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# White Paper: Innovative Blockchain Uses in Health Care

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## Introduction

Blockchain, the digital ledger technology that can securely maintain continuously growing lists of data records and transactions, has the power to potentially transform health care, according to industry experts. By simplifying and expediting the way the health care industry processes data in such areas as revenue cycle management, health data interoperability and supply chain validation, blockchain has the power to dramatically reduce back-office data input and maintenance costs and improve data accuracy and security.

This white paper summarizes several use cases for employing blockchain technology in five key data-driven areas:

1. **Longitudinal health care records** – Can blockchain enable patient records to securely link and be accessible across non-affiliated provider organizations to improve care coordination?
2. **Automated health claims adjudication** – By using a "smart contract" structure, can blockchain help seamlessly adjudicate payers' and patients' provider payments for a more cost-efficient process?
3. **Interoperability** – Can blockchain overcome current patient data interoperability issues and gather the information needed to more effectively support population health initiatives for large health systems?
4. **Online patient access** – Will blockchain technology enable patients to more easily, effectively and securely gain access to their own medical records?
5. **Supply chain management** – Can blockchain enhance health care contract management and reduce costs by allowing such features as real-time contract tracking and execution?

For the benefit of readers not yet fully familiar with the dimensions and potential of blockchain technology, this white paper initially defines blockchain and its applicability in business, particularly in financial services. We also briefly explain and illustrate how blockchain works. From the primary portion of this white paper – blockchain's applicability in health care and considerations for its implementation – readers in the health care industry will come away with a much deeper understanding of blockchain's potential for their organizations.

## What is Blockchain?

As readers may know, blockchain is the supporting architecture now used in e-finance as a widely accepted electronic currency. It's captured health care professionals' increasing interest due to the extended functionality of blockchain and emerging application program interface (API) services that enable and expedite several collaborative, financial and operational services processes. These processes are intended to save money, increase trust between buyers and sellers, and enable data-sharing.

According to Broeder, et al / Accenture (2016, p.5), "Blockchains are cryptographic protocols that allow a network of computers (nodes) collectively to maintain a shared ledger of information without the need for complete trust between the nodes. Each blockchain database is a time-sequenced chain of events that have been authenticated using a consensus mechanism specified by the protocol. The mechanism guarantees that, as long as the majority of the network validates the blocks posted to the ledger (i.e., chain) as per the stated governance rules, information stored on the blockchain can be trusted as reliable. This ensures that the transaction data is replicated consistently across the network. The effect of the distributed consensus mechanisms often means that all of the nodes of the network hold all the information stored on the blockchain.

"From a regulatory and audit perspective, entries can be added to but not deleted from the distributed ledger. A network of communicating nodes running dedicated software that replicates the ledger among the participants on a peer-to-peer basis performs the maintenance and validation of the distributed ledger. All information shared on the blockchain has an auditable trail – a traceable digital 'fingerprint.' The information on the ledger is pervasive and persistent and creates a reliable 'transaction cloud' so that data cannot be lost and consequently eliminates single-point-of-failure risks and data fragmentation disparities among counterparties.

"From a security perspective, cryptography protects the data via a number of different mechanisms. Users can address privacy and transparency needs using different consensus mechanisms specified by the protocol and public and private key pairs. A blockchain environment protects information at the data element level, rather than in aggregate, and appropriate parties can only access data using appropriate permissions as defined by the protocol."

## The Promise of Blockchain

In 2016, the Office of the National Coordinator (ONC) for Health Information Technology sponsored a white paper national contest to generate promising blockchain use cases in health care, especially in support of the Triple Aim and interoperability. The contest produced many interesting white papers, some of which are reviewed here. The ONC also sponsored a national "code-a-thon," ending in March, 2017, in which software developers provided proofs of concept and hopefully ground-breaking blockchain code to help accelerate its application in the health care industry. The ONC will share these results later in 2017.

Concurrently, vendors such as IBM, the Tierion/Philips partnership (Netherlands), Brontech (Australia), GEM (U.S.), and Guardtime (Europe) have been developing their own conceptual blockchain applications. It is interesting to note that consulting firms and other companies are hiring blockchain analysts and technicians in anticipation of accelerating blockchain development projects. Historically, IBM has contributed approximately half of the blockchain open source code; the percentage of non-IBM code continues to increase from contributions of 122 blockchain development community members (Groenfeldt, 2017).

Blockchain is such a hot topic of interest in health care that HIMSS featured a blockchain technology symposium at its Orlando 2017 conference: "Blockchain in Healthcare: A Rock Stars of Technology Event," presented by Tamara StClaire, previously chief innovation officer at Conduent Health (formerly Xerox Healthcare).

According to StClaire, "there's a lot of movement" in health care toward adopting blockchain technology. She cited research from IBM, which showed that 16 percent of payer and provider executives expect to have a commercial blockchain application at scale in 2017. She also noted a recent study from Deloitte, which found that health care and life sciences plan the most aggressive deployments of blockchain across all industries, with 35 percent of respondents saying their company plans to deploy it within the next year (Miliard, 2017). Such blockchain-enabled innovations may provide the health care industry's long-sought solutions to interoperable health care, as well as several other important health care applications.

## A Technical Look at Blockchain

The most familiar current use of blockchain is with the electronic currency, Bitcoin, whose blockchain transactions involve moving specific amounts of Bitcoin currency from one account to another. Anyone can verify a particular Bitcoin account by using appropriate software tools to examine the transactions on the public blockchain (Ivan, 2016, p. 3). The term "blockchain" comes from the distributed database that blockchain uses. It creates a chain of transaction blocks or a "block chain" to store information. The chain is an electronic, shared, secured distributed ledger with a specialized purpose. For Bitcoin, this translates to a ledger that manages the ownership and exchange of the Bitcoin currency.

