# Introduction to Named Data Networking

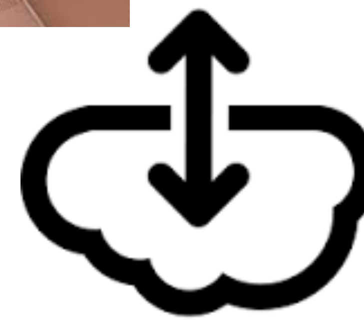
FYI, not HW or exam material

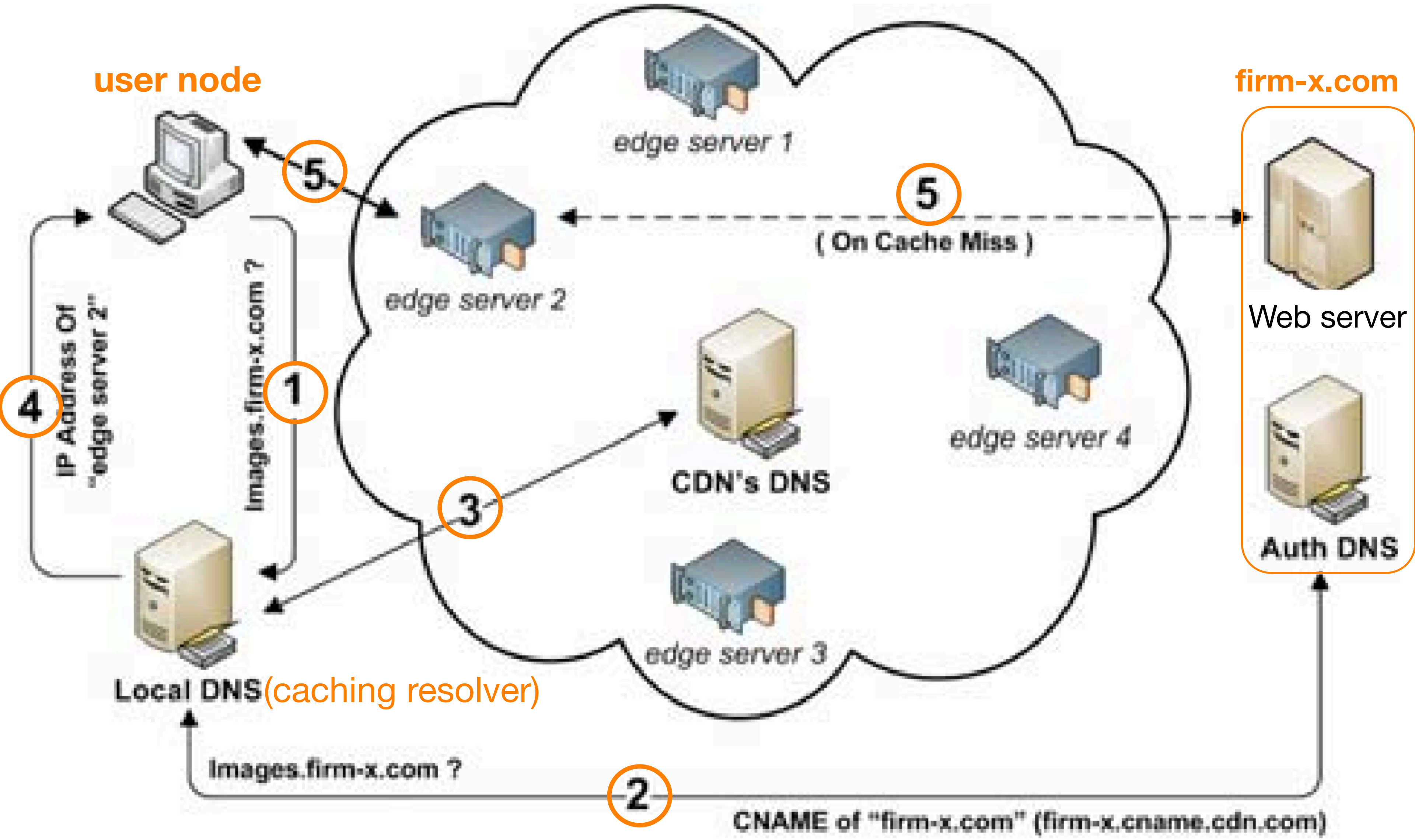
# Today’s Plan

- Why Internet even needs a new architecture
- Assuming it is needed,
  - How to figure out how this new architecture should look like?
  - When would Internet move to this new architecture?

# A simple example

- Jon starts the morning at Starbucks, music streaming
  - TCP connection between his phone and server, thru WiFi
- When Jon walks out to the train station: WiFi fades → move Internet connectivity to cellular
  - TCP connection: interface specific
    - Re-establish TCP connection
- Gets on the train
  - Train offers free WiFi
    - the phone has to re-establish TCP connection (again)
  - Others listen to the same music, can they share the download?





user node
firm-x.com
edge server 1
5
edge server 2
5
( On Cache Miss )
Web server
IP Address Of
"edge server 2"
4
Images.firm-x.com ?
1
CDN's DNS
edge server 4
3
Auth DNS
edge server 3
Local DNS(caching resolver)
Images.firm-x.com ?
2
CNAME of "firm-x.com" (firm-x.cname.cdn.com)

# A number of solutions developed over time

- To be able to use multiple interfaces on a phone: multipath-TCP developed
- To handle server load: CDN (content distribution network) developed
- To make CDN work: DNS hack developed
  - the phone’s DNS lookup for itunes.apple.com
- Now DNS servers get new work to do: Make sure to pick a good IP address for  a CDN box
  - Working?
  - Closest to the requester?
- Have not mentioned the complexity at data centers yet
- Have not mentioned **security** yet

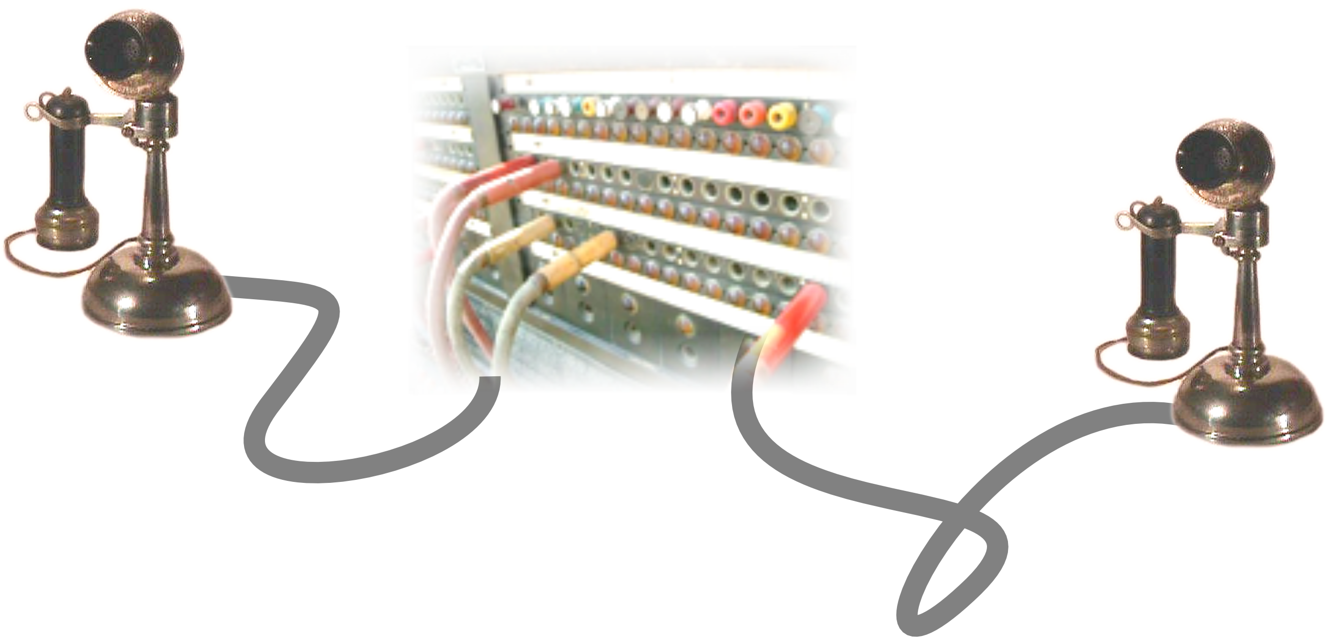
```
[Lixia:~/papers/iotdi-2016] lixia% dig itunes.apple.com
; <<>> DiG 9.8.3-P1 <<>> itunes.apple.com
;; global options: +cmd
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 8328
;; flags: qr rd ra; QUERY: 1, ANSWER: 4, AUTHORITY: 8, ADDITIONAL: 8

;; QUESTION SECTION:
;itunes.apple.com.        IN   A

;; ANSWER SECTION:
itunes.apple.com.           2157   IN   CNAME itunes-cdn.itunes-apple.com.akadns.net.
itunes-cdn.itunes-apple.com.akadns.net.  252 IN CNAME itunes.apple.com.edgekey.net.
itunes.apple.com.edgekey.net.            289 IN CNAME e673.e9.akamaiedge.net.
e673.e9.akamaiedge.net.                    9 IN A     104.68.98.172

;; AUTHORITY SECTION:
e9.akamaiedge.net.    2557 IN   NS   n5e9.akamaiedge.net.
e9.akamaiedge.net.    2557 IN   NS   a0e9.akamaiedge.net.
e9.akamaiedge.net.    2557 IN   NS   n3e9.akamaiedge.net.
e9.akamaiedge.net.    2557 IN   NS   n0e9.akamaiedge.net.
e9.akamaiedge.net.    2557 IN   NS   n1e9.akamaiedge.net.
e9.akamaiedge.net.    2557 IN   NS   n2e9.akamaiedge.net.
e9.akamaiedge.net.    2557 IN   NS   n4e9.akamaiedge.net.
e9.akamaiedge.net.    2557 IN   NS   a1e9.akamaiedge.net.

;; ADDITIONAL SECTION:
a0e9.akamaiedge.net.  4557 IN   AAAA 2600:1406:1c:f000:9029:a648:25fb:2656
a1e9.akamaiedge.net.  2557 IN   AAAA 2600:1406:1c:f000:902c:a648:25fb:2656
n0e9.akamaiedge.net.  2557 IN   A    63.141.195.111
n1e9.akamaiedge.net.  4557 IN   A    184.51.100.13
```

