Fractional-Overlap Declustered Parity: Evaluating Reliability for Storage Systems

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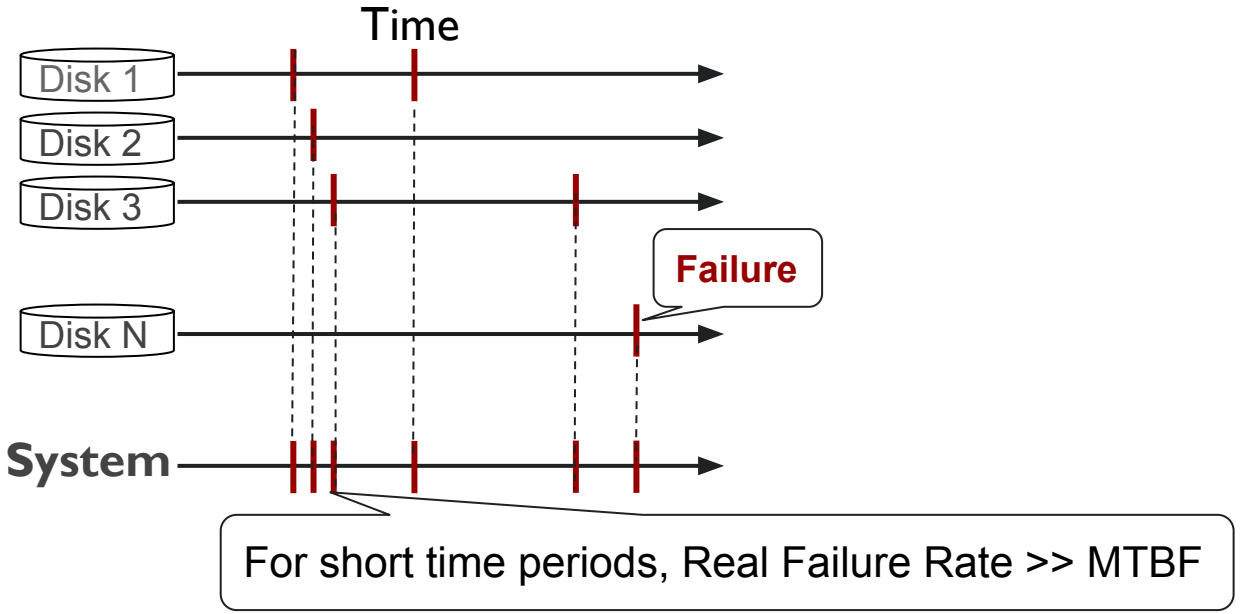
Correlated Failures

Correlated failures within compressed time windows make storage systems highly vulnerable to data loss.



