PDC Project

Parallel Algorithms for Butterfly Computations

PERFORMANCE ANALYSIS

Tool Used : TAU

Hamdan Sajid	Muhammad Mujtaba	Maria Naeem
22i-0872	22i-1102	22i-0812

Section K

Github: https://github.com/mmujtaba0085/parallel-butterfly-counter

Execution Time & Speedup (MPI + OpenMP):

Dataset #1: Bipartite_Graph_50k

Serial Execution Time: 7.09174 seconds

Processes	Parallel (s)	Speedup
2	4.02249	**1.76**
4	3.49078	**2.03**
8	6.57926	**1.07**

- Best speedup at 4 processes (speedup 2.03).
- When increasing from 4 to 8 processes, speedup drops to 1.07 — meaning performance worsens with more processes.
- This suggests that for 50k data size, the overhead (like communication and synchronization between processes) start dominating when using too many processes (8 in this case).

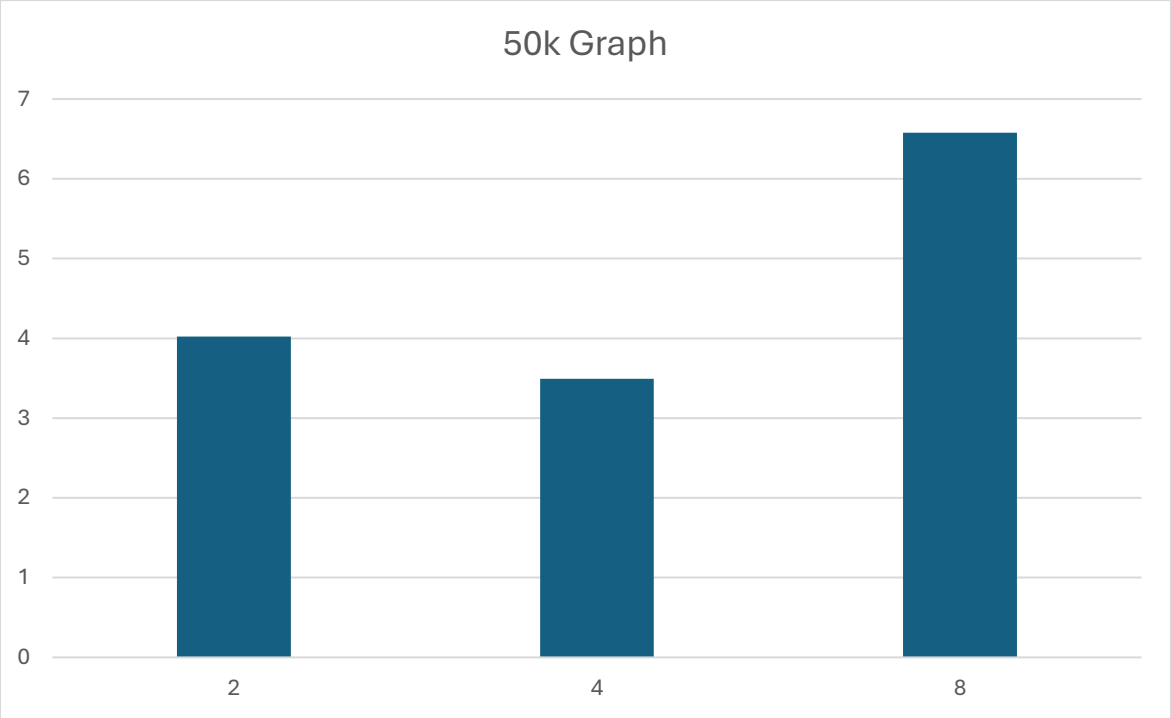
Dataset #2: Bipartite_Graph_100k

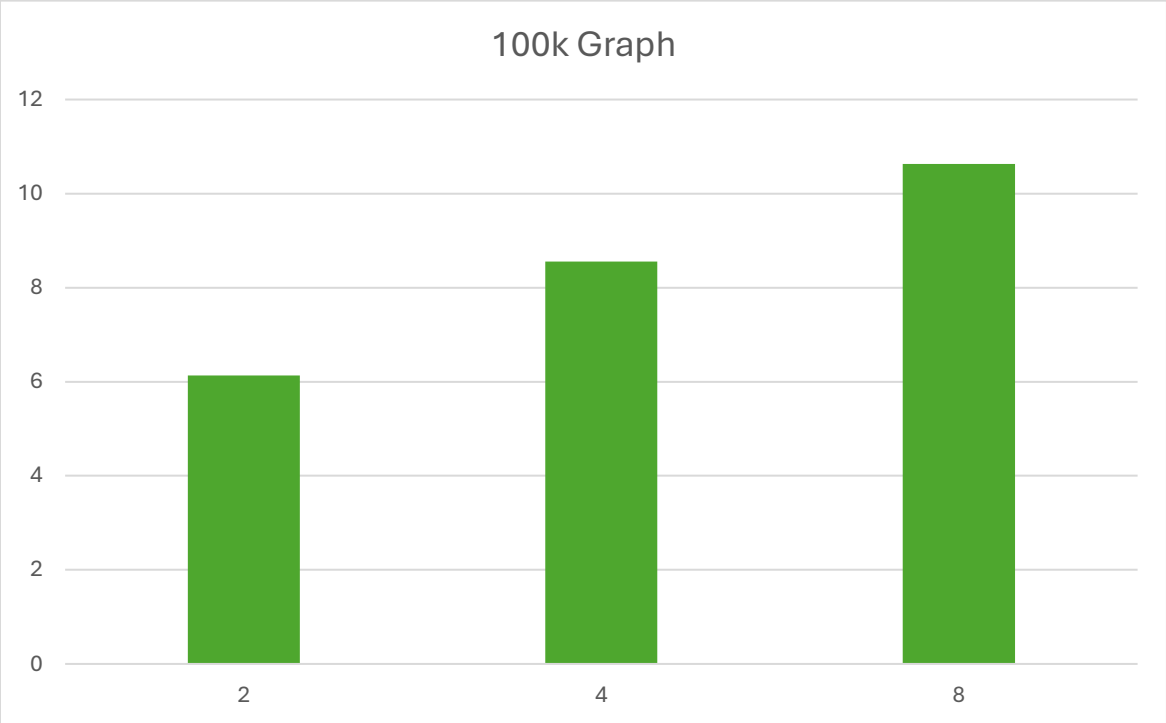
Serial Execution Time: 19.4348 seconds

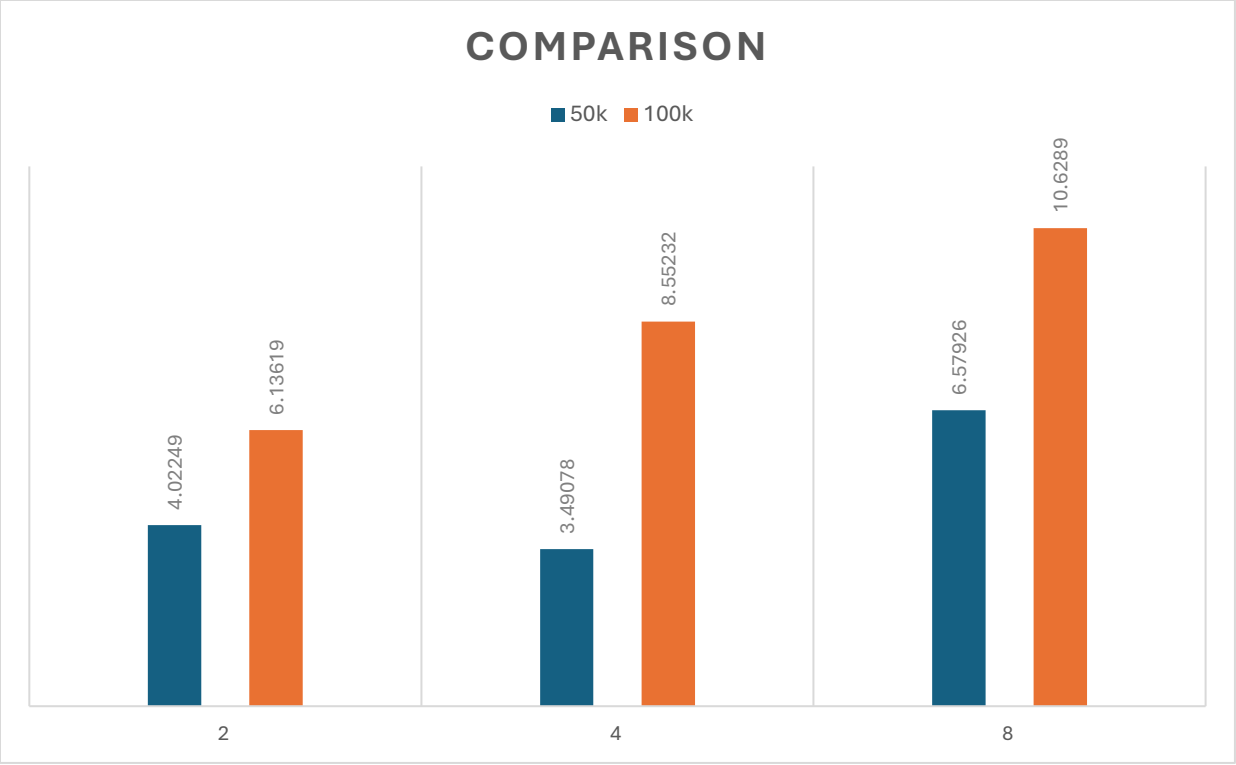
Processes	Parallel (s)	Speedup
2	6.13619	**3.16**
4	8.55232	**2.27**
8	10.6289	**1.82**

