Comparing Open vSwitch (OpenFlow) and P4 Dataplanes for Agilio™ SmartNICs

Johann Tönsing

May 24, 2016

Agenda

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- Contributions of OpenFlow, Open vSwitch and P4
- OpenFlow features missing in P4, and P4 features missing in OpenFlow
- Architecture of Open vSwitch accelerated by a SmartNIC
- Architecture of a P4 SmartNIC datapath
- Performance considerations
- Next steps: proposals towards convergence and alignment

Contributions of OpenFlow

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Architectural Principle:

- Logically Centralized, Decoupled Control

Model:

- Defined by specification: dataplane protocols, pipeline of match-action tables

(Soon: dataplane protocols no longer in main specification, dynamic dataplane protocol definition being considered)

Interface:

- Protocol (handcrafted, binary C struct style)

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Well known SDN (and older) principle -
not unique to OpenFlow

No plans to abandon —
perhaps add selective delegation, hierarchies

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Too limited: annoying to have to create specification revisions to add protocols, behavior

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Interface:

- Protocol (handcrafted, binary C struct style)

Software usually built using libraries with callable APIs

Protocol can be a language independent interface (but prefer automated marshalling, e.g. Thrift)

Need faster interface mechanism (e.g. callable API) for datapath extension code

Contributions of P4

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Architectural Principle:

- Language enabling datapath programming
- Deployable with central or distributed control, as switch or part of switch

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- Datapath protocols and behavior are defined by a program (not enshrined in a standard)

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- Evolving - currently callable API is *generated*

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Useful to enable protocols and behavior to rapidly evolve: killer app = flexibility

Useful as a unambiguous model of programmable and fixed datapath behavior

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Convenient for initial experimentation

However complicates matters for controllers - need to link with different library for each version of each program

Consider generic interface instead

Contributions of Open vSwitch Evaluated

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Widely deployed virtual switch

- Integrated with many controllers, cloud management systems (OpenStack, ODL, ONOS…)

Accepted into Linux kernel

- Uses Linux kernel facilities where appropriate, e.g. for connection tracking or QoS

Developed by community as open source project

- Frequently leading OpenFlow standards

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OpenFlow Features not in P4

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- At any time, the SDN controller can send a flow add or flow modify message:
  - … creating a new table or a new control flow path,
  - … matching an additional field or invoking an additional action, etc.

- In P4, actions, tables, and control flow options are pre-declared in the program

- Solutions to retain dynamic functionality with OpenFlow compatibility:
  - JIT compile program variant with a capability once it is first required [analogous to PyPy]
  - Cache these variants - remember last used (issue: when to “garbage collect”)

- Solutions to avoid need for dynamic functionality
  - Model (e.g. TTP) is used to declare required functionality (e.g. action list patterns) at start time
  - No changes needed to OpenFlow otehrwise (device returns error if functionality unsupported)

P4 Features not in OpenFlow

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- Too many to list here! Nice!
- Flexibility can actually be a problem for controllers, cloud management systems: difficult to generically support all datapath programs / program versions
  - Solution: “plugin” into controller to go along with datapath program
    - Run time interface becomes distributed system infrastructure (RPC)
  - Solution: implement functionality with a well defined (less rapidly evolving) interface
- Run-time interface generated from program is problematic - too many libraries / modules for controller writers to consume
  - Consider generic interface also: APIs to discover and access objects
  - Generated interface remains useful for fast datapath extension software (… see demo …)

OVS Acceleration using Agilio™ SmartNIC

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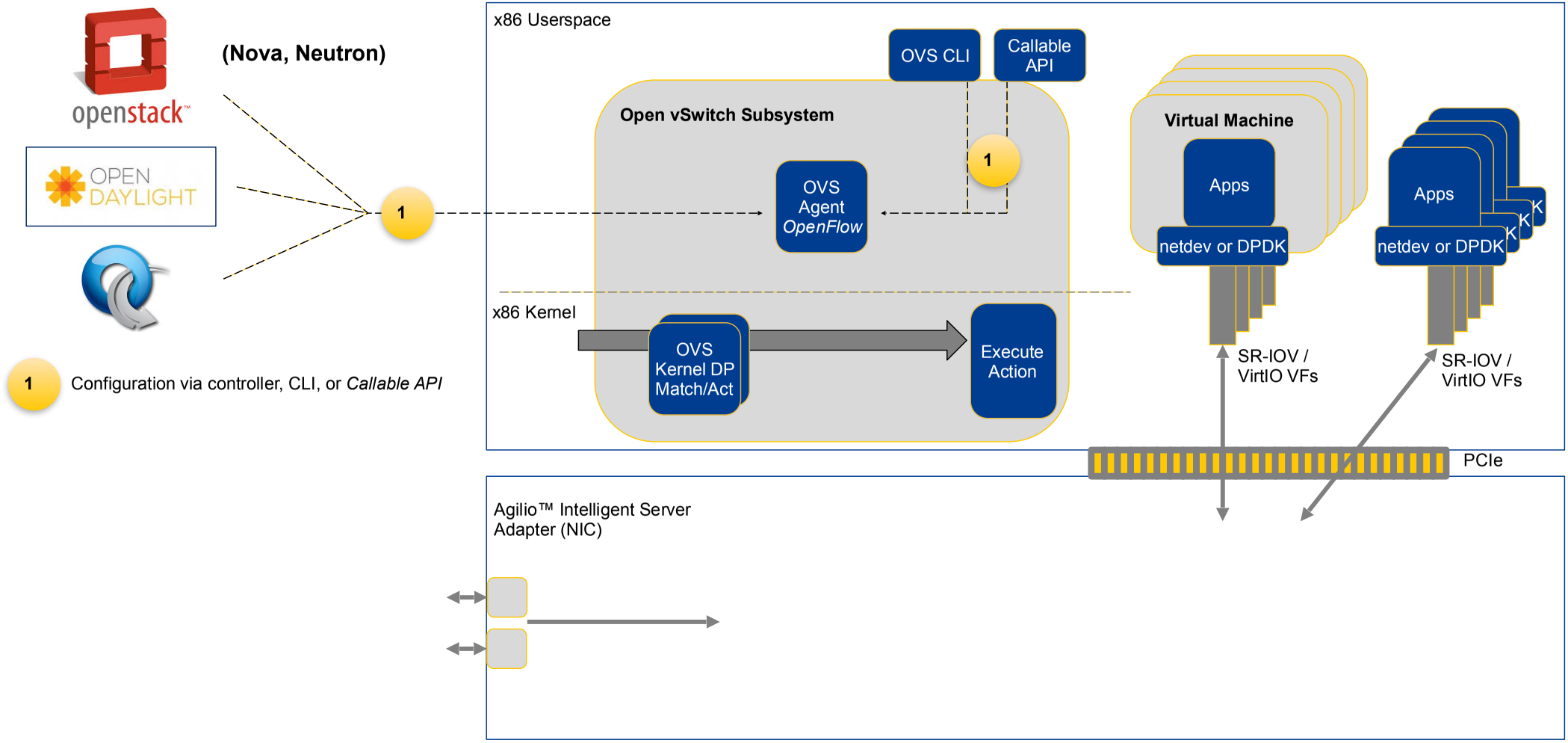

