Privacy Enhanced Distributed Ledger Technology and Hyperledger Implementation

IEEE MOROCCO
BLOCKCHAIN
SUMMIT 2024

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Why listen to this talk?

- Blockchain has valuable properties, but conflicts with privacy and exception management – “immutable” - deletion impossible

➡ Sometimes we don’t need blockchain, only some features

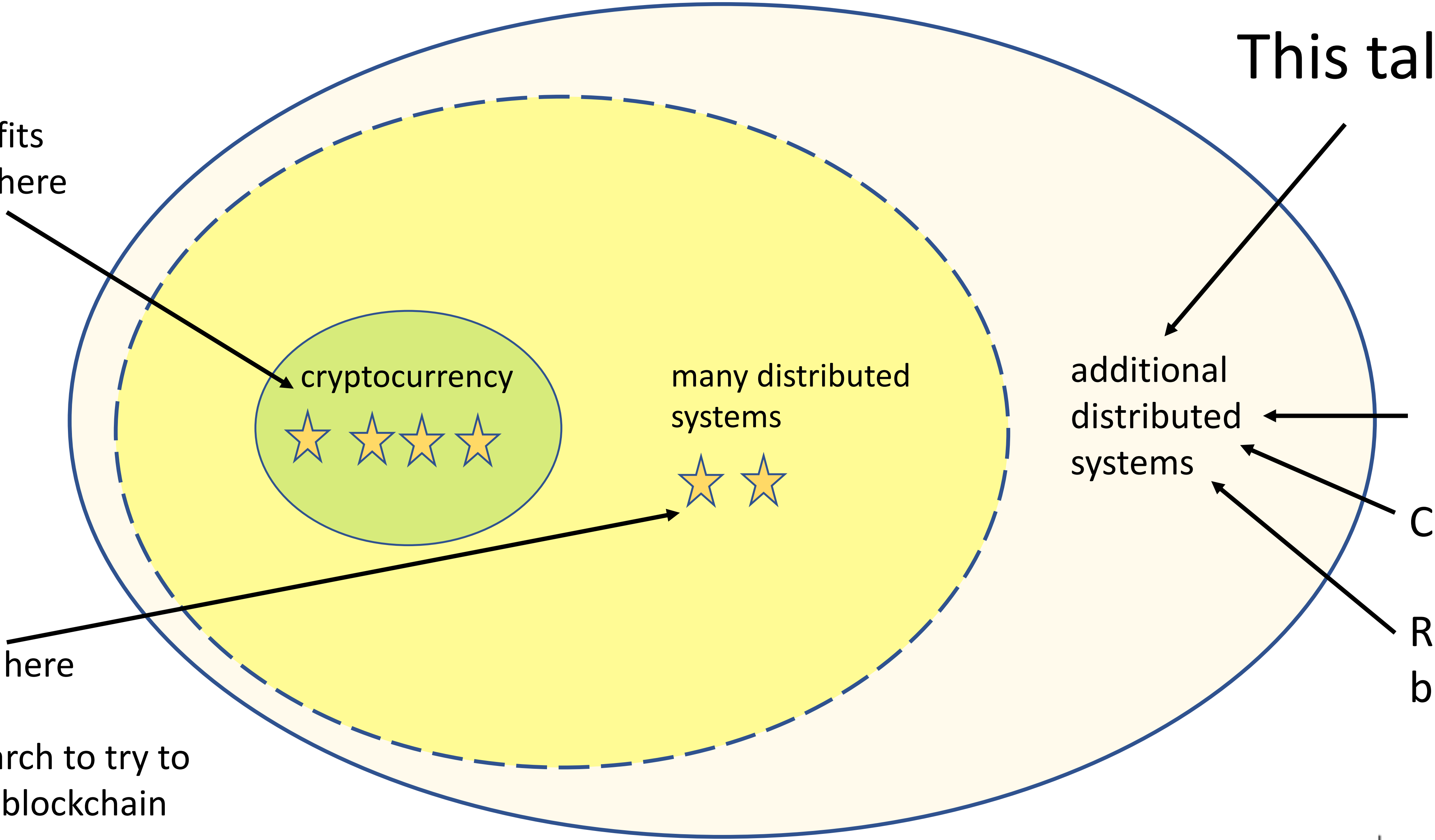
- Data block matrix → distributed trust, integrity protection of blockchain,
  but allows controlled edits for privacy or block re-use

