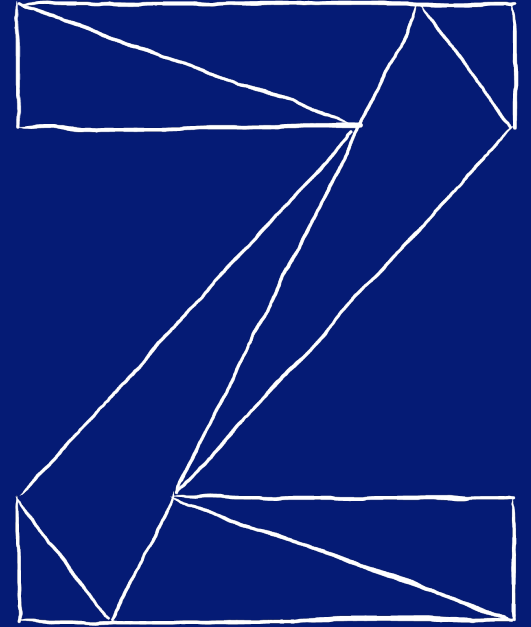# Linux on IBM Z News

—

Stefan Raspl
Linux on IBM Z Development

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Agenda

- Linux on IBM Z Distributions

- GA2 News for IBM z14 and LinuxONE

- SMC for Linux on Z

- Pervasive Encryption

- Kernel News

Supported Linux Distributions

	Emperor II	Rockhopper II	Emperor	Rockhopper	zEnterprise — zEC12, zBC12	zEnterprise — z196, z114	System z10, System z9
	z14 M0x	z14 ZR1	z13	z13s			
● **Certified by Linux partner**							
RHEL 7	●	●	●	●	●	●	
RHEL 6	●	●	●	●	●	●	●
RHEL 5			●		●	●	●
SLES 15	●	●	●	●	●		
SLES 12	●	●	●	●	●	●	
SLES 11	●	●	●	●	●	●	●
Ubuntu 18.04	●	●	●	●	●		
Ubuntu 16.04	●	●	●	●	●		

Overview shows Linux distributions in service.

Extended support is available for Linux distributions that are out of service.

Last update 04/12/2019

See www.ibm.com/systems/z/os/linux/resources/testedplatforms.html for latest updates and details.

z14 Hardware Certification

z14 ZR1, Rockhopper II

| z14 M0x, Emperor II |
| z14 ZR1, Rockhopper II |
| z13, Emperor |
| z13s, Rockhopper |
| zEnterprise – zEC12, zBC12 |
| zEnterprise – z196, z144 |
| System z10 and System z9 |

z14 ZR1, Rockhopper II

Linux partner certifications for this hardware:

Canonical hardware certifications:

- Ubuntu 18.04 LTS: z14 ZR1 and Rockhopper II
- Ubuntu 16.04 LTS: z14 ZR1 and Rockhopper II

Red Hat hardware certifications for z14 ZR1:

- RHEL 7.3 and RHEL 6.9

SUSE hardware certifications:

- SLES 12 SP2: z14 ZR1 and Rockhopper II
- SLES 11 SP4: z14 ZR1 and Rockhopper II

IBM tested distributions on this hardware:

Canonical distribution with the kernel-level and cryptography libraries:

- *Ubuntu 16.04.3 LTS:* LTS kernel 4.4.0-116; *Crypto libs:* TKE9.0, csulcca-5.2.23-12, libep11_1.3.2-1, libep11-dev_1.3.2-1

Red Hat distributions with the kernel-level and cryptography libraries:

- *RHEL 7.4:* 3.10.0-693.21.1.el7; *Crypto libs:* TKE9.0, csulcca-5.2.23-12, ep11-host-1.3.2-0, ep11-host-devel-1.3.2-0
- *RHEL 2.6.32-696.23.1.el6; Crypto libs:* TKE9.0, csulcca-5.2.23-12, ep11-host-1.3.2-0, ep11-host-devel-1.3.2-0

SUSE distributions with the kernel-level and cryptography libraries:

- *SLES 12 SP3:* kernel 4.4.120-94.17; *Crypto libs:* TKE9.0, csulcca-5.2.23-12, ep11-host-1.3.2-0, ep11-host-devel-1.3.2-0
- *SLES 11 SP4:* kernel 3.0.101-108.35; *Crypto libs:* TKE9.0, csulcca-5.2.23-12, ep11-host-1.3.2-0, ep11-host-devel-1.3.2-0; RoCE Express2 is not supported

