Unleashing the Network of Red Hat OpenShift Container Platform on z/VM and RHEL KVM for IBM Z & LinuxONE

When to use Multus CNI and other tunings

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Linux on IBM Z Performance

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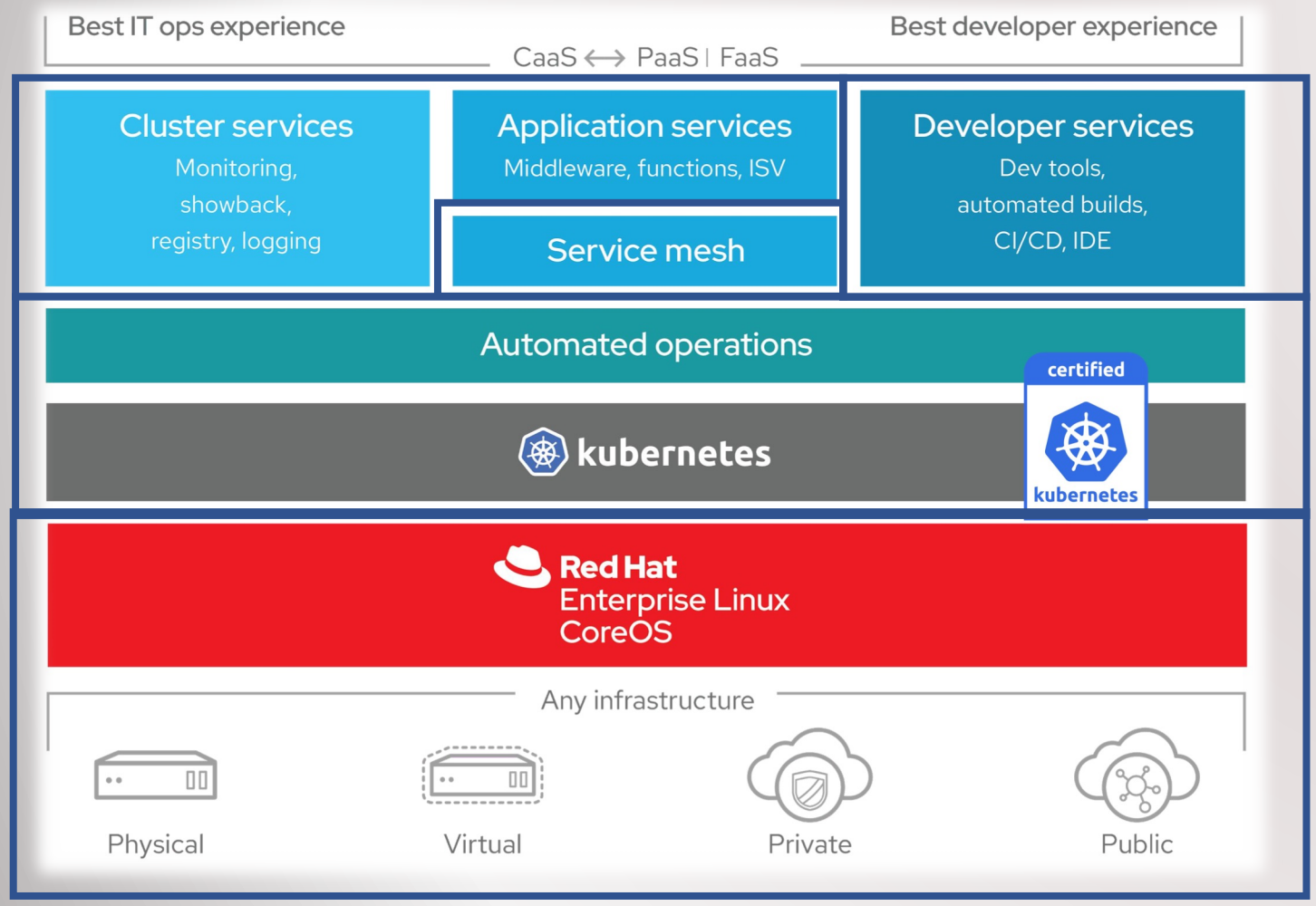
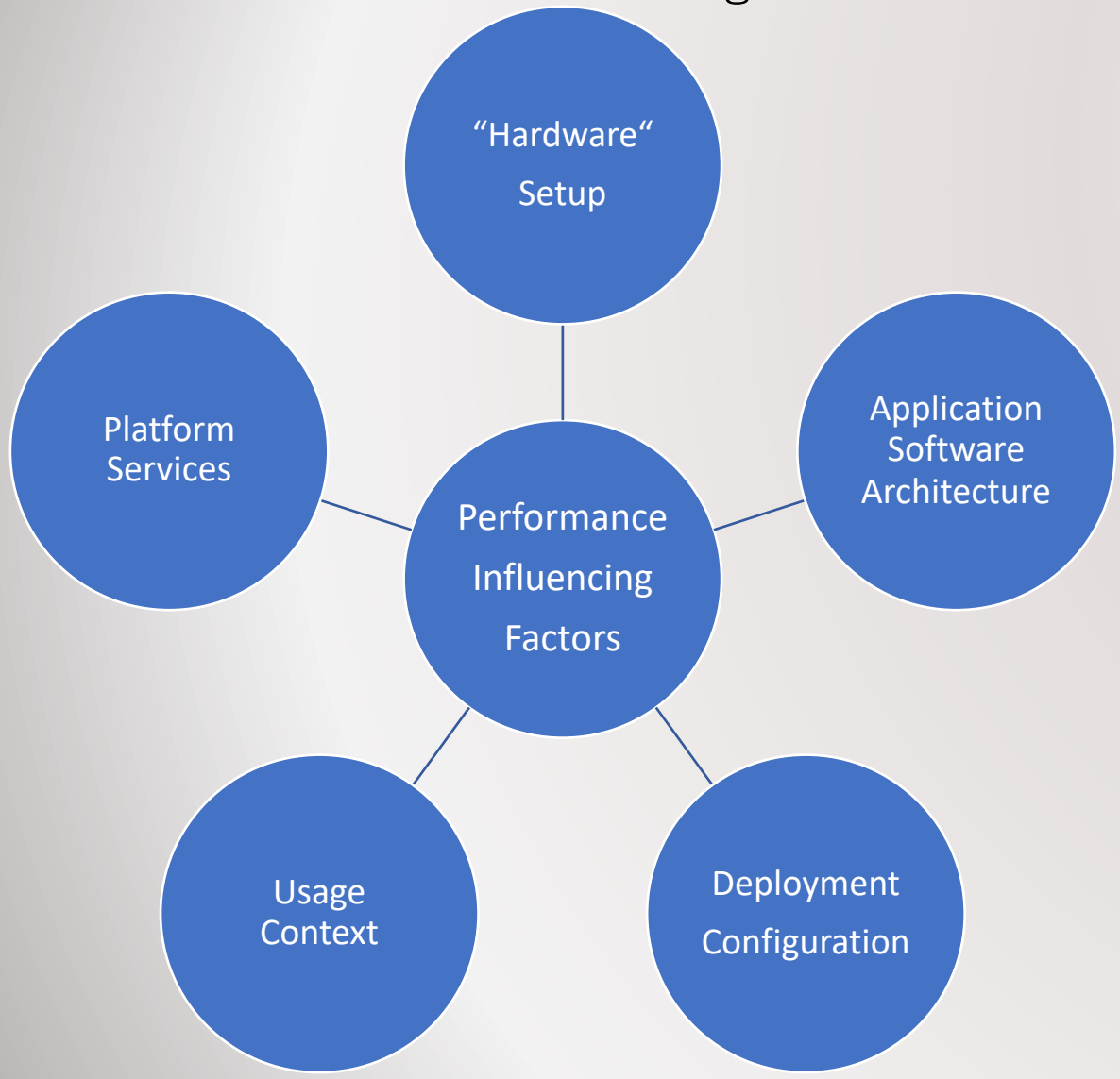
Red Hat OpenShift Container Platform (RHOCP) in a Nutshell



- Manage
  - resources, .e.g. public/private cloud
  - infrastructure, e.g. network
  - operating system, e.g. Linux performance settings
- Development
  - of applications using CI/CD pipeline
  - … in different programming languages
  - … and code repositories
- Deployment
  - of applications in containers
  - … to be scaled
  - … and made reliable
- Operation
  - Monitoring, logging
  - Middleware, operators
  - Network topology

Performance and its influencing factors



- CPU/memory/.. resources
- Hypervisor, i.e. z/VM, KVM,…

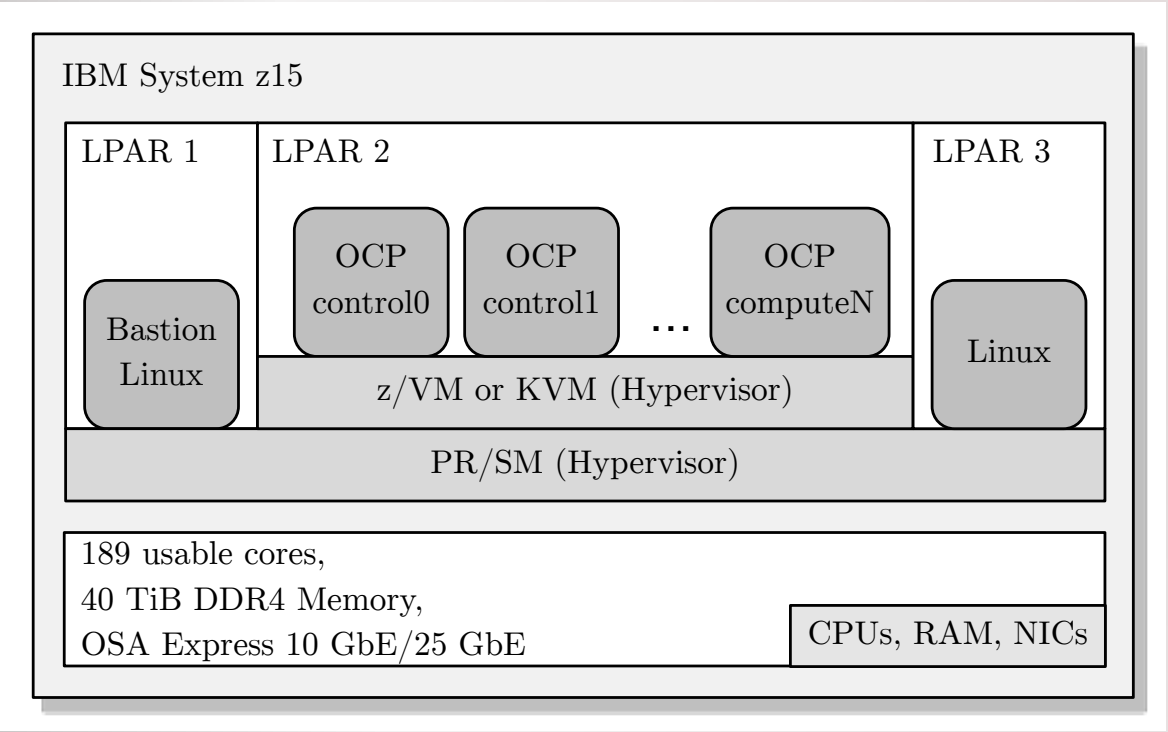
- Monolythic Application
- Service oriented
- Microservices

