Shared Memory Communications for Linux on IBM Z

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KVM on IBM Z Development

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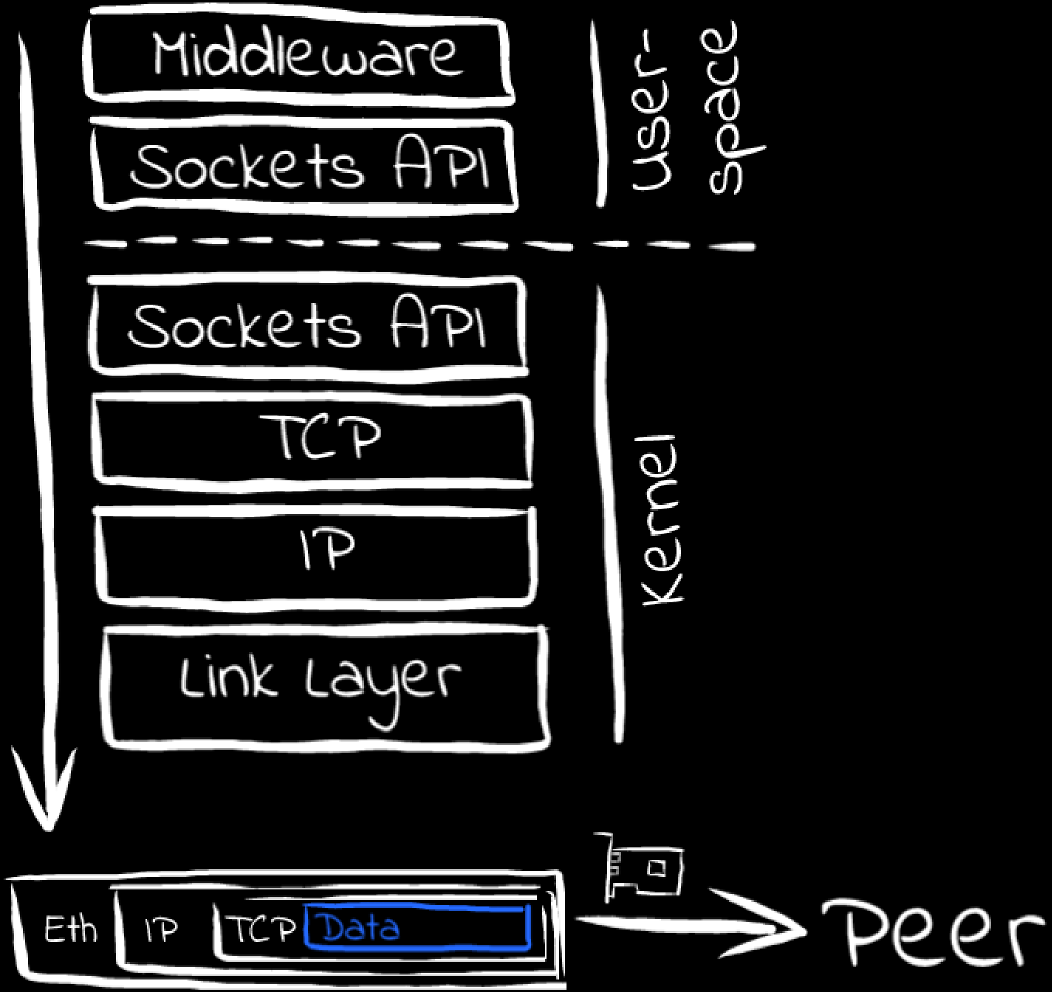
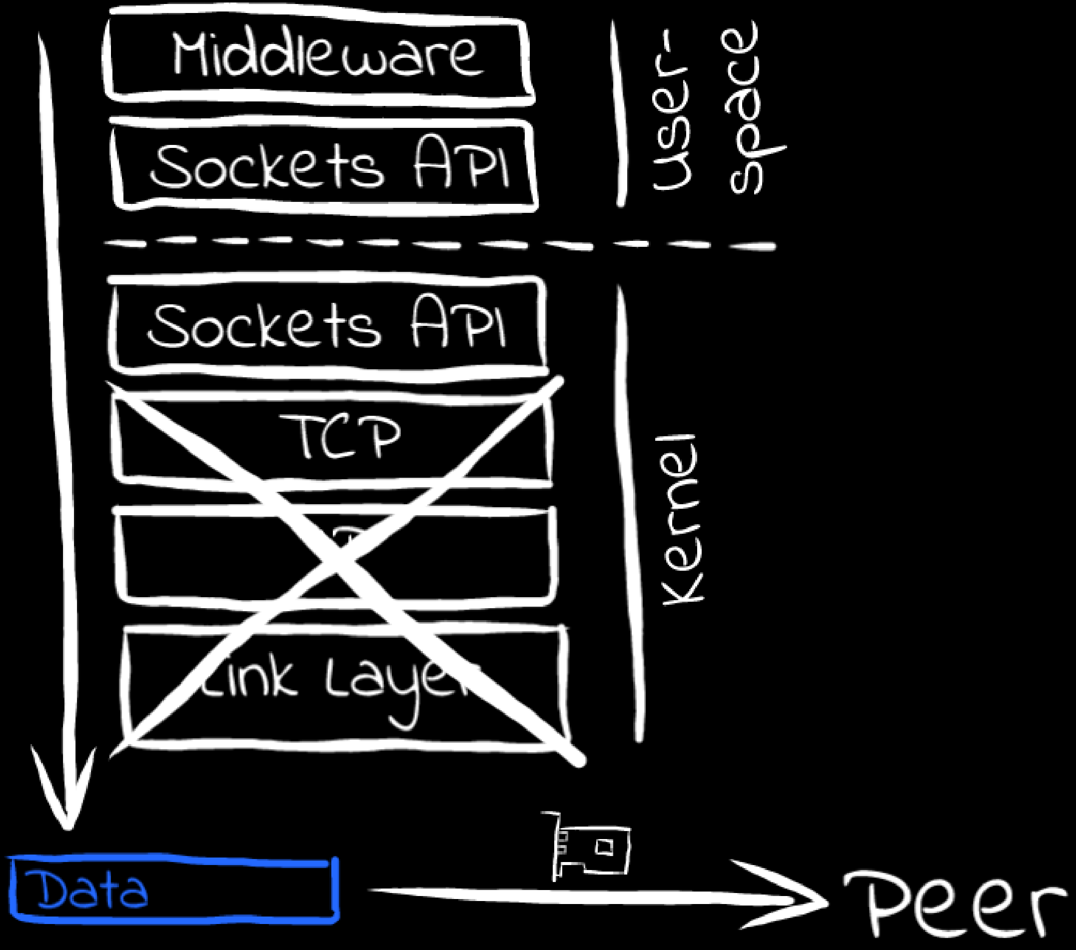
- SMC Basics
  - Motivation
  - The SMC Protocol
  - Benefits
- SMC for Linux on Z
  - SMC-D and SMC-R
  - smc-tools
- SMC in Action
  - Usage Examples
  - Deploying SMC
  - Tips & Tricks
- Miscellaneous

