



UCL

UCL Centre for Blockchain Technologies

Discussion Paper Series

Q2 2020



Foreword

Here we are with the second run of our discussion papers series. This time we decide to have it focused on something that has affected all our lives in recent months: COVID-19. We are all conscious that blockchain could offer solutions to a large range of issues in this environment, from secure tracking to anonymization solutions.

In this series issue, we report one paper addressing smart contracts and how to devise tolls within the blockchain environment to make them flexible and adaptable to black swan events. We all recognize that the interface between technology, law and society must be soft and adaptable, however technology is excellent in the precision of execution, less so in flexibility and interpretation. We believe this paper by Niall Roche and Alastair Moore is an excellent contribution to progressing the debate in a direction that we encourage many to explore.

Interestingly, the peak of the COVID-19 pandemic has seen little adoption of innovative approaches and new technologies with a strong reliance on poor performing but consolidated methodologies. At the same time, the lockdown has given a chance to individuals to deepen their understanding of new topics and has created a new technology-enabled space for the community to come together with innovation. Now, it is the time when this underground work is emerging with ideas and solutions that will pave our way ahead.

Enjoy your reading

Tomaso Aste

UCL CBT Scientific Director & Chairman of the Editorial Board

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Acknowledgement

The editorial board wishes to thank Anna Gorbatcheva for her high-quality work and strong perseverance, without which this discussion paper series would have never been possible.

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Oraclised Data Schemas: Improving contractual Certainty in uncertain Times

Niall Roche & Alastair P Moore

Editorial Board



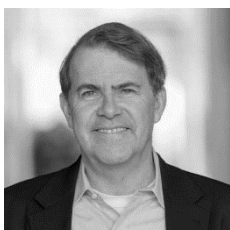
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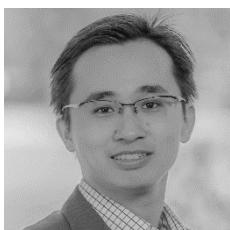
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Discussion Paper

Oraclised Data Schemas: Improving contractual certainty in uncertain times

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Disclaimer

Any opinions expressed here are those of the author(s). Research published in this series may include views on policy, but the department itself takes no institutional policy positions. This paper can represent preliminary work and are circulated to encourage discussion. Citation of such a paper should account for its provisional character. A revised version may be available directly from the author.

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1. Abstract

The rapid spread of the COVID-19 pandemic and the resulting government restrictions to individuals and selected business sectors has caused unprecedented interruptions and uncertainty. The scale of this disruption is manifest in the changes in GDP figures. According to the Office of National Statistics[23], the UK GDP fell by 20.4% in April 2020, which is in line with the predictions of the OECD for advanced economies. The OECD predicted the overall direct initial hit in many major advanced economies' GDP to be between 20-25% [3]. This has had serious financial consequences not only for the affected sectors, but also the firms that insure and underwrite different types of economic activity.

Furthermore, as current restrictions are lifted in response to reduced infection risks and changing policy, there is a need for parties to be able to enter into agreements where the trading environment may be subject to rapid change. If a sector is restricted again in response to changing infection rates, it may be necessary for contracts to explicitly deal with temporal conditions that are applicable at local or regional level. Examples might include a commercial lease based on turnover or a service level agreement based on supply of goods restricted by closing a manufacturing facility.

In this paper, we set out an approach to adaptable contract clauses based on different data sources. Our approach uses i) an *oracle* to serve data from designated sources relating to COVID-19 and the trading restrictions that are in force ii) a schema to represent the data structures and a methods for parsing the data, and iii) a legal lexicon for integration into smart contracts. In combination, these can be used to develop dynamic legal agreements that can adapt to *black swan* events such as pandemic and a range of dynamic regulatory restrictions. This paper presents details of our implementation of an oricalised data schema and discusses future developments of the system.

Keywords: *Blockchain oracle, smart legal contracts, adaptive legal agreements*

2. Introduction

The COVID-19 pandemic¹ has caused widespread uncertainty for people and small businesses, who feel the financial impact of the pandemic due to supply chain issues, government restrictions, reduced customer footfall, and spending power. It is difficult for parties to agree the details of contracts in this environment of uncertainty. This uncertainty could come in the form of new government policy, a new intervention measure introduced to counter changes in the rate of infection and transmission or general economic unpredictability.

Legal agreements are, in many cases, not well equipped to respond to changing restrictions and legislation. Simple examples of parameterised contract might reference a single source of data, for example a base interest rate of a specified bank but in general contracting clauses are not responsive or revised once memorialised.

For example, in response to the pandemic recent UK government legislation and the UK Law Society guidance² has required changes to the liabilities and penalties related to house purchases³ where the proposed solution can be used to determine when the restrictions were lifted by the government to allow real estate related transactions as the revised regulations refer to clauses surrounding the date of lifting of restrictions plus 30 days to be an important part of revising the contract.

There is a need for reliable information that can be used to guide and govern contractual obligations and performance to mitigate risk. Examples include tenancy agreements, insurance contracts and business interruption (BI) insurance and there are instances where they are not clear and comprehensive in the handling of the current situation. The adoption of local and regional restrictions that adapt based on local infection rates and risk factors mean that contracts need to be adaptive to their environment. To be effective, these contracts need

¹https://en.wikipedia.org/wiki/COVID-19_pandemic

²<https://www.lawsociety.org.uk/support-services/advice/articles/coronavirus-covid-19-information-for-members/>

³<https://www.lawsociety.org.uk/support-services/advice/articles/coronavirus-covid-19-and-residential-conveyancing-transactions/>

to have a trusted source of data, an agreed data schema, and a legal lexicon that can add clarity to legal agreements. The combination of these elements can lead to a fair and transparent set of legal agreements that can add clarity to an uncertain future.

We propose an integrated approach to improving the current approach by:

1. Define a universal standard of legal lexicon that will help provide increased levels of guidance and clarity in interpreting contracts in a fast-changing environment.
2. Building an open source set of data standards to govern crises related reporting. This could include regional number of deaths, infections, beds used by hospitals or transmission rates, in addition to government restrictions on certain types of businesses.
3. Create a method to reduce interpretation issues with contracts affected by a crisis such as a pandemic. Automation of aspects of legal agreements, using smart contracts, can improve their ability to be adaptive and dynamically adjust obligations in the agreement based on information from a trusted third-party.

This paper sets out to unite a number of these concepts into a cohesive set of elements that can form a trusted set of data sources that are collected, aggregated, and verified. Then, they are made available on distributed platforms such as IPFS⁴ and published into a data trust models such as Ocean Protocol⁵. Our approach aims to source data from multiple trusted sources and make available for a range of potential data consumers, including smart contracts.

A platform such as Ocean Protocol is useful for sourcing data and algorithms to process the data, such as NLP models to extract data into a standard schema for use by contracts. The current implementation developed uses the Provable[34] platform, but the intention of the authors is to explore other options such as Chainlink⁶, and algorithms that run inside Ocean Protocol or SingularityNET⁷ to act as a trusted source.

⁴<https://ipfs.io>

⁵<https://oceanprotocol.com>

⁶<https://chain.link>

⁷<https://singularitynet.io>

These contracts can run on a range of permissioned and permission-less Distributed Ledger Technology (DLT) systems. An implementation for Hyperledger Fabric⁸ is available, with Ethereum⁹ planned to follow. As part of the Open Source Accord Project¹⁰, the sample legal smart contract has been developed. The sample pandemic policy contract that can use data returned from the initial oracle and the DLT code are listed in public repositories detailed in Appendix B.

