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

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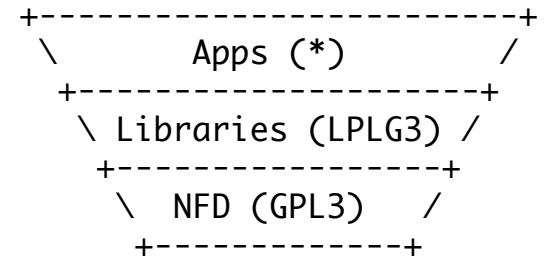
University of California, Los Angeles,

NDN team

ICNRG Interim Meeting

San Francisco, CA, October 2, 2015

# Progress in the past year

- Expand and improve supporting libraries

- One major release and five minor releases
  - next full major release this month
  - [http://named-data.net/doc/NFD/current/releases.html](http://named-data.net/doc/NFD/current/releases.html)

- 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

```
+------------------------+
\          Apps (*)         /
 +---------------------+
  \ Libraries (LPLG3) /
   +-----------------+
    \    NFD (GPL3)    /
     +------------+
```

| | | | |
|---|---|---|---|
| NdnCon | Chronochat-js | ndnfs | NDNFit |
| ndnrtc | ChronoShare | NDNoT | OpenPTrack-NDN |
| NLSR | ndn-traffic-generator | ndnrjs | Building Management |
| repo-ng | Federated Wiki | Matryoshka | ndn-hangman |
| ndn-tools | ndn-bms | ndnstatus | NDNWhiteboard |
| ChronoChat | ndn-lighting | NDNVideo | photoSharing |

# Community Involvement

- Mailing lists
    - nfd-dev: 100+  (http://www.lists.cs.ucla.edu/mailman/listinfo/nfd-dev )
    - ndn-interest: 340+ ( http://www.lists.cs.ucla.edu/mailman/listinfo/ndn-interest)
    - 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

# 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*) Packet Fragmentation in NDN: Why NDN Uses Hop-By-Hop Fragmentation.* NDN-0032.
- (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)
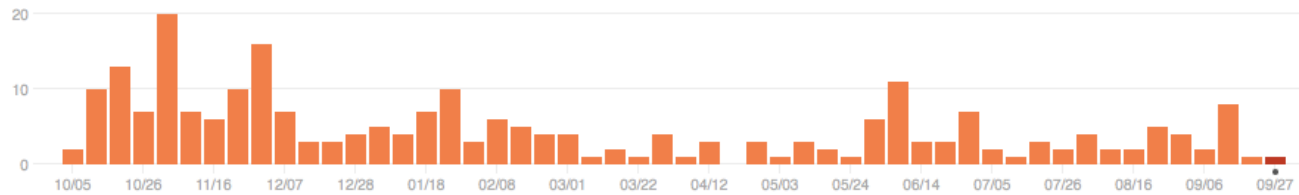  - Navigo: Interest Forwarding by Geolocations in Vehicular Named Data Networking (WoWMoM'15)

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

# Active Development

- Weekly code commits at Github
  - NFD

  - ndn-cxx

  - jndn
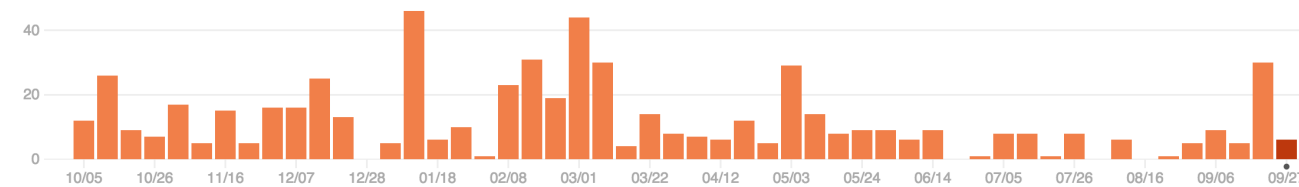
  - PyNDN2
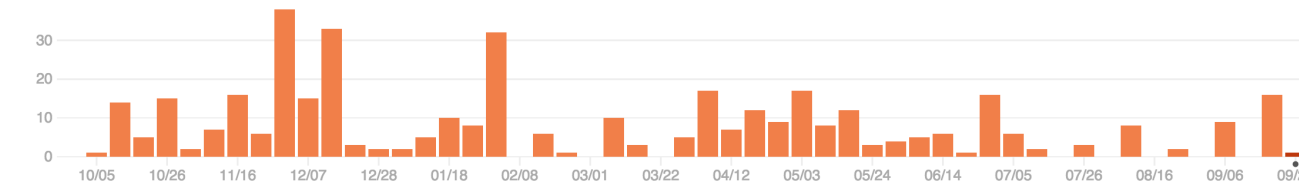
# Multi-Platform Suport

- NFD now runs on Android
  - https://github.com/named-data-mobile/NFD-android
  - A few pilot applications
    - Simple game https://github.com/dchimeraan/ndn-hangman
    - NDN Whiteboard https://github.com/sumitgouthaman/NDNWhiteboard
    - Photo sharing app 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
  - http://redmine.named-data.net/projects/ndn-embedded/wiki
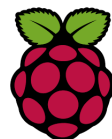
# Evaluation Platforms

