Blockchain
Potential in Healthcare

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Presenter

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MHS GENESIS Content and Configuration Co-lead

DHA Health Informatics

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CDR Roger Boodoo, M.D

Roger Boodoo

CDR Roger Boodoo completed his 2-year Clinical Informatics fellowship in June 2018 at the University of Illinois, Chicago. During the fellowship, he developed an interest in blockchain technology's applicability to healthcare. He began to research blockchain protocols and to work on use-cases involving novel incentive models to motivate patients. He spearheaded an Enterprise Imaging (EI) strategy which included evaluating imaging workflows from many departments, engaging stakeholders, and assessing vendor solutions for the storage, retrieval, and display of DICOM and non-DICOM images throughout the enterprise.

Dr. Boodoo has practiced as a Radiologist at the Fort Belvoir Community Hospital and held many leadership positions as a Medical Officer in the US Navy and Marine Corps. CDR Boodoo enlisted in the Navy as an E-1 corpsman and deployed on the USNS Comfort to Haiti, then later served as a USMC Battalion Surgeon including a combat tour in Haditha, Iraq with the 3/1 Infantry Battalion.

Disclosures

- In the context of this presentation, Dr. Roger Boodoo owns non-trivial amounts of cryptocurrencies (Bitcoin, Ethereum).
- The views expressed in this presentation are those of the author and do not necessarily reflect the official policy or position of the Department of Defense, nor the U.S. Government.
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Learning Objectives

At the conclusion of this activity, participants will be able to:

1. Identify the fundamentals of Blockchain and Smart Contracts.

2. Discuss the potential of Blockchain and current use-cases in the Health care setting.

3. Analyze use-cases in their area of specialization for future pilots and projects.

Word Cloud Exercise

■ What is the first thought that comes to mind when you hear the word Blockchain?

Background

HIMSS News

ONC Announces Winners of Blockchain Challenge

September 09, 2016

On Monday, August 29, the Office of the National Coordinator for Health IT (ONC) unveiled fifteen winners from over 70 submissions for the Use of Blockchain in Health IT and Health-related Research Challenge. A Blockchain is a data structure that can be time-stamped and signed using a private key to prevent tampering. Challenge participants addressed ways that Blockchain technology might be used in health and health IT to protect, manage, and exchange electronic health information.

2016 ----------------------------------- 2018

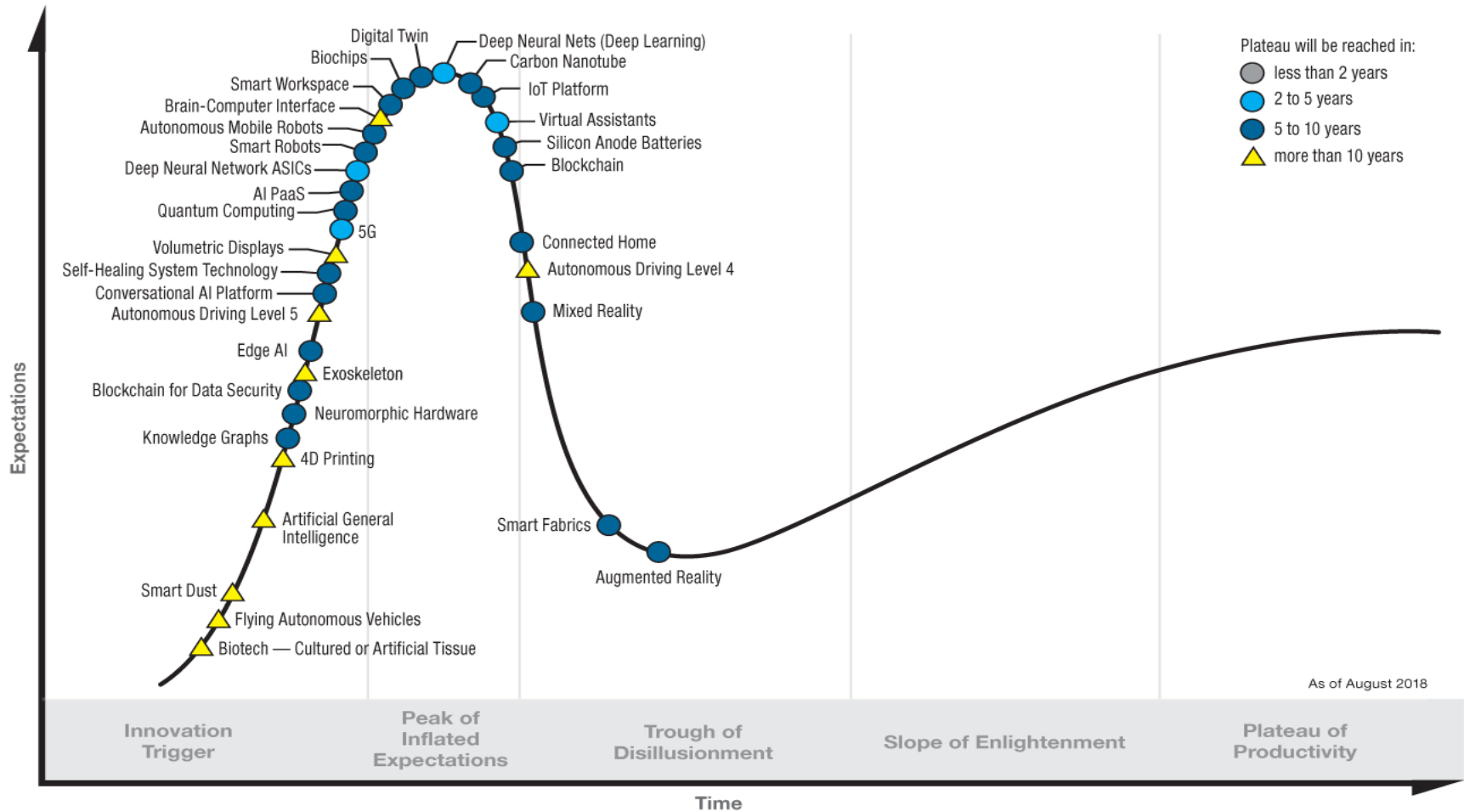Image taken from https://www.himss.org/news/onc-announces-winners-blockchain-challenge

Blockchain Rabbit Hole

Image taken from
https://steemitimages.com/640x0/https://steemitimages.com/DQmWvGngFEQYh5kxiGiP4KqDQtuDbCvyCTRryNfM3sH6cNb/bitcoin-rabbit-hole.png

Hype Cycle for Emerging Technologies, 2018

Expectations

Plateau will be reached in:
- less than 2 years
- 2 to 5 years
- 5 to 10 years
- more than 10 years

Digital Twin
Biochips
Smart Workspace
Brain-Computer Interface
Autonomous Mobile Robots
Smart Robots
Deep Neural Network ASICs
AI PaaS
Quantum Computing
5G
Volumetric Displays
Self-Healing System Technology
Conversational AI Platform
Autonomous Driving Level 5
Edge AI
Blockchain for Data Security
Exoskeleton
Neuromorphic Hardware
Knowledge Graphs
4D Printing
Artificial General Intelligence
Smart Dust
Flying Autonomous Vehicles
Biotech — Cultured or Artificial Tissue

Deep Neural Nets (Deep Learning)
Carbon Nanotube
IoT Platform
Virtual Assistants
Silicon Anode Batteries
Blockchain
Connected Home
Autonomous Driving Level 4
Mixed Reality
Smart Fabrics
Augmented Reality

Innovation Trigger | Peak of Inflated Expectations | Trough of Disillusionment | Slope of Enlightenment | Plateau of Productivity

Time

As of August 2018

gartner.com/SmarterWithGartner

Gartner®

"Medically Ready Force...Ready Medical Force"

9

Introduction

Bitcoin: A Peer-to-Peer Electronic Cash System

Satoshi Nakamoto
satoshin@gmx.com
www.bitcoin.org

Abstract. A purely peer-to-peer version of electronic cash would allow online payments to be sent directly from one party to another without going through a financial institution. Digital signatures provide part of the solution, but the main benefits are lost if a trusted third party is still required to prevent double-spending. We propose a solution to the double-spending problem using a peer-to-peer network. The network timestamps transactions by hashing them into an ongoing chain of hash-based proof-of-work, forming a record that cannot be changed without redoing the proof-of-work. The longest chain not only serves as proof of the sequence of events witnessed, but proof that it came from the largest pool of CPU power. As long as a majority of CPU power is controlled by nodes that are not cooperating to attack the network, they'll generate the longest chain and outpace attackers. The network itself requires minimal structure. Messages are broadcast on a best effort basis, and nodes can leave and rejoin the network at will, accepting the longest proof-of-work chain as proof of what happened while they were gone.

- 31 Oct 2008 published

- Author still unknown

- Genesis block mined on 3 Jan 2009

- Why?

