WHITEPAPER

Abstract

Weather can have a big impact on people's livelihood and even survival. According to the Food and Agriculture organisation of the United Nations, $93 billion was lost in crop and livestock productions due to natural hazards and disasters in developing countries between 2005 and 2014[1]. Hydrological and meteorological hazards counts for 90% of total disaster losses worldwide which may slow overall economic growth, especially where agriculture and food production account for a large share of gross domestic product and employment. Three quarters of the world's least developed countries and small island states can provide only minimal early warnings or none at all.

The current weather data industry has two main categories of players; private and public National Meteorological Services (NMS). Public weather data services are siloed by their country borders and lack efficient consistent ways of sharing data. Private weather data services are optimising for cost, relying on lower quality weather observations and therefore losing overall data quality.

Thor is a social enterprise that provides an open technology platform to distribute weather and climate related data, making it easier for NMS and other organisations to share their data. To read data from Thor you need a Thor Weather Data Read Token. The token cost represents any cost associated with the processing of the request. Raw weather observations are only charged for compute power to respond but processed data such as forecasts can have associated royalty fees added by the forecaster. Data contributors who write data to the platform are rewarded with tokens. Thor incentivises data contributors by giving higher rewards to those contributing high quality and rare data points. This drives higher coverage in areas that are currently underserved with weather information.

For Thor to succeed there needs to be a willingness of NMS and existing weather station owners sharing their data, the tokenisation needs to be easily understood by users and the token to be listed on exchanges. It is also important for Thor to build key partnerships with weather station providers to enable rollouts by organisations or nations in developing countries to start collecting data in areas currently not covered.

Thor will enable developing nations to easier roll out weather services to their citizens as they no longer need to implement the technology infrastructure to deliver the services. We hope to see increased food production thanks to more accurate weather forecasting and GDP increases. Early warning systems should lead to fewer deaths and decreased crop damage. Weather doesn't stop at borders and a decentralised system enables a global community.

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[1] "The impact of disasters on agriculture - FAO." http://www.fao.org/3/a-i7279e.pdf. Accessed 13 May. 2018.

Contents

Introduction

Weather is one thing that we can't control but affects us all. For some the weather can have a big impact on their livelihood and even survival. There needs to be a way for everyone to access the best possible weather information.

The World Economic Forum's Global IT Report in 2015 highlights that it is not just access to digital infrastructure that matters, but also the "data deficit" in many countries, particularly in the Global South, thanks to constraints on how data can be created, collected, transmitted and used. Closing the four "gaps" which contribute to this deficit - it's existence, access, governance and usability - gives countries, regions and cities many ways to enhance development.

Weather related disasters may slow overall economic growth, especially where agriculture and food production still account for a large share of gross domestic product and employment. Financial losses from droughts, floods and storms can cripple families, communities and even nations; leaving them in poverty loops. Inaccurate or non-existent weather forecasts affects many farmers in developing countries. Thor is here to change all of that.

Thor is a global, open and decentralized weather data platform using blockchain technology. Removing silos of weather data, enabling innovation and a borderless infrastructure.

Weather station owners and foreasters will be incentivised to contribute high quality data and improving coverage. Rarer and higher quality data points will result in greater rewards. Thor will enable more reliable and accessible weather forecasts, ultimately enabling farmers to make better choices and reduce financial losses.

Contributors are rewarded with the Thor Weather Data Read Token. People or organisations who want to read data, such as weather forecasters, insurance companies or researchers, use tokens to gain access.

So how are we going to get this data into the hands of farmers? Using a simple feature phone farmers can request a forecast from Thor Weather via SMS.

This is just the beginning, the benefit of an open system is that it fosters an ecosystem of innovative weather services.

Impact Opportunity

Problem Scope and Vision

According to the Food and Agriculture organisation of the United Nations, $93 billion was lost in crop and livestock productions due to natural hazards and disasters in developing countries between 2005 and 2014[2]. Hydrological and meteorological hazards counts for 90% of total disaster losses worldwide. Farmers in developing parts of the world, like Africa, are suffering the most from the negative effects of unreliable and inaccessible weather forecasts.[3] They aren't able to get the most out of their land and face lower income yields and food shortages. These financial losses from droughts, floods and storms can cripple families, communities and even nations; leaving them in constant poverty loops. There needs to be a change. And that change starts with data.

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[2] "The impact of disasters on agriculture - FAO." http://www.fao.org/3/a-i7279e.pdf. Accessed 13 May. 2018.
[3] "How a lack of access to reliable weather data is hurting African farmers." 4 Jul. 2017, http://theconversation.com/how-a-lack-of-access-to-reliable-weather-data-is-hurting-african-farmers-80011. Accessed 13 May. 2018.
[4] "The impact of disasters on agriculture - FAO." http://www.fao.org/3/a-i7279e.pdf. Accessed 20 May. 2018.

It has been estimated that between 1970 and 2012, more than 2 million people have died from natural disasters and hazards, most in developing countries. Even more concerning is that the majority of weather stations are found in developed parts of the world who hold a working infrastructure (as seen in figure 1.1). Three quarters of the world's least developed countries and small island state can provide only minimal early warnings or none at all. In, Africa, almost half of all on-the-ground weather stations do not report data.

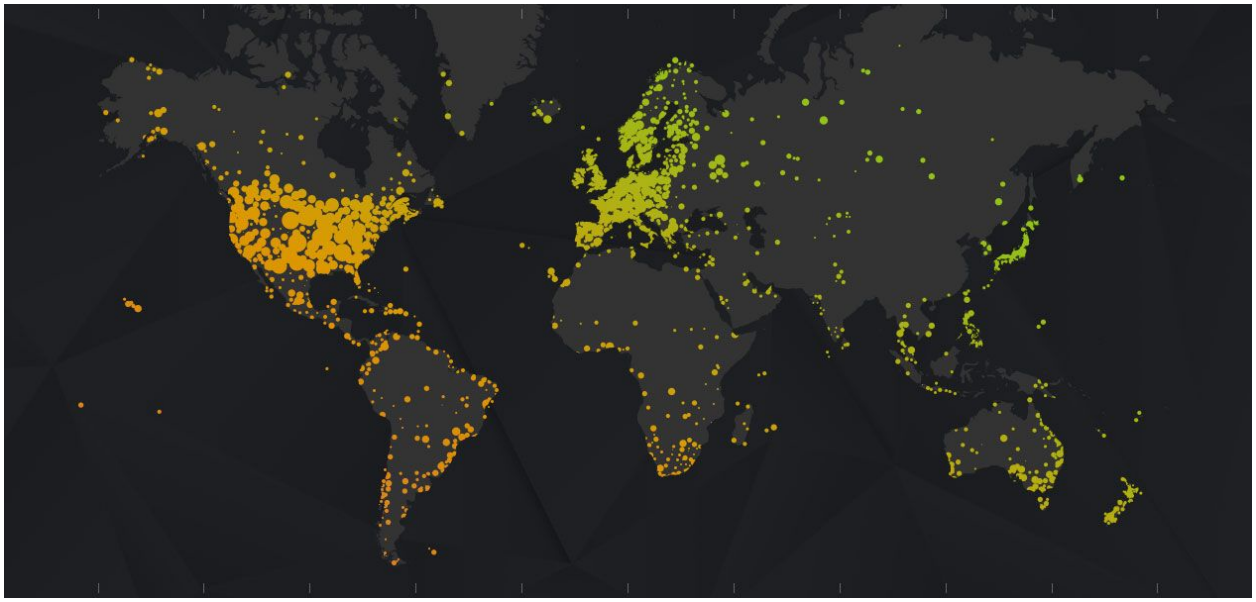

Figure 1.1 Weather station network

It comes with no doubt that better and more weather data presents massive opportunities. Thor is here to change all of that. With the help of Blockchain technology we are creating a global, open and decentralized weather data platform. Removing silos of weather data and enabling and innovative and borderless infrastructure for the developing parts of the world.

Our aim is to democratise weather data and ultimately improve the accuracy and reliability of weather forecasts. With accurate weather forecasts:

1. Communities can prepare for floods and plan ahead for planting their crops; reducing damage caused and improve livelihood.
2. Governments and health officials can better predict disease outbreaks of vector-borne diseases, including malaria, and use the information to drive mitigation efforts
3. Transportation and logistical operations of food and medicine can be better planned out, reducing the risk of late arrivals
4. The energy sector can anticipate peak demand and adjust production accordingly

The World Bank Group's research shows that countries can save US$13 billion in asset losses annually by investing in hydromet, as well as saving US$22 billion in losses to well-being, and US$30 billion through a resulting increase in productivity. [5] All of this has massive implications that more reliable and accurate weather data can drastically improve a nation and their economy.

