Design of Semantic Information Broker for Localized Computing Environments in the Internet of Things

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Introduction: Internet of Things (IoT)

- Multitude of physical and digital objects in our daily life
- Localized IoT environments appear everywhere
- Environment inhabitants perceive “smart services”
Smart Spaces: The M3 Architecture

- Multidevice, Multidomain, Multivendor
- Infrastructure: Semantic Information Broker (SIB) maintains smart space content in RDF triples
- Application: Knowledge Processors (KPs, agents) run on IoT devices
- Interaction: Blackboard and Pub/Sub
- Smart space: KPs share ad-hoc knowledge and reason over it to construct services
Existing SIB Implementations

- Smart-M3 SIB: the first official prototype

- RIBS: targets resource limited devices

- OSGi SIB: higher level of modularity and portability (Java-based)

- RedSIB: evolution of Smart-M3 SIB with Redland triplestore
## SIB Implementations: Properties

<table>
<thead>
<tr>
<th></th>
<th>Smart-M3 SIB</th>
<th>RIBS</th>
<th>OSGi SIB</th>
<th>RedSIB</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Language</strong></td>
<td>C</td>
<td>ANSI C</td>
<td>Java</td>
<td>C</td>
</tr>
<tr>
<td><strong>Triplestore</strong></td>
<td>Piglet</td>
<td>Bitcube</td>
<td>Jena</td>
<td>Redland</td>
</tr>
<tr>
<td><strong>Features</strong></td>
<td>glib library, SSAP, WQL</td>
<td>lightweight, KSP, constant access latency</td>
<td>SPARQL and reasoning support</td>
<td>improved subscription, SPARQL support</td>
</tr>
<tr>
<td><strong>Drawbacks</strong></td>
<td>no SPARQL support, performance problems</td>
<td>cubical memory consumption</td>
<td>resource-demanding, incompatible with other SIBs</td>
<td>performance problems</td>
</tr>
</tbody>
</table>

Research prototypes, unsuitable for localized IoT environments
Crucial SIB Properties

- **Simplicity**: SIB architecture is easy to elaborate, evolve and understand by third-party developers.

- **Extensibility**: SIB architecture provides a modular way of enhancing the functionality.

- **Dependability**: SIB operation is resilient. SIB runs continuously for lengthy time periods. In case of failures, SIB recovers its working state.

- **Portability**: Host devices for SIB are diverse. Traditional Linux and Windows based systems as well as embedded systems (e.g., OpenWrt on routers).
Redesigning: Our Approach

- Based on RedSIB
- Eliminated D-BUS
- Plug-in approach: dynamic libraries
- Modular architecture
- Qt framework
Renewed SIB Architecture

Access points
- Access Point (TCP)
- Access Point (DBUS)
- Access Point (TCP-SSL)
- Other Access Point

Access Point Manager
- Load/Init
- Set links
- Send request
- Send err/notif
- Send response
- Sent command

Scheduler
- Add command
- Send response
- Delegate command
- Return command response

Commands handlers
- Insert/Remove/update/query
- SPARQL
- SPARQL Update
- Other operations
- Persistent commands handler
- Subscription
- SPARQL Subscription
- SPARQL Update
- Other persistent operation

Redland triplystore

<Protocol> parse/create functions
KSP parse/create functions
SSAP parse/create functions
Smart Space Access Protocols

SSAP: join, leave, insert, remove, update, (un)subscribe

KSP differences:

- compact binary format;
- transactions are based on the SPARQL 1.1 (and SPARQL UPDATE) only;
- no join and leave operations;
- possibility to define the maximum size for SIB response;
- additional persistent operations, which continuously change the smart space content.
## Spectrum of Supported Access Operations

<table>
<thead>
<tr>
<th>Type</th>
<th>Operations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Basic operations (SSAP)</strong></td>
<td><strong>Session management</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Content access and management</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Persistent operations</strong></td>
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<tr>
<td><strong>Extended operations</strong></td>
<td><strong>Persistent Insert, Remove, Update</strong></td>
</tr>
<tr>
<td></td>
<td><strong>SIB configuration rules</strong></td>
</tr>
<tr>
<td><strong>SPARQL operations</strong></td>
<td><strong>SPARQL</strong></td>
</tr>
<tr>
<td></td>
<td><strong>SPARQL Update</strong></td>
</tr>
</tbody>
</table>
Subscription Mechanism (as in RedSIB)

1. Scheduler
   - Delegate command (new subscription)
   - Return command response

2. Persistent command handler (subscription)
   - Create and fill Redland subworld, store
   - Make first request
   - Response to first request
   - Use

3. Redland triplestore

4. Delegate command (insert/remove/update)
   - Threads: Subscription-1, Subscription-2, Subscription-3, Subscription-N

5. Command handler (insert/remove/update/query)
   - Perform operation

6. Notify: check subscription, update subworlds
   - Check: Subworld, Subworld, Subworld, Subworld, Subworld

Properties of renewed SIB

- **Simplicity**: functional allocation into modules, D-BUS is eliminated.

- **Extensibility**: modular architecture allows to extend SIB functionality (new protocols, operations, rules).

- **Dependability**: SIB implementation takes into account problems of other SIBs. Code is based on Qt framework which contributes dependability.

- **Portability**: D-BUS removal and cross-platform Qt framework allows to run SIB on Windows and Linux machines as well as various embedded devices.
Conclusion

- Renewed SIB design for the smart space applications development
- Simplicity, extensibility, dependability and portability of SIB
- Compatibility with previous Smart-M3 applications for Smart-M3 SIB and RedSIB
- New opportunities for application development due to advanced smart space access operations

Thank you for attention

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