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Running Linux on IBM Z: Hybrid Workloads and Cloud-Native Application Support

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Abstract

Linux on IBM Z, also known as zLinux, is a paradigm of innovation in enterprise computing. It exploits the unique architecture of IBM Z mainframes to provide a robust, secure, and highly efficient operating system for modern workloads.

This paper analyzes the architectural details of zLinux, its operational benefits, and practical applications and compares those against other popular Linux distributions and virtualization technologies. It delves into its seamless integration with z/OS, elaborating on configuration methodologies and real-world use cases, including support for cloud- native applications on zLinux. The findings bring forth zLinux as a game-changer in hybrid IT infrastructures, underlining its strategic position in meeting evolving enterprise demands through scalability, security, and innovation.

Keywords: IBM Mainframe; z/OS; zLinux; IBM Z; Linux on Z; LinuxONE; Hypervisor; Virtualization; Mainframe Modernization; Containerized Workloads; Hybrid Application Development; Cloud-native workloads on z/OS; Docker on z/OS

Introduction

IBM Z mainframes have formed a central part of enterprise IT for many years due to their unrivaled reliability, security, and scalability. Linux on IBM Z further extends these strengths to the modern workloads that help bridge the gap between legacy systems and modern computing constructs such as containerization, cloud-native applications, and advanced analytics. The paper represents an in-depth investigation of the architecture of zLinux, its integration with z/OS, and its operational benefits in solving hybrid IT environments.

This paper explains the value proposition of zLinux in enterprise modernization and inno vation through comparisons with other technologies and the presentation of implementation examples.

History of Linux on IBM Z

Since its early days, Linux on IBM Z, otherwise known as Linux on zSystems, has undergone significant changes alongside developments of IBM's virtualization technologies. The following is a timeline showing key milestones in both:

1960s-1970s: Early Virtualization Efforts

- 1966: IBM introduced virtual memory with the CP-40/CMS, an early ancestor of modern virtualization on mainframes. [1]
- 1972: IBM officially released VM/370, the first version of its virtual machine operating system for the System/370, marking a major milestone in mainframe virtualization. [1]

1980s: Processor Resources/Systems Manager (PR/SM) and Logical Partitioning

- PR/SM, introduced in 1988: It was with the System/3090 that IBM introduced PR/SM, which laid the core for logical partitioning and, thereby, for virtualized environments. LPAR technology allowed the virtualization of the physical mainframe into multiple virtual machines, each running its operating system. [3]

1990s: Inception of Linux and First Ports

- 1998-1999: The "Bigfoot" project, driven by Linas Vepstas, first started working on porting Linux onto IBM's System/390 servers. This project was an independent distribution that would form the foundation of later work. [2]
- December 1999: IBM released a series of patches and additions to the Linux 2.2.13 kernel, which formed the first mainline Linux support for IBM Z. [4]

2000s: Formal Adoption and Expansion

- 2000: Formal product announcements from IBM supporting Linux on the mainframes, including announcing IFL or Integrated Facility for Linux Engines, special purpose processors dedicated to Linux processing. [2]
- 2000: IBM introduced the z/VM, a successor to VM/ESA, designed to support huge numbers of Linux virtual machines on IBM Z systems. [5]
- 2001: Linux guest support went live with z/VM, allowing it to host Linux workloads efficiently. [6]

2010s: Enhanced Virtualization and LinuxONE

- 2015: IBM introduced the LinuxONE family of servers to run Linux workloads on the mainframe. IBM announced LinuxONE Emperor, which comes on a z13 processor-based machine, and LinuxONE Rockhopper, which runs on the z12 processor-based platform. [8]
- 2016: IBM announced KVM, an open-source hypervisor on IBM Z Systems, providing an alternative option for virtualization solution on IBM Z hardware that leverages the Linux Kernel's KVM module. [7]

2020s: Continued Innovation

- 2022: IBM celebrated the 50th anniversary of its VM family, highlighting decades of virtualization innovation foundational to hosting Linux on IBM Z systems. [9]

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The picture below illustrates the different innovations in Linux on Z over the years.

Figure 1: Illustrating last 20 years of IBM's innovation for Linux on Z. [10]

Virtualization & Hypervisors

As we have seen from the history of Linux innovation on IBM Z, virtualization is at the core of it and the basis for LPAR technology. Hypervisor is the key component that made virtualization possible. Below are different types of hypervisors. [11] [14] [15]

- **Type 1 hypervisor:** Bear metal or firmware-based that runs right on physical hardware interacting directly with CPU, memory, and physical storage. IBM Z and IBM LinuxONE use Processor Resource/System Manager (PR/SM) as a type-1 hypervisor to define and manage resources for LPARs.
- **Type 2 hypervisor:** Software-based hypervisor that runs as an application in an OS, often called an embedded or hosted hypervisor. IBM z/VM and KVM are good examples of type-2 hypervisors as they run on top of LPAR, which type-1 hypervisor PR/SM manages.