Key points

- Blockchain -> integrity protection, write-only blocks
- Data block matrix -> integrity protection, read-write blocks

- Drop-in compatibility for Hyperledger Fabric applications
- Released and available
- Also high-volume, low-capacity such as IoT -> re-use blocks
- Scalability potential where ledger size is a factor

Market, range of applications for DLT



This talk here

Blockchain fits pretty well here

cryptocurrency

many distributed systems

additional distributed systems

Privacy

Corrections

Re-use blocks

Not as well here

Much research to try to get around blockchain properties

Why use redactable DLT for privacy?

- Permanence/immutability conflicts with ‘right to erasure’ privacy regulations
- Privacy rules such as European Union General Data Protection Regulation (GDPR) require that all information related to a particular person can be deleted at that person's request
  - *any personal* data "concerning an identified or identifiable natural person"
  - includes pseudo-anonymized data linkable to person
  - US states adopting similar privacy rules, including California and Virginia

New focus on logistics, shipping, Internet of Things (IoT)
– capability for exception management means more practical DLT
- also cases where storage is limited, such as IoT, where block re-use helpful

What's been tried to solve blockchain/privacy conflict?

- Don't put personal data on blockchain – but pseudo-anonymized data are still considered personal; Financial transactions are obviously personal data

- Encrypt data and destroy key to delete – but data must be secure for decades (e.g., DES replaced in only 17 years)

- Chameleon hash function – non-standard cryptography

- Off-chain storage of sensitive data – what if on-chain index to off-chain data is also sensitive?

Many blockchain applications don’t need blockchain, just some blockchain features

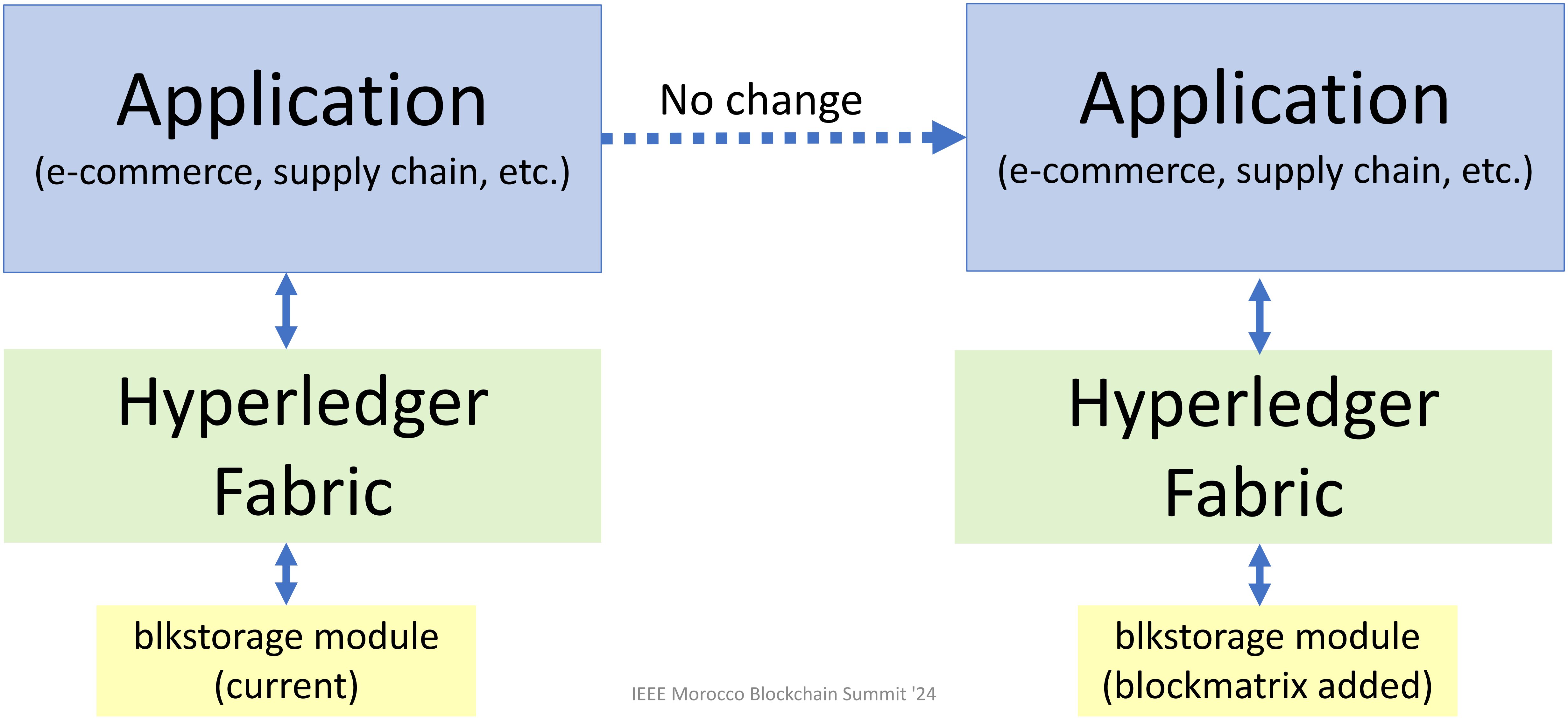
Datablock matrix –two hash values per block instead of linked chain

