* + 1. **Regular battery usage probabilities**

In this subsection, we examine the effects of HP packet arrival rate on different performance metrics for regular battery usage probabilities, i.e., and . The comparison is made between the scenario without a regular battery and the default values. The results are illustrated in Fig. 5-26 to Fig. 5-36.

In Fig. 5 - 26, the relationship between the expected number of all packets in the system and the HP packet arrival rate is depicted. This is analyzed for different regular battery usage probabilities . When comparing the curves of and for , , and , it becomes apparent that the curve for is relatively lower than that of for both and . This difference can be attributed to the higher probabilities of regular battery usage. With a higher probability, there is a greater chance for a packet to be served using the regular battery, thereby reducing the number of packets that need to wait in the system. In addition, it is important to note that in the case of , the curve for initially surpasses the curve for but eventually falls below it. This behavior can be attributed to the increased system load. As the load becomes heavier, the energy supply may not be sufficient to meet the energy request rate (). Consequently, with lower probabilities of using the regular battery, packets experience longer waiting times in the system, which in turn increases the likelihood of impatience. Furthermore, when considering , we observe that initially increases and then gradually decreases as increases. As the increases, LP packets experience longer wait times in the queue. This prolonged waiting makes LP packets more susceptible to impatience and priority discipline, leading to an increase in . However, as the continues to increase, the impact on LP packets reaches a point where the queue congestion becomes more severe. Consequently, gradually decreases.

In Fig. 5 - 27, the relationship between the expected number of all packets in the system and the HP packet arrival rate is depicted. This is analyzed for different regular battery usage probabilities . When comparing the curves of and for , , and , it becomes apparent that the curve for is relatively lower than that of for both and . This difference can be attributed to the higher probabilities of regular battery usage. With a higher probability, there is a greater chance for a packet to be served using the regular battery, thereby reducing the number of packets that need to wait in the queue. In addition, it is important to note that in the case of , the curve for initially surpasses the curve for but eventually falls below it. This behavior can be attributed to the increased system load. As the load becomes heavier, the energy supply may not be sufficient to meet the energy request rate (). Consequently, with lower probabilities of using the regular battery, packets experience longer waiting times in the system, which in turn increases the likelihood of impatience. Furthermore, when considering , we observe that initially increases and then gradually decreases as increases. As the increases, LP packets experience longer wait times in the queue. This prolonged waiting makes LP packets more susceptible to impatience and priority discipline, leading to an increase in . However, as the continues to increase, the impact on LP packets reaches a point where the queue congestion becomes more severe. Consequently, gradually decreases.

In Fig. 5-28, the relationship between the mean waiting time of all packets and the HP packet arrival rate is depicted. This is analyzed for different regular battery usage probabilities . When comparing the curves of and , , and it is evident that the curve with is lower than the curve for . This difference arises from the higher probabilities of regular battery usage, resulting in shorter waiting times for packets in the system. In addition, due to the non-preemptive priority of HP packets over LP packets, most LP packets remain backlogged and await service in the queue. Consequently, the curve for is consistently higher than that of for both and . Additionally, the difference between the curves of for and appears smaller compared to the disparity between the curves of . Lastly, the utilization of a regular battery as an auxiliary energy resource yields significant improvements in the performance of both HP and LP packets, as evident from the overall results.

In Fig. 5-29, the relationship between the mean waiting time of all packets in the packet queue , , and and the HP packet arrival rate is depicted. This is analyzed for different regular battery usage probabilities . When comparing the curves of and , , and it is evident that the curve with is lower than the curve for . This difference arises from the higher probabilities of regular battery usage, resulting in shorter waiting times for packets in the queue. In addition, due to the non-preemptive priority of HP packets over LP packets, most LP packets remain backlogged and await service in the queue. Consequently, the curve for is consistently higher than that of for both and . Additionally, the difference between the curves of for and appears smaller compared to the disparity between the curves of . Lastly, the utilization of a regular battery as an auxiliary energy resource yields significant improvements in the performance of both HP and LP packets, as evident from the overall results.