- Best speedup at 2 processes (speedup 3.16) — excellent gain here.
- As you increase to 4 and then 8 processes, speedup **drops** (2.27 and 1.82 respectively).
- So even with a larger dataset (100k), adding more than 2 processes leads to diminishing returns — likely due to overhead again.

Visualized Performance:

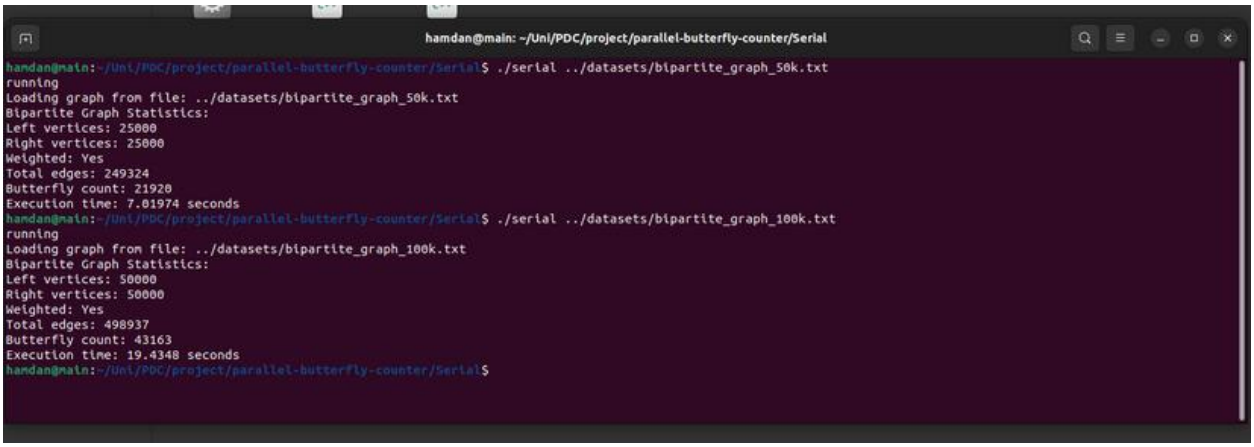





COMPARISON
50k
100k
4.02249
6.13619
3.49078
8.55232
6.57926
10.6289
2
4
8

Screenshots (With Profiling):

Serial



Parallel:

50k, 2 Processes

```
Loading graph from file: parallel-butterfly-counter/datasets/bipartite_graph_50k.txt
Bipartite Graph Statistics:
Left vertices: 25000
Right vertices: 25000
Weighted: Yes
Total edges: 249324
MPI distribution: 12500 vertices per process (+0 remainder)
Each process finished counting local wedges with OpenMP parallelism
Wedge counting time: 0.607069 seconds
Wedge pairs that could form butterflies locally: 1485/320146 (0.463851%)
Communication time: 2.35065 seconds
Butterfly counting time: 0.271449 seconds
Butterfly count: 21920
Total hybrid parallel execution time: 4.02249 seconds
Showing performance analysis with pprof...
Reading Profile files in profile.*

NODE 0;CONTEXT 0;THREAD 0:
---------------------------------------------------------------------------------------
%Time    Exclusive    Inclusive       #Call      #Subrs  Inclusive Name
              msec   total msec                          usec/call
---------------------------------------------------------------------------------------
100.0        2,098       21,600           1           8   21600270 .TAU application
 80.0       17,276       17,276           1           0   17276398 MPI_Init_thread()
  7.2        1,544        1,544           2           0     772278 MPI_Recv()
  3.0           16          655           2           2     327652 MPI_Bcast()
  3.0          639          639           2           0     319564 MPI Collective Sync
  0.1           25           25           1           0      25237 MPI_Finalize()
  0.0        0.029        0.029           1           0         29 MPI_Comm_rank()
  0.0        0.028        0.028           1           0         28 MPI_Comm_size()
---------------------------------------------------------------------------------------

USER EVENTS Profile :NODE 0, CONTEXT 0, THREAD 0
---------------------------------------------------------------------------------------
NumSamples   MaxValue   MinValue  MeanValue  Std. Dev.  Event Name
---------------------------------------------------------------------------------------
         2      1E+05          4      5E+04      5E+04  Message size for broadcast
---------------------------------------------------------------------------------------

NODE 1;CONTEXT 0;THREAD 0:
---------------------------------------------------------------------------------------
%Time    Exclusive    Inclusive       #Call      #Subrs  Inclusive Name
              msec   total msec                          usec/call
---------------------------------------------------------------------------------------
100.0        1,743        2,883           1           8    2883982 .TAU application
 21.5          620          620           1           0     620943 MPI_Init_thread()
 17.3          497          497           2           0     248758 MPI_Send()
  0.6           16           16           2           2       8469 MPI_Bcast()
  0.2            4            4           1           0       4634 MPI_Finalize()
  0.0        0.506        0.506           2           0        253 MPI Collective Sync
  0.0        0.001        0.001           1           0          1 MPI_Comm_rank()
  0.0        0.001        0.001           1           0          1 MPI_Comm_size()
---------------------------------------------------------------------------------------

USER EVENTS Profile :NODE 1, CONTEXT 0, THREAD 0
---------------------------------------------------------------------------------------
NumSamples   MaxValue   MinValue  MeanValue  Std. Dev.  Event Name
```

50k, 4 Processes

```
Loading graph from file: parallel-butterfly-counter/datasets/bipartite_graph_50k.txt
Bipartite Graph Statistics:
Left vertices: 25000
Right vertices: 25000
Weighted: Yes
Total edges: 249324
MPI distribution: 6250 vertices per process (+0 remainder)
Each process finished counting local wedges with OpenMP parallelism
Wedge counting time: 0.254914 seconds
Wedge pairs that could form butterflies locally: 148/103842 (0.142524%)
Communication time: 2.46318 seconds
Butterfly counting time: 0.229541 seconds
Butterfly count: 21920
Total hybrid parallel execution time: 3.49078 seconds
Showing performance analysis with pprof...
Reading Profile files in profile.*

NODE 0;CONTEXT 0;THREAD 0:
---------------------------------------------------------------------------------------
%Time    Exclusive    Inclusive       #Call      #Subrs  Inclusive Name
              msec   total msec                          usec/call
---------------------------------------------------------------------------------------
100.0        3,164       12,011           1          12   12011300 .TAU application
 67.5        8,108        8,108           1           0    8108150 MPI_Init_thread()
  4.3          513          513           6           0      85641 MPI_Recv()
  1.8          102          217           2           2     108768 MPI_Bcast()
  1.0          115          115           2           0      57678 MPI Collective Sync
  0.1            6            6           1           0       6932 MPI_Finalize()
  0.0        0.039        0.039           1           0         39 MPI_Comm_rank()
  0.0        0.033        0.033           1           0         33 MPI_Comm_size()
---------------------------------------------------------------------------------------

USER EVENTS Profile :NODE 0, CONTEXT 0, THREAD 0
---------------------------------------------------------------------------------------
NumSamples   MaxValue   MinValue  MeanValue  Std. Dev.  Event Name
---------------------------------------------------------------------------------------
         2      1E+05          4      5E+04      5E+04  Message size for broadcast
---------------------------------------------------------------------------------------

NODE 1;CONTEXT 0;THREAD 0:
---------------------------------------------------------------------------------------
%Time    Exclusive    Inclusive       #Call      #Subrs  Inclusive Name
              msec   total msec                          usec/call
---------------------------------------------------------------------------------------
100.0          888        2,995           1           8    2995504 .TAU application
 39.1        1,171        1,171           1           0    1171060 MPI_Finalize()
 16.5          493          493           2           0     246670 MPI_Send()
 10.2          305          305           1           0     305767 MPI_Init_thread()
  4.6           20          136           2           2      68350 MPI_Bcast()
  3.9          116          116           2           0      58137 MPI Collective Sync
  0.0        0.003        0.003           1           0          3 MPI_Comm_rank()
  0.0        0.002        0.002           1           0          2 MPI_Comm_size()
---------------------------------------------------------------------------------------

USER EVENTS Profile :NODE 1, CONTEXT 0, THREAD 0
```

