Extended Abstract: Building Mobile Application Frameworks for Disconnected Data Management

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ABSTRACT

In resource-constrained environments, organizations helping disadvantaged communities often rely on mobile devices as their field worker's primary computing device. While over two-thirds of the world's population have mobile phones, less than half the world's population is connected to the Internet [14]. Thus, many existing mobile frameworks that rely on Internet connectivity are not well suited to long periods of disconnected data collection and management. Furthermore, many existing frameworks are generally aimed at developers or users with significant technical skills and/or financial resources, making it difficult for organizations in resource-constrained communities to adapt mobile frameworks to their highly context dependent field deployments. My research focuses on creating tools that adapt mobile technologies to meet the needs of under-served populations by creating a modular, service-based mobile application framework suited to disconnected data management. The aim is to enable organizations to create domain-independent mobile applications by leveraging customizable frameworks designed to adapt to extreme mobile networking conditions. Designing flexible tools that are configurable by global development organizations necessitates new abstractions that are usable by non-programmers with limited technical expertise. These abstractions should be based on open standards to enable interoperability with other tools to establish an ecosystem of modules that can be used together or independently to create custom information management solutions.

1. INTRODUCTION

For mobile devices to be useful in solving global problems, researchers need to not only expand the capabilities of the technology but also expand how the technology can be applied in varying environments and constraints. Information technology has transformed the collection, analysis, and use of data. However, the variability in resources, infrastructure, and technical expertise across different communities has prevented the digital revolution from benefiting all populations equally. Many organizations (e.g., rural health providers, government agencies) lack the infrastructure to effectively collect digital data and have historically used paper. Gathering accurate information and aggregating data quickly is essential for organizations to have a timely and sustainable impact.

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Mobile computing technologies are often one of the few technologies available for use in global development interventions for data collection and management. According to a 2016 World Bank report, over 90% of the world's population already lives within mobile coverage but less than half the world's population is connected to the Internet [14]. The scenario where billions of people have mobile phones (over two-thirds of the world's population have a mobile phone[14]) but lack Internet connectivity will likely continue for years. Organizations working in remote areas are bypassing traditional desktop and laptop computers in favor of mobile devices to create information services in resource-constrained environments. Smartphones and tablets are preferred because of their mobility, lower power requirements, and their ability to connected o the Internet via multiple networking options including cellular networks. Unfortunately, many existing mobile application frameworks are designed for use in high-resource environments and are not appropriate for the challenges of resource-constrained environments for two reasons: 1) skilled software developers are required to make customizations which is problematic in resource-constrained contexts as highly skilled personnel are not readily available and remote international consultants are expensive; and 2) existing frameworks often assume Internet connectivity and while some frameworks offer local data caches they often lack the full offline replication and synchronization capabilities required to enable field workers to work offline for weeks.

To enable resource-constrained organizations to have a malleable data collection and analysis toolkit we created Open Data Kit (ODK) [5, 10] to empower users to build information services in under-resourced contexts that often lack technology infrastructure and expertise. ODK is a modular and extensible suite of open-source tools that assumes relatively low computer literacy to enable the widest variety of users. It's modular framework is designed to leverage open standards to enable interoperability between composable components that can be mixed and matched. ODK has been used in a diverse set of domains including public health, disaster response, environmental monitoring, documenting human rights abuses, and carbon credit markets. Over 700,000 unique visitors from 232 different countries/territories have visited the ODK website (currently $>$30,000 hits/month). Additionally, over 210,000 users have installed ODK Collect from Google Play, which excludes installs directly from ODK's website and ODK derivative apps. Analytics reports that ODK Collect is used daily by thousands of users in more than 130 separate countries. While ODK 1.x [10] was designed to replace and enhance paper-based data collection, the focus on simplicity created limitations that made it difficult for organizations to adapt the tool suite to certain types of scenarios. Therefore, ODK was expanded to include a second tool suite (ODK 2.0) with enhanced functionality focused on *data management* versus ODK 1.x's focus on *data collection* [5]. ODK 2.0 has been piloted by a variety of organizations in over 18 countries. My research is focused on creating multiple mobile frameworks for operation in resource-constrained environments.