Within health care, a blockchain may involve a number of different uses, as this white paper details.

A transaction block is replicated across a collection of computers connected as a peer-to-peer network that constitutes the blockchain. Every computer participating in the peer-to-peer network is referred to as a node. Advanced cryptography allows for the nodes to interact anonymously and securely on the network (Culver, 2016, p. 4). Here is a more concise definition: "A distributed tamperproof database that secures all records that are added to it, wherever they exist. Each record contains a timestamp and secure links to the previous record" (Broderson, et al., 2016, p. 2).

In order for a node to add a transaction to the blockchain, a consensus of the networked nodes is required to determine where the transaction should appear. This consensus occurs when a majority of the nodes agree on the next "block" of transactions to add to the chain.

The Bitcoin developer guide provides a simple illustration of the block concept in Figure 1 below.
The illustration above shows a simplified version of a blockchain. A block of one or more new transactions is collected into the transaction data part of a block. A series of hashes connect via the header, and with the header having a

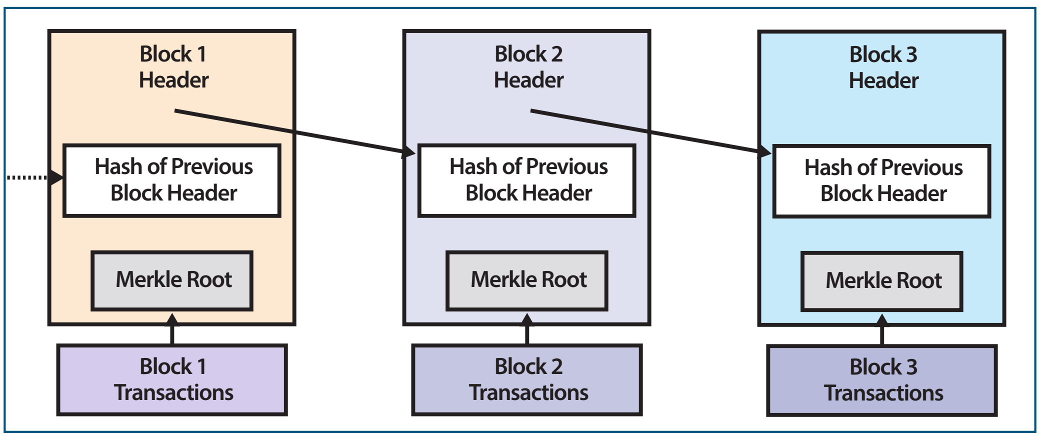


*Figure 1. Simplified Blockchain Concept (Anonymous, 2017)*

reference to the previous hashed copy form the ability to chain together transactions. Copies of each transaction are hashed, and the hashes are then paired, hashed, paired again, and hashed again until a single hash remains – the Merkle root of a Merkle tree. The Merkle root is stored in the block header. Each block also stores the hash of the previous block's header, chaining the blocks together. This ensures that a transaction cannot be modified without modifying the block that records it, and all of the following blocks. The definition of a Merkle is that it is the root node of a Merkle tree, a descendant of all the hashed pairs in the tree. Block headers must include a valid Merkle root descended from all transactions in that block. (Anonymous, Bitcoin.org, 2017).

Figure 2 on the next page associates the Bitcoin financial blockchain concept with a health care blockchain concept.

Figure 3 on the next page presents some high-level concepts showing what health care data could be included in a blockchain's transaction, and how other data associated with a blockchain transaction would be stored off-chain. The concept of on-chain vs off-chain transactions will be an important concept as agreements on health care blockchain transactions become a negotiated national standard.

Health care blockchain development will continue to benefit from rapid, technical advances in the blockchain financial applications realm. For example, in March 2017, IBM announced the first enterprise-ready blockchain service based on Hyperledger Fabric, version 1.0. IBM touts Hyperledger Fabric as "the leading open-source, general-purpose blockchain fabric built for enterprises." IBM contributed much of the code to the early stages of Hyperledger Fabric and has

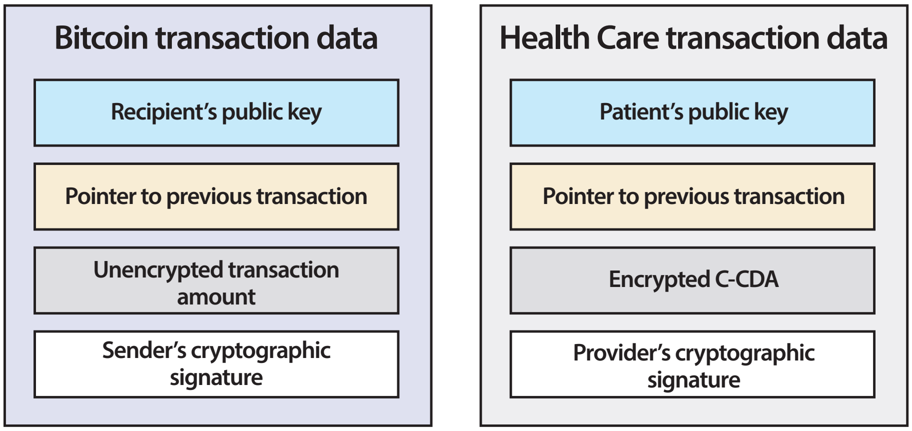


*Figure 2. Comparison of Financial to Health Care Blockchain (Ivan, 2016, figure 3)*

| | On-Chain data | Off-Chain data |
|---|---|---|
| **Data types** | • Standardized data fields containing summary information in text form (e.g. age, gender) | • Expansive medical details (e.g. notes) and abstract data types (e.g. MRI images, human genome) |
| **Pros** | • Data is immediately visible and ingestible to all connected organizations, making blockchain the single source of truth | • Storage of any format and size of data |
| **Cons** | • Constrained in the type and size of data that can be stored | • Data is not immediately visible or ingestible, requiring access to each health care organization's source system for each record<br>• Requires Off-Chain micro-services and additional integration layers<br>• Potential for information decay on the blockchain |

