NDN Open mHealth Use Case Scenario for 2014

NDNEx - Physical Activity Data Ecosystem

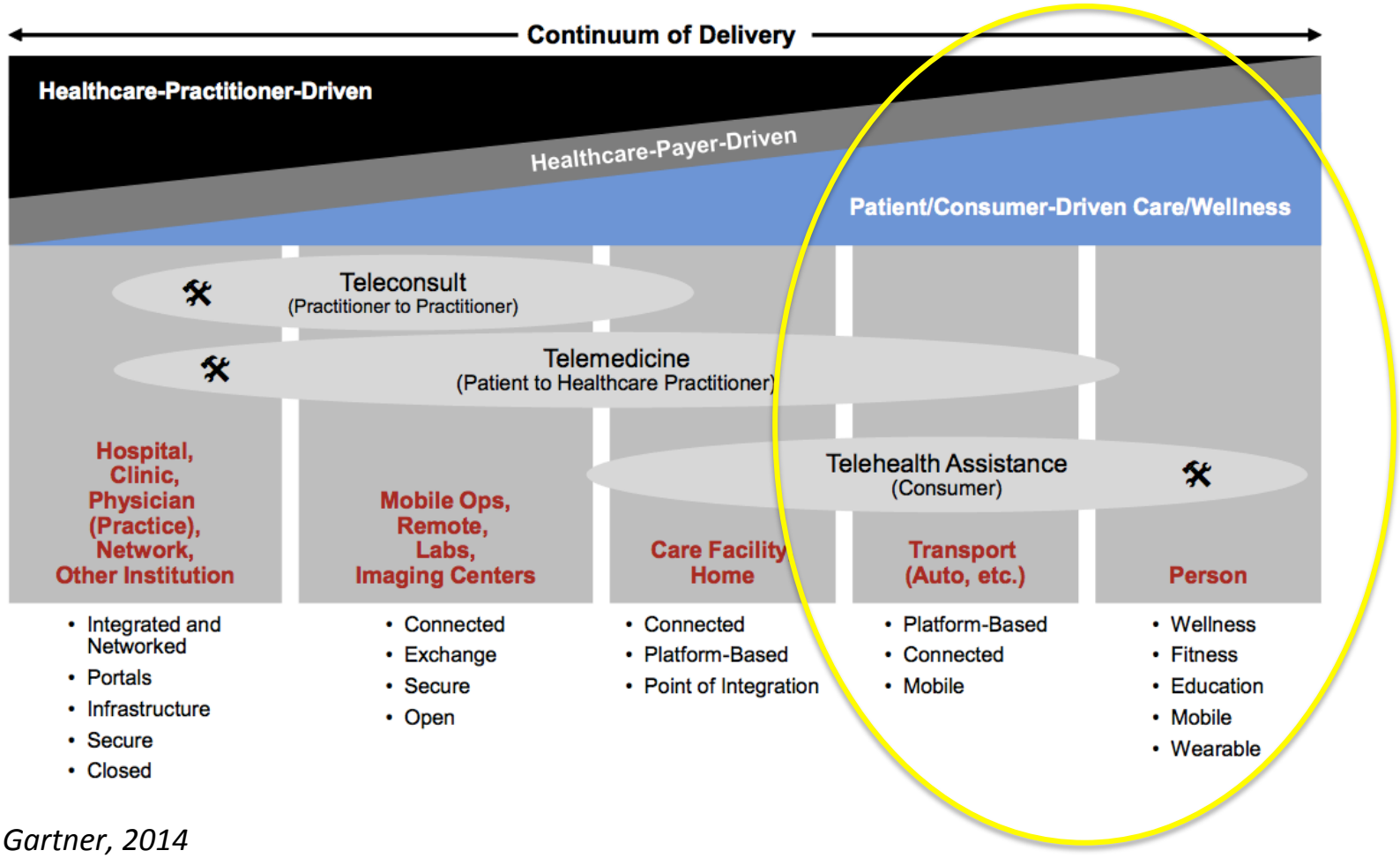
Draft 1 - August 12, 2014

Intent of this Presentation

- Recap Open mHealth network environment for NDN NP research.
- **Identify a specific use case / driver application "NDNEx" within Open mHealth for collaborative research in 2014.**
- Provide an initial "recasting" of that application within an NDN-inspired, data-dissemination based paradigm.
- Focus on what technology from the existing Open mHealth reference architecture can be re-used rather than re-created.
- Suggest areas for collaboration with partner universities and researchers.
- Outline work plan and next steps.

NDN focus within “mobile health”

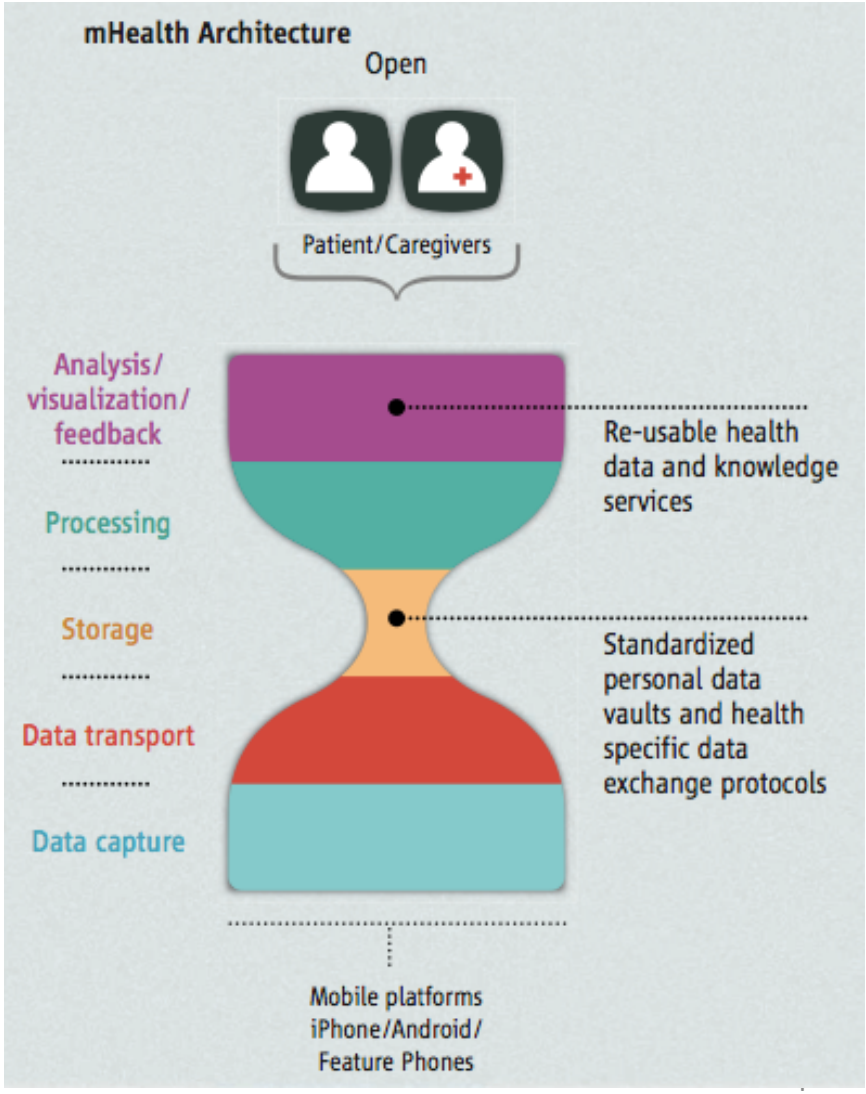
Consumer-facing mHealth applications can have significant impact but do not rely on integration with EHRs / HIPAA-compliant systems for initial success.



Gartner, 2014

Open mHealth Fundamental Idea:
Data rather than System Interoperability

- Interoperable, Internet-inspired **data exchange as the backbone of the application ecosystem**
- **Thin waist of open data interchange** standards that will enable an ecosystem of **sensing, storage, analysis, and user interface components** to support medical discovery and evidence-based care
- Market-supported, patient-centered landscape of innovative health applications
- **Patient-controlled, privacy-aware data exchange** across device, component, and application boundaries



D. Estrin (Cornell), I. Sim (UCSF)

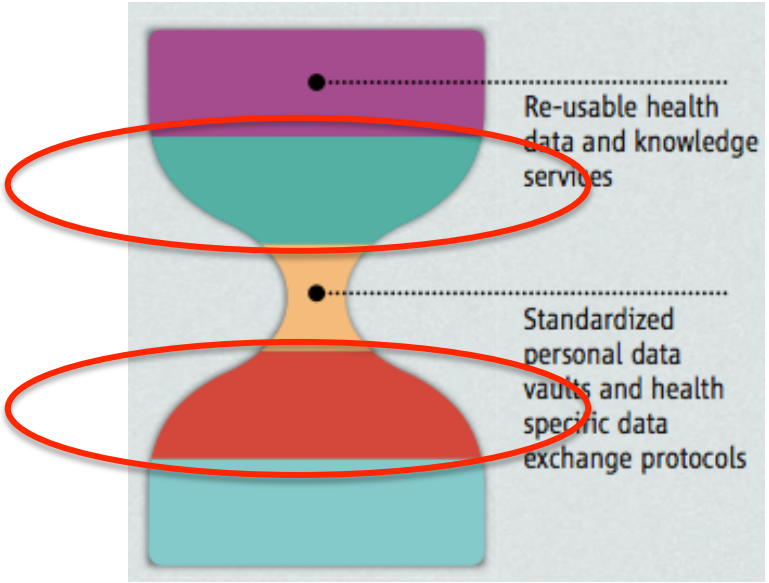
Same Challenges, Different Layers

For this application in particular, NDN provides much more relevant functionality at the network layer than IP.

