Linux on System z
Current and Future Technology

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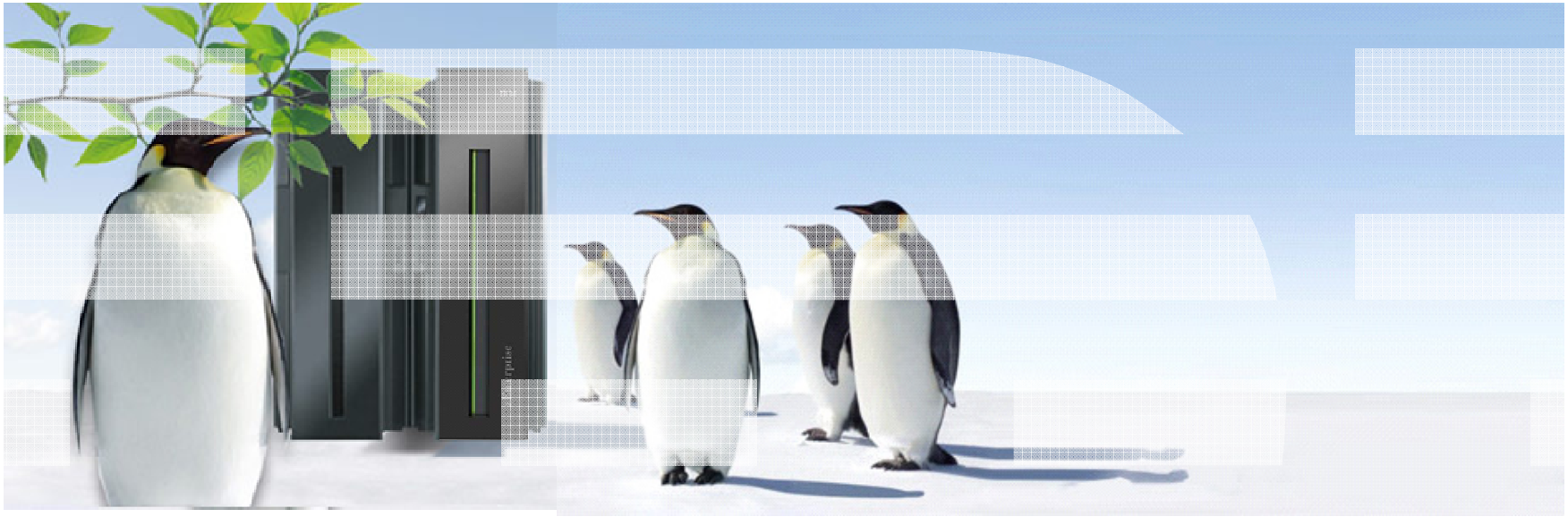

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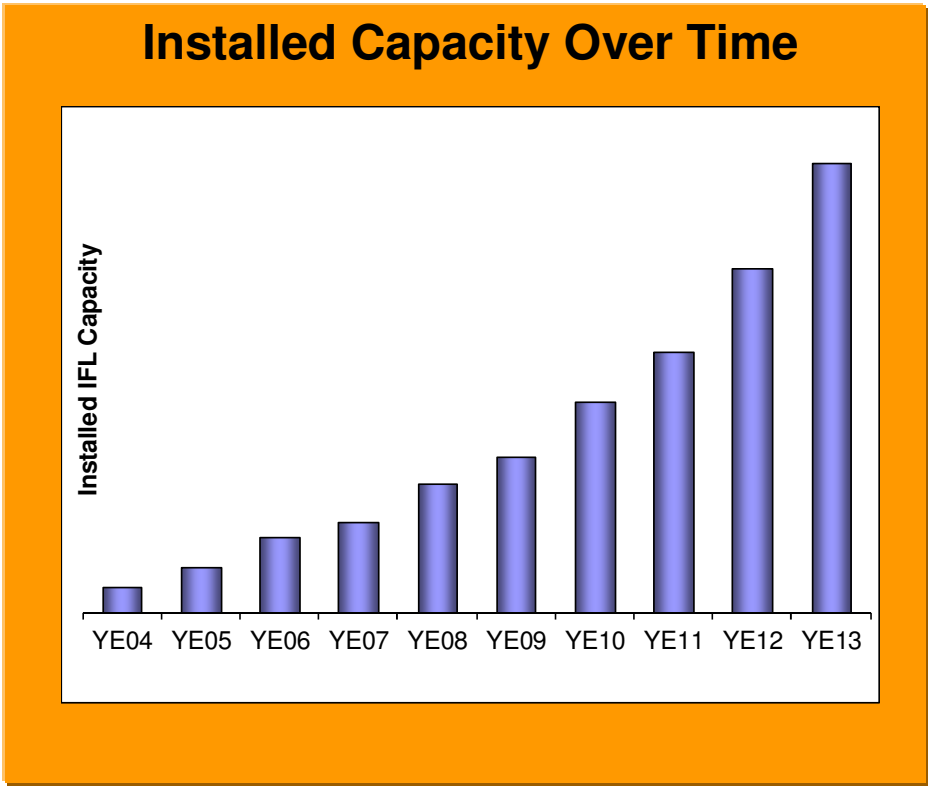
Linux on System z introduction

