OVS Acceleration using Network Flow Processors

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Agenda

- Background: OVS on Network Flow Processors
  - Network device types => features required => acceleration concerns
- OVS Acceleration Options
  - OVS (or OpenFlow) Agent Only
  - Offloading OVS with Fallback
    - Examples:
      - Userspace <=> accelerator
      - Userspace <=> kernel <=> accelerator
      - Userspace <=> (kernel OR accelerator)
      - Userspace <=> (kernel AND accelerator)
- Observations
- Evolution
- Conclusions

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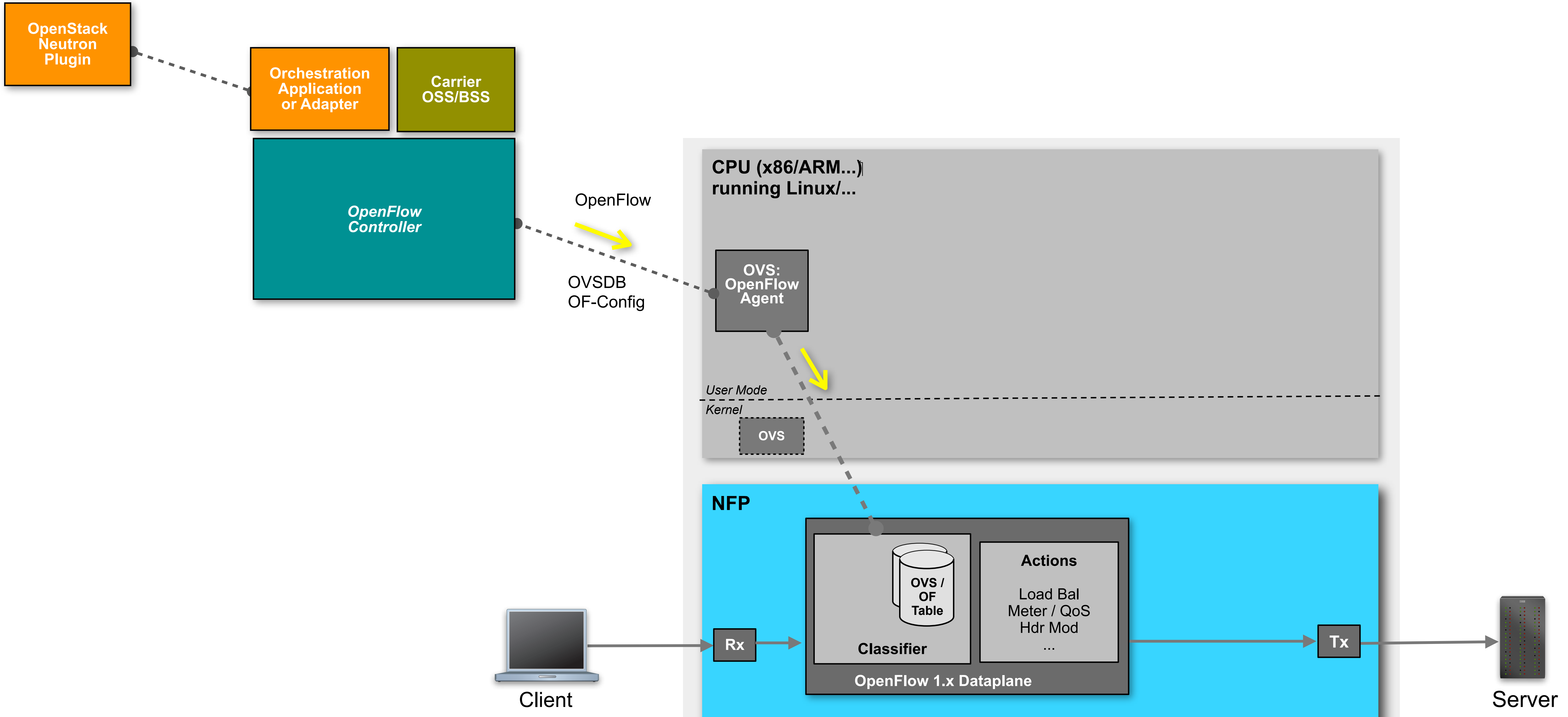
Summary: OVS on Network Flow Processors



Network Flow Processor Powered Networking Device

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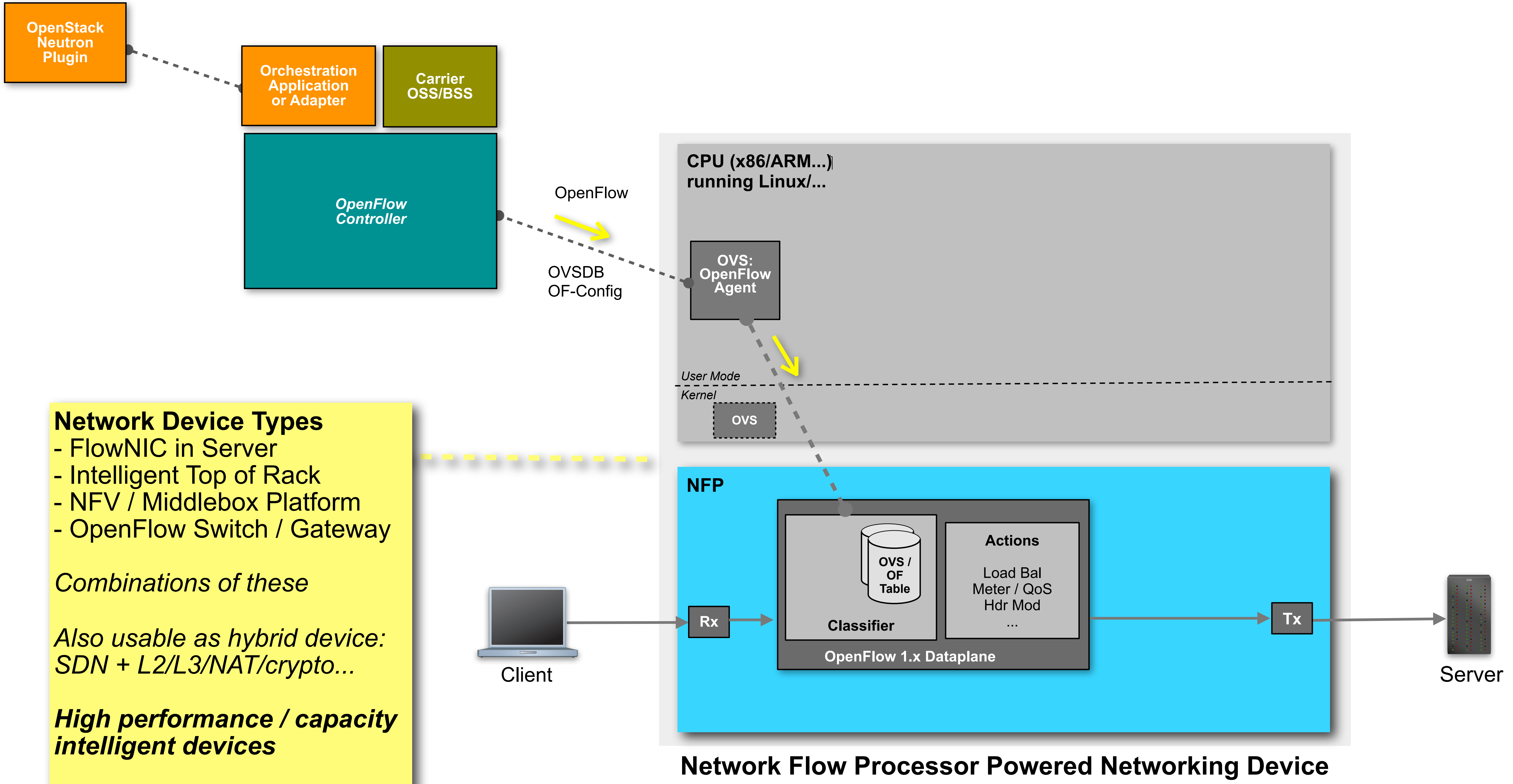

Network Device Types
- FlowNIC in Server
- Intelligent Top of Rack
- NFV / Middlebox Platform
- OpenFlow Switch / Gateway

Combinations of these

Also usable as hybrid device: SDN + L2/L3/NAT/crypto...

