Integrated solution for field operations

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Abstract: This paper presents the authors' approach to design and to implement mobile applications for field operations. Internal on-field studies can yield the fact that the value-added by mobile solutions is correlated with the easiness of their integration with each other and with the underlying information systems. Moreover, the fast-growing mobile market brings new concepts to the mass and industrial applications design can benefit from these. As a consequence, a simple components-based approach has been applied to design and develop mobile applications for field operations and on-site experiments of the resulting applications have been conducted.

Keyword: field operations; mobile devices; software integration

1 Introduction

Nowadays, the reduction of outages duration is a primary goal for nuclear utilities, in order to maximize the power station availability. One of the potential improvements consists in better integrating field operators within operation teams. A better integration must be achieved by introducing mobile solutions. Up to now, most of the on-field operations rely on the use of paper-based documentation or procedures. This yields to induced delays that cannot be reduced. Moreover, the overall data processing can be error-prone, as soon as the data must be manually re-processed to feed the information systems. The usage of mobile solutions, using either lightweight handheld devices or tablets, enables to reduce those delays and to improve the overall data quality. Based on both our internal feedbacks and human factor studies, we have established that field operators are often required to perform several different activities during their shift or in a given time frame. As a consequence, mobile applications must fit the actual need to enable efficient context switching. The user must be able to start, suspend and resume any application, without any data loss. Without this flexibility, it is difficult to really improve the on-field performance.
This paper doesn't deal with the choice of mobile devices or tablets. It is focused on software architecture to fulfill nuclear operation needs.

2 The limits of vendor-provided mobile solutions

Asserting the necessity to enable efficient and smart context switching between all of the mobile applications required by the on-field activity performance, the fact is that the integration between vendor-provided applications is at least difficult whenever possible. Even if the different applications are designed to run on the same mobile operating system, there is little chance that those applications truly cooperate.

As a matter of fact, one of the most important share of the value added by introducing mobile solutions lies in the integration with the information system (*e.g.* synchronization mechanisms for rounds, tagouts, *etc.*), even with process data servers or data historians for periodic tests performance.
In conclusion, nuclear utilities must take the role of mobile software integrator.

3 The functional case study

The functional case study is a result of joint operations, human factor and engineering people work. It can be seen as a compromise, mixing operation and IT needs.

It is the result of two studies: one in the Penly 1300 MW station (in Normandy) for general field operators needs, the other for developing the concept of smart padlocks, managed with the use of field procedures in a tablet device.

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Operations have really expressed the need of being able to share data between mobile applications. For example, they want to see, in a line-up module, that no tagout is present on one equipment of their procedure; they also want to send automatically a round data to a log book, to access to process data during a periodic test, synchronize their procedure automatically with another field operator, *etc.* The minimum set of applications will consist in integrated modules for rounds, tagouts, alignment procedures, operation procedures, periodic tests and work requests. These modules will have to interact together, *a minima*, through the equipment codes, such as 1CEX012PO.

Today, mobile applications have been designed to be started and ended. Few of them can be interrupted, and restarted in their operation context. This is not fully adapted to real field operation activities, observed on field. One simple example is a leak discovered during a round. Today, with many softwares available on the market, it is not possible to interrupt the round application, to shift to a work request module, and to come back to the round application. Moreover, the need is to be able to monitor the progress of all concurrent activities, in order to help the field operator at organizing his work.

Another point is that team performance can be improved by working together more efficiently. Is it possible to be informed, in real time, of the work performed by other field operator colleague, in order to better synchronize the team? In the Golfech 1300 MW station (in south west of France) we have developed an integrated application, allowing field operators to synchronize line-up activities in real time.

Another important point is to bridge the gap between field and centralized teams. Operators must be able to access the station IT network from field. No full wireless network coverage is required, but hot spots must be implemented on field, allowing data exchanges (wireless or wired, according to the company policy).

