COMP6452 Software Architecture for Blockchain Applications: Introduction

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Agenda:

- Part 1: Course Summary
  - Lecturers and Tutor
  - Learning Outcomes, Course Outline, Assessments
- Part 2: Topic Overview
  - What is Blockchain, and Why Does it Matter?
  - Blockchain-based Applications
  - Blockchain Functionality
  - Blockchain Non-functional Properties
  - Blockchain Architecture Design
- Part 3: Impact
  - Use Cases
  - Disruptive Potential of Blockchains

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Who are we?

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Lecturers and Tutor

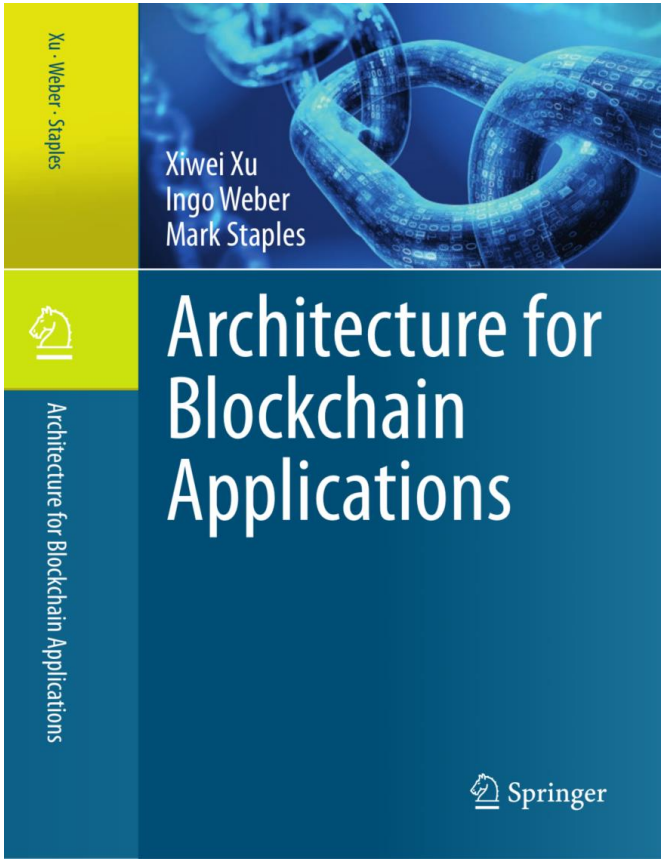
- Dr Ingo Weber:
  - Principal Research Scientist & Team Leader @ Data61, CSIRO; Conjoint Assoc. Prof. @ CSE, UNSW; Adjunct Assoc. Prof. @ Swinburne University.
  - PhD from University of Karlsruhe (TH); MSc from the University of Massachusetts, Amherst, USA.

- Dr Xiwei (Sherry) Xu:
  - Senior Research Scientist @ Data61, CSIRO & Conjoint Lecturer @ CSE, UNSW
  - PhD from UNSW
  - Working on blockchain since 2015

- Dr Mark Staples:
  - Senior Principal Research Scientist & Team Leader @ Data61, CSIRO; Conjoint Assoc. Prof. @ CSE, UNSW
  - PhD from University of Cambridge; BSc and BInfTech (Hons) from University of Queensland
  - Leading member of ISO standardization for Blockchain (ISO/TC 307).

- Sin Kuang Lo:
  - PhD student @ Data61, CSIRO and UNSW
  - Tutor

Book: Architecture for Blockchain Applications



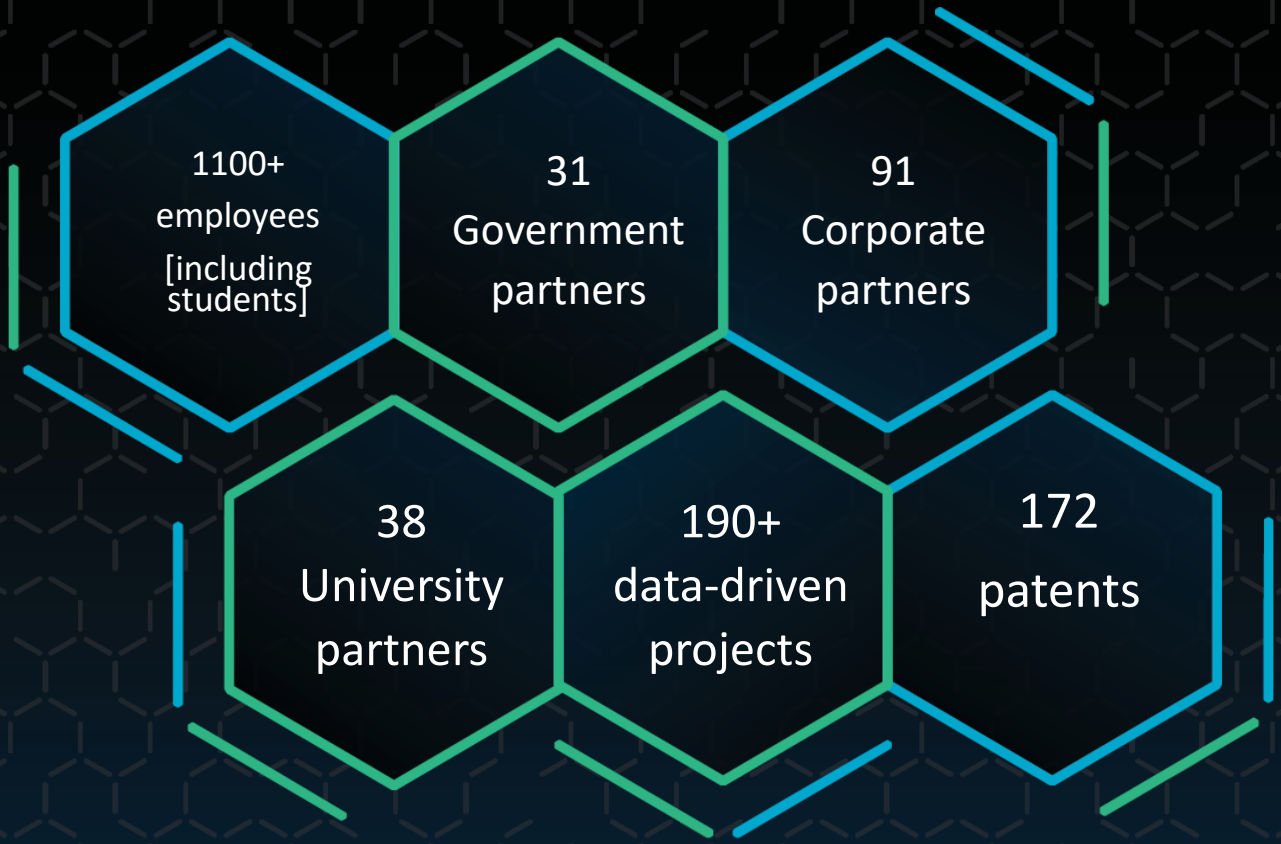
Xiwei Xu, Ingo Weber, Mark Staples.

Architecture for Blockchain Applications.

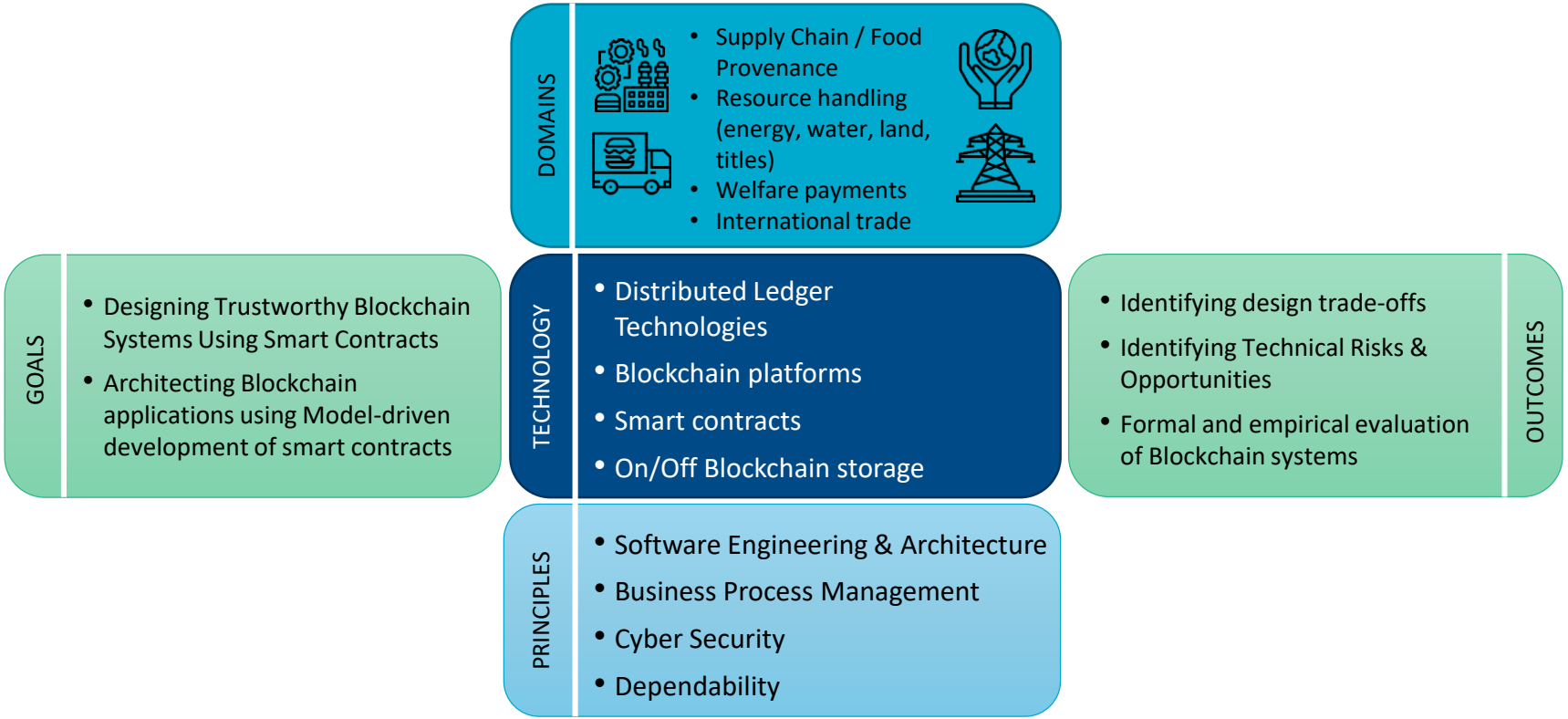
Springer, 2019.

