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On Reliability of COTS Hardware

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Agenda

- Differences between “Telecom Hardware” and COTS Hardware
- Analysis Framework
- Enhancing Application Reliability via Backups – Theoretical
    - With one backup (1+1)
    - With Different Types of Data Centers (type 1 – type 4)
- Remarks

Comparing "Telecom Hardware" and COTS (Commercial of the Shelf) Hardware

Telecom Hardware

- Strong fault detection and fault isolation capabilities at hardware level
- Well established traditions on software upgrade, patching, and maintenance
- Reliably Central Office assumed

COTS Hardware

- May have smaller "mean time between failure" (MTBF)
- Relative smaller "mean time to repair" (MTTR)
- COTS procedures for software upgrade, patching, and maintenance contribute more to "scheduled down time"
- Different grade of reliability for data centers

New Item to Consider for COTS – Site Down Time

Telecom Hardware

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- Different grade of reliability for data centers

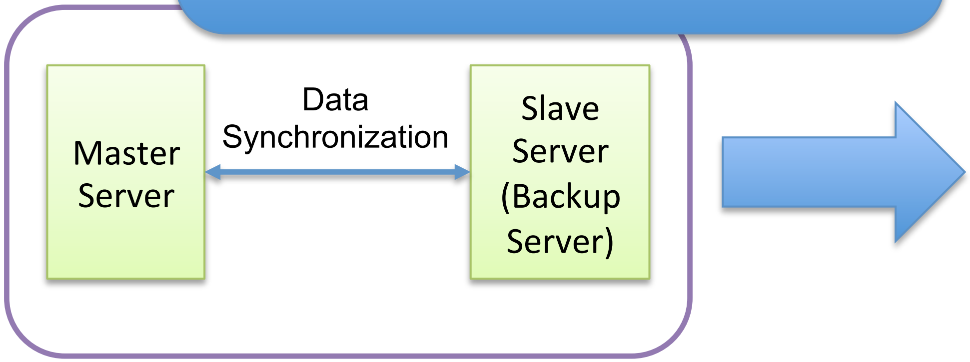
- Site downtime (scheduled, non-scheduled) with varying duration and varying intervals

Types of DC		Reliability	
	Type 1		99.671%
	Type 2		99.741%
	Type 3		99.982%
	Type 4		99.995%

Common Mechanisms to Improve Reliability – Application Level Backup

Various Failures

- Hardwar Failure
- Hypervisor/OS Failure
- Application Failure



Benefits of Application Level Backup:

- Against failures
- Facilitate maintenance and upgrade

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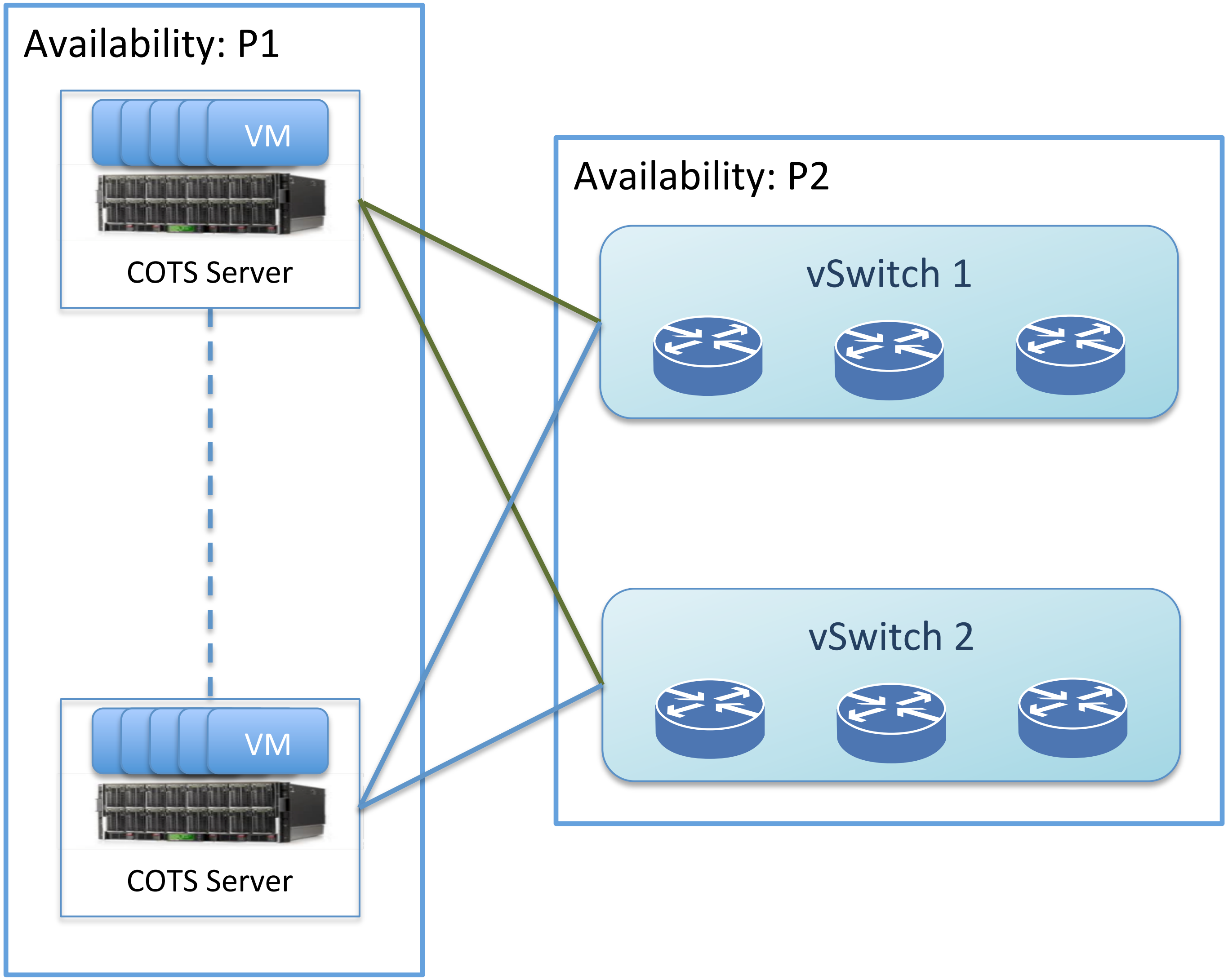
System availability P1 * P2