High performance / capacity intelligent devices

Improved efficiency

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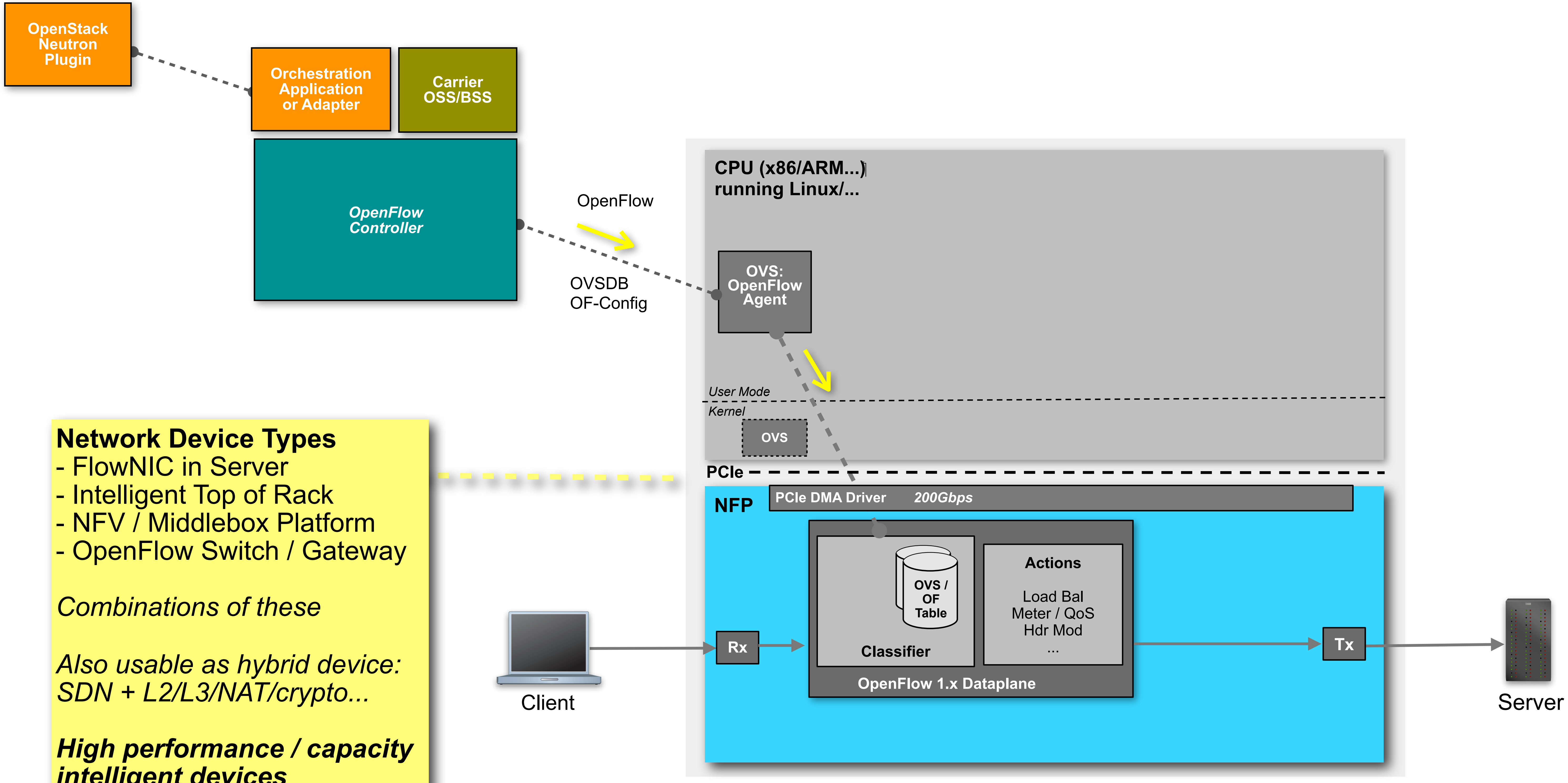

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NFP: 200+ core / 200+G networking / 200G PCIe
(200G=2x100G full duplex: line rate=300Mpps, complex processing target = 60Mpps, 6Mfps)

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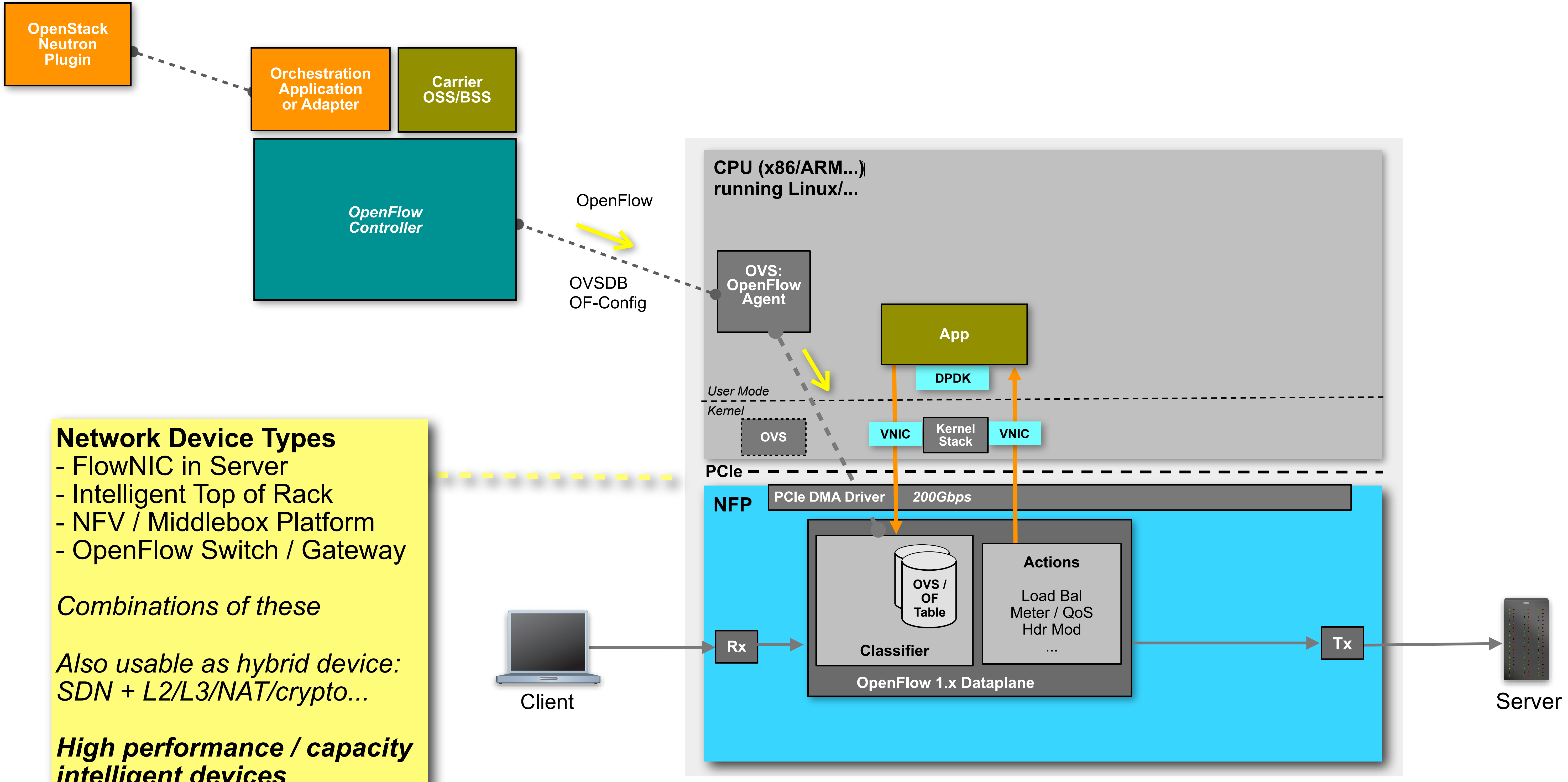

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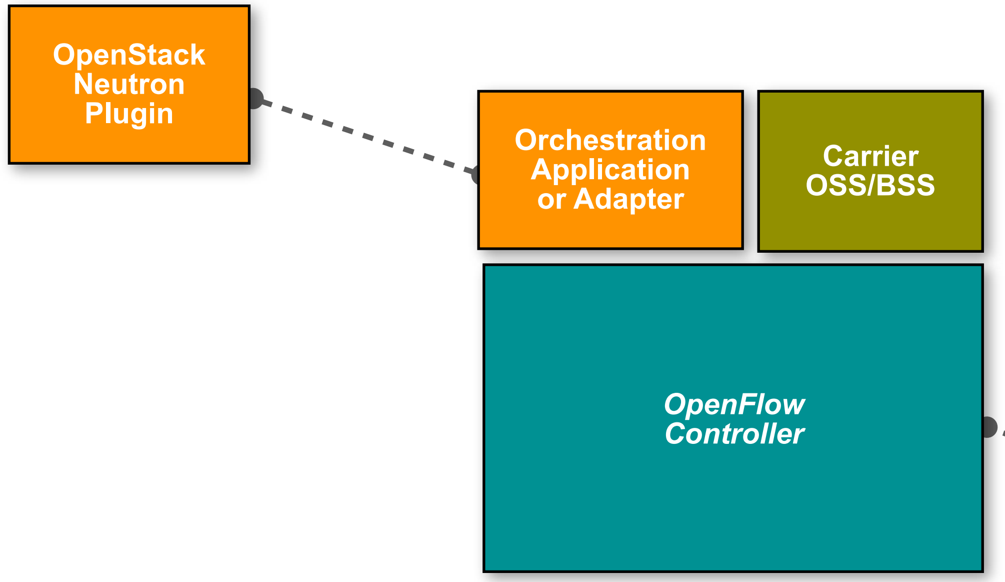

