On Potential Research Directions on Blockchain and Smart Contracts

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My Research Group

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carlos
My Research Experience

several projects on contract-regulated biz interactions

get control of your personal data – it is yours

make the Internet good for sending and retrieving data.

enforce contractual rights, obligations and prohibitions at run-time with blockchain and smart contracts

UCN
User Centric Networking

UMOBILE
Universal Mobile Centric Opportunistic Communications Architecture

TESCON
Tools for Enforcement of Smart Contracts

2001
2014
2018

Univ. Ncl

Univ. Cam
Why blockchain and smart contracts?

• What is blockchain?
• What is it good for?
• Who needs it?
  • Me, I need it!!!
Motivation: I’d been invited to a XV b/day party!

Contributions in **cash** are very welcome!
Money transfer: Traditional Bank-mediated Approach

Alice has account with ABC

- 5 USD

Barclay’s acct

bank2bank pay protocol

ABC’s acct

+ 5 USD

Bob has account with Barclays

Banking system
Problems with Bank-mediated Transfers

- It takes ages (several days).
- There is a exchange rate that the bank abuses.
- The bank transaction fees (typically 15 to 30 pounds).
- It excludes people without bank accounts.
What Role does the Bank Play?

- The bank is a centralised Trusted Third Party (TTP).
- This TTP solves several potential transaction problems:
  - Alice has enough money in her account to cover the transaction.
  - Alice does not spend the same coin two or more times (double spending).
  - The money is deposited in Bob’s account.
- How does the bank (two or more might be involved) do its job?
  - It has a centralised ledger with records of all the Txs: it knows Alice’s and Bob’s balances.
  - It has a database with Alice’s and Bob’s personal information (name, address, sex, etc.).
Bitcoin to the Rescue– Let us Get Rid of the Bank

- They built Bibcoin--- an online system that facilitates person-to-person (for ex. Alice to Bob) money transfer in BTC cryptocurrency (10 USA = 0.10 BTC aprox.).
  - person-to-person means directly, without the bank mediating between the two parties. Some people call it pee-to-peer.
- No banks in the middle means goods things
  - Business: No transaction fees, no money transfer time, no abusive exchange rate, no need to have a bank account, no need to disclose my transaction habits to the bank, etc.
  - Technical: no dependency on the functionality of the bank that might suffer breakdowns.
- No bank in the middle means potential problems as well.
  - No guarding to control illegal Txs (see Silk Road case), no body to resort to if I loose my money,...
Competition Joins the Race

• Bitcoin shook the banking and financial system.
• Competition appeared quickly
  • Ethereum, Hyperledger, etc.
How does Bitcoin Solve the Problem?

• It relies on a decentralised (distributed) data structure called the Decentralised Ledger (DL) or the blockchain.
  • Indelible (append only).
  • Decentralised (replicated at several nodes).
• It runs consensus algorithms to synchronised the replicas with each other: ensures that eventually, all of them have identical information about all transactions.
• It uses cryptographic techniques (eg. public key technology) to identify senders and receivers of money.
• It runs a **smart contract**: a piece of code that ensure (enforce) that only valid Txs take place: right amount of money and to the right receiver.
What is a Smart Contract?

1. The data buyer is entitled to present the data seller offers with offers to buy data data ...

2. The data seller is free to use her discretion to either reject the offer or ...

In the diagram:
- Data buyer (Bob) and data seller (Alice) are connected via a Smart Contract, used for producing contract-regulated operations.
- Alice's domestic sensors (S₁, S₂, Sₙ) are connected to the data repository, used for enforcing contract-regulated operations.
Beyond Bitcoin’s Cryptocurrency

- Bitcoin’s cryptocurrencies was only the first application.
- It was enough to generate commercial and research interest.

New business models (banking, health, ...) and new computation paradigms, new...
Bitcoin Offered a Pragmatic Solution to old Consensus Problem?

- Bitcoin offers a pragmatic solution to the old and fundamental consensus problem.
At the Heart of Blockchain is Consensus

- Bitcoin offers a pragmatic solution to a very old distributed systems problem: consensus--- all about running algorithms between $n \geq 2$ networked computers that store a copy of a piece of data on their local disks to ensure that the content of the copies are identical (agree with each other).
Life Before and After Bitcoin

• The solution to this problem took the research community by storm.
• We are devising Bitcoin-based solution to old and new problems.
Decentralised Ledger as a Middleware Service

- The decentralised ledger used by blockchain platforms (Bitcoin, Ethereum, Hyperledger, ...) can be regarded as a piece of **generic** middleware service.
  - Generic: that can be used for supporting a large class of applications. Cryptocurrencies is only one of them.
  - What kind of applications?

Stateful application: the next operation depends on the current state of the shared data.