Basics

Image courtesy of https://www.themandarin.com.au/107179-blockchain-in-government-the-possibilites-after-the-hype/

- **<u>Ledger</u>**: Append only, immutable

- **<u>Secure</u>**: Using cryptography, tamper-resistant

- **<u>Shared</u>**: Provides transparency among participants

- **<u>Distributed</u>**: Scalable and more resilient to attacks

Blockchain Main Components

Image courtesy of https://www.themandarin.com.au/107179-blockchain-in-government-the-possibilites-after-the-hype/

- Hash Functions

- Transactions

- Private/Public Keys and addresses

- Ledgers

- Blocks and the Chain

Blockchain Components: Hashing

Image taken from: https://www.npr.org/sections/thesalt/2013/10/11/232106472/what-s-in-that-chicken-nugget-you-really-don-t-want-to-know

Blockchain Components: Transactions

Image courtesy of https://blog.hlongvu.com/post/zokf50gdv0-Understanding-btcd-Part-3-How-to-sign-Bitcoin-transaction
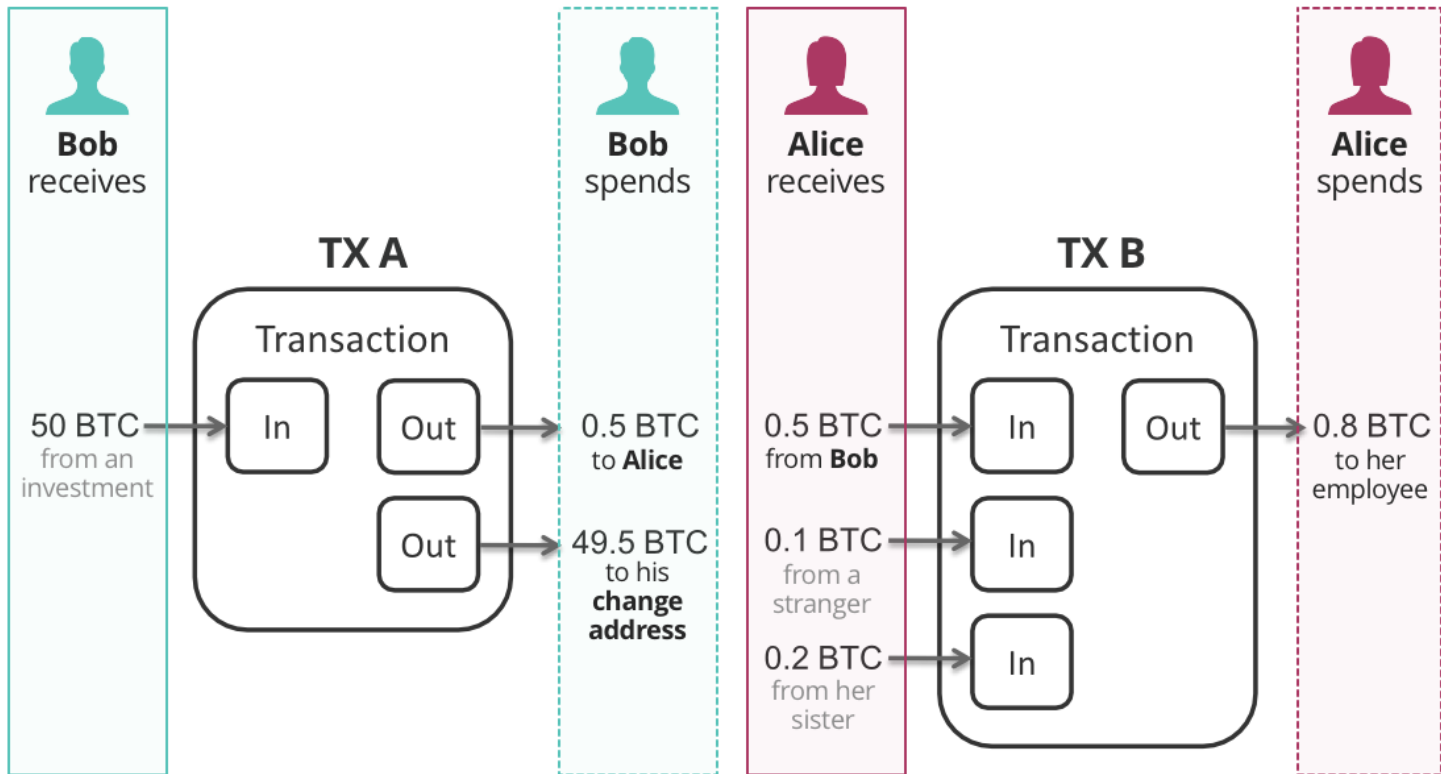
BTC = Bitcoin

Blockchain Components:
Key Cryptography
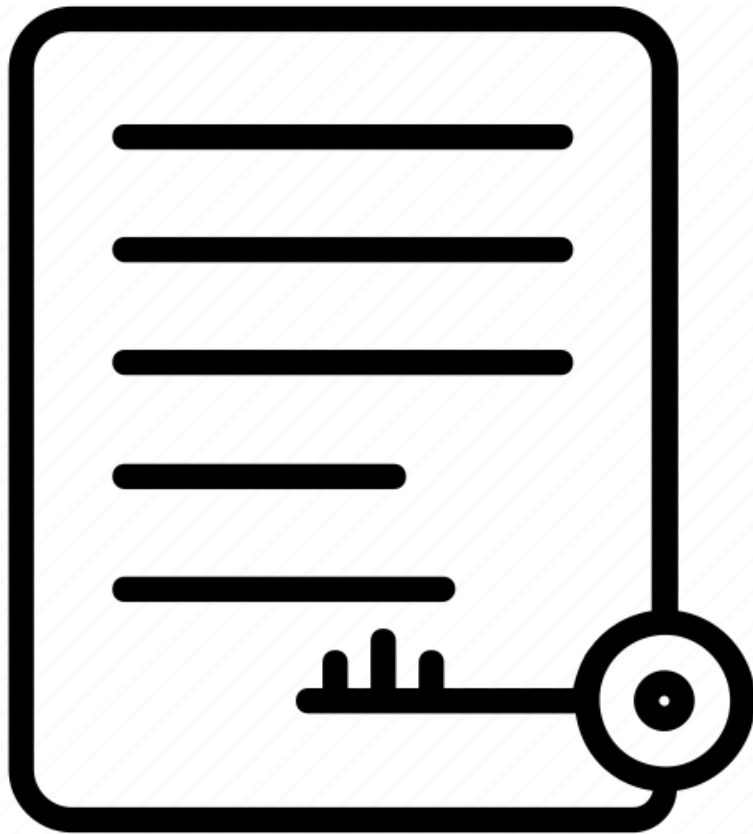
- Public and Private Keys

- Private keys used to sign transactions

- Public keys are public

Blockchain Components: Blocks

Block 0
index: 0
timestamp: 17:15 1/1/2017
data: "block0data"
hash: 0xea34ad...55
previousHash: 0

Block 1
index: 1
timestamp: 17:17 1/1/2017
data: "block1data"
hash: 0xf6e1da2..deb
previousHash: 0xea34ad...55

Block 2
index: 2
timestamp: 17:19 1/1/2017
data: "block2data"
hash: 0x9327eb1b..36a21
previousHash:
0xf6e1da2..deb

Image courtesy of https://www.quora.com/What-is-a-blockchain-then-is-it-a-coding-or-a-default-coding-process

Blockchain Components: Distributed Ledgers

Image courtesy of https://revolutionary-entrepreneur.com/a-gentle-introduction-to-blockchain/
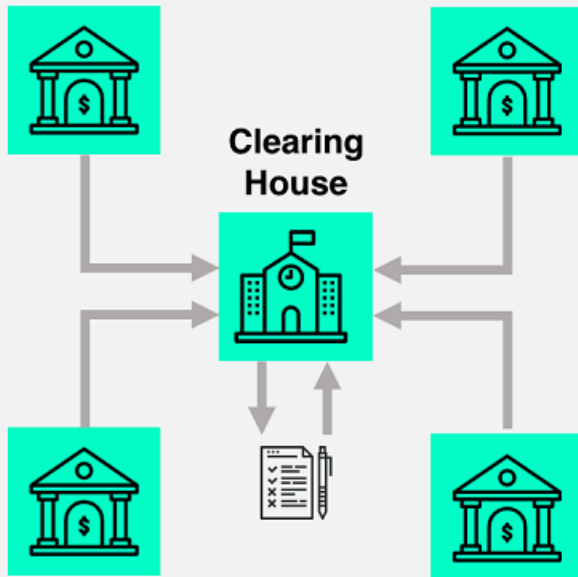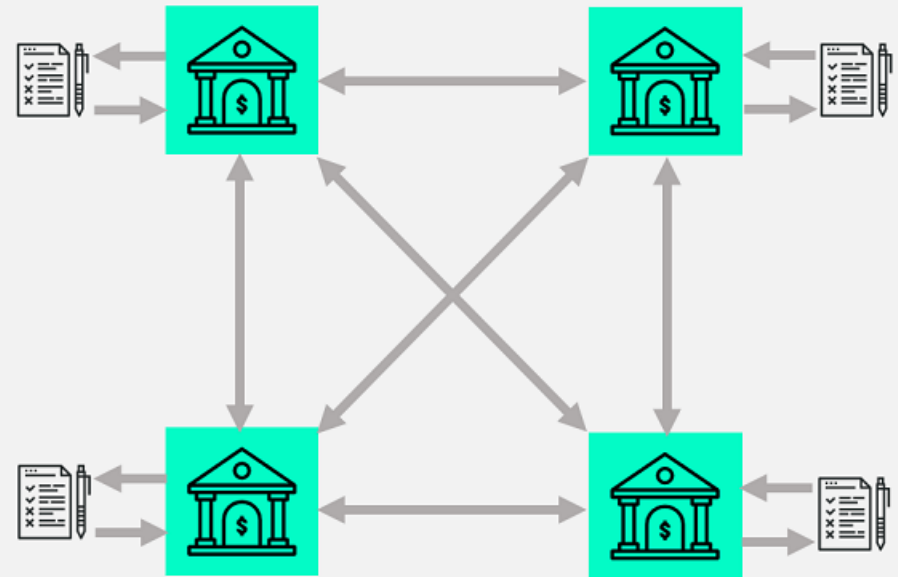
Distributed Ledger Technology

GLOBAL BITCOIN NODES DISTRIBUTION

Reachable nodes as of Sun Aug 18 2019 10:16:27 GMT-0400 (Eastern Daylight Time).

