NDN Project Progress

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www.named-data.net
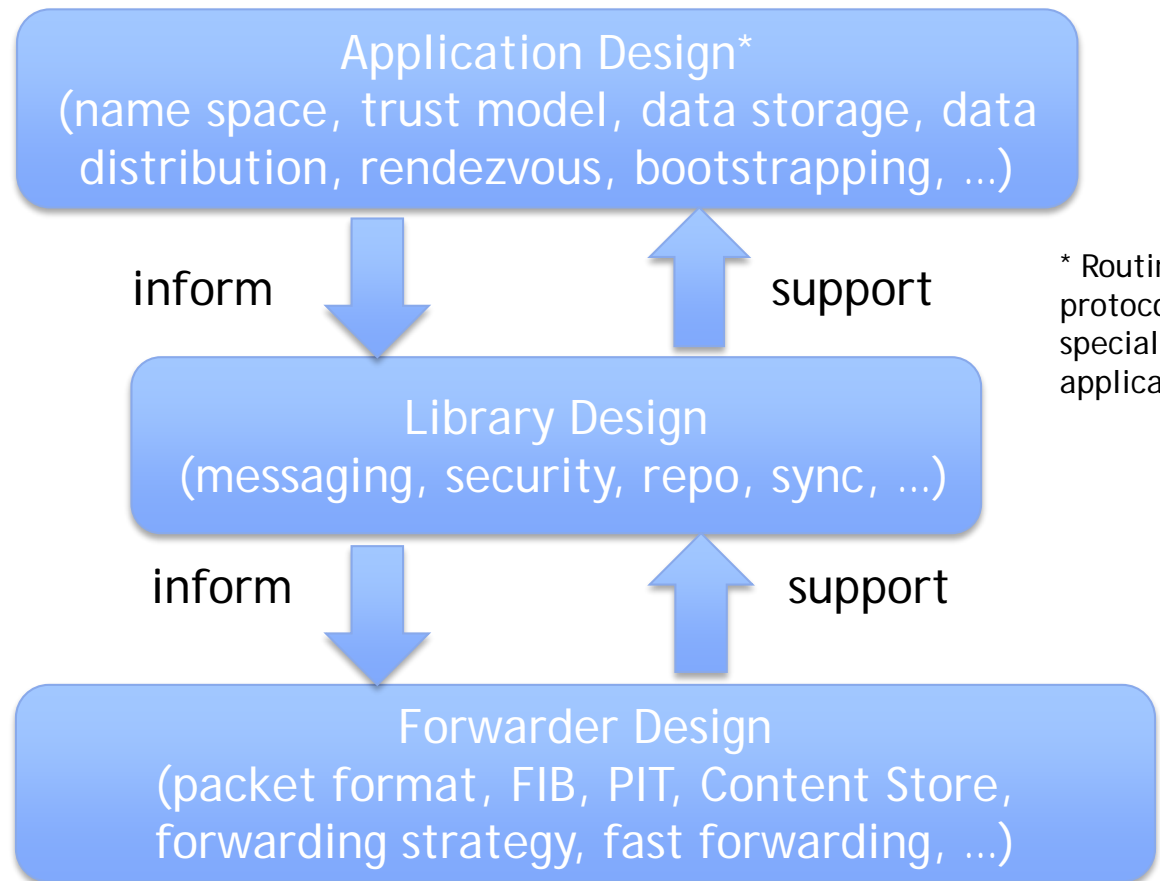
NDN Project

- Started in August 2010
- 12 institutions
- Lixia Zhang: Lead PI
- Van Jacobson: Architect
- http://www.named-data.net/

NDN Architecture Development [1]

- application-driven

- test and deploy on operational testbed

- conduct real-world demos

Application Design*
(name space, trust model, data storage, data distribution, rendezvous, bootstrapping, ...)

inform

support

* Routing protocol is a special application.

Library Design
(messaging, security, repo, sync, ...)

inform

support

Forwarder Design
(packet format, FIB, PIT, Content Store, forwarding strategy, fast forwarding, ...)

[1] L. Zhang, A. Afanasyev, J. Burke, V. Jacobson, kc claffy, P. Crowley, C. Papadopoulos, L. Wang, B. Zhang, Named Data Networking, to appear in *ACM SIGCOMM CCR* (also *NDN Technical Report 0019*)

Progress

All code is open source at https://github.com/named-data/.

- Multimedia applications
    - NDNVideo [2]
    - ChronoChat [3]
    - NDN-RTC
    - ChronoShare [4]
- IoT applications
    - Building automation and management [5, 6]
    - vehicular net [7]
- routing protocol [8] and forwarding strategy
- Scalable forwarding engine
- Security
    - trust model
    - DDoS
    - Anonymity
- Libraries
   - NDN-CCL, NDN-CXX, pyNDN2, ndn-js, ChronoSync [9], NDN repo

NDNVideo [2]

- Live and pre-recorded streaming to multiple consumers.