In Fig. 5-30, the relationship between the throughput of all packets and the HP packet arrival rate is depicted. This is analyzed for different regular battery usage probabilities . When comparing the curves of and it is evident that the curve with is always higher than the curve with . This disparity arises due to the higher probabilities of regular battery usage. With a higher probability, there is a greater likelihood that the packets in the queue can be served, resulting in a higher throughput. Furthermore, for , it can be observed that the throughput remains constant at as increases. This phenomenon occurs because, in the absence of the regular battery as an auxiliary energy resource, the effective service rate is limited by the arrival rate of harvested energy. Consequently, the throughput reaches a maximum capacity of and remains unchanged with increasing .

In Fig. 5-31, the relationship between the energy loss probability and the HP packet arrival rate is depicted. This is analyzed for different regular battery usage probabilities . When comparing the curves of and it is evident that the curves are all the same and equal to zero.

In Fig. 5-32, the relationship between the blocking probability of all arrived packets and the HP packet arrival rate is depicted. This is analyzed for different regular battery usage probabilities . When the packet queue becomes full, packets are blocked regardless of their priority. Therefore, the probabilities of blocking a packet, , , and , are the same for both and . Furthermore, when comparing the curves of for different regular battery usage probabilities, it becomes evident that the curve for is higher than the curve for . This difference arises from the lower probabilities of regular battery usage. With lower probabilities, the likelihood of serving packets waiting in the queue decreases, making it easier for the packet queue to become full and resulting in a higher probability of packet blocking.

In Fig. 5-33, the relationship between the total loss probability of all arrived packets and the HP packet arrival rate is depicted. This is analyzed for different regular battery usage probabilities . we can observe that as the HP packet arrival rate increases, the values of ,, and for are consistently higher than those for . This difference arises due to the lower probabilities of regular battery usage. With lower probabilities, the packet queue is more prone to congestion, increasing the likelihood of packet loss due to blocking or impatience. Moreover, the overall results demonstrate that utilizing the regular battery as an auxiliary energy resource leads to an improvement in the performance of both HP and LP packets.

In Fig. 5-34, the relationship between the impatient loss probability of all arrived packets and the HP batch arrival rate is depicted. This is analyzed for different regular battery usage probabilities . It can be observed that in most cases, the curves with are higher than the curves with . Additionally, as the HP packet arrival rate increases, the two sets of curves tend to converge and become closer to each other. This behavior can be attributed to the scenario of , where the energy supply is relatively insufficient. Even with an increase in , a large number of arrived packets are prone to being blocked due to the limited availability of energy resources. Consequently, the probability of packets becoming impatient in the queue decreases, leading to a smaller difference between the two sets of curves.

In Fig. 5-35, the relationship between the impatient loss probability of all admitted packets and the HP packet arrival rate is depicted. This is analyzed for different regular battery usage probabilities . It is evident that the curve with is consistently lower than the curve with for and . This discrepancy arises from the higher probabilities of regular battery usage. When the regular battery is more likely to be utilized, packets can be immediately served, reducing the likelihood of them losing patience in the queue. In addition, due to the non-preemptive priority of HP packets over LP packets, most LP packets experience backlogging and wait in the queue. Consequently, is consistently higher than for both and . Furthermore, the difference between the curves of for and appears smaller compared to the difference between the curves of . Lastly, the overall results demonstrate that employing the regular battery as an auxiliary energy resource leads to significant improvements in the performance of both HP and LP packets.

