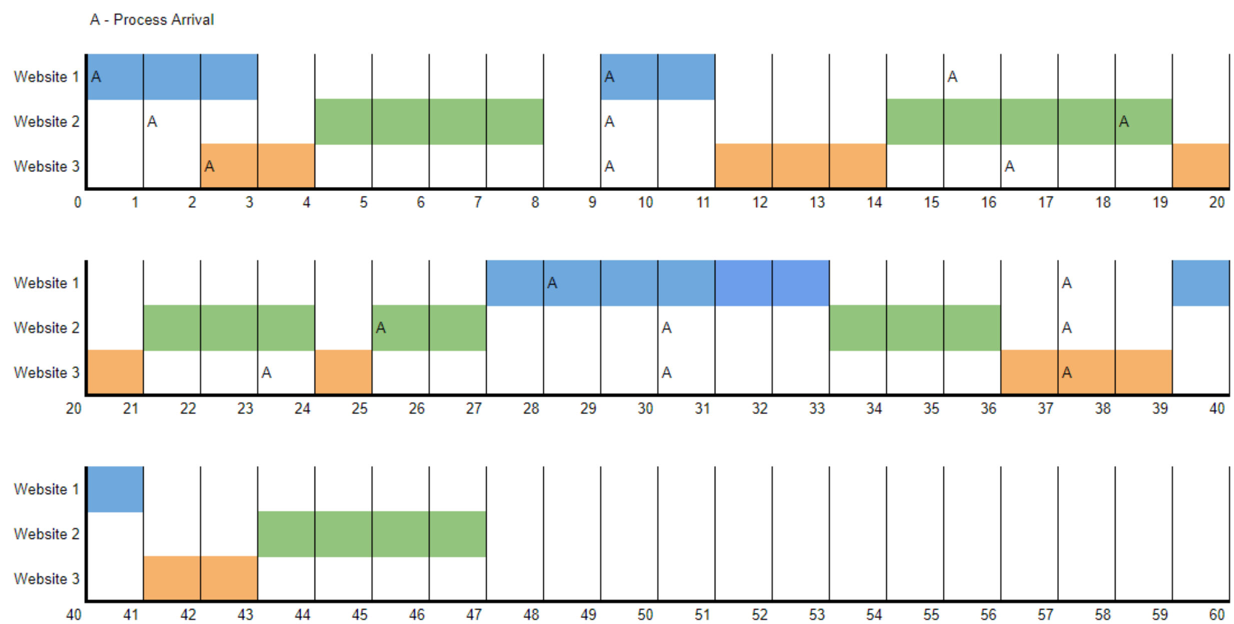
Answer 1

a)



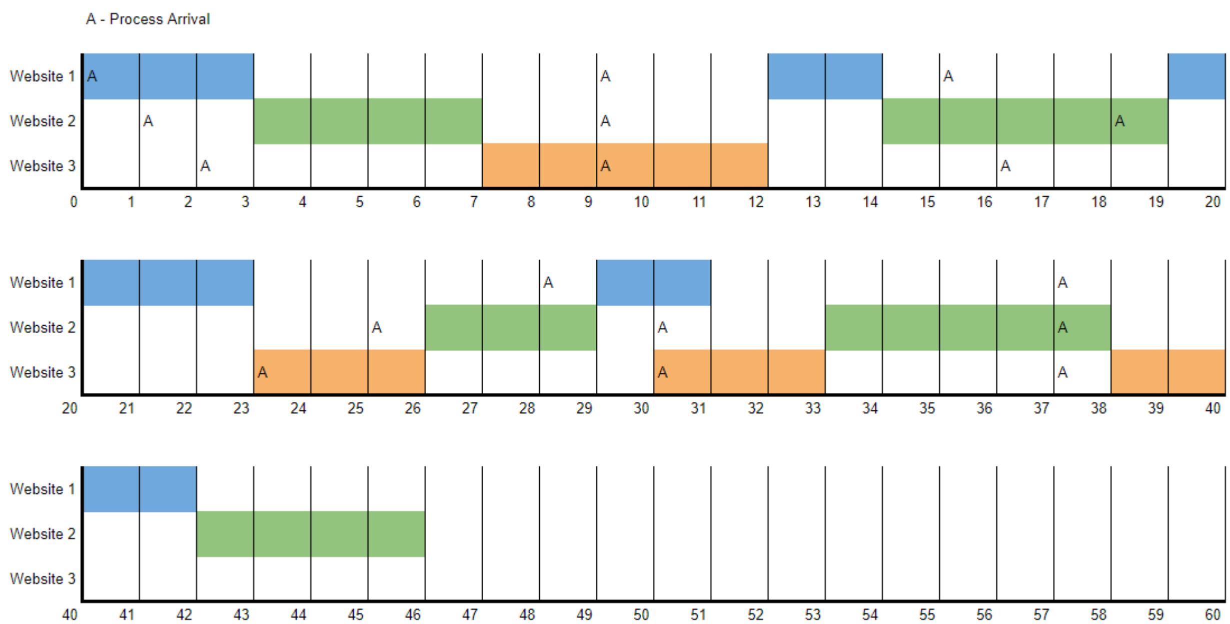
b) If we calculate the exponentially weighted moving average using $\alpha = 0.5$, using the following equation:

$$\begin{cases} ??, & \text{if } t = 1 \\ \alpha \times Y_{t-1}, & \text{if } t = 2 \\ \alpha \times Y_{t-1} + (1-\alpha) \times S_{t-2}, & \text{if } t > 2 \end{cases}$$

Then we'd get the following mean values at the arrival of each request:

Index	Website 1	Website 2	Website 3
1	?	?	?
2	1.5	2	1
3	1.75	3.5	2
4	2.875	3.25	2
5	2.4375	2.625	1.5
6	-	2.8125	2.25

From here we'd get the following schedule:



c) If we calculate the response time averages for each of the request types, alongside with the total average response time, for both occasions with prevision *(TABLE 1.1, PAGE 10)*, and without prevision *(TABLE 1.2, PAGE 10)*, we can clearly see that the total average did increase with the lack of clairvoyance, with the average response time for the impossible schedule being 5.9 units of time per request, while in the possible schedule being 6.24 units of time per request.

d) If we calculate the average length of the requests for the different websites, we get that the average request length for website one is 2.6 units of time; for website two it is 3.5 units of time; and finally for website three it is 2.2 units of time.

With that in mind, the website with statistically smaller request is the third one. If we calculate the average slowdown for the requests in each of the schedules *(TABLE 1.3, PAGE 10)*, we get that the average slowdown for the system that predicts the future is 2.2, while in the system that doesn't predict the future it is 2.4. As such, the non-prediction of the future does also negatively impact this specific resource.

e) To start off here, we need to find the order that is predicted with both 0.3 and 0.8, as such, let's use the following formula:

$$\begin{cases} ??, & \text{if } t = 1 \\ \alpha \times Y_{t-1}, & \text{if } t = 2 \\ \alpha \times Y_{t-1} + (1-\alpha) \times S_{t-2}, & \text{if } t > 2 \end{cases}$$

And get the tables of the calculated average request length at the arrival of each request, for each α *(TABLE 1.4, PAGE 11)*, and then proceed to calculate the prediction error average for each website, under each value of α *(TABLE 1.5, PAGE 11)*. From here we can finally get the average prediction error overall for each α, and we get that it is: $0.95 - \alpha = 0.5$, $0.7 - \alpha = 0.3$, $1.1 - \alpha = 0.8$.

Since the further from 1 the value is the greater the error margin, then the closest match will be $\alpha = 0.5$, with a 0.05 error margin, compared with the 0.1 error margin for $\alpha = 0.8$ and an error margin of 0.3 for $\alpha = 0.3$.

Answer 2

a) The scheduler embedded with this HDD follows a similar approach to the SCAN Scheduling Method. The invocation only occurs at the FIRST request, and when the head of the disk reaches either Track number 11 and Track number 0.

The way it seems to work is, if the queue is empty and a request is given, then the HDD will attempt to reach that request, however, since the Disk Head only switches moving directions upon hitting Track 11 or Track 0, then the disk might have to make extra moves in order to hit that first request. If that is the only request in the queue, it'll stop, and wait for further requests.

