systemd

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Outline

Init system

- First process started by the kernel (pid 1)
- Responsible for bringing up the rest of userspace
  - Mounting filesystems
  - Starting services
  - . . .
- Also the parent for orphan processes
- Traditional init system on Linux: sysVinit
  - Inherited from Unix System V
  - With additional tools (insserv, startpar) to handle dependencies and parallel initialization

systemd

- Written (since 2010) by Lennart Poettering (Red Hat) and others
- Now the default on most Linux distributions
- Shifts the scope from *starting all services* (sysVinit) to managing the system and all services
- Key features:
  - Relies on cgroups for
    - Services supervision
    - Control of services execution environment
  - Declarative syntax for unit files $\leadsto$ more efficient/robust
  - Socket activation for parallel services startup
  - Nicer user interface (systemctl & friends)
- Additional features: logging, timer units (cron-like), user sessions handling, containers management

Behind the scenes: cgroups

- Abbreviated from *control groups*
- Linux kernel feature
- Limit, account for and isolate processes and their resource usage (CPU, memory, disk I/O, network, etc.)
- Related to namespace isolation:
  - Isolate processes from the rest of the system
  - *Chroots on steroids*
  - PID, network, UTS, mount, user, etc.
- LXC, Docker $\approx$ cgroups + namespaces (+ management tools)

cgroups and systemd

- Each service runs in its own cgroup
- Enables:
  - Tracking and killing all processes created by each service
  - Per-service accounting and resources allocation/limitation
- Previously, with sysVinit:
  - No tracking of which service started which processes
    - PID files, or hacks in init scripts: `pidof` / `killall` / `pgrep`
    - Hard to completely terminate a service (left-over CGI scripts when killing Apache)
  - No resources limitation (or using `setrlimit` (= `ulimit`), which is per-process, not per-service)
- Also isolate user sessions $\leadsto$ kill all user processes (not by default)
- More information: Control Groups vs. Control Groups and Which Service Owns Which Processes?

systemd-cgls: visualizing the cgroups hierarchy

```
├─1 /sbin/init
├─system.slice
│ ├─apache2.service
│ │ ├─1242 /usr/sbin/apache2 -k start
│ │ ├─9880 /usr/sbin/apache2 -k start
│ │ └─9881 /usr/sbin/apache2 -k start
│ ├─system-getty.slice
│ │ ├─getty@tty1.service
│ │ │ └─1190 /sbin/agetty --noclear tty1 linux
│ │ └─getty@tty2.service
│ │   └─24696 /sbin/agetty --noclear tty2 linux
│ ├─system-postgresql.slice
│ │ └─postgresql@9.4-main.service
│ │   ├─1218 /usr/lib/postgresql/9.4/bin/postgres -D /var/lib/postgresql/9.4/main -c
│ │   ├─1356 postgres: checkpointer process
│ │   ├─1357 postgres: writer process
│ │   ├─1358 postgres: wal writer process
│ │   ├─1359 postgres: autovacuum launcher process
│ │   └─1360 postgres: stats collector process
│ ├─gdm.service
│ │ ├─1209 /usr/sbin/gdm3
│ │ └─1238 /usr/bin/Xorg :0 -novtswitch -background none -noreset -verbose 3 -auth /
└─user.slice
  └─user-1000.slice
    ├─session-1.scope
    │ ├─ 1908 gdm-session-worker [pam/gdm-password]
    │ ├─ 1917 /usr/bin/gnome-keyring-daemon --daemonize --login
    │ ├─ 1920 gnome-session
    │ ├─ 1966 /usr/bin/dbus-launch --exit-with-session gnome-session
```

