Extensibility as a Collaboration Enabler: A Case Study for Group-Context-Aware Mobile Applications

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Advanced Mobile Systems (AMS) Initiative
May 9, 2012
1. REPORT DATE
09 MAY 2012

2. REPORT TYPE

3. DATES COVERED
00-00-2012 to 00-00-2012

4. TITLE AND SUBTITLE
Extensibility as a Collaboration Enabler: A Case Study for Group-Context-Aware Mobile Applications

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

6. AUTHOR(S)

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
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8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR’S ACRONYM(S)

11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
SEI Architecture Technology User Network Conference (SATURN 2012), May 7-11, 2012, St Petersburg, FL.

14. ABSTRACT
Context-aware mobile applications can sense and respond to changes in environment or context. An example is a location-based application that uses GPS coordinates to define the information displayed to mobile users based on their current location. Our work focuses on the integration of an individual’s context with that of nearby individuals operating as part of a group or unit, such as in the military or first-responder situations. This integrated context can then be used to enhance the precision of information provided to users and give a more complete picture of the status of a mission. Given the early stages of the research process when there are many unknowns, we defined extensibility as the main architectural driver. This work has provided the ability to leverage the architecture to support collaboration. By identifying extensibility scenarios early in the design process, we were able to construct an architecture that supports multi-organizational collaboration to construct and evaluate different pieces of the architecture: context data models, context sources such as sensors, context reasoning engines and rules, and context visualization activities. This has allowed us to reach out to researchers from multiple universities and industry, resulting in synergistic research and development furthering the goals of all participants.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:
   a. REPORT
      unclassified
   b. ABSTRACT
      unclassified
   c. THIS PAGE
      unclassified

17. LIMITATION OF ABSTRACT
   Same as Report (SAR)

18. NUMBER OF PAGES
   26

19a. NAME OF RESPONSIBLE PERSON
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Background
Architecture Drivers and Scenarios
Architecture Decisions
Extensibility as a Collaboration Enabler — Results
Conclusions
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Context-aware mobile applications are capable of sensing and responding to changes in their environment or context.

Group-context-aware mobile applications integrate the individual’s context with that of nearby individuals operating as part of a group or unit, such as in the military or first responder situations.

Integrated context is used to enhance the precision of information provided to users as well as a more complete picture of the status of a mission.

- Goal is to produce a capability that can sense as much of the emerging context as possible and apply that context to filter data such that only the most relevant information is displayed.
Group-Context-Aware Mobile Applications

Desired characteristics of the solution include:

- Capturing context information on a handheld device in a non-intrusive manner.
- Extending the sources of contextual information beyond location and time.
- Storing context information and disseminating this information to peers.
- Capturing and using context information efficiently without imposing an unreasonable burden on handheld device resources.
- Integrating local and group context information and only displaying information that is of relevance to the individual and mission according to pre-defined rules.
Motivation

One of the more interesting results of this work has been the ability to leverage the architecture to support collaboration.

By identifying extensibility scenarios early on in the design process, we were able to construct an architecture that supports multi-organizational collaboration to construct and evaluate different pieces of the architecture:

- context data models
- context data storage
- context sensors
- context reasoning engines and rules
- context views

This has allowed us to reach out to researchers from multiple universities and industry, resulting in synergistic research and development, furthering the goals of all participants.
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Business and Architectural Drivers

Business Drivers

• Opportunistic integration of new technology
• Ease of integration with components produced by collaborators
• Applicability of architecture to different edge-enabled applications

To meet business drivers we defined **extensibility** as the main architectural driver.
# Extensibility Scenarios

<table>
<thead>
<tr>
<th>#</th>
<th>Name</th>
<th>Attribute Concern</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Add a New Sensor</td>
<td>Separation of Concerns</td>
</tr>
<tr>
<td>2</td>
<td>Add a New Sensor</td>
<td>Modifiability</td>
</tr>
<tr>
<td>3</td>
<td>Add a New Communication Mechanism</td>
<td>Separation of Concerns</td>
</tr>
<tr>
<td>4</td>
<td>Add a New Communication Mechanism</td>
<td>Modifiability</td>
</tr>
<tr>
<td>5</td>
<td>Add a New Context Event / Action</td>
<td>Separation of Concerns</td>
</tr>
<tr>
<td>6</td>
<td>Add a New Context Event / Action</td>
<td>Modifiability</td>
</tr>
<tr>
<td>7</td>
<td>Add a New Context View</td>
<td>Separation of Concerns</td>
</tr>
<tr>
<td>8</td>
<td>Add a New Context View</td>
<td>Modifiability</td>
</tr>
</tbody>
</table>
### Scenario 3: Add a New Communication Mechanism

