

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 –

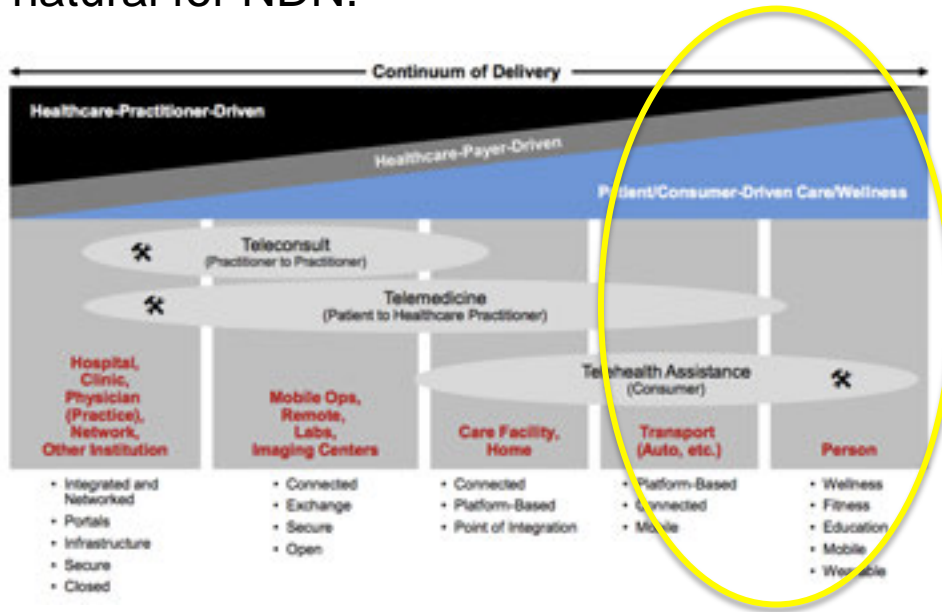
- **App / strategy relationships.**
- **Traffic measurement requirements.**
- **Performance requirements.** (Finally!)

NDNFit

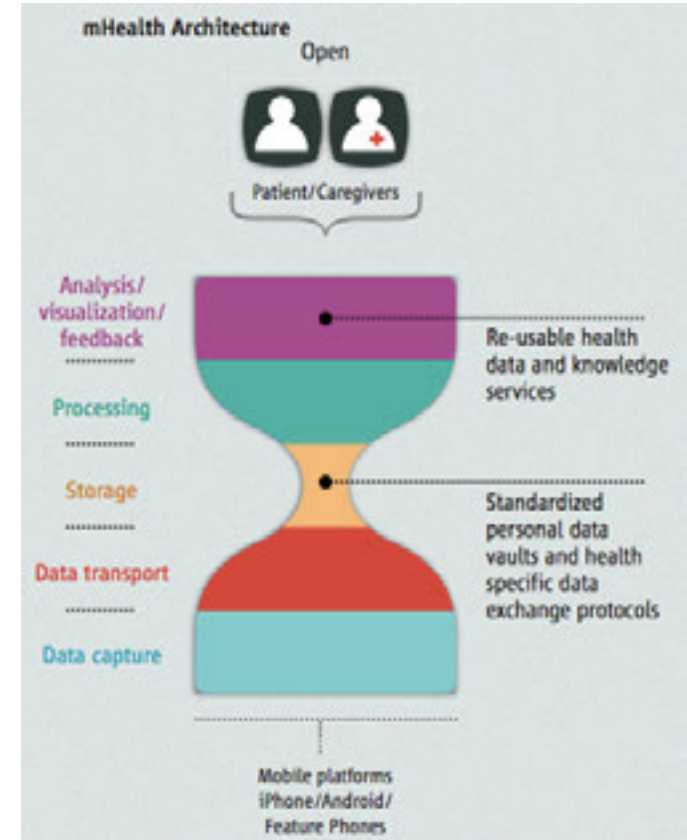
Haitao Zhang, Alexander Afanasyev, Jianxun Cao, Euihyun Jung, Jiewen Tan, Jeff Thompson, Yingdi Yu, Jeff Burke, Dan Pei, Christian Tschudin, Lixia Zhang, and others.

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

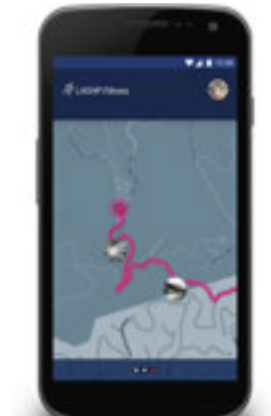
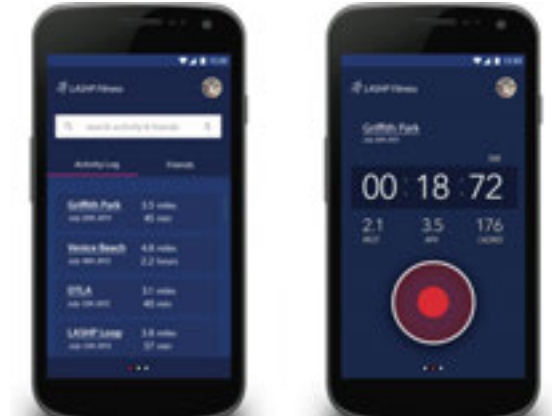


NDNFit: Open mHealth example application

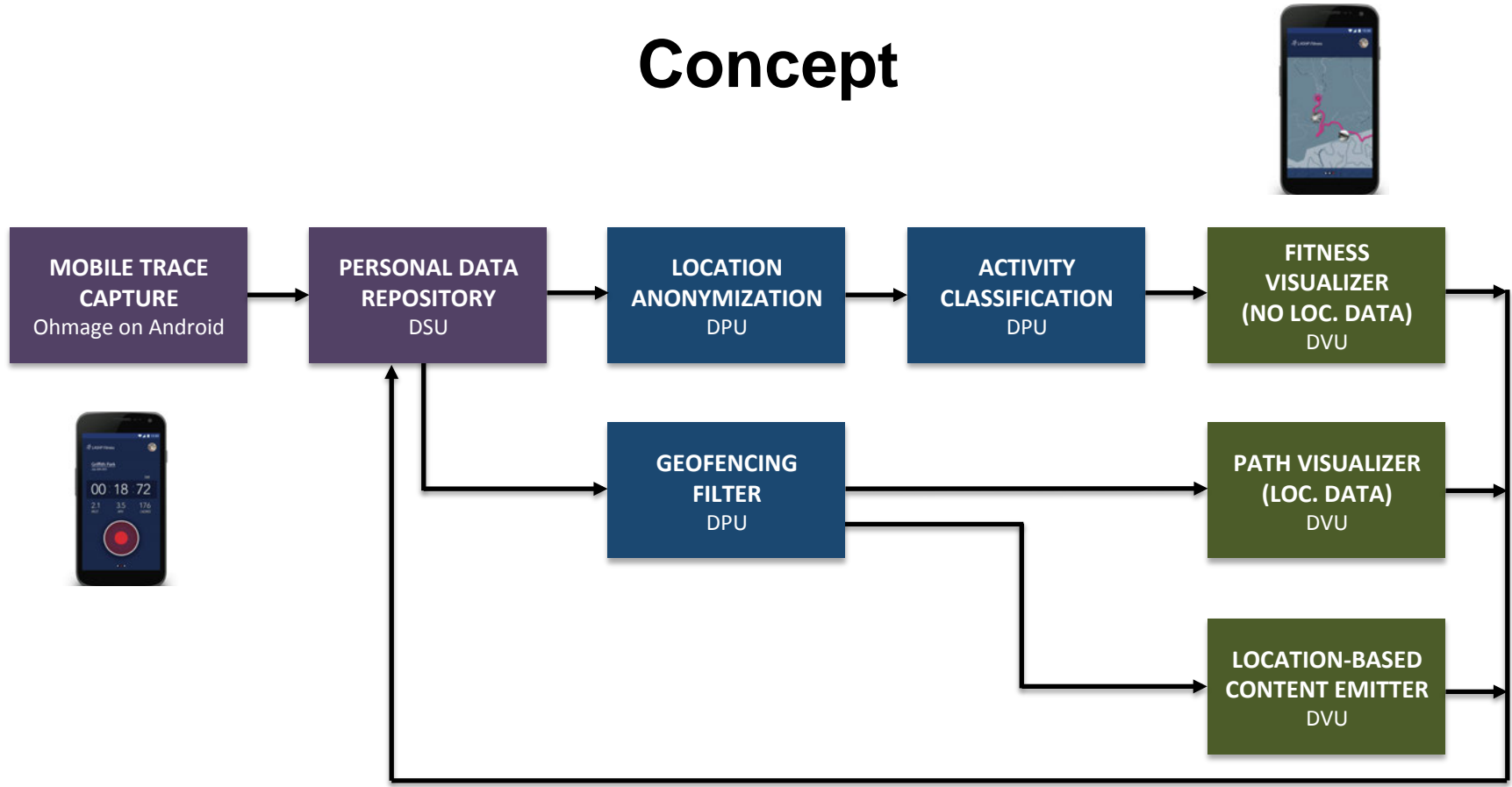
How do we conceive and build a familiar-looking application that demonstrates interaction in this ecosystem?

