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Designing and Adapting Services to Create Value Outside a Hospital Using Blockchain Architecture:

Care Delivery in Patient Ecosystem

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ABSTRACT

As healthcare systems develop innovative services to create value for patients outside the hospital or clinical care facility, they face a major challenge. They need a communication architecture to support the sharing of information among the healthcare providers, patients, and external partners to fulfill the value created. The current electronic medical record systems of hospitals do not extend to many of these external partners unless they are part of the provider network. This paper proposes the use of blockchain architecture to address this challenge. By modeling service innovations used to create value as a set of service exchanges among providers, patients, and partners, the providers decide when blockchain architecture may complement their own extended EMR system in fulfilling the value they create to address patient needs. The authors use gamification to improve patient adherence to treatment plans designed to fulfill the value created and adapt the value created to reflect the changing patient ecosystem. The paper concludes with discussion and directions for future research.

KEYWORDS

Blockchain, Care Delivery, Care Transition, Incentives, Intelligent Agents, Patient Ecosystem, Public Health, Service Modeling

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1. INTRODUCTION

Healthcare providers have begun to leverage advanced technology to provide innovative services to patients while they are in the hospital. These innovations include real-time locator sensors (RTLS) to track patient flows in emergency and patient rooms to reduce delays within the hospital (Stahl et al, 2014), optimally scheduled operating rooms to improve efficiencies and reduce surgical delays (Cardoen et al 2010), and improved services delivered in patient rooms such as faster responses to patient calls using technologies such as call bells, smart beds, wearables, etc. (Tanniru et al, 2018). Some of these service innovations are process focused such as multi-disciplinary rounding (Fowler et al, 2018). Many of these innovations are designed to reduce costs and improve patient satisfaction. However, with changes in reimbursement policies based on patient satisfaction and hospital readmission within 30-days after patient discharge, service innovations to coordinate cate outside a hospital have become an important focus (Medicare, 2013).

Several service innovations in support of care delivery outside a hospital were discussed in the literature (Dreyer et al, 2014). Some of these include provider interventions in the care of chronic care patients (Coleman et al, 2006), engagement of multiple external care providers in the care of patients (Naylor et al, 2004), and the engagement of community members to reduce health inequities (Jack et al, 2009). Some of these innovations are designed to address the needs of high risk population groups (Bradley et al, 2014), and others are used to support patient engagement through enhanced communication (Ghosh et al, 2014), nurse engagement in discharge planning (Kelley et al, 2013), and engagement of nurse/physician teams in addressing complex cases (Jones et al, 2013). The service innovations outside a hospital use a mix of technologies (Herzig et al, 2016, Weiner et al, 2016) including tele-health consultations and mobile apps (Koh et al, 2016). The effectiveness of service innovations is based on how closely the value created (treatment plans) matches the value fulfilled outside the hospital. Much of this value fulfillment relies on information sharing to support coordination of treatment adherence activities among patients, partners, and providers.

A service has many dimensions along which it is assessed by the customer (Parasuraman et al, 1985). Service expectations can change along any of these dimensions (some esthetic/comfort oriented and some knowledge/competency oriented) and influence perceived value as patients engage in the use of such a service. In the post-Internet era, value perceived through a service can be influenced by evolving technologies and virtualizations of patient interaction with providers and partners. How treatments developed by providers are in fact adhered to by patients is harder to assess when such a service is provided not by the hospital alone but by many other external partners. With social determinants (WHO, 2013) influencing how care related services reach the patient population, especially when they call for the engagement of non-clinical partners, the patient is further removed from the provider, thus making perceived value harder to assess.

Since differing goals of clinical and non-clinical partners, as well as patients, influence the treatment adherence, the challenge for providers designing service innovations to support care delivery outside a hospital is tracking and addressing values gaps in service, i.e. between treatment plans (value created) and treatment adherence (value perceived during use). Ngo and O'Cass (2009) argue for innovation to meet higher levels of customer equity. In healthcare, value creation and fulfillment outside a hospital requires aligning the goals of care providers with those who provide care (market orientation) and use of intervention strategies such as gamification to increase such alignment while addressing patient equity. Hence the research question: How can we model service innovations to surface value gaps so improvements can be made in successive value cycles and address health inequities? In this paper, we provide a decomposition of the service model into service exchanges, so that gaps in alignment of goals can be tracked and addressed, using a distributed communication architecture.

The paper is organized as follows. Section Two will discuss prior research on modeling services to create value and its implementation using a mix of internal and partner resources and introduce the design approach that uses decomposition of service model into service exchanges. Section Three formalizes the service design approach using multiple use cases and illustrates how it can be used to align goals using a mix of incentives and technology. Section Four illustrates the need for a distributed architecture such as blockchain to tailor service design to meet distinct patient needs. Section Five discusses the use of gamification using blockchain to align the goals of patients and providers. Section Six shows how such a blockchain implementation can be used to refine value created by learning about value-in-use using intelligent agents. Section Seven provides some managerial implications and directions for future research before making some concluding remarks.

