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Internet of Things, Blockchain and Shared Economy Applications

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Abstract

This paper explores how the Internet of Things and blockchain technology can benefit shared economy applications. The focus of this research is understanding how blockchain can be exploited to create decentralised, shared economy applications that allow people to monetise, securely, their things to create more wealth. Shared economy applications such as Airbnb and Uber are well-known applications, but there are many other opportunities to share in the digital economy. With the recent interest in the Internet of Things and blockchain, the opportunity exists to create a myriad of sharing applications, e.g. peer-to-peer automatic payment mechanisms, foreign exchange platforms, digital rights management and cultural heritage to name but a few. While many types of shared economy scenarios are proliferating, few of them, so far, leverage the Internet of Things and blockchain as technologies to build distributed applications. This paper discusses how we might make use of the Internet of Things and blockchains to create secure shared economy distributed applications. Presented are examples of such distributed applications in the context of an Internet of Things architecture using blockchain technology.

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Keywords: Internet of Things; blockchain; distributed applications; smart contracts; peer-to-peer; Radio Frequency Identification.

1. Introduction

Chianese et al. tell us that: "The adoption of future Internet technology, and in particular of its most challenging components like the Internet of Things (IoT) and Internet of Services, can constitute the basic building blocks to progress towards unified information and communication technology platforms for a variety of applications" [1]. This paper explores that discussion further when describing how IoT and distributed ledger technologies (or blockchains) may provide excellent opportunities to develop distributed applications (Dapps) for the shared economy.

Recently, there has been considerable interest in shared economy applications whereby people can monetise their things; consider the success of Airbnb or Uber. Indeed, there are many applications already being deployed to exploit our things[2]. However, very few of them are currently implemented as Dapps using IoT and blockchain technology. By utilising IoT, we can facilitate the sharing of our existing devices, vehicles, buildings, etc., by embedding sensors and network connectivity that enable our things to collect and exchange data. Then, by integrating blockchain technology into the IoT architecture, we can keep an immutable ledger of all those shared transactions. Furthermore, we can share without requiring a trusted third party, which effectively eliminates the 'middle man', allowing sharing applications to operate in a decentralised peer to peer (P2P) mode. Slock.it is an example of this technology; it embeds a blockchain into a property[3], thus allowing users who purchase a Slock[4] to use a Dapp to gain access. This paper introduces an IoT design fiction called ExpressIT. We then discuss, illustrated with a small number of use case

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scenarios, IoT and blockchains as key enabling technologies. Finally, we consider future work that will explore our next steps in the area of IoT and blockchain technology.

1.1. Background — ExpressIT

The University of Sussex and American Express recently concluded a significant InnovateUK (formally the UK Technology Strategy Board) project entitled 'Connecting Virtual Communities to the Digital Economy Through Micro-Payment Technologies'. The project set up a Digital Hub[5] to explore how payments and rewards technologies, particularly micro-payments[6] [7], could be integrated into digital economy applications. Project demonstrators included a bill sharing application called BillSplitter[8], a smart shopping basket[9], a rewards gateway[10] to complement the American Express Payment Gateway[11] and a vehicle-based payments system called AutoPay[12]. One of the final demonstrators for the project focused on developing an IoT demonstrator prototype called ExpressIT[13].

ExpressIT (short for American Express IoT) is a future prototype IoT application that integrates several of the project modules organised as a 'design fiction'[14]. ExpressIT integrates many modules, including SmartBasket, AutoPay, Rewards Gateway and Payment Gateway alongside other design-fiction prototypes such as Journey Planner, Driver Monitor and Journey Monitor. ExpressIT bases its vision upon the 'Internet of Things' concept, whereby uniquely identifiable objects and their virtual representations aggregate functionalities and communicate with each other through a service-orientation approach. ExpressIT interacts with real life objects, such as a user's vehicle and kitchen appliances, and automates certain tasks that would otherwise need a direct human input. A design fiction video[15] illustrates the ExpressIT concept.

However, ExpressIT, while encompassing the concepts of IoT, does not currently deploy the perceived advantages fostered by blockchain technology. We are addressing that shortcoming in our new project, with our industrial collaborators, called *Shared Things*.

