Hey, You Darned Counters! Get Off My ASIC!

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OpenFlow counters: good news and bad news

Good news about OpenFlow counters:

- There are counters for every flow-table rule (packets, bytes, duration)
- So the controller has visibility into every flow

Bad news about OpenFlow counters:

- Every flow's counters act exactly the same way
- Sending all counters to the controller is expensive
- … as is polling all of those counters

Specific issue from the DevoFlow paper (SIGCOMM 2011):

- How can the controller ask to see only "significant" flows?
- DevoFlow solution: add "triggers" to OpenFlow rules
  - E.g., "send report when this flow exceeds 500 packets"
  - Or, "send report when this flow exceeds 500MB/sec."
  - **But: it's hard to add this kind of novel counter function to an ASIC**

Why do we keep the counters on the ASIC?

Historically, the ASIC has been the only place where we can count fast enough

- And prior to SDNs, we didn't interact with the counters very often

But on-ASIC counters create several problems:

1. Lack of flexibility
   - Hard to introduce new kinds of counters, such as DevoFlow
2. Cost of reading and manipulating counters
   - The switch-local CPU has to poke around in the ASIC to do this
3. ASIC area
   - Counters take space, and DevoFlow triggers can take a lot more
4. ASIC complexity
   - Counter-related functions complicate the chip

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These are the reasons that initially got us started thinking about counters

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This is the reason that actually seems to matter.

ASICs vs. rapid innovation

ASICs have long design cycles

- Multiple years from “we should add this feature” to shipping products
- New trains leave the station only once in a while

It’s hard to anticipate future uses of SDN counters

- So it’s hard to figure out what to put on an ASIC to support future uses

OpenFlow/SDN: **largely a reaction to the slow pace of ASIC innovation**

- So: move the locus of innovation to software

Software-Defined Counters (in one slide)

No counters on the ASIC!

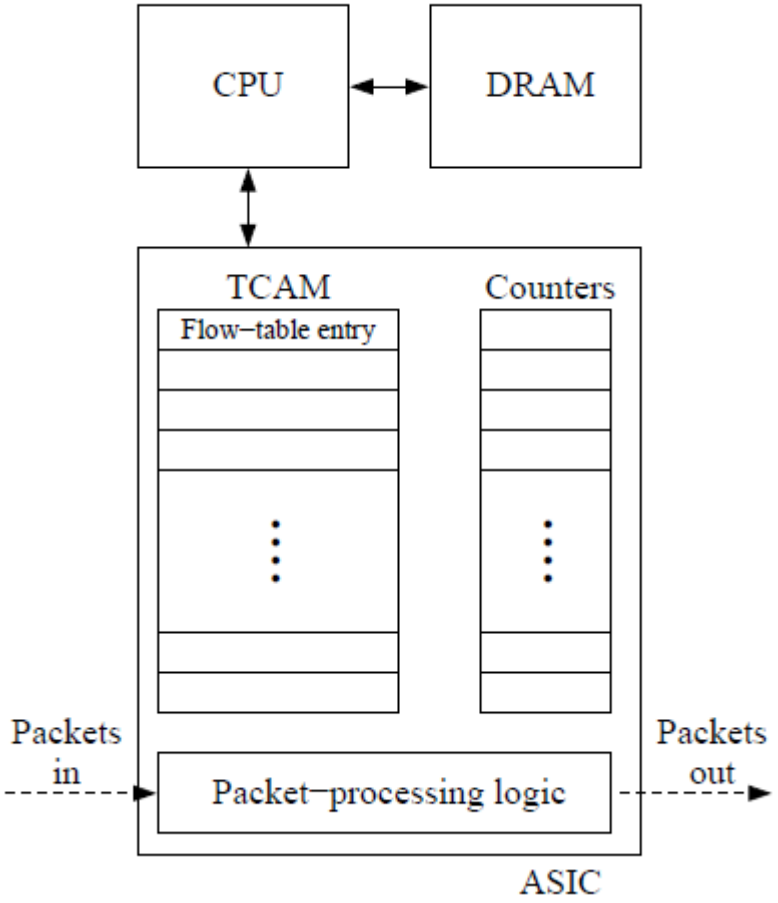
ASIC generates an *event record* on each packet arrival