What sending data through BSD sockets looks like

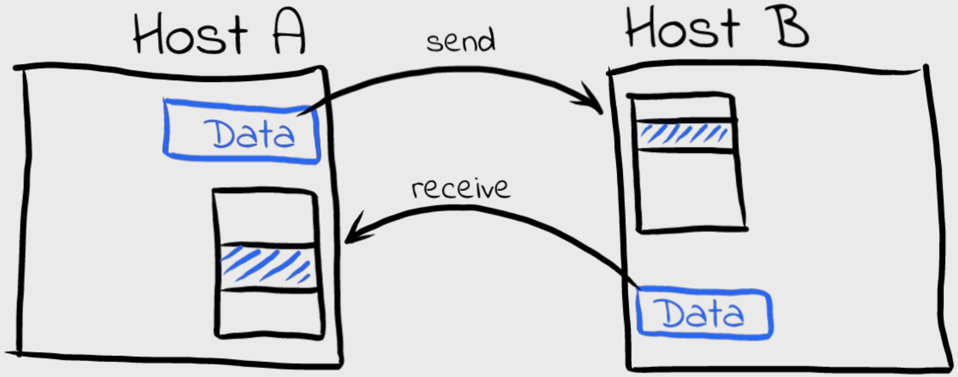


What if we had a simple buffer to write data to and let hardware do the rest...?



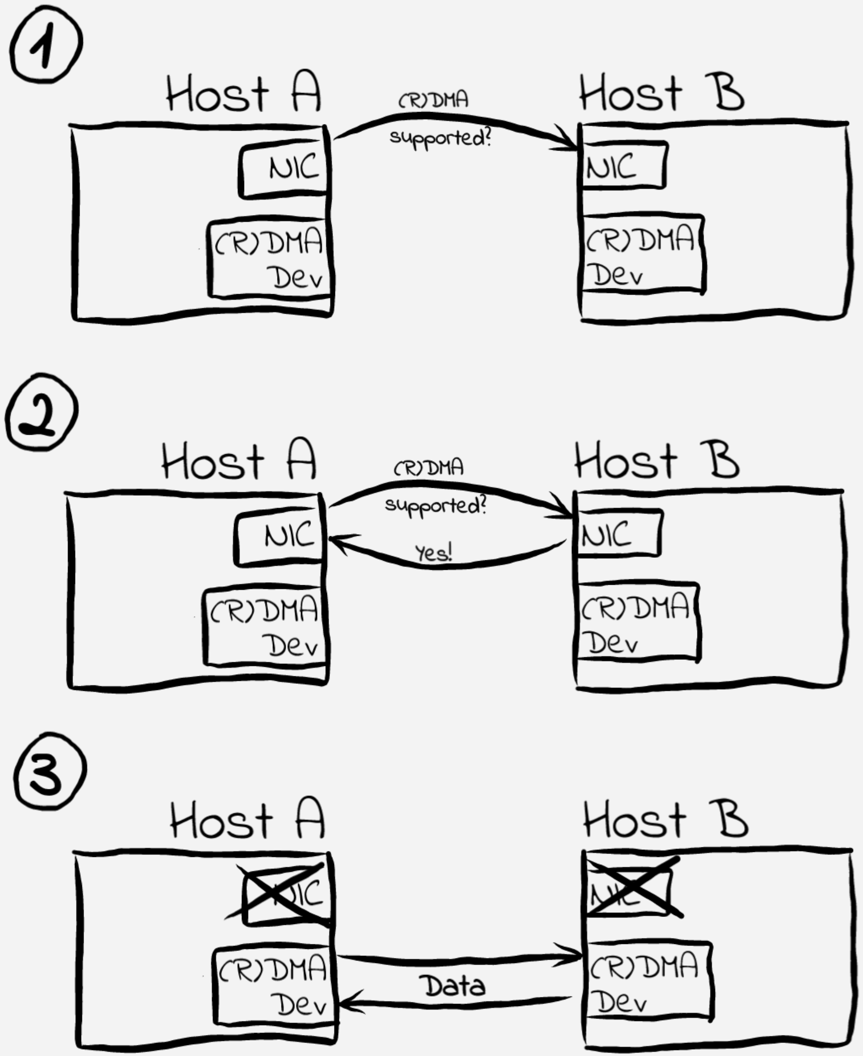
The RDMA Approach

- RDMA (**R**emote **D**irect **M**emory **A**ccess) based technology originating from Infiniband (IB)
- Enables a host to read or write directly from/to a remote host's memory with drastically reduced use of remote host's CPU (interrupts required for notification only)
- Native / direct application exploitation requires rewrite of network-related program logic, deep level of expertise in RDMA and a new programming model
- Therefore, provide a transparent approach:
  - **SMC-R**: Use RDMA over Converged Ethernet (RoCE) technology
    - Unlike IB, RoCE does not require unique network components (host adapters, switches, security controls, etc.)
    - Utilize existing Ethernet fabric with RDMA capable NICs and switches
  - **SMC-D**: Use DMA when both hosts are within a Z system via virtual PCI device



