NDN-NP Applications Update

Jeff Burke
NDNcomm 2015

Collaborative work by many.

Reformulation

Storytelling

=> What if streaming media could be composed just-in-time?

=> What if expeditionary networks were the norm?

Health and Wellness

=> What if the user was the root of trust for their own data?

Building management / IoT

=> What if there was no assumption of perimeter security?

Real-time conferencing

=> What if it's about what the *network* can deliver, not reaching a producer?

Outline

Four applications covered in this talk:

- **NDNFit** (user-centric health & wellness)
- **NDN UX** (user experience of identity / data sharing in NDNFit)
- **EBAMS** (and IoT)
- **NDN-RTC** (low-latency media / conferencing)

Also, the team has been working on scientific data apps (covered in the next presentation) and higher-level communication protocols (sync, infomax).

More about all of these in other presentations, demos, breakouts.

NDN-NP Progress So Far

Where we started –

- **Incorporate security**: Name-based trust definition, verification, confidentiality.
- **Practical deployment** needs that yield research challenges: publisher mobility, autoconfig, trust bootstrapping, etc.
- **Higher-level communication concepts** – e.g., sync, manifests.

What also emerged –

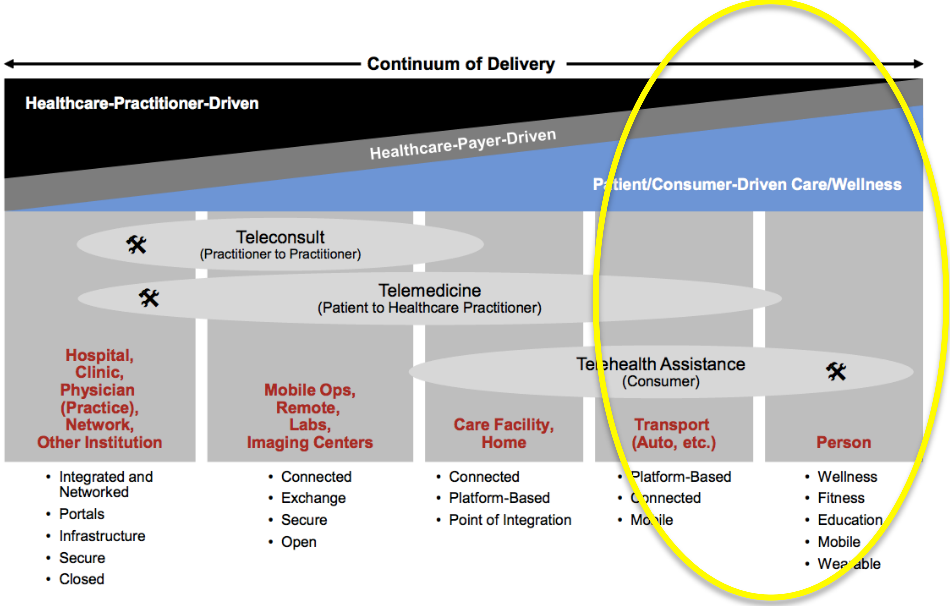
- **App / strategy relationships**.
- **Traffic measurement requirements**.
- **Performance requirements**. (Finally!)

NDNFit

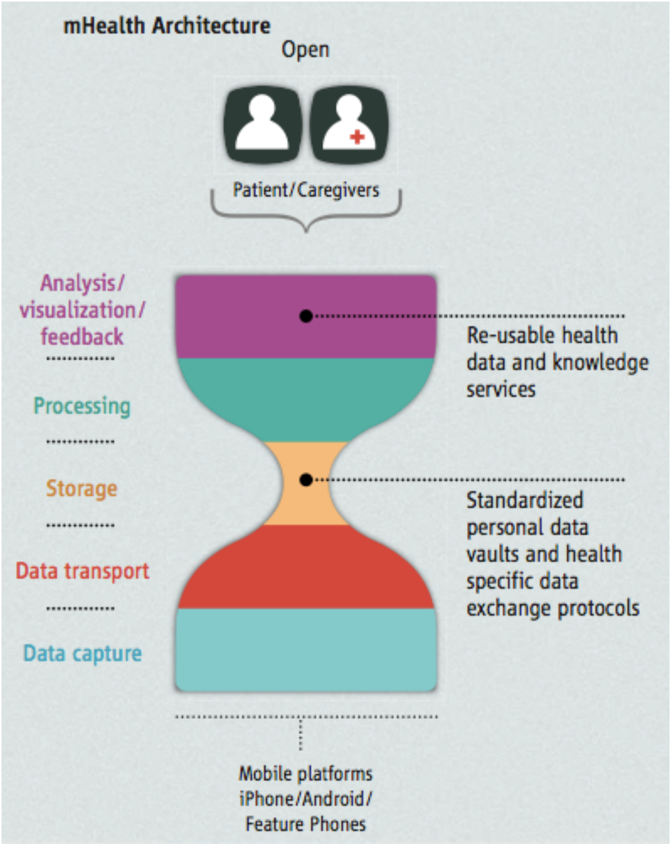
Haitao Zhang, Alexander Afanasyev, Jianxun Cao, Euihyun Jung, Jiewen Tan, Jeff Thompson, Yingdi Yu, Jeff Burke, Dan Pei, Christian Tschudin, Lixia Zhang, and others.

NDNFit: Open mHealth example application

An ecosystem conceived with data exchange as the thin waist (Sim & Estrin, 2010), which is natural for NDN.



Gartner, 2014

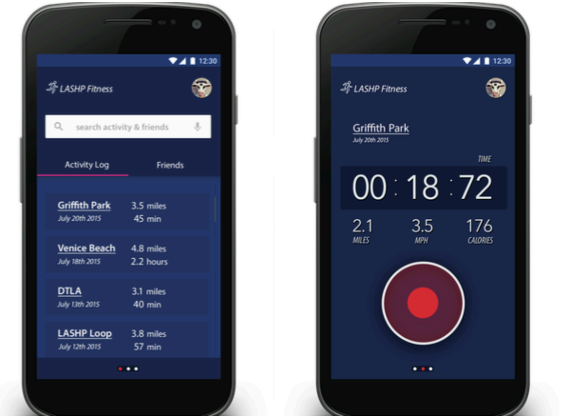


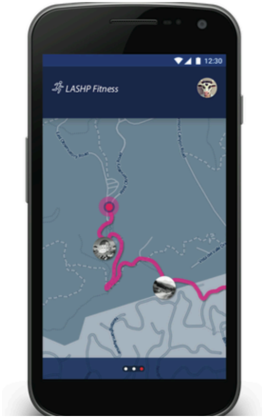
NDNFit: Open mHealth example application

How do we conceive and build a familiar-looking application that demonstrates interaction in this ecosystem?

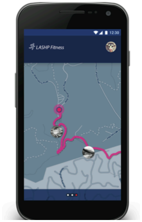
NDN enables a user-centric reformulation of health and wellness data management.

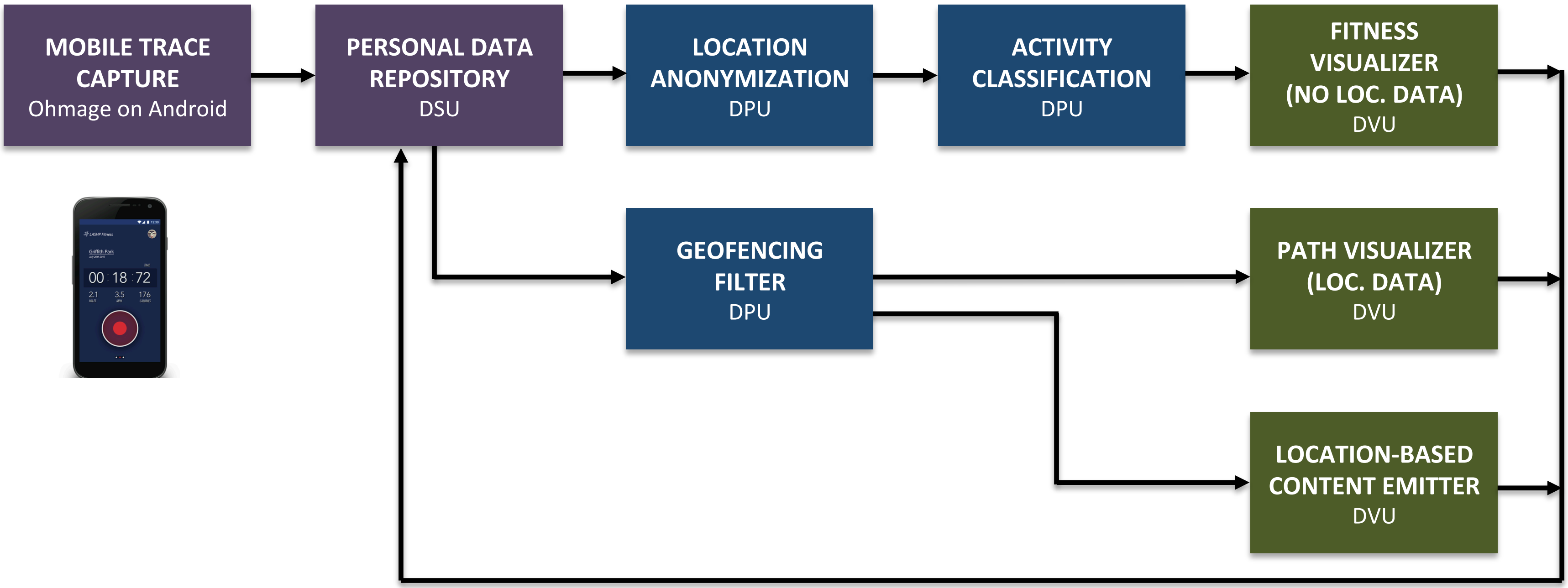
One simple step: the user can be the root of trust.



