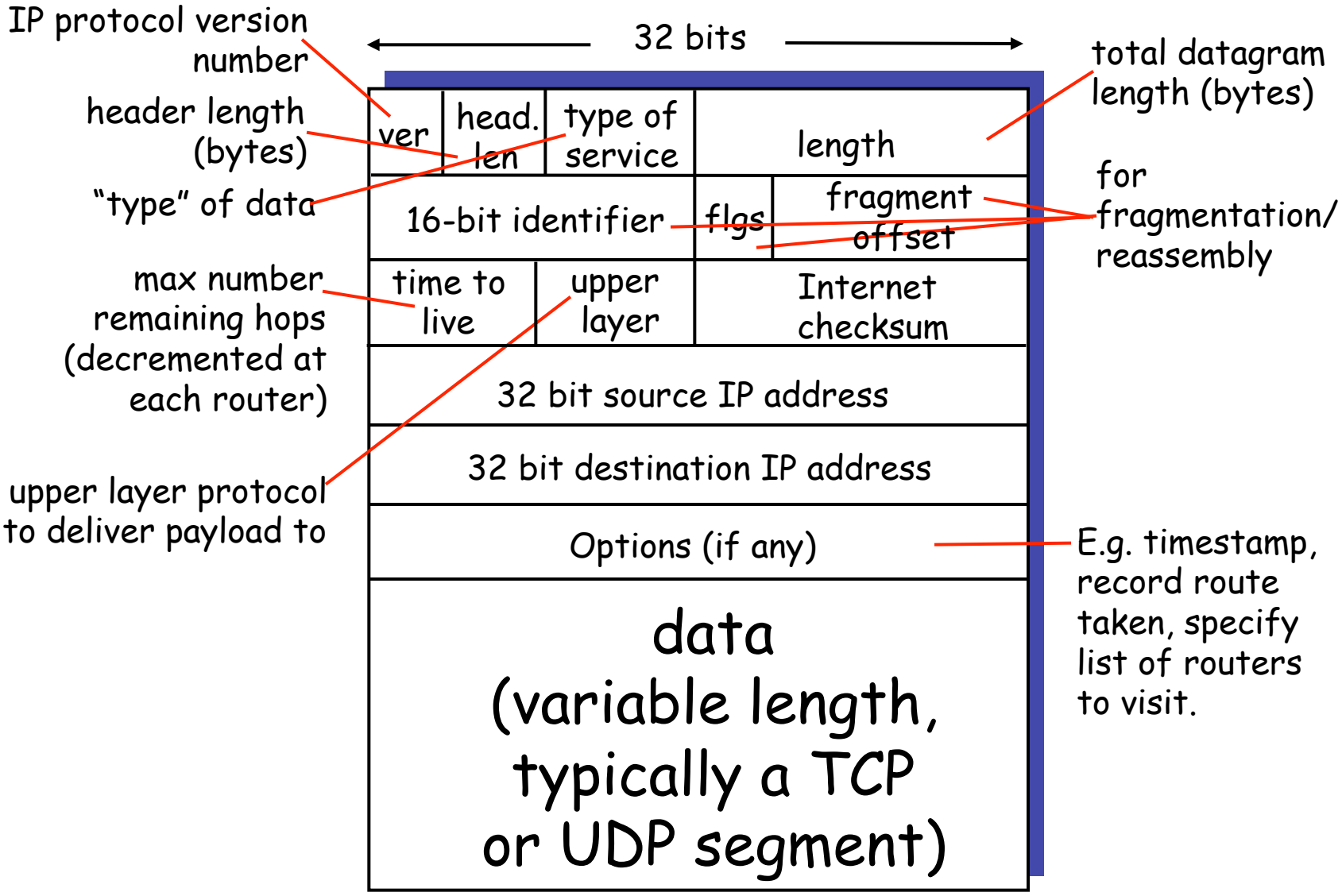
Two Focal Points in NDN

- Focus on the what not the where
- Secure the data not the container

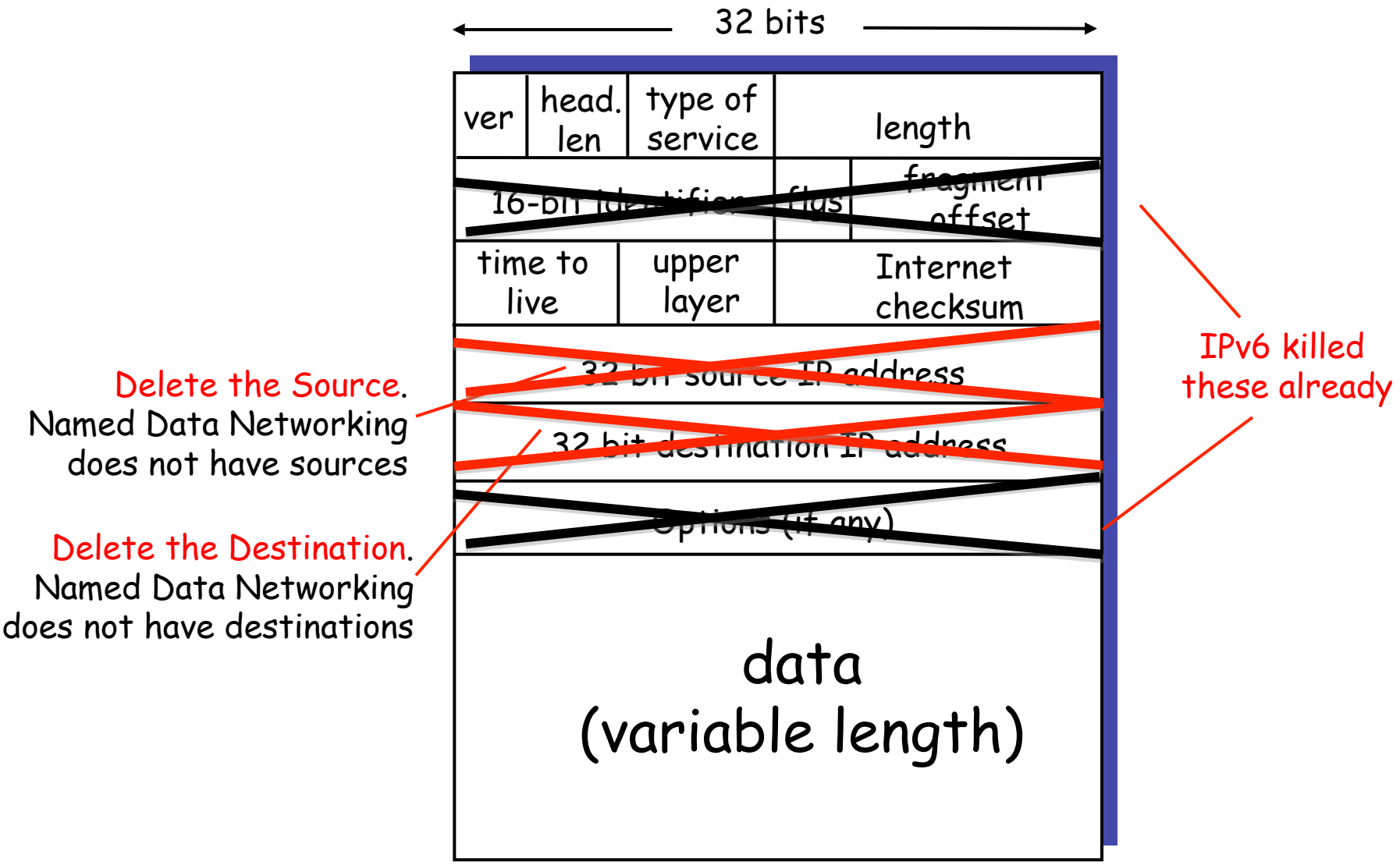
NDN Operation

- Interest packets
- Data packets
- Enhanced Forwarding
  - Pending Interest Table (PIT)- new!
  - Content Store (CS) – new!
  - Forwarding Information Base (FIB) – similar to IP