Linux on IBM Z Distributions: SUSE

- **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

  - 12/2018 SLES12 SP4: Kernel 4.12, GCC 4.8

    - EOS 31 Oct. 2024; LTSS: 31 Oct. 2027

- **SUSE Linux Enterprise Server 15**

  - 07/2018 SLES 15 GA: Kernel 4.12, GCC 6.4 / 7.1

  - EOS 31 July 2028; LTSS: 31 July 2031

Linux on IBM Z Distributions: Red Hat

- **Red Hat Enterprise Linux 5**

  – 03/2007 RHEL 5 GA: Kernel 2.6.18, GCC 4.1.0

  – 09/2014 RHEL 5 Update 11

  – EOS 31 Mar. 2017; ELS: 30 Nov. 2020

- **Red Hat Enterprise Linux 6**

  – 11/2010 RHEL 6 GA: Kernel 2.6.32, GCC 4.4.0

  – 06/2018 RHEL 6 Update 10

  – EOS 30 Nov. 2020; ELS: 30 June 2024

- **Red Hat Enterprise Linux 7**

  – 06/2014 RHEL 7 GA: Kernel 3.10, GCC 4.8

  – 10/2018 RHEL 7 Update 6

  – EOS 30 Jun. 2024; ELS: tbd

- **Red Hat Enterprise Linux 8**

  – 05/2019 RHEL 8 GA: Kernel 4.18, GCC 8.2.1

  – EOS: Expected for 2029; ELS: tbd

Linux on IBM Z Distributions: Canonical

- **Ubuntu 16.04 (Xenial Xerus)**

  - 04/2016 Ubuntu 16.04 GA: Kernel 4.4, GCC 5.3.0+ LTS-Release

  - 08/2017 Ubuntu 16.04.03 LTS

- **Ubuntu 18.04 (Bionic Beaver)**

  - 04/2018 Ubuntu 18.04 GA: Kernel 4.15, GCC 7.2.0 LTS-Release

- 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

GA2 for z14 & LinuxONE

IBM Adapter for NVMe
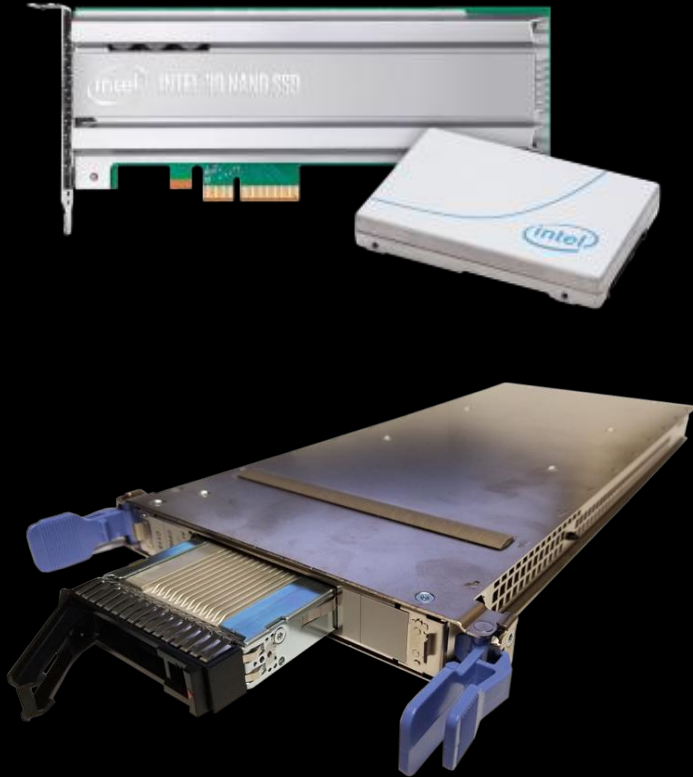
- Two cards have been tested
    - Intel PN SSDPE2KX010T801 (1TB)
    - Intel PN SSDPE2KX040T801 (4TB)
- Customer is free to use any NVMe card
- Uses the standard NVMe Linux kernel driver (`nvme.ko`)
- Support available for
    - SLES 12 SP4
    - SLES 15
    - RHEL 7.6 (*)
    - RHEL 8
    - Ubuntu 18.04 (*)

* please update the kernel to the latest level

For a whitepaper on NVMe performance see
https://www.ibm.com/us-en/marketplace/linuxone-emperor-ii/resources

IBM FCP Express 32S

- High-speed network technology for SANs

- 32 Gigabits per second fibre-channel

- The IBM Z specific zfcp Linux driver is used to drive traffic over the FCP Express 32S cards

    - The existing driver works without changes

    - To report the new link speed of 32 Gbps one small kernel patch has been added in 2017

IBM OSA-Express7S
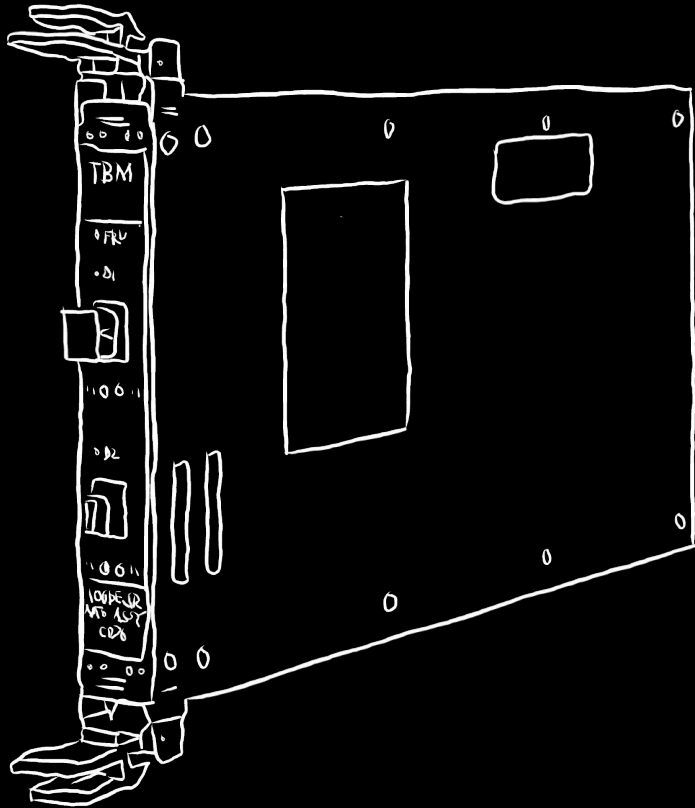
- 25 GbE networking adapter

- Strictly requires 25GbE optics and switches – no dynamic switching to 10GbE!

- Availability: April 9, 2019

- The IBM Z specific `qeth` Linux driver drives traffic

  - Existing driver works without changes

  - Small patch required to report correct link speed

  - Likewise `qethqoat` (part of s390-tools) to report correct model generation

IBM RoCE Express2

- 25 GbE networking adapter

- Strictly requires 25GbE optics and switches – no dynamic switching to 10GbE!

