

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

Marc Novakouski  
Grace A. Lewis  
Enrique Sánchez

Software Engineering Institute  
Research, Technology and Systems Solutions (RTSS) Program  
Advanced Mobile Systems (AMS) Initiative  
May 9, 2012



**Software Engineering Institute**

Carnegie Mellon

© 2012 Carnegie Mellon University

Copyright 2012 Carnegie Mellon University.

This material is based upon work supported by the Department of Defense under Contract No. FA8721-05-C-0003 with Carnegie Mellon University for the operation of the Software Engineering Institute, a federally funded research and development center.

Any opinions, findings and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the United States Department of Defense.

#### NO WARRANTY

THIS CARNEGIE MELLON UNIVERSITY AND SOFTWARE ENGINEERING INSTITUTE MATERIAL IS FURNISHED ON AN "AS-IS" BASIS. CARNEGIE MELLON UNIVERSITY MAKES NO WARRANTIES OF ANY KIND, EITHER EXPRESSED OR IMPLIED, AS TO ANY MATTER INCLUDING, BUT NOT LIMITED TO, WARRANTY OF FITNESS FOR PURPOSE OR MERCHANTABILITY, EXCLUSIVITY, OR RESULTS OBTAINED FROM USE OF THE MATERIAL. CARNEGIE MELLON UNIVERSITY DOES NOT MAKE ANY WARRANTY OF ANY KIND WITH RESPECT TO FREEDOM FROM PATENT, TRADEMARK, OR COPYRIGHT INFRINGEMENT.

This material has been approved for public release and unlimited distribution except as restricted below.

Internal use: \* Permission to reproduce this material and to prepare derivative works from this material for internal use is granted, provided the copyright and "No Warranty" statements are included with all reproductions and derivative works.

External use: \* This material may be reproduced in its entirety, without modification, and freely distributed in written or electronic form without requesting formal permission. Permission is required for any other external and/or commercial use. Requests for permission should be directed to the Software Engineering Institute at [permission@sei.cmu.edu](mailto:permission@sei.cmu.edu).

\*These restrictions do not apply to U.S. government entities.



# Agenda

Background

Architecture Drivers and Scenarios

Architecture Decisions

Extensibility as a Collaboration Enabler — Results

Conclusions



# Agenda

## Background

Architecture Drivers and Scenarios

Architecture Decisions

Extensibility as a Collaboration Enabler — Results

Conclusions



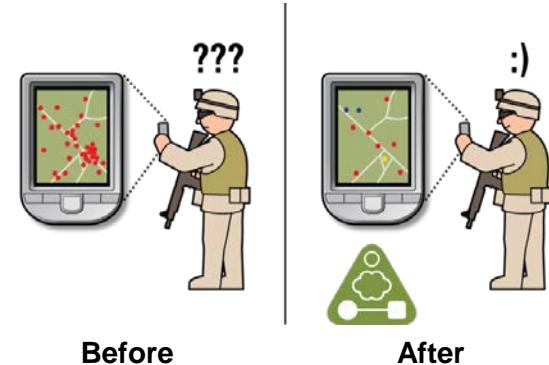
# Group-Context-Aware Mobile Applications 1

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

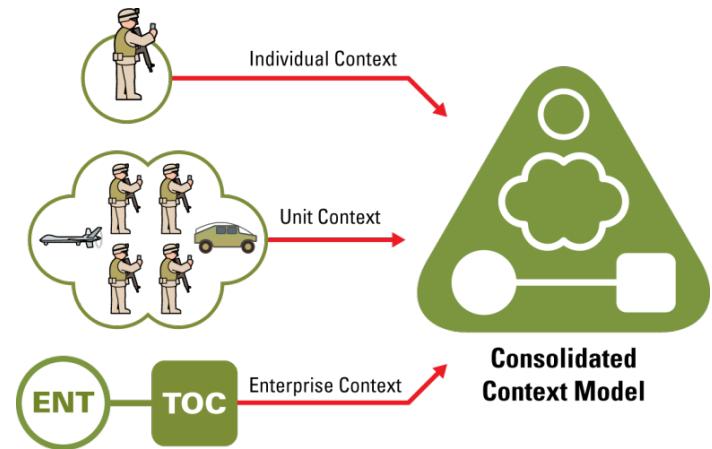
- Goal is to produce a capability that can sense as much of the emerging context as possible and apply that context to filter data such that only the most relevant information is displayed