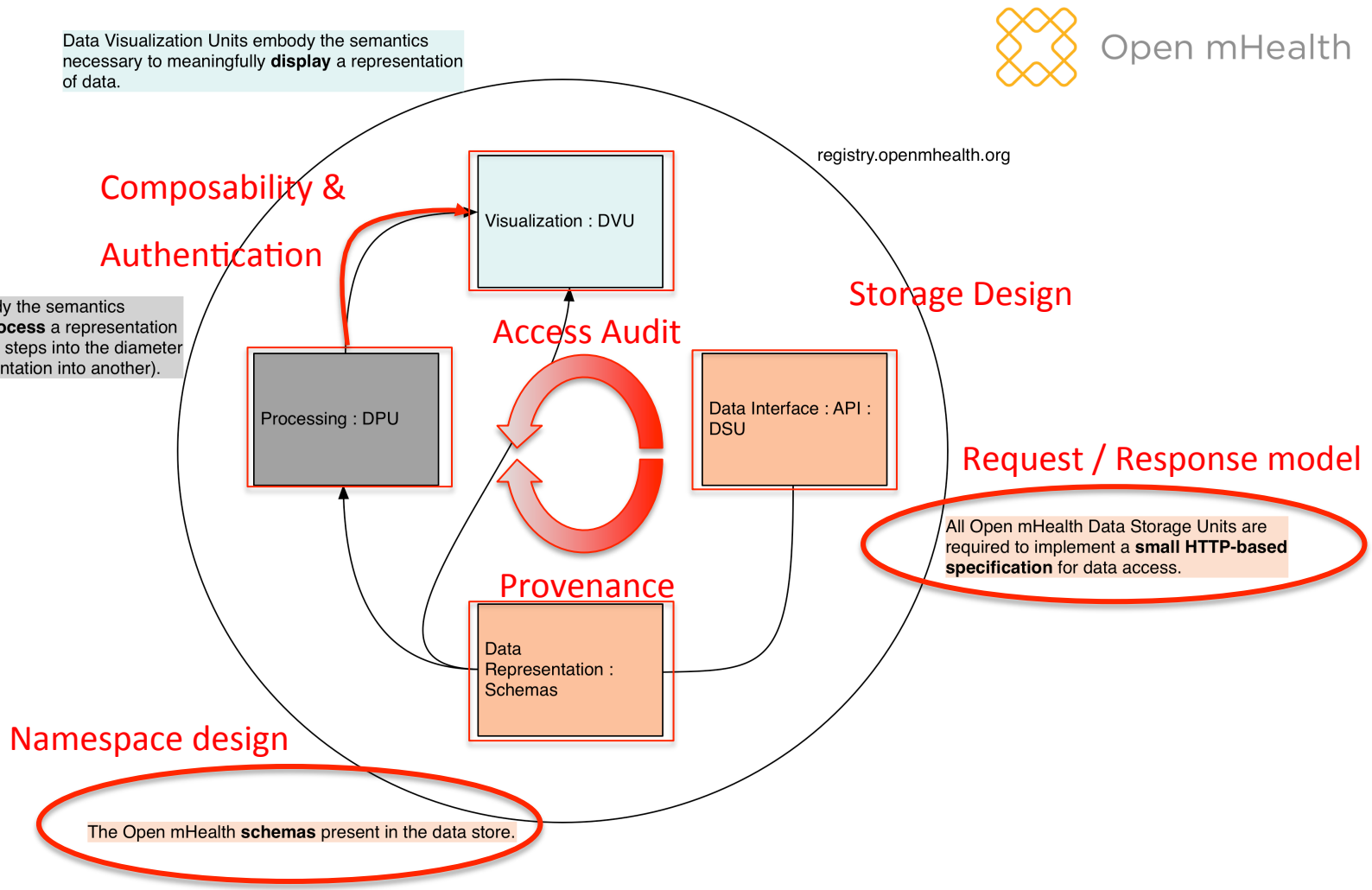
So solutions in NDN have much more direct impact on the scalability, security, and ease of development; we need not build up additional layers on IP to get near the app challenges.

- Namespace / schema design
- Repository / storage design
- Service composability
- Authentication / identity assurance
- Data provenance
- Access auditing
- Mobile publishing
- Legal requirements for success

Open mHealth arch. looks a lot like NDN



Mapping the Open mHealth Architecture to NDN



http://openmhealth.org/

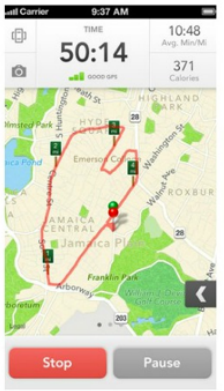
Open mHealth Fundamental Idea:
Data rather than System Interoperability

So, for our use case, focus on a simple ecosystem of composable services rather than a single silo'ed application.

2014 Open mHealth Driver Application

NDNEx - Physical Activity Data Ecosystem

- "NDNEx" for "NDN-Exercise"
- Supporting physical activity is both a critical part of building healthy communities and a key retail market.
- For NDN-NP in 2014, explore a **non-proprietary ecosystem for consumer physical activity data.**
- Start with **end-user mobile+web application** that captures and reports walking, jogging, and running activity.
- Calculate and report activity metrics based on GPS and accelerometer data – both automatically and self-identified rounds of exercise.
- Ad-hoc and formal groups or teams.
- Capable of location-based content "push" during the exercise, which can be used for health, entertainment, local, and team-related content.
- Commercial parallels: Nike+, Fitbit, etc.
- Envisioned as an open-data ecosystem, with different service providers at different stages in the processing chain, rather than a silo'ed application.



2014 Open mHealth Driver Application:

NDNEx - Physical Activity Data Ecosystem

- Existing work to leverage in this area:
  - Open mHealth Toolset – including Ohmage reference platform and the *Lifestreams* concept.
  - Past CENS/UCLA participatory sensing research in activity classification, self-surveillance privacy, mobile phone based data collection.
  - REMAP's funded collaborations on Urban Trails and technology for Parks with California State Parks, the Western National Parks Association, National Park Service, and the City of Los Angeles.

Leverage Existing Components

Capture: Ohmage+Mobility.

http://ohmage.org/

ohmage is an open-source participatory sensing technology platform. It supports expressive project authoring; mobile phone-based data capture through both inquiry-based surveys and automated data capture as well as temporally and/or spatially triggered reminders, data visualization and real-time feedback; privacy respecting data management; and extensible data exploration. All captured data are automatically timestamped, geocoded and uploaded for analysis and visualization.

Leverage Existing Components

Storage: Open mHealth Data Storage Unit (DSU) Design.

https://github.com/openmhealth/developer/wiki/DSU-Overview

The Open mHealth DSU (Data Storage Unit) API Specification is an open specification for unified information sharing across disparate data streams. The idea is simple: create an easy-to-understand set of APIs that allow siloed data stores to share information. Third-party applications that understand this API specification can then create a single set of tools to access data across any of the servers.

Leverage Existing Components

Processing: Open mHealth Data Processing Unit (DPU) Design.

https://github.com/openmhealth/developer/wiki/Open-mHealth-and-Data-Processing

DPUs are stateless modules that input and output data. They are designed to be embedded in other software or called remotely. They do not produce anything directly visible, but are the brains and muscles of an application. The concept of a DPU is inspired by the Unix Philosophy of creating small functional tools that can be chained and reused, rather than a single large application.

Leverage Existing Components

Processing: Named Function Networking Concept.

http://www.named-function.net/

Names serve to access and invoke functions, which incidentally can produce passive content once it is needed. New questions arise from this point of view, namely how the network organizes the flow of functions, which brings us squarely into active networking turf.

Leverage Existing Components

Location-based Content: IMLab Trails Database.

http://gizmodo.com/los-angeles-launches-an-interactive-urban-trail-system-1541248828

The **LASHP Trails Mobile Website** gives residents and visitors to Northeast Downtown Los Angeles site-specific access to a dynamic combination of historic information and health-related activities along urban trails starting and ending at the Los Angeles State Historic Park. In collaboration with LA City Planning, the students, their parents, teachers, lawmakers, community members, and the California Endowment discussed the possibility of formalizing this trail network. California State Parks and the UCLA Interpretive Media Laboratory (IMLab) were asked to develop a proposal to formalize this trail network through a combination of wayfinding markers and a digital site that would incorporate historical information and images, along with calorie counting and mileage tracking capabilities.

Leverage Existing Components

Analytics / Presentation: Ohmage Front-end for Mobilize.

https://wiki.mobilizingcs.org/app/web

The web frontend (powered by the ohmage project) is used to provide students secure access to their data. It supports secure login, campaign management, data management and basic campaign monitoring and visualization. The students can review and share their data to the growing data set collected by their class. The web frontend can also be used to discover the answers to basic statistical inferences in real-time as data is being collected. When data collection is complete, the web frontend allows for easy exporting of the data to a more thorough statistical analysis tool.

