Project-1 Task-3 results :

Snapshot of Mean batch and percentile batch (combined) for RT and non-RT messages for varying $MIAT_{nonRT}$:

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PS C:\Users\nayan> & C:/Users/nayan/AppData/Local/Programs/Python/Python311/python.exe "c:/Users/nayan/Documents/IoT Analytics/Projects/Task_3.py"
Enter the mean inter arrival time of RT messages, M_I_AT_RT: 7
Enter the mean service time of RT messages, M_ST_RT: 2
Enter the mean service time of non RT messages, M_ST_nonRT: 4
Enter the number of batches, m: 51
Enter the batch size, b: 1000
RT Message Statistics - Mean Batches:
  MIAT_nonRT      mean  95th percentile                    confidence interval  error margin
0         10  2.794444         3.054240   (2.7484238930378897, 2.840463486310073)      0.092040
1         15  2.803032         3.067883    (2.761550070339552, 2.844514352142269)      0.082964
2         20  2.824496         3.059567   (2.782860876209237, 2.8661317153383203)      0.083271
3         25  2.774874         3.085661    (2.726594151705397, 2.823154222706651)      0.096560
4         30  2.805943         3.105711   (2.7567758342560955, 2.855109699055716)      0.098334
5         35  2.829725         3.124434   (2.778742776723565, 2.8807068412613406)      0.101964
6         40  2.790533         3.020273  (2.7484744503463476, 2.8325909220678644)      0.084116
NonRT Message Statistics - Mean Batches:
  MIAT_nonRT      mean  95th percentile                   confidence interval  error margin
0         10  8.981967        11.466509   (8.593126139421743, 9.370807562104728)      0.777681
1         15  5.762629         6.485036   (5.635731806234366, 5.889526829364367)      0.253795
2         20  4.991998         5.525558  (4.897637629617544, 5.0863574707482035)      0.188720
3         25  4.542378         4.945240   (4.469171261221557, 4.615585727422254)      0.146414
4         30  4.288512         4.660623   (4.225164210598332, 4.351860343316631)      0.126696
5         35  4.165849         4.433279   (4.109596962009667, 4.222101692725897)      0.112505
6         40  3.993460         4.374780   (3.931406797182794, 4.055514162047645)      0.124107
Percentile Batch Statistics - RT Messages:
  MIAT_nonRT      mean  95th percentile                    confidence interval  error margin
0         10  8.289873         9.280417   (8.110059161825987, 8.46968591776045)      0.359627
1         15  8.484553         9.495704   (8.30304436027148, 8.666061882456473)      0.363018
2         20  8.567006         9.495075  (8.407336854631465, 8.726674276316347)      0.319337
3         25  8.327198         9.406714    (8.13230026160656, 8.52209492553428)      0.389795
4         30  8.449402         9.597785  (8.254159579759902, 8.644644206293714)      0.390485
5         35  8.534196         9.738015   (8.327899382761036, 8.74049207528061)      0.412593
6         40  8.370216         9.264797   (8.203263435748237, 8.53716839565677)      0.333905
Percentile Batch Statistics - NonRT Messages:
  MIAT_nonRT       mean  95th percentile                      confidence interval  error margin
0         10  35.486207        46.418739   (33.62441851150524, 37.347995037849984)      3.723577
1         15  20.527382        23.947005    (19.93039376601074, 21.12436989429253)      1.193976
2         20  17.713009        20.586922   (17.206395773976954, 18.219621742234036)      1.013226
3         25  15.491553        17.635171   (15.122634902088025, 15.860471190923446)      0.737836
4         30  14.438600        16.106503   (14.092039204271135, 14.785160723422539)      0.693122
5         35  14.042902        15.254067   (13.772915641171485, 14.312888866455141)      0.539973
6         40  13.138000        14.969767    (12.85429603889373, 13.421703843964567)      0.567408
PS C:\Users\nayan>
```

Task 3.1:

Snapshot of Statistics (Mean, 95th Percentile, confidence intervals) for Mean batch for RT and non-RT messages for varying $MIAT_{nonRT}$:

```
RT Message Statistics - Mean Batches:
  MIAT_nonRT      mean  95th percentile                    confidence interval  error margin
0         10  2.794444         3.054240   (2.7484238930378897, 2.840463486310073)      0.092040
1         15  2.803032         3.067883    (2.761550070339552, 2.844514352142269)      0.082964
2         20  2.824496         3.059567   (2.782860876209237, 2.8661317153383203)      0.083271
3         25  2.774874         3.085661    (2.726594151705397, 2.823154222706651)      0.096560
4         30  2.805943         3.105711   (2.7567758342560955, 2.855109699055716)      0.098334
5         35  2.829725         3.124434   (2.778742776723565, 2.8807068412613406)      0.101964
6         40  2.790533         3.020273  (2.7484744503463476, 2.8325909220678644)      0.084116
NonRT Message Statistics - Mean Batches:
  MIAT_nonRT      mean  95th percentile                   confidence interval  error margin
0         10  8.981967        11.466509   (8.593126139421743, 9.370807562104728)      0.777681
1         15  5.762629         6.485036   (5.635731806234366, 5.889526829364367)      0.253795
2         20  4.991998         5.525558  (4.897637629617544, 5.0863574707482035)      0.188720
3         25  4.542378         4.945240   (4.469171261221557, 4.615585727422254)      0.146414
4         30  4.288512         4.660623   (4.225164210598332, 4.351860343316631)      0.126696
5         35  4.165849         4.433279   (4.109596962009667, 4.222101692725897)      0.112505
6         40  3.993460         4.374780   (3.931406797182794, 4.055514162047645)      0.124107
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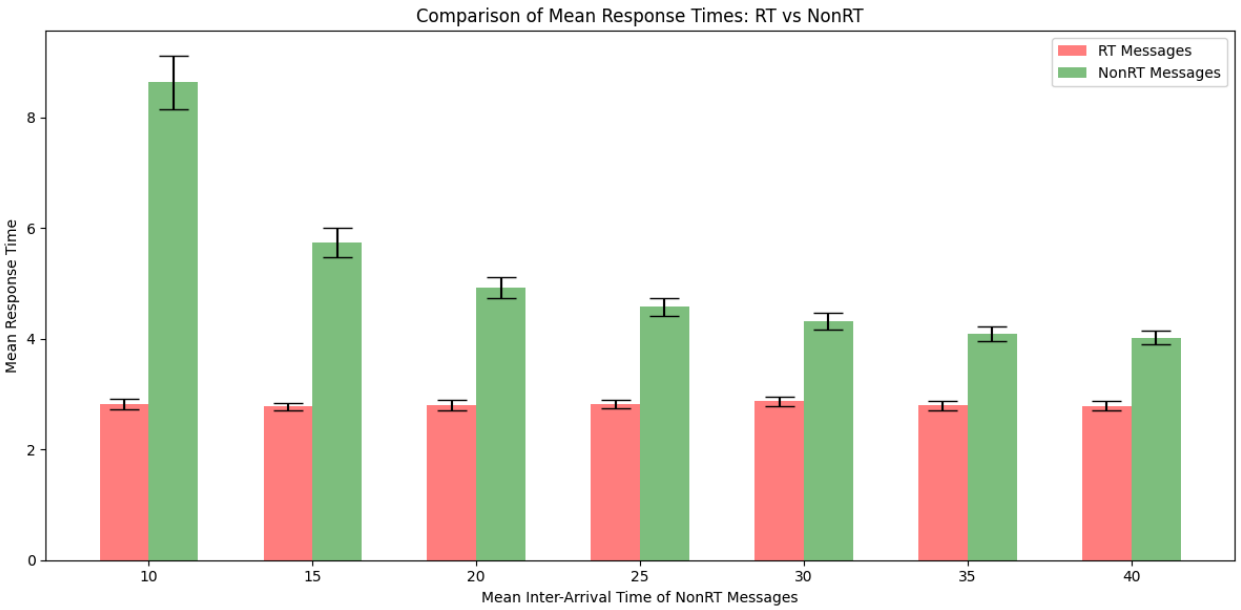
Graph of Mean batch for RT and non-RT messages for varying $MIAT_{nonRT}$:



Based on the simulation results of Task 3.1, below are the observations about the response times of Real-Time (RT) and Non Real-Time (non-RT) messages in relation to the mean inter-arrival time (MIAT) for NonRT messages:

Firstly, the prioritization of RT messages is evident. Despite varying MIAT for NonRT messages, RT messages consistently exhibit lower response times due to their higher priority. This consistency underscores the effectiveness of the prioritization mechanism in ensuring prompt service for RT messages.

Secondly, a significant disparity in response times is observed for NonRT messages when compared to RT messages. This disparity arises from the interruptions caused by incoming RT messages, which result in NonRT messages being relegated to the queue. This highlights the impact of prioritization on NonRT message processing.

Furthermore, an increase in MIAT for NonRT messages leads to a decrease in their average response time. This trend can be attributed to the reduced frequency of NonRT message arrivals, which in turn minimizes queue disruptions and enhances processing efficiency.

Additionally, the confidence intervals for NonRT messages narrow as MIATnonRT increases. This indicates a shift towards a more predictable response time distribution, with a lesser 'fat-tailed' characteristic. It suggests that the system becomes more stable and reliable with increased MIAT for NonRT messages.

A critical observation is the identification of a stabilization point around a MIATnonRT of 30. Beyond this point, further increases in MIATnonRT do not substantially improve response times, indicating an optimal balance between MIATnonRT and processing efficiency.

Also, at higher MIATnonRT values, particularly around 30 and above, the average response times for NonRT messages tend to align more closely with their mean service times. This convergence indicates a reduced impact of RT message interruptions at higher MIATnonRT values.

In conclusion, the simulation effectively demonstrates the impact of message prioritization on queue management. RT messages maintain consistently low response times due to prioritization. For NonRT messages, the interplay between MIATnonRT and server responsiveness is crucial, with an optimal stabilization point identified for efficient processing.

Task 3.2:

Snapshot of Statistics (Mean, 95th Percentile, confidence intervals) for Percentile batch for RT and non-RT messages for varying $MIAT_{nonRT}$:

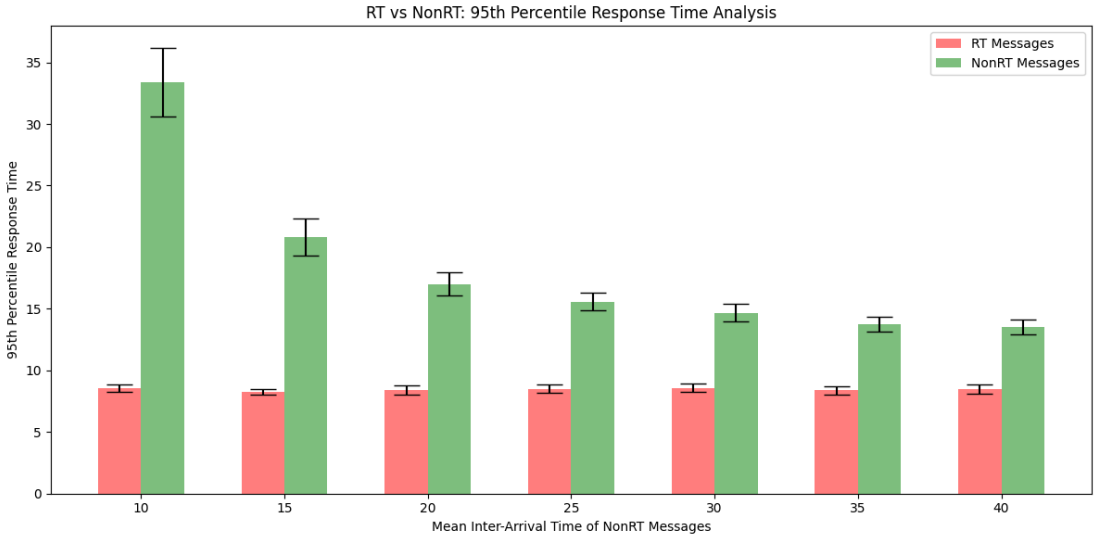
Percentile Batch Statistics - RT Messages:

	MIAT_nonRT	mean	95th percentile	confidence interval	error margin
0	10	8.289873	9.280417	(8.110059161825987, 8.46968591776045)	0.359627
1	15	8.484553	9.495704	(8.30304436027148, 8.666061882456473)	0.363018
2	20	8.567006	9.495075	(8.407336854631465, 8.726674276316347)	0.319337
3	25	8.327198	9.406714	(8.13230026160656, 8.52209492553428)	0.389795
4	30	8.449402	9.597785	(8.254159579759902, 8.644644206293714)	0.390485
5	35	8.534196	9.738015	(8.327899382761036, 8.74049207528061)	0.412593
6	40	8.370216	9.264797	(8.203263435748237, 8.53716839565677)	0.333905

Percentile Batch Statistics - NonRT Messages:

	MIAT_nonRT	mean	95th percentile	confidence interval	error margin
0	10	35.486207	46.418739	(33.62441851150524, 37.347995037849984)	3.723577
1	15	20.527382	23.947005	(19.93039376601074, 21.12436989429253)	1.193976
2	20	17.713009	20.586922	(17.206395773976954, 18.219621742234036)	1.013226
3	25	15.491553	17.635171	(15.122634902088025, 15.860471190923446)	0.737836
4	30	14.438600	16.106503	(14.092039204271135, 14.785160723422539)	0.693122
5	35	14.042902	15.254067	(13.772915641171485, 14.312888666455141)	0.539973
6	40	13.138000	14.969767	(12.85429603889373, 13.421703843964567)	0.567408

Graph of Percentile batch for RT and non-RT messages for varying $MIAT_{nonRT}$:



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Analyzing the percentile batch data from the simulation of Task 3.1, below are the noteworthy insights regarding the mean response times of Real-Time (RT) and Non Real-Time (NonRT) messages as a function of the mean inter-arrival time (MIAT) for NonRT messages.

Firstly, the results exhibit a similarity in response times between RT and NonRT messages. Notably, the response time for RT messages remains relatively consistent across different MIATnonRT values. This consistency indicates the efficiency of the prioritization mechanism in managing RT messages. However, it's important to note that the average response time is influenced by the 95th percentile values, which inherently consider potential delays due to queued RT messages.

Secondly, the prioritization of RT messages contributes to their prompt processing, ensuring a stable response time. However, this prioritization also leads to a higher average response time than the mean service time for these messages, particularly when considering the 95th percentile values. This underscores the impact of high-priority message processing on overall system performance.

Thirdly, for NonRT messages, an increase in MIATnonRT correlates with a decrease in their mean response time. This trend suggests that fewer NonRT messages in the queue lead to more efficient processing. However, despite the decrease in response time, the mean response time for NonRT messages remains higher than their mean service time, a result of considering the 95th percentile values from each batch.

Moreover, the response time for NonRT messages begins to stabilize around a MIATnonRT of 30. This stabilization, accompanied by a decreasing confidence interval, indicates that the mean response time approaches the 95th percentile. Consequently, the distribution of response times becomes 'slimmer,' suggesting less variability and greater predictability in the system's performance.

In conclusion, the simulation's percentile batch analysis offers valuable insights into the dynamics of message processing in a prioritized system. It highlights the implications of message priority and arrival patterns on observed response times, particularly when percentile values are considered. The stabilization of response times and the narrowing of confidence intervals at higher MIATnonRT values show the importance of system's reliability and consistency, demonstrating the intricate balance between efficiency and predictability in message processing operations.