The Design and Implementation of Open vSwitch

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Open vSwitch

What is Open vSwitch?

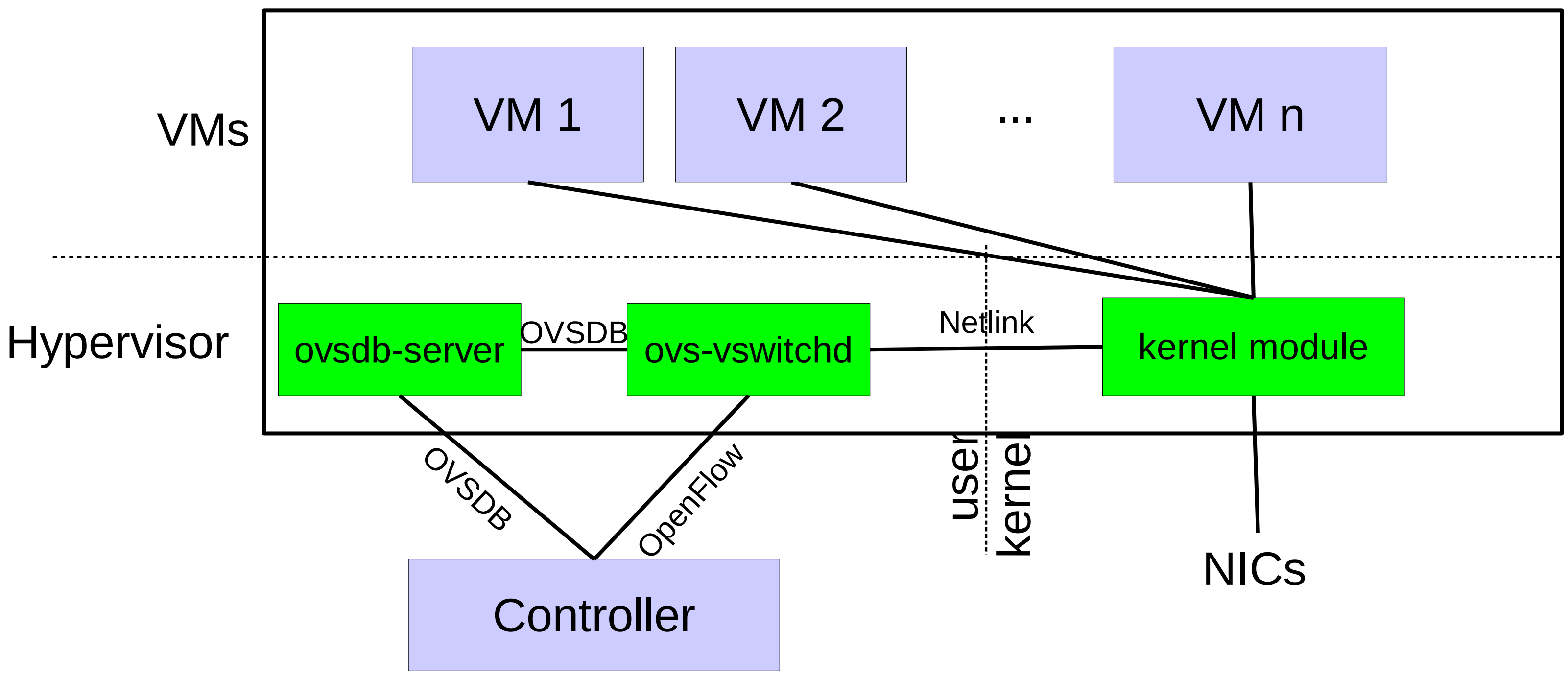
From openvswitch.org:

“Open vSwitch is a production quality, multilayer virtual switch licensed under the open source Apache 2.0 license. It is designed to enable massive network automation through programmatic extension, while still supporting standard management interfaces and protocols (e.g. NetFlow, sFlow, SPAN, RSPAN, CLI, LACP, 802.1ag).”