CSIRO: Australia's National Science Agency

Data61: Australia's Digital Innovation Powerhouse



Blockchain Research at Data61 – Overview



Course Structure

Learning Outcomes

After the course, you will be able to:

- Explain the principles of blockchain and which roles it can play in an application architecture
- Decide on the suitability of blockchains and how to design applications on them
- Make functional and non-functional trade-offs for blockchain-based applications
- Build small applications on blockchain

Course Outline (1)

Week	Date	Lecturer	Lecture Topic	Relevant Book Chapters	Notes
1st	18 Feb	Ingo Weber	Introduction	1. Introduction 4. Example use cases	
2nd	25 Feb	Ingo Weber	Existing Blockchain Platforms	2. Existing Blockchain Platforms (1h on smart contract dev)	Assignment 1 out (Monday before lecture)
3rd	4 Mar	Sherry Xu	Blockchain in Software Architecture 1	3. Varieties of blockchain 5. Blockchain in Software Architecture (including software architecture basics) 1/2	
4th	11 Mar	Mark Staples	Blockchain in Software Architecture 2	5. Blockchain in Software Architecture (Non-functional properties and trade-offs) 2/2	Pitching session Assignment 1 due (Wednesday)
5th	18 Mar	Sherry Xu	NFPs 1	6. Design Process for Applications on Blockchain (DevOps of blockchain) 9. Cost	
6th	25 Mar	Mark Staples	NFPs 2	10. Performance	Mid-term Exam (1 hour)

Course Outline (2)

Week	Date	Lecturer	Lecture Topic	Relevant Book Chapters	Notes
7th	1 Apr	Mark Staples	NFPs 3	11. Dependability and Security	Assignment 2 out (Monday before lecture)
8th	8 Apr	Sherry Xu	Design Patterns for Blockchain Applications	7. Blockchain Patterns (design pattern basics, design pattern language)	
9th	15 Apr	Ingo Weber	Model-Driven Engineering	8. Model-driven Engineering for Applications on Blockchains (model-driven basics, UML)	Assignment 2 due (After tutorial)
10th	22 Apr	Easter Holiday			
11th	29 Apr	Guest Lecturer + Mark Staples	Guest Lecture and Summary	AgriDigital? Summary (including Epilogue content) Discuss disruptive potential, high-level opportunities and risks	Guest Lecture 2-hour and Summary of the Lecture

Assessments

Assessment Title	Assessment Type	Marks
Assignments (2)	Assignment	2x 12.5
	Two assignments where you will analyse and implement blockchain scenarios.	
Mid-term quiz	Quiz Test	25
	Mid-term quiz conducted in class on material covered up to that point.	
Final Exam	Examination (central)	50
	A written examination, testing all course content, with a focus on material from the second half of the course. Students must obtain a **passing grade on the exam** in order to pass the course (i.e. < 50% of the exam points means failing the course).	

Marking & Course Website

- To pass the course, your **overall mark must be 50 or higher**, and your **mark in the final exam must be 25 or higher**. The overall final mark will be the sum of your marks for each component if you pass the course.
- Marking will be done according to this formula:

```
if (final >= 25)
        then total = ass1 + ass2 + mid_exam + final_exam;
else
        total = final_exam * 2;
```

- Course website:

  https://webcms3.cse.unsw.edu.au/COMP6452/19T1/

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What is Blockchain, and Why Does it Matter?

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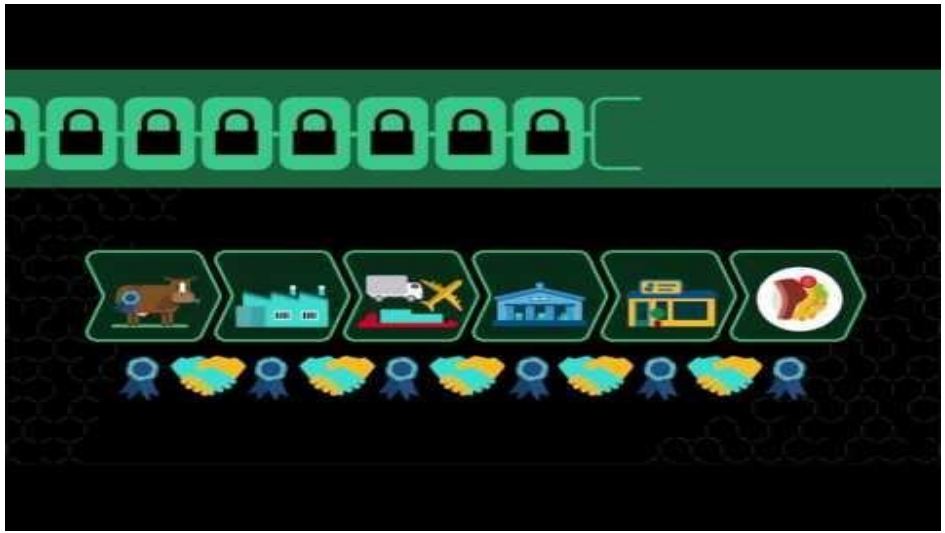
What is a Blockchain?

Visualization of a Blockchain: http://ethviewer.live

What is the Beef about Blockchain?

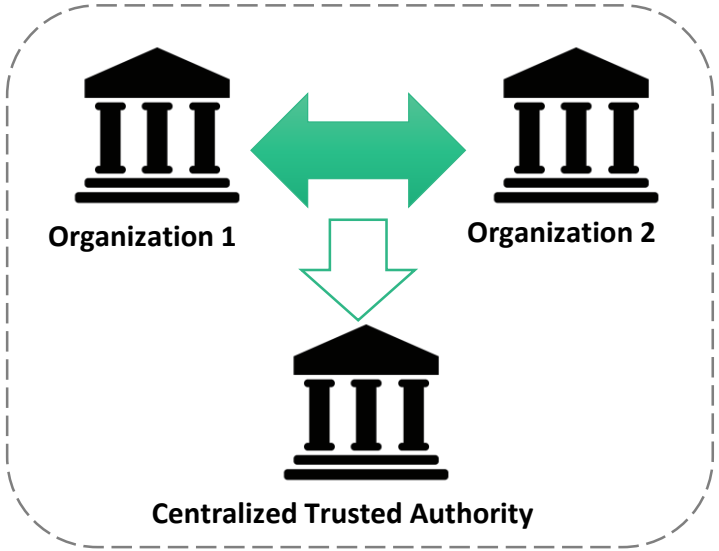


Applications coming soon:

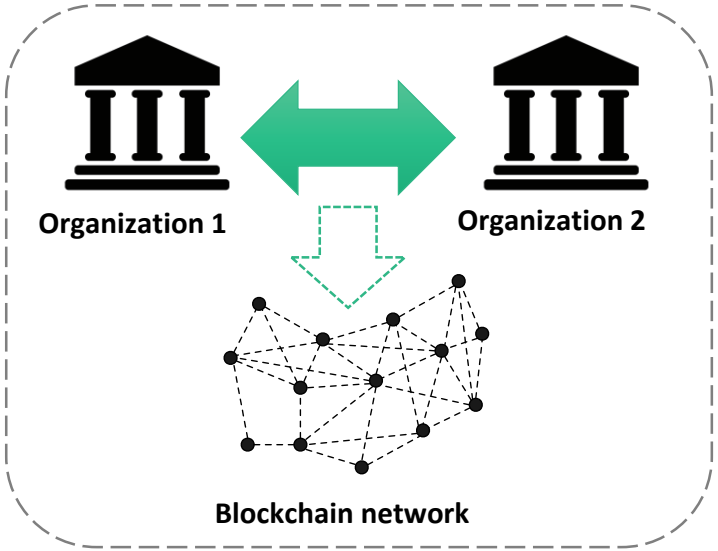
- NSW electronic driver licences
- ASX system for settlement of trades

