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Blockchain Advancements to Sustainable IT Systems

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A B S T R A C T

The modern digital economy relies heavily on information technology (IT) systems to support communication, business, entertainment and more. However, the expanding digital footprint of society also comes with significant environmental costs. IT infrastructure and operations currently account for up to 1.5% of global greenhouse gas emissions (Belkhir & Elmeligi, 2018). Electronic waste from discarded hardware is also rising sharply, with over 53 million metric tons generated globally in 2019 alone (Forti et al., 2020).

As IT systems continue to scale up to meet the world's growing digital demands, their sustainability impacts are becoming impossible to ignore. New approaches are urgently needed to maintain essential IT services for society, while also reducing associated energy usage, waste, and other environmental burdens. Blockchain technology, with its decentralized and transparent architecture, presents a promising pathway to develop more sustainable IT systems for the future. This paper provides a comprehensive review of how blockchain innovations can promote sustainability across IT infrastructure, operations and supply chains. First, the fundamental architecture and attributes of blockchain technology are outlined. Next, emerging use cases and applications where blockchain can optimize sustainability of IT systems are analyzed in depth. Key opportunities and challenges for blockchain

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integration are discussed, along with a forward outlook on the technology's future development and adoption trends.

Overview of Blockchain Technology:

A blockchain is essentially a distributed digital ledger that is maintained by a decentralized, peer-to-peer computer network rather than any central authority. Transactions are recorded in cryptographically secured "blocks" that are chained together chronologically and distributed across all nodes in the network. This creates an immutable, shared record of all activity that is highly tamper-resistant and transparent (Christidis & Devetsikiotis, 2016).

Several unique attributes of blockchain architecture lend themselves well to improving sustainability in IT systems:

Decentralization - Rather than relying on massive, centralized data centers, blockchain networks distribute storage and processing tasks horizontally across many nodes. This means no single entity controls the network. Redundancy provided by thousands of nodes makes the overall infrastructure resilient while reducing reliance on energy-intensive server farms.

Transparency - The entire history of transactions is viewable to all participants in a blockchain network. This provides end-to-end traceability and visibility into how assets exchange hands over time. For physical supply chains, blockchain can connect real world steps to digital records.

Security - Blockchains achieve highly secure data transmission through cryptographic techniques like hashing and digital signatures. Records are near impossible to alter after the fact. This prevents tampering, builds trust and reduces errors.

Automation - Smart contracts enable complex business rules and workflows to be encoded into blockchain transactions and executed automatically when conditions are met. This reduces overhead costs associated with manual processes.

By incorporating these core features into IT infrastructure, operations and supply chain management, blockchains offer a framework to curb sustainability impacts like energy usage, waste and emissions. The following sections provide an in-depth analysis of emerging use cases and real-world examples where blockchain is adding transparency, optimizing processes and promoting sustainability in IT.

Optimizing IT Infrastructure through Blockchain:

In traditional centralized IT architecture, massive amounts of data are stored and computing tasks are performed in large data centers. These facilities consume enormous amounts of electricity to power servers, cooling systems and network equipment. In 2013, data centers accounted for about 2% of total US electricity demand, on par with the consumption of the entire airline industry (Shehabi et al., 2016). The rise of cloud computing and Internet-of-Things devices is projected to drive a 60% increase in global data center energy use by 2030 (Masanet et al., 2020).

Blockchain decentralization presents an opportunity to distribute storage and processing away from these centralized hubs and onto peer nodes across the internet. This horizontal scaling approach follows the edge computing trend of moving computing closer to the user. Blockchain networks harness the unused storage and computing capacity sitting dormant in devices like laptops and smartphones (Khan & Salah, 2018). While individually these nodes have limited power, in aggregate they form a resilient collective infrastructure.

Some estimates indicate blockchain networks could feasibly handle global storage needs while cutting IT infrastructure energy usage by more than half (Lielacher, 2017). Decentralized cloud storage projects like Filecoin, Sia and Storj allow users to rent out spare hard drive capacity to the network and receive cryptocurrency payments in return. Data is encrypted, split into fragments and distributed across different nodes for redundancy. This eliminates centralized data silos prone to hacking.The Ethereum blockchain takes decentralization further by providing a distributed global computing platform for "smart contracts". Rather than relying on a few centralized servers, any Ethereum node can execute code in a virtual machine. Users pay fees in the cryptocurrency "ether" to run applications on this decentralized world computer. Distributing computations in this manner can handle high workloads efficiently. For example, a stock exchange application called Devexperts ran 20 times faster on Ethereum infrastructure versus centralized cloud servers (Devexperts, 2015).

Overall, shifting data storage and processing tasks onto global blockchain networks offers a more sustainable model by reducing reliance on massive, electricity-hungry data centers. Optimal decentralization configurations to balance energy efficiency, cost and performance are still being explored. But the general principle holds promise to curb the rising environmental footprint of centralized IT infrastructure as global data demands continue accelerating.

Enabling Sustainable Supply Chains for IT Hardware:

While blockchain can optimize the back-end infrastructure of IT systems, it also has emerging use cases on the hardware manufacturing side. Blockchain’s transparency and traceability capabilities can enable more sustainable supply chains for IT components like microchips, batteries and display panels.

IT hardware often has complex supply chains spanning multiple countries and dozens of specialized component makers. Unsustainable practices like child labor, unsafe working conditions and pollution frequently occur out of sight. Even well meaning hardware vendors struggle to map and monitor all tier 2 and tier 3 suppliers in far flung locations (Saberi et al., 2019).

