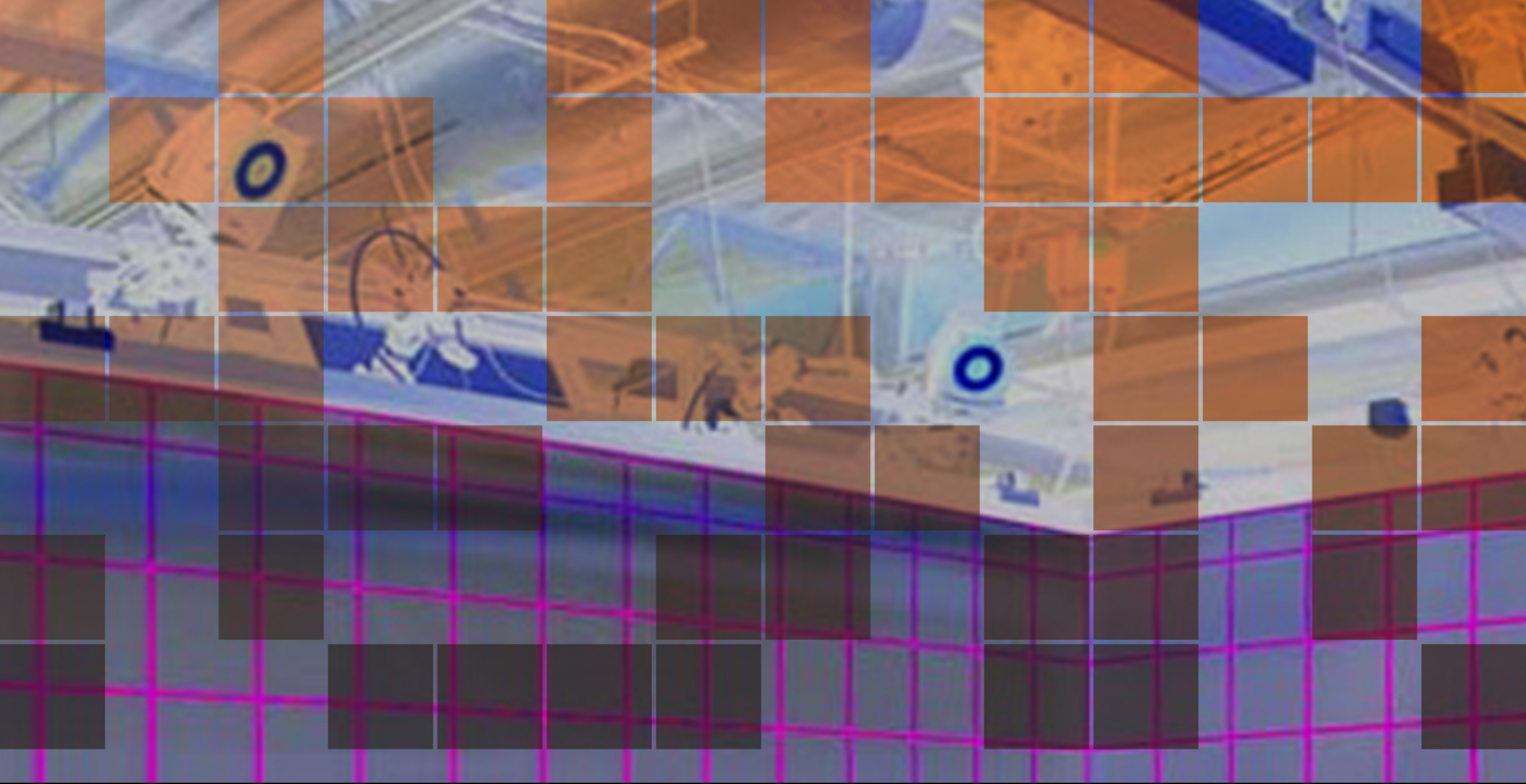
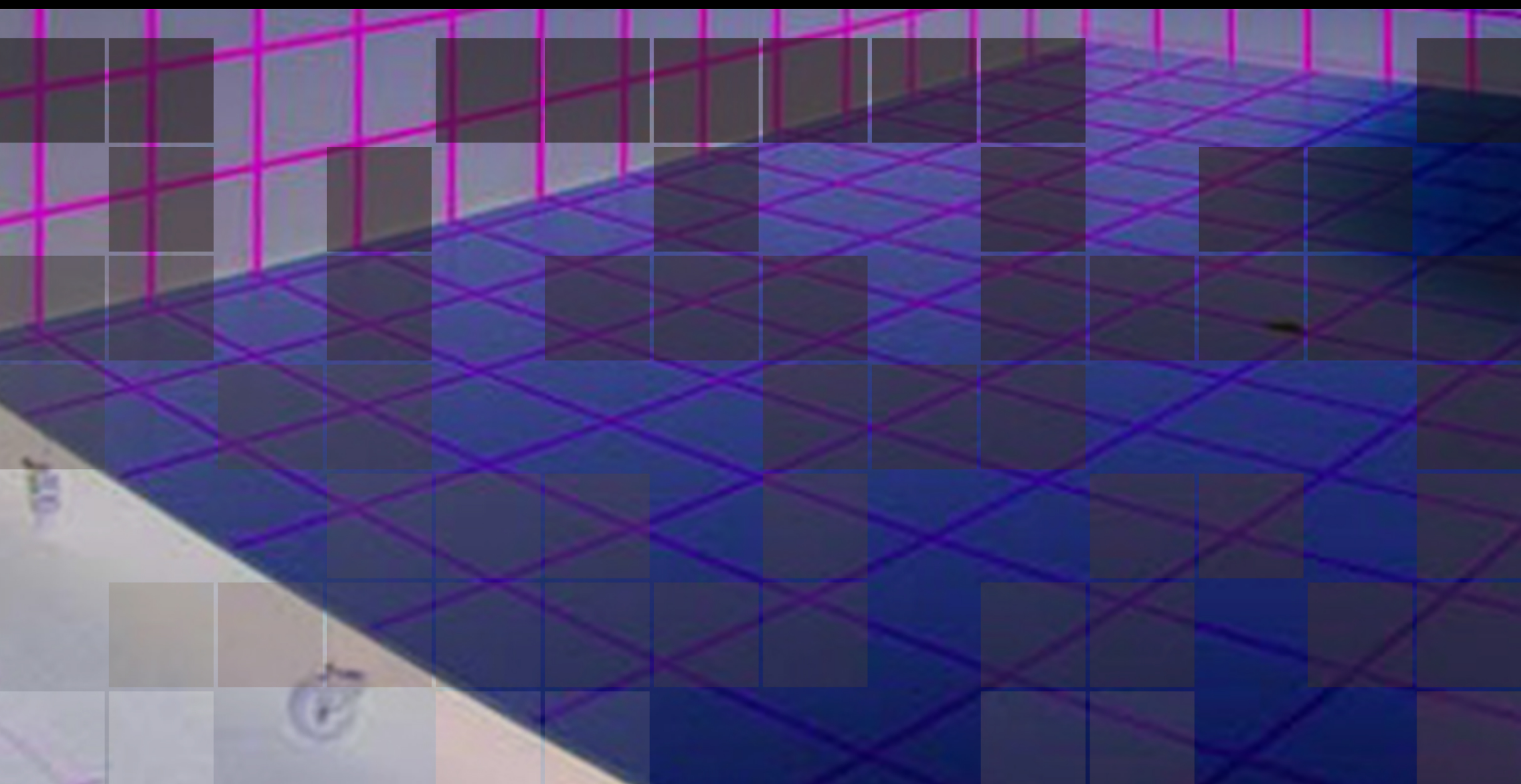


Money in Metaverses

Bitcoin in global social immersive mixed reality systems

John O'Hare & Allen Fairchild



Published by j.ohare@salford.ac.uk for the Cyber Foundry Programme at The University of Salford

Raw GitHub hyperlink

First printing, March 2022

Contents

I — State of the art and proposal

0.1 Conflict of interest statements 15

1 Introduction 17

1.1 Abstract 17
1.2 Introduction 17

2 Web3 / decentralised web 19

2.1 Semantic web 19
2.2 Spatial web 21
2.3 Webs of trust 21
2.4 Emerging consensus 22
2.5 Example applications 24
2.5.1 Podcasting2.0 24
2.5.2 Crowd funding 24
2.5.3 Distributed exchanges 24
2.5.4 NFT marketplaces 24
2.5.5 Slashtags / Hypercore 24
2.5.6 Distributed DNS applications 25
2.5.7 Impervious browser 25
2.6 The common thread 25

3 DLT, Blockchain, and Bitcoin 27

3.1 Ethereum 29
3.1.1 Mining and Gas 30
3.1.2 Upgrade roadmap 30
3.2 Bitcoin 30
3.2.1 The Bitcoin Network Software 32
3.2.2 Mining and Energy concerns 32
3.2.3 Bitcoin nodes 34

3.2.4 Upgrade roadmap . . . 35
3.2.5 Risks . . . 35
3.3 Extending the BTC ecosystem . . . 35
3.3.1 Block & SpiralBTC . . . 35
3.3.2 BTCPayServer . . . 36
3.4 Lightning (Layer 2) . . . 36
3.4.1 Micropayments . . . 37
3.4.2 LNBits . . . 37
3.4.3 Etleneum . . . 40
3.4.4 Message passing . . . 40
3.5 Liquid federation (layer 2) . . . 40
3.6 Bitcoin Layer 3 . . . 40
3.6.1 LNP/BP and RGB . . . 41
3.6.2 Synonym & Omnibolt . . . 41
3.6.3 DLCFD . . . 41
3.7 Bitcoin adjacent chains . . . 41
3.7.1 Stacks and STX . . . 41
3.7.2 Sovryn and RSK . . . 41
3.7.3 Sidechains . . . 42
3.7.4 Spacechains . . . 42
3.7.5 Drivechain . . . 42
3.7.6 Softchains . . . 42
3.7.7 Statechains . . . 42
3.8 Other chains and networks . . . 43
3.8.1 Solana . . . 43
3.8.2 AVAX . . . 43
3.8.3 Luna . . . 43
3.8.4 Crosschains . . . 44
3.8.5 Decentralised data . . . 44
4 Money in the real world . . . 45
4.1 Defining money . . . 45
4.2 International money transfer networks . . . 45
4.2.1 Swift, ISO 20022, and correspondence banking . . . 46
4.2.2 VISA etc . . . 46
4.2.3 Money transfer operators . . . 46
4.2.4 Digital disruptive fintech . . . 46
4.2.5 Stablecoins . . . 46
4.3 Central bank digital currencies . . . 47
4.4 Bitcoin as a money . . . 47
4.5 Does DeFi matter to SMEs . . . 49
5 Distributed Autonomous Organisations . . . 51
6 Distributed Self Sovereign Identity . . . 53
6.1 Some basics about distributed identity . . . 53
6.1.1 DID principles . . . 53
6.1.2 primatives . . . 53

6.1.3 What's in a DID document? 53
6.1.4 What are the challenges? 53
6.1.5 keystone uses 53
6.2 Technologies 53
6.2.1 Slashtags 53
6.2.2 LNURL-Auth 54
6.2.3 Sovrin 54
6.2.4 Keri 54
6.2.5 Atala Prism 54
6.2.6 Microsoft ION 54
6.2.7 Atala Prism (ADA Ecosystem) 54
6.3 User stories / behaviours 54
6.4 Comparing the technologies 55
6.5 Testing and Recommendations 55

7 Non Fungible Tokens 57
7.1 Energy concerns 57
7.2 Is any of this useful? 58
7.3 User stories / behaviours 58
7.4 Comparing the technologies 58
7.5 What are the options 58
7.6 Why choose bitcoin again 59

8 Metaverses 61
8.1 History and market need 61
8.2 Post 'Meta' metaverse 62
8.2.1 Mixed reality as a metaverse 62
8.3 Digital Land 62
8.3.1 Secondlife 63
8.3.2 The new stuff 63
8.4 Global enterprise perspective 63
8.5 NFT as metaverse narrative 63
8.6 MMORG games and NFTs 63
8.7 Crypto metaverses 64
8.8 Social VR software options 64
8.8.1 Second Life 64
8.8.2 Spatial 64
8.8.3 MeetinVR 64
8.8.4 Glue 65
8.8.5 Mozilla Hubs 65
8.8.6 FramesVR 65
8.8.7 AltSpace 65
8.8.8 Engage 65
8.8.9 VRChat 66
8.8.10 NEOSVR 66
8.8.11 Facebook Horizon Workrooms 66
8.8.12 Vircadia 66

8.8.13 WebXR . . . 66
8.8.14 Integration with web and game engines . . . 66
8.9 User stories . . . 66
8.10 Recommendations for value transfer . . . 67
8.11 Bitcoin market gap . . . 67
8.11.1 Money . . . 67
8.11.2 Identity proofs . . . 67
8.11.3 Digital object tracking . . . 67
8.11.4 Object transfer and trading . . . 67

9 Hardware and software choices to support this . . . 69
9.1 Why choose nix . . . 69
9.2 Networking layer . . . 69
9.2.1 Proxmox . . . 69
9.2.2 VyOS firewall . . . 69
9.2.3 Privacy aspects and using TOR etc . . . 70
9.3 Bitcoin on Nix . . . 70
9.3.1 Bitcoin Core . . . 70
9.3.2 Lighting LND and LNBits . . . 70
9.3.3 Electrum server . . . 70
9.3.4 C-Lightning and CLBoss . . . 70
9.3.5 Backup & Watchtower . . . 71
9.4 Liquid sidechain and Lightning (NFT enabled) . . . 71
9.4.1 Sovrin . . . 71
9.4.2 KERI . . . 71
9.5 Metaverse . . . 71
9.5.1 Vircadia . . . 72
9.6 Messengers . . . 72
9.7 WebM . . . 72

10 Example deployment . . . 73
10.1 GitHub . . . 73

11 Back to the metaverse . . . 75
11.1 Potential applications . . . 75
11.1.1 AI multiview digital signage . . . 75

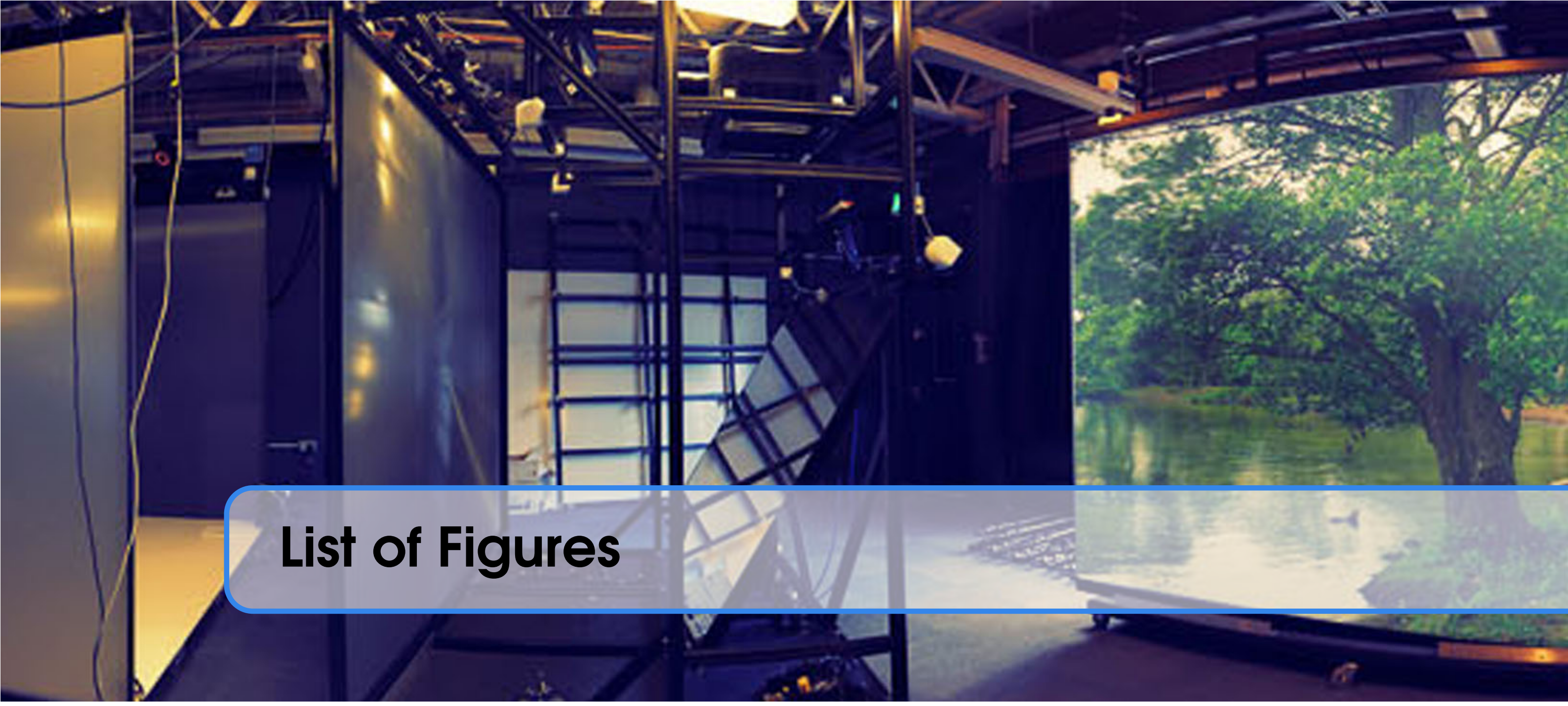
12 Conclusions . . . 77

13 Future work . . . 79

II Guides for deploying the software

III Erata
13.1 Author Biographies . . . 85

Bibliography 87
Articles 87
Books 88



List of Figures

1.1 Web 3, Metaverse, and Bitcoin are inter-sectional technologies. 18

2.1 Semantic Web Stack (CC0 image) 20
2.2 Deloitte Spatial Web Overview Reused with permission. 21
2.3 Edelman 2020 trust barometer (rights requested) 22
2.4 A meme showing differing approached to logging in on a website. 23
2.5 ARK slide on Web3. Rights requested 26

3.1 Dan Held: Bitcoin prehistory (rights requested) 28
3.2 Intersecting disciplines. Reused with permission: Dhruv Bansal, Unchained Capital 29
3.3 Growth in settlement value on the Bitcoin network. 31
3.4 Bitpaint: Contributions to the Bitcoin ecosystem. Reused with permission. 32
3.5 Intimate tie between energy and money, Henry Ford 33
3.6 Hash rate suddenly migrates from China (Reuse rights requested) 33
3.7 Goldman suggest growth opportunity and potential demonetisation of gold? . 34
3.8 Arcane research lightning adoption overview. 38
3.9 One of the many prebuilt and kit options for Lightning 'point of sale' 39
3.10 Allocations given at the beginning of public blockchain, by Messari. 43

4.1 Potential market exposure to Bitcoin as a money 49

8.1 Elon Musk agrees with this on Twitter 61

List of Tables

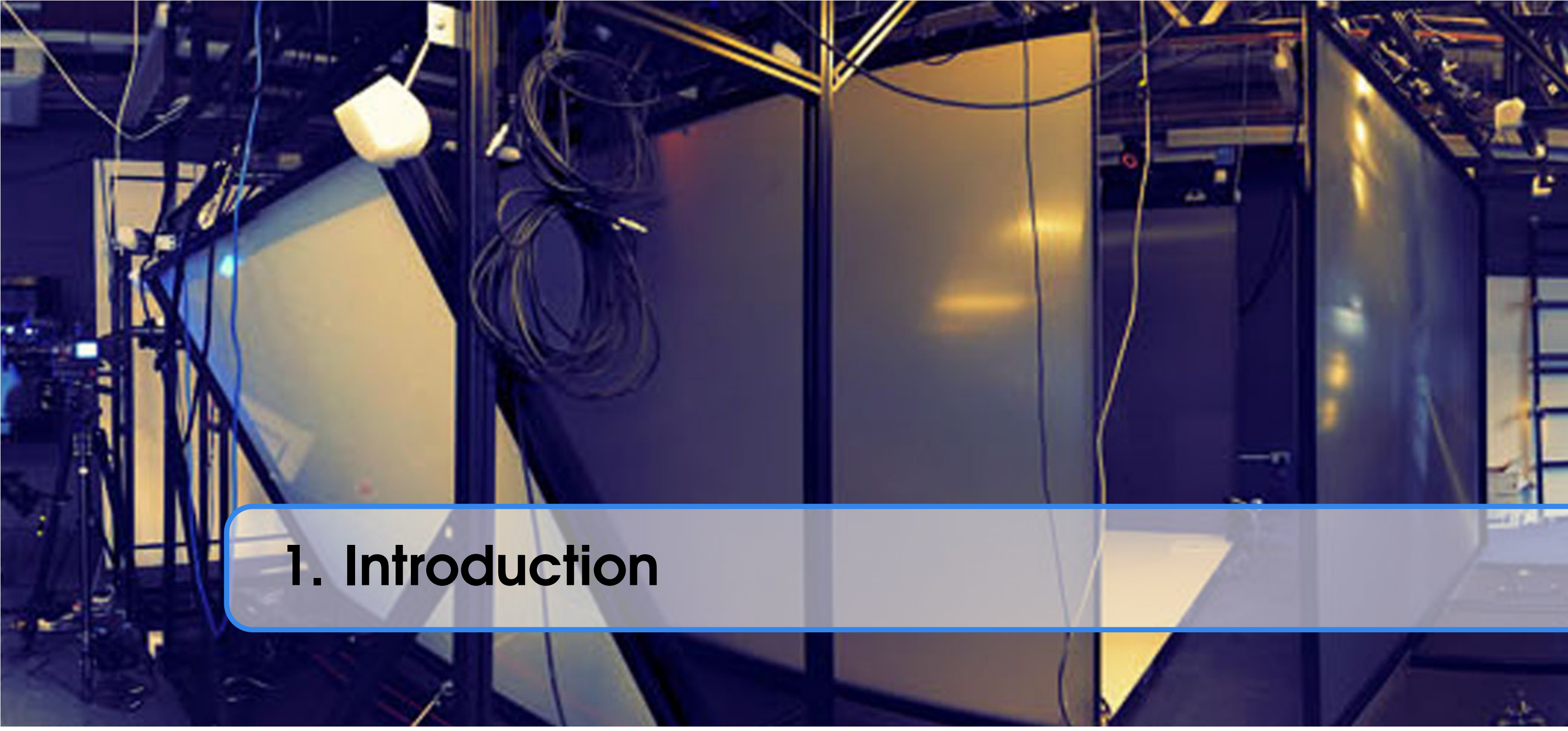
7.1 This table is basically broken and out of date and will be sorted out soon! 59

State of the art and proposal

1 Introduction 17
2 Web3 / decentralised web 19
3 DLT, Blockchain, and Bitcoin 27
4 Money in the real world 45
5 Distributed Autonomous Organisations 51
6 Distributed Self Sovereign Identity 53
7 Non Fungible Tokens 57
8 Metaverses 61
9 Hardware and software choices to support this 69
10 Example deployment 73
11 Back to the metaverse 75
12 Conclusions 77
13 Future work 79

0.1 Conflict of interest statements

The authors own small numbers of various of the tokens referenced in the papers for experimentation and/or investment purposes. This includes Solana, Ethereum, and Bitcoin locked on the Lightning network. No NFTs are owned at this time. There are no financial stakes in the development of any of these ecosystems.