- Fields: **`ruleNumber, byteCount`**
- 32 bits is enough for ~500K rules
- Small on-ASIC buffer for event records
- Full buffer blocks are DMAed to off-ASIC DRAM

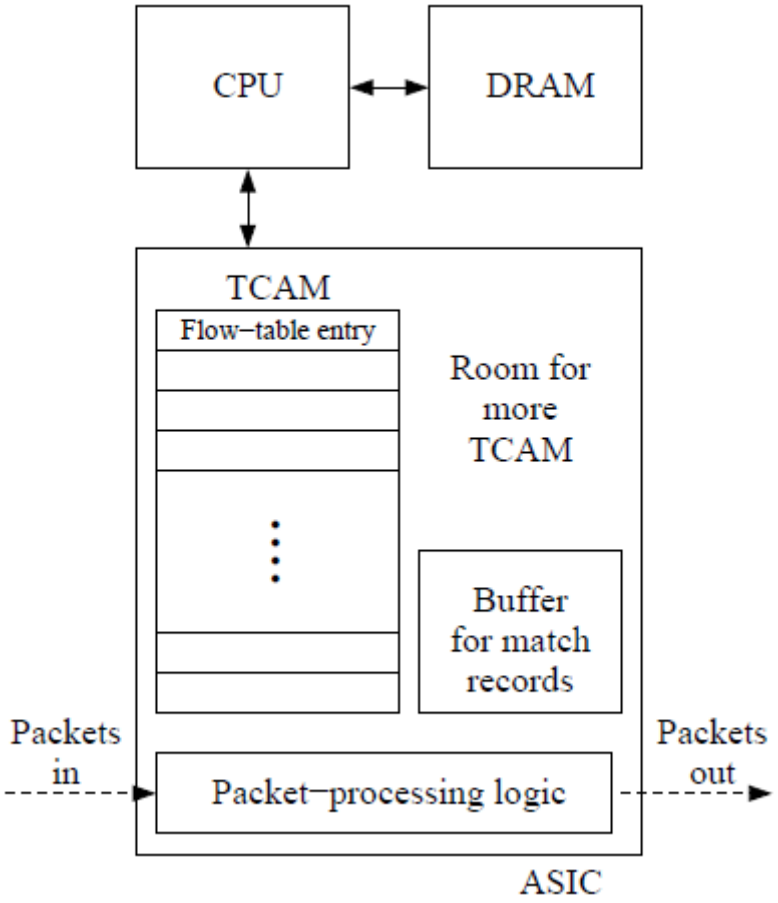
Switch-local CPU reads the event-record stream from DRAM

- Updates standard OpenFlow counters, also stored in DRAM
- Can implement novel counter features with SW-only changes