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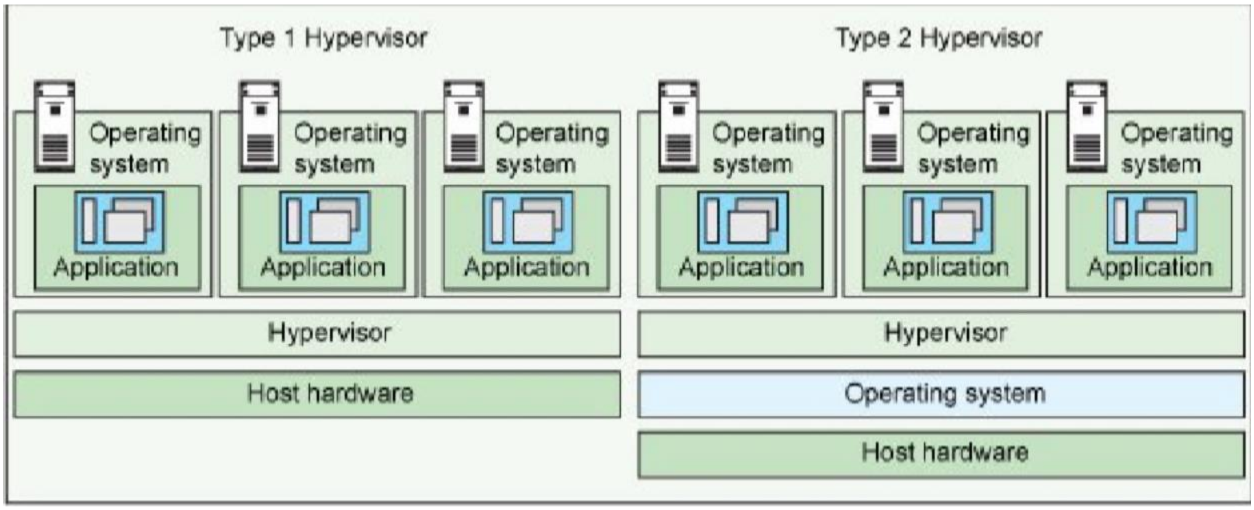

Figure 2: Illustrating different types of Hypervisors. [15]

IBM Z and IBM LinuxONE offer multiple levels of virtualization, allowing support for different configurations needed to support various workloads. The picture below illustrates different levels of virtualization that are possible using IBM Z/LinuxONE infrastructure. [11]

- **Level 1:** Illustrates the usage of PR/SM and LPAR as a virtualization layer.
- **Level 2:** Illustrates the usage of z/VM or KVM for type-2 hypervisor-based virtualization on top of an LPAR managed by PR/SM.
- **Level 3:** Shows two layers of z/VM, increasing the level of virtualization.
- **Level 4:** Shows the Linux containers running on the Docker engine on top of z/VM or KVM.