Video & reports: https://www.data61.csiro.au/blockchain

Blockchain – replacing centralized trusted authority

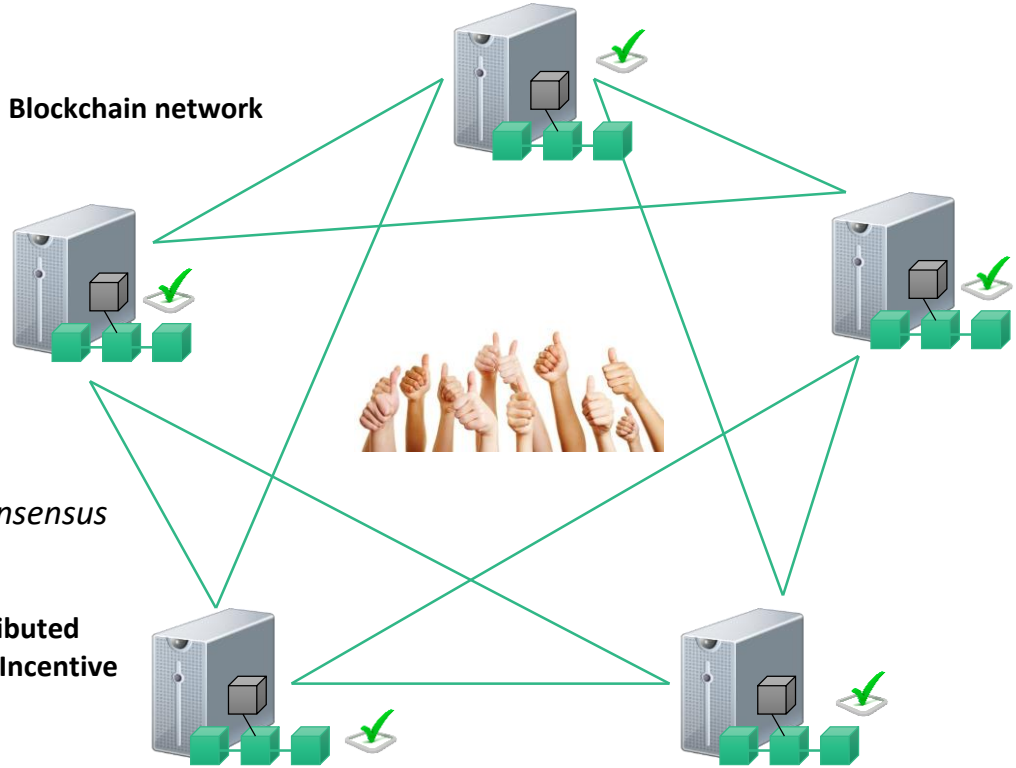


Traditional trusted environment



Blockchain trustless environment

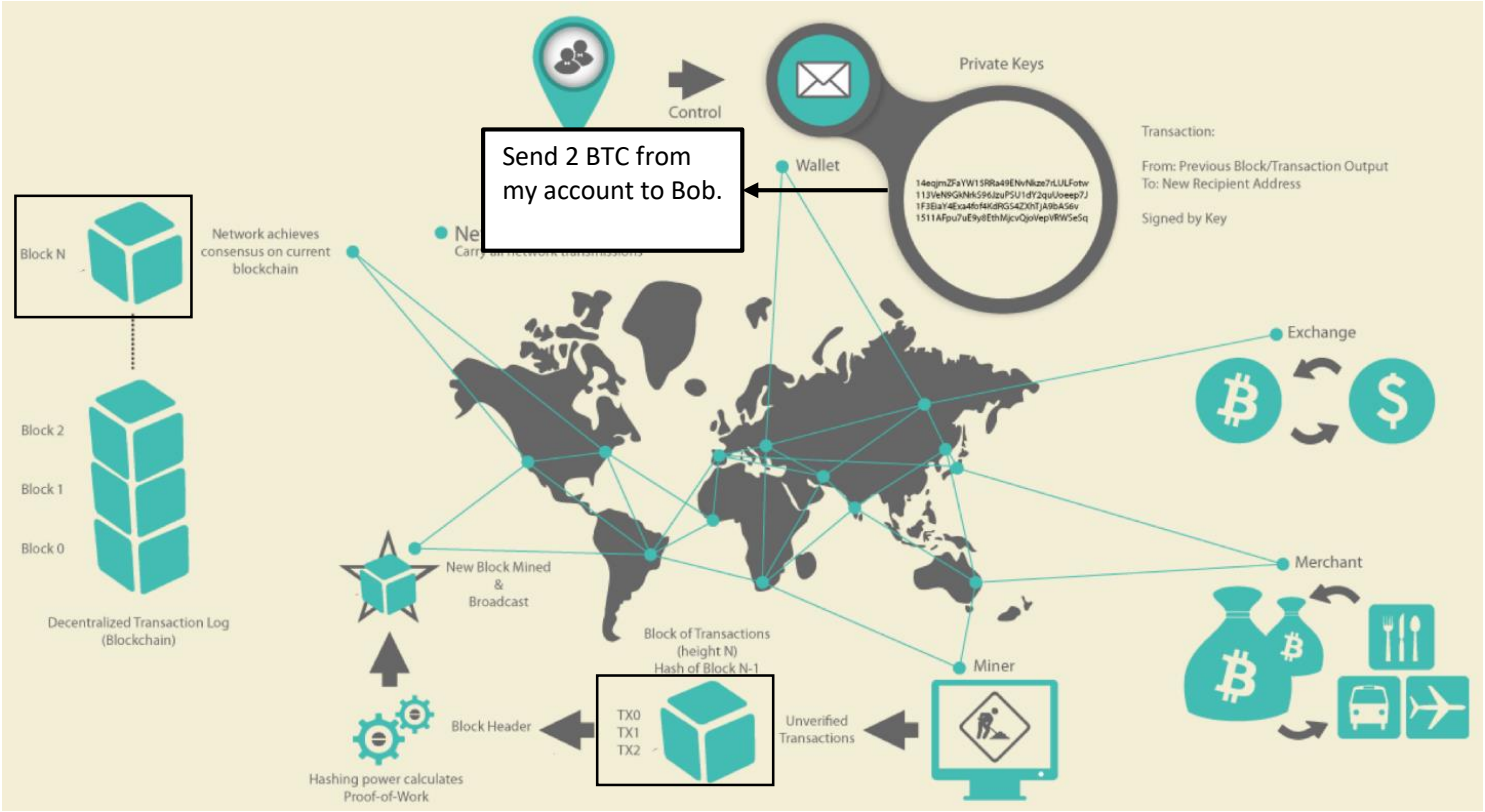
How?



- **Immutable data base**
  - Public ledger
- **Every node hosts a replica**
  - Distributed consensus
    - *No central owner of consensus*
- **Transaction is verified by every node**

- **Combination of knowledge from Distributed Systems, Peer-to-Peer, Cryptography, Incentive Systems and Game Theory**

Blockchain 1st gen — Cryptocurrency



Users:

- create transactions,
- sign them, and
- announce them to network

Miners:

- receive transactions
- include them in a new block,
- (try to) append the new block to the data structure

When a transaction is part of the data structure, it has taken place (though it's a bit more complicated – more later).

Blockchain 2nd gen – Smart Contracts

- 1st gen blockchains: transactions are financial transfers

- Now Blockchain ledger can do that, and store/transact any kind of data

- Blockchain can deploy and execute programs: Smart Contracts
  - User-defined code, deployed on and executed by whole network
  - Can enact decisions on complex business conditions

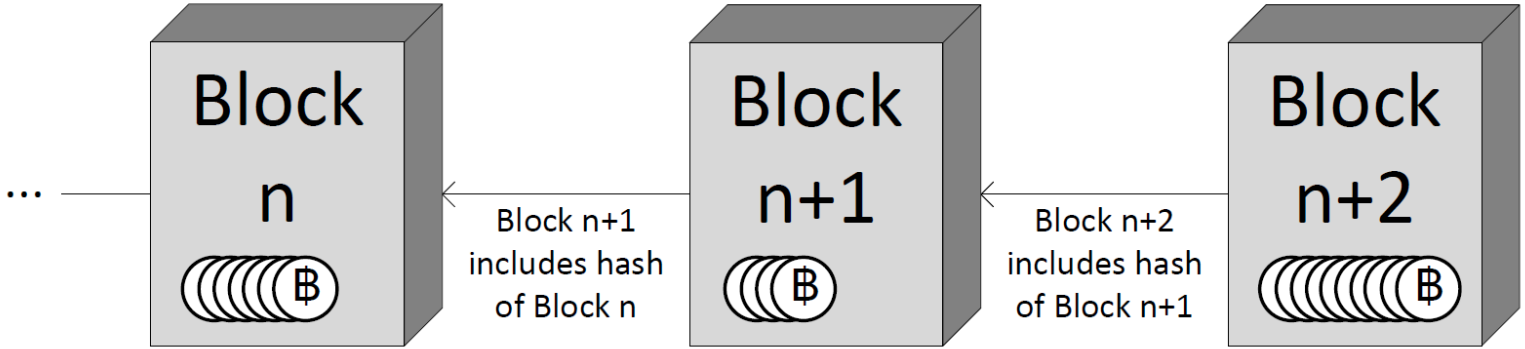
  - Can hold and transfer assets, managed by the contract itself
  - Ethereum: pay per assembler-level instruction

So what?

- Well, blockchains are exciting because they can be used as a new foundation for re-imagining systems:
  - a neutral infrastructure for processing transactions and executing programs
  - potentially interesting for innovation at **all touch-points** between organizations or individuals
  - ➢ **blockchain applications have the potential to disrupt the fabric of society, industry, and government**
- Blockchains can also be used as a technology platform to handle hard issues of data replication and system state synchronization with high integrity.

Defining Blockchain (1)

- **Distributed Ledger**
  - An “append-only” transaction store distributed across machines
  - A new transaction might reverse a previous transaction, but both remain part of the ledger
- **Blockchain**
  - A distributed ledger structured into a linked list of blocks.
  - Each block contains an ordered set of transactions
  - Use cryptographic hashes to secure the link from a block to its predecessor.



Defining Blockchain (2)

- A **Blockchain System** consists of
  - A blockchain network of nodes
  - A blockchain data structure
    - For the ledger replicated across the blockchain network
    - Full nodes hold a full replica of the ledger
  - A network protocol
    - Defines rights, responsibilities, and means of communication, verification, validation, and consensus across the nodes in the blockchain network
    - Includes ensuring authorisation and authentication of new transactions, mechanisms for appending new blocks, incentive mechanisms

Defining Blockchain (3)

- A **Public Blockchain** is a blockchain system with the following characteristics:
  - Has an open network
    - Nodes can join and leave without requiring permission from anyone
  - All full nodes can verify new transactions and blocks
  - Incentive mechanism to ensure the correct operation
    - Valid transactions are processed and included in the ledger and invalid transactions are rejected
- A **Blockchain Platform** is the technology needed to operate a blockchain
  - Blockchain client software for processing nodes
  - The local data store
  - Alternative clients to access the blockchain network

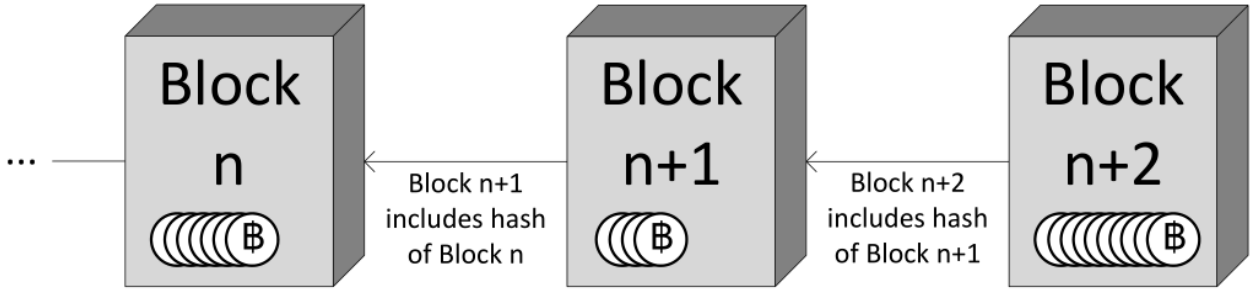
Decentralised Applications and Smart Contracts

- **Smart contracts**
  - Programs deployed as data and executed in transactions on the blockchain
  - Blockchain can be a computational platform (more than a simple distributed database)
  - Code is deterministic and immutable once deployed
  - Can invoke other smart contracts
  - Can hold and transfer digital assets
- **Decentralized applications** or **dapps**
  - Main functionality is implemented through smart contracts
  - Backend is executed in a decentralized environment
  - Frontend can be hosted as a web site on a centralized server
    - Interact with its backend through an API
  - Could use decentralized data storage such as IPFS
  - "State of the dapps" is a directory recorded on blockchain: https://www.stateofthedapps.com/

Blockchain defined (1/4)

Verbatim from the Book

- **Definition 1 (Distributed Ledger).** A Distributed Ledger is an *append-only store of transactions* which is distributed across many machines.
- **Definition 2 (Blockchain (Concept)).** A Blockchain is a *distributed ledger* that is structured into a *linked list of blocks*. Each block contains an ordered set of transactions. Typical solutions use cryptographic hashes to secure the link from a block to its predecessor.



Blockchain defined (2/4)

Verbatim from the Book

- **Definition 3 (Blockchain System).** A Blockchain System consists of:
  - a *blockchain network* of machines, also called *nodes*;
  - a *blockchain data structure*, for the ledger that is replicated across the blockchain network. Nodes that hold a full replica of this ledger are referred to as *full nodes*;
  - a network *protocol* that defines rights, responsibilities, and means of communication, verification, validation, and consensus across the nodes in the network. This includes ensuring *authorization and authentication* of new transactions, mechanisms for appending new blocks, incentive mechanisms (if needed), and similar aspects.

Blockchain defined (3/4)

Verbatim from the Book

- **Definition 4 (Public Blockchain).** A Public Blockchain is a *blockchain system* that has the following characteristics:
  - it has an *open network* where nodes can join and leave as they please without requiring permission from anyone;
  - all full nodes in the network can *verify each new piece of data* added to the data structure, including blocks, transactions, and effects of transactions; and
  - its protocol includes an *incentive mechanism* that aims to ensure the correct operation of the blockchain system including that valid transactions are processed and included in the ledger, and that invalid transactions are rejected.

Blockchain defined (4/4)

Verbatim from the Book

- **Definition 5 (Blockchain Platform).** A blockchain platform is the *technology needed to operate a blockchain*. This comprises the blockchain client software for processing nodes, the local data store for nodes, and any alternative clients to access the blockchain network.
- **Definition 6 (Smart Contract).** Smart contracts are *programs* deployed as data in the blockchain ledger, and executed in transactions on the blockchain. Smart contracts can *hold and transfer digital assets* managed by the blockchain, and can invoke other smart contracts stored on the blockchain. Smart contract code is *deterministic and immutable* once deployed.
- **Definition 7 (dapp).** A decentralized application or dapp is a software system that is designed to provide its main functionality through smart contracts.

