

**Caregiver Coordination as an enabler to a hospital to home initiative within the context of healthcare delivery**

By

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Submitted to the System Design and Management program  
in partial fulfillment of the requirements for the degree of

**Master of Science in Engineering and Management**

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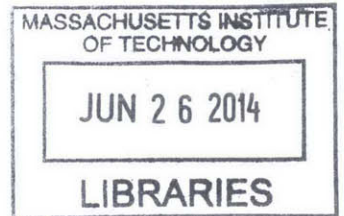
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## Abstract

The Hospital to Home architecture aims to provide a successful transition for patients leaving the hospital in order to improve health outcomes and minimize hospital readmission. This thesis analyzes the current hospital to home system, explores its flows and proposes a better architecture to improve the patient transition from the hospital to home. It makes a significant contribution by proposing a new architecture based on a patient-centric approach within the framework of the Hospital to Home (H2H) initiative called Caregiver Coordination. In this architecture, we propose the creation of a web and mobile based application that allows patients and caregivers to interact easily with each other to help manage the patient's wellbeing. We include a short summary illustrating how this new architecture can address the two main problems: (1) the decentralization of the discharge plan and (2) the dependency on the interactions among diverse stakeholders. We propose to:

1. Analyze and critique the existing hospital to home architecture
2. Follow an existing architecture pattern/framework
3. Recommend a new architecture
4. Create a Caregiver Coordination application using an open source framework to enable a successful transition of patients from hospital to home

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# 1. Introduction and Motivation

## 1.1 Executive Summary

The Hospital to Home architecture aims to provide a successful transition for patients leaving the hospital in order to improve health outcomes and minimize hospital readmission [1]. However, after the analysis of the current system and its architecture, which is widely considered “state-of-the-art”, we discovered that the architecture is ad-hoc; it has a poor consideration of the downstream influences and lacks a holistic

view. One of the challenges is that there are diverse stakeholders involved who have very different value flows and communication channels. Additionally, incentives are not well aligned with the fulfillment of the end user needs (patient) and there is no a clear overall “owner” of the system. Finally, it lacks a tool to enable patients to interact easily with their care team of doctors, nurses and caregivers.

Therefore, the system goal, which is to provide

a successful transition from the hospital to home for the patient, is not achieved. In fact, one of the non-desired emergent behaviors of this architecture is the extra cost incurred by the stakeholders: readmissions are estimated to cost \$17 billion/year in the US [2] and \$700 million/year in the province of Ontario [3].

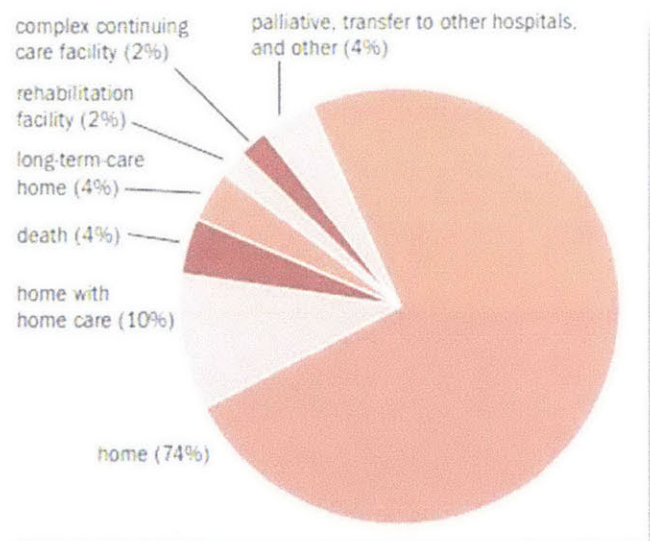


Figure 1: Discharge Destination of Hospitalized Patients in Ontario, 2009, Office of the Auditor General of Ontario [3]

In order to provide a more holistic Hospital to Home architecture and to improve upon the flaws of the current system, we propose a new architecture based on a patient-centric approach within the framework of the Hospital to Home (H2H) initiative called Caregiver Coordination. In the proposed architecture, we will create a web and mobile based application that allows patients and caregivers to interact easily with each other to help manage the patient's wellbeing. We include a short summary illustrating how this new architecture can address the two main problems: (1) the decentralization of the discharge plan; and (2) the dependency on the interactions of multiple stakeholders.

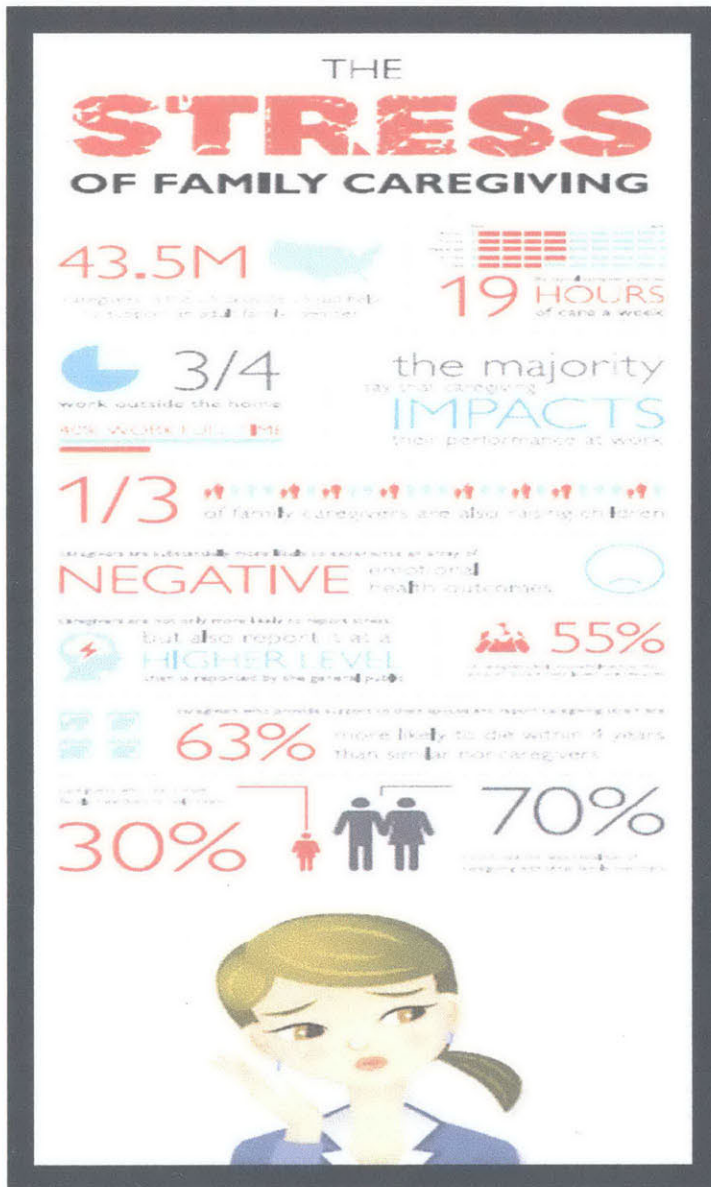
## 1.2 Motivation

My family members and I are involved in managing my parents' wellbeing. There are 43.5 million caregivers like me and my family in the United States who provide unpaid help to support an adult family member. 70 percent share the responsibility with other family members, as opposed to taking on the burden alone. The typical caregiver provides 19 hours of care a week [4].

A third of these family caregivers are also raising children. Three quarters work outside the home while 40 percent work full time. The majority says that caregiving impacts their performance at work [5].

Caregivers are substantially more likely to experience an array of negative emotional health outcomes [6]. 55 percent of caregivers report that they feel overwhelmed by the amount of care their loved one requires. Caregivers are not only more likely to report stress, but also report it at a higher level than is reported by the general public [7]. Caregivers who provide support to their spouse report caregiving strain are 63 percent more likely to die within 4 years than similar non-caregivers [8].