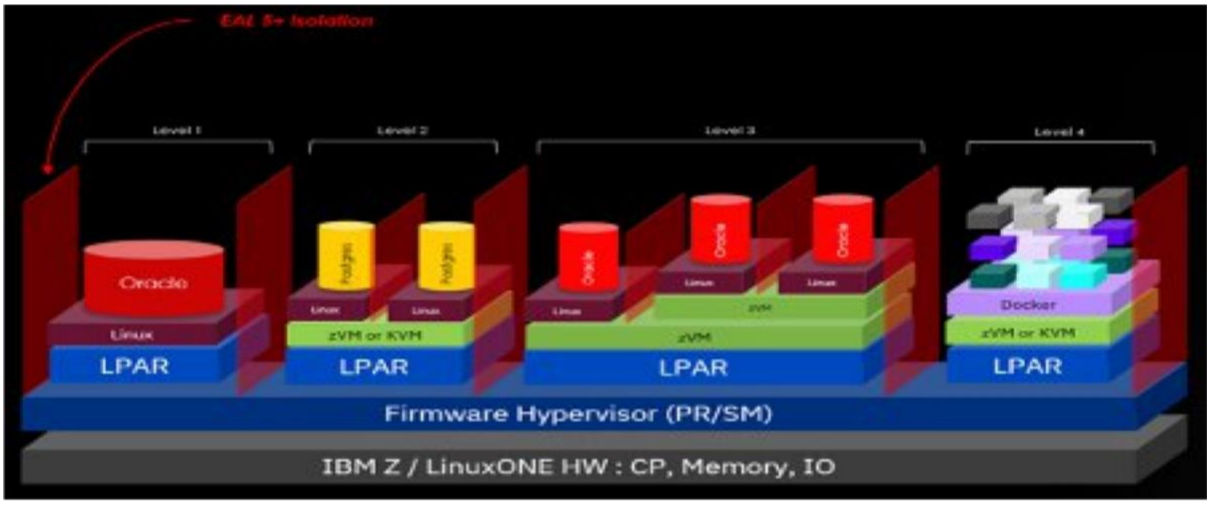

Figure 3: Illustrating sample implementation using different levels of virtualization. [11]

The Workloads on PR/SM LPARs on an IBM Z or IBM LinuxONE system enjoy a high level of isolation, Evaluation Assurance Level 5+ (EAL 5+) isolation. That means the workloads running on IBM Z on separate LPARs enjoy the same isolation level as those running on separate physical servers. This architecture and highly efficient isolation level ensures a very secure environment for workload in every LPAR. [11]

Overview of zLinux

Linux on IBM Z brings the best of both worlds: the open-source flexibility of Linux and the hardware capability of IBM Z mainframes. Supporting distributions such as Red Hat Enterprise Linux, SUSE Linux Enterprise Server, and Ubuntu, IBM has built zLinux for diverse workloads ranging from traditional transactional processing to modern AI and analytics. [12]

Below are some of the unique advantages Linux on IBM Z offers:

- **Sustainable IT:** Consolidate workloads with up to 2000 x86 cores in one system, reducing energy and costs.
- **Architecture:** zLinux embraces IBM Z's horizontal scalability, advanced cryptography, and peerless virtualization for efficiency. The architecture ensures high performance while maintaining the integrity of compatibility with legacy and modern applications.
- **Security:** From pervasive encryption to secure service containers, hardware- enforced isolation, the most stringent set of compliance requirements are satisfied by the security framework. IBM Z hardware can encrypt up to 19 billion transactions daily, ensuring privacy and compliance.
- **Enhanced performance:** Using IBM Z reduces latency by 4.7x and boosts throughput with optimized workload colocation.
- **Unmatched scalability:** IBM Z architecture can scale thousands of VMs or containers on a single, high-efficiency system.
- **Reliable and cost-effective:** Achieve 99.999% uptime while lowering operational costs through consolidation.

Linux on IBM Z vs. x86

Any modern enterprise-grade computing, such as microservice implementation, containerization, or cloud workloads, can be supported on both Linux on IBM Z and x86 with similar implementation approaches. What differs in running these workloads on IBM Z is the performance, scalability, and cost optimizations that IBM Z offers for Linux- based workloads, especially for large-scale and critical environments. [13]

While comparing both implementation options, the Total Cost of Ownership
(TCO) would be critical in showing each option's overall cost and savings. One of the key values that Linux on IBM Z can offer is its significant savings on total cost of ownership down to software licenses, down to CO2 carbon footprint reduction, and enhanced availability, security, and reliability features. IBM conducted a study to compare TCO between Linux on Z and x86 implementations for processing the

same workload over 5 years. Based on this study, here are the savings Linux on IBM Z yields compared to the x86 implementation for the same workload. [13]

- 58% lower energy consumption.
- 33% less floor space.
- 76% lower software costs.

The below picture illustrates the overall cost comparison between x86 and Linux on IBM Z.

