Named Data Networking

Patrick Crowley

New Frontiers in Networking
MIT, 2015-04-30

observable networks

Cloud-based network security
Founder, CTO
No connection to NDN

Main Point in One Slide

NDN is based on a simple, coherent idea

IP's communication abstraction: **channel between two endpoints**
      Based on telephones
      Abstraction is root cause for many Internet problems

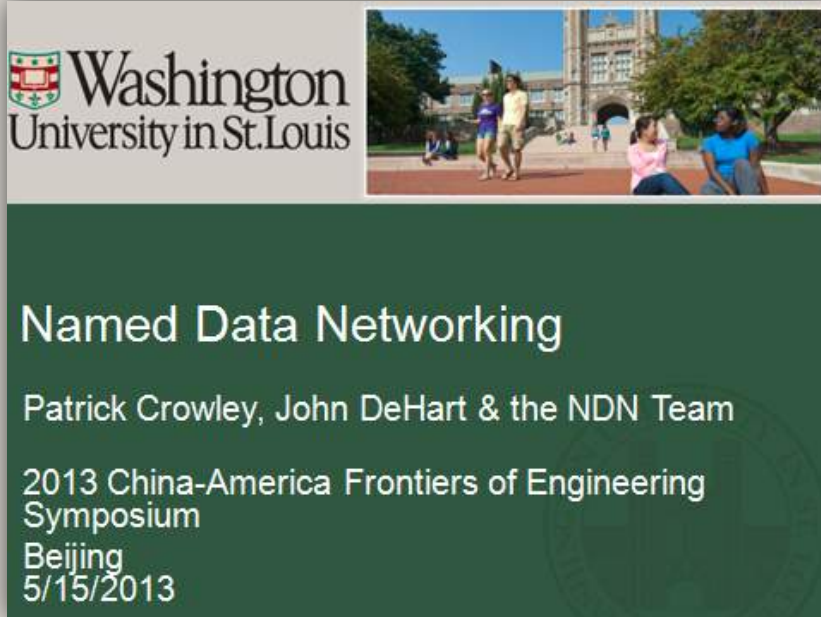NDN's communication abstraction: **request for named data**
      Based on the web
      Much better fit for today's networks, new future possibilities

Agenda

- Introduce Named Data Network (NDN)

- Describe the project and its goals

- Illustrate NDN concepts

- Describe how we work

Share This Presentation?

Named Data Networking

Patrick Crowley, John DeHart & the NDN Team

2013 China-America Frontiers of Engineering Symposium
Beijing
5/15/2013

What is the best way for me to share these slides with you right now?

What about video? What would happen if it became popular?

Trust This Message?


```
From: C. D. (Dan) Mote, Jr. <dmote@email.edu>
Date: Mon, May 13, 2013 at 7:39 PM
Subject: Congratulations!
To: Patrick Crowley pcrowley@wustl.edu

Dear Prof. Crowley,

I write to inform you that you have been elected a
Fellow to the National Academy of Engineering. As you
may understand, this designation follows a process of
nomination and subsequent vote by existing Fellows.
Congratulations.


Sincerely,
C.D. Mote, Jr.
President-Elect, National Academy of Engineering
```

Easy to forge Internet communications!

Use Connected Environment/IoT?

3 Challenges Caused By 1 Problem

Telephony/Internet Process
1. Find the **number/address** for the one you want to talk to.
2. Use that number to establish a **point-to-point connection**.
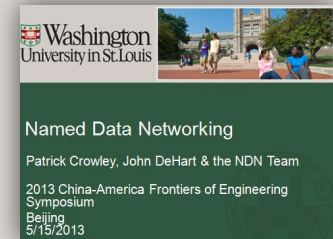3. Communicate!

Sharing — *Must know address*
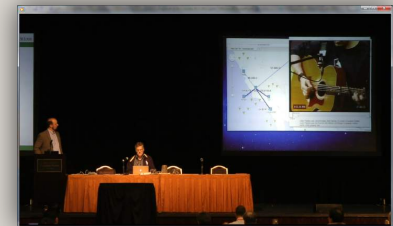Trust — *Place all trust in address*
IoT — *Know & trust all addresses*

A Simpler Way

Suppose your device could ask for what it wanted?

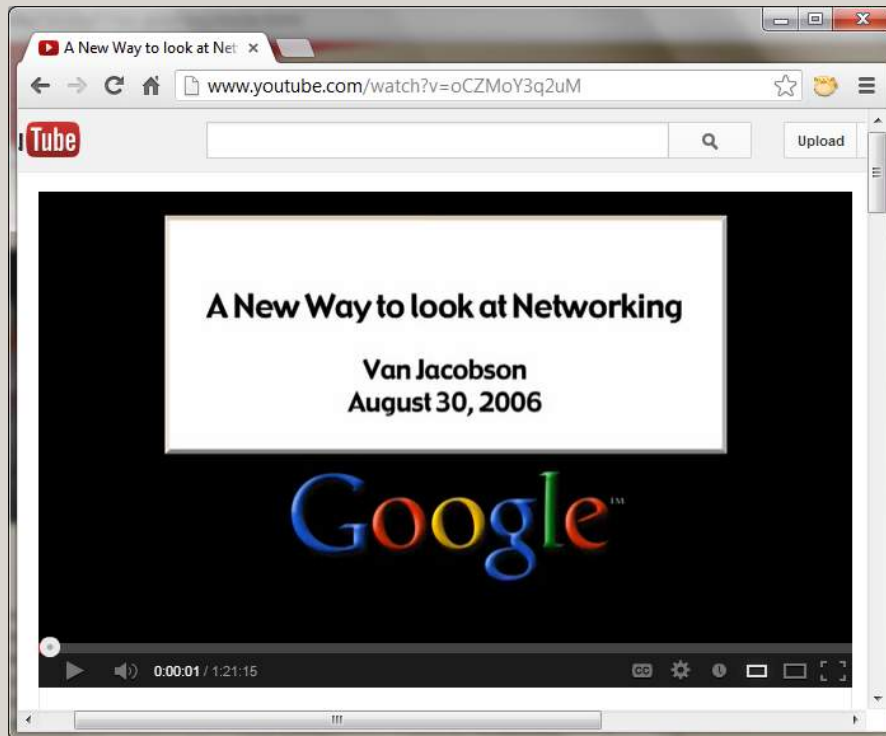/wustl.edu/pcrowley/talks/CAFOE_2013.pdf

/wustl.edu/pcrowley/video/thinkpad

/room/thermostat/1/status

The Web Has Named World's Data!

