DATA MANAGEMENT IN AMBIENT ASSISTED LIVING PLATFORMS APPROACHING IOT: A CASE STUDY

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INTRODUCTION
Heterogeneity (coarse classification):
  - behavioral (or habits-related) [1, 2]
  - physiological [3, 4]
  - environmental (or ambient-related) [5, 6]
  - healthcare [7, 8]

• Volume
• Velocity
• Variety, volume, and velocity: commonly mentioned features in the field of Big Data [9]

• Big Data commonly referred to in conjunction with Internet of Things (IoT) paradigm

• Remarkable affinity between AAL and IoT, but

• AAL exhibits specific requirements and constraints, about:
  • data processing (local / remote)
  • data delivery format (raw data / aggregated information)
  • data sharing / access options
AIMS OF THE WORK

• To investigate the emerging approaches to data handling and management in IoT-oriented AAL platforms, by resorting to the state of the art literature

• To discuss the findings with respect to a practical AAL implementation, assumed as a case study

• To highlight the peculiarities expressed by AAL in data handling, thus contributing to the discussion around IoT reference models and architectures
SOA: DATA HANDLING AND MANAGEMENT IN AAL
Aims of IoT in AAL: to facilitate data collection (e.g. RFID, NFC), to make communication establishment easier and more effective [10]

- IoT frameworks for AAL shall support bidirectional flows of information (Closed Loop Principle)

Communication protocols: trade-off among lifetime, security level, and pre-processing of sensors-generated data

- Data analysis capabilities needed to enable anomaly detection at the sensor level [11]
- Anytime + anywhere access to sensor data: constant network connectivity required
- Need to reduce the amount of data to be transmitted: event-based data transmission [12], processing tasks to aggregate data for a compact representation of relevant information [13], learning from user’s decisions [14]
• Cloud-based big data management frameworks:
  • data mining + machine learning algorithms: from sensors data to knowledge
  • real-time processing of large data volumes: clustering, classification, feature selection [15]
  • heterogeneous data collected by AAL platforms cannot be efficiently supported by flat and data-agnostic management frameworks, but demand for differentiated processing, to ensure service-specific requirements

• Local data processing:
  • collected data analysis and validation [16]
  • interoperability of AAL system with other platforms
  • algorithms and protocols for data privacy, integrity, access control
  • security mechanisms to protect locally stored data [17]
DATA MANAGEMENT IN AAL: A CASE STUDY
• Several sub-systems / functional domains managed by a local server [18]:
  • home automation
  • sensors for behavior detection
  • health monitoring
  • human-system interfaces
• Heterogeneous devices (environmental sensors, home appliances, virtual sensors, smart objects)
• Heterogeneous transmission technologies and gateways: CAN-bus, ETH, WiFi, Bluetooth, NFC, SubGHz technologies
• Different interfaces tailored to users’ needs: Smart TV, touchscreen devices, NFC-enabled devices (tap-based interaction), depth sensors
• Local server:
  • relational DB management, aggregation tasks (REST services)
  • report tasks (JSON objects), connection to a remote cloud-based platform
LIVING LAB DEPLOYMENT
• The local server hosts a unified DB including:
  • tables populated by each sensor / device
  • aggregated tables generated by *aggregation tasks*
• Sensor-populated tables:
  • **power consumption** table ↔ power metering sub-system
  • **sensors** table ↔ environmental and AAL sub-systems
  • **user state** table ↔ smart object (smart shoes)
  • **reminders** table ↔ health operator / caregiver
  • **body sensor network concentrator (BSNC)** table ↔ smart object (wearable device)
• Aggregated tables generated by REST services:
  • **report_consumption**: hourly power consumption in a day
  • **report_activities**: % amount of daily activity by monitored subject
  • **report_cooking**: daily report on time spent cooking
  • **report_presence**: daily report on time spent at home / out of home
• Aggregated tables transferred daily to the remote platform as JSON objects
Table 1: Records in the local DB tables hosting sensor-generated data

<table>
<thead>
<tr>
<th>power consumption</th>
<th>user state</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field</td>
<td>Data Type</td>
</tr>
<tr>
<td>id</td>
<td>int(11)</td>
</tr>
<tr>
<td>id_meter</td>
<td>int(5)</td>
</tr>
<tr>
<td>bnode</td>
<td>varchar(20)</td>
</tr>
<tr>
<td>name</td>
<td>varchar(50)</td>
</tr>
<tr>
<td>type</td>
<td>varchar(50)</td>
</tr>
<tr>
<td>level</td>
<td>int(2)</td>
</tr>
<tr>
<td>date</td>
<td>Date</td>
</tr>
<tr>
<td>time</td>
<td>Time</td>
</tr>
<tr>
<td>timestamp</td>
<td>int(13)</td>
</tr>
<tr>
<td>power</td>
<td>int(11)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>reminders</th>
<th>BSNC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field</td>
<td>Data Type</td>
</tr>
<tr>
<td>drug</td>
<td>varchar(30)</td>
</tr>
<tr>
<td>quantity</td>
<td>Text</td>
</tr>
<tr>
<td>time</td>
<td>Time</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 2: Records in the local DB tables hosting aggregated data