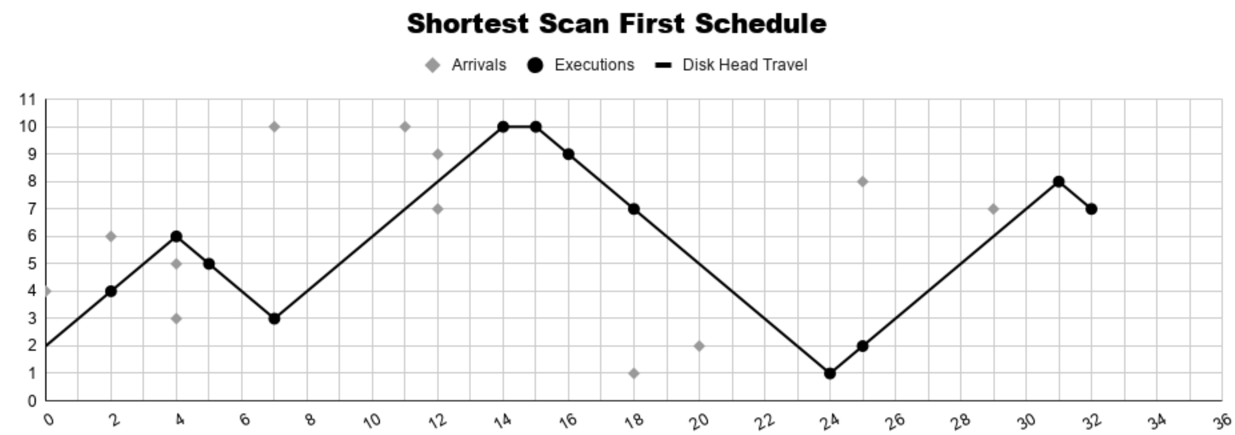
If however, there are other request in the queue, it'll attempt to serve them. This is where the scheduling policy comes in. The scheduler calculates what requests to serve, and in what order, after it reaches either Track 0 or Track 11. So if another request arrives in between the travels, it'll have to wait for the Disk Head to move to one of the edges before it's actually inserted into the service queue.

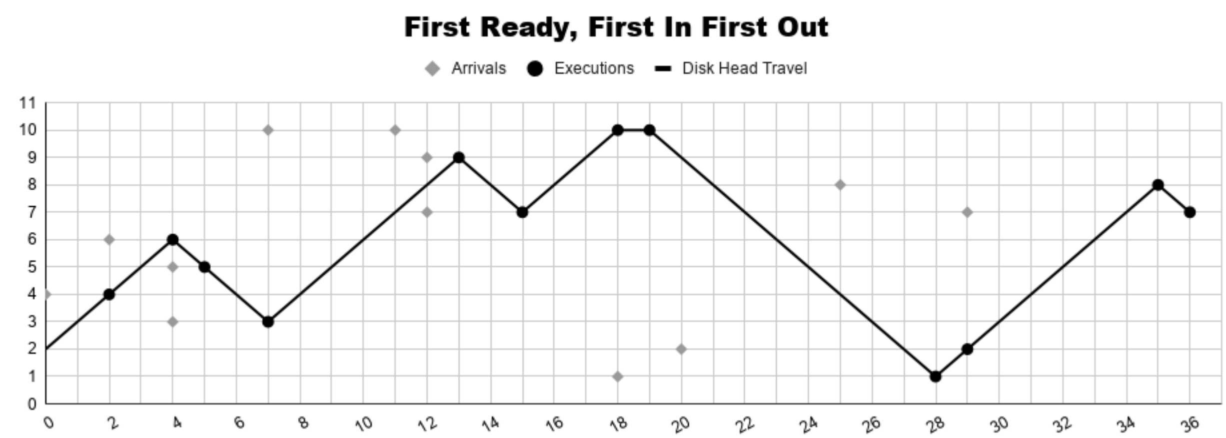
When it comes to the order in which it serves the requests it found when it hit one of the edges, the HDD seems to serve them in order of proximity, so if the head just hit Track 11, it'll begin serving requests at Track 10, and if it just hit Track 0, it'll begin serving requests at Track 1.

b) Since the HDD only re-calculates the serving order once it hits one of the edges, it often can be traveling for a while without serving any request before it reaches an edge and realizes it needs to serve them. If we instead have the disk re-calculating the serving order whenever a request arrives, then we can reduce the response time.

If we calculate the response times for both of these cases *(TABLE 2.1, PAGE 11)*, we can see that the average response time for the Current Scheduler is 7.42 Time Units, while for the Improved Scheduler is 6.58 Time Units. This might not be a lot, but it still does improve overall response time by almost 1 Time Unit. It does however still suffer from some of the downfalls of the Current Scheduler, as the Disk Head can take a long time to return to a specific Track.

c) If we use these two methods to schedule our HDD Schedule, then we'll get the following Disk Head Movement Charts:





From here it is clear that the Disk Head will travel less during the Shortest Scan First Schedule. When it comes to response times, if we calculate the response time for each of these schedules *(TABLE 2.2, PAGE 12)*, we can see that Shortest Scan First still comes out ahead, with an average response time of 4.08 Units, compared to the FR-FCFS's average of 5.58 Units.

From these two Schedulers, and even when comparing to our first scheduler and the improved version of that scheduler *(TABLE 2.1, PAGE 11)*, the best option is Shortest Scan First Schedule.

