
“In the next century, planet earth will don an electronic skin.
It will use the Internet as a scaffold to support and transmit its sensations”

[Neil Gross 1999](#)

Web and Mobile Engineering

Trends and Challenges from Internet of Things (IoT) perspective

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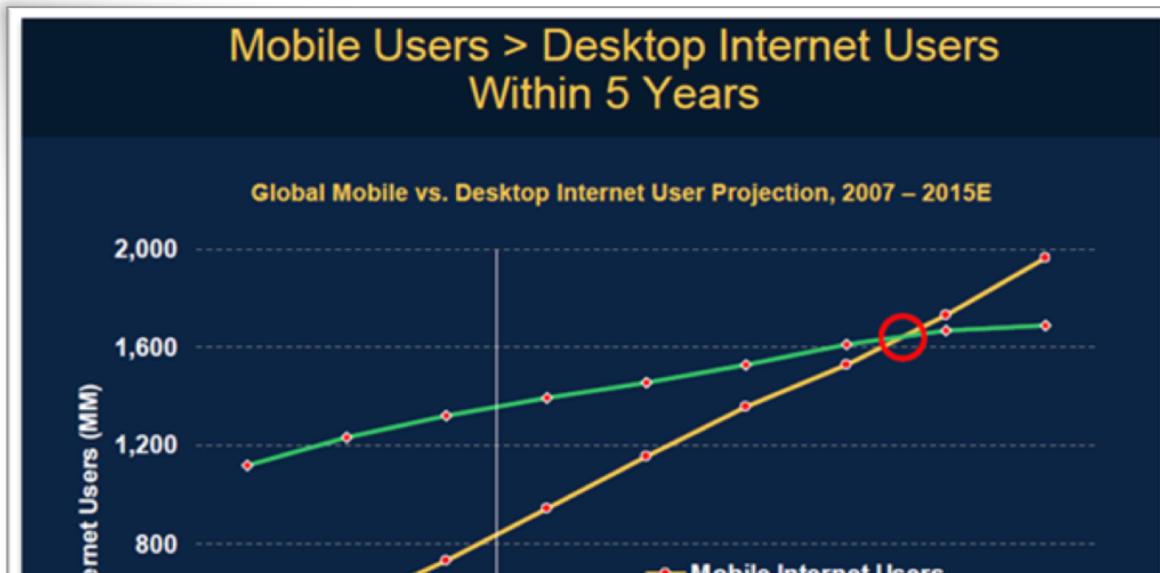
MALMÖ HÖGSKOLA

.....

?

- Web?
- Mobile?
- Engineering?

Miniaturization → diffusion



- Today there are more devices connected to the Internet than people living in the world
 - 1.8 d/p (2010), 3.5 d/p (2015), 6.6 d/p (2020)
- ➔ In the very near future, pretty much everything you can imagine will wake up and connect *people, processes, data and things* anywhere and anytime

Web evolution: Technologies everywhere



Sharing

Contributing

Contextualizing

The power of Web: its ubiquity



At Stake

- Lots of smartphones



- Lots of operating systems Android iOS Windows BlackBerry

- Platform Fragmentation



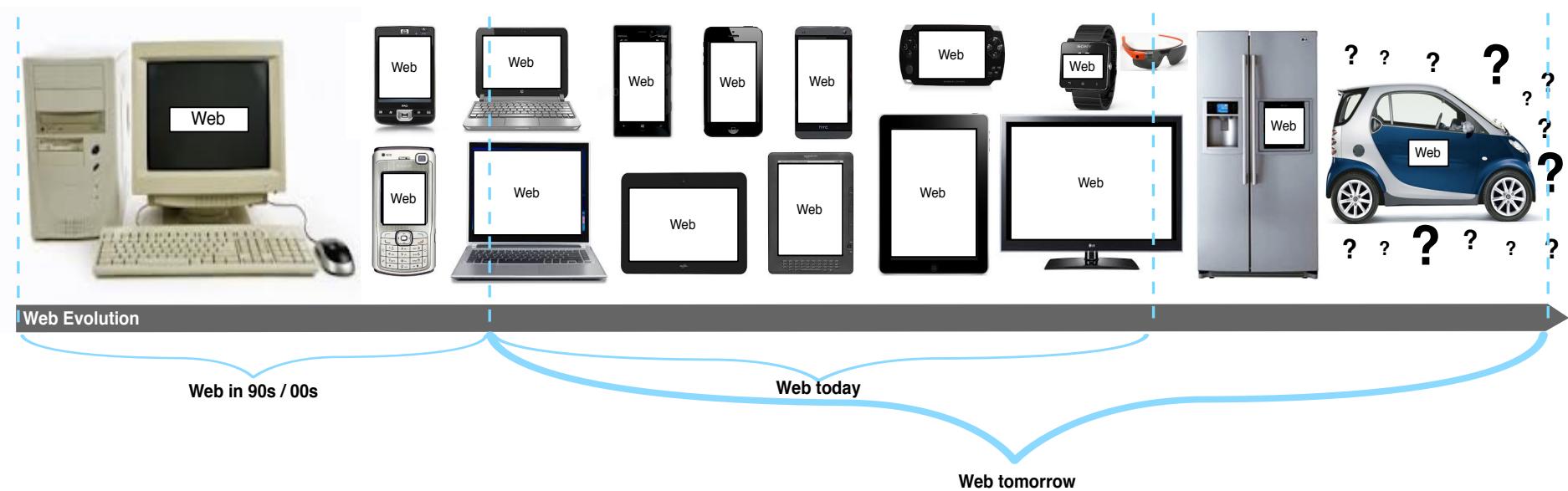
Image: <http://topandroids.wordpress.com/2012/12/20/what-is-android-fragmentation/>

T. Wasserman, "Technical and Business Challenges for Mobile Application Developers," Mobicase 2010.

At Stake (cont'd)



- From OS fragmentations we are moving to Browsers fragmentations
- The challenge is more than just mobility.



Diversity is not a bug...it's an opportunity 😊



Source: <http://stephanierieger.com/diversity-is-not-a-bug/>

Source: <http://bradfrostweb.com/blog/mobile/beyond-media-queries-anatomy-of-an-adaptive-web-design/>

Medium and Context

GPS

Touch

Sensors (A/V)

Contacts

Portability

Location-Aware

Intimate and
Interactive

Physical
Intelligence

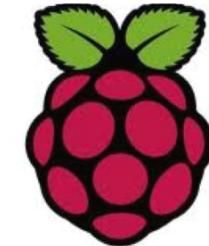
Personal and
Social

Relevant at Point
of Consideration

Enabling technologies



*net***duino**



Challenges or Opportunities

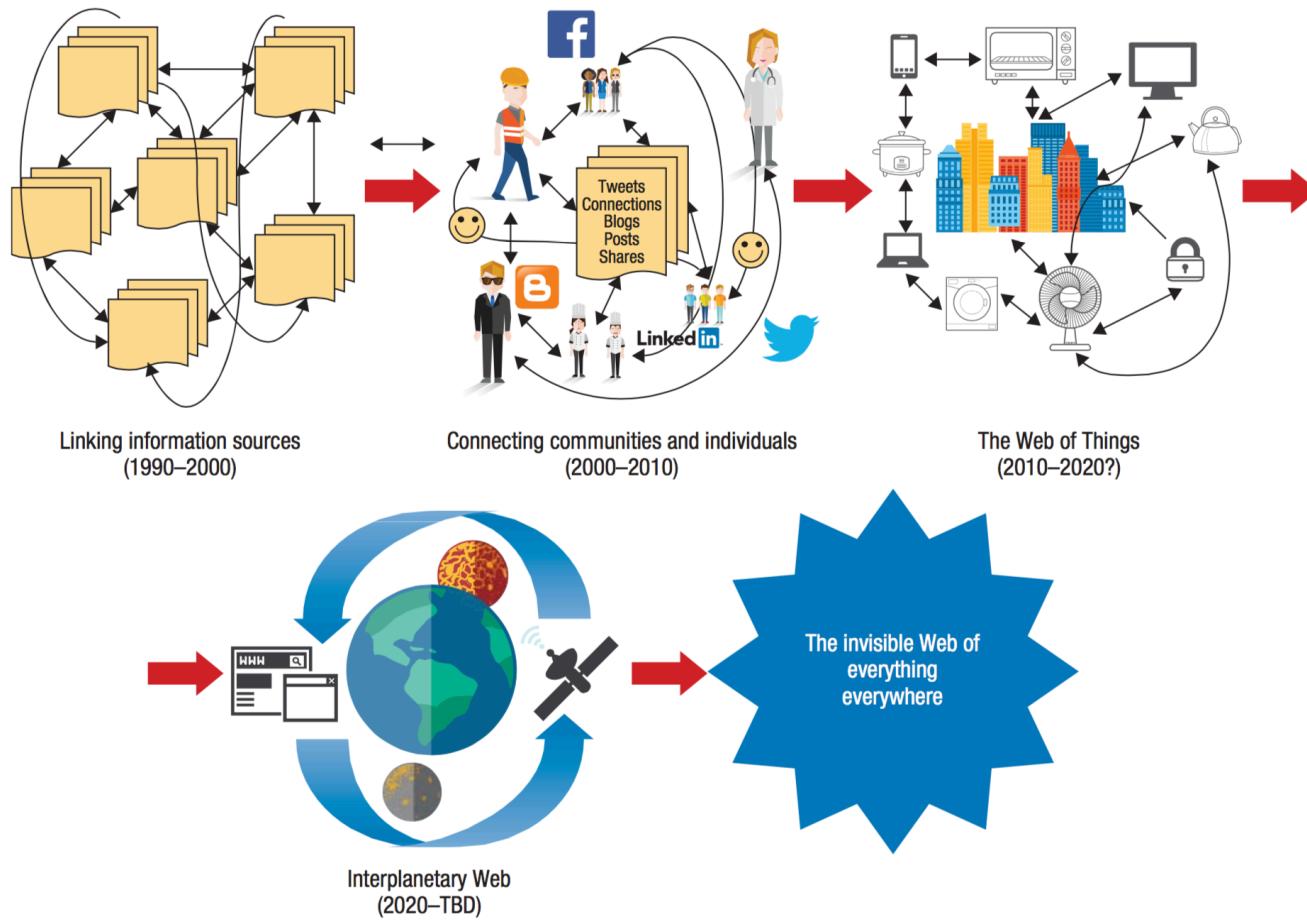
- **Platform fragmentation:** Across all stages of the software lifecycle, fragmentation affects development and deployment time, in particular the fragmentation of mobile software;
- **Dynamic requirements:** Addressing dynamic requirements in heterogeneous device environments to minimize costs, especially through the evolution of web and mobile software;
- **Interoperability:** Integration issues between new components/modules and external systems to challenge and expand the architecture for/in diverse contexts;
- **Architectural challenges:** Addressing the architectural needs for deploying flexible applications and maintaining architectural integrity

A worldwide computing environment

New Mobile Landscape

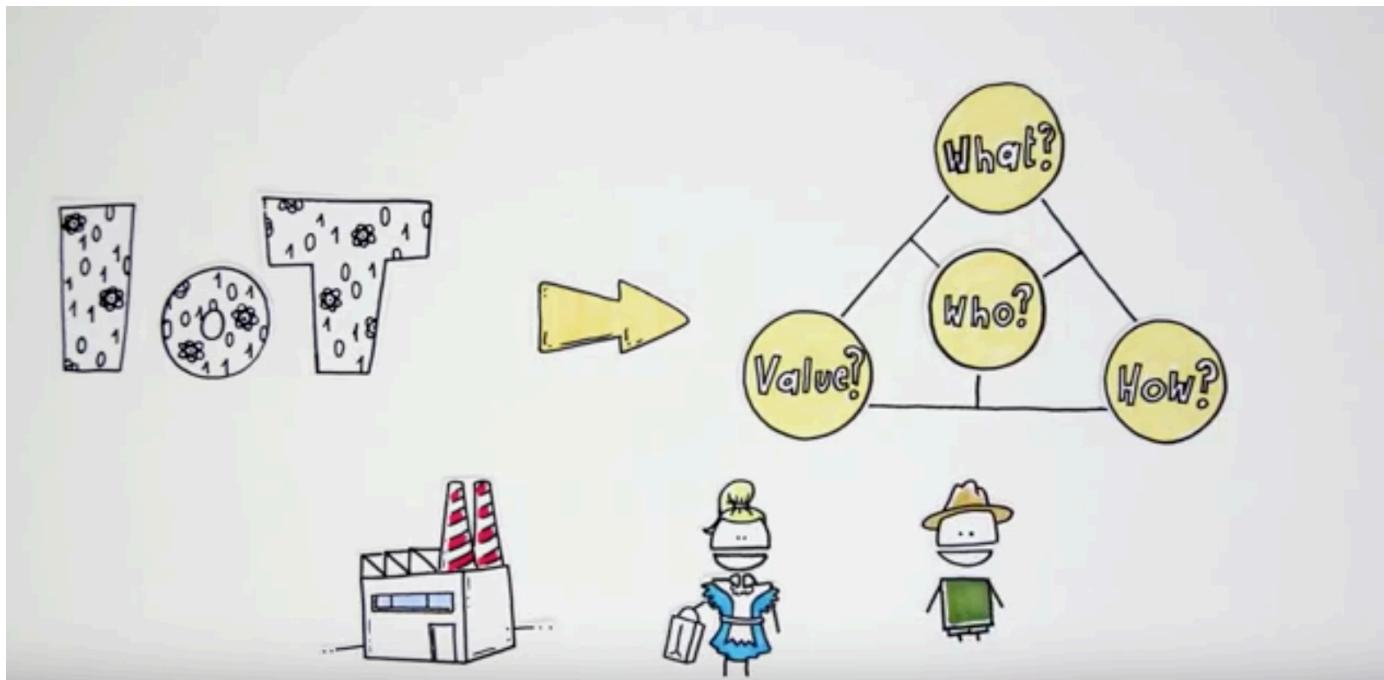


From past to future...