# Group-Context-Aware Mobile Applications <sub>2</sub>

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



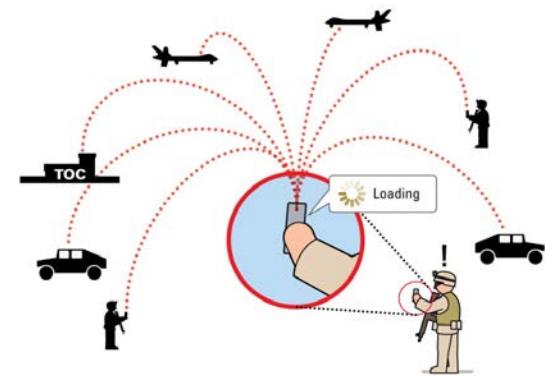
# Motivation

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



# Agenda

Background

## Architecture Drivers and Scenarios

Architecture Decisions

Extensibility as a Collaboration Enabler — Results

Conclusions



# 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

#	Name	Attribute Concern
1	Add a New Sensor	Separation of Concerns
2	Add a New Sensor	Modifiability
3	Add a New Communication Mechanism	Separation of Concerns
4	Add a New Communication Mechanism	Modifiability
5	Add a New Context Event / Action	Separation of Concerns
6	Add a New Context Event / Action	Modifiability
7	Add a New Context View	Separation of Concerns
8	Add a New Context View	Modifiability



# Scenario 3: Add a New Communication Mechanism

<b>Scenario</b>	Add a New Communication Mechanism	
<b>Attribute</b>	Extensibility	
<b>Attribute Concern</b>	Separation of Concerns	
<b>Scenario Refinement</b>	<b>Stimulus</b>	Developer
	<b>Stimulus Source</b>	Developer identifies a communication mechanism that can be used to share context data with other mobile devices
	<b>Environment</b>	Developer is sufficiently comfortable with application to make changes in a reasonable amount of time
	<b>Artifact</b>	Communications Manager of the context-aware system
	<b>Response</b>	Communications Manager is changed to implement message passing using the new communication mechanism
	<b>Response Measure</b>	Aside from communication-mechanism-specific code, only the Communications Manager is changed to accommodate the new communications mechanism.



# Scenario 5: Add a New Context Event / Action

<b>Scenario</b>	Add a New Context Event/Action	
<b>Attribute</b>	Extensibility	
<b>Attribute</b>	Separation of Concerns	
<b>Concern</b>		
<b>Scenario</b>	<b>Stimulus</b>	Developer
<b>Refinement</b>	<b>Stimulus Source</b>	Developer identifies a new event that can be detected by examination of context data
	<b>Environment</b>	Developer is sufficiently comfortable with application to make changes in a reasonable amount of time
	<b>Artifact</b>	Context Engine of the context-aware system
	<b>Response</b>	Context Engine is changed to detect the conditions for the event and generate a new action when it is detected
	<b>Response Measure</b>	Only the Context Engine is changed to allow for detection of events and generation of actions