2. RELATED WORK

Various research projects focus on improving world-wide Internet connectivity by extending infrastructures (e.g., Google's Loon[2], long distance WiFi[13], village base stations[11]); however, until global Internet connectivity is available at an affordable price, a parallel approach is needed to create mobile application frameworks designed to operate in challenged networks environments. In ICTD research, multiple research projects have explored how organizations can use mobile technology to improve efficiency. An early example was CAM [12], which leveraged J2ME phones to build custom mobile applications that used barcodes to augment paper forms and trigger custom prompts for data entry. Unfortunately, CAM's custom scripting language created a barrier for non-programmers that many projects including ODK struggle to avoid. Another early example was the E-IMCI project [7] which improved an organization's effectiveness in remote locations by encoding complex medical workflows on PDAs. Additionally, there are existing open-source application frameworks for building mobile apps with JavaScript/HTML, such as Apache Cordova [1], that help programmers write a single application that can run on multiple platforms (e.g., Android, iOS). What differentiates ODK from other solutions is its focus on providing a suite of inter-operable tools that 1) aims to be customizable to a deployment context by a non-programmer and 2) can operate in disconnected environments.

3. PROGRESS TO DATE

My research has contributed to multiple iterations of ODK tools that have evolved based on user feedback and experiences from field deployments. The first version of ODK [10] helped organizations simplify data collection for a diverse set of ICTD applications. Once organizations experienced the efficiencies mobile devices produced, they began to request more features to leverage additional capabilities to collect more sophisticated data. This lead to the creation of a second set of modular tools that constructs a more complex and flexible mobile application framework. The ODK 2.0 vision paper [5] discusses how feedback from users and developers led to redesign the ODK system architecture and the beginning of multiple mobile research projects.

ODK 2.0 is a modular service-oriented framework that provides different levels of adaptability to enable users of varying technical skill levels to tailor the software to their specific use case. These abstractions are designed to be customizable by 'deployment architects', a non-programmers that adapts off-the-shelf software to an organization's deployment context. ODK 2.0 is designed to be a flexible information management solution for a variety of use cases with complex workflows. Specifically, ODK 2.0's framework is designed to handle scenarios where previously collected data is often revisited and updated such as logistics management, public health, and environment monitoring (scenarios that ODK 1.x struggled to fulfill because previously collected data is unavailable). To address this common case, ODK Tables [4] was created to simplify displaying and curating previously collected data. The ODK Sensors framework [3] was created to simplify the task of integrating external hardware sensors into an organization's data collection and management workflow via the ODK 2.0 ecosystem by providing abstractions to simplify sensor drivers development. The sensors framework provides a common interface that abstracts communication channels minimizing sensor driver code.

Smooth operation in disconnected environments is a core tenant of ODK 2.0's design. It's synchronization protocols and structures are designed to be resilient in extreme mobile networking conditions such as low bandwidth and high latency environments. ODK 2.0 replicates data to mobile devices enabling the application framework to preserve full functionality in disconnected environments, while maintaining the feel of connectivity via data synchronization as connectivity becomes available. ODK Submit [6] was designed to provide a framework for organizations to flexibly adapt their application to transfer data using appropriate network channels based on network conditions and data requirements.

Additionally, I have partnered with organizations to conducted field studies to validate ODK's framework. For example, PATH deployed a mobile application (called mPneumonia) to improve health care providers' diagnosis and management of childhood pneumonia [8]. The project illustrated how ODK 2.0 simplified building a mobile clinical applications with complex medical workflow integrated with a sensor. PATH conducted user studies in Ghana where interviewees reported mPneumonia was "easy to use" [9].

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