California State University Los Angeles

EE 515 Systems Performance Analysis – Section 81

Final Project/Case Study

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Acknowledgement

In performing our project, we had to take the help and guideline of some respected persons, who deserve our greatest gratitude. The completion of this project gives us much pleasure. We would like to show our gratitude to Prof. Joel K. Harris, EE 515, California State University Los Angeles for giving us a good guideline for project throughout numerous consultations, calculations and introduced us to the Methodology of work. We would also like to expand our deepest gratitude to you who directly involved and guided us in writing this project.

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Objective:

We were given several tasks to achieve in this project. Our project is divided into main three parts. In part A, we need to perform system analysis, where we have some value of the probability density function (PDF) in time of period (0<t<5) using geostationary science for found reliability parameter. A microprocessor that is planned to be used in an orbiting weather satellite in geostationary orbit above the Earth has been found to have the following reliability parameters:

$$f(t) = \begin{cases} 0.000275t^3 & \text{for: } 0 \le t \le 5 \text{ years} \\ 0 & \text{elsewhere} \end{cases}$$

For the given above PDF, we were asked to find the following reliability parameters for the individual microprocessors:

- Reliability at 4 years – R(4)
- Failure rate at 4 years – F(4)
- MTTF
- Median operating time (tmedian)

In the part B, we were asked to find the system reliability (R_{system}) for the given pair of microprocessors.

Finally in part C, we are suppose to suggest and analyze the design approaches to improve the reliability of this circuit card that will use the microprocessor described above? We were told to remember that being deployed on an orbiting satellite, such options as removing/replacing the card, repairing the card or the µP are not possible, as once the satellite is launched, it is impossible to repair it or bring it back for maintenance.

Study for Part A:

Before we start the system performance analysis, we need to understand the basics of Reliability function, Failure function, Median operating time (tmed) and Mean time failure rate(MTTF).

- *Reliability function*:
  The most frequently used function in life data analysis and reliability engineering is the reliability function. This function gives the probability of an item operating for a certain amount of time without failure. As such, the reliability function is a function of time, in that every reliability value has an associated time value. The reliability function can be derived using the previous definition of the cumulative density function. Note that the probability of an event happening by time t (based on a continuous distribution given by f(x), or f(t) since our random variable of interest in life data analysis is time, or t) is given by:

$$F(t) = \int_{0,\gamma}^{t} f(s)ds$$

- Reliability at 4 years – R(4):

  R(t) = P(T > t) = 1 – P (T ≤ t)
  R(t) = 1 f (t)

  Put the value of f(t) in the above equation than we will get the reliability,
  R(t) = 1 - $\int_0^t f\ (t\ )$ dt
  R (t) = 1 - $\int_0^t 0.000275\ t^3$dt
  R (t) = 1 - 0.000275 [$t^4/4\ ]_0^t$
  R (t) = 1 – 0.00006875 t^4

  Put t = 4,
  R (4) = 0.9824

- ## *Failure rate:*

The failure rate of a system usually depends on time, with the rate varying over the life cycle of the system. For example, an automobile's failure rate in its fifth year of service may be many times greater than its failure rate during its first year of service. One does not expect to replace an exhaust pipe, overhaul the brakes, or have major transmission problems in a new vehicle. The instantaneous failure rate h(t) at time t is defined to be:

$$h(t) = \lim_{x \to 0} \frac{1}{x} \frac{F(t+x) - F(t)}{R(t)} = \lim_{x \to 0} \frac{R(t) - R(t+x)}{xR(t)}$$

$$h(t) = \frac{f(t)}{R(t)}$$

- Failure rate at 4 years – F(4):

Failure function = Failure rate = f (T) / R (t)

Thus F (4) = f (4) / R (4)

= 0.000275 (4)^3 / 0.9824

F (4) = 0.0179

- ## *Mean Time To Failure (MTTF)*:

*Mean Time To Failure (MTTF)*is a basic measure of reliability for non-repairable systems. It is the mean time expected until the fi rst failure of a piece of equipment. MTTF is a statistical value and is meant to be the mean over a long period of time and a large number of units. Technically, MTBF should be used only in reference to a repairable item, while MTTF should be used for non-repairable items. However, MTBF is commonly used for both repairable and non-repairable items.
For example, three identical systems starting to function properly at time 0 are working until all of them fail. The first system failed at 100 hours, the second failed at 120 hours and the third failed at 130 hours. The MTBF of the system is the average of the three failure times, which is 116.667 hours. If the systems are non-repairable, then their MTTF would be 116.667 hours.