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

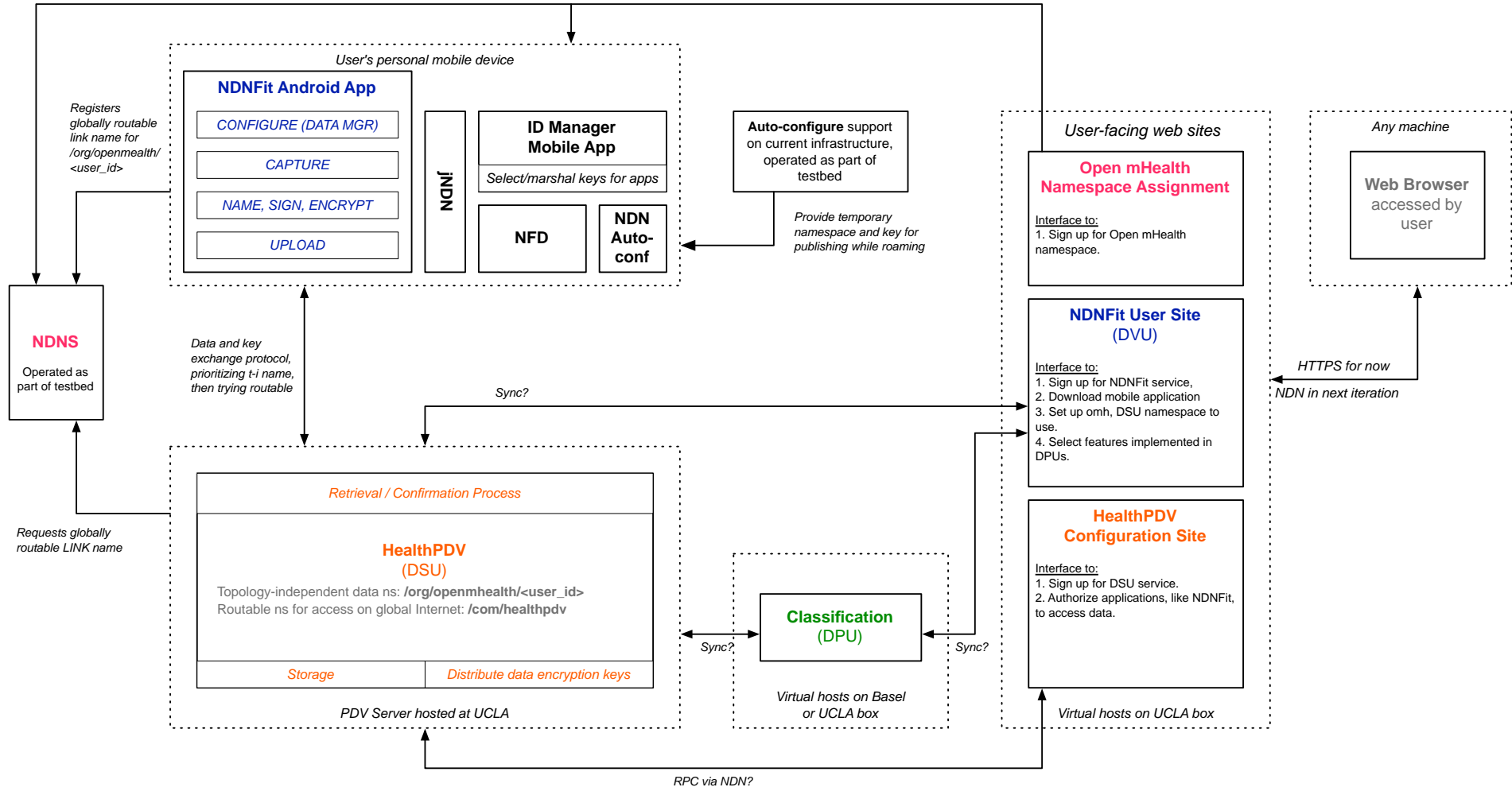
One simple step: the user can be the root of trust.

