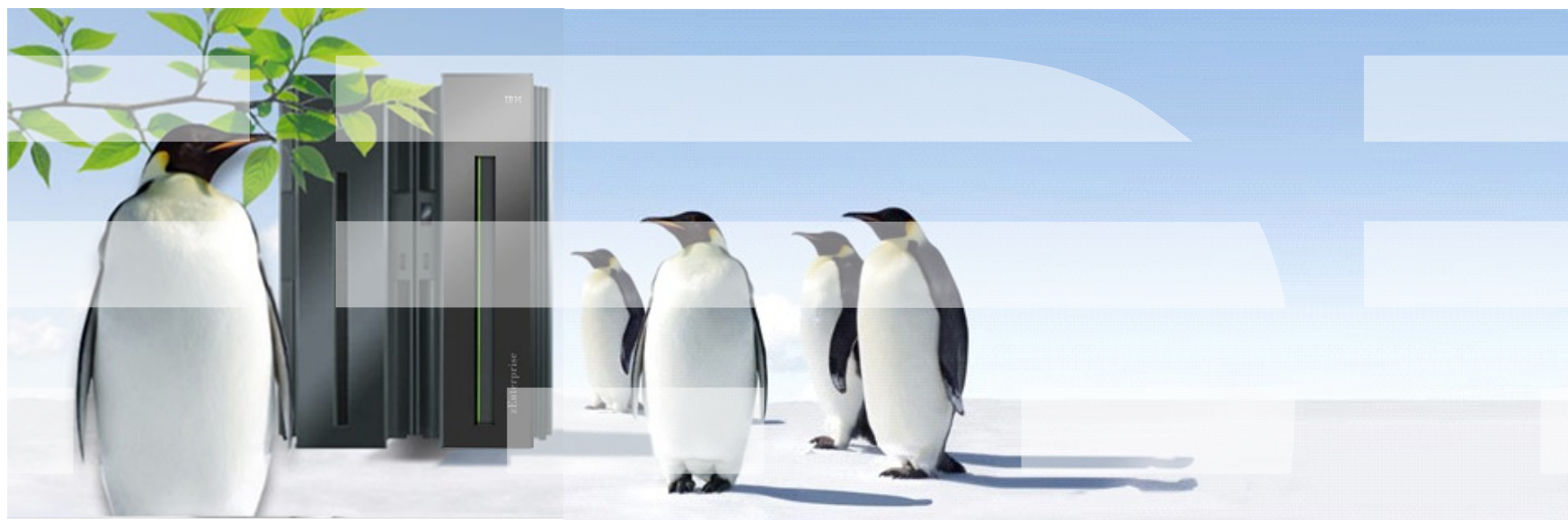


# What's New in Linux on System z

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IBM Lab Böblingen, Germany  
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Session 15700



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# Linux on System z introduction