- Mean Time To Failure (MTTF):

MTTF = $\int_0^5 R\,(\,t\,)dt$

= $\int_0^5 (1 - 0.00006875\ t^4)$ dt

= 4.95703

Calculating MTBF of a drive

$$failure\ rate\ of\ drive = \sum_{i=1}^{n} \frac{failure\ rate\ of\ n\ component}{MTTF\ of\ n\ component}$$

example

$$= \frac{3}{NAND\ MTTF} + \frac{10}{resistor\ MTTF} + \frac{5}{buck\ converter\ MTTF} + \cdots$$

$$MTBF\ of\ drive\ (unit\ in\ hours) = \frac{1}{failure\ rate}$$

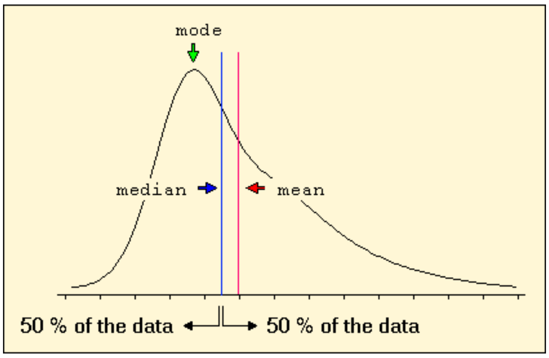
- ***Median operating time (tmed):***

The median is the number separating the higher half of a data sample, a population, or a probability distribution, from the lower half. The median of a finite list of numbers can be found by arranging all the observations from lowest value to highest value and picking the middle one. For any probability distribution on the real line R with cumulative distribution function F, regardless of whether it is any kind of continuous probability distribution, in particular an absolutely continuous distribution (which has a probability density function), or a discrete probability distribution, a median is by definition any real number m that satisfies the inequalities.

$$\mathrm{P}(X \le m) \ge \frac{1}{2} \text{ and } \mathrm{P}(X \ge m) \ge \frac{1}{2}$$

or, equivalently, the inequalities:

$$\mathrm{P}(X \le m) = \mathrm{P}(X \ge m) = \int_{-\infty}^{m} f(x)\,dx = \frac{1}{2}.$$



- Median operating time (tmedian):

$$To\ find\ t\ such\ that \int_0^t f(t)dt = 0.5$$

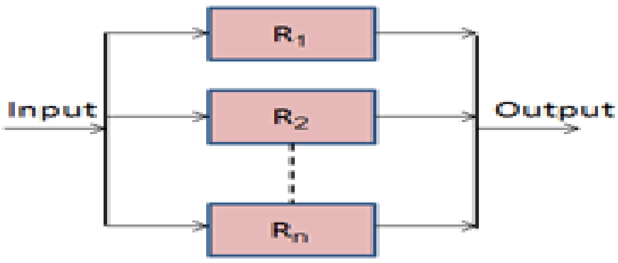
$$= \int_0^t 0.000275t^3 dt = 0.5$$

$$= t = 9.23473$$

$$t_{median} = 9.23473$$

Study for Part B:

Here we were asked to find the system reliability (Rsystem) for the given pair of microprocessors. As in given statement, the proposed circuit design using the 2 microprocessors in parallel. Parallel system is a system in which many calculations are carried out simultaneously, operating on the principle that large problems can often be divided into smaller ones, which are then solved at the same time. Parallel system architecture has become the dominant paradigm in computer architecture, mainly in the form of multi-core processors. This is a system that will fail only if they all fail.



Let's consider the overall pair of microprocessors R1 and R2.
The reliability of the R1 = 0.9971
R2 = 0.8911

We can fine the reliability of the system Rsystem by using following Rsystem formula for parallel circuit:

Rsystem = 1- (1 – R1) (1 – R2)
= 1- (1 – 0.9971) (1 – 0.8911)
= 1- (0.0029) (0.1089)
= 1- (0.0003158)
Rsystem = 0.99968 or 99.96% (Rsystem for parallel)

To verify the reliability if the circuit is in series.

Rsystem = R1.R2
= (0.9971) (0.8911)
Rsystem = 0.88851 or 88.85% (Rsystem for series)

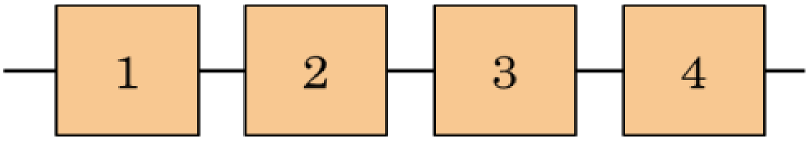
The above calculations concludes that the Rsystem is 0.99968 which is way better than if our system was design in series.