- Internet is facing (lots) problems today
- The root cause?

**“The farther backward you can look, the farther forward you are likely to see.”**

**— Winston Churchill**

# Telephone Network as the 1st Communication system



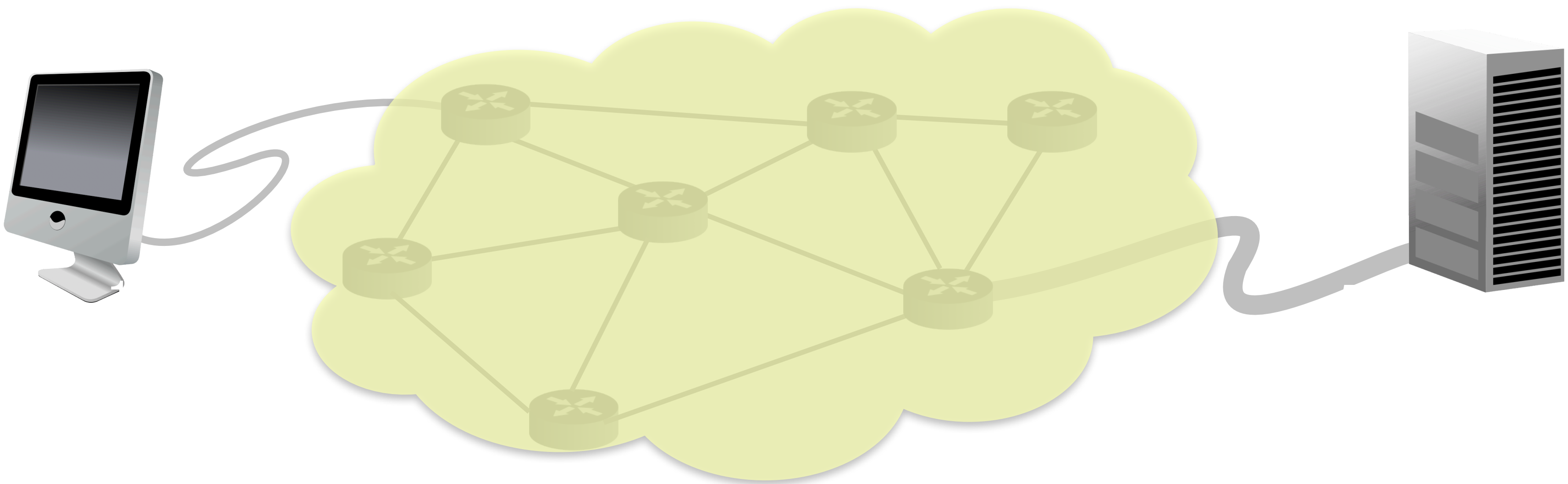
Focused on building the *wires* between 2 ends

# The change over time

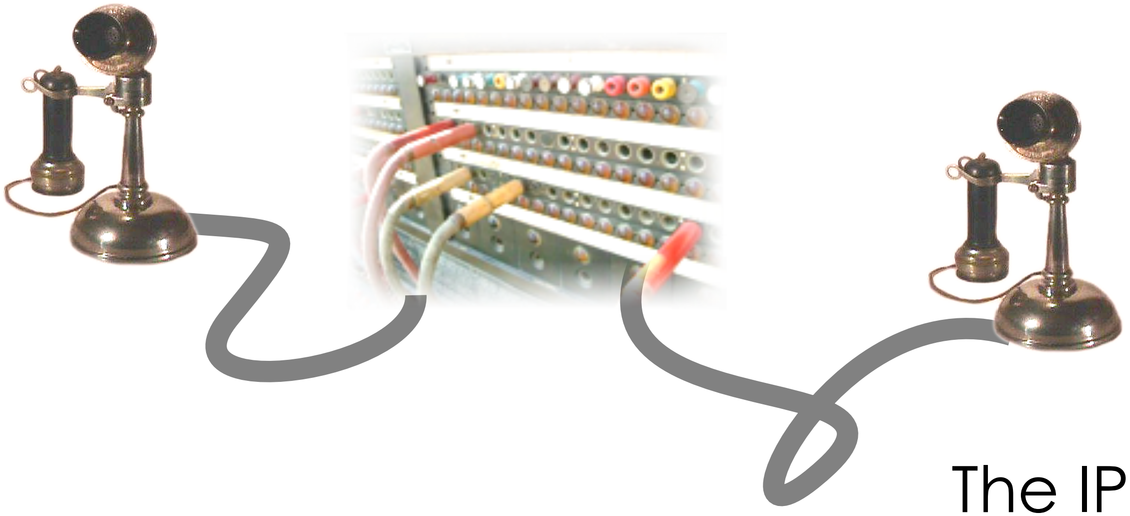
- Telephone networks last a long time
  - until computers were invented
- “On Distributed Communications Networks”
  - by Paul Baran, IEEE Transactions on Communications, March, 1964.
- Why a new design: Technology advanced, goals changed
  - need robust communication system for "second strike capability”
  - providing common services for a wide range of users & applications