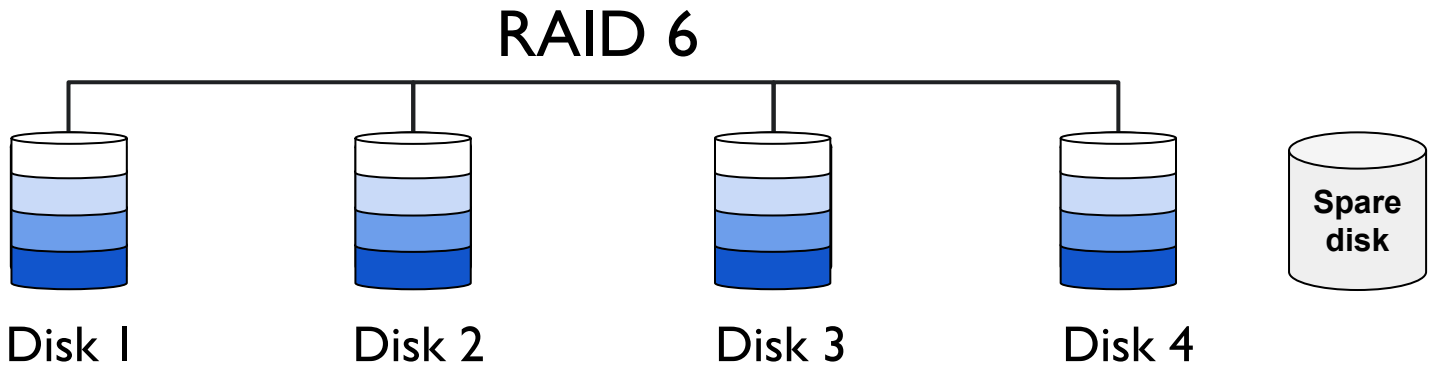
Failure Models

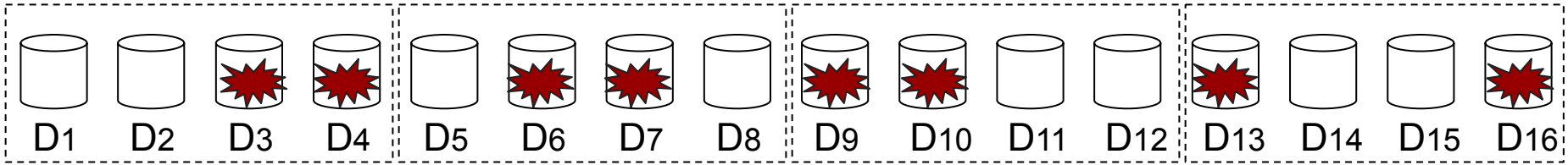
How do we model correlated failures ...

Types	Models
Poisson Failures	$Poisson(\frac{1}{MTBF})$
Exponential Failures	$Exp(\frac{1}{MTBF})$
Batch Failures	$Exp(\frac{1}{MTBF})\&Exp(\frac{1}{0.1MTBF})$

Traditional RAID

RAID (Redundant Array of Inexpensive Disks)

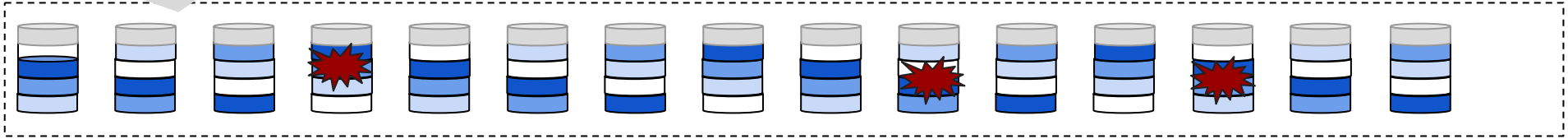




Declustered Parity (DP)

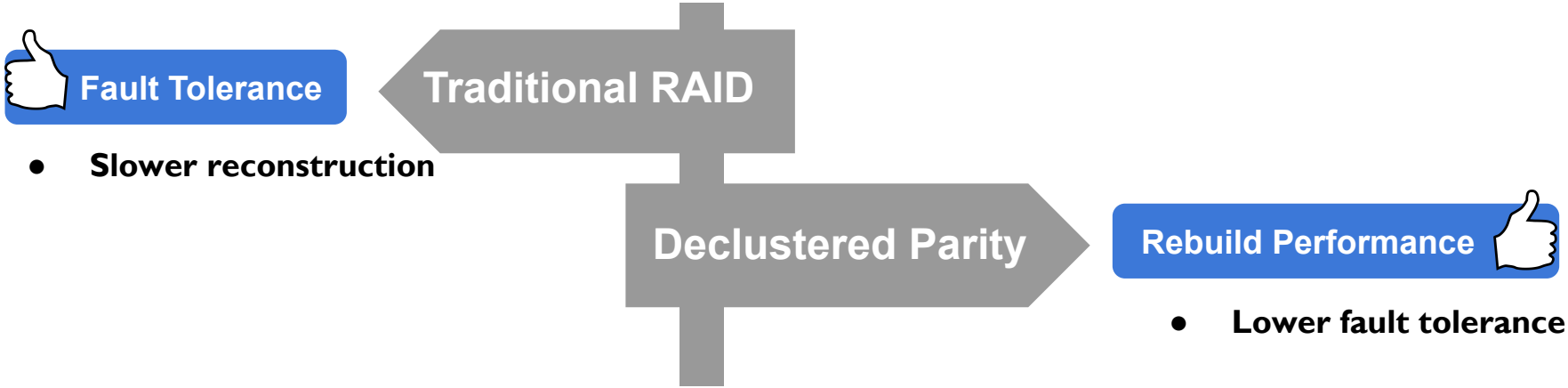
Data/parity are declustered or spread across all disks.