Cryptocurrencies and Tokens

- **Cryptocurrencies**
  - 'Baked in' to the core platform of public blockchains -base currency of blockchains
  - Symbiotic relationship
    - Blockchain keeps track of the ownership of portions of that currency, e.g. Alice owned 2Ether, transferred 1 Ether to Bob, offered 0.01Ether to miner
    - Cryptocurrency enables the incentive mechanism for blockchain operations
- **Digital tokens**
  - Created and exchanged using smart contracts
  - Represent assets
    - Fungible asset: individual units are interchangeable, e.g. company share, gold
    - Non-fungible asset: represents a unique asset, e.g. cryptokitties, car title
- **Not all applications are the same:**
  - Transferring coins / tokens vs. tracking movement of physical goods
  - Core difference: where is the default version of the truth, on or off-chain?

Fungible and Non-fungible Tokens

- Fungible tokens: interchangeable
  - E.g., $2 coin, $10 note
  - Main concern: how many?
  - Ethereum: ERC20 standard
    - https://theethereum.wiki/w/index.php/ERC20_Token_Standard
    - Example: OmiseGO (OMG).

      “The OmiseGO blockchain comprises a decentralized exchange, liquidity provider mechanism, clearinghouse messaging network, and asset-backed blockchain gateway. … It uses the mechanism of a protocol token to create a proof-of-stake blockchain to enable enforcement of market activity amongst participants. Owning OMG tokens buys the right to validate this blockchain, within its consensus rules.”

- Non-fungible tokens
  - E.g., houses, cars, patents
  - Main concern: which ones?
  - Ethereum: ERC721
    - https://github.com/ethereum/EIPs/issues/721
    - Example: cryptokitties https://www.cryptokitties.co/

    -fungible, individual, and their appearance depends on the individual features

Blockchain Applications

Blockchain-based Application

- A **blockchain-based application** (or just **blockchain application**) makes significant use of blockchain
  - dapps are an example, but the concept is far broader
  - significant portions of such applications can be based on traditional systems.
- Globally, many financial services companies, enterprises, startups, and governments are exploring suitable applications
- Areas include supply chain, electronic health records, voting, energy supply, ownership management, and protecting critical civil infrastructure
- By now, most if not all industry sectors have explored blockchain use

- The course (and the book) are about what you need to know to design and build blockchain-based applications

Application Areas – Enterprises and Industry

- **Supply chain**: store key events to ensure goods provenance and logistic visibility
- **IoT**: device access control and software/configuration updates
- **Utility resources and services**: monitoring and payment of usage
- **Digital rights and IP management**: A trusted media asset registry to store hashes, meta-data or other identifier on blockchain and manage access and right information
- **Data management**: A metadata layer for decentralized data sharing and analytics - to discover and integrate large datasets and data analytics services
- **Proof of existence**: store a timestamped record of a hash of the document
- **Inter-divisional accounting**: A shared distributed ledger of inter-divisional accounts
- **Corporate affairs**: Board and shareholder voting and registration

Application Areas – Financial Services

- **Digital currency**
  - New form of money transferred without 3rd parties
  - Programmable money: attach policies to specific parcels of currency
- **(International) payments**
  - Via digital currency with local exchanges between the digital currency and FIAT currencies
  - Pseudonymous: but usually have regulatory requirements to have identity, e.g. Anti-Money Laundering (AML)
- **Reconciliation for correspondent banking**
  - Banks can create a single shared ledger of accounts maintained in real-time
- **Securities settlement**
  - The exchanged assets are represented by tokens using smart contracts
  - Payment are made using tokens or native cryptocurrency
- **Markets**
  - Provides a platform for making and accepting offers to trade assets or services
  - Record the status of the offers
- **Trade finance**
  - Evidence trade-related documents
  - Automate payments

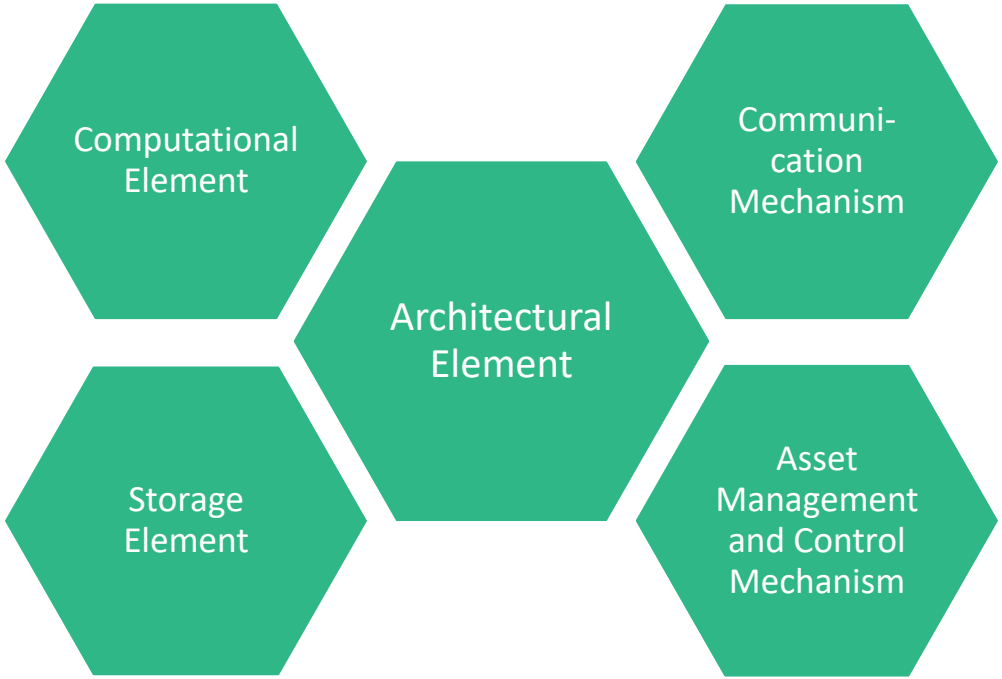
Application Areas – Government Services

- **Registries and identity**
  - Including identities of persons, companies or devices; licensing; qualification; and certification
- **Grants and social security**
  - Automate the process coordination for application, decision making, and payment distribution
  - Allow conditional payments through programmable money – e.g. NDIS – where the money checks the conditions for spending it when attempting to do so
- **Resource quota management**
  - Government granted quotas, allocations, rights to physical resources could be awarded and tracked through tokens
  - E.g. water access licenses can provide rights to take a certain volume of water from specific sources during specific time frames
- **Taxation**
  - Automate tax collection using smart contract

Blockchain Functionality

Functions Blockchain can provide in a dapp

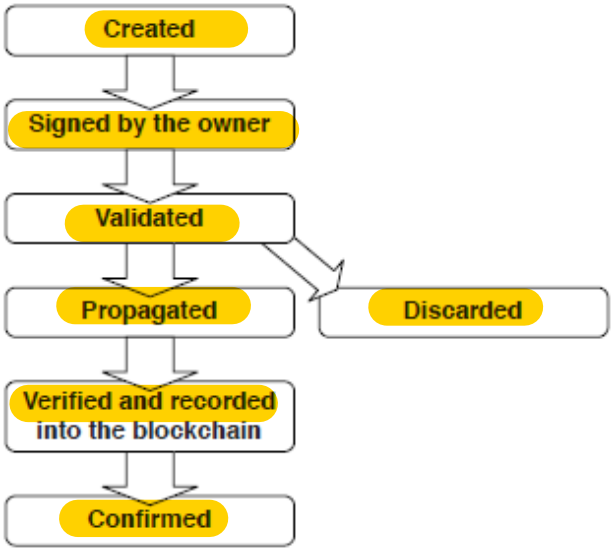
- Blockchain as…



Blockchain Functionality

Blockchain as Storage Element

- Append only data store – prevent tampering of data
  - An ordered list of blocks, where each block contains a small (possibly empty) list of transactions.
  - Each block in is “chained” back to the previous block, by containing a hash of the previous block
- Transactions
  - Information is recorded within the transactions
  - Update blockchain states
  - Store code, variables, and results of function call results
  - Public key and digital signatures are normally used to identify accounts and to ensure integrity and authorisation of transactions



Blockchain Functionality

Blockchain as a Computational Infrastructure

- Smart contracts: programs, typically small in size, on the blockchain (e.g. escrow)
- Architectural decision
  - Which parts of data and computation should be placed on-chain or kept off-chain since the amount computation power, data storage space and control of read accesses on a blockchain can be limited
  - A common practice: store hashed data, meta-data and small-sized public data on-chain and keep large and private data off-chain
- There are existing platforms (e.g. IPFS) that can be used for providing a data layer on top of blockchain
- Oracles: interacting with the external world

Blockchain Functionality

Blockchain as a Communication Mechanism

- Transactions that are announced get broadcast across the network
- Committing a transaction to the data structure may be required before regarding the transaction as final
  - …or the receiver can already act based on the announcement

Blockchain as an Asset Management and Control Mechanism

- Cryptocurrency and tokens are virtual assets
- Typically, only the owner can control them
- More complex models can be implemented, e.g.:
  - Multi-signature or threshold voting (more than one account controls an asset)
  - Escrow: smart contract code controls an asset
- Very customizable through smart contracts

Blockchain Non-functional Properties

Blockchain Non-functional Properties

- Immutability
  - If data is contained in a committed transaction, it will eventually become immutable
- Non-repudiation
  - The immutable chain of cryptographically-signed historical transactions provides non-repudiation of the stored data
- Integrity: cryptographic tools support data integrity
- Transparency: public access (on permission-less blockchains)
- Equal rights
  - Allows every participant the same ability to access and manipulate the blockchain
- Trust: Achieved from the interactions between nodes within the network

Blockchain Non-functional Properties

Limitations

- Data privacy
  - No privileged users
  - Tradeoff between data privacy and transparency
- Scalability
  - Size of the data: due to the global replication of all data across the network
  - Transaction throughput: 3-20 transactions per second (tps)
    - VISA network handles 1700 tps on average
  - Latency of data transmission
    - Write latency caused by propagation
    - Number of transactions included in each block (1MB for bitcoin)
    - Latency between submission and confirmation caused by consensus protocol
- All addressed through various research and development
  - But there is no one-size-fits-all solution (yet?)

