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Architecting Mobile Enterprise App

A Modeling Approach to Adapt Enterprise Applications to the Mobile

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Abstract

Mobile business applications have become the trend of the day. However, studies suggest that most of the mobile business applications so far are lightweight, consisting of a few thousand lines of code. Indeed, most of these mobile business apps are nothing more than specialized information query engines relying on the backend server to process the queries. However, we now see a trend toward making enterprise-size apps mobile[1]. But if the "design while coding" approach may have worked for limited size applications, this is clearly not enough for enterprise-size apps. Indeed, such applications will encounter the same maintenance problems as traditional applications. In this paper we propose an agile architecting approach to adapt the enterprise apps to the mobile. This approach promotes the code understandability Quality Attribute to lower the future maintenance cost of the application.

Categories and Subject Descriptors 1.2.10 [**Software Engineering**]: Software Architectures – Languages, Patterns

General Terms Documentation, Design, Theory

Keywords Robustness diagram, Architecture patterns, Quality Atributes, Tactics, Mobile enterprise app design.

1. Introduction

According to several surveys, mobile business applications are the trend of the day, although not all surveys agree on the strength of the trend [3][15] [29]. However, studies suggest that most of the mobile business apps are lightweight, consisting of a few thousand lines of code [27][15]. Indeed, first generation mobile business apps were little more than specialized information query engines relying on the backend server to process the queries. With the growing interest in B2B and B2E mobile apps [15], mobile development becomes mainstream.

[1] Such as the IBM's Mobile First initiative.

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But, if the "design while coding" approach may have worked for first generation mobile apps, this is clearly not enough for the new generation of enterprise-size apps. Indeed, such application will likely encounter the same maintenance problems as traditional distributed application, with a few more specific problems due to mobility. Therefore, time is right for the adoption of a more formal, but agile, development process such as Scrum [9] that was lacking so far. The challenge is really to "scale up" mobile development [27]. Although many issues must be resolved, in this paper we concentrate on the architectural issues of migrating enterprise apps to the mobile device, while keeping the system "understandable" to lower the cost of maintenance[2]. Again, this architecting phase must be compatible with an agile methodology. This is why we introduce a pattern-based technique supported by the well-known Robustness Diagrams of UML [22][1]. Both these approaches are not new, but we found them especially adapted to the agile architecting of mobile applications. It is worth mentioning that some researchers do believe in the MDD/MDE approach as a solution to the "code once deploy everywhere" paradigm [5] [21]. However, this approach is controversial since it only speeds up a tiny part of the software development lifecycle, namely code generation [10]. Moreover the detailed models required to generate the code are not compatible with the agile approach.

In section 2, we present the challenges of the migration of an enterprise application to the mobile platform. In section 3 we provide a small reminder of the robustness diagram concepts. In section 4 we show how the semantics of the software components can be specified using the robustness objects and the CRC cards. In section 5 we elaborate on the development of distributed and mobile applications. In section 6 we present the way the mobile and server part of the application architecture can be modeled using the robustness diagram. Section 7 addresses some important quality attributes of the mobile version of the application. Finally section 8 concludes the paper.

2. Migrating enterprise applications

Enterprises have developed hundreds of applications over the years. When an enterprise application must go mobile, the engineering question is [24]: "How do I transform my existing enterprise application to be mobile enabled". What people want to achieve is to offer the same services on the mobile platform as on the desktop and to allow the users to be immediately comfortable

[2] Nowadays it is widely known that the maintenance part of the software lifecycle amounts to about 60%-80% of the total cost [25], among which code understanding is estimated to take the the lion's share (about 50%).