# IP changed the way of building communication systems

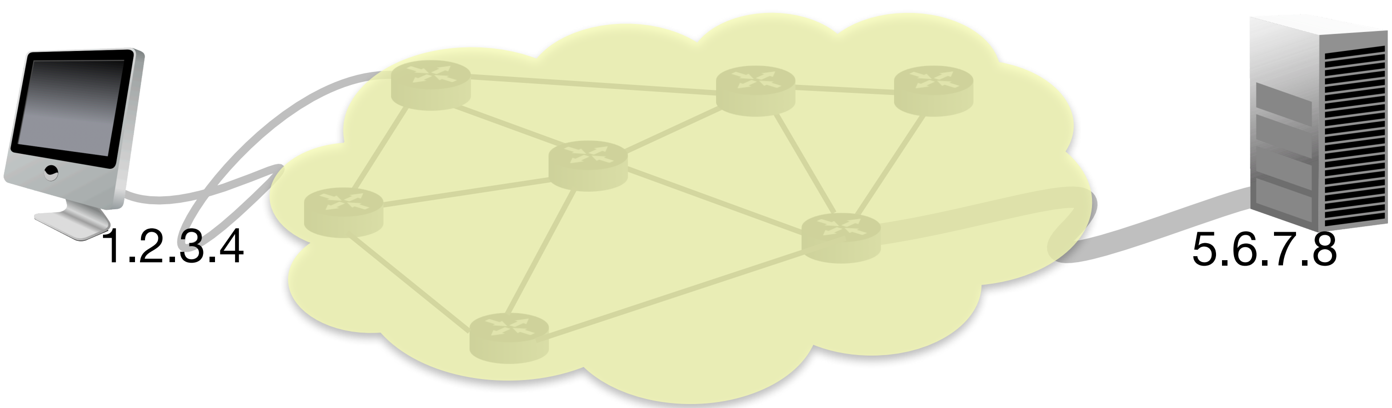
RFC791: Internet Protocol Specification



Focused on delivering packets to destination *node*

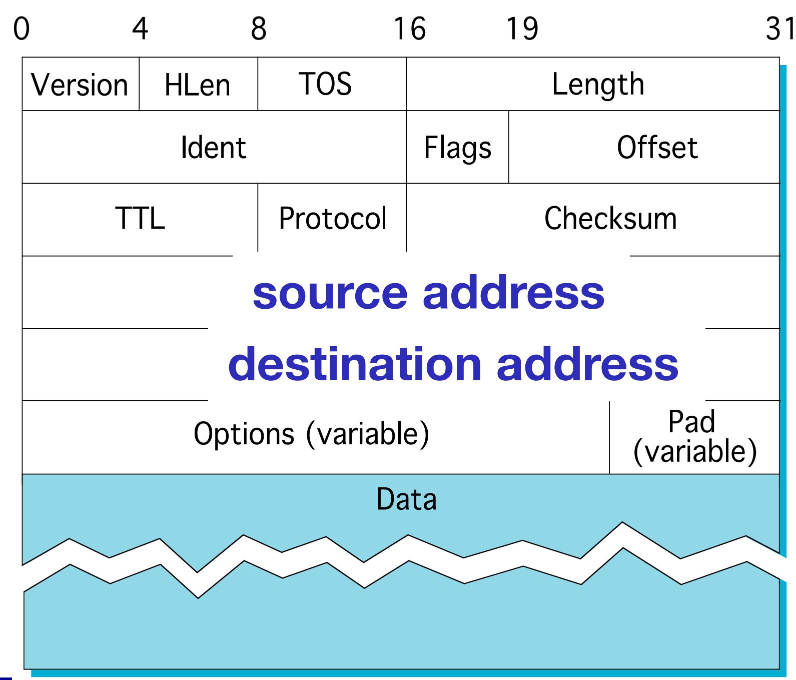


The IP model separated source-to-destination packet delivery from the specifics of which paths to take

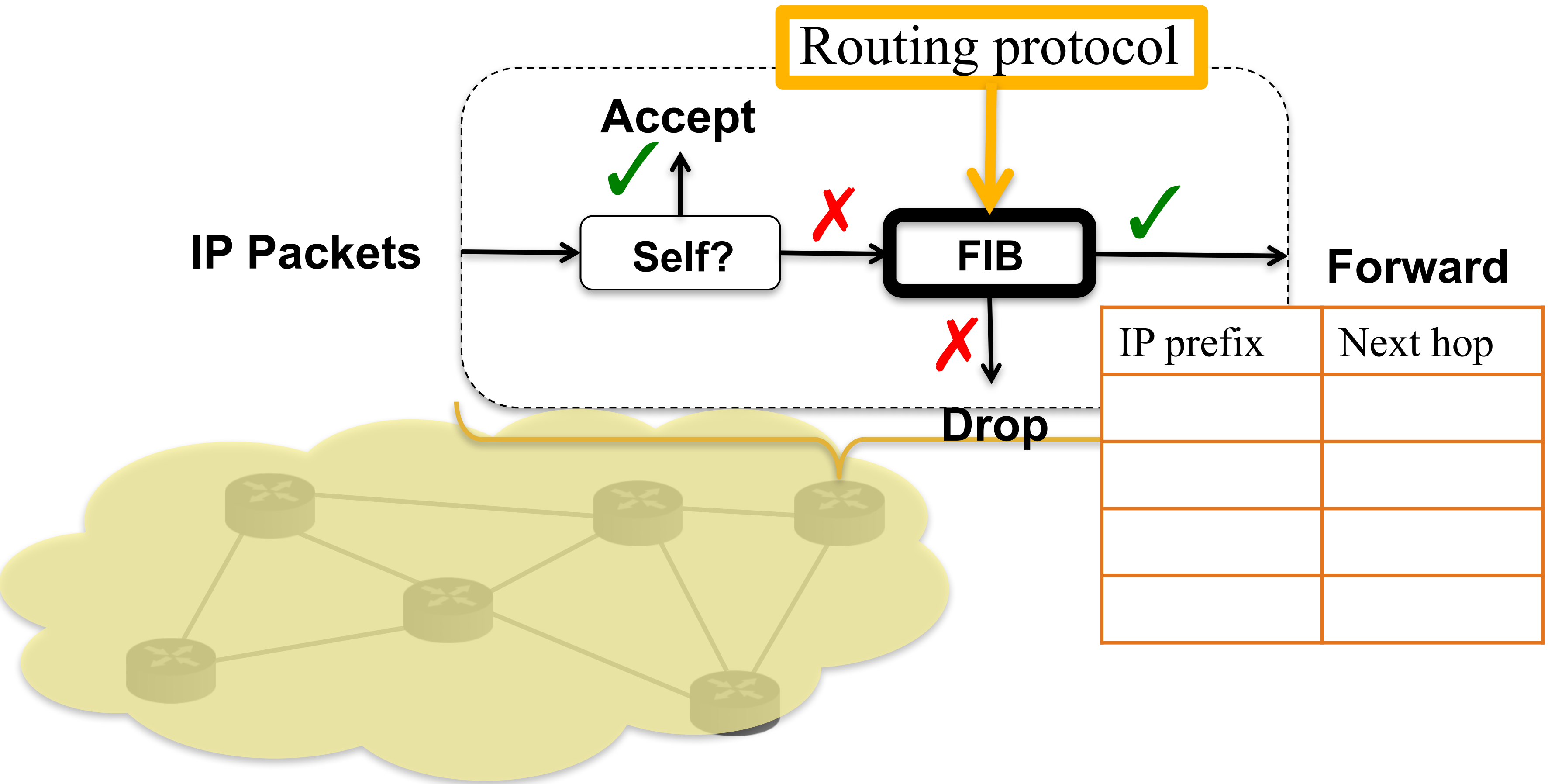


# Today's Internet

- Created gizzalins of applications, a whole world of contents
- IP got us here, but was not designed for this reality
  - The central *abstraction* is a host identifier
  - The communication model: point-to-point conversation between a host pair