*Figure 3. Pros/Cons On-Chain vs. Off-Chain Data. (Housman, D., White, M., Filipova, M., Quarre, F., Barr, D., Nesbitt, A., Fedesova, A., Killmeyer, J., Israel, A., Tsai, L., 2016, p. 6)*

developed tools to make blockchain development and governance easier (Groenfeldt, 2017). This open source product continues to advance security and cloud functionality for blockchain.

## Potential Blockchain Uses in Health Care Applications

Now that we've defined blockchain and summarized its technical dimensions, let's review its potential applicability in five areas of health care that industry leaders indicate as most promising.

### 1. Longitudinal health care records – using blockchain to securely link across various health care provider organizations and, over time, a patient's health care records.

How might blockchain be used longitudinally across health care records? For example, Weiss (2015) provides a futuristic health care blockchain-enabled scenario in which patient "Jane" has an acute episode and is attended to by an emergency medical technician (EMT) who swipes Jane's interactive wristband (also an example of an Internet of Things (IoT) scenario) to get her health care blockchain ID number (via a blockchain account supported by security). The details of this encounter are then broadcast ahead to Jane's primary care physician and hospital, who use blockchain encryption key security to obtain messaging and access to her now-updated blockchain health care account with all of the encounter details recorded by the EMT. This kind of futuristic vision for the use of blockchain is also driving considerable research and programming of proof-of-concepts sponsorship by the ONC to build a foundation for implementing blockchain-enabled health care technologies.

2. **Automated health claims adjudication – using blockchain to support enabling concepts such as "disintermediation and trustless exchange" using a "smart contract" structure.**

A smart contract structure enables a node to execute a transaction for the contract. This logic ensures correct completion of claims and supports compliance audits using business rules (Miliard, 2017). Culver (2016) presented a solution using a blockchain smart contract concept integrated with Health Level Seven International's Fast Healthcare Interoperability Resources (FHIR) standard, and the use of APIs to provide near-real-time claim adjudication. FHIR functionality and APIs would store information about the claim adjudication as a reference URL associated with the

