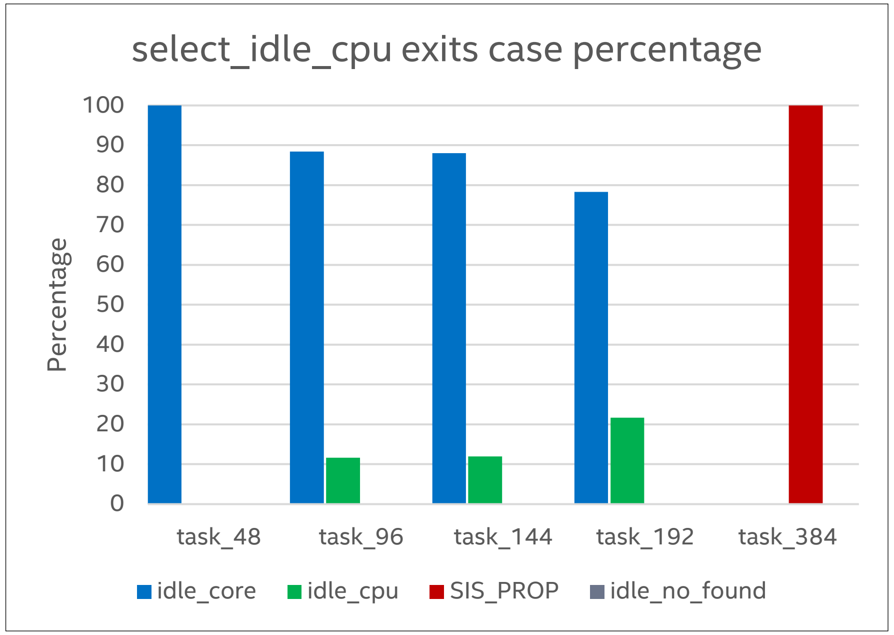
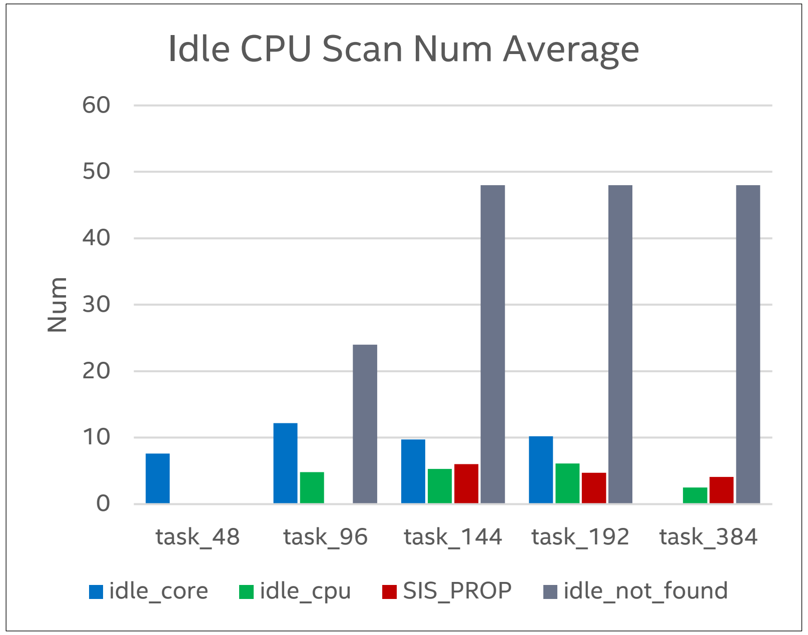
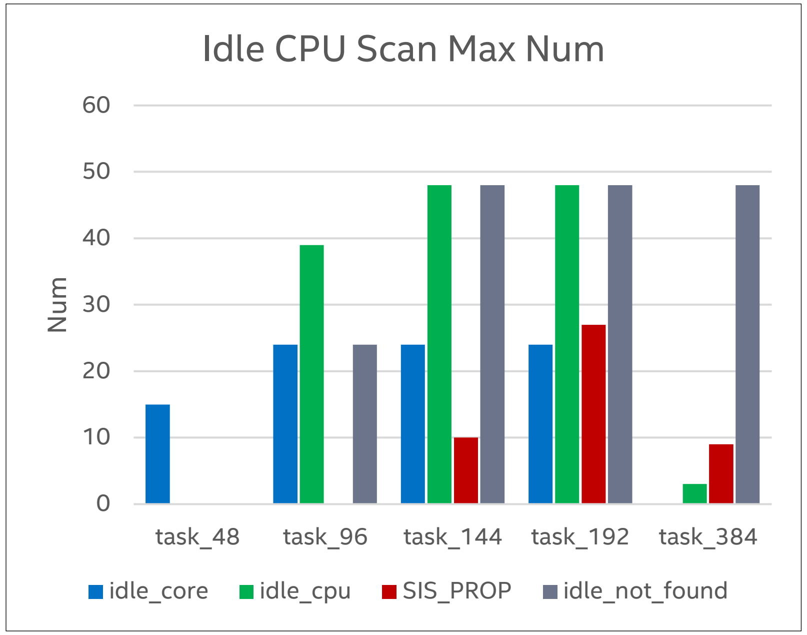
Problem: select_idle_cpu() not scalable

