Modeling patient care outside the hospital and exploring related use-cases involving blockchain technology

Mohan Tanniru and Robert Tanniru

1. Introduction

Healthcare providers have focused on leveraging advanced technology to provide cost-effective, high-quality clinical care while patients are in the hospital. They have started to design innovative digital (IT-enabled) services to improve care plans created between providers and patients to address specific medical conditions. Some examples include real-time locator sensors (RTLS) to track patient flows in emergency and patient rooms to reduce delays within the hospital [1]; optimally scheduling operating rooms to improve efficiencies and reduce surgical delays [2]; and wearables, smart beds and structured patient calls to nursing staff for quicker action when patient conditions deteriorate, reduced patient falls and associated complications, and improved responsiveness to patient needs [3]. In addition, service innovations, such as multidisciplinary rounding with minimal technology, have been used to support collaboration among care staff to track critical patient events for immediate follow-up as well as to engage patients in their care plans [4].

Coordination of patient care when a patient moves out of the hospital to their home or other healthcare facility (e.g. a skilled nursing facility) has become an important quality indicator for healthcare organizations. Unanticipated patient readmission to a hospital after discharge has also become an important cost driver globally. In the US, the Affordable Care Act has started to penalize healthcare providers for excessive readmission rates within 30-days after discharge [5]. Often referred to as care transition, several best practices have been suggested for potential exploration and adoption [6]. These include provider interventions in the care of high-risk patients [7], transition care models that engage multiple external care providers [8], and project RED that engages community members [9]. Other models discussed to address care transition include following up on care of certain population groups [10], empowering patients using enhanced communication [11], engaging nurses from regional institutions in some discharge planning activities [12], and using the participation of specialists/nurse practitioners as intermediaries in
complex cases [13]. A multi-faceted approach, using technologies when appropriate, is shown often to be more effective [14,15]. Some of the technologies used here include tele-health consultations, mobile apps for communication and sending alerts, etc. [16].

Healthcare organizations face a few challenges as well as opportunities as they begin to move some discharge planning activities [17] to external care providers and to patients and family members as part of care transition. The challenges include learning about clinical and non-clinical actors in the patient ecosystem and their capability to coordinate activities needed to support care transition and using technologies to share information, such as patient data, follow-up schedules, and follow-up questions. More importantly, there is a need to align the goals of healthcare providers and external actors who are supporting patients in giving patients access to quality care at a lower cost. The opportunities include making care accessible to patients within their ecosystem and empowering them with support from family and community members as well as technology to self-manage their health condition.

Supporting care transition outside healthcare organizations thus needs to address both the alignment and resource sharing challenges, while taking advantage of technologies to expand the number of clinical and non-clinical actors who can support such care transition. The goal of this paper is to model the care transition services systematically to identify resource sharing challenges and leverage advances in distributed network architectures, specifically blockchain architecture, to support such resource sharing outside a hospital.

The paper is organized as follows. Section Two will use service dominant (S-D) logic research to model care transition services. Section Three uses this model to identify the resources that need to be shared by actors within multiple ecosystems for both preventive and transitional care post-discharge. Section Four illustrates the design of two blockchain implementations to support care outside a hospital. Section Five shows how such implementations can adapt to changes in the ecosystem outside the provider using AI and smart agents. The final section provides some concluding remarks and directions for future research.

2. Developing a Model for Care Transition

The increasing share of services in today’s knowledge economy, including manufacturing firms [18], is leading all organizations to view themselves as service providers and work with
customers in co-creating value that is supported by innovative products or services. Service dominant logic research considers value creation or cocreation with customers as an important first step in identifying the service exchanges needed to create value between care providers and customers, and then using a mix of internal and external resources to fulfill value propositions [19]. We will use some examples of care provided within a hospital to illustrate how value creation can be modeled using S-D logic terminology.

Patients receive several services in a patient room. Some are initiated by a patient, such as calling clinical staff for pain medication, bathroom visits, ordering food, etc. Others are initiated by clinical staff, such as monitoring patient vital signs, washing hands before treating patients, and taking patients to labs for diagnostic tests. Independent of who initiates a service, each service exchange involves the engagement of at least two actors, the care provider and the care recipient (or customer), and together they create a value (or generate an agreed upon outcome). In this value creation, they may use other resources.