Blockchain -> distributed trust, integrity protection, immutablity

Datablock matrix –> distributed trust, integrity protection, editable

- Open source
- Incorporated into Next Gen Access Control
- NOT to replace blockchain, to provide alternative tools for distributed system design
- Hyperledger Fabric component available

Compatible with Hyperledger applications



Application

(e-commerce, supply chain, etc.)

No change

Application

(e-commerce, supply chain, etc.)

Hyperledger Fabric

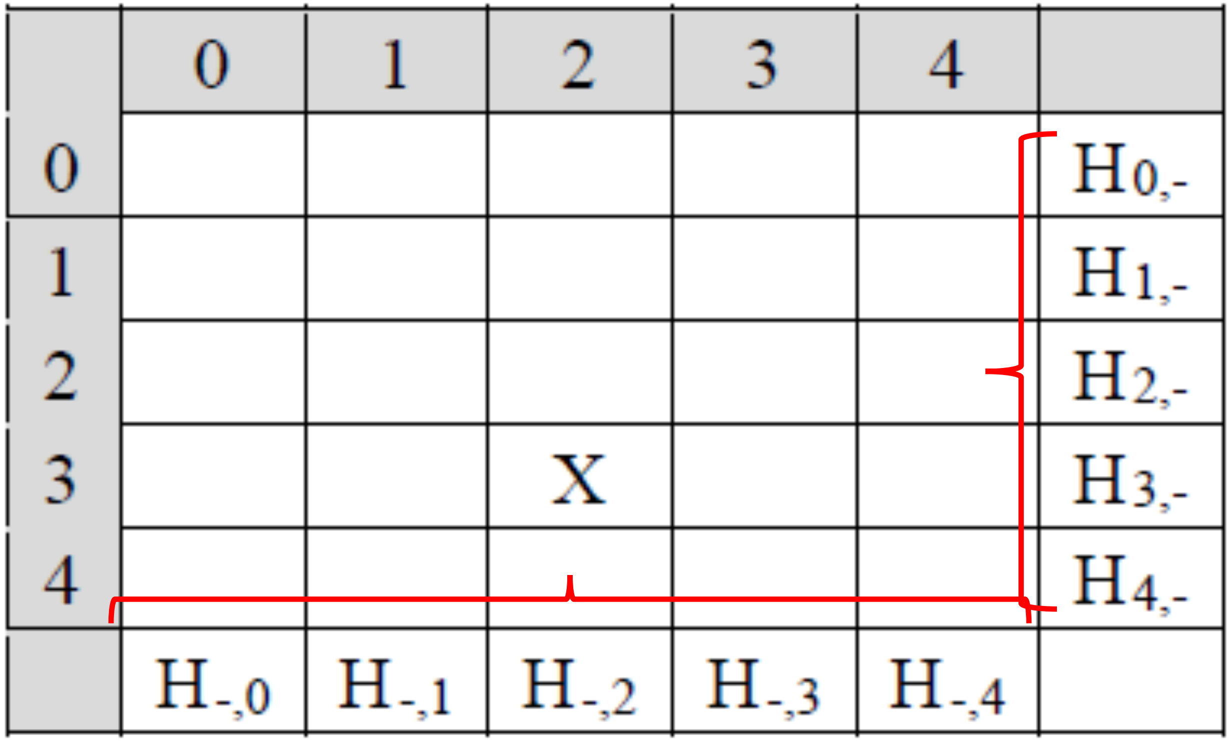
Hyperledger Fabric

blkstorage module (current)

blkstorage module (blockmatrix added)

Datablock matrix data structure

