OTF-CPT

On-the-fly Critical Path Tool

IT Center | RWTH AACHEN UNIVERSITY

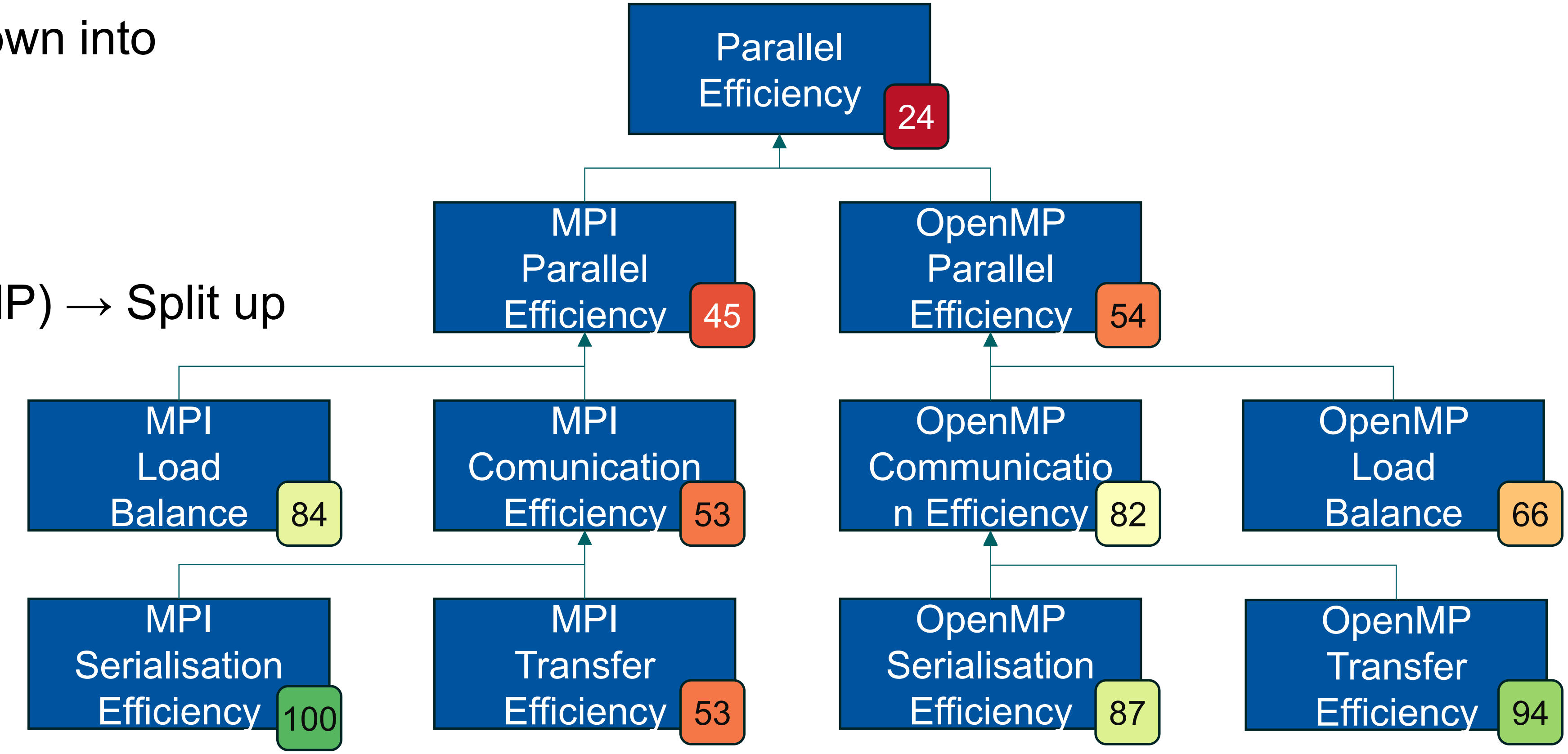
Hybrid Model Factors

- Highlight issues in the parallel structure of an application

- Parallel Efficiency breaks down into
  - Load balance
  - Serialization
  - Transfer