- 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")

# Edge Support

- Autoconfig and local hub discovery
  - Combination of various techniques to automatically discover and connect hosts to NDN testbed.
  - [http://named-data.net/doc/NFD/current/manpages/ndn-autoconfig.html](http://named-data.net/doc/NFD/current/manpages/ndn-autoconfig.html)
  - [http://named-data.net/doc/NFD/current/misc/local-prefix-discovery.html](http://named-data.net/doc/NFD/current/misc/local-prefix-discovery.html)
- 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
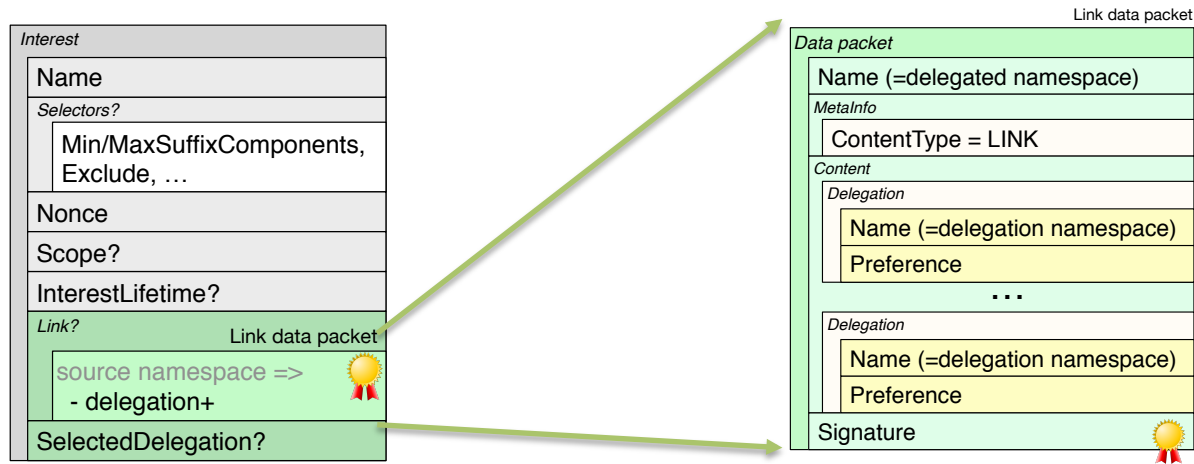  - E.g., TCP, UDP, Ethernet
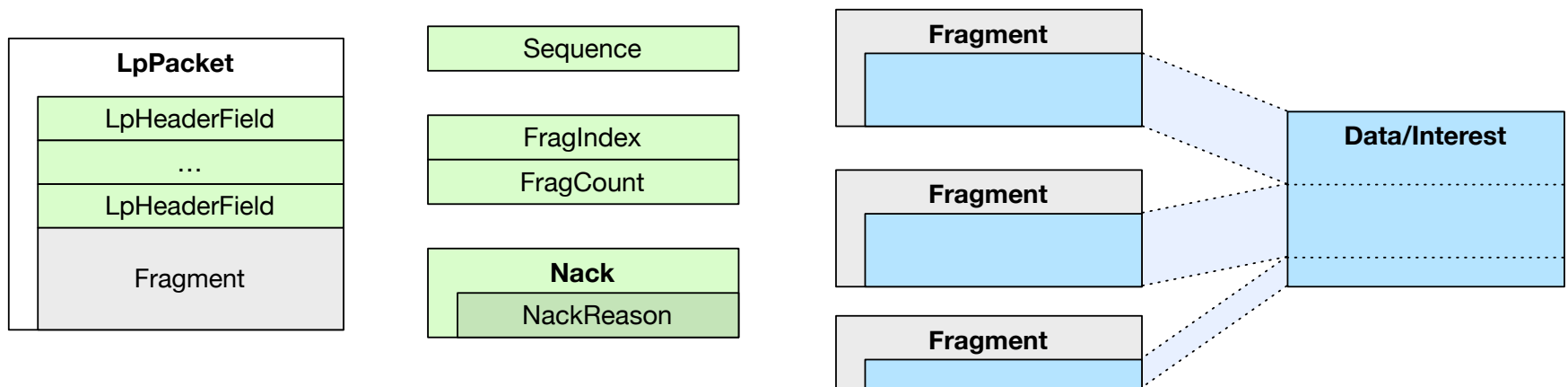
# Network NACK

- 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/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

# 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
  - http://named-data.net/doc/ndn-cxx/current/tutorials/security-library.html
- Schematized trust (see ICN'15 paper)
  - application to NFD, NLSR, and other apps
  - http://named-data.net/doc/ndn-cxx/current/tutorials/security-validator-config.html

- 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
  - http://named-data.net/doc/ndn-cxx/current/tutorials/certificate-format.html
- 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