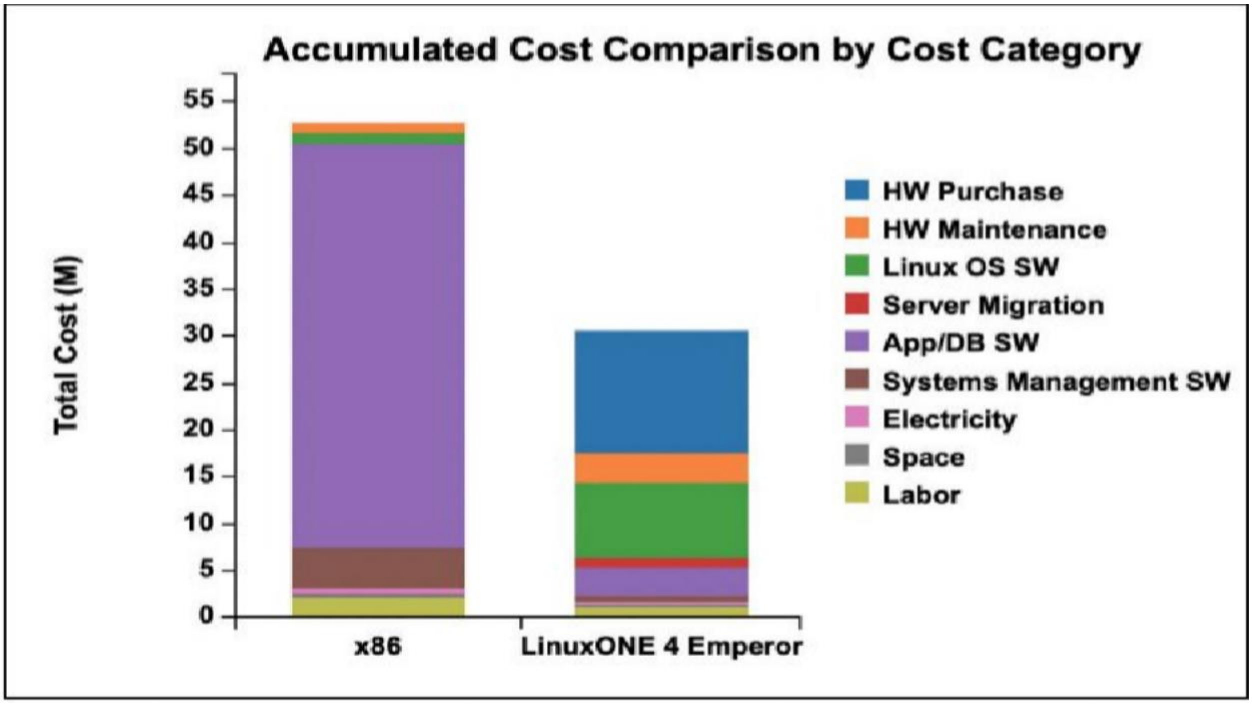

Figure 4: Illustration of cost comparison between x86 and LinuxONE implementation. [13]

Different options to run Linux OS and Linux-based apps on IBM Z

Below are different options available to run Linux OS or the Linux workloads on IBM Z hardware.

1. **zLinux (Linux on IBM Z)**: IBM allows Linux distributions that are compiled for s390x architecture like RHEL (Red Hat Enterprise Linux), SLES (SUSE Linux Enterprise Server), and Ubuntu Server to run directly on LPAR that Processor Resource/Systems Manager (PR/SM) manages. This option supports only the three Linux distributions supported by IBM. The workload benefits from using Integrated Facility for Linux (IFL) processors in this option. [12]

2. **IBM LinuxONE:** LinuxONE is a highly optimized and special offering from IBM for enterprise-grade Linux workloads that provides high security, scalability, and performance, similar to the traditional IBM Z offers for mainframe workloads. IBM LinuxONE can use z/VM or KVM hypervisors on top of PR/SM to support multiple VMs in a single LPAR. LinuxONE is also ideal for running containerized cloud- native workloads using platforms like Kubernetes and OpenShift. The workloads running on IBM LinuxONE benefit from using IFL processors. [12]

3. **z/VM (Virtual Machine):** z/VM is a type 2 hypervisor for IBM Z that allows multiple Linux instances (virtual machines) to run simultaneously on an LPAR that PR/SM manages. The preference is to use IBM-supported Linux distributions like REHL, SLES, and Ubuntu, but z/VM can also support other Linux distributions compiled for s390x architecture. z/VM enables the server consolidation to run the Linux instances along with the existing mainframe workload on the same IBM Z hardware. [12]

4. **KVM (Kernel-based Virtual Machine):** Like z/VM, KVM is a type 2 hypervisor that allows multiple Linux instances on a single LPAR. Unlike z/VM, KVM is an open-source virtualization technology further optimized by IBM. KVM and QEMU (Quick Emulator) can support non-s390x architectures like Linux distributions compiled for x86. [12]

Below are a few considerations for the options discussed above.

- It is preferred to use the 3 Linux distributions RHEL, SLES, and Ubuntu, as IBM collaborates closely with those organizations to optimize the KVM that is part of their Linux distribution Kernal to ensure the virtualization fully leverages the advanced features of IBM Z architecture like crypto processing, memory virtualization efficiency, I/O optimization, support for high- performance Linux guests. [12]

- All Linux workloads in the options mentioned above will use the specialty IFL engines, reducing the overall cost and not sharing the resources with existing IBM Z workloads. [12]

- Running Linux directly on an LPAR is common in workloads where dedicated resources are required or very high performance needs to be delivered, like in the case of a very large database or intensive processing jobs. It minimizes performance degradation due to overhead from other virtualization layers.

