Deadline scheduling in the Linux kernel

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July 8, 2019

Introduction

Story: A new coffee machine

Components:

- Brewing controller
- User interface controller
- Web interface

Linux for real-time

First approach: run Linux as a task in real-time hypervisor

- examples: RTAI, RTLinux, Xenomai
- maintenance of HAL and microkernel for real-time
- custom tools and API necessary for real-time part

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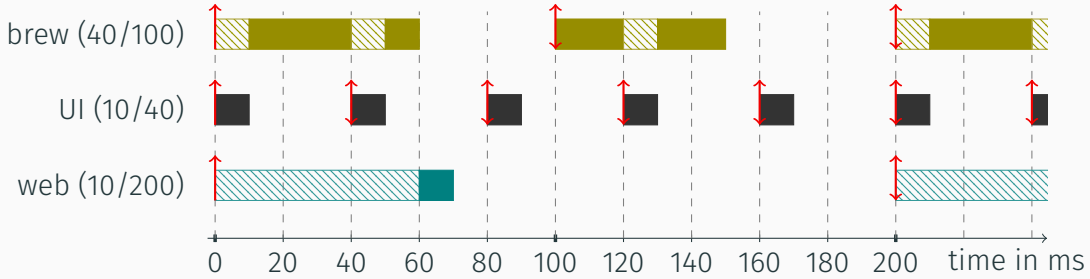
- PREEMPT_RT patchset
- real-time scheduler

Design of a realtime scheduler

Real-time Tasks

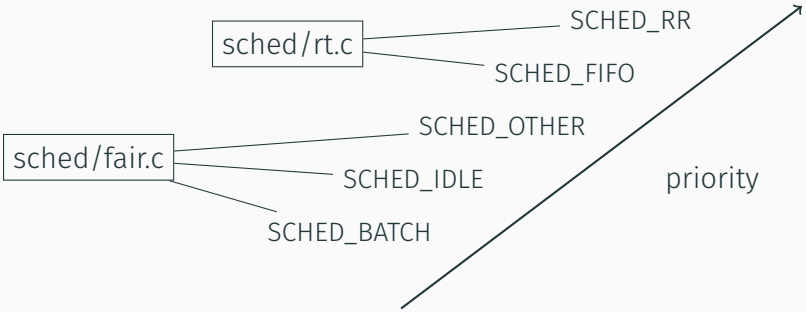
Properties of real-time tasks: *runtime*, *deadline* and *period*

For our coffee machine:



Related Work

- Linux/RK: resource reservation, CPU (fixed priority) and disk (EDF)
- SCHED_SPORADIC: priority based, aimed for inclusion in mainline but failed
- OCERA: resource-reservation based scheduler, as loadable kernel module
- LITMUS^{RT}: real-time scheduling testbed, not aiming to be production quality
- ExShed: kernel extension to allow scheduler implementation in user space
- Linux modular scheduling framework



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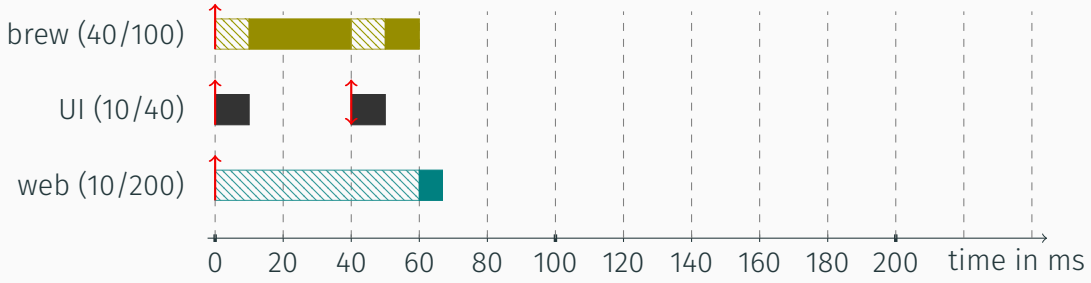

