The Potential of Blockchain for Transforming the Urgent and Emergency Care

Daniela America da Silva, Samara Cardoso dos Santos, Wilson Cristoni Neto, Luiz Coura, Robison Egydio Lopes Junior, Gildarcio Sousa Gonçalves, Jose Crisóstomo Ozório Junior, Leonardo Guimarães, Alyson Basilio, Fabio Kfouri, Breslei Max Reis da Fonseca, Juliana F. Pasquini Martinez, Anderson Gomes, Paulo Diego Barbosa da Silva, Johnny Marques, Luiz Alberto Vieira Dias, Adilson Marques da Cunha, Paulo Marcelo Tasinaffo

Electronic Engineering and Computing Department
Brazilian Aeronautics Institute of Technology
São José dos Campos, São Paulo, Brazil
Email: stagiho-bd@googlegroups.com

***Abstract*—During the 1st Semester of 2018, at the Brazilian Aeronautics Institute of Technology (Instituto Tecnológico de Aeronáutica - ITA), a successful Collaborative Interdisciplinary Problem-Based Learning (Co-IPBL) experience took place. At that time, more than 20 undergrad and graduate students from 3 different courses within just 16 academic weeks had the opportunity of conceptualizing, modeling, developing, and testing a Computer System based upon Big Data, Blockchain Hyperledger, Micro-services, and other emerging technologies for government and private organizations. This Co-IPBL was performed with the participation of a medical technical team from the Hospital of Clinics at the Faculty of Medicine of the University of São Paulo focusing in Urgency and Emergency Care. The purpose of this system was to aggregate data from actors, such as External Regulations of Heath Care, Hospital Internal Regulation, Hospital Emergency, Urgency Care, and Urgency Institutes, by integrating them into just one decision making process, to improve Urgency and Emergency Care. This academic research project was named in Portuguese *Soluções Tecnológicas Aplicáveis ao Gerenciamento de Informações Hospitalares Ostensivas com Big Data - STAGIHO-DB*, meaning in English "Technological Solutions Applicable for Managing Ostensive Hospital Information with Big Data - TSA4MOHIBD. Differently from other existing university systems, Research Centers, Governmental Agencies, Public or Private systems, this one was academically developed and tested in just 16 calendar weeks, applying Scrum Agile Method and Value Engineering. This research work was stored in a Google site and implemented as a Proof of Concept (PoC), by using emerging technologies, such as the Blockchain Hyperledger, a common database of health care information that doctors and providers could access. It represents one example of how to address the old problem of teaching, learning, designing, and implementing complex intelligent systems to solve health care problems, by collaboratively working with technical teams facing real problems of Urgency and Emergency Health Care.**

Keywords-Health Care System; Big Data; Internet of Things; Agile method and testing; Intelligent Systems; Micro-services Architecture; Cloud Computing; Blockchain; interdisciplinarity; Collaborative problem-based learning.

I. Introduction

This paper tackles the development of an academic project using the Collaborative Interdisciplinary Problem-Based Learning (Co-IPBL). Two issues are emerging in health care as clinicians face the complexities of current patient care: the need for applying new technologies in health care management and the need for these professionals to collaborate with professionals from engineering and computer science background.

Interdisciplinary health care teams with members from many professions usually answer calls, by working together, collaborating, and communicating closely to digitize patients' care [10]-[12].

This research work provides an integration of 3 different courses taught at the Brazilian Aeronautics Institute of Technology (*Instituto Tecnológico de Aeronáutica - ITA*): CE-240 Database Systems Projects, CE-245 Information Technologies, and CE-229 Software Testing. It involved some cooperative work with technical Physicians from Urgent and Emergency Health Care at the Hospital of Clinics from the Faculty of Medicine at the University of São Paulo, Brazil.

It also describes a practical application of collaborative and interdisciplinary concepts, by using the Scrum Agile Method [1]-[3] and Value Engineering. This academic project was driven by ITA to generate expertise on developing, integrating, and managing Emergency and Urgency Health Care in the Hospital of Clinics [4].

This project was named in Portuguese *Soluções Tecnológicas Aplicáveis ao Gerenciamento de Informações Hospitalares Ostensivas com Big Data - STAGIHO-DB*, meaning in English, "Technological Solutions Applicable for Managing Ostensive Hospital Information with Big Data-TSA4MOHIBD". It has considered the development of a Software System, involving Patients, Doctors, Hospitals, and Suppliers, for decision making, by using: Scrum Agile method; Value Engineering; Big Data; Blockchain Hyperledger[9], software quality, reliability, safety, and testability. Scrum Agile Method, Value Engineering, and its best practices were used, in order to develop a computer system to satisfy project requirements in a time frame of just 16 academic weeks.

 ISBN: 978-1-61208-651-4

This TSA4MOHIBD Project [5] was divided into two groups of application: External Regulation and Internal Regulation, by sharing its development among four student teams, which were responsible for developing different functional requirements involving the verification of quality, reliability, safety, and testability.

This research work project was developed by using NodeJs[15] for the development of Java Micro-services (fine-grained services), NoSQL Databases [16] to stored the internal data for the Hospital, Blockchain Hyperledger [9] to stored the electronic health records, Kafka [17] for message exchanging in the common communication data bus, and other emerging technologies. During this collaborative project development, more than 20 students have practiced the roles of Product Owners (POs), Scrum Masters (SMs), and Team Developers (TDs). At the end of this project, a total of 48 User Stories (USs) had been planned to compose the Product Backlog. However, only 36 of them were developed within 3 monthly sprints.At the end of each sprint, reviews and retrospective meetings took place. Moreover, the Acceptance Test Driven Development (ATDD) [6] was applied by generating a minimum, necessary, and sufficient set of artifacts stored at [5].