with the mobile version. Some researchers addressed the challenge of producing mobile app for several mobile platforms while minimizing the re-development effort through a Model Driven Development approach [21] [5][19][13][24]. But we targeted another challenge: how to build the mobile version of an existing enterprise application while maximizing its understandability. To support this goal, we propose a new tactic [4] for the Understandability Quality Attribute that we call "Mimic Architecture": *the best way to make some software artifact understandable by a maintenance engineer is to build it similarly to some other artifact the maintenance engineer already understand*s. Consequently we propose to mimic, on the mobile, the architecture of the client-server version of the application (below, we call it the *desktop version* since the front-end is a desktop machine). Of course platform constraints will somewhat impact the final design of the technical architecture on the mobile. But our tactic will allow the maintenance engineer to be comfortable with the mobile version of the application while enabling him to adapt it to the specifics of the platform. Now what we need is an agile way to model the architecture. We found the Robustness Diagrams of UML [22] (also called the Analysis Diagram) to be a perfect fit for the task, targeting the right level of detail. The use of the robustness diagram could appear old-fashioned compared with modern software architecture languages. But Rosenberg et al. wrote [23] in the context of the Iconix methodology p.41 : "Robustness diagrams: We "rescued" these from Jacobson's Objectory work because we discovered that use case–driven development simply worked better with these diagrams than without them". We could say the same in our context. Hence, starting from a scenario-based architecting process using the robustness diagram, we show how the application of well-known patterns helps the mobile application designer to represent the key design elements. Finally it must be highlighted that robustness modeling is independent of any specific implementation technique and operating system.

3. Background : Robustness Diagrams

The Robustness diagram emerged from the work of Ivar Jacobson in the early 90's [16]. It is included in UML (the analysis diagram[3]) and is one of the models of the Unified Process (UP). Some agile development methodologies have embraced the robustness diagram as the first (or even the only) step in the building of the architecture of an application (see for example Agile Modeling [2] and Iconix [23]). Robustness diagrams use 3 UML stereotypes called the *Boundary*, the *Controller* (or Control Object) and the *Entity* which have their own specific icon. They represent the three fundamental roles software elements could play in a system: communicating with the outside world (Boundary), storing information (Entity) and processing information (Controller). The latter also coordinates the work of the other two elements (Boundary and Entity) to implement a use-case. Each use-case could be assigned either a single Controller to manage all the activities in the use-case or several Controllers to manage each individual subtasks in the use-case [1]. To represent the external entities (user or device) with which our own system must communicate, UML uses the *Actor* modeling element. Although Jacobson initially recommended using one Boundary per actor [16], the trend today for human actors is rather to use one Boundary per screen or per interaction mode. In figure 1, we present the example of a robustness diagram for the *Borrow Book* use-case of a simple library management system. *User* and *Printer* are actors. *QueryScreen* and *PrinterInterface* are Boundary objects, *Manage borrowings* is a Controller and finally *Book* and *Borrower* are both Entity objects. The links between the object represent collaborations (as identified in the CRC cards [28] of each object).

[3] Robustness diagram are supported in Rational Software Architect when applying the UML profile : "RUP Analysis" to a model

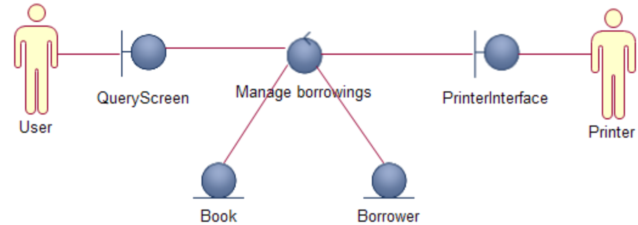


Figure 1. Robustness diagram

These five objects represent the high level roles of the software elements required to implement the use-case. It is important to highlight that Boundaries are only *interfaces* to communicate with the actors. If the communication with an actor is complex, the handshake must be processed by a specific Controller [16]. In the example above, if the communication with the Printer is complex we could add a specific Controller to manage it. This diagram is well suited to the description of architectures at the communication, data access and processing element level. This is indeed the right level of description to design distributed application architectures, without delving into technical details that would hide the key elements' responsibilities.

Use case analysis is basically conducted in three phases.

First: identify the candidate objects to implement the use-case:

- Identify the actors and assign one Boundary object for each actor (one per screen or interaction mode for human actors).
- Identify the information sources accessed in the use-case and create one Entity object per source.
- Identify the subtasks in the use-case and assign a Controller to each of them. Also, assign a Controller to each complex communication with an actor.

Second: analyze each step of the use-case and assign responsibilities to each of the robustness objects involved in the step. The result of this analysis can be documented using CRC cards [28].

