Blockchain for Good? Digital Ledger Technology and Sustainable Development Goals.

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Abstract

Blockchain technology (aka Distributed Ledger Technology or DLT) is a novel configuration of Peer-to-Peer, cryptographic and distributed computing technologies that have the potential to shift the internet from an internet of information to an internet of value network, with significant disruptive potential. To date, the cryptocurrency 'bitcoin' is the application of DLT that has attracted most attention, not all of it favourable. However, DLTs are about much more than cryptocurrencies and, as Kranzberg's (1986) first law of technology, that 'Technology is neither good nor bad; nor is it neutral' reminds us, we can ethically frame applications of new technologies. To date, research has tended to focus on the technical characteristics of DLTs, and there has been little reflection on potential socially and environmentally beneficial use cases: Blockchain for Good (B4G). The aim of this this exploratory and descriptive paper is to reflect on innovative B4G applications that could help deliver socially and environmentally beneficial outcomes, framed in terms of the UN's Sustainable Development Goals, through challenging existing business models and providing new opportunities for value creation

1. Introduction

For nearly thirty years, fuelled by an increasing evidence base of anthropogenic environmental degradation as well as growing awareness of global scale injustice and inequality, from lack of food to labour exploitation, the notion of Sustainable Development (WCED, 1987) has galvanised action across the most signficant domains of human activity. Sustainable Development was defined in the Brundtland report as 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs'. The re-casting of the UN's eight Millennium Development Goals (UN Millennium Project, 2005) as 17 Sustainable Development Goals (SDGs), comprising of 169 targets to be achieved by 2030, suggests that considerable effort is required if we are to achieve this objective (UN, 2015).

Technological innovations have been mobilised in the cause of Sustainable Development, ranging from those that incrementally enable better use of resources (De Marchi, 2012) to those that exploit the affordances of the digital infrastructure to develop new platform-based business models such as the sharing economy and collaborative consumption (Botsman and Rogers, 2010).

The Blockchain (aka Distributed Ledger Technology or DLT) is a novel configuration of Peer-to-Peer (P2P), cryptographic and distributed computing technologies that promise an innovation at least as disruptive and transformative as the internet has been (Welch, 2015; Davidson et al., 2016; McWaters, et al., 2016; Adams et al., 2017). This promise lies in its capacity to move value (money and other digital assets) across the internet in as seamless and unencumbered a fashion as is the case currently for information.

To date, attention has focused principally on DLT use cases as cryptocurrencies (e.g. Bitcoin) and in financial services[1] such as for improving the efficiency and reliability of clearing and remittance services (Ali, et al., 2014; McWaters, et al., 2016). However, DLTs clearly have applicability for widespread use in other areas (Walport, 2016).

In this paper, we focus on what the technology might achieve, not on how it works. Our exploration is framed in the current debate about the potential impact of DLTs, for good or ill (Kranzberg, 1986; Krugman, 2013). Specifically, the purpose is to extend this debate into an exploration of DLT use cases where it is being used for socially and environmentally beneficial ends: Blockchain for Good (B4G).

We proceed as follows: First, we describe our approach to this exploratory research. Second, we offer a brief overview of the technological characteristics of the Blockchain. Third, we examine the notion that DLTs have unique affordances rendering them appropriate solutions to the SDGs. Consequently, in this article we begin to explore the impact of DLTs on the UN's Sustainable Development Goals which is the contribution of the paper.

2. Approach

The UN's SDGs provide a vision for governmental, corporate and civic action, throwing down the gauntlet of widespread and systemic change. Social systems move from one technological regime to another, but technologies do not fulfil societal functions on their own. Artefacts by themselves have no power; they do nothing (Geels, 2005). Affordance theory suggests that an artefact is perceived in terms of its action possibilities. To promote the uptake of B4G, it is therefore necessary to understand the affordances of DLTs and how these might be mobilised in support of the SDG agenda.

Drawing on Gibson's (1978) work on the ecology of perception, Pea (1993: 51) describes as 'Affordance' the "perceived and actual properties of a thing, primarily those functional properties that determine just how the thing could possibly be used". An affordance, then, is what an object or technology offers, provides or furnishes in the context of use: a chair 'affords' sitting or an improvised ladder, a bicycle 'affords' travel or exercise.