The IPv4 Datagram Format



Two Simple Changes



NDN Packets

Interest Packet

Content Name:
Identifies the data I want to receive

Selector: identifier publisher, etc

Nonce

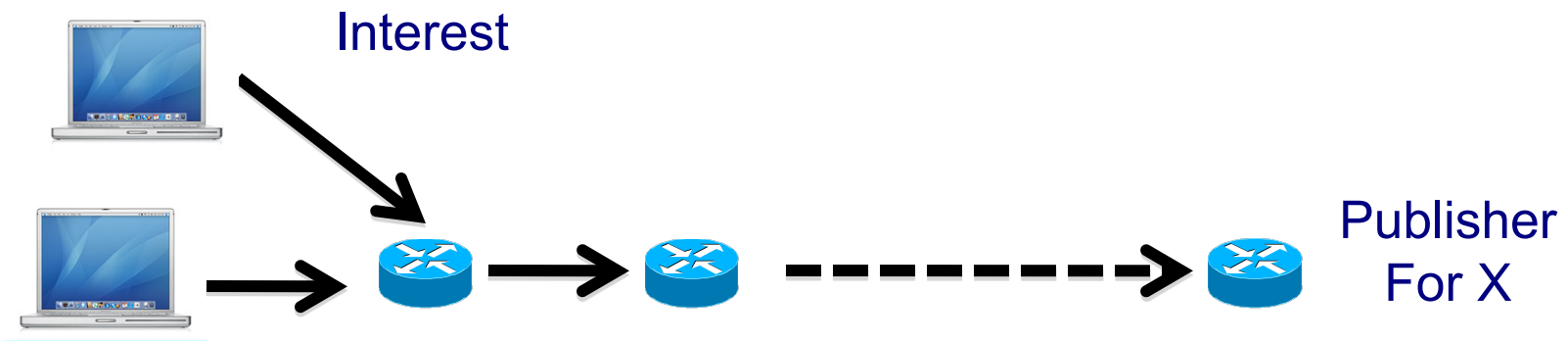
Data Packet

Content Name:
Identifies the data in this packet

Signature: Required for all packets

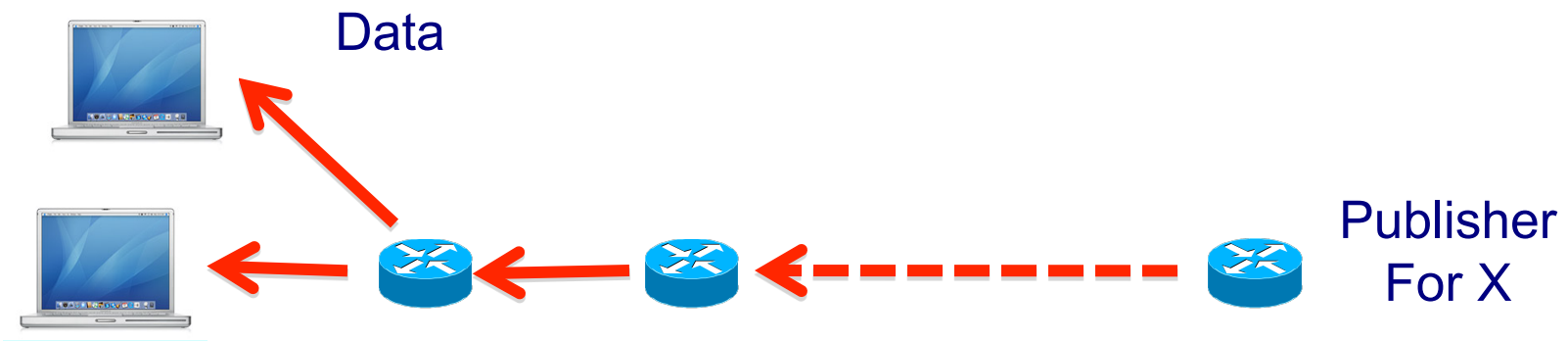
Data

NDN Forwarding: Interests



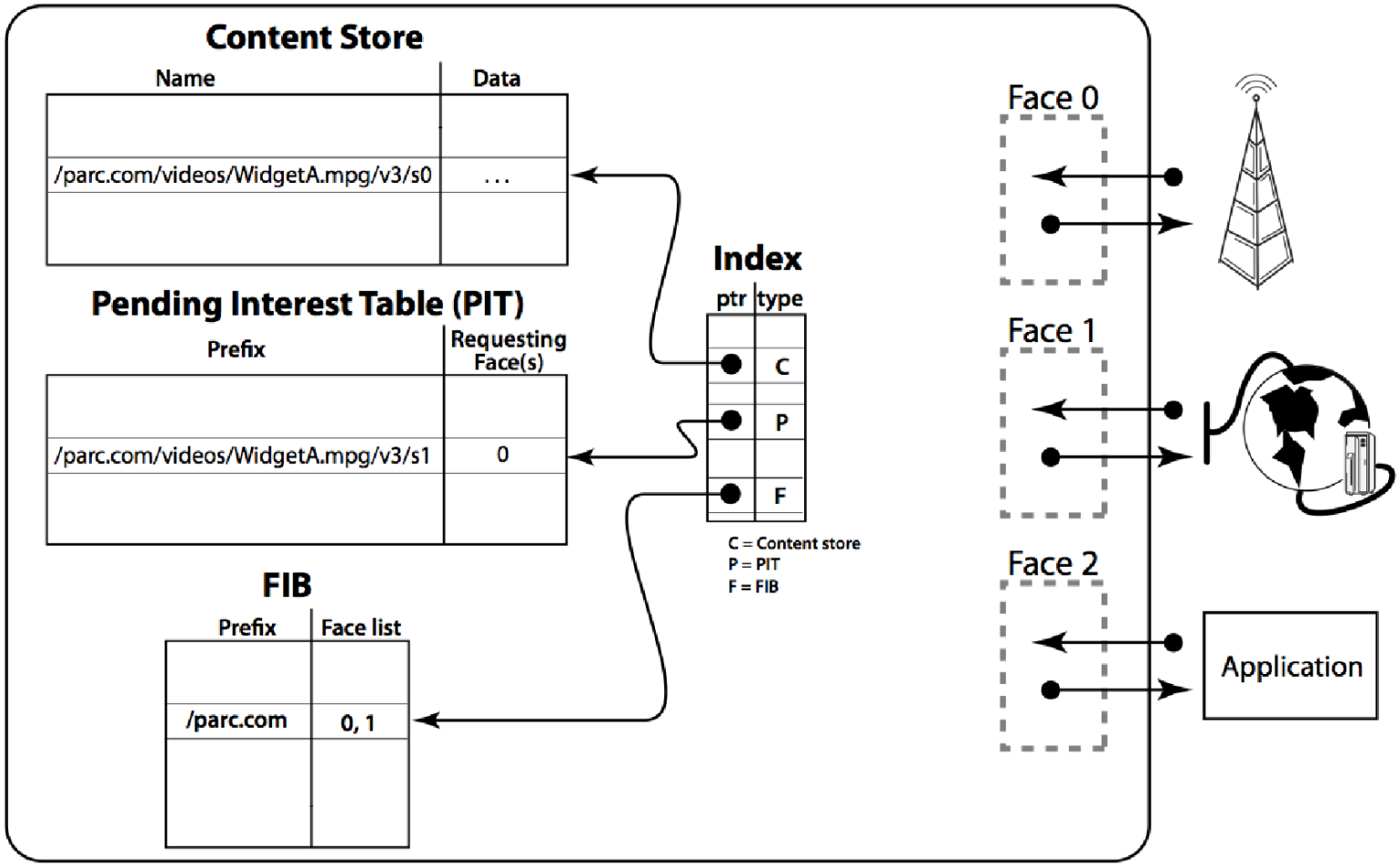
- Interest: Content Name (CN) = X
- Forward interest towards Publisher (X)
- Mark incoming faces as wanting X (lay down breadcrumbs)
- Merge same interests for X

NDN Forwarding: Data

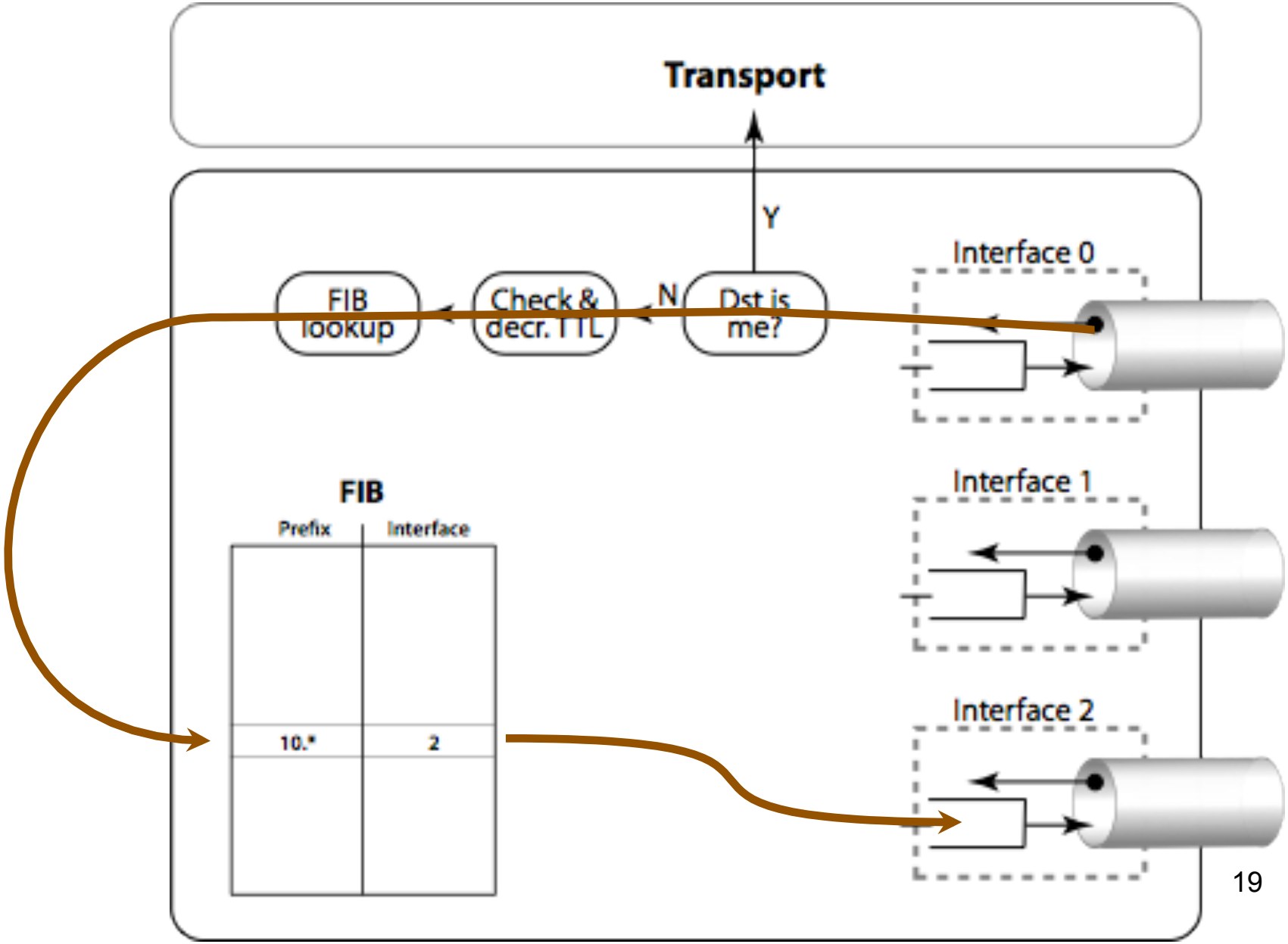


- Data: Content Name (CN) = X
  Forward Data back to where interests came from
  - Follow the breadcrumbs back to requestors
  - Delete breadcrumbs
- Duplicate at appropriate routers
- Cache data at each router

