CHAMBER OF DIGITAL COMMERCE

Blockchain Healthcare & Policy Synopsis

AN EXECUTIVE REPORT OF THE

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES &

NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY'S

BLOCKCHAIN CHALLENGE

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PART I: BLOCKCHAIN CHALLENGE HEALTHCARE & RESEARCH WORKSHOP

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Blockchain in Healthcare and Research Workshop

Overview:

On Monday and Tuesday September 26-27, 2016, the Office of the National Coordinator for Health Information Technology (ONC) and the National Institute of Standards and Technology (NIST) sponsored the Blockchain in Healthcare and Research Workshop. There were presentations about the technical side of blockchain as well presentations about the potential uses of blockchain technology in the health sector by government officials, industry experts, and authors of the submitted white papers.

The discussions centered around: (1) introducing blockchain technology and cryptography (2) discussing when blockchain technology is and is not an effective technology to be used in the healthcare sector (3) describing how identity systems and blockchain systems can be integrated together to enable privacy and security for patients, doctors, and industry (4) potential use cases for blockchain in the healthcare sector, and (5) describing the next steps that need to be taken to effectively implement the technology.

Link to Workshop Website:
https://oncprojectracking.healthit.gov/wiki/display/TechLabI/Use+of+Blockchain+in+Healthcare+and+Research+Workshop

Key Takeaways:

1. Healthcare records on the blockchain could be an effective tool for maintaining the security and privacy of patients' records.

2. The participants see the advantages of using blockchain technology in the medical sector, but there is still debate over which type of blockchain technology should be used.

3. There is a focus on using blockchain technology to integrate alternative methods, such as (IoT) devices, to help patients get better care and control over their private medical information.

4. There needs to be interoperability among the separate blockchain systems, requiring common standards, which NIST is currently working to develop.

5. Partnerships between the private and public sectors will be important in order to successfully integrate blockchain technology into the healthcare sector.

Office of the White House Introduction

The Fabric of Trust: Inter weaving Security, Privacy, and Accountability

Tim Polk, The White House, Office of Science and Technology Policy (OSTP)

- Users of technology will circumvent cybersecurity rules if those rules are preventing the users from getting their required tasks done.
- Currently, a federal cybersecurity R&D strategic plan has been requested by Congress. The goal of the plan is to find a way to make cybersecurity less burdensome while maintaining its effectiveness. The technology must be designed, developed, deployed, and operated in a way that deters adversaries from launching malicious attacks against sensitive data, such as electronic medical records (EMRs).
- There are three separate timeframes for the different goals in the plan:
  - 1-3 Years: Effective and efficient risk management of cybersecurity
  - 3-7 Years: Secure development and operation of cybersecurity (i.e. sustainably secure payments)
  - 7-15 Years: Effective and efficient defensive deterrence (having cybersecurity so effective that it is not profitable for the attacker to attack the system)
- We need to encourage the separate regulatory agencies to be more innovative by finding projects where they can integrate new technologies, such as blockchain.

Blockchain Level Setting

Introduction To Blockchains

John Kelsey, National Institute of Standards and Technology (NIST)

- Similar to a chess board, blockchain technology allows us to see and agree on the state of the board. By using blockchain technology, we can agree on the state of the system even if we do not trust each other.
- Blockchain could be an important technology for the medical sector because it is a sequence of hash chained records that cannot be changed (immutable).
- In a permissionless-based blockchain, processing the transactions can be expensive due to the proof of work that is required.
- A permission-based blockchain system may be an alternative, even though it cannot be completely trusted. An alternative to the proof of work based system, for example, could be to have 5 trustees, and allow the majority of those trustees to verify the transaction on the blockchain.
- With a permissions based system, the idea of having to trust the trustees may be challenging, especially when it is normally a bad idea to build crypto protocols that rely on enforcement mechanisms outside the traditional legal system.

NIST Cryptography Standards for Blockchain Applications

Lily Chen, National Institute of Standards and Technology (NIST)

- There are two different types of cryptography: symmetric and public key.
- Symmetric key cryptography is where 2 people share the same private key to both encrypt and decrypt information.
- Public key cryptography is when there are two different keys that are used (1) a public key for encryption and (2) a private key for decryption.
- In Public Key cryptography, when it comes to digital signatures, the private key is used for signing the data and the public key is used for verifying the digital signature.
- There need to be standards developed for both cryptography and digital signatures in order for there to be interoperability among the different blockchains. NIST has already requested input from stakeholders regarding these standards and is working on finalizing them.
- In developing these standards, NIST has the option of adopting the standards already developed by other organizations, or developing completely new standards.
  Cryptography Standards:
  http://nvlpubs.nist.gov/nistpubs/ir/2016/NIST.IR.7977.pdf
  Digital Signatures Standards:
  http://nvlpubs.nist.gov/nistpubs/FIPS/NIST.FIPS.186-4.pdf

