第1章 计算机设计基础

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1.7 可靠性--Dependability

- 可靠性：广义上包括可靠性、安全性和可用性

（Dependability is a deliberately broad term to encompass many facets including reliability, security and availability.）

- 计算机系统的可靠性：用于表示系统提供给用户服务的质量，这里“可靠性（ Dependability ）”可用“信任（reliance）”代替。

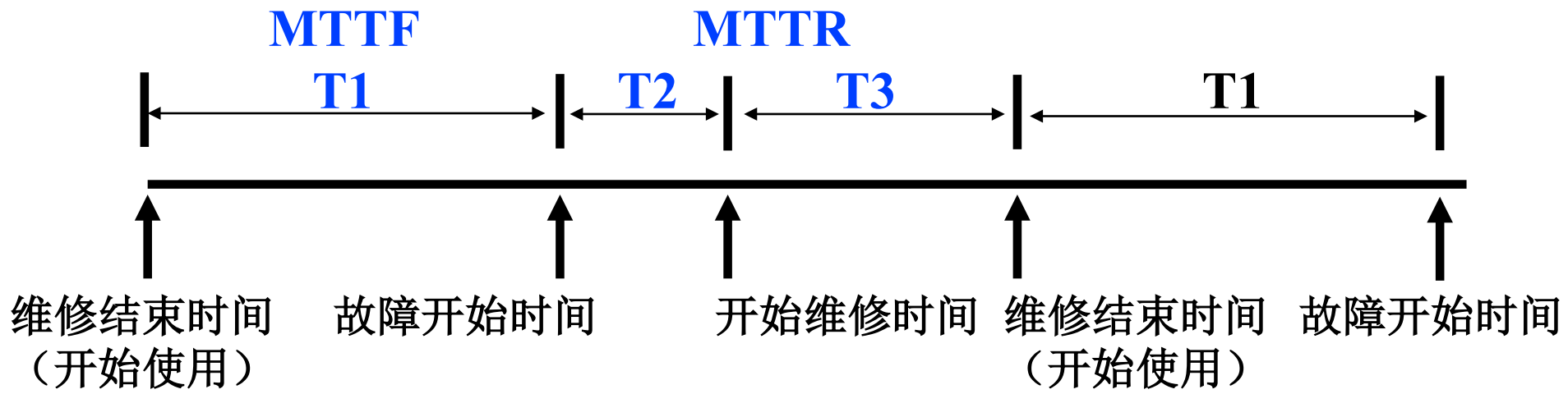
例如：一个笔记本电脑能用多久才出现故障？

◆ MTTF (Mean Time To Failure，平均无故障时间)，指系统无故障运行的平均时间，取所有从系统开始正常运行到发生故障之间的时间段的平均值。

MTTF =∑ T1/ N

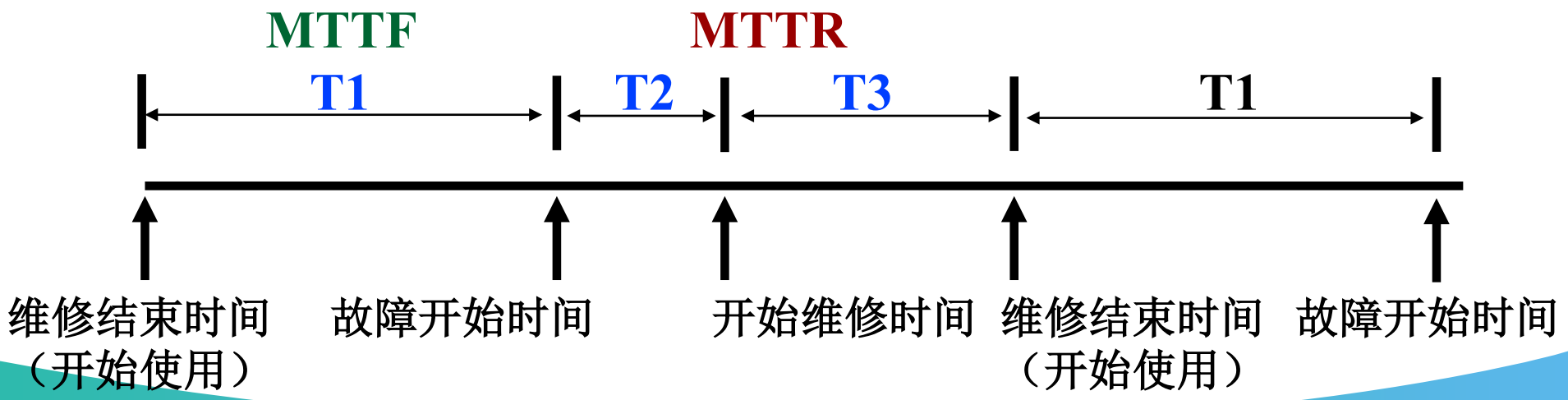
◆ MTTR (Mean Time To Repair，平均修复时间)，指系统从发生故障到维修结束之间的时间段的平均值。MTTR =∑(T2+T3)/ N

