Results of benchmarking tests on nuc6

These are the preliminal results of my benchmarking of the ROS2 Transport layer with CycloneDDS using irobot's ros2-performance tooling to setup a system with a multitude of "dumb" publishers and subscribers of different ros topics.

The following things were benchmarked:

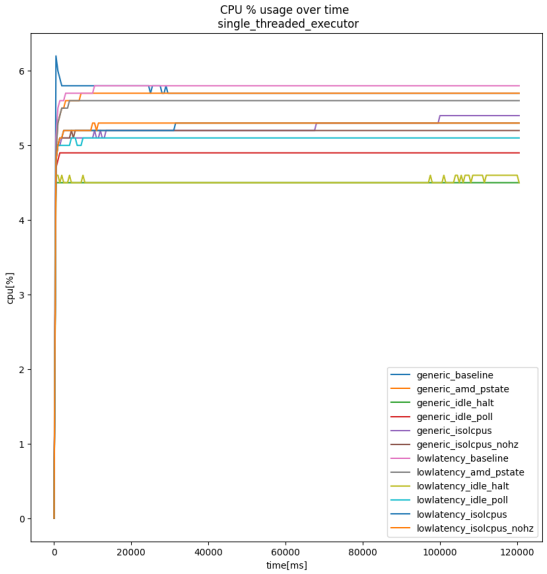
- CPU % usage
- Memory usage
- Mean topic latency
- Number of *late* messages
- Number of *too late* messages

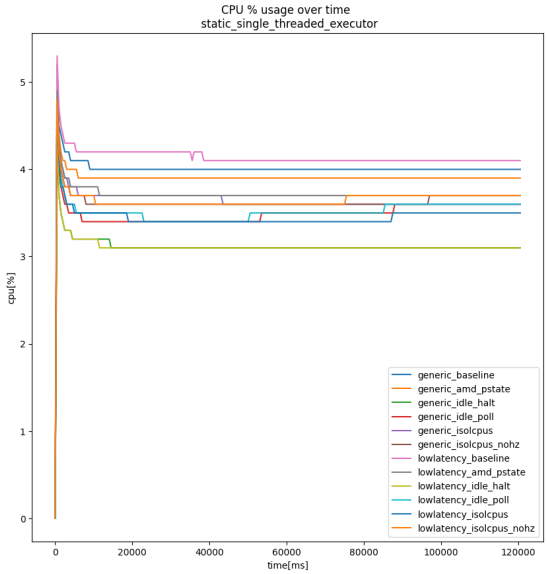
In these experiments a message is classified as *too late* when its latency is greater than `min(period, 50ms)` and a message is classified as late `min(0.25 * period, 5ms)`, where `period` p is the publishing period of that particular topic. Meaning a topic on which messages are published with `100Hz` has a period of `10ms` and would be considered *late* if the subscriber handles them `publishingTime + 2.5ms` and *too late* after `publishingTime + 10ms`.

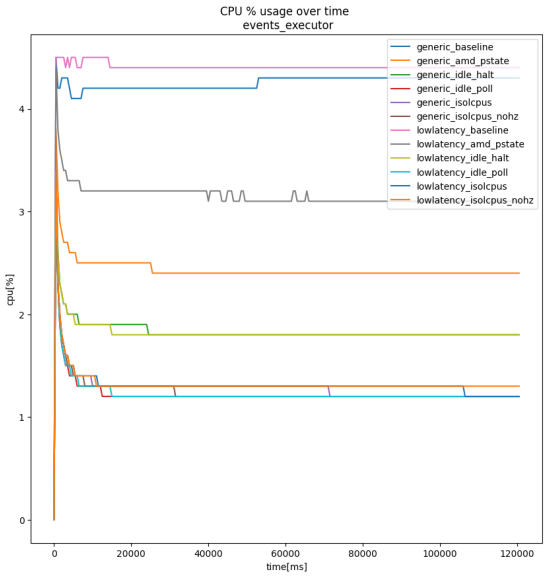
When messages are handled *too late* it means, that given enough runtime not all messages of the topic will be handled by the subscriber and some will need to be dropped, once the cumulative latency $L_t = \sum_{i=1}^{n} m_{isub} - m_{ipub}$ of the topic message m is greater than p.

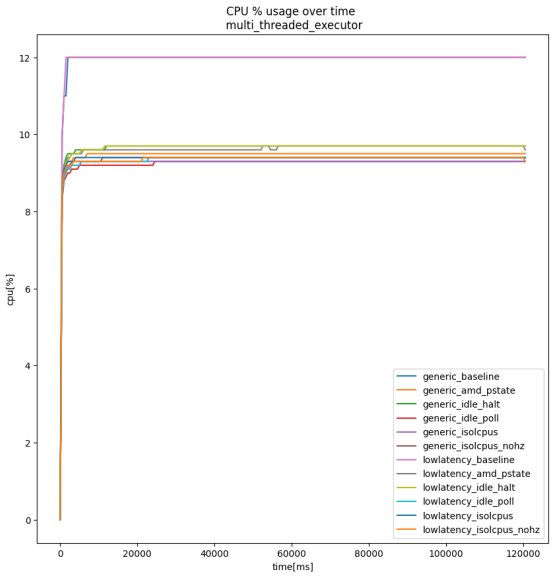
The different setups of the experiments are describe in the last section.