Motivating Model

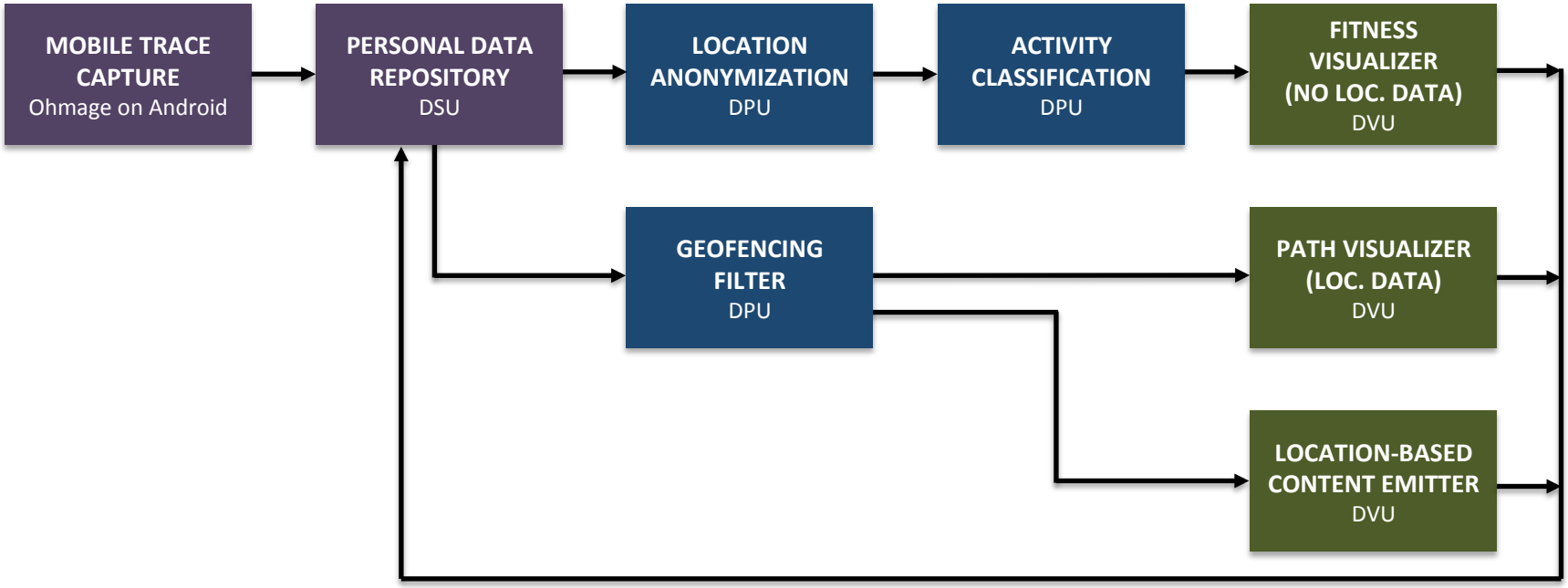
UCLA / Cornell “Lifestreams” Concept

Hsieh, Cheng-Kang, et al. "Lifestreams: a modular sense-making toolset for identifying important patterns from everyday life." *Proceedings of the 11th ACM Conference on Embedded Networked Sensor Systems*. ACM, 2013.
https://www.dropbox.com/s/l0721457faswj5k/a5-hsieh.pdf

Smartphones can capture diverse spatio-temporal data about an individual; including both intermittent self-report, and continuous passive data collection from onboard sensors and applications. The resulting personal data streams can support powerful inference about the user's state, behavior, well-being and environment. However making sense and acting on these multi-dimensional, heterogeneous data streams requires iterative and intensive exploration of the datasets, and development of customized analysis techniques that are appropriate for a particular health domain.

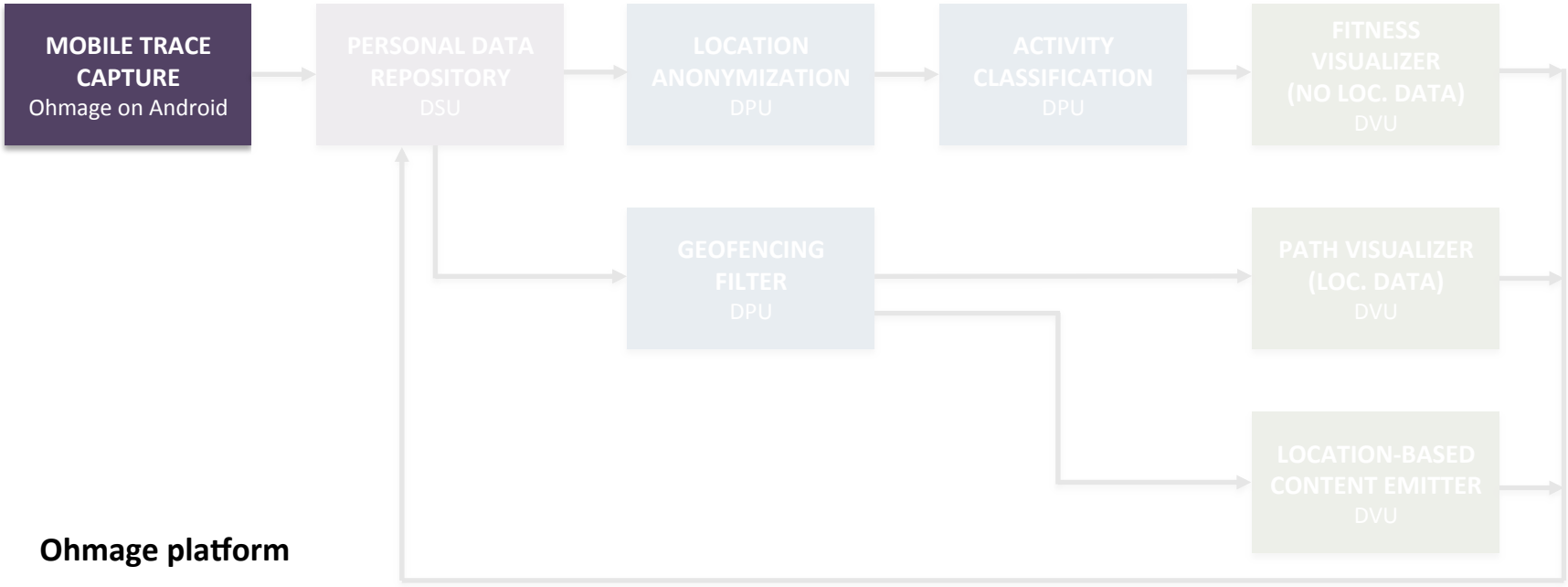
Lifestreams is a modular and extensible open-source data analysis stack designed to facilitate the exploration and evaluation of personal data stream sense-making. Lifestreams analysis modules include: feature extraction from raw data; feature selection; pattern and trend inference; and interactive visualization. The system was iteratively designed during a 6-month pilot in which 44 young mothers used an open-source participatory mHealth platform to record both self-report and passive data about their diet, stress and exercise. Feedback as participants and the study coordinator attempted to use the Lifestreams dashboard to make sense of their data collected during this intensive study were critical inputs into the design process. In order to explore the generality and extensibility of Lifestreams pipeline, it was then applied to two additional studies with different datasets, including a continuous stream of audio data, self-report data, and mobile system analytics. In all three studies, Lifestreams' integrated analysis pipeline was able to identify key behaviors and trends in the data that were not otherwise identified by participants.

Conceptual Block Diagram: Data Flow



Data flow for a single user who gets 1) fitness / activity metrics, 2) walking or running path visualizations, and 3) location-based content during exercise – all through the same ecosystem, but from different providers.

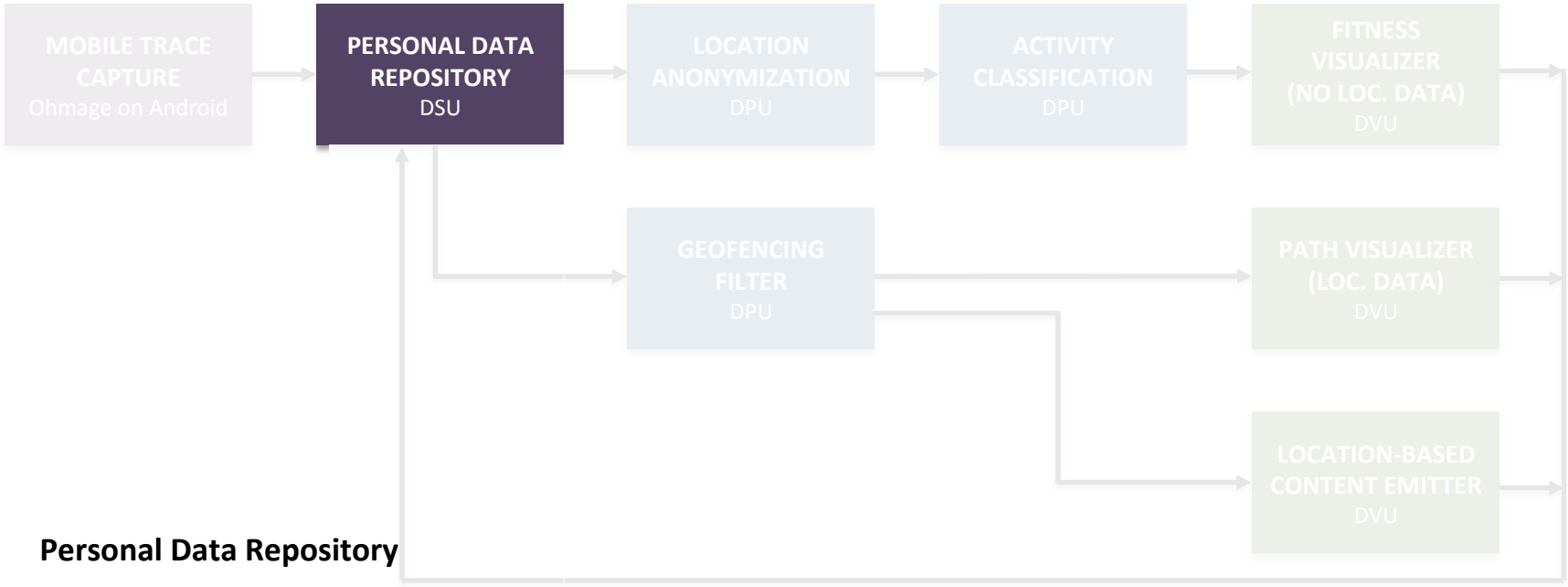
Conceptual Block Diagram: Data Flow



Ohmage platform

- http://ohmage.org/
- Tangmunarunkit, H., et al. "Ohmage: A General and Extensible End-to-End Participatory Sensing Platform." *In submission.* http://ohmage.org/static/ohmagehome/papers/ohmage.pdf