Obtaining support from family members appears to make a substantial difference in the lives of caregivers. People who feel adequately supported in their care giving have, on average, significantly lower levels of stress than other caregivers. They report less feeling of loneliness and isolation, and are less likely to report feeling depressed or sad [9]. The following Infographic was published by Philips in 2013 [10]:



- Caregivers, numbering at least 43.5 million in the US alone, provide unpaid support to adult family members.
- In addition to caregivers that provide unpaid support to adult family members, there are paid caregivers such as Doctors and Clinicians.
- Target Audience: The intended users of the Caregiver Coordination application are family caregivers: people who take care of older adults, most often parents or spouses, who are frail, ill or disabled.
- Family Caregivers may also hire or otherwise coordinate the actions of contractors who provide caregiving services. They may receive the assistance of friends or volunteer organizations. Collectively, these individuals provide a network of care that supports the frail elder. Any member of this network may need to use the caregiver coordination app [10].

Figure 2: Caregiver Coordination Infographic (Philips.com) [10]

## 1.3 Summary

In this thesis, I propose to:

- Analyze and critique the existing hospital to home architecture
- Follow an existing architecture pattern/framework
- Recommend a new architecture
- Propose the creation of a caregiver coordination application using an open source framework to enable a successful transition of patients from hospital to home

## 2. Hospital-to-Home Initiative

### 2.1 Hospital-to-Home Defined

Hospital to Home (H2H) is a national quality improvement initiative. The goal of H2H is to reduce hospital readmissions. H2H can be described as being broad-based and inclusive, incorporating the viewpoints of patients, family caregivers, clinicians across the continuum of care, integrated health systems, communities, policy-makers and payers [11]. The illustration below displays the vision for the H2H user network.

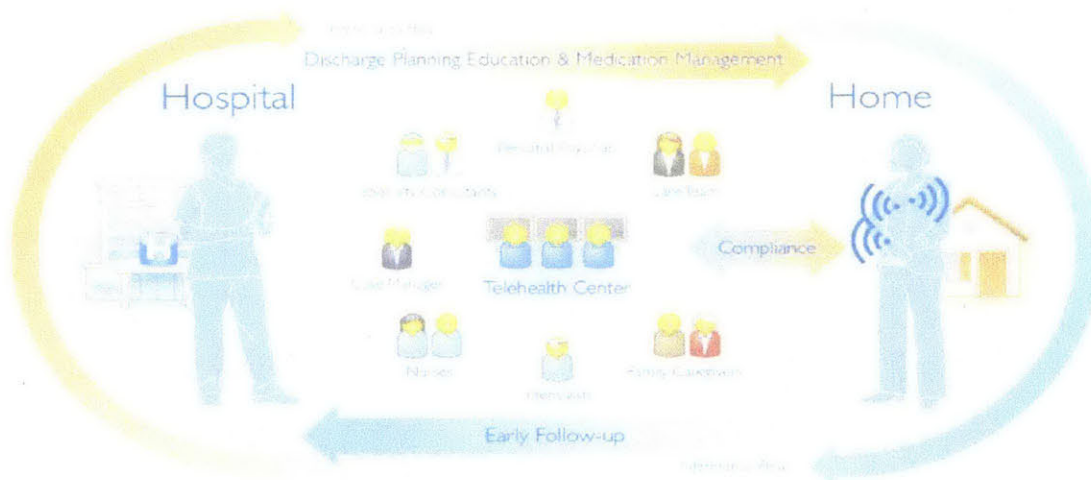


Figure 3: Hospital-to-Home user network (courtesy of Philips Healthcare)

### 2.2 Background

The architecture that currently exists to enable the transition of a patient from the hospital to their home is based on traditional processes, where the patient is given a set of instructions upon discharge.

After we have identified the flaws, we intend to use the same system architecture critical analysis framework to create an improved architecture of an application that will better enable the H2H

initiative [12]. The application will be in the form of a caregiver coordination platform, or a patient-centric tool, that supports the management of health and wellbeing during one's transition from hospital to home. This caregiver coordination may incorporate the patient's care community, meaningful health information, and relevant products & services.

We will use the System Architecture Critical Analysis Framework from the MIT System Architecture program [13] and [14]:

ID	Frame	Question to answer
1	Upstream Influences	Does it satisfy the stakeholder needs?
2	Upstream Influences	Does it meet the goals of the system?
3	Upstream Influences	Can it compete effectively in the marketplace?
4	Upstream Influences	Does it incorporate appropriate technology?
5	Upstream Influences	Does it meet the strategic business goals?
6	Upstream /Downstream Influences	Does it meet or exceed present and future regulations?
7	Downstream Influences	Is it operable, maintainable, sustainable and reliable?
8	Downstream Influences	Can it be evolved / modified as appropriate?
9	Downstream Influences	Is it modular?
10	Downstream Influences	Can the design be implemented as envisioned?
11	Downstream Influences	Can be implemented with existing/planned capabilities?
12	Downstream Influences	Are operational considerations incorporated?
13	Downstream Influences	Does it contain unnecessary (potentially anchoring/constraining) implementation details?
14.	Holistic Frame	Does it answer why, what, how, where, when, who, and how much?
15	Holistic Frame	Is it easy to understand, consistent, and simple while maintaining minimal gratuitous complexity?
16	Holistic Frame	Is it elegant?

Table 1: System Architecture Critical Analysis Framework (Ed Crawley, MIT ESD.34)

## 3. Existing Hospital to Home system

### 3.1 Description of Architecture

Based on general hospital procedures and constraints, patients are typically discharged very quickly and therefore need to understand how to handle their care at home [15]. There is a significant amount of information that needs to be transferred from the hospital care team to the patient and caregiver. This transition process is usually handled by a Transition Coordinator, who is either a specialized nurse or a social worker.

The Transition Coordinator creates a discharge plan for each patient. Depending on the patient's condition, the details of each plan may differ. However, each plan typically consists of the following:

- Pre-discharge assessment of patient and caregiver
- Development of patient-specific discharge plan
  - List of all medications, including dosages, quantities, and instructions
  - Treatment, activity, diet instructions
  - Schedules for follow up appointments
  - Consultation recommendations and provider contact information
  - Educational literature
- Maintenance of communication with patient's hospital team

The above discharge summary is given to the patient and caregiver via verbal and written instructions. The nurse may show the caregiver a demonstration of a specific procedure (like caring for wound dressings) or may give an instructional handout. Often, the hospital staff will not teach these tasks until the day of discharge, which is typically a very hectic time and can be

overwhelming. The discharge plan relies on remembering a lot of information and understanding the, sometimes complicated, paper instructions.

There are also several people involved in the hospital to home transition including the doctors, nurses, pharmacists, social workers, visiting nurses, family and friends. It is important that the discharge plan is understood by everyone involved so that there is no discontinuity in care. This can be quite difficult since the patient’s primary care doctor may not have been involved during the hospital stay and often it is difficult for him/her to get back in touch with the original nurse who managed all of the details. The figure below illustrates some of the needs of the main beneficiaries in the system.

