carpETHii Group Report

BETH Blockchain for Sustainability Hackathon
ETH Zurich Lecture 851-0591-01L
February 2019

Dhaouadi Wassim	*<dwassim@ethz.ch>*
Frey Marc-Philippe	*<marfrey@ethz.ch>*
Michalec Vladimir	*<vmichale@ethz.ch>*
Weinold Michael	*<mweinold@ethz.ch>*
Zweig Yoel	*<zweigy@ethz.ch>*

All members contributed equally to this report.

Contents

1 Introduction

This report documents the solution our team "carpETHii" developed during the BETH Blockchain for Sustainability 2019 hackathon. Our solution addresses the WWF challenge of creating an ecosystem platform that sustainably aligns nature and socio-economical development interests. Two WWF supported bison rewilding sites in the Carpathian mountains in Romania are studied as a pioneer implementation of this concept.

1.1 The Bison Challenge Context

By the start of the 20th century, the European Bison (*Bison Bonasus*) had been hunted to effective extinction all over Europe [1], including the Carpathian Mountains in Romania. Bisons, however, are imperative to the well-being of ecosystems through their ability to act as landscape architects and as an indicator species [2]. Their behavior assists in the inter-connectivity of the landscape, facilitating the movement of other species, while also maintaining the fragile balance between the areas of open and forested pastures [3]. Furthermore, their movement also opens up the soil underneath, assisting in the fertilization of indigenous plant species. Consequently, WWF, in conjuncture with Wildlife Romania, have begun introducing the European Bison at two reintroduction sites in the Carpathian mountains with the hope of reestablishing the balance in the local ecosystem.

The success of the project is strongly dependent on an effective collaboration between the local community and the responsible NGOs. Currently, the affected communities in the Carpathian mountains have no stake in ensuring that their ecosystem is healthy and protected. Instead, many rely on illegal activities such as logging or wildlife trade in an attempt to supplement their incomes at the expense of the preservation of the ecosystem [4]. Moreover, local governance and the use of resources is concentrated amongst the community members with the most political power and are often shaped by short term opportunities. As a result, the resource allocation in the area is inefficient and unsustainable in the long run [2].

In order to strive towards socially and economically sustainable wildlife preservation activities, WWF has commissioned the development of an application that aims to solve some of the aforementioned difficulties. The application should create an independent and transparent ecosystem, where preservation measurements and impact metrics are used to fund local social developmental goals, with the purpose of aligning the goals of investors, the NGOs and the local communities. Furthermore, a tamper-proof, traceable and community driven system for fund allocation should be implemented in order to create trust and value amongst the communities. Finally, the applications should attempt to enable a sustainable and self-regulating trade-off between the conservation of the natural resources and the development of the local community.

1.2 The Potential of Blockchain Technology

Although blockchain has received a lot of media coverage as the underlying technology behind Bitcoin, the technology allows for many additional use cases that are unrelated to crypto assets. In particular, blockchain has the potential to be used effectively in the context of the WWF challenge introduced above.

Blockchain technology is a decentralized database that eliminates the need of trusted intermediaries, allowing the secure transfer of assets or information over the internet [5]. Instead of relying on a third-party verification (such as banks), blockchain uses a distributed consensus mechanism that relies on monetary incentives (in the form of crypto assets) given to participating members of the network in order to verify transactions [6]. Once a transaction is verified, it is executed and recorded on a 'tamper-resistant database' that can be accessed on demand, either publicly or privately [7]. Additionally, the main benefits of the blockchain technology can be described as [7]:

- A database that records completed transactions and is distributed among all members of the network.
- A verification mechanism that validates transactions based on the consensus of participating members.
- A tamper-proof transaction history that records the participating members of the transaction, its purpose and its unique timestamp.
- A platform where smart contracts can be used to trigger monetary transactions automatically, eliminating the need for an 'overseeing' party.

The usage of blockchain is able to solve a few of the difficulties encountered by WWF. First of all, by introducing a private, decentralized network that determines the allocation of resources based on a community consensus, and not the desire of the individuals that hold the most political power, corruption within the community can be reduced. This also allows for more efficient and sustainable allocation of resources based on actual community needs. Secondly, the immutability of the records ensures a high level of security and transparency - ideal properties for a reliable local governance system. Community members can hold one another accountable for certain actions, and can improve their own standing within the community by performing tasks that are beneficial to the preservation activities. Finally, the usage of smart contacts in the blockchain, ones that cannot be tampered with, allow the community to predefine important preservation tasks and to couple the release of monetary incentives to the completion of such tasks. This features allows to reward engaged community members as a recognition of their involvement.

The aforementioned problem of decentralized governance has been discussed extensively in literature. A recent example is the case of Backfeed. Backfeed is platform that aims to promote decentralized cooperation within a community. It attempts to address the issue of creating trust within a community when the sharing of resources and assets is involved (as opposed to solely tokens of monetary value) [8]. In the Backfeed ecosystem, agents can define tasks and contribute independently to their communities' goals. Instead of using a conventional consensus mechanism such as Proof-of-Work (as used in Bitcoin), Backfeed proposes a Proof-of-Value consensus mechanisms. This is a peer-to-peer evaluation method that allows community members to determine the effective value created by other agents. Furthermore, the introduction of a reputational score within the community enables the platform to allocate importance to members whose beneficial contributions align best with the ideals of the overall community [8].

When a community member completes a task, or contributes to the goals of the community, the value created is evaluated by the other members. If the contribution is evaluated positively, the member receives a monetary reward as well as an increase in reputational score, which will then increase their standing within the community [6]. The reputational score of the members can only be increased through successful completion of tasks or evaluations of other contributions, and can only be issued when the community reaches a consensus [8]. Due to the nature of the challenge the WWF faces with the local communities in the Carpathian Mountains, some of the aforementioned principles in decentralized governance were adapted to fit our specific challenge and included in the final solution.

1.3 Implementation of Blockchain in the Context of the Challenge

The proposed solution will be introduced and explained in Section 2 of this report. In essence, through the introduction of a direct cash token, an involvement-based voting token and a performance function that measures the state of the system, a blockchain solution for the challenges faced by the WWF was created. Section 3 of this report analyses the state of the implementation of the solution while Section 4 addresses the implementation of IoT sensors in our concept. Finally, our proposed solution will be evaluated and discussed in Section 5 of this report.

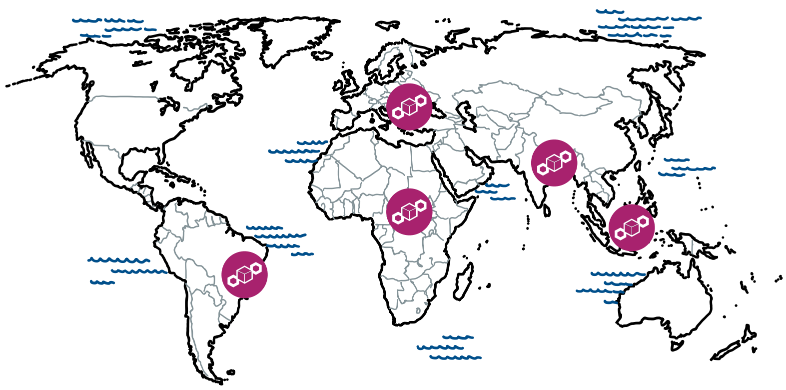

Figure 1: World map showing locations of different conversational projects that all utilize blockchain technology. Map adapted from [9].