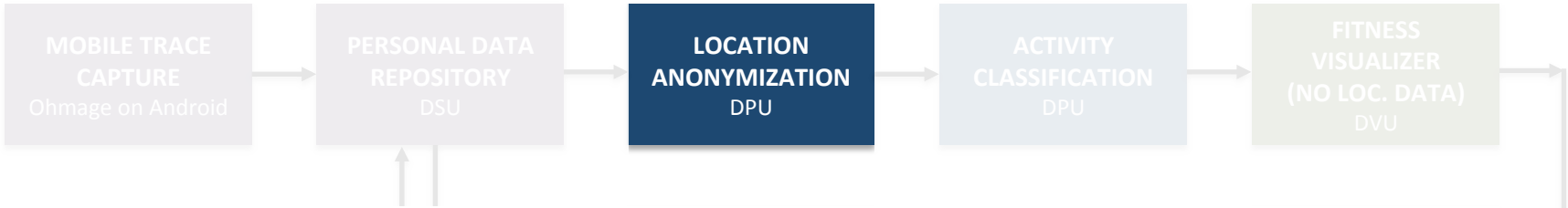
Conceptual Block Diagram: Data Flow



Personal Data Repository

- Kang, J., Shilton, K., Estrin, D., Burke, J. "Self-surveillance privacy." *Iowa L. Rev.* 97 (2011): 809. http://escholarship.org/uc/item/1jk8b2q1.pdf
- Mun, Min, et al. "Personal data vaults: a locus of control for personal data streams." *Proceedings of the 6th International Conference*. ACM, 2010. http://remap.ucla.edu/jburke/publications/Mun-et-al-2010-Personal-Data-Vaults.pdf

Conceptual Block Diagram: Data Flow



Location Anonymization

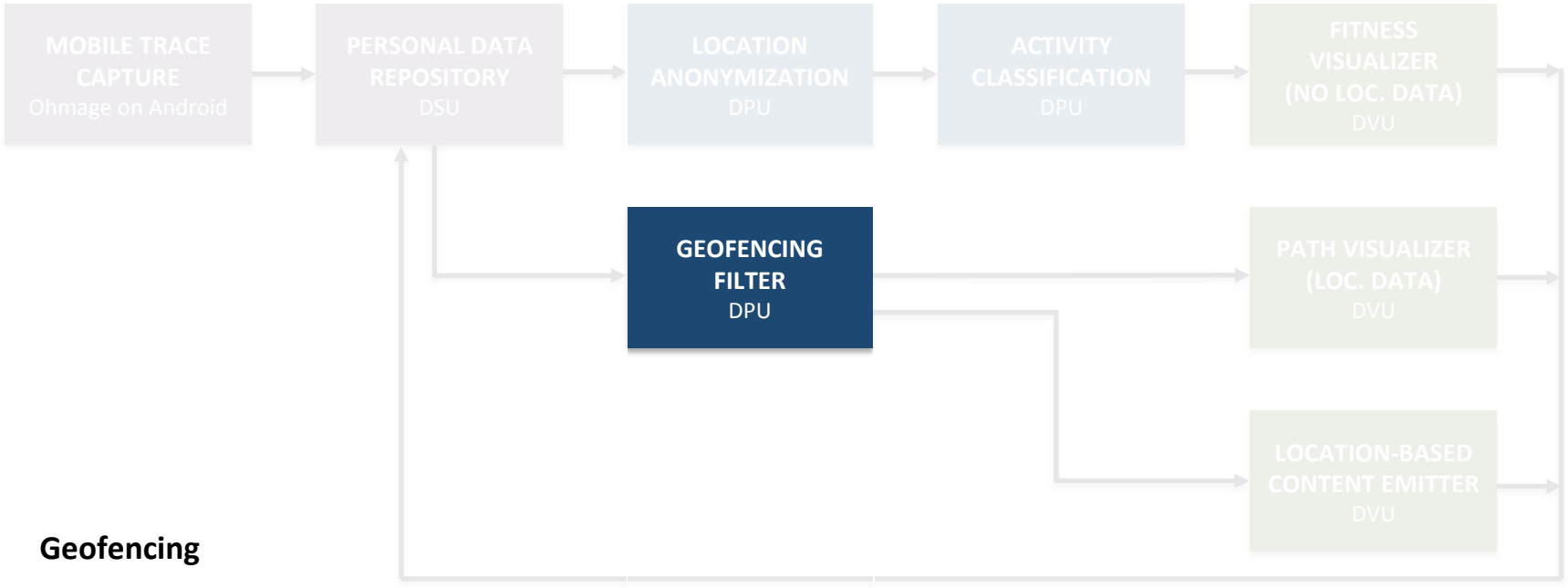
- Avoid providing specific location information to services that do not need it. Range of techniques from the simple, which may be used here, to the more sophisticated.
- Krumm, John. "A survey of computational location privacy." *Personal and Ubiquitous Computing* 13.6 (2009): 391-399. http://msr-waypoint.com/en-us/um/people/jckrumm/Publications%202008/computational%20location%20privacy%20preprint.pdf
- Xu, Toby, and Ying Cai. "Location anonymity in continuous location-based services." *Proceedings of the 15th annual ACM international symposium on Advances in geographic information systems*. ACM, 2007. http://lbsstorage.googlecode.com/svn/trunk/Location-based%20Services/3.1%20Anonymity%20based%20defense/%5B21%5DLocation%20anonymity%20in%20continuous%20location-based%20services.pdf
- Zang, Hui, and Jean Bolot. "Anonymization of location data does not work: A large-scale measurement study." *Proceedings of the 17th annual international conference on Mobile computing and networking*. ACM, 2011. https://research.sprintlabs.com/publications/uploads/mobi13k-zang.pdf

Conceptual Block Diagram: Data Flow

Activity Classification

- Generate classified / tagged location data, or simply activity streams based on GPS and accelerometer data.
- Some classification currently built-in to the Ohmage Mobility utiliyt on the mobile device: http://ohmage.org/static/ohmagehome/docs/Mobility%20tech%20report%20%28dec%202013%20v2%29.pdf
- Hsieh, Cheng-Kang, et al. "Lifestreams: a modular sense-making toolset for identifying important patterns from everyday life." *Proceedings of the 11th ACM Conference on Embedded Networked Sensor Systems*. ACM, 2013. https://www.dropbox.com/s/l0721457faswj5k/a5-hsieh.pdf
- Longstaff, Brent, Sasank Reddy, and Deborah Estrin. "Improving activity classification for health applications on mobile devices using active and semi-supervised learning." *Pervasive Computing Technologies for Healthcare (PervasiveHealth), 2010 4th International Conference on-NO PERMISSIONS*. IEEE, 2010. http://research.cens.ucla.edu/people/estrin/resources/conferences/2010-mar-Longstaff.pdf

