Service Intelligence Support for Medical Sensor Networks in Personalized Mobile Health Systems

Dmitry Korzun[1], Ilya Nikolaevskiy[2], Andrei Gurtov[3,4]

[1] Petrozavodsk State University, Russia

[2] Aalto University, Finland

[3] Helsinki Institute for Information Technology, Finland

[4] ITMO University, Saint Petersburg, Russia

This work is supported by the Ministry of Education and Science of the Russian Federation within project # 14.574.21.0060 (RFMEFI57414X0060) of Federal Target Program “Research and development on priority directions of scientific-technological complex of Russia for 2014–2020”.

ruSMART 2015
The 8th conference on Internet of Things and Smart Spaces
August 26, 2015, St.-Petersburg, Russia

Preliminaries

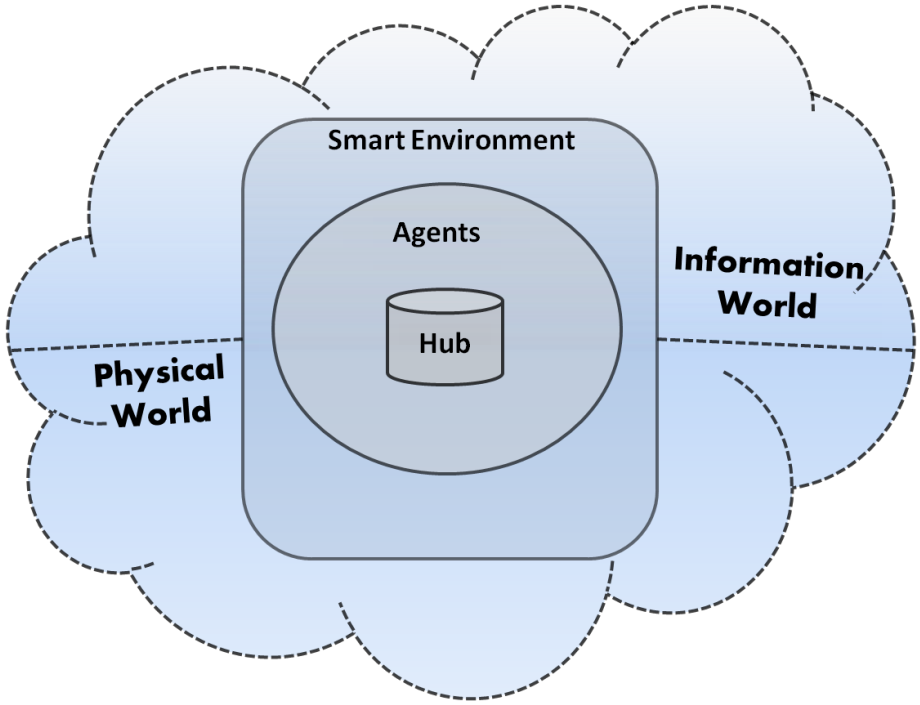
- Traditional healthcare systems: existing
  - Backend services for use primarily by medical personnel at hospitals;
  - Customized implementations.
- Mobile Health (m-Health) scenarios: emerging
  - Patients are mobile, not persistently located at hospitals;
  - Use of the backend services enhanced with the “live” personal mobile data and patient’s context.
- Medical Sensor Network (MSN)
  - Devices that a patient is equipped with (e.g., wearable, implantable);
  - Producer of personal mobile data and context about the patient.
- Service Intelligence for MSN
  - Inclusion of personal MSN data to the entire healthcare system;
  - Construction of personalized services based on 1) MSN data and 2) backend healthcare services.

Concept Development Problem

- Architectural system model:
  - Personalized m-Health systems can be dynamically attached to the whole healthcare system (backend services);
  - At the patient's side: an IoT environment with medical and non-medical devices;
  - Personal mobile gateways (e.g., smartphone) are primary control and integration points for a personalized m-Health system.
- Support for the service intelligence
  - Enhancing the backend services of healthcare system: enabling services to be closer to the user (patient and medical personnel);
  - Services are not based purely on electronic health records;
  - Utilization of various personal mobile data (medical and non-medical, dynamical and contextual).