Blockchain Reality Check - Alternatives

Evaluating Blockchain and Alternatives

Mance Harmon, Ping Identity

- Hashgraph is a new alternative to blockchain, that allows technology to use algorithms to build community trust. It was designed by Swirlds.
  http://www.swirlds.com/swirlds-emerges-stealth-blockchain-alternative-technology-better-security-fairness-without-wasteful-mining/
- There have been 3 stages of blockchain technology:
  - 2009-2013: Transfer of digital currency
  - 2013-2015: Record ownership
  - 2015 – Present: Smart contracts
- The current stage of evolution is matching parties that want to engage in contracts.
- The technology being developed must prevent the following: changing history, disruptions, and unfairly influencing order.
- The difference between Hashgraph versus blockchain technology is that the order in which the transactions are authenticated cannot be unfairly manipulated with Hashgraph.
- Hasgraph has the potential to allow for millions of transactions per second. There have already been tests in which 200,000 transactions per second were allowed to be authenticated.
- With Hasgraph, the authentication of transactions is done through the technique termed by Swirlds as gossip, where members of the network verify the transactions by voting on their authenticity.

Blockchain Challenges in Real Life

Stephen Wilson, Constellation Research

- The first step of blockchain was allowing the exchange of real value without knowing anything about each other.
- However, the next stage of blockchain is using application programming interfaces (APIs) to allow other types of data to be stored on the blockchain as well.
- One challenge in using blockchain technology for other uses is that it was designed originally for digital assets and not physical assets. In order for the physical assets to be linked to blockchain technology, they will need to be registered off chain.
- When it comes to blockchain technology being used in the healthcare industry, there will be some challenges to confidentiality (permissioned blockchains will be better but since they are built on smaller pools this weakens security), authority (blockchain is trustless but healthcare is hierarchical), and decentralization (there can be decentralization of data but not of authority).
- Blockchain technology can be effective in different markets of the healthcare sector; for example, as it has with the unbanked, blockchain technology can help those without healthcare.

"Fit for Purpose" Distributed Ledger Technology (DLTs)

Drummond Reed, Respect Network

- While there is no one DLT to rule them all, there are many different types of DLT being developed, each of which can each be effective depending on their specific use case (solving specific data sharing program for each specific community).
- Distributed ledger technology (DLT) has three basic components:
    1. Every transaction on the ledger is cryptographically signed.
    2. Every transaction on a ledger is cryptographically chained.
    3. Every transaction on the ledger is cryptographically replicated (via a consensus protocol).
- One DLT system being developed is SOVRIN, which is being developed by Evernym as a DLT system that takes the best characteristics of both permission-based and permissionless DLT systems (trust of public system/security of the permission-based systems).

  http://www.evernym.com/technology/
- SOVRIN has 2 pools: a validator pool (writer) and the observer pool (reader). and is currently in sandbox mode with its code and governance under review.
- As healthcare institutions will not trust a permissonless blockchain system, it will be important for the industry to design a system with characteristics as close as possible to permissionless systems so that its benefits can be integrated into the permission-based systems that are developed.

Blockchain Reality Check-Challenges

DHS Identity Innovations Grants
Many Sporny, Digital Bazaar

- There needs to be global standardization when it comes to identity blockchains because they need to have interoperability.
- Many blockchain technologies are useful when organizations want to share and audit data, but many of those systems are not practical for identity management.
- There needs to be an ecosystem in order to develop common standards for blockchain technology. The Group W3C is currently working on creating these standards and needs healthcare organizations, as well as the industry, to provide input on what the appropriate standards should be.
  https://www.w3.org/community/blockchain/
- When it comes to healthcare, blockchain technology has the potential to do the following:
  1. Real item verification of doctor's license status
  2. Drug delivery supply chain auditability
  3. Insurance claim fraud detection
  4. Continuing education validation
- Digital wallets could be used to store a set of medical records allowing the patient to have their records in digital form, giving them control of who sees their medical information.

IoT Device Identity
Tiana Laurence and Andrew Yashchuk, Factom IRIS

- Factom is developing an identity system that uses blockchain technology by using fingerprints as a measure to verify identity.
- In the system developed by Factom, there are two levels of security: the security of the blockchain and the internal security measures that are taken by Factom.
- The Factom system allows the parties to transmit, store, and receive data securely.