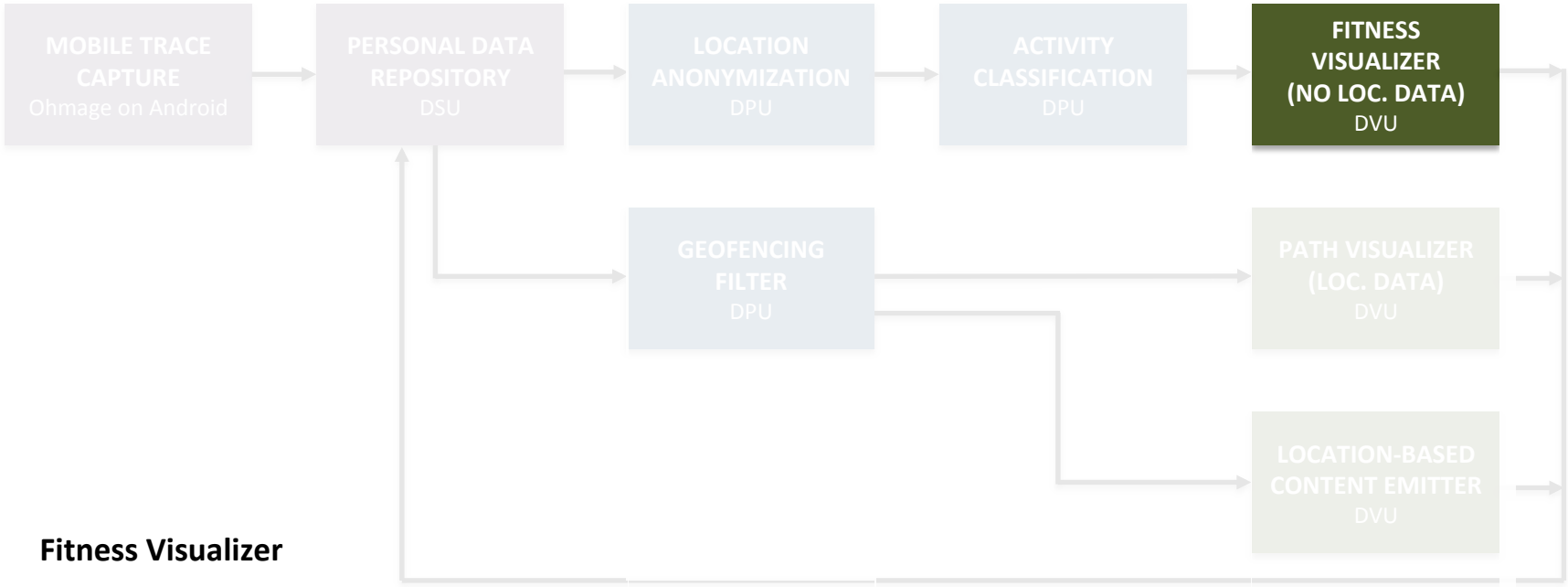
Conceptual Block Diagram: Data Flow



Geofencing

- Prevent service activation / data access outside of a location boundary.
- Implemented as (transparent) post-processor on raw location data.

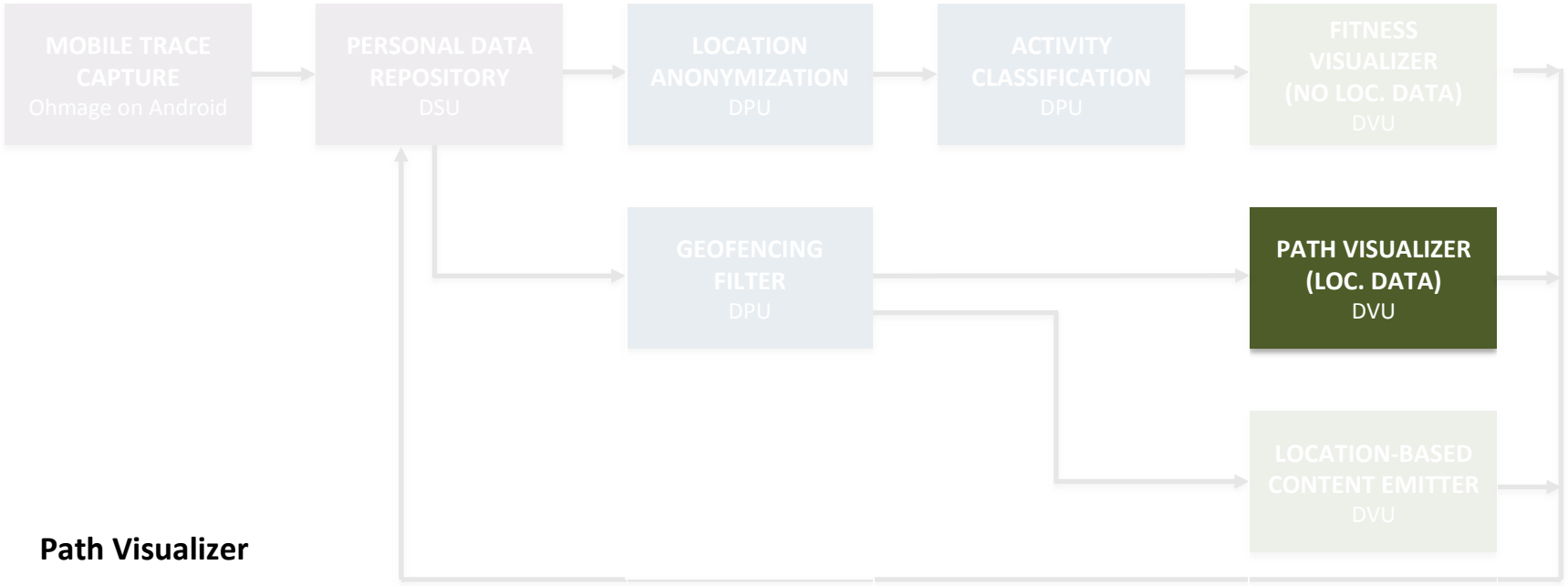
Conceptual Block Diagram: Data Flow



Fitness Visualizer

- Start with Ohmage front end (see previous slides).
- Web-based front end using NDN-JS to access derived data without location information.
- Examples: http://quantifiedself.com/fitbit/

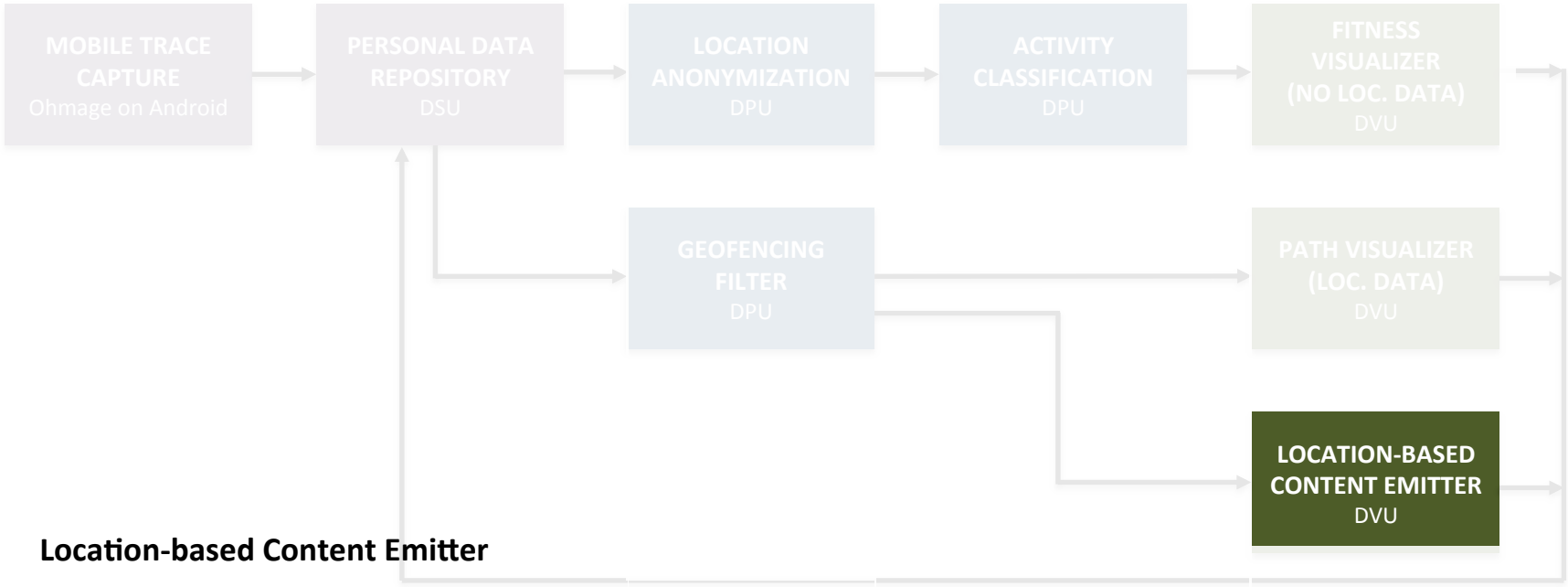
Conceptual Block Diagram: Data Flow



Path Visualizer

- Web-based front end using NDN-JS with access to geofenced location information, providing (for example) running trail visualization.
- Perhaps use many GPX format visualizers. E.g., http://flowingdata.com/2014/02/05/where-people-run/