1. Introduction

1.1 Abstract

We present a state of the art and positioning paper about Web3, Bitcoin, and 'Metaverse'; describing the intersections and synergies. A high level overview of Web3 technologies leads to a description of blockchain, and the Bitcoin network is specifically selected for detailed examination. Suitable components of the extended Bitcoin ecosystem are described in more depth. Other mechanisms for native digital value transfer are described, with a focus on 'money'. Metaverse technology is over-viewed, primarily from the perspective of Bitcoin and extended reality.
Bitcoin is selected as the best contender for value transfer in metaverses because of it's free and open source nature, and network effect. Challenges and risks of this approach are identified. A cloud / virtual machine technology stack can be downloaded and deployed from GitHub to experiment with the technologies, with a focus on cybersecurity best practice. This deployable lab is designed to inform development of secure value transaction, for small and medium sized companies. Next steps are touched upon in the conclusion.
This is an incomplete document and may frankly contain a bunch of errors. Usual v0.1 caveats apply. It's 100% opensource (unlicense) so if something seems wrong pertaining to your project, or you have a suggestion for an improvement, then submit a PR to GitHub. There's a bunch of place holder text using the Lorem Ipsum insert from LaTeX. If you see that, skip to the end of the section. Targeting April 2022 for a final draft. 20 working days left.

1.2 Introduction

This document presents a high level view of technologies and potential within the emergent Web3 and metaverse narrative, focusing around the transmission of value within and across such global networks, with a further focus on the Bitcoin monetary network. It was written to organise the thoughts of the authors, who were unfamiliar with Bitcoin technologies until recently.
As adoption of these technologies increases it will be necessary for people, and AI actors, to pass economic value between themselves. These 'goods and services' interactions, within the virtual social spaces, should be underpinned by a trust system, which scales globally, and presents low friction. Current secure international payment rails are poorly suited to such interactions; indeed it is likely with legacy systems, that parties would be forced to leave the metaverse application, and instead navigate their banking applications to exchange value with overseas entities in a secure fashion. This might conceivably take several days.
The whole landscape of money and value transfer is changing. This is has immediate implications

for SMEs. It is timely then to explore the potential of recent technologies, which can address metaverse interactions in *business to business* (B2B), *business to customer* (B2C), and the newer C2C (social commerce; *creator to consumer, customer to customer, consumer to consumer[15]).* Figure 1.1 demonstrates how some of these domains intersect. This paper seeks to overview and explain the available open source technologies. It supports an open source github repository which enables SMEs to access these emergent platforms and ecosystems. It aims to build toward a minimum viable product for trust minimised transfer of value within a social immersive space.
Referencing is in two styles; academic works are numeric, while opinion pieces, grey stats, and pertinent news articles are hyperlinked in blue from the text. As the paper develops the veracity of the citations should improve. It is likely that this document is incomplete as you are reading it as it's designed to be an open ended and open source resource. It is an experiment in a living document and repository.

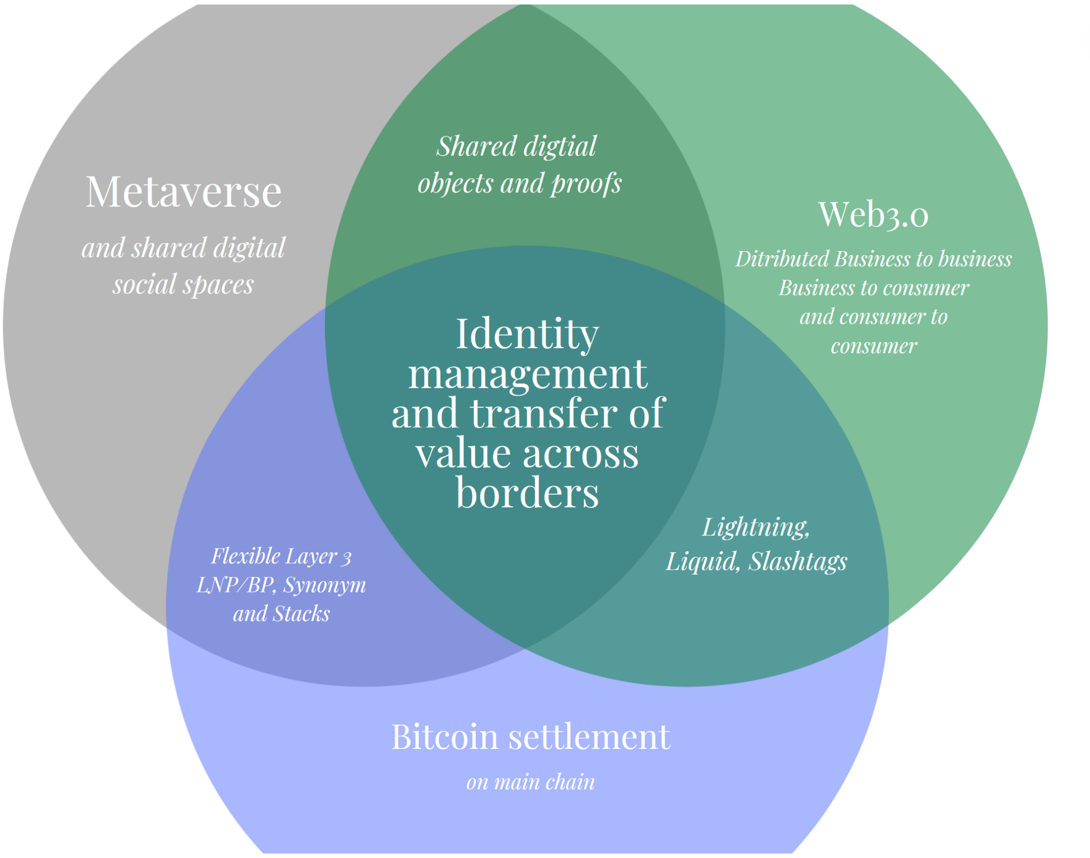


Figure 1.1: Web 3, Metaverse, and Bitcoin are inter-sectional technologies.

2. Web3 / decentralised web

Web3 is a rapidly evolving set of technologies and specifications which are drifting further from their origin. Decentralised web is perhaps a more useful name, but focus in this section will be on the evolution of the popularised term Web3.

2.1 Semantic web

The “semantic web” definition of Web3.0 has been somewhat overhauled by other innovations in decentralised internet technologies, now evolving toward the slightly different Web3 moniker. Tim Berners Lee (of WWW fame) first mentioned the semantic web in 1999 [0].

“I have a dream for the Web [in which computers] become capable of analyzing all the data on the Web – the content, links, and transactions between people and computers. A "Semantic Web", which makes this possible, has yet to emerge, but when it does, the day-to-day mechanisms of trade, bureaucracy and our daily lives will be handled by machines talking to machines. The "intelligent agents" people have touted for ages will finally materialize.”

Attention developed around three core themes, ubiquitous availability and searchability of data, intelligent search assistants, and highly available end points such as phones, and ‘internet of things’ devices. This is certainly manifesting in home devices, but few people think of this as a Web3 revolution. The framework can be seen in Figure 2.1.

Since ratification of the standards by the World Wide Web (W3C) consortium it seems that their imperative toward decentralisation has become lost. Instead it can be seen that Facebook, Amazon, Google, and Apple have a harmful oligopoly on users data [0]. This is as odds with Berners-Lee’s vision.

It is worth taking a look at his software implementation called Solid, which is far more mindful of the sovereignty of user data.

“Solid is an exciting new project led by Prof. Tim Berners-Lee, inventor of the World Wide Web, taking place at MIT. The project aims to radically change the way Web applications work today, resulting in true data ownership as well as improved privacy. Solid (derived from "social linked data") is a proposed set of conventions and tools for building decentralized social applications based on Linked Data principles. Solid is modular and extensible and it relies as much as possible on existing W3C standards and protocols.”

Excitement around this kind of differentiated trust model, hinted at in ubiquitous availability of data (and implemented explicitly in Solid), has led to exploration of different paths by cyptographers, and this will be described later.

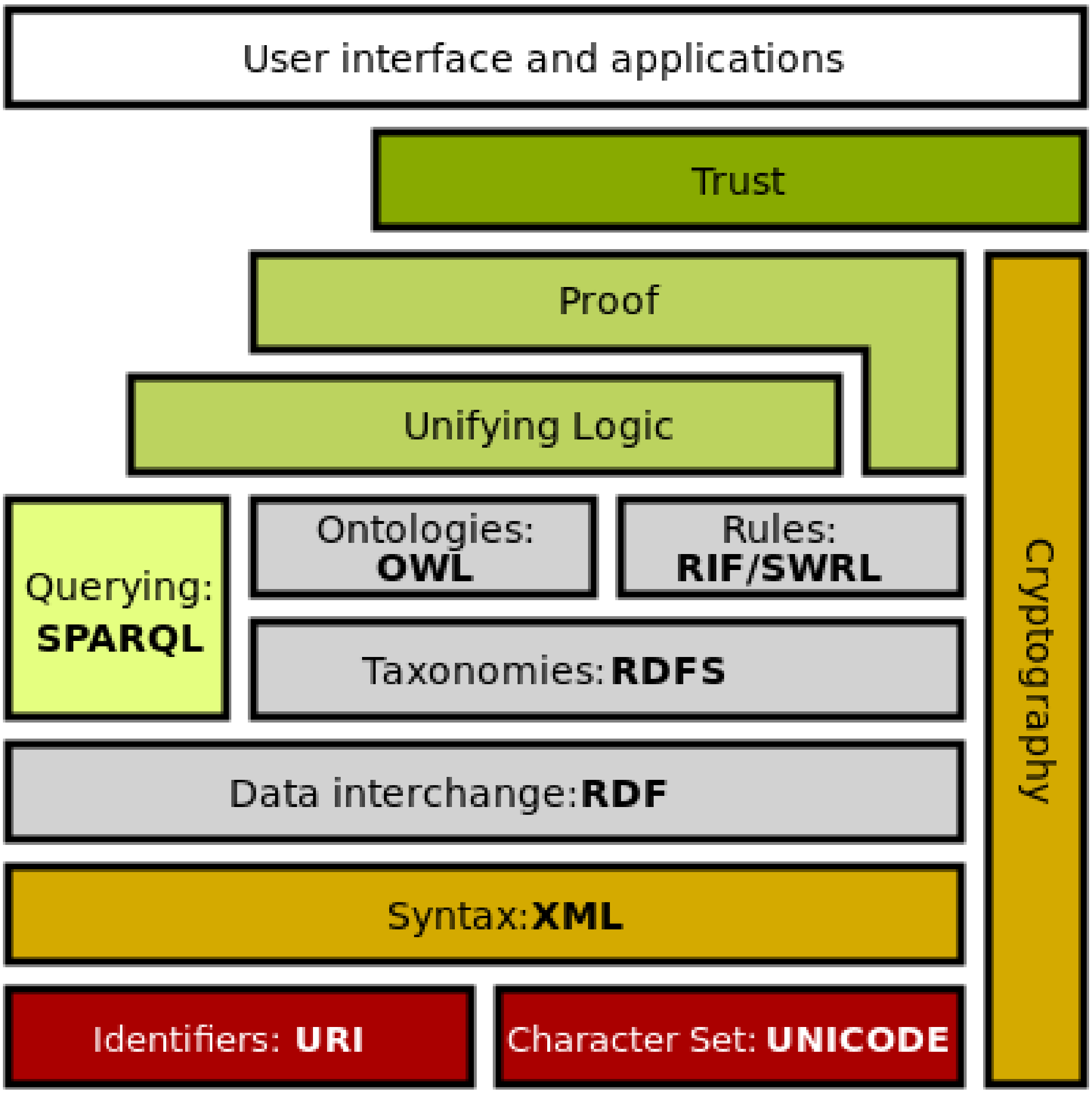


Figure 2.1: Semantic Web Stack [CC0 image]

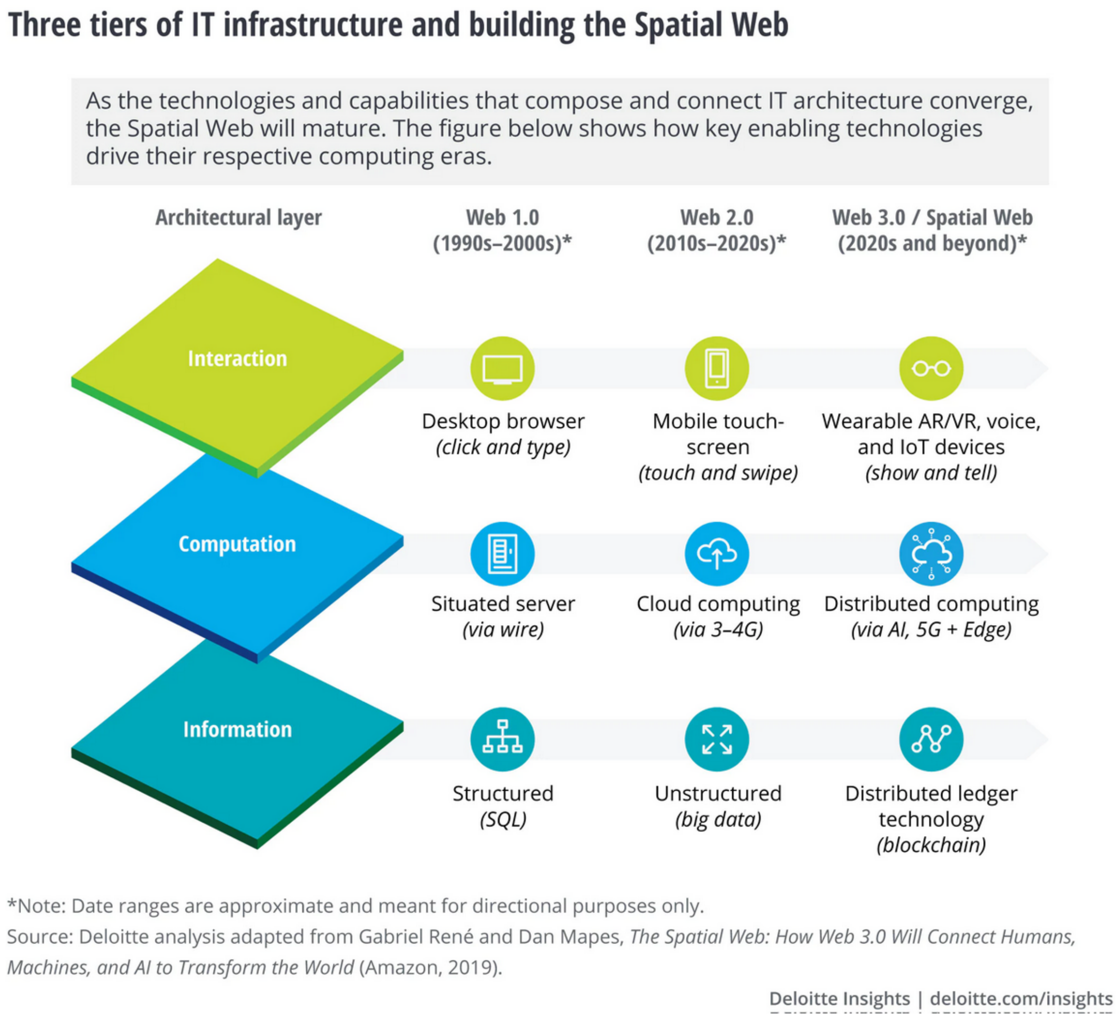


Figure 2.2: Deloitte Spatial Web Overview Reused with permission.

2.2 Spatial web

"The Spatial Web", a blurring of the boundaries between digital and geospatialised physical objects, seems to have developed from the strands in the original W3C scope around devices in the real world. It has been concentrating around AR and VR, but is being marketed and amplified with the same references to availability of data (See Figure 2.2 from a Deloitte accounting report). This too is finding little traction in practice, though obviously the component technologies continue to enjoy rapid development. Nontheless, this interpretation of Web3 becomes valuable when examining Metaverse later.

2.3 Webs of trust

More recently Web3 is being touted as a way to connect content creators directly to content consumers, without centralised companies acting as gatekeepers of the data. It implies that all users have a cryptographic key management system, to which they attach metadata, that they make requirements of peers with whom they communicate, and that they maintain trust 'scores' with peers.

It seems likely that this new model is less driven by a market need, and more by the high availability

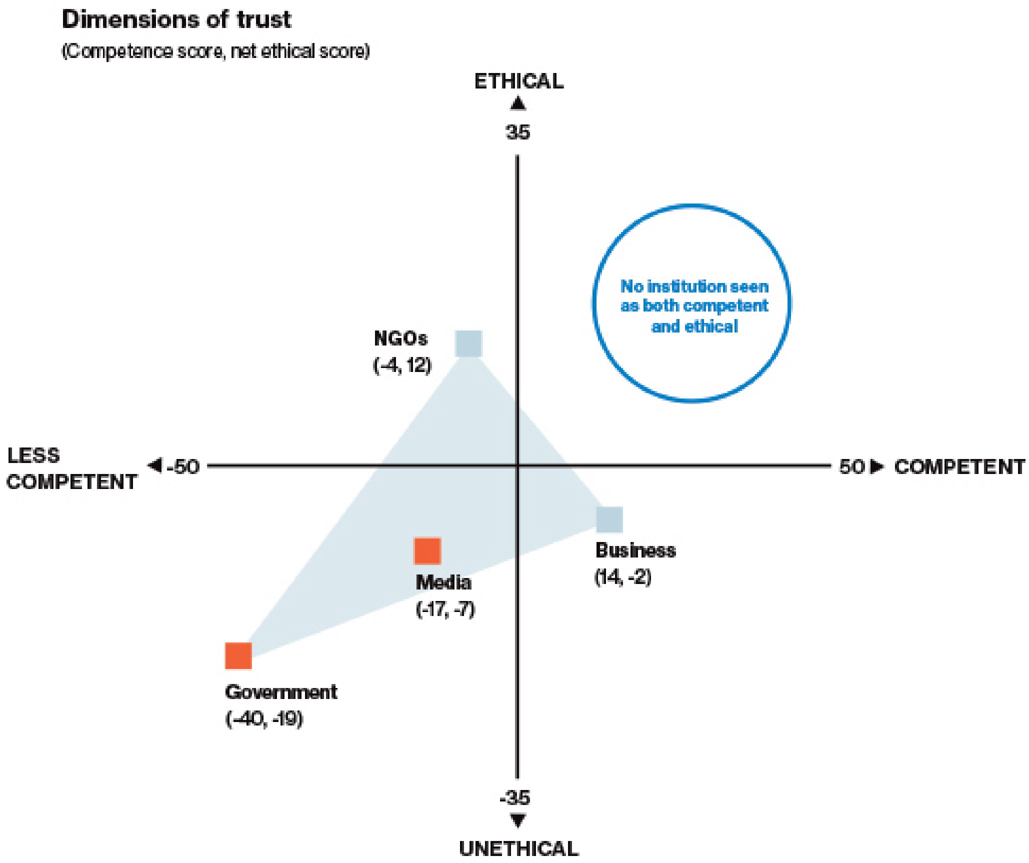


Figure 2.3: Edelman 2020 trust barometer [rights requested]

of tools which allow this to happen (the ecosystems described later). Add to this a social response to the collapse in trust of companies such as Facebook (Figure 2.3), a wish by consumers to pass more of the economic incentive to content creators, without the 'rent seeking' layer afforded by businesses, and a healthy dose of mania driven market speculation.

2.4 Emerging consensus

It's possible to frame Web3 as a hugely complex and inefficient digital rights management system (DRM). DRM is something that users of the internet are increasingly familiar and comfortable with. It's somewhat debatable whether decentralising this is worthwhile. The thesis of the developers of the technology seems to be that without it, control of 'value' will accrete over time, to one or more hegemonic controlling entities. It's a strong argument, but there is a substantial counter argument emerging that users just don't want this stuff. The nervousness of legislators in the USA to the attempt by Facebook/Meta to enter this peer to peer value transmission space is telling in terms of the perception of who is driving Web3.

At the end of 2021 there is much furore on Twitter over what Web3 might be, and who it 'serves'. A meme which compares the different ways to "log in" to the internet perhaps highlights the primary problem best, and is seen in Figure 2.4. Users are expecting to use badly written, buggy, economically vulnerable 'crypto' wallets to log into websites. It doesn't seem to make much sense yet on the face of it.

The current hype cycle is ignoring the legacy definitions described above and instead focusing

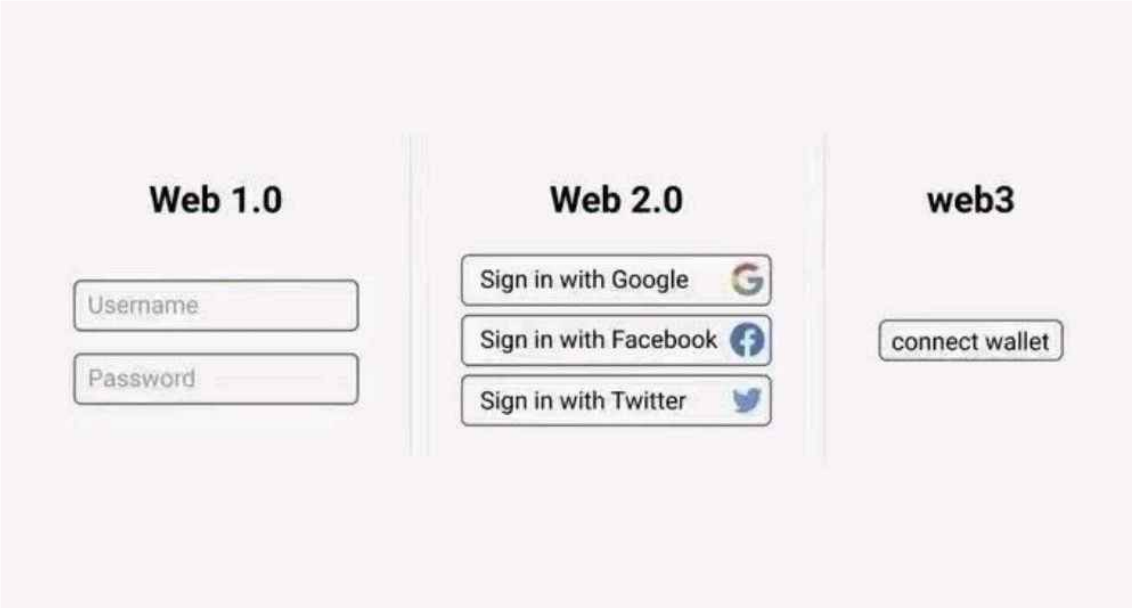


Figure 2.4: A meme showing differing approached to logging in on a website.

almost exclusively on Ethereum based peer to peer projects (more on these later). It can be seen that the description is somewhat in the eye of the beholder.
This new hyped push for Web3 is being driven by enormous venture capital investment. A16Z are a major player in this new landscape and have released their ten principles for emergent Web3.