Interesting facts and numbers

Linux on IBM System z in 4Q2013

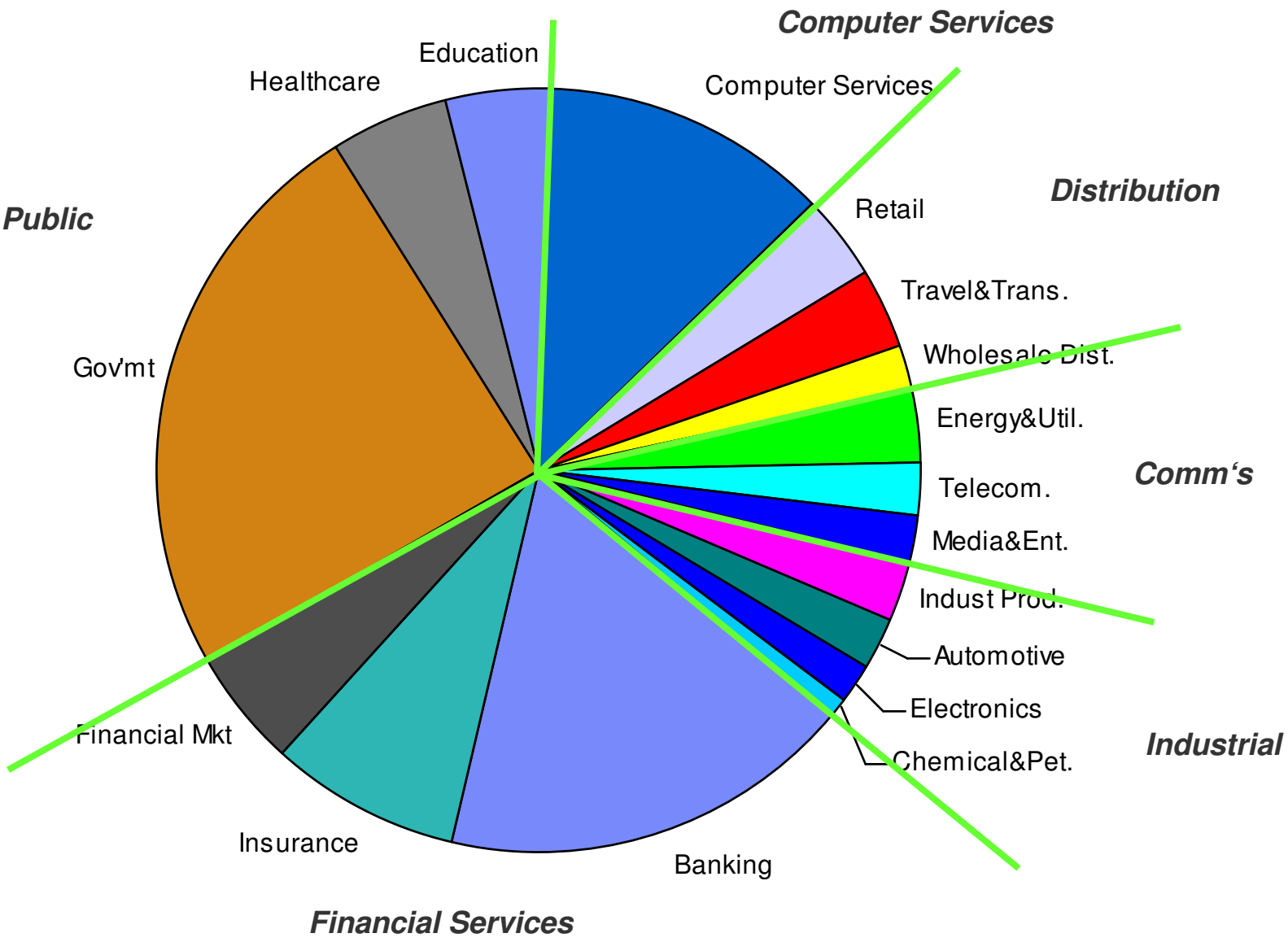
*Installed Linux MIPS at 49% CAGR**

- **Installed IFL MIPS increased 31% from 4Q12 to 4Q13**
- **78 of the top 100 System z Customers are running Linux on the mainframe as of 4Q13 ****
- **26.7% of Total installed MIPS run Linux as of 4Q13**
- **38% of System z Customers have IFL's installed as of 4Q13**
- **58% of new FIE/FIC System z Accounts run Linux (FY10-3Q13)**
- **34% of all System z servers have IFLs**



* Based on YE 2003 to YE 2013
**Top 100 is based on total installed MIPS

Linux on z omnipresent in Industry



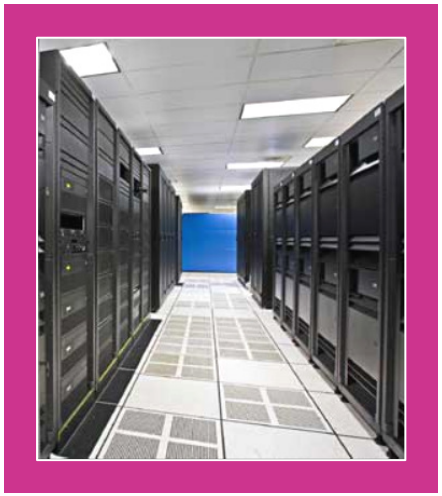
Facts on Linux

- Linux kernel 1.0.0 was released with 176,250 lines of code
  How many lines of code has the kernel version 3.13 ?
  - 17,931,010 lines of code (+3,283,977 since v3.0)
- How many of the world's top 500 supercomputers run Linux (Nov 2013)?
  482 / 96.4%
- What percentage of web servers run Linux (Feb 2014) ?
  67.1% run Unix, of those 53.3% run Linux (45.1% unknown) = 35.7%
- What percentage of desktop clients run Linux (Jan 2014) ?
  1.93% via Linux, 6.75% via Android
- What is the architecture with the larges amount of core changes?
  ARM, with ~115 KLOC per release for v3.x, followed by mips and powerpc with ~26 KLOC and x86 with ~23 KLOC. System z (alias s390) had an average of ~7 KLOCS

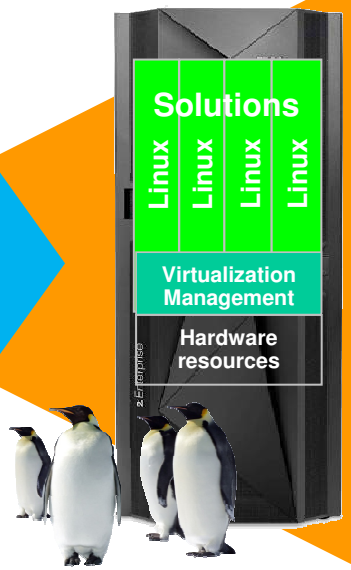
- Linux is Linux, but …features, properties and quality differ dependent on your platform and your use case

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

The Enterprise Linux Server – Linux scalability per excellence



Improved effectiveness and efficiency



- Operational and management reduction
- Software acquisition and licensing cost reduction
- Maximized hardware utilization
- Network reduction
- Collocation of data and applications
- Floor-space and energy reduction
- Growth inside a server
- Improving security
- Disaster recovery cost reduction and simplicity

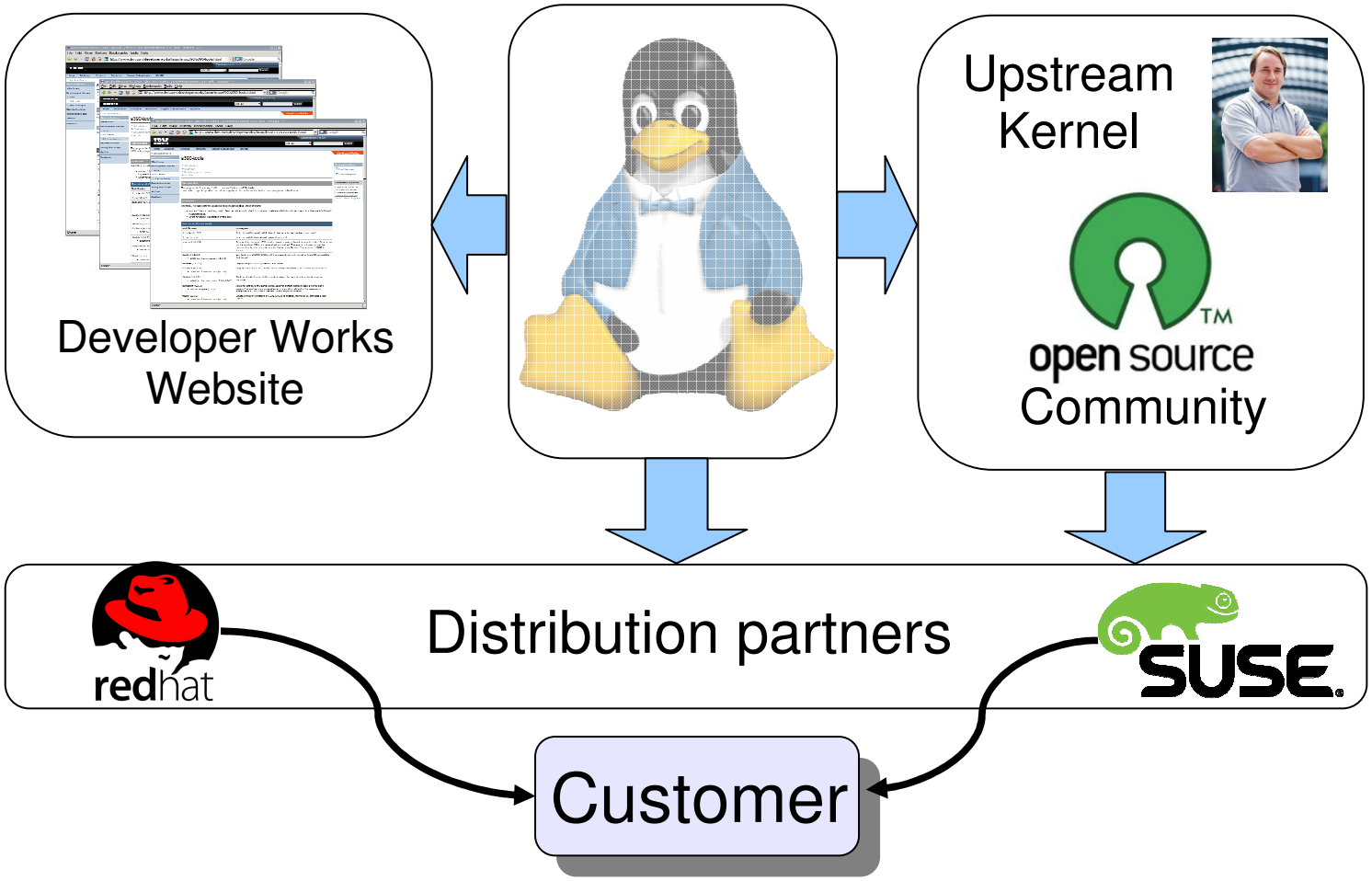
IBM Enterprise Linux Server

Designed to provide unrivaled power, performance, security, and flexibility for all kind of Linux workloads in a single economical server, replacing the complexity of distributed systems.

