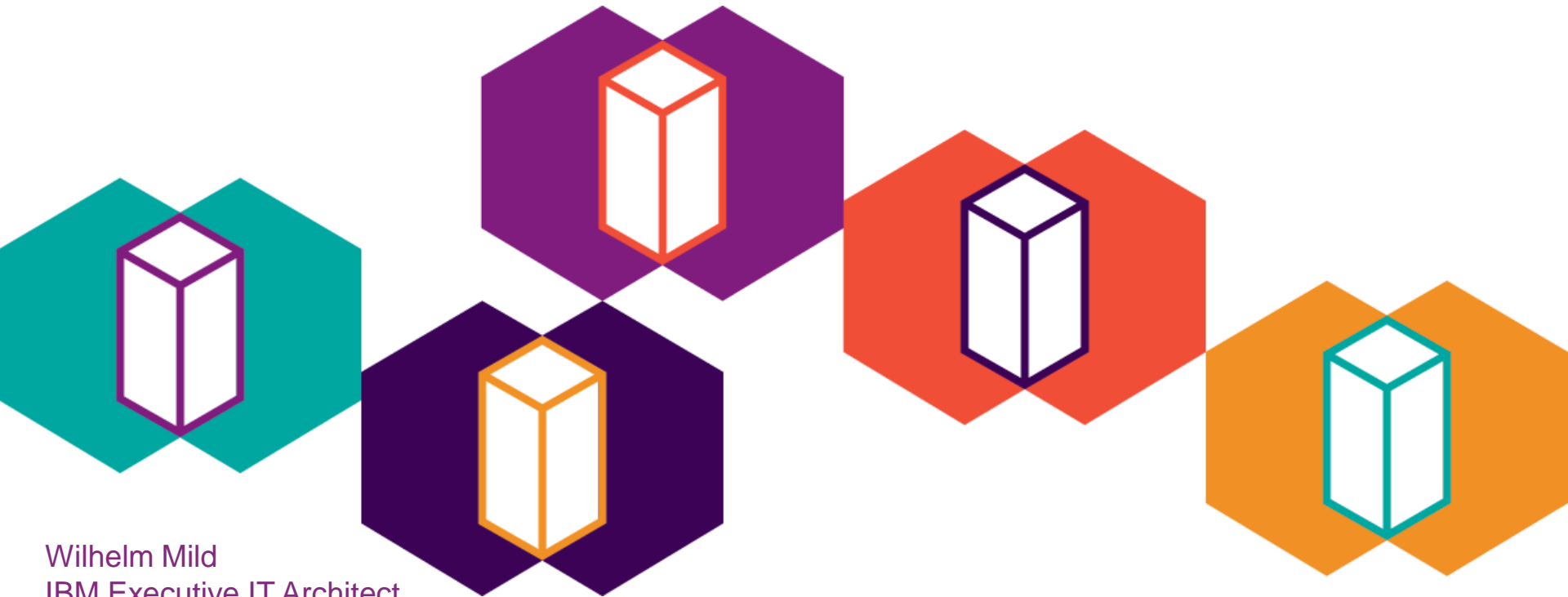


# Linux on z Systems News and exploitation



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IBM Executive IT Architect  
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# Linux on IBM z Systems introduction