For each User Story (US), more than one test case and acceptance test were developed. The integration strategy between groups of subsystem components occurred, by using Micro-services, a Commom Data Communication Bus, and Blockchain Hyperledger, allowing information to be available via broadcast to every hospital area and also to the External Regulator named CROSS (named in Portuguese Central de Regulação de Ofertas de Serviços de Saúde and meaning in English the Regulation Center for Health Services Offerings).

An overview of the Urgency and Emergency Care flow is presented in Figure 1.

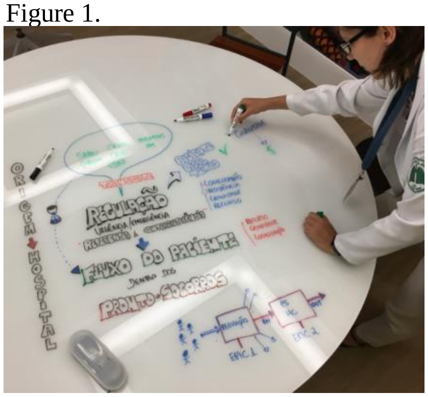

Figure 1. The Emergency and Urgent Care Overview.

In Section II, we describe the attributes of Urgent and Emergency Care at the HCFMUSP. In Section III we present the Proof of Concept and The Proposed System Architecture. In Section IV, we present the specific characteristics of Blockchain Architecture. In Section V, we state our conclusions and suggest possible topics for future research.

II. The Urgency and Emergency Health Care In the HCFMUSP

Before starting the academic year, some students from the Brazilian Aeronautics Institute of Technology (ITA) had a planning meeting with some members of the Emergency Care in the Hospital of Clinics from the Faculty of Medicine at the University of São Paulo (in Portuguese, Hospital da Clínicas da Faculdade de Medicina de São Paulo - HCFMUSP).

On that opportunity, the internal members of the hospital have presented some details of the internal and external regulation and clarified the diagram presented in Figure 1. At that time, there was also an on-site visit to some emergency areas and hospital sectors and it was agreed that some information should be shared with ITA developers, such as students and professors, in order to provide requirements specifications for the next steps of project development.

A. Regulations

Regulations of Hospitals and Health Units attending Urgencies and Emergencies are usually carried out by the Health Care Supply Regulatory Center (CROSS). Some urgencies and emergencies are referred to the CROSS by: the Mobile Emergency Response Service (in Portuguese, Serviço de Atendimento Móvel de Urgência - SAMU); the Military Police Operations Center (in Portuguese, Central de Operações Policias Militares - COPOM); the Firefighter Operations Center (in Portuguese, Centro de Operações do Corpo de Bombeiros - COBOM); and/or Health, Secondary Hospitals, and Specialized Hospitals.

It is through the CROSS that the HCFMUSP use to be contacted, in order to respond to urgencies and emergencies. An emergency patient may also arrive by the regular entrance of the HCFMUSP and after contacting the CROSS (usually via email or through the CROSS Web Portal), the HCFMUSP will screen through an Internal Emergency and Emergency Control Center to filter relevant cases for hospital care. Definitions of Urgency and Emergency Health Care are described in Table I.

TABLE I. THE PRINCIPLES OF URGENT AND EMERGENCY CARE

Principles	Resource utilization
Universal Access, Integrality (end-to-end view), Prioritization	Regionalization (Health Offices, Ambulatory Medical Assistance, Hospitals); Hierarchy (The hierarchical division is performed by the health care secretary)

B. The External Regulation

The Health Care Secretary of São Paulo understood the regulation as an important tool for the management of public health systems, which has among its objectives the equity of the access implemented through dynamic actions executed in an equitable, orderly, timely and rational way, creating the CROSS, which brings together actions aimed at regulating access in hospitals and outpatient areas, contributing to the integrality of the assistance, providing the adjustment of the available health care supply to the immediate needs of the citizen as described at [13].

Regarding the existing scenario, some characteristics of current Urgent and Emergency Care processes are described on Table II and Table III.