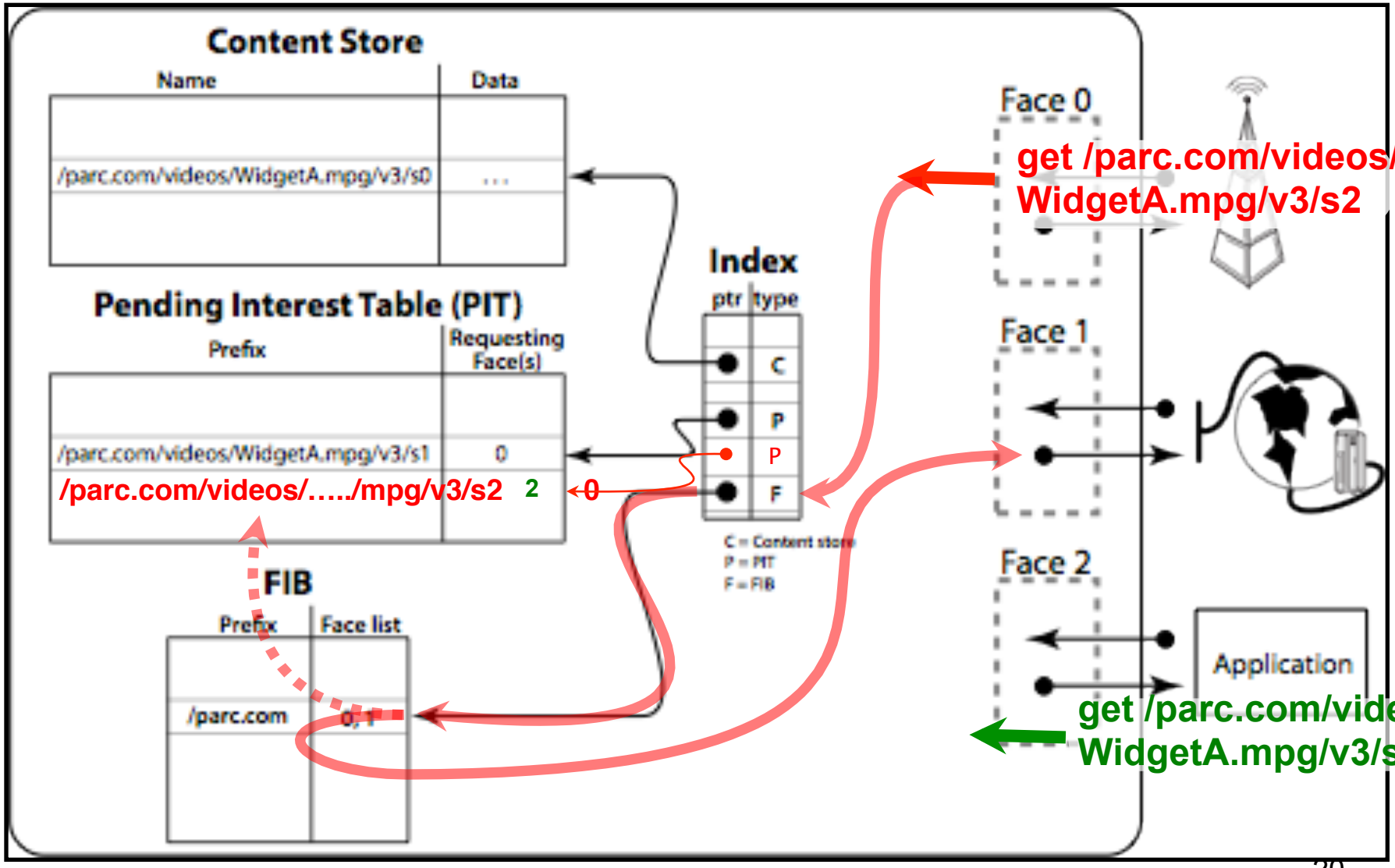
Forwarding Process



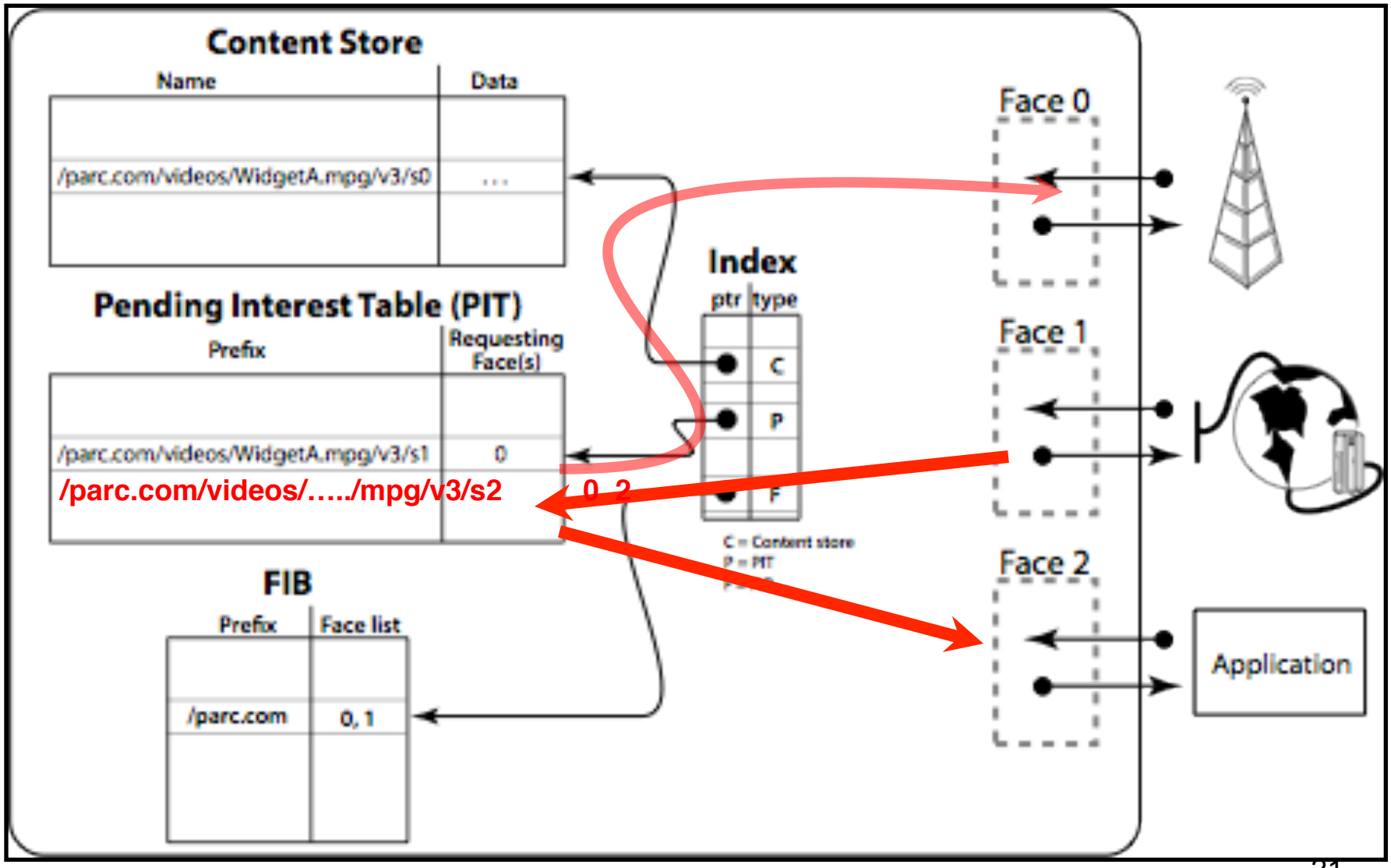
Comparison with IP Packet Forwarding



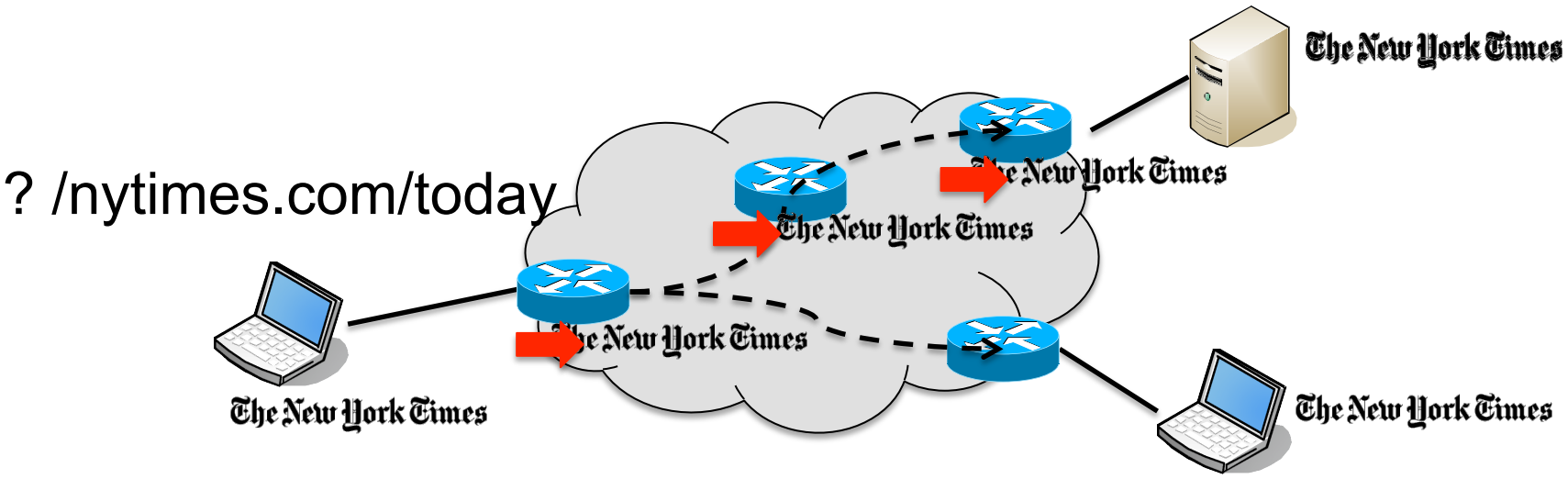
NDN Interest Forwarding



NDN Data Forwarding

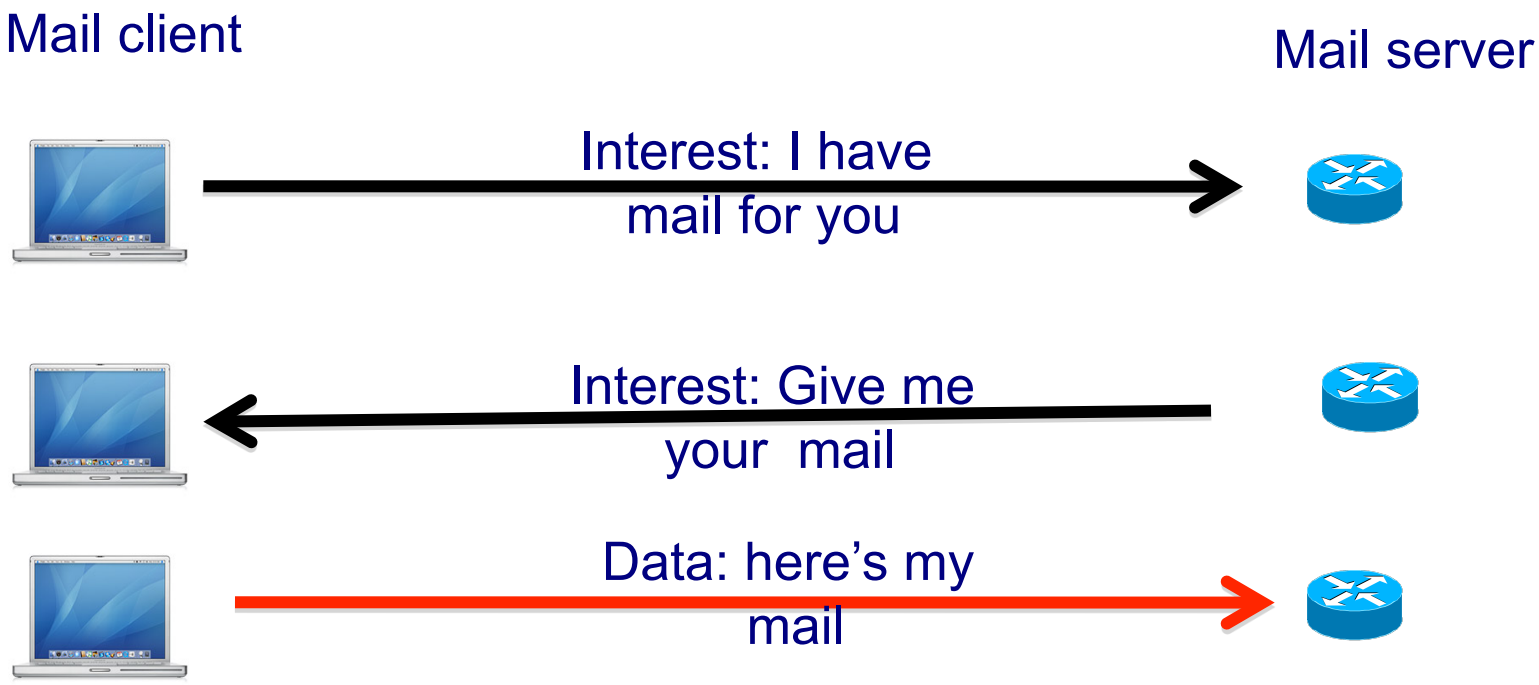


Summary



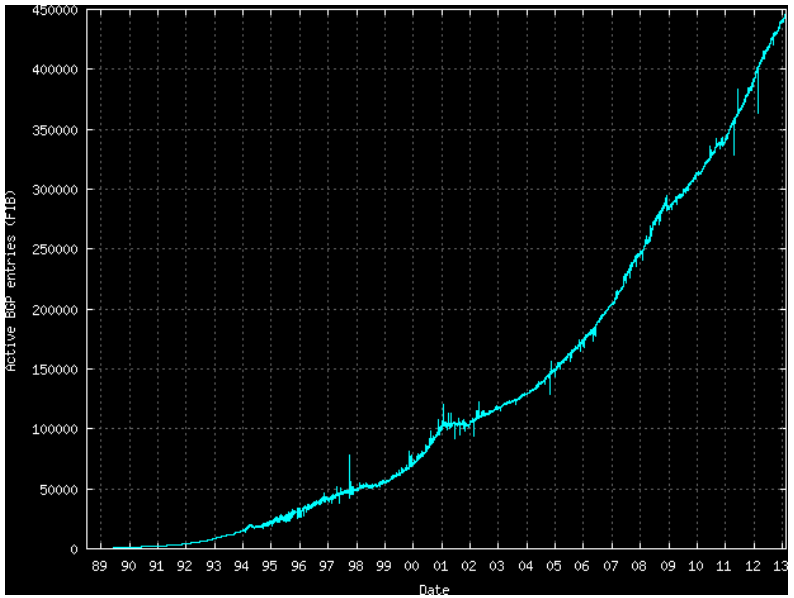
- Route on content names
- Content from anywhere: not just the producer
- “Breadcrumbs” & de-duplication of requests
- Cache retrieved data in Content Store (CS)

Example: Delivering Mail



Can it Scale?

- WUSTL Results for NDN Forwarding
  - (in submission)