# Agenda

Background

Architecture Drivers and Scenarios

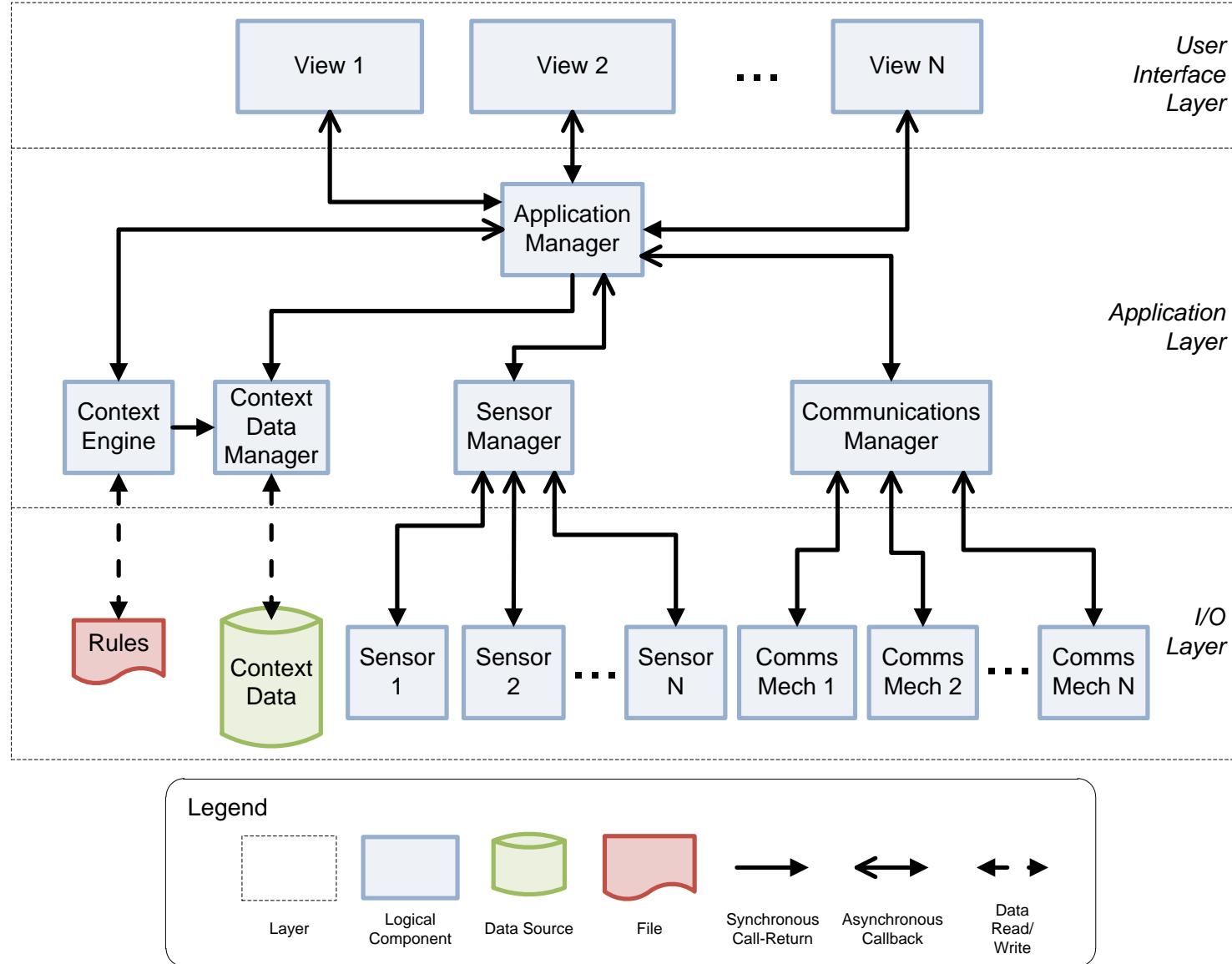
**Architecture Decisions** 

Extensibility as a Collaboration Enabler — Results