Decentralized Identifiers (DIDs): Solving the Root Identity Problem
Drummond Reed, Respect Network

- DLT is being used for identity in ways that allow for security, scalability, and reliability.
- When it comes to identifiers, there needs to be a consensus on having global identifiers.
- There are two worldviews on identifiers: DIDs (decentralized identifiers) and CIDs (cryptographic identifiers)/ The goal is to bring both worldviews together to develop a unified global standard.
- When using blockchain technology, steps to take for ensuring privacy in regards to identity include:
  1. Allowing multiple DIDs for personal and pseudonym management
  2. Avoid storing private attributes on a public ledger
  3. Use anonymous credentials (zero knowledge proofs) whenever possible
- A concept known as the SOVERIGN button is being developed that would utilize blockchain technology to create one identity for logging into all devices (similar to facebook).

Decentralized Certification Service

Adam Migus, XCELERATE Solutions

- Public blockchains could be used to develop a Decentralized Certification Service (DCS) that would make it possible to verify identity and certifications on multiple healthcare systems. This would allow for pseudo anonymity, minimalism, and consent.

- Through this type of system, individuals could also assert their qualifications to any federal, state or local government that trusts the intermediary without having to provide any additional identity.

- With multiple healthcare systems, synchronizing all the information is problematic. However, if there is one single type of authentication instead of many separate logins, the system may be more efficient.

Blockchain Challenge Presentations

Blockchain: The Chain of Trust and its Potential to Transform Healthcare – IBM's Point of View

Srini Attili and Shahram Ebdollahi, IBM Global Business Service Public Sector

- Centralized information is vulnerable to attacks. Blockchain technology, by combining the internet with different protocols, has the potential to put privacy and control back in the hands of the owner of the data.

- IBM is a part of the Hyperledger Project, which has 4 key elements:
    1. Shared ledger to provide for transparency and a single source of truth
    2. Privacy and security by only providing data access to those that are authorized
    3. Consensus by requiring all parties to agree to the network verified transactions
    4. Smart contracts by embedding the business terms of the transaction in the blockchain and executing those transactions

- In the healthcare system, only 10% of data referred is regarding clinical factors, 30% is genomics, and 60% is exogenous factors or things that happen outside the clinical setting such as nutrition and home monitoring.

- When measuring all of these factors, the data must be digitalized in order to conduct experiments, analyses, and studies. There needs to be an ecosystem that allows for all of the data to be measured in an efficient way.

- Some use cases for blockchain technology in the healthcare sector include: payments, traceability for counterfeit drug prevention, and clinical trial results.

- One other important use of blockchain technology is for the exchange of health data records, which includes: consent management by the data being available for a specified period of time through patient consent, exchanging those health data records, and having an index 360 view of those patients' medical records.

- Regulations in the EU and the US will require unique device identification system to adequately identify medical devices (UDIs) through their distribution and use. Blockchain technology will be an important asset to help the medical sector comply with these new requirements.

- Interoperability and enabling data will be important. One possible standard is the HL7 from the Fast Healthcare Interoperability Resources (FHIR).

Blockchain: Securing a New Health Interoperability Experience

Brian Kalis and Hanif Dharamsi, Accenture, LLP

- By using blockchain technology, there can be faster, more efficient, and highly secure business to business and business to consumer transactions within the healthcare sector.
- In order to have interoperability among the different systems, there need to be core technical standards and functions, and certification to support the adoption and optimization of health IT.
- There is a large number of redundant data in the medical system that is costing billions of dollars in unnecessary costs. Blockchain technology could help rectify by integrating the redundant data into one system.

Blockchain Technologies: A discussion on how the claims process can be improved

Kyle Culver, Humana, Inc.

- Billing and insurance related costs will reach $315 billion by 2018 and there needs to be a solution for better managing these costs.
- Blockchain technology can help the health plan, government, and provider communicate better with one another, along with providing access to smart contracts to assist with mediating insurance claims.
- By combining cryptography and identity technology, blockchain technology can be an effective tool in the healthcare sector. The technology can help reduce costs, drive interoperability among the different healthcare systems, and accelerate innovation.