- Trade-off decision for deployment
- High locality vs. high distribution

- Workload pattern
- # concurrent users
- Data amount

- Kubernetes Layers/Operators
- Software defined network
- Prometheus
- etcd,…

General system setup: IBM z15

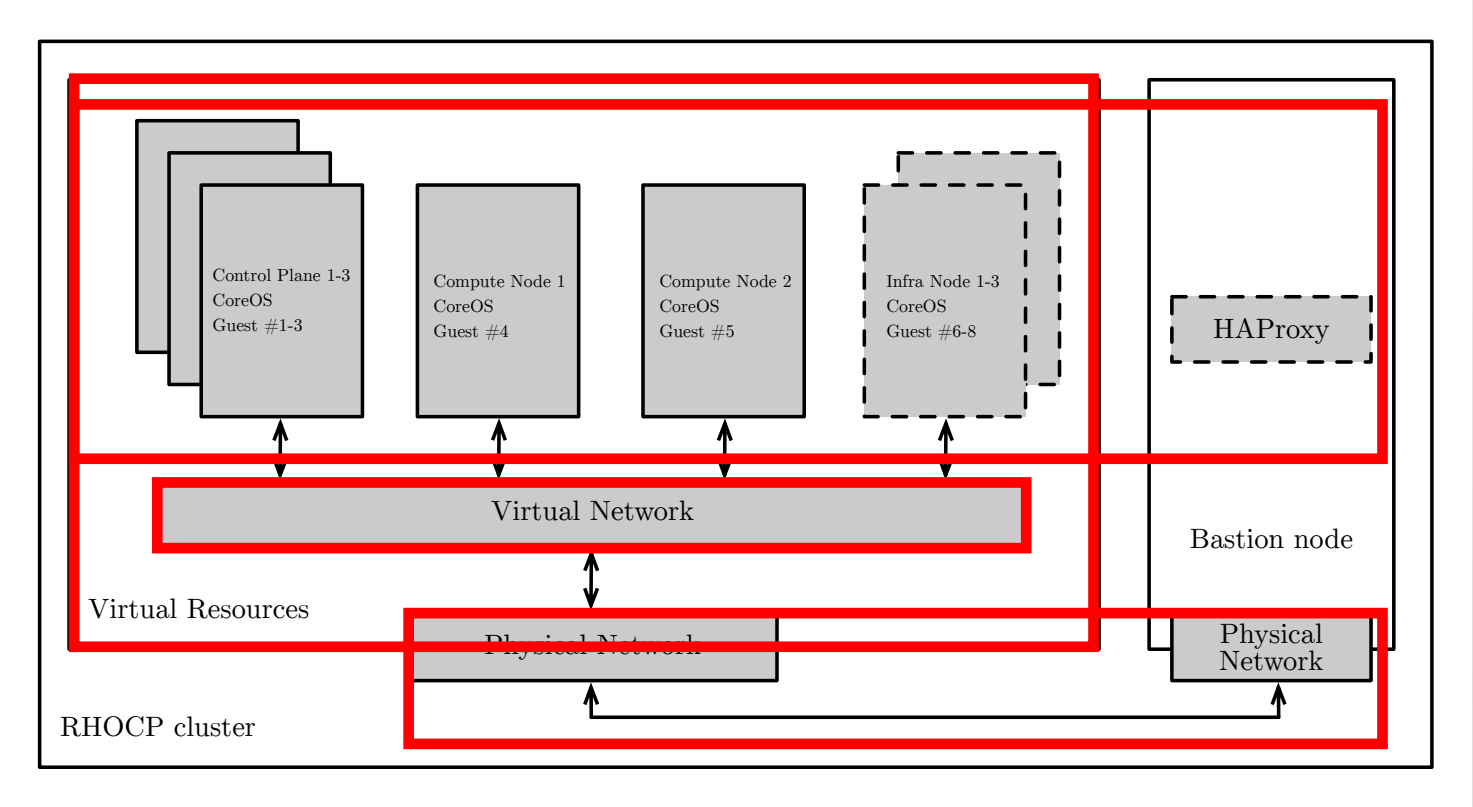


RHOCP LPAR resource configuration
- 16 IFLs + SMT2 each
- 200 GB memory each
- Dedicated OSA Express 7s 10 GBit/s to each LPAR

RHOCP configuration
- 3 control planes with 4 vCores, 32 GiB memory each
- 4 compute nodes with 4 vCores, 32 GiB memory each
- 2 infra nodes with 4 vCores, 32 GiB memory each
- bastion with 16 vCores, 16 GB, dedicated OSA Express 7s (LPAR 1)

External LPAR 3
- RHEL 8.x Linux
- 32 vCores, 32 GiB memory, dedicated OSA Express 7s

RHOCP Cluster architecture general



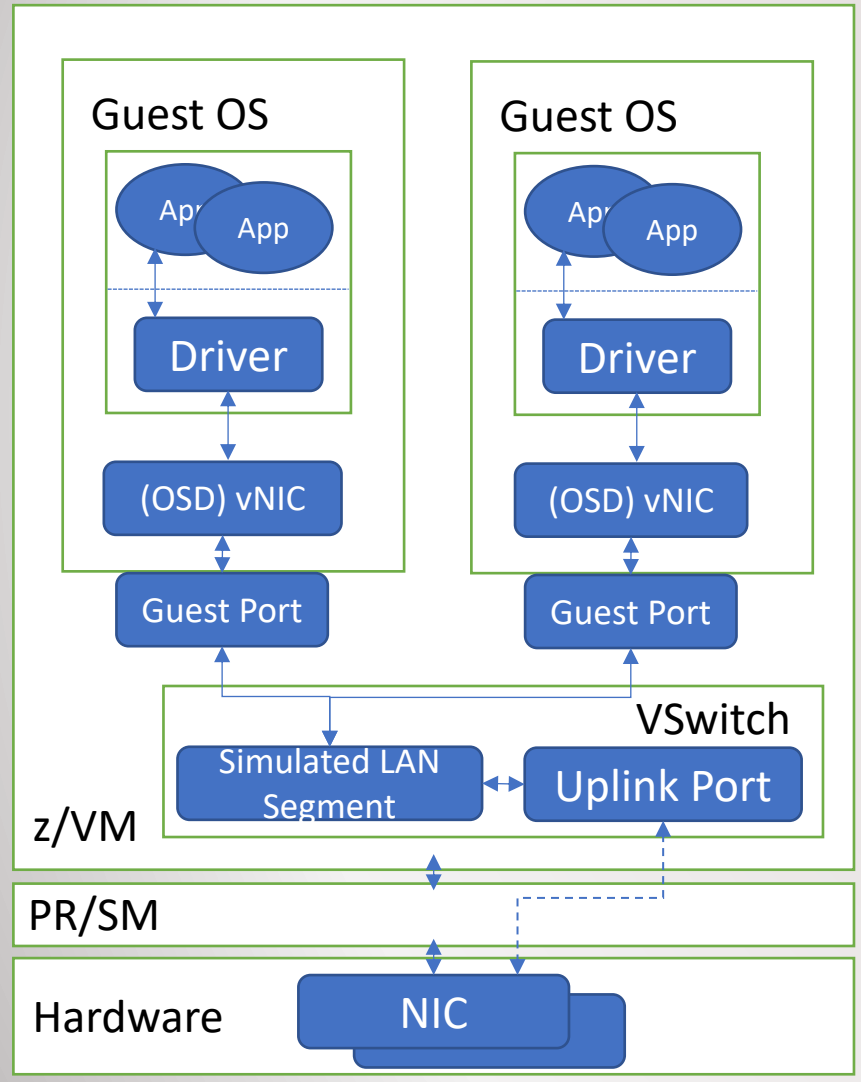
OCP nodes
- Control planes
- Compute nodes
- Infrastructure nodes
- Bastion node (for e.g. perimeter network)
- All infrastructure related pods (i.e. router, prom,...) moved to infrastructure nodes

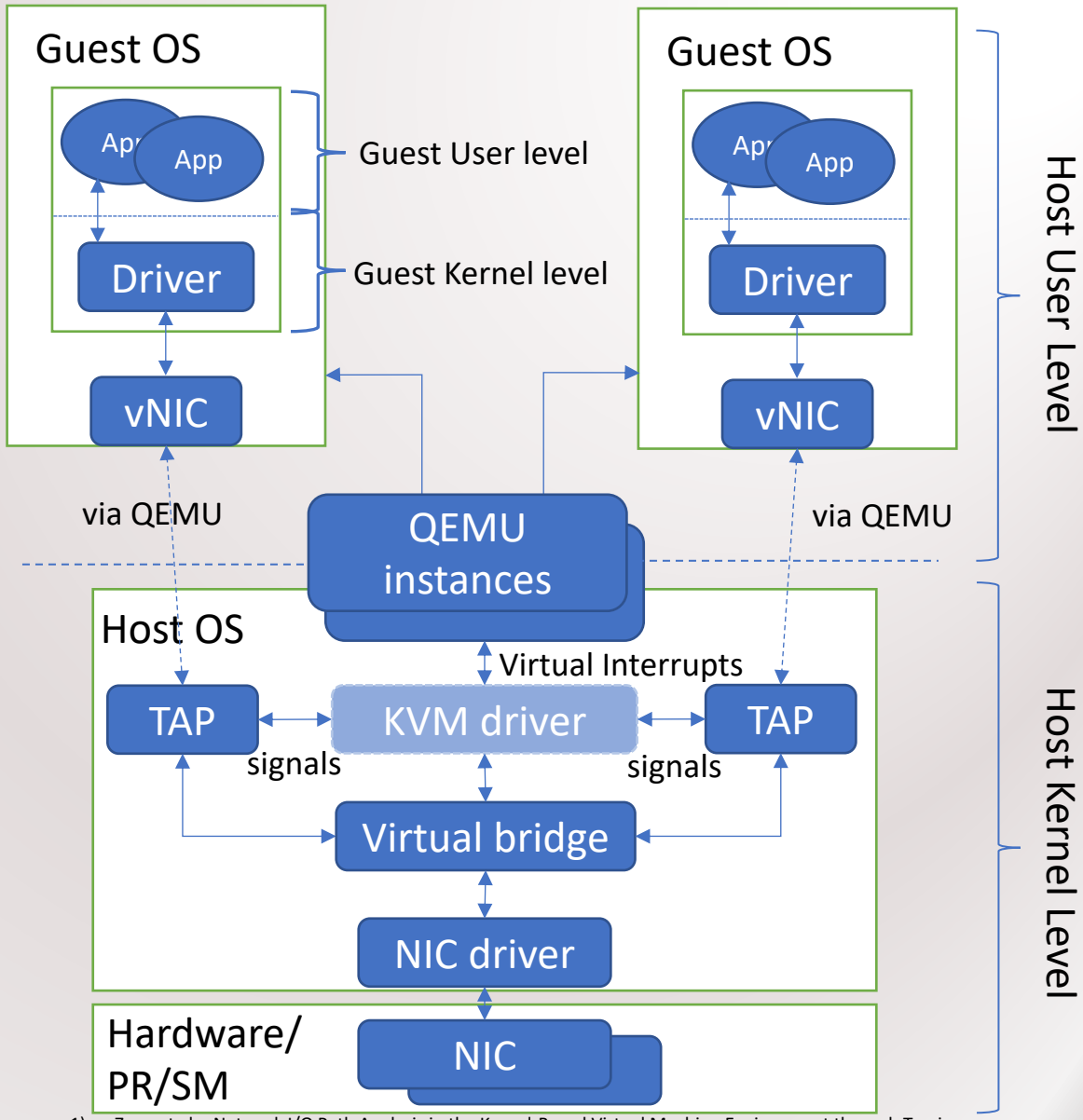
Virtual resources
- KVM on IBM Z & z/VM hypervisor
- z/VM VSWITCH
- Tap + bridge

Virtual OCP network
- SDN Provider: OpenShift-SDN (replaced by OVN-kubernetes)
- CNI Plugins

Physical Network
- OSA Express 7s NICs

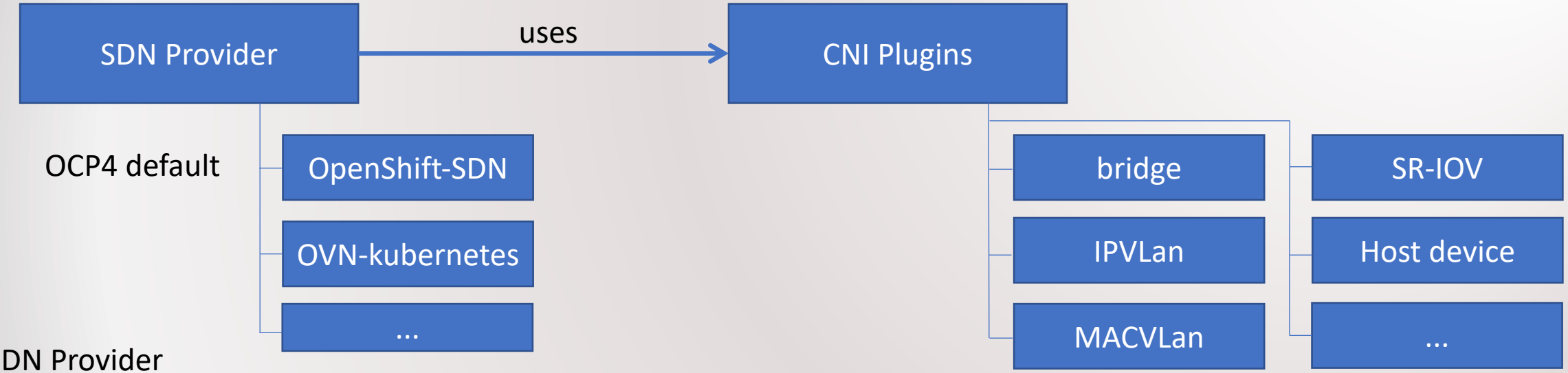
Network: z/VM & VSWITCH vs. KVM & Tap+bridge