# IP' Node Model

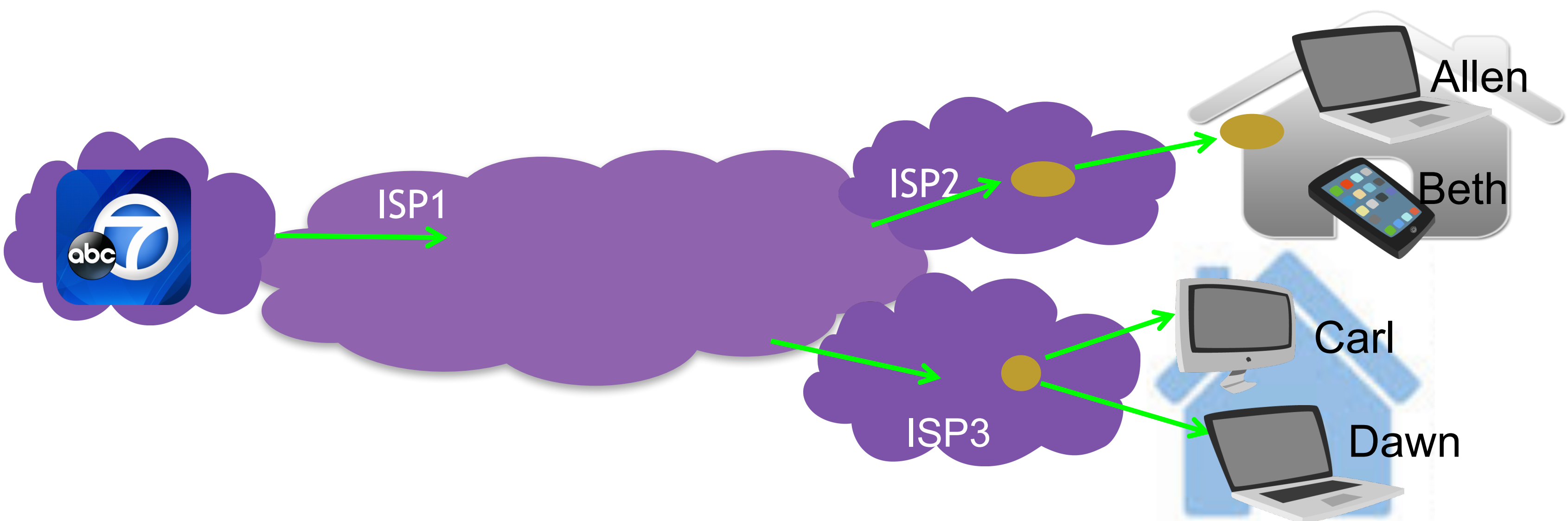



One-way traffic, stateless, no storage

# How well IP serves today's applications

Example 1: content delivery

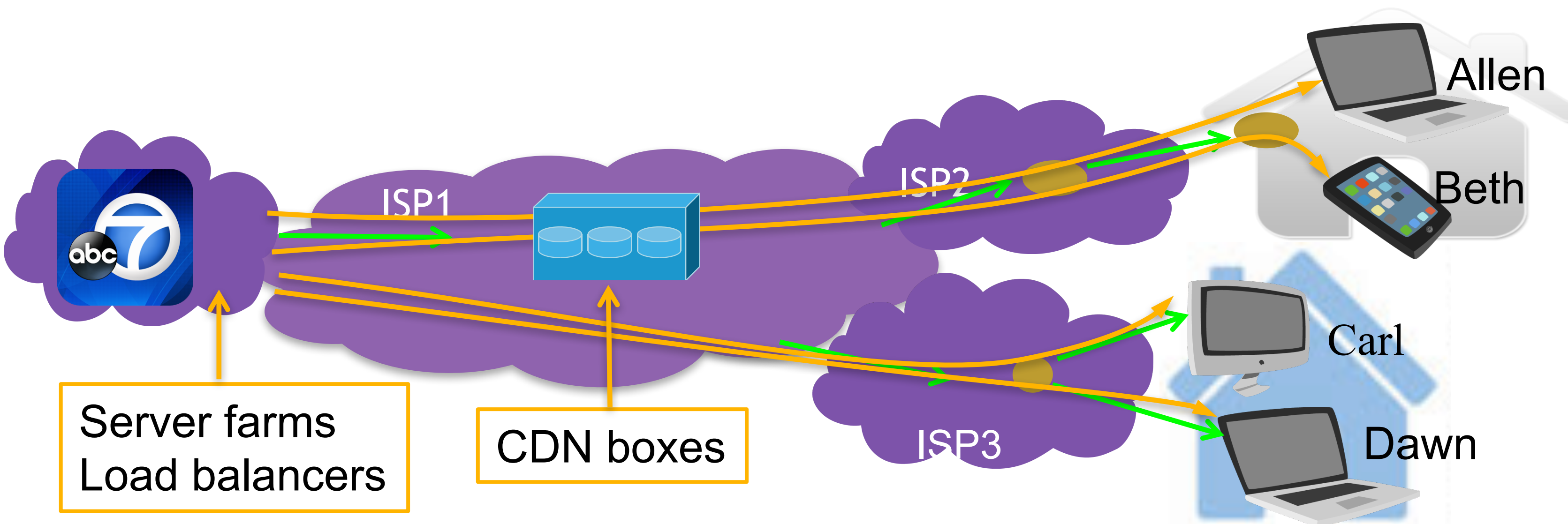
- Applications request data by names; network name packets by IP addresses



# How well IP serves today's applications

Example 1: content delivery

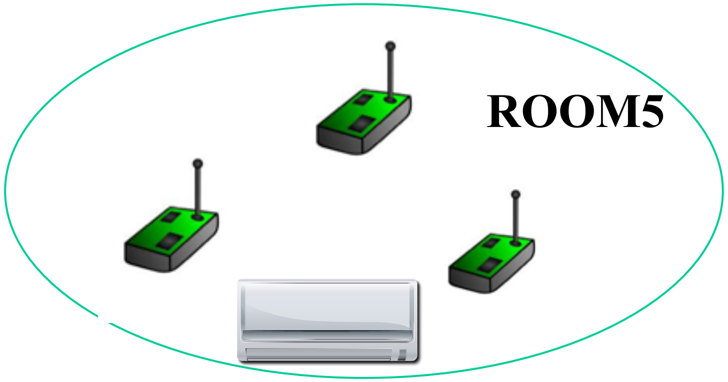
- Applications request data by names; network name packets by IP addresses
- IP delivers data between two end points
  - Multiple users may request the same data



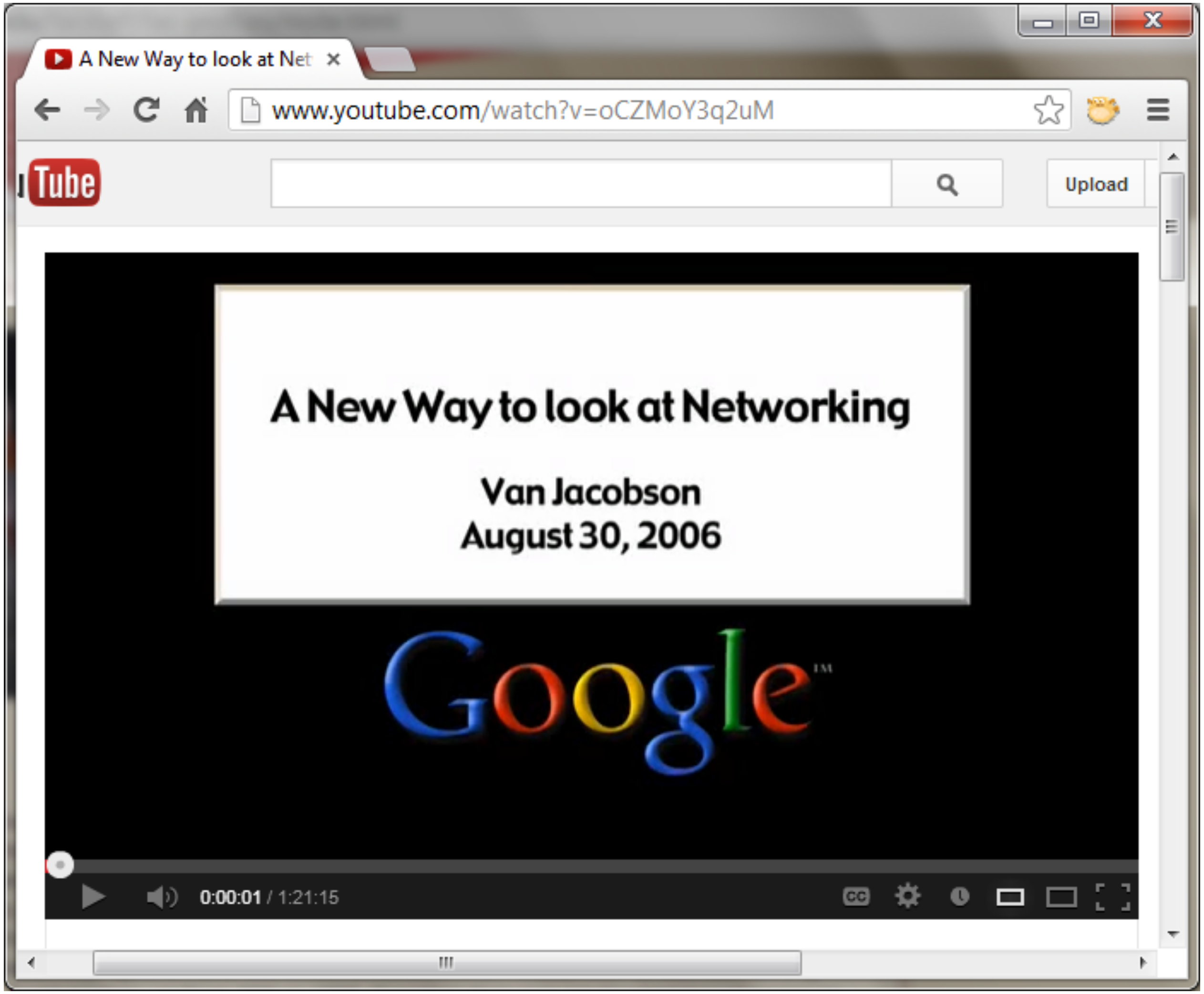
# How well IP serves today's applications

Example 2: emerging network applications

"ROOM5 temperature?"