A Blockchain Profile for Medicaid Applicants and Recipients: Engaging the public in a new infrastructure for health data

Alessandro Voto, Blockchain Futures Lab – Institute for the Future

- Three areas where blockchain technology can be effectively used when it comes to Medicaid applicants and recipients:
    1. Loss of benefits – transitioning from Medicare to private insurance
    2. Reinstatement of benefits
    3. Change of state of residence—connect with government services to determine if you have changed a state
- Some blockchain related technologies that could help Medicaid applicants and recipients include: hierarchical deterministic wallets, zero knowledge proofs, oracle services, and smart contracts.
- A smart health profile could be linked to a pseudonymous profile, in order to protect privacy.
- Zero knowledge proofs can keep encrypted data secret and be used to provide proof of identity without having to disclose private information, such as your social security number. One challenge will be that zero knowledge proofs will only last as long as the encryption technology is effective.
- Regarding oracle services, instead of having humans using algorithms to predict things, competing robots could also be used to determine what is or is not a valid piece of evidence.

ModelChain: Decentralized Privacy-Preserving Healthcare Predictive Modeling Framework on Private Blockchain Networks

Tsung-Ting Kuo, and Lucila Ohno-Machado, Health System Department of Biomedical Informatics,
University of California San Diego

- The sharing of cross institutional healthcare information helps advance research and facilitate quality improvement initiatives. However, with this practice, there is also the risk of improper disclosure of personal health information.
- ModelChain would use blockchain technology for privacy preserving machine learning. This would allow each participating site to contribute to a model parameter estimation (model data) without revealing any patient health information (no observational level data would be shared).
- ModelChain would solve many of the current problems with the existing systems today including: single point of failures for hacking and breaches, records and data being mutable (can be changed), and the problems associated with synchronizing large amounts of existing medical data.
- It is important to build on the existing health IT infrastructure in order to have interoperability within the existing health IT system.

The Use of a Blockchain to Foster the Development and Use of Patient-Reported Outcome Measures (PROMs)

Jason Goldwater, National Quality Forum

- Blockchain technology can help with the development and use of patient reported outcome measures (PROMSs).
- By using PROMs, there can be more focus on the patient's experience of care. The patient would have the ability to include their perspective on the burden and impact of the disease, as well as receive better communication from the provider on available options for treatment.
- In general, developing measures in the healthcare industry is expensive with each measure taking 2-3 years to develop and costing around $500,000.
- The Internet of Things (IoT) linked with blockchain technology could be helpful with PROMs, as over 220 million people have access to IoT devices such as cell phones. These patients could use their IoT devices to track their personal health related data and report that data back to their providers.
- By integrating blockchain technology with the IoT, data can be updated continuously, allowing the patient and provider to measure and adjust care based on the status of the patient, all in real time.
- Instead of cloud storage, the medical sector through blockchain technology can integrate data through application programming interfaces (APIs) in a way that fixes interoperability problems and allows all of the separate data to be integrated together.

"MedRec" Using Blockchain for Medical Data Access and Permission Management
Ariel Ekblaw, MIT Media Lab

- MedRec is a decentralized record management prototype for electronic health records (EHRs) that uses blockchain technology.
- The system provides an immutable log, as well as easy access to medical information across providers and treatment sites.
- MedRec manages authentication, auditability, and data sharing by allowing the application programming interface (API) to integrate with the providers existing databases, allowing for interoperability within the existing healthcare system.

A Blockchain-Based Approach to Health Information Exchange Networks
Kevin Peterson, Mayo Clinic

- The goal of the project is to share healthcare data in a consortium in order for all parties to not only agree on the exchange mechanism, but also agree on the structure and semantics of the data to be exchanged.
- As an alternative to Proof of Work of the permissionless-based blockchain, the Mayo Clinic proposes a proof of work based on structural and semantic interoperability using Fast Healthcare Interoperability Resources (FHIR) profiles.
- The patient data should be stored off chain with the blockchain storing references to the patient data as opposed to actual patient data, ensuring that patient data is not publicly disclosed.

Next Steps for Blockchain Use in the Healthcare Industry

Experts Panel: Discussion of Next Steps and Open Q&A

Jason Goldwater, National Quality Forum
- Progress in the healthcare sector moves slower than many other industries because changes takes longer.
- Blockchain technology should only be applied in areas where it can be useful in the medical sector, such as quality reporting, identity management, and interoperability.
- Identifying management using blockchain technology will be a key future use in the healthcare sector.

Kyle Culver, Humana, Inc.
- The users (general public) must be educated on what blockchain is and how it can help them as patients.
- There need to be appropriate use cases in order to make projections on what blockchain technology can do in the medical sector five years from now.

