# Towards Latency-Aware Linux Scheduling for Serverless Workloads

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# Motivation

- Originally interested in local-first self-scaling unikernels
- Running on Kubernetes requires rapid adjustment of Linux CPU shares in response to load spikes
- However, we observed that
  - At low utilisation, a small CPU share doesn't matter because of work-conservation[ OK! ]
  - At high utilisation, the system suffers performance degradation and adjusting CPU shares did not help [ BAD! ]
- Problem? How the Linux Completely Fair Scheduler (CFS) treats *cgroups*

**Fractal: Automated Application Scaling**


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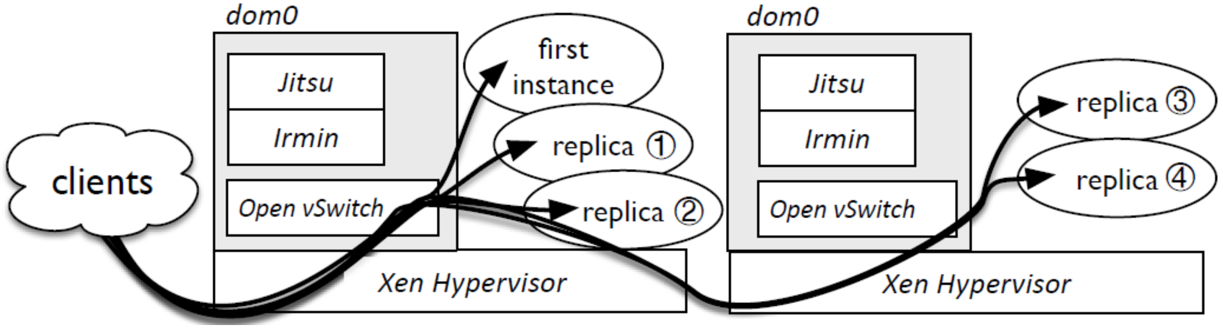
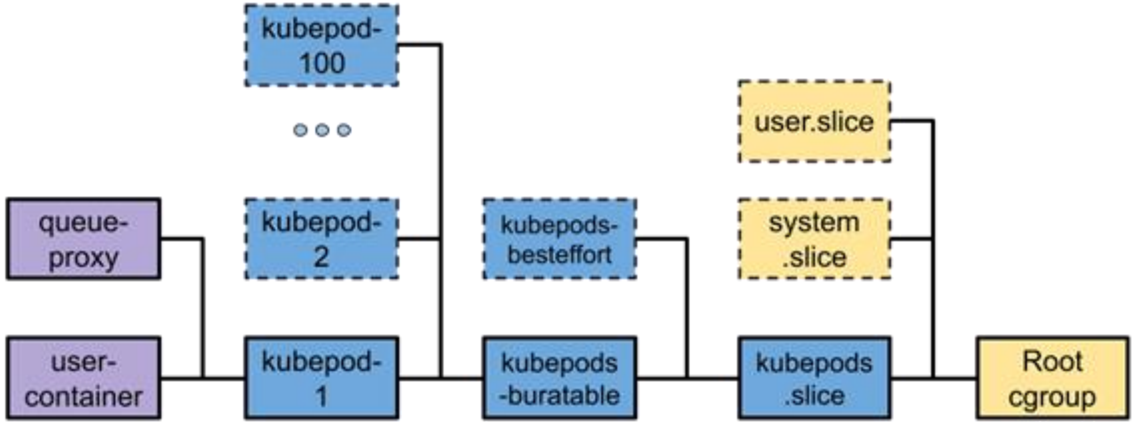
***https://arxiv.org/abs/1902.09636***