Our approach

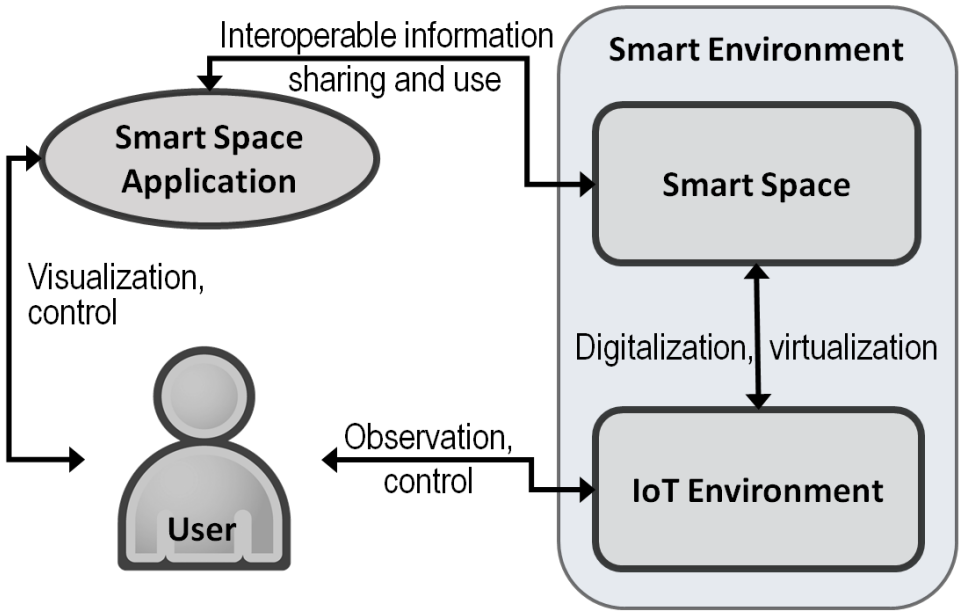
- The smart spaces paradigm
  - with technologies adopted from IoT and Semantic Web.
- Dynamic relation of multi-source data (medical and non-medical) forming a smart space
  - Information hub that semantically relates personal information with backend services;
  - Support for semantics-based analysis of collected data and derived knowledge in this space.



- The Smart-M3 platform is used as an open source solution oriented to a wide range of IoT-aware multi-domain applications.