A technology affordance is "an action potential…what an individual or organization with a particular purpose can do with a technology" (Majchrzak and Markus, 2012). As 'action potential', DLTs can be regarded as a generative mechanism (Volkoff and Strong, 2013) through which the SDGs might be achieved. Following Seidel *et al.* (2013), identifying the affordances of novel technologies that relate to realising SDGs can assist organizations and scientists create the future in which the challenges of sustainability, such as hunger, climate change and social justice, can more determinedly be addressed. That is, what are the affordances of DLTs and how might these affordances contribute to the realisation of the SDGs?

The following thematic analysis (Thomas and Harden, 2007) is based on a preliminary search, consisting of keyword searches on the internet, snowballing and expert recommendations, to accumulate a database of instances of B4G practice. Currently, the database consists of approximately 70 discrete B4Gs and the number is expected to grow. At

[1] See, for example http://www.r3cev.com/ R3 is a financial innovation firm managing a consortium of some of the world's leading financial institutions to design and deliver DLTs to the global financial markets

this stage of our exploratory work, inclusion criteria remain quite relaxed and the database consists of B4Gs ranging from the speculative, such as AidCoin (Currion, 2015) to fully operational (e.g. Banqu[2]).

3. Blockchain for good

The Blockchain first appeared, largely unheralded, in 2008. Attention, instead, was directed toward the application whose existence Blockchain Technology made possible. The focal application, and the first to run on a blockchain, was the crypto-currency Bitcoin (Nakamoto, 2008; Lemieux, 2013).

The significance of the underlying DLT, is that it enables the digital transfer of value without the need for a trusted third party. Simply put, DLT allows anyone to transact with anyone anywhere on a P2P basis. DLTs enhance the transparency of information exchanges (including payments and deposits), making trust obligations much easier to discharge between transacting parties. This service is normally provided by intermediaries such as banks. DLT reallocates these responsibilities to computers and algorithms (Ali, et al., 2014; Welch, 2015; McWaters, et al., 2016). Because of the way in which the technology is configured to allow P2P digital exchange of value, the blockchain, to many observers, represents a revolutionary and disruptive innovation (Swan, 2015; Zuberi & Levin, 2016).

Fundamentally, a blockchain is a ledger of transactions of digital assets: of who owns what, who transacts what, of what is transacted and when. Transactions are not recorded on a single database, but distributed on the computers of the network of users (nodes) of the system. No single entity owns or controls the ledger and so network members can view the recorded transactions. Transactions are recorded and stored in ‘blocks’ and each block linked chronologically (hence chain) and cryptographically to those which precede it to create an immutable, tamper-resistant record. All transactions are time-stamped to provide a record of when transactions occurred and in what order: this assures against ‘double spending’ and tampering with previous transaction records (Reber and Feuerstein, 2014). The ledger is ‘kept honest’ by network consensus, a transaction validation process undertaken by network users, which includes checking that digital signatures are correct through a process known as ‘mining’: mining is incentivised by reward systems. Once a block is accepted by the network and added to the chain, it cannot be changed: it is a permanent, transparent and immutable record.

Consequently, DLTs may be characterised as globally distributed, P2P, open ledgers of exchange providing an immutable and verifiable record and encrypting the identities of users that is hard to tamper with. Davidson et al. (2016) describe DLTs as a new general purpose technology which are, by definition, highly pervasive and can impact entire economies giving rise to *creative destruction* (Schumpeter, 1934; Jovanovic and Rousseau, 2005) with the potential to disrupt any centralized system that coordinates valuable information (Wright and De Filippi, 2015).

This represents a fundamental change in the way in which humans can exchange value, and two important implications follow. First, because the technology provides the required trust to give peers the confidence to exchange value directly, the requirement for socially-constructed institutional third-party providers of trust is significantly reduced: they become disintermediated. The second implication is that the blockchain presages a new functionality for the internet: *it moves from an internet of information to an internet of value* (Swan, 2015). It means, that for objects that can be expressed in code, multiple novel application possibilities are opened up, and raises the question, how can blockchain technology that

[2] http://www.banquapp.com/

creates immutable, tamper-resistant distributed records of transactions of digital assets be applied in the service of SDGs?

