Managing Matryoshkas: Testing Nested Guests

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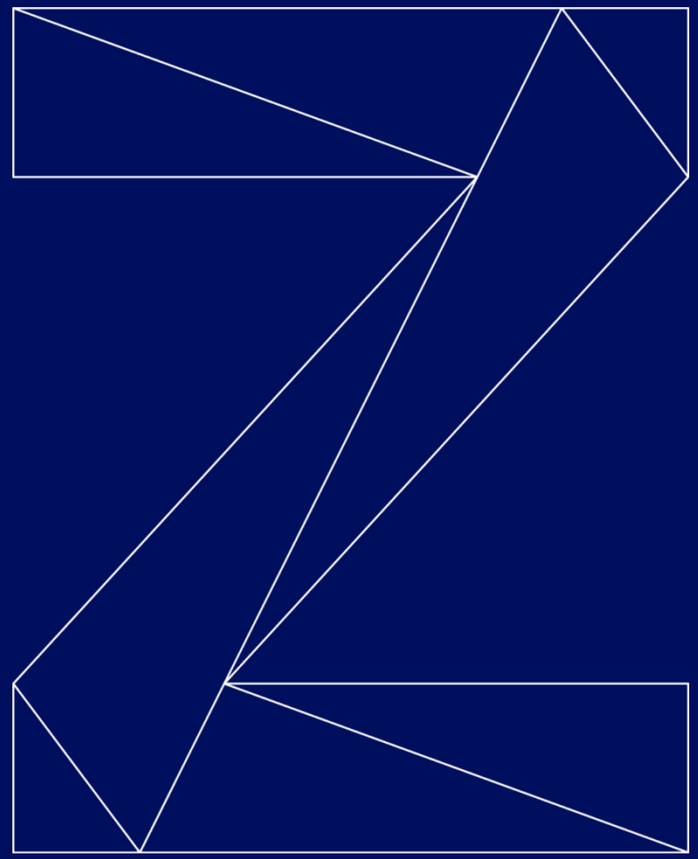

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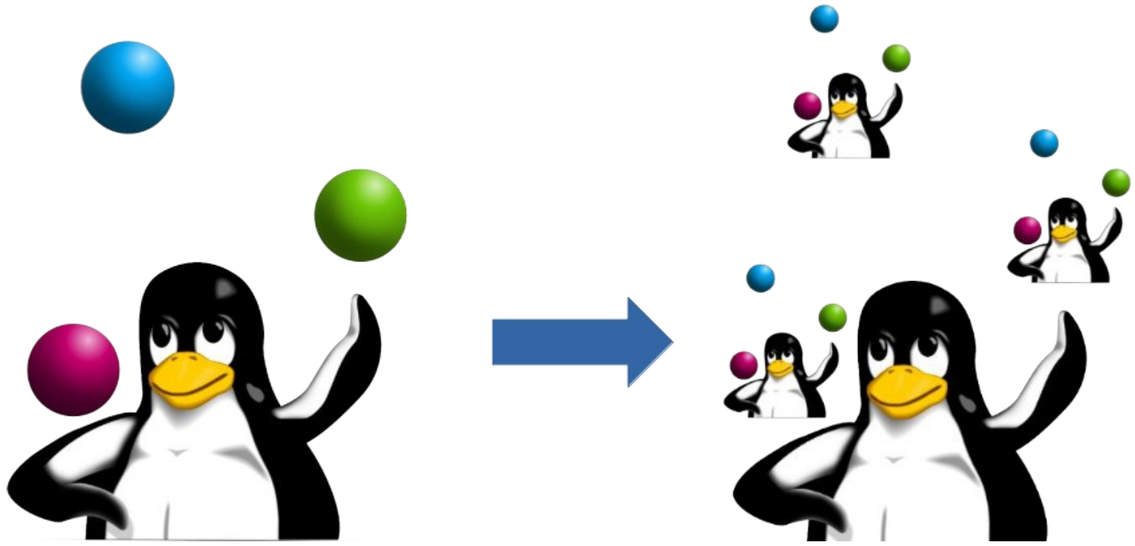
Agenda

What is Nested Virtualization?
Testing Nested Virtualization
Demo
New Approach
  Design Goals, Ideas, and Details
What's next?