- SIS_PROP not work as expected
  - Idle core scan not throttled at all
  - Idle CPU scan not throttled very well
- Select_idle_cpu() scale poorly, searching up to max number of LLC CPUs frequently



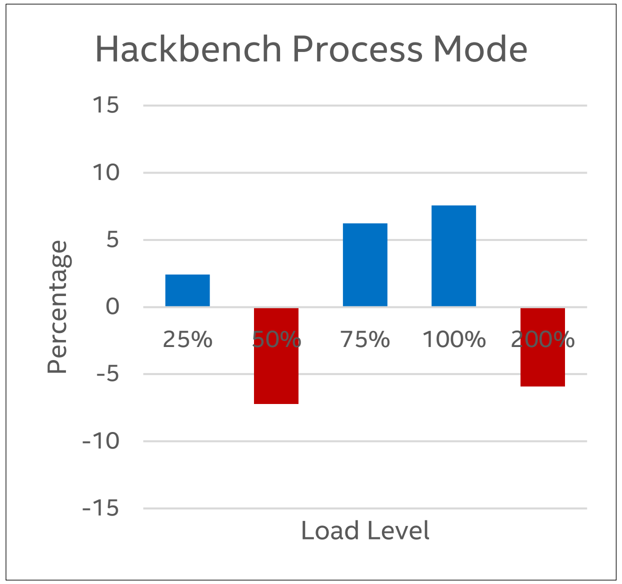


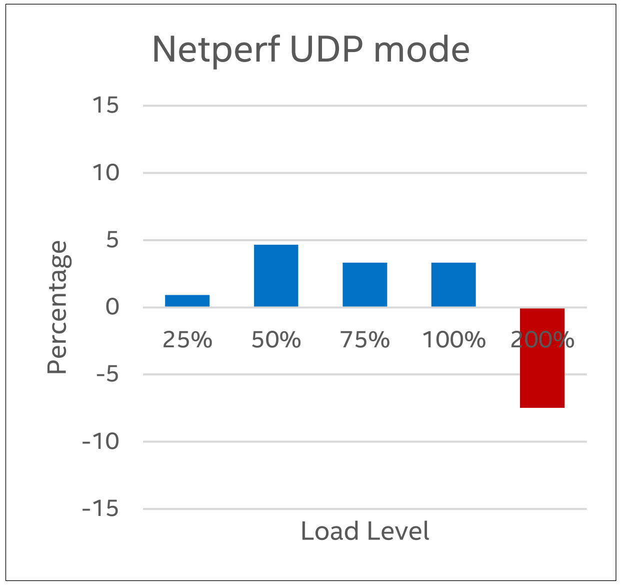


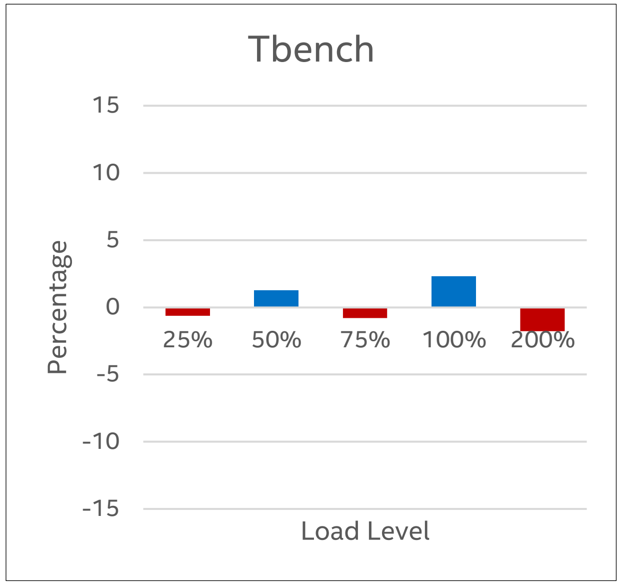
- **Hardware: 4 nodes , 96 cores, 192 CPUs (24core/48HT in one LLC domain)**

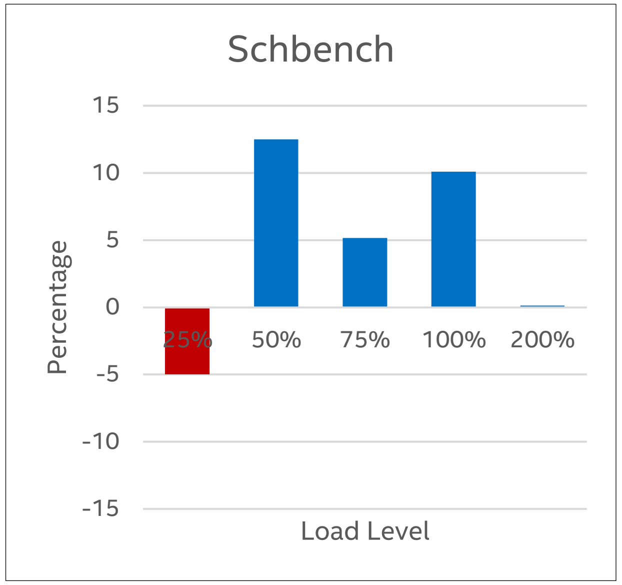
Proposal: Idle CPU Mask

- Track Idle CPUs per LLC domain
  - Bit Set every Idle entry
  - Bit Clear every scheduler tick if not idle (update ratelimited)