3.1 Blockchain properties

Mattila (2016) points out that the technology stack components of DLTs is diverse and can be configured in a variety of ways, resulting in different DLT architectures, implying the need for design decisions. Blockchains can be categorized as Permissioned/Permissionless (aka Unpermissioned) and Specific Purpose Blockchains optimized for the management of assets and General Purpose Blockchains designed to allow users to write their own programs to be stored on the blockchain and automatically executed in a distributed manner. Notwithstanding these divergences, DLTs share certain characteristics which may be more or less attenuated depending on context of application, in particular: the distributed (decentralized) consensus mechanism, immutability, algorithmic trust, resilience against manipulation, and secure information sharing.

Nakamoto's (2008) white paper describes what might be considered to be a pure form of DLT, that is to say a permissionless blockchain encompassing a network of participants that are not known to one another and each of them can access the blockchain with complete freedom to read or write to it, no actor can prevent any other actor from contributing content nor can any actor remove any previously validated contribution; and consensus is incentivised through economic mechanisms. Permissionless Blockchains are therefore highly censorship resistant and can provide an immutable[3], network-validated global record of transaction histories – right up to the present moment.

On the other hand, anyone[4] may have a copy of the ledger in a permissioned blockchain, but only certain authorised parties may write to it and the consensus process is determined by the owner(s) of that blockchain, usually carried out by trusted actors in the network (CPTM, 2016). Assuming that chosen actors honestly and disinterestedly validate transactions, then permissioned blockchains can offer certain advantages, in at least two respects: first, they can be designed with specific functionality in mind and second alternatives to economically-incentivized validation mechanisms (proof-of-work) can be incorporated. As a result, permissioned blockchains can be more efficient and faster than unpermissioned versions (CPTM, 2016) but at the cost of reduced security, immutability and censorship-resistance (Mattila, 2016).

A sub-category of the permissioned blockchain is the private blockchain in which only certain authorised users have access to the database, whether for reading or writing, which tend to exist behind some organizational firewall, but offer within-group transparency, privacy and control, for a defined set of users.

Whether or not they truly are DLTs continues to be debated, but the permissioned blockchain does have a role in helping deliver the SDG agenda. In the following, we explore some of these further and consider their affordance in terms of the SDGs.

3.2 Blockchain mining

In the Bitcoin blockchain, transactions are validated by network members (nodes) in a process known as mining. This distributed, network-member-driven process, performs the function of the centralized trusted third party intermediary model. Network participants compete with each other using computer power (known as proof-of-work) to validate blocks of transactions every 10 minutes or so. The proof-of-work is difficult to produce but easy for

[3] Immutable to the extent that that particular blockchain continues to be maintained. It is not clear what happens in the circumstance that the blockchain ceases to continue.

[4] Anyone, subject to, of course, the nature of the permissions.

other nodes to verify and so transaction validity is established by majority consensus of network members. The miner that first successfully validates a block is rewarded with newly minted bitcoins[5].

That network members commit resources to validating transactions contributes to the cryptographic security and fraud resilience of the bitcoin blockchain. It is configured in such a way that it makes more sense for would be attackers to participate as miners (greater opportunity for reward at lesser cost), thus increasing the resilience of the blockchain (Doguet, 2013; Fox-Brewster, 2015; Welch, 2015).

However, the computationally intensive method of proof-of-work has been described as costly and wasteful (McWaters, et al., 2016). As miners around the world competitively dedicate resources to validate transactions, Aste (2016) estimates about a billion Watts are consumed globally every second to produce a valid proof of work for Bitcoin.

In light of this, alternative validation mechanisms are being investigated, some of which resonate with the SDG agenda but also relax some of the communitarian properties of the proof-of-work approach (such as openness to the whole community). Dierksmeier and Seele (2016) argue that it should be possible to promote ethical goals in society, e.g., by hitching the 'mining' to the creation of ecological or social benefits. Certainly, reducing energy consumption in the process would generate ecological benefits and, a small number of initiatives have emerged in this area. SolarCoin[6], for example, rewards generators of solar energy with new coin; another, GridCoin (Halford, 2014) introduces a novel algorithm based on work done in Berkely Open Infrastructure for Network Computing projects: miners are incentivized to participate in scientific projects (e.g. healthcare & space exploration) aiming to provide benefit to humanity. In the CureCoin blockchain, the bitcoin validation calculations are replaced by (useful) protein folding tasks: mining CureCoin helps science through simulating protein behaviour and providing these data to research scientists.