- Vendor-provided mlx5 Linux driver required

SMC

What sending data through BSD sockets looks like
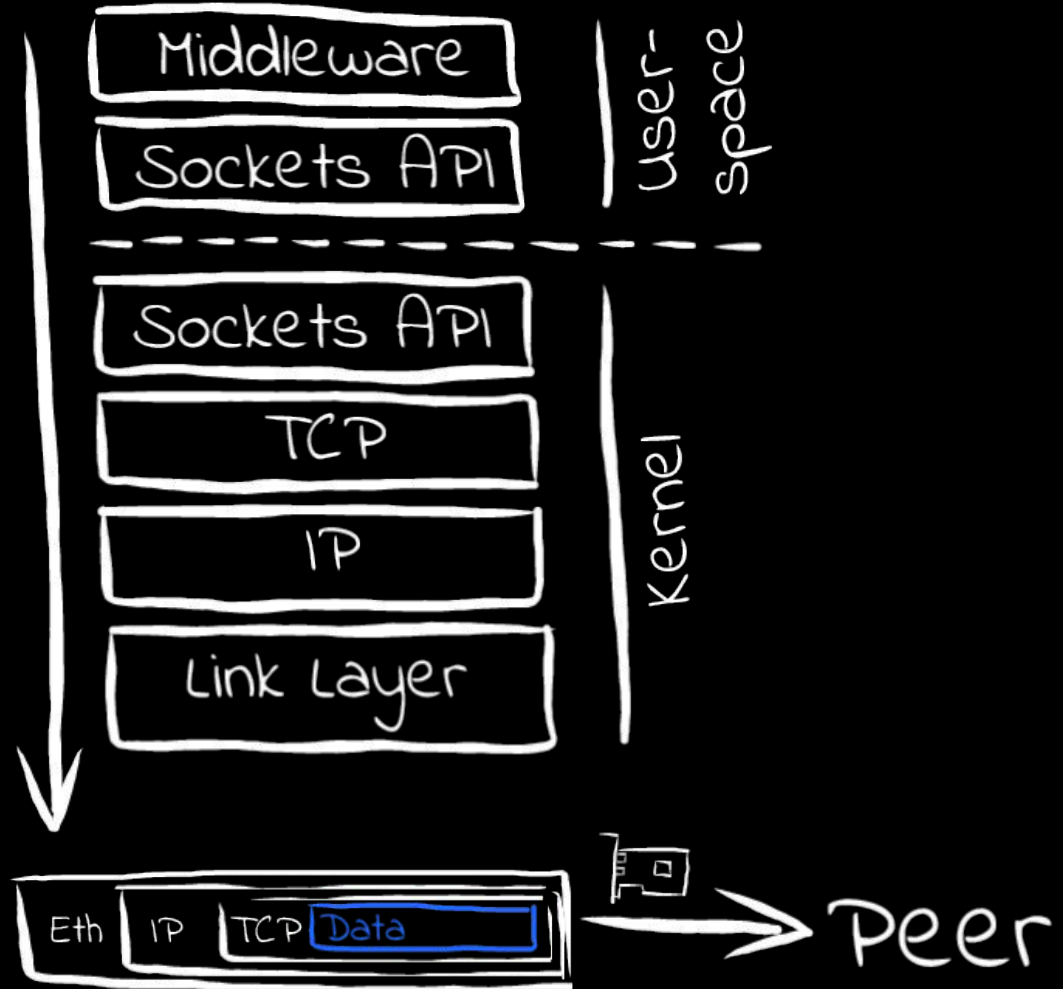
What if we had a simple buffer to write data to and let hardware do the rest…?
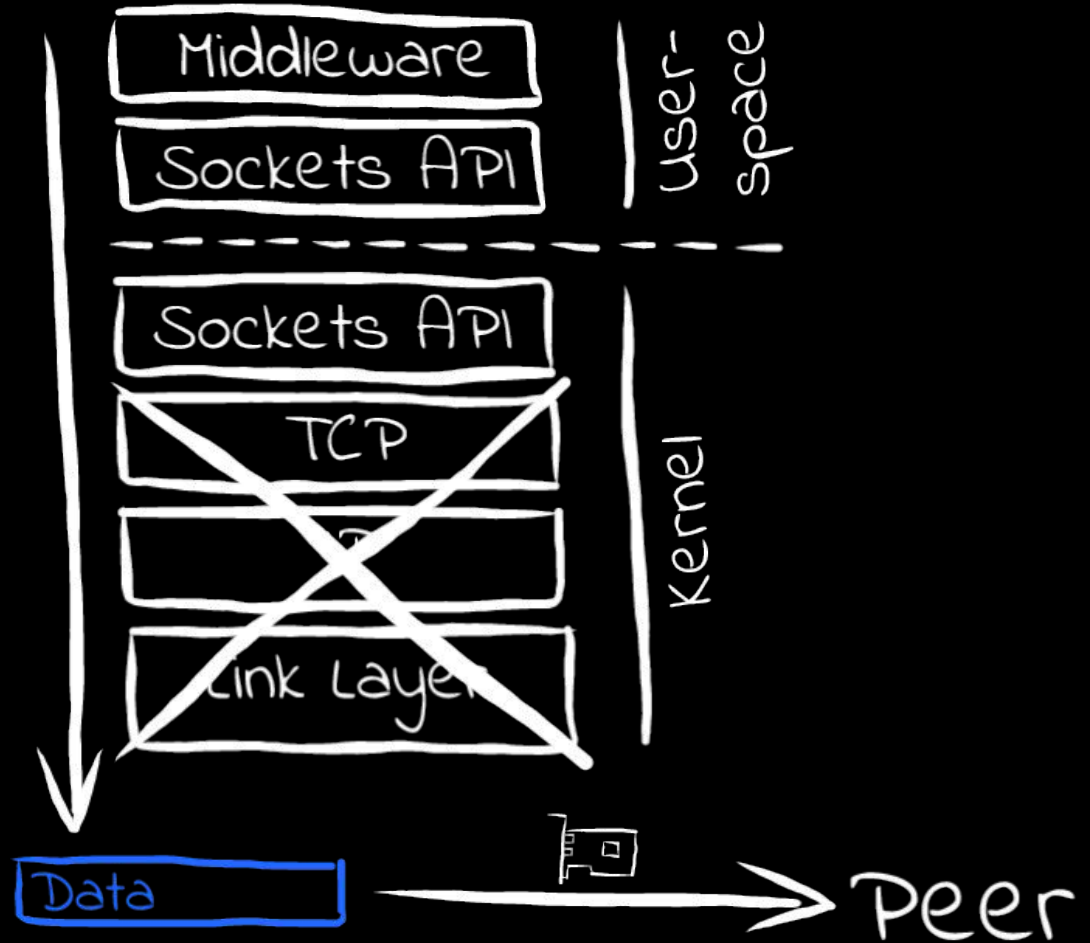
What if we had a simple buffer to write data to and let hardware do the rest…?