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

By volume, most digital communications are delivered via HTTP, aka requests for named data

/www.youtube.com/watch?feature=player_detailpage&v=oCZMoY3q2uM#t=1736s

Core Idea

Modern **communication** consists of
requests for named data

Today's **networks** are based on
host-to-host connections

NDN is a general-purpose network protocol built
on requests for named data

Named Data Networking

- Leverages the strengths of the Internet, addresses weaknesses
  - Layers efficiently atop Ethernet, Bluetooth, UDP, TCP, …

- Naturally accommodates
  - Mobile devices **(name data not just end hosts)**
  - Wireless and other broadcast-based link types **(easy for interests/data)**
  - Data authentication and security, privacy, anonymity **(pkts are signed)**
  - Policy-based forwarding, routing with loops **(names permit policy expression)**

- With NDN, we aim to show that
  - Communication is more secure
  - Infrastructure is more efficiently utilized
  - Applications are simpler

Replace the Internet?

NDN : Internet :: Internet : Bell System

NDN operates gracefully atop the Internet Protocols, and does not require wholesale replacement

NDN Team

- Project launch: 9/1/2010, part of NSF FIA Program
- NSF FIA Next Phase: started 4/15/2014.
- Research Areas: Architecture, Routing, Security, **Applications**, Scalable Forwarding

UCLA: **Van Jacobson (Google)**, Jeff Burke, **Lixia Zhang**
University of Arizona: Beichuan Zhang
University of California, San Diego: Kim "kc" Claffy
Colorado State University: Christos Papadopoulos
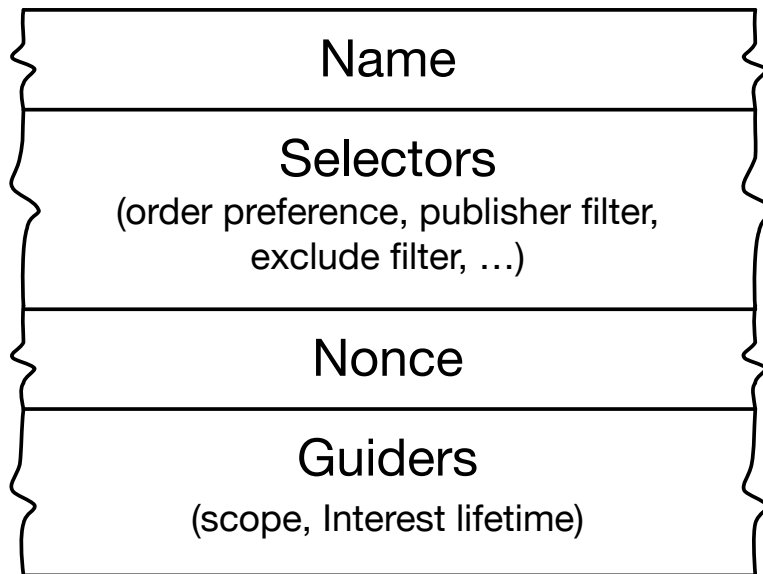University of Illinois, Urbana-Champaign: Tarek Abdelzaher
University of Memphis: Lan Wang
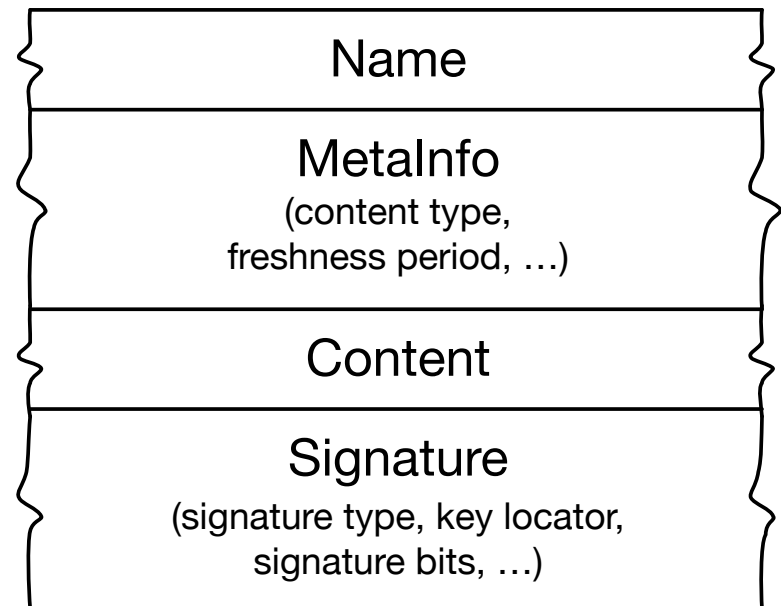University of Michigan: J. Alex Halderman
Washington University: Patrick Crowley

Two Packet Types

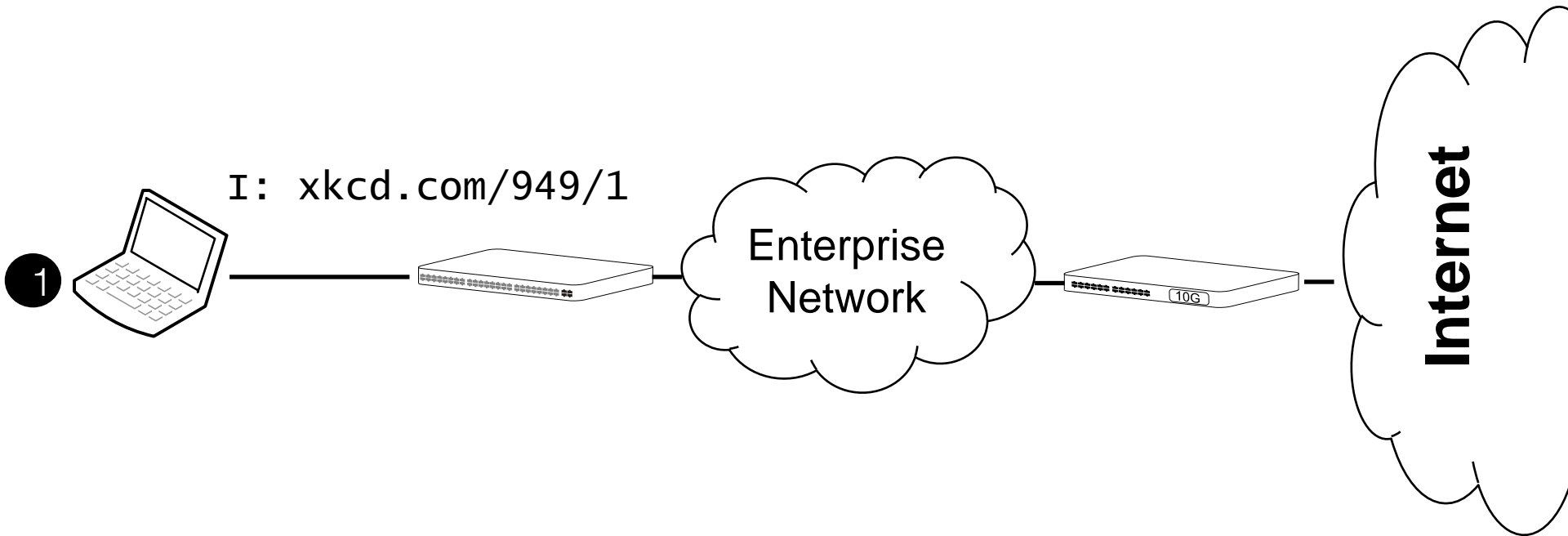| Interest Packet	Data Packet
Name	**Name**
Selectors (order preference, publisher filter, exclude filter, …)	**MetaInfo** (content type, freshness period, …)
Nonce	**Content**
Guiders (scope, Interest lifetime)	**Signature** (signature type, key locator, signature bits, …)