Greg Shannon, White House House-Office of Science & Technology Policy (OSTP)
- Blockchain technology allows us to put our trust in a technology that can provide security, privacy, and accountability.
- By applying blockchain technology to transactions, the existing process could become more efficient and many existing fees that intermediaries charge could be wiped away in the healthcare sector.

Anthony Trenkle, IBM

- NIST will play a key role in standards, and the ONC will play a key role in defining the use cases and barriers to implementing blockchain technology in the healthcare sector.
- It will be important to have partnerships between both the private and public sectors in order to help the industry develop.
- The stakeholders must look at the underlying technology of the blockchains that are being developed to ensure they will be appropriate for their intended uses.
- As blockchain technology is developed, some of the existing healthcare companies may see it as disruptive and challenge its implementation.

Andy Truscott, Accenture, LLP

- It is essential that blockchain technology only be developed and applied to the uses for which it was invented. There are many uses within the healthcare sector that are inappropriate for blockchain technology.
- The key area where blockchain technology can significantly help the medical sector is with the storing and recording of medical data and clinical records.

PART II: SUMMARY OF TOP 15 BLOCKCHAIN CHALLENGE WHITE PAPERS

DEPARTMENT OF HEALTH AND HUMAN SERVICES DOCUMENT SUBMISSIONS

Overview:

On June 20, 2016, the Office of the National Coordinator for Health Information Technology (ONC) requested submissions of white papers on the "Blockchain and Its Emerging Role in Healthcare and Health-Related Research," in what the ONC called the "Ideation Challenge." The goal of the Challenge was to investigate the relationship between blockchain technology and its use in Health IT and/or Health Related research. The 15 winners of the Ideation Challenge are summarized below.

Announcement of the Blockchain Challenge
https://www.healthit.gov/newsroom/blockchain-challenge

Department of Health and Human Services Submissions Instructions:
https://s3.amazonaws.com/public-inspection.federalregister.gov/2016-16133.pdf

List of ONC Blockchain Winners
http://www.hhs.gov/about/news/2016/08/29/onc-announces-blockchain-challenge-winners.html

1. Blockchain and Health IT: Algorithms, Privacy, and Data [PDF – 507 KB] - PDF

A peer-to-peer network that enables parties to jointly store and analyze data with complete privacy, with the potential to empower precision medicine clinical trials and research.

MIT's Experimental Learning calls for the adoption of the OPAL/ENIGMA program, an encrypted platform that is able to create a stable environment for the storage and analysis of healthcare information to address privacy and security concerns of stakeholders. This proposed program resolves supply chain issues, and the storage and manipulation of health information. MIT's Experimental Learning expressed concerns on how to comply with different state regulations, specifically regarding patient privacy and rules on health information exchange, leading to the development of an interoperable health IT ecosystem. This system preserves health IT infrastructure but also provides an immutable, auditable record of actions for patients and practitioners alike. MIT calls for the support of the ONC because OPAL would be the ideal data repository architecture based on a peer-to-peer network through a permissioned blockchain. The data stored in OPAL is secure but can also be queried to be accessed with credentials through the blockchain. OPAL can also be applied to precision medicine in order to improve trials and executing adaptive platforms to allow data abstraction from electronic health records.

Authors: Ackerman Shrier A, Chang A, Diakun-thibalt N, Forni L, Landa F, Mayo J, van Riezen R, Hardjono, T.
Organization: Project Pharm Orchard of MIT's Experimental Learning "MIT FinTech: Future Commerce."

2. Blockchain: Securing a New Health Interoperability Experience [PDF – 609 KB] - PDF

Blockchain technologies solutions can support many existing healthcare business processes, improve data integrity, and enable at-scale interoperability for information exchange, patient tracking, identity assurance, and validation.

Accenture proposes integrating current health IT investments with a permissioned blockchain/DLT environment in order to drive better patient outcomes. Distributed Ledger Technology (DLT) could solve issues with data integrity, privacy, creating highly robust audit trails, and securing healthcare records. It could also solve issues with identity proofing and recording patient consent. The DLT's ability for non-repudiation and auditability of each healthcare transaction can empower patients. The benefits of using a blockchain identity include enabling complete record integrity and transparency. The integrated nature of the blockchain means that the technology links the disparate identities of authenticated patients to the points of care for both patients and healthcare professionals. This concept envisions the storage of actual patient and provider data "off-chain" with access via a secure hash function stored on the blockchain, satisfying the ONC's desire for regulatory structure. The blockchain in this proposed solution would ensure that each transaction is anonymous.