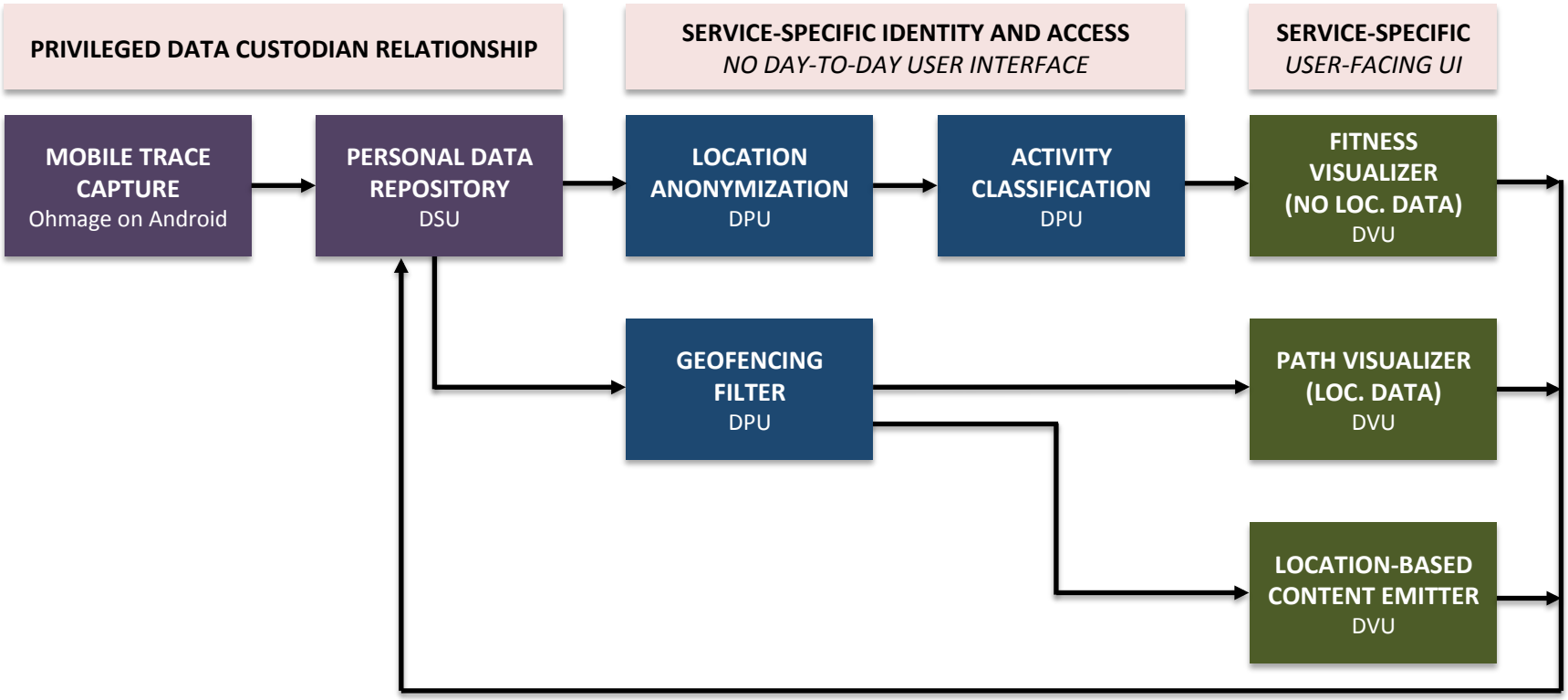
Conceptual Block Diagram: Data Flow



Location-based Content Emitter

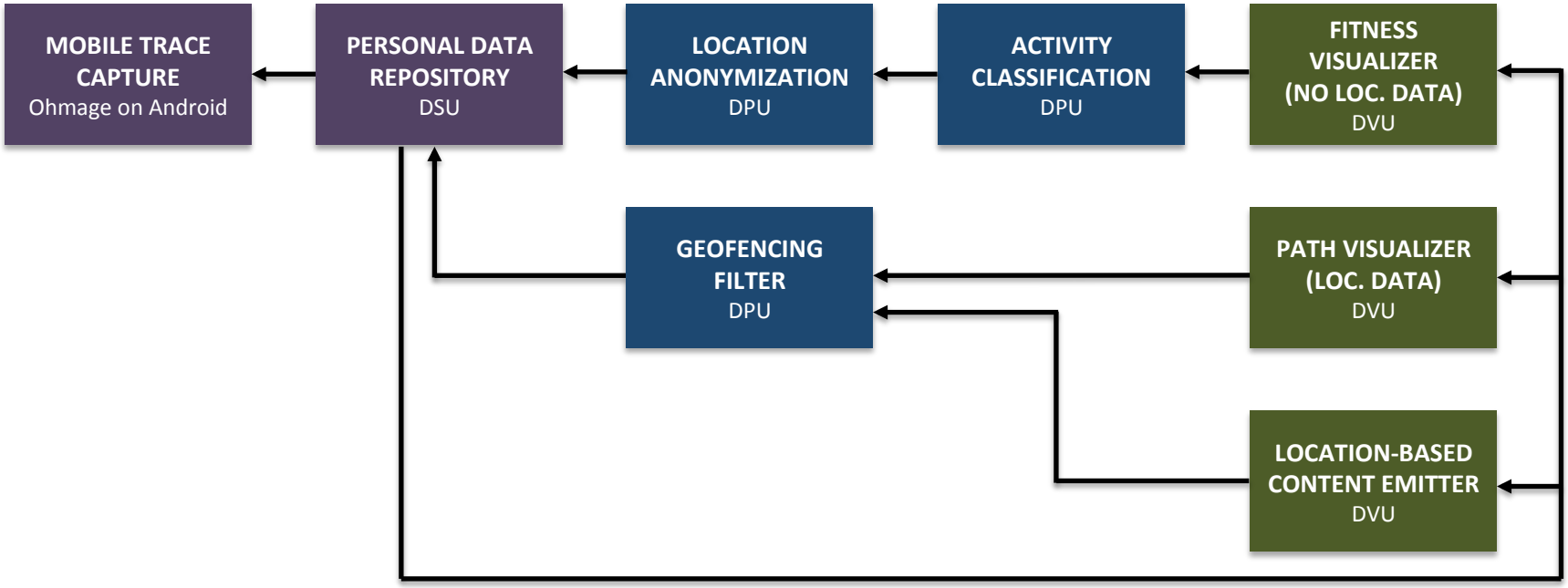
- Web-based front end using NDN-JS with access to geofenced location information, providing location-specific content back to the mobile user.

Identity and Data Domains

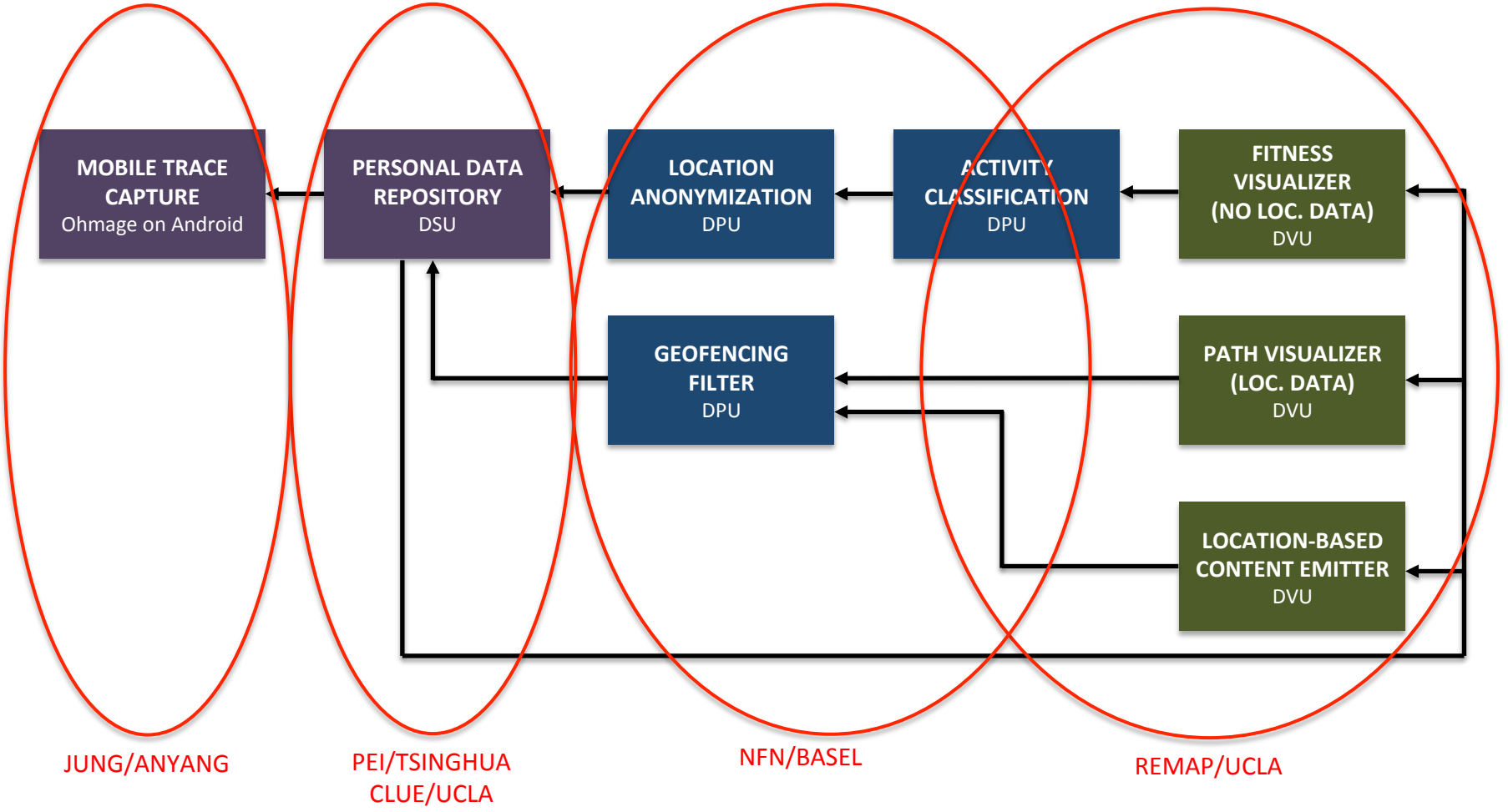


- Each processing block in this diagram may come from a different service provider.
- User may have different identity per service (or at least per flow).
- Each step tends to generate derived data that must also be stored and may not be associated with the original identity.

Beginning the NDN Design: *Interest* Flow



Possible Collaborative Approach??