2.1 Impact of COVID-19 and Insurance

As estimated by the OECD [3], the financial impact from the pandemic on GDP is typically between 20-25% in many major advanced economies. In the UK alone, GDP fell by 20.4% in April 2020¹¹. The long term impact of the pandemic and the likely resulting economic downturn is likely to have ongoing financial repercussions for years to come.

The pandemic has had a economic impact due to factors such as:

1. Government enforced closures, or limited trading ability, such as restaurants only able to open for take away or delivery
2. Limitations on concurrent customer occupancy, where allowed
3. Reduced customer footfall due to travel restrictions
4. Consumer confidence issues and unwillingness to go outside
5. Lack of consumer spending due to furloughing
6. Ongoing economic uncertainty
7. Supply chain and fulfilment issues

The economic impact on businesses has also being compounded by a lack of clarity in contractual arrangements with parties such as

⁸<https://www.hyperledger.org/use/fabric>

⁹<https://ethereum.org>

¹⁰<http://accordproject.org>

¹¹<https://www.ons.gov.uk/economy/grossdomesticproductgdp/bulletins/gdpmonthlyestimateuk/april2020>

suppliers, landlords, customers, and insurers leading to ongoing risks for businesses.

In particular, the insurance industry has been slow to respond to the fallout of COVID-19 with a number of high profile news reports¹² and legal challenges^{13 14} being taken against insurance companies that are not paying compensation, despite indications that their policies consider pandemics¹⁵. Lack of clarity from regulators and government has worsened the situation with COVID-19. Even where clarity has been provided, there is still ambiguity in contractual commitments¹⁶.

On 5 March 2020, the Government added COVID-19 to the list of 'notifiable diseases' under the Health Protection (Notification) Regulations 2010¹⁷. According to the Department of Health and Social Care, this was to help companies seek compensation through their insurance policies for losses arising as a result of the pandemic.

However, despite this declaration, there are ongoing issues. One issue with many agreements, such as insurance policies, are references to compensation not being applied when a force majeure event occurs. In English law, there is no agreed meaning or legal doctrine of force majeure, which is why it is always so heavily debated¹⁸.

Aside from insurance issues, the impact has several secondary effects. For example, government-mandated, enforced business closures or restrictions. Another example is the reduction of operating capabilities and consumer demand. The economic impact on businesses influences their ability to make rental payments and other obligations. While government schemes, such as business rate freezing and staff furlough schemes, may help, the reality is that many businesses will struggle to make rental payments.

¹²<https://www.oecd.org/finance/Initial-assessment-of-insurance-coverage-and-gaps-for-tackling-COVID-19-impacts.pdf>

¹³<https://www.insuranceage.co.uk/insurer/7512706/covid-19-hiscox-under-fresh-attack-for-back-tracking-on-bi-claim>

¹⁴<https://www.insurancebusinessmag.com/uk/news/breaking-news/fca-offers-latest-in-covid19-business-interruption-test-case-224883.aspx>

¹⁵<https://life.spectator.co.uk/articles/COVID-19-has-exposed-the-hypocrisy-of-insurance-companies/>

¹⁶<https://www.abi.org.uk/news/news-articles/2020/03/statement-on-business-insurance-and-coronavirus/>

¹⁷<https://www.gov.uk/guidance/notifiable-diseases-and-causative-organisms-how-to-report#list-of-notifiable-diseases>

¹⁸<https://www.bmmagazine.co.uk/legal/a-force-to-be-reckoned-with/>

Many existing rental agreements do not take these types of considerations into account and given the complexity of business closures, partial closures, local infection rates and restrictions, there is a need for flexibility in repayment arrangements to reflect the reality of the impacts these businesses are facing. A dynamic lease agreement that takes into consideration local restrictions through adjusting of payment arrangements by updating rental amounts, payback duration or freezing repayments during closure periods, or moving to a percentage of turnover model, could be considered with a sufficiently agile and accurate set of data points and smart clauses.

This type of construct already exists. For example, there are parametric flood insurance policies¹⁹ - so when water rises above a certain threshold and hits a sensor, the insurance policy becomes effective and pays compensation. In this case, the compensation involves a small degree of due-diligence to be performed and a time window for false positives while there are some restrictions, nevertheless, it is a positive move forward in the industry towards automatic detection and settlement.

There is a natural fit with this type of automated process and DLT-based solutions. As outlined in [47], there are three elements that need to be trusted in a transaction, the counterparty, the intermediary and the dispute resolution mechanism. DLT can be used for all three. Emerging decentralised solutions include Etherisc[32] and NexusMutual[28]. They provide automated compensation for flight delays, flood damage, hurricane and crop damage according to weather report and a satellite image from decentralised geospatial data providers such as FlyingCarpet²⁰ and potentially Earth Observation[4]. Etherisc has already made a payout to smallholder farmers in Sri Lanka when extreme weather conditions occurred²¹. Decentralised dispute resolution is also maturing with approaches like Kleros²² and Mattereum²³, amongst others.

¹⁹<https://floodflash.co>

²⁰<https://www.flyingcarpet.network>

²¹<https://www.artemis.bm/news/blockchain-based-parametric-weather-insurance-in-first-payouts/>

²²https://kleros.io/whitepaper_en.pdf

²³https://mattereum.com/wp-content/uploads/2020/02/mattereum-summary_white_paper.pdf

3. A Schema to represent COVID-19 Data

We define a schema for representing unprecedented events, such as COVID-19, to enable clauses to be written with these types of events in mind. It is hoped that this initiative will reduce cost and disruption associated with contracts that are impacted by events, such as the ones in the following non-exhaustive list of force majeure events:

1. War, terrorism, and civil unrest
2. Industrial disputes
3. Financial crashes
4. Natural and climate events such as earthquake, storm, fires and flooding
5. Health crisis, including future pandemics

There is no clear universal legal lexicon to describe these events. So, without a formal definition and data representation, it is challenging to reason with them from a contract perspective. While it is difficult to attempt to define all potential types of unexpected events, the authors propose an initial set of vocabulary to start to capture a set of potential force majeure events.

The authors have built on existing representations in use and have adapted the <http://www.schema.org> definitions of SpecialAnnouncement¹ to use as a base for describing events such as a pandemic. Given that there have been a number of pandemics in recent years (SARS, MERS, Ebola), there is a specific definition for each event including the novel coronavirus COVID-19². Both Google³ and Microsoft⁴ have added support for metadata added to websites using this format to appear in search results. An online

¹<https://schema.org/SpecialAnnouncement>

²<https://www.wikidata.org/wiki/Q81068910>

³<https://developers.google.com/search/docs/data-types/special-announcements>

⁴<https://www.bing.com/webmaster/help/special-announcement-specifications-5cbd6249>

tool is available to assist website developers in creating data that confirms to the schema ⁵.

