# Interferences between Communications and Computations in Distributed HPC Systems

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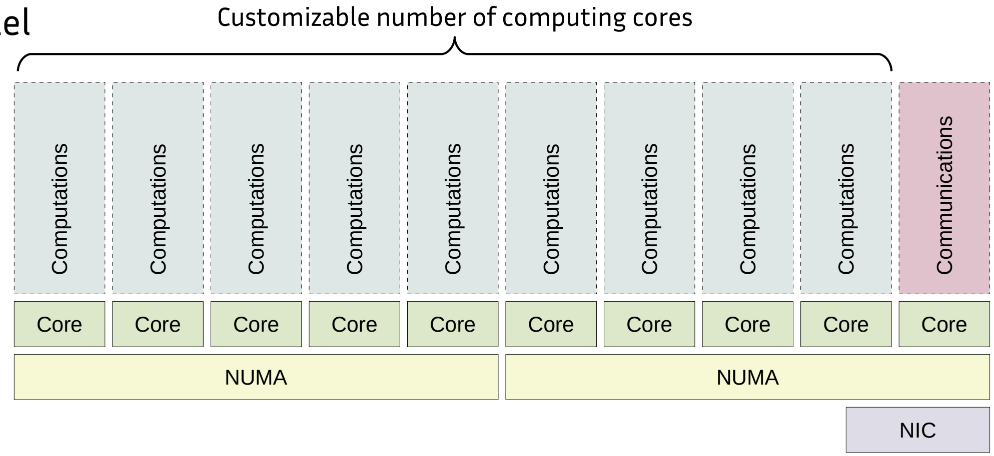
# Introduction

- Communications: one of key factors for scalability
- Computations and communications in parallel: raising trend to get better performances
- Are there interferences between computations and communications ?
- Yes, communications can impact computations
  - Langguth, X. Cai, and M. Sourouri. 2018. Memory Bandwidth Contention: Communication vs Computation Tradeoffs in Supercomputers with Multicore Architectures. In 2018 IEEE 24th International Conference on Parallel and Distributed Systems (ICPADS). 497–506
  - T. Groves, R. E. Grant, and D. Arnold. 2016. NiMC: Characterizing and Eliminating Network-Induced Memory Contention. In 2016 IEEE International Parallel and Distributed Processing Symposium (IPDPS). 253–262.
- What about computations impacting communications ?

# Context

- Distributed StarPU applications
  - Task-based runtime system for heterogeneous architectures

- Computations and communications in parallel
  - **One thread dedicated to communications**
  - Other threads perform computations
  - One thread bound per core

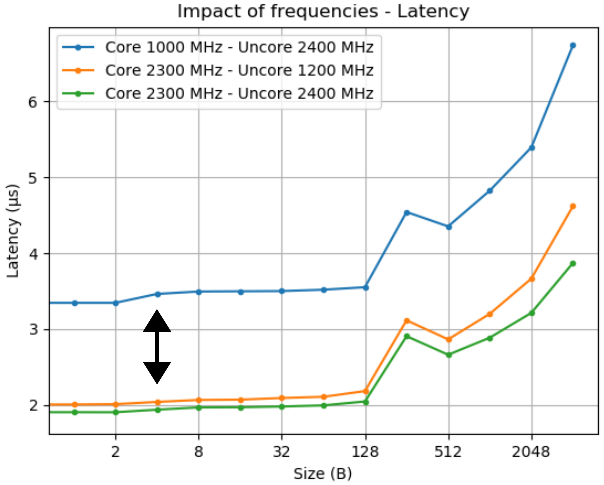


# Origins of interferences ?

- Hypotheses:
  - > Processor frequency variations
  - > Memory contention

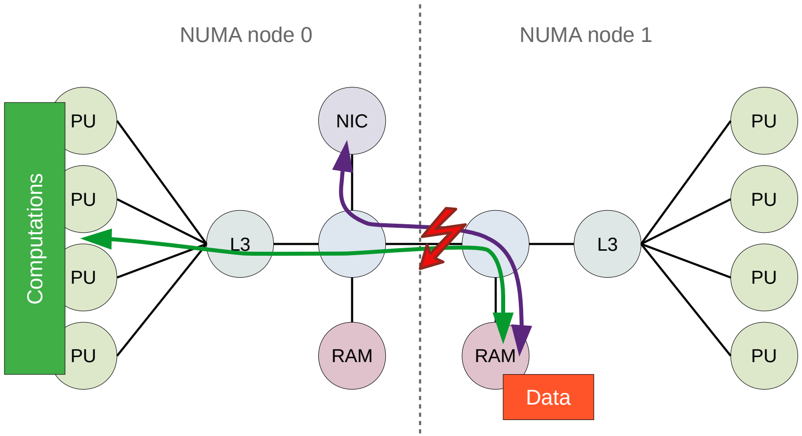
# Frequency variations

- Network performances are comprised of:
  - > Software overhead, to set up the communication
  - > Memory transfer time, to move the data between main memory and NIC
- Duration of these two steps: influenced by processor frequencies
- Processor frequencies: can change according to workload
- Lower processor frequencies → lower network performances



# Memory contention

> For computations, data move between RAM and cores
> For communications, data move between RAM and NIC
> → **Contention on memory bus** !