Alice, Bob, Clare are independent parties

Remote interaction under mutual distrust

Synchronised copies:
Middleware services of the Decentralised Ledger

- Data synchronisations by means of consensus algorithms (ex. Proof of Work).
- Operation enforcement by means of smart contracts.

\[ \text{Node}_B \]

\[ \text{Alice} \rightarrow \text{data (copy}_B\text{)} \rightarrow \text{smart contract}_B \rightarrow \text{Appl}_B \rightarrow \text{Bob} \]

\[ \text{ tslint: } \text{Node}_A \]

\[ \text{consensus}_A \rightarrow \text{data (copy}_B\text{)} \rightarrow \text{smart contract}_A \rightarrow \text{Appl}_A \]

\[ \text{ tslint: } \text{Node}_C \]

\[ \text{consensus}_C \rightarrow \text{data (copy}_C\text{)} \rightarrow \text{smart contract}_C \rightarrow \text{Appl}_C \]

\[ \text{o- operation (Alice pays Bob 1 BTC).} \]
\[ \text{cco- contract compliant operation} \]
What are Blockchains Good for?

• I believe that it is a piece of science and technology with large potential beyond cryptocurrencies.

• It can help solve problems that in the past could be solved only in a centralised manner.

• Centralisation is good because it is simple but

• Centralisation is bad because of the dependency on the single party placed in the middle.
Examples of Research on Blockchain Applications

• I will discuss some example that can be mapped into other similar applications.
Indelible Records on Blockchain

- We produce records that
  - follow the “write once–read many times” model.
  - are immune (not affected) to accidental or malicious alterations.
  - are kept for good and always available (for reading) from anywhere, not necessarily to the general public.
    - consultation and verification.
  - Examples: birth/death certificates, medical records, property (land) registries, university certificates.
- The indelibility property that blockchain offers seems ideal for storing such records.
- Pioneering studies have been conducted in Honduras (developing country afflicted by violence, corruption and untrusted governments).
1. Alice passed her final exam.

2. Her examiners place certificate in a blockchain.

3. Anybody can see it. OK for a uni certificate but what about medical records?
1. Alice’s Dr places medical record on blockchain but protected by a smart contract.

2. Only some people can read it.

Ex of contract clauses:

- c1: Dr has the right to access the records at any time.
- c2: Researcher has the right to access the record only after biz hrs.
Smart Contracts can Help Create Records from Records automatically and systematically

Ex of a contractual clauses
C1: On Alice’s 18\textsuperscript{th} b/day create Med Record3.
C2: If Med Record2 and Med Record3 exist then create Med Record4
Food Policies Enforcement with Smart Contracts

- Tsen: Sensor
- Lsen: Location
- Pi: Computer
- Smart food container
- Smart contract on blockchain (instance N1)
- Smart contract on blockchain (instance N2)
- Smart contract on blockchain (instance N3)

T: Temperature
L: Location

If T > 0, contract violation

T = -2
L = Toronto

T = 3
L = Miami

T = 0
L = Rio
Is Blockchain Here to Stay?

- Yes, Bitcoin, Ethereum and other blockchains have been operating for years and has proved that the idea works?
- Yet, in my view, they is still at experimental stage and looking for the killing application.
- There are hurdles to clear
Bitcoin Mining is Burning the Planet

• Bitcoin mining (computation required to validate a Tx) consumes a ridiculous amount of energy [Feeding the Blockchain Beast, Peter Fairley]

• The energy consumed by a second of Bitcoin mining is equivalent to the energy consumed by 325,000 houses.

• A Bitcoin Tx consumes 5,000 times more energy than a Visa Tx
Bitcoin is too slow

• The response time of Bitcoin (and other blockchain) is too slow for applications that demand quick response (sec, milliseconds).

Quick response: real time applications: ex. car sensors
Bitcoin does not Scale Up

- Bitcoin can process only about 7 transactions per second.
- Visa can process 2,000 per second.
Cambridge Potential Solution to Blockchain Limitations

- Use a hybrid (combined) solution:
  - centralised smart contract enforcement + decentralised smart contract enforcement.
Conclusions

• The Bitcoin paper opened innovative business and research directions.

• Blockchains and smart contracts (its two core concepts) are generic and can be used in the implementation of applications of several domains.
  - smart contracts and blockchains complement each other, however smart contracts can be used without blockchains and blockchains can be used without smart contracts.
  - Contracts have been the subject of research interest long time before Bitcoin (see http://www.cl.cam.ac.uk/~cm770/).

• Besides blockchain and smart contracts potential, one has to keep in mind that these technologies are currently at research state, thus their actual contribution to business applications is still waiting validation.
• Questions and observations are very welcome.
References

• “Feeding the Blockchain Beast”, P. Fairley, Spectrum. IEEE Oct 2017
• Distributed Ledger Technology: beyond block chain. A report by the UK Government Chief Scientific Adviser, 2015.