- Less latency
- Lower CPU usage
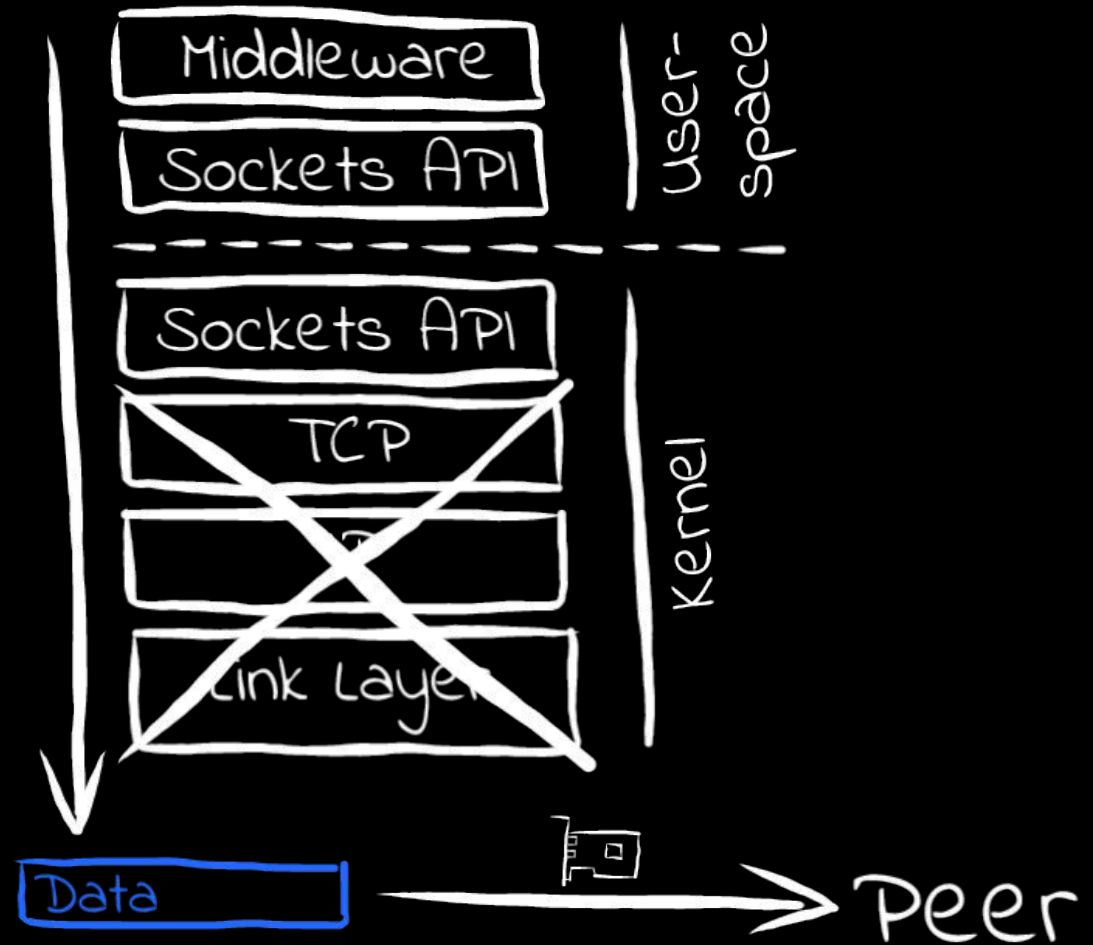
SMC-R Overview

- Cross-CEC connectivity using **RoCE Express** cards

- IBM Z hardware requirements
  - IBM zEC12 and zBC12, or later
  - LinuxONE Emperor and Rockhopper, or later
  - Classic and DPM mode supported

- RoCE Express cards
  - RoCE Express & RoCE Express2 cards supported
  - Switches need to support and enable *Global Pause* (standard Ethernet switch flow control feature as described in IEEE 802.3x)

- PNET ID configuration
  - IOCDS or smc_pnet (→see *smc-tools* package)
  - Use OSA or RoCE card for regular connectivity

- **Notes**:
  - Linux on Z can use a single RoCE card for regular and RDMA traffic!
  - No link failover!
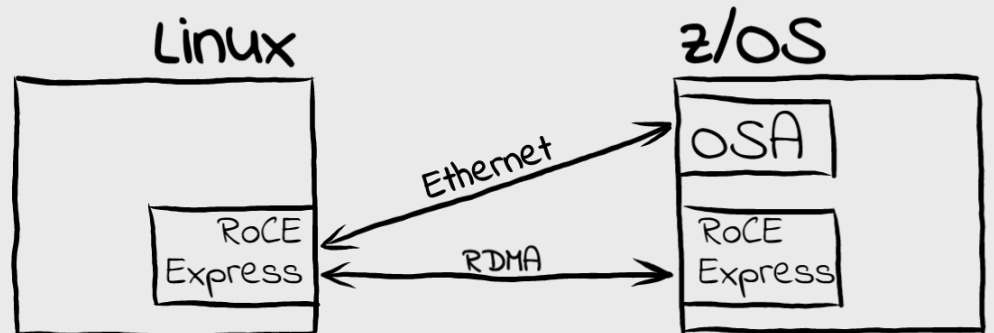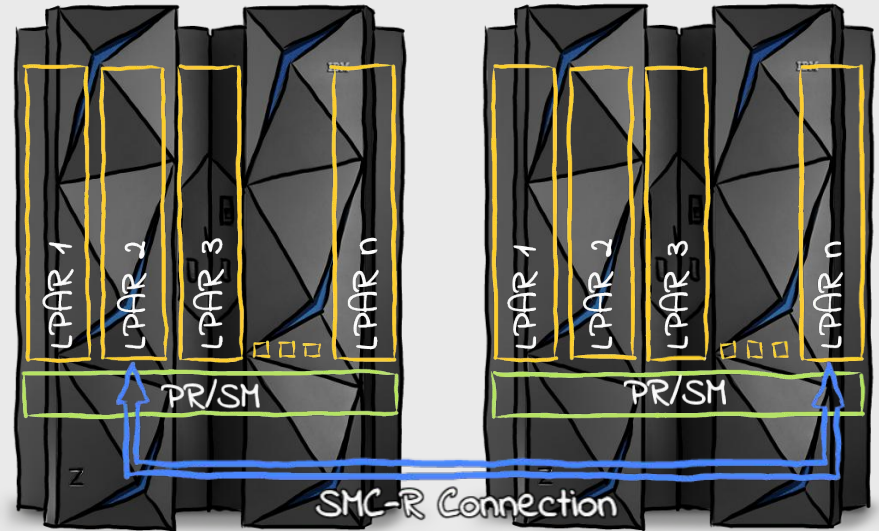
SMC-D Overview

- Intra-CEC connectivity using ***Internal Shared Memory*** (ISM) devices

- IBM Z hardware requirements
  - IBM z13 (requires driver level 27 (GA2)) and z13s, or later
  - LinuxONE Emperor and LinuxONE Rockhopper, or later
  - Classic mode only (i.e. DPM not supported)

- ISM devices
  - *Virtual* PCI network adapter of new VCHID type ISM
    - No PCI bus usage
    - No extra hardware required
  - Provides access to memory shared between LPARs
  - 32 ISM VCHIDs per CPC, 255 VFs per VCHID (8K VFs per CPC total) I.e. the maximum no. of virtual servers that can communicate over the same ISM VCHID is 255
  - Each ISM VCHID represents a unique (isolated) internal network, each having a unique Physical Network ID

