Named Data Networking

Lixia Zhang

UCLA Computer Science Department

August 12, 2014

NDN Team

UCLA

Jeff Burke
Van Jacobson (architect)
Lixia Zhang

UCSD

Kim Claffy

Colorado State University

Christos Papadopoulos

ARIZONA

Beichuan Zhang

THE UNIVERSITY OF MEMPHIS

Lan Wang

UNIVERSITY OF MICHIGAN

Alex Halderman

ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Tarek Abdelzaher

Washington University in St. Louis

Patrick Crowley

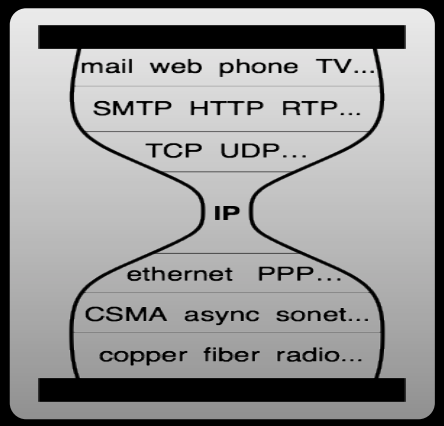
Marching Order

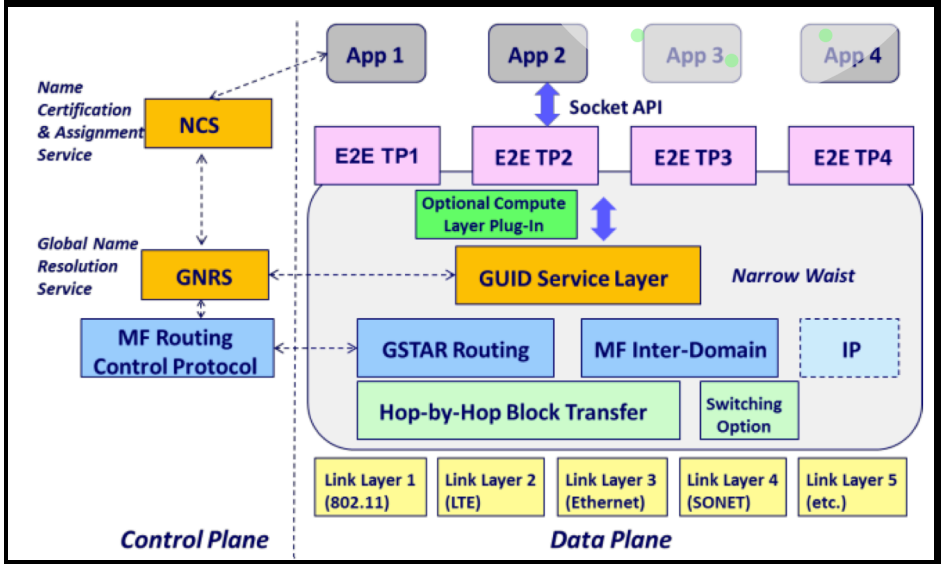
"We would like to become smarter about NDN/CCN and other new approaches to networking:

- What is it?
- How does it work?
- How will NDN change things?
- What is the current status?
- What are the research needs?"

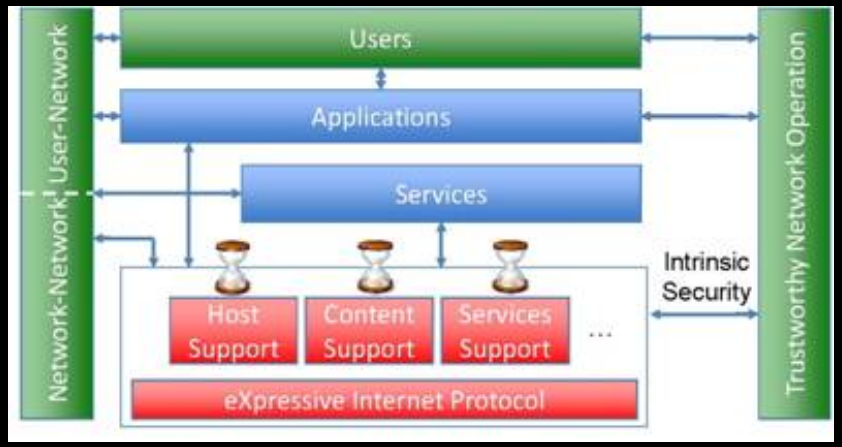
Multiple new approaches to networking

- Software Defined Networking
- Mobility First





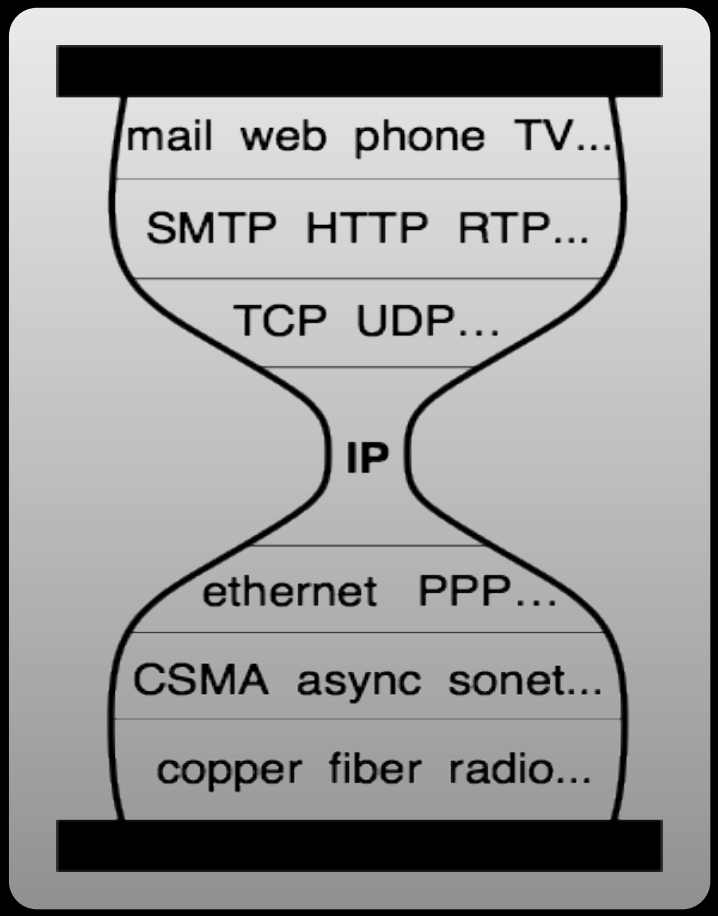
eXtensible Internet Arch. (XIA)



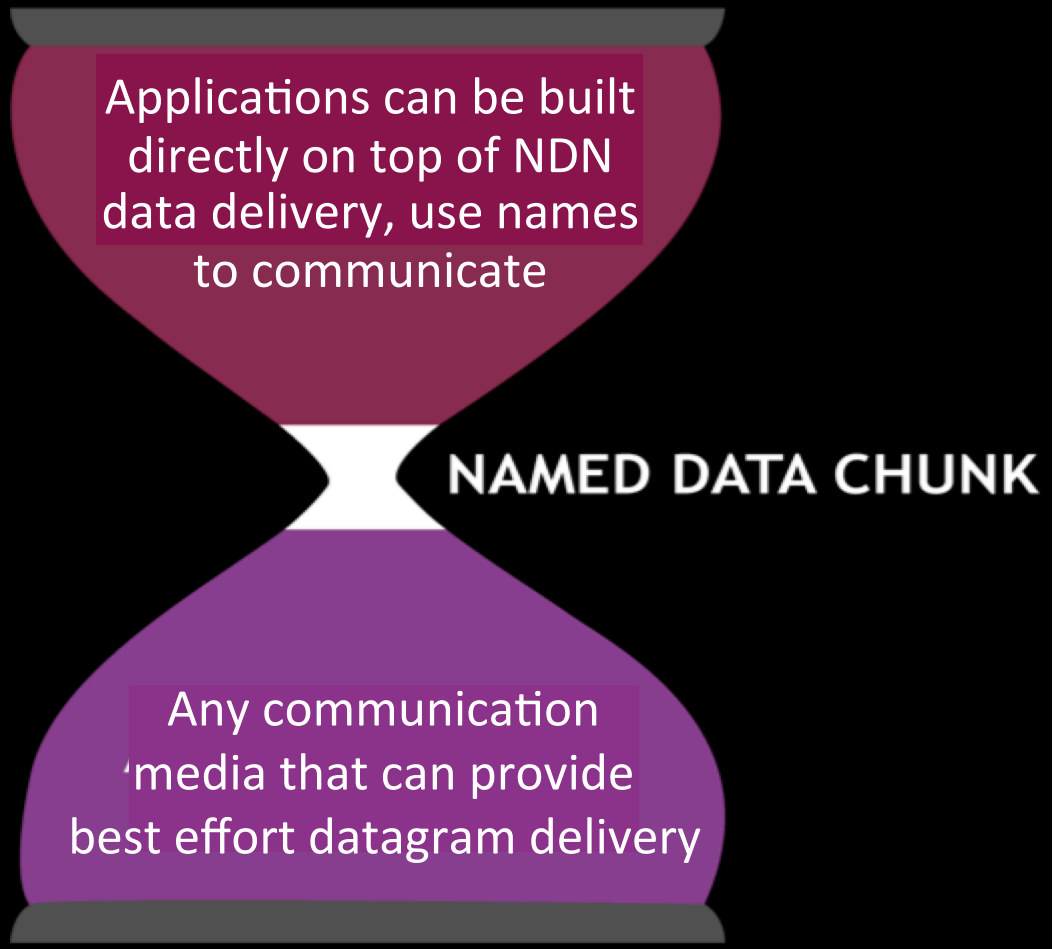
NDN: fixing the root cause – the TCP/IP architecture itself

NDN: What Is It?