In Fig. 5-36, the relationship between regular energy consumption ratio for serving all packets and the HP packet arrival rate is depicted. This is analyzed for different regular battery usage probabilities . For , we observe that as increases, the initially increases and then decreases. The gradually increases, while the gradually decreases. The reason is when increases, the energy supply in the system becomes insufficient, leading to a higher probability of packet impatience in the queue. Consequently, the number of served packets decreases, causing the to increase initially. In addition, due to the non-preemptive priority of HP packets over LP packets, as more HP packets enter the server and complete their service, fewer resources are available for serving LP packets. This results in a gradual decrease in the . However, when , which means that the regular battery is never used, the corresponding curves remain zero throughout the observation. This is because without the regular battery as an energy source, no energy is consumed or utilized, leading to a constant value of zero.

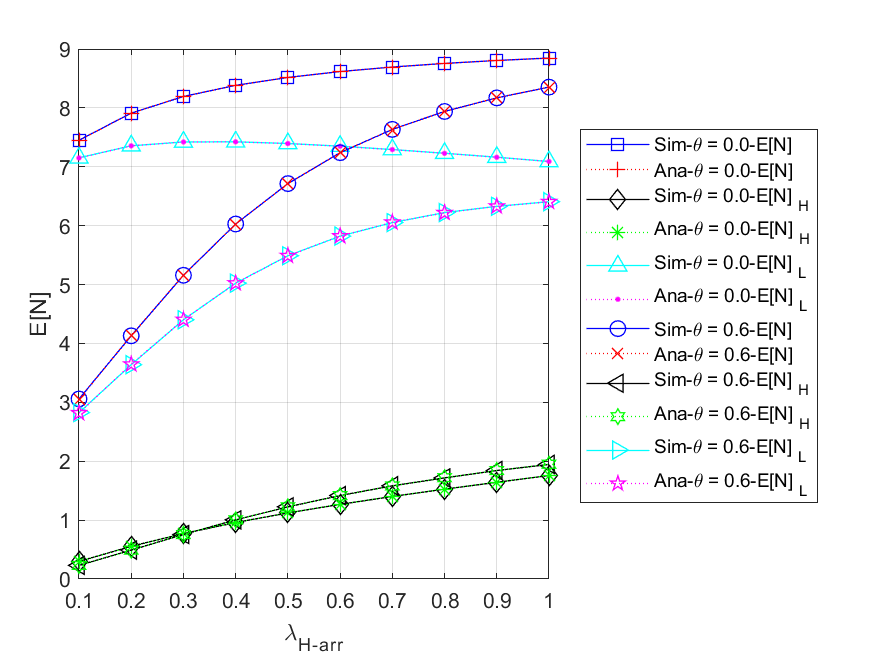


Fig. 5 - 26: The expected number of all () packets in the system vs. the HP packet arrival rate for different regular battery usage probabilities