`systemd-cgtop`: per-service resources usage

```
Path                                                            Tasks   %CPU   Memory  Input/s Output/s

/                                                                  92   68.8        -       0B   243.9K
/system.slice                                                       -   65.8        -        -        -
/system.slice/ModemManager.service                                  1      -        -        -        -
/system.slice/NetworkManager.service                                2      -        -        -        -
/system.slice/accounts-daemon.service                               1      -        -        -        -
/system.slice/apache2.service                                       3    0.1        -        -        -
/system.slice/atd.service                                           1      -        -        -        -
/system.slice/avahi-daemon.service                                  2    0.0        -        -        -
/system.slice/colord.service                                        1      -        -        -        -
/system.slice/system-postgresql.slice                               8   66.0        -   340.4K   112.4M
/system.slice/system-postgresql.slice/postgresql@9.4-main.service   8      -        -        -        -
/system.slice/systemd-journald.service                              1      -        -        -        -
/system.slice/systemd-logind.service                                1    0.0        -        -        -
/user.slice                                                        13    1.6        -        -        -
/user.slice/user-1001.slice                                         -    1.6        -        -        -
/user.slice/user-1001.slice/session-2.scope                         4      -        -        -        -
/user.slice/user-1001.slice/session-4.scope                         6    1.6        -        -        -
/user.slice/user-1001.slice/session-6.scope                         5      -        -        -        -
```

Requires enabling `CPUAccounting`, `BlockIOAccounting`, `MemoryAccounting`

Managing services with `systemctl`

- What is being manipulated is called a *unit*: services (.service), mount points (.mount), devices (.device), sockets (.socket), etc.
- Basic commands:

sysVinit	systemd	notes
service foo start	systemctl start foo	
service foo stop	systemctl stop foo	
service foo restart	systemctl restart foo	
service foo reload	systemctl reload foo	
service foo condrestart	systemctl condrestart foo	restart if already running
update-rc.d foo enable	systemctl enable foo	auto-start at next boot
update-rc.d foo disable	systemctl disable foo	disable auto-start
	systemctl is-enabled foo	

- There's auto-completion (`apache2` and `apache2.service` work)
- Several services can be specified:
  `systemctl restart apache2 postgresql`

systemd and runlevels

- With sysVinit, runlevels control which services are started automatically
  - 0 = halt; 1 = single-user / minimal mode; 6 = reboot
  - Debian: no difference by default between levels 2, 3, 4, 5
  - RHEL: 3 = multi-user text, 5 = multi-user graphical
- systemd replaces runlevels with targets:
  - Configured using symlinks farms in `/etc/systemd/system/`**`target`**`.wants/`
  - `systemctl enable/disable` manipule those symlinks
  - `systemctl mask` disables the service and prevents it from being started manually
  - The default target can be configured with `systemctl get-default/set-default`
  - More information: The Three Levels of "Off"

Default targets (bootup(7))

```
local-fs-pre.target
         |
         v
(various mounts and   (various swap   (various cryptsetup
 fsck services...)     devices...)        devices...)       (various low-level   (various low-level
         |                  |                  |             services: udevd,     API VFS mounts:
         v                  v                  v             tmpfiles, random     mqueue, configfs,
  local-fs.target      swap.target     cryptsetup.target    seed, sysctl, ...)      debugfs, ...)
         |                  |                  |                    |                    |
         \__________________|_________________ | ___________________|____________________/
                                              \|/
                                               v
                                        sysinit.target
                                               |
          ____________________________________/|\________________________________________
         /                  |                  |                    |                    \
         |                  |                  |                    |                    |
         v                  v                  |                    v                    v
     (various           (various               |                (various          rescue.service
    timers...)          paths...)              |               sockets...)               |
         |                  |                  |                    |                    v
         v                  v                  |                    v              rescue.target
   timers.target      paths.target             |             sockets.target
         |                  |                  |                    |
         \__________________|_________________ | ___________________/
                                              \|/
                                               v
                                         basic.target
                                               |
          ____________________________________/|                               emergency.service
         /                  |                  |                                         |
         |                  |                  |                                         v
         v                  v                  v                                 emergency.target
     display-        (various system    (various system
 manager.service         services           services)
         |             required for            |
         |            graphical UIs)           v
         |                  |           multi-user.target
         |                  |                  |
         \_________________ | _________________/
                           \|/
                            v
                  graphical.target
```