Market Size and Opportunity

The market for weather data and services is huge. We aim to tackle developing nations who are drastically affected by this but to add context to the size of that market, it is useful to understand the positive effects that we are seeing in developed nations.

If we look at a developed nation with an established met office like the United Kingdom, we can get an idea of the benefits of the weather. In 2015 the UK met office predicted the value from the data provided was worth close to £1.5 billion to the economy. These included benefits to the public, aviation, land transport and damage avoidance.[6]

Another developed nation with an established met office is the United States. In 2014 the aggregate annual valuation of weather forecasts for the economy was $31.5 billion. This return is 6.2 times as high as the total expenditure on actually making the forecasts available via public and private spending of $5.1 billion. The spend being made up of $1.7 billion in private and $3.4 billion in public. America is one of the rare economies with the means to properly benefit from the data they collect from weather[7]. If we break down the spend, there is 15 million weather products produced such as earthquake reports, tornado and flash flood warnings, air quality alerts and the three, five and ten day extended weather forecast.

We aim at tackling the most of the developing world who have an ample use case for this platform. In particular Africa who have a estimated population of 1.6 billion people, of which 70% of those rely directly on agriculture for their livelihood. Improved services for farmers can result in double or in some cases triple of their current income. For example in Uganda, with a population of 40 million, will take their income per capita from the current $600 to $1,200. This could bring Uganda as a nation hugely out of poverty and closer to a middle-income nation by 2020 alone. Then there is another 50+ countries to tackle.[8]

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[5] "Improving Weather Forecasts Can Reduce ... - World Bank Group." 12 Sep. 2017, http://www.worldbank.org/en/news/feature/2017/09/12/improving-weather-forecasts-can-reduce-losses-to-development-in-africa. Accessed 16 May. 2018.
[6] "How valuable is the Met Office? - Met Office." 20 Apr. 2016, https://www.metoffice.gov.uk/about-us/what/pws/value. Accessed 20 May. 2018.
[7] "The Value of Government Weather and Climate Data | Department of ...." 2 Sep. 2014, https://www.commerce.gov/news/blog/2014/09/value-government-weather-and-climate-data. Accessed 20 May. 2018.
[8] "Agriculture is the key to a prosperous Africa - Financial Times." 6 Dec. 2017, https://www.ft.com/content/7b8a97ea-d9d7-11e7-a039-c64b1c09b482. Accessed 20 May. 2018.

In 2015 the world banking group set a business plan which suggested that with the increase of 2 degrees per, the region needs $5-10 billion a year to adapt. Most of these need to be weather support services to help predict the shock weather changes. $2billion of the world banking groups $16 billion proposed will be allocated to various climate financing instruments, of which the Thor weather platform will fall under.[9]

We already have an existing relationship with the Bank of Papua New Guinea, which would be our first test case to help implement and develop our service. PNG has a current population of 8 million people and a GDP of $2,613 per capita. A number of countries in Africa like Burkina Faso, Côte d'Ivoire, Ethiopia, Ghana, Kenya, Rwanda who are actively investing in agriculture resources are seeing a rise of productivity in farmlands of 6% and a GDP increase of more than 4%.[10] If our improved weather information can benefit PNG even with a 1% GDP increase then we can see a huge use case benefit for the intended market.

[9] "World Bank Group unveils $16 Billion Africa Climate Business Plan to ...." 24 Nov. 2015, http://www.worldbank.org/en/news/press-release/2015/11/24/world-bank-group-unveils-16-billion-africa-climate-business-plan-to-tackle-urgent-climate-challenges. Accessed 20 May. 2018.
[10] "Agriculture is the key to a prosperous Africa - Financial Times." 6 Dec. 2017, https://www.ft.com/content/7b8a97ea-d9d7-11e7-a039-c64b1c09b482. Accessed 20 May. 2018.

Competitor Analysis

Today big players like IBM, are taking a huge piece of the pie within this space. Having acquired The Weather Company in 2015, they now own and operate weather.com, intellicast.com, and Weather Underground and own over 300,000 of the worlds weather stations. They also partner with social impact projects like TAHMO, whose aim is to increase the number of weather stations in Africa. Other big names include “Accuweather” and World Meteorological Organisation. Of course, all of this data is stored within their own servers and together, these institutions own the centralisation of weather data.

An increasing number of communities and individuals are now running their own personal weather stations (PWS) solely for enjoyment and education, however some owners share their results with others. There are services such as The Citizen Weather Observer Program (CWOP), which facilitates the sharing of information from personal weather stations. This data is submitted through the use of software, a personal computer, and an internet connection (or amateur radio) and are utilized by groups such as the National Weather Service (NWS) when generating forecast models. [11]

However, all of this begs the question - what are the incentives for these individuals providing this data? To what extent do they know what their data is being used for? The storing and cataloging of raw data becomes increasingly under the control of corporate interests.

[11] "Weather station - Wikipedia." https://en.wikipedia.org/wiki/Weather_station. Accessed 15 Apr. 2018.

Major Players in Weather Forecasting Services market are: [12]

Company	Size	Description	Pros	Cons
WeatherBlock	3 employees - 7 advisors, Jan 2018 launch - relatively new	A decentralized ecosystem for peer-to-peer weather data exchange	• Are deploying weather stations with partner company (bloomsky) • Already established product and relationships	• Not serving most of the developing world • Privatising the data • Initially requires proprietary hardware • Solution requires a constant Internet connection and a node running (separately to the weather station) (and actively punishes those that drop offline) • Heavily profit driven
Right weather	1 employee	Right Weather provides accurate and updated forecasts for Southern New England	• Offering weather predictions for extremes • Highly localised weather data • Founded by Broadcast Meteorologist Fred Campagna	• Private forecasting so it is not open data • Only servicing new england area • Not highly functioning website
The Nation Oceanic and Atmospheric Administration	6000 employees	Agency focusing on the weather and ocean	• Government backed by US department of Commerce •	• Focused primarily on US without signs of expanding •
Hometown forecast services	8 employees, active since 2011	Hometown Forecast Services, Inc. (HFS)	• Delivery forecasting	• Are only providing local

[12] "Weather Forecasting Services Industry 2017 Global Market By ...." 13 Oct. 2017, https://industrytoday.co.uk/pr_and_marketing/weather-forecasting-services-industry-2017-global-market-by-segment--types--regions--applications-and-forecast-to-2022. Accessed 15 Apr. 2018.

		is a leading provider of weather forecasting information serving a variety of commercial industries, media, and government agencies.	● Have a team including meteorologists	US data
The Weather company	1000 employees.	The Weather Company, an IBM Business, is the world's largest private weather enterprise.	● Largest private weather enterprise ● Backed by IBM ● Includes brands like the Weather Underground ● Founded in 1978, so history of connections and a solid brand in the space	● Siloed weather data ● Doesn't provide free access to weather observations
Weather Underground	50 employees - largest network of personal weather station	Founded in 1995 as the first online weather service, Weather Underground supplies weather data solutions to the many of the leading media companies and millions of users across the globe through their mobile apps and website wunderground.com	● First online weather service ● Is go to place for many weather providers ● Over 250,000 personal weather stations worldwide ● Community based platform	● Doesn't provide free access to weather observations ● Targeted at the developed world

Geopolitical and cultural-social-economic challenge

Governments

It is known in Africa that governments and development agencies don't understand and prioritise the value of climate and weather data. This has stifled investment in infrastructure and proper functioning of state institutions charged with collecting and serving climate and weather data.[13]

Strong political support is needed to increase smart systems through partnerships – between national authorities, technical agencies, non-governmental organisations and the private sector.

Africa needs to acknowledge and welcome the role of the private sector too. Without its investment, Africa won't be able to bridge the massive gap in infrastructure needed to collect reliable data, and to make it easily available.

Forecasters

Forecasters make money from selling their forecasts, and many don't see a need to do it another way. Consequently, there is an unwillingness to provide open access to forecasts as this would give away their methods on predicting weather.

The National Meteorological and Hydrological Services is mandated by national laws and recognised in the Convention of the World Meteorological Organization. Its aim is to collect and serve meteorological and hydrological forecasting and warning systems at country level. But it operates well below capacity in several African countries because of under funding and low visibility.

