NDN protocol development: status of reference implementations, supporting software releases, open architecture research issues

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Progress in the past year

• Expand and improve supporting libraries

• One major release and five minor releases
  – next full major release this month

• Expanded list of supported platforms, new features and bug fixes
Reference Implementation Status

- Free software approach
- NFD: NDN Forwarding Daemon
  - New flexible packet format based on TLV
  - Modular and extensible design
  - Support for multiple forwarding strategies
- Libraries: full featured implementations in a variety of languages
  - C++ (full + lightweight), Java (se+android), JS (in-browser+nodejs), Python
- Apps: [https://github.com/named-data](https://github.com/named-data)

<table>
<thead>
<tr>
<th>Libraries (LPLG3)</th>
<th>Apps (*)</th>
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<td>NFD (GPL3)</td>
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Community Involvement

• Mailing lists
  – nfd-dev: 100+ (http://www.lists.cs.ucla.edu/mailman/listinfo/nfd-dev)
  – ndnSIM: 300+ (http://www.lists.cs.ucla.edu/mailman/listinfo/ndnsim)

• Code contributors across NDN projects
  – 70+ (many outside of NDN team)

• NDN on Github
  – https://github.com/named-data
  – 20+ forks of NFD, ndn-cxx
  – 48+ forks of ndnSIM

• 1st NDN Hackathon
  – http://ndncomm.github.io/
  – 25 participants, 7 projects (out of 19 project proposals)

• NDNComm2015
  – 100+ people from 63 institutions and 13 countries
# NDN Consortium

## Founding Universities (8)
- Colorado State University
- University of Arizona
- University of California, Los Angeles (UCLA)
- University of California, San Diego
- University of Illinois, Urbana-Champaign
- University of Memphis
- University of Michigan
- Washington University in St. Louis

## Industry (10)
- Alcatel-Lucent
- Brocade
- Cisco Systems
- Fujitsu Laboratories of America
- Huawei Technologies
- Intel Corporation
- Juniper Networks
- Panasonic Corporation
- Verisign, Inc.
- ViaSat

## Academic / Non-profit (9)
- Anyang University, Korea
- Northeastern University
- The MITRE Corporation
- Tongji University, China
- Tsinghua University, China
- University of Basel, Switzerland
- University of Maryland, College Park
- Université Pierre et Marie Curie Sorbonne Universités, France
- Waseda University, Japan

[http://named-data.net/consortium-members/](http://named-data.net/consortium-members/)
Technical Memos on NDN Architectural Design

- (rev2) Consumer-Producer API for Named Data Networking. ICN’15/NDN-0017
- (rev3) Schematizing and Automating Trust in Named Data Networking. ICN’15 / NDN-0030
- (rev1) Scalable Name-Based Packet Forwarding: From Millions to Billions. ICN’15
- (rev15) NDNLPv2 spec (http://redmine.named-data.net/projects/nfd/wiki/NDNLPv2)
- (rev1) ICN Packet Format Design Requirements. draft-icn-packet-format-requirements-01.
- (rev4) SNAMP: Secure Namespace Mapping to Scale NDN Forwarding, GI’2015 / NDN-0004
- (rev1) Public Key Management in Named Data Networking. NDN-0029
- (rev4) NFD Developer’s Guide. NDN-0021
- (rev1) Fetching content in Named Data Networking with embedded manifests. NDN-0025
- (rev1) NDN Technical Memo: Naming Conventions. NDN-0022
- (rev1) Kite: A Mobility Support Scheme for NDN. NDN-0020
- (rev1) A World on NDN: Affordances & Implications of the Named Data Networking Future Internet Architecture. NDN-0018
- Packet Forwarding Speed vs. Processing: Implementation Tradeoffs in Handling Selectors
- NDN Name Discovery
- LINK - description
- Why Variable Length Wire Encoding is Important
- Implicit Digest vs. Content Hash
FYI: Recent Papers from NDN Team

- **ICN’15**
  - Scalable Name-Based Packet Forwarding: From Millions to Billions
  - Consumer / Producer communication with application level framing in Named Data Networking
  - NDN-RTC: Real-time videoconferencing over Named Data Networking
  - Schematizing and Automating Trust in Named Data Networking
- **Other**
  - SNAMP: Secure Namespace Mapping to Scale NDN Forwarding (GI’2015)
  - The Story of ChronoShare, or How NDN Brought Distributed Secure File Sharing Back (MASS CCN’15)
  - Named Data Networking in Climate Research and HEP Applications (CHEP2015)
  - Synchronizing Namespaces with Invertible Bloom Filters (ACNS’15)
  - Navigo: Interest Forwarding by Geolocations in Vehicular Named Data Networking (WoWMoM’15)