To illustrate the concept, let us take a simple example: a patient asks a nurse in the room for assistance to go to bathroom. This is represented using the following terminology and abbreviations. VP is the value proposition (supported by a service exchange between two actors), SE is the service exchange between actors; * implies existence of both actors being present to initiate the service; and -> implies reaching the outcome (or goal) state or creating the value.

VP [BathroomSupport]= SE[PatientAsksForBathroomSupport*NurseInTheRoom -> PatientInBathroom]

If nurses are not in the room, patients and staff communicate using two technologies: PillowTalk1 (button1 of a PillowTalk technology), used to call a nurse assistant, and a text message on VoltePhone, used by the assistant to receive an alert message to respond. This is represented as follows and shown as a state transition network in Figure 1 (Highlighted letters below are used in the network).

VP [SendRequest] = SE [PatientNeedForBathroomVisit*Pillowtalk1->NurseasstVolteAlert]
VP [NurseAsstResponds] = SE [NurseasstAvailable*NurseasstVolteAlert->NurseasstComesToRoom]
VP [NurseAttendsToRequest] = SE [NurseasstComesToRoom*PatientAsksForBathroomSupport->PatientInBathroom]
Here, there are multiple actors involved (patients, technology, nursing assistant) in creating value for the patient (or major value proposition), and creating this value needs the fulfillment of three mini-value propositions occurring in sequence. Each of these mini-value propositions use service exchanges between human and machine actors.

- Patient needing to go to bathroom presses button 1 of the PillowTalk to trigger an alert on the VoltePhone of nursing assistant
- Nursing assistant being available and receiving the alert on the phone leads to nursing assistant coming to room
- Patient asks the nurse to visit bathroom when the nurse comes to room, and this leads to patient visiting the bathroom.

The state transition network is shown in Figure 1. The service exchange between actors is shown on the left-hand side of the “bar” or “|”, and the value created from this exchange or outcome is shown on the right-hand side of the bar. The “bar” represents a transition of input states to an output state. The input and output states are shown in circles and, if there is a “1” in these circles, the input states are said to be “True,” and this leads to the output state being “True” or will have a 1 in the circle representing the output state. The circles are known as places, the “|” is a transition, and the network representation is often referred to as Petri Network.

From here on, for simplification, we will represent the value created by the provider to meet a customer need as a series of state transitions, with the output state written in boldface.

\[
VP \ [\text{BathroomSupport}] = \text{PatientNeedForBathroomVisit*Pillowtalk1*NurseasstVolteAlert*}
\text{NurseasstAvailable*NurseasstComesToRoom*PatientAsksForBathroomSupport*PatientInBathroom}
\]
Coming back to the value proposition related to BathroomSupport, a smartbed with sensors can be used to trigger an alert when a patient tries to get out of bed. This interaction replaces use of PillowTalk1. For patients with high risk, the bedsensors are set to position true or ON. When patients try to get out of bed, an alert is sent to all nurses, and an outside room light gets turned on (i.e. “FlashingRoomLightsON”). When a nurse walks in, the flashing room lights get turned off.

\[
V_{\text{P[FallRisk]}} = \\
\text{PatientMovement} \cdot \text{BedSensorsOn} \cdot \text{VolteAlert} \cdot \text{NurseAvailable} \cdot \text{NurseComeToRoom} \cdot \text{PatientReady} \cdot \text{PatientinBathroom} \\
\text{VolteAlert} \cdot \text{RoomLightOff} \cdot \text{FlashingRoomLightOn} \\
\text{NurseComeToRoom} \cdot \text{RoomLightsFlashingOn} \cdot \text{RoomLightsOff}
\]

2.1 Use of Inferencing One of the benefits of such representation is to use inferencing based on facts or observed states to simulate the network and detect where service gaps may occur. For example, if the relationship between input and output states can also be represented using predicate calculus, function (subject, object), then one can use forward or backward chaining to support inferencing. For example, the Petri Network representation used above can be used to describe the relationships in predicate calculus as follows:

SendRequest ((PatientNeedForBathroomVisit, Pillowtalk1), NurseasstVolteAlert)  
NurseAsstResponds ((NurseasstAvailable, NurseasstVolteAlert), NurseasstComesToRoom)  
NurseAttendsToRequest ((NurseasstComesToRoom, PatientAsksForBathroomSupport), PatientInBathroom)

In this paper, we will not discuss inferencing and network simulation. The next section uses service modeling to discuss care services, preventive as well as care transition post discharge, outside a hospital and how various actors in the patient ecosystem are used to integrate resources to provide care.

