ns-3 Performance and the SPEC CPUv8 Benchmark Suite

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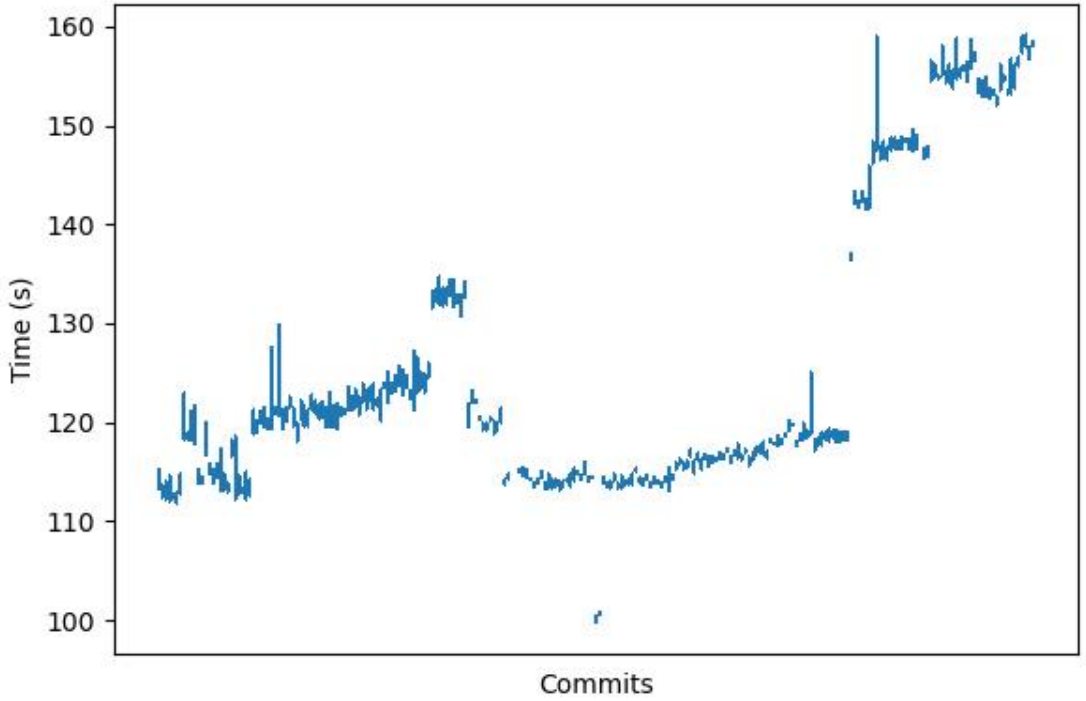
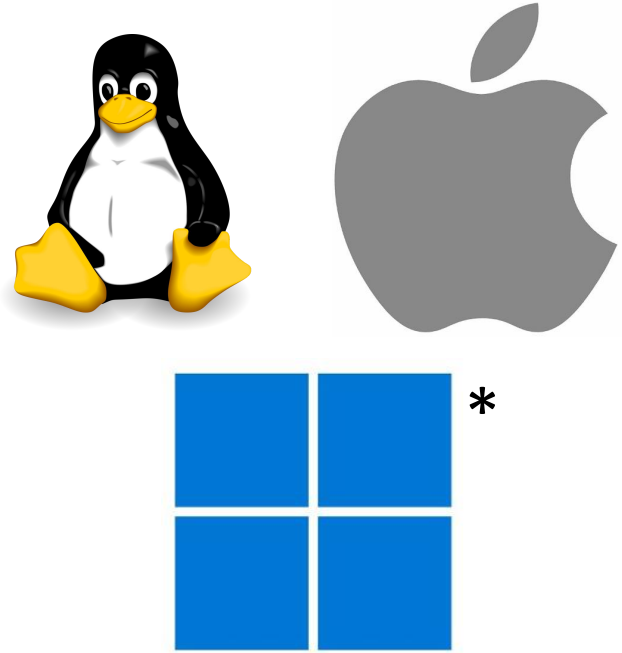
Current state of ns-3