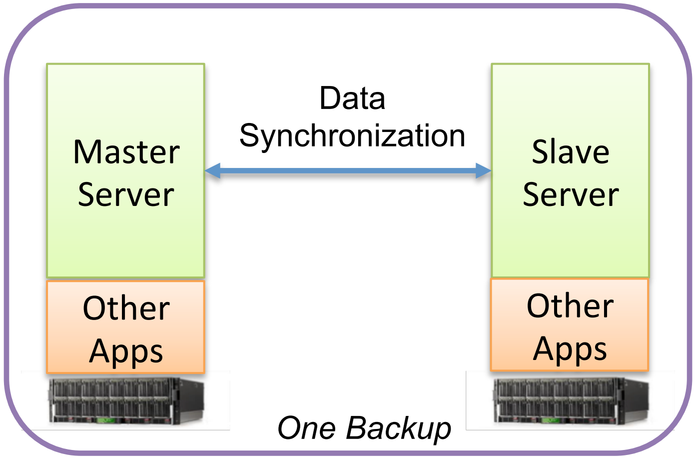
Introducing COTS – Focusing on Server Part of Reliability

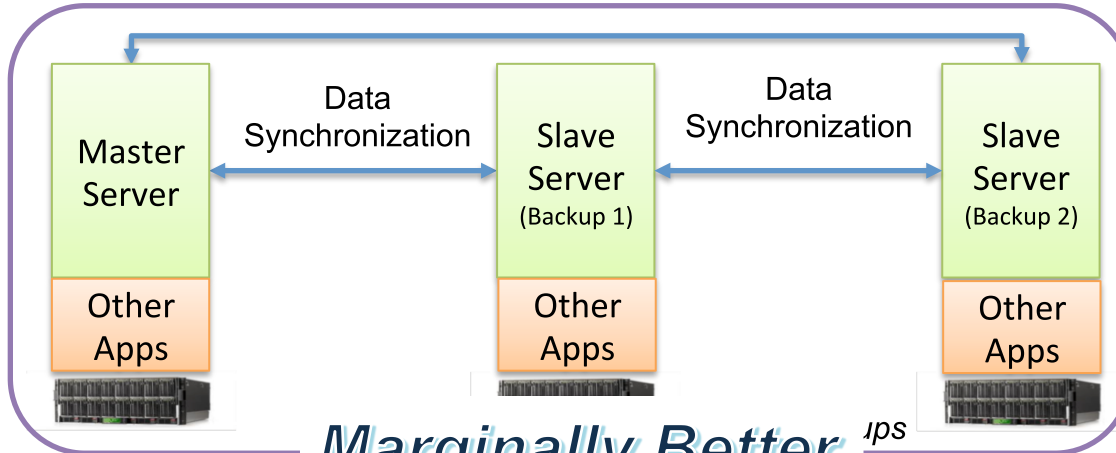
Network Element Availability/Hop	10	12	14	16	18	20	22	24	26	28	30
0.99	0.990857	0.987092	0.982772	0.977935	0.972614	0.966842	0.96065	0.954066	0.94712	0.939837	0.932244
0.999	0.999901	0.999858	0.999807	0.999748	0.999681	0.999608	0.999526	0.999437	0.999341	0.999237	0.999126
0.9999	0.999999	0.999999	0.999998	0.999997	0.999997	0.999996	0.999995	0.999994	0.999993	0.999992	0.999991
0.99999	1	1	1	1	1	1	1	1	1	1	1

Providing 5 9s reliability with 4 9s availability per networking equipment

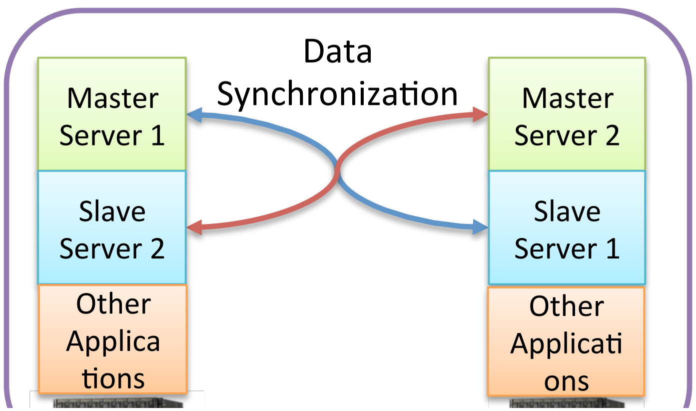
Is it possible to have servers with 4 9s (or even 3 9s) availability to provide overall 5 9s reliability?