System-level design



Traditional SDN switch



SDC switch with off-ASIC CPU

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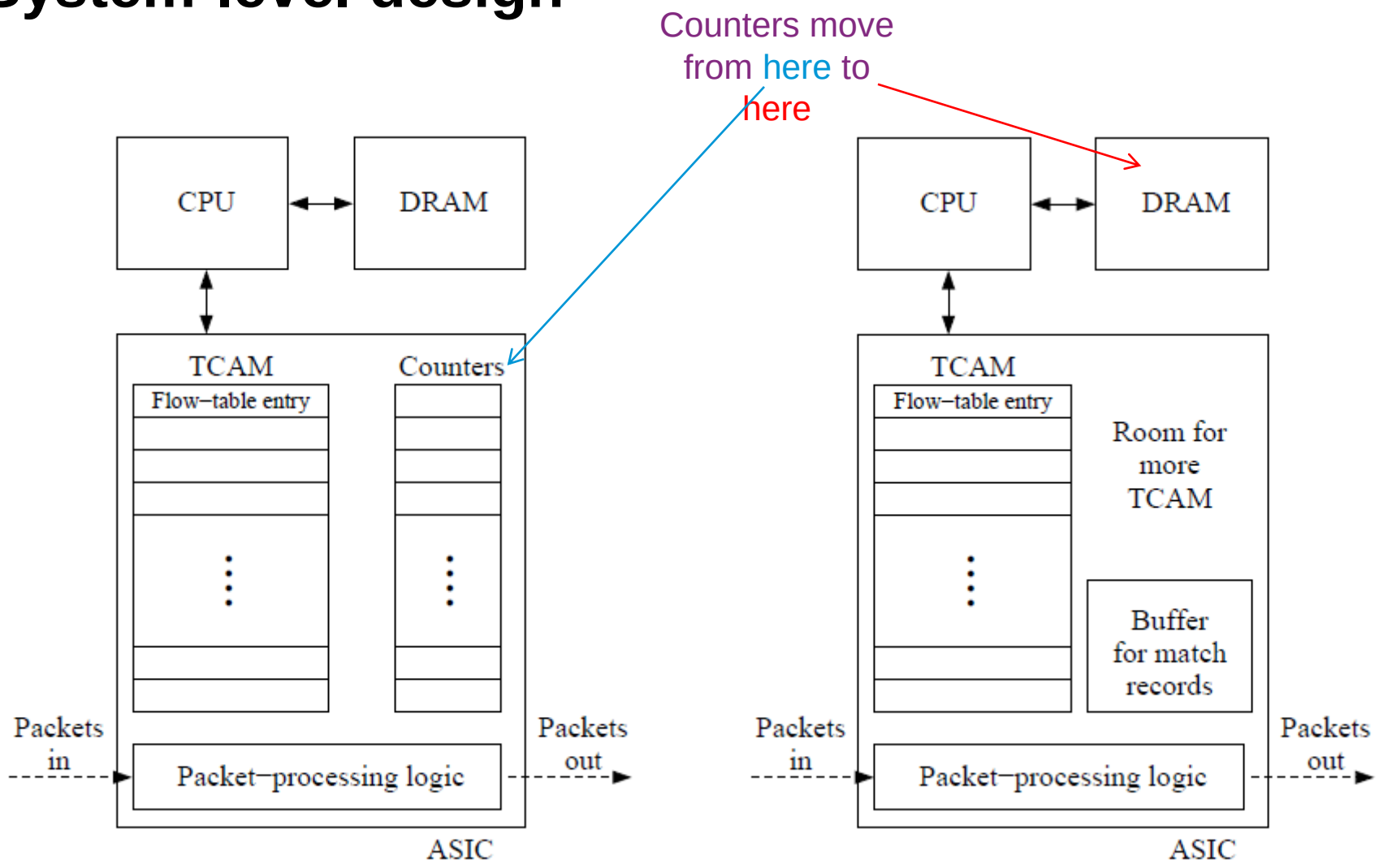


Traditional SDN switch

SDC switch with off-ASIC CPU

Examples of features that SDC could support

DevoFlow extensions:

- Triggers: store trigger values in DRAM; check trigger on each update
- Rate-based triggers: keep EWMA of bytes/sec in DRAM (perhaps)

Immediately discard “uninteresting” records:

- Possibly useful for implementing `Limit` clause in the Frenetic Language

Multi-flow triggers: send report when some subset of flows hits threshold:

- E.g., “connections to Web server together account for 1 Gbit/sec”

Flow-creation-rate triggers:

- E.g., “more than 100 new flows/sec into a laptop”

Emulate sFlow, NetFlow, or RMON

- Makes it easier to integrate OpenFlow into a legacy environment

How could this possibly work?

We need to worry about:

1. ASIC-to-CPU bandwidth: how many bytes/sec can we transfer via DRAM?
2. CPU processing costs: how many event records/sec can the CPU process?

