VIRTUALIZATION & CLOUD INFRASTRUCTURE DEVROOM
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#snapsafety: de-duplicating state across Virtual Machine clones

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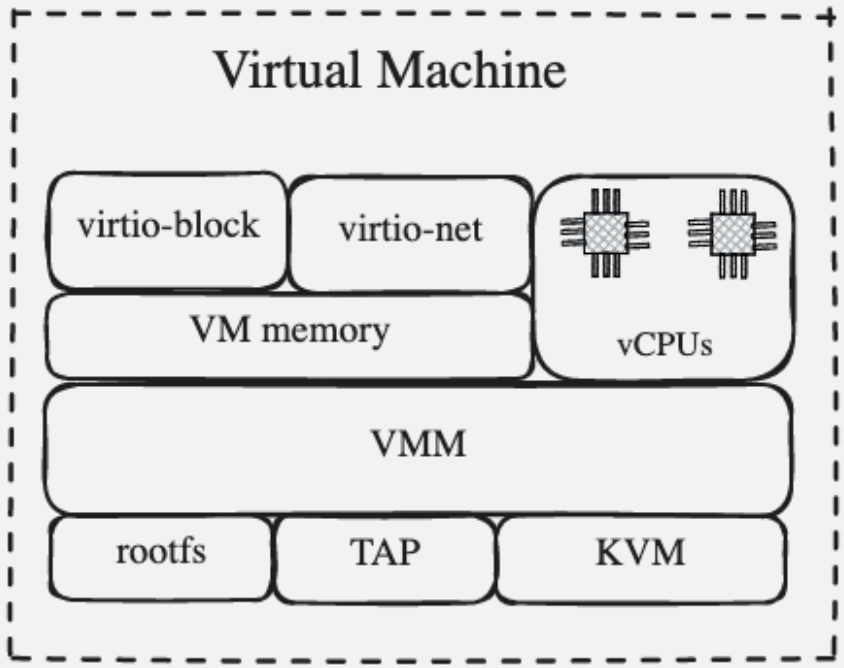
Agenda

1. Virtual Machine snapshots
2. #snapsafety: What’s wrong with VM snapshots?
3. #snapsafety mechanisms
4. System-level #snapsafety
5. Next steps

Virtual Machine snapshots

Virtual Machine snapshots



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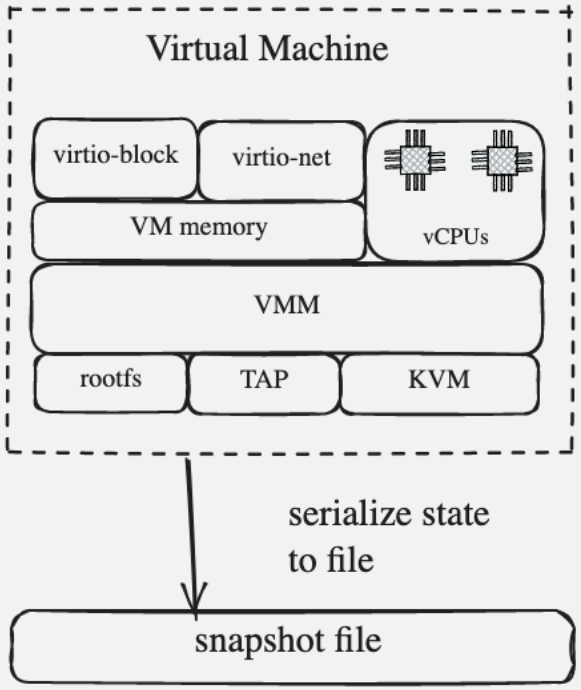
Virtual Machine snapshots