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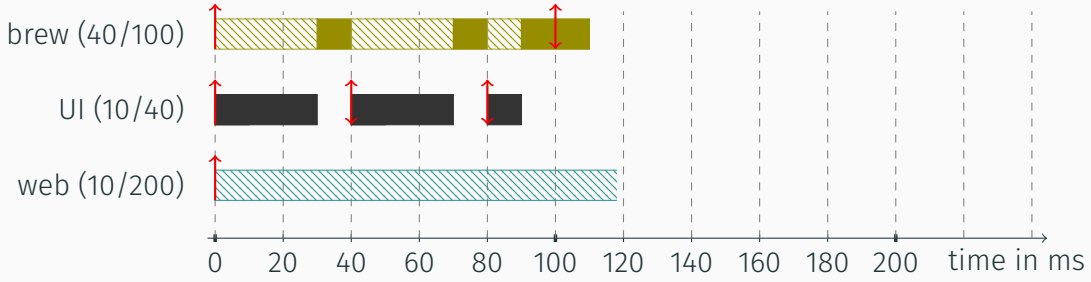

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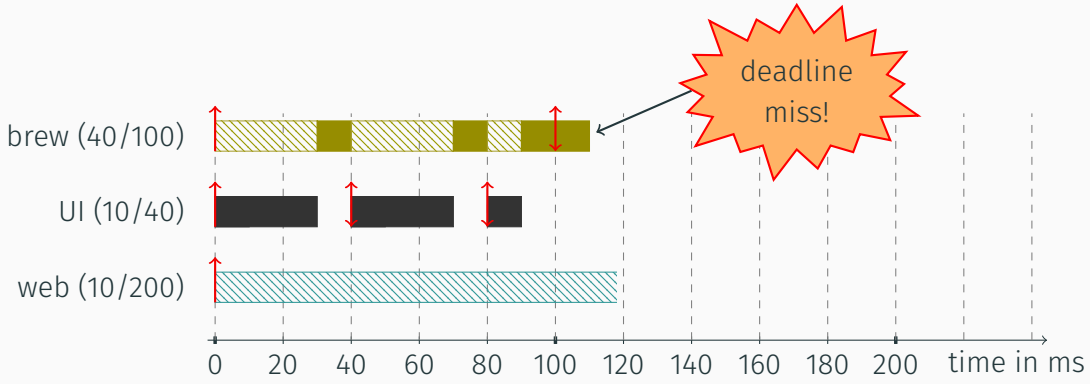


Algorithm

For each Task (Q_i / T_i), keep track of:

- budget (remaining runtime) q_i and
- scheduling deadline d_i

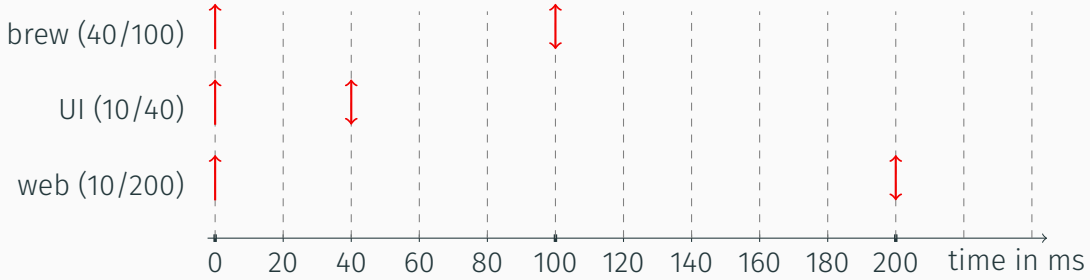
When a task wakes up:

- set new deadline $d_i = t + T_i$ and recharge budget if $q_i < (d_i - t_i)\frac{Q_i}{T_i}$
- pick task with earliest deadline and run it
- while running, decrease budget according to runtime
- if budget reaches zero, task is throttled until recharging happens at time d_i