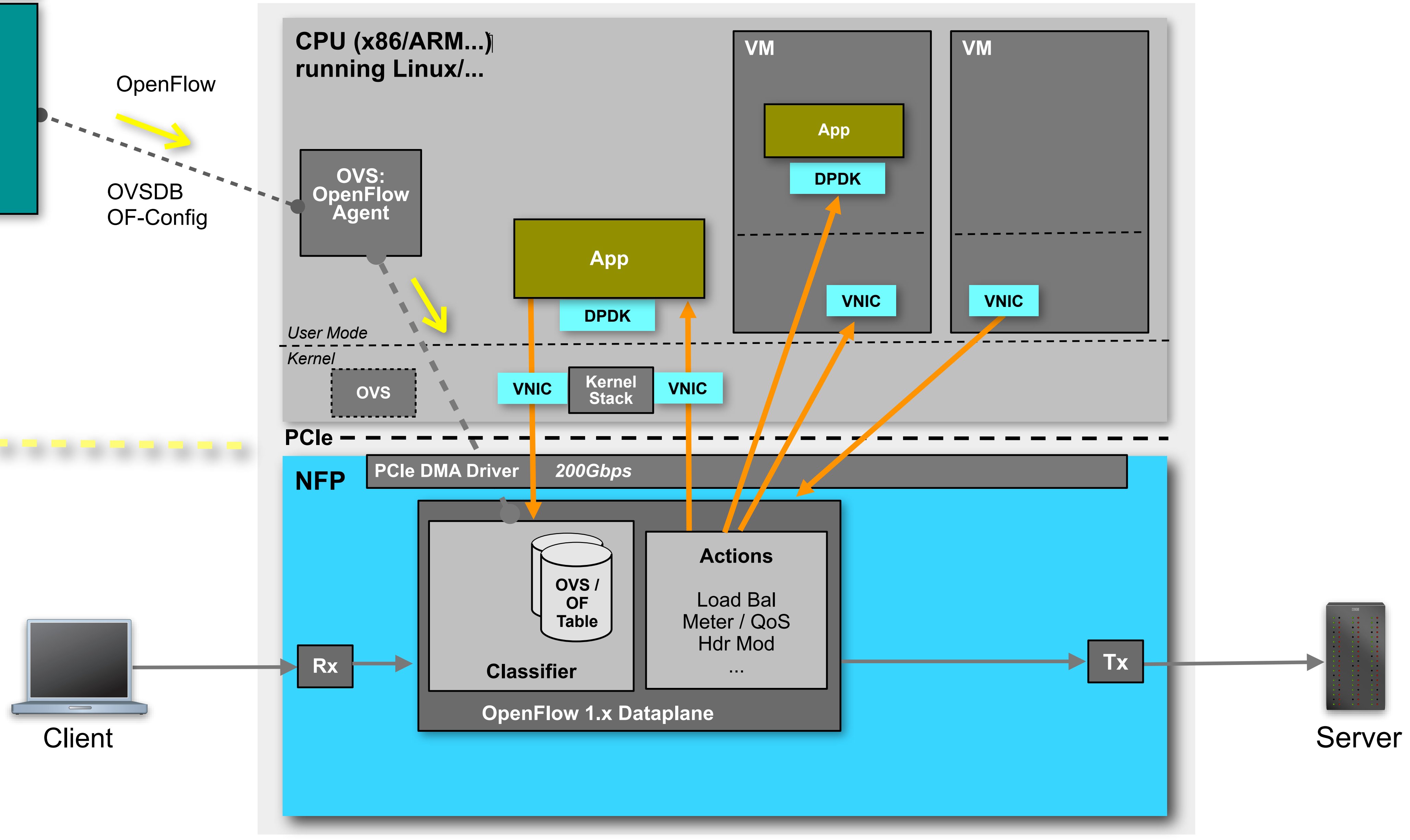

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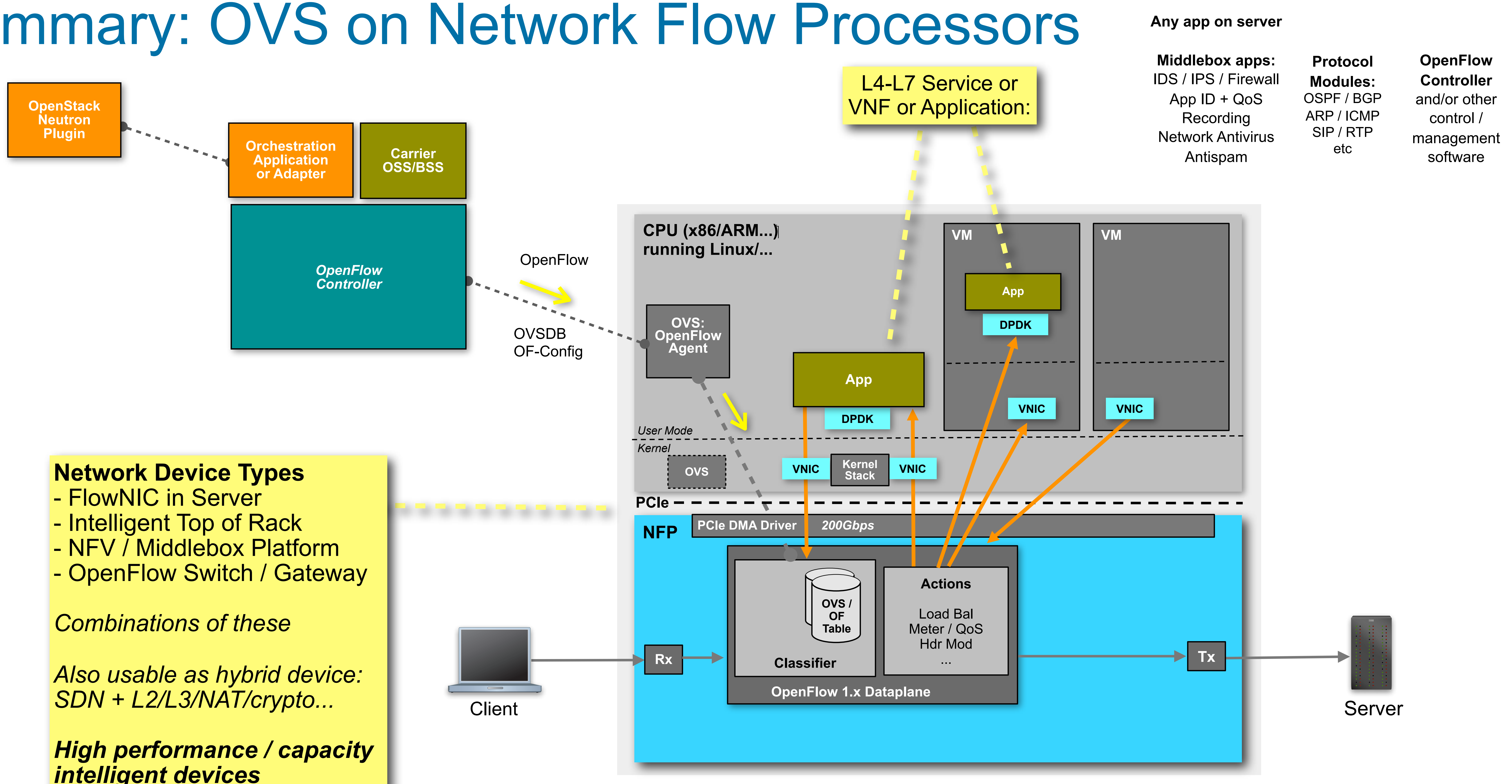

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Summary: OVS on Network Flow Processors

Any app on server

Middlebox apps:
IDS / IPS / Firewall
App ID + QoS
Recording
Network Antivirus
Antispam

Protocol Modules:
OSPF / BGP
ARP / ICMP
SIP / RTP
etc

OpenFlow Controller
and/or other
control /
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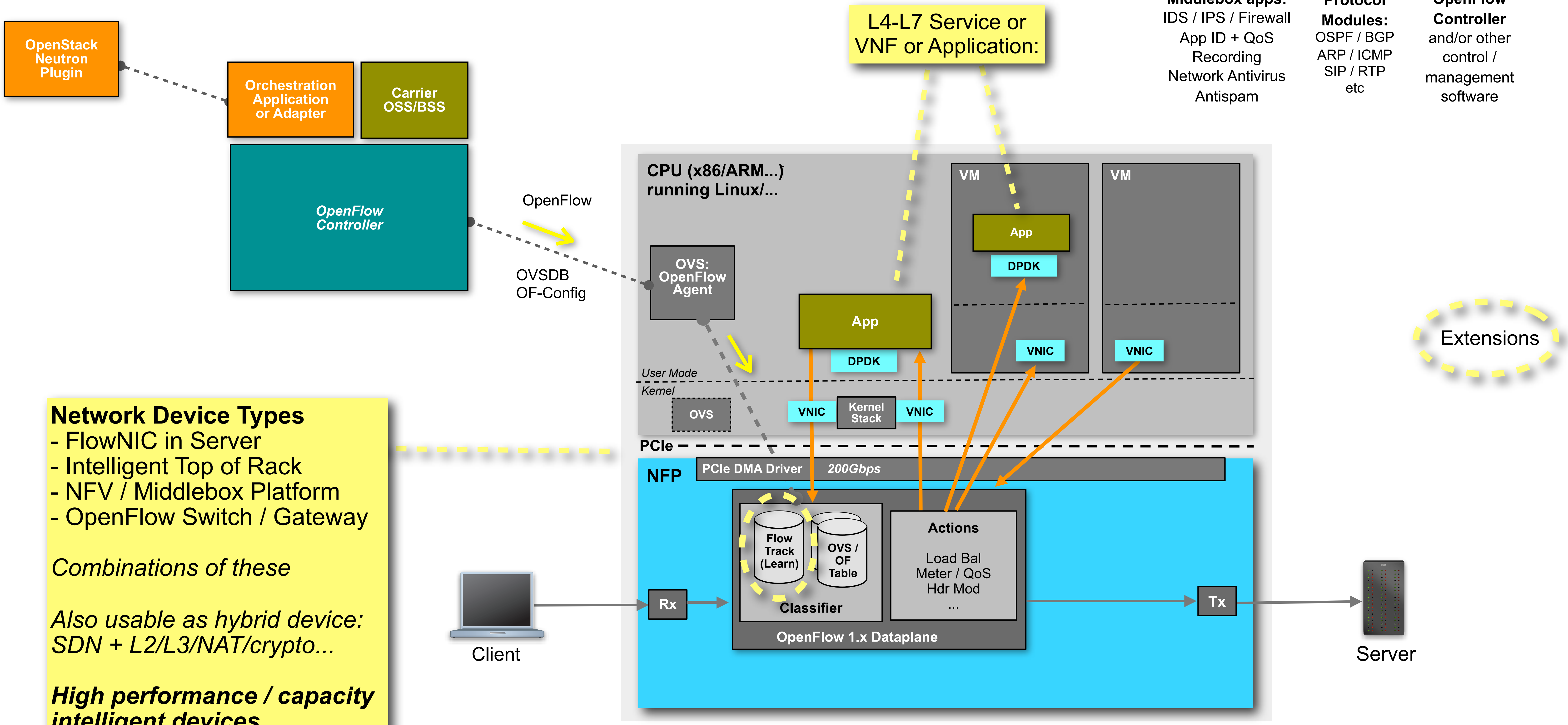

