Pushing the limits: 1000 guests per host and beyond
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(Q)Emus predominately travel in pairs, and while they can form large flocks, this is an atypical social behaviour that arises from the common need to move towards a new food source. - Wikipedia
Pushing the limits: 1000 guests per host and beyond

Agenda

What is this about?
The test setup
What we tested
Challenges
Conclusion
What is this about?

KVM runs on...
What is this about?

- Finding limits of our machine/architecture and KVM/QEMU/Libvirt
- How far can we go given a sufficient host configuration and where does it break?
  - How many guests?
  - How many block and network devices?
  - Which resources are necessary?
  - Wh configuration settings are needed to support large configurations?
- Testing the extreme limits, not necessarily recommended to run in production
- No performance measurements
Pushing the limits: 1000 guests per host and beyond

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Test setup

Host:
System Type: z13 (Type: 2964 Model 701 NE1)
Central Storage: 2 TB
CPUs: 64 (shared)

Guests:
RHEL 7.1 & SuSE 12
Memory: 1024 MB
CPUs: 2
Disk: Raw image files on SCSI disks
Network: Linux bridged
Test setup

~# cat /proc/cpuinfo

vendor_id       : IBM/S390

# processors    : 64

bogomips per cpu: 20325.00

features        : esan3 zarch stfle msa ldisp eimm dfp edat etf3eh highgprs te

cache0          : level=1 type=Data scope=Private size=128K line_size=256 associativity=8

cache1          : level=1 type=Instruction scope=Private size=96K line_size=256 associativity=6

cache2          : level=2 type=Data scope=Private size=2048K line_size=256 associativity=8

cache3          : level=2 type=Instruction scope=Private size=2048K line_size=256 associativity=8

cache4          : level=3 type=Unified scope=Shared size=65536K line_size=256 associativity=16

cache5          : level=4 type=Unified scope=Shared size=491520K line_size=256 associativity=30

processor 0: version = 00, identification = 11C667, machine = 2964

processor 1: version = 00, identification = 11C667, machine = 2964

processor 2: version = 00, identification = 11C667, machine = 2964

...

processor 63: version = 00, identification = 11C667, machine = 2964

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What is this about?
The test setup

**What we tested**

Challenges

Conclusion
What we tested

- Start **4096** guests
- Assign **4096** virtio-block devices to a guest
- Use **16384** virtio-block devices per host
- Assign **1024** virtio-net devices to a guest
- Assign large amount of resources to the host, e.g. use more than **8TB** RAM for the host
- Concurrent live guest migrations of > **64** guests
- ...
Agenda

What is this about?
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Conclusion
General: memory dumps can take very long

- Amount of memory in servers has increased faster than bandwidth of memory and storage
- On s390 we have the possibility to take memory dumps even in very early or late stages
- Not kdump but IBM stand-alone dump tools
- Downside: no filtering of memory and only 1 CPU available
- Writing a memory dump of a multi-TB system can take days

- For kvm guests with huge memory sizes guest debugging with gdb is a workaround
Host: adding network devices

- 2048 macvtap devices:
  - found problem in s390 qeth driver code
  - Each macvtap device is assigned its own MAC address
  - List of MAC addresses in hardware needs to be re-populated every time we add a macvtap device
  - Causes long delays (76.5 seconds for 50 devices) and eventually leads to stalls
  - Working on fix for qeth driver

- System limits hit:
  - Linux bridges limited to 1024 ports → add more bridges
  - Max. number of IPv6 routes
    IPv6: Maximum number of routes reached, consider increasing route/max
    → Set ipv6.sysctl.ip6_rt_max_size = 8192
Attaching 4096 disks to the host

- System limits hit:
  - Max. number of inotify watches
    `systemd-udevd: inotify_add_watch(7, /dev/dm-1784, 10) failed: No space left on device`
    → set fs.inotify.max_user_watches=<some big number>
  - Number of file descriptors
    - ...

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Counting file descriptors...

- Mostly eventfds, one per virtqueue
- For example: a virtio-net device is using
  - one virtqueue for TX/RX (depending on multiqueue or not)
  - one virtqueue for CTRL
  - /dev/tap
  - /dev/vhost-net + 3 irqfds
  - 8 FDs in total
- Add 1000 virtio-net devices
- We need many!
Pushing the limits: 1000 guests per host and beyond

Use many virtio-block devices
Attach 4096 disks to a guest
- What could possibly go wrong, right?