Third, verify that the collaboration of all the analyzed robustness objects do implement the behavior specified by the use-case. Sequence diagram are sometimes used to perform this validation.

The integrity rules for robustness diagrams are simple [22]:

- Actors can only communicate with Boundaries.
- Boundaries can only communicate with Controllers.
- Entities can communicate with Controllers and Entities.
- Controllers can communicate with all objects.

This technique works well to represent the responsibilities of the components of a distributed application [18]. When an application is split in two or more subsystems distributed over a network, each subsystem sees the other subsystems it must collaborate with as actors (Figure 2).

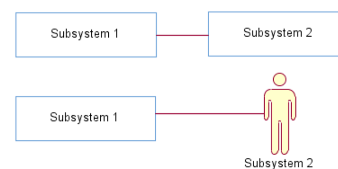
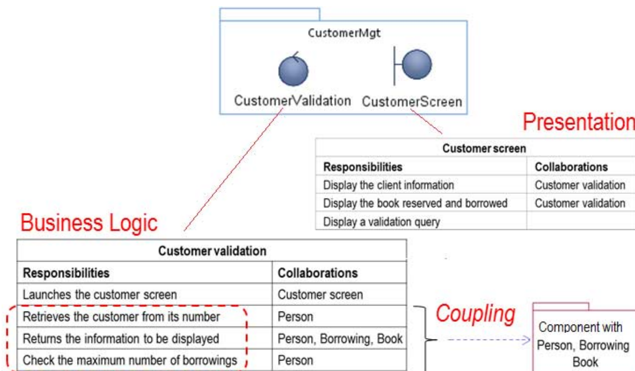


Figure 2. Modeling the environment as actors

Boundaries are therefore used to communicate with these actors. Following the same idea, from a mobile device the server system it must collaborate with is considered as an actor. The same is true for the mobile device seen from the server.

4. Component's functional semantics

When designing the large grain logical architecture of an application, which is done early in a project, one key step is to identify the components and assign them responsibilities. This is challenging since the components' responsibilities come from the contained implementation classes which are unknown at this stage. However, the robustness diagram can help. Indeed, by assigning robustness objects to a component we simultaneously define its functional semantics. The latter will be derived from the contained robustness objects' responsibilities. The size of the components (the number and kind of robustness objects contained) is decided based on the coupling, cohesion and reuse potential of the component. Cohesion and coupling can be determined from the collaboration among the robustness objects that is described in their CRC cards [28]. In figure 3 we present the way the semantics is assigned to a component which comes from the responsibilities of the contained robustness objects. As we can observe, the *CustomerMgt* component contains two robustness objects. Its responsibilities are therefore those described in the contained objects' CRC card. In the *CustomerValidation* CRC card we see that the Controller must collaborate with the Entities *Person*, *Book* and *Borrowing* located in another component. Therefore this creates some coupling between both components.



Customer screen	
Responsibilities	Collaborations
Display the client information	Customer validation
Display the book reserved and borrowed	Customer validation
Display a validation query	

Customer validation	
Responsibilities	Collaborations
Launches the customer screen	Customer screen
Retrieves the customer from its number	Person
Returns the information to be displayed	Person, Borrowing, Book
Check the maximum number of borrowings	Person

Figure 3. Component semantics

As the next step in the design of a logical architecture, the components can be arranged in layers to reflect their reuse potential. Figure 4 presents the logical architecture of our simple library application. We only present the *borrow book* service which uses the *customer validation* service. In the application-specific layer we place the *Borrowing* component which represents an end-user service specified by a use-case. This component uses the *CustomerValidation* component whose responsibility is to validate the information about the customer (display of the customer's information, validate the number of books borrowable simultaneously,…). Since the latter is potentially reusable by some other application-specific component, it is located in the domain-specific layer. The *DOM* component (Domain Object Model) contains the access to the information data sources, in particular the information on users, books and borrowings. Finally the *System* component is responsible for the printing services. It contains the printer interface (Boundary) and a Controller used to manage the communication with the printer which is supposed to be complex. In particular, this Conroller would format information before sending it to the printer.