- PNET ID configuration
  - IOCDS only
  - Use HiperSockets devices, OSA, or RoCE cards for regular connectivity
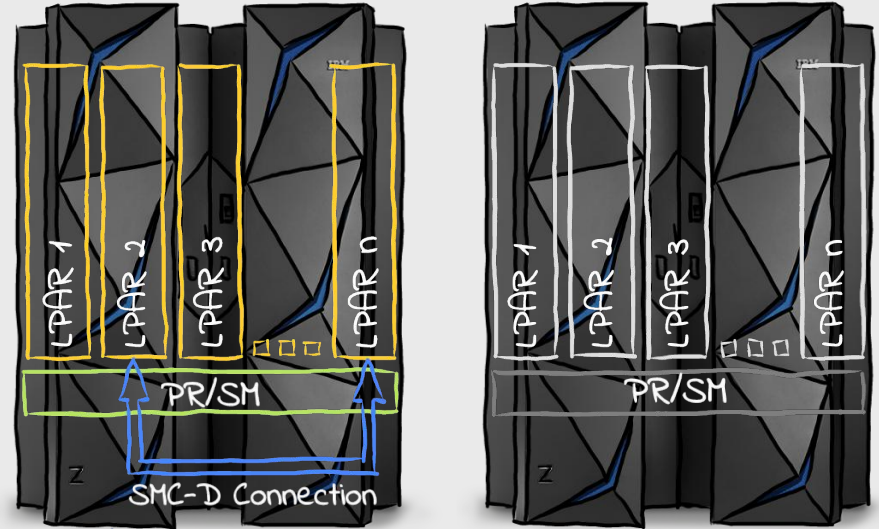
SMC-R vs. SMC-D Comparison

Feature	SMC-R	SMC-D
Intra-CEC	yes	yes
Cross-CEC	yes	no
RDMA Device	RoCE	ISM
Interface Type	PCI	PCI
Bus used	PCI	-
PNET ID Definition	IOCDS, or smc_pnet	IOCDS
Failover	tbd	n/a
Upstream Status	Initial code upstream in Linux kernel 4.18	Initial code upstream in Linux kernel 4.19
Linux Distributions	SLES 12 SP4 / Ubuntu 18.10 / RHEL 8	

Pervasive Encryption

Technical Foundation

- IBM z14 and LinuxONE – Designed for Pervasive Encryption

    - CPACF – Dramatic advance in bulk *symmetric* encryption performance

    - Crypto Express6S – Doubling of *asymmetric* encryption performance for TLS handshakes

- Linux on IBM Z – Ecosystem combined with IBM z14 and LinuxONE capabilities

    - Network security – Enterprise scale encryption and handshakes using z14 CPACF and SIMD

    - `dm-crypt` – Transparent volume encryption using *industry unique CPACF protected-keys*

    - Secure Service Container – Automatic protection of data and code for virtual appliances

- z/VM – New: Encrypted paging support

    - z/VM 6.4 APAR VM65993

CPACF Performance

- CPACF performance depends on the size of buffers being en-/decrypted

- The larger the buffer the better the performance

    - Best performance with ≥ 4kB buffers

- `dm-crypt` always used 512 byte buffers

- Starting with Linux kernel 4.12 and cryptsetup 2.0:

    - `dm-crypt` can use 4kB buffers

Relative AES GCM/XTS
in memory performance

	512B	4kB
z13	1	1.5
z14	4	13

Data in Flight

- openSSL and libcrypto
    - De-facto standard TLS and crypto libraries used by many projects, no IBM Z specific configuration required
    - Exploitation of IBM Z CPACF and SIMD code by libcrypto (w/o ibmca engine)
    - Focus on TLS 1.2 and 1.3 ciphers
    - Support for z14 AES-GCM accepted for openSSL version 1.1.1-alpha2
- IPsec
    - De-facto standard TLS and crypto libraries used by many projects
    - Transparently uses CPACF through the in-kernel crypto API
    - Kernel 4.15 and later use new CPACF instruction for AES-GCM
- GSKit
    - IBM C library for TLS and crypto, e.g., used by IBM HTTP Server (IHS) and many IBM Software products
    - Uses IBM Z CPACF
    - Release 8.0.50.82 and later use the new z14 CPACF instructions
- Java 8 / JCE
    - De-facto standard TLS and crypto libraries used by many projects
    - Java 8 service refresh 5 and later use z14 CPACF instructions

Data at Rest

- dm-crypt: block device / full volume encryption
    - Uses in-kernel crypto API
    - Granularity: disk partition / logical volume
    - New protected key option
- ext4fs with encryption option: file system encryption
    - Uses in-kernel crypto API
    - Granularity: file, directory, symbolic link
- NFS v4 with encryption option: encryption of file transport
    - Uses in-kernel crypto API
- SMB v3.1: encryption of file transport
    - Uses in-kernel crypto API
- Spectrum Scale (GPFS) with encryption option: file encryption
    - Uses GSKIT or CLiC in user space
    - Granularity: file
- DB2 native encryption: data base encryption
    - Uses GSKIT in user space

Kernel crypto automatically uses CPACF for AES if the module `aes_s390` is loaded

