Erasure Coding in Windows Azure Storage

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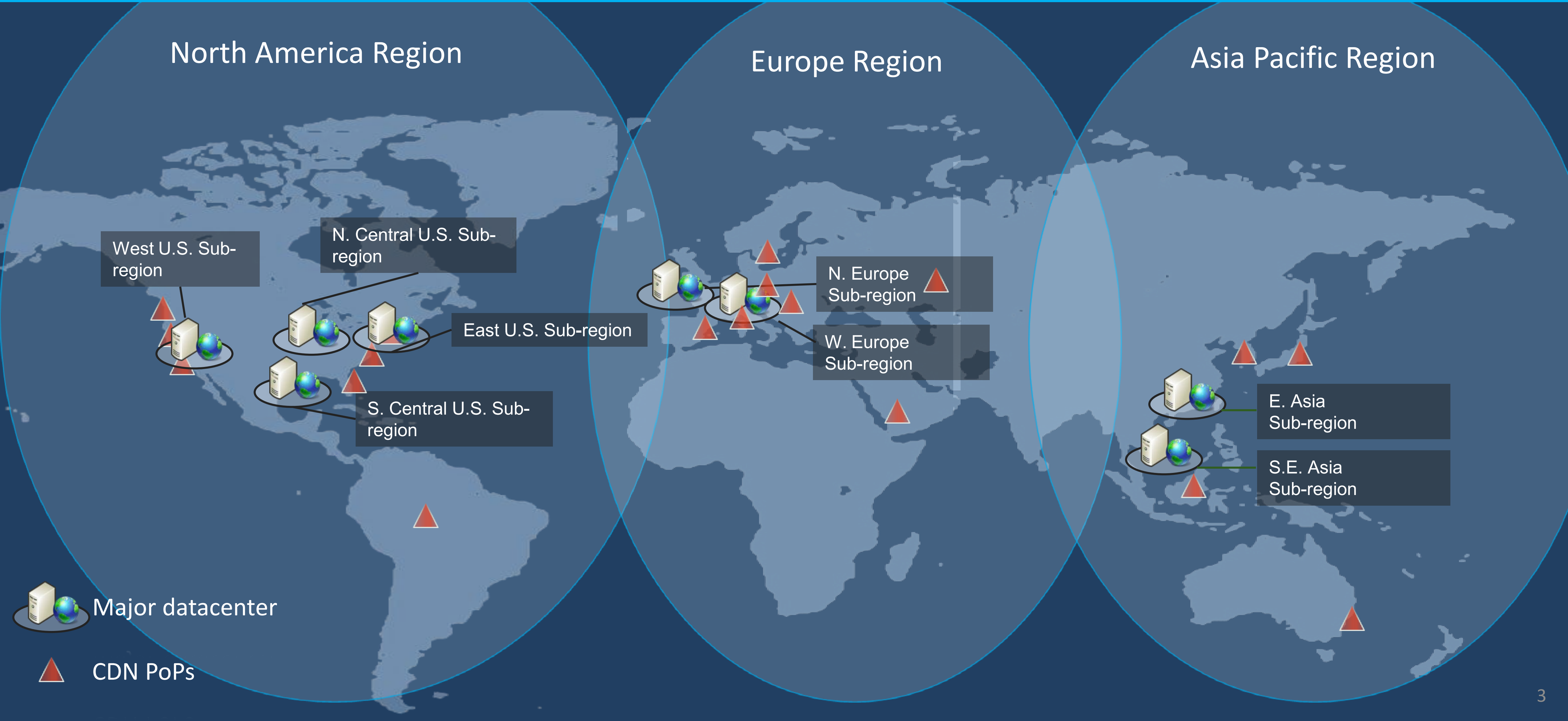
Outline

- Introduction to Windows Azure Storage (WAS)
- Conventional Erasure Coding in WAS
- Local Reconstruction Coding in WAS

Windows Azure Storage



Windows Azure Storage

- Abstractions
  - **Blobs** – File store in the cloud
  - **CDN** – High performance file delivery through proximity caching
  - **Drives** – Durable NTFS volumes for Windows Azure applications
  - **Tables** – Massively scalable NoSQL storage
  - **Queues** – Reliable storage and delivery of messages

- Easy client access
  - Easy to use REST APIs and Client Libraries
  - Existing NTFS APIs for Windows Azure Drives