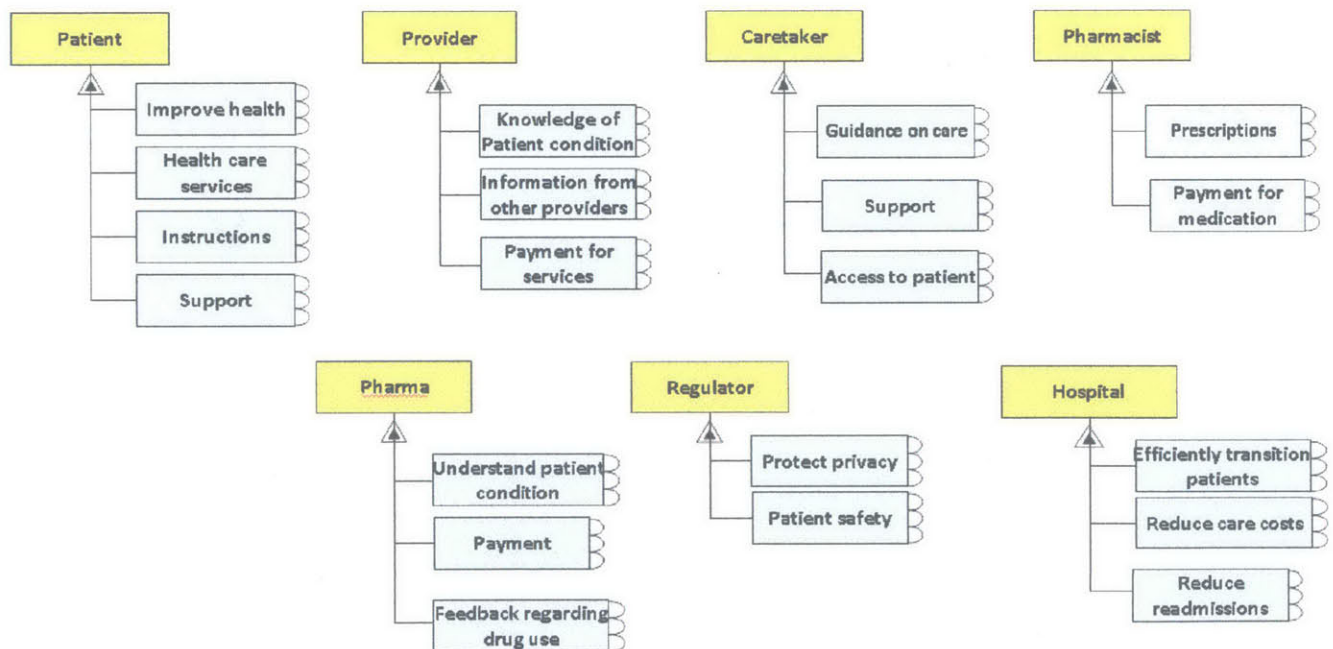


Figure 4: Beneficiaries and Needs for the Hospital-to-Home System

The existing hospital to home system relies on the expertise of the transition coordinator to effectively communicate the discharge plan and provide resource recommendations for the home



caregivers. The system also relies on the patient's and caregivers' capabilities to execute the discharge plan and follow the instructions as intended.

## **3.2 Analysis of Architecture**

The following analysis is based on the framework illustrated in Table 1.

### **3.2.1 Upstream Influences Frame**

#### **1. Does it satisfy the stakeholder needs?**

The main stakeholder is the patient, and if the discharge plan is carried out effectively and all the follow-up instructions and medication guidelines are followed, this existing system should meet the patients' needs. Such needs include an easier interface as well as helping the staff interact with the patients [16]. However, the fact that patients are returning to the hospital to receive additional care implies that there is a failure in the system and therefore the existing architecture is not meeting the stakeholder needs.

#### **2. Does it meet the goals of the system?**

Similar to #1, the failure of the system to satisfy the stakeholder needs also suggests that the goals of the system are not met. The goals of the system are to improve the patient's health and to provide guidelines to achieve a successful recovery. A secondary goal is to prevent the return of the patient to the hospital. As discussed in the introduction, the traditional system is flawed and therefore does not meet these stated goals.

#### **3. Can it compete effectively in the marketplace?**

Currently, this is the only Hospital to Home system in place. Thus, there are no other systems to effectively compare against. However, if we look at the systems in place to transition patients from arrival, to triage, to admission, to surgery, to post surgery, to being ready for discharge, then this Hospital to Home Transition and Monitoring System fails miserably. In the case of the

latter, there is real time feedback on the status of the patient to the interested parties, and also alerts to inform the interested parties when a certain threshold has been crossed. None of these features exist in the case of the former. It is essentially an 'open loop' system.

#### **4. Does it incorporate appropriate technology?**

Many of the documents and literature given to the patients and caregivers are in the form of pamphlets, individual papers, and sometimes website links. The notes that patients are expected to maintain are typically paper-based. These hardcopies often get lost once the patient returns home, or are forgotten when the patient visits their primary care for the follow-up appointments. The discharge plan documentation requires much human interaction and verbal information transfer. The patient/caregiver is still required to do a lot of work, such as seeking physician offices, scheduling appointments, picking up medications, and coordinating with their care team. Therefore, the existing system does not take advantage of the convenience of current technology (EHR – Electronic Health Records), and is therefore both very time consuming and particularly prone to human error.

#### **5. Does it meet the strategic business goals?**

No, refer to #1 & #2. The goal of the system is to provide a successful transition from the hospital to home for the patient, thereby improving health outcomes and preventing hospital readmission. The fact that the U.S. spends over \$17 billion per year for readmissions is indicative of the failure to meet healthcare cost targets. The United States has deemed that the personal TeleHealth ecosystem is of benefit to the quality of life while reducing costs at the same time [17].

#### **6. Does it meet or exceed present and future regulations?**

Nationally, roughly 20 percent of patients that are admitted to the hospital with heart conditions or pneumonia are readmitted within 30 days of discharge. In order to provide accountability, the Centers for Medicare & Medicaid Services (CMS) in the U.S. plan to reduce their payments for hospital readmissions for these conditions. Based on recent studies, the reasons for patient readmissions include ineffective discharge plan communication by transition coordinator, poor patient compliance, inadequate follow-up care, and unreliable system support. Based on this information, it is apparent that the current system, if left alone, will not meet stringent future regulations that are based on healthcare reimbursement.

### **3.2.2 Downstream Influences Frame**

#### **7. Is it operable, maintainable, sustainable and reliable?**

The existing hospital to home system has been operable as described above for over 30 years. The reason that the system flaws are noticed is because the hospital readmission rates are very high. Therefore, based on the data, the current system is not sustainable because of the costs associated with each hospital bed occupant.

For the same reason of high readmission rates, the current system is deemed to be unreliable. It is assumed that the post discharge care for patients is sufficient to ensure continuous recovery of the patient at their home. Instead, there is minimum follow-up by the hospital staff and there are not checks to ensure that the patient is following the prescribed regime. The transition coordinator may be spending a lot of time reviewing the discharge plan with the patient/caregiver, but after the patient is discharged there is no reliable way to ensure compliance.

#### **8. Can be evolved / modified as appropriate?**

Since each patient receives a personalized discharge plan, the design is flexible and therefore can be evolved and modified. It is up to the patient's hospital care team and the transition coordinator to define a personalized plan based on the patient's condition and support they will have once they are at home. Because each hospital may have a different process with various management methods, the discharge systems are widely varied and patient-provider specific.

**9. Is it modular?**

Similar to #8, the system is very modular since it is developed for the needs of each patient [18]. The patient may or may not need a visiting nurse agency or medical equipment. The flexibility in the current discharge system allows for modularity. Patients can also be grouped by their condition, which allows ease of management.

**10. Can the design be implemented as envisioned?**

The design can be executed as envisioned, however it is not always implemented and followed through. The flaws in the system that lead to hospital readmissions are that there are no controls that enforce compliance and there is a lack of provider accountability. Patients are expected to carry through with their care plan, but often do not have the resources or knowledge to do so.

**11. Can be implemented with existing/planned capabilities?**

The intentions of the current system should allow for implementation with existing capabilities. However, it is often difficult for patients/caregivers to make the link across systems. There may be several doctors, services, and personnel to coordinate with and this can be extremely burdensome and time consuming for the patient/caregiver.

**12. Are operational considerations incorporated?**

As read in the literature, the contingency process is to recommend that the patient return to the hospital. As a patient or caregiver reviews the discharge plan and considers readmission to the

hospital as an alternative to home care, the caregiver may be less willing to follow the instructions completely. In the current system there is no directions/tools provided for a patient or caregiver to clearly identify that the recovery period is over and that the patient is fully healed; or that the recovery is progressing smoothly (besides visiting the primary caregiver). Thus the absence of this ability could be another source for readmissions as the patients of caregiver may not be aware of positive and conversely negative indicators.

**13. Does it contain unnecessary (potentially anchoring/constraining) implementation details?**

Although a discharge plan contains many details about a patient's care, all of this information is critical to the health of the patient and is therefore necessary. However, the format of the information can often be overwhelming and disorganized, so it may lead the patient to confusion, resulting in non-compliance. The details are critical, but the expectations that the patients will be able to follow the plan as presented in their paper instructions or remember the verbal discussions are unrealistic.

### **3.2.3 Holistic Frame**

**14. Does it answer why, what, how, where, when, who, and how much?**

The discharge plan system that has been described does answer most of these questions. The team realized that the "how" question is perhaps the most ambiguous. Even though the discharge plan outlines the what, where, and when, it does not specify how the patient will be able to manage, coordinate, and keep track of their health related activities. There are no tools that are given to the patient or caregiver to assist in the "how" aspect and this has shown to lead to non-compliance and insufficient care.

