Instituto Superior Técnico

MSc in Electrical and Computer Engineering

2nd Cycle Integrated Project in Electrical and Computer Engineering

Blockchain Information Systems

Work by:
Diogo Moura

Number:
86976

Oriented by:
Prof. Sérgio Guerreiro
Prof. João Sequeira
Pedro Samorrinha

Organization:
Instituto Superior Técnico
Instituto Superior Técnico
Link Consulting Group

2021/2022

Contents

1 Motivation and definition of the problem in study in the Dissertation

The foreseeable breakthrough of the next generation of robotic systems in flexible automation in both small and medium enterprises (SMEs) and global market companies depends primarily on the Physical Human-Robot interaction - pHRI - development over the next years.

Physical Human-Robot interaction has several applications, ranging from:

1. shop floor logistics and manipulation
2. professional service robots
3. assisitve devices for the disabled
4. service robots in domestic applications

Robotic assistance in manual processes that advantageously partner human and robot workers has an enormous unexplored potential to amplify productively in processes that previously could not be automated due to technological, cost, or efficiency reasons.

Furthermore, very promising application domains of the technology are in the professional service sector (e.g., hospital support systems) and in the logistics domain (food logistics and quality inspection), which are so far to a large extent still purely manual work places.

Robots can generate several types of data and the amount is very vast:

1. RGB or RGB-d images
2. RFID (Radio Frequency Identification) signals
3. Audio Data

However, this data needs to be ingested and needs to be integrated into applications and business processes.Moreover, the large amount of data that the SR generates must obey privacy and security requirements.Compliance to General Data Protection Regulation (GPDR) requires 'privacy-by-design', whereby data protection safeguards are built into technology early on.

Also, transparency is a core principle enshrined in Art. 5 (1)(a) of the GDPR. In European data protection, transparency law is an obligation.

In this line of reasoning, we also define as a problem the lack of control and transparency in privacy in HRI.

This thesis motivation is to solve the of problems of privacy, transparency and integration into business processes and applications of robots and humans in a multi-actor information system.

The objective is to create a multi-actor blockchain Information System and business processes so that the interaction of applications, robots and humans into a multi-actor information system is created.

Furthermore, the motivation is to have a system where the data generated by robots can be stored safely, robustly and transparently, so the Information System is blockchain-based.

Therefore, the problems being studied in the dissertation are:

1. Use of a Blockchain Information System as storage for a multi-actor information system
2. Integration of this Information System into Business Processes and Applications

2 Framing of the Subject in the Scientific Area and State-of-the-Art revision

This thesis proposes to create a multi-actor information system composed of several components:

- robots
- blockchain storage
- offchain storage
- business processes integration

Each of this agents or components has a state-of-the-art itself, which compose the state-of-the-art of the Multi-Actor Blockchain-based Information System as a whole.

2.a Robots State-of-the-Art

Example of social robot: Multi-Robot Cognitive Systems Operating in Hospitals (MOnarCH) SR, operating in the healthcare environment in Instituto Portugues de Oncologia – Lisbon (IPOL).

Example of interactions: MOnarCH Robot (Mbot) assists hospitalized children and staff by interacting with them. It can patrol and socially interact with the people in the hospital corridors and rooms, play with hospitalized children and even act as a teaching assistant in the pediatrics classroom by projecting videos related to the class content.

2.b Blockchain State-of-the-Art

Traditional blockchain Systems use Proof-of-Work (PoW). This type of validation is very computational-intensive and utilizes a lot of resources.

Proof-of-Stake (PoS) consensus algorithms make blockchain networks more efficient by eliminating the energy-intensive computational mining process inherent in Proof-of-Work protocols.

PoS algorithms incentivize users to confirm network data and ensure security through a process of collateral staking.

An iteration of the concept known as Delegated Proof of Stake (DPoS) works similarly, but features a voting and delegation mechanism that makes the process more democratic.

Because there are a limited number of validators, DPoS allows the network to reach consensus more quickly.

Testing and experimentation continue on PoS algorithms, including delegated PoS. This concept has shown immense promise for increasing the efficiency, transaction speed, and throughput of blockchain protocols, which is necessary for more enterprise uses as the industry grows and looks to disrupt more complex and larger markets.

Polkadot uses NPoS (Nominated Proof-of-Stake) as its mechanism for selecting the validator set. It is designed with the roles of validators and nominators, to maximize chain security. Actors who are interested in maintaining the network can run a validator node.