CROSS-CUTTING
DATA NAMESPACE DESIGN – INITIATED BY UCLA
TRUST / SECURITy DESIGN – U. MICHIGAN AND UCLA

Next Steps: Recall Initial Research Goals

- Naming and application design
  - Translate existing REST-based approach? How quickly to move to a new model of data exchange where transactions are mostly about (for example) keys.
  - What schema? Initially, try direct mapping of Open mHealth schema to names
  - Borrow ideas from Named Function Networking concept for distributed processing
  - How to best handle mobile publishing?
- Trust and security
  - Replacing Oauth2 for distributed processing is critical
  - Data encryption requirements
  - Name privacy issues
- Storage in the network
  - Interaction of personal and shared stores
  - Support for mobile publishing
  - Data filtering at the repo?
  - New legal / economic relationship between the players

Next Steps for NDNEx

- Confirm that this use case is a good driver for AY2014 and field comments / questions. (August)
- Analyze Ohmage (August/September).
- Expand case study to explain from end-user perspective and present at NDNComm. (September)
- Preliminary namespace and trust design. (Fall)
- …

mHealth Reality Check

- Are your systems interoperable?
  - Estrin & Sim in *Science*, 2010. *Open mHealth*.
- Are you using open standards?
  - WHO, 2013. *eHealth unit.*
- How will you evaluate?
  - Greenhalgh et al. in BMC Med Res. Methodology, 2011. *Realist and meta-narrative evidence synthesis*.

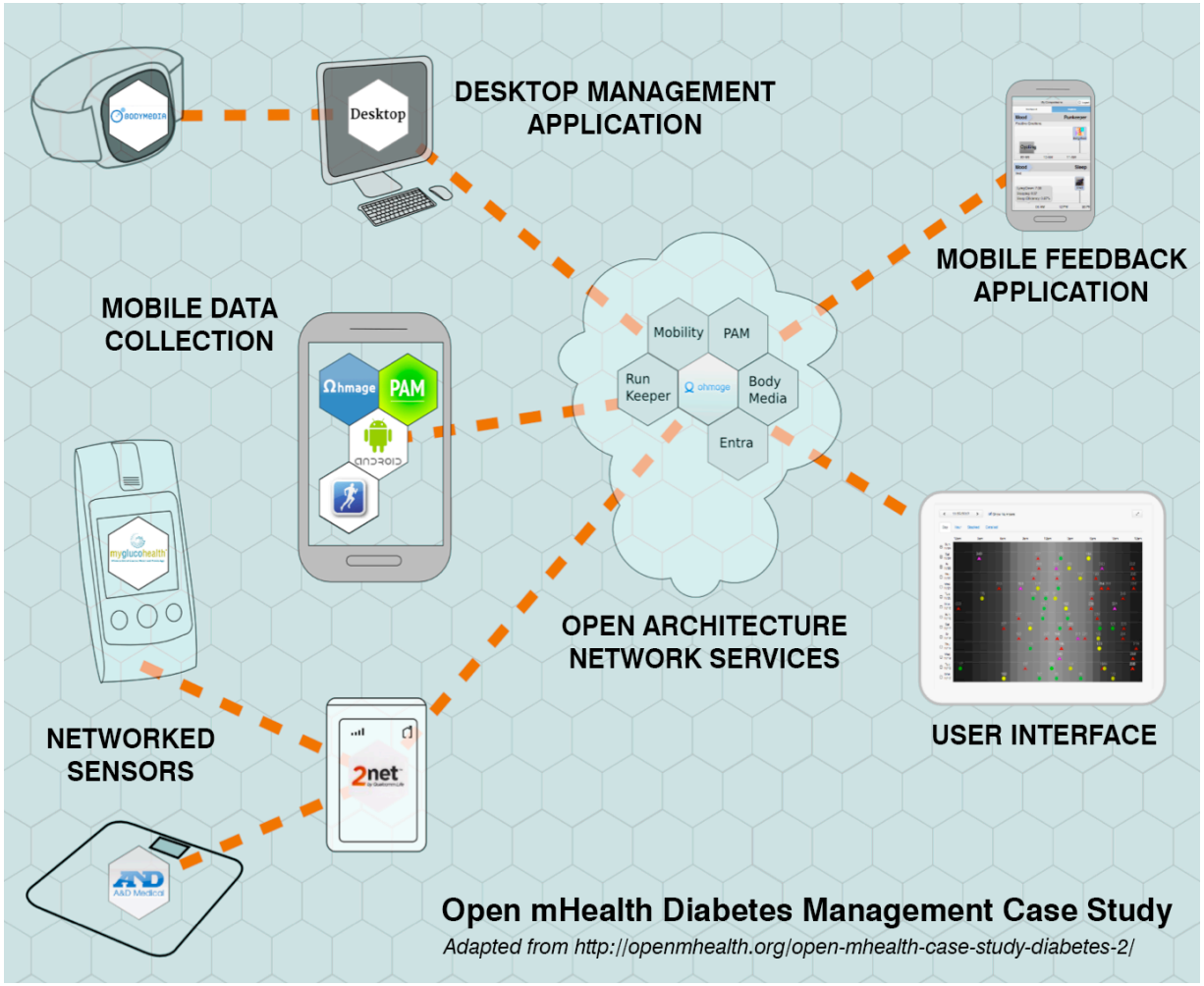
PLOS Medicine Editors. "A reality checkpoint for mobile health: three challenges to overcome." *PLoS Medicine* 10.2 (2013).

ADDITIONAL SLIDES

Open mHealth: Motivation

- Mobile health (mHealth) has emerged as both an important commercial market and a key area of Health IT, a national priority.
- The 2013 mHealth Summit will host over 4,500 participants. Recent surveys suggest there are over 13,000 health-related apps available to Apple iPhone users, and over 6000 for Android users.
- The Internet's role as a critical enabler of mHealth will grow further over the next decade.
- Continuation of our "participatory sensing" application; motivation of NDN library support for mobile handsets.

Open mHealth: Approach



Diabetes Mgmt Use Case

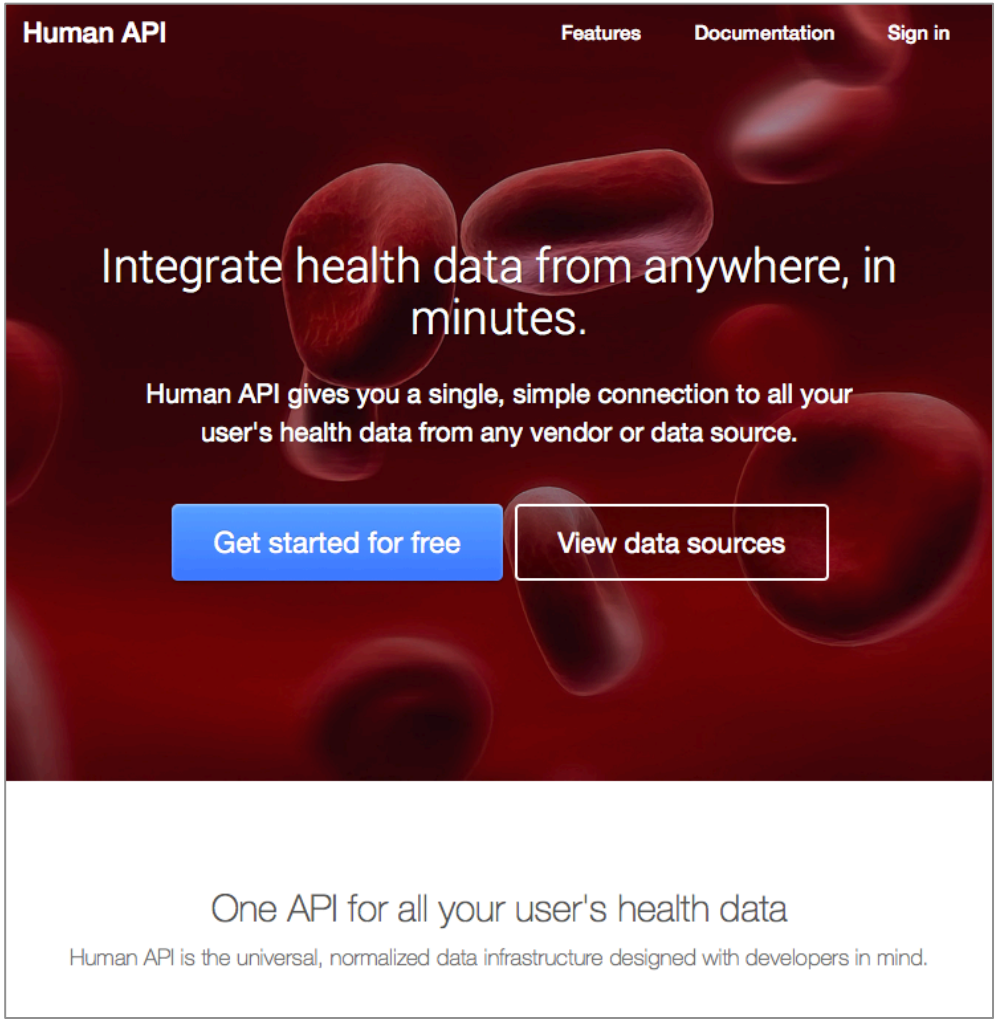
App, partner	Data generated	Technical details
Entra Health Systems	1. Glucose levels (from glucometer) 2. Weight (from A&D weighing scales)	Both the glucometer and A&D scales sync via the Qualcomm 2net Life device and are uploaded to the 2net Life cloud. The data is then sync'ed to the Entra cloud and ultimately retrieved through the ohmage DSU.
Qualcomm Life's 2Net Hub	Data from both Entra devices above 'pass' through the.	Receives uploads from Entra devices.
BodyMedia	Sleep.	Data from a device is pulled from BodyMedia's server and into ohmage using BodyMedia's own APIs.
Runkeeper	Exercise: events, duration, intensity.	Uses Open mHealth DSU API to allow data to be converted and pulled in via ohmage via RunKeeper HealthGraph API.
PAM (Photographic Affect Meter):	Mood	PAM app uploads to ohamge.
ohmage	1. Movement (via ohmage 'mobility' app). 2. Food (via 'notes' feature)	storage* processing and integration application used to proxy all the data pulled in from the above applications. Ohmage mobility background app goes directly to ohmage server.

