Using Blockchain to Address Interoperability Concerns in Healthcare

Government and public health authorities are undertaking several initiatives to boost the health IT system, which in turn is expected to enable high-quality and personalised care. The main goal is to empower and educate consumers by equipping them with a real-time digital picture of their health. Electronic health record (EHR) adoption, which is the first step in realising this goal, has already gained momentum. The next step is to ensure a seamless flow of health information across stakeholders that will make the information usable and enable better decision-making.

The ability of health IT systems to share information with each other and use that shared information is called interoperability. According to Premier Healthcare Alliance, lack of interoperability results in a loss of 150,000 lives and US$18.6 billion every year. Furthermore, the current healthcare ecosystem is shifting toward a value-based care model, which is extremely dependent on data-driven decision-making. Interoperability ensures that the right data is made available to the right person at the right time. Interoperability is the extent to which different IT systems and applications communicate with each other, exchange information, and analyse the information that has been exchanged. Electronic health record (EHR) interoperability would permit authentic real-time data to be shared among various stakeholders such as hospitals, patients, pharmacies, labs, payers and public health authorities in an efficient and secure manner.

The United States federal government allocated US$27 billion to subsidise EHR adoption in the healthcare sector. This allocation was part of the Health Information Technology for Economic and Clinical Health (HITECH) act in 2009. The US Department of Health and Human Services (HHS) Office of the National Coordinator for Health Information Technology (ONC) has also expressed the need for interoperability in its Shared Nationwide Interoperability Roadmap.

Benefits of EHR

EHR has multiple benefits for the healthcare ecosystem:

- Information availability in a structured form lowers administrative costs and chances of clinical errors.
- A consolidated repository of an individual's health information enhances data mining and analytics capabilities.
- Better accessibility to health records furthers patient ownership of health and wellness.
- Technology-backed systems optimise operating and administrative expenses.
- Transparent information availability improves physician efficiency and quality of care.
- Data-driven decision-making improves value-based reimbursement eligibilities.

However, thus far the healthcare ecosystem has not realised the intended benefits of EHR. Out of 465 vendors in the EHR market, the top four vendors dominated 62% of the market in 2015. This oligopoly of vendors has created perverse incentives leading to lack of innovation, collaboration, and interoperability. In addition, there are other issues, such as the absence of interoperable platforms, which create a multitude of problems.

Issues Created Due to Absence of Interoperability

There are several problems created by the absence of interoperability:

- Restricted data sharing: The predominant EHR products on the market today restrict the free flow of patient information across various product platforms. Most vendors impose interfacing costs for data transfer. The healthcare system incurs additional costs due to clinical test duplications that occur because of restricted information availability.
- Non-availability of a unified patient view: The current solutions offered by EHR vendors are siloed and thus fail to capture the bigger picture of a patient's overall journey. There is no common platform or API that allows the various proprietary and legacy systems to seamlessly communicate with each other.
- Lack of meaningful insights: The benefits of data mining and data warehousing are severely restricted by the unavailability of complete data and the reluctance of EHR vendors to build customised interfaces.

Challenges in Enabling EHR Interoperability

The absence of interoperability is resulting in huge losses (monetary and otherwise); however, the number of initiatives the healthcare ecosystem has initiated to address the situation have been far below expectation. Many factors contribute to stakeholder reluctance with regard to EHR interoperability:

- Misaligned incentives: The stakeholders' incentives are misaligned with regard to the goals of interoperability.
  - **Suppliers:** Every EHR vendor currently sells its own proprietary systems. If interoperability becomes a reality, their customers will no longer encounter proprietary lock-in and will be free to choose any vendor. Therefore, interoperability would dilute the EHR vendors' competitive advantage and cannibalise their existing revenue streams.
  - **Buyers:** Current EHR systems users have invested billions of dollars in buying and setting up legacy EHR systems. Adoption of an interoperable platform might require them to replace their existing legacy systems, which could result in the potential loss of billions of dollars.
- Lack of data sharing: Traditionally, data sharing between payers and providers has been an issue, mainly because they were working independently and did not share any common data exchange standards. This schism has created a cultural inertia for these stakeholders with regard to interoperability adoption. However, because of the current push toward value-based care, many initiatives have been initiated to unify

care financing and care delivery, which requires seamless information sharing among stakeholders.

- Data security and integrity: The vision of a single interoperable platform that potentially makes all healthcare data accessible at one location raises important security and privacy concerns. The recent Anthem medical data breach and WannaCry ransomware attack are proof that the threat of cyber attack is real. With interoperability coming into play, if the entire healthcare database is located on one central platform, the database becomes a target for cyber attackers. Also, it is extremely important that health data is accurate and cannot be tampered with by any authority in any way.
- Government regulations: With the large number of stakeholders operating in a messy information processing landscape, forcing interoperability on the system is not an option. Actual implementation would require buy-in from all the stakeholders, who must be willing to adopt certain governance principles and business agreements. However, the role of government authorities would be important in providing guidance and certification requirements and standards in a timely fashion.