9548 NODES

24-hour charts »

Top 10 countries with their respective number of reachable nodes are as follow.

RANK	COUNTRY	NODES
1	United States	2370 (24.82%)
2	Germany	1931 (20.22%)
3	France	605 (6.34%)
4	Netherlands	501 (5.25%)
5	China	383 (4.01%)
6	Canada	331 (3.47%)
7	Singapore	329 (3.45%)
8	United Kingdom	296 (3.10%)
9	Russian Federation	259 (2.71%)
10	n/a	218 (2.28%)

More (94) »

nodes.earn.com/nodes/?q=Germany
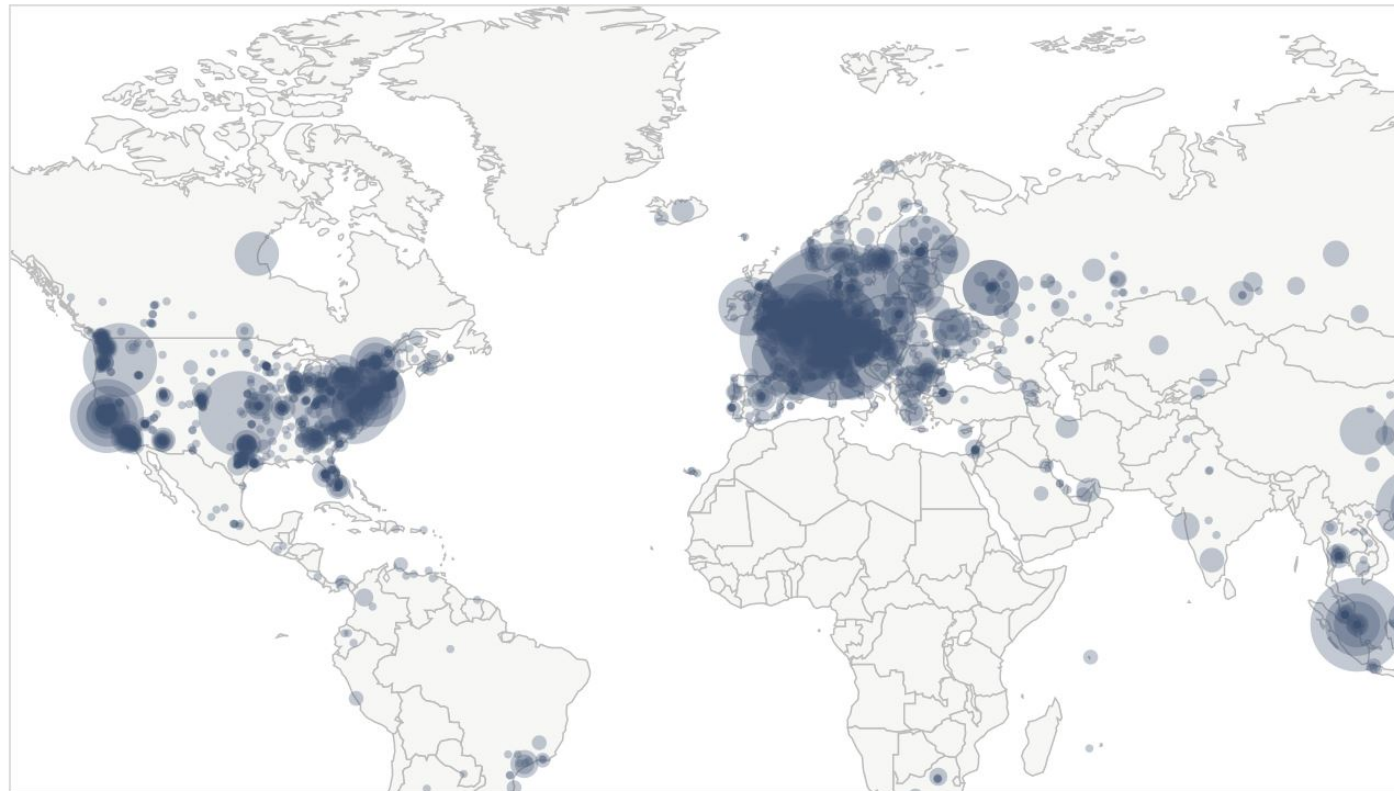
Map shows concentration of reachable Bitcoin nodes found in countries around the world.

LIVE MAP

"Medically Ready Force…Ready Medical Force"

Two Main Types of Blockchains

Permission-less (public)

- Ex: Public Internet

- Open to anyone

- Resource intensive for consensus mechanism

- Native cryptocurrency

Permissioned (private)

- Ex: Corporate Intranet

- Person must be authorized

- Minimal resources needed to operate

- Optional cryptocurrency

Consensus Models

■ Who gets to publish blocks to the network?

■ Genesis Block: Initial state is agreed upon

■ Every block is linked to the previous block

■ Every block can be verified and bad actors are excluded

■ NO NEED TO HAVE A TRUSTED THRID PARTY

Consensus Models: Proof of Work

■ Proof of Work

- ▪ To publish a block have to solve a computationally intensive puzzle

- ▪ Solving the puzzle is difficult

- ▪ Checking the solution is easy

■ Many Consensus Models
- ▪ Proof of Stake, Round Robin, Proof of Authority, Elapsed Time

Image taken from https://cointelegraph.com/news/top-five-biggest-crypto-mining-areas-which-farms-are-pushing-forward-the-new-gold-rush
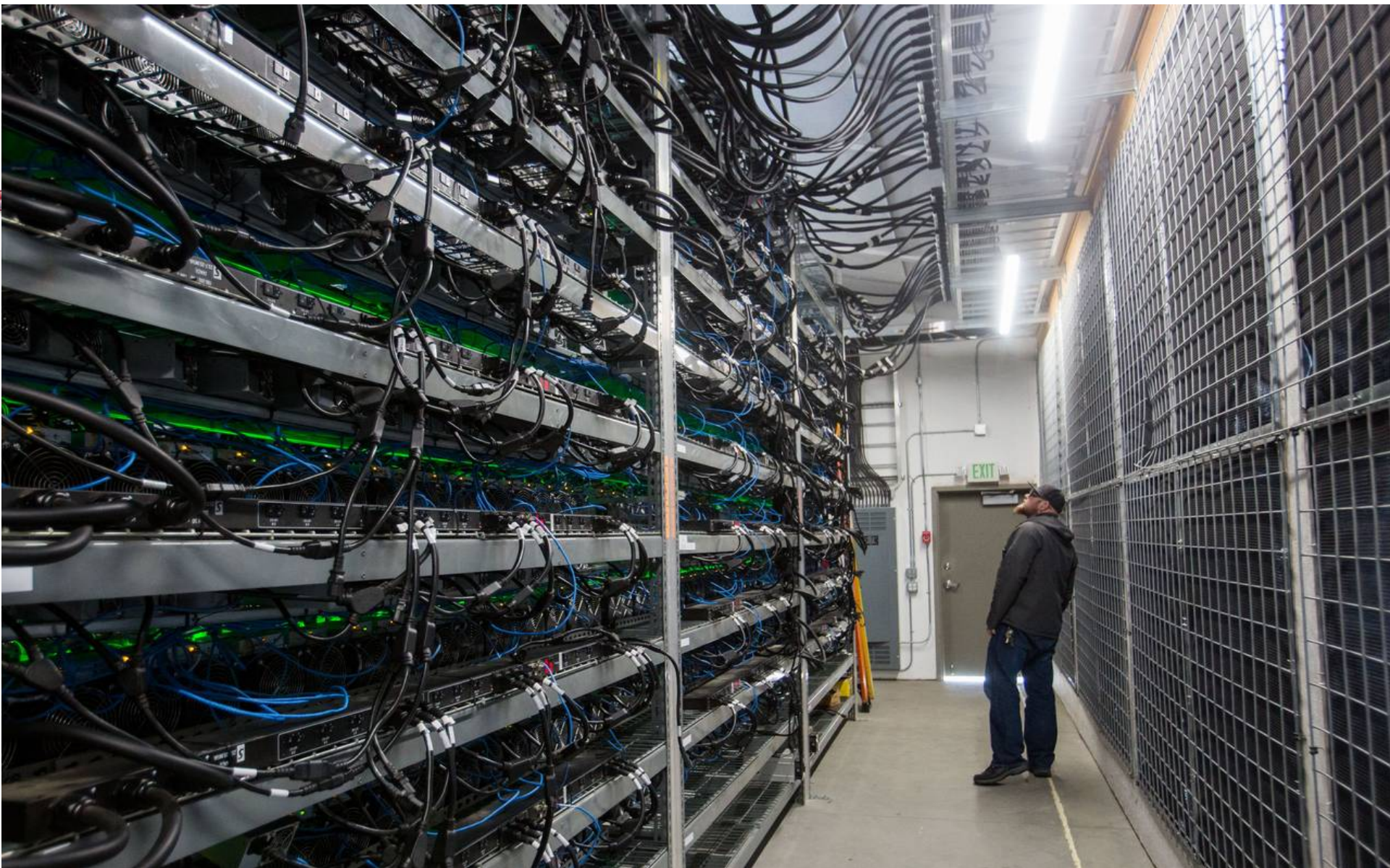
"Medically Ready Force...Ready Medical Force"