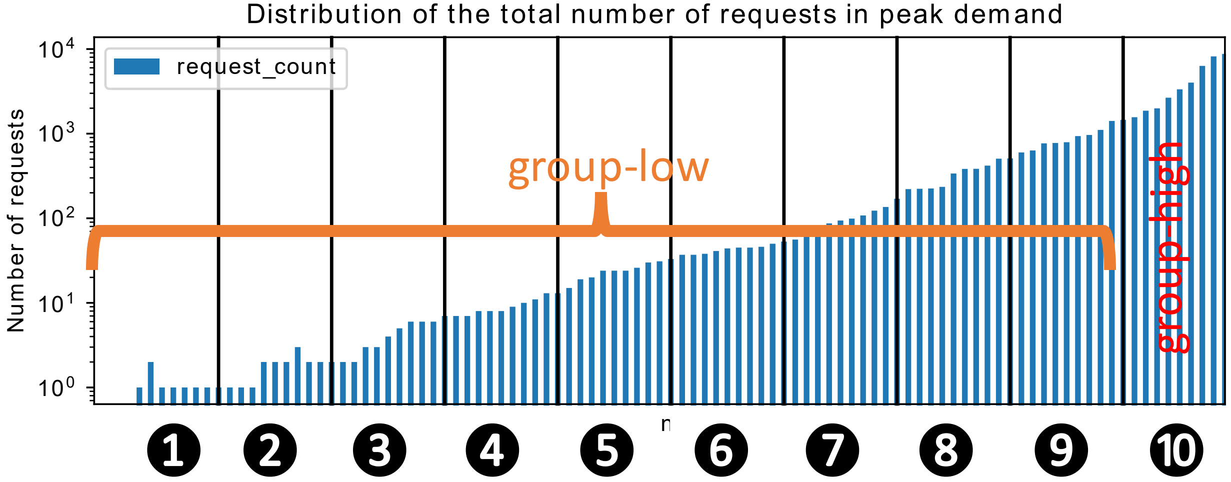


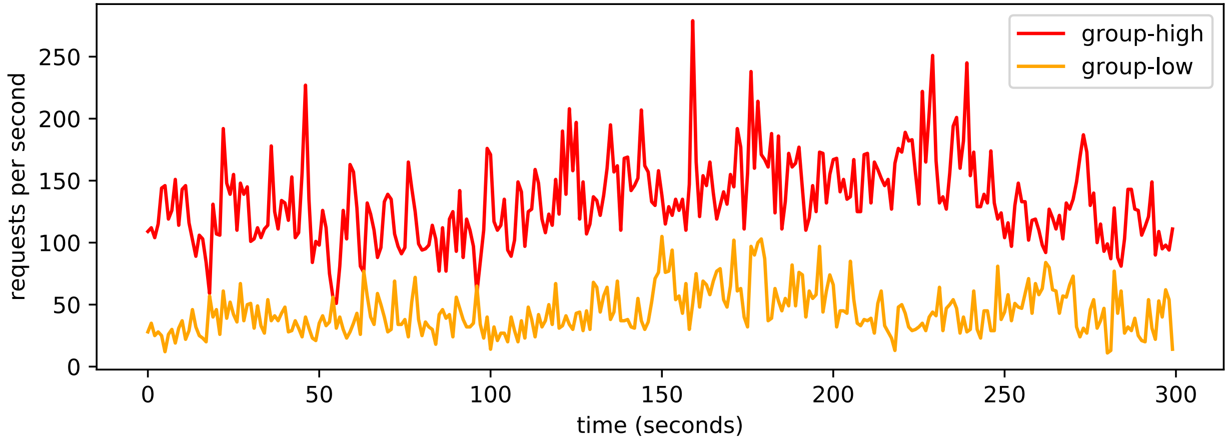
# Completely Fair Scheduling with cgroups

- CFS ensures each runnable task receives a minimum timeslice (~4ms), growing the scheduling period as needed (i.e., to 4*N* ms for *N* tasks)
- Consider high-density serverless workloads
  - $10^2$ – $10^3$ functions per node
  - Concurrent requests per function
- With group scheduling, each cgroup is scheduled as a single whole to prevent a cgroup gaming the system by creating many tasks
- Results in many context switches to achieve CFS fairness across task hierarchy