Linux on System z distributions

What is available today

Building a Linux distribution for System z



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)
- **Others**
  - Debian, Slackware,
  - Support may be available by some third party

Linux Distributions - Status as of April 2014

- SLES 10 SP4
  - **Available since 04/2011**
- SLES 11 SP3
  - **Available since 07/2013**
- SLES 12
  - **Announced at SuseCon in 11/2013**
  - **Expect ALS (Architecture Level Set) to IBM z196**
- RHEL 5.10
  - **Available since 10/2013**
- RHEL 6.5
  - **Available since 11/2013**
- RHEL 7
  - **Announced and available as Beta since 12/2013**
  - **Expect ALS (Architecture Level Set) to IBM z196**

Supported Linux Distributions

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

✔ 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) Recommended level: RHEL 6.3

(2) Recommended level: RHEL 5.8

(3) Recommended level: SLES 11 SP3

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

(5) 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.

(6) 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.

 source: http://www.ibm.com/systems/z/os/linux/resources/testedplatforms.html

Current Linux on System z Technology

Features & Functionality developed in the **past 2 years**
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)**

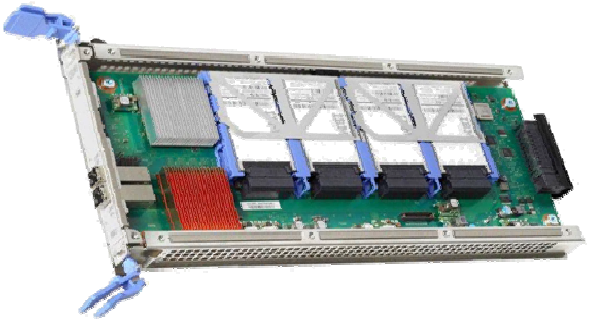
  - New generation of crypto adapters plug-able into the I/O drawer
  - New type 10 which uses a bit field to indicate capabilities of the crypto card
- **Native PCI feature cards (base in kernel 3.8, ongoing)**
  - Support for native PCIe adapters visible to the operating system
- **Oprofile zEC12 hardware sampling support (kernel 3.10)**
  - Extend the hardware sampling to support zEC12

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 – Core kernel

- **Two stage dumper / kdump support (kernel 3.2, s390-tools-1.17.0)**
  - Use a Linux kernel to create a system dump
    - Use a preloaded crash-kernel to run in case of a system failure
    - Can be triggered either as panic action or by the stand-alone dumper, integrated into the shutdown actions framework
  - Pro
    - Enhanced dump support that is able to reduce dump size, shared disk space, dump to network, dump to a file-system etc.
    - The makedumpfile tool can be used to filter the memory of the crashed system
    - Dump disk space sharing is possible for server farms using network dump
  - Con
    - kdump is not as reliable as the stand-alone dump tools
    - kdump cannot dump a z/VM named saved system (NSS)
    - For systems running in LPAR kdump consumes memory

Linux on System z features – Core kernel

- **Allow to compare dump system with boot system**

  - With z/VM 6.2 Single-System-Image it is possible to move active Linux instances between different z/VM instances
  - To aid debugging a log of past live-guest-relocations is made available in both the live system and in the dump of a system

- **Fuzzy Live Dump (kernel 3.5)**

  - Add the capability to generate a dump of a live system.
  - Not all data structures will be consistent but the dump may still be useful.

- **AP adapter resiliency (kernel 3.7)**

  - Improve RAS capabilities of the AP bus and the zcrypt devices.
  - External AP bus configuration changes are now handled correctly.

Linux on System z features – FICON

- **Extended DASD statistics (kernel 3.1)**

  - Add detailed per-device debugging of DASD I/Os via debugfs
  - Useful to analyze problems in particular for PAV and HPF

- **DASD sanity check to detect path connection errors (kernel 3.3)**

  - An incorrect physical connection between host and storage server which is not detected by hardware or microcode can lead to data corruption
  - Add a check in the DASD driver to make sure that each available channel path leads to the same storage server

- **FICON Express8S hardware data router support for FCP (kernel 3.2)**

  - Hardware data router support requires an adapted qdio request format.
  - Improves performance by reducing the path length for data.

Linux on System z features – Networking

- **Support VEPA Mode (kernel 3.8, s390-tools 1.22)**

  - Virtual Ethernet Port Aggregator (VEPA) mode support
  - All packages are sent to the networking switch to enable external routing
  - Reduces CPU overhead in the virtual machine
  - Uses the security, filtering, and management features of the physical switch

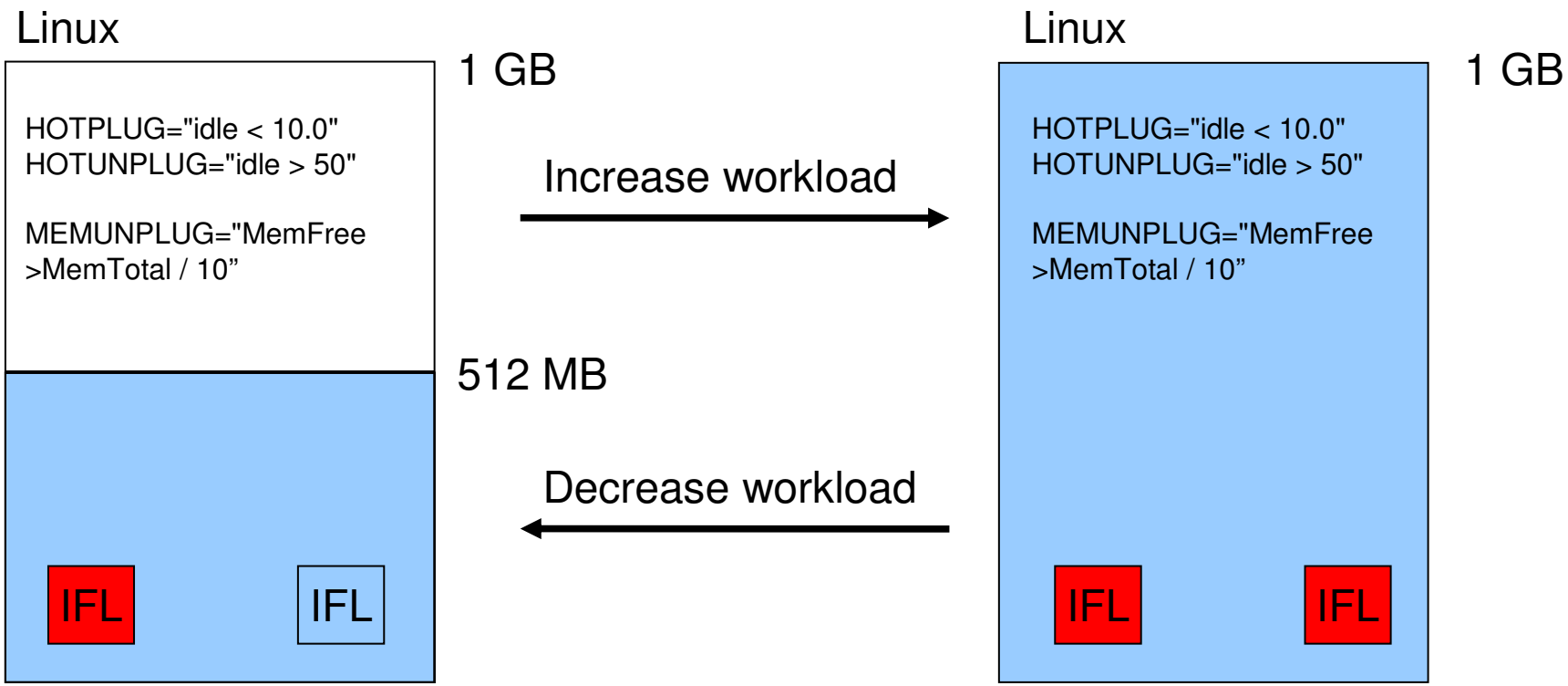
- **Extend lscpu tool and add new chcpu tool (util-linux 2.21)**