The Web is evolving from an interconnection of static information sources to a programmable interconnection of static and dynamic information, people, communities, things, and eventually planets.

Video: IoT



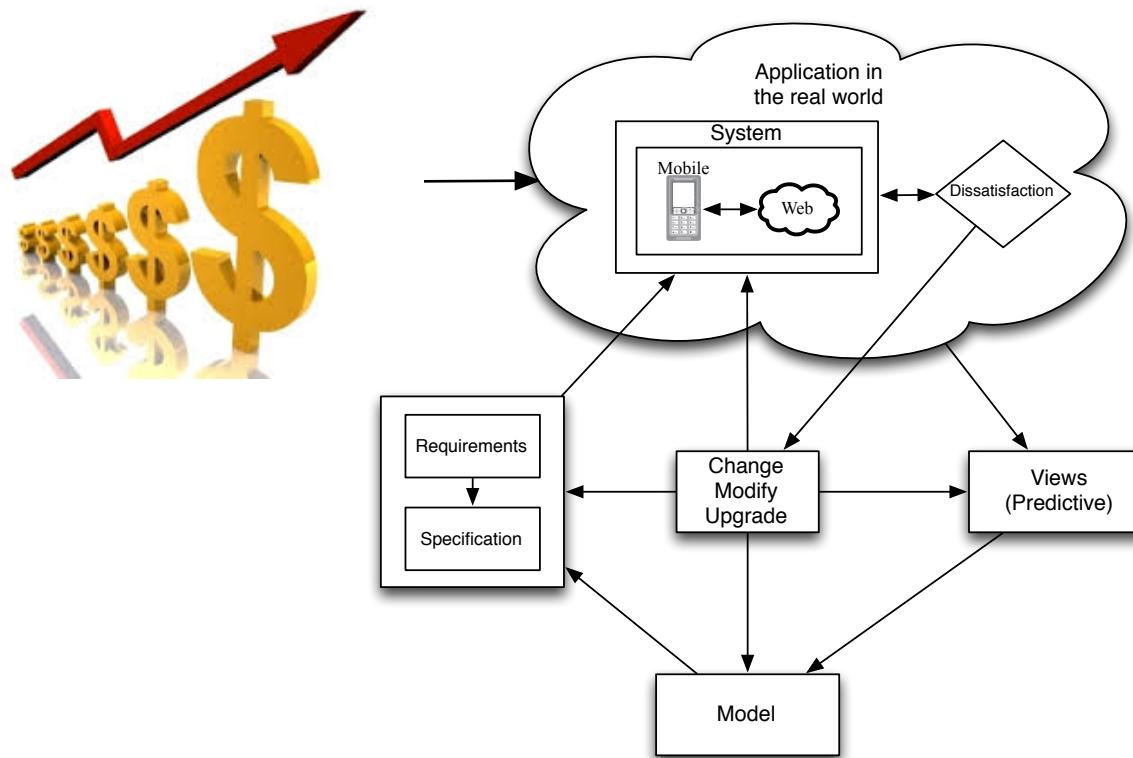
https://www.youtube.com/watch?v=kYQ_PHOCjyg

Cross platform neutral applications

- For the IoT:

“all user types must be able to create platform-neutral applications from services and resources”

Dynamic Requirements and Software Evolution



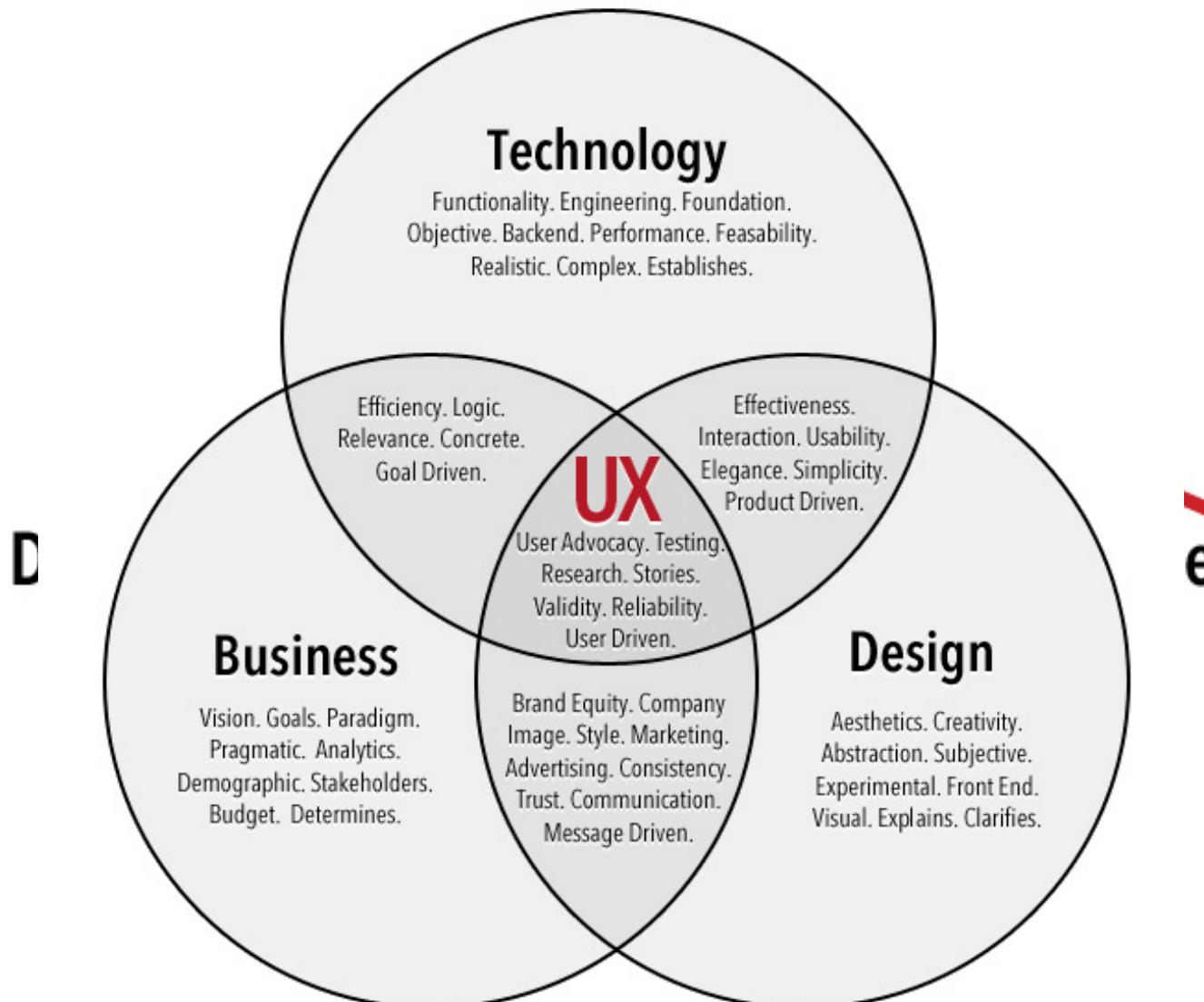
Constant changes, modification and upgrade, users needs and the rapid evolution of technologies

Motivated by Lehman, M.M, "Programs, Lifecycles and Laws of Software Evolution," Proceedings of the IEEE, 1980

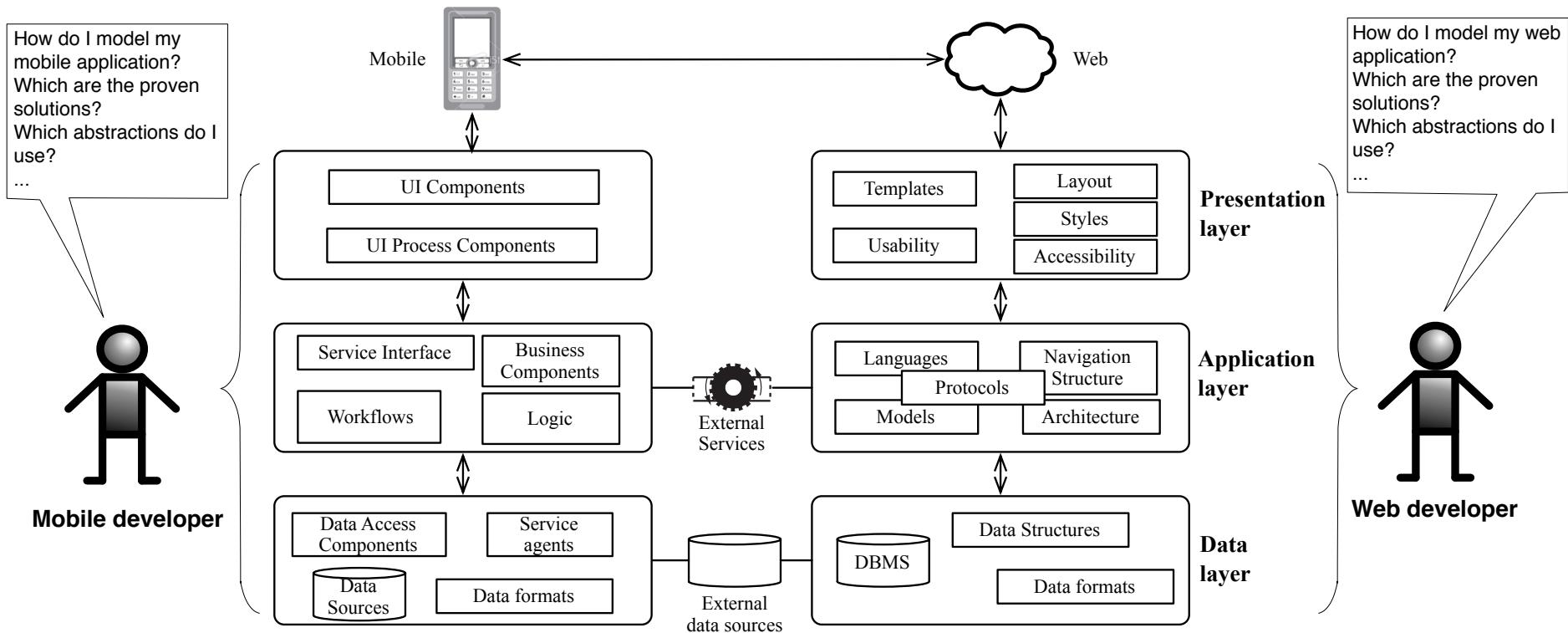
What are the needs to address some of the challenges?

- The need to use Open Data Standard formats
- The need to support Diverse Settings and Dynamic Change of Environments
- The need to Change and Adapt to New Technologies
- The need to Extend with Existing and New Tools
(Add/Upgrade/Modify features)
- The need to reduce the development and deployment time