- Task wakeup path very sensitive to change
  - Scan efficiency improved but performance not universal win





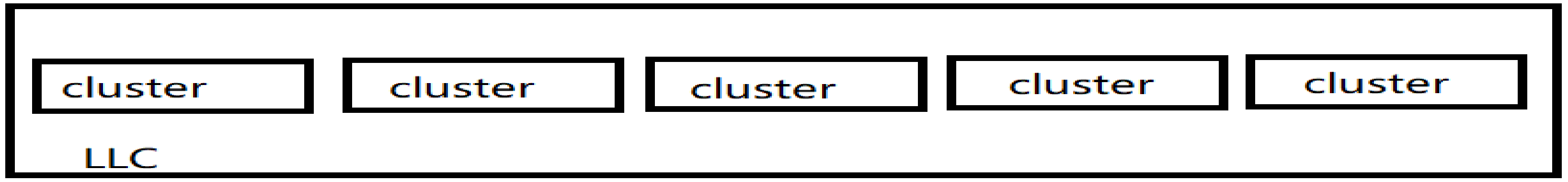




- **Kernel: V5.14 V.S. Idle_CPU_mask V10**

Cluster Topology Level

- Hardware Topology
  - ARM64 Kunpeng920 32/24cores share LLC, each 4 cores of them share L3 tag/internal bus
  - X86 Jacobsville has 24 cores sharing LLC, but each 4 cores sharing L2



- Needs
  - Add scheduler level for cluster to support load balance between clusters to decrease resource contention and increase memory bandwidth