The schema specifies mechanisms to refer to RSS feeds and on-line sources related to these types of SpecialAnnouncements. These links can point to official sources such as the WHO⁶, but also to local government sources such as school closures ⁷. There are also specific structures for travel bans⁸ and transport closures ⁹. Below is an example SpecialAnnouncements to illustrate diseaseSpreadStatistics.

```
1 {
2   "@context": "http://schema.org",
3   "@type": "SpecialAnnouncement",
4   "name": "2019 Novel Coronavirus (COVID-19) in
      Washington",
5   "datePosted": "2020-03-19T10:00:00Z",
6   "url": " https://www.doh.wa.gov/emergencies/coronavirus
      ",
7   "category": "https://www.wikidata.org/wiki/Q81068910",
8   "spatialCoverage" : {
9     "@type": "State",
10    "name": "Washington"
11  },
12  "diseaseSpreadStatistics" : {
13    "@type": "Dataset",
14    "name" : "Confirmed Cases / Deaths by County",
15    "description" : "The number of confirmed cases and
      deaths for each county in Washington State.",
16    "distribution" : {
17      "@type": "DataDownload",
18      "contentUrl": "http://example.gov/coronavirus-
      cases.csv",
19      "encodingFormat" : "text/csv"
20    }
21  }
22 }
```

Data structures for referencing datasets in the schema include:

⁵<https://classyschema.org/SpecialAnnouncement>

⁶<https://www.who.int>

⁷<https://schema.org/schoolClosuresInfo>

⁸<https://schema.org/travelBans>

⁹<https://schema.org/publicTransportClosuresInfo>

1. <https://schema.org/Dataset>
2. <https://schema.org/Observation>
3. <https://schema.org/DataFeed>

A List of pertinent Schema Elements include:

Closure notice	an indication of closure of a business or amenity
Quarantine guidelines	a set of recommendations for quarantine
Travel restrictions	a list of restrictions on travel
Announcement of revised hours and shopping restrictions	a set of restrictions on trading hours permitted
diseaseSpreadStatistics	a dataset relevant to tracking the spread of the virus
LocalBusiness	business types referred to
SpacialCoverage	smaller geographical region or local area referred to
CivicStructure	relevant for services and amenities such as libraries that are referred to
PhysicalActivity	relevant for businesses such for gyms, sports, and recreational activities
LeisureTimeActivity	relevant for recreational restrictions such as cafes bars and public meetings
OccupationalActivity	relevant for occupations impacted such as barbers, hairdressers etc.
ActionAccessSpecification	a group of requirements that a must be fulfilled in order to perform an Action
eligibleRegion	geographical region referred to
availabilityEnds	can represent a time period for restrictions to ease
availabilityStarts	can represent a time period for restrictions to start

3.1 Schema Limitations

The above data schema elements provide the basis of a structure defining sources of information and representation mechanisms for consumption by interested parties. However, the main issue is that while the schema is good at providing a structure for categorisation and referencing a set of relevant data, it does not define the structure of the data it is referencing. This data can be in unstructured, or semi-structured HTML or structured formats such as CSV, XML or JSON, but with no universal schema to describe the content.

While this is a good start, however, it is not a complete solution because the data returned from these sources needs to be processable by the Lexicon understood by end consumer of the data. Given that there are multiple data structures used by each provider, for example in the US alone there are different structures used between states and at a national level, there is a need to amend the data into a single structure before processing. In addition, in a large dataset, the data required may be a tiny subset of the overall data. For example, the total number of deaths in a specific time period may be only required rather than the breakdown per region per day over a long time period, which is what the raw dataset may contain. These are significant issues. As [20] and [29] describe, Smart Contracts are generally limited in processing capability, and, in the case of a permissionless system such as Ethereum, incur gas costs for processing time used. Also, as new sources of data are added, the parsing logic would need to be updated, requiring modifying the Smart Contract code, something that is at worst, not possible, and at best, not practical and cost effective. Even in a permissioned setting, the impact of the additional processing would have an impact on the overall performance of the system and the ability to test and maintain it.

To handle the parsing and filtering complexity and management overhead of maintaining ingestion of the raw data sets, and the various error conditions that could happen, an intermediate processing step is required. The authors propose a type of middleware approach towards solving these practical issues with the complexity of data aggregation, processing, and validation being handled at the oracle level, rather than at the client. The raw data files are processed into a schema depending on the needs of the *consumer*, with a far smaller and simpler scheme used to transfer the data needed, in the correct format, to the consumer.

In the proof of concept implementation we have provided the following five schema:

1. A schema to represent the number of confirmed cases and deaths
2. The 'R' rate - the virus reproduction rate
3. The UK Alert Level as published by the Joint Biosecurity Centre (JBC)¹⁰. At the time of writing, there was no published version of this at a regional level because the JBC was in the process of being setup
4. The list of business closed as published in government COVID-19 legislation¹¹
5. A schema to indicate if a pandemic has been officially declared

For brevity data sources and the full schema are available in Appendix C and Appendix D. The descriptive schema and DataFeeds, Observations and Datasets linked, both in raw format and processed variants after data extraction are stored in IPFS and can be published in platforms such as Ocean and Singularity. Depending on the use case and the consuming smart contract platform, data can be retrieved directly from hosted Endpoints, or via oracle platforms such as Provable¹², or Chainlink to proxy the data from hosted endpoints or where possible, retrieved from these decentralised platforms.

Bindings from the schema into Smart Contract/Chaincode languages such Solidity¹³ Vyper¹⁴ (Ethereum) or Kotlin¹⁵ (Corda) Go/Node JS (Hyperledger Fabric) will need to be created to facilitate use of the data along with the logic that uses the data. The current code base has a starting point for this in the Hyperledger Fabric implementation using Provable and also contains an Accord Project legal smart contract in the Ergo¹⁶ programming language as reference that can receive inputs from data retrieved according to the schema and a Lexicon with which to process the returned data. We intend to add additional bindings to future platforms too, and contributions and collaborations are welcome.

¹⁰<https://www.instituteforgovernment.org.uk/explainers/joint-biosecurity-centre>

¹¹<https://www.gov.uk/government/publications/further-businesses-and-premises-to-close/further-businesses-and-premises-to-close-guidance>

¹²<https://provable.xyz>

¹³<https://github.com/ethereum/solidity>

¹⁴<https://github.com/vyperlang/vyper>

¹⁵<https://kotlinlang.org>

¹⁶<https://www.accordproject.org/projects/ergo/>

4. Data Sources

The data sources examined by the authors includes a range of government and health organisations at a global and national level, with a view towards using regional sources such as local authorities and health providers in a wider, non-UK specific framework. Some of the data sources explored include:

1. <https://github.com/owid/covid-19-data/tree/master/public/data>
2. <https://covid19.who.int/>
3. <https://ourworldindata.org/coronavirus-source-data>
4. <https://ourworldindata.org/coronavirus-testing>

The Health Protection (Coronavirus, Restrictions) (England) (Amendment) (No. 2) Regulations 2020 is a Statutory Instrument from the UK government that outlines the legislation relating COVID-19 restrictions¹. These SI documents contain information about statues of law and updates in a live document available in XML² and RDF³ formats, making them good candidates for effective parsing.

We took a snapshot of the regulations impacting businesses in the UK at the time of writing this paper, when restrictions were about to lift. The restrictions in some case were starting to lift in certain sectors and regions, with Scotland and Wales continuing to having more restrictions in place than England. Government indications are that restrictions may be enforced, or relaxed, depending on the infection rate and population characteristics. The UK government announced a pandemic alert level, that would give an alter rating, depending on local conditions but this serves to highlight the fractured and non-uniform nature of the data that is pertinent to these types of contractual obligations.

