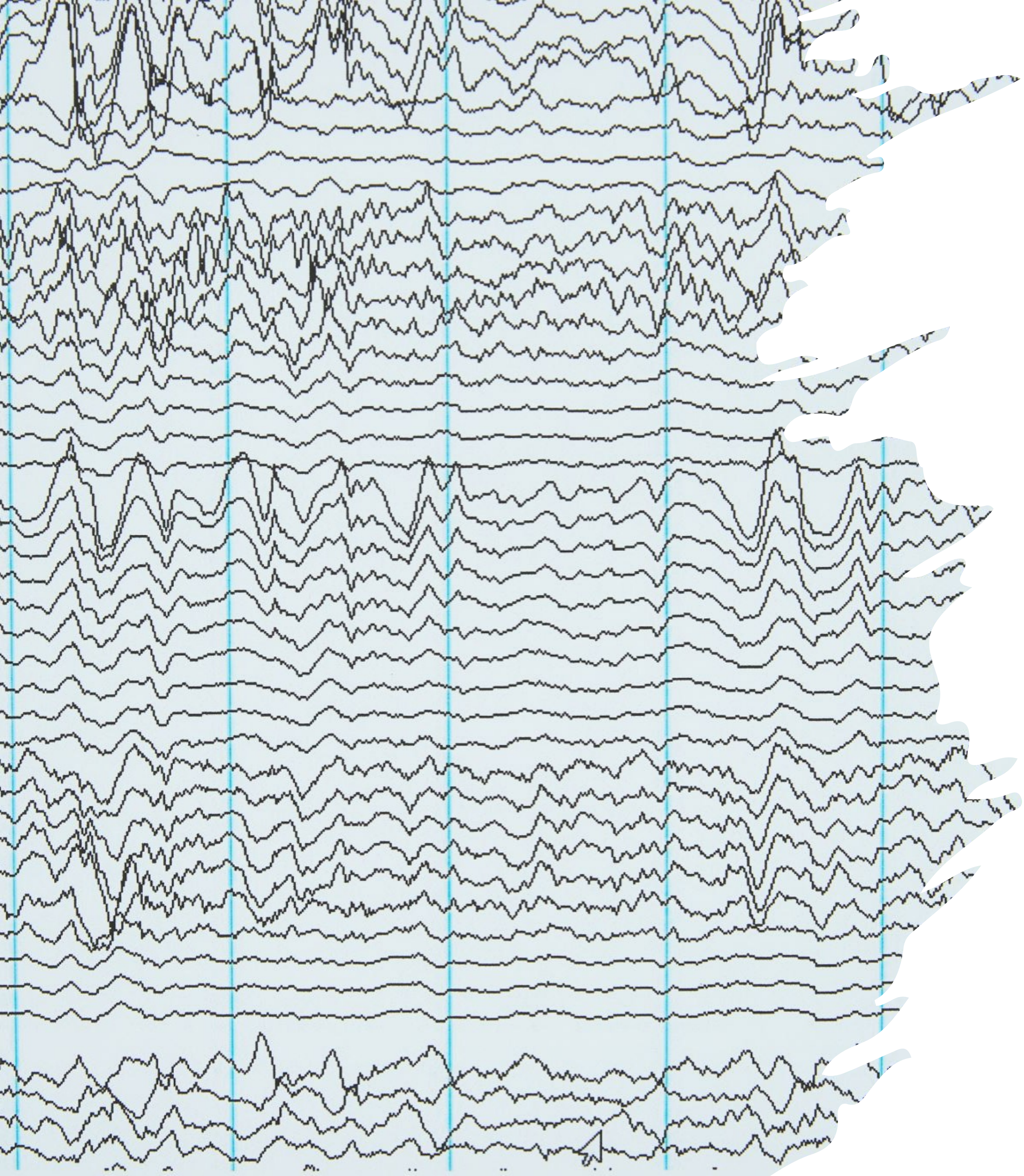

AF_XDP impact on Latency

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I – Motivation

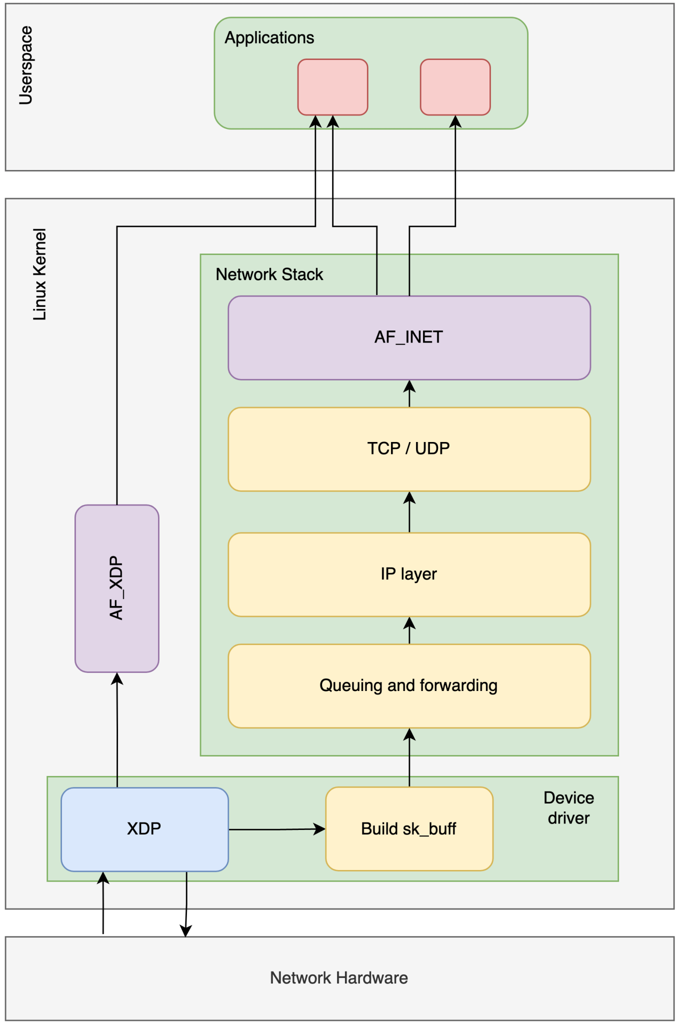
Impact of microseconds in cloud environments

- Today -> lot of microservices, every microsecond is important
- Hardware has really high bandwidth now (40Gbps – 100 Gbps)
- Packet processing in the network stack is the slower side
- Need to improve performance -> Throughput
- Need to lower latency

Packet processing mitigation techniques

- Bypass the Linux kernel networking stack
  - kernel space -> **XDP**
  - user space -> **AF_XDP**
  - user space -> DPDK
- XDP and AF_XDP are fully integrated into the Linux environment

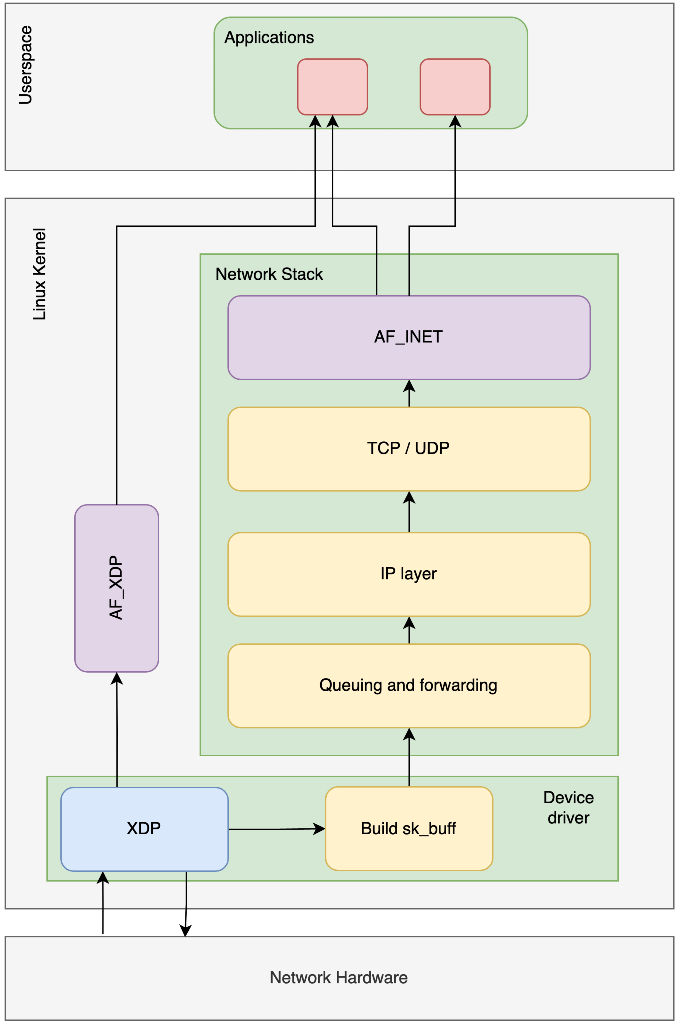
Introduction to XDP



- First hook in the network stack
- In driver space
- Allows the bypass of the networking side when receiving packets