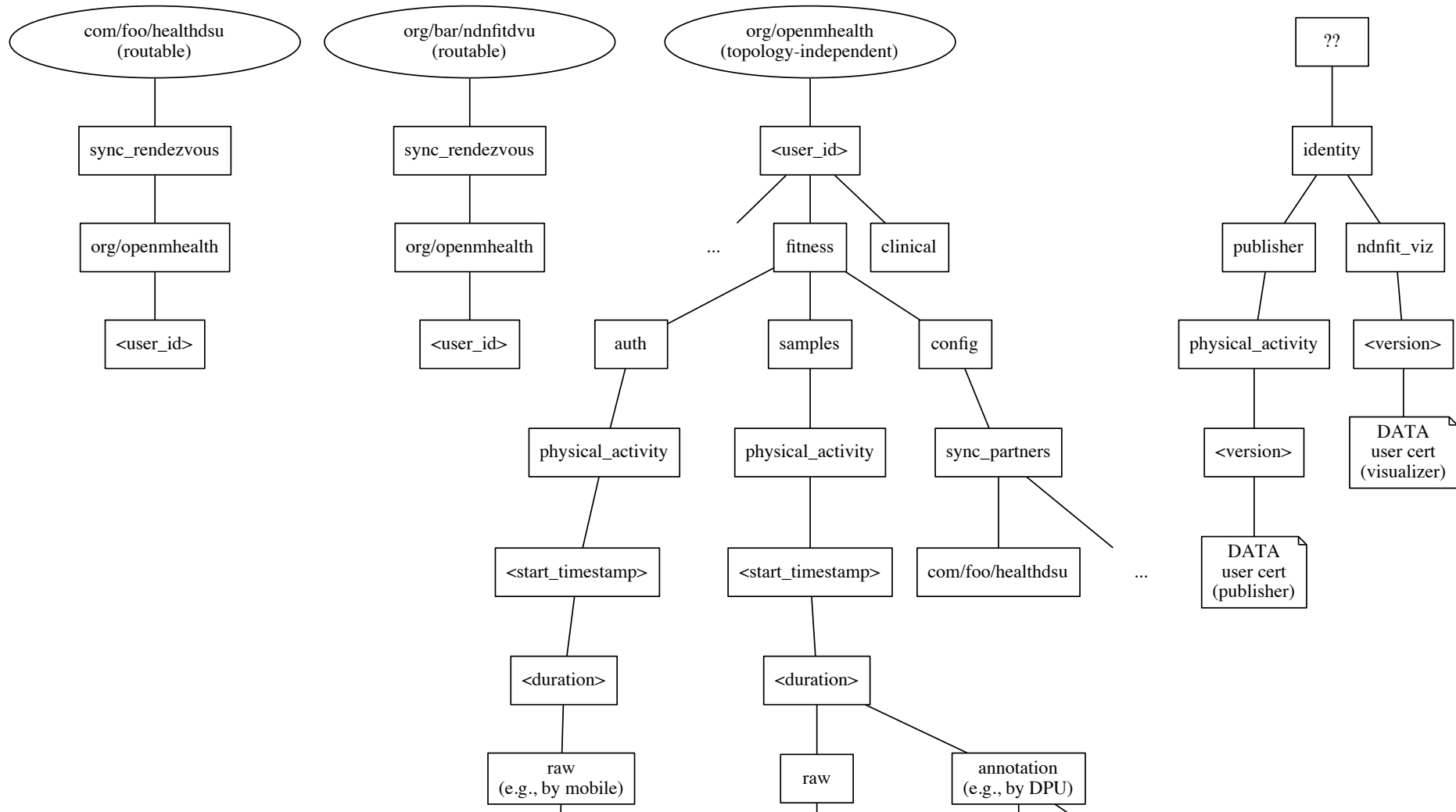


Concept



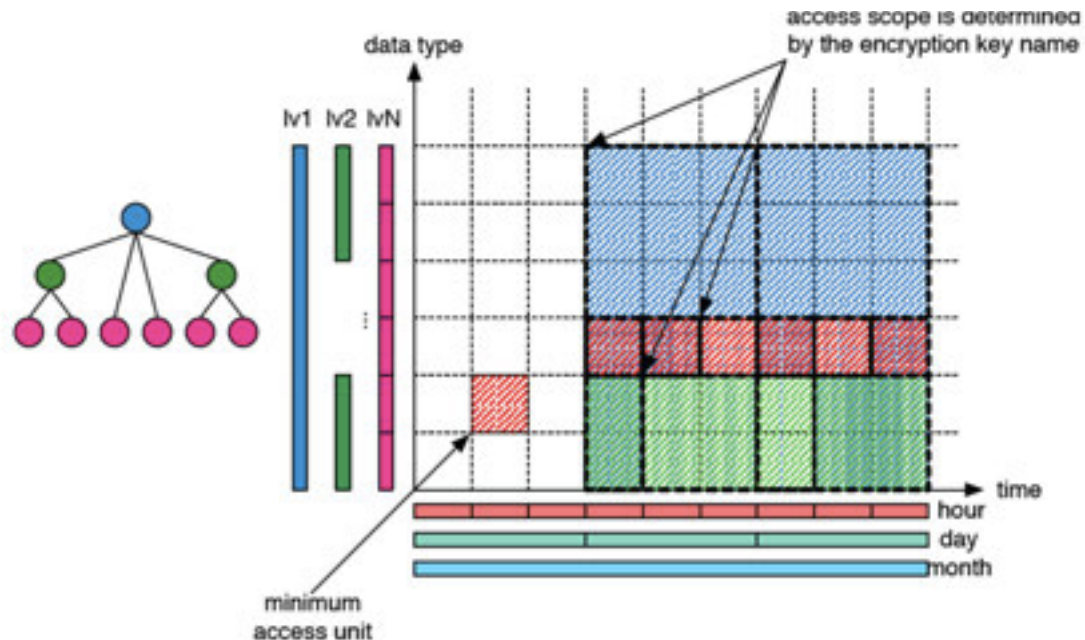
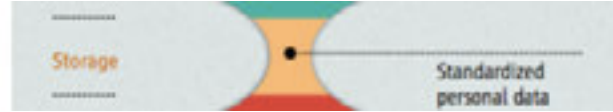
Authorization to publish in the
/org/openmhealth/<user_id> namespace





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 namespace.
- 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

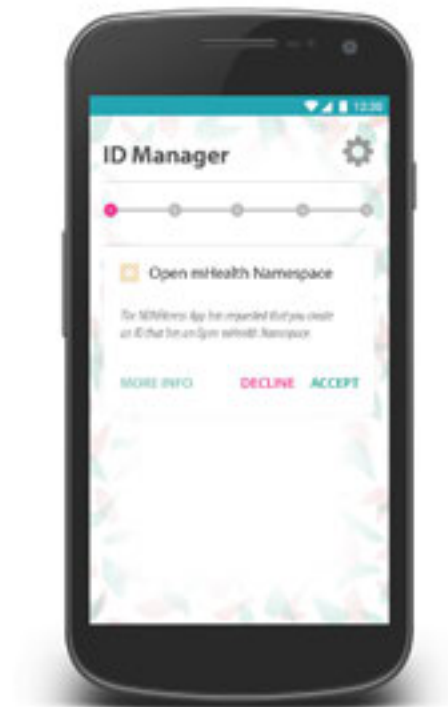
- How do we get users involved in signing their data?

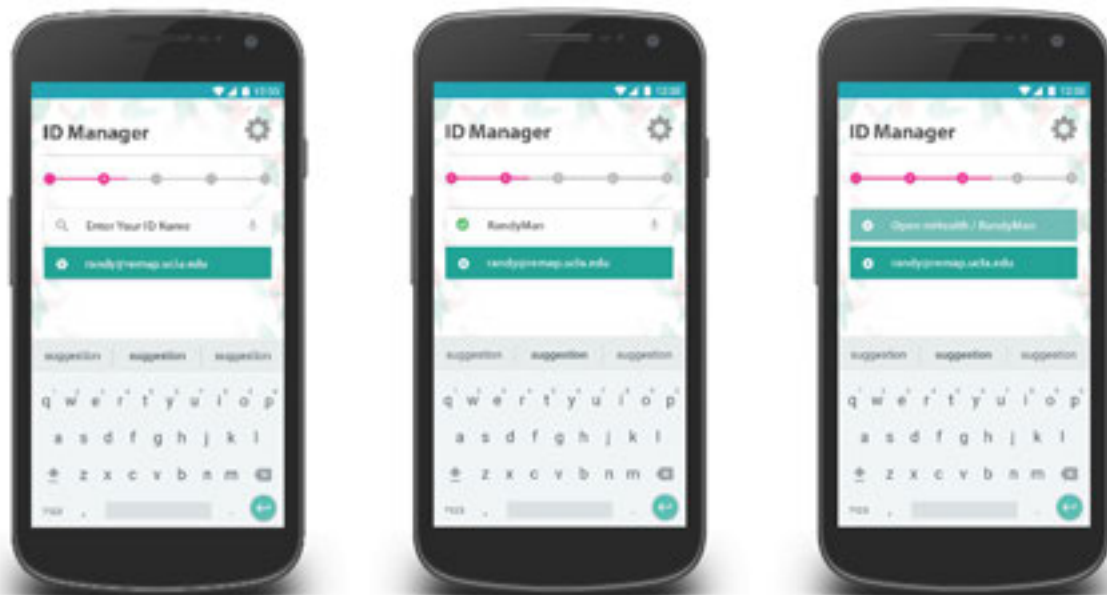
Managing access control of personal data

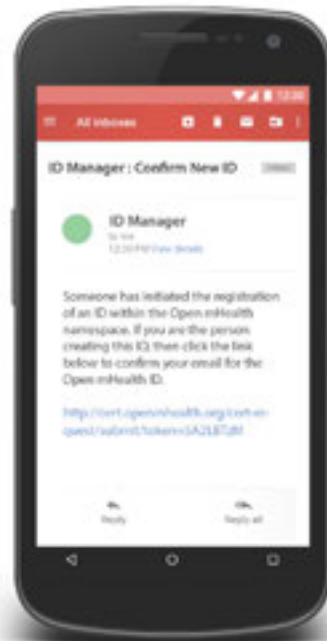
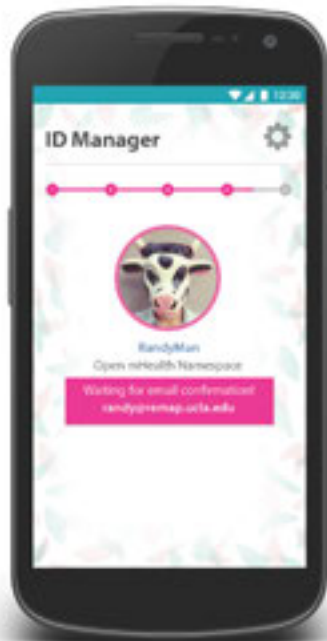
- How do we make data-centric security usable for personal data?