Study for Part C:

To justify and get the actual results we need to test our design approaches in different possible combinations. This will helps us to understand the reliability and redundancy of the system.

Case # 1

- ***Series System*** :
  This is a system in which all the components are in series and they all have to work for the system to work. If one component fails, the system fails.

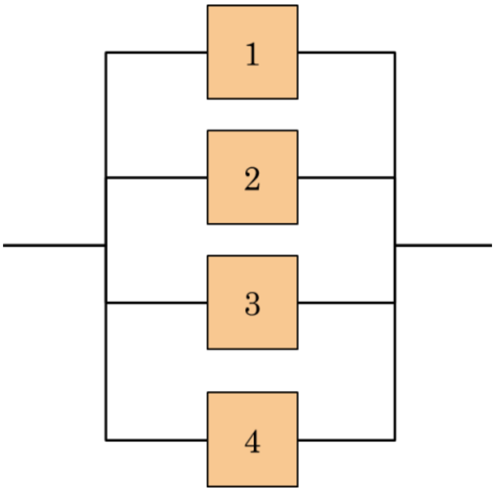


Consider :
R1=0.999
R2=0.899
R3=0.915
R4=0.989
For system reliability: Rsystem

Rsystem = R1. R2. R3. R4
Rsystem =(0.999) (0.899) (0.915) (0.989)
Rsystem = 0.8127 or 81.27%

Case # 2:

- ***Parallel System*** :
  This is a system that will fail only if they all fail.



Consider :

R1=0.999

R2=0.899

R3=0.915

R4=0.989

For system reliability: Rsystem

Rsystem = 1- (1-R1) (1-R2) (1-R3) (1-R4)

Rsystem = 1- (1-0.999) (1-0.899) (1-0.915) (1-0.989)

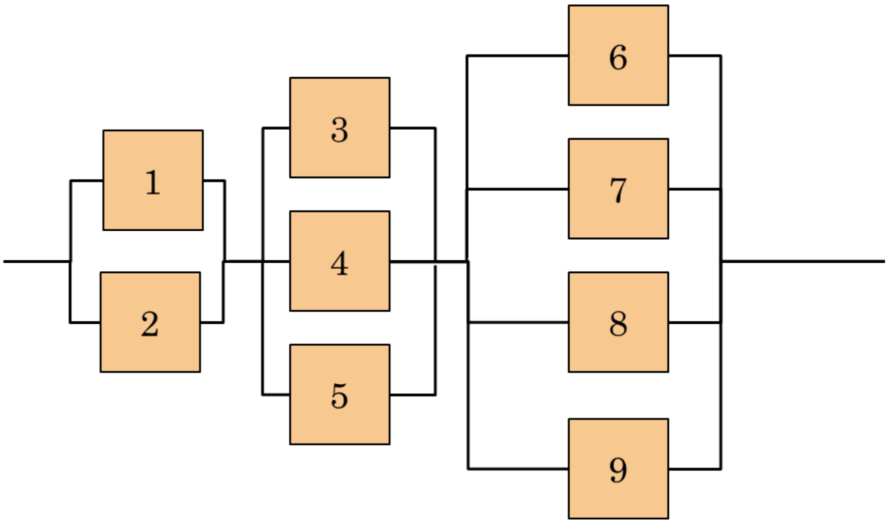
Rsystem = 1 – (0.001)(0.101)(0.085)(0.011)

Rsystem = 1 – (0.000000094)

Rsystem = 0.99999 or 99.999%

Case # 3:

Now here in this case we will discuss Series-parallel system with 9 units.



Consider:

R1=0.999
R2=0.899
R3=0.915
R4=0.989
R5=0.921
R6=0.933
R7=0.870
R8=0.951
R9=0.902

The system consists of three groups of blocks arranged in series. Each block is, in turn, formed by elements in parallel. First we must calculate:

R1 and R2=1−(1−0.999)(1-0.899)
=1-(0.001)(0.101)
=1-0.000101
R1 and R2 =0.9998 or 99.98%

So it is possible to estimate:

$R3,R4,R5 = 1-(1-0.915)(1-0.989)(1-0.921)$
$= 1-(0.085)(0.011)(0.079)$
$= 1-0.00007386$
$R3,R4,R5 = 0.99992$ or 99.99%

Then we must calculate the reliability of the last parallel block:

$R6,R7,R8,R9 = 1-(1-0.933)(1-0.870)(1-0.951)(1-0.902)$
$= 1-(0.067)(0.13)(0.049)(0.098)$
$= 1-0.00004182$
$R6,R7,R8,R9 = 0.99995$ or 99.995%

Finally, we proceed to the series of the three blocks:

$Rsystem = (R1,R2)\cdot(R3,R4,R5)\cdot(R6,R7,R8,R9)$
$Rsystem = (0.9998)(0.99992)(0.99995)$
$Rsystem = 0.9996$ or 99.96%

Conclusion:

Based of our group study and results of the above cases, we determine that parallel circuits or system are much more reliable and redundant than the series. As we noticed the reliability of system in case 2 for parallel circuit system was 99.99% as compared to case 1 which was for series circuit system 81.27%. this shows us a huge difference in results as we used the same sample of 4 processors. Even 3 of them has individual reliability was more than 90% but it shows a big decline in series circuits.

A variety of hardware architectures allow multiple computers to share access to data, software, or peripheral devices. A parallel database is designed to take advantage of such architectures by running multiple instances which "share" a single physical database. In appropriate applications, a parallel server can allow access to a single database by users on multiple machines, with increased performance. Parallel systems usually give results which fall somewhere between pure plurality/majority and pure PR systems.

Characteristics of a Parallel System:

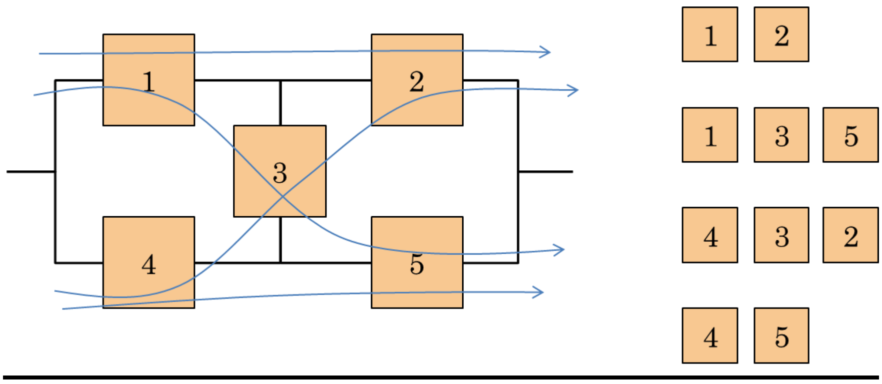
- Each processor in a system can perform tasks concurrently.
- Tasks may need to be synchronized.
- Nodes usually share resources, such as data, disks, and other devices.
- Parallel processing architectures may support:
  - Clustered and massively parallel processing (MPP) hardware, in which each node has its own memory.
  - Single memory systems-also known as symmetric multiprocessing (SMP) hardware, in which multiple processors use one memory resource

- Coordination of concurrent tasks is called synchronization. Synchronization is necessary for correctness. The key to successful parallel processing is to divide up tasks so that very little synchronization is necessary. The less synchronization necessary, the better the speedup and scaleup.

Ways to increase reliability and redundancy:

As we already concluded our given task but we decided to show some more alternative ways to increase the reliability and redundancy of the circuit.

Suggestion #1

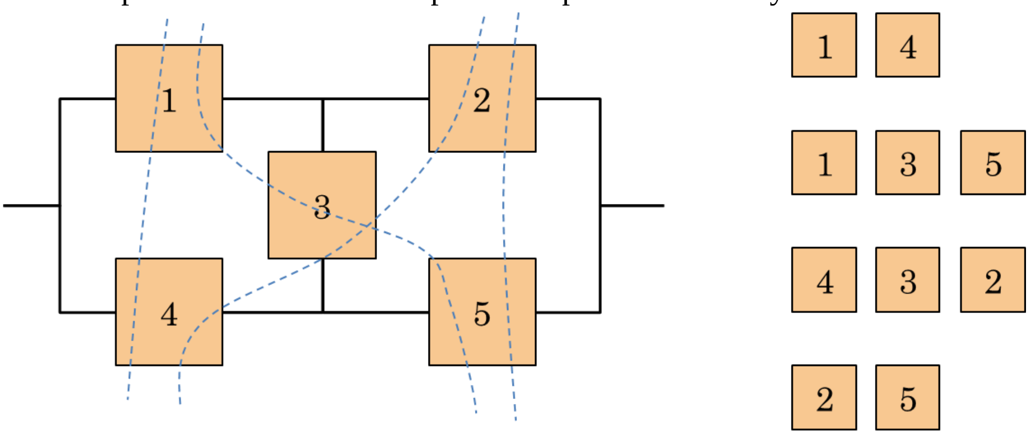


The above diagram shows us the very reliable and redundant system. As we showed, the system contain 5 units (microprocessors in our case) connecting into series and parallel connection. We suggest to put the unit 3 in the middle to increase the redundancy as if one node is fails, the signals have other ways to get to their destination.

