# Profiling MPI code to identify bottlenecks

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Slides: git.io/fAV4t

# MPI, briefly

- MPI: **M**essage **P**assing **I**nterface
- Born in 1991, now at version 3.1
- Single Program Multiple Data model
  - Same program runs multiple times (on one or more nodes)
  - Communication is explicit
- Point-to-point send and receive
- **I**mmediate (non-blocking) versions
- Point-to-all (broadcast) operations
- Collectives, e.g. reductions (sums, maxima, minima, etc.)

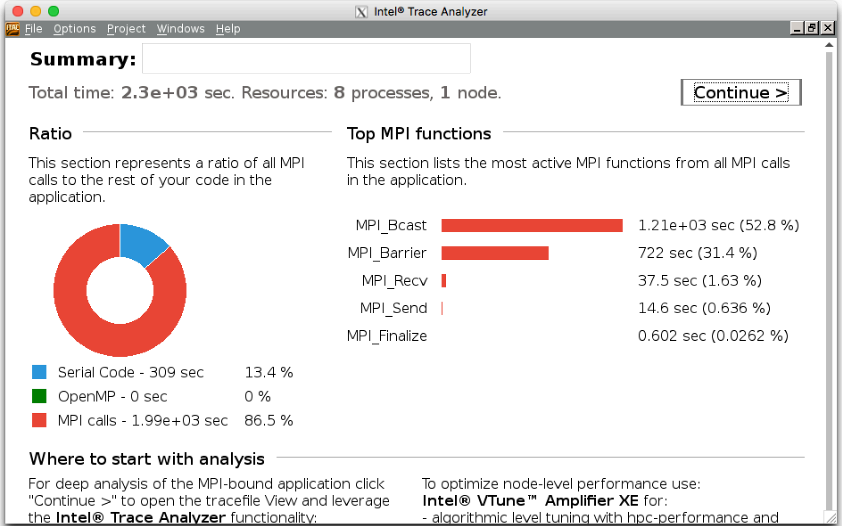
# Profiling MPI

- Intel MPI provides profiling tools

  ```
  source /apps/compilers/intel/2018.3/itac_2018/bin/itacvars.sh
  mpirun -trace [my_application]
  ```

- Output can be *large*, so choose a small problem size
- Visualise the results with `traceanalyzer`

# Summary view

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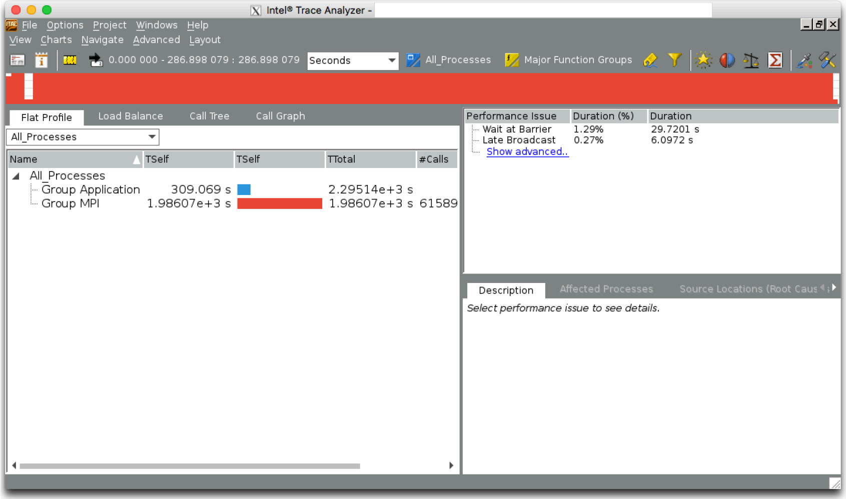
# Whole application timeline

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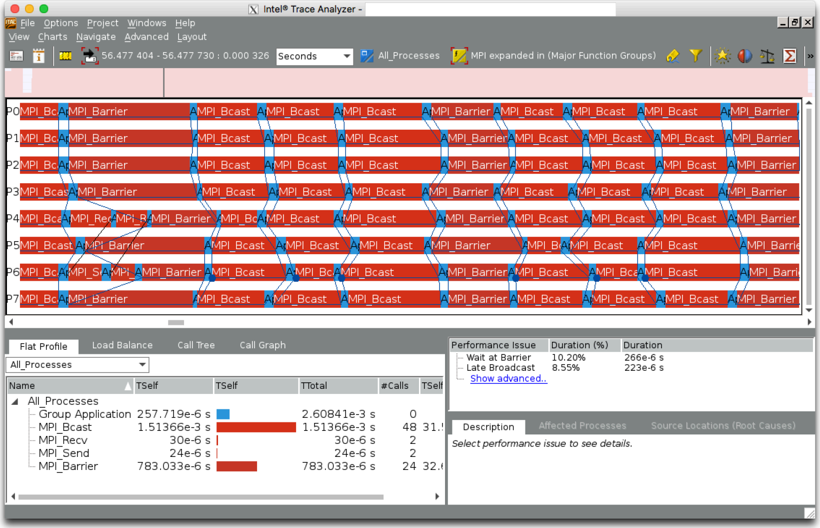
# Detailed timeline

