Architectures Explored

What’s inside blockchain, and how it fits in a systems architecture

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Blockchain Explored Series

- IBM Blockchain Platform Explored
- Modeling Applications
- **Architectures Explored**
- Fabric Explored
- What’s New in Tech

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IBM **Blockchain**

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Blockchain Data Structures

Describing the blockchain using computer science principles

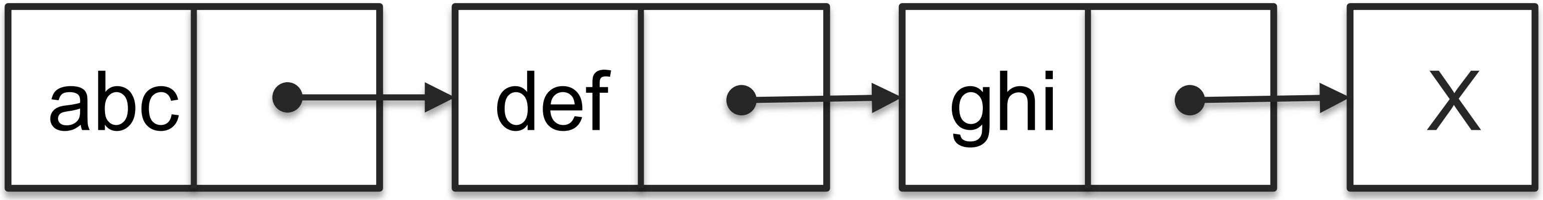
Operational Considerations

Consensus, integration, security, business and non-functional requirements

Optimizing Performance

The Linked List

- Linear collection of data elements
- Each element is linked to the next
- Concept dates from 1955



One-Way Hash Functions

- Any function that can be applied to a set of data that is guaranteed to produce the same output for the same input
- One-way means that you can’t derive the input from the output
- Often, outputs are *unlikely* to repeat for different inputs
- Forms the basis of much cryptography

h(abc) = 7859
h(def) = 8693
h’(7859) = ?
h(abc) = 7859

The Hash Chain

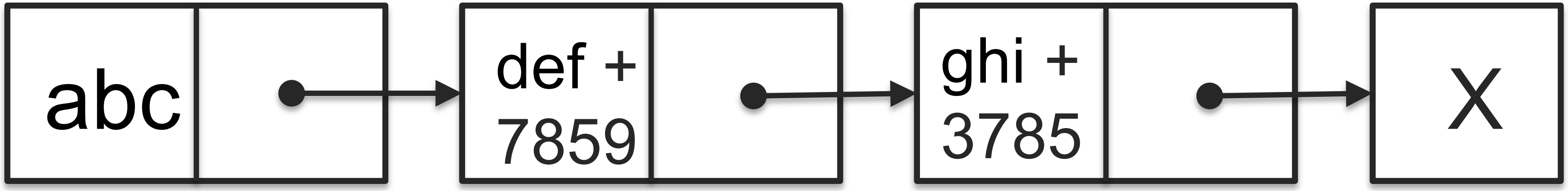
Hash chain: A successive application of a hash function

$$h(h(h(abc))) = 1859$$

Can combine new data with each successive hash:

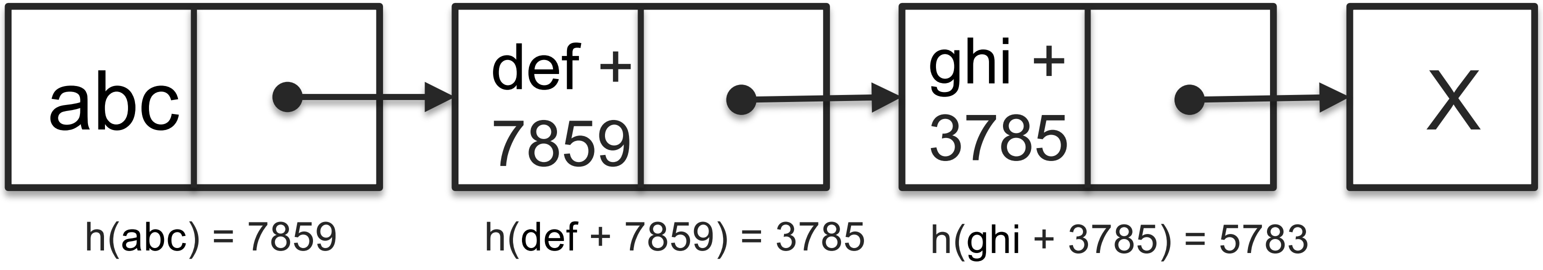
$$h(ghi+h(def+h(abc))) = 5783$$

Using this concept you can produce a tamper resistant linked list:

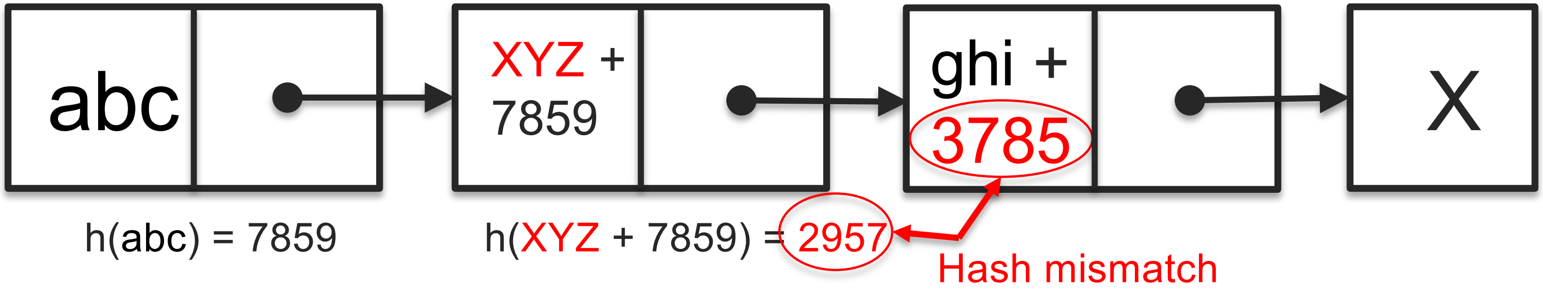


h(abc) = 7859 h(def + 7859) = 3785 h(ghi + 3785) = 5783

How is This Tamper Resistant?



- Any modification to a data element means that the hashes will not match up
  - You would need to recreate the downstream chain