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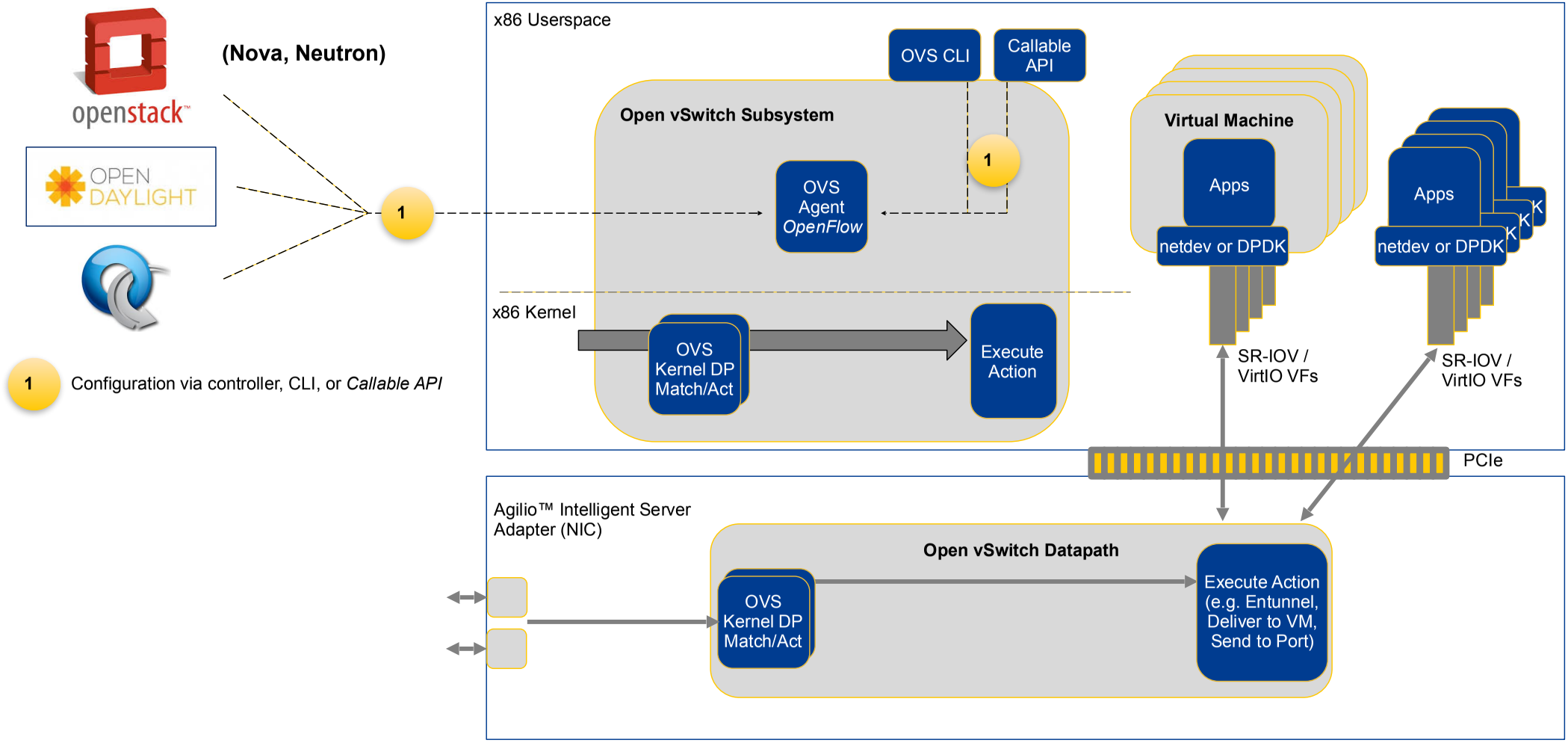

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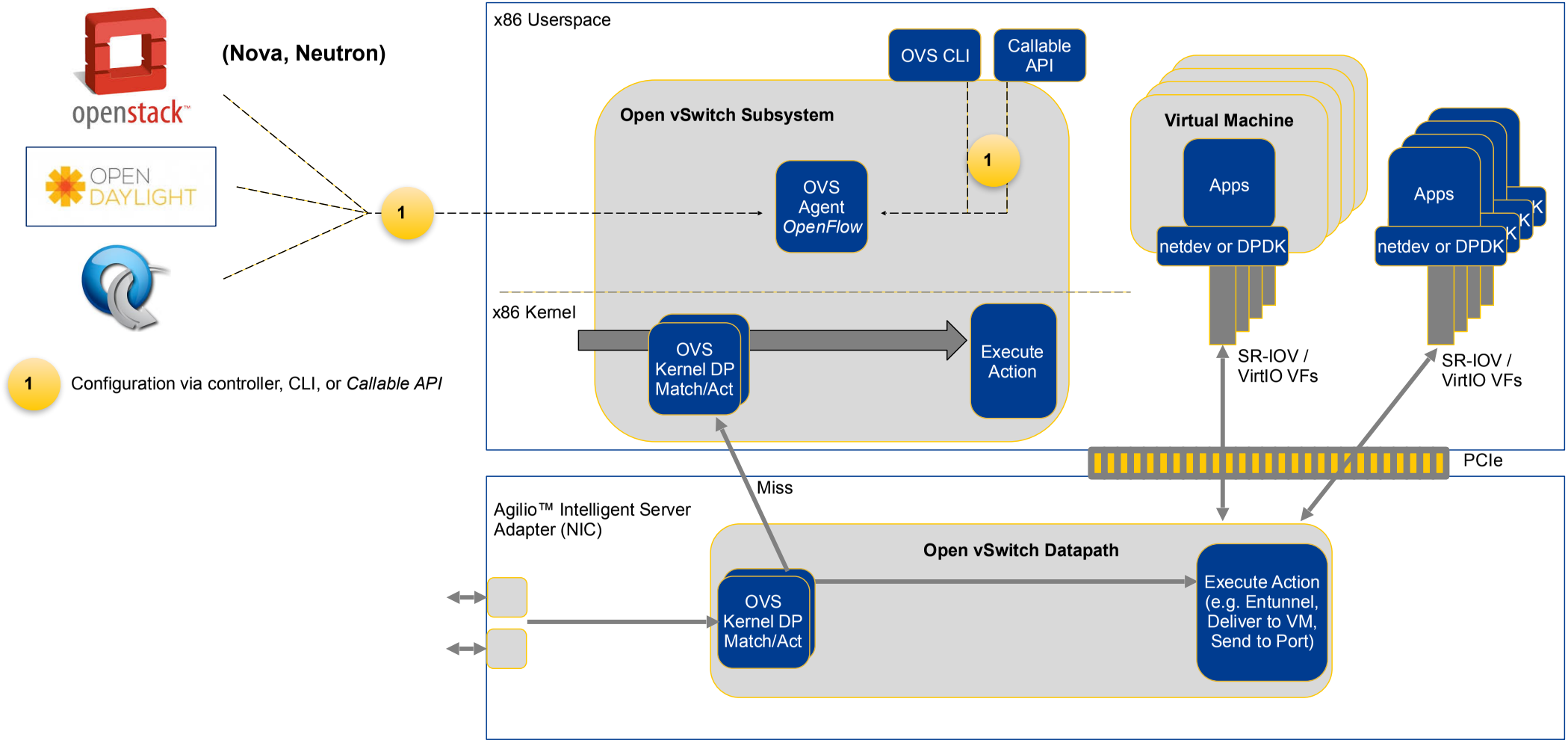

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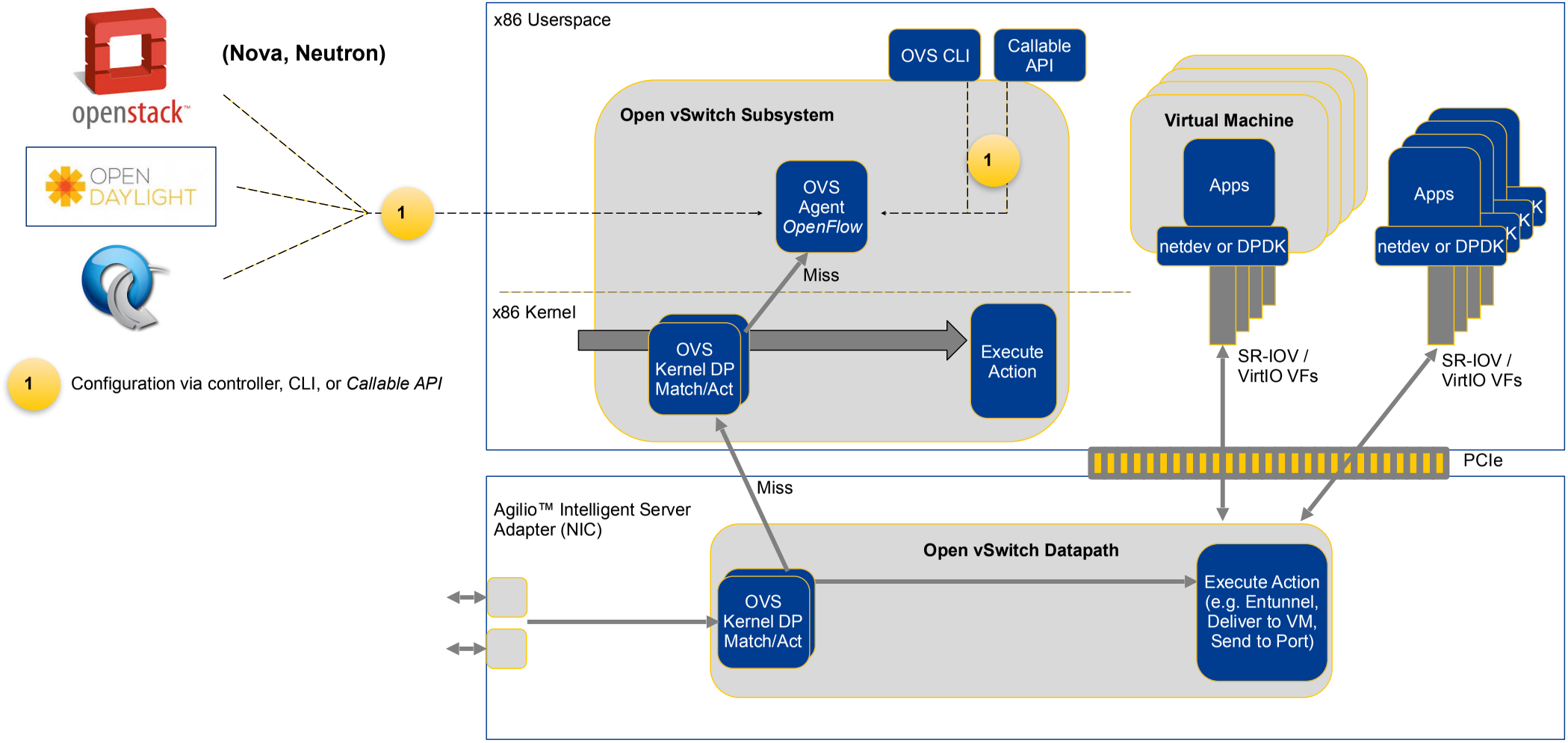