- Establish a clear vision to foster decentralized digital infrastructure
- Embrace multi-stakeholder approaches to governance and regulation
- Create targeted, risk-calibrated oversight regimes for different web3 activities
- Foster innovation with composability, open source code, and the power of open communities
- Broaden access to the economic benefits of the innovation economy
- Unlock the potential of DAOs
- Deploy web3 to further sustainability goals
- Embrace the role of well-regulated stablecoins in financial inclusion and innovation
- Collaborate with other nations to harmonize standards and regulatory frameworks
- Provide clear, fair tax rules for the reporting of digital assets, and leverage technical solutions for tax compliance

Many of the mentioned components here will be described later in the paper. This list seems targeted toward the coming regulatory landscape, and could be considered at odds with the original tenants of an organically emergent, decentralised internet.
Dante Disparte, chief strategy officer of Circle, said in testimony to US senate hearing; that Web 1 was ‘read’, Web 2 was ‘read write’, and that Web 3 will ‘read write own’. The important takeaway here is not so much this oft quoted elevator pitch for Web3, but the fact that legislative bodies now consider this technology a force which they need to be aware of and potentially contend with. The suggestion is that this is happening regardless of a decent use case or definition.
It’s a complex evolving narrative, and clearly contradictions are common. Into this confusion this paper advances a narrow take, and toolset, which might extract some value from the technologies, while maintaining a low barrier to entry.

2.5 Example applications

2.5.1 Podcasting2.0

Podcasting 2.0 leverages RSS (the original dissemination system for podcasts) and the Bitcoin Lightning network, to enable so-called ‘value for value’ broadcasting. Subscribers use one of a variety of apps to stream microtransactions of Bitcoin directly to the content creators as they listen to the podcast. No intermediate business takes a cut. Some variation on this model exists, such as John Carvalho’s crowd funded podcast “The Biz” which progressively unlocks more minutes for everyone based on crowd funded donations.

2.5.2 Crowd funding

At time of writing a crowd funding initiative based around a digital decentralised construct called a DAO (explained later in detail) managed to raise $46 million dollars to bid for a copy of the US constitution at Southerbys auction house. The attempt narrowly failed, but the press heralded this new era of “Web3” economic might. This model might be the only use for DAOs and is likely just a way to avoid regulatory scrutiny. There is more detail on DAOs later.

2.5.3 Distributed exchanges

There are dozens of decentralised exchanges deployed on various blockchains. These platforms allow users to trade back and forth between various tokens (including ‘normal money’ stablecoins), and charge a fee for doing so. They operate within the logic of the smart contracts, within the distributed blockchains. This makes them extremely hard to ban, and as a result they operate in a legal gray area. At the extreme end of this is “distributed apps” (dApps) and “Decentralised Finance” (DeFi) which allows users access to complex financial instruments without legal or privacy constraints. DeFi will be touched on briefly later.

This is a huge area, and of only limited interest to the topics expanded in this paper. It’s perhaps worth noting BitcoinDEX, which runs in javascript in a web browser. It is effectively uncensorable, auditable by the user, and has no counter party risk since it operates entirely in the Bitcoin network. It is clearly an early prototype, but manages this complex feature without the more expressive logic of more ‘modern’ public blockchains.

2.5.4 NFT marketplaces

NFT markets are far more centralised services which match ‘owners’ of digital assets with potential buyers. The concept is a staple of the more recent interpretation of Web3, even though in practice these seem to be centralised concerns. Opensea claims to be the largest decentralised NFT marketplace, but they have the ability to remove listings in response to legal challenges. This seems to fly in the face of Web3 principles. NFTs are currently a deeply flawed technology but seem likely to persist and will be covered later.

2.5.5 Slashtags / Hypercore

Slashtags is a web of trust model decentralised peer to peer model which assigns metadata and trust scores to ‘any’ data and connection, with a security model rooted in the Bitcoin cryptographic ‘keys’ but crucially not the bitcoin network. This makes it interoperable with bitcoin but not reliant upon it. In principle this allows users to build complex networks of inherited trust bi-directionally with their networks over time. Every connection to a peer can be a new schema, with individual metadada managed by the user. It is new and has low adoption at this time. The user controls the source of the data and can allow them to be used by centralised services. This flips the authentication and data management paradigm of Web2 around, putting the user in charge of their data. This is a familiar concept to the DID/SSI communities (described later) but with significant investment. As

Slashtags use keys as endpoints they act as a web of naming and routing, bypassing the existing web infrastructure of DNS. It is likely very complex to use in practice and will be revisited later. It is being paired with the Hypercore protocol for peer to peer data sharing, more specifically the 'hole punching' capability of the hypercore system which ensures connections through firewalls[0]. The first application by the affiliated Hyperdivision team is an open source pear to peer live video streaming app called Dazaar. Once again, it's not clear yet who wants or needs this bit-torrent style service.

2.5.6 Distributed DNS applications

There are many perceived problems with having centralised authorities for overseeing the database which translates between human readable internet names and the underlying machine readable address notation. The databases which manage this globally are already somewhat distributed, and this distributed trust model is managed through a cryptographic chain of trust called DNSSEC which is capped by a somewhat bizarre key ceremony. The authority around naming is centralised in ICANN. There has been talk for many years about 'properly' distributing this database using decentralised/blockchain technologies[16]. The nature of this problem means that it either moves from control by ICANN, or it does not, and so far it has not, but there are many attempted and somewhat mature attempts at this difficult problem. Of these Namecoin is the most prominent, and is a fork of Bitcoin. The ubiquity of Bitcoin in such systems is perhaps becoming apparent.

2.5.7 Impervious browser

It might be that the future of Web3 comes in the guise of integrated suites such as the proposed Impervious web browser. They say that "without centralized intermediaries" it features:

- Zoom, without Zoom.
- Google Docs, without Google.
- Medium, without Medium.
- WhatsApp, without WhatsApp.
- Payments, without banks.
- Identity, without the state.

This is obviously leading marketing hype, but what they're talking about here is an integration of the components mentioned in this paper. If they can get critical mass around this browser then perhaps the Web3 market can be kickstarted.

2.6 The common thread

One feature which persists throughout all of these interpretations of Web3 is the need for decentralised trust. If there is to be no central controlling party(s) as in the Web 2 model then nothing can happen without a cryptographically secure underpinning, which favours no party beyond the terms of their collectively agreed rights and privileges. From this base layer we also get the potential for secure and trust minimised identity management. This nascent field of distributed identity management is explained later. From distributed trust models we can see 'trustless' transmission of economic value. The ability to send value from one person to another person or service without a third party. This whole area is 'Crypto', which is increasingly seeping into the human consciousness, and saw an astonishing $13B of capital investment in 2021 alone. At time of writing the industry is a over 2 trillion dollar market. According to Nathaniel Whittemore, a journalist for Coindesk, "The Web3 moniker positions this industry in opposition to big tech". In practice it seems that this is just another avenue for existing players to experiment with new models of control, and is rife with scams.

Of their 2022 'Big Ideas' report, ARK investment LLC (who manage $50B tech investment) said the following (Figure 2.5), which connects some of the dots already mentioned, and leads us into

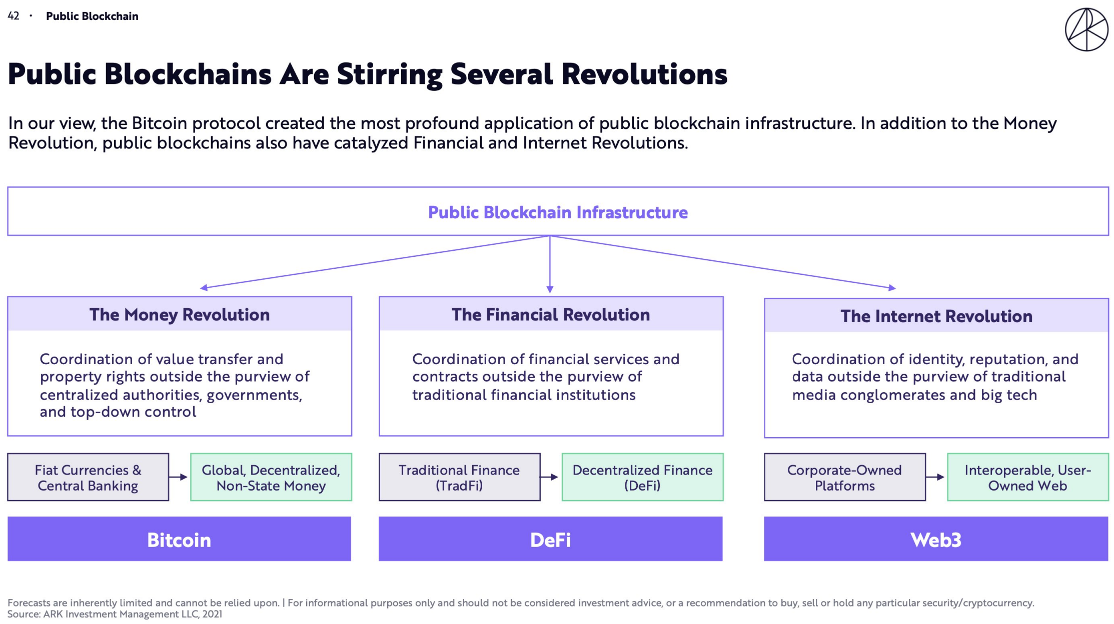


Figure 2.5: ARK slide on Web3. Rights requested

the next section which is Blockchain and Bitcoin:
"While many (with heavily vested interests) want to define all things blockchain as web3 we believe that web3 is best understood as just 1 of 3 revolutions that the innovation of bitcoin has catalyzed.

- *The Money Revolution*
- *The Financial Revolution*
- *The Internet Revolution"*

All these new 'crypto' technologies are bound tightly together, but there is currently very little meaningful value to be seen. The rest of this paper will focus on the money revolution element of this shift in internet technologies, and attempt to build a case for it's use in metaverse applications.

3. DLT, Blockchain, and Bitcoin

Distributed ledger technology (DLT) is a data structure distributed across multiple managing stakeholders. A subset of DLT is blockchain, which is a less efficient, immutable data structure with a slightly different trust model. Rauchs et al. of the Cambridge Centre for Alternative Finance provide a detailed taxonomy and conceptual framework [24]. It can be seen in their paper that the definitions are somewhat unclear in literature.
DLT, and especially blockchain, are rapidly gaining ground in the public imagination, within financial technology companies (FinTech), and in the broader corporate world.
The technology and the global legislative response are somewhat immature, and misapplications of both technologies are commonplace.
Distributed trust models emerged from cryptography research in the 1970s when Merkle, Diffie, and Hellman at Stanford figured out how to send messages online without a trusted third party [11, 22].
Soon after the 1980s saw the emergence of the cypherpunk activist movement, as a reaction to the emerging surveillance state [30, 9]. These early computer scientists in the USA saw the emerging intersectionality between information, computation, economics, and personal freedom [18]. Online discussion in the early nineties foresaw the emergence of trans-national digital markets, what would become the WWW [0, 0]. The issues of privacy and the exchange of digital value (digital / ecash)were of foremost importance within these discussions and while privacy was within reach thanks to “public/private key pairs” ecash proved to be a more difficult problem.
Adam Back’s 1997 ‘hashcash’ [2] paved the way for later work by introducing the concept of ‘proof of work’. This was built upon by Dai [10], Szabo [28], Finney [0], and Nakamoto amongst others. In all it took 16 years of collaboration on the mailing lists to attack the problem of trust minimised, distributed, digital cash. The culmination of these attempts were Bitcoin [23]. This is illustrated by Dan Held in Figure 3.1.
This is now a wider ecosystem of technologies.

There is enormous complexity and scope, as seen in Figure 3.2, and yet genuinely useful products are elusive. It can be argued that the whole concept of crypto/blockchain is somewhat flawed, as the vast majority of the technology offerings are not properly distributed, and "there are many scenarios where traditional databases should be used instead"[8].
It is surprising hard to pin down a simple explanation for the features which define blockchain. These “key takeaway” from Investopedia are a neat summary however.

- Blockchain is a specific type of database.

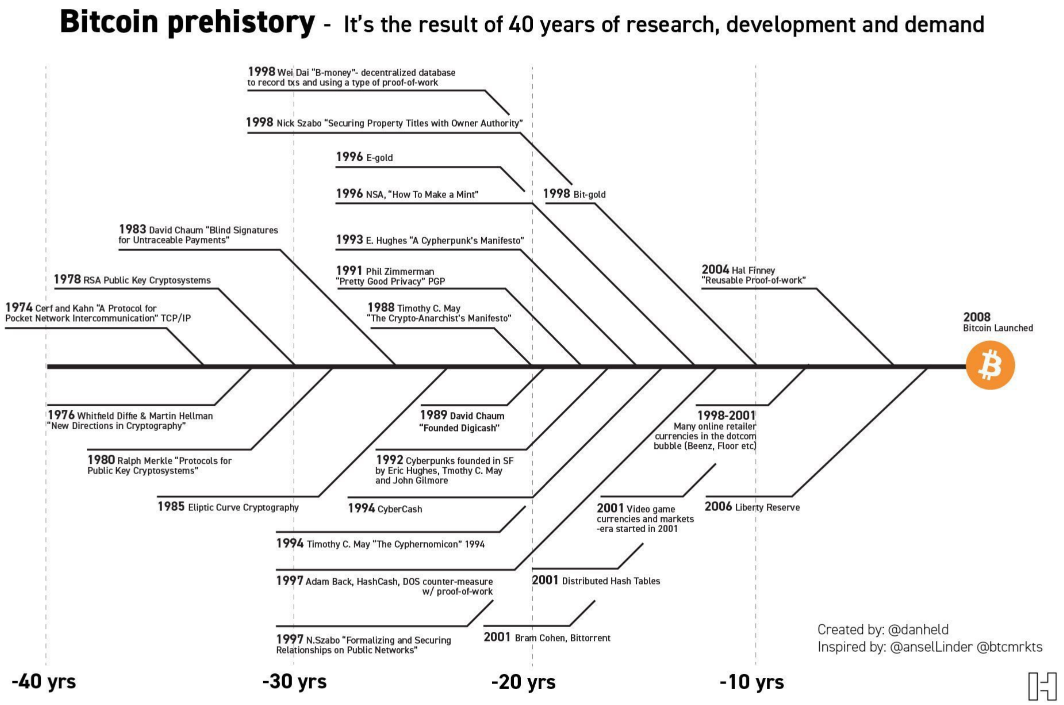


Figure 3.1: Dan Held: Bitcoin prehistory [rights requested]

- It differs from a typical database in the way it stores information; blockchains store data in blocks that are then chained together.
- As new data comes in it is entered into a fresh block. Once the block is filled with data it is chained onto the previous block, which makes the data chained together in chronological order.
- Different types of information can be stored on a blockchain but the most common use so far has been as a ledger for transactions.
- In Bitcoin's case, blockchain is used in a decentralized way so that no single person or group has control—rather, all users collectively retain control.
- Decentralized blockchains are "append only". In effect this means that the data entered becomes irreversible over time. For Bitcoin, this means that simple economic transactions are permanently recorded and viewable to anyone.

In principle blockchains provide a differentiated trust model. With a properly distributed system blockchain can be considered "trust minimised". This is important for some, but not all people. In an era when data breaches and corporate financial insolvency intersect with a collapse in trust of institutions, it is perhaps useful to have an alternative model for storage of data, and value. Thanks to a natural fit with strong encryption, and innate resistance to censorship by external parties, these systems lend themselves well to 'borderless' applications. Finally, a host of well engineered open source code repositories makes the cost of adoption relatively low.

Within DLT/blockchain there seem to be as many opinions on the value of the technology as there are implementations. There are thousands of different 'chains' and many more tokens which represent value on them. A majority of these are code forks of earlier projects. Most are defunct yet still have some residual 'value' locked up in them as a function of their 'distributed' tokens.

Because the space is comparatively new, subject to scant regulation, and often open source, it is possible to clone a github, change a few lines of code, and front it with a website in order to create

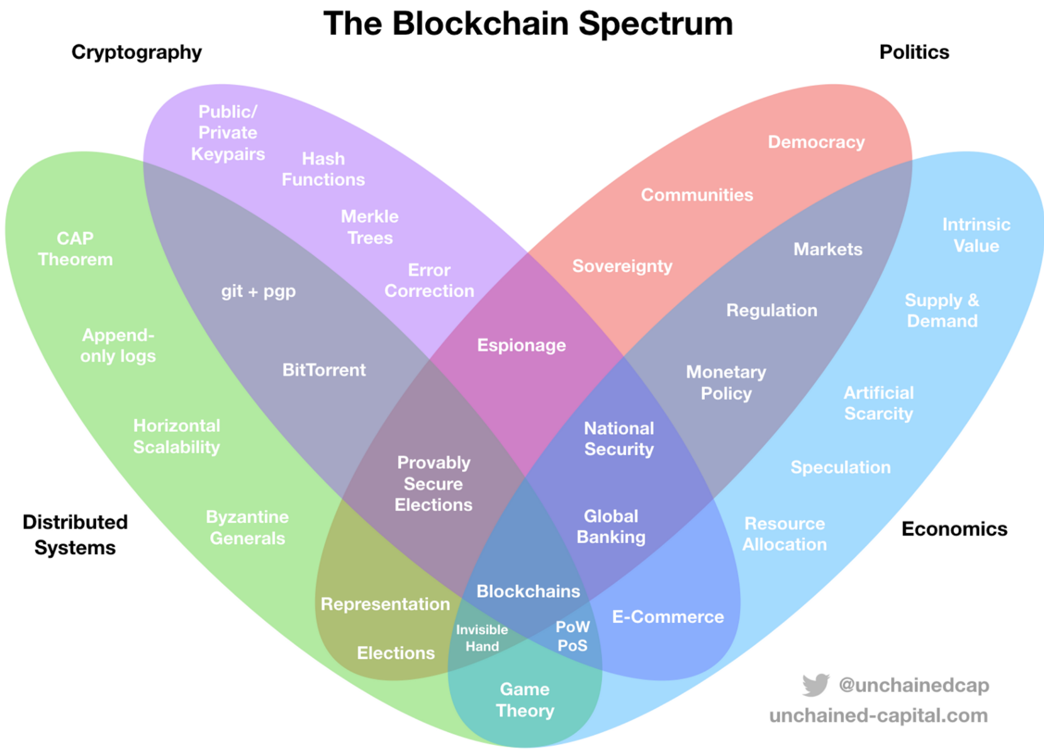


Figure 3.2: Intersecting disciplines. Reused with permission: Dhruv Bansal, Unchained Capital

'scams', and this happens very often [13].
The following sections give an overview of the major strands of the technology. First is Ethereum, mainly to discount it's use and get to more accessible offerings.

3.1 Ethereum

Ethereum [7] is the second most secure public blockchain (by about 50%), and second most valuable by market capitalisation (though this comparison is somewhat strained). It is the natural connection from Web3 to the rest of the paper, so it will be considered first.
It is touted as 'programmable money'. It, unlike bitcoin, is Turing complete, able to run a virtual machine within the distributed network (albeit slowly), and can therefore process complex transactional contracts in the settlement of value. This has given rise to the new field of 'distributed finance', or DeFi (described later), alongside many interesting trust minimised immutable ledger public database ideas.
There are trade-offs and problems with Ethereum (Eth/Ether) which currently increase the 'participation floor' and makes the network far less suitable for entry level business to business use. The ledger itself being a computational engine, with write only properties, is enormous. Specialist cloud hardware is required to run a full node (copy of the ledger), and partial nodes are the norm. Even partial nodes are run chiefly by one specialist cloud provider (Infura). Moreover the network is centrally controlled by its creator and the 'miners'. There is a strong case to answer that Eth is neither distributed, nor trustless, and in fact therefore fails to be differentiated from a DLT, undermining some of it's claims.
With that said there are many talented developers doing interesting work on the platform, and innovation is fast paced. It is entirely normal for technology projects to launch their distributed

ledger idea on and within the Ethereum network. These "initial coin offering" generate tradable tokens which can accrue value or demonstrate smart contract utility. Such is the level of nefarious activity on these networks that they have a poor reputation, and are difficult to audit, launch, and maintain. The overriding problem of using a blockchain for utility applications is that people can and will simply lie for criminal purpose when entering data into the ledger. It is far more likely that Ethereum is simply a speculative bubble than any of the claims for utility being born out.

3.1.1 Mining and Gas

Ethereum has a significant barrier to entry because of high fees to use the network. The system is Turing complete; able to programatically replicate any other computational system. This includes endless loops in code, so it is trivial to lock up the computational bandwidth of the while system, in a smart contract commitment, through a web wallet. To mitigate this existential 'denial of service attack' the 'gas' system demands that users spend some of their locked up value to operate on the network. In this way a transaction loop would quickly erode the available gas and stop looping. As the popularity of the system has grown, so too have the gas fees. It can sometimes cost hundreds of dollars to do a single transaction, though it is more normally just a few tens of dollars. This is a huge problem for potential uses of the network. It is currently a proof of work system like Bitcoin (this is described in the next section), and has a huge energy footprint to secure the network. It also ties up global supply of PC graphics cards used for it's mining model, making them far more expensive.

3.1.2 Upgrade roadmap

Ethereum was designed from the beginning to move to a 'proof of stake' model where token holders underpin network consensus through complex automated voting systems based upon their token holding. This is now called Ethereum Consensus Layer. Like much of the rest of 'crypto' the proposed changes will concentrate decisions and economic rewards in the hands of major players, early investors, and incumbents. This is a far cry from the stated aims of the technology.
Primarily because of the barrier to entry, we do not intend for Ethereum to be in scope as a method for value transfer within metaverses at this time.

