Service Blueprint for Improving Clinical Guideline Adherence via Mobile Health Technology

Y. O'Connor, C. Heavin, S. O' Connor, J. Gallagher, J. Wu, J. O'Donoghue

Abstract**—**Background: To improve the delivery of paediatric healthcare in low resource settings, Community Health Workers (CHW) have been provided with a paper-based set of protocols known as Community Case Management (CCM). Yet research has shown that CHW adherence to CCM guidelines is poor, ultimately impacting health service delivery. Digitising the CCM guidelines via mobile technology is argued in extant literature to improve CHW adherence. However, little research exist which outlines how (a) this process can be digitised and (b) adherence could be improved as a result. Aim: To explore how an electronic mobile version of CCM (eCCM) can overcome issues associated with the paper-based CCM protocol (inadequate adherence to guidelines) vis-à-vis service blueprinting. This service blueprint will outline how (a) the CCM process can be digitised using mobile Clinical Decision Support Systems software to support clinical decision-making and (b) adherence can be improved as a result. Method: Development of a single service blueprint for a standalone application which visually depicts the service processes (eCCM) when supporting the CHWs, using an application known as Supporting LIFE (SL eCCM app) as an exemplar. Results: A service blueprint is developed which illustrates how the SL eCCM app can be utilised by CHWs to assist with the delivery of healthcare services to children. Leveraging smartphone technologies can (a) provide CHWs with just-in-time data to assist with their decision making at the point-of-care and (b) improve CHW adherence to CCM guidelines. Conclusions: The development of the eCCM opens up opportunities for the CHWs to leverage the inherent benefit of mobile devices to assist them with health service delivery in rural settings. To ensure that benefits are achieved, it is imperative to comprehend the functionality and form of the eCCM service process. By creating such a service blueprint for an eCCM approach, CHWs are provided with a clear picture regarding the role of the eCCM solution, often resulting in buy-in from the end-users.

Keywords**—**Adherence, community health workers, developing countries, mobile clinical decision support systems, CDSS, service blueprint.

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I. Introduction

THE need to reform the delivery of healthcare services to accommodate the demands of modern societies is a global reality. Health care provision varies internationally with those in developing countries struggling more than their developed country counterparts. However, there is growing evidence [1] for the use of mobile information and communication technology to revolutionise the delivery of healthcare services (commonly referred to as Mobile Health or mHealth). This is catalysed by the continuing expansion of mobile markets and telecommunication, primarily in developing countries [2]. Mobile technologies are perceived as clinically pertinent tools for addressing absent or limited healthcare infrastructure in remote and resource-poor areas. In a developing world context, paediatric mHealth pilot studies have shown improvements in communication, disease monitoring and management, emergency response and human resource coordination [3]. Yet, it is argued [4] that more work is needed to extend mHealth pilot studies to large-scale nationwide implementations; especially when it is reported that children under the age of five are affected the most by limited healthcare resources. Unfortunately, it is reported by the World Health Organisation (WHO) that 6.3 million children under age five died in 2013, approximately 7 times greater than in Europe [5].

To assist in reducing child mortality rates the WHO and UNICEF introduced clinical guidelines to assist Community Health Workers (CHWs) when diagnosing and treating a number of serious illnesses in children such as malaria and infantile diarrhoea. These paper-based set of guidelines known as the Community Case Management or CCM are a subset of a wider collection of guidelines known as Integrated Management of Childhood Illness (IMCI). IMCI was originally designed to address the fragmentation of primary health care services for children in low resource settings which resulted from the use of vertical programmes for specific public health concerns such as tuberculosis, malaria and HIV/AIDS [6]. The CCM guidelines require CHWs in rural, remote clinics to undertake a child health assessment using a set of medical algorithms and flowcharts [7]. These are designed to turn a child's presenting symptoms into an illness classification which guides the CHW to the appropriate treatment, counselling and/or referral for a sick child. However, poor CHW adherence to the paper-based CCM guidelines is widely reported in the literature, which may result is less effective healthcare delivery.