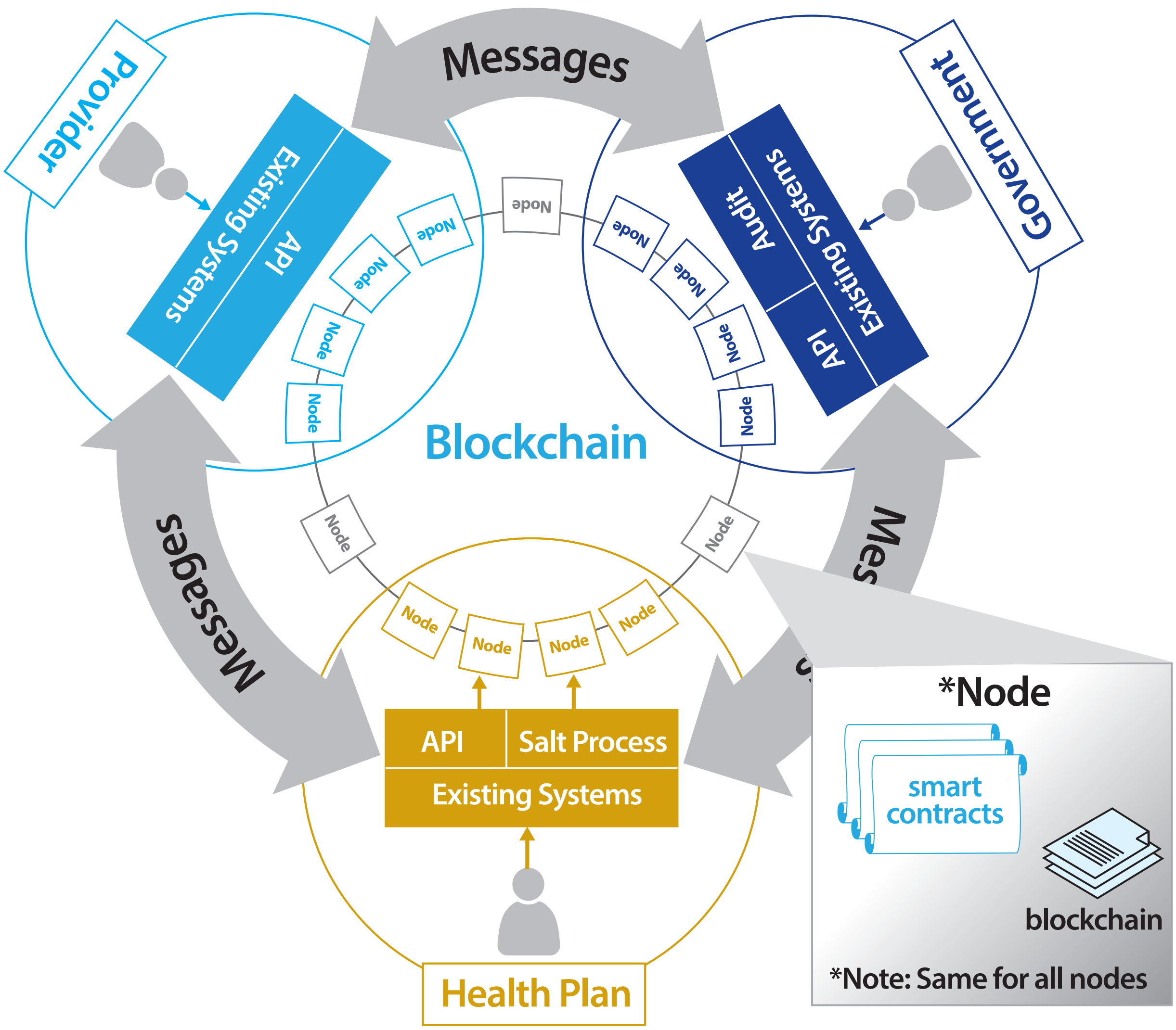


*Figure 4. Smart Contracts Consortium Architecture Concept (Culver, 2016, p.5)*

applicable block in the blockchain. APIs also control messaging among blockchain constituents that notify them of action taken or of steps they need to take to complete the claim adjudication. For example, the blockchain claims adjudication process enables payers to send remittances to providers, and could also have extensions that allows patients to process payments to providers using their bank or health savings accounts. Figure 4 on the previous page shows a conceptual architecture.

Culver recommends a consortium among the government, providers and payers that supports smart contract processing. A consortium limits access to the health care smart contracts blockchain to better manage security and access to these contracts, and also serves as a forum to discuss and reach agreement on standardization topics. Figure 5 below presents security concepts in support of a conceptual blockchain architecture.

### 3. Interoperability – using blockchain to facilitate the gathering of massive amounts of patient data to aid population health initiatives.

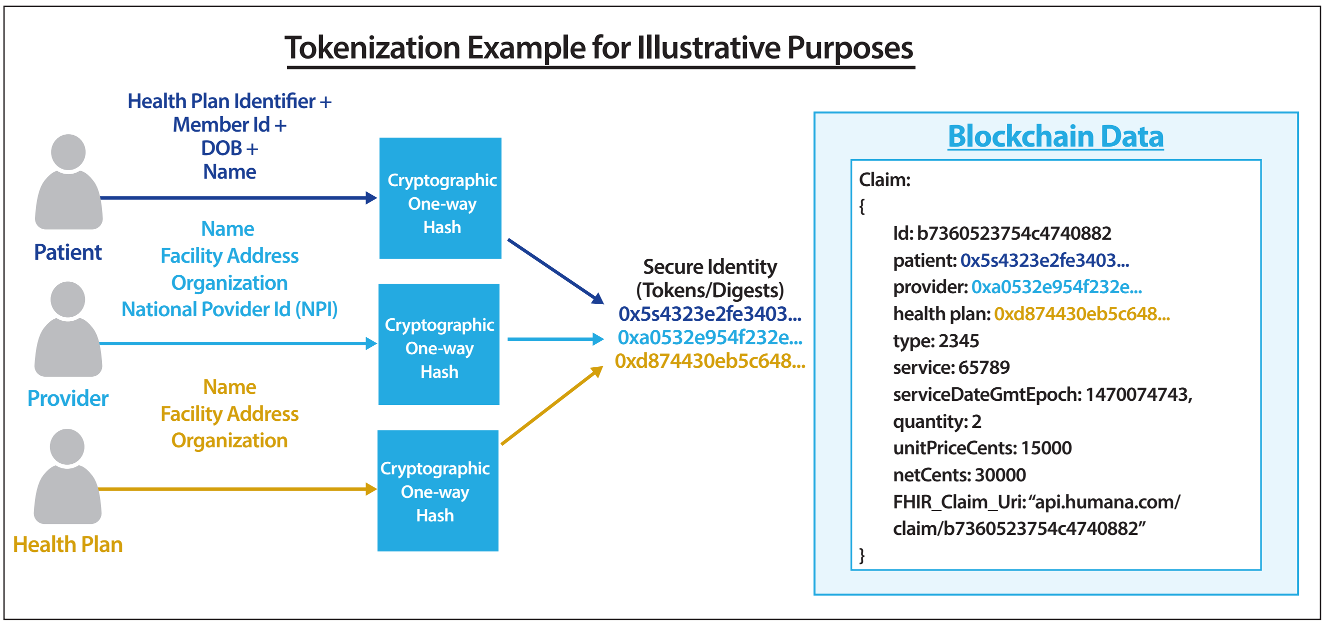


*Figure 5 Blockchain Cryptographic / Hash Security Concept (Culver, 2016, p.6)*

Broderson et al of Accenture (2016) presented the ONC with a white paper that discussed how blockchain technology could assist patient health care data interoperability. Broderson asserted that blockchain has the potential to address several current interoperability technology challenges: "The blockchain methodology addresses many of the issues with current health IT paradigms that involve security (specifically data integrity) and privacy, immutably assuring expressed identities, creating highly robust audit trails and improving healthcare-related security for both providers and patients (Broderson, et al., p.1)."

It would appear that blockchain architecture can fully support HIPAA's Protected Health Information (PHI) federal laws and regulations surrounding health care patient data, based on the ONC's avid interest in blockchain's cryptographic hash technology. This capability, in conjunction with the immutability concept of a distributed transactional ledger, promise architectural capabilities that would overcome current impediments to interoperable patient health care data among interested health care providers, payers and patients.