  - Improve the lscpu tool to display CPU topology and CPU state
  - Add the new chcpu tool to change CPU state, rescan CPUs and change the CPU dispatching mode (horizontal vs. vertical polarization)

Optimize with cpuplugd

6.2 11.2

- **Improve memory ballooning with cpuplugd (s390-tools 1.15.0)**
  - A number of improvements to the memory balloon part to cpuplugd to make it more useful.
  - Under z/VM only



lscpu & chcpu

11.3

- **Extend lscpu tool and add new chcpu tool (util-linux 2.21)**
  - Improve the lscpu tool to display CPU topology and CPU state
  - Add the new chcpu tool to change CPU state, rescan CPUs and change the CPU dispatching mode (horizontal vs. vertical polarization)

```
# lscpu -a
  Architecture:          s390x
  CPU op-mode(s):        32-bit, 64-bit
  Byte Order:            Big Endian
  CPU(s):                3
  On-line CPU(s) list:   0-2
  Thread(s) per core:    1
  Core(s) per socket:    1
  Socket(s) per book:    1
  Book(s):               3
  Vendor ID:             IBM/S390
  BogoMIPS:              18115.00
  Hypervisor:            z/VM 6.2.0
  Hypervisor vendor:     IBM
  Virtualization type:   full
  Dispatching mode:      horizontal
  L1d cache:             96K
  L1i cache:             64K
  L2d cache:             1024K
  L2i cache:             1024K
```

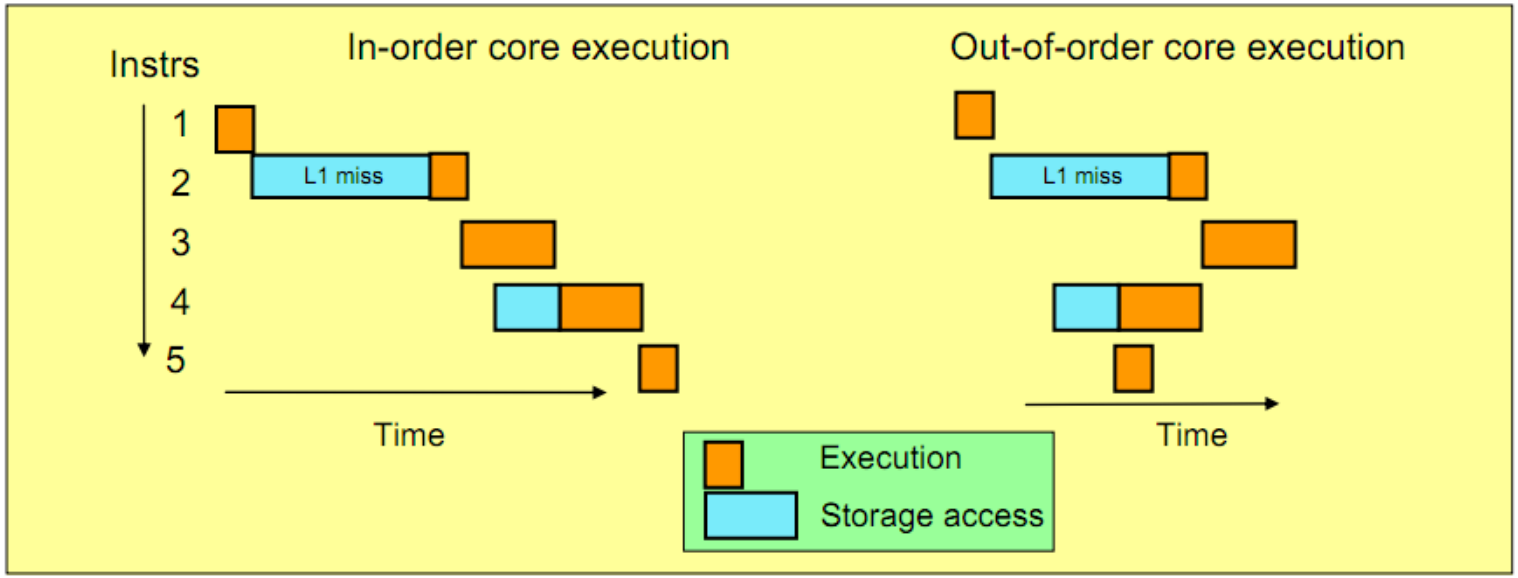
- Change CPU configuration, e.g. disable a CPU

```
# chcpu -d 2
  CPU 2 disabled
```

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



Future Linux on System z Technology

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

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 <= 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 – I/O improvements

- **No automatic port rescan on events (kernel 3.7)**
  - The rescan of a zfcp 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 – 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 BFP 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.