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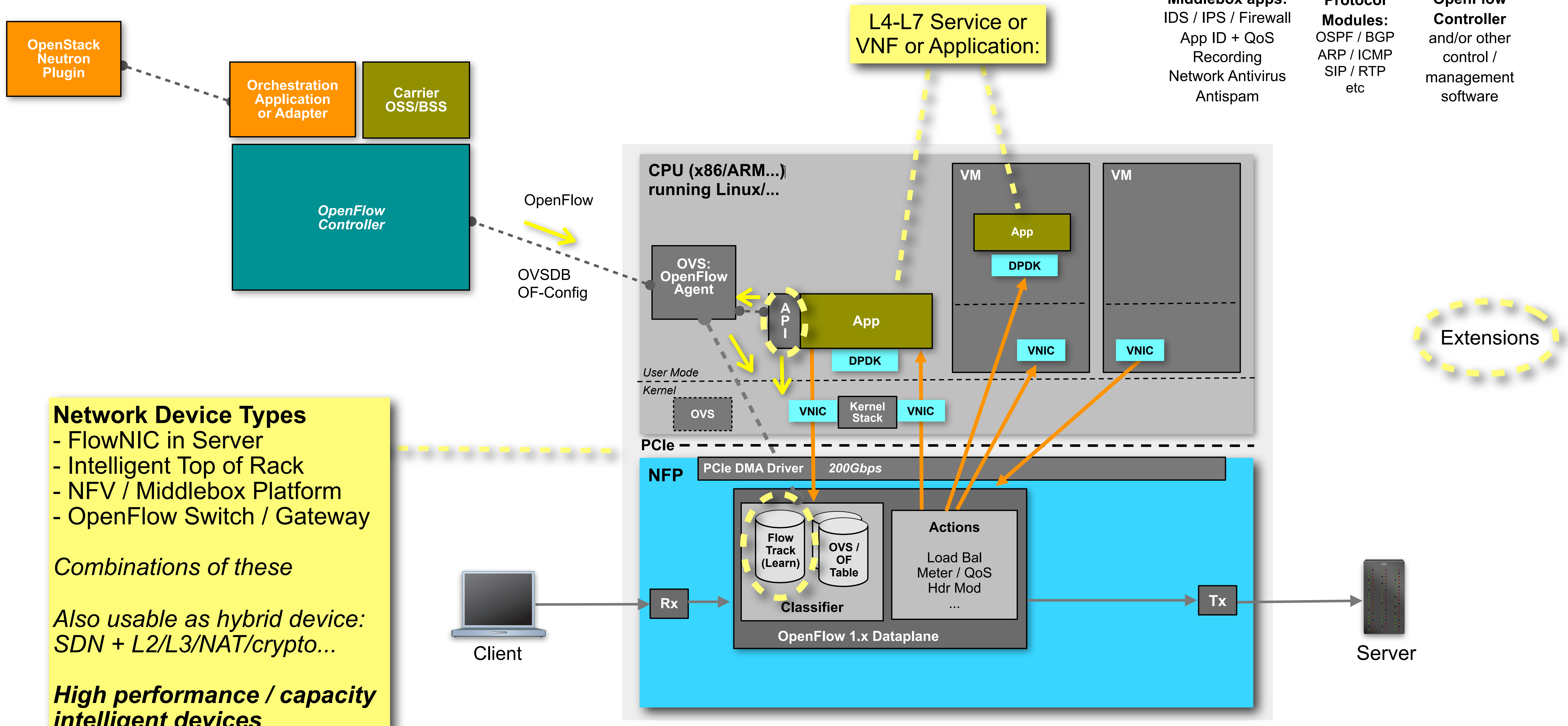

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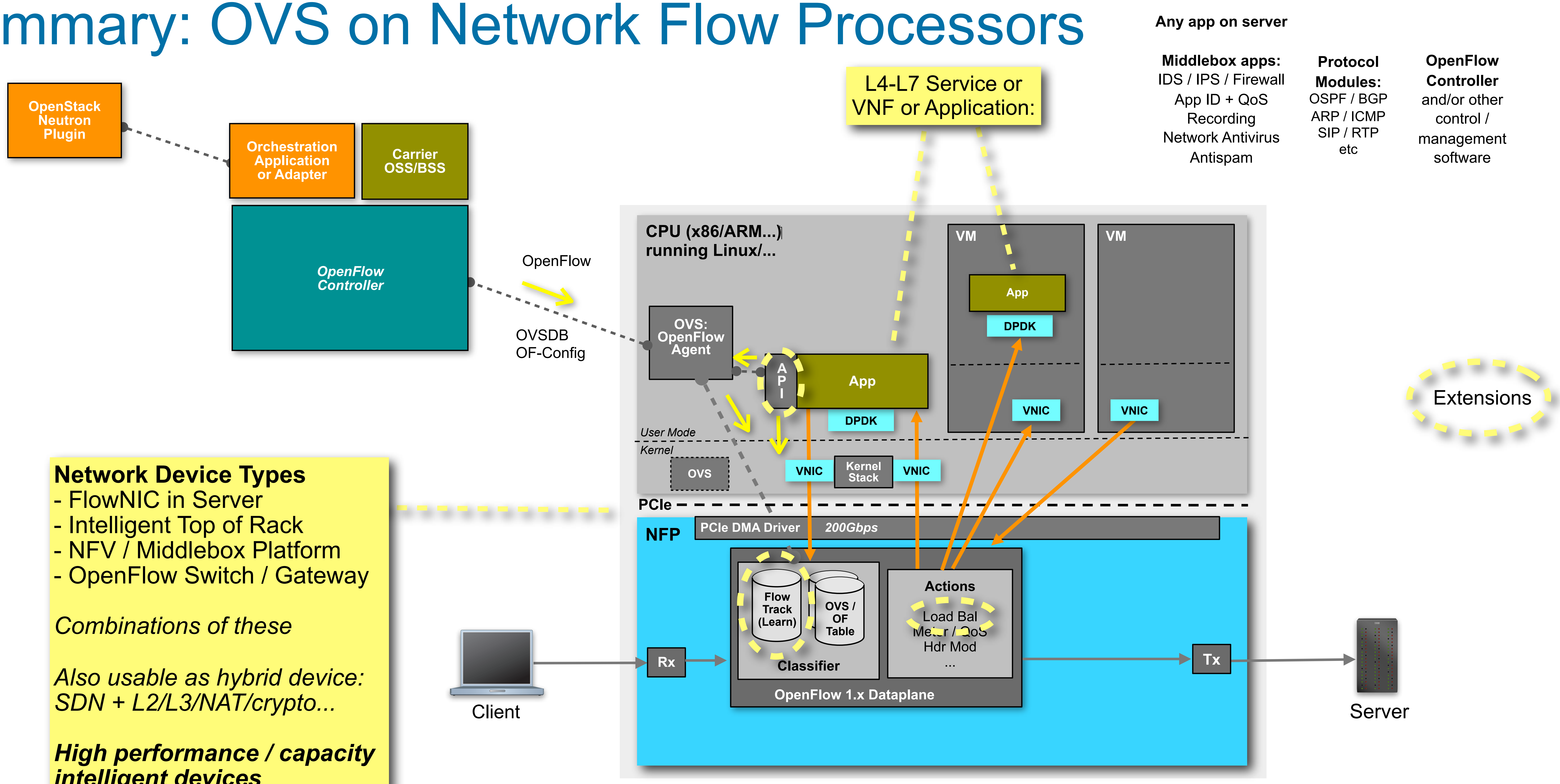

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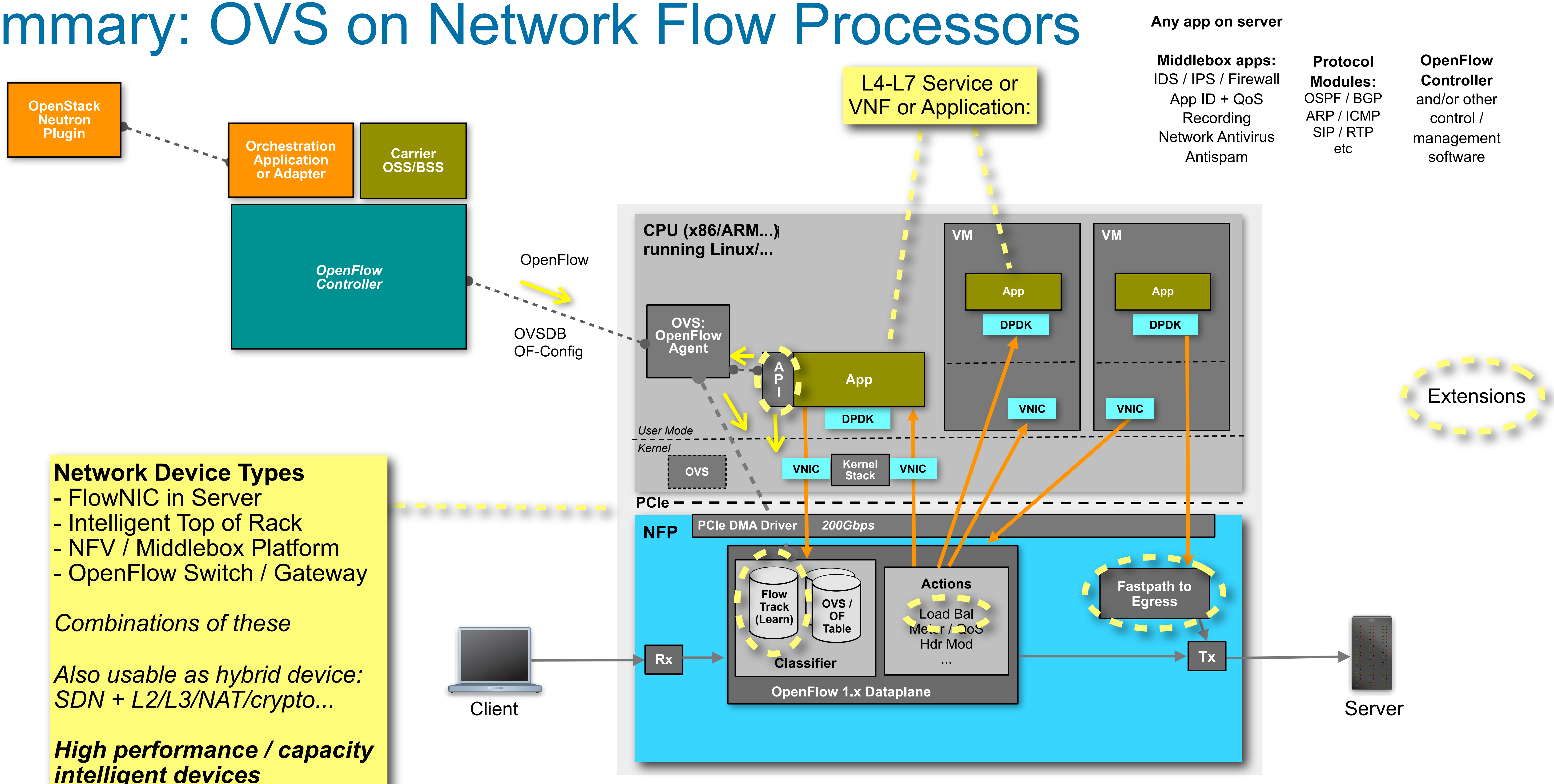