- A data structure that provides integrity assurance using hash-linked records while also allowing the deletion of records
- Stores hashes of each row and column
- => each block within the matrix is protected by two hashes
- Suggested use for private/permissioned distributed ledger systems



	0	1	2	3	4	
0						$H_{0,-}$
1						$H_{1,-}$
2						$H_{2,-}$
3			X			$H_{3,-}$
4						$H_{4,-}$
	$H_{-,0}$	$H_{-,1}$	$H_{-,2}$	$H_{-,3}$	$H_{-,4}$	

Figure 1. Block matrix

How does this work?

- Suppose we want to delete block 12

- disrupts the hash values of $H_{3,-}$ for row 3 and $H_{-,2}$ and column 2

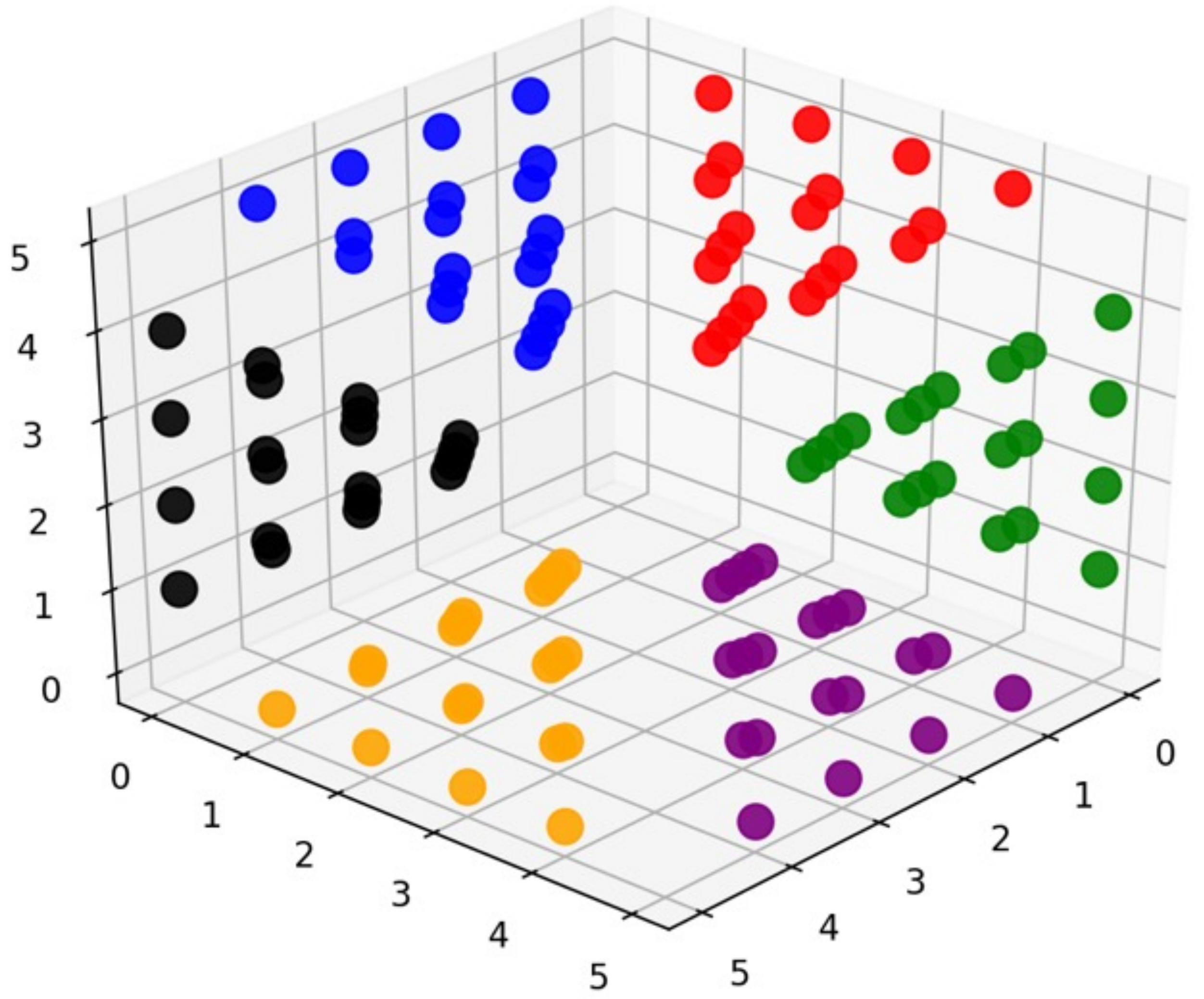
- blocks of row 3 are included in the hashes for columns 0, 1, 3, and 4