Farmers/End-users of forecasts

In the horn of Africa, farmers in Somalia are grappling with droughts and poor rainy seasons. This has affected food production, making more than 5 million people food insecure. These farmers have no knowledge of how long and how intense the droughts will be. Accurate forecasts would certainly help them, but they would also need education and planning support to help them make the right decisions with this information. Religious beliefs may also come in the way as praying for weather in times of scarcity is considered an Islamic tradition. Scientific weather forecasts may be seen as a threat to their religion.

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[13] "How a lack of access to reliable weather data is hurting African farmers." 4 Jul. 2017, http://theconversation.com/how-a-lack-of-access-to-reliable-weather-data-is-hurting-african-farmers-80011. Accessed 13 May. 2018.

Business Model Validation

Business Model

Industry Overview

The current weather data industry has two main categories of players; private and public National Meteorological Services (NMS). Many countries are investing in weather observation, forecasting and alerting systems as this saves lives and revenue for their citizens. There are also private players making plans to provide weather forecasts to the public and information services in the insurance market. For insurance companies, it is in their best interests to provide advice and identify possible adverse weather conditions for those they insure to reduce the odds of having to pay out claims.

Public weather data services are siloed by their country borders. As the world has become more connected the weather data hasn't followed suit. Despite the nature of weather moving across continents we don't see any consolidated storage model of data in this space. Still today we see inconsistent distribution of data and a very local focus. The World Bank are working at raising awareness of this issue due to the big impact on people in the world.[14]

Private weather data services are optimising for cost and therefore losing quality. Companies operating for shareholder profit are cutting corners with deploying lower cost weather stations that report less accurate readings compared to expensive stations deployed by the public sector.

The industry lacks a platform to efficiently share and distribute data. As mentioned above, the problem of not sharing data in a consistent format across weather observing organisations hasn't been solved. NMS are often in line with the World Meteorological Organisation (WMO) often sharing their data free of charge but have the right to charge reasonable costs for processing and infrastructure to ensure they can provide these services. Unfortunately private players consuming weather observations by small scale contributors, such an individuals, aren't making the data available freely and thus creating blank spots on the weather data map.

[14] "Forecasting for Catastrophes: How Investment in Weather Services ...." 23 Mar. 2017, http://www.worldbank.org/en/news/feature/2017/03/23/forecasting-for-catastrophes-how-investment-in-weather-services-can-save-lives-and-grow-economies. Accessed 18 May. 2018.

Thor Services

Thor overview

Thor is a social enterprise that provides a platform to distribute weather and climate related data. It is fundamentally a decentralised weather data platform - connecting actors throughout the weather data life cycle with an aim to cover as much of the earth as possible. It enables the writing of data and the reading of data in a global decentralised system. To keep in line with the beliefs that weather data is a global issue the revenue model must support that.

This system enables a coherent way of making data available to combat the issue of inconsistent data schemas. Data being stored in different formats and units is making it difficult for organisations to share their data and scientists to work with it.

Thor incentivises players to contribute data and relies on partnerships with weather station providers. By giving higher rewards to those contributing high quality and rare data points, there is an incentive to cover areas that are not currently benefiting from weather observations.

Thor Weather data ecosystem

Thor's weather data ecosystem relies on high quality and high coverage data. Data contributors will be incentivised with higher rewards if they are covering an area with data points that are rare, and less reward if they are covering an already highly monitored area. This model is intended as a rough guide to work for both raw data providers as well as processed data providers (such as forecasts).

This process incentivises participation in the platform from governments, organisations and individuals. There is a clear correlation between collecting weather observations and being able to get more reliable weather forecasts. The data contributors get rewarded at the end of each month, so the system gets a chance to verify the quality and assess coverage, with a Thor Weather Data Read Token.

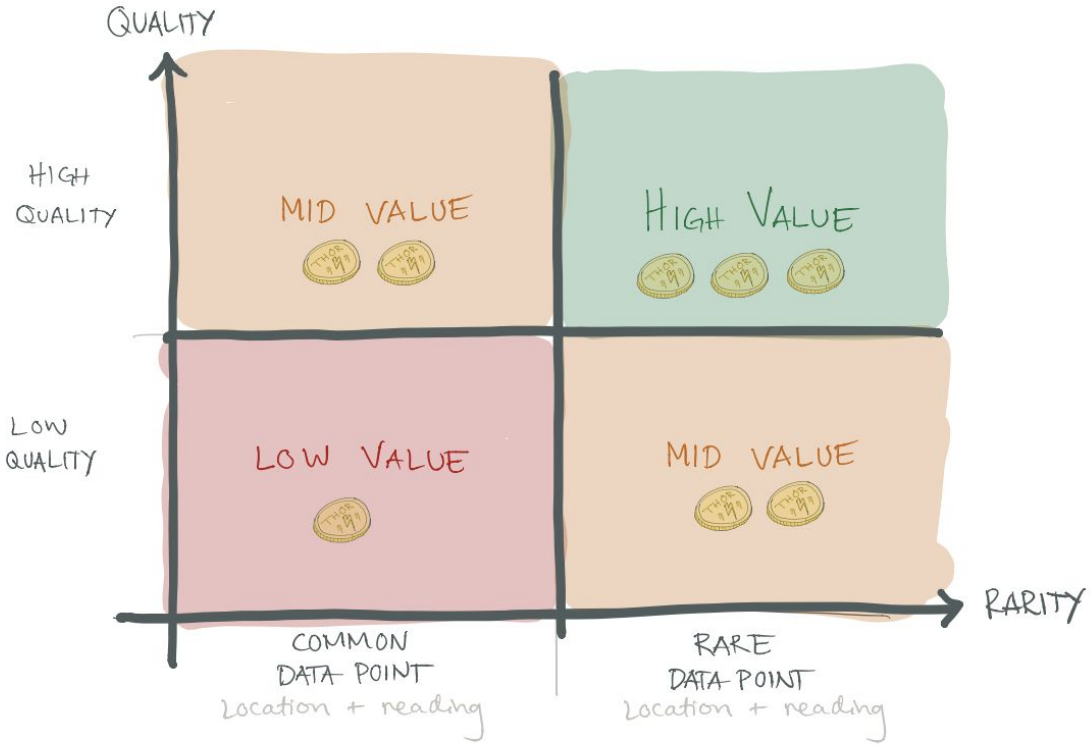

Figure 2.1 Data valuation visualisation

The Thor Weather Data Read Token (WDR Token) is the currency for consuming data. As a contributor you have free access to your data but will be charged based on the cost of processing and retrieving the data. To pay for this processing you will have to use WDR Tokens.

Data contributors can sell their WDR Tokens to generate revenue for themselves. The token is a reward given for writing data. As it is the currency for reading data it creates a market to sell tokens on. A token isn't tied to a specific data set. As a data contributor It means you don't just get rewarded if the specific data you contributed got consumed. For example, if a data contributor is collecting weather observations in a low coverage area like Rwanda and sells their WDR Tokens on the market, the person using the tokens to read that data from any region, like North America.

Thor services

Paid services	*Weather platform* Thor can bootstrap a nation or region into having an operating weather forecasting distribution system. Setting up a highly accessible platform and running forecasting models on data requires highly skilled meteorologists and engineers. *Data access* Thor charges for processing power to process data requests but not for the data itself. Processed data contributors like forecasters, have the choice to charge a royalty fee for their data. **Request cost** = request process time + request data size + (optional) royalty The charging model enables transparency that the data itself can be free but Thor charges only for the processing of the request.
Free services	*Raw data* Thor weather leans on the values of the World Meteorological Organisation that raw weather observations are free of charge. In these instances the reader is only charged WDR Tokens for the processing of the request, not the data. *My own data* Data contributors can access their own data royalty fee even if they have indicated to charge a royalty fee for their data. Thor does not own the data contributed to the platform. *Provide a public free service on Thor* If an organisation wants to provide free public access to their data they can. An organisation can sponsor services and pay the bill for requests made to retrieve their data. Data reads will be subsidised by the WDR Tokens they've acquired by contributing data.

	Forecasting services Thor runs an open source forecasting model providing short and mid term weather forecasts. Access Thor or other royalty free weather forecasts for a location via web, mobile or SMS from royalty free forecasters. Thor will on a donation based model provide services to distribute royalty free forecasts.