- No session semantics => scalability. Tested for ~1000 clients from 1 src

- First Interest sent can randomly access a keyframe at any timecode

- Leverages caching.
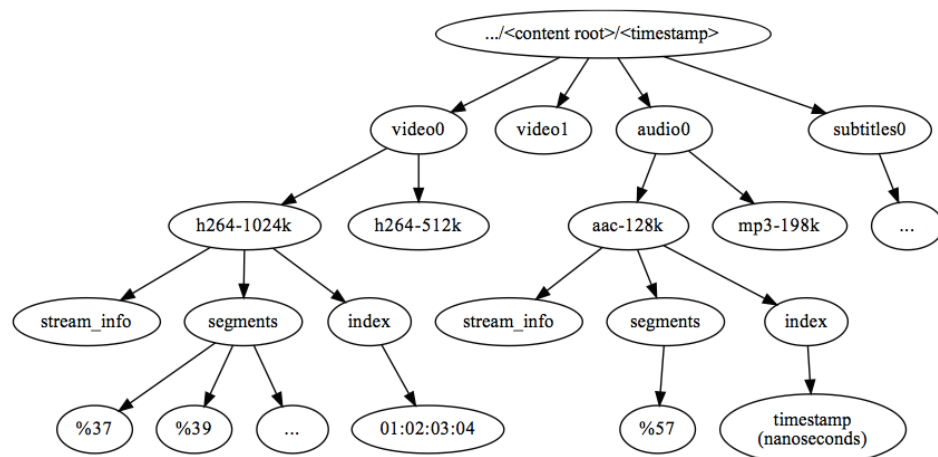
[2] D. Kulinski, J. Burke, and L. Zhang. "Video Streaming over Named Data Networking," *IEEE COMSOC MMTC E-Letter*, 2013.

ChronoChat [3]

- **server-less** chat application based on ChronoSync

- chat messages are synchronized among participants

- leverage multicast nature of NDN

| Interest	Interfaces
/prefix/digest	0,1,2
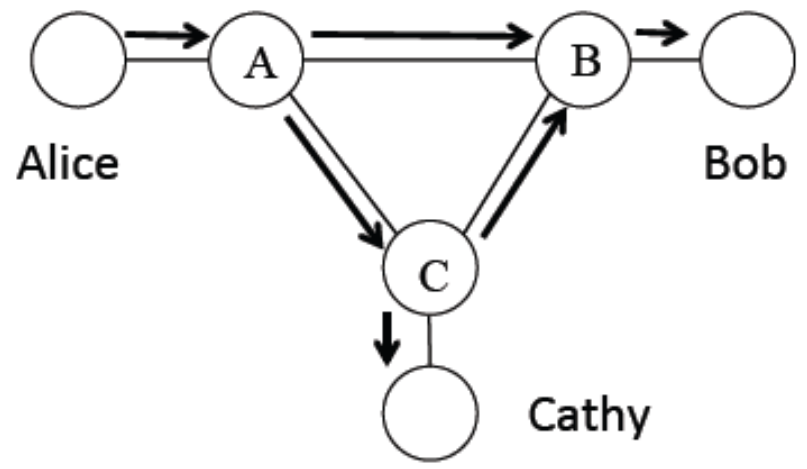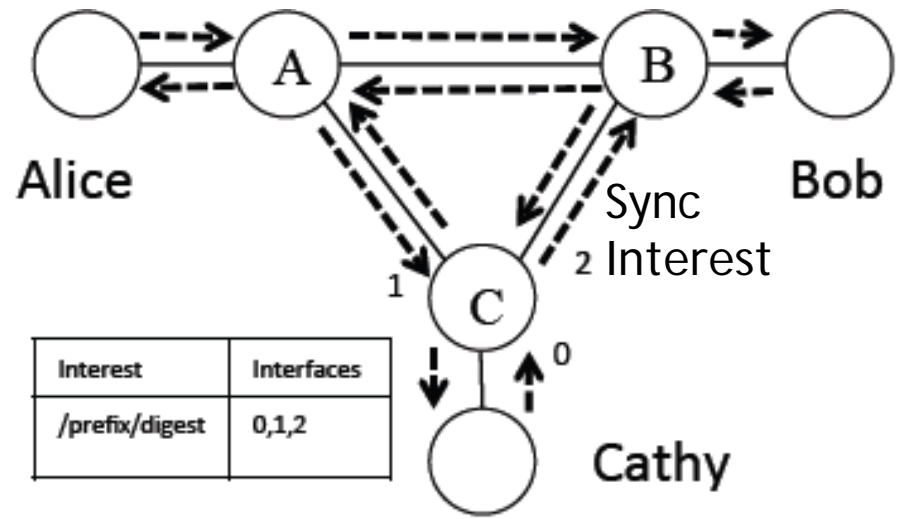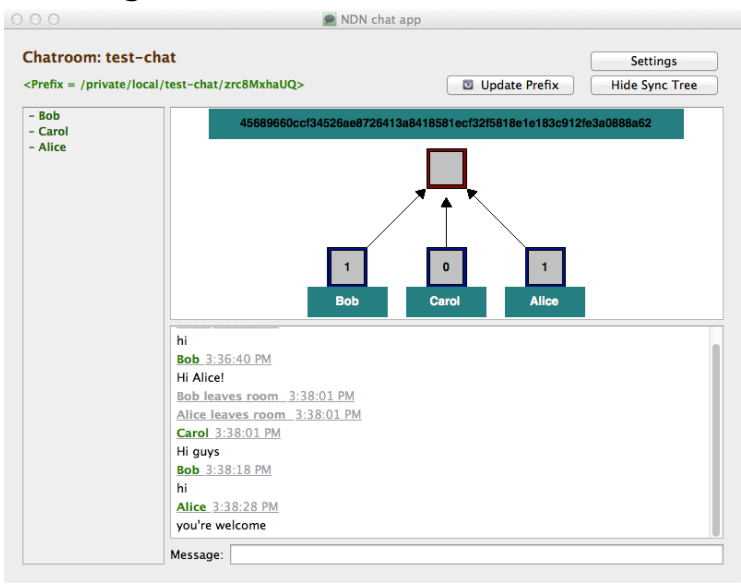
Alice's Sync Data Packet