distributed spare space | parallel reads/writes | ZFS dRAID | GridRAID



The probability of data loss is 100%

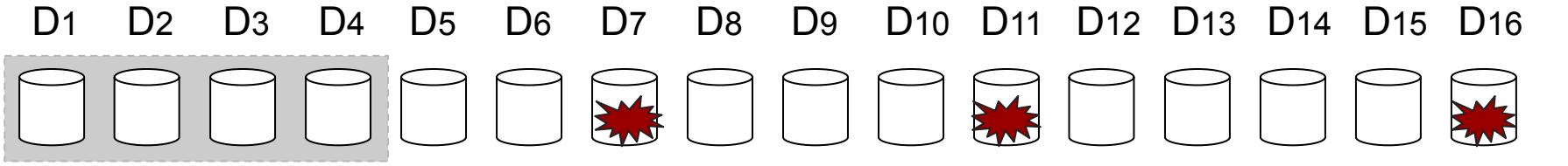
Motivations



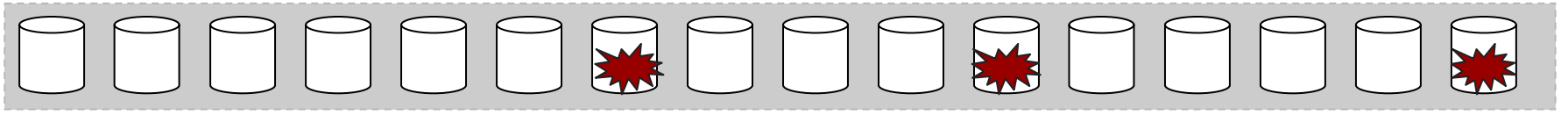
How the interactions between fault tolerance and rebuild performance together impact system reliability is still unclear.

Fractional Overlap Declustered Parity

FODP, a flexible tool to explore the middle space between fault tolerance and rebuild performance.



- Flexible rebuild performance
- Uniform data distribution
- Adjustable failure domains
- Higher fault tolerance

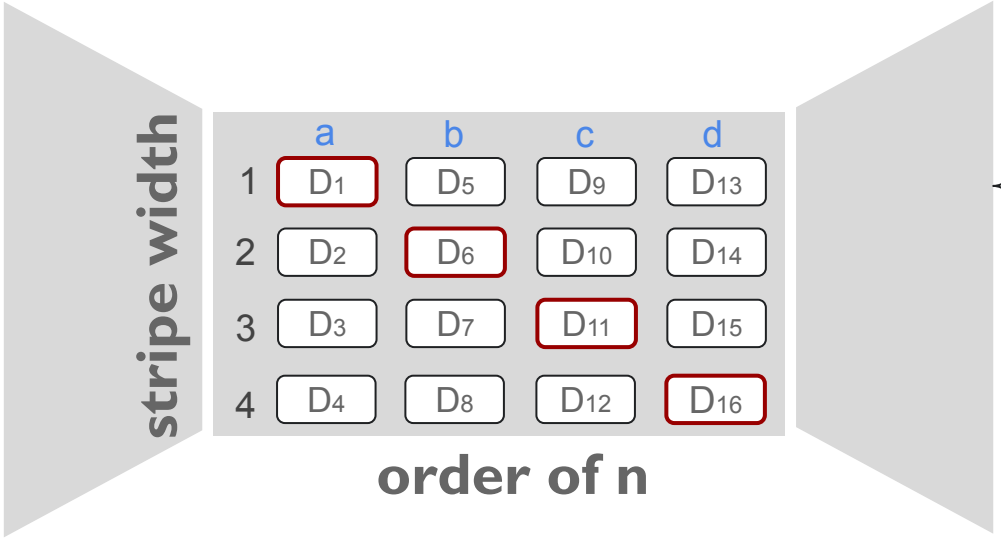


FODP Construction

Latin square of order n:

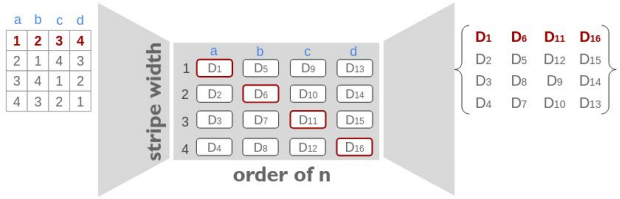
- a n×n array over n elements and each element appears once in each row and column.

a	b	c	d
1	**2**	**3**	**4**
2	1	4	3
3	4	1	2
4	3	2	1



D1	**D6**	**D11**	**D16**
D2	D5	D12	D15
D3	D8	D9	D14
D4	D7	D10	D13

Overlap fraction



Each latin square corresponds to n disk subsets that cover the whole disk matrix.