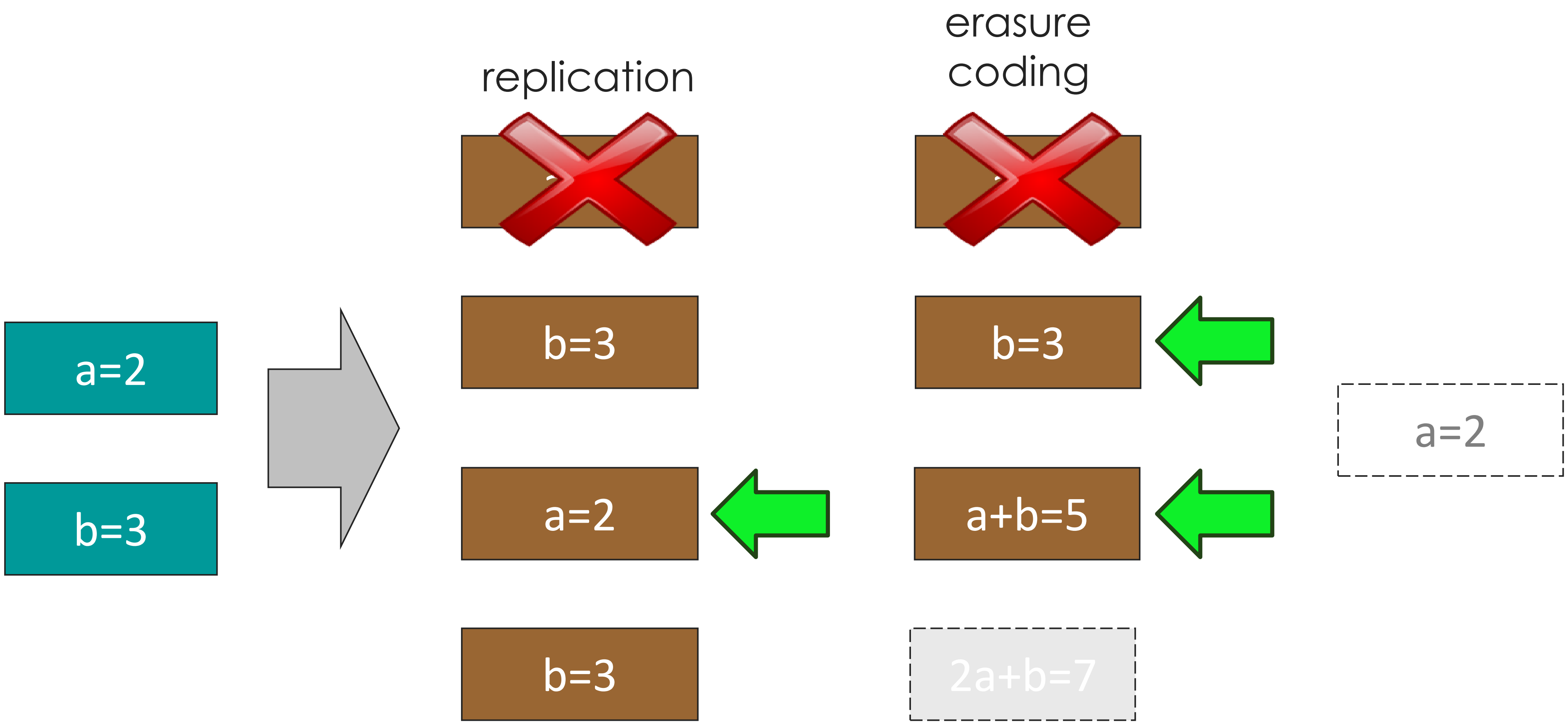
Massive Distributed Storage Systems in the Cloud

- Failures are norm rather than exception
- As the number of components increase, so does the probability of failure

$$MTTF_{First} = MTTF_{One} / n$$

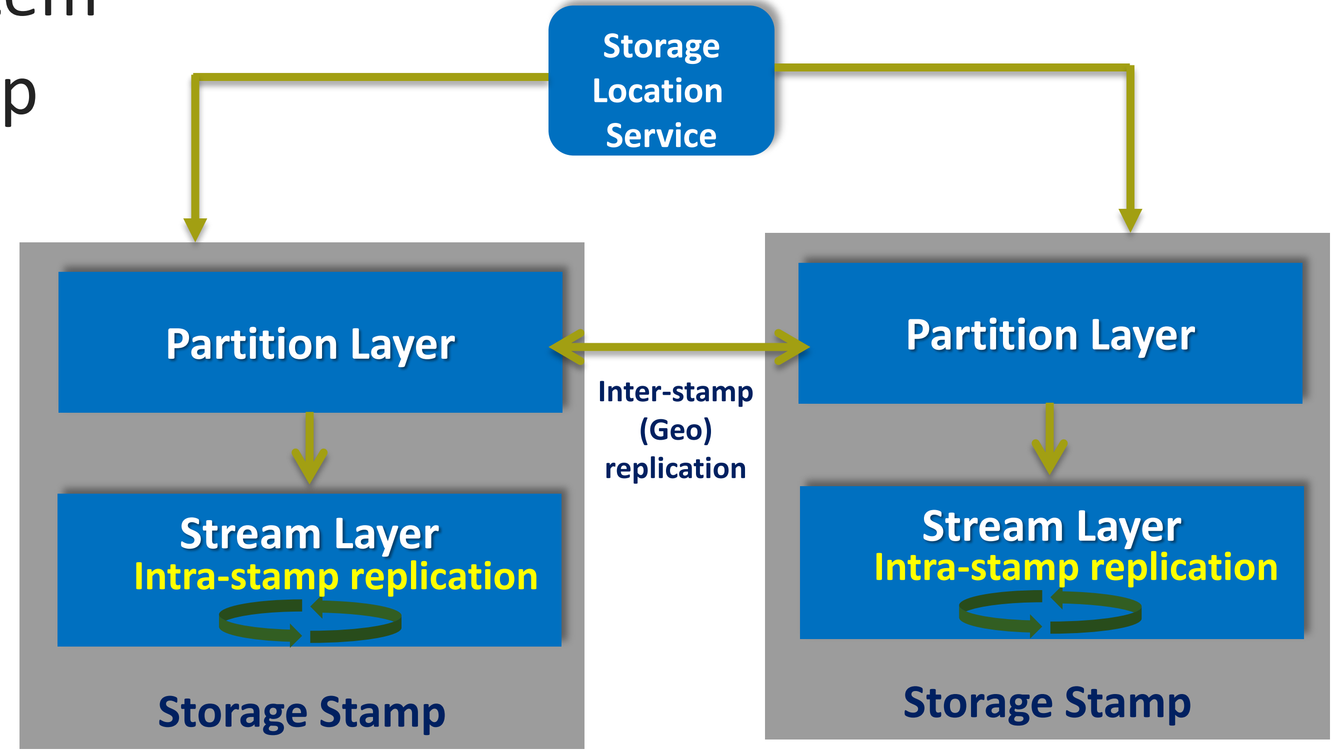
- Redundancy is necessary to cope with failures
- Replication vs. Erasure Coding?