- Software router prototype
- Preliminary hardware design
- Multi-gigabit forwarding rates for:
  - Name-based FIBs, based on real world URLs, of 1-3M entries;
  - Synthetic FIBs, based on model of future namespace, of up to 1B entries.



http://www.cidr-report.org

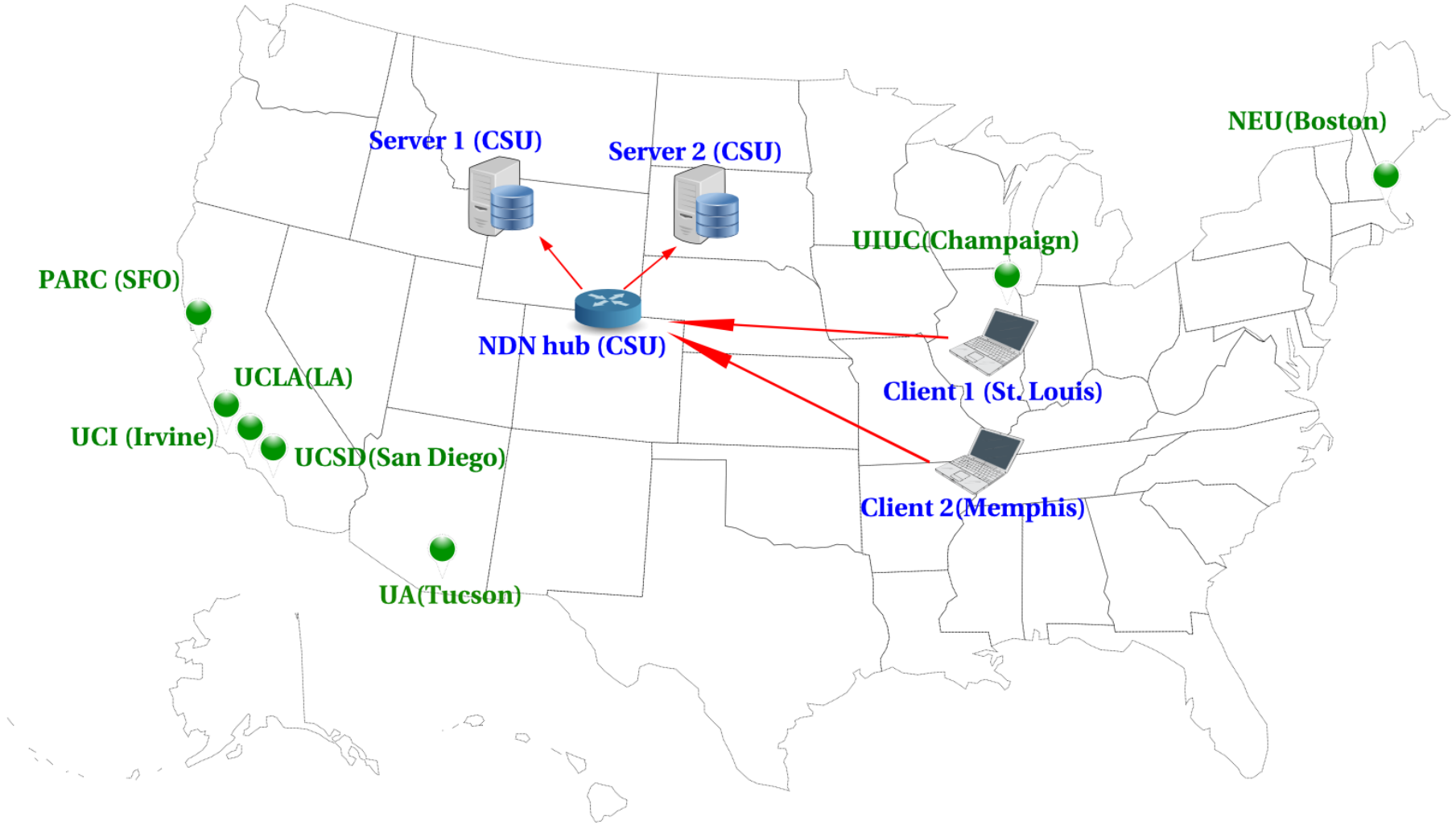
All	New	Deleted	Transferred	TLD
144,040,087	155,151	136,956	239,097	All TLDs
107,508,504	115,331	100,189	194,269	.COM
15,033,351	16,353	13,437	20,649	.NET
10,204,641	9,829	7,165	10,224	.ORG
7,185,246	8,227	12,882	8,916	.INFO
2,305,965	3,715	1,875	2,895	.BIZ
1,802,380	1,696	1,408	2,144	.US

