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Introducing Hardware Content Inspection Accelerator Into the Network Security Applications

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Agenda

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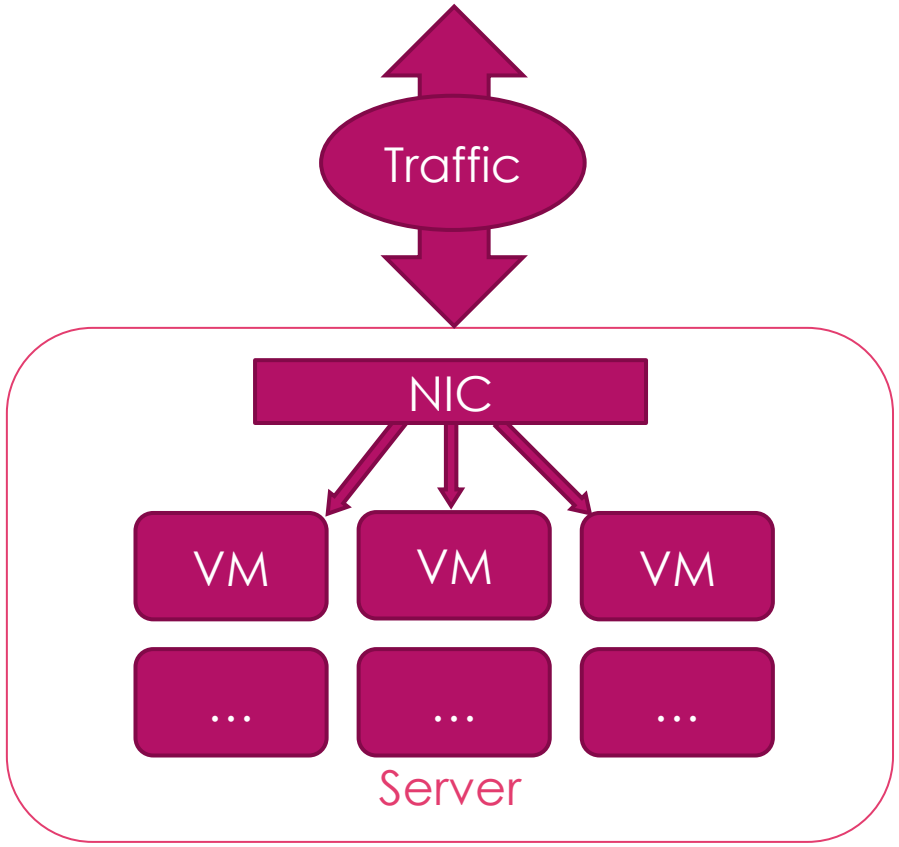
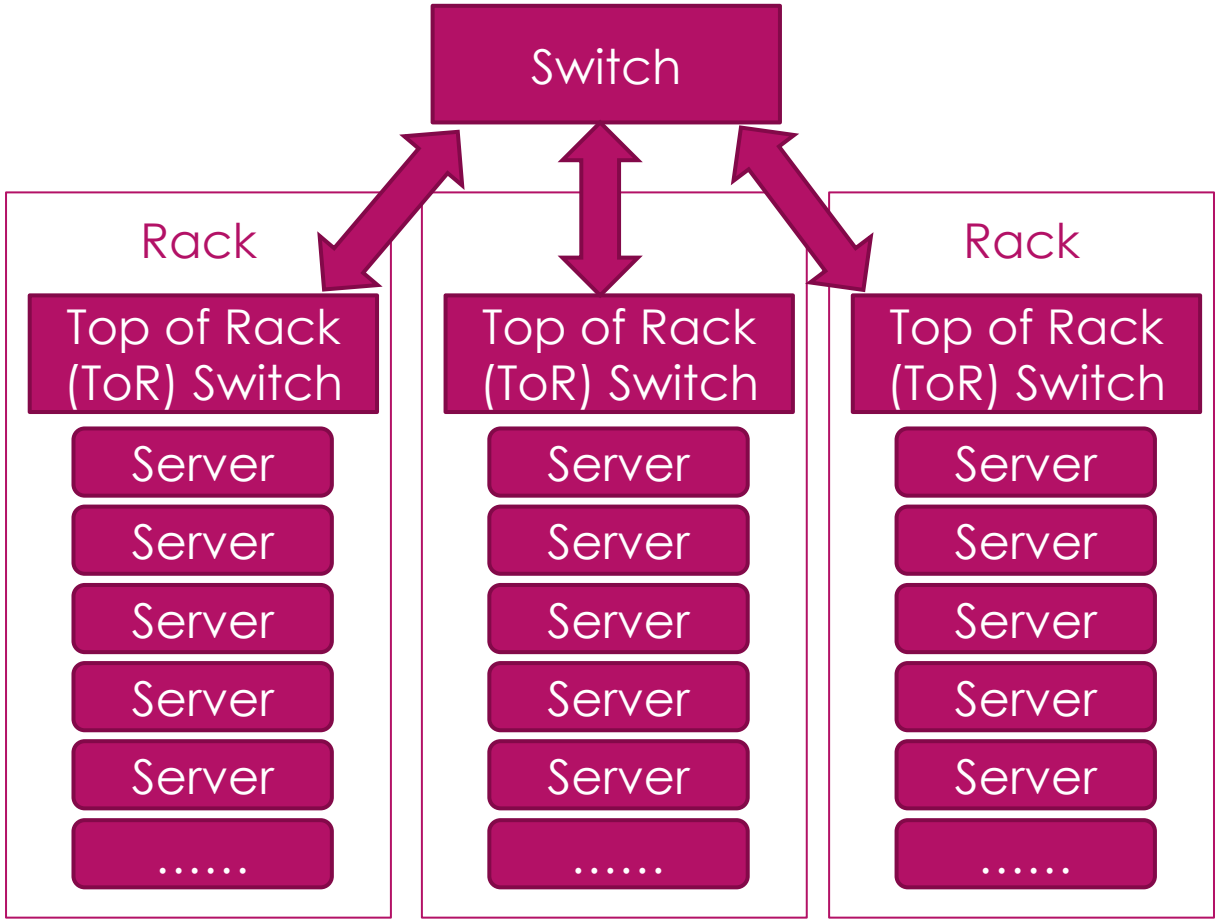
- Introduction
- Background
- Problem
- Challenge
- Solution
- Acknowledgement
- Reference & QA