In single-CPU case, all deadlines are hit if sum of Q_i/T_I is less than 1

Example

	brew	UI	web
budget	40	10	10
deadline	100	40	200



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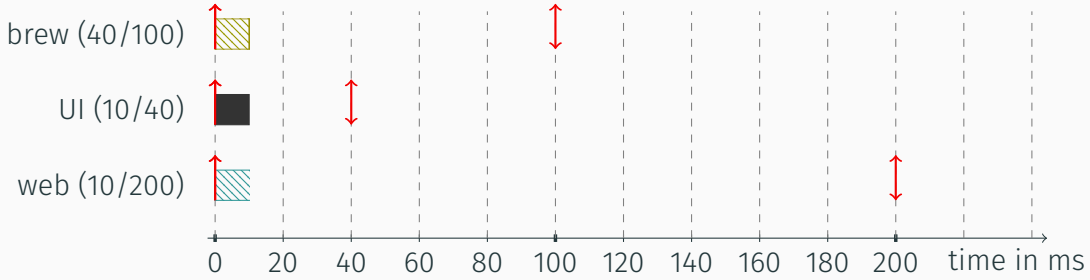
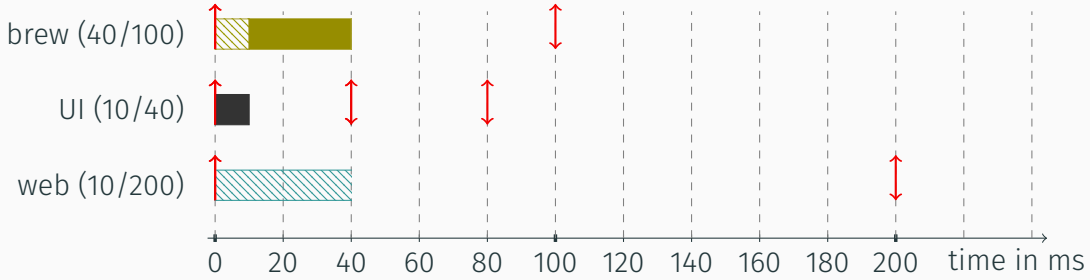


Example

	brew	UI	web
budget	10	10	10
deadline	100	80	200



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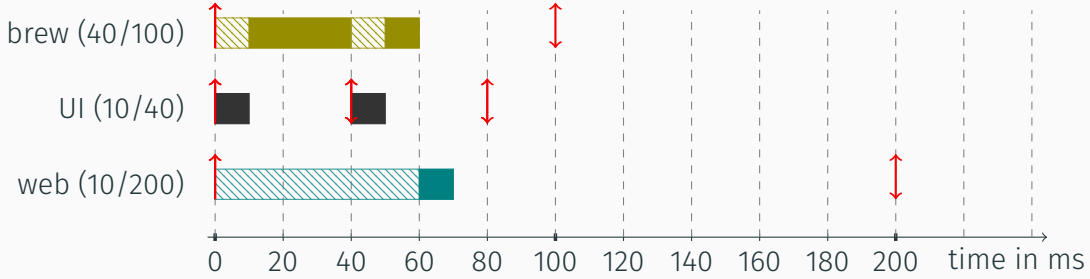
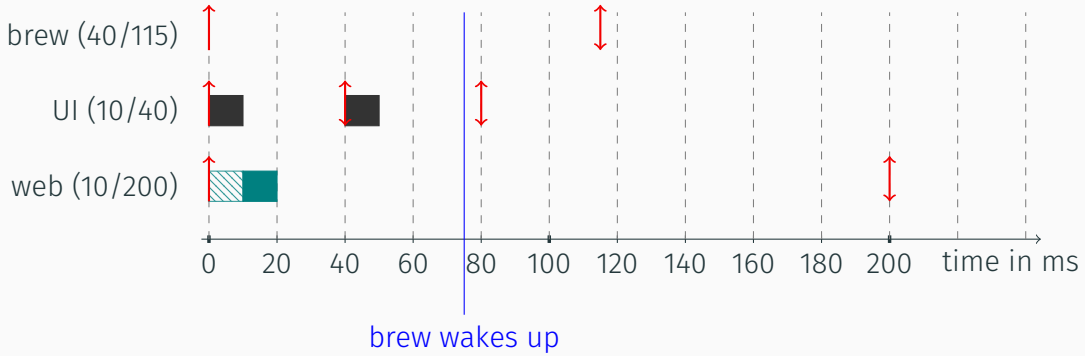