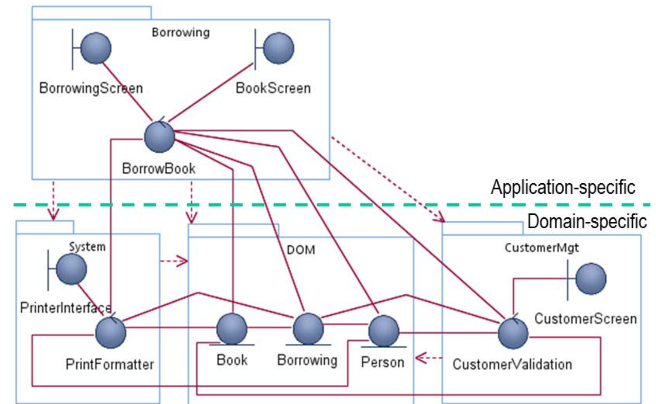


Figure 4. Logical architecture of a simple library system

5. Distributed vs mobile computing

Traditionally, applications get distributed to satisfy several quality attributes such as *performance*, *reliability*, *security*, etc [26]. The implementation is usually distributed among several powerful server machines in well monitored environments. But in the case of the mobile version of an enterprise application the situation is quite different. The motivation is to make information more accessible by adding a new information distribution channel. But the mobile devices are neither as powerful nor as seamlessly connected as the server machines. In particular, when information is stored both on the mobile and on the server, intermittent network access may lead to a partition [6]. Therefore, the quality attributes to address with the mobile version of the enterprise application are

1. *Usability*
2. *Performance*
3. *Maintainability*
4. *Consistency of application's data*
5. *Availability of service*
6. *Partition tolerance*

Although *usability* and *performance* have probably been properly addressed when building the desktop version of the enterprise application, they must be reworked to adapt it to the mobile device's environment (screen size, specific input devices, low communication bandwidth,…). *Maintainability* must also be addressed because it is highly desirable not to worsen the maintainability of the application when moving it to the mobile. The last three quality attributes are closely interdependent through the famous CAP theorem [6]. When the mobile device is disconnected from the network, users of the enterprise app should nonetheless be able to continue working with the device. In this case, the challenge is to manage the partition explicitly by properly detecting it and recovering it [6]. For example this challenge has been faced by the designers of Agropedia [20], a big agricultural knowledge base and social media in India, when moving to the mobile. Indeed, when working in a rural location in India, the network may not be available at all but the users must nonetheless be able to work with the application[4]. In order to cope with the

[4] T.V. Prabhakar, private conversation, 2013.

problem, the first step to architect the mobile version of the application is to assess the desired value for each quality attribute. Next the application must be architected to comply with these quality attribute values [4]. It is worth mentioning that the Mobile Cloud Computing approach is not an answer to the network availability problem since it requires all computation and data storage be localized in the cloud [11]. This supposes accessibility to the Mobile Network services. As far as application architecture is concerned, to enhance maintainability all these constraints and challenges must explicitly be dealt with in the design. This is an instance of the Designers' Paradox [14]: "If you want to be flexible and independent of something, it must be explicitly covered in the design; otherwise you risk an implicit coupling that resists change". These design constraints will therefore be explicitly represented in the robustness model and the responsibilities objects.

6. Robustness diagram for mobile computing

When moving an application to a distributed architecture, a few concepts from the Pattern community are helpful. First and foremost the *Proxy* pattern followed by the *Façade* pattern [7][12]. However, to optimize the understandability of the mobile version of an enterprise app we apply the *Mimic Architecture* tactic i.e. we build, on the mobile, a component topology similar to that of the client-server version and add the communication components on both sides (on the mobile device and on the enterprise server). Next, we carefully adapt this logical architecture to account for the desired quality attributes while trying to maintain the understandability of the resulting architecture. Let us consider again the example of the simple library system architecture (Fig.4). On the server side we must first add the component that will manage the remote access from the mobile device (Fig.5, highlighted).

