Bottom Billion Architecture – A Generic Software Architecture for ICTD Use Case Scenarios

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Abstract
The ICT for Development (ICTD) research field still lacks a generic architecture approach unifying software development tasks in ICTD research. With a common approach technical ICTD research could evolve from single point solutions narrowed to one specific use case or technology towards a shared approach following the common goal of providing ICT access in ICTD use case scenarios. In this paper we present the replication of the Bottom Billion Architecture (BBA) in a second use case scenario. The BBA was developed and evaluated in a procurement use case in South Africa. The replication takes place in a cashew supply chain in Ghana whose current inefficient paper based organization hampers collaborative business with the established economy. The BBA prototype has been deployed for a five month pilot phase with about 400 participating cashew farmers. With this successful replication of the same architecture in two different use case scenarios we are now able to evaluate its capabilities to serve as a generic architecture for various technical ICTD use case scenarios.

Keywords
Software architecture, Mobile HCI, Technical ICTD

ACM Classification Keywords

D.2.11 [Software Architectures]: Patterns. H.5.2 [Information Interfaces and Presentation (e.g., HCI)]: User Interfaces – User-centered design.

General Terms

Software architecture, Mobile HCI, Technical ICTD

Introduction

A review of architectural approaches in technical ICT for Development (ICTD) [12] projects reveals a wide range of different ICT access solutions. Some follow a desktop computer approach (e.g., Telecenters [8, 10]) others a mobile approach (e.g., CAM [9]). A few even evolved from the one to the other like Warana Unwired [13]. All those concepts make absolute sense in the projects they have been developed but still are use case specific point solutions. To build a sound technical ICTD foundation a generic software architecture supporting ICTD [7] research across use case scenarios, projects, and technical implementations is needed. And since the common goal of all individual technical ICTD concepts is to provide ICT access within ICTD use case scenarios the logical next step is to combine them to unite the field and move forward together with collaborative architecture improvements. That is what we propose with the Bottom Billion Architecture (BBA) [6] – a generic software architecture that combines and extends existing ICT access architecture concepts to be reused in different ICTD use case scenarios. In this paper we will further strengthen the generalizability [2] of the BBA, which was developed and evaluated in a procurement use case in rural South Africa, by replicating it within another use case scenario – the cashew supply chain in Ghana.

The cashew nut production and processing supply chain in Ghana is only one example of an agricultural supply chain (e.g., Shea Butter, Coffee), being a major source of income for emerging economies. The global annual production of in-shell cashew is about two million tons from which West Africa provides more than one fourth. However, 90% of the cashew produced in West Africa is exported for processing (shelling, peeling, grading) to India, Viet Nam, and Brazil. Thus much of the value of the cashew nut supply chain is exported to other countries. Our research work takes place within the African Cashew Initiative (ACi) project [1] which purpose it is to strengthen the global competitiveness of cashew production and processing in Africa and to support small scale cashew farmers to gain additional income through increased productivity. ACi will provide the environment (e.g., processing plants) to process cashew nuts in Ghana. The ICT enabled transparent process will foster collaborative business with the established economy and support food traceability from farmer to buyer which is a key requirement for certifications like Fair Trade. In the current use case scenario we have almost 400 participating cashew farmers that are organized in a cashew cooperative – 50-200 farmers per buying station (place where the cashew farmers sell their cashew nuts), 1 union manages 7 buying stations (collects their cashew nuts and organizes the pre-financing), 1 processor collects the cashew nuts from either the buying stations directly or from the union.

In the following chapters we provide information on the applied research methodology, the BBA architecture, the system implementation in the cashew use case and some first evaluation results and next steps.