GSKit and latest versions of CLiC use CPACF for AES

Linux File System Stack with dm-crypt
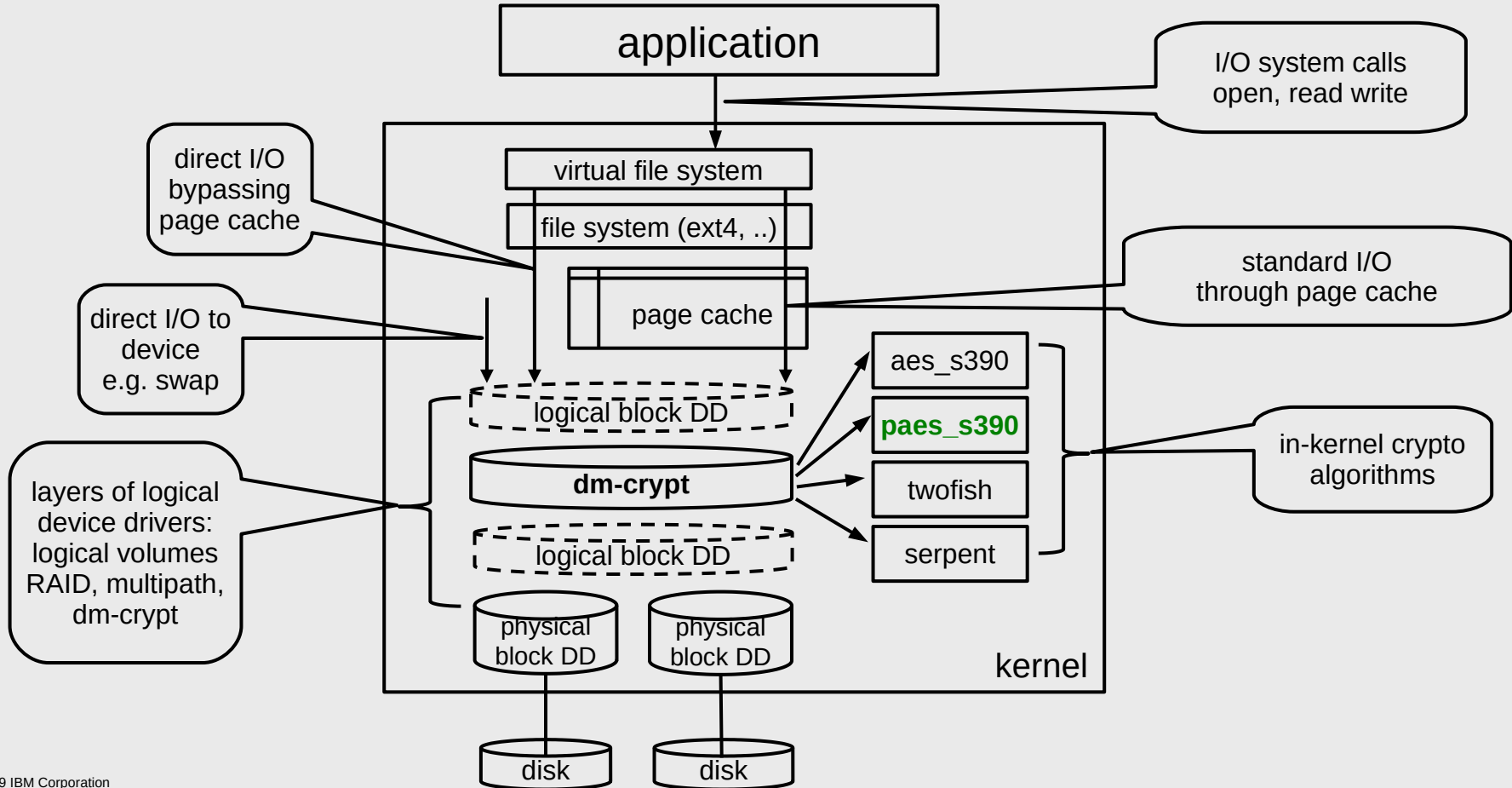
Protected keys with CPACF

1. Generate secure symmetric key

2. Convert to protected symmetric key

3. Using protected symmetric key to encrypt/decrypt

Linux / LPAR / CEX

data / data

CPACF

symmetric key

CEX master key (KEK)

LPAR temporary key (KEK)

sym. key wrapped with CEX master key

sym. key wrapped with LPAR key
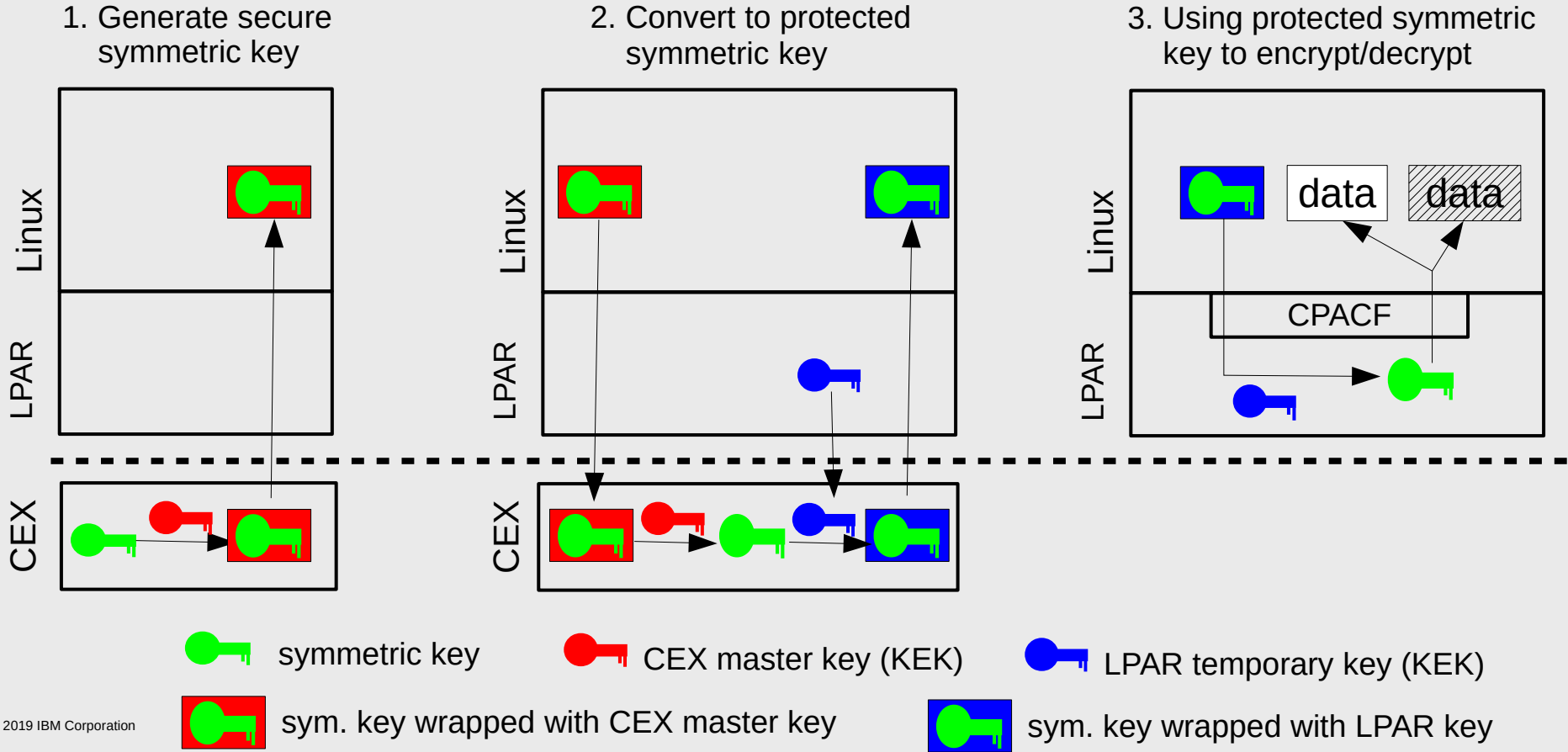
`pkey` kernel module (kernel 4.11)

