Jens Freimann

19/08/2015

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

[2]

Agenda

What is this about?

The test setup

What we tested

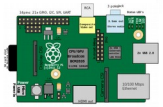
Challenges

Conclusion

What is this about?

KVM runs on...

[4]



[5]

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

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Agenda

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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

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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

Agenda

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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 ressources to the host,
  e.g. use more than **8**TB RAM for the host
- Concurrent live guest migrations of > **64** guests
- ...

Agenda

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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
    - ...

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!

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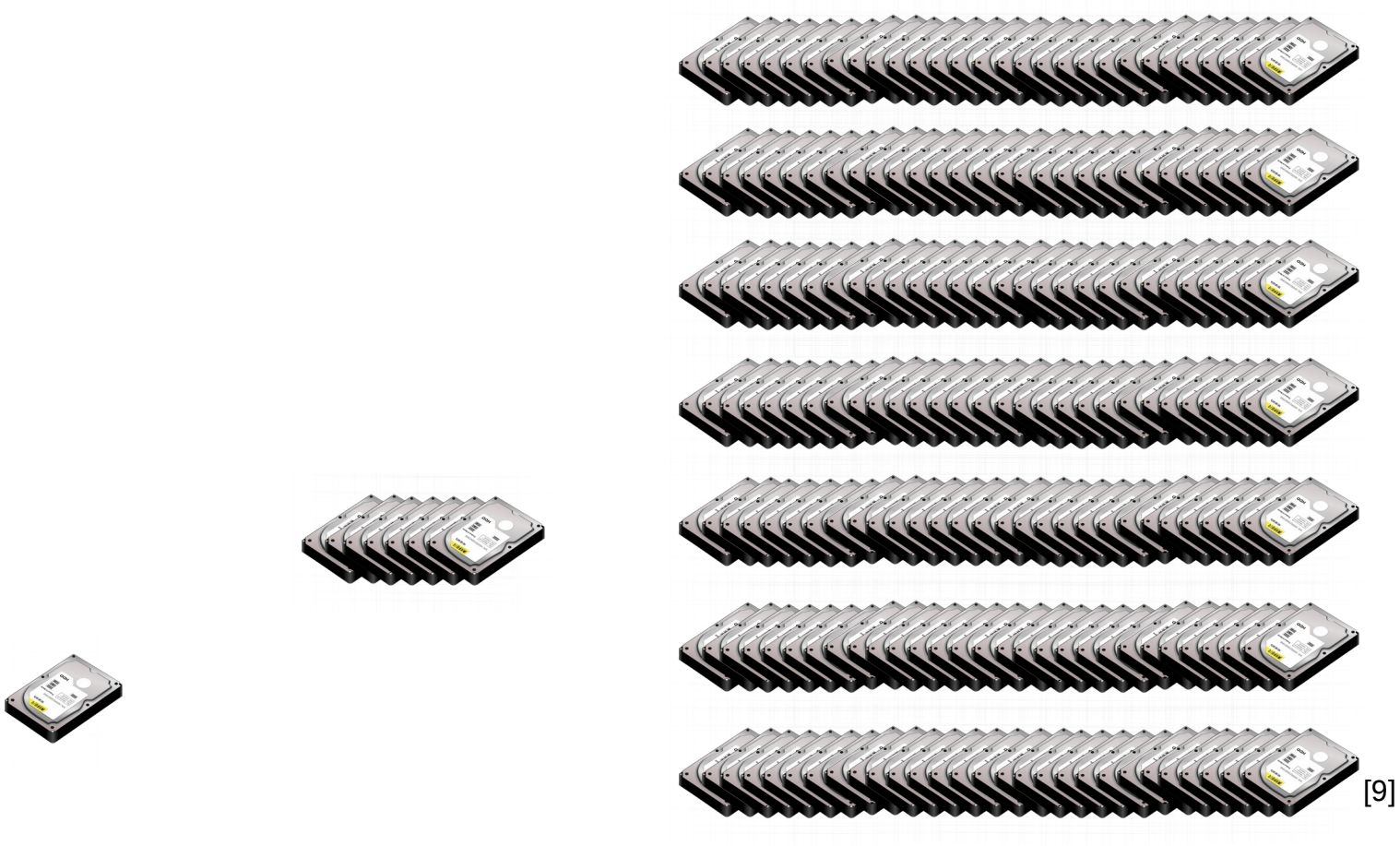
Use many virtio-block devices



[9]