2. SERVICE MODELING AND DECOMPOSITION

The increasing share of services in today's knowledge economy, including manufacturing firms (Ovchinnikov et al, 2014), is leading all organizations to view themselves as service providers and work with customers outside their business (in customer ecosystem) to create value. Such *value creation* is supported by several service exchanges, each designed to help understand the customer decision making process during value creation and customer experience post purchase (or during value-in-use) (Vargo et al, 2008). To improve agility with which the value propositions are fulfilled, organizations rely on the use of technology and resources from external partners (Lusch et al, 2015). Fulfilling these value propositions with agility may lead to different institutional arrangements and knowledge needs, and over time may lead to developing new markets (Wieland et al, 2017).

Unlike traditional businesses, healthcare organizations face a few challenges as they transform to become service driven using innovative care delivery models outside a hospital. They need to work with a mix of technologies used by patients and clinical and as well as non-clinical partners. This means creating an architecture

Figure 1. Model to provide care in patient ecosystem

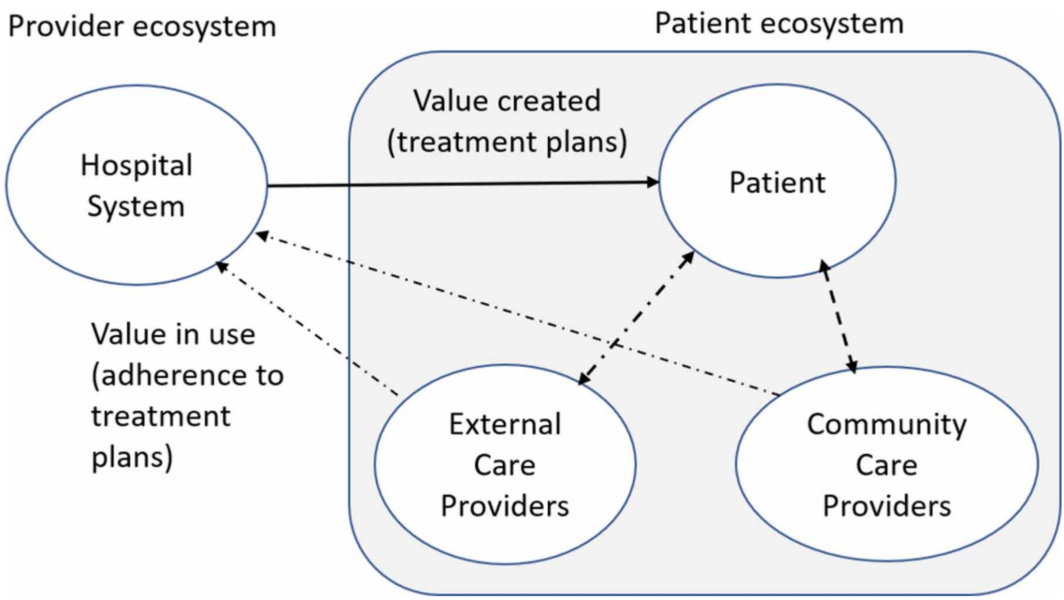


Figure 2. Service exchange model to support mental health

that can support information sharing to coordinate the activities needed to ensure patient adherence to treatment plans. To understand this challenge, let us use the service model shown in Figure 1. The patient ecosystem here includes both clinical care providers or institutions (e.g. pharmacies, diagnostic labs, rehab facilities, etc.) and non-clinical care providers (e.g. social workers, community organizations, etc.). These are referred to as actors of the patient ecosystem. While the solid line is what is shared with the patient (i.e. treatment plan), information on its adherence is shown as a dotted line. These dotted line interactions between patients and clinical and non-clinical providers are not coordinated by any one of them and the goals of those interacting are not often aligned.

We will illustrate this further in Figure 2 by documenting how a healthcare system in Michigan uses an innovative service model to support patients with mental health challenges (Plum et al, 2020). Here, the care provider at a hospital recommends a patient, diagnosed with mental health challenges, to visit a mental health (MH) rehab facility for consultation and support. The innovative service here includes the use of a community health worker (CHW: a non-clinical actor) to assist the patient visit the rehab facility. It also includes complementing the doctor's diagnosis with the competencies of a mental health psychotherapist (MHP: a clinical actor). The rehab facility (another clinical actor) prepares reports for the doctor after the patient visit. The value creating service model is decomposed into multiple service exchanges that support sharing of information among many actors to coordinate activities needed to fulfill the value created.

In summary, the goal of providers is to support care outside a hospital but aligning their goal with the patient's goal calls for the use of incentives to potentially overcome health inequities or constraints i.e. provide transport assistance using CHW or send a patient an alert to remind them of the visit. The use of MHPs here is to give incentives to doctors so they can do a comprehensive diagnosis and develop treatment plans that can influence patient adherence. Lack of such diagnosis is often cited as the reason for opioid drug abuse by patients with mental health issues (Dowell et al, 2019). Ultimately, actors interacting in a service exchange want to complete this exchange as defined to create value and aligning their goals using incentives when appropriate is key to reducing gaps in value created.

The American Psychological Association (APA, 2015) defines "incentive" as an external stimulus that motivates the behavior of those involved in a service exchange. Relevance is key to motivate actors involved in a service exchange even if such an exchange calls for a change. Such relevance can be established if actors understand the need for change (content theories), the value of change (process theories) and are motivated to change (contemporary change theories) (Saif et al, 2012). For example, giving access to an MHP expert can motivate the doctor to change the diagnostic process and include mental health assessment as needed to improve adherence. Similarly, giving access to CHW can motivate a patient to visit the rehab facility by changing their routine to improve their health. As we will see in the later sections, one may need explicit incentives such as financial rewards to motivate a patient to seek treatment.