In most environments, where resource efficiency and workload consolidation are concerns, using either z/VM or KVM to host multiple VMs on a single LPAR is generally preferable. Using z/VM or KVM is one way of leveraging the strengths of IBM Z and LinuxONE in virtualization and resource sharing, thus making them ideal for running several workloads concurrently. [12]

Below are additional options for running Linux workloads under z/OS on IBM Z machines. While they are not the options to run Linux OS directly, these options provide valuable containerization options for Linux-based applications. These options don't use IFL engines; they rely on zIIP or CP engines as they are running under z/OS.

- **zCX (z/OS Container Extensions):** zCX allows Linux containers to run directly within z/OS, enabling the integration of Linux applications to run alongside the existing z/OS workloads. [16]

- **zCX for OpenShift:** zCX for OpenShift extends the zCX platform by enabling OpenShift container orchestration directly within z/OS environments. [16]

- **z/OS Container Platform (zOSCP):** zOSCP is a relatively new technology IBM brings to run containerized z/OS UNIX applications. zOSCP allows isolated large-scale cloud-native workloads in z/OS environments. [17]

The image below illustrates the options for running Linux OS and applications on IBM Z or LinuxONE infrastructure.

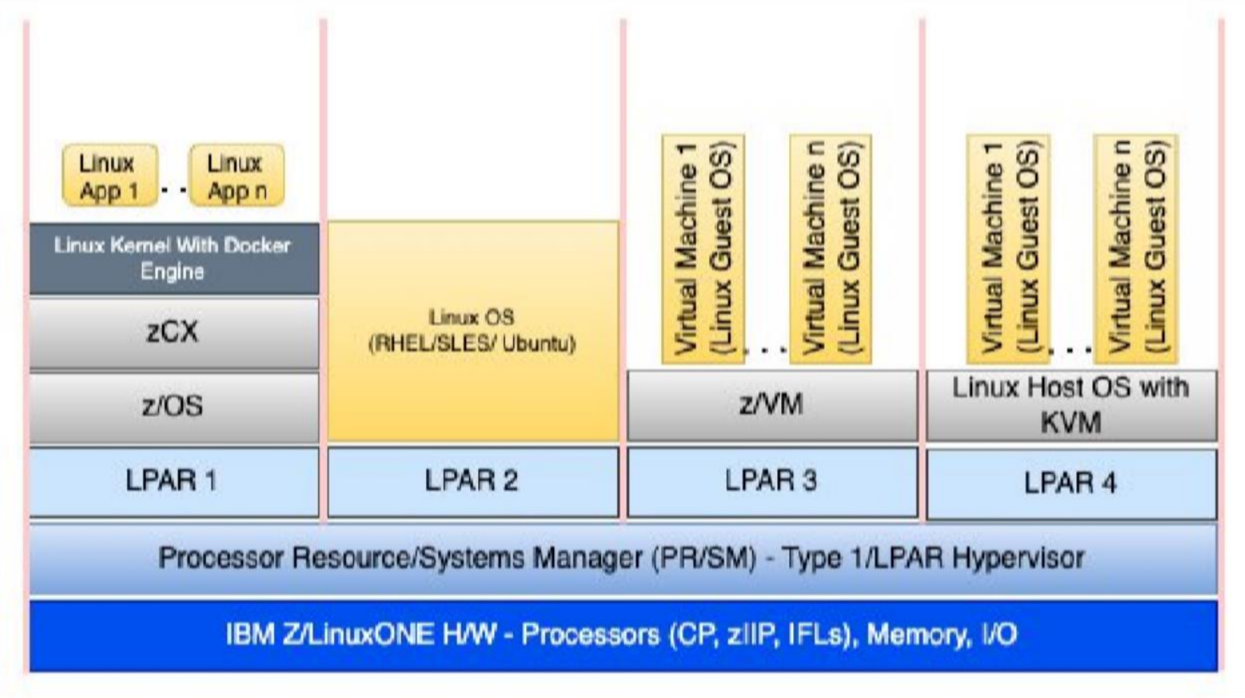

Figure 5: Illustration of different options to run Linux OS or Linux workloads on IBM Z or LinuxONE infrastructure. [18]