# Experimental workload

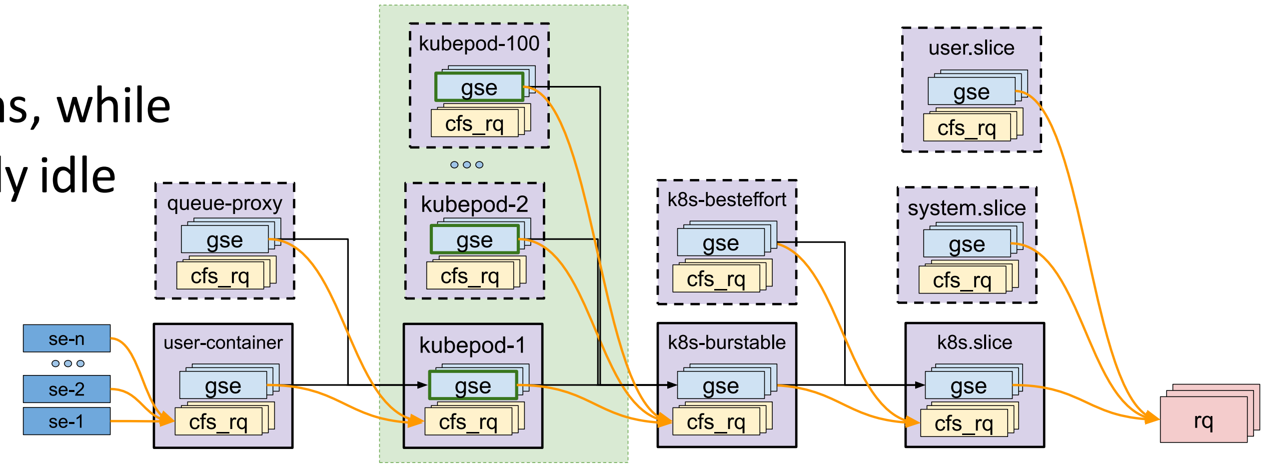



- Azure Function Invocation trace
  - 119 functions over two weeks
  - K8s limit of 110 pods/node
  - Use top 100 functions, leaving 10 pods for admin functions
- Then, per 5 minute bucket,
  - Sort into 10 demand bands ordered by request arrival rate
  - *group-high* mixes highest intensity band for each bucket
  - *group-low* mixes lowest 9 intensity bands for each bucket

# CFS–Least Loaded First (CFS–LLF)

- Serverless workloads are skewed:
  - most compute happens in a few functions, while
  - most functions are short-lived and mostly idle
- Reduce context switch overheads by allowing some of the tail functions to complete and get out of the way




- Adjust the CFS dynamic priority based the existing *per-entity load tracking* (PELT) mechanism rather than on minimum *vruntime*
  - Each task has a dynamic load credit estimated over a ~4 seconds (i.e., youngest tasks first)
  - Group tasks (equivalently, cgroups) into *function sandboxes* via addition of *cpu.func_sandbox* property

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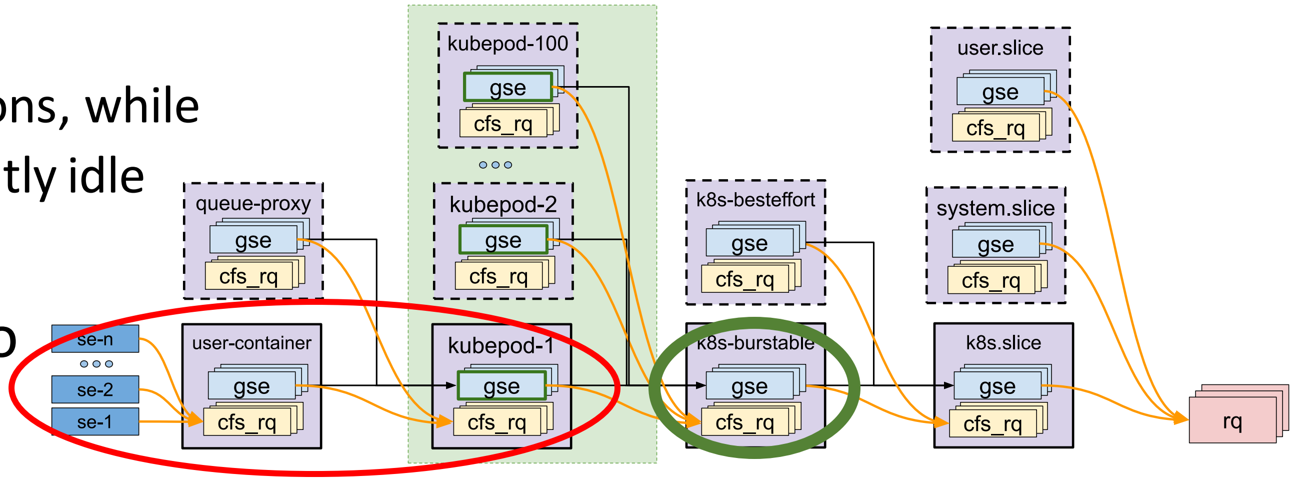