http://www.whois.sc/internet-statistics/

The Power of Naming

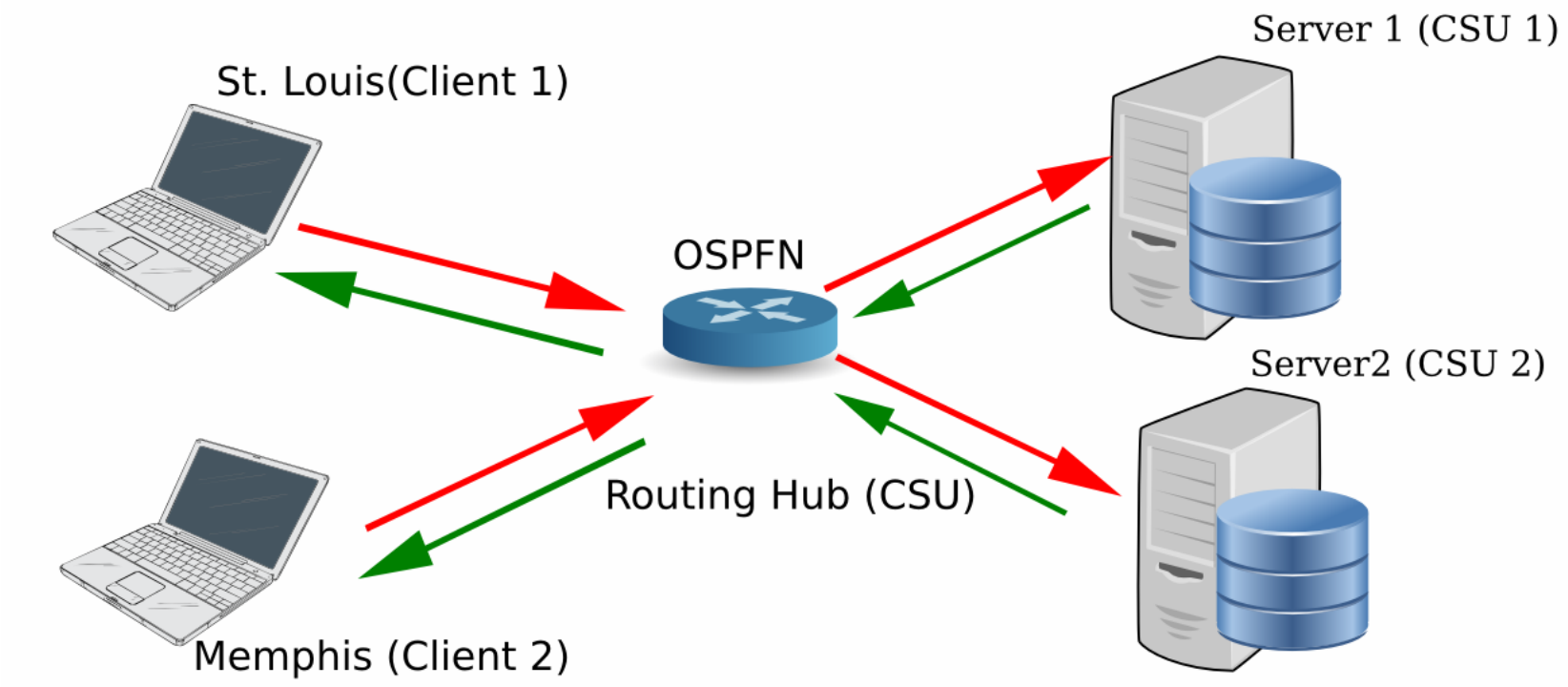
- Naming can fetch the data transparently regardless of location
  - Requests can go to appropriate place
- Naming can result in generation of new data
  - Can ask for data that does not yet exist!

Experiment Topology



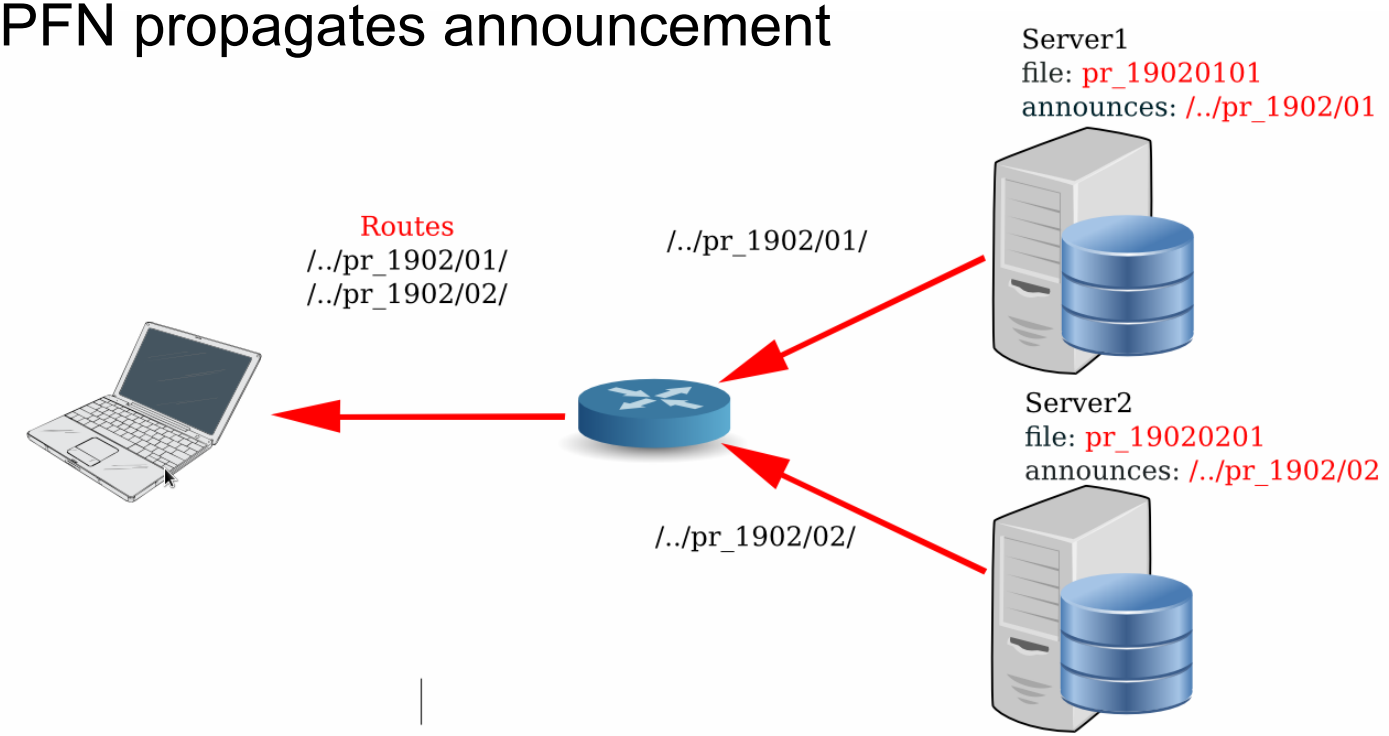
Experiment Setup

- Two servers and two clients
- Servers at CSU, clients at Memphis and St. Louis
- Nodes exchange routes using OSPFN



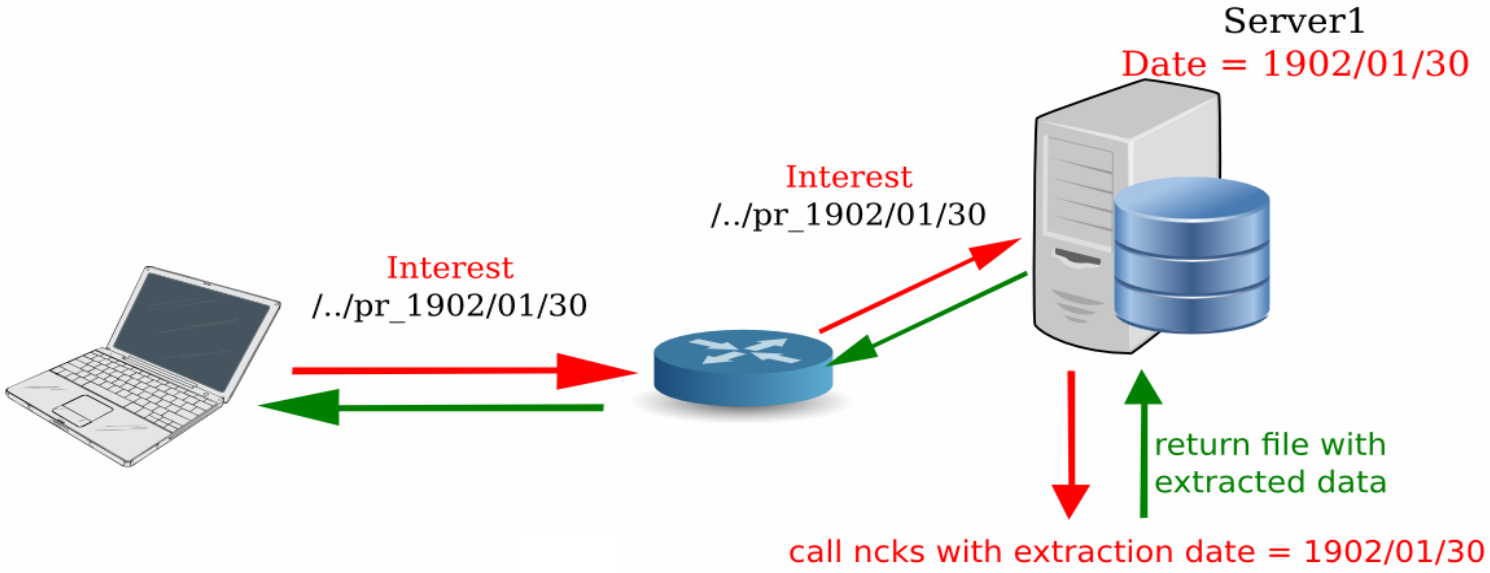
Announcements

- Servers have .nc files, each .nc file have one month's data
- Route announcements in network are based on filename
- Each server advertises one prefix for a file
  - Server having file pr_19020101.nc announces /../ pr_1902/01/
- OSPFN propagates announcement