**15. Is it easy to understand, consistent, and simple while maintaining minimal gratuitous complexity?**

No, the issue with the current system is that it is complicated and leaves the patient confused and helpless. In addition there is no centralized hub for the patient to go to for guidance, as their primary care may not have been involved in their hospital stay. In addition, the complicated medication regiments also cause a lot of confusion and the result of missing a dose or not adhering can cause serious side effects and death.

**16. Is it elegant?**

This system is very human intensive and relies on point-to-point communication between people and a significant amount of follow through and pro-active activity. Peoples' lives tend to be very busy and without convenience and constant interaction, it is inevitable that there will be gaps in compliance. This existing system is not elegant in that it is decentralized, ambiguous, and piecemeal.

### **3.3 Summary**

Answering the questions above helped identify the flaws in the current system, but also identified some of the needs that should be considered in a future system. For instance, the main system flaw is that the discharge plan is decentralized and it relies too much on human-to-human interactions, information sharing, and detailed reporting. Without the necessary tools or controls to help people execute this, it is clear why this system is considered ineffective and broken.

However, an important and positive aspect of this system is that it is personalized and modular. Patients have many different conditions and needs and a specific discharge plan must be created based on a case-by-case evaluation. Although, the convenience of technological tools will help

patient compliance and information sharing, it is important that the system be flexible enough to account for a variety of patient-provider needs.

This “Upstream, Downstream, Holistic Framework” analysis identified 16 attributes that are critical for an architecture of a complex system. This framework uncovered several architecture considerations, both positive and negative, of the current Hospital-to-Home architecture.

In the next section, we use this added knowledge to consider a new concept for the Hospital-to-Home architecture.

## 4. Proposed architecture

The result of our analysis led us to propose a new architecture for Hospital to Home that is more streamlined, effective, and reliable. We wanted to push our analysis further by tackling the flaws we identified, specifically:

- Lack of interaction between the different caregivers in managing the patient's wellbeing
- Decentralization of the discharge plan
- Dependency on multiple stakeholders to interact and share data
- Lack of feedback and compliance

We have conceptualized an efficient patient centric system within the framework of the Hospital to Home (H2H) initiative and have named it Caregiver Coordination. The following diagram depicts the features of the Caregiver Coordination:



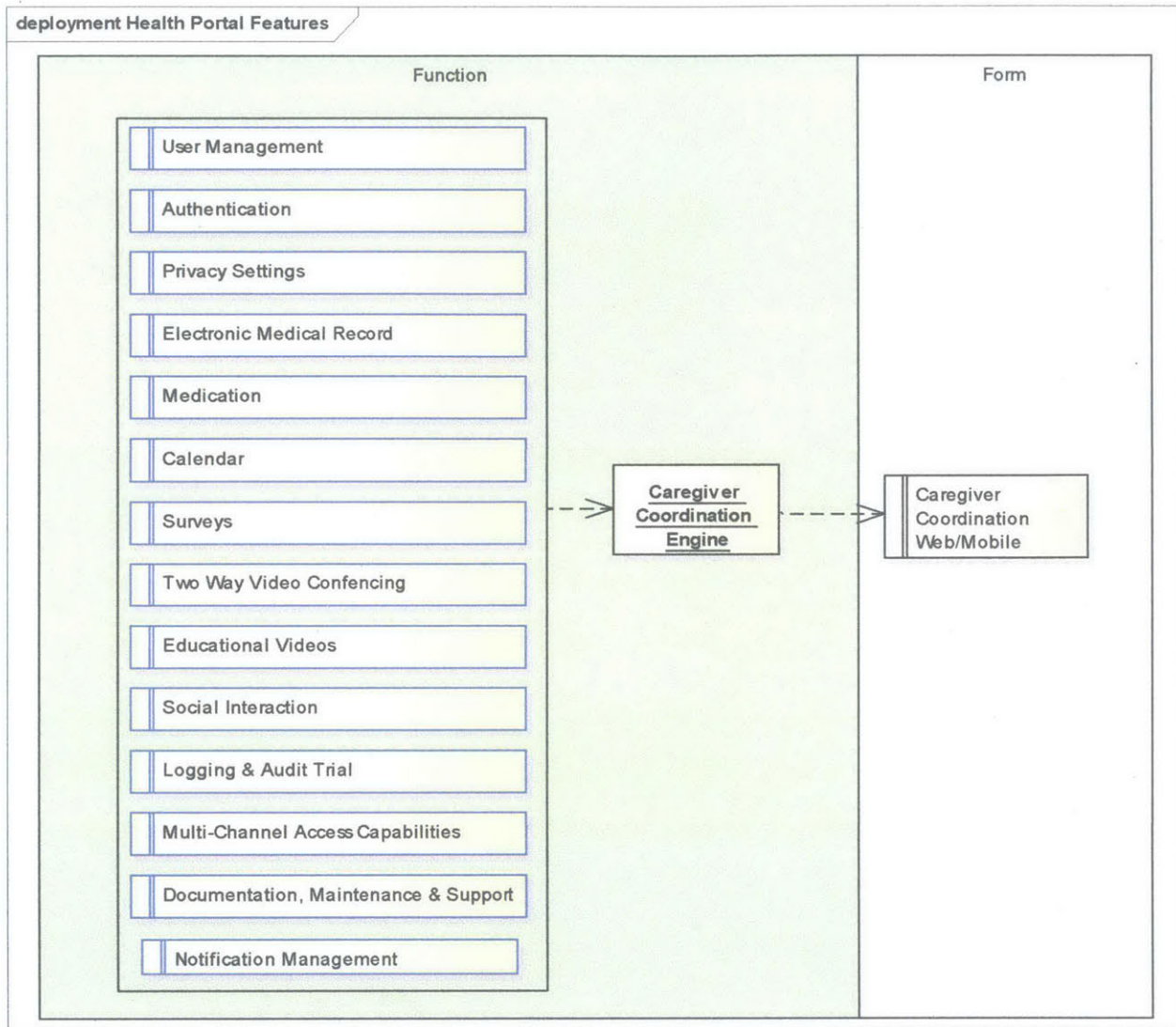


Figure 5: Caregiver Coordination Platform Features

## 4.1 Business

### 4.1.1 Value Proposition

The Caregiver Coordination application (GCA) provides substantial benefits to the different stakeholders:

- For the **care teams**, the GCA addresses the growing number of chronically ill patients by providing information and tools they need to confidently and efficiently deliver high-

quality humanistic care. This help caregivers treat a growing number of patients by providing the information and tools they need to confidently and efficiently deliver high-quality humanistic care from hospital discharge to home.

- For **patients** and **families**, the platform offers personalized information and tools to help them understand their hospital discharge and adhere to ongoing care.
- For the **insurance companies** and **taxpayers**, the platform drives down the cost of healthcare while improve the quality of healthcare.

The following are additional benefits for patients:

- Direct contact with doctors through the web, mobile devices or call center and therefore saving money and time.
- Search the nearest doctor or specialist, getting reviews and other references.
- Get instant access to electronic health records.
- Get medication reminders and medical appointments.

Additional benefits for doctors and health institutions:

- Assist more patients using the platform.
- Easy access to the patient's electronic records.
- Enhance communication between the platform stakeholders and users.

## 4.1.2 Features

To provide quality healthcare to patients leaving the hospital, a successful H2H initiative needs to include the following features:

- User Management
- Authentication
- Privacy Settings

- Electronic Medical Record
- Medication
- Calendar
- Surveys
- Two Way Video Conferencing
- Education Videos
- Social Interaction
- Logging & Audit Trail
- Multi-Channel Access Capabilities
- Documentation, Maintenance & Support
- Notification Management

### 4.1.3 Definitions

This section defines some of the terms used in the Caregiver Coordination application [19]:

- **Caregivers:** Healthcare professionals and family members.
- **Community:** A particular network of caregivers, using the caregiver coordination application. The Community consists of one Community Leader, and any number of additional Community Members. A community is organized around one or more people who receive the care.
- **Community Leader:** Sets up the care giving Community, invites other users to participate in the Community, and otherwise administers the Community.
- **Community Members:** The Community Leader and the other members who have accepted an invitation to join the Community.