TABLE II. THE EXTERNAL REGULATION - SUMMARY

Current	Details
About Patient Care	Regional units use paper data; dependence on people; patient is directed to the wrong place; lack of resources for care; patient late to the correct location.
About Logistics	Problems mapping criticality versus logistics; manage public versus outsourced ambulances; prioritization versus type of illness; and HCFMUSP also receives patients from other countries (e.g., from Latin America and Africa).
About the Patient Behavior	High demand; everyone wants to come to HCFMUSP; after getting treatment in HC, patient also does not want to return to the regional hospital.
About the Internal Controller	Hospital can not refuse care; the HCFMUSP internal controller evaluates requests and redirect the patient to another Hospital; loss of patient history until arrival at HCFMUSP; data bad described versus delay in the assistance; vacancy zero versus no vacancy in the hospital; internal Controller working as "technical advisor" for the regulator; patients only for evaluation versus how long ambulance needs to wait.
About the Governance	It is unknown, which professionals are in the Health Care Centers; and it is also unknown the availability of beds on Health Care Centers. The regulator has the bed map and can be confirmed with the regulator if the hospital could visualize the availability in other hospitals also. It is unknown, why the Health Center refuses the care requested by the regulator.
About the Standards	There are Laws that regulate how the HCFMUSP Internal Controller should work; there are internal Norms in Hospitals and Health Centers; the Regulator has also specific standards; knowledge from job description of all professionals involved is also required; and there are also norms regulating the external transport of patients.
About Systems Integration	The HCFMUSP accesses the Regulator System, via Portal, and access only requests directed to it; it does not have visibility of care from other health centers; regulator requests are manually checked in the Regulator Portal; regarding the Volume of Orders (as an example, an estimation from the month of June 2017, 2000 applications were received by the Regulator, 540 accepted by the Controller of the USP and out of them, only around 30 could have a vacancy of 0 - which means that the patient has to be accepted; there is no integration between data flows; a typical flow of data on the HC is: Health Units -> Regulator - > HC Internal Controller; a typical flow of data within the HC is: Regulator + Electronic Record at the Reception + Internal Controller; there is a lack of synchronism between actions; the regulator, in the attendance, needs to obtain data from the patient and his illness; and demographic data are needed (from where the patient comes, how he is coming, and when he is arriving).
About the Management of Beds	Treats how to direct the patient in the internal flow (e.g., available beds and specialists); as an example from a Real Scenario, the patient has arrived at 03:00 am to perform an endoscopy, had to stay within the ambulance, mainly because the Hospital did not know of his arrival and can not do the endoscopy. The patient has waited until the morning, because it was not possible to direct the patient in the internal flow; the doctor who was attending the emergency has no contact with the HC and the COBOM system also use to work separately from the HCFMUSP. The COBOM has a manual chart to manage service resources (e.g., where vehicles are located); and the external systems involved in the service are not integrated.

TABLE III. THE EXTERNAL REGULATION - INTERACTIONS

Current	Details
About Data Quality	International Statistical Classification of Diseases and Related Health Problems (ICD) has many groupings and sub-classifications difficult to use in Emergency and Urgency Care; it is necessary to use specific fields to quickly reclassify disease and type of an emergency (e.g., if it is heart attack, trauma, Glasgow (level of consciousness), among others); and Diagnosis Related Groups (DRG) should be used to speed up case classification.
About the Human Factor	The are many problems with reliability of data and the correct use of the systems (e.g., word abbreviations are dependent on the form the clerk expresses).
About the Telemedicine	The doctor attending an emergency does not have contact with the HCFMUSP.
About the Hierarchy	There are some problems in the scheduling of care and diagnostic problems that generate unnecessary referrals to Specialized Hospitals; and problems in the hierarchy, which cause slowness so that the correct patient arrives at the HCFMUSP in the correct time.

C. The Internal Regulation

The Internal Regulation is the area responsible in the Hospital for verifying availability to receive a Patient and will also make the contact with the appropriate hospital institute to evaluate if a Patient could be transferred to the Hospital. With regards to the existing scenario, some characteristics of the existing Internal Flow in Urgency and Emergency Care process are described on Table IV.

TABLE IV. THE INTERNAL REGULATION

Current	Details
About the Lobby	It has only one entrance; the stretchers change places; and there is a "virtual bed number" and no "real" fixed number.
About the Identification	There is a bracelet to identify patients; patients who arrive in ambulances use open tokens and are also screened; If a patient is unconscious, he receives a number; and The Manchester Protocol Risk classification is used, which also defines the maximum time for the first service and provides a green / blue classification that does not necessarily leads to the opening of a card. In this case, the patient may be redirected to another region.
About Patient Care	Many patient cares are provided in the lobby; Nurses need to walk between stretchers; doctors can not forget to see the patients; and patients can not fail to take prescribed drugs.
About Patients in the Emergency Room	There is no information about what happens, after the patient passes the entrance door and arrives at the Emergency Room; there are patients who wait for 6 hours in Emergency Room and have not been attended for some reason (e.g., Hospital busy or

Current	Details
	unable to attend); there is only one Patient Card; and there is an assessment of what patient's risk is.
About the Internal Flow of Patients	After screening, patients are referred to an emergency or general medical clinic; and patients may also require evaluation of multiple professionals.
About the Internal Flow of Physicians	There are 11 Medical Teams and sometimes Doctors need to make an assessment of one Patient in the Building of another Institute (e.g., a Neurosurgeon may be in another building evaluating a patient or in a Surgical Center); Medical Specialists move more; and Physicians have mobile, but the signal for mobile does not work well inside buildings that do not have signals with good intensity of the Telephony Operator, but they have a good signal of WiFi. For this reason, Doctors have again used the technology of Pager.
About the Internal Flow of Nurses	Nurses usually stay in more fixed places pre-determined for them.

III. REQUIREMENTS

A. The Proof of Concept as an Assigned Mission

To reduce the scope and complexity of the system to be developed, a mission assigned was developed to the rescue of motorcycle accident victims, mainly because it is a frequent occurrence in the city of São Paulo. On a regular work day, every 15 minutes, the SAMU assists a motorcyclist in the city of São Paulo. Most of victims are not made up of motoboys. Usually, they are drivers who use vehicles (motorbikes) to go to work or are weekend drivers. Rehabilitation of those who are injured is usually time-consuming and laborious, as described below:

- 40\% of motorcycle accident victims need to undergo complex surgeries and long physiotherapy treatments;

- The most serious injuries caused by motorcycle accidents are usually in the skull and spine;

- Most motorcycle riders use the vehicle as transport, only for 2 hours a day, usually to move between home and work place;

Most of them have been injured before;

- Of the total number of accidents initially investigated, 2% resulted in death of motorcyclists;

- Of the total number of injuries: 48% had serious injuries, 17% in the legs and feet; 12% in arms; and 23% had other types of trauma;

- Most of them were discharged immediately after care and only 18% had to be hospitalized; and

- Considering the annual costs, about R$ 100 million are invested by the Orthopedics Institute of the HC, exclusively for the recovery of motorcyclists: "These are patients who, in the first six months of hospitalization, cost about R$ 300 thousands to the Hospital, on surgeries, ICU hospitalizations, occupations of wards, use of medications, among other procedures.