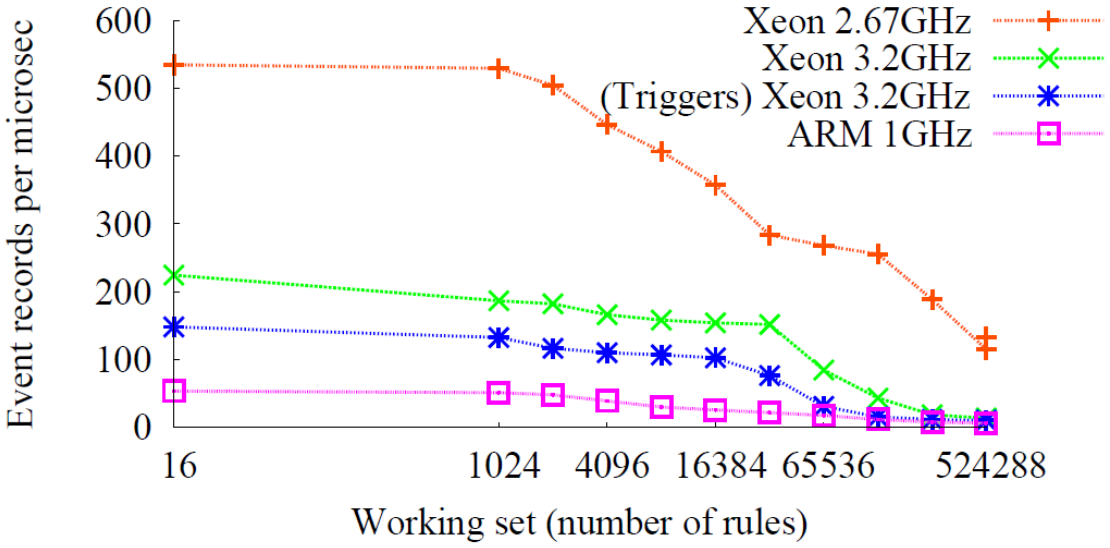
Fundamental issue: what event rates can we expect?

- (assumes: 48-port 10GbE switch)
- Worst case: 714M events/sec (2.9GByte/sec)
  - Even this worst-case bandwidth is achievable with DDR3 DRAM
- "realistic" full-load case (400B/pkt): 150M events/sec (572MByte/sec)

How could this possibly work?

Experiments (in paper) suggest older Xeon should handle 150M events/sec

- *If* working set of rules (counters) is fairly small (~1024 – 4096)
  - Likely to be true for a data-center network; not likely for core Internet router
  - Newer CPUs (e.g., Xeon/Nehalem) can handle much higher rates
  - 3 C(



Techniques to reduce bandwidth and event rates

Bandwidth reduction: compress event records

- Huffman-encoding of rule numbers
- Short encodings of popular packet sizes

Event-rate reduction: exploit locality

- Keep a small on-ASIC cache, indexed by rule number
- Coalesce event records in this cache
  - Adds a **`packetCount`** field to the event record format
  - Tag certain flow-table rules as “do not coalesce”, if necessary
- Stream evicted entries to CPU (via DRAM)

