Tackling Parallelization Challenges of Kernel Network Stack for Container Overlay Networks

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- OS level virtualization
- Lightweight

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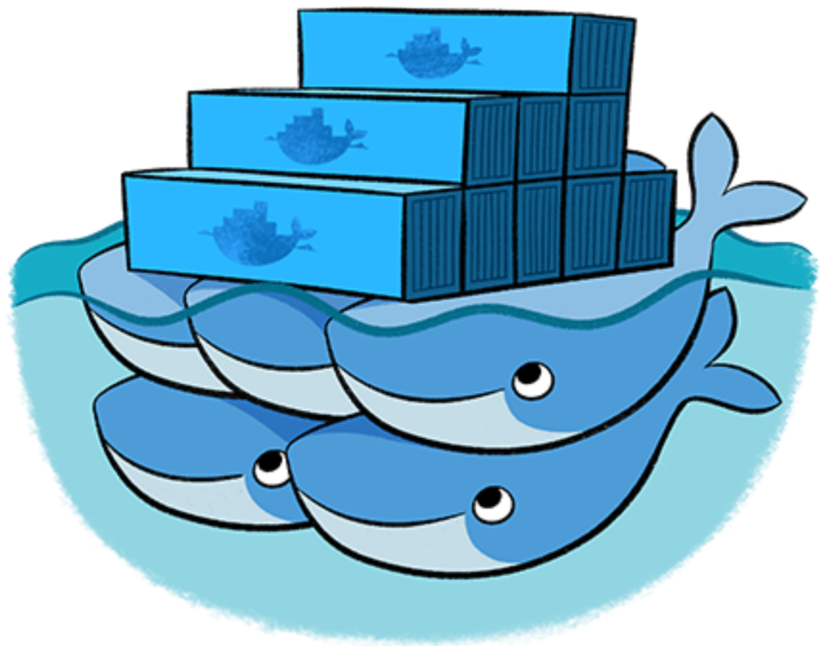
Overlay Networks Are the Technique For Containers Connectivity

- Typical overlay network solutions: Docker Overlay, Flannel, Calico, Weave
- They are generally built upon the tunneling approach like using **VxLAN** protocol.



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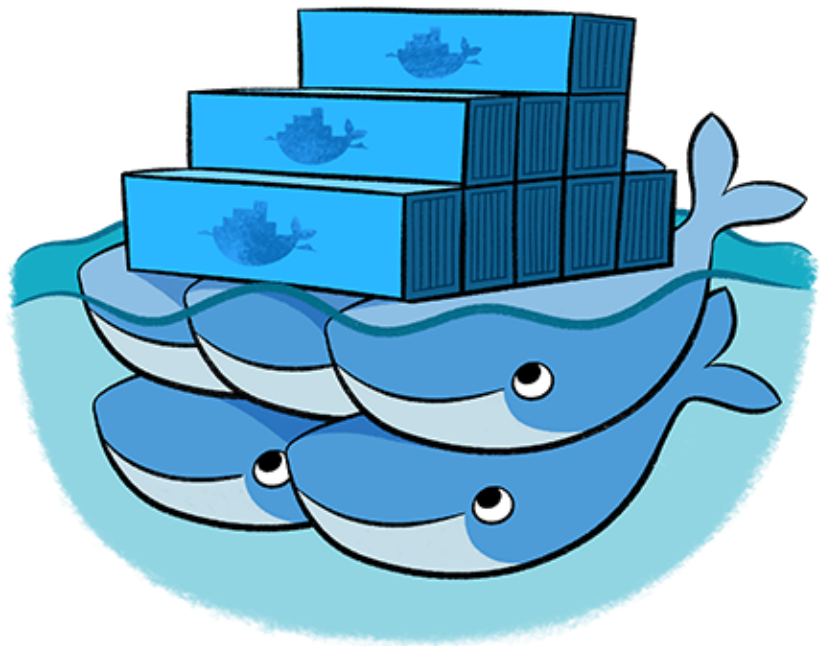

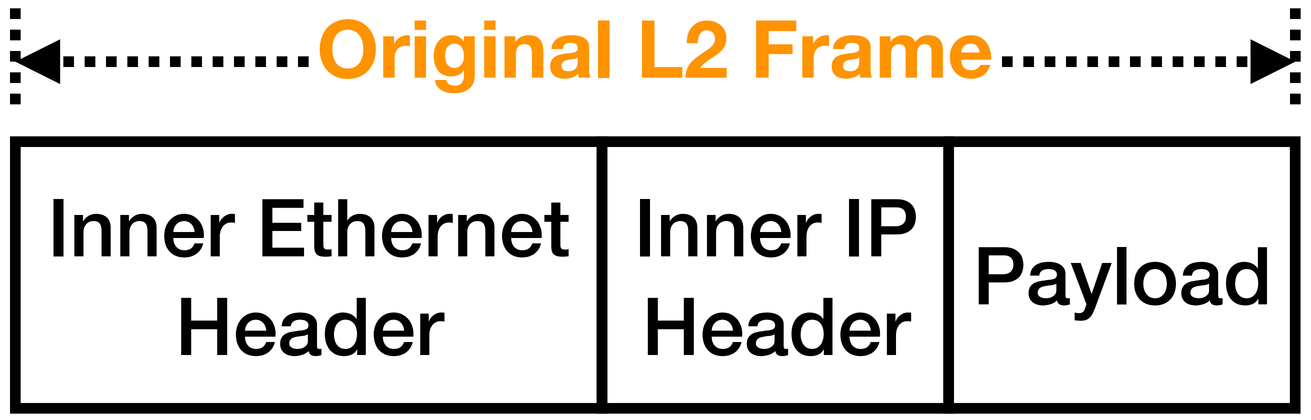

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VxLAN Encapsulated Packet

Original L2 Frame

Outer Ethernet Header	Outer IP Header	Outer UDP Header	VxLAN Header	Inner Ethernet Header	Inner IP Header	Payload	FCS

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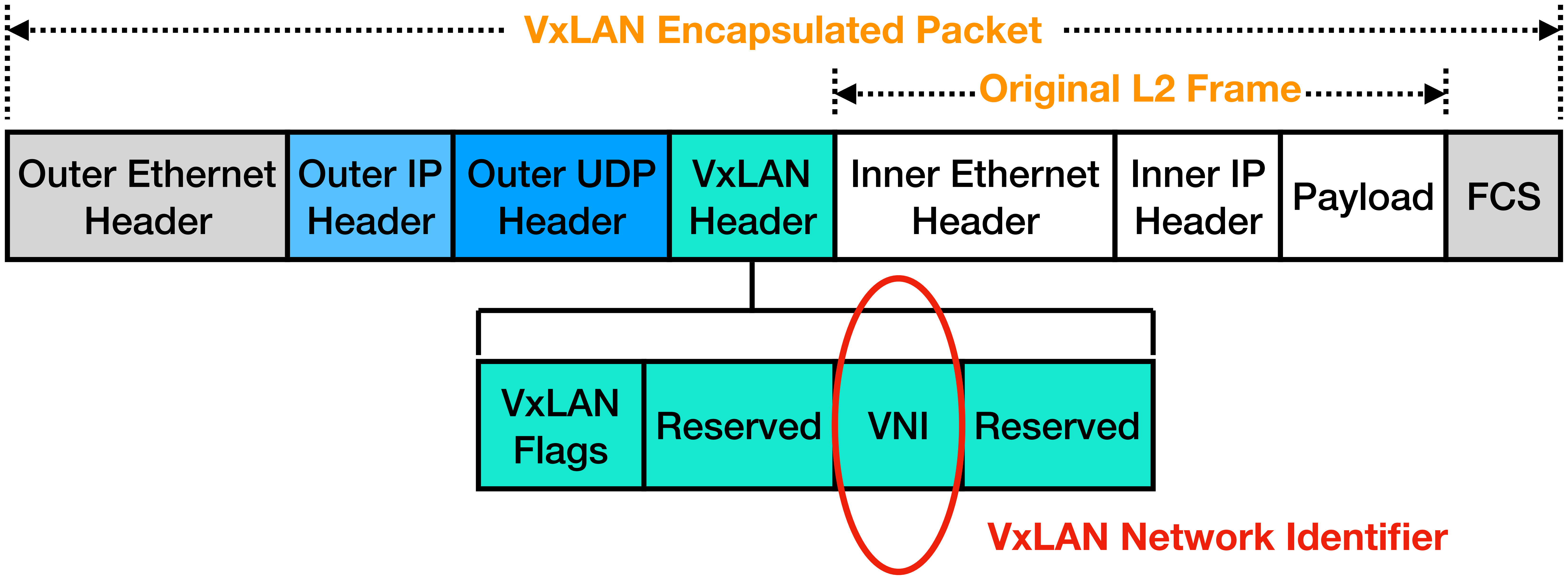

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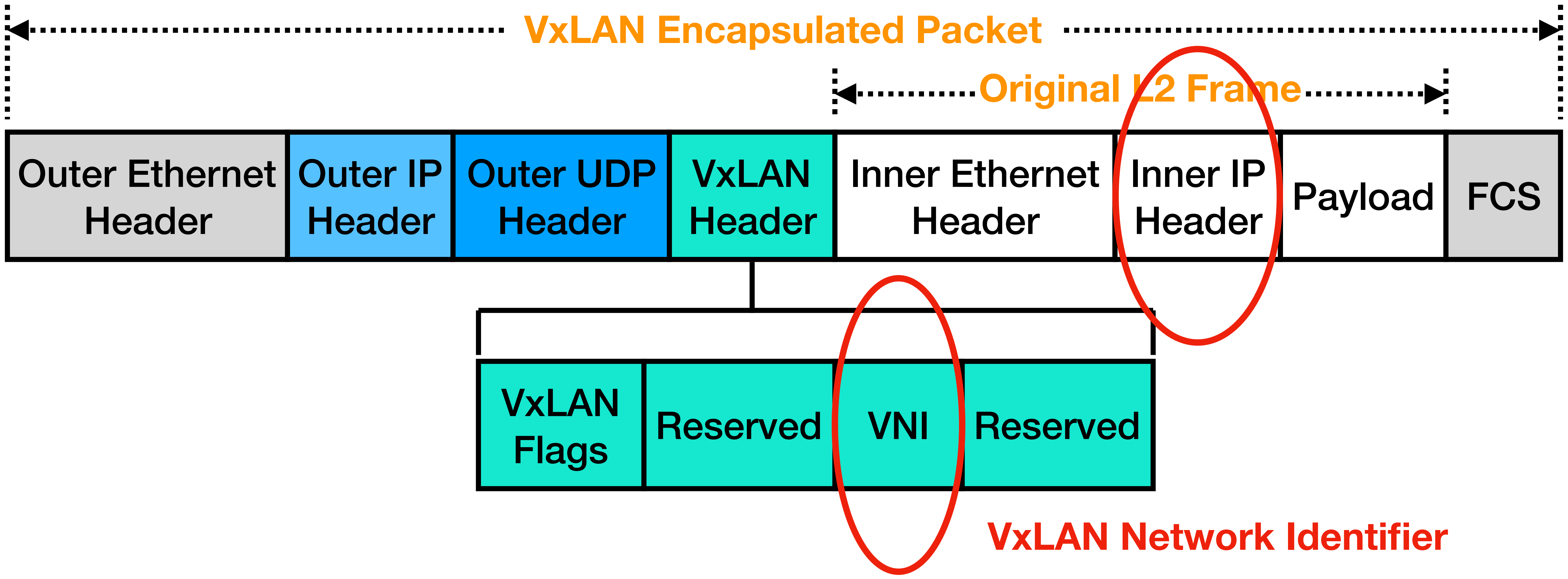

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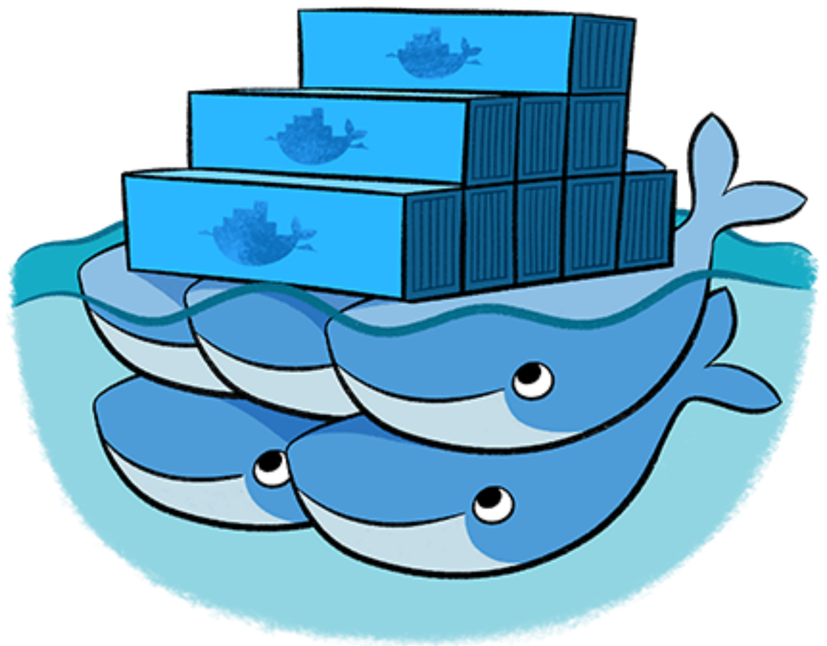

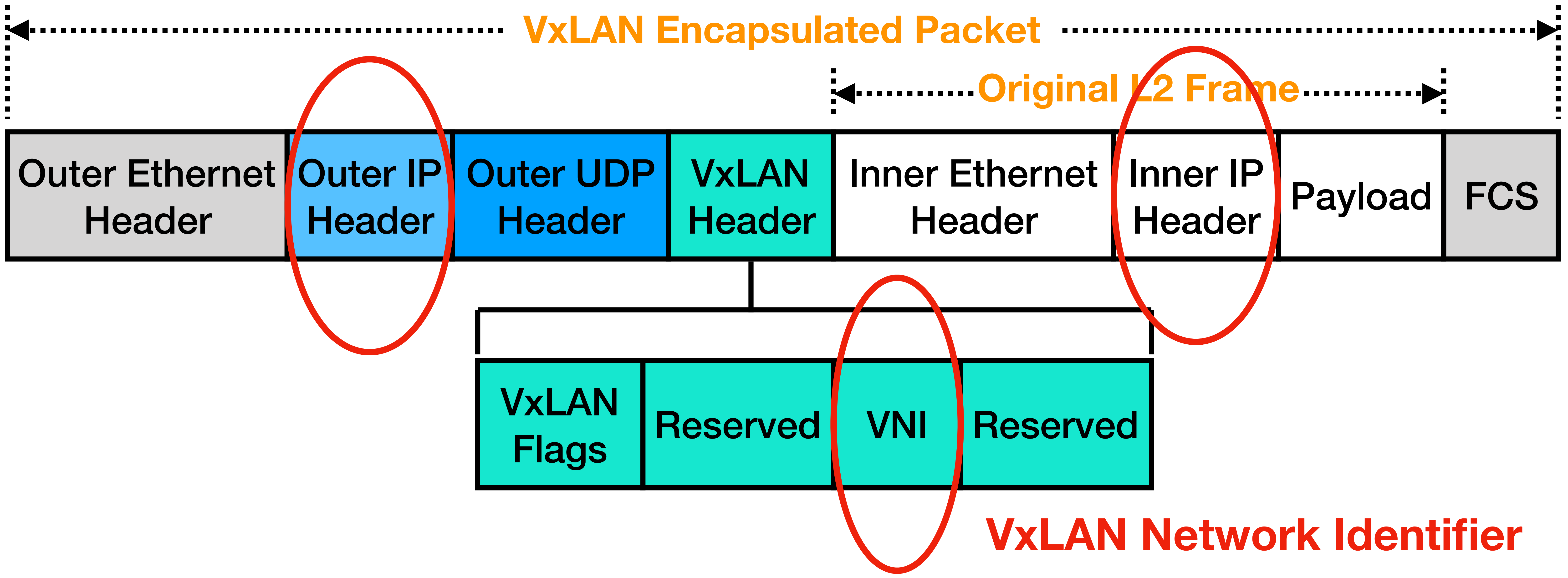

Network Packet Processing Path

- **Prolonged** network packet processing path
- **Additional** virtual devices overhead

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Receiving Side

Native

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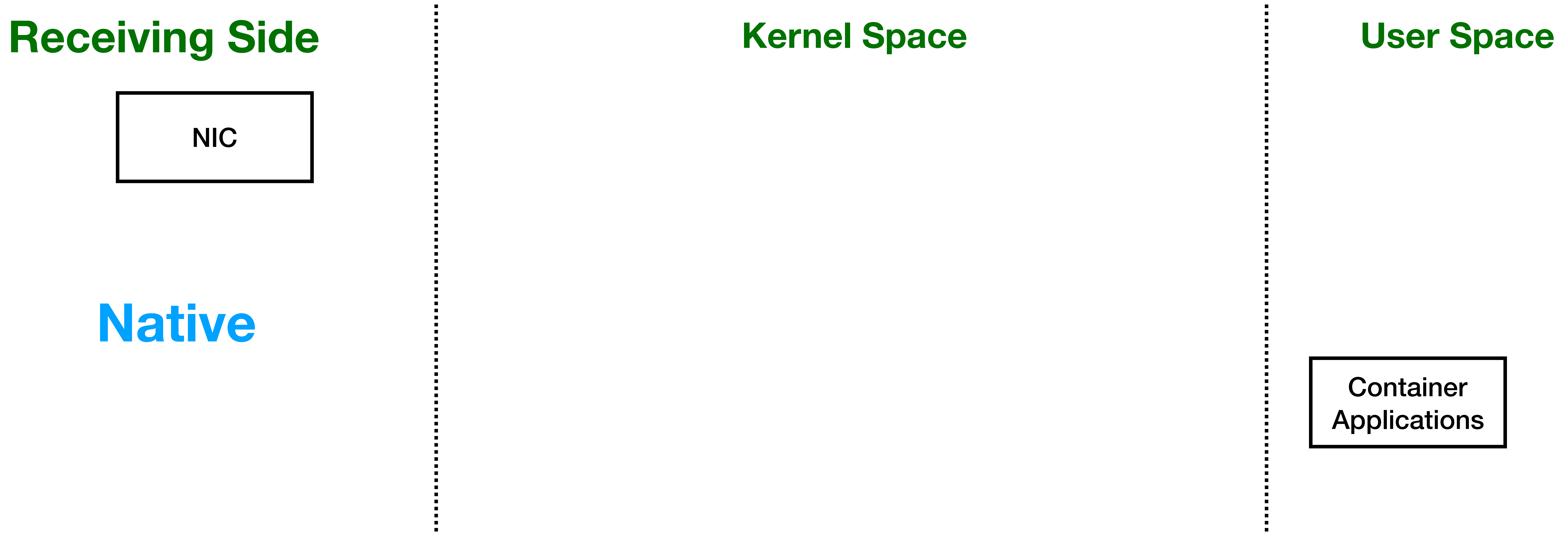