BLOCKCHAIN 2.0: ETHEREUM (7/2015)

Image taken from https://observer.com/2018/02/ethereum-founder-vitalik-buterin-cryptocurrency-could-drop-near-zero-anytime/
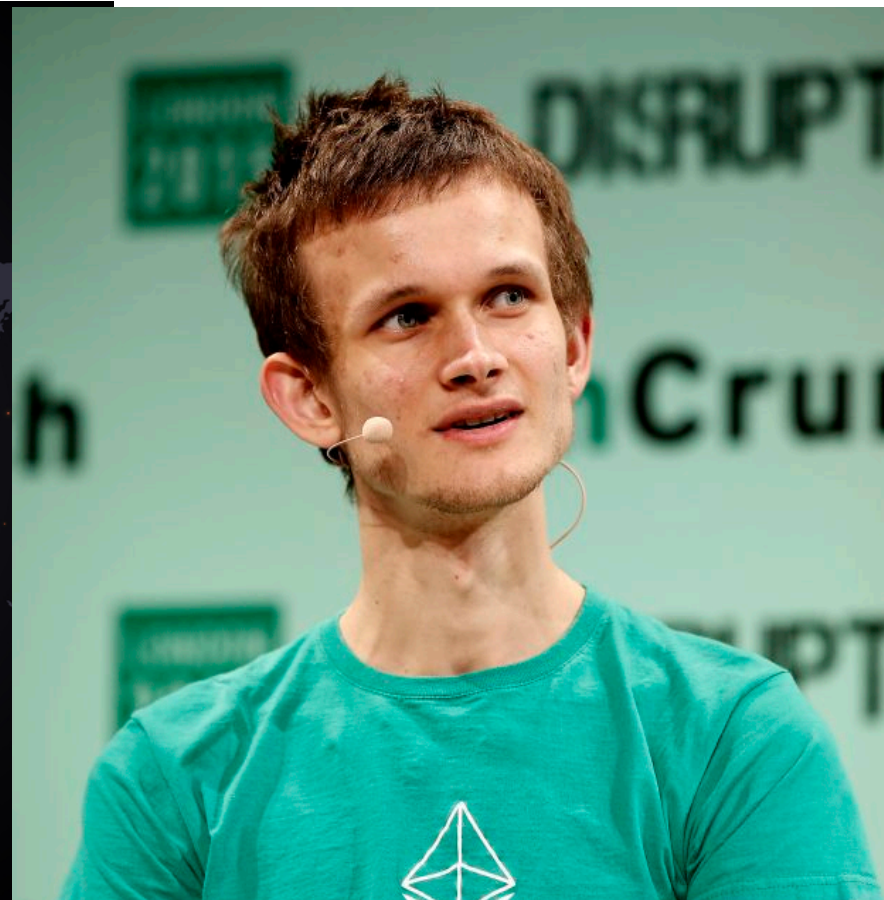
"Medically Ready Force...Ready Medical Force"

Ethereum

Ethereum White Paper
A NEXT GENERATION SMART CONTRACT & DECENTRALIZED APPLICATION PLATFORM
By Vitalik Buterin

When Satoshi Nakamoto first set the Bitcoin blockchain into motion in January 2009, he was simultaneously introducing two radical and untested concepts. The first is the "bitcoin", a decentralized peer-to-peer online currency that maintains a value without any backing, intrinsic value or central issuer. So far, the "bitcoin" as a currency unit has taken up the bulk of the public attention, both in terms of the political aspects of a currency without a central bank and its extreme upward and downward volatility in price. However, there is also another, equally important, part to Satoshi's grand experiment: the concept of a proof of work-based blockchain to allow for public agreement on the order of transactions. Bitcoin as an application can be described as a first-to-file system: if one entity has 50 BTC, and simultaneously sends the same 50 BTC to A and to B, only the transaction that gets confirmed first will process. There is no intrinsic way of determining from two transactions which came earlier, and for decades this stymied the development of decentralized digital currency. Satoshi's blockchain was the first credible decentralized solution. And now, attention is rapidly starting to shift toward this second part of Bitcoin's technology, and how the blockchain concept can be used for more than just money.

■ Native cryptocurrency (Ether)

■ General purpose

■ Smart Contract platform

■ Run decentralized Apps

■ Ethereum Virtual Machine

Smart Contracts

Image retrieved from https://steemit.com/blockchain/@jaichai/ijch-ethereum-s-new-smart-contract-language-or-how-to-ward-off-an-exodus-and-attract-more-developers
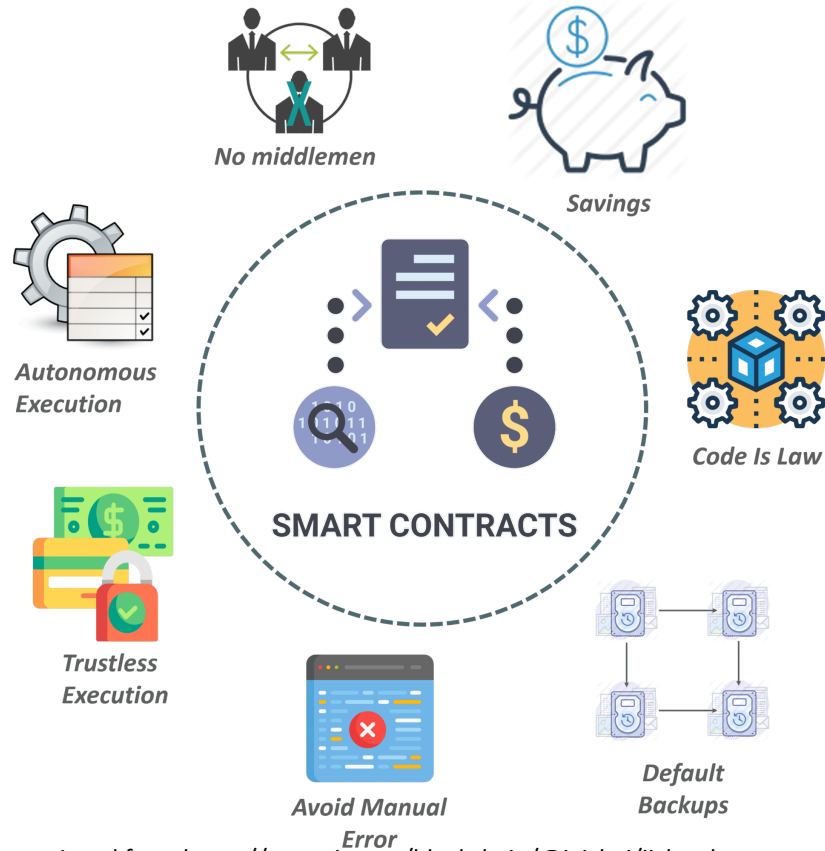
- ■ If this, then that code

- ■ Collection of code and data

- ■ Extend and Leverage blockchain

- ■ Must be deterministic

- ■ Acts as the "trust" agent

Ethereum: Many Tokens Types

ERC-20: A CLASS OF IDENTICAL TOKENS

ERC-721: A CLASS OF UNIQUE TOKENS
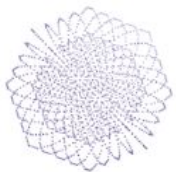
Image courtesy of http://www.google.com/url?sa=i&rct=j&q=&esrc=s&source=images&cd=&ved=
2ahUKEwjr3Mf4-pHkAhXLMd8KHbo4AwoQjhx6BAgBEAI&url=http%3A%2F%2Fblog.naver.com%2FPostView.nhn%3FblogId%3Dtyami%26logNo%3D221284123884%26
categoryNo%3D47%26parentCategoryNo%3D0%26viewDate%3D%26currentPage%3D1%26postListTopCurrentPage%3D1%26from%3Dsearch&psig=AOvVaw21-
3hVMzbH0vZ2Kdyx_vbb&ust=1566408073067074

Forks

- Soft
- Hard
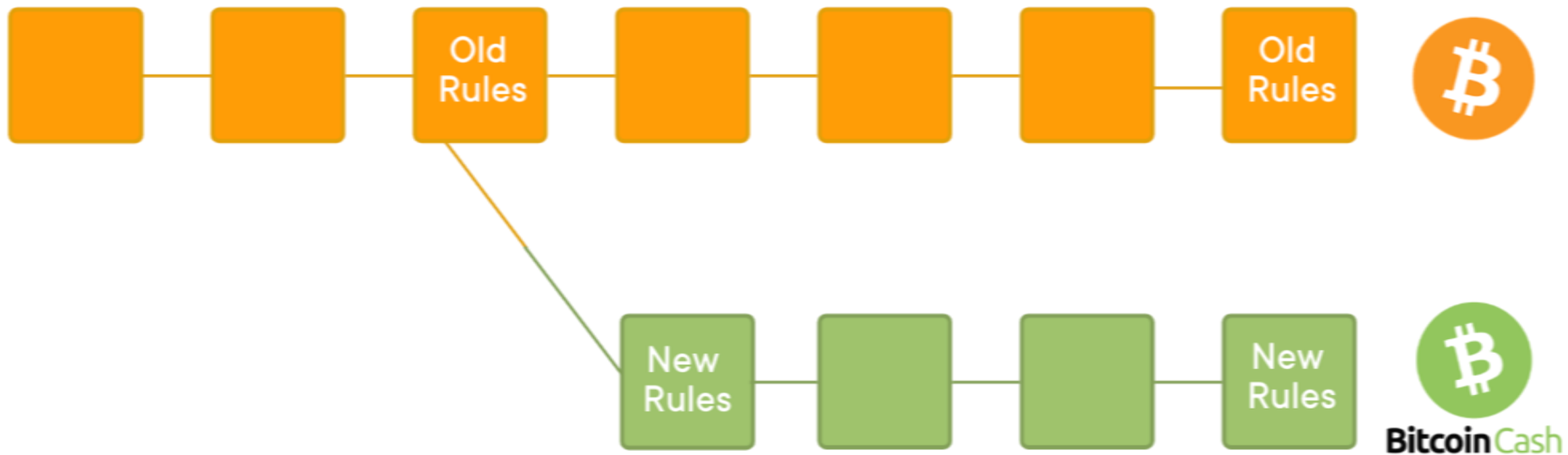
- Same blockchain continues
- Split in blockchain (2+)