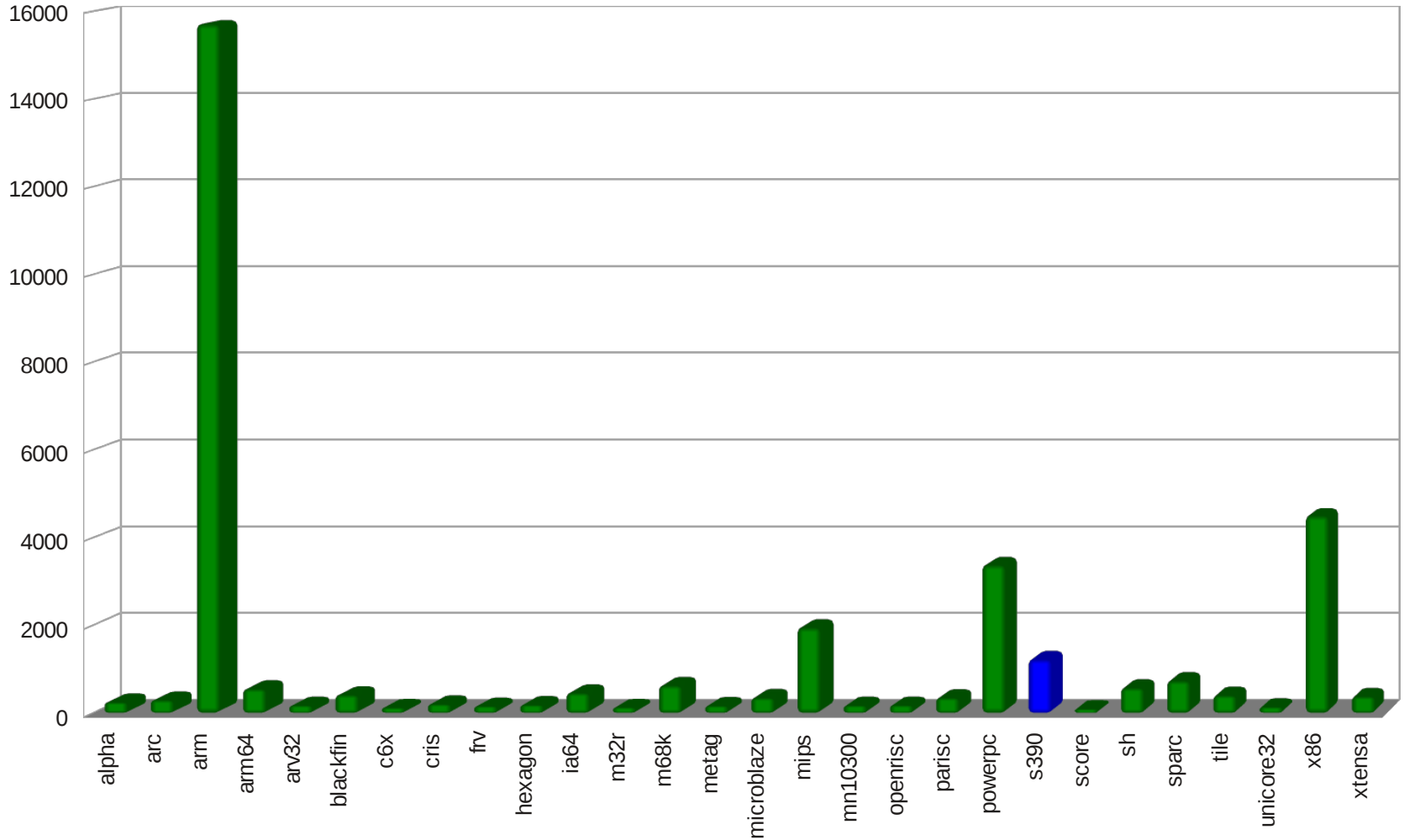
Interesting facts and numbers

## Facts on Linux

- Linux kernel 1.0.0 was released with 176,250 lines of code  
How many lines of code has the kernel version 3.15 ?  
18,632,671 lines of code (+3,985,638 since v3.0)
- How many of the world's top 500 supercomputers run Linux (June 2014)  
485 / 97%
- What is the biggest (known) Linux installation (June 2014)?  
Tianhe-2 with 3,120,000 cores rated at 33,862.7 TFLOPS/s
- What percentage of web servers run Linux (June 2014)  
67.6% run Unix, of those 56.7% run Linux (41.8% unknown) = 38.3%
- What percentage of desktop clients run Linux (May 2014) ?  
2.07% via Linux, 8.75% via Android based on web access statistics
- What is the architecture with the largest amount of core changes in v3.x  
ARM ~112 KLOC/release, mips and powerpc ~25 KLOC/release,  
x86 ~23 KLOC/release. System z (alias s390) ~7 KLOC/release.
- **Linux is Linux**, but ... features, properties and quality differ dependent on your platform and your use case

Source: <http://kernel.org>  
<http://top500.org/statistics>  
<http://w3techs.com>  
<http://www.w3counter.com>