1.2. Shared Things

The *Shared Things* project is about monetising shared economy applications. To facilitate this new work, *Shared Things* has begun with two closely related research threads that have a particular focus on investigating: 1) Mobile financial wearables and IoT, 2) IoT in a sharing economy. The project is particularly interested in gaining a better understanding of how to develop, implement, test and evaluate sharing economy Dapps by using real-world scenarios and working prototypes. Underpinning both these project threads are some key IoT and blockchain technologies.

2. Key IoT Technologies

In an interview with RFID Journal[16], Kevin Ashton, the man credited with coining the phrase "Internet of Things", described the Internet as being dependent on human beings. However, Ashton supposed that humans are time limited, so they are unable to capture too many real-world 'things' (such as data about the fuel that powers our heating or drives our car's engines). Hence, the Internet represents our ideas, rather than 'things'. However, a functioning society depends on 'things' and Ashton proposed that that's where the next-generation Internet would help. He concluded that an Internet of Things based on computer-generated data would enable us to become more efficient: "we would know when things needed replacing, repairing or recalling"[16]. Ashton went on to say that the key IoT technology will be Radio-frequency identification (RFID) and sensor technologies that will allow computers to: "observe, identify and understand the world without the limitations of human-entered data"[16].

The world of IoT has evolved since Ashton's original speech; Li et al.[17] describe enabling IoT technologies that have created an: "inter-connected worldwide network based on sensory, communication, networking, and information processing technologies". Chianese et al. describe: "BIG DATA, whose opportunities and challenges lie not only in the huge volumes involved, but also in the heterogeneity of information assets and their distribution"[18]. Gubbi et al.[19] describe IoT as "making a computer sense information without the aid of human intervention". They detail a unified framework where ubiquitous sensing and actuating devices share information across dynamically scalable, highly reliable, cloud computing services. Thus, they have a vision of a 'cloud-centric IoT', which comes about because IoT creates an unprecedented amount of data. However, they also recognise that security and ownership of that data will be critical, and while the cloud-centric model offers a potential solution to scaling to billions of connected devices, it does not necessarily provide a solution to the security challenges of IoT. Pureswaran et al.[20] agree: "In a network of the scale of the IoT, trust can be very hard to engineer and expensive, if not impossible, to guarantee". Li et al.[17] list five security and privacy issues that need addressing for IoT: 1) Security and privacy from the social, legal and cultural perspectives, 2) Trust mechanisms, 3) Communication security, 4) User privacy, 5) Security of services and applications. Pureswaran et al.[20] also believe that the solution lies in trustless P2P networks, or blockchains, where there's no central authority or single point of failure.

2.1. Blockchains

Blockchain technology first came to prominence in early 2009, through the cryptocurrency Bitcoin (BTC). Since then BTC has flourished; at the time of writing, its total market capitalisation was over US$6 billion. However, blockchain, the technology that underpins BTC, could, according to Swan, have far-ranging consequences for all aspects of modern society[21]. Blockchain technology is a distributed public ledger of transactions that the authors of a report for the UK Government describe as "essentially an asset database that can be shared across a network of multiple sites, geographies or institutions"[22]. Swan identifies blockchain as: "the integration and automation of human/machine interaction and the machine-to-machine and IoT payment network for the machine economy"[23]. An important aspect of blockchain is that they also include algorithms that provide a secure mechanism for electronic collaboration without relying upon a central authority for trust[22]. Additionally, blockchain have the ability to execute autonomous scripts. That is the concept of smart contracts; data-driven code that can represent verifiable application logic and help automate a system's rule set[24].