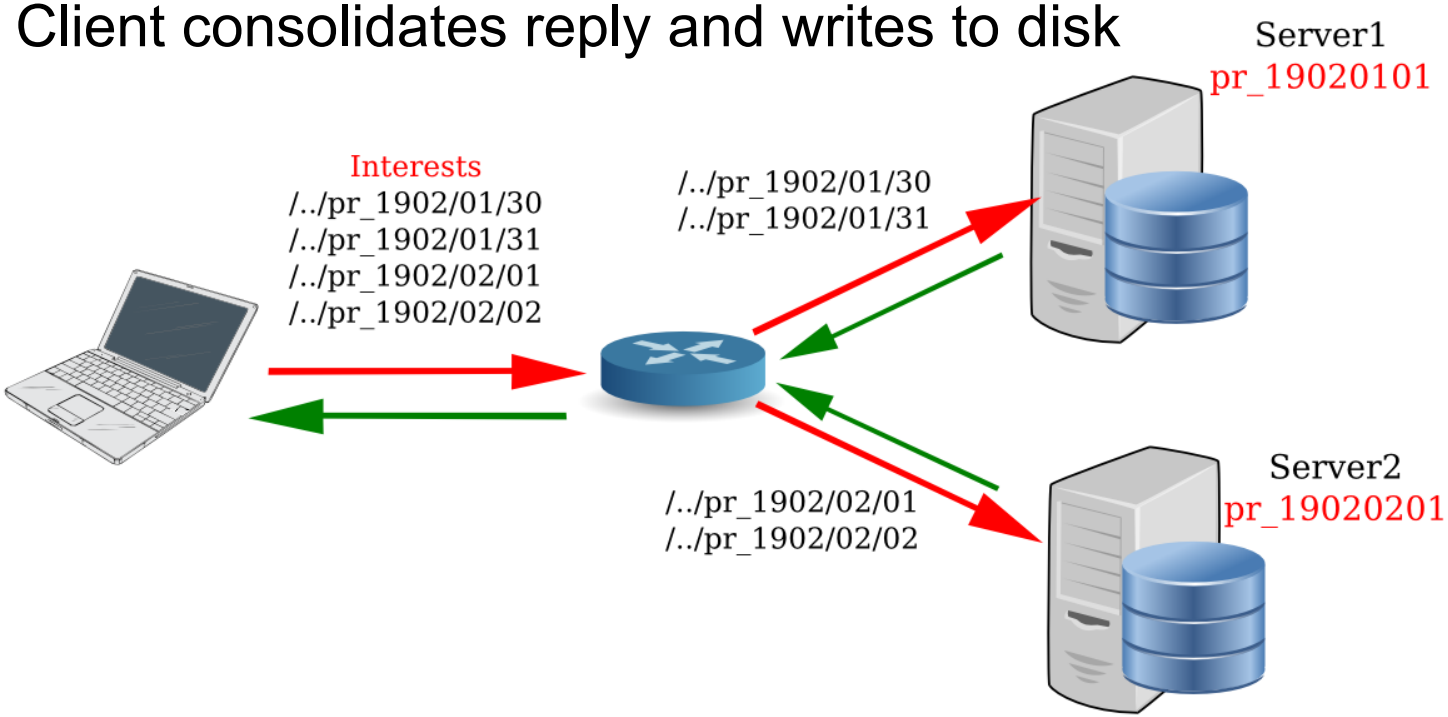
Dynamic Data Generation

- Servers parse interest names and find the date range
- Pass date range to ncks tool.
- ncks tool extracts data, writes to file and returns the filename to server
- Server sends back file



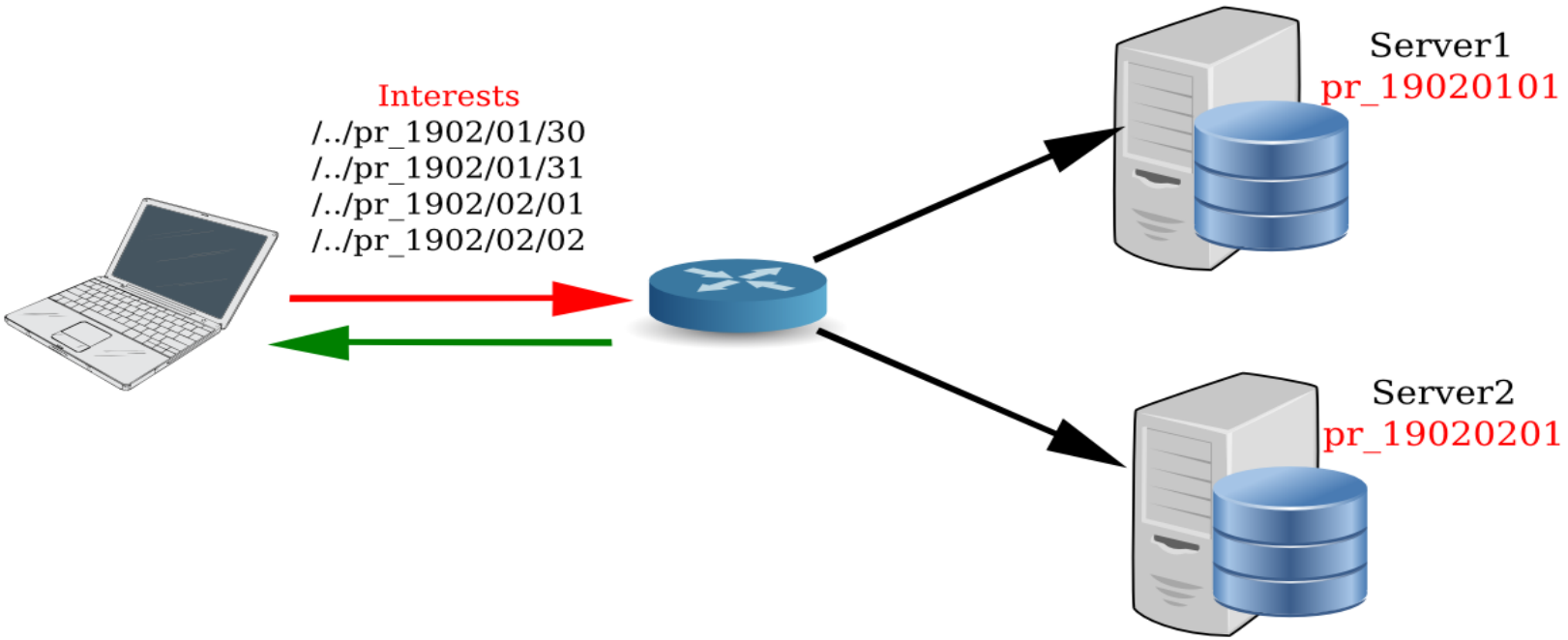
An Example Data Request

- Want data for Jan 30 – Feb 02
- Client expresses interests, one for each day
- Interests for Jan 30-31 go to server1
- Interests for Feb 01-02 go to server2
- Data is dynamically generated and sent back
- Client consolidates reply and writes to disk



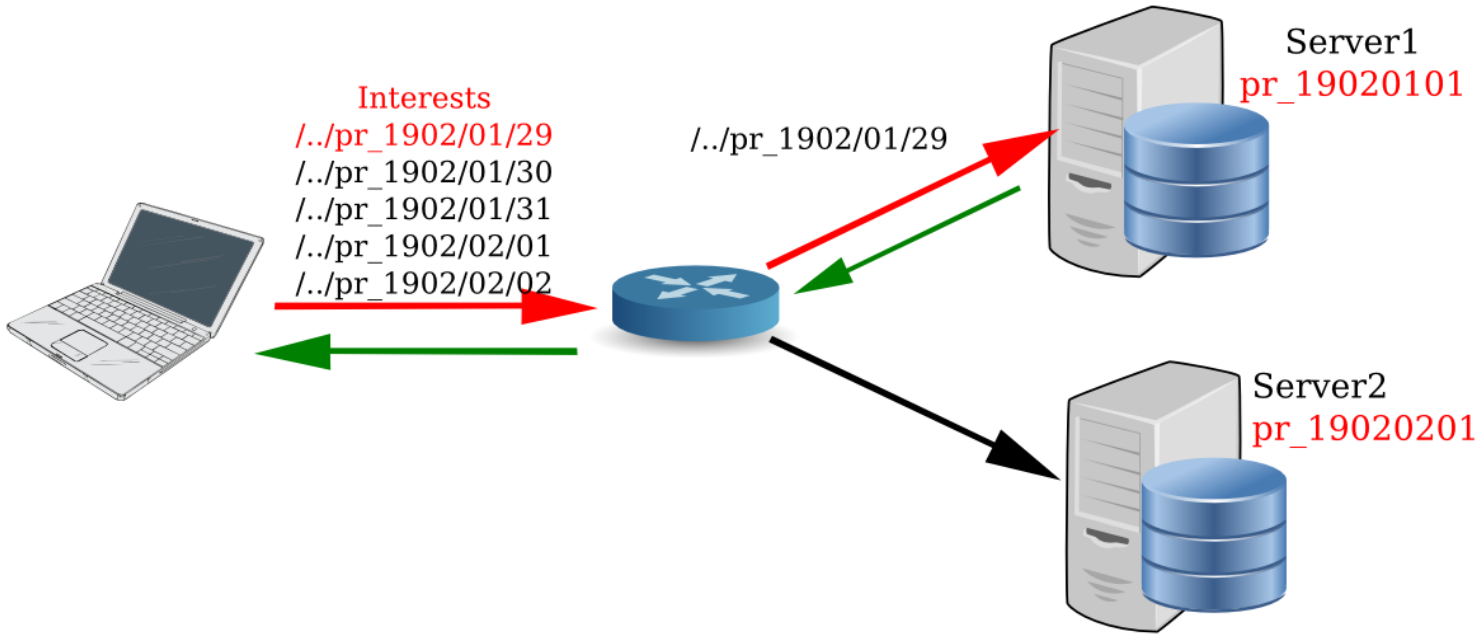
Repeat Requests and Cache

- If asked for same data, requests are answered from cache
- Saves transmission time, extraction time and transfer time



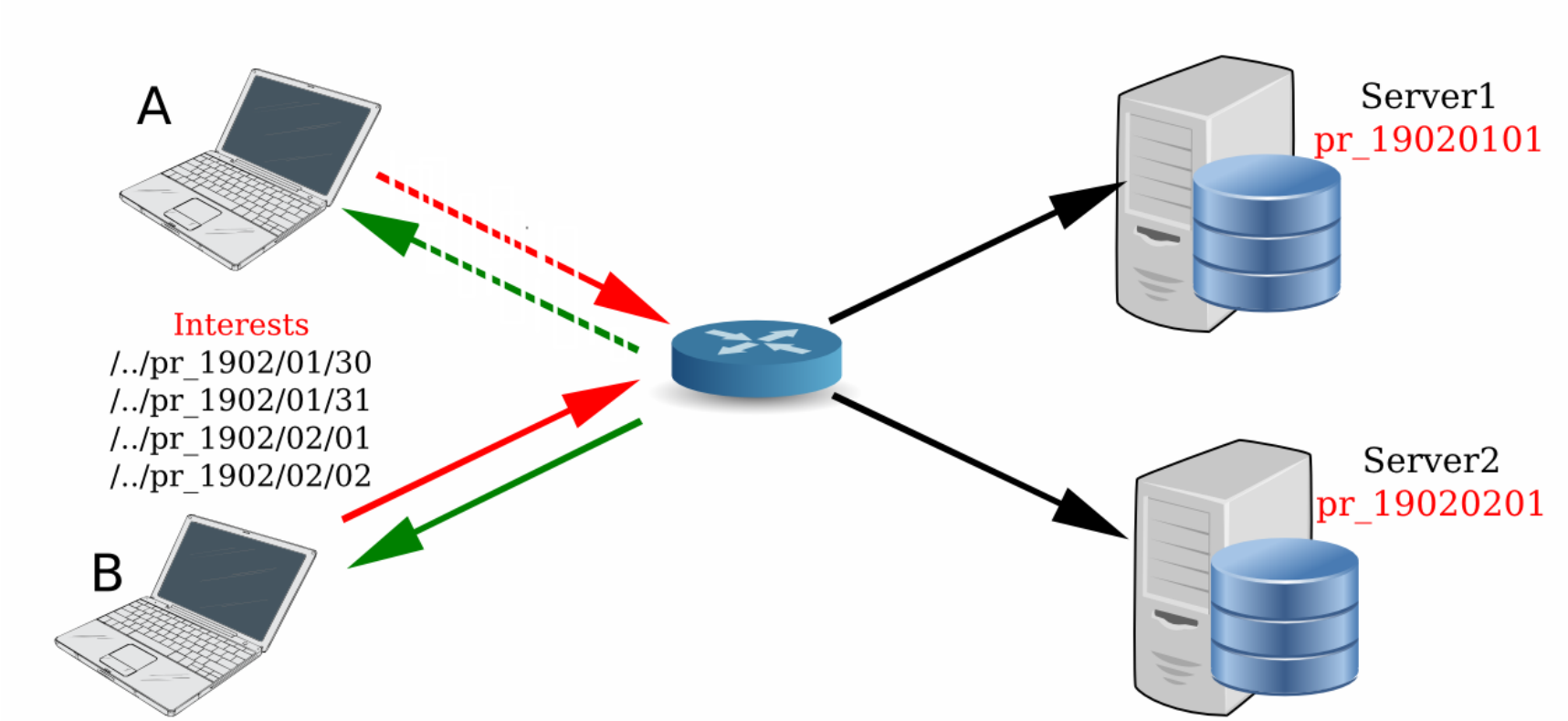
Partially Cached Data

- What happens if we ask for Jan 29 – Feb 2 ?
- Request for data not cached goes to server
- Rest is answered from cache



