Lazy Means Smart

Reducing Repair Bandwidth Costs in
Erasure-coded Distributed Storage Systems

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Technion

Joint work with
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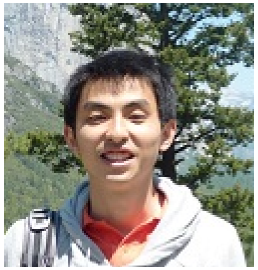
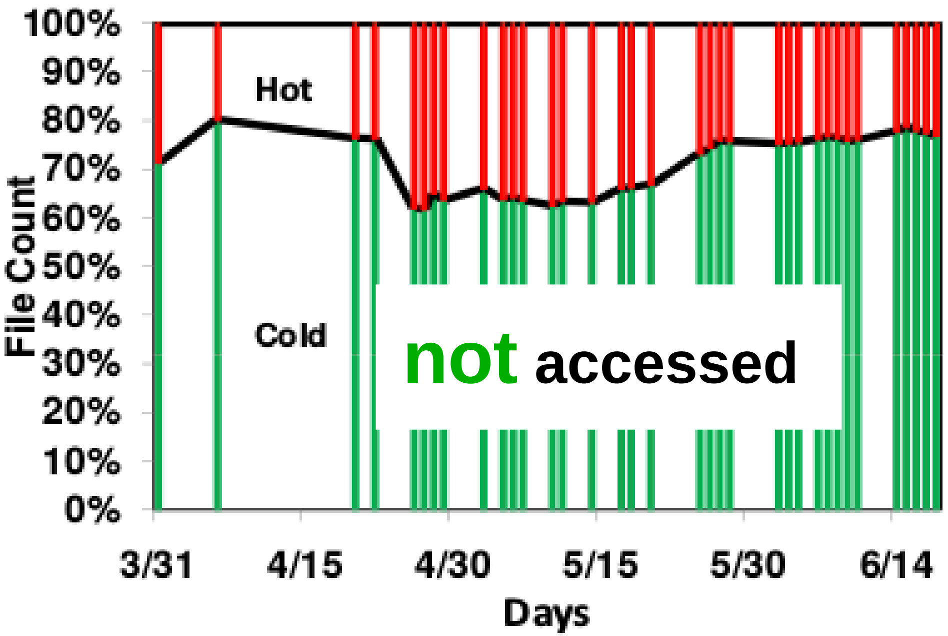


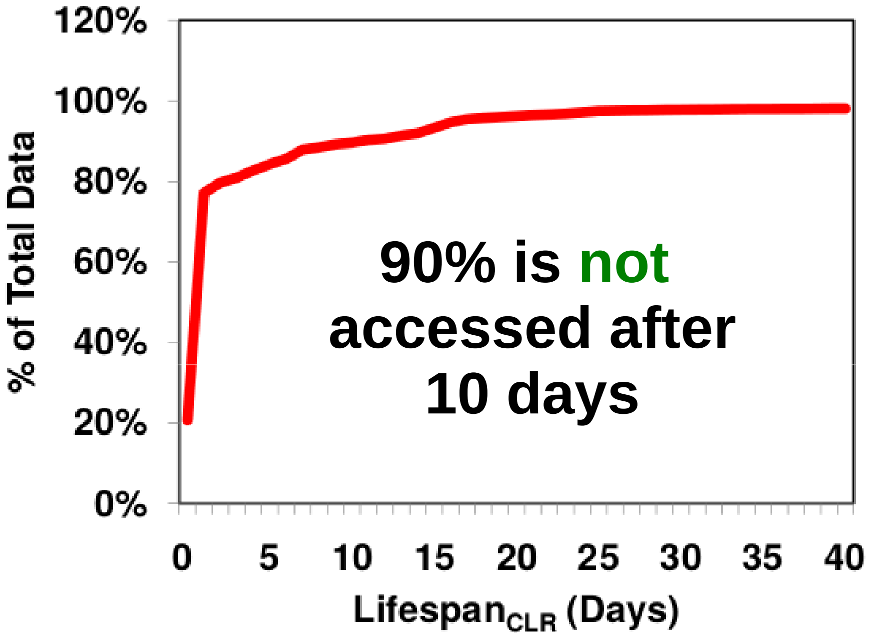
The amount of data is growing

BUT! lots of it is cold!

Cold data in Yahoo! cluster



not accessed



90% is not accessed after 10 days

From: “GreenHDFS: Towards An Energy-Conserving, Storage-Efficient, Hybrid Hadoop Compute Cluster”, Kaushik & Bhandnarkar, HotPower, 2010

Special properties of cold storage system

- Fast retrieval
- Few read accesses
- **Low cost**

vs. archival storage

vs. “hot” storage

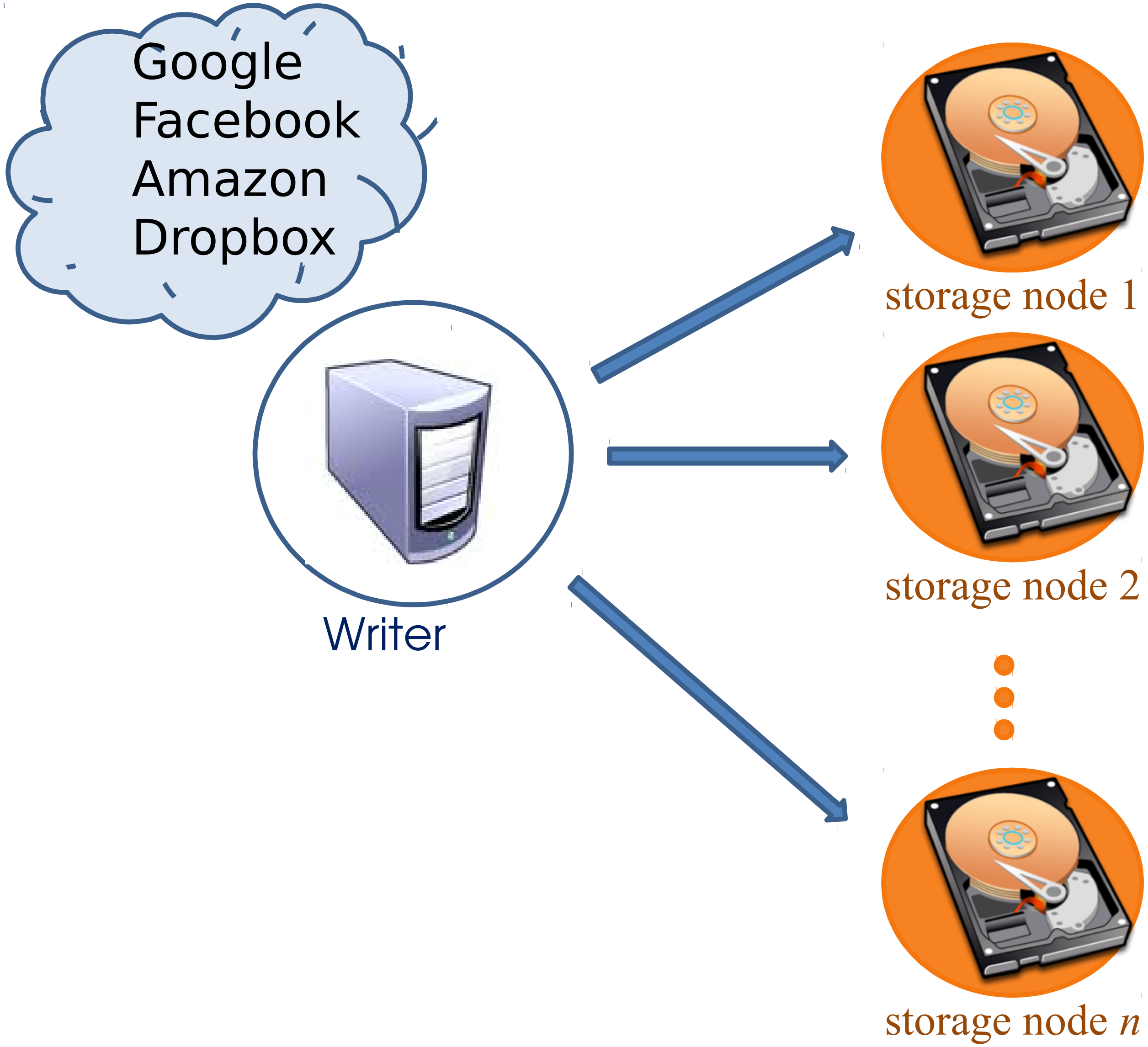
Cold = Existing users

Hot = New users

This talk

- Lazy recovery – a storage scheme for cold data
  - lower **network** cost
  - higher **storage** efficiency
  - higher **reliability**

Distributed storage system (DSS)



