Programmable In-Network Security for Context-aware BYOD Policies

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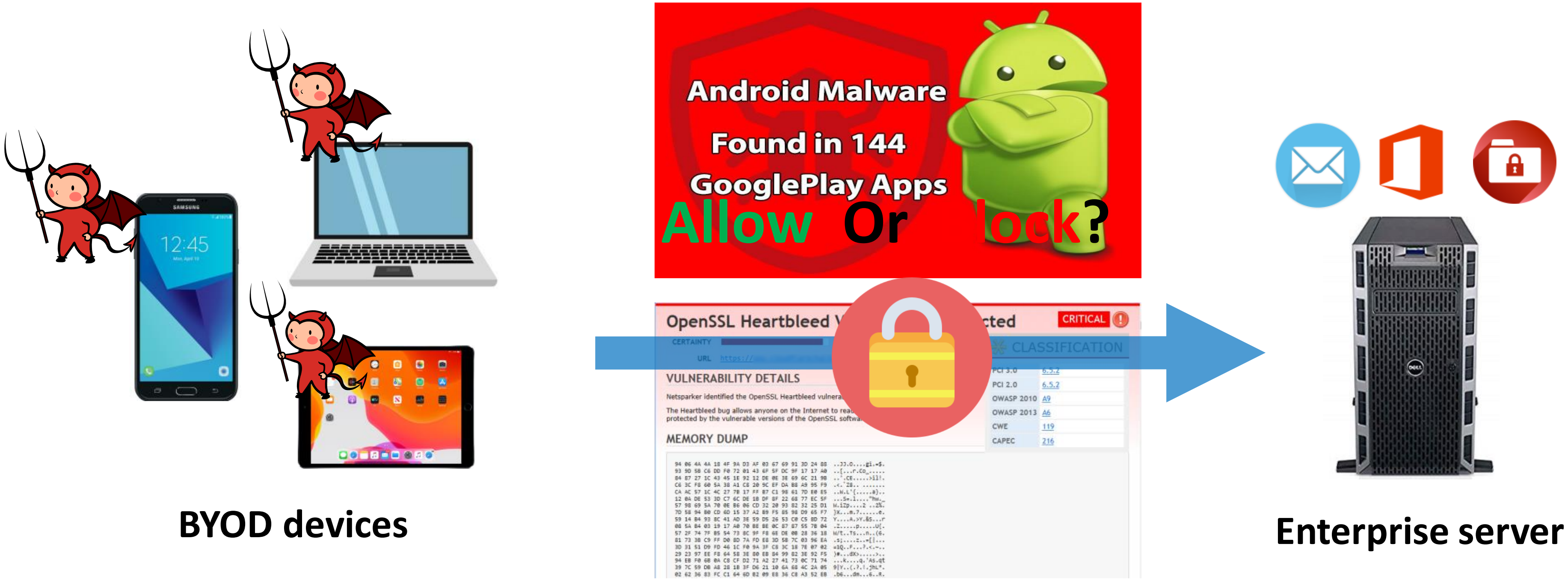
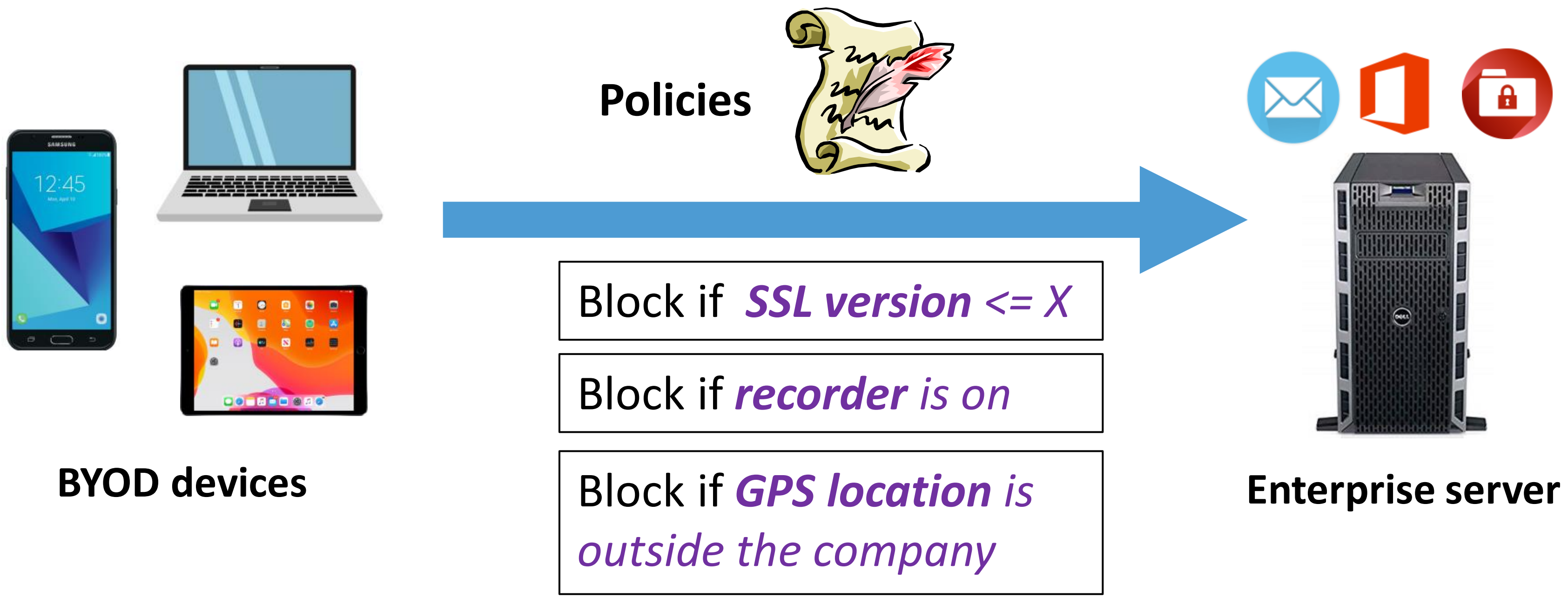
BYOD: Bring Your Own ~~Device~~ Risks