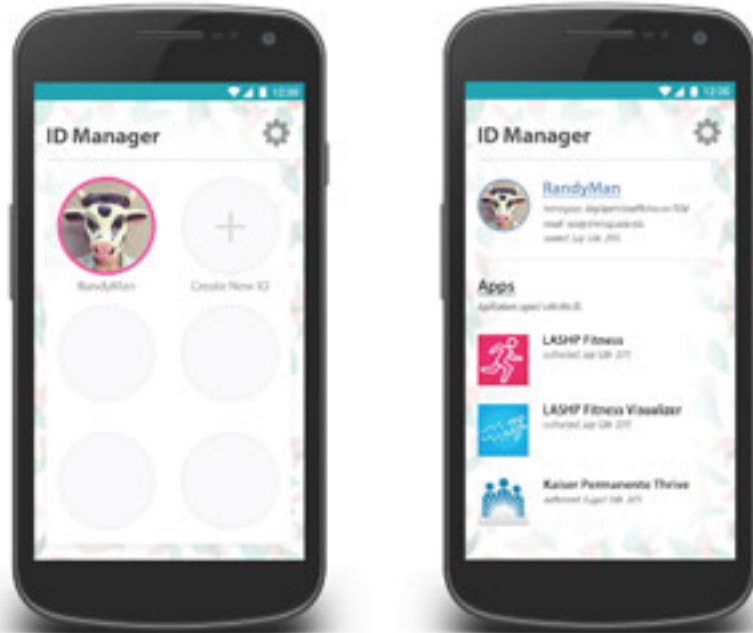
Data-centric Interoperability

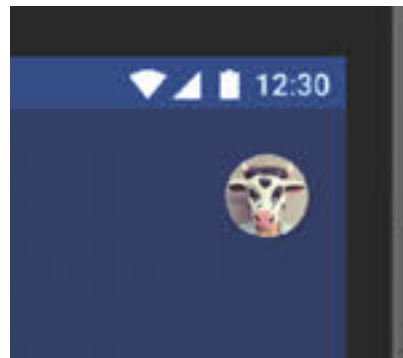
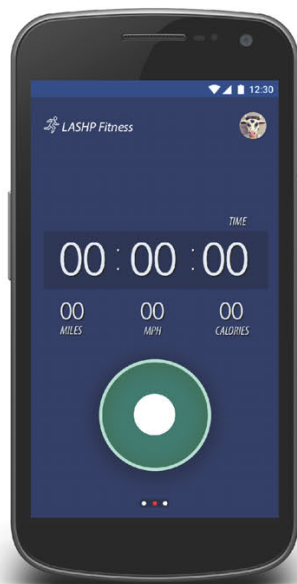
- What design choices can be made that move us towards a data-centric ecosystem rather than silo'ed applications?