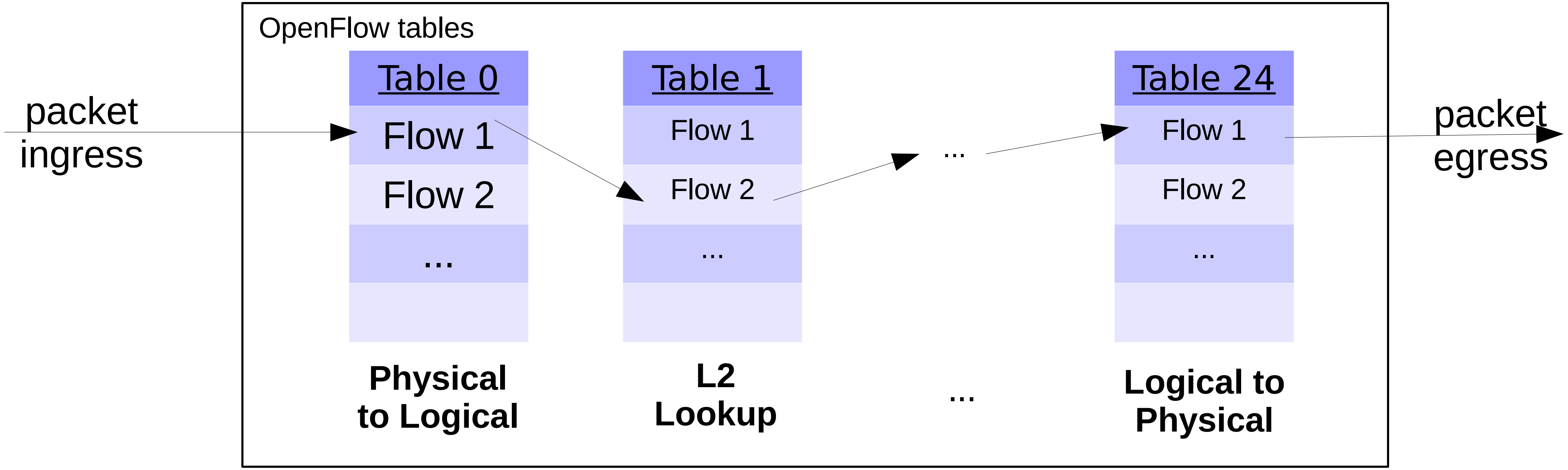
Where is Open vSwitch Used?

- Broad support:
  - Linux, FreeBSD, NetBSD, Windows, ESX
  - KVM, Xen, Docker, VirtualBox, Hyper-V, …
  - OpenStack, CloudStack, OpenNebula, …
- Widely used:
  - Most popular OpenStack networking backend
  - Default network stack in XenServer
  - 1,440 hits in Google Scholar
  - Thousands of subscribers to OVS mailing lists