¹<https://www.legislation.gov.uk/uksi/2020/500/regulation/2/made>

²<https://www.legislation.gov.uk/uksi/2020/500/regulation/2/made/data.xml>

³<https://www.legislation.gov.uk/uksi/2020/500/regulation/2/made/data.rdf>

COVID Alert Levels		
Level	Description	Action
5	As level 4 and there is a material risk of healthcare services being overwhelmed	Social distancing measures increase from today's level
4	A COVID-19 epidemic is in general circulation; transmission is high or rising exponentially	Current social distancing measures and restrictions
3	A COVID-19 epidemic is in general circulation	Gradual relaxing of restrictions and social distancing measures
2	COVID-19 is present in the UK, but the number of cases and transmission is low	No or minimal social distancing measures; enhanced testing, tracing, monitoring and screening
1	COVID-19 is not known to be present in the UK	Routine international monitoring

Figure 1: The UK Pandemic Alert Levels^a

^ahttps://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/884352/slides_-_11_05_2020.pdf

The dynamics of the current situation makes the process of tracking what businesses can open, for what purpose, in which region, and subject to what restrictions may adapt on a daily or weekly basis. Responding to this new reality will require a step change for several industries, requiring a comprehensive strategy involving legal agreements that adapt to the changeable business environment.

It is assumed that there will be a need for some manual verification of the data initially, until reliable ML models can adequately cope with this data, or the data providers provide a more structured data representation. Where this is the case, the proposed solution records the original source data used, so where there has been manual data wrangling where natural language processing (NLP), heuristics, string manipulation, and approaches such as regular expressions and XPath fail and a human needs to adjust data manually into a valid schema definition. In these cases, there is still a clear audit trail back to the source data and the deviation between the automated outputs and validated human outputs can be seen. In these types of cases a regulator, or stakeholder with oversight, such as the Law Society in the UK (or an international equivalent), can validate these types of changes for full accountability. A full list of these data sources and the schema defined to represent the data is included in Appendix C.

4.1 Oracles

Ensuring trust in data provided for processing in agreements is a central tenant of the proposed approach. We propose a system of trust to validate data from a number of providers and ensure trust through the entire chain into execution of the legal agreements. Typically, in a trust-less DLT system an external provider of truth is referred to as an *oracle*. The oracle concept has been discussed in relation to a number of blockchain solutions including [7]. This concept is at the core of the proposed approach.

Some potential uses of oracles as outlined in [10] and [15] include:

1. applications that need a good source of randomness e.g. in determining the winner in a game of chance such as [21] [43] [33]
2. connecting to data feeds from a third party conveying the latest currency conversion rates and for sports and financial markets prediction markets such as [45], Hivemind (formerly TruthCoin)[42], Gnosis[24], PDFS[25] and Augur[9], [22] (acquired by Chainlink⁴)
3. networked to devices such as temperature sensors for certain types of agriculture and supply chain contracts such as [1]
4. as outlined in (insurance section) part of parametric insurance agreements (list the solutions below) [16]

4.1.1 Oracle and Trust

We proposed approach builds on the oracle concept by proposing a set of components that collect, aggregate and validate data from disparate sources, then packaging it in an agreed scheme that allows it to be used in a Lexicon outlined in a range of automated contracts. The project provides flexibility in the deployment of these components in exiting oracle platforms, proving transparency and an audit trail of data as it is sourced, processed, delivered and consumed.

⁴<https://www.forbes.com/sites/darrynpollock/2018/11/01/cornells-town-crier-acquired-by-chainlink-to-expand-decentralized-oracle-network/#918a32728543>)

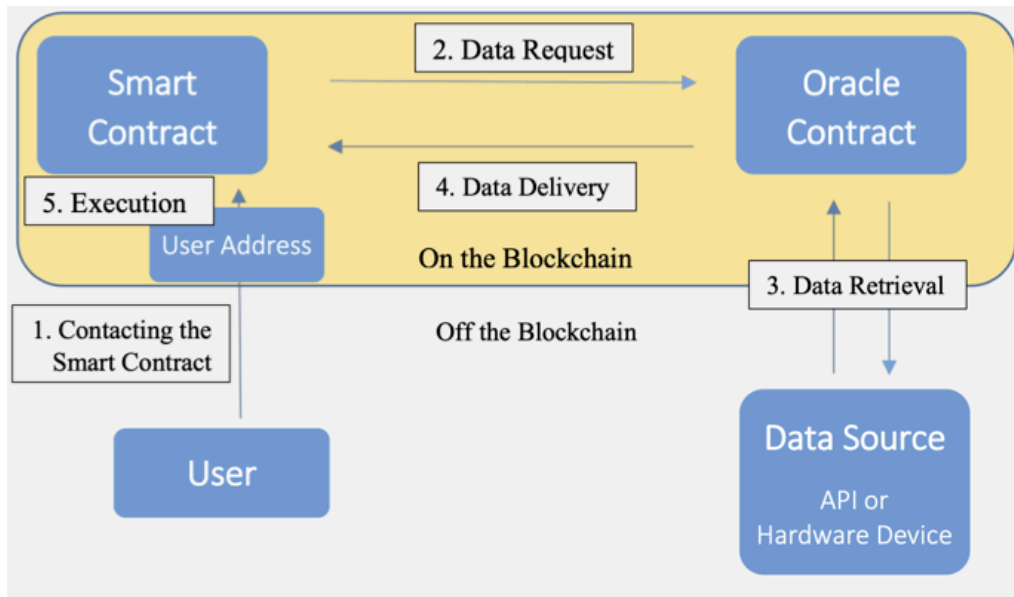


Figure 2: Automated oracle structure [10]

Many DLT solutions function as closed-system, where trust is provided by the security of the underlying architecture and consensus mechanisms or what is often referred to as *trust by computation* [8] and providing *trustless trust* [26, 46].

While trust is provided at a peer-to-peer level it is restricted to accessing on-chain data and communicating with peer nodes. As described in [20] smart contracts and DAOs⁵ need exit-points of interaction with the outside world, this can be facilitated using oracles to record information from the physical world. [46] and that information can come from sources such as sensors and IoT devices[1] but also from trusted data providers including humans.

The high level process for off-chain data retrieval and validation of third party supplied data is outlined in Figure 2. Validation of the data retrieved can be achieved by using approaches such as TLSNotary [41] and is an approach used by oracle platforms such as Provable.xyz (formerly Oraclize)[34] and [22] now part of [21]. A comprehensive comparison of Oracle Platforms and the various technology approaches used to ensure trust in each platform can be found in [5].

Oracles such as[11] [27] are protocols that are incentivised as a decentralised network of records to perform computation by rewarding participants who submit results that are closest to the median of

⁵https://en.wikipedia.org/wiki/Decentralized_autonomous_organization

all submitted results and detecting errors. Trust is achieved by the number of validators involved and their economic incentives to provide a truthful and accurate response. These incentives are derived from [37] and based on Nash Equilibrium with oracles that are found to provide inaccurate answers have less influence on future aggregation processes.

