A cloud-based REST platform for real-time health resources availability registering, discovering and matching in pandemic crisis conditions

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***Abstract*—Resources shortage during a time of crisis is a typical but also dangerous situation that health systems need to mitigate. When the health crisis reaches a global level, this shortage becomes more critical and spans across all related resource categories and types (materials, equipment, personnel etc). The aim of this work is to present an online flexible platform, based on a combination of REST API and messaging technologies, that targets at offering a mechanism for swift registration of resource types across affected entities, government or private institutions, individual or corporate donors and volunteers. A full range of functionalities is presented, including dynamic submission of resource availability or demand, matchmaking based on criteria, investigation of supply or demand status, asynchronous alerting, general overview of the situation as well as analytics capabilities. Thus either centralized government coordination or individual corporate or volunteer efforts can be redirected and optimize the distribution and usage of resources.**

Keywords—cloud computing, resource management, service platform, resource discovery, health systems

I. Introduction

A. *Motivation*

In times of crisis, like the recent Covid-19 pandemic, one of the main challenges faced by health authorities, institutions and government agencies is the timely and efficient handling of resources needed for dealing with the effects of the crisis[1]. Chaotic situations, unexpected peaks in demand for specific material as well as globalized supply chains, disrupted by the effects of the pandemic in one part of the chain, result in heavy shortages in equipment and material. Links between this shortage and mortality rates have already started to be investigated and substantiated([12,13]). Furthermore, over-exposure of medical and other key personnel to the handled disease also affects the availability of the latter, rendering health systems vulnerable and unable to meet the unusually high expectations. Effects on medical personnel may include unavailability due to contagion, burnout or even extreme psychological fatigue[2].

Other cases of critical resources may include data that are needed in search for a cure, such as clinical data, research data, information on medical protocols etc which could be distributed among collaborating facilities and aid in the faster research and testing for new drugs and vaccines. Even though the full scope of data sharing includes a wide list or requirements for meeting legal and ethical concerns (e.g. as discussed in [3]) which goes beyond the scope of this work, initial discovery between potential collaborators is a first step towards the right direction.

On the other side, the effects of the pandemic have mobilized a large part of society, including small and large corporations and individuals, regarding contributing to the common mitigation effort through donating abundant resources or personal skills, changing the production lines towards needed material creation etc. Proper and timely coordination of activities and resources is of paramount importance in such a context ([4,5,6]), so that local or remote redundancies per resource type can be redistributed[7], material demands discovered and concentrated, private or corporate donations or abilities directed towards the elements in greater need.

B. *Platform Scope and Impact*

The aim of this work is to present a flexible, service oriented platform that enables the registration, documentation, presentation and discovery of different types and categories of materials needed for the mitigation of the pandemic effects. Matchmaking between user requests and available supplies can be performed (including radius of interest) again through REST API based functionalities. Thus the proposed framework enables:

- Registration of various stakeholders in one central registry and thus ability to discover and connect with one another (government authorities, private companies, health institutions, volunteers etc)
- Coordinating entities (such as government organizations, health authorities etc) to overview and assess the current resource situation across an area, identifying localities in abundance or shortage of a given resource type
- Participating entities (health institutions, hospitals, commercial providers) to submit their demand or supply availability per category and resource type and find a match
- Participating entities such as donors, volunteers or manufacturers to investigate what are the current needs of a country, region or city and thus select a priori the type of donated material or skill that fits best
- Donors or manufacturers to gain visibility of their actions (and according positive publicity) through the

incorporation in a central Donor Leaders Scoreboard per resource type and category, creating gamification conditions that are expected to boost the donation process

- The aforementioned interactions can be performed synchronously (via the exposed REST API) or asynchronously (by enabling a similar setup of a backend messaging system), so that notifications regarding new supplies or demands can be sent at the time of issuing

The paper proceeds as follows. In Section II related work is presented, while in Section III the main overview of the platform is given. Section IV describes the main functionalities and platform process while Section V concludes the paper. It is necessary to stress that the framework at this time targets primarily for awareness and mutual discovery between the involved parties and does not support the direct implementation of the transaction. Parties are expected to engage on their own in a bilateral communication in order to actually conclude resource transfer. Such related aspects are identified as future work in the Conclusions section, primarily through the extension of the framework with blockchain and smart contracts.