In this section, we used decomposition of service into several service exchanges to potentially isolate interactions that can contribute to value gaps in a service. The next section will discuss a formal way to design these service exchanges, so each can fulfill a specific value proposition. Collectively all these value propositions will create the value to a patient.

3. FORMAL DESIGN OF SERVICE EXCHANGES

Let us use a simple example of a patient in a skilled nursing facility (a clinical care provider) who calls on a nurse to visit a bathroom. The service exchange (SE) that creates the value proposition (VP), i.e., patient's need to visit a bathroom (value), is supported by two actors (patient and nurse). "*" implies the existence of both actors present to initiate the service exchange and -> implies completing the service exchange and creating the value. In this case, value is created by fulfilling the value proposition (i.e. patient visits the bathroom).

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 nurse assistant so she can respond. This is represented as follows and shown as a state transition network in Figure 3 (Highlighted letters below are used in the network).

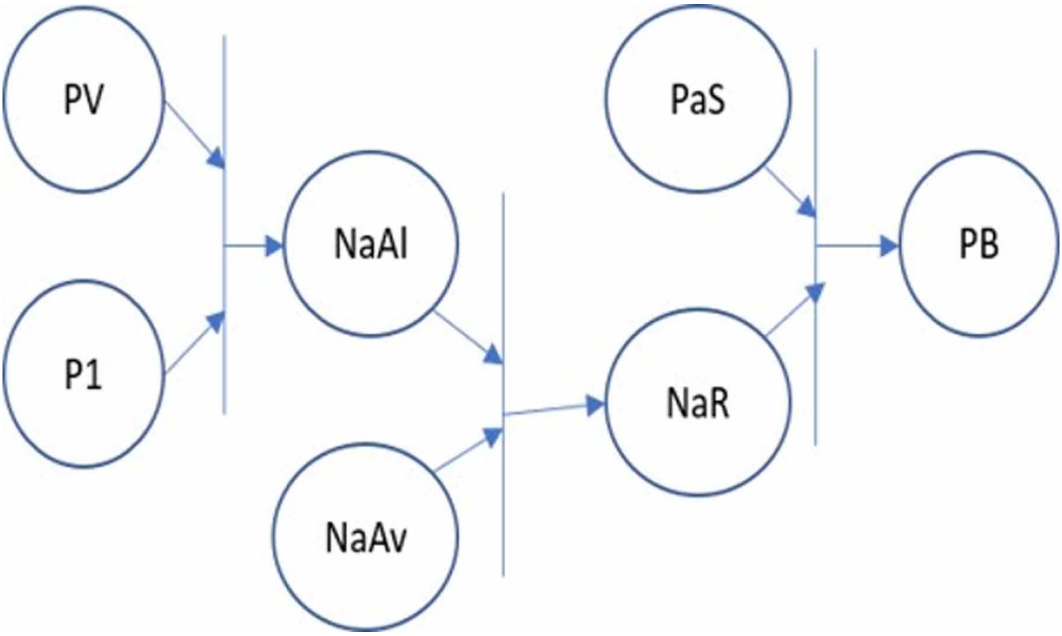
VP (BathroomSupport)= VP (SendRequest) * VP (NurseAsstResponds) * VP (NurseAttendsToRequest)
VP (SendRequest) = SE (**P**atientNeedForBathroom**V**isit***P**illowtalk**1**->**N**urse**a**sstVolte**Al**ert)
VP (NurseAsstResponds) = SE (**N**urse**a**sst**Av**ailable***N**urseasstVolte**Al**ert->**N**urse**a**sstComesTo**R**oom)
VP (NurseAttendsToRequest) = SE (**N**urse**a**sstComesTo**R**oom***Pa**tientAsksForBathroom**S**upport->**P**atientIn**B**athroom)

Here, there are multiple actors involved (patients, technology, nursing assistant) in creating value for the patient (or major value proposition). The value is created by the fulfillment of three service exchanges each with mini-value propositions occurring in sequence. Each of these mini-value propositions use 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 nursing assistant to visit the bathroom when the nurse comes to room, and this leads to patient visiting the bathroom.

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

Figure 3. A state network representation



VP (BathroomSupport) = PatientNeedForBathroomVisit*Pillowtalk1***NurseasstVolteAlert*** NurseasstAvailable***NurseasstComesToRoom***PatientAsksForBathroomSupport***PatientInBathroom**

In some cases, a request to create value can come from not a human actor but a technology, For example, for patients who are susceptible for a fall the bed sensors of their smartbed can be turned ON (a position true). When patients try to get out of bed, an alert is sent to all nurses and an outside light of the patient room gets turned ON (i.e. “FlashingRoomLightsON”). When a nurse walks in, the flashing room lights get turned off.