Google
Facebook
Amazon
Dropbox

Writer

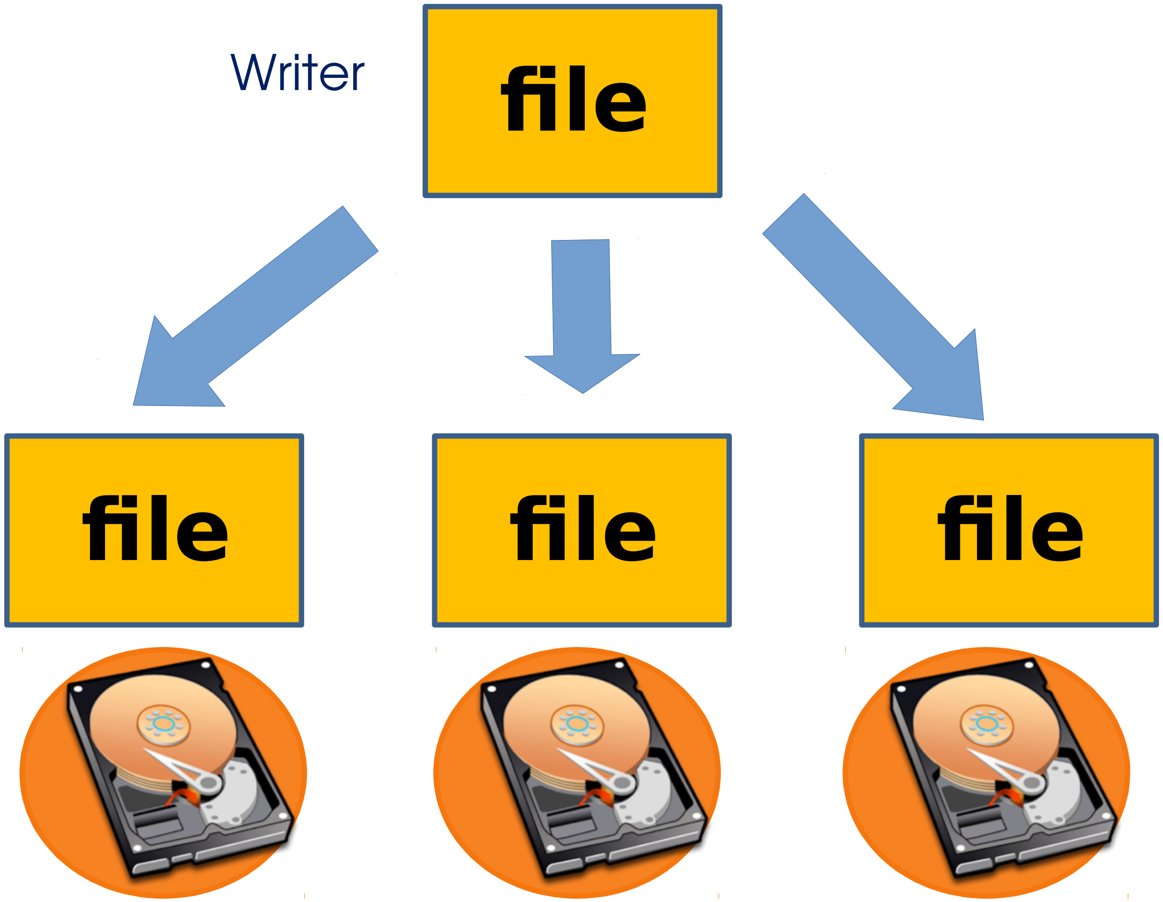
storage node 1

storage node 2

storage node *n*

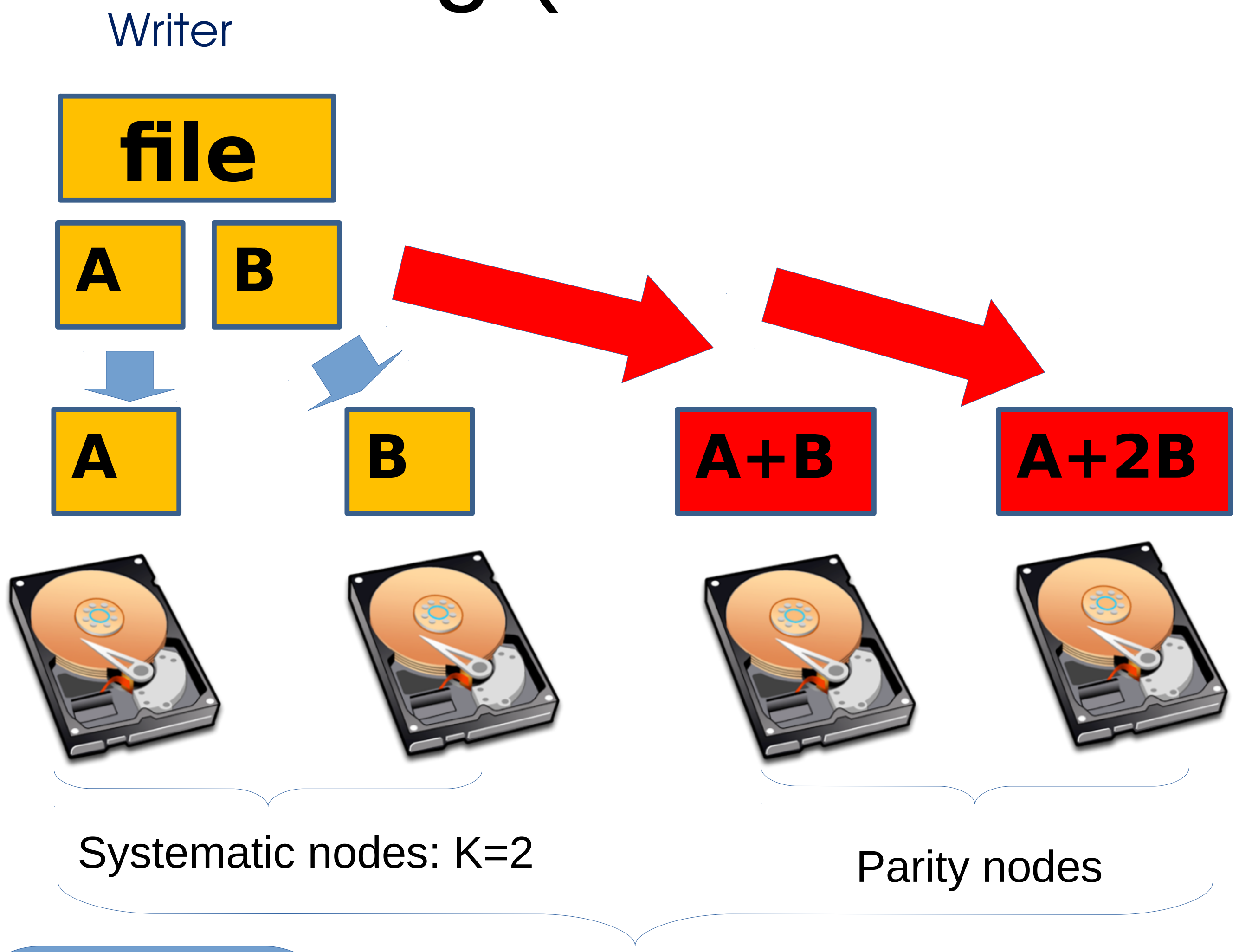
Need redundancy to handle failures

3x replication



Tolerates 2 node failures, pays **3x** in storage

Alternative to replication: Erasure coding (Reed-Solomon)



Writer

file

A B

A

B

A+B

A+2B

Systematic nodes: K=2

Parity nodes

Total nodes **per stripe**: N=4

RS(N=4,K=2)

N-K=2 → survives 2 failures

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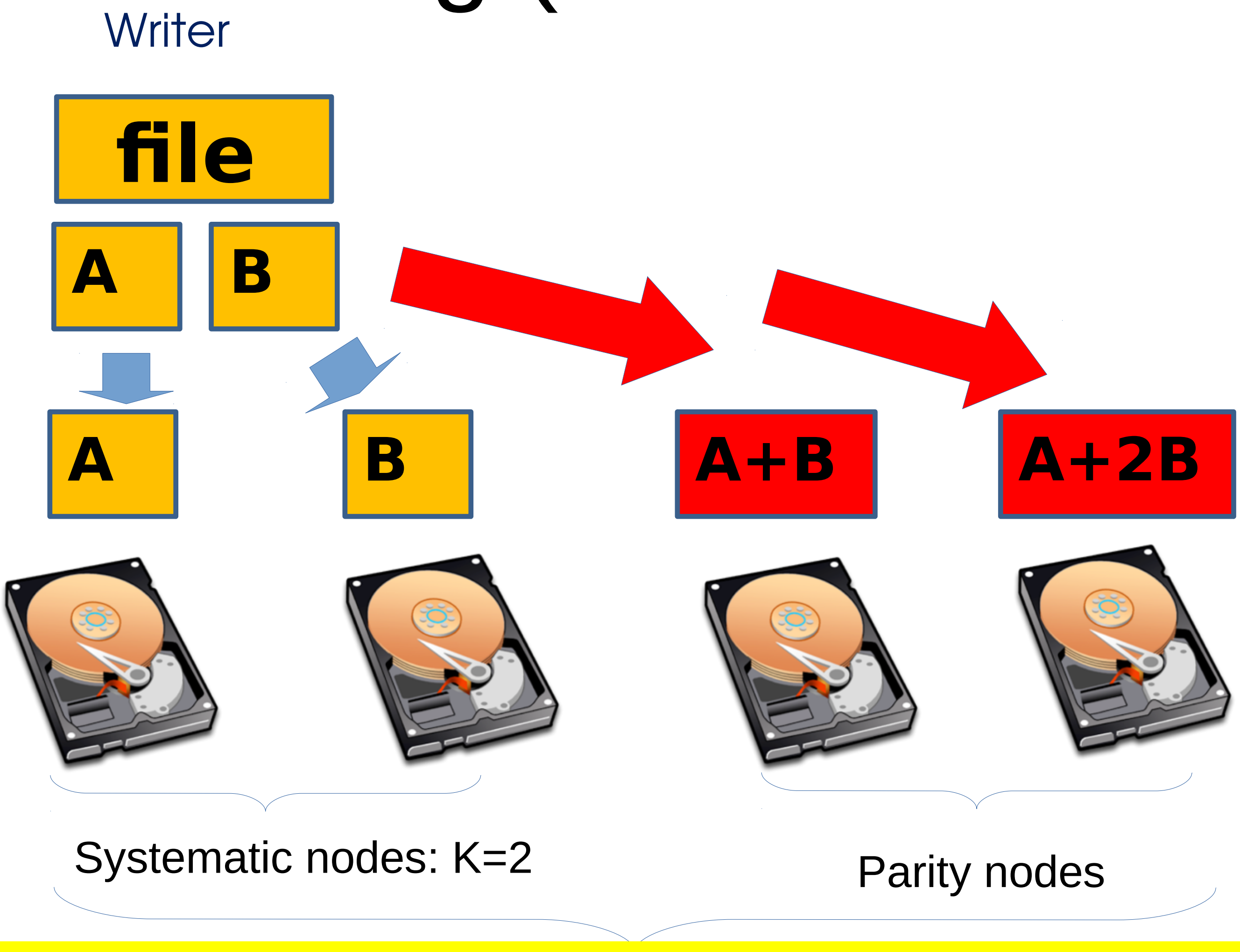

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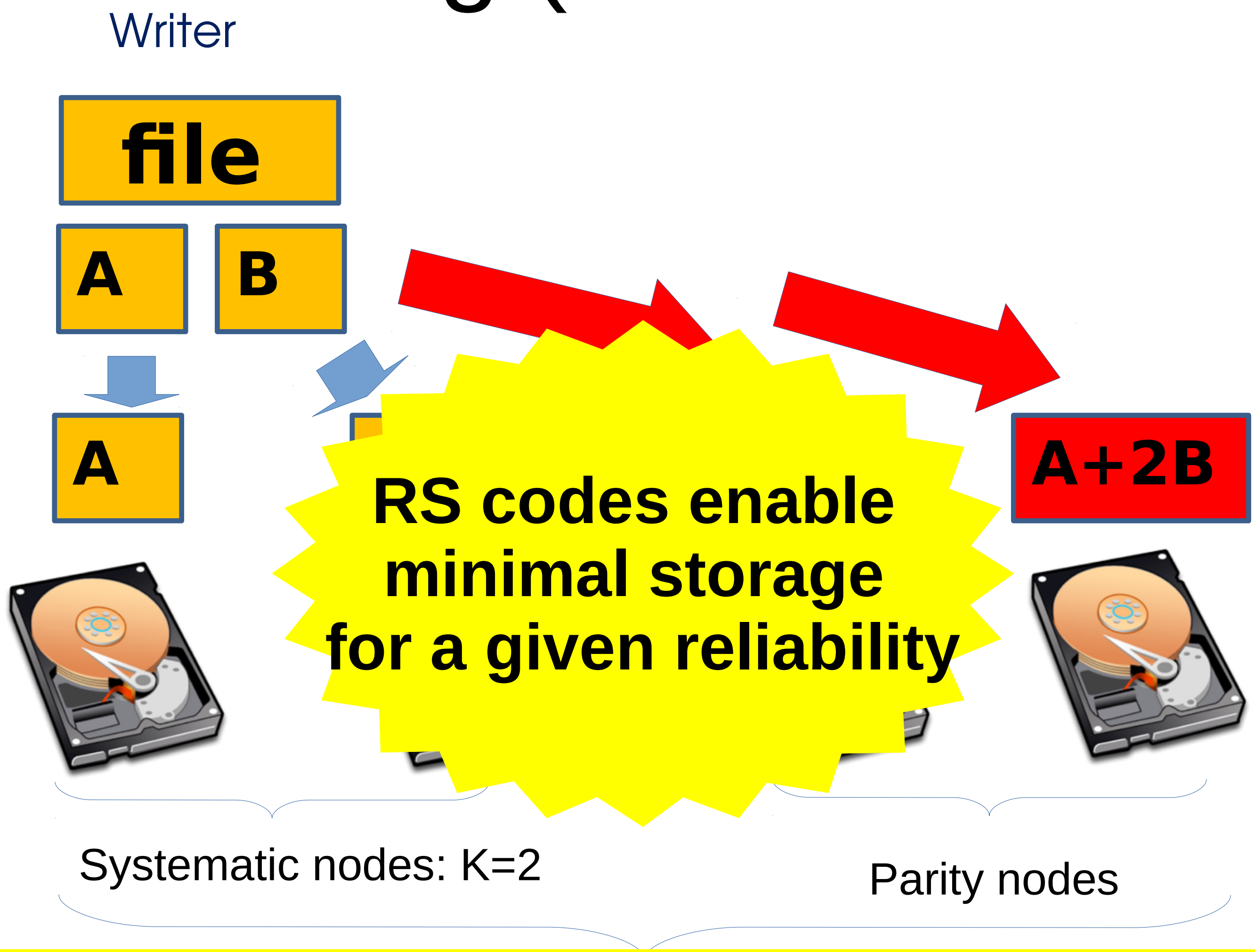


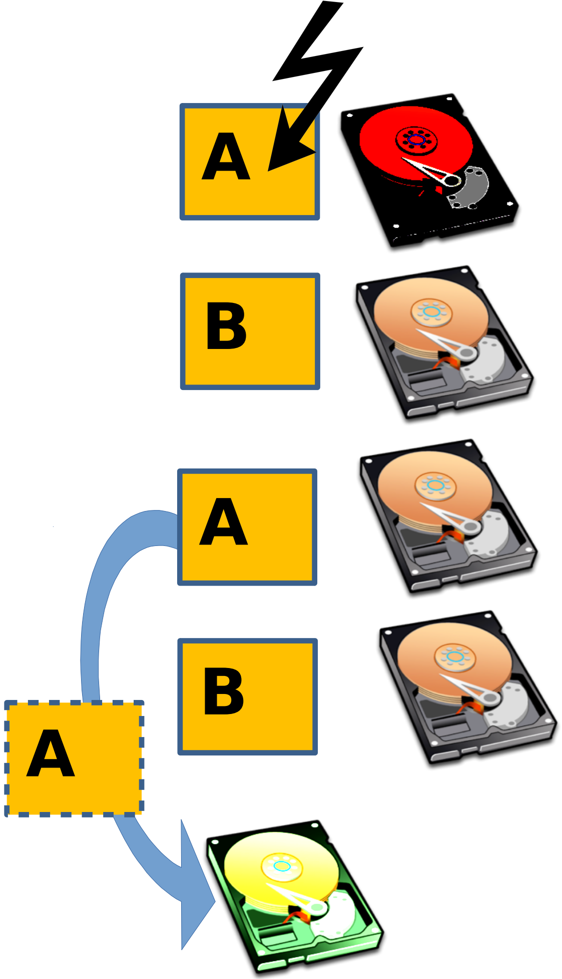
RS codes enable minimal storage for a given reliability