- Tested this a while ago, but limit was 1024 due to select()
- Change from select() to poll() between QEMU 1.4 – 1.5
- Target: 4096, started with: 1000
- Guest startup time with 1000 disks attached: 13 minutes
- Problem: Calling bdrv_drain_all() in each virtio_reset() call for every BlockDriverState
- Fix: Call aio_poll() per AioContext instead, save many aio_poll()'s
  → down to 16 seconds for 1000 disks
- Upstream commit:

  commit f406c03c093f1451ac0ba7fde31eeb78e5e5e417
  Author: Alexander Yarygin <yarygin@linux.vnet.ibm.com>
  Date:   Wed Jun 10 14:38:17 2015 +0300

    block: Let bdrv_drain_all() to call aio_poll() for each AioContext
- 4096 disks is possible with this fix
Using 16384 virtio-block disks

- Started 16 guests, each assigned 1024 virtio-block devices

  `qemu-system-s390x: -drive file=/guestimages/data3/mydomain.img,if=none,id=drive-virtio-disk0,format=raw,serial=skel,cache=none,aio=native: could not open disk image /guestimages/data3/zs93k1g08166.img: Could not refresh total sector count: Bad file descriptor`

- Discovered that `/proc/sys/fs/aio-nr` is the same as `/proc/sys/fs/aio-max-nr`
- Not enough aio contexts available
- Fix by increasing `fs.aio-max-nr`
Starting 4096 guests
... because it's such a nice even number
Starting 4096 guests
… because it's such a nice even number

Many system limits had to be tweaked:

journal: Failed to find user record for uid '107': **Too many open files**
→ create file /etc/systemd/system/libvirtd.service.d/openfiles.conf and add LimitNOFILE=4096
Number of file descriptors (of course!)

Increase max PTYs
journal: internal error: process exited while connecting to monitor: 2015-04-04T15:41:07.159443Z
qemu-system-s390x: -chardev pty,id=charconsole0: **Failed to create chardev**
sysctl.conf: kernel.pty_max = 8192

Max processes/threads exceeded
• pthread_create_returns -EAGAIN → insufficient resources
• LimitNPROC=1048576 in libvirtd.service
• In qemu.conf max_process=8192

Not enough memory → increase to 2TB
kernel: [sched_delayed] sched: RT throttling activated
followed by multiple page allocation failures.
kernel: top: **page allocation failure**: order:4, mode:0x1040d0

Sources: [14],[15],[16]
Starting 4096 guests
systemd says hello :)
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Starting 4096 guests
Guests running

```
top - 11:03:47 up 1 day, 59 min, 4 users, load average: 133.44, 400.06, 312.86
Tasks: 8569 total, 24 running, 8545 sleeping, 0 stopped, 0 zombie
%Cpu(s): 60.7 us, 9.8 sy, 0.0 ni, 19.2 id, 0.0 wa, 0.7 hi, 7.0 si, 2.6 st
KiB Mem: 21102485+total, 14060241+used, 70422444+free, 418040 buffers
KiB Swap: 10240000+total, 0 used, 10240000+free. 1124296 cached Mem
scroll coordinates: y = 1/8569 (tasks), x = 1/12 (fields)

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<th>USER</th>
<th>PR</th>
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<th>RES</th>
<th>SHR</th>
<th>S</th>
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</tbody>
</table>
```
Starting 4096 guests

Guests running

```
[root@zs93k1 ~]# virsh list --all | wc -l
8796
[root@zs93k1 ~]# virsh list | wc -l
3985
```

```
[root@zs93k1 ~]# free -h

Mem:	2.0T	1.3T	661G	268M	410M	1.1G
-/+ buffers/cache:	1.3T	662G
Swap:	976G	0B	976G
```

Running CPU and network stress tools
Starting 4096 guests

a running guest
Starting 4096 guests
strict overcommit and glibc per-thread arenas

- We use many threads in QEMU, for vcpu threads, io threads,...
- Glibc has per-thread memory pools (arenas)
- Arenas are created per thread but are limited on the basis of cores the system has
- MALLOC_ARENA_MAX is calculated by
  ((NUMBER_OF_CPU_CORES) * (sizeof(long) == 4 ? 2 : 8))
  - 8 memory pools per core * 64 MB arena size
  - For example with 64 cores i.e. = 64 * 8 = 512 arenas
  - 512 arenas * 64 MB per arena = 32 GB
  - Uses lots of address space
Starting 4096 guests
strict overcommit and glibc per-thread arenas (continued)