Various Backup Schemes

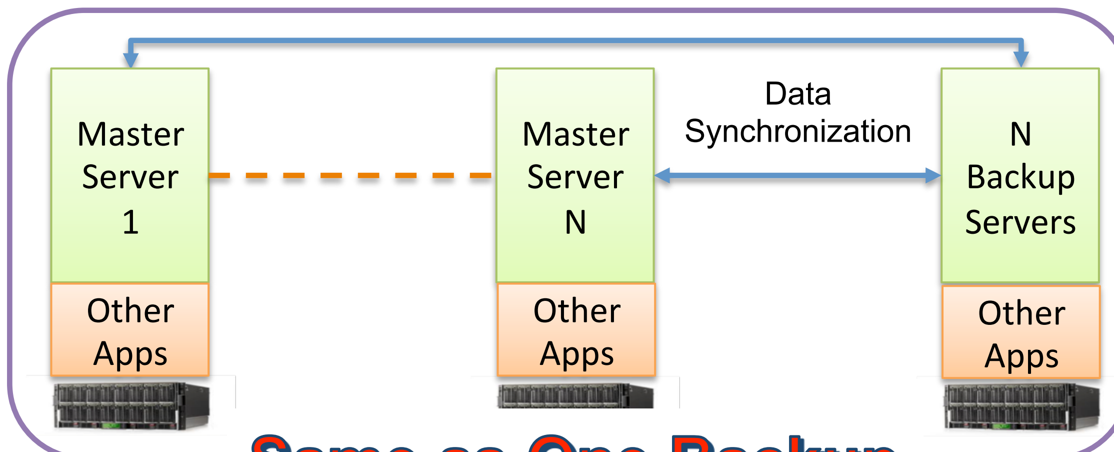




Marginally Better



1:1, Same as One Backup



Same as One Backup

http://wwwen.zte.com.cn/endata/magazine/ztecommunications/2014/3/

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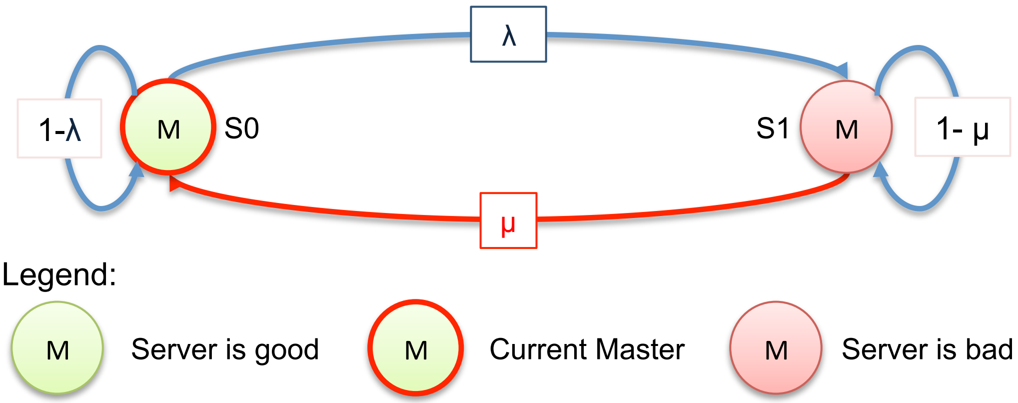
A Simple Example – Markov State Transition Model