- No addresses
- Publishers bind names to data; receivers verify

NDN Interest Forwarding

1. Do I have this data?

2. Is a request already pending?
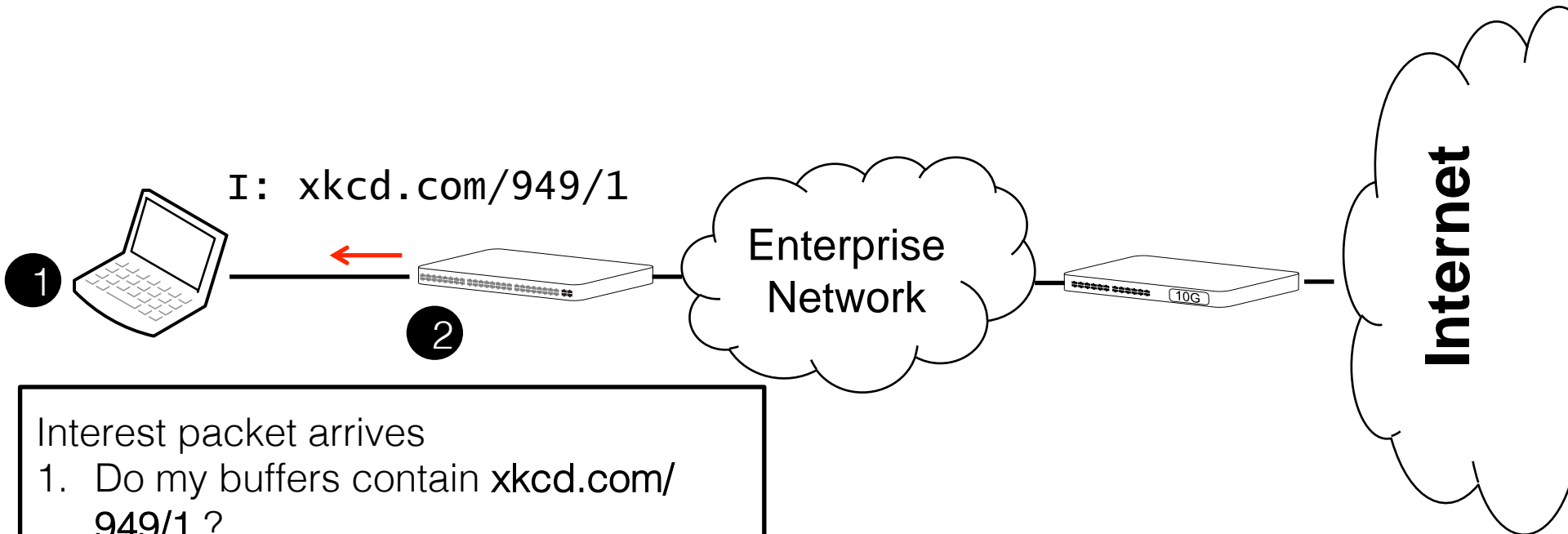

3. Which next hop might lead to the source?

NDN Forwarding Illustrated

1 Emit Interest: xkcd.com/949/1

I: xkcd.com/949/1

1

Enterprise Network

10G

Internet

NDN Forwarding Illustrated

1 Emit Interest: xkcd.com/949/1

2 Interest arrives at switch

I: xkcd.com/949/1

1

2

Enterprise Network

10G

Internet

Interest packet arrives
1. Do my buffers contain xkcd.com/949/1 ?
2. Is a pending request for it in flight?
3. Where should I forward the interest? Add arriving interface to the pending interest list.