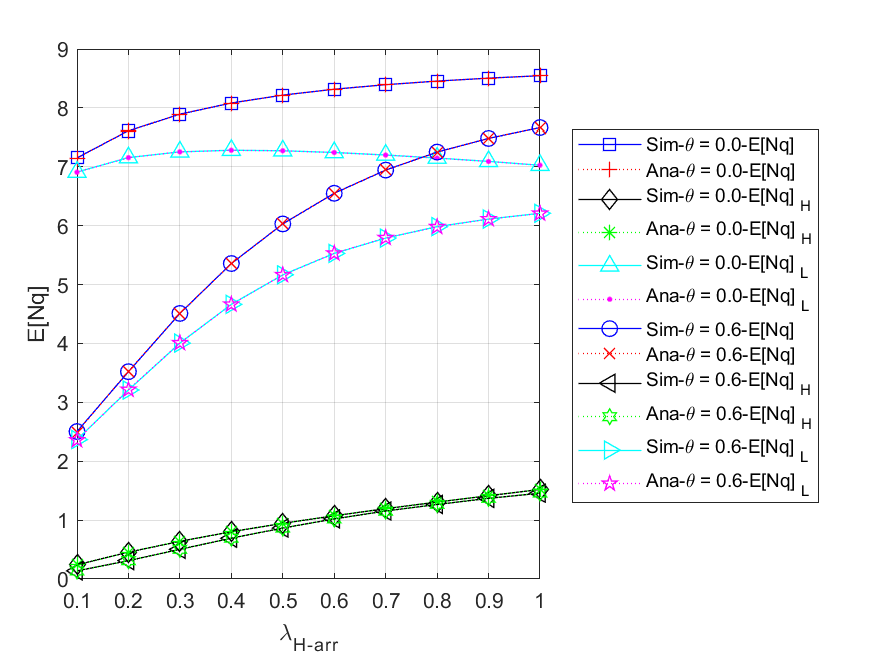


Fig. 5 - 27: The expected number of all () packets in the queue vs. the HP packet arrival rate for different regular battery usage probabilities

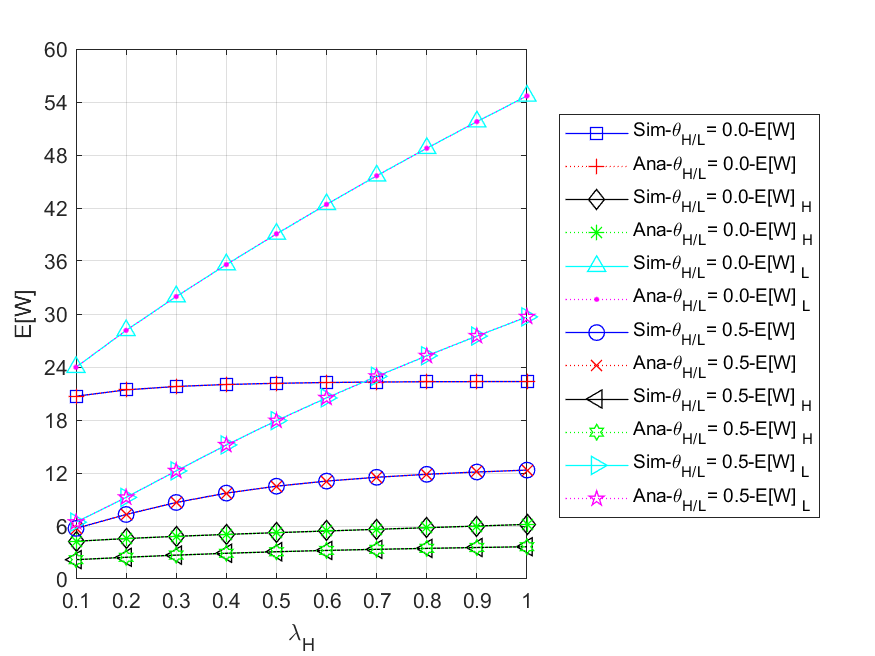
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Fig. 5 - 28: The mean waiting time of all () packets in the system vs. the HP packet arrival rate for different regular battery usage probabilities