<table>
<thead>
<tr>
<th>Scenario Refinement</th>
<th>Attribute</th>
<th>Attribute Concern</th>
</tr>
</thead>
<tbody>
<tr>
<td>Add a New Communication Mechanism</td>
<td>Extensibility</td>
<td>Separation of Concerns</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Stimulus</th>
<th>Developer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stimulus Source</td>
<td>Developer identifies a communication mechanism that can be used to share context data with other mobile devices</td>
</tr>
<tr>
<td>Environment</td>
<td>Developer is sufficiently comfortable with application to make changes in a reasonable amount of time</td>
</tr>
<tr>
<td>Artifact</td>
<td>Communications Manager of the context-aware system</td>
</tr>
<tr>
<td>Response</td>
<td>Communications Manager is changed to implement message passing using the new communication mechanism</td>
</tr>
<tr>
<td>Response Measure</td>
<td>Aside from communication-mechanism-specific code, only the Communications Manager is changed to accommodate the new communications mechanism.</td>
</tr>
</tbody>
</table>
## Scenario 5: Add a New Context Event / Action

<table>
<thead>
<tr>
<th>Scenario Refinement</th>
<th>Attribute Concern</th>
<th>Attribute</th>
<th>Stimulus Source</th>
<th>Environment</th>
<th>Artifact</th>
<th>Response</th>
<th>Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stimulus</td>
<td>Extensibility</td>
<td>Developer</td>
<td>Developer identifies a new event that can be detected by examination of context data</td>
<td>Developer is sufficiently comfortable with application to make changes in a reasonable amount of time</td>
<td>Context Engine of the context-aware system</td>
<td>Context Engine is changed to detect the conditions for the event and generate a new action when it is detected</td>
<td>Only the Context Engine is changed to allow for detection of events and generation of actions</td>
</tr>
</tbody>
</table>
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Architectural Decision 1: Communications Interface

Challenge: Integration of very different communication mechanisms

- Different protocols support different use cases
- Target hardware is unknown
- Need to adapt to target network capability

Solution

- Common service interface provides generic communication methods and callbacks that individual protocols can adapt as necessary
- Allows any sequence of communication events to account for differences in protocols
Architectural Decision 2: Sensor Interface

Challenges

• Integration of any current or future available sensor
• Control of sample rate and change threshold

Solution

• Common sensor interface provides generic communication methods that individual sensor implementations can adapt to as appropriate
Problem

Peer review of the architecture raised the issue that a single thread would cause high-frequency sensors to overwhelm the application.

Simple experimentation demonstrated that this was indeed a problem.

Solution

• Sensors implemented as Android Services (processes separate from the application).
• Communication via IPC to insulate application from high poll rate impact.

Tradeoff

• Higher complexity in sensor implementation although interface hides as much as possible.

![Diagram showing sensor services and their onValueChanged() methods with rates.](image-url)
Architectural Decision 3: Context Model “At the Center”

Challenges

• Easy creation of rules based on contextual data captured via sensors or user input
• Standardized rule processing

Solutions

• Generic and extensible context model that can handle a wide range of situations, environments, data
• Standardized rule set read by application from XML file

Tradeoff

• Both sensors and views have to know the context model element that they are affecting — strong coupling
Architectural Decision 4: Standardized Messaging

Challenge

• Easy creation of views that can capture and/or display context data

Solution

• Publish/subscribe interface
  – Standardized set of actions that can be created by the context engine as the result of fired rules
  – Application manager publishes actions created by context engine as standardized events
  – Views subscribe to events

Legend

Logical Component
File
Asynchronous Callback
Data Read/Write
First Responder Application Architecture

![Diagram showing the architecture of a first responder application]

Legend:
- Layer
- Logical Component
- Data Source
- File
- Synchronous Call-Return
- Asynchronous Callback
- Data Read/Write
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Results

The extensible architecture enables productive collaboration

- Sensor and communication service interface enable 3rd parties to contribute new/novel sensor and protocol implementations
- Standardized rule set approach allows enables adaptation to different context data models
- Standardized messaging enables easy integration of new context data views
Results

Collaborators at GMU were able to modify their unique communication protocol to interface with application architecture in just a few weeks.

Collaborators are working on developing a group context data model, unconstrained by implementation details and without affecting our progress in the meantime.

Collaborators within SEI planning to integrate related projects for QoS management, code offloading, and end-user programming with no foreseen complications.
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Extensibility as an architecture driver enables productive collaborative research and development

Scenario-driven architecture design along with peer architecture evaluation is useful even for small projects

- Concrete definition of quality attribute requirements
- Early identification of risks and tradeoffs
Contact Information

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