



PEA – FINAL PROJECT

JASKARAN RAM - I0735884 - 2023

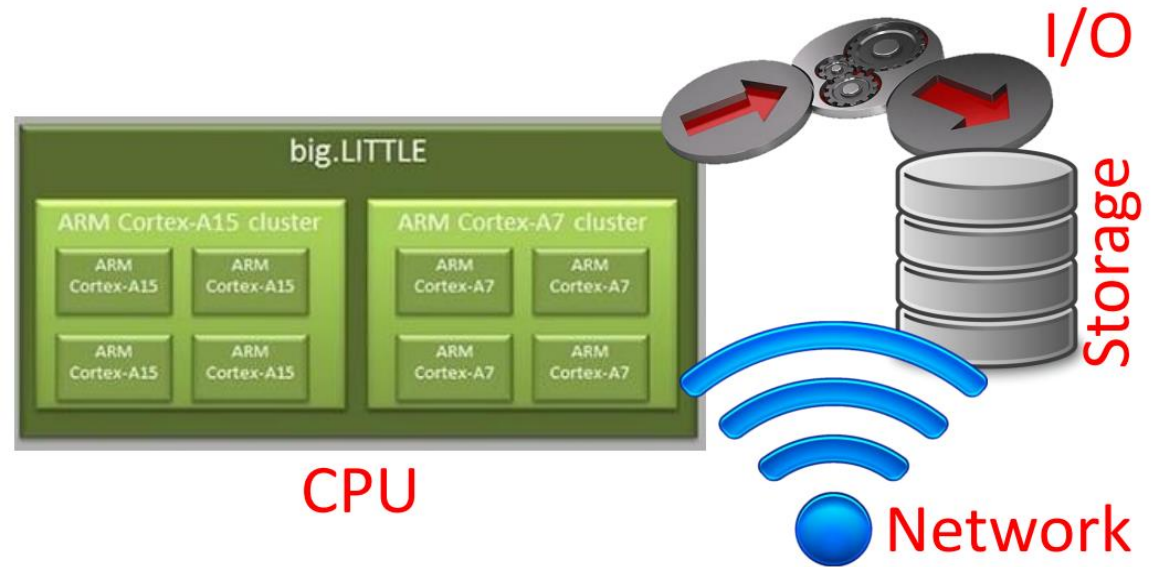
TYPE B

MARCO GRIBAUDO

GOAL OF THE PROJECT

Performance of a Big-Little architecture

- Determine the best assignment probability distribution of tasks:
 - Test a few alternatives of probabilities of assigning a heavy computation task to an efficiency core and of assigning low computation task to a high-performance core.
- Determine the system throughput in each scenario.



CHARACTERISTICS OF THE MODEL

- A system characterized by a Big-Little architecture is characterized by **4 high performance cores**, and **8 energy efficient cores**.
- It is used by **NB = 10** heavy computation tasks, and **NL = 32** low computation tasks.
- The scheduler will mainly schedule heavy computation tasks on the high-performance cores, while low computation tasks on the energy efficient cores. However, to better use the resources, there is also a **small** probability that tasks will be assigned the other way round
- The execution times of the tasks on the cores are collected in the following traces (all expressed in sec):

	High Performance Cores	Energy Efficient Cores
Heavy computation tasks	TraceB-HH.txt	TraceB-HE.txt
Low computation tasks	TraceB-LH.txt	TraceB-LE.txt



All these components can be considered working in processor sharing, with an **exponential** service time (different per type of job), whose **average** is described in these tables:

	I/O	Storage	Network
Heavy computation tasks	50 msec	200 msec	5 msec
Low computation tasks	150 msec	10 msec	120 msec

OTHER COMPONENTS

FITTING

By means of MATLAB and having at disposal samples of the durations of the corresponding execution times, I was able to define the characteristics of the various departments, exploiting the method of moments and fitting the traces according to several distributions, such as Uniform, Exponential, Hyper-Exponential, Hypo-Exponential and Erlang (they were enough to fit well). Then, looking at the coefficient of variation and at the curves in the graph I chose the most appropriate rate for each of the traces