[3] Z. Zhu, C. Bian, A. Afanasyev, V. Jacobson, and L. Zhang. Chronos: Serverless multi-user chat over NDN. *Technical Report NDN-0008*, NDN Project, October 2012.
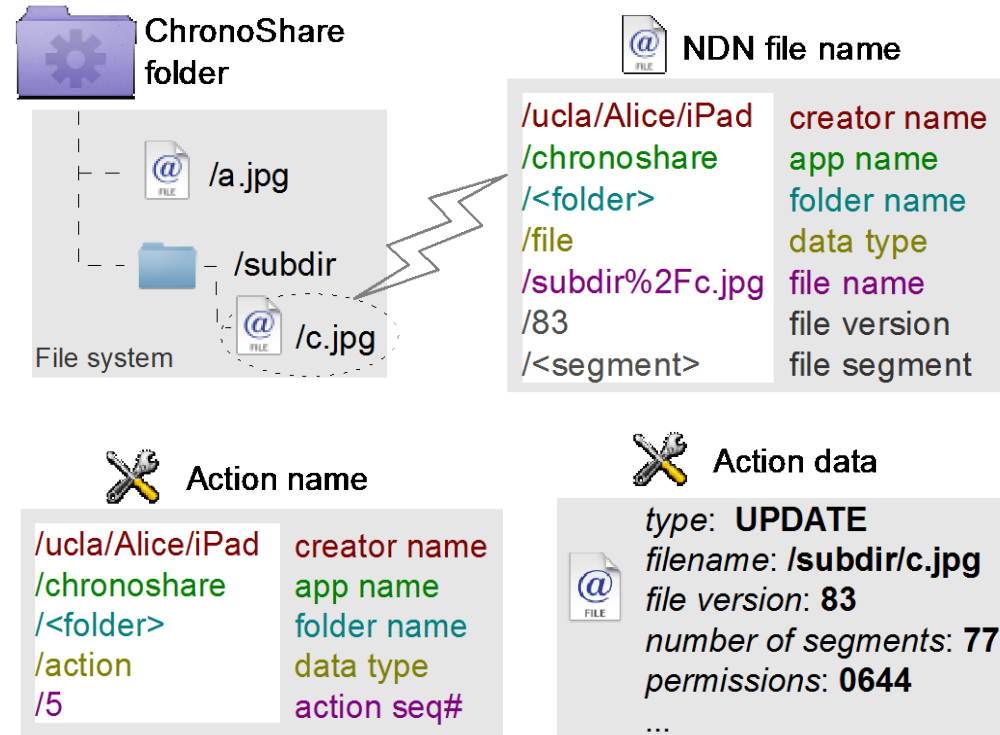
ndnrtc

- Real-time audio/video/text chat application enabling multi-peer conferencing over NDN.

- Explore how to handle packet losses and delays while maintaining a session-less approach.

- Supports new TLV packet format.

- Based on WebRTC codebase, using ChronoSync for conference discoveries.

- Expected release: June 2014.
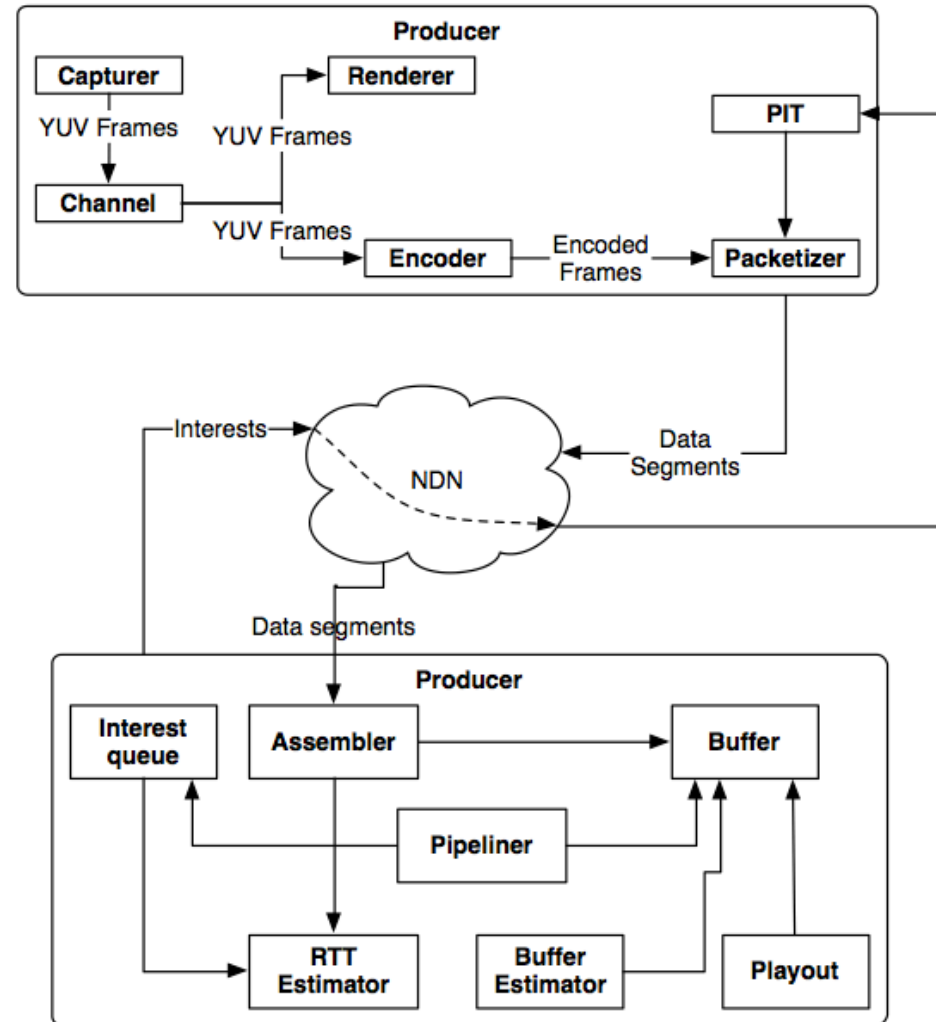
# ChronoShare: Distributed File Sharing and Editing [4]

- Think Google Drive, but no centralized server
  - Different users can share folders.
  - Each user can sync folders on different devices.

