P4 Programmable Data-Plane Switches

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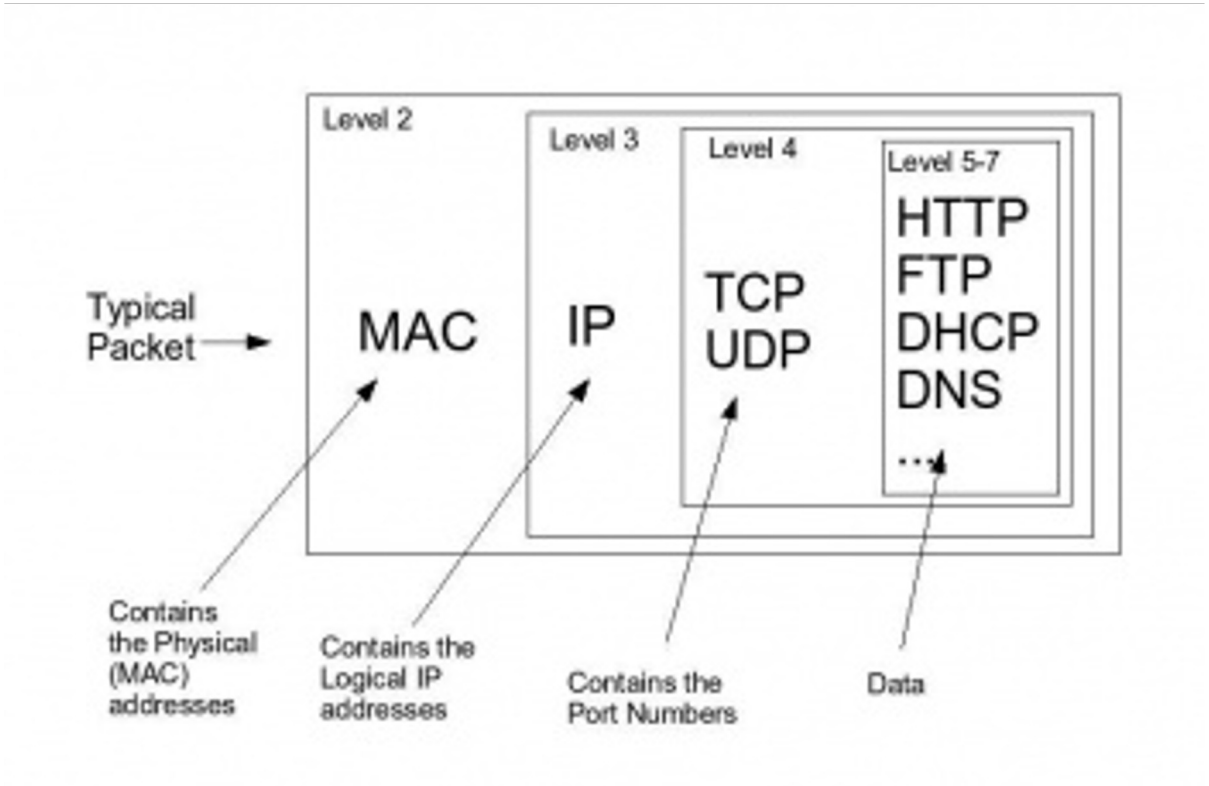
Introduction/Background

- Vendors like Cisco or Juniper control new feature rollout
- Switches configurable not programmable
- New protocol development expensive and time-consuming

Packet

- Essentially a letter
  - Message
  - Info about message
- Mail
  - Mailboxes
  - Mail trucks
  - Post offices
- Formatted unit
  - Control Info in header and footer
  - Data can be split between multiple packets



https://computersciencewiki.org/images/thumb/e/ec/Networkpacket.jpg/350px-Networkpacket.jpg