git commits per architecture in 3.x

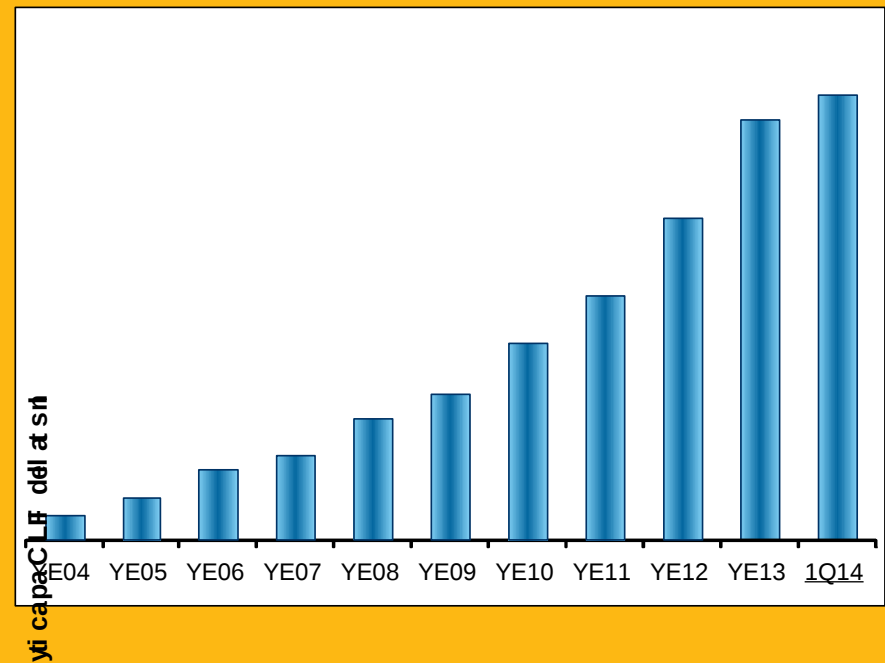


## Linux on IBM System z in 1Q2014

*Installed Linux MIPS at 49% CAGR\**

- 26.4% of Total installed MIPS run Linux as of 4Q13
- Installed IFL MIPS increased 24% from 1Q13 to 1Q14
- 39% of System z Customers have IFL's installed as of 1Q14
- 80 of the top 100 System z Customers are running Linux on the mainframe as of 1Q14 \*\*
- 34% of all System z servers have IFLs
- 55% of new FIE/FIC System z Accounts run Linux (FY10-FY13)

### Installed Capacity Over Time



\* Based on YE 2003 to YE 2013

\*\*Top 100 is based on total installed MIPS

# Linux on System z distributions

What is available today

## Linux on System z distributions in service

- **SUSE Linux Enterprise Server 9 (GA 08/2004)**
    - Kernel 2.6.5, GCC 3.3.3, Service Pack 4 (GA 12/2007), end of regular life cycle
  - **SUSE Linux Enterprise Server 10 (GA 07/2006)**
    - Kernel 2.6.16, GCC 4.1.0, Service Pack 4 (GA 04/2011)
  - **SUSE Linux Enterprise Server 11 (GA 03/2009)**
    - Kernel 2.6.27, GCC 4.3.3, Service Pack 1 (GA 06/2010), Kernel 2.6.32
    - Kernel 3.0, GCC 4.3.4, Service Pack 3 (GA 07/2013)
  - **Red Hat Enterprise Linux AS 4 (GA 02/2005)**
    - Kernel 2.6.9, GCC 3.4.3, Update 9 (GA 02/2011), end of regular life cycle
  - **Red Hat Enterprise Linux AS 5 (GA 03/2007)**
    - Kernel 2.6.18, GCC 4.1.0, Update 10 (GA 10/2013)
  - **Red Hat Enterprise Linux AS 6 (GA 11/2010)**
    - Kernel 2.6.32, GCC 4.4.0 Update 5 (GA 11/2013)
  - **Red Hat Enterprise Linux AS 7 (GA 06/2014)**
    - Kernel 3.10, GCC 4.8
  - **Others**
    - Debian, Slackware,
- 8 – Support may be available by some third party



## Supported Linux Distributions

Distribution	zEnterprise - BC12 and EC12	zEnterprise - z114 and z196	System z10	System z9	zSeries
RHEL 7	✓ (1)	✓ (1)	✗	✗	✗
RHEL 6	✓ (2)	✓	✓	✓	✗
RHEL 5	✓ (3)	✓	✓	✓	✓
RHEL 4 (*)	✗	✓ (6)	✓	✓	✓
SLES 11	✓ (4)	✓	✓	✓	✗
SLES 10	✓ (5)	✓	✓	✓	✓
SLES 9 (*)	✗	✓ (7)	✓	✓	✓

✓ 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.

(1) Please see the [Red Hat Release Notes and Installation Guide](#), the [Red Hat Known Issues](#) and the [example generic.prm files \(PDF, 9KB\)](#)

(2) Recommended level: RHEL 6.3

(3) Recommended level: RHEL 5.8

(4) Recommended level: SLES 11 SP3

(5) Recommended level: SLES 10 SP4 with latest maintenance updates

(6) RHEL 4.8 only. Some functions have changed or are not available with the z196, e.g. the Dual-port OSA cards support to name one of several. Please check with your service provider regarding the end of service.

(7) SLES 9 SP4 with latest maintenance updates only. Some functions have changed or are not available with the z196, e.g. the Dual-port OSA cards support to name one of several. Please check with your service provider regarding the end of service.

✗ Indicates that the distribution is not supported by IBM on this server.

(\*) The distribution is out of service, extended support is required.