# Experimental protocol

- **Goal**: compare performances of computations and communications alone and in parallel
  - → benchmarking program
- 3 steps:
  1) Computations alone
  2) Communications alone
     } to get their nominal performances → Compare them
  3) Computations and communications in parallel → to see the impact of one on each other → Compare them

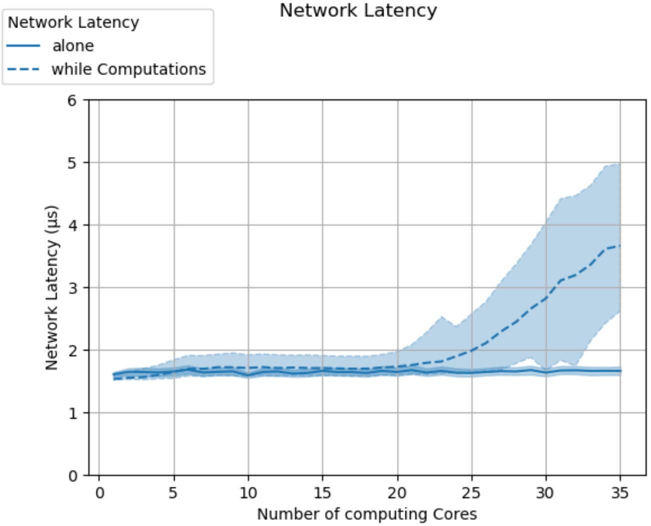
- Computations:
  - Memory-bound: STREAM kernels:

```
COPY : for(i=0; i<ARRAY_SIZE; i++) A[i]=B[i]
TRIAD: for(i=0; i<ARRAY_SIZE; i++) C[i]=A[i]+3.14*B[i]
```

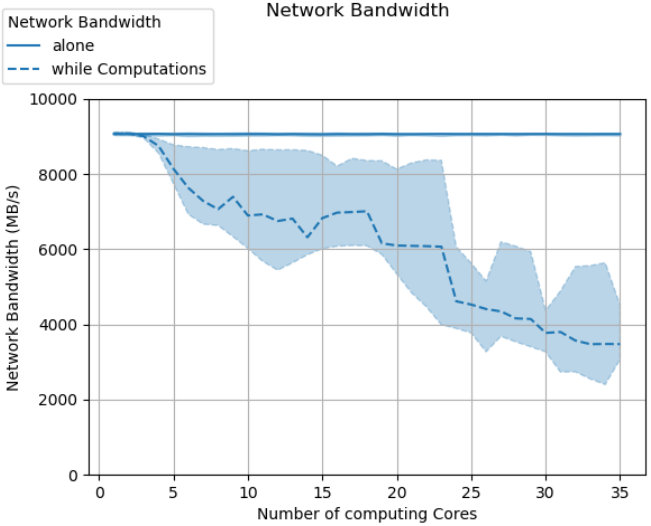
    → memory bandwidth per core (higher is better)
  - Embarrassingly parallel, independant from communications

- Communications:
  - 2 MPI processes (one per node)
  - Ping-pongs to measure network latency (with 4 B) and bandwidth (with 64 MB)

# Impacts of memory contention



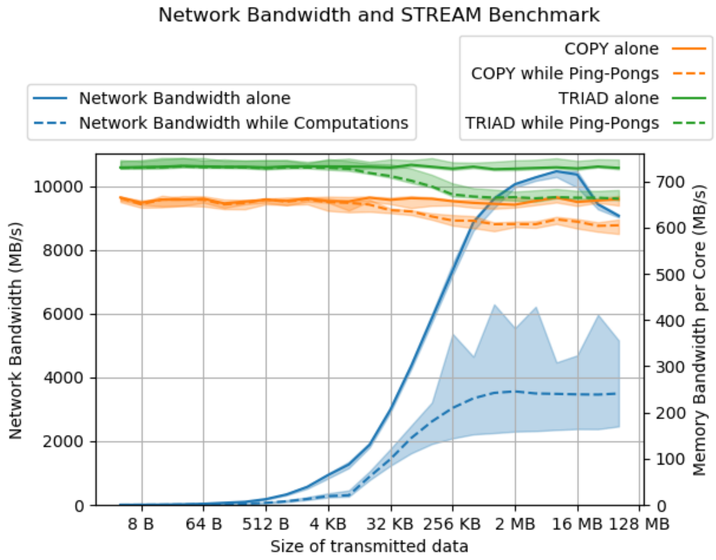

Network Latency Benchmark: **4 B**




Network Bandwidth Benchmark: **64 MB**

- Network latency impacted from 23 computing cores
- Network bandwidth impacted from 3 computing cores