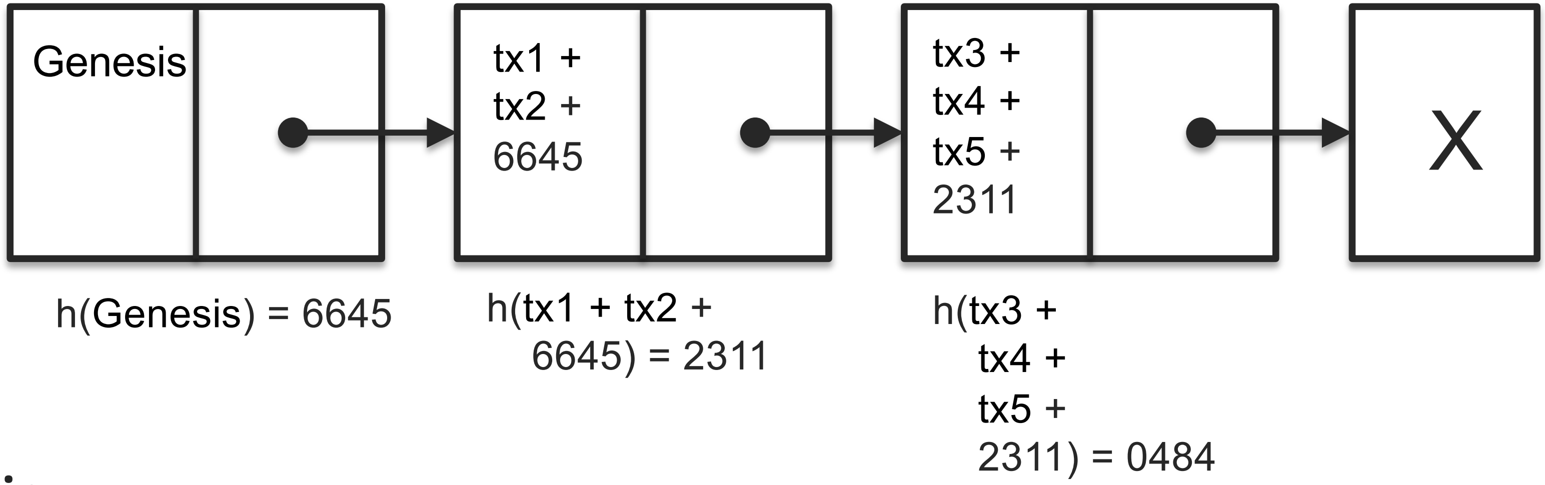


Applied to Blockchain

- A blockchain is a hash chain (*with optimizations* that we'll cover shortly)

- Each element (block) in the linked list is a set of zero or more transactions
  - Transactions are an implementation-dependent data object

- First block known as a genesis block
  - May contain some identifying string or other configuration metadata



Some Problems with This Approach

- In the event of tampering, it can be difficult to identify which transaction was modified (particularly when there are many transactions in a block)
  - It is not feasible to have one transaction per block

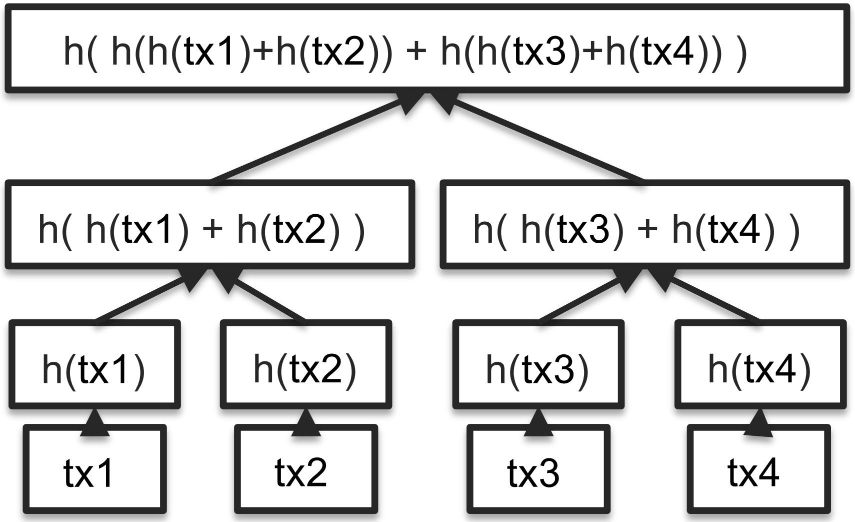
- It requires all transaction data in order to retain integrity of chain

- Searching transactions is linear (time consuming)

Merkle Tree

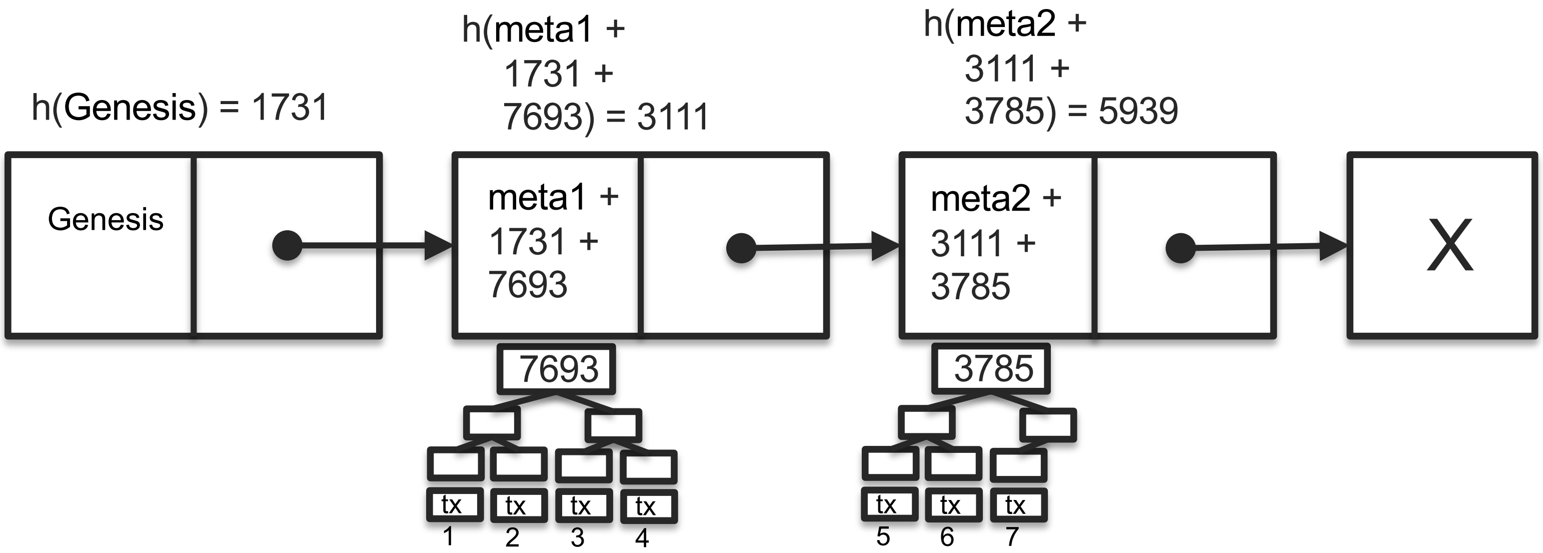
- It is possible to optimise the chain data structure if we arrange it as a tree
  - Makes it easier to identify tampering without sacrificing stability
  - Makes it quicker to traverse

- However, this makes it impossible to add new transactions without re-hashing root nodes



Combining Tree and Chain

- Each element in the chain contains:
  - A pointer (“Merkle root”) to the tree of transactions
  - Other metadata (e.g. timestamp)
  - A hash of the previous block’s data (i.e. Merkle root, metadata and hash)



Common Transactions

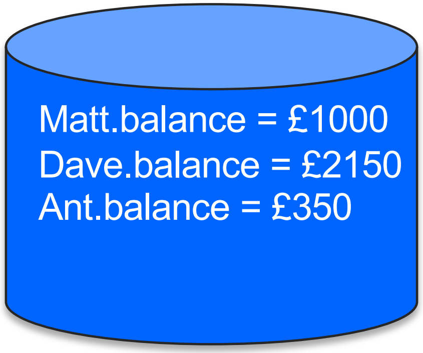
- What’s Dave’s balance?