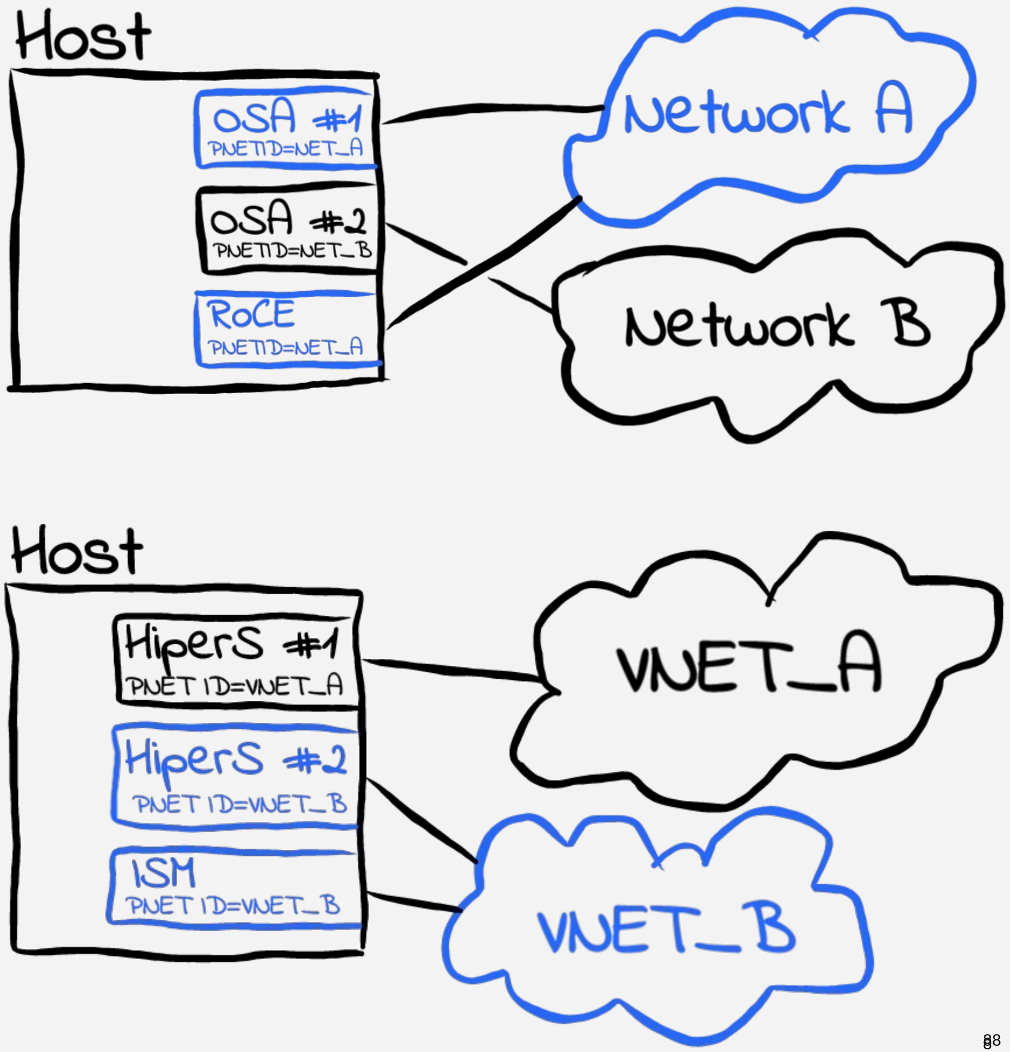
Overview

- For each new TCP connection:
  - Start out with a regular TCP/IP connection
  - Advertise and negotiate details about the peers’ (R)DMA capabilities
  - Switch over to an (R)DMA device for actual traffic depending on the peers’ capabilities
  - Original connection through NICs remains active but idle



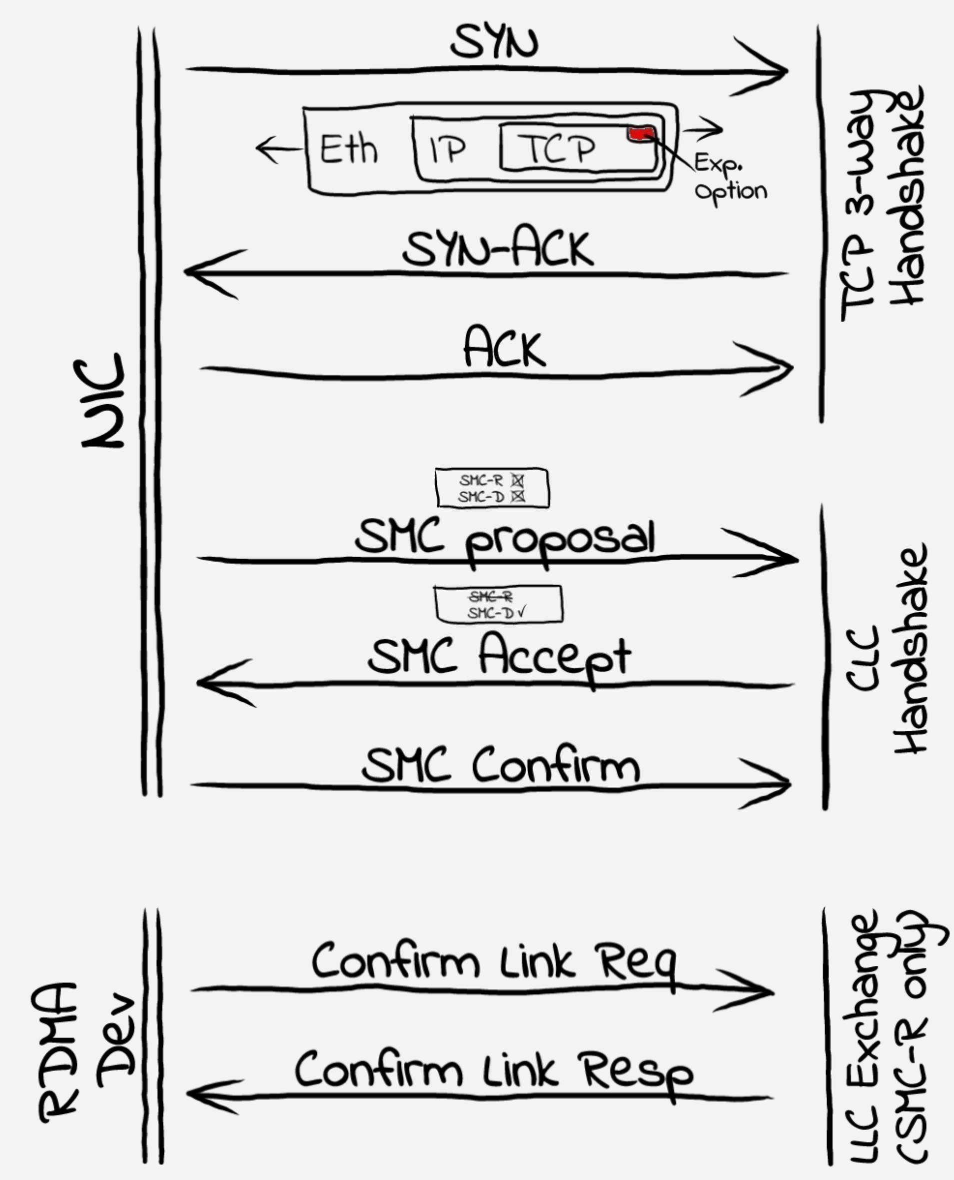
PNET IDs

- PNET ID: Physical network identifier
- Customer-defined value to logically group NICs and RDMA adapters connected to the same physical network
- Define in
  - IOCDS, or
  - using `smc_pnet` tool (SMC-R only)
- Typically associate
  - OSA and RoCE cards, or
  - HiperSockets and ISM devices



