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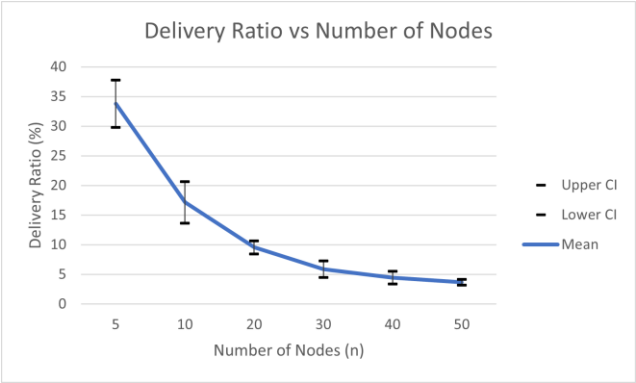
# EECE5155 Homework 1

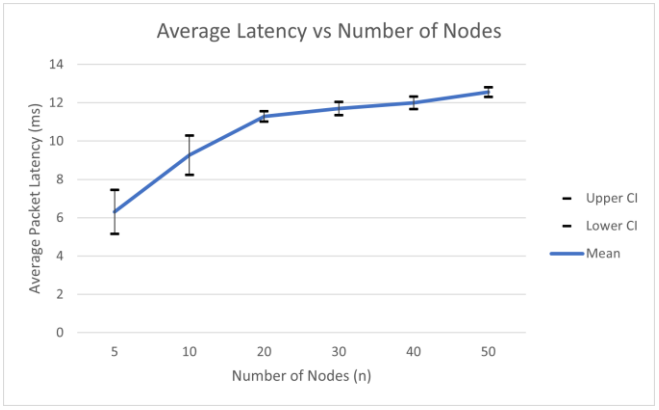
**Question 2.)**

**Average Delivery Ratio:**




The plot above shows my simulations Average Delivery Ratio when the number of nodes was increased from 5 to 50. At the smallest number of nodes simulated, the average value across the 10 individual simulations I ran was about a 34% delivery ratio with each node attempting to transmit 1000 packets. Using the 95% confidence interval, I calculated my margin of error to be about ±3.5 from this value of 34%. As suspected, when the number of nodes increased, the average delivery ratio plummeted as well, because of the increased traffic the sink node experienced and the increased chance of packets colliding. At 50 nodes, the average delivery ratio was about 3.67%, which matches the trends from the figure shown in the homework assignment document.

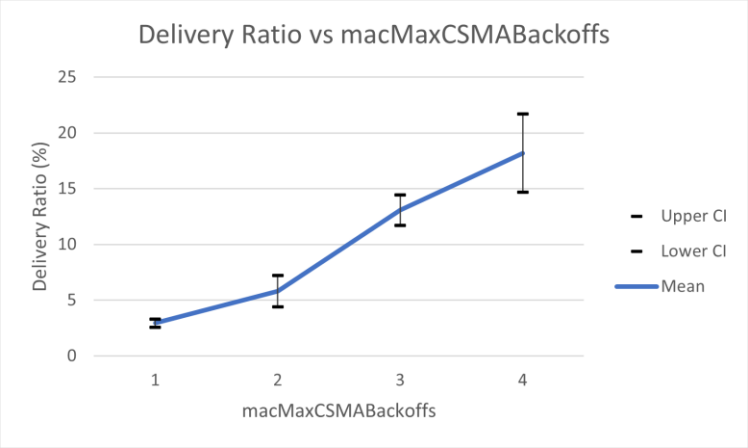
**Average Packet Latency:**




The average packet latency increased when the number of nodes also increased. The initial average value was about 6.3ms for 5 nodes and increased linearly to a value of 12.5ms when 50 nodes were accessing the channel. This trend seems correct as the latency would only increase

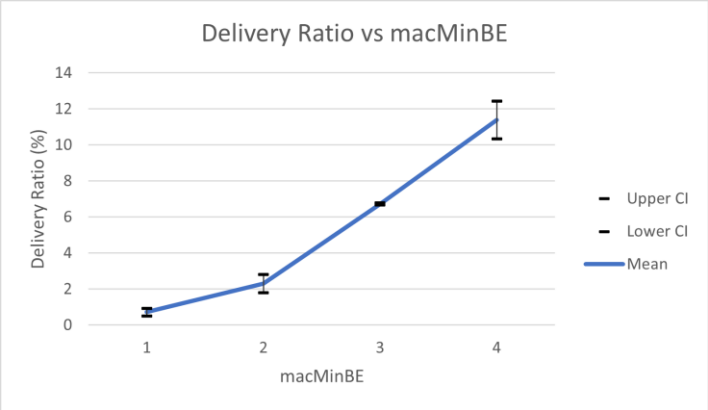
when more and more nodes would contend for the channel, which not all could, so they were forced to generate more backoffs. When the successful packets were received, the latency would be calculated from the time the packets were created till they successfully arrived at the sink node. The margin of error calculated for this plot were all within 0.26 to 1.15 for all of the runs, which seems reasonable.