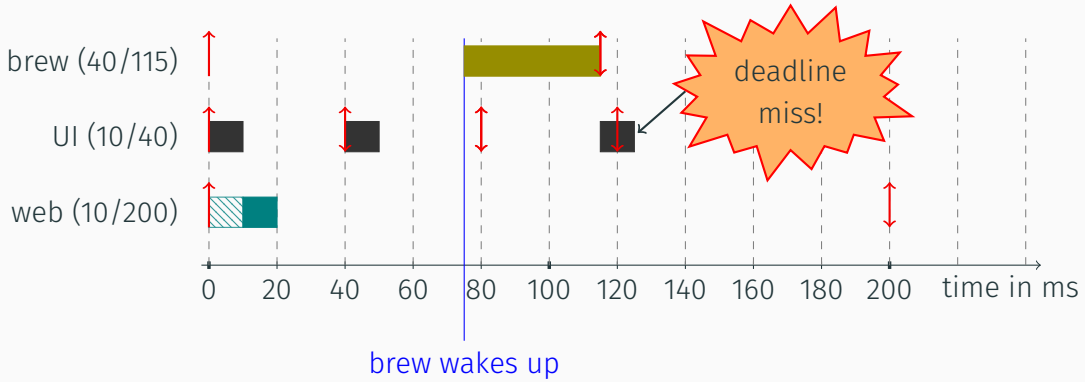
Example 2

	brew	UI	web
budget	40	0	0
deadline	115	80	200



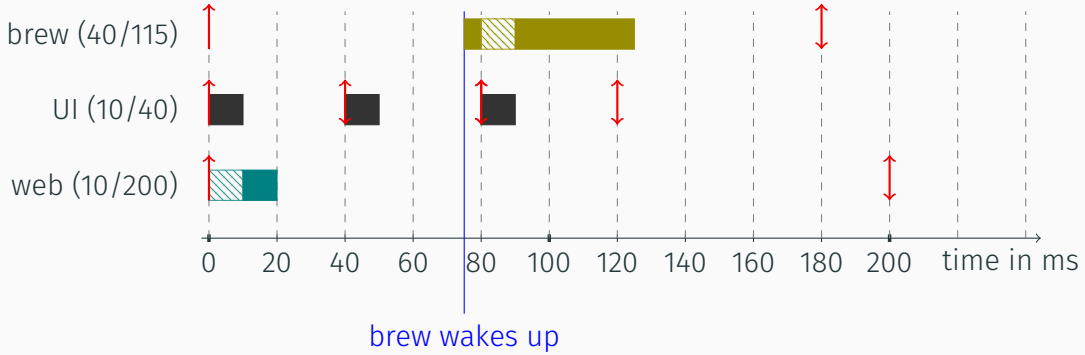
Example 2

	brew	UI	web
budget	0	10	0
deadline	115	120	200



Example 2

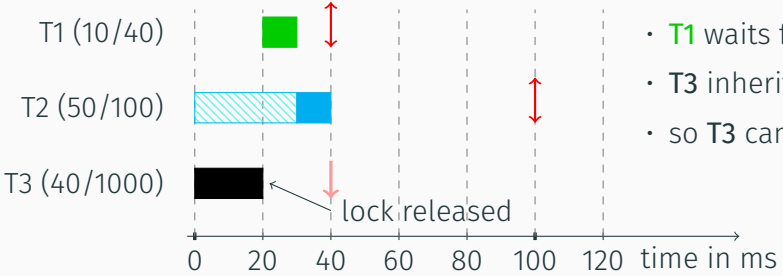
	brew	UI	web
budget	40	10	0
deadline	180	120	200