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

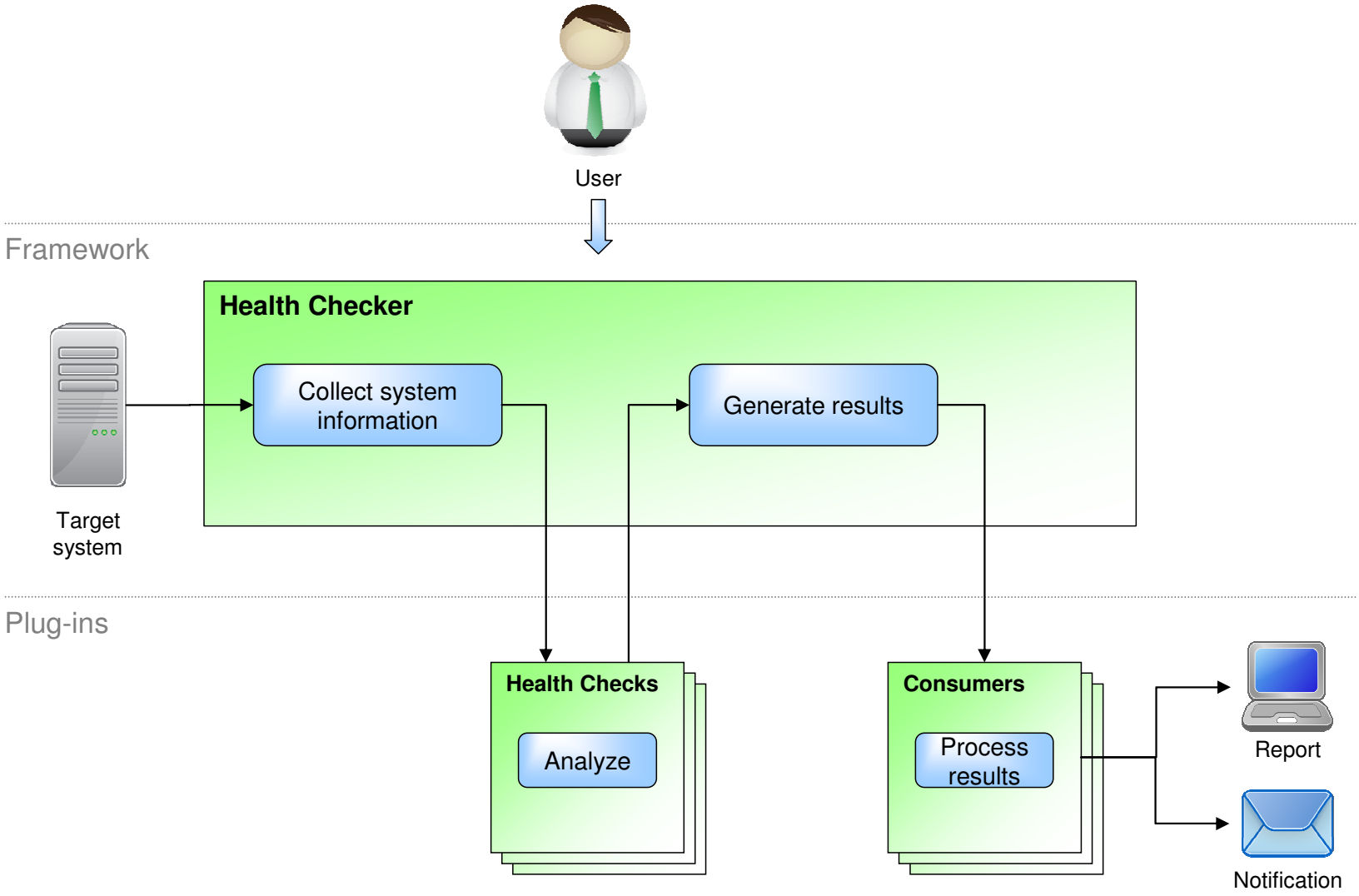
System z toolchain

- **Oprofile z196 hardware customer mode sampling (kernel 3.3)**
  - Extend the hardware sampling to support z196.
- **Oprofile zEC12 hardware sample support (kernel 3.10)**
  - Extend the hardware sampling to support zEC12
- **Valgrind System z support**
  - Valgrind is a generic framework for creating dynamic analysis tools and can be used for memory debugging, memory leak detection and profiling (e.g. cachegrind)
  - Valgrind is in essence a virtual machine using just-in-time (JIT) compilation techniques
  - Memory debugging is available with Valgrind version 3.7.0

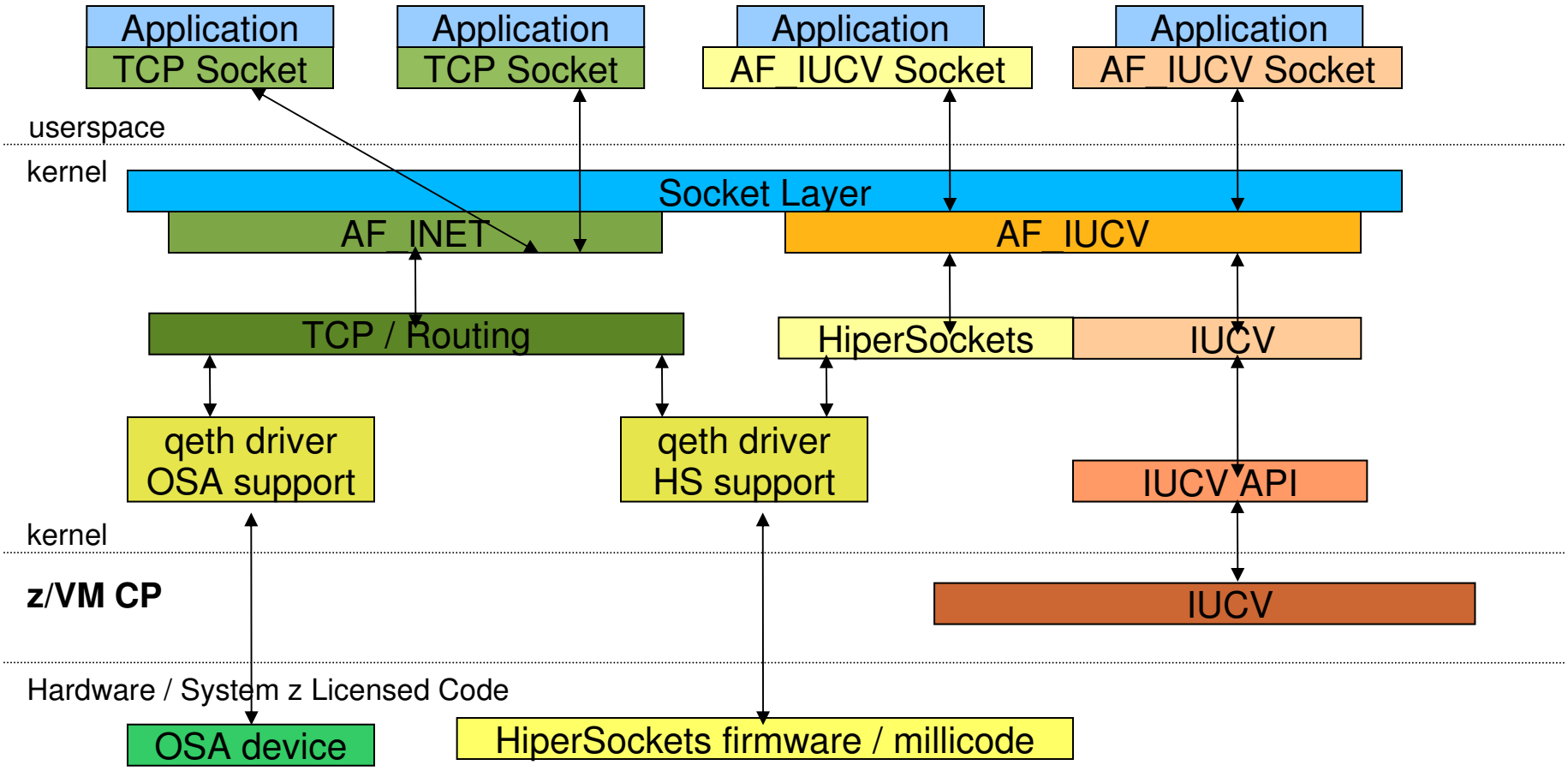
LNXHC – Linux Health Checker

- 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



Linux on z network options and interfaces



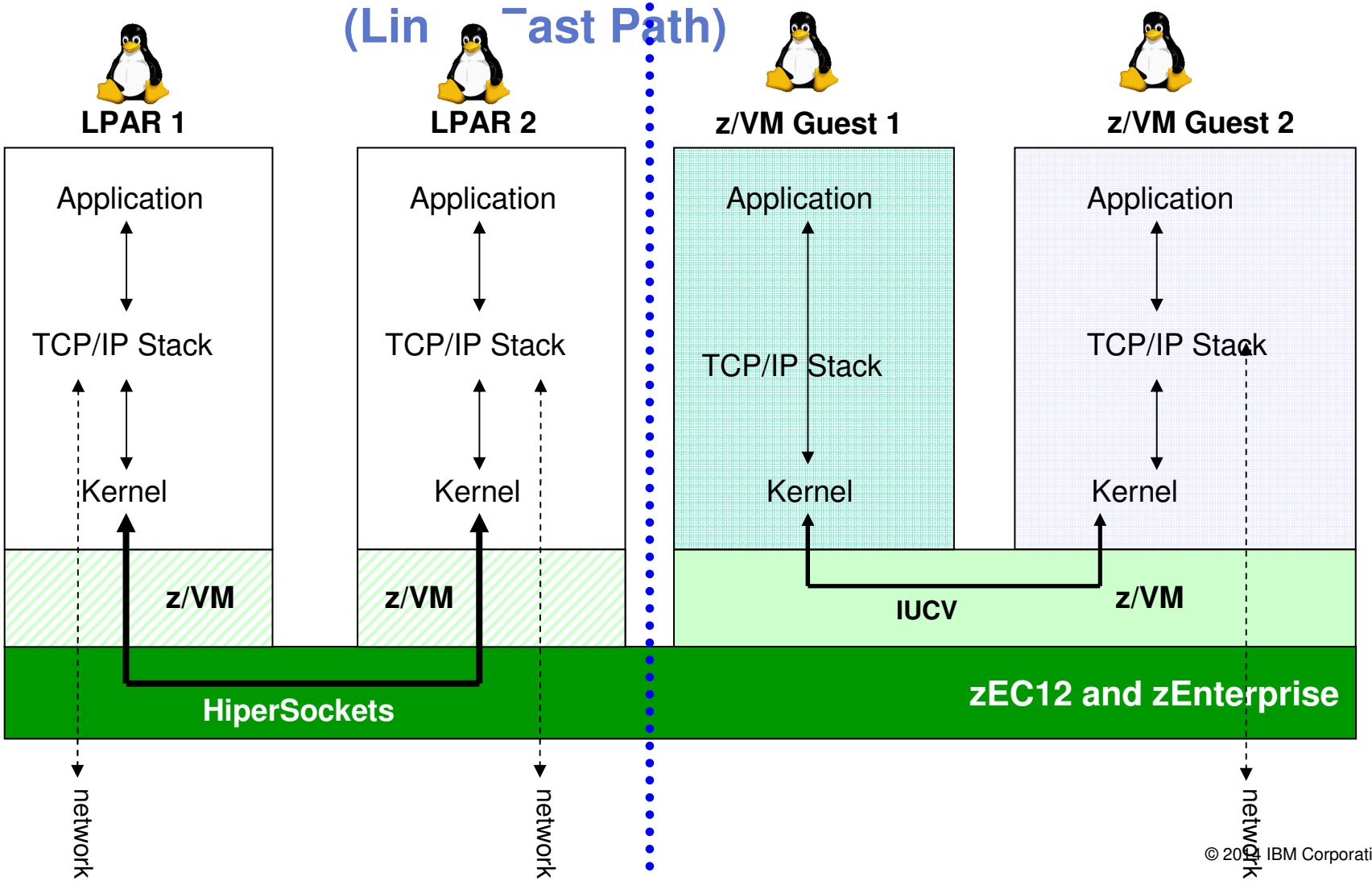
z/VM IUCV – Inter-User Communication Vehicle