- Performance-wise
  - Deltas since 3.36



- Compatibility-wise
  - Archs: x86/aarch64/power10



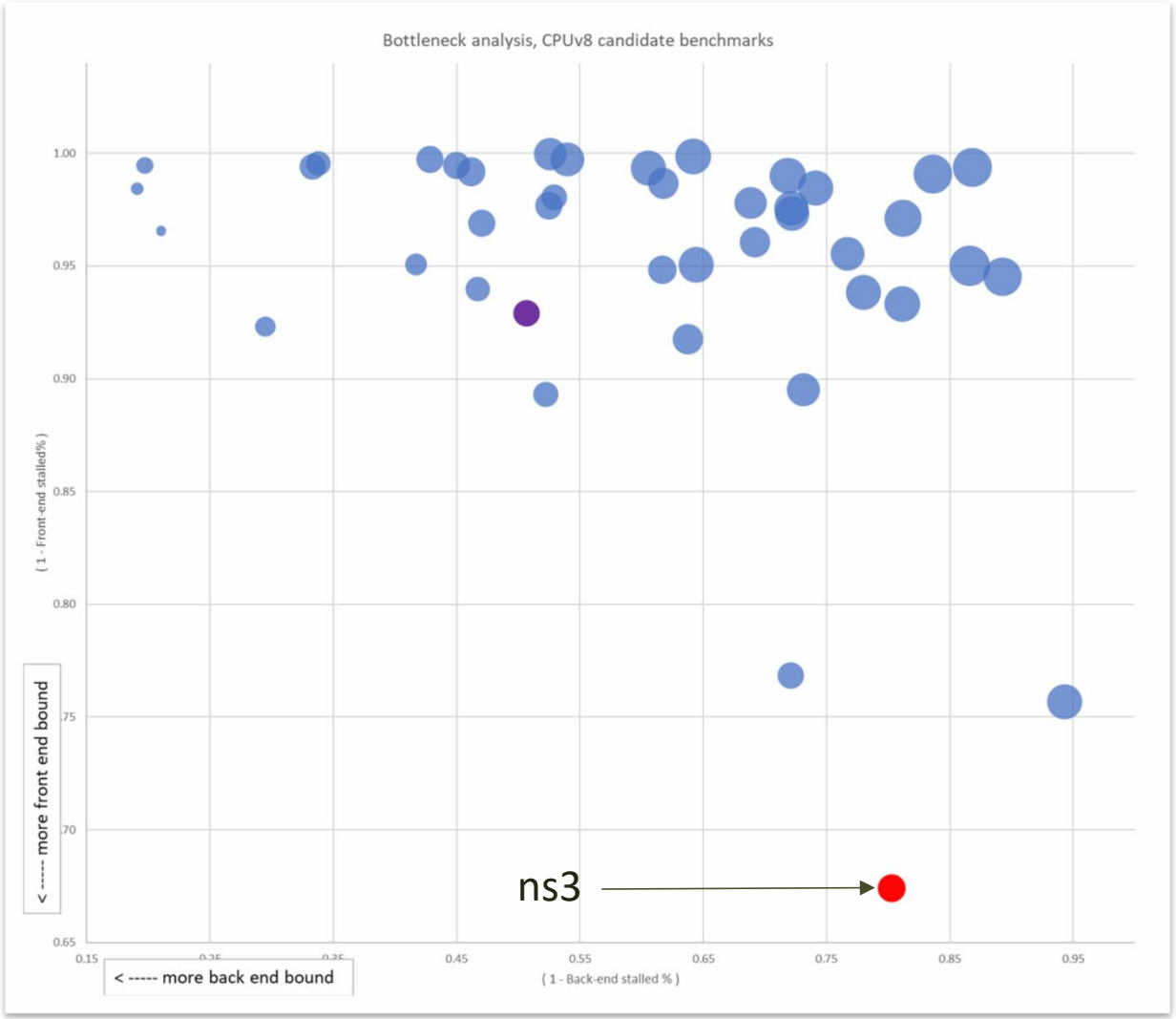
* With MinGW/gcc toolchain

Candidate for SPEC CPU Benchmark Suite

- The SPEC CPU committee seeks to cover a wide variety of microarchitectural behaviors
- Helps future CPU designers guide their product choices

"There are three types of lies: lies, damned lies, and statistics." – Mark Twain

ns-3 is an outlier in terms of CPU front-end bottlenecks



- Behaves similarly to cloud and microservice workloads due to code, iTLB and iCache misses causing stalls

```
Performance counter stats for 'specinvoke':

     457292.91 msec task-clock                #    0.998 CPUs utilized
1769327776947      instructions              #    1.29  insn per cycle
                                             #    0.31  stalled cycles per insn
1370278588879      cycles                    #    2.997 GHz
 540693646762      stalled-cycles-frontend   #   39.46% frontend cycles idle
 217359274622      stalled-cycles-backend    #   15.86% backend cycles idle

458.264462252 seconds time elapsed

446.445848000 seconds user
 10.480770000 seconds sys
```