- How?
  - Each user's actions (on file) form a stream of data.
 - Use ChronoSync to distribute knowledge of user actions

ChronoShare folder

/a.jpg

/subdir

/c.jpg

File system

NDN file name

/ucla/Alice/iPad	creator name
/chronoshare	app name
/<folder>	folder name
/file	data type
/subdir%2Fc.jpg	file name
/83	file version
/	file segment

Action name

/ucla/Alice/iPad	creator name
/chronoshare	app name
/<folder>	folder name
/action	data type
/5	action seq#

Action data

type: **UPDATE**
filename: **/subdir/c.jpg**
file version: **83**
number of segments: **77**
permissions: **0644**
...

[5] A. Afanasyev, Z. Zhu, L. Zhang, The story of ChronoShare, or how NDN brought distributed file sharing back

Building Automation and Management [5,6]

- Explore challenges in sensing and actuation at a campus scale.

- Improve application development process, management, interoperability and security.

- Practical work so far: NDN interfaces to BacNET and Modbus sensing, authenticated lighting control.

- Partner: UCLA Facilities Management.
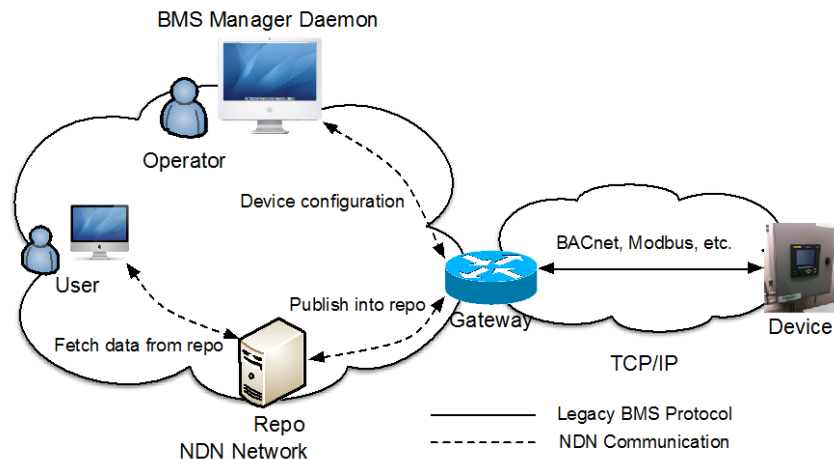
UCLA NDN Building Monitoring Testbed
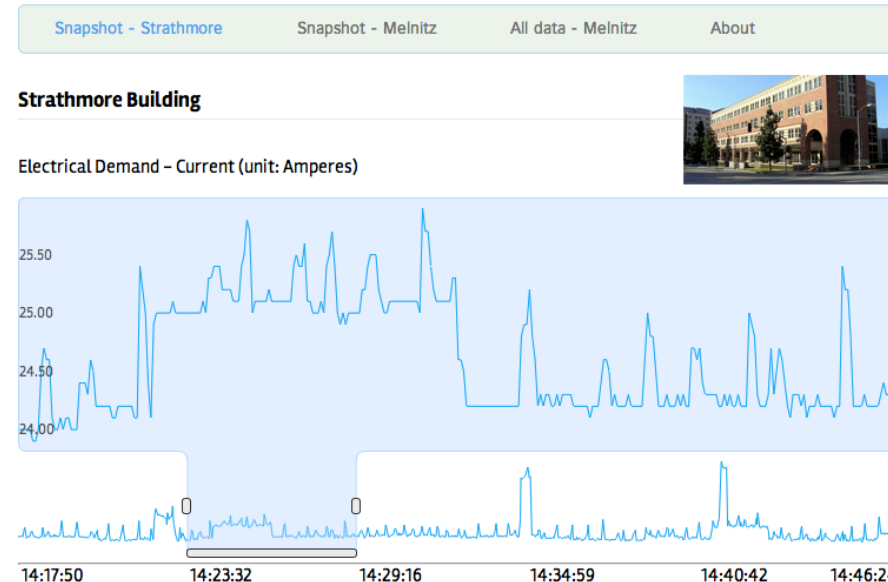
[5] Burke et al. Securing instrumented environments over Content-Centric Networking: the case of lighting control. In *IEEE INFOCOM NOMEN Workshop*, Apr. 2013.
[6] Shang et al., "Securing Building Management Systems Using Named Data Networking," *IEEE Network*, May/June 2014.
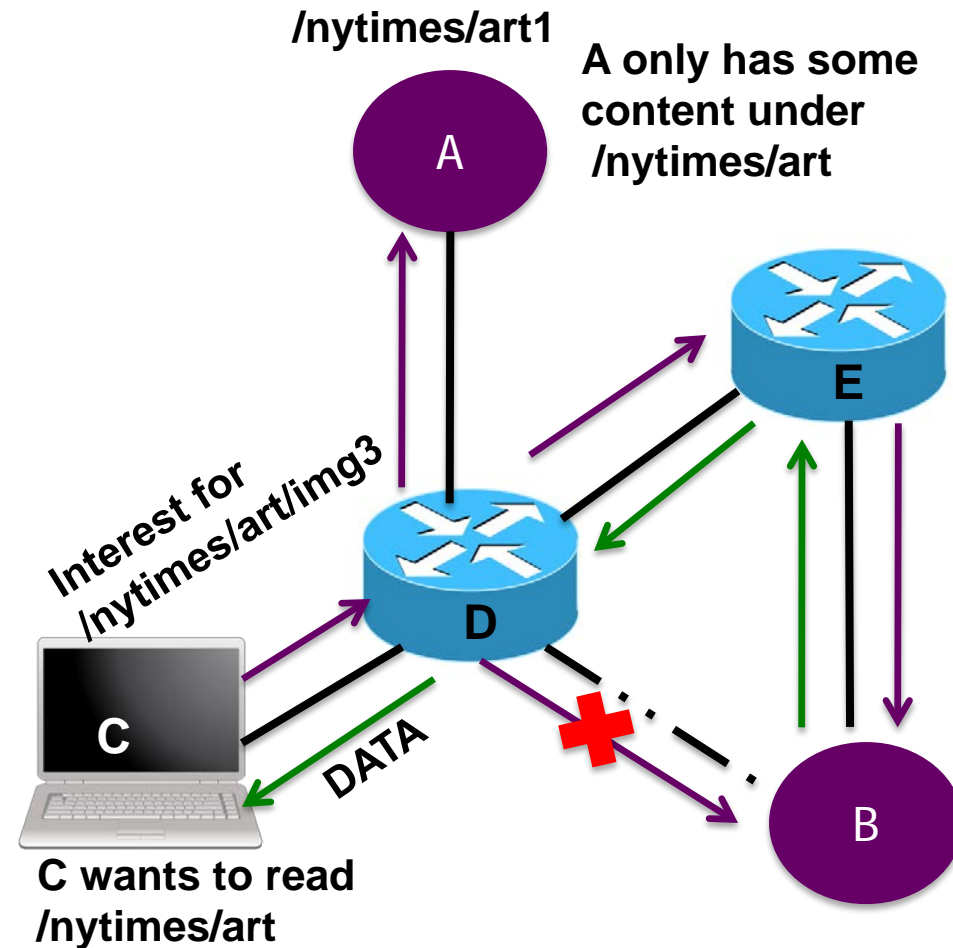
Building Automation and Management [6]