Replication vs. Erasure Coding



WAS Stream Layer

- Append-Only Distributed File System
- Provides replication inside a stamp
- Streams are very large files
  - Has file system like namespace
  - Ordered list of pointers to extents

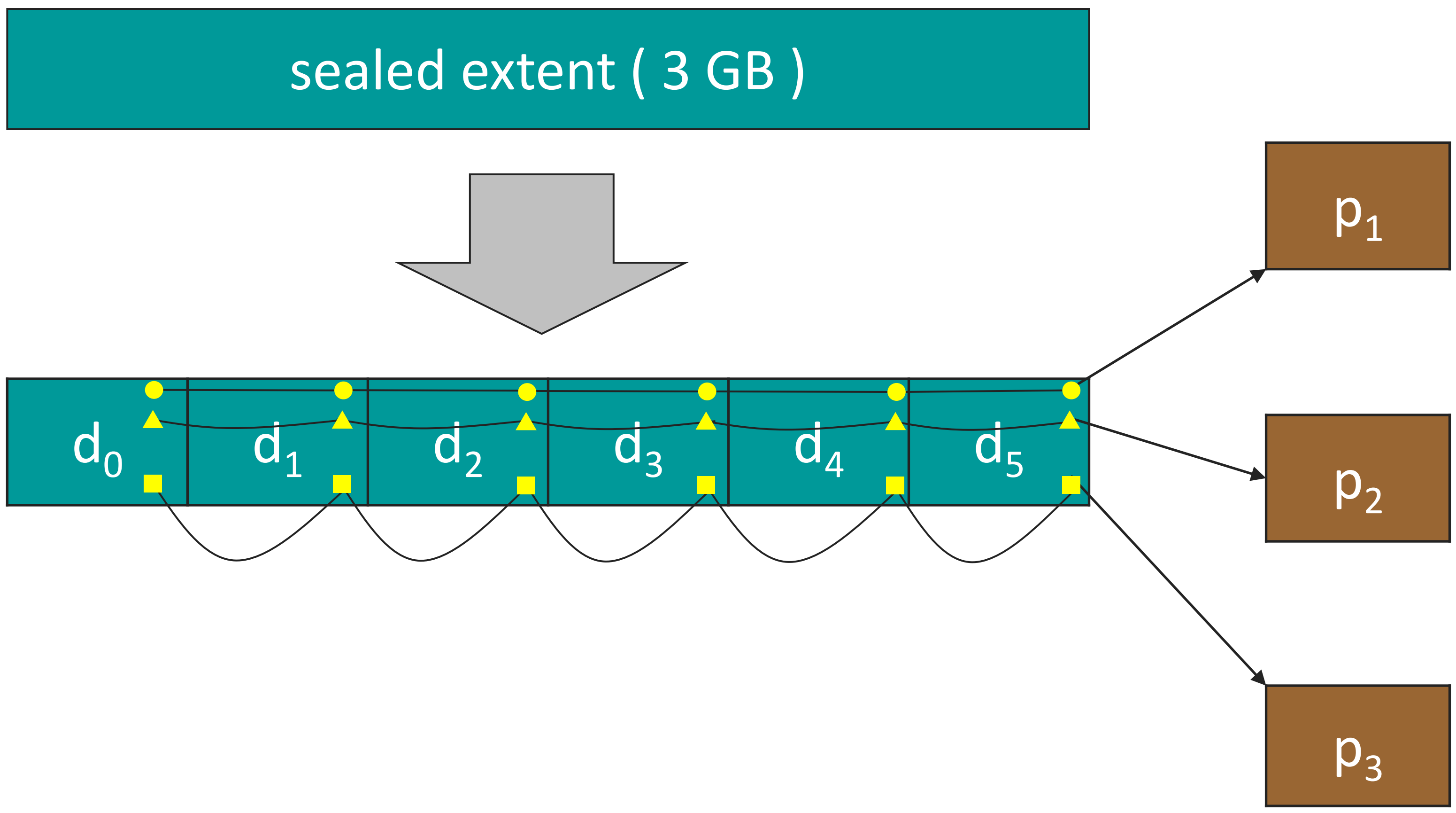


- Extents
  - Unit of replication
  - Sequence of blocks
  - Size target (3GB), unsealed/sealed

Replication and Erasure Coding

- Extents triple replicated
  - when first created
  - and while being appended
- Extents sealed at around 3GB
  - Erasure coded in the background
  - When erasure coding finishes, full replicas are deleted
  - Policies to choose between replication, erasure coding, or a mix