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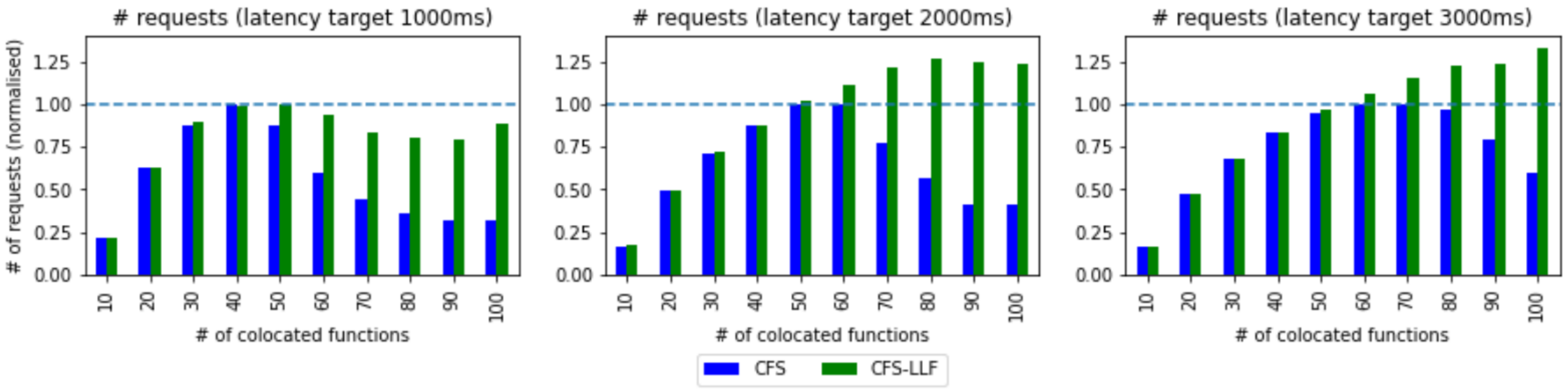
# Result? CFS–LLF mitigates impact of overload




- Allows the tail of least-loaded functions to complete and get out of the way
- Allows the (relatively) small number of most-loaded functions to also make useful progress

# Conclusions

- CFS can be “good enough” under low CPU utilisation
- CFS-LLF mitigates performance degradation as load increases in high density serverless setups
  - Relaxing fairness in favour of short-lived functions (useful, fair, & safe)
  - Reduces stress on CFS run queues
- CFS-LLF is compatible with K8s and portable to other frameworks
  - Requires no coordination with control planes, requires no workload training
- Next
  - Extending evaluation to diverse serverless benchmarks
  - Hotspot functions can be rapidly identified using the kernel load metric: can this allow them to be rapidly auto scaled to other cluster nodes?