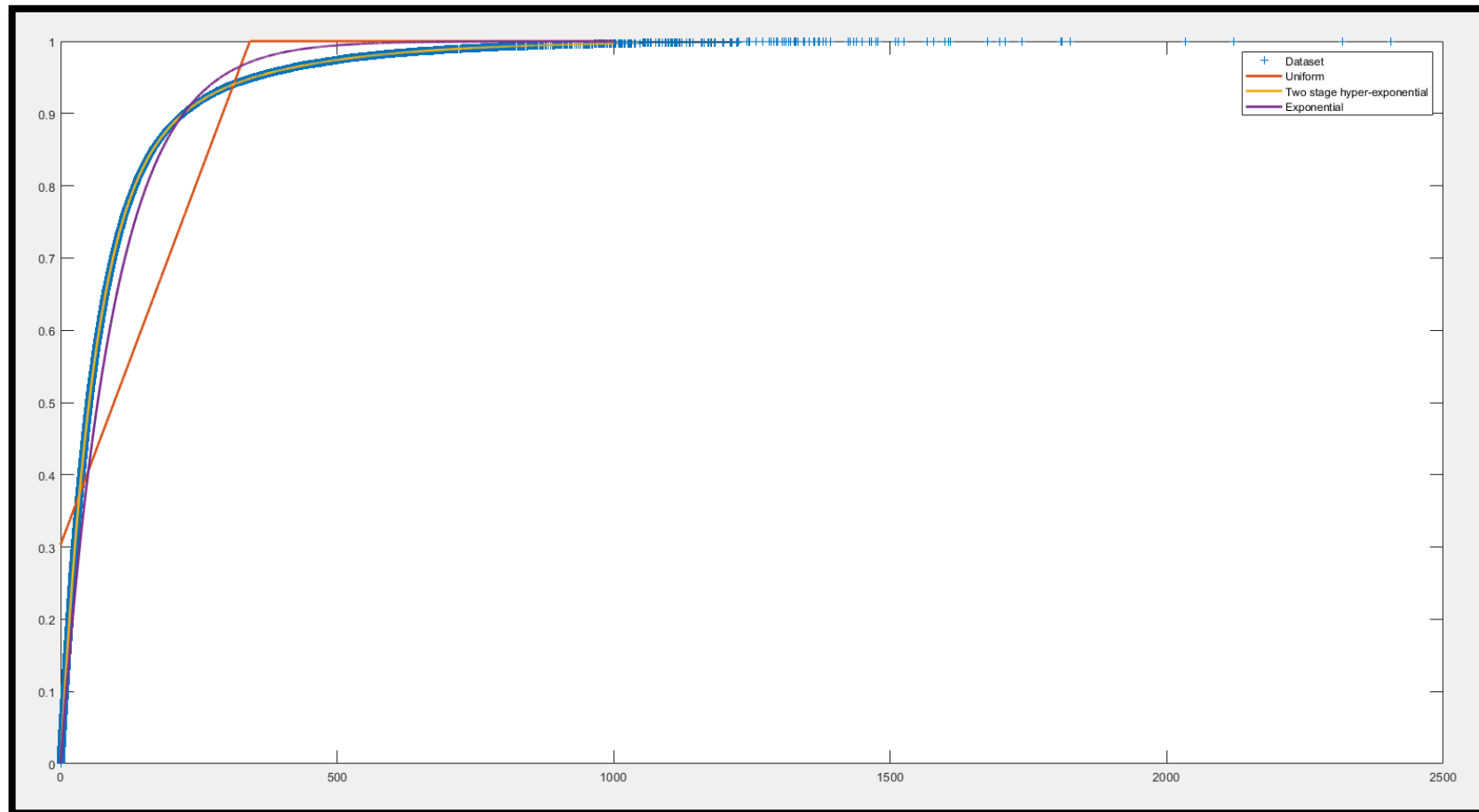
Method of moments is used to determine the best parameters producing samples with characteristics similar to the one measured in the real trace



$$\begin{aligned}\mu_1 &\equiv E[W] = g_1(\theta_1, \theta_2, \dots, \theta_k), \\ \mu_2 &\equiv E[W^2] = g_2(\theta_1, \theta_2, \dots, \theta_k), \\ &\vdots \\ \mu_k &\equiv E[W^k] = g_k(\theta_1, \theta_2, \dots, \theta_k).\end{aligned}$$



FITTING I - HE



Heavy Computations

Energy Efficient cores

Moments:

- I. Moment: 96.5605
- II. Moment: 29425.2
- III. Moment: 1.83159e+07

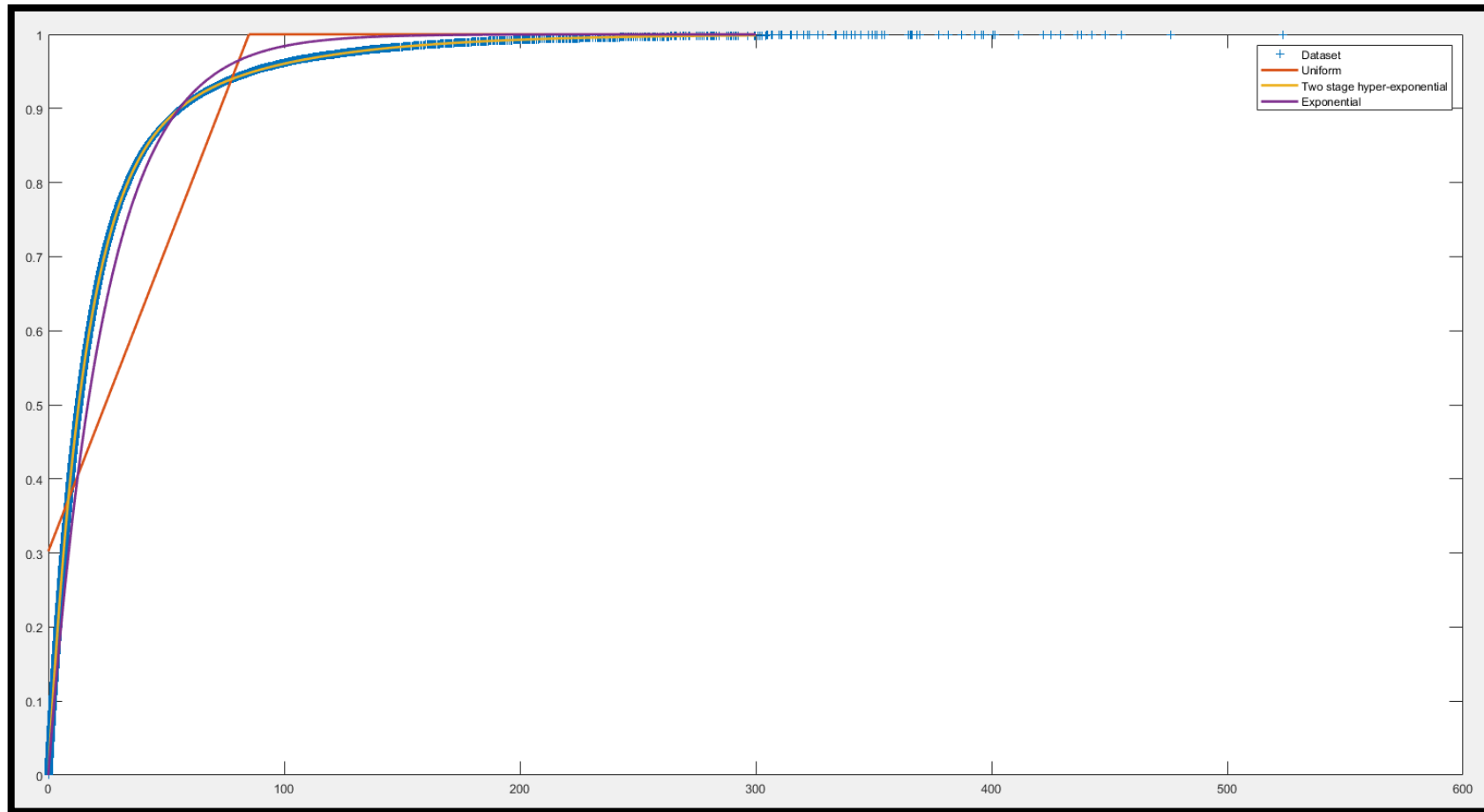
CV: 1.46829

Distribution:

2 stages hyper-exponential

- $p = 0.20066$
- $\lambda_1 = 0.00411398$
- $\lambda_2 = 0.0167277$

FITTING II - HH



Heavy Computations
High Performance cores

Moments:

- I. Moment: 24.1255
- II. Moment: 1820.78
- III. Moment: 278560

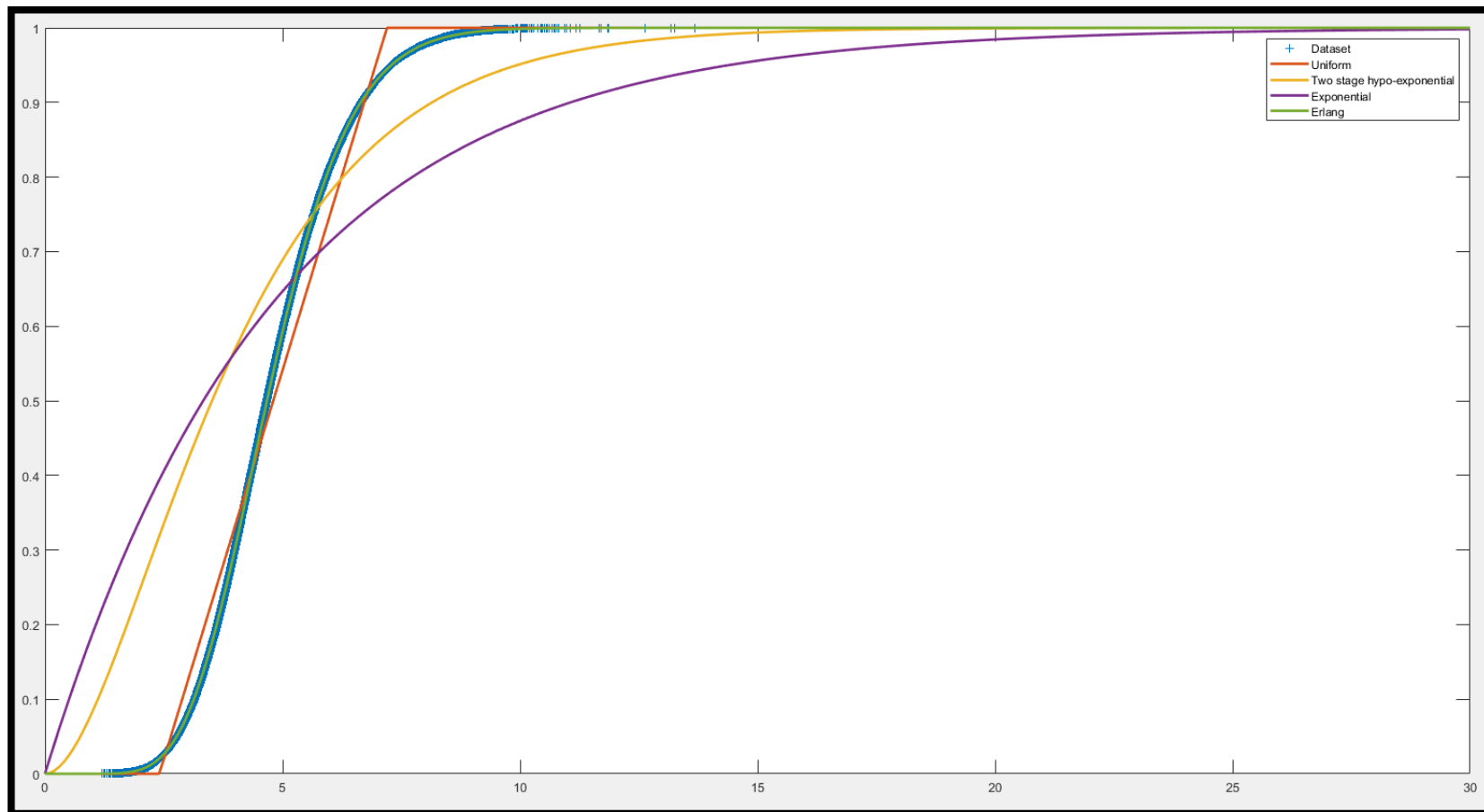
CV: 1.45886

Distribution:

2 stages hyper-exponential

- $p = 0.206686$
- $\lambda_1 = 0.0167711$
- $\lambda_2 = 0.0672208$

FITTING III - LE



Low Computations
Energy Efficient cores

Moments:

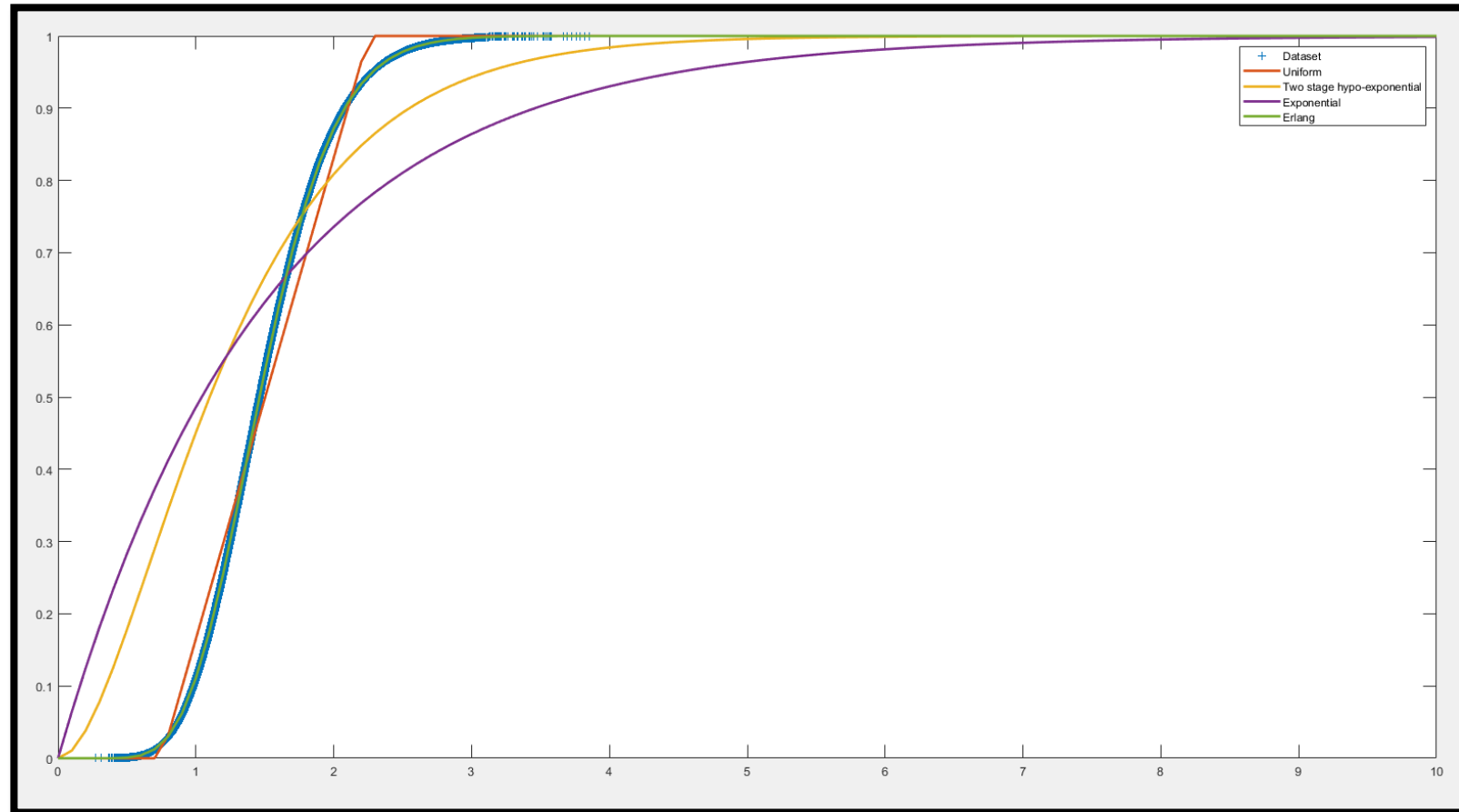
- I. Moment: 4.80413
- II. Moment: 24.9919
- III. Moment: 139.942

➤ CV: 0.28784

Distribution:

- Erlang $k = 12$
- $\lambda = 2.49785$

FITTING IV - LH



Low Computations
High Performance cores

Moments:

- I. Moment: 1.5025
- II. Moment: 2.44536
- III. Moment: 4.28698

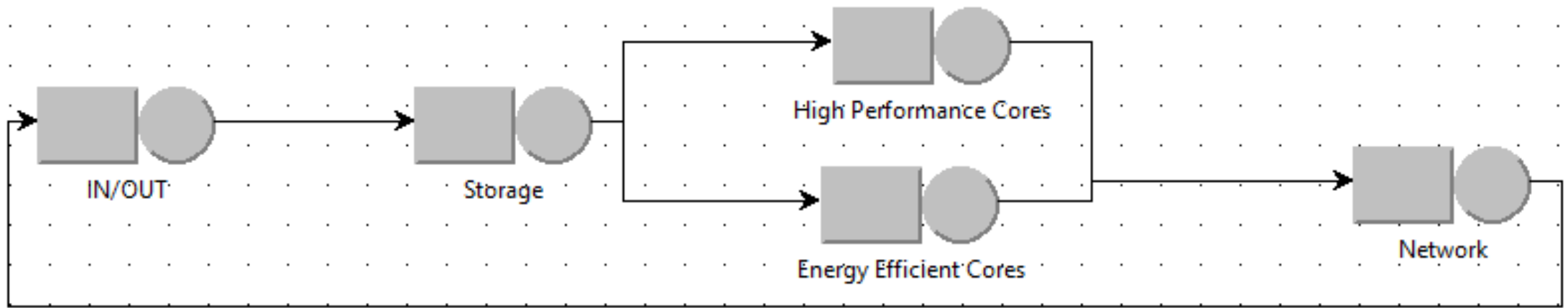
➤ CV: 0.288477

Distribution:

- ❑ Erlang $k = 12$
- ❑ $\lambda = 7.98671$

MODEL DEFINITION

- I modeled my components using [JMT's JSIMgraph](#) tool, allowing me to synthesize separable models—a system in which the order of components is irrelevant.
- All components operate under Processor Sharing with a defined Service Time. Concerning the Input/Output, Storage, and Network components, I simply expressed the parameters of the exponential distribution provided in the text. For the High Performance/Energy Efficient Cores components, I estimated the probabilistic distribution using the fitting technique, as explained in previous steps.
- As mentioned earlier, this is a closed model with precisely 10 Heavy tasks and 32 Low computation tasks, for which I created two Closed classes with their respective populations.
- The most **critical** aspect pertains to routing, where I evaluated various scenarios to optimize the system's Throughput (and also Response Time). In the next slides there are various scenarios studied.



I could have added a router but it would have been superfluous since I can do the routing with any component.

PERFORMANCE INDICES ANALYZED

PROBABILITIES : all Heavy Tasks on High Performance and Light Tasks on Energy Efficient

Throughput
Average throughput for each selected class at each selected station.

Station Name:	High Performance Cores	Class Name:	-- All --
Conf.Int/Max Rel.Err:	0.99 / 0.03	Analyzed samples:	40960
Min:	0.1439	Max:	0.1528
Average value:	0.1482	<input type="button" value="Abort Measure"/>	
<input type="button" value="Hide instantaneous values"/>			

Click on green bars to see the simulation time, the sample average (blue), and the sample values (green).

Station Name:	Energy Efficient Cores	Class Name:	-- All --
Conf.Int/Max Rel.Err:	0.99 / 0.03	Analyzed samples:	14080
Min:	1.6207	Max:	1.7104
Average value:	1.6644	<input type="button" value="Abort Measure"/>	
<input type="button" value="Hide instantaneous values"/>			

Click on green bars to see the simulation time, the sample average (blue), and the sample values (green).

Utilization
Average utilization for each selected class at each selected station. For multi-server queueing stations this is average utilization of each server. The utilization of a delay station is the average number of customers in the station (may be greater than 1).

Station Name:	High Performance Cores	Class Name:	-- All --
Conf.Int/Max Rel.Err:	0.99 / 0.03	Analyzed samples:	10000
Min:	-	Max:	-
Average value:	1.0000	<input type="button" value="Abort Measure"/>	
<input type="button" value="Hide instantaneous values"/>			

Right-click to save it.
Click on green bars to see the simulation time, the sample average (blue), and the sample values (green).

Station Name:	Energy Efficient Cores	Class Name:	-- All --
Conf.Int/Max Rel.Err:	0.99 / 0.03	Analyzed samples:	12800
Min:	0.9714	Max:	1.0286
Average value:	1.0000	<input type="button" value="Abort Measure"/>	
<input type="button" value="Hide instantaneous values"/>			

System Throughput
Average throughput of the entire system for each selected class.

Station Name:	Network	Class Name:	-- All --
Conf.Int/Max Rel.Err:	0.99 / 0.03	Analyzed samples:	56320
Min:	1.7884	Max:	1.8426
Average value:	1.8151	<input type="button" value="Abort Measure"/>	
<input type="button" value="Hide instantaneous values"/>			

System Response Time
Average response time of the entire system for each selected class.


Station Name:	Network	Class Name:	-- All --
Conf.Int/Max Rel.Err:	0.99 / 0.03	Analyzed samples:	33280
Min:	22.7007	Max:	23.4959
Average value:	23.0983	<input type="button" value="Abort Measure"/>	
<input type="button" value="Hide instantaneous values"/>			


*WORST ROUTING CONFIGURATION,
even it represents the main indications about routing*

PERFORMANCE INDICES ANALYZED


RANDOM ROUTING


Throughput
Average throughput for each selected class at each selected station.