# Current Linux on System z Technology

Key features & functionality already  
contained in the SUSE & Red Hat Distributions

## IBM zEnterprise EC12 and BC12 support

### ▪ **Transactional execution (kernel 3.7)**

- Also known as hardware transactional memory
- CPU features that allows to execute a group of instructions atomically
- Optimistic execution, if a transaction conflicts a rollback to a saved state is done



### ▪ **Storage class memory – Flash Express (kernel 3.7)**

- Internal Flash Solid State Disk (SSD)
- Accessed via Extended Asynchronous Data Mover (EADM) sub-channels
- Support for concurrent MCL updates with kernel version 3.8



### ▪ **Support for Crypto Express 4S cards (kernel 3.7)**

- New generation of crypto adapters plug-able into the I/O drawer
- New type 10 which uses a bit field to indicate capabilities of the crypto card



### ▪ **Native PCI feature cards (base in kernel 3.8, ongoing)**

- Support for native PCIe adapters visible to the operating system

### ▪ **Oprofile zEC12 hardware sampling support (kernel 3.10)**

- Extend the hardware sampling to support zEC12



## System zEC12 features – Transactional Execution



- **Transactional execution is a concurrency mechanism of the CPU comparable to database transactions**
  - Several reads and stores from/to memory logically occur at the same time
  - Improves performance for fine-grained serialization
  - Useful for lock-less data structures and speculative compiler optimizations
- **Two types of transactions: constraint and non-constraint**
- **Conflicting memory accesses will cause the transaction to abort**
  - Transaction abort is rather expensive
  - Constraint transaction will automatically restart
  - Ratio of successful vs. aborted transaction is important for performance
- **Kernel support is required to enable user programs to use transactional execution**
  - Control registers setup
  - Debugging support for additional PER controls via ptrace

# System zEC12 features – Transactional Execution



11.3



6.4

## Example of a list\_add operation

```

struct spinlock_t list_lock;
struct list_head list_head;
void list_add(struct list_head *new)
{
    spin_lock(&list_lock, 0, 1);
    list_add(new, &list_head);
    spin_unlock(&list_lock, 1, 0);
}

```

Typical pattern:

1) lock, 2) a short operation, 3) unlock

### Traditional code:

```

# spin_lock
    larl    %r3,list_lock
    lhi     %r1,1
lock:  lhi     %r0,0
       cs     %r0,%r1,0(%r3)
       ltr    %r0,%r0
       jne    lock
# list_add
    larl    %r4,list_head
    lg     %r5,0(%r4)
    stg    %r4,0(%r2)
    stg    %r5,8(%r2)
    stg    %r2,0(%r5)
    stg    %r2,8(%r4)
# spin_unlock
    cs     %r1,%r0,0(%r3)
    br     %r14

```

### Transactional code

```

# begin transaction
tbeginc 0,0

# list_add
    larl    %r4,list_head
    lg     %r5,0(%r4)
    stg    %r4,0(%r2)
    stg    %r5,8(%r2)
    stg    %r2,0(%r5)
    stg    %r2,8(%r4)
# end transaction
tend

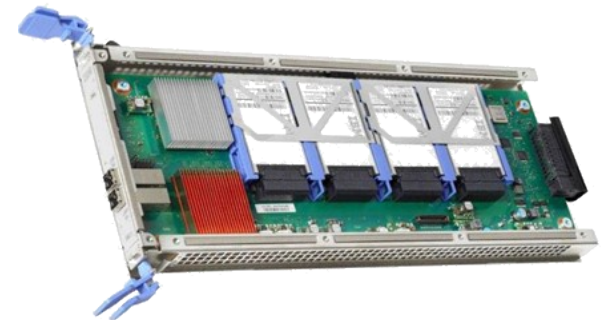
br     %r14

```

## zEC12/zBC12 features – Flash Express

 11.3 6.4

- **PCIe I/O adapter with NAND Flash SSDs**
  - Flash Express cards are plugged as pairs to build a RAID10
    - Pair is connected with interconnect cables
    - Card replacement is concurrent if one card fails
  - Up to 4 pairs of cards are supported (4 \* 1.4TB = 5.6TB)
- **New tier of memory: Storage Class Memory**
  - Accessed via Extended Asynchronous Data Mover (EADM) subchannels via the new Storage Class Memory (SCM) block driver
- **Flash Express is split into memory increments**
  - Memory increments are assigned to LPARs via the SE or HMC
  - Memory increment size is 16 GB
- **Flash Express is not persistent over IML**



## Linux on System z features – 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
- zEC12/zBC12 comes with new instructions
  - Transactional Memory support
  - Improved branch instructions

# Emerging Linux on System z Technology

Upcoming features & functionality from IBM



## GPFS for Linux on System z

- **The GPFS file system running on Linux on System z**
  - Enable software solutions dependent on GPFS
  - Position GPFS as alternative to OCFS2 for SLES
  - Enable Linux on System z for High Availability (HA) solutions with GPFS
- **Elastic Storage for Linux on System z**
  - Express Edition of Elastic Storage 4.1 will be the base for Linux on System z support
  - Linux instances in LPAR mode or on z/VM (on the same or different CECs)
  - Up to 16 cluster nodes (same or mixed Linux distributions/releases)
  - Support for ECKD™-based storage and FCP-based storage
    - Only DS8000® is supported
- **Minimum supported Linux distributions**
  - SuSE Linux Enterprise Server (SLES) 10 SP3 + Maintweb-Update
  - Red Hat Enterprise Linux (RHEL) 6.5 + Errata Update
- **See also:** IBM Elastic Storage for Linux on System z -  
Enhance your Linux on System z environment with clustered file system  
Speaker Jay Brenneman