Protocol Details

- Start out with regular transport via e.g. OSA or HiperSockets
- SMC capability indicated by TCP experimental option during TCP 3-way handshake
- CLC handshake used to exchange info for SMC transport → adds additional round-trips
- Fallback to regular TCP/IP in case of failure at any point during setup
- In case of matching capabilities: Switch to (R)DMA device
- No fallback to or usage of regular TCP/IP connection beyond this point!
- See RFC 7609 “IBM's Shared Memory Communications over RDMA (SMC-R) Protocol” (https://tools.ietf.org/html/rfc7609) for a detailed description

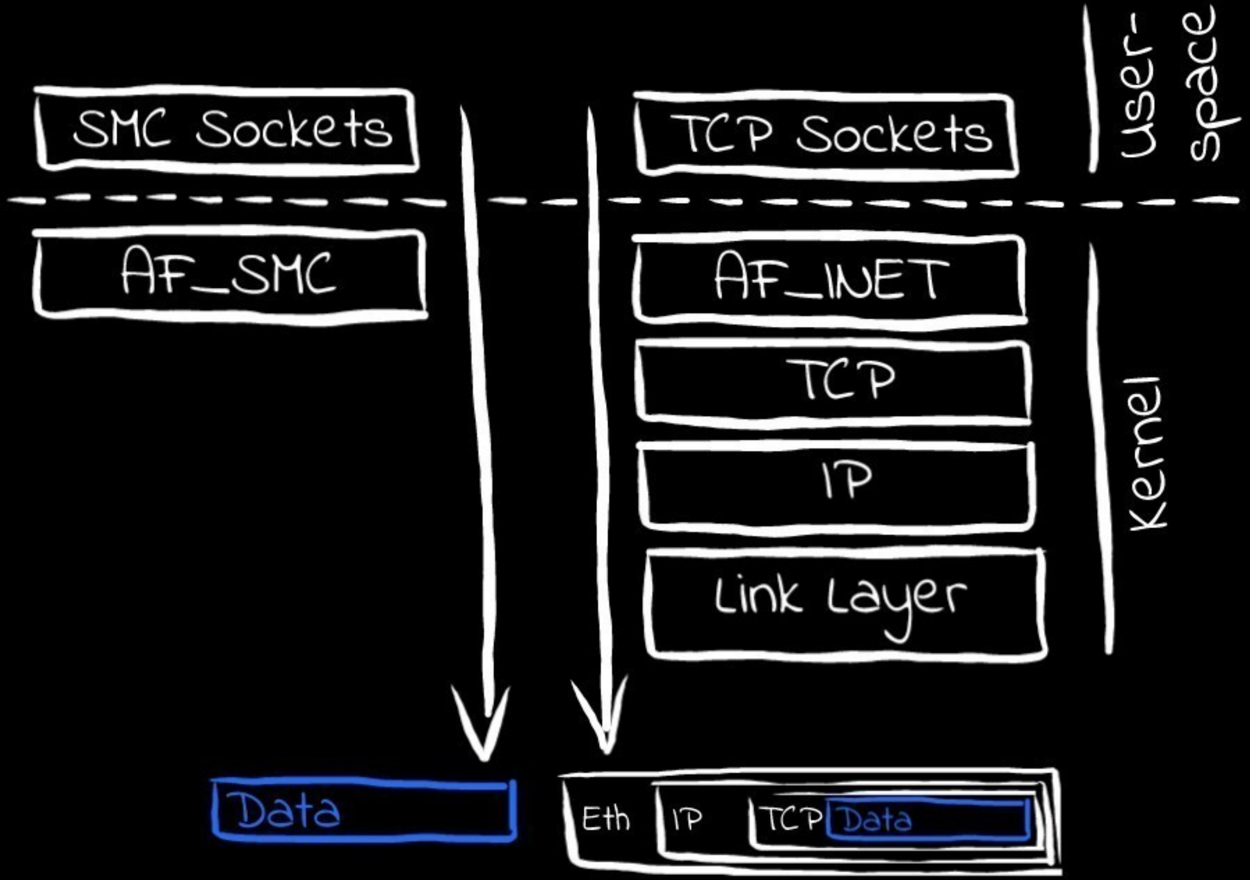


Why a Hybrid Protocol?

Leverages key existing attributes:

- Follows standard TCP/IP connection setup
- Dynamically switches to (R)DMA (SMC)
- Preserves critical operational and network management TCP/IP features such as:
  - Minimal (or zero) IP topology changes
  - Transparent to channel bonding, load balancers and VLANs
  - Preserves existing IP security model (e.g. IP filters, policy, VLANs, SSL etc.)
  - Minimal network admin / management changes
  - Built-in failover capabilities for RDMA devices

Less latency
Lower CPU usage



Full BSD sockets API compatibility

1) Install kernel with SMC-D/R support
2) Install smc-tools (shipped with distro, or see https://ibm.biz/BdiZ5m)
3) In IOCDS:
   - Define (R)DMA devices
   - Assign PNET IDs to networking devices
   - Alternative: Use `smc_pnet` in Linux (SMC-R only)
4) In applications' `socket()` calls, replace `AF_INET` with `AF_SMC`, i.e.:

```
int s, ipv6 = 0;
s = socket(AF_SMC, SOCK_STREAM, ipv6);
```

Run your applications unmodified

- SMC is transparent to existing applications – no changes required
- Use `smc_run`, also provided by smc-tools:

```
smc_run <my_application>
```

- Or use preload library directly, provided by smc-tools, to enable existing applications:

```
export LD_PRELOAD=libsmc_preload.so
```

Preserve Existing Security Model

- The hybrid nature of SMC (beginning with regular TCP/IP, then switching to SMC) allows existing IP and TCP layer (i.e. IP and port-based) security features to automatically apply to SMC connections.
- This includes:
  - SSL/TLS
  - IP Filters, Traffic regulation, Intrusion detection systems
  - Auditing based on IP addresses and ports
- Not supported:
  - IPSec tunnels
  - Deep Packet Inspection
- No changes from a user perspective required