Validators assume the role of producing new blocks in BABE, validating parachain blocks, and guaranteeing finality. Nominators can choose to back select validators with their stake. Nominators can approve candidates that they trust and back them with their tokens.

Ceramic maintains consensus for individual data streams. This is in contrast to traditional blockchain systems where consensus is maintained on the entire global ledger, or to distributed database systems where consensus is maintained for the entire database. Maintaining consensus at the level of individual data objects allows Ceramic to be much more scalable, as nodes only need to track information for the Streams that they care about, rather than for all Streams on the network. This also allows different Streams to use different consensus models - allowing for a flexible and extensible consensus system that can evolve over time and be tailored to specific use cases. In Ceramic, consensus is handled by individual StreamTypes, meaning new StreamTypes introduced in the future may also introduce new consensus mechanisms.

Table 1: *Comparision between different blockchains*

Blockchain	Type	Tax/s	fee/Tax (USD)	confirmation time
Bitcoin NB	PoW	7	3.421	5 minutes
Ethereum1.0	PoW	20	5.966	5 minutes
Ethereum2.0	PoS	100k	0.000293	12 seconds
EOS	dPoS	4k	0	0.5 seconds
Ceramic Network	Variable	TBA	Variable	Variable
Solana	PoS and PoH	50k	0.00025	5 minutes
PolkadDot	NPoS	1k	0.6862	2 minutes
Cardano	PoS	1M	0.4	10 minutes

Some of the state-of-the-art blockchain system:

1. EOS
2. Ceramic Network

EOS advantages:

- zero transaction fees
- very fast

EOS disadvantages:

- centralization
- not a real blockchain

Ceramic Network advantages:

- fast
- decentralized
- allows to define streams of data

Ceramic Network disadvantages:

- non-zero transaction fees
- not on production environment

2.c Offchain Storage State-of-the-Art

InterPlanetary File System (IPFS)

2.d Blockchain Storage

Previous work was done in IST regarding transmission of robots to blockchain information systems, without integration into business processes.

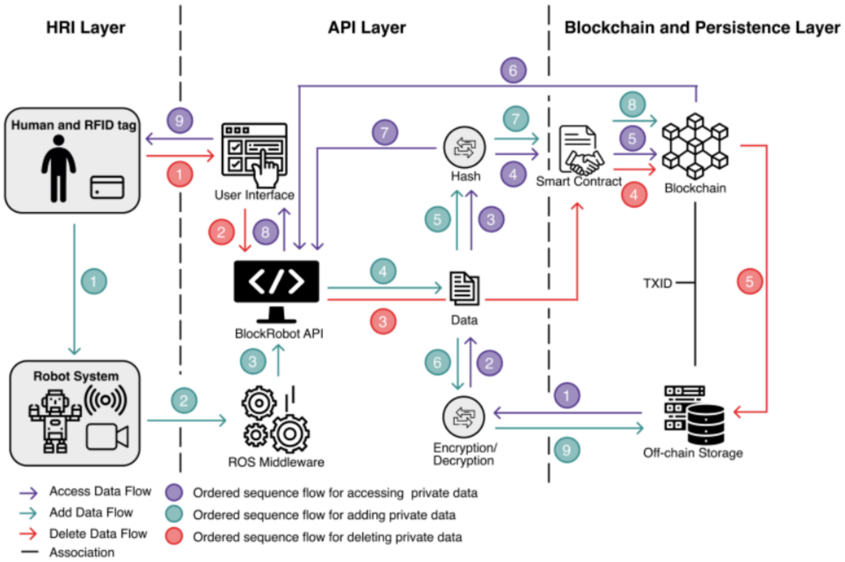

Figure 1: *High-level System Architecture of BlockRobot*

This solution implements an API with which the Robots can communicate with using the ROS Middleware and Humans through an Angular User-Interface. A hash of the data is stored in the blockchain and the data itself is stored off-chain. The data is stored encrypted off-chain and can be validated using the on-chain hash.

2.e Business Processes Integration State-of-the-Art

Business Process Engines enable high-performance flexibility, extensibility, and a consistent environment for deploying EAI, Internet B2B, EDI, and business process management projects.

The Business Process Engine performs integration activities, known as services.