TCP/IP



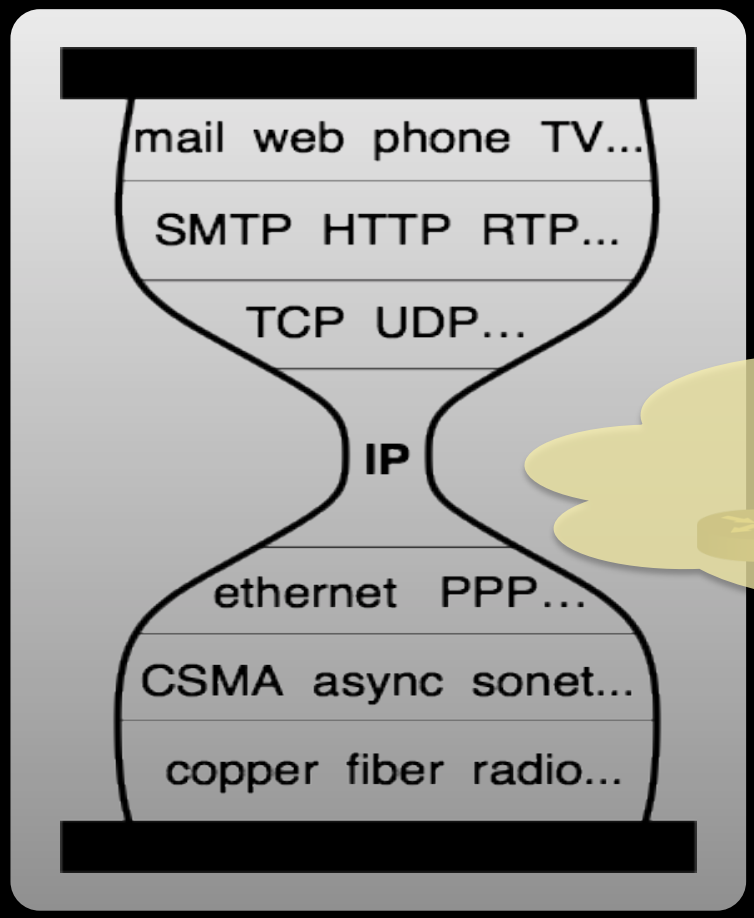
NDN



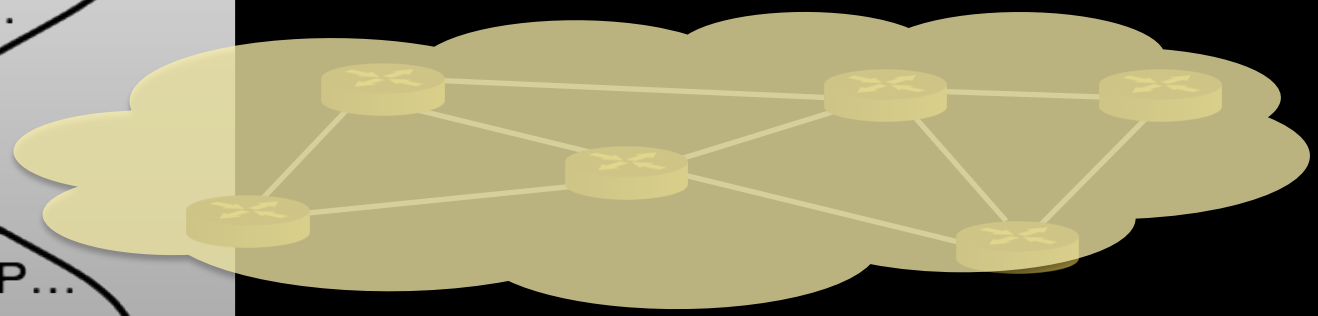
How does NDN work?