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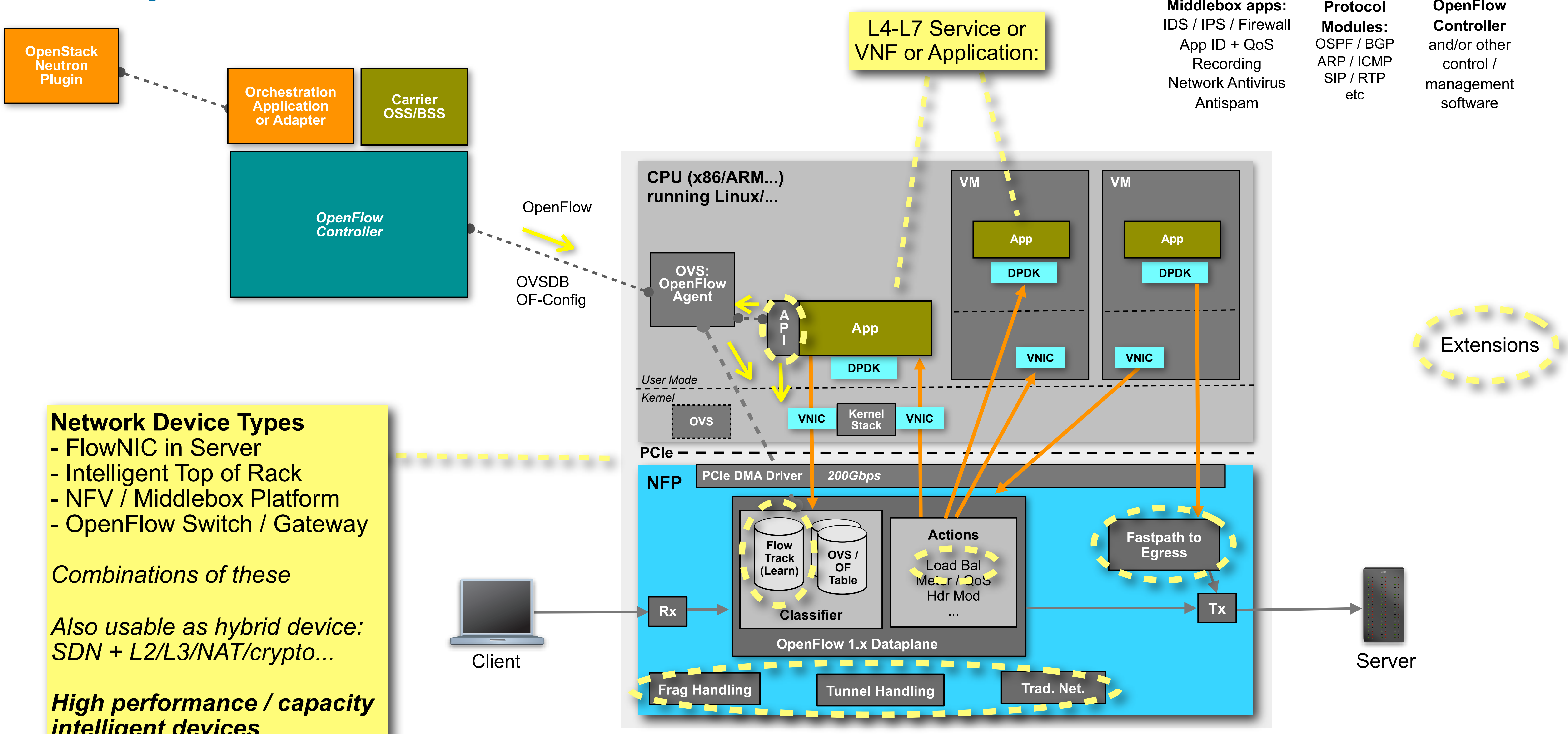

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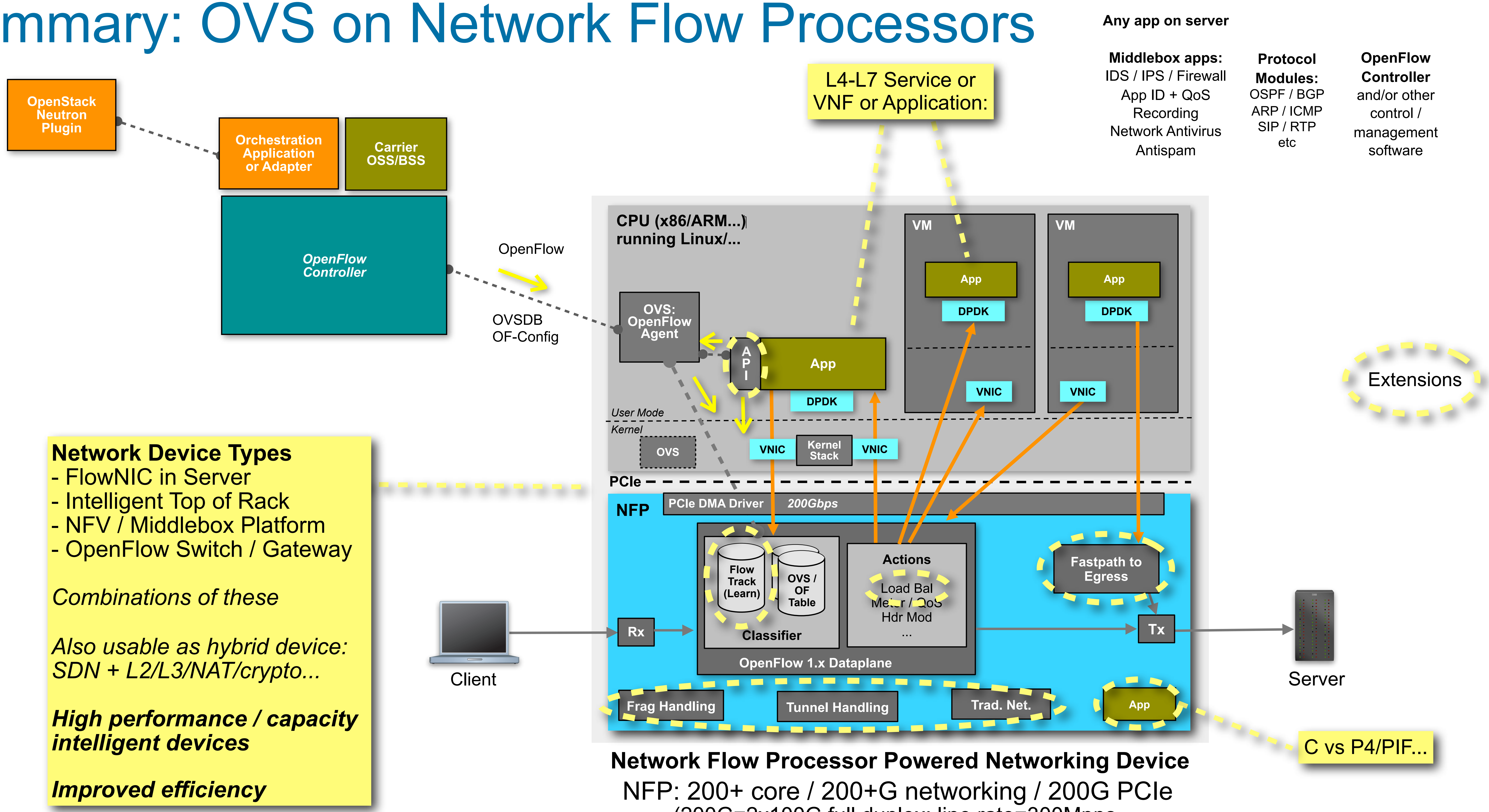