- Next: Port the NDN platform to support work at the embeded device level, starting with Raspberry PI as a platform for experimentation.

- Target in-home appliance-to-appliance-to-gateway communication and applications (cf. AllSeen)

- Consider discovery, bootstrapping, storage / data custodian functionality.

- Three demo nodes planned:
    - Occupancy (PIR)
    - Remote A/V control (HDMI-CEC)
    - Security / webcam
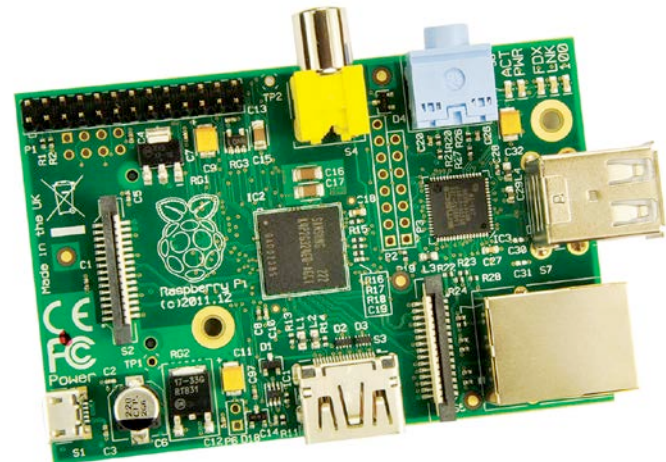
Routing in NDN

- ## Requirement: Routing based on "name"
  - Guides each "interest" packet to all potential providers (all paths)
  - Some providers may not have all content in a "name"

- ## Non-requirement: Fast routing convergence
  - Stateful forwarding plane can adapt to changes

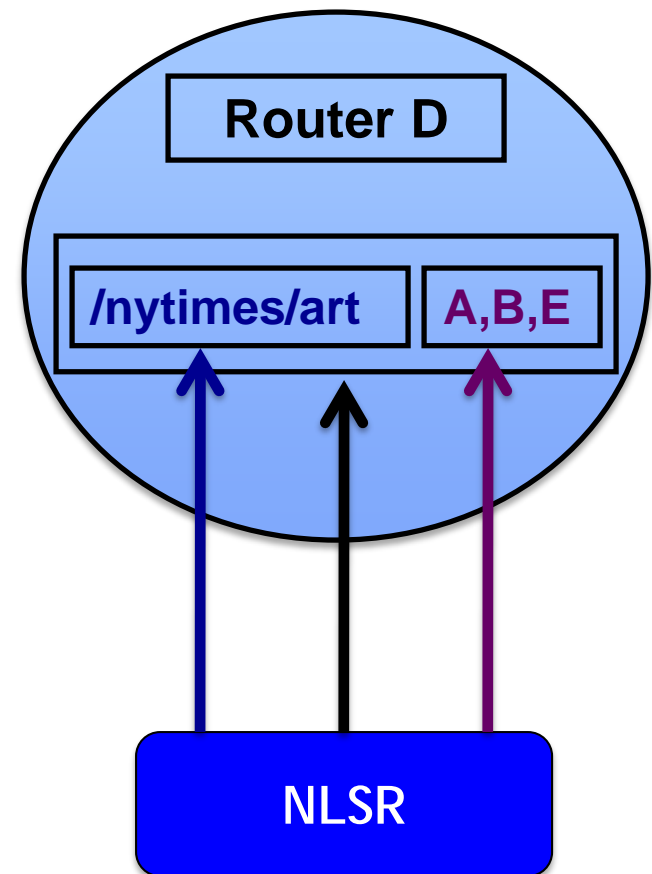**/nytimes/art1**

A only has some content under /nytimes/art

A

E

Interest for /nytimes/art/img3

D

C

DATA

B

C wants to read /nytimes/art

D's FIB:	/nytimes/art	A, B, E

Named Data Link State Routing (NLSR) [8]