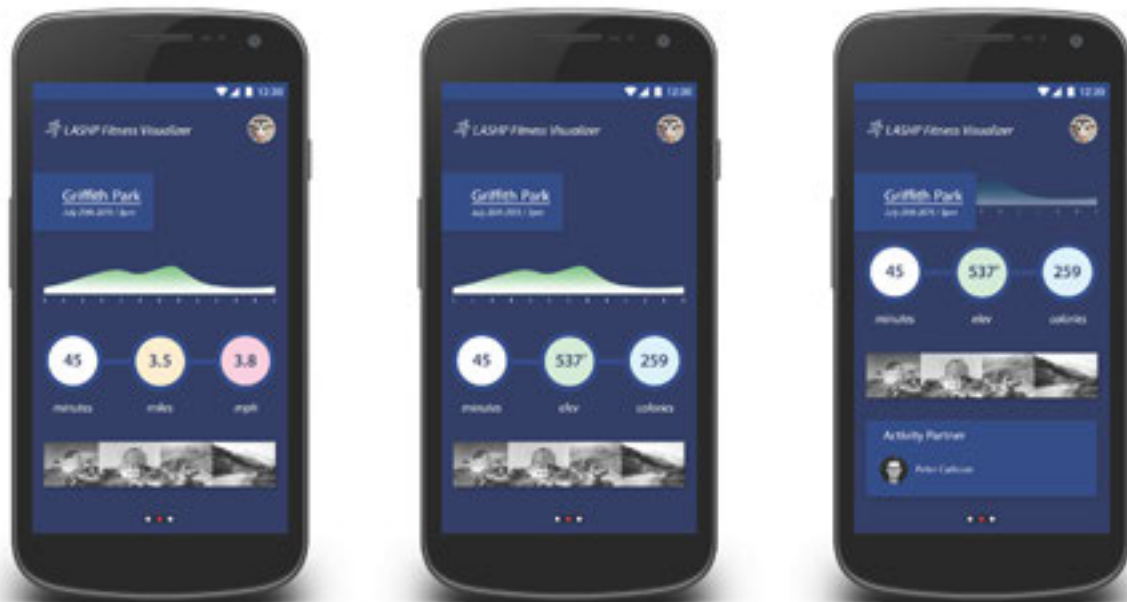








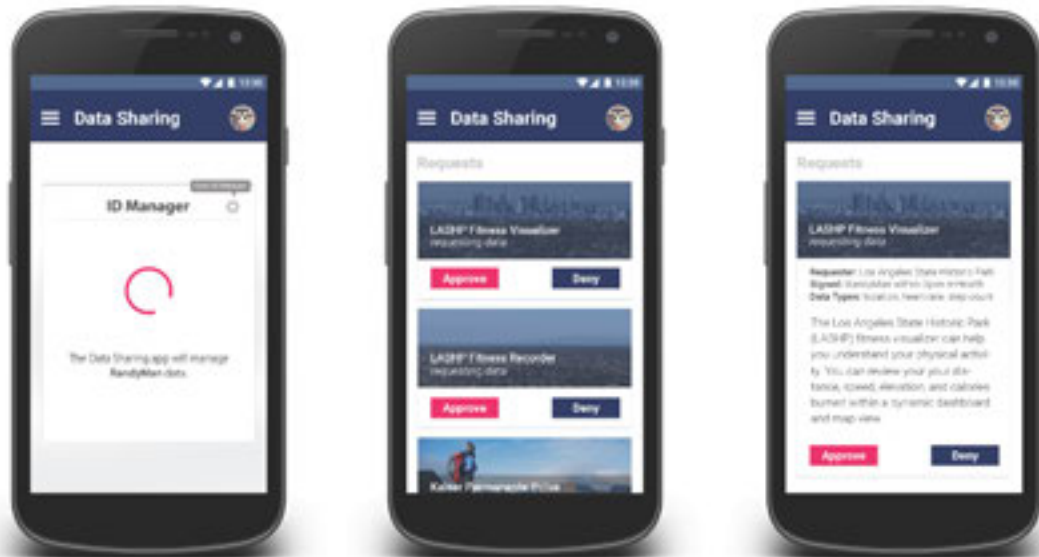


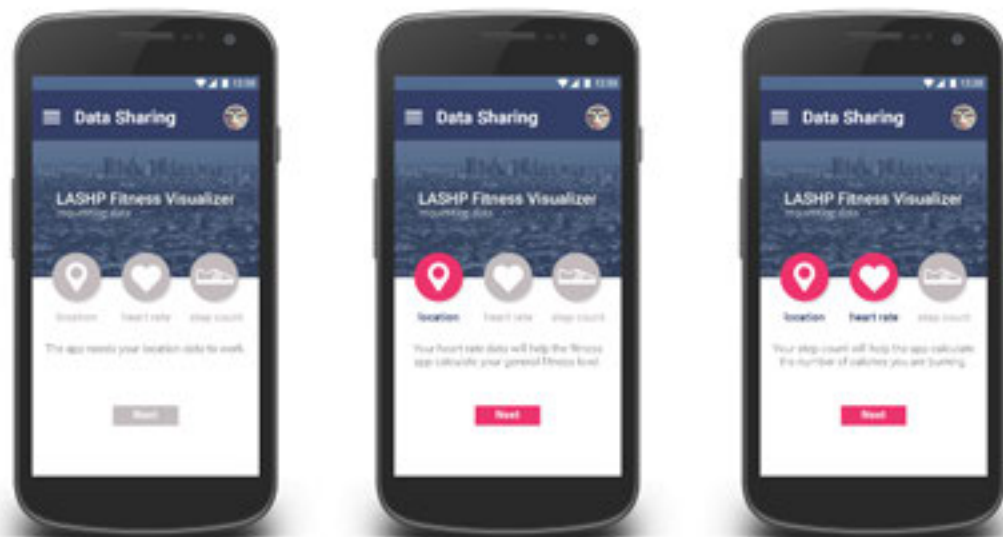


Fitness Visualizer Dashboard

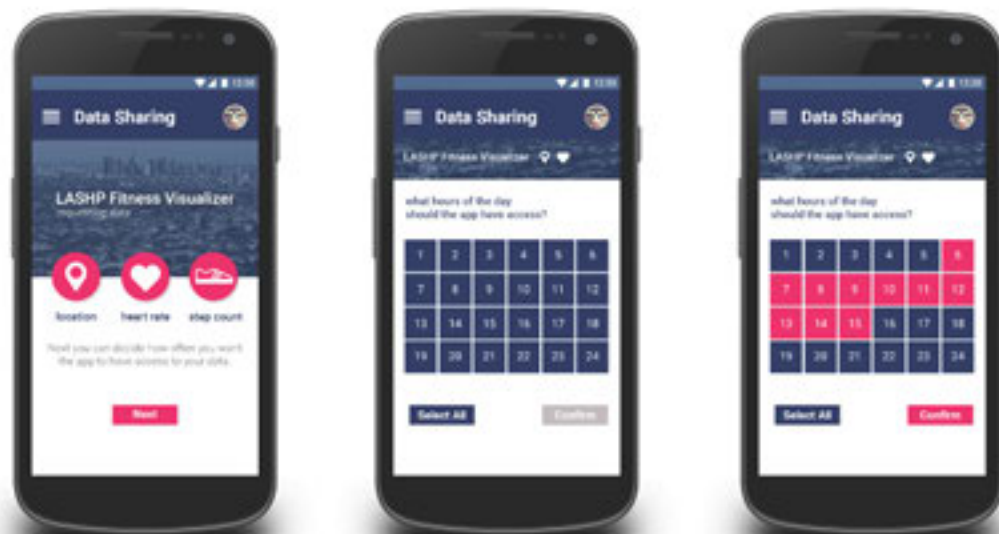
But this application is a new kind

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

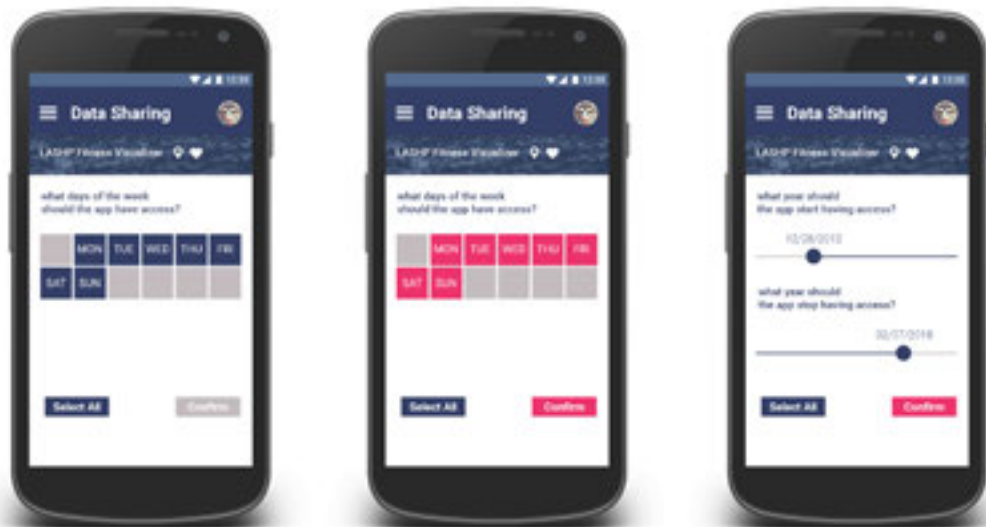




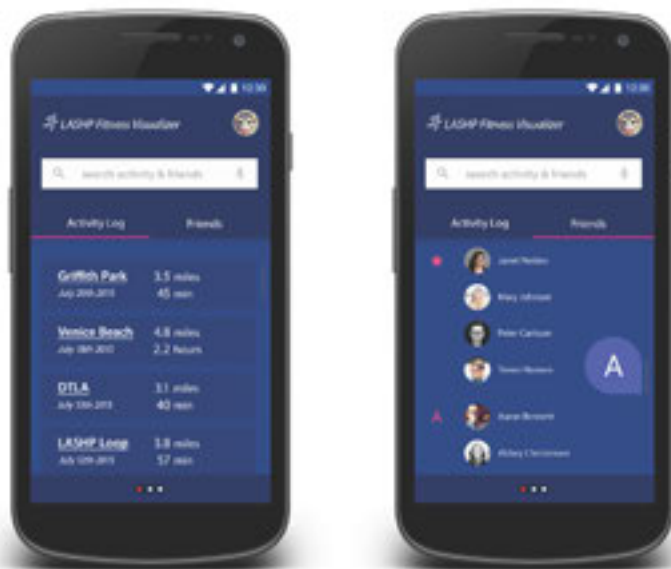
Confirm Data Types



Selecting Hours of the Day



Selecting Days of the Week



Challenges

NDN Namespaces

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

Identity management & Data signing

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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.)

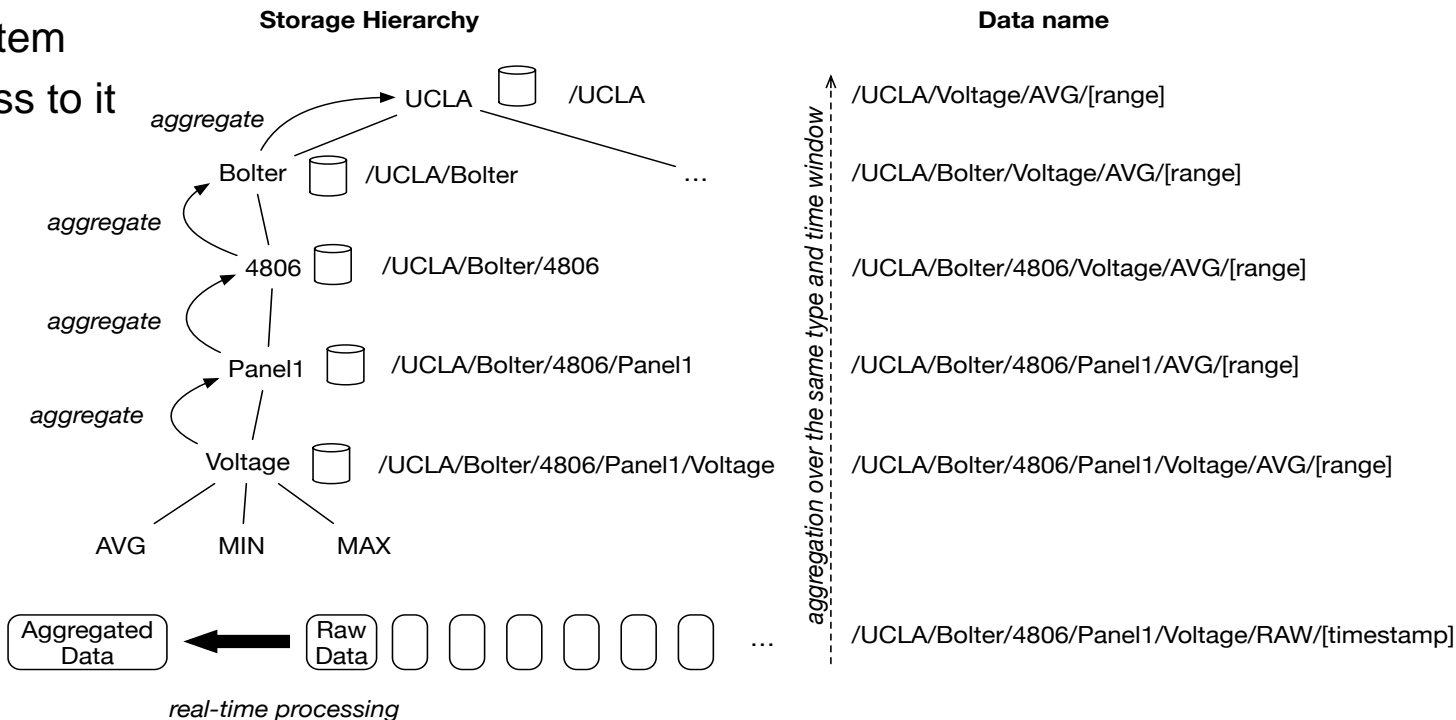
Looking initially at NDN-native hierarchical storage: keeping the data near the devices, then aggregating upwards.