Inspired by T. Høiland-Jørgensen *et al.*, 'The eXpress data path: fast programmable packet processing in the operating system kernel'

Introduction to AF_XDP

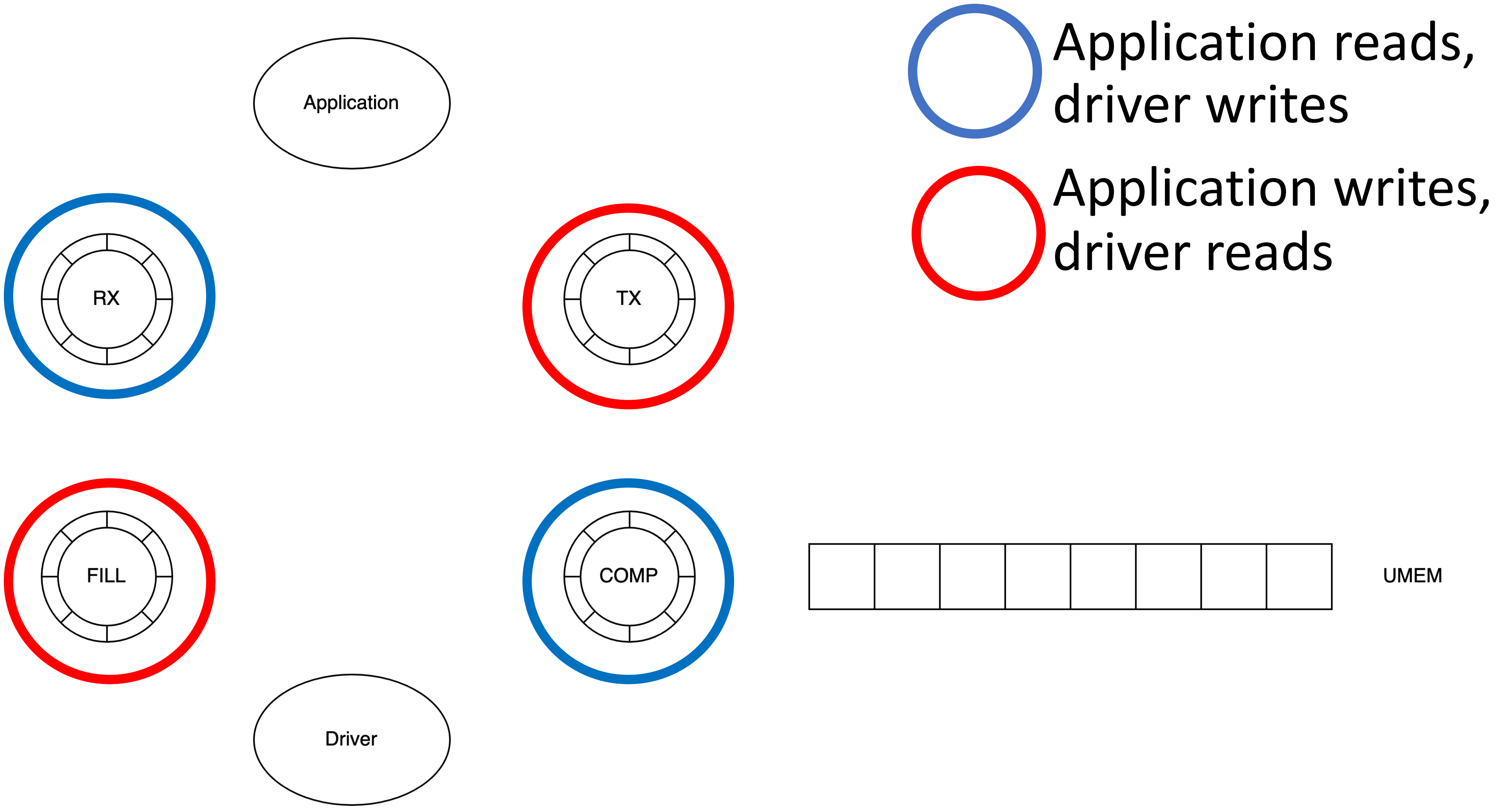


- Socket type like classic AF_INET
- Used to communicate with the network through the XDP hook
- XDP send to AF_XDP socket on receiving side
- AF_XDP write directly to the hardware when sending

Inspired by T. Høiland-Jørgensen *et al.*, ‘The eXpress data path: fast programmable packet processing in the operating system kernel’

Underlying principle of AF_XDP

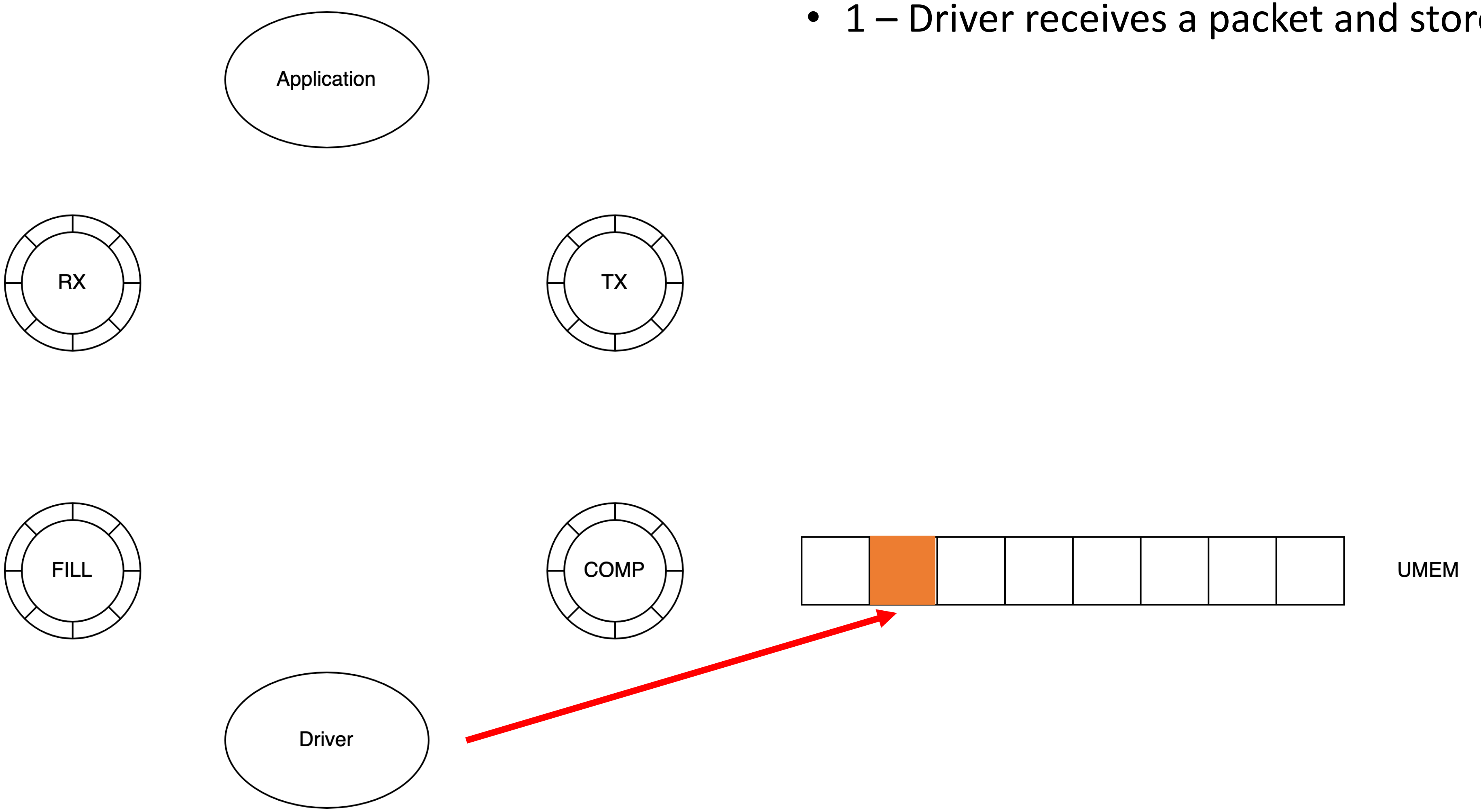
RX : Signals that a packet has been received
TX : Signals that a packet has to be transmitted
Fill and **completion** rings: Exchanging ownerships on memory frames (UMEM)



