Standard-based and Distributed Health Information Sharing for mHealth IoT Systems

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Outline

- Context and objective

- Proposed Architecture and how we achieved it

- Results and evaluation

- Conclusion and next steps
Some Context...

- Increasing costs of healthcare worldwide

- New technology available
  - Better and smaller sensors
  - Low Power Communication Technologies

- New Personal Health Devices
  - Bluetooth Low Energy, USB, ZigBee, etc
Health Data Everywhere

- Now Personal Health Devices export their data using wireless technologies

- Enables new Health Services to be available in the Cloud

- These services enables Personal Health Information to be transmitted directly to their doctors anytime anywhere
  - *From device directly to the cloud*

- *True Patient Remote Monitoring using wireless technologies*
Internet of Things?

- Resuming...
  - Connected PHDs enables a new type of information on the Internet: *Health Information*

- Therefore it is necessary to transport and share these data in a standardized way!
  - Avoid fragmentation of services

- The objective of this work is to answer:
  - *How to design and deploy standard-based Connected Health Services in the Internet of Things?*
Connected Health Vision and Architecture

Based on international organizations guidelines, such as Continua Health Alliance

LAN Devices

Application-Hosting Devices

WAN Device

Health Record Device

PAN Devices

LAN Interface

WAN Interface

xHRN Interface

IoT
In a general view, the communication model of PHDs have two layers:

- **Health Communication Model**
  - Used to model health data
  - IEEE 11073 for PHD modeling

- **Transport Control**
  - Communication technologies such as BT, BLE, etc..
  - IoT technologies and protocols such as TCP/IP, CoAP, etc.
IEEE 11073 is a family of standards that define how PHDs should communicate and share information.

Transport Agnostic
- Can be transported over different technologies: Bluetooth, USB, TCP, etc...

Adopted by International Associations
- Ex. Continua Health Alliance (http://www.continuaalliance.org)
IEEE 11073, How it works?

- Two type of devices:
  - Agents
    - Personal Health Devices
    - Data sources
  - Managers
    - Data collectors/sinks
    - Aggregators

- IEEE 11073 defines the communication flow
  - Messages for Association, Connection, etc…
Designing an IoT-ready Connected Health Service

- **Start point:** *Personal Health Devices*

- Based on a simple *Internet of Things* point of view, we classified PHDs in two types:

  - **Gateway-Based devices,** which are PHDs that collect health information and send it to a gateway device.
    - This gateway processes and transforms the data in order to be transported in the Internet.

  - **Internet-Ready devices,** which are PHDs that generate data already prepared for the Internet.
    - This means that the information is already formatted in an IP friendly way, and this information will not be changed in order to be transported in the Internet.
Health Gateway-Based devices

- A gateway encapsulates the health data before sending it to the cloud.
- Most of current devices and solutions are Gateway-Based devices
  - Gateway in tablets, UPnP, etc...

![Diagram of Health Gateway system]

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**Health Data**

**IP Packet**

**Data Health Gateway**

**Internet**
Some Examples

- **Smartphones as Gateways**
  - Body-sensors constantly send data to the nearby gateway: Smartphone

- **UPnP**
  - UPnP Networks already available at your home. UPnP gateways can share health information with Consumer Electronics devices.
Internet-Ready devices

- The PHD exports data already ready for the Internet
Advantages

- No need for specific (and often vendor specific) health gateways
  - You just need standard/generic Internet Gateways

- Reducing the probability of error when manipulating the packets.
  - Even if packets pass through an Internet gateway, it is not necessary to change it.
Gateways and Managers

- Based on IEEE 11073 model and our PHD classification we identify these devices in our path:
  - Internet Gateways
  - Health Managers
  - Health Services

- Our Challenge: *Integrate legacy services with new IoT technologies*
  - Legacy services are based on local *Personal Health Managers*
  - With the new IoT vision defines a new type of manager: *Internet Health Manager*
Proposed Architecture

- In a simple view:
  - Distributed Managers and based on standards
Implementation

Tools:
- **Antidote** IEEE 11073 library
  - ANSI C = Portability (Linux, Android, Windows, etc…)
  - Based on plugins
  - It was developed and used a **plugin** for CoAP
- **LibCoAP** for Agent
- **CoAP.NET** for Internet Health Manager
  - In the Cloud

Development:
- Agent implemented on Linux platform
- A manager implemented in a Web Server in the Cloud (AWS)
- The agent was configured with the Web Server address
- The Web Server was integrated with a Health Service available in the Market
Integration with Health Services

- We used SigHealth platform as our base service
  - Platform already available in the market
We implemented and integrated a new path for IHMs.
Integration Details

IEEE Agent Sends APDU

11073Client

CoAP Client

IEEE Manager handles APDU

11073Server

coap://::1/x73 CoAP Server

IEEE 11073 APDU Exchange

Temporally save Measurements

IEEE 11073 APDU Exchange

Encapsulate data into PHI and Send

Close Session

Store PHI

Health Service

Health Service stores PHI

Web services

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Integration Evaluation

- Health information was sent using both types of managers for the same user
  - For Personal Health Managers we used SigHealth Android App
  - For Internet Health Managers we used a IEEE11073/CoAP agent in a Linux Platform

- The proposed architecture merged information for both types into SigHealth’s PHR
Comparing with TCP/IP

- IEEE 11073 APDUs were exchanged using CoAP PUT messages
  - For the same IEEE 11073 transaction with 9 packets and 425 bytes:
    - 12 CoAP packets and 1295 bytes were exchanged
    - Almost 37% less packets than TCP
    - When using simple IEEE 11073 transactions, we can obtain a gain of more than 50% less traffic!
Networking Evaluation - Retransmissions

- Using the same developed IEEE11073/CoAP agent, messages were exchanged using different channels
  - Wi-Fi with an ADSL link (30Mbps)
  - 3G HSDPA network
  - 2.5G EDGE network
- In all cases, the IEEE11073/CoAP Server (IHM) was running in the Cloud (AWS)

<table>
<thead>
<tr>
<th>PHY</th>
<th>Packet Retransmissions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wi-Fi and ADSL (30Mbps)</td>
<td>0%</td>
</tr>
<tr>
<td>3G HSDPA</td>
<td>3.2%</td>
</tr>
<tr>
<td>2.5G EDGE</td>
<td>40.91%</td>
</tr>
</tbody>
</table>
Networking Evaluation - Duration

- **Wi-Fi + ADSL** - mean duration: 0.762s
- **3G HSDPA** - mean duration: 1.444s
- **2.5G EDGE** - mean duration: 5.358s

Delay < 3s
Can be used for monitoring systems
IEEE 11073 QoS requirements
Conclusions and Next Steps

- We presented a new definition and approach to propose a connected health architecture and integrate it with legacy services.

- The integration of IEEE11073/CoAP in the cloud showed to be feasible.

- Optimization of CoAP IEEE 11073 implementation still needed:
  - Make use of CoAP piggyback feature.

- It is necessary to evaluate Security and Privacy aspects of CoAP:
  - Health Information must be kept secure and private.
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  - [http://www.embeddedlab.org](http://www.embeddedlab.org)

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