2 Concept

In this section, the main concept is presented using two drawings in Figure 2.1 and Figure 2.2. The drawings represent the conceptual work behind the solution, and will be used to explain the concept chronologically. First, the general architecture of the solution will be presented, before going into further detail on the performance function. Finally, open questions concerning the concept are considered and discussed

2.1 Concept Overview Diagram

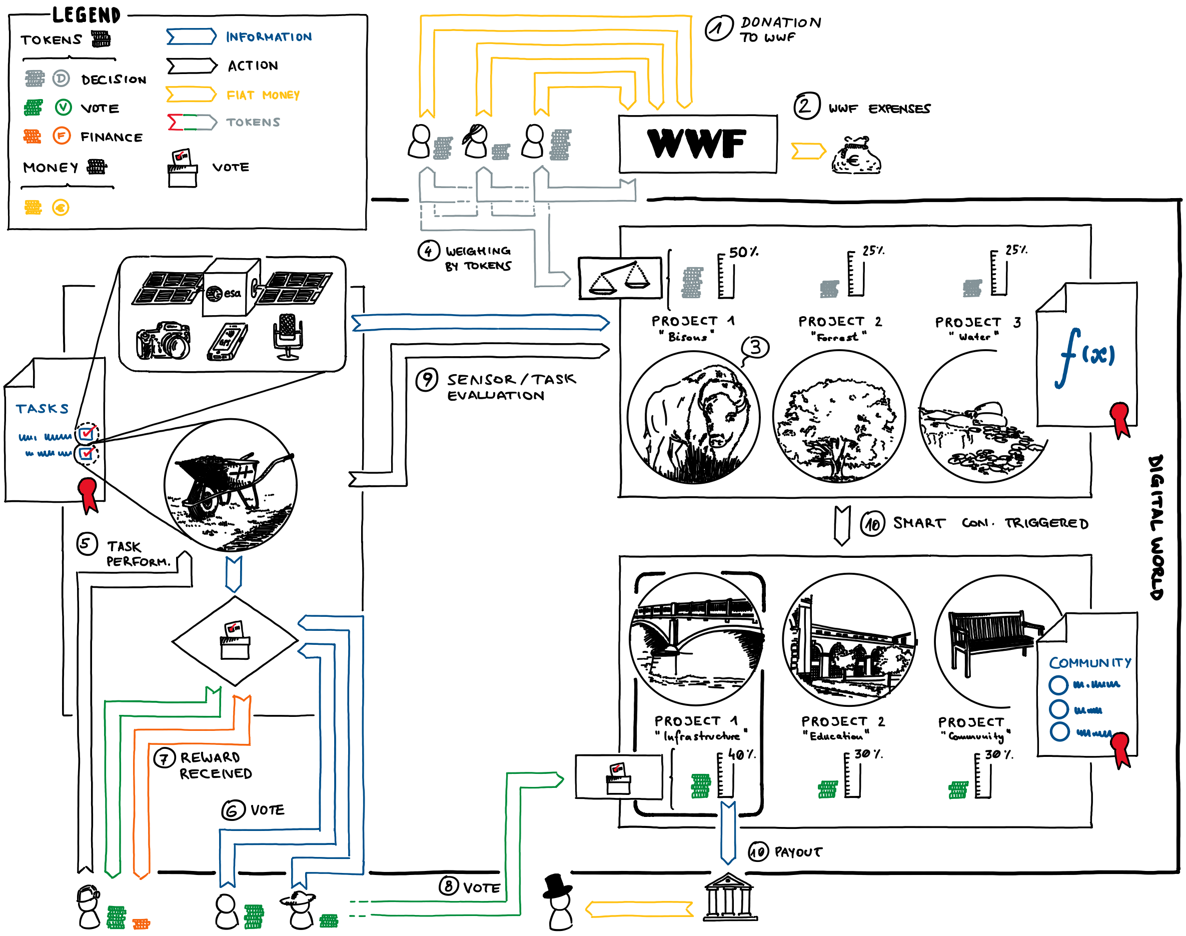

Figure 2: Concept drawing of the incentivising system. Arrows indicate actions or transmission of information, according to color shown in the legend. The performance function is enlarged and annotated in greater detail in Figure 2.2. The annotations are explained in greater detail in Table 1 below.
Drawing by Michael Weinold [10].

#	Step	Description
1	Donation to WWF	Stakeholders donate money to WWF and receive a **Decision Token** in return.
2	WWF Expenses	WWF splits the money into two pots. One is used to cover the expenses of WWF's activities including bison transportation, set-up of sensors, etc. The remaining money is combined into a community pot on Blockchain.
3	Indicators	The overall state of the ecosystem is measured through performance indicators such as the number of bison or the level of deforestation.
4	Weighing by Tokens	The Stakeholders distribute their **tokens** to the projects that interest them the most, creating a weighting for the key performance indicators.
5	Tasks Performed	Community members can register for a given task and complete it. Once the task is completed, there are two ways to verify it. Some tasks are sensor related, others required community validation. Tasks that allow automatic verification, such as through GPS data, get verified automatically.
6	Vote	Alternatively, the community votes on the task completion to verify it.
7	Reward Received	Through the completion of the task, the community member receives a **Voting Token** and a **Finance Token**. The **Finance Token** is a cash alternative that is redeemed with WWF directly.
8	Vote	The **Voting Token** is used by the community member to cast their vote towards a community project they would like to have realized (**tokens** can only be used once)
9	Sensor/Task Evaluation	At regular intervals, sensor and task information are used to determine the health of the state of the environment through a smart contract. The details are explained on the next slide.
10	Payout	The determination of the state then triggers the Smart Contract that releases the funds to the most voted community project.

Table 1: Description of steps annotated in the concept drawing in Figure 2.1.