3.3 The internet of value(s)

The previous section describes how social or ecological benefit can be linked to the production of alt-currencies. This section focuses on how these benefits can be linked to currency use. The notion of *coloured coins* (Bradbury, 2013) is used to denote a small part of a coin with specific attributes which may represent anything from physical assets to a community's values. By moving coloured coins through network, asset ownership can be securely transferred. Similarly, coins coloured with values, in which morals, principles or ethics are embedded in the code, can allow individuals to align their spending closely with their values.

Taghiyeva *et al.* (2016) describe a proof-of-concept pilot for a blockchain-based Islamic crypto-currency in which transactions and Muslim values, including a blended anti-radicalisation agenda, are aligned: a currency with a community's desirable social principles engineered-in. This resonates with Helbing's (2013; 2014) concept of *Qualified Money* where values can be embedded in DLTs. CarbonCoin[7] claims to be the first digital currency with a conscience, designed to engage the environmentally conscious community. Such possibilities raise important questions about whose values are embedded into a currency and who does the engineering.

[5] For more details on mining, see Antonopoulos, A.M. (2014). Mastering Bitcoin: unlocking digital cryptocurrencies, O'Reilly Media, Inc.; Swan, M. (2015). Blockchain: Blueprint for a New Economy, O'Reilly Media, Inc., and: http://www.coindesk.com/information/how-bitcoin-mining-works/

[6] https://solarcoin.org/

[7] http://carboncoin.cc/

In terms of assets, DLTs provide a mechanism both for their registration and transfer. A number of commentators have argued that this may prove a boon in developing or politically unstable economies for the registration of individual's property rights. Where there is a lack of trust in central authorities to maintain uncorrupted registers of assets, such as property title, these may be recorded immutably, transparently, and verifiably on a blockchain. Already, a number of pilots and trial projects are underway: Bitland[8] use DLT to map land title in Ghana providing a registry of ownership which subsequently facilitates the mobilization of capital as well as a transparent property market. Similar initiatives can be found in Honduras (Alejandro, 2016), Sweden (Rizzo, 2016) and Georgia (Shin, 2016). Progress has been slow and success mixed (ODI, 2016), attesting to the still emergent nature of the technology. Indeed, it is too easy to get carried away by the theoretical potential of DLTs. While a blockchain based registry of assets may be transparent and immutable, for it to be meaningful in terms of economic participation and activity it must exist within a stable infrastructure: armed aggressors, for example, may still unlawfully seize property regardless of whether or not it is recorded on the blockchain. However, the existence and immutability of the record may act as a deterrent against such behaviour.

3.4 Supply chain

Assets can be registered to the blockchain using unique keys. This provides a register of ownership as well as tracking and pattern of ownership over time. Initiatives that have leveraged this affordance, include Everledger[9], a permanent ledger for diamond certification and related transaction history transparently recording ownership history and reducing crime, and Provenance[10] who provide a system for tracking materials and products in a manner that is public, secure and inclusive. For the SDGs, this means that claims (e.g., not blood-diamonds or sustainably fished tuna) can be demonstrated to be authentic right through the supply chain, shifting the value system towards origin and provenance (Greenspan, 2015).

DLT applications are also being explored in the energy market both as a system enabling individuals to sell excess solar-generated electricity to each other without going through third parties (e.g. PowerLedger[11] and TransActive[12]) as well as developing a market infrastructure for carbon trading, an independent ledger of the permits to emit Earth's allowance of greenhouse gases (Casalotti, 2016). One scenario is that, within a short time, every individual on the planet, for example, be issued with an annual carbon allocation trackable on a DLT.

3.5 Innovations in governance

Blockchains are distributed ledgers transparently recording transactions of assets which, as the notion of *Qualified Money* (above) attests, can include computationally embedded features such as programmable money (cryptocurrencies), programmable contracts (i.e. smart contracts), and organizations made of software (Potts *et al.*, 2016). Here, *code* substitutes for *trust*, and allows for new types of commerce. Appropriately designed, these can be the building blocks of new forms of economic and social governance that meet the objectives of the SDGs.