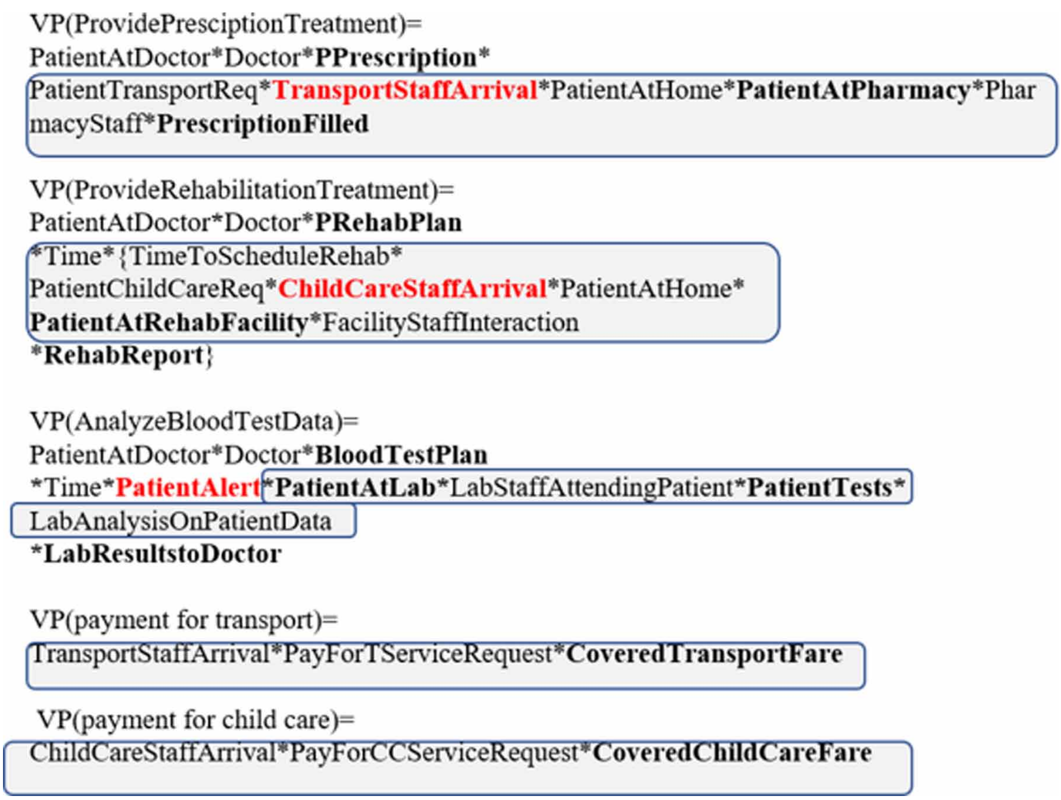
VP(FallRisk)= PatientMovement*BedSensorsOn***VolteAlert***NurseAvailable***NurseComeToRoom***PatientReady*PatientinBathroom
VolteAlert*RoomLightOff***FlashingRoomLightOn**
NurseComeToRoom*RoomLightsFlashingOn***RoomLightsOff**

We will use this notation to represent three different use cases where innovations are used to create value.

3.1. Mental Health Prevention

This service innovation was discussed in section 2. The role of a mental health psychotherapist (MHP) and community health worker (CHW) are to help align the

Figure 4. Service exchanges to create value for use case 3.3



goals of both the doctor and patient and the result is a treatment plan that schedules patient to visit a rebab facility a number of times. The "RehabVisitTimes" are extracted from the MH Rehab Schedule (a new resource added to the service exchange) and CHWs visit to patients at home is triggered automatically

VP (ProvidePatientMentalHealthCounseling) = PatientAtDoctor*D*MHP***MHRehabSchedule***Time*{**RehabVisitTimes***CHW*PatientAtHome***PatientAtRehabFacility***RehabStaffInteraction***PatientRHCounseling***Time***RehabReportsSentToD**}

3.2 Sexually Transmitted Disease Prevention Through Education and Counseling

The same organization used another innovation to educate patients on sexually transmitted diseases. The service model uses peer navigators from a local LGBTQ organization to help patients overcome their personal challenges. The peer navigators are selected from a data base of individuals who are willing to provide such support. These actors and resources act as incentives to help influence behavioral change.

ProvideAIDSCounseling = PatientAtDoctor*D*LGBTQOrg*NavigatorDataBase***PeerNavigator***{Time*PatientAtHome***PatientsAtCounselingCenter***CouseingStaffInteraction***PatientSECounseling***Time***CounselingReportsToD**}