Interesting facts and numbers



## Fun facts around Linux on IBM z Systems

---

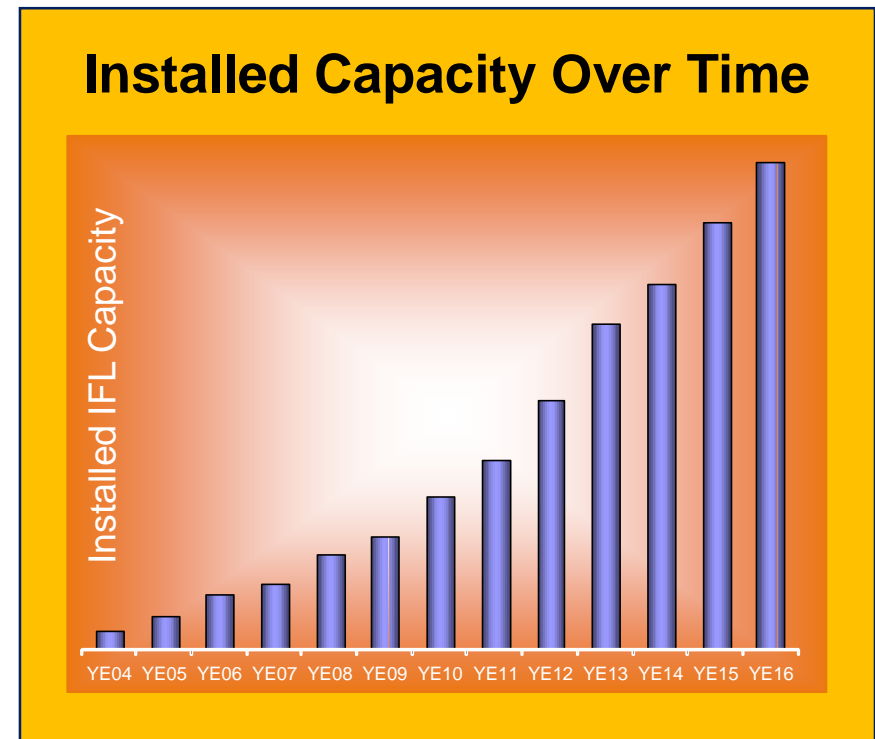
- How many git commits are there in the main Linux repository up to v4.10  
649,791 commits (602,736 without merge commits, %7 merge commits)
- How many of these git commits are s390 related?  
~7,118 commits (~1.1%)
- What is the maximum of lines added by a single git commit up to v4.10?  
git commit d7e09d0397e84eef “staging: add Lustre file system client support”,  
258,994 insertions(+)
- What is the maximum of lines added by a single git commit for s390?  
git commit 4a71df50047f0db6 “new qeth device driver”, 13,498 insertions(+)
- What is the average size of a git commit in v4.x (patch lines)?  
148.31 over all git commits in v4.0 – v4.10
- What is the average size of a s390 commit in v4.x (patch lines)?  
223.83 lines for s390 related git commits in v4.0 - v4.10

# Linux on IBM z Systems in 4Q2016



- *Installed Linux MIPS at 40% CAGR\**

- 49% of z Systems Customers have IFL's installed as of 4Q16
- Installed IFL MIPS increased by 14% YTY from 4Q15 to 4Q16
- 93 of the top 100 z Systems Enterprises are running Linux on z as of 4Q16 \*\*
- 29.5% of Total installed MIPS run Linux as of 4Q16
- 37% of all z Systems servers have IFLs
- 63% of new FIE/FIC z Systems accounts run Linux



\* Based on YE 2003 to YE 2016    \*\*Top 100 is based on total installed MIPS



---

# Linux on IBM z Systems distributions

What is available today



# Linux on IBM z Systems distributions

---

- **SUSE Linux Enterprise Server 10**
  - 07/2006 SLES10 GA: Kernel 2.6.16, GCC 4.1.0
  - 04/2011 SLES10 SP4; **EOS 31 Jul. 2013; LTSS: 30 Jul. 2016**
- **SUSE Linux Enterprise Server 11**
  - 03/2009 SLES11 GA: Kernel 2.6.27, GCC 4.3.3
  - 07/2015 SLES11 SP4: Kernel 3.0, GCC 4.3.4; EOS 31 Mar. 2019;
  - LTSS: 31 Mar. 2022
- **SUSE Linux Enterprise Server 12**
  - 10/2014 SLES12 GA: Kernel 3.12, GCC 4.8
  - 11/2016 SLES12 SP2: Kernel 4.4, GCC 4.8
  - 09/2017 SLES12 SP3
  - Last SP: EOS 31 Oct. 2024; LTSS: 31 Oct. 2027



# Linux on IBM z Systems distributions

---

- **Red Hat Enterprise Linux AS 4**
  - 02/2005 RHEL4 GA: Kernel 2.6.9, GCC 3.4
  - 02/2011 RHEL4 Update 9; EOS 29 Feb. 2012; ELS: 31 Mar. 2017
- **Red Hat Enterprise Linux AS 5**
  - 03/2007 RHEL5 GA: Kernel 2.6.18, GCC 4.1.0
  - 09/2014 RHEL5 Update 11; EOS 31 Mar. 2017; ELS: 30 Nov. 2020
- **Red Hat Enterprise Linux AS 6**
  - 11/2010 RHEL6 GA: Kernel 2.6.32, GCC 4.4.0
  - 03/2017 RHEL6 Update 9; EOS 30 Nov. 2020; ELS: tbd
- **Red Hat Enterprise Linux AS 7**
  - 06/2014 RHEL7 GA: Kernel 3.10, GCC 4.8
  - 11/2016 RHEL7 Update 3; EOS 30 Jun. 2024; ELS: tbd
  - 2017 RHEL 7 Update 4