NDN Forwarding Illustrated

1. Emit Interest: xkcd.com/949/1

2. Interest arrives at switch

3. Interest arrives at gateway
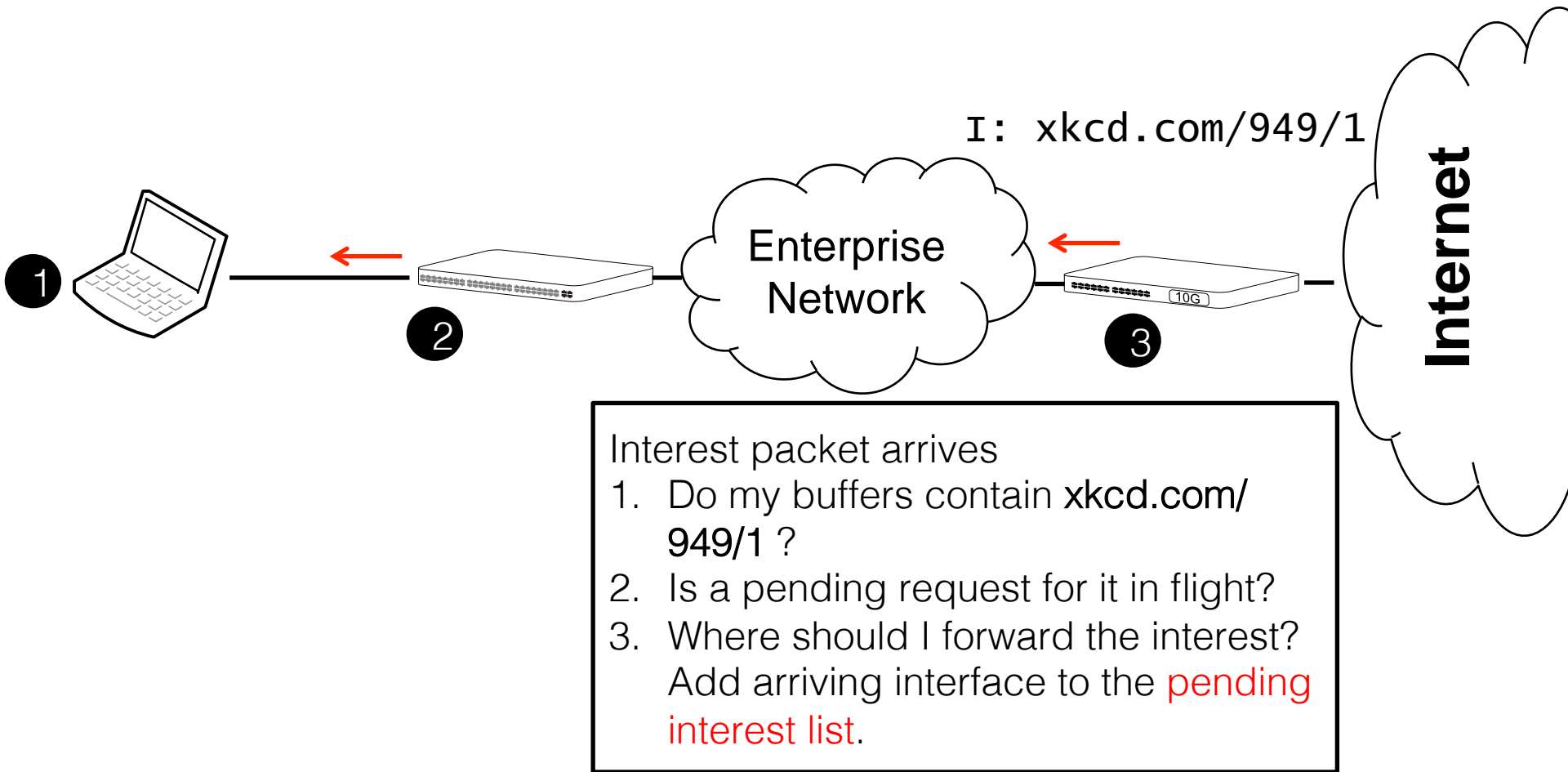
I: xkcd.com/949/1

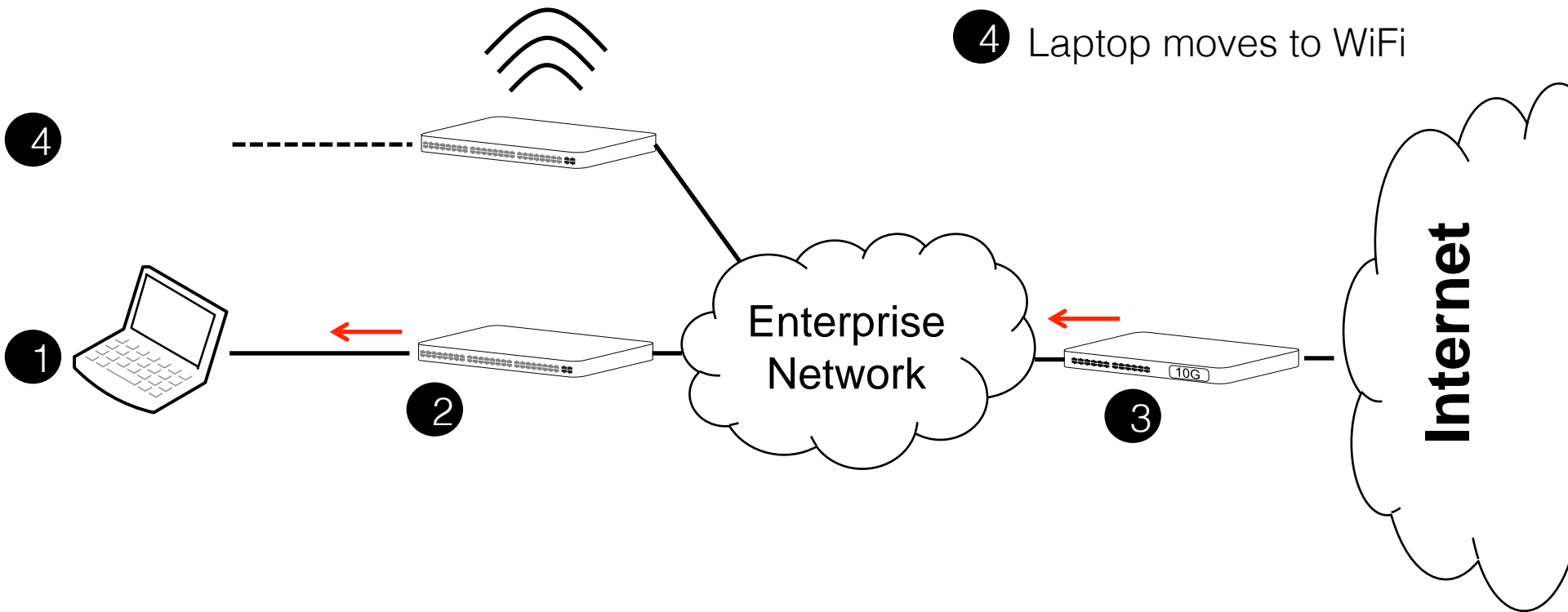**Internet**

Enterprise Network

1

2

3

Interest packet arrives
1. Do my buffers contain xkcd.com/949/1 ?
2. Is a pending request for it in flight?
3. Where should I forward the interest? Add arriving interface to the pending interest list.

NDN Forwarding Illustrated

1 Emit Interest: xkcd.com/949/1

2 Interest arrives at switch

3 Interest arrives at gateway

4 Laptop moves to WiFi

Enterprise Network

Internet

10G

NDN Forwarding Illustrated

1 Emit Interest: xkcd.com/949/1

2 Interest arrives at switch

3 Interest arrives at gateway

4 Laptop moves to WiFi

5 Data arrives

Enterprise Network

Internet

Data packet arrives
1. Store data packet in buffer.
2. Send packet out any matching interfaces on the pending interest list.
3. Remove pending entries.