Nested Virtualization

- Turn guest into host
- Use cases:
  - Development/Testing
  - Production
  - Training
- Terminology:
  - “L0” - bare metal host, running KVM
  - “L1” - VM running on “L0”, acting as hypervisor
  - “L2” - VM running on “L1” - called nested guest
  - And so on…

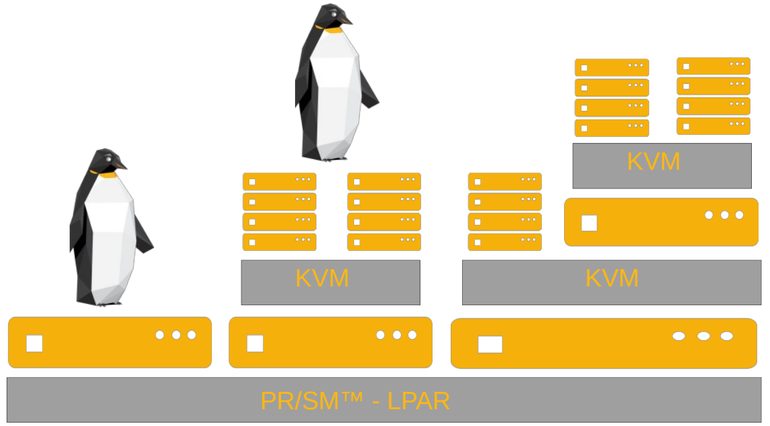


Source: http://events17.linuxfoundation.org/sites/events/files/slides/Nesting%20KVM%20on%20s390x%20-%20David%20Hildenbrand_0.pdf

Nested Virtualization on s390x

- Requirements:
  - Kernel >= 4.8
  - `kvm.nested=1`
  - QEMU >= 2.9
  - CPU host model
- Multi-level nesting support
- Hardware assisted via SIE (*Start Interpretive Execution*)
- Migration works between different levels
- Supports migration of L1 guest with L2 guest running[1]

[1] See https://www.linux-kvm.org/page/Nested_Guests



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Testing nested virtualization

Available Test Suites/Frameworks for QEMU/KVM (and libvirt)

- Avocado-VT: tp-libvirt, tp-qemu
- Avocado_qemu
- kvm-unit-tests
- Libvirt TCK
- Linux Virtualization Tests (virt-test) (legacy only)
- Supernested

→ Avocado-VT seems to be the most evolved framework

Shortcomings for nested virtualization tests

Shortcomings of Avocado-VT for nested virtualization testing:

- Interaction with host using Python
- Interaction with the guests is done via SSH using bash

  Why?

  Wouldn’t it be great if we can simply reuse our host code in the nested guest, the new “host”?

Guest interaction (aka linux_hw_check.py)

```
priv_key = os.path.join(self.vm_hw['key_path'], 'id_rsa')
with ssh.Session(('127.0.0.1', ssh_port),
                 ('root', priv_key)) as session:
    # cpu
    proc_count_cmd = 'egrep -c "^processor\s\:" /proc/cpuinfo'
    self.assertEqual(int(self.vm_hw['smp']),
                     int(session.cmd(proc_count_cmd).stdout_text.strip()))

    # memory
    match = re.match(r"^MemTotal:\s+(\d+)\skB",
                     session.cmd('cat /proc/meminfo').stdout_text.strip())
    self.assertIsNotNone(match)
    exact_mem_kb = int(self.vm_hw['memory']) * 1024
    guest_mem_kb = int(match.group(1))
    self.assertGreaterEqual(guest_mem_kb, exact_mem_kb * 0.9)
    self.assertLessEqual(guest_mem_kb, exact_mem_kb)
```

Source: Presentation “The functional test beast: tame it, bring it home and make it your pet” (https://events19.linuxfoundation.org/wp-content/uploads/2017/12/The-Functional-Test-Beast-Tame-it-Bring-it-Home-and-Make-it-your-Pet-Cleber-Rosa-Red-Hat-Inc..pdf)

Shortcomings for nested virtualization tests

- Debugging of nested guest code is hard
- Common tasks, e.g. hot (un)plugging a device
  - Workarounds are often used:
    - Sleeps
    - Busy loops for polling
    - Coarse-grained “`udevadm settle`”

    Wouldn’t it be great to use pyudev[1] everywhere?
- Different semantics
  - e.g. `Popen(…)` vs. `session.cmd()`

    Wouldn’t it be great to have the exact same semantic in the guest as in the host?
- Error handling? Stack traces?