Answer 3

a)

Task	Period *T* (ms)	WCET *C* (MCC)
SF	2.5	0.8
AS	7	2.3
AESA	200	5
DAS - MDT	10	4
DAS - LPD	20	6
DAS - FCCM	12.5	3
DAS - FVT	25	5
CNI	20	12

b) If we assume that 1MHz will deal with 1MCC per second, then we know that 1GHz will deal with 1MCC per millisecond. With that in mind, we can adapt the WCETS to use ms under each GHz measurement *(TABLE 3.1, PAGE 12)*, with that in mind, we can now apply the following equation:

$\sum_{i=1}^{m} \frac{C_1}{T_1} \leq m \times (2^{\frac{1}{m}} - 1)$

To figure out whether the task-set is scheduleable at a certain speed. Two things should be noted here, firstly, $m = 8$, since we have 8 tasks. Secondly, if the equation doesn't hold, it still doesn't mean that it isn't scheduleable, so we'll need to actually attempt to schedule the tasks if need be.

With that said, at $1GHz$, the equation turns to $2.41 \leq 0.72$, this doesn't hold, and if we attempt to schedule the tasks, we'll end up missing a deadline at 10ms for the MDT task *(SCHEDULE 3.1, PAGE 13)*. If we then do this again for $2GHz$, the equation turns to $1.21 \leq 0.72$, and the schedule once again doesn't work, as we miss the deadline for CNI at 20ms *(SCHEDULE 3.2, PAGE 13)*. If we repeat this again for $3GHz$, the equation turns to $0.80 \leq 0.72$, however we are able to schedule all tasks without any conflict *(SCHEDULE 3.3, PAGE 14)*.

If we make the same assumptions around GHz/MCC/ms, and try to use EDF on the values *(TABLE 3.1, PAGE 12)*, we can make use of the following equation:

$\sum_{i=1}^{m} \frac{C_1}{T_1} \leq 1$

A couple things that should be noted on this equation are that, once again $m = 8$, and that this time, this is a requirement of EDF schedules, so if the equation doesn't add up for a certain speed, then we know it can't be scheduled.

Once again, $1GHz$ and $2GHz$ fail the equation, however $3GHz$ does seem to work with it. This does bring up an issue, now we know both of the required speeds for EDF and RM are between $2GHz$ and $3GHz$.

After some looking, it seems that we need a CPU with at least $2.5GHz$ to run EDF, as $2.4GHz$ results in the equation: $1.00565 \leq 1$, which doesn't hold, while with $2.5GHz$ the equation results in: $0.95542 \leq 1$, which does hold.

When it comes to RM, it seems that the sweet spot is $2.7GHz$. Neither $2.6GHz$ nor $2.7GHz$ uphold the equation, but when scheduling them, if we use $2.6GHz$, the scheduler misses a deadline at 25ms for FVT *(SCHEDULE 3.4, PAGE 15)*, while with $2.7GHz$ the task set is fully scheduleable *(SCHEDULE 3.5, PAGE 15)*.

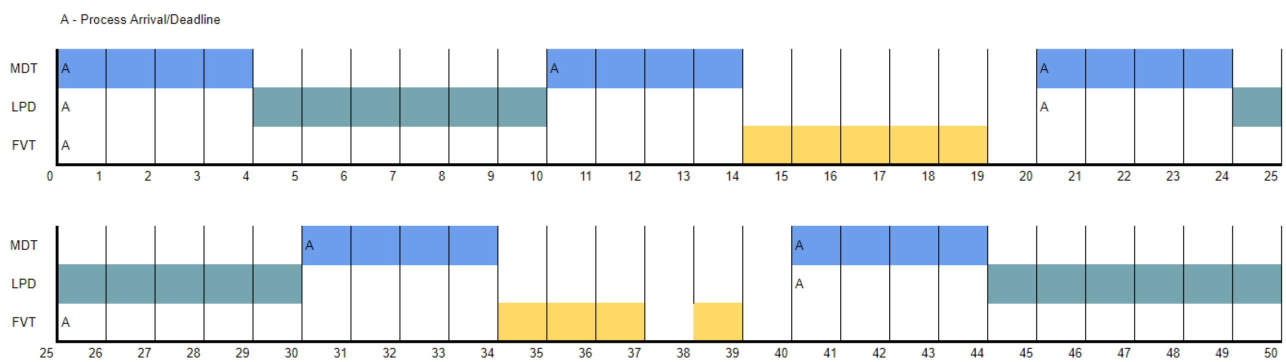
c) If we opt for the single CPU, and we know we need at least $2.5GHz$, then we need a CPU with a speedup of $\frac{2.5}{1} - 1 = 1.5$, so the cost will be $C^{2.5} = 50^{1.5} = 353.553$. On the other hand, we'd need 3 CPUs that run at $1GHz$ in order to obtain the same result, so the cost would be $3 \times 50 = 150$. As such, we should opt for a 3 CPU machine to minimize costs.

d) Assuming we'd pick the multi-processor design, we need at least 3 CPUs to maintain the load of the system at $2.5GHz$.