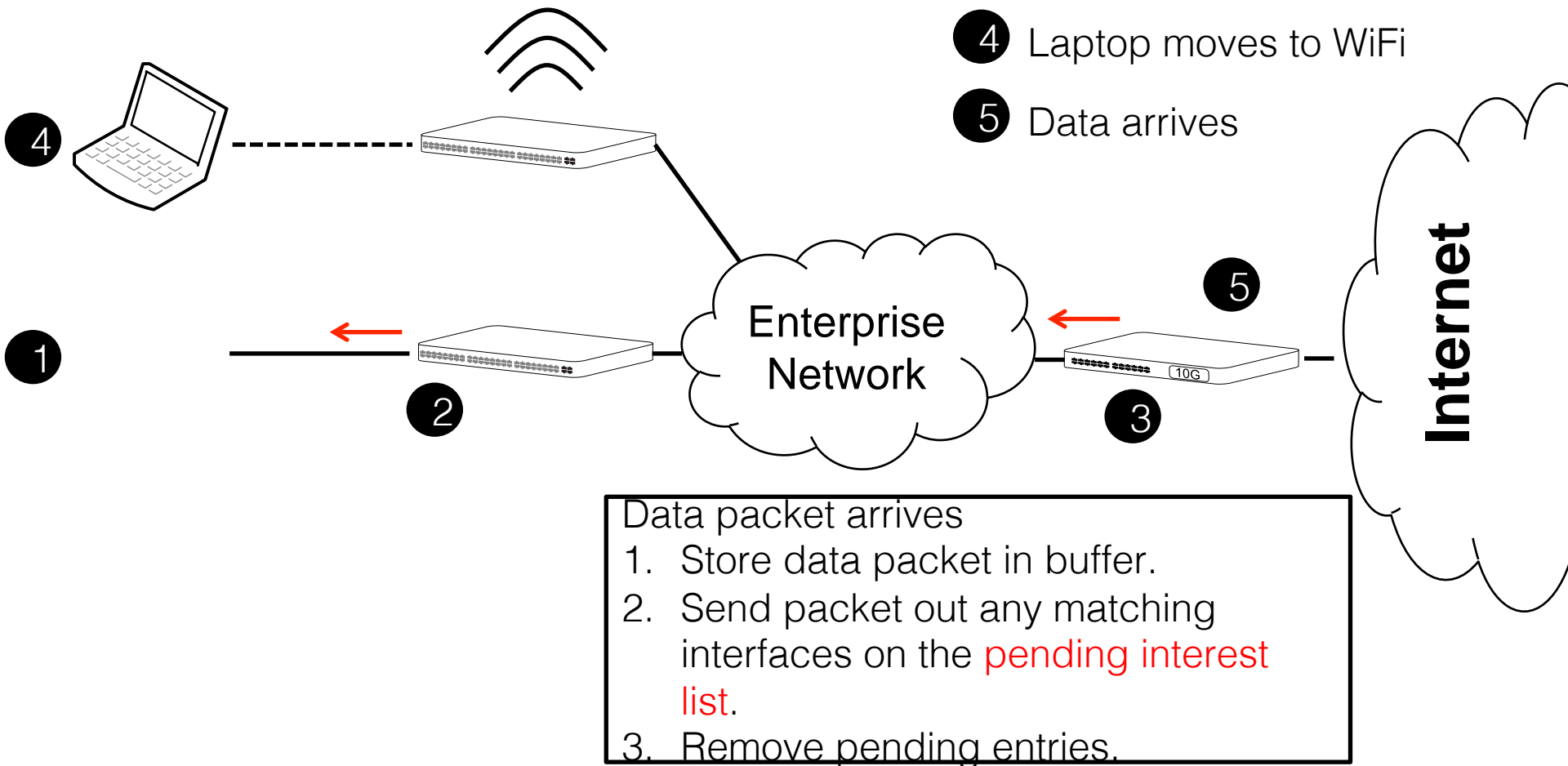# NDN Forwarding Illustrated

1 Emit Interest: xkcd.com/949/1

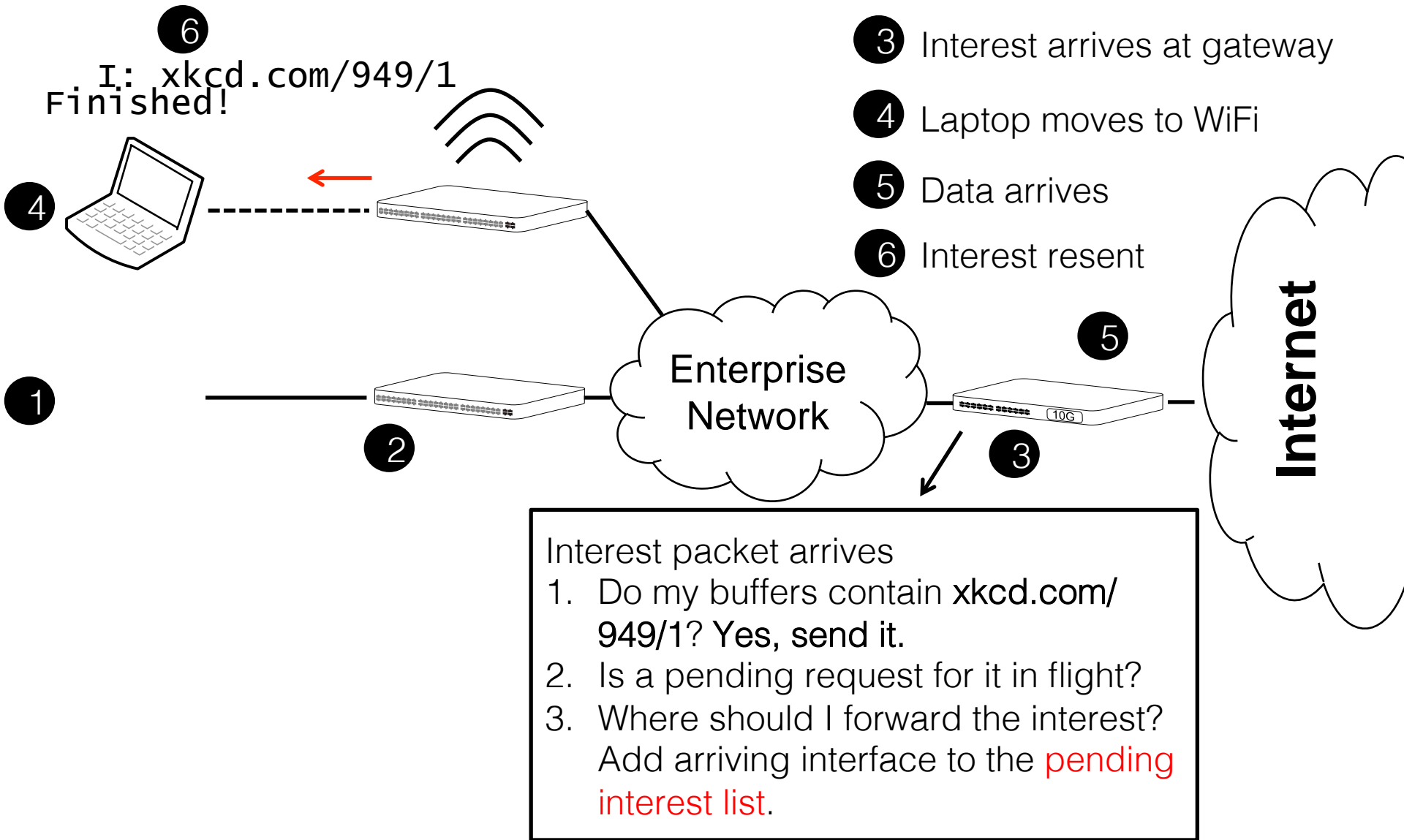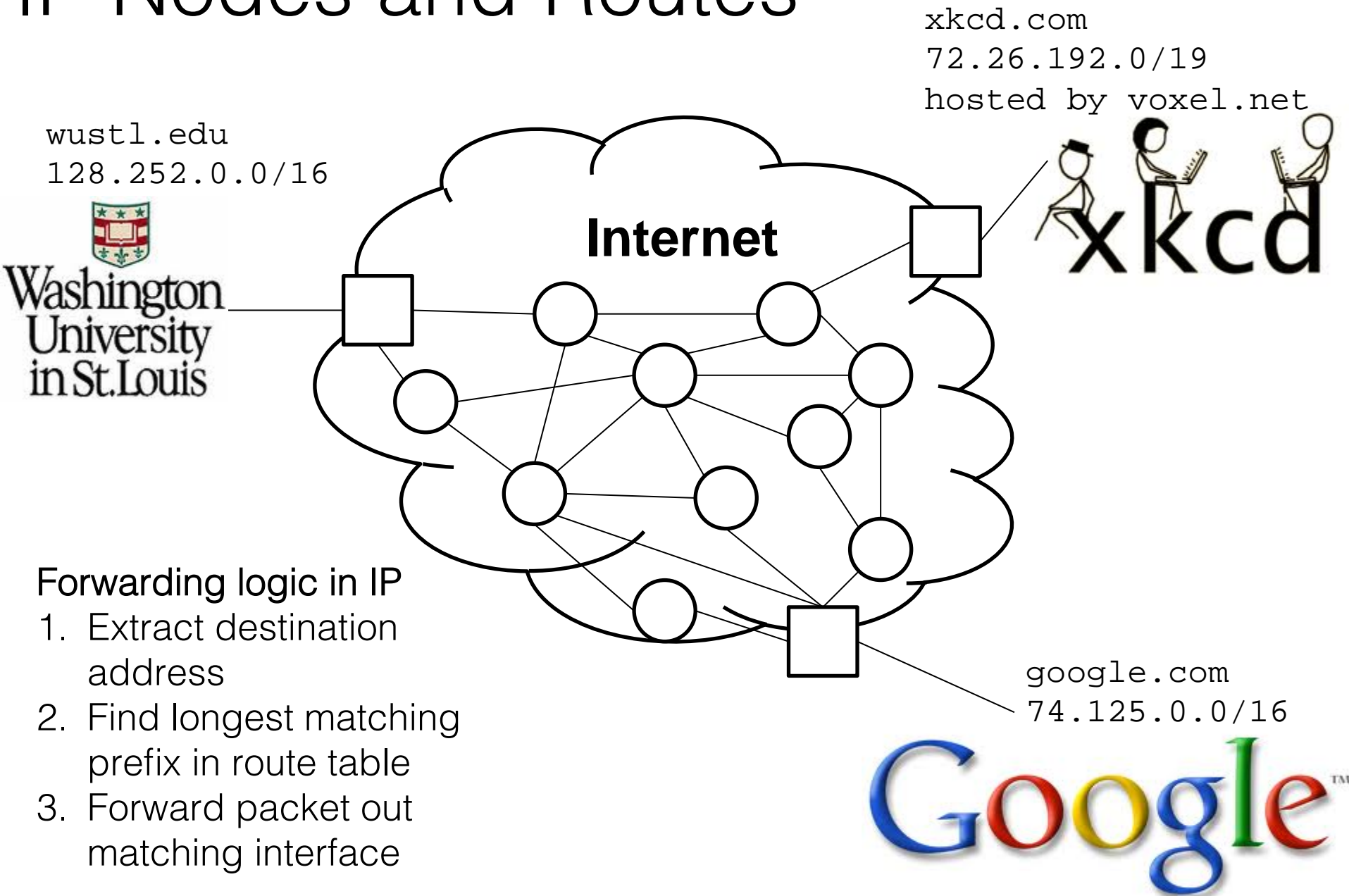2 Interest arrives at switch

3 Interest arrives at gateway

4 Laptop moves to WiFi

5 Data arrives

6 Interest resent

6

I: xkcd.com/949/1
Finished!

4

Internet

Enterprise Network

5

2

3

1

Interest packet arrives
1. Do my buffers contain xkcd.com/949/1? Yes, send it.
2. Is a pending request for it in flight?
3. Where should I forward the interest? Add arriving interface to the pending interest list.

IP Nodes and Routes

xkcd.com
72.26.192.0/19
hosted by voxel.net

wustl.edu
128.252.0.0/16

Internet

Forwarding logic in IP
1. Extract destination address
2. Find longest matching prefix in route table
3. Forward packet out matching interface