Egberts[20] proposes to use oracles to achieve *Verifiable off-chain Computation*. Ensuring the integrity of the output is crucial for trust to be preserved in the system:

Computational integrity implies that a reported response o of a computation C is correct with respect to a request i and dataset S such that $o = C(S)$, ensuring that a prover P correctly reports the output rather than a more favorable output to the prover.[33]

To achieve integrity, oracles generally perform their computation by executing in what is claimed to be a sandboxed environment, in some cases a type of Trusted Execution Environments (TEE) [35] to ensure that the results are not compromised [39] [34] [33] [21]. One approach outlined by the Enterprise Ethereum Alliance⁶ for secure off-chain compute [36] involves using the Intels Software Guard Extensions (SGX)⁷ as it is a set of extensions to the Intel architecture that aims to provide integrity and confidentiality guarantees to security sensitive computation [14]. Whilst a number of vulnerabilities have been identified with SGX as illustrated in [13], [30] and [6]. Another TTE, ARMs TrustZone⁸ is also supported by [21] but also has vulnerabilities⁹ and [12]. [1] have been working on their own hardware implementation of a TEE¹⁰. There have also been issues with oracles and exploits and this topic remains an active research area with further discussion around comparisons of oracle approaches and vulnerabilities to be found in [10], [5] and¹¹ ¹².

⁶<https://entethalliance.org>

⁷<https://software.intel.com/content/www/us/en/develop/topics/software-guard-extensions.html>

⁸<https://developer.arm.com/ip-products/security-ip/trustzone>

⁹<https://research.checkpoint.com/2019/the-road-to-qualcomm-trustzone-apps-fuzzing/>

¹⁰<https://medium.com/iotex/iotex-post-mainnet-roadmap-vita-token-member-portal-avoboard-8eb66e75687f>

¹¹<https://medium.com/fabric-ventures/decentralised-oracles-a-comprehensive-overview-d3168b9a8841>

¹²<https://hackernoon.com/a-discussion-of-the-oracle-problem->

4.1.2 Solution Overview

While sources of data originate from centralised authorities, such as governments and organisations such as the WHO, it is provided in a range of formats and is not always well structured in forms useful for computation and are not reliably archived making it difficult to audit what values were available on a particular date and time. Sometimes this data is published under an Open Data initiative, or from a documented API endpoint. But more commonly, data is available in formats such as XML, JSON or CSV, but in other cases in structured HTML, but sometimes in unstructured HTML representation that is difficult to scrape reliably due to underlying changes. From a smart contract consumer perspective, this type of approach leads to complexity as outlined in [10], [5]. There are practical difficulties for even simple approaches of making a url request and attempting to parse on-chain or even relaying on basic data extraction techniques such as XPath operation, such as would be supported in an oracle such as Provable, or [21].

A more complex solution is necessary both to have a reliable extraction mechanism, and a set of validation tests to ensure that the data format is as expected. This can be an early warning of an issue with the underlying data source being unavailable, or that the structure of the data has changed leading to an extraction issue. The impact of these types of issues needs to be managed to avoid interruption issues or errors in contracts that rely on the data. These types of interactions need to be clearly defined and agreed error scenarios considered, such as *back offs* in the event of reliable data not being available and avoiding scenarios where the output that is processed is really an error message, or some type of text content that is not the valid output, this could have serious consequences when decisions are made on the data returned.

In this case there are data validators that provide processing and validation work of the data retrieved and storage on a network like IPFS. The processing could be the collection and extraction using approaches such as XPath, regular expressions, or more advanced techniques requiring some use of Natural Language Processing (NLP) such

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as information extraction (IE)¹³, NER¹⁴ and question and answering¹⁵ to query the data set. Sharing models trained for the specific purposes of this type of data extraction may require fine tuning existing models such as BERT [17] and [31]RoBERTa and there is an opportunity for the community to provide ML models trained for this purpose. These models can be both trained on data made available on data marketplaces such as Ocean Protocol[33] and SingularityNET[2] and the trained models made available on these platforms too.

Provables *computation-datasource*¹⁶ runs a docker container to execute code and the last line of any console output is returned to the caller. There are some limitations on the size of the process that can be run as it runs in an *AWS Micro Instance*¹⁷, which has computational constraints and is limited to maximum runtime of 5 mins, including setup time. This provides a means of transparency in the code that was run as the container cannot be edited by the caller or by the supplier of the image and provided that the execution environment Amazon AWS and the oracle platform provider Provable are trusted, there is a reasonable level of trust in the code that was run and the output of that code.

We implemented a proof-of-concept implementation outlined in 3 using the Provable *computation-data-source*, this works well for permissionless approaches such as Ethereum, but at the time of development, there was an outstanding feature request for access to the computation data source from the API developed for Hyperledger Fabric¹⁸. The authors reached out to Provable, who responded indicating that access to this type of feature would be available in a premium version of the platform. The authors instead used the Provable URL and IPFS data sources to access the output of data collectors that ran in an *AWS Lambda*¹⁹ environment that executed data collection and storage in IPFS. In addition to IPFS a number of decentralized file storage systems exist and are compared in[44].

There may need to be an incentive mechanism for this activity or covered by regulators such as the Law Society or industry groups and regulators, or consortia of insurance companies. As described

¹³https://en.wikipedia.org/wiki/Information_extraction

¹⁴<https://en.wikipedia.org/wiki/NER>

¹⁵https://en.wikipedia.org/wiki/Question_answering

¹⁶<https://docs.provable.xyz/#data-sources-computation>

¹⁷<https://aws.amazon.com/blogs/aws/new-amazon-ec2-micro-instances/>

¹⁸<https://www.hyperledger.org/use/fabric>

¹⁹<https://aws.amazon.com/lambda/>

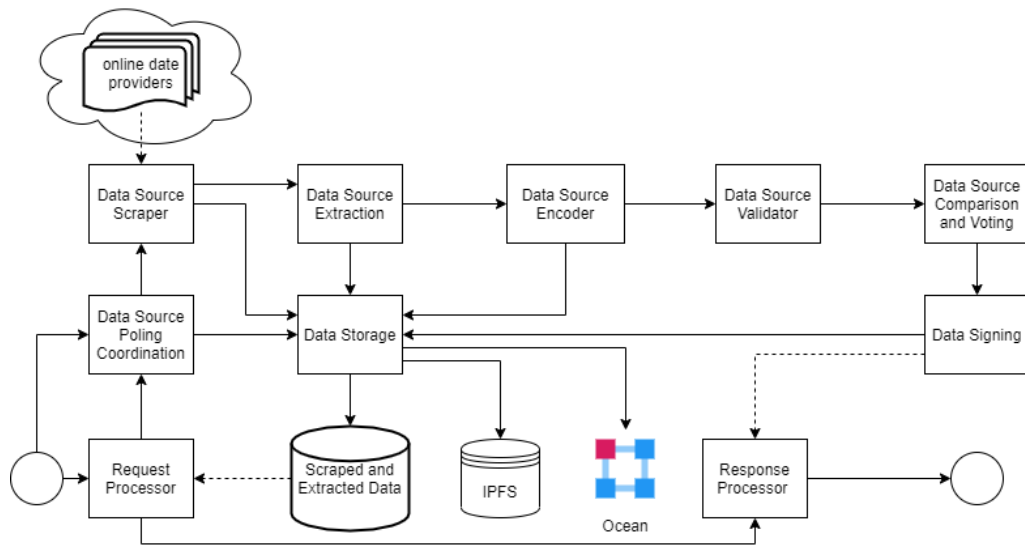


Figure 3: High Level Solution Overview

earlier, the risks of Oracle independence need to be carefully considered and appropriate incentive mechanisms and oversight be employed throughout the process.

