

OS08b: Virtual Memory with Linux *

Jens Lechtenbörger

Computer Structures and Operating Systems 2023

1 Looking at Memory with Linux

(Specifics of Linux are not part of learning objectives; however, the following illustrates [shared memory](#), and `/proc` will be revisited in other presentations.)

1.1 Linux Kernel: `/proc/<pid>/`

- `/proc` is a pseudo-filesystem
 - See <https://man7.org/linux/man-pages/man5/proc.5.html>
 - * (Specific to Linux kernel; incomplete or missing elsewhere)
 - “Pseudo”: Look and feel of any other filesystem
 - * Sub-directories and files
 - * However, files are no “real” files but meta-data
 - Interface to internal **kernel data structures**
 - * One sub-directory per process ID
 - * OS identifies process by integer number
 - * Here and elsewhere, `<pid>` is meant as **placeholder** for such a number

1.1.1 Video about `/proc`

This video, “Looking at `/proc`” by Jens Lechtenbörger, shares the presentation’s license terms, namely [CC BY-SA 4.0](#).

The video shows some aspects of the `/proc` filesystem related to memory management, which are described in more abstract form on subsequent slides.

1.1.2 Drawing about `/proc`

Warning! External figure **not** included: “`/proc`” © 2018 Julia Evans, all rights reserved from [julia’s drawings](#). Displayed here with personal permission. (See [HTML presentation](#) instead.)

*This PDF document is an inferior version of an OER HTML page; free/libre Org mode source repository.

1.1.3 Drawing about man pages

Warning! External figure **not** included: “Man pages are amazing” © 2016 Julia Evans, all rights reserved from julia’s drawings. Displayed here with personal permission.

(See HTML presentation instead.)

1.2 Linux Kernel Memory Interface

- Memory allocation (and much more) visible under `/proc/<pid>`
- E.g.:
 - `/proc/<pid>/pagemap`: One 64-bit value per virtual page
 - * Mapping to RAM or swap area
 - `/proc/<pid>/maps`: Mapped memory regions
 - `/proc/<pid>/smaps`: Memory usage for mapped regions
- Notice: Memory regions include **shared** libraries that are used by lots of processes

1.3 GNU/Linux Reporting: smem

- User space tool to read `smaps` files: `smem`
 - See <https://linoxide.com/memory-usage-reporting-smem/>
- Terminology
 - **Virtual set size** (VSS): Size of virtual address space
 - **Resident set size** (RSS): Allocated main memory
 - * Standard notion, yet overestimates memory usage as lots of memory is shared between processes
 - Shared memory is added to the RSS of every sharing process
 - **Unique set size** (USS): memory allocated exclusively to process
 - * That much would be returned upon process’ termination
 - **Proportional set size** (PSS): USS plus “fair share” of shared pages
 - * If page shared by 5 processes, each gets a fifth of a page added to its PSS

1.3.1 Sample smem Output

```
$ smem -c "pid command uss pss rss vss" -P "bash|xinit|emacs"
  PID Command                USS    PSS    RSS    VSS
  765 /usr/bin/xinit /etc/X11/Xse  220    285    2084   15952
 1390 /bin/bash -c libreoffice5.3  240    510    2936   13188
  826 /bin/bash /usr/bin/qubes-se  256    524    3008   13204
  750 -su -c /usr/bin/xinit /etc/   316    587    3368   21636
 1251 bash                    4864   5136   7900   26024
 2288 /usr/bin/python /usr/bin/sm  5272   6035   9432   24688
 1145 emacs                    90876  93224  106568 662768
```

1.3.2 Sample smem Graph

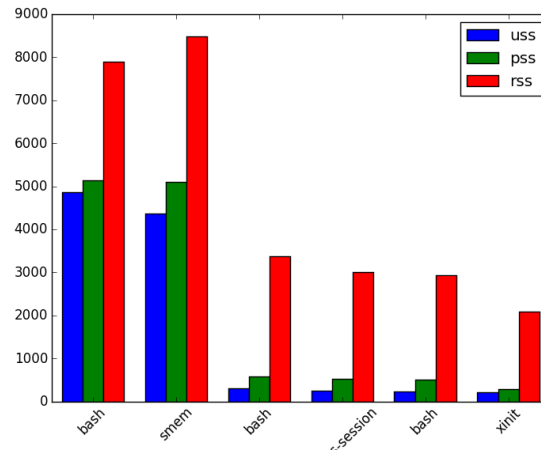


Figure 1: `smem --bar pid -c "uss pss rss" -P "bash|xinit"` (“Screenshot of smem” under CC0 1.0; from GitLab)

License Information

This document is part of an Open Educational Resource (OER) course on Operating Systems. Source code and source files are available on GitLab under free licenses.

Except where otherwise noted, the work “OS08b: Virtual Memory with Linux”, © 2017-2022 Jens Lechtenbörger, is published under the Creative Commons license CC BY-SA 4.0.

No warranties are given. The license may not give you all of the permissions necessary for your intended use.

In particular, trademark rights are *not* licensed under this license. Thus, rights concerning third party logos (e.g., on the title slide) and other (trade-) marks (e.g., “Creative Commons” itself) remain with their respective holders.