Based on previously reported motorcycle accident data, the development of the TSA4MOHIBD project should be able to provide an adequate management for the control of victim assistance only considering motorcycle accidents, in such a way that:

- Those motorcycle accident victims (PATIENTS) may be appropriately diagnosed, promptly identified and/or attended to;

- PHYSICIANS may have computers and/or computer tools capable of providing preventive and appropriate planning, scheduling, and controlling of motorcycle accident emergency services, for example, identifying the needs of: hospitalization time; procedures; medical teams; procedures for surgery preparations; as well as the availability of operating rooms and Intensive Theraphy Units;

- The HOSPITAL and/or the INTERNAL CONTROLLER shall have computers and/or computer tools capable of using appropriate technologies to provide efficient screening methods, prioritization of care, patient and physician locations within the HOSPITAL, in order to locate, if necessary, other HOSPITALS to attend emergencies of motorcycle accident victims, according to the criticalities and needs from specialized treatments of the PATIENTS;

- HOSPITAL must have adequate computers and/or computer means to collaborate in the process of managing large data flows, involving efficient attendance of injured motorcycle patients, by using appropriate technologies and efficient screening methods for this type of emergency;

- SUPPLIERS of medicines, devices and/or technologies must have appropriate tools to participate in logistics and/or supply process to be used in care and/or care for victims from motorcycle accidents attended by urgency and emergency of HOSPITALS;

- PHYSICIANS and NURSES must have appropriate tools to provide care to victims from motorcycle accidents attended by the urgency and emergency of the HOSPITAL, for example, to identify them from their entrance hall, by verifying and controlling also the movement of the stretchers, according to internal flows of required services;

- Each confirmed case of motorcycle-injured PATIENT can and should generate, within the inventory control of a HOSPITAL, the release of care kits containing materials and medications, according to the size of events. In these cases, in addition to medicines, other supplies can and should be considered important, such as blood bags for transfusions, as accident victims need quick rescue and motorcycle accidents kill from blood loss;

- The population/society should have access to computers and/or computer tools of the System Project involving the TSA4MOHIBD and/or the Real-time TSA4MOHIBD capable of providing appropriate records, management, controls, and governance of resources used in the area of Health Care;

- Public administration must have reliable data to provide a comprehensive situational awareness to support decision making for accidents and/or crises, involving motorcycle accidents.

B. The Proposed System Architecture

In order to provide appropriate speed in the communication with the Regulator and also to allow the

 ISBN: 978-1-61208-651-4

Regulator to know in advance the number of bed vacancy in the Hospital, it is suggested that the communication between the Regulator and the Hospital works similarly to the AirBnB model. Then, the hospital will publish in a data bus communication vacancy, physicians, and specialists available and also the Regulator will publish a request for a patient to be attended and its initial conditions. On top of that, it will run an Artificial Intelligence algorithm to verify that the Regulator needs a Patient to be treated and will also match the required care with the Hospital that has vacancy to receive the Patient. The Artificial Intelligence algorithm, after finding the appropriate Hospital, will place in the same data bus a message to the Hospital. Some External Flow Architecture Details are shown in Figure 2.

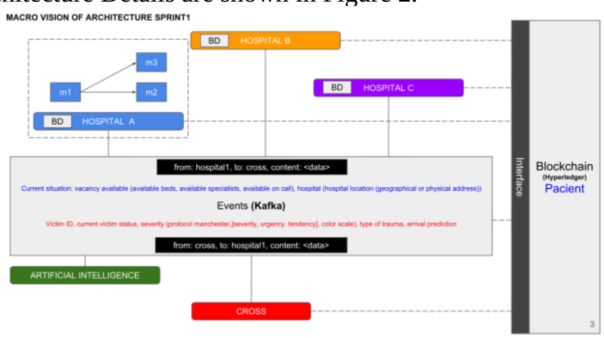

Figure 2. The External Flow Architecture.

In the Hospital at the Internal Regulator, the operator will analyze the request and through the application system he will place a message in the Data Bus, by informing to Artificial Intelligence algorithm that the Patient was accepted and will inform straight the Urgency Care Unit that a Patient will arrive, also informing the date and time of the estimated arrival. The patient information will be available in the Blockchain Hyperledger, and then, data from the CROSS and also data about the Patient will be internally matched in the Hospital.

Some important details about how it will work will also be presented in the Blockchain Architecture section. From that point onwards, the planning for Patient Care will be started prior to the Patient arrival. When the Patient arrives the technical team, the bed, and the required examination and health care steps will proceed as per suggested planning. After acceptance from the Internal Controller, the intelligence of the system will place a message to the Regulator, by informing that the Patient was accepted by the HCFMUSP. Some Internal Flow Architecture Details are shown in Figure 3.

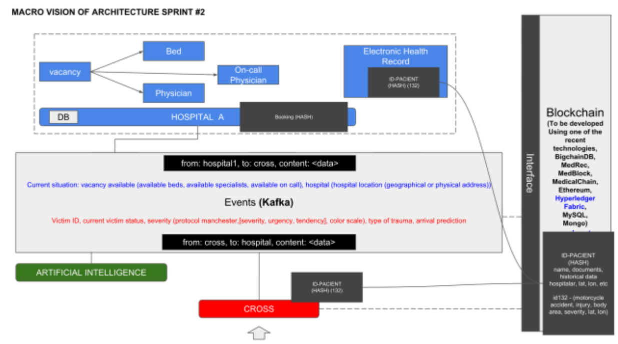

Figure 3. The Internal Controller Flow Architecture.