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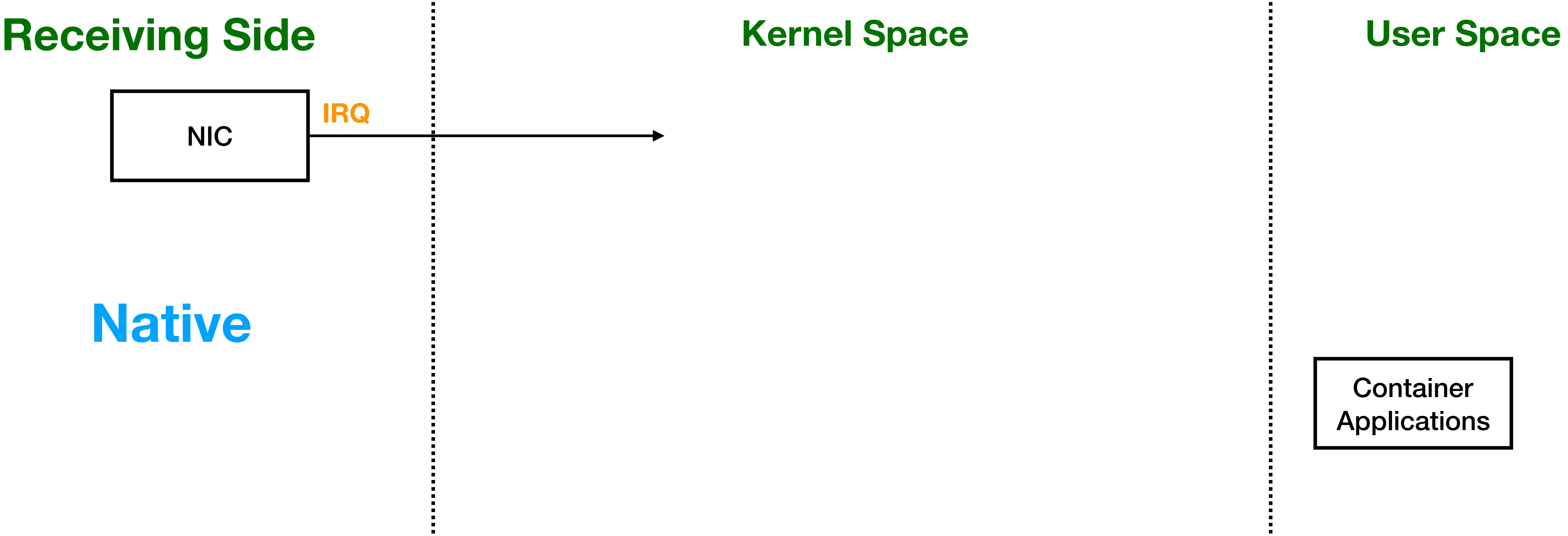

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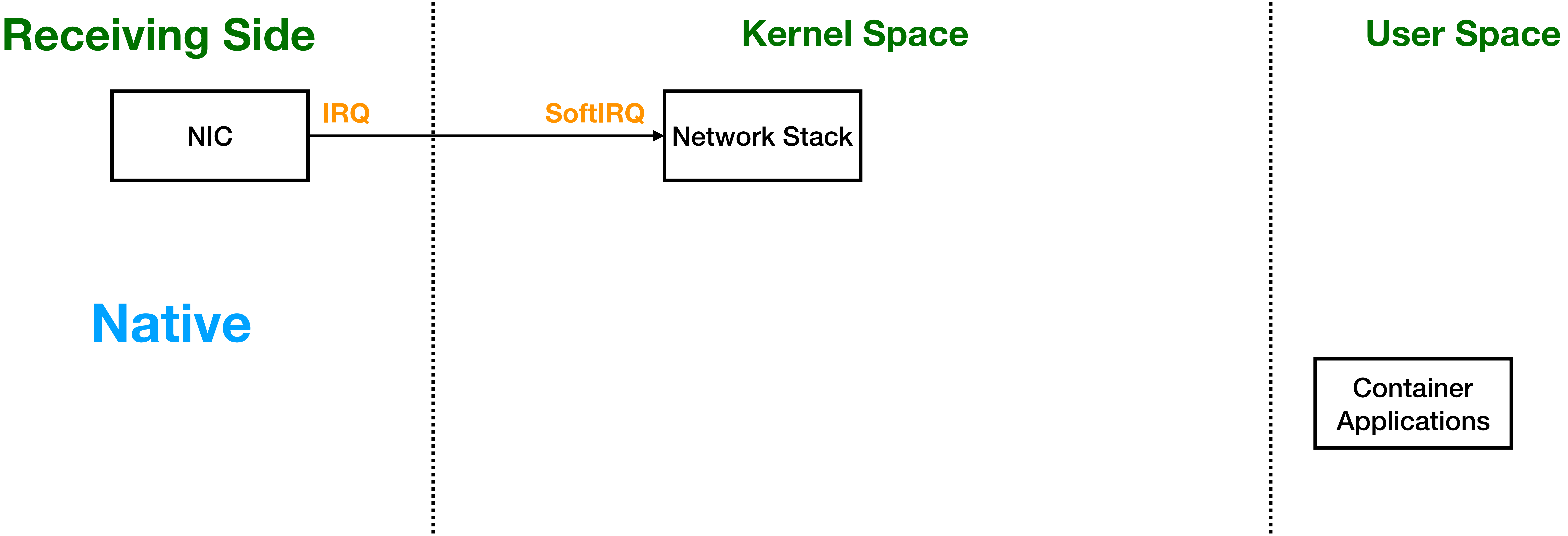

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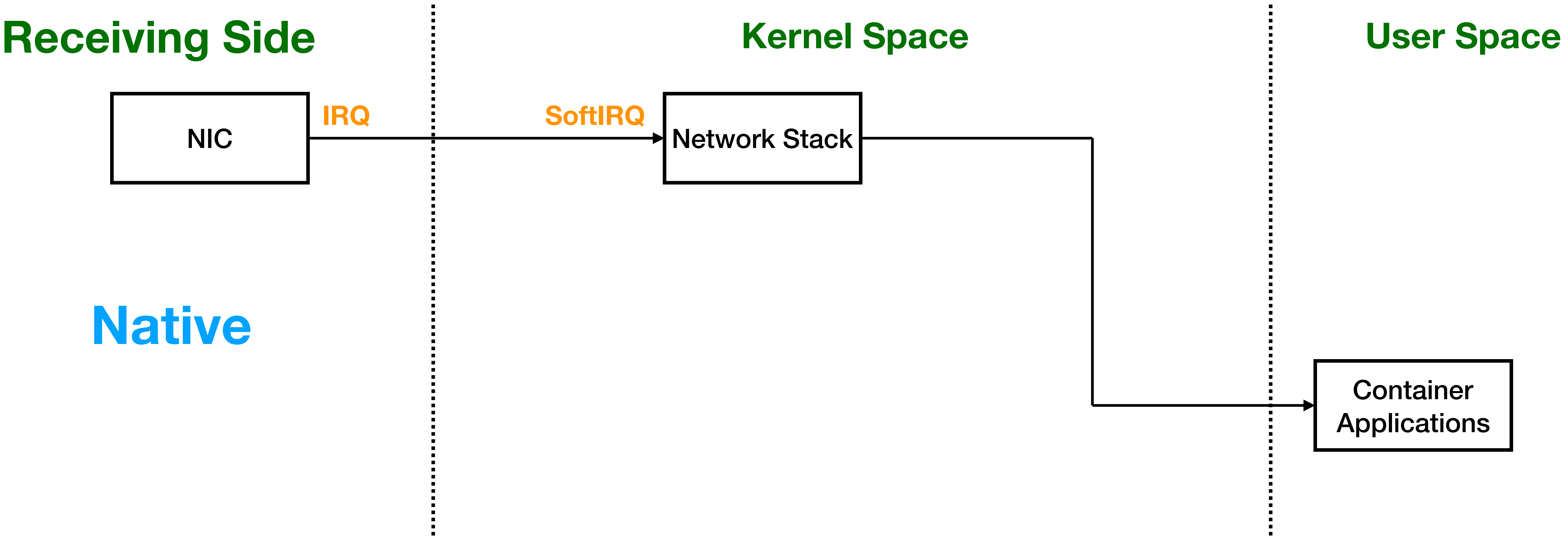

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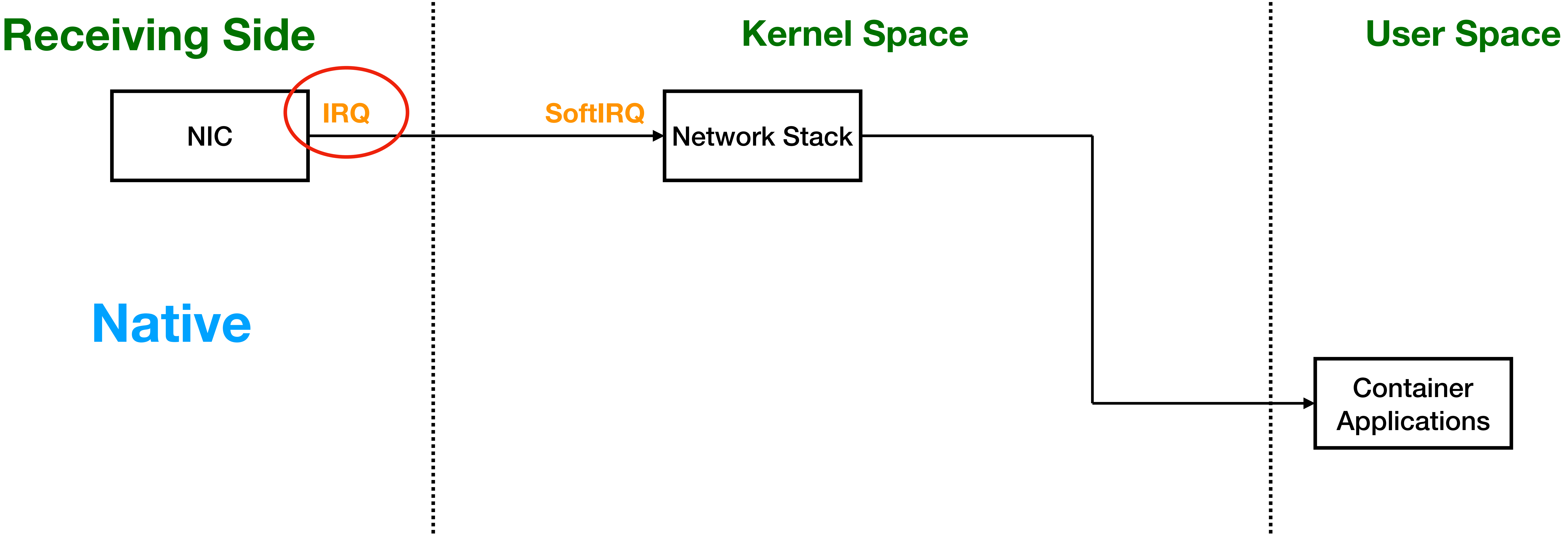

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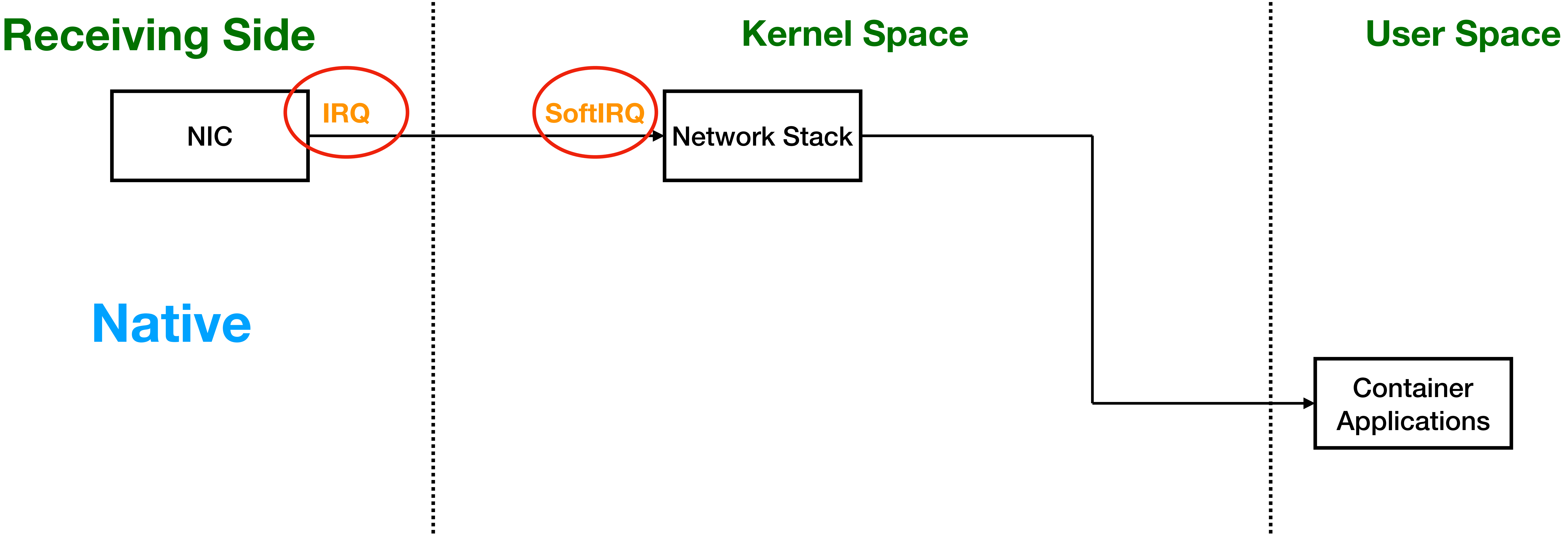

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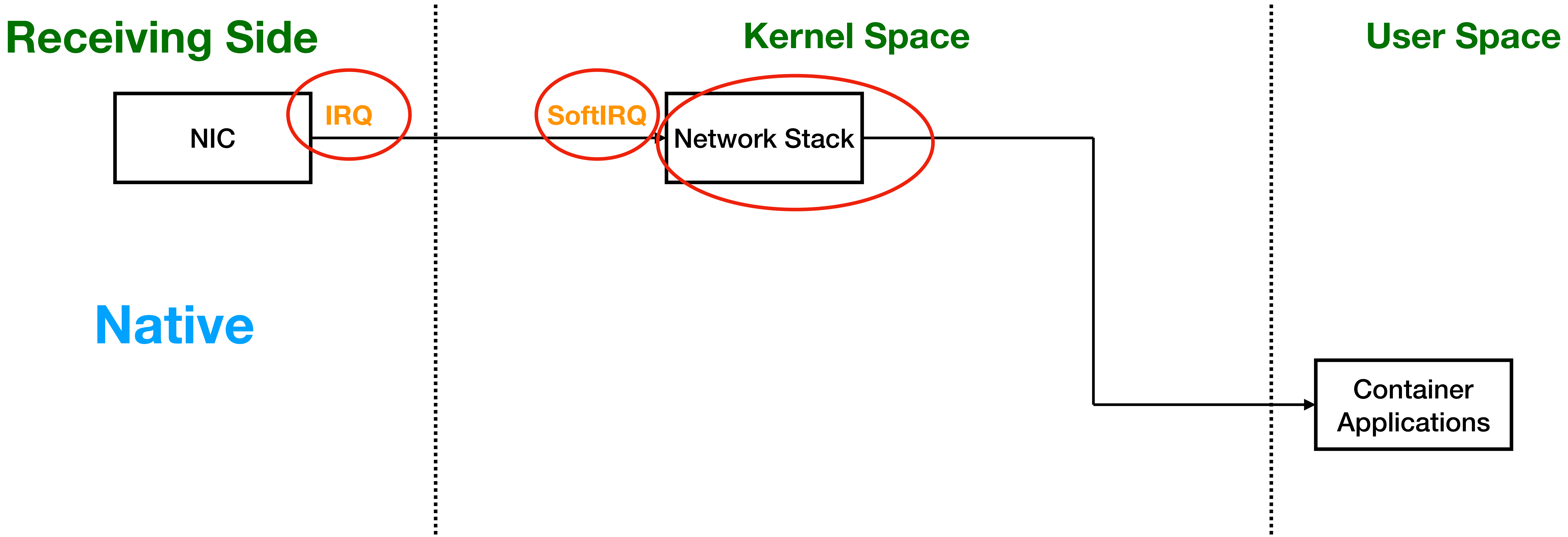

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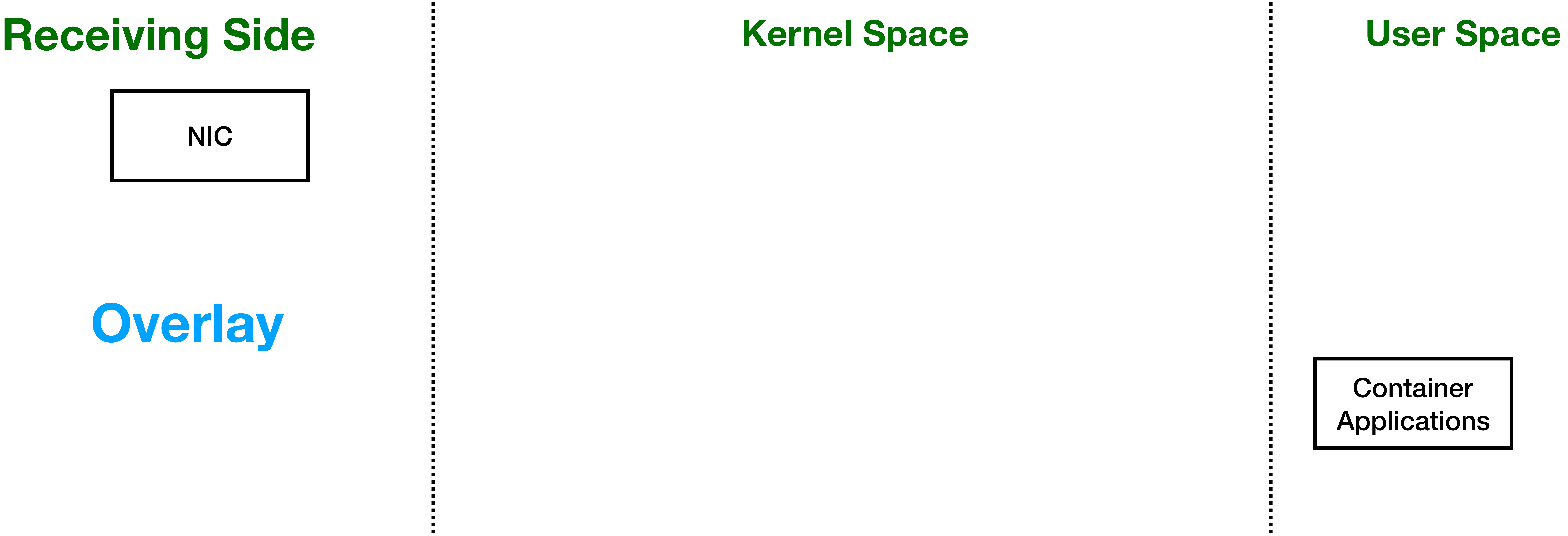