2.2 Performance Function Diagram

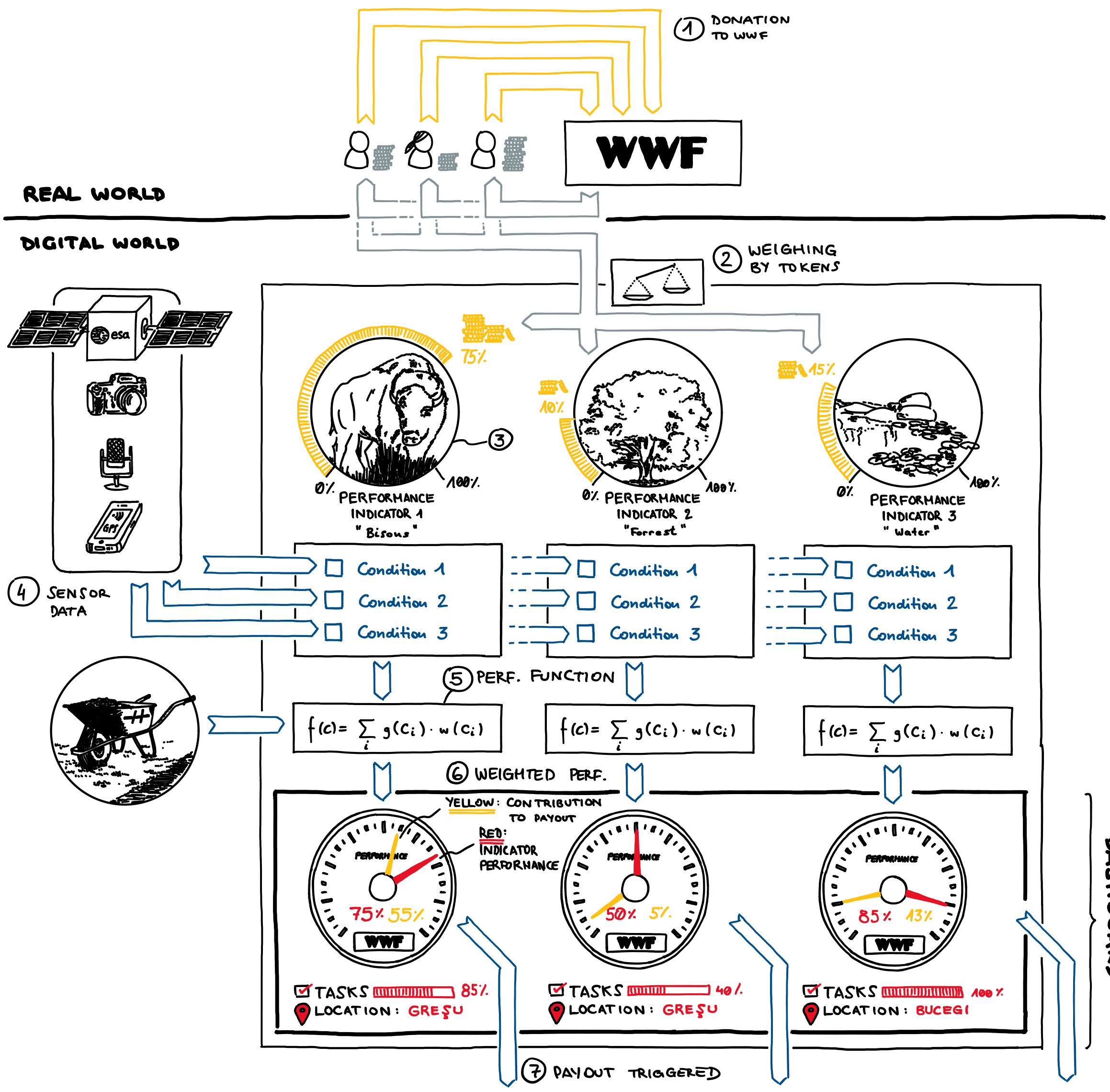

Figure 3: Concept drawing of the performance function, embedded in the overall concept shown in Figure 2.1. The annotations are explained in greater detail in Table 2 below. The icons and arrows utilize the legend of Figure 2.1. Drawing by Michael Weinold [11].

#	Step	Description
1	Donation to WWF	Stakeholders donate money to WWF and receive **Decision Tokens** in return.
2	Weighing by Tokens	Investors allocate the **Decision Tokens** to their desired performance indicator. These votes will then be used as a weighting mechanism for final pay-out of the allocated donations.
3	Indicators	The overall state of the ecosystem is measured through performance indicators such as the number of bison or the level of deforestation.
4	Sensor Data	Using sensor data, the 'health' of the performance indicators is evaluated against a predefined baseline. This is shown in red on the performance dial.
5	Performance Function	The performance function inside the smart contract uses the 'health' of the indicator, the number of tasks completed by the community, and the weighting assigned by the stakeholders.
6	Weighted Performance	The result is the weighted contribution to the final state of the indicators. This is shown in yellow on the performance dial.
7	Payout Triggered	This weighted performance determines the pay-out though the smart contract shown on the overview slide.

Table 2: Description of steps annotated in the concept drawing in Figure 2.2.

2.3 Further Thoughts on Project Payouts

The voting procedure determining which project is paid out might lead to a large disbalance in investments between communities. One can expect that one geographic community shows little or no interest in seeing financial investments benefit another geographical community. While this may hamper the eagerness of small communities to perform tasks, it could also lead to a healthy level of competition between not only individuals, but also whole communities. We have thus identified two voting procedures that each try to mediate the shortcomings of the other.

In our *"winner takes it all"* method, only one project is selected, based on the total number of votes by community members. Payout, considering ecosystem indicator health, goes to this project only, increasing local impact of donated money. While larger settlements do not necessarily have to hold more voting tokens, they are more easily accumulated there. Adverse effects on smaller communities might occur, potentially reducing the number of communities willing to participate in tasks.
The *"weighted payout"* method on the other hand allows for a broader distribution of investments. Money is paid out not only to the project with the most votes, but allocated to other projects as well. This comes at the cost of reduced impact due to the larger number of projects receiving funds. Here, funding may not be enough to realize projects large enough to attract the attention of community members.

2.4 Further Thoughts on Verification

As a successfully performed task not only entails voting rights, but also monetary rewards, the verification of such tasks is especially challenging. While some tasks can be verified by independent sensor data, this approach is limited by the sheer complexity of the necessary algorithms and the cost of manpower. This leaves most of the verification up to other community members. In the worst case scenario, all community members always "collude" to minimize their effort and maximize their payout. To prevent similar situations, a point based trust system is used. Completed tasks lead to accumulation of trust points. Completion of extraordinary tasks leads to accumulation of "medals". These community member attributes are all input parameters of the weighting function, together with the geographical location of the individual. The exact implementation of the function will largely depend on the quality of submissions and the reliability of verifications.

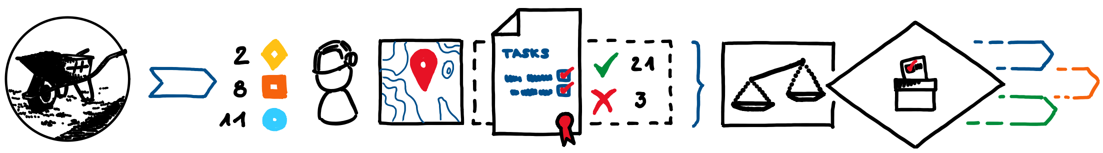

Figure 4: Concept drawing of the weighting mechanisms used for reliability ranking of community members. The icons and arrows utilize the legend of Figure 2.1.

3 Implementation

In this section, the implementation and all technical details of our solution are laid out, using Figures 6 and 5. The installation instructions needed to run our code is given at the end of the report.