Best explained by comparison with IP

Today's TCP/IP Internet Architecture

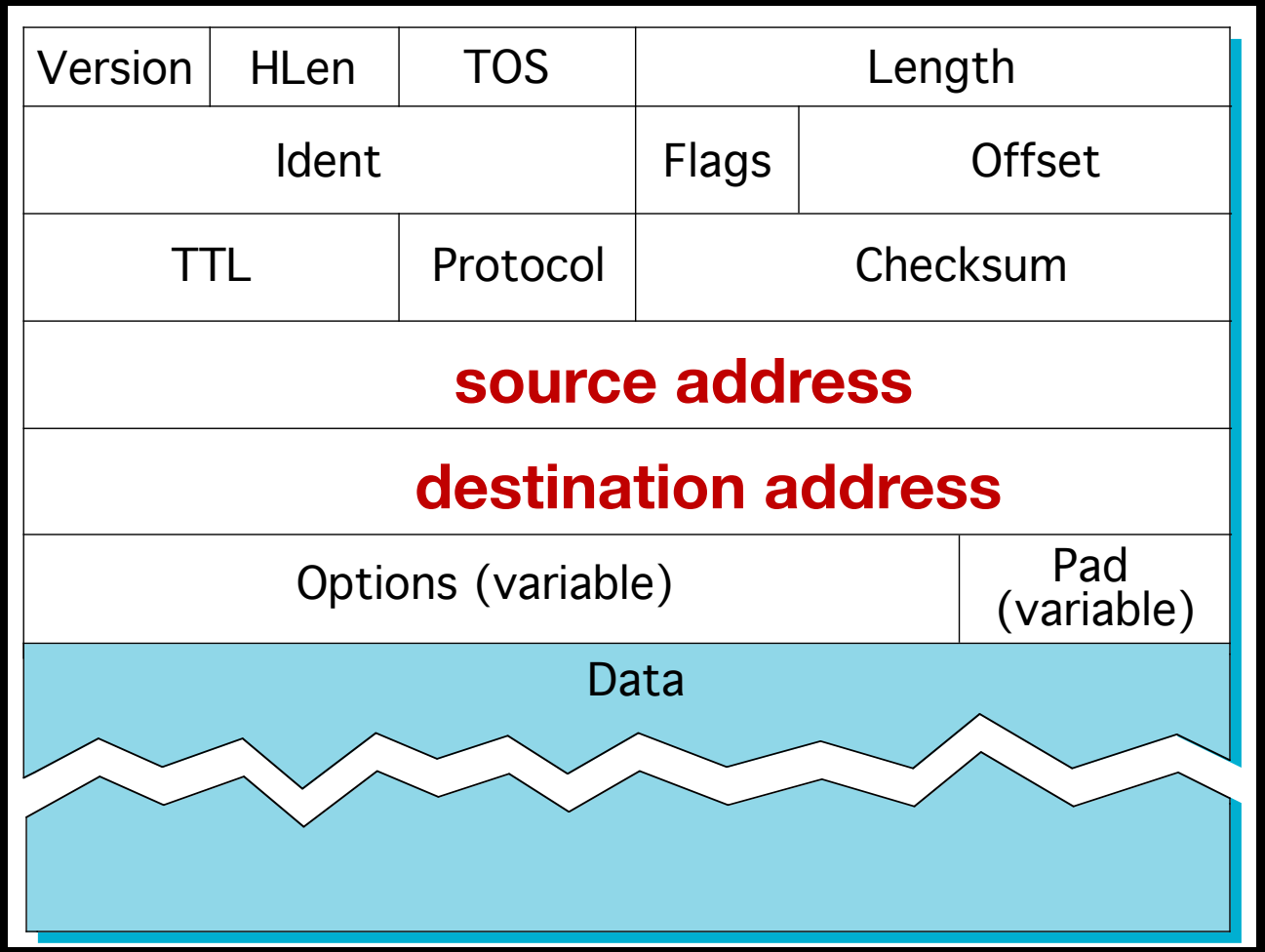


Best effort IP packet delivery to destination IP addresses

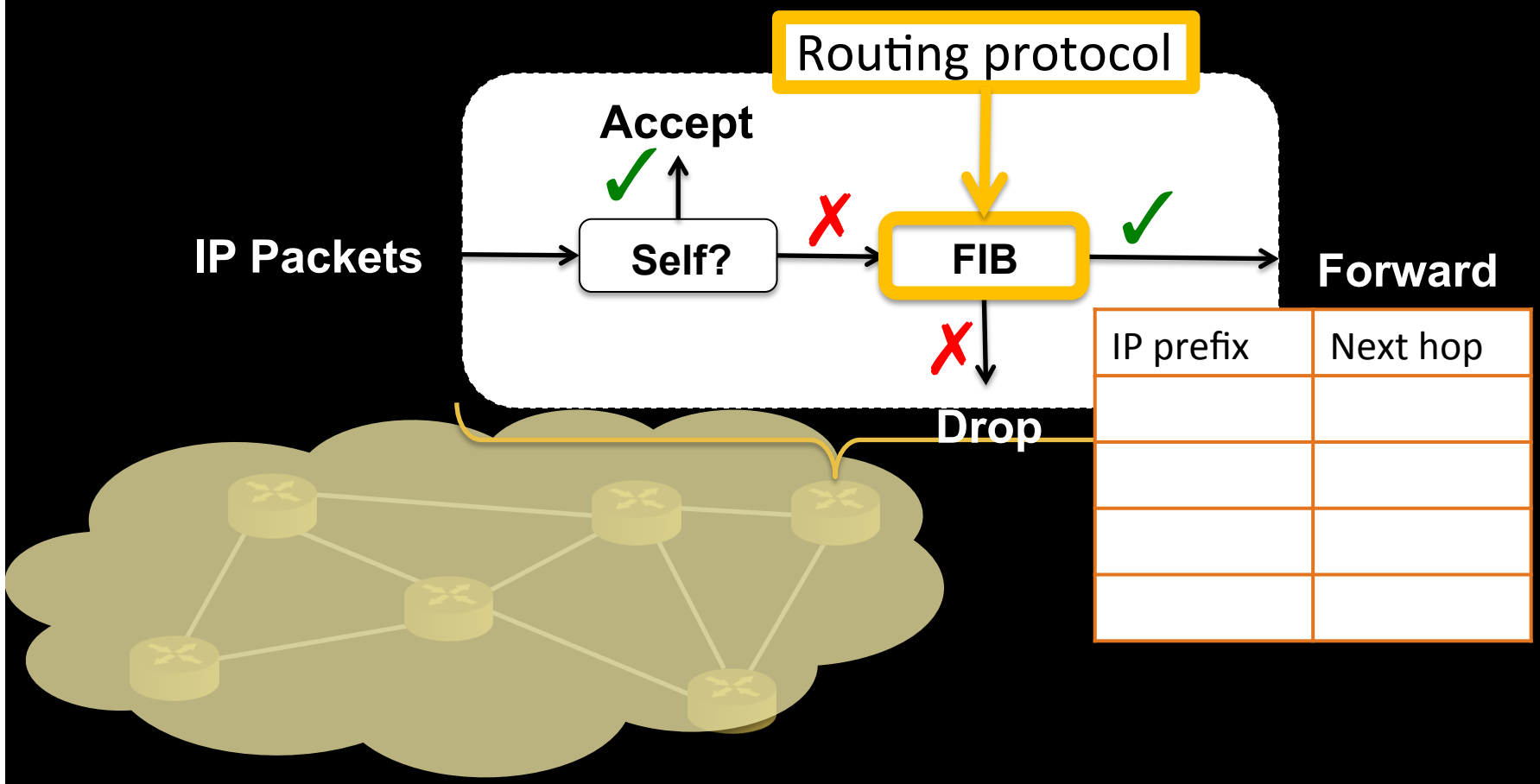


The anchor of the architecture: IP address space

IP Packet Format



IP' Node Model

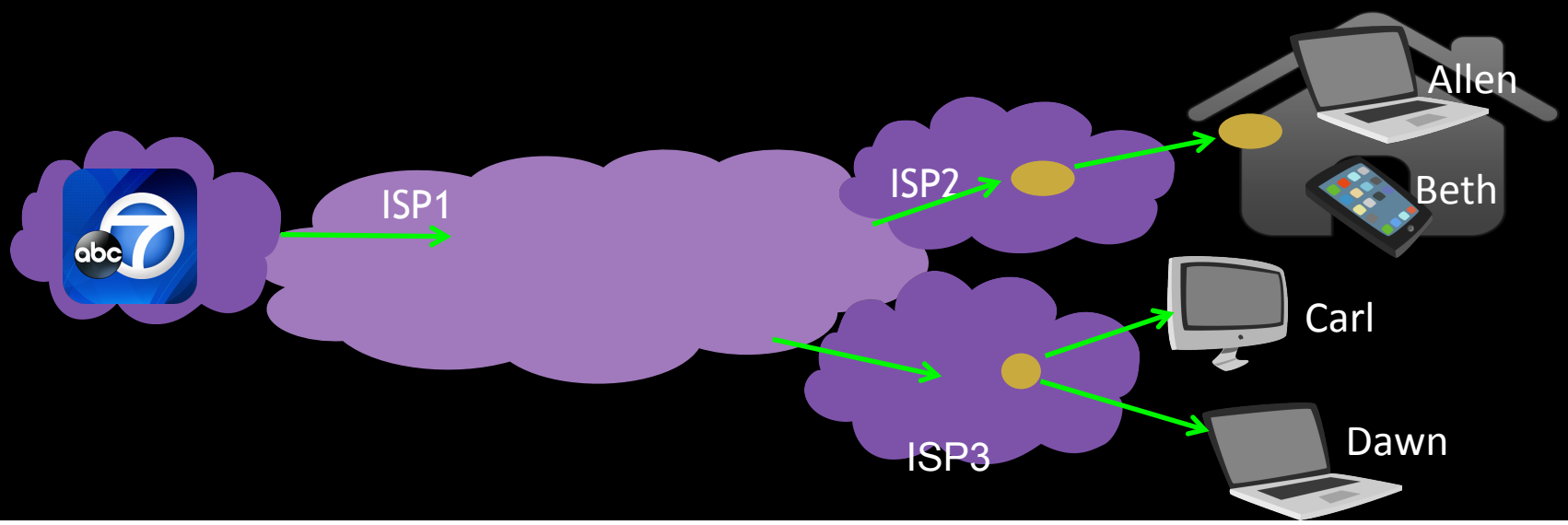


One-way traffic, stateless, no storage

How well IP serves applications

Example 1: content delivery

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

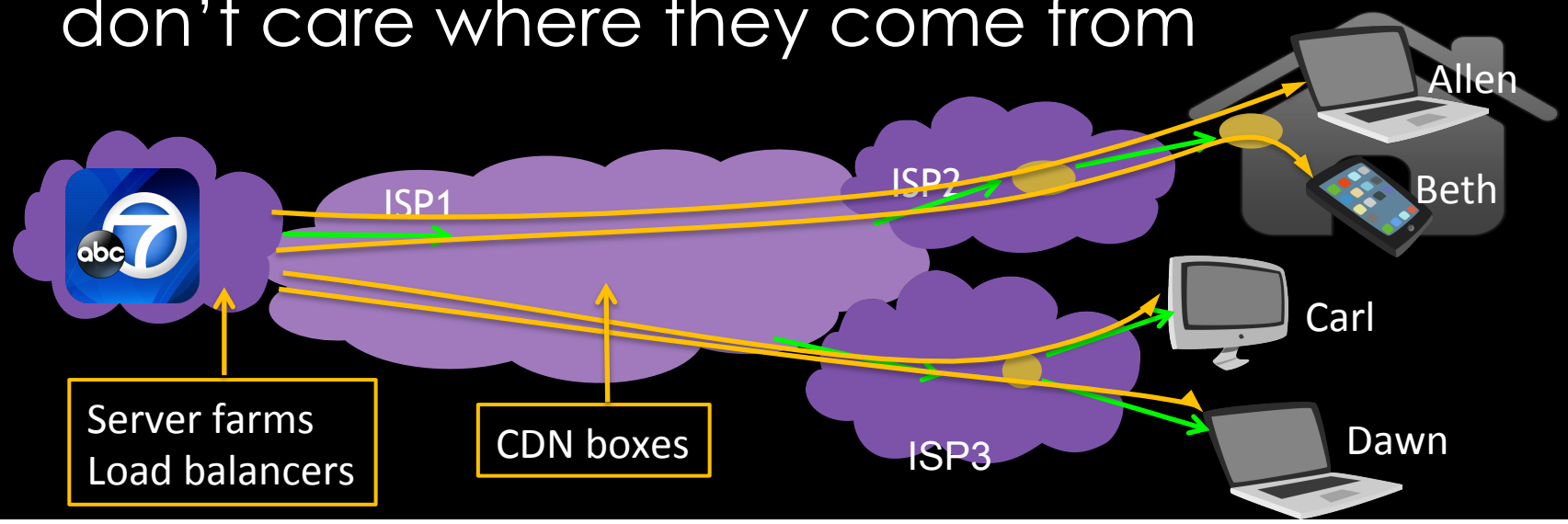


http://abc7.com
http://abc7.com/news/
http://abc7.com/traffic/
http://abc7.com/video/
http://abc7.com/weather/
http://abc7.com/news/1-killed-in-60-freeway-crash-in-city-of-industry/

How well IP serves applications

Example 1: content delivery

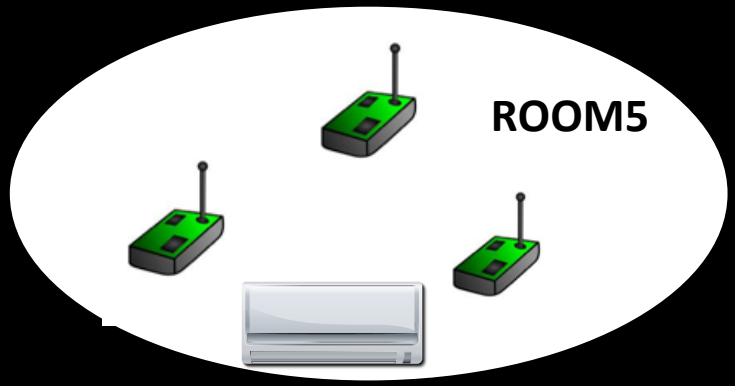
- Applications request data by names; network name packets by IP addresses
- IP delivers data between two end points
  - Multiple users may request the same data, don't care where they come from



How well IP serves applications

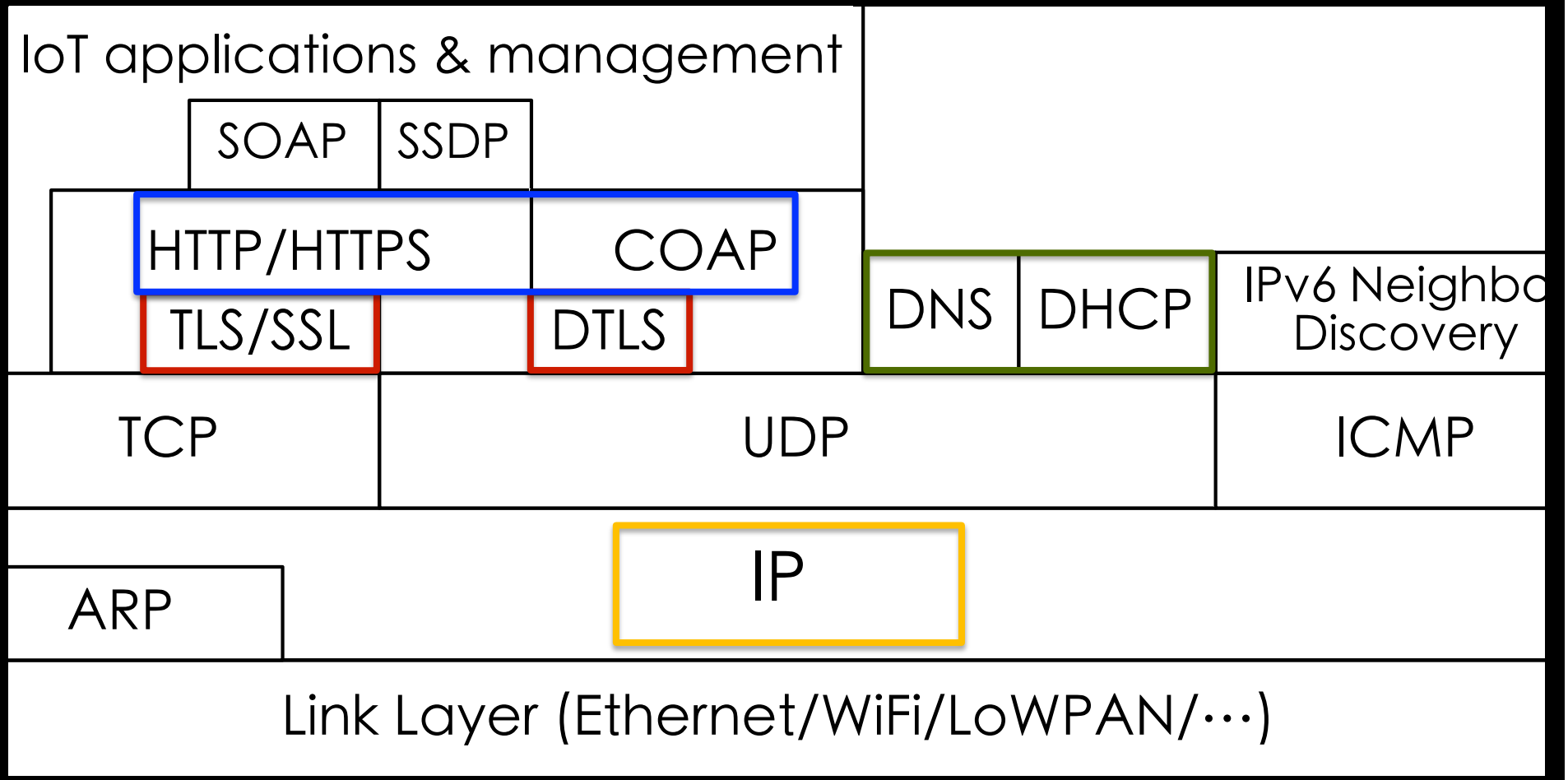
Example 2: emerging network applications