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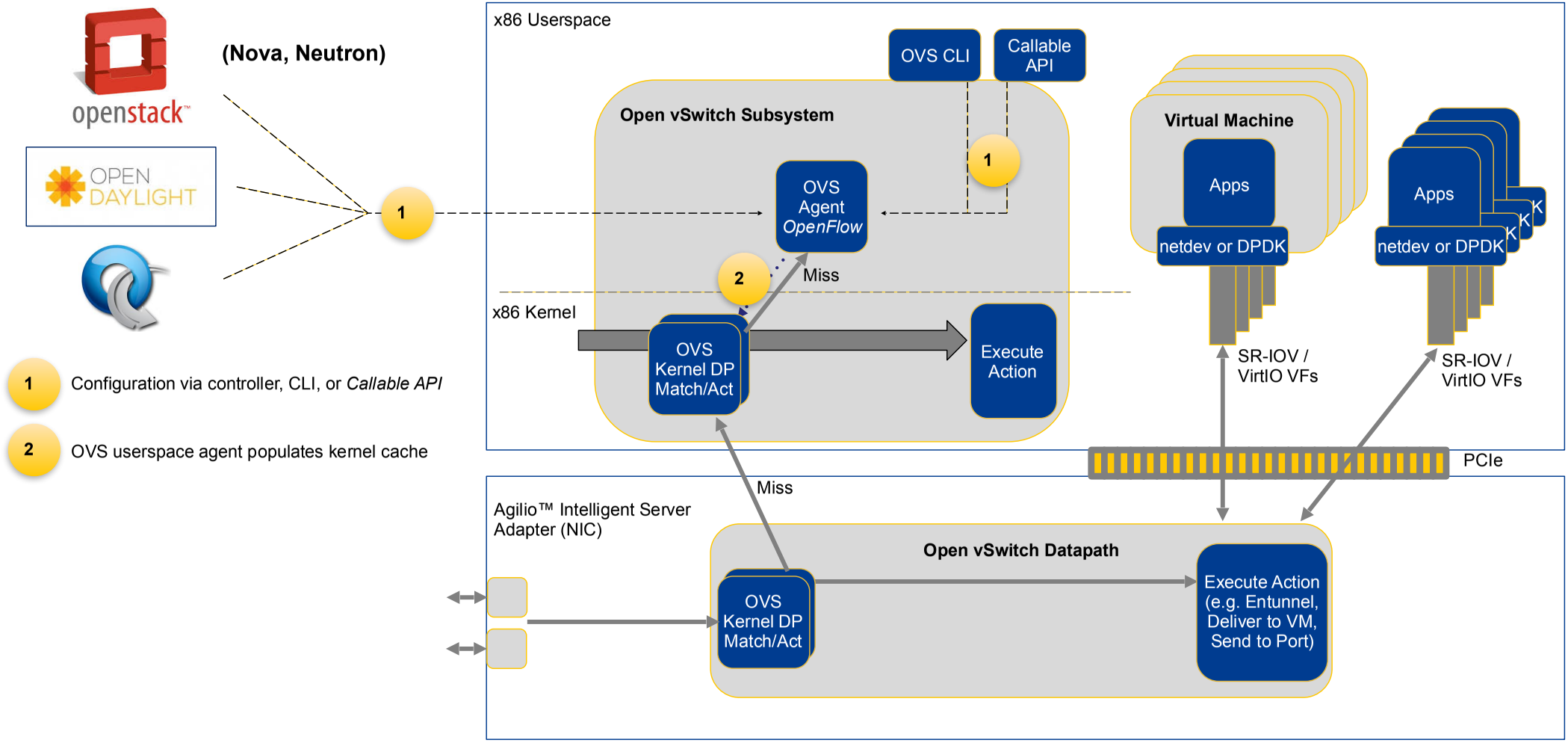

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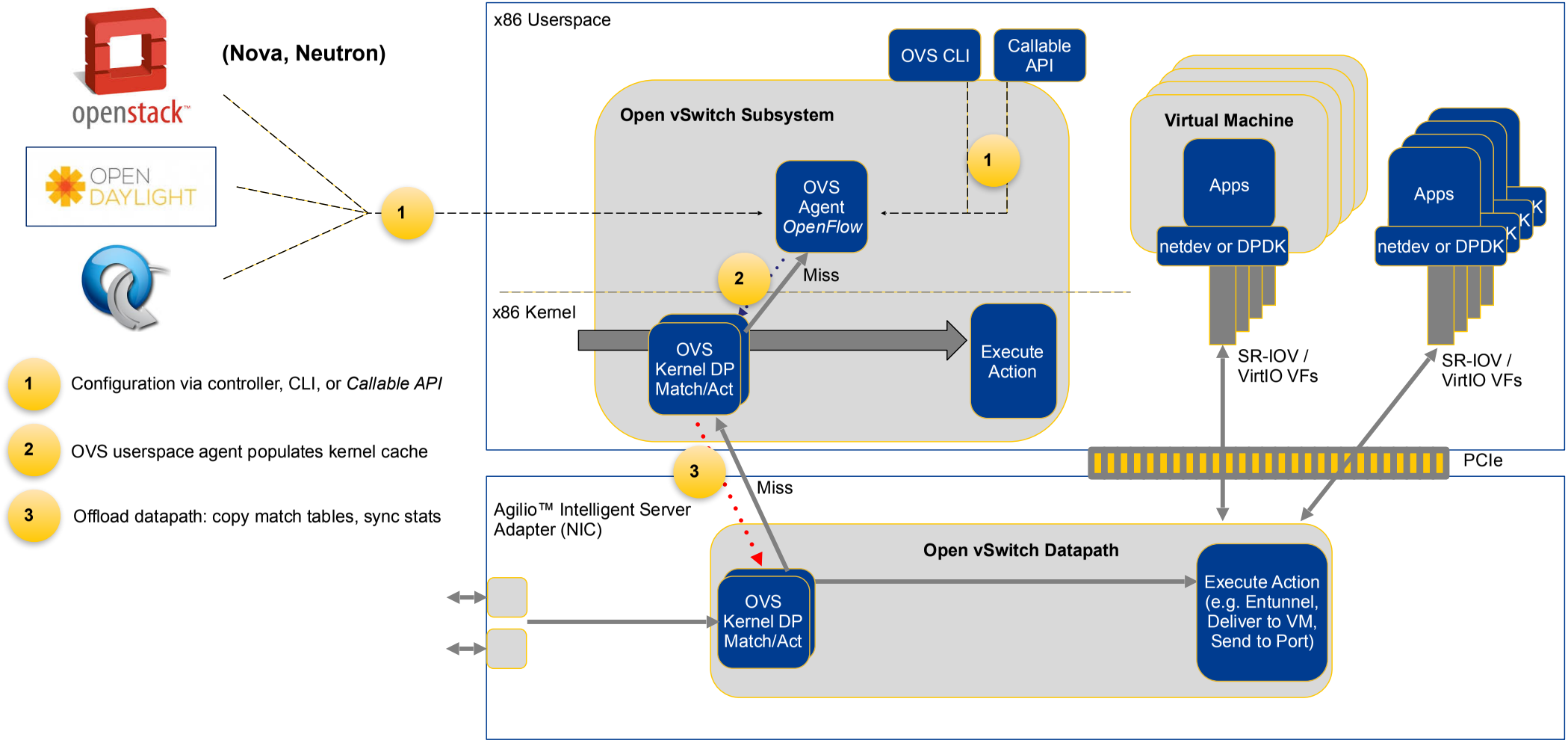

1. Configuration via controller, CLI, or *Callable API*
2. OVS userspace agent populates kernel cache
3. Offload datapath: copy match tables, sync stats