The last important functional need is to provide generic services, shared by all the modules. This is the case for equipment recognition (QR codes, RFID, *etc.*), access to station documents, access to IT equipment data (such as tagouts, work request, position, normal operation position, supplies, *etc.*), download / upload of data, synchronization, notifications, *etc.* These common services can be seen as the glue of the integrated system, allowing data exchange and providing a principle of coherence required by human factor design rules.

At EDF, it is required to print and highlight P&ID drawing before going on field. The request of being able to access P&ID drawing directly on mobile devices is surprising. Indeed, how a small screen could be more efficient than an A3 drawing? In fact, the underlying functional need is that field operators would like to be able to verify, anytime and anywhere that the right label has been placed on the right equipment. In fact, equipments can be dismounted and remounted, and labels may have been switched. As a consequence, the topology provided by P&ID drawings provides a potential solution; other solutions certainly exist and should also be evaluated. As usual, the main point is to focus on the underlying needs, not on the preconceived solutions.

4 How the mass market can help us to design better mobile applications

Considering mobile solutions, three markets seem relevant at first sight: the laptop, the tablet and the smartphone markets. But, we need to be more specific. In fact, laptops can hardly replace our old Windows Mobile-based industrial devices. Even if we need to consider new usages for tablets and lightweight laptops, the first need to be addressed is the fact that, for on-field operations the device needs to fit in a pocket. The smartphone market has known a fast growing rate for several years and, nowadays, two major companies lead that market.

Why, as an industrial company, does this matter? Considering the market volumes, we cannot lead that technology market and thus it’s our best interest to study how we can use and adapt the mobile technology to our benefit. As those mobile technologies provide solutions, they challenge us with new kinds of issues: devices and applications lifecycles and management, interfaces with the information systems, cyber security, wireless technologies and more. We will not address all those issues in the present paper. We will rather focus on mobile applications design and development because we believe that the value exists at first by providing usable applications.

We all have experimented, at a personal level, the smartphone market explosion. The transposability from our personal to our professional experience must be considered as an opportunity.

The Android framework has been used to design and develop the applications presented further in this article. The first reason why we have chosen the Android framework is that its concepts fit with our understanding of on-field activities. Moreover, Android breaks the smartphone / tablet segmentation and, even if the fragmentation may be an issue, one does not depend on a unique manufacturer. At the time of designing those applications, Microsoft's mobility products was not mature enough, even nonexistent, to be considered.
Eventually, the relative openness of the Android framework allows the non-personal user to be independent, in some measure, from Google and its services layers. In facts, some of the Android concepts initially implemented to fulfill with Google's interests can be used to build a better mobile ecosystem for industrial applications.

5 A component-oriented approach to develop industrial mobile applications

5.1 Leveraging the android platform

At the time of evaluating the Android framework as a candidate for our mobile developments, the Activity component retained our attention. Indeed, the lifecycle of an Android Activity implements what we called efficient context switching earlier in the introduction. Multitasking is one of the fundamentals of the Android platform and this is achieved by providing components (from four different types: activities, services, content providers and broadcast receivers) to build an Android application, each serving different purpose and distinct lifecycles. There is a native interoperability between components.

The main advantage of the Android framework is this component-oriented approach. At mass-market level, this advantage is not so obvious, except for Google with the Google Play Services, but at enterprise or industrial level it provides an opportunity to refine mobile software management from application management to component or functional module management. The value is simplifying development and the maintenance. For example, a unique service can provide QR code scanning capabilities using either the embedded camera or a dedicated and specialized Bluetooth device depending on the Android device configuration and independently of the application. The application will interact with the service interface, never knowing which device has been used. The service can be shared between several different applications, evolve in a standalone manner, except for the interface and is installed once on the mobile device. The reusability is thus maximized, at the cost of dependency management. With a monolithic approach, a QR code service upgrade would lead to a full application upgrade.