3.2 Bitcoin

The first practical blockchain was the Bitcoin network [23], some two decades after Haber et al. first described the idea [0] It can be considered a triple entry book keeping system [12, 14], the first of it's kind, integrating a 'provable' timestamp with a transaction ledger. Some see this as the first major innovation in ledger technology since double entry was codified in Venice in fourteen seventy five[25].
It was created pseudonomously in 2009 as a direct response to the perceived mishandling of the 2008 global financial crisis, with the stated aim of challenging the status quo and the unequal access to opportunity it provides. The IMF has recently conceded that the Bitcoin poses a risk to the traditional financial systems, so it could be argued that it is succeeding in this original aim. The "genesis block" which was hard coded at the beginning of the 'chain' contains text from The Times newpaper detailing the second bank bailout.
Satoshi Nakamoto (the name of the publishing entity) disappeared from the forums forever in 2010. Although there were some earlier experiments (hashcash, b-money etc), Bitcoin is the first viably decentralised 'cryptocurrency'; the network is used to store economic value because it is judged to be secure and trusted. It is a singular event in that it became established at scale, such that it could be seen to be a fully distributed system, without a controlling entity. This is the differentiated trust model previously mentioned. This relative security is the specific unique selling point of the

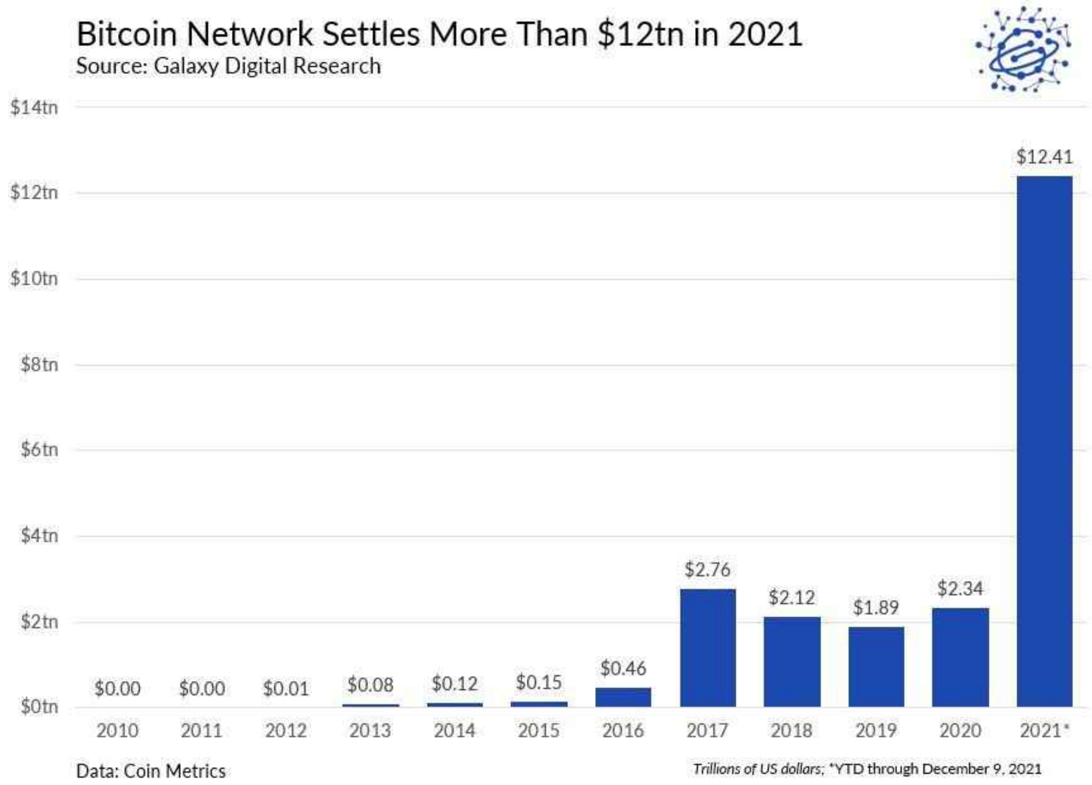


Figure 3.3: Growth in settlement value on the Bitcoin network.

network. It is many times more secure than all the networks which came after based on a like for like comparison of transaction 'confirmations'. This network effect of Bitcoin is a compounding feature, attracting value through the security of the system. It is deliberately more conservative and feature poor, preferring instead to add to it's feature set slowly, preserving the integrity of the value invested in it over the last decade. At time of writing it is a top quartile largest global currency and has settled over $12 trillion Dollars in 2021, though Makarov et al. contest this, citing network overheads, and speculation [0]. Institution grade 'exchange tradable funds' which allow investment in Bitcoin are available throughout the world, and the native asset can be bought by the public easily through apps in all but a handful of countries as seen in Figure 3.3. Only around 7 transactions per second can be settled on Bitcoin. The native protocol does not scale well, and moreover this in an inherent trade-off as described by Croman et al. in their positioning paper on public blockchains [0]. Over time competition for the limited transaction bandwidth drives up the price to use the network. This effectively prices out small transactions, even locking up some value below what is a termed the 'dust limit' of unspent transactions too small ever to move again [0].
Bitcoin has developed quickly, with a faster adoption than even the internet itself. It is now a mature ecosystem, and is seeing adoption as a corporate treasury asset.
Adoption by civil authorities is increasing, and legislators the world over are being forced to adopt a position. Many city treasuries have added it to their balance sheet, and it is legal tender in the country of El Salvador[1], and this will be explored more later. Global asset manager "Fidelity" wrote the following in their 2021 trends report.
"We also think there is very high stakes game theory at play here, whereby if bitcoin adoption increases, the countries that secure some bitcoin today will be better off competitively than their peers. Therefore, even if other countries do not believe in the investment thesis or adoption of bitcoin, they will be forced to acquire some as a form of insurance. In other words, a small cost can be paid today as a hedge compared to a potentially much larger cost years in the future. We

therefore wouldn't be surprised to see other sovereign nation states acquire bitcoin in 2022 and perhaps even see a central bank make an acquisition."

3.2.1 The Bitcoin Network Software

There isn't a single github which can be considered the final arbiter of the development direction, because it is a distributed community effort with some 400 developers out of a wider 'crypto' pool of around 9000 contributors. Development and innovation continues but there is an empahasis on careful iteration to avoid damage to the network. Visualisation of code commitments to the various open source software repositories can be seen at Bitpaint youtube channel and in Figure 3.4.

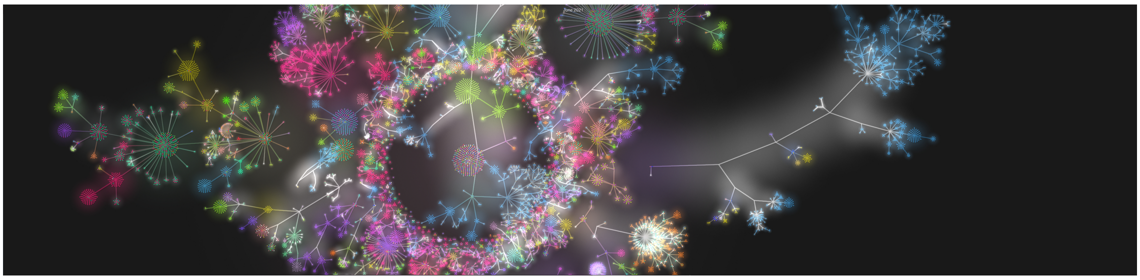


Figure 3.4: Bitpaint: Contributions to the Bitcoin ecosystem. Reused with permission.

Bitcoin core is the main historical effort, but there are alternatives (LibBitcoin in C++, BTCD in Go, and BitcoinJ in Java).

3.2.2 Mining and Energy concerns

Bitcoin uses a staggering amount of energy to secure the blockchain, and this has climate repercussions. It is an industrial scale global business with 'mining companies' investing hundreds of millions of pounds at a time specialist ASIC mining hardware and facilities. This is Adam Back's "proof of work", and is essential to the technology. The Cambridge Bitcoin Energy Consumption Index monitors this energy usage.
Such businesses can mine a Bitcoin for around $5k-$10k per coin, so the profit margins are considerable (based on 30-40 Joule/terahash and power rate less than 5 cents /kilowatt hour and excluding hardware costs). This is not to say that all mining is, or should be, so concentrated. Anyone running the hashing algorithm can get lucky and claim the block reward. PoW ties the value of the 'money' component of Bitcoin directly to energy production. This is not a new idea as can be seen in Figure 3.5. Henry Ford proposed an intimate tie between energy and money to create a separation of powers from government.

The potential ecological footprint of the network has always been a concern; Hal Finney himself was thinking about this issue with a mature Bitcoin network as early as 2009.
Proponents of the technology say that the balance shifted dramatically in 2021 with China outright banning the technology; this has forced the bulk of the energy use away from 'dirty coal' as seen in Figure 3.6. Some analysts propose mitigations, or even suggest that 'ending financialisation' through use of Bitcoin may be net positive for the environment. Recently for example Baur and Oll found that *"Bitcoin investments can be less carbon intensive than standard equity investments and thus reduce the total carbon footprint of a portfolio."*[4].

The power commitment to the network is variously projected to increase, or level off over time, but certainly not decrease. The industry now argue that economic pressures mean that most of the 'hashrate' is generated by renewable energy[6]. Certainly there is growing interest and adoption of so called "stranded energy mining" which cannot be effectively transmitted to consumers, and is

ERCHANDISE
ISED IN THE
IS GUARANTEED

New York

First to Last—the T

XXI No. 27,412 (Copyright, 1921, New York Tribune Inc.) SUNDAY, DECEMBE

Artist Women Attacked

n of John R.
ur Identified
e Line-Up by
irl and Matron

Ford Would Replace Gold With Energy Currency and Stop Wars

Declares if Government Will Give Him Muscle Shoals Plant He Can Demonstrate Success of Plan to Substitute Natural Wealth as Basis of World's Money

FLORENCE, Ala., Dec. 3.—Henry Ford and Thomas A. Edison arrived here to-day to inspect the Muscle Shoals nitrate plant, which the Detroit

bankers who to-day control the bulk of the world's gold supply. No matter to what country they as individuals claim allegiance, they all play the same game to keep the gold they have in their own

Craig U
$10,00
Educati

Slash Into Sch
Suggested to
to Obtain Re
$350,516.52

Figure 3.5: Intimate tie between energy and money, Henry Ford

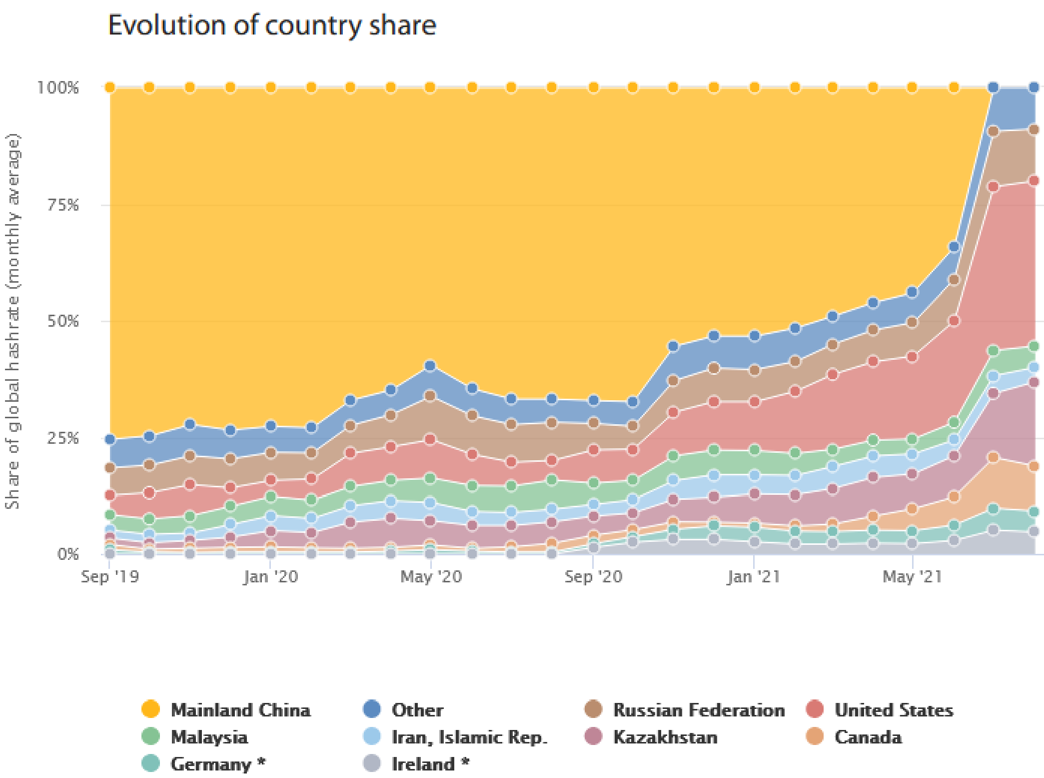


Figure 3.6: Hash rate suddenly migrates from China [Reuse rights requested]

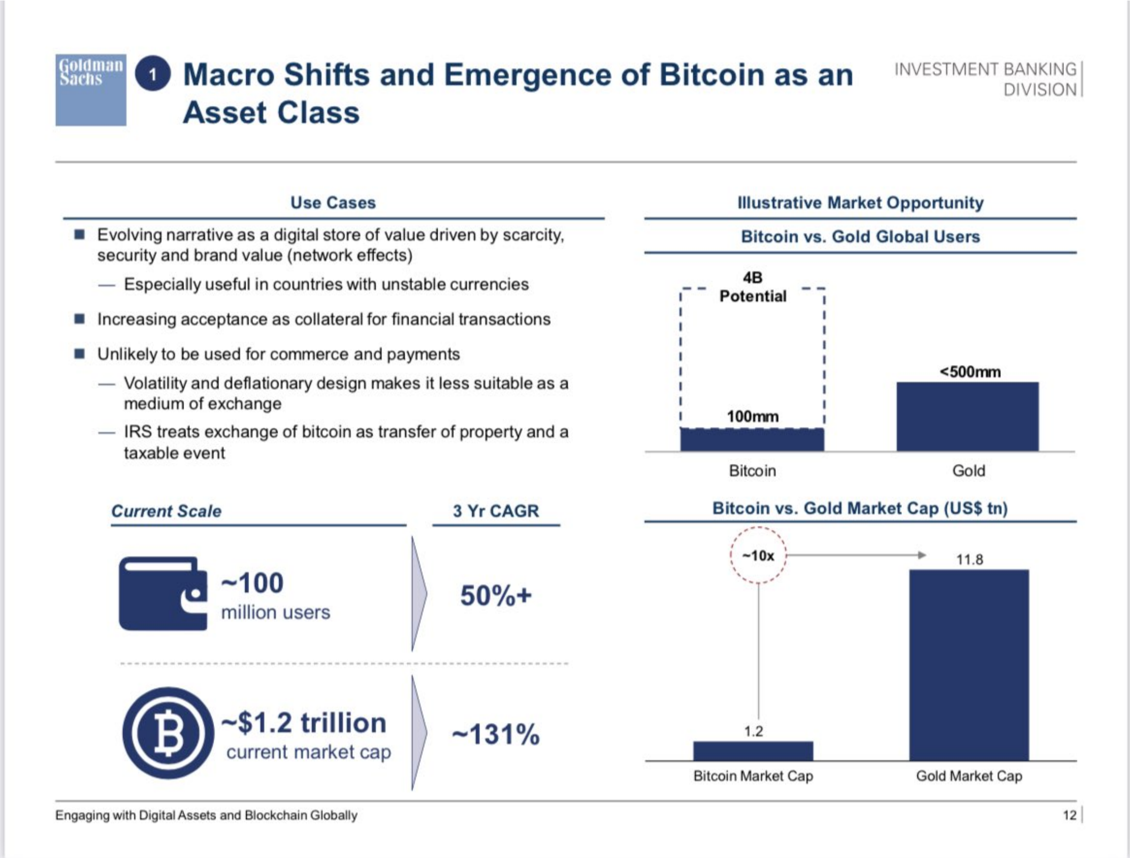


Figure 3.7: Goldman suggest growth opportunity and potential demonetisation of gold?

thereby sold at a huge discount while also developing power capacity [3]. The most cited example of this is El Salvador's 'volcano mining' which is supporting their national power infrastructure plans. A more poignant example is the Mechanicville hydro plant in the USA. The refurbishment of this 123 year old power plant is being funded by Bitcoin mining. This is the "buyer of last resort" model first advanced by Square Inc. Critics highlight the potential impact of mining on local energy prices[5]. The debate whether this consumption is 'worth' it is complex and rapidly evolving. Is a trillion dollar asset which potentially replaces the money utility of gold, but doesn't need to be stored under guard in vaults (Figure 3.7), worth the equivalent power consumption of clothes dryers in North America? Probably not with the current level of adoption, but this is an experiment in replacing global money. This paper offers no firm opinion.

3.2.3 Bitcoin nodes

The Bitcoin network can be considered a triumvirate of economic actors, each with different incentives. These are:

- Holders and users of the tokens, including exchanges and market makers, who make money speculating, arbitraging, and providing liquidity into the network.
- Miners, who profit from creation of new UTXOs, and receive payments for adding transactions to the chain. In return they secure the network.
- Node operators, who enforce the consensus ruleset which the miners must abide by in order to propagate new transaction into the network. In return node operators optimise their trust minimisation, and help protect ths network from changes which might undermine their speculation and use of the tokens.

There are currently around 150,000 bitcoin nodes distributed across the world. Since and IT engineer Stadicus released his Raspibolt guide in 2017 there has been an explosion of small scale Bitcoin and Lightning node operators. Around thirty thousand Raspberry Pi Lighting nodes (which are also by definition bitcoin nodes) run one of the following open source distributions, with the most noteworth explained alongside their standout featureset:

- Raspiblitz offers fully opensource lightning focused functionality with a touchscreen display
- Mynode focuses on easy of use through a web interface and has many modules which users can try out.
- Umbrel is a more user friendly multi purpose node allowing access to a suite of Bitcoin and self sovereign individual tools.
- RoninDojo is designed for use alongside the privacy focused Samourai mobile wallet.
- Nix bitcoin focuses on security of the underlying operating system by building on NixOS.
- NODL is a premium prebuilt node focusing on security of the more performant hardware, and underlying operating system. It offers additional privacy tools.
- Start9 Embassy is a small form factor prebuilt unit at a lower price. It is a venture capital funded project with a more restrictive license but offers a suite of easy to use self sovereignty tools including Bitcoin.

Rather than using one of these distributions we plan to support a new metaverse focused suite of these tools based around the nix distribution. Consider mining the NYDIG primer for information

3.2.4 Upgrade roadmap

Taproot
BIP-119

3.2.5 Risks

- The block reward is reduced every 4 years (epochs). This means a portion of the mining reward is trending to zero, and nobody knows what effect this will have on the incentives for securing the network through proof of work.
- Stablecoins are a vital transitional technology (described later) but do not meaningfully exist yet on the Bitcoin network. This may change.
- Bitcoin lacks privacy by design. All transactions are publicly viewable. This is a major drag to the concept of BTC as a money.
- The Lightning network (described later) has terrible UX design at this time.
- The basic 'usability' of the network is still poor in the main. Any problems which users experience demand a steep learning curve and risk loss of funds. There is obviously no tech support number people can call.
- Only around one billion unspent transactions can be generated a year on the network. This means that it might become impossible for everyone on the planet to have own their own Bitcoin address (with it's associated underpinning UTXO).

3.3 Extending the BTC ecosystem

The following section are by no means an exhaustive view of development on the Bitcoin network, but it does highlight some potentially useful ideas for supporting metaverse interactions in a useful timeframe.

3.3.1 Block & SpiralBTC

Block (formally the payment processor "Square" is now an umbrella company for several smaller 'building block' companies, all of which are major players in the space.
SpiralBTC, formally 'Square Crypto' (a subsidiary of Square) is funding development in Bitcoin and Lightning. Their main internal product is the Lightning Development Kit (LDK). This promis-

ing open source library and API will allow developer to add lightning functionality to apps and wallets. It is a useful contender for our metaverse applications. They also fund external open source development.

3.3.2 BTCPayServer

BTCPayServer is one of the recipients of a Spiral grant. It is a self hosted Bitcoin and Lightning payment processor system which allows merchants, online, and physical stores and businesses to integrate Bitcoin into their accounting systems.

check the roadmap Quisque facilisis auctor sapien. Pellentesque gravida hendrerit lectus. Mauris rutrum sodales sapien. Fusce hendrerit sem vel lorem. Integer pellentesque massa vel augue. Integer elit tortor, feugiat quis, sagittis et, ornare non, lacus. Vestibulum posuere pellentesque eros. Quisque venenatis ipsum dictum nulla. Aliquam quis quam non metus eleifend interdum. Nam eget sapien ac mauris malesuada adipiscing. Etiam eleifend neque sed quam. Nulla facilisi. Proin a ligula. Sed id dui eu nibh egestas tincidunt. Suspendisse arcu.

3.4 Lightning (Layer 2)

Lightning was a 2016 proposal by Poon and Dryja [0], and is a community driven liquidity pool which enables scaling and speed improvements for the Bitcoin network. It is mainly 'powered' by thousands of volunteers who invest in hardware and lock up their Bitcoin in their nodes, to facilitate peer to peer transactions. Zebka et al. found that although the network is "fairly decentralised" it is more recently skewing to larger more established nodes [29]. Though this is a grassroots technology the nature of the design means it can likely be trusted for small scale commercial applications.
The following text is from John Cantrell, an engineer who works on Lightning.

"The Lightning Network is a p2p network of payment channels. A payment channel is a contract between two people where they commit funds using a single onchain tx. Once the funds are committed they can make an unlimited amount of instant & free payments over the channel. You can think of it as a tab where each person tracks how much money they are owed. Each time a payment is made over the channel both parties update their record of how much money each person has. These updates all happen off-chain and only the parties involved know about them. When it's time to settle up the two parties can take the final balances of the channel and create a channel closing transaction that will be broadcast on chain. This closing transaction sends each party the final amounts they are owed. This means for the cost of two on-chain transactions (the opening and closing of the channel) two parties can transact an unlimited number of times and the overall cost of each transaction approaches zero with every additional transaction they make over the channel. Payment channels are a great solution for two parties to transact quickly and cheaply but what if we want to be able to send money to anyone in the world quickly and cheaply? This is where the Lightning Network comes into play, it's a p2p network of these payment channels. This means if Alice has a payment channel with Bob and Bob has a channel with Charlie that Alice can send a payment to Charlie with Bob's help. This idea can be extended such that you can route a payment over an arbitrary number of channels until you can reach the entire world. Routing a payment over multiple channels uses a specific contract called a Hash Time Locked Contract (HTLC). It introduces the ability for Bob and any other nodes you route through to charge a small fee. These fees are typically orders of magnitude smaller than onchain fees. This all sounds great but what if someone tries to cheat? I thought the whole point of Bitcoin was that we no longer had to trust anyone and it sure sounds like there must be some trust in our channel partners to use the Lightning Network? The contracts used in Lightning are built to prevent fraud while requiring no trust. There is a built-in penalty mechanism where if someone tries to cheat and is caught then they lose all of their money. This does mean you need to be monitoring the chain for fraud attempts."

Lightning is a key scaling innovation in the bitcoin network at this time. It is seeing rapid development and adoption (Figure 3.8). The popular payment app "Cash App" integrates the technology, and 'Lightning Strike' services the USA, El Salvador, and Argentina with zero exchange and tranmission fees.