Differentiating factors

Social enterprise model	Thor doesn't aim to generate profit for any shareholder but to continue to invest profits in the product and goal to provide more reliable weather data, forecasts and services.
Removing siloes	Through enabling the unified weather data storage model on a decentralised platform Thor creates a trusted data store. Different actors in the weather data space will benefit from data being stored in a consistent structure, on a more open platform; and only needing to go to one source for all of their weather data needs.
A unified data model for weather data	Currently meteorological organisations provide different structures of data making it difficult to consolidate. Thor enables innovation through a consistent method of storing data.
A weather data platform as a service	Weather data providers do not need to run their own infrastructure to distribute data. They can rely on Thor to provide a platform for data distribution.
Open Platform	Thor will not require data contributors to have specific, certified hardware in order to contribute data to the platform.
Uses Blockchain	Through the use of a blockchain we are able to ensure that weather data contributed is immutable, that the data can be trusted between parties/countries and that we can use tokens to incentivise participation in the platform.

The Thor Weather Data Read Token (WDR Token)

In the Figure 3.1 below you see a Weather station owner - the owner can be a government, organisation or individual. The weather station owner publishes data to Thor Services. The user will be rewarded monthly based on how rare and how high quality the data is. Quality is determined based on the accuracy of the data measured by closely located stations. The organisation awarding the token to the weather station owner is Thor Foundation.

Figure 3.1 Weather token story image 1

In Figure 3.2 the Weather Station owner is putting their tokens up for sale. This can either be done automatically on their behalf by Thor or they can receive their tokens and put them up for sale themselves. Someone who wants to read data can then purchase the tokens to be able to make Thor API calls. The token is strictly used for the cost of an API call. There is nothing to suggest that a token binds to a specific piece of data.

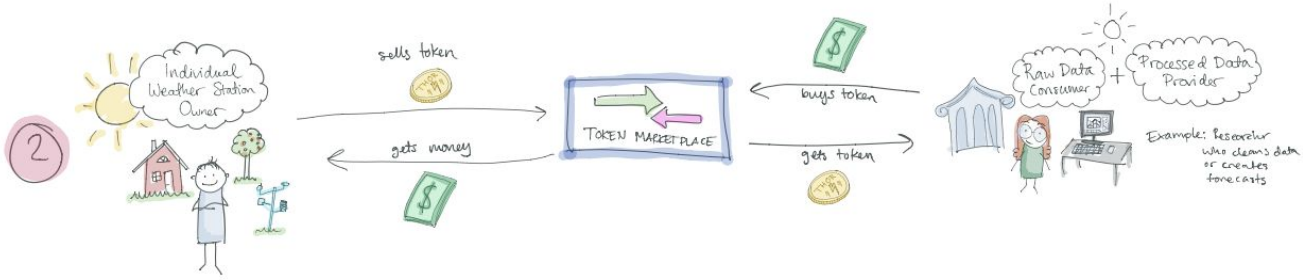

Figure 3.2 Weather token story image 2

In Figure 3.3 you will see several transactions.

- **3.a.** Shows the person who bought data writing back weather forecast data onto Thor Services. In exchange for providing forecasts the person receives Data Read tokens.
- **3.b** Shows a company buying raw weather data using tokens they have obtained.
- **3.c** Shows how an app developer is paying for API calls to get forecasts as he is showing weather forecasts on his app.

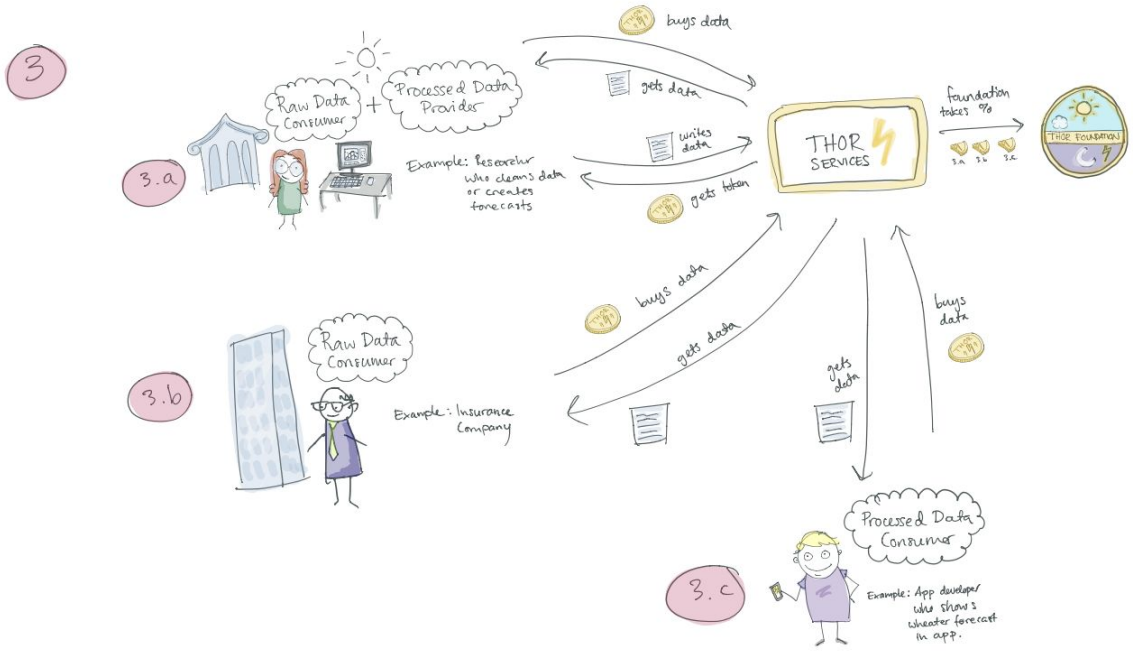

Figure 3.3 Weather token story image 3

In the far right of the picture you see the Thor Foundation. For every piece of data read the Thor Foundation takes a piece of the cost. This serves a few purposes as it allows the Thor Foundation to remove tokens from the system and it enables the Thor Foundation to trade the tokens for money to fund its operational costs.

The fourth (4) image shows how the Thor Weather Foundation is taking tokens out of circulation or selling them for money to ultimately invest in the technical infrastructure of Thor.

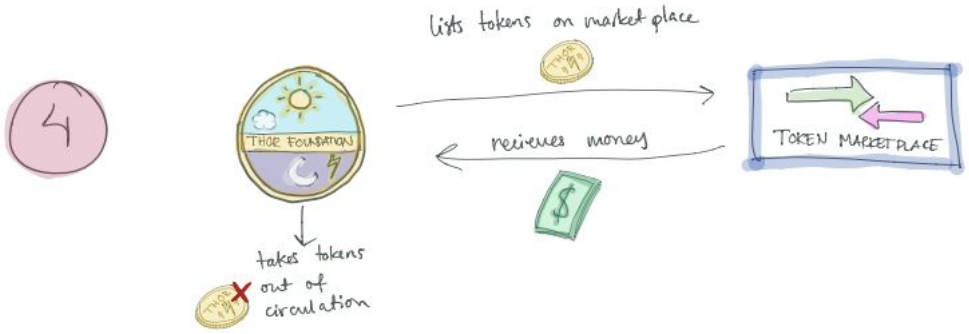

Figure 3.4 Weather token story image 4

Validation Plan

Assumptions Discussion

There are a number of assumptions that we have made that will enable Thor to succeed. The main ones are the willingness of met offices to become nodes, existing weather station owners sharing their data, the tokenisation would be easy to understand and implement for users and exchanges will list the token.

Part of the revenue that a met office makes is from owning and selling their weather data to support other services and stakeholders in their relevant ecosystem. Thor blockchain enhances their ability to do that; empowering them with more accurate global weather information. However, having a global infrastructure for weather data means that their customers may be able to access the data directly, questioning the willingness of the met office or other institutions to be a node on the network. We are already scheduling meetings and calls with different potential entities that could be nodes to discuss the likelihood of partnerships.

Weather station owners have a number of different opportunities to store their weather data on popular entities like weather underground or even their own website for little to no return. We would be asking them to share this data with the Thor blockchain with the incentive of receiving our utility tokens that can be traded. Although the sharing allows for a better ecosystem of weather data, it is an assumption that all weather providers are moved in this way. To validate this, we have a number of weather data providers within the teams network, but also aim to host focus groups of weather data providers to ask they how and what a solution would need to provide for them to do so.