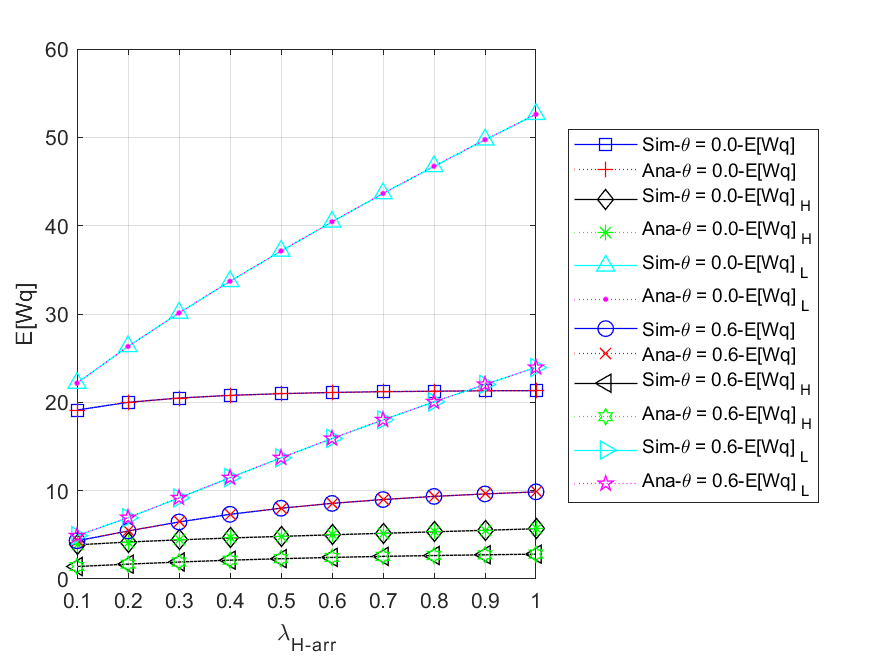


Fig. 5 - 29: The mean waiting time of all () packets in the queue vs. the HP packet arrival rate for different regular battery usage probabilities

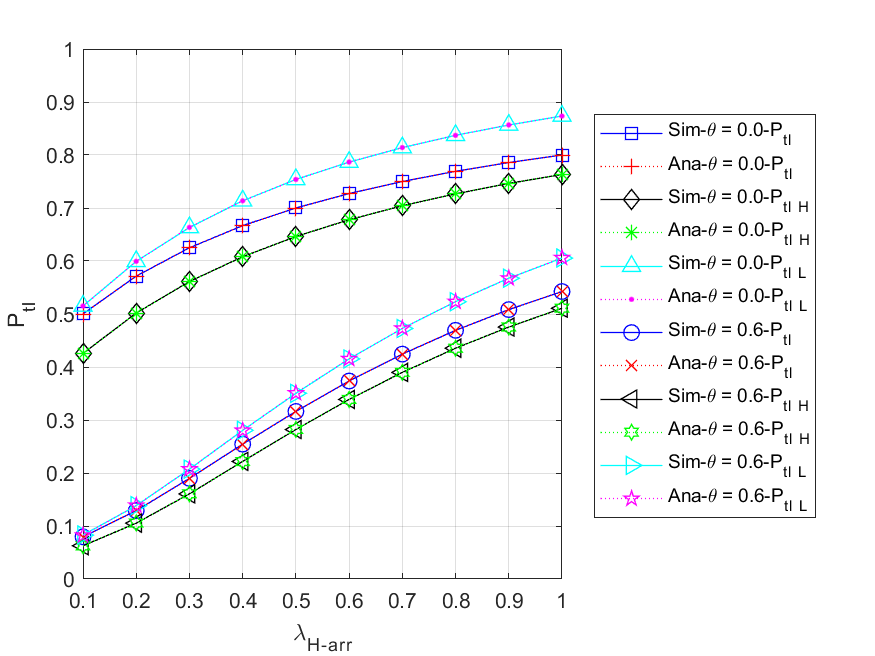


Fig. 5 - 30: The throughput of all () packets vs. the HP packet arrival rate for different regular battery usage probabilities