After a Patient arrived at the Hospital, his Electronic Health Record could be read by any Institute from inside of the HCFMUSP, and information about patient care steps, as all the current bed management in the Hospital, would be presented in a dashboard that could be available for the governance team, by physicians and nurses looking at the next steps of the Patient Care. Some internal management information are shown in Figure 4.

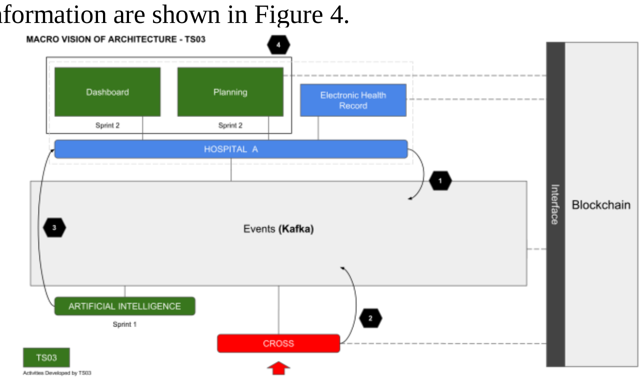

Figure 4. The Dashboard for Patient Care.

IV. THE BLOCKCHAIN ARCHITECTURE

A. *Blockchain Applications in Health Care*

Blockchain technology and smart contracts have a variety of application in Health Care and, as recently reported, there are multiple advantages, such as a common database of health information that doctors and providers could access, no matter what electronic medical system they use, higher security and privacy, less admin time for doctors, so there is more time to spend on patient care, and even better sharing of research results to facilitate new drug and treatment therapies for disease, as recently mentioned by a research published by Forbes [7].

In the open-source landscape map for healthcare-related blockchain published in GitHub [8], there are multiple companies in the early stage of applying this technology as shown in Figure 5.

 ISBN: 978-1-61208-651-4

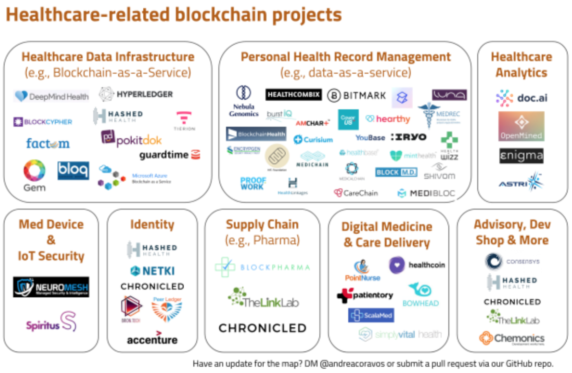

Figure 5. The open-source landscape map for healthcare-related blockchain.

The Blockchain proposed for the Urgency and Emergency Care at the HCFMUSP explores how Blockchain Hyperledger [9][14] and smart contracts could be used to provide an interesting and innovative way to keep references of the Patient data, since the occurrence of the emergency until the completion of Patient treatment in the Hospital.

To do this, first we discuss the need of two separate and private blockchain networks and then, we propose an architecture that is able to use those different networks applied to the motorcycle accident Proof of Concept.

B. *The Blockchain Proposal for the HCFMUSP*

For the Urgency and Emergency Care at the HCFMUSP, our proposal is to use two separate Blockchain networks: one for Patient and other for Attendance.

The Blockchain Patient network has overall patient information and is a private network with information that can be accessed by the CROSS and any other Institution that would like in the future to access Patient Identification (e.g., Single Health System, in Portuguese, named Sistema Único de Saúde - SUS).

The Blockchain Attendance network has detailed patient information and all the heath care details performed by the Hospital. And it is a private network with information that can be accessed only by the Hospital and internal institutes. For future work, examination details could be also stored in this Blockchain network. The main benefit of isolating patient's data from patient's own care is to provide data safety, since confidential information will be managed only by the hospital. The indirect benefit is to allow that two different groups of students learning Blockchain could also learn separately and then, the integration has worked smoothly during the Sprint 3 of the TSA4MOHIBD project, focusing in the Integration.

The Blockchain Hyperledger implementation also makes use of encapsulated micro-services allowing smooth funcionalities' integrations, which were developed during Sprint 1, focusing in the External Flow implementation, and Sprint2, focusing in the Internal Flow Implementation. The steps followed to assist a patient using the Blockchain Hyperledger architecture are shown in Figure 6, on Table V and Table VI.

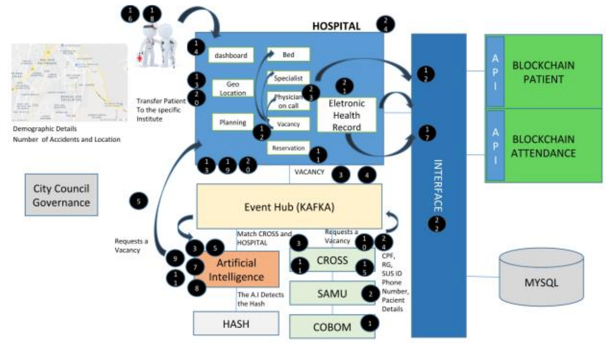

Figure 6. The Architecture for the Urgency and Emergency Patient Care.