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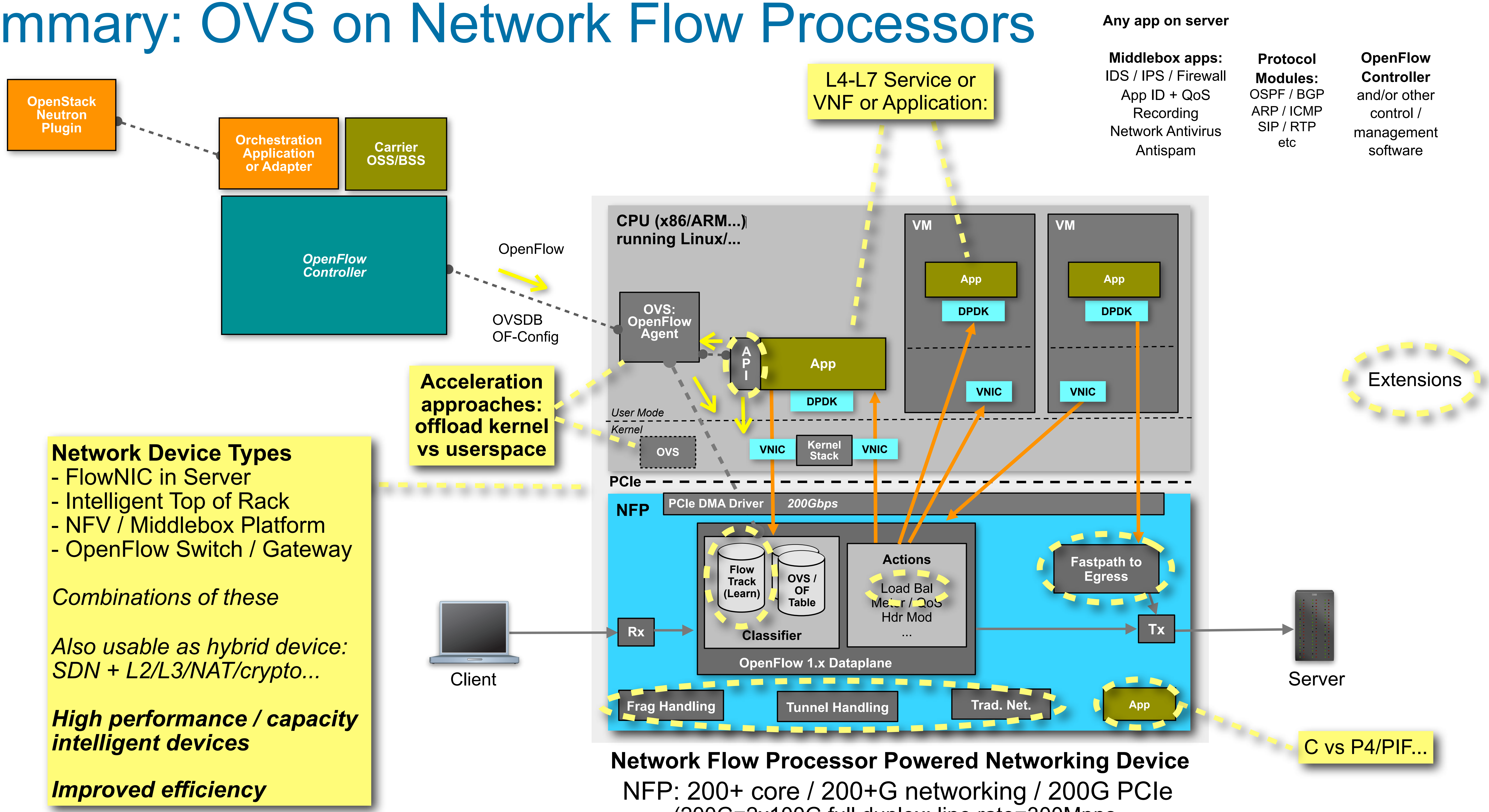

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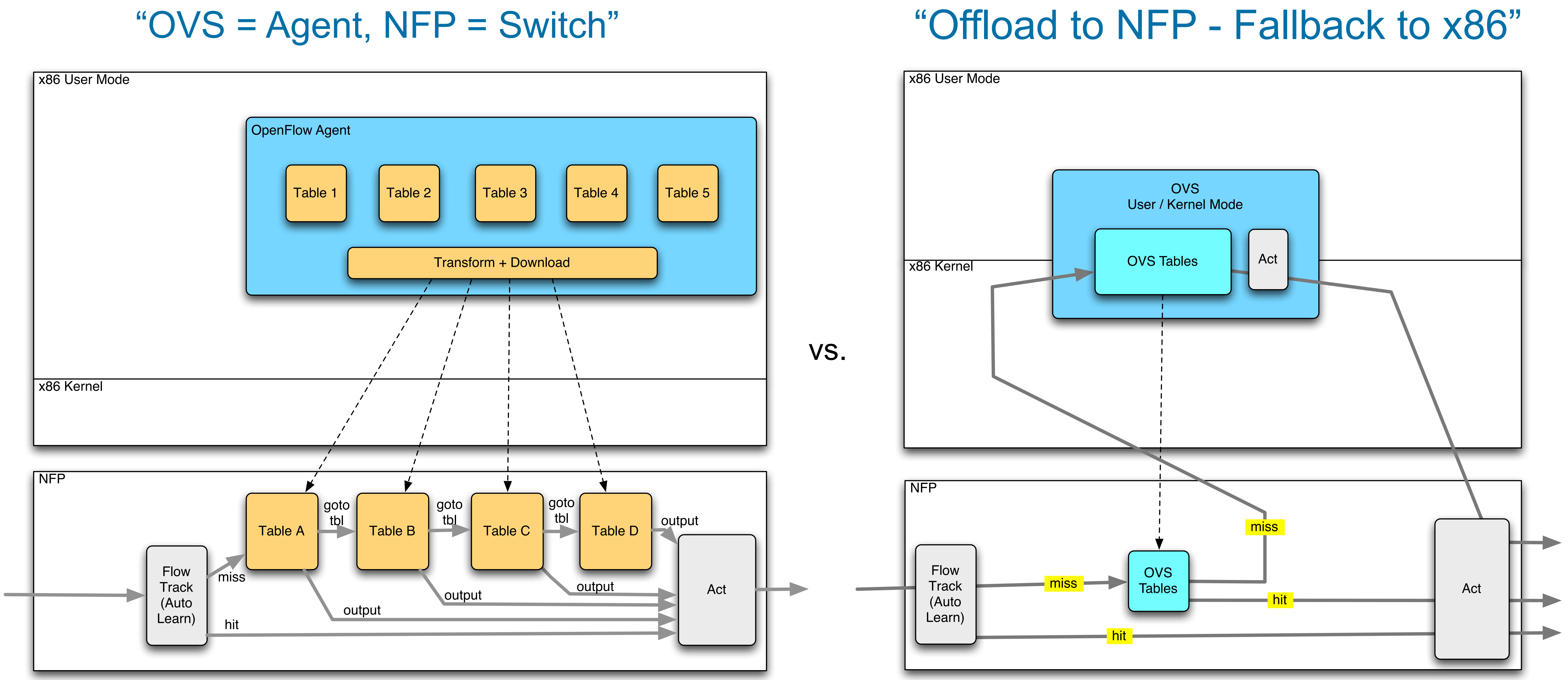
OVS Acceleration Approaches: OVS Agent vs OVS Offload/Fallback



- Fallback reasons: table lookup miss (table overflow vs. not full but no entry matched), unsupported classification (e.g. unsupported protocol), unsupported action, and/or deliberate hand-off to agent (e.g. packet in to controller)
- Most appropriate approach depends on features / perf. needed (related to type e.g. NIC in server, intelligent TOR, mbox / gateway)
  - In part depends on performance required vs. achievable with attached x86 (or other CPU)

All variations support packet delivery from NFP directly to (host / guest) x (kernel / user mode), tunnel handling in NFP...

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"OVS Agent Only" Features

- Dataplane feature set "limited" to what switch/NIC hardware (NFP) supports
  - Could exceed what OVS dataplane offers (e.g. set individual header fields, not just entire L2/L3 header like OVS kernel datapath)
  - Netronome's implementation actually fairly complete (with high performance):
    - OpenFlow 1.3+ with 250 tables, Ethernet / VLAN / MPLS / IPv4+v6 / TCP / UDP... matching + actions (set/push/pop/dec TTL), metering, QoS, logical port style tunnel termination/origination (VXLAN / [NV-]GRE / ...)
    - Extensions: fragmentation, ICMP stack, IP stack (route lookup / ARP processing) for tunnels, load balancing, improved QoS...
- Approach can support (host or guest) x (user or kernel mode) data delivery (incl. SR-IOV)
  - Apps (kernel netdev / user mode driver) modeled as virtual ports - after app transited, packets re-injected into pipeline
  - Apps (user mode driver) can trigger egress fastpath - after app transited, packet sent directly to egress port
  - Load balancing to application instances (static + stateless vs. dynamic + stateful)
- Each physical switch/NIC port represented by a VNIC instance in x86 (typically host kernel netdev)
  - Exposes physical port statistics, link state -- Linux commands e.g. ethtool / ip / ifconfig just work
  - In-band control: my MAC traffic diverted, broadcast / multicast copied (without needing OpenFlow table entries)
  - Permits sniffing traffic (tcpdump) - detects promiscuous mode on/off (could offload BPF too)
- Flow tracking table
  - Manual population / modification via API (n M mods/s) or OpenFlow (mods/s are limited by controller / agent)
  - Auto learning - n M microflows/s - optionally using API to update policy / obtain statistics