google.com
74.125.0.0/16

IP Nodes and Routes

xkcd.com
72.26.192.0/19
hosted by voxel.net

wustl.edu
128.252.0.0/16

Washington University in St.Louis

Internet
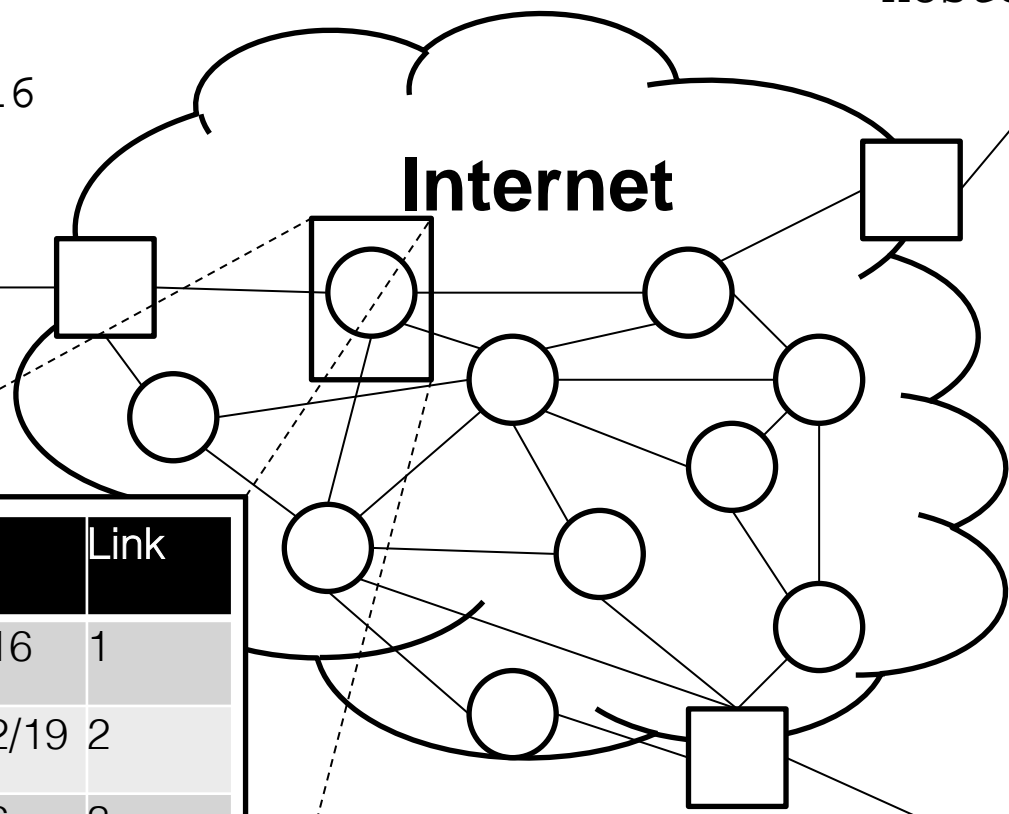
xkcd

Matching Prefix	Link
128.252/16	1
72.26.192/19	2
74.125/16	3

1   2

3

4

google.com
74.125.0.0/16

Google™

NDN Nodes and Routes

xkcd.com
72.26.192.0/19
hosted by voxel.net

wustl.edu
128.252.0.0/16

Internet

Matching Prefix	Link
wustl.edu	1
xkcd.com	2, **3**
google.com	1, **3**, 4

google.com
74.125.0.0/16
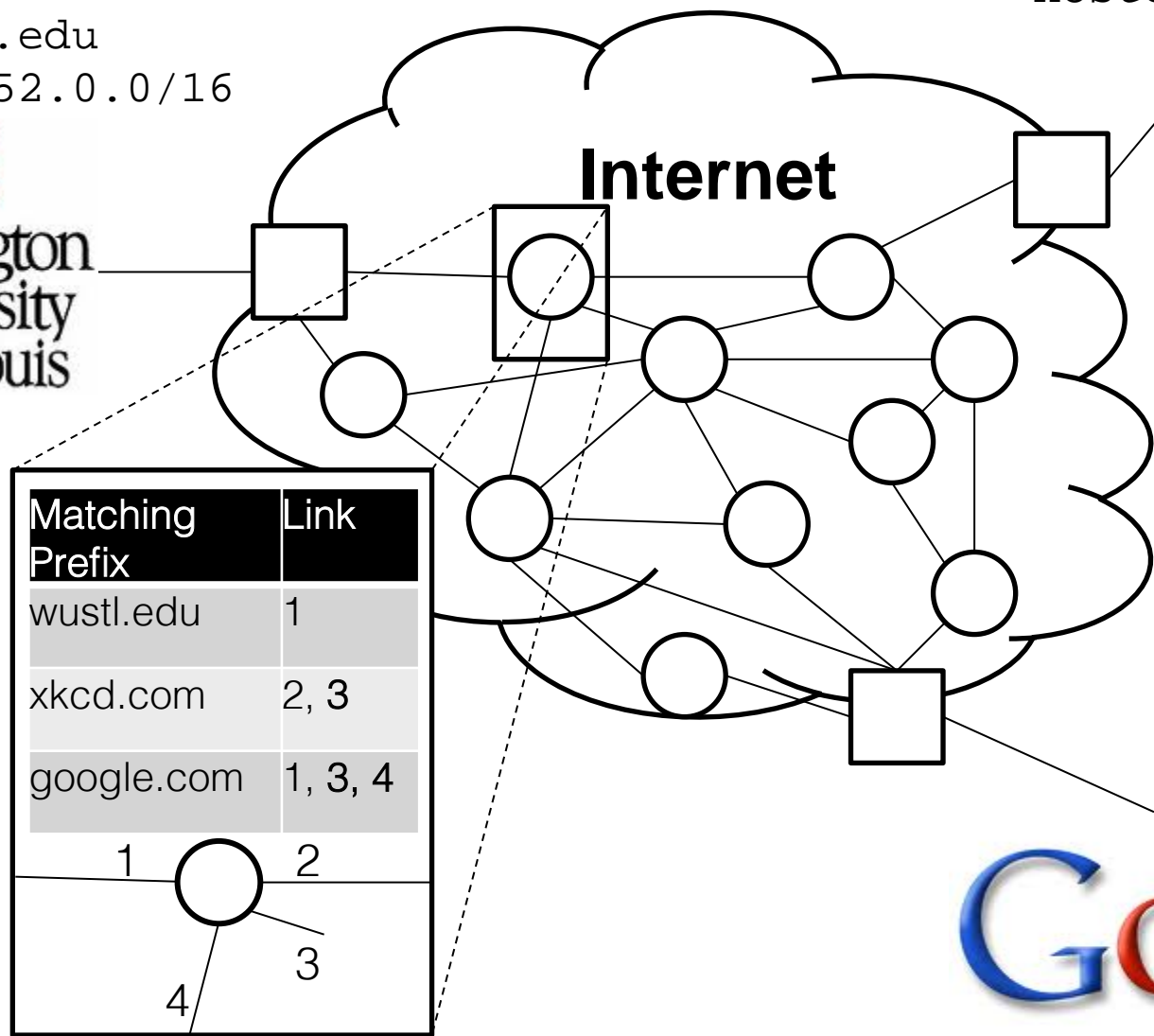
Questions

- Can NDN efficiently support host-to-host patterns?
- Can NDN efficiently support user-specific data and services?
- Can you count clicks and ad impressions in NDN?

Yes!

- Can you efficiently route all those names?
- Can you scale the forwarding plane?
- Can you prove security and privacy properties?

Yes, mostly!

Evaluation: We focus on use cases

- Team includes two app-focused PIs
  - Jeff Burke (UCLA), Tarek Abdelzehar (UIUC)

- NDN-NP agenda includes two focus environments

- Developed a growing collections of apps
  - HD Audio/Video player, "DropBox", decentralized group chat, building automation, stage lighting, …

- We conduct annual, real-world demonstrations

- We compare to the Internet's state-of-the-art

End-to-end Focus is Primary

- Do NDN applications and services work, given real-world contexts?