TABLE V. THE STEPS FOR THE URGENT AND EMERGENCY PATIENT CARE – EXTERNAL FLOW

Step	Details
1	The fire department team receives notification of an accident (via process, not system implementation), by updating the occurrence of 14:17 Auto x Moto, Rua Coronel João Cabanas, 650 - Grajaú, 1 vehicle, victim rescued by SAMU # 193R. 4:14 PM - 27 May 2018
2	The SAMU, in contact with the CROSS, informs the details about the accident and the patient. The name of the patient is informed as well as that the biker's legs, ankles, and feet have been affected (via process, not via implementation system).
3	The CROSS requests a slot on the message data bus. With the message bus, it was created an INTELLIGENCE that reads CROSS requests and messages that the HOSPITAL generates checking that hospitals have beds available for the care.
4	Hospitals, including the HCFMUSP, post a message every 15 minutes, reporting the total available vacancies and there are 3 vacancies in the Emergency and Central Institute. Current situation: vacancy available (available beds, available specialists, available on call), hospital (hospital location (geographical or physical address))
5	The INTELLIGENCE reads the message data bus and verifies that the HCFMUSP has a vacancy available and sends a message directly to the HCFMUSP, informing patient's data and his current situation. Victim ID, current victim status, severity (from the manchester protocol, color scale), type of trauma, and arrival prediction).
6	Information about the accident region is also shared with the CROSS in the message data bus. PATIENT ID (HASH) name, CPF, RG, documents (SUS), latitude, longitude for example: id132 - (motorcycle accident, injury, body area, severity, lat, lon) Rua Coronel João Cabanas, 650 - Grajaú.
7	The victim is taken to the Hospital by the SAMU ambulance (The communication with the SAMU occurs via the process, not through the system).
8	At the HCFMUSP, the Control Planner makes the consultation to specialists, beds, and through demographic data verifying how long the PATIENT will arrive at the HC, and that the transportation will be made by SAMU.
9	Upon verification by the Controlling Party, a message is posted by INTELLIGENCE on the bus to the CROSS, confirming the acceptance of the procedure TS03-US103 PATIENT. If the CONTROLLING PLANT did not accept the PATIENT, the INTELLIGENCE would verify the vacancy in another HOSPITAL (This is a recommendation, but not implemented yet).
10	The CROSS confirms to the SAMU that the PATIENT will be directed to the HCFMUSP (implemented via process, not via system yet).

 ISBN: 978-1-61208-651-4

Step	Details
11	Upon confirmation of the PATIENT by the Internal Controller, the Internal Controller also advises the Emergency Room to prepare the internal flow to receive the PATIENT.

TABLE VI. THE STEPS FOR THE URGENT AND EMERGENCY PATIENT CARE – INTERNAL FLOW

Step	Details
12	In the Emergency Room, the internal flow of activities begins to prepare care. PATIENT data, via blockchain, are received and some actions for the reservation are initiated. The vacancy is reserved. The bed is reserved in procedure TS01-US299b and a physician is booked.
13	Service planning starts, Exams, Operating room. Patient's travel time to the Hospital areas are also calculated and estimated.
14	The Internal CONTROLLER shows the situation of the HOSPITAL after reserving the bed, also verifying available specialists, available beds, and the Physician on call. The Emergency Dashboard also provides an up-to-date view upon reservation and service planning.
15	The CROSS may request other vacancies, to refer other patients according to the occurrences, if necessary.
16	PATIENT arrives at the HCFMUSP.
17	The Emergency Unit, through the data of the PATIENT locate in the BLOCKCHAIN, finds the his Electronic Health Record. / get (getAll) / get / {hash} (getByHash).
18	The necessary identification is made, by using QR Code bracelets (This is also a recommendation, not implemented yet).
19	All PATIENTS care are performed according to pre-planning.
20	According to results from tests, the PATIENT will need surgery by the orthopedic team, he is not at risk, and his transfer can be done to the Orthopedics and Traumatology Institute - OTI (This is also a recommendation not implemented yet).
21	The PATIENT remains in URGENCY and EMERGENCY for one day, and through the internal flow he is transferred the next day to the OTI.
22	PATIENT records are updated through the blockchain and can be consulted by the OTI.
23	After the transfer, the vacancy is made available at the Urgency and Emergency of the Central Institute.
24	New services follow the same flow for receiving motorcycle accident victims in the city of São Paulo. According to some OTI statistics, every 15 minutes, a motorcyclist suffers an accident in the City of São Paulo.

C. *The Blockchain Implementation*

For the Urgency and Emergency Care at the HCFMUSP, our proposal is to use two separate Blockchain networks: one for Patient and other for Attendance.

For the implementation, it was identified the four main flows for the Blockchain Hyperledger integration. The following details are shown in Figure 7.

- Register Assets (e.g Physicians, Hospitals);
- Authorize a PATIENT Care;
- Perform PATIENT Care; and
- Register information from the PATIENT Care.

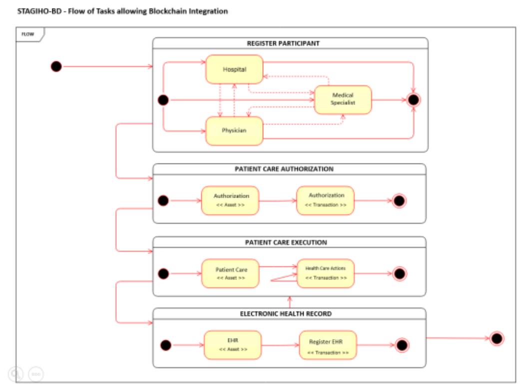

Figure 7. Some Blockchain Integration Activities.

