Turbo-Sched

A scheduler for sustaining Turbo Frequencies for longer duration

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Outline

- Turbo Frequencies
  - Problem with Power budget
  - How to sustain?
- CFS design
  - Problem with task spreading
- TurboSched Algorithm
- Results
- Future plans

Turbo Frequencies

- Many SMP servers have support for P-states in the range of Turbo Frequencies
- These P-states burn more power
- Power budget is fixed for a chip
- Systems may be **throttled to a lower frequency** if power consumption exceeds this power budget
- This makes difficult to sustain Turbo Frequencies for longer duration

How to sustain?

CPU-IDLE

- CPU-Idle allows system to goto Idle/C-states in absence of any workload
- Deeper the C-states level, more the power savings
- Advantageous for sustaining Turbo frequencies
- Keeping fewer CPUs idle saves power which can be **channeled to busier CPUs**
- *TurboSched Policy*: keep maximum possible CPUs idle

CFS: Why cannot sustain Turbo?

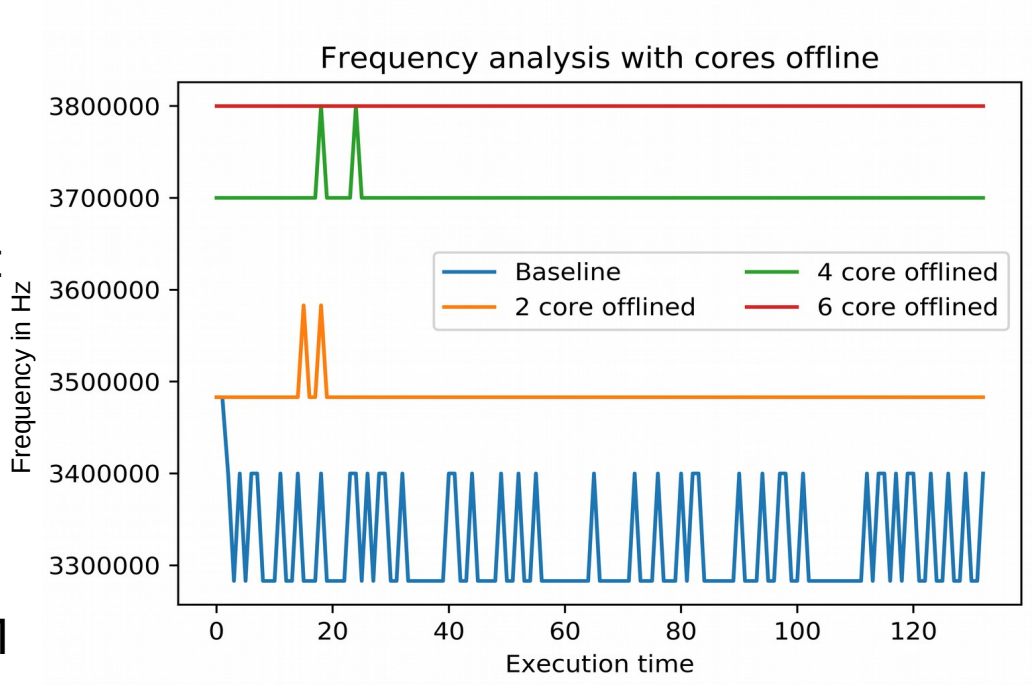
Task Spreading

- Base of CFS for SMP systems is to spread tasks as much as possible to effectively utilize system resources
- Pros:
  - Better task wake-up/turn around time
  - Better cache resource utilization
  - Better memory throughput
- Cons:
  - Wake up task on idle CPU if any available