II. Related Work

Since COVID-19 appeared early this year numerous works have been developed in order to help health care systems and personnel facing critical supplies shortage. The proposed methods range from updated medical protocols to new manufacturing techniques or purely technological solutions. Following, a number of these approaches are presented, given that they can either be directly comparable to our case (the technology based ones) or can offer insights as to what types of services and facilities should be offered as categories through our platform.

One approach to address the problem of critical shortage of supply chain for Personal and Protective Equipment (PPE) was to focus on methods for reprocessing PPE[1]. The main issue is that most PPE is one-time use only, which makes reprocessing rather difficult. Techniques involve chemical methods such as usage of vaporised hydrogen peroxide (VHP) and UV irradiation technologies for sterilization. Another approach was through the evaluation of distributed digital manufacturing via Open-Source Hardware[6]. It was discovered that most medical products at some point had an open source development, although, only a small portion(~15%) of the technologies that make the open source device possible are freely available. This is an indication that categories of offered services should also include specific facilities (e.g. PPE reprocessing, 3d printing capabilities etc.) and/or that offered patents or open source designs can also be types of offered resources.

When critical supplies are simply not enough, scoring systems and prioritization of cases has already started to gain attention in the medical world[14], adapting to the conditions of a pandemic. The latter approach can also serve as a baseline for deciding to which entities the offered material from an online platform should be redirected in order to have the maximum effect.

From the technology domain, the benefits of using a flexible, service oriented solution have been substantiated even before the pandemic. Creating a cloud based information sharing platform with accurate and timely data increases a hospital's awareness and responsiveness to material needs. As a result inventory costs, supply costs and supply shortages are reduced, as well as proper patient treatment[8]. Linking supply chain management systems through integrated service based solutions has gained ground in the recent past[15], especially when dealing and interacting with established IoT management systems. However, when the typical supply chains fail, as in the case of a pandemic, then new sources of material need to be found and dynamically joined. Enabling external entities such as donators or new suppliers can prove beneficial in this case, as supported by the presented platform in this work.

Service based frameworks have also emerged in the ehealth domain (or beyond) for distributed discovery and sharing of resources (e.g. [16] for genomic data, [17] for genomic service workflows, [19] for recycling), based on REST APIs, authentication, as well as specific queries enablement. However typically these solutions are adapted to a given domain and problem, thus more difficult to become agile in order to cover more cases of materials or generic dynamic processes, including for example resource availability from crowdsourcing. Other cases involve the usage of services and Node-RED specifically in order to create applications for monitoring of patients and investigating the usage of predictors in the Covid case and beyond[18].

In conclusion, by creating a flexible and agile REST platform for information sharing on medical supplies and donations the critical resource shortage can be handled more efficiently and, given the flexibility, more material (or wider resource categories) sources can be discovered to optimize the procedure. Even though the full automation of the solution would require also linking with existing inventory systems, the presented platform's ability to easily accept such information through REST interfaces can alleviate much of the burden of such an integration.

III. Platform Architecture

A. Platform Overview

The platform overview appears in Fig. 1, including the main actors, functionalities and building blocks. As mentioned in the Introduction, a number of different actors/entities are expected to interact with the platform, including government and health agencies, typical commercial entities and donors. The functionalities are all implemented via a REST API so that they can be easily incorporated in existing applications, platforms, inventory systems or interfaces. Alongside the service oriented interface, a UI layer has also been implemented as a prototype interface for the high level interaction with the stakeholders. For the future, extensions to these interfaces (e.g. mobile apps) are foreseen. The main building blocks of the platform involve authentication mechanisms, analytics queries towards the backend database, matchmaking rationale, donor score-boarding as well as automated setup of the messaging system in order to enable asynchronous notification of stakeholders in the case of submission of requests a posteriori of their demand request.

B. Technologies Used

The overall solution is implemented in Node-RED, an event driven application development framework based on node.js. Node-RED is very flexible in terms of code development, while enabling a flow programming style that eases development especially in highly complex and fragmented environments. Furthermore, it supports a multitude of clients for integrating with a large variety of known systems. The overall REST API that implements the system was developed in Node-RED, as well as supporting functionalities such as database manipulation and integration, UI elements and the integration with the messaging system. The messaging system itself is based on RabbitMQ, a mature and extensively adopted open source AMQP protocol based implementation, that has also been used in distributed monitoring functionalities (e.g. in [9]). Reverse geolocation is performed via usage of the Google Geocoding API. The overall framework is launched from the Google Compute Engine Cloud.