**Average Delivery Ratio vs macMaxCSMABackoffs:**




The simulation results above show a linear increase in the average deliver ratio when the number of allowed CSMA backoffs was increased. At the lowest value of 1 CSMA backoff, the average delivery ratio was about 3% with about ±0.3 margin of error across the 10 simulations. Since the nodes were only allowed 1 backoff, if the channel was not free by the time their backoff timer expired, then their packet would be dropped. Since this simulation was run with 30 nodes, there was a high chance that when a majority of the nodes backoff timers expired, the channel would be busy, which explains why the delivery ratio was so low. As the number of allowed backoffs for the nodes increased, the average delivery ratio increased as well, because the nodes had more and more chances of attempting to access the channel and deliver a packet to the sink node. When the nodes were allowed 4 backoffs, the average deliver ratio was about 18.2% and my margin of error was about ±4.9 from this value, which was the largest margin of error for these simulations. However, it seems correct that the average delivery ratio would increase when the 30 nodes were allowed to take 4 backoffs before having to drop the packet they were attempting to send to the sink node.

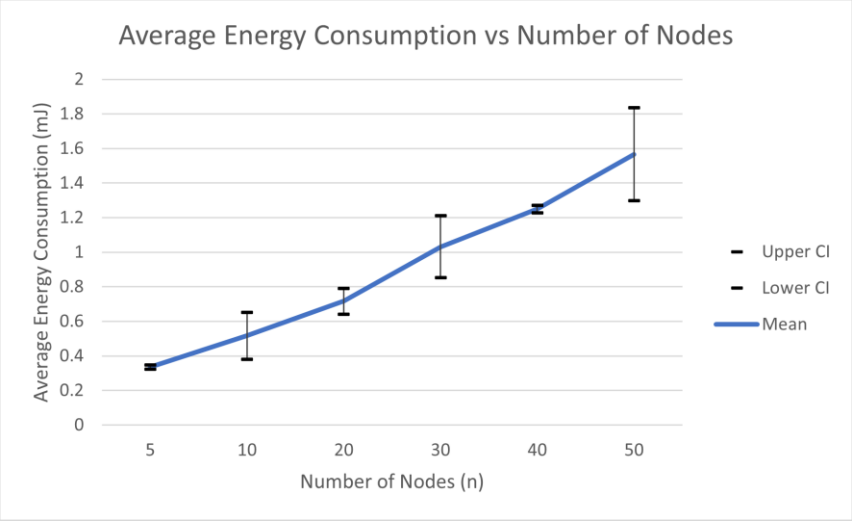
**Average Delivery Ratio vs macMinBE:**




For this simulation, we were asked again to simulate with the number of nodes being 30 and observing the average delivery ratio when the macMinBE value was varied from 1 to 4. When the value of macMinBE was 1, the average delivery ratio was about 0.72%. Since the backoff exponent was at the lowest it could be, the backoff timer set by each of the 30 nodes was set between a random int value between 0 and 1. So either the nodes waited 1 sec to or kept trying to access the channel again right away even though they were instructed to generate a backoff timer since the channel was not free. This explains why the average delivery ratio would be lower than 1% and nearly at a value of 0% delivery ratio. When the macMinBE value was increased, the nodes had a better chance at generating a longer backoff timer, so that packets would not collide or be dropped. When the macMinBE value was 4, the average delivery ratio was about 11.4% with about a ±1.7 margin of error. This result performed better than the first figure when simulating average delivery ratio vs number of nodes equal to 30, because the macMinBE value for those results was set to 3. So by increasing the random backoff time for the 30 nodes, resulted in a better average delivery ratio.

**Question 3.)**

**Average Energy Consumption:**



The plot above shows the average energy consumption when the number of nodes increased from 5 to 50 and displays a linear trend with the energy increasing as the number of nodes increases. The Power received was computed towards the total energy when performing the Clear Channel Assessment and the Power transmitted was computed towards the total energy when sending the data packets. Then at the sink node, the energy was divided out by the number of received packets. When simulating only 5 nodes, the average energy was about 0.35 mJ and increased to only about 1.56 mJ when simulating 50 nodes. I would expect the energy to be at least tenfold the amount at 5 nodes. This simulation seemed like the results were not as accurate though the energy did show an increasing trend with the increase in number of nodes.