Decentralization

Deployment

Deployment Option	Impact			
	Fundamental properties	Cost efficiency	Performance	Flexibility
Public blockchain	⊕⊕⊕	⊕	⊕	⊕
Consortium/community blockchain	⊕⊕	⊕⊕	⊕⊕	⊕⊕
Private blockchain	⊕	⊕⊕⊕	⊕⊕⊕	⊕⊕⊕

Decentralization

Permissions

- A blockchain may be permissioned: having one or more authorities act as a gate for participation
  - Permission to join the network, to initiate transactions, to mine, to create an asset etc.
  - Suitable in regulated industries. E.g. banks are required to establish real-world identity of transacting parties
  - Depends on the size of the network
  - Tradeoffs between permissioned and permission-less blockchain
    - Transaction processing rate, cost, flexibility, reversibility, etc.
  - Permission management mechanism may become a single point failure

Anonymity

- Zero-knowledge proofs
  - Maintain a secure ledger
  - Private payment without disclosing the parties or amounts involved
  - E.g. Zcash encrypts the payment information in the transactions and uses a cryptographic method to allow verifying the encrypted transaction
- Mixing services
  - Groups several transactions together
    - Payment contains multiple input addresses and multiple output addresses
  - Examples: Monero, CoinJoin, Blindcoin, CoinSwap

Blockchain Architecture Design

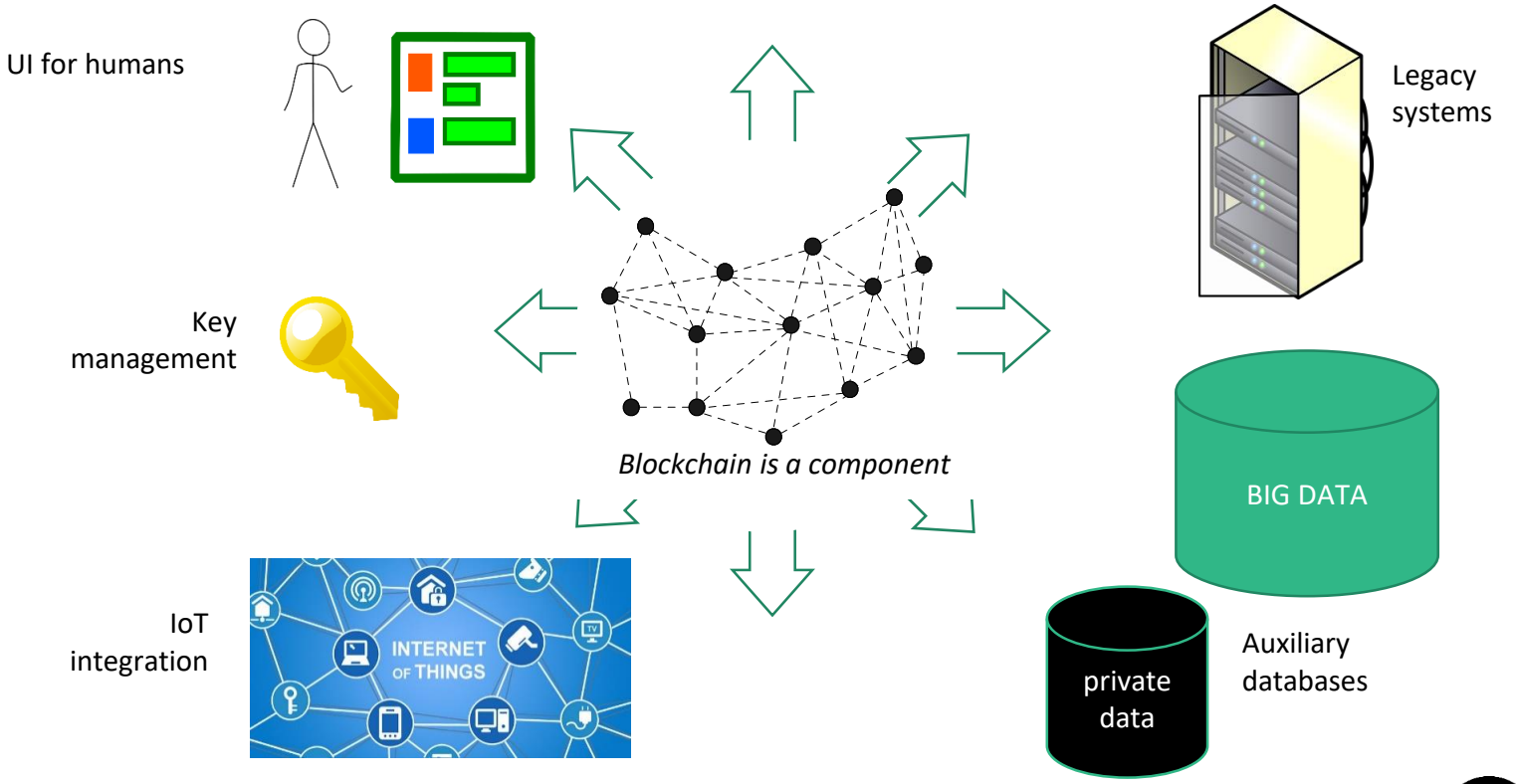
Overview

- Many **interesting applications** for Blockchain
  - Basically of interest in most lack-of-trust settings where a distributed application can coordinate multiple parties
  - Examples:
    - Supply chains
    - Handling of titles, e.g., land, water, vehicles
    - Identity
  - Many startups and initiatives from enterprises / governments
- ... but also many **challenges**
  - When to use blockchain
  - Trade-offs in architecture
    - Downsides: cost, latency, confidentiality
    - What to handle on-chain, what off-chain?

Relevant Topics in the Course

- Architecting applications on Blockchain:
  - Taxonomy and design process
  - Blockchain as an element in an architecture
    - Functional and non-functional properties of blockchain
  - Blockchain Patterns
  - Cost: how much will using blockchain cost?
  - Latency: simulation under changes
  - Security and Dependability
- Model-driven development of smart contracts
  - Business process execution
  - Model-based generation of registries and UIs

Blockchains are Not Stand-Alone Systems



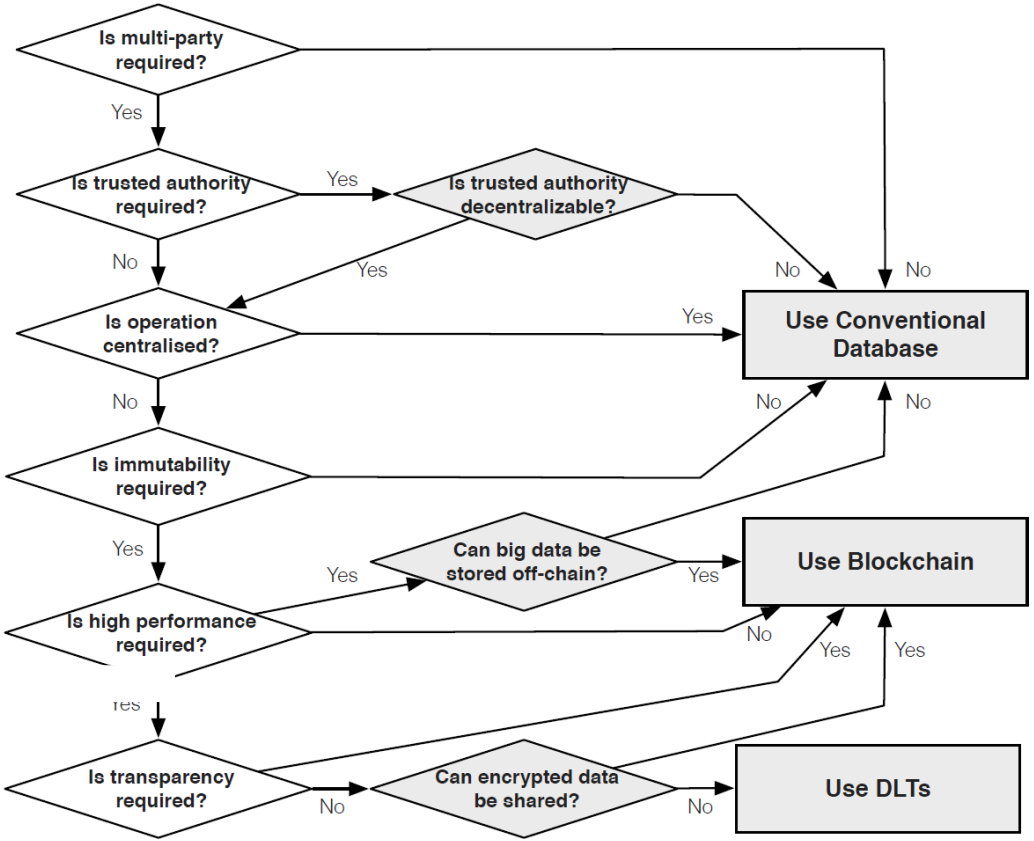
Non-Functional Trade-Offs

- Compared to conventional database & script engines, blockchains have:
  - (-) Confidentiality, Privacy
  - (+) Integrity, Non-repudiation
  - (+ read/ - write) Availability

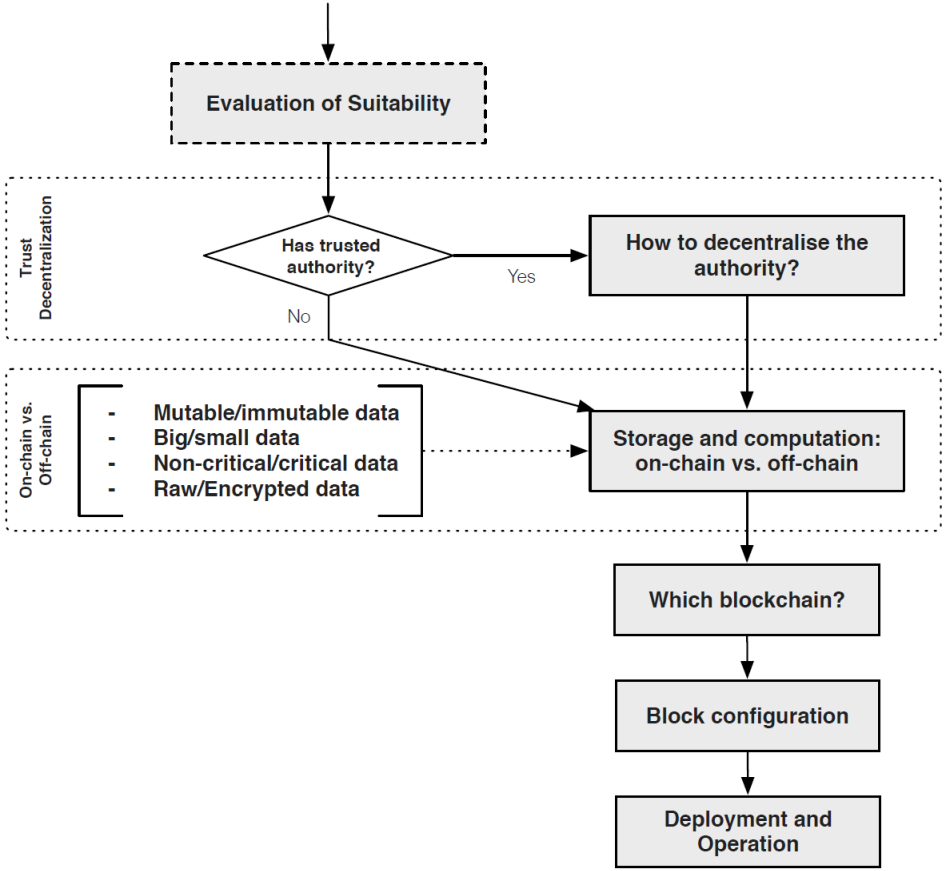
  } Security: combination of CIA properties

  - (-) Modifiability
  - (-) Throughput / Scalability / Big Data
  - (+ read/ - write) Latency

Evaluation of Suitability



Design Process for Blockchain-Based Systems



Taxonomy

Blockchain-related design decisions regarding (de)centralisation, with an indication of their relative impact on quality properties