OVS Acceleration using Agilio™ SmartNIC

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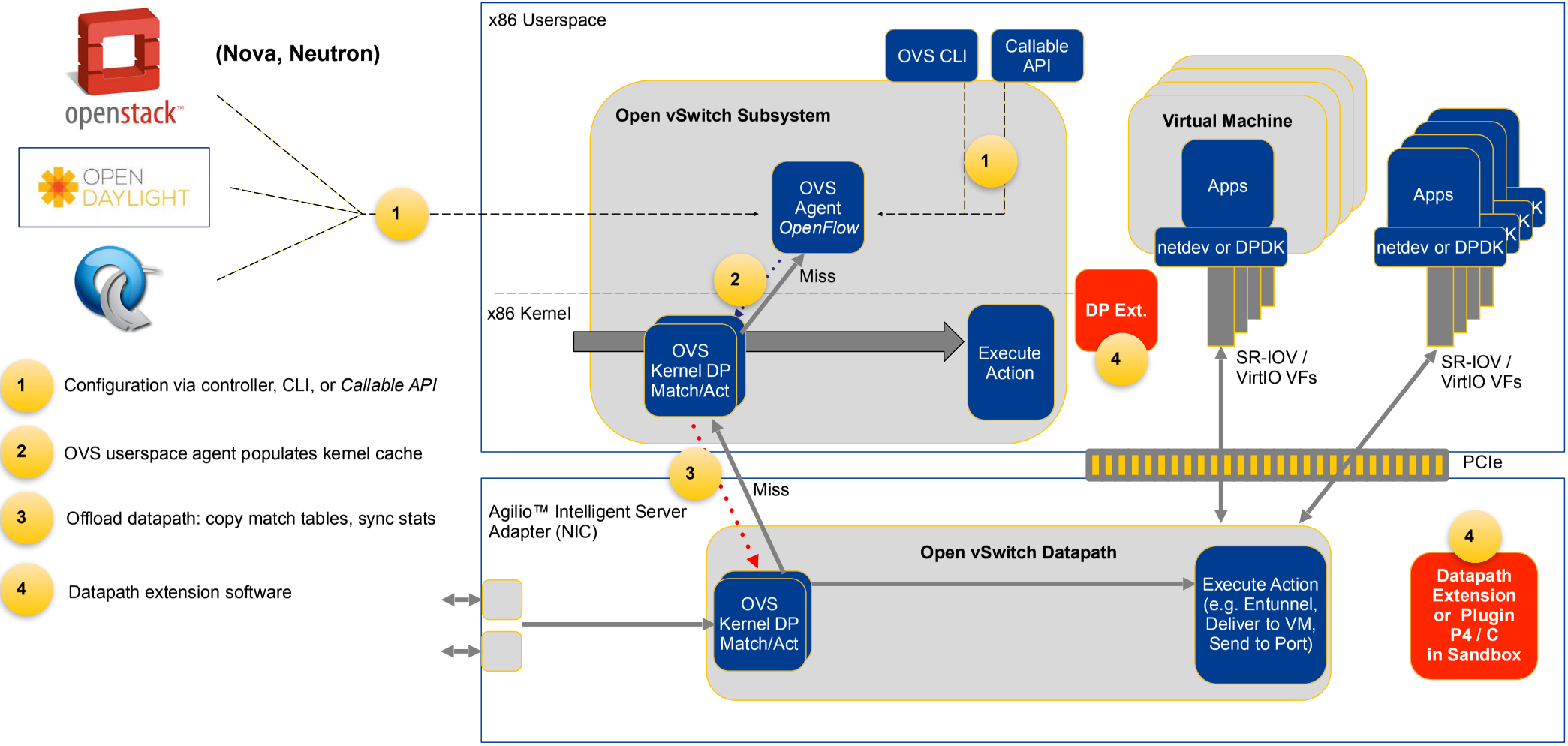

P4 for SmartNICs with VNF and µVNF chaining

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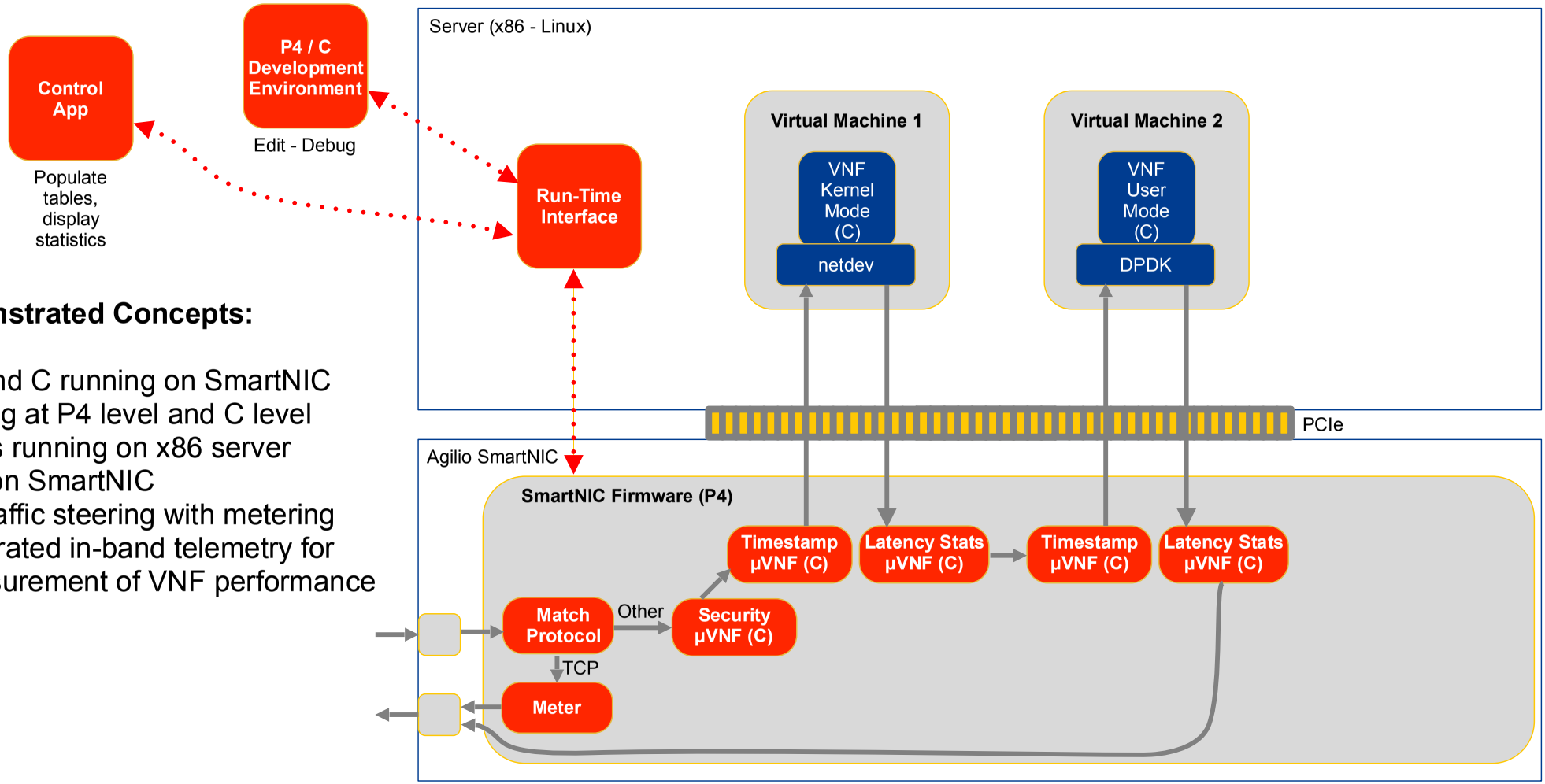

Demonstrated Concepts:

- P4 and C running on SmartNIC
- Debug at P4 level and C level
- VNFs running on x86 server and on SmartNIC
- P4 traffic steering with metering
- Integrated in-band telemetry for measurement of VNF performance