Use cases for hybrid and cloud-native workloads

Below are several use cases and considerations for running hybrid and cloud-native workloads using different options to run Linux OS or containerization options within z/OS. [18]

- **Collocating Applications with IBM Z Applications and Data**:
- **Use Case:** Deploying cloud-native applications near existing IBM Z applications and data for low latency and better performance.
- **Considerations:**
- For high-speed data transfers, IBM Z provides technology like HiperSockets and SMC-D (Shared Memory Communication - Direct).
- IBM also provides special AI accelerator engines for AI or machine learning-related workloads that can be added benefit in addition to low latency data access capability.
- **Example:** Real-time analytics running in Linux on LinuxONE while processing data streaming from a z/OS-based transaction system.
- The below picture illustrates the connectivity between Linux workloads and existing z/OS workloads

through high-speed HiperSockets and SMC- D technology across different LPARs.

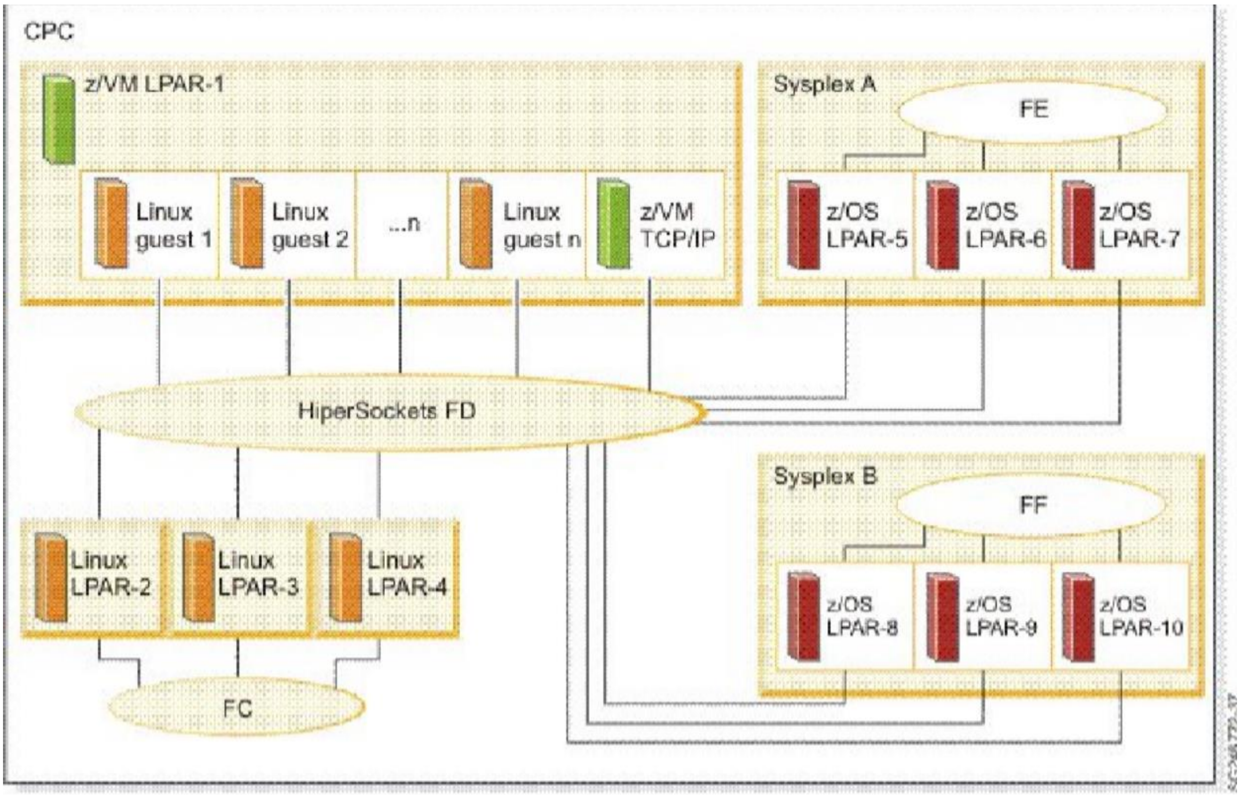

Figure 6: Illustration of HiperSockets usage across different LPARs. [19]

- **Extending Existing Functions with New Cloud-Native Components**:
- Use Case: Augmenting core z/OS applications with new functionalities developed as cloud-native services running on Linux.
- Example: Add a new customer-facing web application hosted on Linux on IBM Z, interfacing with existing mainframe applications via APIs.
- The picture below illustrates several options for deploying cloud-native applications alongside the existing z/OS-based functionality.