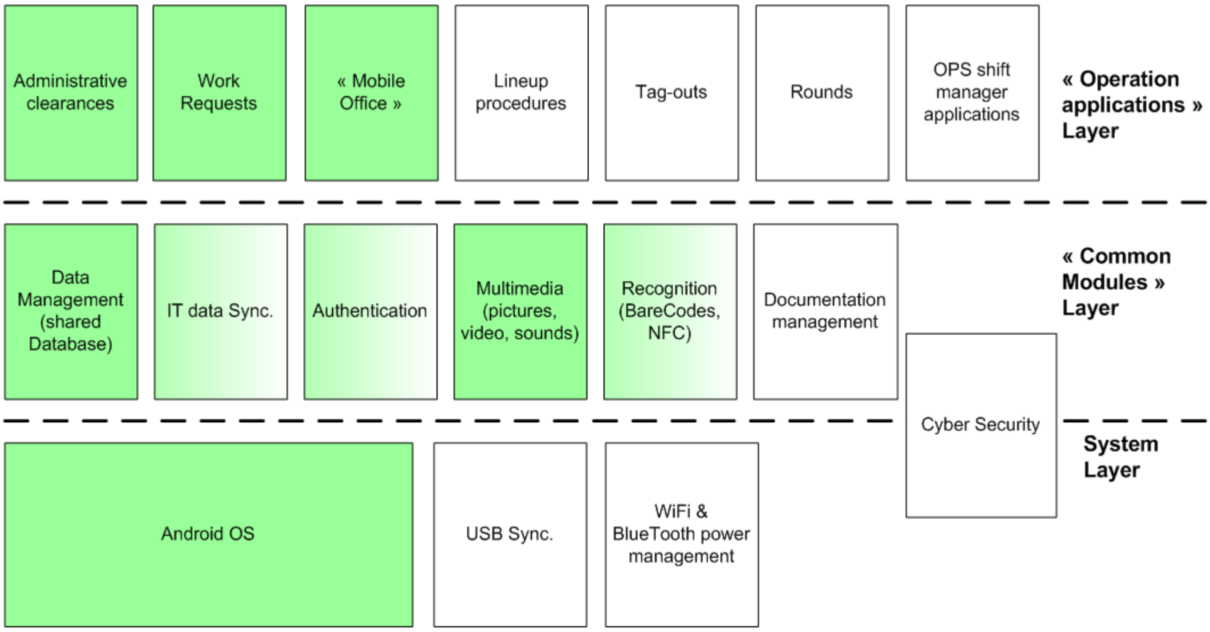

Fig. 1 Simplified modular approach to Android mobile development.

5.2 A case study on the modular design of our mobile applications

As described in the previous sections, we need to build our mobile application on functional shared components instead of providing monolithic applications. The Android platform provides us with the opportunity to apply this kind of modular design to industrial application, as depicted in the Fig. 1.

In this section, we will focus on two scopes of application: tagouts and work requests.

The Figure 2 shows both application packages and their dependencies. Both applications share the following components:

- Authentication and Data Synchronization Services.
- Operation ContentProvider: the internal embedded database has been designed to support the business model of each application. These models are accessed through this component.
- Recognition Service is a functional component providing QR code scanning features.

The Work Requests application relies on two supplementary components: the Camera and the Sound Recorder Activities.

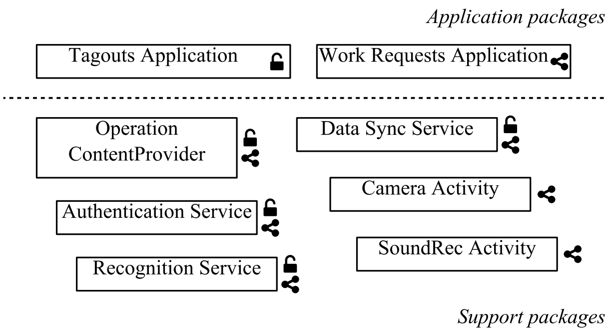

Fig. 2 Two different applications and their dependencies.