Iterative Process: User Experience design



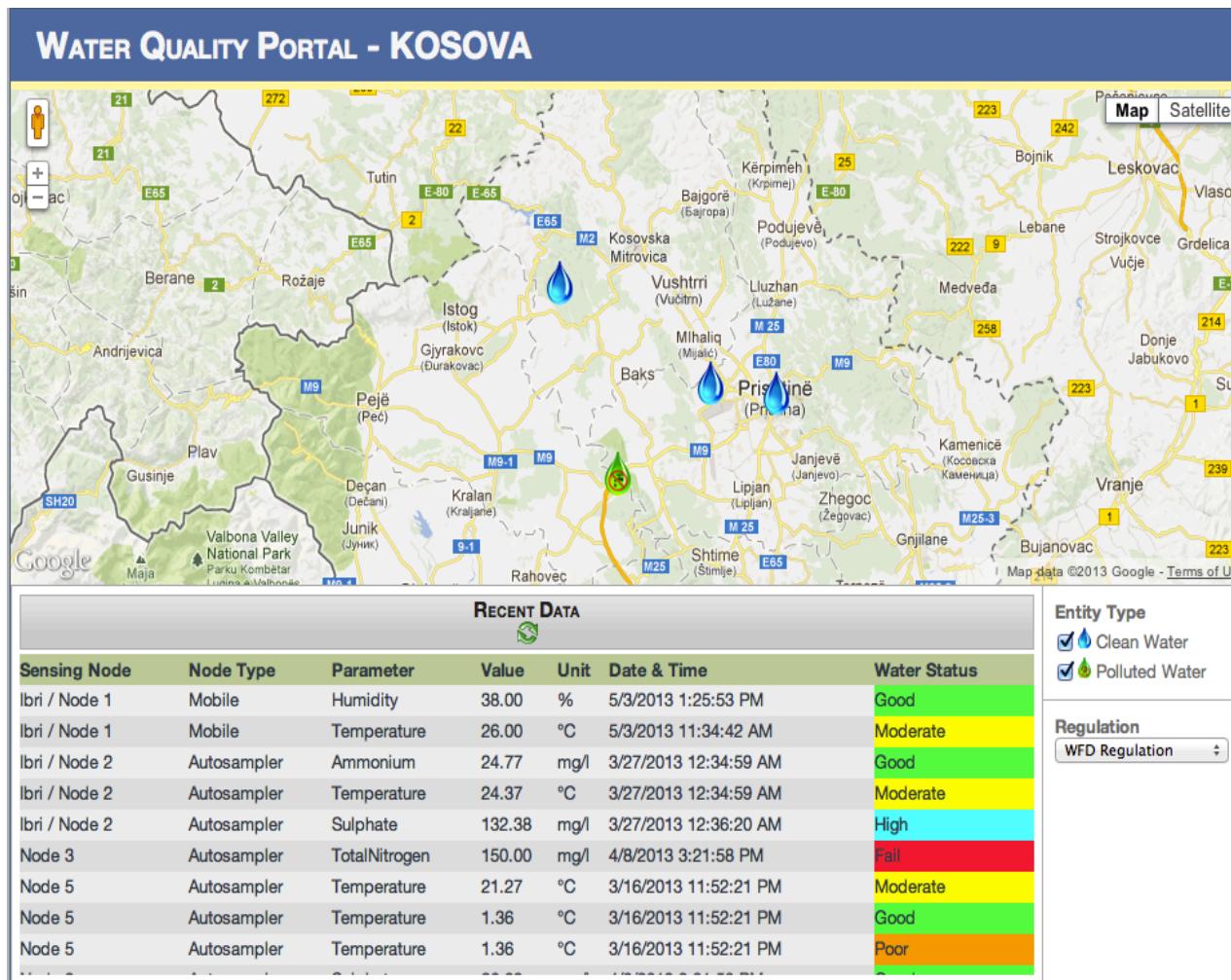
Web and Mobile Engineering Scenario



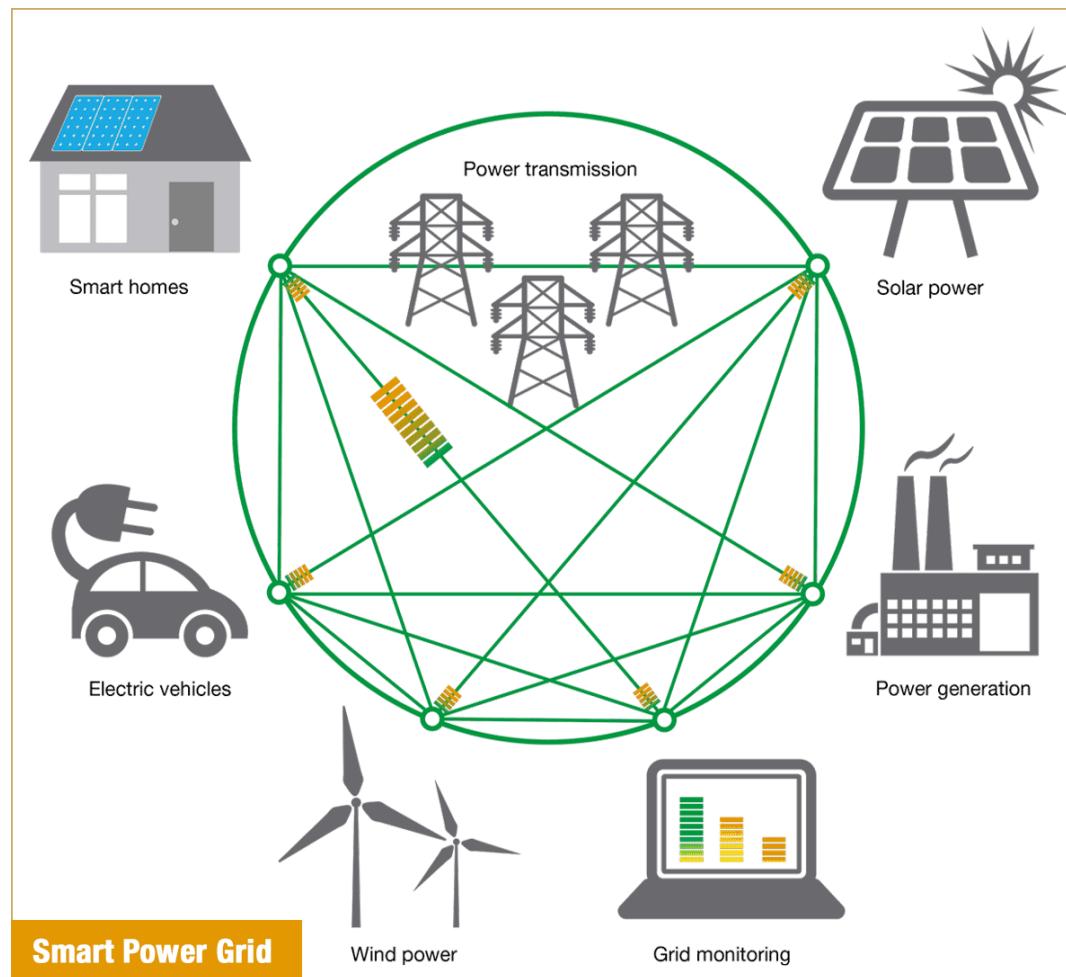
Our cases

RESEARCH AND DEVELOPMENT

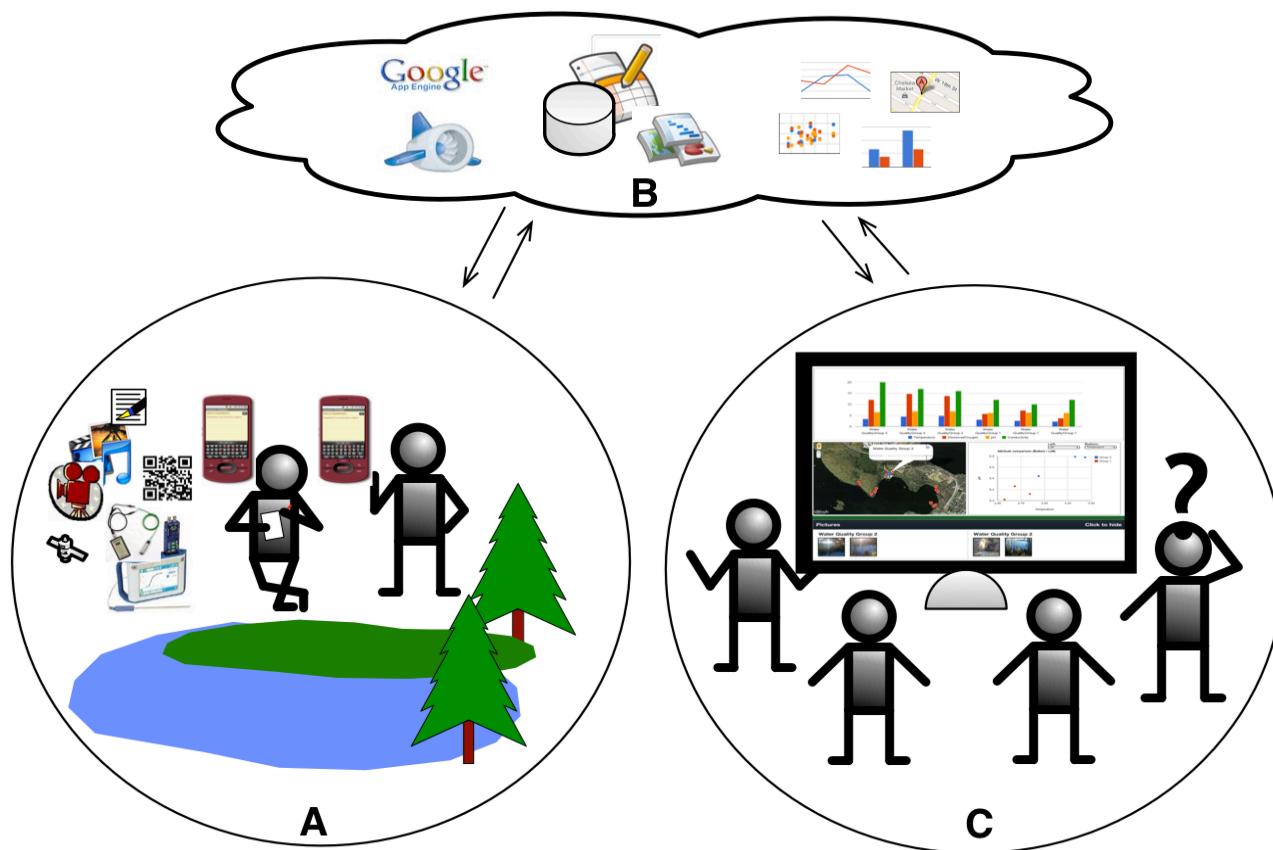
Environment



Energy

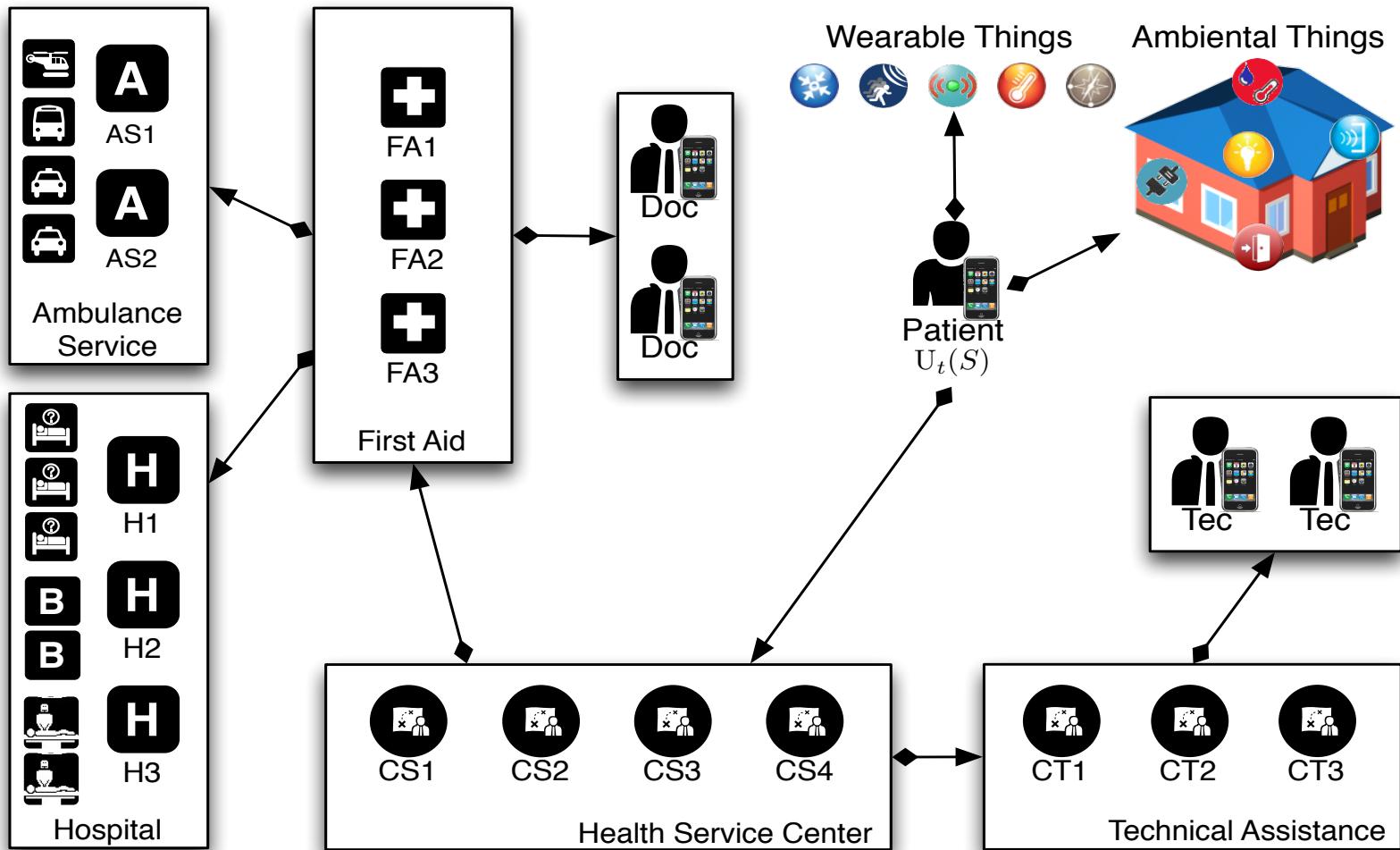


Education

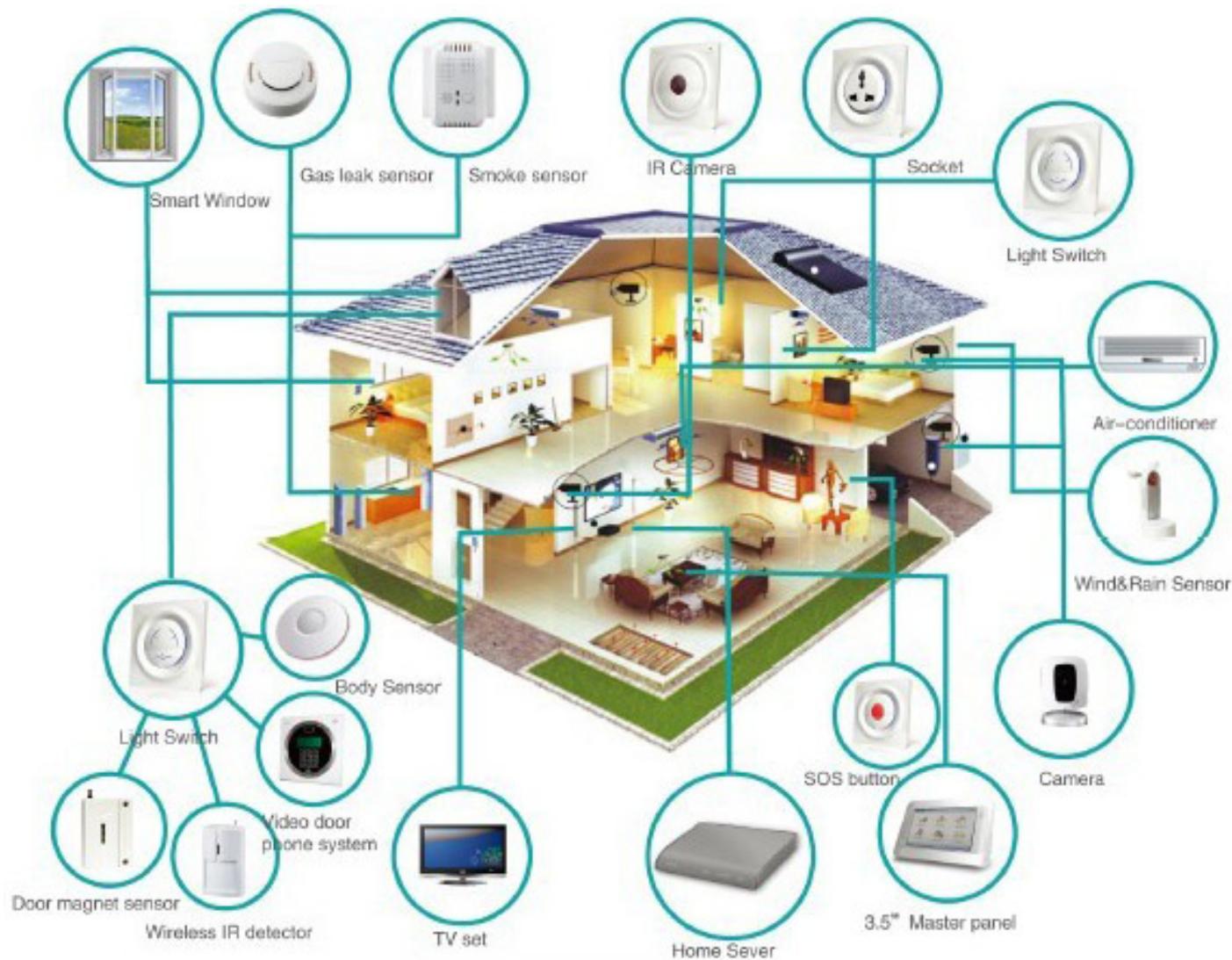


Mobility, service-oriented systems, distributed environments, the need for reflection, and collaborative technologies.

E-Health



Smart homes



Trends

RESEARCH AND DEVELOPMENT

to create airport of the future with
of the



SWEDISH
ICT INTERACTIVE

long
through
is your

o of a
y, it is
machines

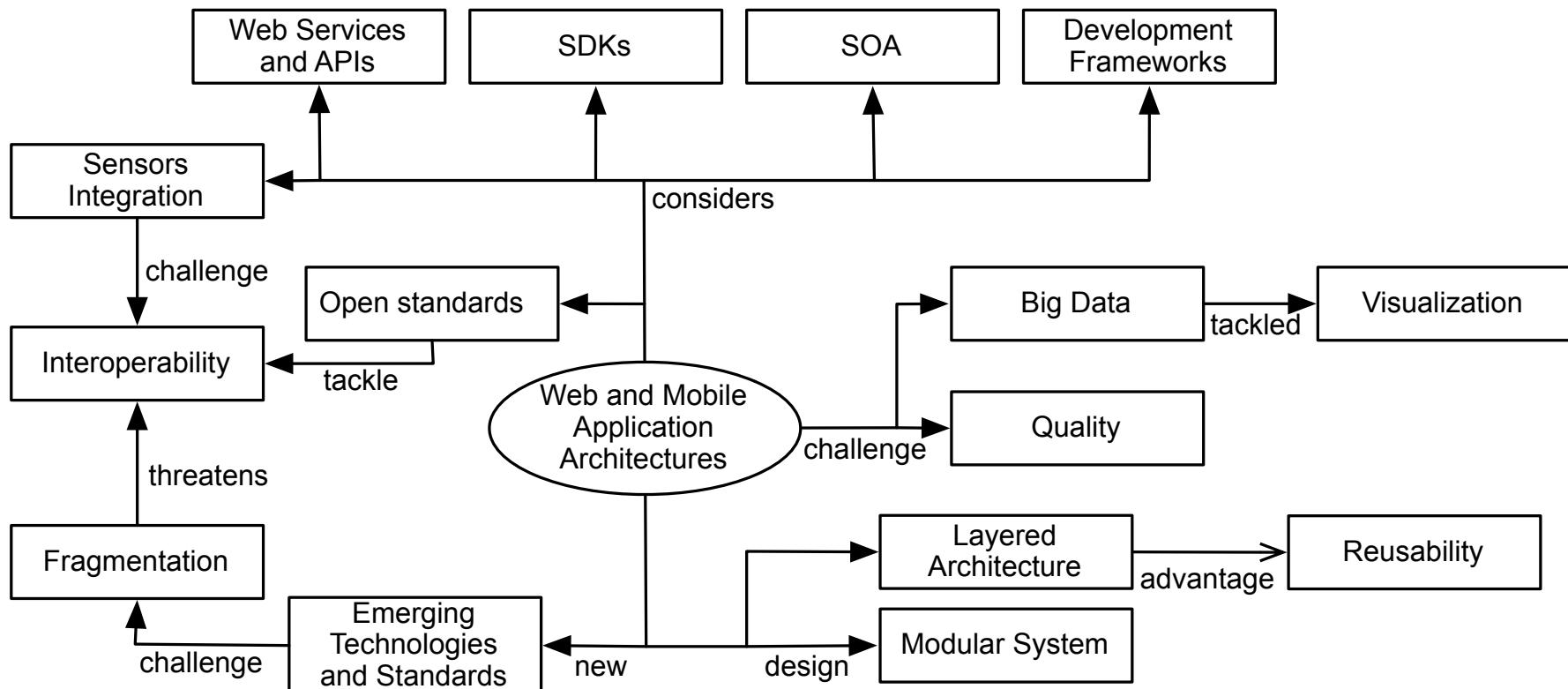
VISIT

New opportunities

IoT enables the emergence of appealing and promising application domains, which open:

- New **research** opportunities
 - Methodology, tools, models, technologies, protocols, paradigms, frameworks, standards ...
- New **business** opportunities
 - Environment, energy, agriculture, transportation, education, health, comfort, sports, entertainment, ...

Web and Mobile Engineering Challenges



MY RESEARCH FOCUS

Research focus

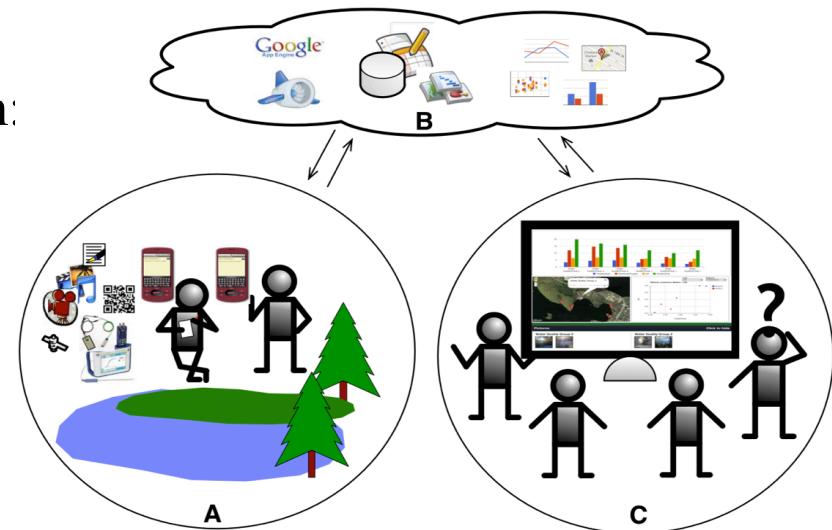
- Exploring an Open Architecture concept
 - Design and Development of Web and Mobile Software