5. Architecture

Our approach of separation of components and a layered architecture mean that the proposed solution is portable to a range of data sources, data trusts and DLT platforms. Moreover, while the data outputs are consumable in a range of DLT platforms, Smart Contract platforms and legal smart contract platforms such as Accord. Figure 4 illustrates the high-level proposed architecture.

The proposed solution includes details of data collectors in Appendix B and the schema in Appendix D to manage (a set of) oracle(s) to support smart (legal) contracts that can respond to global events such as:

1. Pandemics (such as COVID-19)
2. Civil Unrest
3. Significant Climate events
4. Natural Disasters

The high-level steps performed can be summarised as:

1. The consumer of the data, e.g. a Smart (Legal) Contract monitors incoming events originated from an oracle
2. A data extractor is defined to source data from one of more networked sources such as a web url or other data feed from official sources or published government legislation
3. The retrieved data is stored in IPFS for future audit
4. The required text or numeric data is extracted using techniques such as rules / heuristics based on the underlying structure of the data. This can include XPath, XML Parsing, JSON parsing, Regular Expressions and using Machine Learning models with NLP

5. The extracted data is embedded in a defined Schema see D for examples so that it be processed effectively by the consuming smart contract
6. the extracted data is stored in IPFS for future audit and for serving to consumers
7. The extracted data is validated against expected parameters to ensure it is within expected ranges, if this fails the data is not returned, but a predefined error response instead. This should ensure that a contract will not get inaccurate data to process, leading to unexpected side-effects and inaccurate outcomes
8. The extracted data is registered in a data trust such as Ocean Protocol for further validation. This data can be useful to other researchers and developers of COVID-19 applications
9. The consumer receives the event and validates the authenticity of the data received and actions the data (e.g. executes certain clauses or logic is invoked with the data received as a parameter

For the initial proof-of-concept the authors selected 5 measures of the spread of COVID-19, see Section 3. As an example, the first Oracle records the number of COVID-19 cases and deaths per month in England. We have implemented a proof of concept smart policy agreement that adapts based on the input of these Oracles. The code is available publicly with detail in Appendix B and more details on the proof-of-concept can be found at ¹ and ². The trigger parameters used are set out in Table 5.1.

¹<https://challenge.globallegalhackathon.com/gallery/5ec84aef202da60044c03d6b>

²<https://devpost.com/software/covidhack-oracle-provable>

Oracle	Triggers and Clause
1	[number of cases] published by Public Health England Oracle 1 records more than [minCases] cases per [cases-TimePeriod]
2	[legislation] published by UK Government Oracle 2 records that [businessType] must not open [at all]/[other than for takeaway]
3	[whether pandemic exists] published by the World Health Organisation Oracle 3 records that there is a pandemic in [affectedRegion]
4	[total number of deaths] as published by NHS England Oracle 4 records more than [minDeaths] deaths per [deathsTimePeriod]
5	[pandemic alert rating] in [London] as published by the Joint Biosecurity Centre (JBC) Oracle 5 records a [pandemicAlertLevel] rating of more than 3

Table 5.1: Summary of Clauses and triggers

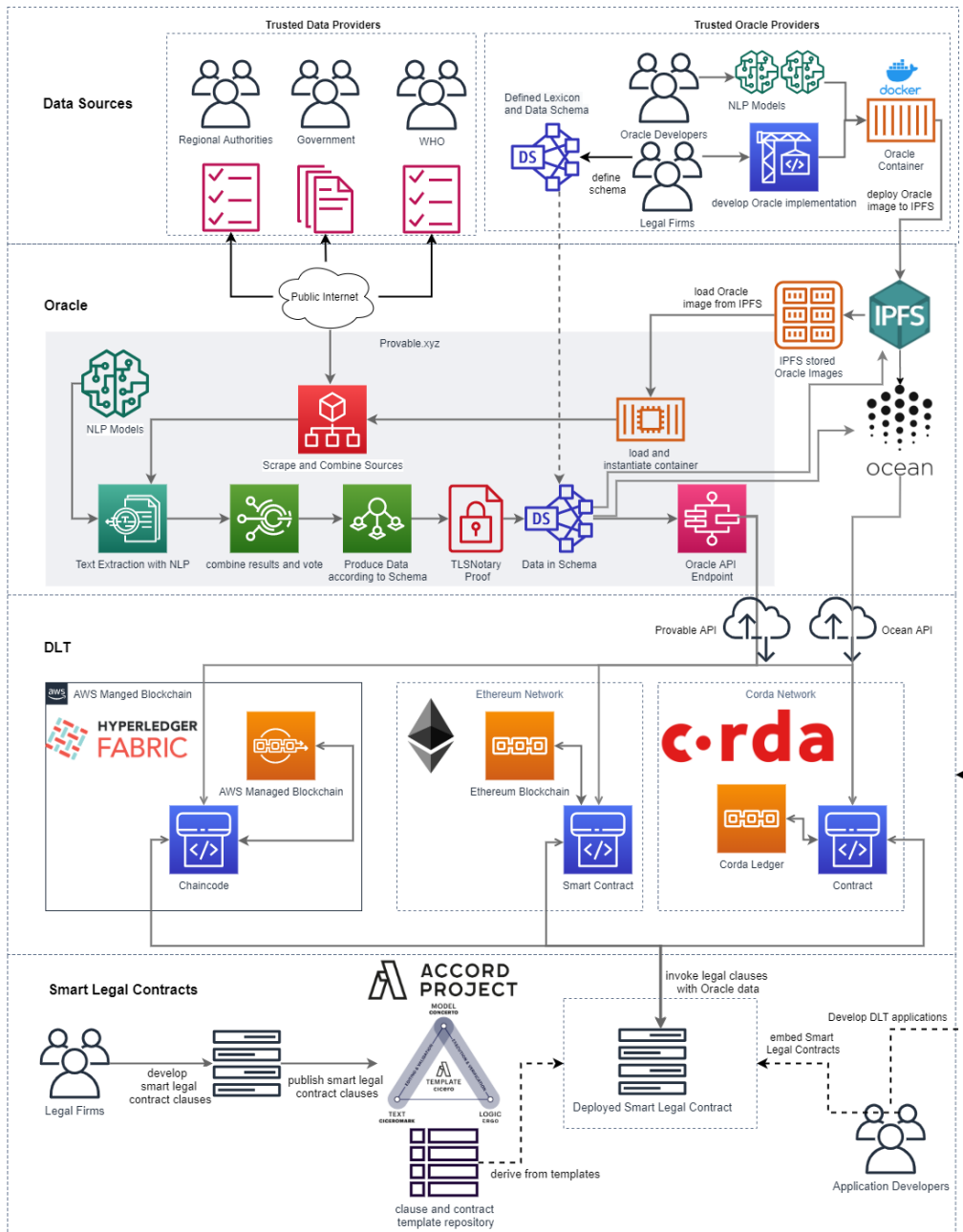


Figure 4: Proposed Solution Architecture

6. Conclusions and Future work

From our analysis, given ongoing uncertainty and the likelihood of future pandemics and related events, there are a number of applications for this technology. These applications include, but are not limited to, parametric pandemic insurance that are linked to business interruption schemes or rental and lease agreements. The approach has application in the construction sector and for tracking climate-related events such as storms and significant events such as floods and earthquakes. Benefits in cost savings from automation and increased accuracy of processing payment calculations and a shared audit trail of contract parameters, inputs and claims obligations can lower overall administrative cost from manually managing policies and increase certainty.