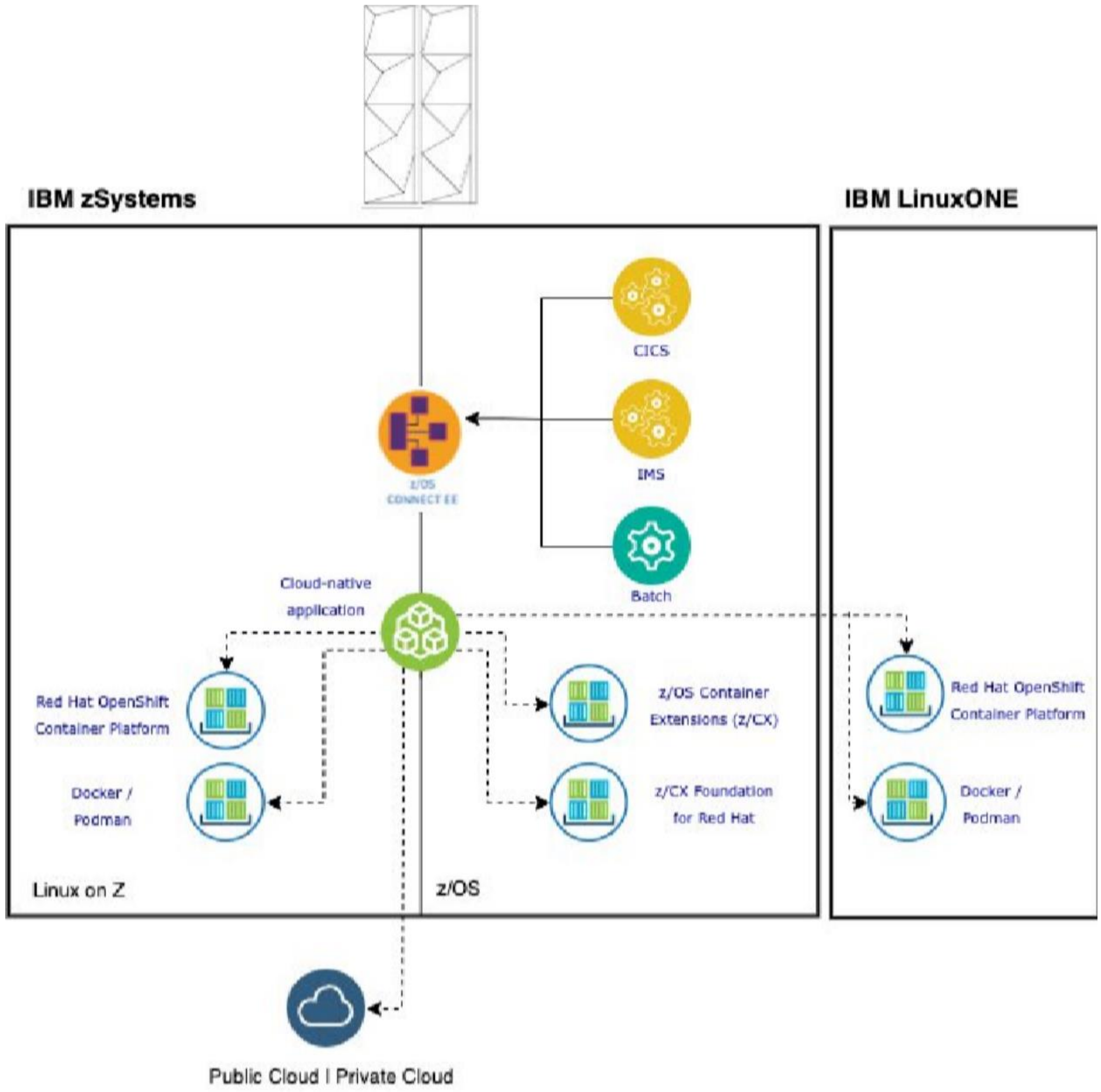

Figure 7: Illustration of different options to deploy a cloud-native application. [18]

- **Improving the Already Existing Functions by Incremental Modernization:**
- Use Case: The aim is to incrementally rewrite parts of a mainframe application in modern languages, deploying them on Linux as microservices to run the hybrid workloads.
- Example: Refactoring a certain module in the COBOL application to a Java-based microservice on Linux on IBM Z for better maintainability.
- **Virtualizing IBM Z Data for the Sake of New Access:**
- Use Case: Using data virtualization techniques, access to IBMZ. Data without data replication can combine IBM Z with other data.