- Does Matt have funds to clear a £1000 transaction? (Assuming no overdraft)

#	Transaction	Initiator	Receiver	Amount
1	Create a/c	Cash	Matt	£1000
2	Create a/c	Cash	Dave	£2000
3	Transfer	Matt	Dave	£100
4	Create a/c	Cash	Ant	£500
5	Transfer	Ant	Matt	£50
6	Transfer	Ant	Dave	£200
7	Transfer	Dave	Matt	£100
8	Transfer	Dave	Ant	£50
9	Transfer	Matt	Ant	£50

World State

- It is clearly not feasible to reparse the entire transaction log to complete a new transaction
- Blockchains often include an associated database (world state) – e.g. Hyperledger Fabric
- Transactions become a set of creates, reads, updates and deletes of records in this data store

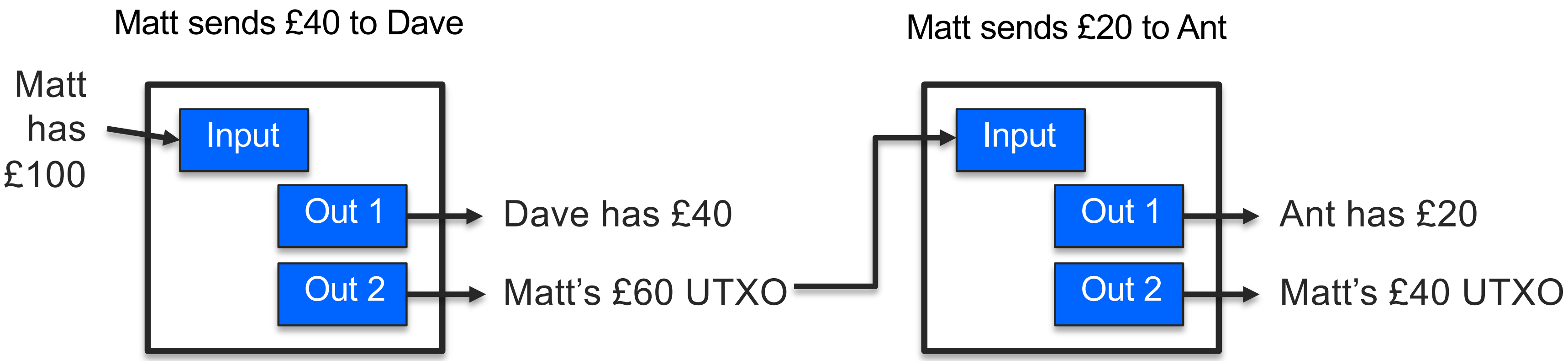


Matt.balance = £1000
Dave.balance = £2150
Ant.balance = £350

#	Transaction	Initiator	Receiver	Amount
1	Create a/c	Cash	Matt	£1000
2	Create a/c	Cash	Dave	£2000
3	Transfer	Matt	Dave	£100
4	Create a/c	Cash	Ant	£500
5	Transfer	Ant	Matt	£50
6	Transfer	Ant	Dave	£200
7	Transfer	Dave	Matt	£100
8	Transfer	Dave	Ant	£50
9	Transfer	Matt	Ant	£50

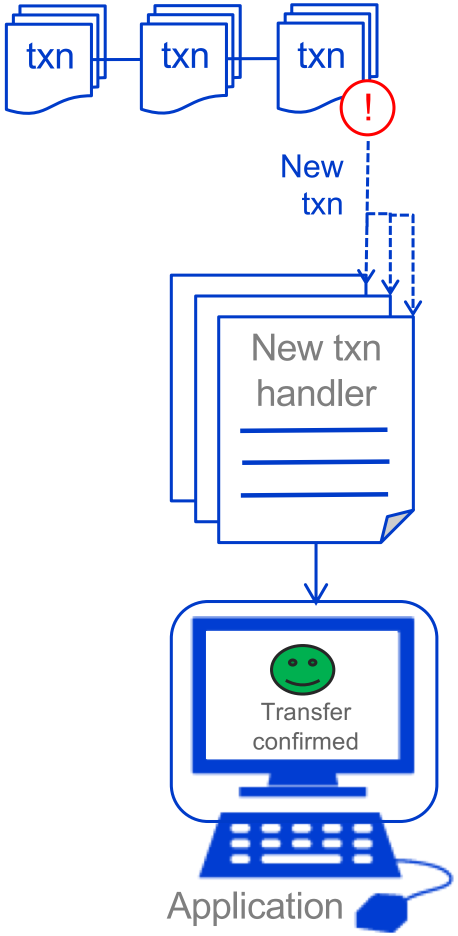
Unspent Transaction Outputs

- Some blockchains (e.g. Bitcoin) don’t maintain balances
  - Transactions are linked to earlier transactions using an ID (TXID)
  - Outputs always equal inputs
  - Unspent funds are marked as an “Unspent Transaction Output” (UTXO)
  - Only UTXOs can be used as inputs (to prevent double spending)
  - Your “balance” is the aggregation of all of your UTXOs
- In Bitcoin, if your application doesn’t specify the UTXO output then the miner gets the excess!



How Events are Used in Blockchain

- In computing, an event is an occurrence that can trigger handlers
  - e.g. disk full, fail transfer completed, mouse clicked, message received, temperature too hot…
- Events are important in asynchronous processing systems like blockchain
- The blockchain can emit events that are useful to application programmers
  - e.g. Transaction has been validated or rejected, block has been added…
- Events from external systems might also trigger blockchain activity
  - e.g. exchange rate has gone below a threshold, the temperature has gone up, a time period has elapsed…



Blockchain Data Structures

Describing the blockchain using computer science principles

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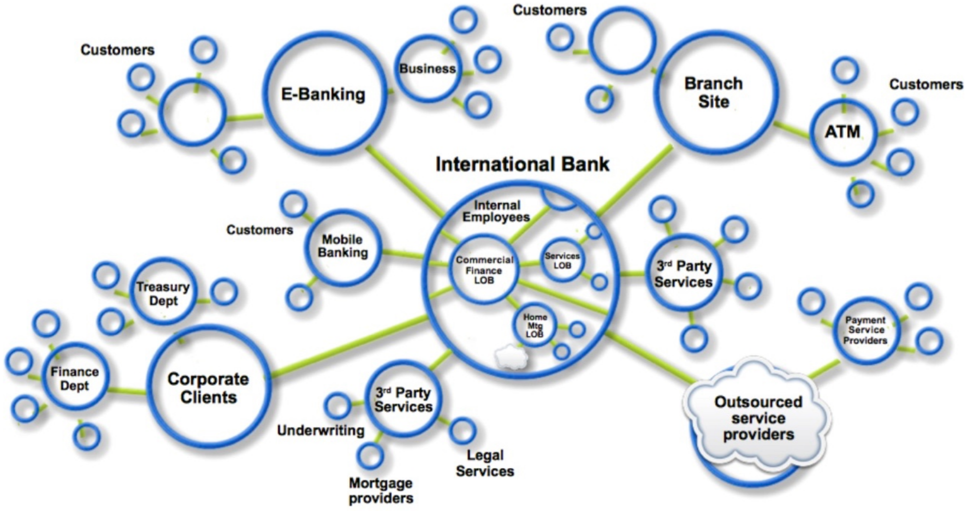
Consensus, integration, security, business and non-functional requirements

Optimizing Performance

The Power of the Network

- These data structures are just bytes on disk
- Can still be manipulated or destroyed (e.g. by a DB admin)
- Proof (and trust) in the blockchain comes from the power of the network…

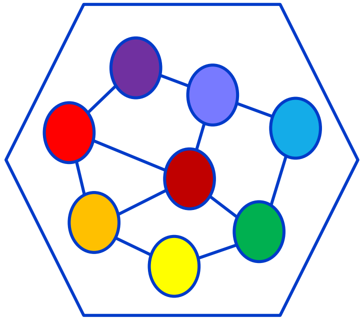


Network Nodes

- A blockchain network comprises a set of nodes that share information
  - Usually peer-to-peer
  - Some blockchains are worldwide, others are private to a business network
  - It might make sense to have one node per business network participant, but this is not necessarily so