II. Community Health Worker Adherence

Following the CCM strategy has proven to provide numerous benefits to paediatric health services in low resource settings [8], [9] yet maintaining the provision of these services in some developing regions is not without challenges [10]. There exists common issues which are detrimental to the livelihood of sick children including incomplete child health assessments, incorrect diagnosis and treatment, and missed referrals. It is documented that achieving consistent CHW adherence in CCM is a continuing problem [11]. For instance, studies on IMCI adherence in Tanzania were examined and found that the majority of CHWs perceived that the document intensive guidelines took too long to use and preferred to perform child health assessments from memory [12],[13].

It is proposed that utilising an electronic version of CCM provided on mobile technology (referred herein as eCCM) is an approach to improve adherence to CCM guidelines [14]. The use of Personal Digital Assistants (PDA) in assisting CHWs through the CCM algorithm was explored and improvements in terms of CHW adherence to the guidelines were identified [12]. Similarly, an evaluation on the utilisation of a handheld PDA device installed with IMCI software protocols in Tanzania found local CHWs perceived that the delivery of healthcare services was faster and easier to use than the paper-based method while further enhancing their decision-making capabilities [15]. Overall 73% of healthcare workers in their study believed the PDA enhanced their adherence to the IMCI guidelines. The subsequent section describes how eCCM can be utilised in healthcare service delivery.

III. Positioning eCCM as Part of Health Service Deliver

Before one can explore health service delivery of eCCM, one first needs to understand what is meant by the concept of a 'service'. A review of the literature pertaining to "services" reveals that most definitions of a service focus on the customer and on the fact that services are provided as solutions to customer problems [16] or create value [17]. Therefore, a service is defined in the context of this paper as a "dynamic set of activities which create value/solve a problem through the lens of the customer" [18, p.101].

Research shows that healthcare providers were more confident when delivering healthcare services (i.e. diagnosing and treating patients) via the eCMM on mobile technologies [15]. Electronic Clinical Decision Support Systems (eCDSS) can provide further benefits to healthcare providers. eCDSS is defined as "software that is designed to be a direct aid to clinical decision-making, in which the characteristics of an individual patient are matched to a computerised clinical knowledge base and patient specific assessments or recommendations are then presented to the clinician or the patient for a decision" [19, p. 528]. eCDSS's have been proven to be effective in improving practitioner performance in diagnosis, disease management and drug dosing and prescribing [20]-[22]. This is due to their ability to collate and integrate large amounts of patient information, undertake complex analysis and present the results to physicians in a timely fashion [23] which in effect automates elements of the clinical decision making process.

Introducing eCDSS as part of eCCM guidelines has profound benefits and has been proven to increase benefits to CHWs in terms of adherence. However, there is a dearth of research which outlines how (a) this process can be digitised and (b) adherence could be improved as a result. To address this under-investigated gap in literature, this paper describes the service blueprint underpinning the proposed eCCM, a system for administering the CCM protocol using low cost technologies (i.e. smartphone technology). One way to achieve this is to leverage service blueprinting, a design tool for depicting one of the initial development stages of Information and Communication Technology (ICT) solutions. Blueprinting this type of healthcare service delivery can assist in revealing how and where the eCCM solution integrates into a CHWs work practices. Moreover due to its exclusive division of components (which are subsequently described) it is evident, following this service blueprinting approach, how the optimum eCCM solution may offer a just-in-time [24] decision support approach to CHWs. The next section describes the Supporting LIFE (SL) eCCM mobile application which will be used as an exemplar for depicting the service blueprint.

IV. Supporting Life eCCM Application

SL eCCM app is an open source Android mobile application used for delivering healthcare to sick children between two months and five years in one of the poorest regions of the globe, Malawi, Africa. The application (SL eCCM) replicates the World Health Organisation (WHO) and UNICEFs validated paperbased CCM decision aid, routinely used by CHWs in Malawi (see Fig. 1). As a result, SL eCCM asks CHWs to enter the same information they would usually be required to gather using standard practice, specifically: socio-demographic information (e.g. date of birth, gender), answer a series of clinical questions (e.g. presence/absence and duration of symptoms) and take clinical measurements (e.g. breathing rate).