Tolerates **2** node failure, pays **2x** in storage

2 failures

Repair bandwidth problem: recovery costs more bandwidth

Replication



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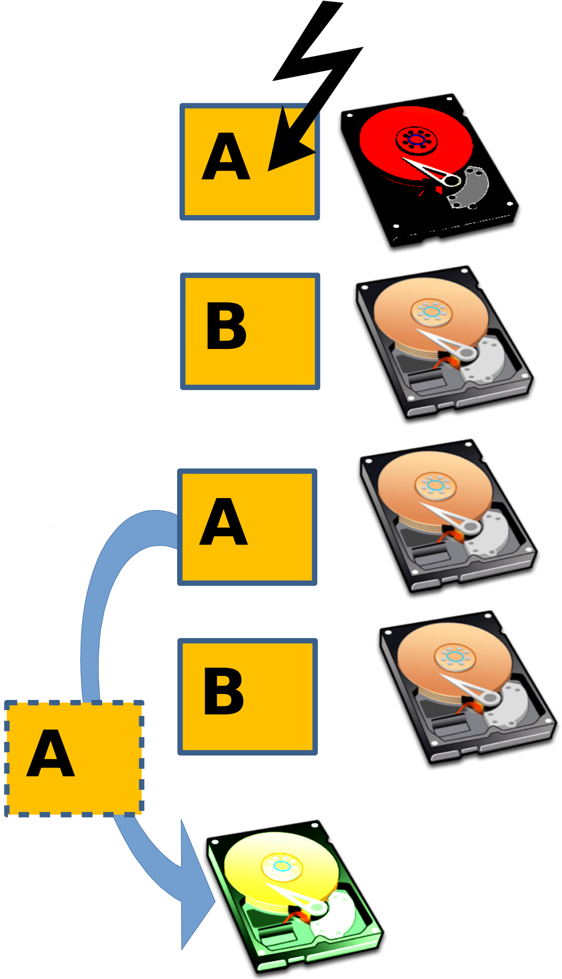
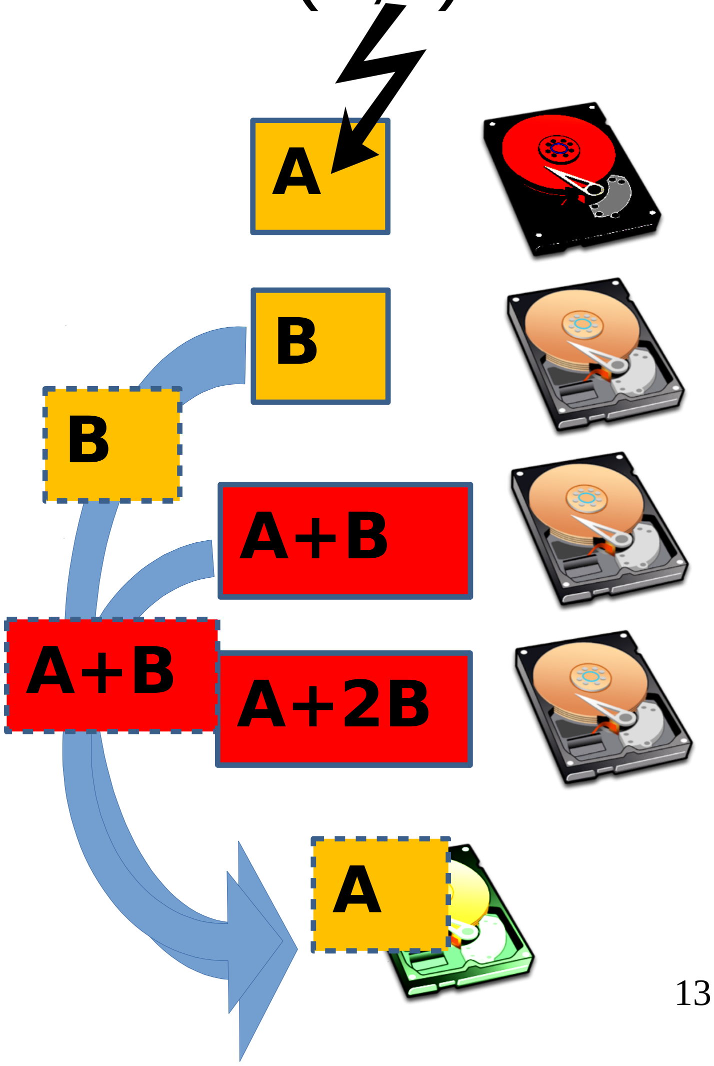


RS(4,2)



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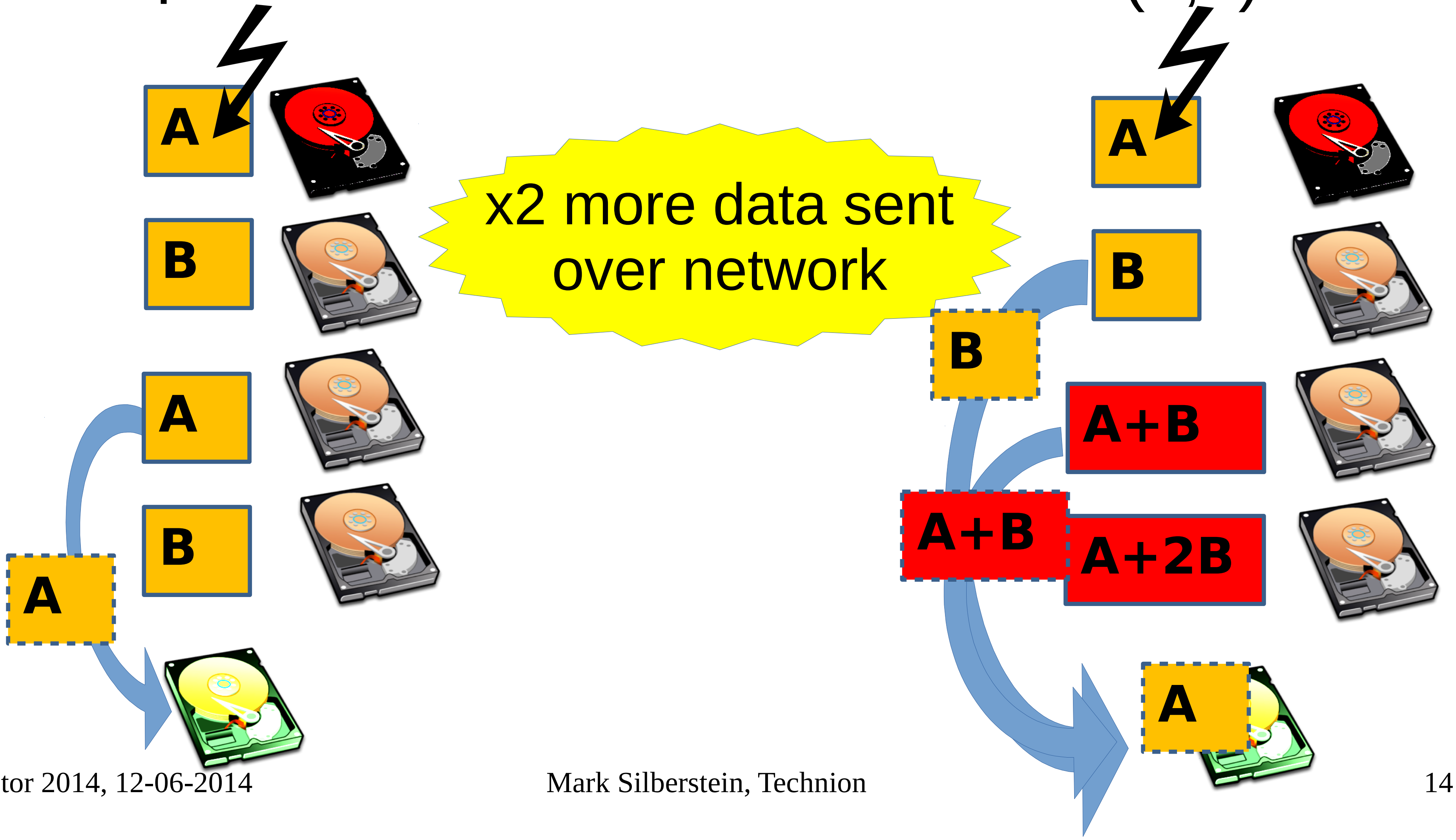
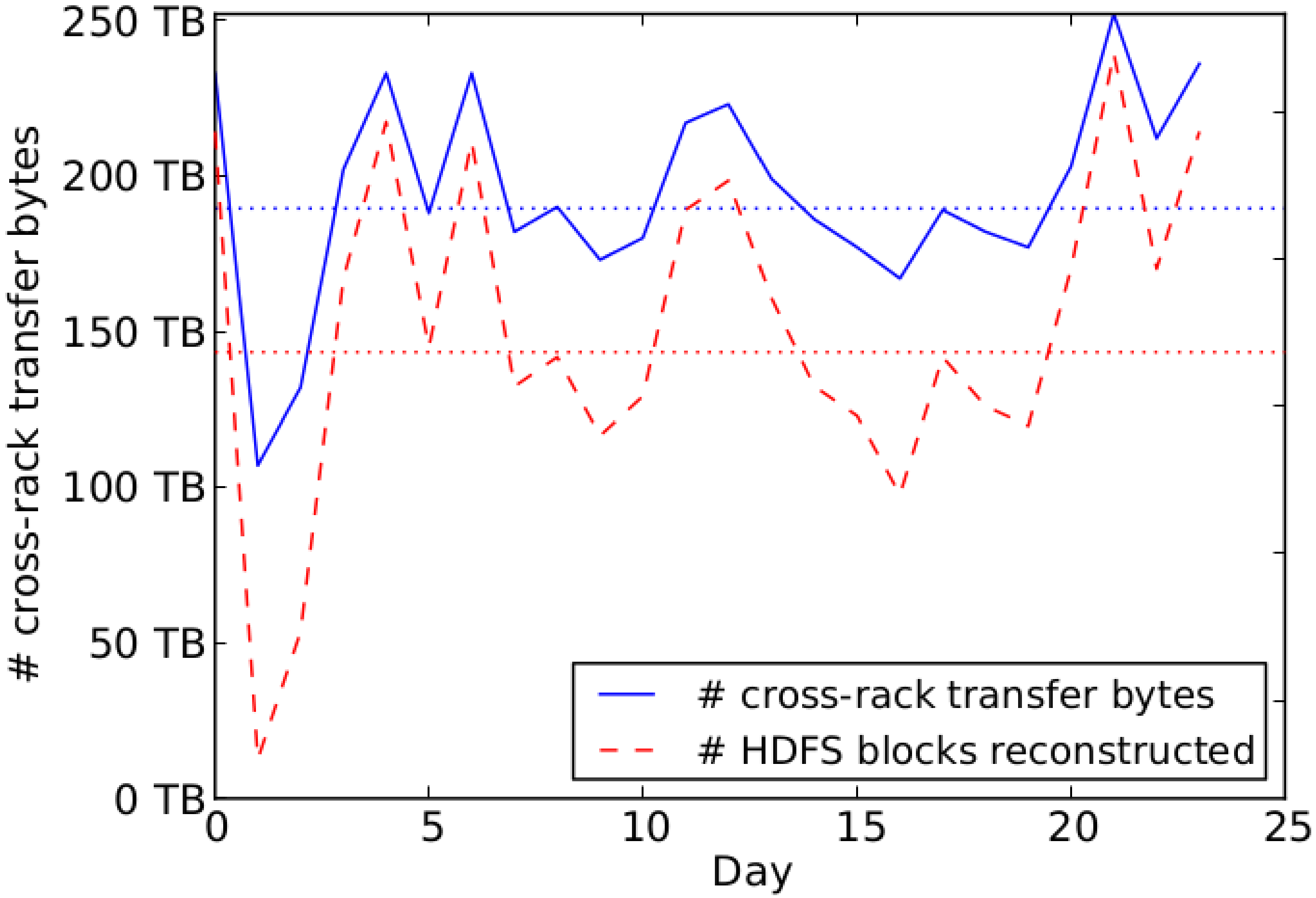


x2 more data sent over network

It is a real problem



Facebook N-nodes cluster, RS(14,10)

From K. Rashmi et.al., “A Solution to the Network Challenges of Data Recovery in Erasure-coded Distributed Storage Systems: A Study on the Facebook Warehouse Cluster”, HotStorage 2013

Root cause:
frequent recovery from **many nodes**

- Recovery is network-expensive!
- We pay the price after one node out of N failed

Root cause: **frequent** recovery from **many nodes**

Others: Change coding scheme to improve recovery costs

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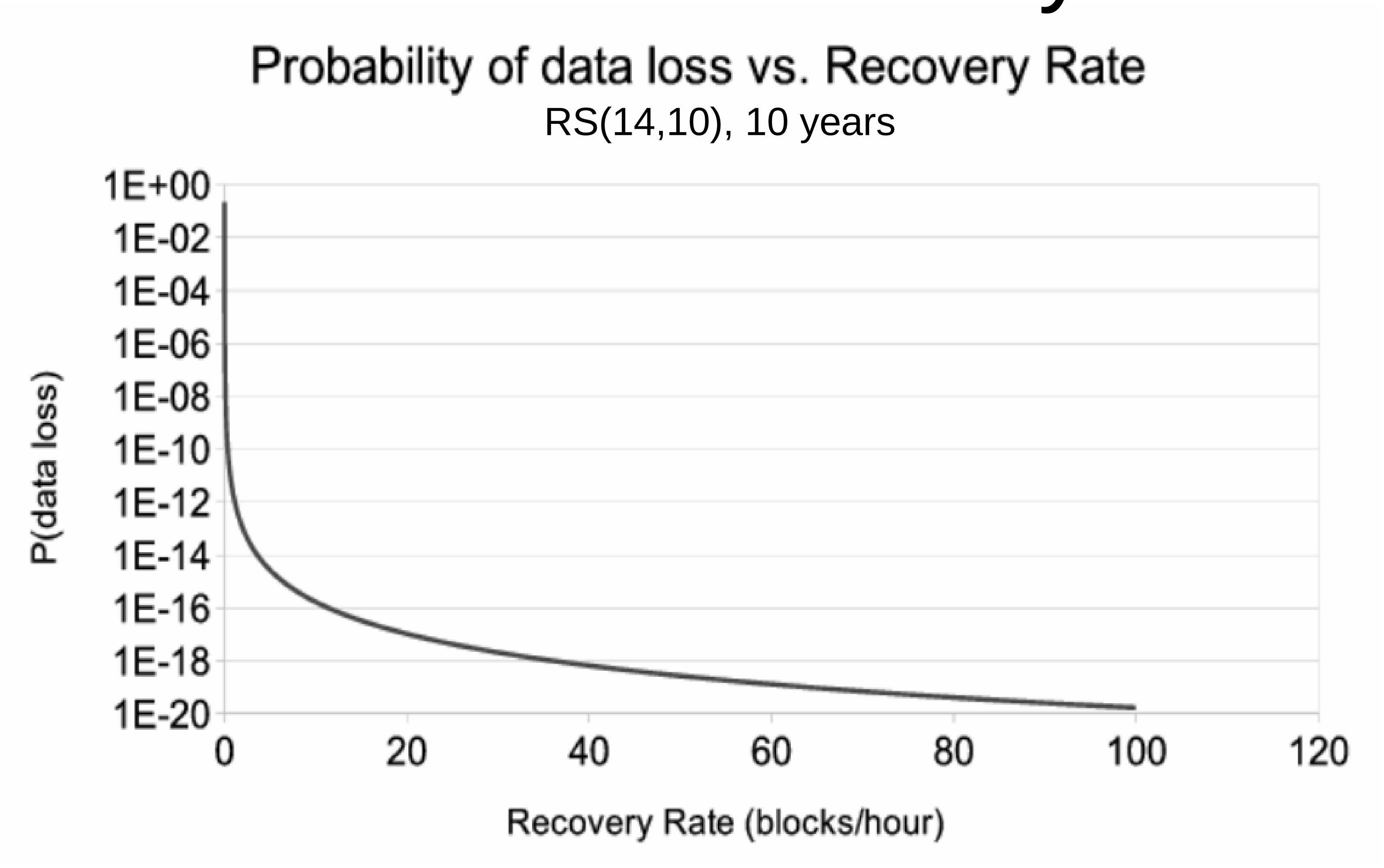
- We pay the price after one node out of N failed