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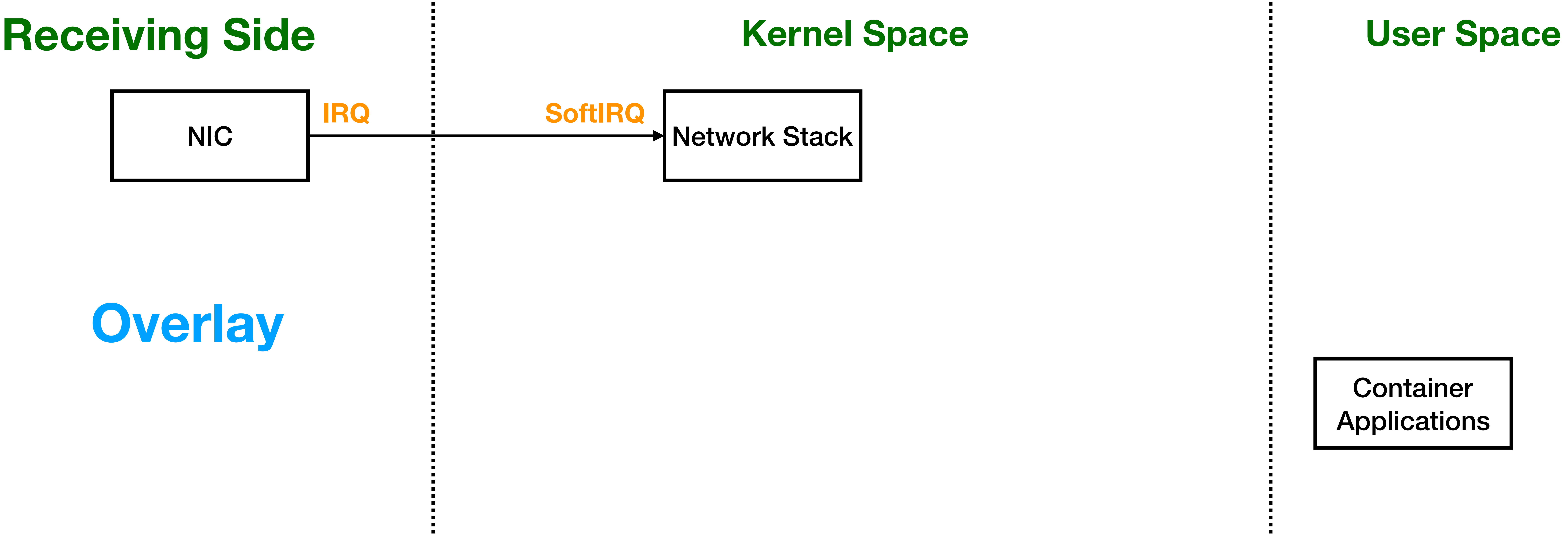

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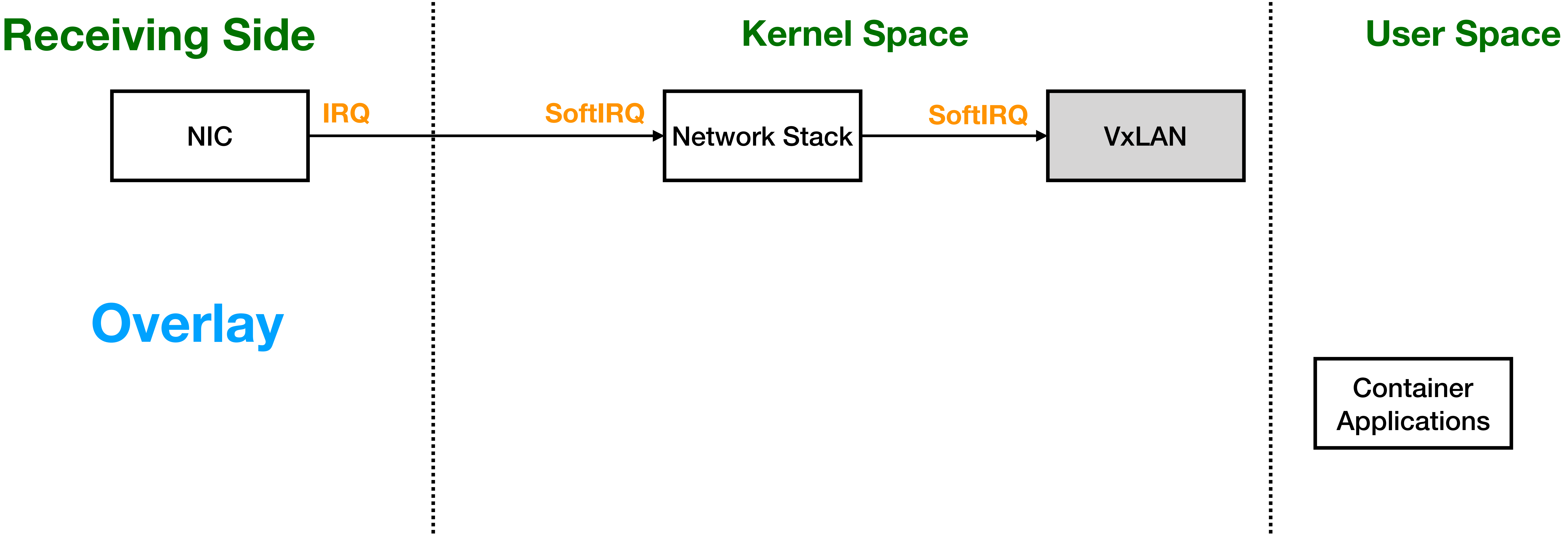

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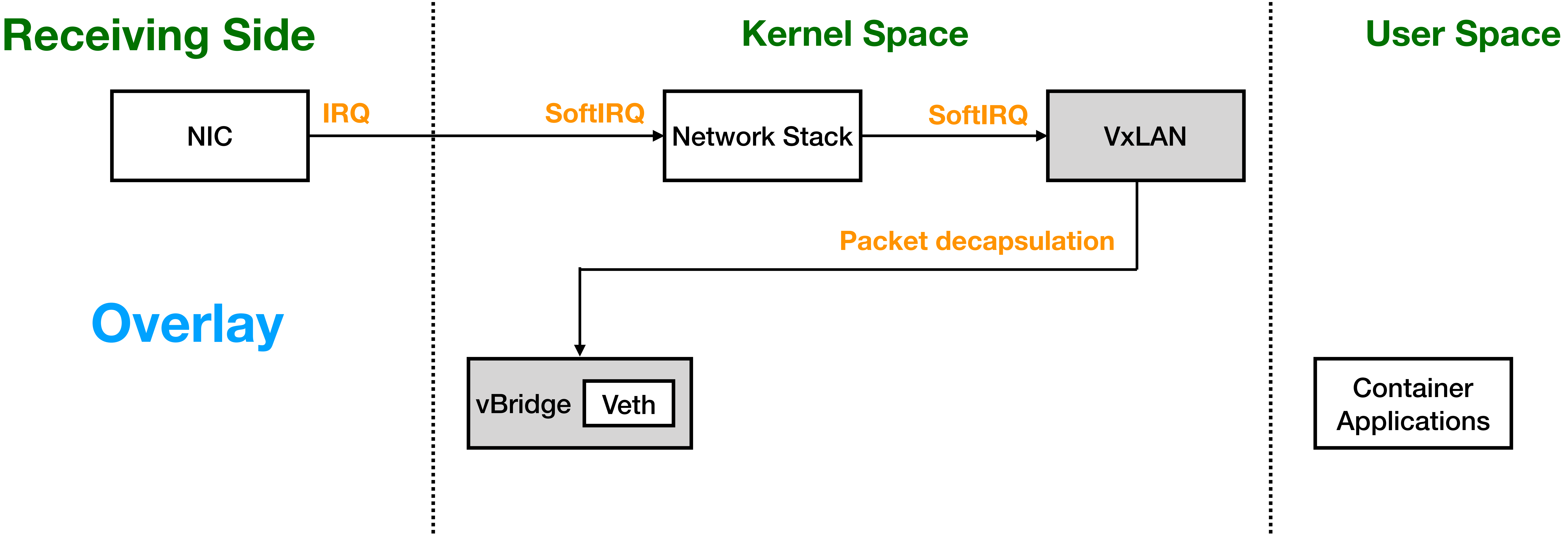

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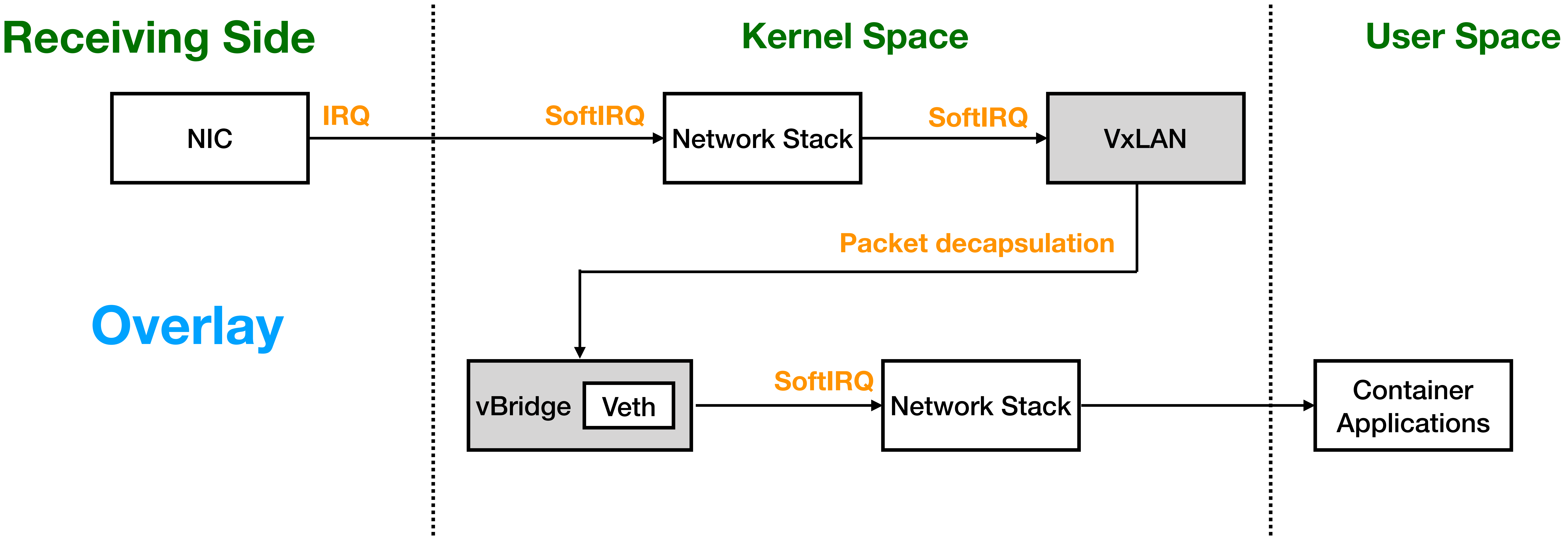

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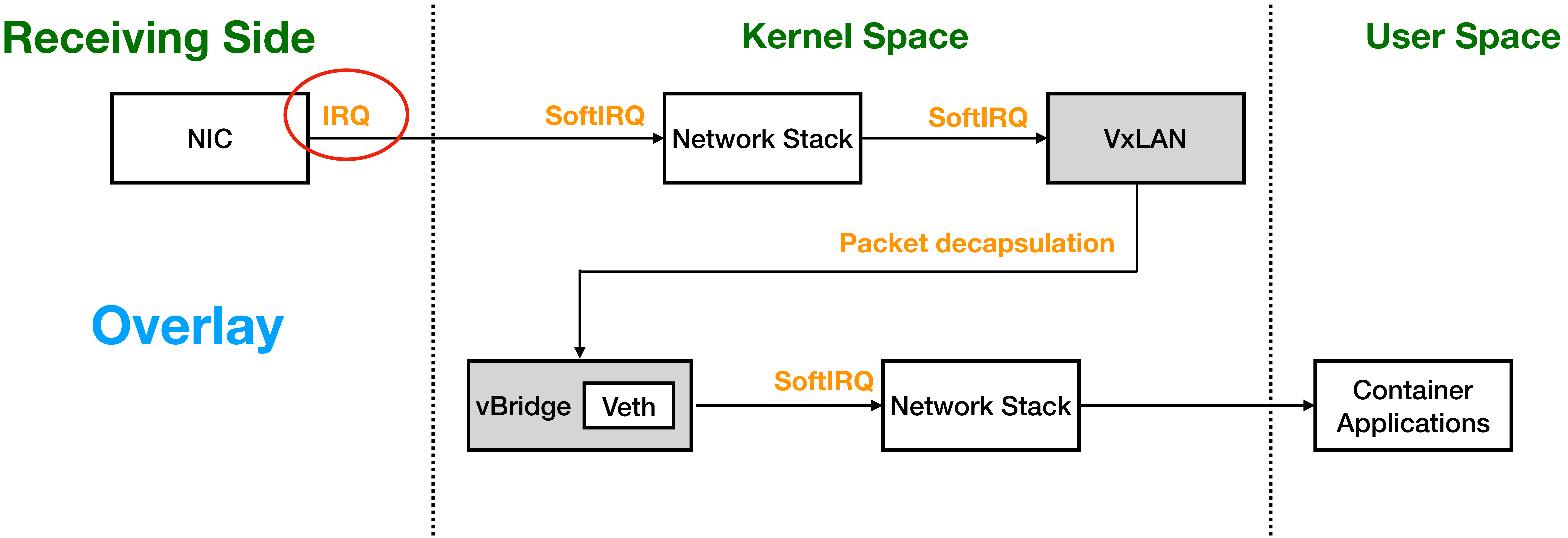

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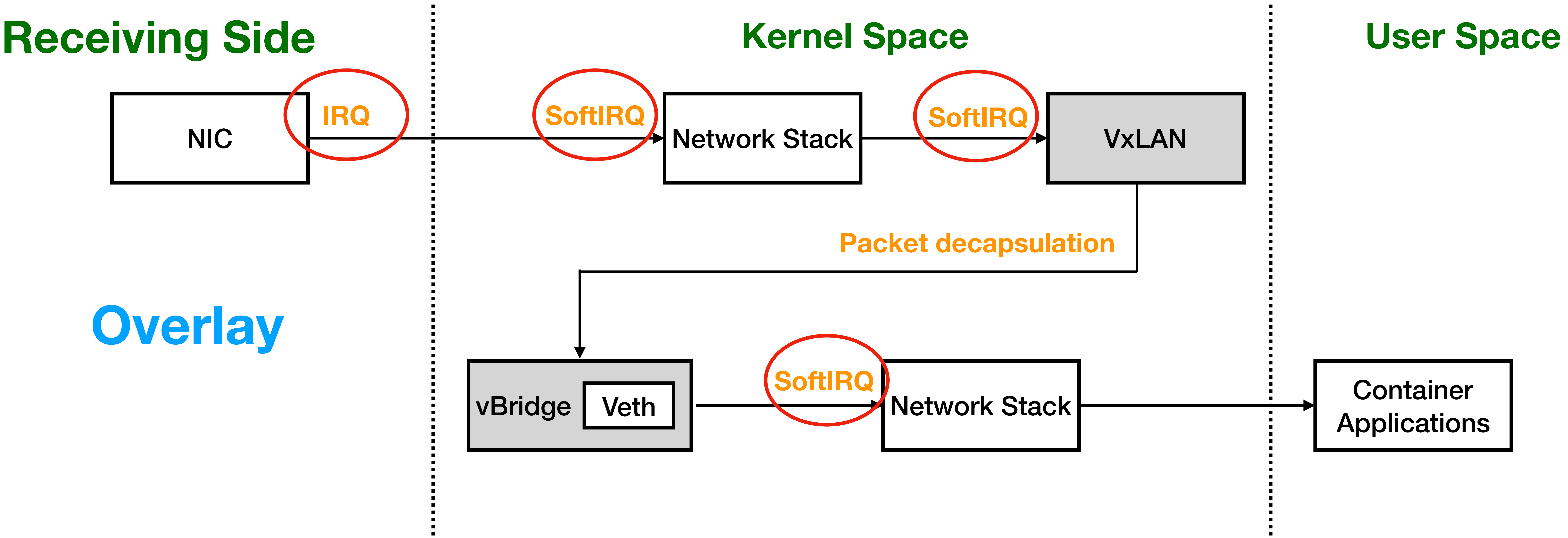