Analyzing startup performance

- Fast boot matters in some use-cases:
  - Virtualization, Cloud:
    - Almost no BIOS / hardware checks $\rightsquigarrow$ only software startup
    - Requirement for infrastructure elasticity
  - Embedded world
- `systemd-analyze time`: summary

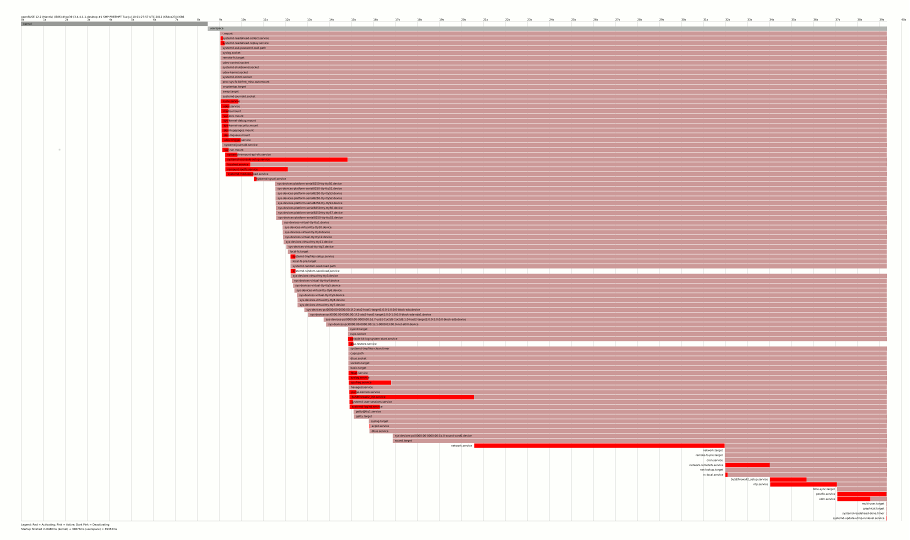
```
Startup finished in 4.883s (kernel) + 5.229s (userspace) = 10.112s
```

- `systemd-analyze blame`: worst offenders

```
2.417s systemd-udev-settle.service
2.386s postgresql@9.4-main.service
1.507s apache2.service
240ms NetworkManager.service
236ms ModemManager.service
194ms accounts-daemon.service
```

systemd-analyze plot

- Similar to bootchartd, but does not require rebooting with a custom `init=` kernel command-line



systemd-analyze critical-chain

- Shows services in the critical path

```
graphical.target @5.226s
└─multi-user.target @5.226s
  └─exim4.service @5.144s +81ms
    └─postgresql.service @5.142s +1ms
      └─postgresql@9.4-main.service @2.755s +2.386s
        └─basic.target @2.743s
          └─timers.target @2.743s
            └─systemd-tmpfiles-clean.timer @2.743s
              └─sysinit.target @2.742s
                └─networking.service @2.589s +153ms
                  └─local-fs.target @2.587s
                    └─run-user-117.mount @3.877s
                      └─local-fs-pre.target @223ms
                        └─systemd-remount-fs.service @218ms +4ms
                          └─keyboard-setup.service @157ms +61ms
                            └─systemd-udevd.service @154ms +2ms
                              └─systemd-tmpfiles-setup-dev.service @113ms +33ms
                                └─kmod-static-nodes.service @102ms +10ms
                                  └─system.slice @96ms
                                    └─-.slice @94ms
```

Exploring the system status

- Listing units with `systemctl list-units` (or just `systemctl`):
  - active units: `systemctl`
  - List only services: `systemctl -t service`
  - List units in failed state: `systemctl --failed`
- Whole system overview: `systemctl status`
- GUI available: `systemadm`

