1. With a message size of 1 we will see a larger effect of the alpha part of the alpha betta model. This is shown as the time per message is incredibly small at 263 microseconds, but the overall time is at just over one full second. As we add in the data from the message size of eight, we see that the time per message only increases by 2 microseconds and the overall message time reduces to just under a second. This shows the alpha part of the alpha beta model is about 250 microseconds or 250000 nanoseconds. Now as to the beta part of the model, the program kindly reports our gigabytes per second we just need to convert to the proper units which results in 17.016 bytes per nanosecond. One trend I noticed is that our largest message size is not the best performing one. This is because we achieve a better balance between the alpha and beta values as the larger message start requiring more time to fill the buffers then we save by sending less messages.

2. The largest message that the default code runs at is 4096, as any message larger than that will result in a dead lock. The following table contains the time for full ring communication.

| Message Size | 1 | 8 | 64 | 512 | 4096 | 32768 | 256K | 1M |
|---|---|---|---|---|---|---|---|---|
| Time in nanoseconds | 186,000,000 | 200,000,000 | 215,000,000 | 663,000,000 | 2,145,000,000 | 2,916,000,000 | 5,196,000,000 | 4,976,000,000 |

Note: The 1M time is smaller that the others but I believe that this is just variance between runs.

3. Mat-Vec-Mul performance. Note that performance increases at a decreasing rate, I believe that this is because of the problem size and the cost of communication between each process.

| Number of processes | 1 | 2 | 4 | 8 | 16 |
|---|---|---|---|---|---|
| GFLOPS | 2.25 | 4.48 | 8.15 | 11.42 | 13.62 |
| Time in seconds | 0.010 | 0.005 | 0.003 | 0.002 | 0.002 |
| % Speed up vs 1 | 0 | 200% | 333% | 500% | 600% |

Images of raw program output for ping pong and ring.

Ping Pong

```
[u1350778@lab1-8 MPI1 - Inprogress]$ mpicc -O3 -o pingpong pingpong.c
[u1350778@lab1-8 MPI1 - Inprogress]$ mpirun -np 2 ./pingpong
Message length: 1 , GBytes/sec: 0.030 , NIters: 990099 , Time taken per message (microsecs): 0.263 , Total time (secs): 1.043
Message length: 8 , GBytes/sec: 0.241 , NIters: 925925 , Time taken per message (microsecs): 0.265 , Total time (secs): 0.983
Message length: 64 , GBytes/sec: 1.604 , NIters: 609756 , Time taken per message (microsecs): 0.319 , Total time (secs): 0.779
Message length: 512 , GBytes/sec: 5.705 , NIters: 163398 , Time taken per message (microsecs): 0.718 , Total time (secs): 0.469
Message length: 4096 , GBytes/sec: 10.652 , NIters: 23832 , Time taken per message (microsecs): 3.076 , Total time (secs): 0.293
Message length: 32768 , GBytes/sec: 17.016 , NIters: 3042 , Time taken per message (microsecs): 15.406 , Total time (secs): 0.187
Message length: 262144 , GBytes/sec: 15.085 , NIters: 381 , Time taken per message (microsecs): 139.022 , Total time (secs): 0.212
Message length: 1048576 , GBytes/sec: 10.766 , NIters: 95 , Time taken per message (microsecs): 779.149 , Total time (secs): 0.296
[u1350778@lab1-8 MPI1 - Inprogress]$
```

Ring

```
Ring Communication: Message Size = 1; 0.014 Gbytes/sec; Time = 0.186 sec;
Ring Communication: Message Size = 8; 0.102 Gbytes/sec; Time = 0.200 sec;
Ring Communication: Message Size = 64; 0.715 Gbytes/sec; Time = 0.215 sec;
Ring Communication: Message Size = 512; 1.307 Gbytes/sec; Time = 0.663 sec;
Ring Communication: Message Size = 4096; 0.959 Gbytes/sec; Time = 2.145 sec;
Ring Communication: Message Size = 32768; 0.851 Gbytes/sec; Time = 2.916 sec;
Ring Communication: Message Size = 262144; 0.491 Gbytes/sec; Time = 5.196 sec;
Ring Communication: Message Size = 1048576; 0.486 Gbytes/sec; Time = 4.976 sec;
[u1350778@lab2-24 MPI]$
```