We aim to gather a range of collaborators from across industry sectors to join together to help to develop data aggregators, extractors and validation logic, in addition to help to define new schema definitions and contribute to legal lexicon and libraries of clauses, for different type of legal contracts and jurisdictions. We have contributed the candidate list of executable clauses to the library of the Accord Project, see Appendix B, but the clause logic can be applied in other solutions such as OpenLaw¹. The oracles and data schema components can be used in a variety of DLT platforms and smart contracts solutions as outlined in Appendix D.

We have focused our efforts on addressing the COVID-19 pandemic to address an immediate issue with the insurance industry, but there are several directions for future work. For example, depending on the choice of oracle platform in use and the trust requirements, there may be a number of decentralised oracles performing these actions and combining data from multiple sources for consolidation into a single response. We have used Provable initially, but wish to explore further oracle platforms in the next phase. It is likely that a multi-oracle approach may be needed in practice to serve different use cases and consumer types.

¹<https://www.openlaw.io>

The real estate and construction sectors in particular, are of interest we intend to expand the proof-of-concept implementation into looking at the impact of the pandemic on buying and selling houses. As mentioned in Section 2, recent UK government legislation and the UK Law Society guidance² made changes to the liabilities and penalties related to house purchases³ the proposed solution can be used to determine when the restrictions were lifted by the government to allow real estate related transactions as the revised regulations refer to clauses surrounding the date of lifting of restrictions plus 30 days to be an important part of revising the contract. A contract diagram that outlines the authors' proposed implementation is available in E.

The penalty for not adhering to the completion date involves a penalty payment that is determined by the Law Society⁴. The current system requires making a phone call for historical rates, the actual rate is published by the law society, but is a fixed 4% above the Barclays base rate⁵, something that can easily be done automatically with the oracle approach proposed. The authors have discussed these types of proposals with the UK Law Society as a potential route forward to increase innovation, transparency and improving efficiencies. The authors have extended the work developed in Real Estate Working Group of the Accord Project and developed during the Digital Streets^{6 7} to consider the revised regulations. A contract diagram that the authors have developed is in E

While some of restrictions are lifting, in certain areas the impact of COVID-19 will be felt by business for some time to come, in addition to a potential significant global downturn resulting from the pandemic [38]. This approach can be useful to help with restriction lifting (subject to conditions), especially as authorities move to structured approaches and legislation for certain sectors, and in certain regions.

²<https://www.lawsociety.org.uk/support-services/advice/articles/coronavirus-covid-19-information-for-members/>

³<https://www.lawsociety.org.uk/support-services/advice/articles/coronavirus-covid-19-and-residential-conveyancing-transactions/>

⁴<https://www.lawsociety.org.uk/support-services/advice/articles/standard-conditions-of-sale/>

⁵<https://www.lawsociety.org.uk/support-services/help-for-solicitors/practice-advice-service/q-and-as/how-do-you-calculate-interest-rates-for-late-completion-/>

⁶<https://hmlandregistry.blog.gov.uk/2019/05/24/could-blockchain-be-the-future-of-the-property-market/>

⁷<https://drive.google.com/file/d/1BGz1emjnYR0bPIrraXBo90VhVells5C3/view?usp=sharing>

While the approach put forward in this paper will be too late for many businesses already impacted by the pandemic we hope this will galvanise new approaches to technologies. Our approach to responsive contracts to a range of data inputs that reflect the reality of environment factors will enable industries to be better able to cope with new crisis situations such as climate change, economic downturns and other events that are typically classed as *Force Majeure*.

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A. Endpoints

The deployed Oracle web services are available at the following urls:

`https://l15zi0rwzf.execute-api.eu-west-2.amazonaws.com/dev/
check_corona_cases_uk`

`https://l15zi0rwzf.execute-api.eu-west-2.amazonaws.com/dev/
get_uk_alert_level`

`https://l15zi0rwzf.execute-api.eu-west-2.amazonaws.com/dev/
check_pandemic`

`https://l15zi0rwzf.execute-api.eu-west-2.amazonaws.com/dev/
get_uk_infection_rate_level`

B. Source Code

The Oracle code is available at the following github repositories:

<https://github.com/niallroche/covidhack-oracle-provable>

The legal smart contract code is available at the following github repository:

<https://github.com/niallroche/covidhack-legalsmartcontract>

We have built upon our initial submission to the recent Global Legal Hackathon and have extended using IPFS and Ocean Protocol. More information on hack is available at:

<https://challenge.globallegalhackathon.com/gallery/5ec84aef202da60044c03d6b>

C. Data Sources

WHO <https://www.euro.who.int/en/health-topics/health-emergencies/coronavirus-covid-19/news/news/2020/3/who-announces-covid-19-outbreak-a-pandemic>

Public Health England <https://www.gov.uk/guidance/notifiable-diseases-and-causative-organisms-how-to-report#list-of-notifiable-diseases>

UK Government websites, UK Government COVID regional alert level:

<https://www.instituteforgovernment.org.uk/explainers/joint-biosecurity-centre>

<https://www.gov.uk/government/publications/further-businesses-and-premises-to-close/further-businesses-and-premises-to-close-guidance>

UK Legislation

<http://www.legislation.gov.uk/uksi/2020/327/schedule/made>

D. Data Schema

Extract from UK cases and deaths

```
1 {"Total number of lab-confirmed UK cases": 283311, "Daily
   number of lab-confirmed UK cases": 1650, "Total number
   of COVID-19 associated UK deaths": 40261, "Daily number
   of COVID-19 associated UK deaths": 357, "nations": [{"
   nation": "Scotland", "total_cases": 15582, "rate": 286.5
   , "total_deaths": 2395, "total_deaths_last_month": {"
   total_cases": 819, "time_period_start": "2020-05-06", "
   time_period_end": "2020-06-05"}}, {"nation": "England",
   "total_cases": 154258, "rate": 275.6, "total_deaths": 35
   948, "total_cases_last_month": {"total_cases": 22762, "
   time_period_start": "2020-05-05", "time_period_end": "20
   20-06-04"}
2 ...
```

Ocean Protocol Meta Data Listing available from:

https://raw.githubusercontent.com/niallroche/covidhack-oracle-provable/master/serverless/oracle_pandemic/ocean/pandemic_template.json

```
1 {
2
3   "main": {
4
5     "type": "dataset",
6
7     "name": "COVID-19 UK Gov Dataset",
8
9     "dateCreated": "2020-03-13T10:17:09",
10
11    "author": "Mishcon de Reya LLC",
12
13    "license": "CC0: Public Domain Dedication",
14
15    "price": "0",
```

```
16
17     "files": [
18
19         {
20
21             "contentType": "text/plain",
22
23             "contentLength": "525047",
24
25             "compression": "plain",
26
27             "index": 0,
28
29             "url": "http://QmbMLrxJTnKJfgY72YasaXr49
30                 JxjzfAbrbppfnCgPWFAP/sample_1000.csv"
31         },
32
33         {
34
35             "contentType": "application/json",
36
37             "contentLength": "525047",
38
39             "compression": "plain",
40
41             "index": 0,
42
43             "url": "ipfs://QmbMLrxJTnKJfgY72YasaXr49
44                 JxjzfAbrbppfnCgPWFAP/schema.json"
45         },
46
47         {
48
49             "contentType": "text/html",
50
51             "url": "https://https://www.gov.uk/guidance/the-r-
52                 number-in-the-uk"
53         }
54     ]