EBAMS Test Environment: Mini-EBAMS

Hierarchical Data Storage on NDN

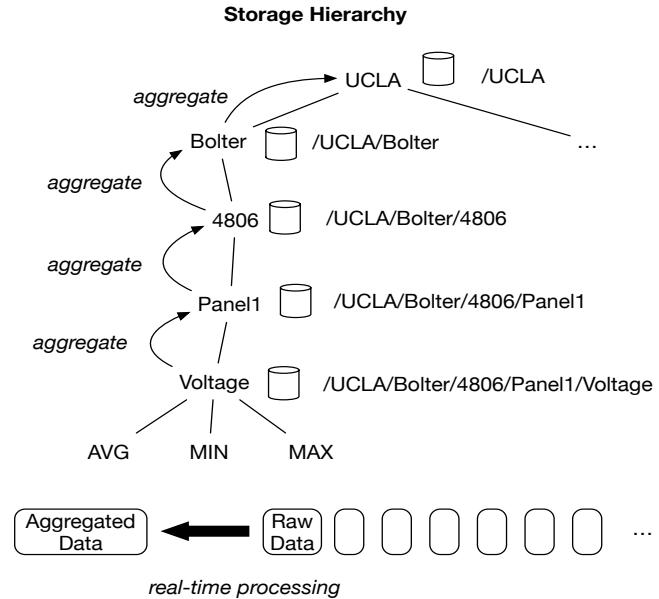
- Real UCLA Data
- Mini-NDN system
- NDN-JS access to it

See Zhehao Wang's poster for more.

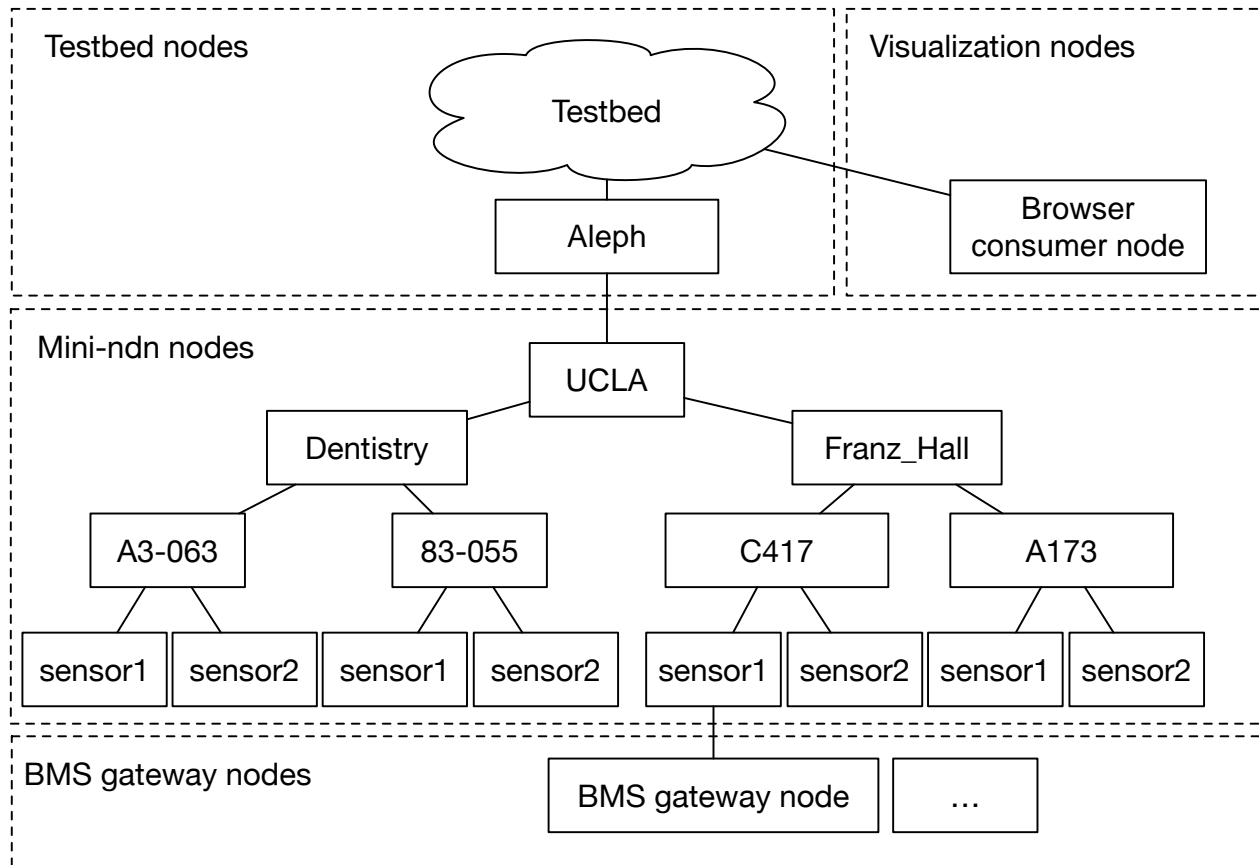


Hierarchical storage

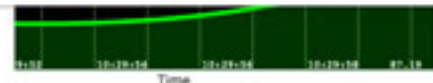
- Raw data collected, kept, and batched only at the leaf nodes.
- Leaf nodes publish aggregated (min, sum, avg, etc) data at fixed time window.
- Non-leaf nodes fetch the aggregated data from all of its children, and aggregate the data after all children respond.
- Non-leaf nodes can publish aggregates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



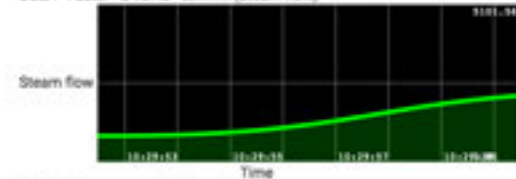
Mini-EBAMS



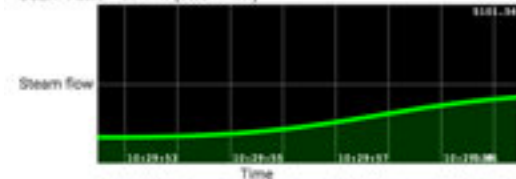
UCLA BMS Browser Consumer Concept (Steam flow)



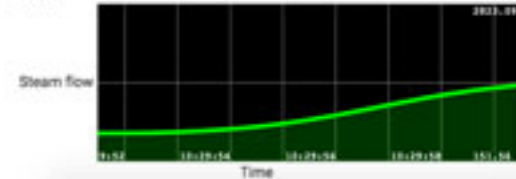
UCLA - Factor - a-937.a - stm.flw (Steam flow)



UCLA - Factor - stm.flw (Steam flow)