1) Zeng et al. - Network I/O Path Analysis in the Kernel-Based Virtual Machine Environment through Tracing
2) Ren et al. - Shared-Memory Optimizations for Inter-Virtual-Machine Communication

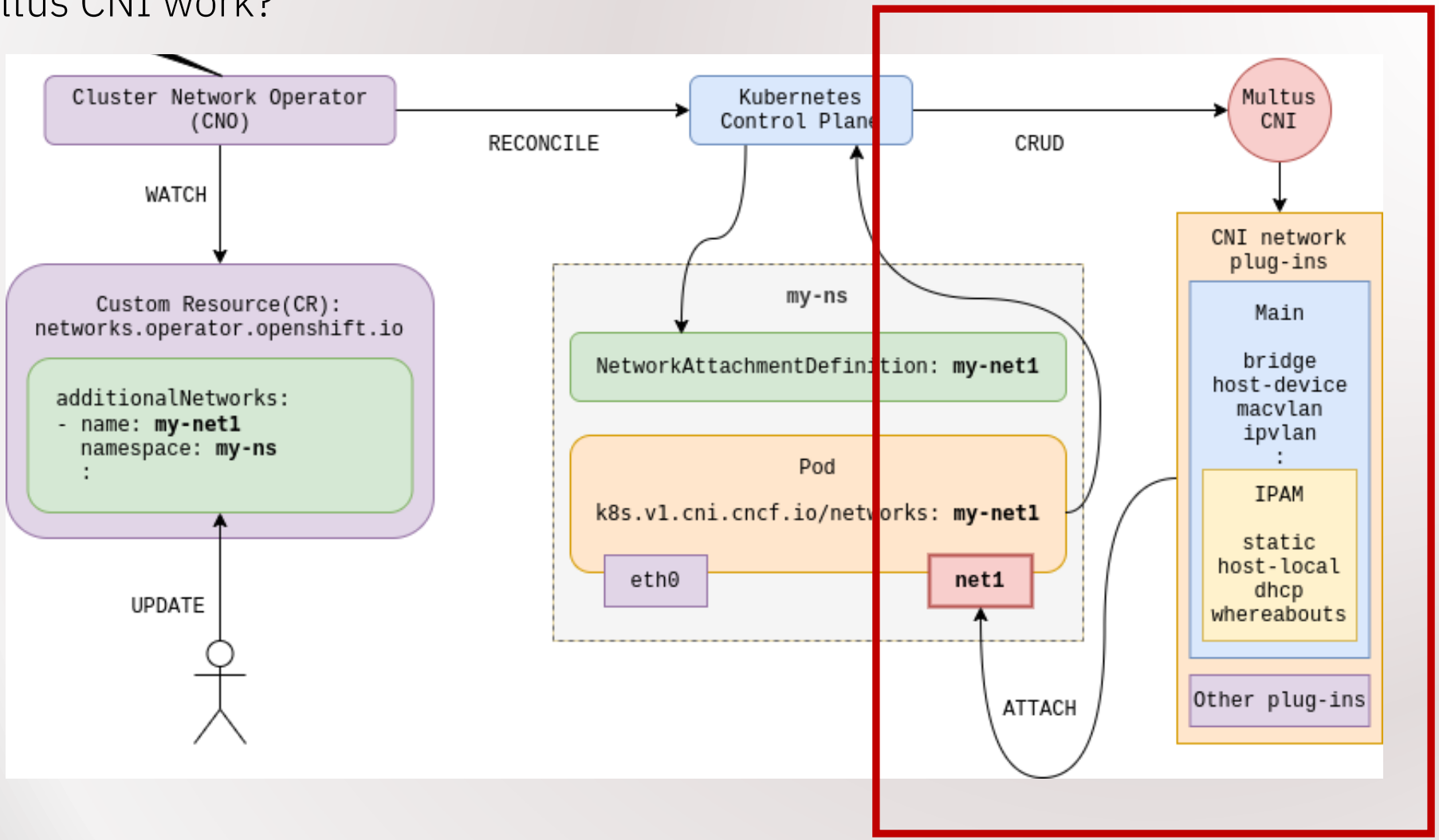
Software defined network (SDN) provider: High level overview



SDN Provider
- Attaches virtual interfaces (provided by CNI plugins) to containers
- Routes traffic between virtual interfaces by tables
- Defines higher-level functions for packet processing (e.g. firewall)

CNI (Plugins)
- Container virtual interface is a specification (i.e. a contract)
- Defines container‘s network connectivity
- Defines how to allocate and remove resources required for the connectivity
- Plugins implement CNI
- Can be attached by the SDN provider to the containers

How does Multus CNI work?



https://cloud.redhat.com/blog/using-the-multus-cni-in-openshift

CNI Plugins: VXLAN vs. IPVLan vs. host-device

OpenShift-SDN+VXLAN

\+
- Default configuration
- Using *Multus* additional interfaces can be attached to pods
- Fast in co-located scenarios with large packet sizes

−
- Slower and lower efficiency in several scenarios especially for external connections

IPVLan

\+
- Good trade-off between performance and functionality
- Layer2 mode shows best performance in our scenarios

−
- Higher configuration effort (Multus CNI required)
- Latency and throughput slower in co-located scenario

host-device

\+
- Highest performance and efficiency for external scenarios
- Easy to configure for single pods such as a database pod

−
- Only one instance per node can use host device
- For use with Multus higher authority needed
- Might bypass some networking stack and features (NetworkingPolicy object rules)

Scenario based reconfiguration of cluster to get best performance

Network setting: Receive Flow Steering (RFS)

- RFS tunes the network performance in terms of throughput and response time
- Is a **trade-off between latency/throughput and CPU usage**
- Depending on the scenario RFS can
  - improve latency, throughput and efficiency
  - improve latency and throughput but decrease efficiency
- Can RFS considered harmful?
  - **Usually RFS has positive effects on latency, and throughput**
  - In resource contention scenarios (e.g. too few CPU cores, NIC saturation) RFS can lead to throughput degradation

If you have **too high over-commitment RFS can increase the steal-time** even more what can end up in lower performance

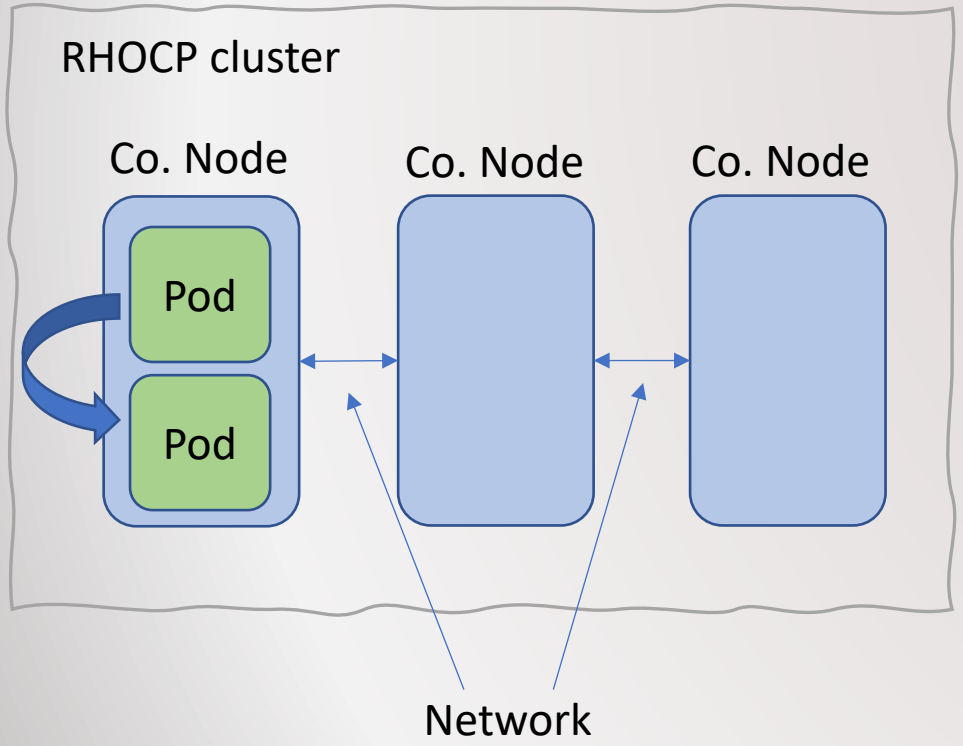
How is RFS working?

- RFS checks if packet processing is running on CPU of destination thread
- If not, the table is updated and packet processing is performed on the target core
- This uses positive cache effects more efficient
- RFS can be used with Openshift-SDN+VXLAN as well as CNI Plugins

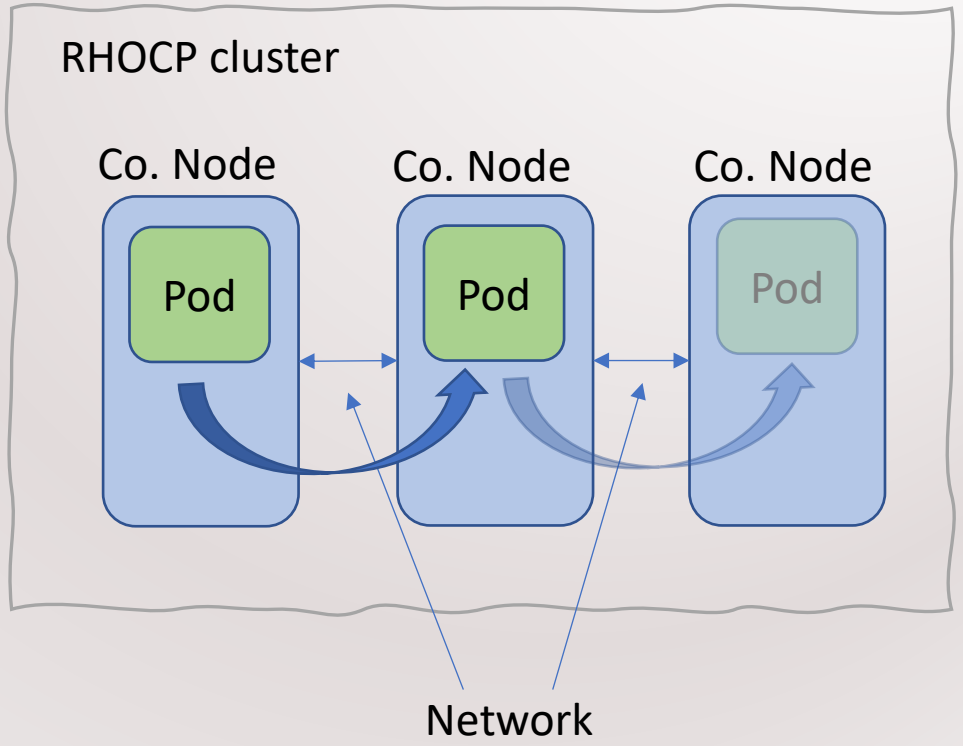
Deployment strategy: same node vs. cross node deployment

- Same node: Pods are located on the same physical or virtual machine (such as an OCP compute node)
- Cross node: Pods are spread over one or several physical or virtual machines

Same node deployment



Cross Node deployment

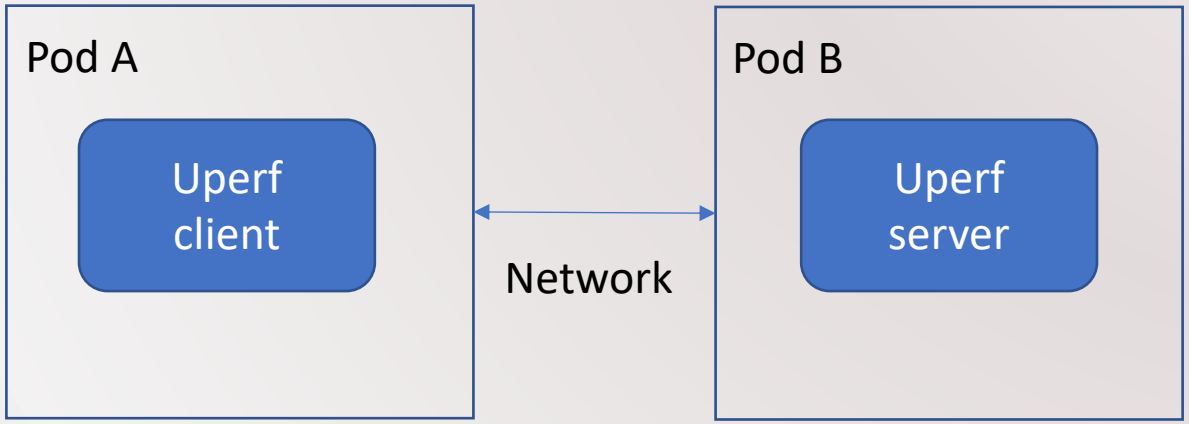


- On z/VM and KVM on IBM Z compute nodes were installed on same LPAR and CEC
- HA considerations (several LPARs, cross CEC setups) might show different results