Packet Switches

Hubs

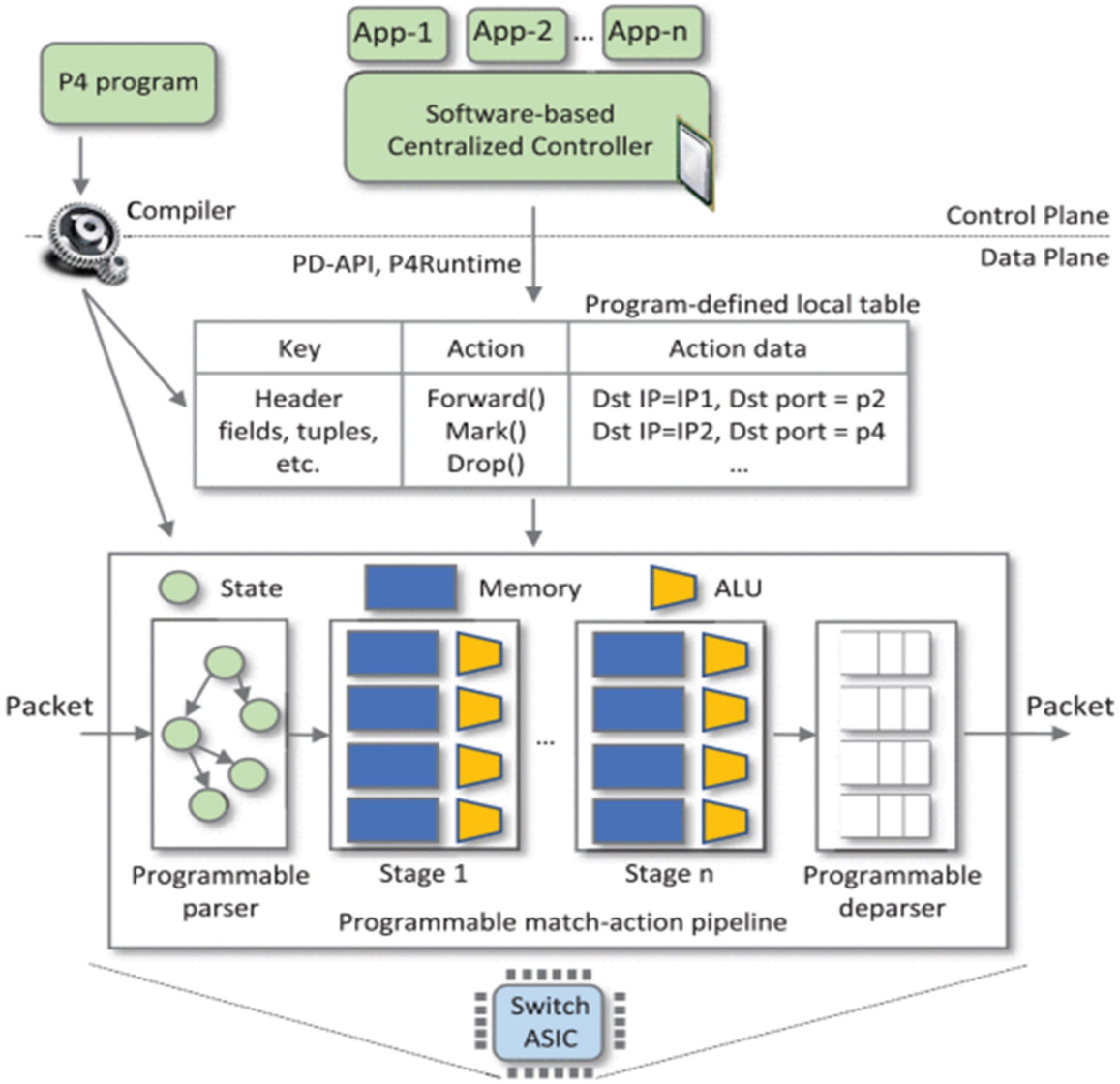
- Physical Layer
  - Same as cabling
- Send all packets out all ports
  - Insecure
  - Promiscuous hosts
  - Inefficient
- No simultaneous streams
  - Getting unwanted packets
  - Other hosts cannot transmit

Switches

- Use hardware addresses to send to the right port
  - Plug ‘n Play
- Configurable Switches
- Some have advanced features
  - Inter-VLAN Routing
    - Multiple logical networks on same hardware