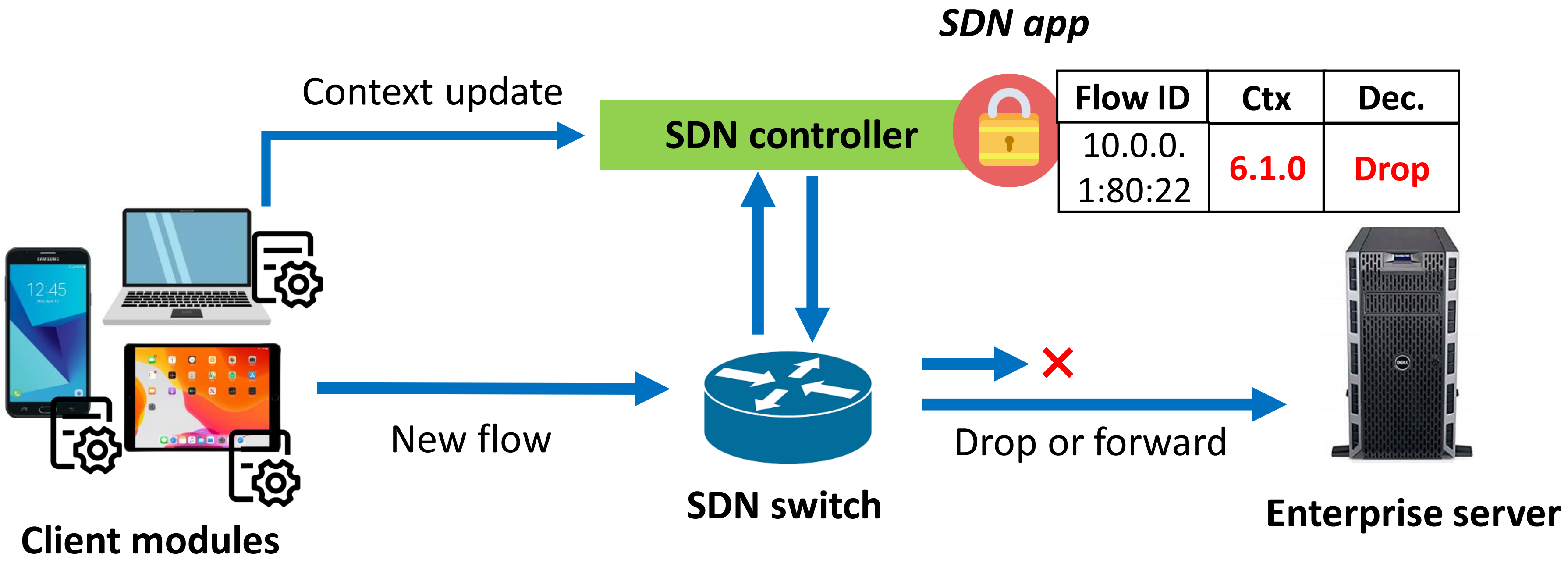
- BYOD devices: Less well managed and easier to be compromised
- Need to access control for BYOD clients