API, shared resources, multicore

User level API: two new syscalls `sched_setattr` and `sched_getattr`

Shared resources: inherit deadline of blocked task



- T1 waits for lock hold by T3
- T3 inherits deadline of T1
- so T3 can preempt T2

Multicore: partitioned (via cpuset) and global supported

Evaluation

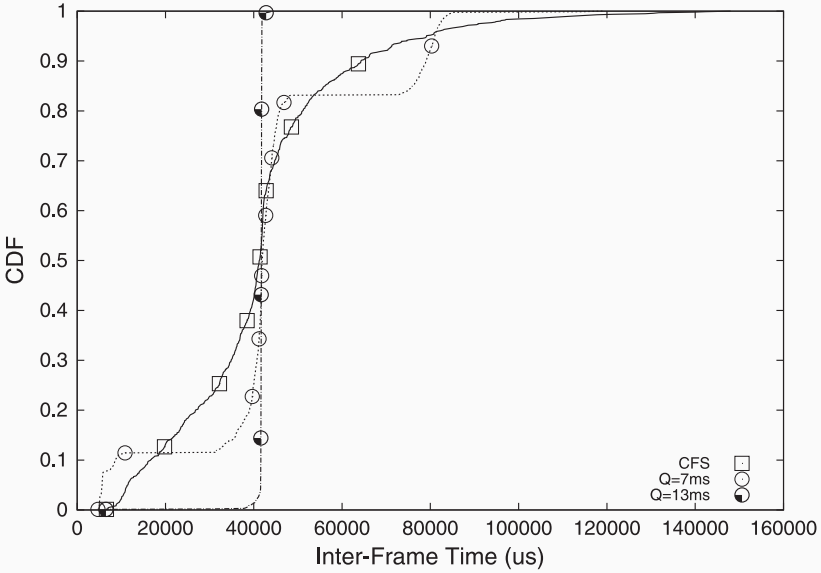
Synthetic workload (partitioned)

U(%)	SCHED_DEADLINE(%)	SCHED_FIFO(%)	SCHED_OTHER(%)
60	0	0	0.58
70	0	0	1.87
80	0	0.003	6.03
90	0	0.38	10.20

Synthetic workload (global, six cores)

U(%)	SCHED_DEADLINE(%)	SCHED_FIFO(%)	SCHED_OTHER(%)
500	0.027	0.001	3.303
510	0.023	0.002	4.310
520	0.051	0.011	4.992
530	0.099	0.023	6.046
540	0.138	0.230	7.093
550	0.239	0.271	8.097
560	0.289	0.380	9.977
570	0.351	0.640	11.554
580	0.618	1.380	15.384
590	1.295	2.535	19.774

MPlayer on loaded system



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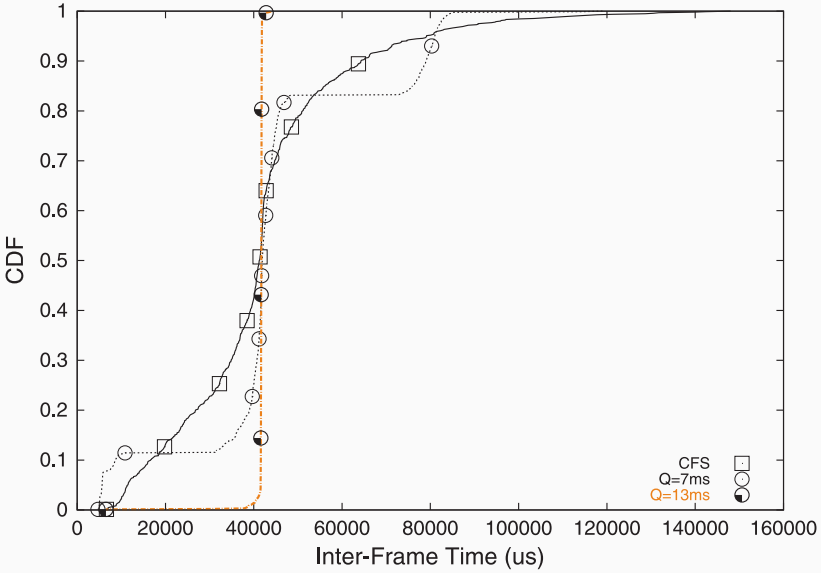