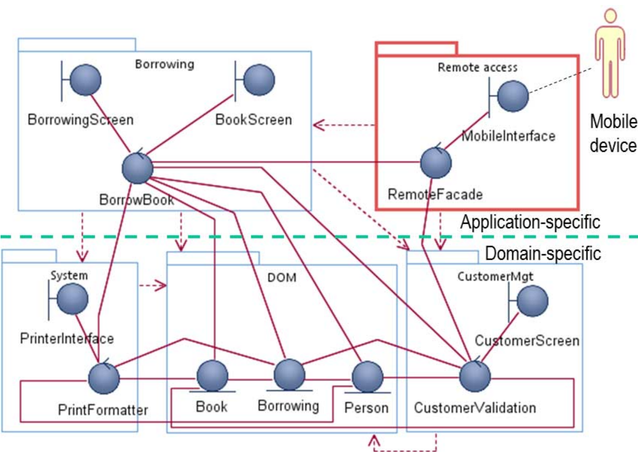


Figure 5. Logical architecture of the desktop version with remote access

At this level of granularity, the mobile device is modeled as an Actor connected to a specific Boundary (*MobileInerface*). Since the communication is complex, we must manage it explicitly. This is represented by the Controller object called *RemoteFacade*. Indeed this represents a *Façade* because all the services offered by the enterprise server will be access through this object. The communication component must be located in the application specific layer because it will expose services implemented by objects in the same layer and the layer below (*BorrowBook* and *CustomerValidation*). Therefore it cannot be located in the domain specific layer to comply with the strict top-down access principle among the layers. Now we must model the mobile device's logical architecture. We start with the same architecture as the desktop version but replace the Controllers with Controller proxies. At this level of design, proxies must be understood as *responsibility proxies*. Indeed they have the same responsibilities as their server's counterpart but will actually forward some or all of the responsibility requests to them. The choice of the request to process locally or to forward to the server will depend on the desired quality attributes (availability, performance, consistency of data, partition tolerance). Finally we must also add an extra component that will manage the remote access to the server (Fig.6, highlighted)

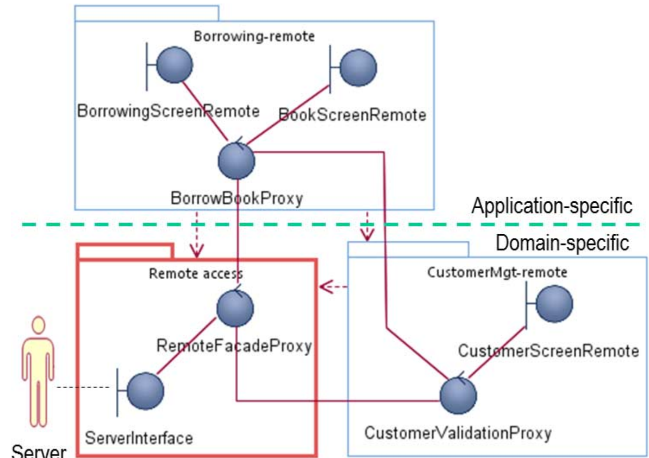


Figure 6. Mobile's logical application architecture

All the Boundaries but *ServerInterface* represent the UI on the mobile device and are therefore specific to the device. The *BorrowBookProxy* and *CustomerValidationProxy* Controllers expose the same services as their server counterpart. They process the requests issued from the screens either locally or by forwarding the request to their server's counterpart. However, these proxies do not communicate with the remote server directly but through the communication component which contains the *RemoteFacadeProxy*, the counterpart of the *RemoteFacade* on the server The former is the single point of communication with the server. The *RemoteAccess* component on the mobile is not located in the application-specific layer but in the domain-specific layer since it must be accessible from the component in this very layer too (for example the *CustomerValidation-remote* component). This is the only topological dissymmetry between the logical architectures in the mobile and in the desktop versions. It must be highlighted that the mobile application architecture is "lighter" than the desktop version since most of the processing and data are located on the server and accessed through the proxies. But the topology remains globally the same which promotes better understanding by the maintenance engineer (provided that he knows the desktop version of course). The main specific parts in the mobile version of the application are the user interfaces represented by the boundaries in the *Borrowing-remote* and *CustomerValidation-remote* components. They must optimize the usability quality attribute (QA) through the relevant use of the UI tools of the device. The following figure (Fig.7) shows the communication path from a request issued through the *BookScreenRemote* on the mobile device to the book information source which contains the information to be displayed (the detailed information on a book). Although this architecture is simple and optimizes the under-

standability QA hence the maintainability QA, it may not satisfy some of the other QA's. In particular, performance may be heavily impacted in case of poor network connection.