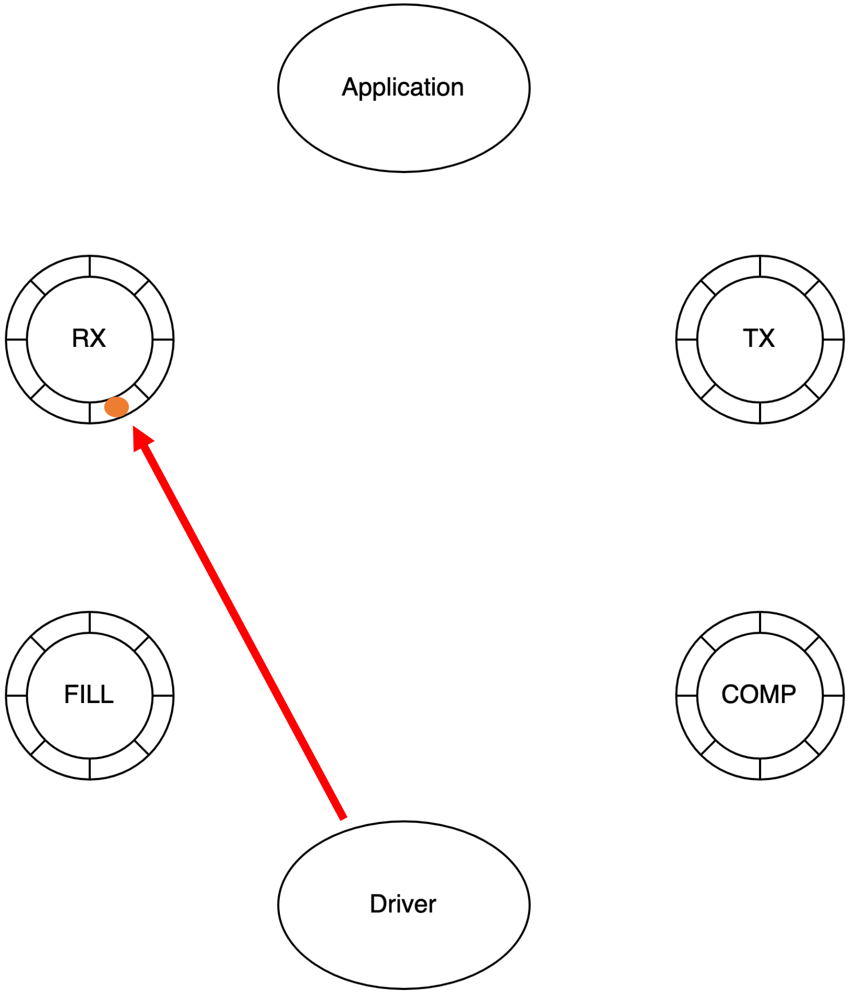
II – AF_XDP packet flow

AF_XDP receive example

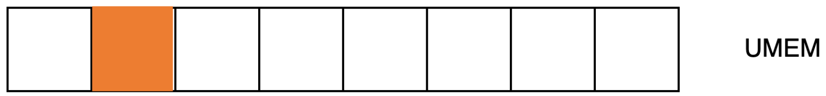
- 1 – Driver receives a packet and store it into the memory



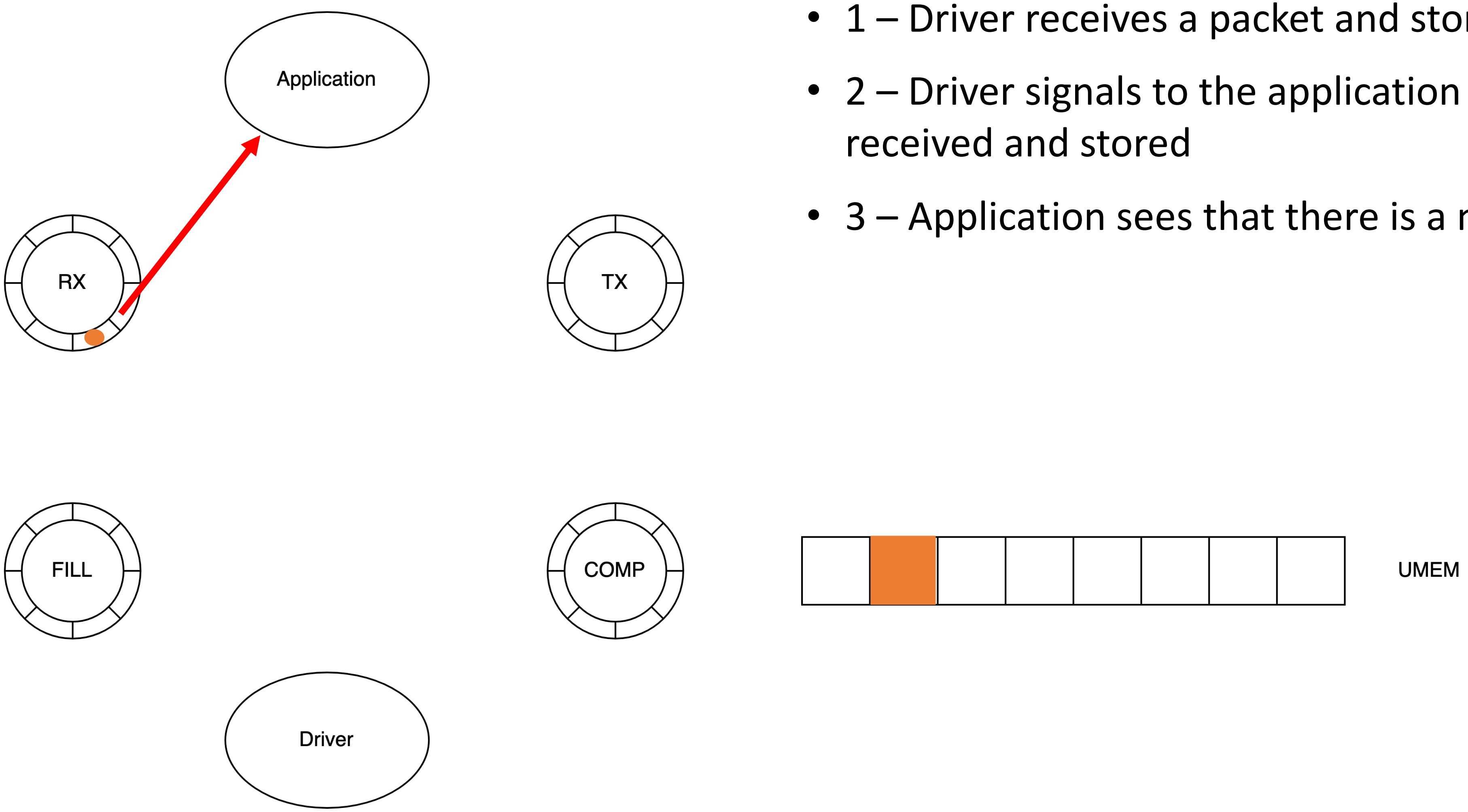
AF_XDP receive example



- 1 – Driver receives a packet and store it into the memory
- 2 – Driver signals to the application that a packet has been received and stored