- **Task:** An individual item of work or event being undertaken by Community Members as part of their care giving. Some examples of tasks include “take mom to appointment”, “pay bills”, or “prepare meal”. The caregiver coordination application provides a way for community members to create, assign and share tasks. Tasks within the application are created by Community Members.
- **Responsible Party:** Some tasks may have a particular Community Member who is expected to ensure that they are completed. This community member is known as the responsible party. Not every task will have a responsible party.
- **Volunteer:** The action of choosing to become the Responsible Party for a task
- **User:** A person who is using the app. Typically a Community Member, but could person who has downloaded the app but who has not yet registered.

## 4.2 Architecture Assessment

In order to build an application that works on multiple devices and channels, we needed to choose a technology framework that allows us to create one application that can be adapted to different forms and channels. This section outlines some of the technology options to implement the solution and our recommendation.

Even though, there are a variety of cross platforms tools to create our Caregiver Coordination application, we decided to evaluate two open source cross platforms: PhoneGap and Appcelerator. Those two open source cross platforms were compared to native Software Development Kits, iPhone SDK and Android SDK.

## 4.2.1 Key Architecture Considerations and Principles

### 4.2.1.1 Architecture Considerations

The following are some of the key architecture considerations in choosing a cross platform framework:

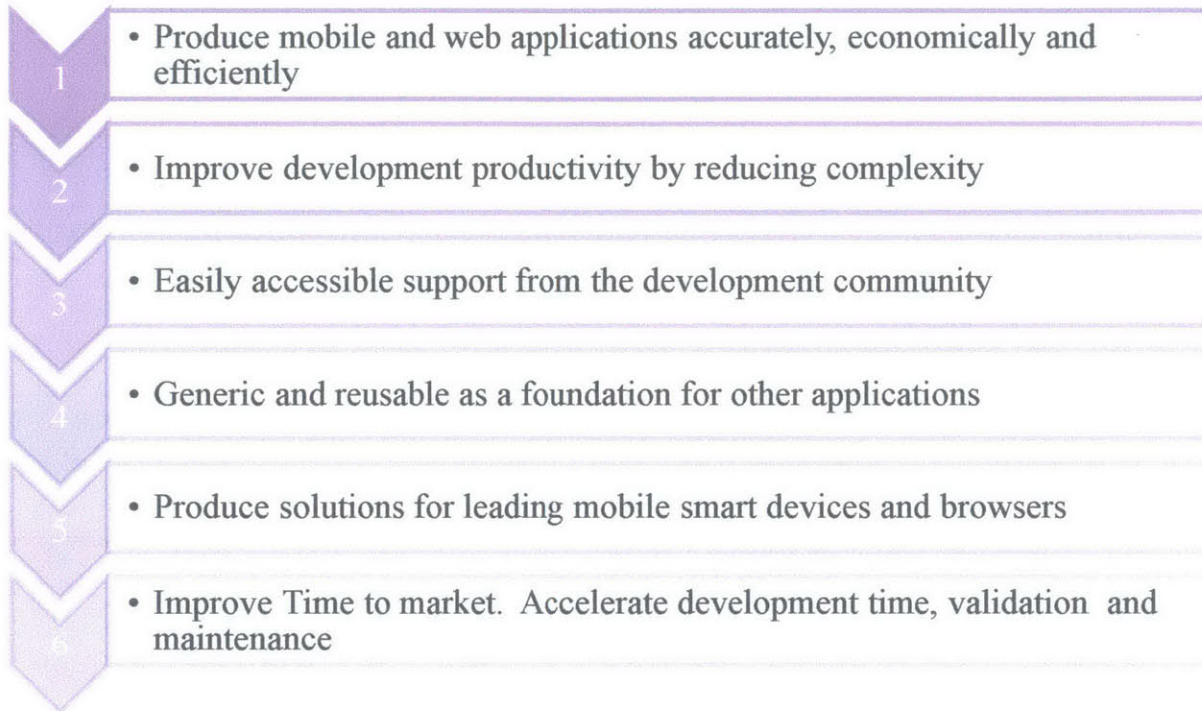


Figure 6: Key Architecture Considerations

### 4.2.1.2 Principles

We understand that the system is complex and involves different stakeholders with different interest and priorities in mind. Without having the full support of the different stakeholders, the Caregiver Coordination will not achieve the desired result. Since we are dealing with an IT system, we decided to apply some of Dr. Tang's principles to our proposed architecture.

#### **Principle 1 (Taktchronicity):**

Dr. Tang emphasized the fact that IT should be viewed as a product-service system (PSS) in which value must be co-created and co-produced in taktchronicity.

**Principle 2 (Define Caregiver coordination system in terms of IT services):**

The IT service does not deal only with software and hardware, but instead, the IT space (in his mental model) is divided into four spaces:

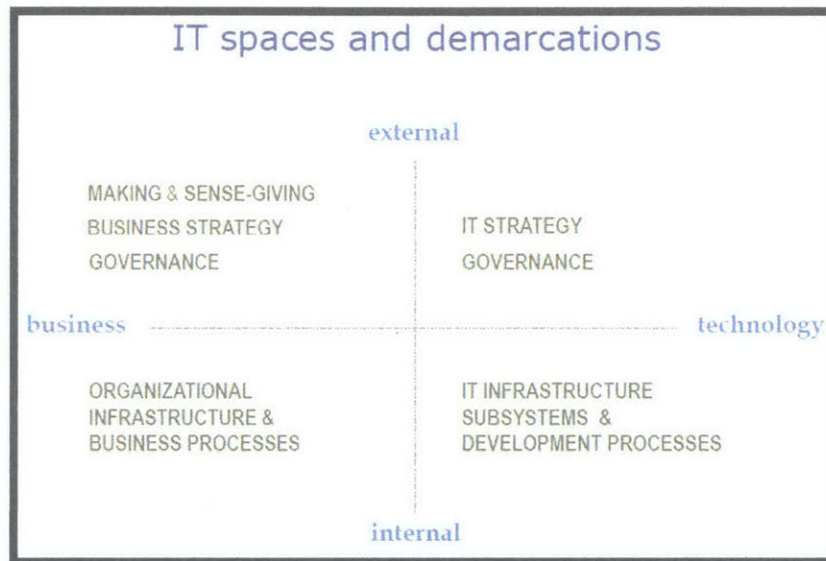


Figure 7: IT spaces and demarcations – Dr. Tang [18]

IT as a service is not only a technical issue, it is also a business strategy issue and thus there is a need to propose a solution based on Dr. Tang’s four IT spaces and demarcations.

**Principle 3 (Complexity):**

The Caregiver Coordination solution will be a complex system that lessens complicatedness, which is considered good complexity, as Dr. Tang puts it: “Complexity is like cholesterol. There is good complexity and there is bad complexity. Complexity that reduces complicatedness is good. The challenge is to architect complexity”. [18]

## 4.2.2 Architecture Assessment Analysis

The following is a high-level application context diagram of the Caregiver Coordination application and system interactions:

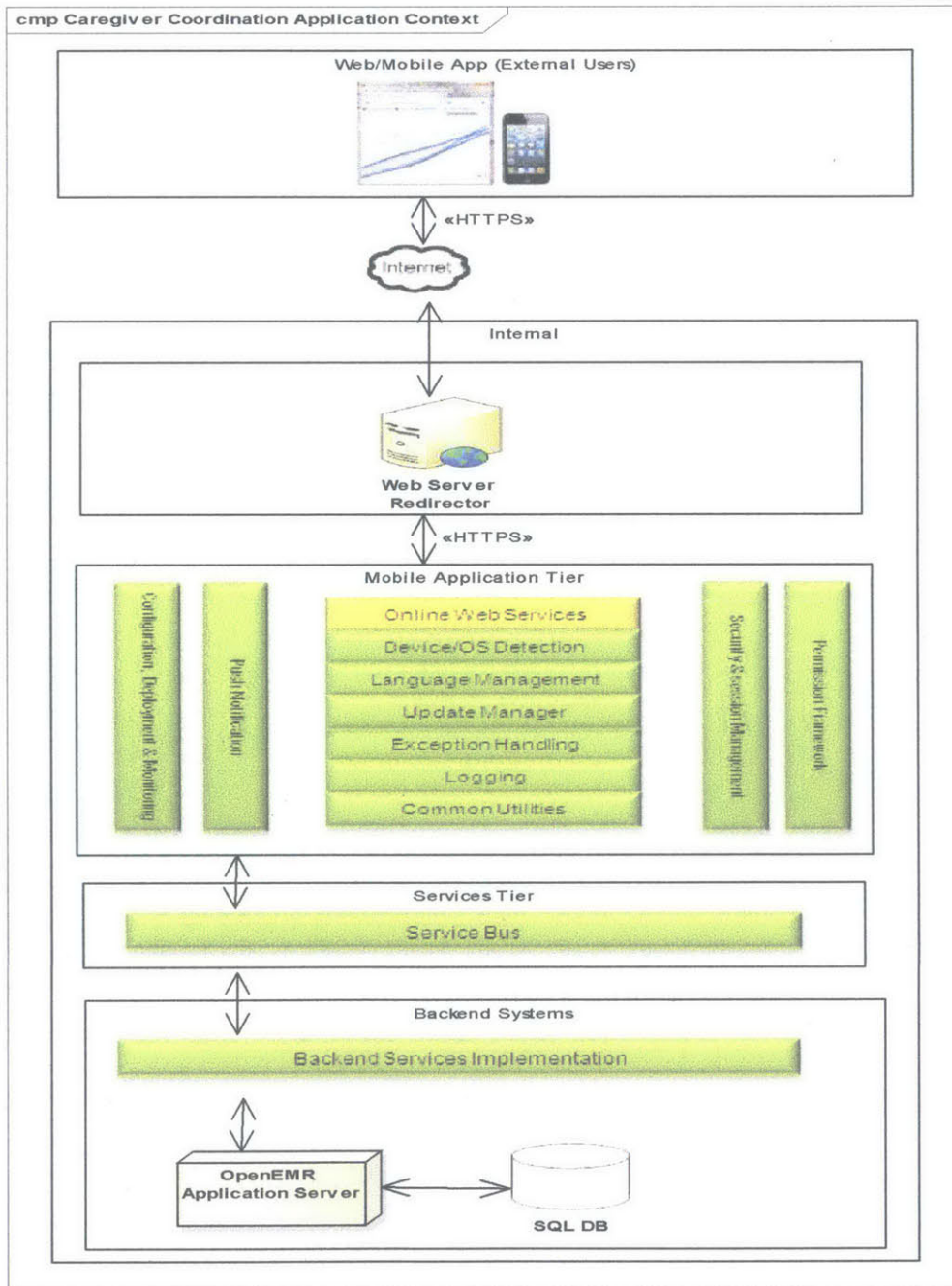


Figure 8: Caregiver Coordination Application Context

As part of the fully integrated solution, three components are identified:

- **Front end application** (Native application and web based application)
- **Application server** (middle tier, web services and database)
- **Backend services and Infrastructure and Deployment**

## 4.2.2.1 Front end application

### 4.2.2.1.1 Requirement

The requirement is to create a native mobile application and a web based application. The native mobile application is to be deployed to the Apple apps store and to the Google Play store. The web based application should work on all major browsers.

To meet the multi-channel capabilities, there is a need to choose a cross platform to create the caregiver coordination application.

The choice was between a cross platform Integrated Development Environment (Create once, run everywhere) or Native SDKs:

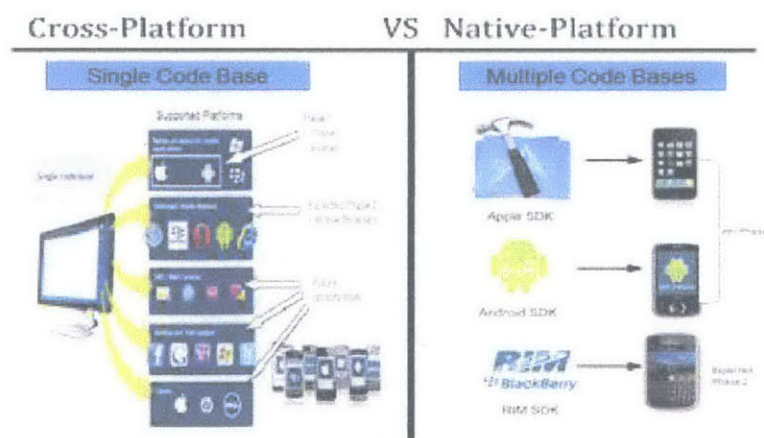


Figure 9: Single Code Base vs. Multiple Code Bases [20]



### 4.2.2.1.2 Framework Summary

The following is summary of the different frameworks evaluated as part of my job at Philips Home Monitoring in 2012:

Framework	Tools	Keywords	Description
Native	iOS SDK	Apple Inc, Native, iOS only, Mac OSX Dev Env., Objective C	Developed by Apple Inc. and available since the beginning of 2008, this SDK allows for writing of native applications for iPhone, iPad and iPod. While providing the strongest integration with the device's native features, the developers are constrained to the Mac OSX development environment and mandated of programming ability in Objective C.
	Android SDK	Google Inc., Native, Java/XML, flexible Dev. Env.	Developed by Google Inc. and available since the end of 2007, this SDK allows for writing of native applications for all Android devices. Offers flexibility in development platforms and methods (through IDE or from command line) while maintaining strong binding with the full set of device features.
Hybrid	Titanium Appcelerator	HTML/CSS/JS/Python/PHP, Native UI	Differentiating themselves from other 'hybrid' class peers, Titanium, Instead of going breadth wise and covering the entire smart phone range they are taking the depth wise approach. Titanium apps are one of the best performing & true native UI applications with the vast native device feature API set. Another differentiator is they bundle a JS engine while packaging and not rely on the default browser's JS engine.
	PhoneGap	HTML5/CSS3/JS	PhoneGap provides access to a spectrum of native features such as accessing camera, accelerometers, providing connectors for analytics, social networking apps, mashups all built under one umbrella suing the built-in JS APIs while the views are created using web technologies. Bundling with tools like Sencha and JQuery, PhoneGap can be used to builds applications that look truly native. PhoneGap also claims support for 6 different platforms including all major Smartphone OS, Symbian, etc.

Table 2: Framework Summary

### 4.2.2.1.3 Recommendation

After evaluating several cross platforms, the recommendation is to use Titanium Appcelerator.

Titanium offers two platforms [21]:

- Titanium SDK allows users to create rich native iOS, Android, hybrid, and mobile web apps from a single JavaScript-based SDK. The Titanium Mobile SDK leverages over 5,000 device and mobile operating system APIs to develop native iOS, Android, hybrid, and mobile applications that perform and behave just like they were written in Objective-C (iPhone and iPad) or Java (Android phone and tablets) native apps that deliver user-optimized experiences.

### Features

- Supports 5,000+ native APIs
- JavaScript-based development platform
- Support for iOS, Android, and HTML5 mobile application development

### Benefits

- 70% faster than developing in Objective-C or Java
- Single mobile application development platform
- Unlimited extensibility

Figure 10: Titanium SDK [21]

- Titanium Studio is an all-inclusive powerful Eclipse-based integrated development environment (IDE).