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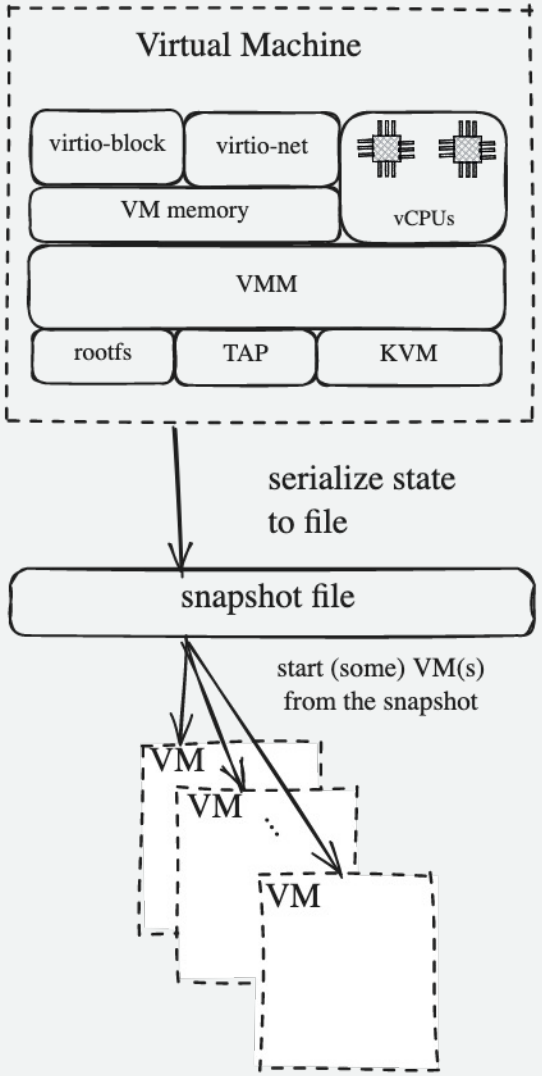
Virtual Machine snapshots



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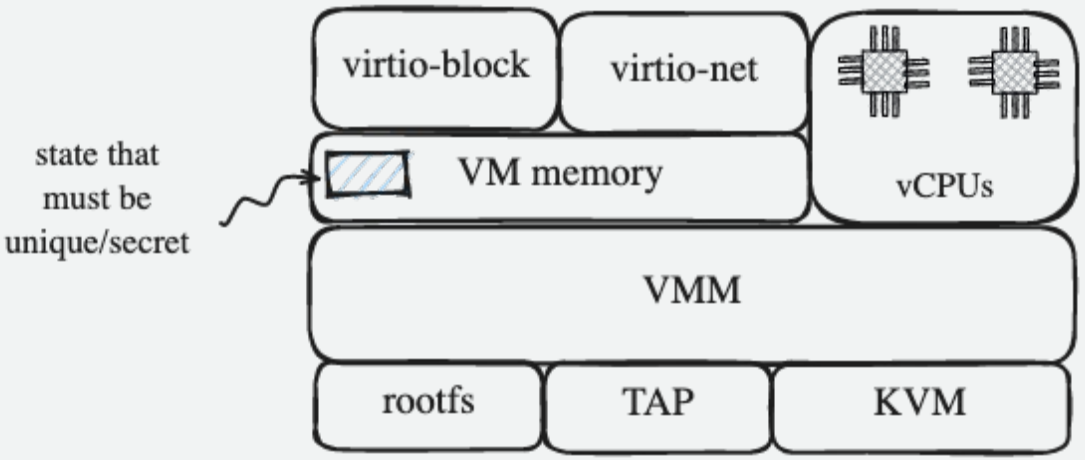
Which we can later use to launch one or more identical VMs

#snapsafety: What's wrong with VM snapshots?



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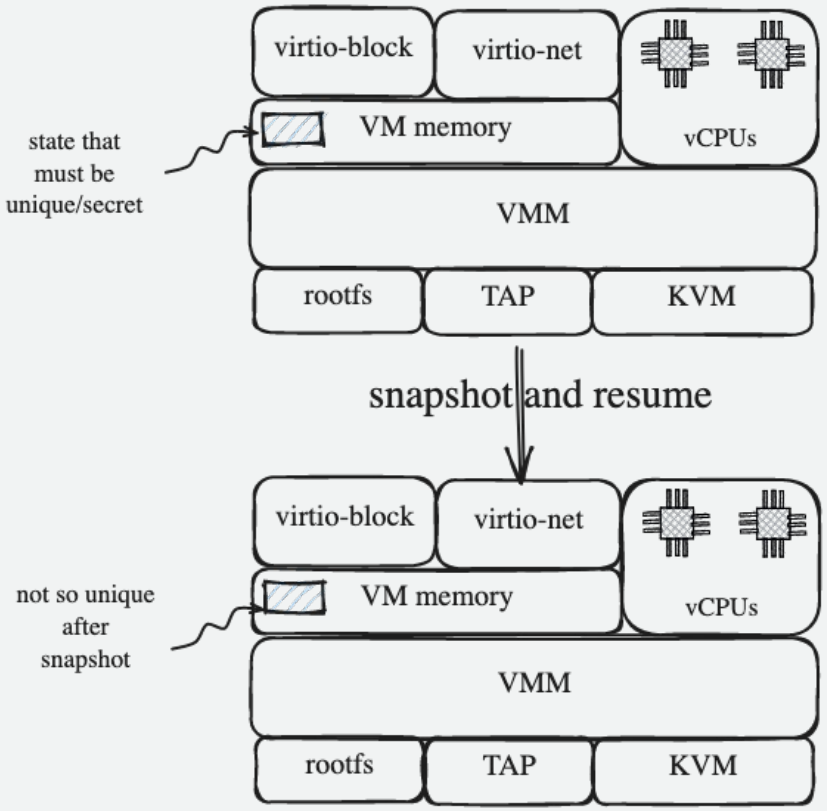