✓ SPECrate mcf has up to +25.1% on Jacobsville ; + 13.574% on Kunpeng920
✓ stream has up to +19.85% on Kunpeng920
✓ Patch V1 sent after several RFCs, expecting review:
https://lore.kernel.org/lkml/20210820013008.12881-1-21cnbao@gmail.com

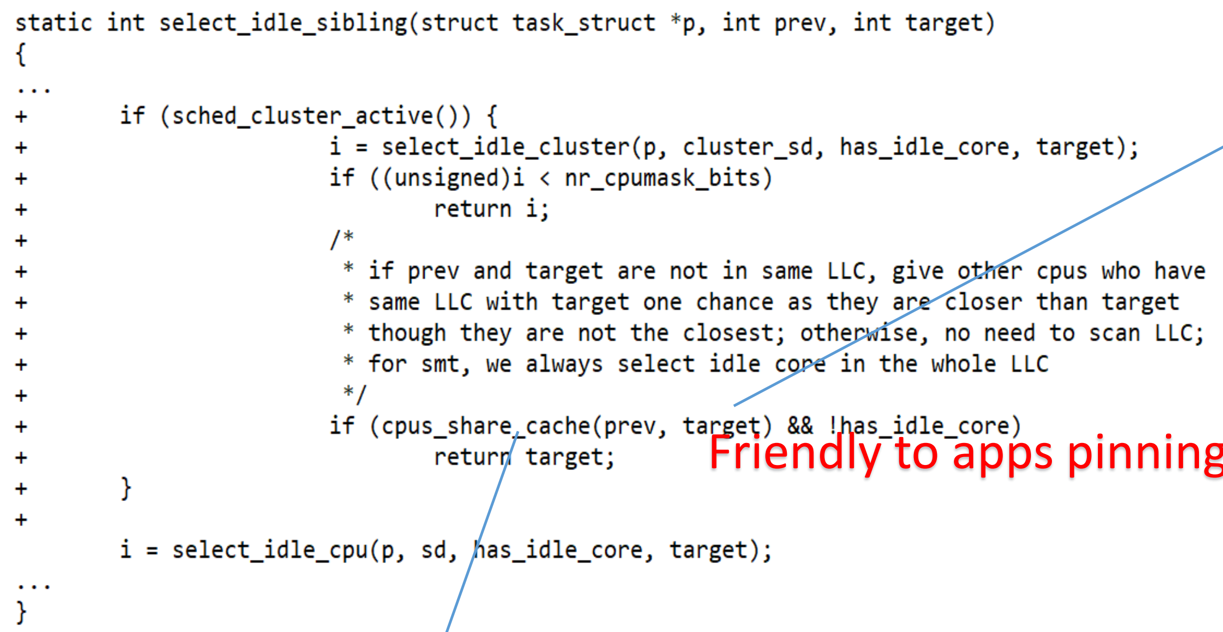
  - Scan cluster before scanning LLC in wake_affine to leverage the lower communication latency within cluster

✓ much more tricky; RFC sent but formal patch not yet. Latest version: https://op-lists.linaro.org/pipermail/linaro-open-discussions/2021-June/000219.html

Scanning cluster first

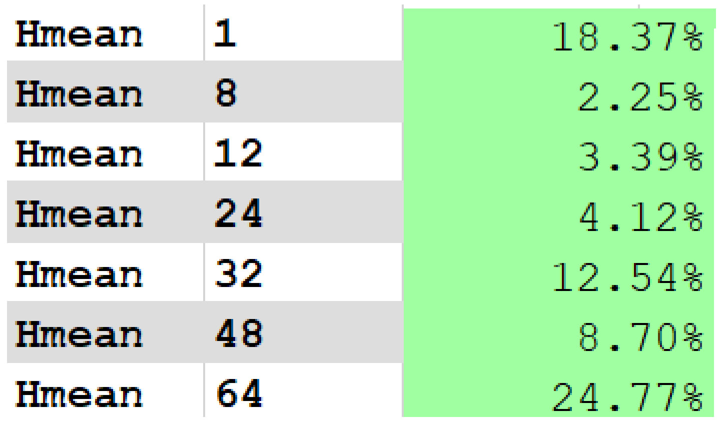
- https://op-lists.linaro.org/pipermail/linaro-open-discussions/2021-June/000221.html