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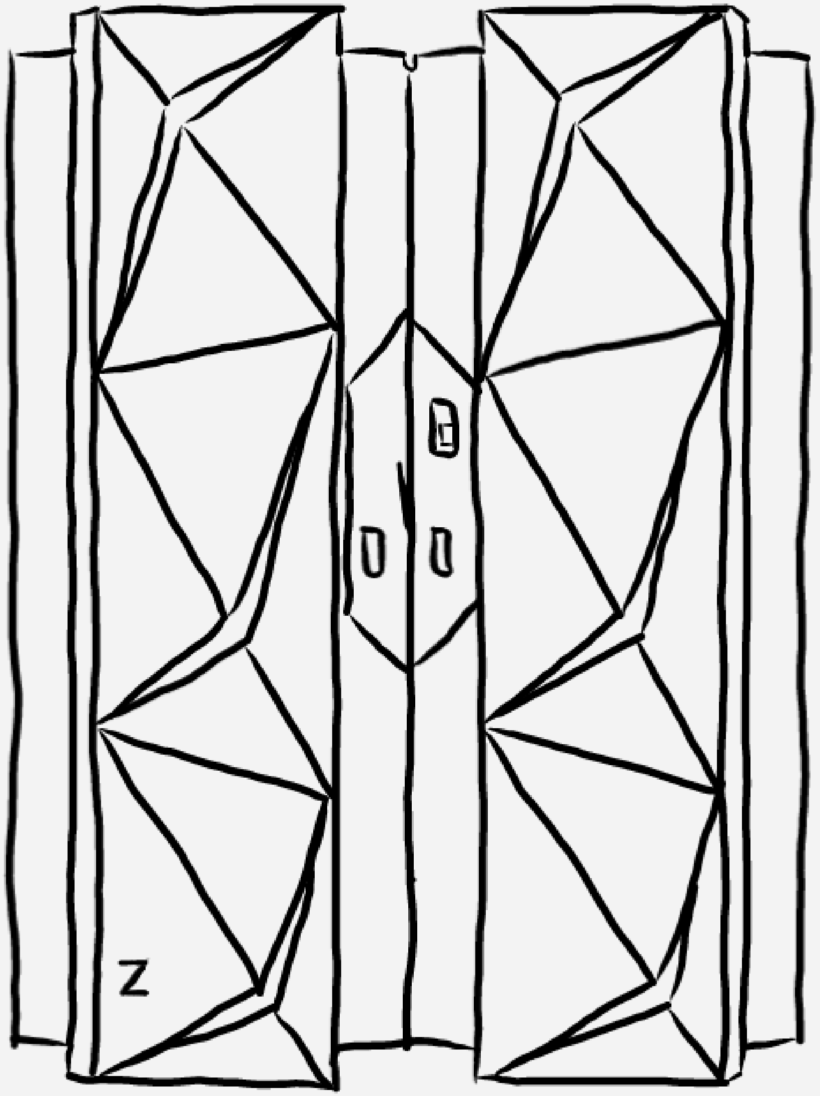
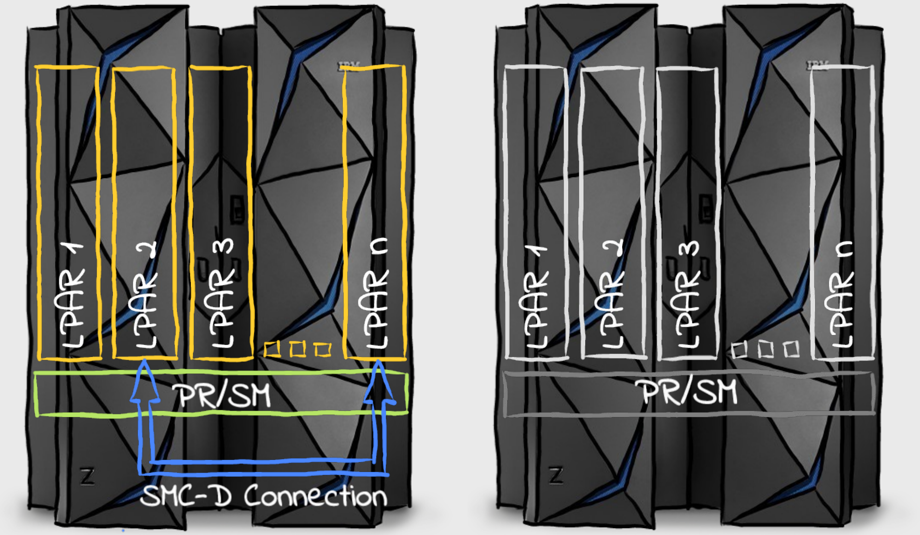