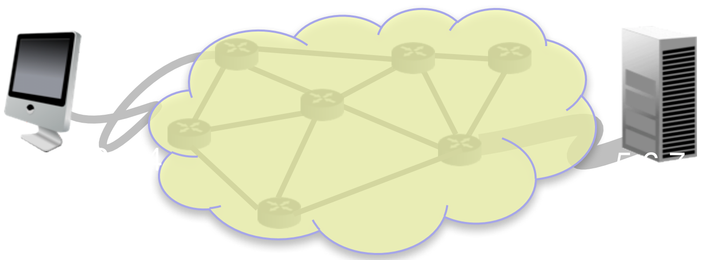

"Turn on air conditioner"



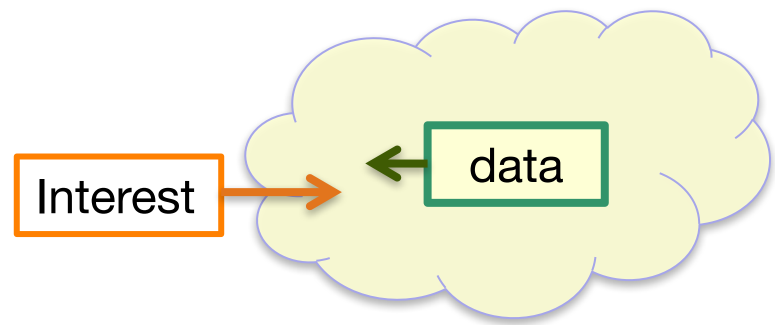

https://www.youtube.com/watch?v=oCZMoY3q2uM

# Core Idea

Today's Internet is based on host-to-host connections



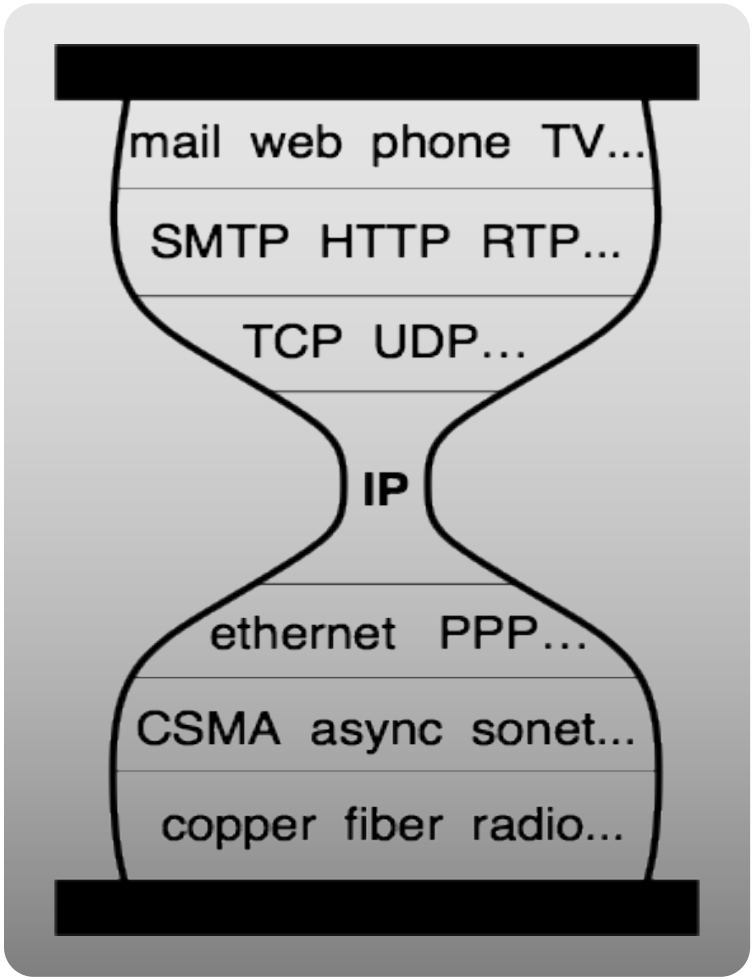
Modern communication consists of requests for named data



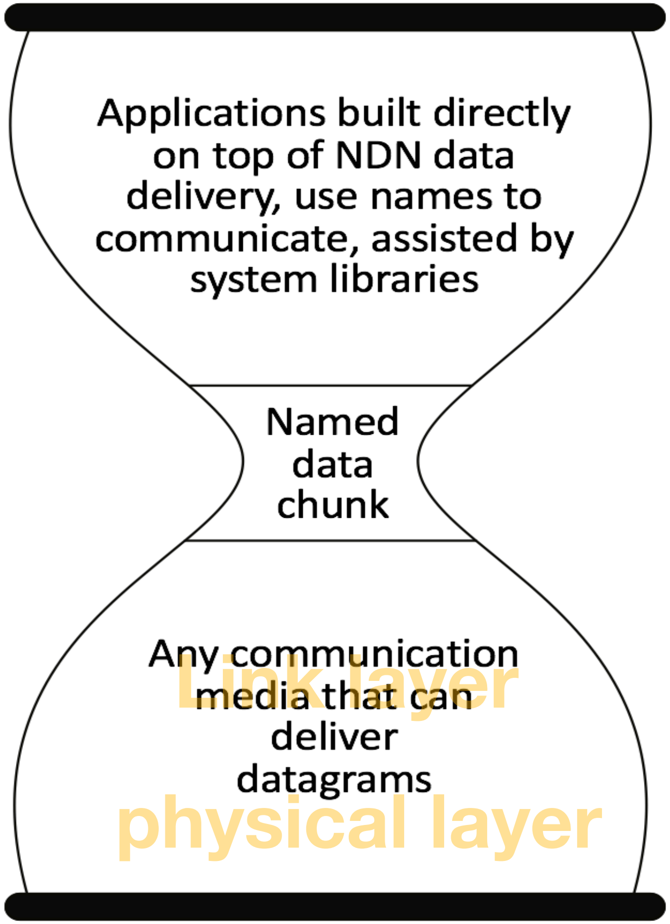

NDN: a general-purpose network protocol supporting requests for named data

# NDN: Preserving Hourglass Shape

TCP/IP




NDN



# Two Packet Types

Interest packet

| **Data name** (may carry a few optional parameters) |
|---|

Data consumers send Interest packets

Data packet

| **Data name** |
|---|
| meta information |
| Data |
| **Crypto signature** |

*Whoever* has the matching Data packet can reply

- Publisher binds name to data; receivers verify
- No address !

# Content Naming

- Names are generated by applications, opaque to the network
  - Packet granularity
  - Hierarchical
    - identify content relationship & facilitate aggregation
  - Every data packet carries a signature, binding the name to the content

User/application supplied name

**/named-data.net/videos/content-centric-networking/version#/segment#**

Globally routed name

application

Application instance

Naming convention/
automatic

# Applications fetch data by names, today

- My browser: get nytimes.com
- What happens today:
  - Translate that name to IP addresses
  - identify packets by piecing together parameters from multiple protocol layers
    - nytimes.com → destination IP address
    - packets for nytimes.com identified by a combination of

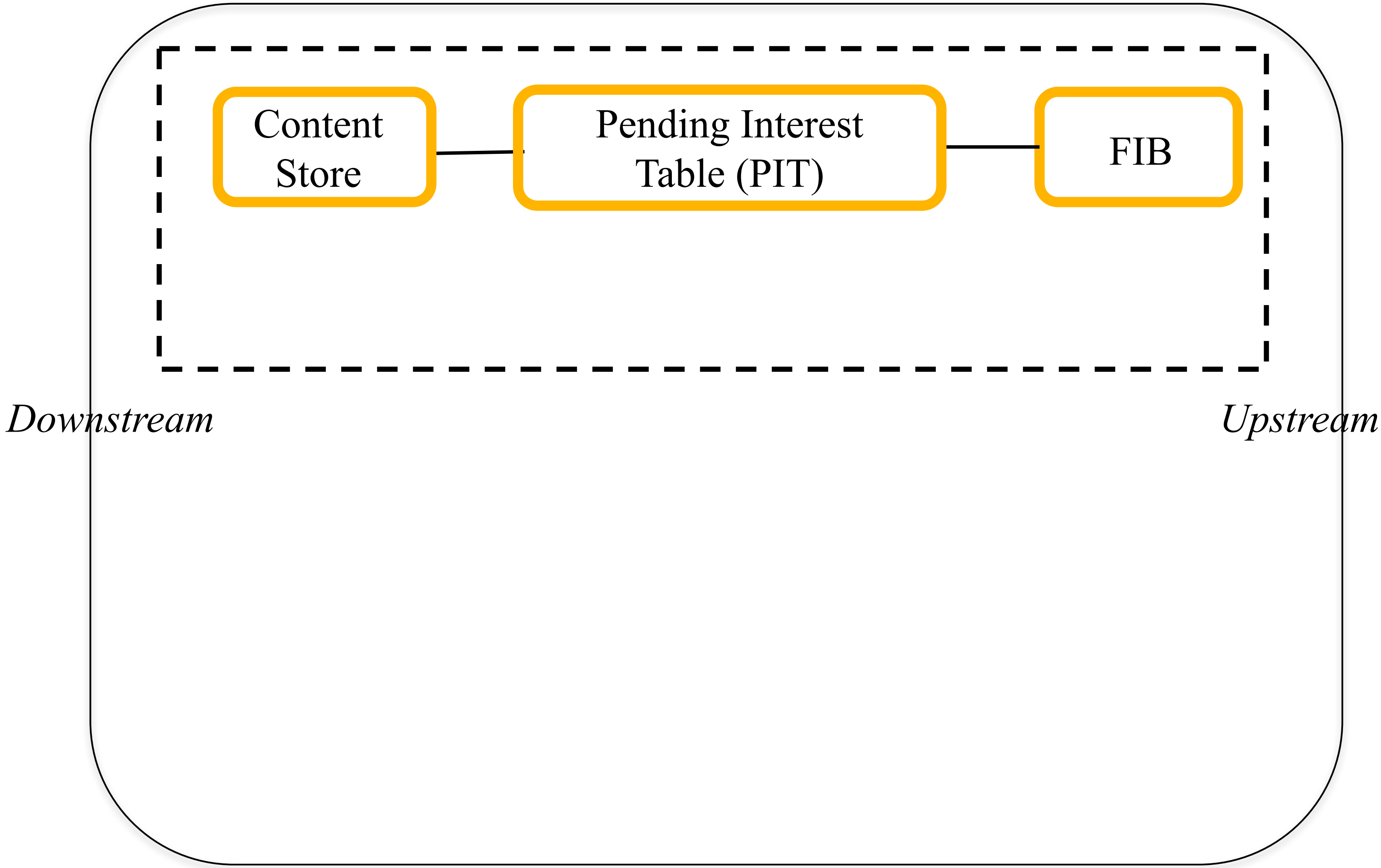
[senderIP, recvIP, Protocol-ID, send-port#, recv-port#, seq#]