 - Heterogeneous device environments
 - Constantly evolving and dynamic requirements.

Building the concept - the approach

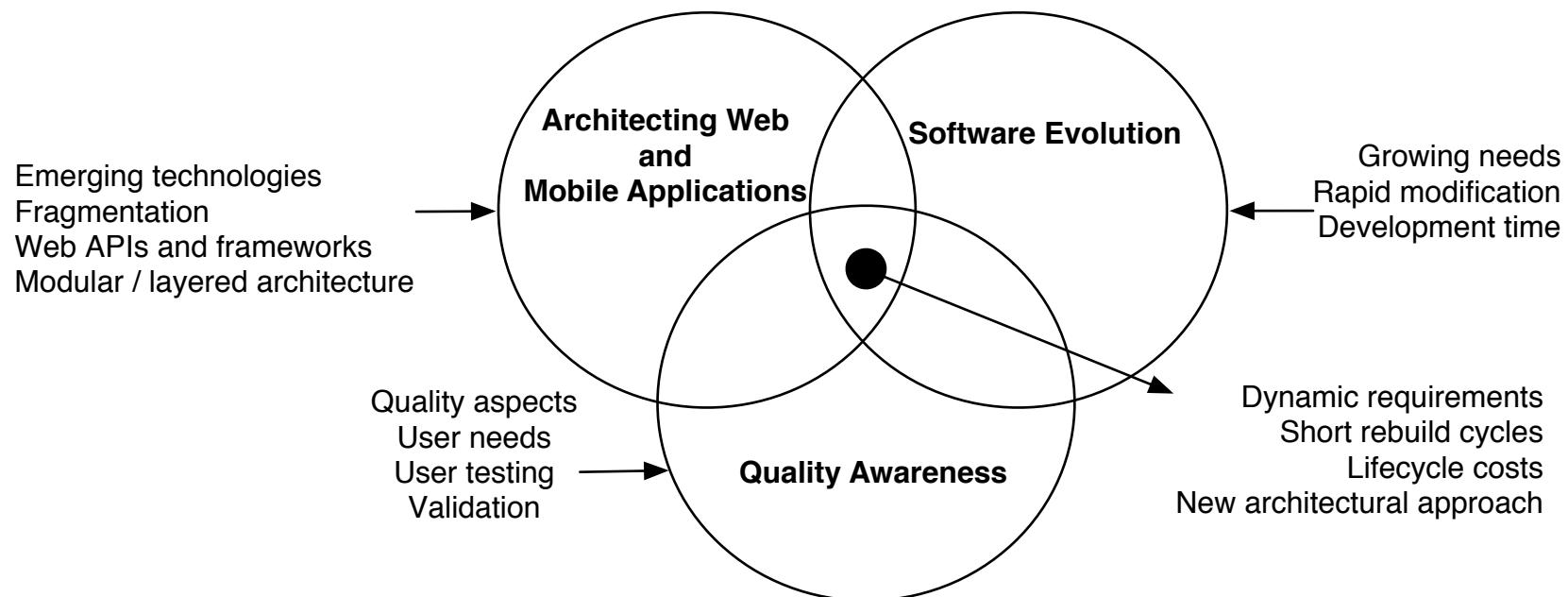
- Systematic Literature Study
 - What features are of primary importance for characterizing an open architecture?
- Project LETS GO
 - Design and implementation of the architecture and system, assessment and validation (more 500 users tested)
 - What are the needs that an open architecture should fulfill when dealing with constantly evolving and dynamic requirements in heterogeneous device environments?
- Three Follow-up Cases
 - Validation

Project LETS GO - the case: System, Users and Settings

- One of the aims of the Learning Ecology through Science with Global Outcomes (LETS GO) project [13] was to support “open inquiry learning” using mobile science collaborators that provide open software tools and resources, and participation frameworks for learner project collaboration, mobile data and media capture, publishing, analysis, and reflection.
- From a software engineering perspective, fulfilling these aims introduces a number of stakeholders, as well as functional and architectural requirements.
- The system was used by more than:
 - 500 users
- Settings
 - Water Quality
 - Soil Quality
 - GeoAudioNotes
 - Etc.



