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FlowBlaze.p4: a library for quick prototyping of stateful SDN applications in P4

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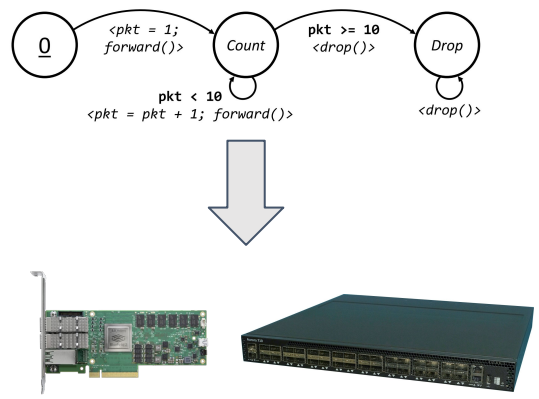
Outline

- Introduction
- The FlowBlaze architecture
- FlowBlaze.p4 library
- Using FlowBlaze.p4: Packet Limiter
- Use Case: Multi-Class Rate Limiter
- Conclusions

Introduction - 1

5G and Mobile Edge Computing requires offloading of network functions to data plane

- **P4**: reference language for data plane programming
- **State Machine**: powerful abstraction to develop stateful packet processing
- **FlowBlaze**: EFSM-based stateful packet processing architecture



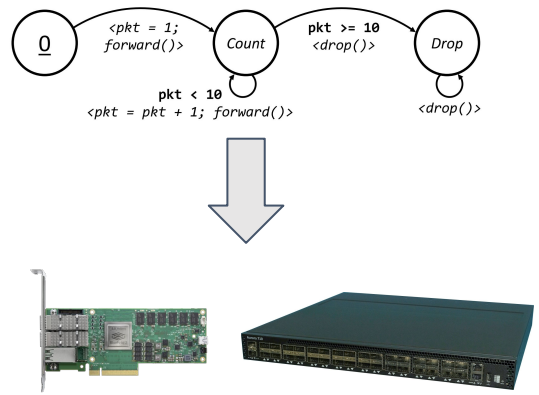
Introduction - 2

Issues with FlowBlaze utilization:

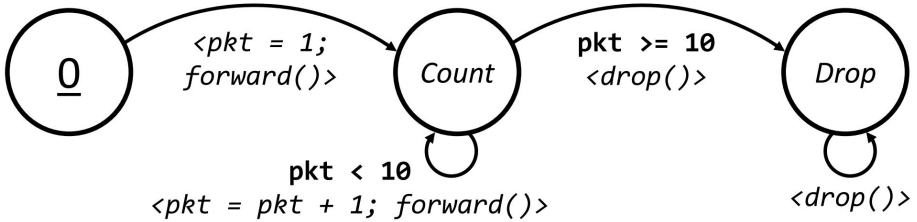
- Missing prototyping platform
- Manual (error-prone) mapping from EFSM to FlowBlaze table entries
- No FlowBlaze P4 implementation

FlowBlaze.p4:

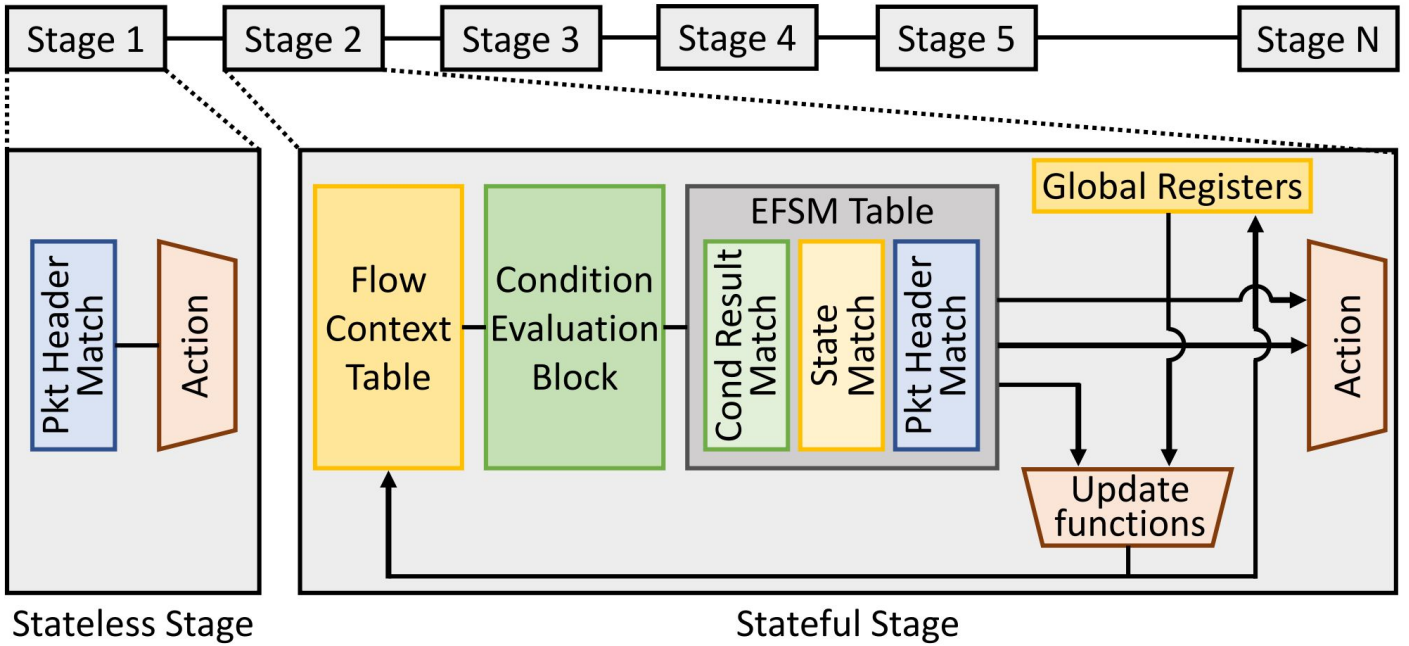
- FlowBlaze library implementation in P4
- Open source library
- GUI to automatically translate EFSM into table entries
- Exploit all the tools from the P4 Community



The FlowBlaze* architecture - 1



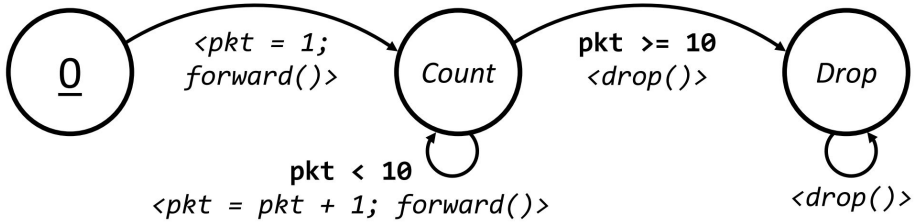
- EFSM based stateful packet processing
- Multi-stage: stateless (OpenFlow like) + stateful (EFSM-based) stages