"ROOM5 temperature?"

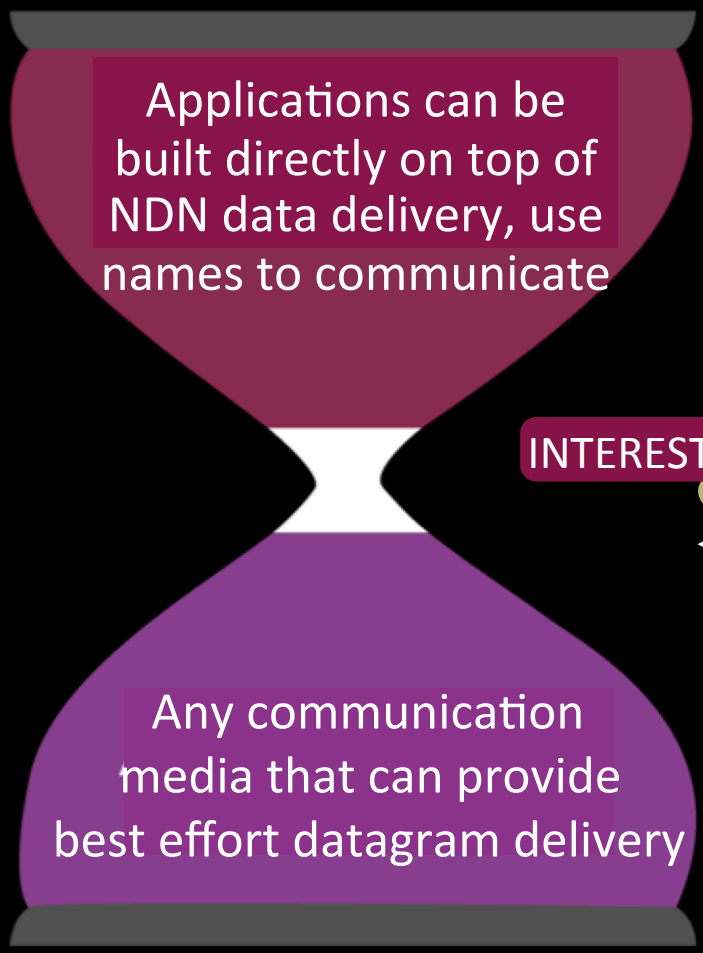


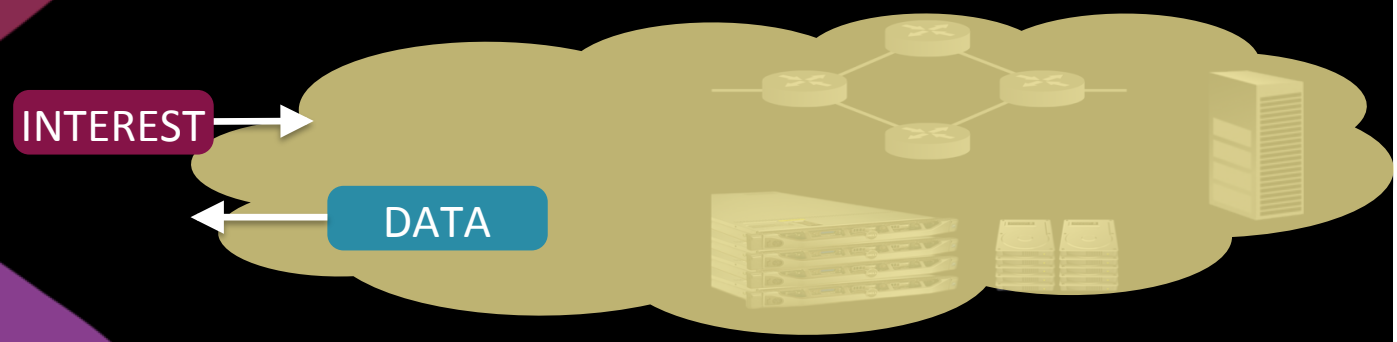
"Turn on air conditioner"

TCP/IP-based IoT architecture

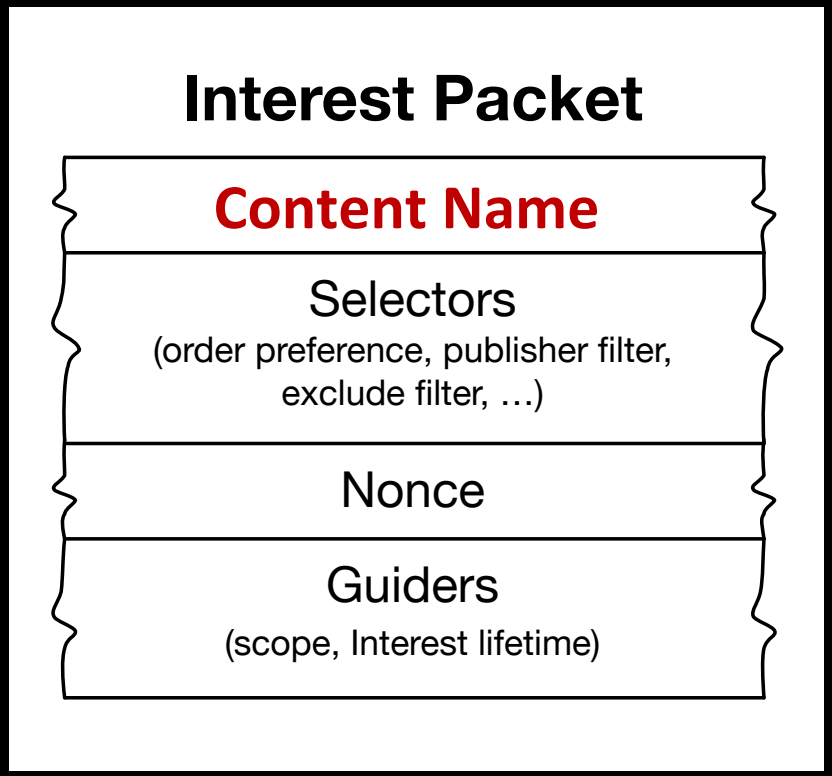


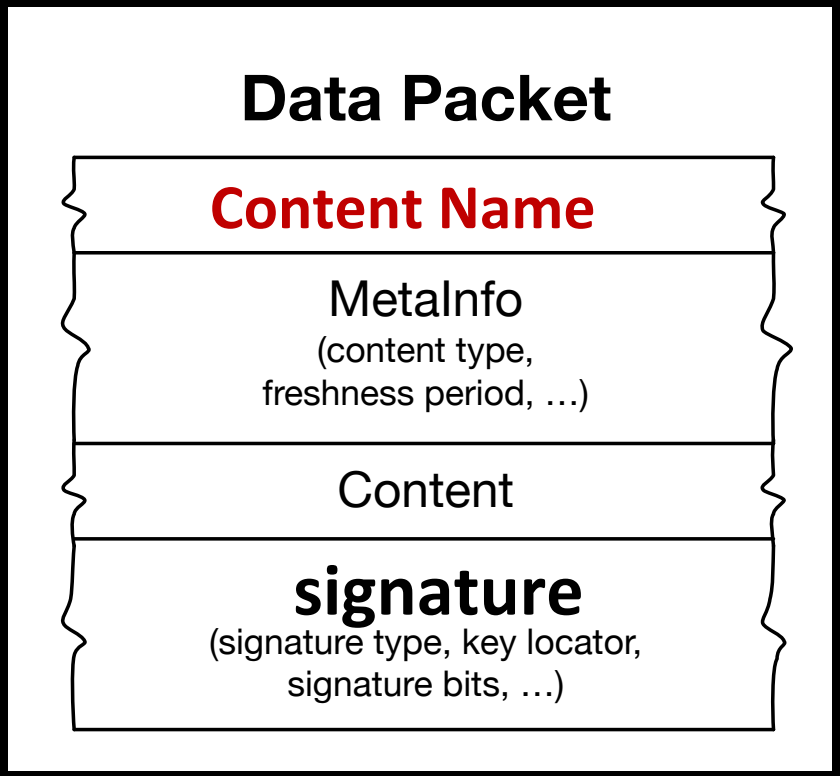
How does NDN work?