(General) network performance tuning ideas

How to Benchmark the Network: uperf & workloads

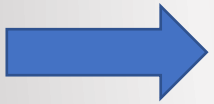
Uperf: A network (micro) benchmark
- Two sets of workloads
  - **Request Response** (latency)
  - **Streaming** (throughput)
- Several numbers of simultaneous **connections** (1-50-250)
- Different **request sizes** (1x1-200x1000-200x30000 B)



Results:
- Latency in us/ms
- Throughput in MiB/s
- CPU load, i.e. user/system/steal
- Efficiency, i.e. throughput/CPU load

Preliminary Discussions

- Controlled analysis environment
  - Dedicated IFLs (no over-commitment)
  - No other LPARs running in parallel
  - Dedicated NICs (OSA Express 7s)
  - Workload has no external dependencies

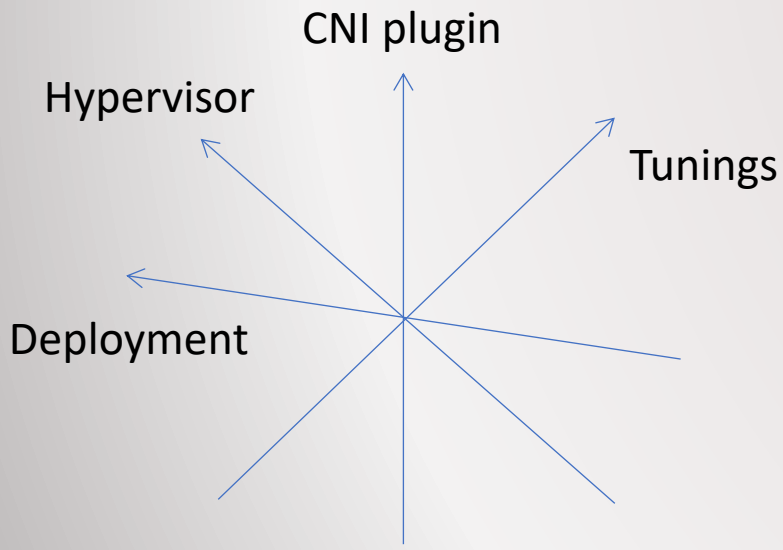


No trade-off decisions made in terms of cost, availability,... **focus on performance only**

- Technology comparison
  - Comparison of technology does not mean one is good and one is bad
  - It just means under certain conditions one technology can outperform the other
- Study stats
  - 720 measurement series
  - 60 hours measurement time
  - 10 GB resulting data to be analysed

General tuning recommendations and decision space

- **General recommendations are hard**
- The more general, the less precise - **use scenario dependant tuning hints**
- This slide deck focusses on **networking performance**
- For optimal configuration **trade-off decisions** required
- Trade off decisions can be derived from decision space:



- Hypervisor: z/VM vs. KVM on IBM Z
- Deployment: local deployment vs. distributed deployment
- Network tuning: Receive flow steering on/off
- CNI Plugins
  - Default-SDN
  - IPVLan
  - Host device

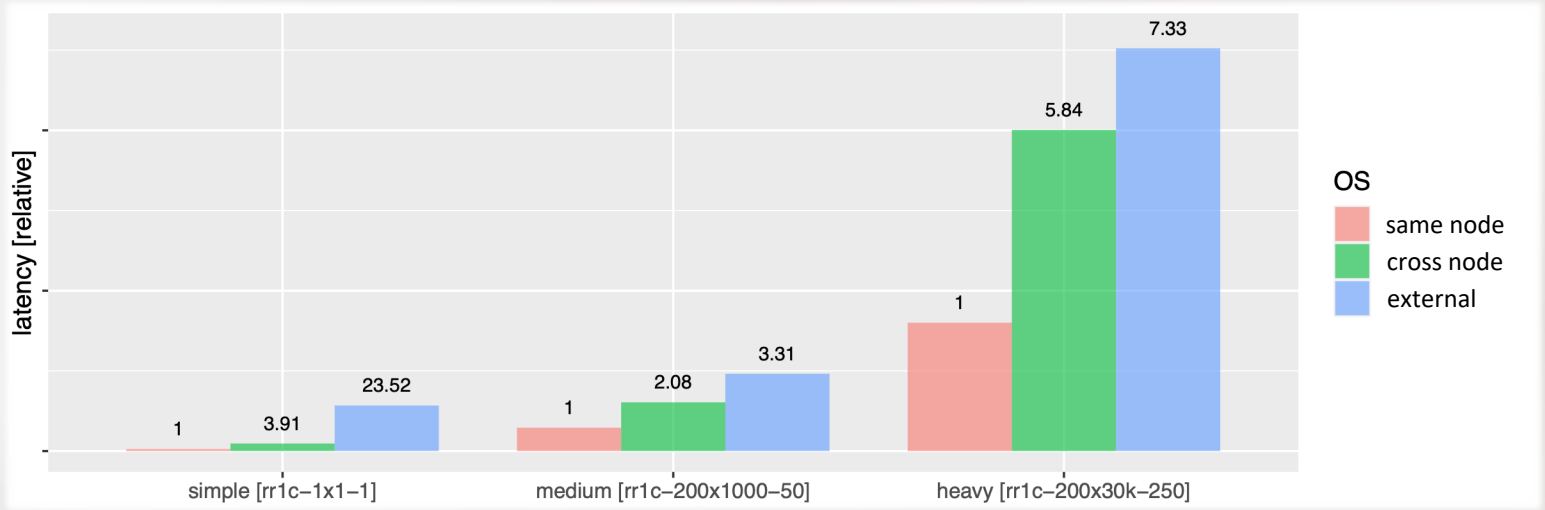
Further influencing factors:

- Number of network connections
- Network packet sizes
- Workload pattern: Request/response vs. streaming workload
- CPU over-provisioning

General (architecture) tuning ideas: Deployment

1. Deploy locally

- **Deploy** services with frequent interaction as **local as possible**
- Communication **between workers** is more **expensive**
- Communicate to external systems shows longest response times (with Openshift-SDN and VXLAN)
- **Trade-off between CPU resources, availability and scalability features required**



General (architecture) tuning ideas: Avoid over-provisioning

2. Avoid too much over-provisioning

- Over-provisioning can lead to unstable cluster
  - etcd leader changes and leader voting required
  - Consumes even more CPU
- Cluster operators working in the background
- KVM and z/VM **have to do a lot more than with usual Linux installations**
- **Steal time can go up, wastes CPU** and **prevents workload** from beeing scheduled
- **Network performance can be degraded** because z/VM VSWITCH needs resources as well
  - If VSWITCH is slow the applications waiting for network I/O might slow down
  - Ripple effects through the architecture (affecting other pods) is possible

General (architecture) tuning ideas: Avoid background tasks

3. Avoid too much background noise

- Use **LPAR dedicated to RHOCP**
- **No other services** should run on the same LPAR
- Can degrade performance of your RHOCP significantly
- RHOCP operators doing quite a lot in the background
- Might lead to concurrency situation between
  - Hypervisor scheduling
  - CPU resources
  - Networking resources
  - Disk I/O resources

General (architecture) tuning ideas: Apply tunings to your cluster

1. Use **infrastructure** nodes
2. Enable **RFS** in your cluster (more infos later in this slides)
3. Use **HPAV devices** if you use ECKD
4. **Tune your hypervisors**
    1. Tune LPAR weights
    2. Adjust sched_migration_cost_ns for KVM on IBM Z
    3. Tune z/VM CPU share

More information to be found:

- General performance overview
- OCP on Z - Performance, Quality & Best Practices
- How to setup infra nodes
- How to setup PAV devices

Hypervisor performance and efficiency: z/VM vs. KVM on IBM Z

- Overall performance / efficiency[1]
- No further decisions considered (such as deployment, workload, etc.)
- Default-SDN used
- RFS tuning on

	#cases
z/VM vs. KVM on IBM Z “overall“ performance & efficiency[2]:	7/15

- Workload pattern:

z/VM vs. KVM on IBM Z request/response (rr) performance & efficiency[2]:	6/15
z/VM vs. KVM on IBM Z streaming performance & efficiency[2]:	2/15
z/VM vs. KVM on IBM Z – rr many external connections efficiency[2]:	13/15
z/VM vs. KVM on IBM Z – rr many external connections performance[2]:	8/15

- KVM on IBM Z with higher steady state load might reduce efficiency especially with many workers beeing smaller sized
- KVM on IBM Z slower within worker internal communication (see next slide)

[1]efficiency excludes higher steady state load of the cluster. Focus on networking efficiency such as throughput per core and latency efficiency only.
[2]the bars represent how often one of the technologies/settings have shown at least 10% better performance compared to the other.

Deployment strategy: same node & cross node deployment – z/VM vs. KVM on IBM Z

- Default-SDN used
- RFS tuning on
- **Same node deployment**:

	#cases
z/VM vs. KVM on IBM Z request/response performance & efficiency:	13/15
z/VM vs. KVM on IBM Z streaming performance & efficiency:	10/15

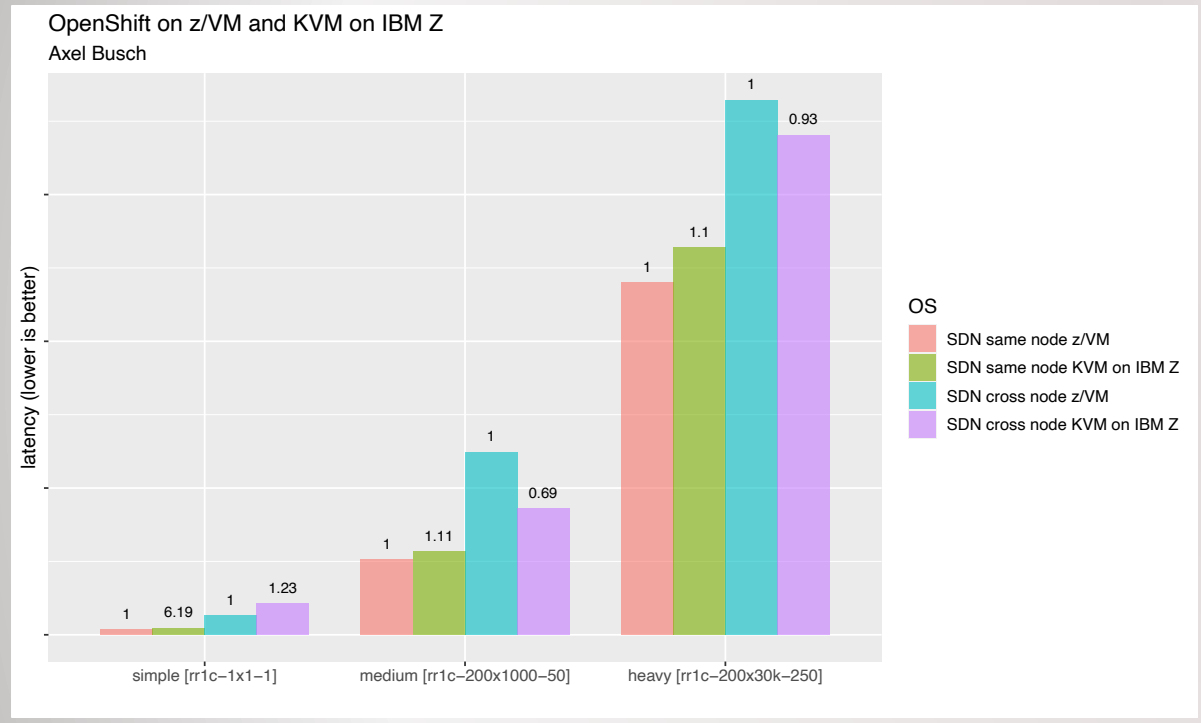
- **Cross node** deployment (i.e. client/server spread over several nodes):

z/VM vs. KVM on IBM Z request/response performance & efficiency:	7/15
z/VM vs. KVM on IBM Z streaming performance & efficiency:	3/15