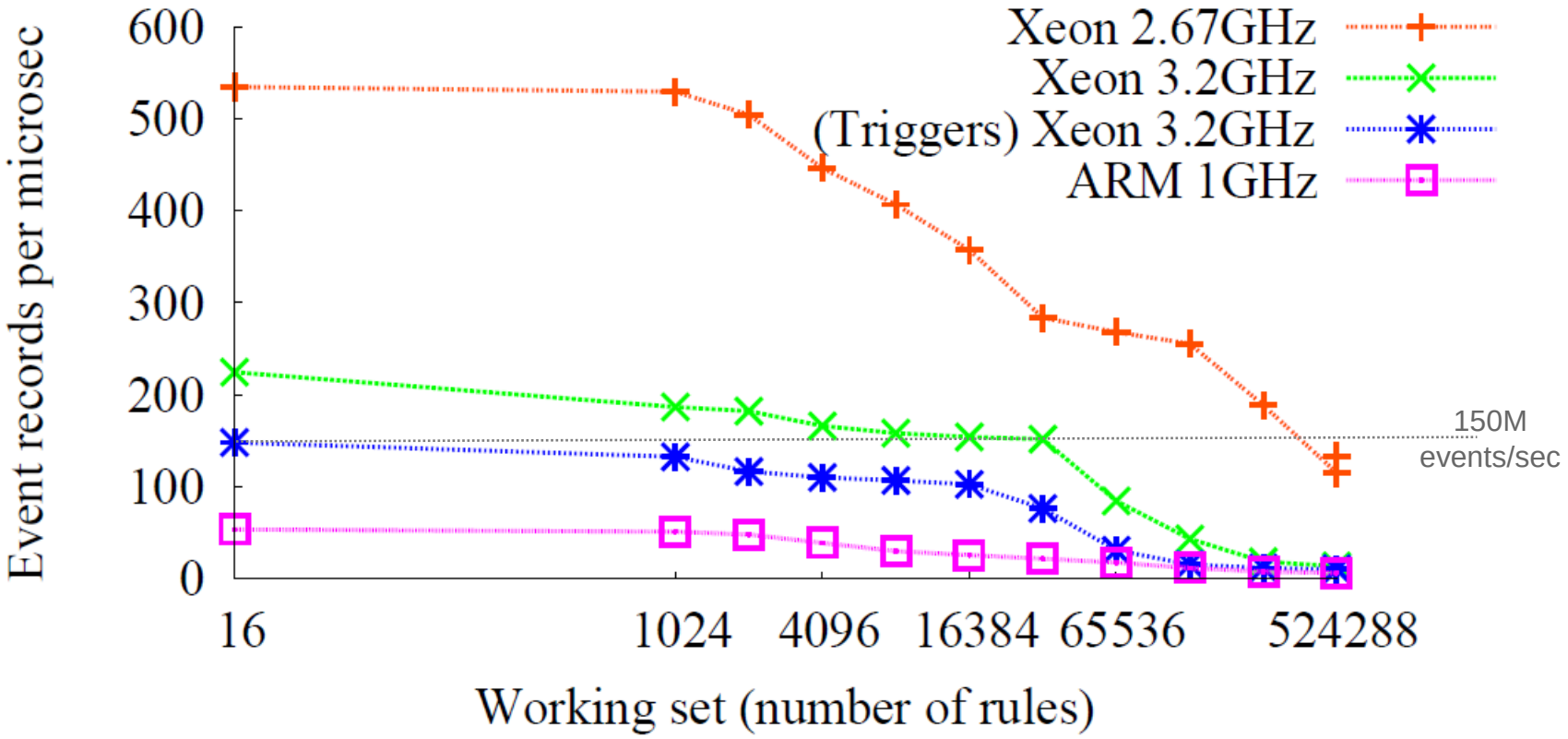
Worst-case: discard excess event records:

- Drop-tail, or randomly (to reduce sampling bias)
- Or tag some flow-table rules as “important” or “boring”

Summary: Software-Defined Counters

- Enable more flexible SDN counters
- Get stuff off of the ASIC
- Ride trends in DRAM and embedded-CPU technology
- Simplistic analysis suggests it might actually work