In addition to the technical capabilities of the blockchain architectures, there remains additional technical challenges, such as performance under high transactional volumes, the negotiation of on-chain and off-chain data that will require a consortium of technical and health care experts to define emergent blockchain health care standards, and a manageable developmental roadmap for a health care blockchain framework.

### 4. Online patient access – using blockchain to allow patients to securely access their longitudinal health care records.

Blockchain technology can allow patients to access their longitudinal care records by providing them with a security key that matches their provider's security key. (Broderson et al., 2016, p. 2). Broderson addressed three blockchain capabilities that make blockchain a potentially useful technology tool for health care data interoperability: 1) creating secure and trusted health record data; 2) linking identities while preserving anonymity of patient encounter and other transactional data; and 3) recording patient consent. Broderson noted that detailed patient information is maintained "off chain" using encryption key technology to access the original data stored off-chain in a provider source. Blockchain's distributed ledger architecture, made up of discrete, immutable transactions, preserves the necessary details and provenance to be able to reference and link in off-chain sources.

Broeder (2016) points out several problems with blockchain that will need to be resolved for health care applications, such as online patient access. For starters, blockchain, once it begins to be implemented, will be perceived by those in health care as yet another tool to help achieve health care data interoperability. As a result, blockchain will need to demonstrate it can address several potential challenges to emerge from as-yet undefined regulatory and legal requirements. These may include regulations and requirements guiding updating and removing data from the blockchain and overcoming node computing and processing resource and security failures (such as those that Bitcoin has suffered).

Another blockchain interoperability perspective was offered by Eckblaw (2016) in his white paper about a proposed "MedRec" concept, which is a blockchain-enabled patient medical record. For example, the MedRec approach enables the sharing of medical records directly with a patient, using blockchain technology. MedRec addresses four major issues: fragmented, slow access to medical data; system interoperability; patient agency; and improved data

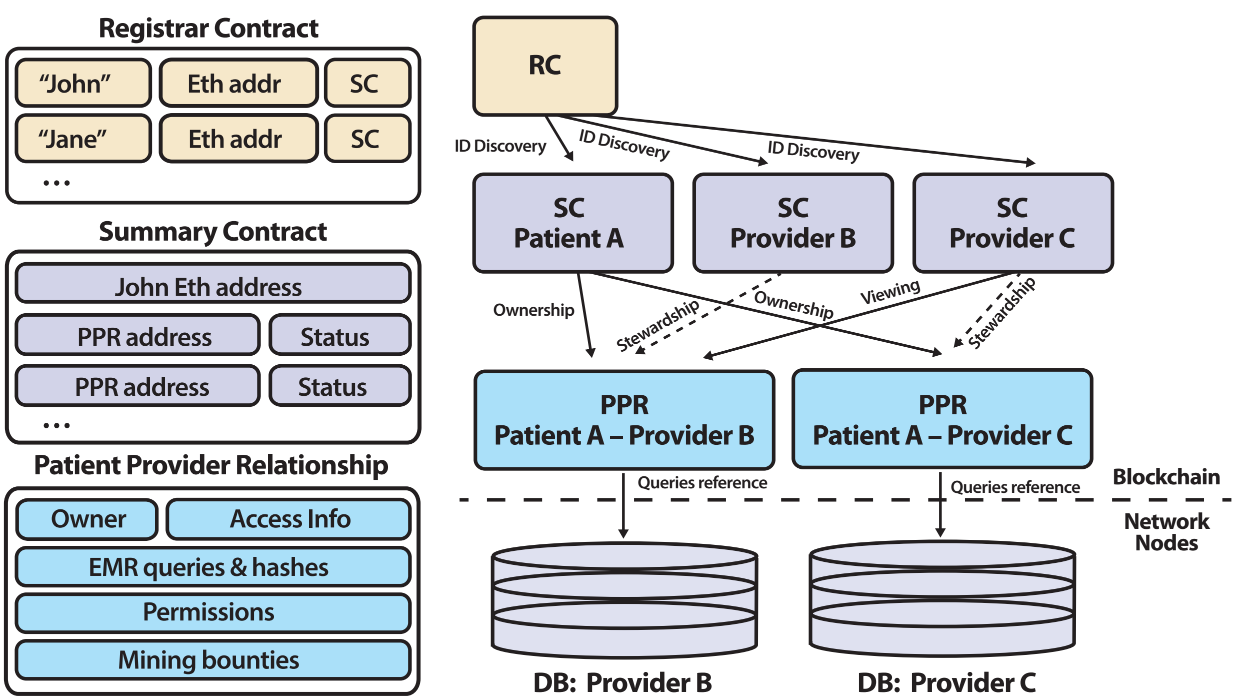


*Figure 6. MedRec's Smart Contracts Architecture (Eckblaw, Azaria, Hamalka, & Lippman, 2016) MedRec smart contracts on the left, showing data content for each contract type. Sample relationship graph between contracts and network nodes on the right.*

quality and quantity for medical research (Eckblaw, et al., 2016, p.2). Blockchain nodes are able to integrate with EHR structures to mask patient data for medical research. MedRec also uses the blockchain smart contracts functionality to support blockchain member registration, patient-provider relationship authentication and a summary contract that provides blockchain transactional "bread crumbs" to find medical record information of interest.