Each one of these components is an independent installable package. The application is able to use each of these components through an interface contract. Each application is responsible at runtime for the dependency checking.

During implementation, it seems rather natural to factorize authentication and data synchronization services as components. Indeed, the related codes need not to be duplicated in each project, following the simple "Don't Repeat Yourself" principle. The same principle is valid for the QR code recognition service. For the operation content provider, the application models are different but we have chosen to provide both models through a single service instance, allowing resources usage reduction.

Fig. 3 Tagouts application.

Fig. 4 Line-ups application.

5.3 Managing mobile applications development

Applications have been designed and developed in direct link with the end-users on the basis on non-formal, collaborative communications. Iterative, incremental regular releases are a requirement to get the most of the collaboration between end-users and developers. This leads faster to a better final product focused on what matters to the users.

6 On-site experiments

Two site experiments have been conducted.

The first one deals with a project of smart padlocks that have been invented at EDF/R&D [1], [2]. These padlocks are used for tag-outs, to guaranty safe work condition to maintenance people. They monitor the cable that secures the equipments position (valve, breaker) and their lever position. Periodically, each padlock transmits its diagnosis to a centralized monitoring software, which alerts operations in case of failure (unexpected opening, cable cheek failure, *etc.*). Our mobile solution for tag-outs, as depicted in Fig. 3, allows each field operator to download the tag-out procedures into his hand held device, to start the procedure with its different steps, to recognize each equipment and its associated padlock, to verify the state of each padlock and finally to upload the completed procedure to the padlock's monitoring software. Notifications can warn the operator of any changes. This application has been tested in the Dampierre power station (900 MW in center of France) with good results.

The second application is about new line-up practices. At EDF, we have decided to optimize the restart of the circuits after outage. One of the ideas is to prepare the filling of circuits (water, air, gas, *etc.*) at the same time the field operator removes the tagouts (chains, tags and padlocks). Traditionally, these operations are performed in two phases. The first phase consists in removing the tagouts, and the second one to place equipment (valves, breakers, *etc.*) in the required position. Here, both activities are performed at the same time: tagout procedures and alignment procedures are shared. An example of line-up procedure is shown in Fig. 4.

Our mobile application allows merging this tagout and alignment procedures, to download them into a hand held device, to perform the procedure and to upload it when the work is done. We also developed, based on site requests, a functionality allowing field operators to stop a procedure and to share the remaining work with other colleagues. The idea

Fig. 5 Complementary applications for field operations.

was to help operator to easily share their work, without need to come back in control room. It has been necessary to analyze procedures, and to define two categories of them: procedures for which no precise order is required, procedures for which a precise order is mandatory. This experiment has obliged us to develop a dedicated server, in interface between the station IT system and the mobile applications. This is one of the consequences of implementing a mobile solution in an existing environment. Half of the effort has been allocated to this development. It has to be considered in such projects. Training of field operators is now finished, and the beginning of the experiment is scheduled for September 2014.

7 Other modules

Other modules have been developed, in order to promote the idea of the interest of the integrated approach.

The first one is an application that displays the content of human performance tools. These tools are reminders for secure communication, cross control, prejob briefing, *etc.* For this, we have developed a container, allowing operations to implement easily html documents to the application. This application and its concept of usage will also be tested in Golfech.

As required by the human factor studies, we have developed a module in order to monitor, on field, all activities performed in parallel. This module summarizes, for a shift, all the applications that have been started and their progress. Combined with this, another screen shows all the data to download or to upload to the mobile server.

8 Conclusions

At EDF / R&D, we have developed an industrial solution with the aim of integrating data and field operators' activities.

This solution is based on human factor studies, advanced mobile architecture design and iterative development including end users.

The next field experiments will be an important point of decision for the Power Generation Division, in order to continue, or not, developing specific software for field operation.

Any case, we have demonstrated that utilities have an important role to play in the integration of the solutions, due to the absolute necessity to integrate field data and procedures.

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