$$\mu = \frac{1}{Server\ MTTR\ (recover\ time)}$$

$$\lambda = \frac{1}{Server\ MTBF}$$

Chapman – Kolmogorov Equation

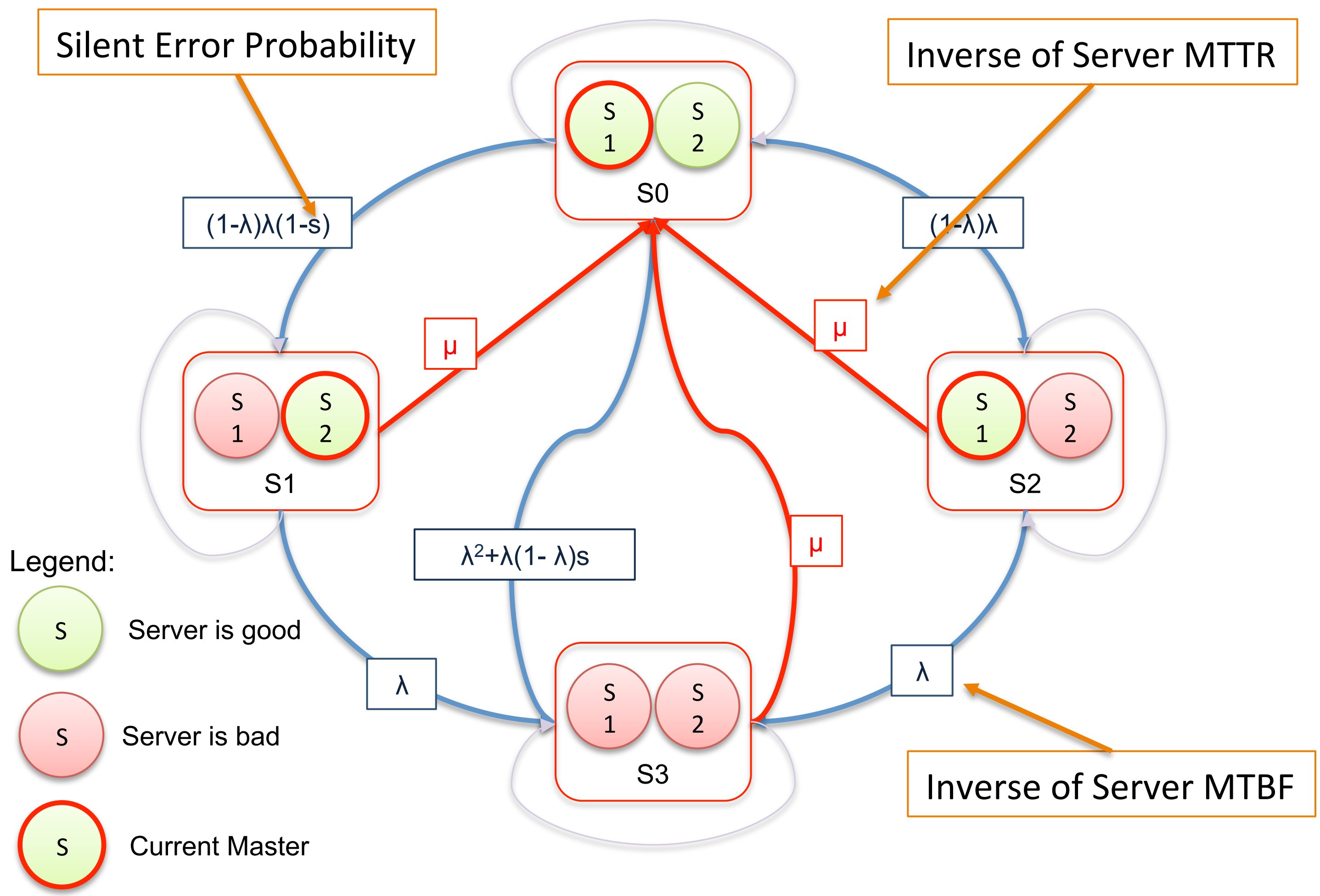
$$\lambda P_0 = \mu P_1$$

$$P_0 + P_1 = 1$$

The Result

$P_0 = \frac{\mu}{\lambda+\mu}$ and $P_1 = \frac{\lambda}{\lambda+\mu}$ or $A_S^0 = P_0 = \frac{\mu}{\lambda+\mu} = \frac{MTBF}{MTBF+MTTR}$