Legend: ⊕: Less favourable, ⊕⊕: Neutral, ⊕⊕⊕: More favourable

Design Decision	Option	Impact			
		Fundamental properties	Cost efficiency	Performance	#Failure points
Fully Centralised	Services with a single provider (*e.g.*, governments, courts)	⊕	⊕⊕⊕	⊕⊕⊕	1
	Services with alternative providers (*e.g.*, banking, online payments, cloud services)				
Partially Centralised & Partially Decentralised	Permissioned blockchain with permissions for fine-grained operations on the transaction level (*e.g.*, permission to create assets)		⊕⊕	⊕⊕	*
	Permissioned blockchain with permissioned miners (write), but permission-less normal nodes (read)				
Fully Decentralised	Permission-less blockchain	⊕⊕⊕	⊕	⊕	Majority (nodes, power, stake)
		Fundamental properties	**Cost efficiency**	**Performance**	**#Failure points**
Verifier	Single verifier trusted by the network (external verifier signs valid transactions; internal verifier uses previously-injected external state)	⊕⊕	⊕⊕	⊕⊕	1
	M-of-N verifier trusted by the network	⊕⊕⊕	⊕	⊕	M
	Ad hoc verifier trusted by the participants involved	⊕	⊕⊕⊕	⊕⊕	1 (per ad hoc choice)

Also consider skills available for a specific platform

Taxonomy

Blockchain-related design decisions regarding storage and computation, with an indication of their relative impact on quality properties

Design Decision		Option	Impact			
			Fundamental properties	Cost efficiency	Performance	Flexibility
Item data	On-chain	Embedded in transaction (Bitcoin)	⊕⊕⊕⊕	⊕	⊕	⊕⊕
		Embedded in transaction (Public Ethereum)		⊕⊕⊕⊕	⊕	⊕⊕⊕
		Smart contract variable (Public Ethereum)		⊕⊕	⊕⊕⊕	⊕
		Smart contract log event (Public Ethereum)		⊕⊕⊕	⊕⊕	⊕⊕
	Off-chain	Private / Third party cloud	⊕	~KB Negligible	⊕⊕⊕⊕	⊕⊕⊕⊕
		Peer-to-Peer system		⊕⊕⊕⊕	⊕⊕⊕	⊕⊕⊕
Item collection	On-chain	Smart contract	⊕⊕⊕⊕	⊕⊕⊕⊕ (public)	⊕⊕⊕⊕	⊕
		Separate chain		⊕ (public)	⊕	⊕⊕⊕⊕
Computation	On-chain	Transaction constraints	⊕⊕⊕⊕	⊕	⊕	⊕
		Smart contract				
	Off-chain	Private / Third party cloud	⊕	⊕⊕⊕⊕	⊕⊕⊕⊕	⊕⊕⊕⊕

Taxonomy

Blockchain-related design decisions regarding blockchain configuration

Design Decision		Option	Impact			
			Fundamental properties	Cost efficiency	Performance	Flexibility
Blockchain scope		Public blockchain	⊕⊕⊕	⊕	⊕	⊕
		Consortium/community blockchain	⊕⊕	⊕⊕	⊕⊕	⊕⊕
		Private blockchain	⊕	⊕⊕⊕	⊕⊕⊕	⊕⊕⊕
Data structure		Blockchain	⊕⊕⊕	⊕	⊕	⊕
		GHOST	⊕⊕	⊕⊕	⊕⊕	⊕
		BlockDAG	⊕	⊕⊕⊕	⊕⊕⊕	⊕⊕⊕
		Segregated witness	⊕⊕⊕	⊕⊕	⊕	⊕
Consensus Protocol	Security-wise	Proof-of-work	⊕⊕⊕	⊕	⊕	⊕
		Proof-of-retrievability	⊕⊕⊕	⊕	⊕	⊕
		Proof-of-stake	⊕⊕	⊕⊕	⊕⊕	⊕⊕⊕
		BFT (Byzantine Fault Tolerance)	⊕	⊕⊕⊕	⊕⊕⊕	⊕
	Scalability-wise	Bitcoin-NG	⊕⊕⊕	⊕	⊕	⊕
		Off-chain transaction protocol	⊕	⊕⊕⊕	⊕⊕	⊕⊕⊕
		Mini-blockchain	⊕⊕	⊕⊕	⊕	⊕⊕
Protocol Configuration	Security-wise	X-block confirmation	⊕	⊕	⊕	⊕⊕⊕
		Checkpointing	⊕⊕⊕	⊕⊕⊕	⊕⊕⊕	⊕
	Scalability-wise	Original block size and frequency	⊕⊕⊕	n/a	⊕	n/a
		Increase block size / Decrease mining time	⊕	n/a	⊕⊕⊕	n/a
New blockchain	Security-wise	Merged mining	⊕⊕⊕	⊕⊕	⊕	⊕
		Hook popular blockchain at transaction level	⊕⊕	⊕	⊕⊕	⊕⊕⊕
		Proof-of-burn	⊕	⊕	⊕⊕⊕	⊕⊕
	Scalability-wise	Side-chains	⊕⊕⊕	⊕	⊕	⊕
		Multiple private blockchains	⊕	⊕⊕⊕	⊕⊕⊕	⊕⊕⊕

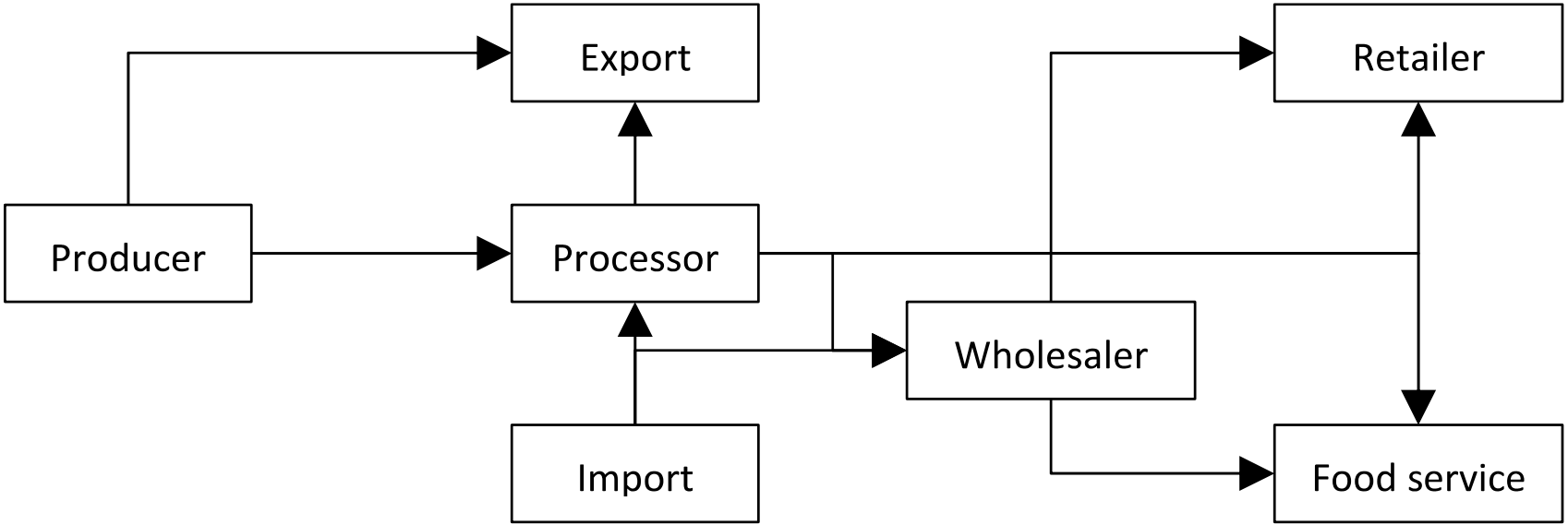
Agenda:

- Part 1: Course Summary
  - Lecturers and Tutor
  - Learning Outcomes, Course Outline, Assessments
- Part 2: Topic Overview
  - What is Blockchain, and Why Does it Matter?
  - Blockchain-based Applications
  - Blockchain Functionality
  - Blockchain Non-functional Properties
  - Blockchain Architecture Design
- Part 3: Impact
  - Use Cases
  - Disruptive Potential of Blockchains

Use Cases

Use Case: Supply Chains

Sample Agricultural Supply Chain Network



Using Blockchain for Supply Chains

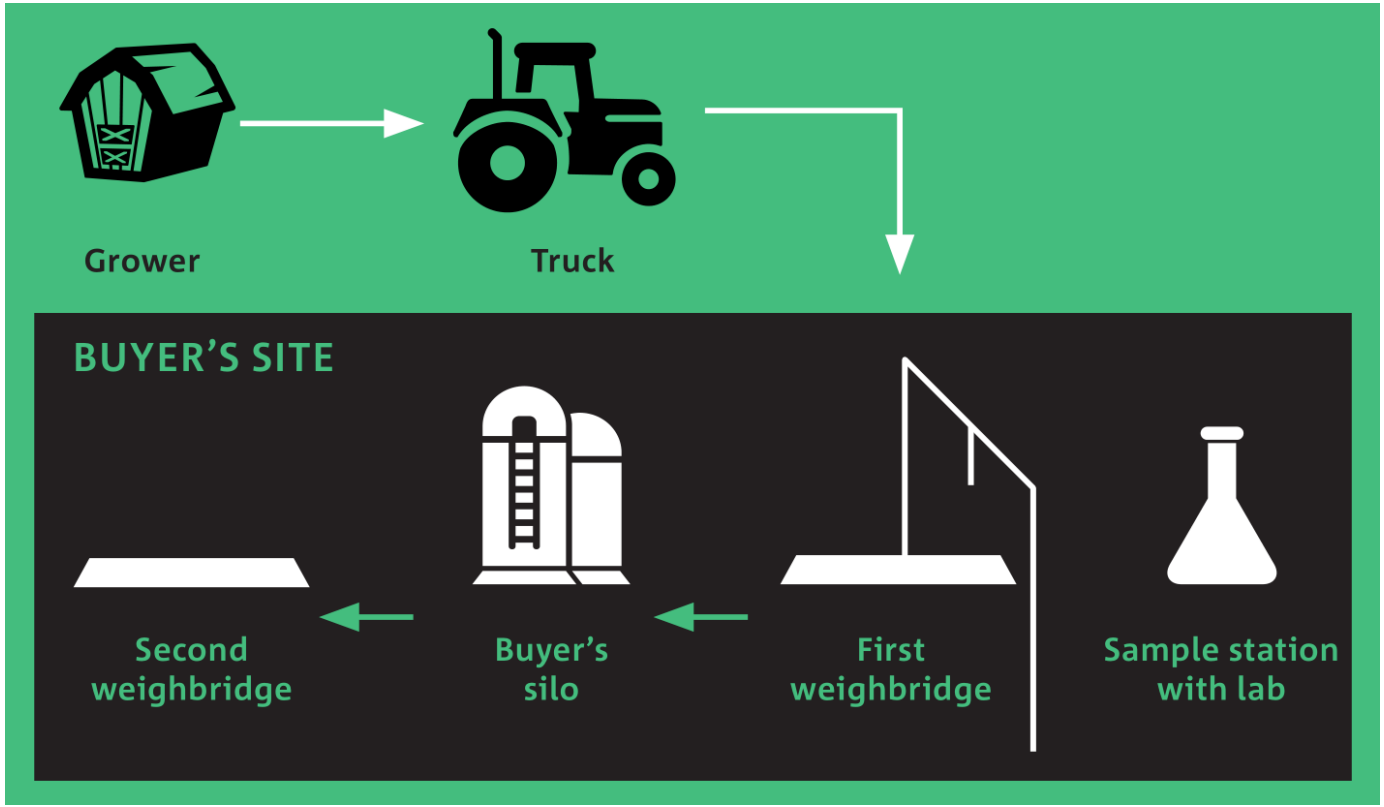
- Why?
  - Irrefutable, tamper-proof data store
    - Prevent or detect counterfeiting
  - Smart contracts can check integrity and authorization / authentication
  - Can solve other problems:
    - Counter-party risks
    - Lack of trust, e.g., in coopetition
    - Supply chain transparency

    ...