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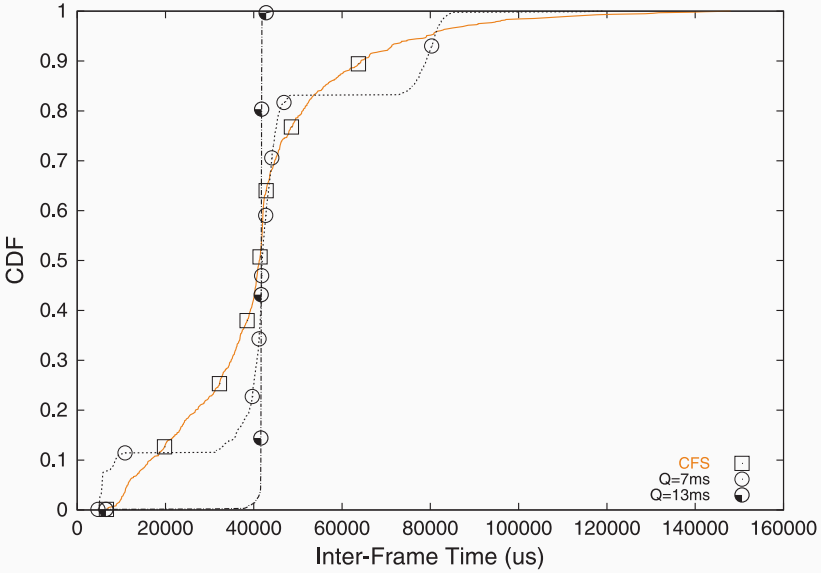