Station Name:	High Performance Cores	Class Name:	-- All --
Conf.Int/Max Rel.Err:	0.99 / 0.03	Analyzed samples:	35840
Min:	1.2670	Max:	1.3368
 Average value:	1.3009	<input type="button" value="Abort Measure"/>	
<input type="button" value="Hide instantaneous values"/>			
Click on green bars to see the simulation time, the sample average (blue), and the sample values (green).			

Station Name:	Energy Efficient Cores	Class Name:	-- All --
Conf.Int/Max Rel.Err:	0.99 / 0.03	Analyzed samples:	10240
Min:	1.2360	Max:	1.3086
 Average value:	1.2713	<input type="button" value="Abort Measure"/>	
<input type="button" value="Hide instantaneous values"/>			
Click on green bars to see the simulation time, the sample average (blue), and the sample values (green).			

Utilization
Average utilization for each selected class at each selected station. For multi-server queueing stations this is the average utilization of each server. The utilization of a delay station is the average number of customers in the station (may be greater than 1).

Station Name:	High Performance Cores	Class Name:	-- All --
Conf.Int/Max Rel.Err:	0.99 / 0.03	Analyzed samples:	655360
Min:	0.5935	Max:	0.6186
 Average value:	0.6060	<input type="button" value="Abort Measure"/>	
<input type="button" value="Hide instantaneous values"/>			
Click on green bars to see the simulation time, the sample average (blue), and the sample values (green).			

Station Name:	Energy Efficient Cores	Class Name:	-- All --
Conf.Int/Max Rel.Err:	0.99 / 0.03	Analyzed samples:	23040
Min:	0.9875	Max:	1.0125
 Average value:	1.0000	<input type="button" value="Abort Measure"/>	
<input type="button" value="Hide instantaneous values"/>			

System Throughput
Average throughput of the entire system for each selected class.

Station Name:	Network	Class Name:	-- All --
Conf.Int/Max Rel.Err:	0.99 / 0.03	Analyzed samples:	46080
Min:	2.5055	Max:	2.6295
Average value:	2.5660	<input type="button" value="Abort Measure"/>	
<input type="button" value="Hide instantaneous values"/>			

System Response Time
Average response time of the entire system for each selected class.


Station Name:	Network	Class Name:	-- All --
Conf.Int/Max Rel.Err:	0.99 / 0.03	Analyzed samples:	143360
Min:	15.8898	Max:	16.7648
Average value:	16.3273	<input type="button" value="Hide"/>	


Much better performance but still not optimized (for example Utilization)

PERFORMANCE INDICES ANALYZED


LEAST UTILIZATION


Throughput
Average throughput for each selected class at each selected station.

Station Name:	High Performance Cores	Class Name:	-- All --
Conf.Int/Max Rel.Err:	0.99 / 0.03	Analyzed samples:	143360
Min:	1.9291	Max:	2.0373
 Average value:	1.9817	<input type="button" value="Abort Measure"/>	
<input type="button" value="Hide instantaneous values"/>			
Click on green bars to see the simulation time, the sample average (blue), and the sample values (green).			

Station Name:	Energy Efficient Cores	Class Name:	-- All --
Conf.Int/Max Rel.Err:	0.99 / 0.03	Analyzed samples:	35840
Min:	1.2462	Max:	1.2901
 Average value:	1.2678	<input type="button" value="Abort Measure"/>	
<input type="button" value="Hide instantaneous values"/>			
Click on green bars to see the simulation time, the sample average (blue), and the sample values (green).			

Utilization
Average utilization for each selected class at each selected station. For multi-server queueing stations this is the average utilization of each server. The utilization of a delay station is the average number of customers in the station (may be greater than 1).

Station Name:	High Performance Cores	Class Name:	-- All --
Conf.Int/Max Rel.Err:	0.99 / 0.03	Analyzed samples:	40960
Min:	0.9406	Max:	0.9700
 Average value:	0.9553	<input type="button" value="Abort Measure"/>	
<input type="button" value="Hide instantaneous values"/>			
Right-click to save it. Click on green bars to see the simulation time, the sample average (blue), and the sample values (green).			

Station Name:	Energy Efficient Cores	Class Name:	-- All --
Conf.Int/Max Rel.Err:	0.99 / 0.03	Analyzed samples:	24320
Min:	0.9875	Max:	1.0125
 Average value:	1.0000	<input type="button" value="Abort Measure"/>	
<input type="button" value="Hide instantaneous values"/>			

System Throughput
Average throughput of the entire system for each selected class.