Another interesting MedRec component is its blockchain node technology, which is configured to integrate with the EHR. It adds these components to the blockchain node: Backend Library, Ethereum Client (a developer command line interface for creating code), Database Gatekeeper (a tool to manage interfaces into databases) and EHR Manager (a tool to support interface activity with the electronic health record). These can be executed on servers, combining to create a coherent, distributed system. MedRec provides a prototype implementation of these components that integrates with an SQLite database and is managed through a MedRec user interface (Eckblaw, 2016). MedRec in Figure 6 above offers a more tangible instantiation of a health care blockchain architecture. The following Figure 7 shares a closer look at the node component's design.

This concept of interoperable, blockchain enabled data is shared by other researchers. The provider, payer and the patient could add information to the health care episodes that would comprise the extended health care record. Ivan (2016) sees a future-state option wherein the EHR has an integrated blockchain PHR capability that enables multiple providers and the patient to develop a longitudinal health care record comprised of any number of health care episodes, regardless of health care setting, over time. This is depicted in Figure 8, on the next page, in Ivan's conceptualization of an integrated and interactive blockchain capability.

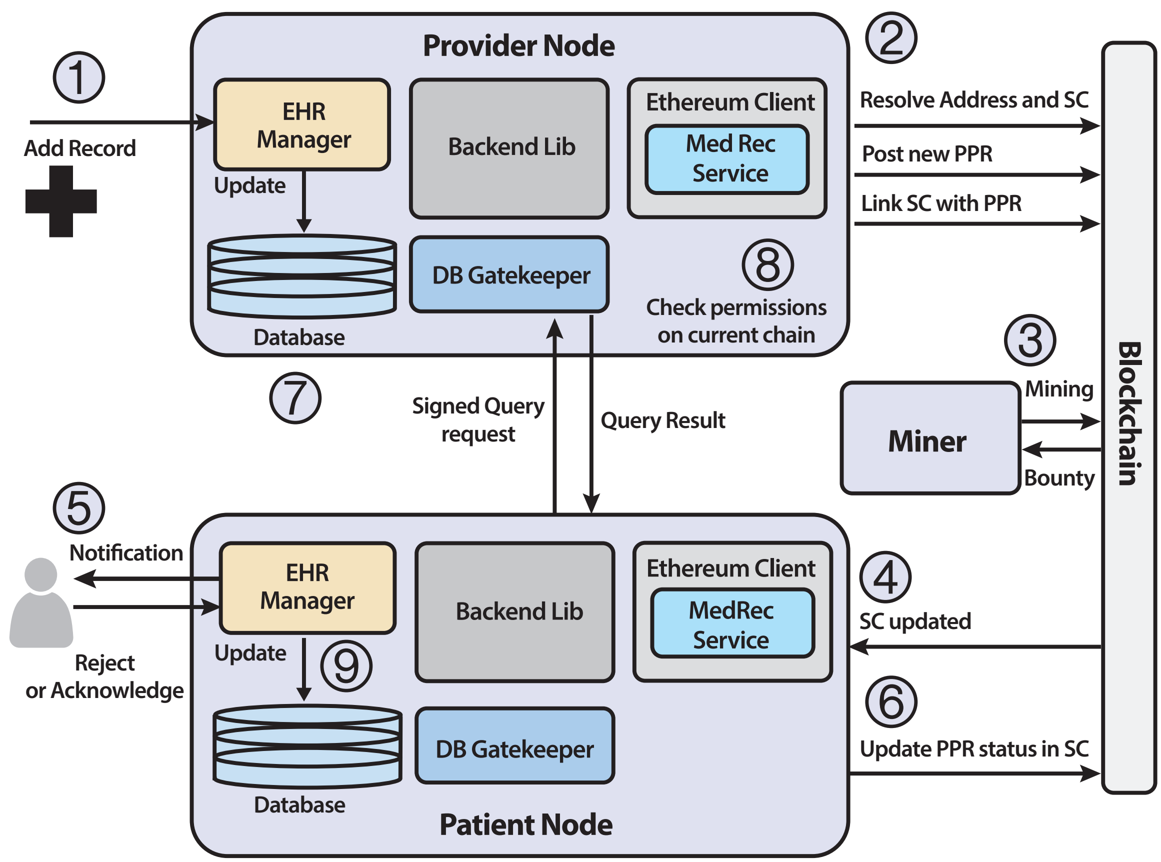


*Figure 7. MedRec's Custom Blockchain Node Design (Eckblaw, Azaria, Hamalka, & Lippman, 2016)*

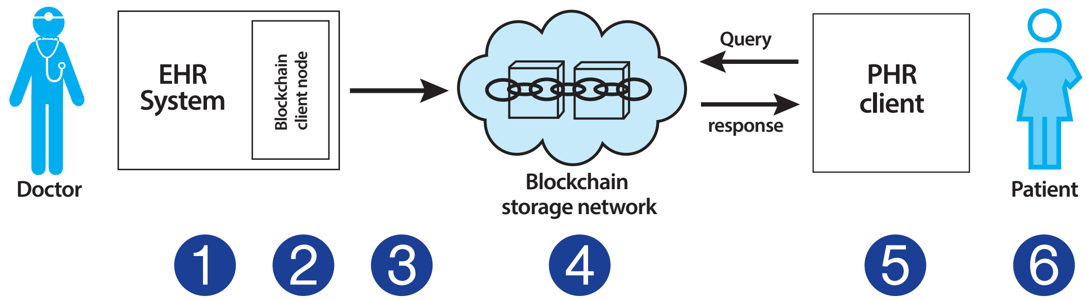


*Figure 4. Architecture and data flow for the EHR with built-in blockchain client (option 1).*