3. Modeling Care Outside a Hospital for Preventive and Transitional Care

Care outside a hospital is often designed to address prevention as well as transition of care post-discharge. While care transition post-discharge has received attention due to reimbursement penalties, there has been significant discussion recently on challenges healthcare professionals and communities are facing in preventive care, especially with the recent discussion on the measles
outbreak and opioid addictions. There is a need to bring multiple community resources to help consumers who show conditions, such as mental health problems and drug addiction, and communicable diseases, such as AIDS, from reaching a serious state. The next two examples show how one public health organization has used community resources to innovatively address two specific situations.

3.1 Mental Health Prevention

The organization used an innovative approach to address the mental health conditions of patients. The primary care doctor (D) uses a mental health psychotherapist (MHP), another clinical actor, to develop a mental health rehabilitation schedule for a patient. The patient is asked to use the support of a community health worker (CHW) to visit these rehab facilities at periodic intervals. The rehab facility prepares reports that are then sent to the doctor. This is modelled as shown below:

\[
VP \text{ [ProvidePatientMentalHealthCounseling]} = \\
\text{PatientAtDoctor} \times \text{D} \times \text{MHP} \times \text{MHRehabSchedule} \times \text{Time} \times \{ \text{RehabVisitTimes} \times \text{CHW} \times \text{PatientAtHome} \times \text{PatientAtRehabFacility} \times \text{RehabStaffInteraction} \times \text{PatientRHCounseling} \times \text{Time} \times \text{RehabReportsSentToD} \}
\]

Note that “RehabVisitTimes” is extracted multiple times from the MH Rehab Schedule, and for each of these times a CHW is called in to visit the patient at home and take her to the Rehab Facility. After counseling, periodically (monthly or weekly), a report is generated and sent to the doctor. The red color used here illustrates the role of two actors outside the routine clinical preventive program to ensure adherence to mental health rehabilitation – an innovation that is considered important for certain population groups.

3.2 Sex (or AIDS) education and counseling

In the second case, when a patient from the LGBTQ community visits a doctor for consultation, the doctor consults with a local LGBTQ organization to identify a potential support person that may have gone through the treatment process before (called peer navigators). Such peer navigators are used to help the patient seek education and counselling at an appropriate counselling center. Again, reports are prepared periodically and sent to the doctor.

\[
\text{ProvideAIDSCounseling} = 
\]
The above two preventive care services are shown below as a state transition network in Figure 2. It identifies all input and output states as P’s (places), and the actions that transition input states to output states are identified by a “|”. The latter are marked with a number associated with a value proposition (MH: Mental Health or SE: Sex Education). Some of the input or output states can be resource documents (reports, schedules, time, etc.), and others are merely actors (human or machine).

Figure 2. Care Transition Network for Two Preventive Conditions

The shaded part of the network represents the patient ecosystem. It includes clinical care providers (Rehab and counselling centers) and non-clinical care providers (CHWs, peer navigators and LGBTQ organizations) as non-clinical care providers of the patient ecosystem. The data shared by the provider and patient ecosystems are the MHRehab schedule, RehabReports, and CounselingReports to D. Referring to the resources, the state transition network may at times not identify all resources and these are added upon further investigation (e.g. LGBTQ organization may identify potential peer navigators using a data base of such peer navigators based on their regional proximity to the patient). This is added as an input to the transition SE1.
Figure 3 below shows the actor-resource interaction architecture across the two ecosystems, with actors shown outside a “circle” that has resources.

![Diagram of Actor-Resource Interaction in Patient and Provider Ecosystems]

**Figure 3. Actor-Resource Interaction in Patient and Provider Ecosystems**

Note that by separating the two ecosystems, one can explore the design of the data/communication architecture for each ecosystem differently and explore where the intersections to support data synchronization between the two are, if the data is stored independently. Of course, actors can be provided access to a single source of this data. Given that many healthcare organizations do not want to be actively involved in coordinating the external provider and non-clinical personnel that support the patient ecosystem, having this separated can lead to potential exploration of a distributed network architecture such as blockchain for such purposes, as we will discuss later. Let us look at the actor-resource interaction architecture for case transition situations post-hospital discharge.