“Context-aware” policies for BYOD



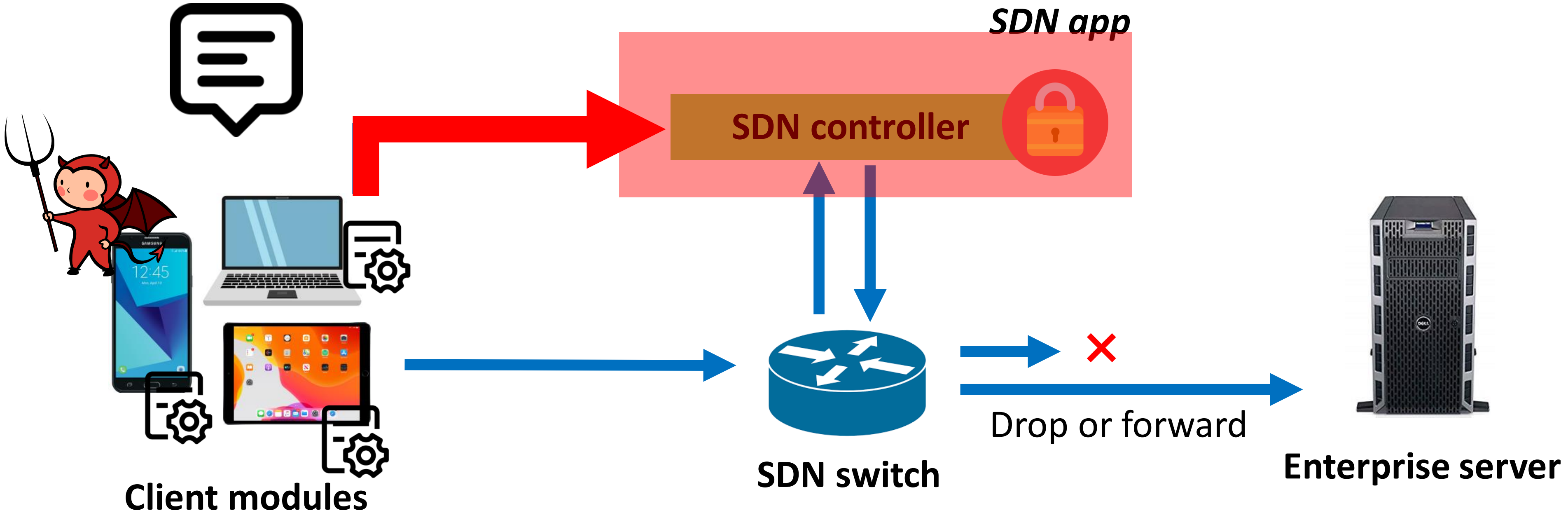
- Making precise security decisions by dynamically adapting to security contexts
- How to enforce these policies?

State of the art: SDN-based defense



- Client modules collect client-side information
- BYOD policies are managed and enforced in an SDN “app”