1. *Upon completing an encounter, the EHR saves data locally, prepares a C-CDA version of the encounter data, and transfers it to the built-in blockchain client.*
2. *The built-in blockchain client encrypts the document using the patient's public key and connects to the blockchain to transmit the document.*
3. *The C-CDA document, along with metadata about the document's source and subject, is commited as a transaction to the blockchain. The nodes of the blockchain network use a consensus algorithm to determine the transaction's validity, and when a quorum of nodes agrees to the change, it is permanently committed to the public ledger.*
4. *The blockchain stores all documents for all patients.*
5. *The PHR client is able to connect to the blockchain and download all documents for the patient. The documents are decrypted using the patient's private key.*
6. *The patient is able to view the documents and share them with other providers.*

*Figure 8. Integrated EHR Blockchain Capability (Ivan, 2016, figure 4)*

## 5. Supply chain management – using blockchain to benefit contract administration and significantly reduce contract costs.

Blockchain technology may innovate health care contract management by providing real-time contract tracking, execution and ability for users to determine the satisfactory completion of contracts (Culver, 2016). Williams (2015) described a futuristic scenario in which blockchain-enabled technologies automate supplier contract fulfillment and also provide the consumer with information about the ingredients, quality and source of drugs being purchased by a provider. This additional information could be made available at the point of care if a provider or pharmacist wanted to know such details. As a futuristic application in health care, automated supplier contracts and applied analytics pertaining to a wide range of digitized metadata about goods and services could ramp up productivity and promote quality control over supply chain activities and outcomes. The implications are that increased productivity contributes to reduced costs in health care supply chain management, and improvements in quality control contribute to overall patient care quality.

Williams (2015) points out that a blockchain-enabled supply chain can assign an identity to people, to organizations, and even to goods in order to transparently track the sources of goods as they pass from one organization to the next, and manages exchanges and payments between sellers and buyers. The concept of trustless "smart contracts" (with no third-party intermediaries) saves money and reduces failure points. Smart contracts don't require a third party to ratify the completion of contract performance. A smart contract blockchain service has the potential to reduce contract administration overhead costs by eliminating third party and human error. It may also enhance buyer-supplier relationships.

## Blockchain Implementation Considerations

Krawiec, et al. (2016) of Deloitte published a decision-making framework that could be applied to emerging blockchain use cases. This may be helpful in correlation with the arrival of blockchain-enabled health care products on the market. Taking into account ONC sponsorship, and research and development by a number of private vendors, such as Philips and smaller developers, we may begin to see blockchain-related products starting to emerge in late 2017. Figure 9 presents Deloitte's decision framework. Note that the framework provides a blockchain usage criteria, and also two key blockchain security models in its implementation phase.

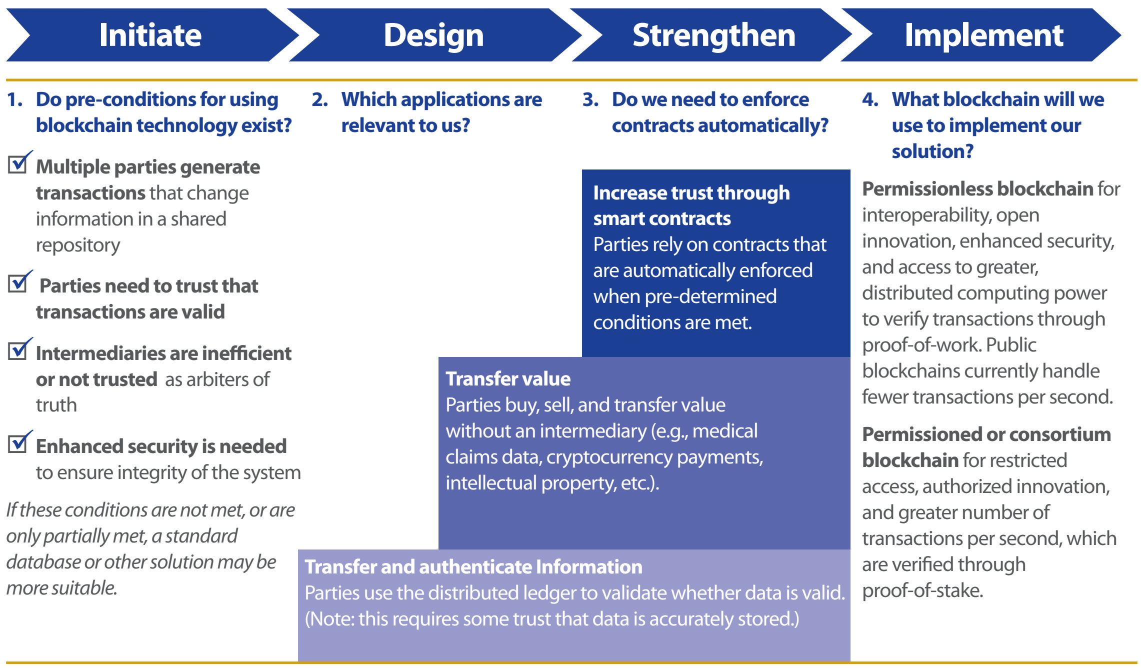


*Figure 9. Example of a Blockchain Technology Decision Framework (Krawiec, R., Housman, D., White, M., Filipova, M., Quarre, F., Barr, D., Nesbitt, A., Fedesova, A., Killmeyer, J., Israel, A., Tsai, L., 2016, p. 2)*

Krawiec (2016, pp. 9-10) provides a conceptual health care blockchain ecosystem and delineates some national-level steps toward a future implementation of blockchain wherein the ONC could play a coordinating role and could perhaps also provide incentives for participation:

- **Map and convene the ecosystem.** The ONC and HHS could play a coordinating role for blockchain health care implementations.
- **Establish a consortium to experiment.** HHS could play a role in convening participants in a blockchain consortium to guide and support initial implementations.
- **Design and execute experiments.** These are proof-of-concept implementations of blockchain technology for specific use cases that ideally include multiple parties and address the full lifecycle of transaction sets.
- **Consider the investment.** Krawiec suggests starting investment in short-term projects; he however notes the potential of up to $20 billion in potential savings to the health care industry over the long-term.
- **Establish suggested guidelines for blockchain.** The ONC has the opportunity to set standards for block transactions so that there is a common, national standard that can support a growing number of participants, thus driving up the value for blockchain as an enabling technology.