OVS “on” P4 Datapath

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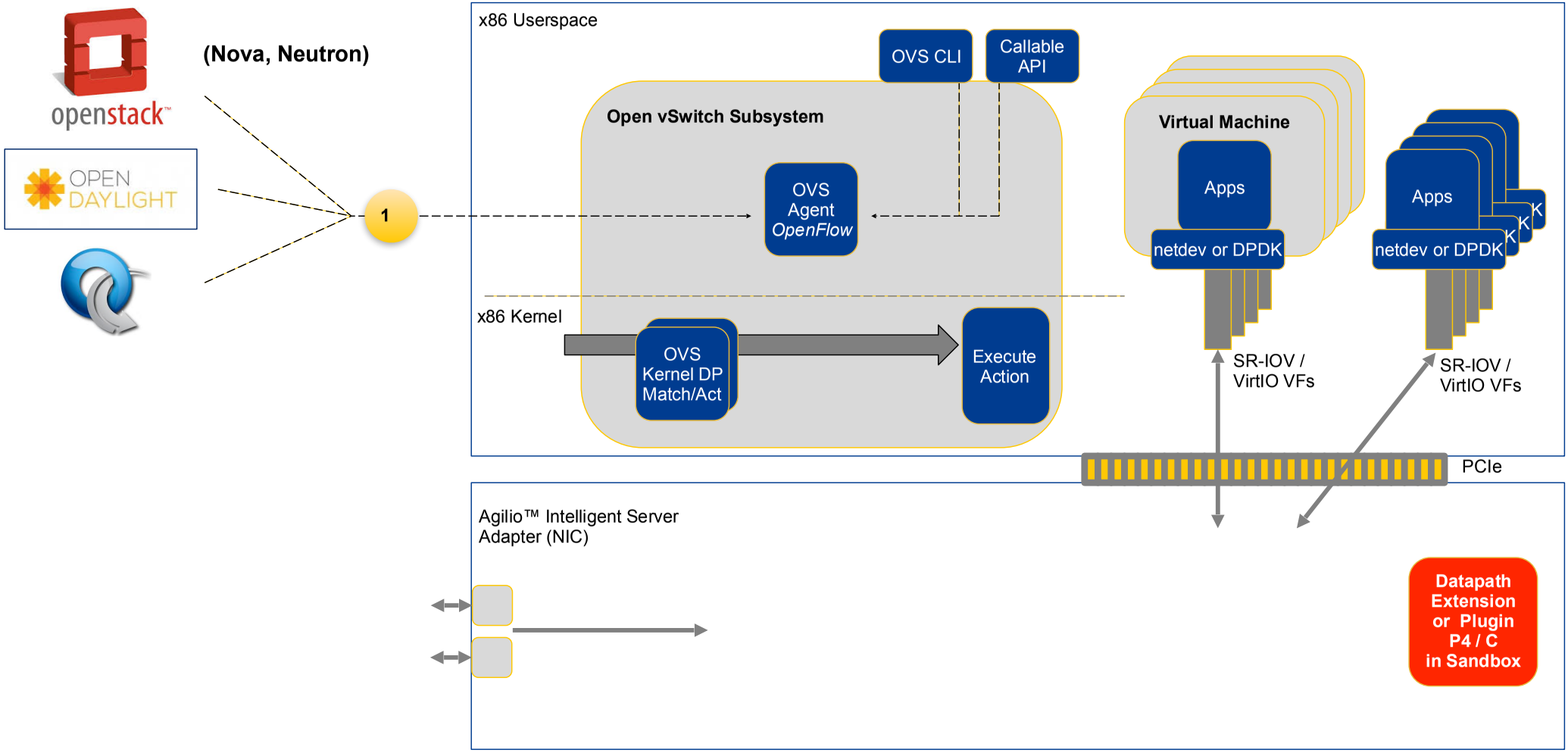

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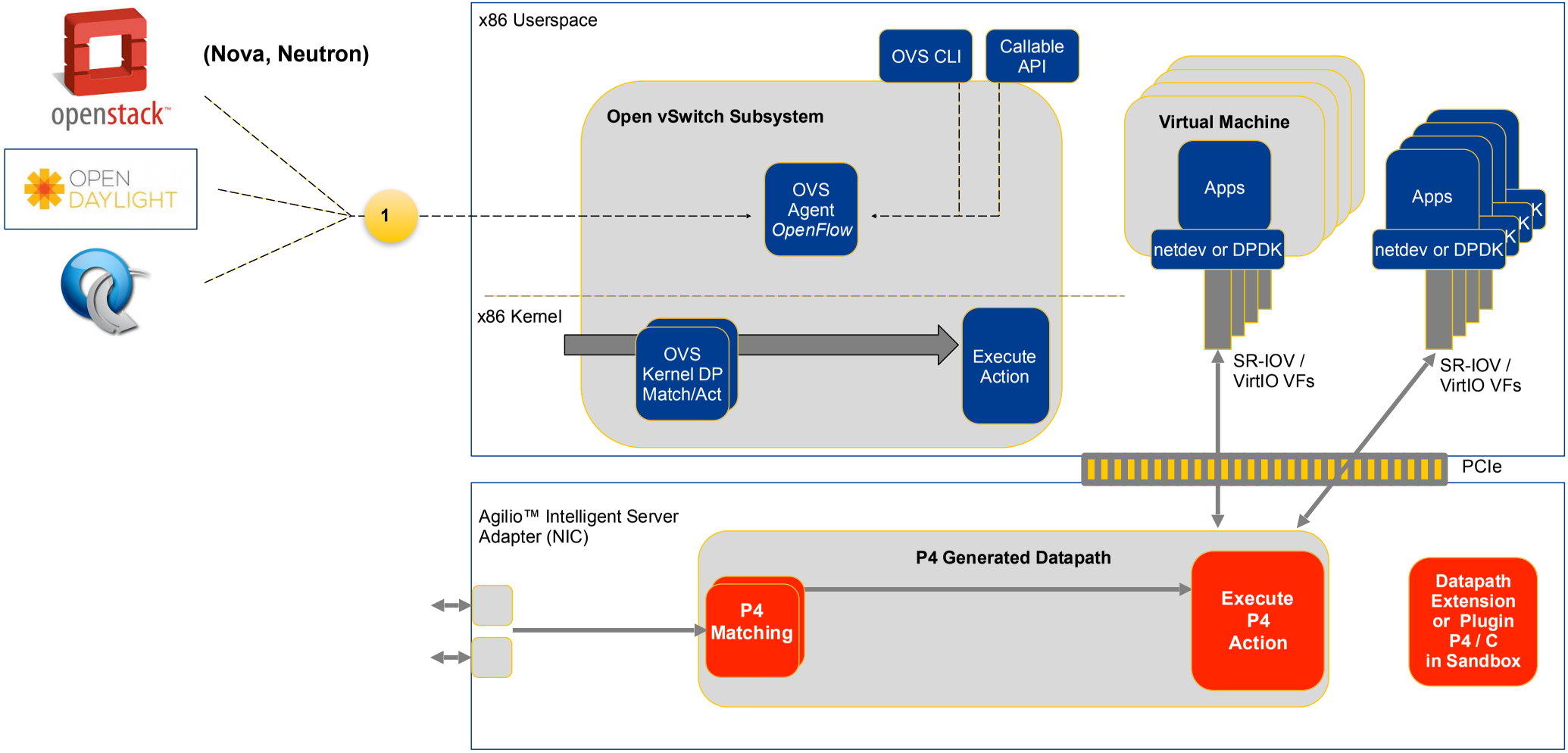

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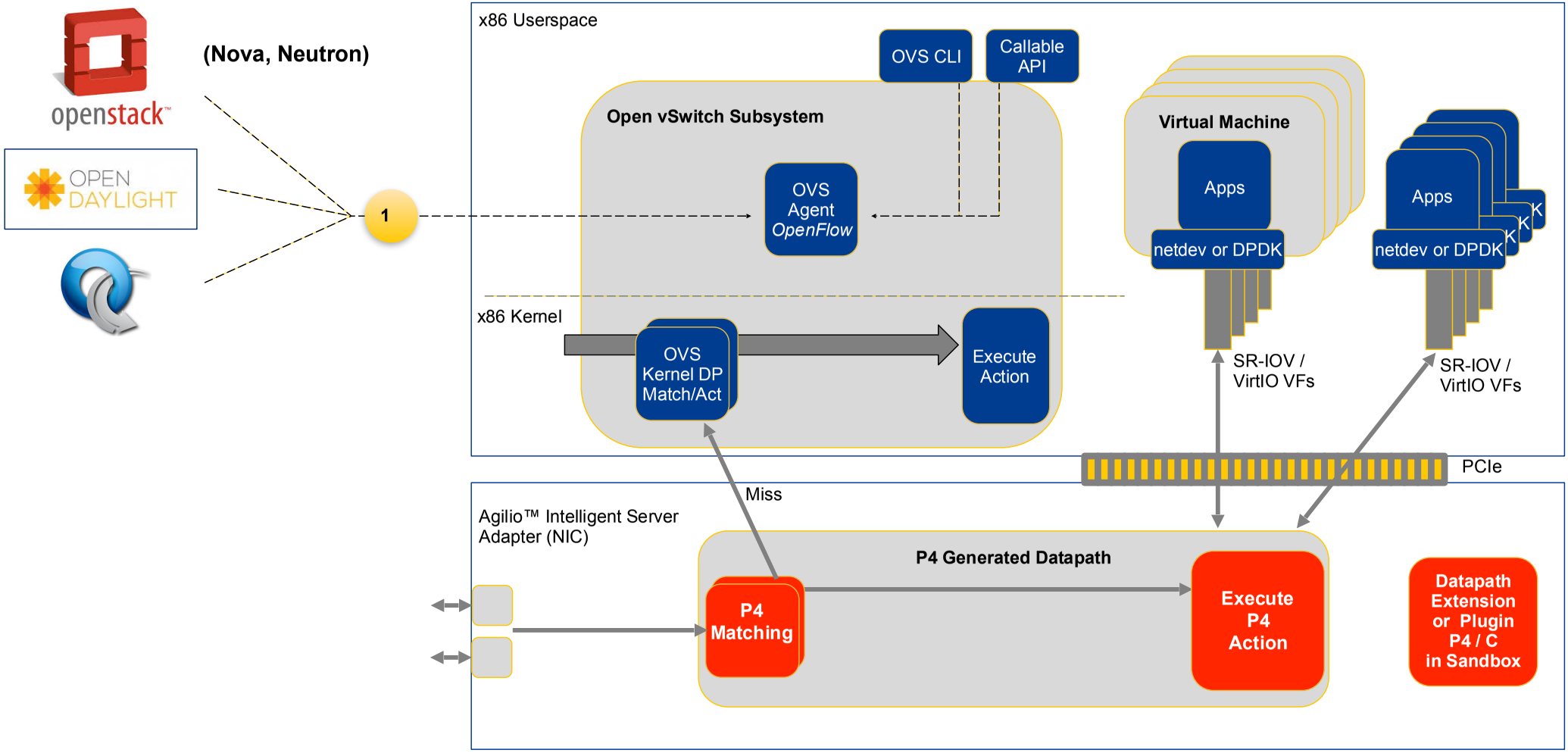