- Each disk has (stripe-width-1) **overlaps** within a disk subset.

Overlap fraction λ for each disk:

$$\lambda = \frac{overlaps}{N-1}$$

	RAID	FODP	SODP	DP
	λ_{min}	$\lambda < 1$	$\lambda = 1$	$\lambda > 1$
Rebuild Perf	L	M	H	H
Fault Tolerance	H	H	M	L

Mutually Orthogonal Latin Squares

Two latin squares are **mutually orthogonal**:

- Any order pair of entries from each latin square in the same row and column occurs exactly once.

1	2	3	4
2	1	4	3
3	4	1	2
4	3	2	1

+

1	3	4	2
2	4	3	1
3	1	2	4
4	2	1	3

→

1,1	2,3	3,4	4,2
2,2	1,4	4,3	3,1
3,3	4,1	1,2	2,4
4,4	3,2	2,1	1,3

- With any given order of n, there can be at most (n-1) mutually orthogonal latin squares (MOLS).

MOLS in FODP

L_1

	a	b	c	d
1	1	2	3	4
2	2	1	4	3
3	3	4	1	2
4	4	3	2	1

L_2

1	3	4	2	
2	4	3	1	
3	1	2	4	
4	2	1	3	

L_3

1	4	2	3	
2	3	1	4	
3	2	4	1	
4	1	3	2	

	a	b	c	d
1	D1	D5	D9	D13
2	D2	D6	D10	D14
3	D3	D7	D11	D15
4	D4	D8	D12	D16

D1	D6	D11	D16	$\lambda = \frac{3}{15}$
D2	D5	D12	D15	
D3	D8	D9	D14	
D4	D7	D10	D13	

D1	D7	D12	D14	$\lambda = \frac{6}{15}$
D2	D8	D11	D13	
D3	D5	D10	D16	
D4	D6	D9	D15	

D1	D8	D10	D15	$\lambda = \frac{9}{15}$
D2	D7	D9	D16	
D3	D6	D12	D13	
D4	D5	D11	D14	

Trade-offs in FODP

FODP gives us the flexibility to explore the trade-offs between fault tolerance and rebuild performance.

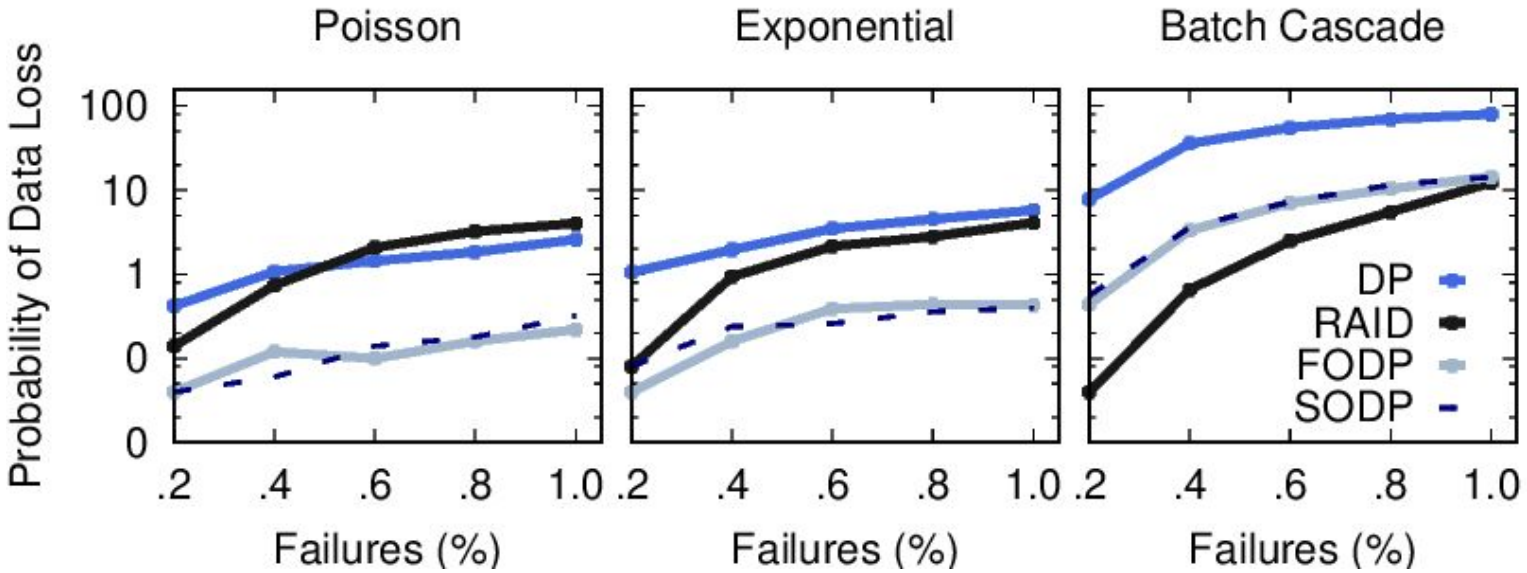
- The lower λ is, the more failures that can be tolerated.
- The larger λ is, the more overlaps can be used for rebuilds.