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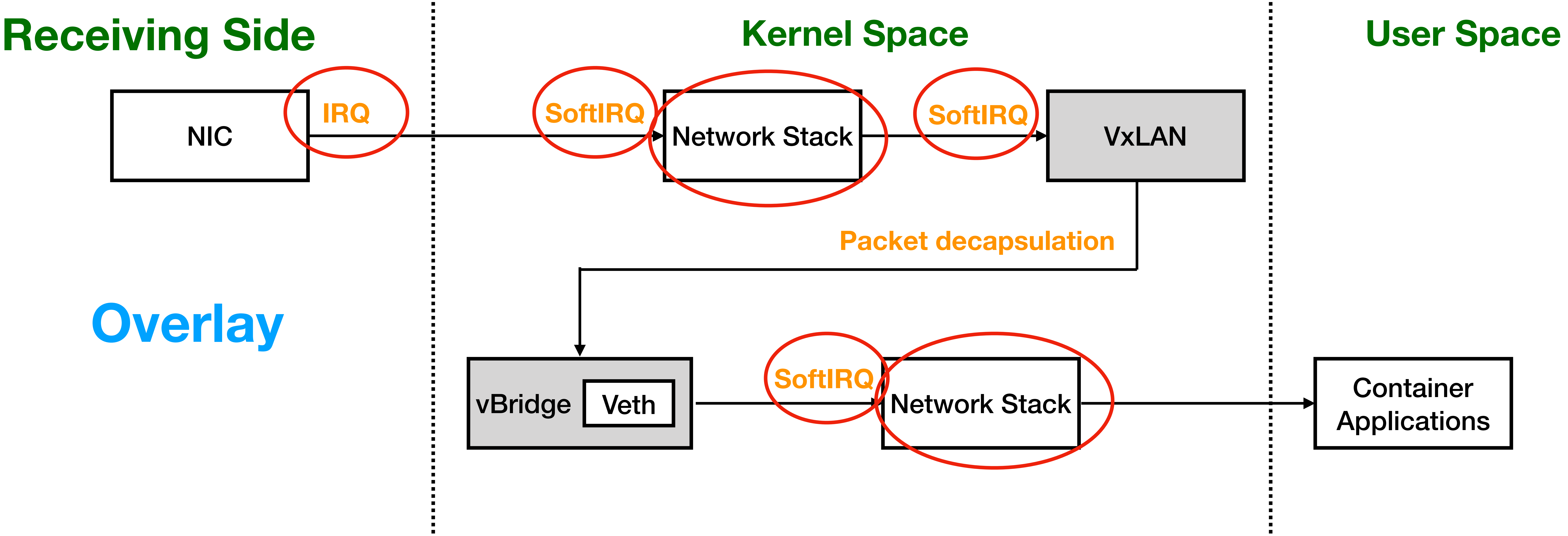
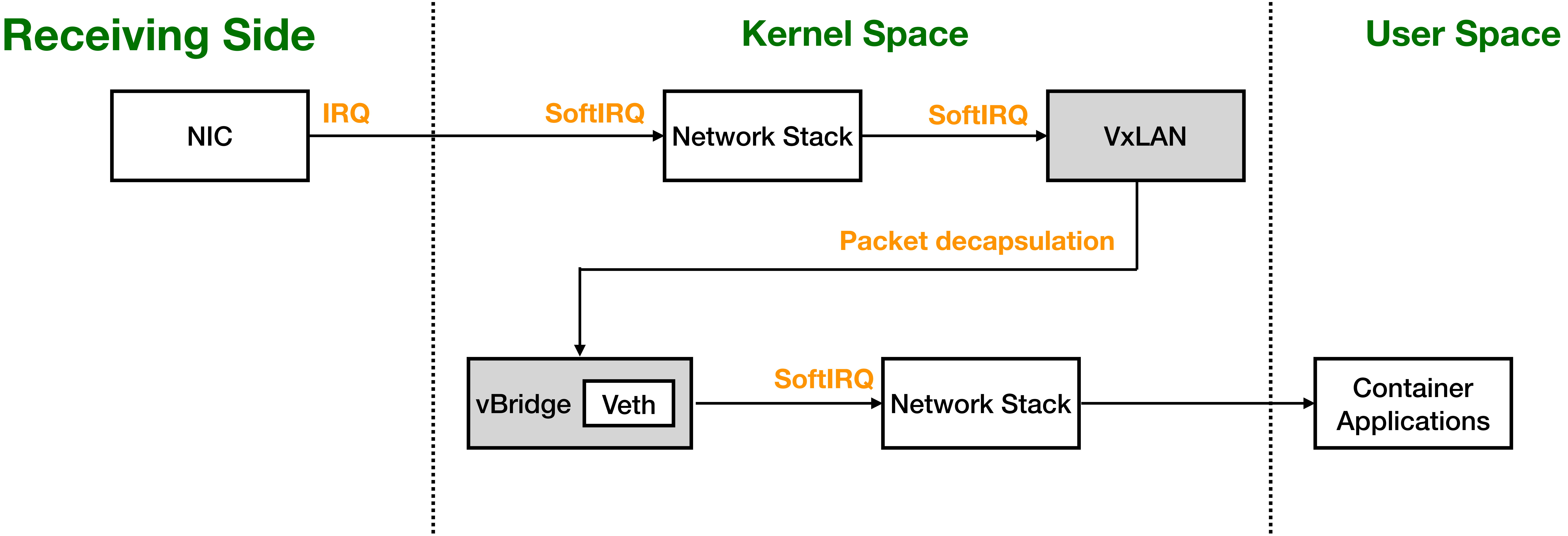


Existing Optimizations for Packet Processing



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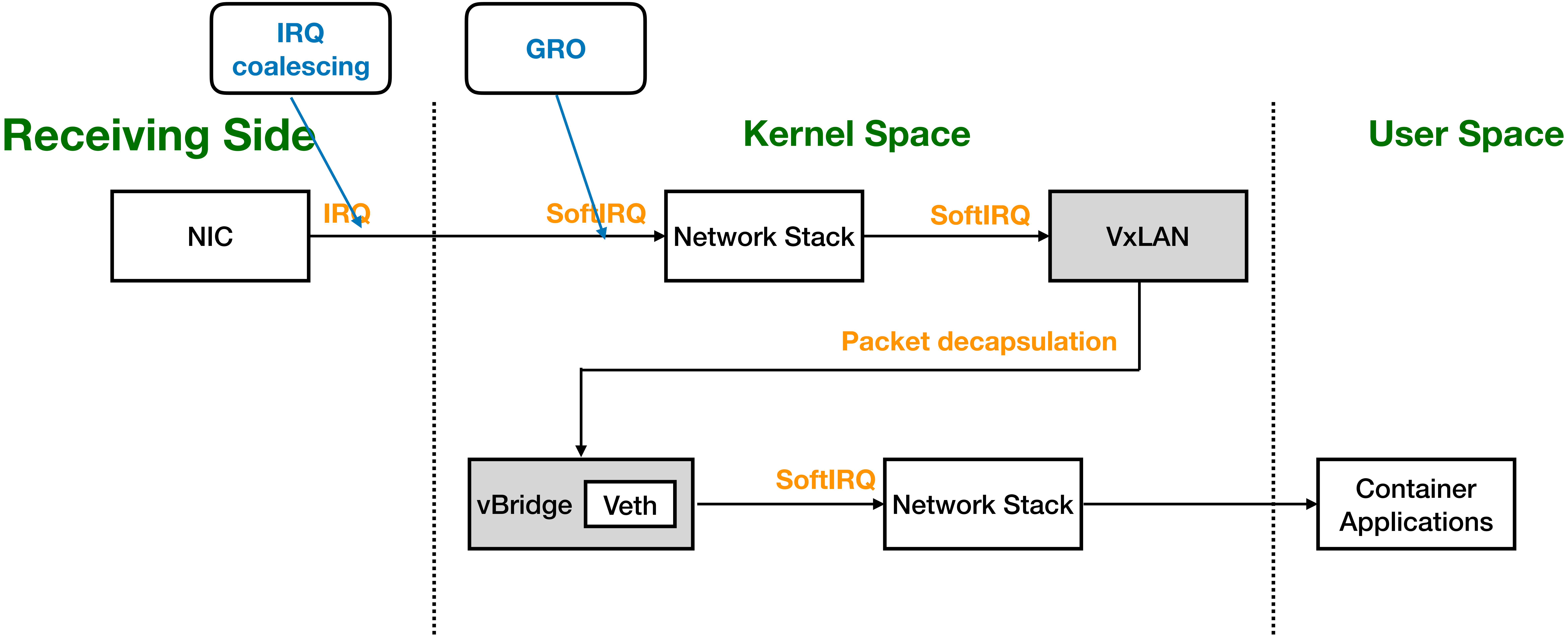

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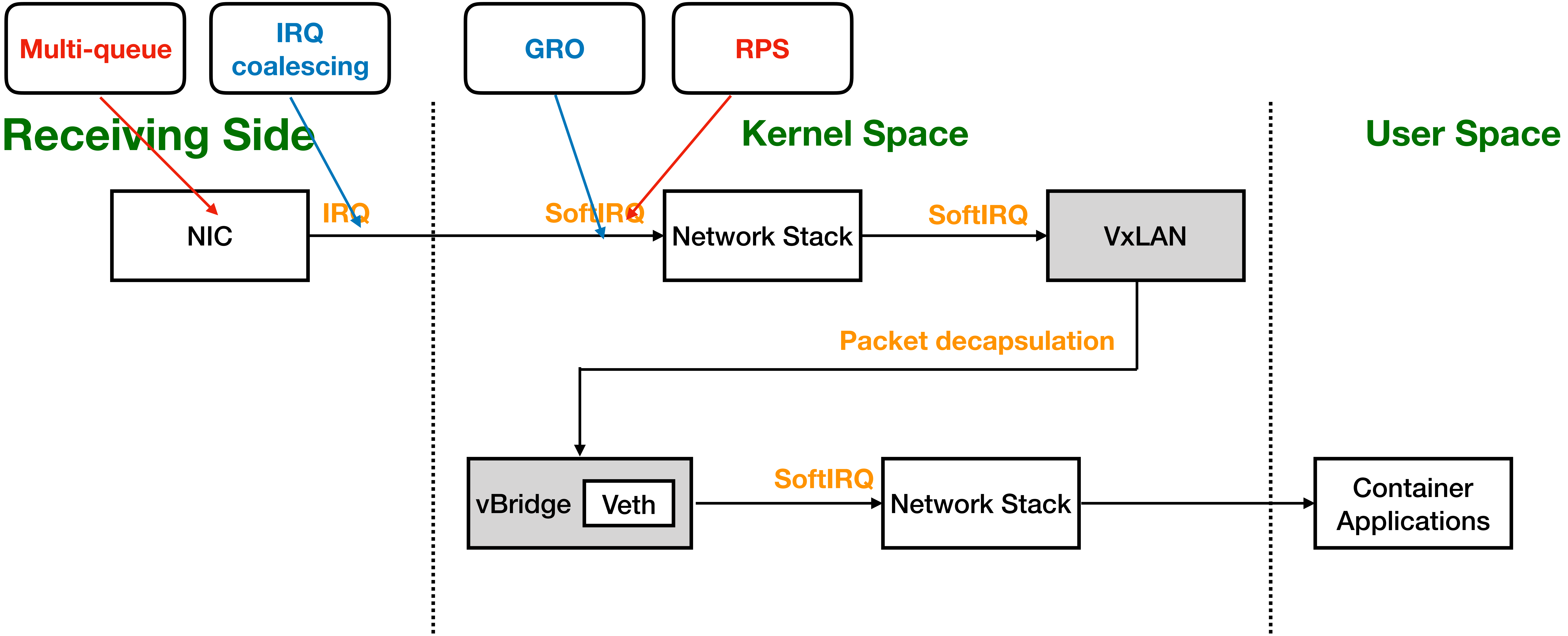

Experimental Settings

Hardware			Software	
CPU	**Memory**	**NIC**	**Throughput**	**CPU Usage**
2.2 GHz	64GB	**40Gbps**	iPerf3	mpstat
10 cores		Multi-queue		

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S1 - Native **S2 - Linux Overlay** **S3 - Docker Overlay**

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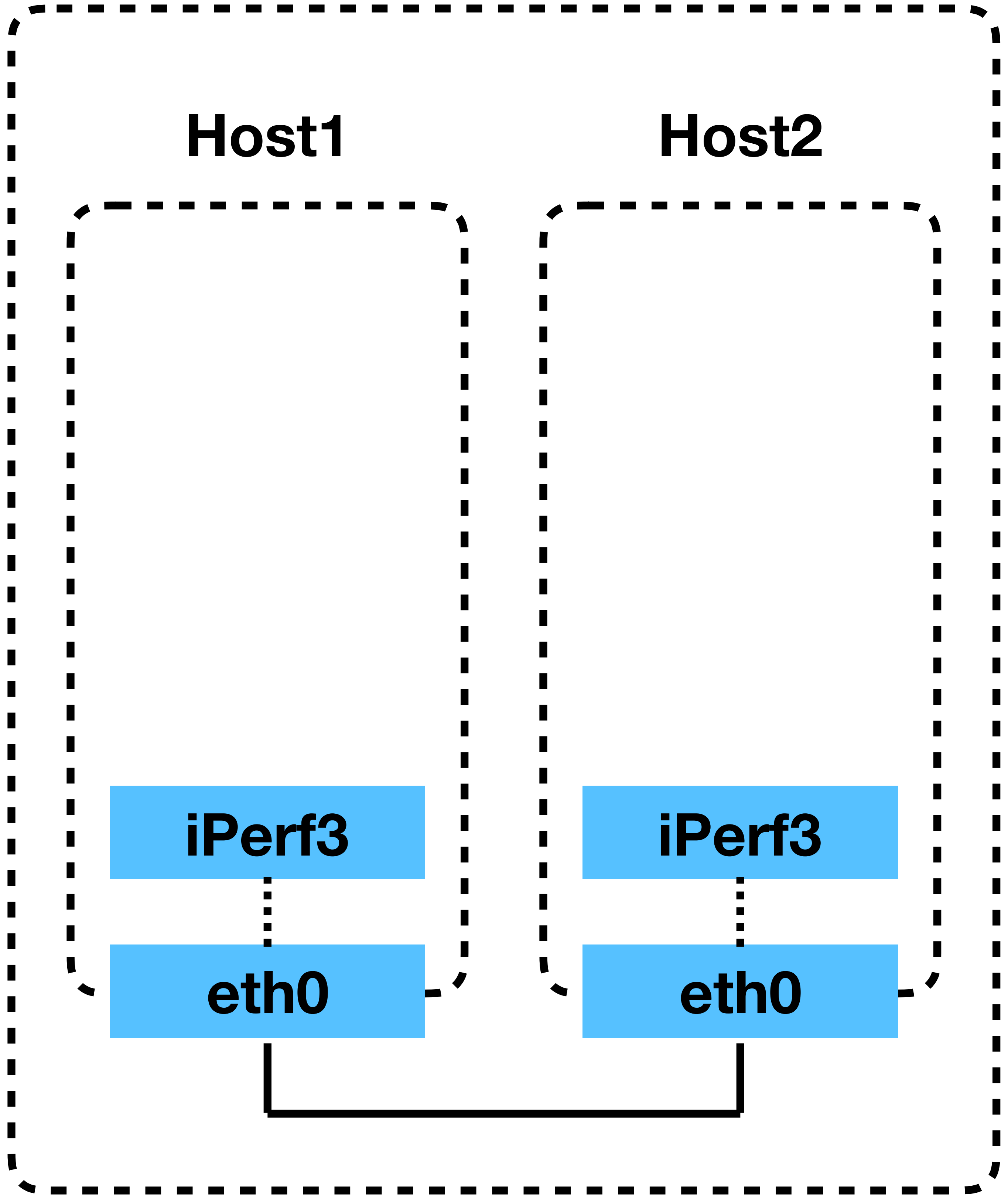

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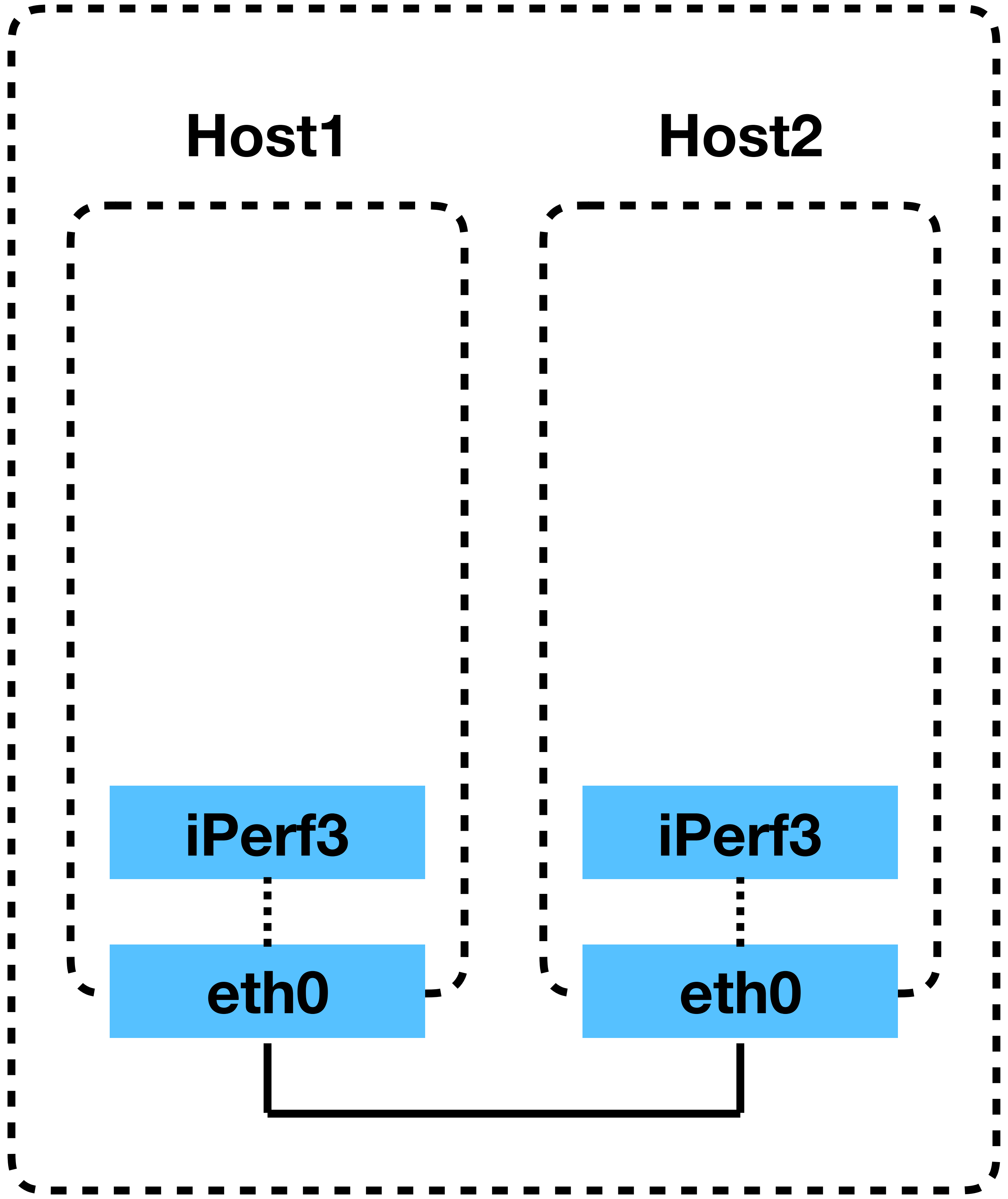