It allows for unbound scaling of transactions (millions of transations per second compared for instance to around 45,000 TPS in the VISA settlement network). Transaction costs are incredibly low, and the transaction speed virtually instantaneous.
The main Lightning network git is the Daemon here but it's worth knowing that Lighting itself really needs access to both a Bitcoin full node, and the Tor private network layer. Both Donner Labs and Zebedee have code packages which allow interaction with the lightning network within Unity. In all likelihood users would have to run a lightning / Bitcoin node and have their users interact with it. This would allow instantaneous transactions of Satoshis (the Bitcoin unit of account) between users. It would not resolve how to move money into Bitcoin or lightning. This could be handled through a web store (BTCPay Server). This is another overhead which would need weighing but opens the door to real value transacting at scale and with high security.
Setting up and running a lightning node is even more difficult. It is recommended to buy a third party hosted BTC / Lightning / BTCPayserver stack.

3.4.1 Micropayments

Possibly the most important affordance of the Lightning network is the concept of micropayments, and streaming micropayments. It is very simple to transfer even one satoshi on Lightning, which is one hundred millionth of a bitcoin, and a small fraction of a penny. This can be a single payment, for a very small goods or service, or a recurring payment on any cadence. This enables streaming payments for any service, or for remittance, or remuneration. These use cases likely have enormous consequences which are just beginning to be explored. Integration of this capability into metaverse applications will be explored later.

3.4.2 LNBits

LNBits is an open source, extensible, Lightning 'source' management suite. It is self hosted, and can connect to a variety of Lightning wallets, further abstracting the liquidity to provide additional functionality to network users. Remember that all of these tools run without a third party, on a £200 setup, hosted at home or within a business. The best way to explore this is to describe *some* of the plugins.

- "Accounts System; Create multiple accounts/wallets. Run for yourself, friends/family, or the whole world!"
- Events plugin allows QR code tickets to be created for an event, and for payments to be taken for the tickets.
- Jukebox creates a Spotify based jukebox which can be deployed online or in physical locations.
- Livestream provides an interface for online live DJ sets to receive real-time Lightning tips, which can be split automatically in real-time with the music producer.
- TPoS, LNURLPoS & OfflineShop support online and offline point of sale (Figure 3.9).
- Paywall creates web access control for content.
- LightningTipBot is a custodial Lightning wallet and tip handling bot within the popular on Telegram instant messenger service.

Together these plugins are incredibly useful primitives which are likely to be translatable to a multi party metaverse application. A proposal for building a more specific plugin along these lines is detailed later.

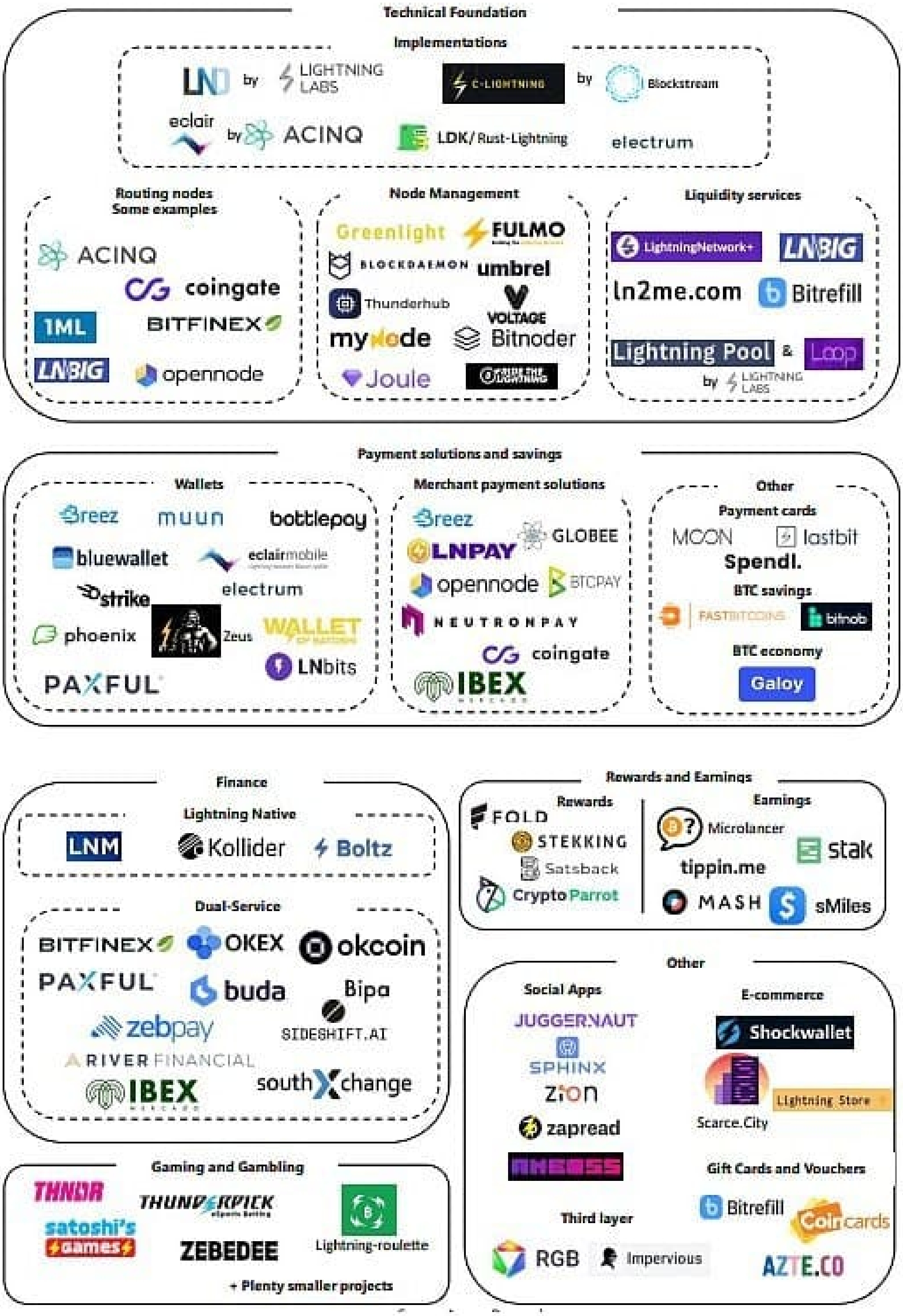


Figure 3.8: Arcane research lightning adoption overview.

Figure 3.9: One of the many prebuilt and kit options for Lightning ‘point of sale’

3.4.3 Etleneum

Etleneum is a centralised smart contract platform built around Lightning invoices. It is most notable as a sign of things to come. There are many small contracts available to try on the site, such as a simple market for moving value between lightning and Bitcoin layer 1, or this simple auction. Contracts are able to operate on data drawn from the wider web, and automatically send and receive lightning payments based on conditional states. It should be viewed as an experiment which allows tinkering in smart contracts, and therefore potentially useful for the software proposed in the final section.

3.4.4 Message passing

Quisque facilisis auctor sapien. Pellentesque gravida hendrerit lectus. Mauris rutrum sodales sapien. Fusce hendrerit sem vel lorem. Integer pellentesque massa vel augue. Integer elit tortor, feugiat quis, sagittis et, ornare non, lacus. Vestibulum posuere pellentesque eros. Quisque venenatis ipsum dictum nulla. Aliquam quis quam non metus eleifend interdum. Nam eget sapien ac mauris malesuada adipiscing. Etiam eleifend neque sed quam. Nulla facilisi. Proin a ligula. Sed id dui eu nibh egestas tincidunt. Suspendisse arcu.

3.5 Liquid federation (layer 2)

"Federation members contribute to the Liquid Network's security, gain voting rights in the board election and membership process, and provide valuable input on the development of new features. Members also benefit from the ability to perform a peg-out without a third party, allowing their users to convert between L-BTC and BTC seamlessly within their platform."

Now 63 members

Bitmatrix, Digital Markets (DIGTL), GMO Coin, Mempool, Specter, and Zaprite are now part of the 63-member group.

El Salvador volcano bonds stuff Quisque facilisis auctor sapien. Pellentesque gravida hendrerit lectus. Mauris rutrum sodales sapien. Fusce hendrerit sem vel lorem. Integer pellentesque massa vel augue. Integer elit tortor, feugiat quis, sagittis et, ornare non, lacus. Vestibulum posuere pellentesque eros. Quisque venenatis ipsum dictum nulla. Aliquam quis quam non metus eleifend interdum. Nam eget sapien ac mauris malesuada adipiscing. Etiam eleifend neque sed quam. Nulla facilisi. Proin a ligula. Sed id dui eu nibh egestas tincidunt. Suspendisse arcu.

3.6 Bitcoin Layer 3

Increasingly important features of modern blockchain implementations are programmability through smart contracts, and issuance of arbitrary tokens. Assigning a transaction to represent another thing like an economic unit, energy unit, or real world object, and operating on those abstractions within the chain logic. Chief among these use cases are stablecoins such as Tether, which are pegged to national currencies and described in the next section. Bitcoin has always supported very limited contracts called scripts, and stablecoin issuance has existed in Bitcoin since Omni Layer. Omni was the first issuer of Tether, but more recently these important features have passed to other layer one chains. This year is likely to see the resurgence of this capability on Bitcoin, which of course benefits from a better security model. In order to properly understand the use of Bitcoin based technologies in metaverse applications it is necessary to examine what these newer 'layer 3' ideas bring.

3.6.1 LNP/BP and RGB

Placeholder text from the RGBFAQ.
RGB is a scalable & confidential smart contracts system for Bitcoin & lightning network. They embrace concepts of private & mutual ownership, abstraction and separation of concerns and represent "post-blockchain", Turing-complete form of trustless distributed computing which does not require introduction of "tokens".

3.6.2 Synonym & Omnibolt

Omnibolt github Quisque facilisis auctor sapien. Pellentesque gravida hendrerit lectus. Mauris rutrum sodales sapien. Fusce hendrerit sem vel lorem. Integer pellentesque massa vel augue. Integer elit tortor, feugiat quis, sagittis et, ornare non, lacus. Vestibulum posuere pellentesque eros. Quisque venenatis ipsum dictum nulla. Aliquam quis quam non metus eleifend interdum. Nam eget sapien ac mauris malesuada adipiscing. Etiam eleifend neque sed quam. Nulla facilisi. Proin a ligula. Sed id dui eu nibh egestas tincidunt. Suspendisse arcu.

3.6.3 DLCFD

Discrete log contracts are a form of externally arbitrated smart contract. Work is being done to extend this primitive to lightning.

Marty Bent “This particular contract allows (currently) one party to lock in a stable amount of USD value in BTC to avoid bitcoin price volatility while their counterpart takes a long position on BTC. As bitcoin’s price moves, the contract allocates sats to one party to make sure the individual who is engaged in the contract to lock in a USD value of bitcoin is doing just that. If the price of bitcoin goes up, sats are allocated to the individual who is taking the long position. If the price of bitcoin goes down, sats are allocated to the party looking to lock in a stable USD value. All of this happens on the Bitcoin blockchain and the Lightning Network. No obscure governance token, DAO, or central third party holding USD in a bank account necessary. All that is needed are sats and a willing counter-party.” Quisque facilisis auctor sapien. Pellentesque gravida hendrerit lectus. Mauris rutrum sodales sapien. Fusce hendrerit sem vel lorem. Integer pellentesque massa vel augue. Integer elit tortor, feugiat quis, sagittis et, ornare non, lacus. Vestibulum posuere pellentesque eros. Quisque venenatis ipsum dictum nulla. Aliquam quis quam non metus eleifend interdum. Nam eget sapien ac mauris malesuada adipiscing. Etiam eleifend neque sed quam. Nulla facilisi. Proin a ligula. Sed id dui eu nibh egestas tincidunt. Suspendisse arcu.

3.7 Bitcoin adjacent chains

3.7.1 Stacks and STX

“Stacks is an open-source network of decentralized apps and smart contracts built on Bitcoin.”
This novel approach saw the launch of a layer 1 blockchain token called STX, which is used in a similar way to gas in Ethereum. but claims settlement on the Bitcoin network. This is achieved through a novel bridging approach which they call Proof of Transfer (PoX).
Stacks users say this hybrid approach is a pragmatic solution which enables dApps, smart contracts, DeFi, NFTs etc without compromising security. In practice the speculative component of the STX tokens which underpin these operations clouds the issue somewhat. It is a potentially useful middle ground solution with a great deal of developer attention.

3.7.2 Sovryn and RSK

Quisque facilisis auctor sapien. Pellentesque gravida hendrerit lectus. Mauris rutrum sodales sapien. Fusce hendrerit sem vel lorem. Integer pellentesque massa vel augue. Integer elit tortor, feugiat quis, sagittis et, ornare non, lacus. Vestibulum posuere pellentesque eros. Quisque venenatis ipsum dictum nulla. Aliquam quis quam non metus eleifend interdum. Nam eget sapien ac mauris malesuada adipiscing. Etiam eleifend neque sed quam. Nulla facilisi. Proin a ligula. Sed id dui eu nibh egestas tincidunt. Suspendisse arcu.

Ingamar | Top of the Block: Lightning <> Rootstock Bridge for lnBTC <> Stablecoin swaps

Exchange

Repo 1

Repo 2

Repo 3

Bridge aggregator

Rest API docs

3.7.3 Sidechains

Quisque facilisis auctor sapien. Pellentesque gravida hendrerit lectus. Mauris rutrum sodales sapien. Fusce hendrerit sem vel lorem. Integer pellentesque massa vel augue. Integer elit tortor, feugiat quis, sagittis et, ornare non, lacus. Vestibulum posuere pellentesque eros. Quisque venenatis ipsum dictum nulla. Aliquam quis quam non metus eleifend interdum. Nam eget sapien ac mauris malesuada adipiscing. Etiam eleifend neque sed quam. Nulla facilisi. Proin a ligula. Sed id dui eu nibh egestas tincidunt. Suspendisse arcu.

3.7.4 Spacechains

Quisque facilisis auctor sapien. Pellentesque gravida hendrerit lectus. Mauris rutrum sodales sapien. Fusce hendrerit sem vel lorem. Integer pellentesque massa vel augue. Integer elit tortor, feugiat quis, sagittis et, ornare non, lacus. Vestibulum posuere pellentesque eros. Quisque venenatis ipsum dictum nulla. Aliquam quis quam non metus eleifend interdum. Nam eget sapien ac mauris malesuada adipiscing. Etiam eleifend neque sed quam. Nulla facilisi. Proin a ligula. Sed id dui eu nibh egestas tincidunt. Suspendisse arcu.

3.7.5 Drivechain

Quisque facilisis auctor sapien. Pellentesque gravida hendrerit lectus. Mauris rutrum sodales sapien. Fusce hendrerit sem vel lorem. Integer pellentesque massa vel augue. Integer elit tortor, feugiat quis, sagittis et, ornare non, lacus. Vestibulum posuere pellentesque eros. Quisque venenatis ipsum dictum nulla. Aliquam quis quam non metus eleifend interdum. Nam eget sapien ac mauris malesuada adipiscing. Etiam eleifend neque sed quam. Nulla facilisi. Proin a ligula. Sed id dui eu nibh egestas tincidunt. Suspendisse arcu.

3.7.6 Softchains

Quisque facilisis auctor sapien. Pellentesque gravida hendrerit lectus. Mauris rutrum sodales sapien. Fusce hendrerit sem vel lorem. Integer pellentesque massa vel augue. Integer elit tortor, feugiat quis, sagittis et, ornare non, lacus. Vestibulum posuere pellentesque eros. Quisque venenatis ipsum dictum nulla. Aliquam quis quam non metus eleifend interdum. Nam eget sapien ac mauris malesuada adipiscing. Etiam eleifend neque sed quam. Nulla facilisi. Proin a ligula. Sed id dui eu nibh egestas tincidunt. Suspendisse arcu.

3.7.7 Statechains

There are many **??**proposals for layer 2 scaling solutions for the bitcoin network. Ruben Somsen **??**describes Softchains, Stateschains, and Spacechains, while Drivechain is described by the author Paul Sztorc on the project web pages. They are all hypothetical with the exception of sidechains.

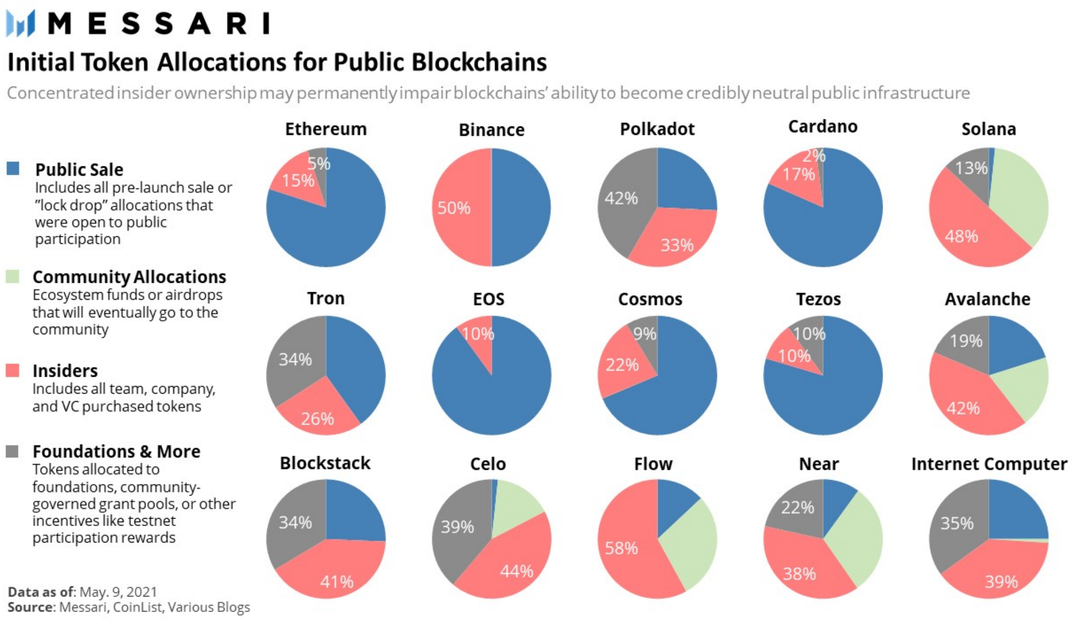


Figure 3.10: Allocations given at the beginning of public blockchain, by Messari.

3.8 Other chains and networks

It's useful to make some 'honourable mentions' of other options as this technology is moving so fast.

Figure 3.10 shows the allocations of proportions of value within different chains.

3.8.1 Solana

Quisque facilisis auctor sapien. Pellentesque gravida hendrerit lectus. Mauris rutrum sodales sapien. Fusce hendrerit sem vel lorem. Integer pellentesque massa vel augue. Integer elit tortor, feugiat quis, sagittis et, ornare non, lacus. Vestibulum posuere pellentesque eros. Quisque venenatis ipsum dictum nulla. Aliquam quis quam non metus eleifend interdum. Nam eget sapien ac mauris malesuada adipiscing. Etiam eleifend neque sed quam. Nulla facilisi. Proin a ligula. Sed id dui eu nibh egestas tincidunt. Suspendisse arcu.

3.8.2 AVAX

Quisque facilisis auctor sapien. Pellentesque gravida hendrerit lectus. Mauris rutrum sodales sapien. Fusce hendrerit sem vel lorem. Integer pellentesque massa vel augue. Integer elit tortor, feugiat quis, sagittis et, ornare non, lacus. Vestibulum posuere pellentesque eros. Quisque venenatis ipsum dictum nulla. Aliquam quis quam non metus eleifend interdum. Nam eget sapien ac mauris malesuada adipiscing. Etiam eleifend neque sed quam. Nulla facilisi. Proin a ligula. Sed id dui eu nibh egestas tincidunt. Suspendisse arcu.

3.8.3 Luna

Quisque facilisis auctor sapien. Pellentesque gravida hendrerit lectus. Mauris rutrum sodales sapien. Fusce hendrerit sem vel lorem. Integer pellentesque massa vel augue. Integer elit tortor, feugiat quis, sagittis et, ornare non, lacus. Vestibulum posuere pellentesque eros. Quisque venenatis ipsum dictum nulla. Aliquam quis quam non metus eleifend interdum. Nam eget sapien ac mauris malesuada adipiscing. Etiam eleifend neque sed quam. Nulla facilisi. Proin a ligula. Sed id dui eu nibh egestas tincidunt. Suspendisse arcu.

3.8.4 Crosschains

RUNE? Quisque facilisis auctor sapien. Pellentesque gravida hendrerit lectus. Mauris rutrum sodales sapien. Fusce hendrerit sem vel lorem. Integer pellentesque massa vel augue. Integer elit tortor, feugiat quis, sagittis et, ornare non, lacus. Vestibulum posuere pellentesque eros. Quisque venenatis ipsum dictum nulla. Aliquam quis quam non metus eleifend interdum. Nam eget sapien ac mauris malesuada adipiscing. Etiam eleifend neque sed quam. Nulla facilisi. Proin a ligula. Sed id dui eu nibh egestas tincidunt. Suspendisse arcu.

3.8.5 Decentralised data

Something about Filecoin? ARWeave? IPFS etc Quisque facilisis auctor sapien. Pellentesque gravida hendrerit lectus. Mauris rutrum sodales sapien. Fusce hendrerit sem vel lorem. Integer pellentesque massa vel augue. Integer elit tortor, feugiat quis, sagittis et, ornare non, lacus. Vestibulum posuere pellentesque eros. Quisque venenatis ipsum dictum nulla. Aliquam quis quam non metus eleifend interdum. Nam eget sapien ac mauris malesuada adipiscing. Etiam eleifend neque sed quam. Nulla facilisi. Proin a ligula. Sed id dui eu nibh egestas tincidunt. Suspendisse arcu.

4. Money in the real world

It is necessary here to briefly examine what money actually is. In the previous section Bitcoin can be viewed in a couple of different lights. As a self custody digital bearer asset it can be viewed as 'property', like gold. Indeed this has long been one of the assertions of the community and it finds favour in law. 'Money' though is a far more slippery concept to grasp. It seems very likely that Bitcoin is evolving as a money, and it's important to define that, but there are many other kinds of money within the online world which can potentially transfer value within virtual social spaces.

4.1 Defining money

It is hard to find a universally accepted definition of what money is. The best approach is to look at the properties of a thing which is asserted to be a money. In his book 'A history of money', Glyn Davies identifies "cognisability, utility, portability, divisibility, indestructibility, stability of value, and homogeneity".

Stroukal (2018) examines Bitcoins' likely value as a money from an Austrian economics perspective and identifies "portability, storability, divisibility, recognizability, homogeneity and scarcity".