- Example: A Linux-based business intelligence tool accesses mainframe data that has been virtualized, along with cloud-based data sources, for reporting.

These patterns demonstrate how integrating Linux environments with IBM Z systems can facilitate application modernization, enabling organizations to add functionality, improve performance, and move toward cloud-native architectures while continuing to leverage their existing mainframe assets.

Conclusion

Linux on IBM Z epitomizes the convergence of traditional mainframe computing, and contemporary IT demands. The integration of zLinux with z/OS has made it possible to renew IT infrastructures without losing the reliability and security of mainframe systems for enterprise businesses. There is no match for its scalability, performance, and cost-efficiency; thus, it is a cornerstone for hybrid IT models. With the changing landscape of IT, zLinux is positioned to transform how organizations can innovate and be competitive in a global environment.

References

1. IBM Corporation, "VM History and Heritage". IBM August 2022. Retrieved November 2024 from https://www.vm.ibm.com/history/
2. Wikipedia, "Linux on IBM Z". October 2024. Retrieved November 2024 from https://en.wikipedia.org/wiki/Linux_on_IBM_Z
3. Wikipedia, "Logical partition". October 2024. Retrieved November 2024 from https://en.wikipedia.org/wiki/Logical_partition
4. "Linux on the mainframe: Then and now" by Elizabeth K Joseph, September 2019. Retrieved November 2024 from https://opensource.com/article/19/9/linux- mainframes-part-2
5. Wikipedia, "z/VM". October 2024. Retrieved November 2024 from https://en.wikipedia.org/wiki/Z/VM
6. IBM Corporation, "VM History Timeline visualization". IBM August 2022. Retrieved November 2024 from https://www.vm.ibm.com/history/timeline.html
7. IBM Corporation, "Introducing KVM for IBM z Systems". IBM 2016. Retrieved November 2024 from https://www.vm.ibm.com/education/basics/introkvm.pdf
8. IBM Community, "IBM Z, IBM Power Systems, LinuxONE and other wonders". IBM March 2021. Retrieved November 2024 from https://community.ibm.com/community/user/ibmz-and-linuxone/blogs/eduardo- ortega1/2021/03/04/ibm-z-ibm-power-systems-linuxone-and-other-wonders?communityKey=53d759c6-31ad-4ebd-b518-0696ea821f14
9. IBM Corporation, "IBM VM 50th anniversary". IBM August 2022. Retrieved November 2024 from https://www.vm.ibm.com/history/50th/index.html
10. IBM Corporation, "20 Years of Linux on Z". IBM September 2020. Retrieved November 2024 from https://newsroom.ibm.com/20-Years-of-Linux-on-Z
11. IBM Corporation, "Why it is no overstatement to call IBM Z / IBM LinuxONE the Mother of all platforms in Virtualization?". IBM June 2021. Retrieved November 2024 from https://www.ibm.com/blogs/digital-transformation/in-en/blog/why-it-is-no- overstatement-to-call-ibm-z-ibm-linuxone-the-mother-of-all-platforms-in- virtualization/
12. IBM Corporation, "Linux on IBM Z mainframe". Retrieved November 2024 from

https://www.ibm.com/z/linux
13. IBM Corporation, "Linux on IBM Z mainframe". IBM Redbooks September 2024. Retrieved November 2024 from https://www.redbooks.ibm.com/redbooks/pdfs/sg248217.pdf
14. IBM Corporation, "What are hypervisors?". Retrieved November 2024 from https://www.ibm.com/think/topics/hypervisors
15. IBM Corporation, "Hypervisors and virtualization in a Cloud environment". IBM May 2024. Retrieved November 2024 from https://developer.ibm.com/articles/cl- hypervisorcompare/
16. IBM Corporation, "What is z/OS Container Extensions?". IBM April 2024. Retrieved November 2024 from https://www.ibm.com/docs/en/zos/3.1.0?topic=extensions- what-is-zos-container
17. IBM Corporation, "What is IBM z/OS Container Platform?". IBM July 2024. Retrieved November 2024 from https://www.ibm.com/docs/en/zoscp/1.1.0?topic=what-is-zos- container-platform
18. IBM Corporation, "Application modernization for IBM Z architecture". IBM May 2024. Retrieved November 2024 from https://www.ibm.com/community/z-and- cloud/application-modernization-patterns/
19. IBM Corporation, "HiperSockets". IBM 2010. Retrieved November 2024 from https://www.ibm.com/docs/en/zos-basic-skills?topic=mainframe-hipersockets