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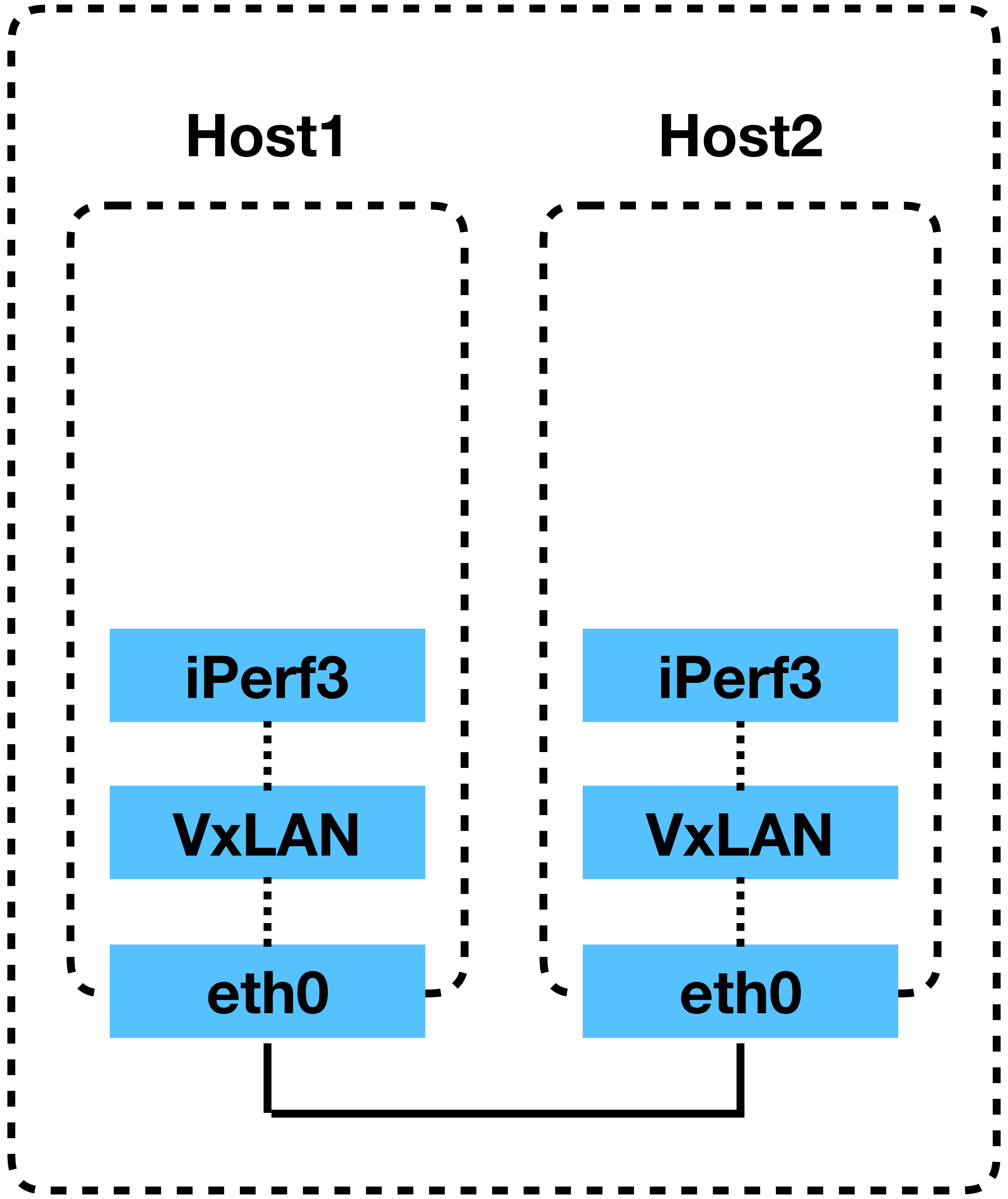

S3 - Docker Overlay

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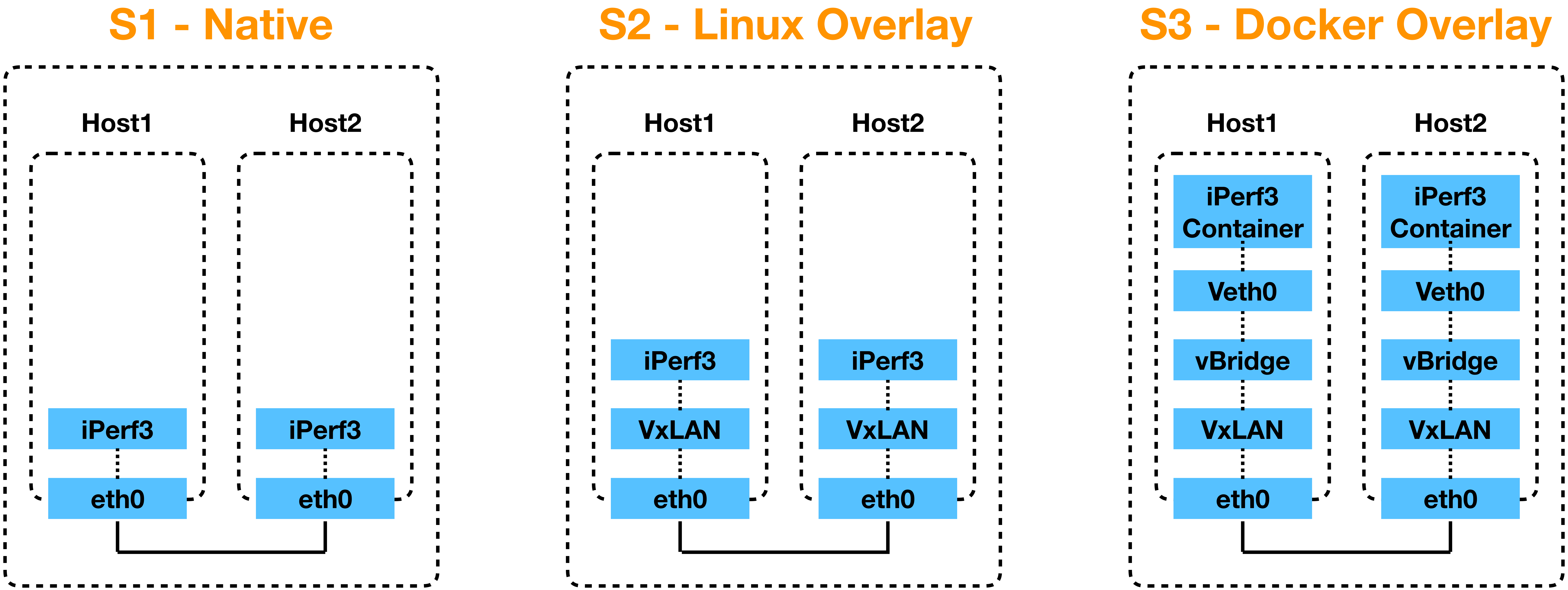
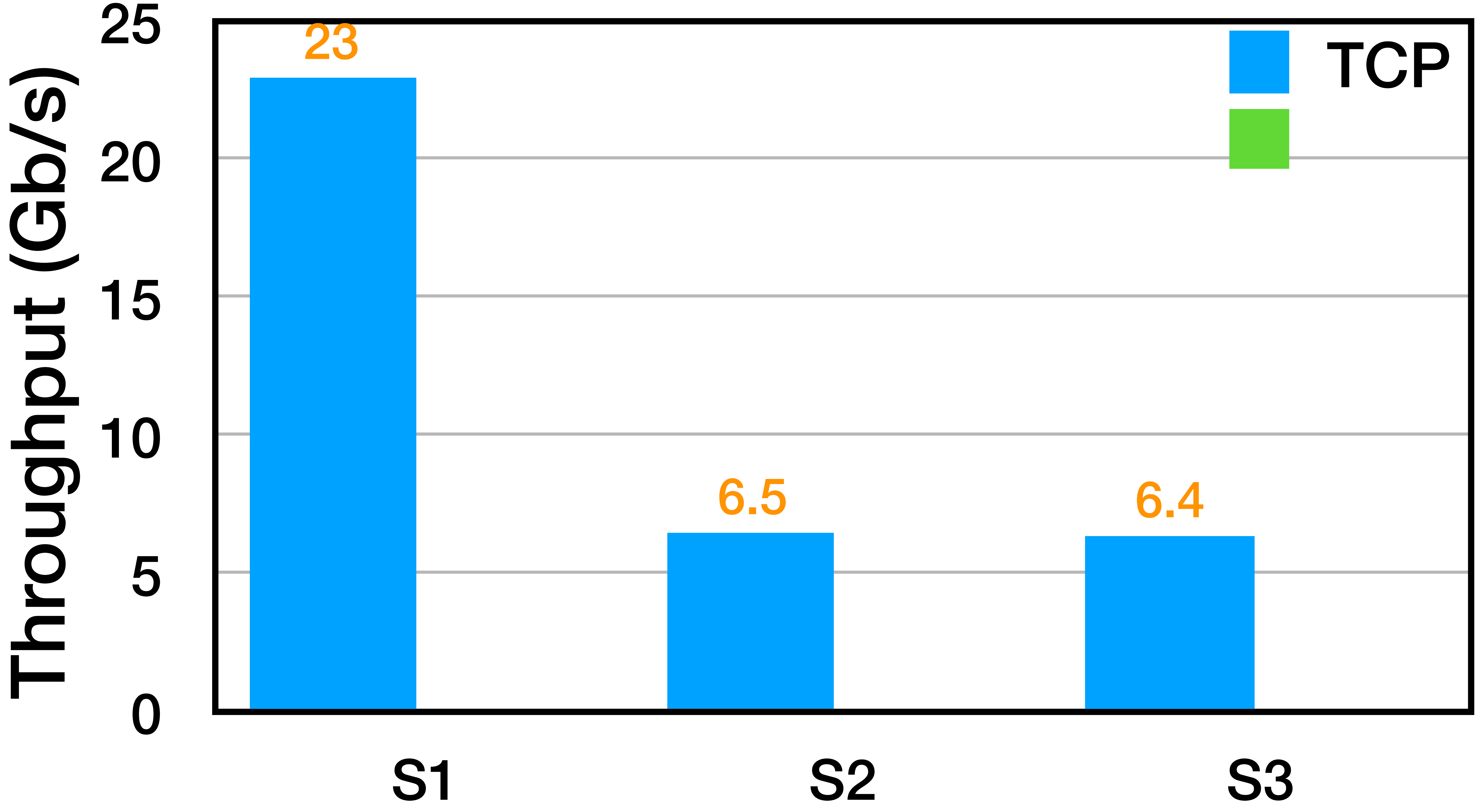


Single Flow Performance



TCP and UDP Throughputs under Three Different Cases

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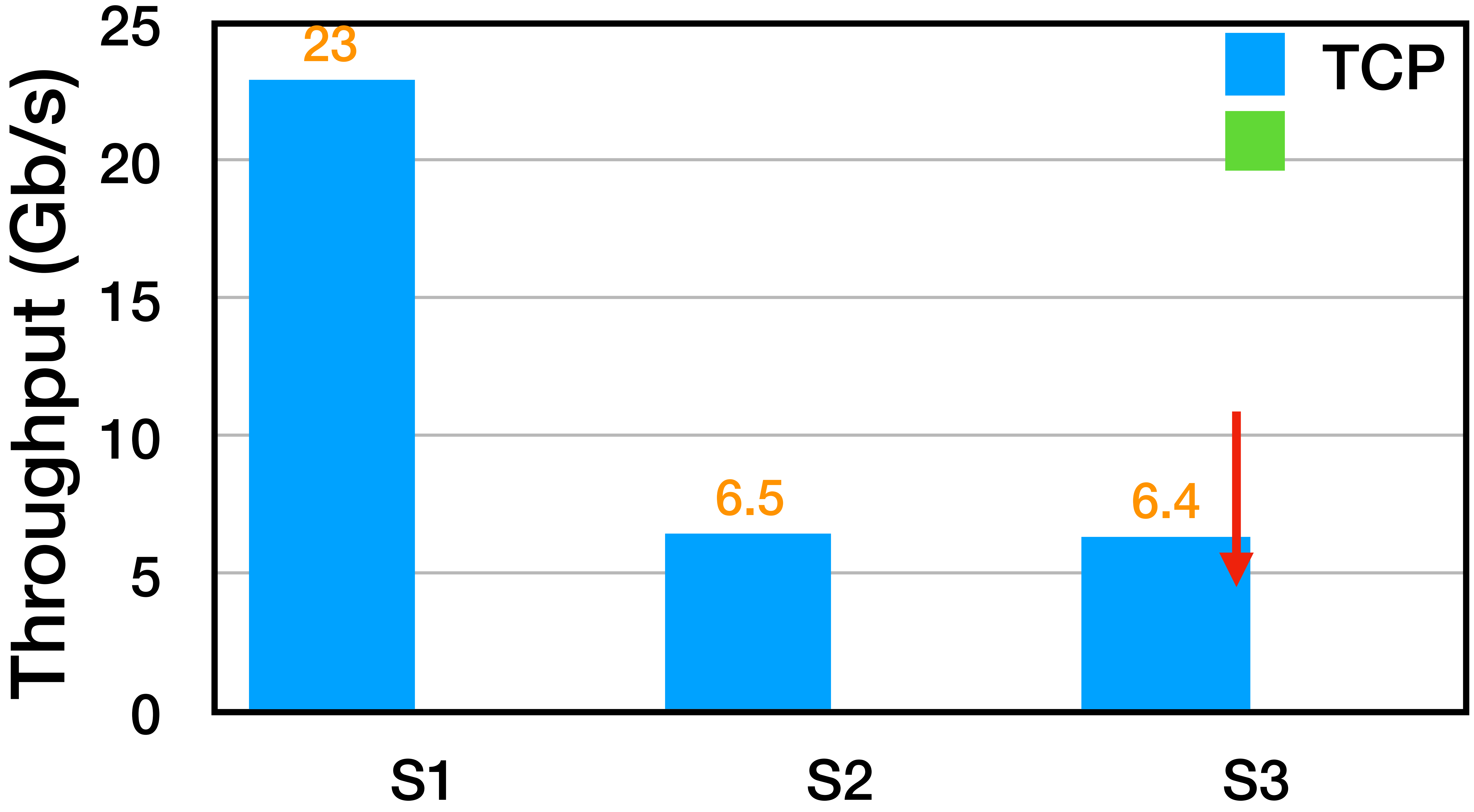

TCP and UDP Throughputs under Three Different Cases

- **TCP Throughput** of Docker Overlay case drops **72%** compared with native case.