# Backup slides

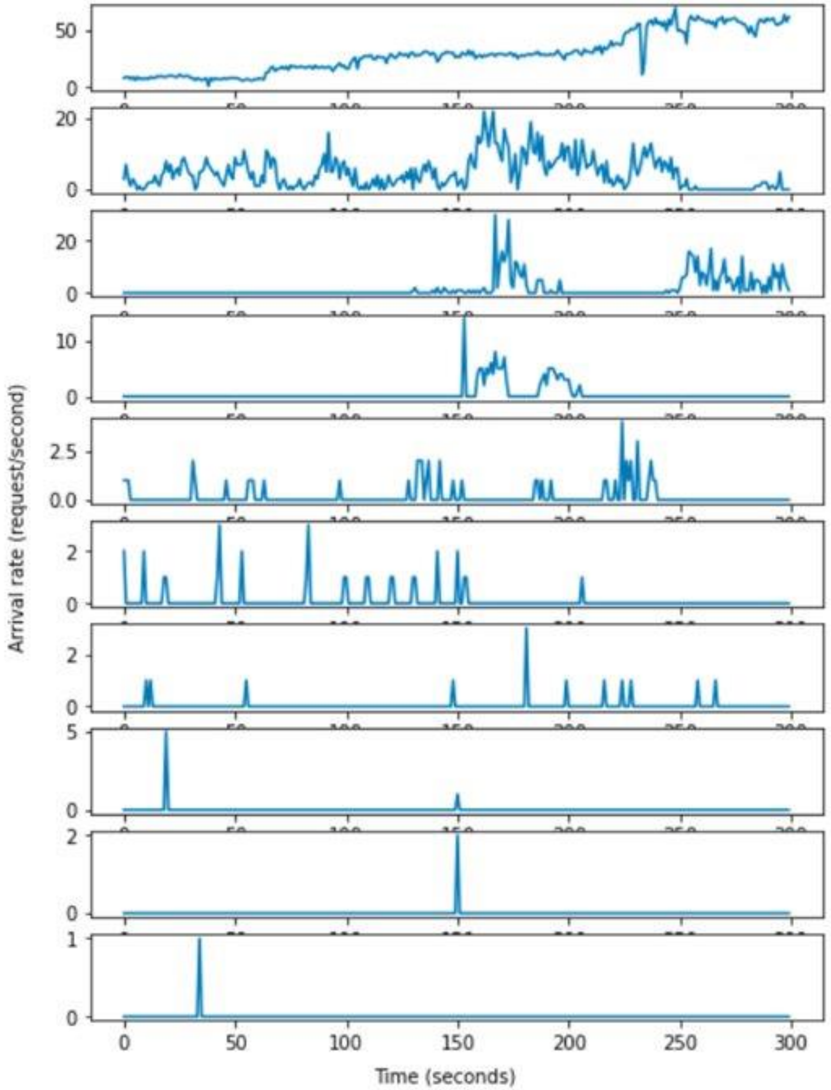
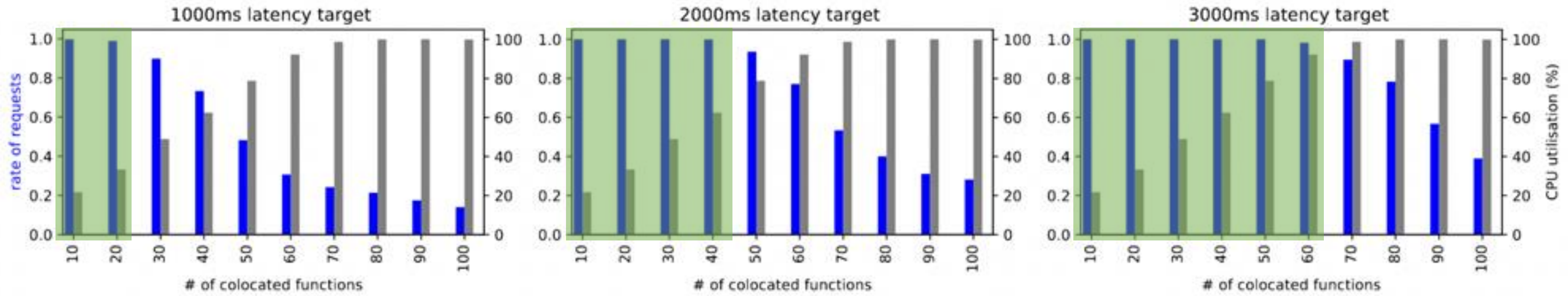
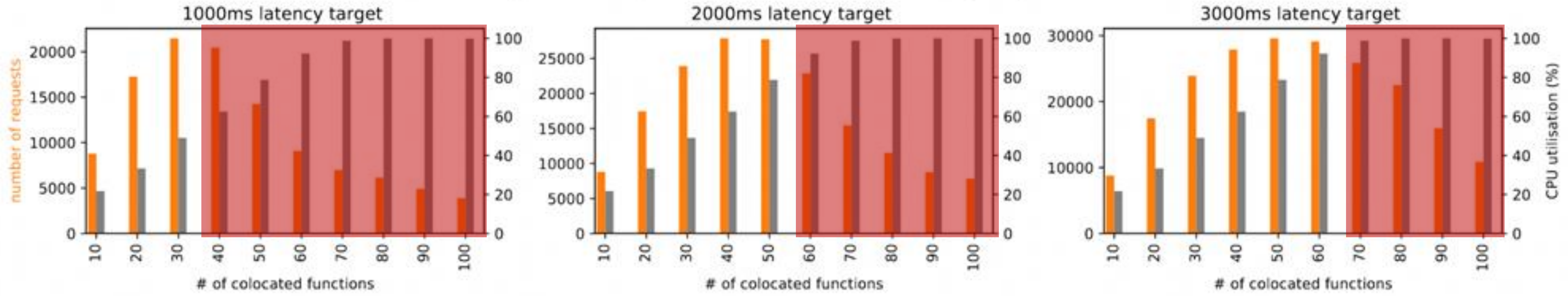