This work: play with recovery frequency

Problem: decreasing recovery rate decreases durability



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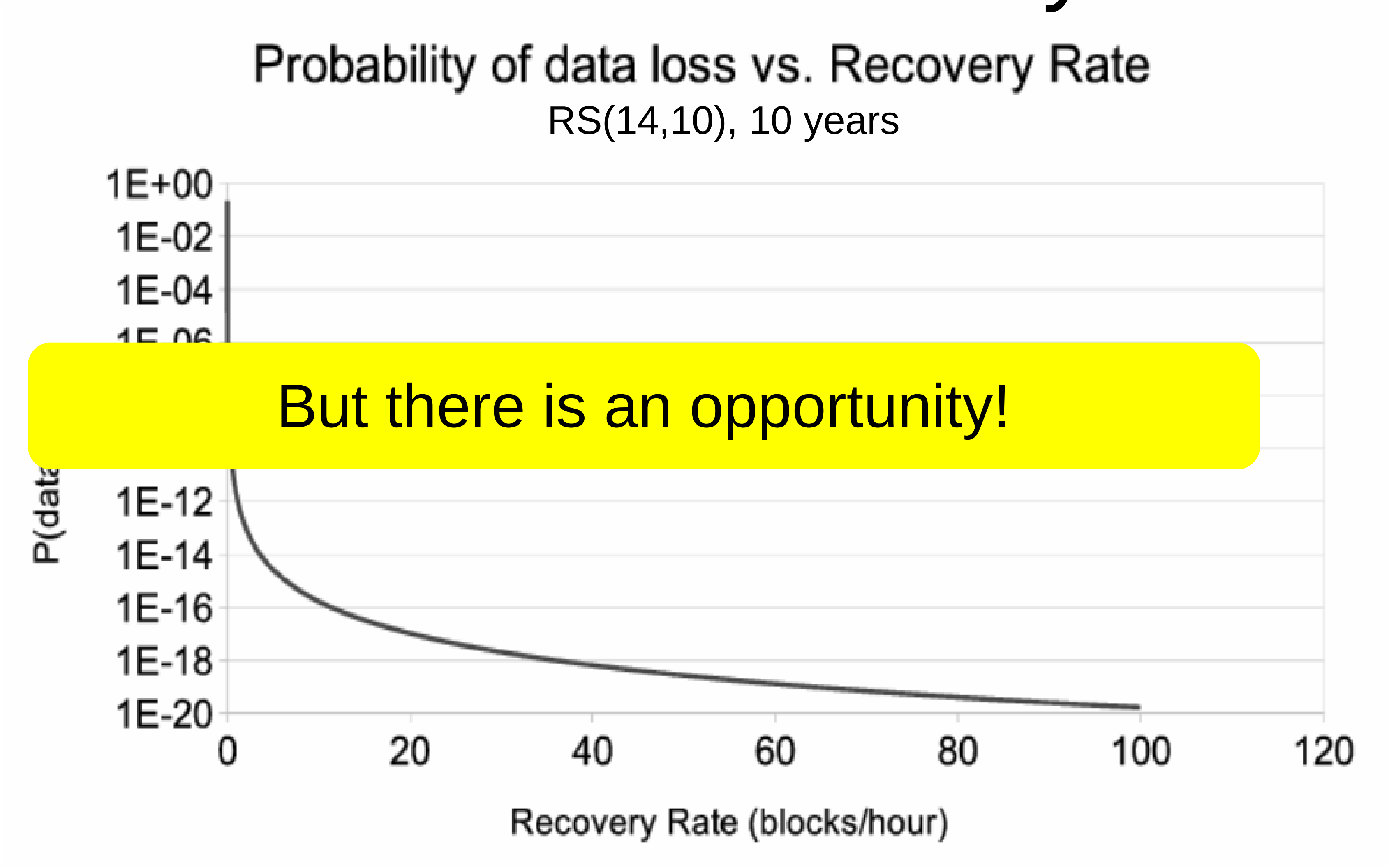
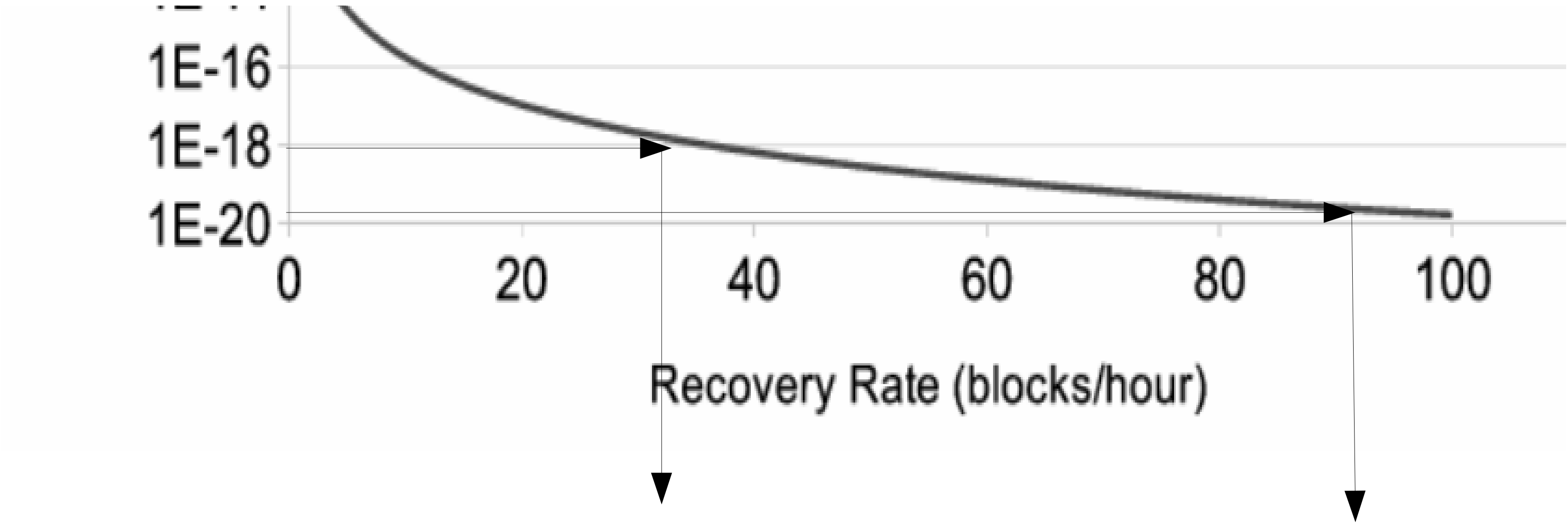


But there is an opportunity!

Do we really need durability that high?



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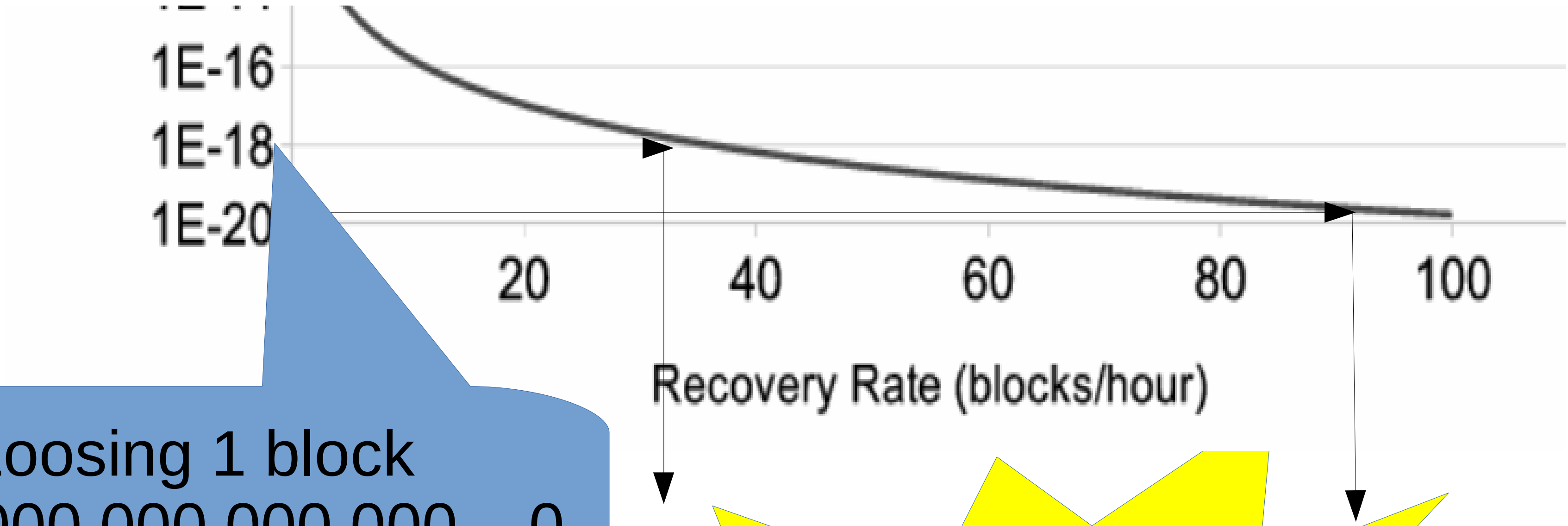

Loosing 1 block
in 10,000,000,000,000,...0
years

3x bandwidth
reduction

Lazy recovery approach

- Don't recover upon the first failure – wait until *F* failures
  - Was first used in P2P systems
- Benefits:
  - Less false-positive recoveries of transient failures
  - Recovery costs are amortized
- Slight decrease in reliability, slight increase in storage, massive decrease in bandwidth

3PB system RS(15,10)

Example: RS(15,10), recover 2 failures

Reliability: similar to RS(14,10)

	Standard (1 failure)	2 failures	3 failures
Repair traffic /day	**65 TB**	**15.3 TB**	**8 TB**