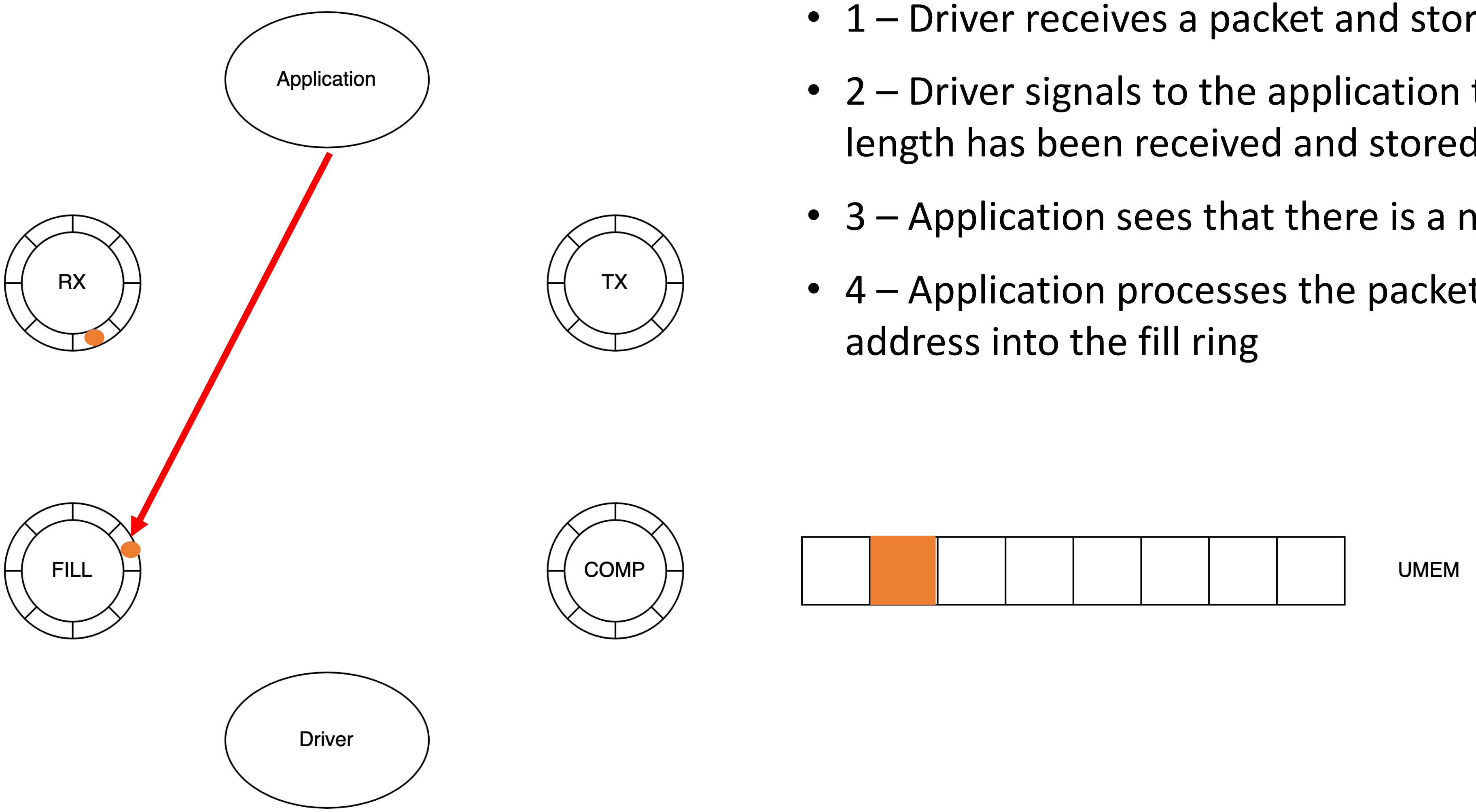


AF_XDP receive example



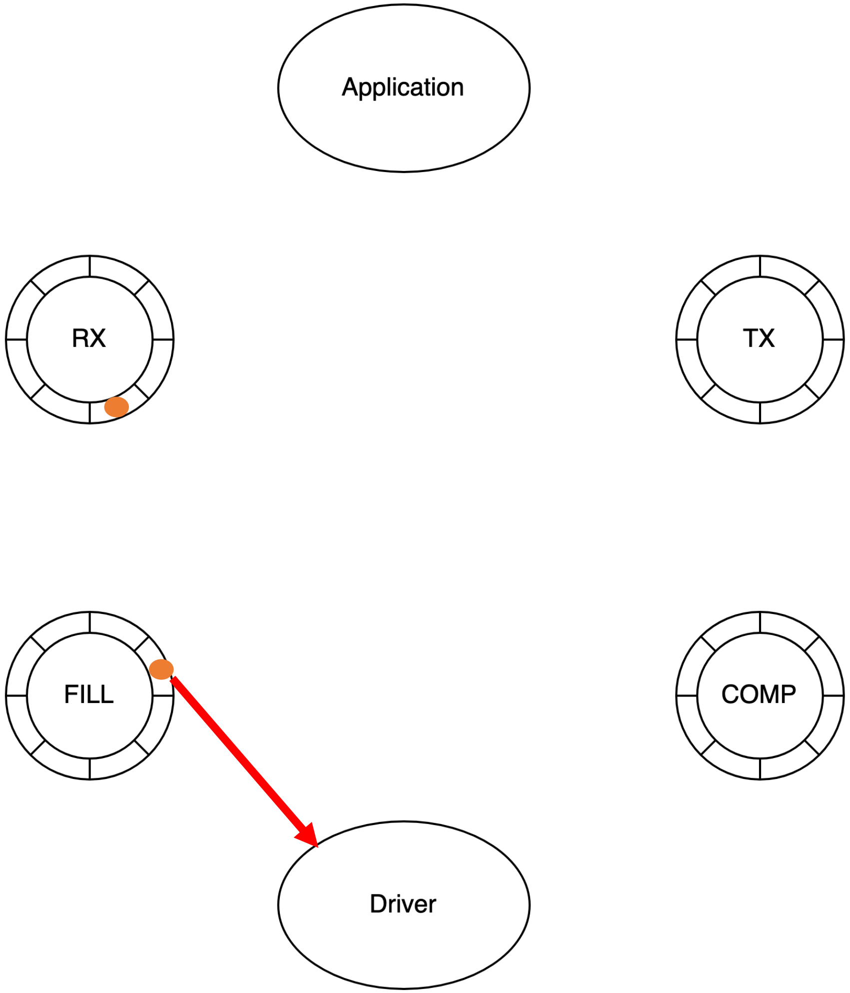
- 1 – Driver receives a packet and store it into the memory
- 2 – Driver signals to the application that a packet has been received and stored
- 3 – Application sees that there is a new packet into its RX ring

AF_XDP receive example



- 1 – Driver receives a packet and store it into the memory
- 2 – Driver signals to the application that a packet of a certain length has been received and stored at a particular address
- 3 – Application sees that there is a new packet into its RX ring
- 4 – Application processes the packet, and put its memory address into the fill ring