- **A communications facility inside of z/VM**
- **A program running in a z/VM guest communicating**
  - With another virtual machine within same z/VM
    - Running Linux on z/VM
    - Running other Operating System (for instance VSE)
  - With a CP system service
  - With itself
- **IUCV interrupt control functions to**
  - establish and remove communication paths
  - transfer messages

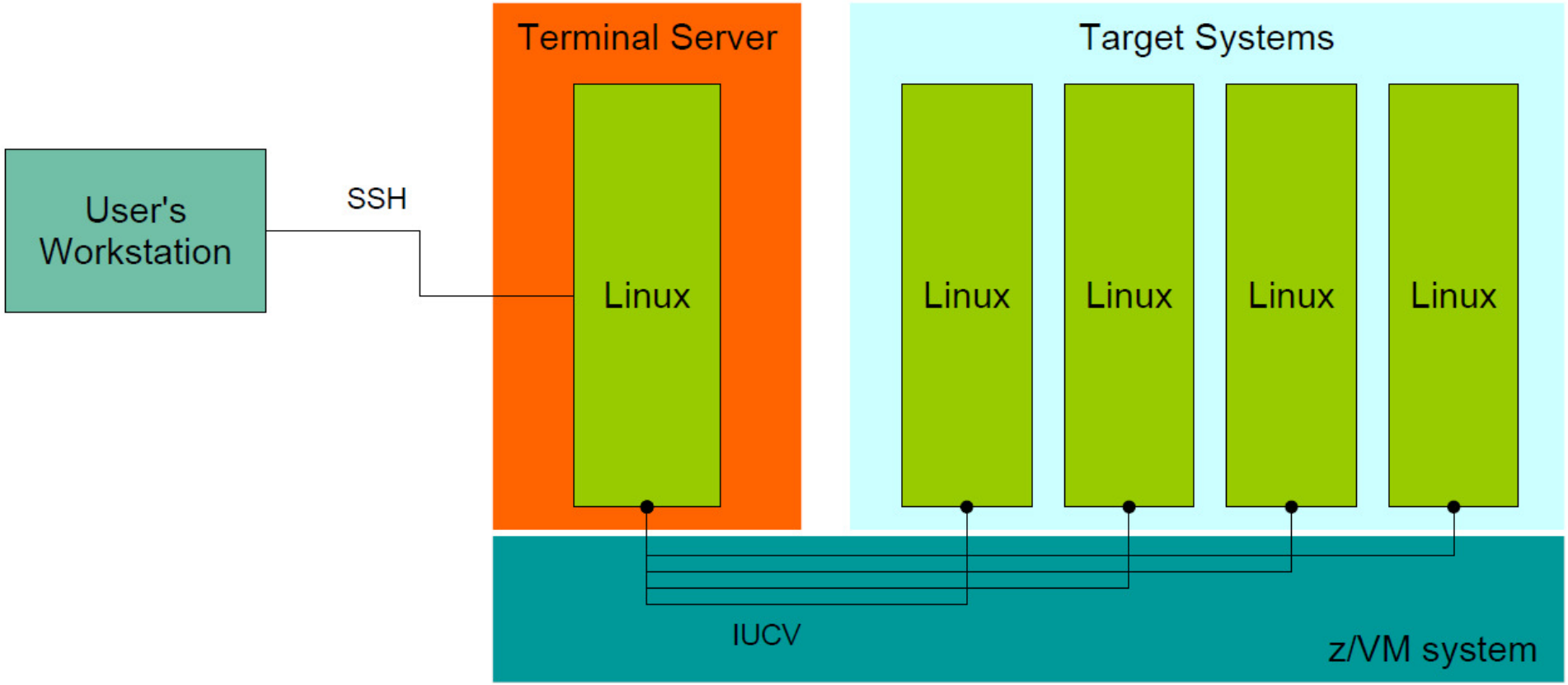
HS versus IUCV communication in a z/VM-mode LPAR

– Supported by z/VM, Linux and z/VSE (Linux Fast Path)

Faster communication between Linux applications



A Terminal Server environment using z/VM IUCV without TCP/IP



Services for IBM FlashSystem Solution

Consider for Linux on System z

Quickly integrate IBM FlashSystem and IBM System Storage® SAN Volume Controller (SVC) into your storage environment

IBM FlashSystem and SVC Integration Bundle

- Configuration of IBM FlashSystem and SVC
- Configuration of SVC advanced function
- Knowledge transfer session
- Sold with bundle as a standard offering

FlashSystem SVC Data Migration

- Migration planning session
- Configuration of FlashSystem and SVC
- Migration of data and servers
- Knowledge transfer session
- Optional offering

Services offerings available from IBM Systems Lab Services and Training. To learn more about IBM FlashSystem services and other related products and services, contact stgls@us.ibm.com or visit: **ibm.com**/systems/services/labservices