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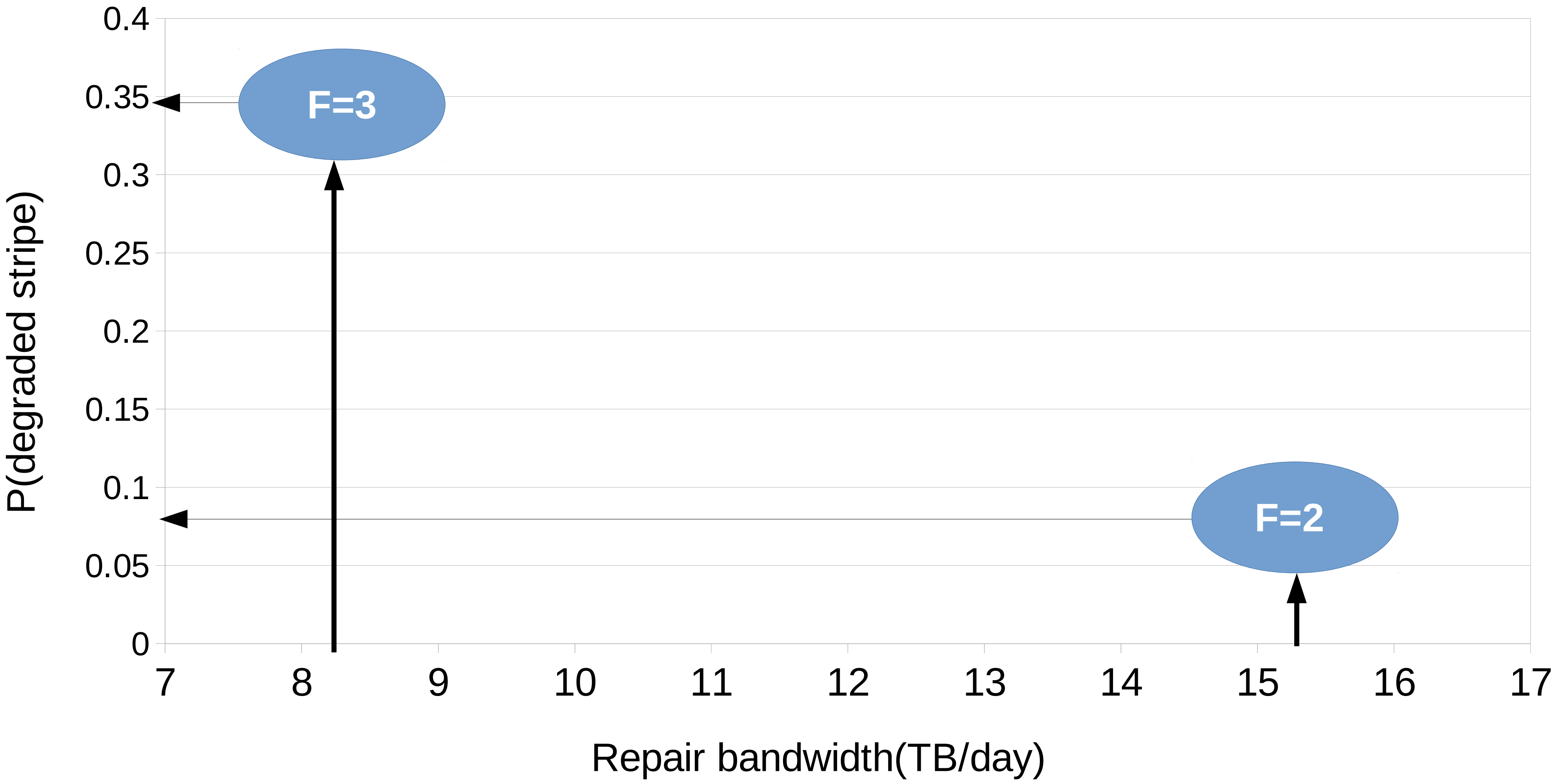
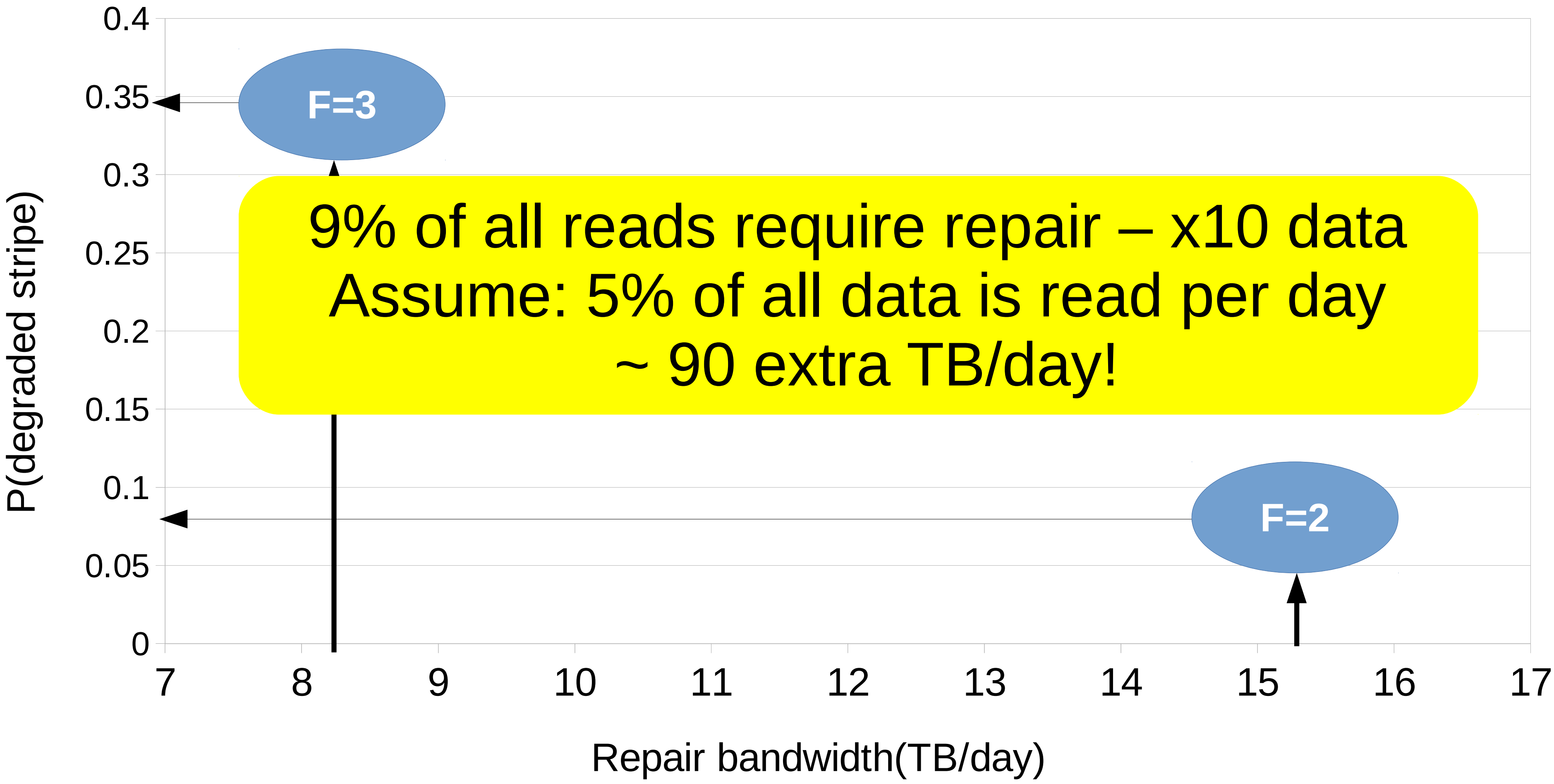
BUT!!!

Lots of degraded stripes!

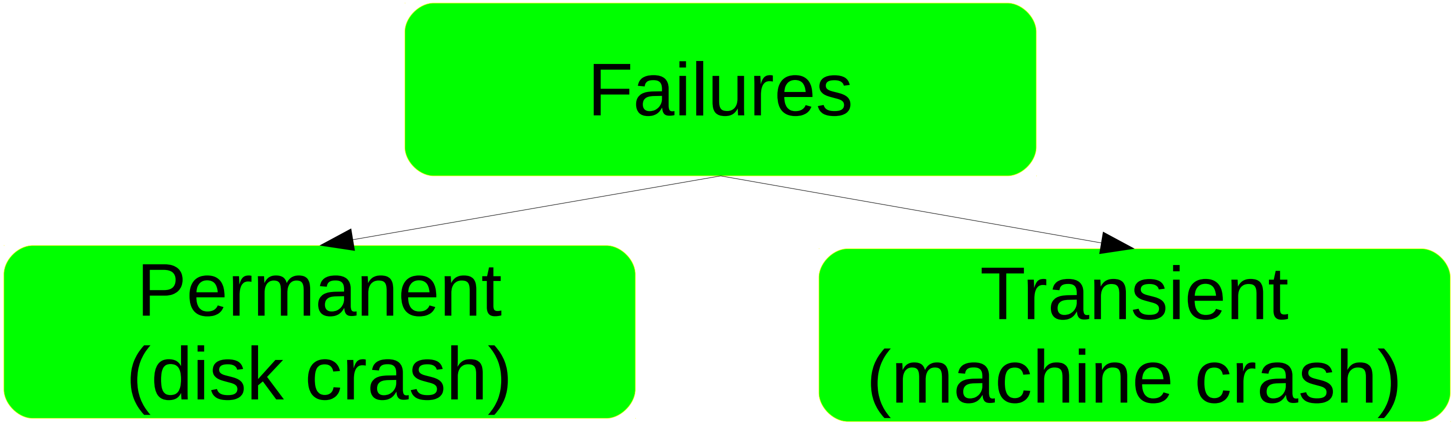


Lots of degraded stripes!



9% of all reads require repair – x10 data
Assume: 5% of all data is read per day
~ 90 extra TB/day!

Root cause

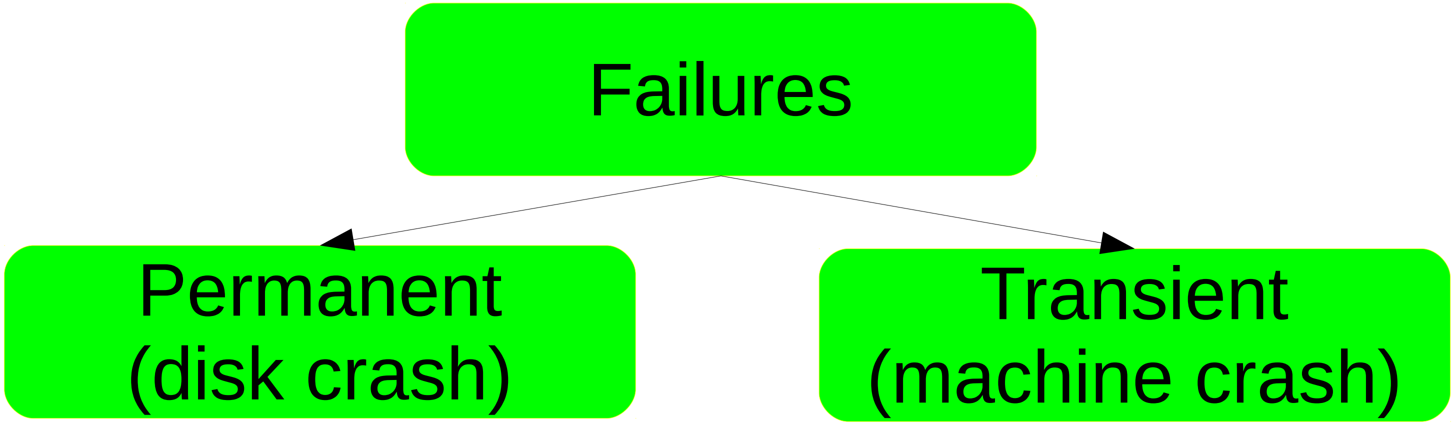

Failures

Permanent
(disk crash)

Transient
(machine crash)

- **Transient** recover by themselves – laziness pays off
- **Permanent** never recover – stripes remain degraded

Root cause



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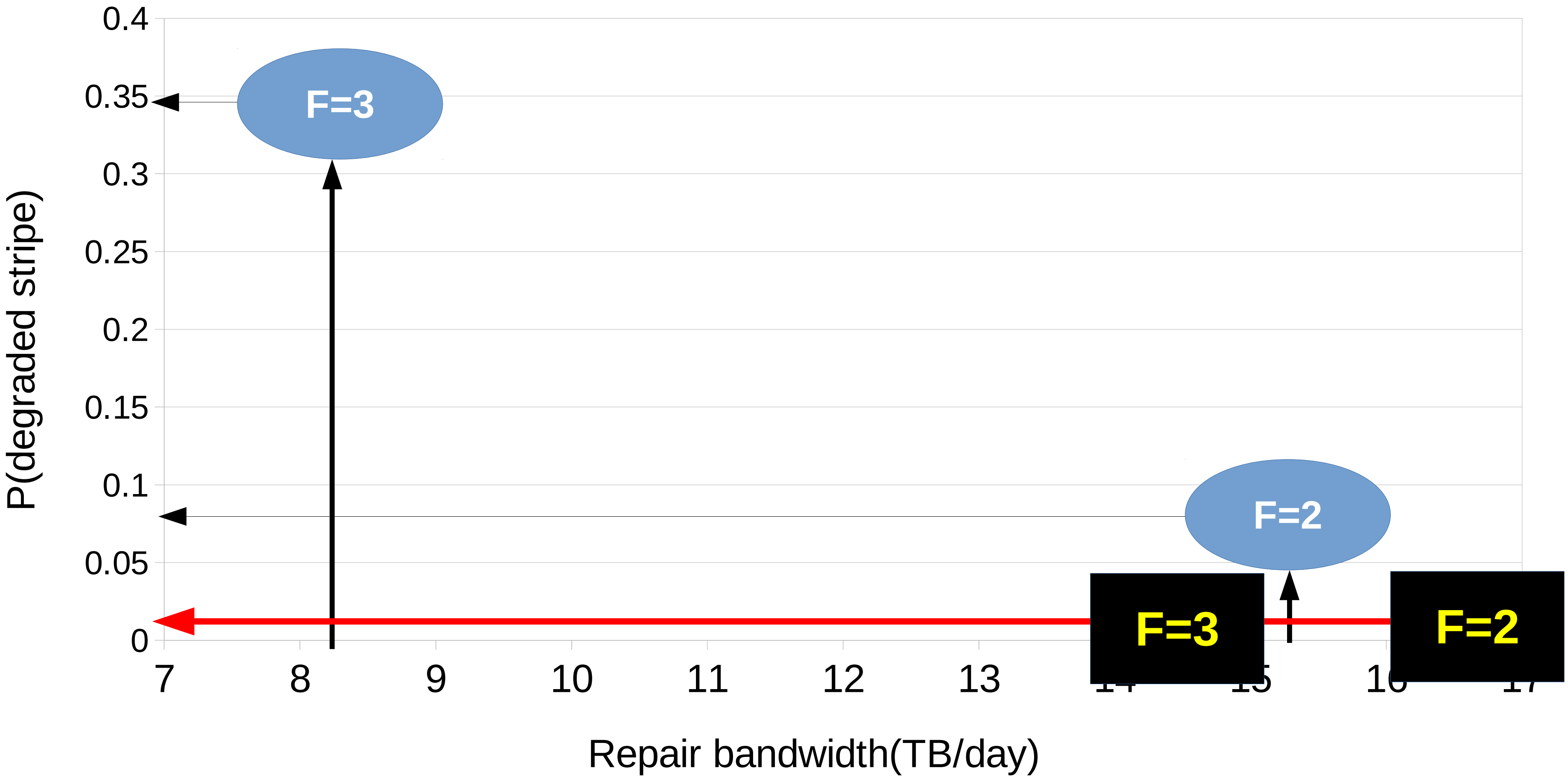
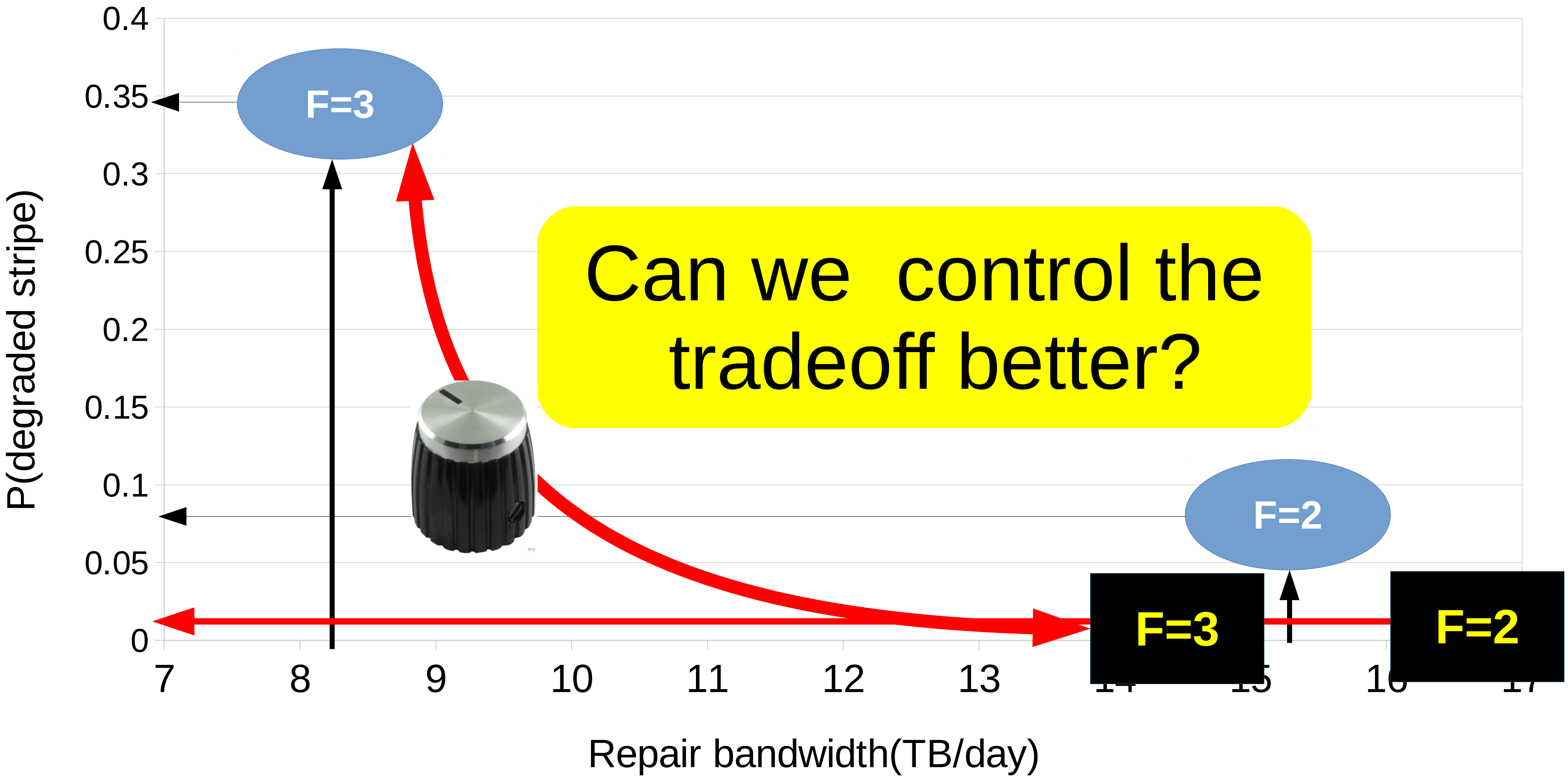
Try 2: use lazy recovery **ONLY** for transient failures