Limitations of the SDN-based defense

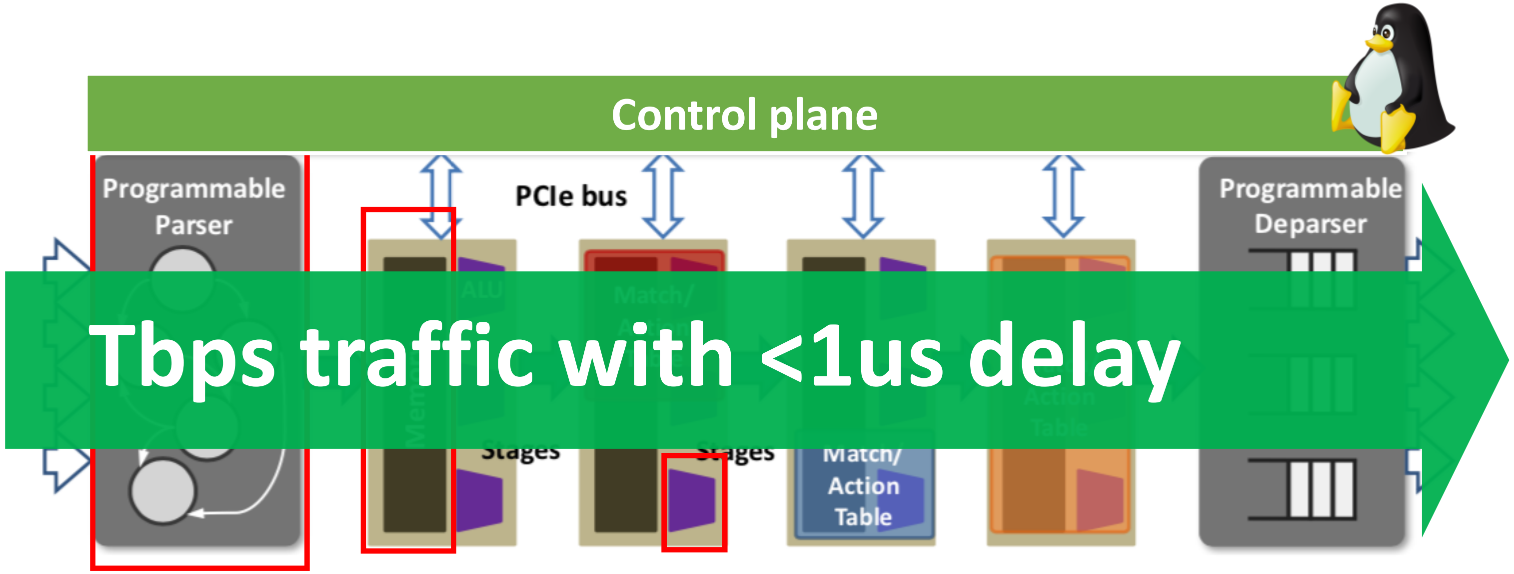


- Low defense agility: Context updates need to traverse the software controller
- Vulnerable to control plane DoS attacks [AvantGuard - CCS'13]
- Root cause: Lower processing speed of the SDN controller software

Research question

Can we address the limitations of SDN-based BYOD defense?

Opportunity: Programmable data planes



- Switch features:
  - Programmable parser: Customized protocols
  - Stateful processing
  - Arithmetic operations
  - General-purpose control plane
- High performance : <1us delay for Tbps traffic
- Can we transform these hardware features to security benefits for BYOD?

P4: Language for data plane programming

Customized headers

```
header myTunnel_t {
    bit<16> proto_id;
    bit<16> dst_id;
}

struct headers {
    ethernet_t    ethernet;
    myTunnel_t    myTunnel;
    ipv4_t        ipv4;
}
```

Match/action processing

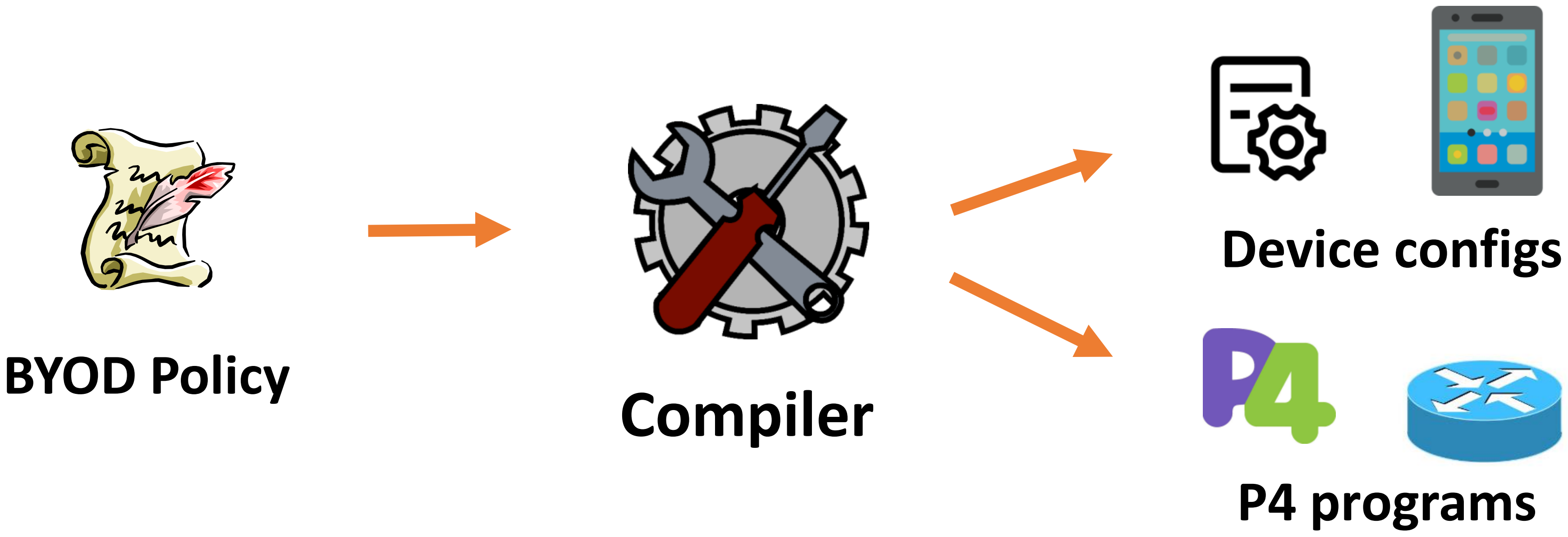
```
table ipv4_lpm {
    key = {
        hdr.ipv4.dstAddr: lpm;
    }
    actions = {
        ipv4_forward;
        drop;
        NoAction;
    }
    size = 1024;
    default_action = NoAction();
}
```