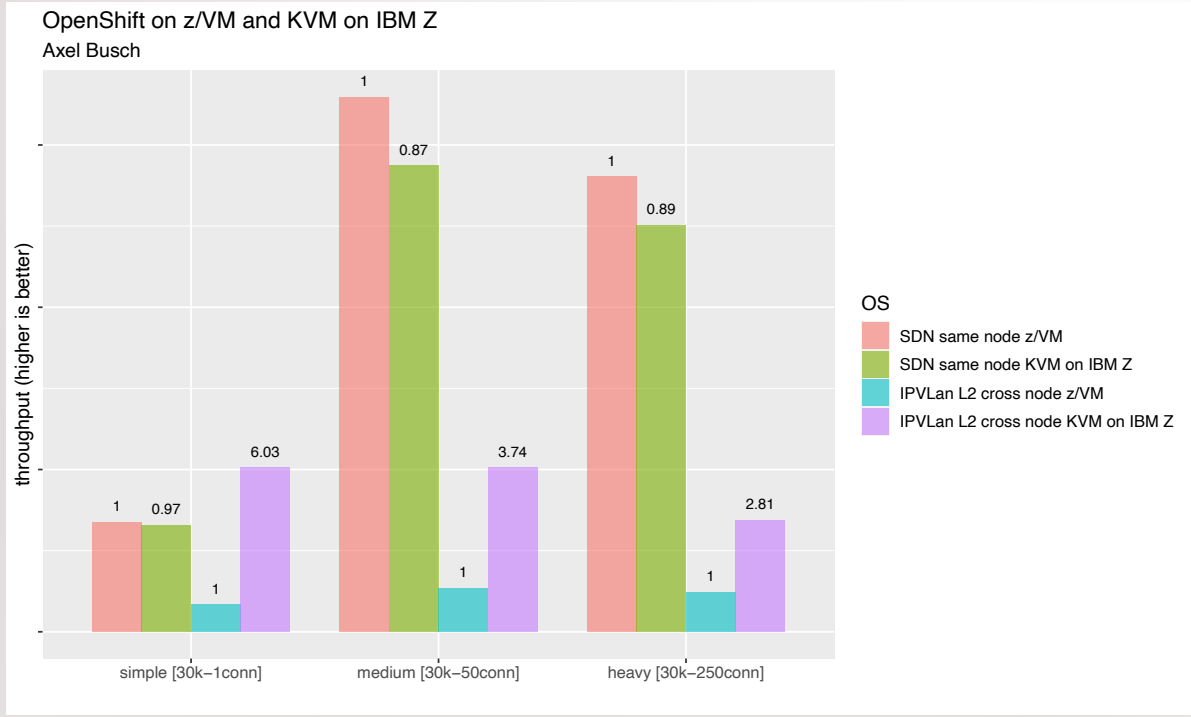
- No winner, more of a situational pro and con tradeoff
- Depending on your **deployment strategy** your decision might be in favor of z/VM or KVM on IBM Z

Let's see some values: z/VM vs. KVM on IBM Z – latency and throughput

latency

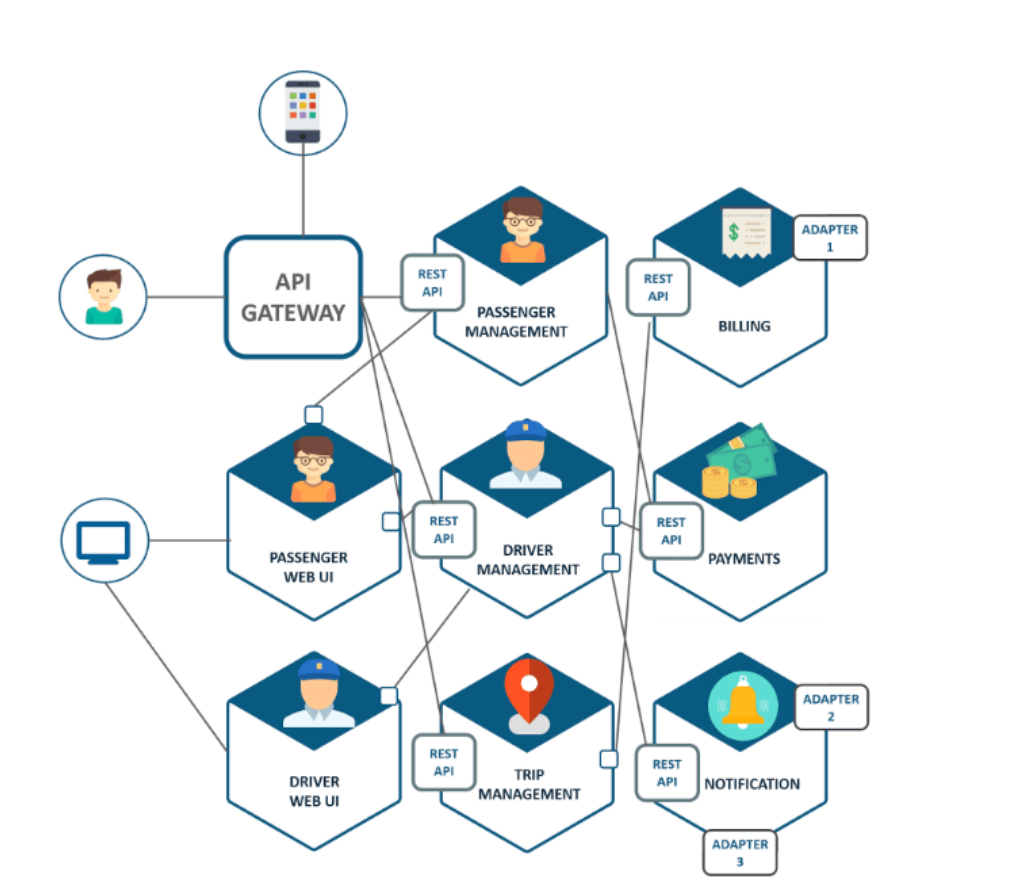


throughput



- When it comes to latency the numbers might not differ a lot
- Relevant if maximum performance should be obtained or long service chains lead to long service response times
- However, **latency can add up quickly** and must be multiplied by the **number of interactions** between pods

Example: Uber passenger Web UI

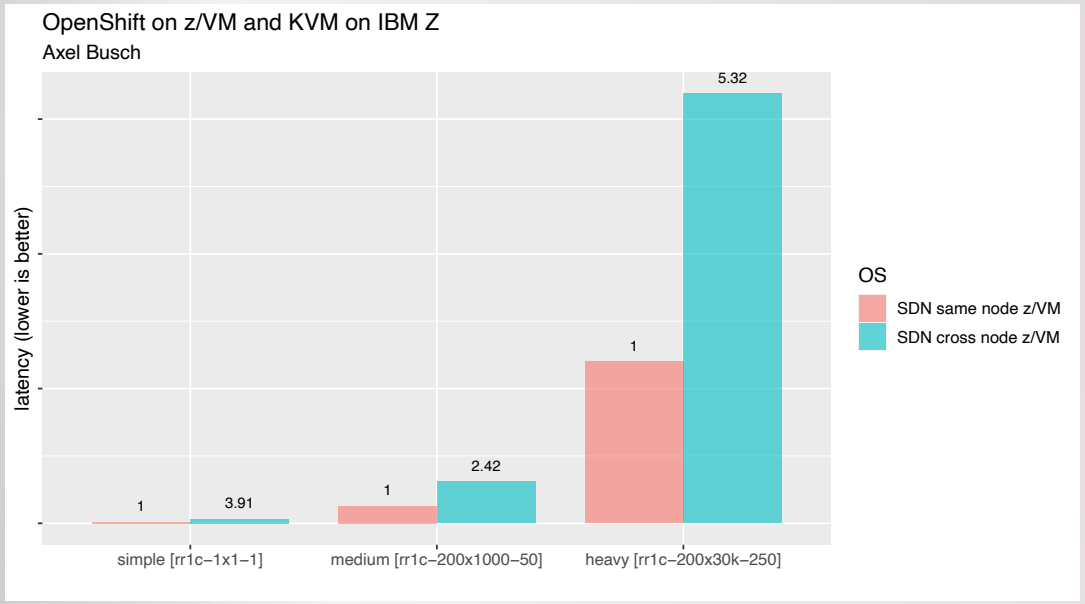


https://blog.dreamfactory.com/microservices-examples/

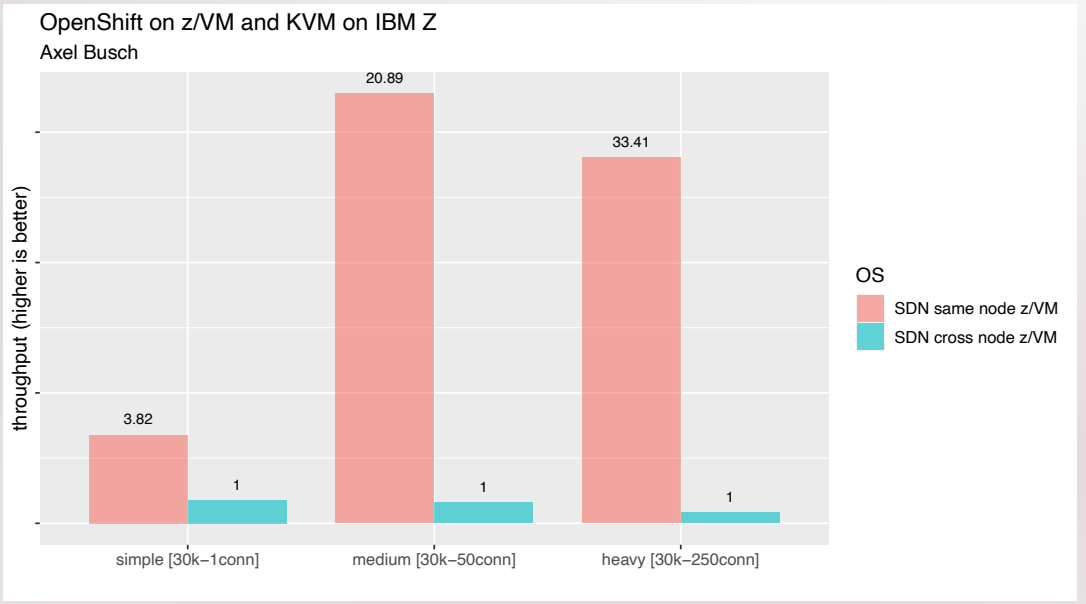
Let's see some values: same node vs. cross node deployment - latency & throughput

- Default-SDN
- No Multus CNI Plugin used
- RFS off
- **Focus on deployment**

latency



throughput

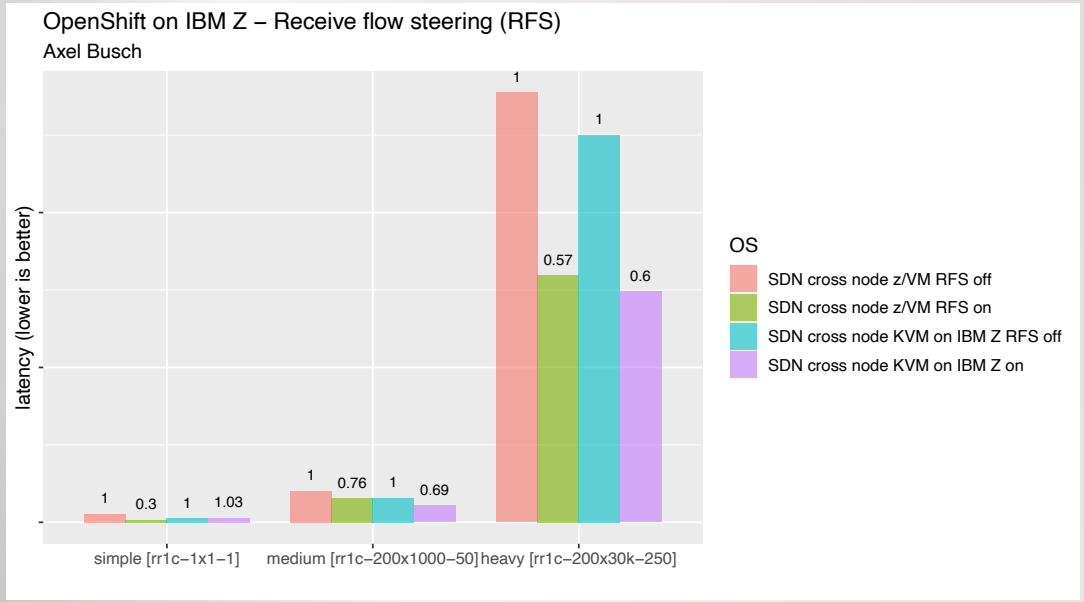


- Deployment of pods transferring data is crucial for the resulting service performance
- **Latency can go *up* to 5x-6x** comparing same node and cross node scenarios
- **Throughput can go *down* to 3%** comparing same node and cross node scenarios