1+1 System – Markov State Transition Model

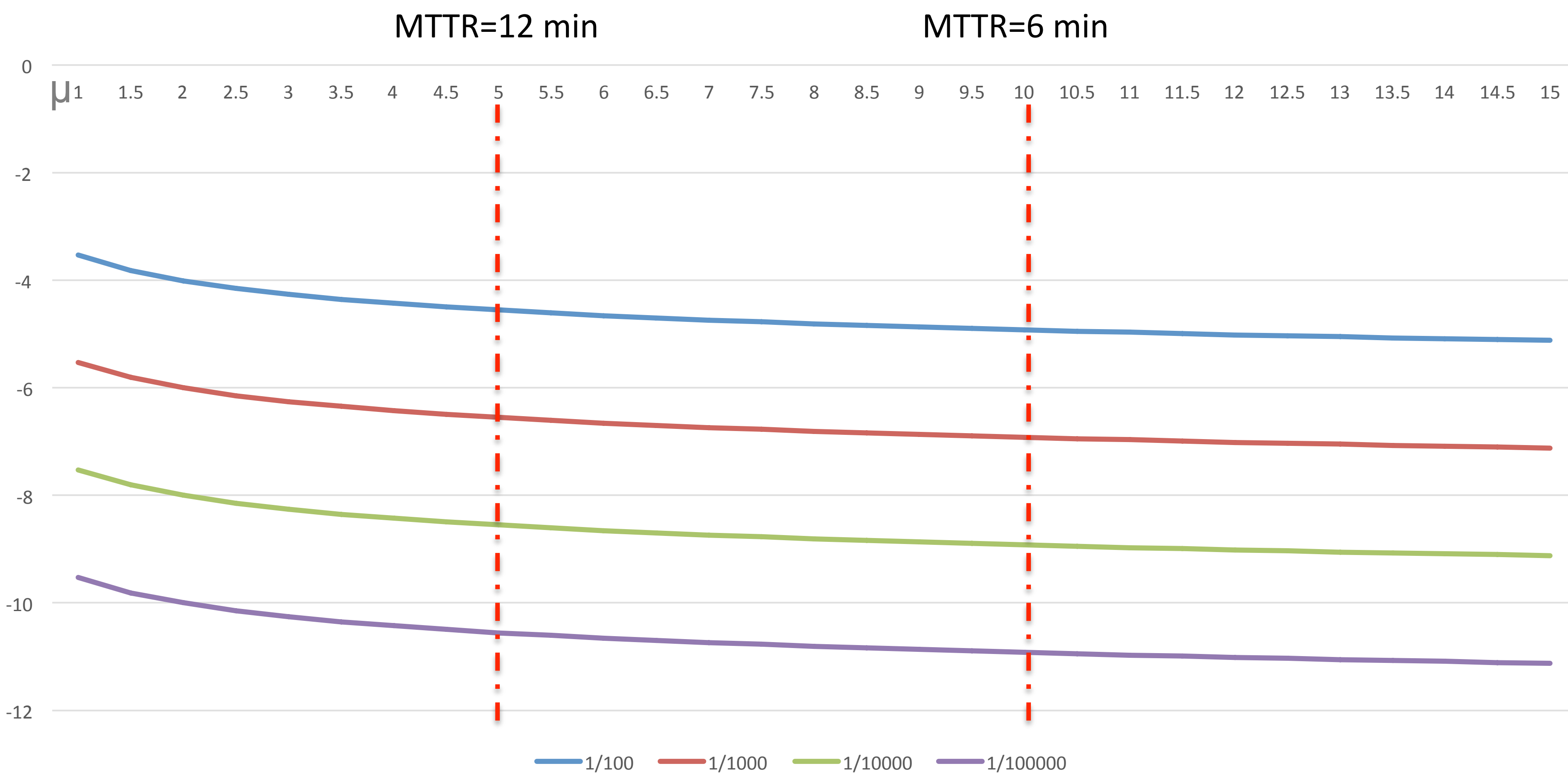


Solving the Global Balancing Equation for Getting overall System Availability (1+1)

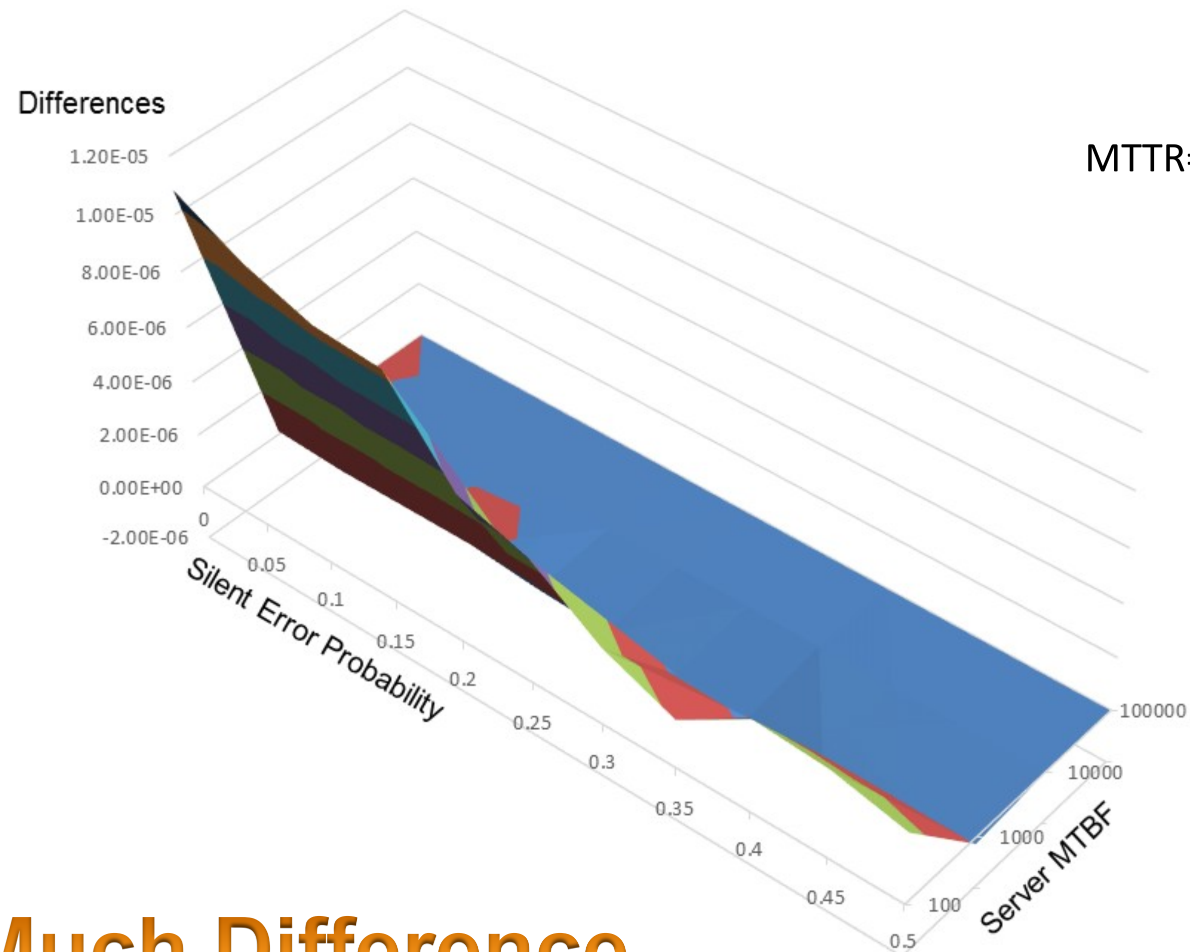
$$A_S^{1+1} = \frac{\mu(\mu+3\lambda-2\lambda^2)}{(\lambda+\mu)(1-(1-\lambda)^2+\mu)} - \frac{\lambda(1-\lambda)\mu}{(\lambda+\mu)(1-(1-\lambda)^2+\mu)} s = \frac{\mu}{(\lambda+\mu)} + \frac{\lambda(1-\lambda)\mu}{(\lambda+\mu)(1-(1-\lambda)^2+\mu)} (1-S)$$