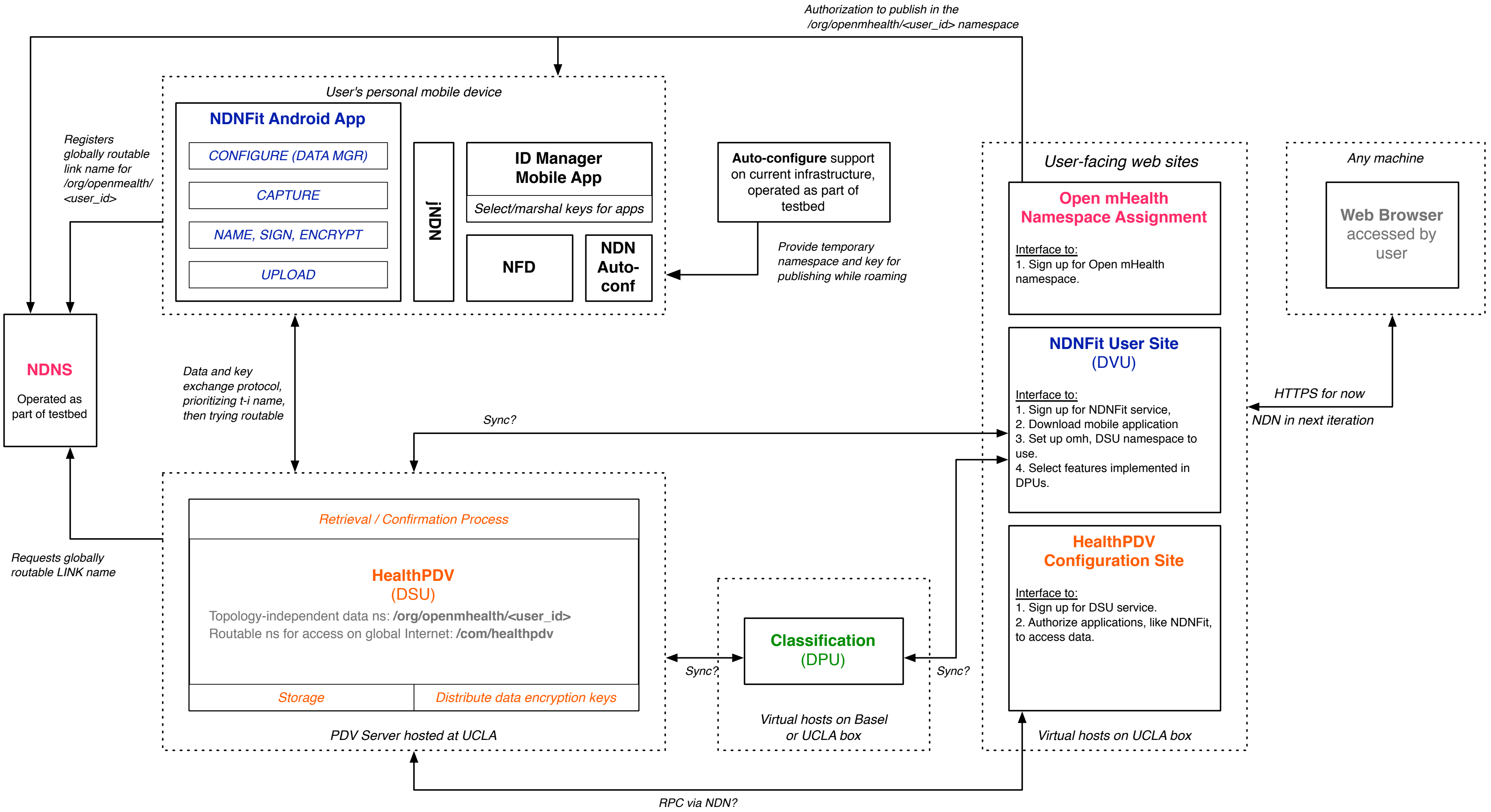


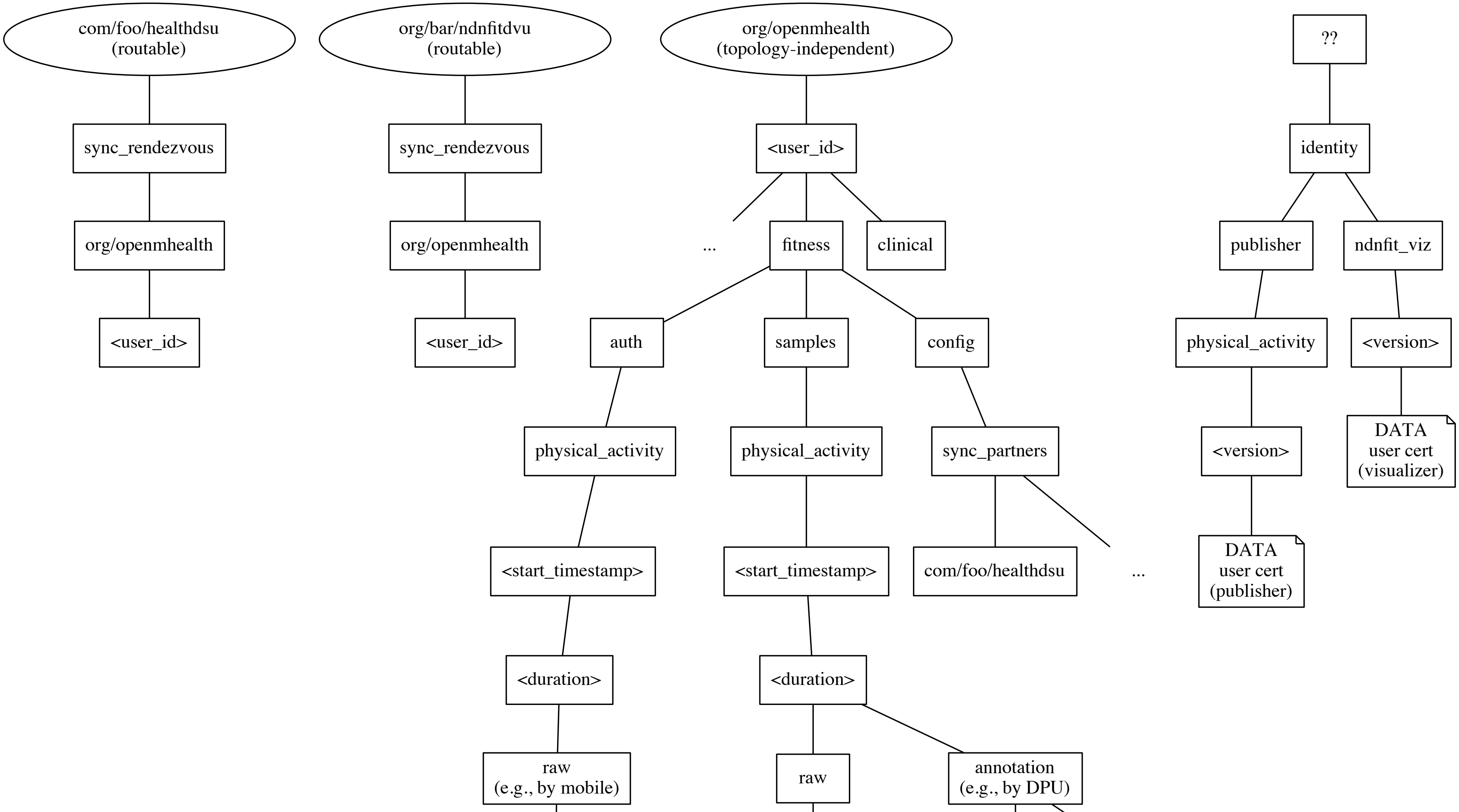
Concept



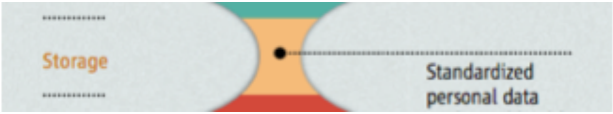


MOBILE TRACE CAPTURE
Ohmage on Android
PERSONAL DATA REPOSITORY
DSU
LOCATION ANONYMIZATION
DPU
ACTIVITY CLASSIFICATION
DPU
FITNESS VISUALIZER (NO LOC. DATA)
DVU
GEOFENCING FILTER
DPU
PATH VISUALIZER (LOC. DATA)
DVU
LOCATION-BASED CONTENT EMITTER
DVU

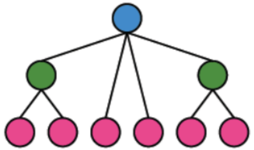

Authorization to publish in the
/org/openmhealth/<user_id> namespace
User's personal mobile device
NDNFit Android App
CONFIGURE (DATA MGR)
CAPTURE
NAME, SIGN, ENCRYPT
UPLOAD
jNDN
ID Manager
Mobile App
Select/marshal keys for apps
NFD
NDN
Auto-
conf
Auto-configure support on current infrastructure, operated as part of testbed
Provide temporary namespace and key for publishing while roaming
Registers globally routable link name for /org/openmealth/<user_id>
NDNS
Operated as part of testbed
Data and key exchange protocol, prioritizing t-i name, then trying routable
Sync?
User-facing web sites
Open mHealth
Namespace Assignment
Interface to:
1. Sign up for Open mHealth namespace.
NDNFit User Site
(DVU)
Interface to:
1. Sign up for NDNFit service,
2. Download mobile application
3. Set up omh, DSU namespace to use.
4. Select features implemented in DPUs.
HealthPDV
Configuration Site
Interface to:
1. Sign up for DSU service.
2. Authorize applications, like NDNFit, to access data.
Virtual hosts on UCLA box
Any machine
Web Browser
accessed by
user
HTTPS for now
NDN in next iteration
Requests globally routable LINK name
Retrieval / Confirmation Process
HealthPDV
(DSU)
Topology-independent data ns: /org/openmhealth/<user_id>
Routable ns for access on global Internet: /com/healthpdv
Storage
Distribute data encryption keys
PDV Server hosted at UCLA
Sync?
Classification
(DPU)
Sync?
Virtual hosts on Basel
or UCLA box
RPC via NDN?