For the authorization in the Blockchain, two flows were identified: the first one to authorize Assets and the second to authorize and finalize Patient Care. Some details are shown in Figure 8.

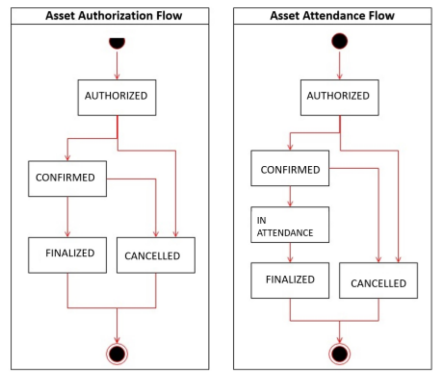

Figure 8. Some Blockchain Authorization Activities.

Some Graphical Interfaces are shown in Figure 9 and Figure 10.

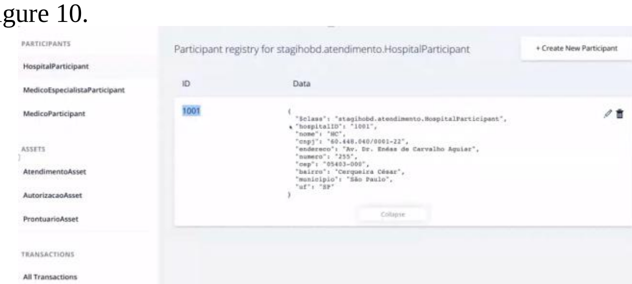

Figure 9. The Hospital Participant.

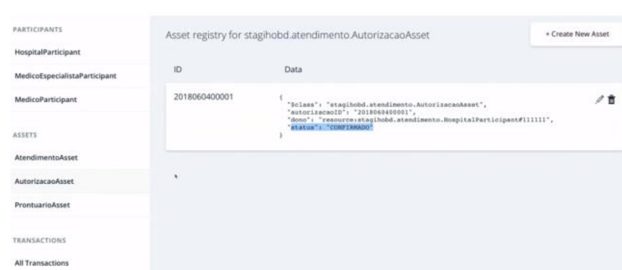

Figure 10. The Patient Authorization.

V. CONCLUSION

This paper aimed to describe the development of an academic interdisciplinary project using Scrum agile method and its best practices, in order to develop a prototype for a Proof of Concept (PoC), by using a Computer System based on Big Data, Blockchain Hyperledger, Micro-services, and other emerging technologies applied to Urgency and Emergency Care.

This academic research project was named in Portuguese as "*Soluções Tecnológicas Aplicáveis ao Gerenciamento de Informações Hospitalares Ostensivas com Big Data - STAGIHO-DB*", meaning in English, "Technological Solutions Applicable for the Management of Ostensive Hospital Information with Big Data - TSA4MOHIBD", a Computer System based on Big Data, Blockchain Hyperledger, Micro-services, and other emerging technologies for governmental organization and private sector.

The purpose of this system was to aggregate data and integrate sectors such as External and Internal Regulations through its PATIENTS, HOSPITALS, PHYSICIANS, and HEALTH SUPPLIERS, for the decision making process related to Urgency and Emergency Care, involving motorcycle accidents. The TSA4MOHIBD project was developed by students from three different Computer Science courses taught at the Brazilian Aeronautics Institute of Technology (*Instituto Tecnológico de Aeronáutica – ITA*), on the 1st Semester of 2018.

A. Specific Conclusions

The use of interdisciplinarity in 3 courses of Computer Science has worked as expected, since students were able to know how to work in teams to successfully develop a complex computer system.

The cloud computing environment has been widely used by students to enable collaborative work from distance, by using remote meetings, personal websites, and an official project website.

The Scrum framework has been adapted to the reality of the interdisciplinary academic environment of ITA, helping the entire team of more than 20 students to offer value to stakeholders at the end of each sprint and also at the end of this project.

The application of Test Driven Development (TDD) and Acceptance Testing Driven Development (ATDD) techniques in the project was closely related to the interdisciplinary approach adopted, since acceptance tests were created by CE-229 Software Testing course students, while the Blockchain and NodeJS applications were implemented by CE-240 Database System Project and CE-245 Information Technologies course students.

The Blockchain Hyperledger, NodeJs, MongoDB, and MySQL Databases were hosted on the AWS Cloud services and have represented the main tools applied for integrating services from External and Internal Regulations.

The main results obtained from the use of the TSA4MOHIBD project prototype were successful.

Its operating logic was established and all teams were able to perform development integration, by defining and accomplishing the phases of an Assigned Mission, mapping User Stories to functionalities for the External and Internal regulations integration, which variables and detailed characteristics would be changed as inputs and/or outputs.

At the end of this project, in just 17 weeks, it was possible to demonstrate the building of the Collaborative Interdisciplinary Project TSA4MOHIBD, without completeness, but following a model with quality, reliability, safety, testability, norms, and standards applicable to a product of this nature.

Finally, students have presented the TSA4MOHIBD Academic Project Prototype, as the final project for their courses, as a Proof of Concept (PoC) to professors, entrepreneurs, and some invited guests from industry and academia.

B. General Conclusions

The academic development of a critical intelligent system is a rewarding experience that can be used in different undergrad and graduate courses.

The use of interdisciplinarity, Blockchain Hyperledger, cloud computing, and agile methods seems to be an interesting novel and exciting way to achieve academic goals, in just one semester of 17 weeks and can also be extended to other knowledge domains.