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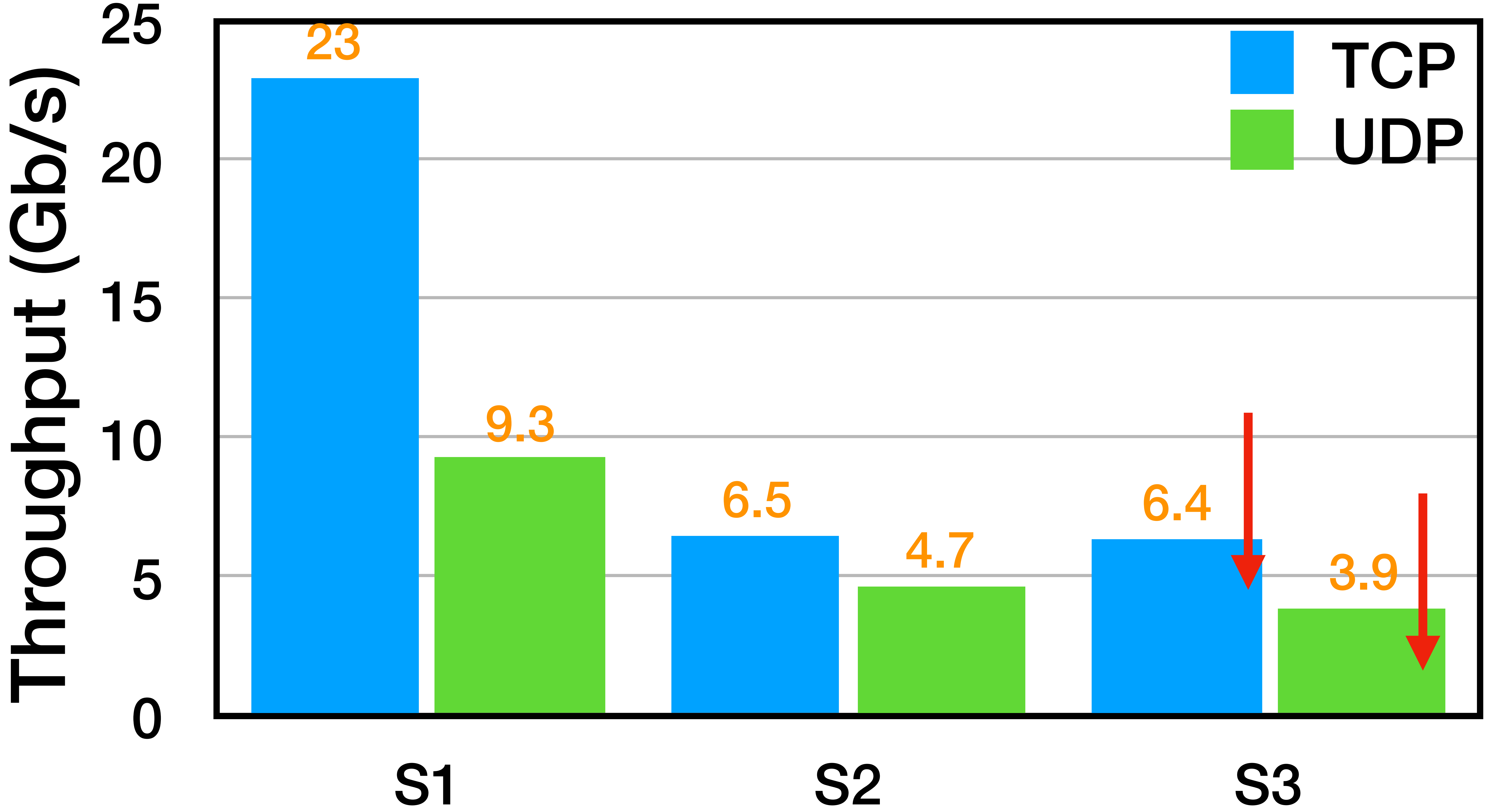
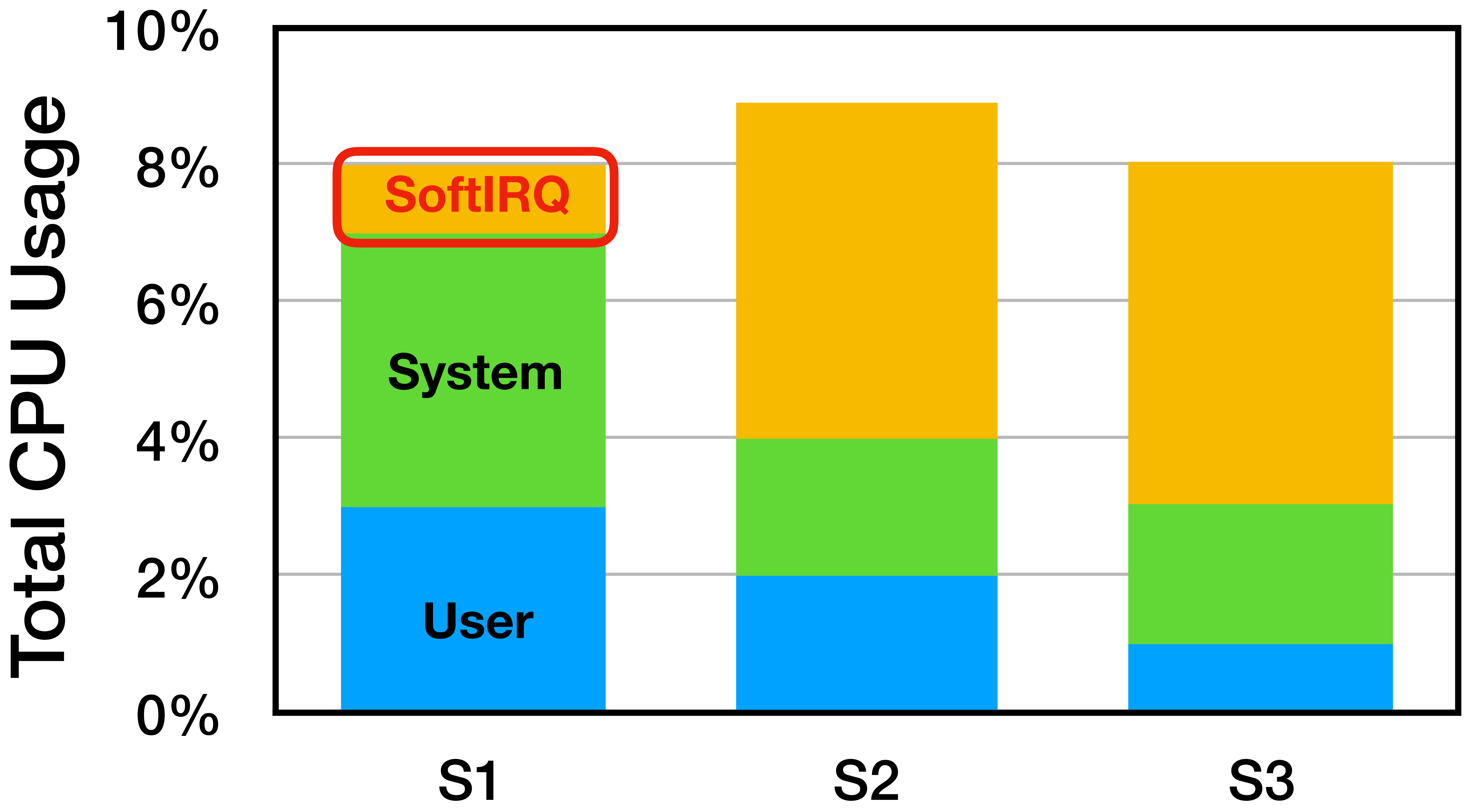


TCP and UDP Throughputs under Three Different Cases

- **TCP Throughput** of Docker Overlay case drops **72%** compared with native case.
- **UDP Throughput** drops **58%**.

Single Flow Performance



CPU Usage under Three Different Cases for TCP

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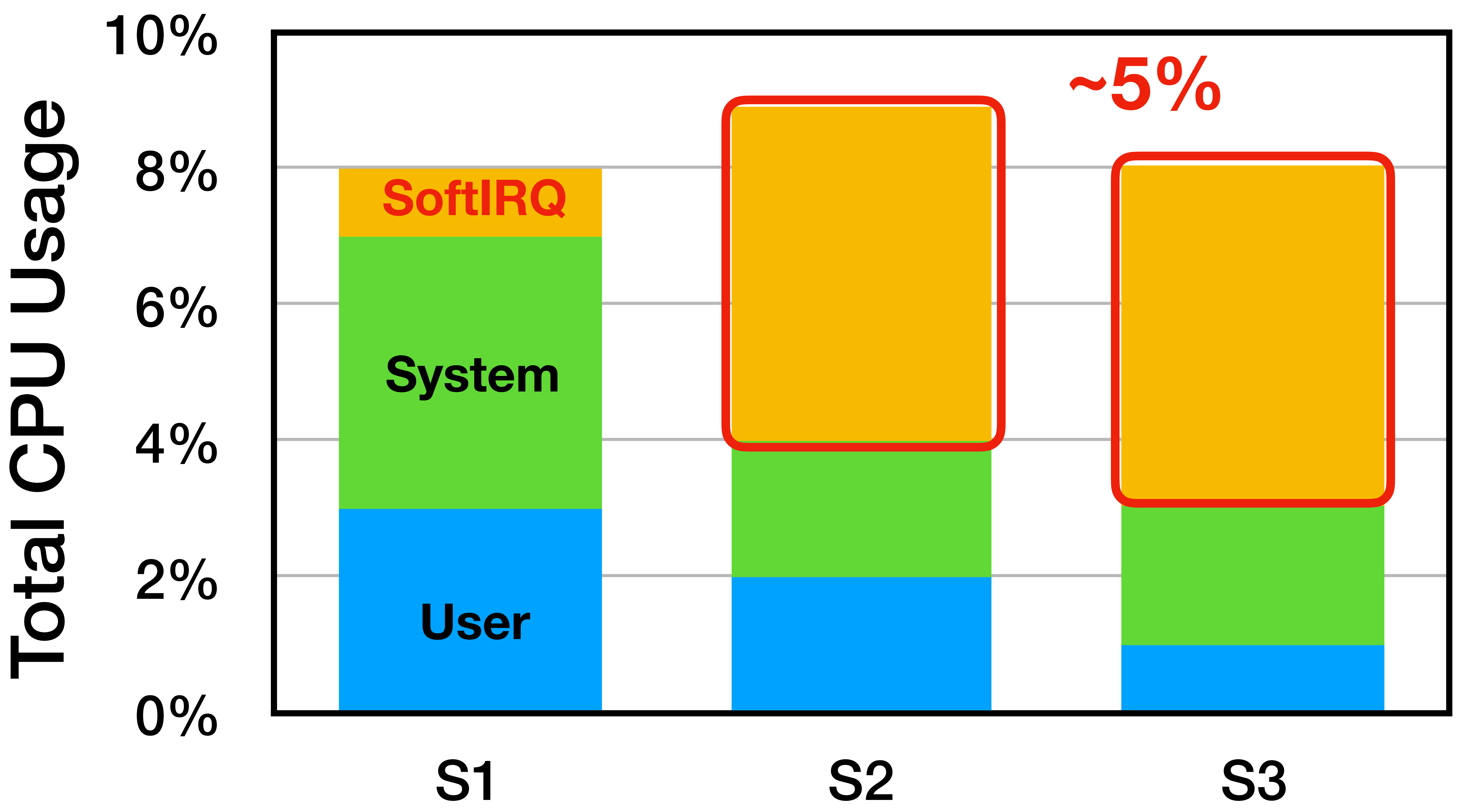

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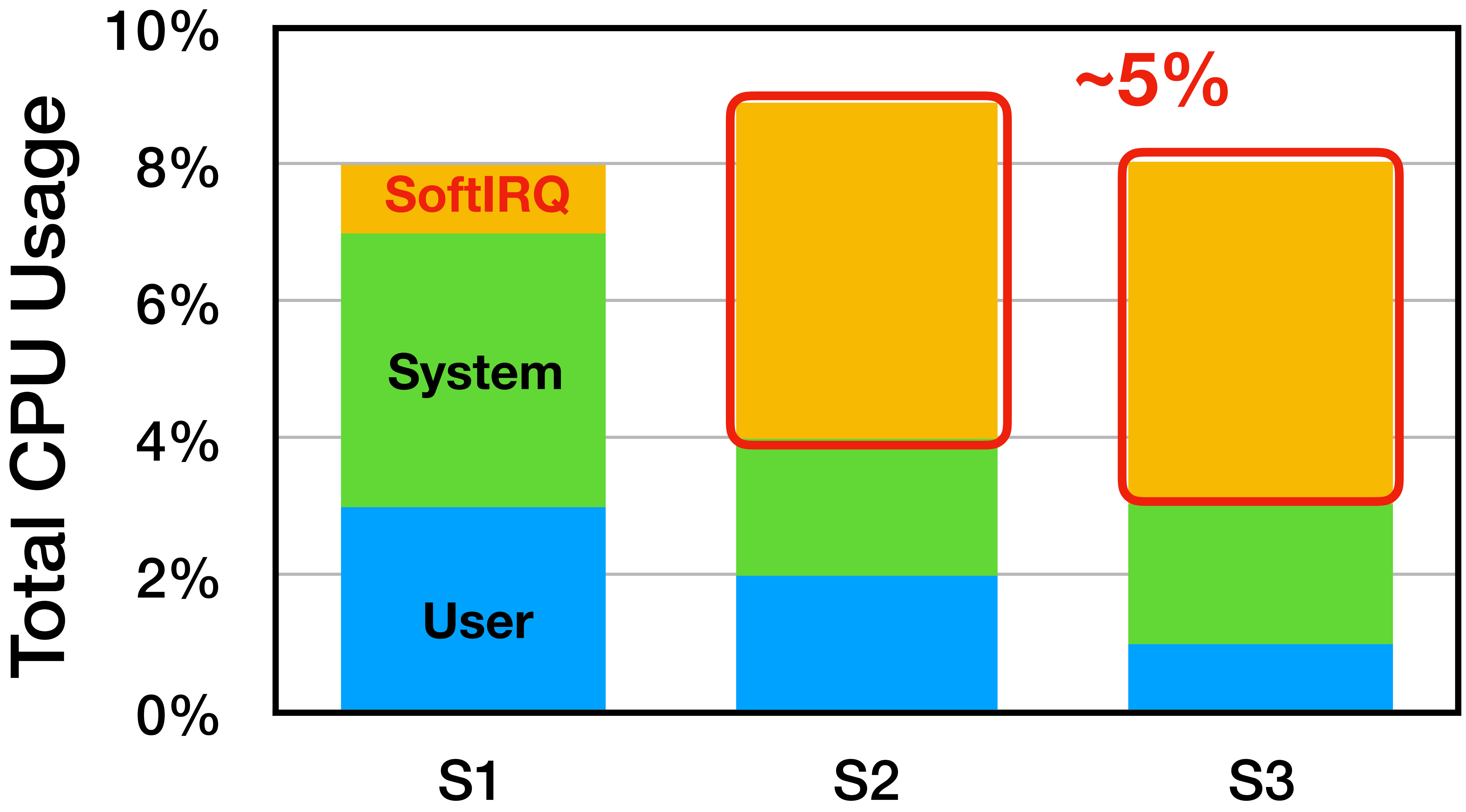

CPU Usage under Three Different Cases for TCP

- Packet processing overhead **fully saturates** one cpu core in two overlay cases.
- Current solutions **can't scale** single flow performance.

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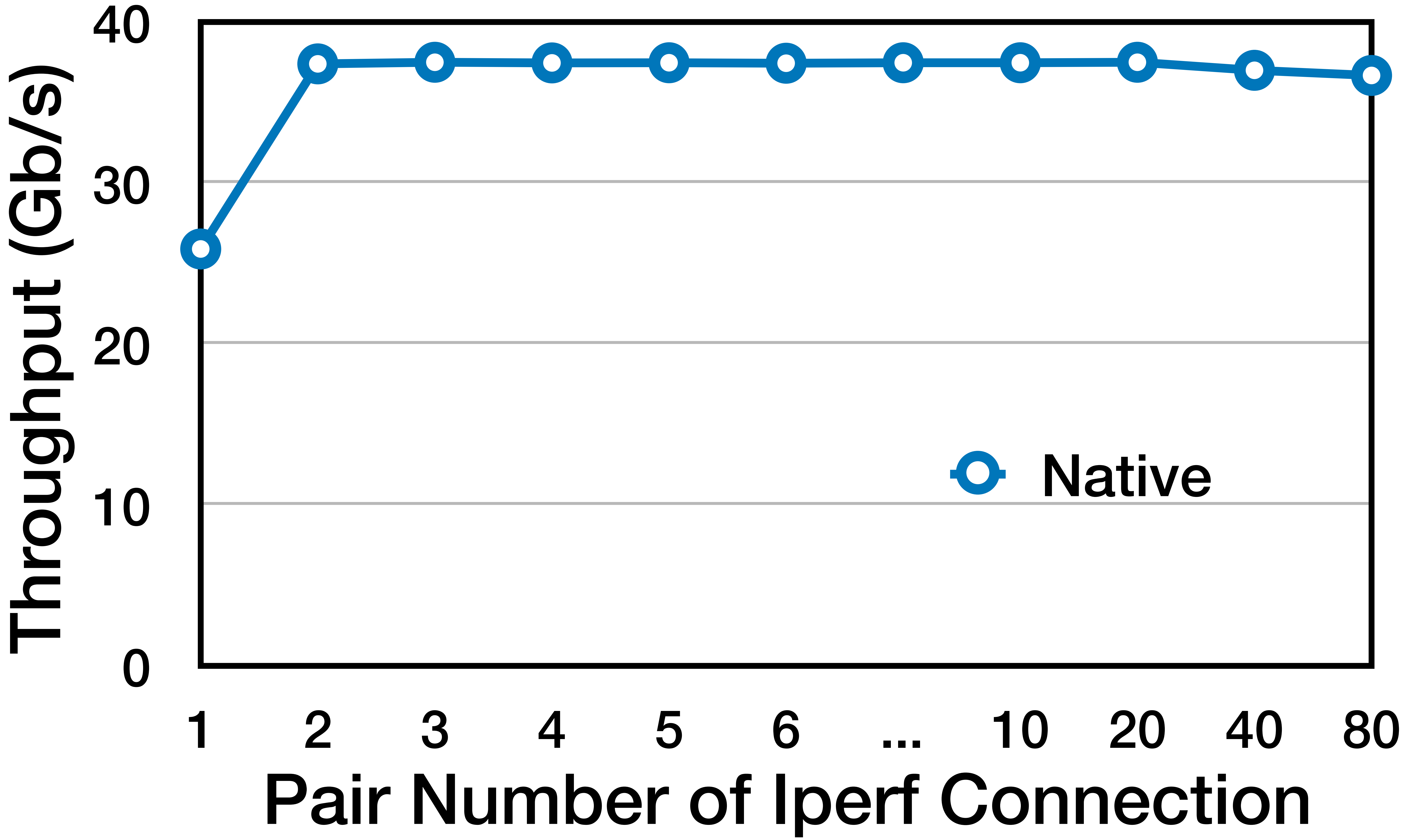
Multiple Flows Performance



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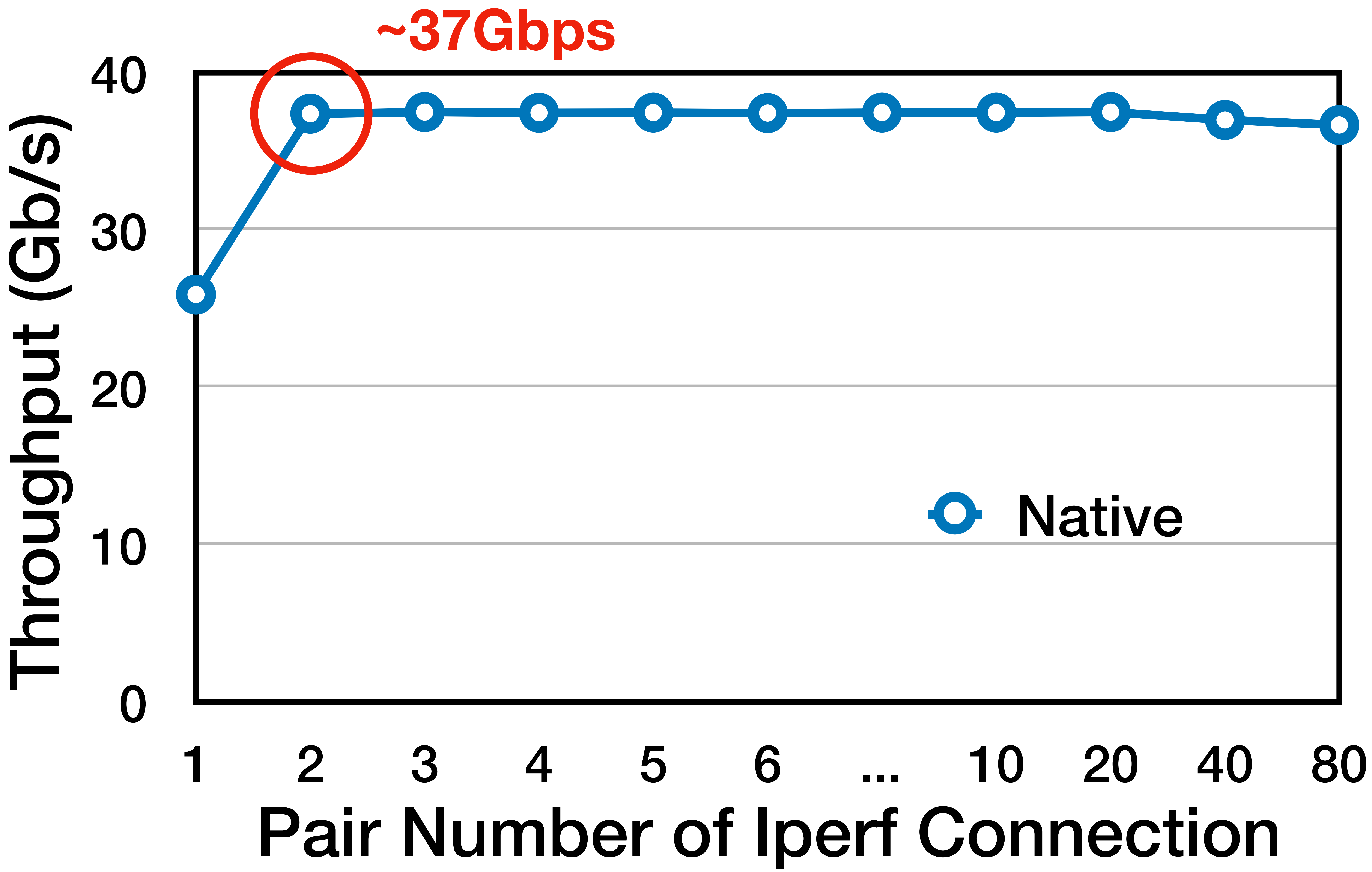

- Native case quickly reaches ~**37 Gbps** under TCP with only **2 pairs**.