Conventional Erasure Coding – Reed-Solomon 6+3



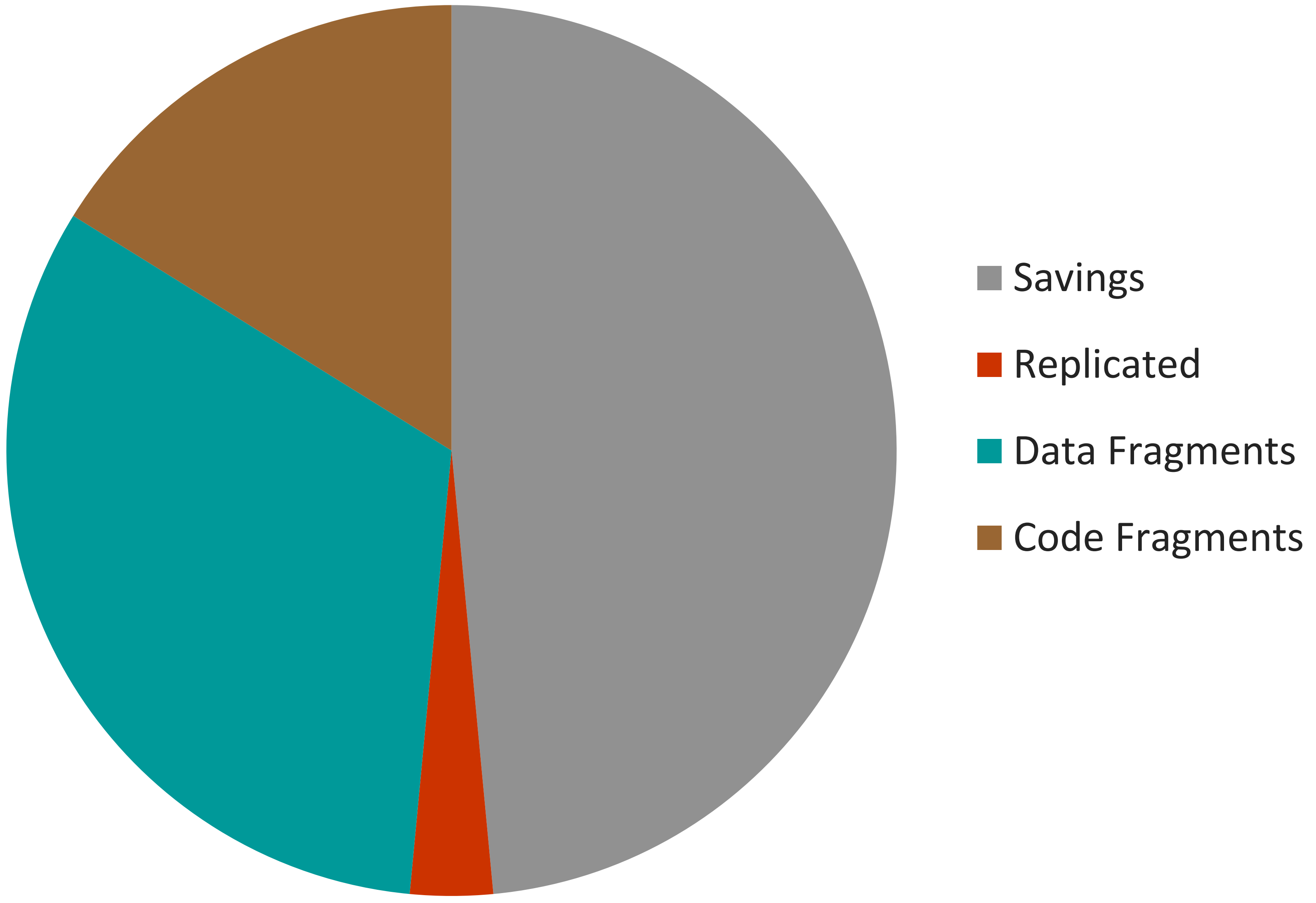
Designing For Erasure Coding - 1

- Arithmetic for Erasure Coding
  - Direct use of Galois Field operations is costly
  - Use bit-matrix and XOR transformations
- IO scheduling
  - Reconstruction/recovery/on-demand traffic need to be prioritized and throttled carefully
- Data consistency
  - Checksum handoff and verification between all levels
  - Scrub periodically

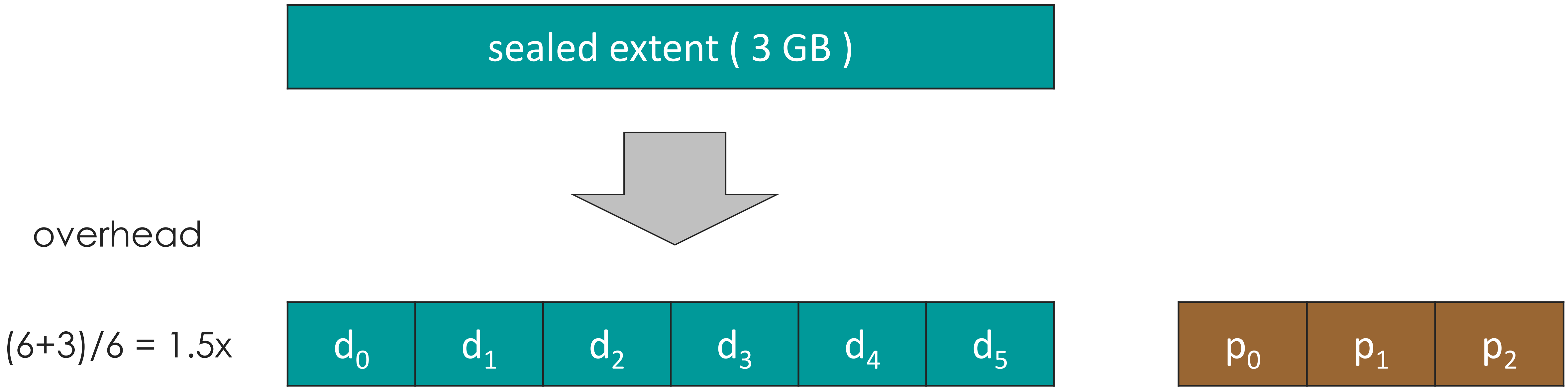
Designing For Erasure Coding - 2

- Efficient/fast on-demand reads
  - Reconstructing larger blocks for reuse
- Replica Placement for reliability
  - Each replica or fragment for an extent placed in independent fault domains
  - Replicas/fragments are placed across upgrade domains to keep high availability during rolling upgrades

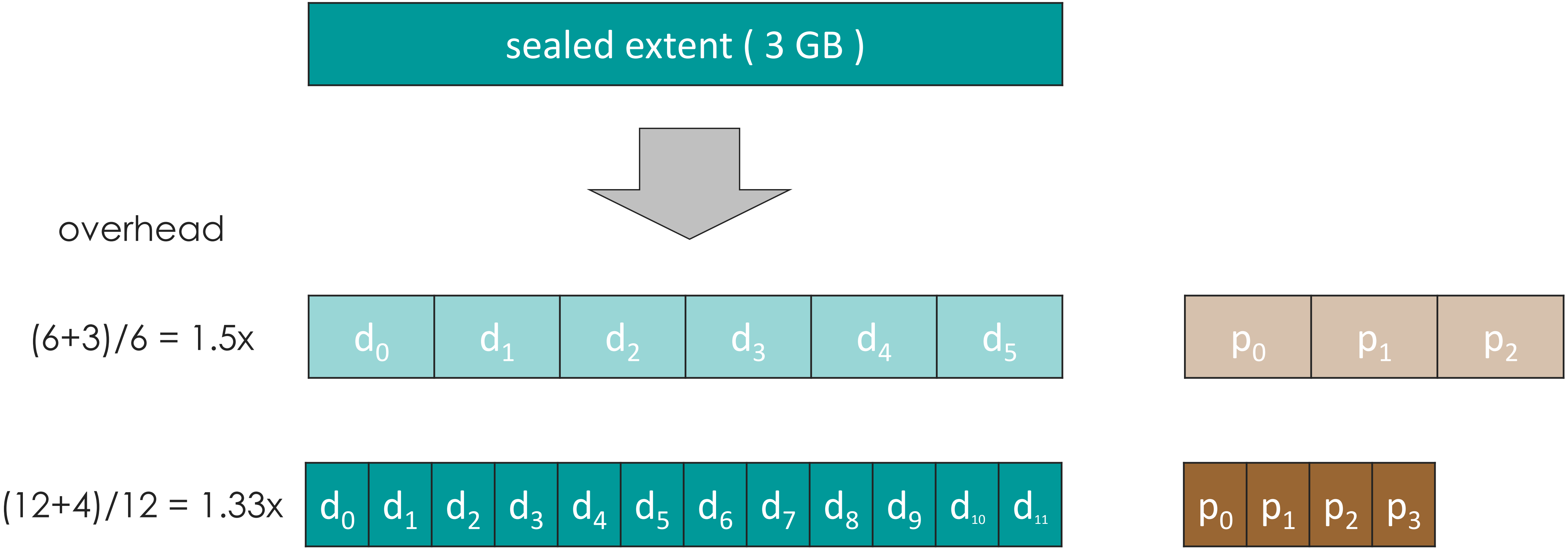
Space Savings with RS 6+3 (over 3-replication)