AF_XDP receive example



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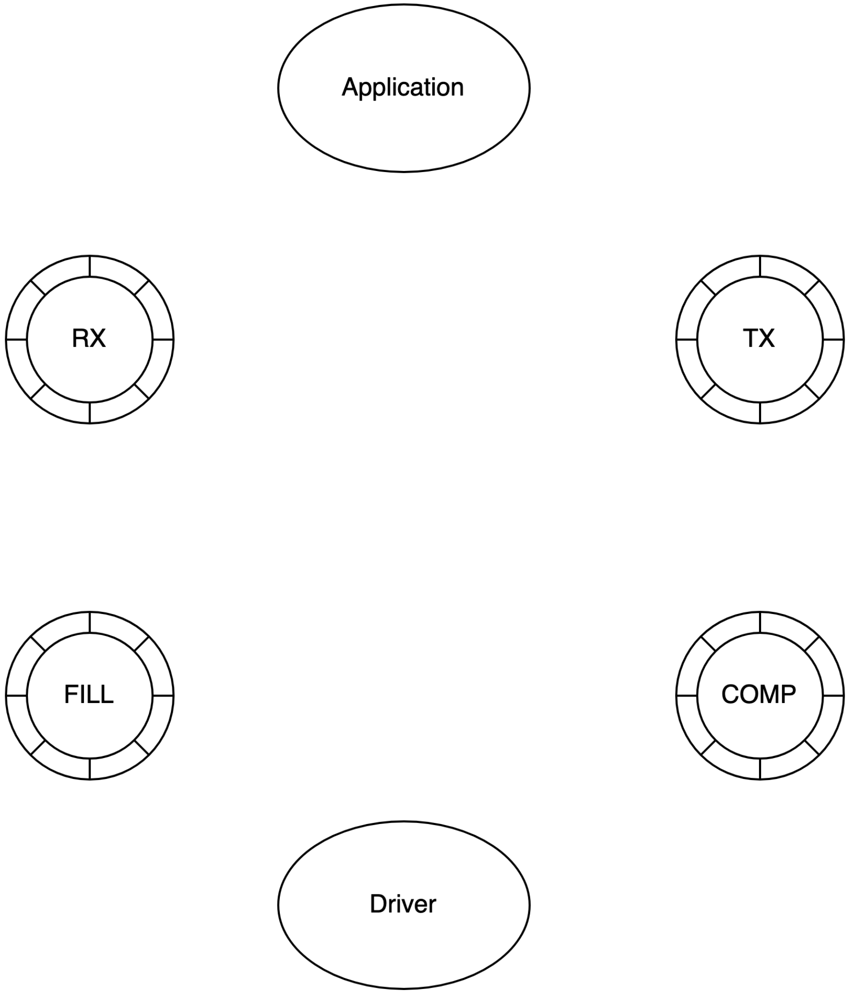
- 2 – Driver signals to the application that a packet of a certain length has been received and stored at a particular address
- 3 – Application sees that there is a new packet into its RX ring
- 4 – Application processes the packet, and put its memory address into the fill ring
- 5 – Driver sees that there is a new entry into the fill ring and can therefore release the memory address used for the packet

AF_XDP receive example



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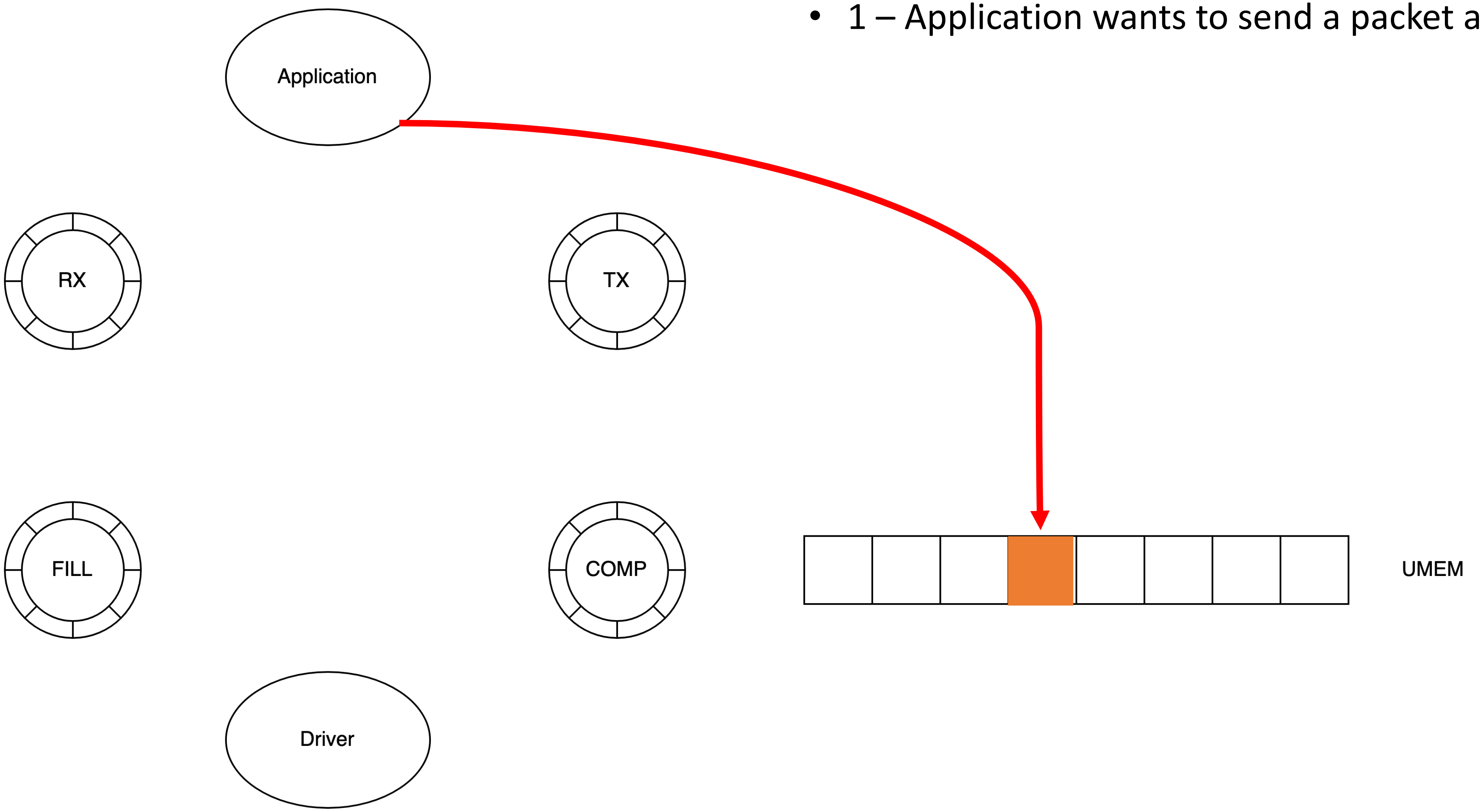
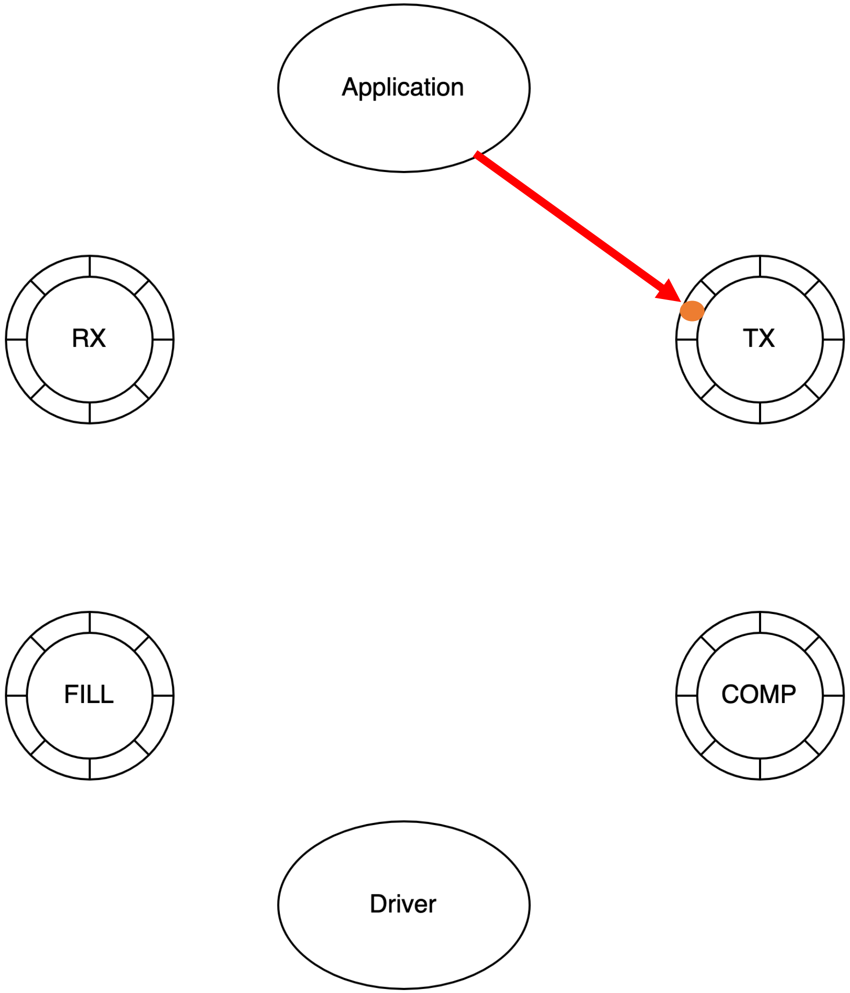
AF_XDP send example