# Doing the same in NDN:
# a much simpler picture

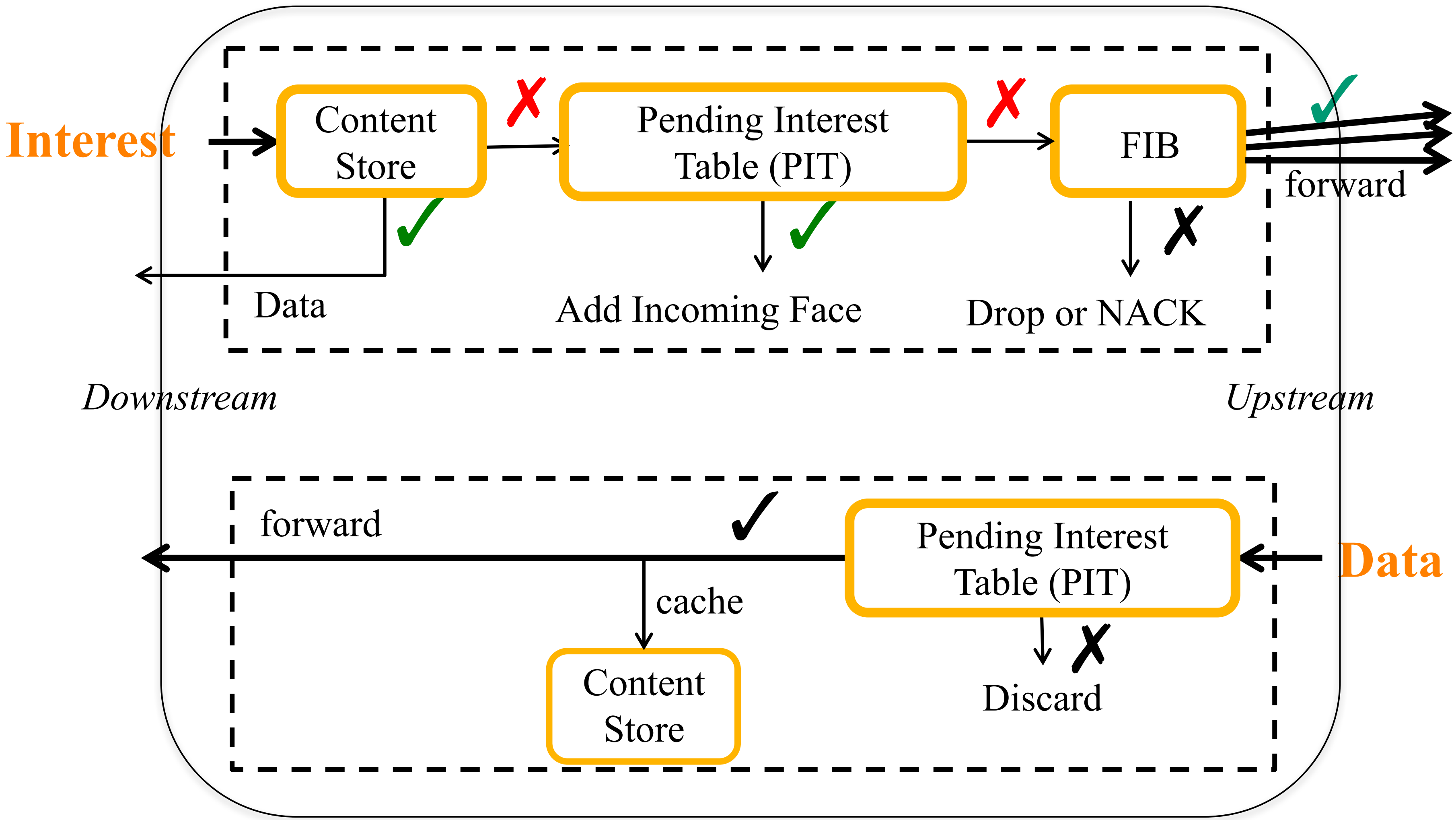
To retrieve front page of nytimes.com

- My browser: Send an Interest with name
  /nytimes.com/web/index.html
- NewYorkTimes Web server: listening for any incoming Interest with the name prefix
  /nytimes.com/web/
  - Receive the Interest packet
  - Create data packet, *add signature*
  - Send out to the incoming interface of the Interest