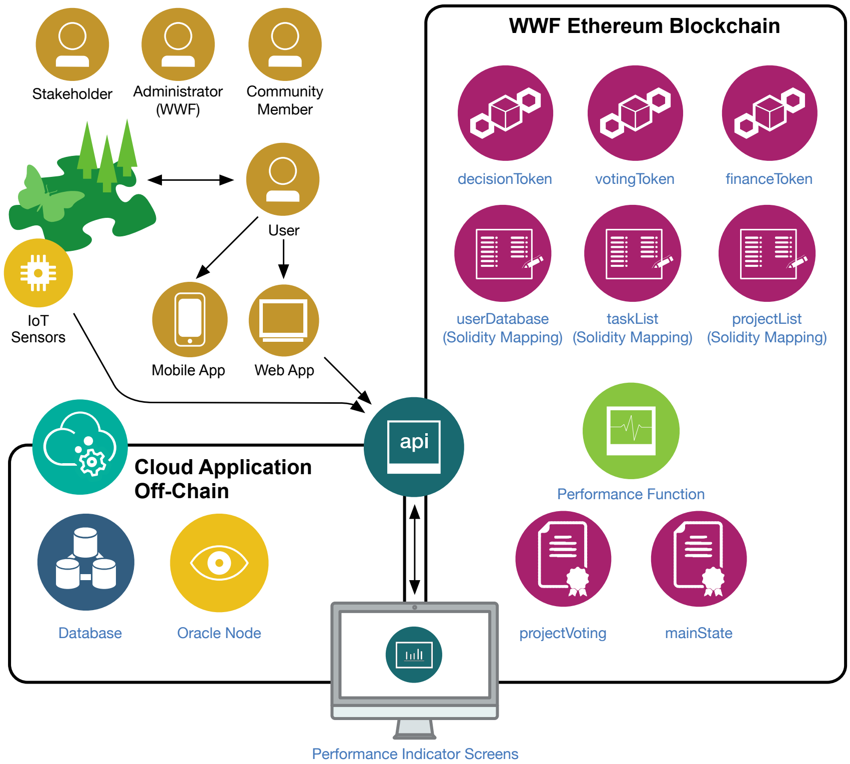

Figure 5: System architecture of our project, as laid out in this section. A more detailed diagram is shown in Figure 6.

3.1 System Design

As described in the first chapter, a blockchain based solution has a number of distinct advantages:

- It fits the non-monetary incentivization use-case very well
- It guarantees immutability of the data (corruption in the communities)
- The database is automatically distributed to blockchain nodes (WWF is active globally)

Our system uses a private blockchain network (Ethereum, in our prototype) with nodes running in WWF offices all around the world. Partners of WWF could also run blockchain nodes to increase trust even more. Since all nodes are private, it makes sense to switch to a Proof-of-Stake [12] algorithm to save computational power and therefore energy. Clients can communicate with the blockchain using a web-interface or, preferably, a mobile application which will host their wallet. In both cases, special attention needs to be paid to key generation and secure storage of the private key. The system architecture of our solution is displayed in Figure 5.

The main element is an Ethereum blockchain network consisting of following smart contracts:

- mainState – where the main logic is implemented
  - Users of the system are created and stored in this contract: stakeholders, administrators and community members
  - This contract distributes Tokens to Stakeholders and Community members
  - The task list is stored and tracked in this contract
  - The performance function of the ecosystem from Figure 2.2 is computed here with input from:
    * Subjective voting of stakeholders
    * Input from ecosystem IoT sensors
    * Tasks successfully completed by the community members
  - projectVoting – this contract stores local community projects with their ranking and status

All the objects necessary to be stored within smart contracts are stored in *Solidity* mapping objects:

- userDatabase (users of the system)
- taskList (list of tasks to be done)
- projectList (list of projects to be developed in the community)

One part of the solution is the use of an off-chain cloud-based service, which serves as:

- A database for large files (photos, files, etc.) – it is very inefficient to store large files on the blockchain. These files will be stored off-chain and only their hash will be stored on-chain to prevent tampering with the files
- An Oracle [13] for IoT sensors used to measure the state of the ecosystem – data from the sensors need to be aggregated to a meaningful number, this aggregation will not be performed on the blockchain since this is very computationally intensive.

IoT sensors will be placed in the environment to track the state of the ecosystem and also to prove that certain tasks have been completed (some tasks can be evaluated automatically).
All these system parts will communicate using API calls between each other. The sensors will talk with the off-chain oracle and only after evaluating/aggregating the data, oracle will make an API call to the blockchain.

An important part of the solution is the placement of outdoor screens in the community, which will display the state of the ecosystem, the current ranking of the to-be-implemented projects,the ranking of the top-performing community members etc. This should serve as another method of visually incentivizing community members to perform tasks and preserve the natural ecosystem.

3.2 Tokens

The solution uses standard *ERC20* tokens [14] to be exchanged between parties. These tokens are implemented as separate smart contracts according to the guidelines of *ERC20*. The following tokens are implemented:

- decisionToken – token given to the stakeholders for their support of the project, which can be used to give preference to the project implemented
- votingToken – token that users get for performing tasks and then can use to vote for community projects
- financialToken – token that represents the monetary reward for the users after task completion, can be redeemed at WWF for local currency

3.3 Smart Contracts

The smart contracts used in our solution are written in *Solidity* and meant to be deployed on a private Ethereum network (*Ganache* [15] was used for testing purposes).

The following smart contracts (*Solidity* source files) are part of the solution:

- mainState (mainState.sol) – contains implementation of the main logic
  - Users of the system are created and stored in this contract – stakeholders and community members
  - This contract distributes tokens to stakeholders and community members
  - The task list is stored and tracked in this contract
  - Ecosystem performance function is computed here with input from:
    - Subjective voting of stakeholders
    - Input from ecosystem IoT sensors

    * Tasks successfully completed by the community members

- projectVoting (projectVoting.sol) – this contract stores local community projects with their ranking and status
- CarpETHii Community Token (CETHc.sol) – a.k.a. voting token - private token that gets distributed to the community members and can be used for voting
- CarpETHii Investor Token (CETHi.sol) – a.k.a decision token - private token distributed to the investors that represent their stake in the system, it can also provide weight to the performance indicators
- EuroWWFcoin (wwefc.sol) – a.k.a finance token - private (non-volatile) token distributed to the community members that can be exchanged for currency at WWF.

These smart contracts should be deployed to the Ethereum blockchain in the following order:

- First all 3 *ERC20* contracts need to be deployed, their addresses noted down
- Then the projectVoting contract needs to be deployed, which needs the address of CETHc (Voting Token) address as a parameter
- Lastly, the mainState contract needs to be deployed, with addresses of all previously deployed contracts as parameters

3.4 IT elements for Future Implementation

The following IT parts of the proposed solution were not implemented during the hackathon because of complexity and lack of time:

- Performance function for ecosystem health computation
- Image database (and other files)
- Oracle node for sensors data aggregation
- Mobile application