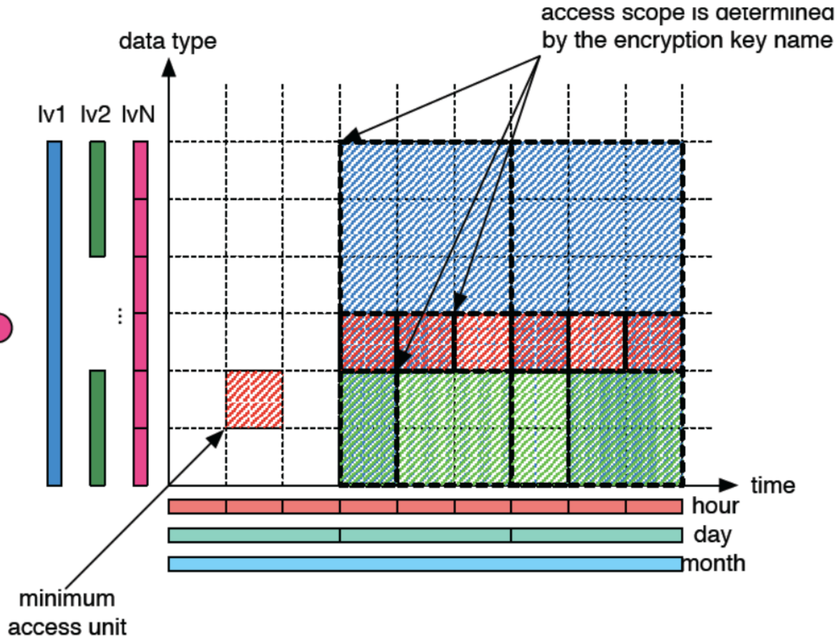

com/foo/healthdsu
(routable)
sync_rendezvous
org/openmhealth
<user_id>
org/bar/ndnfitdvu
(routable)
sync_rendezvous
org/openmhealth
<user_id>
org/openmhealth
(topology-independent)
<user_id>
...
fitness
clinical
auth
samples
config
physical_activity
physical_activity
sync_partners
<start_timestamp>
<start_timestamp>
com/foo/healthdsu
...
<duration>
<duration>
raw
(e.g., by mobile)
raw
annotation
(e.g., by DPU)
??
identity
publisher
ndnfit_viz
physical_activity
<version>
<version>
DATA
user cert
(visualizer)
DATA
user cert
(publisher)

Data-Centric Security



- Good fit for this application.
- Schematized trust
  - Initial design developed.
  - jNDN support for Android.
- Name-based access control
  - Names capture dimensions we want to manage.
- New pieces / future areas
  - Access control for NFN processing blocks.
  - Name confidentiality.





Challenges

- Life-long data. Enabling the user to “move” data storage from provider to provider and maintain the same namepsace.
- Usable security. Schematized trust and name-based security are conceptually simple, but work to be done on how to provide this power to developers in a simple way.
- Best type of sync protocol(s) for mobile upload, storage – processing.
- Access control between processing blocks.
- Publisher mobility.
- See Haitao Zhang’s poster for more information.

User Experience for NDNFit

Dustin O’Hara, Jeff Burke

LASHP Fitness Website

Informed by REMAP's ongoing work with the Los Angeles State Historic Park (LASHP), the NDN Fitness applications will be branded to reflect the identity of the park and landscape of downtown Los Angeles.

Once the user is at the LASHP fitness website they are directed to download the fitness recorder and fitness visualizer apps through a trusted "app store" mechanism that has yet to be determined.

But this application is a new kind

- **User owns the data**
- **Ecosystem of interoperable applications**
- **Named data!**

Bridging the NDN architecture with users

NDN Namespaces

- How are users introduced to the application namespaces?
- How much exposure to the namespaces is necessary?

Identity management & Data signing

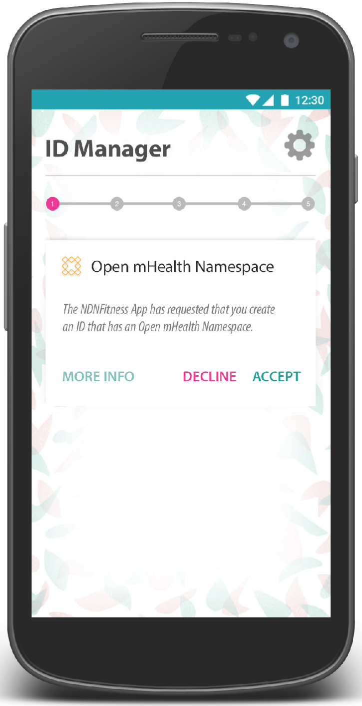
- How do we get users involved in signing their data?

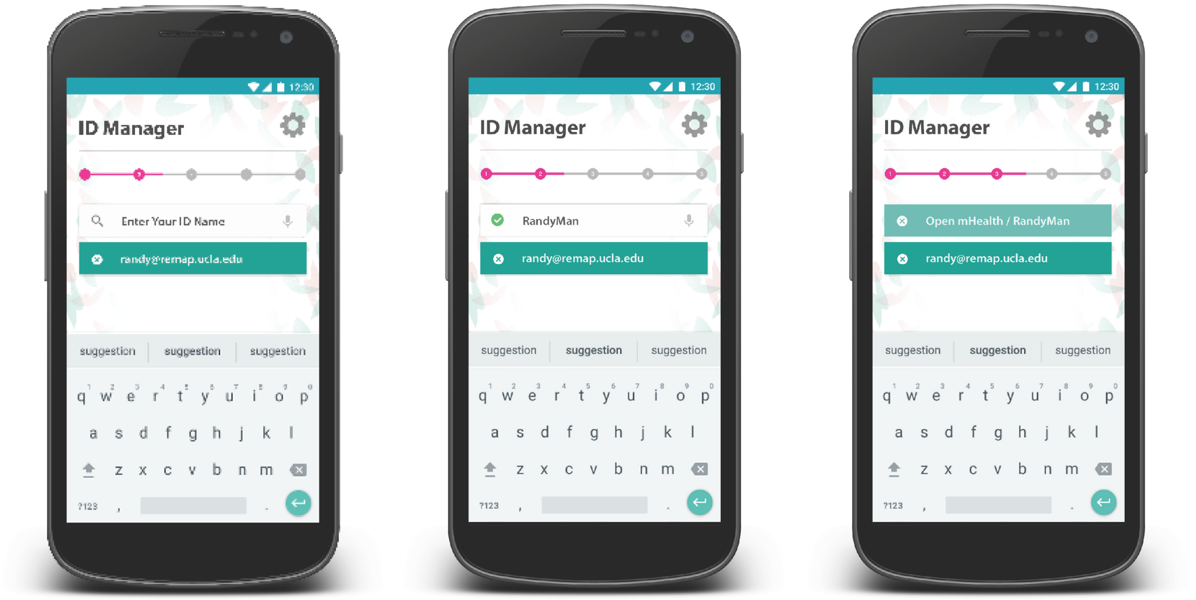
Managing access control of personal data

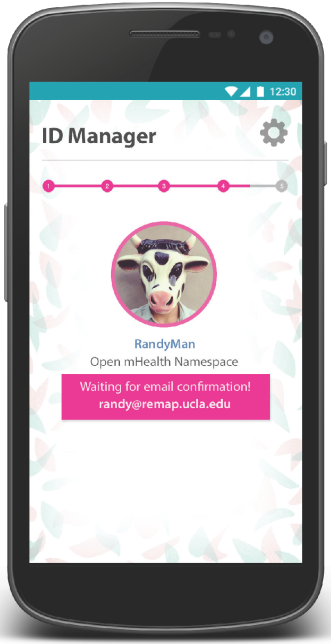
- How do we make data-centric security usable for personal data?

Data-centric Interoperability

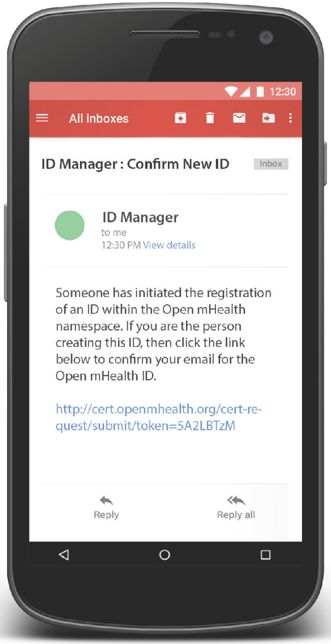
- What design choices can be made that move us towards a data-centric ecosystem rather than silo’ed applications?