Stateful registers

```
// count the number of bytes seen since the last probe
register<bit<32>>(MAX_PORTS) byte_cnt_reg;
// remember the time of the last probe
register<time_t>(MAX_PORTS) last_time_reg;
```

- Reconfigures switch pipeline for header manipulation
- Has the potential to enforce BYOD policies at linespeed
- Downside: P4 is low-level, non-trivial to develop and maintain

Poise: Programmable In-network Security



- **Language**: An expressive language for defining BYOD policies
- **Compiler**: Generates device configurations and switch programs
- **P4 data plane design**: A dynamic and efficient security primitive

Outline

- Motivation
- Poise Design
  - The Poise language
  - Compiling Poise policies
  - Data plane design
- Evaluation
- Conclusion

The Poise language

Primitive Actions

A ::= drop | fwd(port) | flood | log

Expressions

E ::= v | $e_1 + e_2$ | $e_1 - e_2$ | $e_1 * e_2$ | M

Constant Lists

L ::= nil | v, L

Predicates

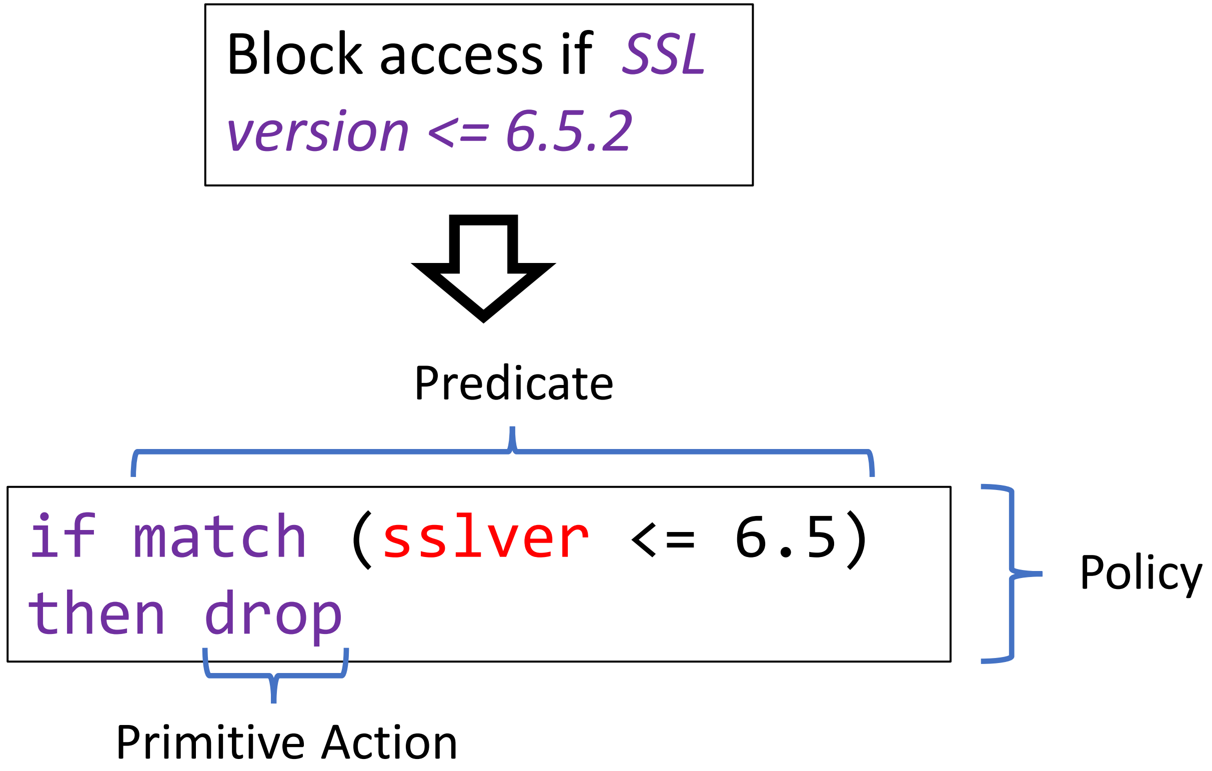
P ::= match($e_1 \circ e_2$) | match($h \circ e$) | match(h in l) | P&P | (P|P) | !P