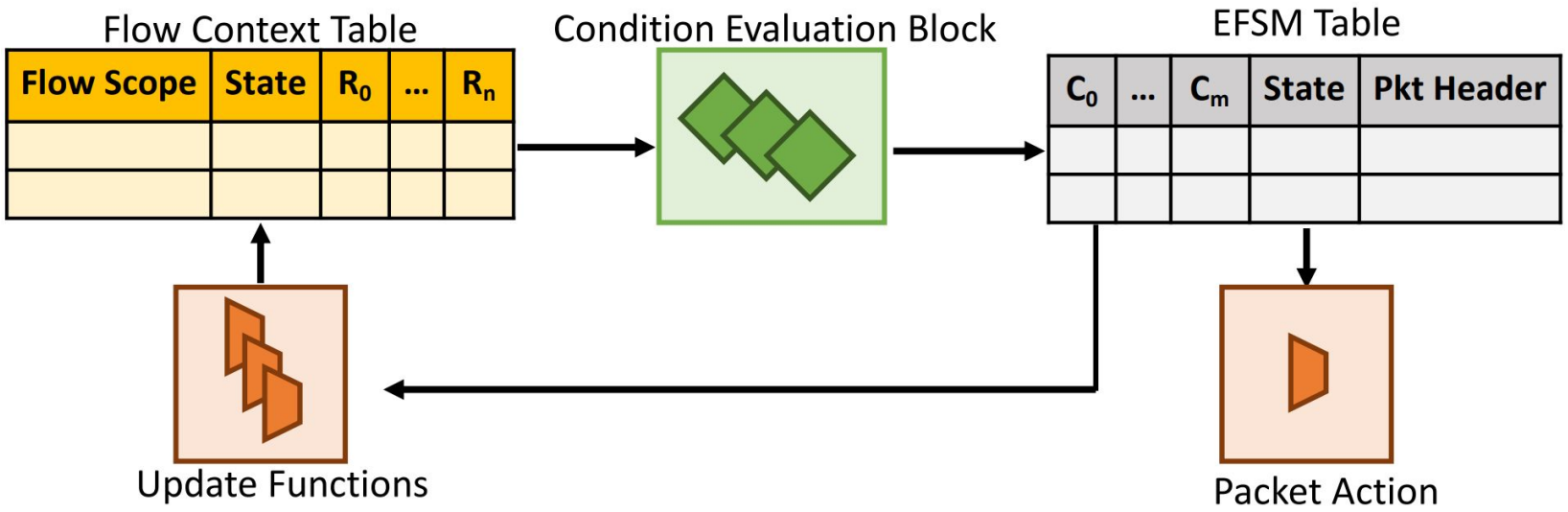
** S Pontarelli, et al. "Flowblaze: Stateful packet processing in hardware", USENIX NSDI 2019*

The FlowBlaze architecture - 2

Stateful Stage



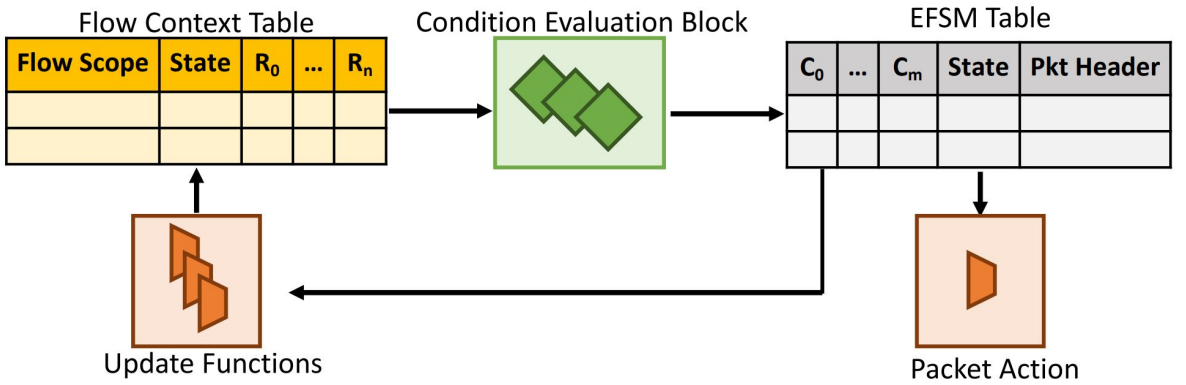
- Arbitrary Flow Definition with associated context (State and Flow Data Variable - FDV)
- Conditions evaluated on the FDVs (`<,>, <=, >=, ==, !=`)
- Transitions in EFSM Table (`if <conditions> and <state> then <new_state, actions>`)
- Update FDVs (`+,-,*,<<,>>`) and packet action (e.g., `forward, drop`…)