5.2+ 10.2+

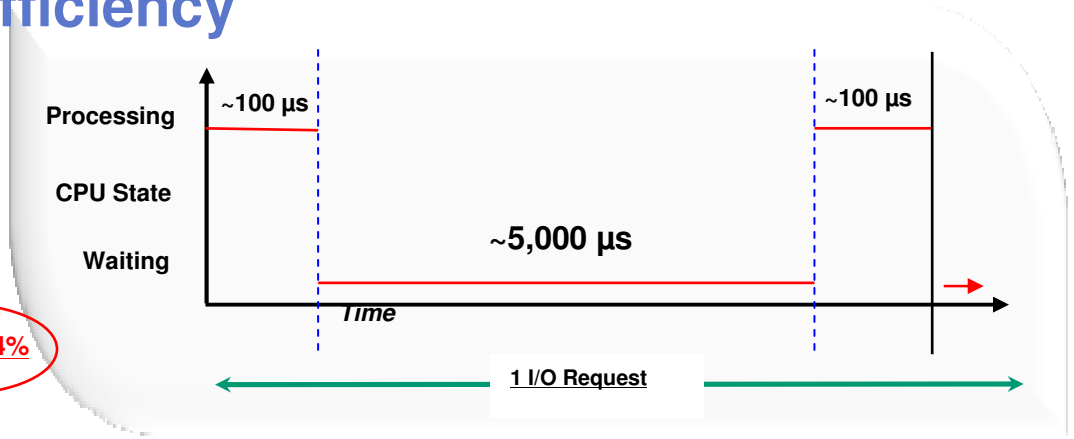
6.3+ 11.2+

Microsecond latency maximizes CPU utilization/efficiency

I/O Serviced by Disk

1. Issue I/O request ~ 100 µs
2. Wait for I/O to be serviced ~ 5,000 µs
3. Process I/O ~ 100 µs

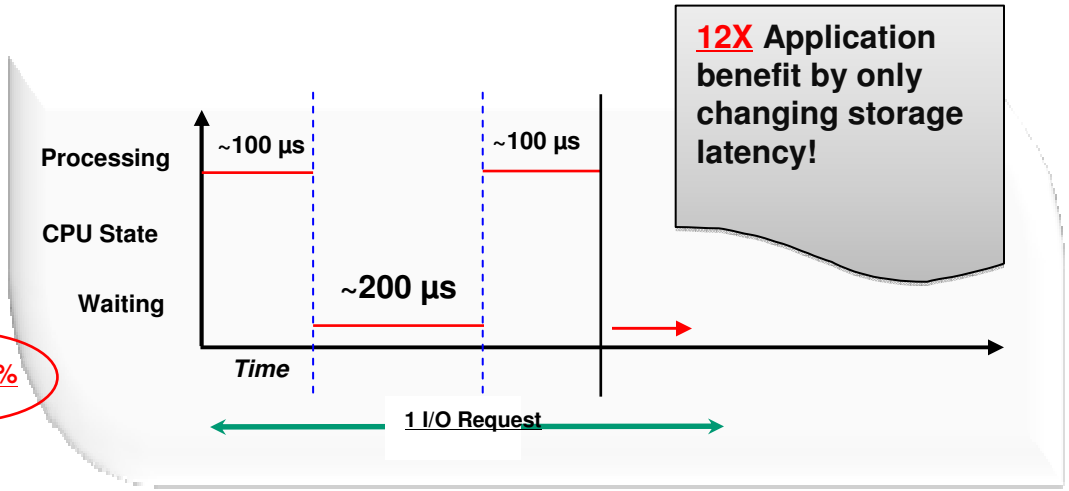
- Time to process 1 I/O request = 200 µs + 5,000 µs = 5,200 µs
- CPU Utilization = Wait time / Processing time = 200 / 5,200 = ~4%



I/O Serviced by IBM FlashSystem

1. Issue I/O request ~ 100 µs
2. Wait for I/O to be serviced ~ 200 µs
3. Process I/O ~ 100 µs

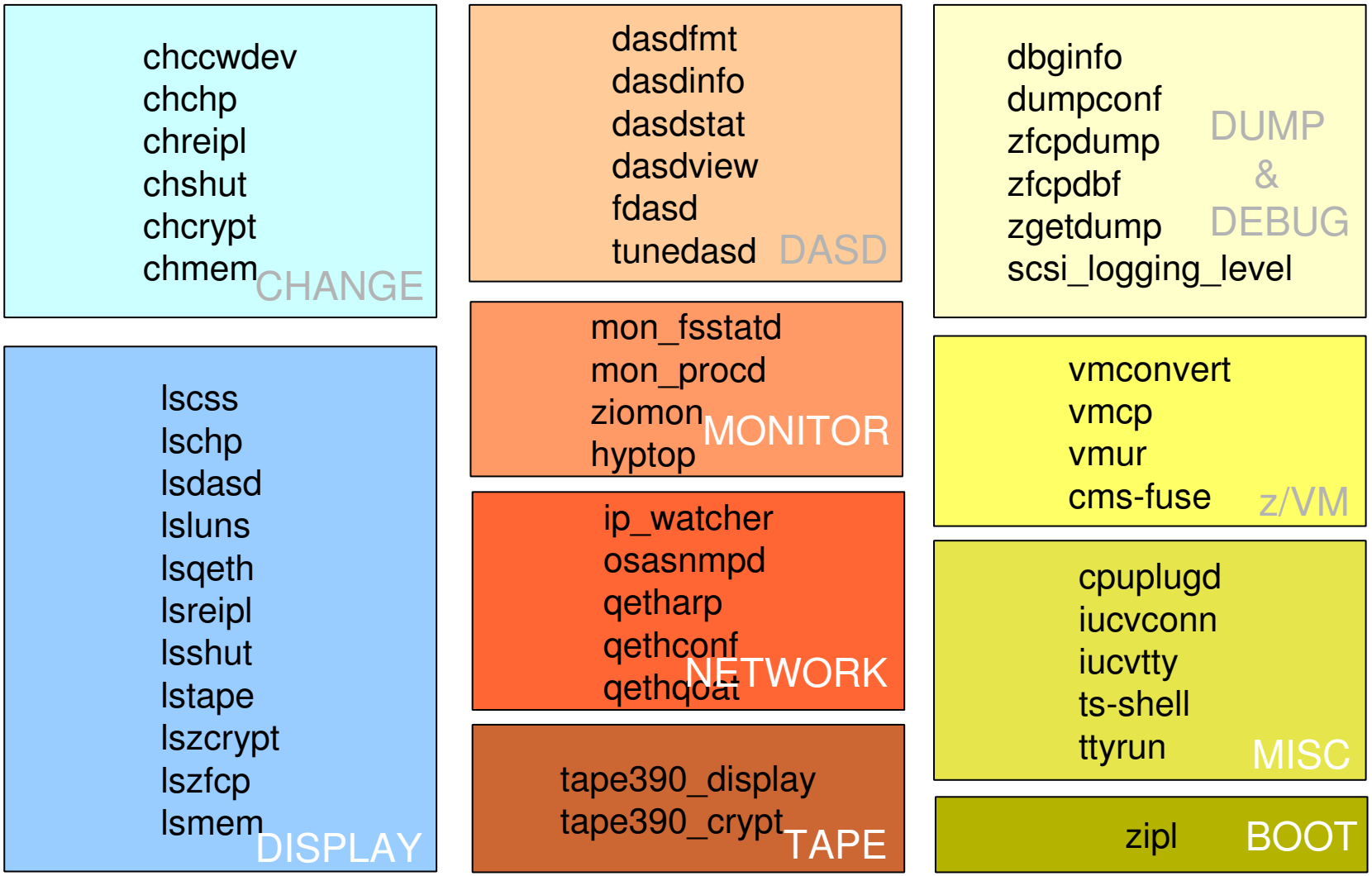
- Time to process 1 I/O request = 200 µs + 200 µs = 400 µs
- CPU Utilization = Wait time / Processing time = 200 / 400 = 50%



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, and 6
  - 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