Open vSwitch Architecture

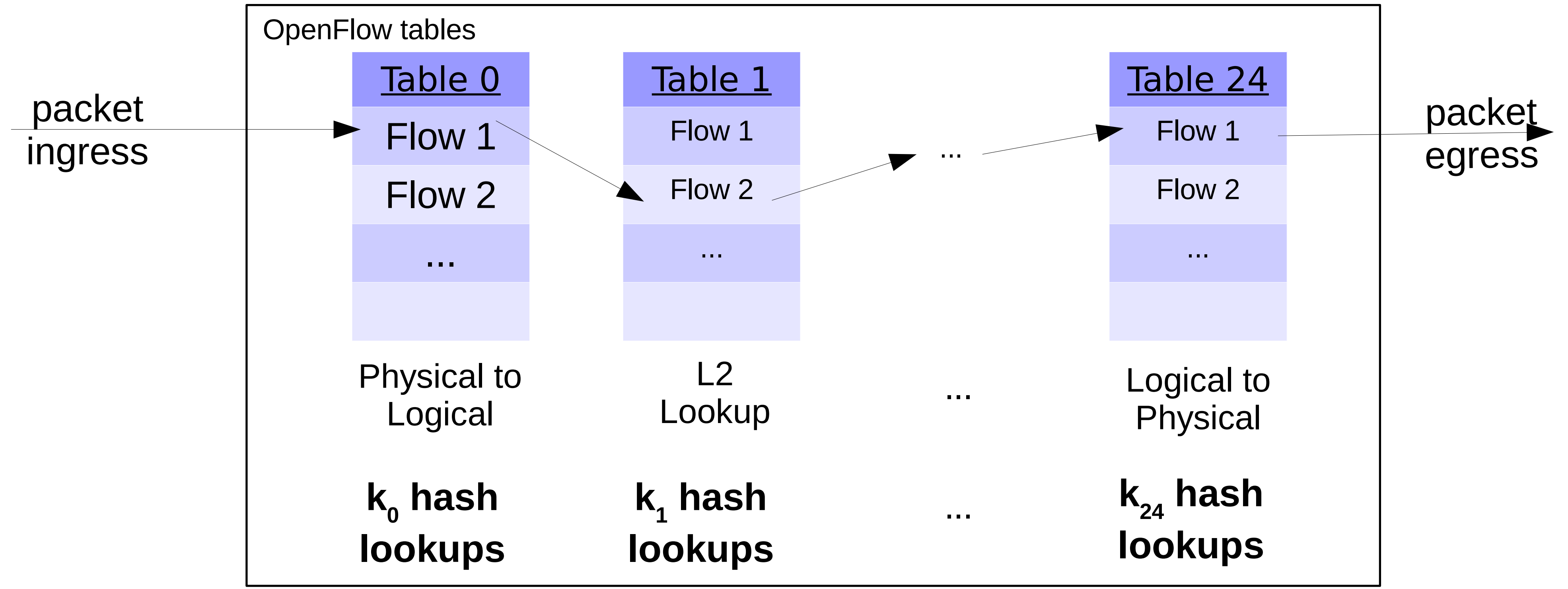


Use Case: Network Virtualization



OpenFlow Pipeline

Implications for Forwarding Performance



100+ hash lookups per packet for tuple space search?

Non-solutions

- All of these helped:
  - Multithreading
  - Userspace RCU
  - Batching packet processing
  - Classifier optimizations
  - Microoptimizations
- None of it helped enough: % versus x.

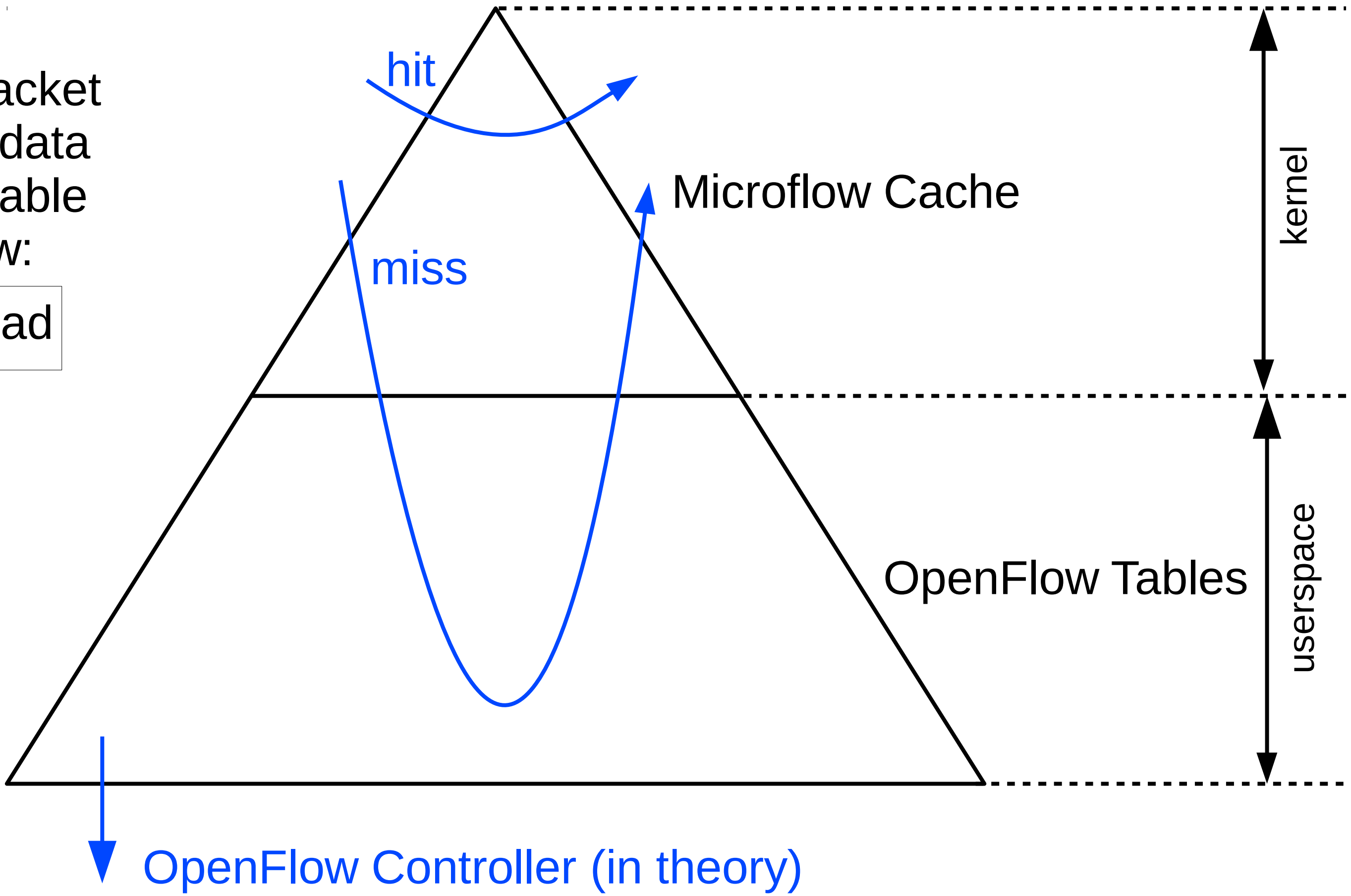
Classification is expensive on general-purpose CPUs!