• Link State routing for NDN

• NLSR is designed to meet routing needs of NDN:

  • Generates FIB

  • FIB entries are name based

 • Calculates multiple faces for each FIB entry

Naming in NLSR

- Follow the hierarchy within a network
  - Easy to identify the relationship among entities
  - Easy to associate keys with key owners
- Router
  - /<network>/<site>/<router>: e.g., /ndn/memphis/rtr1
- Updates
  - /<network>/NLSR/LSA/<site>/<router>/<process>/<type>/<version>
- Keys
  - NLSR key: /<network>/<site>/<router>/<process>/key
  - Router key, operator key, …

Routing Security and Trust Model

Signing and verification in NLSR

- Every NLSR Data packet is signed.
- "Key locator" includes information about the key.
- Receiver retrieves the key and verifies the signature.
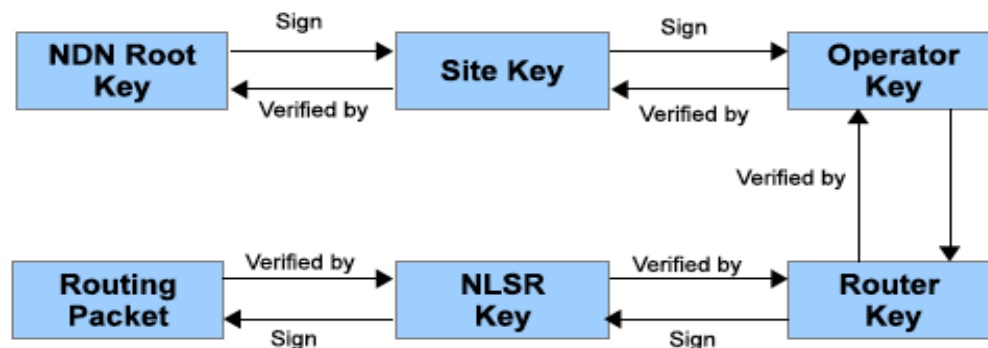
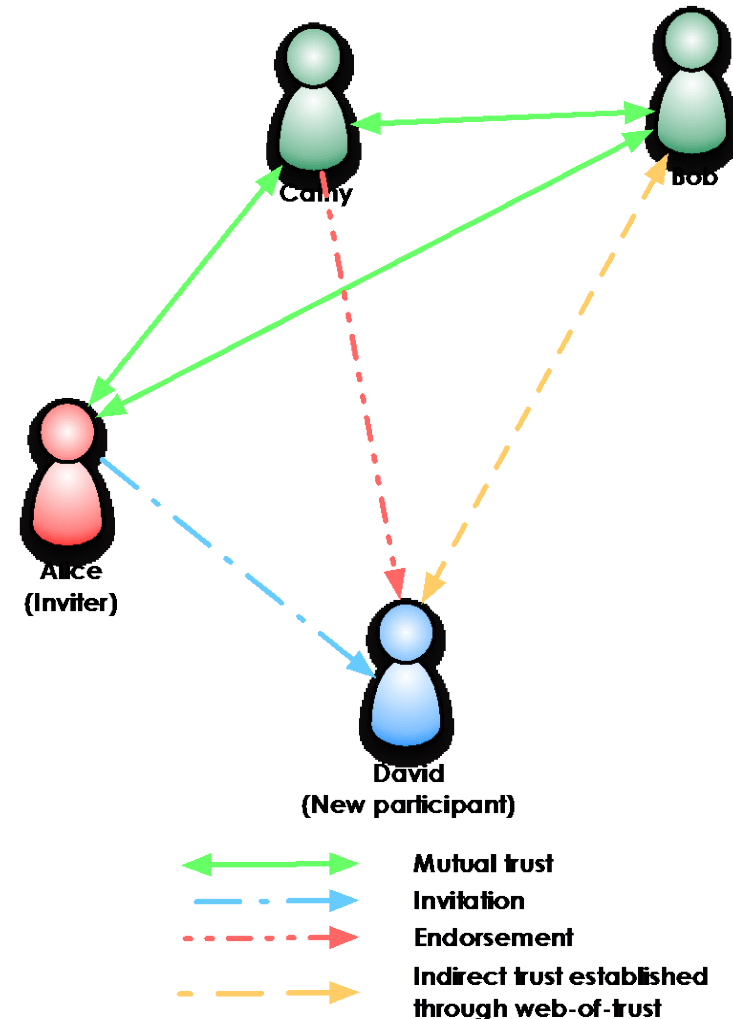| Key Owner	Key Name
Root	/<network>/key
Site	/<network>/<site>/key
Operator	/<network>/<site>/<operator>/key
Router	/<network>/<site>/<router>/key
NLSR	/<network>/<site>/<router>/<process>/key

Web-of-Trust Model

- secure ChronoSync-based applications
  - hierarchical trust model does not match peer-to-peer synchronization
- invitation-based management of sync group membership
- endorsement-based certificate authentication

Cathy

Bob

Alice
(Inviter)

David
(New participant)

Mutual trust

Invitation

Endorsement

Indirect trust established
through web-of-trust

Scalable Forwarding Engine Design

- Requirements
  - data structures to store millions to billions of names
  - fast table lookup of variable-length names
  - fast packet processing
- NDN project's progress
  - multi-million entry FIBs stored in less than 10MB [10]
  - FIB lookup speeds on the order of microseconds [10]
  - PIT: 37 to 245 MiB memory for 100 Gbps throughput (small enough to fit in fast memory chips) [11]

[10] H. Yuan, T. Song, and P. Crowley. Scalable NDN forwarding: Concepts, issues and principles. In *ICCCN*, 2012.
[11] H. Yuan and P. Crowley. Scalable pending Interest table design: From principles to practice. *IEEE INFOCOM*, 2014.