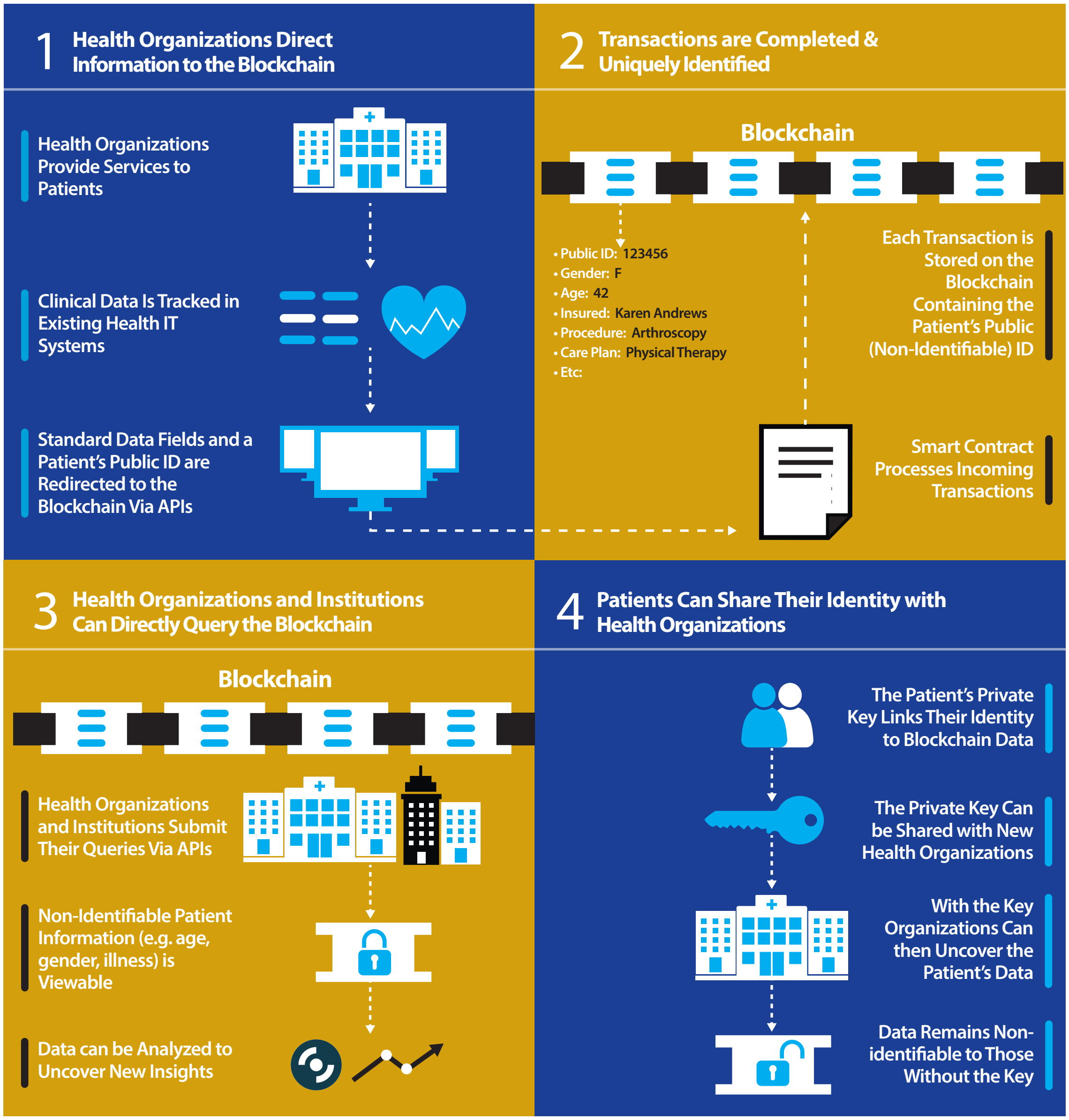


*Figure 10. A Conceptual Blockchain Health Care Ecosystem (Krawiec, R., Housman, D., White, M., Filipova, M., Quarre, F., Barr, D., Nesbitt, A., Fedesova, A., Killmeyer, J., Israel, A., Tsai, L., 2016, p. 4)*

## Conclusion

This white paper presents several promising use cases for applying blockchain technology in health care, especially related to interoperability, claims adjudication, supply chain and longitudinal patient care records. The most important takeaway to keep in mind is that blockchain, while progressing quickly, is still very much an emerging technology.

However, if support for blockchain from the ONC continues, we may see national or regional ONC-sponsored experimental implementations that may soon lead to meaningful advances in new solutions that lower overall health care costs and contribute toward improved patient participation, and even contributions toward health care research. Given the speed of advancement in blockchain technology, health care professionals would be wise to closely track new blockchain-related health care applications.

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