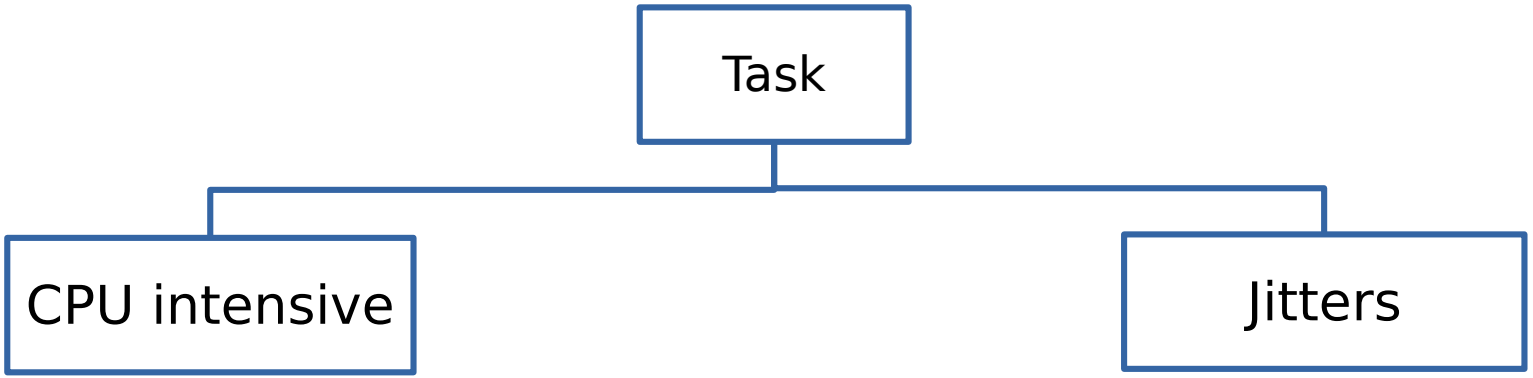
Adapting CFS for Turbo

Task Packing

- Keep fewer CPUs idle
- This allows us to over-clock few cores thereby remaining within power budget
- Experimentation
  - Hot-Plugging out few cores have shown to sustain turbo frequencies
  - Results shows Max frequency available at the given time on a IBM POWER9 system



Task classification



- Usually CPU bound important tasks
- Memory/cache hungry tasks
- Performance oriented
- ***CFS is the best algorithm***

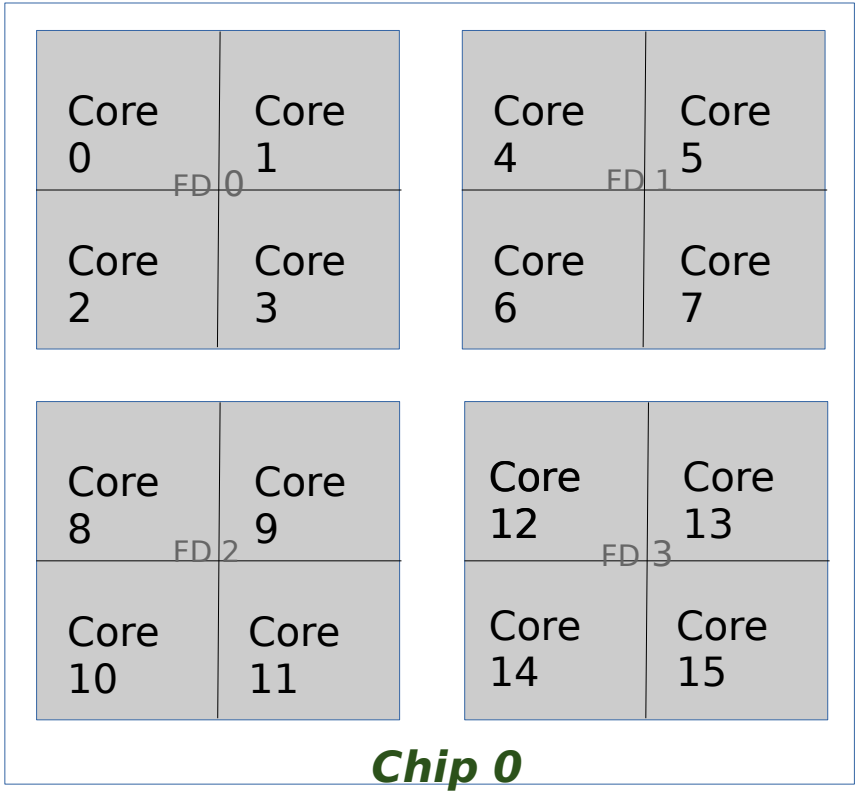
- Usually system daemons/house keeping task
- Low utilization and/or bursty workload
- ***Sleeps before load balance gets invoked***
- ***Can be packed to Intensive CPUs***
- ***CFS is not a good choice***