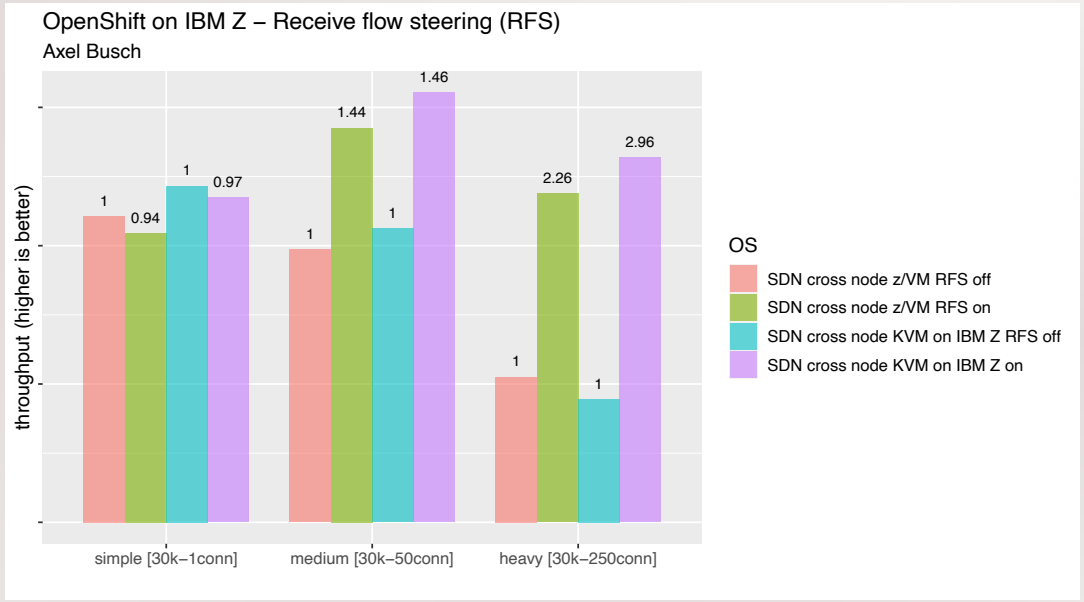
Network tunings: Receive flow steering on/off

- Especially beneficial in **non co-located scenarios**
  - Latency up to factor 3.33x better
  - Throughput up to factor 2.96x better
- Benefit especially for **medium and large** number of parallel **connections**
- For both, z/VM and KVM on IBM Z

latency



throughput



CNI Plugins: Default-SDN vs. IPVLAN vs. Host-device

- **Cross node** deployment
- With the exception of streaming workloads, both **IPVLan L2 and host-device are always better than Default-SDN**

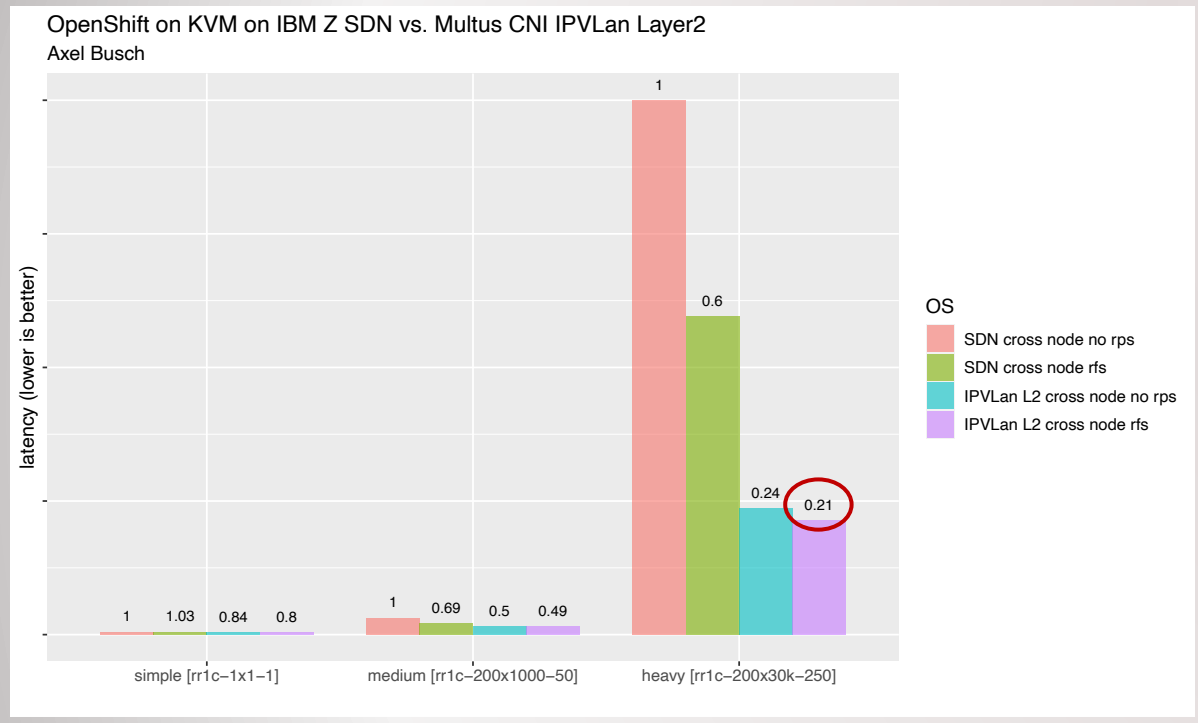
- IPVLAN vs. SDN performance:  11/15 cases

- host-device vs. SDN performance:  11/15 cases

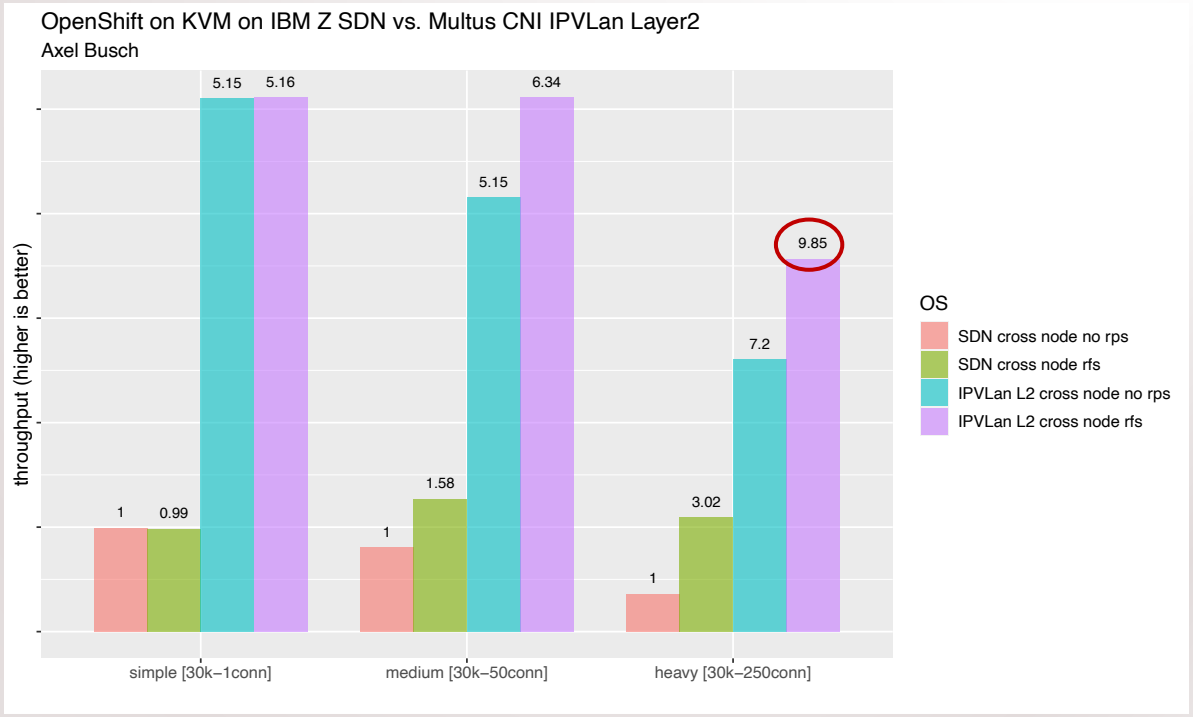
- IPVLan vs. host device?
- Usually prefer IPVLan L2 except for some scenarios.
  - **Host device** can show great performance in cases with **many connections and large packet sizes**
  - **Host device can be much more efficient compared to Default-SDN as well as IPVLan L2**
  - On KVM on IBM Z **host device shows up to 8** times more efficiency **compared to Default-SDN**
  - On KVM on IBM Z **host device can show up to 3** times more efficiency **compared to IPVLan L2**

Let's see some values: Default-SDN vs. IPVLan L2 – latency & throughput

latency



throughput



- IPVLan L2 especially beneficial in **non-colocated scenarios**
- Useful for selected pods with **high networking performance requirements**

- **Latency** improvement up to **factor 5x** (relative to SDN performance)
- **Throughput** improvement up to factor **9.85x** (relative to SDN performance)

Guideline: How to decide what to choose?

- Some ideas for **default values**:
- Low maintainance overhead
- Low-moderate networking load
- No high latency critical services
- Small chain of services

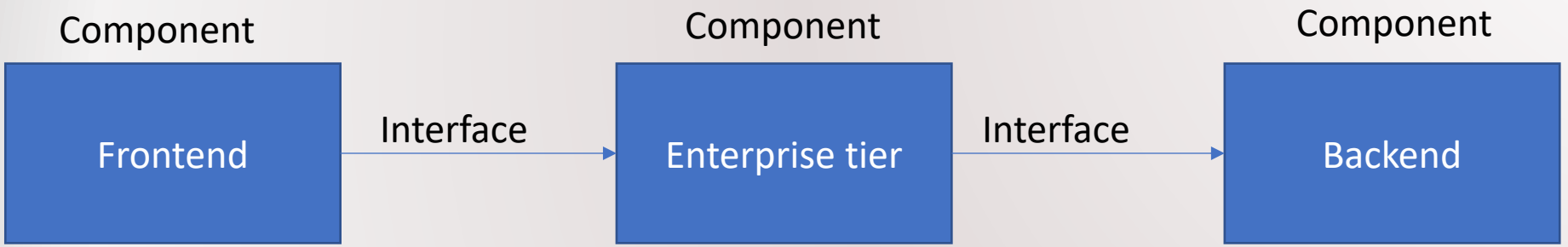
Use OpenShift-SDN (default), turn RFS on and use 2-3 infra nodes

- For other requirements such as long service chains or high networking load use scenario-based tuning ideas
- **Focus on technologies** may be **too imprecise** for own application purpose.
- Nevertheless, important to understand impact on performance and efficiency
- **Used as a basis to make right decisions** regarding project **requirements**