Image taken from https://www.swissborg.com/blog/bitcoin-fork

Blockchain Limitations

- Scalability

- 51% attacks

- Need to interact with the real world

- Energy intensive

Blockchain Demo

■ https://anders.com/blockchain/hash.html

BLOCKCHAIN + HEALTHCARE

Image courtesy of https://www.google.com/url?sa=i&rct=j&q=&esrc=s&source=images&cd=&ved=2ahUKEwixjp_0-5HkAhUhc98KHX8ODPEQjRx6BAgBEAQ&url=https%3A%2F%2Fafiaxconnectedcare.org%2F2019%2F07%2F18%2Finteroperability-in-healthcare-systems-successes-and-new-challenges%2F&psig=AOvVaw24x_h_mGDv973it4cxPwcQ&ust=1566408329227418

Healthcare Blockchain Applications and Opportunities: 2019 - 2020

- **Consent Management**

  - ❑ Stored in EMR, paper, fax, etc.

  - ❑ Patient level consent does not exist. i.e Advance Directives

  - ❑ Start-ups working on radical revision

Healthcare Blockchain Applications and Opportunities: 2019 - 2020

■ **Tokenized Health Outcomes**

❑ Token can represent anything

❑ A measure of pt outcomes

❑ May augment grants

❑ Driver of value-based care.

Image courtesy of https://robottip.com/how-did-health-care-costs-get-so-high/

Healthcare Blockchain Applications and Opportunities: 2019 - 2020

■ **Micropayments and remittance**

❑ Wellness dApps to provide incentives to patients (Sweatcoin, Healthcoin)

❑ Development of easy to use payment interface

❑ Tracking/paying of co-pays and shared employee expense

Healthcare Blockchain Applications and Opportunities: 2019 - 2020

■ **Provider Credentials and Data**

❑ Long, expensive process

❑ Provider directories need to be maintained

❑ Marketplace for previously verified credentials.

Image taken from https://www.cra.com/company/news/charles-river-analytics-demonstrates-traumatic-injury-prediction-app-tatrc-open-house

Healthcare Blockchain Applications and Opportunities: 2019 - 2020

■ **Supply Chain Integrity**

Healthcare Blockchain Applications and Opportunities: 2019 - 2020

FDA STATEMENT

Statement on data accuracy issues with recently approved gene therapy

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For Immediate Release: August 06, 2019

Statement From: Director - Center for Biologics Evaluation and Research (CBER)
Dr. Peter Marks M.D. PhD.

Image taken from https://www.fda.gov/news-events/press-announcements/statement-data-accuracy-issues-recently-approved-gene-therapy

❑ Clinical Trials Data

"Medically Ready Force...Ready Medical Force"

Healthcare Blockchain Applications and Opportunities: 2019 - 2020

- ■ Dispersed data

- ■ Multiple stakeholders

- ■ Poor clinical trial participation

- ■ Sensitive information

Image retrieved from http://www.mcall.com/news/local/mc-nws-state-of-emergency-county-capsules-20180626-story.html

Healthcare Blockchain Applications and Opportunities: 2019 - 2020

Image courtesy of https://www.twipu.com/SouthwestViral
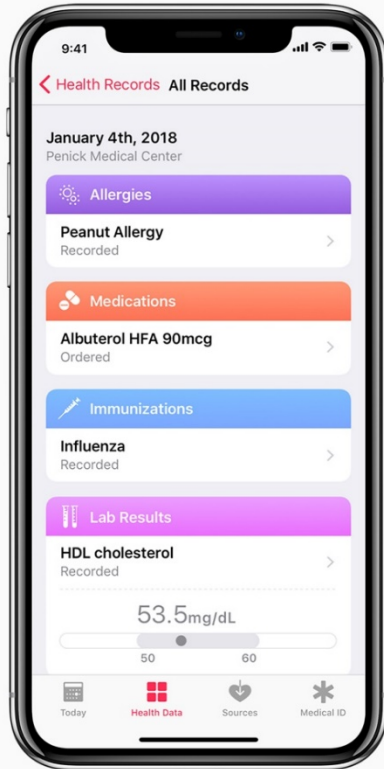
■ Personal Health Record

■ Patient owned

■ Immutable audit trail

■ Trust??

Healthcare Blockchain Applications and Opportunities: 2019 - 2020

❏ Retain ownership of IP

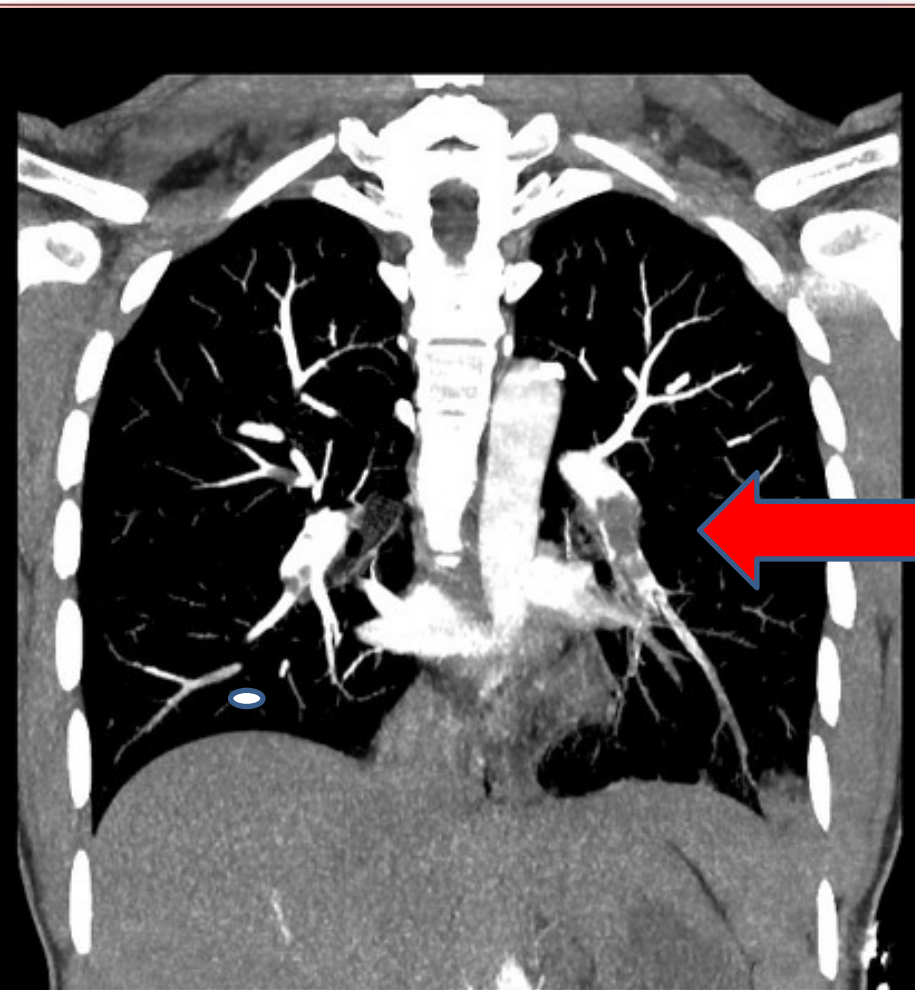*"Medically Ready Force…Ready Medical Force"*