# Linux on IBM z Systems distributions

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- **Ubuntu 16.04 (Xenial Xerus)**
  - Canonical and IBM announced an Ubuntu based distribution on LinuxCon 2015 in Seattle
  - 04/2016 Ubuntu 16.04 GA: Kernel 4.4, GCC 5.3.0+
  - 04/2017 Ubuntu 17.04 GA: Kernel 4.10, GCC 6.3.0+
  - Lifecycle:
    - Regular releases every 6 months and supported for 9 months
    - LTS releases every 2 years and supported for 5 years
    - LTS enablement stack will provide newer kernels within LTS releases
    - <http://www.ubuntu.com/info/release-end-of-life>
- **Others**
  - Debian, Slackware,
  - Support may be available by some third party



# Supported Linux Distributions

Distribution	LinuxONE Emperor		LinuxONE Rockhopper		
	z13	z13s	zEnterprise - zBC12 and zEC12	zEnterprise - z114 and z196	System z10 and System z9
RHEL 7	✓ (1)	✓ (1)	✓ (3)	✓ (3)	✗
RHEL 6	✓ (1)	✓ (1)	✓ (4)	✓	✓
RHEL 5	✓ (1)	✗ (10)	✓ (3)	✓	✓
RHEL 4 (7)	✗	✗	✗	✓ (8)	✓
SLES 12	✓ (2)	✓ (2)	✓	✓	✗
SLES 11	✓ (2)	✓ (2)	✓ (6)	✓	✓
SLES 10 (7)	✗	✗	✓ (7)	✓	✓
SLES 9 (7)	✗	✗	✗	✓ (8)	✓
Ubuntu 16.04	✓	✓	✓	✗	✗

 Indicates that the distribution (version) has been tested by IBM on the hardware platform, will run on the system, and is an IBM supported environment. Updates or service packs applied to the distribution are also supported. Please check with your service provider which kernel-levels are currently in support.



Please check the link for minimum required kernel levels.

See [www.ibm.com/systems/z/os/linux/resources/testedplatforms.html](http://www.ibm.com/systems/z/os/linux/resources/testedplatforms.html) for latest updates and details.



---

# Current Linux on IBM z Systems Technology

Key features & functionality already  
contained in the Distributions



# Tag legend

## Supported distributions

- x.y** for SUSE SLES <X> Service Pack <Y>, e.g. **12.1** for SLES12 SP1
- x.y** for RHEL <x> Update <y>, e.g. **7.2** for RHEL7.2
- x.y** for Ubuntu x.y, e.g. **16.04** for Ubuntu 16.04 LTS

## Supported environments

- LPAR** usable for systems running under LPAR
- z/VM** usable for guests running under z/VM
- KVM** usable for guests running under KVM



# IBM z13 Support

- **Vector extension facility (kernel 3.18)**

- Also known as single-instruction, multiple data (**SIMD**)
- 32 128-bit vector registers are added to the CPU
- 139 new instructions to operate on the vector registers
- User space programs can use vectors to speed up all kinds of functions, e.g. crc checksums, ...
- Simple exploit: use new glibc runtime (strlen, strcpy, ...)
- 







- **CPU multi threading support (> kernel 3.19)**

- Also known as simultaneous multi-threading (**SMT**)
- Once enabled the multi threading facility provides multiple CPU threads for a single core (2 threads for SMT-2).
- The CPU threads of a core share certain hardware resources such as execution units or caches
- Avoid idle hardware resources, e.g. while waiting for memory





# IBM z13 Support

- **Extended number of AP domains (kernel 3.18)**
  - AP crypto domains in the range 0-255 will be detected (was 15)
- **Crypto Express 5S cards (kernel 4.0)**
  - New generation of crypto adapters with improved performance
- **z13 cache aliasing (kernel 4.0)**
  - Shared objects mapped to user space need to be aligned to 512KB for optimum performance on z13
- **Drawer scheduling domain level (kernel 4.8)**
  - Add another scheduling domain to reflect the exact machine structure for z13.
  - There are now: drawer(new), node, book(old), MC and SMT domains
  - Older kernel versions folded drawer and nodes into books



# Compiler Toolchain

## • zEnterprise 196 exploitation (gcc 4.6)



- Use option `-march=z196` to utilize the new instructions added with z196
- Use `-mtune=z196` to schedule the instruction appropriate for the new out-of-order pipeline of z196
- Re-compiled code/apps get further performance gains through 110+ new instructions

## • zEC12/zBC12 exploitation CPU (gcc 4.8)



- Use option `-march=zEC12` to utilize the instructions added with zEC12
- Use option `-mtune=zEC12` to schedule the instructions appropriate for the pipeline of zEC12
- Transactional memory support, Improved branch instructions

## • z13/z13s exploitation CPU (gcc 5.2)



- Use option `-march=z13` to utilize the instructions added with z13
- Use option `-mtune=z13` to schedule the instructions appropriate for the pipeline of z13
- SLES12SP1 support with the gcc 5.3.1 toolchain module

**Tip:** The default compiler is often somewhat backlevel. Need to install an optional newer compiler.

- Code runs faster but not on older machines.