2% of degraded stripes



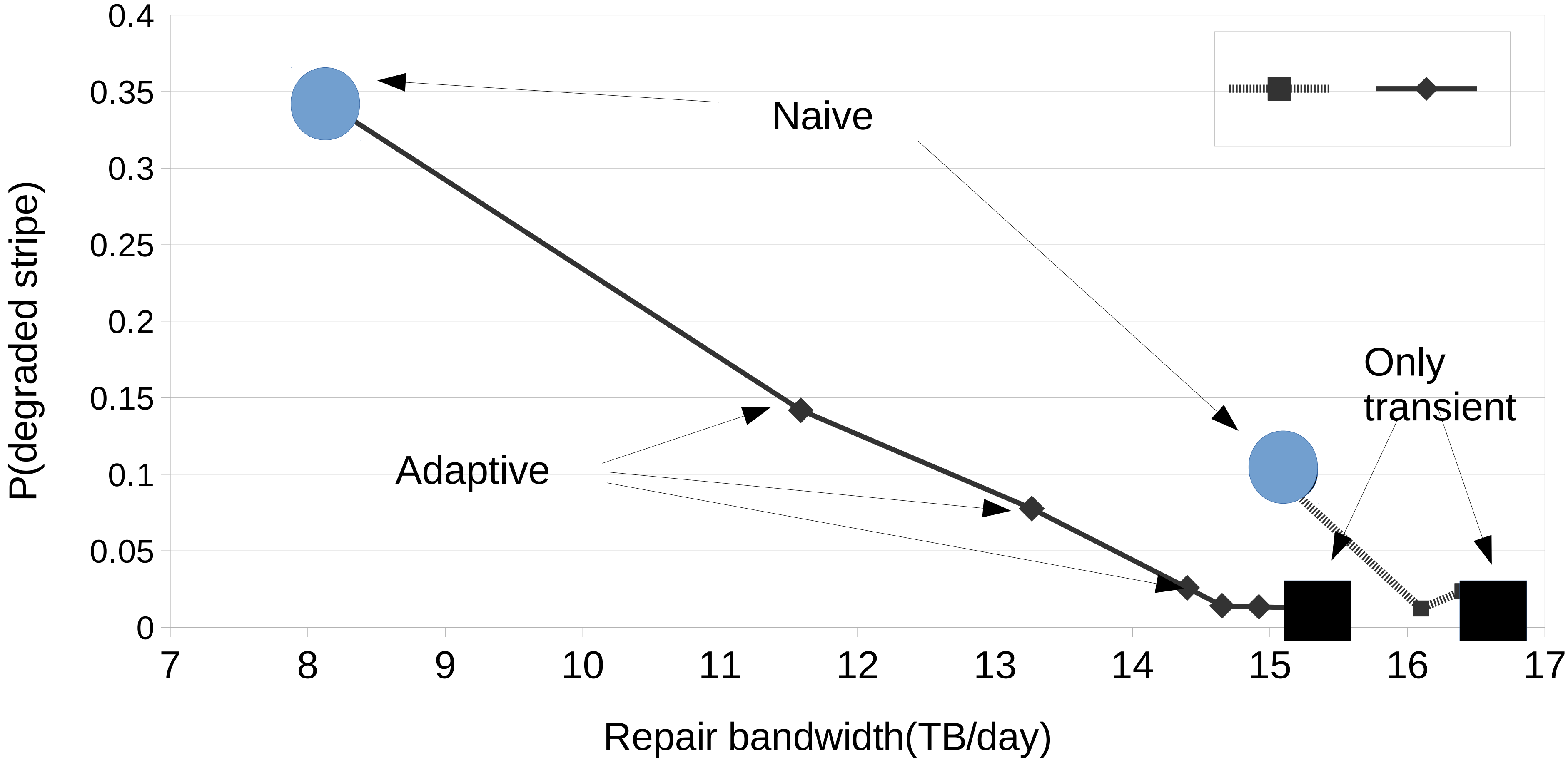
2% of degraded stripes



Adaptive recovery

- As before – lazy recovery for all transient failures
- Lazy recovery for permanent failures if system-wide permanently degraded below a target threshold
- Otherwise switch to eager recovery for permanent failures

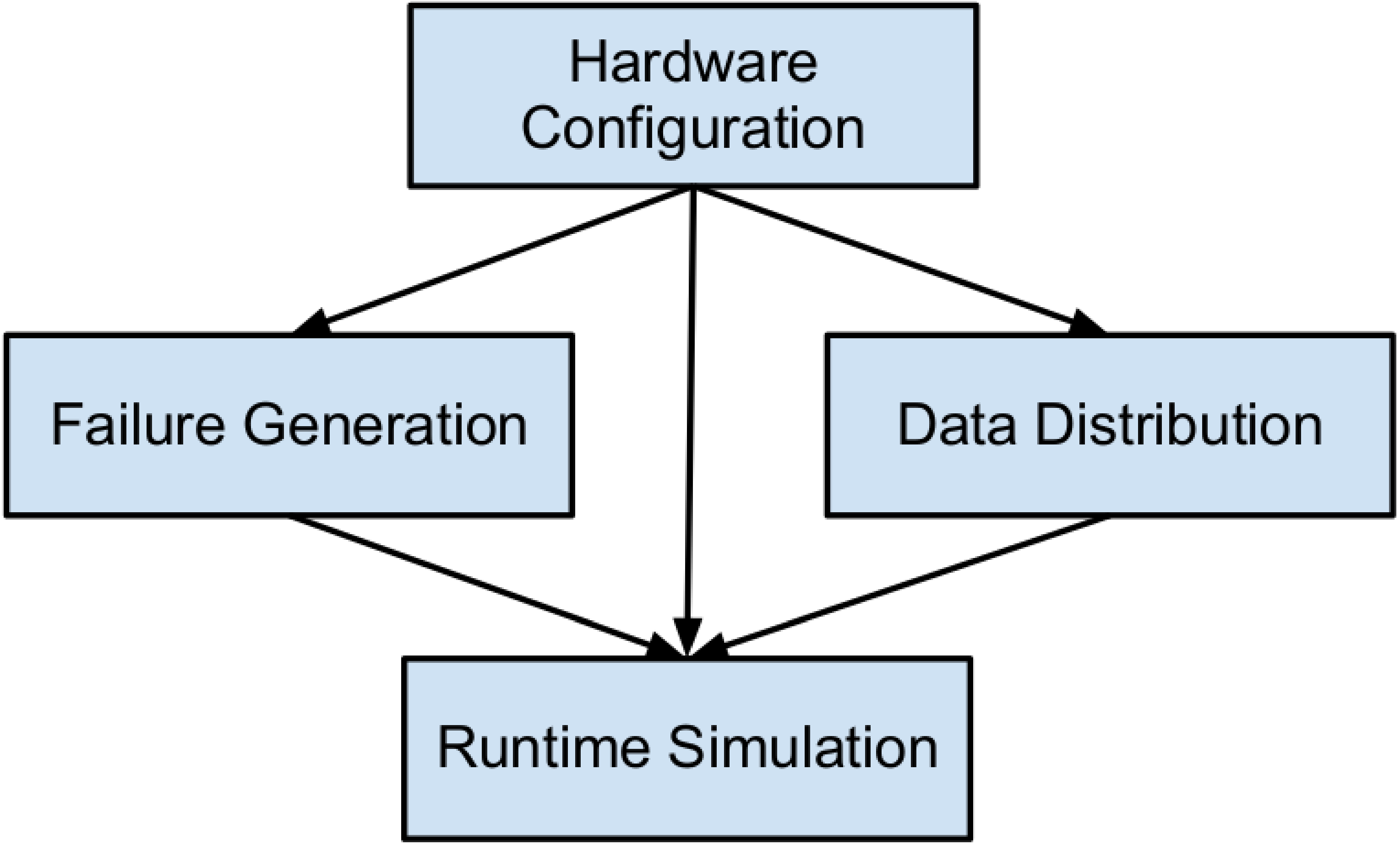
Putting it all together RS(15,10)



Evaluation methodology

- Problem: need to measure 10-years data-loss statistics of 3 PB system
- Solution:
  - Simulation: repair bandwidth and stripe degradation under realistic failure models
  - Modeling: data loss probability

DS-SIM: distributed storage simulator



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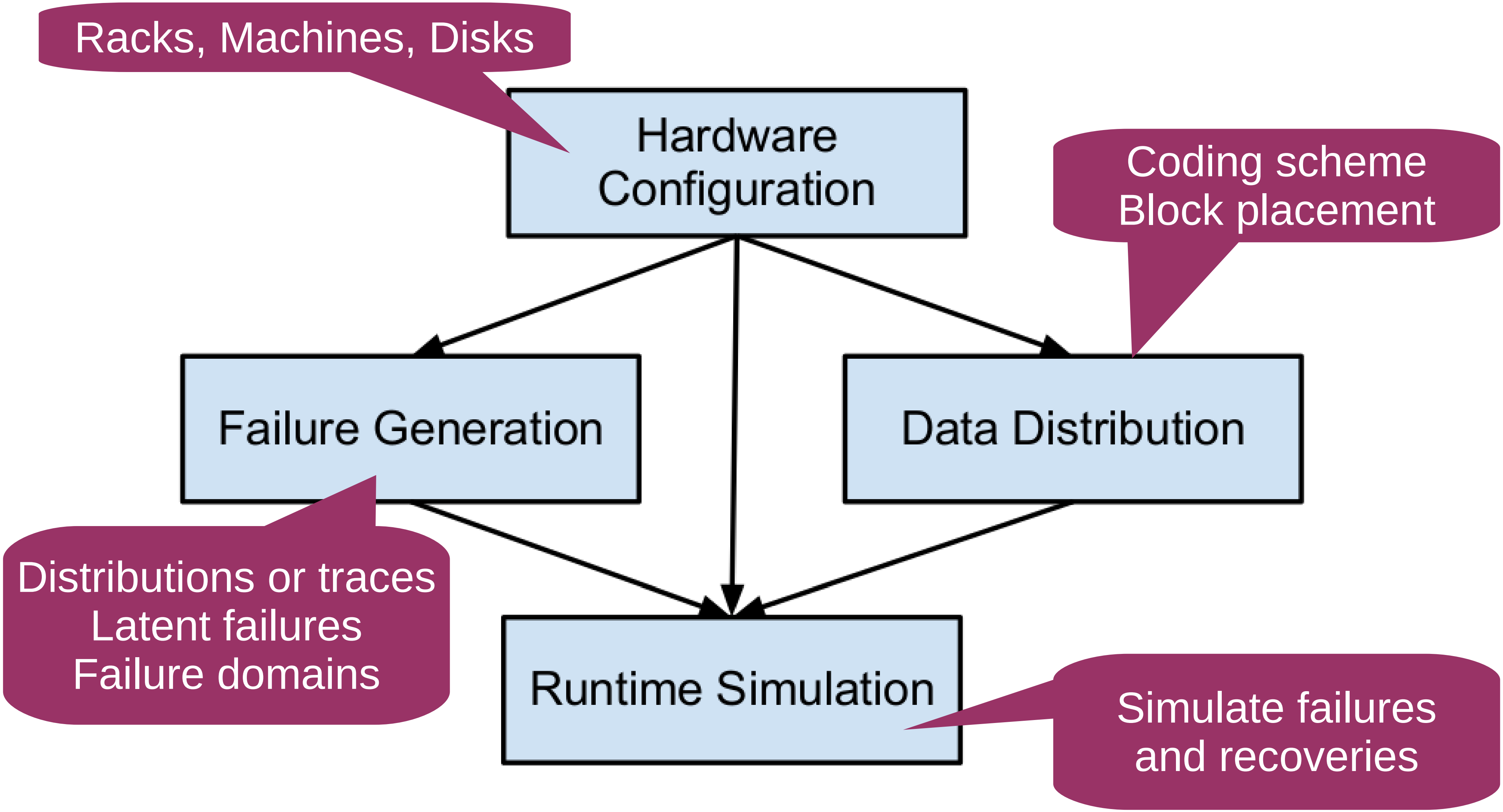