Monitors

M ::= count(P)

Policies

C ::= A | if P then C else C | (C|C)



- An expressive language for writing context-aware policies
  - Predicates on customized client contexts
  - Support pre-defined primitive actions

Compiling Poise policies

```
if match (sslver <= 6.5)
then drop
```

```
header ctx_t {
  sslver: 16
}
```

```
table decision_tab
{
   key = {ctx.sslver: exact}

   entries = {
      <= 6.5.0: dec = DROP
      >  6.5.0: dec = ALLOW
   }
}
```

- Contexts (sslver) are compiled to customized header fields
- Security actions (if-else) are compiled to match/action table entries
- Advanced features: Policy composition, resource optimizations, etc

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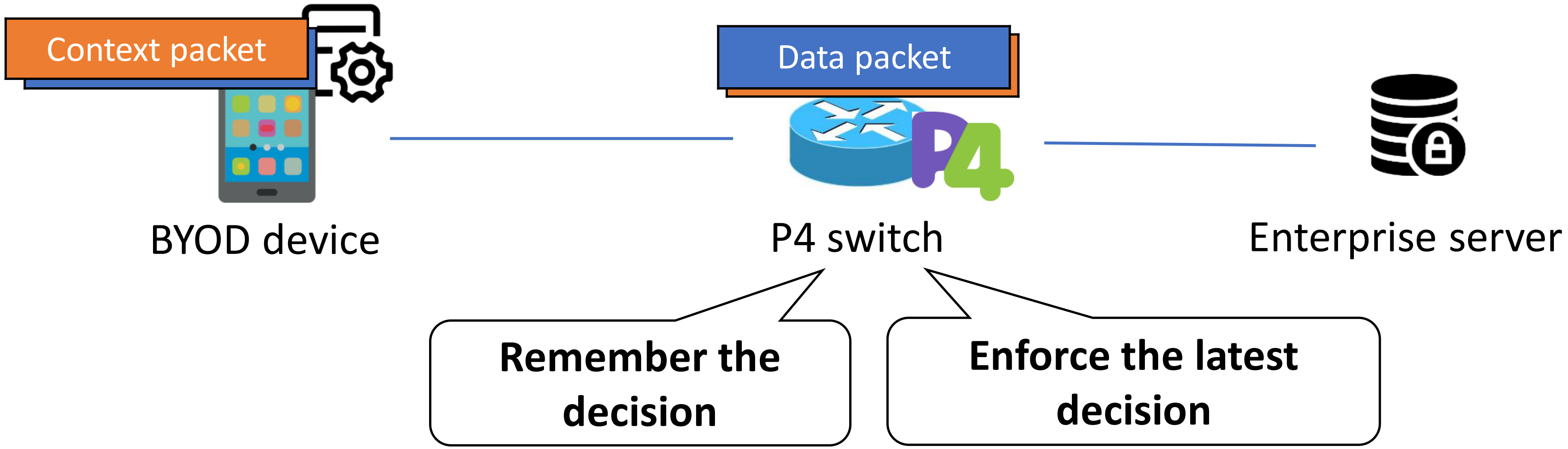
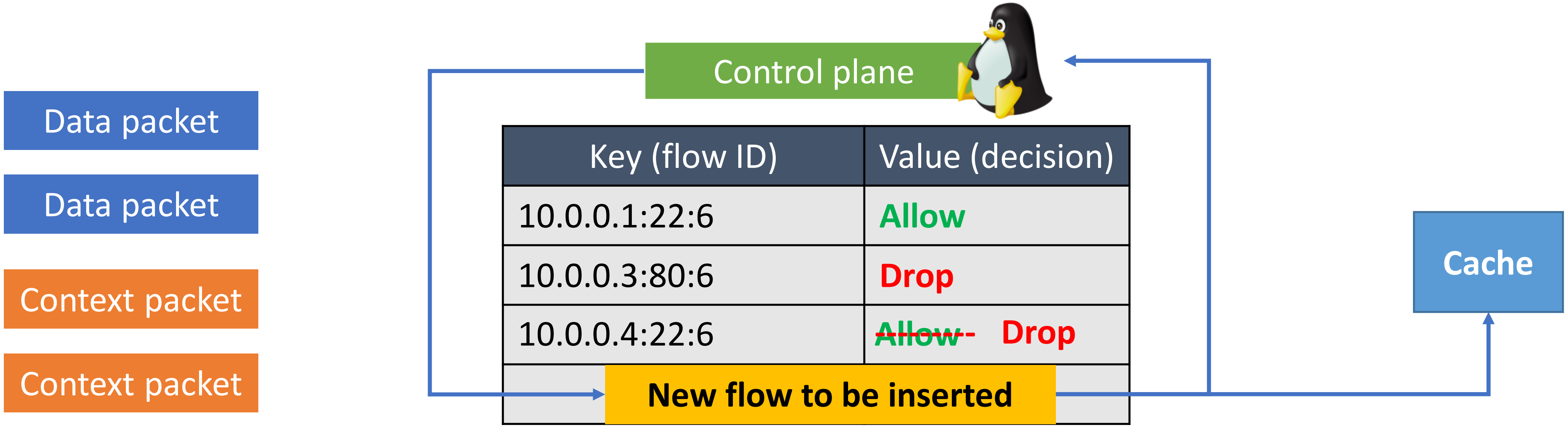
An efficient in-network primitive