To overcome limitations of restricted access to equipment (e.g. watch/clock for capturing breathing rate) a breathing rate tool (SL breath counter) is embedded within the application. During assessment of a sick child the CHW is required to tap the screen in time with each observed inhalation. As standard CCM specifies breathing rate be measured for 60 seconds, the SL breath counter will be pre-set to this time period on all devices. SL eCCM app does allow the user flexibility to select a shorter monitoring period (i.e. 15, 30 or 45 seconds), if they prefer. To comply with standard CCM specification if shorter time periods are selected, the underpinning algorithm of the SL eCCM app determines the time between occurred tap events, to give a breath count reflective of 60 seconds. After the selected time period has elapsed, the number of breaths a child has taken is visually displayed, automatically populated in the relevant field and used by the clinical decision rule to compute illness classification and treatment recommendations (see Fig. 2).

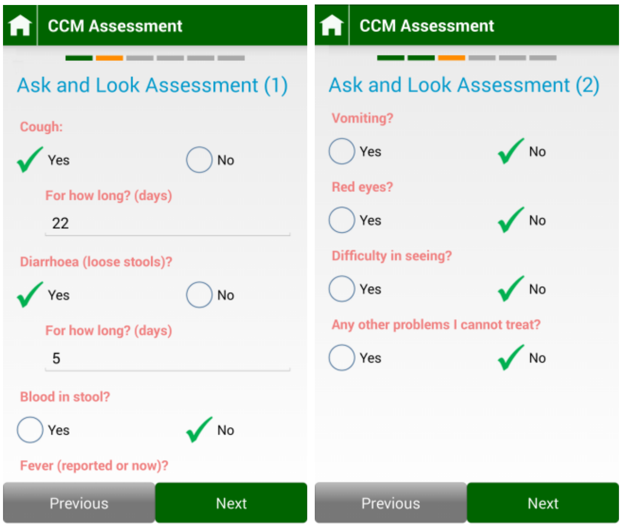

Fig. 1 Sample Screenshots of the SL eCCM App

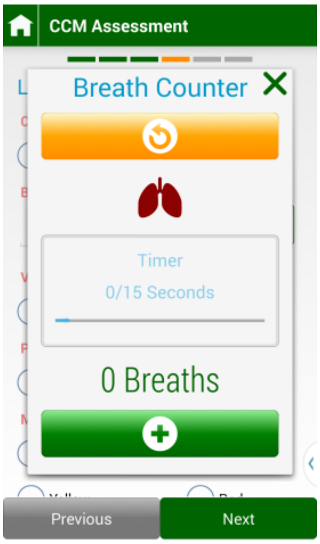

Fig. 2 SL eCCM App Breath Counter

V. Supporting Life eCCM Architecture

The SL eCCM app was developed in Java for android-based devices (Android 3.0, Honeycomb, or above) to create dynamic and robust decision-making tools to assist medical professionals out in the field. The Eclipse Integrated Developer's Environment (IDE) and the Android Developer Tools (ADT) Plugin were used to facilitate this development. RESTful web services to coordinate medical data flow to the web servers running on Amazon EC2 instances were also utilised. The middle-tier is constructed using the Spring framework, JPA and Maven. As the application is developed for use in Malawi, Africa the Message Queuing Telemetry Transport (MQTT) protocol was chosen to facilitate low network connectivity and bandwidth. This allows data to be transmitted between the database on the Cloud server and Android device using JavaScript Object Notation data interchange format.

The next section outlines the service blueprint for SL eCCM app. More importantly it provides a detailed map of the health service delivery of CCM and indicates where CHWs may be supported to improve their overall performance i.e. adherence of CCM.

VI. Service Blueprinting

Service blueprinting is a design tool developed by Shostack [25] which is often utilised to facilitate clearer communication of processes to customers. This technique describes all activities that are carried out by a service provider and its customer to deliver a service. It assists in creating a visual depiction of the service process that highlights the steps in the process, the points of contact that take place, and the physical evidence that exists, all from a customer's point of view (classified into five categories, see Table I) [26].