# Miscellaneous new kernel features

- Support for IPL Device in Any Sub-Channel Set (kernel 4.4)**

LPAR z/VM 12.2 16.04
  - Allows to boot the OS from a device with an address '0.x.yyyy' with x != 0
  
- Add a statistic for diagnose calls (kernel 4.4)**

LPAR z/VM KVM 12.2 16.04
  - Provide the number of diagnose calls per CPU via '/sys/kernel/debug/diag\_stat'
  - Useful to find lock contention problems, watch the values for diag 044 and diag 09c
  - The high value on CPU #0 is due to a timing loop at IPL

```
# cat /sys/kernel/debug/diag_stat
```

	CPU0	CPU1	CPU2	CPU3	
diag 008:	0	0	0	0	Console Function
diag 00c:	0	0	0	0	Pseudo Timer
diag 010:	0	0	0	0	Release Pages
diag 014:	0	0	0	0	Spool File Services
diag 044:	663700	1	1	1	Voluntary Timeslice End
diag 064:	0	0	0	0	NSS Manipulation
diag 09c:	3	2	3	1	Relinquish Timeslice
diag 0dc:	0	0	0	0	Appidata Control
diag 204:	0	0	0	0	Logical-CPU Utilization
diag 210:	0	0	0	0	Device Information
diag 224:	0	0	0	0	EBCDIC-Name Table
diag 250:	0	0	0	0	Block I/O
diag 258:	1	0	0	0	Page-Reference Services
diag 288:	0	0	0	0	Time Bomb
diag 2c4:	0	0	0	0	FTP Services
...					

# Miscellaneous new kernel features

- **LPAR offset handling (kernel 4.8)**

- Initialize the Linux system clock with the physical TOD clock,
- effectively removing the LPAR offset
- Get Linux to a consistent time base in regard to other machines



- **2GB pages for hugetlbf (kernel 4.8)**

- Extend the huge page support to allow 2GB huge pages next to 1MB large pages
- Access 2GB pages either through the mmap() or SysV shared memory system calls
- Transparent Huge (THP) Pages are not affected by this, they stay at 1MB pages
- Promises to speed up Java with large heap sizes and databases with big SGAs



- **Vector optimization for CRC32 (kernel 4.8)**

- Cyclic redundancy checks (CRCs) are error-detecting codes commonly used in network protocols and file systems
- Speed up the in-kernel CRC32 code by use of vector instructions





# Vector optimization for CRC32 in the kernel



## Inner loop of crc32\_be:

```

# %v9 contains a magic constant, %v1-%v4 the intermediate checksum
LOOP:      VLM                %v5,%v8,0,%r3          # load next 64 bytes st
          VGFMAG             %v1,%v9,%v1,%v5          # 1st GF(2) multiplication
          VGFMAG             %v2,%v9,%v2,%v6          # 2rd GF(2) multiplication
          VGFMAG             %v3,%v9,%v3,%v7          # 3th GF(2) multiplication
          VGFMAG             %v4,%v9,%v4,%v8          # 4th GF(2) multiplication
          aghi                %r3,64                  #
buf = buf + 64
          aghi                %r4,-64                 #
len = len - 64
          cghi                %r4,64                 #
check remaining length
          jnl    LOOP                    # loop if >= 64 bytes
remain
    
```

9 instructions to do crc32 for 64 bytes → much faster than original implementation  
SIMD instruction VGFMAG does 2 multiplications and an add in a single instruction



# Container Support for Docker

- **Docker provides lightweight containers**
  - Self contained set of files to package an application
  - with all of its dependencies
- **Applications in containers share the OS kernel**
  - **No virtualization – no virtualization overhead**
- **“Build, Ship, and Run Any App, Anywhere”**
  - One implementation of a container solution that runs the same anywhere
  - Maintained by Docker, Inc.
  - Docker Hub cloud-based registry service, see <https://hub.docker.com>
- **Power tool to build, modify, deploy, run, manage containers**
  - E.g. “docker run hello-world”