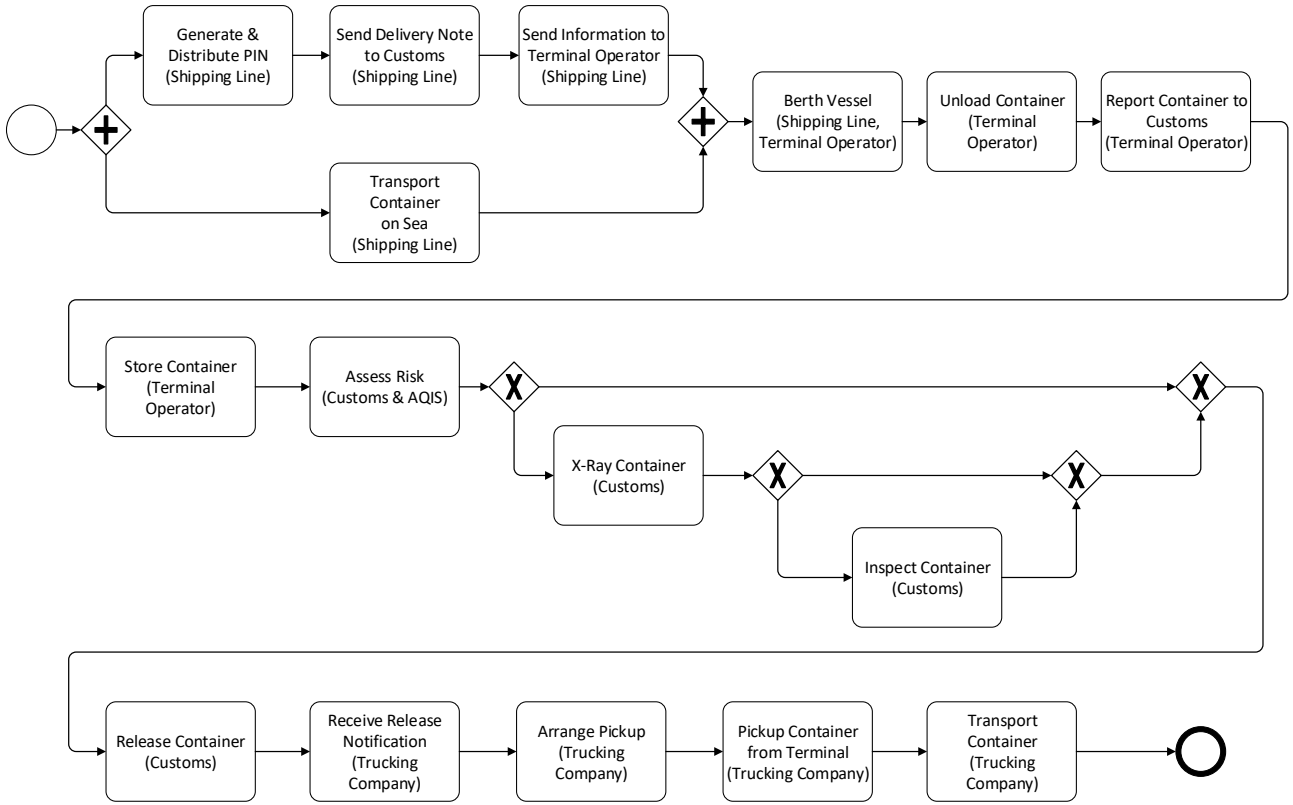
- How?
  - Record supply chain events on blockchain, e.g.:
    - GS1 EPCIS events
    - Other tag scans
    - Phytosanitary certificates
  - Check that event sequences are correct, e.g. through
    1. Process conformance
    2. Business rules adherence
    - Can be on-chain or off-chain
    - Regulatory compliance

Example: AgriDigital's first pilot

see https://www.data61.csiro.au/blockchain / Chapter 12 in the book



Example: Sea Import to Australia



Some Benefits of using Blockchain in Supply Chains

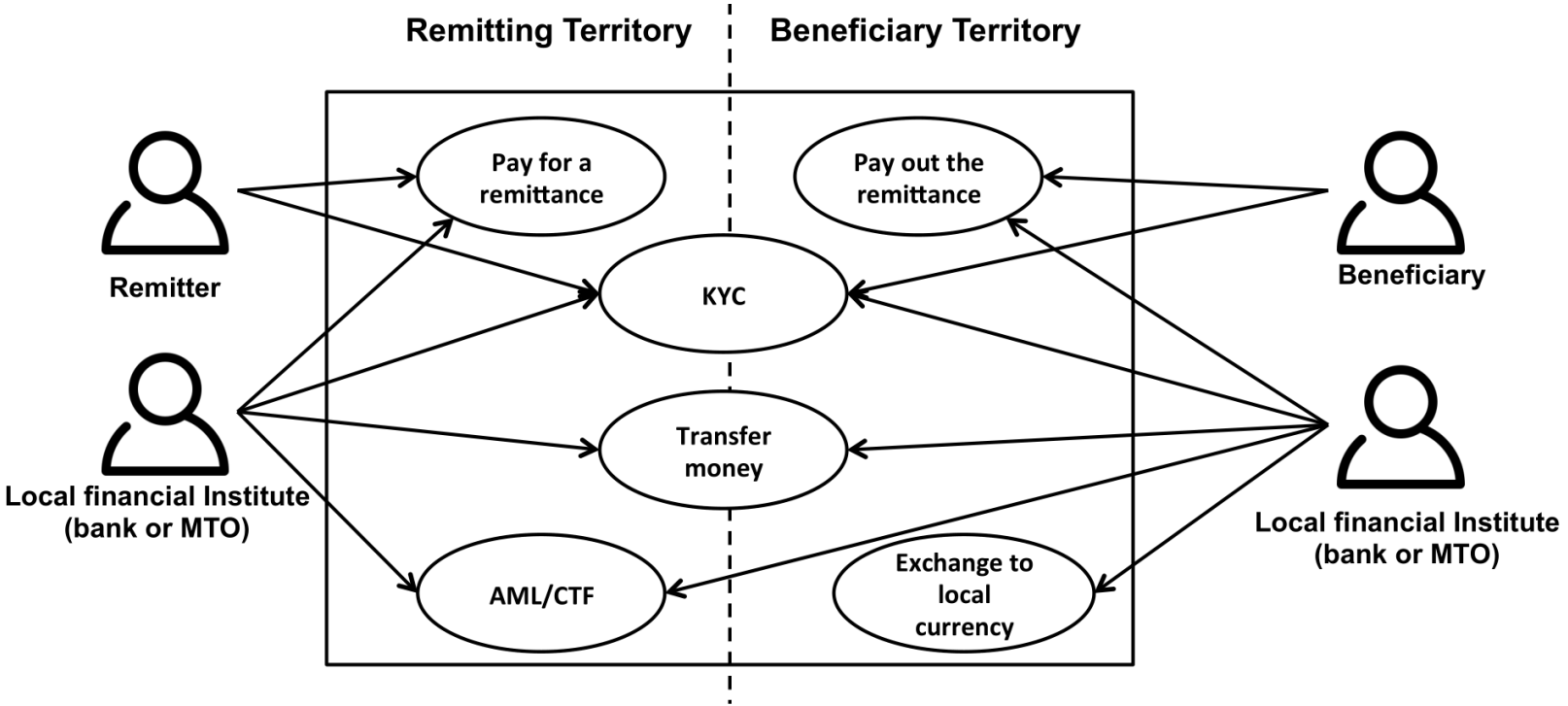
- Electronic titles to supply chain goods
  - Ensure ownership, right to sell, etc are handled correctly
  - Reduce financial risk – e.g.: if a buyer goes bankrupt before paying for the goods, the seller still owns them
- Establish identity and authenticity for:
  - Requester
  - Other relevant supply chain participants
- Check financial record / trustworthiness
- Ensure correctness of specific supply chain documents
  - E.g., invoice, purchase order, ...

Use Case: International Money Transfers

- Many workers in Australia regularly send money back to their families overseas
  - Up to 10% of GDP in some developing countries (and even 27% in Tonga and 20% in Samoa)
  - High remittance costs have serious effects in these countries
- Remittance costs in Pacific Island countries are among the highest in the world
  - For example, to send $200 from Australia to Vanuatu costs $33.20 and $28.60 to Samoa
- Issues:
  - Many parties involved, sometimes little transparency
  - Difficulties of satisfying AML/CTF (Anti-Money Laundering/Counter-Terrorism Financing) regulation, especially where the receiving party may not have a bank account.
  - High latency, with transaction times up to 5days.