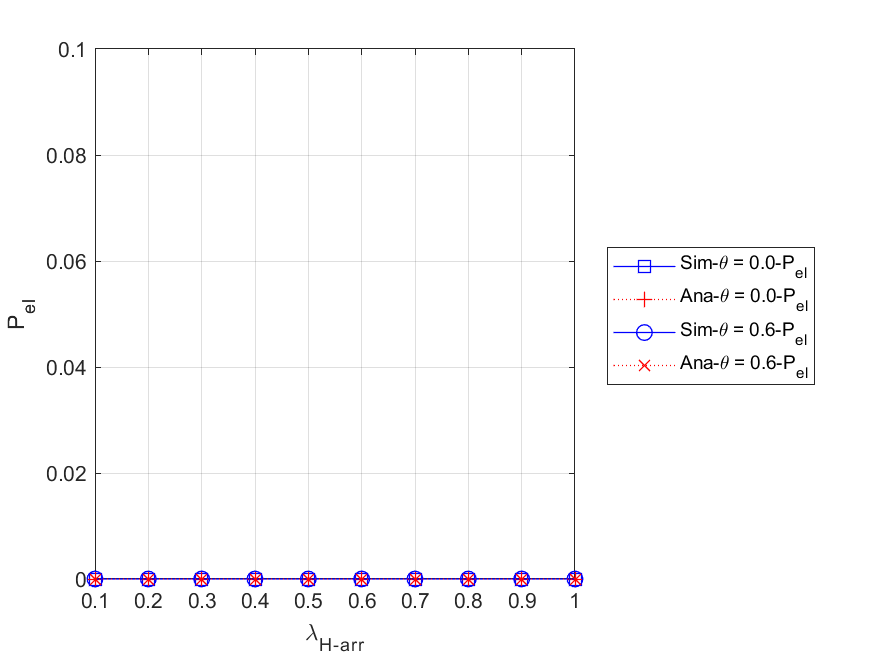


Fig. 5 - 31: The energy loss probability vs. the HP packet arrival rate for different regular battery usage probabilities

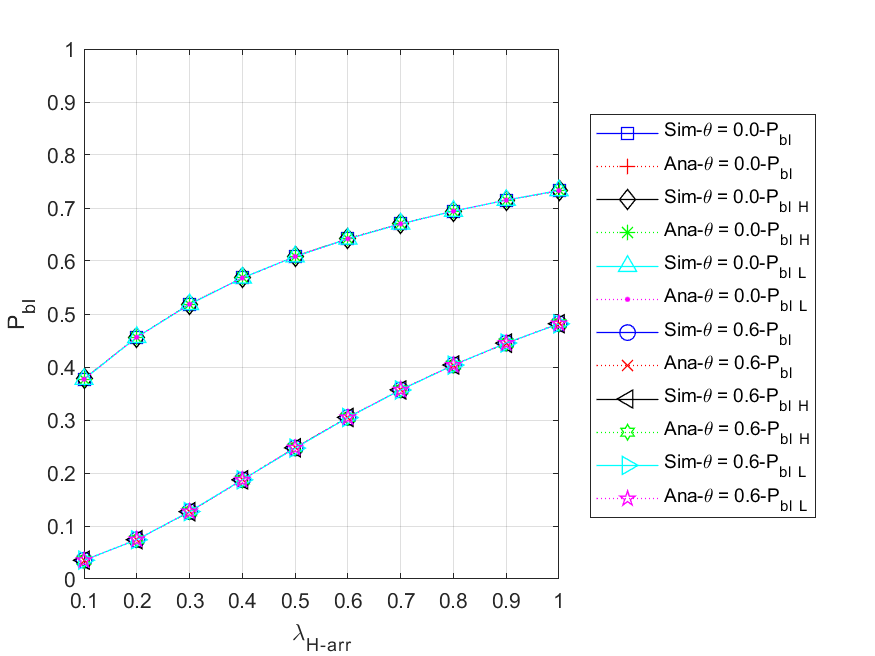


Fig. 5 - 32: The blocking probability of all () arrived packets vs. the HP packet arrival rate for different regular battery usage probabilities