12:30
ID Manager
1
2
3
4
5
Open mHealth Namespace
The NDNFitness App has requested that you create an ID that has an Open mHealth Namespace.
MORE INFO
DECLINE
ACCEPT

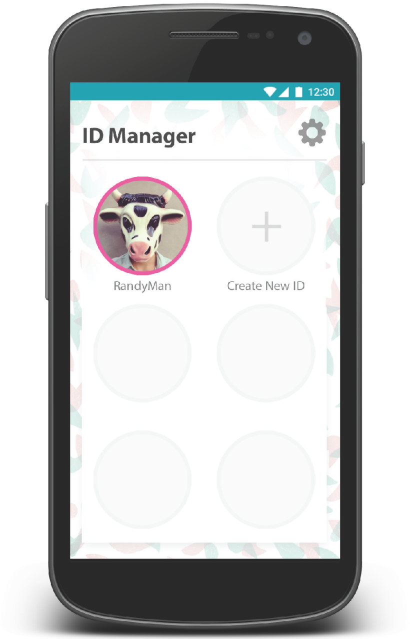

12:30
ID Manager
Enter Your ID Name
randy@remap.ucla.edu
suggestion suggestion suggestion
12:30
ID Manager
RandyMan
randy@remap.ucla.edu
suggestion suggestion suggestion
12:30
ID Manager
Open mHealth / RandyMan
randy@remap.ucla.edu
suggestion suggestion suggestion



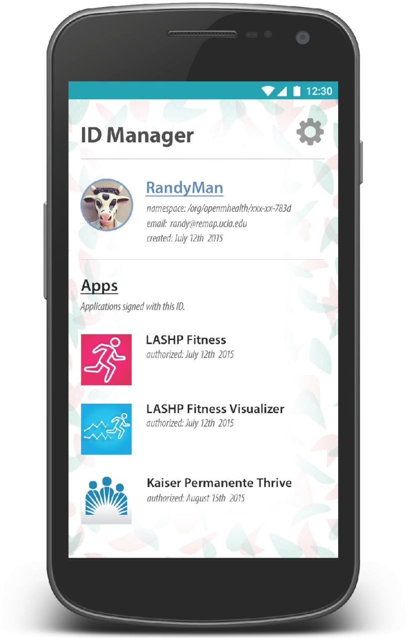
12:30
ID Manager
RandyMan
Open mHealth Namespace
Waiting for email confirmation!
randy@remap.ucla.edu



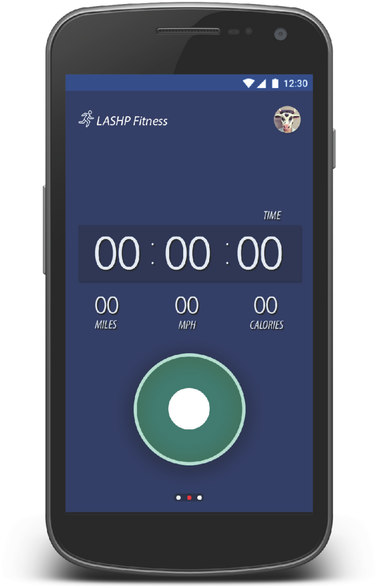
12:30
All inboxes
ID Manager : Confirm New ID
Inbox
ID Manager
to me
12:30 PM View details
Someone has initiated the registration of an ID within the Open mHealth namespace. If you are the person creating this ID, then click the link below to confirm your email for the Open mHealth ID.
http://cert.openmhealth.org/cert-request/submit/token=5A2LBTzM
Reply
Reply all

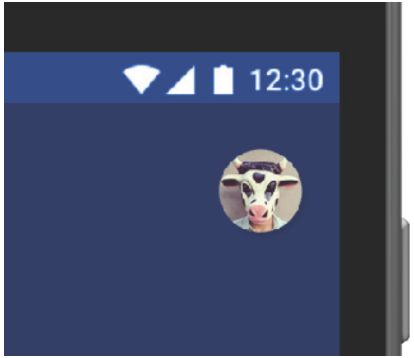


12:30
ID Manager
RandyMan
Create New ID



12:30
ID Manager
RandyMan
namespace: /org/openmhealth/xxx-xx-783d
email: randy@remap.ucla.edu
created: July 12th 2015
Apps
Applications signed with this ID.
LASHP Fitness
authorized: July 12th 2015
LASHP Fitness Visualizer
authorized: July 12th 2015
Kaiser Permanente Thrive
authorized: August 15th 2015

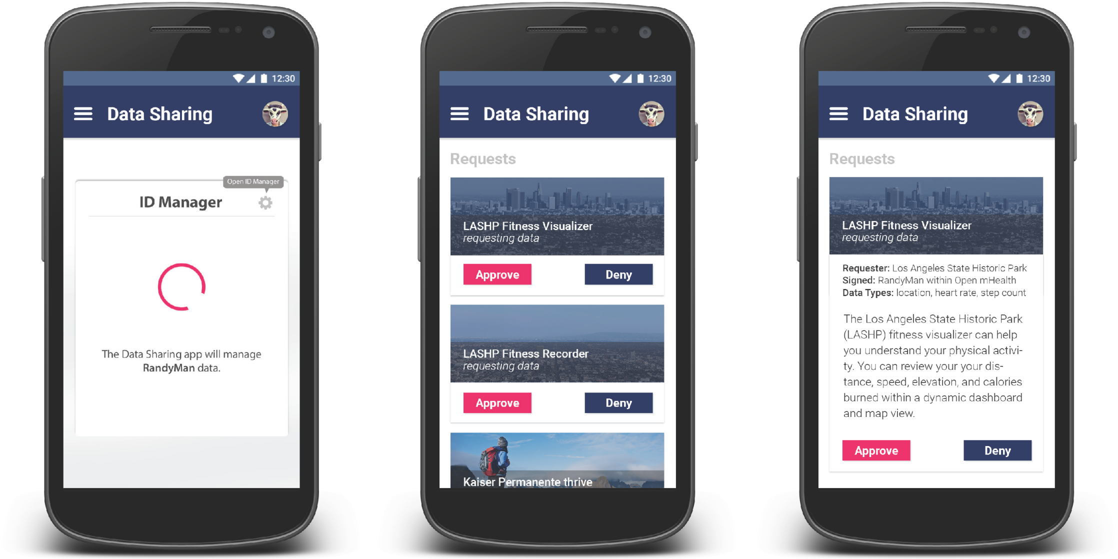

12:30
LASHP Fitness
TIME
00 : 00 : 00
00
MILES
00
MPH
00
CALORIES

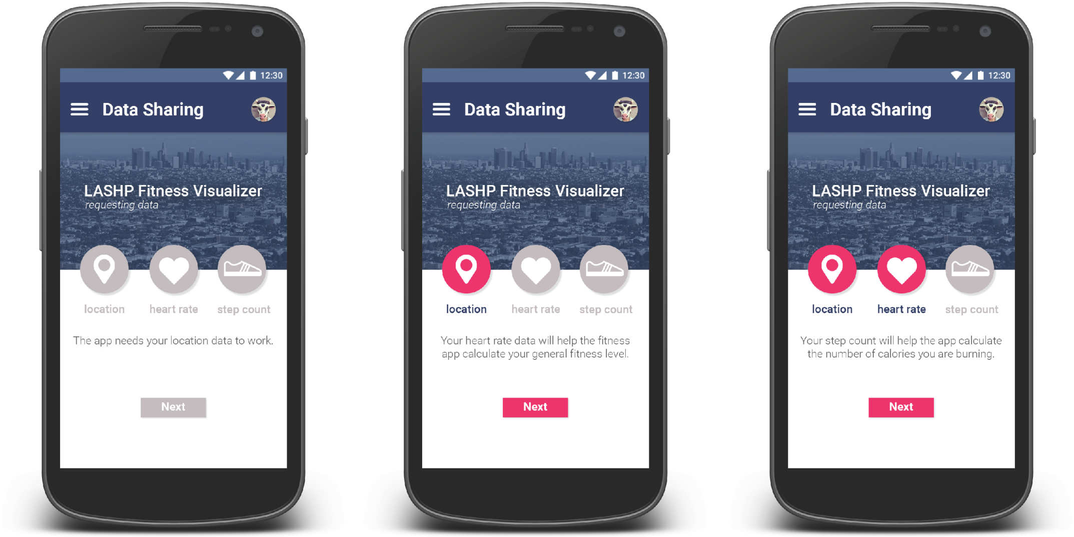

12:30

Fitness Visualizer Dashboard

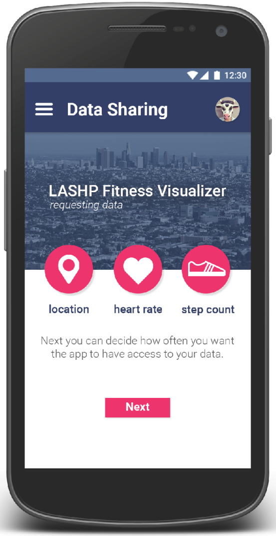
But this application is a new kind

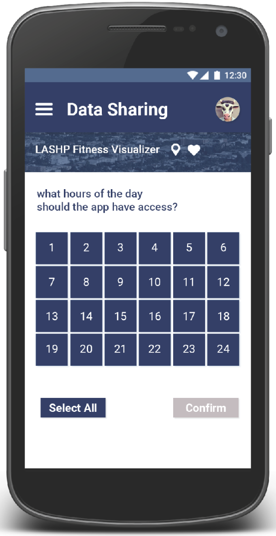
- User owns the data
- Ecosystem of interoperable applications
- Named data!

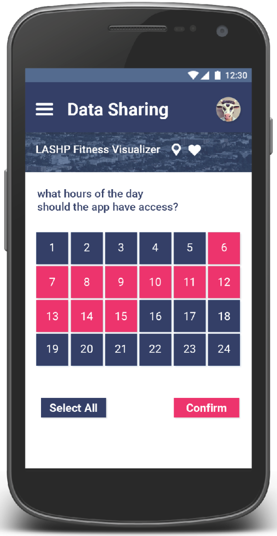

12:30
Data Sharing
Open ID Manager
ID Manager
The Data Sharing app will manage RandyMan data.
12:30
Data Sharing
Requests
LASHP Fitness Visualizer
requesting data
Approve
Deny
LASHP Fitness Recorder
requesting data
Approve
Deny
Kaiser Permanente thrive
12:30
Data Sharing
Requests
LASHP Fitness Visualizer
requesting data
Requester: Los Angeles State Historic Park
Signed: RandyMan within Open mHealth
Data Types: location, heart rate, step count
The Los Angeles State Historic Park (LASHP) fitness visualizer can help you understand your physical activi-ty. You can review your your dis-tance, speed, elevation, and calories burned within a dynamic dashboard and map view.
Approve
Deny