Areas of concern and the focus

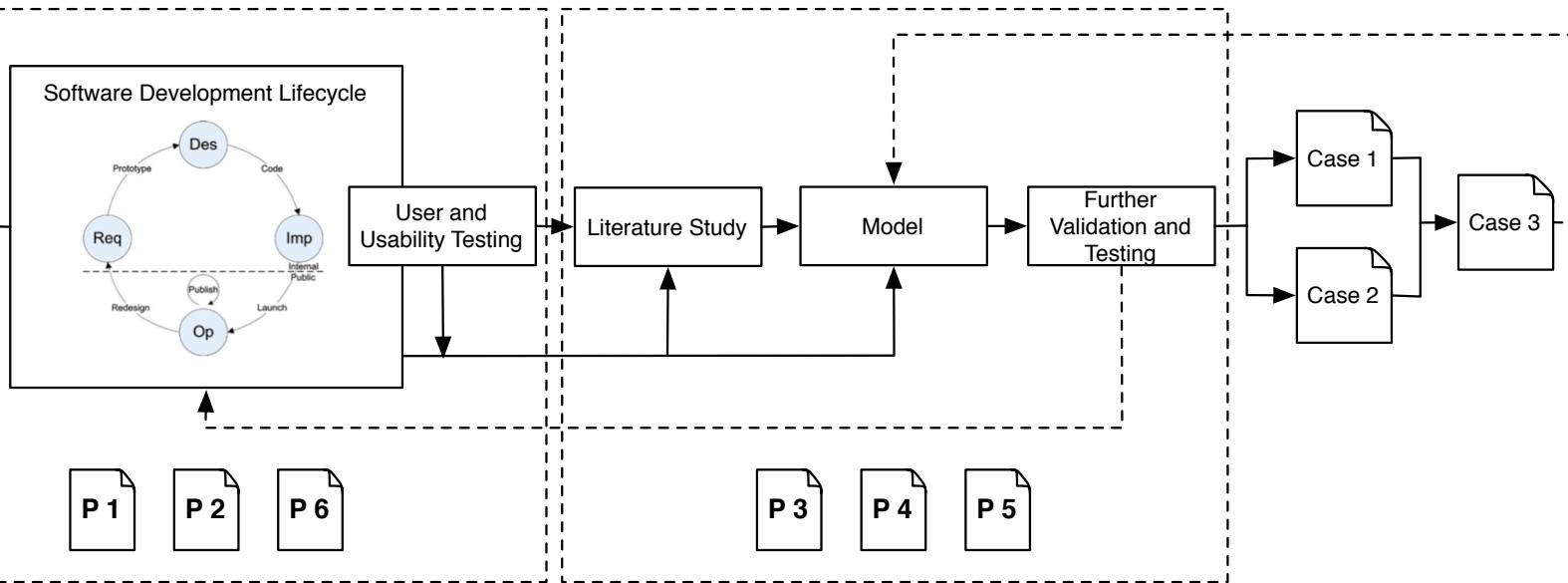


Research Goal and Questions

- **Goal:** to identify a new architectural approach and analyze the openness features of it when dealing with heterogeneous device environments, together with constantly evolving and dynamic requirements.
- **Q1.** What are the needs that an architectural approach should fulfill when dealing with constantly evolving and dynamic requirements in heterogonous device environments?
- **Q2.** What features are of primary importance for characterizing one such architectural approach?
- **Q3.** How to assess and validate such an architectural approach?

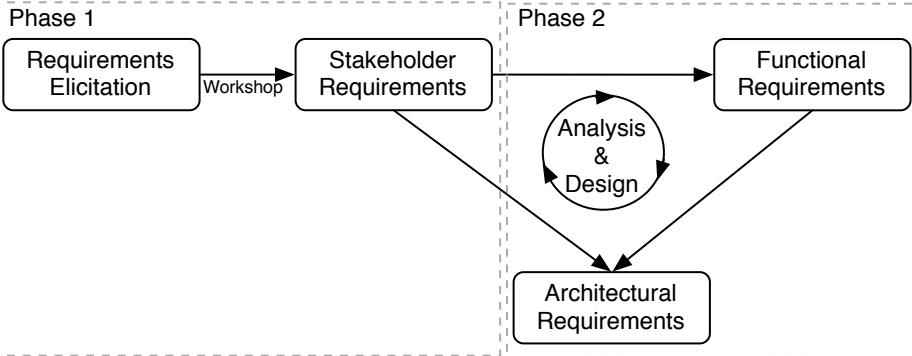
No.	Activity	Methods	Perspective	Participants
1	Requirements Elicitation workshop	Qualitative	Researcher	Teachers/ Researchers and developers
2	Software development lifecycle by employing extensive prototyping	Quantitative	Developer/ Researcher	6 developers/4 researchers/2 architects
3	User testing study with observations	Qualitative	End-user/Researcher	500 participants K-12 schools, students, teachers, domain experts

Perspective: Architecting Web and Mobile Applications, Software Evolution and Quality Awareness



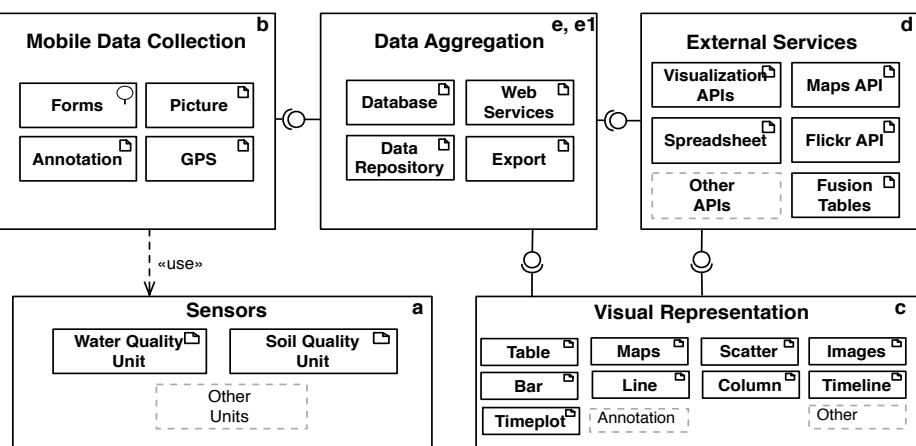
		Mixed	Researcher/ Industry	4 developers from the IT industry, 1 software architect, 2 students, 1 designer, 1 teaching assistant
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The Architecture Design and Application



Phases of architectural requirements identification

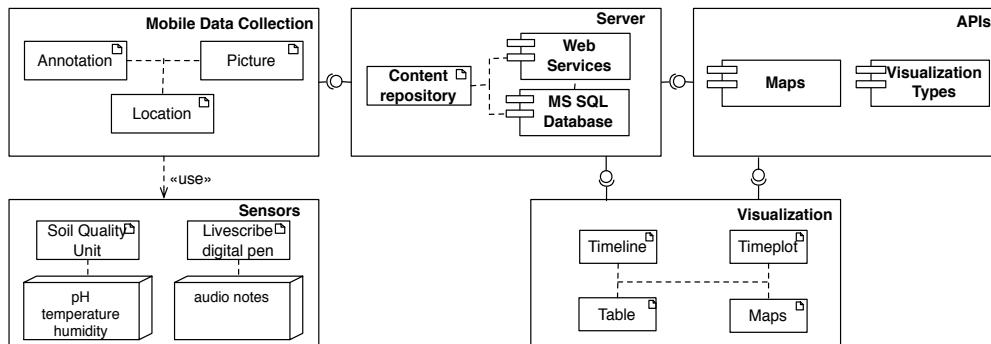
Stakeholder Requirements	Functional Requirements	Architectural Requirements
Provide sensor network	The system should be able to collect geo-tagged content and sensor data.	a. Sensor components
Provide data collection tools	The system should provide features for data annotation	b. Mobile unit components
Provide data visualization tools	The system should be able to visualize geo-tagged content and sensor data	c. Visualization and collaboration components
Provide live mapping tools	The system should provide digital map representation	
Provide collaboration tools	The system should represent data using various visualizations techniques/types	d. External services components
Provide an easy to use system	The system should provide data filtering capabilities and administration	e. Server and data aggregation components
Affordable cost of hardware	The system should have a content repository	e1. Data repository components
Multiple application support and easy integration	The system should have a mobile and web interface	a, b, c and e, e1



Initial Architecture

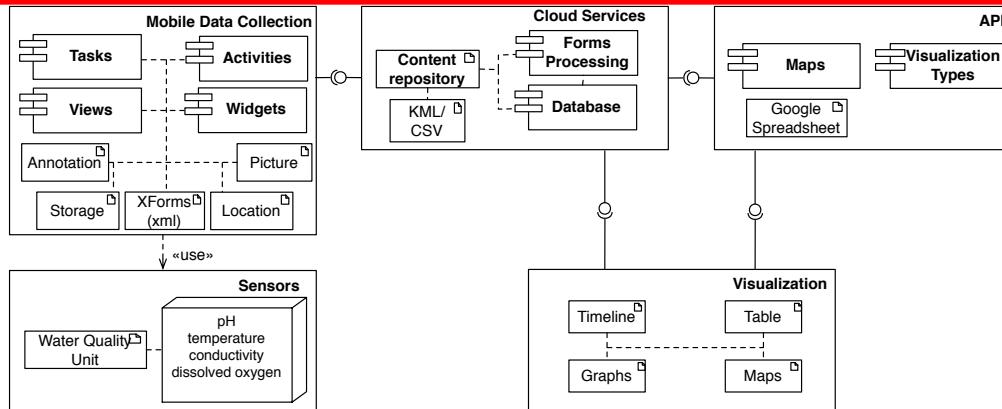
Implementation overview

First



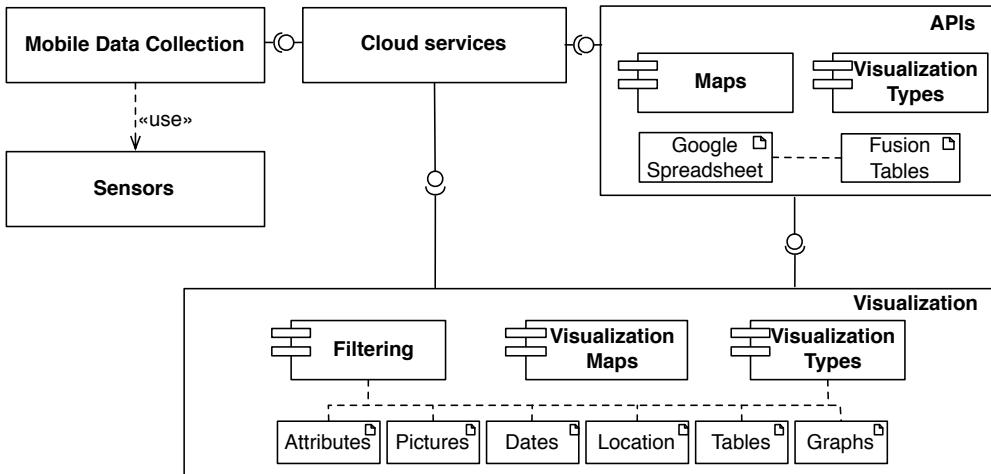
Throwaway

Second



Throwaway

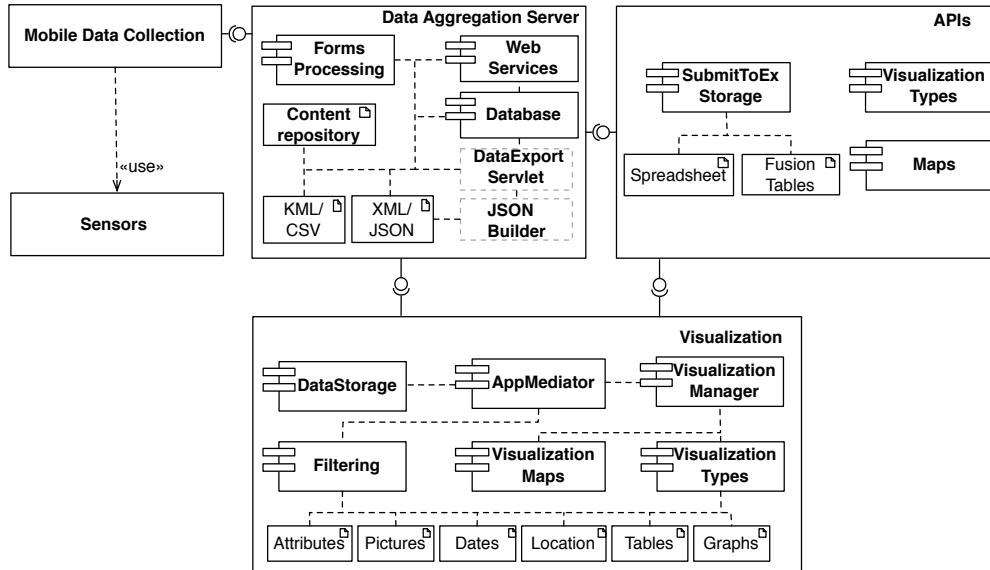
Third



Evolutionary
Usability study

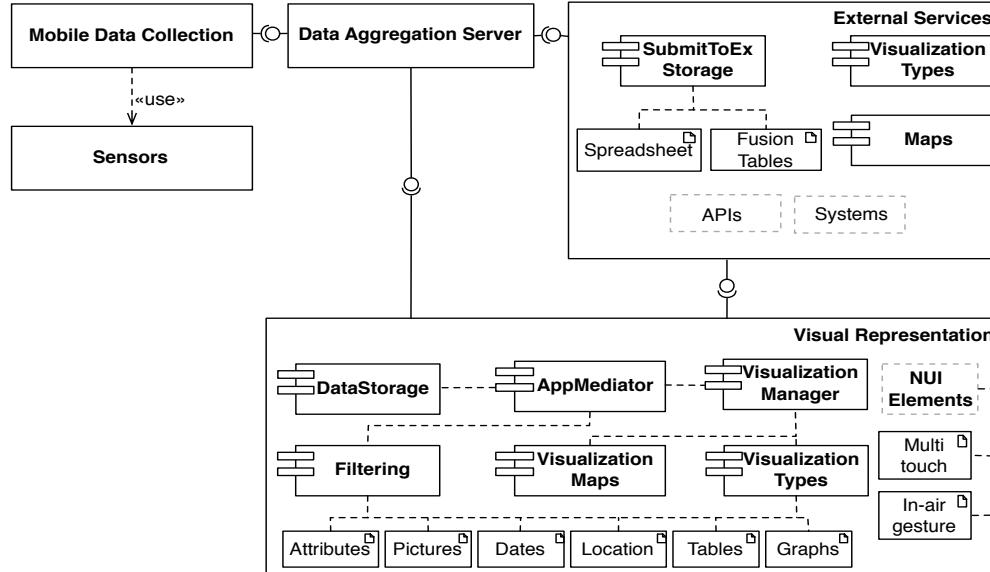
Implementation overview (cont'd)