- 1 – Application wants to send a packet and put it into the UMEM

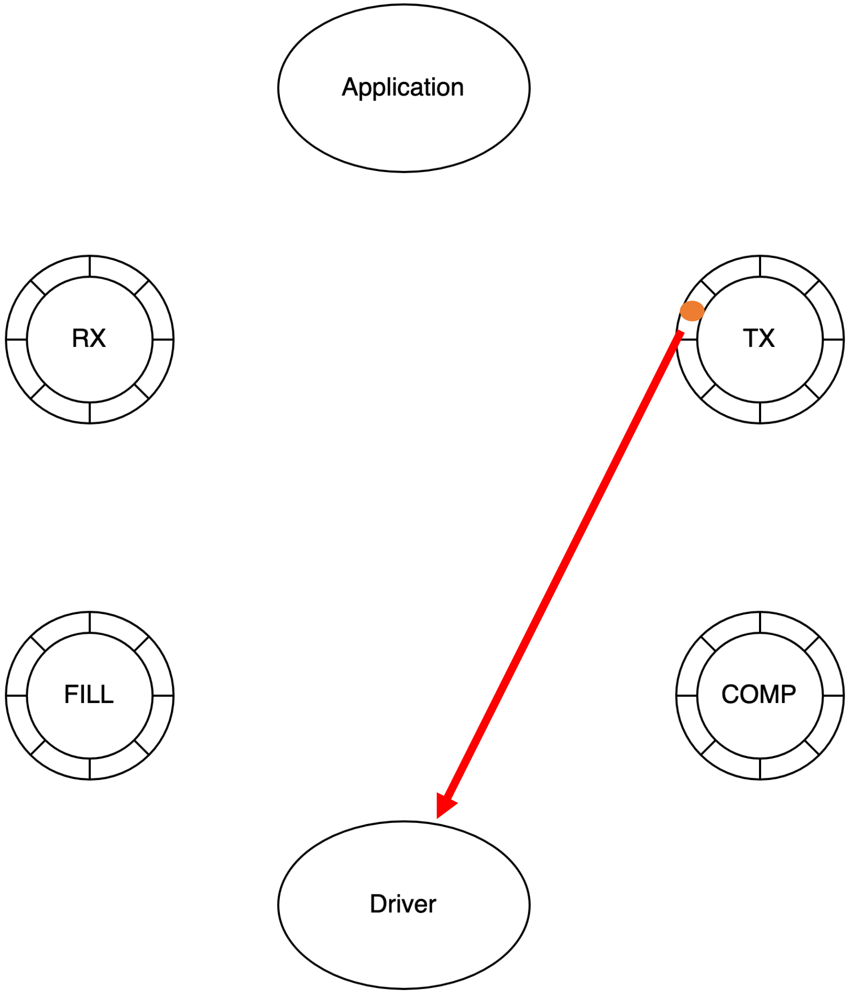


AF_XDP send example



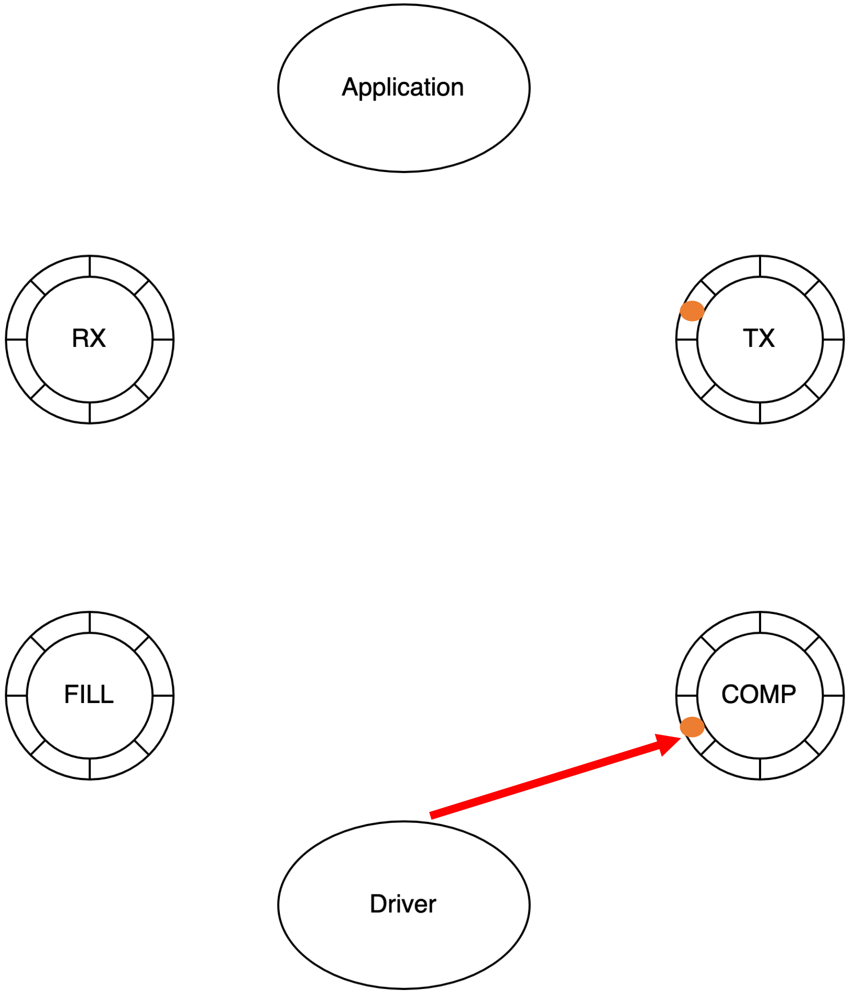
- 1 – Application wants to send a packet and put it into the UMEM
- 2 – Application signals to the driver that a packet has to be sent by putting it into the TX ring

AF_XDP send example

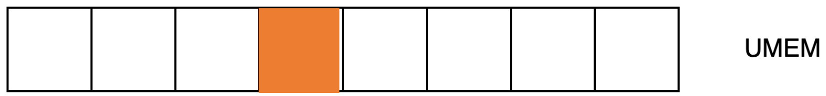


- 1 – Application wants to send a packet and put it into the UMEM
- 2 – Application signals to the driver that a packet has to be sent by putting it into the TX ring
- 3 – The drivers sees a new packet in the TX ring and send it