OVS Cache v1: Microflow Cache

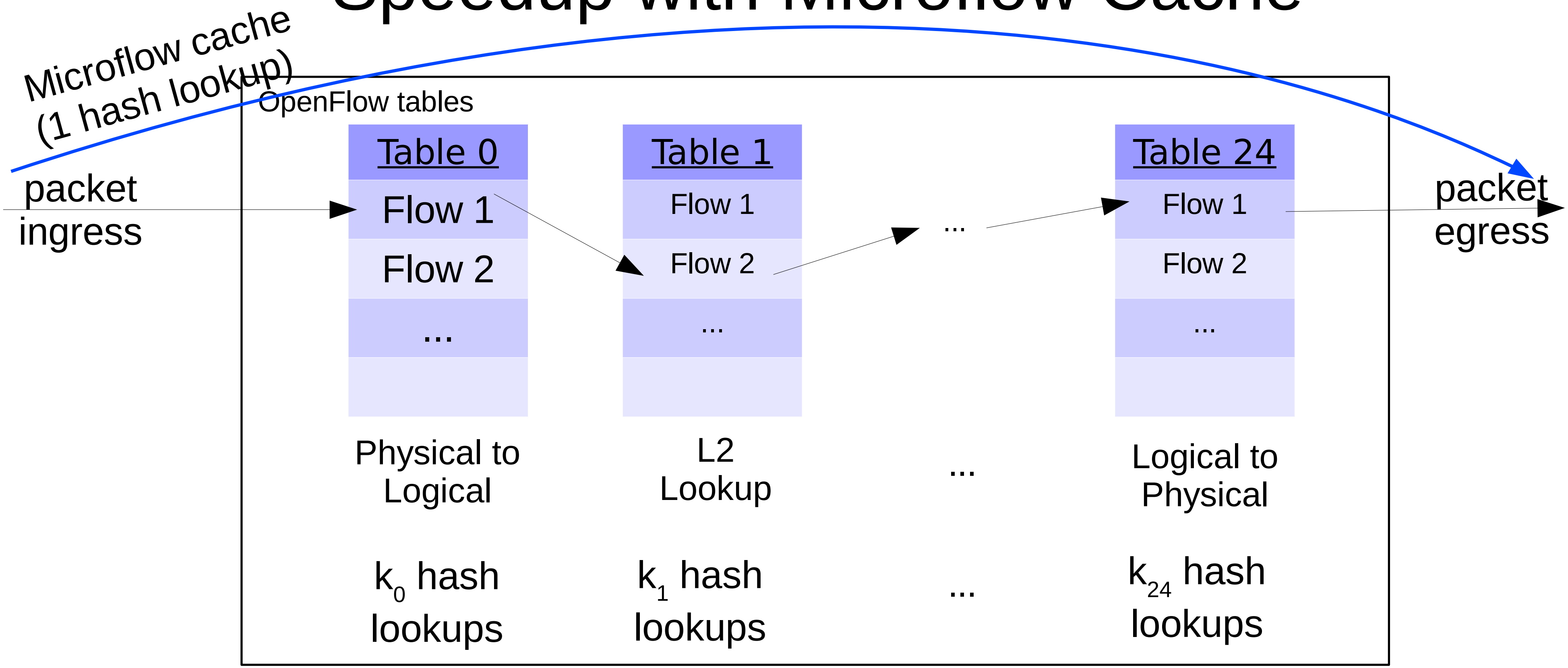
Microflow:

- Complete set of packet headers and metadata
- Suitable for hash table
- Shaded data below:

Eth	IP	TCP	payload



Speedup with Microflow Cache



From 100+ hash lookups per packet, to just 1!

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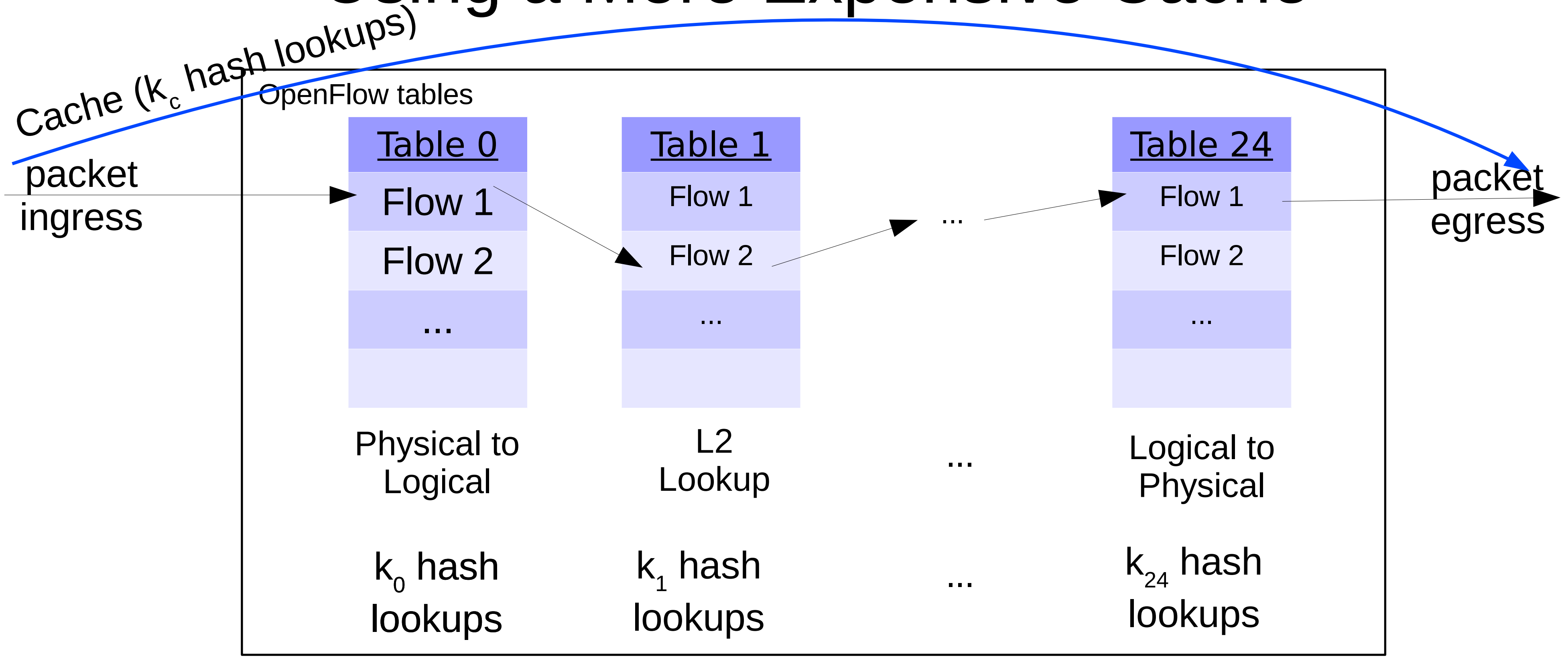
Microflow Caching in Practice