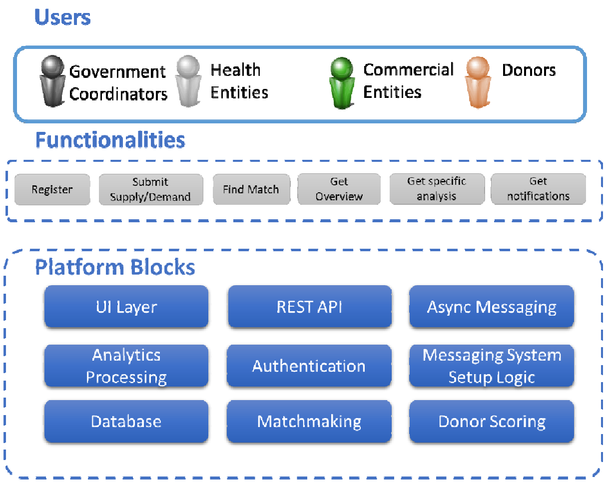

Fig. 1: Platform Overview

C. REST API Implementation

The aforementioned API implementation includes overall 13 methods that offer the main or supporting functionalities of the platform. An indicative screenshot of its implementation in the Node-RED framework appears in Fig. 2. The flow based programming style as well as the abstraction achieved by this framework enables the rapid development of APIs as well as their supporting backend logic. Reuse of programming logic is substantially enhanced.

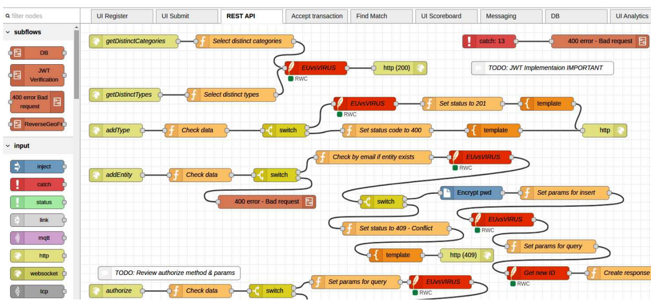

Fig. 2: REST API example implementation in Node-RED

D. Data Model

The overall data model consists of only 5 tables in the backend database (one for entities details, one for supplies, one for demands, one for categories and types incorporation and one for donors scoring). With relation to resource types distinction, two levels of annotations have been defined. One based on the generic category (e.g. human resources, facilities, equipment, materials) and one on the specific items per category (e.g. doctors, nurses, respirators, masks, intensive care units, 3d printing facilities etc.). We acknowledge that this is a simplistic approach and for the future more elaborate and standardized approaches should be followed for categorizations and products.

During the design of the data model, specific considerations were applied in order to reduce the size of the database and enhance the scalability of the solution. In such a context, it was decided that the designed platform is not anticipated to behave like a typical inventory system (thus having multiple rows per entity for all the performed transactions) but only as a surplus or shortage documentation platform. Based on this rationale, each entity can have only one entry in the supply or demand table per category and type of resource (unique key being the combination of entity ID, resource category and resource material). Thus with every call made towards the platform, the respective quantity of this combination (entity ID, resource category and resource material) is only updated (inserted only at the first call made for this category, type and entity). If the call is made for finding resources, this row is stored in the Demands table and matchmaking is performed against the Supplies table and vice versa. This enables keeping the database size small and flexible.

In the entities table, details about each entity such as location, contact points, tokens etc are maintained while the categories table includes the enumerated categories and types of resources that can be extended without affecting the remaining implementation that takes dynamically the distinct entries from this table. The Donor scoreboard table includes the current scoring for each contributing entity. The scoreboard rationale is that each time a donation supply is performed that extends the current number of available material offered by this entity, the respective difference is added as points for that entity.

IV. Functionalities and Process

Following, details on the main achieved functionalities as well as process steps are included per type of interaction with the platform.

A. Registration Process

All entity types need to register with the platform, thus creating their unique entity ID and entry in a respective backend entities table, and receive an authentication token in response. This is needed in order to ensure in further stages that the call made by an entity is indeed originating from that registered entity, based on the Web Token scheme (JSON Web Token IETF standard (RFC7519)). Upon registration, the entities need also to pinpoint their location through inserting their latitude and longitude coordinates (in the REST API version of Table 1) or just right clicking their location on a map in the UI (Fig. 3). Other useful information is included, such as contact points (for the follow-up actions after matchmaking).