50k, 8 Processes

```
Loading graph from file: parallel-butterfly-counter/datasets/bipartite_graph_50k.txt
Bipartite Graph Statistics:
Left vertices: 25000
Right vertices: 25000
Weighted: Yes
Total edges: 249324
MPI distribution: 3125 vertices per process (+0 remainder)
Each process finished counting local wedges with OpenMP parallelism
Wedge counting time: 0.209784 seconds
Wedge pairs that could form butterflies locally: 20/34146 (0.058572%)
Communication time: 3.92859 seconds
Butterfly counting time: 0.406966 seconds
Butterfly count: 21920
Total hybrid parallel execution time: 6.57926 seconds
Showing performance analysis with pprof...
Reading Profile files in profile.*

NODE 0;CONTEXT 0;THREAD 0:
---------------------------------------------------------------------------------------
%Time    Exclusive    Inclusive       #Call      #Subrs  Inclusive Name
              msec   total msec                          usec/call
---------------------------------------------------------------------------------------
100.0        4,487     1:17.234           1          20   77234816 .TAU application
 91.1     1:10.342     1:10.342           1           0   70342032 MPI_Init_thread()
  1.5          221        1,125           2           2     562580 MPI_Bcast()
  1.3          981          981          14           0      70133 MPI_Recv()
  1.2          904          904           2           0     452072 MPI Collective Sync
  0.4          298          298           1           0     298667 MPI_Finalize()
  0.0        0.019        0.019           1           0         19 MPI_Comm_rank()
  0.0        0.017        0.017           1           0         17 MPI_Comm_size()
---------------------------------------------------------------------------------------

USER EVENTS Profile :NODE 0, CONTEXT 0, THREAD 0
---------------------------------------------------------------------------------------
NumSamples   MaxValue   MinValue  MeanValue  Std. Dev.  Event Name
---------------------------------------------------------------------------------------
         2      1E+05          4      5E+04      5E+04  Message size for broadcast
---------------------------------------------------------------------------------------

NODE 1;CONTEXT 0;THREAD 0:
---------------------------------------------------------------------------------------
%Time    Exclusive    Inclusive       #Call      #Subrs  Inclusive Name
              msec   total msec                          usec/call
---------------------------------------------------------------------------------------
100.0          615       14,085           1           8   14085296 .TAU application
 78.4       11,048       11,048           1           0   11048432 MPI_Finalize()
  8.1        1,134        1,134           1           0    1134298 MPI_Init_thread()
  8.0        1,128        1,128           2           0     564112 MPI_Send()
  1.1           69          159           2           2      79510 MPI_Bcast()
  0.6           89           89           2           0      44932 MPI Collective Sync
  0.0        0.002        0.002           1           0          2 MPI_Comm_rank()
  0.0        0.001        0.001           1           0          1 MPI_Comm_size()
---------------------------------------------------------------------------------------
```