Perf stat from Ampere Altra

- It is a good candidate* for SPEC CPUv8 selection

* no promises and no guarantee of success

An official score card, SPECrate 2017 Int

SPEC CPU®2017 Integer Rate Result

Supermicro

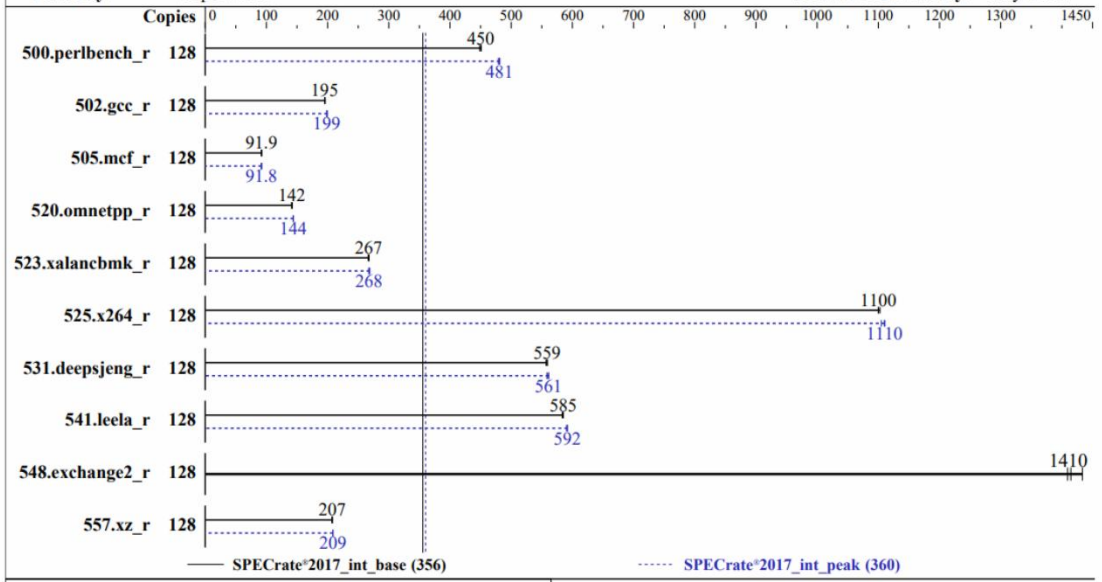
SuperServer ARS-210M-NR
(R12SPD-A , Ampere Altra Max M128-30)

SPECrate®2017_int_base = 356

SPECrate®2017_int_peak = 360

CPU2017 License: 001176
Test Sponsor: Supermicro
Tested by: Supermicro

Test Date: Nov-2022
Hardware Availability: Nov-2022
Software Availability: May-2022



Hardware

CPU Name:	Ampere Altra Max M128-30
Max MHz:	3300
Nominal:	3000
Enabled:	128 cores, 1 chip
Orderable:	1 chip
Cache L1:	64 KB I + 64 KB D on chip per core
L2:	1 MB I+D on chip per core
L3:	32 MB I+D on chip per chip
Other:	None
Memory:	512 GB (8 x 64 GB 2Rx4 PC4-3200AA-R)
Storage:	1 x 4 TB NVMe SSD
Other:	None

Software

OS:	CentOS Stream release 8 Kernel 4.18.0-383.el8.aarch64
Compiler:	C/C++/Fortran: Version 10.2.1 of Ampere GCC GNU Compiler Collection
Parallel:	No
Firmware:	Version 1.1 released Oct-2022
File System:	xfs
System State:	Run level 3 (multi-user)
Base Pointers:	64-bit
Peak Pointers:	64-bit
Other:	Jemalloc memory allocator library v5.2.1
Power Management:	BIOS and OS set to prefer performance at the cost of additional power usage.