- blocks of column 2 are included in the hashes for rows 0, 1, 2, and 4

	0	1	2	3	4	
0	●	1	3	7	13	$H_{0,-}$
1	2	●	5	9	15	$H_{1,-}$
2	4	6	●	11	17	$H_{2,-}$
3	8	10	12	●	19	$H_{3,-}$
4	14	16	18	20	●	$H_{4,-}$
	$H_{-,0}$	$H_{-,1}$	$H_{-,2}$	$H_{-,3}$	$H_{-,4}$	etc.

Structure can be extended to multiple dimensions

- Block dispersal for 3 dimensions
- Location in sectors 0..5 according to *b* mod 6 for block *b*



Why use this data structure?

Again, many blockchain applications <u>don't need blockchain</u>, <u>just some features</u>

Enlarge the market for blockchain

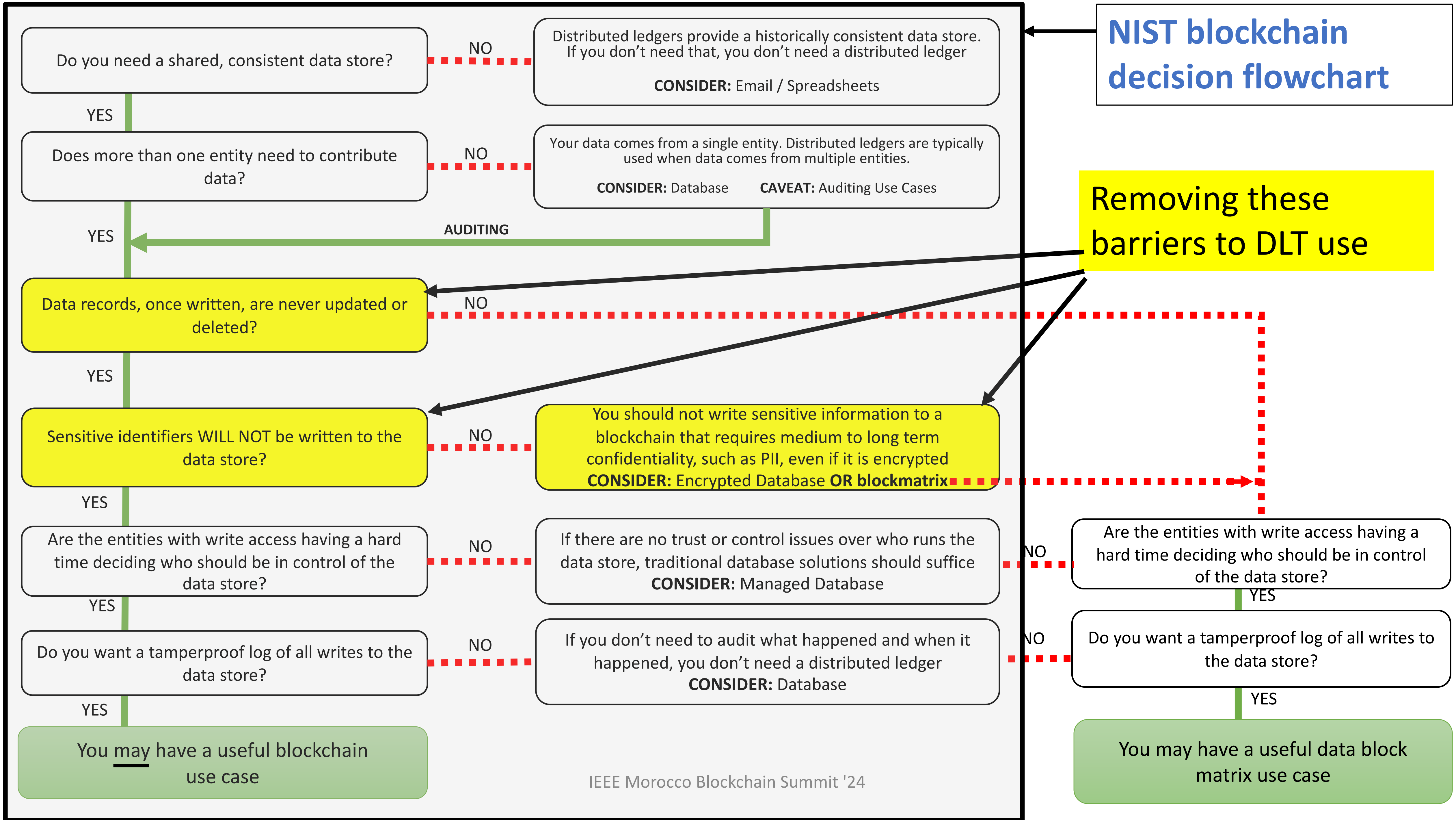
- Solve the conflict between blockchain and privacy regulations
- Allow for corrections or block re-use

Replace network communication with local data

- You can obviously do this with conventional database functions, but
- New data structure adds integrity checks as in blockchain
- Re-writing blocks can be more practical for high-volume, or where storage is limited

Lightweight, easy-to-use component for distributed system design

NIST blockchain decision flowchart



Do you need a shared, consistent data store?

NO

Distributed ledgers provide a historically consistent data store. If you don't need that, you don't need a distributed ledger

CONSIDER: Email / Spreadsheets

YES

Does more than one entity need to contribute data?

NO

Your data comes from a single entity. Distributed ledgers are typically used when data comes from multiple entities.

CONSIDER: Database **CAVEAT:** Auditing Use Cases

AUDITING

YES

Data records, once written, are never updated or deleted?

NO

YES

Sensitive identifiers WILL NOT be written to the data store?

NO

You should not write sensitive information to a blockchain that requires medium to long term confidentiality, such as PII, even if it is encrypted

CONSIDER: Encrypted Database **OR blockmatrix**

YES

Are the entities with write access having a hard time deciding who should be in control of the data store?

NO

If there are no trust or control issues over who runs the data store, traditional database solutions should suffice

CONSIDER: Managed Database

YES

Do you want a tamperproof log of all writes to the data store?

NO

If you don't need to audit what happened and when it happened, you don't need a distributed ledger

CONSIDER: Database

YES

You may have a useful blockchain use case

Are the entities with write access having a hard time deciding who should be in control of the data store?

NO

YES

Do you want a tamperproof log of all writes to the data store?