Server MTBF / Silent Error Probability (MTTR=6 min)	100 (Server 3 9s)	1000 (Server 4 9s)	10000 (Server 5 9s)	100000 (Server 6 9s)
0	0.999988046	0.99999988	0.999999999	1
0.1	0.999889341	0.999989893	0.999998999	0.9999999
0.2	0.999790636	0.999979906	0.999997999	0.9999998
0.3	0.999691932	0.999969919	0.999996999	0.9999997
0.4	0.999593227	0.999959932	0.999995999	0.9999996
0.5	0.999494522	0.999949945	0.999994999	0.9999995
0.6	0.999395818	0.999939958	0.999994	0.9999994
0.7	0.999297113	0.999929971	0.999993	0.9999993
0.8	0.999198408	0.999919984	0.999992	0.9999992
0.9	0.999099704	0.999909997	0.999991	0.9999991
1	0.999000999	0.99990001	0.99999	0.999999

System Unavailable Probability for various MTTR and server MTBF when $s=0$ in LOG scale



Differences in Availability between Theoretical Data and Simulation for 1+1 Backup Case



MTTR=6 minutes

Not Much Difference

Improvement of 1+2 (dual backup) v.s. 1+1 (single backup)

Defining the "percentage" of improvement as $100 * \frac{(1-A_s^{1+2})-(1-A_s^{1+1})}{(1-A_s^{1+1})}$

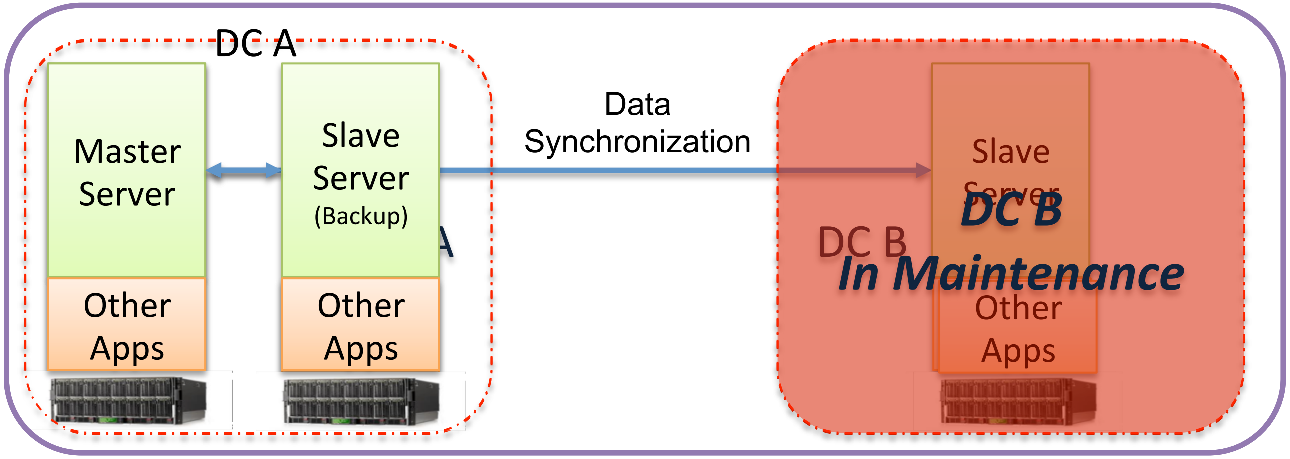
Server MTBF / Silent Error Probability (MTTR=6 min)	100 (Server 3 9s)	1000 (Server 4 9s)	10000 (Server 5 9s)	100000 (Server 6 9s)
0	98.62532979	99.86175406	99.98616794	99.9990748
0.1	9.510399053	1.057811857	0.106966794	0.01070851
0.2	4.431332489	0.468978185	0.047169643	0.004719614
0.3	2.613180554	0.271797379	0.027287936	0.002729817
0.4	1.682131036	0.173409178	0.017394077	0.001739884
0.5	1.118510139	0.114680068	0.011496796	0.001149956
0.6	0.742238487	0.075820122	0.007598201	0.000759961
0.7	0.474389109	0.048328568	0.004841856	0.000484261
0.8	0.274909995	0.02794865	0.002799487	0.000279984
0.9	0.121313666	0.012312984	0.00123313	0.000123309
1	0	0	0	0