- Tremendous speedup for most workloads
- Problematic traffic patterns:
  - Port scans
    - Malicious
    - Accidental (!)
  - Peer-to-peer rendezvous applications
  - Some kinds of network testing
- All of this traffic has lots of short-lived microflows
  - Fundamental caching problem: low hit rate

Using a More Expensive Cache



If $k_c << k_0 + k_1 + \ldots + k_{24}$: benefit!

Naive Approach to Populating Cache

Combine tables 0...24 into one flow table. Easy! Usually, $k_c << k_0 + k_1 + \ldots + k_{24}$. But:

Table 0
ip_src=*a*
ip_src=*b*
ip_src=*c*
ip_src=*d*

n_1 flows

×

Table 1
ip_dst=*e*
ip_dst=*f*
ip_dst=*g*
ip_dst=*h*

n_2 flows

× ··· ×

Table 24
eth_dst=*i*
eth_dst=*j*
eth_dst=*k*
eth_dst=*m*

n_{24} flows

=

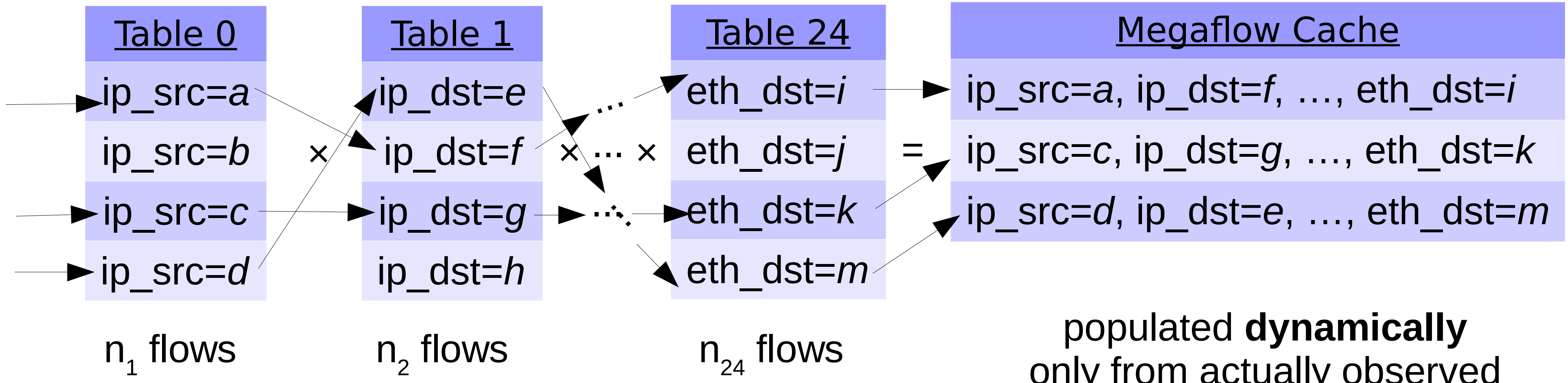
Table 0+1+...+24
ip_src=*a*, ip_dst=e, …, eth_dst=*i*
ip_src=*a*, ip_dst=e, …, eth_dst=*j*
ip_src=*a*, ip_dst=e, …, eth_dst=*k*
...
ip_src=*d*, ip_dst=*h*, …, eth_dst=*k*
ip_src=*d*, ip_dst=*h*, …, eth_dst=*m*

up to $n_1 \times n_2 \times \cdots \times n_{24}$ flows

“Crossproduct Problem”

Lazy Approach to Populating Cache

Solution: Build cache of combined "megaflows" **lazily** as packets arrive.



populated **dynamically** only from actually observed packets

Same (or better!) table lookups as naive approach.
Traffic locality yields practical cache size.