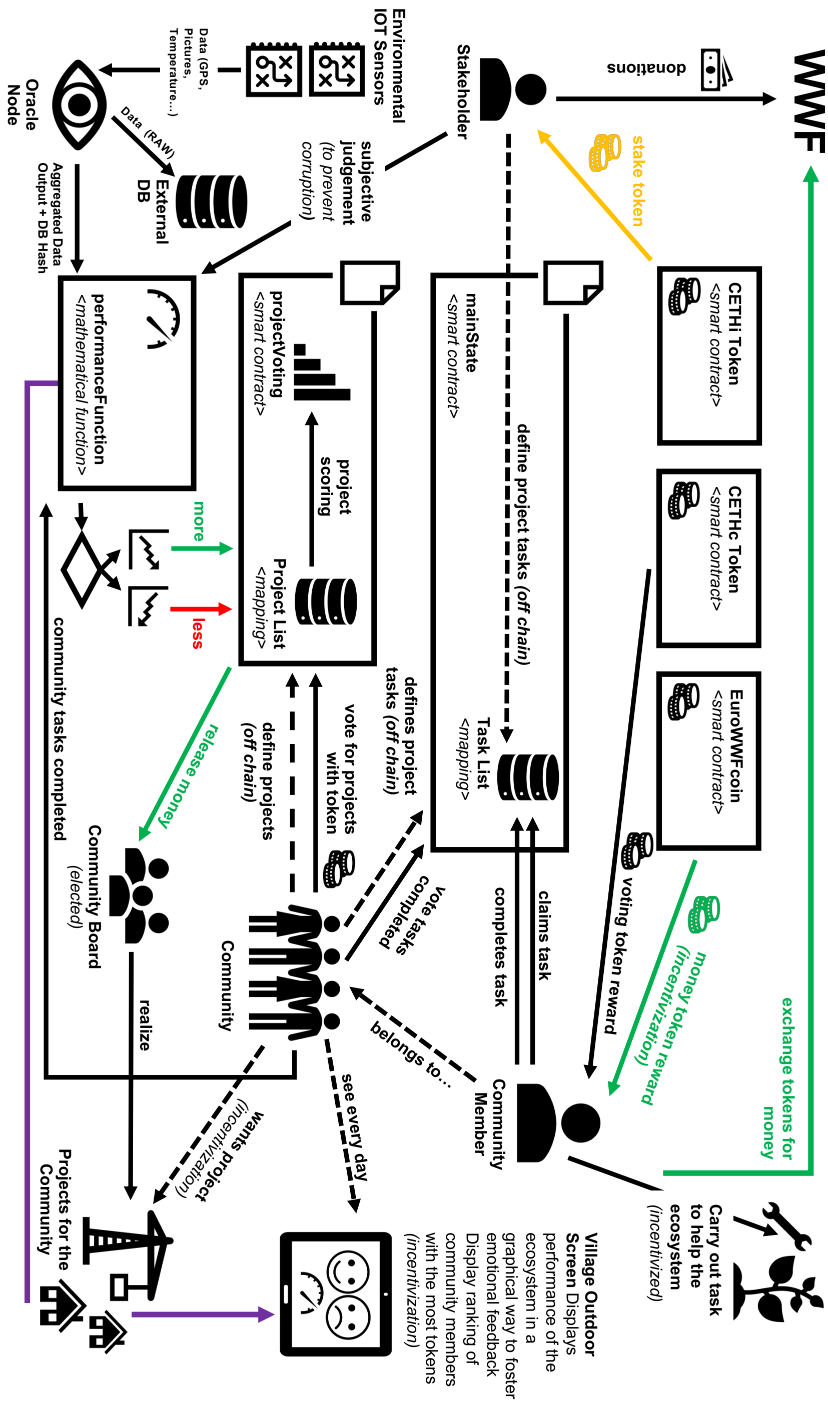

Figure 6: System architecture of our project, as laid out in the previous section. A simplified overview can be found in Figure 5.

3.5 Webpage

Design: The aim of the webpage is to offer an easy way for sponsors and local residents to access information from the Ethereum blockchain by presenting a user-friendly and intuitive interface while hiding the complexity of the underlying implementation.
Our current website (slightly extended since the hackathon) offers the following four sections: "Home", "Donor", "Data" and "Task List". The sections are not yet fully implemented, but offer an idea on how a potential webpage could be structured. Here we will quickly outline the idea behind of each of the sections:

- The "Home" section offers an overview of the WWF project. It provides general information about the Carpathian mountains, the need for strengthened preservation and motivation to participate in this effort both as a sponsor and as a local resident.
- The "Donor" section presents additional information to people interested in becoming a donor. It outlines in more detail the necessary steps to support a project and explains the level of control that a donor has over his investments. An easy interface to support a chosen project via Ethereum is offered.
- The "Data" section presents various dashboards displaying sensor measurements, project status, money collected, successful community projects and so on. The goal is to provide as much information as possible to both incentivize further participation and provide open access to relevant data.
- The "Task List" section lists all available tasks to be performed by the local community. All necessary information is provided and people can claim a task for themselves via the provided interface to gain rewards.

We use the *Iridium* HTML&CSS template by *templated.co* [16] (released for free under a Creative Commons Attribution 3.0 license) and have adapted it to our purposes, mainly changing the HTML code and adding some functionality. Using *nodejs*, we run the website on a local server on port 3000. Using HTML POST requests, we store collected information from the website on our local server. However, the server is not yet connected to the blockchain.

Extensions: Both the webpage and the server are currently very minimalistic and can be extended with more advanced functionality:

- The different sections of the webpage are mostly made of skeleton code. They would obviously need to be extended with additional functionality.
- The server needs to be able to communicate with the blockchain, calling contracts and retrieving information. Here it will be important to consider what functionality should be included on the webpage and what should be done directly by the user, as we want to keep the whole project decentralized without relying too much on a single point.