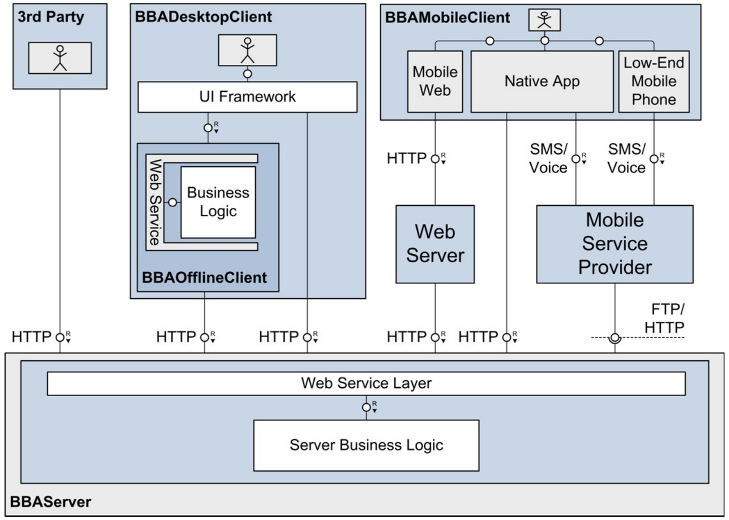

Figure 1. Bottom Billion Architecture – High level component block diagram

Methodology

Successful research in an emerging economies context requires research methodologies adapted to the specific circumstances [11]. Otherwise the possibility to fail is quite high due to the completely different set of cultural and infrastructural requirements [5]. Beside the business process research to ensure a smooth shift to the ICT enabled process our main focus was on technical ICTD topics. The User Centered Technical ICTD (UCTICTD) Lifecycle [4] provides a set of specifically for the technical ICTD context adapted Mobile HCI research methods with a clear focus on user centered design and action research. We have developed and evaluated the UCTICTD Lifecycle in a three year research project in rural South Africa. With the replication of the UCTICTD Lifecycle in this use case we will further refine the concept and show its generalizability. Following the UCTICTD Lifecycle our overall framework is realized as a Living Lab in which we involve end users as co-creators and do experimentation in real world settings. In March 2011 we have deployed the first version of the iterative prototype within the use case scenario and iteratively improved it together with the end users in several action research cycles. The UCTICTD Lifecycle has shown its applicability within the cashew use case and thus its generalization capabilities to fit into different Technical ICTD use case scenarios.

BBA Replication in the Cashew Use Case

The BBA (see Figure 1) has been developed and evaluated during the C@R research project [3] in rural South Africa within a procurement use case scenario. In this chapter we will describe the details of the BBA replication in the cashew use case scenario. Since the BBA is an architecture concept the building block implementations can vary depending on the specific use case requirements. Based on the cashew use case requirements we have used a different subset of the BBA as within the first implementation for the procurement use case in rural South Africa. The main building blocks of the BBA implemented in the cashew supply chain are the BBA Server, BBA Desktop (Offline) Client and the Native App BBA Mobile Client using the SMS and HTTP data channel.

BBA Server

The BBA Server is the central instance and serves as the central information source and synchronization unit as well as integration point to any 3rd party client via its web service interface. Its main features are to communicate with the mobile service provider, maintain a central consolidated and consistent database and to realize a lightweight synchronization mechanism to communicate with BBA Desktop Clients and BBA Mobile Clients, both occasionally online and always online. The technical implementation of the BBA Server is based on an Apache Geronimo application server and a PostgreSQL database.