# Current Linux on IBM z Systems Technology

Platform features & functionality from IBM



# Blockchain on Linux on IBM z Systems

---

- **Blockchain** is a technology for a new generation of transactional applications.
- **2 of the 3 IBM Blockchain offerings use Linux on IBM z Systems:**
  - The **High Security plan of IBM Blockchain on Bluemix** – cloud
  - **IBM Blockchain on IBM z Systems** – on premise
- Both profiting from **qualities of z Systems** (security, availability, performance):
  - Co-location with business data
  - Isolated partitions in memory keep ledgers separate and secure
  - High availability and scalability of IBM z Systems
  - Hardware encryption with built-in accelerators
  - Reduced data center footprint, simplified management, energy savings



# IBM DB2 with BLU acceleration

---

- **IBM DB2 Advanced Enterprise Server Edition 11.1** provides a comprehensive database solution for the enterprise
  - **DB2 BLU:** Incorporates **in-memory columnar technology**
    - **parallel vector processing (SIMD)**
    - **data compression**
    - **data skipping** for faster insight without the limitations of in-memory-only systems (partial database load)
- **Supported distributions:**
  - Red Hat Enterprise Linux 7.1 or newer
  - SUSE Linux Enterprise Server 12 or newer
  - Ubuntu 16.04 LTS Server



# IBM Spectrum Scale 4.2.3

---

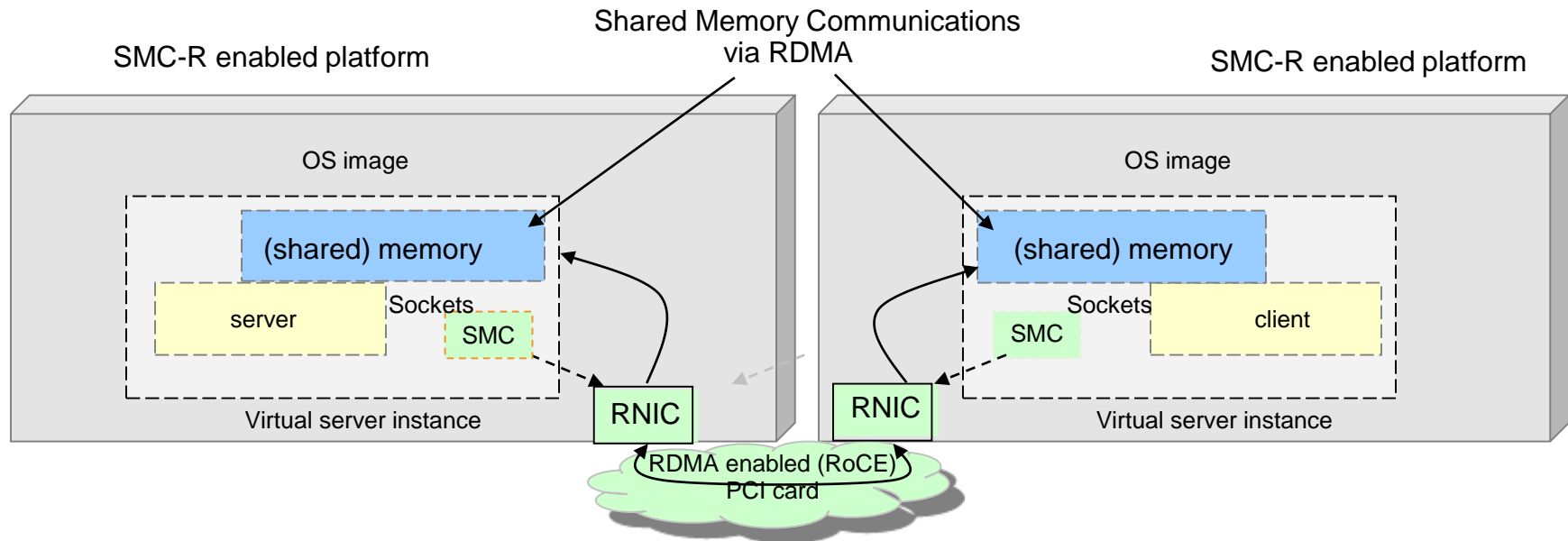
- **IBM Spectrum Scale** is a high performance shared-disk file management solution
  - provides fast, reliable access to data from multiple servers
  - built on IBM General Parallel Filesystem (GPFS) technology
- **Features of the Advanced Edition:**
  - Asynchronous multisite disaster recovery (DR), enabling active/passive configuration at the fileset level
  - Information lifecycle management (ILM)
  - Support of the IBM Spectrum Protect™ v7.1.4 backup- archive and Space Management client
  - Support for ECKD DASD and FCP attached SCSI disks
  - Heterogeneous clusters with client nodes without local storage access running Linux distributions from Red Hat and SUSE on x86 and Power®, and AIX® on Power
  - Supports of the a lot of IBM storage systems: IBM System Storage® DS8000® series, IBM Storwize® V7000 Disk Systems,...
- **Supported distributions:**
  - Red Hat Enterprise Linux 6.5 or newer
  - SUSE Linux Enterprise Server 11 SP3 or newer
  - Ubuntu 16.04 LTS Server