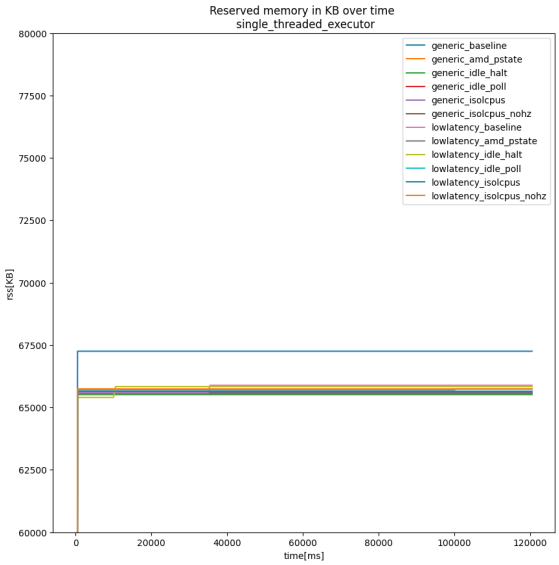
Comparisons of latency and resources

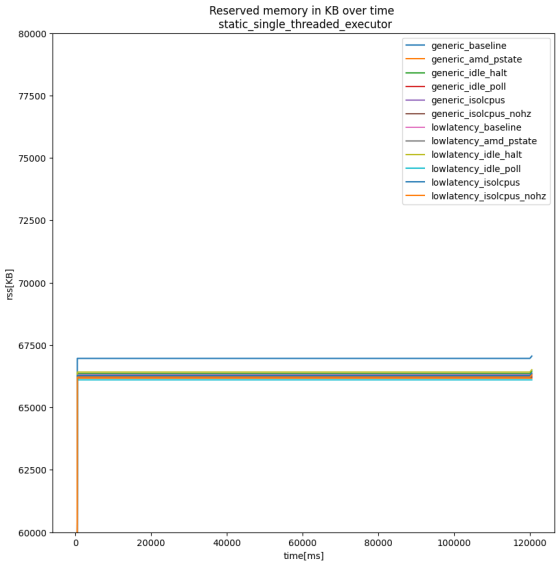


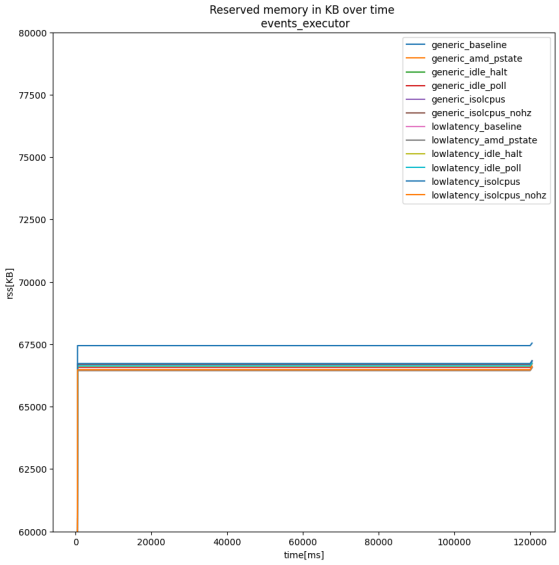


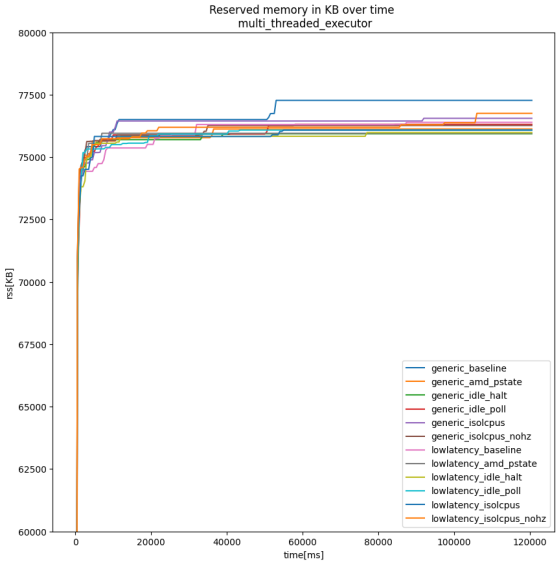


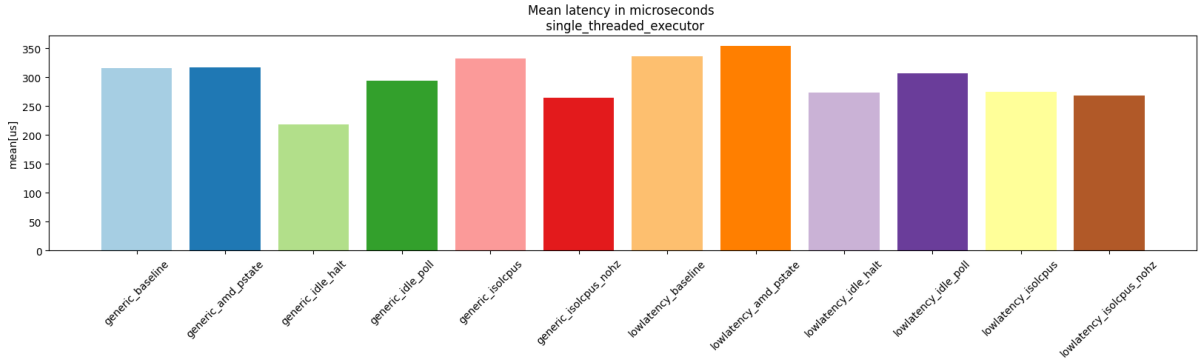


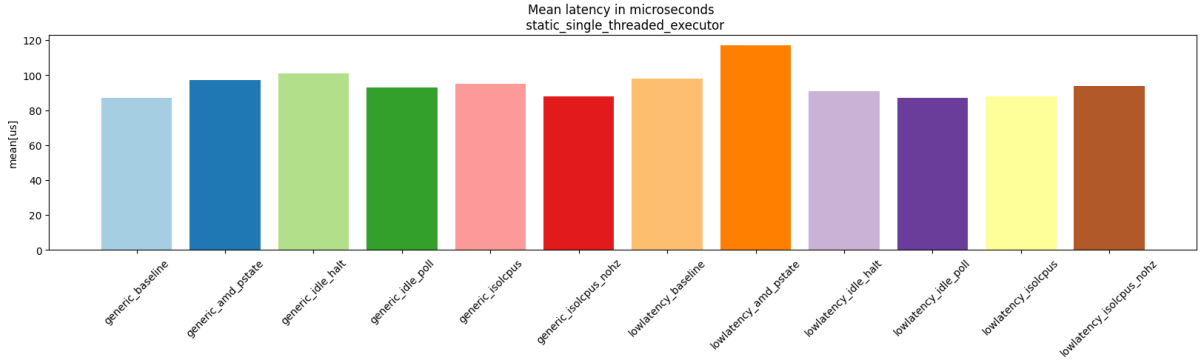

Reserved memory in KB over time
single_threaded_executor
rss[KB]
time[ms]
generic_baseline
generic_amd_pstate
generic_idle_halt
generic_idle_poll
generic_isolcpus
generic_isolcpus_nohz
lowlatency_baseline
lowlatency_amd_pstate
lowlatency_idle_halt
lowlatency_idle_poll
lowlatency_isolcpus
lowlatency_isolcpus_nohz

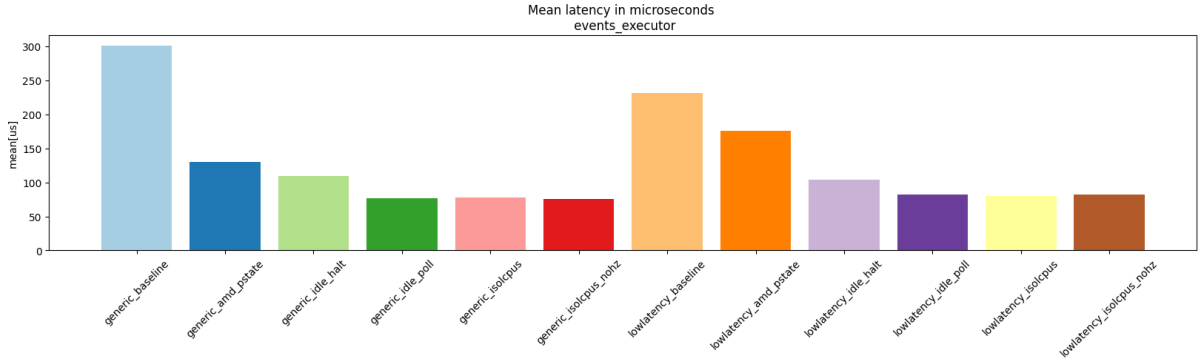