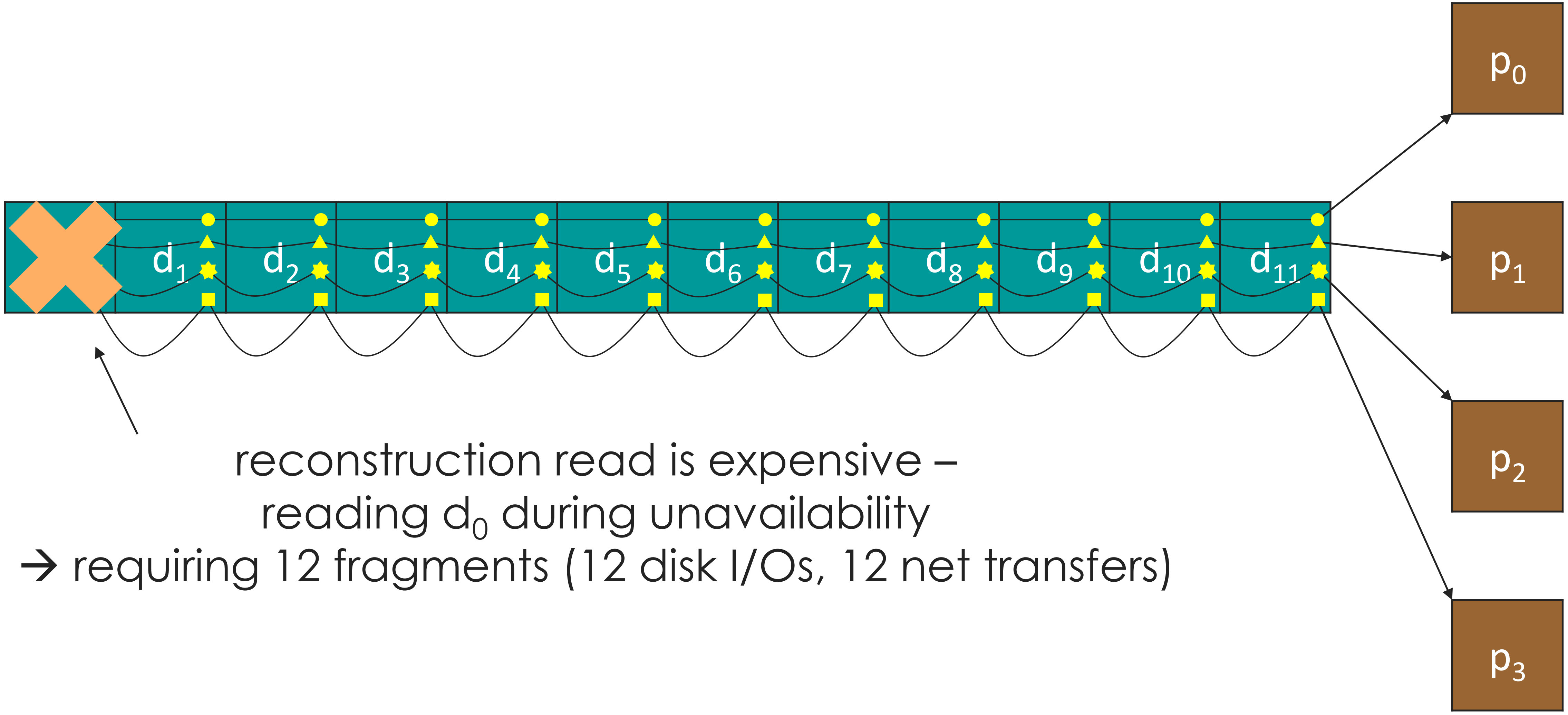
How to Further Reduce Storage Cost?



How to Further Reduce Storage Cost?



Challenge



reconstruction read is expensive –
reading d_0 during unavailability
→ requiring 12 fragments (12 disk I/Os, 12 net transfers)

Reconstruction Read – When?