TABLE I
Human-to-Technology Service Blueprint Components

Component	Description
1.Physical Evidence	Refers to all the tangible items that customers are exposed to when a service process is being delivered.
2.Customer Actions	Include those steps that customers take or experience as part of the service being examined.
--- Line of Interaction--- Separates the customer's actions area from the service provider area, representing the interaction between them.	
3.Onstage Technology	Describes the interface between the customer and the technology
--- Line of Visibility--- Distinguishes between actions visible and invisible for customers	
4.Backstage Technology	Describes the backend technology activities
--- Line of Internal Interaction--- Distinguishes between front and back office activities	
5.Support Process	Depicts the activities that facilitate the service and are completed by individuals who are not contact employees and/or additional support systems. Such activities also encompass technology-based and other systems that are needed for the service to be delivered.

Using these components as a guide, Fig. 3 depicts the service blueprint associated with SL eCCM app standalone solution. It is important to note, however, that different customer segments can have different blueprints so there may be many blueprints for one service [26]. For the purpose of this blueprint, the customer is the CHW (i.e. end-user who delivers healthcare services to children using the SL eCCM app solution). This blueprint is a 'preliminary' prototype and is considered a concept blueprint based on an evaluation of the CCM handbook [26]. As this service (eCCM) is a relatively new concept, the blueprint for this new service will be presented at a high level [26]. For example, the assessment details are not portrayed in-depth in this illustration but include the recording of details pertaining to danger signs, cough/breathing, diarrhoea, fever, ears, malnutrition and anaemia, immunization status and feeding when required.

Fig. 3 demonstrates the service blueprint for offline SL eCCM app use, which is synchronised to a server once the end-user has connectivity (referred to as standalone applications). Given the intermittent nature of the data services in many developing countries, a standalone eCCM approach was taken to ensure that the CHW's can use SL eCCM app notwithstanding the availability of an internet connection.