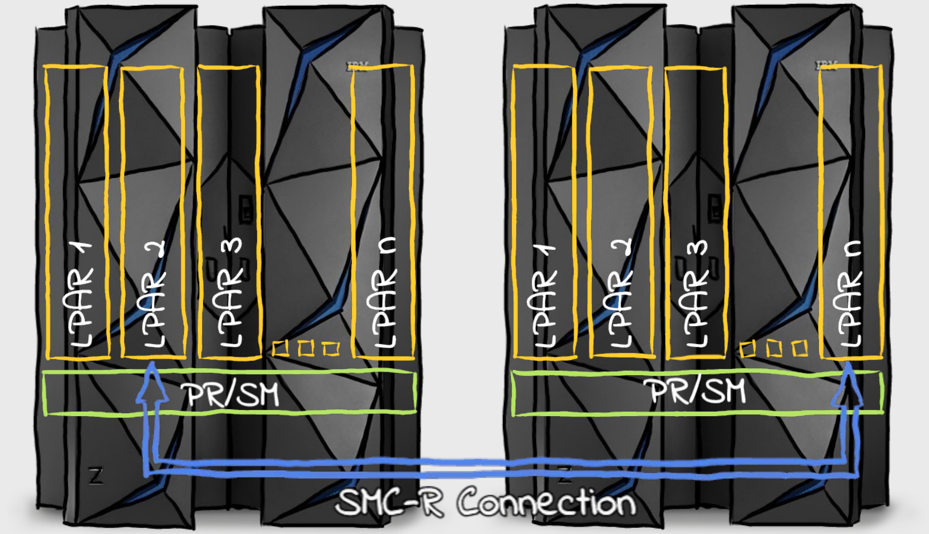
SMC-D Overview

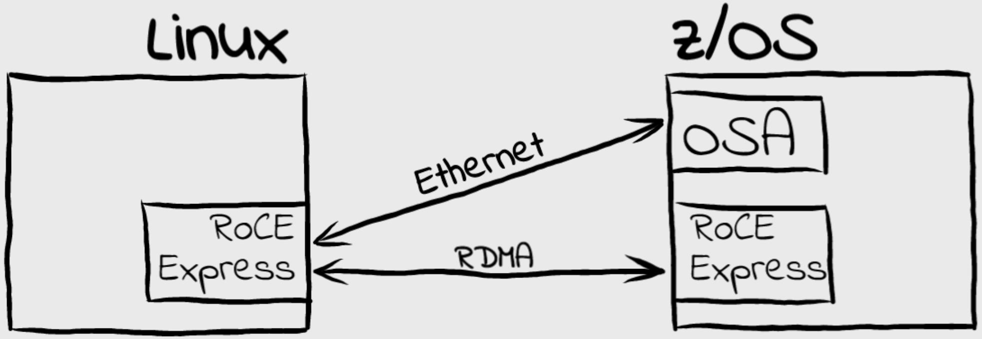
- Intra-CEC connectivity using **Internal Shared Memory** (ISM) devices
- IBM Z hardware requirements
  - IBM z13 (requires driver level 27 (GA2)) and z13s, or later
  - LinuxONE Emperor and LinuxONE Rockhopper, or later
  - Classic mode only (i.e. DPM not supported)
- ISM devices
  - Virtual PCI network 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, OSA or RoCE cards for regular connectivity



SMC-R Overview

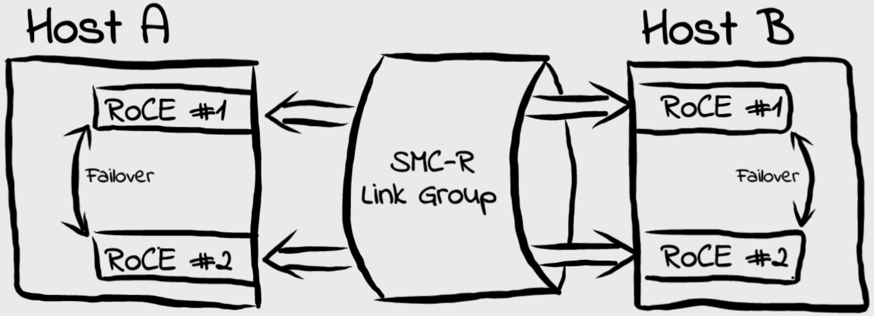
- Cross-CEC connectivity using **RoCE Express** cards
- IBM Z hardware requirements
  - IBM z12EC and z12BC or later
  - LinuxONE Emperor and Rockhopper or later
  - Classic and DPM mode supported
- RoCE Express cards
  - RoCE Express & RoCE Express2 cards supported
  - Switches need to support and enable Global Pause (standard Ethernet switch flow control feature as described in IEEE 802.3x)
- **Note**:
  Linux on Z can use a single RoCE card for regular and RDMA traffic!
- PNET ID configuration
  - IOCDS or `smc_pnet` (→see smc-tools package)
  - Use OSA or RoCE card for regular connectivity

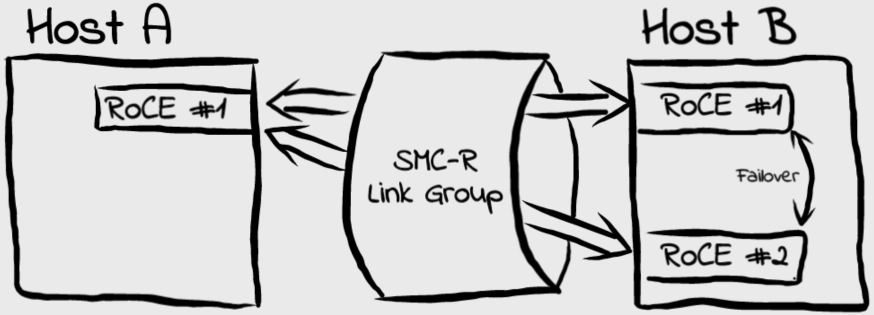


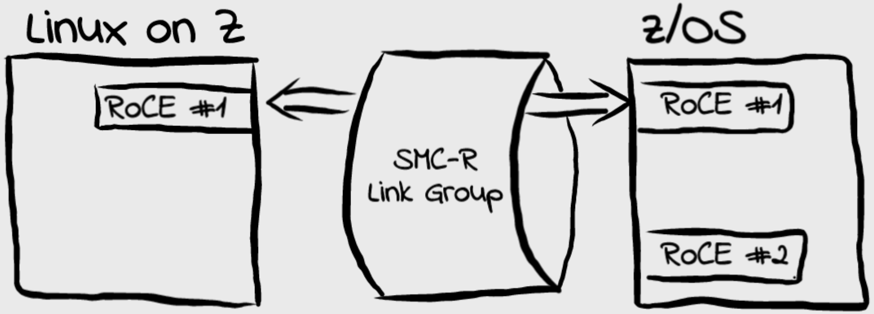


SMC-R Link Groups

- SMC-R **link groups** provide for load balancing and recovery
  - New TCP connection is assigned to the SMC-R link with the fewest TCP connections
  - Load balancing only performed when multiple RoCE Express adapters are available at each peer
- **Full redundancy** requires:
  - Two or more RoCE Express adapters at each peer
  - Unique system internal paths for the RoCE Express adapters
  - Unique physical RoCE switches
- **Partial redundancy** still possible in the absence of one or more of these conditions
- Linux on Z:
  - No failover support (yet)







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 (anticipated)

smc-tools Package Overview

- Current version: v1.1.0
- smc-tools provides the following commands:
  - `smc_pnet`
    - Associate NICs via PNET ID in software
    - Does **not** modify/create IOCDS entries
    - Also works with bonding and VLAN devices
    - **Note**: PNET IDs defined in IOCDS always override
  - `smc_run`: Enable a binary application to use SMC.
  - `smcss`: Information about SMC-enabled sockets and link groups. Includes information on SMC mode used, as well as TCP fallbacks