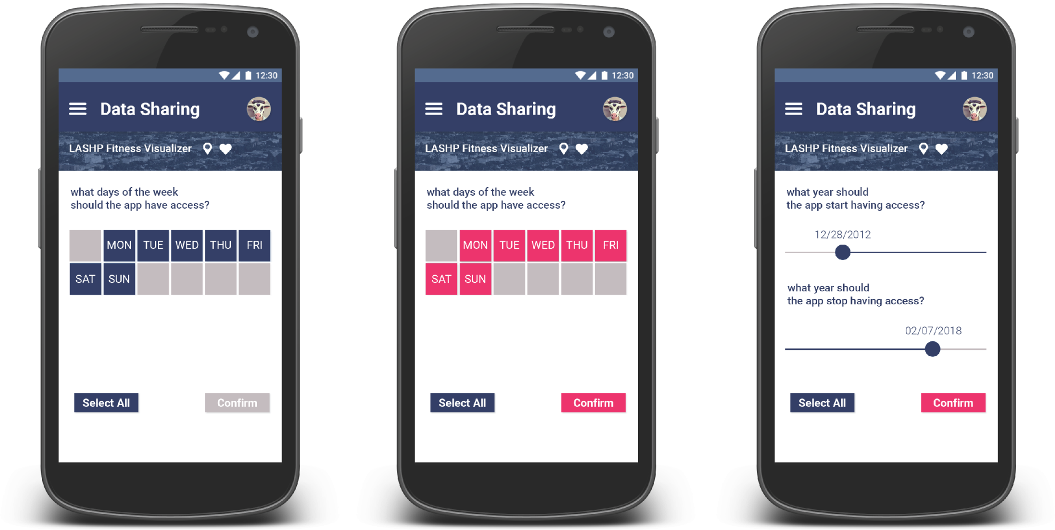
Confirm Data Types



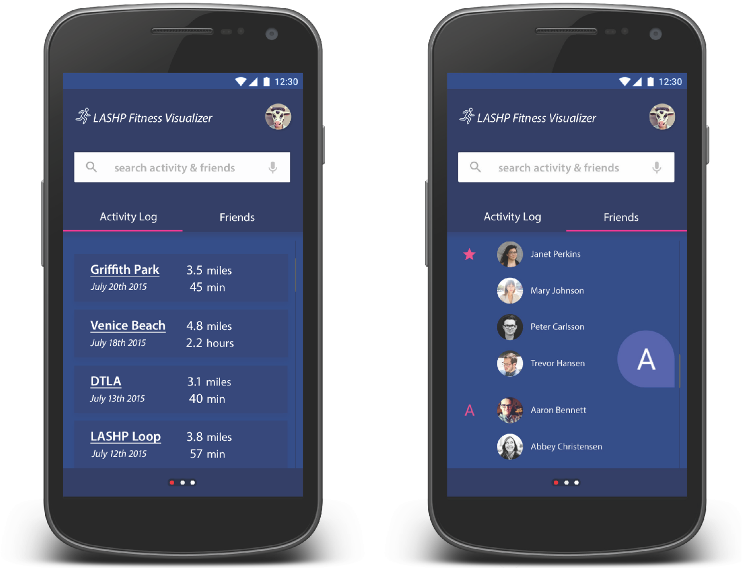




Selecting Hours of the Day



Selecting Days of the Week


12:30
LASHP Fitness Visualizer
search activity & friends
Activity Log
Friends
Griffith Park
July 20th 2015
3.5 miles
45 min
Venice Beach
July 18th 2015
4.8 miles
2.2 hours
DTLA
July 13th 2015
3.1 miles
40 min
LASHP Loop
July 12th 2015
3.8 miles
57 min
Janet Perkins
Mary Johnson
Peter Carlsson
Trevor Hansen
A
Aaron Bennett
Abbey Christensen

Challenges

NDN Namespaces

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- How much exposure to the namespaces is necessary?

Identity management & Data signing

- How do we get users involved in signing their data?

Managing access control of personal data

- How do we make data-centric security usable for personal data?

Data-centric Interoperability

- What design choices can be made that move us towards a data-centric ecosystem rather than silo’ed applications?

- See Dustin O’Hara’s poster for more discussion.

Enterprise Building Automation & Management

Zhehao Wang, Wentao Shang, Jiayi Meng, Adeola Bannis, Jeff Thompson, and others.

From Enterprise to Space to Thing

Objective

Explore the Internet of Things, in the context of building automation and management, from the top-down and the bottom up.

Platforms

- Enterprise (Siemens BMS)
- Smart Space (Raspberry PI)
- Thing (Arduino)

Moving to **system of systems** work – composing end-user experiences across these platforms.

From Enterprise to Space to Thing

Dealing with typical data warehousing challenges became an exploration of how to decompose SQL queries, or other standard query types, onto NDN-stored data. (Initial work by Wentao Shang.)

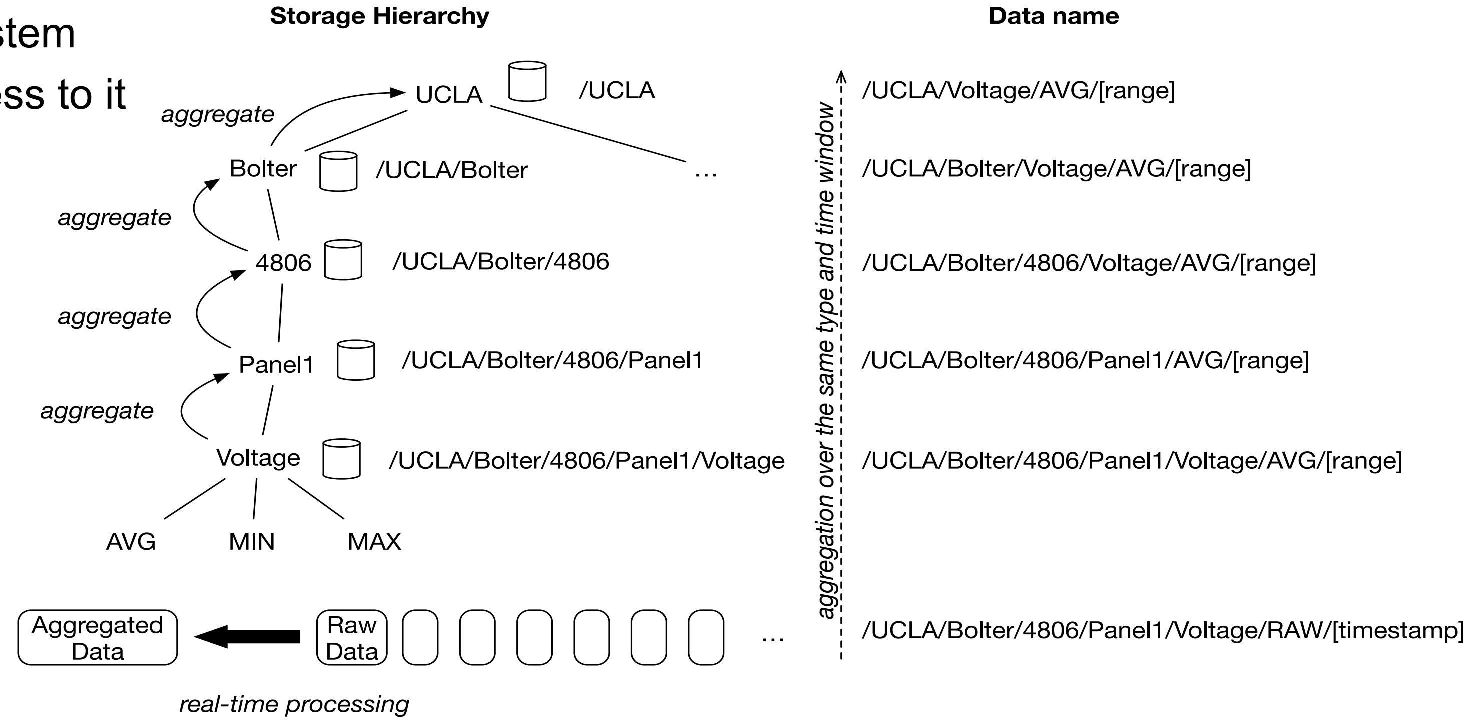
Looking initially at NDN-native hierarchical storage: keeping the data near the devices, then aggregating upwards.

EBAMS Test Environment: Mini-EBAMS

Hierarchical Data Storage on NDN

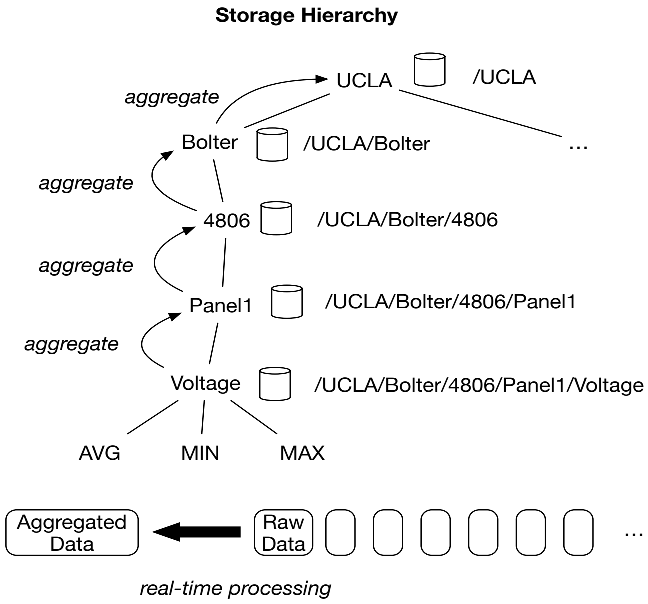
- Real UCLA Data
- Mini-NDN system
- NDN-JS access to it

See Zhehao Wang's poster for more.