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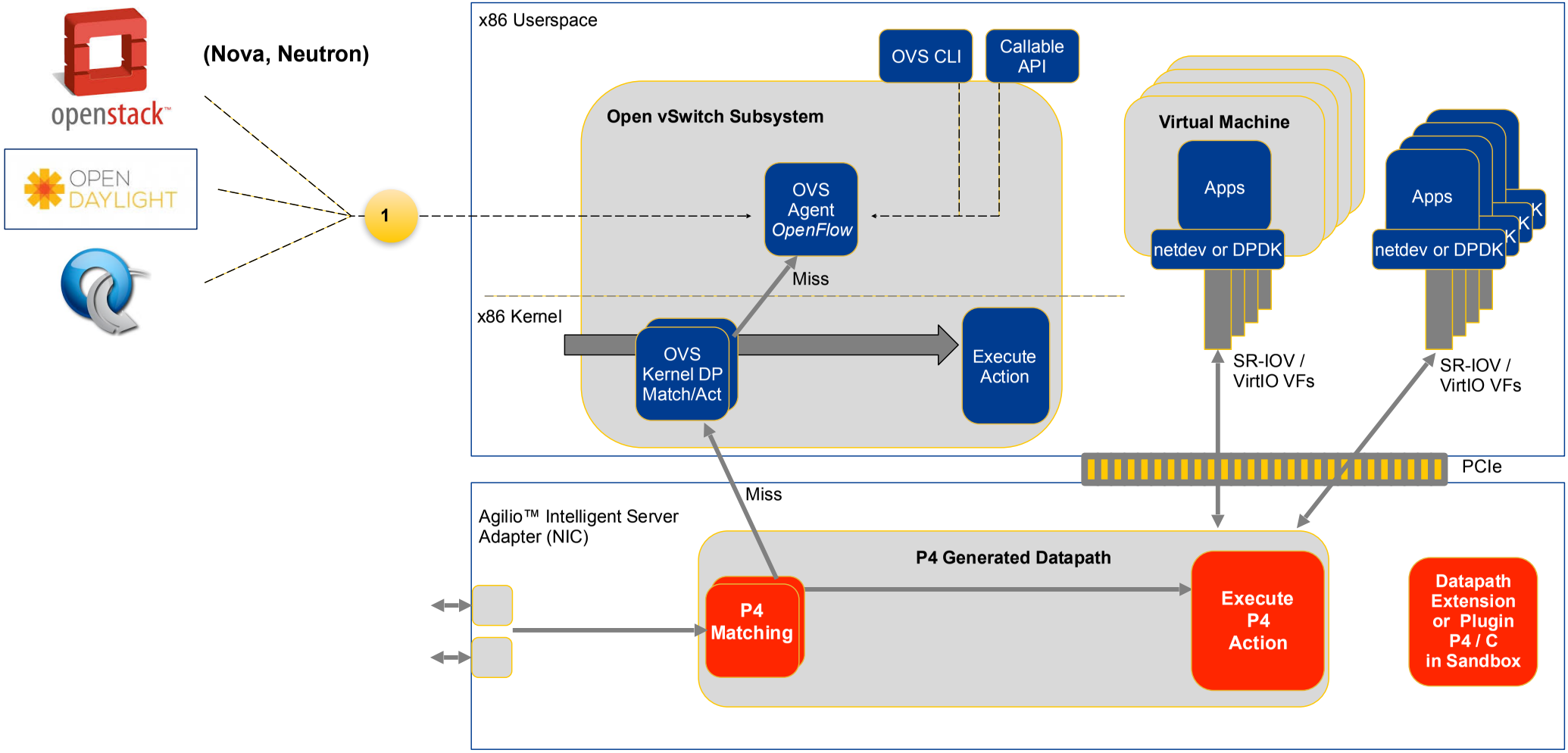

P4 “into” OVS Datapath

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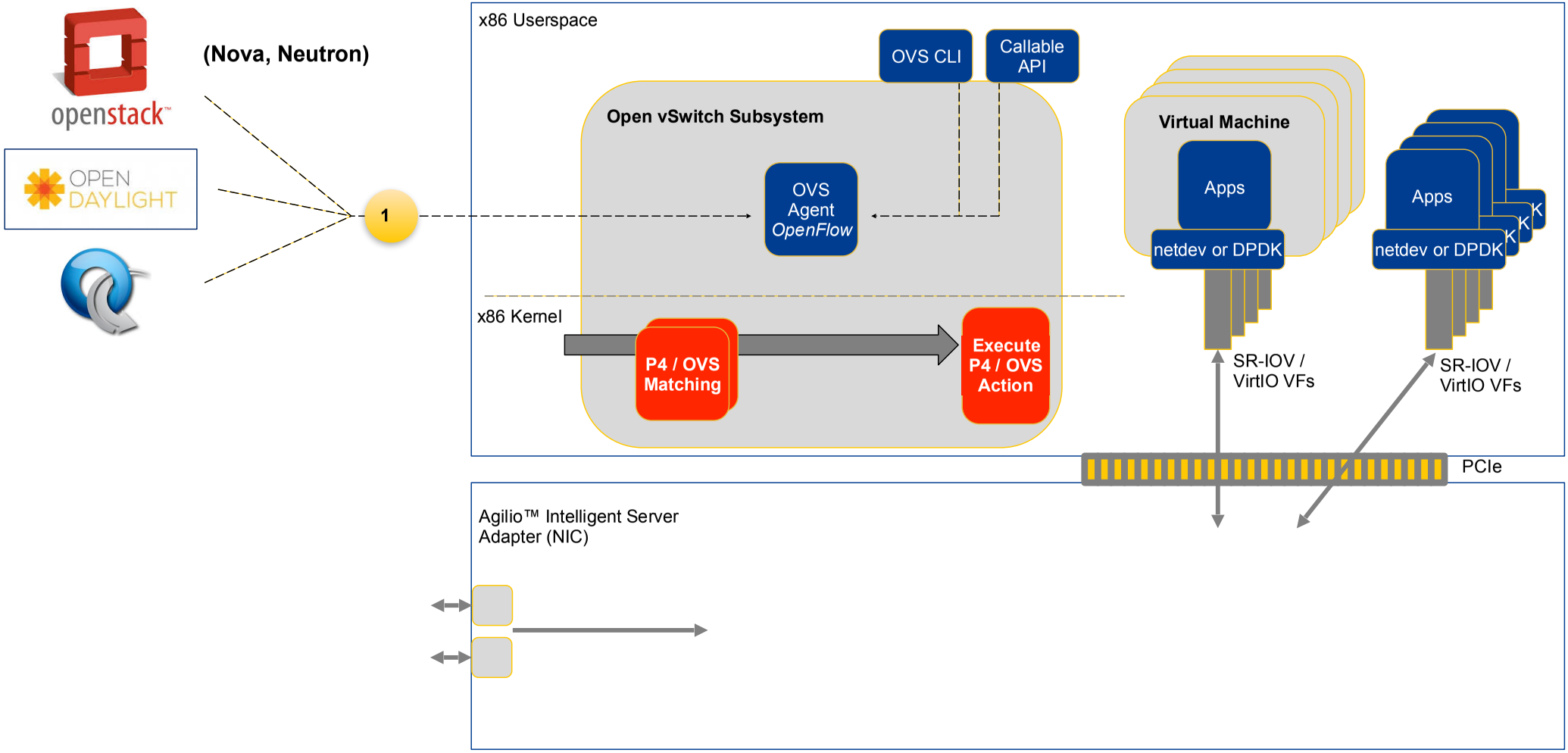