Diabetes Mgmt Use Case - Impact

- Self-learning
- Increased accountability
- Improved sensitivity to hypoglycemic symptoms
- Increased sense of safety
- More informed decision making

Other examples

- HumanAPI
  - Also OAuth 2.0
  - Apparently similar objectives to Open mHealth
- Ginger.io
  - Platform for predictive modeling

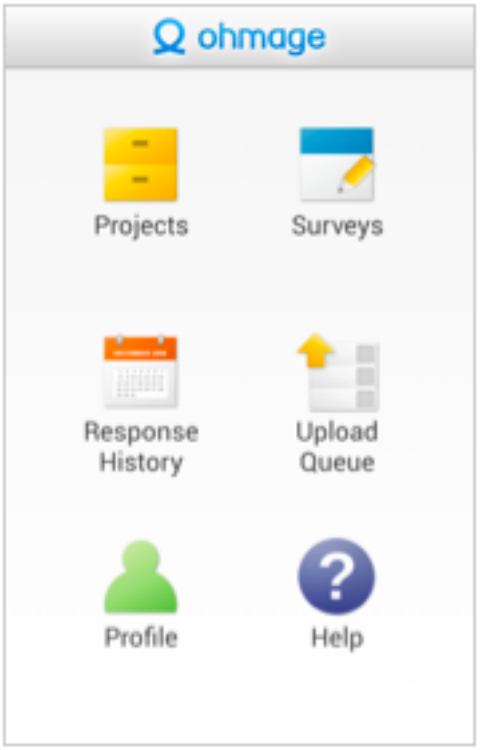


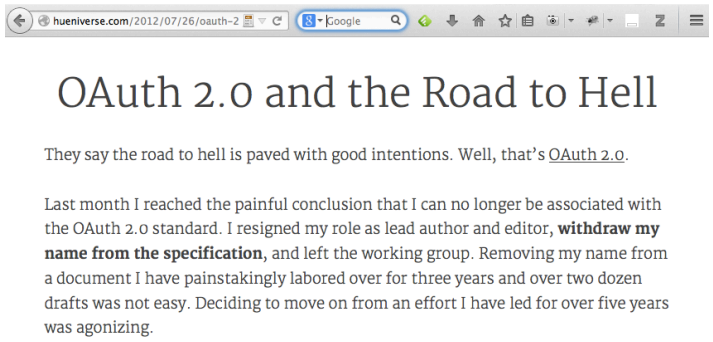
Related Prior Work

- **Personal Data Vault** – NDN Annual Report 2011-2012.
- **Self-surveillance privacy**. J. Kang, K. Shilton, D. Estrin, J. Burke and M. Hansen. *Iowa Law Rev.* 97 (2011): 809.
- **Open mHealth architecture: an engine for health care innovation.** Estrin, D., and Sim. I. *Science(Washington)* 330.6005 (2010): 759-760.
- **PEIR, the personal environmental impact report, as a platform for participatory sensing systems research**. Mun, M., Reddy, S., Shilton, K., Yau, N., Burke, J., Estrin, D., ... & Boda, P. (2009, June). Proc. ACM Mobisys 2009.

Ohmage: Reference Application

- Plan to create/port a mobile client for the Ohmage reference platform, which currently incorporates:
  - Mobile application
  - LAMP stack back-end
  - REST communication
- Key pain point is OAuth 2.0: Implementation relies on this – doesn't scale to the DPU model and has numerous problems. Quickly identified by Open mHealth lead architect as a primary challenge.
- Same approach (apparently) used in Human API mentioned earlier.



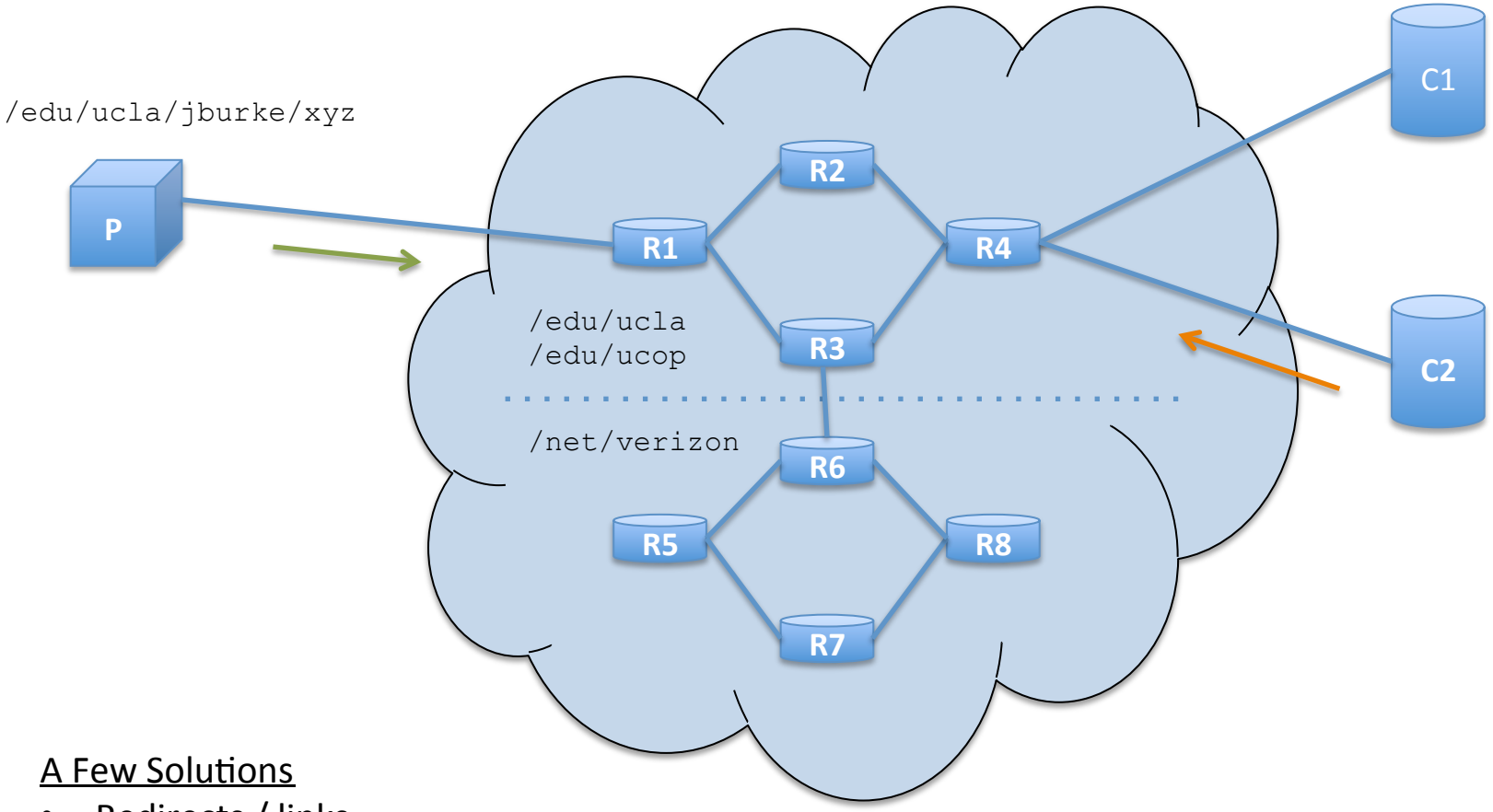

hueniverse.com/2012/07/26/oauth-2

OAuth 2.0 and the Road to Hell

They say the road to hell is paved with good intentions. Well, that's OAuth 2.0.

Last month I reached the painful conclusion that I can no longer be associated with the OAuth 2.0 standard. I resigned my role as lead author and editor, **withdraw my name from the specification**, and left the working group. Removing my name from a document I have painstakingly labored over for three years and over two dozen drafts was not easy. Deciding to move on from an effort I have led for over five years was agonizing.

Mobile publishing



A Few Solutions

- Redirects / links
- Home repo(s) republish
- Registration in multiple locations

NDN – Suitability / Benefits

- **Open mHealth already focuses on named data as the "thin waist" of interoperability.**
- **Data-centric security** a good match, and could be a major improvement over a current pain point – OAuth, in terms of ease of development and overall security.
- **Distributed storage** is straightforward to implement. Could drive a new **data-diffusion focused model** for this application.
- **Reduction in overhead** for request-response architecture should be useful given that many apps are always running on a variety of types of devices.
- Intrinsic **disruption tolerance and multi-path support** are a good fit for mobile devices if challenges of mobile publishing can be addressed.

Open mHealth: Proposed Milestones

- Review limitations in current IP-based architecture for Open mHealth needs. (Y1)
- Design namespace, repository, trust and communication model for use cases, e.g., diabetes or PTSD treatment (Y1; updated in Y2)
- Repository implementation providing backing storage for prototype applications. (Y1)
- Integrate named data networking into the Ohmage mobile data collection framework. (Y2)
- Pilot user-facing application using NDN, for beta testing by Open mHealth project team. (Y2)