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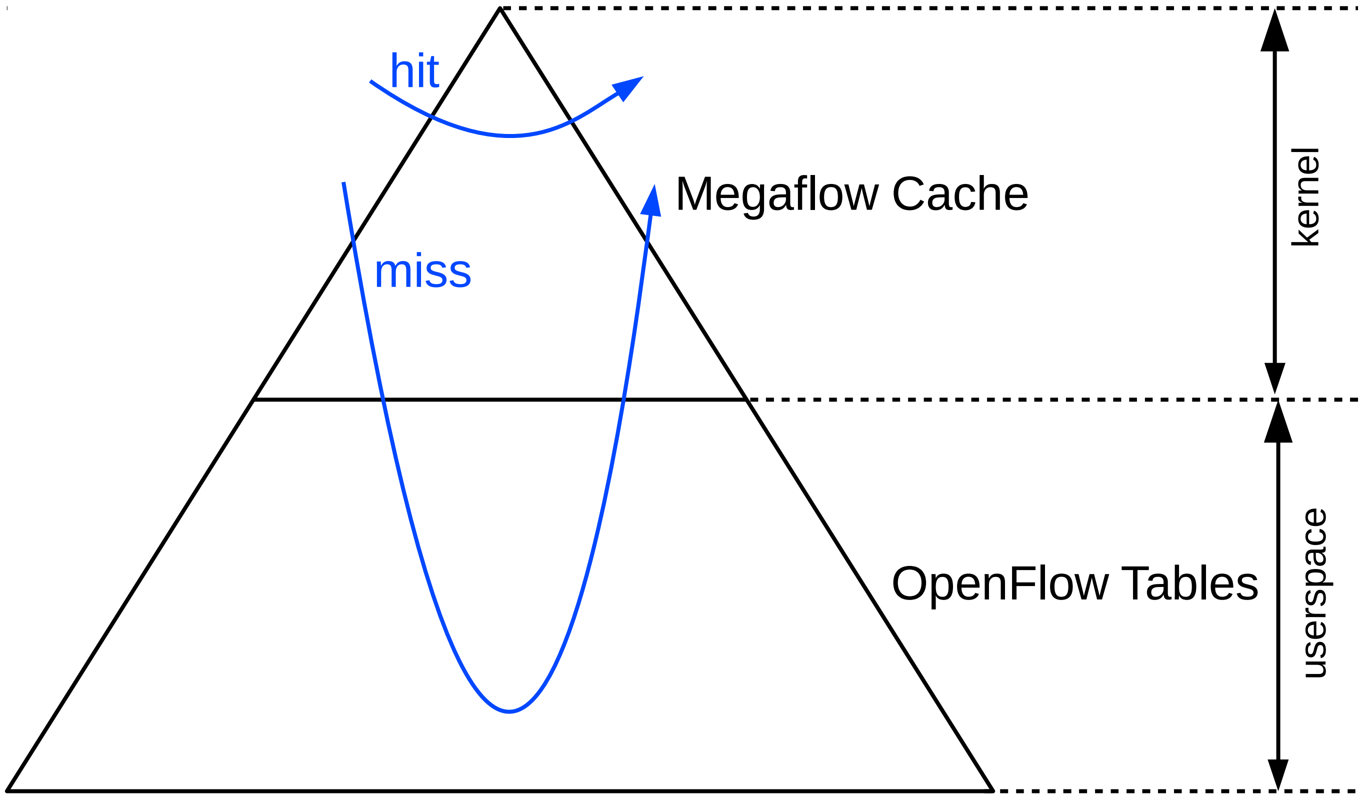
OVS Cache v2: “Megaflow” Cache



Making Megaflows Better

- Megaflows are more effective when they match fewer fields.
  - Megaflows that match TCP ports are almost like microflows!
  - Described approach matches every field that appears in any flow table
- Requirements:
  - online
  - fast
- Contribution: Megaflow generation improvements (Section 5).