Reserved memory in KB over time
static_single_threaded_executor
rss[KB]
time[ms]
generic_baseline
generic_amd_pstate
generic_idle_halt
generic_idle_poll
generic_isolcpus
generic_isolcpus_nohz
lowlatency_baseline
lowlatency_amd_pstate
lowlatency_idle_halt
lowlatency_idle_poll
lowlatency_isolcpus
lowlatency_isolcpus_nohz

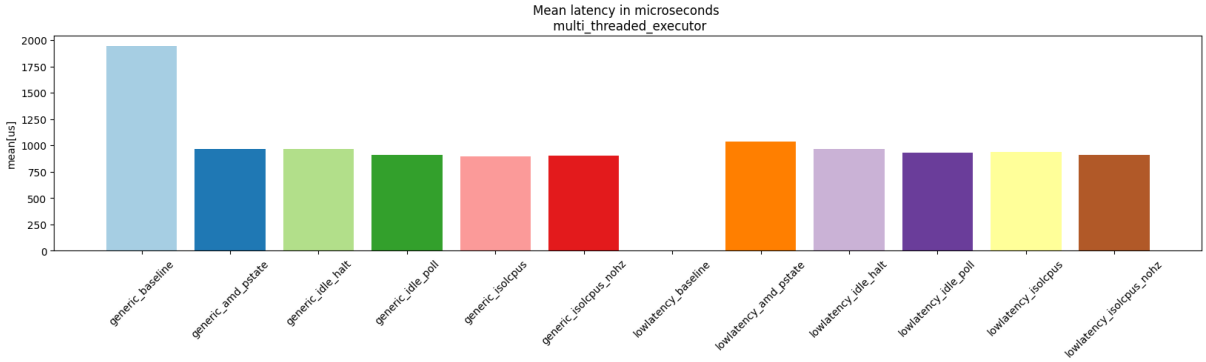

Reserved memory in KB over time
events_executor
rss[KB]
time[ms]
generic_baseline
generic_amd_pstate
generic_idle_halt
generic_idle_poll
generic_isolcpus
generic_isolcpus_nohz
lowlatency_baseline
lowlatency_amd_pstate
lowlatency_idle_halt
lowlatency_idle_poll
lowlatency_isolcpus
lowlatency_isolcpus_nohz