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After taking a snapshot and starting new VMs from it, this property is lost

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- Other(?)

#snapsafety mechanisms

Virtual Machine Generation ID (VMGenID)

- Notification mechanism that lets VM know it started from a snapshot
- ACPI virtual device, emulated by VMM, provides generation ID to guest
  - Cyptographically random 128-bits
  - Changes every time the VM resumes from a snapshot
- Linux kernel uses the generation ID to reseed its PRNG
- Relies on handling of ACPI notification
  - Slightly racy

Virtual Machine Generation ID - uevent

- Initial Linux VMGenID implementation did not allow for user space notifications
  - Generation ID used as entropy -> better not expose it
- Extend VMGenID to send a uevent to user space every time generation ID changes
  - Present in Linux >= 6.8
- Asynchronous notification mechanism
  - Perfect fit for applications with event loops

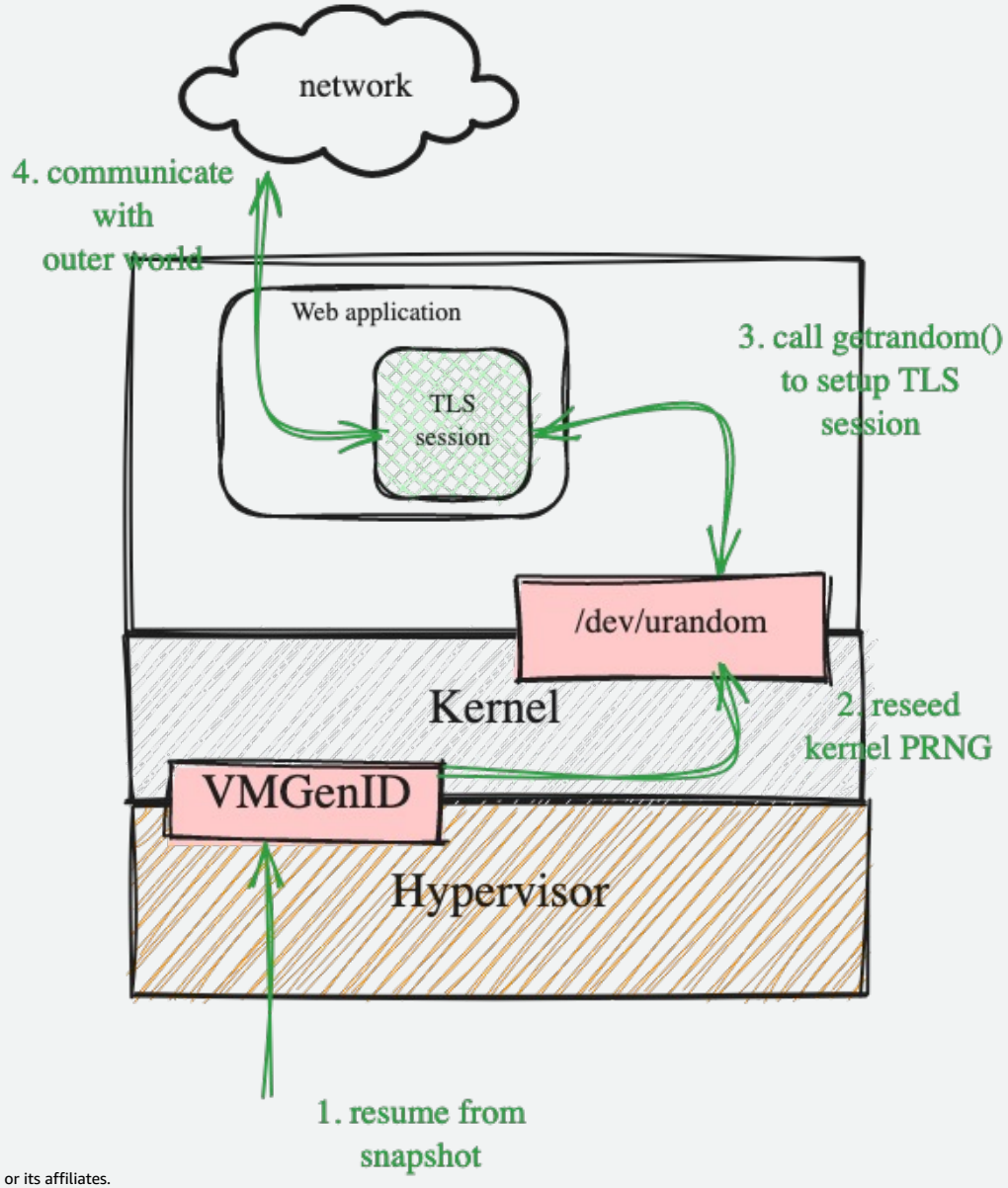
Cryptographically Secure PRNGs

- Often uses for security-sensitive applications, e.g. TLS
- CSPRNGs in runtime systems like JVM
  - Can now use VMGenID uevent mechanism to be notified about snapshots
- CSPRNGs in libraries (OpenSSL, AWS-LC, etc)
  - They don’t have an event loop to check for the event
- We should explore other mechanisms
  - Prediction resistance with HW instructions (RDRAND)
  - Build suitable APIs on top of VMGenID uevent

System-level #snapsafety

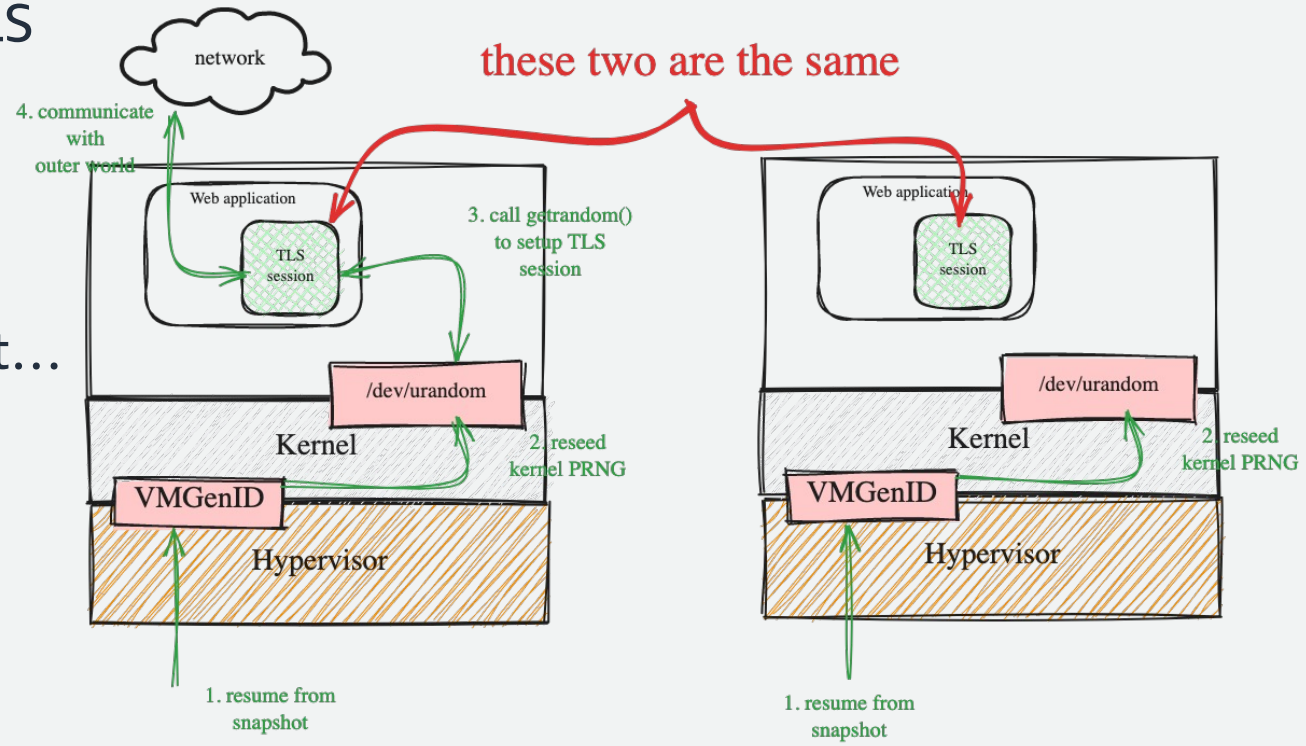
Is VMGenID enough?