SPEC CPU2017 benchmark descriptions

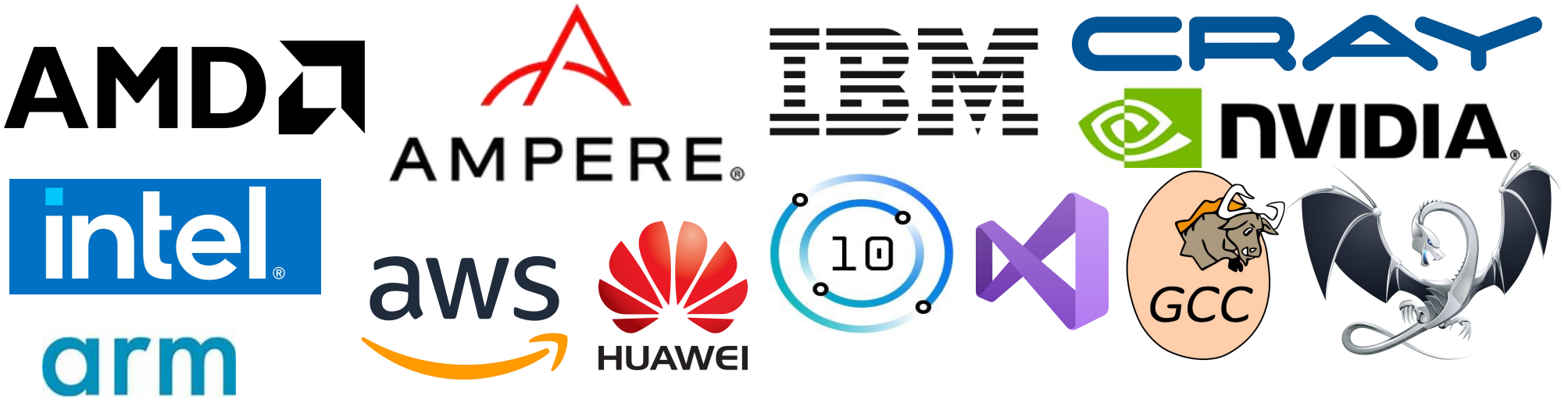
SPEC CPU 2017 has 43 benchmarks, organized into 4 suites:

SPECrate®2017 Integer	SPECspeed®2017 Integer	Application Area
500.perlbench_r	600.perlbench_s	Perl interpreter
502.gcc_r	602.gcc_s	GNU C compiler
505.mcf_r	605.mcf_s	Route planning
520.omnetpp_r	620.omnetpp_s	Discrete Event simulation - computer network
523.xalancbmk_r	623.xalancbmk_s	XML to HTML conversion via XSLT
525.x264_r	625.x264_s	Video compression
531.deepsjeng_r	631.deepsjeng_s	Artificial Intelligence: alpha-beta tree search (Chess)
541.leela_r	641.leela_s	Artificial Intelligence: Monte Carlo tree search (Go)
548.exchange2_r	648.exchange2_s	Artificial Intelligence: recursive solution generator (Sudoku)
557.xz_r	657.xz_s	General data compression

SPECrate®2017 Floating Point	SPECspeed®2017 Floating Point	Application Area
503.bwaves_r	603.bwaves_s	Explosion modeling
507.cactuBSSN_r	607.cactuBSSN_s	Physics: relativity
508.namd_r		Molecular dynamics
510.parest_r		Biomedical imaging: optical tomography with finite elements
511.povray_r		Ray tracing
519.lbm_r	619.lbm_s	Fluid dynamics
521.wrf_r	621.wrf_s	Weather forecasting
526.blender_r		3D rendering and animation
527.cam4_r	627.cam4_s	Atmosphere modeling
	628.pop2_s	Wide-scale ocean modeling (climate level)
538.imagick_r	638.imagick_s	Image manipulation
544.nab_r	644.nab_s	Molecular dynamics
549.fotonik3d_r	649.fotonik3d_s	Computational Electromagnetics
554.roms_r	654.roms_s	Regional ocean modeling