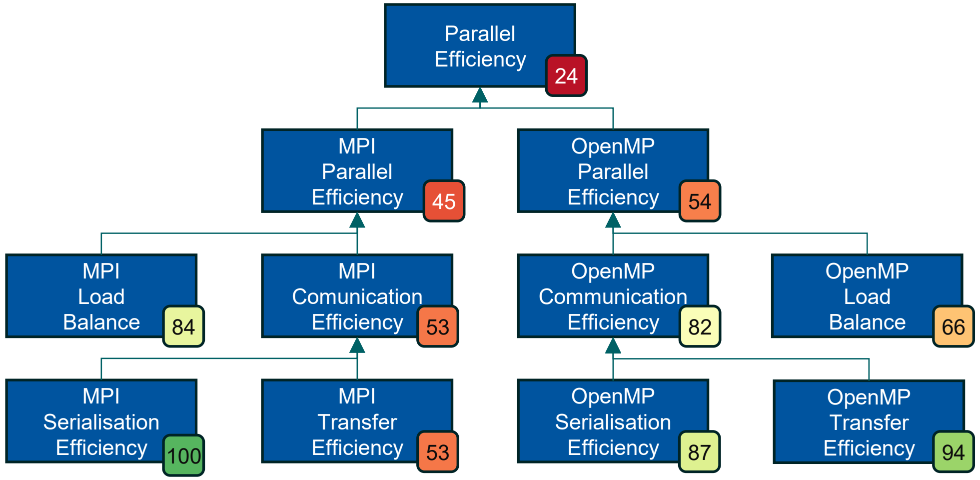
- Hybrid Setups (MPI+OpenMP) → Split up efficiencies

- Child metrics multiply to parent metric



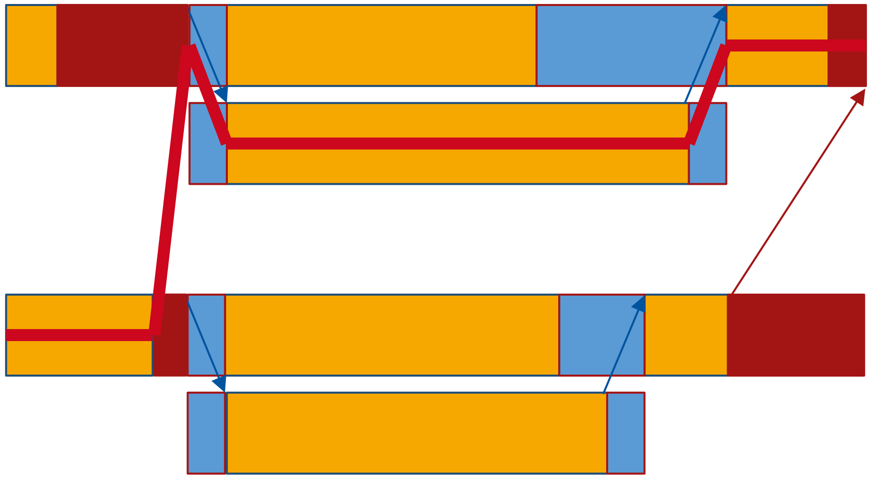
What to measure?

- *Useful time*: execution time outside parallel runtimes
  - Track execution time on each thread excluding time inside MPI / OpenMP runtimes
- *Real runtime*: observed execution time
  - Track wall clock time from start to end.
- *Ideal runtime*: execution time on an ideal machine with 0 communication cost (inf. BW / 0 lat)
  - Track useful time on critical path → assumes 0 communication cost



The Critical Path

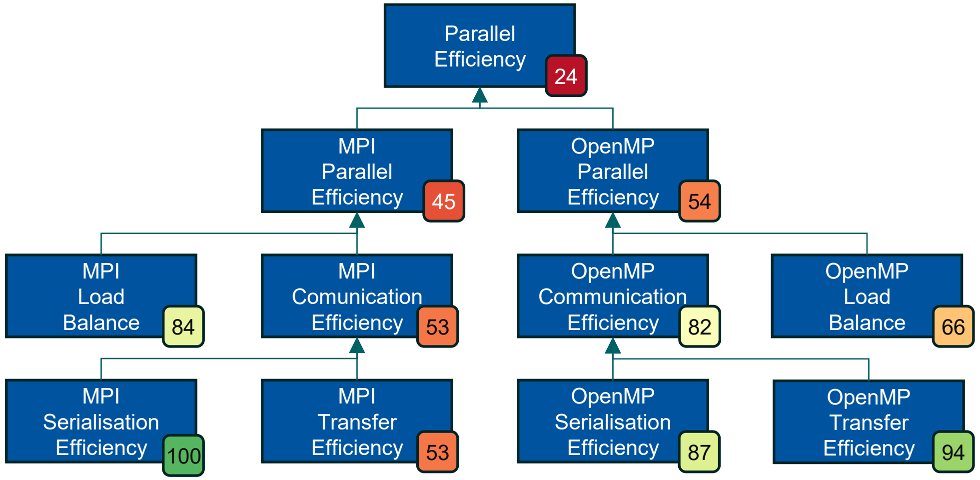
- We measure the length of the *Critical Path* of an application
  - Longest chain of dependent useful computations
  - Defines the total runtime → optimizations outside of the critical path do not directly decrease total runtime
  - Useful computation on the Critical Path vs total runtime shows the cost of synchronization