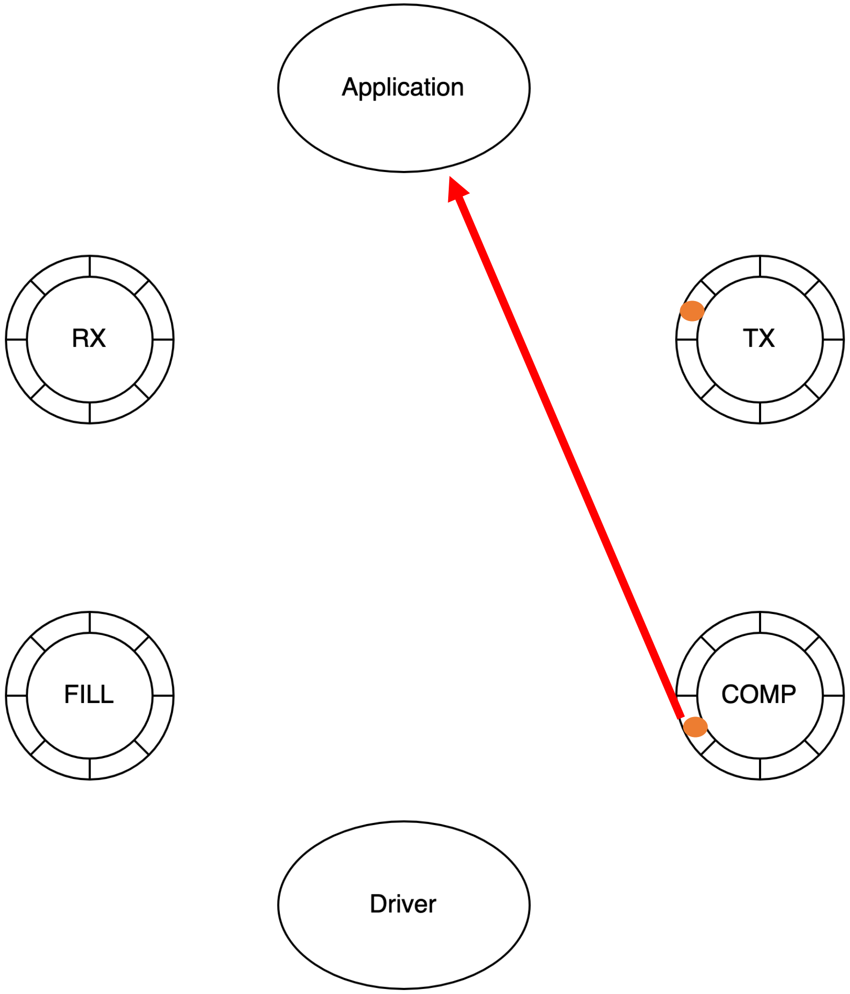
AF_XDP send example



- 1 – Application wants to send a packet and put it into the UMEM
- 2 – Application signals to the driver that a packet has to be sent by putting it into the TX ring
- 3 – The drivers sees a new packet in the TX ring and send it
- 4 – The drivers put the memory area associated with the sent packet into the completion ring

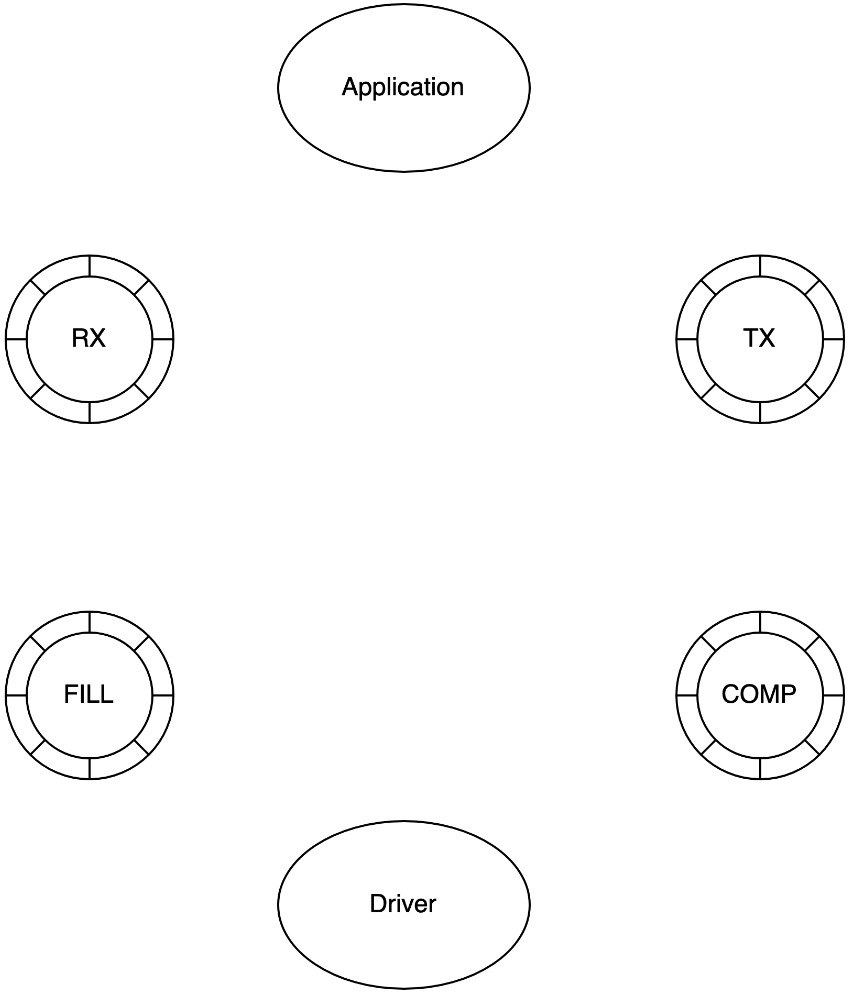


AF_XDP send example



- 1 – Application wants to send a packet and put it into the UMEM
- 2 – Application signals to the driver that a packet has to be sent by putting it into the TX ring
- 3 – The drivers sees a new packet in the TX ring and send it
- 4 – The drivers put the memory area associated with the sent packet into the completion ring
- 5 – Application sees that there is a new entry into the completion ring, release it and can therefore ask to send another packet

AF_XDP send example



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Conclusion on the architecture

- Not as easy as a typical AF_INET socket
- Lot of things to do by hand
- Usage of a library interacting with the low-level API recommended

III – Some results

Our testbed

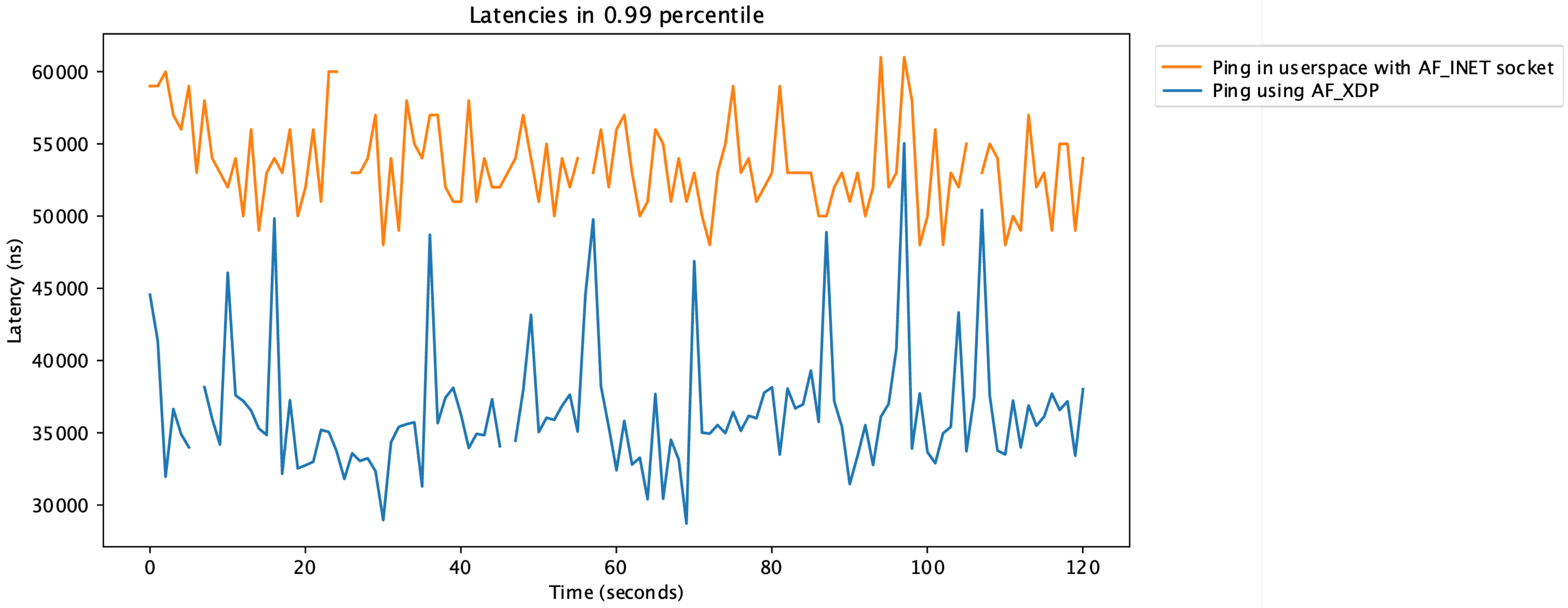
- 2 servers
  - Recent one with AMD EPYC 7443P 24-Core Processor
  - Older one with Intel(R) Xeon(R) CPU E5-2420 v2 @ 2.20GHz
  - Both with 100 Gbps Mellanox network interfaces