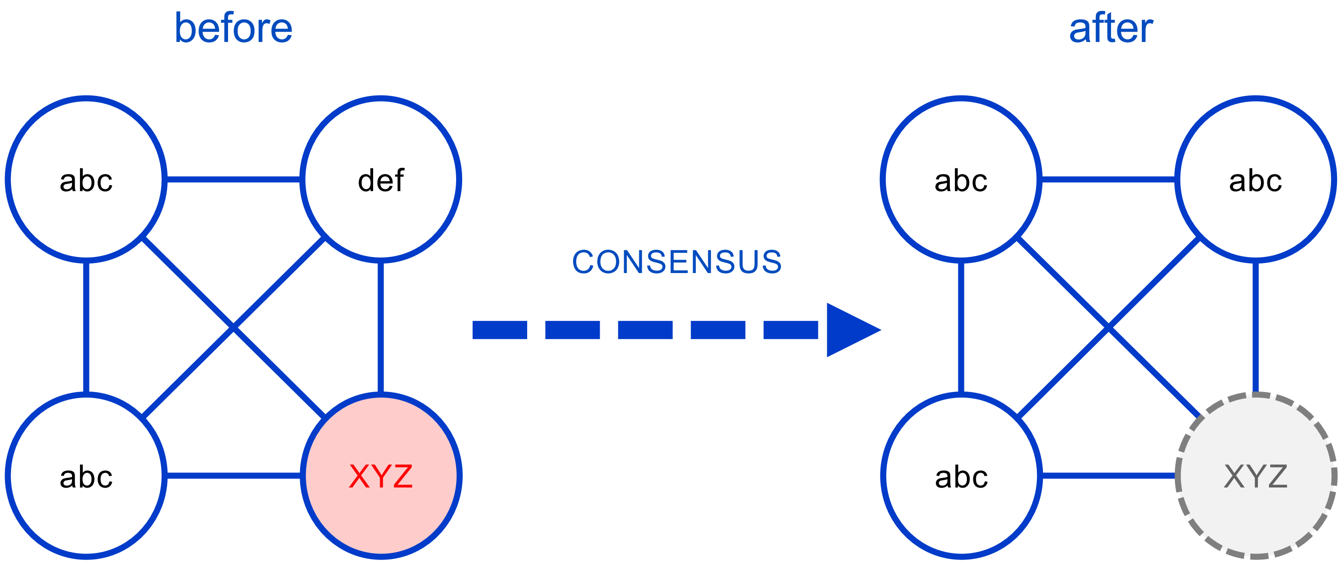
- Responsibilities include
  - Holding and maintaining the ledger
  - Receiving transactions from applications (and other nodes)
  - Validating transactions
  - Notifying applications about the outcome of submitted transactions

- There is an assumption that some nodes might be malicious!
  - Different networks require different tolerances for malicious behaviour



The Art of Maintaining a Consistent Ledger

- Keeping nodes up-to-date
- Fixing any peers in error
- Ignoring all malicious nodes

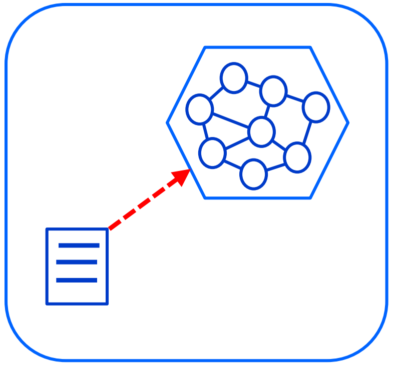


Consensus Algorithms

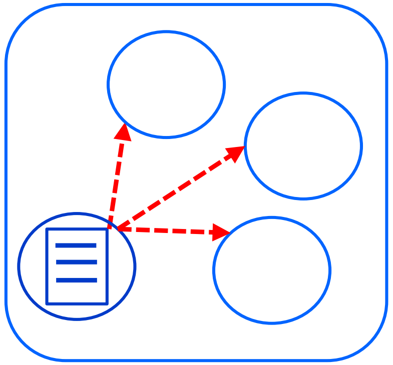
- There are lots of ways of achieving this
  - Proof of Work (e.g. Bitcoin, Ethereum)
  - Proof of Stake (e.g. NXT)
  - Proof of Elapsed Time (e.g. Sawtooth)
  - BFT-based (e.g. Iroha)
  - Apache Kafka/Zookeeper-based (e.g. Fabric)

- Different algorithms have different qualities of service
  - Tolerances for malicious behavior
  - Compute requirements
  - Performance characteristics
  - Need for intrinsic incentives

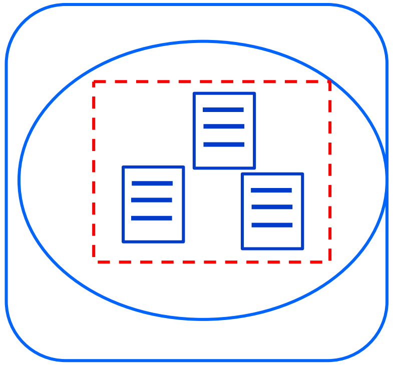
One of Many Transaction Flow Implementations



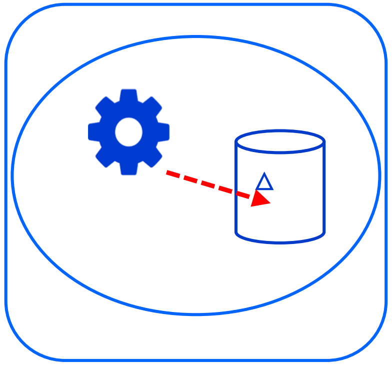
1. The application submits a request to invoke a transaction



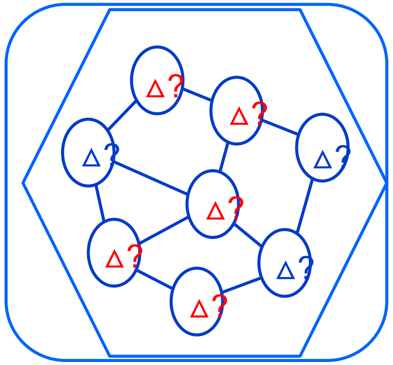
2. The transaction is shared around the network



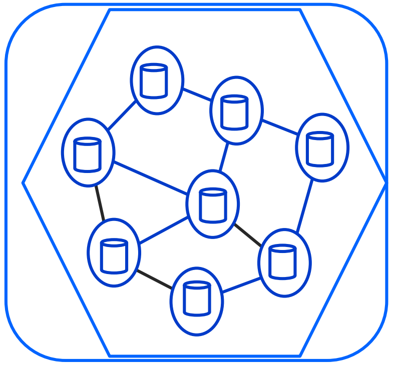
3. A designated peer creates a block containing the transaction