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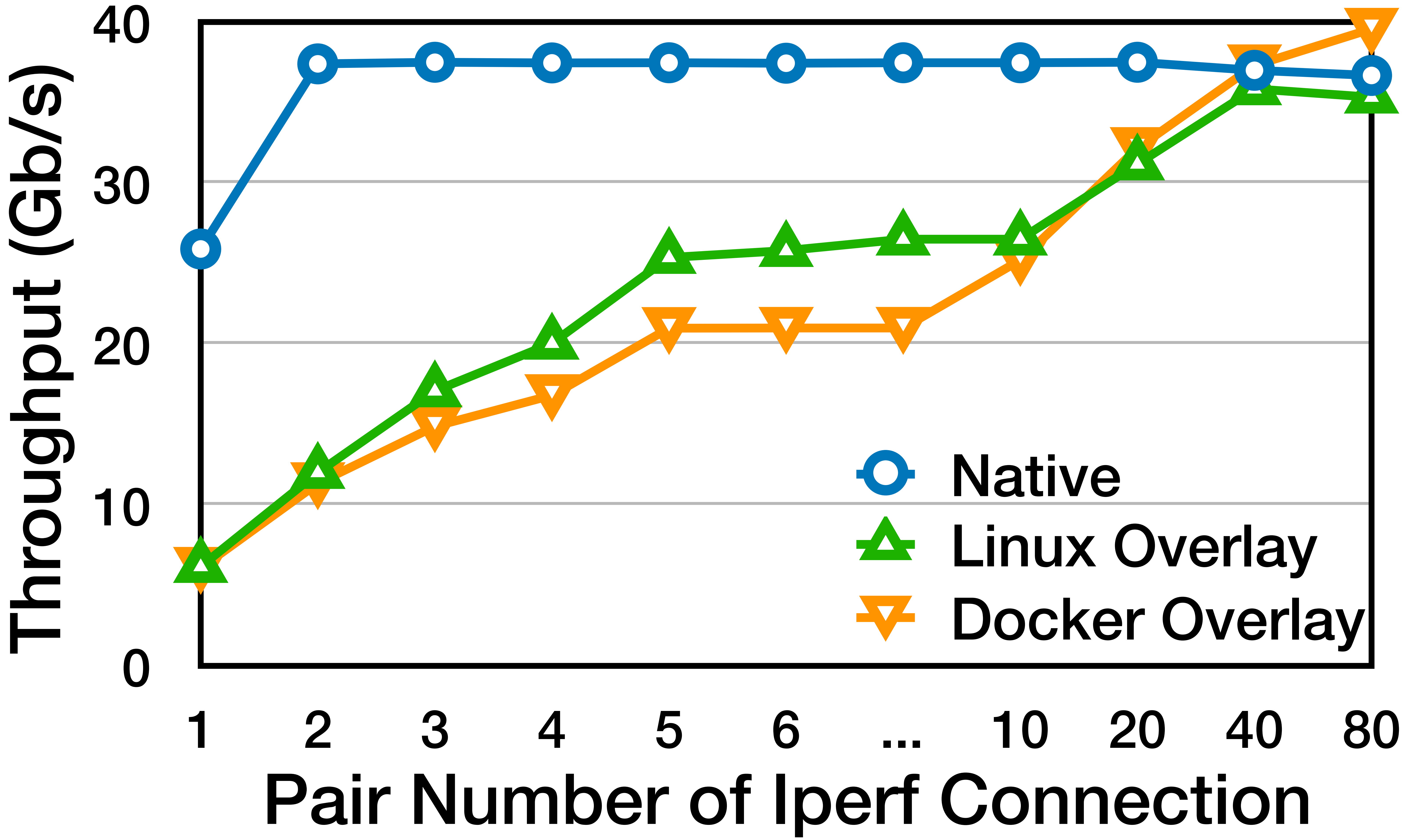

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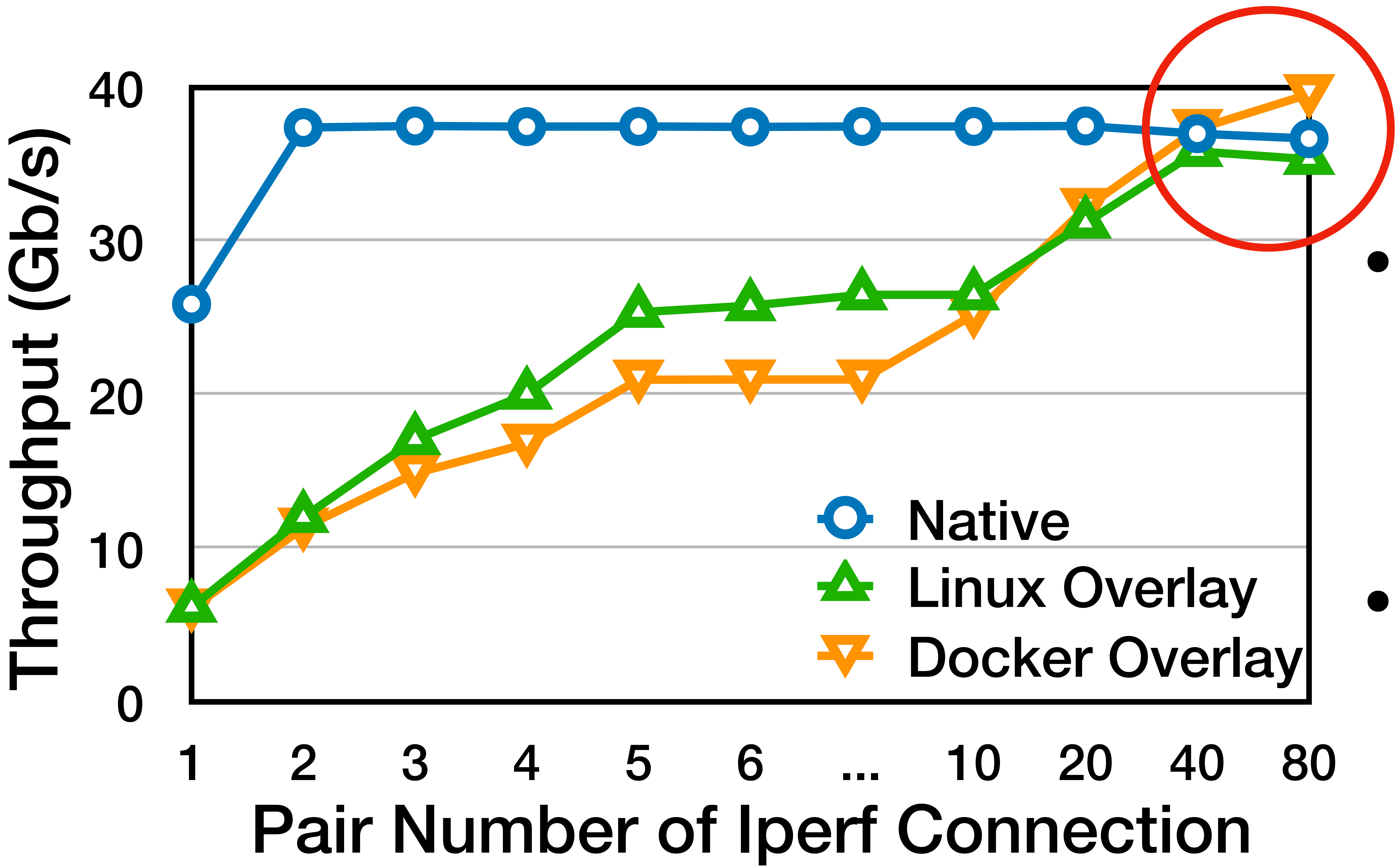

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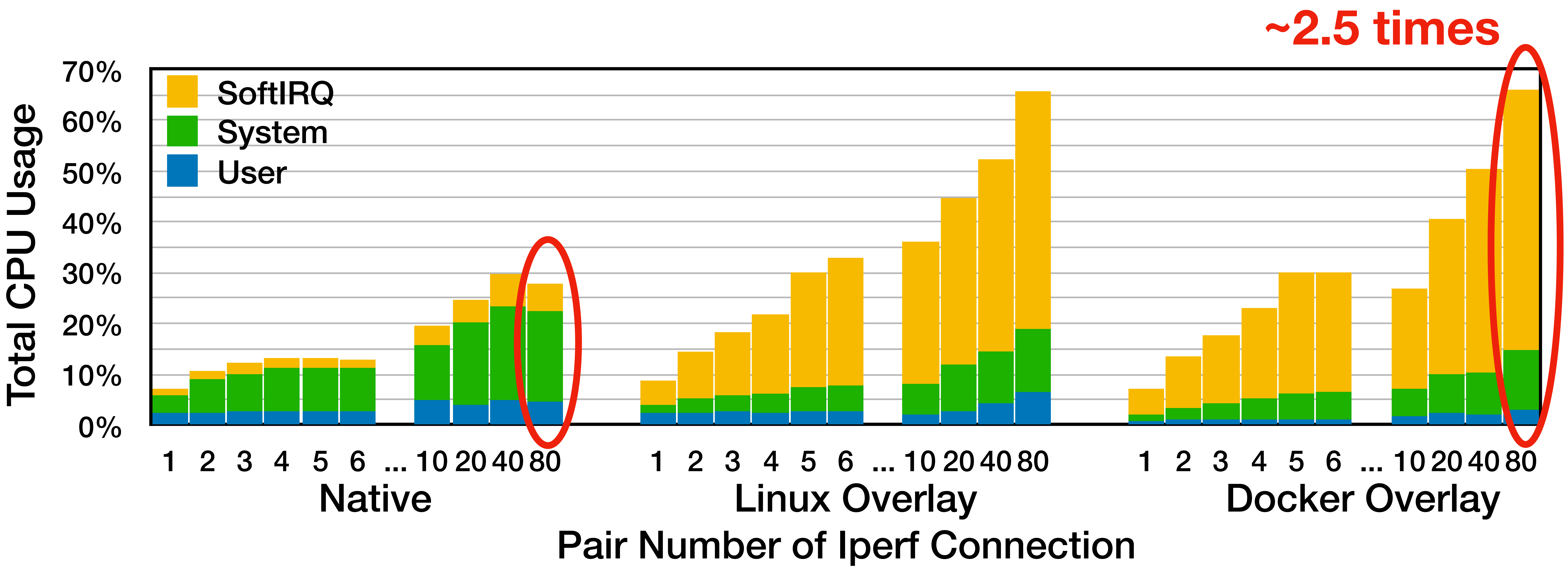

- Under the same throughput (e.g., 40 Gbps), overlay networks consume **much more** CPU resources (e.g., around **2.5 times**) than the native case.

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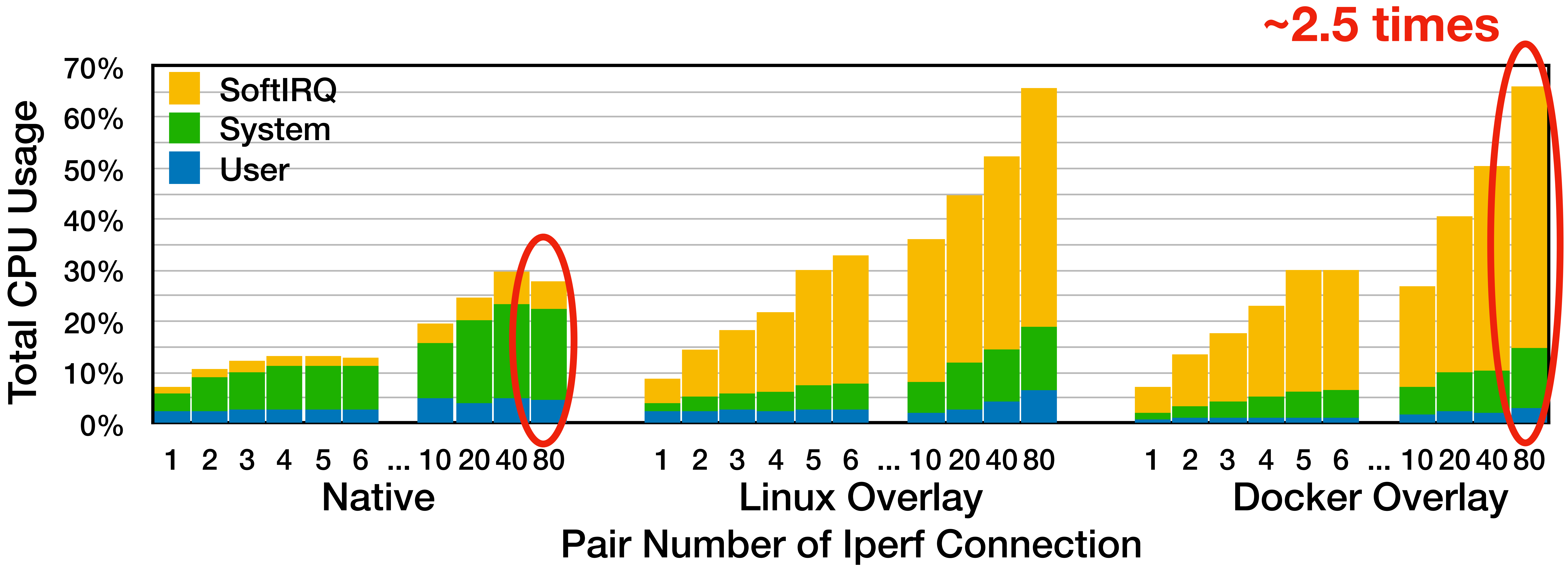
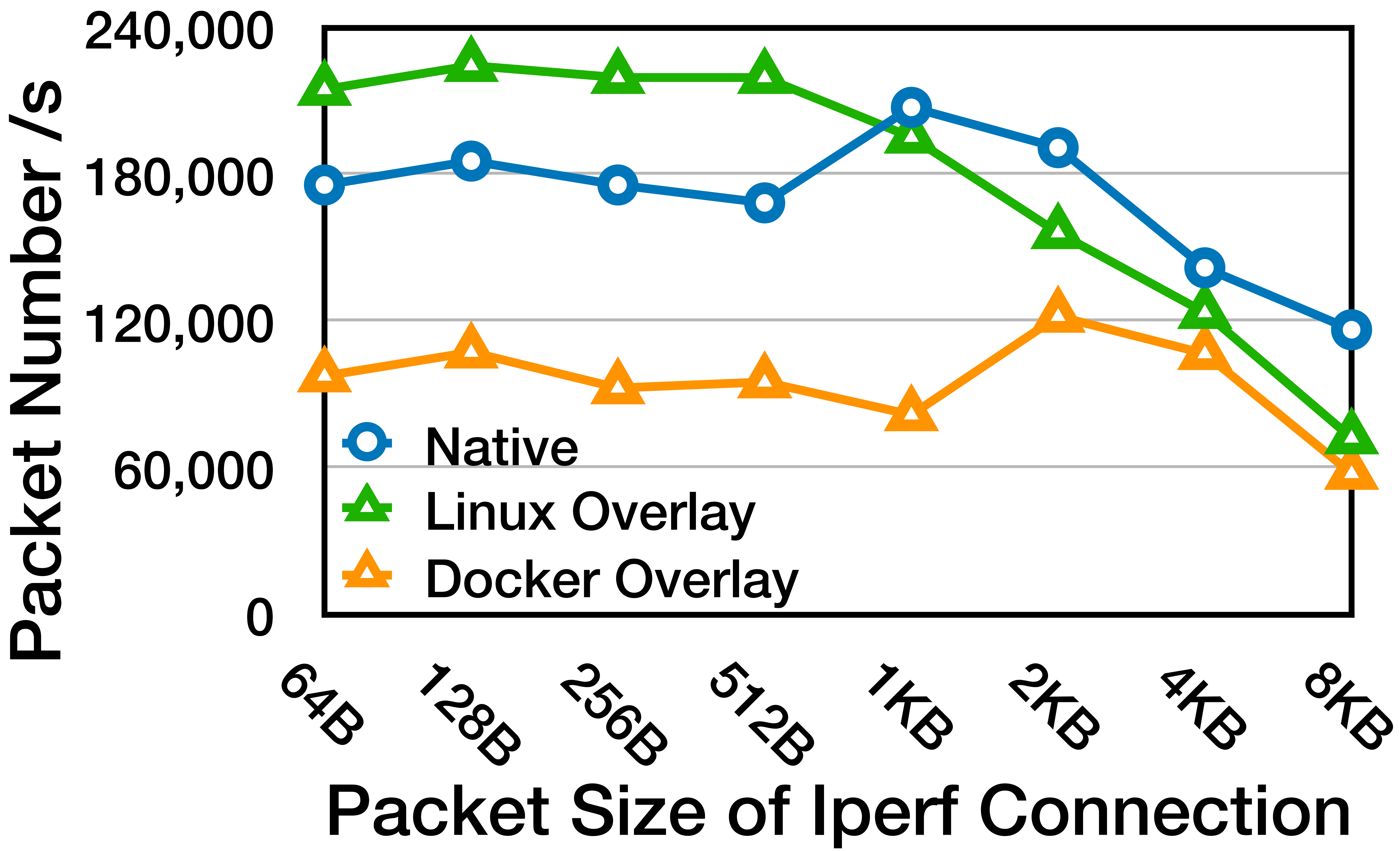


- Bad scalability is largely due to the **inefficient interplay** of many tasks.