UCLA

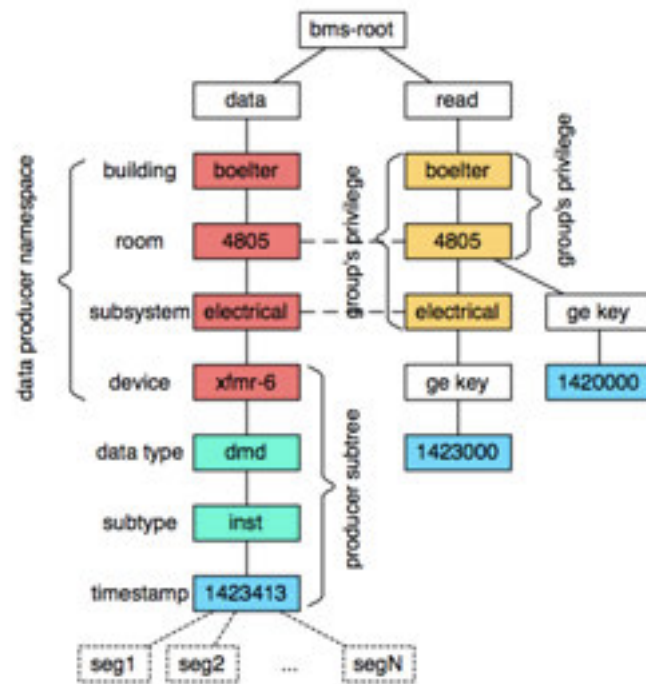


Current namespace

ucla	organization	ucla	
bms	system	bms	
sensors	category	sensors	
young_hall	building	young_hall	
b215	room	data/electrical	
xfmr-6	device	aggregation	subtype (aggregation)
data/electrical	type (data, electrical)	1423123670	Start timestamp
inst	data subtype (instantaneous)	1423123680	End timestamp
1423123667	data timestamp		

Data-Centric Security

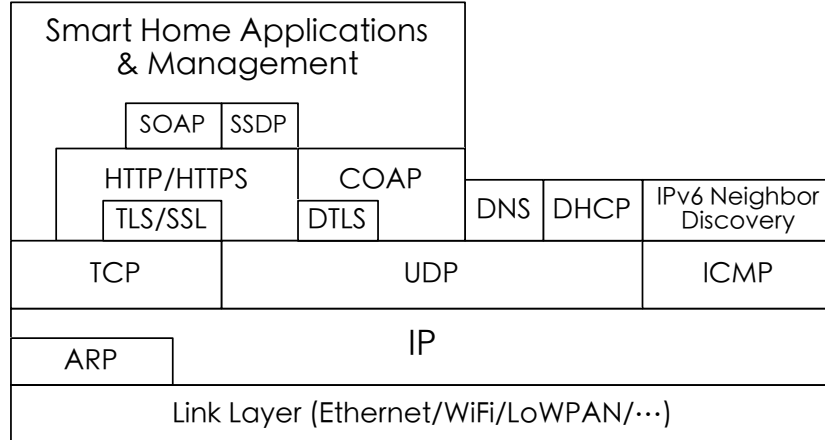
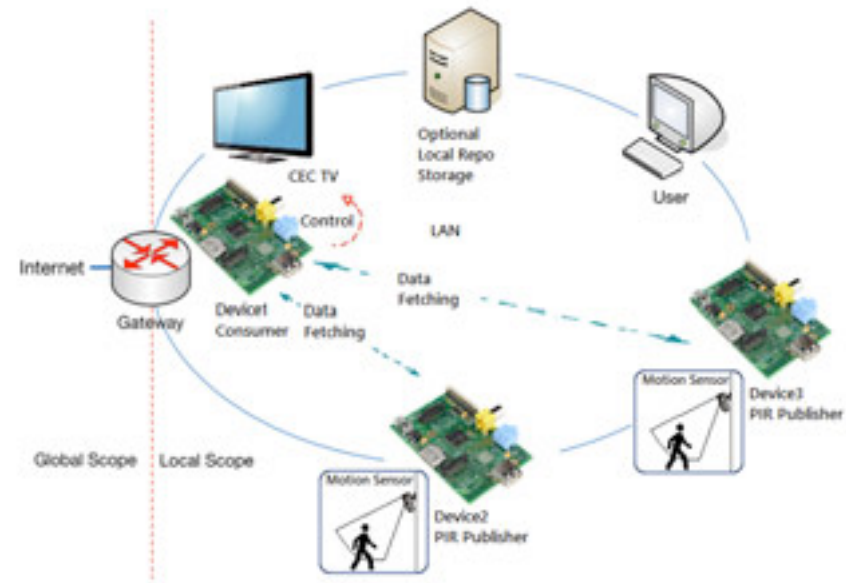
- Schematized trust
 - Initial design developed for hierarchical aggregation.
- Name-based access control
 - Primary access the
 - Provisions for links across namespaces (e.g., into user namespaces), translating previous work by Shang et al. to NBAC.
- Authenticated control



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>



Device Bootstrapping	Device Monitoring	Service Discovery	Smart Home Applications
Data Publishing; Data Consuming; Data Privacy Device Actuation; Access Control			
NDN Layer			
Link Layer (Ethernet/WiFi/LoWPAN/...)			

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.

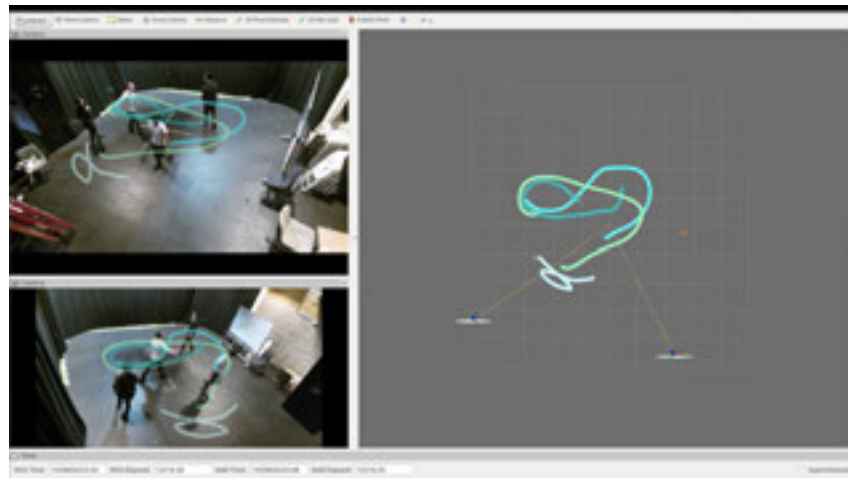
OpenPTrack: Positional tracking for education, arts, and culture.

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.