FODP+1

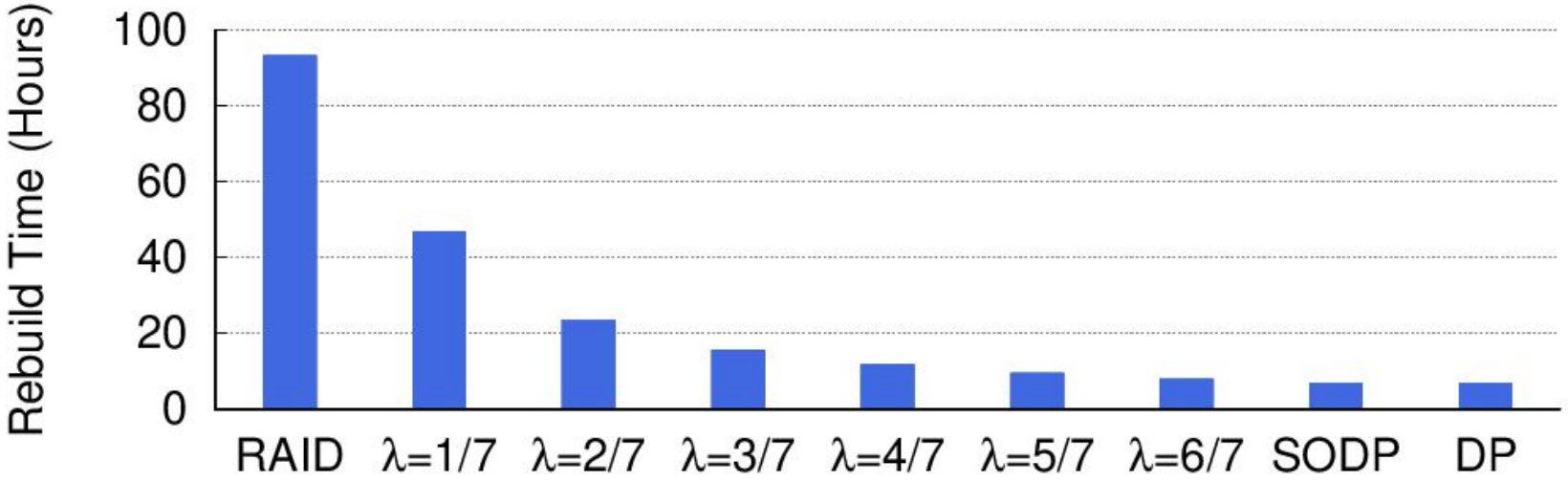
If data loss occurs, FODP loses more data than DP