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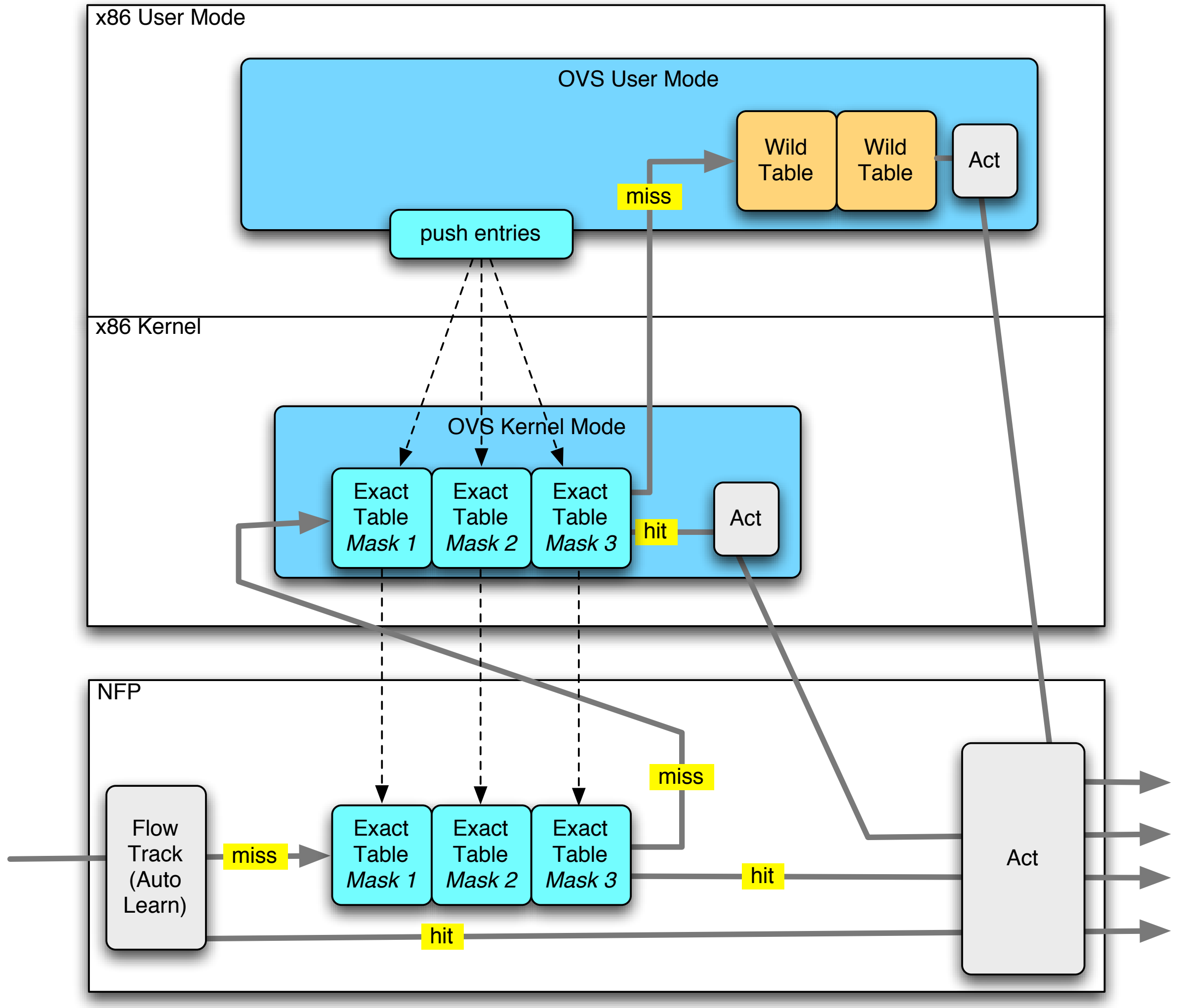
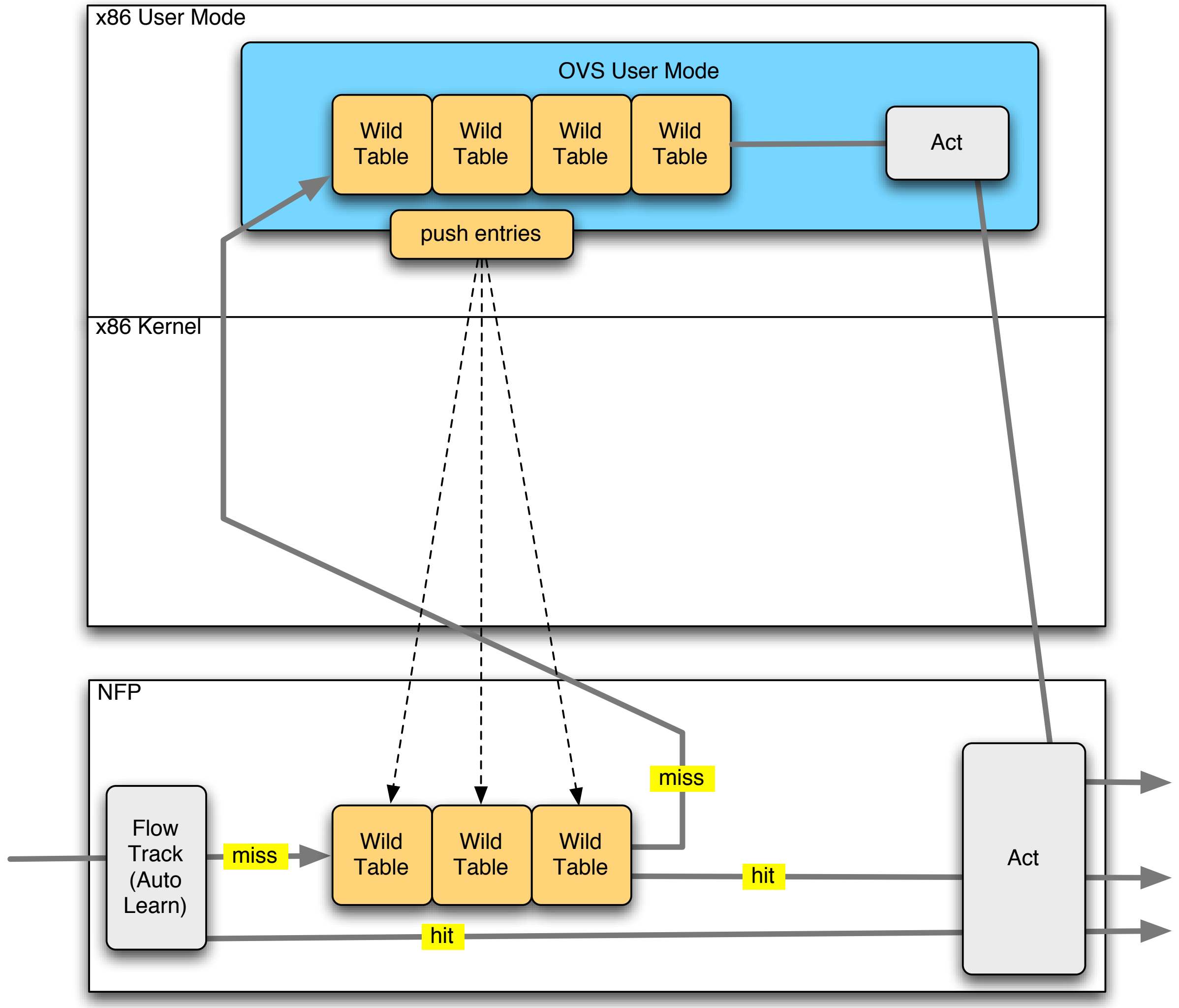
Offloading with Fallback: Offload OVS Kernel vs. Userland



vs.



- Fallback to OVS x86 code to support features not in NFP (yet) or entries not present in NFP tables (e.g. DRAM-less NIC)
- OVS kernel offloaded to NFP, fallback to OVS kernel (and fallback onward to OVS userland as usual)
  - Feature set typically reflects (but can sometimes exceed) OVS kernel datapath capabilities
  - Could be regular OVS userland - but also different userland (BigSwitch, Midokura, PLUMgrid...)
- OVS userland offloaded to NFP, fallback to OVS userland (via zero copy driver e.g. DPDK)
  - OVS kernel datapath not involved / required (no impact on features + performance, fewer issues with upstreaming to kernel.org)
- Either way a VNIC instance (e.g. kernel netdev) per physical port is useful - statistics, link state, sniffing, in-band control (OpenFlow / SSH ...)

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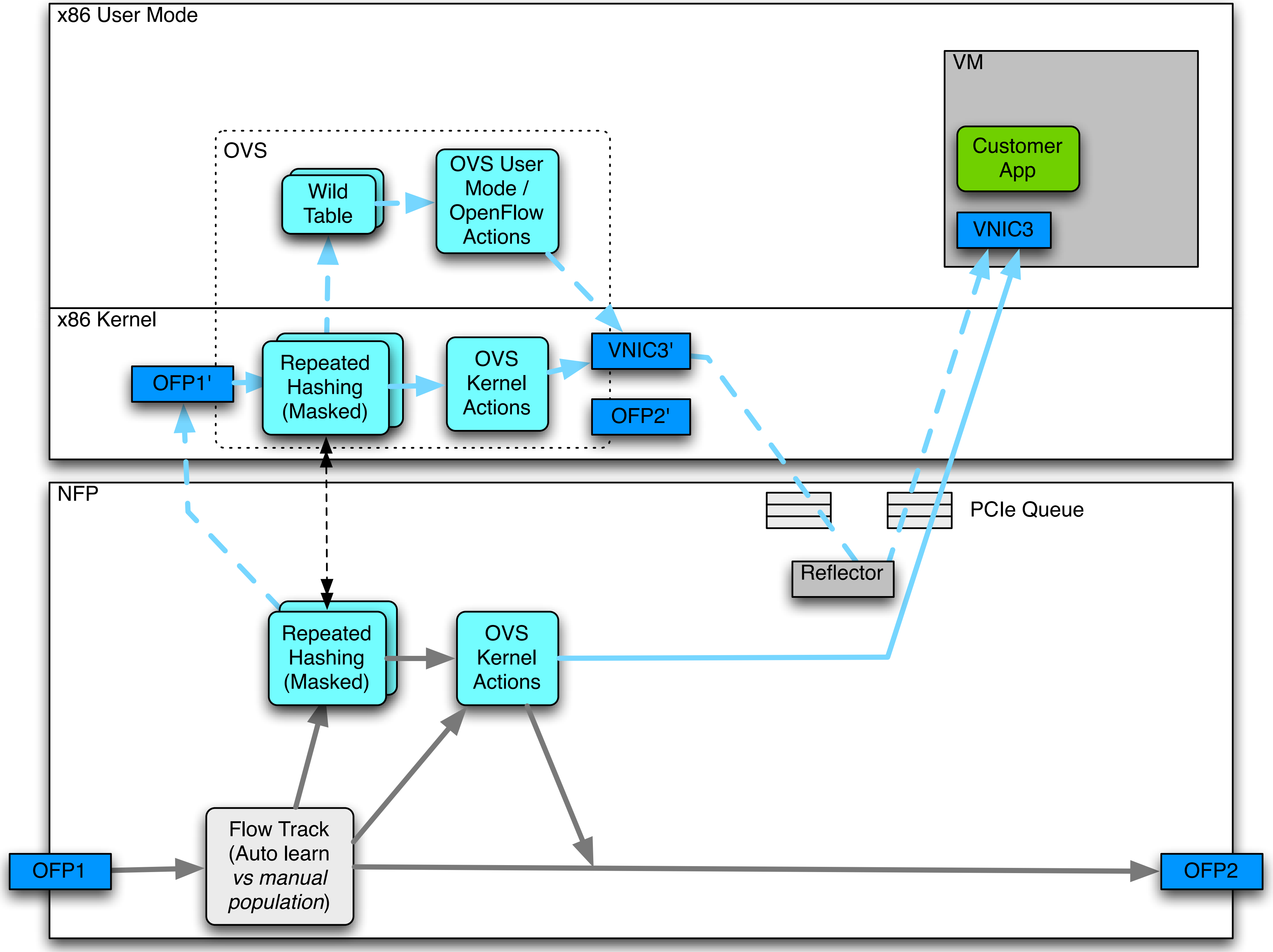
Fallback with Direct Host / Guest Delivery