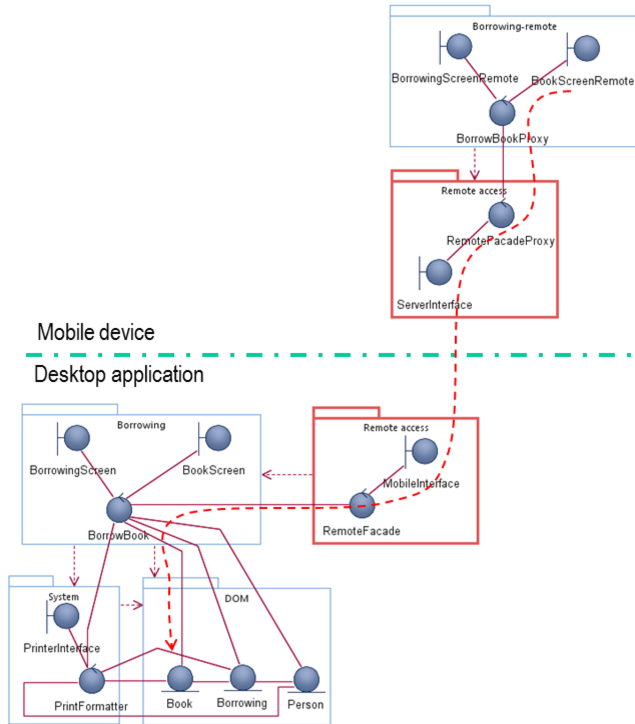


Figure 7. Communication path from the mobile to the server

7. Improving Performance Consistency & Avalability

In the design presented above, a low network bandwidth will affect the Performance QA of the mobile application while an intermittent access to the network will impact its Availability QA.

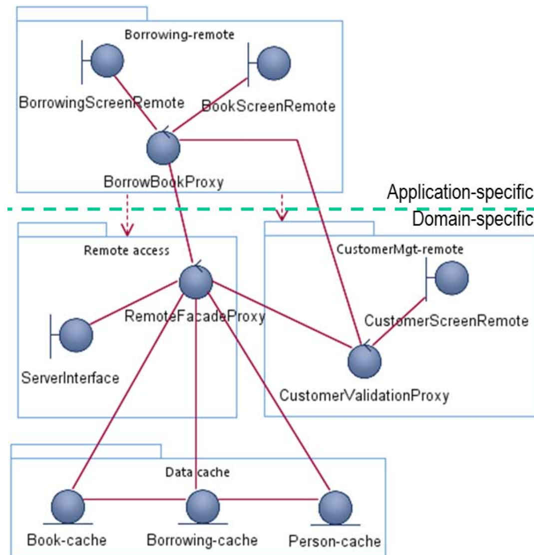


Figure 8. Mobile's logical architecture with data cache

To improve these QAs, one must add some extra responsibility to the proxies. To improve performance problems due to slow network connections, we could implement a data cache managed by the *RemoteFacadeProxy* on the mobile device (*Cache Proxy* pattern [7]), see figure 8. If however the network connection may not be available all the time, we may decide to copy parts of the database on the device which will then lead to a *partition*. In this case the logical architecture on the mobile will even be closer to that of the desktop version (compare with figure 4). Hence, some of the services of the server application will be replicated to the corresponding proxies on the mobile, which will therefore become *semi-proxies*. The choice of the services to replicate depends on the required levels of the Performance, Consistency, Availability and Partition Tolerance QAs. Figure 9 presents such an option.