- Load balancing
  - avoid hot storage node → serve reads via reconstruction
- Rolling upgrade
- Transient unavailability and permanent failures

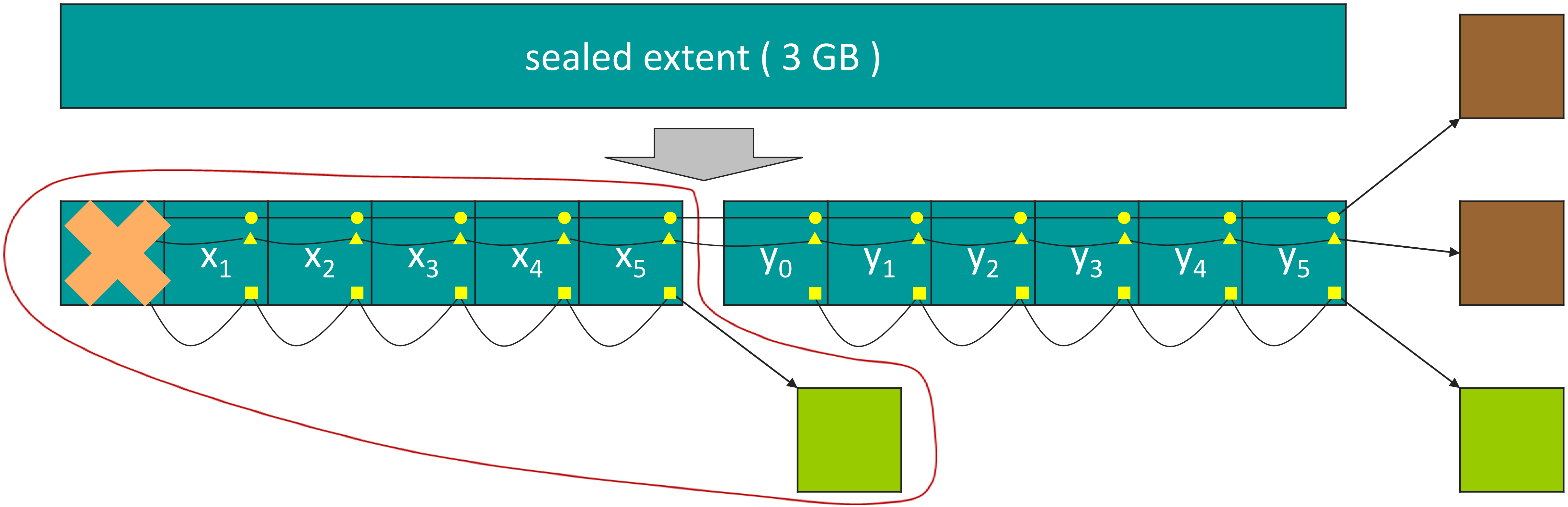
can we achieve1.33x overhead
while requiring only 6 fragments for reconstruction?

Opportunity

- Conventional EC
  - all failures are equal → same reconstruction cost, regardless of failure #
- Cloud storage
  - Prob(1 failure) >> Prob(2 or more failures)

optimize erasure coding for cloud storage
→ making single failure reconstruction most efficient

Local Reconstruction Code

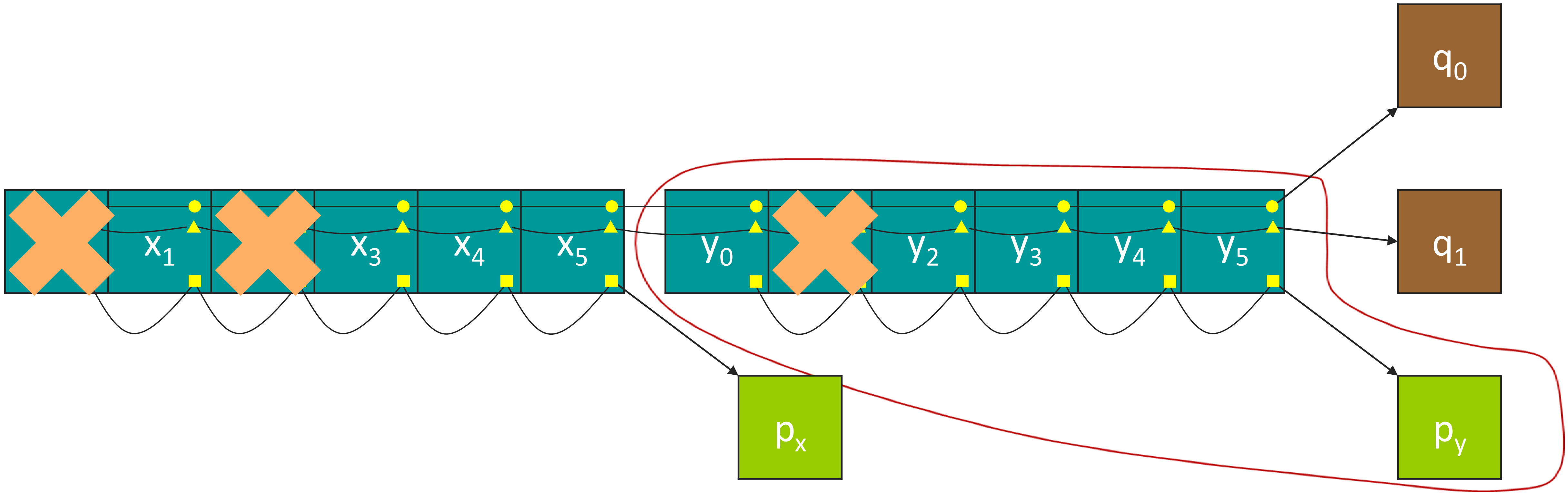


- LRC_{12+2+2}: **12** data fragments, **2** local parities and **2** global parities
  - storage overhead: (12 + 2 + 2) / 12 = 1.33x
- Local parity: reconstruction requires only 6 fragments