# Impacts of message size



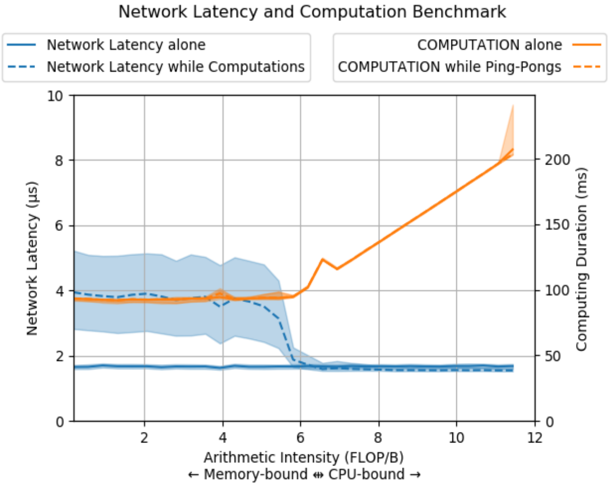

With 35 computing cores

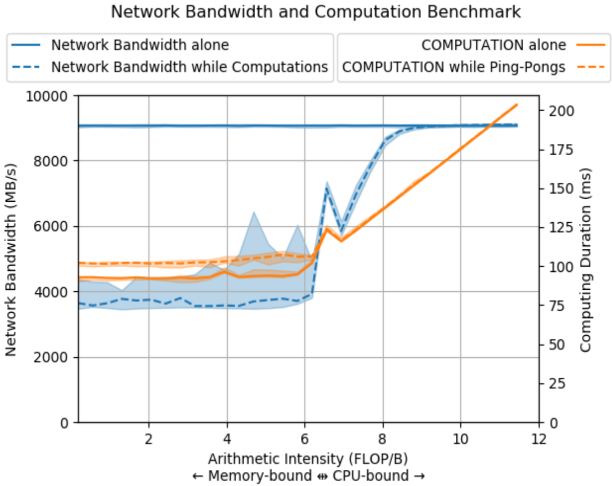
- Large number of computing cores impacts a **wide range of message sizes**

# Impacts of arithmetic intensity

- *Arithmetic intensity*: number of flops per byte of moved data
- → TRIAD with tunable arithmetic intensity

```
for (i = 0; i < ARRAY_SIZE; i++)
    for (c = 0; c < cursor; c++)
        C[i] = A[i] + 3.14 * B[i]
```

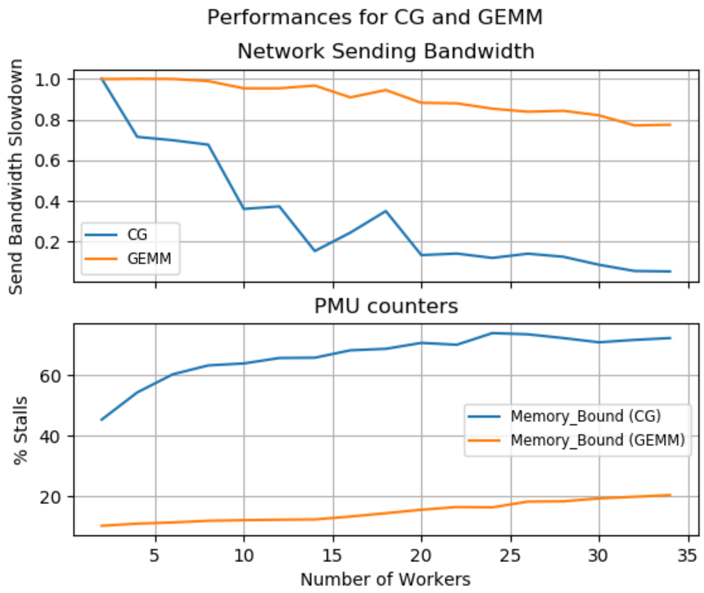



- **Computations more CPU-bound → less trafic on memory bus → less contention**

# Use-cases: computational kernels

- Computational kernels:
  - > Dense conjugate gradient (CG)
  - > Dense general matrix-matrix multiplication (GEMM)
- Metrics:
  - > Impact on network performance
  - > Number of stalled cycles → lost cycles waiting for memory
- CG is **more memory-bound** than GEMM:
  - > CG has more stalls
  - > CG has a **network bandwidth more impacted**



# Conclusion

- Computations and communications in parallel to get better performances in distributed HPC applications
- Side-by-side computations and communications
  - > Can disturb computations
  - > Can **highly impact communications**
- Main factor of interferences: **memory contention**, influenced by placement, message size, arithmetic intensity
- Behaviours also observed with real-world computational kernels
- Future work:
  - > Model these interactions
  - > Take into account these interactions in runtime systems to minimize them
  - > Same study with GPUs

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