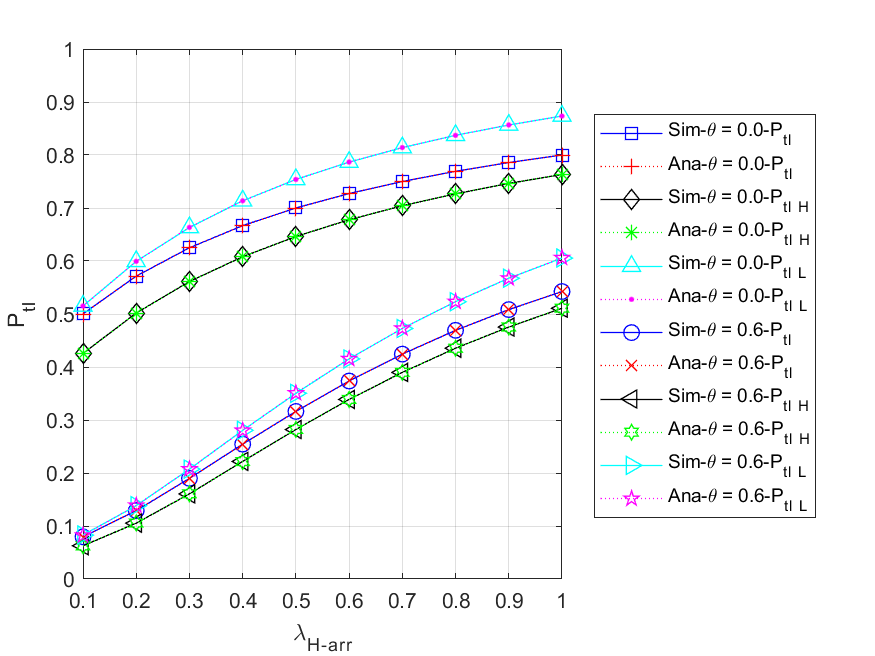


Fig. 5 - 33: The total loss probability of all () arrived packets vs. the HP packet arrival rate for different regular battery usage probabilities

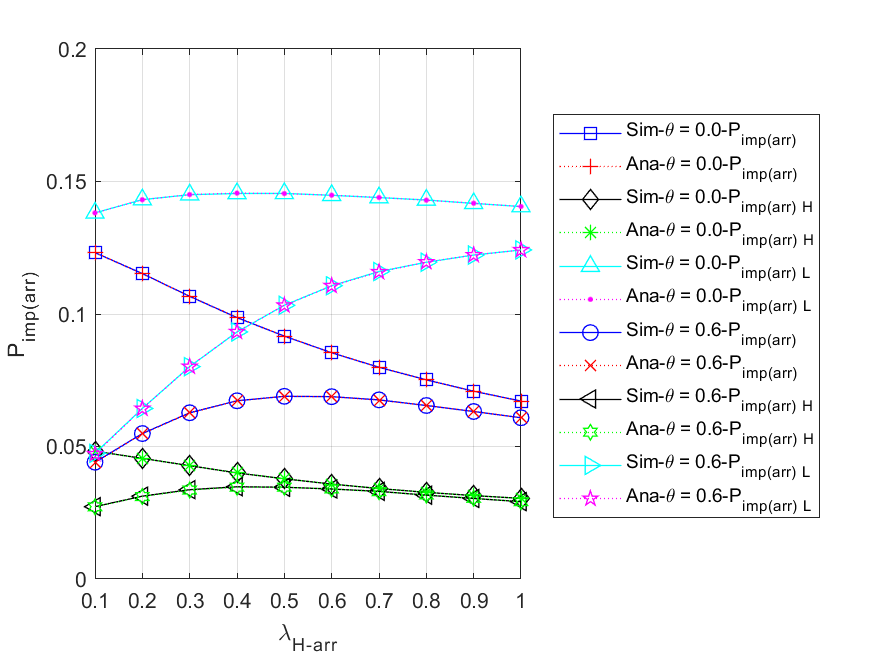


Fig. 5 - 34: The impatient loss probability of all () arrived packets vs. the HP packet arrival rate for different regular battery usage probabilities