A helpfully brief and useful web page by Desjardins from 2015 describes some properties and explains them in layman's terms below:

- Divisible: Can be divided into smaller units of value.
- Fungible: One unit is viewed as interchangeable with another.
- Portable: Individuals can carry money with them and transfer it to others.
- Durable: An item must be able to withstand being used repeatedly.
- Acceptable: Everyone must be able to use the money for transactions.
- Uniform: All versions of the same denomination must have the same purchasing power.
- Limited in Supply: The supply of money in circulation ensures values remain relatively constant.

4.2 International money transfer networks

Quisque facilisis auctor sapien. Pellentesque gravida hendrerit lectus. Mauris rutrum sodales sapien. Fusce hendrerit sem vel lorem. Integer pellentesque massa vel augue. Integer elit tortor, feugiat quis, sagittis et, ornare non, lacus. Vestibulum posuere pellentesque eros. Quisque venenatis ipsum dictum nulla. Aliquam quis quam non metus eleifend interdum. Nam eget sapien ac mauris malesuada adipiscing. Etiam eleifend neque sed quam. Nulla facilisi. Proin a ligula. Sed id dui eu nibh egestas tincidunt. Suspendisse arcu.

4.2.1 Swift, ISO 20022, and correspondence banking

ISO 20022

What is ISO20022

Quisque facilisis auctor sapien. Pellentesque gravida hendrerit lectus. Mauris rutrum sodales sapien. Fusce hendrerit sem vel lorem. Integer pellentesque massa vel augue. Integer elit tortor, feugiat quis, sagittis et, ornare non, lacus. Vestibulum posuere pellentesque eros. Quisque venenatis ipsum dictum nulla. Aliquam quis quam non metus eleifend interdum. Nam eget sapien ac mauris malesuada adipiscing. Etiam eleifend neque sed quam. Nulla facilisi. Proin a ligula. Sed id dui eu nibh egestas tincidunt. Suspendisse arcu.

4.2.2 VISA etc

VISA have announced a “crypto business to business support unit”.

4.2.3 Money transfer operators

International Money Transfer Operators analysis

western union etc, moneygram, transferwise,

4.2.4 Digital disruptive fintech

It seems that the neobank providers of digital banking apps are likely to converge with native digital asset “wallets”. This is also the thesis advanced by the Ark intestments Big Ideas paper.
Strike is a possible the most interesting product in the international fintech arena. It is a ‘global’ money transmitter which uses bank connections in local currencies, but a private version of the Lightning network with settlement on the Bitcoin main chain. In practice users connect the app to their bank and can send money to the bank connected Strike app of another user instantly, and without a fee. This is a far better product than those previously available. In principle it’s open API allows many more application to be integrated into the Strike back end. Twitter already uses this for international tipping (and remittance). It seems that this is a perfect contender for supporting transactions in open metaverse applications, and that may be true, but Strike is currently only available in three countries (USA, El Salvador, Argentina).
Paypal, xoom, Strike, servicing smaller payments, cashapp, venmo, revulot, Quisque facilisis auctor sapien. Pellentesque gravida hendrerit lectus. Mauris rutrum sodales sapien. Fusce hendrerit sem vel lorem. Integer pellentesque massa vel augue. Integer elit tortor, feugiat quis, sagittis et, ornare non, lacus. Vestibulum posuere pellentesque eros. Quisque venenatis ipsum dictum nulla. Aliquam quis quam non metus eleifend interdum. Nam eget sapien ac mauris malesuada adipiscing. Etiam eleifend neque sed quam. Nulla facilisi. Proin a ligula. Sed id dui eu nibh egestas tincidunt. Suspendisse arcu.

4.2.5 Stablecoins

Stablecoins are ‘crypto like’ instruments which are ‘pegged’ at a 1:1 ratio with nationally issued Fiat currencies. In fact they correspond to units of privately issued debt underwritten by a variety of different assets. This is (depending on the issuing company’s model) a far more risky unit of money than the nominal currency that they represent, but they offer significant utility. They allow the user to self custody the cryptographic bearer instrument representing the money themselves, as with blockchain. This may afford the user less friction in that they can transmit the instrument through the newer financial rails which are emerging. The caveat here is that such ‘units’ of money can be frozen by the issuer, and they are subject to the third party risk of the issuer defaulting on the underlying instrument. USDF bank issued private dollar stablecoin

Paypal

Whatsapp, Novi, USDP etc Crypto dollarisaton (myanmar) USDC on Bitcoin?

4.3 Central bank digital currencies

If 2021 was the year of the stablecoin then 2022 is likely to be the year of the central bank digital currency (CDBC). These wholly digital representations of national currencies are oddities in that they are centralised database entries, endorsed and potentially issued by national governments. It is a rapidly evolving space and many nations are now scrambling to catch up. Central bank of Mexico.
The UK has signalled that it is not interested in developing a CDBC at this time, with the Lords economic affairs committee saying:
"The introduction of a UK CBDC would have far-reaching consequences for households, businesses, and the monetary system for decades to come and may pose significant risks depending on how it is designed. These risks include state surveillance of people's spending choices, financial instability as people convert bank deposits to CBDC during periods of economic stress, an increase in central bank power without sufficient scrutiny, and the creation of a centralised point of failure that would be a target for hostile nation state or criminal actors."
In the USA this text from Congressman Tom Emmer shows how complex and interesting this debate is becoming.
Today, I introduced a bill prohibiting the Fed from issuing a central bank digital currency directly to individuals. Here's why it matters:
As other countries, like China, develop CBDCs that fundamentally omit the benefits and protections of cash, it is more important than ever to ensure the United States' digital currency policy protects financial privacy, maintains the dollar's dominance, and cultivates innovation.
CBDCs that fail to adhere to these three basic principles could enable an entity like the Federal Reserve to mobilize itself into a retail bank, collect personally identifiable information on users, and track their transactions indefinitely.
Not only does this CBDC model raise "single point of failure" issues, leaving Americans' financial information vulnerable to attack, but it could be used as a surveillance tool that Americans should never be forced to tolerate from their own government.
Requiring users to open an account at the Fed to access a United States CBDC would put the Fed on an insidious path akin to China's digital authoritarianism.
Any CBDC implemented by the Fed must be open, permissionless, and private. This means that any digital dollar must be accessible to all, transact on a blockchain that is transparent to all, and maintain the privacy elements of cash.
In order to maintain the dollar's status as the world's reserve currency in a digital age, it is important that the United States lead with a posture that prioritizes innovation and does not aim to compete with the private sector.
Simply put, we must prioritize blockchain technology with American characteristics, rather than mimic China's digital authoritarianism out of fear.

4.4 Bitcoin as a money

Since this paper seeks to examine transfer of value within a purely digital environment it is necessary to ask the question of whether Bitcoin is money. It is beyond argument that the Bitcoin network is a rugged message passing protocol which achieves a high degree of consensus about the entries on it's distributed database. Ascribing monetary value to those database entries is a social consensus problem, and this itself is a contested topic.
Jack Mallers, of Strike presentation to the IMF identified the following challenges which he claims are solved by the bitcoin monetary network.

- Speed
- Limited transparency and dependability
- High cost
- Lack of interoperability

- Limited Coverage
- Limited accessibility

Mallers further identifies the attributes of the ideal global money.

- Uncensorable
- Unfreezable
- Permissionless
- Borderless
- Liquid
- Digital

The Bitcoin community believes that Bitcoin is the ultimate money, a 'store of value', chance to separate money from state, increase equality of opportunity and ubiquity of access, while others view it as 'rat poison', or a fraudulent Ponzi scheme. A notable exclusion from the negative rhetoric is Fidelity, the global investment manager, who have always been positive and have recently said:
"Bitcoin is best understood as a monetary good, and one of the primary investment theses for bitcoin is as the store of value asset in an increasingly digital world."
The following paraphrases Eric Yakes, author of 'The 7th Property'. Again, this is an Austrian economics perspective, and like much economic theory the underlying premise is contested[20].
"Paper became money because it was superior to gold in terms of divisibility and portability BUT it lacked scarcity. People reasoned that we could benefit from the greater divisibility/portability of paper money as long as it was redeemable in a form of money that was scarce. This is when money needed to be "backed" by something.
Since we changed money to paper money that wasn't scarce, it needed to be backed by something that was. Since the repeal of the gold standard, politicians have retarded the meaning of the word because our money is no longer backed by something scarce.
So, what is bitcoin backed by? Nothing.
Sound money, like gold, isn't "backed". Only money that lacks inherent monetary properties must be backed by another money that maintains those properties. The idea that our base layer money needs to be backed by something is thinking from the era of paper money. Bitcoin does not require backing, it has inherent monetary properties superior to any other form of money that has ever existed."
Perhaps more than any of these takes, it is worth considering the current public perception of the technology as a money and store of value. This twitter thread from professional sportsman Saquon Barkley, to his half million followers on the platform, captures the mood. He is one of a handful of athletes now being paid directly in Bitcoin.
"I want my career earnings to last generations. The average NFL career is 3 years and inflation is real. Saving and preserving money over time is hard, no matter who you are. In today's world: How do we save? This is why I believe in bitcoin. Almost all professional athletes make the majority of their career earnings in their 20s. With a lack of education, inaccessible tools, and inflation, a sad yet common reality is many enter bankruptcy later on. We can do better. We need to improve financial literacy. Bitcoin is a proven, safe, global, and open system that allows anyone to save money. It is the most accessible asset we've ever seen."

Andrew M. Bailey says *"in an ideal world where governments honour the rights of citizens, they don't spy, they don't prohibit transactions, they manage a sound money supply, and they make sound decisions, the value of bitcoin is very low; we're just not in an ideal world"*

The 2022 ARK Big Ideas report again provides some useful market insight. The posit that demand for the money features of Bitcoin could drive the price of the capped supply tokens to around 1M pounds per Bitcoin as in Figure 4.1.

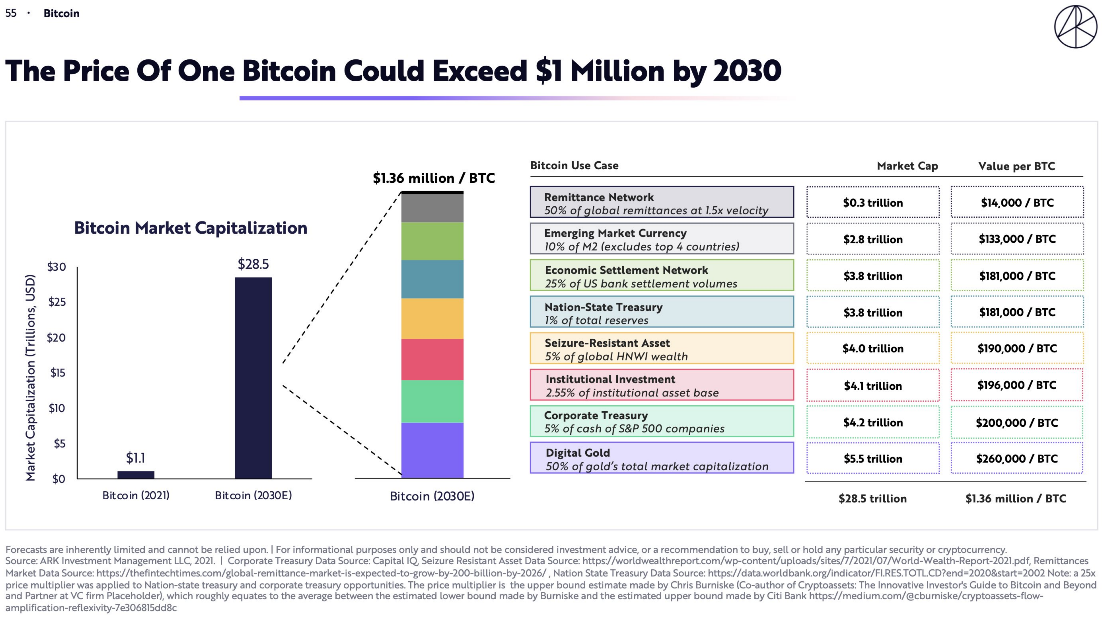


Figure 4.1: Potential market exposure to Bitcoin as a money

4.5 Does DeFi matter to SMEs

DeFi exists because of partial regulatory capture of Bitcoin. It has been commonplace over the last few yearsIt enables trading of value without onerous KYC. Expand. It is likely to be at risk. Quisque facilisis auctor sapien. Pellentesque gravida hendrerit lectus. Mauris rutrum sodales sapien. Fusce hendrerit sem vel lorem. Integer pellentesque massa vel augue. Integer elit tortor, feugiat quis, sagittis et, ornare non, lacus. Vestibulum posuere pellentesque eros. Quisque venenatis ipsum dictum nulla. Aliquam quis quam non metus eleifend interdum. Nam eget sapien ac mauris malesuada adipiscing. Etiam eleifend neque sed quam. Nulla facilisi. Proin a ligula. Sed id dui eu nibh egestas tincidunt. Suspendisse arcu.

BIS report on DeFi

5. Distributed Autonomous Organisations

A DAO is an organistion which is built in distributed code on a blockchain smart contract system. Token holders have voting rights proportional to their holding. The first decentalised autonomous organisation was simply called “The DAO” and was launched on the Ethereum network in 2016 after raising around $100M. It quickly succumbed to a hack and the money was drained. This event was an important moment in the development of Ethereum and resulted in a code fork which preserves two separate versions of the network to this day, though one is falling into obsolescence. In practice DAOs have very few committed ‘stakeholders’ and the same names seem to crop up across multiple projects. Some crucial community decisions within large projects only poll a couple of dozen eligible participants. Its might be that the experiment of distributed governance is failing at this stage.

Perhaps more interesting is the use of the DAO concept to crowd fund global projects, currently especially for the acquisition of important art or cultural items. DAOs are also emerging as a way to fund promising technology projects, though this is reminiscent of the 2017 ICO craze which ended badly and is likely to fall foul of regulations.

Within the NFT and digital art space PleaserDAO has quickly established a strong following. “PleasrDAO is a collective of DeFi leaders, early NFT collectors and digital artists who have built a formidable yet benevolent reputation for acquiring culturally significant pieces with a charitable twist.

Opensea wrangle between IPO and governance token.

ConstitutionDAO, Once upon a time in Shaolin etc

6. Distributed Self Sovereign Identity

This is where an external contributor can add information about DID and SSI

6.1 Some basics about distributed identity

6.1.1 DID principles

persistent identifier (permanent) Resolvable cryptographically verifiable decentralised

6.1.2 primatives

lifetime portable does not depend on third party cannot be taken away

6.1.3 What's in a DID document?

it's to bootstrap the services one or more public keys One or more services which can be used timestamps, sigs, proofs, delegations, authorisations minimum amount of information DID controller = DID subject

6.1.4 What are the challenges?

fragmentations scaling to a world where the user is presented with thousands of signoffs how to visualise and abstract and glom this stuff How to care about the right level of information

6.1.5 keystone uses

- health
- qualifications and certifications
- finance
- contacts
- calendar

6.2 Technologies

6.2.1 Slashtags

Slashtags is a new distributed identity open method being developed by Bitfinex and Tether under the Synonym suite. It uses bitcoin keys for authentication, but communicates a schema through a metadata exchange.

6.2.2 LNURL-Auth

Quisque facilisis auctor sapien. Pellentesque gravida hendrerit lectus. Mauris rutrum sodales sapien. Fusce hendrerit sem vel lorem. Integer pellentesque massa vel augue. Integer elit tortor, feugiat quis, sagittis et, ornare non, lacus. Vestibulum posuere pellentesque eros. Quisque venenatis ipsum dictum nulla. Aliquam quis quam non metus eleifend interdum. Nam eget sapien ac mauris malesuada adipiscing. Etiam eleifend neque sed quam. Nulla facilisi. Proin a ligula. Sed id dui eu nibh egestas tincidunt. Suspendisse arcu.

6.2.3 Sovrin

Sovrin foundation are established global players in distributed identity and we wish to apply to join their federation of credential issuers.

6.2.4 Keri

Quisque facilisis auctor sapien. Pellentesque gravida hendrerit lectus. Mauris rutrum sodales sapien. Fusce hendrerit sem vel lorem. Integer pellentesque massa vel augue. Integer elit tortor, feugiat quis, sagittis et, ornare non, lacus. Vestibulum posuere pellentesque eros. Quisque venenatis ipsum dictum nulla. Aliquam quis quam non metus eleifend interdum. Nam eget sapien ac mauris malesuada adipiscing. Etiam eleifend neque sed quam. Nulla facilisi. Proin a ligula. Sed id dui eu nibh egestas tincidunt. Suspendisse arcu.

6.2.5 Atala Prism

Quisque facilisis auctor sapien. Pellentesque gravida hendrerit lectus. Mauris rutrum sodales sapien. Fusce hendrerit sem vel lorem. Integer pellentesque massa vel augue. Integer elit tortor, feugiat quis, sagittis et, ornare non, lacus. Vestibulum posuere pellentesque eros. Quisque venenatis ipsum dictum nulla. Aliquam quis quam non metus eleifend interdum. Nam eget sapien ac mauris malesuada adipiscing. Etiam eleifend neque sed quam. Nulla facilisi. Proin a ligula. Sed id dui eu nibh egestas tincidunt. Suspendisse arcu.

6.2.6 Microsoft ION

Quisque facilisis auctor sapien. Pellentesque gravida hendrerit lectus. Mauris rutrum sodales sapien. Fusce hendrerit sem vel lorem. Integer pellentesque massa vel augue. Integer elit tortor, feugiat quis, sagittis et, ornare non, lacus. Vestibulum posuere pellentesque eros. Quisque venenatis ipsum dictum nulla. Aliquam quis quam non metus eleifend interdum. Nam eget sapien ac mauris malesuada adipiscing. Etiam eleifend neque sed quam. Nulla facilisi. Proin a ligula. Sed id dui eu nibh egestas tincidunt. Suspendisse arcu.

6.2.7 Atala Prism (ADA Ecosystem)

This Medium post lists the pre-requisites required for interaction with Eth within Unity. At this stage this hasn't been expanded out. It's based around the .NET 'nethereum' library which can be found on their github.

6.3 User stories / behaviours

- As a user I want to.
- As a user I want to.
- As a user I want to.

6.4 Comparing the technologies

Figure 7.1 on the next page compares the technologies discussed so far in the context of the behaviours in section 8.6.
Looking at these row by row it can be seen that:

- Bitcoin is too slow. Additionally the technical challenge of interacting with the network are considerable, and the fees are both high and rising.
- Ethereum ERC721 non fungible tokens might be a possibility for supporting limited edition digital asset sales. A web interface could be built on cloud servers to handle the shop and back end commitments to the Ethereum network. While fully committed transactions would take a few minutes to process the shop itself could inform the users immediately then email out a certificate of ownership. It would be possible to trade these items on other platforms, and conceivable within the app. Prizes (digital assets) could be issued to users for competition activity. The system would be expensive to use, the fees might vary wildly, and the ecological costs might be enormous. Batching transactions could overcome this, but that would rely on substantial take-up of the service, and management overhead.
- Building and issuing and Ethereum based token, in an ICO process or similar seems a disproportionate amount of investment and would be expensive to use.
- A custom private blockchain offers no advantages over a database. It is a difficult thing to implement, but would have better performance and use cost to the users.
- BTC pay server is an interesting open source project which allows companies to host a simple lightning / BTC web shop. It's not clear what the use case is here, but it is well engineered and scalable and should be born in mind when thinking about the other problems and systems.
- Lightning network has open source connectivity into Unity, works well with QR codes, is fast, and has low transaction latency. The only issue is that it offers nothing but marketing hype over and above more traditional digital point of sale layers, and is more difficult to connect to money rails in the UK.
- Coloured coins would allow all of the desirable functionality, but it would be a substantial development challenge, using old open source code, and have high use fees.
- RGB MyCitadel stack seems highly appropriate and is open source but is in development and will not be available until later in the year.

6.5 Testing and Recommendations

Some of these technologies might deliver some value in the near future.

7. Non Fungible Tokens

Nonfungible tokens allow digital and new media artists to connect with audiences without gatekeepers. This is an important supporting innovation for something so recently recognised as valuable art in it's own right. Established mediators and curators of art have been caught totally wrongfooted, and NFTs seem to give a way for them to be cut out completely. This is a compounding, and disrupting paradigm change.

Users of NFT markets have injected around $30 billion into the tokens during 2021. While it is likely that there is currently a speculative bubble, it seems certain that the technology is here to stay. Samsung for instance have announced that their TVs will support not only display of NFTs with artist defined settings in the metadata, but also an integrated marketplace for browsing and purchasing.

Notable examples Mega Mutant Serum.

Wikipedia list

Beeple scam

Peter Thiel, the billionaire venture capitalist who founded PayPal has invested in expanded NTF use cases. The first is 'Royal' which is experimentally selling selling limited NFT tokens which contractually entitle the holder to a portion of music artist royalties. The other is a political funding NFT from Blake Masters to support his senate ambitions.

It is completely reasonable to assert that these use cases could be accomplished without the use of NFT technology, and is part of the hype bubble.

NFT art currently suffers from the same failure of decentralisation already discussed in the Ethererum technology stack, but this is compounded by the normalisation of intermediate art brokers continuing to custody the NFTs even after sale. They are usually selling a pointer to their own servers. The market is nascent and evolving, but it's currently not delivering on it's core promise.

7.1 Energy concerns

It is under discussed within the community that 'minting' non fungible tokens, predominantly on Ethereum, is energy wasteful, on an already energy inefficient platform. As a random example this single collector of a few images accounts for nearly 10 kilotonnes of carbon emissions. This is a subtly different problem to the security of the Bitdooin economic network in that these tokens are clealy non fungible, so cannot be reused again and again in order to reduce the unit environmental impact.

7.2 Is any of this useful?

7.3 User stories / behaviours

- As a user I want to select a digital asset I find in a metaverse and then be offered an option to purchase the asset so I can look at it in my own spaces.
- As a user I want to click on a digital asset I find in a metaverse and be given the opportunity to buy it as a rare digital representation so that only I and a few others are provably certified to own.
- As a metaverse 'land' holder (stakeholder) I would like to reward winners of competitions with real money or digital assets to foster and gamify the system
- As a user I would like to interact with a virtual marketplace where I could swap and trade digital assets with other users so that I continue to feel engaged.
- As a user I would like to create content so I can take it to metaverse locations and monetise it.