Control and Data Planes

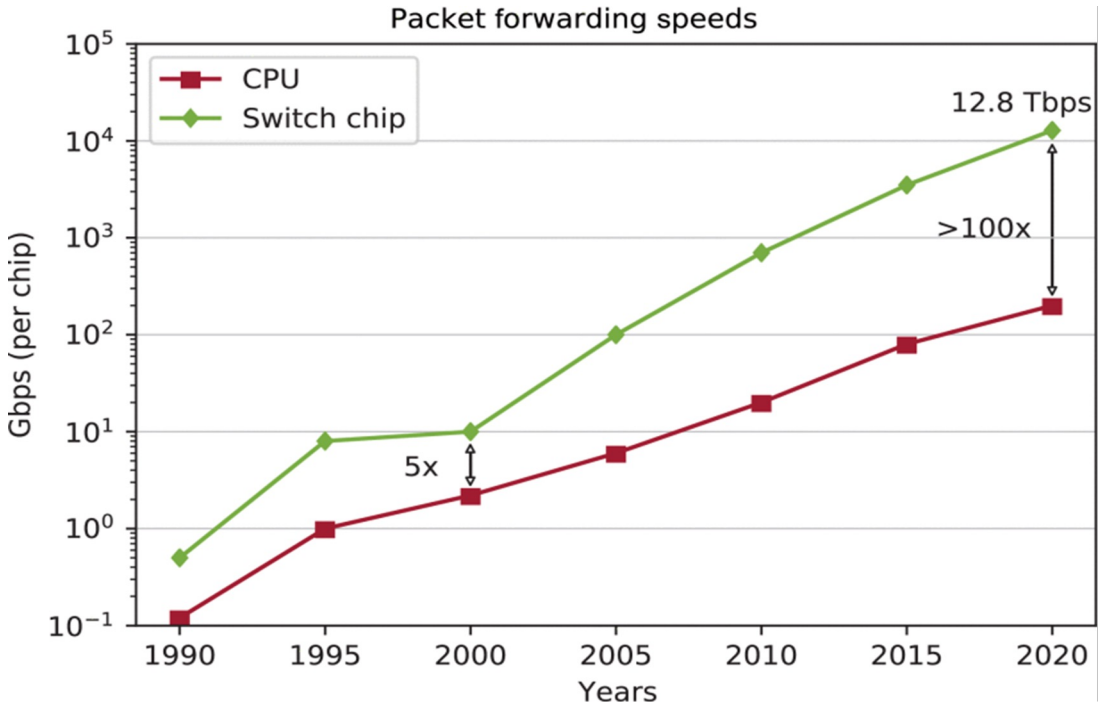
- Control Plane
  - Defines data-plane logic
  - Contains routing table
  - QoS
  - Somewhat configurable
- Data Plane
  - Functions & Processes for packet switching
  - Parser & De-parser
  - Controlled by vendors



E. F. Kfoury, J. Crichigno and E. Bou-Harb, "An Exhaustive Survey on P4 Programmable Data Plane Switches: Taxonomy, Applications, Challenges, and Future Trends," in *IEEE Access*, vol. 9, pp. 87094-87155, 2021, doi: 10.1109/ACCESS.2021.3086704.

P4 (Programmable Protocol-Independent Packet-Processors)

- Domain-Specific Programming language developed in 2014
  - Target-Independent (CPU & ASICs)
  - ASICs are significantly faster
- No native protocol support
  - Everything defined by programmer
- Increase efficiency by offloading processes onto the switch