FlowBlaze.p4 library

Stateful FlowBlaze Stage to P4

Communication between blocks via P4 Packet Metadata
Target: BMv2 software switch



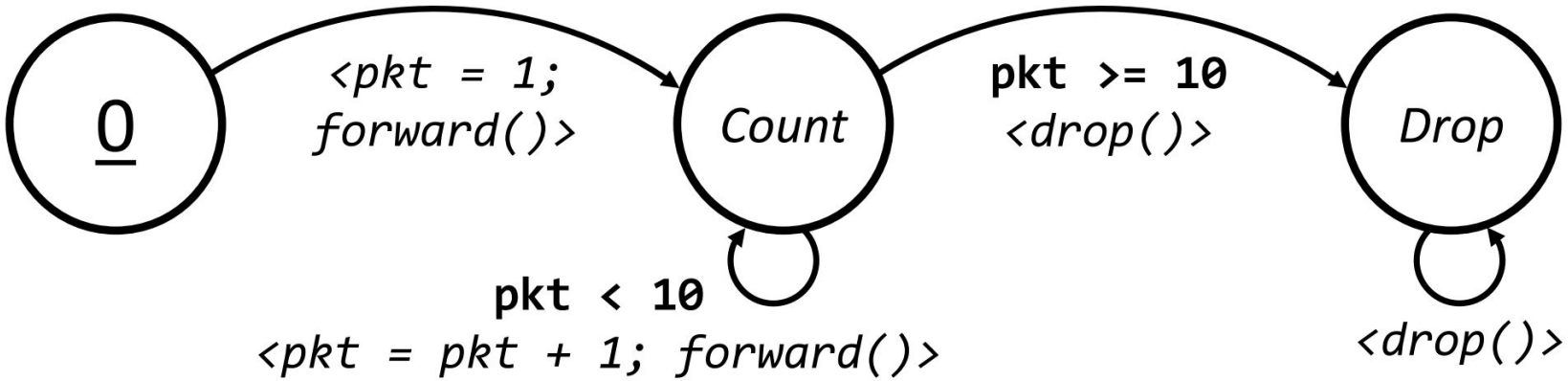
Flow Context	Registers* *Indexing with hash function on the Flow Definition
Conditions	Series of `if` on the Flow Data Variables
EFSM Table	Match Action Table **Match**: `<conditions results, state, arbitrary fields>` **Action**: `<Set new state, Set Packet Action ID, Set Update Functions>`

Packet Action	Match Action Table
	`Match: Packet Action ID`
	`Actions: User Defined P4 Actions`

Update Functions	Series of `if` to map the set update function to the actual action on the FDV

Using FlowBlaze.p4

Packet Limiter: EFSM



Flow Definition

- IPv4 source address

- State **0**
  All the flows starts from this state.
  Transition to the ***Count*** state.
- State ***Count***
  Counts the number of packets.
  Auto-transition that count the packets when below the threshold
  Transition to the ***Drop*** state when reached the threshold (10) packets.
- State ***Drop***
  Drop all the packets.
  "Black-hole" state.

Using FlowBlaze.p4

Packet Limiter: Compile-time Configuration

1. Add FlowBlaze into your P4 application

2. `#define`:

- **Flow Scope:** `source IP address`
- **Packet actions:**
  - `forward()`
  - `drop()`
- **EFSM header match**
- **Condition header**

3. Compile the program

```
#include "../flowblaze_lib/flowblaze_metadata.p4"
#include "headers.p4"
#include "metadata.p4"
#include "../flowblaze_lib/flowblaze.p4"
...
apply {
    if (hdr.ethernet.isValid()) {
        FlowBlaze.apply(hdr, meta, standard_metadata);
        t_l2_fwd.apply();
    }
}
```