Authors: Brodersen C, Kalis B, Mitchell E, Pupo E, Triscott A.
Organization: Accenture LLP

3. Blockchain Technologies: A Whitepaper Discussing how Claims Process can be Improved [PDF – 1 MB] - PDF

Smart contracts, Blockchain, and other technologies can be combined into a platform that enables drastic improvements to the claims process and improves the healthcare experience for all stakeholders.

Culver proposes a solution to engineer a platform to leverage both blockchain technologies and Fast Healthcare Interoperability Resources in order to increase efficiencies, enable real time adjudication, decrease fraud, and make agreements between stakeholders transparent. Culver wishes to limit his proposed blockchain to a consortium where smart contracts are developed to support providers and health plan agreements, as well as agreements between patients and health plans. The consortium would consist of three stakeholder groups including the government, the provider, and the health plan. This platform would make each enrollment and disenrollment public, enabling providers and patients to have conversations about out of pocket costs and other complications, which would drastically reduce billing and insurance related costs.

Author: Culver K.
Organization: Unaffiliated

4. Blockchain: Opportunities for Health Care [PDF – 787 KB] - PDF

Presentation of an implementation framework and business case for using Blockchain as part of the health information exchange to satisfy national healthcare objectives.

Deloitte addresses the fact that while blockchain technology might not be the cure for all data standardization issues or system integration challenges, it offers a promising new framework to amplify and support the integration of healthcare information across a range of uses and stakeholders. In order for healthcare organizations to use blockchain, they need to verify a patient's digital identity, genetics data, or prescriptions history. A blockchain transaction layer could additionally enable immediate access to a rich set of non-patient identifiable information. This information can easily be made available to research institutions and existing government initiatives. Deloitte distinguishes the difference between permissionless blockchain and permissioned blockchain. While permissionless blockchain enables broader access to providers and patients alike for open-permissionless innovation, permissioned blockchain expedites a transaction process. Deloitte calls for a network of interconnected computer (i.e. nodes) to supply the computing power necessary to create blocks once transactions have been completed. Deloitte believes the implementation of blockchain technology will reduce complexity, enable trustless collaboration, and secure immutable information.

Authors: Krawiec RJ, Barr D, Killmeyer K, Filipova M, Nesbit A, Israel A, Quarre F, Fedosva K, Tsai L.
Organization: Deloitte Consulting LLP

5. A Case Study for Blockchain in Healthcare: "MedRec" Prototype for Electronic Health Records and Medical Research Data [PDF - 591 KB]. - PDF

A decentralized record management system to handle electronic health records, using Blockchain technology that manages authentication, confidentiality, accountability, and data sharing.

The MIT Media Lab proposed MedRec, a decentralized record management system to organize electronic health records using blockchain technology. MedRec manages authentication, confidentiality, accountability, and data sharing, while prioritizing patient agency. The blockchain content of MedRec represents data ownership and viewership permissions shared by members of a private peer-to-peer network. The platform also offers a designed contract that aggregates references to all of a user's patient provider relationship, thus providing a single point reference. The member's identity is then confirmed via cryptography. Additionally, Ethereum smart contracts would be used to create representations of existing medical records stored within the nodes on the network and would contain metadata regarding record ownership.

Authors: Ekblaw A, Azaria A, Halamka J, Lippman A.
Organizations: MIT Media Lab, Beth Israel Deaconess Medical Center

6. [The Use of a Blockchain to Foster the Development of Patient-Reported Outcome Measures [PDF – 195 KB] - PDF](#)

Use of the Internet of Things (IoT) in combination with Blockchain technology for Patient.

The National Quality Forum discussed how blockchain technology, by using the internet of things (IoT), could help with acquiring Patient Related Outcome Measures (PROMs) or outcomes that are directly related to the patient. PROMs include symptoms and other aspects of health that are related to quality of life indicators, such as physical or social function, treatment adherence, and satisfaction with treatment. One alternative to the use of standardized instruments in collecting data and providing a foundation for the development of a PROM is the use of technologies associated with the Internet of Things (IoT). There is a significant amount of data being generated through IoT devices, including electronic medical records (EMRs), quantified self-tracking devices, smartphone applications, and personal health records (PHRs) that can provide information on a patient's health status. This information could be comingled with social networks, crowdsourced studies, and the Quantified Self community, which collects and shares biophysical assessments. Blockchain technology could then secure this data through a digital "fingerprint" that uniquely identifies the transactions and secures them on the blockchain or distributed ledger. The transactions could include: the current heart rate, blood pressure, current mood, compliance with daily medication protocols, number of calories burned over an hour, number of steps walked, etc.