3.3 Engaging Patients in Multiple Care Related Activities

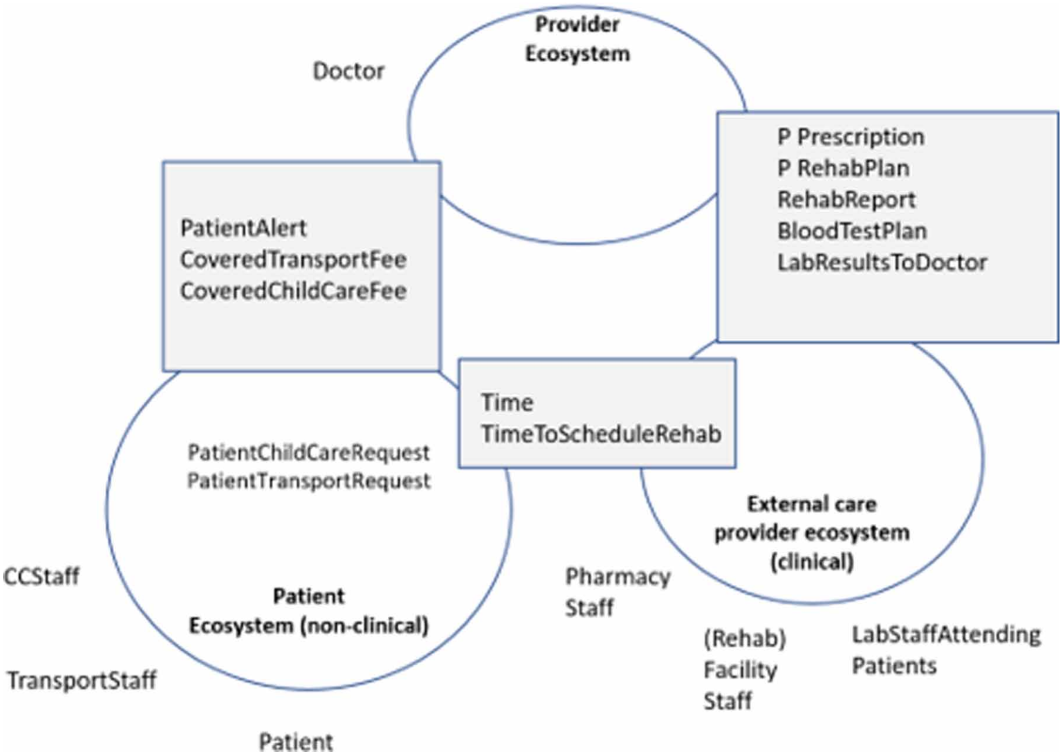
Patients are often asked to engage in several activities post discharge from a hospital as a part of a treatment plan. Examples of such activities include picking up prescriptions, visiting rehab facilities, visiting a physician for follow-up, or undertaking diagnostic tests. However, patients fail to perform these activities due to resource constraints (e.g. financial need to pay for transportation, child-care services when patients must complete these activities, etc.) or other personal constraints (e.g. getting time off from work, not remembering when the visit is, etc.). Today, many hospitals use organizations such as Aunt Bertha (https://www.auntbertha.com/) to identify social and community agencies who can help patients address some of their resource and personal challenges. Figure 4 summarizes these interactions.

In summary, each service exchange represents a value proposition and cumulatively they lead to fulfilling the value created. Not performing any of these can contribute to value gaps. Each service exchange may call for a sharing a resource such as information, money, social or emotional support, etc. Some of these resources are used to complete an activity and others are used to motivate people to complete the activities. Figure 5 summarizes the resources shared among actors for the case discussed in section 3.3. By separating data resource from financial and time-based resources, the implementation can address appropriate security and data synchronization needs when technology is used to support these service exchanges. The number of actors involved in these services exchanges, the technological maturity of the systems these actors use to communicate, and the degree of alignment in their goals will all influence the complexity of the architecture needed to support the communication and coordination of these service exchanges to create value. Next section will discuss some strategies used to design an architecture to support value creation and its fulfillment.

4. BLOCKCHAIN ARCHITECTURE TO IMPLEMENT SERVICE MODELS

Many technologies are used today by health systems to educate patients (using portals and mobile apps), address their work pressures (using text alerts and reminders), provide clarity by answering questions (using social media and digital intermediaries), and support self- management of health condition (using wearables). When such support of patients is coordinated by a health system, it can be integrated to the electronic medical record system and coordinated by the same system. However, many of the actors who support patients are outside the health system. This means, incentives are needed to motivate patients and others to engage in service exchanges needed to fulfill the value propositions the health system creates. Given that the

Figure 5. Actor resource interaction in care delivery across multiple ecosystems



patient population is diverse, incentives developed must be tailored to support distinct population groups. Also, incentives can vary depending on how sick a patient is (after a hospital discharge to address a chronic condition, or a preventive care). So, tailoring incentives to support completion of service through information shared can vary in each case. The following question was posed to the former president and CEO of a hospital system: *What factors should be considered when modeling services outside a hospital and how are they different for preventive care vis-à-vis care transition post discharge?* Some strategies he recommended include:

Preventive Care

- Segment the population based on demographic characteristics for tailoring of messages.
- Tailor message shared to create distinct value:
    - Time: Timely information on immunizations; periodic information on healthy practices
    - Who: Select those whom patients trust (providers, influencers, authority figures, etc.)
    - Motivators: Incentives or penalties (e.g., not able to send a child to school; not able to go to work because of contagious diseases; coupons for food/ transportation when they get flu shots)

- ◦ Frequency: More frequent if it is important

Care Transition

- Segment the information to specific audience (general: frequently asked questions; specific: dietary guidelines for diabetics, exercise regime for heart patients, advisories to seniors during holidays, etc.)
- Reinforce messages from physicians, influential members, peer group representatives
- Specific incentives and peer rankings to motivate desired behavior.

These differences point to the need for an architecture that supports sharing of diverse information among many different actors, some in real time and some periodically, and some based on context, etc. Also, the architecture needs to support sub-sets of service exchanges using a different or sub- network (e.g. interaction among certain patients with similar disease) but connected to a broader network for information sharing. This led to the consideration of an architecture that needs no central coordination and ensures trust among actors by virtue of its design: Blockchain. Blockchain technology is shown to be most appropriate when there is no central coordinating entity trusted to support resource exchange among actors in a secure manner. Managing distributed records (Glaser et al, 2017), sharing data in a decentralized marketplace (Chowdhury et al, 2018), and building applications in a decentralized digital architecture (Limieux et al, 2017) all illustrate the role of blockchain architecture can play when actors in distributed enterprises need shared resources to address a common goal.