To a degree, with a network solution, the success relies on the quality of participants and data to that network. Like mentioned earlier it is a chicken and egg situation between data providers and customers paying for data. Tokenisation is an incentive to form the network and increase the quality of it, making it useful to all entities. However, the way most of the players in this market is direct fees to data which is probably a more simpler process as it stands. However, we have to anticipate that our form of tokenisation is compelling enough to attract users and won't be too foreign in this area to convince entities to participate. As we discuss with the potential nodes and weather station owners we will explore of they will take and understand the token situation and further understand the parts of the network that we should incentivise around.

To add value to the token and deeply fund the ecosystem, we would need the transfer of the token to be a real possibility. In this case, we would need exchanges to be willing to add our token in their marketplace. There are a number of structural elements that we would need to adhere to for the token to be available but we are anticipating that once this is done we would be able to stock them on exchanges. An issue with a number of exchanges are that they aren't as user friendly but are more willing to house coins, whereas the more popular exchanges like

coinbase are really strict with the coins that they offer. We are researching the terms and what it takes to better inform us on how we can build out our token to be valuable to the users and also be credible to the exchanges.

Assumptions and Validations Table

Below is a collection of assumptions needed for Thor to be successful and work and outlined steps needed to validate these assumptions.

Assumption	**Validation Steps**
We can work with Meteorological organisations to establish a unified data schema for weather data	Build partnerships with organisations to work out the most viable shared data schema. We need to connect with these players to validate there is an interest from them to contribute to these standards. We have already made contract with the Innovation Manager of the Swedish National Metrological Services organisation (SMHI). Through this connection we plan to better understand in what format they store their data and how they arrived at this design decision. Through this connection will also try to find contact at other Meteorological organisations. In addition to this, we will search for contact details online of people that could help us and make contact with them.
That 3rd parties will be willing to host our nodes to join the Thor platform	Through our research, we have identified several governments and NGOs that have shown an active interest in tackling some of the problems that the Thor platform can help solve; especially those covered by the Sustainable Development goals as outlined by the UN. We will keep a close eye on the public conversations happening in this space and aim to reach out to the people involved in relevant areas (such a flood prevention systems and food security); informing them of the work that we are doing and how it can benefit the countries that they represent. Once we have made progress with the development of the platform then we will look to start giving demonstrations of the platform to these people. From there we can discuss the benefits of hosting a node to see if they are receptive to the idea.
There are parties, like insurance	Carry out research to validate this assumption. Initial

companies, interested to read weather data who aren't data contributors to enable the WDR Token market to be healthy.	research indicates there is a market for this.[15] We would need to reach out to key players who would be interested in reading data to validate that there indeed is a market for reading data. We need to accurately measure the size of this market in terms of how much players currently charge for data consumption and how many clients are reading data to be able to assess if we can be competitive with our model providing our data contributors with enough incentive.
There is value in understanding weather and the forecasts of weather	Market size reports indicate there is a market for this kind of data.[16] The value is both direct and indirect. Directly from those willing to pay to retrieve the data. Indirectly as a rise in revenue by taking better actions based on better understanding of weather. However further research to understand the competitor landscape is needed to validate where the biggest market opportunities are. To begin with we assume a focus on the developing world.
Developing countries need more accurate and accessible weather services	Research the accuracy of weather forecast quality in developing countries. Our findings indicate poor accuracy. [17] This leads to low yields as citizens in agriculture aren't able to make the most our their land and nations struggle to put in measure for weather related disasters. We have connected with a climate change scientist based in Vietnam that focuses on agriculture and food security. She works directly with the farmers there and could potentially help us work with farmers to understand the technology that they have access to and the technical solution that would best suit the farmers for delivering weather forecasts to them. Based on papers from the World Meteorological Organisation we have name of people globally that are specialists in the area - we plan to make contact with

[15] "601 billion reasons why weather data can transform the insurance ...." http://www.ibmbigdatahub.com/infographic/601-billion-reasons-why-weather-data-can-transform-insurance-industry. Accessed 18 May. 2018.
[16] "Forecasting for Catastrophes: How Investment in Weather Services ...." 23 Mar. 2017, http://www.worldbank.org/en/news/feature/2017/03/23/forecasting-for-catastrophes-how-investment-in-weather-services-can-save-lives-and-grow-economies. Accessed 18 May. 2018.
[17] "Developing countries and weather forecasts | Public Radio International." 2 Jun. 2008, https://www.pri.org/stories/2008-06-02/developing-countries-and-weather-forecasts. Accessed 20 May. 2018.

	them to see if they can further help us understand the extent of the problem and how our solution could be rolled out to farmers.
Weather forecasters are willing to distribute and sell their forecasts on the Thor Platform rather than via their own technical infrastructure	It gives forecasters and opportunity to distribute forecasts without the setup of an entire system. We need to assess what costs forecasters today incur leveraging their systems to understand if we can compete and give them higher profit margins using our royalty based system where the forecaster themselves sets the value of their forecast.
We can generate enough revenue or get enough investment or donations to stay afloat long enough to get traction and become self sustaining	We have a rough idea of the costs involved with our outlined timeline, but we would require some more time to finalise these. From there, we would need to start reaching out to organisations that might be willing to offer us grants or help fund us during the initial development of the platform; through to starting to generate revenue. During this process we would need to keep re-evaluating the costs involved to fully understand how the cost involved in running the platform at scale.
That we are able to get weather station providers to partner with us	We have found several suitable devices that are cheap to buy, easy to deploy and use Open Source software; that would make excellent partners. At the top of our list is 3D Paws and TAHMO - since these both have a track record of successfully deploying weather stations in developing countries and have shown to be open to partnerships. We plan to start by reaching out to representatives of these two companies to understand if they would be willing to partner with us in an initial limited trial.
That existing weather station owners will be willing to send the data they are capturing to the Thor platform	There is a lot of evidence that weather stations being deployed both in developing and developed countries send their data for free to closed platforms (such as Weather Underground). We believe that the Thor platform and the eventual ecosystem that it will grow will have a lot of value to offer these people. We would initially look at the partnerships that we could strike up with existing weather station providers and see how we could leverage the existing communities to spread the word.
That there will be a marketplace for the tokens	The ideal situation would be for us to list our token on the most well known, centralised exchanges such as

	Binance, OKEx, Huobi etc. once we have finalised details of the token and got a testnet up and running then we would reach out to these exchanges to understand the process required to list the token, the cost involved and the timelines. We would also reach out to more decentralised exchanges such as ShapeShift, OpenLedger etc. to similarly understand the situation. As a worst case scenario, we could also look at creating our own marketplace for the tokens.

Stakeholder Analysis

Stakeholder overview

Thor relies on several key partnerships and clients to make an impact in the world. Below are the key stakeholders outlined and how we believe we should work with them.

Key Partners

Weather station producers are a key partner to make Thor work. There are more than one possible provider in the market. Two examples are 3D-PAWS and Thamo who build low cost weather stations. We need to be careful to partner with a station producer that is happy for the owner of the data to store it where they see fit, in this case Thor.

World Meteorological Organisation is a key partner as it gives access to engagement with National Meteorological Offices across the globe. Close partnerships with these organisations are vital as Thor needs to stand on the shoulders of their knowledge.

National Meteorological Organisations are potential weather data contributors as well as forecast providers. They already have the infrastructure and expertise to run forecasts and run their models for regions they currently aren't doing. This would be very beneficial for them.

The World Bank, with an interest to raise developing countries out of poverty, has a key interest in weather data and forecasts as it can enable economic growth if fully leveraged. Engaging with the World Bank could open doors to contacts in different regions.

Key Clients

Insurance companies can use weather alerts to help policyholders avoid damages that can lead to claims ultimately allowing them less expense.

Weather forecasters need weather observations to run forecasting models. To be able to effectively run their models they have an interest in the format of the data, frequency and quality. We need to ensure these clients are well maintained as their ability to create forecasts and write them back to the system are key to its value proposition.

Governments who do not currently have an accessible weather system for their nation and want to leverage Thor and one of its weather station provider partners to roll out a system that benefit their citizens.