# NDN’s node model



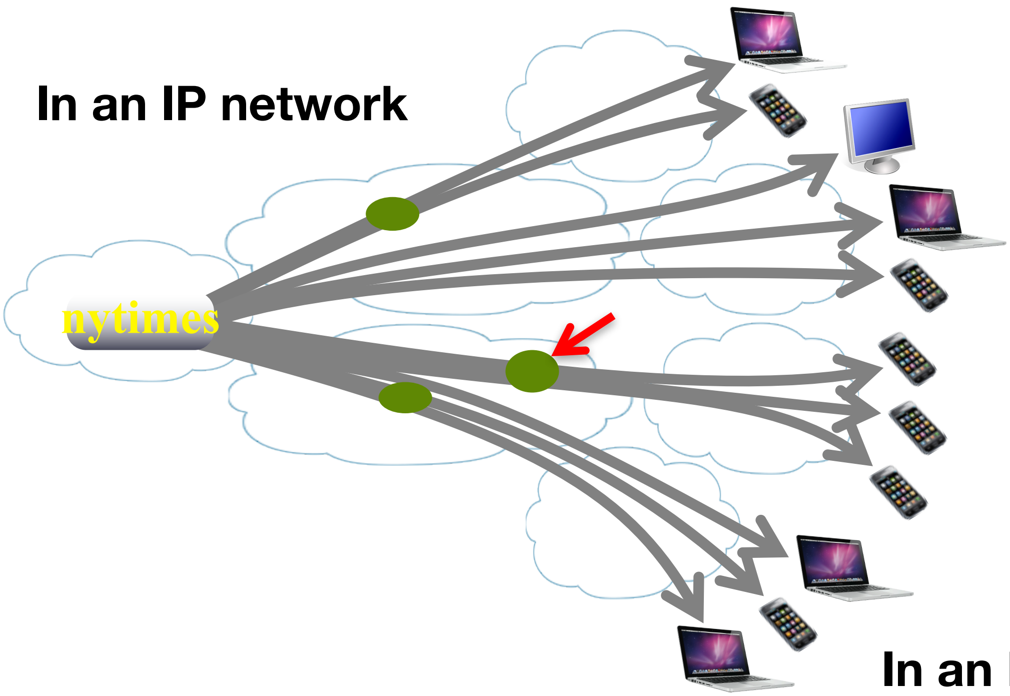
# NDN's node model




2-way packet flow, fetch, stateful, with storage

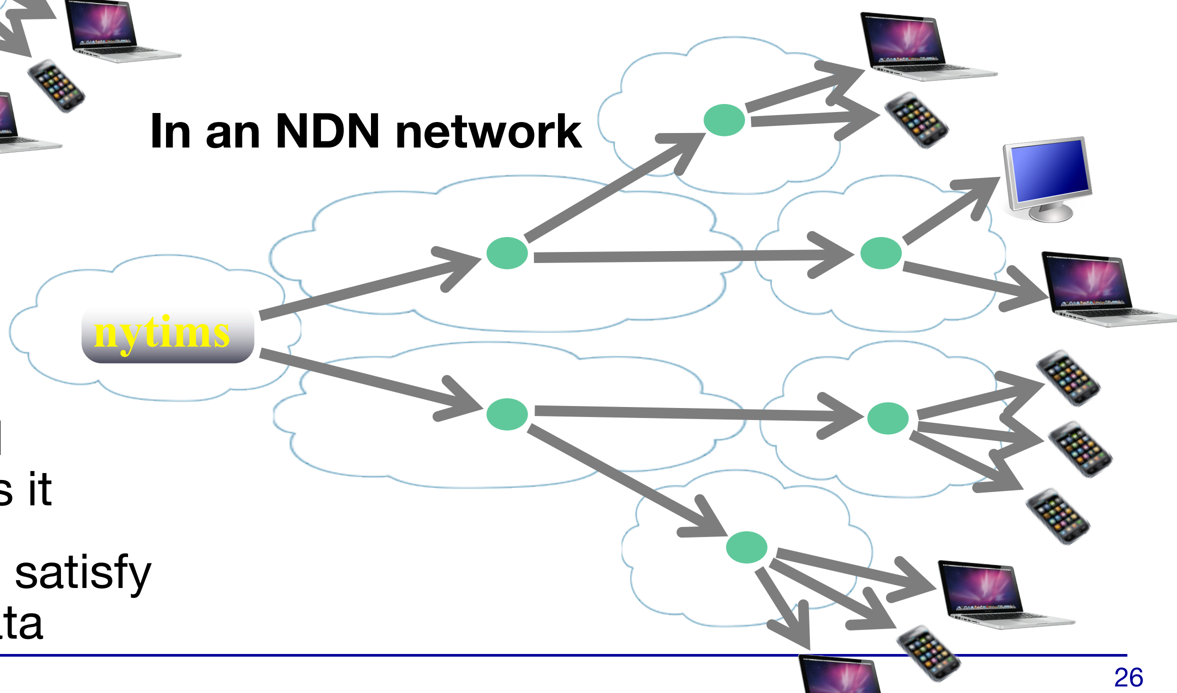
# What’s the difference to the network

In an IP network




- Router forwards each packet towards its destination
- The packet is useless after been forwarded

In an NDN network

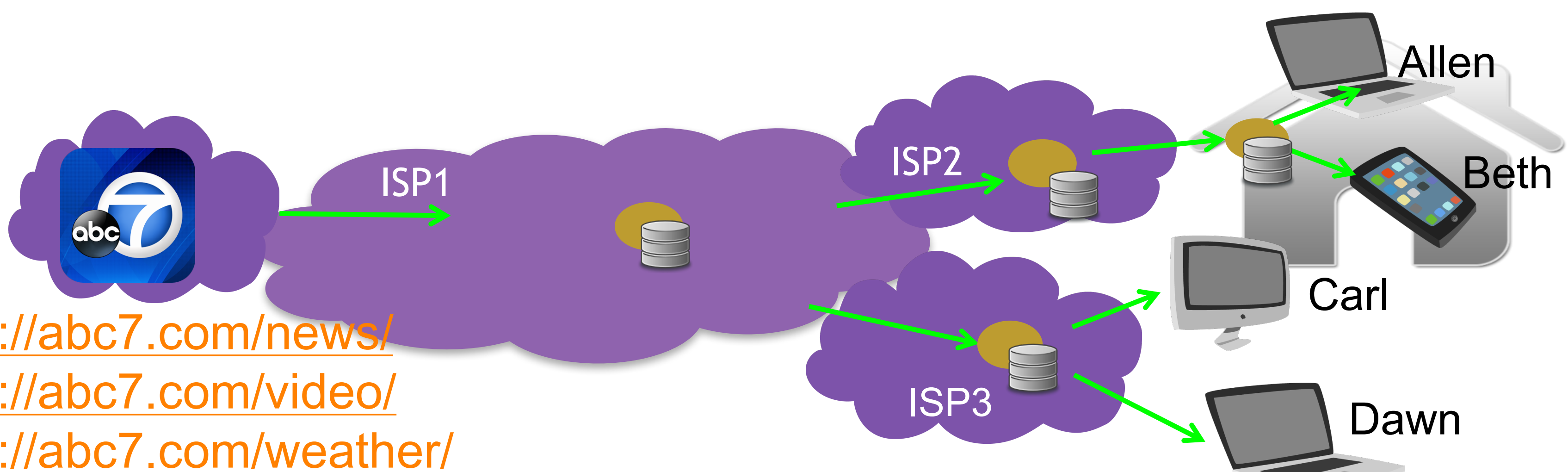



- Each data packet is meaningful independent from who requests it
- Data packets can be cached to satisfy future requests for the same data

# How well NDN can serve applications

Example 1: content delivery

- Network uses app. data names for delivery
- Multiple users request the same data: net can retrieve from nearby copy
  - Name + data-signature enables in-network storage




http://abc7.com/news/
http://abc7.com/video/
http://abc7.com/weather/
http://abc7.com/news/1-killed-in-60-freeway-crash-in-city-of-industry/

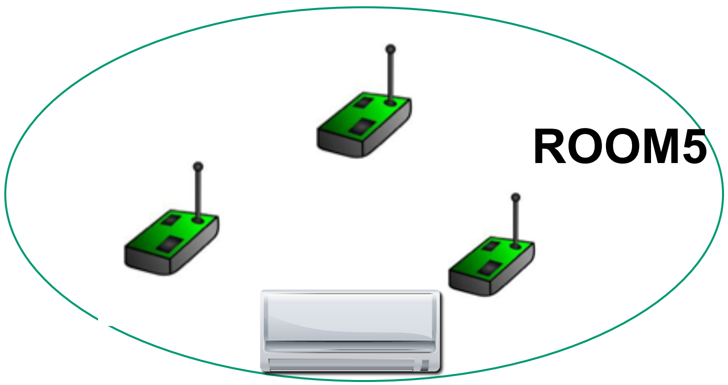
# How well NDN can serve applications

## Example 2: emerging network applications

**“ROOM5 temperature?”**

INTEREST(/ucla/bldg#/room5/temp) →

← DATA (name|data|signature)




**“Turn on air conditioner”**

INTEREST(/ucla/bldg#/room5/AC-on/sig) →

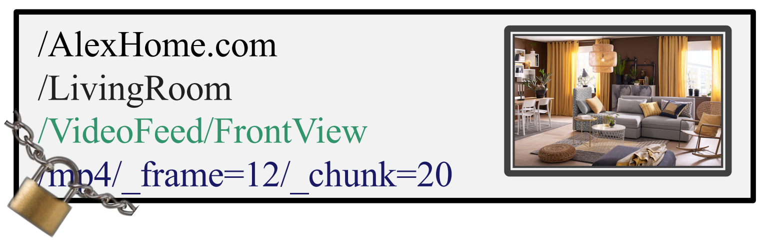
← DATA (name|ACK|signature)

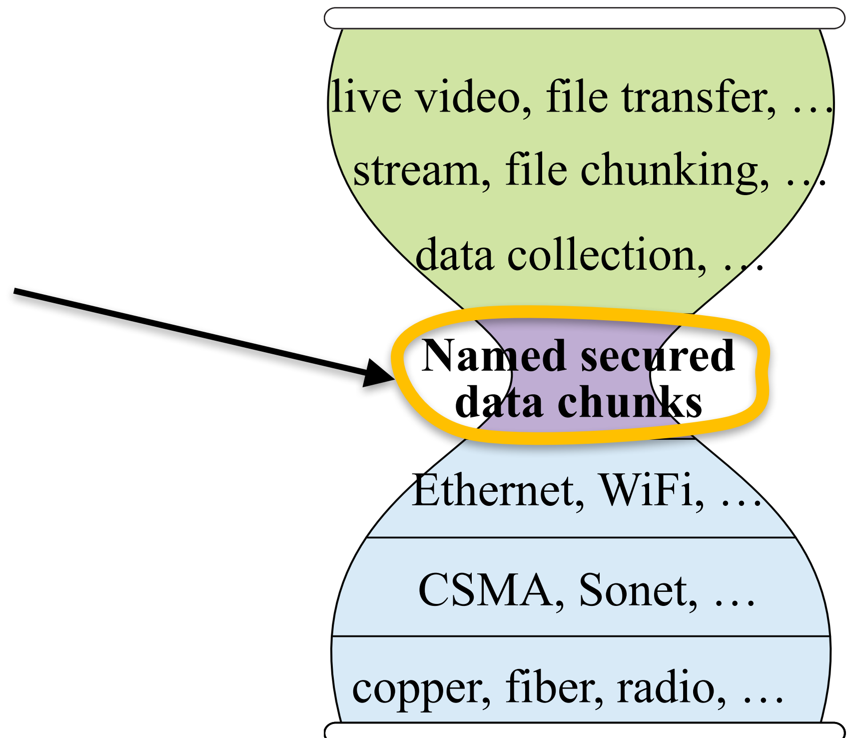
INTEREST(/traffic/LA/HW405/location) →

← DATA (name|data|signature)