The idea of the blockchain as a universal trustless database is expanded further by Greenspan[25], who says the blockchain is a distributed multi-version concurrency control database (MVCCDB) with "a few more bells and whistles". Garzik et al. agree with the idea of BTC as a type of database that solves the multi-master replication problem of distributed systems[26]. MVCCDB have mechanisms that prevent conflicts, much the same as blockchain technology that ensures the spending of single outputs more than once. Greenspan explains that MVCCDB increase reliability and throughput through replication, which requires complex mechanisms for conflict resolution[27]. A blockchain achieves this by design, through its P2P consensus model. Greenspan goes on to describe the "bells and whistles that BTC blockchain transactions perform over and above a traditional distributed MVCCDB. Firstly, the total quantity of BTC in a transaction's inputs must cover the total number of BTC in the outputs. That rule behaves similarly to a database stored procedure, except that it is impossible to circumvent. Secondly, BTC transactions use public-private key cryptography. That makes BTC act like a database with a publicly auditable per-row permission scheme. That, Greenspan believes, is a novelty in database technology[25]. It is such mechanisms that make Swan argue for using blockchains as a secure large-scale data management tool[28]. Indeed, Pureswaran et al.[20] believe that the blockchain is the breakthrough technology for IoT.

3. Blockchain Integrated IoT Scenarios

It is perhaps ironic that Uber, as one of the most recent disruptive technologies, is an ideal candidate itself for disruption with blockchain. Below we describe some other interesting scenarios.

3.1. AutoPay

Jane gets into her car to drive to work; she's a busy mother and senior manager for a large corporate. The car automatically synchronises with Jane's smart phone's AutoPay service, a system that provides security and trust by 'embodying' Jane through smart contracts on its blockchain interface. That allows it to operate as an Autonomous Payment device. AutoPay initiates several features on Jane's in-car display; it links to Journey Planner (JP), and Jane enters into AutoPay JP her office as her destination. AutoPay JP determines, by interrogating vehicle data, that the car is low on fuel, so it automatically plots a route via a convenient petrol station that is advertising competitive fuel prices. After filling up with fuel (automatically paid for by AutoPay's smart contract feature), Jane receives a message over the AutoPay Siri interface that her work car park is full and that AutoPay JP has initiated a smart contract exchange and paid for another car park, a short distance from her office.

While at work, Jane receives a message that SmartBasket has tendered her daily shopping list to local retailers, determined the one with the best prices, paid for it all, and has organised delivery, which arrives soon after Jane gets home from work. Later that same evening, Jane's daughter, Alice, asks to borrow the car. Alice's smart contract with Jane's car gives her access, but it does not enable the vehicle to make autonomous payments for everything; smart contracts are precisely that – smart; they are customisable for each family member. So, Alice can refuel, but she can't treat her friends to a drive through MacDonalds using her mother's AutoPay service. Besides, even if Alice were able to pay for things she should not, Jane would quickly find out because she would be able to check the immutable transaction history on AutoPay's interface to the car's blockchain's ledger. Fig. 1. illustrates the AutoPay scenario.

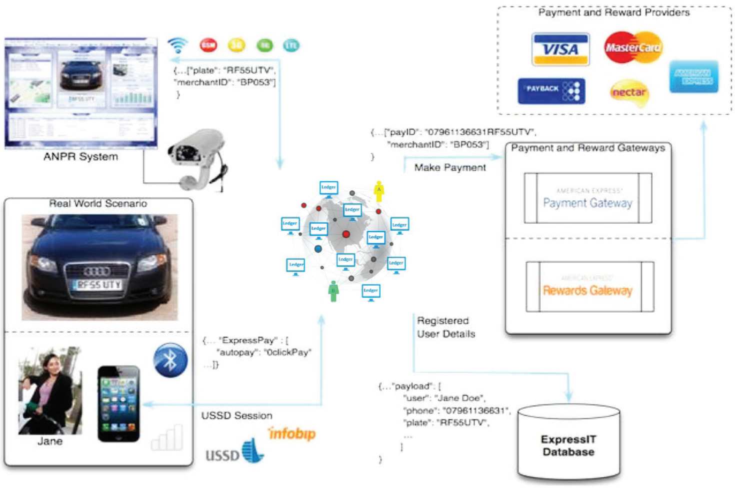

Fig. 1. AutoPay[12]

3.2. John's International Tour

A 2015 travel weekly report mentions a 20% rise in international travel[29]. This implies a significant rise in the amount of cash based leftover foreign currency (LFC). Indeed, a study from Zopa indicates that the British alone have an estimated 2.92 billion British Pounds (GBP) of unused foreign currency[30]. If the UK situation scales to the global population, then there's a considerable amount of wealth lying unused. Therefore, a blockchain based currency exchange application has the potential to bring a huge amount of LFC back into circulation, which could prove extremely beneficial to the global economy. Thus, LFC makes an ideal blockchain application scenario.