## Future Linux on IBM z Systems Technology

Software which has already been developed  
and integrated into the upstream packages  
- but is **not yet available** in any  
Enterprise Linux Distribution

# SMC-R concept / overview



RDMA technology provides the capability to allow hosts to logically share memory. The SMC-R protocol defines a means to exploit the shared memory for communications - transparent to the applications!





# SMC-R - Shared Memory Communication over RDMA

---

- Shared Memory Communications over RDMA (SMC-R)
  - new networking protocol allowing applications to exploit RDMA over Converged Ethernet (RoCE) with the socket interface
- Linux support for SMC-R uses a new address family **AF\_SMC**
  - The addressing scheme is the same as TCP, to “port” an application to SMC-R simply replace AF\_INET with AF\_SMC:

```
tcp_socket = socket(AF_INET, SOCK_STREAM, 0);
```

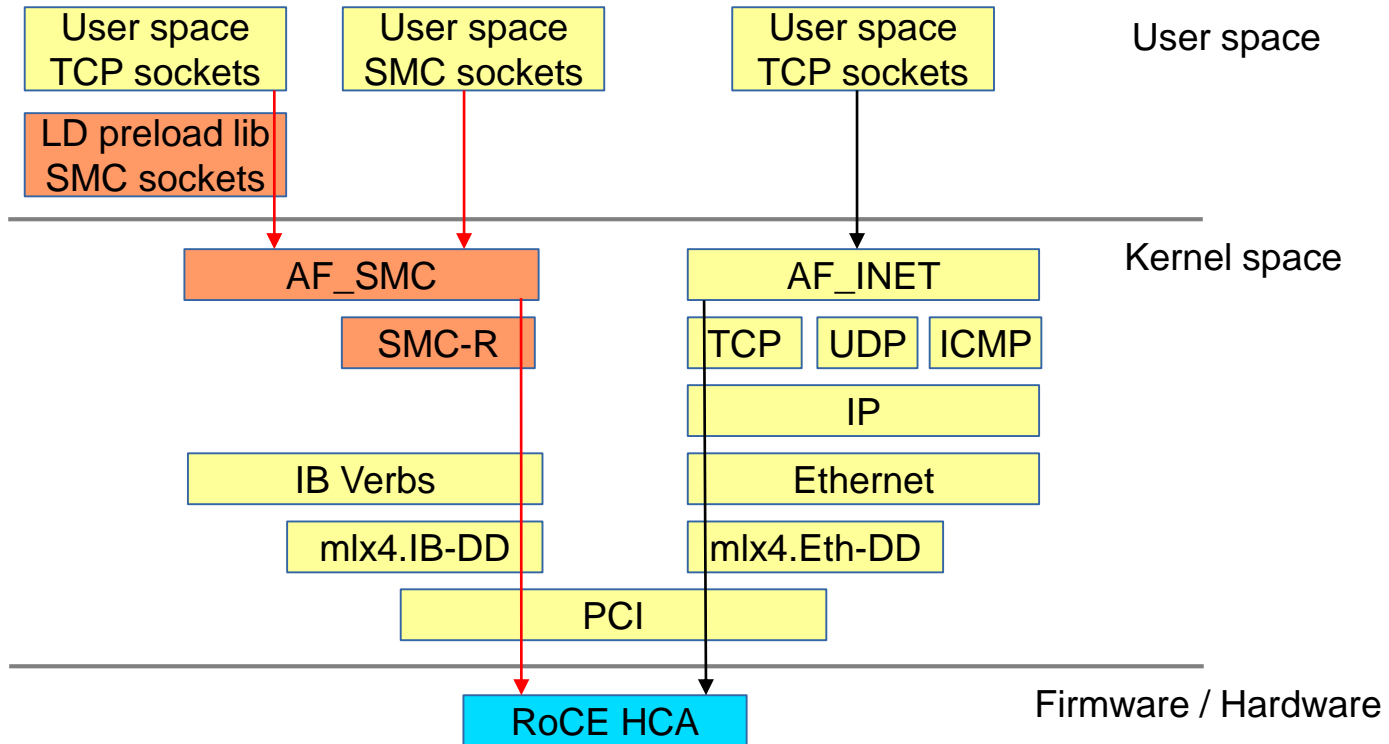
by

```
tcp_socket = socket(AF_SMC, SOCK_STREAM, 0);
```