- ...
- usually kernel memory accounting treads this correctly, but...
- ... with strict overcommit the entire memory is accounted as “in use”
- malloc() fails much earlier
- This will get worse as number of cores increase!
- Capped by MALLOC_MAX_ARENA
- Control by setting <qemu:env name='MALLOC_ARENA_MAX' value='16'/>
Migrating many guests concurrently
Migrating many guests concurrently – TCP port range for migration

- There's a default port range for migration in libvirt
- When we're running out of ports:
  
  `error: internal error: Unable to find an unused port in range 'migration' (49152-49215)`

- Ports can be specified as part of the virsh command line to circumvent this
- ...or configurable with migration_port_min and migration_port_max in qemu.conf
Migrating many guests concurrently – max. SSH connections

- sshd has a default limit of 10 sessions
- When testing migration of > 64 guests we had to increase this limit
- Change /etc/ssh/sshd_config and set MaxSessions to a higher number

  # Authentication
  ...
  #MaxSessions 128
QEMU: Memslot limitation

/*
 * Some of the bitops functions do not support too long bitmaps.
 * This number must be determined not to exceed such limits.
 */

#define KVM_MEM_MAX_NR_PAGES ((1UL << 31) - 1)

- ((1UL << 31) - 1) * 4k pages → 8TB
- Limit is per memslot
- Currently we have only one memslot for RAM.
- Would need to implement support for multiple memslots in s390x

<table>
<thead>
<tr>
<th>Processor Memory</th>
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</tr>
<tr>
<td>NC9</td>
</tr>
<tr>
<td>NE1</td>
</tr>
</tbody>
</table>
Host: system with 9TB memory

commit c47386fcb81833e266b0e955f127c92c195dcdc2
Author: Martin Schwidefsky <schwidefsky@de.ibm.com>
Date: Wed May 13 14:33:22 2015 +0200

7cded342c: s390/mm: correct return value of pmd_pfn

Git commit 152125b7a882df36a55a8eadbea6d0edf1461ee7
"s390/mm: implement dirty bits for large segment table entries"
broke the pmd_pfn function, it changed the return value from
'unsigned long' to 'int'. This breaks all machine configurations
with memory above the 8TB line.

Cc: stable@vger.kernel.org # 3.17+
Signed-off-by: Martin Schwidefsky <schwidefsky@de.ibm.com>
s390x/kvm: Irqchip route reallocation

- We create a new irqfd per virtqueue
- Every time a new irqfd is created we reallocate the irqchip routing table in the kernel
- With many devices and many virtqueues this causes delays
- Interface of KVM_SET_GSI_ROUTING allows to add a bunch of routing entries in one go. However currently it is not used that way. One entry is added after another.
- For every entry that's to be added we do ioctl(KVM_SET_GSI_ROUTING) and then in the kernel we allocate a new table, re-populate it and add the new entry.
- Fixed by adding all routes to the routing table in QEMU first and then do the ioctl to commit the routing table to the kernel

commit 35d4a70da363e3909beb5d74f35649db25a6004d
Author: Jens Freimann <jfrei@linux.vnet.ibm.com>
Date: Mon Jul 27 16:53:27 2015 +0200

  s390x/kvm: make setting of in-kernel irq routes more efficient
KVM: IRQchip limit

- The in-kernel irqchip is limited to 1024 pins
- For s390 already extended to 4096
- When limit exceeded devices fall back to qemu internal irqfd handling
- Problem: one irqfd is set up per virtqueue (mapping to queue indicator), so queues per irqchip are exhausted fast
  - virtio-net devices possible = 4096 / 3 virtqueues = 1365
- Ideas:
  - Bump up number of pins even further
  - Tweak irqfd interface to support a payload containing an offset to the summary indicators.
    - Then we would not have to set up routes for every single virtqueue

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Conclusion

- Linux (and KVM) scales quite well, most often a matter of adjusting ulimits
  - ipv6.sysctl.ip6_rt_max_size
  - sshd: #MaxSessions 128
  - libvirtd: min_port_range, max_port_range
  - systemd: LimitNOFILE
  - sysctl: kernel.pty.max, fs.aio-max-nr, fs.inotify.max_user_watches

- One problem in systemd which is already fixed upstream

- In-kernel IRQchip limits virtio devices

- Apart from some smaller issues, no major code findings in Libvirt/QEMU/KVM

- No fundamental design problems in our stack Libvirt/QEMU/KVM
Questions ?
Thank you!
Pushing the limits: 1000 guests per host and beyond

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