Racks, Machines, Disks

Hardware Configuration

Coding scheme
Block placement

Failure Generation

Data Distribution

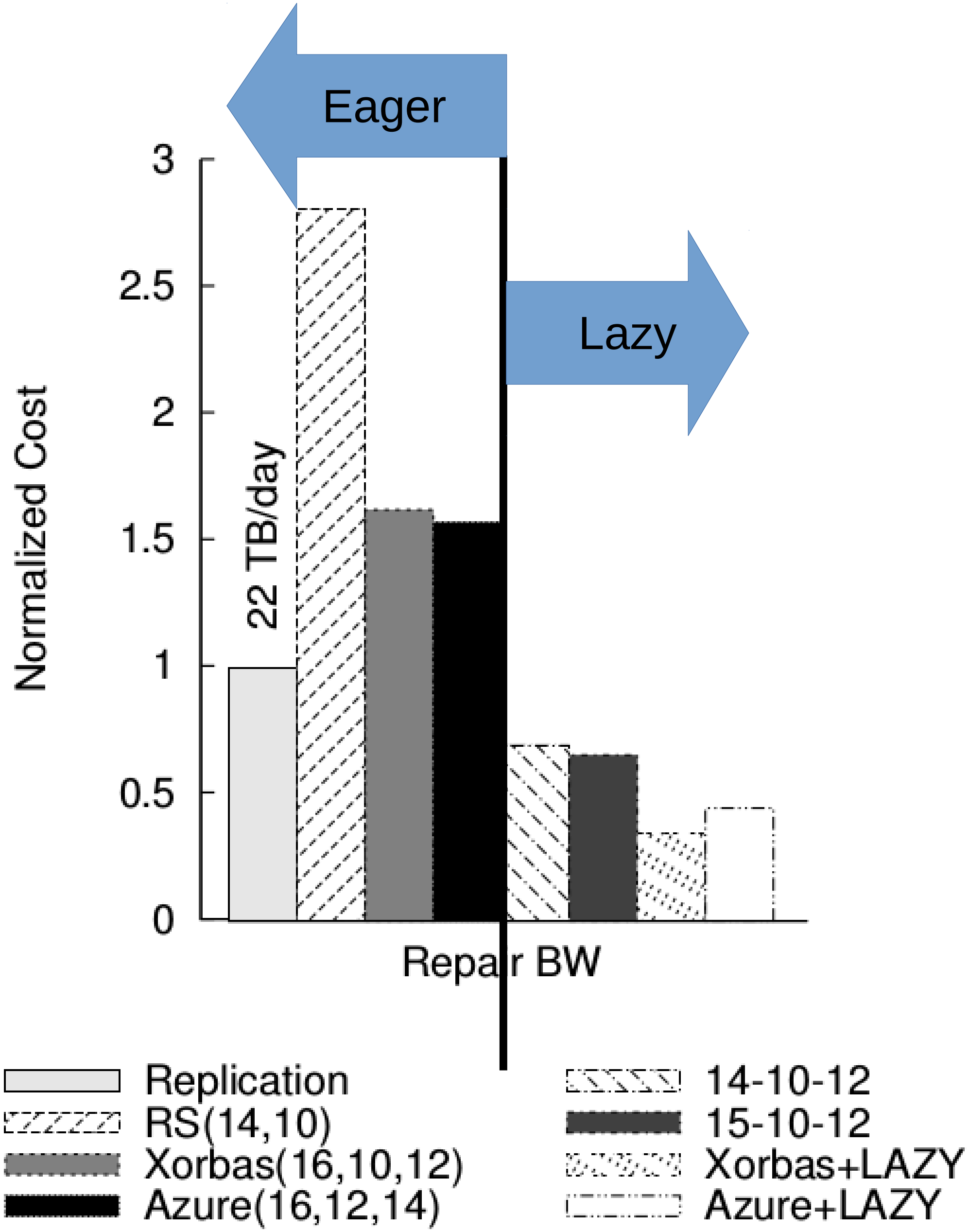
Distributions or traces
Latent failures
Failure domains

Runtime Simulation

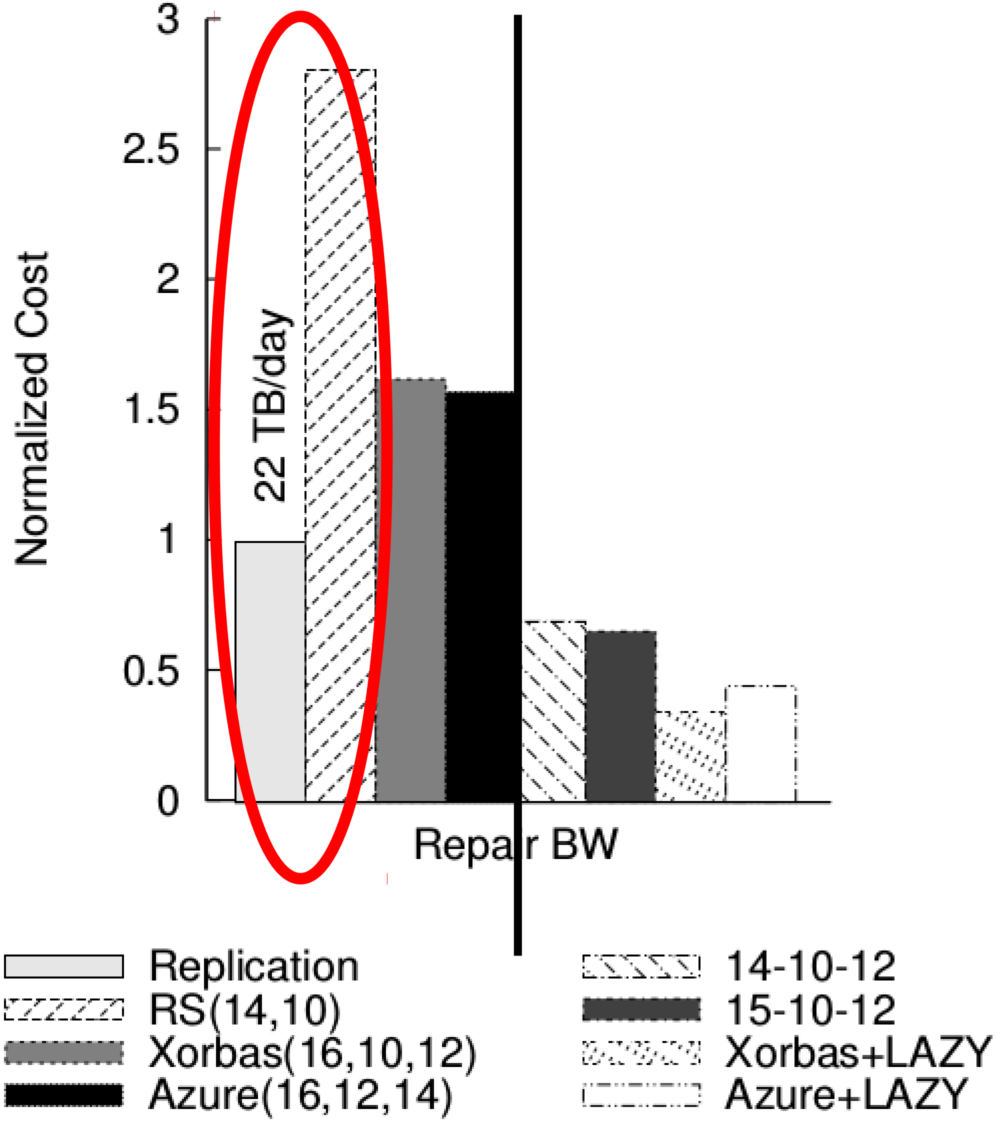
Simulate failures
and recoveries

Simulation parameters

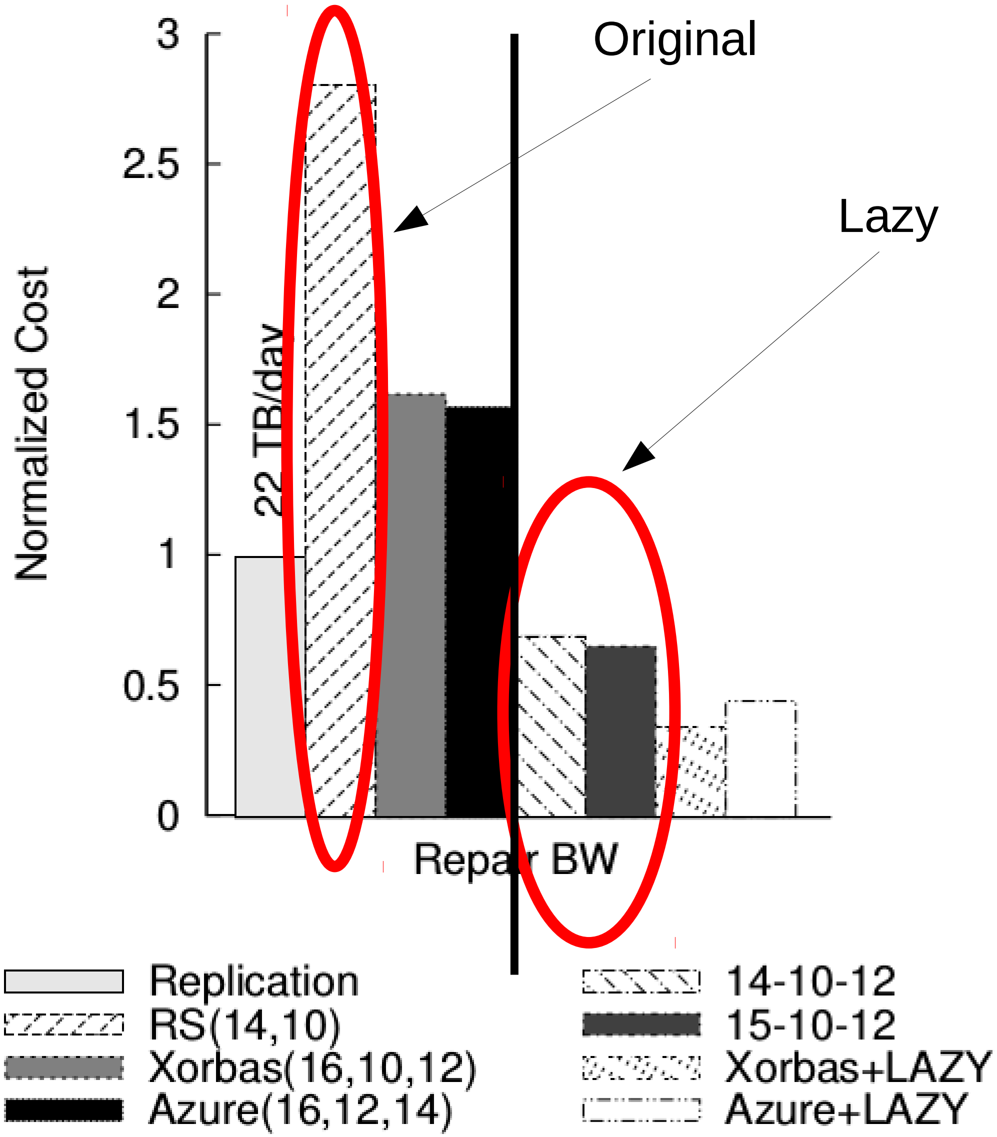
- 3 PB system, 35 racks, million strides, 10 years
- Failure distributions from previous works by Google, Facebook, Microsoft, Yahoo, CFDR trace repository
- 4 types of codes + their lazy versions


Eager
Lazy
3
2.5
2
1.5
1
0.5
0
Normalized Cost
22 TB/day
Repair BW
Replication
RS(14,10)
Xorbas(16,10,12)
Azure(16,12,14)
14-10-12
15-10-12
Xorbas+LAZY
Azure+LAZY