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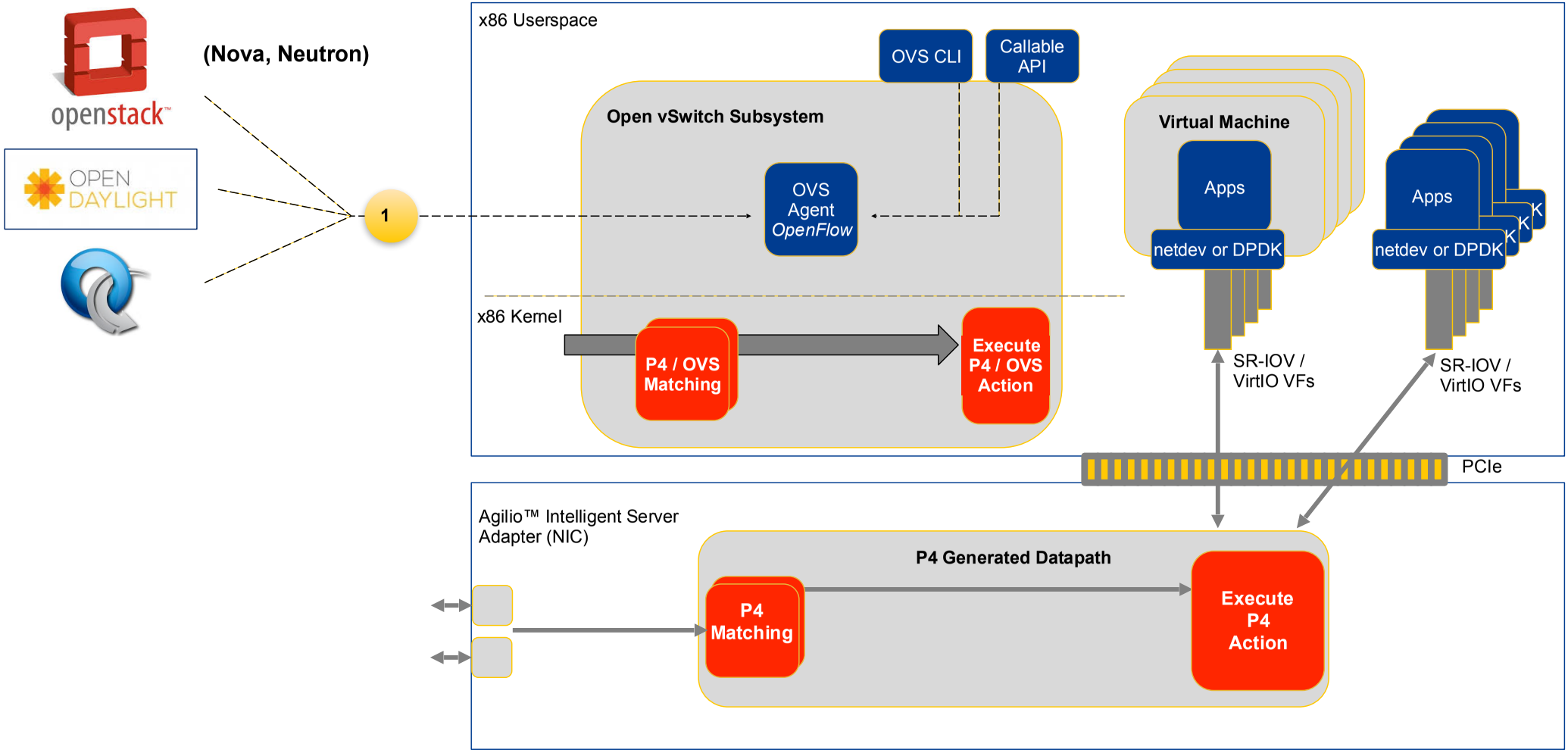

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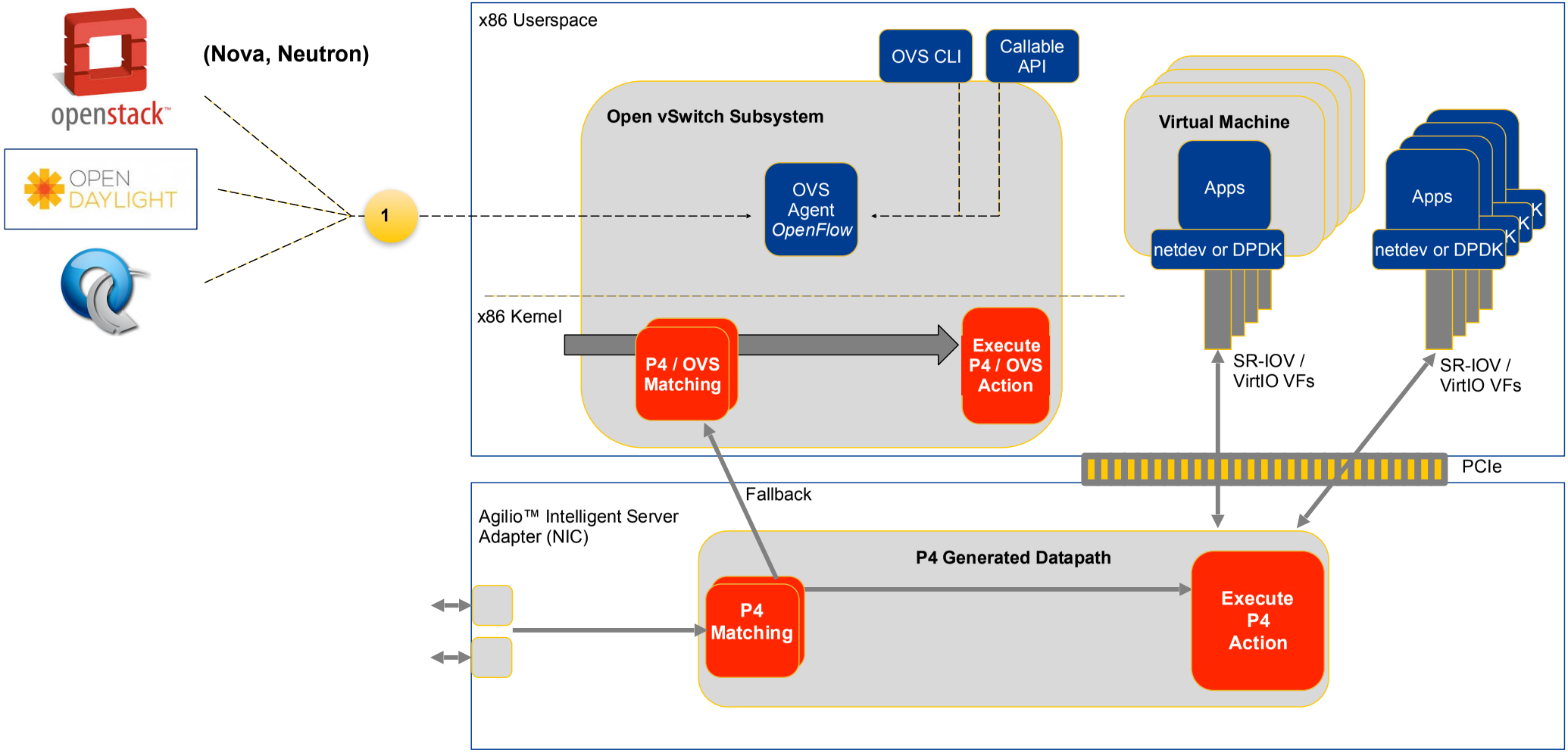