Blockchain can connect real world steps in IT supply chains to immutable digital records. Sensors and tags attached to components can track key metadata like location, temperature, timestamps and custody changes as products move through multiple facilities and logistics steps. Recording this physical flow onto a tamper-proof blockchain ledger provides end-to-end transparency from factory to finished product.

For example, the startup Chronicled uses Bluetooth-powered sensors attached to electronics to monitor temperature conditions and automatically log events like freezing or overheating to the Ethereum blockchain. Chronicled also runs sustainability audits at factories and registers results onchain, with links to audit reports (Chronicled, 2020). This enables any stakeholders to review supply chain events and factory audit credentials on the tamper-proof ledger.

Blockchain tracking upholds manufacturers' sustainability claims by making supply chains fully auditable. Discrepancies between recorded events and purported policies get flagged for investigation.

This accountability mechanism pressures suppliers to uphold environmental and labor standards in order to do business with major hardware vendors. Integrating sustainability metrics into supply chain quality control via blockchain is seen as a scalable solution as global supply chains continuously expand and diversify (Saberi et al., 2019).

Automating IT Asset Management with Blockchain :

In addition to optimizing infrastructure and supply chains, blockchain automation can also drive sustainability improvements in IT asset management. IT assets like servers, computers and mobile devices consume massive amounts of energy over their lifetimes, especially from manufacturing, transport, and disposal after use (Ercan, 2021). Much of this lifecycle energy usage stems from manual processes riddled with inefficiencies. Emerging blockchain applications focus on using automation, transparency and decentralization to optimize IT asset management.

One major source of energy waste is 'zombie' servers, or data centers full of servers kept running even when mostly idle. Estimates suggest 30% of servers run below 10% utilization (Desautels, 2020). Keeping unused servers powered on stems from overprovisioning to meet peak demand. It also arises when organizations lose track of assets and keep paying colocation fees. The United Nations Environment Program estimates zombie servers globally waste $19 billion and 6.7 million tonnes of CO_2 annually (Desautels, 2020).Blockchain automation can prevent zombie servers by tracking IT assets from procurement to retirement. When purchasing from hardware vendors, unique digital IDs for servers get initialized onto a blockchain ledger. These IDs auto-log utilization metrics like processing activity. Decentralized sensors can remotely track metrics and trigger blockchain transactions. Smart contracts then auto-execute processes like powering down or deprovisioning servers that hit low utilization thresholds. All lifecycle events up until asset disposal get logged via blockchain for transparency.

Other common scenarios like hardware theft, illegal resale or transfers also get automatically prevented via blockchain policy enforcement. Companies can integrate accounting systems so the ledger ties real-world assets to financial flows. Automating inventory auditing and real-time tracking enables leaner, more accountable IT asset management workflows overall (Woodhead et al., 2019).While still at nascent stages, automated asset management using blockchain, AI and IoT presents has huge potential to eliminate waste, unnecessary costs and energy usage across IT hardware lifecycles. Industry experts predict adoption will accelerate as blockchain and sensor platforms mature over the next 5-10 years.

Key Challenges and Outlook for Blockchain in IT

This paper has highlighted a variety of blockchain applications that can drive sustainability improvements in IT infrastructure, supply chains and operations. However, there remain significant barriers to mainstream enterprise adoption and scaling up these solutions. Technical limitations around speed, storage, security and costs are still being addressed through ongoing blockchain platform development and research (Casino et al., 2019).

Integration with legacy enterprise systems poses further challenges. Migrating processes like supply chain tracking or asset management onto entirely new decentralized protocols requires learning curves and process redesigns. Uncertainty around evolving regulations for cryptocurrencies and decentralization also hinders blockchain adoption, as companies shy away from deploying business-critical systems onto novel platforms with compliance ambiguity (AR Kunduru 2023).

Given these barriers, incremental blockchain adoption seems more realistic than abrupt and sweeping changes. Supply chain tracking for transparency seems most poised for adoption in the short term, with proven pilot projects already underway. Automating back-end infrastructure and core IT processes via blockchain will likely take 5-10 more years of development, testing and integration. But by the end of the decade, we could feasibly see blockchain becoming a widespread pillar of more sustainable IT, according to experts (Columbus, 2020).

The key to realizing this potential is acknowledging blockchain as an experimentational technology still in its infancy. Patience, iteration and collaborative knowledge sharing between researchers and enterprises will scaffold blockchain's evolution beyond hype to real-world sustainability solutions. Overall, the long-term outlook remains highly promising.

Conclusion:

As digitalization accelerates across society, pressures mount for IT systems to curb their growing environmental footprints stemming from e-waste, infrastructure emissions and inefficient processes. Blockchain presents a timely opportunity to rearchitect core IT foundations in a more sustainable manner.

The decentralized, transparent and automated attributes of blockchain hold unique promise to optimize supply chains, infrastructure and operations. Early use cases suggest blockchains can distribute processes away from data centers into peer-to-peer networks, enable transparent auditing of hardware manufacturing, and automate asset management workflows.

However, mainstream adoption still faces barriers around technical limitations, integration costs and policy uncertainty. Collaborative development and iterative testing will be crucial to harness blockchain's sustainability potential. With diligent progress, blockchain could play an integral role in building sustainable IT foundations to support society's digital needs into the future.

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