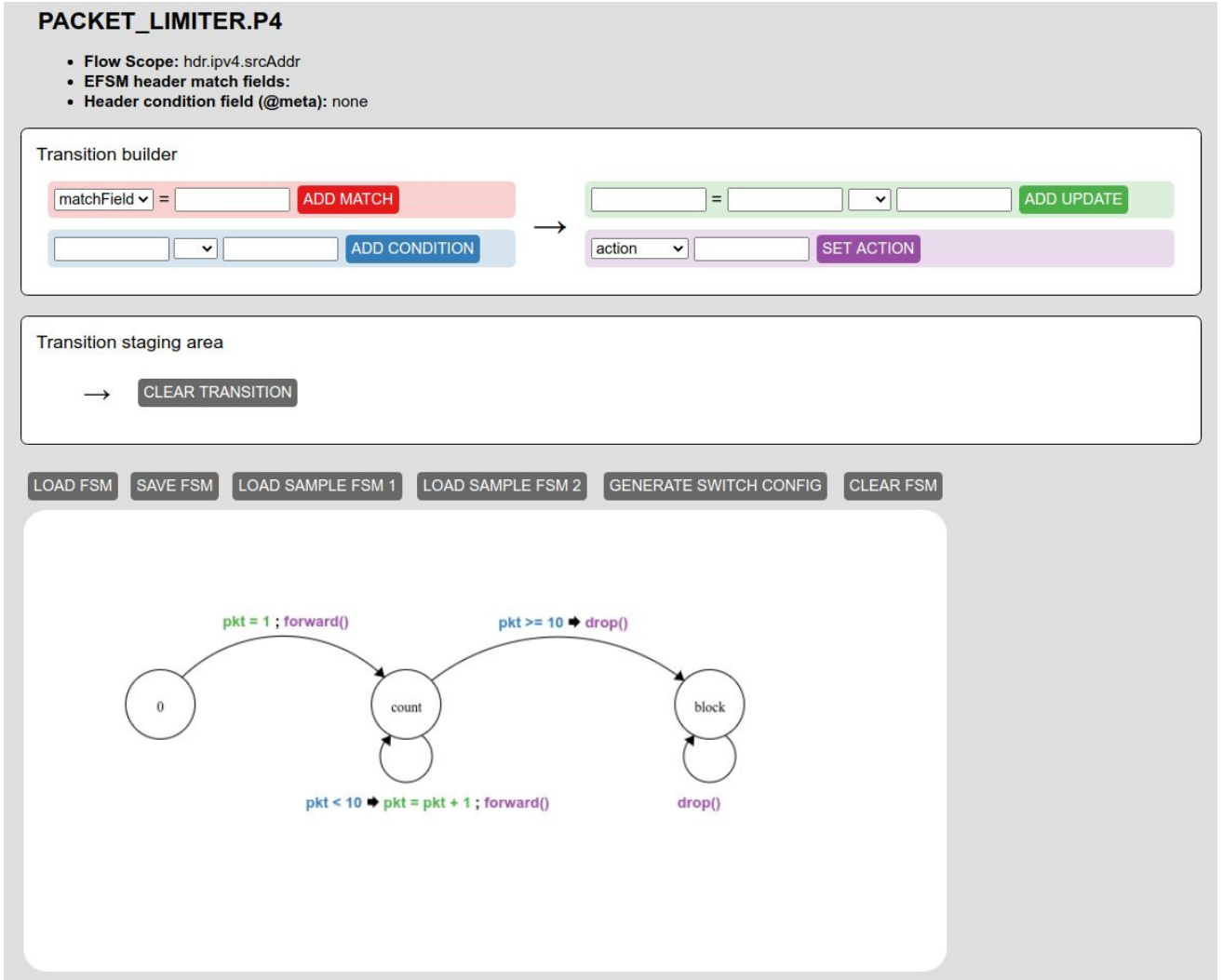
```
#define FLOW_SCOPE { hdr.ipv4.srcAddr }
#define CUSTOM_ACTIONS_DEFINITION @name(".FlowBlaze.forward") \
                                  action forward() { \
                                    \
                                  } \
                                  @name(".FlowBlaze.drop") \
                                  action drop() { \
                                    mark_to_drop(standard_metadata); \
                                    exit; \
                                  }
#define CUSTOM_ACTIONS_DECLARATION forward; drop;
// Configuration parameter left black because not needed
//    #define METADATA_OPERATION_COND
//    #define EFSM_MATCH_FIELDS
//    #define CONTEXT_TABLE_SIZE
```