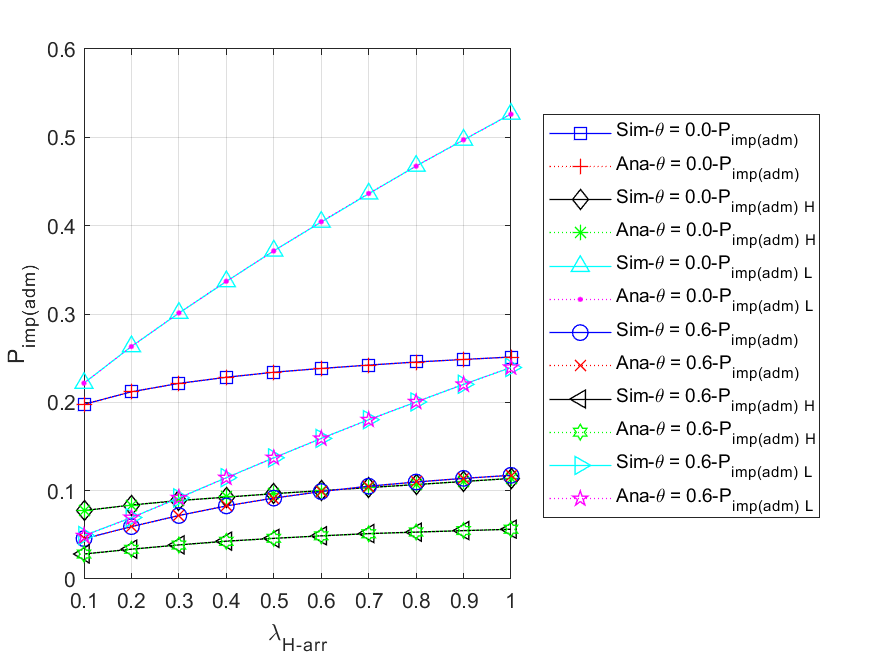


Fig. 5 - 35: The impatient loss probability of all () admitted packets vs. the HP packet arrival rate for different regular battery usage probabilities

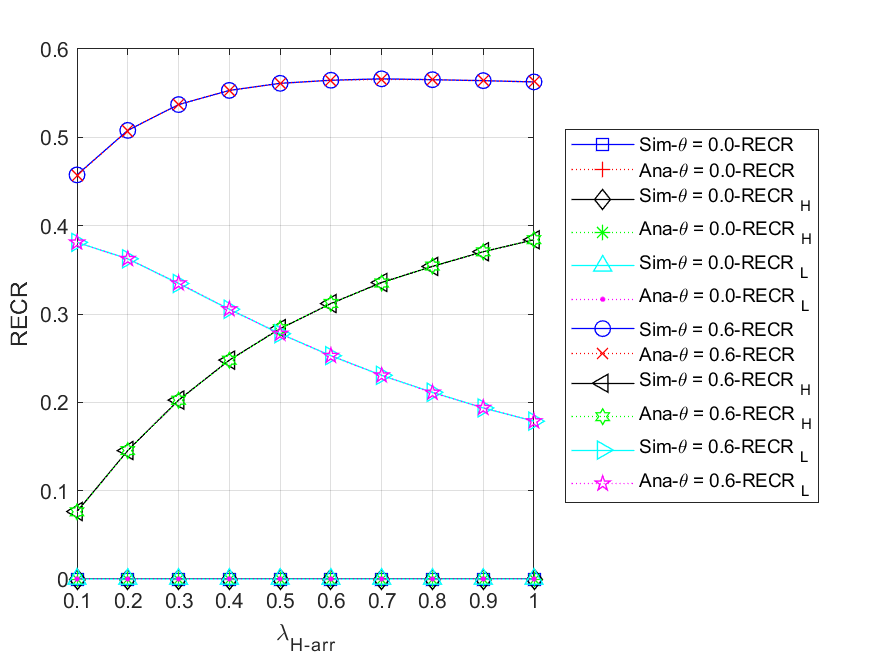


Fig. 5 - 36: The regular energy consumption ratio for serving all () packets vs. the HP packet arrival rate for different regular battery usage probabilities