NDN Network Environment: Open mHealth

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Abstract

The abstract.

I. Introduction

As part of the NSF-supported NDN "Next Phase" research from 2014-2016, the NDN project team has selected two network environments, **Open mHealth** and **Enterprise Building Automation & Management**, and one application cluster, **Mobile Multimedia**, to drive our research, verify the architecture design, and ground evaluation of the next phase of our project. The two environments represent critical areas in the design space for next-generation Health IT and Cyberphysical Systems, respectively. They also extend work started in the previous NDN FIA project on participatory sensing and instrumented environments to focus on specific application ecosystems where we believe NDN can address fundamental challenges that are unmet by IP. Based on the successful initial results of previous NDN research, we have identified Mobile Multimedia as an application area of cross-cutting relevance, motivated not only by the network environments above but our team's desire to further develop NDN by using it for our everyday communication.

This technical report provides background information on the **Open mHealth** network environment including key application challenges faced using IP and describes the design for a pilot application that the NDN team is building. It serves as the primary design document for this application.

A. *Open mHealth Background*

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 [3]. The Internet's role as a critical enabler of mHealth will grow further over the next decade.

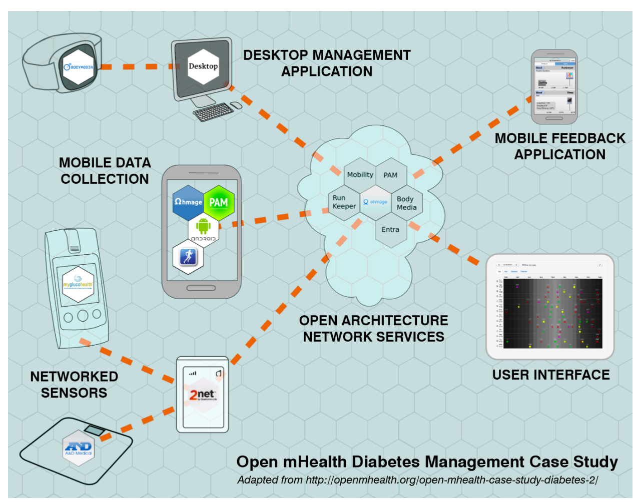

Fig. 1. Networked data producers and consumers in a diabetes management case study from the Open mHealth team, who promote interoperability between mobile health components via community-standardized data exchange. [5]

Mobile health continues our work in the first NSF-supported NDN project on participatory sensing. To explore mHealth as a network environment for NDN, our team will collaborate with the Open mHealth project [1] led by Deborah Estrin (Cornell) and Ida Sim (UC San Francisco). Within the many applications of mobile technology to health, Open mHealth focuses on leveraging the public's everyday mobile devices (cell phones, tablets, etc.) to extend evidence-based interventions beyond the reach of traditional care and thereby improve disease management and prevention. For example, mobile applications exist or have been proposed to manage: pre- and post-natal care of mothers [6]; diabetes [11], [12]; everyday activity in stroke patients and others with chronic disease [2]; and community exposure to environmental pollutants [8].

The Open mHealth team envisions that the Internet will interconnect 1) data capture, 2) secure storage, 3) modeling and analytics, and 4) user interface components to create a modular, layered sense-making framework. Such applications will use low-level state classifications of raw data (e.g., estimated activity states such as sitting, walking, driving from continuous accelerometer and location traces) to derive mid-level semantic features (e.g., total number of ambulatory minutes, number of hours spent out of house), that can be mapped to behavioral biomarkers for specific diseases (e.g., chronic pain, diabetes, multiple sclerosis, fatigue, depression, etc) [4].

For example, Figure 2 shows a network of open components for self-care of diabetes, which affects 25.8M people in the U.S., less than half of whom meet recommended standards, such as blood glucose index levels, for managing their own health. Type 1 diabetics continuously self-monitor blood glucose and insulin levels, and other important factors such as diet and exercise. Many developers are exploring mobile health technologies to assist self-monitoring and diabetes management, since almost all patients have access to mobile health capable technology [11]. But such applications often have proprietary or siloed designs that inhibit data exchange, e.g., data streams from apps for blood glucose and physical activity do not easily integrate, a missed opportunity to provide more comprehensive analysis and coaching to the patient and more complete longitudinal data to providers.

The Open mHealth team instead advocates an interoperable, Internet-inspired approach. They propose a 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. In the same way that the Internet's IP layer enabled innovation and interoperability among distributed devices, they believe a common and open approach to mHealth data exchange will encourage the emergence of a market-supported, patient-centered landscape of innovative health applications. Central to this vision is patient-controlled, privacy-aware data exchange across device, component, and application boundaries. The focus on *data exchange as the backbone of the application ecosystem* makes open mHealth an excellent network environment to both drive and evaluate NDN.

B. Collaboration

We will partner with the Open mHealth team – both its leadership and developers – to understand the requirements and current state-of-the-art in this network environment, as well as limitations they face from the current Internet architecture. We will pick one or more applications (e.g., diabetes management or post-heart attack health management) that are representative of the envisioned ecosystem, and port existing software of the Open mHealth team to the NDN architecture. We will use an interactive development process, soliciting regular feedback from the Open mHealth team.