NDN Common Client Libraries (NDN-CCL) [ ]

- Clean slate/portable libraries with a consistent API

- Make it easy for developers to create applications

- Multiple languages: C++, JavaScript, Python, Java

- Main classes follow architectural abstractions: Name, Interest, Data, Face

- Wire-format independent

- TLV support

- Experimental digital signature/security API that will evolve with research.

Name Class

A Name holds an array of Name.Component and represents an NDN name.

[C++]:   Namespace: `ndn`

[Python]:   Module: `pyndn`

Name Constructors

Name Constructor (array of components)

Create a new Name with the optional components.

[C++]:
```
Name(
    [const std::vector<Name::Component>& components]
);
```

[JavaScript]:
```
var Name = function Name (
    [components    // Array<Uint8Array>]
)
```

[Python]:
```
def __init__(self
    [, components # Array<string>]
)
```

named-data.net/codebase/platform/documentation/ndn-ccl-api

NDN Platform Release

- **http://named-data.net/codebase/platform/**
  - building blocks of NDN platform
  - ndnSIM simulator

- a new release every few months

- Latest version: Version 0.3 alpha 1 released on Feb. 27, 2014.

- Next release (soon) will contain new forwarder (NFD), new library and NLSR.

NDN Testbed
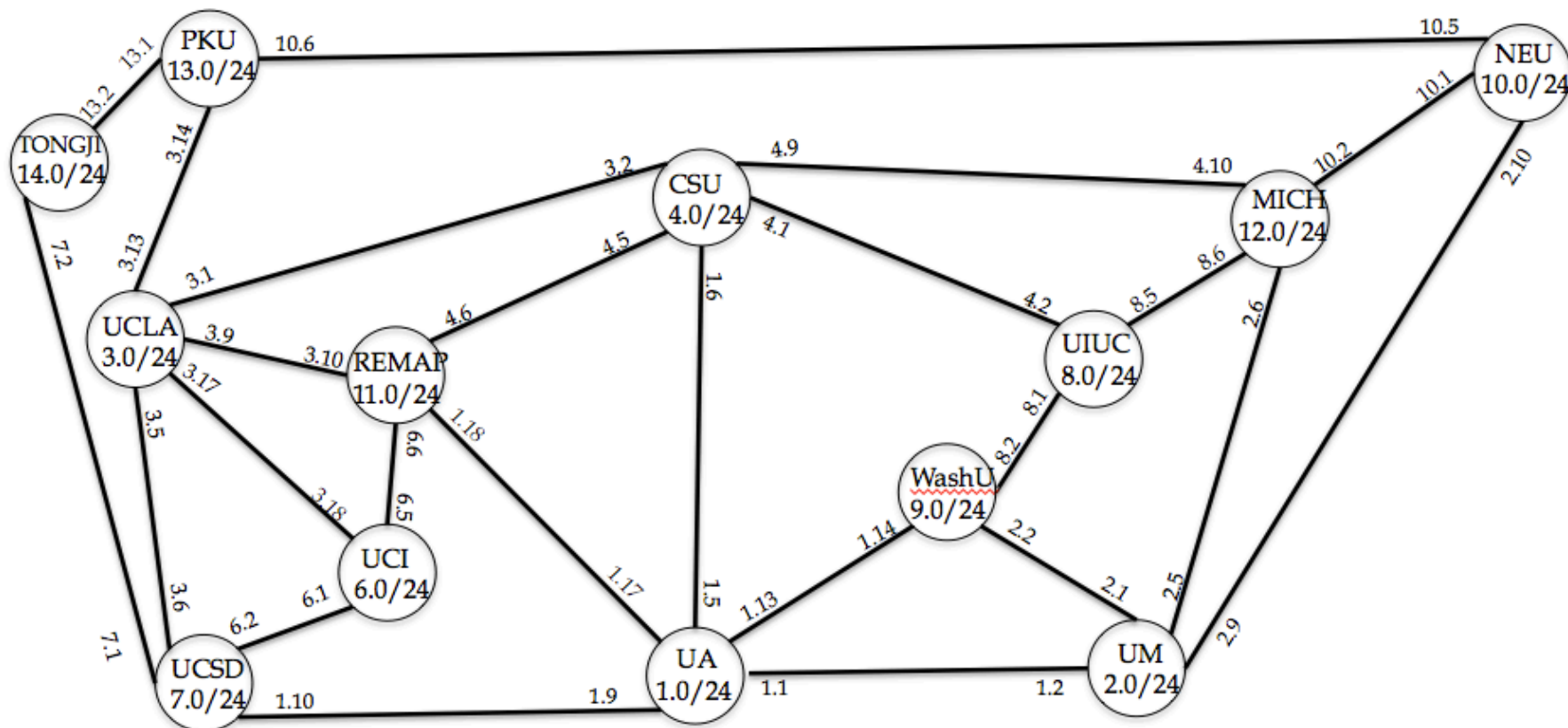
More info at http://named-data.net/ndn-testbed/
Contact us if interested in joining the testbed.