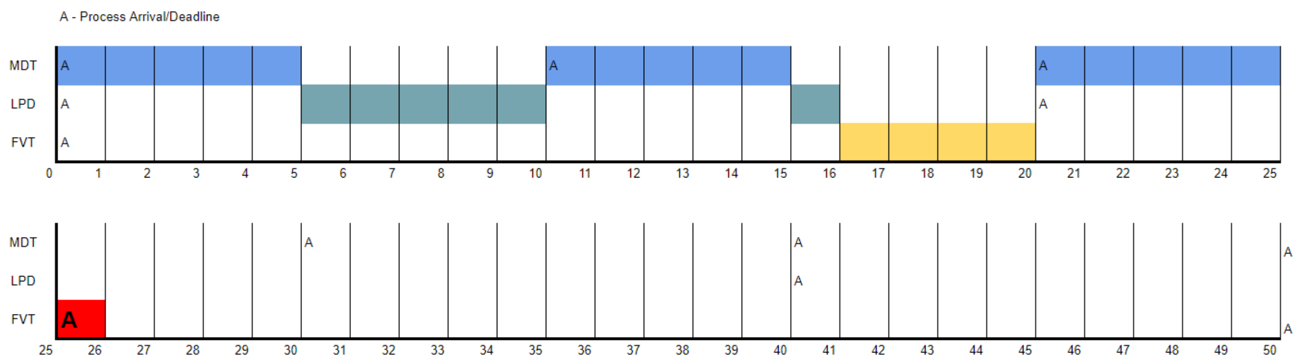
Since we are using EDF, we can make use of the EDF formula, as well as the WCET values at 1GHz *(TABLE 3.1, PAGE 12)* to get the task-to-processor assignment.

If we form the following three groups: [CNI, AS], [SF, FCCM, FVT], [AESA, MDT, LPD], then we can run the EDF formula, and we get, respectively, $0.93 \leq 1$, $0.76 \leq 1$, $0.73 \leq 1$. With that, we have a stable matching of task-to-processor using EDF.

e)



f) Firstly, lets run the RM equation on the values for these tasks under $1GHz$ *(TABLE 3.1, PAGE 12)*, if we do so we'd get: $0.9 \leq 0.78$, so from here we don't really get much information, so let's try actually scheduling them and see what happens. If we do so we get:



As we can see FVT does in fact miss its deadline, and, as such, this task-set is no scheduleable under RM.

Auxiliary Materials

All these materials were obtained using Google Spreadsheets. The actual spreadsheet can be found here `https://bit.ly/3kMX7Rl`

TABLE 1.1

	Website 1	Website 2	Website 3
Index 1	3 Units	7 Units	2 Units
Index 2	2 Units	10 Units	5 Units
Index 3	16 Units	6 Units	5 Units
Index 4	5 Units	2 Units	2 Units
Index 5	4 Units	6 Units	9 Units
Index 6	-	10 Units	6 Units
Average	6 Units	6.8 Units	4.8 Units
Total Average		5.9 Units	

TABLE 1.2

	Website 1	Website 2	Website 3
Index 1	3 Units	6 Units	7 Units
Index 2	5 Units	10 Units	3 Units
Index 3	8 Units	11 Units	9 Units
Index 4	3 Units	10 Units	3 Units
Index 5	5 Units	8 Units	3 Units
Index 6	-	9 Units	3 Units
Average	4.8 Units	9 Units	4.7 Units
Total Average		6.24 Units	

TABLE 1.3

	With Prediction	Without prediction
Index 1	1	3.5
Index 2	1.7	1
Index 3	2.5	4.5
Index 4	2	3
Index 5	3	1
Index 6	3	1.5
Average	2.2	2.4
Total Average	2.3	