Impact of Failures

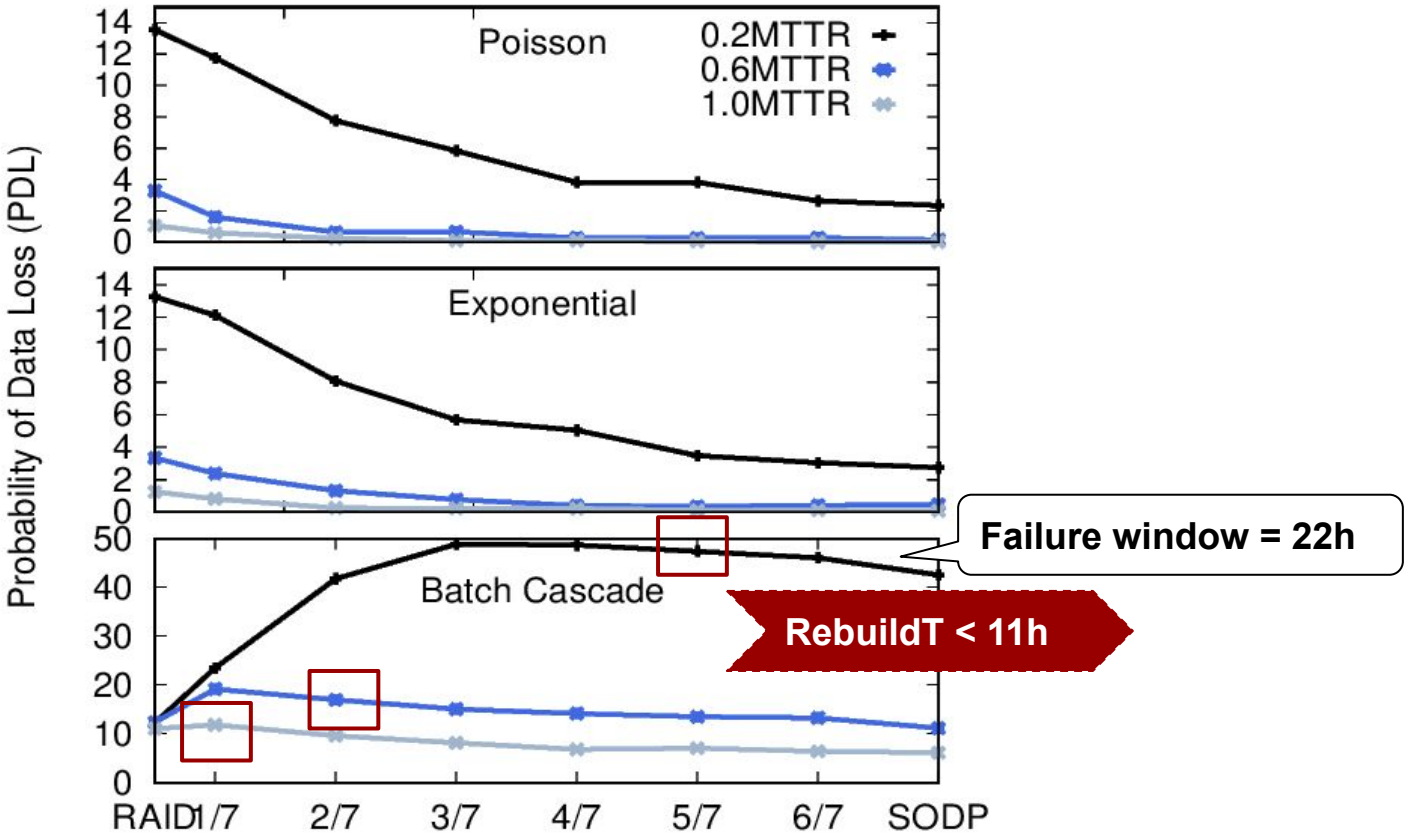
Assume MTBF = 0.5 MTTR in Campaign system with 11+2 configurations within each server.



Impact of Overlap Fraction



Impact of Overlap Fraction



FODP Conclusion

"*Why should we address correlated failures?*"

Storage systems are becoming **larger** and **denser** and failures are increasingly **correlated in time**!

FODP, a flexible tool to study and explore rebuild performance and failure domains in systems.

FODP-Plus-One, reducing the magnitude of data loss by adding a layer of parity on top of FODP stripes.

CERES

Thank you!
Questions?

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