**Figure 10.** Arrival rates of the top segment found in the 10 demand bands from Figure 3

# Contention under serverless workloads



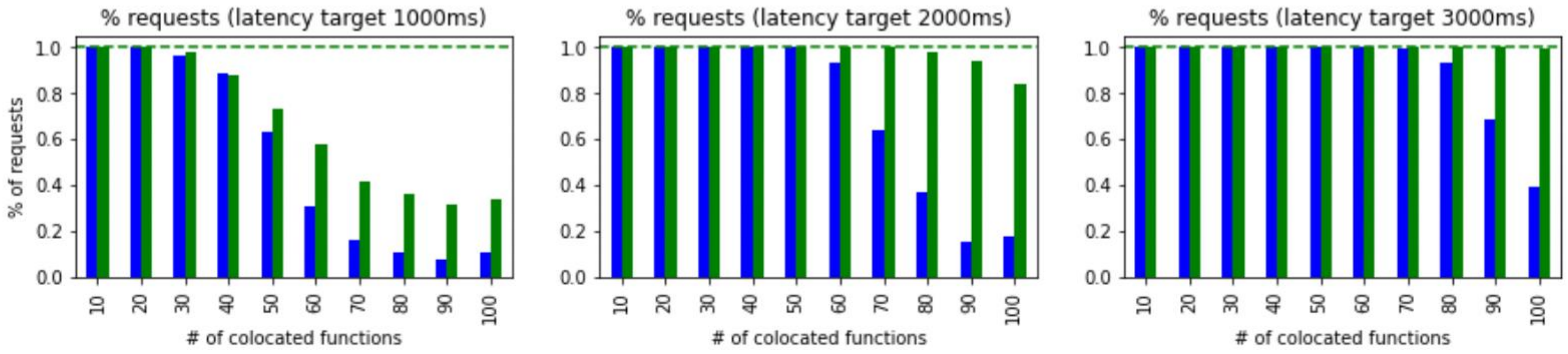

(a) Percentage of requests meeting latency targets.