- NFP sends fastpathed (non-fallback) packets directly to (host or guest) x (kernel or userspace) - e.g. to SR-IOV VF VNIC3
- Fallback traffic sent to host (kernel / userspace): presented to OVS via e.g. VNIC OFP1' --- say OVS outputs to VNIC3'
- Reflector forwards from VNIC3' to VNIC3 (no need to re-process in pipeline as already processed by fallback code)

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Offloading with Fallback: Combos

- Hybrid OVS userland / kernel offload + fallback
  - Easy: multiple switch instances: some userland, others kernel - each physical port attached to one of these
  - Harder: within a switch instance, some traffic sent to kernel, other traffic to userland
    - Based on what?
      - Determination whether userspace processing will be needed - if so, skip kernel?
        - Does not make sense if userspace fallback is minority of traffic / userspace is slower than kernel
      - Default to userspace, change to kernel when kernel processing is needed (for e.g. conntrack, IPsec, etc.)
        - Useful if userspace is faster than kernel
    - Is determination accurate?
      - Hopefully easy and accurate for entire microflow if based on traffic type (stateless)
      - Handing over or starting mid-flow can causes issues (entry state missing in tables, statistics wrong etc.)
    - Not urgent to implement on high functionality / capacity / throughput platform like NFP as most traffic is handled by it..
- Hybrid SDN / traditional networking, hybrid OpenFlow and non-OpenFlow features
  - Traditional forwarding = L2/L3
    - Again, easier if ports attached to distinct traditional or switch instances (internal ports to link them)
    - Otherwise need one mechanism (SDN/traditional) to be primary, other secondary, or need third classifier as tie-breaker
  - Non-OpenFlow features like tunnel handling (e.g. VXLAN / IPsec) / firewalling / NAT / other “black box” features
    - Invocation of features via built in behavior (e.g. my MAC / traffic type) vs. explicitly via an OpenFlow action / logical port etc.
    - Some need IP stack (ARP, route lookup, frag tracking, fragment / defragment) or other kernel functionality
- Examples as implemented on NFP
  - Logical port style VXLAN / GRE termination handled via OVS kernel style mechanisms (lookup tunnel header + inner header together in tables)
  - IP stack (route lookup to obtain egress port + source IP) and ARP processing for tunnel origination, leveraging Linux stack (entries are cached on NFP)
  - IKE for IPsec, leveraging Linux usermode code
  - Fragment tracking (without reassembling fragments) + peeking into tunnels (without terminating them) + flow tracking -- implemented “before” OVS / OpenFlow

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Observations

- NFPs support all these acceleration approaches (implemented agent, usermode offload, kernel offload)
  - Certain approaches may be more or less suited to more limited acceleration hardware
- Offload with fallback degrades gracefully (features e.g. classification / actions, also capacity)
  - Fallback to kernel vs to usermode?
    - Where are the existing standard features (kernel e.g. conntrack, vs. usermode e.g. richer OpenFlow)?
    - Which parts of the code do OVS community customize most often / readily?
    - Which is most performant (e.g. DPDK or other userspace driver avoiding some kernel overheads vs. cache in kernel)?
- Offloading OVS kernel does not necessarily yield the highest performance - examples of issues:
  - OVS kernel datapath functionality limited, e.g. broad brush actions: decrement TTL => replace L3 header
  - Number of entries in OVS kernel tables could explode or experience churn (even with megaflow changes)
- Offloading OVS userspace simplifies supporting acceleration hardware with varying intelligence / capacity
  - In kernel / at netlink (DPIF), entries have been "compiled" to low level => easier when seeing higher level intent in user mode
- Deciding where to perform processing (userspace / kernel / accelerator, OVS specific code / standard Linux kernel code etc.) could be complex
  - NFP's OVS kernel offload is fully featured, has large table capacity etc. => easy to offload all kernel table entries with small kernel patch
  - For more limited devices, decision making may be more complex - functionality split => table entry positioning - best handled in userspace
  - *Can still decide in userspace to offload directly to accelerator, vs. via kernel to accelerator*

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Evolution of Dataplane Flexibility

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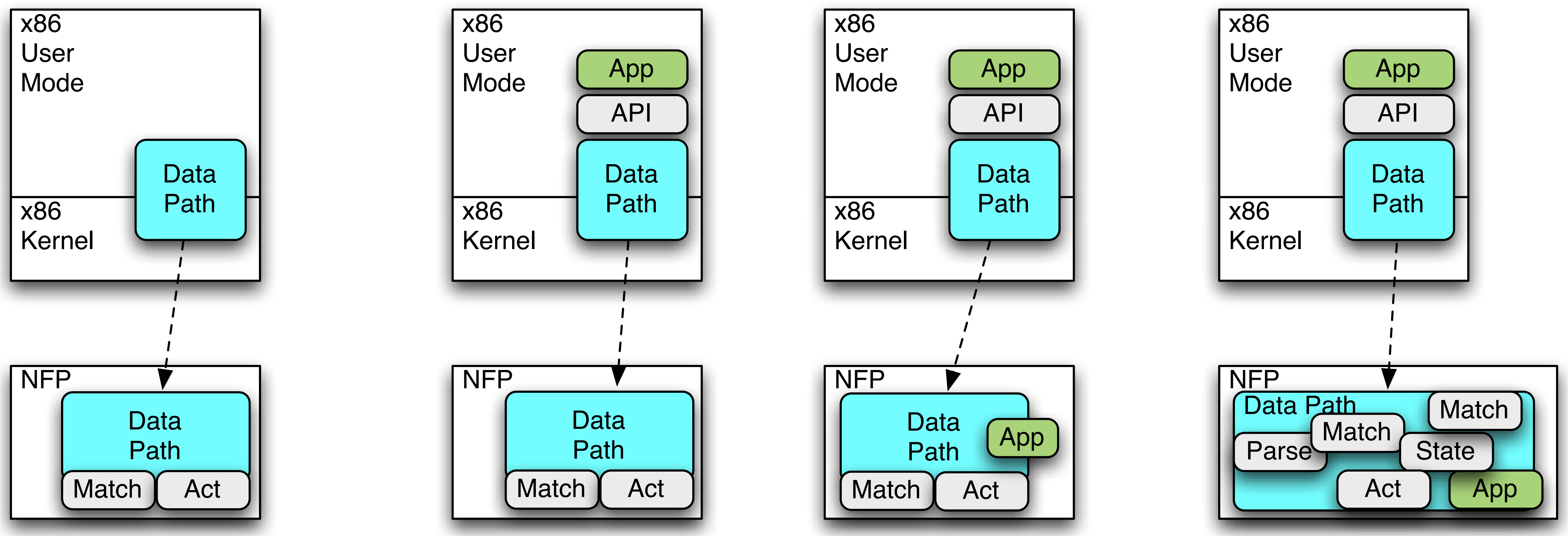
Offload / Acceleration
(drop in replacement)

x86 Apps Calling APIs
Compatible / Open Sourced
vs. Vendor Extension

Datapath Extensions in NFP
Native Code (e.g. C)

Flexible Datapath Abstraction
OpenFlow 2.x, P4, PIF, eBPF...



t

OVS/OpenFlow Match Action

Linux IPsec

Linux Firewall

Linux L2/L3 Fwd

RDMA

...

t

Flow API

Load Balancing API

Crypto API

Forwarding API

RDMA API

...

t

Custom tunnel

Custom action

Custom matching

...

t

Protocol agnostic flexible parsing

Arbitrary arrangement of matching tables

Matching without tables

State storage / retrieval

Complex actions

Event handling

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Conclusions + Next Steps

- Performance examples (details depend on traffic patterns, number and type of flow entries / actions etc.)
  - Using “20G” NFP, measured >20x speedup vs. unaccelerated OVS (IP + MPLS forwarding use case, multi table)
    - Difference can be larger for more complex actions / tunnels / traffic patterns - e.g. VXLAN, IPsec, high flow setup rates
    - Observed flow tracker performing flow learning (5-tuple) at 12Mfps
  - Expect further improvement (~3x-10x) for “200+G” NFP
  - Capacities: millions or tens of millions of flow entries, 100,000s of tunnels (requirements vary per device type)
  - => *Order(s) of magnitude improvement achievable using acceleration*

- Questions for OVS community
  - Where to focus going forward - implement features in kernel (for which OSes) vs. implement in userspace (cross OS / lightweight) vs. both
  - Considerations: TTM, software only performance, ease of acceleration, leveraging existing code / developer skill sets, ease of maintenance
- Questions for Linux and other OS communities
  - Leverage OVS vs implement different mechanisms e.g. tunnel termination/origination, QoS, eBPF / PIF...
- Questions for all
  - How best to support acceleration hardware, without duplicating efforts
  - (Excluded due to lack of time: specific API proposals for table manipulation APIs, acceleration “objects” and APIs: Linux/OVS/other...)

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