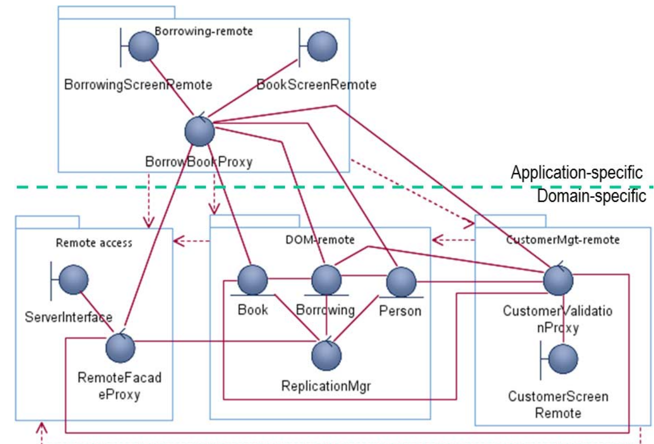


Figure 9. Mobile's logical architecture with DB replication

A new Controller (*ReplicationMgr*) has been introduced in the *DOM-remote* component to manage the replication of data from the server to the mobile device. Finally, on the server side the multiple accesses from several mobile devices could be controlled by the *RemoteFacade* to implement different synchronization strategies using for example the *Proactor* pattern [26]. This behavior will consequently be documented in the CRC card of the *RemoteFacade* object.

8. Conclusion

In this paper we present an approach to model the high level logical architecture of mobile enterprise applications. We applied it to the problem of the migration of a desktop-based client server enterprise application to the mobile. The technique is based on a well-known modeling technique: the UML Robustness Diagram, supplemented by architectural patterns. We have showed how this diagram can help the designers to address and document the key architectural decision in the process, without delving into technical details. We found this technique to be at the adequate granularity level to let the designer select the fundamental architectural options while staying agile. In particular, the distribution of processing and data can easily be represented. In contrast with the approaches based on MDE, our proposal represents a higher level of abstraction and does not target the same issue. Rather than trying to generate code from a model, then requiring this model to include all the specifications to the finest level of logical details, we stay at a higher level of abstraction to represent only the large grain options. To increase the software architecture understandability, we propose a new tactic for the migration of enterprise applications to the mobile: *Mimic Architecture*. This tactic suggests that the software on the mobile be architected similarly to

that of the desktop version. Therefore, the maintenance engineers will be able to immediately understand the role and responsibilities of the components on the mobile since they are supposed to know already the architecture of the desktop version. Our contribution is therefore:

1. To show how the robustness objects can be used to specify the functional semantics of the components of some logical software architecture.
2. To show how the robustness diagram can help with the architecting of the mobile part of an enterprise application.
3. The proposal of a new tactic, *Mimic Architecture*, to improve the understandability hence the maintainability of mobile enterprise apps.

9. State of the art

Although research papers abound in the domain of code writing and generation for the mobile platform, there are almost no references on the migration of enterprise app to the mobile and on the high level modeling of such applications. For example Parada and de Brisolara [21] present and MDE approach for android which target the very detailed level of application architecture. The same is true to the approach of Balagtas-Fernandez [5], Khambati et al. [19], Heitkötter et al. [13] or Roychoudhury and Kulkarni [24]. The proposal of Bowen and Hinze [8] also target the generation of code from models but the latters are much more formal than in our approach. Indeed the generated code can be inputted to a device emulator of their own. Again, in all these approaches, the models required to generate the code are very detailed and obfuscate the key decision to satisfy the QAs. Moreover this level of model design is not very compatible with the agile processes.

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References

[1] Ambler S. *Robustness Diagrams*. http://www.agilemodeling.com/artifacts/robustnessDiagram.htm. (Accessed in August 2013).

[2] Ambler S. *Agile Modeling: Effective Practices for eXtreme Programming and the Unified Process*. Wiley (2002).

[3] Appcelerator/IDC *Q2 2013 Mobile Developer report*. www.appcelerator.com.s3.amazonaws.com/pdf/developer-survey-Q2-2013.pdf. (Accessed in August 2013).

[4] Bass L., Clements P., Kazman R. *Software Architecture in Practice 3rd edition*. Addison-Wesley (2013).

[5] Balagtas-Fernandez F.T. Model-Driven Development of Mobile Applications. *Proc. 23rd IEEE/ACM Int. Conf. on Automated Software Engineering* (2008).