Frequency domain (FD)

- Many SMP systems also support *SMT or Hyper-threading modes*
- A core can have multiple threads(called CPUs) depending on SMT mode
- Frequency controlling is **per core** in such systems
- Other way around, providing *more frequency to a CPU in a core leads to more frequency for all the threads* in the core
- But, *IDLE domain is per core*
- So, **Task packing needs to be done across cores**
- TurboSched Policy: Keep maximum possible **Cores** Idle

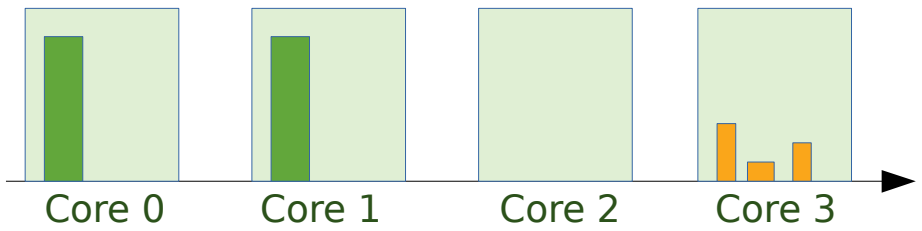
Experimental Setup

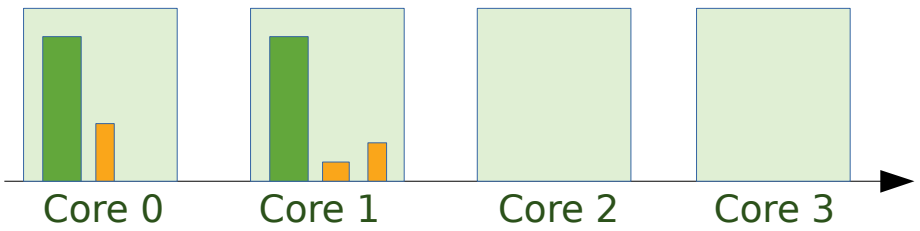
- IBM Power 9 system:
  - Arch: POWERPC
  - Cores: 16
  - SMT: 4 per core
  - Rated frequencies: 2.1 – 3.2 GHz
  - Turbo freq: 3.2 - 3.8 GHz (18%)
  - FD: Set of 4 Cores
- Workload:
  - Intensive: Integer ops, MIPS scales with freq
  - Jitter: Timed Int ops, frequency invariant
  - Sibling thread regression= ~4%



Ways to pack tasks

- **Isolate**
  - ➔ Create a dedicated core to pin all jitters there
  - ➔ Intensive tasks uses CFS spreading policy
- **Side by side packing**
  - ➔ Keep jitters on near by threads where Intensive tasks are running
  - ➔ Use CFS when no such tasks are found