```

```
55     ],
56
57     "datePublished": "2020-03-13T10:24:05"
58
59 },
60
61 "additionalInformation": {
62
63     "description": "Data files related to UK deaths and
64                   cases related to COVID-19, containing raw data
65                   available from uk gov and processed data files into
66                   a data schema usable by smart contracts",
67
68     "copyrightHolder": "Mishcon de Reya LLC",
69
70     "categories": ["Health"]
71 }
```

E. COVID-19 revised real estate contract

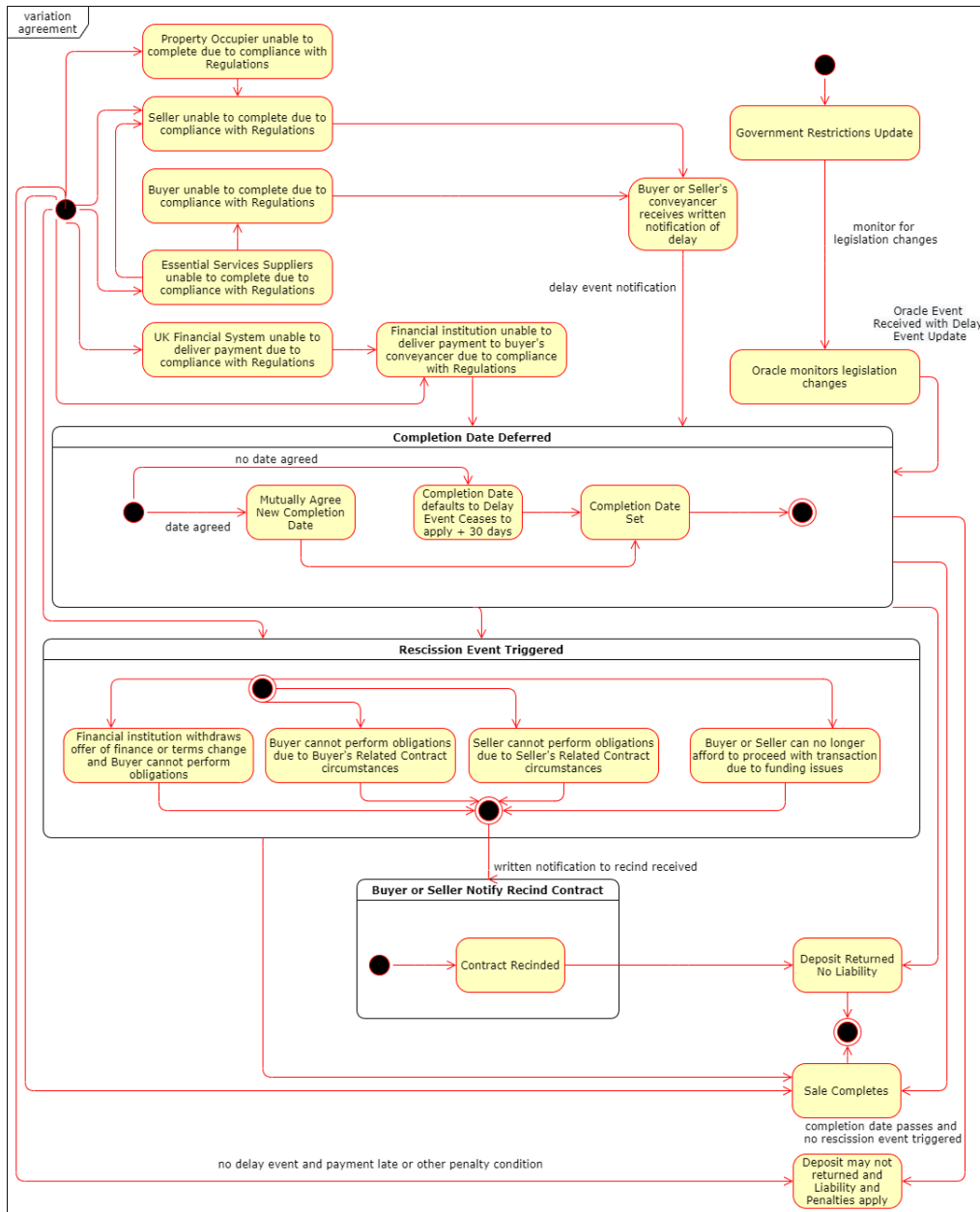


Figure 5: COVID-19 real estate contract diagram

About UCL CBT

The UCL CBT is the first centre globally to actively focus on blockchain-related research on the adoption and integration of Blockchain and Distributed Ledger Technologies into our socio-economic system.

The unique characteristics of the CBT at UCL provides a cross-sectoral platform connecting expertise and drawing knowledge from eight UCL departments centrally in one place. The CBT is a centre of excellence fostering open dialogue between industry players and sharing expertise and resources. It is a neutral think tank providing consultancy services to industry members, dedicated knowledge-transfer activities and cutting-edge in-house solutions.

For engagement outside of the academic world, the CBT's activities have been tailored to industry and policymakers' needs. The UCL CBT draws on its world-leading academic expertise to produce blockchain solutions for industry, start-ups and regulators. With a community of over 180 Research & Industry Associates and Industry Partners, it is the largest Academic Blockchain Centre in the world.

Notable Work

- The CBT released a report on the current adoption of DLT in global physical supply chains. The report featured an analysis of over 100 different projects taking place all over the world in the Grocery, Pharmaceutical and Fashion industries. Access the report [here](#).
- The CBT is leading the Blockchain Technology for Algorithmic Regulation and Compliance (BARAC) project. This is the largest publicly funded blockchain project aimed at the public sector that will be defining feasibility guidelines to policymakers, industry and regulators by identifying problems and associated solutions with a bottom-up approach, built through case studies and proof of concept platforms. For this project, the CBT is partnering with the Financial Conduct Authority and the Singapore Monetary Authority and financial groups and Fintech companies like Banco Santander and R3.
- The CBT is a founding member of the [Covid Task Force](#) alongside The International Association for Trusted Blockchain Applications (INATBA) and the European Commission. The task force is convening key players in the global blockchain ecosystem to identify deployable technology solutions that address governmental, social, and commercial challenges caused by COVID. As well as identifying solutions, the Task Force will work to expedite their deployment.
- The CBT successfully funded nine research proposals that investigated topics including stable coin policy, smart contract innovation, blockchain economics and blockchain governance models. Research teams who were funded were made up of individuals from a variety of academic and industry organisations. Learn more about the projects [here](#).
- The CBT launched the Block-Sprint hackathon to promote DLT innovation in the financial services sector. Over 160 individuals took part in the 2019 edition forming teams made up of industry practitioners, academics, and students. Learn about the winners and innovate ideas that were generated in the hackathon [here](#).

About the Discussion Paper Series

The *UCL CBT Discussion Paper* is published on a quarterly basis featuring the latest developments in the blockchain and DLT space. The aim of the discussion paper series is to share recent developments and state-of-the-art solutions on blockchain and DLT of researchers from an interdisciplinary background with the CBT community. All accepted submissions are available in the CBT paper database.

The submissions are circulated among the members of the UCL CBT Editorial Board, led by the Scientific Director so that the results of the research receive prompt and thorough professional scrutiny.

If you are interested in submitting a paper to be included in forthcoming editions, please visit our website [here](#) to see what the latest theme and criteria for submission are.

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