Application
MPI Comm
OpenMP

On The Fly Critical Path Tool (OTF-CPT)

- Forward-only analysis
  - we only need the metrics of the critical path, but not the concrete path
- Times are measured on thread level and propagated on the critical path
- Relevant metrics: useful computation, time outside the OpenMP runtime
- Relevant critical paths: global, process-local, thread-local
- Calculate hybrid model factors at the end of execution
  - High level overview over parallel application performance



OTF-CPT: Usage

- Run your parallel application normally
  - No recompilation necessary
- Tool provided as library: libOTFCPT.so
- Use LD_PRELOAD to run application with the tool
- Set OMP_TOOL_LIBRARIES for OpenMP-Support
- Outputs statistics and the hybrid model factors

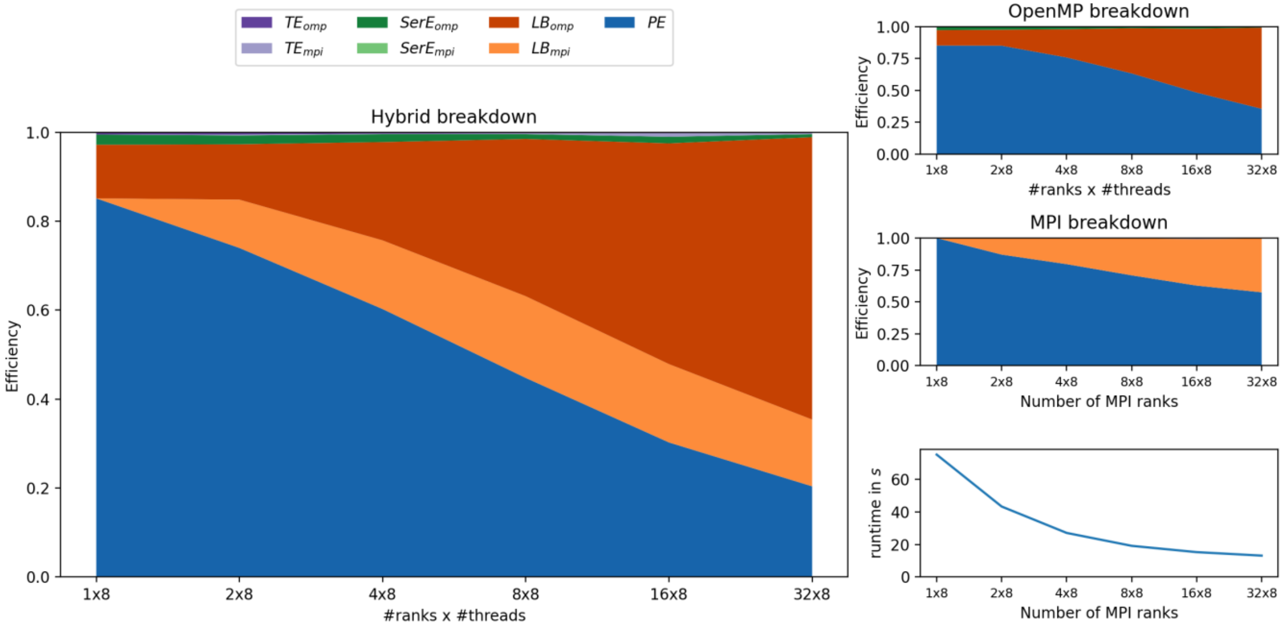
```
$ export OMP_NUM_THREADS=8
$ mpirun -np 32 \
env LD_PRELOAD=./libOTFCPT.so \
OMP_TOOL_LIBRARIES=./libOTFCPT.so \
./hybrid-application

... APP OUTPUT
--------CritPath Analysis Tool results:--------
=> Number of processes:          32
=> Number of threads:            256
=> Average Computation (in s):   34.797
=> Total runtime (in s):         37.146

----------------POP metrics----------------
Parallel Efficiency:                  0.937
  Load Balance:                       0.976
  Communication Efficiency:           0.960
    Serialisation Efficiency:         0.989
    Transfer Efficiency:              0.971
  MPI Parallel Efficiency:            0.956
    MPI Load Balance:                 0.981
    MPI Communication Efficiency:     0.974
      MPI Serialisation Efficiency:   0.997
      MPI Transfer Efficiency:        0.977
  OMP Parallel Efficiency:            0.980
    OMP Load Balance:                 0.995
    OMP Communication Efficiency:     0.986
      OMP Serialisation Efficiency:   0.992
      OMP Transfer Efficiency:        0.994
-------------------------------------------
```