Not needed for this example

Using FlowBlaze.p4 (continued)

Packet Limiter: Run-time Configuration

4. Run the GUI:
   - Add states as in the EFSM
   - Build the transitions as in the drawn EFSM:
     - Match + Condition
     - Update Function + Packet Action
5. Run in Mininet with the provided Docker infrastructure



Use Cases

Multi-Class Rate Limiter

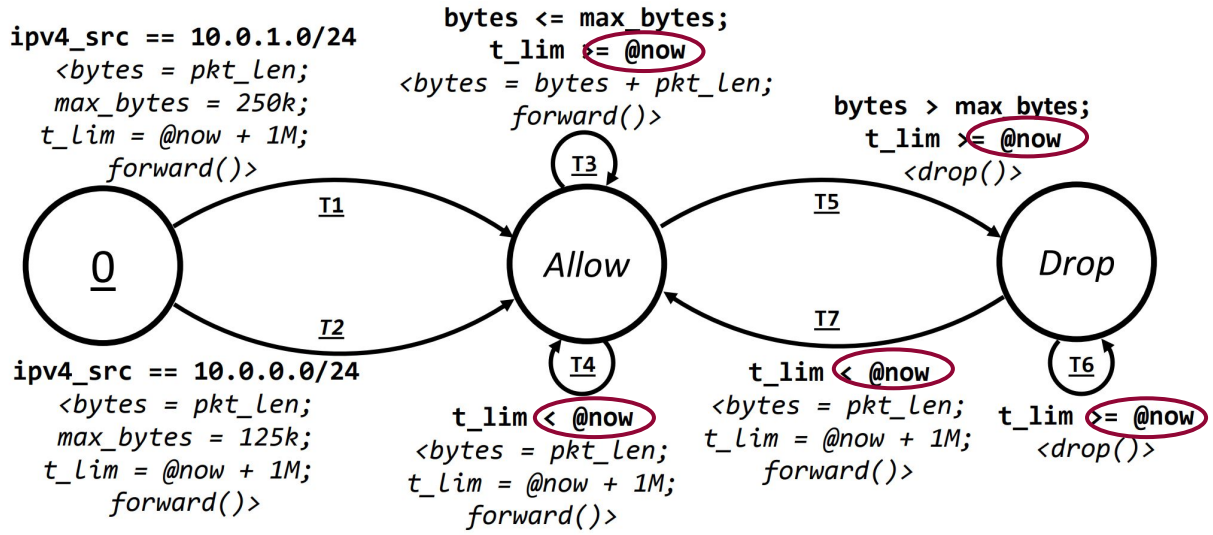
Flow Definition

- IPv4 source address

- State **0**
  All the flows starts from this state.
  "Classify" the traffic by the source IP address setting the *max_bytes* FDV

- State ***Allow***
  Let traffic through, counting the bytes
  Transition to the ***Drop*** state if in the predefined time-slot more than *max_bytes* passed.

- State ***Drop***
  Drop all the packets.
  Transition back to the ***Allow*** state when time-slot ends.



Time-based transition:
@now is the packet ingress timestamp

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Conclusions

- FlowBlaze: abstraction for stateful packet processing based on EFSM
- Missing: prototyping platform and P4 implementation

We provide:

- **FlowBlaze.p4**: a library for prototyping with FlowBlaze and P4
- **GUI**: automatic translation of EFSM into runtime configuration
- **Docker-based environment**
- **Open source:** available on GitHub

Future works:

- ONOS Integration
- DC-style fabric integration (e.g., Trellis)

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Demo later today!

"Demonstrating FlowBlaze.p4: fast prototyping for EFSM-based data plane applications"

https://github.com/ANTLab-polimi/flowblaze.p4


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