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Goal of Research

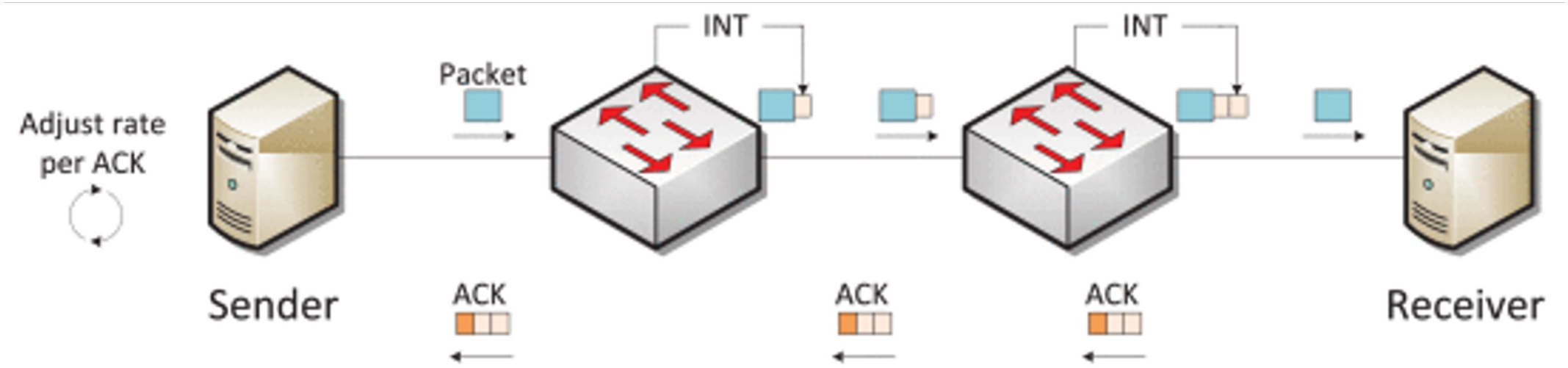
Use the programmability of this hardware to develop real-world applications.

Specific Aims

1. Explore potential applications
2. Develop example applications
3. Deploy in test networks

In-Band Network Telemetry (INT)

- Add metadata in transit
- Real-time telemetry
- Adjust sending rates to reduce congestion
- Congestion greatly reduced speed
- Imagine video buffering or quality dip



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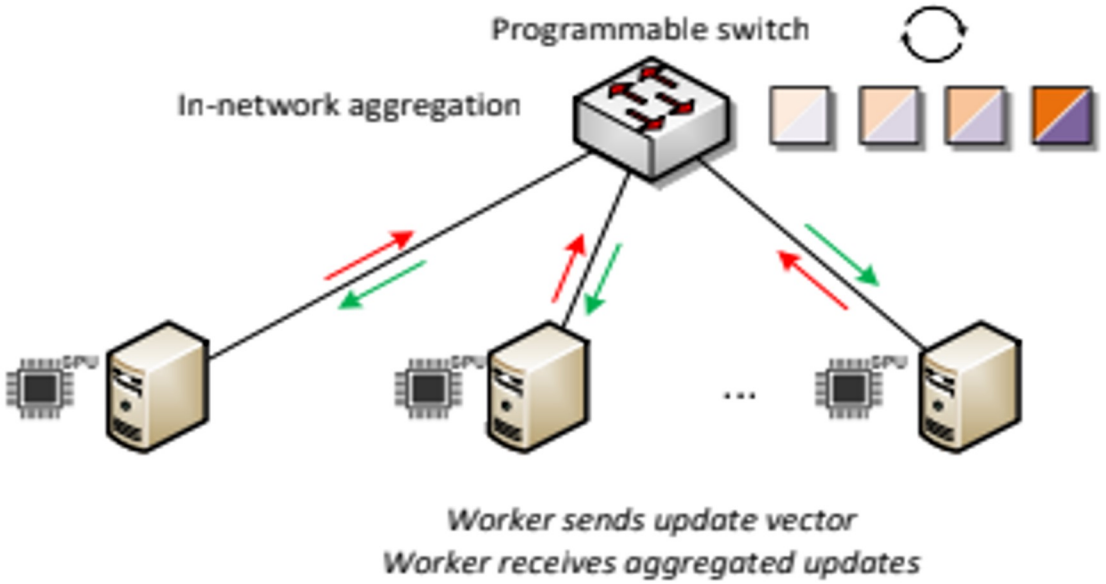
Machine Learning Aggregation

- Aggregate calculations on switch instead of on workers
- Aggregation requires little computing effort