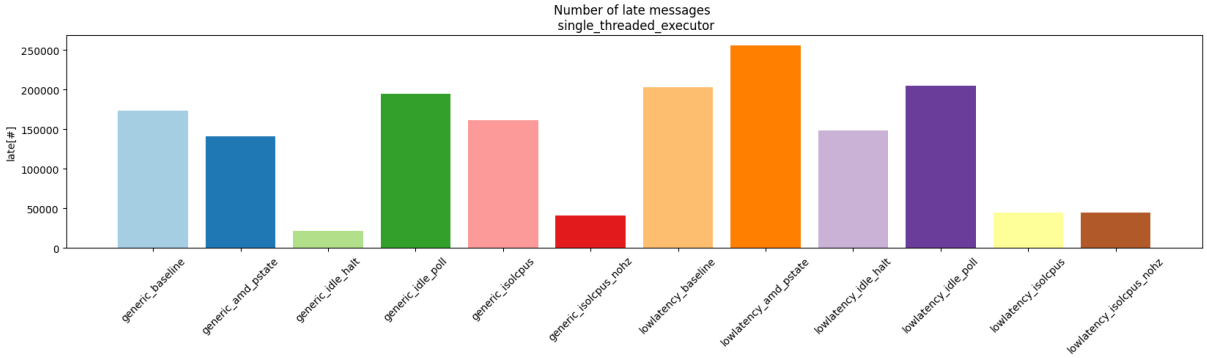

Reserved memory in KB over time
multi_threaded_executor
rss[KB]
time[ms]
generic_baseline
generic_amd_pstate
generic_idle_halt
generic_idle_poll
generic_isolcpus
generic_isolcpus_nohz
lowlatency_baseline
lowlatency_amd_pstate
lowlatency_idle_halt
lowlatency_idle_poll
lowlatency_isolcpus
lowlatency_isolcpus_nohz

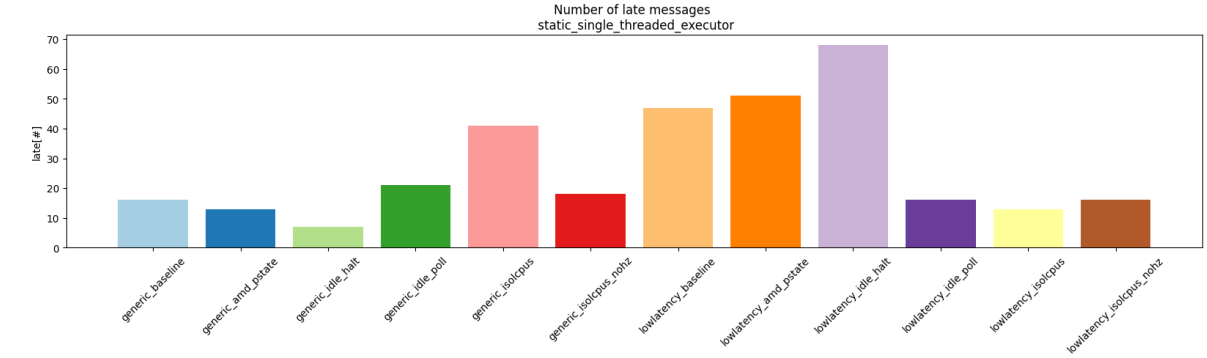

Mean latency in microseconds
single_threaded_executor
mean[us]
0
50
100
150
200
250
300
350
generic_baseline
generic_amd_pstate
generic_idle_halt
generic_idle_poll
generic_isolcpus
generic_isolcpus_nohz
lowlatency_baseline
lowlatency_amd_pstate
lowlatency_idle_halt
lowlatency_idle_poll
lowlatency_isolcpus
lowlatency_isolcpus_nohz

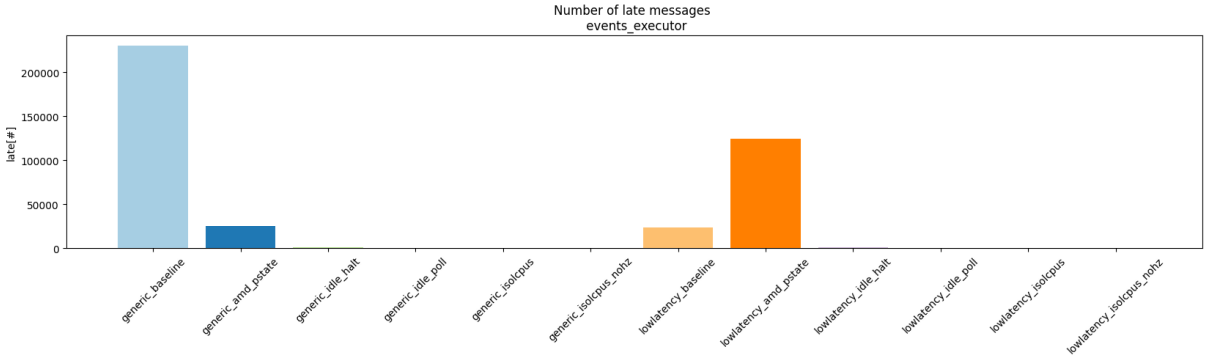

Mean latency in microseconds
static_single_threaded_executor
mean[us]
0
20
40
60
80
100
120
generic_baseline
generic_amd_pstate
generic_idle_halt
generic_idle_poll
generic_isolcpus
generic_isolcpus_nohz
lowlatency_baseline
lowlatency_amd_pstate
lowlatency_idle_halt
lowlatency_idle_poll
lowlatency_isolcpus
lowlatency_isolcpus_nohz