100k, 2 Processes

```
Loading graph from file: parallel-butterfly-counter/datasets/bipartite_graph_100k.txt
Bipartite Graph Statistics:
Left vertices: 50000
Right vertices: 50000
Weighted: Yes
Total edges: 497555
MPI distribution: 25000 vertices per process (+0 remainder)
Each process finished counting local wedges with OpenMP parallelism
Wedge counting time: 1.18353 seconds
Wedge pairs that could form butterflies locally: 2779/635771 (0.437107%)
Communication time: 3.64238 seconds
Butterfly counting time: 0.331469 seconds
Butterfly count: 43179
Total hybrid parallel execution time: 6.13619 seconds
Showing performance analysis with pprof...
Reading Profile files in profile.*

NODE 0;CONTEXT 0;THREAD 0:
---------------------------------------------------------------------------------------
%Time    Exclusive    Inclusive       #Call      #Subrs  Inclusive Name
              msec   total msec                          usec/call
---------------------------------------------------------------------------------------
100.0        4,796        8,439           1           8    8439266 .TAU application
 23.0        1,940        1,940           2           0     970360 MPI_Recv()
 18.2        1,531        1,531           1           0    1531940 MPI_Init_thread()
  1.4          120          120           1           0     120848 MPI_Finalize()
  0.6           40           49           2           2      24520 MPI_Bcast()
  0.1            8            8           2           0       4412 MPI Collective Sync
  0.0        0.029        0.029           1           0         29 MPI_Comm_size()
  0.0        0.026        0.026           1           0         26 MPI_Comm_rank()
---------------------------------------------------------------------------------------

USER EVENTS Profile :NODE 0, CONTEXT 0, THREAD 0
---------------------------------------------------------------------------------------
NumSamples   MaxValue   MinValue  MeanValue  Std. Dev.  Event Name
---------------------------------------------------------------------------------------
         2      2E+05          4      1E+05      1E+05  Message size for broadcast
---------------------------------------------------------------------------------------

NODE 1;CONTEXT 0;THREAD 0:
---------------------------------------------------------------------------------------
%Time    Exclusive    Inclusive       #Call      #Subrs  Inclusive Name
              msec   total msec                          usec/call
---------------------------------------------------------------------------------------
100.0        4,029        4,994           1           8    4994432 .TAU application
 10.6          527          527           2           0     263840 MPI_Send()
  4.5           29          225           2           2     112586 MPI_Bcast()
  4.2          207          207           1           0     207727 MPI_Init_thread()
  3.9          195          195           2           0      97796 MPI Collective Sync
  0.1            4            4           1           0       4232 MPI_Finalize()
  0.0        0.001        0.001           1           0          1 MPI_Comm_rank()
  0.0        0.001        0.001           1           0          1 MPI_Comm_size()
---------------------------------------------------------------------------------------

USER EVENTS Profile :NODE 1, CONTEXT 0, THREAD 0
---------------------------------------------------------------------------------------
```

100k, 4 Processes

```
Each MPI process will use up to 4 OpenMP threads
Loading graph from file: parallel-butterfly-counter/datasets/bipartite_graph_100k.txt
Bipartite Graph Statistics:
Left vertices: 50000
Right vertices: 50000
Weighted: Yes
Total edges: 497555
MPI distribution: 12500 vertices per process (+0 remainder)
Each process finished counting local wedges with OpenMP parallelism
Wedge counting time: 0.39856 seconds
Wedge pairs that could form butterflies locally: 239/206716 (0.115618%)
Communication time: 6.24442 seconds
Butterfly counting time: 0.917805 seconds
Butterfly count: 43179
Total hybrid parallel execution time: 8.55232 seconds
Showing performance analysis with pprof...
Reading Profile files in profile.*

NODE 0;CONTEXT 0;THREAD 0:
---------------------------------------------------------------------------------------
%Time    Exclusive    Inclusive       #Call      #Subrs  Inclusive Name
              msec   total msec                          usec/call
---------------------------------------------------------------------------------------
100.0        8,892       11,915           1          12   11915599 .TAU application
 18.0        2,145        2,145           1           0    2145060 MPI_Init_thread()
  5.8          692          692           6           0     115365 MPI_Recv()
  1.0           23          118           2           2      59220 MPI_Bcast()
  0.8           94           94           2           0      47361 MPI Collective Sync
  0.6           67           67           1           0      67115 MPI_Finalize()
  0.0        0.026        0.026           1           0         26 MPI_Comm_size()
  0.0        0.024        0.024           1           0         24 MPI_Comm_rank()
---------------------------------------------------------------------------------------

USER EVENTS Profile :NODE 0, CONTEXT 0, THREAD 0
---------------------------------------------------------------------------------------
NumSamples   MaxValue   MinValue  MeanValue  Std. Dev.  Event Name
---------------------------------------------------------------------------------------
         2      2E+05          4      1E+05      1E+05  Message size for broadcast
---------------------------------------------------------------------------------------

NODE 1;CONTEXT 0;THREAD 0:
---------------------------------------------------------------------------------------
%Time    Exclusive    Inclusive       #Call      #Subrs  Inclusive Name
              msec   total msec                          usec/call
---------------------------------------------------------------------------------------
100.0        1,753        5,866           1           8    5866074 .TAU application
 46.7        2,742        2,742           1           0    2742300 MPI_Finalize()
 10.0          585          585           2           0     292826 MPI_Send()
  7.4           25          431           2           2     215722 MPI_Bcast()
  6.9          406          406           2           0     203102 MPI Collective Sync
  6.0          353          353           1           0     353666 MPI_Init_thread()
  0.0        0.002        0.002           1           0          2 MPI_Comm_rank()
  0.0            0            0           1           0          0 MPI_Comm_size()
---------------------------------------------------------------------------------------

USER EVENTS Profile :NODE 1, CONTEXT 0, THREAD 0
---------------------------------------------------------------------------------------
```