Microbenchmark results



"Triggers" means checking against byte-count and packet-count thresholds

Locality analysis

Previous work

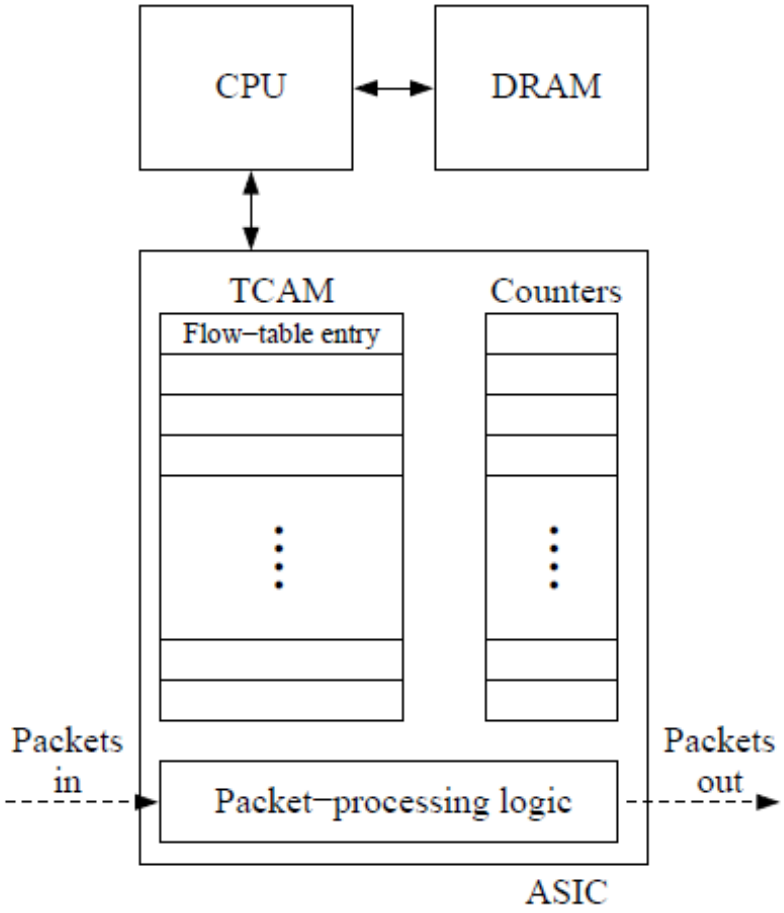
- Benson *et al.* 2009: no more than 10K active flows at any switch
  - Usually much lower
- Tavakoli *et al.* 2009: data-center OpenFlow switches require <=5K entries

Trace-based analysis using 1K-entry cache

- Benson's data-center traces: hit rates between 78% - 97%
- Jan 2009 CAIDA traces: hit rates between 43% - 52%

Thank you

System-level design



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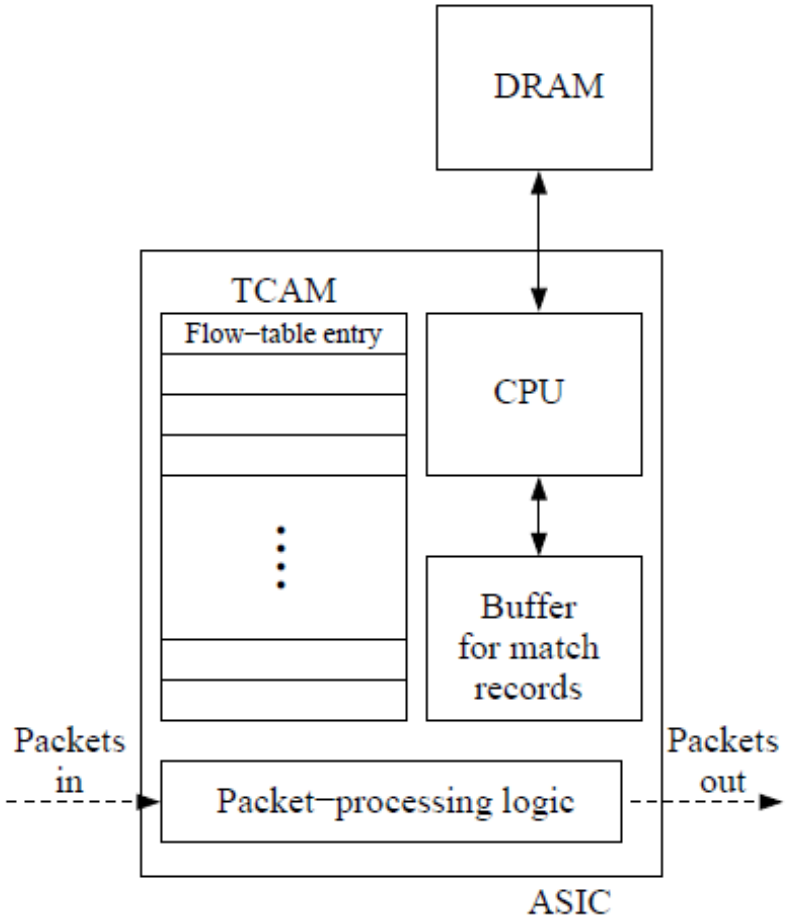

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