## XL C/C++ for Linux on System z Managed Beta Program

### ■ XL C/C++ for Linux on System z

- Will be part of a family of advanced C/C++ compiler products already available on z/OS, AIX, and Linux on Power.
- Expected to ease application migration to Linux on System z through:
  - Conformance to the latest C and C++ programming standards
  - Compatibility with GNU C/C++
  - Will maximize application performance through IBM's industry-leading optimization technology

### ■ Benefits of participating in this Beta include:

- Opportunity to influence the product and future product direction
- Ability to test code and documentation, and help ensure compatibility in their environment
- Free education, code, and documentation during the beta
- Free support by development during the beta for questions and problems

For more information and how to submit a nomination to participate see

<http://bit.ly/xlbeta>

## Future Linux on System z Technology

Software which has already been developed  
and integrated into the upstream packages

- but is **not yet available** in any  
Enterprise Linux Distribution

## PCI support



- **Native PCIe feature cards introduced on zEC12 and zBC12**
  - 10GbE RoCE Express, network card for SMC-R
  - zEDC Express, data compression/decompression card
  
- **Native PCIe adapter concept**
  - Plugged into an PCIe I/O drawer
  - Managed by an internal firmware processor (IFP)
  - Device driver for the PCIe function is located in the operating system
  
- **Uses standard Linux PCI support and drivers with some constraints**
  - Only MSIX, no port I/O, memory mapped I/O by use of PCI load/store instructions
  - Provides ability to assign individual functions of an adapter to an LPAR
  - Converted System z architecture code to use generic hardirqs
  - Only selected PCIe adapters are known to the IFP and surfaced to the OS

## 10GbE RoCE Express

### ■ Native PCIe networking card

- 10 Gigabit remote direct memory access (RDMA) capable network card
- Uses Infiniband RDMA over Converged Ethernet (RoCE) specification
- Up to 16 10GbE RoCE Express adapters per machine
- Reduced latency and lower CPU overhead
- Supports point-to-point connections and switch connection with an enterprise-class 10 GbE switch

### ■ Software support

- z/OS V2R1 with PTFs supports SMC-R with RoCE
- z/VM support planned
- Linux support in available upstream but not included in any distribution yet



## zEDC Express

- **Native PCIe data compression / decompression card**
  - Up to 8 adapters can be installed into a single machine
  - With large blocks, it can compress data at more than 1 GB per second
  - Implements compression as defined by RFC1951 (DEFLATE)
  - Comparable to “gzip -1”
- **Software support**
  - z/OS V2R1, V1R13 and V1R12 with PTFs
  - Linux device driver to gain access to zEDC has been posted on LKML and has been accepted into the upstream kernel
  - The zlib open source library is a C implementation commonly used to provide compression and decompression services.



## System z kernel features – memory management

- **Add support for physical memory > 4TB (kernel 3.3)**
  - Increase the maximum supported memory size from 4TB to 64TB.
  - Memory sizes large than 4TB require a 4-level page table
  - Makes memory accesses by the kernel slightly slower, the kernel will automatically use a 3-level page table for memory sizes  $\leq$  4TB
  
- **Transparent huge page support (kernel 3.7)**
  - Make the common code transparent huge page support available for Linux on System z.
  - With THP 1MB pages will be used to back normal anonymous memory mappings.
  - Any application will benefit from using huge pages.
  - Not as effective as using the large pages directly, no memory savings for page tables due to huge page splitting.
  
- **Add page table dumper (kernel 3.7)**
  - Add a sysfs interface to read the current layout of the kernel address space.
  - Useful information for the kernel developer.

## System z kernel features – memory management

- **Implement write protection based dirty page detection (kernel 3.8)**
  - Convert dirty page detection from the change-bit in the storage key to a fault based method. An unmodified page is now always mapped read-only.
  - Due to dirty page accounting for memory mappings no additional faults are necessary
  - Removes the storage key operations to detect page dirty state
  
- **Implement fault based referenced page detection (kernel 3.12)**
  - Convert referenced page detection from the reference-bit in the storage key to a fault based method. An old page is now always mapped with the invalid bit set (no read, no write access).
  - New mappings are always created with the software referenced bit set
  - Removes the storage key operations to detect page referenced state.
  