`systemctl status` service

```
● avahi-daemon.service - Avahi mDNS/DNS-SD Stack
   Loaded: loaded (/lib/systemd/system/avahi-daemon.service; enabled)
   Active: active (running) since Wed 2015-04-01 21:49:28 CEST; 27s ago
 Main PID: 2858 (avahi-daemon)
   Status: "avahi-daemon 0.6.31 starting up."
   CGroup: /system.slice/avahi-daemon.service
           ├─2858 avahi-daemon: running [grep.local]
           └─2859 avahi-daemon: chroot helper

Apr 01 21:49:28 grep avahi-daemon[2858]: No service file found in /etc/avahi/services.
Apr 01 21:49:28 grep avahi-daemon[2858]: Joining mDNS multicast group on interface eth0.IPv
Apr 01 21:49:28 grep avahi-daemon[2858]: New relevant interface eth0.IPv6 for mDNS.
Apr 01 21:49:28 grep avahi-daemon[2858]: Joining mDNS multicast group on interface eth0.IPv
Apr 01 21:49:28 grep avahi-daemon[2858]: New relevant interface eth0.IPv4 for mDNS.
Apr 01 21:49:28 grep avahi-daemon[2858]: Network interface enumeration completed.
Apr 01 21:49:28 grep avahi-daemon[2858]: Registering new address record for fe80::d6be:d9f
Apr 01 21:49:28 grep avahi-daemon[2858]: Registering new address record for 152.81.5.183 on
Apr 01 21:49:28 grep avahi-daemon[2858]: Registering HINFO record with values 'X86_64'/'LIN
Apr 01 21:49:29 grep avahi-daemon[2858]: Server startup complete. Host name is grep.local.
```

Includes:

- Service name and description, state, PID
- Free-form status line from `systemd-notify(1)` or `sd_notify(3)`
- Processes tree inside the cgroup
- Last lines from journald (syslog messages and stdout/stderr)

Configuring services by writing unit files

- With sysVinit: shell scripts in `/etc/init.d/`
  - Long and difficult to write
  - Redundant code between services
  - Slow (numerous `fork()` calls)
- With systemd: declarative syntax (.desktop-like)
  - Move intelligence from scripts to systemd
  - Covers most of the needs, but shell scripts can still be used
  - Can use includes and overrides (`systemd-delta`)
  - View config file for a unit: `systemctl cat atd.service`
  - Or just find the file under `/lib/systemd/system/` (distribution's defaults) or `/etc/systemd/system` (local overrides)

Simple example: atd

```
[Unit]
Description=Deferred execution scheduler
# Pointer to documentation shown in systemctl status
Documentation=man:atd(8)

[Service]
# Command to start the service
ExecStart=/usr/sbin/atd -f
IgnoreSIGPIPE=false # Default is true

[Install]
# Where "systemctl enable" creates the symlink
WantedBy=multi-user.target
```

Common options

- Documented in `systemd.unit(5)` ([Unit]), `systemd.service(5)` ([Service]), `systemd.exec(5)` (execution environment)
- Show all options for a given service:
  `systemctl show atd`
- Sourcing a configuration file:
  ```
  EnvironmentFile=-/etc/default/ssh
  ExecStart=/usr/sbin/sshd -D $SSHD_OPTS
  ```
- Using the `$MAINPID` magic variable:
  ```
  ExecReload=/bin/kill -HUP $MAINPID
  ```
- Auto-restart a service when crashed: (≈ runit / monit)
  ```
  Restart=on-failure
  ```
- Conditional start:
  ```
  ConditionPathExists=!/etc/ssh/sshd_not_to_be_run
  ```
  Conditions on architecture, virtualization, kernel cmdline, AC power, etc.

Options for isolation and security

- Use a network namespace to isolate the service from the network:
  `PrivateNetwork=yes`
- Use a filesystem namespaces:
  - To provide a service-specific `/tmp` directory:
    `PrivateTmp=yes`
  - To make some directories inaccessible or read-only:
    `InaccessibleDirectories=/home`
    `ReadOnlyDirectories=/var`
- Specify the list of `capabilities(7)` for a service:
  `CapabilityBoundingSet=CAP_CHOWN CAP_KILL`
  Or just remove one:
  `CapabilityBoundingSet=~CAP_SYS_PTRACE`
- Disallow forking:
  `LimitNPROC=1`