TABLE 1.4

Index	Actual Length of Jobs			Predicted Length (a = 0.5)			Predicted Length (a = 0.3)			Predicted Length (a = 0.8)		
	Website 1	Website 2	Website 3	Website 1	Website 2	Website 3	Website 1	Website 2	Website 3	Website 1	Website 2	Website 3
1	3	4	2	?	?	?	?	?	?	?	?	?
2	2	5	3	1.5	2	1	0.9	1.2	0.6	2.4	3.2	1.6
3	4	4	2	1.75	3.5	2	1.23	2.34	1.32	2.08	4.64	2.72
4	2	2	1	2.875	3.25	2	2.061	2.538	1.524	3.616	3.328	2.144
5	2	3	3	2.4375	2.625	1.5	1.461	2.3766	1.3668	2.3232	2.2656	1.2288
6	-	4	2	-	2.8125	2.25	-	2.56362	1.85676	-	2.85312	2.64576

TABLE 1.5

Index	Prediction Error (Actual Jobs)			Prediction Error (a = 0.5)			Prediction Error (a = 0.3)			Prediction Error (a = 0.8)		
	Website 1	Website 2	Website 3	Website 1	Website 2	Website 3	Website 1	Website 2	Website 3	Website 1	Website 2	Website 3
1	1	1	1	?	?	?	?	?	?	?	?	?
2	1	1	1	0.75	0.4	0.3333333333	0.45	0.24	0.2	1.2	0.64	0.5333333333
3	1	1	1	0.4375	0.875	1	0.3075	0.585	0.66	0.52	1.16	1.36
4	1	1	1	1.4375	1.625	2	1.0305	1.269	1.524	1.808	1.664	2.144
5	1	1	1	1.21875	0.875	0.5	0.7305	0.7922	0.4556	1.1616	0.7552	0.4096
6		1	1		0.703125	1.125		0.640905	0.92838		0.71328	1.32288
Average	1	1	1	0.96	0.9	0.99	0.63	0.71	0.75	1.17	0.99	1.15
Total Average		1			0.95			0.7			1.1	

TABLE 2.1

	Current Scheduler	Improved Scheduler
R1	2 Units	2 Units
R2	2 Units	2 Units
R3	11 Units	11 Units
R4	13 Units	13 Units
R5	3 Units	1 Unit
R6	19 Units	19 Units
R7	17 Units	17 Units
R8	1 Unit	1 Unit
R9	4 Units	1 Unit
R10	2 Units	2 Units
R11	9 Units	4 Units
R12	6 Units	6 Units
Average	7.42 Units	6.58 Units
Total Average	7 Units	

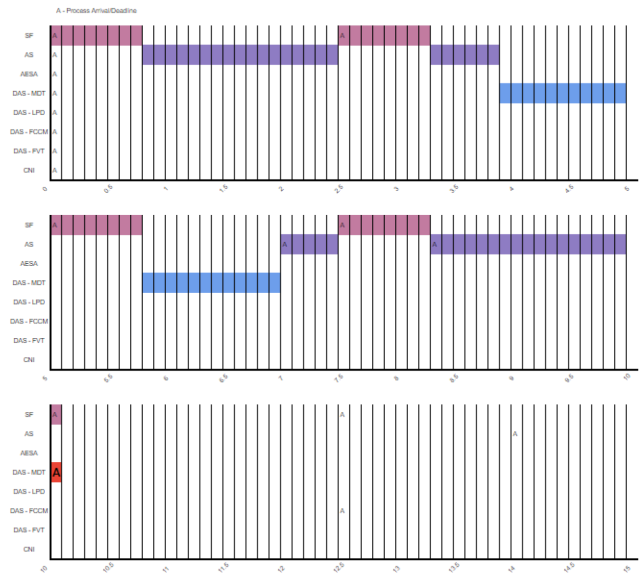
TABLE 2.2

	SSF	FR-FCFS
R1	2 Units	2 Units
R2	2 Units	2 Units
R3	1 Unit	1 Unit
R4	3 Units	3 Units
R5	7 Units	11 Units
R6	4 Units	8 Units
R7	4 Units	1 Unit
R8	6 Units	3 Units
R9	6 Units	10 Units
R10	5 Units	9 Units
R11	6 Units	10 Units
R12	3 Units	7 Units
Average	4.08 Units	5.58 Units
Total Average	4.83	