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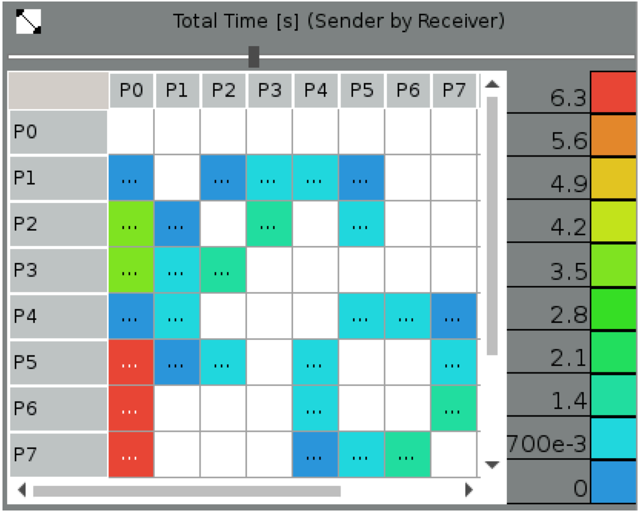
# Message pattern

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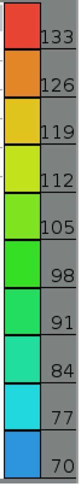
# Reductions summary

Total Time [s] (Collective Operation by Process)

| | P0 | P1 | P2 | P3 | P4 | P5 | P6 | P7 |
|---|---|---|---|---|---|---|---|---|
| MPI_Barrier | 78.7392 | 71.0828 | 75.2938 | 74.9894 | 74.9034 | 80.9084 | 81.9725 | 81.0336 |
| MPI_Bcast | 135.816 | 135.979 | 136.28 | 136.192 | 129.22 | 129.325 | 129.7 | 130.231 |
| Sum | 214.556 | 207.062 | 211.573 | 211.181 | 204.123 | 210.233 | 211.673 | 211.264 |
| Mean | 107.278 | 103.531 | 105.787 | 105.59 | 102.062 | 105.117 | 105.836 | 105.632 |
| StdDev | 28.5386 | 32.4483 | 30.4929 | 30.601 | 27.1583 | 24.2083 | 23.8639 | 24.5985 |



# Ways forward

- We found that:
  - `MPI_Barrier` and `MPI_Bcast` taking up a lot of time
  - Communications are scattered throughout the program
  - Very small amounts of compute between each communication
  - Coordinator-worker pattern
  - Some minor load balancing concerns
- Things to think about
  - Can we use a peer-to-peer pattern instead?
  - Can we increase the amount of work between communications?
  - Is the direction we're parallelising appropriate?
- If that fails, consider more advanced MPI features

# TIL #1: MPI-IO

- Avoid channelling all I/O through a single rank/node
- Higher performance for reading and writing data
- Works really well with subarray types

```
call MPI_File_Open(comm, 'con', MPI_Mode_Rdonly, &
MPI_Info_Null, mpi_fh)
call MPI_File_Set_View(mpi_fh, 0_8, MPI_Real, mpiio_type, &
"native", MPI_Info_Null)
call MPI_File_Read_All(mpi_fh, theta, &
3 * ksizex_l * ksizey_l * ksizet_l, &
MPI_Real, status)
call MPI_File_Close(mpi_fh)
```

# Subarray types

```
subroutine init_single_halo_type_4(direction, position, size4, datatype, typet)
  integer, intent(in) :: direction, position, size4
  type(MPI_Datatype), intent(in) :: datatype
  type(MPI_Datatype), intent(out) :: typet
  integer, dimension(4) :: sizes, subsizes, starts
  sizes = (/ ksizex_l + 2, ksizey_l + 2, ksizet_l + 2, size4 /)
  subsizes = (/ ksizex_l, ksizey_l, ksizet_l, size4 /)
  subsizes(direction+1) = 1
  starts = (/ 1, 1, 1, 0 /)
  starts(direction+1) = position
  call MPI_Type_Create_Subarray(4, sizes, subsizes, starts, &
                    MPI_Order_Fortran, datatype, typet)
  call MPI_Type_Commit(typet)
  return
end subroutine init_single_halo_type_4
```

# Persistent MPI communications

- Each `MPI_Send`/`MPI_Recv` pair has an overhead
- For a tight loop, this wastes time
- Instead, use `MPI_Send_Init`/`MPI_Recv_Init` outside the loop
- `MPI_Start`/`MPI_StartAll` inside
- Also need `MPI_Wait`/`MPI_WaitAll`
- Speedup achieved will depend on architecture/communications fabric combination
- Collectives planned for MPI 3.2, e.g. `MPI_AllReduce_Init`

# Thanks for listening!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