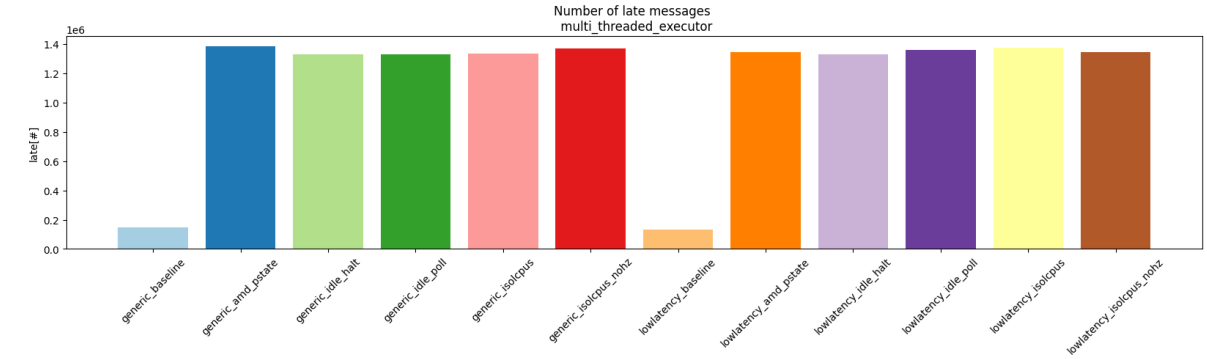

Mean latency in microseconds
events_executor
mean[us]
0
50
100
150
200
250
300
generic_baseline
generic_amd_pstate
generic_idle_halt
generic_idle_poll
generic_isolcpus
generic_isolcpus_nohz
lowlatency_baseline
lowlatency_amd_pstate
lowlatency_idle_halt
lowlatency_idle_poll
lowlatency_isolcpus
lowlatency_isolcpus_nohz

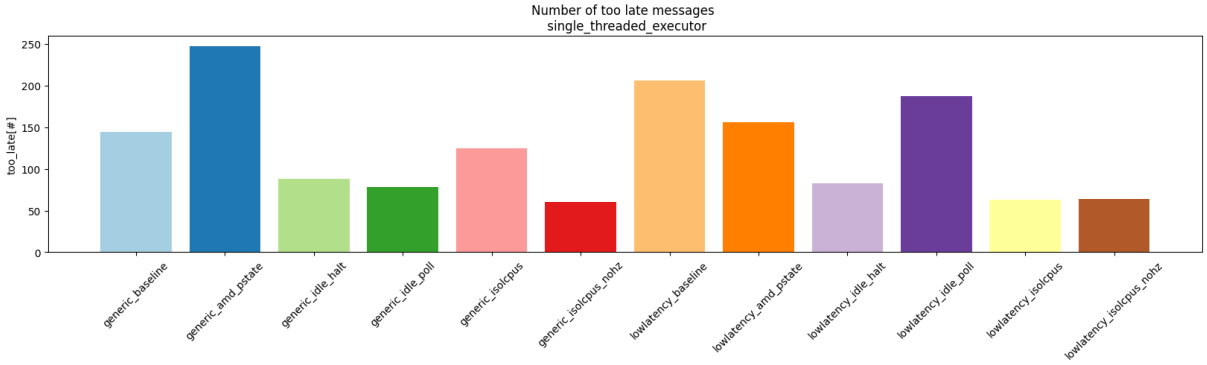

Mean latency in microseconds
multi_threaded_executor
mean[us]
0
250
500
750
1000
1250
1500
1750
2000
generic_baseline
generic_amd_pstate
generic_idle_halt
generic_idle_poll
generic_isolcpus
generic_isolcpus_nohz
lowlatency_baseline
lowlatency_amd_pstate
lowlatency_idle_halt
lowlatency_idle_poll
lowlatency_isolcpus
lowlatency_isolcpus_nohz

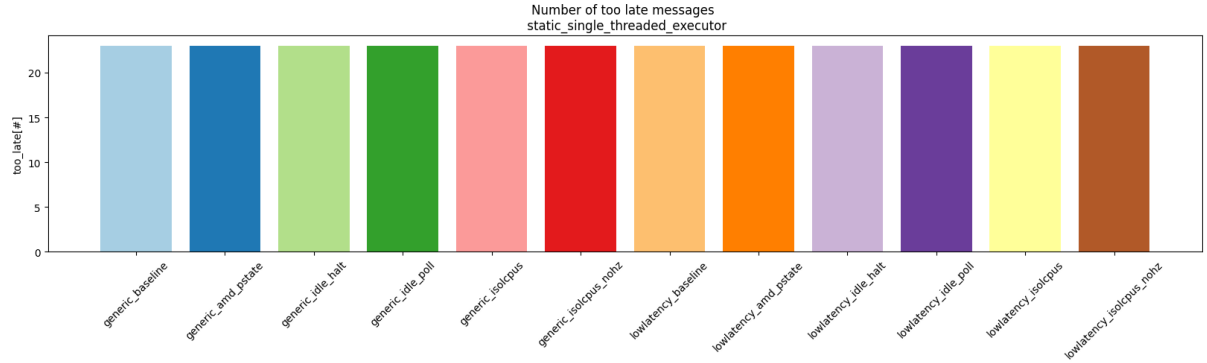

Number of late messages
single_threaded_executor
late[#]
0
50000
100000
150000
200000
250000
generic_baseline
generic_amd_pstate
generic_idle_halt
generic_idle_poll
generic_isolcpus
generic_isolcpus_nohz
lowlatency_baseline
lowlatency_amd_pstate
lowlatency_idle_halt
lowlatency_idle_poll
lowlatency_isolcpus
lowlatency_isolcpus_nohz