**Tables used for calculating and plotting graphs:**

## Average Delivery Ratio

| Trial | Delivery Ratio (%) | Number of Nodes (N) | Mean | Std | CI Range | Upper CI | Lower CI | Run 0 | Run 1 | Run 2 | Run 3 | Run 4 | Run 5 | Run 6 | Run 7 | Run 8 | Run 9 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 33.766 | 5 | 33.77 | 5.609690425 | 3.476858258 | 37.24286 | 30.289142 | 27.9 | 40.98 | 29.04 | 29.12 | 36.8 | 28.78 | 36.92 | 42.34 | 28.78 | 37 |
| 2 | 17.134 | 10 | 17.13 | 4.918243137 | 3.048302664 | 20.1823 | 14.085697 | 5.18 | 20.92 | 21.16 | 16.78 | 21.45 | 19.43 | 17 | 19.18 | 17.11 | 13.13 |
| 3 | 9.5695 | 20 | 9.57 | 1.546918891 | 0.958772644 | 10.52827 | 8.6107274 | 5.36 | 9.345 | 10.09 | 9.4 | 9.53 | 10.18 | 10.45 | 10.49 | 10.37 | 10.48 |
| 4 | 5.884333 | 30 | 5.884 | 1.948829932 | 1.20787511 | 7.092208 | 4.6764579 | 0.41 | 6.34 | 6.43 | 6.54 | 6.91667 | 6.52333 | 6.79 | 6.67333 | 6.47 | 5.75 |
| 5 | 4.4505 | 40 | 4.451 | 1.50550047 | 0.933101713 | 5.383602 | 3.5173983 | 0.1675 | 4.975 | 4.9575 | 4.8875 | 4.925 | 4.87 | 4.91 | 4.8675 | 4.9875 | 4.9575 |
| 6 | 3.6782 | 50 | 3.678 | 0.660312687 | 0.409258523 | 4.087459 | 3.2689415 | 1.806 | 3.788 | 3.85 | 3.908 | 3.82 | 3.928 | 3.886 | 3.876 | 3.938 | 3.982 |

## Average Packet Latency

| Trial | Average Packet Latency (ms) | Number of Nodes (N) | Mean | Std | CI Range | Upper CI | Lower CI | Run 0 | Run 1 | Run 2 | Run 3 | Run 4 | Run 5 | Run 6 | Run 7 | Run 8 | Run 9 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 6.305399 | 5 | 6.305 | 1.851680369 | 1.147662294 | 7.453061 | 5.1577367 | 4.576 | 8.59561 | 7.7901 | 4.576 | 4.57642 | 4.576 | 4.576 | 7.61055 | 7.64537 | 8.53194 |
| 2 | 9.268291 | 10 | 9.268 | 1.659559901 | 1.028586982 | 10.29688 | 8.239704 | 4.576 | 9.77877 | 10.0233 | 9.58586 | 9.53217 | 10.0309 | 9.61525 | 9.93369 | 9.64384 | 9.96313 |
| 3 | 11.28396 | 20 | 11.28 | 0.441067554 | 0.273371479 | 11.55733 | 11.010589 | 10.58 | 11.3658 | 12.2584 | 11.0482 | 11.5936 | 11.2228 | 11.3334 | 10.911 | 11.2903 | 11.2361 |
| 4 | 11.69699 | 30 | 11.7 | 0.565836962 | 0.350702938 | 12.04769 | 11.346287 | 10.6163 | 12.889 | 11.8147 | 11.2927 | 11.88 | 11.4658 | 11.7087 | 11.8486 | 11.6847 | 11.7694 |
| 5 | 11.99379 | 40 | 11.99 | 0.534820405 | 0.33147903 | 12.32527 | 11.662311 | 11.4392 | 13.0011 | 12.2358 | 11.3946 | 11.3771 | 11.6674 | 12.2132 | 12.3211 | 11.873 | 12.4154 |
| 6 | 12.5611 | 50 | 12.56 | 0.41493208 | 0.257172842 | 12.81827 | 12.303927 | 11.9711 | 12.1921 | 12.8591 | 12.6286 | 12.3656 | 12.8424 | 12.6179 | 13.4336 | 12.3747 | 12.3259 |