- [http://named-data.net/publications/](http://named-data.net/publications/)
Active Development

• Weekly code commits at Github
  – NFD
  – ndn-cxx
  – jndn
  – PyNDN2
Multi-Platform Support

• NFD now runs on Android
  – A few pilot applications
    • Simple game [https://github.com/dchimeraan/ndn-hangman](https://github.com/dchimeraan/ndn-hangman)
    • NDN Whiteboard [https://github.com/sumitgouthaman/NDNWhiteboard](https://github.com/sumitgouthaman/NDNWhiteboard)
    • Photo sharing app [https://github.com/ohnonoho/photoSharing](https://github.com/ohnonoho/photoSharing)

• Raspberry Pi, Arduino, Odroid
  – Used to prototype smart home devices, IoT

• DD-WRT and OpenWrt
  – Home routers

• Other embedded systems
Evaluation Platforms

• Every release of NFD is tested and deployed on the global NDN testbed.
• For evaluation, users now have a set of choices with different tradeoffs between scale and fidelity
  • NDN Testbed
    • 26 sites in US, China, France, Switzerland, Spain, Norway, Italy, Korea, Japan
    • http://named-data.net/ndn-testbed/
  • Open Network Lab, Emulab, ...
    • https://onl.wustl.edu/
  • Mini-NDN
    • https://github.com/named-data/mini-ndn
  • ndnSIM 2.1
    • http://ndnsim.net/2.1/
Architectural Features Available for Experimentation

• Edge support
  – minimize manual configurations

• NDNLPv2
  – hop-by-hop packet delivery assistance

• Network NACK
  – router-level “no”

• LINK object
  – name referrals (“delegations”)

ICNRG Interim Meeting
Edge Support

• Autoconfig and local hub discovery
  – Combination of various techniques to automatically discover and connect hosts to NDN testbed.

• Automatic Prefix Propagation
  – Producer connects to gateway and securely register its content prefixes with the gateway.
  – Needed for the last hop delivery of interests to the producer
NDNLPv2: Link Protocol for NDN

- Within one hop, under the NDN Interest/Data layer.
- A set of link services over underlying transport
  - Fragmentation/reassembly
  - Loss detection/recovery
    - done extensive simulations already
  - Link failure detection
  - Network NACK
- Services are optional depending on the type of transport
  - E.g., TCP, UDP, Ethernet
Network NACK

• When a node cannot fetch the data, generate a NACK to signal the downstream to explore other options.
  – Loop, link failure, no route, congestion, ...

• Return the unsatisfied Interest together with an error code as the NACK

• Downstream node explores other forwarding options.

• [http://redmine.named-data.net/projects/nfd/wiki/NDNLPv2](http://redmine.named-data.net/projects/nfd/wiki/NDNLPv2)
• [http://redmine.named-data.net/issues/2520](http://redmine.named-data.net/issues/2520)
LINK Object

- LINK is a new type of content object, which links one name to another.

- Used to support mobility, and routing scalability.
- Available in NFD/libraries
  - [http://redmine.named-data.net/issues/2587](http://redmine.named-data.net/issues/2587)

Strategy

• Version 4 of the Best Route Strategy
  – Support Interest retransmission with exponential back-off of the suppression interval
  – http://redmine.named-data.net/issues/3156 v4
  – http://redmine.named-data.net/issues/1913 v3
  – http://redmine.named-data.net/issues/1871 v2

• The Access Strategy for end hosts
  – Multicast to learn which host provides the content and remember what has been learned
  – http://redmine.named-data.net/attachments/download/201/access-router-strategy_20141220.pptx

• The Adaptive SRTT-based Forwarding strategy for hyperbolic routing

• Support LINK object for mobility and routing scalability
Security

- Tutorial
- Schematized trust (see ICN’15 paper)
  - application to NFD, NLSR, and other apps
- PIB service to manage public keys and publish certs
  - http://redmine.named-data.net/projects/ndn-cxx/wiki/PublicKey_Info_Base
- Improved signing APIs for better usability
- Signed Interest
  - http://named-data.net/doc/ndn-cxx/current/tutorials/signed-interest.html
- New NDN certificate format
- Experiments with automated testbed certificate issuance
Future Plan

• Forwarding Strategy
  – new strategies to support IoT, sensors, mobile and DTN environments
  – composable strategy towards the vision of a limited VM
• NDN over constrained communication channels
• Scoped communication
  – within enterprise, homes, etc.
• Hop-by-hop interest limit mechanism for congestion control
• Moving towards the plug-in-play model
  – auto-configuration, self-discovery, self-configuration
• Optimizations and refinements
  – Packet format, packet processing, data structures and algorithms, crypto
• Facilitate usable content-based security
  – authenticity, confidentiality, privacy