4. The block's transactions are executed and output stored in a delta

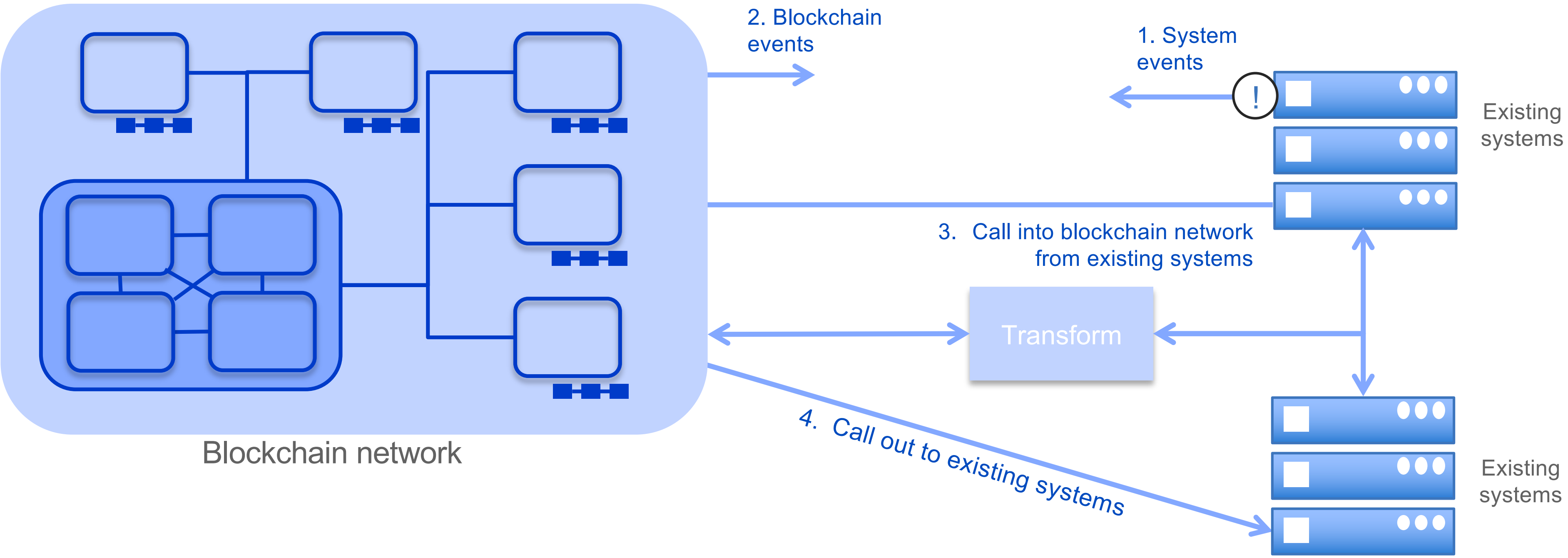


5. The network attempts to agree the correct result

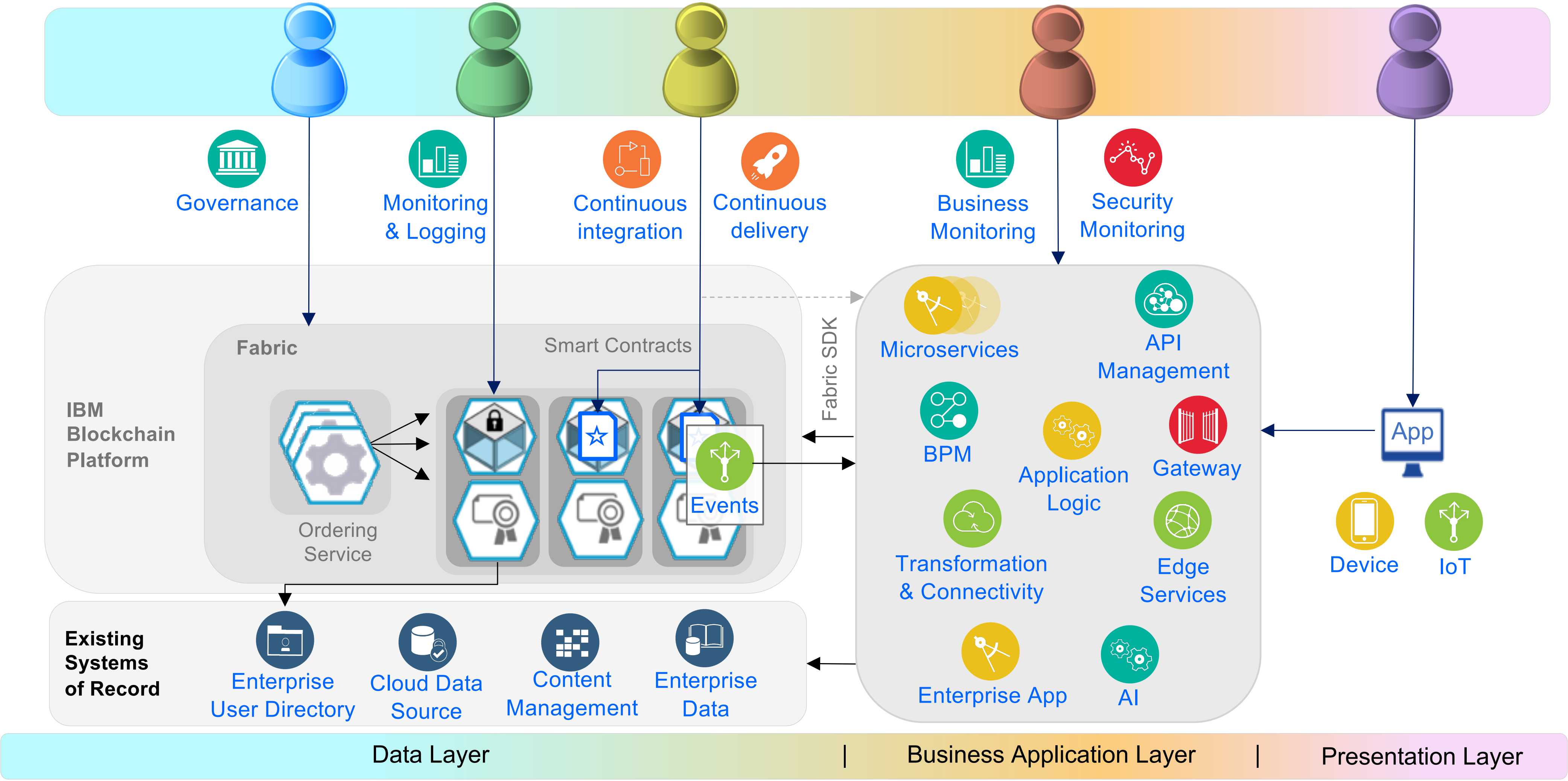


6. If there is agreement, the correct output is applied to the world state

Integrating with Existing Systems – Possibilities



How the architecture fits with enterprise services and processes



Non-determinism in blockchain

- Blockchain is a distributed processing system
  - Smart contracts are run multiple times and in multiple places
  - As we will see, smart contracts need to run deterministically in order for consensus to work
    - Particularly when updating the world state

- It's particularly difficult to achieve determinism with off-chain processing
  - Implement oracle services that are guaranteed to be consistent for a given transaction, or
  - Detect duplicates for a transaction in the blockchain, middleware or external system

random()

getExchangeRate()

getDateTime()

getTemperature()

incrementValue
inExternalSystem(…)

Security: Public vs. private blockchains

Public blockchains

- For example, Bitcoin
- Transactions are viewable by anyone
- Participant identity is more difficult to control

Private blockchains

- For example, Hyperledger Fabric
- Network members are known but transactions are secret

- Some use-cases require anonymity, others require privacy
  - Some may require a mixture of the two, depending on the characteristics of each participant

- Most business use-cases require private, permissioned blockchains
  - Network members know who they’re dealing with (required for KYC, AML etc.)
  - Transactions are (usually) confidential between the participants concerned
  - Membership is controlled

Business Considerations

- As a B2B system, blockchain adds a number of aspects that are not typical in other projects:
  - Who pays for the development and operation of the network?
  - Where are the blockchain peers hosted?
  - When and how do new participants join the network?
  - What are the rules of confidentiality in the network?
  - Who is liable for bugs in (for example) shared smart contracts?
  - For private networks, what are the trusted forms of identity?