NDN Packet Formats



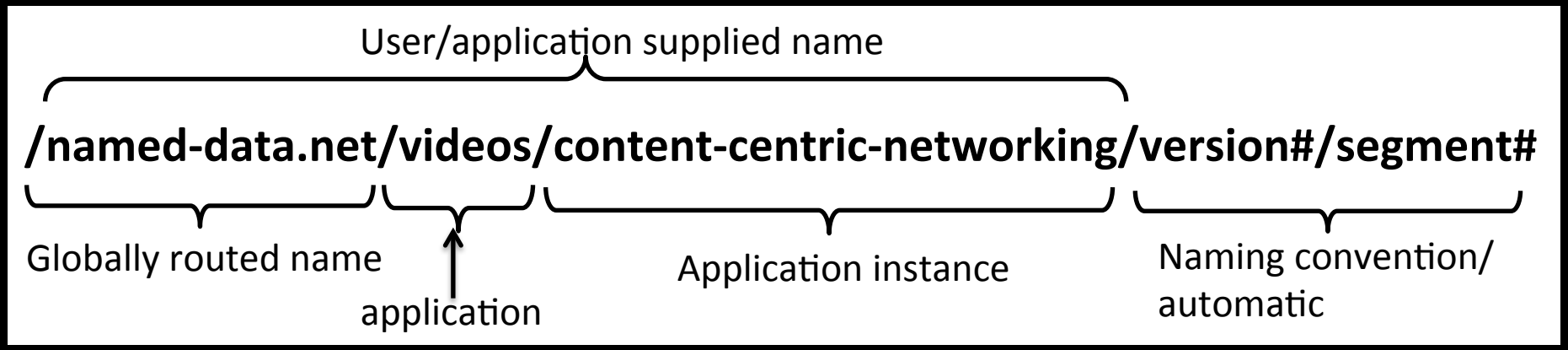


Data consumers send Interest packets

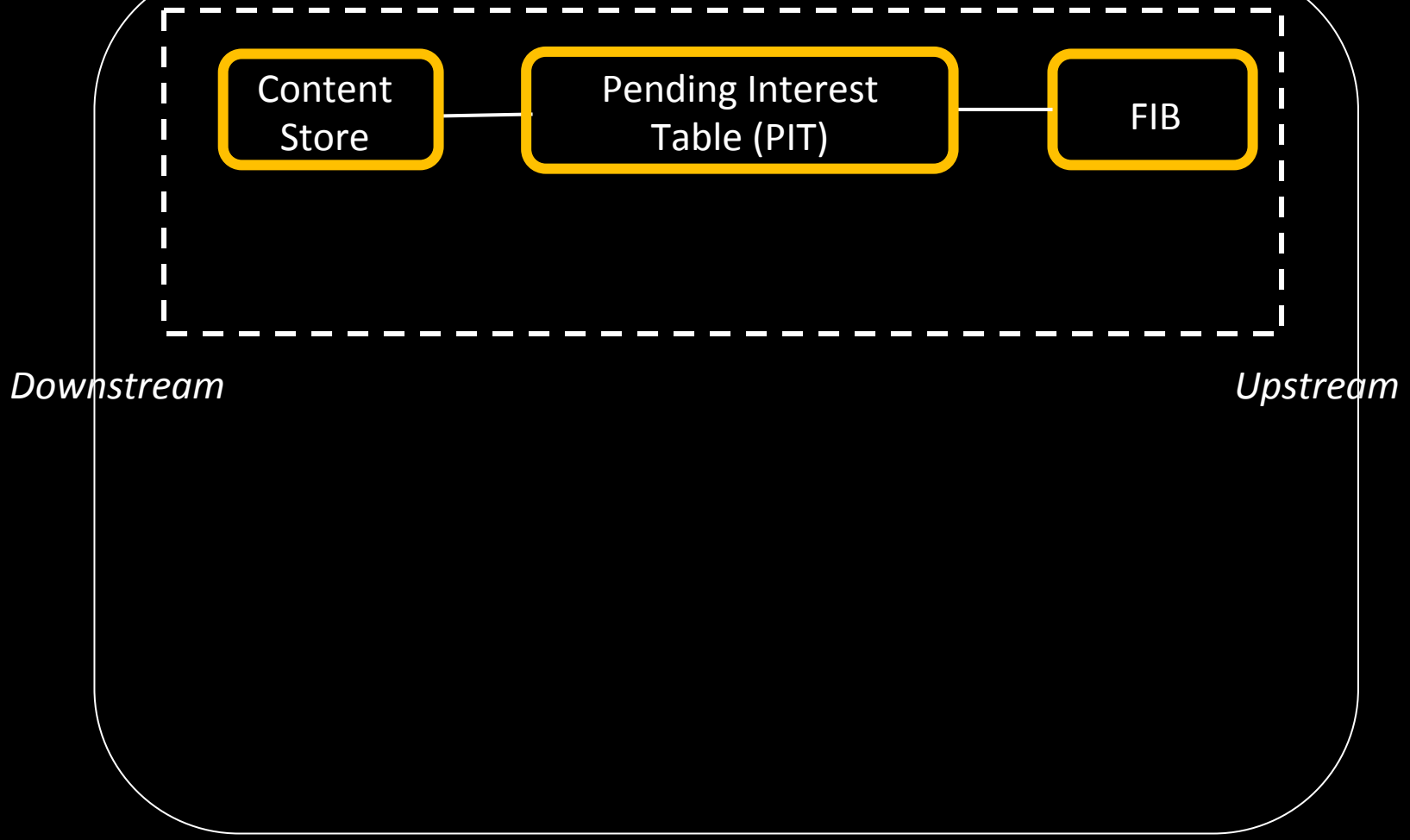
Whoever has the matching Data packet can reply

Content Naming

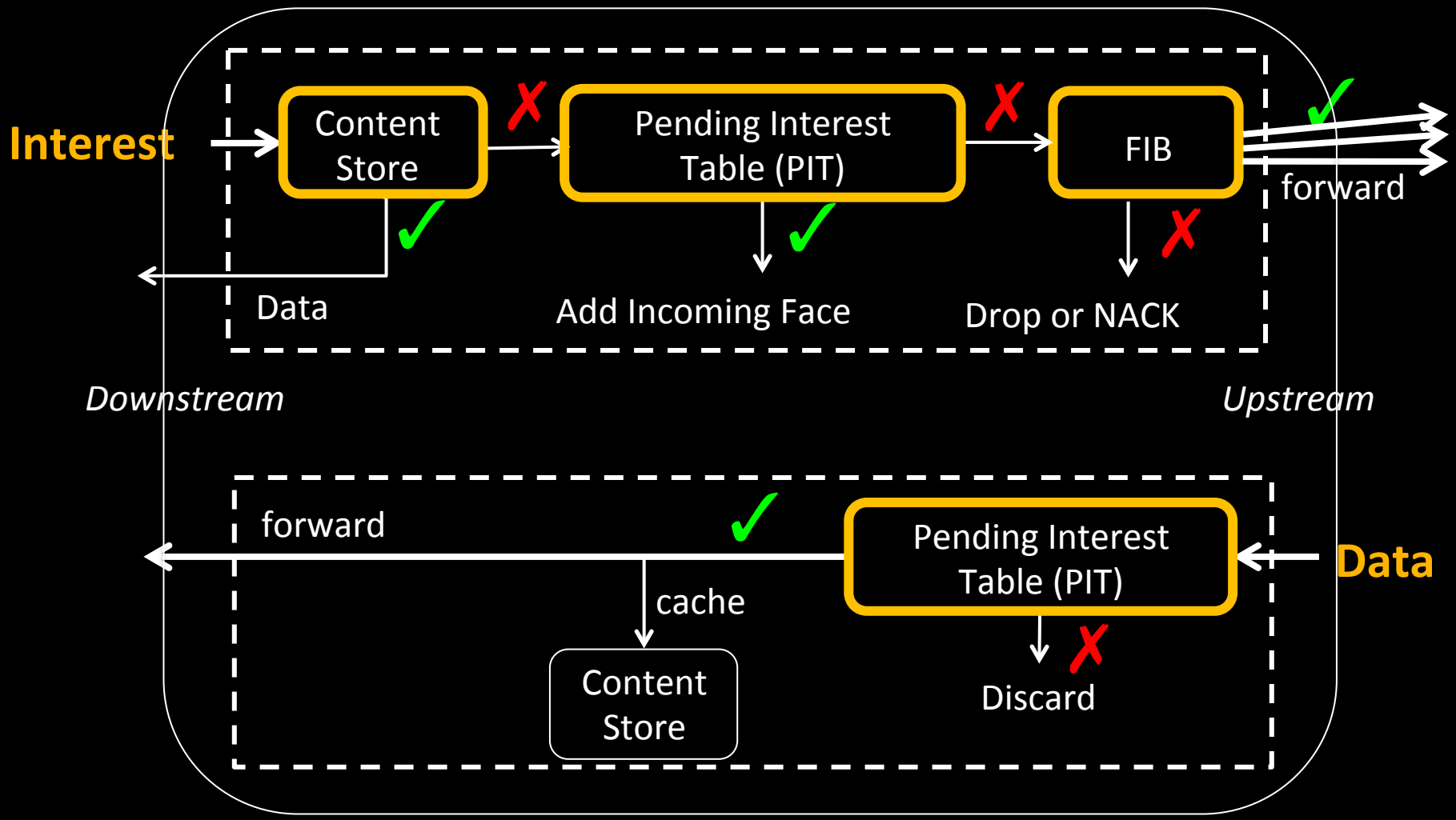
- Names are generated by applications, opaque to the network
  - Packet granularity
  - Hierarchical
    - identify content relationship & facilitate aggregation
  - Every data packet carries a signature, binding the name to the content



NDN's node model



NDN's node model



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

NDN's stateful forwarding plane enables

- Multicast delivery
- Scalable content distribution
- Multipath forwarding
- Closed Feedback loop
  - Built in performance measurement at every router
  - Congestion control

Forwarding Strategy

A new component at every forwarder

Takes input from

- FIB: each entry can have a rank-ordered list of output interfaces
- Forwarding policies
- Measured delay and throughput