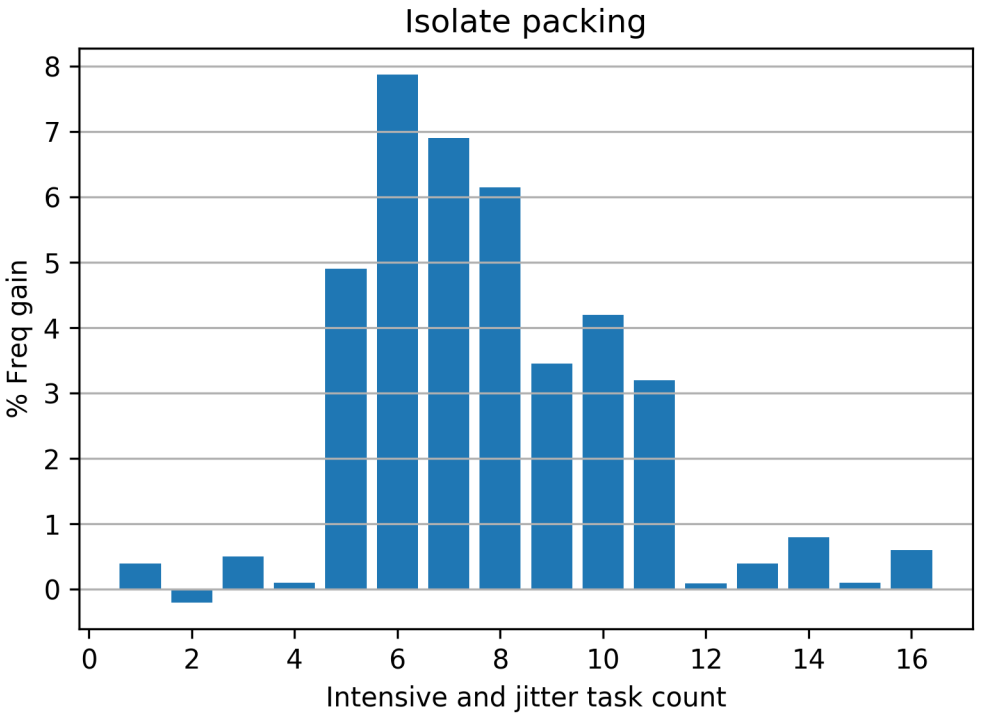


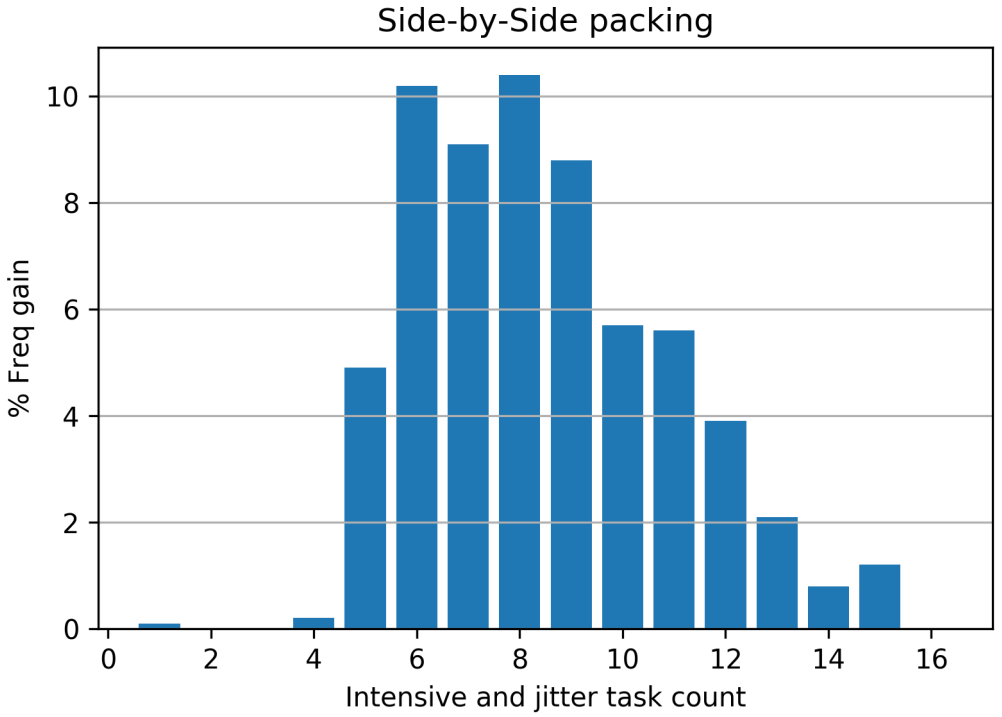
Intensive task utilization

Jitter task utilization

Isolation vs Side by side packing

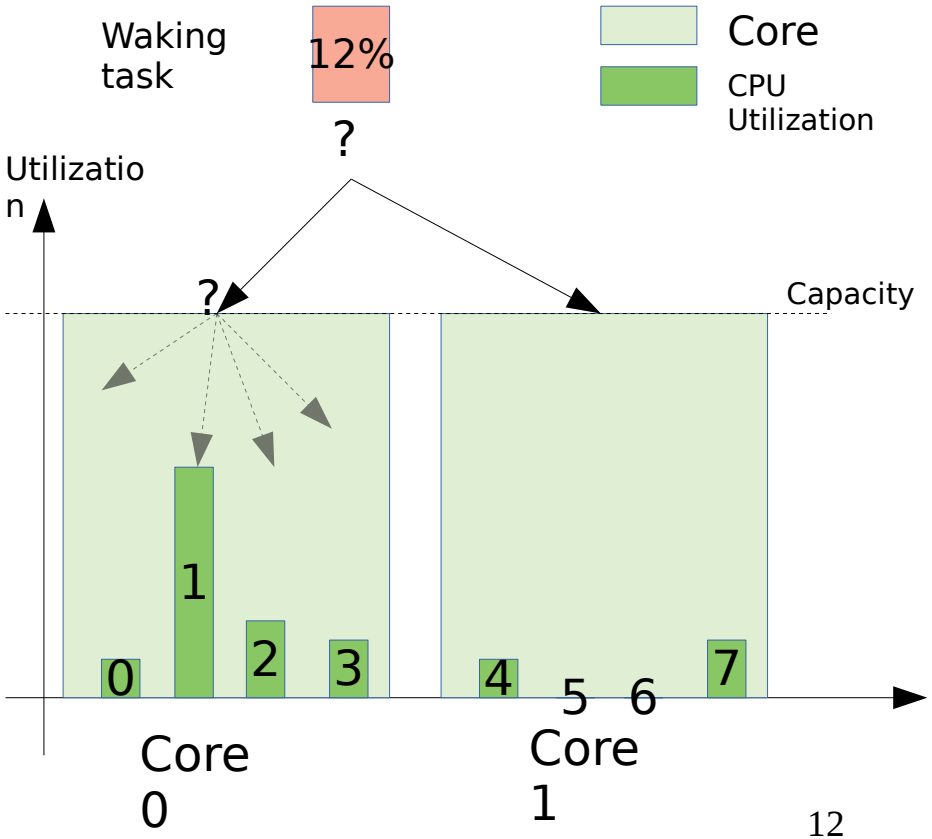
- Frequency advantage w.r.t. CFS





Task wake-up logic

- Given waking task utilization, where it should be placed?
- Given scenario:
  - CFS may pick CPU 5/6
- TurboSched:
  - Optimize for ***Performance/Watts***
  - ***Policy:*** Find **first-fit core** and **least util CPU** to wake a task
  - Iterative scan on DIE/LLC domain
  - Don’t select cores with util <12.5%



TurboSched Tipping Point

- What is ***core occupation capacity?***
- On SMT systems, the capacity of core scales linearly w.r.t. the online threads(SMT Mode).
- So,

  Core capacity= (1 +SMT-mode/8) * capacity_of(any CPU)