One More Thing – Ensuring Reliability in LRC

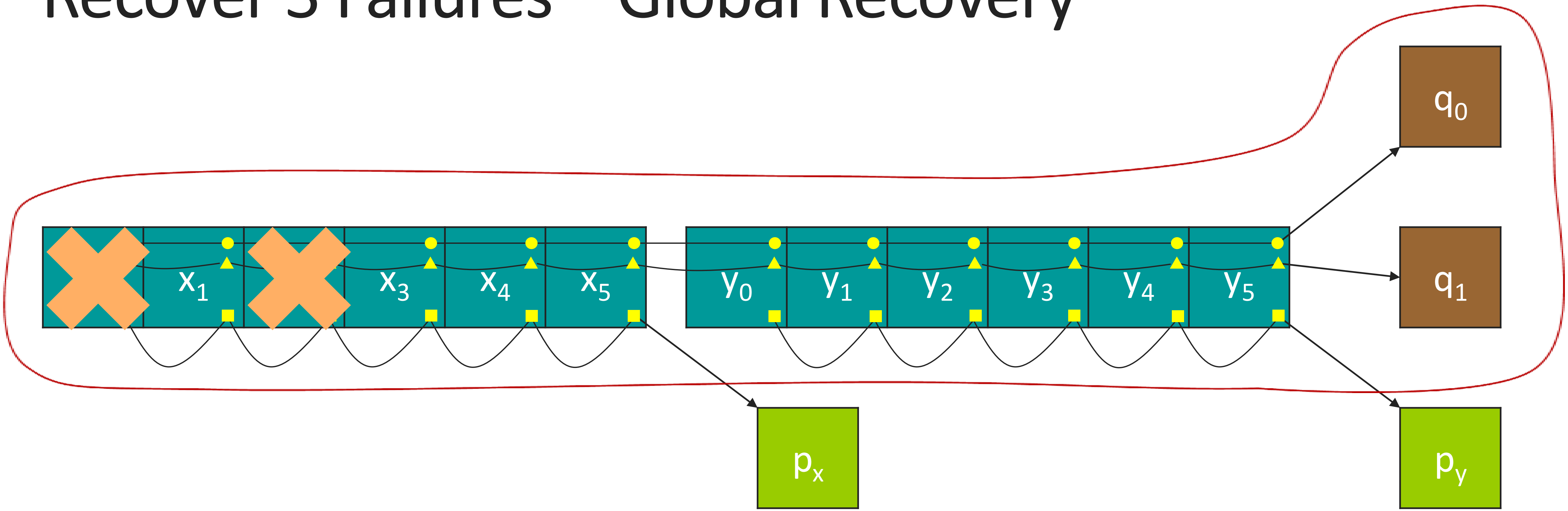
- LRC_{12+2+2} needs to recover
  - arbitrary 3 failures
  - as many 4 failures as possible

Recover 3 Failures – Local Recovery



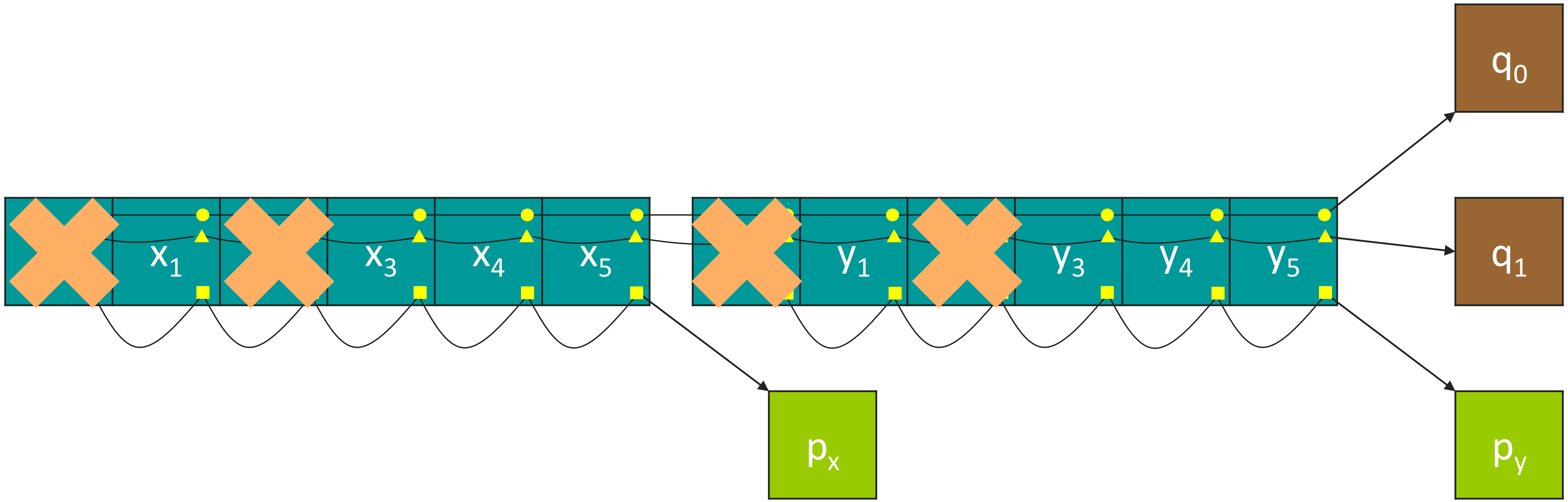
recover y_1 from p_y (group y)

Recover 3 Failures – Global Recovery



recover y_1 from p_y (group y)
recover x_0 and x_2 from q_0 and q_1

Recover 4 Failures – More Challenging



how to recover the 4 failures and all similar cases?
(see paper)

Properties of LRC

- Achieving recovery limit
  - LRC_{12+2+2}: arbitrary 3 failures and 86% of 4 failures
  - reliability: RS_{12+4} > LRC_{12+2+2} > RS_{6+3}