Fourth



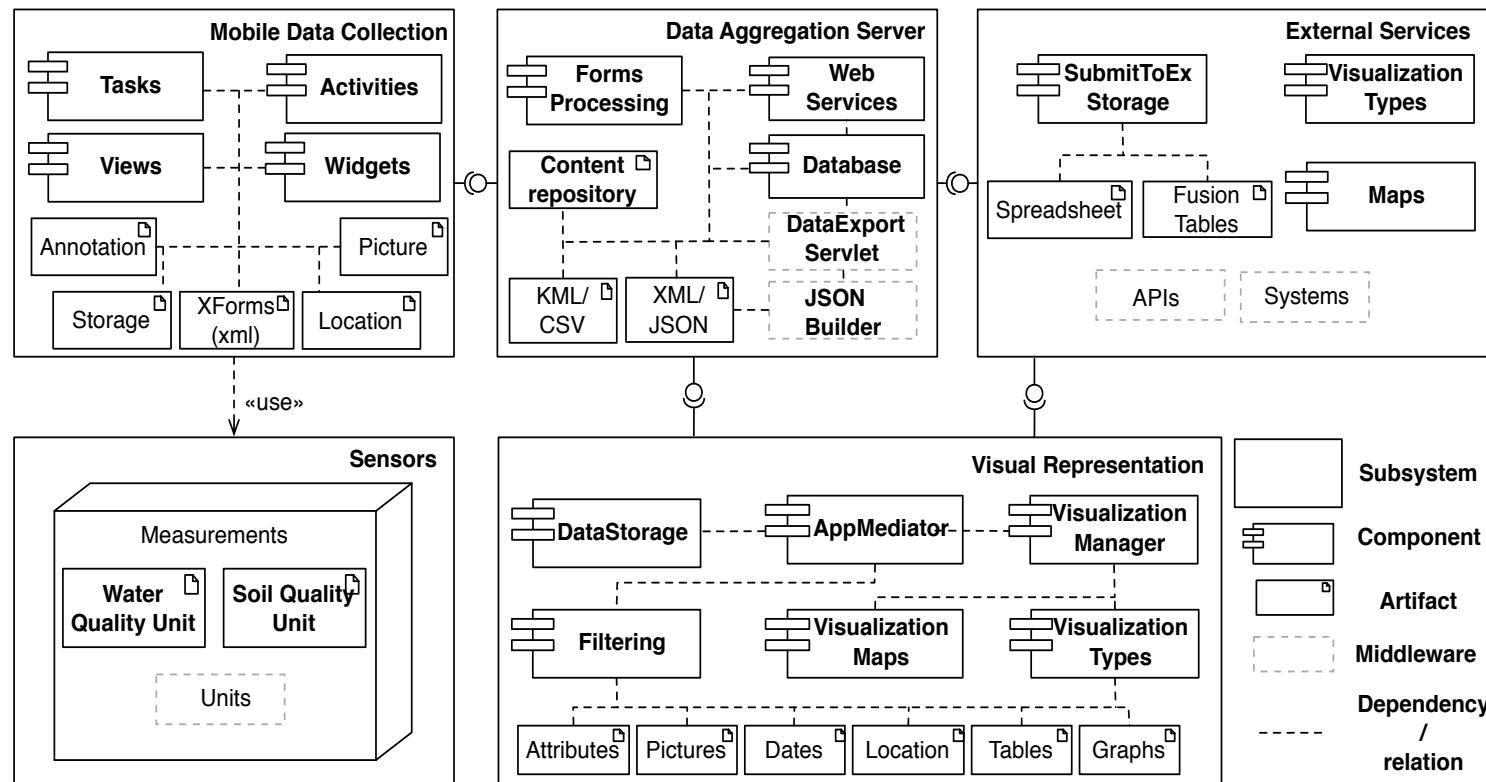
Evolutionary

Fifth

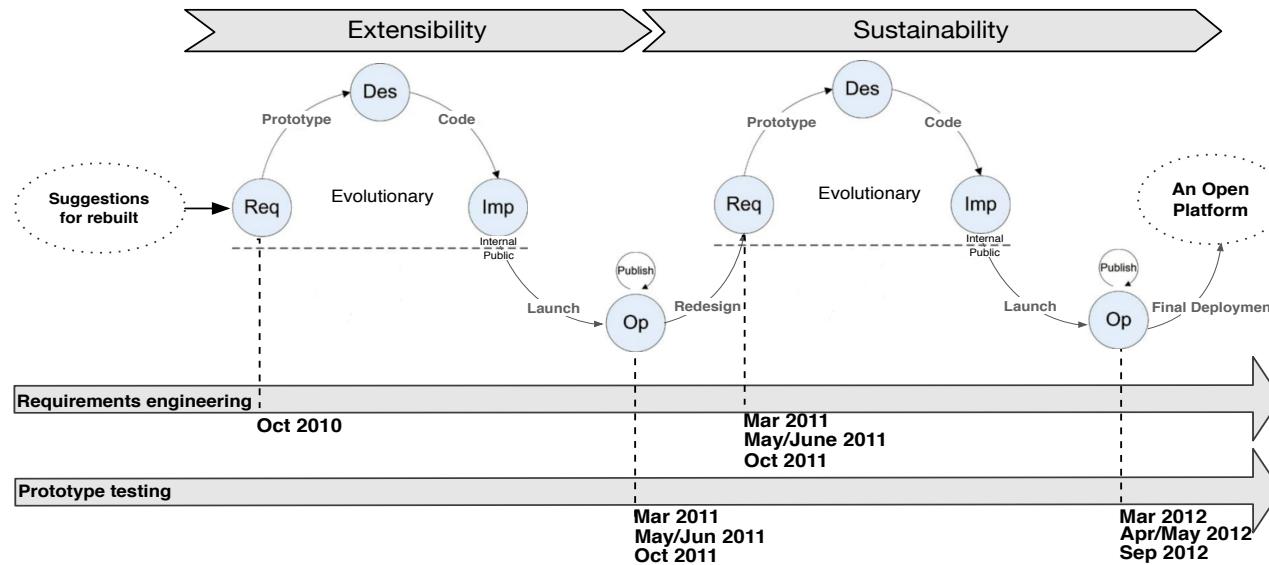
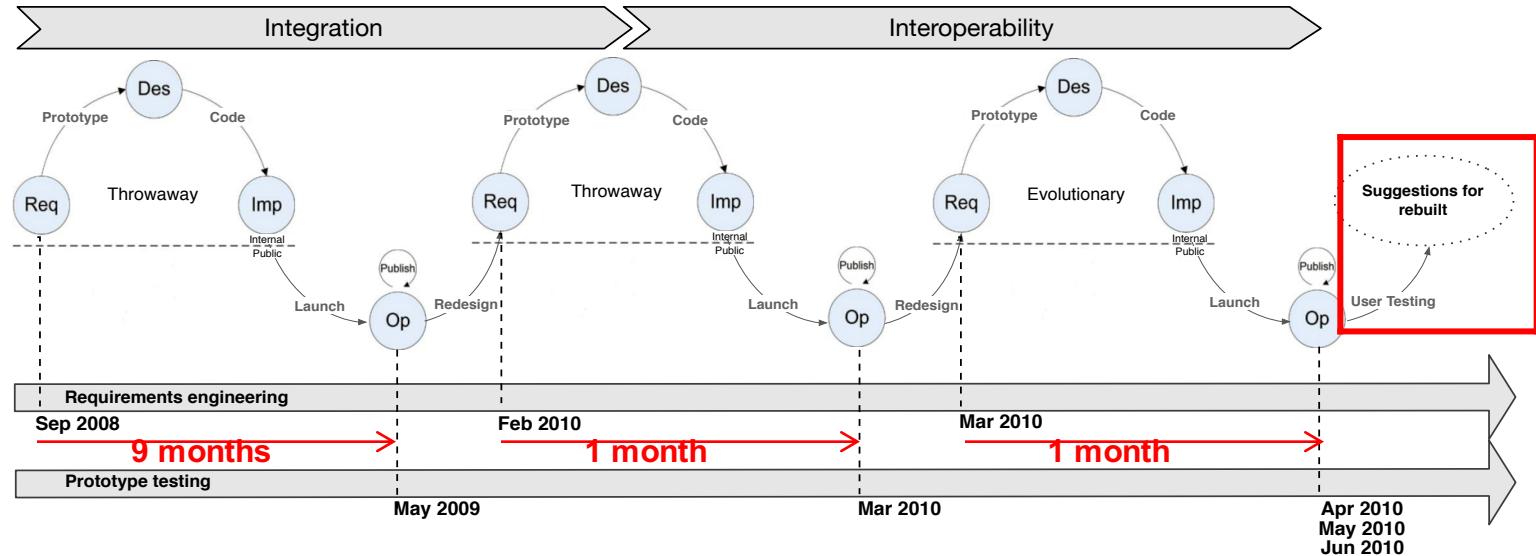


Evolutionary

An overview of the final architectural components and artifacts



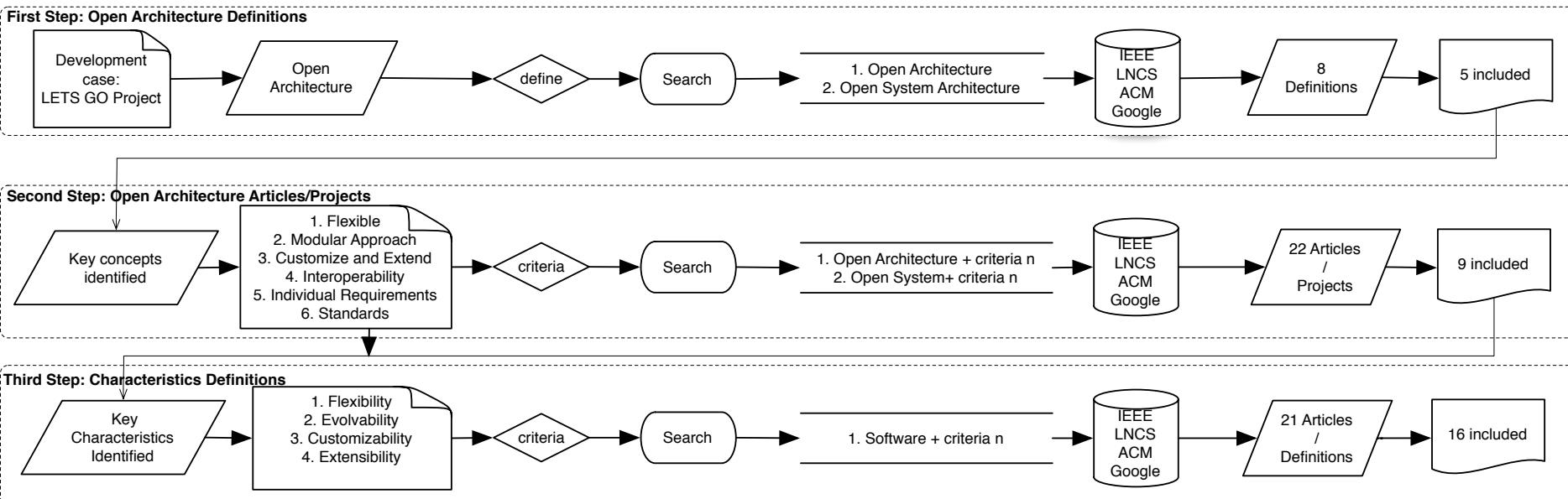
The Evolution of the System - Analysis



Building/Exploring the Open Architecture

- The research efforts demonstrated that a combination **of service-oriented approaches** and **modularity** with **open source components** and **open standard data formats** guided us exploring the notion of ***open architecture*** and adopting these ideas in our architectural decisions.
- *Architectural aspects are defined as: “the set of principal design decisions made about a system; it is a characterization of the essence and essential of the application”* (Taylor et al, 2009)
- In the scope of this research the openness of the architecture is related to the ability of the system to grow in terms of new services, devices, and subsystems attached to it.

Survey approach - the characteristics of open architecture

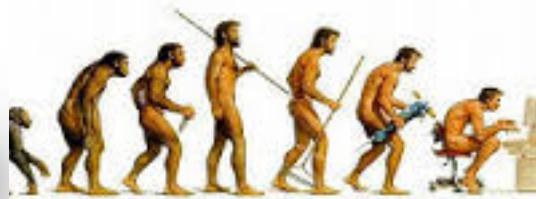


Towards openness: the open architecture approach

- Open architecture in the area of web and mobile design and development is characterized:



Flexibility



Evolvability



Customizability



Extensibility

- system integration and data interoperability
- *grow and evolve over time* in terms of the new services, devices and subsystems attached to it.
- *service-oriented approaches* and modularity with *open source components* and *open standard data formats*
- that allow the software system to easily address *dynamic requirements* by reducing development and deployment time.

Open Architecture characteristics

A web and mobile software application based on an open architecture approach should be considered:

Flexible: if it provides solutions that can be used by users in a wide variety of settings and situations by easily addressing different user's requirements with minimum delays.

Evolvable: if the system can easily be modified to meet new, individual and dynamic requirements by minimizing costs.

Customizable: if it allows users to easily customize features in the system and address their specific individual needs, usually without having access to the source code, thus reducing the deployment time.

Extensible: if it offers easy integration possibilities with other systems and/or tools that take into consideration future growth by expanding/enhancing the architecture with less costly upgrades.