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

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

- Delivery of live audio and video from performance studio at UCLA
  - Jeff Burke's Center for Research in Engineering, Media and Performance (REMAP)
- Lighting control application is NDN-based
- Server at studio homed off REMAP gateway
- Laptop on-site homed off Tokyo gateway
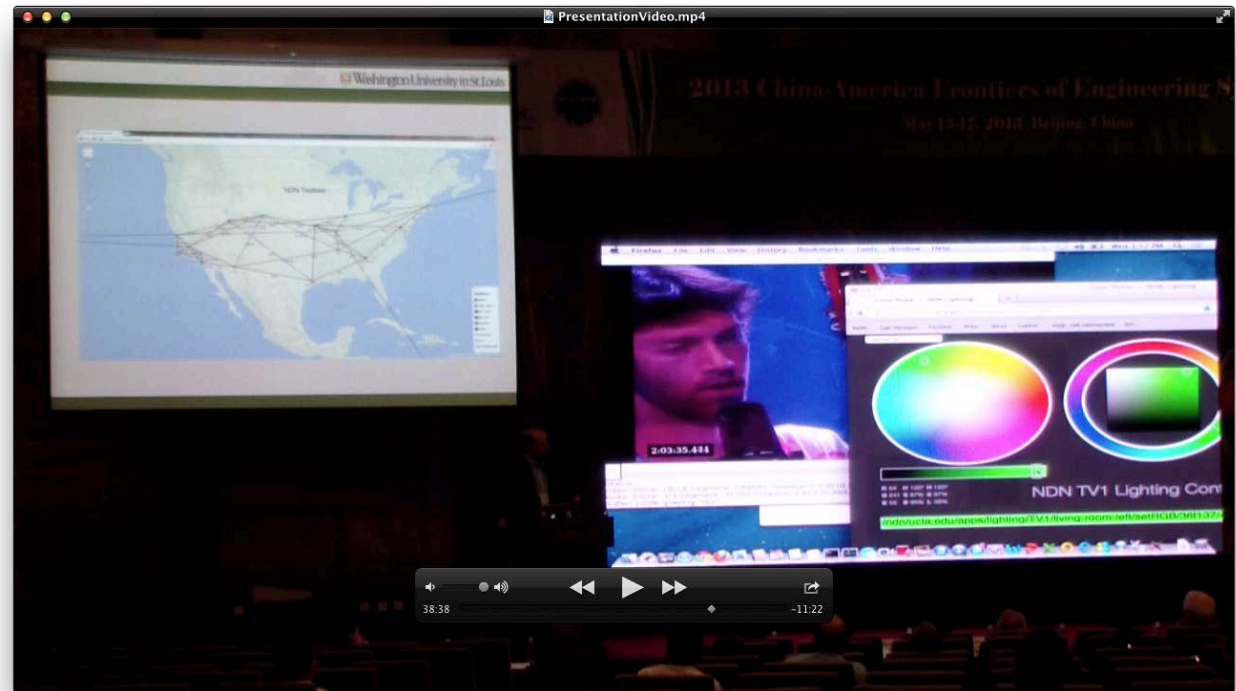
Next Step

- Applications
  - Open M-Health
  - E-BAMS
  - Mobile Media Application Cluster
- Forwarding and routing: Interdomain routing, forwarding strategy
- Security: privacy, trust management

References

1. L. Zhang, A. Afanasyev, J. Burke, V. Jacobson, kc claffy, P. Crowley, C. Papadopoulos, L. Wang, B. Zhang, Named Data Networking, to appear in *ACM SIGCOMM CCR* (also *NDN Technical Report 0019*)

2. D. Kulinski, J. Burke, L. Zhang. Video Streaming over Named Data Networking. *IEEE COMSOC MMTC E-Letter*, 2013.

3. Z. Zhu, C. Bian, A. Afanasyev, V. Jacobson, and L. Zhang. Chronos: Serverless multi-user chat over NDN. *Technical Report NDN-0008*, NDN Project, October 2012.

4. A. Afanasyev, Z. Zhu, L. Zhang, The story of ChronoShare, or how NDN brought distributed file sharing back, under review

5. J. Burke, P. Gasti, N. Nathan, and G. Tsudik. Securing instrumented environments over Content-Centric Networking: the case of lighting control. In *IEEE INFOCOM NOMEN Workshop*, Apr. 2013.

6. W. Shang, Q. Ding, A. Marianantoni, J. Burke, and L. Zhang. Securing building management systems using named data networking. *IEEE Network Special Issue on Information-Centric Networking*, April 2014.

7. G. Grassi, D. Pesavento, G. Pau, R. Vuyyuru, R. Wakikawa, and L. Zhang. VANET via Named Data Networking. In *IEEE INFOCOM NOMEN Workshop*, Apr. 2014.

8. A. Hoque, S. O. Amin, A. Alyyan, B. Zhang, L. Zhang, and L. Wang. Named-data link state routing protocol. In *ACM SIGCOMM ICN Workshop*, 2013.

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9. Z. Zhu, A. Afanasyev, and L. Zhang. Let's ChronoSync: Decentralized dataset state synchronization in NDN. In *ICNP*, 2013.

10. H. Yuan, T. Song, and P. Crowley. Scalable NDN forwarding: Concepts, issues and principles. In *ICCCN*, 2012.

11. H. Yuan and P. Crowley. Scalable pending Interest table design: From principles to practice. *IEEE INFOCOM*, 2014.

12. W. So, A. Narayanan, and D. Oran. Named data networking on a router: Fast and DoS-resistant forwarding with hash tables. In *ACM/IEEE Symposium on Architectures for Networking and Communications Systems (ANCS)*, Oct 2013.

13. M. Varvello, D. Perino, and J. Esteban. Caesar: A content router for high speed forwarding. In *ACM SICOMM Workshop on Information-centric Networking*, 2012.