- Pings on baremetal

Libraries used

- Before everything in libbpf
  - Since libbpf 1.0, everything moved into libxdp
  - Libbpf
    - Found in recent kernels
    - https://github.com/libbpf/libbpf
  - Libxdp
    - Only found in recent version of Redhat?
    - https://github.com/xdp-project/xdp-tools/tree/master/lib/libxdp
- Rust library available
  - https://github.com/DouglasGray/xsk-rs

AF_INET vs AF_XDP

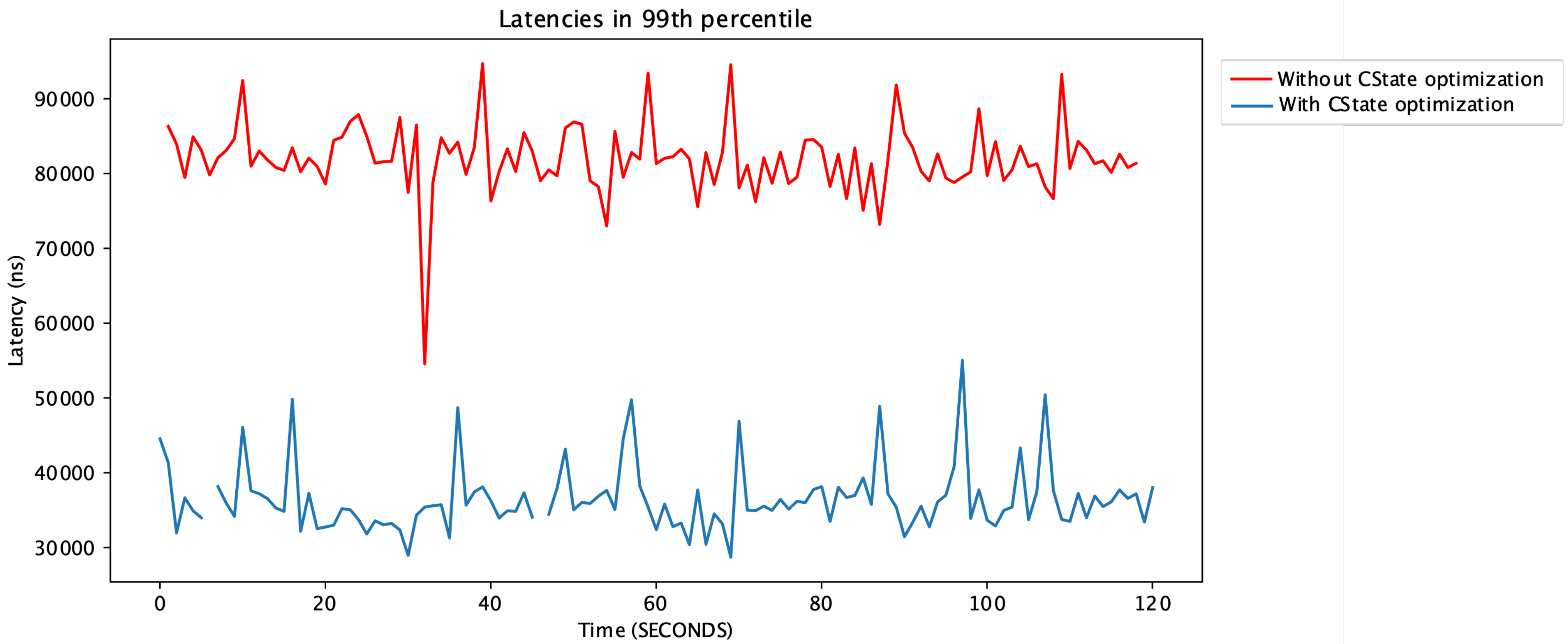


Ping between 2 hosts with AF_XDP and without (lower is better)

Kernel mechanisms impacting latency

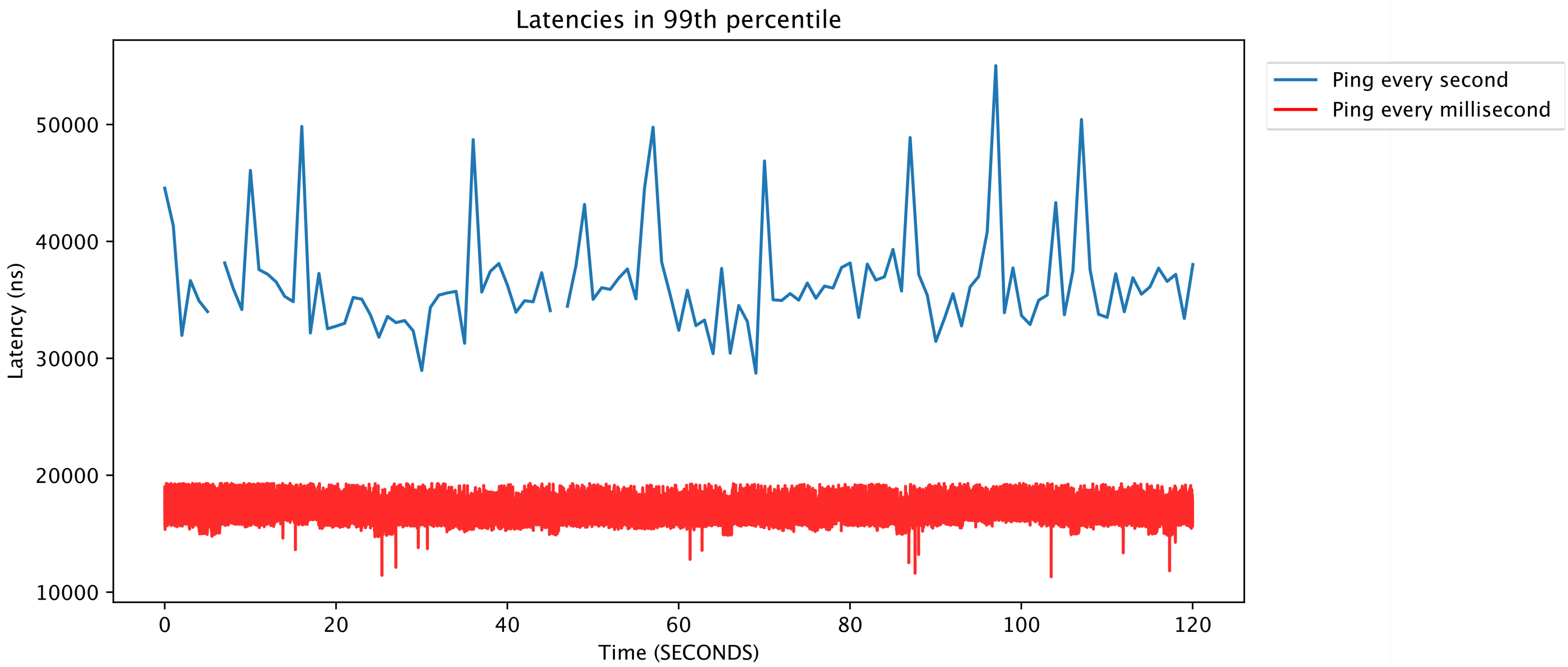
- Cstates
  - CPU might be in an energy saving state
- RX / TX Coalescing
  - Delays packets for batch processing
- NAPI scheduling
  - Driver
- Others?

Impact of CStates



Ping between 2 hosts with AF_XDP

Impact of packet rate on latency



AF_XDP + all kernel optimisations activated

Conclusion

- AF_XDP / XDP allow to have a lower latency than using a classical socket
- Comes with some challenges
  - Using it requires some low level programming
  - Need to rewrite / reuse in user space several networking stack functions

Questions ?

- More info:
  - https://www.kernel.org/doc/html/latest/networking/af_xdp.html
  - M. Karlsson and B. Topel, ‘The Path to DPDK Speeds for AF XDP’
  - W. Tu, Y.-H. Wei, G. Antichi, and B. Pfaff, ‘revisiting the open vSwitch dataplane ten years later’