Station Name:	Network	Class Name:	-- All --
Conf.Int/Max Rel.Err:	0.99 / 0.03	Analyzed samples:	56320
Min:	3.2033	Max:	3.3753
Average value:	3.2871	<input type="button" value="Abort Measure"/>	

System Response Time
Average response time of the entire system for each selected class.


Station Name:	Network	Class Name:	-- All --
Conf.Int/Max Rel.Err:	0.99 / 0.03	Analyzed samples:	368640
Min:	12.6630	Max:	13.1715
Average value:	12.9173	<input type="button" value="Abort Measure"/>	
<input type="button" value="Hide instantaneous values"/>			


It does not comply with the routing directives but is definitely more performing

PERFORMANCE INDICES ANALYZED


JOIN THE SHORTEST QUEUE


Throughput
Average throughput for each selected class at each selected station.

Station Name:	High Performance Cores	Class Name:	-- All --
Conf.Int/Max Rel.Err:	0.99 / 0.03	Analyzed samples:	143360
Min:	2.0295	Max:	2.1188
 Average value:	2.0732	<input type="button" value="Abort Measure"/>	
<input type="button" value="Hide instantaneous values"/>			
Click on green bars to see the simulation time, the sample average (blue), and the sample values (green).			

Station Name:	Energy Efficient Cores	Class Name:	-- All --
Conf.Int/Max Rel.Err:	0.99 / 0.03	Analyzed samples:	102400
Min:	1.2221	Max:	1.2893
 Average value:	1.2548	<input type="button" value="Abort Measure"/>	
<input type="button" value="Hide instantaneous values"/>			
Click on green bars to see the simulation time, the sample average (blue), and the sample values (green).			

Utilization
Average utilization for each selected class at each selected station. For multi-server queueing stations this is the average utilization of each server. The utilization of a delay station is the average number of customers in the station (may be greater than 1).


Station Name:	High Performance Cores	Class Name:	-- All --
Conf.Int/Max Rel.Err:	0.99 / 0.03	Analyzed samples:	10000
Min:	-	Max:	-
 Average value:	1.0000	<input type="button" value="Abort Measure"/>	
<input type="button" value="Hide instantaneous values"/>			
Click on green bars to see the simulation time, the sample average (blue), and the sample values (green).			

Station Name:	Energy Efficient Cores	Class Name:	-- All --
Conf.Int/Max Rel.Err:	0.99 / 0.03	Analyzed samples:	21760
Min:	0.9875	Max:	1.0125
 Average value:	1.0000	<input type="button" value="Abort Measure"/>	
<input type="button" value="Hide instantaneous values"/>			
Click on green bars to see the simulation time, the sample average (blue), and the sample values (green).			

System Throughput
Average throughput of the entire system for each selected class.

Station Name:	Network	Class Name:	-- All --
Conf.Int/Max Rel.Err:	0.99 / 0.03	Analyzed samples:	25600
Min:	3.2048	Max:	3.3935
Average value:	3.2965	<input type="button" value="Abort Measure"/>	
<input type="button" value="Hide instantaneous values"/>			

System Response Time
Average response time of the entire system for each selected class.

Station Name:	Network	Class Name:	-- All --
Conf.Int/Max Rel.Err:	0.99 / 0.03	Analyzed samples:	112640
Min:	12.3325	Max:	12.8669
Average value:	12.5997	<input type="button" value="Abort Measure"/>	
	<input type="button" value="Hide instantaneous values"/>		

BEST ROUTING CONFIGURATION!

Same annotations as last one but a slight improvement of performance

CONCLUSIONS

I have studied and analyzed four scenarios, all with a confidence interval of 99% and a maximum relative error of 3%. I have explored four different routing methods:

1. Core Type-Based Routing:

- ❑ All heavy tasks are executed on high-performance cores, while light tasks are handled by energy-efficient cores (Configuration Requested but not well performing)
- ❑ Despite achieving similar UTILIZATION, this approach doesn't optimize Throughput.

2. Random Routing:

- ❑ This method performs significantly better than the first approach but still has space for optimization.

3. "Least Utilization" Approach:

- ❑ Jobs are routed to the station with the smallest utilization.
- ❑ This configuration has proven to be one of the most efficient.

4. "Join the Shortest Queue" Approach:

- ❑ This configuration has demonstrated to ensure the highest system Throughput and a better average response time.

In summary, after analyzing the four scenarios, the "Join the Shortest Queue" approach has emerged as the most promising, ensuring maximum system Throughput and optimal average response time, even it doesn't comply with the routing directives



THANKS

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