- Remember that each business network participant may have different requirements (e.g. trust)
  - Evaluate the incentives of potential participants to work out a viable business model
    - Mutual benefit → shared cost (e.g. sharing reference information)
    - Asymmetric benefit → money as leveler (e.g. pay for access to KYC)

Trade-offs Between Non-Functional Requirements

Performance

- ○ The amount of data being shared
- ○ Number and location of peers
- ○ Latency and throughput
- ○ Batching characteristics

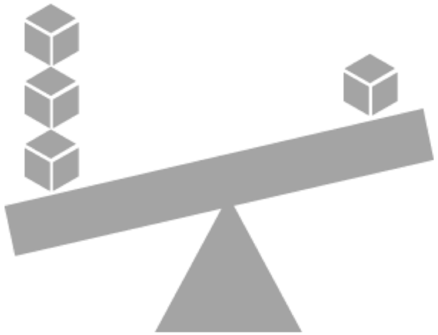
Security

- ○ Type of data being shared, and with whom
- ○ How is identity achieved
- ○ Confidentiality of transaction queries
- ○ Who verifies (endorses) transactions

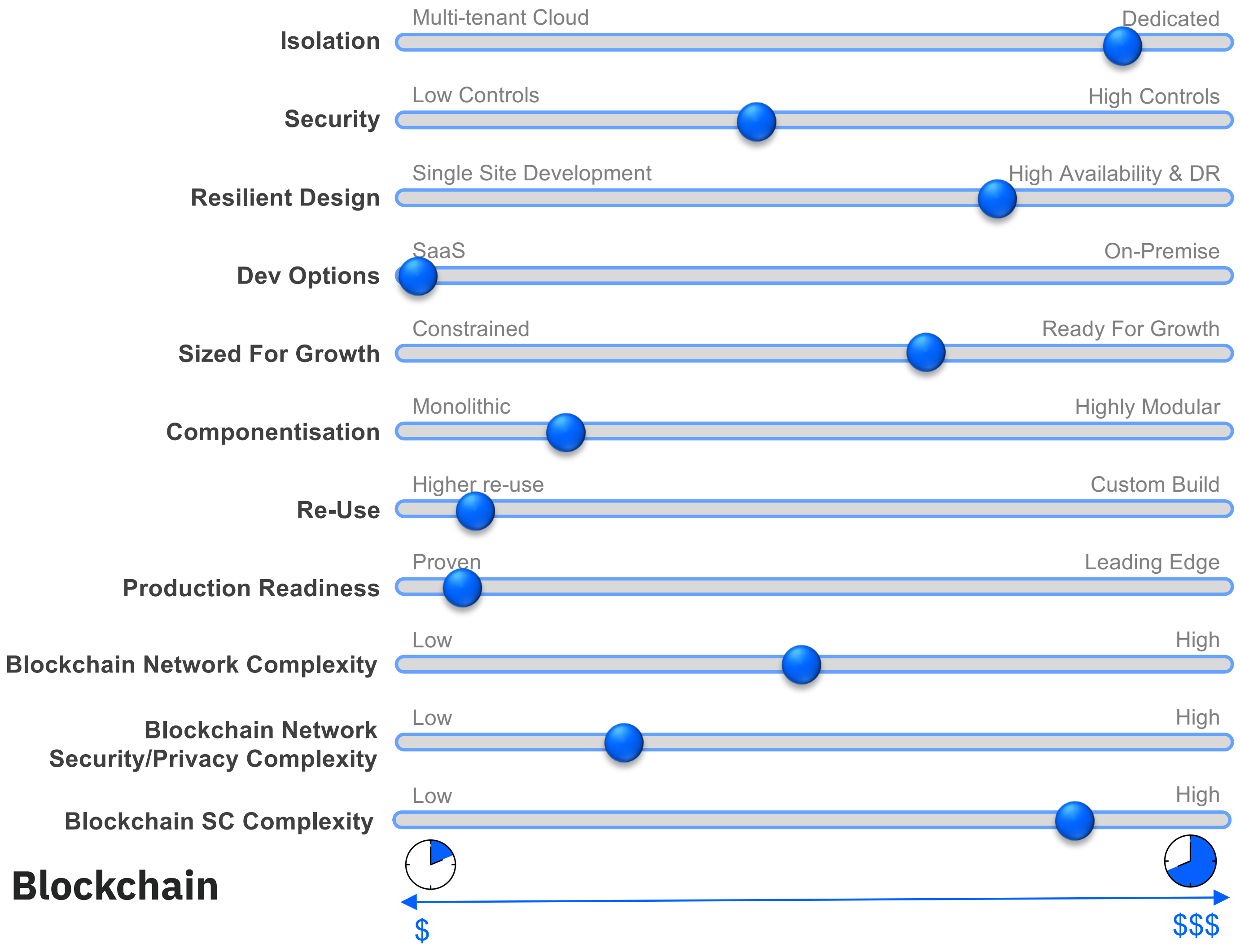
Resiliency

- ○ Resource failure
- ○ Malicious activity
- ○ Non-determinism

Consider the trade-offs between performance, security and resiliency!



Non-Functional Requirements



Isolation	Multi-tenant Cloud	Dedicated
Security	Low Controls	High Controls
Resilient Design	Single Site Development	High Availability & DR
Dev Options	SaaS	On-Premise
Sized For Growth	Constrained	Ready For Growth
Componentisation	Monolithic	Highly Modular
Re-Use	Higher re-use	Custom Build
Production Readiness	Proven	Leading Edge
Blockchain Network Complexity	Low	High
Blockchain Network Security/Privacy Complexity	Low	High
Blockchain SC Complexity	Low	High

Adjust the sliders with the client early in the project so all parties are aligned on the expectations of robustness, isolation, security controls etc. as all these factors have material impact on the cost and complexity of the solution.

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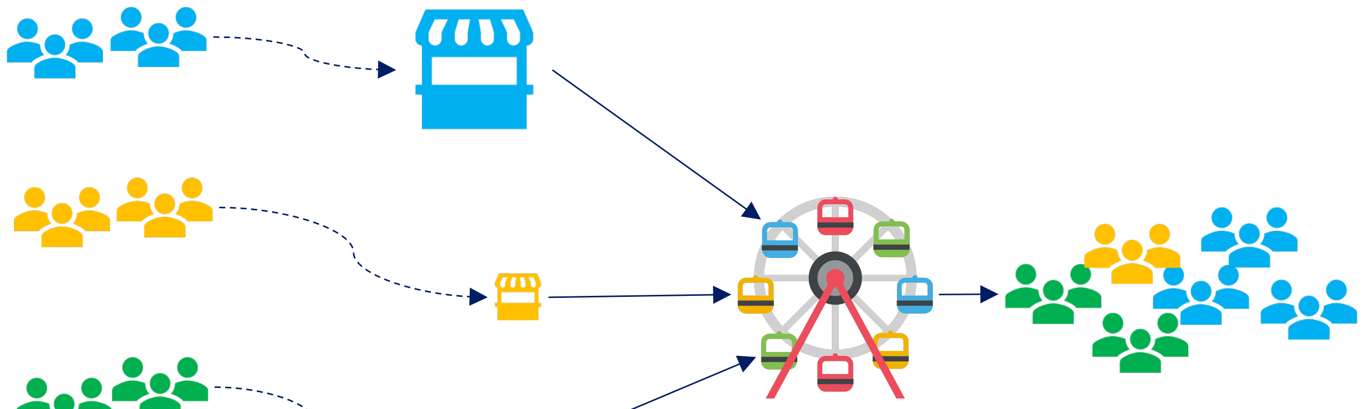
[Optimizing Performance]

What does performance mean in the context of blockchain?

A simple analogy to start with…

How would you maximize the throughput of a Ferris wheel?