Deloitte (Krawiec et al, 2016) proposed several ways blockchain technology can become a new model for health information exchange when there is no clear set of data standards or access rules for sharing patient information in a trusted network. Prior research has used incentive-based models to enhance patients' engagement to improve adherence such as giving patients flexibility to share data with they need to consult for care (Embleema) or allowing physicians to remotely monitor their cancer treatment in real time (Rahman et al, 2019). There are several criteria or conditions discussed that will make blockchain more effective than a centralized data base can be (Routi et al, 2020). Some of these factors include trust building, robustness/fault tolerance, security, and redundancy. For these reasons, we used blockchain technology to align goals using financial incentives and use gamification to change patient behavior for the use case 3 discussed earlier. This is discussed in the next section.

5. QUESTS USING GAMIFICATION TO ALIGN GOALS AND ENSURE ACTIVITY COMPLETION

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 different 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 monetary reward if the task is completed (with a larger portion going to the patient and the remaining going to the Quest arbitrator).
- Step 3. The physician adds the reward and task information into the Quest and assigns it to the patient via a blockchain transaction.
- Step 4. The patient goes to the Quest arbitrator to complete the task. The patient may find which arbitrators of the appropriate role (physician, physical therapist, etc.) are in their area if there is no specific arbitrator designated. Arbitrators must be known and trusted by the Quest ecosystem, and one possible way to credential the arbitrators is discussed in section 5.2.
- 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)

5.1 Blockchain Implementation

The Quest is coordinated and executed using smart contracts written and submitted to the main Ethereum blockchain (Wood, 2014, Buterin et al, 2013). We propose to use Ethereum for a few reasons:

1. Established value of native coin and stable coin: Ether (ETH) and USDC

ETH or USDC can easily be used for monetary transactions in Quest contracts, and both have an established value. If the fluctuating value of ETH is undesirable, Coinbase's stable coin USDC can easily be used in the smart contracts instead to pin the incentive value to the value of the US Dollar. Both currencies are becoming easier for owners to directly spend for day-to-day purchases (Coinbase 2019).

2. Ease of implementation using Solidity programming language.

Ethereum's native programming language, Solidity, has a large community of developers and numerous resources to assist with the development of smart contracts (Solidity, 2019). Common vulnerabilities have been discovered and detailed with best practices for preventing them in the future (Atzei et al, 2017, Smart Contracts, 2019)

3. Community of developers and enthusiasts working to grow Ethereum network.

Ethereum's community is constantly working to make the network easier to use on a number of fronts, from MetaMask (2019) and Coinbase Wallet (2019), making interactions with smart contract enabled websites easier for the end user, to the development of debit cards that withdraw from Ethereum accounts to make it easier for users to spend ETH on day-to-day purchases (Coinbase, 2019). As these services are improved, Quests will become easier to interact with, and the rewards patients receive will be easier to spend.

The reward amount for a Quest is chosen and deposited by the Quest maker at the time the Quest is created. The decision on how much reward to offer can be suggested by a mobile or web app and can be based on an analysis of market factors, previous success rate for the current patient, and other machine learning strategies as described in Section 6. The reward for the Quest is securely held in the smart 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 the one developed by MedCredits (Praver, 2018), which determines the arbitrator's role). The purpose of the arbitrator 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 the reward is distributed immediately. A pilot implementation of this application is shown in the Appendix.

The Quest implementation currently provides rewards to patients and Quest arbitrators, but the patient rewards can be split between patients and others such as Quest delegates (e.g. community health workers, peer navigators, etc.) who are delegated to provide the services patients need like transportation or childcare. Also, the Quest contract can be used to provide time-based alerts to respective actors in the patient ecosystem, or these alerts can be sent to an app on the patient's or other actors' mobile device, thus reducing the need for using data stored in the blockchain for non-clinical care support. In summary, with the ability to use gamification, hospitals can use incentives to engage patients in needed activities to ensure greater alignment of provider and patient goals – adherence to care treatment plans. The next section will discuss how data science from the blockchain data can be used to adapt the way the incentives are structured to support and sustain such adherence in an evolving patient-ecosystem dynamic.

6. ADAPT SERVICE INNOVATION DESIGN TO CHANGES IN PATIENT ECOSYSTEM

Slater and Narver (1994) point out the need to continuously monitor a buyer's entire value chain, as it evolves over time. This is indeed the case in healthcare where efficacy and changes in patient ecosystem dynamics influence effectiveness of value creation and value in use. This is one of the reasons for tracking patient adherence using data from activities suggested by gamification and see which are being adhered to, so incentives can be altered as needed. Vargo and Lusch (2004) argue that the S-D logic calls for not only co-creating value with customers, but leverage technology becoming as operant resource to influence value fulfillment. The agent in blockchain architecture proposed in this section tracks patient adherence to activities recommended and uses the data and insight from its analysis to influence patient behavior, possibly by changing the incentive structures.

One of the main characteristics of blockchain technology is that all transactions are publicly accessible and immutable and allows all actors to engage in various transaction events including analyzing the frequency with which certain service providers are used by patients. By specifically assigning an agent actor on the blockchain to do such analysis, a hospital can decide who they want to invite to be a part of their network to accommodate patient preferences. Other 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.).