s390-tools package: the content



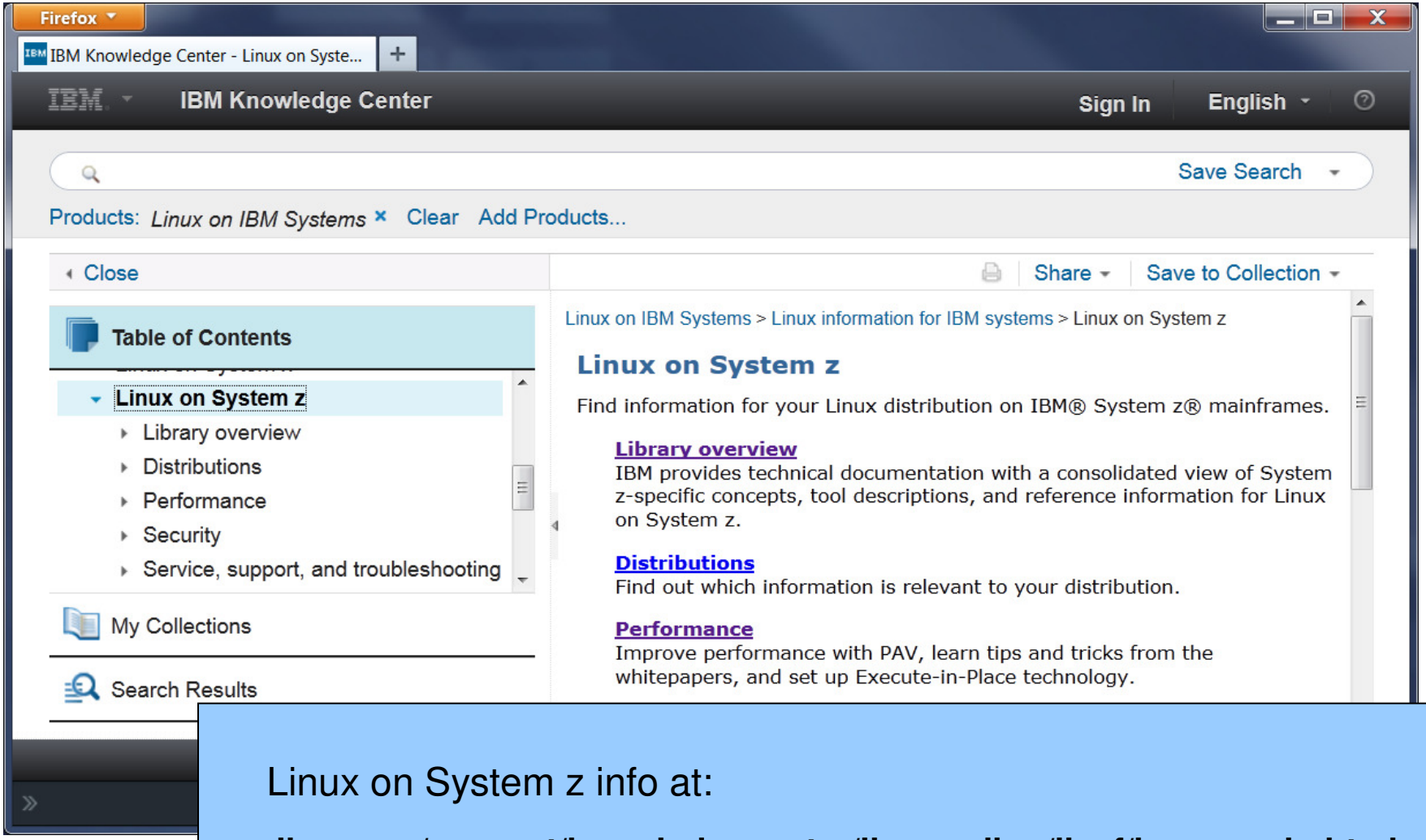
IBM Enterprise Linux Server is open for all solutions (CAMS)

Cloud, Analytics, Mobile and ...

- **Data services - Analytics**
- **Business applications**
- **Mobile applications**
- **Security & Infrastructure services**
- **Email & collaboration services**
- **Business Process Management**
- **Enterprise Content Management**
- **Development & test**
- **Industry Solutions**
- **All managed in a Cloud**

Enterprise Linux Server – the efficient and economic infrastruture for consolidation and new Linux workload deplyoments

New - ibm.com/support/knowledgecenter/

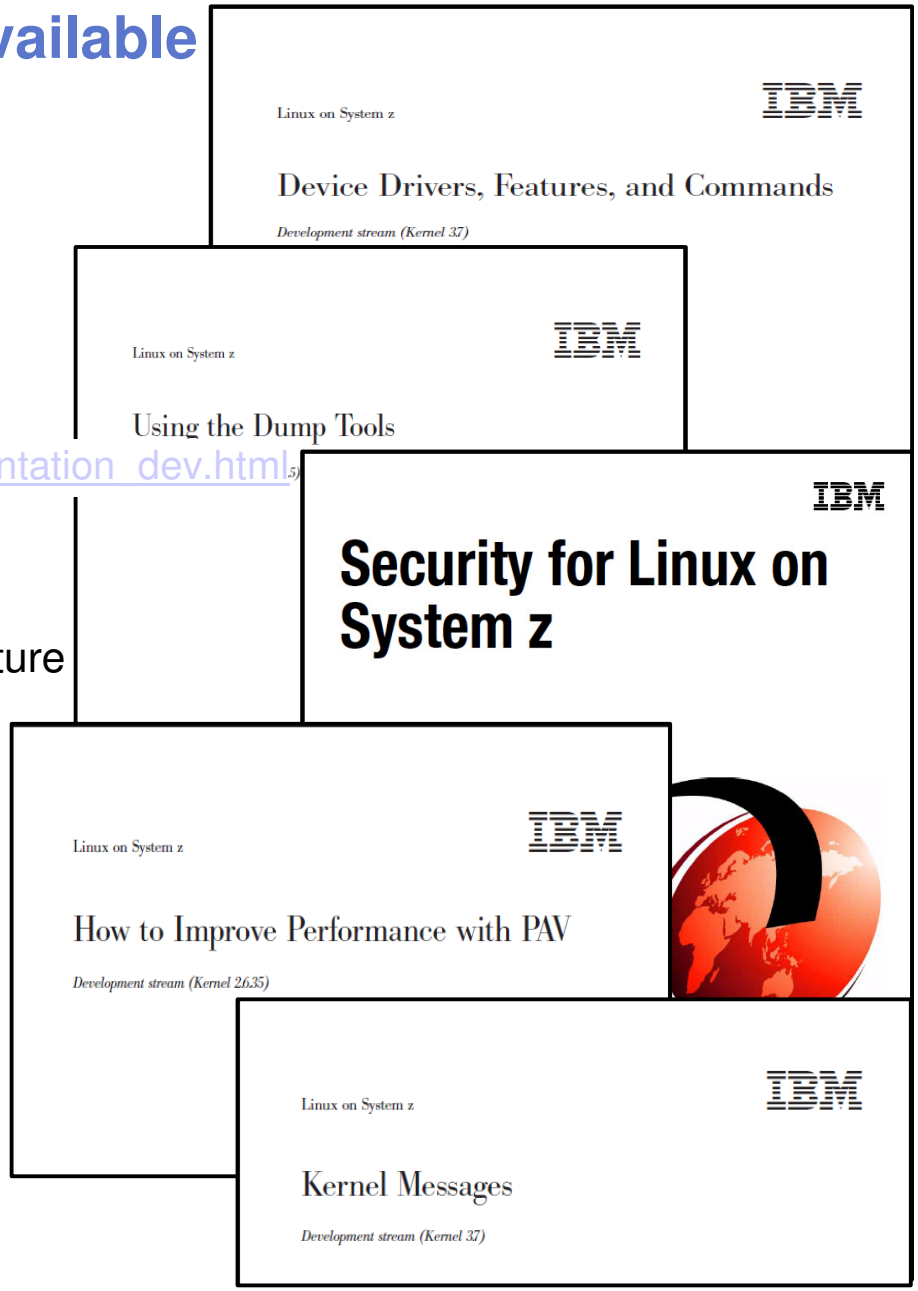


Linux on System z info at:

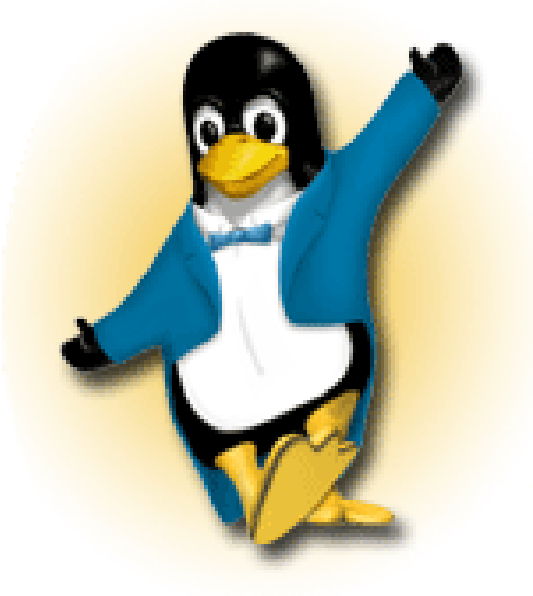
ibm.com/support/knowledgecenter/linuxonibm/liaaf/lnz_r_main.html

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
- **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



Questions?



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Thanks to Martin Schwidefsky for his contribution to the slides.