Options for isolation and security (2)

- Run as user/group: `User=`, `Group=`
- Run service inside a chroot:
  ```
  RootDirectory=/srv/chroot/foobar
  ExecStartPre=/usr/local/bin/setup-foobar-chroot.sh
  ExecStart=/usr/bin/foobard
  RootDirectoryStartOnly=yes
  ```
- Control CPU shares, memory limits, block I/O, swapiness:
  ```
  CPUShares=1500
  MemoryLimit=1G
  BlockIOWeight=500
  BlockIOReadBandwith=/var/log 5M
  ControlGroupAttribute=memory.swappiness 70
  ```
- More information: Converting sysV init scripts to systemd service files, Securing your services, Changing roots, Managing resources

Timer units

- Similar to cron, but with all the power of systemd (dependencies, execution environment configuration, etc)
- Realtime (wallclock) timers: calendar event expressions
  - Expressed using a complex format (see `systemd.time(7)`), matching timestamps like: `Fri 2012-11-23 11:12:13`
  - Examples of valid values: `hourly` (= `*-*-* *:00:00`), `daily` (= `*-*-* 00:00:00`), `*:2/3` (= `*-*-* *:02/3:00`)
- Monotonic timers, relative to different starting points:
  - 5 hours and 30 mins after system boot: `OnBootSec=5h 30m`
  - 50s after systemd startup: `OnstartupSec=50s`
  - 1 hour after the unit was last activated: `OnUnitActiveSec=1h` (can be combined with `OnBootSec` or `OnStartupSec` to ensure that a unit runs on a regular basis)

Timer units example

- `myscript.service`:

```
[Unit]
Description=MyScript

[Service]
Type=simple
ExecStart=/usr/local/bin/myscript
```

- `myscript.timer`:

```
[Unit]
Description=Runs myscript every hour

[Timer]
# Time to wait after booting before we run first time
OnBootSec=10min
# Time between running each consecutive time
OnUnitActiveSec=1h
Unit=myscript.service

[Install]
WantedBy=multi-user.target
```

Timer units example (2)

- Start timer:
  `systemctl start myscript.timer`
- Enable timer to start at boot:
  `systemctl enable myscript.timer`
- List all timers:
  `systemctl list-timers`

Socket activation

- systemd listens for connection on behalf of service until the service is ready, then passes pending connections
- Benefits:
  - No need to express ordering of services during boot:
    - They can all be started in parallel $\leadsto$ faster boot
    - And they will wait for each other when needed (when they will talk to each other), thanks to socket activation
  - Services that are seldomly used do not need to keep running, and can be started on-demand
- Not limited to network services: also D-Bus activation and path activation
- More information: Converting inetd Service, Socket Activation for developers (+ follow-up)

Socket activation example: dovecot

dovecot.socket:

```
[Unit]
Description=Dovecot IMAP/POP3 \
 email server activation socket

[Socket]
# dovecot expects separate
# IPv4 and IPv6 sockets
BindIPv6Only=ipv6-only
ListenStream=0.0.0.0:143
ListenStream=[::]:143
ListenStream=0.0.0.0:993
ListenStream=[::]:993
KeepAlive=true

[Install]
WantedBy=sockets.target
```

dovecot.service:

```
[Unit]
Description=Dovecot IMAP/POP3 \
 email server
After=local-fs.target network.target

[Service]
Type=simple
ExecStart=/usr/sbin/dovecot -F
NonBlocking=yes

[Install]
WantedBy=multi-user.target
```

Socket activation example: sshd

- `sshd.socket`:

```
[Unit]
Description=SSH Socket for Per-Connection Servers

[Socket]
ListenStream=22
Accept=yes

[Install]
WantedBy=sockets.target
```

- `sshd@.service`:

```
[Unit]
Description=SSH Per-Connection Server

[Service]
ExecStart=-/usr/sbin/sshd -i
StandardInput=socket
```

Socket activation example: sshd (2)