Product Roadmap

	Partnerships & Process	Platform	Thor Services
2018 Q2 Q3	Wide-reaching advisory board and partnerships with hardware providers and governments Look for angel/seed investments.	**Thor Data store** The ability to store and access data via Thor APIs An agreed first version of the data store format	MVP to be available to a small and select group of data providers and users.
2018 Q4 **2019** Q1	Make agreements with PNG bank and government to pilot Thor and add first hosts to platform. “PNG Token generation event” will ultimately allow the accelerated platform development and incentivisation of early users onto the platform. Birth of Thor Foundation	**Thor Developer Portal** Enabling developers to interact with and build against the Thor platform Browse data and APIs	
2019 Q2 Q3	Begin beta testing in a country in Asia or Africa. Secure partnership with weather station provider and governments. Grow development and operations team.	**The Thor WDR Token** The launch of the token No tokens will first be available when a data contributor has started contributing data The ability to buy and sell the Thor Weather Data Read Token.	**Consumer friendly data read APIs** Enable more advanced data read APIs where the client defines the data points they want and the format they want it in.
2019 Q4	Relationships with governments and weather institutes to cement Thor as the favoured weather data system vendor and improve weather data.		**SMS Services** Enable the access of weather forecasts via SMS **Thor Web UI** Provide a Thor Web interface on which you can see the status of the data set. See

			locations that are covered and needed coverage areas
2020	**Open Sourcing the Thor project** International partnerships are developed to focus on expansion into global weather freight.	**Thor Open Source Forecast Model** Launch the open source Thor Forecast model	**Open Source Thor Services** Open source the Thor Services platform to enable community contributors.

Technical Architecture

Introduction to Blockchain

“A Blockchain is a continuously growing list of records, called blocks, which are linked and secured using cryptography. Each block typically contains a cryptographic hash of the previous block, a timestamp and transaction data. By design, a blockchain is inherently resistant to modification of the data. Once recorded, the data in any given block cannot be altered retroactively without the alteration of all subsequent blocks, which requires collusion of the network majority. Blockchains are secure by design and exemplify a distributed computing system with high Byzantine fault tolerance.”[18]

The original Blockchain, the Bitcoin Blockchain, introduced in Satoshi Nakamoto’s Whitepaper (Bitcoin: A Peer-to-Peer Electronic Cash System)[19] was quite radical in a number of ways; it proved that it is possible to build a global system that is not controlled by any one person, corporation or entity and that allows a large numbers of unknown actors to agree upon facts (with the Bitcoin Blockchain that was initially the amount of Bitcoins an address owns, the total amount of Bitcoins in existence at a given time, the rules of the system etc.). An open system; that makes it relatively easy for anyone to read or verify the facts - and only a little more difficult to add new facts or update existing ones.

This is all made possible because of a few key properties:

- Immutability of data.
- No single custodian or steward of the data or system.
- An open, transparent system.
- Incentivisation models.
- Peer-to-peer, decentralised design.

[18] "Blockchain - Wikipedia." https://en.wikipedia.org/wiki/Blockchain. Accessed 15 Apr. 2018.
[19] "Bitcoin: A Peer-to-Peer Electronic Cash System - Bitcoin.org." https://bitcoin.org/bitcoin.pdf. Accessed 15 Apr. 2018.

Introduction to BigchainDB

The early blockchain systems such as Bitcoin and Ethereum[20], and a vast majority of the ones developed since, make it incredibly expensive to store data “on-chain” in the blockchain[21]; for a number of reasons such as every node in the network has to store all of the data and to prevent centralisation of the blockchain[22]. Since we want to be able to store large amounts of weather data in our blockchain, we decided instead to base our design on a blockchain solution that was designed from the beginning to store large amounts of data. This is why the Thor platform is built on to of BigchainDB.

“BigchainDB starts with a big data distributed database and then adds blockchain characteristics - decentralized control, immutability and the transfer of digital assets.”[23]

BigchainDB is a decentralised, byzantine fault tolerant[24], immutable, high throughput, low latency blockchain that natively supports rich permissioning and data query capabilities.

	Typical Blockchain	Typical Distributed Database	BigchainDB
Decentralization	✓		✓
Byzantine Fault Tolerance	✓		✓
Immutability	✓		✓
Owner-Controlled Assets	✓		✓
High Transaction Rate		✓	✓
Low Latency		✓	✓
Indexing & Querying of Structured Data		✓	✓

Source BigchainDB whitepaper[25]

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[20] "Ethereum.org." https://www.ethereum.org/. Accessed 16 May. 2018.
[21] "Forever Isn't Free: The Cost of Storage on a Blockchain Database." 19 Jul. 2017, https://medium.com/ipdb-blog/forever-isnt-free-the-cost-of-storage-on-a-blockchain-database-59003f63e01. Accessed 16 May. 2018.
[22] "Vitalik Buterin, “A Next Generation Smart Contract & Decentralized ...." http://www.the-blockchain.com/docs/Ethereum_white_paper-a_next_generation_smart_contract_and_decentralized_application_platform-vitalik-buterin.pdf. Accessed 16 May. 2018.
[23] "Features & Use Cases • • BigchainDB." https://www.bigchaindb.com/features/. Accessed 16 May. 2018.
[24] "The Byzantine Generals Problem - People @ EECS at UC Berkeley." https://people.eecs.berkeley.edu/~luca/cs174/byzantine.pdf. Accessed 16 May. 2018.
[25] "Whitepaper • • BigchainDB." https://www.bigchaindb.com/whitepaper/. Accessed 18 May. 2018.

Why we chose BigchainDB over other blockchains

Most blockchains are not designed for storing large quantities of data, even when deployed as a separate private chain. The current paradigm to get around this is instead store large amounts of data in a decentralised file system (such as the InterPlanetary File System) and place the immutable, permanent link to the the the file into a blockchain transaction[26]. The data isn't readable from a smart contract on the blockchain; it only provides a solution of being able to prove that the data has not been tampered with.

Once the data is stored in these distributed file systems, it becomes very unwieldy work with them; without the ID that was given to the file (linked to somewhere in a blockchain) it's quite difficult to retrieve the original data. Every reading from a weather station would become a separate file of which you would need to keep track.

Without a separate (most likely centralised) indexing service constantly reading every file written to the system (and duplicating most of the data), it would be immensely difficult to answer simple questions such as "what temperature was it on the hottest day in August?".

Ultimately, databases (especially NoSQL databases) are designed from the ground up to handle large amounts of unstructured data efficiently and robustly. To achieve what BigchainDB can out of the box with a blockchain such as Ethereum would be much more complex; requiring managing other systems and making sure they all were kept in sync. This would create a much less fault tolerant system.

[26] "IPFS is the Distributed Web." https://ipfs.io/. Accessed 21 May. 2018.

Architecture Overview

Minimum Viable Product

The initial design of the system will be more centralised and simplistic than the desired final state. The initial compromises will allow us to more rapidly prototype, test and get feedback on the platform from partnered organisations and other stakeholders.