<table>
<thead>
<tr>
<th>report_consumption</th>
<th>report_activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field</td>
<td>Data Type</td>
</tr>
<tr>
<td>id</td>
<td>int(11)</td>
</tr>
<tr>
<td>name</td>
<td>Text</td>
</tr>
<tr>
<td>level</td>
<td>int(1)</td>
</tr>
<tr>
<td>date</td>
<td>Date</td>
</tr>
<tr>
<td>hourly_consumptions</td>
<td>Text</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>report_cooking</th>
<th>report_presence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field</td>
<td>Data Type</td>
</tr>
<tr>
<td>id</td>
<td>int(11)</td>
</tr>
<tr>
<td>name</td>
<td>Text</td>
</tr>
<tr>
<td>date</td>
<td>Date</td>
</tr>
<tr>
<td>events</td>
<td>Text</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
DATA MANAGEMENT POLICIES

• Bidirectional communications between local server and sub-systems within the AAL platform
  • Data exchanges originated upon user’s requests:
    • Software applications running on physical devices / interfaces issue requests to the local server by HTTP protocol
    • Local server replies in the form of JSON objects
  • Data exchanges originated automatically (e.g. based on time triggers):
    • Applications poll REST service on the local server
    • REST service checks current time against pre-defined time triggers
    • Match found: requested data transferred as JSON object to applications

• Unidirectional data flow from local server to remote cloud-based platform (JSON objects generated by REST services)
• 3 types of requests may be issued to the server:
  • `configure`: get information on sub-system configuration
  • `state`: get information on current state of specific sensors within sub-system
  • `command`: issue commands to loads controlled by the sub-system (single or multiple loads)

• HTTP request format: `http://[IP address: port number]/` *
• wildcard * may take different values: `/domotic/configure/bnode`, `/domotic/state/meter/current`, or `/domotic/command?type=[...]
• Other parameters depend on specific command to issue
RESULTS AND DISCUSSION
Table 3: Daily and average amount of DB rows generated by AAL platform. Dates chosen randomly over four months.

<table>
<thead>
<tr>
<th>Sample Date</th>
<th># DB rows (sensors data)</th>
<th># DB rows (power meters data)</th>
<th>Total daily # DB rows</th>
</tr>
</thead>
<tbody>
<tr>
<td>18/02/2015</td>
<td>5455</td>
<td>75</td>
<td>5530</td>
</tr>
<tr>
<td>26/03/2015</td>
<td>3061</td>
<td>555</td>
<td>3616</td>
</tr>
<tr>
<td>31/03/2015</td>
<td>3669</td>
<td>281</td>
<td>3950</td>
</tr>
<tr>
<td>08/04/2015</td>
<td>4122</td>
<td>44</td>
<td>4166</td>
</tr>
<tr>
<td>14/04/2015</td>
<td>6166</td>
<td>375</td>
<td>6541</td>
</tr>
<tr>
<td>21/04/2015</td>
<td>5546</td>
<td>6</td>
<td>5552</td>
</tr>
<tr>
<td>07/05/2015</td>
<td>3996</td>
<td>465</td>
<td>4461</td>
</tr>
<tr>
<td>12/05/2015</td>
<td>3743</td>
<td>39</td>
<td>3782</td>
</tr>
<tr>
<td>22/05/2015</td>
<td>2607</td>
<td>40</td>
<td>2647</td>
</tr>
<tr>
<td>03/06/2015</td>
<td>6911</td>
<td>487</td>
<td>7398</td>
</tr>
<tr>
<td>16/06/2015</td>
<td>3349</td>
<td>35</td>
<td>3384</td>
</tr>
<tr>
<td>22/06/2015</td>
<td>3618</td>
<td>26</td>
<td>3644</td>
</tr>
<tr>
<td>Average</td>
<td>4353</td>
<td>202</td>
<td>4555</td>
</tr>
</tbody>
</table>
AGGREGATED DATA

- Each night server applications execute aggregation tasks
- Aggregated tables and so-called reports (JSON objects) are generated
- Reports are transferred to remote cloud-based platform:
  - **Activity**: daily time % of sleeping, sitting, cooking, walking, stasis ($\approx 1.3$ KB)
  - **Presence**: % of total daily time spent indoor / outdoor ($< 1$ KB)
  - **Energy**: min, max, avg hourly power consumption for each device (72 values per meter) ($\approx 42$ KB)
- Graphical reports and statistics generated on remote cloud-based platform, accessible by web
• Different data management policies:
  • Massive and unobtrusive data collection for behavior analysis, prediction, anomalies detection (e.g. worsening health conditions)
  • Heterogeneous data fusion and synchronization issues

• Differentiated flows of operations:
  • Almost static data (environmental sensors) ↔ local decisions (e.g. open / close windows, switch on / off lights...), daily basis processing, remote collection for long-term observation
  • Time-sensitive data ↔ prompt local action (e.g. falls, alarming events)

• Interoperability issues:
  • Heterogeneous nature of AAL data
  • Required formatting operations performed before data transferring to common remote platform
  • Ensure integrity and standard rules compliance of single sub-systems data (e.g. certified biomedical devices or telemedicine systems)
CONCLUSION
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- AAL platforms have to cope with quite **different** data **requirements** and policies about transmission, storage capabilities, and data processing to create structured relations (long term behavioral analysis)
- Orchestration and data validation by a local server **better than** agnostic data management framework (vertical applications of IoT)
- Experimental case study presented
- Contribution to the definition of an **AAL data management profile** in IoT
Thanks for your attention!

Questions?

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