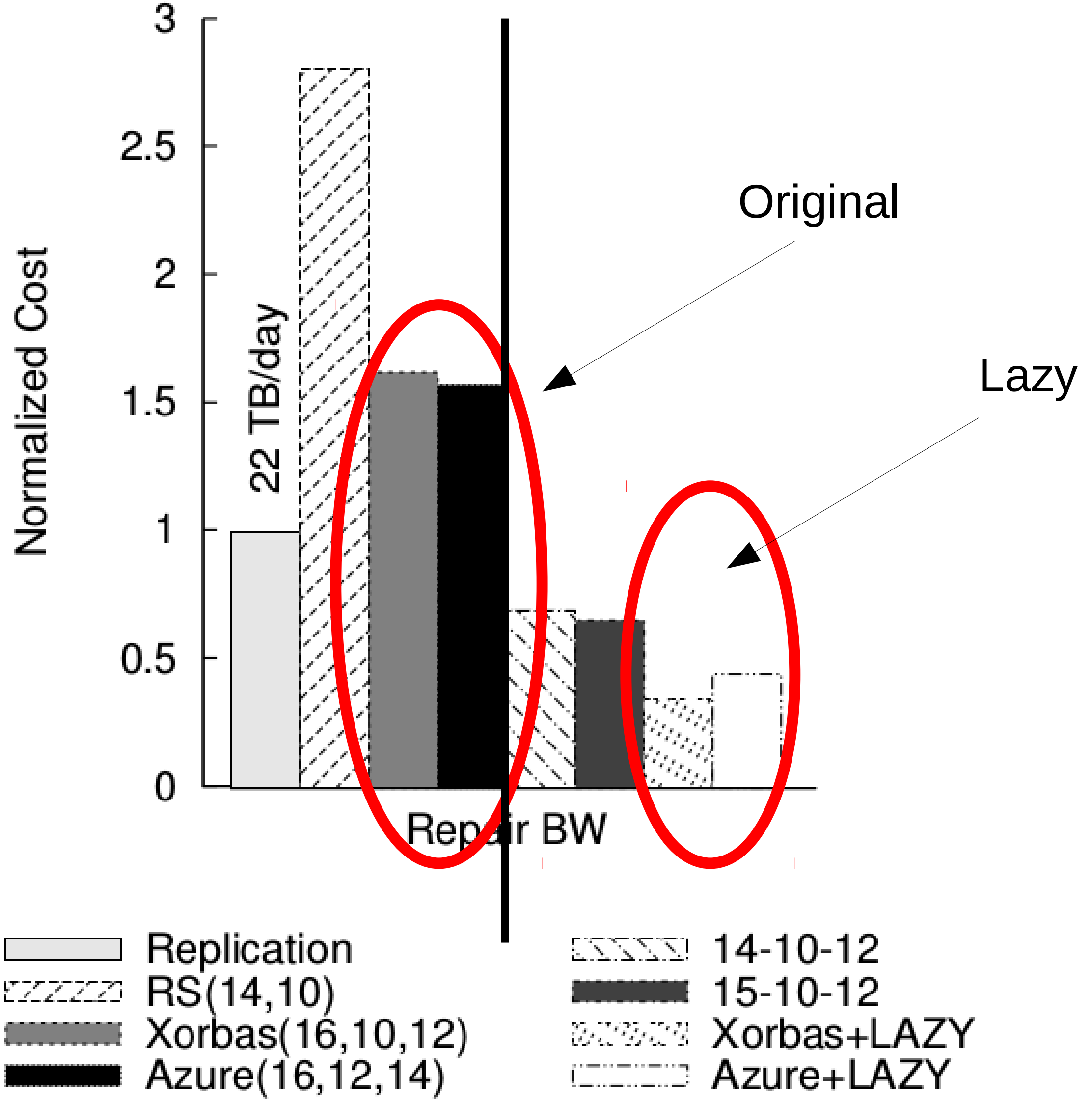
RS codes need ~3x repair bandwidth of replication



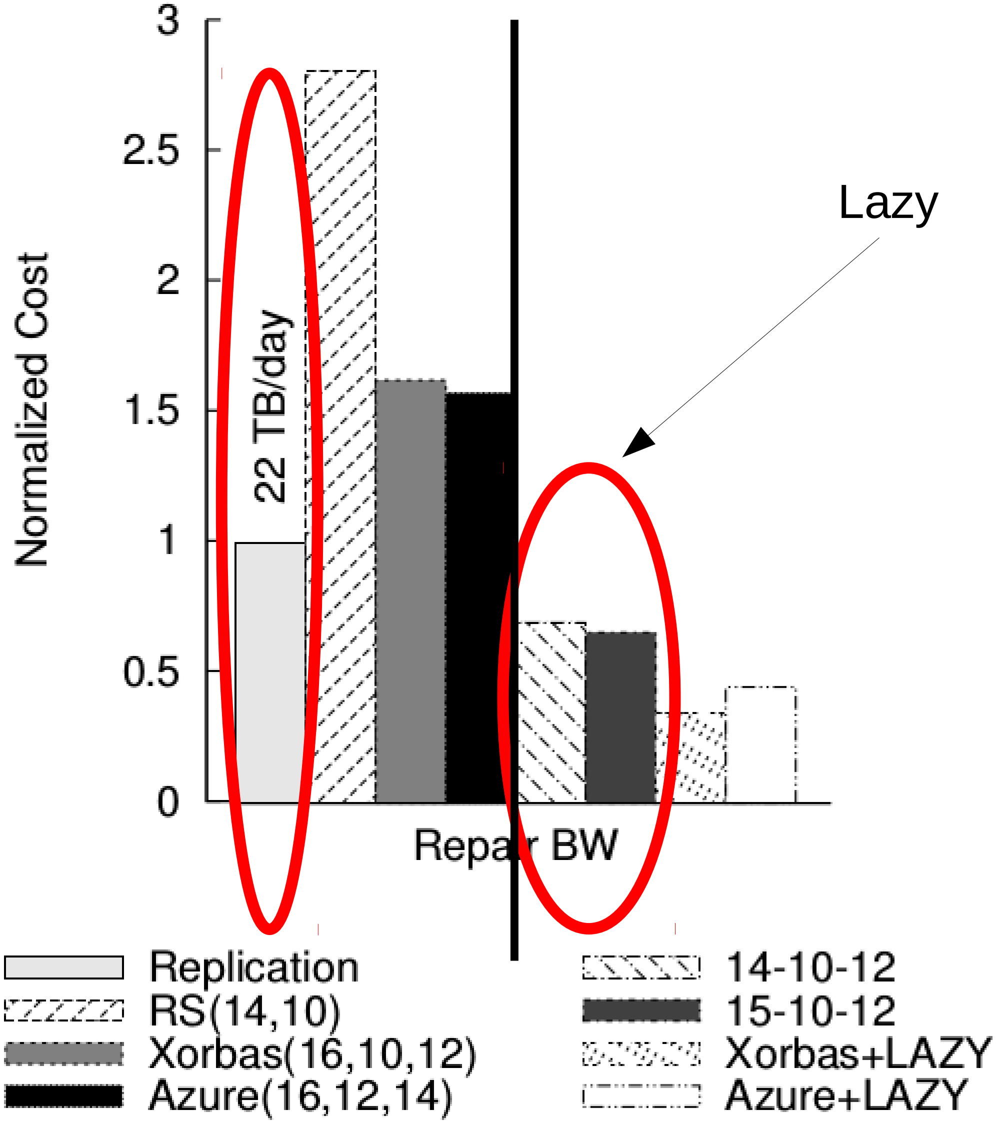
Lazy recovery bandwidth ~4x over traditional RS



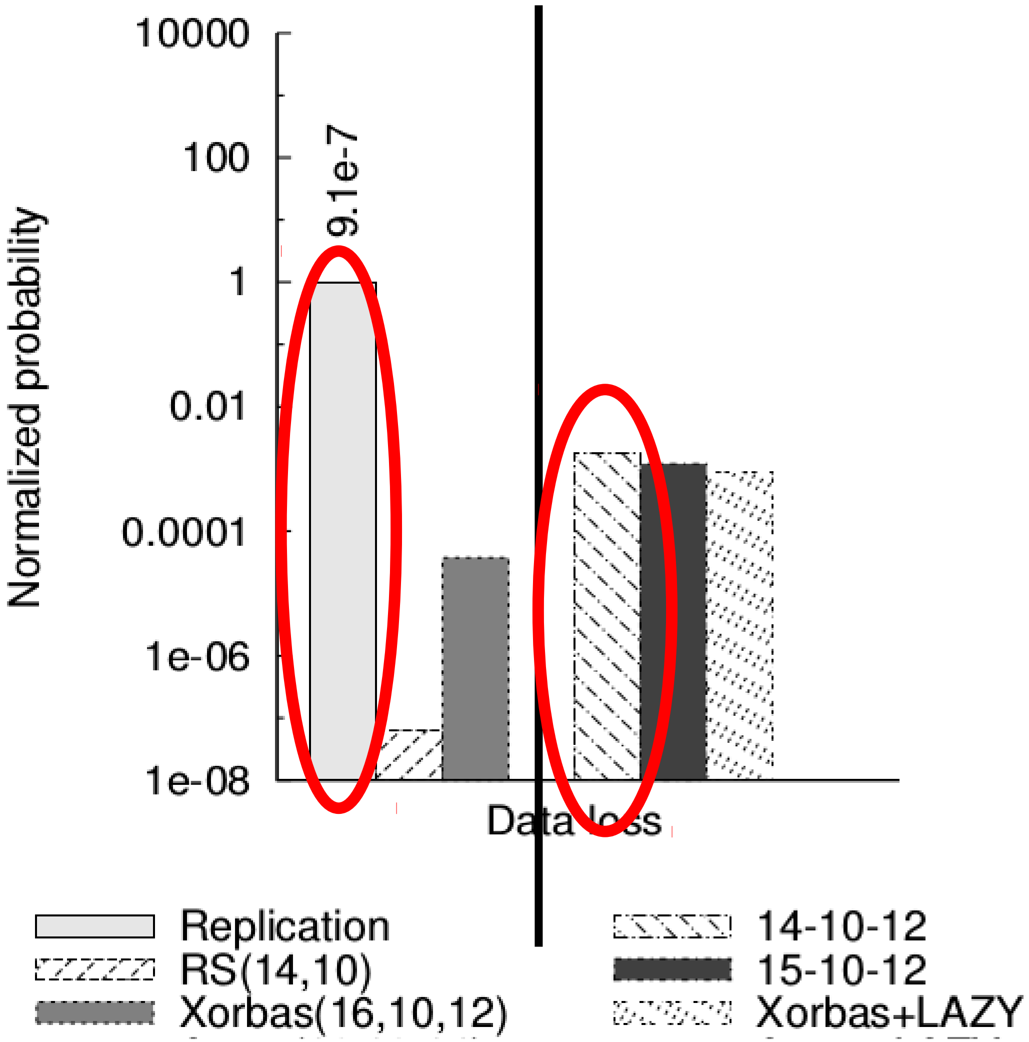
Lazy recovery improves repair-efficient codes



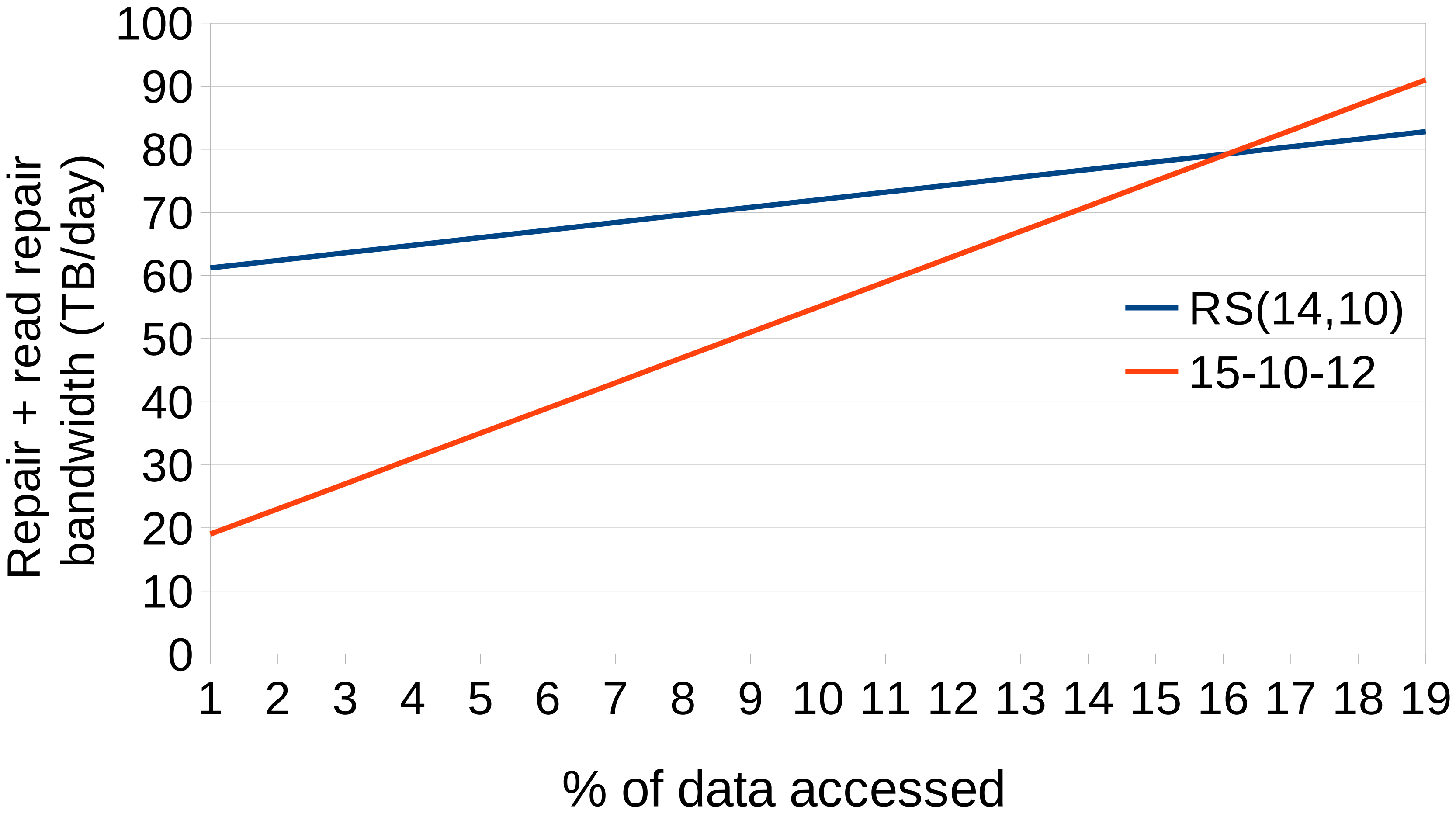
Lazy recovery is more efficient than replication



Lazy recovery is 300 times more reliable than 3-way replication



Lazy recovery wins if less than 15% data gets accessed



Summary

- Lazy recovery makes RS attractive for cold storage:
  - twice less storage, 300x better reliability, 30% lower bandwidth vs. replication
- Lazy recovery is complementary to repair-efficient coding schemes
- DS-Sim enables long-term analysis of coding schemes in large-scale systems

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Thank you!