1. Resume a VM from a snapshot
2. VMM & Linux supports VMGenID
   - ➢ The kernel will reseed its PRNG using the generation ID
3. Some application reads random bytes from /dev/urandom to create a TLS session key
   - ➢ /dev/urandom is safe!!
4. Application starts communicating over network
5. Take a snapshot of the VM



Is VMGenID enough?

- Snapshot at this point will duplicate the TLS state
- Even though the kernel PRNG is safe, the system is not
- Application *could* use VMGenID uevent, but…
  - uevent available in clone, not initial VM
  - Race condition in reacting
- TLS state should not be serialized in the snapshot in the first place



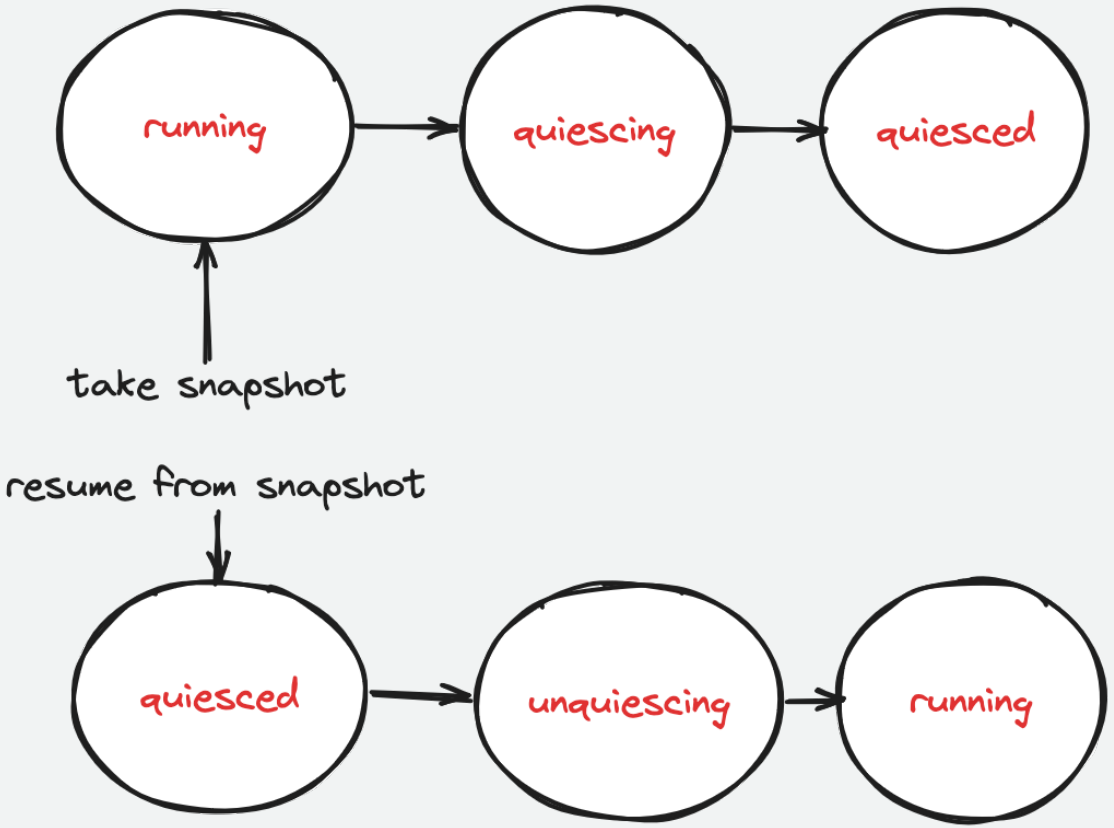
VMGenID is a “post-mortem” mechanism

- Notification that VM has resumed from a snapshot
- Sensitive info might already be in-flight