- Activate with: `# modprobe pkey`

- Provides IOCTLs via `/dev/pkey`

  + `PKEY_GENSEC`

    - Generate a random CCA secure key

  + `PKEY_CLR2SEC`

    - Generate a CCA secure key from a clear key

  + `PKEY_SEC2PROT`

    • Generate a protected key from a CCA secure key

  + `PKEY_FINDCARD`

    • Find an adapter and domain associated with a given secure key

  + `PKEY_SECK2PROTK`

    • First `PKEY_FINDCARD`, then `PKEY_SEC2PROT`

zkey user space tool (s390-tools 1.39)

- Requires `pkey` kernel module

- *Generate* option

  + Generates file with AES secure key (AESDATA)

  + Random key or from clear key

  + Single key for CBC (64 bytes) or two keys for XTS (128 bytes)

- *Validate* option

  + Checks if input file contains a valid AES secure key

  + If yes, displays key attributes

- *Re-encipher* option, requires the CCA package

  + Support master key change on Crypto Express adapter

  + Transforms a valid secure key wrapped by an old master key into a secure key wrapper with a new master key

Function Overview

Function	Component and Upstream versions	Distribution releases
PAES support for dm-crypt: plain format	kernel 4.11: pkey, paes_s390 s390tools 1.39: zkey	RHEL 7.5, RHEL 8 SLES 12 SP4, SLES15 Ubuntu 18.04
Master key rolling support for PAES keys for dm-crypt with plain format	kernel 4.11: pkey, paes_s390 s390tools 1.39: zkey	RHEL 7.5, RHEL 8 SLES 12 SP4, SLES15 Ubuntu 18.04
fast dm-crypt using 4kB sectors	kernel 4.12 cryptsetup 2.0.0	RHEL 7.6, RHEL 8 SLES 15 Ubuntu 18.04
4kB sector support for plain volumes in /etc/crypttab	systemd patches	RHEL 8 Ubuntu 18.10
PAES key repository for dm-crypt with plain format	s390tools 2.4: zkey	RHEL 7.6, RHEL 8 SLES 12 SP4 Ubuntu 18.10
PAES support for dm-crypt: LUKS2 format	kernel 4.11: pkey, paes_s390 cryptsetup 2.0.3	RHEL 7.6, RHEL 8 Ubuntu 18.10
PAES key repository for dm-crypt with LUKS2 format	s390tools 2.6: zkey	RHEL 8 Ubuntu 18.10
Master key rolling support for PAES keys for dm-crypt with LUKS2 format	s390tools 2.6: zkey-cryptsetup	RHEL 8 Ubuntu 18.10

# Kernel News

Linux Kernel – Base IBM Z support

- Add LIC identifier to sysinfo (kernel 4.16)

  LPAR z/VM

  - Display licensed internal code identifier to the output of `/proc/sysinfo`
  - Can be a valuable debugging aid

- IBM z14 Model ZR1 base support (kernel 4.17)

  LPAR z/VM

  - Translate machine type 0x3907 to the ELF platform name "z14"

- I/O device pre-configuration (kernel 4.17)

  LPAR

  - An LPAR managed via DPM mode can retrieve a list of I/O devices via SCLP Store Data
  - FCP devices, OSA-Express, and HiperSockets devices can be enabled automatically
  - This helps with the device selection at installation time

Linux Kernel – Base IBM Z support

- Add `kexec_file_load` system call (kernel 4.17) (18.10) LPAR z/VM KVM

    - The existing kexec interface uses a binary image to boot into a new kernel

    - The `kexec_file_load` interface uses a kernel image in ELF format

    - The ELF format allows you to add additional information, e.g., a signature to verify the integrity of the kernel
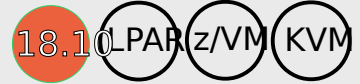
- Rework initial boot sequence (kernel 4.19) LPAR z/VM KVM

    - Move the memory detection to the initial boot phase, some features need the exact memory layout very early

        - Kernel Address Sanitizer (KASAN)

        - Kernel Address Layout Randomization (KASLR)

- Add support for restartable sequences (kernel 4.19) LPAR z/VM KVM

    - Restartable sequences are a lightweight interface to run user code atomically relative to scheduler preemption and signal delivery

    - Typically used to implement fast per-cpu operations in user space

Linux Kernel – Base IBM Z support

- Kernel Address Sanitizer (kernel 4.20)   LPAR z/VM KVM

  - Compile time option for a debug kernel to detect dynamic memory errors

    - Relies on the gcc option `-fsanitize=kernel-address`

- Virtually mapped kernel stacks (kernel 4.20)   LPAR z/VM KVM

  - Allocate the kernel stack for tasks from the vmalloc space

  - Use a guard page to trap kernel stack overflows instead of instructions

  - Slightly faster kernel code and a ~200K size reduction of the kernel

CONFIG_VMAP_STACK=y		CONFIG_VMAP_STACK=n, CONFIG_CHECK_STACK=y	

```
0000000000000000 <fn_a>:                          vs      0000000000000000 <fn_a>:
 000:   c0 04 00 00 00 00    brcl   0,0 <fn_a>              000:   c0 04 00 00 00 00    brcl   0,0 <fn_a>
 006:   eb bf f0 70 00 24    stmg   %r11,%r15,112(%r15)     006:   eb bf f0 70 00 24    stmg   %r11,%r15,112(%r15)
 00c:   b9 04 00 ef          lgr    %r14,%r15               00c:   a7 f1 3f c0          tmll   %r15,16320
 010:   e3 f0 ff d0 ff 71    lay    %r15,-48(%r15)          010:   b9 04 00 ef          lgr    %r14,%r15
 016:   e3 e0 f0 98 00 24    stg    %r14,152(%r15)          014:   a7 84 00 01          je     946 <fn_a+0x16>
 ...                                                        018:   e3 f0 ff d0 ff 71    lay    %r15,-48(%r15)
                                                            01e:   e3 e0 f0 98 00 24    stg    %r14,152(%r15)
                                                            ...
```

Linux Kernel – Crypto Support

- Add support for up to 256 crypto adapters (kernel 4.17)

- AP bus support for alternate drivers (kernel 4.19)
  - Will be needed for the virtualization of crypto cards

- zcrypt multiple device nodes support (kernel 4.20)
  - Add new zcrypt device nodes with restrictions in regard to crypto cards, domains, and available ioctls
  - The restricted zcrypt access is needed for container solutions like docker

- Protected key API for random keys (kernel 4.20)
  - Introduce new ioctls and sysfs attributes to generate random protected and random secure keys
  - Useful to create encrypted paging devices with protected keys
  - The patch to the sysfs attribute can be added to `/etc/crypttab` directly