◆ MTBF (Mean Time Between Failure，平均失效间隔)，指系统两次故障发生时间之间的时间段的平均值。 MTBF =∑(T2+T3+T1)/ N



可靠性的量化

- 模块可靠性：从模块可用到出现故障的持续服务度量
  - MTTF（Mean Time To Failure）
  - MTTR（Mean Time To Repair）
  - FIT （Failures In Time故障率）：1/MTTF
  - MTBF(Mean Time Between Failure) = MTTF+MTTR
- 模块可用性
  - $\frac{MTTF}{MTTF + MTTR} = \frac{MTTF}{MTBF}$



例题　设一个磁盘子系统有如下组件和MTTF:

- 10个磁盘，每一个的MTTF是1 000 000（1百万）小时
- 1个ATA控制器，500 000（50万）小时的MTTF
- 1个电源，200 000（20万）小时的MTTF
- 1个风扇，200 000小时的MTTF
- 1条ATA电缆，1 000 000小时的MTTF

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假设生存周期是按指数分布的，并且故障具有独立性，计算整个系统的MTTF。

解：

$$\text{系统故障率} = 10 \times \frac{1}{1\,000\,000} + \frac{1}{500\,000} + \frac{1}{200\,000} + \frac{1}{200\,000} + \frac{1}{1\,000\,000}$$

$$= \frac{23}{1\,000\,000}$$

$$\text{系统的MTTF} = \frac{1}{\text{系统故障率}} = \frac{1\,000\,000}{23} = 43\,478\text{小时（接近5年）}$$