Consider scenario-based tuning ideas in addition

Scenario-based networking performance tuning ideas

Architecture-Style: Service-oriented Architecture

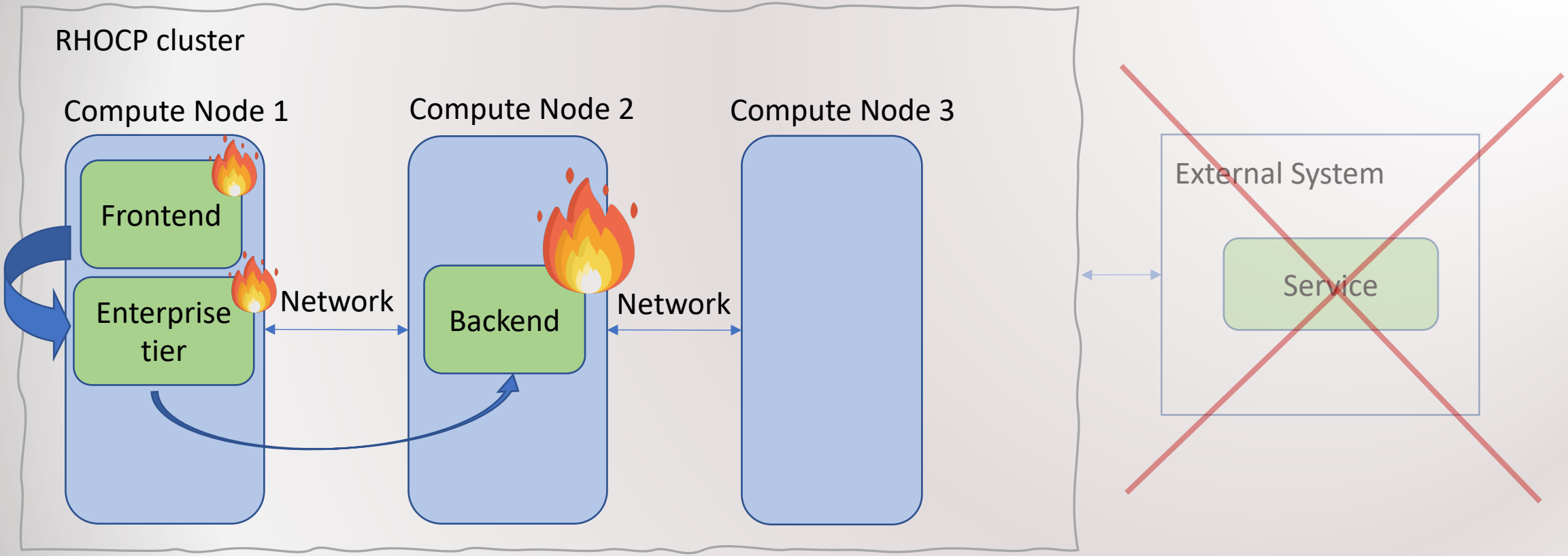


- WebGUI
- Business API
- API (for m2m queries)

- User Authentication
- Business processes
- Business logic
- Presentation logic
- ...

- Database
- Data access objects
- Data Persistency
- ...

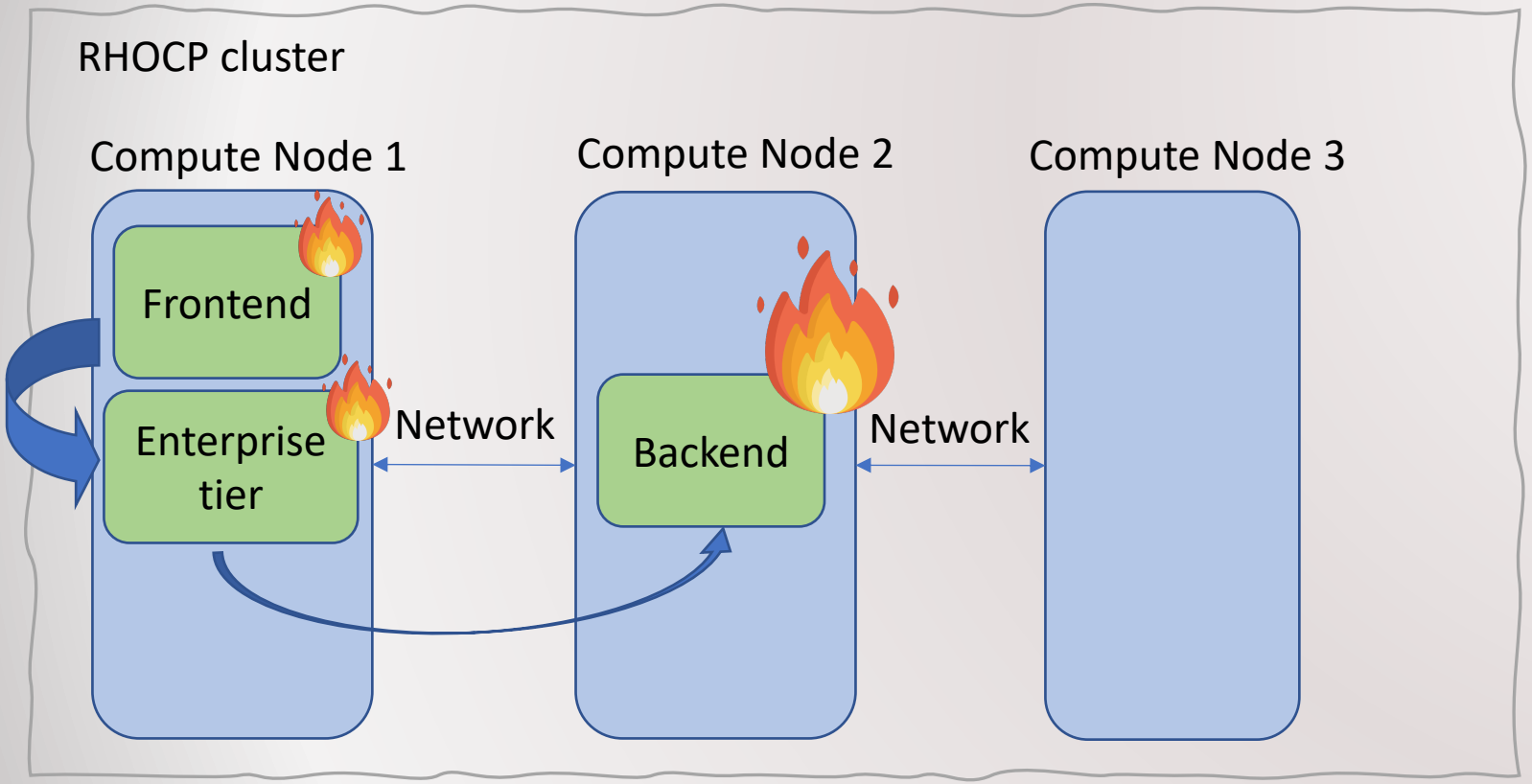
Scenario I: Low database intensive & no external (legacy) systems involved



Assumptions:

- Frontend and Enterprise tier **communicate frequently**
- Enterprise tier and Backend **do not communicate frequently**
- Backend has quite high CPU/memory requirements -> needs to be on worker with enough free resources
- **No external service required**

Scenario I: Focus on frontend & enterprise pod performance and backend CPU demands



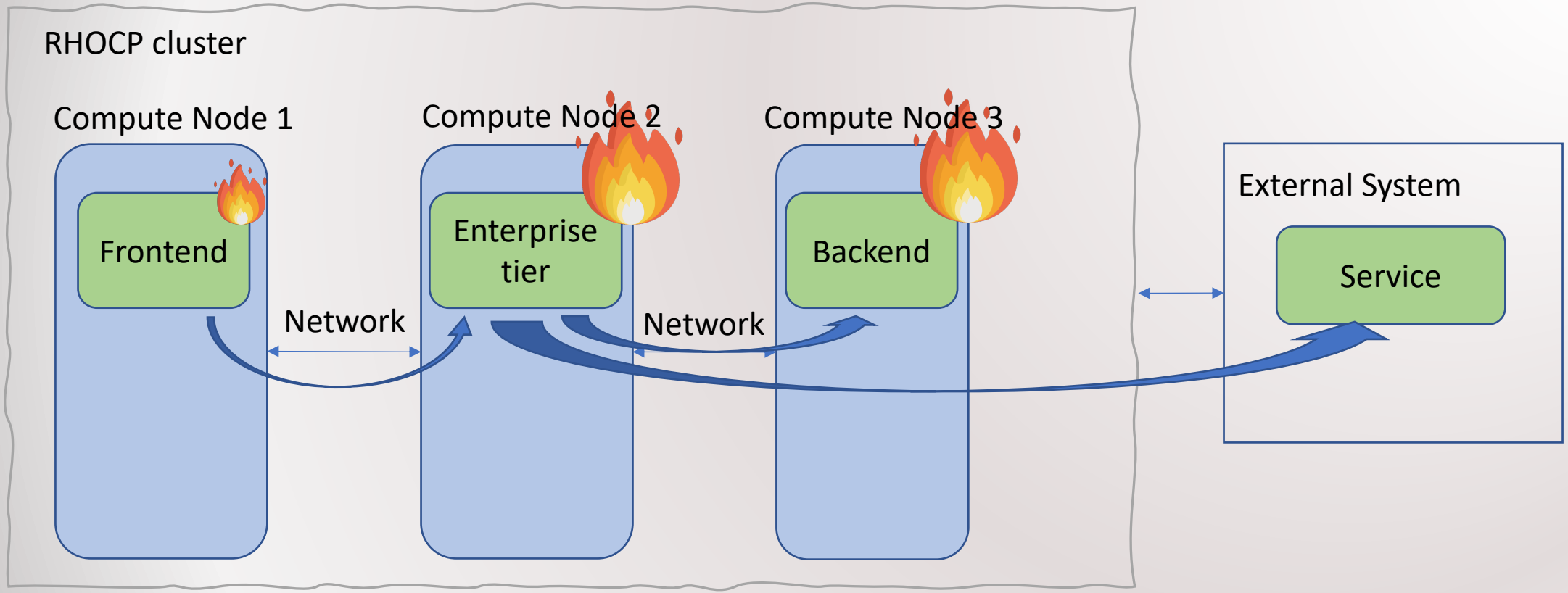
For frontend to enterprise tier:

- Use **SDN** for their communication as **fastest and most efficient** way
- z/VM more efficient and faster than KVM

For enterprise and backend:

- Use **IPVLan Layer2 especially to get best latency**
- With degradation in throughput and latency SDN can be used
- For higher efficiency, better throughput and latency **enable RFS**

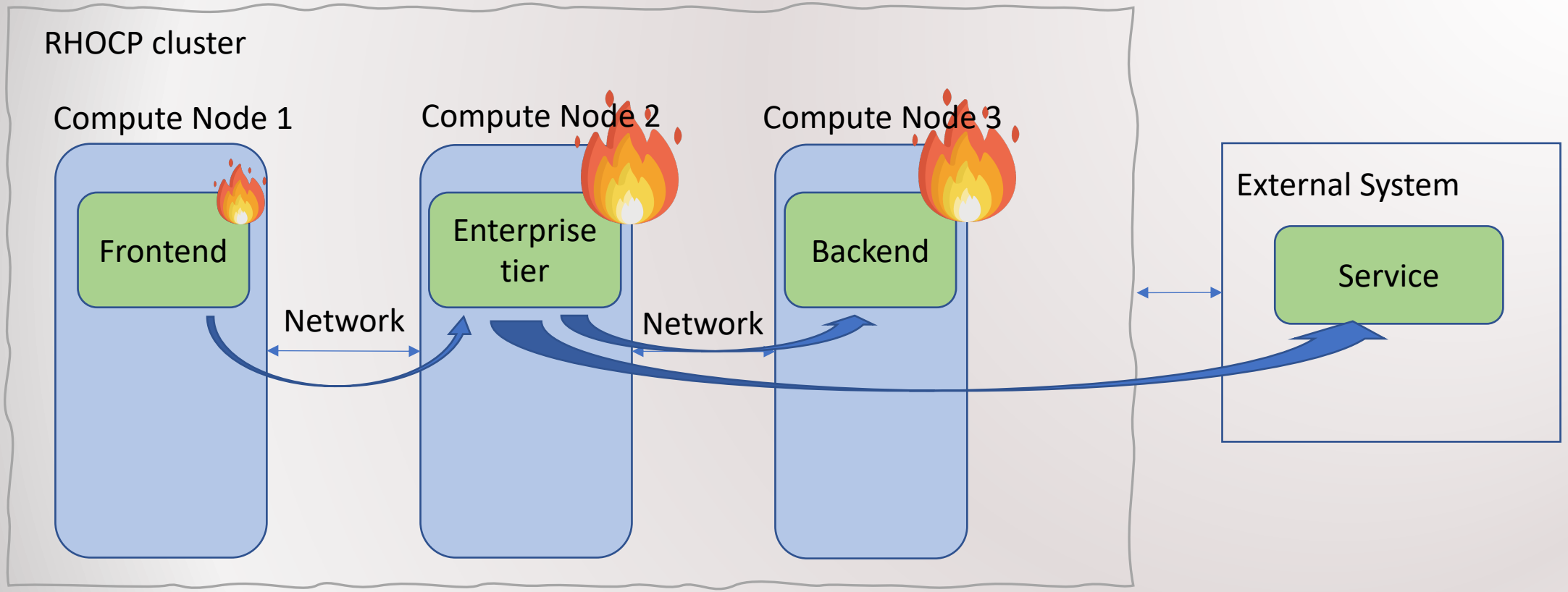
Scenario II: Highly database intensive & external (legacy) systems involved