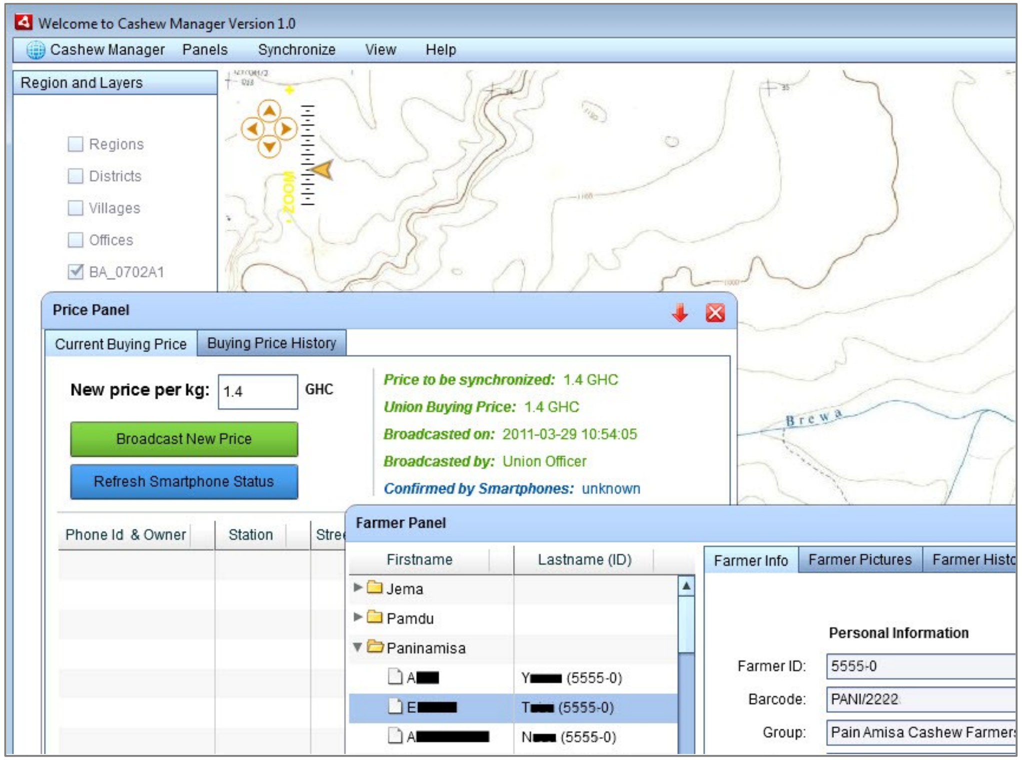

Figure 2. BBA Desktop Client (Only part of the entire screen)

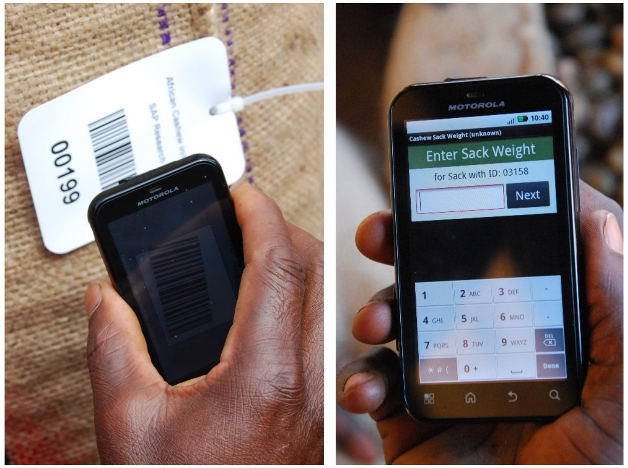

Figure 3. BBA Mobile Client (Scan Sack, Enter Sack Weight)

BBA Desktop Client

The BBA Desktop Client (see Figure 2) runs in offline or online mode depending on available infrastructure. In offline mode a lightweight synchronization mechanism exchanges data with the BBA Server. The decoupled architecture allows using any appropriate UI technology to process or display the available information. The technical implementation in the cashew use case utilizes an Adobe Flex UI, a PostgreSQL database and a PHP middleware. The Adobe Flex UI incorporates a Geographical Information System (GIS) to display the master-, transactional-, and logistics-information on top of a map of the area – a UI concept evaluated already within the procurement use case.