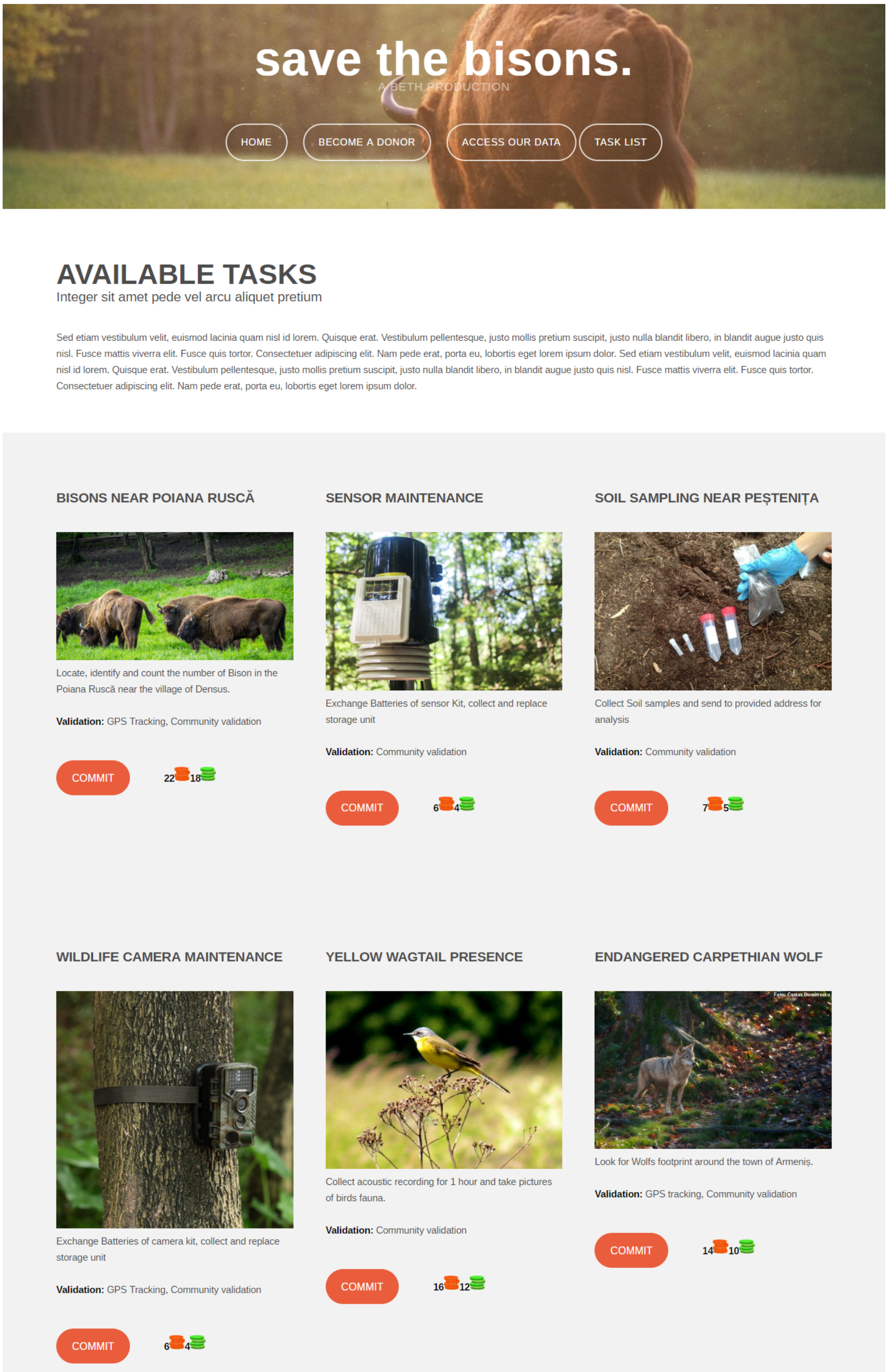

Figure 7: Task list section of the webpage, accessed from a desktop client. Different tokens are displayed next to each project, as explained in Figures 2.1 and 2.2.

4 Sensors and IoT

In this section, all sensors which are related to our concept are presented. The geofence prepared for an Arduino board is presented in greater detail. The use of satellite images for detection of deforestation is presented. Finally, other sensors whose use was only considered and conceptualized will be mentioned as well.

4.1 Geofencing for Community Tasks

One task specified by WWF is that of on-site investigation of the ecosystem. By request of a scientific expert, audio or video material is to be gathered by community members. This material can then be used to verify the presence of certain species in a specified geographic area. To ensure that audio is actually taken at the requested locations, we envisaged a geofenceing program implemented on a GNSS enabled Arduino microcontroller board.

An *Arduino UNO* board was used in combination with a *UBlox Neo 7M* GPS module connected. A GPS antenna was pre-soldered onto the module. The board was programmed with the Arduino IDE [17]. The *tinyGPS++* library was used to extract position data from the raw antenna data [18].

Because a quick sweep of the Arduino Playground [19] returned no good geofences code, a simple implementation was created. Great precision in location was neither required, nor can be guaranteed from a purely topological perspective. Underbrush and tree cover, together with a limited field of view due to mountainous terrain limit GPS accuracy [20] [21]. For this reason, the mean earth radius and horizontal distance calculations were used in the first iteration of the geofencing code. Horizontal distance d around pre-programmed target coordinates specified by a WWF expert or scientist were calculated as

$$d = \sqrt{\Delta x^2 + \Delta y^2 + \Delta z^2} \tag{1}$$

with

$$\Delta x = r_{\earth} \times 2 \tan\left(\frac{\Delta\phi}{2}\right) \tag{2}$$

$$\Delta y = r_{\earth} \times 2 \tan\left(\frac{\Delta\lambda}{2}\right) \tag{3}$$

$$\Delta z = \Delta h \tag{4}$$

with the mean earth radius $r_{\earth} \approx 6370km$ and the geographic coordinates latitude ϕ and λ in radians.

For greater precision, both geoid data for increased precision in elevation data and great-circle distance calculations would have to be implemented. For small distances, the Haversine equation greatly improves the above listed distance calculations [22]

$$d = r_{♁} \times 2 \arcsin \sqrt{\sin^2\left(\frac{\Delta\phi}{2}\right) + \cos\phi_1 \cdot \cos\phi_2 \cdot \sin^2\left(\frac{\Delta\lambda}{2}\right)} \tag{5}$$

An additional correction for deviations of the geoid from mean sea level can easily be extracted from the raw GPS data provided by the antenna. This data is encoded according to the NMEA 0183 standard [23]

```
$GPGGA,hhmmss.ss,llll.ll,a,yyyyy.yy,a,x,xx,x.x,x.x,M,x.x,M,x.x,xxxx*hh
```

where entry 11 gives the desired geoidal separation as the difference between the standard WGS-84 earth ellipsoid and mean sea level.

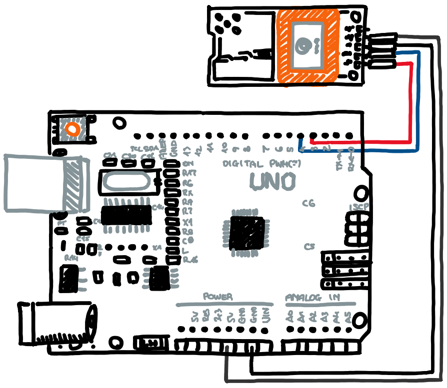

Figure 8: Concept drawing of an Arduino Uno board with a UBlox Neo 7M GPS module connected. A GPS antenna has been soldered to the module. Note, that all wired connections are shown correctly. Serial connections over digital ports have been realized using the SoftwareSerial command in the Arduino IDE [17].

These additional improvements can be implemented quickly, at a later time. Ultimately, the efficiency of the geofencing equipment will largely depend on integration of LoRaWAN or some competing long range communication standard. Because no antennas were provided during the hackathon, neither a hardware- nor a software implementation was not attempted.

4.2 Satellite imaging

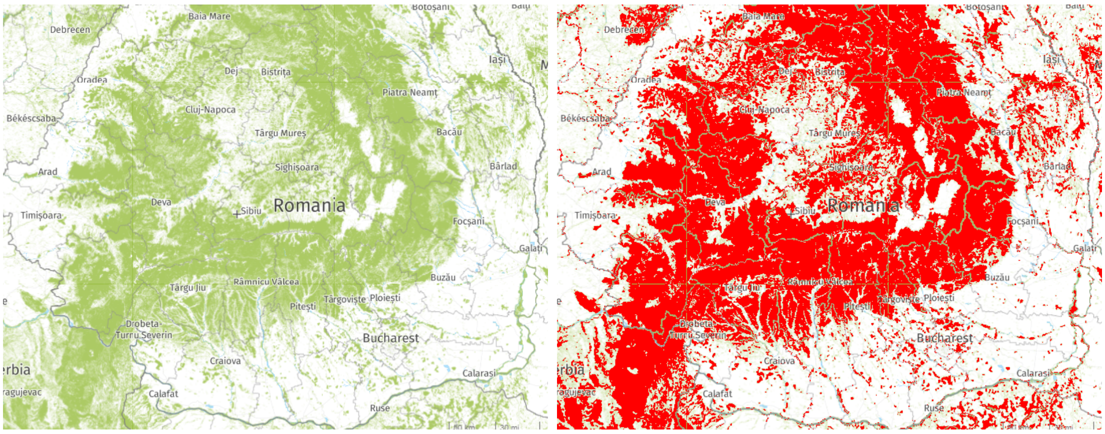

Figure 9: 2016 forest cover extracted from high resolution Landsat satellite images of the Carpathian mountains. Green color represents current vegetation cover. Red color shows the results of image segmentation analysis via color thresholding to measure forest area. Data was provided by GlobalForestWatch [24], while the analysis was done using the image analysis software ImageJ [25].

