Named Data Networking

Introduction and hands on tutorial

by

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Steve DiBenedetto, CSU
Goals for today

• Introduce Named Data Networking (NDN)

• Describe the project and its goals

• Illustrate NDN concepts

• Show how to write simple applications and now to experiment with NFD forwarder
Share This Presentation?

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?
From: C. D. (Dan) Mote, Jr. <dmote@email.edu>
Date: Mon, May 13, 2013 at 7:39 PM
Subject: Congratulations!
To: Alex Afanasyev <alex@email.edu>

Dear Dr. Afanasyev,

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
Use Connected Environment/IoT?
Challenges Caused By a Single 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?

/this_room/alex/talks/GEC21.pptx

/youtube.com/video/ndn/van2006

/ucla/boelter_hall/4th_flor/room412/thermostat/1/status
The Web Has Named World’s Data!

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

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

Use names directly at the networking level

Focus on data, not host-to-host connections

Closed-loop communication

- Forward Interest
- Interest Timeout
- Data

- congestion
- flow balance
- source multicast
- caching

...
Named Data Networking

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

- Naturally accommodates
  - Mobile devices
  - Wireless and other broadcast-based link types
  - Data authentication and security, privacy, anonymity
  - Policy-based forwarding, routing with loops

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

- Project launch: 9/2010, part of NSF FIA Program
  5/2014, part of NSF FIA-NP Program
- Research Areas:
  Architecture, Routing, Security, Applications, Scalable Forwarding

<table>
<thead>
<tr>
<th>UCLA</th>
<th>University of Arizona: Beichuan Zhang</th>
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<tbody>
<tr>
<td>Van Jacobson, Jeff Burke</td>
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<td>Deborah Estrin, Lixia Zhang</td>
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<td>University of California, San Diego: Kim Claffy, Dmitri Krioukov</td>
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<td>Colorado State University: Christos Papadopoulos</td>
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<td>University of Illinois, Urbana-Champaign: Tarek Abdelzaher</td>
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<td>University of Memphis: Lan Wang</td>
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<td>University of Michigan: Alex Halderman</td>
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<td>Washington University: Patrick Crowley</td>
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<td>Northeastern University: Edmund Yeh</td>
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<td>University of Maryland: Katie Shilton</td>
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Two Packet Types

**Interest Packet**

- **Name**
- **Selectors**
  (order preference, publisher filter, exclude filter, …)
- **Nonce**
- **Guiders**
  (scope, Interest lifetime)

**Data Packet**

- **Name**
- **MetaInfo**
  (content type, freshness period, …)
- **Content**
- **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?
1 Emit Interest: xkcd.com/949/1
NDN Forwarding Illustrated

1. Emit Interest: xkcd.com/949/1
2. Interest arrives at switch

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

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
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

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

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

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

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

wustl.edu: 128.252.0.0/16

xkcd.com: 72.26.192.0/19
hosted by voxel.net

google.com: 74.125.0.0/16
# NDN Nodes and Routes

<table>
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<tr>
<th>Matching Prefix</th>
<th>Link</th>
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</thead>
<tbody>
<tr>
<td>/wustl.edu</td>
<td>1</td>
</tr>
<tr>
<td>/xkcd.com</td>
<td>2, 3</td>
</tr>
<tr>
<td>/google.com</td>
<td>1, 3, 4</td>
</tr>
</tbody>
</table>

Internet

/wustl.edu

/xkcd.com hosted by /voxel.net

/google.com

[Diagram showing network nodes and links]
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!
Conclusion (1/2)

• Growing evidence that with NDN
  o Communication is more secure
  o Infrastructure is more efficiently utilized
  o Applications are simpler
  o New things are possible
Conclusion (2/2)

• In coming years
  o Growing commercial interest and experimentation
  o Deployments in greenfields / IP trouble spots
    – IoT, building automation, healthcare, vehicular

• Research community is growing
  o We share an open-source code base with related projects and groups moving forwarding in Europe and Asia
  o NDN Consortium, launched this month, already includes 14 universities, 5 for-profit corporations, and 1 non-profit.
NDN Components

- Apps
- Routing
- Repo

Libraries

NFD

Links and Tunnels
NDN Libraries

• All libraries now reflect fundamental architectural abstractions directly in objects, and wire format manipulation is abstracted.
  o Name, Component
  o Interest, Selectors
  o Data, MetaInfo, SignatureInfo, SignatureValue, KeyLocator
  o Face
  o KeyChain, Validator

• Multiple library efforts
  o NDN-CXX: “C++ for eXtended eXperimentation”
    • C++ (soon to be C++11), Boost (Asio, Filesystem, ...)
  o NDN-CCL: “Common Client Libraries”
    • C++
    • Python (2 and 3)
    • JavaScript (browser and node.js)
    • Java
  o Enables diversity of coding choice
  o Drives us towards specification (and not just implementation)
Security Support

Signing

KeyChain

Manage security credentials
Sign Data and Interests
Decrypt payload
Compile-time trust policy
Run-time trust policy

Validation

Validator classes

http://named-data.net/doc/ndn-cxx/0.2.0/tutorials/security-library.html#signing
Supported Security Features

• Asymmetric cryptography
  - RSA
  - ECDSA

• Symmetric cryptography*
  - AES
  - HMAC

• Trivial cryptography
  - SHA256 digest

• Signing/verification granularity
  - Data packet
  - Set of Data packets*

* work in progress
NDN Platform

• Provide a coherent, usable, and well-documented “platform” for exploring NDN in practical applications – for the NDN project team and external users.

• Use a release “heartbeat” to stimulate interoperability testing and discussion of how the various moving parts work together.

• Along the way, improve access to and consistency of various NDN code projects.

• Open and lightweight process, with no unrealistic centralization or over-management but clear ownership of each component project.

• Managed nodes on the testbed run the Platform.
NDN Platform 0.3 (August 2014)

- **NFD** NDN Forwarding Daemon, version 0.2.0 (1)
- **ndn-cxx** library, version 0.2.0
  - The NDN C++ library with eXperimental eXtensions (CXX)
  - The ndnsec security tools to manage security identities and certificates
- **NDN-CCL** - NDN Common Client libraries suite, version 0.3
  - NDN-CPP C++ / C library
  - PyNDN2 Python library
  - NDN-JS JavaScript library (with Node.js support)
  - jNDN Java library (preliminary)
- **NLSR** - Named Data Link State Routing Protocol , version 0.1.0
- **repo-ng** - next generation of NDN repository , version 0.1.0
- **ndn-tlv-ping** - ping application for NDN , version 0.2.0
- **ndn-traffic-generator** - traffic generator for NDN , version 0.2.0
- **ndndump** - packet capture and analysis tool for NDN , version 0.5

- Partial binary package support on Ubuntu, MacOS X, others...
Community Outreach

• One public Github repo for all code
  o  http://github.com/named-data
• Public Redmine with Wiki documentation for components
  o  http://redmine.named-data.net
• Components website
  o  NFD: http://named-data.net/doc/NFD/
  o  ndn-cxx: http://named-data.net/doc/ndn-cxx/
  o  NLSR: http://named-data.net/doc/NLSR/
• NDN-CCL: http://named-data.net/doc/NDN-CCL/
• Code review
  o  http://gerrit.named-data.net
• Technical reports and NDN technical memos
  o  http://named-data.net/publications/techreports/
• Mailing lists
  o  http://named-data.net/codebase/platform/support/mailing-lists/

Open to contributors and collaborators!
Ready for the Action?