Visualization

- Outputs can be visualized using a provided python script
  - Expects run outputs with the name <PREFIX>-<RANKS>x<THREADS>.* in a single folder.
  - Will search for the OTF-CPT output and parse it
  - Usage: `python CPT-plot.py -o <OUT_DIR> -p <PREFIX> experiment_directory`



#Ranks x #Threads	1x8	2x8	4x8	8x8	16x8	32x8
Global Efficiency	85.2	73.9	59.1	41.8	26.2	15.2
Parallel Efficiency	85.2	74.0	60.2	44.7	30.3	20.4
Load Balance	87.6	76.0	61.6	45.4	31.0	20.6
Communication Efficiency	97.2	97.3	97.8	98.3	97.5	98.8
Serialisation Efficiency	97.7	97.9	98.2	98.8	98.5	99.2
Transfer Efficiency	99.5	99.4	99.6	99.5	99.0	99.6
MPI Parallel Efficiency	100.0	87.1	79.4	70.7	62.7	57.5
MPI Load Balance	100.0	87.2	79.6	70.9	63.2	57.6
MPI Communication Efficiency	100.0	99.8	99.8	99.7	99.2	99.7
MPI Serialisation Efficiency	100.0	100.0	100.0	100.0	100.0	100.0
MPI Transfer Efficiency	100.0	99.8	99.9	99.8	99.2	99.7
OMP Parallel Efficiency	85.2	85.0	75.8	63.2	48.3	35.5
OMP Load Balance	87.6	87.2	77.4	64.1	49.1	35.8
OMP Communication Efficiency	97.2	97.5	97.9	98.6	98.3	99.1
OMP Serialisation Efficiency	97.7	98.0	98.2	98.9	98.5	99.3
OMP Transfer Efficiency	99.5	99.5	99.7	99.8	99.8	99.9
Computational Scalability	100.0	99.9	98.1	93.5	86.5	74.7

Live Demo: NPB

Options and Region of Interest

- Environment variable OTFCPT_OPTIONS controls options

  export OTFCPT_OPTIONS="verbose=1 stopped=1"

- Start and Stop of tool
  - MPI_Pcontrol or omp_control_tool (for OpenMP-only applications)
  - Currently only a single pair of start/stop markers possible

```
MPI_Pcontrol(1); // start
// region of interest
MPI_Pcontrol(0); // stop

omp_control_tool(omp_control_tool_start, 0, NULL); // start
// region of interest
omp_control_tool(omp_control_tool_stop, 0, NULL); // stop
```

OTFCPT_OPTIONS		
Flag Name	**Default Value**	**Description**
stopped	0	Delay the start of measurement until a start marker is encountered
data_path	stdout	Write metric data to "<data_path>-<#procs>x<#threads>.txt". Special values are "stdout" and "stderr". Overwrites the file without checking.
log_path	stdout	Write logging output to "<log_path>.<pid>". Special values are "stdout" and "stderr". Only relevant with verbose=1
verbose	0	Print additional statistics.
enable	1	Use OTF-CPT during execution.

Future Developments

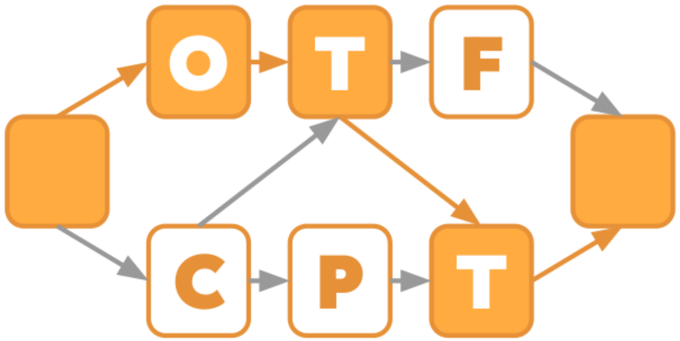
- GPU support
  - target regions using OMPT
  - CUDA events using CUPTI
- Additional OpenMP focused metrics
  - Focus on tasking
- More profiling information
  - Region markers
- Multiple starts and stops

Available on Github and MN5

- The OTF-CPT is available on github

- Also available on MN5 for this workshop
  - Available in /gpfs/scratch/nct_362/RWTH/OTF-CPT
  - Prebuilt for:
    - intel/2023.2.0, impi/2021.10.0
    - intel/2025.2, impi/2021.10.0
    - Intel/2023.2.0, openmpi/4.1.5

  - Please ask for other compiler/MPI combinations (or build yourself)



https://github.com/RWTH-HPC/OTF-CPT