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

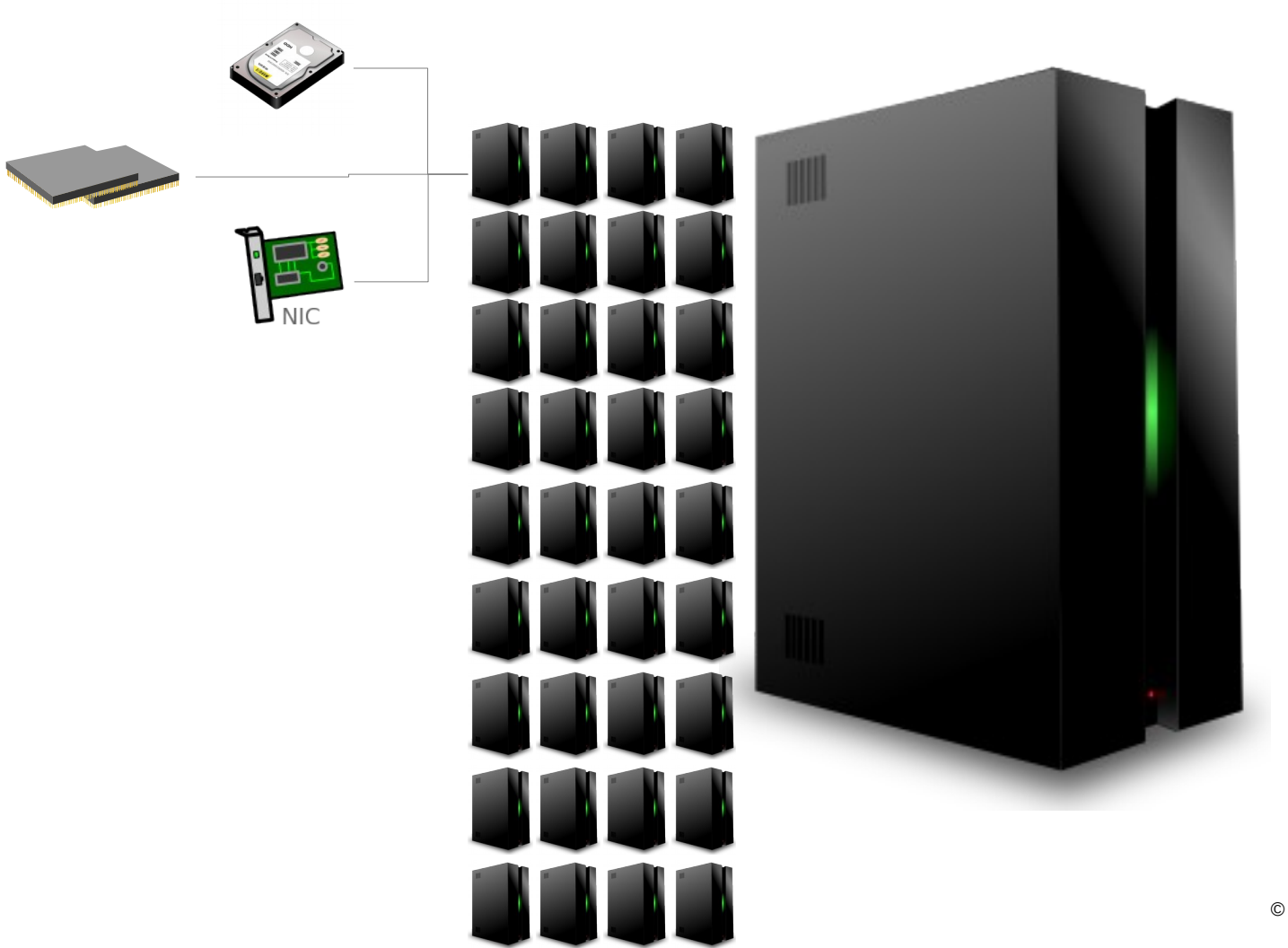
- Started 16 guests, each assigned 1024 virtio-block devices

  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



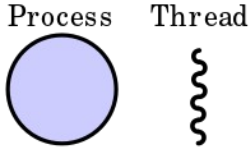
Starting 4096 guests

… because it's such a nice even number

Many system limits had to be tweaked:

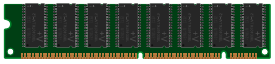
journal: Failed to find user record for uid '107': ***Too many open files***
→ create file /etc/systemd/system/libvirtd.service.d/openfiles.conf and add **LimitNOFILE=4096**
Number of file descriptors (of course!)

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 :)

- On systems with systemd installed there is a static service called systemd-machined
- Libvirt calls systemd-machine::CreateMachine() for every guest started
- Message handling in older versions (at least until v208) of systemd was inefficient

  CreateMachine: Did not receive a reply. Possible causes include: the remote application did not send a reply, the message bus security policy blocked the reply, the reply timeout expired, or the network connection was broken.