Satellite imaging is a very powerful tool to monitor the state of the ecosystem at a large scale. Ecosystem health is strongly correlated to the vegetation area since the flora represents the habitat and food stock of the fauna and it is thus crucial for the sustainable development of the bison population. The forest cover area may thus be used as a key performance indicator, as is displayed in Figure 2.2.

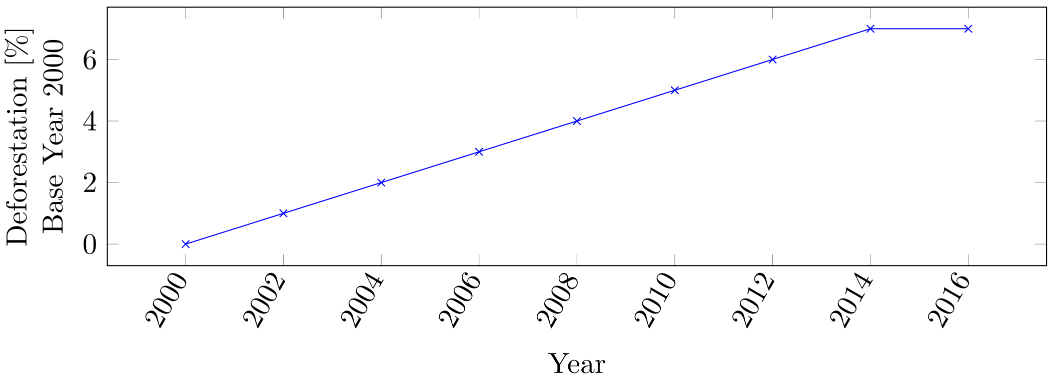

Figure 10: Forest area lost relative to year 2000 near a bison reintroduction zone.

Satellite images are freely available from a number of open sources databases, such as the Landasat archive used in Figure 4.2. The satellite sensors are able to collect the near-infrared light reflected by the chlorophyll molecules in leaves. This can be used to effectively estimate the forest cover area, as shown in Figure 4.2. We used the software

ImageJ [25] to segment the image using color thresholding and extract a measure of the covered area. The process is applied over the same geographical area with historical data from different flyovers. Figure 10 shows the forest area lost in a region near the bison reintroduction point. The loss is mainly due to legal timber exploitation.

4.3 Other IoT devices

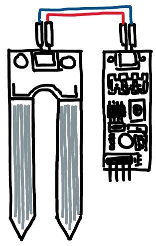

Figure 11: Concept drawing of a soil hygrometer sensor that monitors the moisture content around areas of interest [26].

Other sensors that can be used to monitor the health of the environment and feed the key performance indicators are listed below. The sensor kit may include:

- **Soil Hygrometer Sensor** : A soil humidity sensor that outputs an analog signal proportional to the moisture level. Critically low soil moisture can represent a threat to the flora development and would need an immediate countermeasures. The device is shown in Figure 11.
- **MQ-2Gas Sensor**: This sensor monitors the level of certain harmful gases like Methane and Butane and Smoke. It can be used to detect early onset of vegetation fire and prevent forest fire.
- **Rain Detector Sensor**: This sensor can be used for weather monitoring and provide data about the local pluviometry.
- **Pyroelectric Infrared Sensor**: This sensor can be used to detect the presence of animals around a specific location. It can be implemented around a water point,for example, where animals usually gather and track the general trend of frequentation.

5 Conclusion

5.1 Benefits

The system design and the use of blockchain together serve as means to solve some of the initial challenges faced by the WWF in their Bison reintroduction efforts. The main challenge our proposed solutions attempts to solve is to align the interests of the local community with those of the conservation efforts. As it stands, the local community had no stake in preserving their ecosystem, instead often relying on it to supplement their income. Through the introduction of a community pot derived from the stakeholder donations/investments, the respective communities can assist the development of their area through the completion of preservation tasks. For instance, the completion of tasks such as the maintenance of trails results in a direct monetary incentive for them and should discourage the members from participating in activities that would harm the ecosystem. Whereas with traditional conservation activities all the donations were aimed at exclusively the activities of the WWF, the introduction of community funding gives the solution the opportunity to tie the fortunes of the local community to the overall health of the ecosystem.

Furthermore, the introduction of voting tokens for the successful completion of tasks serves two purposes. First of all, it gives the community members additional incentive to complete the given tasks because they not only receive the monetary incentive, but they also receive voting power to shape the development of their community. Secondly, it redistributed the decisional power among the community members that actively contribute to the conservation efforts. When in the past these decisions would usually lie with the members that hold the most political power, this change fosters a system where merit and effort by community members results in increases influence over time. This, again, should serve as a motivator to the local stakeholders.

The creation of the performance function, as proposed in the concept, also brings with it additional benefits. First of all, it involves the stakeholders in the decisional process of weighing what system indicators are important to them. Consequently, stakeholders are involved in the process of improving the well-being of the ecosystem, hopefully giving them greater interests in the project. Secondly, it is a clear indicator of the health of the system. By reducing the factors that measure the health of the ecosystem to one number, both the stakeholders and the community can see how their efforts are faring. The stakeholders are able to directly see the impact their investment has on the system. The community, on the other hand, can easily see the amount of funds they could benefit from, and how their involvement can increase these funds. As a result, they are incentivized to increase their efforts as it will increase the money that is available to them to further develop their local area.

The use of blockchain as the underlying technology also serves several purposes. The tasks are assigned in the form of smart contracts, some of which are verified independently through the use of sensor data such as GPS. This introduces a tamper-proof task verification method that does not allow community members to cheat the system and ‘pretend’ to complete tasks. The nature of a private blockchain gives the system transparency. Community members can see the activities of others and verify them themselves. As a result, misuse of the system will be noticed by the community and the respective members can be held accountable. This hopes to foster a system that breeds trust due to its transparency. Finally, the use of blockchain allows the removal of any third parties. While WWF is a trusted third party in the set-up of the system and in the initial development phase, it is hoped that over time they remove themselves from the equation, resulting in a concept that is driven by direct stakeholder investments and the efforts of the local community.

5.2 Challenges

In order to allow for successful implementation of this project some technological and social challenges still have to be addressed. Due to the architecture of the system, Blockchain can be a very energy intensive technology. Large public networks that run the proof-of-work consensus mechanism, such as Bitcoin, are known to have significant power consumption (the Bitcoin network, for instance, consumed energy at a rate of 22 Terawatt hours a year in 2018 [27]). While this concept’s implementation of blockchain would require significantly less energy, it serves to prove the importance of such considerations. As such, in rural environments energy efficient implementation of the solution is imperative. Potential avenues to reduce the energy consumption would include running a private blockchain network, and switching the consensus procedure to Proof-of-Stake instead of Proof-of-Work [27].