CONCEPTS

Diagnosis Tracking: Concept
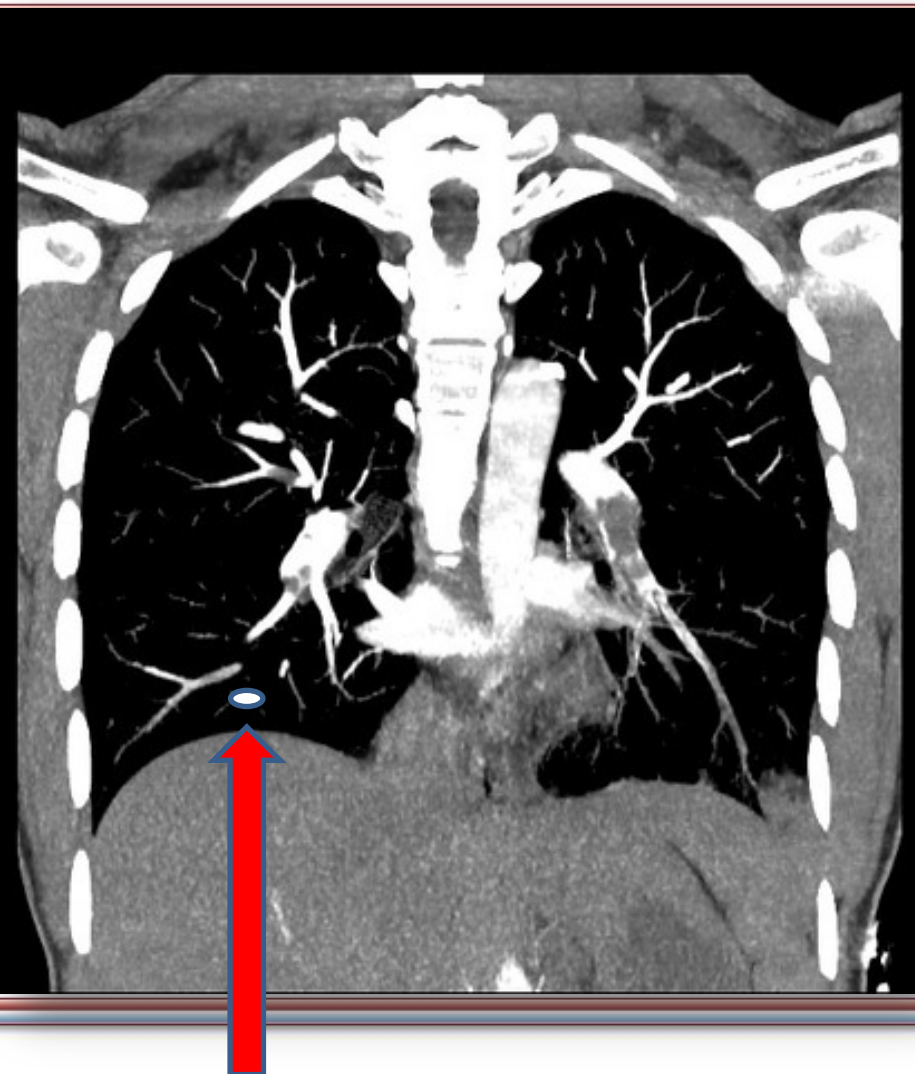
■ 35 y/o patient with acute chest pain:

1. Emergency Medicine Doctor evaluates and orders a Chest CT to exclude a pulmonary embolus.

2. Patient arrives at Radiology Department

3. CT scan performed

4. Radiologist interprets and creates a report

Workflow

Embolus in left pulmonary artery!

Workflow

Radiology Report

IMPRESSION:

1. Acute pulmonary emboli in the left pulmonary artery.

2. A 7mm pulmonary nodule in the right lower lobe. Recommend follow up CT in 6 months.

Problem: Lost to Follow Up

■ Focus is on acute issue

■ Leads to delayed diagnosis

■ Disparate systems

■ Lack of communication

■ Patients are unaware

■ Patient may switch MTFs

■ PCM change frequently
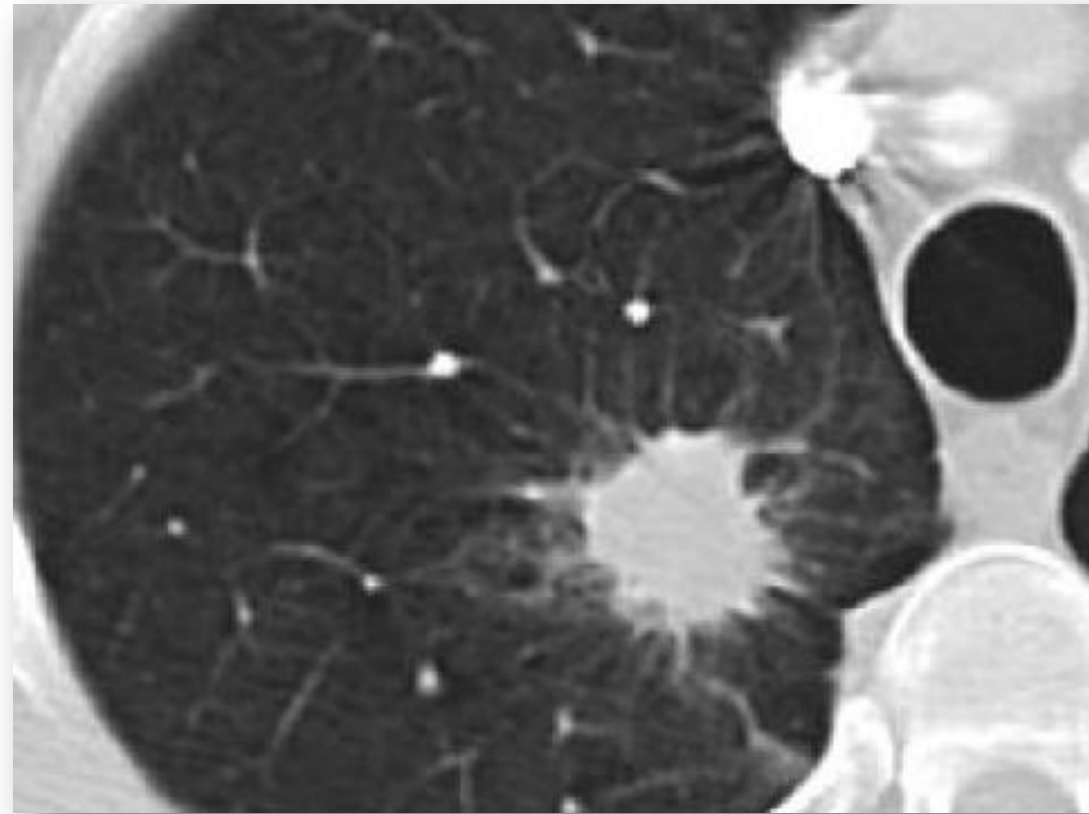
■ Outside images not reconciled

Image courtesy of https://www.lequotidiendumedecin.fr/archives/decouverte-dun-nodule-pulmonaire-solitaire

Algorithmic

Management of Incidentally Detected Pulmonary Nodules
(Fleischner Society 2017 Recommendations)
These recommendations do not apply to Lung Cancer Screening

SOLID NODULES

		Size (average of long- and short-axis diameters)		
		<6 mm (<100 mm³)	6–8 mm (100–250 mm³)	>8 mm (>250 mm³)
Single	Low risk†	No routine follow-up‡	LDCT at 6–12 mos, then consider LDCT at 18–24 mos	Consider CT, PET/CT, or tissue sampling at 3 mos
	High risk†	Optional LDCT at 12 mos‡	LDCT at 6–12 mos, then LDCT at 18–24 mos	Consider CT, PET/CT, or tissue sampling at 3 mos
Multiple*	Low risk†	No routine follow-up	LDCT at 3–6 mos, then consider LDCT at 18–24 mos	LDCT at 3–6 mos, then consider LDCT at 18–24 mos
	High risk†	Optional LDCT at 12 mos	LDCT at 3–6 mos, then LDCT at 18–24 mos	LDCT at 3–6 mos, then LDCT at 18–24 mos

† Consider all relevant risk factors.
‡ Nodules <6 mm do not require routine follow-up, but certain patients at high risk with suspicious nodule morphology, upper lobe location, or both may warrant 12-month follow-up.
* Use most suspicious nodule as guide to management. Follow-up intervals may vary according to size and risk.
LDCT = Low Dose CT