- **Problem**: How to spread context information from client to switch?
  - Strawman solution: Tag every packet with context -- high overhead!
- **Idea**: Periodic context packets per flow: Headers + context, no data
  - **Dynamic**: Decisions are based on the latest context
  - **Efficient**: Data packets unmodified (no embedded contexts)
  - **Adjustable accuracy**: Tunable context packet period

Key data structure: A per-flow table



Per-flow table

- A match/action table to maintain the latest per-flow decision
- Technical challenges:
  - New flow insertion delay (~1ms)
  - Controlling the size of the table
  - Handling DoS attacks (e.g., many new flows)

See more details in our paper!

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Evaluation setup

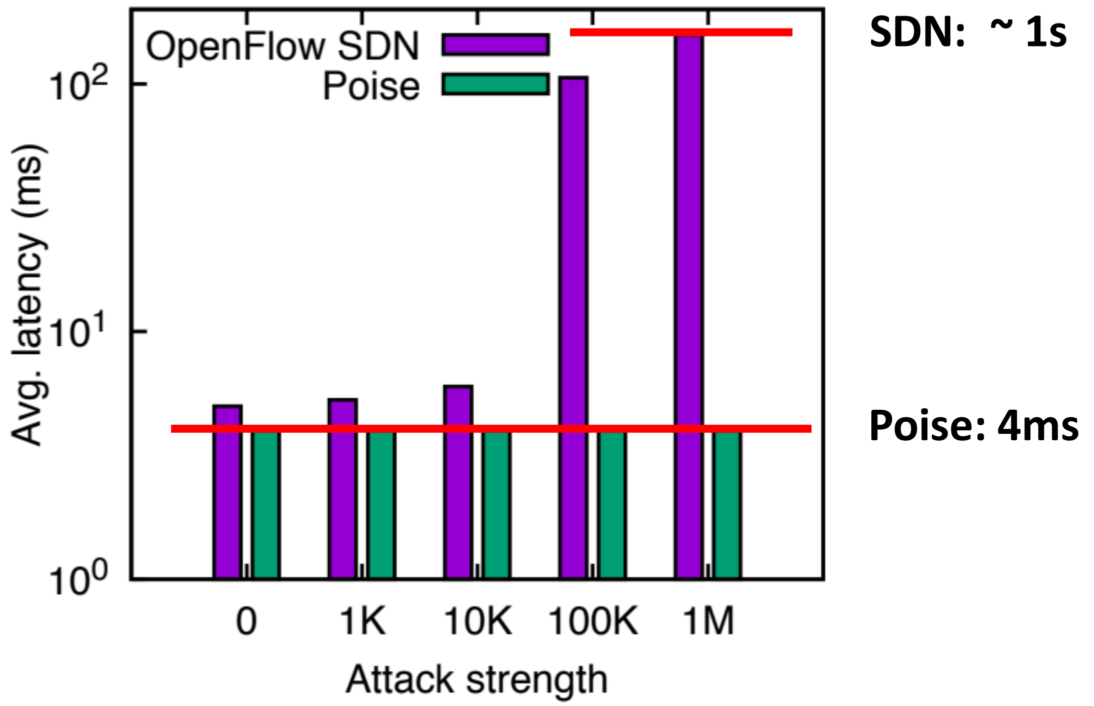
- Prototype implementation
  - Compiler: Bison + Flex
  - Android client module: a kernel module on Linux 3.18.31
  - ~6000 LoC
- Evaluation setup
  - Tofino Wedge 100BF switch 32 X 100 Gbps = 3.2 Tbps