SPEC CPUv8 search program and development

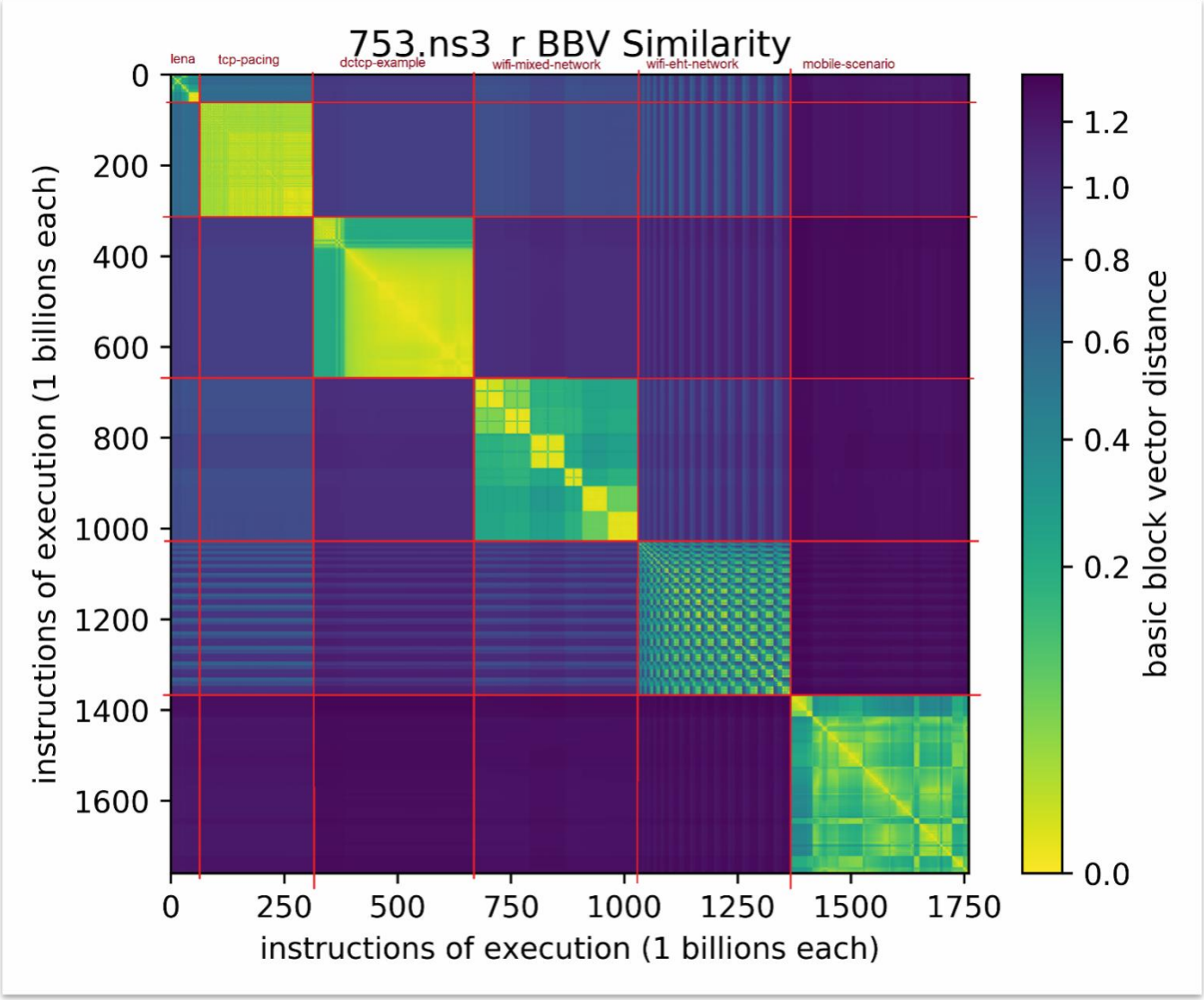
- Predetermined run rules and requirements:
  - 95% CPU bound, in user code (not kernel code, not in I/O)
  - 95% time spent in source code (not standard libraries)
  - Reproducible, verifiable equal work, verifiable results, etc, etc, etc
- Continuous integration exercises on multiple platforms



AMPERE

UnB

Selected workloads to represent ns-3



ns-3 application	Instructions	Runtime (s)[1]
lena-radio-link-failure	62.5 billion	10.9
tcp-pacing	251 billion	60.7
dctcp-example	356 billion	63.1
wifi-mixed-network	359 billion	74.5
wifi-eht-network	337 billion	57.5
mobile-scenario[2]	394 billion	63.5
Total	**1760 billion**	**330.3**

[1] Runtimes from AMD Milan
[2] Custom LTE-based scenario

Win-Win for all parties involved

- Benefits to SPEC
  - New workload in an important application domain (network simulation and modeling)
  - Microarchitectural behaviors that are “off the charts”
  - Cross-collaboration with another technical community
- Benefits to ns-3
  - Broad testing across esoteric platforms and compilers
  - Compliance with C++ standards
  - Hardening of mainline source
  - Learning about different tools, techniques and perspectives on how to profile code from professionals that build the hardware
  - MSVC compatibility patches (upcoming MR)