[1] See https://pyudev.readthedocs.io

Use your host code in the guest

Example Test Case

```
class ExampleTestCase(SshTestCase):
    DOMAIN_NAMES = ['test1']

    def runTest(self):
        guest = self.guests['test1']
        stdout = guest.call(subprocess.check_output, ['hostname']).decode()
        self.assertEqual(stdout, 'qemus390x\n')
        self.assertEqual(guest.call(socket.gethostname), stdout.strip())
```

DEMO TIME

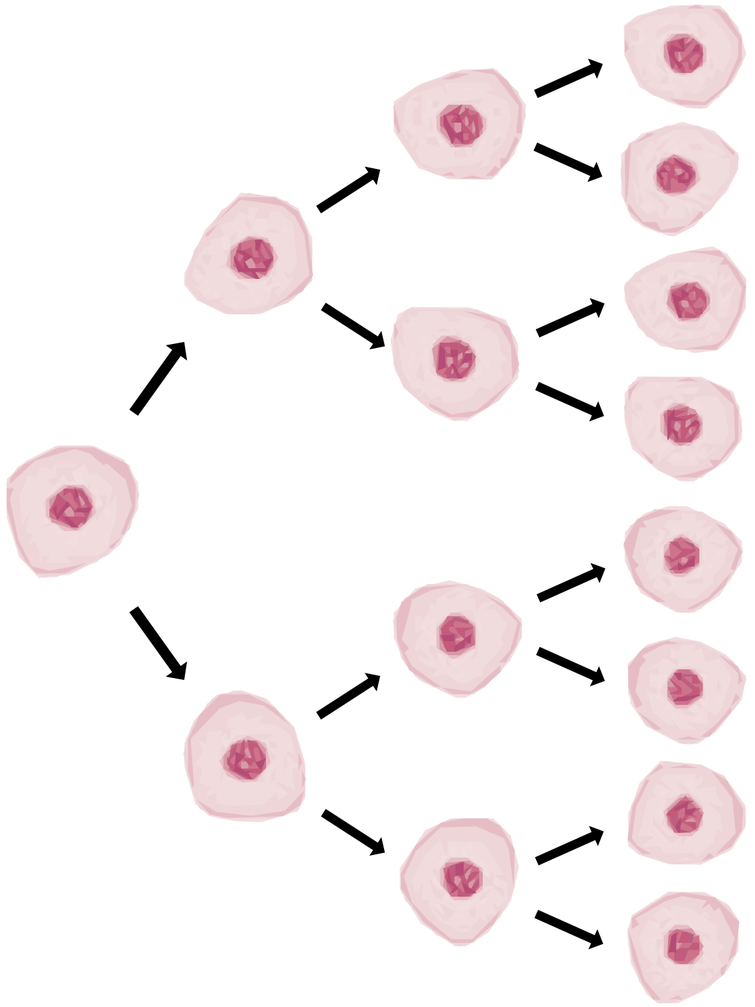
Current state...
Prototype only.

Usage of Mitogen[1]

"[...] make it childsplay to run Python code on remote machines [...]" - David Wilson[2]

- Python library for writing distributed self-replicating programs
- Support for Python2 >= 2.4 and Python3.x
- Python interpreter and SSH client must be installed
  - Zero Python dependencies

    (uses only Python standard library)



Source: https://sweetness.hmmz.org/images/mito1/mitogen.svg

[1] https://github.com/dw/mitogen created by David Wilson
[2] https://sweetness.hmmz.org/page/7/ [visited 23.10.2019]

Mitogen Overview

- Bootstrap: Spins up and hooks up a "remote" Python, e.g. via SSH → This forms a **new context**
  - Function calls in this context:

    Uses `pickle`[1] for marshalling
- Resolves Python dependencies in the remote context transparently[2]
- Has concept of services[3] with a state
  - User-supplied class with explicitly exposed methods, which can be called by other contexts
- Forwards Stdio and logs (`logging` package)
- Supports asynchronous calls

[1] See https://docs.python.org/3/library/pickle.html for details
[2] See https://mitogen.networkgenomics.com/#module-forwarder for details.
[3] See https://mitogen.networkgenomics.com/services.html for details.

```
"""Get number of logical CPUs on host_2 using host_1 as an SSH hop.
Usage: $ python3 count.py host_1 host_2"""
import sys

import mitogen
import psutil

@mitogen.main()
def main(router):
    host_1_ctxt = router.ssh(hostname=sys.argv[1])
    host_2_ctxt = router.ssh(via=host_1_ctxt, hostname=sys.argv[2])
    print(host_2_ctxt.call(psutil.cpu_count, logical=True))
```

Mitogen is not enough...