提高可靠性的方法

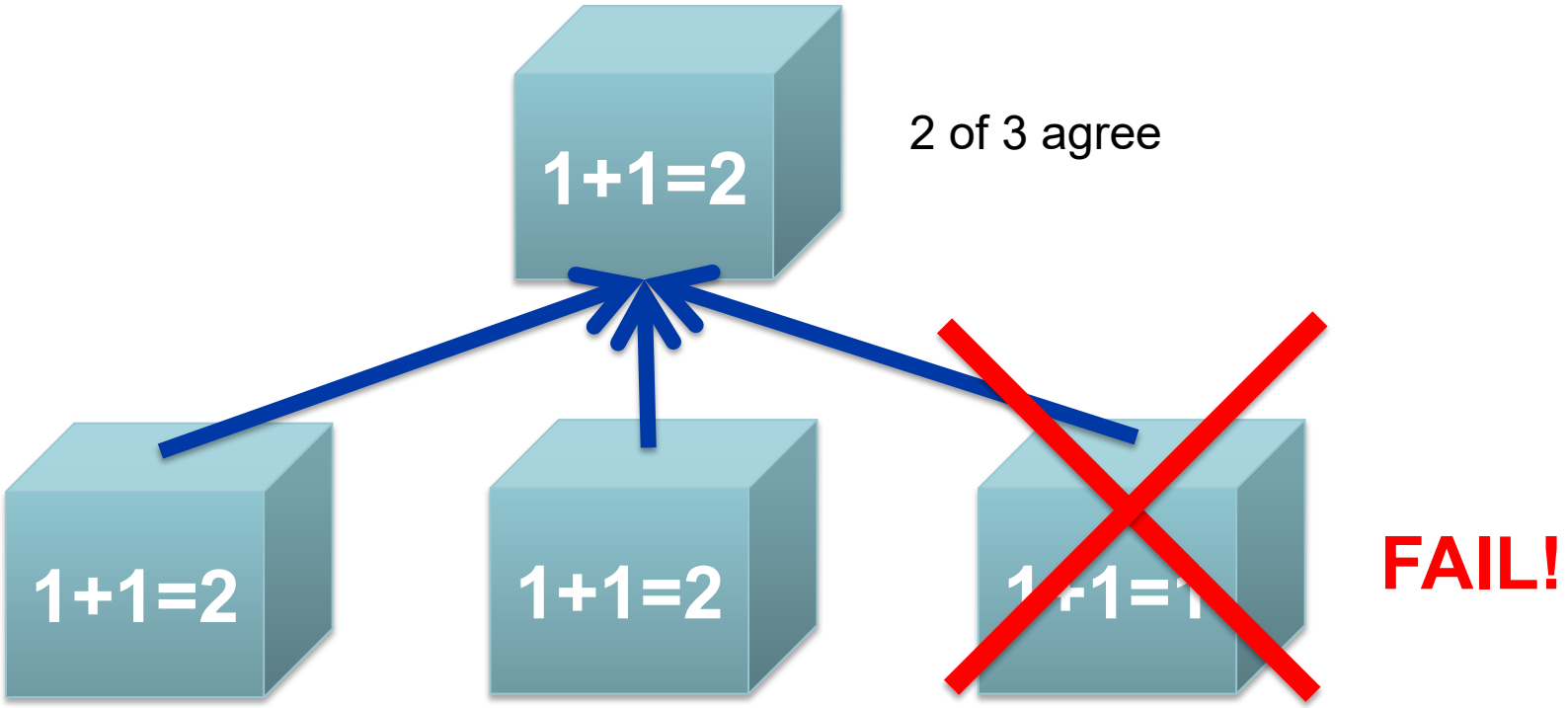
- 冗余（Redundancy）：
  - 时间冗余: 重复操作直到无错
  - 资源冗余: 配置另外的相同部件，有错时用于替代出错部件

Dependability via Redundancy

- **Applies to everything from datacenters to storage to memory to instructors**
  - Redundant datacenters so that can lose 1 datacenter but Internet service stays online
  - Redundant computers was Google's original internal innovation
  - Redundant disks (Redundant Arrays of Independent Disks/RAID)
  - Redundant memory bits (Error Correcting Code/ECC Memory)

Dependability via Redundancy

- Redundancy so that a failing piece doesn't make the whole system fail



Increasing transistor density reduces the cost of redundancy

Example

- **4 disks/server, 50,000 servers**
- **Failure rate of disks: 2% to 10% / year**
  - Assume 4% annual failure rate
- **On average, how often does a disk fail?**
  a) 1 / month
  b) 1 / week
  c) 1 / day
  d) 1 / hour

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50,000 x 4 = 200,000 disks
200,000 x 4% = 8000 disks fail
365 days x 24 hours = 8760 hours

Example

- **Disk subsystems often have redundant power supplies to improve dependability. Assume one power supply is sufficient to run the disk subsystem and that we are adding one redundant power supply.**

1 power supply, 200,000-hour MTTF

Assume it takes on average 24 hours for a human operator to notice that a power supply has failed and replace it. Calculate the reliability of redundant power supplies.

Example

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1 power supply, 200,000-hour MTTF

Assume it takes on average 24 hours for a human operator to notice that a power supply has failed and replace it

$$MTTF_{power\ supply\ pair} = \frac{1}{\frac{2}{MTTF_{power\ supply}} * \frac{MTTR_{power\ supply}}{MTTF_{power\ supply}}}$$

$$= \frac{MTTF^2_{power\ supply}}{2 * MTTR_{power\ supply}} = \frac{200000^2}{2 * 24} = 833,333,333$$

833 333 333 / 200 000 = 4166.7 = 4167

making the pair about 4166 times more reliable than a single power supply.