Megaflow vs. Microflow Cache Performance

- Microflow cache:
  - $k_0 + k_1 + \cdots + k_{24}$ lookups for first packet in microflow
  - 1 lookup for later packets in microflow
- Megaflow cache:
  - k_c lookups for (almost) every packet
- $k_c > 1$ is normal, so megaflows perform worse in common case!
- Best of both worlds would be:
  - k_c lookups for first packet in microflow
  - 1 lookup for later packets in microflow

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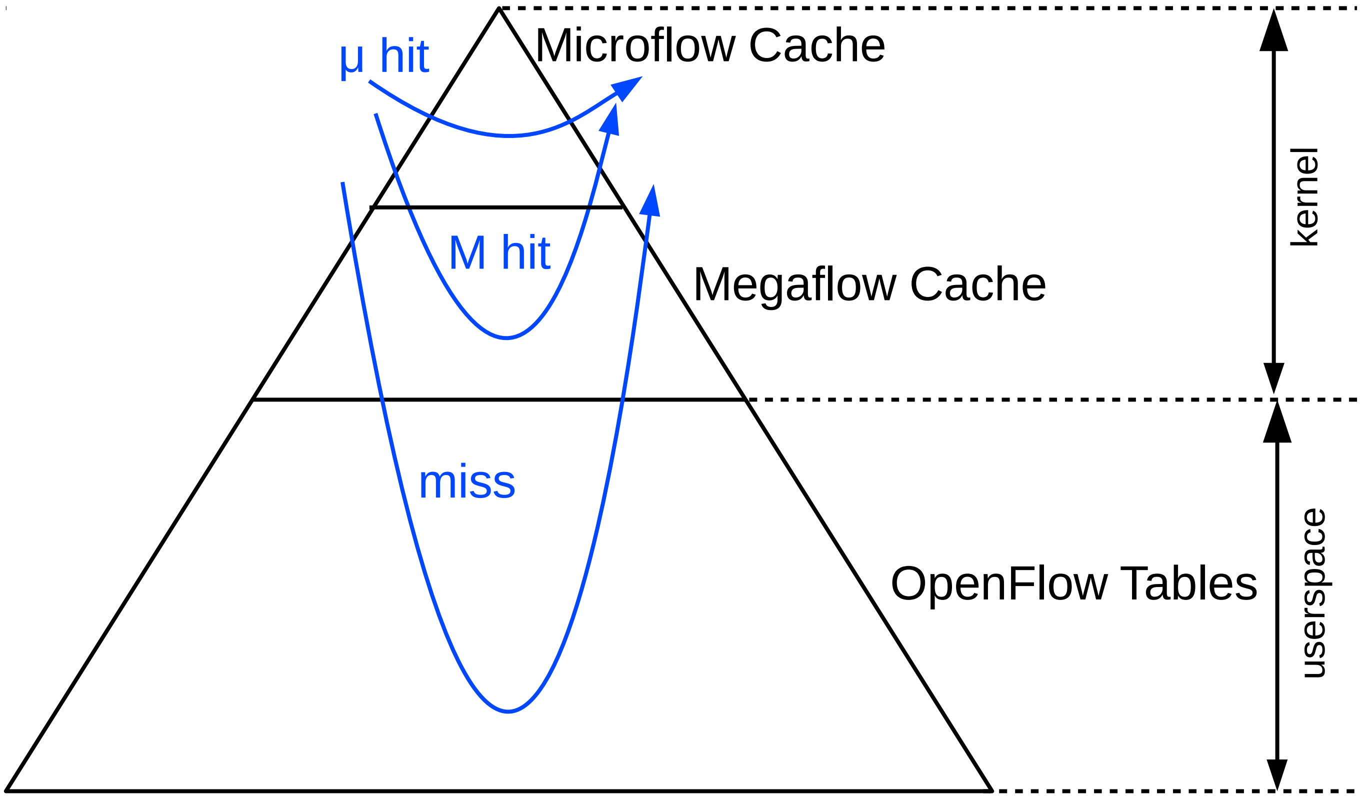
OVS Cache v3: Dual Caches



Parting Thoughts

- Architectural tension: expressibility vs. performance
- OpenFlow is expressive but troublesome to make fast on x86
  - Performance requirements can make applications avoid OpenFlow
- Caching provides OVS with expressibility and performance
- Applications can freely evolve decoupled from performance
  - Specialized code would be **slower**!
- Starting from a more general problem produced better results