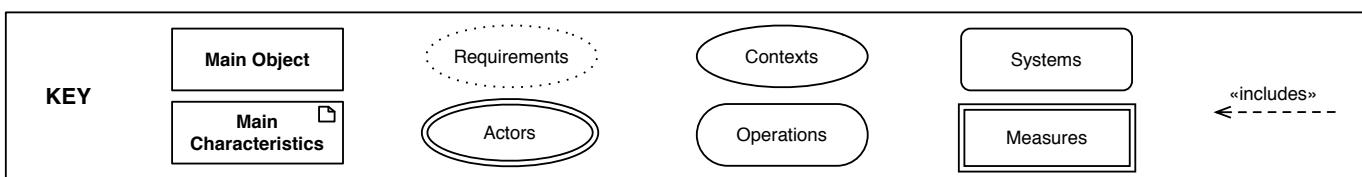
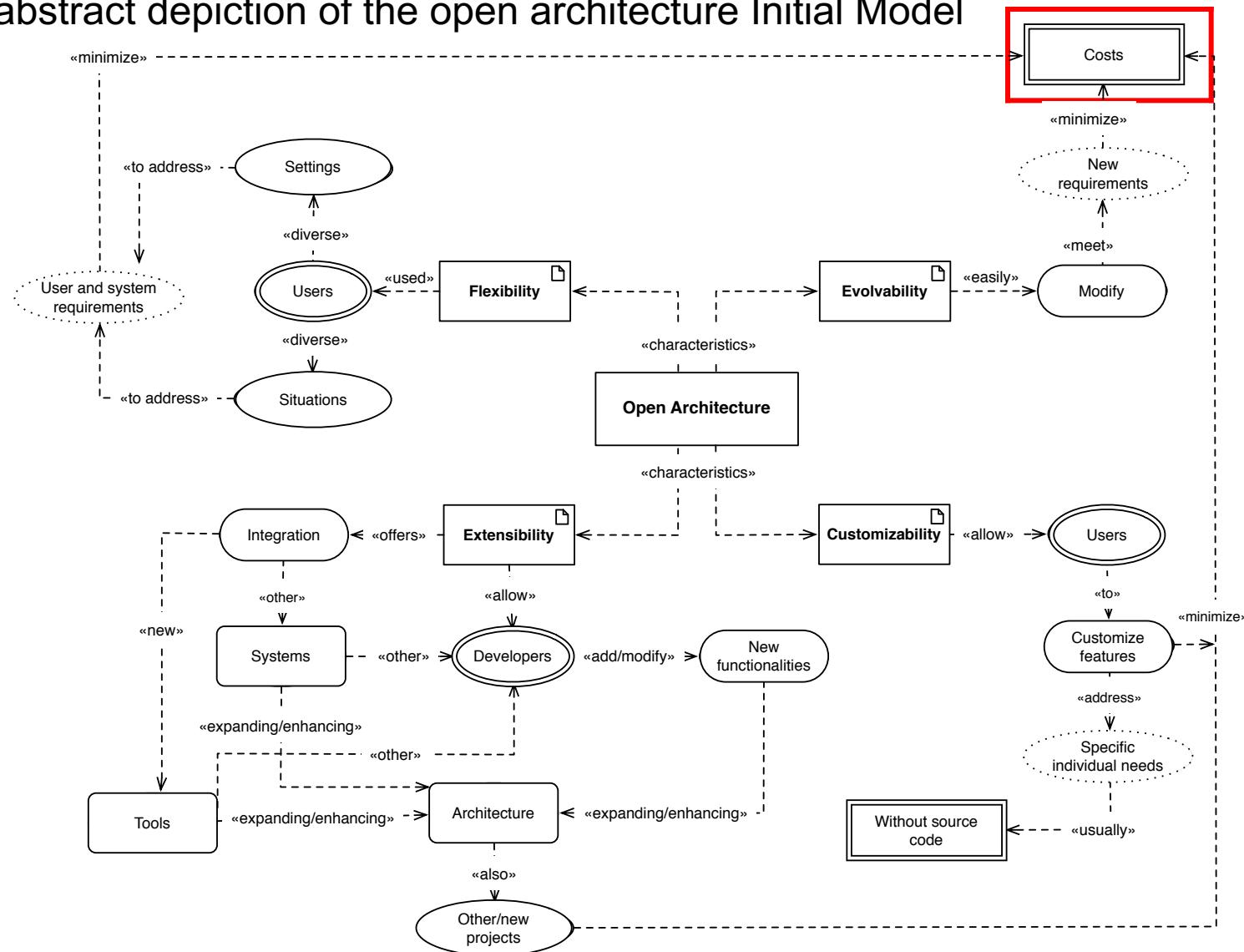
The identified needs

Based on the intensive development efforts throughout the project lifecycle and the continuous deployment and testing with users, we have been able to identify several needs that affected the openness of the application architecture.

The identified NEEDS:

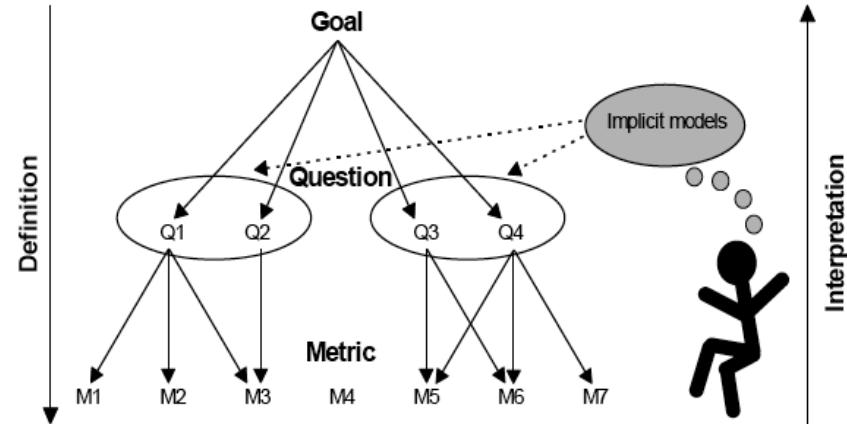
- The need to use Open Data Standard formats (ODS)
- The need to support Diverse Settings and dynamic Change of Environments (DSCE)
- The need to Change and Adapt to New Technologies (CANT)
- The need to Extend with Existing and New Tools (ENET)
- The need to Add/Upgrade/Modify features (AUM)
- The need to reduce the development and deployment time

An abstract depiction of the open architecture Initial Model



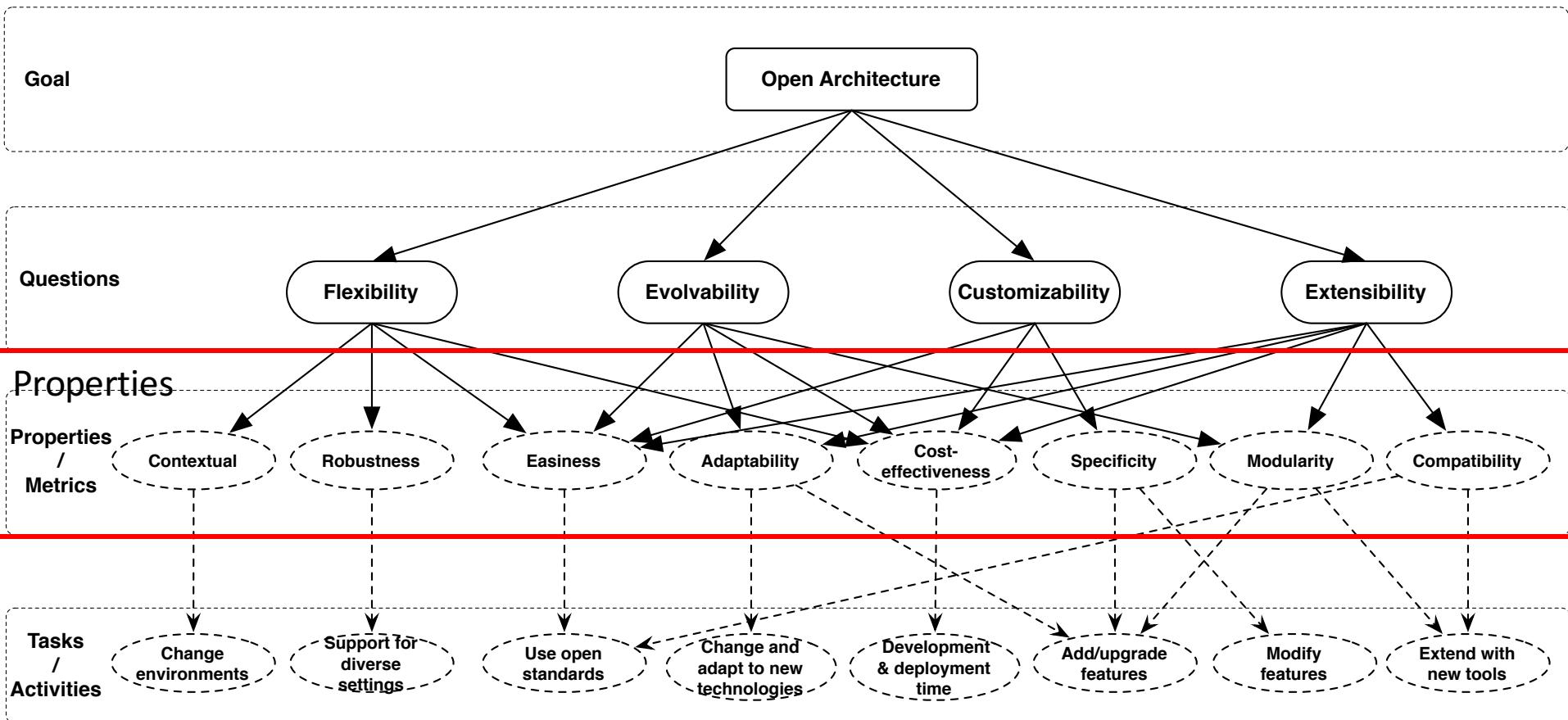
Open Architecture Properties for Validity

- We utilize Goal, Question, Metric approach:
- The GQM approach deals with goal-oriented measurement, '*defines a certain goal, refines this goal into questions, and defines metrics that should provide answers to these questions*' (Basili and Weis, 1984; Solingen and Berghout, 1999)



Object	Open Architecture approach
Purpose	Explore and Analyze
Focus	Possibilities for offering Flexible, Evolvable, Customizable, and Extensible web and mobile software
Viewpoints	Users/designers/developers
Environment	Variety of settings and contexts/other projects

Applying GQM



Properties of Open Architecture

Characteristics:

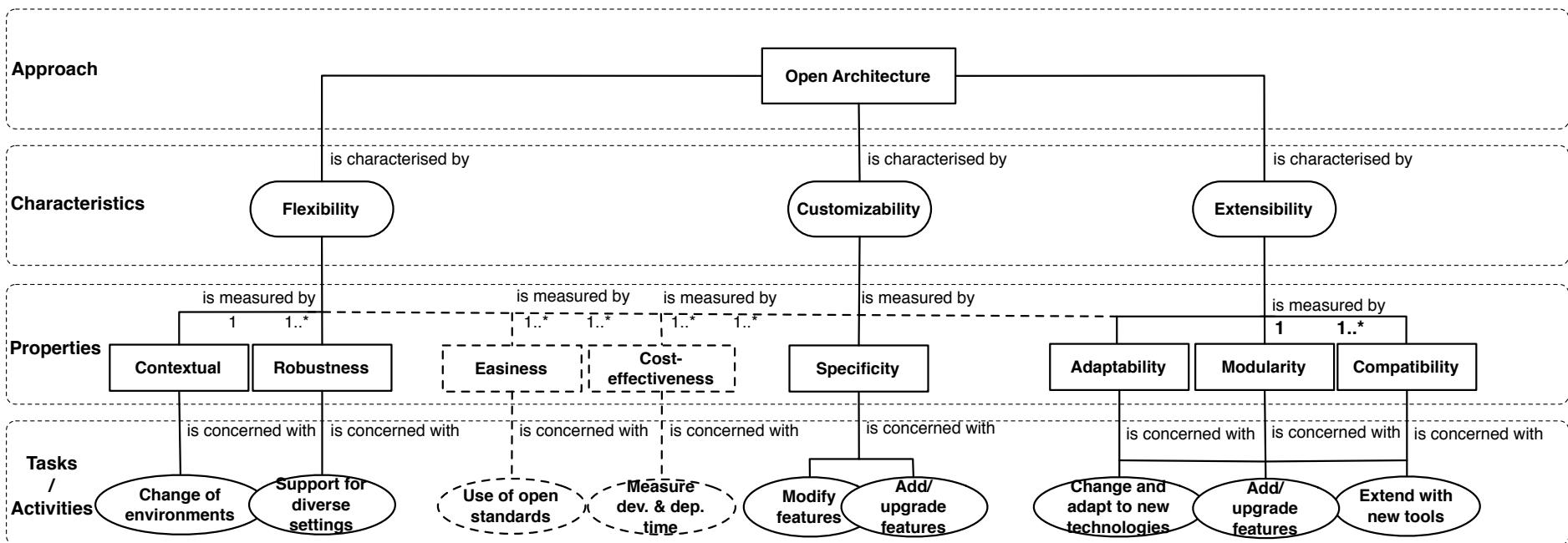
	Flexibility	Evolvability	Customizability	Extensibility
Contextual	X			
Robustness	X			
Easiness	X	X	X	X
Adaptability		X		X
Cost-effective	X	X	X	X
Specificity			X	
Modularity		X		X
Compatibility				X

Mapping the needs with Open Architecture characteristics

	Flexibility	Evolvability	Customizability	Extensibility
The need to provide support for dynamic changes in environments	X			
The need to provide support for diverse settings	X			
The need to use open data standard formats	X	X	X	X
The need to change and adapt to new technologies		X		X
The need to reduce the development and deployment time	X	X	X	X
The need to modify features			X	
The need to extend with new and existing tools		X		X
The need to add/upgrade features		X	X	X

Full cross matching, when it comes to the use of open standards and the reduced development and deployment time.