[6] Brewer E. CAP Twelve Years Later: How the “Rules” Have Changed. *IEEE Computer 45(2)* (Feb 2012).

[7] Buschmann F., Meunier R., Rohnert H., Sommerlad P., Stal M *Pattern-Oriented Software Architecture Volume 1: A System of Patterns.* Wiley (1996).

[8] Bowen J., Hinze A. Supporting Mobile Application Development with Model-Driven Emulation. *Proc. of the Fourth International-Workshop on Formal Methods for Interactive Systems* (2011).

[9] Cohn M. *Succeeding with agile: software development using Scrum.* Addison-Wesley (2010).

[10] den Haan J. *Why there is no future for Model Driven Development.* www.theenterprisearchitect.eu/archive/2011/01/25/why-there-is-no-future-for-model-driven-development (Accessed in August 2013).

[11] Dinh H.T., Lee C., Niyato D., Wang P. *A survey of mobile cloud computing: architecture, applications, and approaches.* Wireless Communications and Mobile Computing. wileyonlinelibrary.com, (Accessed in August 2013).

[12] Gamma E., Helm R., Johnson R., Vlisside J. *Design Patterns: Elements of Reusable Object-Oriented Software*. Addison-Wesley (1995)

[13] Heitkötter H., Majchrzak T.A., Kuchen H. Cross-Platform Model-Driven Development of Mobile Applications with MD2. *Proc of the ACM Symposium on Applied Computing (SAC)* (2013).

[14] Hubert R. - *Convergent Architecture: Building Model-Driven J2EE Systems with UML*. Wiley (2002).

[15] IDC Predictions 2013: Competing on the 3rd Platform. www.idc.com/research/Predictions13/downloadable/238044.pdf (Accessed in August 2013).

[16] InfoQ *Survey: The State of Mobile Development in Q3 2013*. www.infoq.com/news/2013/07/state-mobile-2013. (Accessed in August 2013).

[17] Jacobson I. *Object Oriented Software Engineering: A Use Case Driven Approach*. Addison-Wesley (1992).

[18] Jacobson I., Griss M., Jonsson P. *Software Reuse.* Addison-Wesley (1997).

[19] Khambati A., Grundy J., Warren J., Hosking J. Model-driven Development of Mobile Personal Health Care Applications. *Proc. IEEE Int. Conf. of Automated Software Engineering (ASE)* (2008).

[20] Pappu N., Sarkar R., T.V. Prabhakar. Agropedia: Humanization of Agricultural Knowledge. *IEEE Internet Computing 14(5).* (Sept.-Oct. 2010).

[21] Parada A.G., de Brisolara L.B. A model driven approach for Android applications development. *Proc. Brazilian Symposium on Computing System Engineering (SBESC)* (2012).

[22] Rosenberg D. *Use Case Driven Object Modeling with UML : A Practical Approach*. Adison-Wesley (1999).

[23] Rosenberg, D., Stephens, M. & Collins-Cope, M. *Agile Development with ICONIX Process*. Apress (2005).

[24] Roychoudhury S., Kulkarni V. Mobile Enabling Enterprise Business Applications Using Model driven Engineering Techniques. *Proc. 2nd Workshop on Software Engineering for Mobile Application Development MobiCase'11* (2011).

[25] Rugaber S. - Program Comprehension For Reverse Engineering. *Proc. AAAI Workshop on AI and Automated Program Understanding.* (1992).

[26] Schmidt D., Stal M., Rohnert H., Buschmann F. *Pattern-Oriented Software Architecture Volume 2: Patterns for Concurrent and Networked Objects*. Wiley (2000).

[27] Wasserman A.I. - Software Engineering Issues for Mobile Application Development. *Proc. 2nd Workshop on Software Engineering for Mobile Application Development MobiCase'11* (2011).

[28] Wirfs-Brock R., McKean A. *Object Design: Roles, Responsibilities, and Collaborations.* Addison-Wesley (2003)

[29] Zend *Developer Pulse Survey - Second Quarter 2013*. http://static.zend.com/topics/Zend-Developer-Pulse-report-Q2-2013-0523-EN.pdf (Accessed in August 2013).