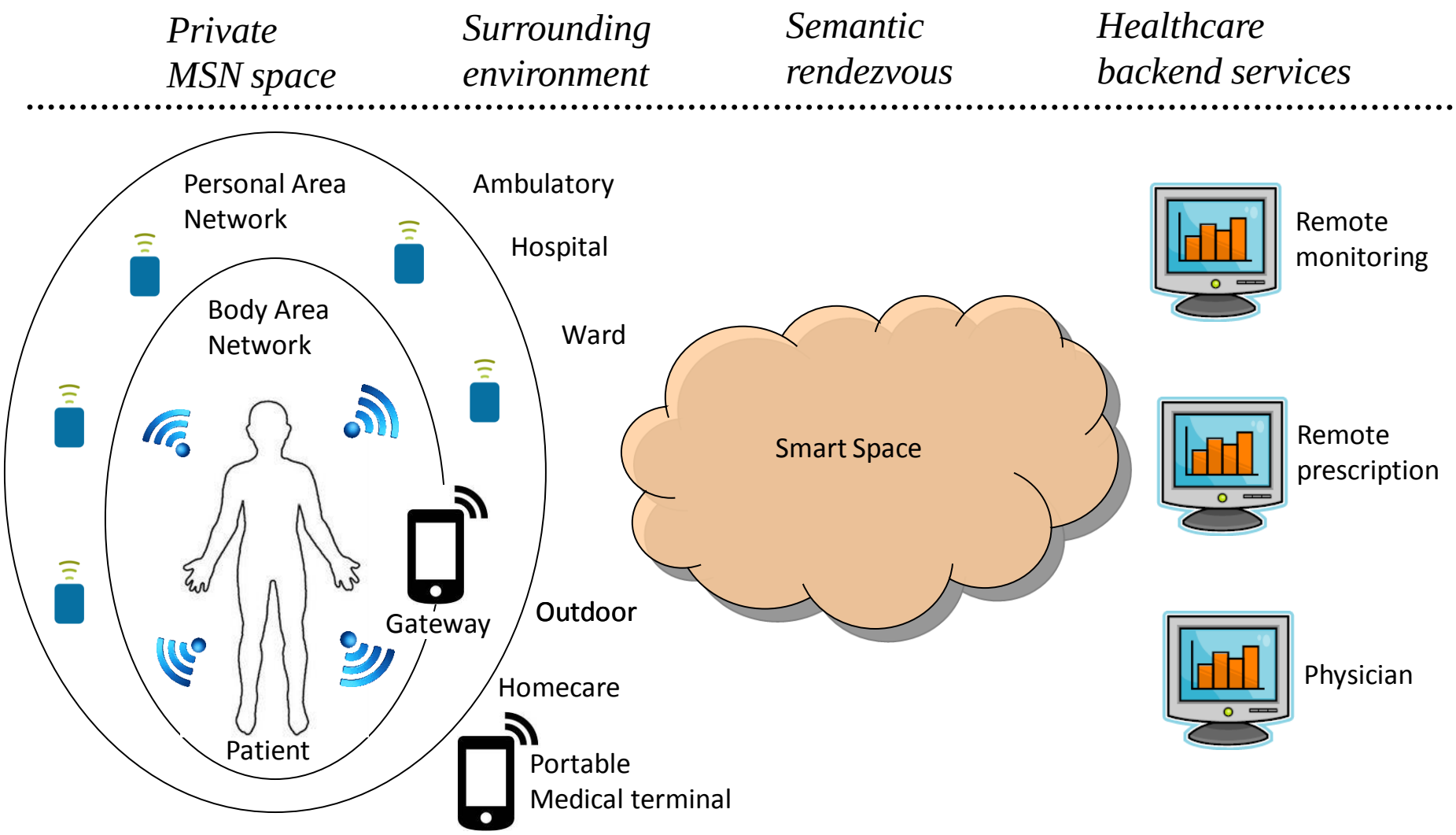
Smart Spaces

- A ubiquitous computing environment is created where mobile users, multisource data, and various services constructed over these data are connected based on ontology-driven information sharing and self-generation.



- Services can be personalized by means of augmentation of personal data to the shared content and customization of required reasoning about the content.
- In m-Health scenario: smart space “accompanies” its patient, MSN feeds the smart space with personal data.

Architectural Model



Layers

- Private MSN space: user plane
  - Personal data producer (medical and non-medical devices);
  - Personal gateway and portable medical terminal (PDM).
- Surrounding environment
  - Network infrastructure: communication;
  - Potential use of non-personal IoT devices: context data.
- Semantic rendezvous
  - Knowledge corpus for integration of patient and hospital;
  - Private MSNs and healthcare services can cooperate based on information collecting and sharing.
- Healthcare backend services: medical plane
  - Specialized data storages on the side of medical facilities;
  - Assessment of clinical data, diagnosis, treatment planning and execution, and feedback to the patient

Mobility

- Patients are remote from the hospital and doctors
  - Gateway aggregates and processes personal data (local treatment);
  - Gateway shares information in the smart space;
  - Gateway receives information from smart space and delivers services to the patient.
- Medical personnel is remote from the patient
  - Doctors are a part of backend services.
- Medical personnel is remote from the hospital
  - Portable Medical Terminal (PMT) is similar to gateway and used by medical personnel to directly access the patient's MSN.

MSN Data

- Simple homogenous structure.
- Time series v_{i1}, v_{i2}, … for sensor $i=1,2,\ldots,n$.
- Local treatment: short time window.
- The whole time series are stored in specialized medical databases (backend services).
- Smart space does not keep much sensor data:
  - Virtual representation of a sensor (its state);
  - Derived knowledge from monitored data;
  - Links to the medical databases.
- Further objects for representation in smart space
  - Patients, services, …
  - Semantic links between represented objects;
  - Many ontologies are already developed for representing patients and medical data.

Multi-agent Design

- Agent = Knowledge Processor (KP in Smart-M3).
- Services are constructed as iterations of agents.

1. **MSN data collector KP**: iteratively feeds the system with health data. The status of this regular process is published in the smart space.

2. Personal data are collected in healthcare system databases. **Service KPs:** recognize their semantics (relations) and publish the knowledge in the smart space.

3. **Service KP:** recognizes a situation in the smart spaces when the service is needed. The notification is represented in the smart space, and all relevant services and mediator KPs start to cooperate in the service construction.

4. **Mediator KP:** initiates task-specific processing in the database using known methods (e.g., time series analysis, pattern recognition). The derived knowledge is published in the smart space (relating with already available content).

5. **UI agent KP:** responds to the service outcome and visualizes it appropriately on the patient side.

Properties for Service Intelligence

- Adaptation
  - The smart space is regularly fed up with recent knowledge on the involved participants and environment.
- Context-Awareness
  - Data coming from patients and medical personnel include contextual data such as geolocation and status.
- Personalization
  - Every patient and medical personnel has personal representation in the smart space (both factual data and semantic relations).
- Proactive Delivery
  - Mediator KPs explicitly represent in the smart space such situations when a service is needed to a client.
  - This representation is detected by service KPs to start appropriate services.

Conclusion

- Reference architectural model for inclusion of personalized MSN-based m-Health systems to an entire healthcare system.
- Conceptual means of making MSN-measured patient's data be shared in the smart space.
- Properties of the service intelligence support (due to smart spaces).
- Other our results in this area:

1.I.Nikolaevskiy, D.Korzun, A.Gurtov. Security for medical sensor networks in mobile health systems. Proc. IEEE Int'l. Symp. on a World of Wireless, Mobile and Multimedia Networks (WoWMoM). June 2014.

2.A.Borodin, Y.Zavyalova, A.Zaharov, I.Yamushev. Architectural approach to the multisource health monitoring application design. Proc. 17th Conf. of Open Innovations Association FRUCT, April 2015.

3.A.Borodin, Y.Zavyalova. EAV Based Approach to Designing Medical data Model for CardiaCare Service. Proc. 9th Int'l Conf. on Mobile Ubiquitous Computing, Systems, Services and Technologies (UBICOMM), July 2015.

Thank you

Dmitry Korzun, dkorzun@cs.karelia.ru