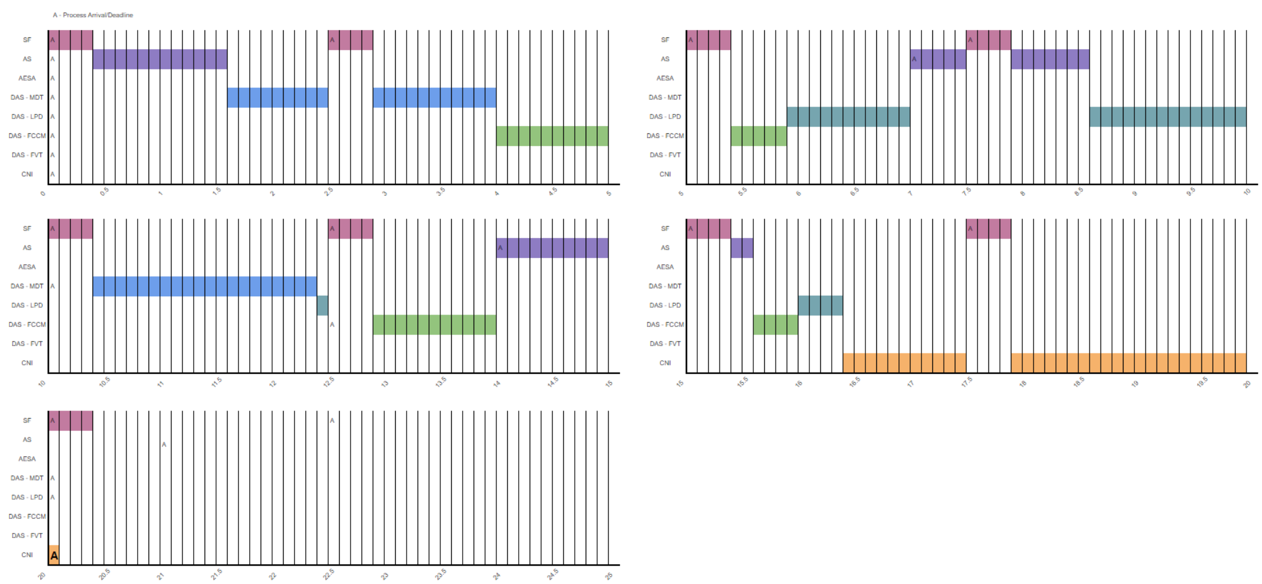
TABLE 3.1

Task	WCET C (ms) (1 GHz)	WCET C (ms) (2 GHz)	WCET C (ms) (2.4 GHz)	WCET C (ms) (2.5 GHz)	WCET C (ms) (2.6 GHz)	WCET C (ms) (2.7 GHz)	WCET C (ms) (3 GHz)
SF	0.8	0.4	0.3333333333	0.32	0.3076923077	0.2962962963	0.2666666667
AS	2.3	1.15	0.9583333333	0.92	0.8846153846	0.8518518519	0.7666666667
AESA	5	2.5	2.083333333	2	1.923076923	1.851851852	1.666666667
DAS - MDT	4	2	1.666666667	1.6	1.538461538	1.481481481	1.333333333
DAS - LPD	6	3	2.5	2.4	2.307692308	2.222222222	2
DAS - FCCM	3	1.5	1.25	1.2	1.153846154	1.111111111	1
DAS - FVT	5	2.5	2.083333333	2	1.923076923	1.851851852	1.666666667
CNI	12	6	5	4.8	4.615384615	4.444444444	4