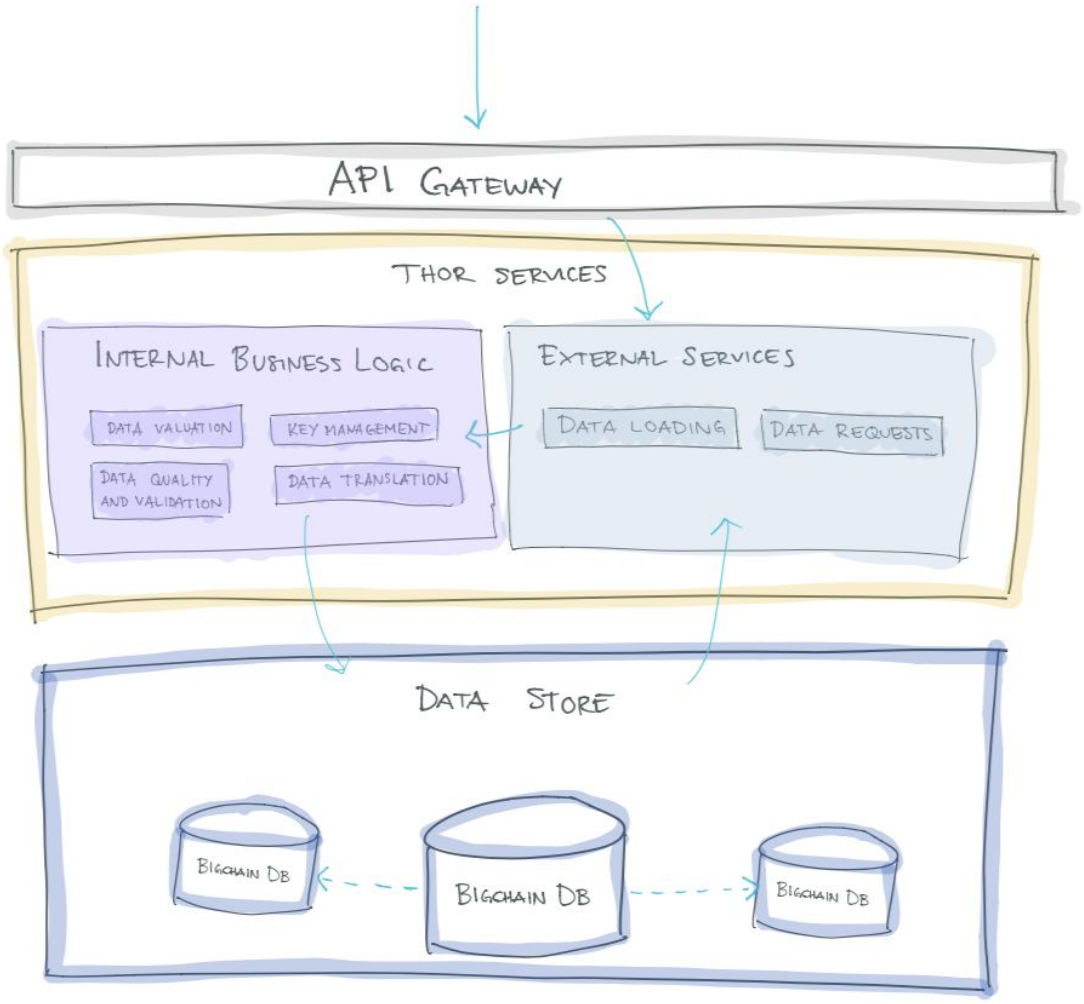

Figure 4.1 High level architecture overview

API Gateway

The **API gateway** removes the initial barriers to entry as well as helping make the Thor platform more robust.

- Users register for API keys (as they would with a non-blockchain system) in order to programmatically interact with the Thor platform. This approach reduces the barrier to entry and has the benefit that it isn't an issue if they lose their API key or don't know how to generate a cryptographically secure private key.

We provide API endpoint matching existing, popular systems, so that uploading data is as easy for the weather data contributor as registering for an API key and slightly modifying the URL that they currently upload data to.

- We have control over the frequency in which users upload or request data from the platform. This helps to prevent against Denial of Service attacks or attacks where users try to fill the BigchainDB with useless data.

Key Custody System

BigchainDB, like other Blockchains, makes use of Public key cryptography[27], which adds a layer of complexity and pushes the extra burden of key management onto the data contributors. To make using the Thor platform easier and more familiar, we manage the private keys for the users in a **key custody system**. This has the substantial benefit that it decouples the key from the weather station identity in the Thor platform. Without this abstraction, if a weather data contributor lost their key then they would no longer be able to submit data for their weather station - and would have to instead re-register the same weather station again; and start from a blank slate and lose access to any tokens earnt.

Data Schema Standard

There currently is not one standard for representing weather data when interacting with existing APIs, so in order to make it as seamless as possible for weather data contributors to upload data to the Thor platform, we **translate the data** to our schema (which we plan to discuss with organisations such as the Met Office to define a standard).

Business Logic

A substantial component of the Thor platform is the **business logic**, this is responsible for

- Performing basic data validation and data quality checks.
- Determining the value of the submitted data.
- Coordinating the internal service such as key management and data translation

[27] "BEPs/13 at master · bigchaindb/BEPs · GitHub." https://github.com/bigchaindb/BEPs/tree/master/13. Accessed 17 May. 2018.

Data Store

We run a locked-down **BigchainDB cluster** on cloud infrastructure, that is currently only accessible through the Thor platform's API.

External Services

We host the following **external services**

- **Data loading** of existing raw weather data and forecasts where it is publically available. This includes scheduled services that reads UK, Norwegian & Swedish weather data (through API calls) on an hourly basis - and stores the data in Thor (through our own API). This has the dual purpose of bootstrapping the data in the blockchain and testing the external facing systems.
- **SMS forecast delivery**. Users can subscribe to have weather forecast, for a specified region, sent to them via text message on a daily basis.
- A **web page** showing weather forecasts, charted raw data and weather station statistics. This can be used by any one to test that data is being loaded and retrieved as expected.
- **Thor weather stations** based on cheap IoT devices to ensure that the end-to-end data uploading process works and continues to do so.

Ultimate Product Vision

The ultimate vision for the technical architecture of the Thor platform is for it to become more decentralised and open; with a wide range of community developed services built on top of it. The Thor platform will also have some of the feature of a Decentralised Autonomous Company - where those with a stake in the system can partake in its governance and help shape the future of the platform[28].

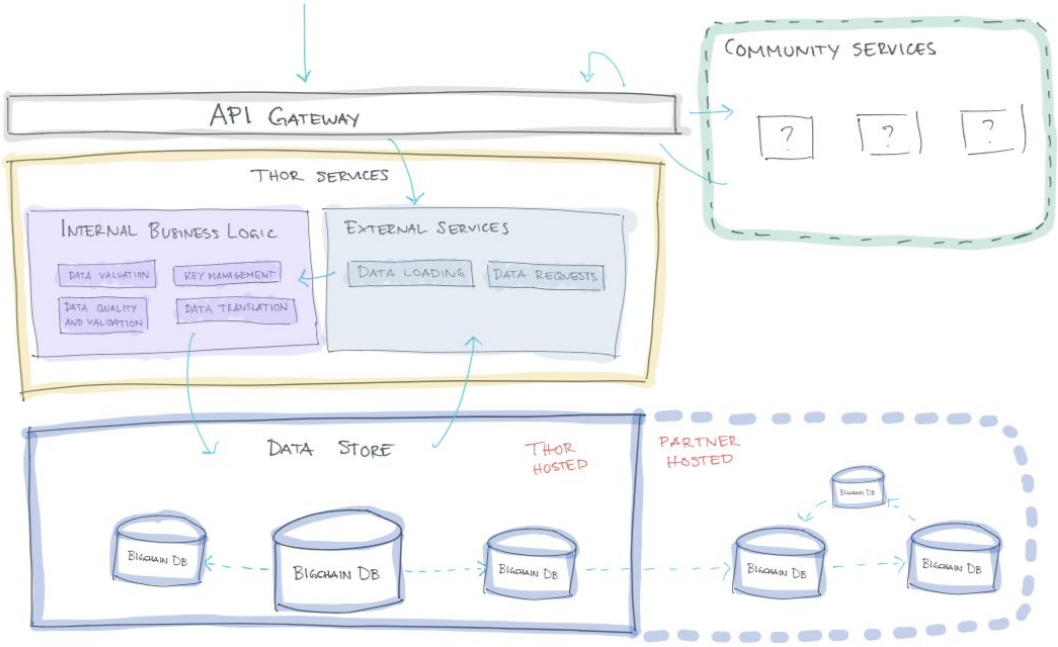

Figure 4.2 Community services added and partners are hosting data

One of the largest changes to the architectural design is the shift to a more decentralised ownership of the platform; where a consortium of stakeholders run Thor full-nodes. Trusted organisations such as Met Offices and government organisations will store some or all of the global weather data by running a node. In doing so they help secure the network. In return they will have direct read access to weather data through their local nodes and be able to use this to provide beneficial weather related services themselves.

There's a conflict between requiring a lot of data to create accurate weather forecasts and the burden of storing all of that data for a long time. We plan to tackle this issue by creating a network topology that is more like a tree of BigchainDB clusters. At the very tip of the tree will be the main cluster where the Golden copy of weather data will be stored; this will be the most coarse grained weather data, but will also be the most reliable - that will be available for years to

[28] "Decentralized autonomous organization to automate ... - Description." https://download.slock.it/public/DAO/WhitePaper.pdf. Accessed 17 May. 2018.

come. Different clusters can fill weather-related data niches - perhaps down to a granularity level of storing the readings from thousands of IoT devices in a city recording weather data every minute. These niche clusters, and the data recorded there, are likely to be short lived with aggregations of the data they have recorded being periodically relayed into the main cluster or clusters further up a tree that could be arbitrarily deep.

The act of submitting proposed aggregations of data from one cluster to another will be a service that can be performed by anyone that is able to run a node in given cluster. There will be incentives to ensure that people are willing to carry out the task and that others are incentivised to ensure these actors don't try to cheat. The **data relayers** will also act to some extent as a **data quality controllers**.