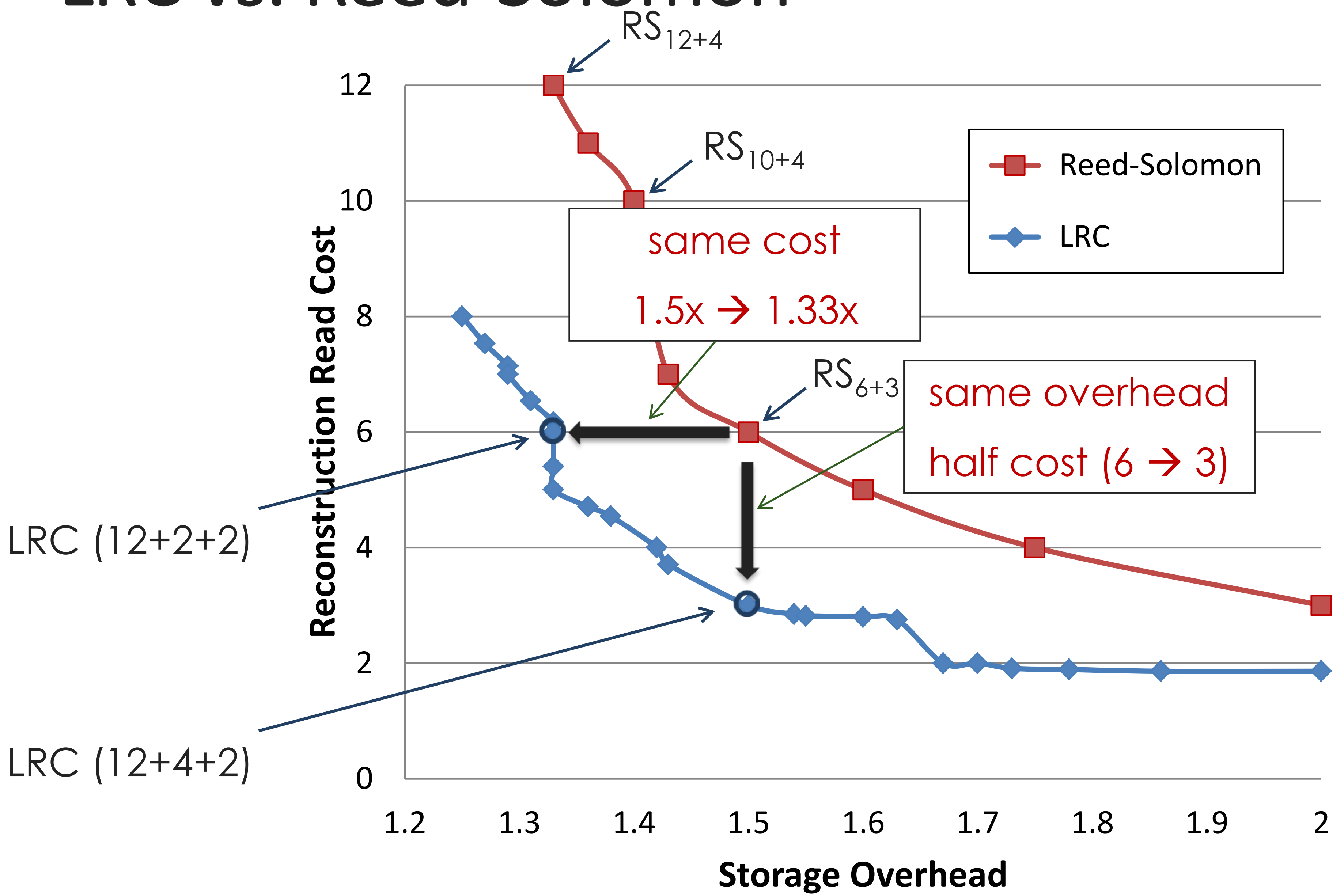
- Requiring minimum storage overhead, given
  - reconstruction cost
  - fault tolerance
    - separate paper to appear in IEEE Trans. on Information Theory

Cost & Performance Analysis

- Vary LRC parameters → trade-off points in 3D space
  - storage overhead
  - reconstruction cost
  - reliability (MTTDL)

- Reliability is a hard requirement
  - set $MTTDL_{3\text{-replication}}$ as target
  - reduce trade-off space to 2D

LRC vs. Reed-Solomon



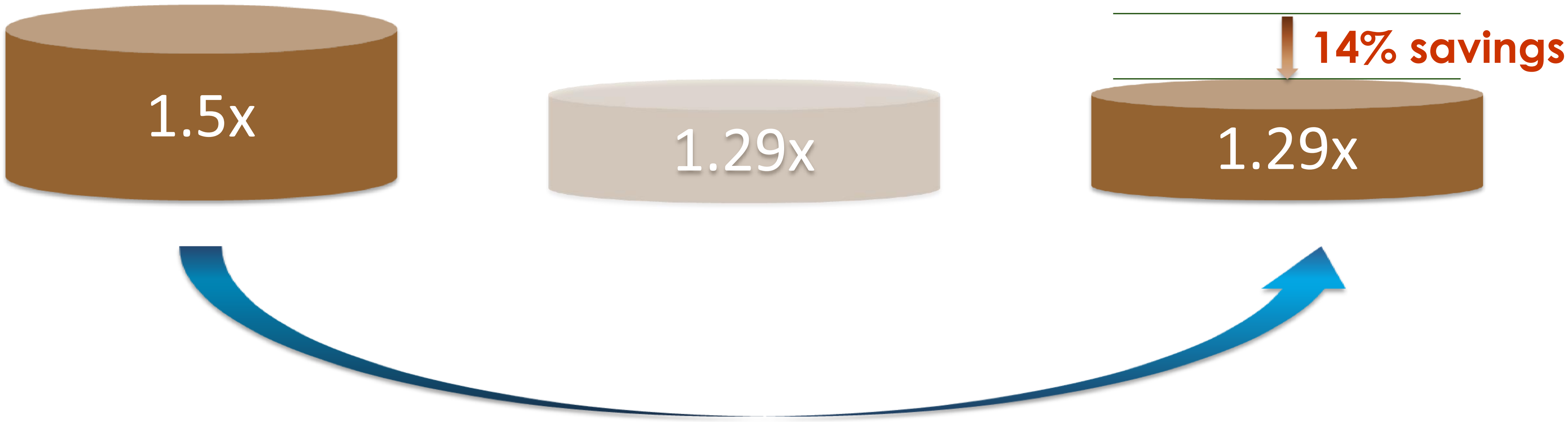
- RS_{10+4}: HDFS-RAID at Facebook
- RS_{6+3}: GFS II (Colossus) at Google

Choice of Windows Azure Storage

RS (6 + 3)
reconstruction cost = 6

RS (14 + 4)
reconstruction cost = 14

LRC (14 + 2 + 2)
reconstruction cost = 7



Summary

- Erasure coding enables significant storage cost savings in Windows Azure Storage with higher reliability than 3-replication

- LRC achieves additional 14% savings without compromising performance

- Windows Azure Storage Team Blog
  - http://blogs.msdn.com/b/windowsazurestorage/