Conclusions



# High-Level Reference Architecture



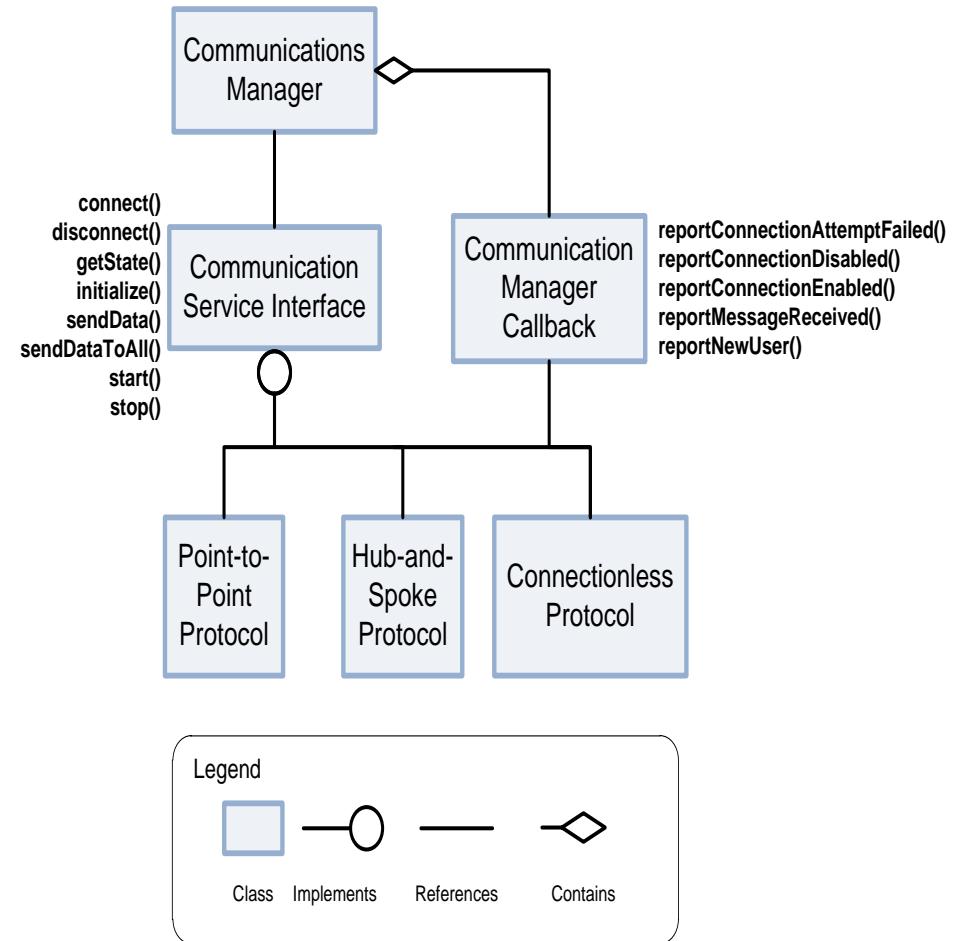
# Architectural Decision 1: Communications Interface