B. Submit Supply or Demand Request and Matchmaking

Following registration, an entity can perform any of the other functionalities. For example they can submit a supply or demand request (Table 2 and Fig. 4), that needs to be accompanied by annotations of the category and type of materials/resources. These categories and types are included in a separate backend DB table, so that they can be extendible independently from other platform functionalities, and their complete available list can be retrieved via suitable REST methods.

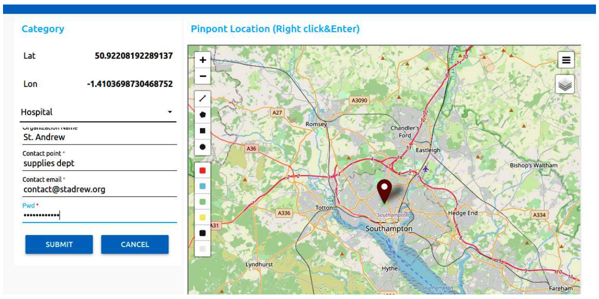

Fig. 3: Entity Registration UI

Table 1: Entity Registration Related REST API

Method Path	Type	Body	Response
/api/addEntity	POST	{name:<name>, lat:<lat>, lon:<lon>, type:<type>, contact_info:<contact_info> key:<key>, email:<email>}	201 - Created 409 - Conflict (email exists) 400 - Bad request

The entity needs also to include the quantity of the resource, whether it is needed or supplied, and whether this query is investigatory or not, through a relevant UI switch. The latter is used for cases that an entity (e.g. donor) has not decided yet the type of contributed resource and needs to examine the demand for the various cases beforehand. Therefore by annotating the request in this manner, their call is not maintained in the backend, only the sorted list (based on radius from their location) is returned (through the /findmatch API method included in Table 2). Matchmaking by radius is performed by calculating distances from the entity locations acquired from the registration process. If the call is marked as final (i.e. they have already decided and are contributing the given resource), the call is registered in the backend and populates the respective supply/demand tables (through the /submitMaterial REST call of Table 2). The list of sorted (by radius) matched counter-requests are also returned in this case, so that communications between the interested parties can initialize. A UI view of the process appears in Fig. 4, along with the defined radius and returned match based on radius, category and type of resource.

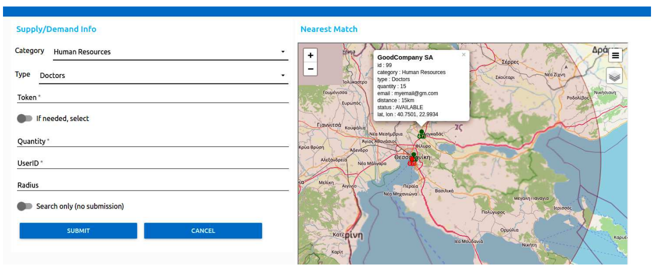

Fig. 4: Submit Supply or Demand Request (including finding match)

C. Dashboard Overview of Conditions

The main dashboard is used for an overview of the conditions across the observed area and can be used by higher level authorities (such as governments or cross border organizations like the EU and the World Health Organization). The main functionality appears in Fig. 5 and is updated in real time with the new submissions of supply and demand.

Table 2: Supply/Demand Submission Related REST API

Method Path	Type	Body	Response
/api/submitMaterial	POST	{userID:<userID> materialCategory:<materialCategory> materialSpecific:<materialSpecific> quantity:<quantity> needed:<true/false>}	200 OK
/api/findmatch	POST	{userID:<userID materialCategory:<materialCategory> materialSpecific:<materialSpecific> quantity:<quantity> needed:<true/false> radius: <radius>}	200 OK