### Features

- ACS-enable your mobile applications
- Advanced app code assisting
- Debug and test your mobile apps on the simulator or a device
- Package and publish your mobile apps to an App Store

### Benefits

- Unified code development environment
- 1-click mobile app deployment to staging environments, hosting services and AppStores
- Support for HTML5, CSS3, Javascript, Ruby, Rails, Python, PHP

Figure 11: Titanium IDE [21]

## 4.2.2.2 Application Server

To enable separation of concerns, an application middle tier will be created as part of this application:

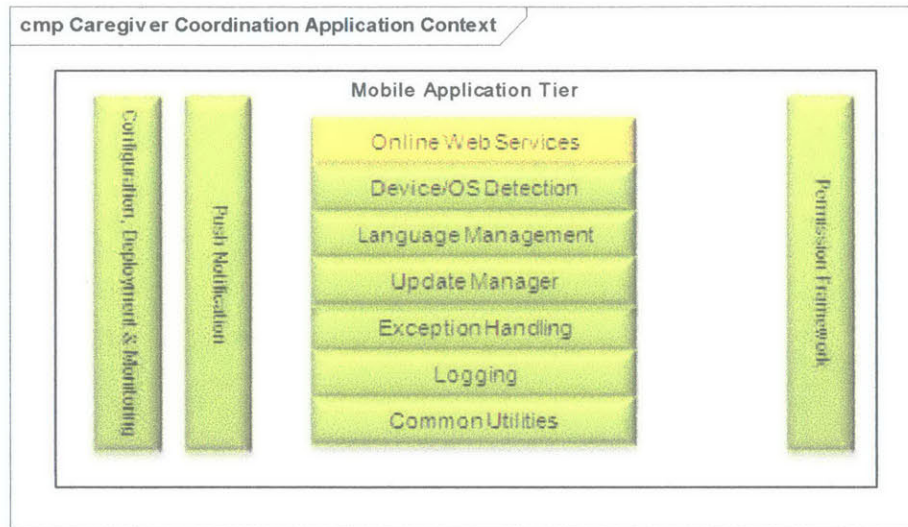


Figure 12: Caregiver Coordination Middle Tier Application Server

The following components will be implemented:

- Configuration, Deployment & Monitoring.
- Security & Session Management.
- Permission Framework: framework to handle page display based on permissions obtained from the Backend Systems.
- Exception Handling: Robust exception and error handling mechanism to handle exceptions and errors from Backend Systems and the front end application. Exceptions across all tiers will be handled.
- Logging: Logging framework for asynchronous logging, to improve the application performance using java messaging services.
- Common Utilities.
- Push Notification.
- Online Web Services (OWS): This component is a web service layer to expose existing services of backend systems to support the front end application (mobile and web).

### 4.2.2.3 Backend Services Infrastructure

OpenEMR application services and MySQL represent the backend. For the purpose of this thesis, a cloud storage and deployment were chosen to implement the solution.

## 4.3 Implementation

To create the caregiver coordination application, we recommend combining two open source frameworks: OpenEMR (web and backend) and Titanium (mobile native application).

The OpenEMR framework is a free. OpenEMR is an open source electronic health records and medical practice management application that can run on Windows, Linux, Mac OS X, and many other platforms. The following are some of the OpenEMR features [22]:

#### Free

- Freely available
- Free to download, use, modify, and upgrade
- Free documentation
- Free support forum
- Open source
- Released under the GNU General Public License

#### ONC Certified

- ONC Complete Ambulatory EHR Certified

#### Patient Demographics

- Track patient demographics

- Primary information (name, date of birth, sex, identification)
- Marital status
- Contact information of patient and patient's employer
- Primary provider
- HIPAA information
- Language and ethnicity
- Insurance coverage
- Deceased Tracking
- Fully Customizable

#### Patient Scheduling

- Supports multiple facilities
- Patient appointment notification via email and SMS
- Compact and flexible appointment calendar
- Calendar features include:
  - Find open appointment slots
  - Categories for appointment types
  - Colors associated with appointment types and facility
  - Repeating appointments
  - Restricting appointments based on type

#### Electronic Medical Records

- Encounters
- Medical Issues

- Medications
- Immunizations
- Forms and clinical notes:
  - Vitals (growth charts included)
  - SOAP note
  - Review of systems
  - Template Driven Forms
    - CAMOS (Computer Aided Medical Ordering System)
    - Nation Notes (WYSIWYG editor)
  - Ability to create and customize forms
- Graphical Charting
- Labs
- Procedures
- Patient Reports
- Referrals
- Patient Notes
- Disclosures
- Electronic digital document management
- Voice recognition ready (MS Windows Operating Systems)
- Paper chart tracking
- Electronic Syndrome Surveillance reporting
- Clinic Messaging
- Dated Reminders

## Prescriptions

- Online drug search
- Track patient prescriptions and medications
- Create and send prescriptions
  - E-Prescribe
  - Print
  - Fax
  - Email
- Customizable layout including options for DEA, NPI and state license numbers.
- In-house pharmacy dispensary support

## Medical Billing

- Flexible system of coding including CPT, HCPCS, ICD9, ICD10 and SNOMED codes, and the ability to add others
- Support for 5010 standards
- Support for electronic billing to clearing houses such as Medavant/Caprio and ZirMED using ANSI X12
- Support for paper claims
- Medical claim management interface
- Insurance Eligibility Queries
- Insurance Tracking Interface
- Accounts Receivable Interface
- EOB Entry Interface
- Customizable to work with a clearing house for automated 835 or ERA entry

## Clinical Decision Rules

- Physician Reminders
- Patient Reminders
- Clinical Quality Measure Calculations
- Automated Meaningful Use Measurement Calculations
- Fully Customizable and Flexible

## Patient Portal

- Reports
- Labs
- Medical Problems
- Medications
- Allergies
- Appointments
- Secure API that Supports Third Party Patient Portals

## Reports

- Appointments
- Patient Lists
- Prescriptions and Drug Dispensing
- Referrals
- Immunizations
- Clinical Measure Calculations
- Clinical Quality Measures (CQM) Calculations



- Automated Measure Calculations (AMC) and Tracking
- Syndromic Surveillance
- Pending Procedure Orders
- Ordered Procedure Statistics
- Paper Chart Tracking
- Sales
- Collections
- Insurance Distributions
- Insurance Eligibility

#### Multilanguage Support

- Supports use of multiple languages within the same clinic
- Currently Supported Languages:
  - English (American)
  - English (Indian)
  - Bahasa Indonesia
  - Chinese (Simplified)
  - Chinese (Traditional)
  - Danish
  - Dutch
  - French
  - Greek
  - Italian
  - Portuguese (Brazilian)

- Portuguese (European)
  - Russian
  - Spanish (Latin American)
  - Spanish (Spain)
  - Swedish
  - Turkish
  - Ukrainian
  - Vietnamese
- Any language can be added and translated in a Collaborative Google Docs Spreadsheet maintained by the OpenEMR community
  - Fully supports UTF-8 encoding

## Security

- Ability to Encrypt Patient Documents
- Supports fine-grained per-user access controls
- Remotely accessible from any modern web browser with a suitable security certificate installed

## Support

- Vast Online Documentation
- Free Online Support Forum
- Free IRC Chat Support Channel
- Numerous Free and Professional Support Options

The OpenEMR can be used as is with minor customization to include the caregiver coordination branding and to expose some interfaces for the mobile native application. The following are screenshots of the some of the features available within the OpenEMR solution:

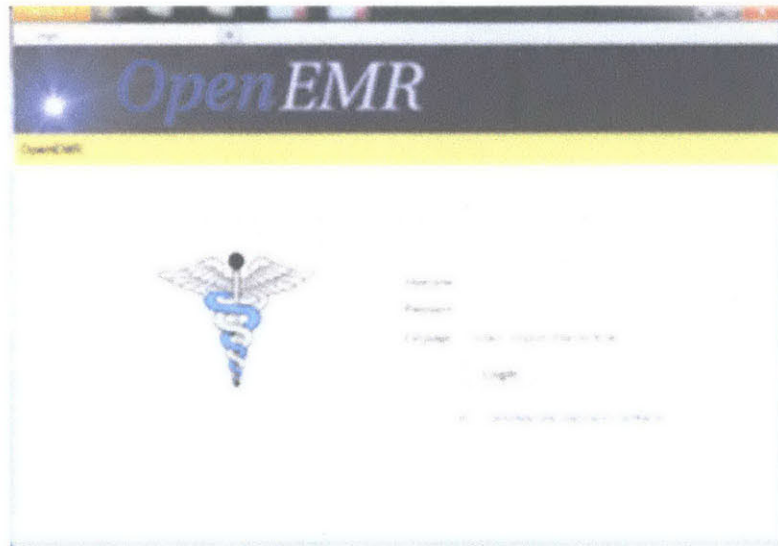


Figure 13: Login

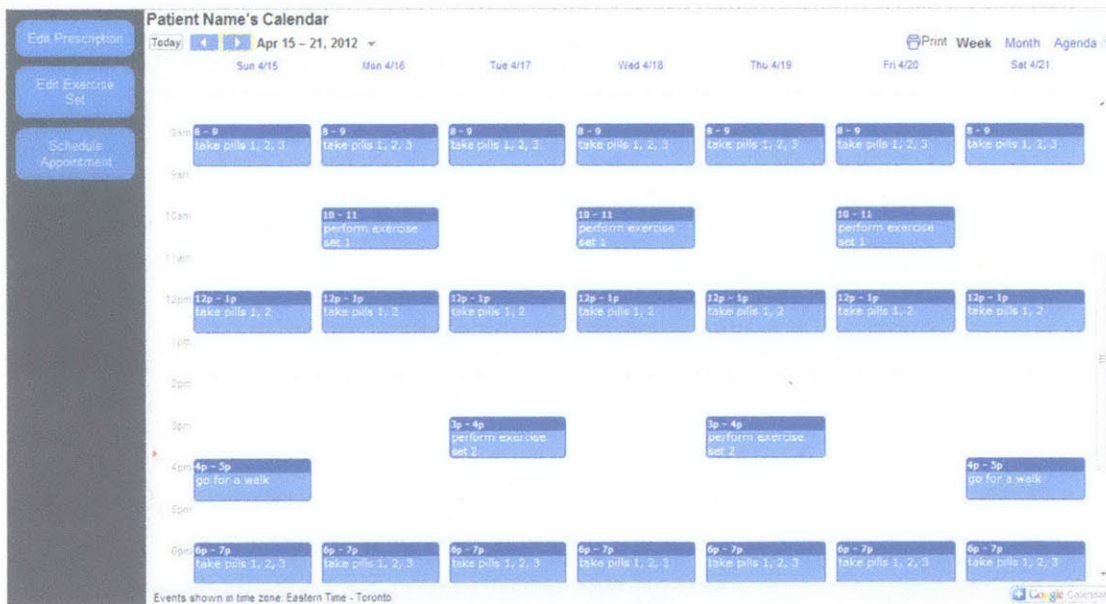


Figure 14: Calendar Feature

Figure 6 illustrates the calendar feature. The calendar feature allows care providers to add or modify medication plans, exercise plans and appointments for patients. The patients can then receive these updates, follow their schedules, and provide feedback upon completion.

The progress of each patient is tacked on the openEMR database, and an appropriate warning message will be generated in the form of an email shown in figure 7. One of the example messages can be “You forgot to take your [medication name] today at 9:00 AM and 12:00 PM”. The messages can also be automatically generated to remind the patient about upcoming schedule. The reminder domain can be extended to text messages or automated phone call with a pre-recorded message. The reminder mechanism will keep the patient in the center, as he/she will always be the first to be alerted when discharge progress is not going in the right direction.

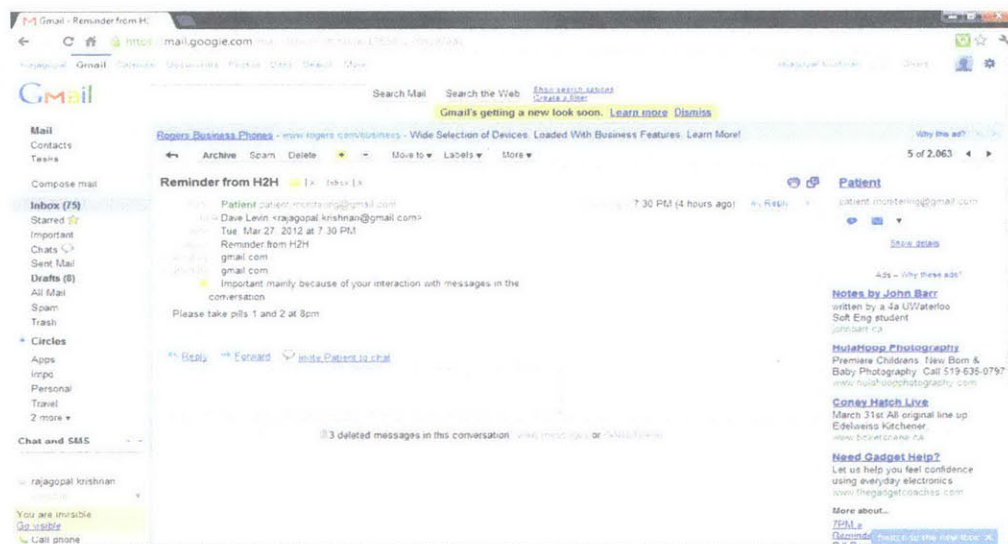


Figure 15: Email reminder sent from the Caregiver Coordination

The following are additional features implemented. The features are from the care coordination application (A.K.A. Care Partner). This application was created for Philips Lifeline:

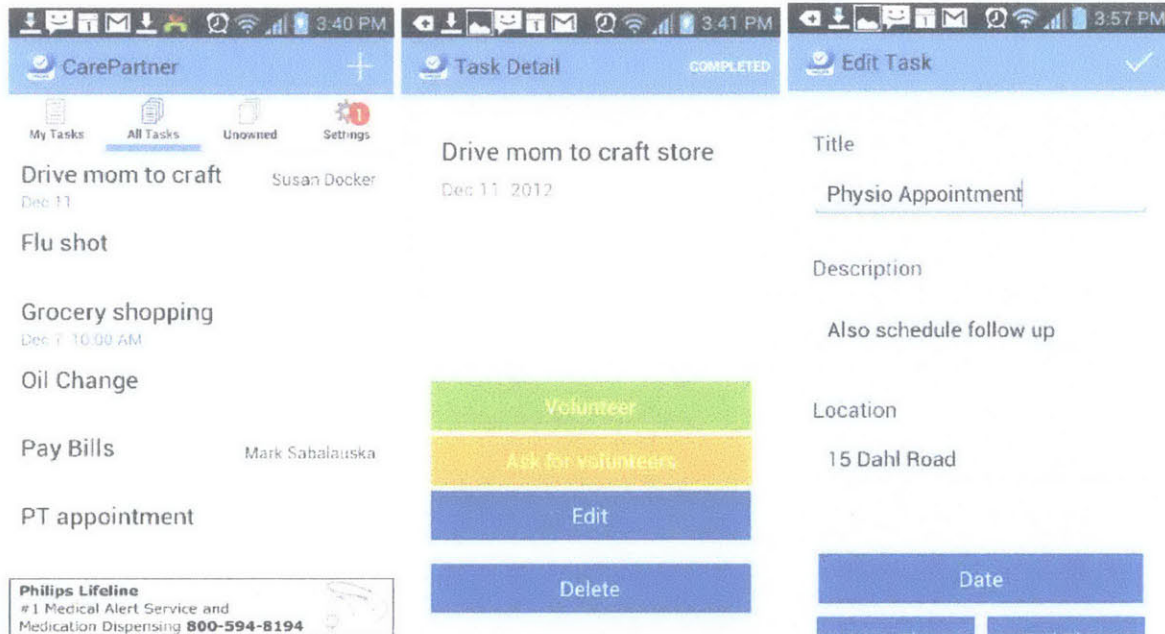


Figure 16: Caregiver Coordination (A.K.A Care Partner Mobile) native application (Philips.com)

## 5. Conclusion

In order to enable a successful transition of patients from the hospital to home and reduce the rate of readmissions, we proposed a new architecture that puts the patient in the center of the universe surrounded by caregivers, whether they are family members, healthcare professionals or simply other patients. Those caregivers will contribute to the wellbeing of the patient.

We understand that the implementation tend to be complex as it requires the buy-in of different stakeholders and integration to systems such as Electronic Medical Records systems. However, we suggest that this system should be implemented in phases until large patients and caregivers start using it which will force other stakeholders to adopt it.

In conclusion, our new architecture will involve the Hospital to Home system stakeholders and will deliver the following features on the caregiver coordination web/mobile based platform:

- ✓ User Management
- ✓ Calendar
- ✓ Health data
- ✓ Messaging
- ✓ Medication
- ✓ Surveys
- ✓ Videos
- ✓ Logging & Audit trail
- ✓ Social Platform
- ✓ Single Sign-on

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