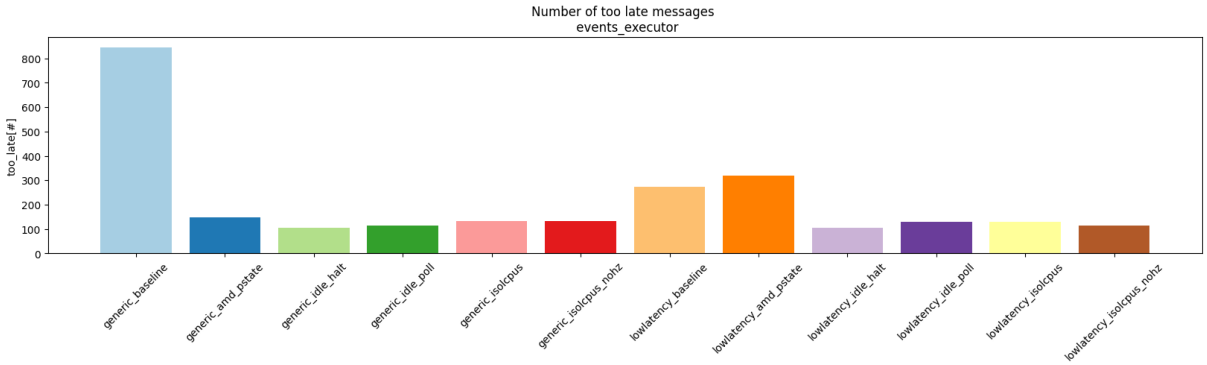

Number of late messages
static_single_threaded_executor
late[#]
0
10
20
30
40
50
60
70
generic_baseline
generic_amd_pstate
generic_idle_halt
generic_idle_poll
generic_isolcpus
generic_isolcpus_nohz
lowlatency_baseline
lowlatency_amd_pstate
lowlatency_idle_halt
lowlatency_idle_poll
lowlatency_isolcpus
lowlatency_isolcpus_nohz

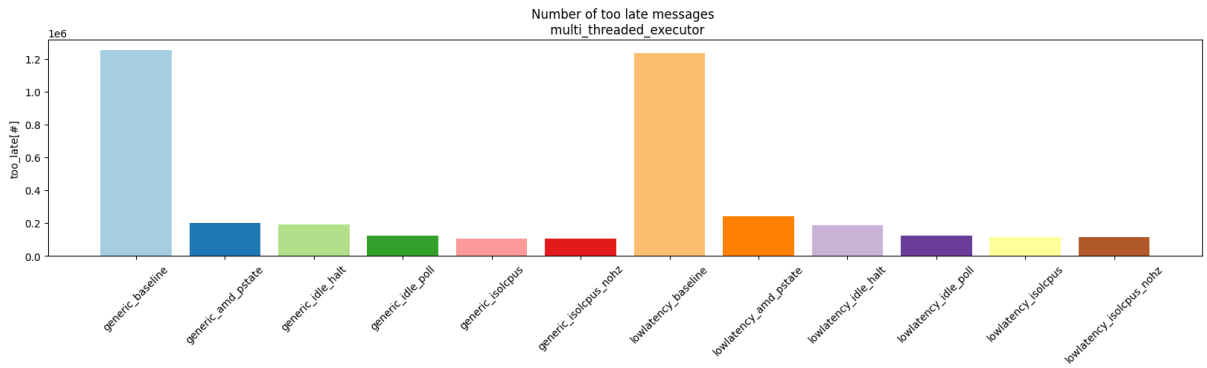

Number of late messages
events_executor
late[#]
0
50000
100000
150000
200000
generic_baseline
generic_amd_pstate
generic_idle_halt
generic_idle_poll
generic_isolcpus
generic_isolcpus_nohz
lowlatency_baseline
lowlatency_amd_pstate
lowlatency_idle_halt
lowlatency_idle_poll
lowlatency_isolcpus
lowlatency_isolcpus_nohz


Number of late messages
multi_threaded_executor
1e6
late[#]
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
generic_baseline
generic_amd_pstate
generic_idle_halt
generic_idle_poll
generic_isolcpus
generic_isolcpus_nohz
lowlatency_baseline
lowlatency_amd_pstate
lowlatency_idle_halt
lowlatency_idle_poll
lowlatency_isolcpus
lowlatency_isolcpus_nohz


Number of too late messages
single_threaded_executor
too_late[#]
0
50
100
150
200
250
generic_baseline
generic_amd_pstate
generic_idle_halt
generic_idle_poll
generic_isolcpus
generic_isolcpus_nohz
lowlatency_baseline
lowlatency_amd_pstate
lowlatency_idle_halt
lowlatency_idle_poll
lowlatency_isolcpus
lowlatency_isolcpus_nohz


Number of too late messages
static_single_threaded_executor
too_late[#]
0
5
10
15
20
generic_baseline
generic_amd_pstate
generic_idle_halt
generic_idle_poll
generic_isolcpus
generic_isolcpus_nohz
lowlatency_baseline
lowlatency_amd_pstate
lowlatency_idle_halt
lowlatency_idle_poll
lowlatency_isolcpus
lowlatency_isolcpus_nohz


