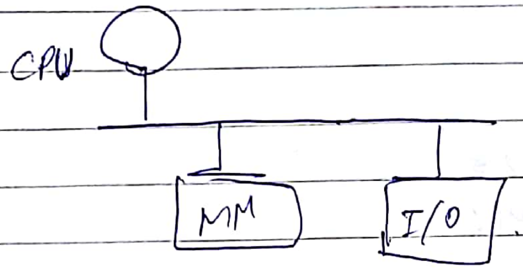
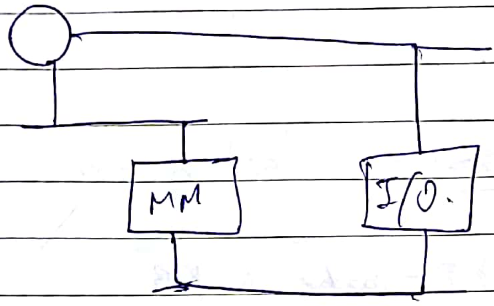
DMA → Direct Memory Access





Reliability, Availability, MTTF, MTBF, MTTR

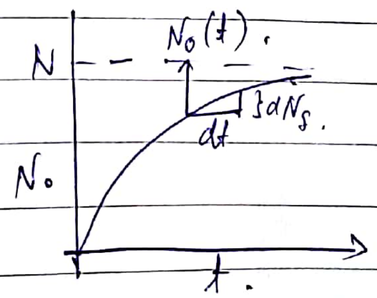
$R(t) = $ prob. $\{S$ is functioning in time $[0, t]\}$.

S ↓ Any device like disk or bulb or something

$N_o(t)$ of N components are operational at t.
$N_f(t)$ of N components ~~are~~ have failed in $[0, t]$.

So, $R(t) = \frac{N_o}{N}$

$$\frac{dR}{dt} = -\frac{1}{N}\frac{dN_f}{dt}.$$

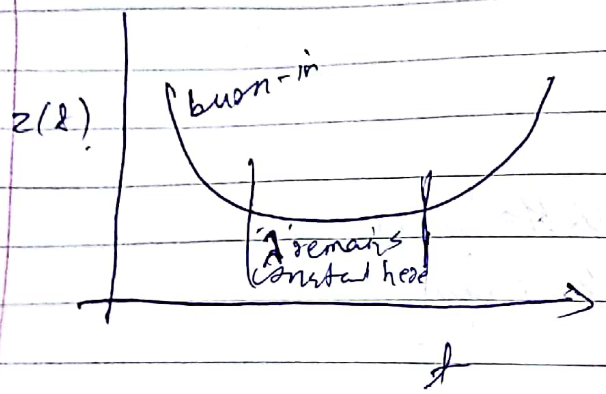


$Z(t)$ (failure rate or hazard rate).

$$= \frac{1}{N_0}\frac{dN_f}{dt} = \frac{-\frac{dR}{dt}}{R}.$$

If $z(t) = \lambda =$ constant:

then $R(t) = e^{-\lambda t}$

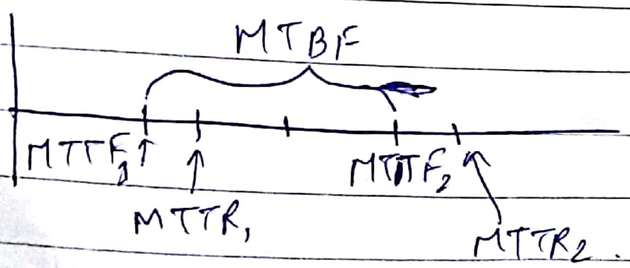


Let x be a r.v. representing lifetime of a component & let F be the cdf of x.

Then, $R(t) = P_r[x > t]$

$$= 1 - F(t) = \int_t^\infty \overset{\lambda e^{-\lambda x}}{f(x)}\, dx = e^{-\lambda t}$$

$$MTTF = \int_0^\infty x \lambda e^{-\lambda x}\, dx = \frac{1}{\lambda}$$



MTTF: Mean time to Failure.