7.4 Comparing the technologies

Figure 7.1 on the next page compares the technologies discussed so far in the context of the behaviours in section 8.6.
Looking at these row by row it can be seen that:

- Bitcoin layer 1 is too slow. Additionally the technical challenge of interacting with the network are considerable, and the fees are both high and likely to rise.
- Ethereum ERC721 non fungible tokens might be a possibility for supporting limited edition digital assets. A web interface could be built on cloud servers to handle the shop and back end commitments to the Ethereum network. While fully committed transactions would take a few minutes to process the shop itself could inform the users immediately then email out a certificate of ownership. It would be possible to trade these items on other platforms, and conceivably within an app. Prizes (digital assets) could be issued to users for competition activity. The system would be expensive to use, the fees might vary wildly, and the ecological costs might be enormous. Batching transactions could overcome this, but that would rely on substantial take-up of the service, and management overhead.
- Building and issuing and Ethereum based token, in an ICO process or similar seems a disproportionate amount of investment and would be expensive to use.
- A custom private blockchain offers no advantages over a database. It is a difficult thing to implement, but would have better performance and use cost to the users.
- BTC pay server is an interesting open source project which allows companies to host a simple lightning / BTC web shop. It's not clear what the use case is here, but it is well engineered and scalable and should be born in mind when thinking about the other problems and systems.
- Lightning network has open source connectivity into Unity, works well with QR codes, is fast, and has low transaction latency. The only issue is that it offers nothing but marketing hype over and above more traditional digital point of sale layers, and is more difficult to connect to money rails in the UK.
- New layer 3 solutions like RGB, stacks, or Synonym might allow cheap and fast in

7.5 What are the options

ETH, SOL, ADA, STX, RGB, Liquid?, RSK, so many others, this is gonna be exhausting to write about. Quisque facilisis auctor sapien. Pellentesque gravida hendrerit lectus. Mauris rutrum sodales sapien. Fusce hendrerit sem vel lorem. Integer pellentesque massa vel augue. Integer elit tortor, feugiat quis, sagittis et, ornare non, lacus. Vestibulum posuere pellentesque eros. Quisque venenatis

	Likely dev time	Cost of Use	Speed of Use	Energy Cost	Open source	Bank connect	Buying things	Prizes	Trading Peer 2 Peer	Arbi to issu
Bitcoin	N/A	~£10 per use	~H	High	Yes	Maybe (Strike)	Yes	Yes	Maybe	Y
Eth ERC721	N/A	~£10 per use	Mins	Very High	Yes	No	No	Yes	Maybe	Y
Eth token	Weeks Months	~£10 per use	Many Mins	High	Maybe	No	Maybe	Yes	Yes	Y
Custom chain	Months	Very low	Secs	Moderte	Maybe	Maybe	Yes	Yes	Yes	Y
BTC pay server + LND	Days but operational overheads	~£10 per use	Secs	Lower	Yes	Yes	Yes	Yes	No	N
BTC L2 and L3	Months	Very Low	Secs	Low	Some	Maybe	Yes	Yes	Yes	N
Colour coins	Months	Very Low	Secs	High	Maybe	Maybe	Yes	Yes	Yes	Ma

Table 7.1: This table is basically broken and out of date and will be sorted out soon!

ipsum dictum nulla. Aliquam quis quam non metus eleifend interdum. Nam eget sapien ac mauris malesuada adipiscing. Etiam eleifend neque sed quam. Nulla facilisi. Proin a ligula. Sed id dui eu nibh egestas tincidunt. Suspendisse arcu.

7.6 Why choose bitcoin again

because it's the true opensource money option, the cost / barrier to entry is far lower than ethereum, and with new technology such as NFT integration directly with DIBA on RGB this integrates. Quisque facilisis auctor sapien. Pellentesque gravida hendrerit lectus. Mauris rutrum sodales sapien. Fusce hendrerit sem vel lorem. Integer pellentesque massa vel augue. Integer elit tortor, feugiat quis, sagittis et, ornare non, lacus. Vestibulum posuere pellentesque eros. Quisque venenatis ipsum dictum nulla. Aliquam quis quam non metus eleifend interdum. Nam eget sapien ac mauris malesuada adipiscing. Etiam eleifend neque sed quam. Nulla facilisi. Proin a ligula. Sed id dui eu nibh egestas tincidunt. Suspendisse arcu.

8. Metaverses

8.1 History and market need

The word metaverse was coined by the author Neal Stephenson in his 1992 novel Snowcrash. It started popping up soon after in news articles and research papers [21].

Remembering VRML: The Metaverse of 1995

The concept of the Metaverse is extremely plastic at this time (Figure 8.1). This section will attempt to frame the context, and explain the increasingly polarised options looking forward.

Both Second Life and more recently the game Fortnite can be seen as precursors. Second Life should rightly be viewed as the first serious attempt at a metaverse, and was being described as such by users as early as 2002/2003. It broke through into academic research and several Universities bought 'digital land' and started talking about using the platform for education [**emp2006putting**, 17, 26, 27]. Businesses began to develop and showcase virtual products. Interest in the platform waned by 2010, although the platform is still operational and under development with around 40k median concurrent users. Surprisingly this is similar to the 2007 peak use, but this is in the context of other platforms now boasting considerably faster growth (more later).

Figure 8.1: Elon Musk agrees with this on Twitter

Epic games Tim Sweeney attaching the word metaverse to social events within fortnite in 2017. "You're seeing the beginning components of the Metaverse coming together now.." - Tim Sweeney Clearly he ignored the extensive work of Second Life here, but fortnite demonstrated a new level of social engagement boasting millions of concurrent users in a single space for major events in the game. Most interestingly events outside of the game logic emerged, with concerts drawing over 10M users on occasion. This has kickstarted a new round of academic interest in the phenomenon [19]. A new era of microtransactions for in game assets has begun, thought this is constrained to the walled economic garden within Epic's servers.

8.2 Post 'Meta' metaverse

The current media around "metaverse" has been seeded by Mark Zuckerberg's rebranding of his Facebook company to 'Meta', and his planned investment in the technology. The second order hype is likely a speculative play by major companies on the future of the internet. There has been a reactive pushback against this by the wider tech community who are concerns about monetisation of biometrics. Observers do not trust these 'Web2' players with such a potentially powerful social medium. It is very plausible that this is all just a marketing play that goes nowhere and fizzles out. It is by no means clear that people want to spend time socialising globally in virtual and mixed reality. These major companies are making an asymmetric bet that if there is a move into virtual worlds, then they need to be stakeholders in the gatekeeping capabilities of those worlds.
Meta,Disney plus, Sportswear manufacturers

Can enough be done to prevent abuse?

It seems like there are four major interpretations of the word.

Facebook have recently rebranding their parent company as 'Meta' and they are aggressively promoting "The Metaverse" as a shared social VR space, chiefly of their design. In Stephenson's 'Snow Crash' the Hero Protagonist (drolly called Hiro Protagonist) spends much of the novel in a dystopian virtual environment called the metaverse. It is unclear if Facebook is deliberately embracing the irony of aping such a dystopian image, but certainly their known predisposition for corporate surveillance, alongside their attempt at a global digital money is ringing alarm bells.
The Grayscale investment trust published a report which views Metaverse as a potential trillion dollar global industry. Such industry reports are given to hyperbole, but it seems the technology is becoming the focus of technology investment narratives.

8.2.1 Mixed reality as a metaverse

Spatial anchors allow digital objects to be overlaid persistently in the real world. With a global 'shared truth' of such objects a different kind of metaverse can arise. One such example is the forthcoming AVVYLAND.

Peleton as a metaverse?

8.3 Digital Land

Quisque facilisis auctor sapien. Pellentesque gravida hendrerit lectus. Mauris rutrum sodales sapien. Fusce hendrerit sem vel lorem. Integer pellentesque massa vel augue. Integer elit tortor, feugiat quis, sagittis et, ornare non, lacus. Vestibulum posuere pellentesque eros. Quisque venenatis ipsum dictum nulla. Aliquam quis quam non metus eleifend interdum. Nam eget sapien ac mauris malesuada adipiscing. Etiam eleifend neque sed quam. Nulla facilisi. Proin a ligula. Sed id dui eu nibh egestas tincidunt. Suspendisse arcu.

8.3.1 Secondlife

Quisque facilisis auctor sapien. Pellentesque gravida hendrerit lectus. Mauris rutrum sodales sapien. Fusce hendrerit sem vel lorem. Integer pellentesque massa vel augue. Integer elit tortor, feugiat quis, sagittis et, ornare non, lacus. Vestibulum posuere pellentesque eros. Quisque venenatis ipsum dictum nulla. Aliquam quis quam non metus eleifend interdum. Nam eget sapien ac mauris malesuada adipiscing. Etiam eleifend neque sed quam. Nulla facilisi. Proin a ligula. Sed id dui eu nibh egestas tincidunt. Suspendisse arcu.

8.3.2 The new stuff

Quisque facilisis auctor sapien. Pellentesque gravida hendrerit lectus. Mauris rutrum sodales sapien. Fusce hendrerit sem vel lorem. Integer pellentesque massa vel augue. Integer elit tortor, feugiat quis, sagittis et, ornare non, lacus. Vestibulum posuere pellentesque eros. Quisque venenatis ipsum dictum nulla. Aliquam quis quam non metus eleifend interdum. Nam eget sapien ac mauris malesuada adipiscing. Etiam eleifend neque sed quam. Nulla facilisi. Proin a ligula. Sed id dui eu nibh egestas tincidunt. Suspendisse arcu.

8.4 Global enterprise perspective

Meta(Facebook)

Nvidia Omniverse is free for creators, Unity etc

Microsoft have just bought Activision / Blizzard for around seventy billion dollars. This is have been communicated by Microsoft executives as a ”Metaverse play”, leveraging their internal game item markets, and their massive multiplayer game worlds to build toward a closed metaverse experience like the one Meta is planning. This builds on the success of early experiments like the Fornite based music concerts, which attracted millions of concurrent users to live events.

8.5 NFT as metaverse narrative

Within the NFT community it is normalised to refer to ownership of digital tokens as participation in a metaverse. This CNBC article highlights the confusion, as this major news outlet refers to Walmart prepares to offer NFTs” as an entry “into the metaverse”. Quisque facilisis auctor sapien. Pellentesque gravida hendrerit lectus. Mauris rutrum sodales sapien. Fusce hendrerit sem vel lorem. Integer pellentesque massa vel augue. Integer elit tortor, feugiat quis, sagittis et, ornare non, lacus. Vestibulum posuere pellentesque eros. Quisque venenatis ipsum dictum nulla. Aliquam quis quam non metus eleifend interdum. Nam eget sapien ac mauris malesuada adipiscing. Etiam eleifend neque sed quam. Nulla facilisi. Proin a ligula. Sed id dui eu nibh egestas tincidunt. Suspendisse arcu.

8.6 MMORG games and NFTs

Traditional gamers have pushed back on the seemingly useful idea of integrating NTFs with traditional games. This may be in part because Ethereum mining has kept graphics card prices high for a decade.

- As a user I want to select a digital asset I find in the AR/VR world and then be offered an option to purchase the asset so I can look at it in my own spaces.
- As a user I want to click on a digital asset I find in the AR app and be given the opportunity to buy it as a rare digital representation so that only I and a few others are provably certified to own.
- As a user I would like to transfer economic value to people and entities I meet in the metaverse such that it is agreed by all parties quickly that value has been provably transferred.

- As a user I would like to access an online marketplace in the metaverse where I swap and trade digital assets with other users so that I continue to feel engaged.
- As a user I would like to create content (inside or outside of the metaverse) so I can take it to metaverse and monetise it.
- As a content creator or influencer I would like to engage with live audiences within the metaverse, and moneytise my opinions and knowledge in real-time. I would like to have a way to split this money with co-collaborators in real time.

8.7 Crypto metaverses

Report on Axie Infinity

Pavia Metaverse Probably the best example in the market at this time with connecting users with one another through blockchain is Satoshis Games 'Litenite'. Litenite is a 'battle royale' game which allows users to earn Satoshis through the Lightning network.
Similarly, and potentially more significantly, Zebedee have brought Lightning based micropayments to Counter Strike, which adds a financial layer directly to eSport, itself a multi billion pound global industry.
Spells of Genesis is a long running card RPG trading game on mobiles which allows "ownership" of items and cards through non-fungible token ecosystems.
There are also hundreds of casinos which operate within and even on blockchain networks. These feel out of scope as they are a different and somewhat regulated offering.

8.8 Social VR software options

In considering the needs of business to business and business to client social VR is it useful to compare software platforms:

8.8.1 Second Life

Notable because it's the original and has a decently mature marketplace. Quisque facilisis auctor sapien. Pellentesque gravida hendrerit lectus. Mauris rutrum sodales sapien. Fusce hendrerit sem vel lorem. Integer pellentesque massa vel augue. Integer elit tortor, feugiat quis, sagittis et, ornare non, lacus. Vestibulum posuere pellentesque eros. Quisque venenatis ipsum dictum nulla. Aliquam quis quam non metus eleifend interdum. Nam eget sapien ac mauris malesuada adipiscing. Etiam eleifend neque sed quam. Nulla facilisi. Proin a ligula. Sed id dui eu nibh egestas tincidunt. Suspendisse arcu.

8.8.2 Spatial

- Very compelling. Wins at wow.
- Great avatars, user generated
- AR first design
- Limited scenes
- Smaller groups (12?)
- Limited headset support
- Intuitive meeting support tools
- No back end integration

8.8.3 MeetinVR

- Good enough graphics, pretty mature system
- OK indicative avatars, user selected
- VR first design

- Limited scenes
- Smaller groups (12?)
- Quest and PC
- Writing and gestures supported
- Some basic enterprise tools integration
- Bring in 3D objects
- Need to apply for a license?

8.8.4 Glue

- Better enterprise security integration
- Larger environments, potential for breakouts in the same space. Workshop capable
- 3D object support, screen sharing, some collaborative tools
- Apply for a license
- Fairly basic graphics
- Basic avatars
- Quest and PC
- Writing and gestures supported
- Mac support

8.8.5 Mozilla Hubs

- Open source, bigger scale, more complex
- Choose avatars, or import your own
- Environments are provided, or can be designed
- Useful for larger conferences with hundreds or thousands of members but is commensurately more complex
- Quest and PC
- Larger scenes within scenes

8.8.6 FramesVR

- Really simple to join
- Basic avatars
- Bit buggy
- 3D object support, screen sharing, some collaborative tools
- Quest and PC
- Larger scenes within scenes
- Runs in the browser

8.8.7 AltSpace

- Microsoft social meeting platform
- Very good custom avatar design
- Great world building editor in the engine
- Doesn't really support business integration so it's a bit out of scope
- Huge numbers (many thousands) possible so it's great for global events
- Mac support

8.8.8 Engage

- Great polished graphics
- Fully customisable avatars
- Limited scenes

- Presentation to groups for education and learning
- PC first, quest is side loadable but that's a technical issue
- BigScreen VR
- Seated in observation points in a defined shared theatre
- Screen sharing virtual communal screen watching, aimed at gamers, film watching
- up to 12 user

8.8.9 VRChat

Quisque facilisis auctor sapien. Pellentesque gravida hendrerit lectus. Mauris rutrum sodales sapien. Fusce hendrerit sem vel lorem. Integer pellentesque massa vel augue. Integer elit tortor, feugiat quis, sagittis et, ornare non, lacus. Vestibulum posuere pellentesque eros. Quisque venenatis ipsum dictum nulla. Aliquam quis quam non metus eleifend interdum. Nam eget sapien ac mauris malesuada adipiscing. Etiam eleifend neque sed quam. Nulla facilisi. Proin a ligula. Sed id dui eu nibh egestas tincidunt. Suspendisse arcu.

8.8.10 NEOSVR

Notable becasue it's trying to integrate crypto marketplaces

8.8.11 Facebook Horizon Workrooms

Quisque facilisis auctor sapien. Pellentesque gravida hendrerit lectus. Mauris rutrum sodales sapien. Fusce hendrerit sem vel lorem. Integer pellentesque massa vel augue. Integer elit tortor, feugiat quis, sagittis et, ornare non, lacus. Vestibulum posuere pellentesque eros. Quisque venenatis ipsum dictum nulla. Aliquam quis quam non metus eleifend interdum. Nam eget sapien ac mauris malesuada adipiscing. Etiam eleifend neque sed quam. Nulla facilisi. Proin a ligula. Sed id dui eu nibh egestas tincidunt. Suspendisse arcu.

8.8.12 Vircadia

We have chosen Vircadia as our development platform for this investigation is it's a community supported free and open source project with some support for economic interaction.

8.8.13 WebXR

Monetisation of WebXR Quisque facilisis auctor sapien. Pellentesque gravida hendrerit lectus. Mauris rutrum sodales sapien. Fusce hendrerit sem vel lorem. Integer pellentesque massa vel augue. Integer elit tortor, feugiat quis, sagittis et, ornare non, lacus. Vestibulum posuere pellentesque eros. Quisque venenatis ipsum dictum nulla. Aliquam quis quam non metus eleifend interdum. Nam eget sapien ac mauris malesuada adipiscing. Etiam eleifend neque sed quam. Nulla facilisi. Proin a ligula. Sed id dui eu nibh egestas tincidunt. Suspendisse arcu.

8.8.14 Integration with web and game engines

(other integrations?)

8.9 User stories

Quisque facilisis auctor sapien. Pellentesque gravida hendrerit lectus. Mauris rutrum sodales sapien. Fusce hendrerit sem vel lorem. Integer pellentesque massa vel augue. Integer elit tortor, feugiat quis, sagittis et, ornare non, lacus. Vestibulum posuere pellentesque eros. Quisque venenatis ipsum dictum nulla. Aliquam quis quam non metus eleifend interdum. Nam eget sapien ac mauris malesuada adipiscing. Etiam eleifend neque sed quam. Nulla facilisi. Proin a ligula. Sed id dui eu nibh egestas tincidunt. Suspendisse arcu.

8.10 Recommendations for value transfer

There are many claims about what blochchain technologies can enable. In the tens of thousands of attempts at utility over the last decade there are surprisingly few chains able to claim any value at all, and those that can often have significant problems in other areas. It is not the intention of this analysis to poke at problems. The primary use case within the context of a shared social space (metavserse) is low friction transmission of value. Remember that interlocutors and entities might have globally different physical locations outside of the real world. What is needed is instant "settlement" of digital bearer instruments within the context of the digital environement. This is fortunately what Bitcoin was designed to do. Additionally it is highly possible that exchange of digital goods (art and objects and provable services) will be required. This is also in scope within this document.

8.11 Bitcoin market gap

Nobody is currently deploying the discussed technologies purely on Bitcoin because it's slower evolution is still catching up. This is a market gap and the following section shows how this might be done.

8.11.1 Money

Quisque facilisis auctor sapien. Pellentesque gravida hendrerit lectus. Mauris rutrum sodales sapien. Fusce hendrerit sem vel lorem. Integer pellentesque massa vel augue. Integer elit tortor, feugiat quis, sagittis et, ornare non, lacus. Vestibulum posuere pellentesque eros. Quisque venenatis ipsum dictum nulla. Aliquam quis quam non metus eleifend interdum. Nam eget sapien ac mauris malesuada adipiscing. Etiam eleifend neque sed quam. Nulla facilisi. Proin a ligula. Sed id dui eu nibh egestas tincidunt. Suspendisse arcu.

8.11.2 Identity proofs

Quisque facilisis auctor sapien. Pellentesque gravida hendrerit lectus. Mauris rutrum sodales sapien. Fusce hendrerit sem vel lorem. Integer pellentesque massa vel augue. Integer elit tortor, feugiat quis, sagittis et, ornare non, lacus. Vestibulum posuere pellentesque eros. Quisque venenatis ipsum dictum nulla. Aliquam quis quam non metus eleifend interdum. Nam eget sapien ac mauris malesuada adipiscing. Etiam eleifend neque sed quam. Nulla facilisi. Proin a ligula. Sed id dui eu nibh egestas tincidunt. Suspendisse arcu.

8.11.3 Digital object tracking

Quisque facilisis auctor sapien. Pellentesque gravida hendrerit lectus. Mauris rutrum sodales sapien. Fusce hendrerit sem vel lorem. Integer pellentesque massa vel augue. Integer elit tortor, feugiat quis, sagittis et, ornare non, lacus. Vestibulum posuere pellentesque eros. Quisque venenatis ipsum dictum nulla. Aliquam quis quam non metus eleifend interdum. Nam eget sapien ac mauris malesuada adipiscing. Etiam eleifend neque sed quam. Nulla facilisi. Proin a ligula. Sed id dui eu nibh egestas tincidunt. Suspendisse arcu.

8.11.4 Object transfer and trading

Quisque facilisis auctor sapien. Pellentesque gravida hendrerit lectus. Mauris rutrum sodales sapien. Fusce hendrerit sem vel lorem. Integer pellentesque massa vel augue. Integer elit tortor, feugiat quis, sagittis et, ornare non, lacus. Vestibulum posuere pellentesque eros. Quisque venenatis ipsum dictum nulla. Aliquam quis quam non metus eleifend interdum. Nam eget sapien ac mauris malesuada adipiscing. Etiam eleifend neque sed quam. Nulla facilisi. Proin a ligula. Sed id dui eu nibh egestas tincidunt. Suspendisse arcu.

9. Hardware and software choices to support this

We propose that the software be deployable into a server based virtual network running on a single system. Our hardware recommendation to run a balanced selection of elements is a quad core 16GB system with two 1TB SSD drives.

9.1 Why choose nix

Quisque facilisis auctor sapien. Pellentesque gravida hendrerit lectus. Mauris rutrum sodales sapien. Fusce hendrerit sem vel lorem. Integer pellentesque massa vel augue. Integer elit tortor, feugiat quis, sagittis et, ornare non, lacus. Vestibulum posuere pellentesque eros. Quisque venenatis ipsum dictum nulla. Aliquam quis quam non metus eleifend interdum. Nam eget sapien ac mauris malesuada adipiscing. Etiam eleifend neque sed quam. Nulla facilisi. Proin a ligula. Sed id dui eu nibh egestas tincidunt. Suspendisse arcu.

9.2 Networking layer

Quisque facilisis auctor sapien. Pellentesque gravida hendrerit lectus. Mauris rutrum sodales sapien. Fusce hendrerit sem vel lorem. Integer pellentesque massa vel augue. Integer elit tortor, feugiat quis, sagittis et, ornare non, lacus. Vestibulum posuere pellentesque eros. Quisque venenatis ipsum dictum nulla. Aliquam quis quam non metus eleifend interdum. Nam eget sapien ac mauris malesuada adipiscing. Etiam eleifend neque sed quam. Nulla facilisi. Proin a ligula. Sed id dui eu nibh egestas tincidunt. Suspendisse arcu.

9.2.1 Proxmox

Quisque facilisis auctor sapien. Pellentesque gravida hendrerit lectus. Mauris rutrum sodales sapien. Fusce hendrerit sem vel lorem. Integer pellentesque massa vel augue. Integer elit tortor, feugiat quis, sagittis et, ornare non, lacus. Vestibulum posuere pellentesque eros. Quisque venenatis ipsum dictum nulla. Aliquam quis quam non metus eleifend interdum. Nam eget sapien ac mauris malesuada adipiscing. Etiam eleifend neque sed quam. Nulla facilisi. Proin a ligula. Sed id dui eu nibh egestas tincidunt. Suspendisse arcu.