Assumptions:

- Frontend and Enterprise tier do **not communicate** in a significant manor
- Enterprise tier and Backend **do communicate frequently (high throughput)**
- **Backend and external service communicate latency as well as throughput critical**
- Backend and Enterprise have quite high CPU/memory demands

Scenario II: Highly database intensive & external (legacy) systems involved

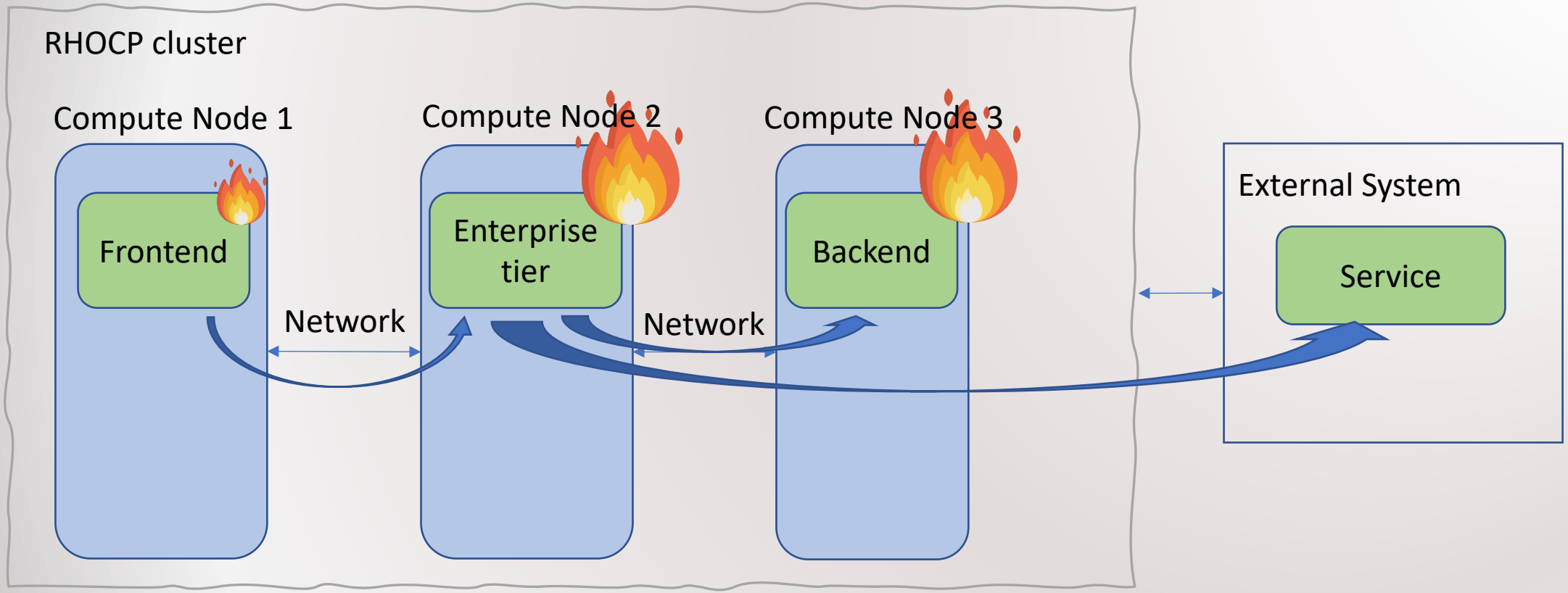


For frontend to enterprise tier:

- Use **SDN** if frontend uses just a few connections in parallel
- Use Multus **IPVLan Layer2 for many parallel connections** as second interface
- Use **RFS** in case of parallel connections (keep an eye on your CPU capacity)

- If **throughput is critical**
  - Deploy frontend and enterprise tier on same node (factor 3x-4x higher throughput possible)
  - Might require to add vCPUs to node 2

Scenario II: Highly database intensive & external (legacy) systems involved



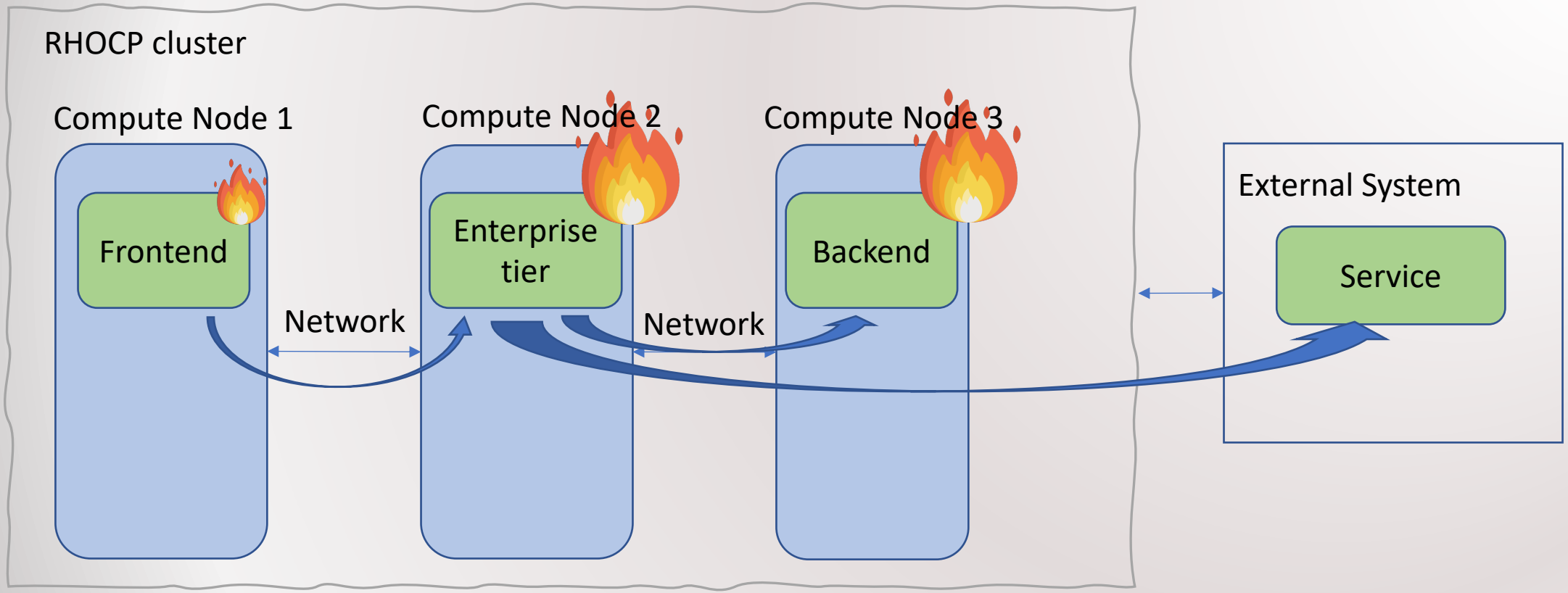
For enterprise tier to backend:

- Use Multus **IPVLan Layer2** as second interface
- Use **IPVLan Layer2 for many parallel connections**
- Use **RFS** (keep an eye on your CPU capacity)

For enterprise tier to external service:

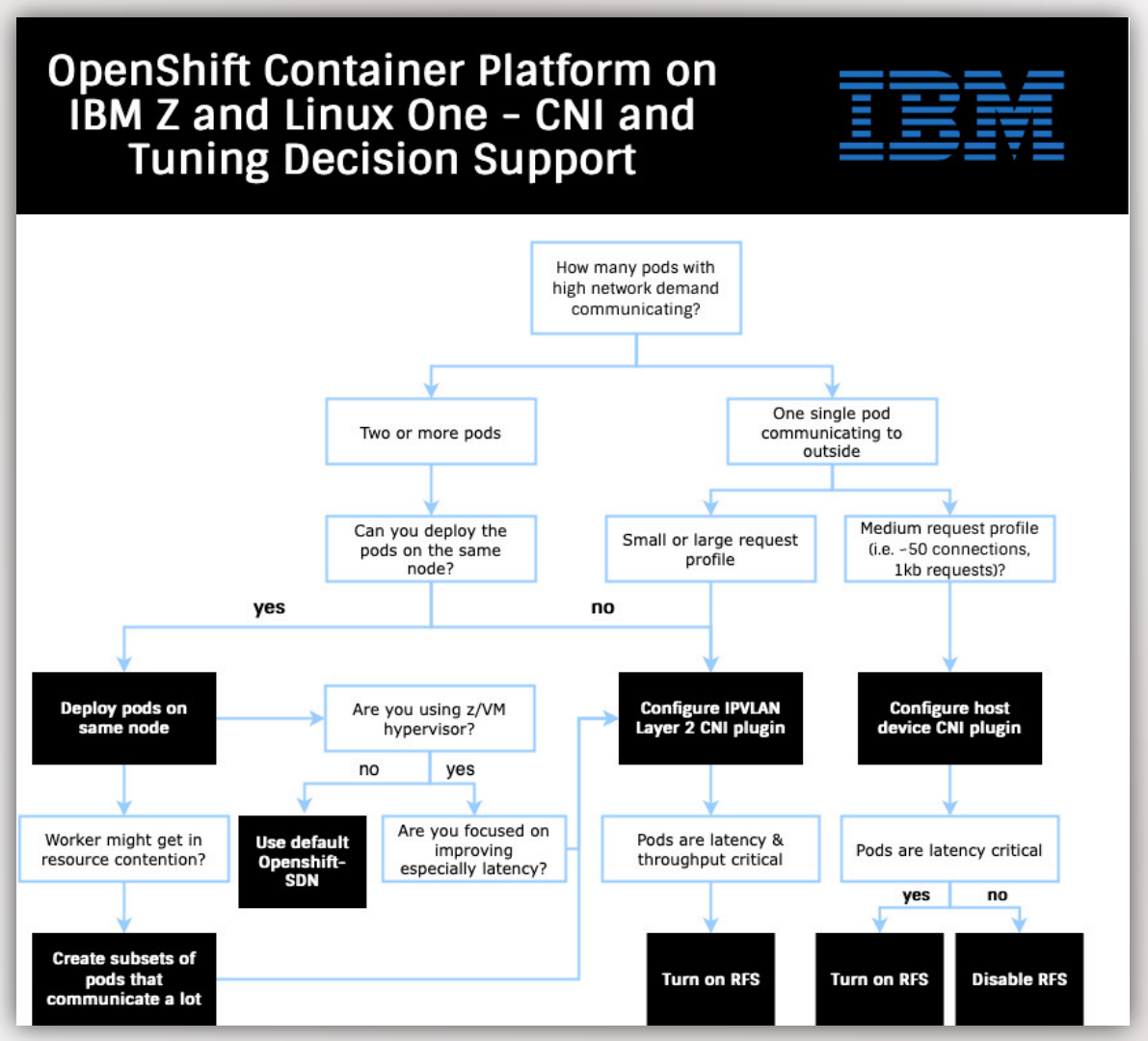
- Use Multus **host device** as third interface
- Use **IPVLan Layer2 for many parallel connections**
- Use **RFS** for many connections (keep an eye on CPU contentions)
- For only 50 connections switch RFS off

Scenario II: Highly database intensive & external (legacy) systems involved



- **Combination** of SDN, Multus IPVLan Layer2 and host device plugin **use different resources of the cluster as best as possible**.
- Highest possible throughput and lowest possible latency for particular pod requirements

Rules of thumb: When which technology/settings?



Summary & Takeaways

Summary

- Introduced the trade-off decisions to be done
- Outlined RHOCP networking architecture and how it works together with Multus CNI, how the plugings work and how they can be used
- General performance tuning ideas: When to use which CNI plugin and tunings
- Scenario-based tuning ideas for RHOCP tuning according to the individual workload and cloud environment

Take aways

- Multus CNI can be used to improve networking performance of RHOCP clusters
- Plugins show different performance attributes for different scenarios, e.g. deployment, workload, system setup
- Combination of plugins and tunings such as RFS, infra nodes must be defined according to the configuration of individual workload and cloud environment

Thank you!

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