BBA Mobile Client

The BBA Mobile Client (see Figure 3) can be realized in various ways (e.g., Mobile Web, native application, Java, SMS only). Depending on available hardware and infrastructure the mobile clients connect with the BBA Server in different ways. In the cashew use case the BBA Mobile Client is implemented as native application client on the Android platform. Since the BBA Mobile Client is used at the buying stations without reliable GPRS network coverage the BBA SMS and HTTP communication concepts are used. Depending on available network coverage a lightweight synchronization mechanism is using either the SMS data channel via a mobile service provider or the HTTP data channel to synchronize in a background service, even when the phone is in standby or the application is closed. Another specific feature is the utilization of a barcode scanner to simplify the identification of a farmer and cashew sack. During the cashew buying and loading (loading the cashew sacks on trucks for transportation to the cashew nut processor) process the BBA Mobile Client is used to scan 2D barcodes attached to the farmer’s booklet and to the cashew sacks. Using the barcode scanner is much less error prone and faster than the manual process.

BBA Unique Features

With the successful replication in the cashew use case we have shown the applicability of the BBA in two completely different use case scenarios. The replication of the same software architecture in two different research projects and scenarios is a key difference compared to existing technical ICTD research outcomes and is the first necessary step towards a generic architecture. Some of the key technical ICTD features of the BBA are summarized as follows. The BBA:

- integrates several existing architecture concepts into one modular architecture.
- supports various offline/online mobile clients (2G, 3G) based on available hardware and infrastructure.
- supports offline/online desktop clients with decoupled UI technologies to fit use case requirements.
- provides a lightweight synchronization mechanism that copes with restricted infrastructure requirements.
- provides extension points to incorporate 3rd party clients connected via a web service interface.
- is scalable on desktop and mobile client side. Only available infrastructure sets the limit.
- supports multi tenancy on desktop and mobile.
- supports generalizability across projects and use case scenarios since the individual components are exchangeable and extensible to fit individual use case requirements.
- (especially the example implementations) follows the Free and open-source software (FOSS) concept to build a sustainable system

Generality Evaluation and Discussion

By replicating BBA in the cashew use case we have been able to minimize the design and development efforts drastically compared to the “from scratch” approach during the former procurement use case. The architectural concepts of the BBA in combination with the methodological concepts of the UCTICTD Lifecycle made prototype development much more efficient and minimized the risk of building inappropriate or incomplete software solutions. For technical ICTD projects in general a reusable generic and evaluated architecture provides important benefits. Technical ICTD use cases do not have to re-invent the wheel but can build on tested architecture concepts, and reuse example technical architecture implementations. A generic architecture approach also makes different solutions comparable or even combinable much easier.

The cashew prototype has been used by 100% of the anticipated end users on a daily basis for the entire cashew pilot phase (Feb-Jun 2011) which shows the high adoption rate of the system. To collect more detailed end user feedback we are organizing another round of end user feedback workshops end of June 2011 which will provide input for the next cyclic prototype iteration. With this successful evaluation results the BBA shows its generalization capabilities for different technical ICTD use case scenarios.

Conclusion and Future Work

With the successful implementation of the ICT enabled cashew supply chain using the BBA we have shown the generalization capabilities of the BBA. We have been able to completely cover the cashew supply chain requirements with the existing BBA concepts. Beside the BBA replication also the UCTICTD Lifecycle has shown its applicability within another technical ICTD use case scenario. The methodology toolset enabled us to execute the research work in an appropriate way and to produce a technical ICTD solution without so called "design versus reality gaps". Next steps are to organize end user feedback workshops and to use the evaluation results to further improve the prototype in cyclic deployments. We will strengthen the system and prepare it for upscaling to support several thousand farmers in Ghana and expand to other African countries as part of the ACi project. Beside this we are currently active expanding the BBA use case portfolio by another agricultural supply chain use case in Ghana. Initial requirements analysis and software architecture design meetings have shown a full coverage of the required features by the BBA concept. With its generic approach the BBA qualifies for various agricultural (e.g., cocoa, coffee, shea, cashew) and procurement use cases even across countries. Design, development and deployment efforts can be executed more efficient and with reduced risk of failure.

Acknowledgements

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