Prototype:



```
static int select_idle_sibling(struct task_struct *p, int prev, int target)
{
...
+       if (sched_cluster_active()) {
+               i = select_idle_cluster(p, cluster_sd, has_idle_core, target);
+               if ((unsigned)i < nr_cpumask_bits)
+                       return i;
+               /*
+                * if prev and target are not in same LLC, give other cpus who have
+                * same LLC with target one chance as they are closer than target
+                * though they are not the closest; otherwise, no need to scan LLC;
+                * for smt, we always select idle core in the whole LLC
+                */
+               if (cpus_share_cache(prev, target) && !has_idle_core)
+                       return target;
+       }
+
        i = select_idle_cpu(p, sd, has_idle_core, target);
...
}
```

Pgbench pinning one numa



Hmean	1	18.37%
Hmean	8	2.25%
Hmean	12	3.39%
Hmean	24	4.12%
Hmean	32	12.54%
Hmean	48	8.70%
Hmean	64	24.77%

Friendly to apps pinning NUMA(lift cluster to "LLC")

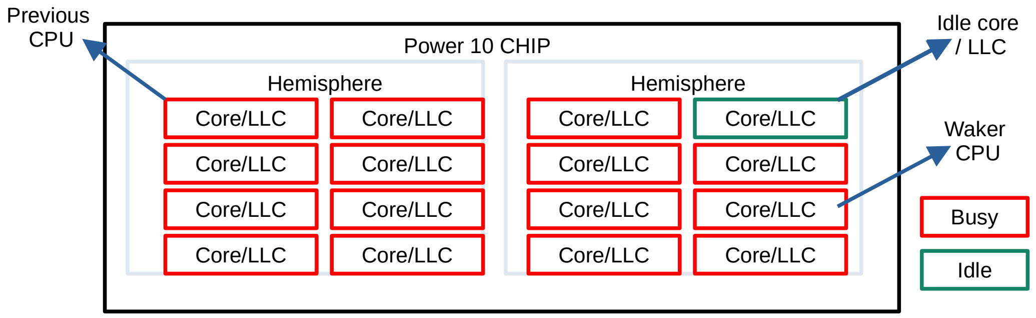
For unpinned apps -> much more tricky

- ✓ scanning cluster has scanned 4 CPUs and spent some time, how to adjust select_idle_cpu() for scanning avg time and SIS accordingly?
- ✓ Seeing idle CPU even system is busy; seeing -2% performance on busy mysqld; removing this "return" and always doing further scan can give positive performance on mysql

Prefer idle(r) cores to cache affinity

At task wakeup, Current scheduler

- Chooses CPU based on load of previous + waking CPU.
- Find an idle core or idle CPU (within chosen CPU LLC).
- On systems with lesser cores per LLC:
  - Maybe no idle cores in chosen LLC, idle cores in other LLC.
- Chosen LLC may have lower idle CPUs compared other LLC.
- Doesn't consider different cache latencies between LLCs within the socket.
  - Nearby LLC idler than the chosen LLC.



Proposed Solution : Idler LLC approach

- Maintain a list of idle cores per LLC.
- If waker and previous CPUs are from a different LLCs.
  - Choose a LLC which has idle core.
  - If no idle cores select a CPU whose LLC has more idle CPUs.
  - Else fallback to existing approach.

Fallback LLC Approach: (Archs that support different Cache latencies)

- Select an idle core within the parent sched-domain on the chosen LLC.
- - If no idle cores in parent sched-domain, select a CPU whose LLC has more idle CPUs.

Searching idle cpu/core

- Looking for an idle CPU takes time
  - It impacts local running task
  - Delays task wake up

- Limit the time spent for searching an idle CPU
  - Don’t waste time searching a nonexistent idle cpu
  - At some point it’s better to simply wake up locally and let LB migrate task

- Using local avg idle is often misleading
  - Do not reflect other CPUs state but only reflect local cpu state

- Using local cpu and task load/utilization
  - Long running task vs missing short idle cpu
  - Short running task vs a lightly loaded local cpu