Collaborations

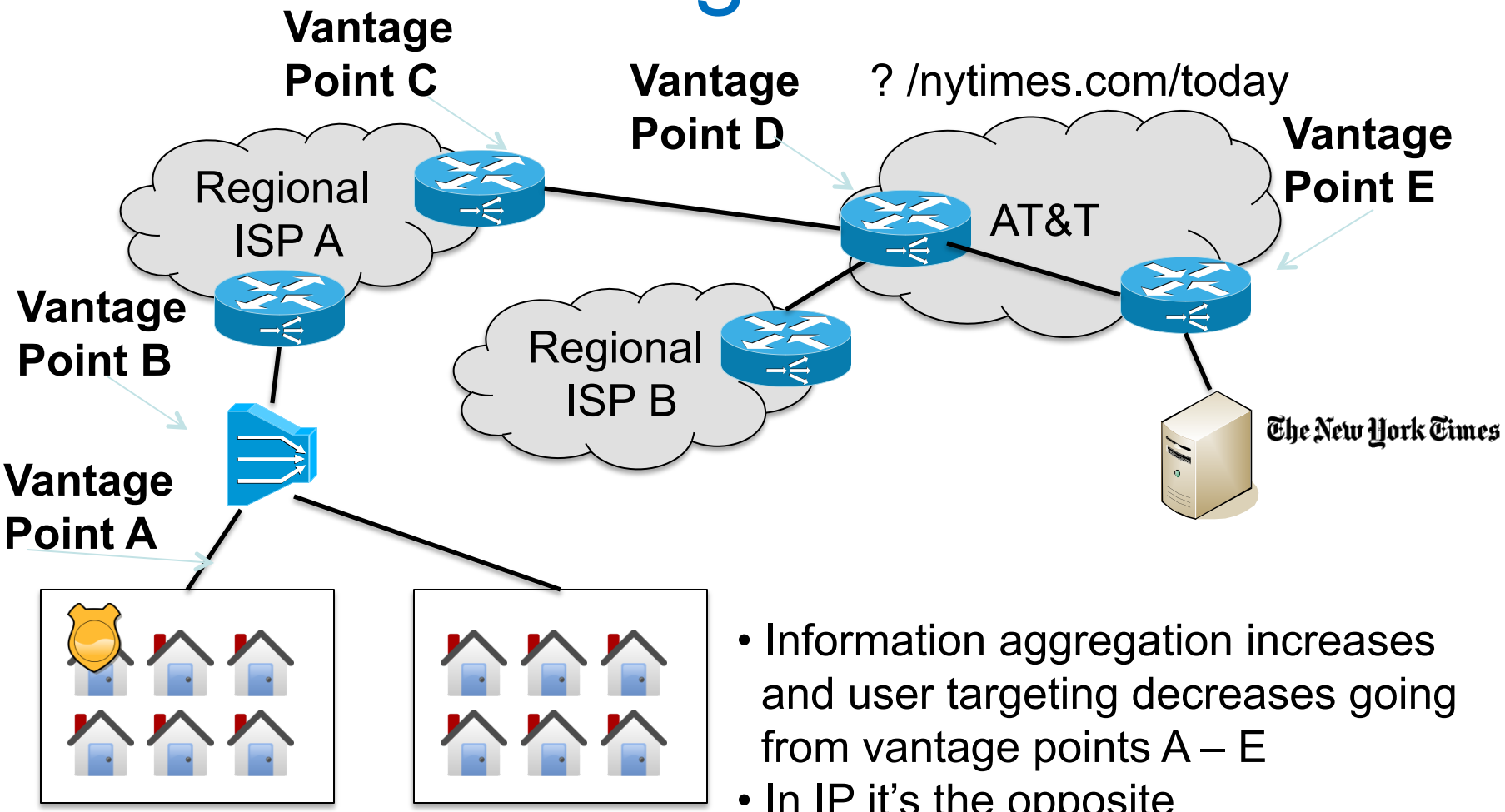
- A asked for data for Jan 30- Feb 2.
- B later asks for same data.
- B receives data from cache.



NDN and Anonymity

- NDN has no endpoint addresses – names in interests and data packets are ephemerally associated with incoming/outgoing faces
- Info retrievable at a router:
  - PIT – interest/data names and associated face information; in-memory, ephemeral (~RTT)
  - Content Store – data names, no face information; in-memory, ephemeral (~nRTT)
  - Attached storage (repo) – data names, no face information; on non-volatile memory, long-lived
- Individual endpoints, however, engaged in a private conversation *can still be identified* by their names

In NDN Vantage Point Matters



- Information aggregation increases and user targeting decreases going from vantage points A – E
- In IP it's the opposite

Recap

- In NDN routers hold ephemeral name-to-interface associations – no e2e associations
- Vantage point matters
- Caching may satisfy interests before they reach your vantage point
- Multipath may divert interests away from your vantage point
- But private parties still visible on the wire

DDoS Attacks

- Classic DDoS is not possible
  - Cannot send packets without interests
- However, can still do Interest packet flooding
  - Standard push-back defenses still possible
  - Smart decisions based on parsing names
- In general, NDN raises the bar

Congestion Control

- Use lessons learned from TCP – mechanisms carry over
  - Define congestion window just like TCP
  - Send interests that fall within the congestion window
  - Use similar AIMD behavior
- Note that receiver window is not needed – receiver pulls what it wants

Key Distribution

- No single way to distribute keys
  - Key distribution outside the architecture
  - Certificates, consensus, out-of-band, applications are free to implement anything that works
  - Packets tell you how to get the key (or may even carry the key with them)
- Key delegation
  - Example: www.nytimes.com can delegate keys to editors for www.nytimes.com/sports, www.nytimes/com/business, etc.

Conclusions

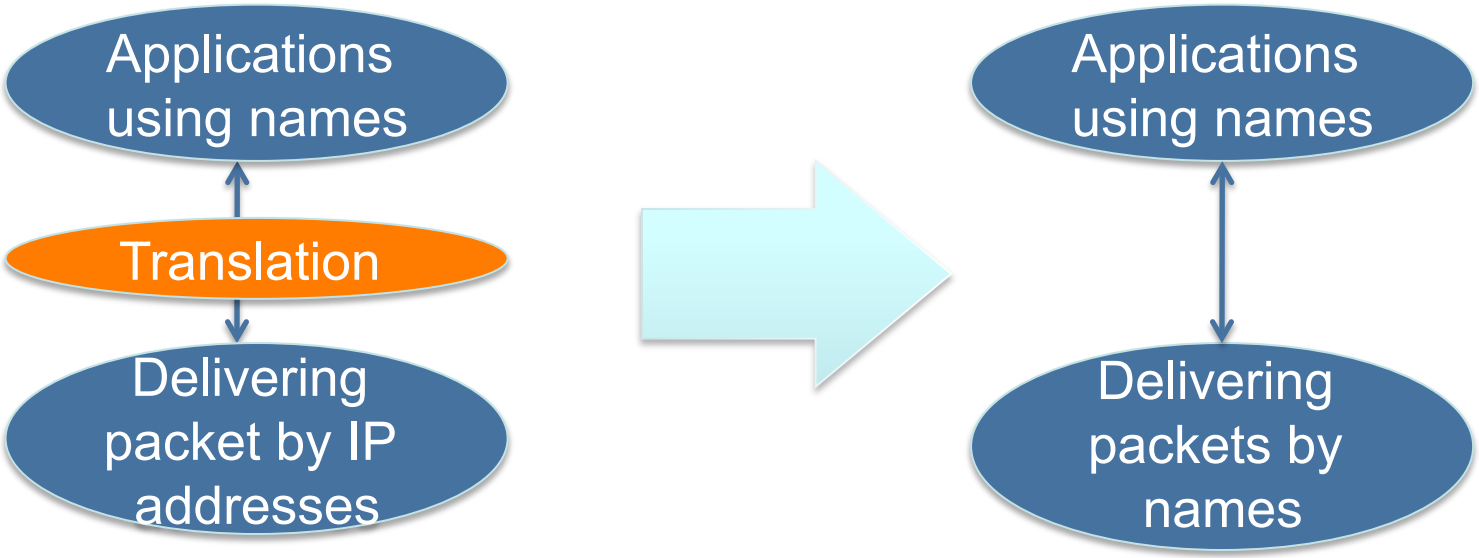
- NDN preserves the hourglass shape of IP but with names at the narrow waist
- Architecture focused on the what, not the where
- New forwarding mechanisms enable multipath, multicast and other group operations
- All content is signed
- More at **http://www.named-data.net/**