Refined Model



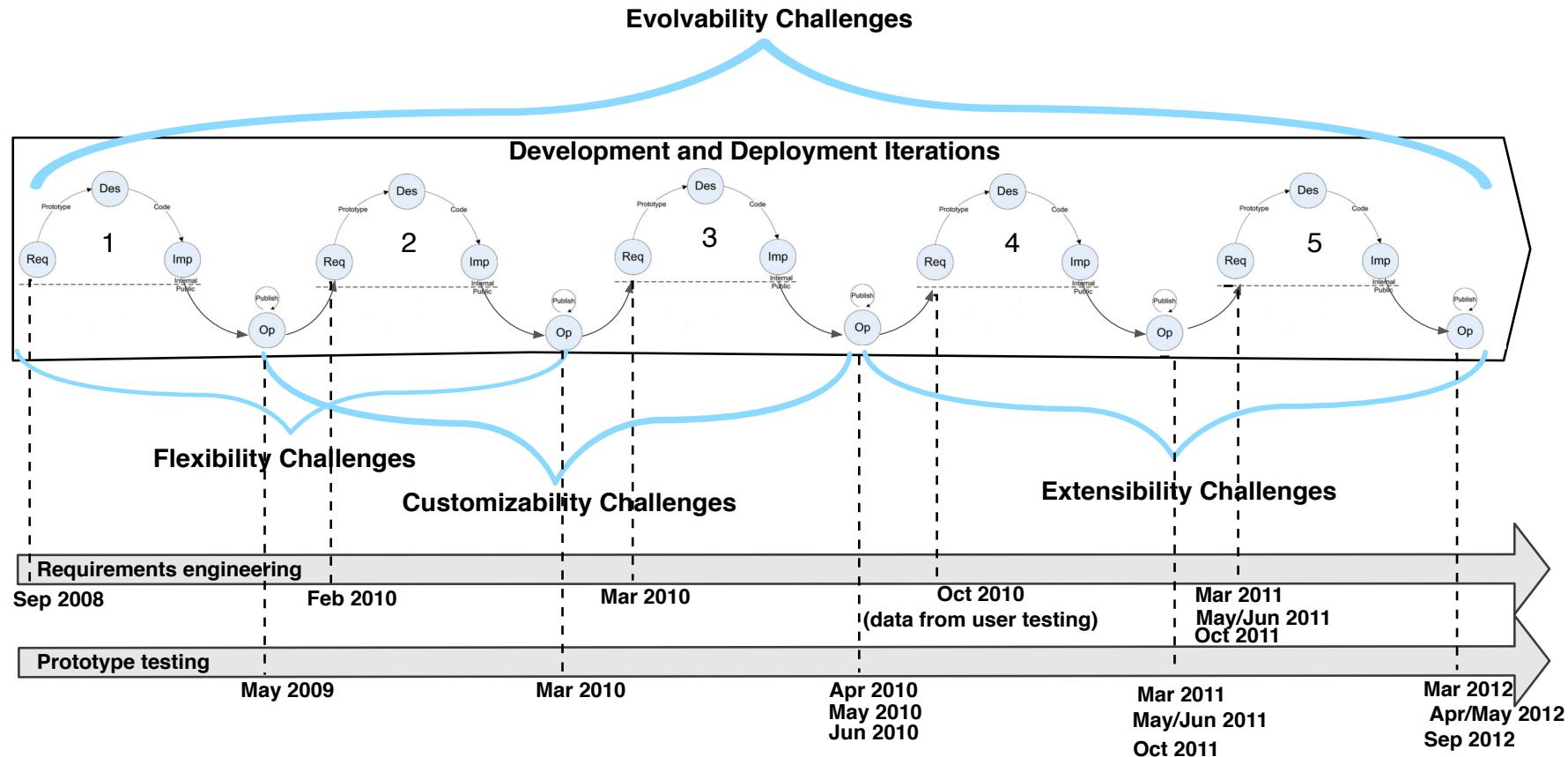
Open Architecture - Redefined

- Open architecture in the area of web and mobile design and development is defined and primarily characterized by having the features of *flexibility*, *customizability* and *extensibility*.
- Open architecture should offer possibilities in terms of system integration and data interoperability as well as the ability of the software to grow and evolve over time in terms of the new services, devices and subsystems attached to it.
- Open architecture combines service-oriented approaches and modularity with open source components and open standard data formats that allow the software system to easily address dynamic requirements by reducing development and deployment time.

Validity cases in summary

Validity cases in summary				
Properties	LETS GO	Case 1	Case 2	Case 3
Contextual	✓		✓	✓
Robustness	✓		✓	✓
Easiness	✓	✓	✓	✓
Adaptability	✓			✓
Cost-effective	✓		✓	✓
Specificity	✓		✓	✓
Modularity	✓	✓	✓	✓
Compatibility	✓	✓		✓

Reflection



Summary

- For developing web and mobile software:
 - A special attention from the day one of the development process needs to be paid to characteristics:
 - Flexibility, Evolvability, Customizability and Extensibility
- This enables your system to become an Open Architecture System
 - Reducing development time
 - Easily integration of new techn
 - Brings quality dimension in sof
 - Addressing dynamic requireme
 - Addressing fragmentation issue



OPEN AND REMAINING CHALLENGES

Standards



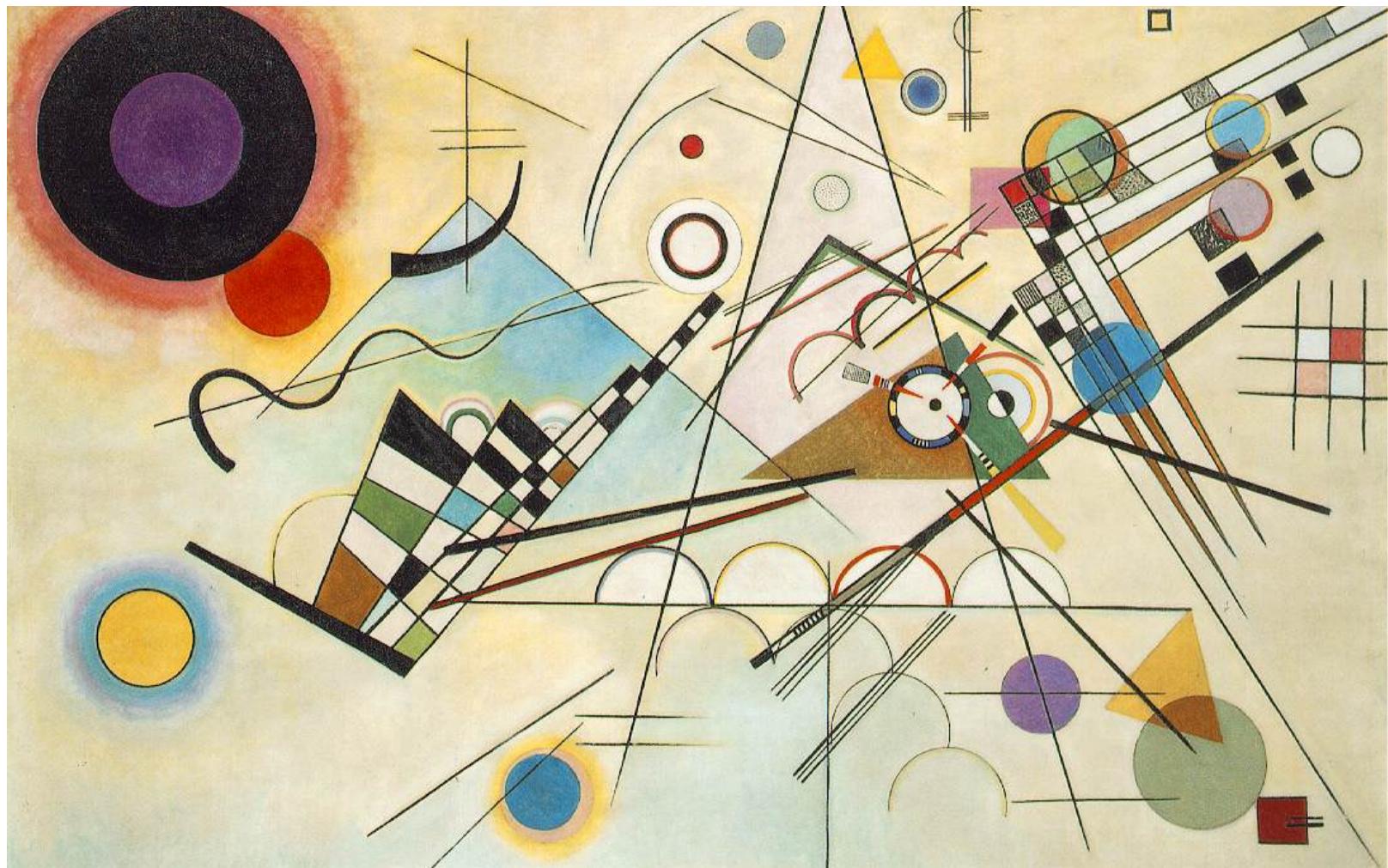
Security and Privacy



Big data



~~Engineering~~ Composition



Kandinsky painting - Composition VIII (1923)



Don't think about how to build an **App**
but
think about how to build a great **Service**

M, Rowehl, Ecosystem overview, 2011

Selected Publications (more than 20)

- **Vogel, B.**, Kurti, A., Kilamo, T. (2015). Teaching Distributed Agile Development to Software Professionals: A Flexible Approach, Proceedings of the 2015 European Conference on Software Architecture Workshops, ACM, Dubrovnik, Croatia.
- Ferati, M., **Vogel, B.**, Kurti, A., Raufi, B., Salvador, D. (2015). Web Accessibility for Visually Impaired People: Requirements and Design Issues, (accepted), Book chapter on *Usability and Accessibility focused Requirements Engineering*, LNCS.
- Weyns, D., Caporuscio, M., **Vogel, B.**, Kurti, A(2015). Design for Sustainability = Runtime Adaptation U Evolution, Proceedings of the 2015 European Conference on Software Architecture Workshops, ACM, Dubrovnik, Croatia.
- **Vogel, B.**, Kurti, A. (2015). An Open Architecture Approach, work in progress, *Journal of Systems and Software*.
- **Vogel, B.** (2014). An Open Architecture Approach for the Design and Development of Web and Mobile Software. *PhD Thesis in Computer Science, Linnaeus University Dissertations No 196/2014*, ISBN: 978-91-87925-24-5, Faculty of Technology at Linnaeus University (LNU) Växjö, Sweden
- **Vogel, B.**, Kurti, A., Mikkonen, T., Milrad, M. (2014). Towards an Open Architecture Model for Web and Mobile Software: Characteristics and Validity Properties. In *Proceedings of the 38th Annual International Computers, Software & Applications Conference (COMPSAC'2014)*, IEEE, Västerås, Sweden, July 21-25, 2014.
- **Vogel, B.**, Kurti, A., Mikkonen, T., Milrad, M. (2014). From Architectural Requirements towards an Open Architecture for Web and Mobile Societal Applications. *1st International Workshop on Inclusive Web Programming - Programming on the Web with Open Data for Societal Applications* (IWP 2014), at ICSE 2014 Workshops - 36th International Conference on Software Engineering (ICSE 2014), ACM, May 31 - June 7, 2014, Hyderabad, India.

Selected Publications (more than 20)

- Vogel, B., Kurti, A., Milrad, M., Johansson, E., & Müller, M. (2014). Mobile Inquiry Learning in Sweden: Development Insights on Interoperability, Extensibility and Sustainability of the LETS GO Software System. *Journal of Educational Technology & Society* (ET&S), 17 (2), 43-57.
- Vogel, B. (2013). Towards Open Architecture System. *9th joint meeting of the European Software Engineering Conference and the ACM SIGSOFT Symposium on the Foundations of Software Engineering* (ESEC/FSE 2013), 2013, ACM.
- Vogel, B., Kurti, A., Milrad, M., Mikkonen, T. (2012). Architectural Concepts: Evolution of a Software System Across Design and Implementation Stages in Dynamically Changing Environments. *Proceedings of the IEEE 36th Annual International Computer Software and Applications Conference Workshops* (COMPSAC 2012), IEEE Izmir, Turkey, July 16-20, 2012.
- Vogel, B., Kurti, A., Milrad, M., and Kerren, A. (2011). An Interactive Web-based Visualization Tool in Action: User Testing and Usability Aspects. In *Proceedings of the 11th IEEE International Conference on Computer and Information Technology* (CIT '11), to be held in Pafos, Cyprus, 31 August-02 September, 2011. IEEE Computer Society Press.
- Vogel, B., Kurti, A., Spikol, D, & Milrad, M. (2010). Exploring the benefits of open standard initiatives for supporting inquiry-based science learning. *Proceedings of the Fifth European Conference on Technology Enhanced Learning, EC-TEL 2010*, held in Barcelona, Spain, September 28 - October 1, 2010, Lecture Notes in Computer Science, Springer-Verlag, Berlin/Heidelberg. pp. 596-601.
- Vogel, B., Spikol, D., Kurti, A., & Milrad, M. (2010). Integrating Mobile, Web and Sensory Technologies to Support Inquiry-Based Science Learning, In *Proceedings of the Sixth IEEE International Conference on Wireless, Mobile and Ubiquitous Technologies in Education* (WMUTE 2010)", held in Kaohsiung, Taiwan, April 12-16, 2010.

Awarded best student paper

• • •

Thank You!