- MTTF（Mean Time To Failure）
- MTTR（Mean Time To Repair）

Exercise 1.12(a)

- **In a server farm such as that used by Amazon or eBay, a single failure does not cause the entire system to crash. Instead, it will reduce the number of requests that can be satisfied at any one time.**

a. If a company has 10,000 computers, each with a MTTF of 35 days, and it experiences catastrophic failure only if 1/3 of the computers fail, what is the MTTF for the system?

Exercise 1.12(b)

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以分钟为单位
10000台计算机出现一次故障的概率为：
故障率：10000/(35*24*60)=0.1984
MTTF=1/故障率=5(分钟）
即约每5分钟可能出现1次故障。

a. (35 / 10000) × 3333 = 11.67 days

- MTTF（Mean Time To Failure）

Exercise 1.12(b)

- **In a server farm such as that used by Amazon or eBay, a single failure does not cause the entire system to crash. Instead, it will reduce the number of requests that can be satisfied at any one time.**

b. If it costs an extra $1000, per computer, to double the MTTF, would this be a good business decision? Show your work.

b. There are several correct answers. One would be that, with the current system, one computer fails approximately every 5 minutes. 5 minutes is unlikely to be enough time to isolate the computer, swap it out, and get the computer back on line again. 10 minutes, however, is much more likely. In any case, it would greatly extend the amount of time before 1/3 of the computers have failed at once. Because the cost of downtime is so huge, being able to extend this is very valuable.

- MTTF（Mean Time To Failure）

Exercise 1.12(c)

- **In a server farm such as that used by Amazon or eBay, a single failure does not cause the entire system to crash. Instead, it will reduce the number of requests that can be satisfied at any one time.**

c. Figure 1.3 shows, on average, the cost of downtimes, assuming that the cost is equal at all times of the year. For retailers, however, the Christmas season is the most profitable (and therefore the most costly time to lose sales). If a catalog sales center has twice as much traffic in the fourth quarter as every other quarter, what is the average cost of downtime per hour during the fourth quarter and the rest of the year?

Application	Cost of downtime per hour	Annual losses with downtime of		
		1% (87.6 hrs/yr)	0.5% (43.8 hrs/yr)	0.1% (8.8 hrs/yr)
Catalog sales center	$90,000	$7,900,000	$3,900,000	$800,000

Figure 1.3

Application	Cost of downtime per hour	Annual losses with downtime of		
		1% (87.6 hrs/yr)	0.5% (43.8 hrs/yr)	0.1% (8.8 hrs/yr)
Brokerage operations	$6,450,000	$565,000,000	$283,000,000	$56,500,000
Credit card authorization	$2,600,000	$228,000,000	$114,000,000	$22,800,000
Package shipping services	$150,000	$13,000,000	$6,600,000	$1,300,000
Home shopping channel	$113,000	$9,900,000	$4,900,000	$1,000,000
Catalog sales center	**$90,000**	**$7,900,000**	**$3,900,000**	**$800,000**
Airline reservation center	$89,000	$7,900,000	$3,900,000	$800,000
Cellular service activation	$41,000	$3,600,000	$1,800,000	$400,000
Online network fees	$25,000	$2,200,000	$1,100,000	$200,000
ATM service fees	$14,000	$1,200,000	$600,000	$100,000

Figure 1.3 Costs rounded to nearest $100,000 of an unavailable system are shown by analyzing the cost of downtime (in terms of immediately lost revenue), assuming three different levels of availability and that down-time is distributed uniformly. These data are from Kembel [2000] and were collected and analyzed by Contingency Planning Research.

Exercise 1.12(c)

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$$\$90{,}000 = (x + x + x + 2x)/4$$
$$\$360{,}000 = 5x$$
$$\$72{,}000 = x$$
$$\text{4th quarter} = 2x = \$144{,}000/\text{hr}$$