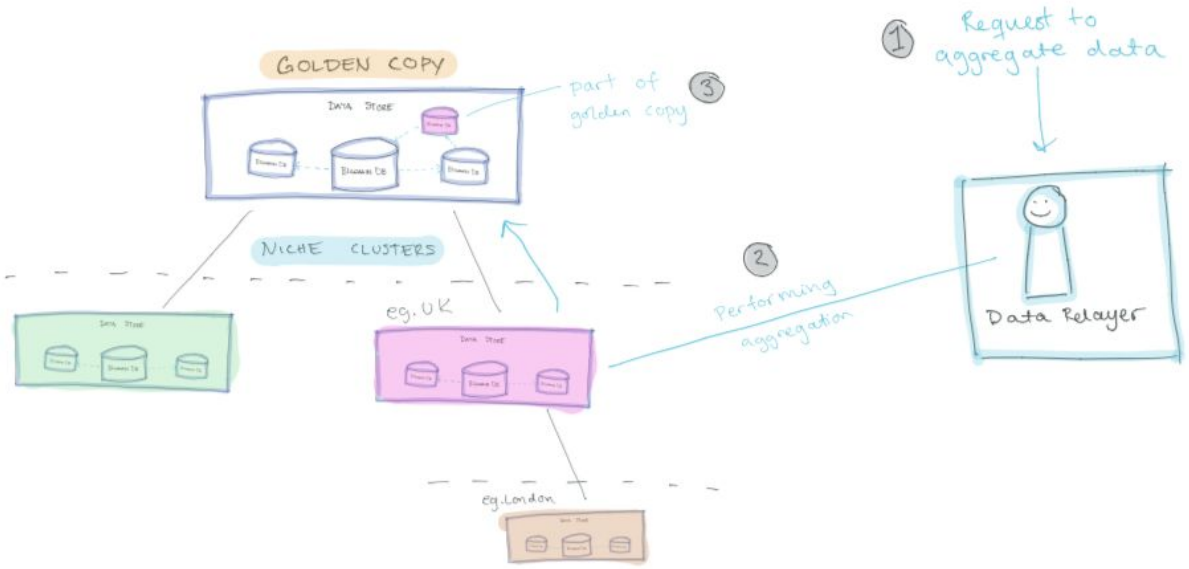

Figure 4.3 Aggregation of data request visualised

As the Thor platform matures and more stakeholders are invested in the project, we plan to move to a **decentralised governance** process. For example, people will be able to put forward proposals for changes to existing data schemas, to support new data schemas (e.g. expanding to storing pollution data), modify system parameters such as the granularity of data stored in the main cluster etc. and stakeholders will be able to vote on them based on their stake in the platform.

Security Considerations

In order for Thor to succeed in our goal of becoming a global store of weather data, we have to take security of the platform very seriously; as well as considering limiting factors of the design.

Potential attacks on the system

- It's possible that a malicious node might try to **modify their local data** in the hope of this propagating throughout the network. Due to the design of BigchainDB, the protocol enforces the immutability of data; any inconsistencies or changes to past data would be ignored by the other nodes[29]. In order for this sort of attack to work, an attacker would need to have compromised over 1/3rd of the nodes[30]. We plan to mitigate this by partnering with trusted organisations to run Thor nodes to secure the platform.
- It's possible that an attacker might try to shut down or Denial of Service (DOS) attack nodes to cause **loss of data.** Since data is replicated throughout the network as long as one node is still running then it could be used to bootstrap new nodes that replace the failed ones[31]. Similarly the decentralised nature of the platform means that if one node is unresponsive (due to a DOS attack) that the data can be re-sent to a different, responsive node on the system and the outcome will still be the same.
- A malicious actor might try to bloat the blockchain by **spamming** lots of data. We can tackle this in a few ways, the Thor nodes can throttle the amount of transactions that they accept from a given weather station, the rewards that, that node gets could be reduced to zero; decentralised governance mechanisms could be put in place where if a majority of the nodes and stakeholders decide that the data is not valuable then it could be removed by forking it out of the blockchain.

Potential Limiting factors

- The Thor nodes become overloaded by **large data queries**. BigcainDB offer the following solution to this problem: "one can create a follower node: a node with Tendermint voting power 0. It would still have a copy of all the data, so it could be used as read-only node. A follower node could offer specialized queries as a service without affecting the workload on the voting validators (which can also write)."[32]
- It is possible that BigchainDB might **not scale to support enough 'transactions per second'** to meet demand (that the platform can't store data quickly enough). Big Data databases are proven to scale linearly with the number of nodes and whilst BigchainDB

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[29] "How BigchainDB is Immutable — BigchainDB documentation." http://docs.bigchaindb.com/en/latest/immutable.html. Accessed 18 May. 2018.
[30] "Tendermint: Consensus without Mining." https://tendermint.com/static/docs/tendermint.pdf. Accessed 18 May. 2018.
[31] "How BigchainDB is Decentralized — BigchainDB documentation." http://docs.bigchaindb.com/en/latest/decentralized.html. Accessed 18 May. 2018.
[32] "Querying BigchainDB — BigchainDB documentation." http://docs.bigchaindb.com/en/latest/query.html. Accessed 17 May. 2018.

is based on a Big Data database the limitation is with the Tendermint consensus mechanism. It is possible that Tendermint can scale to thousands of transactions per second, however, if this is not enough to meet the demand then the architecture of a tree of clusters with relayers can be used to solve provide more capacity.

Impact Measurement

Our aim is to create a global weather system that anyone can participate in to use, store and distribute weather data. We believe that weather should not be siloed by big entities, and that weather data should not stop at borders. The undeveloped parts of the world count for most of our agricultural landscape and with that in mind, we want to begin working with these countries to start building an infrastructure that will aim to educate and improve the lives of those that depend on weather for their livelihood. We aim to work directly with communities within those parts of the world to pilot Thor and follow a “lean startup” method that will undergo quick failures to learn from and improve our service. To do all of this, we will need to partner up with grass-roots organisations whose values are aligned with our own and build relationships with decision makers like governments and banks.

We understand that this is, by no means, an easy task. We’re going to need all the help we can get, whether it be in the form of advisory boards that have a heavy influence or hiring experts within the field that can propel our impact goals. We want to start slow and work in countries with little to no infrastructure, as these are the areas that will reap the most benefit from our platform.

Impact to people and nations

- We want to incentivise and support the deployment of weather stations in areas that are currently under-served - such as most of Africa. Potentially, providing monetary value to those that really need it.
- Farmers will be able to better utilise their land thanks to more accurate weather forecasts
- Governments will be able to better predict disease outbreaks and floods
- Farmers able to plan around getting produce to the market. And governments arranging better shipping and plane exports
- Help nations tackle disease outbreaks
- Help improve a nation's GDP
- Save lives
- Save billions of money in food loss and infrastructure damage

Impact on weather data

- Transparency
- Borderless
- Accuracy
- Reliability
- Unified

Key Indicators

1. Increased food production
2. Increase in GDP
3. Decreased number of deaths
4. Increased weather forecasting accuracy
5. Decreased crop damage

Getting feedback from data providers, data readers and farmers will be an essential part to our decision making and will have profound indications on our product roadmap. There are a number ways in which we would like to collect customer feedback. Below are our a few methods we would like to implement

SMS Questionnaires/Surveys

Seeing that we will be piloting in developing parts of the world, there are very few that have access to internet or smartphones, however, most do have mobile phones connected to a GSM network. We intend to make use of that by sending out questionnaires via SMS. Users will only have to reply with numbers or letters.

Users will also be able to text us any feedback they may have and we will aim to solve their issues promptly.

Email Surveys

Using services like SurveyMonkey, we can send out regular links to our customers in more developed countries. We will aim to keep it short, ask only the questions that we'll use and start with open-ended questions.

Customer Interviews

Every quarter we will aim to conduct customer interviews to get an more in depth analysis of our users experience. Nothing beats actually talking to your target audience. If necessary, we will have local translators to come with us to deal with language barriers. The quality of data will be much better than surveys and will allow us to get deeper, more emotional insights that can be used to create campaign-changing tests.

We'll be able to understand:

- How customers really using our service
- Their barriers to making a purchase
- The deeper emotions motivating our customers

User activity from our own Analytics

Using customer analytics we will be able to see the activity of individual people. This type of data will enable us to make informed decisions if users are finding enough value from using our services. Those that are not finding enough value can be contacted directly to try set up a meeting to discuss or we can send out a survey to better understand why.

When we're filtering through all this feedback, we will be looking out for trends. This is because some of the feedback we receive will come out of nowhere - from customers who were trying to do something undiscovered that an adjustment might get in the way of the rest of our customers. We will reach out to the users who follow a similar trend and get a deep understanding of what they're trying to do and then build something that will make it happen.