Such services achieve some predefined type of integration activity. Examples of service activities performed by the Business Process Engine include:

- Communicating with external applications or middleware (using special services called adapters)
- Performing data manipulations, such as translation, transformation, splitting, and joining
- Routing data based on content or other criteria
- Publishing data to interested subscribers, which may trigger a new business process or allow a running process to continue
- Execution of one or more B2B protocols

- Starting a business process
- Performing operations on SQL (Structured Query Language) database tables or Blockchain Information Systems
- Enabling human interactions within an otherwise automated process

Some example of business process engines are IBM Sterling B2B Integrator, Camunda Business Process Engine, Pega Platform or Red Hat Process Automation Manager.

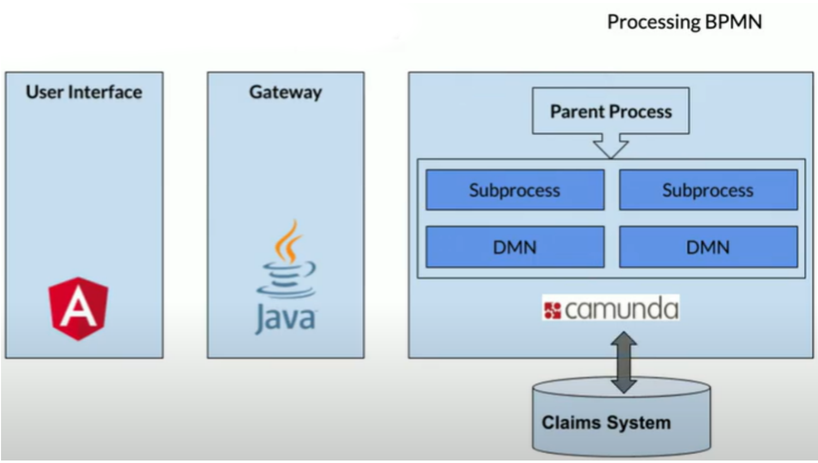

Figure 2: *Application Task stack Camunda for Modern Web Applicationsn as proposed by the Camunda Team*

3 Definition of the proposal and methodologies to use to execute the Thesis objectives

On figure 4, the technological stack and stages of systems integration for traditional IoT application, which can also include robots, can be visualized.

Physical	Selecting equipment based on dimensioning for mechanical size, load, and stress
	Mechanical interfacing (locations, adapter plates, etc.)
	Electrical power supply (voltages and currents for robots, effectors, feeders, etc.)
	Connections for analog signals (shielding, scaling, currents, binary levels, etc.)
	Safety design and risk assessment
Communication	Interconnections for single-bit digital I/O
	Byte-wise data communication, including latencies and bit rates
	Transfer of byte sequences
Configuration	Configuration of messages between interacting devices
	Establishment of services
	Tuning for performance and resource utilization
Application	Definition of application-level functions/ services
Task	Application programming, using the application-level services

Figure 3: *Technological Stack*

Development on application and task-level is the objective of this thesis since it aims at the development of Business Processes' level. However, application level development is also necessary, namely to interact with the blockchain information system, obtain relevant data from the robots and create a user interface.

The chosen blockchain system for the deployment of the Information System was EOS. Zero fees and very fast transactions, in addition to a mature blockchain ecosystem, as opposed to Ceramic Network. Also the ability to deploy smart contracts in the EOS Network, made it a choice, since it enables more freedom

4 Expected Results and Eventual Preliminary Results

The expected business processes to be developed are in the context of hospital assitance by robots.

The expected results are a working system where a robot can transmit information to a Blockchain information system through a business process engine such as Camunda on an event-based approach.

The developed business processes should be relevant in the context of pHRI in the context of Hospital Assistance.

Preliminary results:

- Business processes development on an event-based approach
- Sample Backend Services using Java or C++ for the Camunda engine
- Business processes orchestration using Camunda engine
- Transmission of information from the robot using the ROS middleware
- Front-End draft made in react or Angular

The proposed architecture is as follows:

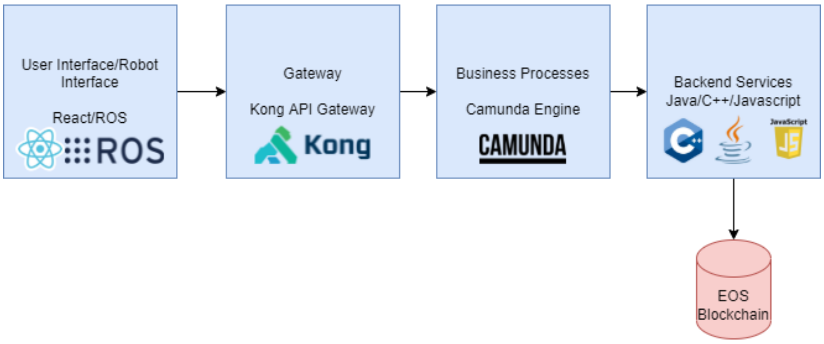

Figure 4: *Proposed architecture*

The architecture can be explained the following way;