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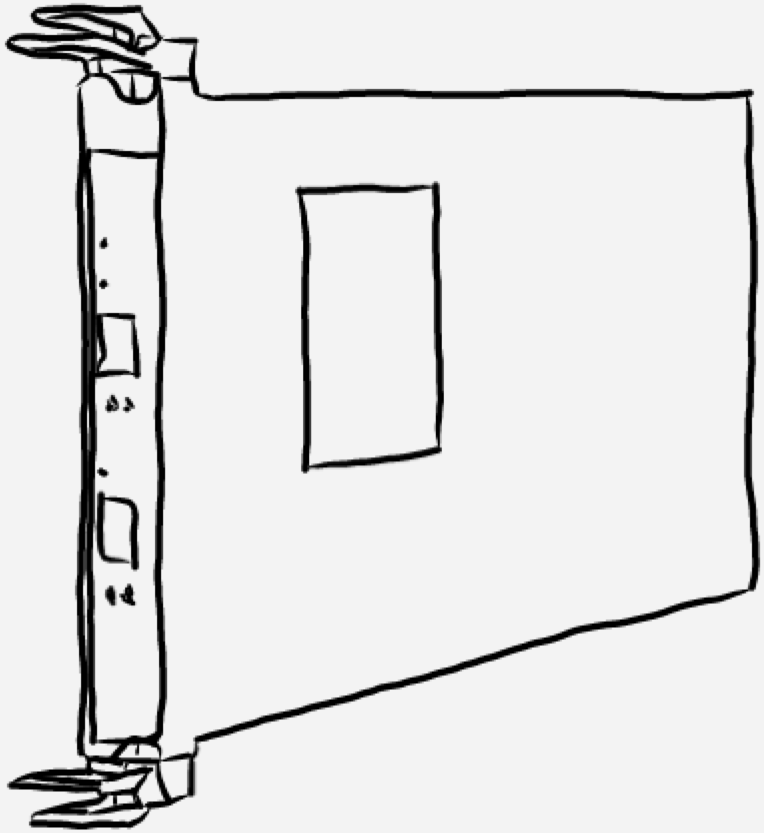


Prerequisites

- □**Direct connectivity** over same IP subnet. I.e. no routed traffic, no peers in different IP subnets, currently built on RoCE V1
- □(R)DMA device(s) attached and configured
- □PNET IDs assigned
- □Linux kernel supports SMC-R and/or SMC-D
- □**TCP only**, i.e. no UDP
- □No IPsec (SSL/TLS works)
- □No NAT (violates same subnet prerequisite)

Usage Example: SMC-D

Prerequisites: Applications in different LPARs on same CEC communicating through HiperSockets. ISM (FID: 80) and HiperSockets devices have the same PNET ID configured in IOCDS in each LPAR.

```
# Hotplug ISM device if not yet visible via 'lspci' command (see next step)
$ echo 1 > /sys/bus/pci/slots/00000080/power

# Verify presence of ISM device
$ lspci
0001:00:00.0 NonVGA unclassified device: IBM Internal Shared Memory (ISM) virtual PCI device

# Run application using smc_run
$ smc_run foo_socks

# Verify that SMC is really used
$ smcss a
State          UID   Inode  Local Address          Foreign Address         Intf Mode
ACTIVE         20000 115762 10.101.4.8:60594       10.101.4.49:3220        0000 SMCD
ACTIVE         20000 112844 10.101.4.8:60592       10.101.4.49:3220        0000 SMCD
ACTIVE         20000 112605 10.101.4.8:60590       10.101.4.49:3220        0000 SMCD
```