Linux Kernel – Block Device Support

- Configurable IFCC handling for DASD (kernel 4.17)   15 LPAR z/VM

  - Add a control how repeated IFCC/CCC errors are handled

  - The `path_autodisable` sysfs attribute can be set per DASD device

- Add zFCP port speed capabilities (kernel 4.18)   LPAR z/VM

  - Decode and display the channel link speed of the FCP Express 32S card

  - The `lszfcp -a` command can be used to show the port speed

- Support DIF (data integrity support) independently of DIX for ZFCP (kernel 5.0)   LPAR z/VM

  - Configure DIF-only mode with kernel parameters: `zfcp.dif=1 zfcp.dix=0`

Linux Kernel – Network Device Support

- Add diag26c support for VNIC info (kernel 4.16) z/VM 〔15〕〔12.4〕〔z/VM〕
  – When running on z/VM use the diagnose X'26C' to find network device related information
  – This is used to find out if the network connection uses layer-2 order layer-3

- Add qeth IPv6 RX/TX checksum offload support (kernel 4.18) 〔LPAR〕〔z/VM〕
  – Enable RX/TX checksum offload for inbound and outbound IPv6 network traffic
  – IPv6 checksum offload is available with OSA Express 4S cards

- Report 25Gbit link speed for qeth devices (kernel 4.20) 〔LPAR〕〔z/VM〕
  – Add the link speed of the OSA Express 7 cards to sysfs and ethtool

- Improve qeth TSO support (kernel 4.20) 〔LPAR〕〔z/VM〕
  – Add TCP segmentation offload for IPv6 and L3 devices, as well as, TSO for L2 devices

Linux Kernel – Performance Analysis

- Provide detailed CPU information for perf record (kernel 4.17)

  - The CPU field with `perf report` has been a fixed string "IBM/S390"

  - Add CPU manufacturer, type, model-capacity, model, version, and CPU-MF authorization to the output

- Provide detailed PMU event descriptions (kernel 4.17)

  - Add JSON files for IBM z10EC, z10BC, z196, zEC12, zBC12, z13, z13s, and z14

  - The description can be retrieved with `perf list`

- Rewrite trace points of the common I/O layer for perf (kernel 4.19)

  - Make the trace point data of the common I/O layer consumable by `perf stat`

- Add the CPU-MF transaction counters to perf (kernel 4.19)

  - Display the number of transactions ends/aborts with `perf stat -T`

LPAR

LPAR

LPAR

LPAR

Linux Kernel – Performance Analysis

- Export CPU-MF sampling data as perf auxiliary trace data (kernel 4.19)   (LPAR)

  - Collect sampling data with `perf record -e rbd000`

  - Display sampling data as raw report `perf report -D` or GUI report `perf report`

- Add auxiliary trace data files to perf (kernel 4.20)   (LPAR)

  - Used with CPU-MF sampling to write individual files for each CPU

  - The `perf config` command is used to specify a target directory with `auxtrace.dumpdir`

  - For each CPU a `aux.smp.##` file will be generated

Further Reading

Documentation

- Video about Pervasive Encryption of Data Volumes - https://youtu.be/jDK3ZwEdX4I

- How-to about Pervasive Encryption of Data Volumes -
  http://public.dhe.ibm.com/software/dw/linux390/docu/l5n1dc00_a_quick_start.pdf

- Linux on Z on DeveloperWorks - https://www.ibm.com/developerworks/linux/linux390/documentation_dev.html

Blogs

- Linux on Z - http://linux-on-z.blogspot.com/

- Containers on IBM Z - https://containersonibmz.com/
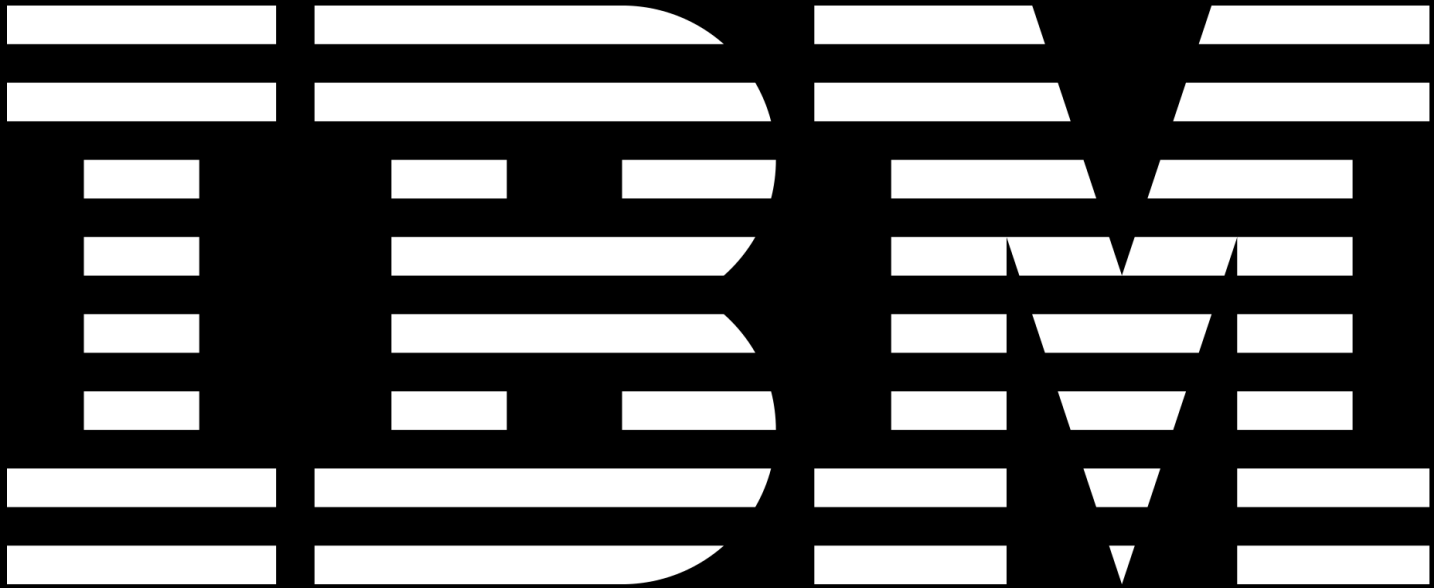
Tag Legend

- Supported distributions

  (x.y) for SUSE SLES <X> Service Pack <Y>, e.g. (12.3) for SLES12 SP3

  (x.y) for RHEL <x> Update <y>, e.g. (7.4) for RHEL7.4

  (x.y) for Ubuntu x.y, e.g. (16.04) for Ubuntu 16.04 LTS

- Suppored environments

  (LPAR) usable for systems running in LPAR mode

  (z/VM) usable for guests running on z/VM