- CreateMachine() timed out because of buggy message handling in systemd
- Fixed with systemd-219 by rewriting message loop

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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)
    PID USER      PR  NI    VIRT    RES    SHR S  %CPU %MEM     TIME+ COMMAND
  39910 qemu      20   0 1788656 490400   8028 S 135.5  0.0   9:33.44 qemu-system-s39
  39732 qemu      20   0 1739188 509052   8032 S 131.7  0.0   9:55.96 qemu-system-s39
  39952 qemu      20   0 1713584 512480   8024 S 131.4  0.0   9:36.17 qemu-system-s39
  39936 qemu      20   0 1727924 486156   8028 S 130.8  0.0   9:30.80 qemu-system-s39
  39685 qemu      20   0 1699568 483452   8024 S 130.1  0.0  10:17.34 qemu-system-s39
  39874 qemu      20   0 1635056 486732   8028 S 130.1  0.0   9:26.30 qemu-system-s39
  39718 qemu      20   0 1649392 486188   8028 S 129.8  0.0  10:00.58 qemu-system-s39
  40058 qemu      20   0 1708464 510620   8028 S 129.8  0.0   9:20.78 qemu-system-s39
  39981 qemu      20   0 1758960 485816   8028 S 129.5  0.0   9:14.50 qemu-system-s39
```

Starting 4096 guests

Guests running

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

```
[root@zs93k1 ~]# free -h
             total       used       free     shared    buffers     cached
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

```
top - 03:17:40 up 18:29,  1 user,  load average: 1.00, 1.01, 1.05
Tasks:  73 total,   1 running,  72 sleeping,   0 stopped,   0 zombie
%Cpu(s): 35.8 us,  0.0 sy,  0.0 ni, 50.0 id,  0.0 wa,  0.0 hi,  0.0 si, 14.2 st
KiB Mem:    917576 total,   269456 used,   648120 free,    34100 buffers
KiB Swap:        0 total,        0 used,        0 free.   177384 cached Mem

  PID USER      PR  NI    VIRT    RES    SHR S  %CPU  %MEM     TIME+ COMMAND
 2093 root      20   0 1064712  19020   6116 S 72.00 2.073 567:23.50 java
    1 root      20   0    6104   4004   2076 S 0.000 0.436   0:02.08 systemd
    2 root      20   0       0      0      0 S 0.000 0.000   0:00.00 kthreadd
    3 root      20   0       0      0      0 S 0.000 0.000   0:00.02 ksoftirqd+
    5 root       0 -20       0      0      0 S 0.000 0.000   0:00.00 kworker/0+
    6 root      20   0       0      0      0 S 0.000 0.000   0:00.11 kworker/u+
    7 root      rt   0       0      0      0 S 0.000 0.000   0:00.00 migration+
    8 root      20   0       0      0      0 S 0.000 0.000   0:00.00 rcu_bh
    9 root      20   0       0      0      0 S 0.000 0.000   0:00.13 rcu_sched
   10 root      rt   0       0      0      0 S 0.000 0.000   0:00.00 migration+
   11 root      20   0       0      0      0 S 0.000 0.000   0:00.02 ksoftirqd+
   13 root       0 -20       0      0      0 S 0.000 0.000   0:00.00 kworker/1+
   14 root       0 -20       0      0      0 S 0.000 0.000   0:00.00 khelper
   15 root      20   0       0      0      0 S 0.000 0.000   0:00.00 kdevtmpfs
   16 root       0 -20       0      0      0 S 0.000 0.000   0:00.00 netns
   17 root       0 -20       0      0      0 S 0.000 0.000   0:00.00 writeback
   18 root       0 -20       0      0      0 S 0.000 0.000   0:00.00 kintegrit+

zs93k1g85009:~ # ps aux| grep java
root      2093 83.8  2.0 1064712 19020 ?       Sl   Aug04 567:44 java -classpath /products/muncher/Muncher.jar com.ibm.wlm.tools.Muncher
root      2963  0.0  0.0   2732   624 ttysclp0 R+   03:18   0:00 grep --color=auto java
zs93k1g85009:~ #
```

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

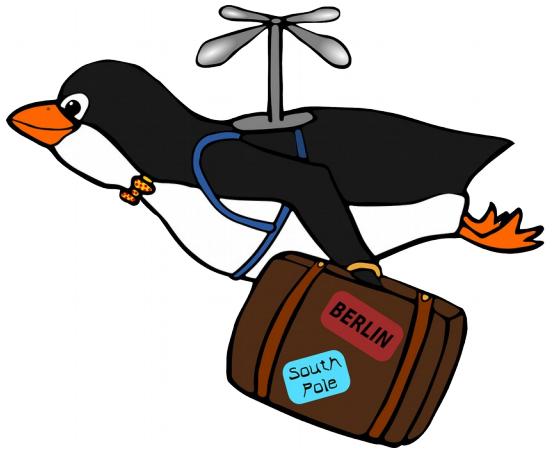
- There's a default port range for migration in libvirt
- When we're running out of ports:
  error: internal error: Unable to find an unused port in range 'migration' (49152-49215)
- Ports can be specified as part of the virsh command line to circumvent this
- ...or configurable with migration_port_min and migration_port max in qemu.conf

[11]

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



[12]

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

Processor Memory

Model	Minimum	Maximum
N30	64 GB	2.5 TB**
N63	64 GB	5.0 TB
N96	64 GB	7.5 TB
NC9	64 GB	10.0 TB
NE1	64 GB	10.0 TB

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 ?

Sources: [13]

Thank you!

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