### 3.3 Modeling Care Transition Post Discharge

Patients are asked to engage in several activities post discharge, as a part of care transition, such as picking up prescriptions, visiting rehab facilities, visiting a physician for follow-up, or undertaking some diagnostic tests. Lack of adherence to these care transition activities can lead to patient readmission and potential health related complications. However, patients, for several reasons, may not engage in these activities. Some of these reasons can be economic (lack of resources to pay for transportation or child-care services) or time related (work-related time constraints leading to either not remembering or finding time to follow through). The service
exchanges are modeled in Figure 4 below. In modeling care transition, social or community actors may be used to address economic or time-related constraints, and their role in care transition services, along with a doctor’s office alert to patients, are highlighted. Also, some of these resources must be paid by some organizations, such as healthcare, community, or insurance companies. The ecosystem external to the provider is shaded in the service exchange modeling. Note that if the shaded portion is removed, it should lead to what a provider orders the patient to do and what the provider should receive upon completing the activities.

Figure 4. Model Separating Provider and Patient Ecosystem Service Exchanges

Figure 5 illustrates further the actor resource interaction across ecosystems. The shaded resources are shown at ecosystem intersection (providers, external clinical care providers, and external non-clinical care providers). Resources that are exclusively affiliated with an ecosystem are shown inside the ecosystem. Such a distinction allows those who are designing value propositions through service exchanges to decide the best way to develop a communication and coordinating architecture. Also, by separating data resources from financial resources and time-
based resources, one can manage these with the level of security needed for each and ensure data synchronization across ecosystem activities.

Figure 5. Actor Resource Architecture for Care Transition Across multiple ecosystems

The modelling process used brings to the surface the two potential challenges – technical and managerial – before an architecture is chosen for effective communication and coordination. The managerial challenge is to align the goals of various actors involved to share resources using service exchanges to create value. The technical challenge, especially when the data is distributed across multiple ecosystems, include time synchronization of data and other resources when changes occur to activities within various ecosystems and addressing the security and privacy of confidential data shared. For example, the mental health and sex education initiatives discussed under preventive care are coordinated by a hospital by aligning the goals of all involved and paying for social services and used a mix of technologies, including phone calls, text alerts, emails and computer databases. However, this approach is not scalable on both technical and managerial dimensions.

Use of incentive models to align goals of actors to engage in resource sharing is a potential approach to address the managerial challenge and will not be discussed here. This is a part of ongoing research. The focus of this paper, as discussed during the introduction, is to use the service
modeling approach to identify how a mix of distributed resource sharing platforms (some centrally coordinated and some using blockchain architecture with no single coordinating entity) can be used to scale preventive and care transition post-discharge, as the number of actors and size of resource shared can become quite large. Also, the volatility of the non-provider ecosystem can make it more difficult to anticipate and plan coordination.

The next section will use two different resource sharing implementations of blockchain to illustrate how characteristics of the resource and actors within the ecosystems can help surface scalability challenges and develop strategies for addressing them. Section 5 provides a framework to help the blockchain architecture adapt to changes in the ecosystem using AI.

4. Blockchain Use-Cases for Patient Care Outside a Hospital

In this section, we illustrate two use-cases. In Case 1, healthcare consumers are socially and economically challenged and face financial constraints that inhibit their ability to follow through on care transition activities (as illustrated in the previous section). In Case 2, healthcare consumers are educated, knowledgeable, and have the capacity to self-manage their health conditions. However, they are constrained by time and need reminder alerts, and they also want to have healthcare choices such as being able to seek information on options, second opinions, etc. Ideally, they want to have control over their patient data so that they can choose providers for preventive or care transition support. We will assume that most readers are familiar with blockchain technology and its potential to support a distributed set of actors and help them coordinate resource sharing to execute a specific set of tasks [20, 21, 22].