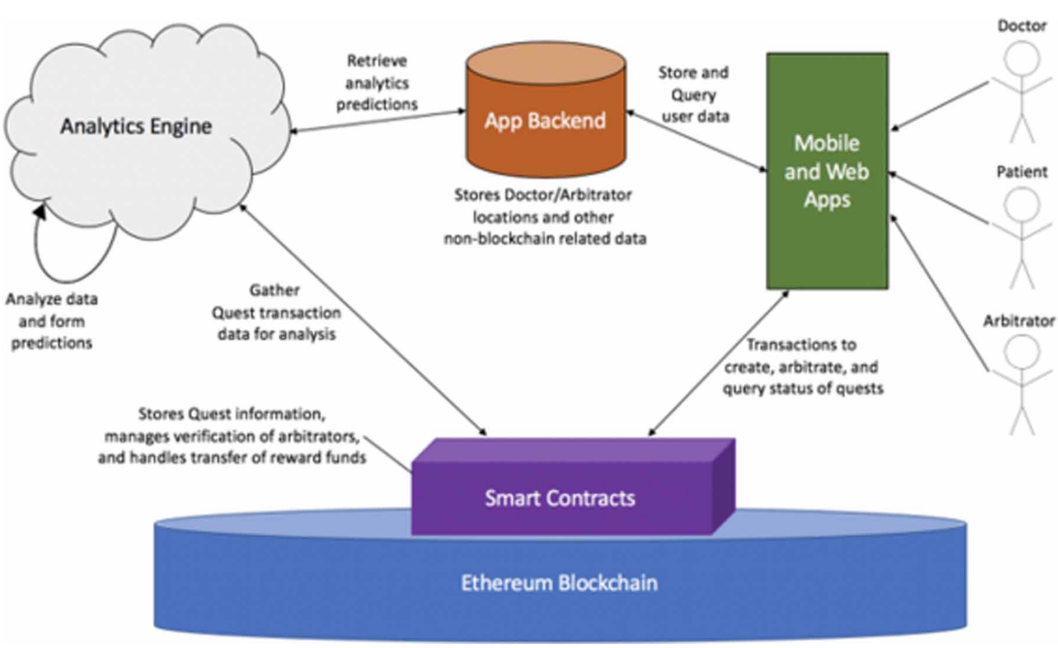
While transactional data on actors can provide insight, analysis of this data is done outside the system and may be used to make changes to the blockchain architecture separately. Such changes may include who is permitted to be on the network and which network, what changes in the smart contracts may be needed to alter patient behavior, etc. In other words, the blockchain network behavior is not altered dynamically. However, a node collecting the data on the network in real time can be used to learn about patient behavior in a changing patient ecosystem dynamic and potentially influence the blockchain architecture to address actor behavior. The architecture used to address this adaptive behavior of the blockchain is discussed next and is shown in Figure 6.

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.

Listed below are some opportunities to tailor the Quest experience based on patient behavior observed from the Blockchain 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, if there is a medical emergency such as measles or a major flu outbreak.
- Based on some general patient demographics, patients may be provided with alerts on diabetic or high blood pressure medication, triggered automatically

Figure 6. Quest Architecture including interaction with an Analytics engine



when certain prescriptions are provided to the patient (e.g. medications related to diabetes, high blood pressure, etc.)

7. DISCUSSION AND DIRECTIONS FOR FUTURE RESEARCH

Currently, the following three use cases are exploring the use of blockchain technology. Note that the provider in each case is interacting with intermediate actors to support patients within three distinct patient ecosystems, and each uses a potentially different architecture to support communication of information and coordination of activities to improve patient adherence to treatment plans.

- A skilled nursing facility (SNF) manages patients discharged from a hospital for longer term care, and a physician/nurse practitioner acts as an independent entity to support SNF staff to care for cardiac patients.
- A mobile unit is interacting with rural patients to provide screening services for glucose monitoring and provides patients a referral to a physician near them. It may also set up appointment from some patients at free clinics.
- A smoking cessation hotline receives walk-in patients as well as referrals from providers. It interacts with patients to recruit and counsel on smoking cessation protocols and reports on patient progress to referral agencies and funding groups.

In the case of the SNF, the nursing home and hospital can use a centrally coordinated system to share information in support of clinical care of the patient. However, the nurse intermediary is supporting cardiac care staff in multiple nursing homes and possibly interacting with patients' family members. This interaction is a mix of clinical and non-clinical support and must be coordinated differently. The interaction between nurse, family and the SNF staff can be an app connected to a blockchain to share information with other actors and health systems.

The mobile unit acts as an intermediary to provide screening services for glucose monitoring and hypertension. It provides physician referrals and sets up appointment with free clinics occasionally. Its interaction with physicians is more direct even though it is through a patient via a paper referral. Its interaction with patients in rural areas is either by phone or via text messaging after the visit. Again, the architecture to support these can be different.

ASHLine uses on-line and fax today to get provider referrals and uses phone calls to engage patients in counseling services. The type of interaction is different with each group, one is clinical, and one is nonclinical.

ASHLine manages two sets of interactions – one with provider for clinical referral and report generation and one with patients and counselors. The patient interaction must be in real time to keep patients engaged but provider reporting can be done periodically. The technologies used with patients must recognize variations in the patient population segments.