Small Packet Performance



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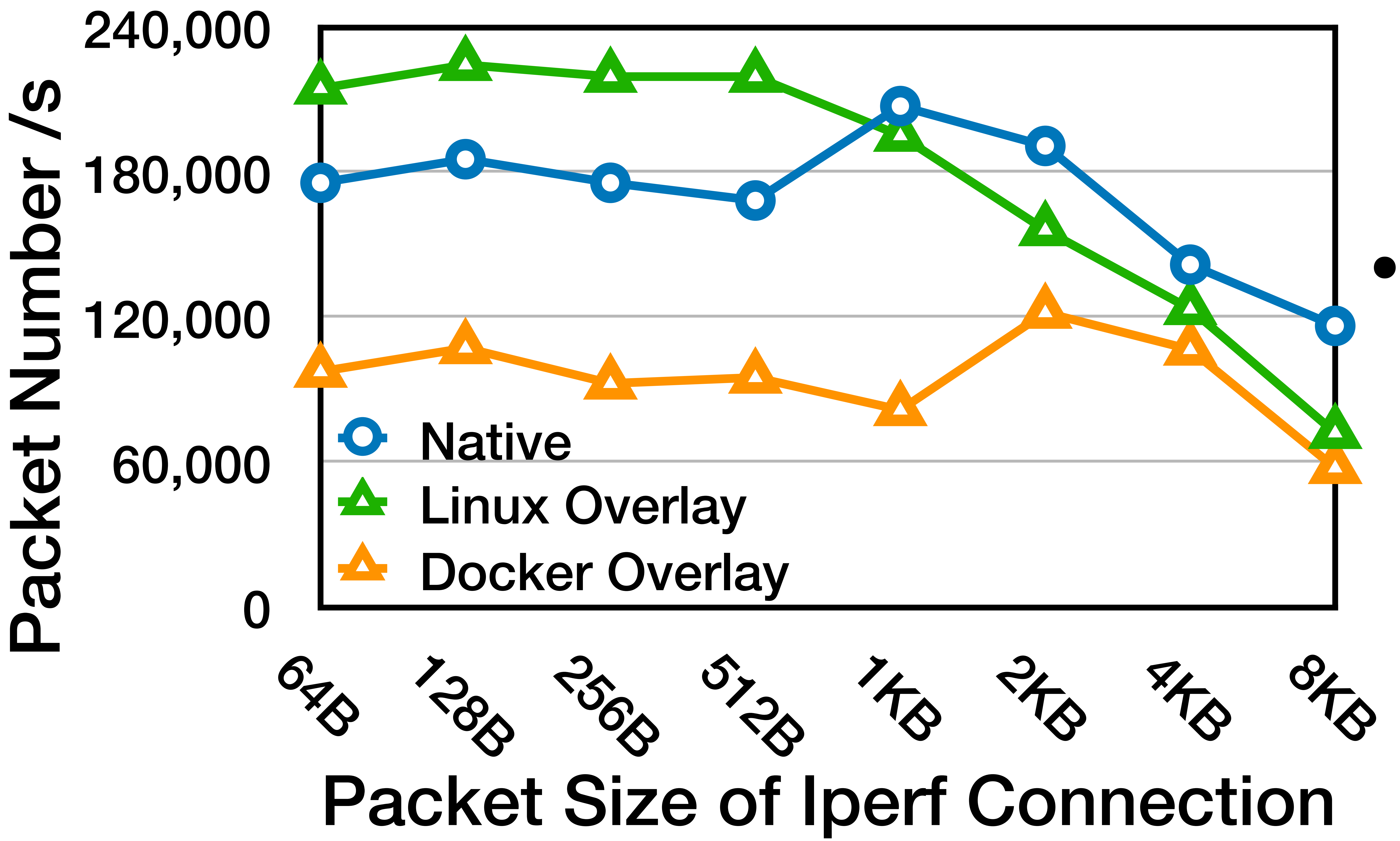
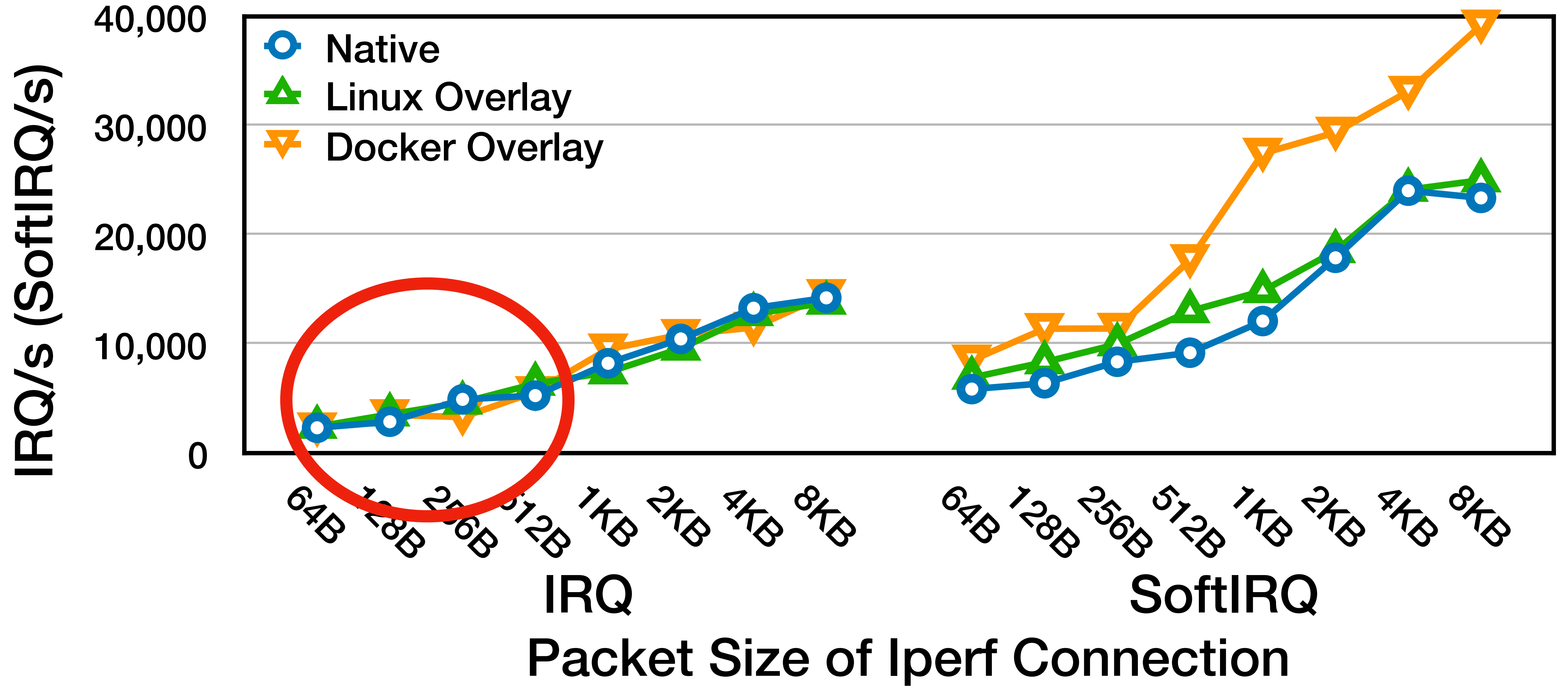


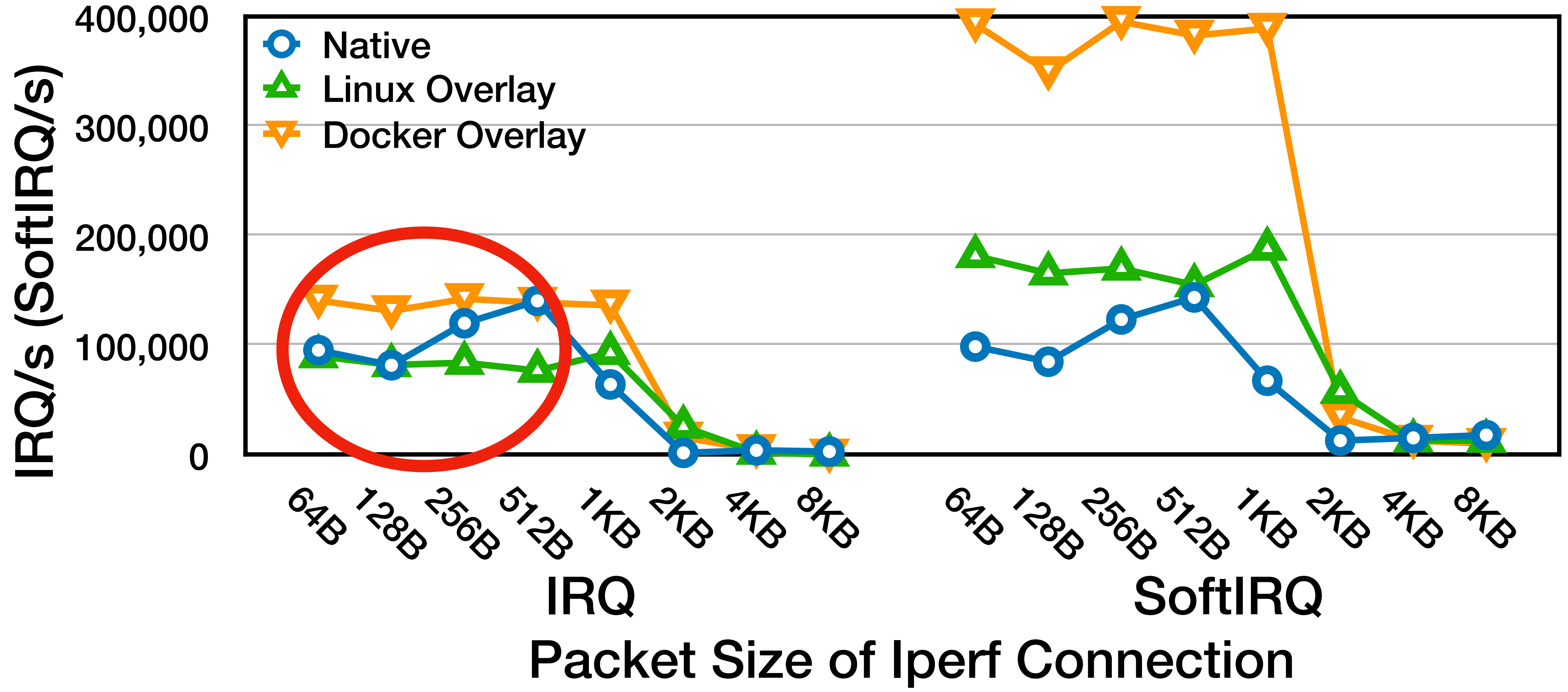
- Docker overlay achieves as low as **50%** packet processing rate of that in the native case.

Interrupt Number with Varying Packet Sizes

Interrupt number for TCP



Interrupt number for UDP



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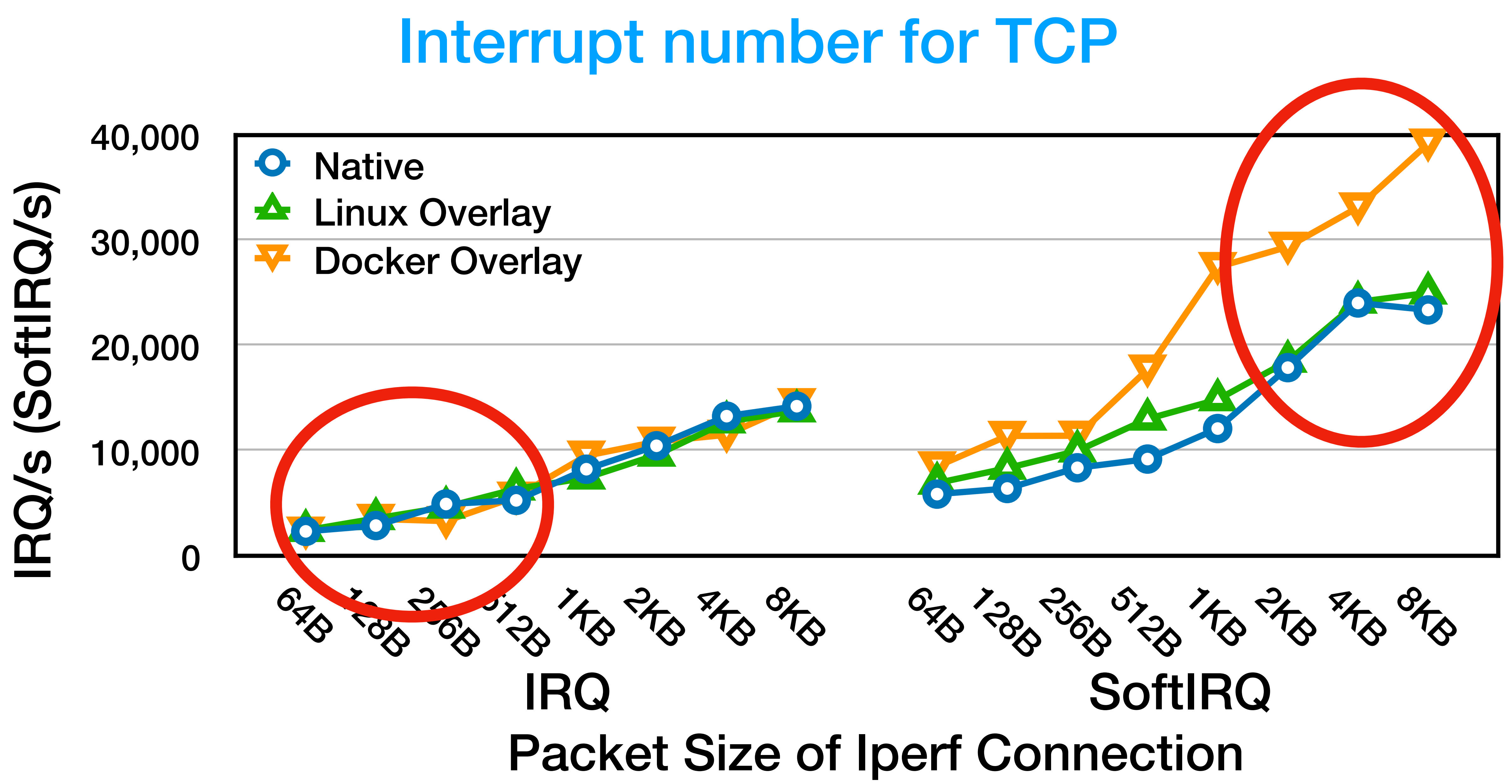

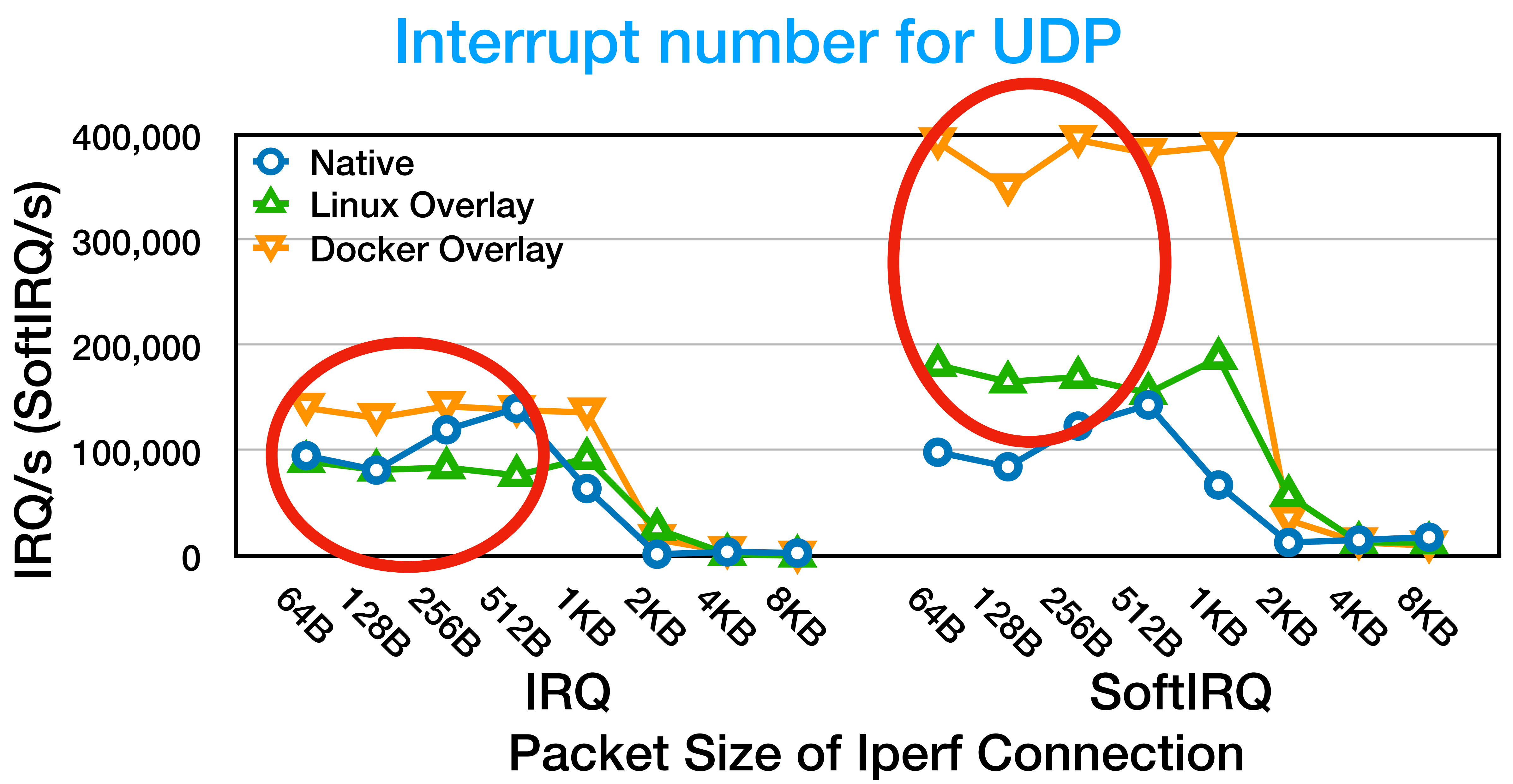

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- **3x** softIRQ numbers are observed in Docker Overlay case compared with the IRQ numbers.

Insights and Conclusions

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- Is it feasible to provide packet-level parallelization for a **single network flow**?
- How can the kernel perform a **better isolation among multiple flows** especially for efficiently utilizing shared hardware resources?
- Can the packets be **further coalesced** with optimized network path for reduced interrupts and context switches?

Thank you!