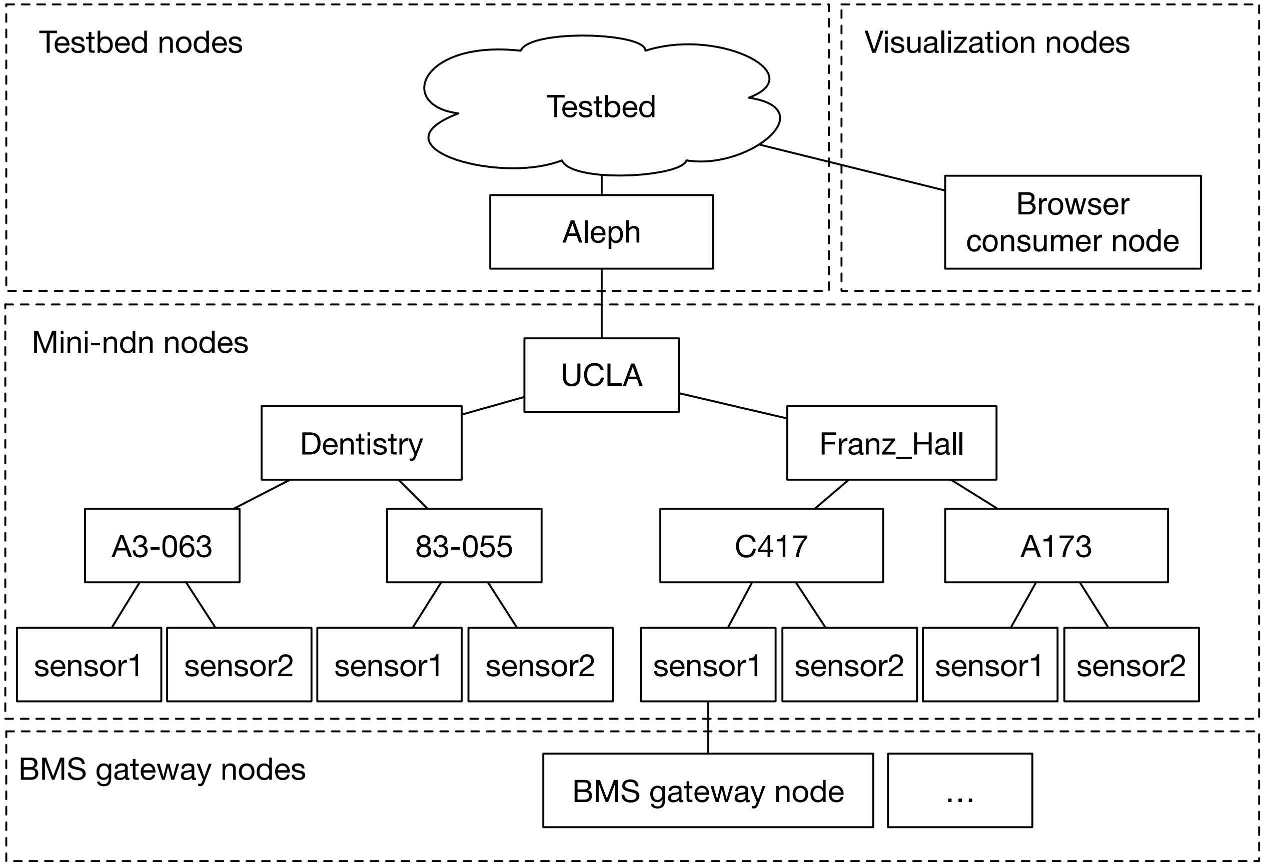


Hierarchical storage

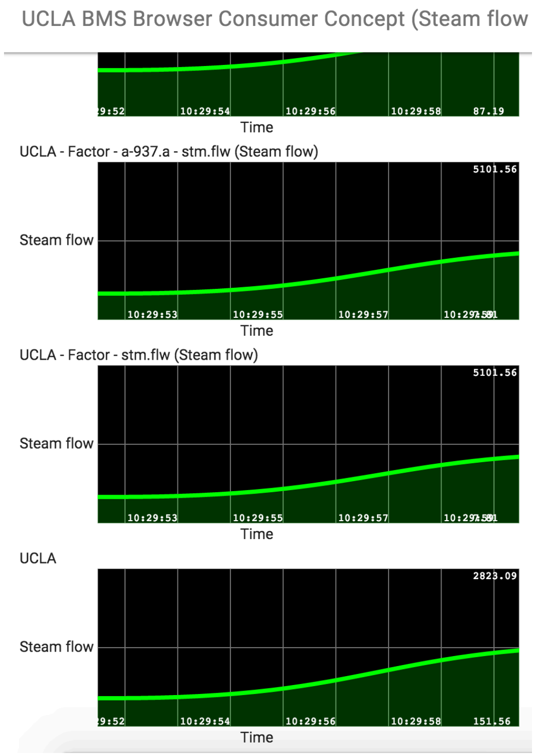
- Raw data collected, kept, and batched only at the leaf nodes.
- Leaf nodes publish aggregated (min, sum, avg, etc) data at fixed time window.
- Non-leaf nodes fetch the aggregated data from all of its children, and aggregate the data after all children respond.
- Non-leaf nodes can publish aggregates with the same time window T; or n * T, n = 1, 2, 3...



Mini-EBAMS



Testbed nodes
Testbed
Aleph
Visualization nodes
Browser consumer node
Mini-ndn nodes
UCLA
Dentistry
Franz_Hall
A3-063
83-055
C417
A173
sensor1
sensor2
sensor1
sensor2
sensor1
sensor2
sensor1
sensor2
BMS gateway nodes
BMS gateway node
...



UCLA BMS Browser Consumer Concept (Steam flow
Time
UCLA - Factor - a-937.a - stm.flw (Steam flow)
5101.56
Steam flow
Time
UCLA - Factor - stm.flw (Steam flow)
5101.56
Steam flow
Time
UCLA
2823.09
Steam flow
Time

Current namespace

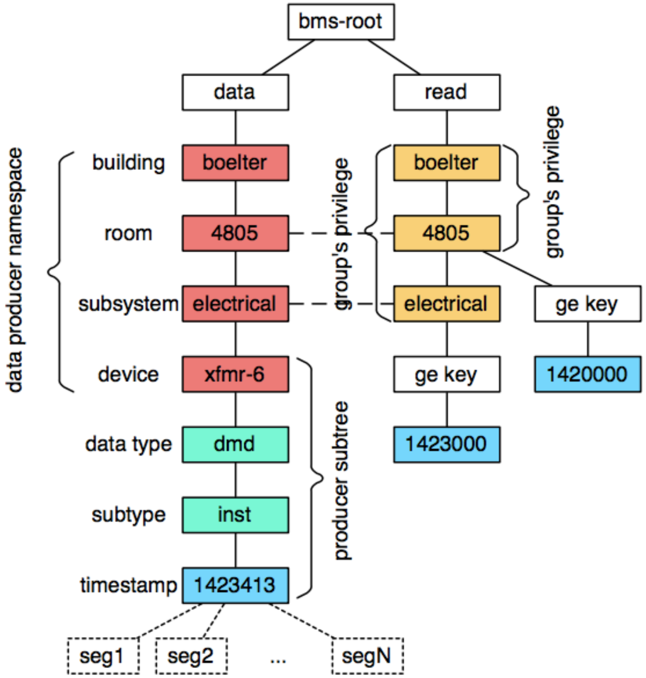
`ucla`	organization
`bms`	system
`sensors`	category
`young_hall`	building
`b215`	room
`xfmr-6`	device
`data/electrical`	type (data, electrical)
`inst`	data subtype (instantaneous)
`1423123667`	data timestamp

`ucla`	
`bms`	
`sensors`	
`young_hall`	
`data/electrical`	
`aggregation`	subtype (aggregation)
`1423123670`	Start timestamp
`1423123680`	End timestamp

3

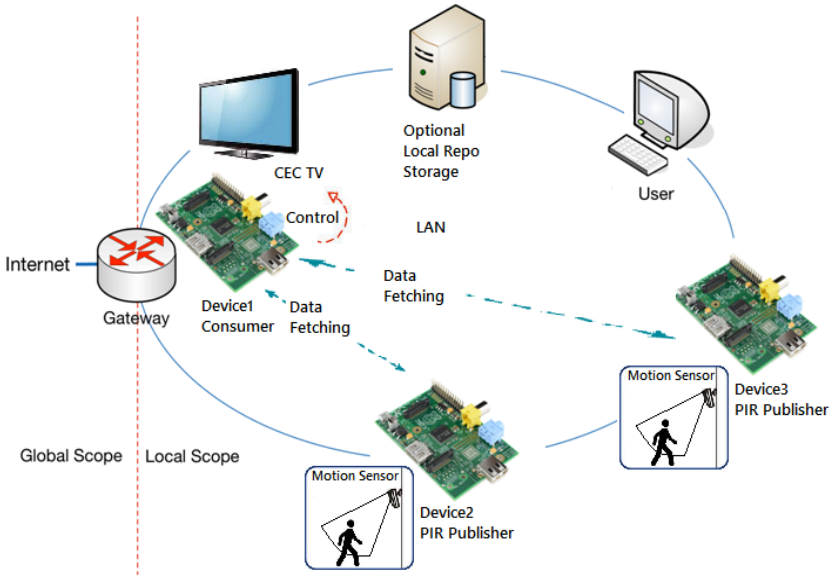
Data-Centric Security

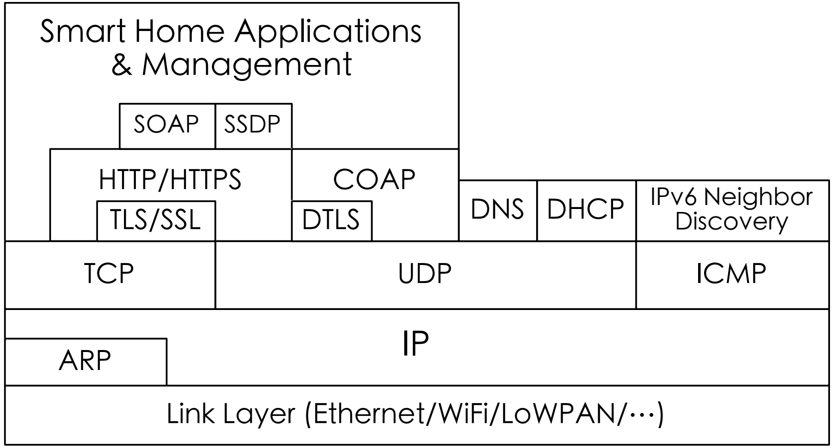
- Schematized trust
  - Initial design developed for hierarchical aggregation.
- Name-based access control
  - Primary access the
  - Provisions for links across namespaces (e.g., into user namespaces), translating previous work by Shang et al. to NBAC.
- Authenticated control