- Defined by National Society

- Recommendations backed by evidence

- Adapted by majority of Radiologists

Proof of Concept:
Blockchain Solution

1. A global problem not currently solved by an existing commercial product.

2. We have a network with participants with many transactions.

3. Need for provenance, immutability, and consensus.

4. Start small, then scale
   ■ Pulmonary nodules are only the tip of the iceberg.

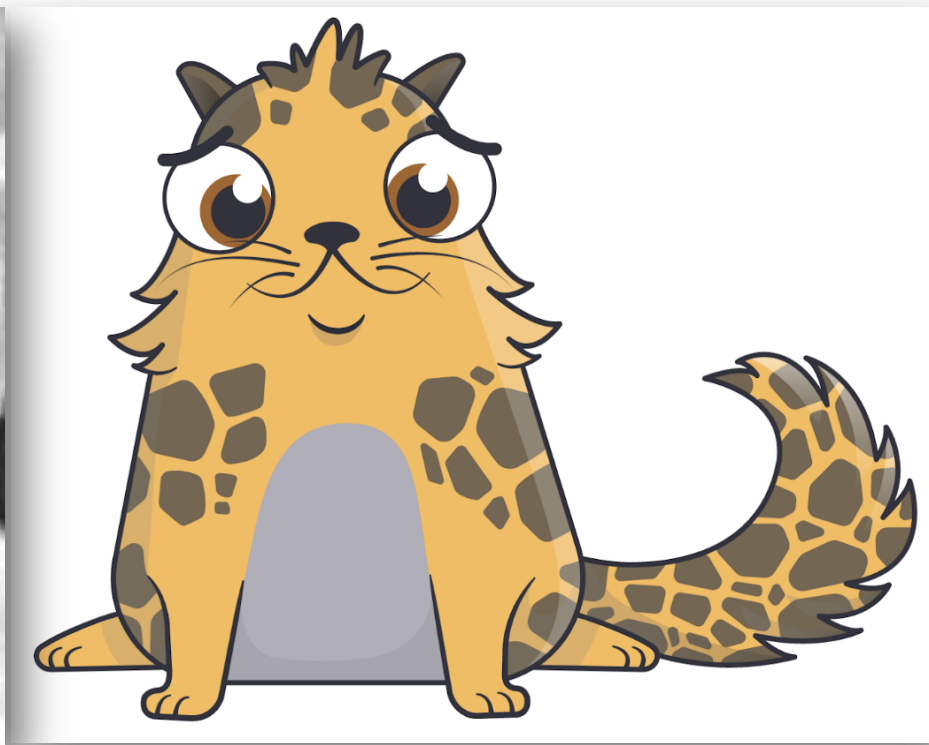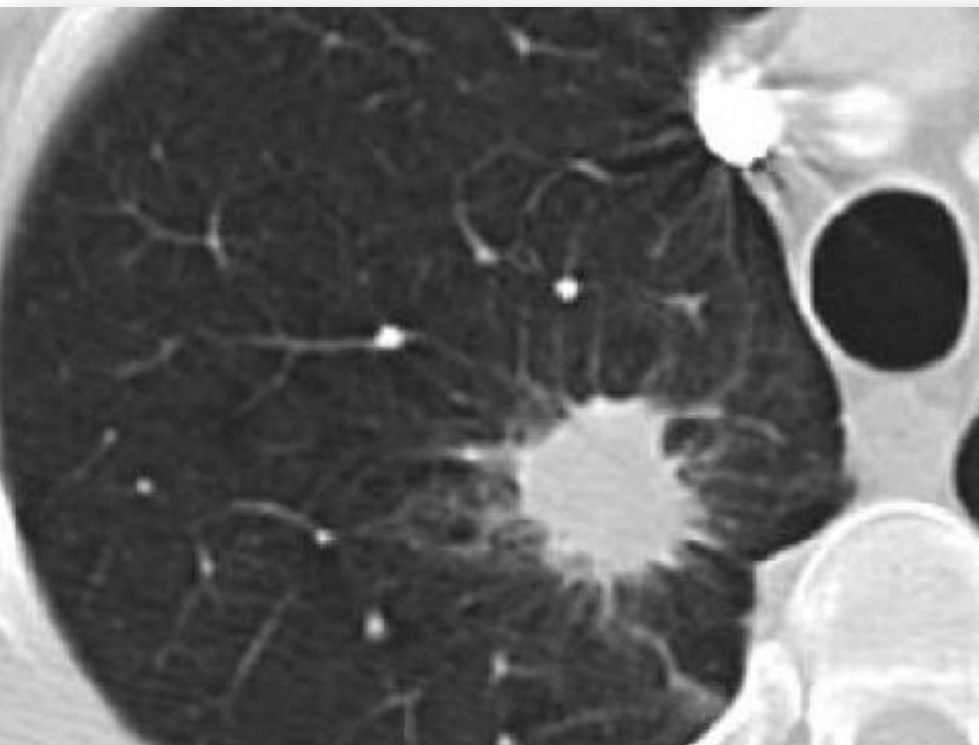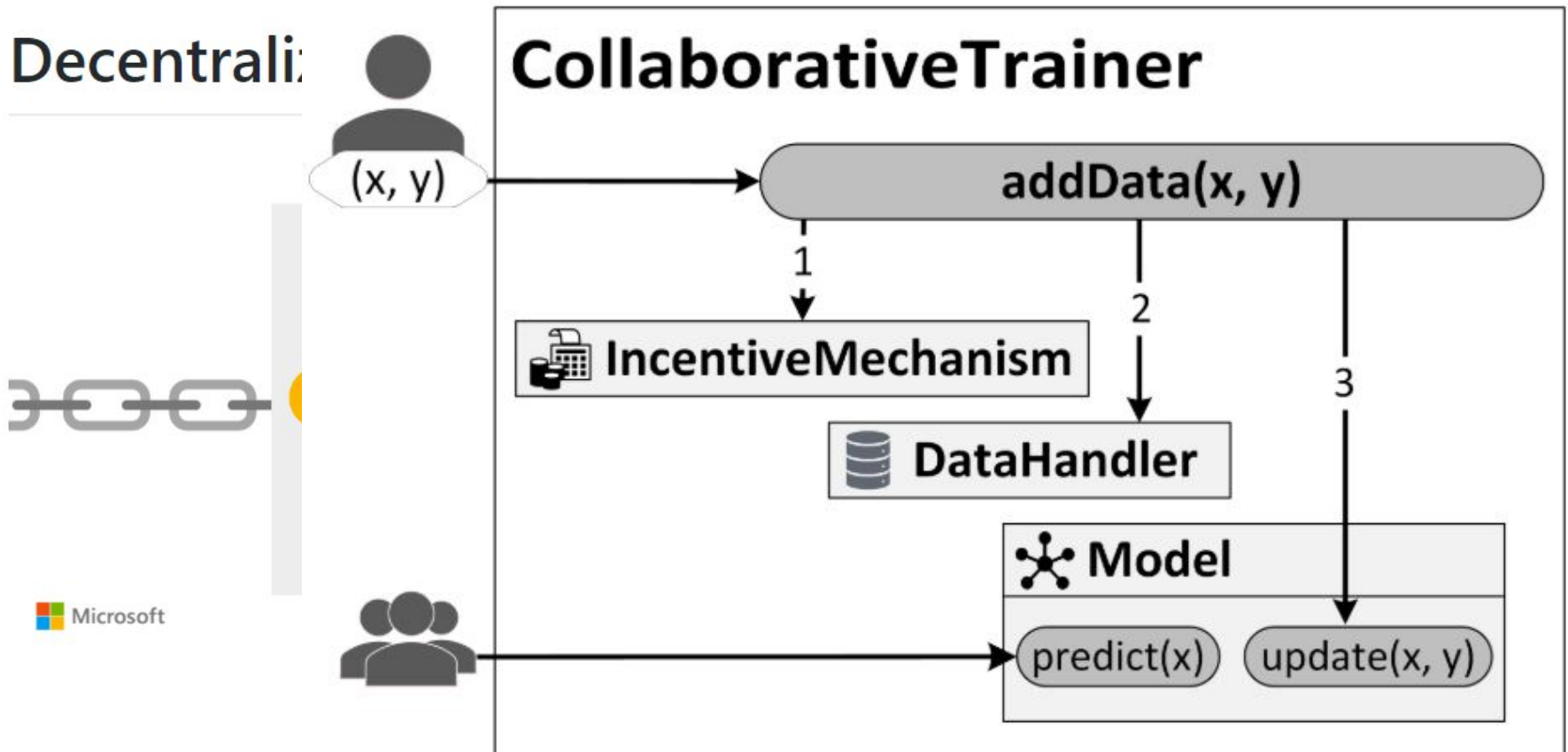*Then rethink traditional processes*

Rethink traditional practices

Image courtesy of https://www.lequotidiendumedecin.fr/archives/decouverte-dun-nodule-pulmonaire-solitaire

Image courtesy of https://blog.mintable.app/2019/04/09/a-proper-examination-of-erc-721s-what-are-erc-721s-and-how-can-they-change-our-lives/

Machine Learning Use-Case
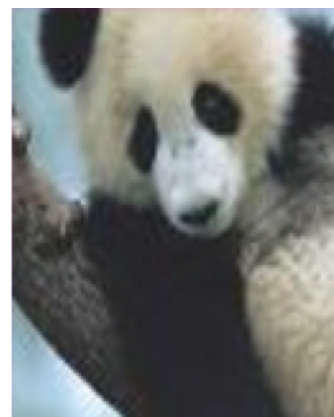

https://github.com/microsoft/0xDeCA10B

Authenticity of Images

"panda"
57.7% confidence

"gibbon"
99.3% confidence

Additional Potential Concepts

- Medical Image Exchange

- Referral Management Efficiency

- Medical Device Management

- Decentralized Governance

Image courtesy of https://www.themandarin.com.au/107179-blockchain-in-government-the-possibilites-after-the-hype/