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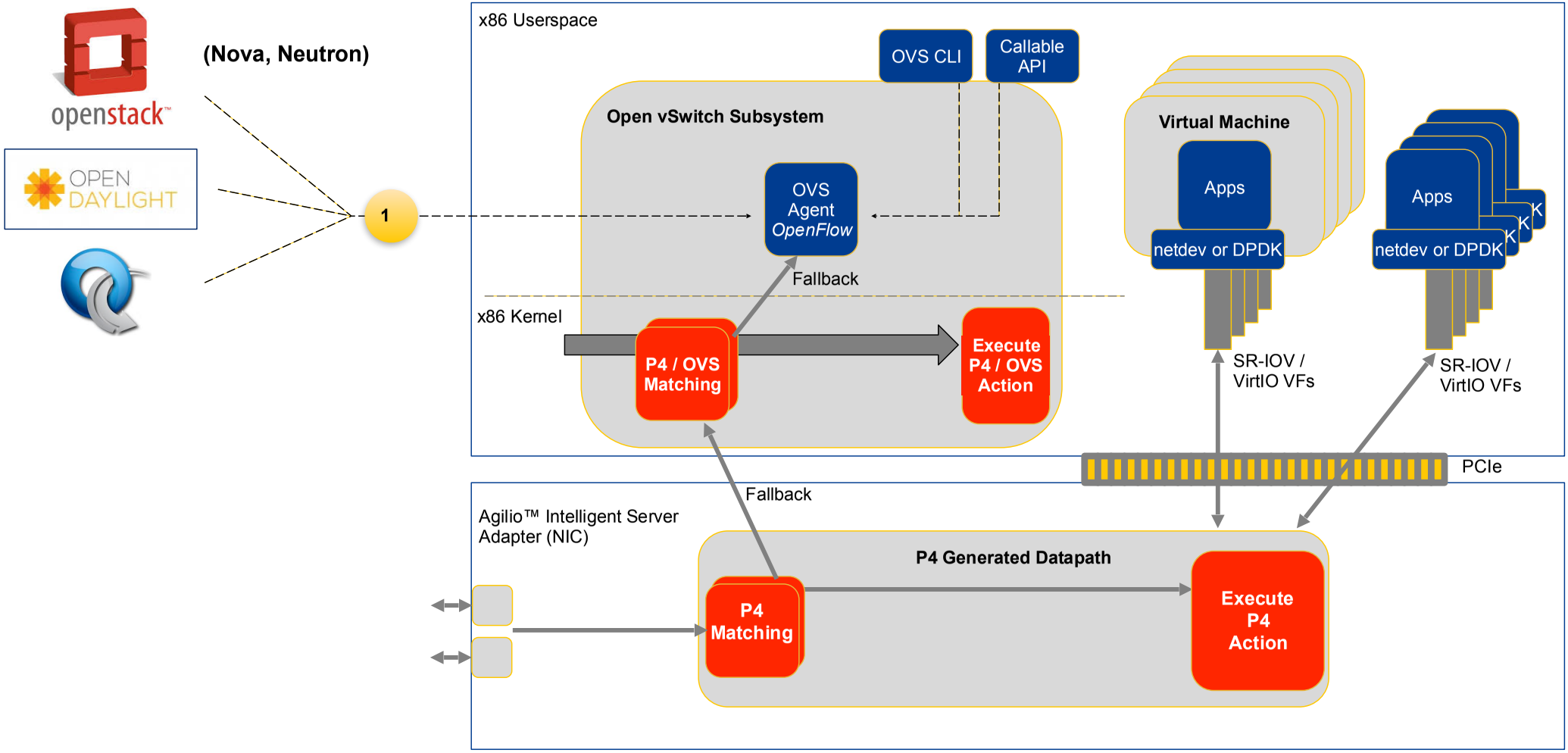

P4 “instead of” OVS (Datapath and Control)

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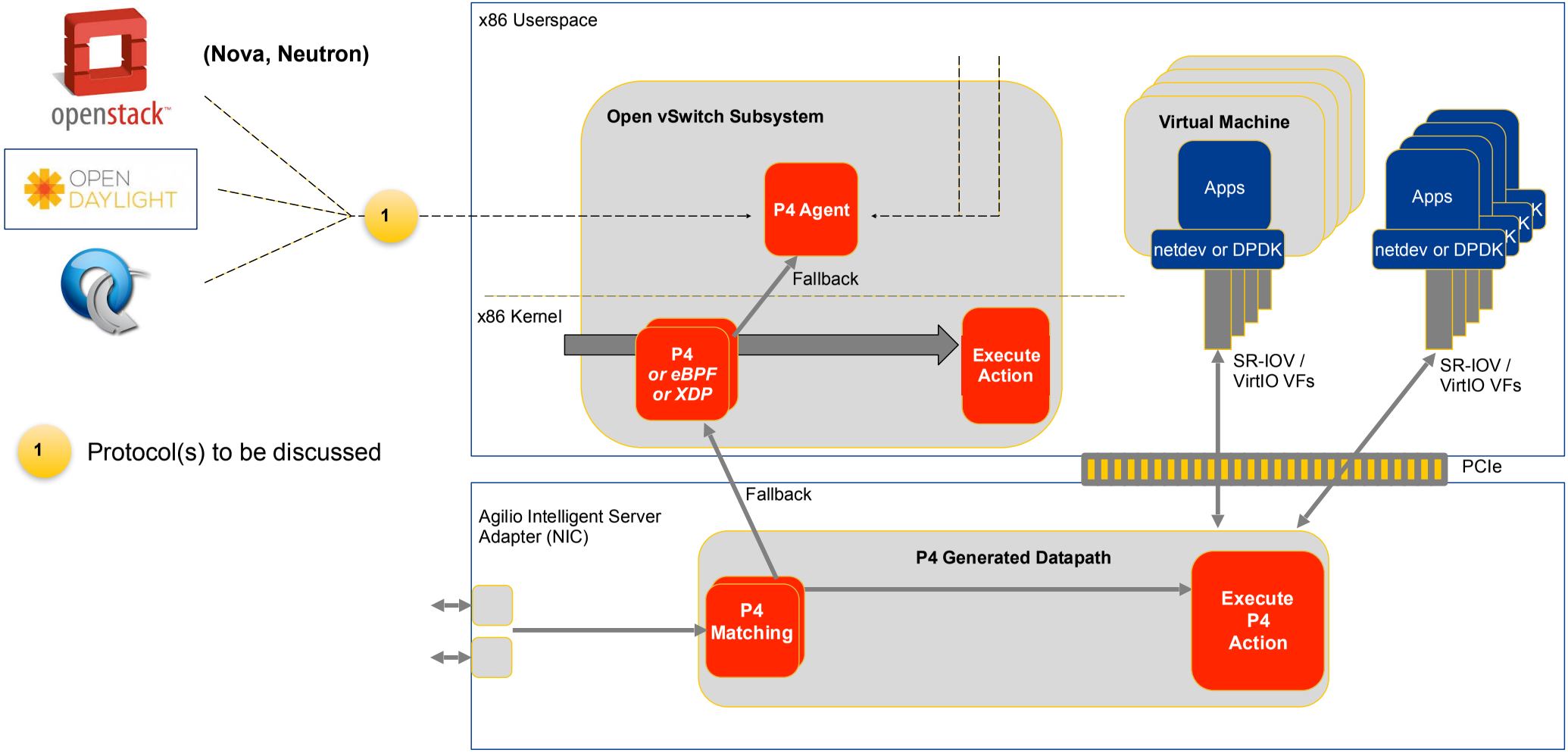

Performance Observations (Agilio™-CX SmartNIC)

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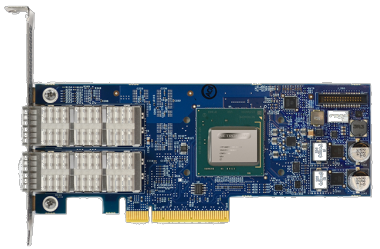
- Simple scenario
  - SmartNIC accelerated OVS: 35 Mpps @ < 1 core
  - P4 on SmartNIC: 36 Mpps @ < 1 core

  => Despite high level language overhead, only deploying the packet processing operations required by the application yields high performance



- More complex scenario
  - Unaccelerated OVS: 11 Mpps @ 22 server cores
  - SmartNIC accelerated OVS: 33 Mpps @ < 1 server core (>60x efficiency)
  - P4 on SmartNIC: 21 Mpps @ < 1 server core (>40x efficiency)

  => Hand-tuned implementation beats P4 (currently beta compiler: room for improvement)

  => Both offer significantly better efficiency (throughput per server core) than unaccelerated OVS

Also available: Agilio™-LX SmartNIC @ ~80 Mpps

Next Steps

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- Enable migration from existing OpenFlow network / cloud control interface to a P4 capable control interface (generated / generic)
  … collaborating with e.g. ONF, Open vSwitch, OpenStack, ODL, ONOS, NFV bodies…
- Standardize a persistent IR with a simple to parse format (YAML / JSON) and a stable schema
  … collaborating with e.g. OpenSourceSDN.org, ONF…
  - Use subset (extract) of IR as model, also as a description of the run-time interface
    - Equivalent: ".h" for ".c"
    - In effect a "TTP"
  - Supports multiple P4 language versions (or, in future, other languages)
    - Behavioral model v2 developers discovered the usefulness of a JSON based "IR"
  - Enables ecosystem of tools (optimizers, visualizers, front / back end compilers, etc.)
- Use Agilio™ SmartNICs
  - … to accelerate existing datapaths - OVS (OpenFlow), Contrail vRouter, Linux…
  - … to implement new datapaths - P4, eBPF/XDP…