Number of too late messages
events_executor
too_late[#]
0
100
200
300
400
500
600
700
800
generic_baseline
generic_amd_pstate
generic_idle_halt
generic_idle_poll
generic_isolcpus
generic_isolcpus_nohz
lowlatency_baseline
lowlatency_amd_pstate
lowlatency_idle_halt
lowlatency_idle_poll
lowlatency_isolcpus
lowlatency_isolcpus_nohz


Number of too late messages
multi_threaded_executor
1e6
too_late[#]
0.0
0.2
0.4
0.6
0.8
1.0
1.2
generic_baseline
generic_amd_pstate
generic_idle_halt
generic_idle_poll
generic_isolcpus
generic_isolcpus_nohz
lowlatency_baseline
lowlatency_amd_pstate
lowlatency_idle_halt
lowlatency_idle_poll
lowlatency_isolcpus
lowlatency_isolcpus_nohz

Interpretation of results

EventsExecutor

- CPU usage
  - without changing idle settings, lowlatency increases cpu usage
  - **best results:** `lowlatency idle poll`
    - `generic`/`lowlatency` does not really factor in
    - isolcpus does not increase performance in benchmark
- Mean latency
  - `isolcpus` does not really improve (only minimally for `lowlatency`)
  - `generic` actually has minimally better results than `lowlatency`
  - **best results:** from `idle poll` onward
- Late messages
  - almost halfed by `lowlatency` for baseline
  - weird: `amd_pstate` significantly improve for `generic`, but makes it worse for `lowlatency`
  - **best results:** both `isolcpus`
    - `generic`/`lowlatency` does not really factor in
    - but everything from `idle poll` onward is about the same
- Too Late messages
  - `lowlatency` significantly improves `baseline`
  - `generic amd_pstate` significantly better than `lowlatency amd_pstate`
  - **best results:** both `idle halt`
    - `generic`/`lowlatency` does not really factor in
    - `isolcpus` increases number of too late messages in comparison

MultiThreadedExecutor

- CPU usage
  - `generic baseline` and `lowlatency baseline` have increased cpu usage
  - all others about the same (no significant changes)
- Mean latency

  - `amd_pstate` has huge improvement
  - `generic` kernel seems generally better
  - `isolcpus` minimally improves for `generic`, but makes it worse for `lowlatency`
  - `isolcpus_nohz` is better than `isolcpus` for `lowlatency`
  - **best results:** `generic isolcpus` (then `lowlatency isolcpus nohz`, `generic isolcpus nohz`, `generic idle poll` are about the same next)

- Late messages
  - **best results:** `lowlatency baseline` (`generic baseline` close second)
  - all other runs significantly worse
  - `generic`/`lowlatency` does not really factor in

- Too Late messages
  - `amd_pstate` significantly decreases number of too late messages
  - `nohz` brings a little improvement
  - **best results:** both `generic isolcpus` (both `lowlatency isolcpus` a little worse)
    * overall `generic`/`lowlatency` does not really factor in
    * `isolcpus` decreases number of too late messages in comparison

Different experiment configurations

Generic Kernel

BASELINE generic kernel

Benchmarking Run Conditions

- generic kernel
- cycloneDDS
- no DDS memory sharing

CPU

- driver: `acpi-cpufreq`
- govenor: `schedutil`
- frequency: 1.40GHz - 1.80GHz
- no isolcpus/taskset pinning

```
BOOT_IMAGE=/boot/vmlinuz-5.19.0-45-generic root=UUID=cd5e7bca-b3b7-4
f05-a542-65db103a4690 ro quiet
```

AMD_PSTATE generic kernel

Benchmarking Run Conditions

- generic kernel
- cycloneDDS
- no DDS memory sharing

CPU

- driver: `amd-pstate`
- govenor: `performance`
- frequency: 400MHz - 4.37GHz
- no isolcpus/taskset pinning

```
BOOT_IMAGE=/boot/vmlinuz-5.19.0-45-generic root=UUID=cd5e7bca-b3b7
-4f05-a542-65db103a4690 ro quiet amd_pstate=passive amd_pstate.
shared_mem=1
```

IDLE_HALT generic kernel

Benchmarking Run Conditions

- generic kernel
- cycloneDDS
- no DDS memory sharing

CPU

- forced c-state 0 by `idle=halt` cmdline, but preserve p-states with HLT instruction
- driver: `amd-pstate`
- govenor: `performance`
- frequency: 400MHz - 4.37GHz
- no isolcpus/taskset pinning

```
BOOT_IMAGE=/boot/vmlinuz-5.19.0-45-generic root=UUID=cd5e7bca-b3b7-4
f05-a542-65db103a4690 ro quiet idle=halt amd_pstate=passive amd_pstate
.shared_mem=1
```

IDLE_POLL generic kernel

Benchmarking Run Conditions

- generic kernel
- cycloneDDS
- no DDS memory sharing

CPU

- forced c-state 0 by `idle=poll` cmdline also disabling p-states completely
- driver: `amd-pstate`
- govenor: `performance`
- frequency: 400MHz - 4.37GHz
- no isolcpus/taskset pinning

```
BOOT_IMAGE=/boot/vmlinuz-5.19.0-45-generic root=UUID=cd5e7bca-b3b7-4
f05-a542-65db103a4690 ro quiet idle=poll amd_pstate=passive amd_pstate
.shared_mem=1
```