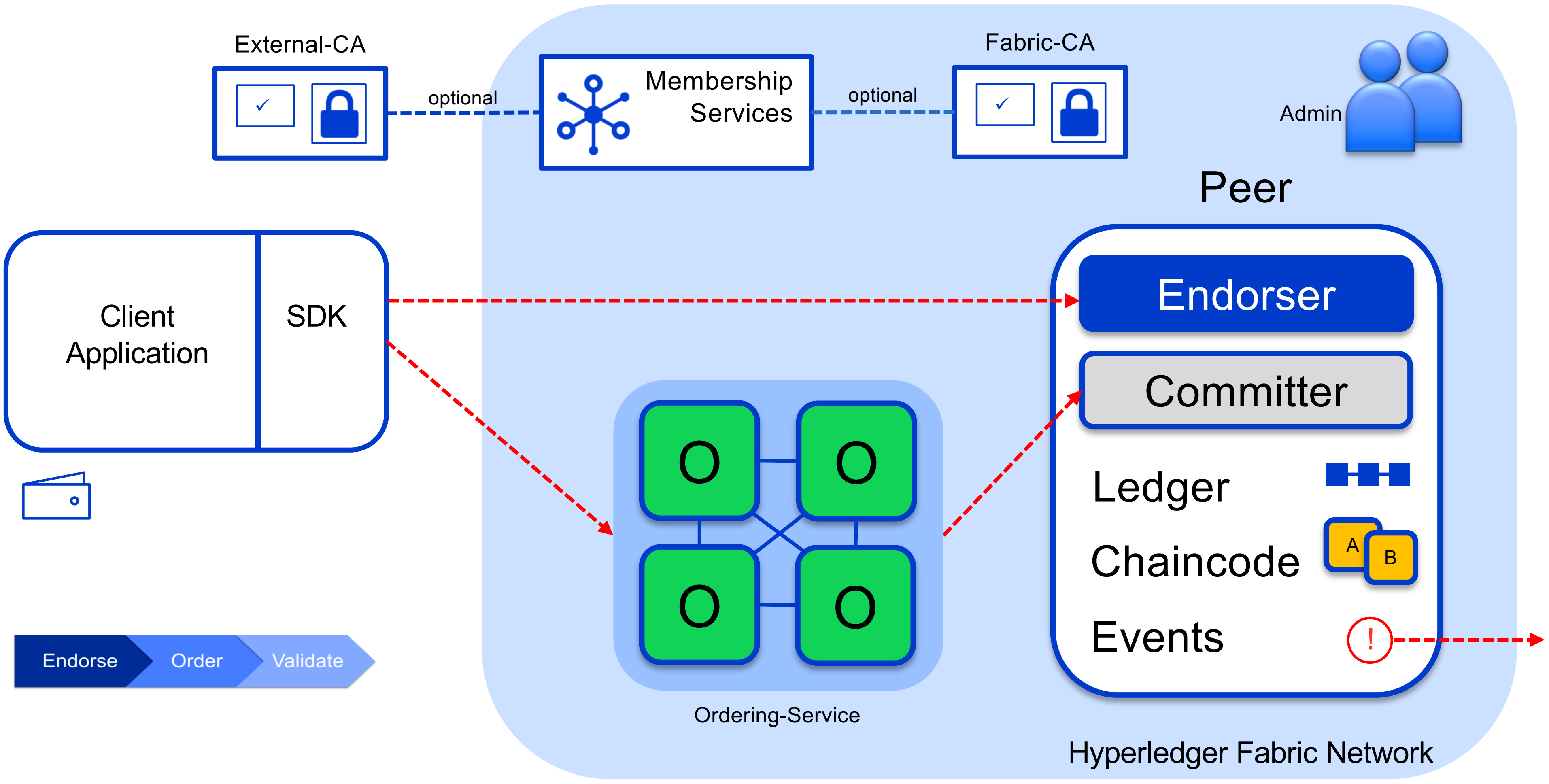
People = *transactions*

Stalls = *client apps*

Gondolas/Pods = *organizations*

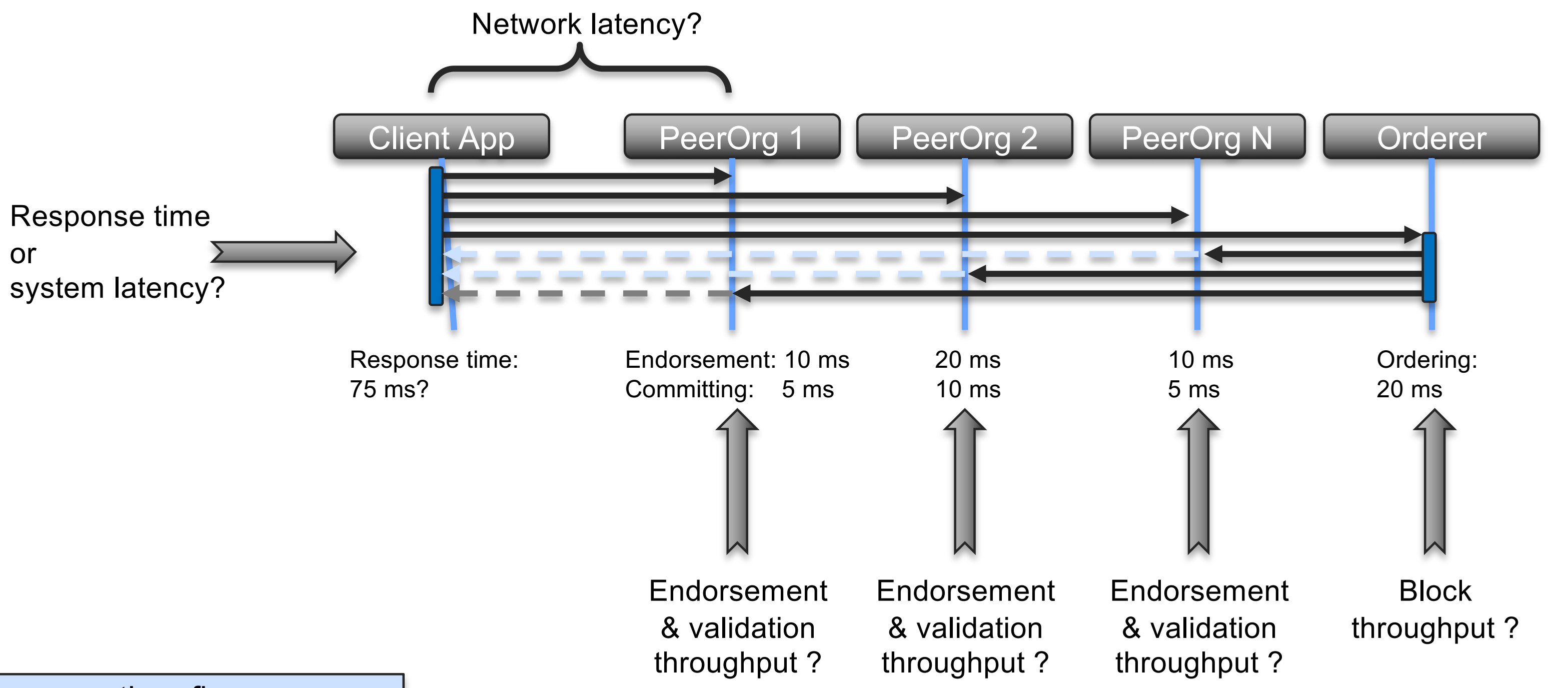
https://www.maxpixel.net/Folk-Festival-Ferris-Wheel-Height-1024217

Recap on Hyperledger Fabric transaction process



So, what do we mean by performance?

Performance can mean anything… and in a de-centralized network the concept is even more vague.



Note: Response time figures are not representative.

and what about the breaking point?
When transactions starts timing out…

What are the Hyperledger Fabric performance levers?