After returning home to London from a business trip to Chicago, John has with him some United States Dollars (USD) that he no longer needs. At the airport gate, using a bespoke smartphone FOREX application, he finds the location of the nearest currency-accepting IoT-enabled smart kiosk. John holds his smartphone close to the booth, which identifies him using NFC to exchange a smart contract via a blockchain application. He deposits his USD and instantly gets an electronic receipt of the deposit using another blockchain based smart contract exchange. Later, John posts his USD to GBP exchange rate using an intelligent system application that stays competitive by adjusting automatically using the latest mid-market rates. Consequently, John soon receives an alert that someone has traded, via a smart contract, at his advertised price and the money has been transferred into John's bank account. Because of the use of the blockchain smart contract, John knows that he can trust the transaction and that his money is safe. Moreover, the blockchain keeps a permanent record of the currency exchange.

3.3. Digital Rights Management

In a Guardian article, James Bartlet reveals that 2012 was the first year that electronic sales of songs surpassed those of their physical counterparts[31]. However, Bartlett describes a situation that is far from a golden age for music because of problems with the distribution and monetisation of digitised copyrighted material. Bartlett points to the secrecy of music rights deals, calling them "Kafkaesque"; for example, there are sync rights, mechanical royalties, songwriter royalties and performance fees. As a consequence, streaming revenue can go to many services, and the artists themselves rarely receive much more than a tiny percentage of the monies generated. Indeed, as of Spring 2015, to earn a US monthly minimum wage of US$1,260, a solo artist signed to Spotify, one of the major streaming services, needed to achieve over 1.1 million streams of one of their songs[32]. Imogen Heap, the Grammy award winning artist[33], commenting on Bartlett's article, says: "in the data-driven era, the movement of music, money and feedback should be frictionless". Heap decided to turn to blockchain technology to realise that frictionless future; her latest song, Tiny Human, was released on the prototype music platform ujo MUSIC[34], which uses blockchain technology to detail under what terms the track may be downloaded. The technology also describes how automated payments are distributed to the song's different contributors. Furthermore, when someone streams the song, the transaction is permanently recorded on the blockchain, which makes it amenable to all kinds of data visualisations and data mining techniques. Moreover, Heap receives immediate payment. That in itself could be a game changer since, currently, it can take months for an artist to receive their royalty payments[31].

However, Tiny Human is still centrally stored. To support the distributed model supposed by Pureswaran et al.[20], Heap could make the song available, via a link on the blockchain, on a distributed, hyperlinked file system such as the InterPlanetary File System (IPFS)[35]. IPFS works much like the BitTorrent service Pirate Bay. Thus, it would maximise Heap's opportunities for revenue because her song could achieve high throughput streaming in a manner that's fault tolerant.

Music is not the only medium that could benefit from the blockchain and IPFS model. Any digital assets could be distributed that way, with huge implications for electronic media. Legal systems currently consider such intangible assets as non-rivalrous, and as Fairfield describes[36], that means that digital media has long since been caught in the quagmire of intellectual property law because there is, supposedly, no way to prevent their duplication. The result is that users own practically no online material; instead, they merely license such material. However, because blockchain technology has mechanisms that resist falsification and duplication, it could change that and make intangible assets rivalrous. Furthermore, blockchains do that at a very low cost, which supports the type of micro-payment models required by music streaming services. Hence, we imagine a future of transparent ownership and use of all digital assets, via blockchains.

4. Conclusion

This paper has explored Sussex's *Shared Things* team's research relationship with IoT. We are focusing on application scenarios and the implementation of Dapps and we are organising, in collaboration with our industrial partners, a summer hackathon where we will be coding working IoT prototypes of scenarios, such as those described above. Longer term, we are looking to deepen our research interests in mobile financials and IoT in a sharing economy, and in both areas we are seeking to integrate wearable technology and the blockchain. Indeed, we believe it is the blockchain's trustless, public ledger, coupled with a distributed file system model provided by, for example, IPFS, that will address the security, transparency and scaling challenges offered by IoT.

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