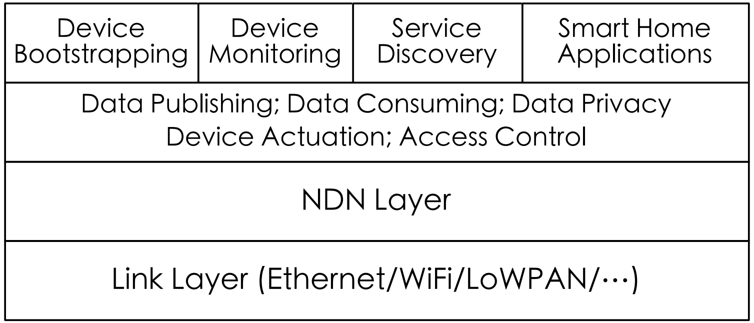


Smart Space (RPI)

- Work at UCLA, University of Arizona.
- Last year, completed a “kit” for IoT experimentation on NDN.
  https://github.com/remap/ndn-pi







Smart Space (RPI)

- COAP comparison - after one-time prefix registration overhead, comparable or improved communication burden.

	Lighting device		Controller		Client device	
Protocol	**Sent**	**Received**	**Sent**	**Received**	**Sent**	**Received**
CoAP-DTLS	279	350	347	369	719	626
NDN-HMAC	140	99	265	104	203	405

A. Bannis & J. Burke. "Creating A Secure, Integrated Home Network of Things with Named Data Networking," in submission.

Smart Space (RPI)

- UA-led work continues in the smart home context:
  - Device bootstrapping: the initial exchange of keys between the device and the controller.
  - Device discovery and configuration: how does a new device learn about existing devices in the home – further work on capabilities.
  - Access control: which device can access which data/device, and do so efficiently.

Smart Space (RPI)

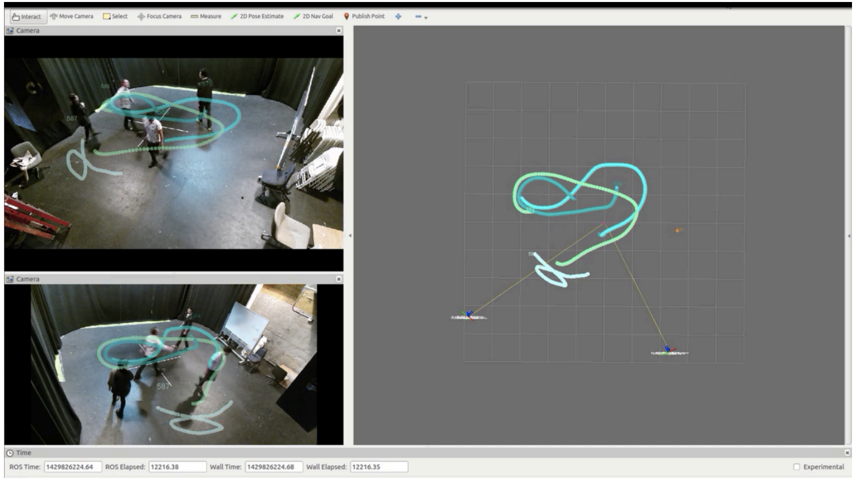
Other types of infrastructure-based sensing.

OpenPTrack: Positional tracking for education, arts, and culture.
Based on the Robot Operating System (ROS)

Data analogous to Active RF for NFL.
Low-latency NDN output, 30Hz tracking.

Leverage what we are learning from NDN-RTC.

Future project: internal ROS messaging via NDN.



Thing (Arduino)

- Demonstrated NDN-CPP library running on Arduino, extended to Bluetooth Low Energy communication at the hackathon.
- The NDN-CPP client library uses C++ features not on Arduino:
  - Standard library resizable vector
  - Standard library reference counting shared_ptr
  - Standard library function objects with bind
  - Exception handling
- But Arduino does have these C++ features:
  - Constructors and destructors
  - Method overloading
  - Namespaces

Thing (Arduino)

NDN-CPP Lite

- Lightweight C++
- No assumptions about memory model
- No support library dependencies
- Application creates and supplies memory
- E.g. initialize a MetaInfo object:
-   MetaInfoLite metaInfo;
- Shared C core between NDN-CPP and NDN-CPP Lite:
  - Packet encoding/decoding
  - Network transport (TCP, etc.)
  - Only standard C library (strlen, math.h, etc.)

Sample Application

- **Register a prefix, receive an** interest over TCP, return an HMAC signed data packet holding an analog measurement
- 28 kilobytes when compiled
- Modifications for Arduino:
  - YunClient bridge for TCP
  - Arduino-optimized SHA256/HMAC code
  - Use Arduino native random number generator

Challenges

- NDN – in particular, schematized trust – seems to fit the problem very well. Management of access control is challenging for outside the enterprise. Lots of interesting work to do on NDN-backed databases / query support.
- System of systems: Provisioning Enterprise, Space, and Thing systems for overlapping applications that include interaction with the Internet and personal mobile devices.
    - Namespace conventions for discovery, negotiation, data access
    - Cross-system trust and granular access control
    - Power consumption and other resources constraints
    - Core services: app-level time synchronization, etc.

NDN-RTC

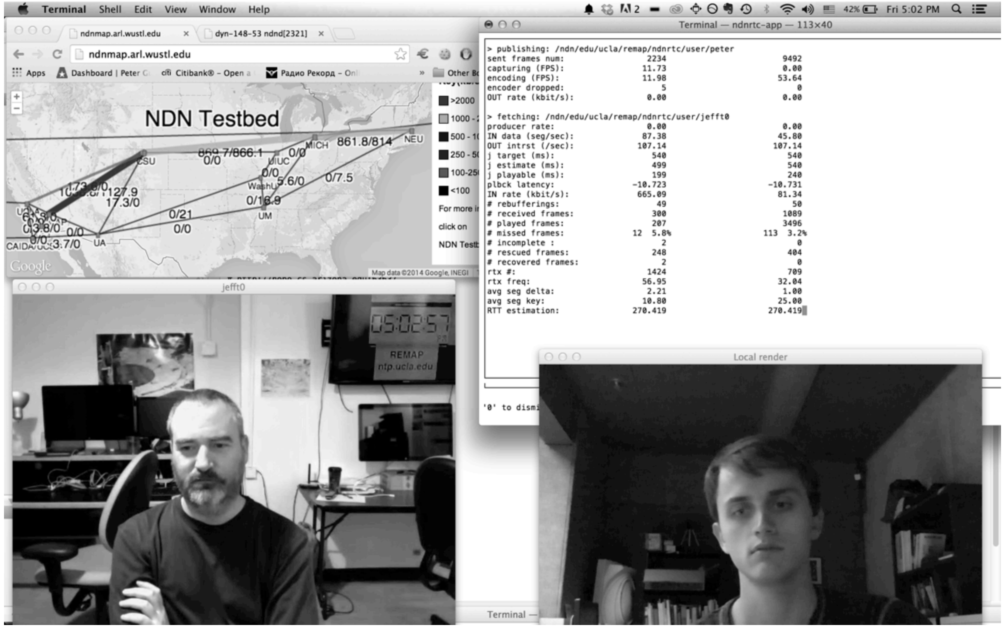
Peter Gusev, Jiachen Wang, Jeff Burke, Lixia Zhang, and others.

NDN-RTC Project Goals

- Functional videoconferencing library and application:
  - Low-latency, interactive data distribution:
    - Multi-party conferences
    - Live broadcasting
  - No **direct communication** between peers:
    - Consumer-driven
    - More freedom for experimentation
  - Wide adoption by NDN community
  - Data-centric security: schematized trust, name-based access control
- Encourage new research initiatives
- Testbed traffic generation and high-load performance testing

NDN-RTC Project 1 Year Ago

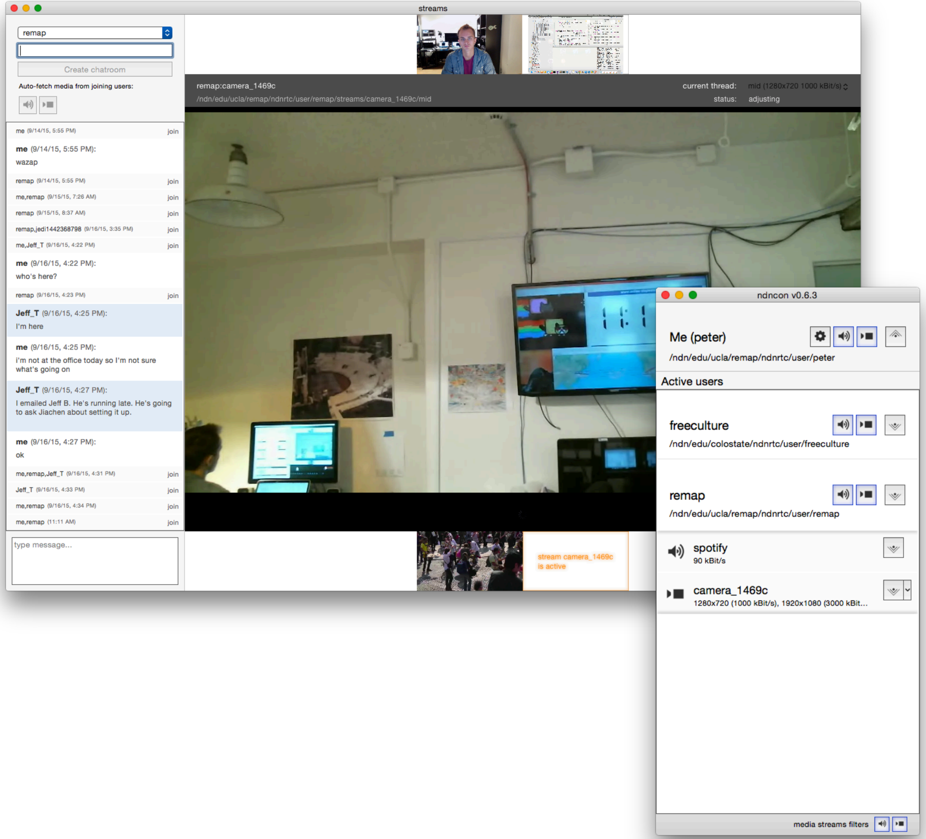
- OS X C++ library
- Console demo app
- No group chats
- Hard to use (user-unfriendly)
- Hard to setup
    - No user auto-discovery
    - Build from sources
- Mediocre streaming efficiency:
    - frequent rebufferings
    - video tearings
    - frequent audio drop-outs