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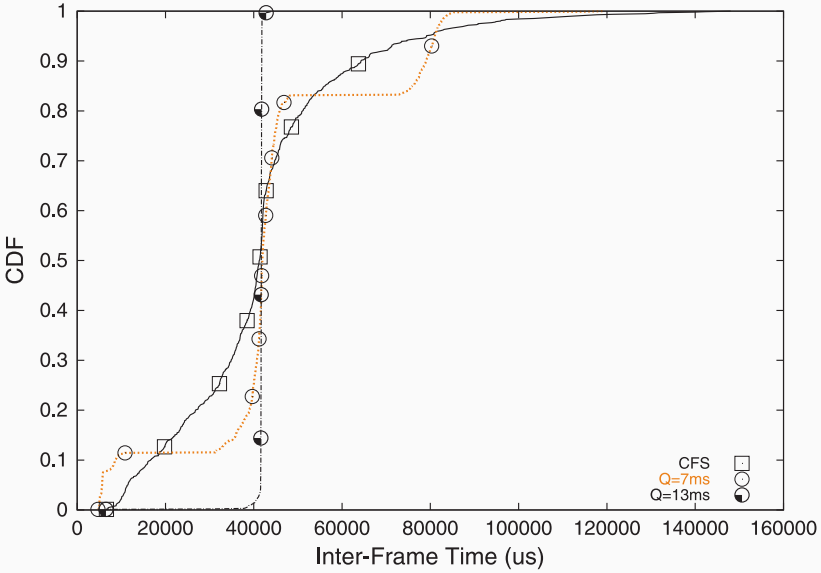
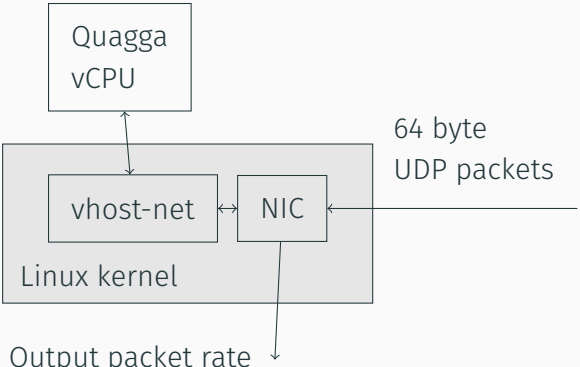
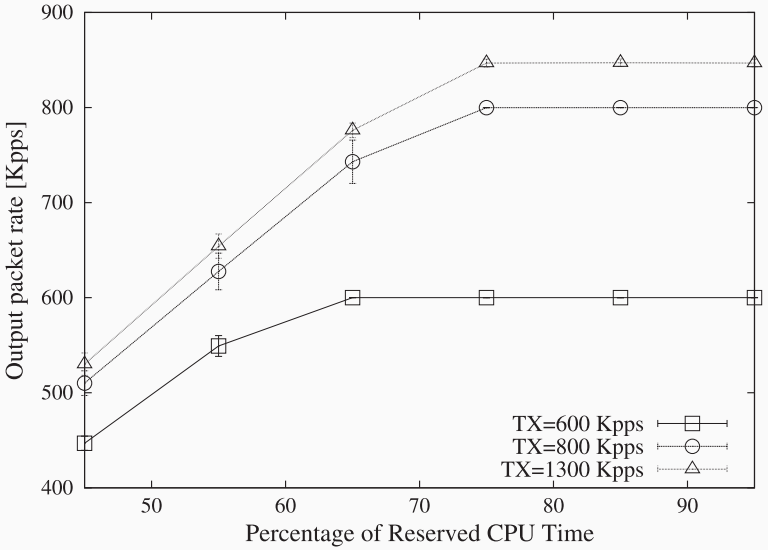


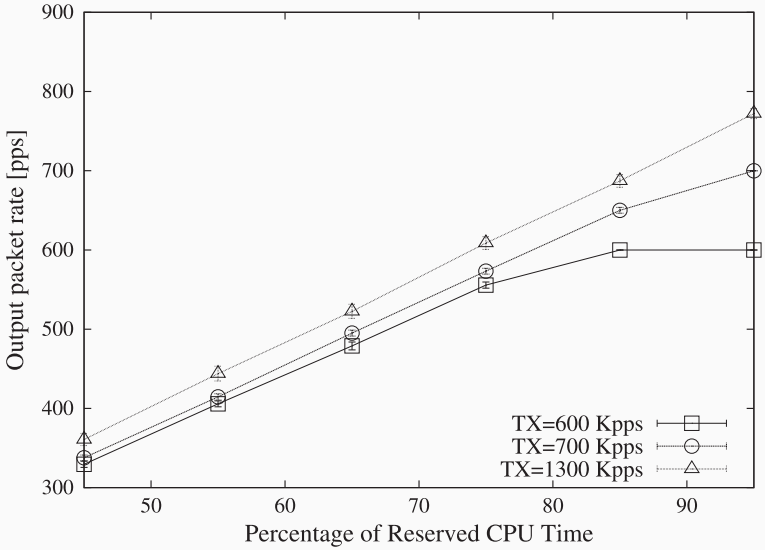
Virtual router



Limit vcpu thread



Limit vhost-net thread



Conclusion

Still some work left:

- M-BWI: Multiprocessor Bandwidth Inheritance
- Power aware algorithms (example: GRUB-PA)
- Support cgroups interface

Not rocket science, but solid implementation of proven concepts (EDF, CBS)

... ready for production use

... upstream in the Linux kernel

... with simple to use API

We can run our coffee machine on stock linux! :)