4.1 Use Case 1: Care Transition of Patients who Need Non-Clinical Care Support

We propose a gamification of the tasks a patient must perform (hereafter referred to as “Quests”). The hospital will create various Quests that a patient should complete post-discharge at various points in time. Each Quest calls on two individuals to interact post-discharge: 1. The Arbitrator is the service provider (i.e. pharmacy, testing lab, etc.), and 2. The Quest Taker is the patient. The patients receive the reward when the task is completed. The arbitrator also receives a portion of the reward amount to offset transaction costs and provide an incentive to join the network. The Quest is administered as follows:
• Step 1: The Quest maker (physician) sits down with a patient and lists several tasks they need to perform (distinct tasks, such as pick up a prescription, get blood tests done, visit a rehab facility X number of times, etc.). Each task is viewed as a separate Quest and can either have a specific arbitrator (a person that the physician recommends the patient see and is already in the network) or one who fulfills a role (a pharmacy or lab a patient can go to complete a task).

• Step 2. The physician agrees to put in some digital currency as a reward if the task is completed (with a larger portion going to the patient and the remaining going to the Quest arbitrator).

• Step 3. Each Quest is entered as a signed transaction to the Quest smart contract on the Ethereum blockchain by the physician.

• Step 4. The patient goes to the Quest arbitrator to complete the task. The patient may find the arbitrators in the area to go to, if there is no one designated. If they go to an arbitrator that is not on the network, there may be a separate credentialing blockchain that validates the role that the arbitrator is playing.

• Step 5. The arbitrator submits a transaction indicating that the Quest is completed.

• Step 6. The reward is distributed to each party (arbitrator and Quest taker automatically)

4.2 Blockchain Implementation of Use Case Scenario 1

The Quest is coordinated and executed using smart contracts written and submitted to the main Ethereum blockchain [22]. The reward for the Quest is securely held in the contract until either the task is completed, and the reward is dispersed to the patient and arbitrator, or else the contract time has expired, and the reward can be retrieved by the Quest maker. All arbitrators must be authorized and validated through a credentialing system (e.g. a token curated registry, such as one developed by MedCredits [23], that determines their role). The purpose of the arbitrators is to make sure patients perform the correct task before marking their Quest as complete. All transactions related to Quests (i.e. creation of the Quest, reward size, arbitrator information, and completion of the Quest) are recorded through the smart contract. After the arbitrator sends the Quest completion transaction, the completion is validated, and a reward is distributed immediately.

4.3 Use Case 2: Care Transition of Patients who Want to Self-manage their Condition

Patients are given control over the data as they get this information from their caregivers and care centers, such as hospitals, physical therapy centers, etc. This information is stored on the
blockchain using HL7 CCDA format. It includes the following significant sections: 1: Allergies; 2: Medications; 3: Problems; 4: Procedures; 5: Results; 6: Social History; and 7: Vital Signs. The patient can provide all or part of the information to other caregivers. The patient not only provides access to a particular care provider, but also is informed of every access of the information. Depending on the need, the patient can give a provider access to the complete record or to any of these sections. Only the patient can provide access to the data, and the data is not transferred to the provider.

4.4 Implementation of Use Case 2

The solution is implemented on a private Ethereum blockchain. There is permissioned access, that is, all users are verified before they get on the system, thus eliminating spurious users who would potentially cause denial of service to genuine users. Ethereum IDs are created by patients and providers when they begin to interact with the system. The architecture of the system has been designed to keep all the Protected Health Information (PHI) on the blockchain while keeping non-PHI information out of the blockchain. Examples of non-PHI information include the publicly available information about providers as well as non-identifiable patient information such as state of residence. Because of the size limits of records in Ethereum, if the patient record is lengthy then the mapping must be chained. The history of provider access to the data is also maintained for the patient to review at any time. An implementation of this can be found at Embleema (available https://www.embleema.com/)

4.5 Digital Platforms Strategies to Support Actor-Resource Interaction

Looking at the two use case implementations, the following observations can be made about how healthcare organizations can use a mix of their internal systems and blockchain architecture for actor-resource interaction in support of care delivery outside a hospital system.

- Hospitals can choose to use their extended EMR systems for various clinical actors to share patient data, while allowing blockchain architecture to manage the non-clinical care providers, as discussed in the Quest implementation.
- Hospitals can also choose to connect their extended EMR to clinical care providers within their network and allow patients, in partnership with the primary care provider, to take
ownership of their data and selectively share it with those outside the hospital network, including interacting with external non-clinical actors.