- `sshd@.service` means that this is an instanciated service
- There's one instance of `sshd@.service` per connection:

```
# systemctl --full | grep ssh
sshd@172.31.0.52:22-172.31.0.4:47779.service  loaded active running
sshd@172.31.0.52:22-172.31.0.54:52985.service loaded active running
sshd.socket                                   loaded active listening
```

- Instanciated services are also used by getty
  - See Serial console and Instanciated services

Logging with journald

- Component of systemd
- Captures syslog messages, kernel log messages, initrd and early boot messages, messages written to stdout/stderr by all services
  - Forwards everything to syslog
- Structured format (key/value fields), can contain arbitrary data
  - But viewable as syslog-like format with `journalctl`
- Indexed, binary logs; rotation handled transparently
- Can replace syslog (but can also work in parallel)
- Not persistent across reboots by default – to make it persistent, create the `/var/log/journal` directory, preferably with:

  ```
  install -d -g systemd-journal /var/log/journal
  setfacl -R -nm g:adm:rx,d:g:adm:rx /var/log/journal
  ```
- Can log to a remote host (with `systemd-journal-gateway`, not in Debian yet)

Example journal entry

```
_SERVICE=systemd-logind.service
MESSAGE=User harald logged in
MESSAGE_ID=422bc3d271414bc8bc9570f222f24a9
_EXE=/lib/systemd/systemd-logind
_COMM=systemd-logind
_CMDLINE=/lib/systemd/systemd-logind
_PID=4711
_UID=0
_GID=0
_SYSTEMD_CGROUP=/system/systemd-logind.service
_CGROUPS=cpu:/system/systemd-logind.service
PRIORITY=6
_BOOT_ID=422bc3d271414bc8bc95870f222f24a9
_MACHINE_ID=c686f3b205dd48e0b43ceb6eda479721
_HOSTNAME=waldi
LOGIN_USER=500
```

Using `journalctl`

- View the full log: `journalctl`
- Since last boot: `journalctl -b`
- For a given time interval: `journalctl --since=yesterday`
  or `journalctl --until="2013-03-15 13:10:30"`
- View it in the verbose (native) format: `journalctl -o verbose`
- Filter by systemd unit: `journalctl -u ssh`
- Filter by field from the verbose format:
  `journalctl _SYSTEMD_UNIT=ssh.service`
  `journalctl _PID=810`
- Line view (≈ tail -f): `journalctl -f`
- Last entries (≈ tail): `journalctl -n`
- Works with bash-completion
- See also: Journald design document, Using the Journal

Containers integration

- General philosophy: integrate management of services from machines (VMs and containers) with those of the host
  - `systemd-machined`: tracks machines, provides an API to list, create, register, kill, terminate machines
  - `machinectl`: command-line utility to manipulate machines
  - other tools also have containers support:
    - `systemctl -M mycontainer restart foo`
    - `systemctl list-machines`: provides state of containers
    - `journalctl -M mycontainer`
    - `journalctl -m`: combined log of all containers
- systemd has its own mini container manager: `systemd-nspawn`
- Other virtualization solutions can also talk to `machined`
- More information: Container integration

More stuff

- New cross-distro configuration files: `/etc/hostname`, `/etc/locale.conf`, `/etc/sysctl.d/*.conf`, `/etc/tmpfiles.d/*.conf`
- Tools to manage hostname, locale, time and date: `hostnamectl`, `localectl`, `timedatectl`
- Support for watchdogs
- Handling of user sessions
  - Each within its own cgroup
  - Multi-seat support
  - `loginctl` to manage sessions, users, seats
- systemd networking: systemd-networkd, systemd-resolved
  - Started as a way to improve networking management for containers

Conclusions

- systemd revisits the way we manage Linux systems
  - *If we redesigned services management from scratch, would it look like systemd?*
- For service developers: easier to support systemd than sysVinit
  - No need to fork, to drop privileges, to write a pid file
  - Just output logs to stdout (redirected to syslog, with priorities)
- Some parts still have rough edges, or are still moving targets, but are promising: journal, containers, networking
- systemd might not be the final answer, but at least it's an interesting data point to look at