World State

- Indexing
- Size of payload

Committing peers

- VSCC Transaction validation
- Peer’s resources

Endorsing peers

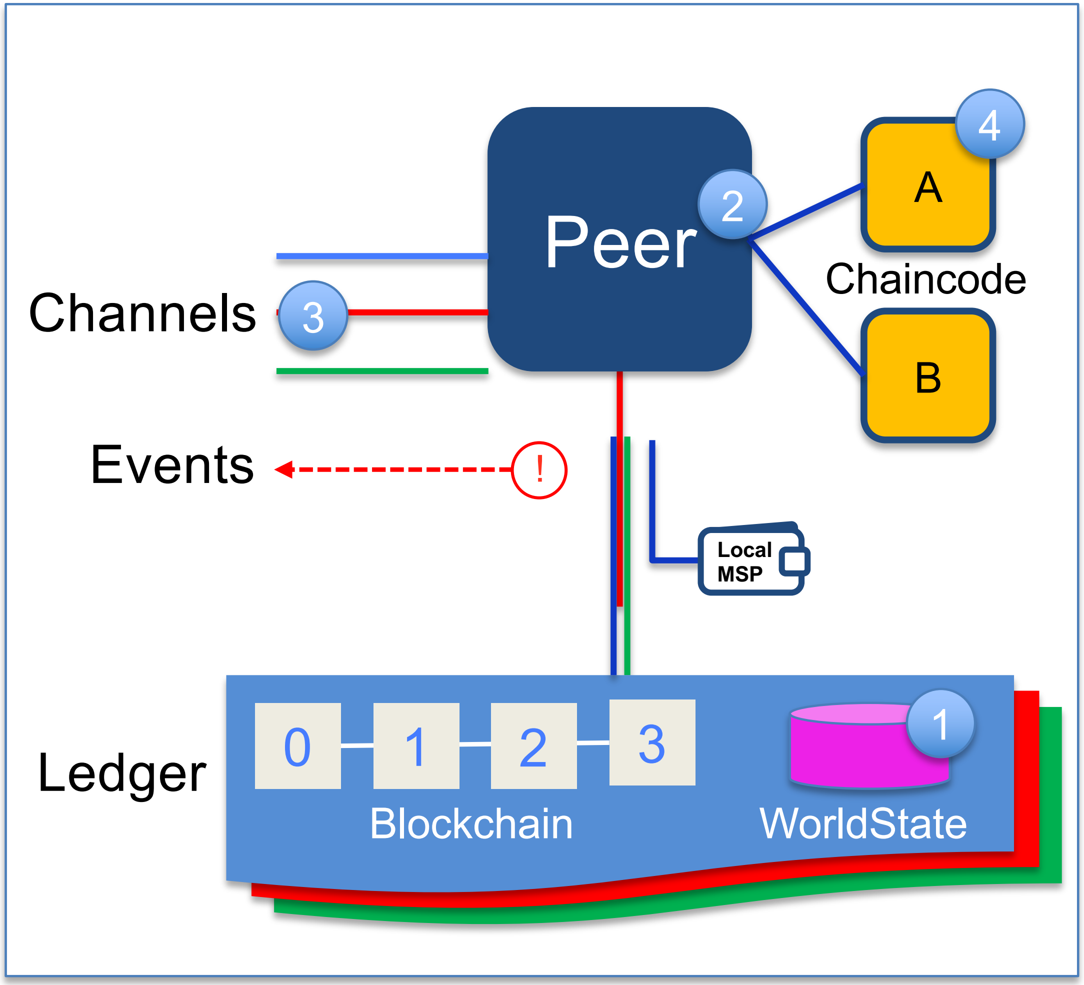
- ESCC Transaction signing
- Peer’s resources

Orderers / Channels (configtx.yaml)

- "absolute_max_bytes"
- "max_message_count"
- "timeout"

Chaincode

- World state queries
- Query aggregation (e.g. Sum)
- Business logic complexity
- Query to external sources (oracles)



What are the Client Application performance levers?

1 Fabric components

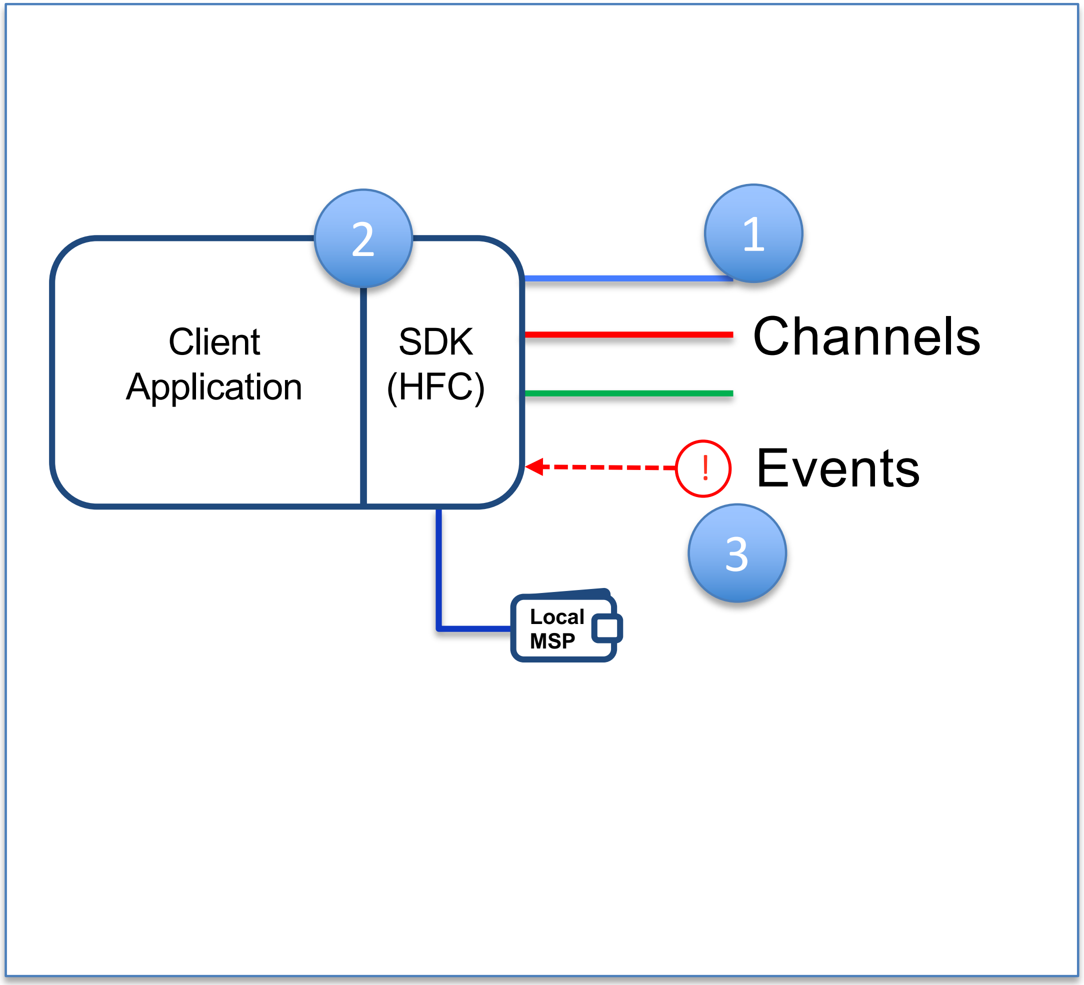
- Network latency
  - To the orderer
  - To the peers of every orgs

2 Fabric SDK / Client Application

- GRPCs Connections reuse
- Endorsement load balancing
  - Don’t always hit the same peer
- Complex Endorsement policies
  - More endorsers = more invocations
- Channel Event Hubs impact
  - How many events should you wait for?

3 Channels

- More peers an organization has on a channel means more events to listen to



Summary

- Blockchain builds on basic computer science concepts:
  - Linked Lists
  - Hash Functions
  - Peer-to-peer networks

- Identify key operational considerations
  - Consensus is the art of maintaining a consistent ledger
  - It is possible to integrate with existing systems, but take care over determinism
  - Security requirements solved through techniques such as encryption and signing
  - Also consider business and non-functional requirements

Thank you

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