Control the timing of snapshot events

- We should do “something” before we even take the snapshot
- Only take snapshot when it is safe to do, e.g. no in-flight TLS connections
- Only resume normal system operation after all components have been notified about resume event

System-level #snapsafety: systemd prototype



Model when it is safe for a system to run:

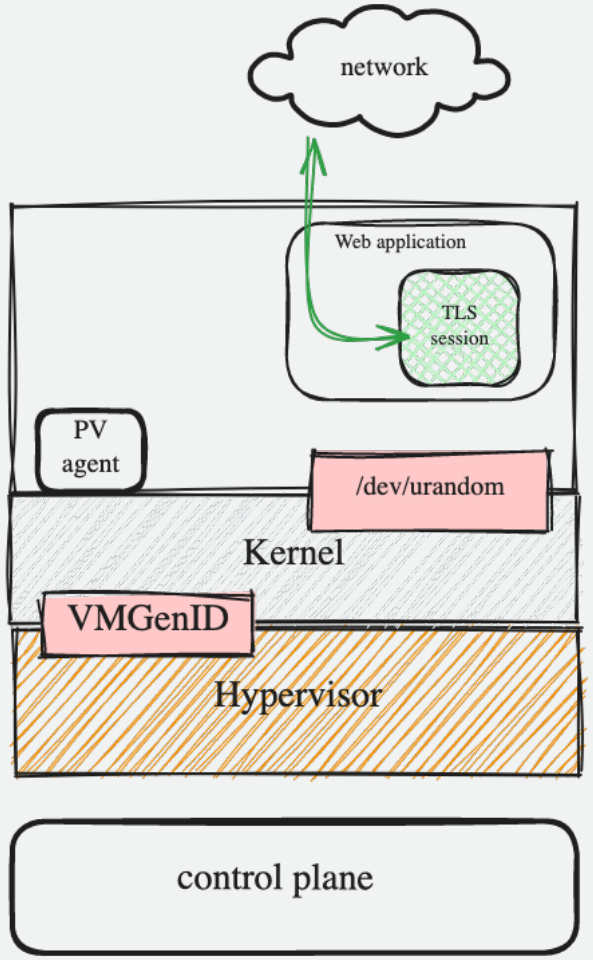
- quiesce before getting a snapshot
- After resuming from snapshot, unquiesce only after it is safe

Inhibitors for quiescing/unquiescing transitions

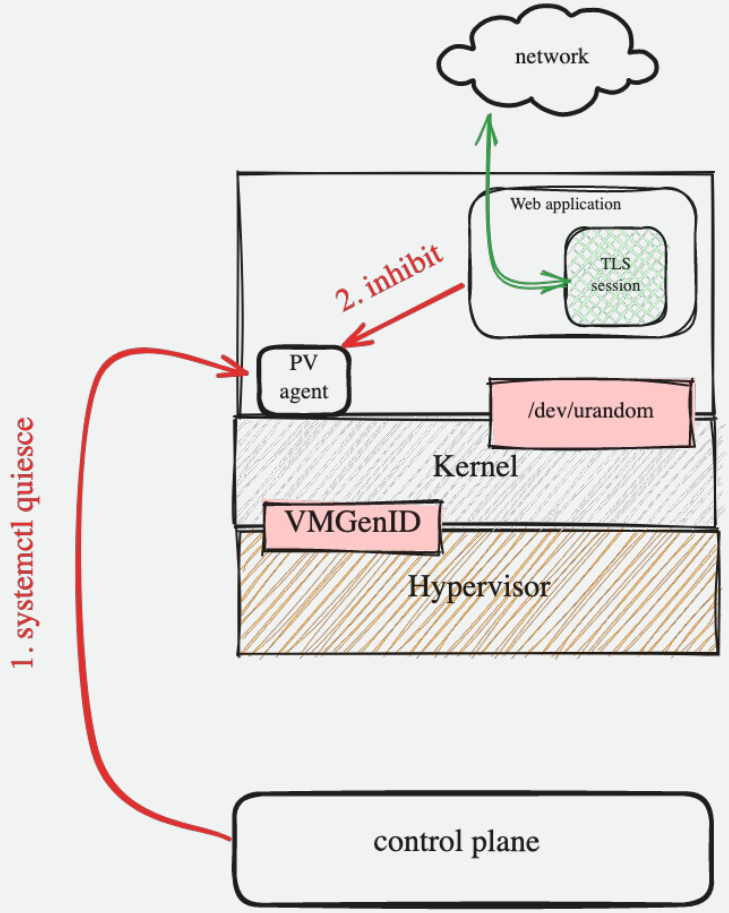
- systemctl suspend?