# Named Data Networking: Built-in Security

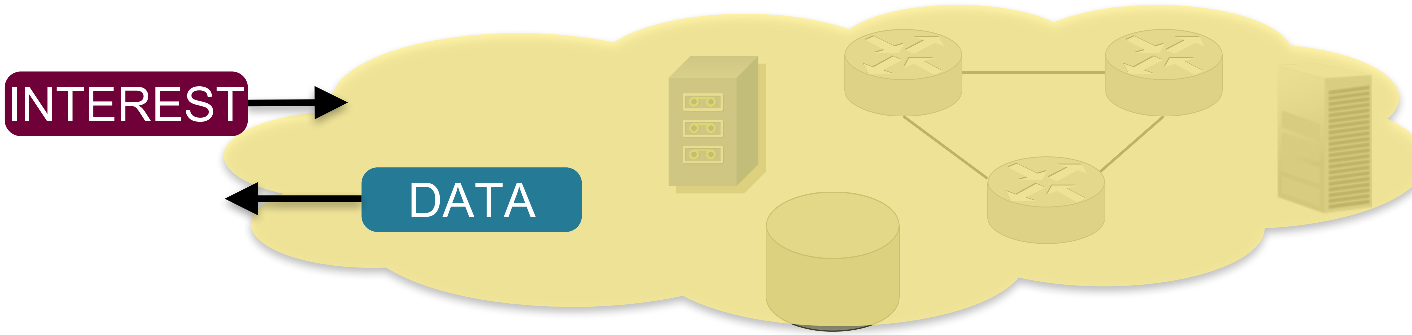
- Hierarchically structured names, shared between application and network layers
- Security
  - Built-in into the networking layer




- Focus on application data
  - Data secured in motion and at rest
- Universal mechanism
  - Same security mechanisms for networking, transport, and application layers

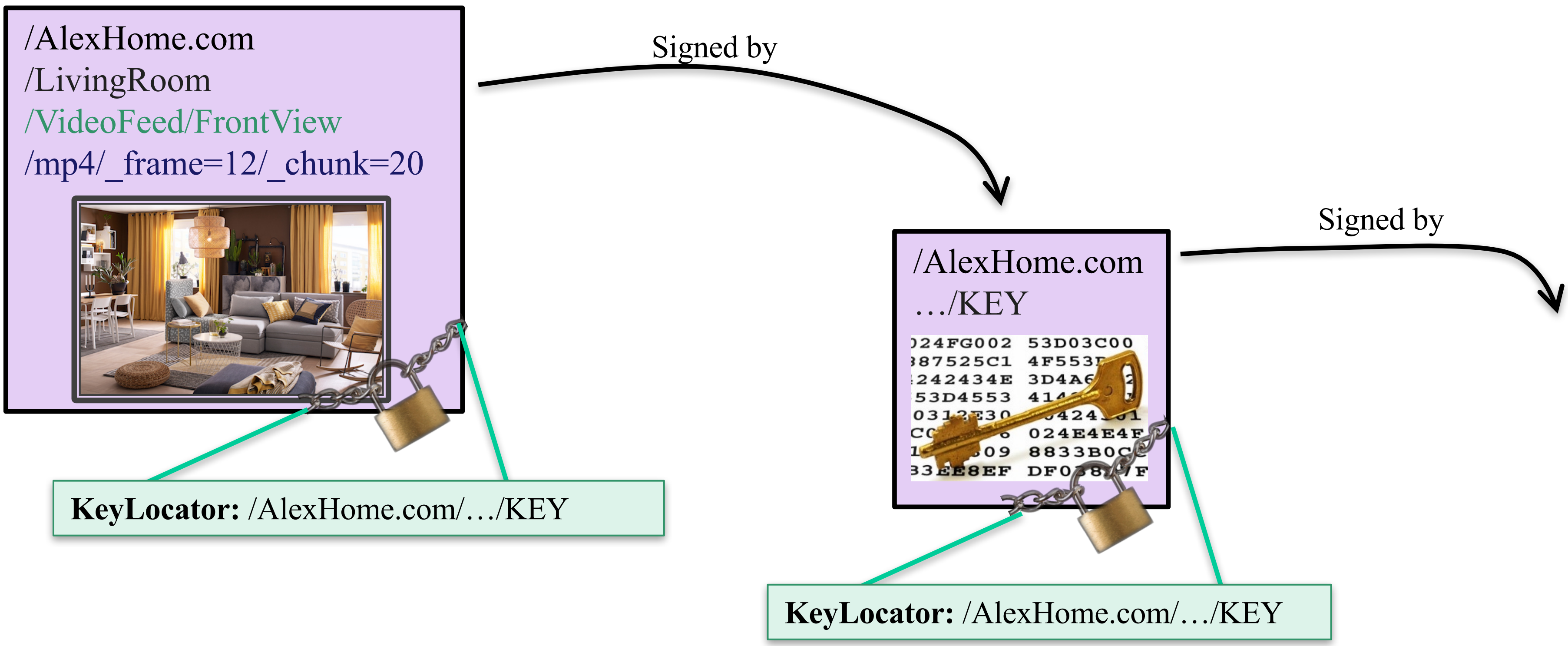
# Security: built into the narrow waist




- Every data packet is signed
  - encrypted whenever needed
  - Data always secured, whether in motion or at rest
- Keys retrieved in the same way as any other content objects

How to verify a key: trust management

# How NDN's Data-Centric Authenticity Works?



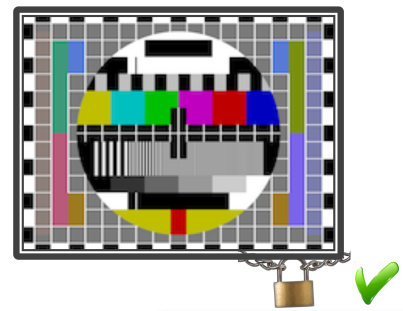
# Not Just One Key

**/AlexHome.com/LivingRoom**/Video Feed **/FrontView**/mp4/_frame=12/_chunk=20

/AlexHome.com/Camera/KEY

A frame from a camera I have installed in my living room

**/AlexHome.com/LivingRoom**/Video Feed **/FrontView**/mp4/_frame=42/_chunk=1



/AlexHome.com/TV/KEY

TV incorrectly trying to publish living room feed

# NDN Transport Function

- What TCP does today
  - Demultiplexing
  - Reliability (including sequencing)
  - Congestion control
  - More recently: multipath TCP
- In NDN
  - Demultiplexing: by names directly
  - Reliability: controlled by applications directly
  - Congestion control: by network layer
  - Multipath forwarding: by network layer

# NDN: Just 3 Simple Ideas

1. Naming data

   → Routing & forwarding by names

2. Securing every data packet

   → removing dependency on transport security

3. Per Interest, per hop forwarding state

   → Creating closed feedback loop

   - measure performance, detect failures

   → Enabling multi-path forwarding

   - Add a strategy module to assist the forwarding decisions

# The road to a new architecture

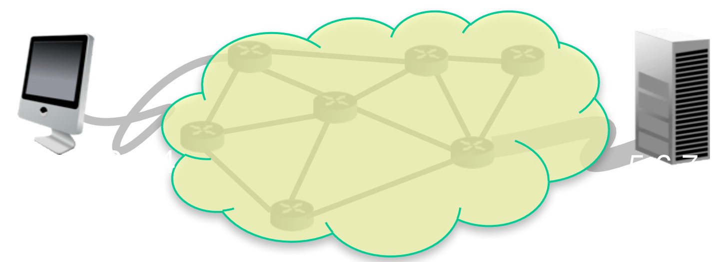
- Application-driven development
  - Running code, useful apps, testbed with real traffic
  - tackling emerging environments and applications where no good IP-based solutions exist

- Incremental Deployment
  - NDN runs on everything, and everything runs on NDN
  - Start as an overlay, the same way as IP did

# What to take home

- Future of networking lies in recognizing the right communication abstraction

- IP conceptualizes communication as between nodes



- NDN directly focuses on the outcome: retrieving data