NDN-RTC Project Today

- Achieves target 350-500ms latency for our conferences.
- HD-quality capable
- Improved streaming performance
  - Up to 7.5Mbit/sec over current testbed; significantly better QoE.
  - Isolated testbed tests (bidirectional streaming)
  - NDN testbed tests with multi-hop paths (bidirectional streaming)
- ***ndncon*** GUI OS X NDN-application:
  - automatic user discovery
  - group text chats
  - screen sharing
  - Easy setup:

```
$ nfdc register / udp://<your_hub>
```

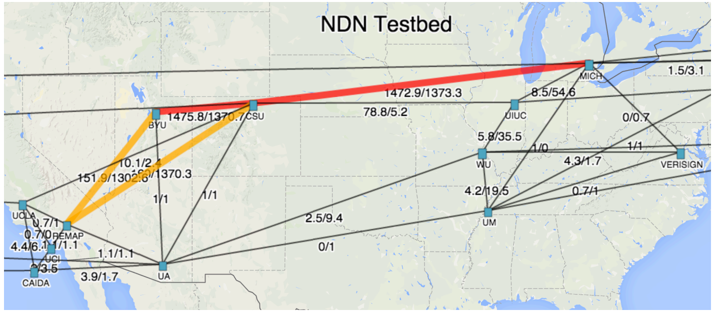


Example NDN-RTC-driven Improvements

- NFD: Revised retransmissions strategy
  - App retransmission was suppressed until Interest times out in PIT
  - Varying Interest lifetime is risky when data is not produced yet or network conditions change
  - BestRoute2 strategy allows early app retransmission without giving up Interest lifetimes
- NDN-CCL: Library support for app-level PIT
  - Common low-latency case: **handle Interests that arrive before data is ready**
  - Need to store Interests in producer-side PIT
  - Same approached used in OpenPTrack real-time person-tracking
- Testbed/NFD: Performance stress-tests (ongoing)
  - 3-9Mbit/sec data streams per producer
  - 9Mbit/sec: ~1000 Interest/sec, ~900 data segments/sec
  - Traffic generator for the testbed

Design & Development Progress

- Design
  - “*Interest Demand*” concept introduction
  - Audio packet bundling
- Implementation
  - Desktop GUI application *ndncon*
    - group chats (ChronoChat2013)
    - automatic user discovery (ChronoSync2013)
    - screen sharing
  - Thread optimization
    - single-threaded architecture, decreased CPU
  - Asynchronous logging
  - Automated test environment (local testbed, NDN testbed)
  - **Ported to Ubuntu**
    - special thanks to **Luca Muscariello** (Orange), **Zhehao Wang** (UCLA)

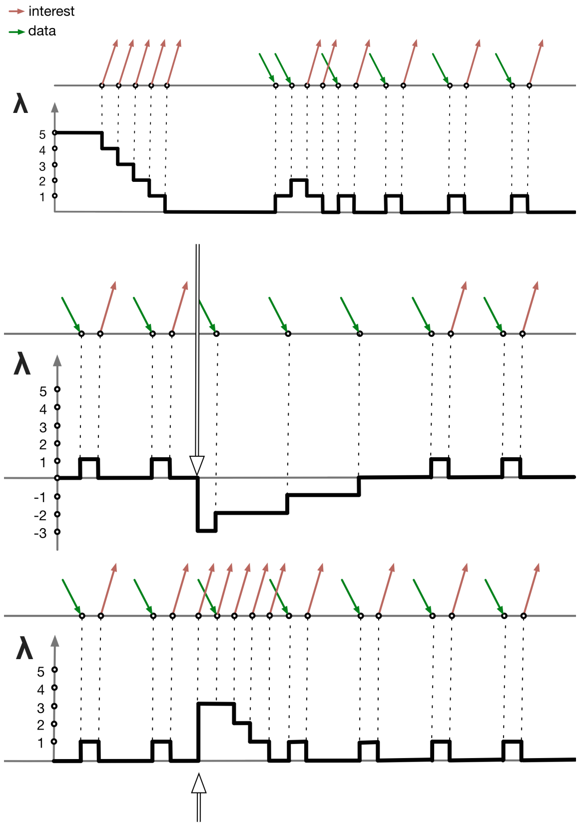


Interest Demand

- ***Outstanding Interests*** ensure latest data delivery
- The **minimal number** of outstanding Interests that ensure latest data retrieval defines "***Interest Demand***"
- *Interest Demand* driven by:
  - DRD (Data Retrieval Delay) – generalized RTT
  - Data inter-arrival delay (producer publishing delay observed by consumer)

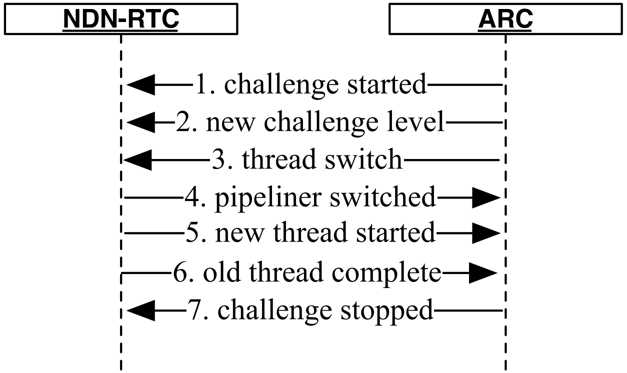
  Interest Demand = DRD / D_{arr}

- Consumer changes *Interest Demand* value in order to adjust fetching **aggressiveness**
- Data-driven Interest expression:
  - Quicker response to new network and publishing conditions
  - Faster and more robust cache exhaustion



Adaptive Rate Control

- Collaboration with Panasonic R&D department
- Established development plan:
  - NDN-RTC modifications, REMAP - **October 2015**
  - ARC implementation[1], Panasonic - **November 2015**
  - Early tests - **December 2015**
  - Full tests – **January-February 2016**
  - Completion – **March 2016**
- Implementation details[2]
  - Gapless stream switching
  - Challenging Interests for bandwidth probing
  - Ongoing monitoring of intrinsic network parameters (DRD, D_{arr}, etc.)

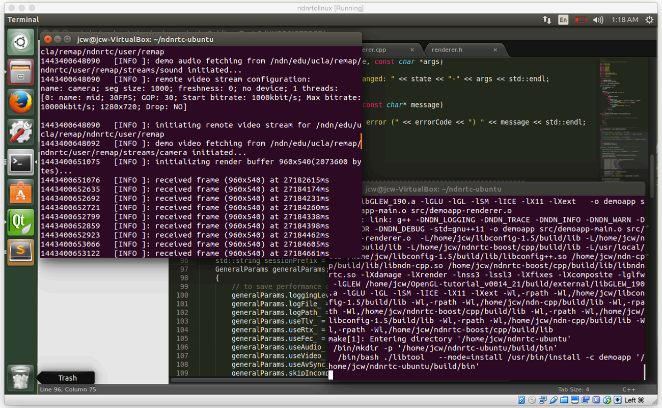


[1] Takahiro, Y. et al. **Consumer driven Adaptive Rate Control for Real-time Video Streaming in Named Data Networking.** *To be presented at Internet Conference 2015, October*

[2] Ohnishi, R. et al. **Adaptive Rate Control integration for NDN-RTC.** *NDNComm 2015, Poster session*

Future Work

- Adaptive Rate Control *(in progress)*
- Linux compatible version *(in progress)*
- Ubuntu headless app *(in progress)*
- Further tests
  - multi-party uni- and bi-directional tests *(ongoing)*
  - NFD performance stress tests *(ongoing)*
  - large-scale tests using headless Ubuntu app
- Data authentication and encryption with multi-party support
- Scalable video coding



Challenges

- **How to robustly detect arrival of latest data?**
  - Desire no **direct** producer-consumer communication
  - Current approach:
    - observe intrinsic network indicators
    - cached (stale) data arrival copies Interest expression pattern
- **How to efficiently encrypt media without losing NDN advantages?**
  - Depends on application objectives – Reformulate conferencing?
  - Leverage broadcast encryption and other schemes
- **How to achieve inter-consumer synchronization?**
  - While preserving no direct communication
  - Consider varying network conditions
- **Where is historical data stored?**
  - Depends on application objectives – drill down into use cases.
  - Audio/Video, chats, attachments, etc.
  - Historical data trust model

Opportunities for Collaboration

- NDN project team plans to use and improve *ndncon*. Help welcome!
- Others can use NDN-RTC library for creating more applications.
- Fundamental improvements in latency performance.
- Incorporation of scalable video coding.
- Deeper research into rate control, interest expression algorithms needed.
- We will be providing tools to use the library for traffic testing and provide feedback on strategy / forwarding.
- Test and port to other platforms
- Need to do simulations to look at algorithm performance under various caching conditions, topologies, and use cases.
- *Please come visit our posters and demos!*