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



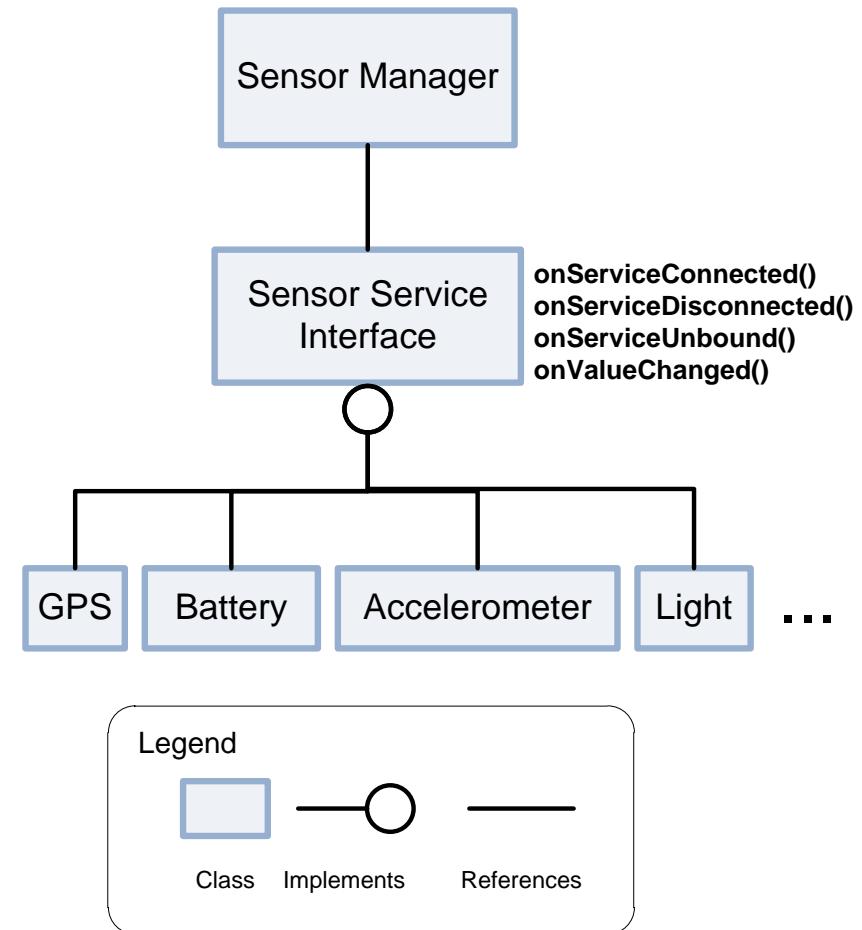
# Architectural Decision 2: Sensor Interface

## 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

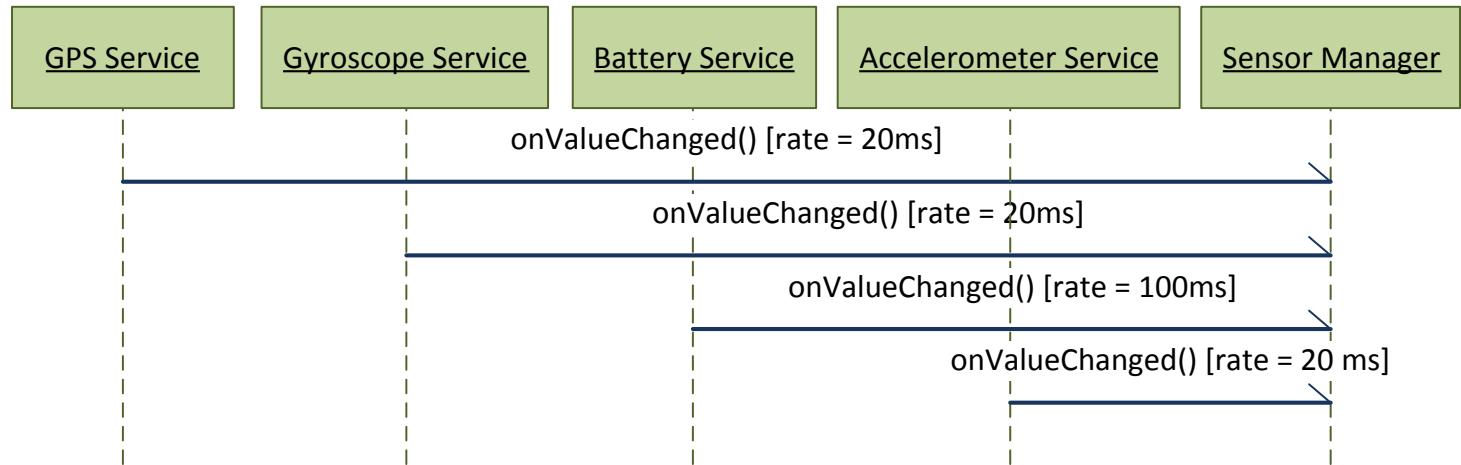
Simple experimentation demonstrated that this was indeed a problem