Blockchain Future

■ Ethereum Enterprise Alliance

    - 250+ companies, 45+ countries

■ Blockchain as a service platforms

    - Microsoft, IBM, Amazon Web Services

■ Blockchain 3.0

    - EOS, NEO, Tezos

■ Ethereum 2.0

    - Sharding, Plasma, Proof of Stake, Nightfall

Return on Investment
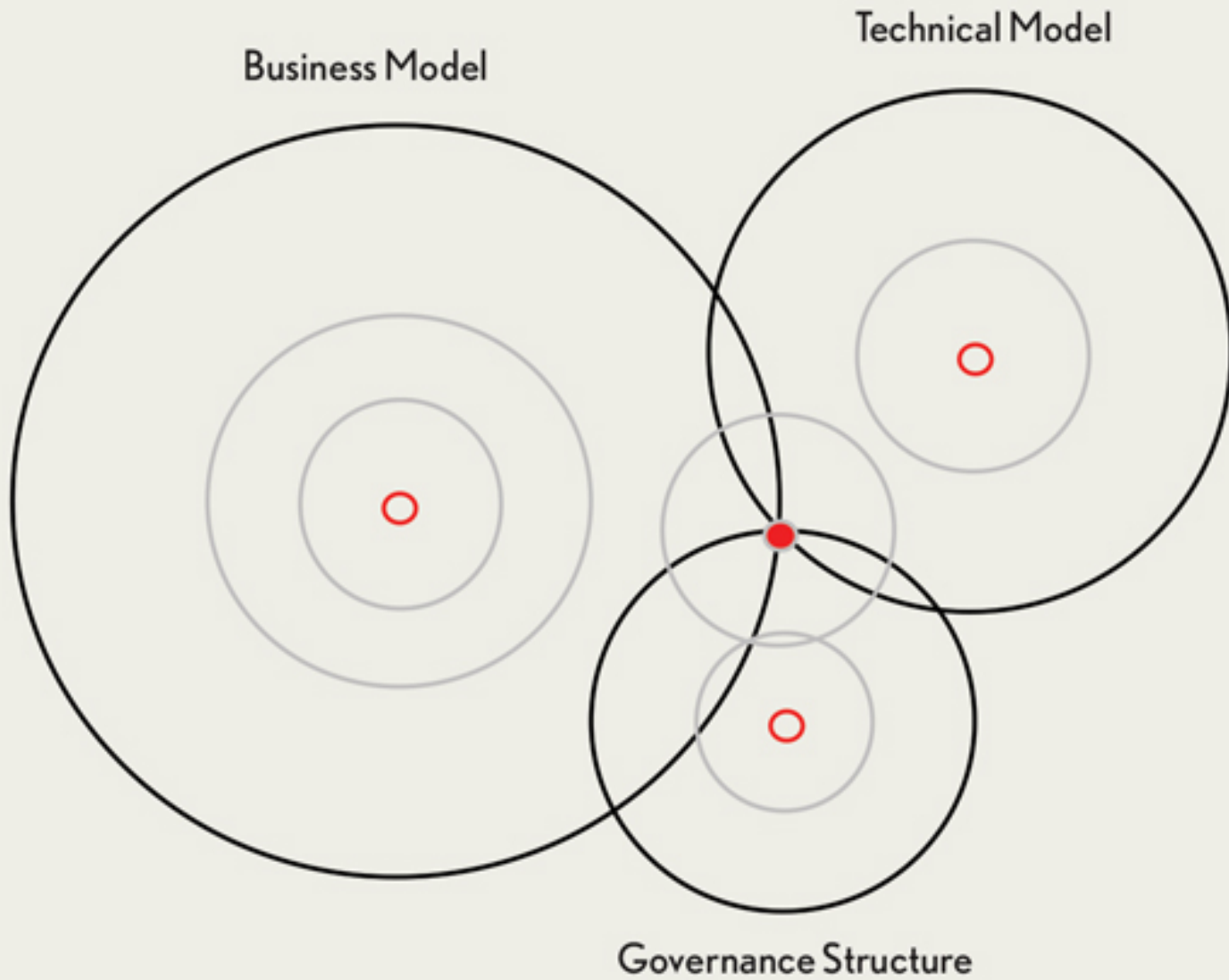

Video

HHS gets ATO for blockchain-based acquisition system

By GCN Staff

Dec 11, 2018

THE SWEET SPOT FOR AN EFFECTIVE BLOCKCHAIN USE CASE

Business Model

Technical Model

Governance Structure

Source: John Bass, Hashed Health 2018

Lessons Learned: ScreenSense Pilot

MATTER

Image curtesy of: https://matter.health

Forward Blockchain

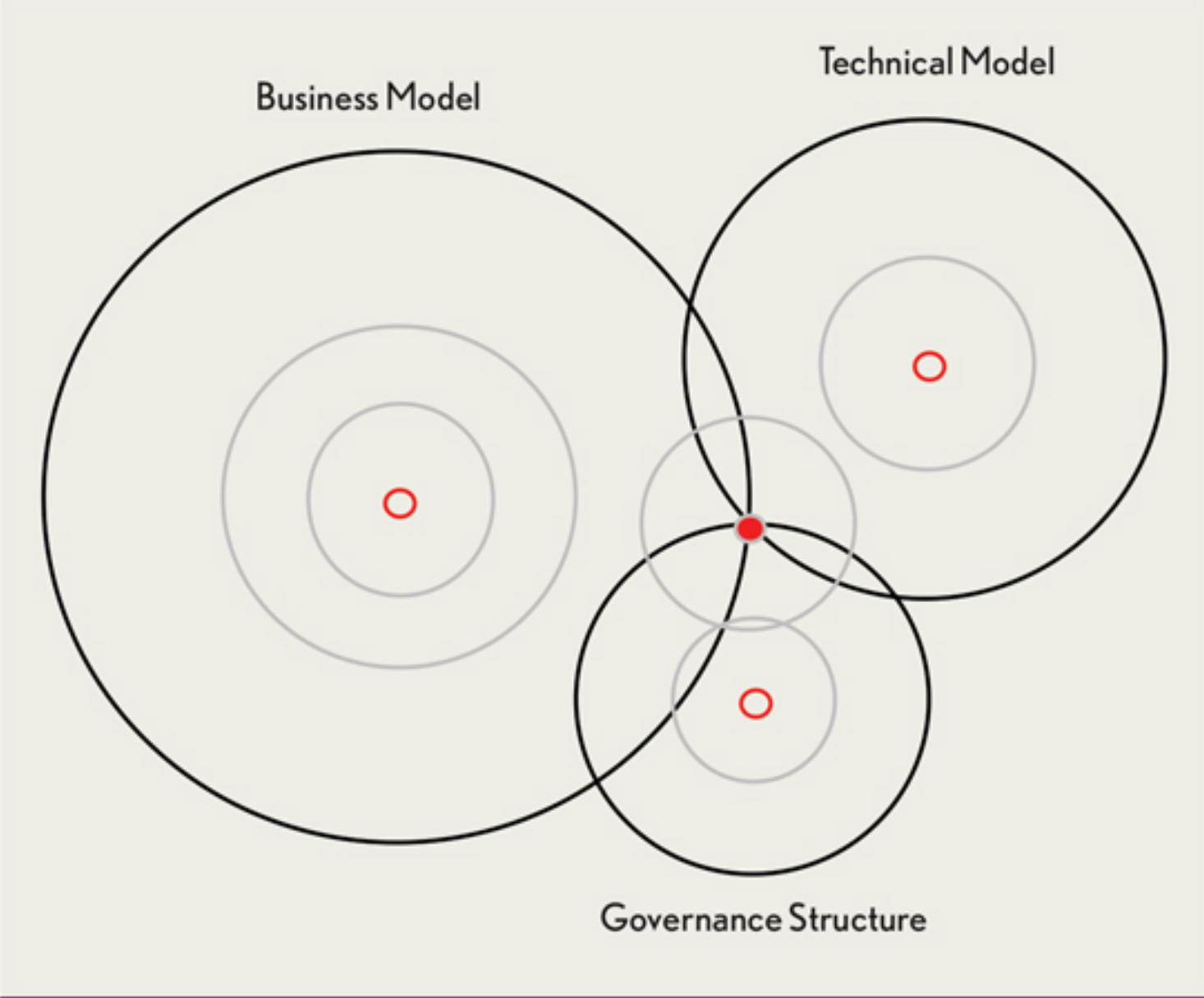Image curtesy of https://www.crunchbase.com/organization/forward-blockchain#section-overview

- **Incentivize patients to participate**

- **Dispensation of tokens needs to be tied to the point of care**

- **Does not violate privacy**

- **Deep auditing capability**

- **Open platform that can be adopted**

Ethe

THE SWEET SPOT FOR AN EFFECTIVE BLOCKCHAIN USE CASE

Business Model

Technical Model

Governance Structure

Source: John Bass, Hashed Health 2018

Key Takeaways

- Blockchain will permeate most existing industries and will create new ones not thought of yet.

- Healthcare is ripe for disruption

- Rethink traditional business practices

- We have the opportunity to lead

Final Quote by Wayne Gretzky

Image taken from https://pbs.twimg.com/media/DJi4hNpU8AAJy1Q.jpg

References

Buterin, V. A next generation smart contract & decentralized application platform. Ethereum White Paper.

   Retrieved from https://github. com/ethereum/wiki/wiki/% 5BEnglish

Halamka, J., Alterovitz, G., Buchanan, W., Cenaj, T., Clauson, K., Dhillon, V.,...Ngo, A. (2019). Top 10 blockchain

   predictions for the (near) future of Health care. Blockchain in Healthcare Today, 2. Retrieved from

   https://doi.org/10.30953/bhty.v2.106

Kuo, T., Zavaleta, Rojas, H.Z., & Ohno-Machado, L. (2019). Comparison of blockchain platforms: A systematic

   review and healthcare examples. Journal of the American Medical Informatics Association, 26, (5), 462–

   478. Retrieved from https://doi.org/10.1093/jamia/ocy185

References

Nakamoto, S. (2008). Bitcoin: Peer-to-peer electronic cash system. Retrieved from

https://nakamotoinstitute.org/bitcoin/

Yaga, D., Mell, P., Roby, N., & Scarfone, K. (2018). Blockchain Technology Overview. National Institute of

Standards and Technology, U.S. Department of Commerce Retrieved from

https://nvlpubs.nist.gov/nistpubs/ir/2018/NIST.IR.8202.pdf

Questions?

- Please submit your questions in the Q&A pod in Adobe Connect

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2. Click on the REGISTER/TAKE COURSE tab.
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    b. If you have not previously used the CEPO LMS click register to create a new account.
3. Verify, correct, or add your profile information.
4. Follow the onscreen prompts to complete the post-activity assessments:
    a. Read the Accreditation Statement
    b. Complete the Evaluation
    c. Take the Posttest
5. After completing the posttest at 80% or above, your credits will be recorded in the LMS. In addition, you will be able to print or download your certificate. Repeat this process for each session you wish to claim CE Credit.
6. You can return to the site at any time in the future to print your certificate and transcripts at https://www.dhaj7-cepo.com/
7. If you require further support, please contact us at dha.ncr.j7.mbx.cepo-lms-support@mail.mil

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