- The Quest implementation currently provides rewards to patients and Quest arbitrators, but the patient rewards can be moved to community health workers, peer navigators, etc. for their service in preventive care, and transportation and childcare service providers in the care transition example.
- By separating the network architectures used for clinical and non-clinical data, greater control can be exercised over patient data sharing while minimize the storage complexity, as external care providers tend to be smaller in number than non-clinical care providers.
- As discussed in the Quest implementation, the Quest contract can be used to provide time-based alerts to respective care providers, or these alerts can be sent to an app on the patient’s mobile device, thus reducing the need for using data stored in the blockchain for non-clinical care support.
- Lastly, as discussed in the implementation of Case 2, most of the patient data can be either coded for reducing storage size or stored outside the system (at the provider), with only links to this data stored on the blockchain network.

In summary, with the ability to use gamification and provide patients with control over their data, blockchain technology can be used to complement the traditional hospital coordinated healthcare system in support of both preventive and care transition post discharge, while allowing patients to seek support services to manage their health condition with greater convenience. The next section will discuss the role of AI in enabling blockchain architecture to adapt to support changing conditions in the patient ecosystem.

5. Leveraging AI to Adapt Care Delivery to Patient Ecosystem Dynamics

One of the main characteristics of blockchain technology is that all transactions are publicly accessible and immutable. This allows for the capturing of interactions between actors as they use the blockchain to engage in various transaction events, such as creating and using data from the blockchain even if sensitive details about the transactions are encrypted. For example, one can identify the frequency with which certain service providers are used by patients in Case 1 or out-
of-the network care providers used by patients for second opinions in Case 2. This analysis, done outside the blockchain, can be used by a hospital to decide who they want to invite to be a part of their network in order to accommodate patient preferences.

Also, predictive analytics may be used to gain insight into the relationship among various factors influencing patients’ use of certain non-clinical or clinical care providers. Examples include determining which services are used together (e.g. prescription filling and diagnostic testing to minimize disruption in patient workflows), the mobility of patients in seeking services (e.g. how clustered are the clinical and non-clinical service providers used by patient groups), and the role of brand in service provider choice (e.g. CVS, Walmart, etc. for prescription filling vis-à-vis geographically closer drug store pharmacies in retail food stores). The data used for such analysis may include data from a node on the blockchain – encrypted data with timestamp and valid actor information, combined with profile data that resides outside the system (address or region, brand, etc.).

While transactional data on actors can provide insight, analysis of this is done outside the system and may be used in make changes to the blockchain architecture separately – who is permitted to be on the network and which network, what changes in the smart contracts may be needed to alter patient behavior, etc. In other words, the blockchain network behavior is not altered dynamically, even if a node collecting the data is on the network. Can the analysis done outside the network to learn about patient behavior in a changing patient ecosystem be used in real time to dynamically change the blockchain architecture to influence clinical or non-clinical behavior? We want to address this question in this section– building a smart agent on the network that can learn and influence the care provided outside the hospital.

5.1 Smart Nodes or Systems

The architecture and interactions between systems for Case 1 are shown in Figure 5. The Quest participants (doctors, arbitrators, and patients) interact with the Quests through a mobile or web application. This app assists the participants in posting transactions to the Ethereum smart contract to create and arbitrate Quests. It also stores and reads non-blockchain information (such as locations of participating doctors and arbitrators) from a backend server. This system also allows for a cloud-based analytics engine to gather data from blockchain transactions and analyze this
data along with doctor/arbitrator locations and non-identifiable patient information to provide suggestions and predictions to assist all Quest participants.