In summary, each of these populations have varying degrees of motivation to adhere to treatment guidelines, especially when it comes to reducing obesity and smoking. The managerial challenge is not just focus on sharing clinical information with each partner to engage patients, but to use incentives to drive behavioral change among patients. Since many of these patients live in different regions, with varying technical, social, and economic challenges, the architecture used can be a hybrid that will support evolving dynamics of the patient ecosystem.

Referring back to the research question in the introduction - how to model service innovations to surface value gaps so improvements can be made in successive value cycles? The answer lies in the analysis of each service model that supports a patient segment and design of the model into service exchanges. Using feasible technologies and a hybrid architectural mix, one can support sharing of information and coordination of activities. Such coordination may use incentives to align goals and use gamification, when appropriate, to change patient behavior. Feedback from such a system should lead to identifying gaps to begin the next value cycle.

8. DIRECTIONS FOR FUTURE RESEARCH

There is significant variability in the intensity of resource sharing as well as the type of resource shared by all actors involved, and the incentive for engaging these actors (including patients) in such resource exchange also varies. As such, one area of future research is to focus on the need for a hybrid architecture needed to connect and coordinate activities of these actors and decide how it may change as the patient dynamics change. In other words, architecture may be offered as a service to support value fulfillment, so service exchange dynamics can dictate the architectural choices made.

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 the type of actors participating in the network and the Quest contracts designed to incentivize patients. In addition, to tailor the necessary non-clinical information can be shared in the social media network that patients have access to.

9. CONCLUSION

In this paper, we modeled care services using value lens based on service-dominant logic research and formalized the service model by decomposing it into a series of service exchanges. These exchanges were used to connect actors and resources which are outside the hospital system and a distributed network architecture such as blockchain was used to implement the service model. A Quest architecture framework is then developed to support gamification so that incentives to patients can be used to align patient and provider goals. Using a mix of technologies such as an agent that collects patient activity, cloud-based storage that combines patient activity with other profile information, and an analytics engine one can adapt the incentives to continually change as patient behavior changes.

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APPENDIX: ACTIVITY FLOW OF QUEST IMPLEMENTATION

Figure 7.

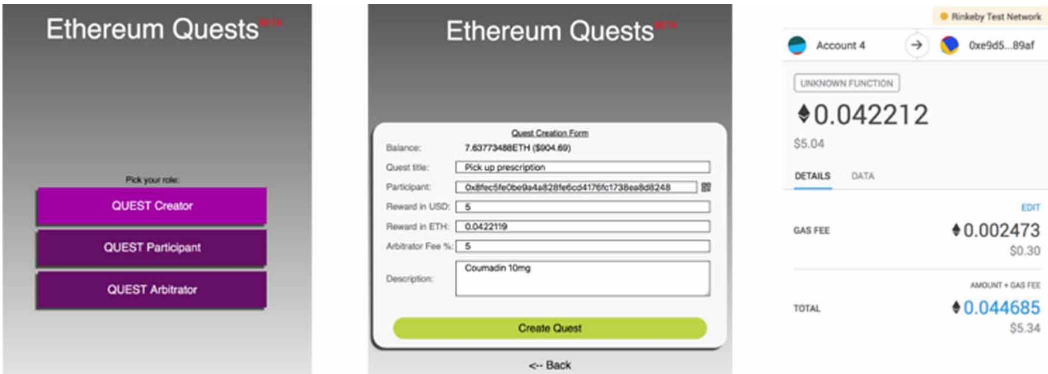

Figure 8.

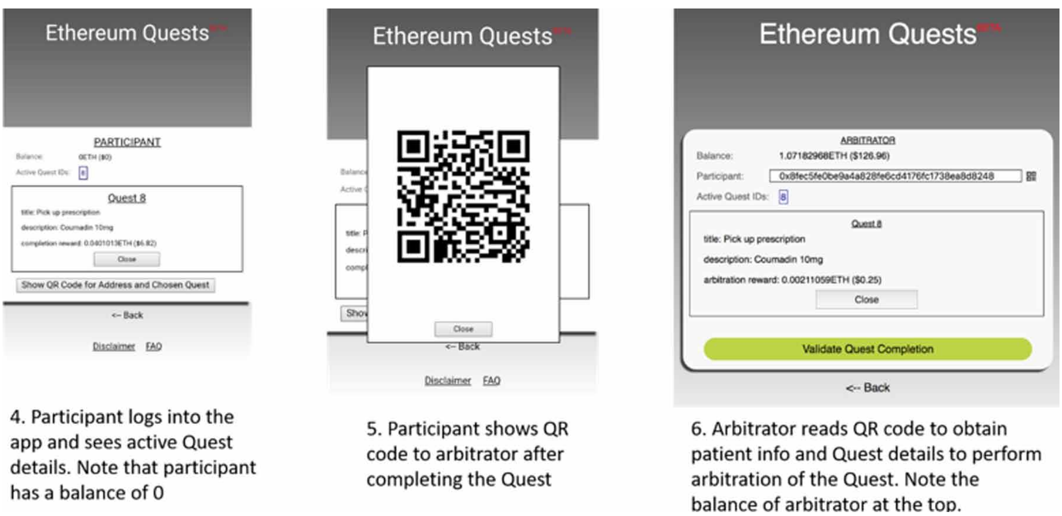

Figure 9.

7. Arbitrator confirms transaction to arbitrate quest completion to Meta Mask

8. Arbitrator receives the reward. Notice an increase in his balance

9. Patient receives the reward. Notice an increase in his balance from zero.