## Average Delivery Ratio vs macMaxCSMABackoffs

| Trial | Delivery Ratio (%) | macMaxCSMABackoffs | Mean | Std | CI Range | Upper CI | Lower CI | Run 0 | Run 1 | Run 2 | Run 3 | Run 4 | Run 5 | Run 6 | Run 7 | Run 8 | Run 9 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2.931334 | 1 | 2.931 | 0.488918914 | 0.303029514 | 3.234364 | 2.6283045 | 1.56667 | 2.98 | 2.87 | 3.15667 | 3.17667 | 3.04333 | 3.16 | 3.10667 | 3.12 | 3.13333 |
| 2 | 5.8133347 | 2 | 5.813 | 1.966859437 | 1.219049708 | 7.032384 | 4.594285 | 0.346667 | 6.74667 | 6.78667 | 5.31333 | 6.6 | 6.67 | 6.54667 | 6.43 | 6.23667 | 6.45667 |
| 3 | 13.062673 | 3 | 13.06 | 1.922019036 | 1.191257851 | 14.25393 | 11.871415 | 7.72333 | 14.0967 | 14.4933 | 12.9567 | 13.85 | 13.4033 | 13.5667 | 13.44 | 13.61 | 13.4867 |
| 4 | 18.187337 | 4 | 18.19 | 4.893185397 | 3.032772001 | 21.22011 | 15.154565 | 7.02667 | 19.3267 | 17.8867 | 25.8933 | 20.5767 | 20.3 | 17.9333 | 16.7367 | 21.08 | 15.1133 |

## Average Delivery Ratio vs macMinBE

| Trial | Delivery Ratio (%) | macMinBE | Mean | Std | CI Range | Upper CI | Lower CI | Run 0 | Run 1 | Run 2 | Run 3 | Run 4 | Run 5 | Run 6 | Run 7 | Run 8 | Run 9 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.7170004 | 1 | 0.717 | 0.333898116 | 0.206948394 | 0.923949 | 0.510052 | 0 | 0.943333 | 1.32667 | 0.6 | 0.58667 | 0.77 | 0.756667 | 0.816667 | 0.586667 | 0.783333 |
| 2 | 2.309334 | 2 | 2.309 | 0.809151208 | 0.501507899 | 2.810842 | 1.8078261 | 0.03 | 2.71333 | 2.53333 | 2.60667 | 2.37667 | 2.36 | 2.55667 | 2.65 | 2.61 | 2.65667 |
| 3 | 6.727333 | 3 | 6.727 | 0.100722994 | 0.062427611 | 6.789761 | 6.6649054 | 6.87333 | 6.63667 | 6.63 | 6.67 | 6.67333 | 6.78 | 6.71667 | 6.83667 | 6.85333 | 6.60333 |
| 4 | 11.384343 | 4 | 11.38 | 1.696822047 | 1.051681875 | 12.43602 | 10.332661 | 7.09333 | 13.2633 | 11.81 | 12.23 | 11.5967 | 11.51 | 11.1167 | 13.0367 | 11.2367 | 10.95 |

## Average Energy Consumption

| Trial | Energy (mJ) | Number of Nodes (N) | Mean | Std | CI Range | Upper CI | Lower CI | Run 0 | Run 1 | Run 2 | Run 3 | Run 4 | Run 5 | Run 6 | Run 7 | Run 8 | Run 9 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.3482973 | 5 | 0.348 | 0.047888266 | 0.02968091 | 0.377978 | 0.3186164 | 0.477788 | 0.321879 | 0.348946 | 0.346805 | 0.32294 | 0.35248 | 0.322263 | 0.315067 | 0.353073 | 0.321735 |
| 2 | 0.5167755 | 10 | 0.517 | 0.190094571 | 0.117819671 | 0.634595 | 0.3989558 | 1.05112 | 0.437537 | 0.433533 | 0.476149 | 0.42627 | 0.44236 | 0.461445 | 0.447951 | 0.46088 | 0.530514 |
| 3 | 0.7167334 | 20 | 0.717 | 0.104395821 | 0.064704011 | 0.781437 | 0.6520294 | 1.01257 | 0.702962 | 0.668901 | 0.693664 | 0.68453 | 0.6798 | 0.677091 | 0.677254 | 0.690156 | 0.680405 |
| 4 | 1.0306635 | 30 | 1.031 | 0.250735564 | 0.155404657 | 1.186068 | 0.8752588 | 1.737 | 0.96697 | 0.922468 | 0.929967 | 0.90911 | 0.98316 | 0.998656 | 0.923957 | 0.925116 | 1.01023 |
| 5 | 1.249778 | 40 | 1.25 | 0.029587085 | 0.018337928 | 1.268116 | 1.2314401 | 1.3019 | 1.20562 | 1.24786 | 1.24534 | 1.25558 | 1.22935 | 1.26427 | 1.28978 | 1.22324 | 1.23484 |
| 6 | 1.566757 | 50 | 1.567 | 0.376249065 | 0.233197302 | 1.799954 | 1.3335597 | 2.62818 | 1.5801 | 1.41437 | 1.41265 | 1.42195 | 1.44464 | 1.41854 | 1.43222 | 1.47264 | 1.44228 |