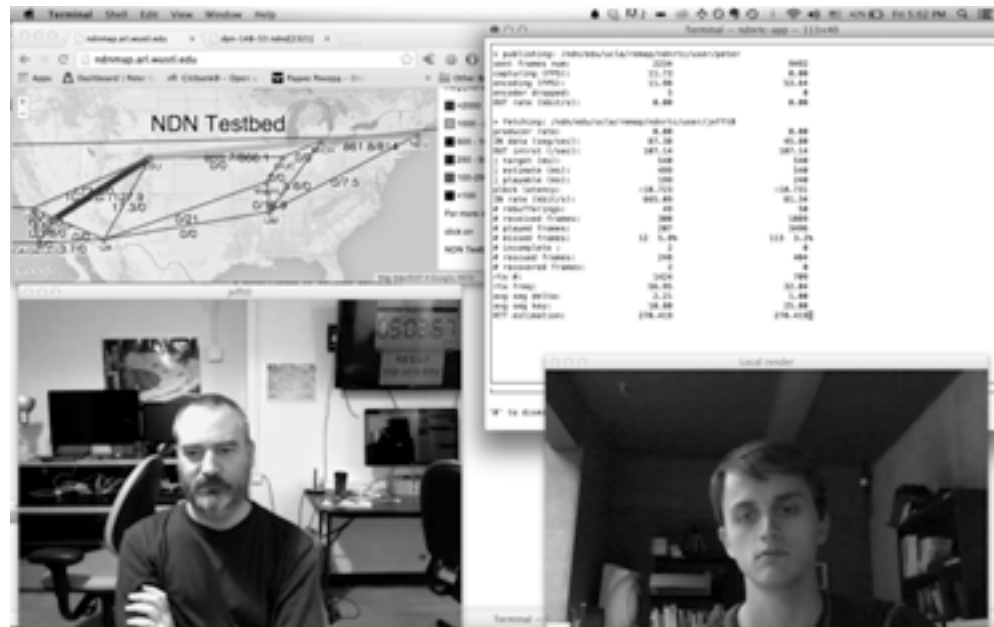
NDN-RTC Project Goals

- 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

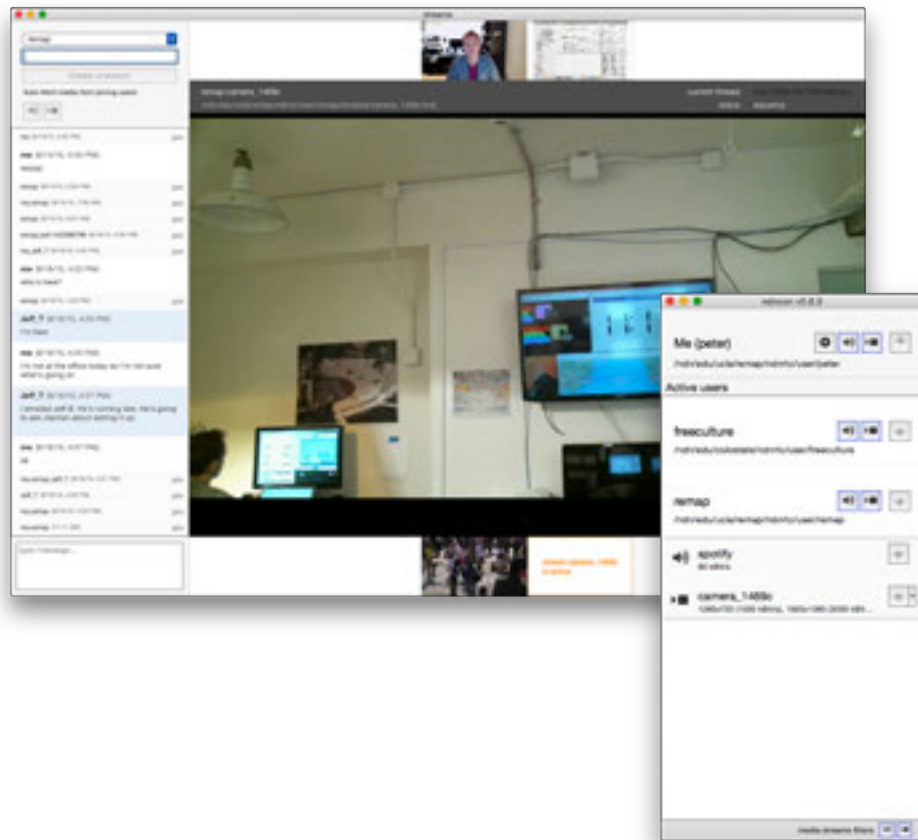
- OS X C++ library
- Console demo app
- No group chats
- Hard to use (user-unfriendly)
- Hard to setup
 - No user auto-discovery
 - Build from sources
- Mediocre streaming efficiency:
 - frequent rebufferings
 - video tearings
 - frequent audio drop-outs



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>
```

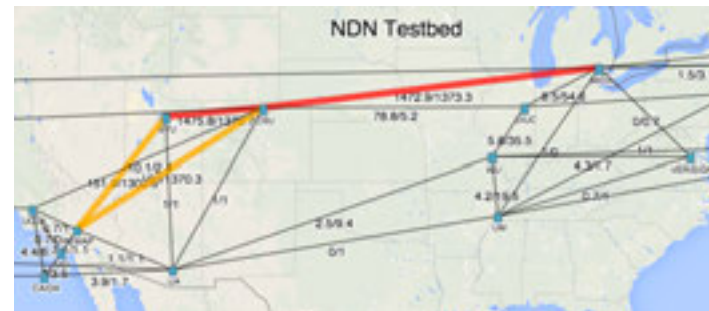


Example NDN-RTC-driven Improvements

- 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 approach 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

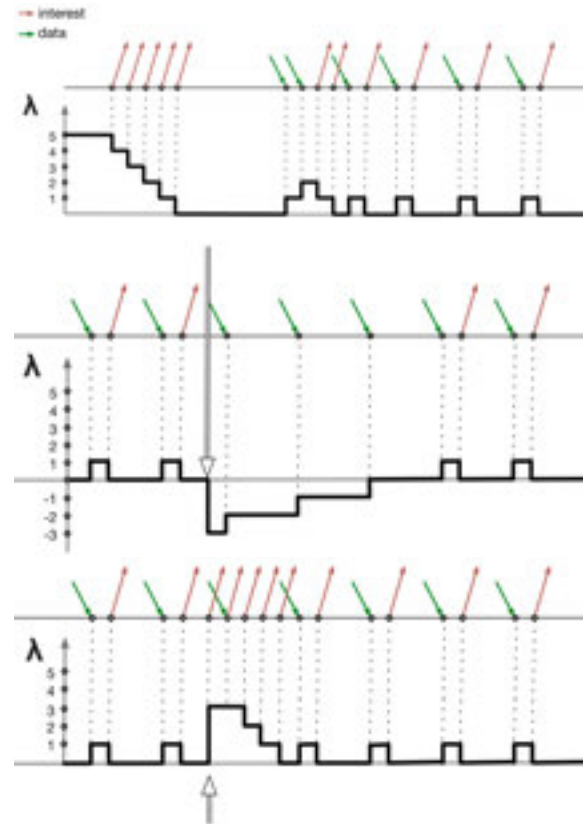
Design & Development Progress

- 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)
- 



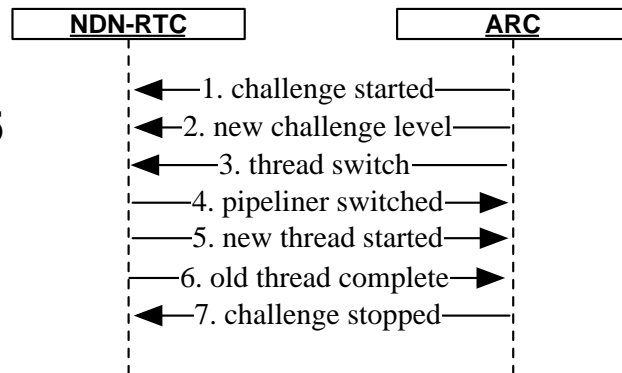
Interest Demand

- **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)
- $$\text{Interest Demand} = \text{DRD} / D_{\text{arr}}$$
- 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 implementation¹, Panasonic - **November 2015**
 - Early tests - **December 2015**
 - Full tests – **January-February 2016**
 - Completion – **March 2016**
- Implementation details²
 - Gapless stream switching
 - Challenging Interests for bandwidth probing
 - Ongoing monitoring of intrinsic network parameters (DRD, D_{arr}, etc.)

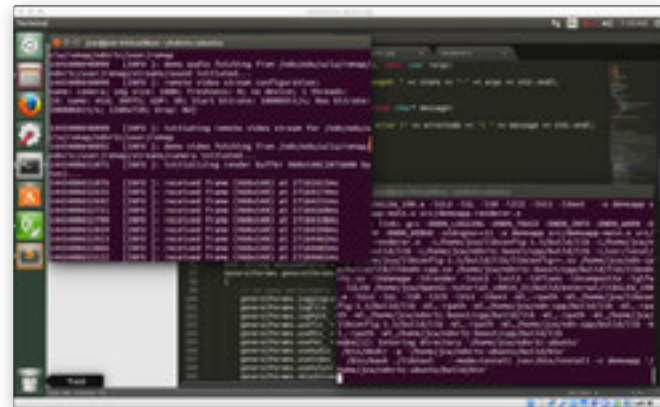


[1] Takahiro, Y. et al. **Consumer driven Adaptive Rate Control for Real-time Video Streaming in Named Data Networking.** *To be presented at Internet Conference 2015, October*

[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!*