1. UI made in react calls the business processes in the API Gateway or they are called directly from the ROS middleware
2. The Business processes are acessible through the API Gateway
3. The Business processes logic is implemented using the Camunda Engine
4. The Backend Services are implemented in C++, Java or Javascript and can be deployed microsservices architecture or single-threaded centralized event-based node.js processing

5. The backend services interact with the blockchain, which will be EOS or possibly additional blockchains

These User interface and Robot Interface interact in the same way with the services provided through the API Gateway. This way, a form of human/robot interaction through blockchain is created in a Multi-actor Information System.

One sample business proccess was already developed, which involves hospital assistance.

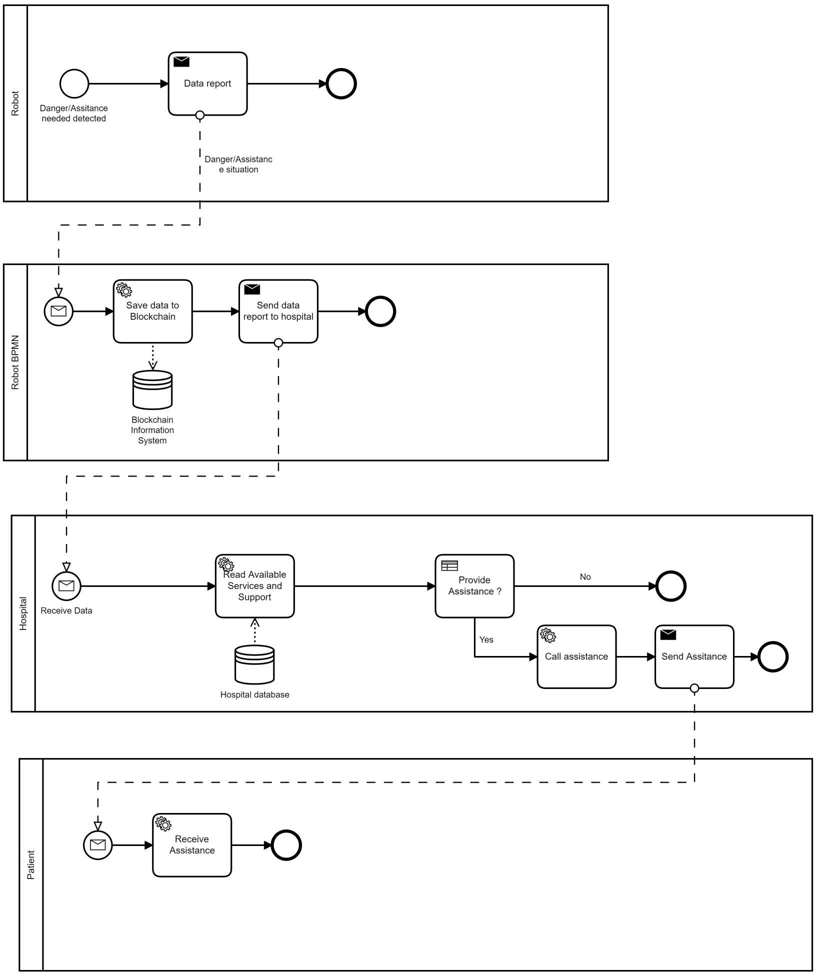

Figure 5: *Business Process draft in the Context of Hospital Assistance*

5 Planification and scheduling of the work to be developed in the Dissertation

Planification:

1. Create Business Processes that are relevant to Robots in Social Systems based on events
2. Create Backend Services which use Blockchain needed to implement those Business Processes
3. Use ROS middleware and python to call those Business Processes on an event-based approach from the robots
4. Development of a frontend to interact with the Business Processes' engine and backend services

5. Development of software for event detecting events on the robot using python and ROS middleware

6 Bibliography

Springer Handbook of Robotics

Delegated POS

Ethereum Gas fees