Forwarding Strategy

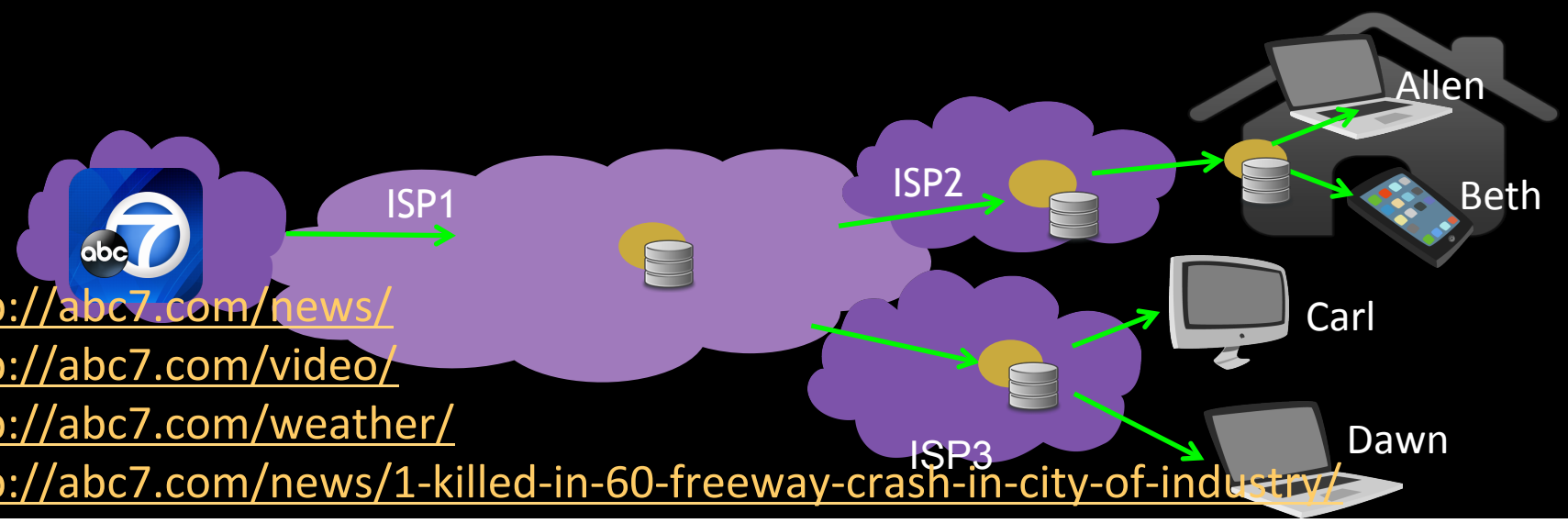
Make decisions on

- Which nexthop(s) to use?
- How fast to forward Interests to each neighbor node?
- If must drop/NACK due to congestion: which Interest?
- What to do when receiving a NACK, or an Interest timing out?
- etc.

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-sig. 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/

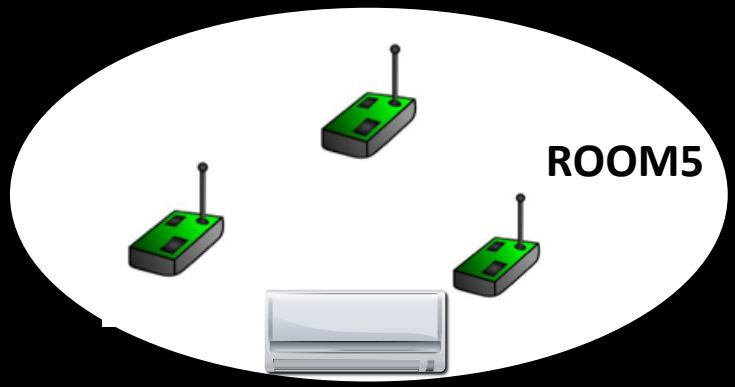
How well NDN can serve applications

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)

How well NDN can serve applications

Ex3: enterprise Building Automation & Management (E-BAM)

Addressing currently spread across many layers in the network:

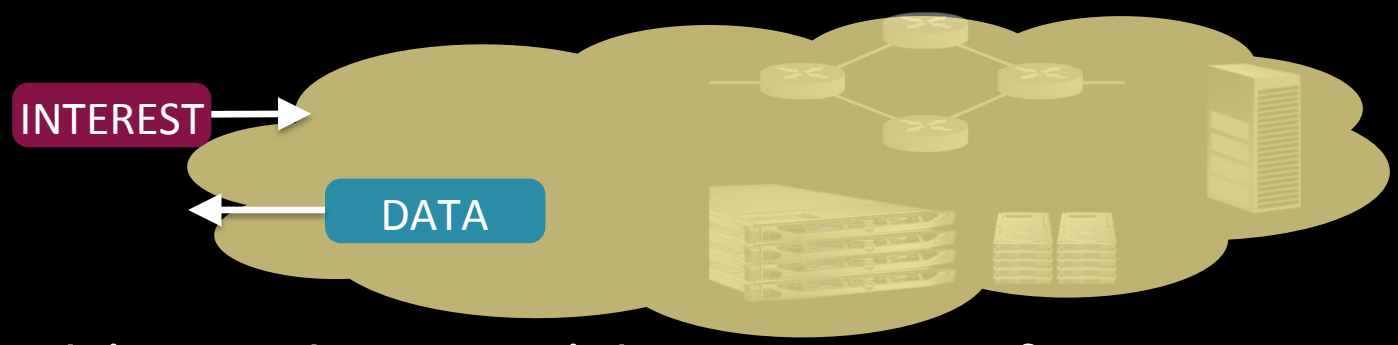
```
VLAN 4
IP 128.97.152.23
Port 4722
Universe 2
Channel 1
Descriptive name or URI
```

NDN namespace design:

- Name hierarchy follows building systems,
  - e.g., building => room > panel => sensor
  - example: /building/room/region/wall_west/downlight

Crypto keys for signing (or HMAC) follow the same hierarchical name space

Security: built into the narrow waist



- Name hierarchy provides context for trust
- Fine-granularity in key/trust management
- 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

Outline

- What is it?
- How does it work?
- How will NDN change things?
- What is the current status?
- What are the research needs?

How will NDN change things?

Address the fundamental challenges facing Internet today

- Scalability
- Enabling new applications
- Empower edge users
- Security

Enabling scalable applications

A case study by WashU: broadcast a laptop's video feed to a global audience

- May'13 CAFOE demo: broadcast to 1K clients around the world over an NDN net
- Software required
  - NDN daemon running on gateways & clients
  - ndnvideo application on clients & server
- Management required
  - The clients connect to NDN testbed
  - The clients know the video name

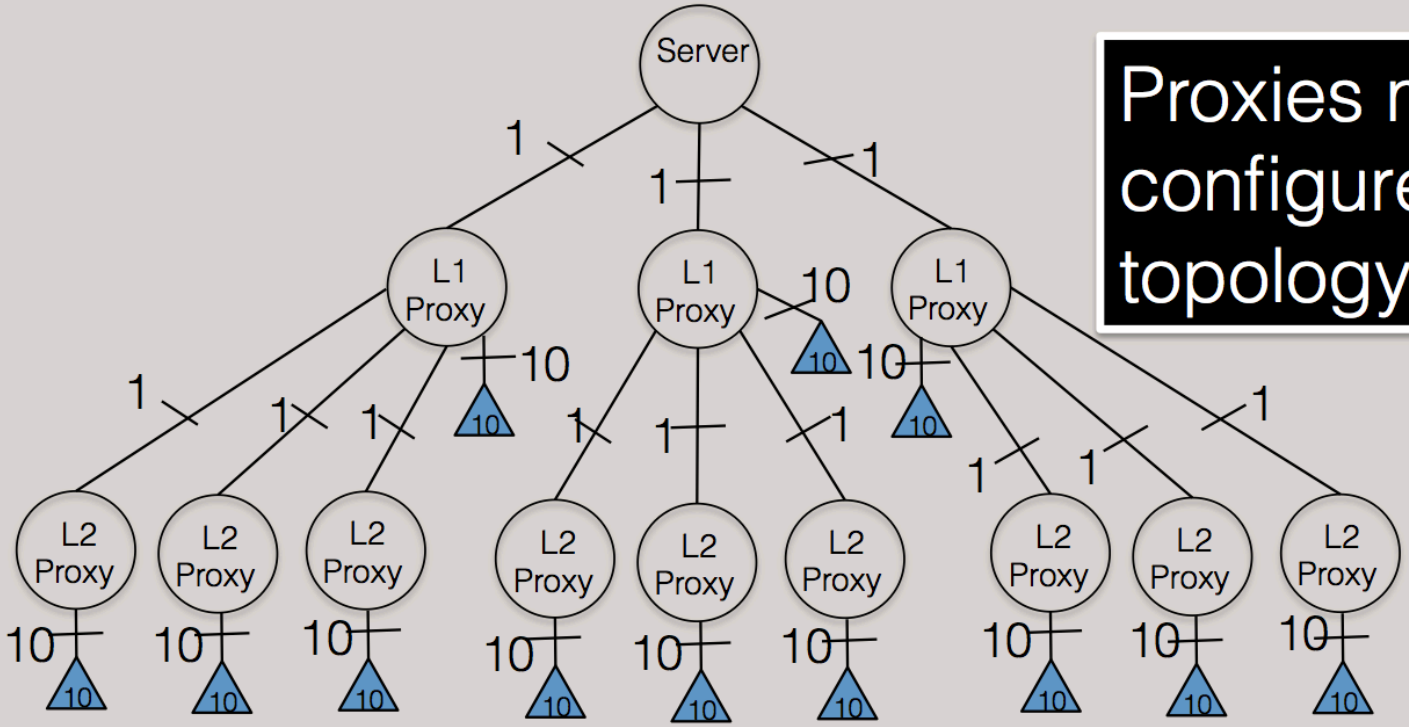
For comparative study: built a comparable broadcast-capable video streaming system

- Distribute video to >100 clients, using HTTP-based clients & proxies

- Software required
  - VLC used as clients and server
  - Proxies run varnish, an HTTP video proxy/cache
    - Commercial-grade sw used by vimeo, BBC, and others
    - Version 3.0, Nov 2011, first support of video streaming

- Management required
  - Proxies must be configured to speak up stream
  - VLC clients know video name
  - VLC clients must know which proxy to connect to