Paravirtual agent to orchestrate everything

State: running (pre-snapshot)



State: quiescing



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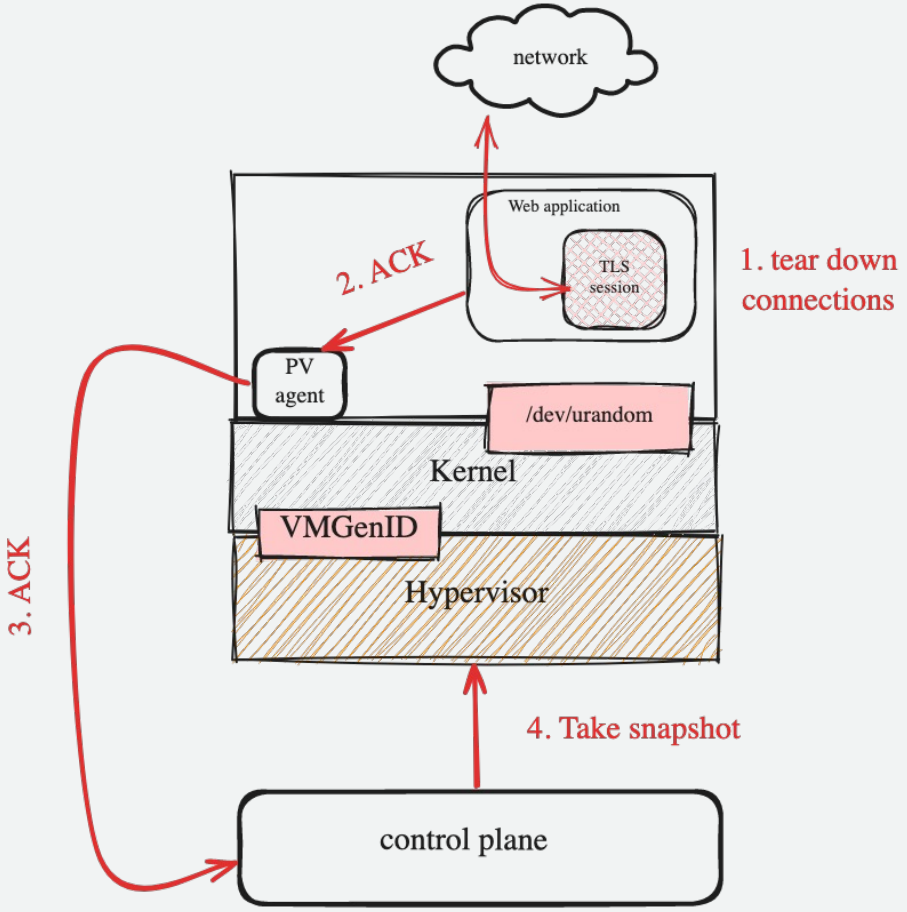
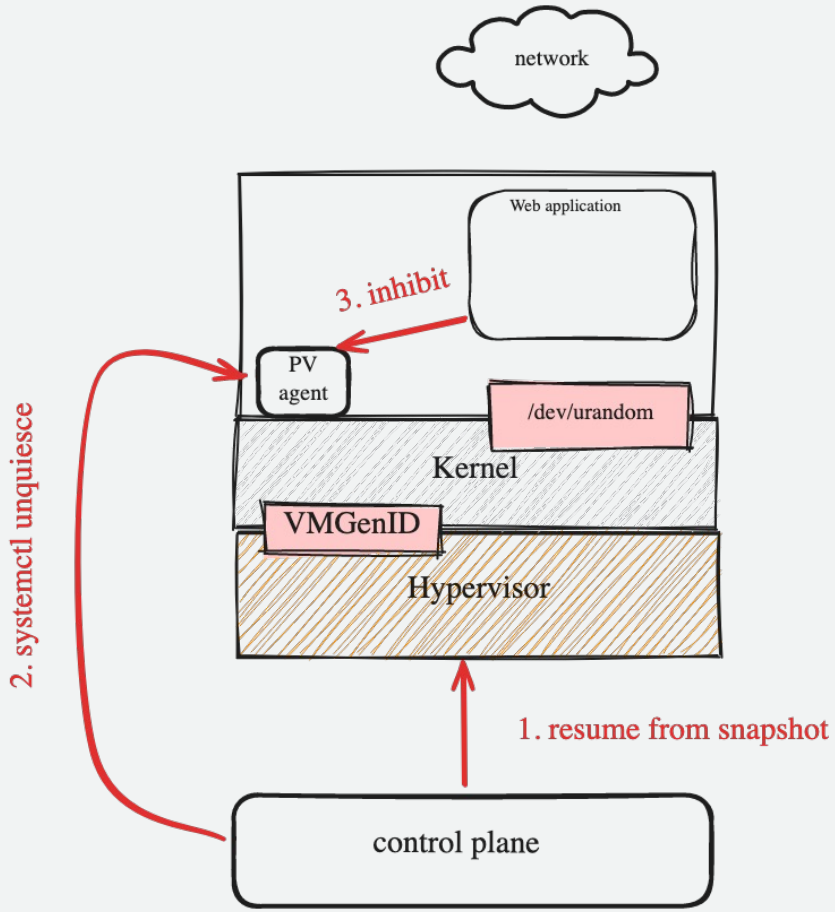
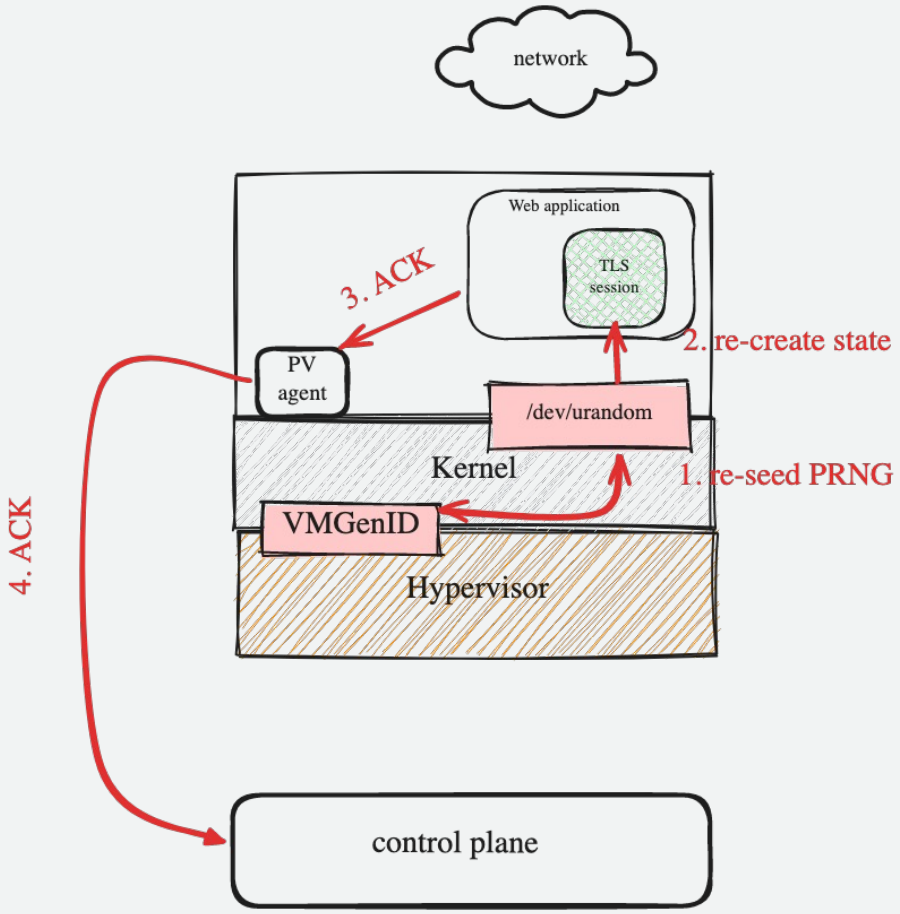


State: unquiescing



State: running (post-resume)



Summary & Next steps

Next Steps

1. Support for VMGenID in Firecracker
2. Work with PRNG owners to find proper ways to make libraries #snapsafe
3. Make systemd #snapsafe
   - Ground work already done in https://github.com/systemd/systemd/issues/19269
   - Hopefully, more service management systems will follow

Q&A

Thank you!

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