Improvement Deteriorates Fast with Silent Error

Revertive Maintenance

Before Maintenance

Start Maintenance when No Fault



After Maintenance

Start Reverting when No Fault

The Impact of Site Maintenance is Negligible (Revertive)

$$A_{\text{siteM}}^{1+1} = 1 - \frac{2\gamma\eta\lambda}{(\lambda+\mu)\left(2\eta\gamma + (\eta+\gamma)(-\lambda^2+2\lambda+\mu)\right)} - \frac{P_3^{1+1}}{1 + \frac{2\eta\gamma}{(\eta+\gamma)(-\lambda^2+2\lambda+\mu)}}$$

$$A_{\text{siteM}}^{1+1} > 1 - P_3^{1+1} - \frac{2\eta\lambda}{\mu^2} = A_s^{1+1} - \frac{2\eta\lambda}{\mu^2}$$

With $\mu = 10$ and $\eta = 1/1000$, the impact would be $2 \times 10^{-5}\lambda$. With a reasonable $\lambda = 1/1000$, the impact will be at 10^{-8} level which is way about 5 9s requirements.

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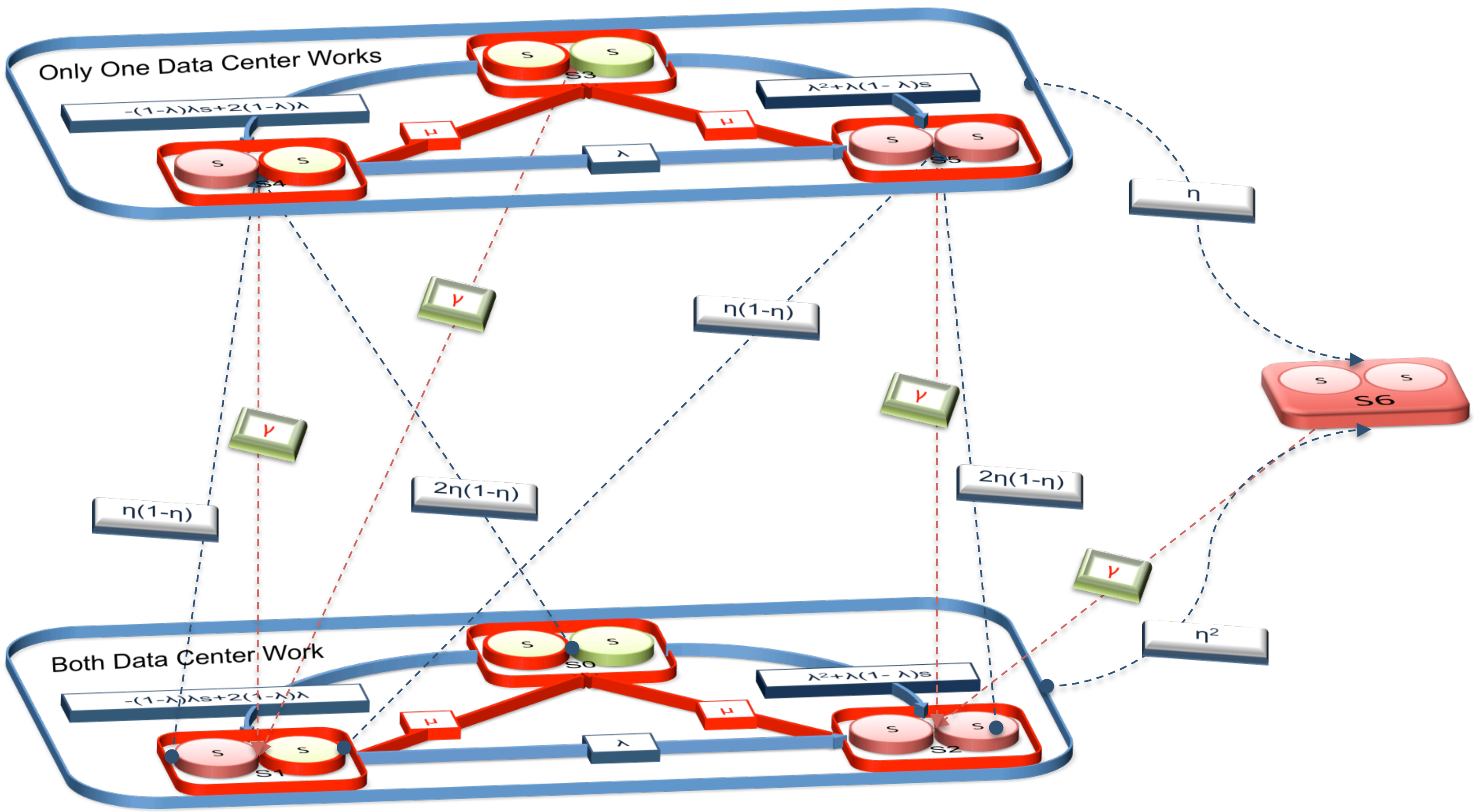
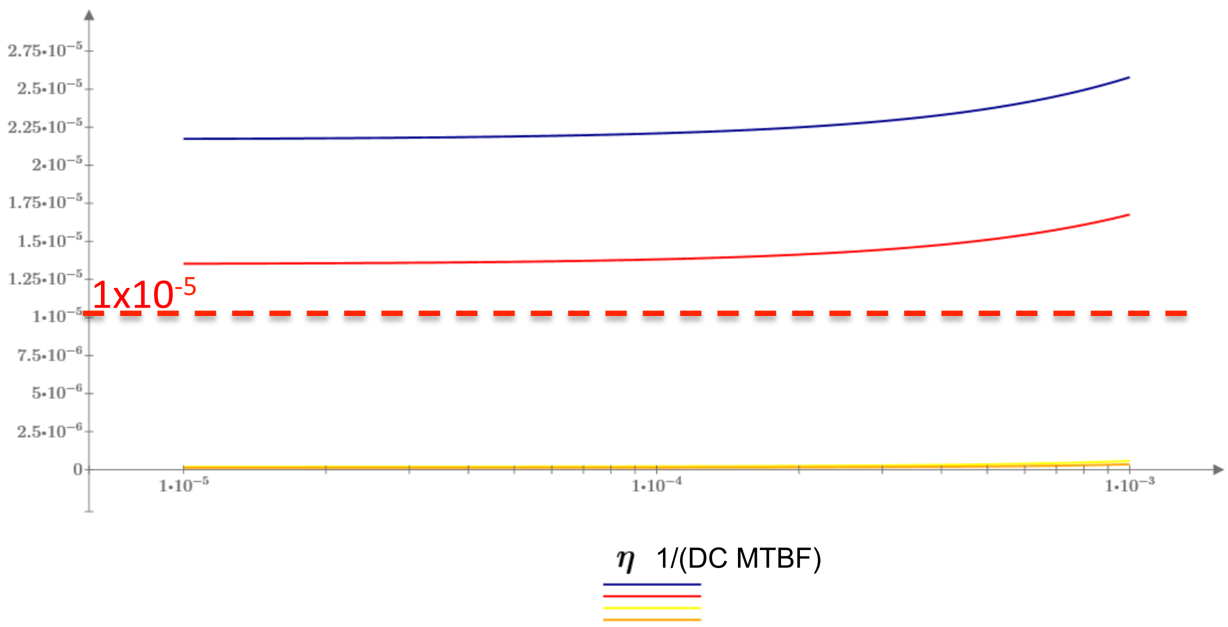
Four Types of Data Centers (ANSI/TIA-942)