HTTP video streaming infrastructure



Proxies must be configured for topology & load

Video Streaming Case Study Summary

- NDN was easier to setup
  - HTTP proxies and clients need topology-specific configuration
  - Using DNS/transparent proxies to avoid this would likely be just as complex
- NDN required no tweaking
  - HTTP proxies needed to be tweaked to support changing loads

Remember NDN is general-purpose

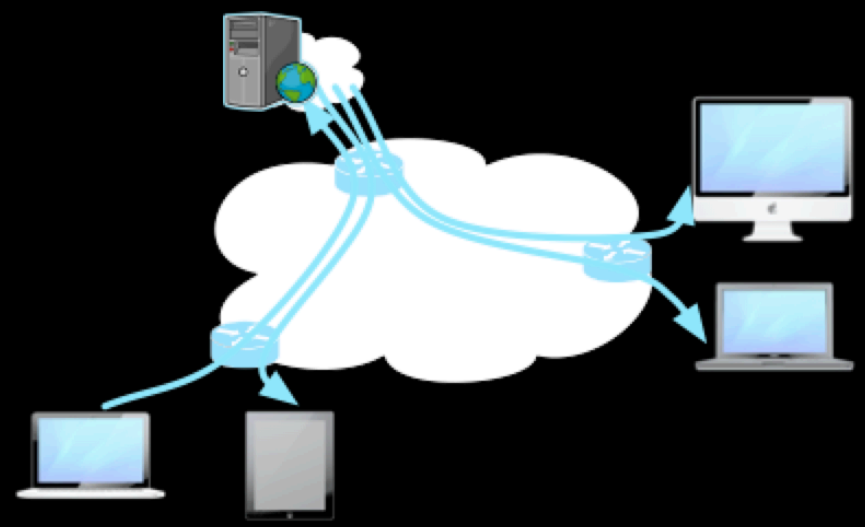
Form more details: http://named-data.net/publications/fia-2013-ndn-perf-11-15-2013/

How will NDN change things?

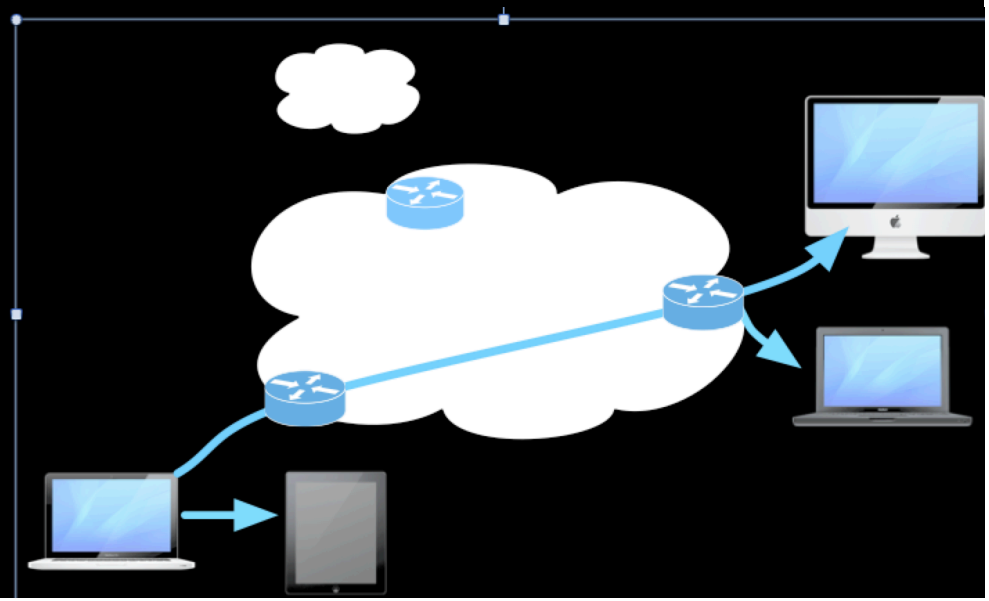
- Enable a new generation of applications that are difficult to support with today's TCP/IP
  - IP enabled a revolution because packet switching is fundamentally more general than circuit
  - NDN as a distribution network: fundamentally more general than IP's point-to-point comm. Model

ChronoShare (aka NDN-Dropbox)

- Today: distributed file sharing is achieved via centralized servers

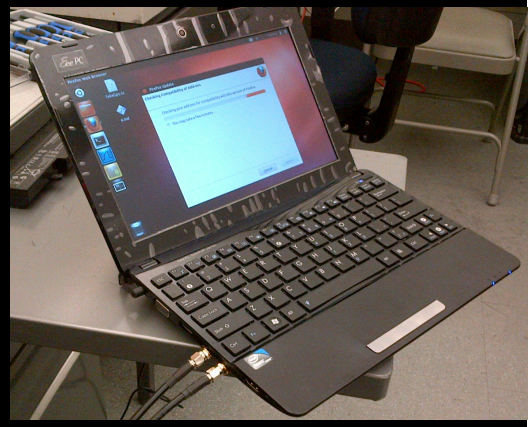


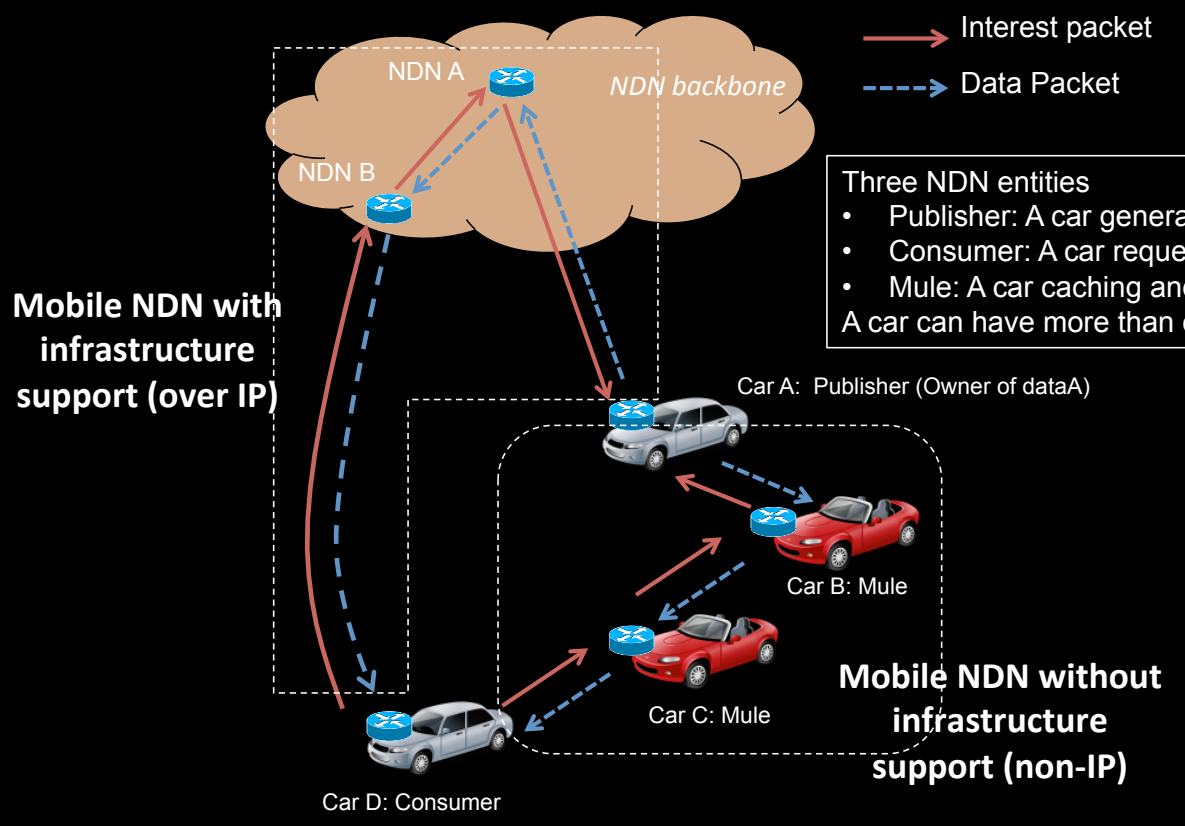
- ChronoShare
  - Use direct link to reach immediate neighbor nodes
  - Connect via IP tunnel for remote parties



Vehicle Networking Demo @UCLA

- Implemented a Linux-based NDN daemon, with enhancement to WiFi broadcast support





Three NDN entities
- Publisher: A car generating data
- Consumer: A car requesting data
- Mule: A car caching and forwarding data

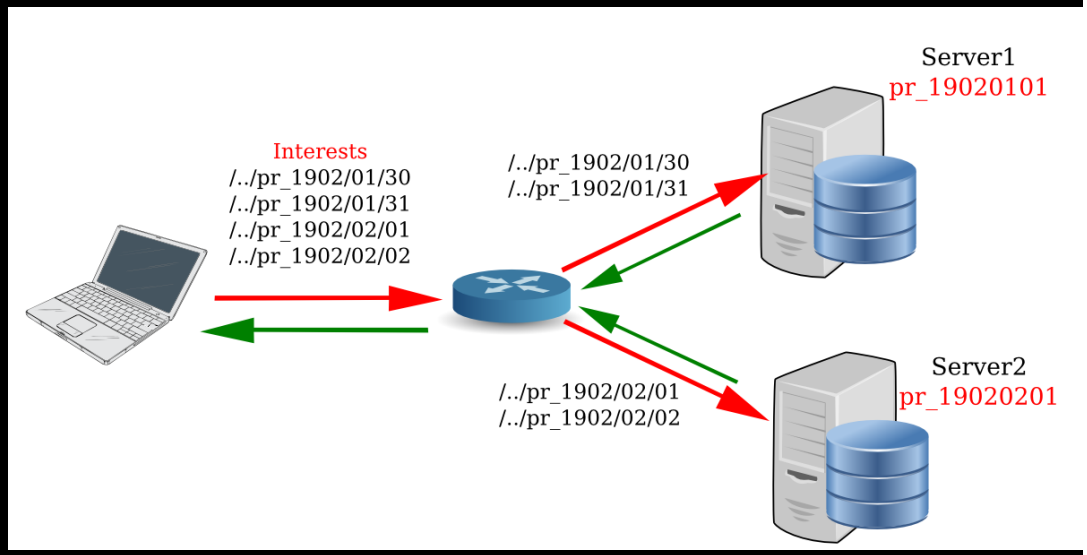
A car can have more than one role at a time.