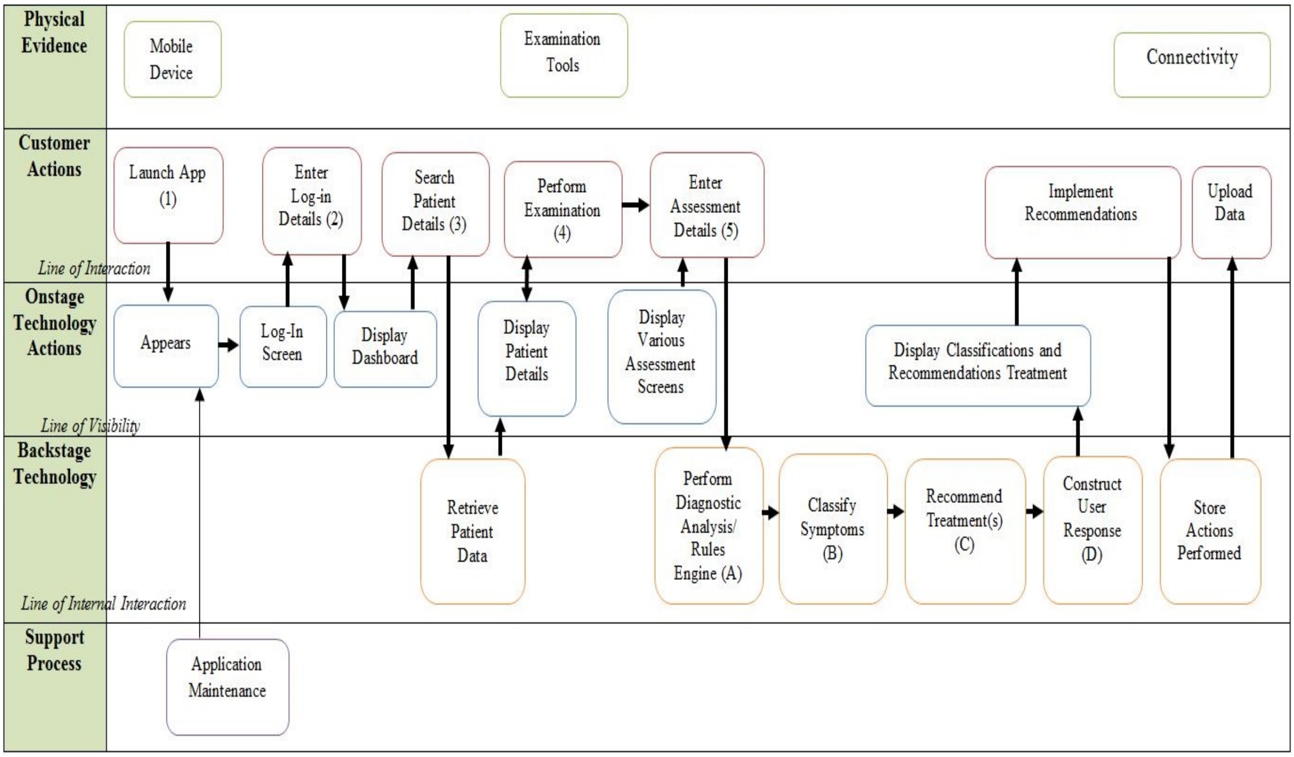

Fig. 3 Service Blueprint for the SL eCCM App

Using eCCM on a smartphone, CHW are first responsible for performing the initial patient assessment (depicted in Fig. 3 as 'Customer Actions', steps 1-5). In the paper-based version, the service delivery process by CHWs would involve following a series of complex algorithms, which have not always produced the correct results. By digitising the process, the algorithm(s) for classifying and treating patients is performed electronically (depicted in Fig. 3 as 'Backstage Technology', steps A-D) and recommendations are put forward to support the CHW decision making around patient diagnosis and treatment. This process is achievable by incorporating eCDSS which provides CHWs with a recommended route to proceed in terms of diagnosing and treating the patient based on a combination of answers to a number of 'look and ask' questions relating to the patient illness as per the WHO and UNICEF CCM guidelines. As a result, adherence to these clinical guidelines may improve as it reduces the complexity of following the algorithms manually and decreases the length of time required to work through the paper protocols. Improvements in terms of adhering to CCM guidelines enhance CHWs performance and subsequently, the quality of healthcare services children receive at the point-of-care.

VII. Discussion

The service blueprint of SL eCCM app presented in this paper outlines the workflow of CHWs in relation to using CCM based software on standalone smartphone devices. It also demonstrates how eCCM could be integrated into their practice to deliver appropriate healthcare services through the codification of the CCM rules to support the CHW decision-making process. For example, the SL eCCM app can take the workload off the CHW by performing background diagnostic analysis based on data entered about the child's presenting symptoms and physical examination. The software or CDSS rule engine helps classify the severity of the child's illness based on the CCM protocols, displays this information to the CHW and also recommends a series of treatments for them to follow. This may help reduce some of the barriers which have been identified in the application of CCM guidelines. Therefore, SL eCCM helps to ensure that children receive appropriate healthcare services while ensuring the service provider (i.e. CHWs) adheres to CMC guidelines.

VIII. Summary and Future Work

As outlined above, adherence to paper-based CCM guidelines in developing countries can be challenging. However, leveraging an eCCM solution can assist CHWs with the delivery of healthcare services to children. To ensure that this approach is feasible it is imperative to comprehend the functionality and form of the eCCM service, which can be achieved by developing a service blueprint. By creating such a service blueprint for an eCCM approach, CHWs are provided with a clear picture regarding the role of the eCCM solution, often resulting in buy-in from the end-users. Beyond CHWs, Ministry of Health decision makers will also have a better depiction as to how the process of eCCM is integrated which could assist in decision-making and any possible adjustment to eCCM in the future. Noteworthy, however, the service blueprint documented here for the SL eCCM app is a starting point to help generate ideas for improving the current system. Further investigation will enable us to enhance accessibility and usability of eCCM initiatives. Presently, a release version of the SL eCCM app (5.0) has been developed as part of the EU funded project called Supporting LIFE (Low cost Intervention for disEase control) to digitise the CCM guidelines using mobile technology (www.sl-technology.eu). To date, the SL eCCM app has been successfully deployed as part of a clinical-technical feasibility study in Malawi with twelve CHWs. Future research will determine the factors affecting adherence to paper-based and mobile technology based eCCM guidelines and examine if the services offered by SL eCCM app as depicted in this paper improves adherence to guidelines. Moreover, the researchers intend to empirically examine the impact of eCCM on various outcomes such as CHWs decision-making process, levels of adherence and potential association with clinical care as part of a Randomised Controlled Trial (RCT) along with the societal impacts the technological initiative has on participating communities.

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