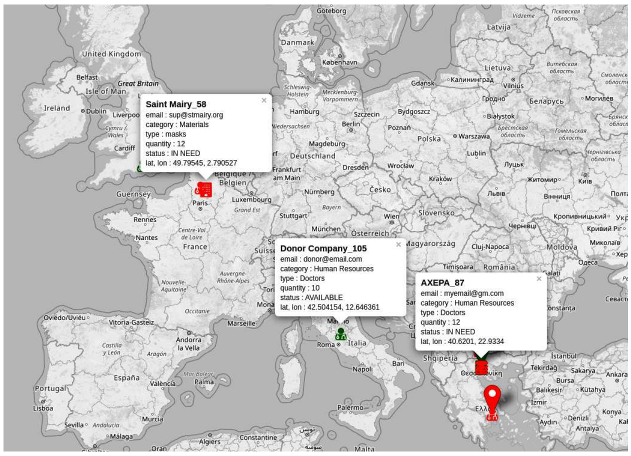

Fig. 5: Main Overview Dashboard Map

D. Analytics View Dashboard

Through the analytics functionality, one can enquire regarding the status of supply and demand for a given type and category, as well as specifically for a given entity (Table 3 and Fig. 6). Further queries will be gradually included in this functionality in order to further extend the processing cases as well as concentrated data.

E. Donor Leaders Scoreboard

The status of supplied materials can be viewed or queried via a separate functionality that enhances visibility of suppliers or donators and thus creates a healthy competition between them, according to the principles of gamification, applied in other domains (such as blood donations[11]). To achieve this, in the dashboard of the UI (Fig. 7) or the respective REST method (Table 4) the material category and type may be selected and in response the sorted by descending order entities are returned.

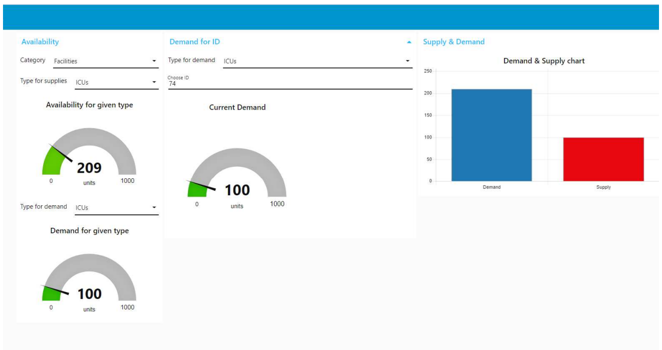

Fig. 6: Analytics View Dashboard

Table 3: Analytics Related REST API

Method Path	Type	Body	Response
/api/supplies/:type/:entityID	GET	-	Returns num of supplies for given type (optional inclusion of entity ID)
/api/demands/:type/:entityID	GET	-	Returns num of demands for given type (optional inclusion of entity ID)
/api/getDistinctCategories	GET	-	Returns all currently defined categories of resources
/api/type/:category	GET	-	Returns all types for a given category

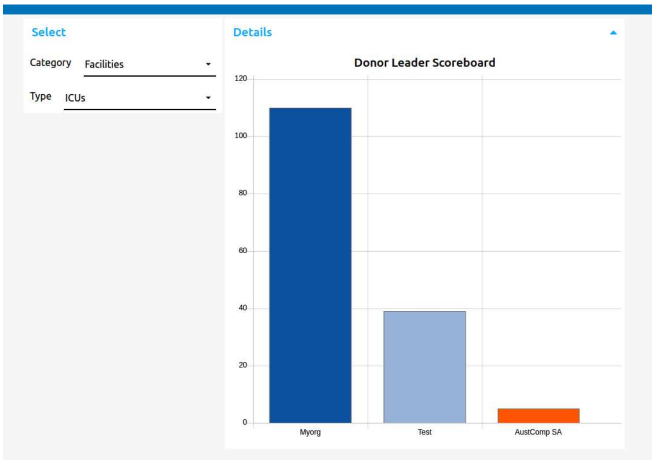

Fig. 7: Donor Leaders Scoreboard

Table 4: Donor relevant REST API

Method Path	Type	Body	Response
/api/donors/:category/:type	GET	-	Descending list of entities and according donated quantities

F. Asynchronous Notifications & Messaging

As mentioned previously, one of the main aspects is the ability to get notified on new submissions (supply or demand related) asynchronously. For this purpose, a messaging system based on RabbitMQ has been linked to the framework (Fig. 8).

Upon each registration, a relevant account/userID is created on the messaging system as well as a consuming (output) message queue per ID. The credentials of this are sent via email to the registered email account of the entity and can be used by clients to listen on the output queue. The messaging account is configured to have write access to a common central topic based exchange so that they can also publish messages regarding new supply or demand items. Topic based exchanges in the used messaging system (RabbitMQ) are input queues that enable the publishing and routing of messages annotated with metadata that can act as filters between producers and consumers of information. These filters can then be set through regular expressions, a feature which enables us to perform selective subscriptions for subgroups of information based on each entity's needs. For the cases that are investigated in the context of this work, such a filter was defined in the following manner:

Country.City.ResourceCategory.ResourceType.Needed

Through this convention one can perform flexible subscriptions based on the level of information they need (e.g. something very specific like Greece.Athens.HumanResources.Doctors.True or something more generic like Greece.*.*.* to get all related information) and get only notifications whose metadata satisfy this filter.