Next to potential energy concerns, the security of the system also has to be addressed in its implementation. It will be important to ensure that all keys and addresses of the community members will be created in a secure way, in order to ensure there is no fraud amongst community members. The network, website and app will have to be properly secured, as the system could pose vulnerable to hacks that attack the community fund. Lastly, the storage of private keys belonging to the community would also have to be taken into consideration, potentially thinking of physical storage solutions, in order to avoid potential unrest that might arise from community members not being able to access their funds.

The system design might also pose some challenges in the future. The performance function was devised conceptually, and has not been implemented in practice. Ultimately, it will have to be subject to iterative testing and optimization in order to arrive to a fair trade-off for all the stakeholders involved. It might also prove to be too prone to inaccuracies as currently constructed and might therefore require evaluation at a later stage. As mentioned in Section 2.3, a challenge will also lie in determining the most effective way to release the funds. WWF, in conjuncture with the local community, will have to determine whether a ‘winner takes it all’ or a ‘weighted payout’ method is most effective.

Lastly, our solution might face some social challenges within the local community. It is possible that the proposed social system might not incentivize the cooperation of the community enough. This could lead the communities to revert back to corruption and unethical behavior. The experiment conducted by [8], in which the social governance system Backfeed was tested, also reported social challenges that may be relevant to this solution. The main challenge they found was that community evaluation of tasks or contributions had the potential to reduce social interactions between community members to economical transactions, reducing the sense of community among members and generating discomfort in some [8]. Furthermore, they also mentioned issues arising from unclear definitions of what successful contributions might look like to the failure to account for human feelings and emotions in the evaluation process.

5.3 Outlook

This concept was devised to assist the reintroduction efforts of the European Bison in Romania by WWF. The solution aims to align the incentives and interests of the local communities with those of the conservation efforts by introducing a monetary reward and social governance system. In exchange for monetary rewards and social influence, local community members are encouraged to participate and contribute to the preservation of the ecosystem. Although, some of the technical implementation was started, it will require additional work in order to complete the system and make it operational. Furthermore, some of the previously identified challenges would also have to be addressed to allow the solution to be used effectively. This report is meant to offer a starting point in working towards employing technological solutions in the conservation efforts. Lastly, the hope is that should the concept prove to be successful, it can be implemented as a blueprint from other conservation activities around the globe.

5.4 Installation Instructions

To run and access our website on a local server, *nodejs* with *express* is required. To start the server, move the current directory to the server.js file and run the command "node server.js" in the terminal. The website should now be online on localhost:3000.

Ganache is required to set up our local blockchain. Loading and deploying of the smart contracts is done in *python3* with the *web3* and *solcx* modules. This can be done by executing the run_contracts.py file.

All code can be found on the GitHub website of our project: `https://github.com/betherworld/carpETHii`

References

1. Squires, N. *Bison released into the Carpathian Mountains in bid to re-establish iconic species in Romania* https://www.telegraph.co.uk/news/2018/05/22/bison-released-carpathian-mountains-bid-re-establish-iconic/. Accessed: 2019-02-27.
2. WWF Switzerland. *WWF Kickoff Presentation* 2019.
3. Insider, R. *Nature in Făgăraș Mountains: The bison in Romania* https://www.romania-insider.com/fagaras-bison-romania. Accessed: 2019-02-27.
4. Few, R. *Combating Wildlife and Forest Crime in the Danube-Carpathian Region* https://europa.eu/capacity4dev/unep/discussions/press-release-combating-wildlife-and-forest-crime-danube-carpathian-region. Accessed: 2019-02-27.
5. Swan, M. *Blockchain: Blueprint for a new economy* ("O'Reilly Media, Inc.", 2015).
6. Davidson, S., De Filippi, P. & Potts, J. Economics of blockchain. *Available at SSRN 2744751* (2016).
7. Swan, M. Anticipating the Economic Benefits of Blockchain. *Technology innovation management review* **7,** 6–13 (2017).
8. Pazaitis, A., De Filippi, P. & Kostakis, V. Blockchain and value systems in the sharing economy: The illustrative case of Backfeed. *Technological Forecasting and Social Change* **125,** 105–115 (2017).
9. Weinold, M. *World Political Map Drawing* https://commons.wikimedia.org/wiki/File:World_Political_Map_2015_Drawing.svg. Accessed: 2019-02-27.
10. Weinold, M. *BETH carpETHii Concept* https://commons.wikimedia.org/wiki/File:BETH_carpETHii_Concept.svg. Accessed: 2019-02-27.
11. Weinold, M. *BETH carpETHii Performance Function* https://commons.wikimedia.org/wiki/File:BETH_CarpETHii_Performance-Function.svg. Accessed: 2019-02-27.
12. *Proof of Stake FAQ* https://github.com/ethereum/wiki/wiki/Proof-of-Stake-FAQ. Accessed: 2019-03-27.
13. *What is a blockchain oracle?* https://blog.apla.io/what-is-a-blockchain-oracle-2ccca433c026. Accessed: 2019-02-27.
14. Vogelsteller, F. & Buterin, V. *ERC-20 Token Standard* https://github.com/ethereum/EIPs/blob/master/EIPS/eip-20.md. Accessed: 2019-02-27.
15. *Ganache one-click Blockchain* https://truffleframework.com/ganache. Accessed: 2019-02-27.
16. *Iridium design by Templated* https://templated.co/iridium. Accessed: 2019-02-27.

17. Weinold, M. *Arduino with GPS Module* https://commons.wikimedia.org/wiki/File:Arduino_with_GPS_Module.svg. Accessed: 2019-02-27.
18. *TinyGPS++ Library* http://arduiniana.org/libraries/tinygpsplus/. Accessed: 2019-02-27.
19. *Arduino Playground* https://playground.arduino.cc/Main/SketchList/. Accessed: 2019-02-27.
20. Henriksen, G. L. J. & Melgard, T. Seasonal Effect of Tree Foliage on GPS Signal Availability and Accuracy for Vehicular Navigation. *Proceedings of the ION GPS-94 7th International Technical Meeting of the Satellite Division of The Institute of Navigation, Salt Lake City* (1994).
21. *GPS Accuracy* https://www.gps.gov/systems/gps/performance/accuracy/. Accessed: 2019-02-27.
22. *Great Circle Distance and Haversine Function* http://mathworld.wolfram.com/GreatCircle.html. Accessed: 2019-02-27.
23. *NMEA Datensatz* http://www.nmea.de/nmea0183datensaetze.html. Accessed: 2019-02-27.
24. *GlobalForestWatch Open-source Web Application* https://www.globalforestwatch.org/. Accessed: 2019-02-27.
25. *ImageJ Image Processing Software* https://imagej.nih.gov/ij/index.html. Accessed: 2019-02-27.
26. Weinold, M. *Humidity Detection Module FC-28* https://commons.wikimedia.org/wiki/File:Humidity_Detection_Module_FC-28.svg. Accessed: 2019-02-27.
27. F., G. *Why bitcoin uses so much energy* https://www.economist.com/the-economist-explains/2018/07/09/why-bitcoin-uses-so-much-energy. Accessed: 2019-02-27.