Smart contracts are computer protocols that facilitate, verify and enforce the performance of a contract: self-executing code. They are the automation of the performance of contracts which only execute when pre-specified conditions are met, thus removing the need for third party resolution. This is an assured and low-cost mechanism that can offer for Bottom of the

[8] http://bitlandglobal.com
[9] http://www.everledger.io/
[10] https://www.provenance.org/
[11] http://powerledger.io/
[12] http://transactivegrid.net/

Pyramid economic actors increased speed, efficiency, and trust that the contract will be executed as agreed, thus enabling arm's length transactions and payments triggered on receipt of goods. A further application is in the realm of providing more secure and inclusive voting and elections. The danger, of course, is that the contract performs no matter what: this raises questions about who writes them (*Quis custodiet ipsos custodies?*), how to write-in flexibility to respond to and incorporate external events, and individual's free will in connecting with them.

It is a small step from smart contracts to Decentralized Autonomous Organizations (DAOs) which are similarly executed by code but, unlike smart contracts, may include a potentially unlimited number of participants (Buterin, 2014). DAOs remain largely untested and use cases relating to SDGs are hard to find: nevertheless, indicative of the infancy of the technology, one major DAO initiative fell victim to misappropriation of approximately $80m (Price, 2016), indicating the need for further developmental work. One area where the concept has been developed is in the creation of DLT mediated organisations made of people but where the governance structure is encoded directly into the technical infrastructure stipulating and enabling the rules and procedures of the organisation that every member of the organisation will have to abide by: such design propositions may help to eliminate fraud and corruption.

3.6 Sharing economy

The sharing economy has been heralded as one solution to the challenges of sustainability by promoting environmentally sensitive forms of consumption, encouraging different models of ownership and addressing issues such as the under-utilisation of assets. However, some scholars recognise a *Dark Side* (Malhotra and Van Alstyne, 2014), partly for its tendency to reinforce the contemporary unsustainable economic paradigm (Martin, 2016), partly because some providers' business models are argued to be as much about evading regulations as about sharing, partly for spreading precarity throughout the workforce, for middlemen sucking profits out of previously un-monetized interactions (Scholz, 2016) and for being unavailable to disadvantaged groups, those of low socioeconomic status and users from emerging regions (Thebault-Spieker *et al.*, 2015).

DLTs address some of these criticisms by decentralising and disintermediating. Embedding sensors into existing assets, our 'things' can collect and share data. By integrating these data into the blockchain, we can keep an immutable ledger of shared transactions without the need for middlemen (Huckle *et al.*, 2016). La'Zooz[13] is a decentralized transportation platform owned by the community and utilising vehicles' unused space enabling people with private cars to share their drive with others traveling the same route: a decentralized Uber.

La'Zooz generates new tokens from 'Proof of Movement' not 'Proof of Work'. As they drive, drivers earn Zooz, passengers pay using Zooz and can also earn Zooz by providing route advice to drivers. Thus La'Zooz offers to provide a ride sharing service that is based on truer sharing economy principles, rather than monetary incentives (Bheemaiah, 2015). The business model moves from rent extraction to value creation in networks: value is distributed amongst those who created it, offering greater reward and opportunity for inclusion.

3.7 Financial inclusion

The opportunity for wider financial inclusion is held up as one of the great promises for SDGs of DLTs. Through automation, disintermediation, low cost and security of transfer comes the opportunity for transactions involving low value units and for remote, disenfranchised, peripheral and marginal communities to connect in new ways either amongst

[13] http://lazooz.net/

themselves or with activities in the wider world. DLTs allow the almost instantaneous transfer of digital tokens, if not at zero cost then at a significantly cheaper rate than established services. This makes the transfer of small amounts of currency economically viable, enabling new actors to enter the field and new opportunities for e-commerce (Athey, 2015). It might be anticipated, then, that reductions in the cost of financial transactions through DLTs will result in widening financial inclusion.

One critical factor in enabling greater financial inclusion is identity which, it is argued (Birch, 2014) will underpin future digital transactions and lies at the heart of realising the potential of DLT. The question of what defines identity is challenging, not least because it "does not lend itself easily to definition nor does it remain unchangeable" (Ajana, 2010: 5).