As we see, signals from unit A make their way to output via unit 2, just in case if unit 2 is failed, the unit A's signals make their way to output via unit 3 and unit 5. Similarly signals from unit 4 could make their way to output via unit 5 but just in case if unit 5 fails, signals from unit 4 make their way to output via unit 3 and unit 2.

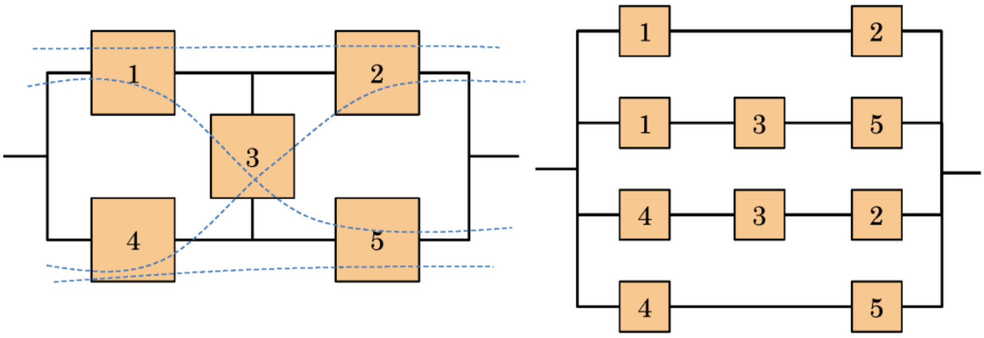
This is a simple example to explain the redundancy and reliability. In such system if any node fails, it didn't fail the system and operations keep running. This would also reduce the load on entire system as if one unit has more work load or data, it will start using alternative ways to get to the output. This will also increase the life of the system.

Minimal Path Set. The system on the left contains the minimal path set indicated by the arrows and shown in the right part. Each of them represents a minimal subset of the components of the system such that the operation of all the components in the subset implies the operation of the system.



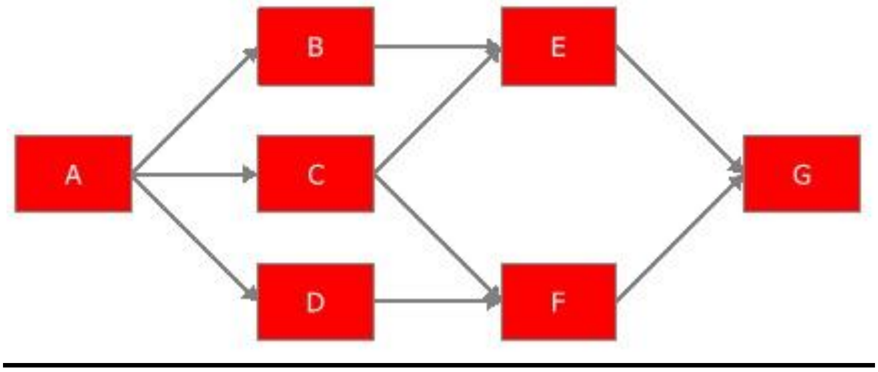
The system of the left contains the minimal cut set, indicated by the dashed lines, shown in the right part. Each of them represents a minimum subset of the components of the system such that the failure of all components in the subset does not imply the operation of the system.

Suggestion # 2:



The above circuit can be used to build equivalent configurations of more complex systems, not referable to the simple series-parallel model. The first equivalent configuration is based on the consideration that the operation of all the components. This configuration is, therefore, constructed with the creation of a series subsystem for each path using only the minimum components of that set. Then, these subsystems are connected in parallel.

Suggestion # 3



The system in the figure above cannot be broken down into a group of series and parallel systems. This is primarily due to the fact that component "C" has two paths leading away from it, where as "B" and "D" have only one. Several methods exist for obtaining the reliability of a complex system including:

- The decomposition method.
- The event space method.
- The path-tracing method.

Here unit A could go through unit B,C,D. It could reach to unit E via unit B,C. Similarly it could reach to unit F via C,D. If either unit E or F fails, unit A would make it way to the output unit G.