100k, 8 Processes

```
oading graph from file: parallel-butterfly-counter/datasets/bipartite_graph_100k.txt
ipartite Graph Statistics:
eft vertices: 50000
ight vertices: 50000
eighted: Yes
otal edges: 497555
PI distribution: 6250 vertices per process (+0 remainder)
ach process finished counting local wedges with OpenMP parallelism
edge counting time: 0.153988 seconds
edge pairs that could form butterflies locally: 17/68782 (0.0247158%)
ommunication time: 7.88711 seconds
utterfly counting time: 0.472087 seconds
utterfly count: 43179
otal hybrid parallel execution time: 10.6289 seconds
howing performance analysis with pprof...
eading Profile files in profile.*

ODE 0;CONTEXT 0;THREAD 0:
---------------------------------------------------------------------------------------
Time    Exclusive    Inclusive       #Call      #Subrs  Inclusive Name
              msec   total msec                          usec/call
---------------------------------------------------------------------------------------
00.0        9,372       14,376           1          20   14376703 .TAU application
14.8        2,131        2,131           1           0    2131235 MPI_Init_thread()
13.8        1,990        1,990          14           0     142209 MPI_Recv()
 6.0          730          860           2           2     430429 MPI_Bcast()
 0.9          129          129           2           0      64932 MPI Collective Sync
 0.1           20           20           1           0      20322 MPI_Finalize()
 0.0        0.584        0.584           1           0        584 MPI_Comm_size()
 0.0         0.03         0.03           1           0         30 MPI_Comm_rank()
---------------------------------------------------------------------------------------

SER EVENTS Profile :NODE 0, CONTEXT 0, THREAD 0
---------------------------------------------------------------------------------------
umSamples   MaxValue   MinValue  MeanValue  Std. Dev.  Event Name
---------------------------------------------------------------------------------------
        2      2E+05          4      1E+05      1E+05  Message size for broadcast
---------------------------------------------------------------------------------------

ODE 1;CONTEXT 0;THREAD 0:
---------------------------------------------------------------------------------------
Time    Exclusive    Inclusive       #Call      #Subrs  Inclusive Name
              msec   total msec                          usec/call
---------------------------------------------------------------------------------------
00.0        1,360       12,284           1           8   12284122 .TAU application
57.4        7,049        7,049           1           0    7049442 MPI_Finalize()
16.9        2,070        2,070           2           0    1035019 MPI_Send()
 8.7          186        1,064           2           2     532152 MPI_Bcast()
 7.1          877          877           2           0     438900 MPI Collective Sync
 6.0          740          740           1           0     740038 MPI_Init_thread()
 0.0        0.002        0.002           1           0          2 MPI_Comm_rank()
 0.0        0.002        0.002           1           0          2 MPI_Comm_size()
---------------------------------------------------------------------------------------

SER EVENTS Profile :NODE 1, CONTEXT 0, THREAD 0
---------------------------------------------------------------------------------------
```