What we have evaluated

- **Correctness**: Can Poise enforce BYOD policies correctly?
- **Overhead**: How much delay or throughput degradation can Poise incur?
- **Scalability**: How complex/large policies can Poise support?
- ✓ **Poise vs. SDN**: Is Poise resilient to control plane saturation attacks?

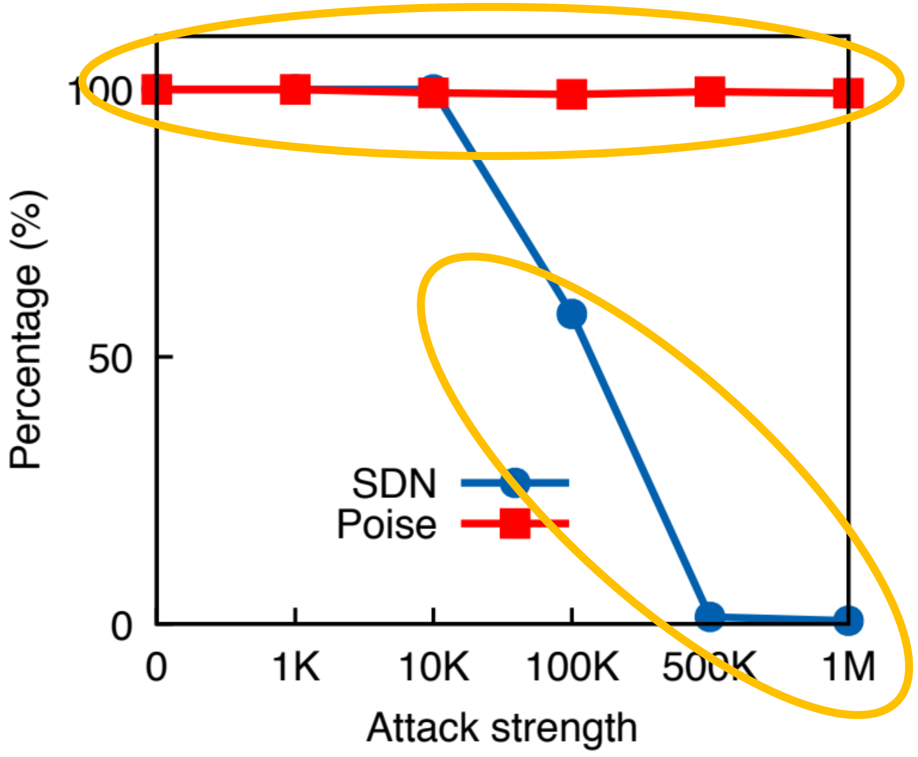
- SDN-based solution: PBS – NDSS’16
  - Floodlight v1.2 + Open vSwitch v2.9.2
- Methodology:
  - DoS attacker: Launch frequent context changes
  - Measure how normal user traffic are affected

Poise vs. SDN: First packet delay



- SDN: Takes ~1 second for the first packet to arrive under heavy attacks
- Poise: Remains at a constant level

Poise vs. SDN: New flow installation



Poise: Installs new flows normally

SDN: Cannot install new flows

- SDN: Fails to install new flows under heavy attacks
- Poise: Almost always installs 100% new flows
- Poise is highly resilient to DoS attacks from malicious clients

Conclusion

- Motivation
  - SDN-based BYOD defense has limitations
- Poise: Programmable In-Network Security
  - An expressive policy language
  - Compiler for generating P4 programs
  - An efficient in-network security primitive
- Poise transforms the hardware features to security benefits

Thank you for listening!

Contact: qiaokang@rice.edu – Looking for 2021 summer internship
https://github.com/qiaokang92/poise