- **Avoiding storage key operations improves performance**
  - The savings in storage key operations outweigh the slightly increase number of faults
  - After IPL a system without KVM will not access the storage keys at all
  - KVM still makes use of storage keys for provide correct guest virtualization



## System z kernel features – core improvements

- **BPF JIT compiler for System z (kernel 3.7)**
  - The Berkeley Packet Filter is an interface and a language definition that allows to pass a filter to the kernel to select network packets to send on a socket
  - The BPF JIT compiler in the kernel translates the interpreted BPF code to System z code.
  - A secondary use of the BPF language is system call filtering.
- **Expose CPU cache topology in sysfs (kernel 3.7)**
  - Add an interface to expose the CPU cache topology to user space.
  - System z only provides information about CPU caches which are private to a CPU, information about shared caches is not exposed.
- **Add interface for partition-resource management (kernel 3.14)**
  - The diagnose 0x304 interface is used to inspect and change the different LPAR partition-resource parameters
  - The LPAR needs to be authorized to participate in CPU management
  - The binary kernel interface allows a system management software to control the partition weight and partition-capping flags

## System z kernel features – core improvements

### ■ CPU-Measurement Sampling Facility (kernel 3.14)

- Uses the hardware CPU sampling facility to take snapshots of a set of sample data at a specified sampling interval, e.g. the cycle counter
- Integrated into the Linux 'perf' tool
- The basic-sampling mode and the diagnostic-sampling mode are supported
- The diagnostic-sampling mode is intended for use by IBM support only

### ■ Example how to record sampling data for an application

```
# perf record -e rB0000 - /bin/df
Filesystem 1K-blocks Used Available Use% Mounted on
/dev/dasda1 6967656 3360508 3230160 51% /
none 942956 88 942868 1% /dev/shm
/dev/dasdb1 6967656 4132924 2474128 63% /root
[ perf record: Woken up 1 times to write data ]
[ perf record: Captured and wrote 0.001 MB perf.data (~29 samples) ]
```

### ■ Display the collected sample data

```
# perf report
```

## System z kernel features – I/O improvements

- **No automatic port rescan on events (kernel 3.7)**
  - The rescan of a zfcplib port following a fabric change event can cause high fabric traffic, especially when many Linux images share an FCP channel over multiple subchannels with NPIV enabled. This can lead to errors due to timeouts.
  - Ports are still scanned when the adapter is set online and on manual user triggered writes to the port\_rescan sysfs attribute.
- **Safe offline interface for DASD devices (kernel 3.8, s390-tools 1.21)**
  - Gracefully complete all outstanding I/O requests before a DASD is set offline.
- **Add robustness against missing interrupts to non-path-grouped internal IO requests (kernel 3.8, s390-tools 1.22)**
  - Improve the Linux behavior in case of a missing interrupt during path grouping
- **Improve speed of dasdfmt (kernel 3.10)**
  - Reorganize format I/O requests and enable usage of PAV.
- **Add channel ID sysfs attribute (kernel 3.10)**
  - Add an attribute to each channel-path description with the channel-ID of the path