Upon submission of a (demand or supply) REST request, this request is also forwarded to the central messaging exchange, after being annotated with the relevant tags, to be directed towards potential consumers registered in this exchange. Category and type of resource are included in the initial request while country and city are extracted from the entity's location through reverse geocoding (via the respective Google API). Furthermore, a relevant binding (link between this entity's consuming queue and the central input exchange) is performed for the specific elements in the request, but for the reverse situation (e.g. if a supplier for cases of demands, if a requester for cases of donations or volunteers). This way if in the future according messages arrive, then this entity can directly and in real-time receive this information by listening on its consuming queue. This binding may be performed also during the find match operation (following a relevant UI switch) in order to cover for cases in which the entities have not yet published their request or offering and need to investigate the current state in an asynchronous fashion.

This setup enables other dynamic types of subscriptions (although not directly linked with the aforementioned REST calls at the moment), for example listen on all types of demands in a city (Greece.Athens.*.*.True), or listen for all types of demands of respirators in Italy (Italy.*.Materials.Respirators.True). One of the benefits of this approach, when it comes to individual volunteers is that it can more easily and flexibly direct them towards a given area of expertise or location.

V. CONCLUSIONS

Concluding, the challenge of managing scarce resources in times of crisis is very significant for a variety of organizations such as governments, health institutions and other organizational stakeholders. Furthermore, the timely investigation of needed material, also based on their geographical distribution, is key for other stakeholders such as private corporations or individuals that want to donate their skills or resources. Thus suitable coordination of all the aforementioned entities is needed as well as cross-organizational information sharing and notification.

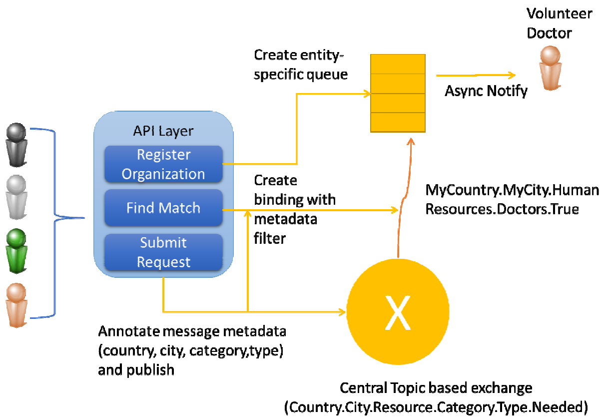

Fig. 8: Link between REST API and Messaging System

The presented framework enables this registration and discovery through its flexible, REST oriented API, empowering the involved entities to interact in real time with the system and between them. Furthermore, this way of offering the functionalities enables the swift and easy integration into existing systems as well as the extension to new interfaces like mobile applications. The framework itself offers a number of functionalities, including registration, authenticated supply/demand request submission, match making as well as asynchronous notifications for new submissions based on the entity's interests and focus points. This enables a dynamic ecosystem in which suppliers and requesters of material can interact and discover each other, even in the harsh conditions of a pandemic. Furthermore, given that at any time the definition of resource categories and types is decoupled from the remaining framework, reassigning these values can make the platform reusable in a different context.

For the future, one of the main extension points includes the ability to actually perform the transaction between discovered entities. Even though in many cases this may involve resource sharing between government organizations (e.g. exchange of material), this action should be documented and accounted for, given the typically strict requirements for accountability of resource management in the public sector. This functionality is anticipated to be included by the integration with a blockchain technology supporting smart contracts (e.g.[10]), in which suitable contract templates may be created for different types of transactions between the platform entities. This will also ensure the validity of the offered resources by donors, as well as the finalization of ownership transfer of the specific resource towards the receiving entity. Another point of extension refers to the application of machine learning approaches that can aid in the matching between supply and demand at a larger scale as well as dockerization of the implementation.

VI. Supplementary Material

The open source code and API reference of the implementation can be found in [20]. A video demonstration can be found in [21].

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