It is possible to integrate products generated with Blockchain Hyperlegder, from different teams and functional segments, such as the Internal and External Regulation, with different technologies for example Micro-services, NodeJs, MongoDB and MySQL Databases, from a minimal organization between teams, by defining separated Blockchain networks with medical ostensive data to be exchanged between each Blockchain network, allowing collective planning among all involved.

This integration can be extended to participants, running on different machines integrated through the Blockchain Hyperledger Patient network.

Hospitals can be considered ledgers and, as proposed in this architecture, can have an specific Blockchain Hyperledger Attendance network were specific Health Care information can be securely and safely stored.

C. Recommendations

It is strongly recommended to align expectations and results that may be compromised and quickly adjusted to review deliverables, when working with emerging technologies. This cycle, in the area of computing science, should be repeated all the time we have to deal with new technologies. It is important to have on the team participants who will face the challenge of learning and preparing a legacy.

It is also fundamental to have participants in the team that could identify in advance where the team could fail with the new technology, proposing improvements and allowing the team to repositioning itself to deliver what is agreed in consensus in the appropriate time. Tutorials prepared by the team during the Blockchain Hyperlegder learning process can be used to demonstrate for all team members to quickly acquire knowledge about this new technology.

This very important legacy from teams will help the next teams to face challenges of using new technologies. It is recommended the continuation of this Project, by starting from what has already been done, possible to obtain and execute, within the courses on the next semesters, on new Sprints, generating the possibility of increasing completeness.

D. Future Work

It is suggested that the process used in this TSA4MOHIBD academic project prototype can be extended to other Blockchain Hyperledger projects and predictive systems, in order to improve estimation of efforts and resources to attend Urgency and Emergency Care.

It is also suggested the use of some simulation processes to measure Urgency and Emergency Care with and without the use of Blockchain Hyperledger supporting health management.

Finally, for future work, it is suggested to expand some cooperation among the ITA, hospitals, innovation foundations, medical suppliers, industries and public and private enterprises, in order to get a selection of academic projects aligned to updated needs from the market.

ACKNOWLEDGMENT

The authors would like to thank the Hospital of Clinics from The Faculty of Medicine at The University of São Paulo, the Brazilian Aeronautics Institute of Technology, the Ecossistema Negócios Digitais Ltda for its finantial support and scholarships, and The Casimiro Montenegro Filho Foundation (FCMF) for their support, during the development of this TSA4MOHIBD Project.

REFERENCES

[1] J. Sutherland, "SCRUM Handbook", Scrum Training Institute Press, 2017

[2] D. Cohen et al., "An Introduction to Agile Methods", Fraunhofer Centerfor Experimental Software Engineering, ADVANCES IN COMPUTERS,VOL. 62., 2004

[3] M. Cohn, "Succeeding with agile: Software development using Scrum",1st Edition, Pearson Education, Inc, 2010

[4] FMUSP, "Medical School of São Paulo", 2018, accessed from http://www.fm.usp.br/fmusp/portal/ in June 10, 2018.

[5] TSA4MOHIBD Project, "Technological Solutions Applicable for theManagement of Ostensive Hospital Information with Big Data", 2018, accessed from https://sites.google.com/site/projetointerdisciplinar2018/ in June 10, 2018.

[6] K. Pugh, "Lean-Agile Acceptance Test-Driven Development: Better Soft-ware Through Collaboration", Addison-Wesley, ISBN 978-0321714084, 2011

[7] Forbes, "This is Why Blockchain will Transform HealthCare", 2017, accessed from https://www.forbes.com/sites/bernardmarr/2017/11/29/this-is-why-blockchains-will-transform-healthcare/13be90781ebe in June 10, 2018.

[8] GitHub, "Open-source landscape map for healthcare-related blockchain", 2018 accessed from https://github.com/acoravos/healthcare-blockchains in June 10, 2018.

[9] Linux Foundation Projects, "Blockchain Hyperledger", 2018 accessed from https://www.hyperledger.org/ in June 10, 2018.

[10] D. A. Silva et al.,"Health Care Information Systems: a Crisis Approach", In 15th International Conference on Information Technology: NewGenerations (ITNG 2018), Las Vegas, 2018

[11] D. A. Silva et al., "Health Care Transformation: An Academic Applica-tion System Case Study", In 10TH IFAC Symposium on Biological andMedical Systems - International Federation of Automatic Control (IFACBMS 2018), São Paulo, Brazil, 2018

[12] J. C. Martins et al., "Using Big Data, Internet of Things, and Agile for Crises Management", In 14th International Conference on InformationTechnology: New Generations (ITNG 2017), Las Vegas, US, 2017

[13] Cross, "Health Care Supply Regulatory Center", 2018, accessed from http://www.cross.saude.sp.gov.br/ in June 10, 2018.

[14] [14] A. Conceicao, F. Silva, V. Rocha, A. Locoro, J. Barguil, "EletronicHealth Records Using Blockchain", XXXVI Brazilian Symposium on Computer Networks and Distributed Systems (SBRC 2018), 2018, accessed from http://www.sbrc2018.ufscar.br/wp-content/uploads/2018/04/07-181717-1.pdf in June 10, 2018.

[15] Linux Foundation Projects, "Node.JS Foundation", 2018, accessed from https://nodejs.org/en/ in 10.June 2018.

[16] Apache Kafka, "Apache Kafka Distributed Stream Platform", 2018,accessed from http://kafka.apache.org/

[17] MongoDB, "MongoDB", 2018, accessed from https://www.mongodb.com/