NO

YES

You may have a useful data block matrix use case

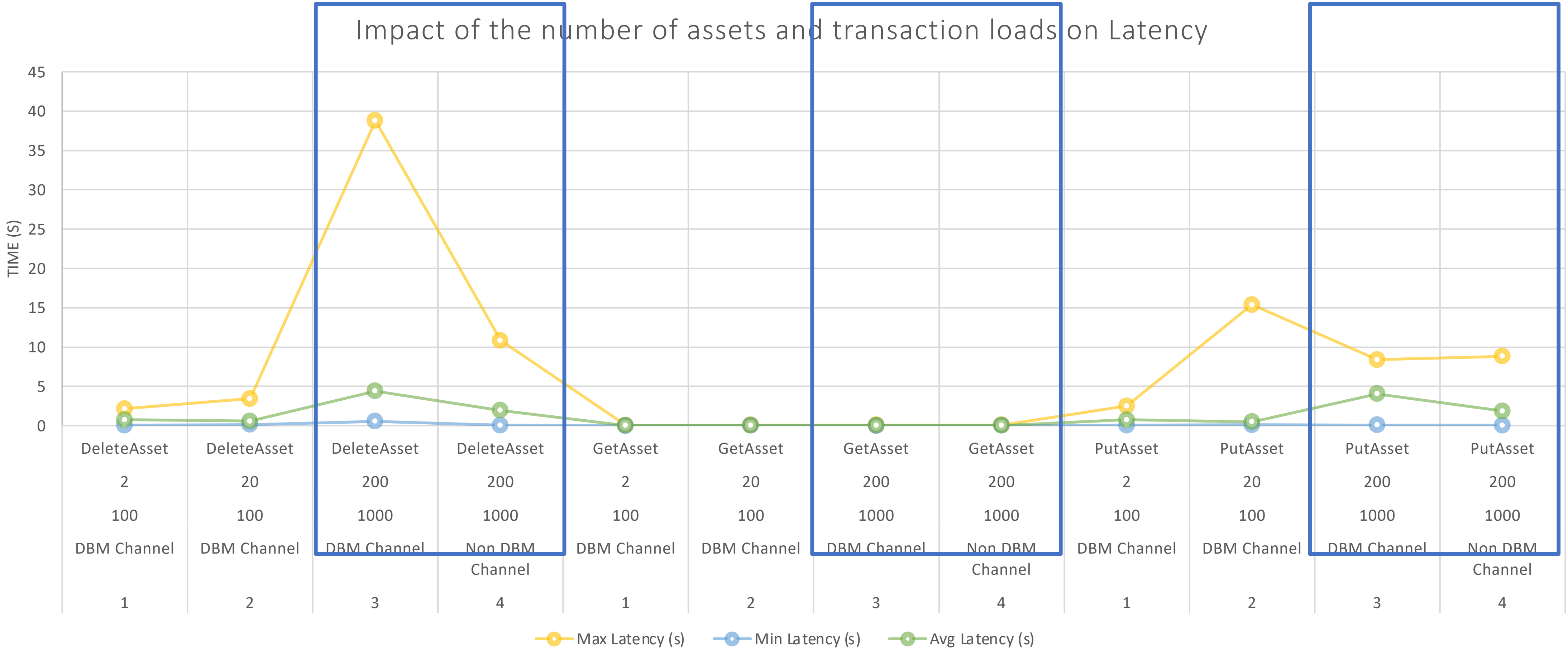
Removing these barriers to DLT use

Hyperledger blockmatrix implementation

- Designed to use existing API as closely as possible – add blocks in same manner as adding to blockchain
- Blockmatrix is <u>configurable by channel</u> (private subnet)
- Configure to use conventional blockchain or blockmatrix
  - If a deployment uses two channels, one can be a blockchain and the other can be a blockmatrix
- RED Ledger = Redactable Enhanced Distributed Ledger
- https://csrc.nist.gov/projects/redactable-distributed-ledger