## 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



# Architectural Decision 3: Context Model “At the Center”

## Challenges

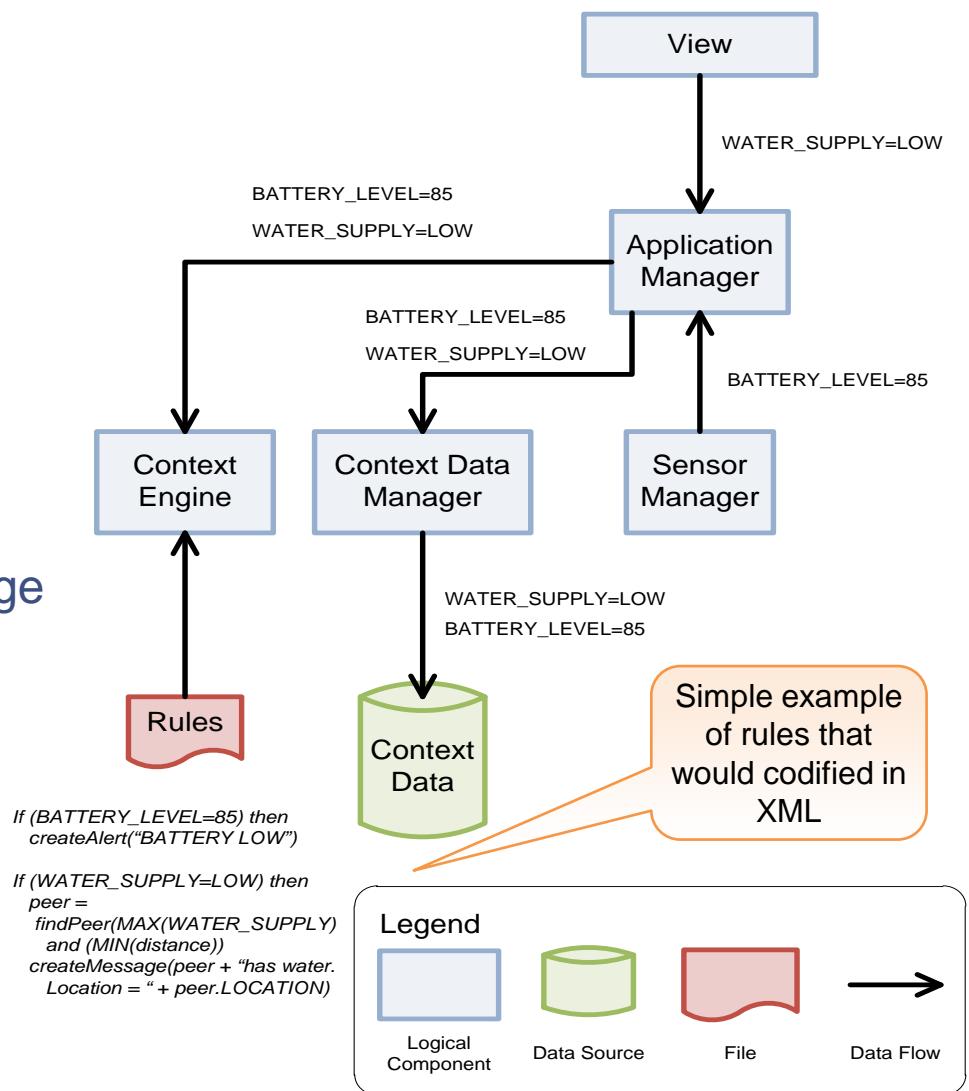
- Easy creation of rules based on contextual data captured via sensors or user input
- Standardized rule processing