Reported Outcome Measures (PROMs).
Author: Goldwater JC.
Organization: National Quality Forum

7. [Powering the Physician Patient Relationship with 'HIE of One' Blockchain Health IT [PDF-162 KB]](#) - [PDF](#)

'HIE of One' links patient protected health information (PHI) to Blockchain identities and Blockchain identities to verified credential provider institutions to lower transaction costs and improve security for all participants.

Dr. Adrian Gropper proposes utilizing blockchain technology in a way that will shift decision making and purchasing power regarding electronic health records (EHRs) from the hospitals to the physicians and patients. Blockchain technology can shift control of health IT away from the hospital by making it only accessible to physicians and patients, which will allow the appropriate decision makers to decide what type of healthcare to pursue, or what the paper describes as the "decision support at the point of care." The technology can also be used to independently advise the patient of out-of-pocket costs, alternative sources, and typical risks while the patient and physician are engaged in making those important decisions.

Author: Gropper A.
Organization: Unaffiliated

8. [Blockchain: The Chain of Trust and its Potential to Transform Healthcare – Our Point of View [PDF- 249 KB]- PDF](#)

Potential uses of Blockchain technology in healthcare including a detailed look at healthcare pre-authorization payment infrastructure, counterfeit drug prevention and detection and clinical trial results use cases.

IBM believes that blockchain technology can support a new generation of transactional applications and business processes by establishing trust, accountability, and transparency. IBM is researching and applying blockchain's distributed ledger and decentralized database solutions to the issues of interoperability, security, record universality, as well as in other areas. Some of the challenges that blockchain will be able to solve include: interoperability accessibility and data integrity, privacy and security, healthcare delivery models and cost, fraud and abuse, process and complexity, consumer engagement, procurement and contracting, and governance and compliance. Some of the ways these problems can be addressed through blockchain is smart contracts, encryption and cryptology, and increased efficiency and transparency.

Organization: IBM Global Business Service Public Sector

9. [Moving Toward a Blockchain-based Method for the Secure Storage of Patient Records [PDF – 270 KB] - PDF](#)

Use of Blockchain as a novel approach to secure health data storage, implementation obstacles, and a plan for transitioning incrementally from current technology to a Blockchain solution.

Ivan D. sees the current methods of recording and sharing data as limitations that restrict the patients' access to their clinical records, reduce availability of essential data to care providers, and create barriers to innovation in the US healthcare system. The proposed solution involves using a patient controlled blockchian based system for clinical record maintenance and sharing. The patient's Electronic Health Records (EHRs) would be encrypted, then sent to and stored in the public healthcare blockchain. After the documents are stored, patients would use a web based or mobile application to view their blockchain contents, as well as to grant or revoke access to specific parties.

10. Author: Ivan D.
11. *Organization:* Unaffiliated

10. **ModelChain: Decentralized Privacy-Preserving Health Care Predictive Modeling Framework on Private Blockchain Networks [PDF – 272 KB]** - PDF

ModelChain is a framework used to adapt Blockchain to enable privacy-preserving healthcare predictive modeling and to increase interoperability between institutions.

The University of San Diego Department of Biomedical Informatics, along with the Division of Health Services Research & Development of the VA San Diego Healthcare System, emphasized how important cross institutional healthcare predictive modeling is when it comes to accelerating research, as well as facilitating quality improvement initiatives. However, they note that it also increases the chance of releasing sensitive patient information. The authors found that the current models for sharing medical information are built around centralized architecture, which present security issues as this info is being shared. By using their proposed ModelChain, however, blockchain technology can help develop the concept known as privacy-preserving machine learning. In this scenario, privacy preserving online machine learning algorithms are applied on blockchains. Next, metadata is used in transactions to disseminate partial models and other meta information. Finally, a new proof of information algorithm on top of the original proof-of-work consensus protocol is designed to determine the order of the online machine learning on blockchains to increase efficiency and accuracy. The white paper also discussed how blockchain technology can solve interoperability issues that were noted in the Nationwide Interoperability Roadmap of the ONC.

Authors: Kuo T, Hsu C, Ohno-Machado L.
Organizations: Health System Department of Biomedical Informatics, University of California San Diego, La Jolla, CA Division of Health Services Research & Development, VA San Diego Healthcare System.