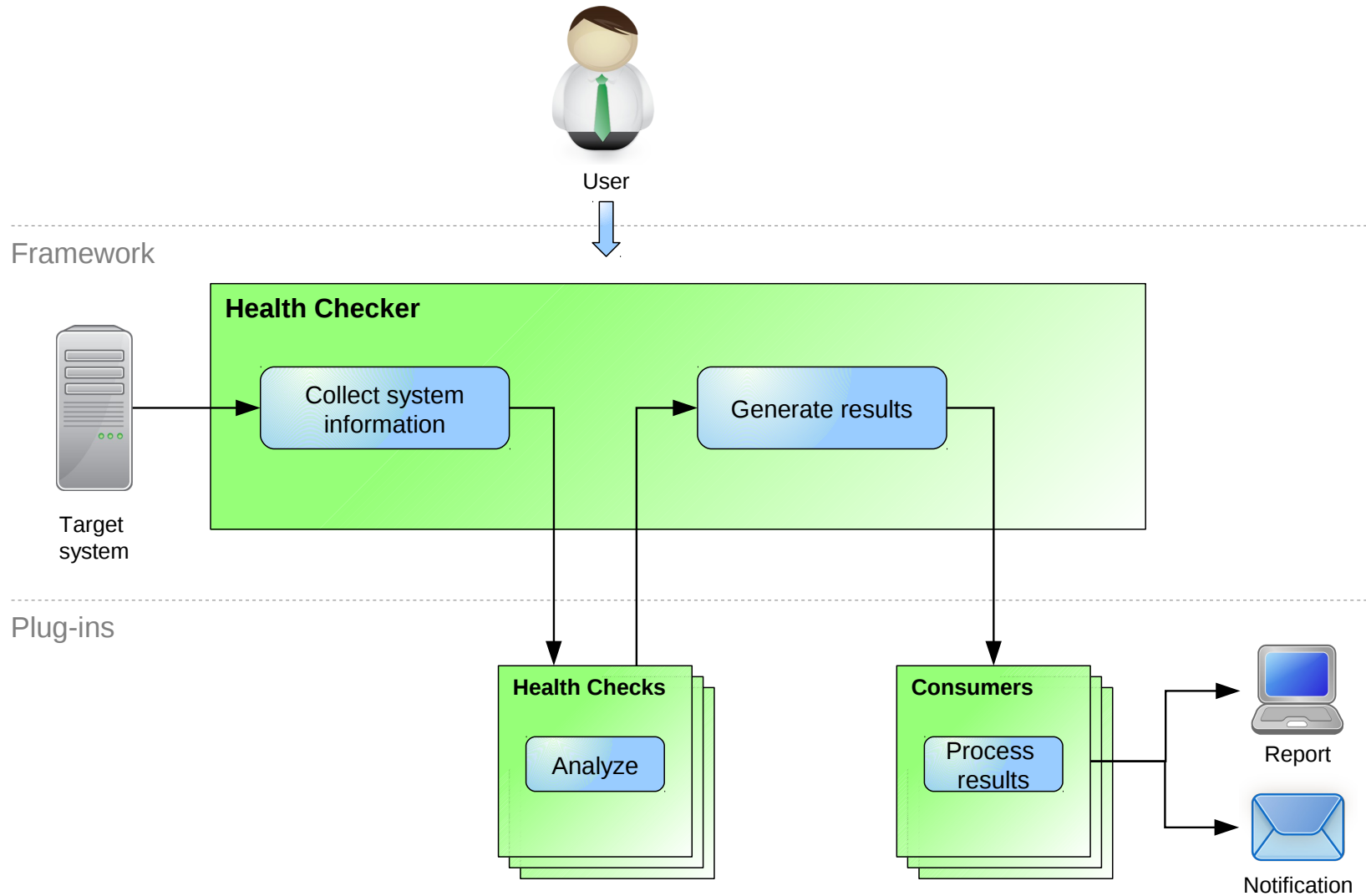
## System z kernel features – networking & security

- **HiperSockets layer 2 bridge port functionality (kernel 3.14)**
  - With Linux acting as a software network bridge the network port acting as the bridge needs to be able to receive frames addressed to unknown MAC addresses
  - HiperSocket devices can be configured as primary and secondary bridge ports
- **Add support for EP11 coprocessor cards (kernel 3.14)**
  - Extend the zcrypt driver with a new capability to service EP11 requests for the Crypto Express4S card in EP11 (Enterprise PKCS#11 mode) coprocessor mode
  - For more information about EP11, see “*Exploiting Enterprise PKCS #11 using OpenCryptoki*”, SC34-2713

## LNXHC – Linux Health Checker

- The Linux Health Checker is a command line tool for Linux.
- Its purpose is to identify potential problems before they impact your system's availability or cause outages.
- It collects and compares the active Linux settings and system status for a system with the values provided by health-check authors or defined by you. It produces output in the form of detailed messages, which provide information about potential problems and the suggested actions to take.
- The Linux Health Checker will run on any Linux platform which meets the software requirements. It can be easily extended by writing new health check plug-ins.
- The Linux Health Checker is an open source project sponsored by IBM. It is released under the Eclipse Public License v1.0
- <http://lnxhc.sourceforge.net/>

# LNxHC – Linux Health Checker system overview



## New - [ibm.com/support/knowledgecenter/](https://ibm.com/support/knowledgecenter/)

The screenshot shows the IBM Knowledge Center interface in a Firefox browser window. The page title is "Linux on System z". The left sidebar contains a "Table of Contents" with a dropdown menu for "Linux on System z" which includes: Library overview, Distributions, Performance, Security, and Service, support, and troubleshooting. Below this are "My Collections" and "Search Results" sections. The main content area has a breadcrumb trail: "Linux on IBM Systems > Linux information for IBM systems > Linux on System z". The main heading is "Linux on System z" with a sub-heading "Find information for your Linux distribution on IBM® System z® mainframes." Below this are three sections: "Library overview" (IBM provides technical documentation with a consolidated view of System z-specific concepts, tool descriptions, and reference information for Linux on System z.), "Distributions" (Find out which information is relevant to your distribution.), and "Performance" (Improve performance with PAV, learn tips and tricks from the whitepapers, and set up Execute-in-Place technology.).