## 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



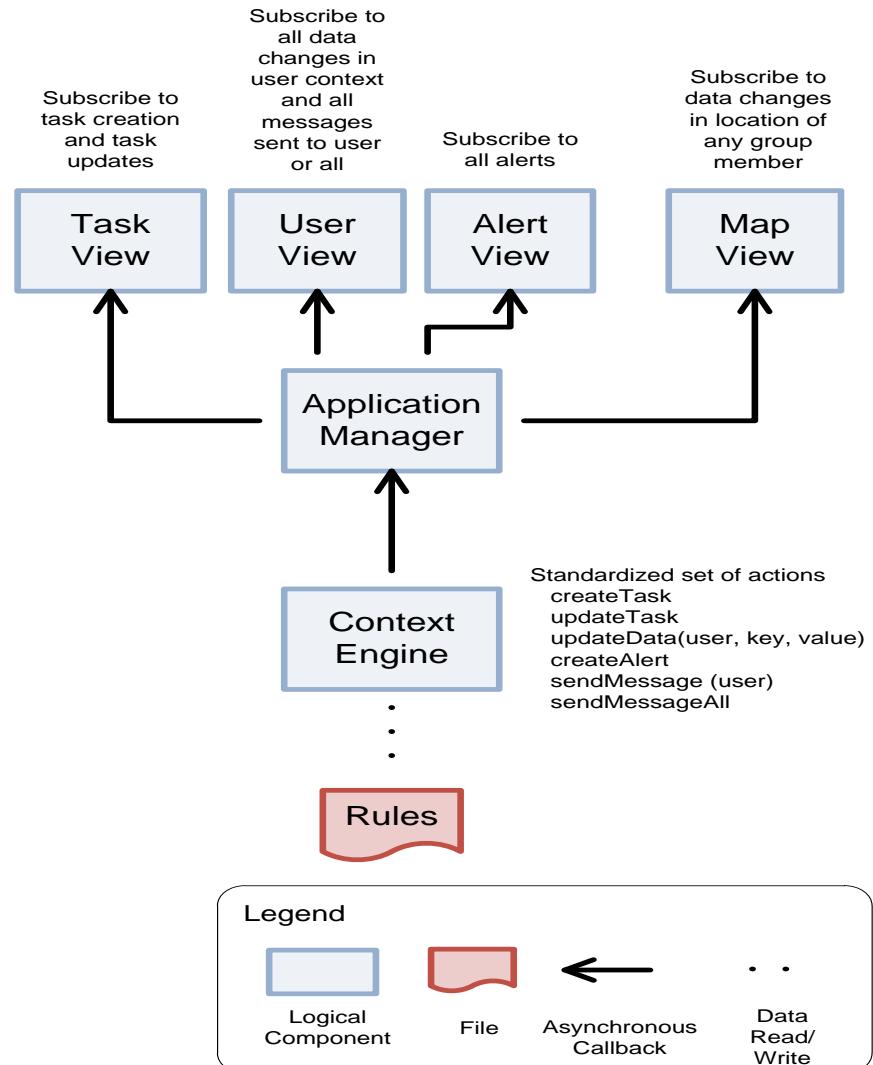
# Architectural Decision 4: Standardized Messaging