1) Handle (un)pickling
2) Mutable state in remote context(s),
   e.g. even placed in a native library (`libvirt-python`)
3) Lifetime of the objects in the remote context(s)

```
def lookup(name):
    import libvirt
    conn = libvirt.open()
    dom = conn.lookupByName(name)
    return dom

dom = guest_1.call(lookup, "demo")
dom.create()
```

Remote invocation via proxy objects

Solution for pickling and state problem

- Contexts return proxy objects and methods for everything
  - Can be used as argument in function calls
- Register trusted classes to the (un)pickler
- Special “dunder method” `__value__` for receiving the actual object
  - Enforce the unpickling of non-registered classes by using `trust` keyword

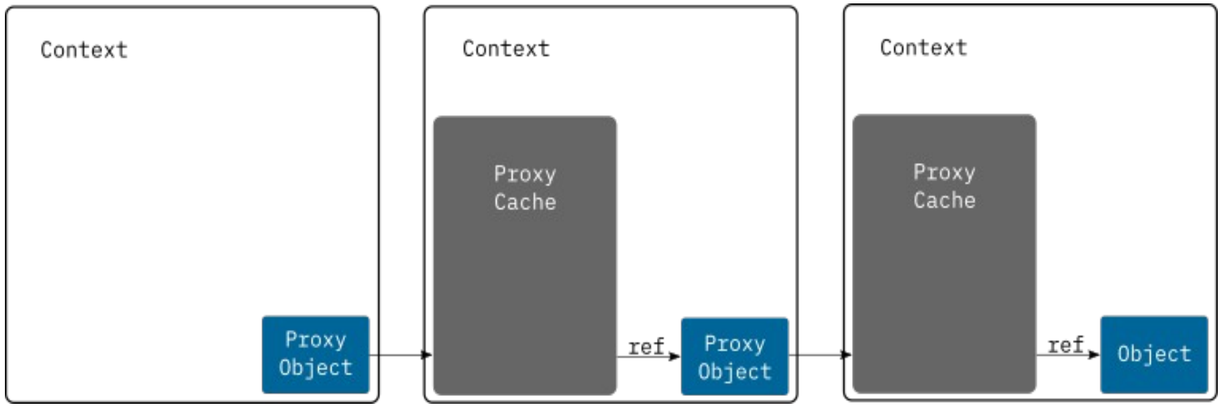
```
def lookup(name):
    global dom
    import libvirt
    conn = libvirt.open()
    dom = conn.lookupByName(name)
    return dom

dom_proxy = guest_1.call(lookup, "demo")
assert isinstance(dom_proxy, ProxyObj)
dom_proxy.create()
# will raise an "mitogen.core.CallError:
# builtins.TypeError: can't pickle PyCapsule objects"
# as a libvirt.virDomain object is not pickleable
dom = dom_proxy.__value__(trust=True)
```

[1] See https://docs.python.org/3/library/stdtypes.html
[2] See https://docs.python.org/3/reference/datamodel.html

Connect Python Object life cycles

Solution for lifetime problem

- Connect life cycle of proxy objects and the actual objects.
  - As long as a proxy object is alive the referred object must not be garbage collected
  - “Transitive proxy object chains”



Conclusions

Advantages

- Guests can run Python host code transparently
  - Less duplicated code
- Usage of Python packages like pyudev in the guests
- Redirection of Stdio/logging in the guests
- Usage of shell commands can be minimized to a minimum

Limitations

- Native dependencies are not copied automatically, e.g. `libvirt.so`
- Python interpreter must be available in the guest and there is an overhead caused by the Python interpreter start
- Pickling limitations
  - use other pickle module, e.g. dill[1]