BACKUP SLIDES

Naming the Content

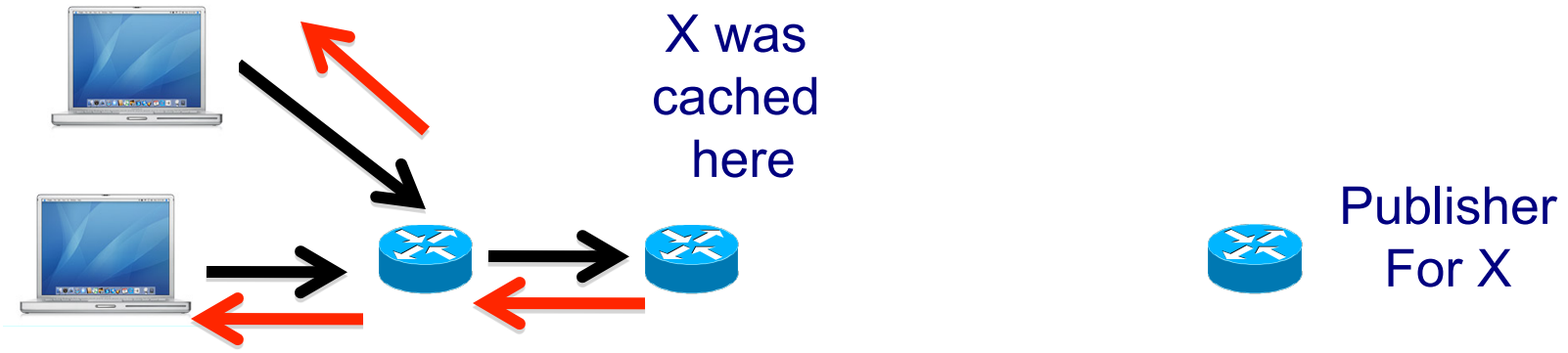
- Client requests www.nytimes.com/today
- Interests go out for each packet:
  - www.nytimes.com/today/packet1
  - www.nytimes.com/today/packet2
  - …
- Routers forward based on www.nytimes.com prefix (longest prefix match, just like IP)
- Data is pulled and cached one packet at a time
- Each packet contains information on how to retrieve the signing key

Communication by Names



- Producer announces data prefix
  - e.g., www.nytimes.com/
- Consumer sends interest
- Producer replies with data

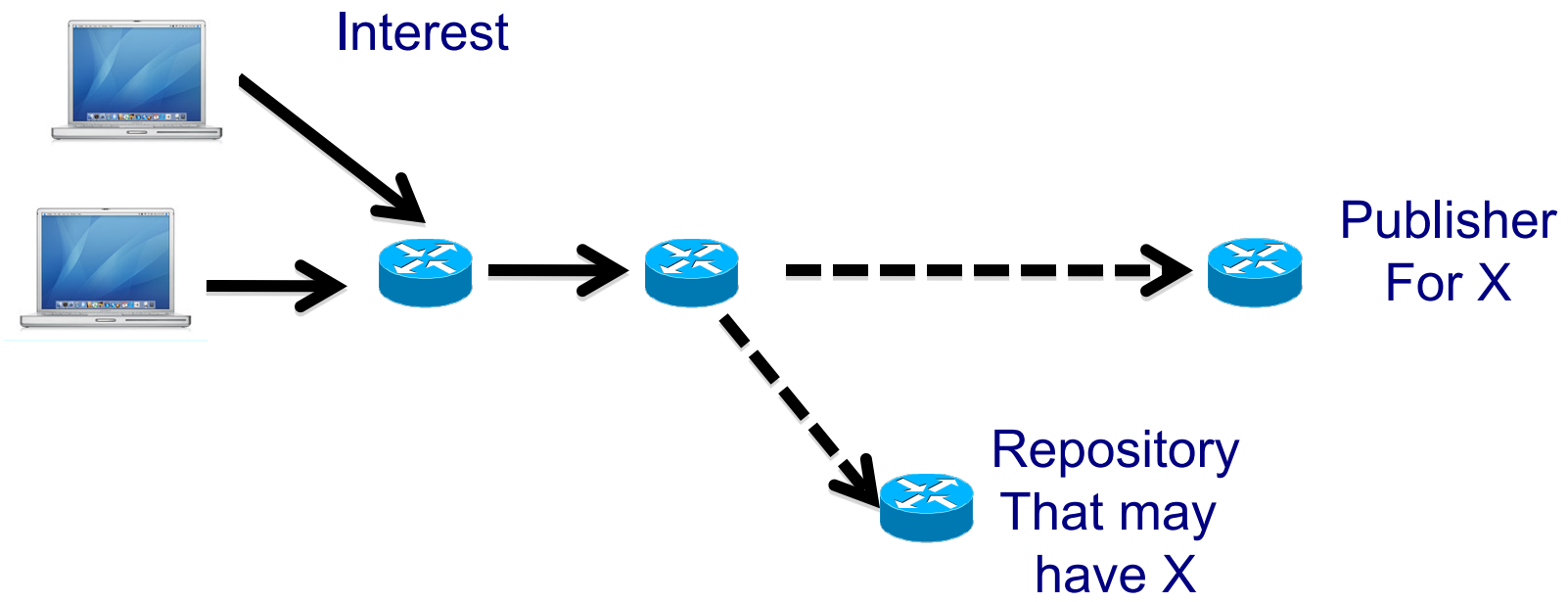
Hitting Cached Data



Interests only go so far until they find the data

Cached data can satisfy requests efficiently

Multipath Interest Forwarding



- Interests may be forwarded opportunistically to many destinations
  - Strategy Layer
- Data may be concurrently retrieved from multiple places

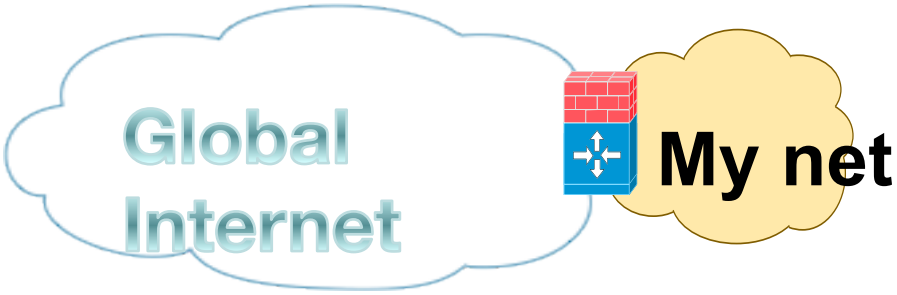
Transparency in NDN

With a search warrant for a router, what can you discover about an ISP's users?

- *Assumption: warrant covers volatile and non-volatile memory*

Network Security in IP: why so Hard?

- **IP identifies interfaces/hosts**
- **Current attempts aim at:**
  - **Securing the box**
  - **Securing the channel**
  - **Securing an IP network by firewall**
- **Securing the perimeter is hard**



30 Years Down the Road

IP changed the world

Interconnections of computers

Moore's Law & silicon revolution

A new world of applications & computing devices

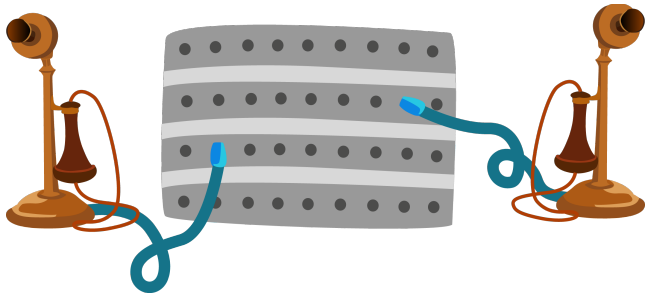
facebook

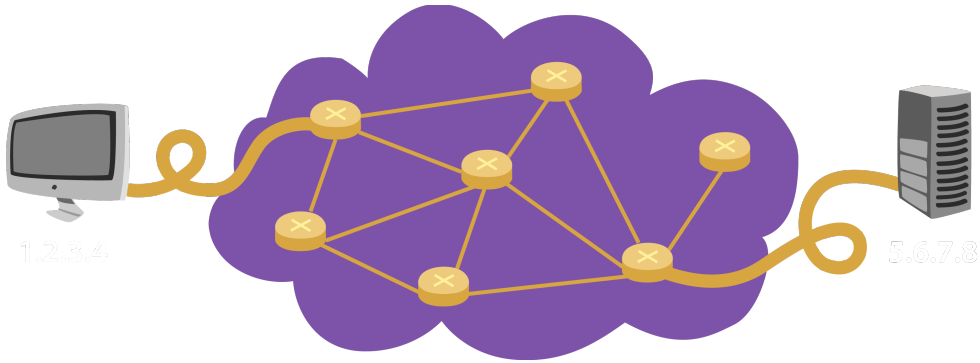
Google

So Why a New Architecture?

- What are the problems with the current Internet?
- Are they worth re-designing the network?
- With the current architecture being so entrenched, can we even deploy a new one?

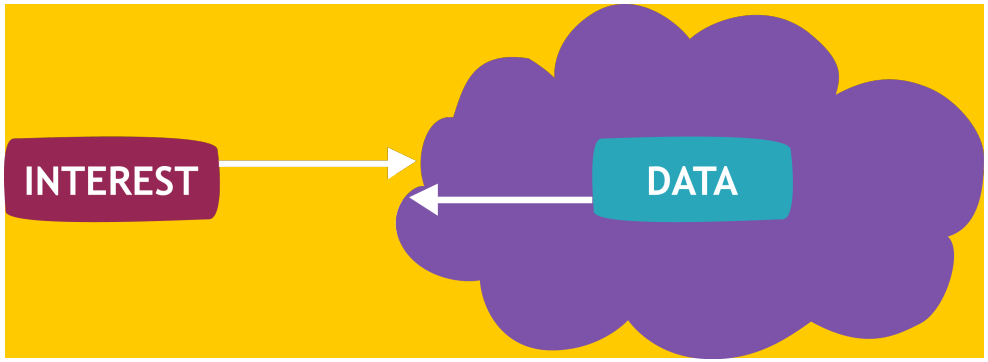
Evolution of Communication Abstraction





Telephone Network:
Focused on building the *wires*

Internet Protocol (RFC791):
Focused on delivering packets to destination *node*



NDN: Focusing on retrieving *data*

Abstracting away the notion of "node"

Superset of node-to-node communication model

A New Way to Think About Security

- ***Secure the Content, Not the Channel!***
  - SSL, VPN, ssh tunnel, ToR, etc all focus on providing a secure channel
  - Users don't really care if the channel is secure, focus on the content
- Require Authentication on ***All*** Content
  - Security is not an option, its part of architecture
- Encrypt the content if you don't trust the channel
  - Encryption is optional and applied where needed