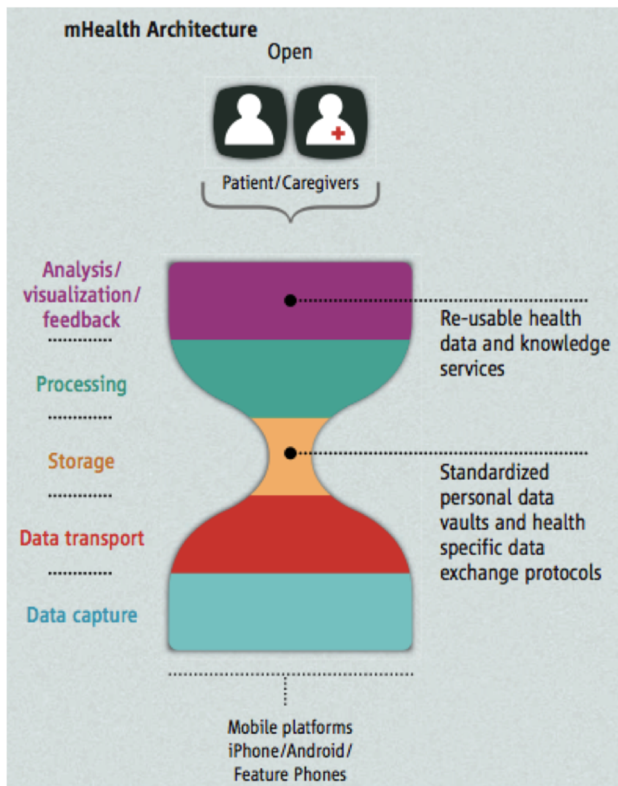

Fig. 2. The Open mHealth architecture uses a data-centric hourglass model, where the interoperability layer ("thin waist") is based on standardized data exchange. [5]

C. Proposed Milestones 2014-2016

- 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)

II. Related Work

A. Previous work by the NDN team

Within the participatory sensing application area of the previous NDN FIA project, we extended the concept of a host-centric "personal data vault" developed at UCLA and USC [7] to create a geographically distributed *personal data cloud (PDC)* using NDN. This prototype went through three iterations reflecting increasing understanding of how to develop applications using NDN. The first version implemented data collections, key management, storage, data transfer and authentication/setup phases in a way largely analogous to TCP/IP based applications. A second revision integrated the PDC architecture into a deployed participatory sensing application at the Center for Embedded Networked Sensing, called Ohmage [9]. The most recent revision transitioned to use the new Sync primitive for transferring content between entities, and removes much of the session-like semantics initially present[1]. This experience will inform work with the Open mHealth team as they continue to develop pilot applications using Ohmage and similar platforms. With the emergence of the Sync primitive and our recently developed ChronoSync synchronization library [13], as well as lighter-weight mobile client options based on NDN.JS [10], we plan to explore end-to-end applications data dissemination via NDN.

B. *Suggested reading*

Estrin, Deborah, and Ida Sim. ”Open mHealth architecture: an engine for health care innovation.” Science 330.6005 (2010): 759-760.

Diabetes Case Study document from openmhealth.org

Hicks, John, et al. ohmage: An open mobile system for activity and experience sampling. CENS Technical Reports 100: 125, 2010.

Kang, J., Shilton, K., Estrin, D., Burke, J., Hansen, M. ”Self-surveillance privacy.” Iowa L. Rev. 97 (2011): 809.

III. Pilot Application

To do (??)

A. *Research Requirements*

Naming and application design. The Open mHealth architecture focuses on data exchange rather than system interoperability, which is well-suited for NDN. Using NDN rather than IP enables Open mHealth applications to be coded using data naming directly rather than having to create abstractions to translate data names to IP-based hosts providing services. We will explore how application architecture can be simplified and map closely to network architecture. With its emerging synchronization primitives, NDN will also enhance network support for synchronizing data across multiple devices.

Trust and security. Because NDN does not rely on perimeter- or channel-based security, it will promote global health data ecosystems rather than previous walled garden approaches. This shift has direct relevance for public health, by enabling research to draw from large populations.

Storage in the network. NDN naturally supports distributed storage, which can ease the burden of fault-tolerance and load-balancing in large networks, reducing cost-of-entry and fostering innovation.

[1] https://github.com/remap/PDC-SYNC

B. Application Objectives

The Open mHealth team envisions that the Internet will interconnect 1) data capture, 2) secure storage, 3) modeling and analytics, and 4) user interface components to create a modular, layered sense-making framework.

Naming and application design

- What schema? Initially, try direct mapping of Open mHealth schema
- Borrow ideas from Named Function Networking concept for distributed processing
- Translate existing REST-based approach or do pure NDN?

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
- Data filtering at the repo?
- New legal / economic relationship between the players

IV. Testbed

V. Design

Review and evaluation of Ohmage reference application and open mHealth schema. Review case studies. Design and prototype alternative trust / security approach to current OAuth2-based mechanism. Design new repository. Provide NDN-CCL and NFD support for Android. Trying replacing REST backend in Ohmage with NDN.

A. Naming

B. Storage

C. Trust

VI. Open Challenges

VII. Conclusion

Acknowledgment

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