11. **Blockchain for Health Data and Its Potential Use in Health IT and Health Care Related Research [PDF – 1.5 MB]** - PDF

A look at Blockchain based access-control manager to health records that advances the industry interoperability challenges expressed in ONC's Shared Nationwide Interoperability

Laure A. Linn and Martha B. Koo discussed how blockchain technology can address many of the interoperability challenges that currently exist in the health IT systems, while providing the technical standards that would allow individuals, healthcare providers, healthcare entities, and medical researchers to securely share electronic health data. The American Recovery and Reinvestment Act required all public and private healthcare providers to adopt electronic medical records (EMRs) by January 1, 2014. The submission proposes a blockchain based control manger to control health records in way that would overcome the existing interoperability challenges made by the Office of the National Coordinator for Health Information Technology (ONC). The suggestion is to use a public blockchain in place of a private blockchain to keep track of the records because it would be vendor neutral and be able to have open standards. However, three challenges of this type of system will need to be addressed including: scalability, access security, and data privacy.

Roadmap.
Authors: Linn L, Koo M.
Organization: Unaffiliated

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12. A Blockchain-Based Approach to Health Information Exchange Networks [PDF-402 KB] - PDF

A Blockchain-based approach to sharing patient data that trades a single centralized source of trust in favor of network consensus and predicates consensus on proof of structural and semantic interoperability.

The Mayo Clinic proposes constructing a new platform that mirrors the Merkle Tree-based structure (or hash tree). The nodes of the tree represent patient record transactions and describe the addition of a resource to the patient record. These transactions on the blockchain would use the HL7 standard from the Fast Healthcare Interoperability Resources (FHIR) via the Uniform Resource Locator (URLs), which would allow institutions to maintain control over their data while maintaining the confidentiality of the provider and the patient. FHIR was chosen as the exchange format not only because it is an emerging standard, but also because it contains support for provenance and audit trails, making it a suitable symbiotic foundation for blockchain ledger entries. This new structure, in conjunction with the usage of the FHIR, can preserve the anonymity of users and the associated context of the data transactions.

Authors: Peterson K, Deedvanu R, Kanjamala P, Boles K.
Organization: Mayo Clinic

13. Adoption of Blockchain to enable the Scalability and Adoption of Accountable Care [PDF-500 KB] - PDF

A new digital healthcare delivery model that uses Blockchain as a foundation to enable peer-to-peer authorization and authentication.

Prakeash R. proposes a new digital healthcare model that uses blockchain technology to enable peer-to-peer authorization and authentication. This new model would result in significant reduction in operational costs and improvements in care delivery. The blockchain can enable providers to actively coordinate and collaborate with other care partners involved such as labs and pharmacies. The keys benefits that result from the adoption of a blockchain based peer-to-peer framework are in the areas of fraud prevention, achieving high quality healthcare, affordable care, and healthcare based on an individual's clinical and socio-environmental factors.

Author: Prakash R.
Organization: Unaffiliated

14. **[A Blockchain Profile for Medicaid Applicants and Recipients [PDF – 190 KB]](#)** - PDF

A solution to the problem churning in the Medicaid program that illustrates how health IT and health research could leverage Blockchain-based innovations and emerging artificial intelligence systems to develop new models of healthcare delivery.

The Institute of the Future proposes a solution to problems within the Medicaid system. The Medicaid system is inefficient. The current system requires its applicants to gather information about their age, citizenship status (including social security number and current residence), family income, and family composition, as well as medical information, such as disabilities. The current system also requires eligibility checks, frequently requiring high administrative costs. The blockchain could integrate this data to allow for a more efficient method of authenticating the participant's eligibility. Three areas where blockchain technology could be effectively used when it comes to Medicaid applicants and recipients are: loss of benefits, reinstatement of benefits, and changes to the state of residence.

Authors: Vian K, Voto A, Haynes-Sanstead K.
Organization: Blockchain Futures Lab - Institute for the Future

15. **[Blockchain & Alternate Payment Models [PDF - 601KB]](#)** - PDF

Blockchain technology has the potential to assist organizations using alternative payment models in developing IT platforms that would help link quality and value.

Yip K. emphasizes that blockchain technology has the potential to assist organizations using alternative payment models in developing IT platforms that would help link quality and value. Unlike traditional IT databases and models, blockchains seek to create a "single source of truth" which can be securely accessed by its members. Blockchain technology has the potential to use claims data, provider information, global patient ID software, and electronic medical systems to provide a robust platform for advancing alternative payment models. Accountable Care Organizations (ACOs) are the most like places to adopt blockchain as they are not hindered by legacy infrastructure and because ACO specific IT platforms have not been fully developed. However, according to the author, payers and health insurance exchanges (HIEs) could still use blockchain in limited applications to increase engagement with their healthcare partners.

Author: Yip K.
Organization: Unaffiliated