Latency

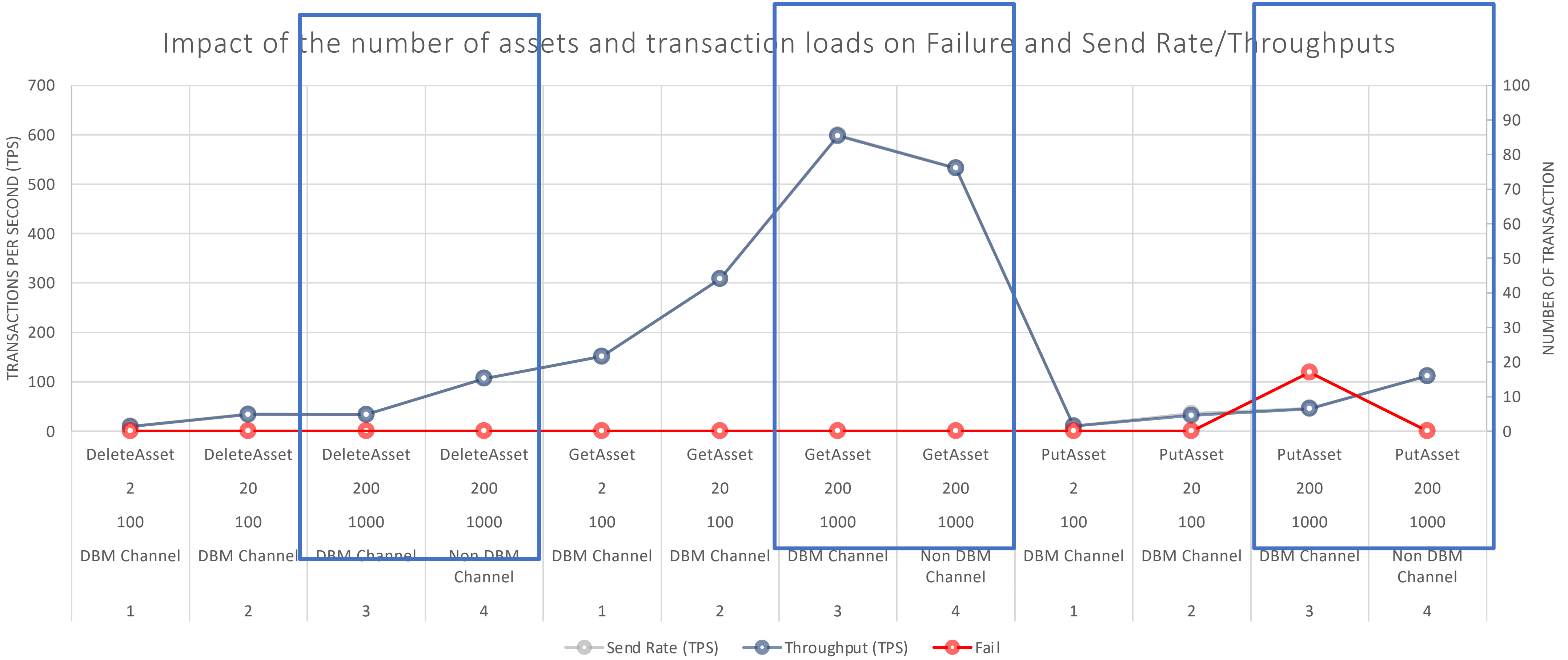
- average latency for GetAsset transactions remains relatively low across all benchmarks
- increase in average latency for DeleteAsset transactions with transaction load and asset count



Throughput

Increased transaction load => higher throughput for GetAsset, but same throughput for PutAsset and DeleteAsset

Summarizing: the Hyperledger Fabric implementation is practical for real-world use



More Information

Foundation:

- Kuhn, R., Yaga, D. and Voas, J., 2019. Rethinking Distributed Ledger Technology. *Computer*, *52*(2), pp.68-72.
- Kuhn, D. R. (2018). A Data Structure for Integrity Protection with Erasure Capability. https://csrc.nist.gov/publications/detail/white-paper/2022/05/20/data-structure-for-integrity-protection-with-erasure-capability/final

Applications:

- Roberts, J. D., Defranco, J. F., & Kuhn, D. R. (2023). Data Block Matrix and Hyperledger Implementation: Extending Distributed Ledger Technology for Privacy Requirements. *ACM Distributed Ledger Technologies: Research and Practice*, 2(2), 1-11.

Project sites with links to source code and publications

- https://csrc.nist.gov/Projects/enhanced-distributed-ledger-technology
- https://csrc.nist.gov/projects/redactable-distributed-ledger

Acknowledgements

- Josh Roberts, Sylvain Chantreau, Cedric Bell, NIST
- Temur Saidkhodjaev, University of Maryland College Park
- Arsen Klyuev, Johns Hopkins University
- Gokhan Kocak, Asena, Inc.