- Alternatively a preload library can be used to intercept the socket call
  - Automatic fallback to AF\_INET if the connection could not be established via SMC
- A first version of the Linux code is now upstream with kernel 4.11-rc1
  - is available as tech preview in **SLES 12 SP3** (GA expected September 2017)
  - The Linux variant is currently incompatible with z/OS
  - Some adjustments on Linux and z/OS required to connect Linux to z/OS via SMC-R



# Linux structure for SMC-R





# Kernel features - PCI improvements

---

- **PCI call logical-processor query interface (kernel v4.6)**
  - Provide a user space interface to submit query requests for installed PCI functions.
- **PCI function-type specific measurement data (kernel v4.7)**
  - Enhances the statistics interface to display PCI function-specific measurement data for IBM z13 and later
- **PCI error reporting interface (kernel v4.9)**
  - Provide a sysfs interface to allow user space programs to trigger a deconfigure-and-repair action for a specific PCI function
- **PCI unique UIDs for domain enumeration (kernel v4.10)**
  - Use the PCI UID for the domain field of the PCI bus-id if firmware guarantees the uniqueness of these values
- **PCI I/O TLB flush enhancement (kernel v4.10)**
  - Reduce the number of RPCIT instructions in case the hypervisor does not announce that RPCIT can be omitted for invalid -> valid translation-table entry updates



# Kernel features - DASD improvements

---

- **Query host access to volume (kernel v4.7)**
  - Add an interface to query if a DASD volume is online to another operation system instance.
- **DASD quick format mode for use with dasdfmt (kernel v4.7)**
  - Add an option to re-initialize an already formatted DASD device, just write VTOC and the label
- **DASD channel path aware error recovery (kernel v4.10)**
  - Improve robustness of the DASD device driver with multiple channel paths
  - If a channel path keeps getting errors the channel path will be removed as long as other paths are available



# Kernel features – Crypto device driver

---

- **zcrypt workload balancing (kernel 4.10)**

- The complexity of a cryptographic request determines how long it will take
- Add requests weights and adapter speed ratings to find a better balance for the work between cards

- **zcrypt multi-domain support (kernel 4.10)**

- The AP bus infrastructure used to support only one cryptographic domain, the associated queue of the card for the one domain has been equivalent to the card
- Add code to differ between a card vs the queues of a card
- Allows to use multiple cryptographic domains simultaneously
- sysfs interface stays compatible to the old layout
- Existing user space code continues to work with the default domain



## Kernel features - miscellaneous

---

- **Scatter-gather for AF\_IUCV sockets (kernel 4.8)**
  - Avoid large continuous kernel buffer allocations for AF\_IUCV under z/VM
- **Show dynamic and static CPU speed in /proc/cpuinfo (kernel 4.8)**
  - Reports the static and dynamic MHz rating of each CPU
- **Add leap seconds to initial system time (kernel 4.8)**
  - The current number of leap seconds is a configuration setting of the local machine
  - If the leap seconds have been set correctly they must be subtracted from the TOD clock to determine UTC
- **Performance enhancement for RAID6 gen/xor (kernel 4.9)**
  - Speed up the RAID6 syndrome and xor functions



# Linux Common code enablements

---

- **KCOV support (kernel v4.8)**
  - Aka “Kernel coverage information”
  - Exposes kernel code coverage information in a form suitable for coverage-guided fuzzing (randomized testing).
- **UBSAN sanitizer (kernel v4.9)**
  - Aka “Undefined behaviour sanity checker”
  - Uses compile-time instrumentation to detect undefined behaviours at runtime.
- **CMA support (kernel v4.10)**
  - Aka “Contiguous Memory Allocator”
  - Allows subsystems to allocate big physically-contiguous blocks of memory.



## s390-tools package – what is it?

---

- **s390-tools is a package with a set of user space utilities to be used with the Linux on IBM z Systems distributions**
  - It is **the** essential tool chain for Linux on IBM z Systems
  - It contains everything from the boot loader to dump related tools for a system crash analysis
  - Latest version dated 09/2016 is 1.36.1
- **This software package is contained in all major (and IBM supported) enterprise Linux distributions which support on z Systems**
  - RedHat Enterprise Linux version 5, 6, and 7
  - SuSE Linux Enterprise Server version 10, 11, and 12
  - Ubuntu 16.04 Xenial Xerus
- **Website:** <http://www.ibm.com/developerworks/linux/linux390/s390-tools.html>
- **Feedback:** [linux390@de.ibm.com](mailto:linux390@de.ibm.com)