MTTR: Mean time to Repair

MTBF: Mean time between Failure.

Availability (Uptime) = $\frac{MTTF}{MTTF + MTTR}$

AFR (Annual Failure Rate)
(% age of devices expected to fail in a year for a given MTTF.

50 K servers, each with 2 disks.
MTTF = 1000 000 hours.
$\sim$ 114 years.

~~AFR~~ = 8760 hours/year.

$\frac{8760}{10^6} \times 10^5$ = 876 disks/year
$\sim$ 2 disks/day

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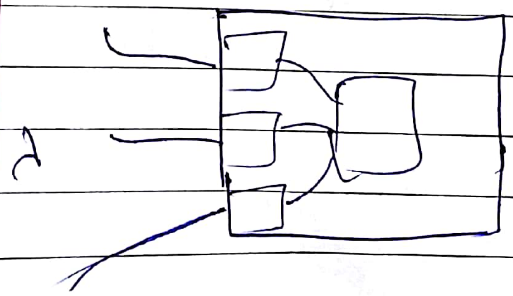
$MTTF = \int_0^\infty t\, f(t)\, dt = \frac{1}{\lambda}$

$f(t) = \lambda e^{-\lambda t} \rightarrow pdf.$
$cdf = 1 - e^{-\lambda t}.$

Core Banking, DR (Data Recovery).

Packet arrivals are Poisson.

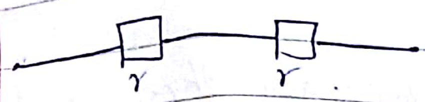


Probability of n packets arrival in time t ~~$\frac{e^{-\lambda t}(\lambda t)^n}{n!}$~~ $\frac{e^{-\lambda t}(\lambda t)^n}{n!}$

How many packets arrive in interval T?
λT.

$$\sum n \frac{e^{-\lambda T} (\lambda T)^n}{n!}$$

R_s r_i (reliability).

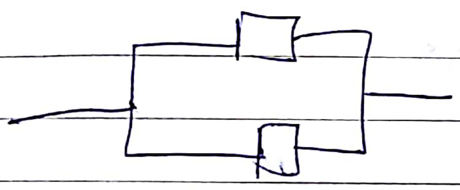


$R_s = r^2$.

Redundancy

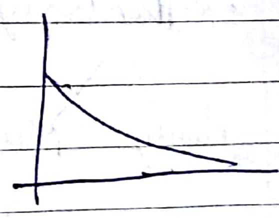
Chipkill

Fault Tolerance



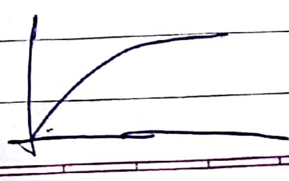
$R_s = 1 - (1-r)^2$.

Assume that $\int_0^\infty t e^{-\lambda t} \, dt = \frac{1}{\lambda^2}$.



$$2 \int t \left(1 - e^{-\lambda t}\right) e^{-\lambda t} \lambda \, dt$$

$$= 2\lambda \left(\frac{1}{\lambda^2} - \frac{1}{(2\lambda)^2} \right) = \frac{3}{2\lambda}.$$



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Disks

- Consists of collection of platters
- Rotate on a spindle at 5400 - 15000 rpm
- Above each surface is an arm containing a R/W head
- Surface divided into concentric circles called tracks
  No. of tracks per surface ~ 10K - 50K.
- Each track has 100-500 sectors

Buffering, Queuing, Caching to increase throughput.

Seek time → to get to the correct track (3-13ms)
Rotation ~~time~~ Latency → to get to the correct sector (2ms).

Total time to read a sector (512 bytes)
= seek time + rot. latency + Transfer time + Disk Controller overhead
~1/2/3 ms   2 ms.   assume < 100MB/sec.   0.2ms.

Transfer time = $\frac{512B}{100MB/sec} \approx 0.005ms$

RAID

- Parallel Disk System.
- Performance via striping.
- Reliability
- Redundancy via multiple disks.

Parity   Mirroring (100% ~~redundan~~ redundancy).