- Workers or dedicated machines aggregate updates
- Switch processes this in-transit and increases efficiency

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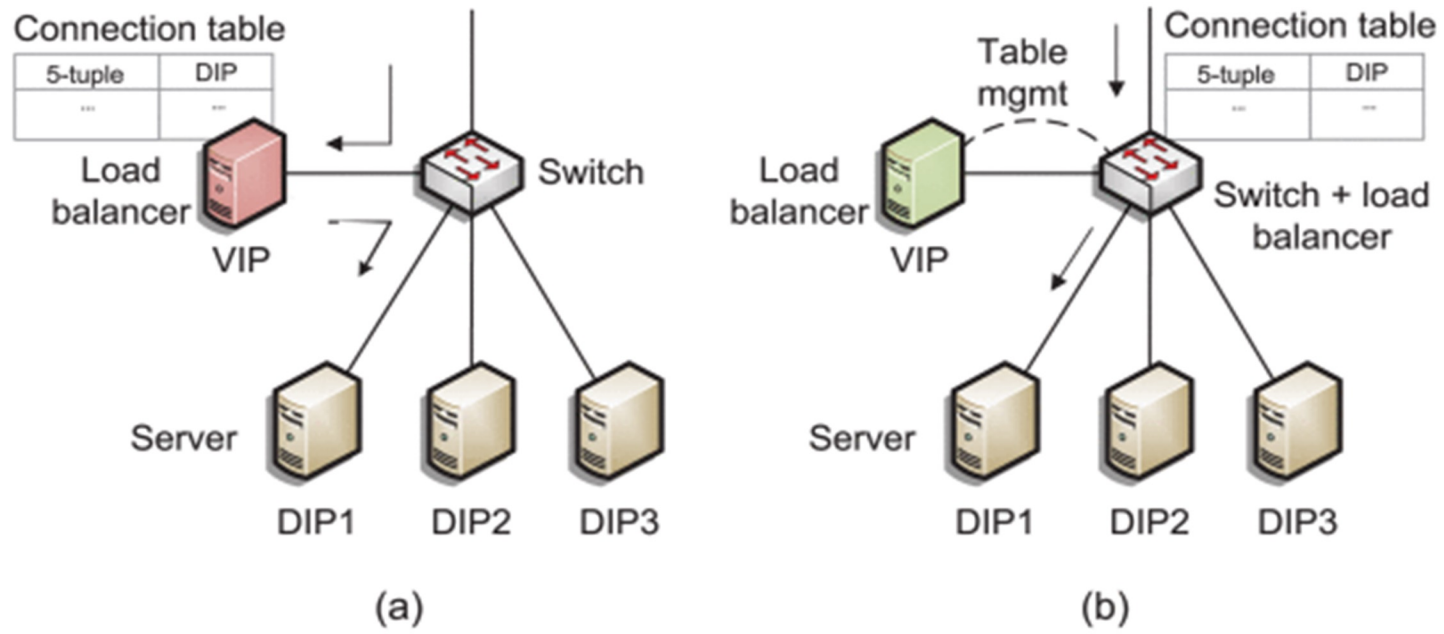
Load Balancer

- Do forwarding on the switch
- Manage table on a server
- Decreases latency

- Load balancer normally routes the packets



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Conclusions & Future Directions

Conclusions:

- Research was primarily exploratory

Future Directions:

- Applications of P4 are limited by what is necessary in a specific installation

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- GSSM
- USC - Columbia

Basic Layer 2 Switch

- Forwards packets based on their header (hdr)
- Decrements TTL

- Below images packet processing
- Other parts of code
  - Computing checksum
  - Defining packet formats

```
action ipv4_forward(macAddr_t dstAddr, egressSpec_t port) {
    standard_metadata.egressSpec_t = port;          // Set egress port for the packet

    hdr.ethernet.srcAddr = hdr.ethernet.dstAddr;    // Set source mac as the switch's mac
    hdr.ethernet.dstAddr = dstAddr;                 // Set destination mac as the orignal destination mac

    hdr.ipv4.ttl = hdr.ipv4.ttl - 1;                // Decrement TTL
}
```