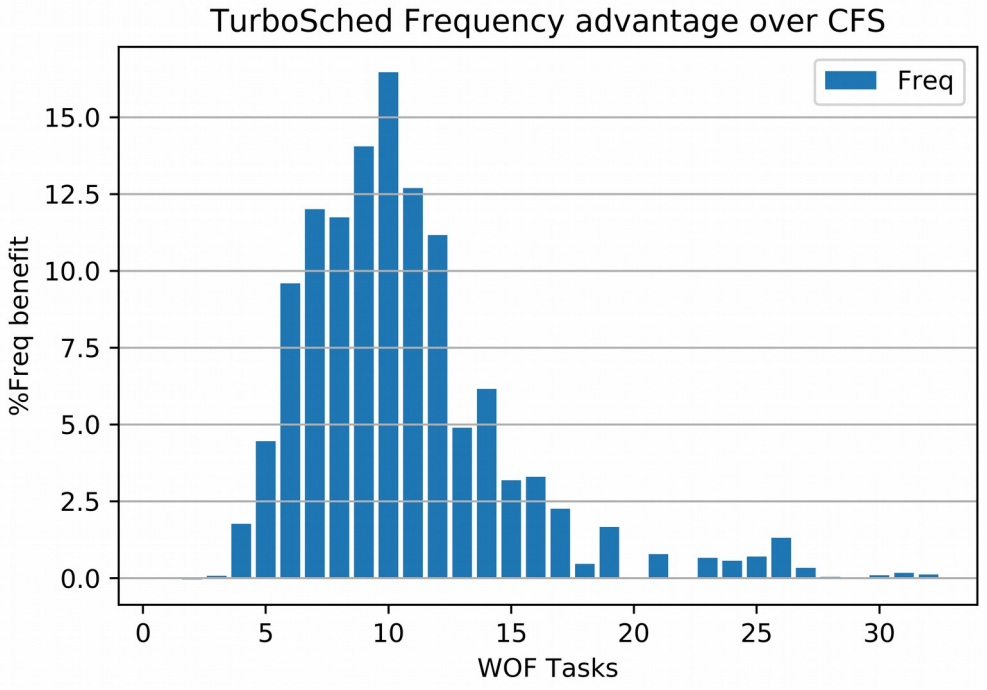
- Such that for SMT-4,

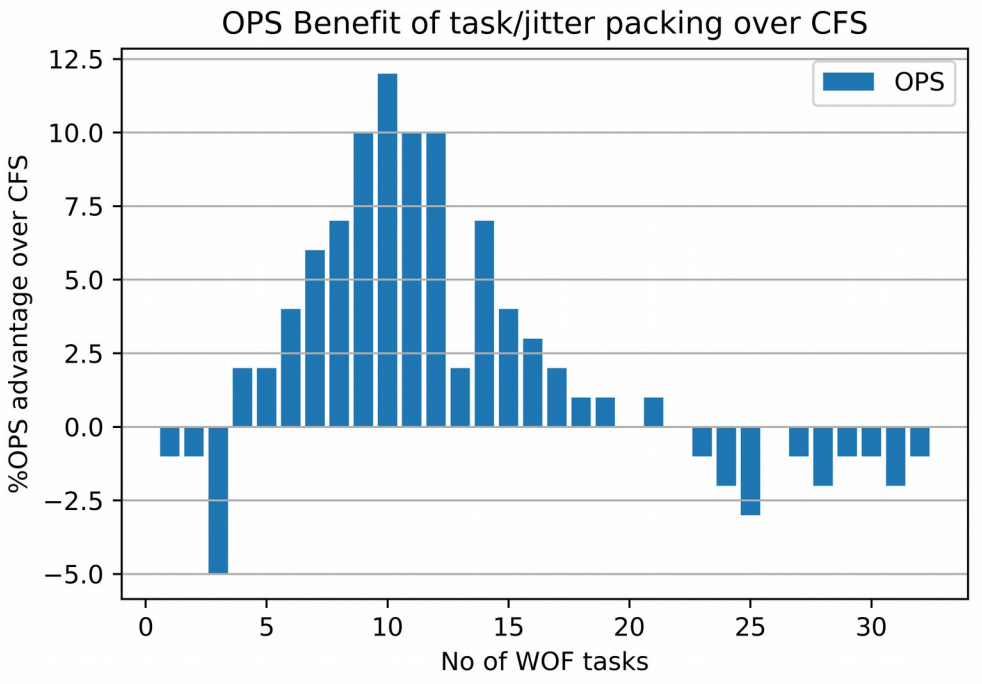
  Core cap = 1.5 * capacity_of(CPU 0)

Results

Results shows a benefit of upto

- 16% frequency benefit
- 12% in workload performance





Future

Use UCLAMP to classify tasks

- **Challenge**: Deals with CPUFREQ, while TurboSched deals with CPUIDLE

Adopt EAS model to control task placement for SMT systems as well.

- **Challenge**: Requested freq and obtained freq can be different in Turbo Range
- EM complexity is higher for >8 CPUs
- Frequency domain can be different making difficult to request frequency per thread/core basis

Contribute at TurboSched RFC: https://lkml.org/lkml/2019/5/16/824

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Thank You

Questions/Ideas?