Type 1	Single non-redundant distribution path serving the IT equipment. Non-redundant capacity components. Basic site infrastructure with expected availability of 99.671%.
Type 2	Meets or exceeds all type 1 requirements. Redundant site infrastructure capacity components with expected availability of 99.741%.
Type 3	Meets or exceeds all type 2 requirements. Multiple independent distribution paths serving the IT equipment. All IT equipment must be dual-powered and fully compatible with the topology of a site's architecture. Concurrently maintainable site infrastructure with expected availability of 99.982%.
Type 4	Meets or exceeds all type 3 requirements. All cooling equipment is independently dual-powered, including chillers and heating, ventilating and air-conditioning (HVAC) systems Fault-tolerant site infrastructure with electrical power storage and distribution facilities with expected availability of 99.995%

1+1 System with Site Error – Markov State Transition Model (Revertive)



Service Impact Error Probability for Various Data Centers



$$E\left(\frac{1}{1000},0,10,\eta,\frac{dc1}{1-dc1}\cdot\eta\right)$$

$$E\left(\frac{1}{1000},0,10,\eta,\frac{dc2}{1-dc2}\cdot\eta\right)$$

$$E\left(\frac{1}{1000},0,10,\eta,\frac{dc3}{1-dc3}\cdot\eta\right)$$

$$E\left(\frac{1}{1000},0,10,\eta,\frac{dc4}{1-dc4}\cdot\eta\right)$$

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Remarks

- It is possible to provide 5 9 availability with COTS hardware with application level backup

- The Impact of MTTR is not significant if it is reasonably small (e.g. less than 10 minutes) for typical hardware MTBF

- The impact of data center scheduled maintenance is negligible

- 5 9 availability with can only be achieved via type 3 and type 4 data centers

COTS Hardware

- May have smaller "mean time between failure" (MTBF)
- Relative smaller "mean time to repair" (MTTR)

- COTS procedures for software upgrade, patching, and maintenance contribute more to "scheduled down time"

- Different grade of reliability for data centers

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Bringing you Closer

Thanks!

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