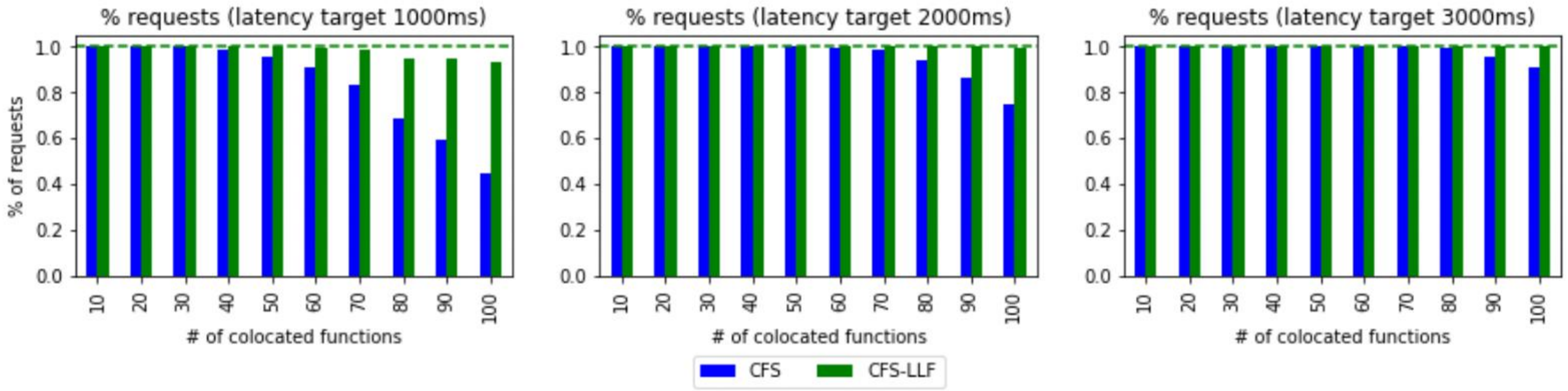

(b) Absolute number of requests meeting latency targets

***As utilisation increases, fewer requests meet their latency target***

# Attainment of latency targets



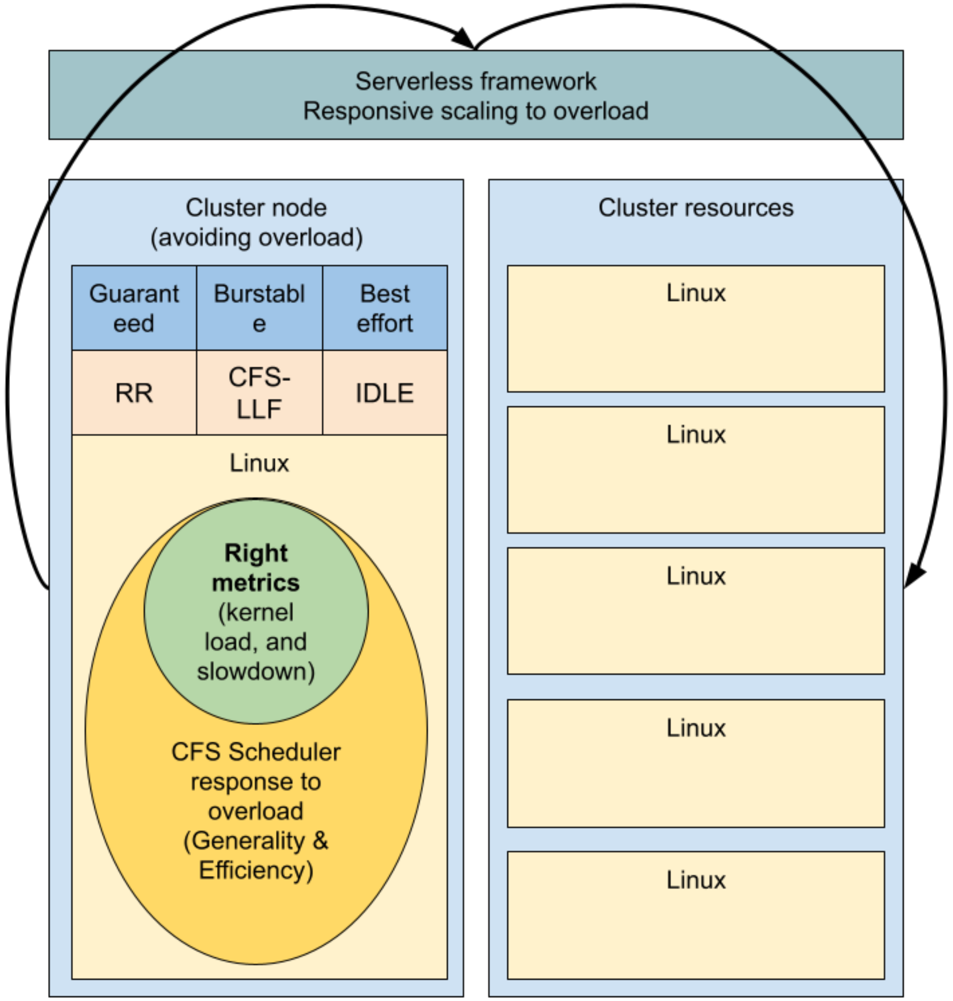

(a) Group high




(b) Group low

# Overload management

- **CFS-LLF,** a kernel scheduler that protects the performance of the long tail of least loaded functions  with no prior training or knowledge of workload, and no coordination with Kubernetes control plane.
- **Contention-aware autoscaling,** a Linux host agent that detects when a cluster node is overloaded and scales the resources of hotspot functions without escalating the issue to other cluster nodes



# Evaluation

- CDFs of achieved latency per function under highest-contention scenario