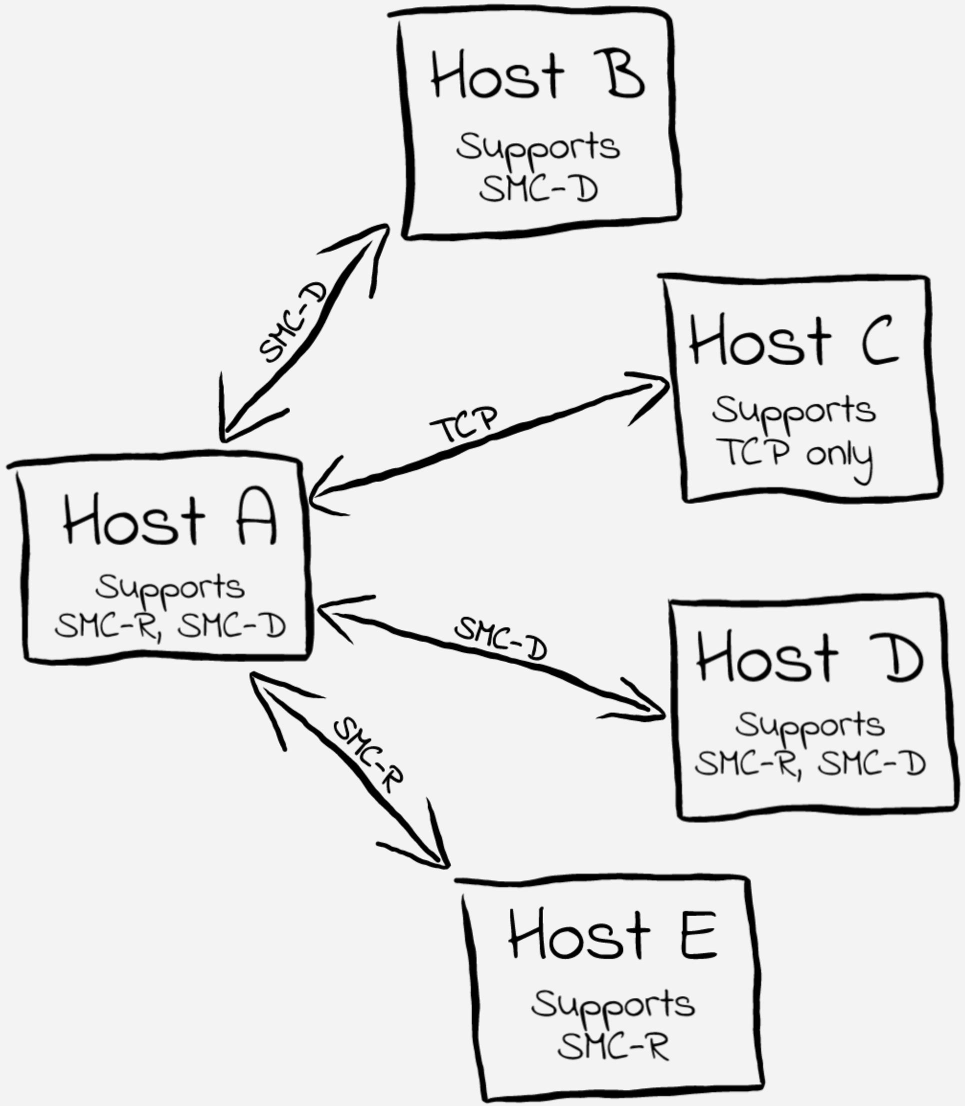
Usage Example: SMC-R

Prerequisites: Existing Applications in LPARs on separate CECs communicating through OSA card `enccw0.0.f500`.
RoCE Express adapter has network interface `ens2` and infiniband interface `mlx4_0` - we will use its 1st port. No PNET IDs configured.

```
# Verify presence of RoCE card
$ lspci
0000:00:00.0 Ethernet controller: Mellanox Technologies MT27500/MT27520 Family [ConnectX3/ConnectX3 Pro Virtual Function]

# Set RoCE card interface UP, and verify
$ ip link set ens2 up
$ ip link show ens2
3: ens2: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc mq state UP mode DEFAULT group default qlen 1000
    link/ether 82:03:14:32:f1:a0 brd ff:ff:ff:ff:ff:ff

# VLANs only: Define an interface, and assign an IP – interface does not need to be in state UP!
$ ip link add dev ens2.201 link ens2 type vlan id 201
$ ip addr add 192.168.23.42/24 dev ens2.201

# Configure PNET ID on OSA and RoCE device:
$ smc_pnet a PNET1 I enccw0.0.f500 D mlx4_0 P 1
$ smc_pnet s
PNET1 enccw0.0.f500 mlx4_0 1

# Run application using smc_run
$ smc_run foo_socks

# Verify that SMC is really used
$ smcss a
State          UID   Inode  Local Address         Foreign Address        Intf Mode
ACTIVE         20000 115762 10.101.4.8:60594      10.101.4.49:3220       0000 SMCR
```

Mixing SMC Usage

- Both variants of SMC can be used concurrently to provide an optimized solution
- Enable SMC independent of peers' capabilities; i.e. no commonality in SMC support on all peers required
- Use
  - SMC-D for local connections
  - SMC-R for remote connections
  - fall-back to regular TCP where neither SMC variant is supported



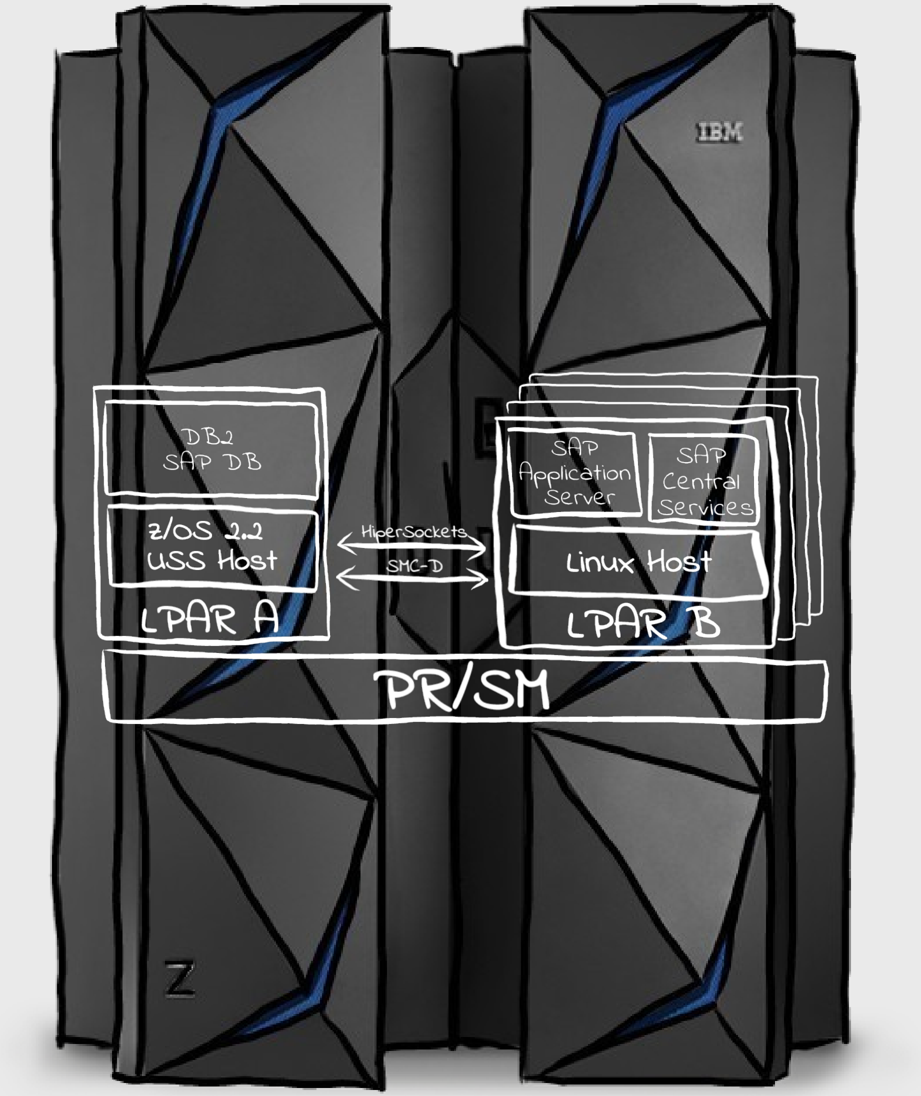
Performance Considerations

- **Expect**:
  - Reduction of CPU usage
  - Lower latency
  - Higher effective throughput
  - Higher maximum throughput (SMC-D only)
- **But consider**:
  - CLC handshake adds add’l round trips prior to actual traffic
    →Minimum number of transmits required to break even

Usage Example: SAP on IBM Z

- Deploy
  - DB2 SAP Database on z/OS
  - SAP Central Services and SAP Application Server on Linux on Z
- Provides lower latency, less CPU used

→ Higher transaction rates



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Summary

Key Attributes

- Leverages existing Ethernet infrastructure (SMC-R)
- Transparent to (TCP socket based) application software
- Preserves existing network addressing-based security models
- Preserves existing IP topology and network administrative and operational model
- Transparent to network components such as channel bonding and load balancers
- Built-in failover capabilities (SMC-R)

Typical Workloads To Benefit

- Transaction-oriented,
- latency-sensitive, and
- bulk data streaming, e.g. when running backups.

References

- **smc-tools Homepage**
  https://www.ibm.com/developerworks/linux/linux390/smc-tools.html
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