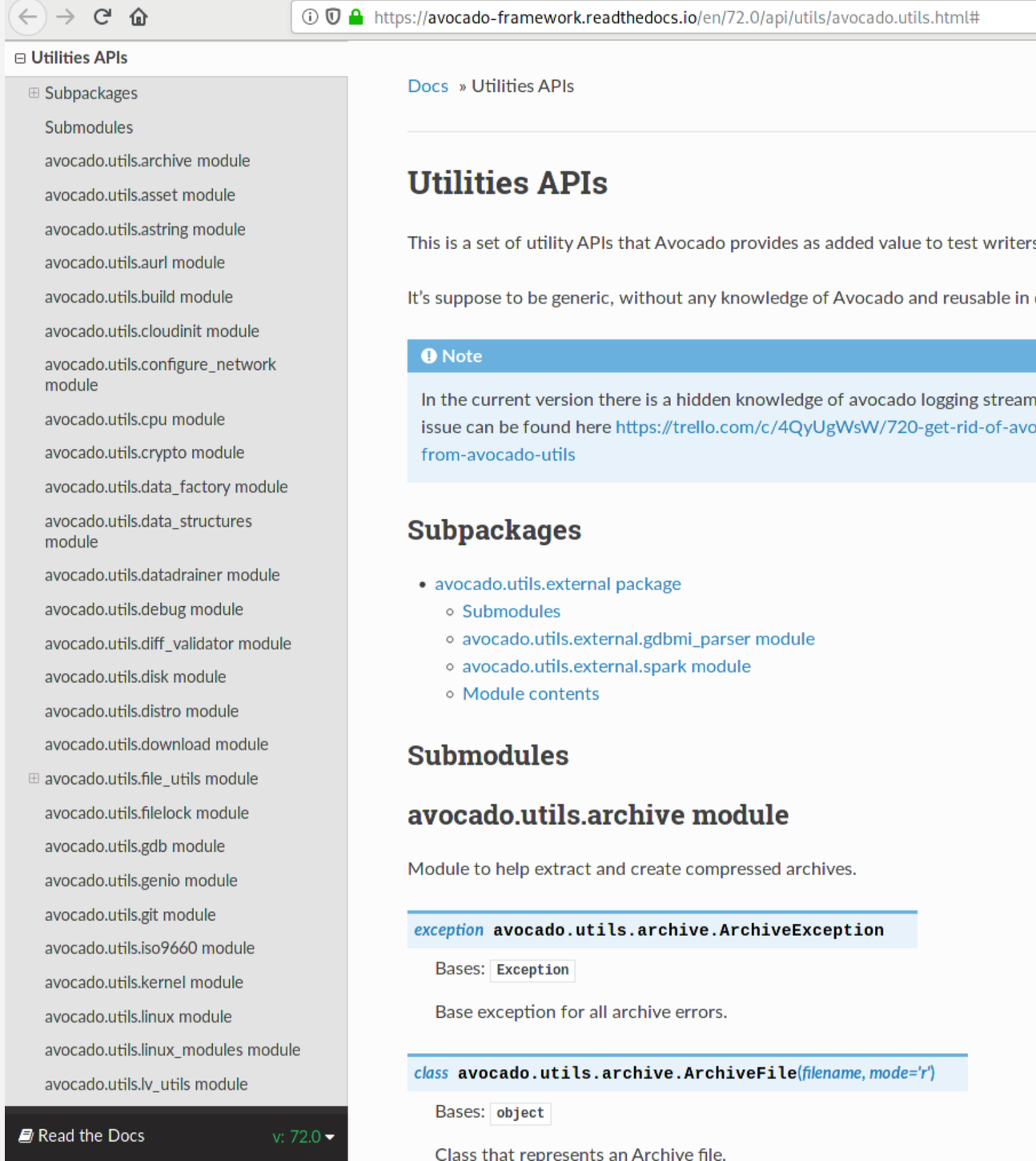
[1] See https://docs.python.org/3/library/pickle.html for details.

Summary

- There is still much to do :/
- Test approaches for nested virtualization already exists, but...
- This new approach:
  - Allows the interaction with the host and guests using Python
  - Recursive reuse of host code in guests
  - Easy management of (nested) guests

What’s next?

- Finish our implementation
- Upstreaming changes to Mitogen
- Make it easier to debug:
  - Implement remote Python Debugger (“remote PDB”)?
- Integrate our framework/tests into Avocado-VT?



Thank you.