Identities are made up of multiple attributes: date and place of birth, parents' names, school, criminal record, employment record, biometrics, papers published etc. These attributes reflect who we are and are configurable depending on who we need to identify ourselves to and for what purpose.

Identity is not a single entity but rather it is a structure composed of configurable identity holons (Fish and Priest, 2011) which, after Koestler (1968), can be understood as autonomous (id)entities in their own right fulfilling particular purposes, functions and objectives yet contained within a higher level structure of identity. That is, configurations of identity attributes are 'whole' or fit-for-purpose in one form or at one level and simultaneously are part of another. In each case each needs to be sufficient to authenticate the claim we are making.

For most, it is relatively straightforward to assemble authenticated attributes of identity (passport, utility bill, etc.), but approximately 1.8bn of the world's population have no legally recognised identity (Dahan and Gelb, 2015). The reasons are various, but the consequence is that the 'identityless' exist on the margins of society unable formally to participate in democratic, educative, healthcare and economic activity.

Part of the problem of identitylessness is the extent to which identity has been a centralised phenomenon, something that, to a large extent, is given to people by some authority. The affordances of DLTs offer an alternative approach to building identities from the bottom up, as the gradual accretion of different attributes of identity. This way, an individual's identity is not under the control or the gift of any central authority, nor is it vulnerable to tampering or theft from malicious third parties. Further, individuals are able to control which attributes may/may not be made public depending on the authentication need. This is currently an area of intense DLT development including initiatives from ID2020[14], BitNation[15], BlockchainBorderBank[16], BanQu[17], and NevTrace[18].

4. Conclusion

Global interest in DLTs is gathering pace, yet the world's vision of what we might be able to achieve with it is as limited as it was with regard to the internet and world wide web in the late 1980s. Far-sightedness is required to imagine the possible contribution of DLTs in addressing sustainability-related challenges. This paper has explored, through affordance theory, how DLTs might contribute to that process.

[14] http://id2020.org/
[15] https://bitnation.co/
[16] http://law.mit.edu/blockchainborderbank
[17] http://www.banquapp.com/
[18] http://nevtrace.com/

Our exploratory desk research has inherent methodological limitations. Intended as a scoping study to begin to explore the notion of B4G, the work is characterized by a high level of subjectivity in both its sample selection and analysis. As such, the results cannot be said to be representative or generalizable at any level. However, in terms of B4G, as an emergent phenomenon or shared interpretative schema that is being co-constructed by a wide ecosystem of actors as a means of giving direction and catalyzing actions, choices and behaviours (Ranson et al., 1980), our findings are interesting inthemselves and provide a promising basis for further research. Obvious extensions of this work include tighter specification of an analytic framework 'for good' and validating initial findings with a panel of experts through Delphi study. The essential premise of technology affordance is that, to understand the uses and consequences of technologies, they must be considered in the context of their dynamic interactions between people and organizations (Majchrzak and Markus, 2012), DLTs are a case-in-point. Further applied research and development are required which, given the sensitivities of the domain, require a multi-stakeholder, living-lab ethnographic approach, to understand which configurations of DLT and their affordances work best in which circumstances and why, as well as the extent to which they can deliver on the sustainability agenda.

Within this limited space, we have presented a rather one-sided, limited perspective and are aware that DLTs are not a universal panacea. The notion of Blockchain for Good inevitably raises questions about its counter, 'Blockchain for Bad', and there exists, beyond the scope of this paper, a body of cautionary literature. Analysing crypto-currencies through the lens of ethical impact, Dierksmeier and Seele (2016) also find detrimental outcomes, such as the facilitation of nefarious consumption. Physicist Stephen Hawking, Elon Musk and, as of 12 November 2016, 8,749 others have signed an open letter counselling against the incautious application of artificial intelligence and DAOs (Russell *et al.*, 2015). DLTs feel no guilt, regret or remorse. This raises questions about who will do the coding. As yet, there is little regulation specific to DLT. Still, might DLTs yet be subsumed by incumbent organizations and authorities as another tool of control and surveillance, or can they really deliver a more democratic, egalitarian, collaborative and sustainable society?

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