Blockchain – the Way Forward

Most organisations and researchers consider blockchain technology to be one of the frontrunners in the race to resolve the EHR interoperability problem. Conceptually, blockchain is primed to solve the healthcare interoperability challenge as it is enabled by distributed ledgers, a system that is similar to the healthcare landscape comprising a complex information ecosystem spread across disparate nodes (payers, providers, EHR platforms, etc). In simple terms, blockchain is a cryptographic or encoded ledger, which is a database of transactions in the form of blocks arranged in a chain. These blocks are validated by multiple users through consensus mechanisms shared across a public or private network.

The basic underlying structure of blockchain can be visually depicted as in Figure 1.

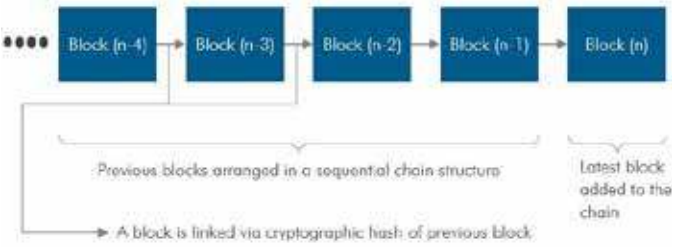

Figure 1

Please note that Figure 1 depicts the underlying structure of blockchain and not the external distributed computing architecture.

New blocks are validated and linked to older blocks, thus making a chain of blocks that show every transaction in the history of that blockchain. Any new information that is added must be linked in a sequentially linear pattern, thus bringing the aspect of scalability under scrutiny.

Blockchain Can Make Interoperability a Reality

Primary blockchain technology features that can help in enabling interoperability are described below:

- Disintermediation: The information is present in the form of a distributed ledger, which has a network of replicated databases that is visible to anyone within the network. The entire chain is continually updated so that every ledger in the network has the identical information. This decentralised nature allows people to trust each other, thus making the need for intermediaries obsolete. In a nutshell, it creates a decentralised database that is synchronised via the internet and makes seamless data-sharing possible across platforms and stakeholders.
- Removal of single node of failure: The shared and replicated nature of blockchain ensures that there is no central authority that manages the database. This, in turn, mitigates the possibility of hacking attacks and makes the system secure.
- Immutability of transactions: The cryptographic hash functions and distributed nature of blockchain ensure that the stored information is time-stamped and tamper-proof. This is extremely important, because only authentic health records are valuable for the stakeholders involved.
- Validation: Transactions are validated through a consensus mechanism (also called proof of work). Without involving any central verification agency, the network itself ensures that the transactions being added to the chain are genuine and authentic.

Several organisations have already started building blockchain-based prototypes to address the issue of EHR interoperability, some of which are described below.

- The US Department of Health and Human Services: HHS held an ideation challenge called "Use of Blockchain in Health IT and Health-Related Research" to encourage blockchain use in health information technology.
- MIT Media Lab and Beth Israel Deaconess Medical Center: These collaborators developed a blockchain-based working prototype called "MedRec." The pilot recorded six months of inpatient and outpatient medication data, including blood work records, vaccination history and prescriptions, thus simulating data exchange among institutions by using two different databases within Beth Israel. The results were very encouraging, and the team is planning to conduct more pilots with a larger network of hospitals.
- Joint research initiative by IBM Watson Health and US Food and Drug Administration (FDA): IBM Watson Health is collaborating with the FDA with the aim of defining a secure, efficient and scalable exchange of health data using blockchain technology.
- Accenture LLP: Accenture is exploring how integrating current health IT investments with a permissioned blockchain technology can be used to create secured and trusted care records, linking identities and securing patient content.
- Deloitte: Deloitte is exploring the application of blockchain technology in multiple healthcare use cases. The company is trying to create a smart contract-based health information exchange, a digital identity layer and a precision medicine database.
- Mayo Clinic: Mayo Clinic is exploring the use of a new consensus algorithm designed to facilitate data interoperability. The approach builds consensus on proof of semantic and structural interoperability.
- HL7: HL7 is a not-for-profit standards-developing organisation that has created a Fast Healthcare Interoperability Resources Specification (FHIR) for EHR exchange. Although the FHIR

specification is comprehensive, free, and fast to develop and implement, it has a few gaps from the point of view of practical implementation. Researchers believe blockchain has the potential to address these technology gaps.