Linux on System z info at:

[ibm.com/support/knowledgecenter/linuxonibm/liaaf/lnz\\_r\\_main.html](https://ibm.com/support/knowledgecenter/linuxonibm/liaaf/lnz_r_main.html)

## Documentation news – Updates available

### ■ Linux Distributions

- SUSE Linux Enterprise Server 11 SP 3
- Red Hat Enterprise Linux 6.4

### ■ Upstream Linux 3.10, 3.11, 3.12

- [ibm.com/developerworks/linux/linux390/documentation\\_dev.html](http://ibm.com/developerworks/linux/linux390/documentation_dev.html)

### ■ Security

- Secure Key Common Cryptographic Architecture  
4.2.10 Application Programmer's Guide
- Libica 2.2.0. Programmer's Guide

### ■ Redbooks

- IBM Wave, Virtualization, Oracle, Security

### ■ Whitepapers

- FileNet P8 5.1, Live Guest Relocation, iSCSI

Linux on System z



Device Drivers, Features, and Commands

*Development stream (Kernel 37)*

Linux on System z



Using the Dump Tools



## Security for Linux on System z

Linux on System z




How to Improve Performance with PAV

*Development stream (Kernel 26.35)*



Linux on System z



Kernel Messages

*Development stream (Kernel 37)*



## 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 System z distributions.
  - It is **the** essential tool chain for Linux on System z
  - It contains everything from the boot loader to dump related tools for a system crash analysis .
  
- This software package is contained in all major (and IBM supported) enterprise Linux distributions which support s390
  - RedHat Enterprise Linux version 4, 5, 6, and 7
  - SuSE Linux Enterprise Server version 9, 10, and 11
  
- 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	dbginfo dumpconf zfcpdump zfcpdbf zgetdump scsi_logging_level DUMP & DEBUG
lscss lschp lsdasd lsluns lsqeth lsreipl lsshut lstape lszcrypt lszfcp lsmem DISPLAY	mon_fsstatd mon_procd ziomon hyptop MONITOR	vmconvert vmcp vmur cms-fuse z/VM
zdsfs FILESYSTEM	ip_watcher osasmpd qetharp qethconf qethqoat NETWORK	cpuplugd iucvconn iucvty ts-shell ttyrun MISC
zdsfs FILESYSTEM	tape390_display tape390_crypt TAPE	zipl BOOT

## s390-tools package: the zdsfs file system

### ▪ zdsfs – mount a z/OS DASD

- The zdsfs file system is based on FUSE
- Use the zdsfs command to mount a z/OS DASD as read-only Linux file system.
- The zdsfs file system translates the z/OS data sets into Linux semantics
- Allows Linux to read z/OS physical sequential data sets and partitioned data sets
  - Physical sequential data sets are represented as files
  - Partitioned data sets are represented as directories that contain the PDS members as files
- Other z/OS data set formats are not supported
- To access a z/OS DASD the raw-track access mode of the DASD must be enabled

## Kernel news – Common code

### ■ **Linux version 3.12 (2013-11-03)**

- RAID5 multithreading
- VFS locking improvements (lockref)
- Better Out-Of-Memory handling
- Improved tty layer locking
- IPC locking improvements

### ■ **Linux version 3.13 (2014-01-19)**

- A scalable block layer for high performance SSD storage
- nftables, the successor of iptables
- Improved page table access scalability in hugepage workloads
- TCP Fast Open enabled by default

## Kernel news – Common code

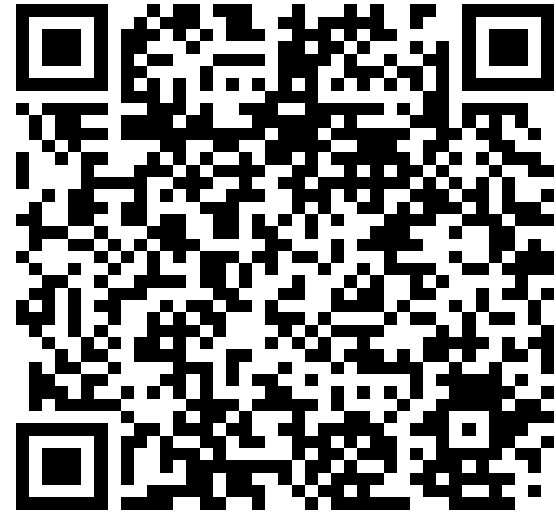
### ■ **Linux version 3.14 (2014-03-30)**

- Deadline scheduling class for better real-time scheduling
- zram memory compression mechanism considered stable
- Btrfs inode properties
- Userspace locking validator
- TCP automatic corking

### ■ **Linux version 3.15 (2014-05-08)**

- Improved working set size detection
- New file locking scheme: open file description locks
- Faster erasing and zeroing of parts of a file
- File cross-renaming support
- FUSE improved write performance

# Questions?



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