## Challenge

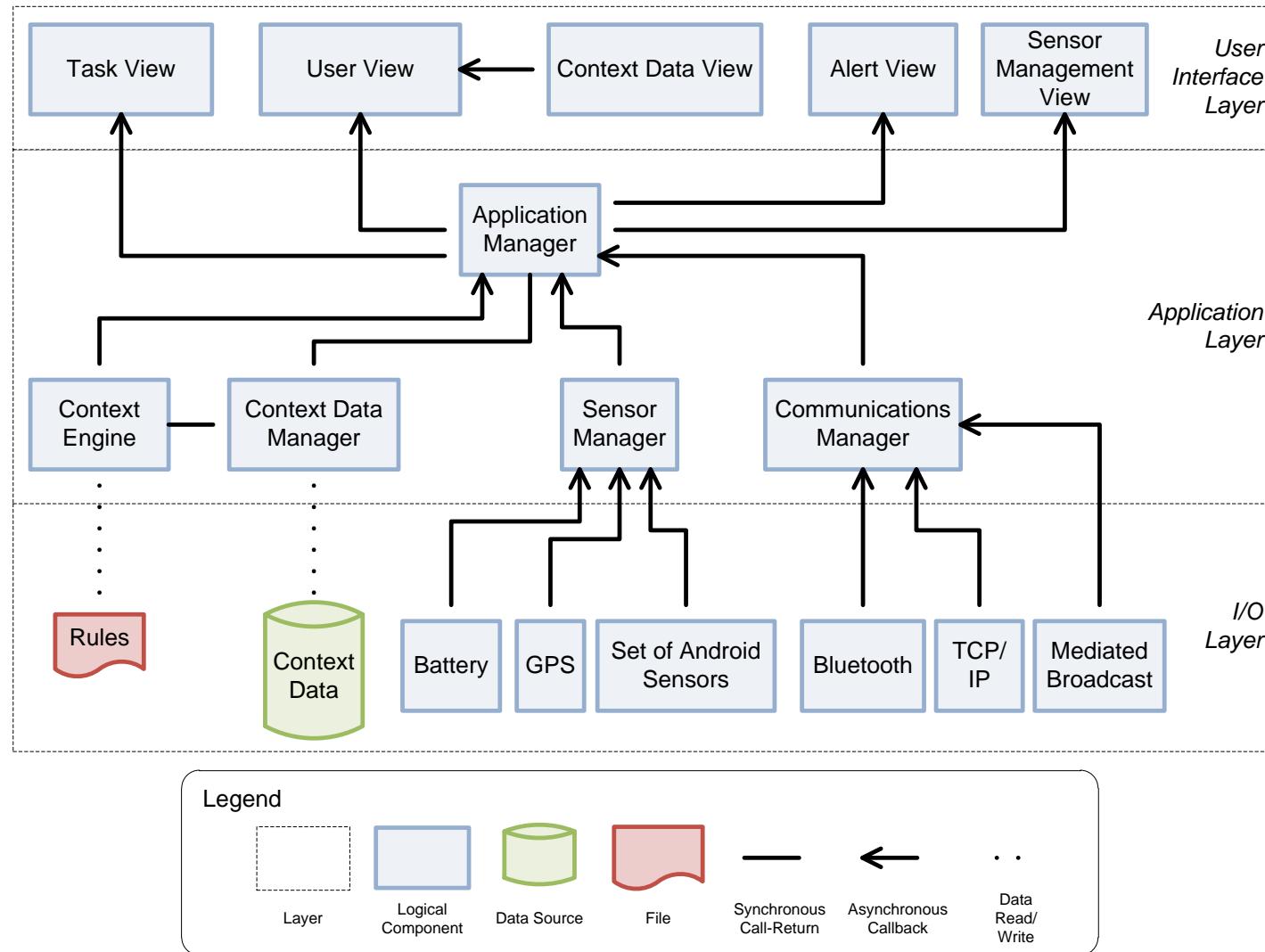
- Easy creation of views that can capture and/or display context data

## 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



# First Responder Application Architecture



# Agenda

Background

Architecture Drivers and Scenarios

Architecture Decisions

**Extensibility as a Collaboration Enabler — Results** 

Conclusions



# Results 1

The extensible architecture enables productive collaboration

- Sensor and communication service interface enable 3<sup>rd</sup> 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 <sub>2</sub>

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



# Agenda

Background

Architecture Drivers and Scenarios

Architecture Decisions

Extensibility as a Collaboration Enabler — Results

**Conclusions** 



# Conclusions

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

## Marc Novakouski

Research, Technology and Systems Solutions (RTSS) Program  
Advanced Mobile Systems (AMS) Initiative

Software Engineering Institute  
4500 Fifth Avenue  
Pittsburgh, PA 15213-2612  
USA

Phone: +1 412-268-4274  
Email: [novakom@sei.cmu.edu](mailto:novakom@sei.cmu.edu)  
WWW: <http://www.sei.cmu.edu/staff/novakom>