- Tokio Marine & Nichido Fire: The Japanese insurance company created a blockchain-based platform for sharing patients' medical information among relevant parties.
- Healthcoin: Healthcoin is a blockchain-enabled platform focusing on insurers and employers. It incentivises people to make lifestyle changes to prevent diabetes.

Barriers to Blockchain Adoption

The practical implementation of blockchain as a platform for interoperability will require the resolution of several issues:

- Scalability: EHRs will contain the comprehensive health records for each citizen, and the information database will keep getting bigger with time. To keep up with this ever-growing database, we need a system that is scalable. Traditional blockchains, due to the inherent nature of blocks being continually added in a chain structure, have limitations on the maximum transaction rate. Blockchain transactions require advanced hardware because of complex transaction processing logic. This raises the question; can blockchain be scaled up rapidly enough to hold EHR data?
- Micropayments: In the near future, the healthcare market will be flooded with connected medical devices. To ensure that these devices are continuously communicating with each other and sharing real-time medical data, micropayments must be enabled across different IoT vendors. As traditional blockchain involves paying a fee to the miners in exchange for their computing power, processing micropayments via blockchain might involve paying a fee that is higher than the transaction amount itself.
- Miners' power play: In traditional blockchain, the validation is done by network participants known as miners. Some of the blockchain-based EHR prototypes that have been developed incentivise public health authorities to participate as miners and give them access to aggregate, anonymised data as mining rewards. This presents an opportunity for this privileged group to filter or postpone certain transactions.

Looking Beyond Blockchain

Tangle, which is an advanced next-generation cryptoplatform developed by the company IOTA, addresses the above-mentioned implementation issues with blockchain. The basic underlying structure of Tangle can be visually depicted as shown in Figure 2.

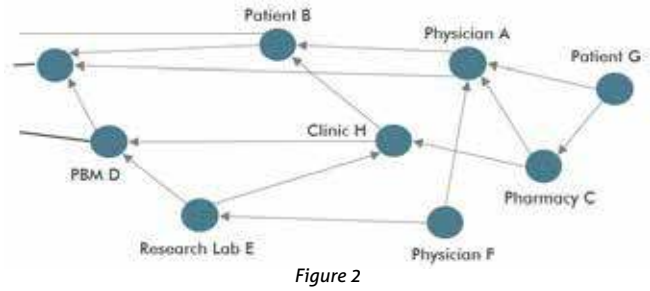

Figure 2

Each node is a separate entity that issues a distinct transaction (an information update, in this case). As is evident from Figure 2, the Tangle network can grow from any node in any direction and does not have to follow a sequential linear structure as blockchain does. This property tremendously increases the scalability potential of Tangle as compared to blockchain.

We expect this platform to be far more successful than blockchain in tackling the issue of EHR interoperability for the following reasons:

- Disintermediation, no single node of failure and immutability of transactions: Just like blockchain, Tangle is also a distributed ledger with replicated databases that contain identical information in encrypted form. Thus, it demonstrates most of the benefits associated with blockchain.
- Scalability:
  - Unlike blockchain, Tangle's skeleton is not based on a sequential chain of blocks. Instead, it uses a directed acyclic graph architecture.
  - This model is especially feasible for EHR because, unlike financial transactions (which are the cornerstone of blockchain) where chain of asset ownership needs to be established, in EHR only the medical data needs to be continually updated, which can be done more efficiently with a network structure rather than a chain structure.
- Transaction validation, enabling micropayments, and countering miner privileges: To issue a transaction on Tangle, users must approve two previous transactions. The more approvals a transaction receives, the more acceptable it becomes. This ensures that no participant has special validation privileges (unlike miners in blockchain) and the validation process is free, thus enabling micropayments.

Despite the apparent advantages of Tangle, adequate research still needs to be done to assess the viability of using it to enable EHR interoperability. Given the sensitive and confidential nature of health data, it is essential to eliminate all possible security concerns before launching any new platform. Keeping these constraints in mind, we propose the creation of a new modified platform that provides the best of both worlds (blockchain and Tangle).

Interoperable Ecosystem – The Final Setup

The proposed platform leverages the strengths of both blockchain and Tangle, but at the same time, it eliminates the limitations of these existing technologies. From among the many different approaches that are possible, below we propose one of the ways in which this can be achieved.