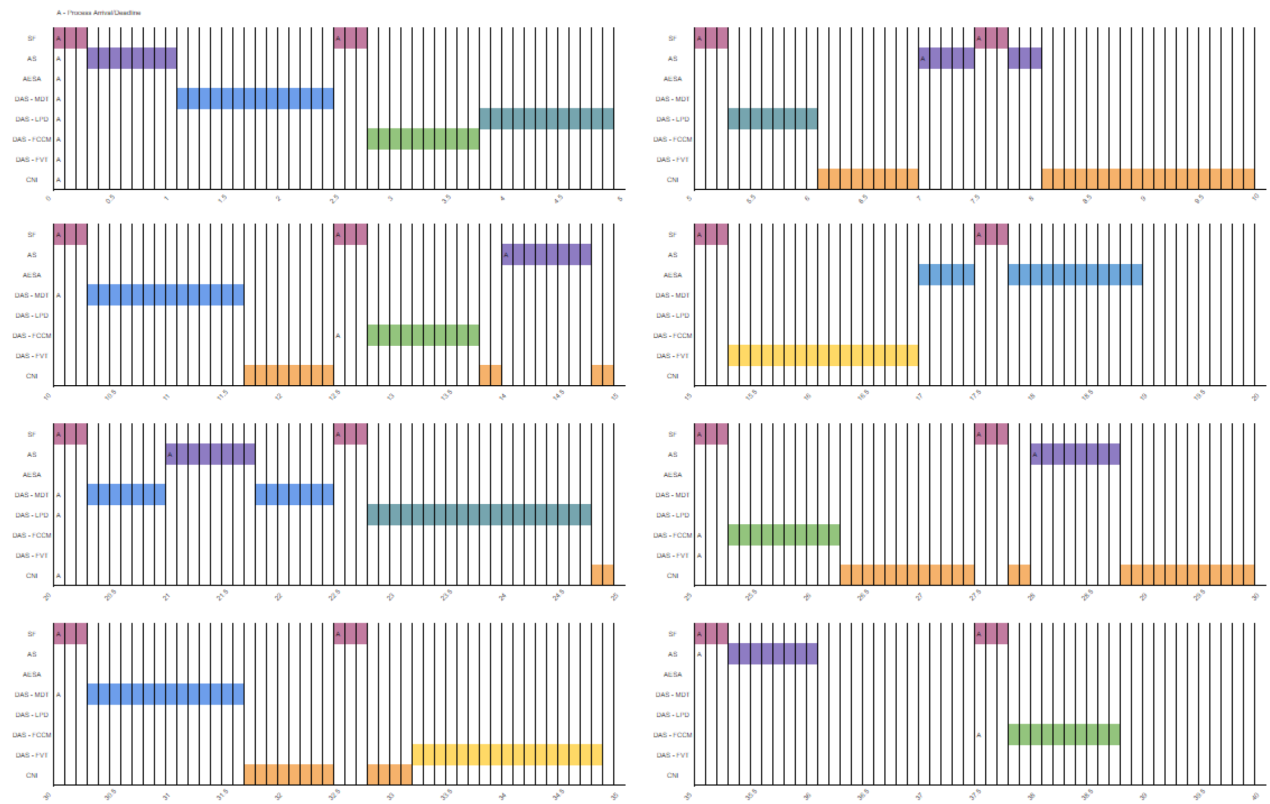
SCHEDULE 3.1



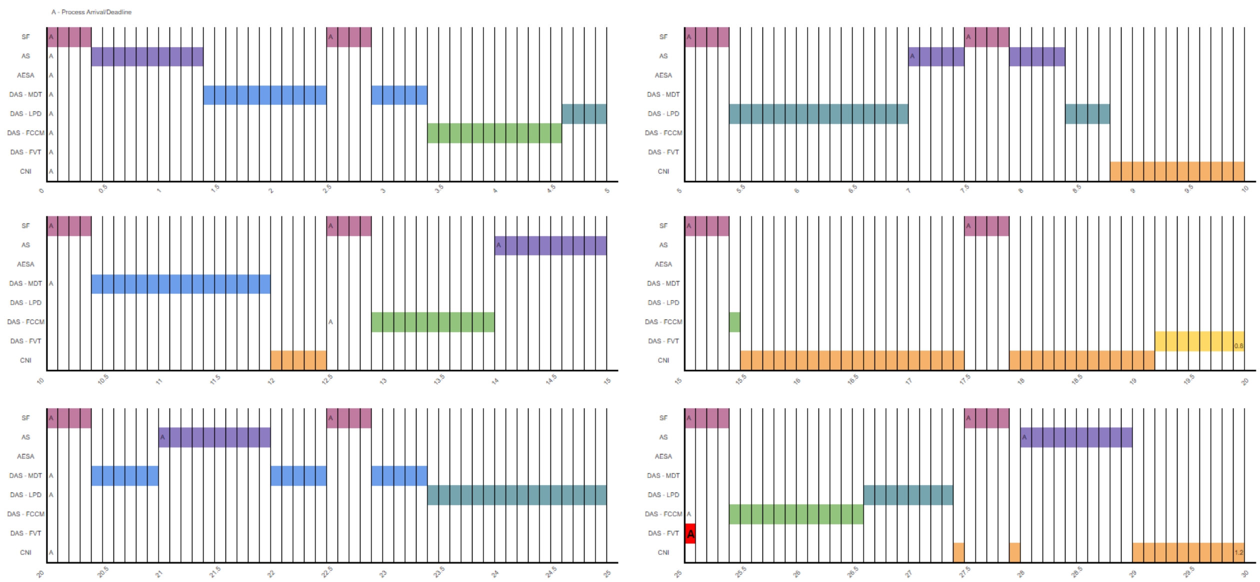
SCHEDULE 3.2



SCHEDULE 3.3


A - Process Arrival/Deadline
SF
AS
AESA
DAS - MDT
DAS - LPD
DAS - FCCM
DAS - FVT
CNI

SCHEDULE 3.4



SCHEDULE 3.5