Not supported by NDN project

Supporting Climate Applications over NDN

- The climate community recognized the importance of structured data naming
  - Mostly targeted to file and dataset naming
  - Provide naming consistency across distributed archives

- The naming can be used directly to data retrieving over NDN



Supported by NSF Campus Cyberinfrastructure. Form more details:
http://meetings.internet2.edu/media/medialibrary/2014/07/21/20140716-papadopoulos-ndn.pdf

Outline

- What is it?
- How does it work?
- How will NDN change things?
- What is the current status?
- What are the research needs?

The Current Status: NDN team (I)

- Application-driven architecture development

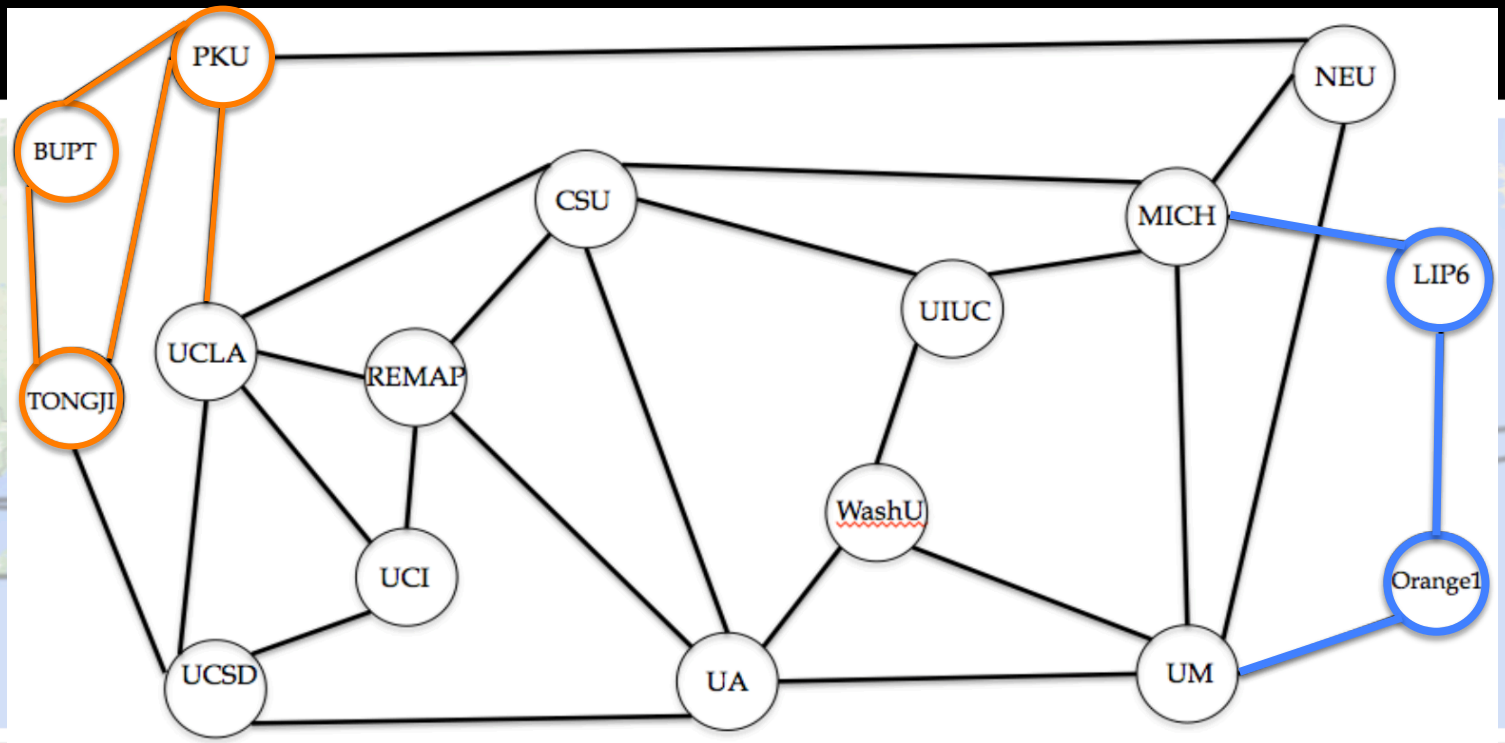
  "Solving real problems forces architectural details to be filled in and, most importantly, verifies and shapes the architectural direction."

- What we have produced:
  - NDN protocol specification
    http://named-data.net/doc/ndn-tlv/
  - NDN platform and libraries with multiple language supports (C++, Python, Javascript)
    https://github.com/named-data
  - A widely used NDN simulator
    http://ndnsim.net

What NDN team has produced (II)

- A running testbed
  - NDN routing prootocols
  - NDN testbed grows continuously, across three continents

    http://named-data.net/ndn-testbed/



What NDN team has produced (III)

- A growing set of applications
  - Fully distributed apps: NDN-chat, NDN-dropbox
  - Vehicular networking
  - Scalable streaming
  - Enterprise building automation & mgmt. (E-BAM)
  - *IoT* broadly defined
  - *Open mHealth*

Annual Demonstrations

Demo Feature	2012 Demo	2013 Demo
Large-scale, wide-area operation	All 4 US time zones, ~300 machines	5 continents, ~1000 machines
Mix of content distribution and interactive apps	4 distinct services	Multiple services
Visualization of both app-level and net-level activity	NDN map	NDN map
Demonstrate both steady-state and react-to-change modes	Drop links during app sessions	Forwarding strategy
Something IP+HTTP cannot do	Scalable video streaming*, multi-path routing	Scalable video streaming*, multi-path routing
Integrated PKI, better security		Show key auth
NDN-based device monitoring		Stage lighting ctrl

The current status: broader community

- The 1st NDN Community meeting
  - September 4-5 at UCLA
- Program Committee
  - Co-Chair: Kim Claffy (UC San Diego)
  - Co-Chair: Jeff Burke (UCLA REMAP)
    - Giovanna Carofiglio (Alcatel-Lucent)
    - Allison Mankin (VeriSign Labs)
    - Dave Oran (Cisco)
    - Christos Papadopoulos (Colorado State University)
    - Eve Schooler (Intel)
    - Beichuan Zhang (U. Arizona)
    - Lixia Zhang (UCLA)

The current status: broader community

- Academic activities in the ICN area (broadly called Information Centric Networking)
  - 3 SIGCOMM ICN workshops (2011-2013)
  - 2 INFOCOM NOMEN workshops (2012-2013)
  - 1st ACM ICN Conference (September 2014)

NDN team is playing a leadership role (though majority of the ongoing efforts seems outside US)

What are the research needs?

- Engaging broader US research community to invest into NDN
- Applying NDN to solve real networking problems
  - The Internet is *already* information-centric
    - youtube, netflix, amazon, facebook
    - new generations of applications
  - Solving info distribution problems via IP point-to-point communication, as we do today, is complex & error-prone

Analogy: consider TCP/IP in early 80's

- Promising new technology
- Largely unknown outside its small community
- Federal funding led TCP/IP to its success
  - BSD development, NSFnet
  - Various research projects over Internet
- A number of problems exposed and resolved through larger scale experimentation
  - DNS development
  - Congestion control
  - Evolution of the routing system
  - and a set of others

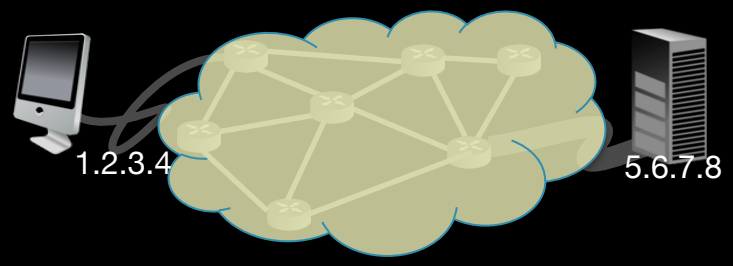
The road to a new architecture

- Application-driven development
  - Running code, useful apps, testbed with real traffic
  - tackling emerging environments and applications where no good IP-based solutions
- Incremental Deployment
  - NDN runs on everything, and everything runs on NDN
  - Start as an overlay, the same way as IP did

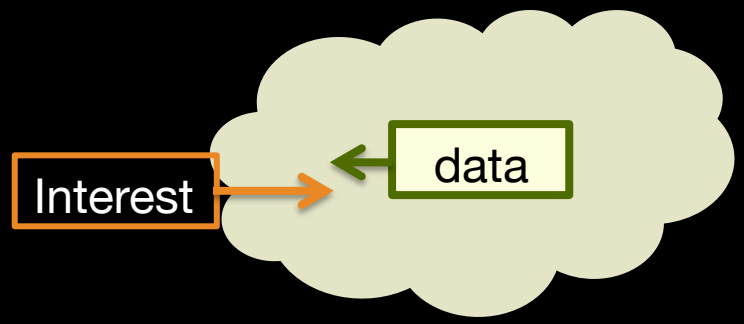
What to take home

- Future of networking lies in recognizing the right communication abstraction

- IP conceptualizes communication as between nodes



- NDN directly focuses on the outcome: retrieving data



For More Information

NDN project website

http://www.named-data.net/

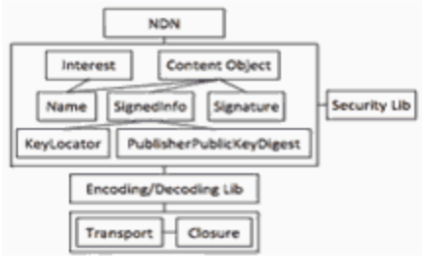
NAMED DATA NETWORKING

Project Architecture Codebase Testbed Publications

VAN JACOBSON TECH TALK @ FISS

NDN VIDEO FROM UCLA TO BEIJING

THE NDN TESTBED IS GROWING



NDN AT INFOCOMM NOMEN 2013