# s390-tools package – the content

chccwdev  
 chchp  
 chreipl  
 chshut  
 chcrypt  
**chmem** Change

dasdfmt  
 dasdinfo  
 dasdstat  
 dasdview  
 fdasd  
 tunedasd DASD

ip\_watcher  
 osasnmpd  
 qetharp  
 qethconf  
 qethqat Network

vmconvert  
 vmcp  
 vmur  
 cms-fuse z/VM

lscss  
 lschp  
 lsdasd  
 lshmc  
 lsluns  
 lsqeth  
 lsreipl  
 lsshut  
 lstape  
 lszcrypt  
 lszfcp Display  
**lsmem**

zipl Boot

tape390\_display  
 tape390\_crypt Tape

cpuplugd  
 iucvconn  
 iucvtty  
 ts-shell  
 ttyrun Misc

mon\_fsstatd  
 mon\_procd  
 ziomon  
 hiptop Monitor

dbginfo Dump  
 dumpconf &  
 zfcpdump Debug  
 zfcpdbf  
 zgetdump  
 scsi\_logging\_level

hmcdrvfs  
 zdsfs Filesystem

# util-linux – the content

chcpu  
**chmem**  
 lscpu  
**lsmem**  
 wdctl  
 zramctl  
 CPU & memory

agetty  
 cal  
 ctrlaltdel  
 dmesg  
 getopt  
 ldattach  
 logger  
 namei  
 script  
 scriptreplay  
 setterm  
 tailf  
 Shell & Terminal

chrt  
 ionice  
 ipcmk  
 ipcrm  
 ipcs  
 kill  
 linux32  
 linux64  
 lsipc  
 lsns  
 nsenter  
 prlimit  
 renice  
 runuser  
 s390  
 s390x  
 setarch  
 setpriv  
 setpriv  
 setpriv  
 setpriv  
 setsid  
 taskset  
 uname26  
 unshare  
 Process

col  
 colcrt  
 colrm  
 column  
 hexdump  
 look  
 more  
 rev  
 ul  
 Input & output

last  
 lastb  
 login  
 lslogins  
 mcookie  
 mesg  
 nologin  
 su  
 sulogin  
 utmpdump  
 wall  
 write  
 User & Login

fallocate  
 findfs  
 findmnt  
 flock  
 fsck  
 fsfreeze  
 fstrim  
 isosize  
 losetup  
 lslocks  
 mkfs  
 mount  
 mountpoint  
 pivot\_root  
 rename  
 switch\_root  
 umount  
 whereis  
 wipefs  
 File-system

adpart  
 blkdiscard  
 blkid  
 blockdev  
 cfdisk  
 delpart  
 eject  
 fdisk  
 lsblk  
 mkswap  
 partx  
 raw  
 rawdevices  
 resizepart  
 sfdisk  
 swapon  
 swapon  
 Disk & media

- Tools rewritten from Perl to C and moved to the util-linux package



- **The central location for finding and organizing information about IBM products**
- **How to get there:**
  - Search for “IBM Knowledge Center” or go directly to <https://www.ibm.com/support/knowledgecenter/>
- **How to get to Linux on IBM z Systems stuff:**
  - Search for “Linux z” within IBM Knowledge Center or go directly to [https://www.ibm.com/support/knowledgecenter/linuxonibm/liaaf/lnz\\_r\\_main.html](https://www.ibm.com/support/knowledgecenter/linuxonibm/liaaf/lnz_r_main.html)
- **Highlights:**
  - Mobile enabled
  - Not only pdf, but also full text view and search
  - Classified by topics
  - Direct links to related information like Redbooks, Whitepapers,...



# Linux on IBM z System reference

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## **Linux on IBM z Systems (official):**

<http://www-03.ibm.com/systems/z/os/linux/index.html>

## **Linux on IBM z Systems (technical):**

<http://www.ibm.com/developerworks/linux/linux390/index.html>

## **z/VM main site:**

<http://www-03.ibm.com/systems/z/solutions/virtualization/zvm>

## **IBM Wave for z/VM:**

<http://www-03.ibm.com/systems/z/solutions/virtualization/wave>

## **IBM Blockchain:**

<https://www.ibm.com/blockchain/index.html>

## **IBM DB2 for Linux:**

<https://www.ibm.com/analytics/us/en/technology/db2/db2-linux-unix-windows.html>

## **IBM Spectrum Scale:**

<http://www-03.ibm.com/systems/storage/spectrum/scale/index.html>

# Questions?







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Distinguished Architect



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