- Many lower-level mechanisms are important to evaluate, but have **secondary** significance
  - Focused evaluations of: routing protocols, forwarding, transport-level synchronization, …

- The value of end-to-end demonstrations
  - They help the team focus on the right issues
  - They help dispel misunderstandings about the architecture
  - Real code in real environments keeps the team honest

Global NDN Testbed: April 2015

- **Consists of 24 Gateway Router Nodes**
  - **9 at sites of the NDN PIs**
  - **15 at sites of collaborators.**
- **Presence on 3 Continents**
  - **North America: 12 in USA**
  - **Asia: 3 in China, 1 in Japan, 1 in South Korea**
  - **Europe: 3 in France, 1 each in Spain, Switzerland, Italy & Norway**
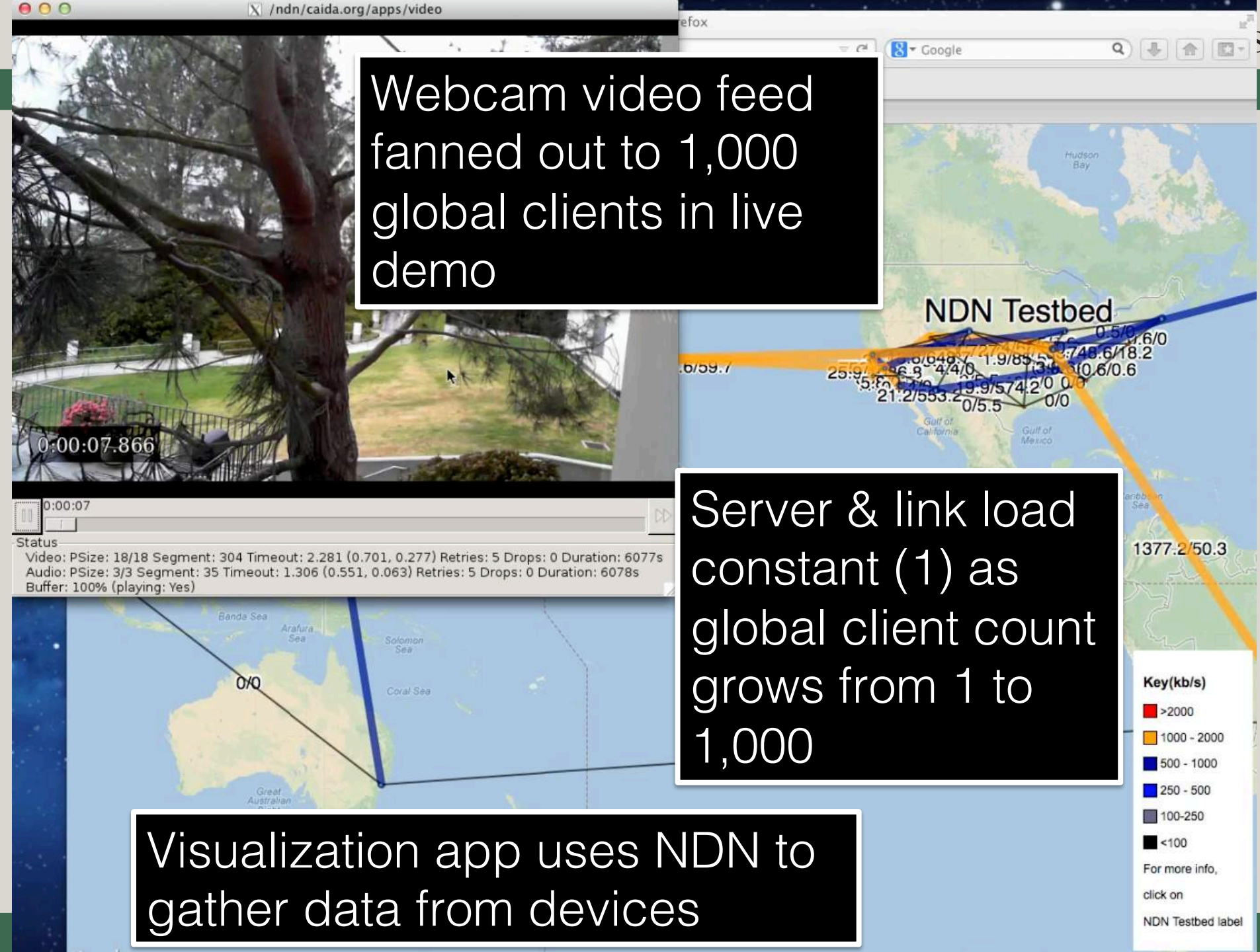

http://ndnmap.arl.wustl.edu
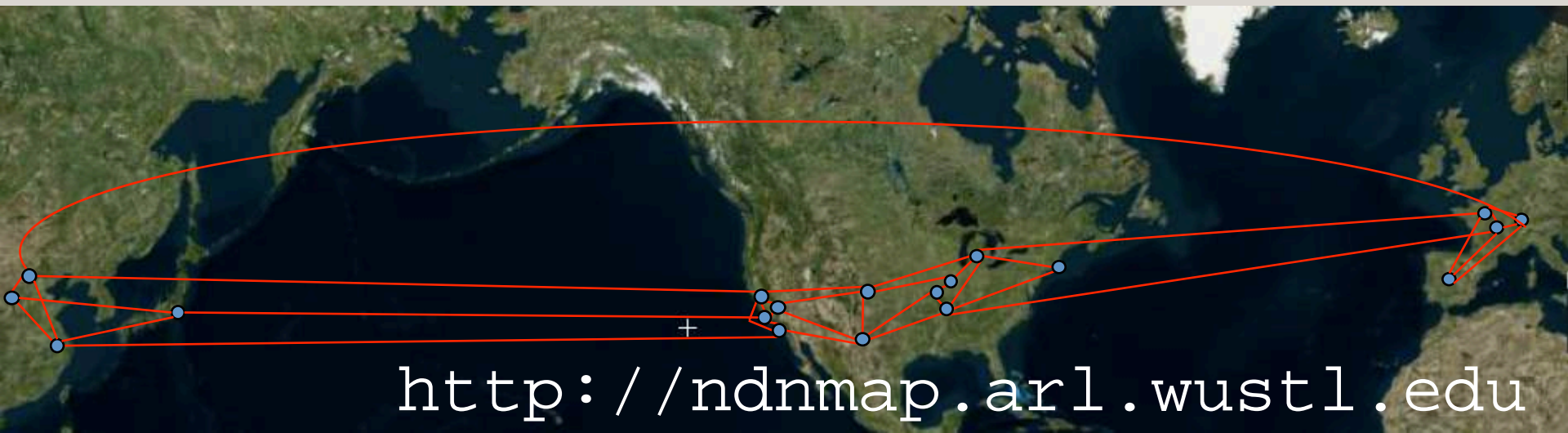
Webcam video feed fanned out to 1,000 global clients in live demo

Server & link load constant (1) as global client count grows from 1 to 1,000

Visualization app uses NDN to gather data from devices

Live bluegrass band performance, NDN-based control of stage lights

Real-time HD video/audio, with remote control of stage lighting elements

Conclusion

- Growing evidence that with NDN
  - Communication is more secure
  - Infrastructure is more efficiently utilized
  - Applications are simpler
  - New things are possible

- Underway
  - Growing industry consortium
  - Active set of early commercial adopters, IETF activities
  - Focused deployments in healthcare, building automation

- Research community is growing
  - We share an open-source code base with projects and groups moving forwarding aggresively in Europe and Asia

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http://named-data.net
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