![Figure 5: Quest Architecture including interaction with an Analytics engine](image)

Some example listed below are opportunities to tailor the Quest experience based on patient behavior observed from the network transactions:

- Patient readmission rate can be analyzed across different Quest types to determine which Quests are the most successful at preventing readmission, and which have the highest completion rate. Quests with high ability to prevent readmission but low Quest completion rate could be suggested to have an increased reward, as they are very high value Quests.
- When a patient seeks a service provider using the app, the providers that the patient can choose may be prioritized based on the distance from the patient’s current location.
- Like any recommendation system, a patient may order clinical and non-clinical service providers based on aggregate patient input on service feedback, which is collected and accumulated outside the blockchain.
- Select message alerts can be sent to patients who may not have visited pharmacies over a given time period, if there is a medical emergency such as measles or a major flu outbreak.
Based on some general patient demographics, patients may be provided alerts on diabetic or high blood pressure medication, triggered automatically when certain prescriptions are provided to the patient (e.g. medications related to diabetes, high blood pressure, etc.)

6. Conclusions and Future Research Directions

In this paper, we modeled care service to patients using service-dominant logic research, so that the actors involved in both preventive and post-discharge care as well as the resources they need to support care are clearly identified. This leads to the design of a network platform that links actors to resources. Since many of the actors and resources are outside the hospital system, there is a need for a distributed network architecture that can operate with minimal coordination, and the role of blockchain architecture is proposed using two example implementations. Given the high degree of volatility in the patient ecosystem, preventive and care transition strategies of healthcare providers are tailored to influence patient behavior in one of the implementations using Quests. A Quest architecture framework is then developed so it can use a mix of technologies: an agent that collects patient activity, cloud-based storage that combines patient activity with other profile information, and an analytics engine to influence the actors supporting the patients and Quest contracts that guide patient behavior through apps used by the actors and the way they share resources using the network.

Future research directions

The challenge of tailoring patient choices to their behavior on clinical and non-clinical service activity (or lack thereof) might not be done within the primary blockchain, but in other social networks set up to complement the blockchain, so the integrity and privacy of the patient data can be sustained. Guiding the patients to these networks through alerts when certain behavior is observed by the smart nodes can make the overall architecture learning based and potentially improve patient adherence to treatments outside a hospital.

We recently put the following question to the former president and CEO of a hospital system: What are some of the challenges in preventive and care transition post discharge, and what might be some suggestions for addressing these challenges, so that learning from patient behavior
can lead to personalized care delivery models outside a hospital? Some strategies he recommended include:

Preventive Care

- Segment the population based on certain demographic characteristics (User groups 1, 2, 3, etc.)
- Develop select resource information to share with patient groups to create value:
  - Providers send public health practice and timelines (e.g., when immunizations are provided)
  - Selected individuals are given permission to send reinforcing information to patients:
    - Signed notification by those who patients view as authoritative or influential
    - Signed or authorized notification on penalties or incentives as applicable (e.g., not being able to send a child to school or go to work because of contagious diseases; or coupons for food/transportation for getting flu shots)
  - Send information broadcasts periodically to influence patient adherence.

Care Transition

- Segment the resource shared such as generic information that can be shared with all patients (e.g. frequently asked questions), or for specific patient groups (e.g. dietary guidelines for diabetics; exercise regime for heart patients; and specific advice during holidays for senior patients, etc.)
- Share reinforcing messages from physicians or influential members of peer groups.
- Share specific incentives and peer rankings of those who engage in desired behavior.
- Share tailored information to specific patient posts or questions.

By reviewing the comments collectively, certain key observations can be made: 1) sharing of non-clinically based information to general patient population by physicians and other influential members of patient population; 2) segmenting patient populations on some broader clinical categories so that messaging to influence patient behavior can be tailored to reduce information overload; 3) sharing incentives (financial or “status” that is focused relative to ranking based on adherence) and at times negative consequences for not adhering to treatment guidelines; and 4) responding to specific patient questions with general messages or tailored messages to that patient or group.
This points to the need for a mix of digital platforms (blockchain to support certain patient actions, social media to interact and share information to influence behavior, hospital system networks to exchange resources among external care providers within their network, etc.). While the public key of clinical and non-clinical actors, including patients, can be used to contribute select resource as needed to blockchain or social media platforms, permissioned access to this resource or its aggregation can be provided to patients or patient groups using their private keys, and apps can be used to alert patients on such access capability or need. The goal is to have the data analyzed from the patient engagement using the analytics engine in order to learn value-in-context (i.e. how the value created is perceived by the patient population), so that improvements can be made to actors participating in the network and the Quest contracts designed to incentivize patients, as well as to tailor the necessary non-clinical information in the companion social media network that patients are provided access to.

References