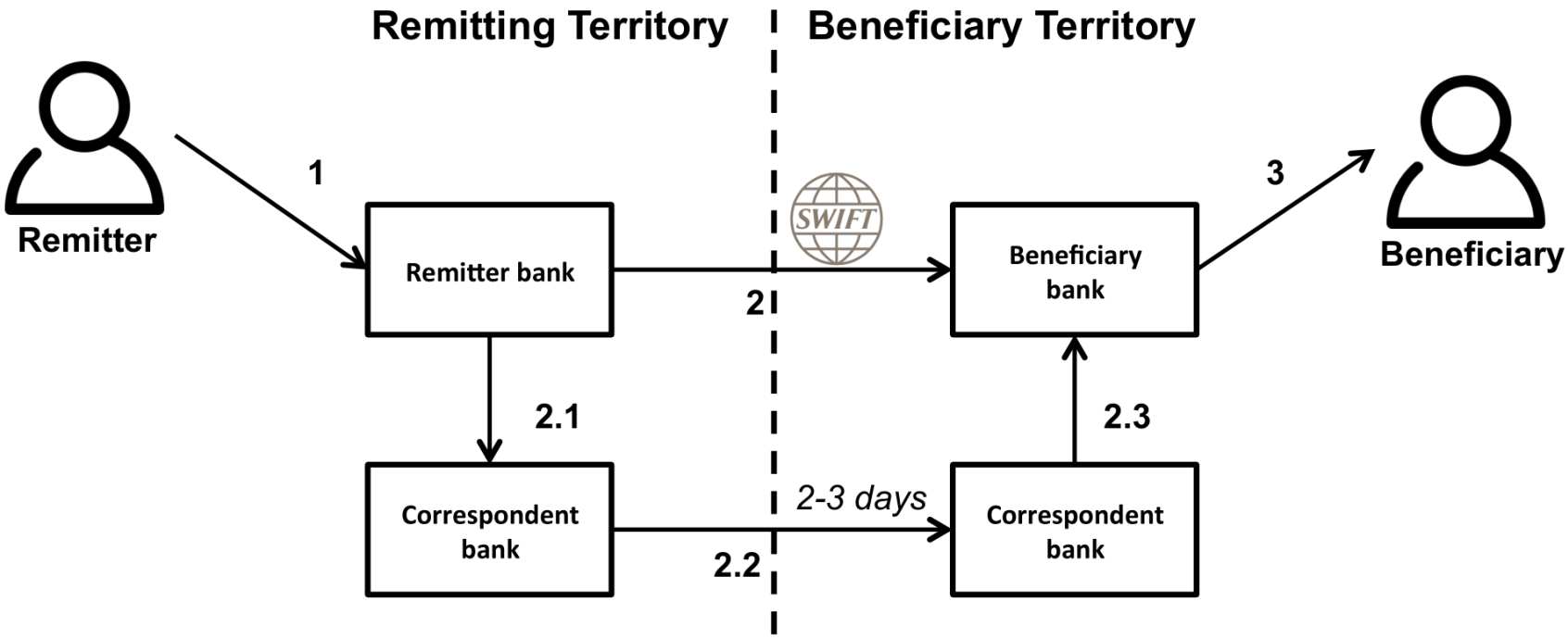
Use Case: International Money Transfers

Stakeholders and Functions



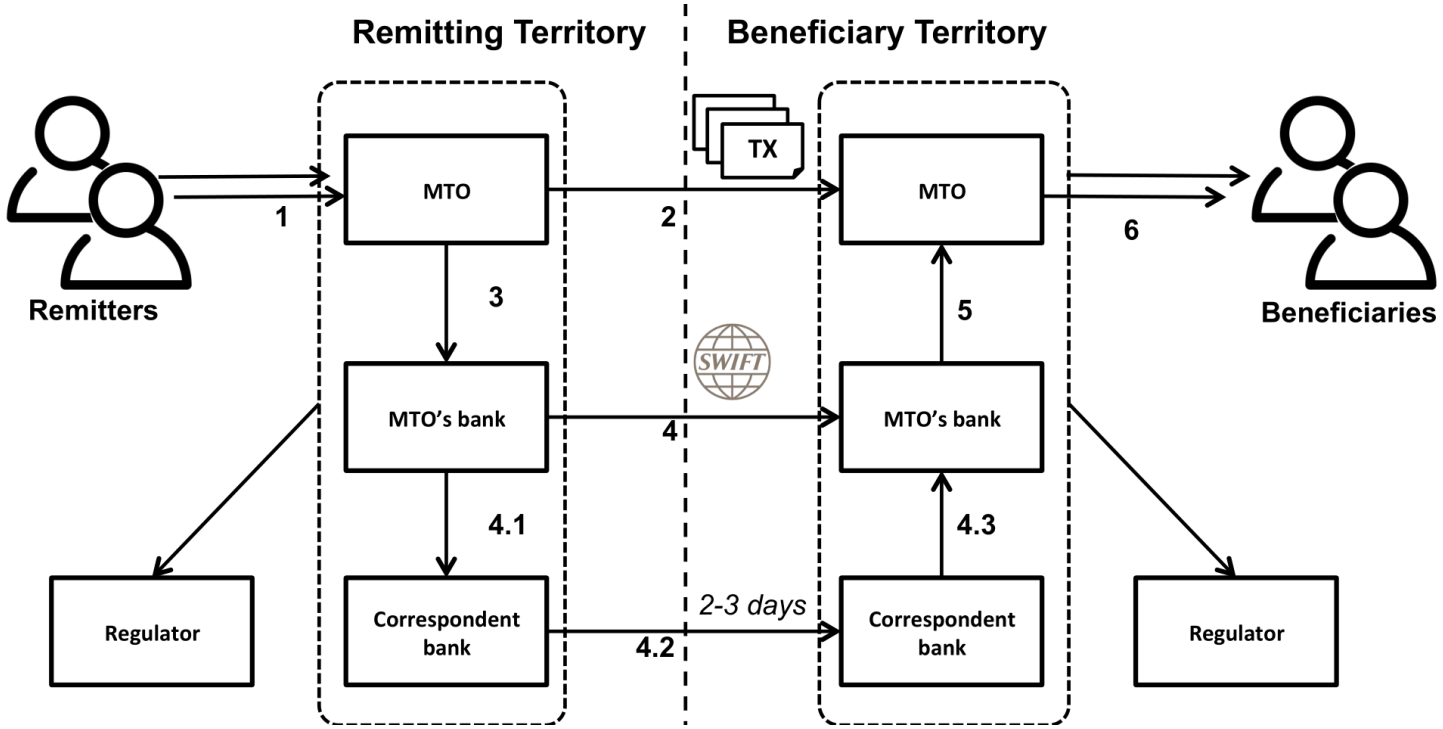
Use Case: International Money Transfers

Remittance through banks



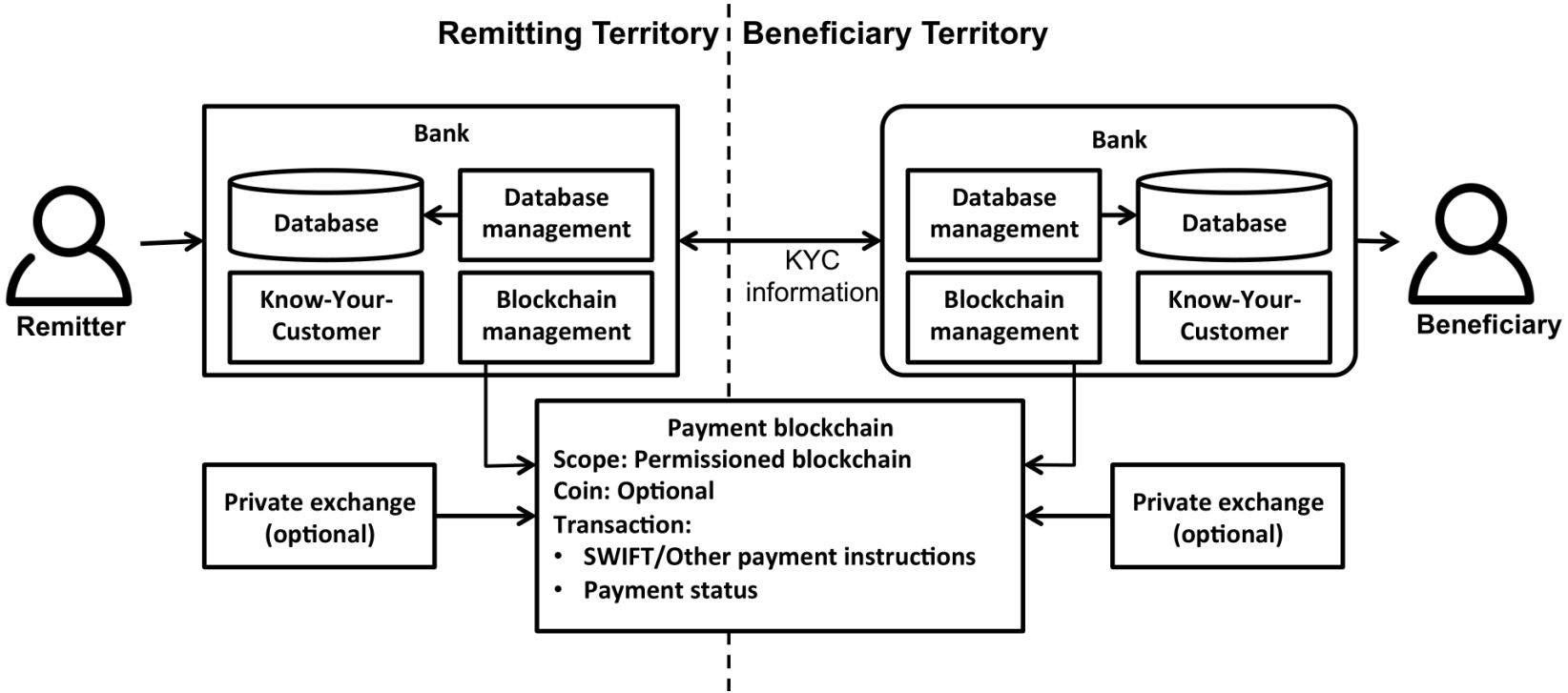
Use Case: International Money Transfers

Remittance through a Money Transfer Operator (MTO)



Use Case: International Money Transfers

Remittance through Blockchain



Alternatively, use existing cryptocurrencies like Bitcoin.

Intl. Money Transfers Non-functional Properties

- Transaction Latency:
  - From days (conventional) to hours or minutes (with blockchain)
- Cost:
  - Depends on the fees charged by various parties – but more parties are involved in the conventional designs
- Transparency:
  - Greater in the blockchain setting; foreign exchange rates might still be unfavourable for the customers
- Barriers to Entry
  - Conventional design requires participants to have banking / financial services licenses, and business relationships with correspondent banks
  - Public blockchains have low barriers to entry, but local regulation still applies to end-points within countries

Disruptive Potential of Blockchains

Disruptive potential? (1/3)

Based on Foreword by Len Bass, PhD, CMU

- Many articles call blockchain a disruptive technology
- Think about the disruption caused by the World Wide Web and the cloud:
  - WWW changed the lives of consumers, cloud changed the lives of the producers
- Blockchain's most direct impact will likely be in the backend
  - But there are exceptions – especially where there is no centralized authority or it cannot be trusted, or going around it pays off
  - Example: the Zaatari refugee camp in Jordan that 'runs' on blockchain

Disruptive potential? (2/3)

Based on Foreword by Len Bass, PhD, CMU

- Example: the Zaatari refugee camp in Jordan that ‘runs’ on blockchain
  - See https://www.technologyreview.com/s/610806/inside-the-jordan-refugee-camp-that-runs-on-blockchain/
- Iris scan allows refugees to spend money from their blockchain accounts
- Outcomes:
  - Saves approx. 98% of fees - similar to half of the international money transfer use case
  - Might serve as identity solution, in absence of government IDs

Disruptive potential? (3/3)

Based on Foreword by Len Bass, PhD, CMU

- Disruptive use cases?
  - Supply chain: increase efficiency, decrease latency and fees
  - Proof of identity:
    - Most disruptive if respective government authorities are dysfunctional or uncooperative
    - NSW virtual driver licence said to use blockchain (but details unknown as yet)
- Advantages of using blockchain can be substantial, but not necessarily disruptive to the consumer
- However, Amara's law says:

> *"We tend to overestimate the effect of a technology in the short run and underestimate the effect in the long run."*

Summary of today:

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Course Outline – next two weeks

Week	Date	Lecturer	Lecture Topic	Relevant Book Chapters	Notes
1st	18 Feb	Ingo Weber	Introduction	1. Introduction 4. Example use cases	
2nd	25 Feb	Ingo Weber	Existing Blockchain Platforms	2. Existing Blockchain Platforms (1h on smart contract dev)	Assignment 1 out (Monday before lecture)
3rd	4 Mar	Sherry Xu	Blockchain in Software Architecture 1	3. Varieties of blockchain 5. Blockchain in Software Architecture (including software architecture basics) 1/2	

Note: **tutorials** run from week 2 to week 9.
They are not mandatory, but helpful,
especially for completing the assignments.

End of Lecture / Consultation

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