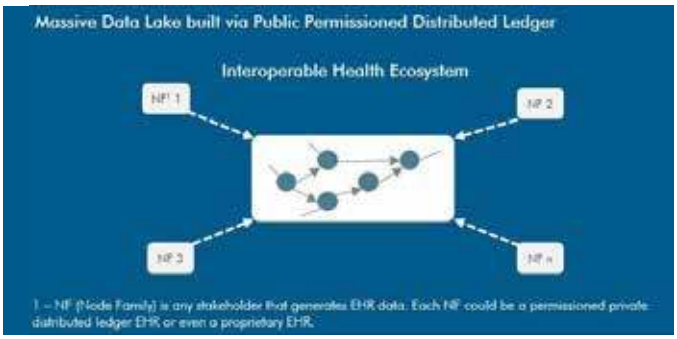

Figure 3

The final platform should be a public permissioned distributed ledger created by the government or a public health body, wherein all participants in the ecosystem can connect and share data. Each node family (comprising clinics, physicians, hospitals and health devices) will be connected to this public ledger; however, the data that they have in their system will be in a permissioned private network or their proprietary EHR. The basic premise of a permissioned private network is the same as that

of a permissioned blockchain. This is essential to provide secure access to healthcare data, because a particular node family, let us say any Hospital X, will have full visibility into its own data but any entity outside Hospital X will only have permissioned access (not unrestricted access) to that hospital's data.

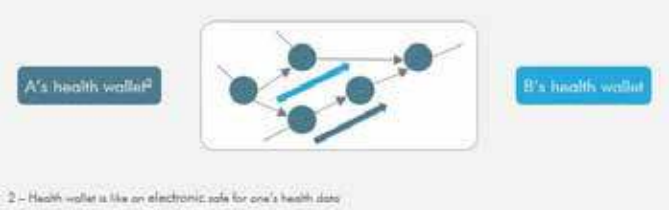

Figure 4

Each node in the network represents a data packet sent by one of the node families. The electronic information exchange standards such as FHIR will enable this seamless transfer of data packets via APIs. Security standards (similar to PCI-DSS standards) need to be integrated within the ecosystem to ensure secure transfer of data packets.

Each individual patient will have their health data stored in a "health wallet," and they will own this data, which is sourced from all the node families (multiple clinics, physicians, hospitals and devices that the individual uses). The health wallet might be accessed via an application on their smartphone. This application will essentially use a public-private key combination to fetch a particular patient's data from the distributed ledger. Each transaction will be encrypted with the patient's public key (visible to all) and can only be decrypted using that patient's secure private key (similar to a password). Therefore, the health wallet application will traverse through the transaction network to identify all the transactions encrypted with a particular patient's public key, but the entire data will be visible only to the patient (and no other stakeholder) after the patient authenticates using their private key.

The overall architecture proposed above fits perfectly in a network with a low level of trust and integrates well with the simple validation process that Tangle offers in its current state.

The Role of the Healthcare Ecosystem as a Whole

If a new platform is to be adopted by all the stakeholders involved in the massive healthcare ecosystem, it needs to be more than a one-organisation show. In addition to overcoming technological challenges, the issues described below must be addressed:

- Stakeholder incentivisation: To bring interoperability to life, all the stakeholders who are part of the healthcare ecosystem need to be incentivised to adopt a new common technology platform. With the current push toward value-based care, providers and payers can be persuaded to adopt this technology. The consumerisation trend among the increasingly tech-savvy patients might be an intrinsic incentive for them to join the network. The challenge comes for stakeholders such as the current EHR vendors, who will lose out on their proprietary investments if the common platform is adopted. Adopting a new technology at such a large scale will lead to loss of productivity during the initial phases of implementation. So, taking a long-term view becomes important; stakeholders must cooperate with each other to overcome the initial challenges.
- Complementary technology enablers: In addition to building the underlying technology backbone, a lot of investment in complementary technology is required. In order to avoid large upfront investment from each individual stakeholder, the entire technology framework needs to be cloud-driven. A host of APIs needs to be developed to enable information sharing among the common platform on the cloud and numerous proprietary databases that are currently in use. Interoperability standards such as FHIR need to be further developed. The IoT standards also need to be compatible with this new technology platform.
- Information exchange standards: The massive initiative of creating an interoperable health data exchange will succeed only if the ecosystem as a whole adopts a common standard. Fast Healthcare Interoperability Resources (FHIR) is one such standard; it has been developed by HL7 to facilitate electronic exchange of healthcare information.
- New business model: For interoperability to be a reality, an entire new business model needs to be developed around the platform and provided the necessary resources. The government also needs to push stakeholders to adopt this common technology platform. Industry consortiums need to be created where the various participants cooperate with and complement each other. For example, cloud infrastructure requirements can be taken up by some participants, building APIs can be taken up by other participants, creating and maintaining the platform itself can be taken up by other players, and so on.

The technology required to implement an EHR system exists, but its widespread adoption is a cultural challenge. Every stakeholder in the massive healthcare ecosystem needs to be incentivised and trained to adopt a new platform. Organisations need to come up with complementary technology that will support the core platform. Finally, everyone needs to be committed to forging past the initial implementation roadblocks in order to realise the long-term benefits of interoperability.

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