9.2.2 VyOS firewall

Quisque facilisis auctor sapien. Pellentesque gravida hendrerit lectus. Mauris rutrum sodales sapien. Fusce hendrerit sem vel lorem. Integer pellentesque massa vel augue. Integer elit tortor, feugiat quis, sagittis et, ornare non, lacus. Vestibulum posuere pellentesque eros. Quisque venenatis ipsum dictum nulla. Aliquam quis quam non metus eleifend interdum. Nam eget sapien ac mauris malesuada adipiscing. Etiam eleifend neque sed quam. Nulla facilisi. Proin a ligula. Sed id dui eu nibh egestas tincidunt. Suspendisse arcu.

9.2.3 Privacy aspects and using TOR etc

Currently some compromises with privacy may be necessary. Power users vs standard users. KYC/AML. tor nodes

9.3 Bitcoin on Nix

Quisque facilisis auctor sapien. Pellentesque gravida hendrerit lectus. Mauris rutrum sodales sapien. Fusce hendrerit sem vel lorem. Integer pellentesque massa vel augue. Integer elit tortor, feugiat quis, sagittis et, ornare non, lacus. Vestibulum posuere pellentesque eros. Quisque venenatis ipsum dictum nulla. Aliquam quis quam non metus eleifend interdum. Nam eget sapien ac mauris malesuada adipiscing. Etiam eleifend neque sed quam. Nulla facilisi. Proin a ligula. Sed id dui eu nibh egestas tincidunt. Suspendisse arcu.

9.3.1 Bitcoin Core

Quisque facilisis auctor sapien. Pellentesque gravida hendrerit lectus. Mauris rutrum sodales sapien. Fusce hendrerit sem vel lorem. Integer pellentesque massa vel augue. Integer elit tortor, feugiat quis, sagittis et, ornare non, lacus. Vestibulum posuere pellentesque eros. Quisque venenatis ipsum dictum nulla. Aliquam quis quam non metus eleifend interdum. Nam eget sapien ac mauris malesuada adipiscing. Etiam eleifend neque sed quam. Nulla facilisi. Proin a ligula. Sed id dui eu nibh egestas tincidunt. Suspendisse arcu.

9.3.2 Lighting LND and LNBits

Lightning Jet automatic rebalance.

Quisque facilisis auctor sapien. Pellentesque gravida hendrerit lectus. Mauris rutrum sodales sapien. Fusce hendrerit sem vel lorem. Integer pellentesque massa vel augue. Integer elit tortor, feugiat quis, sagittis et, ornare non, lacus. Vestibulum posuere pellentesque eros. Quisque venenatis ipsum dictum nulla. Aliquam quis quam non metus eleifend interdum. Nam eget sapien ac mauris malesuada adipiscing. Etiam eleifend neque sed quam. Nulla facilisi. Proin a ligula. Sed id dui eu nibh egestas tincidunt. Suspendisse arcu.

9.3.3 Electrum server

Options on the Blockstream website Quisque facilisis auctor sapien. Pellentesque gravida hendrerit lectus. Mauris rutrum sodales sapien. Fusce hendrerit sem vel lorem. Integer pellentesque massa vel augue. Integer elit tortor, feugiat quis, sagittis et, ornare non, lacus. Vestibulum posuere pellentesque eros. Quisque venenatis ipsum dictum nulla. Aliquam quis quam non metus eleifend interdum. Nam eget sapien ac mauris malesuada adipiscing. Etiam eleifend neque sed quam. Nulla facilisi. Proin a ligula. Sed id dui eu nibh egestas tincidunt. Suspendisse arcu.

9.3.4 C-Lightning and CLBoss

Quisque facilisis auctor sapien. Pellentesque gravida hendrerit lectus. Mauris rutrum sodales sapien. Fusce hendrerit sem vel lorem. Integer pellentesque massa vel augue. Integer elit tortor, feugiat quis, sagittis et, ornare non, lacus. Vestibulum posuere pellentesque eros. Quisque venenatis ipsum dictum nulla. Aliquam quis quam non metus eleifend interdum. Nam eget sapien ac mauris malesuada adipiscing. Etiam eleifend neque sed quam. Nulla facilisi. Proin a ligula. Sed id dui eu nibh egestas tincidunt. Suspendisse arcu.

9.3.5 Backup & Watchtower

Quisque facilisis auctor sapien. Pellentesque gravida hendrerit lectus. Mauris rutrum sodales sapien. Fusce hendrerit sem vel lorem. Integer pellentesque massa vel augue. Integer elit tortor, feugiat quis, sagittis et, ornare non, lacus. Vestibulum posuere pellentesque eros. Quisque venenatis ipsum dictum nulla. Aliquam quis quam non metus eleifend interdum. Nam eget sapien ac mauris malesuada adipiscing. Etiam eleifend neque sed quam. Nulla facilisi. Proin a ligula. Sed id dui eu nibh egestas tincidunt. Suspendisse arcu.

9.4 Liquid sidechain and Lightning (NFT enabled)

Quisque facilisis auctor sapien. Pellentesque gravida hendrerit lectus. Mauris rutrum sodales sapien. Fusce hendrerit sem vel lorem. Integer pellentesque massa vel augue. Integer elit tortor, feugiat quis, sagittis et, ornare non, lacus. Vestibulum posuere pellentesque eros. Quisque venenatis ipsum dictum nulla. Aliquam quis quam non metus eleifend interdum. Nam eget sapien ac mauris malesuada adipiscing. Etiam eleifend neque sed quam. Nulla facilisi. Proin a ligula. Sed id dui eu nibh egestas tincidunt. Suspendisse arcu.

Quisque facilisis auctor sapien. Pellentesque gravida hendrerit lectus. Mauris rutrum sodales sapien. Fusce hendrerit sem vel lorem. Integer pellentesque massa vel augue. Integer elit tortor, feugiat quis, sagittis et, ornare non, lacus. Vestibulum posuere pellentesque eros. Quisque venenatis ipsum dictum nulla. Aliquam quis quam non metus eleifend interdum. Nam eget sapien ac mauris malesuada adipiscing. Etiam eleifend neque sed quam. Nulla facilisi. Proin a ligula. Sed id dui eu nibh egestas tincidunt. Suspendisse arcu.

9.4.1 Sovrin

Quisque facilisis auctor sapien. Pellentesque gravida hendrerit lectus. Mauris rutrum sodales sapien. Fusce hendrerit sem vel lorem. Integer pellentesque massa vel augue. Integer elit tortor, feugiat quis, sagittis et, ornare non, lacus. Vestibulum posuere pellentesque eros. Quisque venenatis ipsum dictum nulla. Aliquam quis quam non metus eleifend interdum. Nam eget sapien ac mauris malesuada adipiscing. Etiam eleifend neque sed quam. Nulla facilisi. Proin a ligula. Sed id dui eu nibh egestas tincidunt. Suspendisse arcu.

9.4.2 KERI

Quisque facilisis auctor sapien. Pellentesque gravida hendrerit lectus. Mauris rutrum sodales sapien. Fusce hendrerit sem vel lorem. Integer pellentesque massa vel augue. Integer elit tortor, feugiat quis, sagittis et, ornare non, lacus. Vestibulum posuere pellentesque eros. Quisque venenatis ipsum dictum nulla. Aliquam quis quam non metus eleifend interdum. Nam eget sapien ac mauris malesuada adipiscing. Etiam eleifend neque sed quam. Nulla facilisi. Proin a ligula. Sed id dui eu nibh egestas tincidunt. Suspendisse arcu.

9.5 Metaverse

Quisque facilisis auctor sapien. Pellentesque gravida hendrerit lectus. Mauris rutrum sodales sapien. Fusce hendrerit sem vel lorem. Integer pellentesque massa vel augue. Integer elit tortor, feugiat quis, sagittis et, ornare non, lacus. Vestibulum posuere pellentesque eros. Quisque venenatis ipsum dictum nulla. Aliquam quis quam non metus eleifend interdum. Nam eget sapien ac mauris malesuada adipiscing. Etiam eleifend neque sed quam. Nulla facilisi. Proin a ligula. Sed id dui eu nibh egestas tincidunt. Suspendisse arcu.

9.5.1 Vircadia

Quisque facilisis auctor sapien. Pellentesque gravida hendrerit lectus. Mauris rutrum sodales sapien. Fusce hendrerit sem vel lorem. Integer pellentesque massa vel augue. Integer elit tortor, feugiat quis, sagittis et, ornare non, lacus. Vestibulum posuere pellentesque eros. Quisque venenatis ipsum dictum nulla. Aliquam quis quam non metus eleifend interdum. Nam eget sapien ac mauris malesuada adipiscing. Etiam eleifend neque sed quam. Nulla facilisi. Proin a ligula. Sed id dui eu nibh egestas tincidunt. Suspendisse arcu.

9.6 Messengers

Matrix, NOSTR, Juggernaut

9.7 WebM

Free open source web video player

Quisque facilisis auctor sapien. Pellentesque gravida hendrerit lectus. Mauris rutrum sodales sapien. Fusce hendrerit sem vel lorem. Integer pellentesque massa vel augue. Integer elit tortor, feugiat quis, sagittis et, ornare non, lacus. Vestibulum posuere pellentesque eros. Quisque venenatis ipsum dictum nulla. Aliquam quis quam non metus eleifend interdum. Nam eget sapien ac mauris malesuada adipiscing. Etiam eleifend neque sed quam. Nulla facilisi. Proin a ligula. Sed id dui eu nibh egestas tincidunt. Suspendisse arcu.

10. Example deployment

Quisque facilisis auctor sapien. Pellentesque gravida hendrerit lectus. Mauris rutrum sodales sapien. Fusce hendrerit sem vel lorem. Integer pellentesque massa vel augue. Integer elit tortor, feugiat quis, sagittis et, ornare non, lacus. Vestibulum posuere pellentesque eros. Quisque venenatis ipsum dictum nulla. Aliquam quis quam non metus eleifend interdum. Nam eget sapien ac mauris malesuada adipiscing. Etiam eleifend neque sed quam. Nulla facilisi. Proin a ligula. Sed id dui eu nibh egestas tincidunt. Suspendisse arcu.

10.1 GitHub

Quisque facilisis auctor sapien. Pellentesque gravida hendrerit lectus. Mauris rutrum sodales sapien. Fusce hendrerit sem vel lorem. Integer pellentesque massa vel augue. Integer elit tortor, feugiat quis, sagittis et, ornare non, lacus. Vestibulum posuere pellentesque eros. Quisque venenatis ipsum dictum nulla. Aliquam quis quam non metus eleifend interdum. Nam eget sapien ac mauris malesuada adipiscing. Etiam eleifend neque sed quam. Nulla facilisi. Proin a ligula. Sed id dui eu nibh egestas tincidunt. Suspendisse arcu.

11. Back to the metaverse

It seems like the primary intersection Current state of the art Libre, Mark Carney synthetic hedgemonic currency, and Keynes baskets

11.1 Potential applications

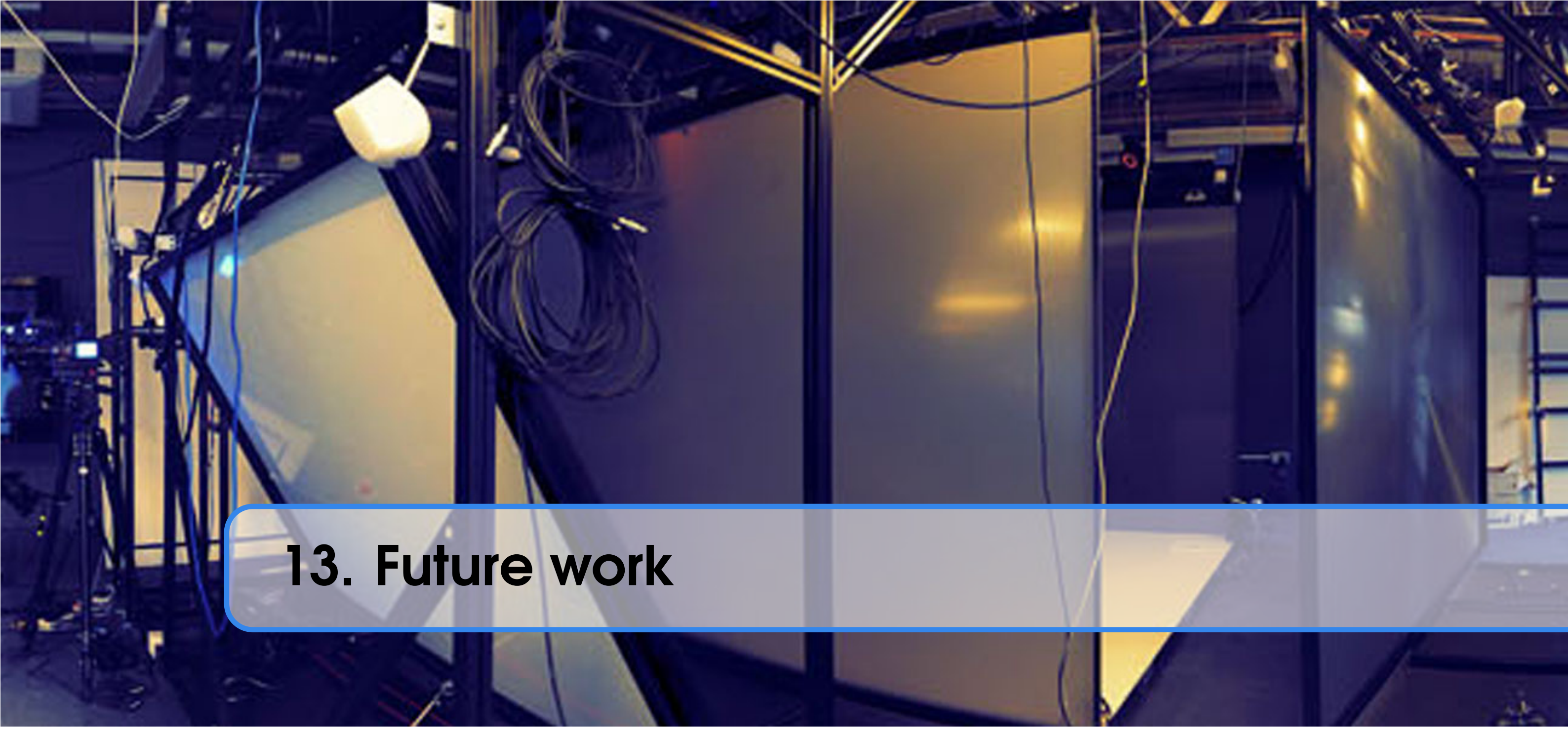
Quisque facilisis auctor sapien. Pellentesque gravida hendrerit lectus. Mauris rutrum sodales sapien. Fusce hendrerit sem vel lorem. Integer pellentesque massa vel augue. Integer elit tortor, feugiat quis, sagittis et, ornare non, lacus. Vestibulum posuere pellentesque eros. Quisque venenatis ipsum dictum nulla. Aliquam quis quam non metus eleifend interdum. Nam eget sapien ac mauris malesuada adipiscing. Etiam eleifend neque sed quam. Nulla facilisi. Proin a ligula. Sed id dui eu nibh egestas tincidunt. Suspendisse arcu.

11.1.1 AI multiview digital signage

Quisque facilisis auctor sapien. Pellentesque gravida hendrerit lectus. Mauris rutrum sodales sapien. Fusce hendrerit sem vel lorem. Integer pellentesque massa vel augue. Integer elit tortor, feugiat quis, sagittis et, ornare non, lacus. Vestibulum posuere pellentesque eros. Quisque venenatis ipsum dictum nulla. Aliquam quis quam non metus eleifend interdum. Nam eget sapien ac mauris malesuada adipiscing. Etiam eleifend neque sed quam. Nulla facilisi. Proin a ligula. Sed id dui eu nibh egestas tincidunt. Suspendisse arcu.

12. Conclusions

Quisque facilisis auctor sapien. Pellentesque gravida hendrerit lectus. Mauris rutrum sodales sapien. Fusce hendrerit sem vel lorem. Integer pellentesque massa vel augue. Integer elit tortor, feugiat quis, sagittis et, ornare non, lacus. Vestibulum posuere pellentesque eros. Quisque venenatis ipsum dictum nulla. Aliquam quis quam non metus eleifend interdum. Nam eget sapien ac mauris malesuada adipiscing. Etiam eleifend neque sed quam. Nulla facilisi. Proin a ligula. Sed id dui eu nibh egestas tincidunt. Suspendisse arcu.



13. Future work

Quisque facilisis auctor sapien. Pellentesque gravida hendrerit lectus. Mauris rutrum sodales sapien. Fusce hendrerit sem vel lorem. Integer pellentesque massa vel augue. Integer elit tortor, feugiat quis, sagittis et, ornare non, lacus. Vestibulum posuere pellentesque eros. Quisque venenatis ipsum dictum nulla. Aliquam quis quam non metus eleifend interdum. Nam eget sapien ac mauris malesuada adipiscing. Etiam eleifend neque sed quam. Nulla facilisi. Proin a ligula. Sed id dui eu nibh egestas tincidunt. Suspendisse arcu. Quisque facilisis auctor sapien. Pellentesque gravida hendrerit lectus. Mauris rutrum sodales sapien. Fusce hendrerit sem vel lorem. Integer pellentesque massa vel augue. Integer elit tortor, feugiat quis, sagittis et, ornare non, lacus. Vestibulum posuere pellentesque eros. Quisque venenatis ipsum dictum nulla. Aliquam quis quam non metus eleifend interdum. Nam eget sapien ac mauris malesuada adipiscing. Etiam eleifend neque sed quam. Nulla facilisi. Proin a ligula. Sed id dui eu nibh egestas tincidunt. Suspendisse arcu.

Guides for deploying the software

Erata

Bibliography 87

13.1 Author Biographies

Bibliography

Articles

[1] Oxford Analytica. “El Salvador bitcoin experiment comes with risks”. In: *Emerald Expert Briefings* oxan-db (2021) (cited on page 31).

[2] Adam Back et al. “Hashcash-a denial of service counter-measure”. In: (2002) (cited on page 27).

[3] Carlos L Bastian-Pinto et al. “Hedging renewable energy investments with Bitcoin mining”. In: *Renewable and Sustainable Energy Reviews* 138 (2021), page 110520 (cited on page 34).

[4] Dirk G Baur and Josua Oll. “Bitcoin investments and climate change: a financial and carbon intensity perspective”. In: *Finance Research Letters* (2021), page 102575 (cited on page 32).

[5] Matteo Benetton, Giovanni Compiani, and Adair Morse. “When Cryptomining Comes to Town: High Electricity-Use Spillovers to the Local Economy”. In: *Available at SSRN 3779720* (2021) (cited on page 34).

[6] Apolline Blandin et al. “3rd global cryptoasset benchmarking study”. In: *Available at SSRN 3700822* (2020) (cited on page 32).

[7] Vitalik Buterin et al. “Ethereum white paper”. In: *GitHub repository* 1 (2013), pages 22–23 (cited on page 29).

[8] Fran Casino, Thomas K Dasaklis, and Constantinos Patsakis. “A systematic literature review of blockchain-based applications: Current status, classification and open issues”. In: *Telematics and informatics* 36 (2019), pages 55–81 (cited on page 27).

[9] David Chaum. “Security without identification: Transaction systems to make big brother obsolete”. In: *Communications of the ACM* 28.10 (1985), pages 1030–1044 (cited on page 27).

[10] Wei Dai. “b-money, 1998”. In: *URL http://www. weidai. com/bmoney. txt.(Last access: 08.04. 2019)* (1998) (cited on page 27).

[11] Whitfield Diffie and Martin Hellman. “New directions in cryptography”. In: *IEEE transactions on Information Theory* 22.6 (1976), pages 644–654 (cited on page 27).

[12] Alessio Faccia and Narcisa Roxana Mosteanu. “Accounting and blockchain technology: from double-entry to triple-entry”. In: *The Business & Management Review* 10.2 (2019), pages 108–116 (cited on page 30).

[13] David Golumbia. “Cryptocurrency Is Garbage. So Is Blockchain.” In: *So Is Blockchain.(June 16, 2020)* (2020) (cited on page 29).

[14] Yuji Ijiri. “A framework for triple-entry bookkeeping”. In: *Accounting Review* (1986), pages 745–759 (cited on page 30).

[15] Kiku Jones and Lori NK Leonard. “Trust in consumer-to-consumer electronic commerce”. In: *Information & management* 45.2 (2008), pages 88–95 (cited on page 18).

[16] Enis Karaarslan and Eylul Adiguzel. “Blockchain based DNS and PKI solutions”. In: *IEEE Communications Standards Magazine* 2.3 (2018), pages 52–57 (cited on page 25).

[17] John Kirriemuir. “A Spring 2008 ‘snapshot’of UK higher and further education developments in Second Life”. In: *Eduserv Virtual World Watch* (2008), page 58 (cited on page 61).

[18] Don Lavoie. "Prefatory Note: The Origins of" The Agorics Project". In: *Market Process, v8, Spring* (1990), pages 116–119 (cited on page 27).

[19] Rick Marlatt. "Capitalizing on the craze of fortnite: Toward a conceptual framework for understanding how gamers construct communities of practice". In: *Journal of Education* 200.1 (2020), pages 3–11 (cited on page 62).

[20] Mathilde Maurel and Gunther Schnabl. "Keynesian and Austrian perspectives on crisis, shock adjustment, exchange rate regime and (long-term) growth". In: *Open Economies Review* 23.5 (2012), pages 847–868 (cited on page 48).

[21] Hilary McLellan. "Avatars, Affordances, and Interfaces: Virtual Reality Tools for Learning." In: (1993) (cited on page 61).

[22] Ralph C Merkle. "Secure communications over insecure channels". In: *Communications of the ACM* 21.4 (1978), pages 294–299 (cited on page 27).

[23] Satoshi Nakamoto. "Re: Bitcoin P2P e-cash paper". In: *Email posted to listserv* 9 (2008), page 04 (cited on pages 27, 30).

[24] Michel Rauchs et al. "Distributed ledger technology systems: A conceptual framework". In: *Available at SSRN 3230013* (2018) (cited on page 27).

[25] Alan Sangster. "The earliest known treatise on double entry bookkeeping by Marino de Raphaeli". In: *Accounting Historians Journal* 42.2 (2015), pages 1–33 (cited on page 30).

[26] Toni Sant. "Performance in Second Life: some possibilities for learning and teaching". In: *Learning and teaching in the virtual world of Second Life* (2009), pages 145–166 (cited on page 61).

[27] Paul Sermon et al. "They live (in Second Life)". In: (2008) (cited on page 61).

[28] Nick Szabo. "Formalizing and securing relationships on public networks". In: *First monday* (1997) (cited on page 27).

[29] Philipp Zabka et al. "Short Paper: A Centrality Analysis of the Lightning Network". In: (2022) (cited on page 36).

Books

[30] David Burnham. *The rise of the computer state*. Random House Inc., 1983 (cited on page 27).