ISOLCPUS generic kernel

Benchmarking Run Conditions

- generic kernel
- cycloneDDS
- no DDS memory sharing

CPU

- forced c-state 0 by `idle=poll` cmdline also disabling p-states completely
- driver: `amd-pstate`
- govenor: `performance`
- frequency: 400MHz - 4.37GHz
- isolcpus cores 0-11 + chrt -r 1 taskset -c 0-11 pinning

```
BOOT_IMAGE=/boot/vmlinuz-5.19.0-45-generic root=UUID=cd5e7bca-b3b7
-4f05-a542-65db103a4690 ro quiet isolcpus=0-11 idle=poll amd_pstate=
passive amd_pstate.shared_mem=1
```

ISOLCPUS_NOHZ generic kernel

Benchmarking Run Conditions

- generic kernel
- cycloneDDS
- no DDS memory sharing

CPU

- forced c-state 0 by `idle=poll` cmdline also disabling p-states completely
- driver: `amd-pstate`
- govenor: `performance`
- frequency: 400MHz - 4.37GHz
- isolcpus & nohz cores 0-11 + chrt -r 1 taskset -c 0-11 pinning

```
BOOT_IMAGE=/boot/vmlinuz-5.19.0-45-generic root=UUID=cd5e7bca-b3b7-4
f05-a542-65db103a4690 ro quiet isolcpus=0-11 nohz_full=0-11 idle=poll
 amd_pstate=passive amd_pstate.shared_mem=1
```

Lowlatency Kernel

BASELINE lowlatency kernel

Benchmarking Run Conditions

- lowlatency kernel
- cycloneDDS
- no DDS memory sharing

CPU

- driver: `acpi-cpufreq`
- govenor: `schedutil`
- frequency: 1.40GHz - 1.80GHz
- no isolcpus/taskset pinning

```
BOOT_IMAGE=/boot/vmlinuz-5.19.0-1027-lowlatency root=UUID=cd5e7bca-b3b7-4f05-a542-65db103a4690 ro quiet
```

AMD_PSTATE lowlatency kernel

Benchmarking Run Conditions

- lowlatency kernel
- cycloneDDS
- no DDS memory sharing

CPU

- driver: `amd-pstate`
- govenor: `performance`
- frequency: 400MHz - 4.37GHz
- no isolcpus/taskset pinning

```
BOOT_IMAGE=/boot/vmlinuz-5.19.0-1027-lowlatency root=UUID=cd5e7bca-b3b7-4f05-a542-65db103a4690 ro quiet amd_pstate=passive amd_pstate.shared_mem=1
```

IDLE_HALT lowlatency kernel

Benchmarking Run Conditions

- lowlatency kernel
- cycloneDDS
- no DDS memory sharing

CPU

- forced c-state 0 by `idle=halt` cmdline, but preserve p-states with HLT instruction
- driver: `amd-pstate`
- govenor: `performance`
- frequency: 400MHz - 4.37GHz
- no isolcpus/taskset pinning

```
BOOT_IMAGE=/boot/vmlinuz-5.19.0-1027-lowlatency root=UUID=cd5e7bca
-b3b7-4f05-a542-65db103a4690 ro quiet idle=halt amd_pstate=passive
amd_pstate.shared_mem=1
```

IDLE_POLL lowlatency kernel

Benchmarking Run Conditions

- lowlatency kernel
- cycloneDDS
- no DDS memory sharing

CPU

- forced c-state 0 by `idle=poll` cmdline also disabling p-states completely
- driver: `amd-pstate`
- govenor: `performance`
- frequency: 400MHz - 4.37GHz
- no isolcpus/taskset pinning

```
BOOT_IMAGE=/boot/vmlinuz-5.19.0-1027-lowlatency root=UUID=cd5e7bca
-b3b7-4f05-a542-65db103a4690 ro quiet idle=poll amd_pstate=passive
amd_pstate.shared_mem=1
```

ISOLCPUS lowlatency kernel

Benchmarking Run Conditions

- lowlatency kernel
- cycloneDDS
- no DDS memory sharing

CPU

- forced c-state 0 by `idle=poll` cmdline also disabling p-states completely
- driver: `amd-pstate`
- govenor: `performance`
- frequency: 400MHz - 4.37GHz
- isolcpus cores 0-11 + chrt -r 1 taskset -c 0-11 pinning

```
BOOT_IMAGE=/boot/vmlinuz-5.19.0-1027-lowlatency root=UUID=cd5e7bca-
b3b7-4f05-a542-65db103a4690 ro quiet isolcpus=0-11 idle=poll amd_pstate
=passive amd_pstate.shared_mem=1
```

ISOLCPUS_NOHZ lowlatency kernel

Benchmarking Run Conditions

- lowlatency kernel
- cycloneDDS
- no DDS memory sharing

CPU

- forced c-state 0 by `idle=poll` cmdline also disabling p-states completely
- driver: `amd-pstate`
- govenor: `performance`
- frequency: 400MHz - 4.37GHz
- isolcpus & no_hz cores 0-11 + chrt -r 1 taskset -c 0-11 pinning

```
BOOT_IMAGE=/boot/vmlinuz-5.19.0-1027-lowlatency root=UUID=cd5e7bca
-b3b7-4f05-a542-65db103a4690 ro quiet isolcpus=0-11 nohz_full=0-11
idle=poll amd_pstate=passive amd_pstate.shared_mem=1
```