Introduction

- Content Inspection
  - Literal Matching
    - Regular Expression (Regex)
- Regex Matching
  - "ARGS_NAMES:/^video\[[0-9]*\]\[\]/"
    - Searching video ID only composed by number
- High Performance Regex Matching
  - Software-based
  - Hardware-based
- Hardware Accelerator
  - NIC/Switch
    - Load balance
    - Flow director
    - …
  - …
- Network Security
  - Firewall
    - Web Application Firewall (WAF)
    - …
  - Network Intrusion System (IDS)
    - Deep Packet Inspection (DPI)
    - …

Background


Traffic
NIC
VM
VM
VM
...
...
...
Server


Switch
Rack
Top of Rack (ToR) Switch
Server
Server
Server
Server
Server
.....
Top of Rack (ToR) Switch
Server
Server
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Server
Server
.....
Rack
Top of Rack (ToR) Switch
Server
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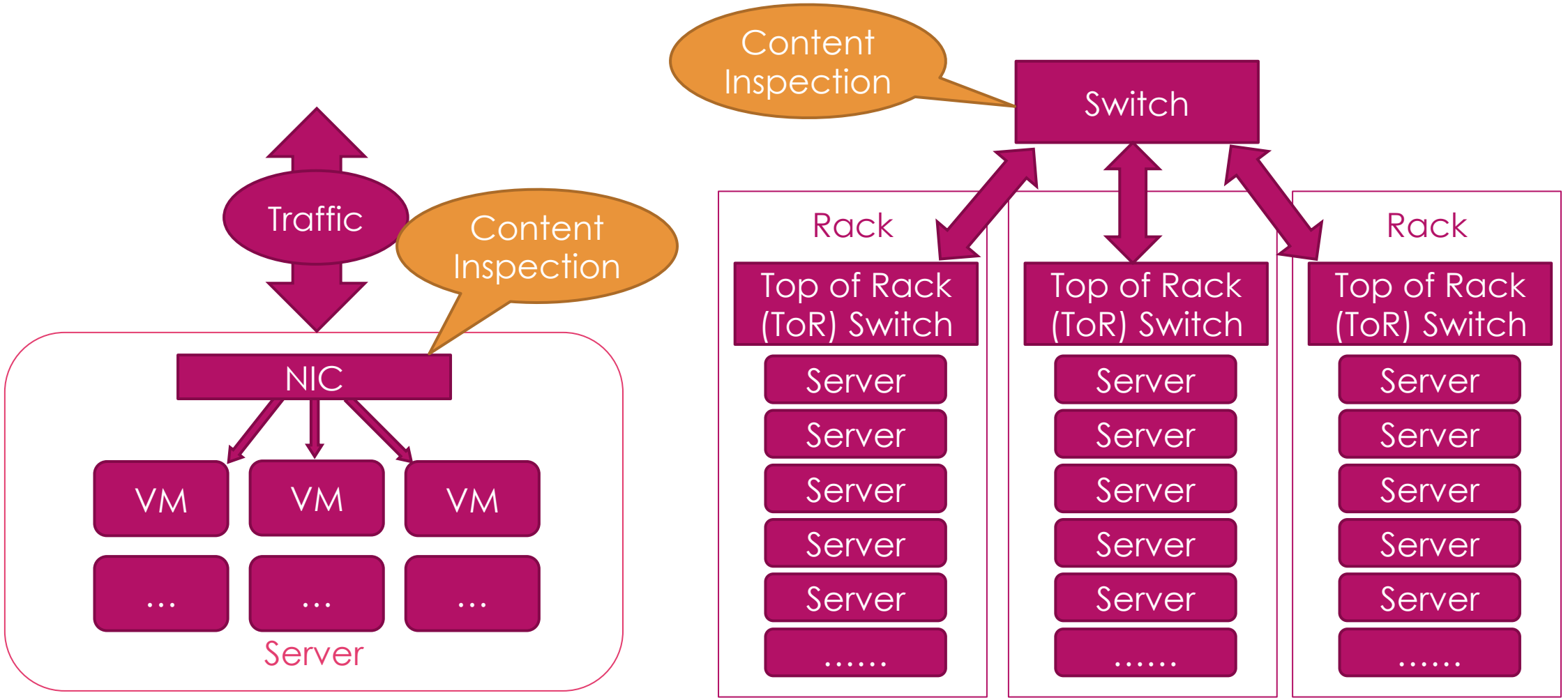
Server
Server
.....

Background


Content Inspection
Switch
Traffic
Content Inspection
NIC
VM
VM
VM
...
...
...
Server
Rack
Top of Rack (ToR) Switch
Server
Server
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Top of Rack (ToR) Switch
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Server
Server
Server
Server
.....

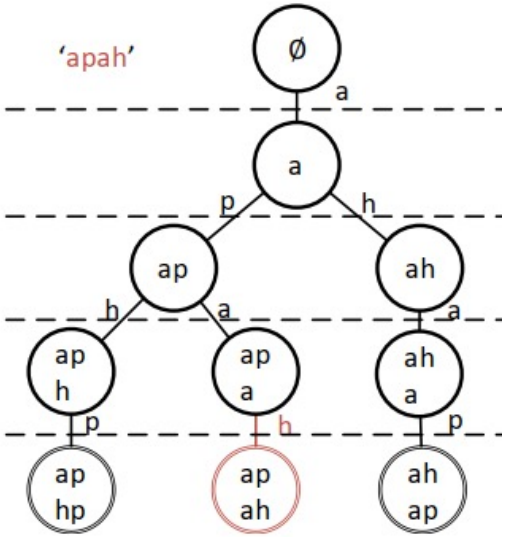
Problem

- Flexibility
  - Software
    - Easy to configurate
  - Hardware
    - FPGA/ASIC-based
      - SmartNIC
      - Configurable Switch
- Performance
  - Software
    - Hyperscan
  - Hardware
    - One order of magnitude (or two) larger than software
- CPU
  - Paying the levitation cost
    - Get data off the NIC through PCI-Express
- GPU/FPGA Acceleration[1,2]
  - Cannot catch up with the dramatic increase of the network traffic (e.g., multi-100s of Gbps) [3]
- PISA
  - Protocol Independent Switch Architecture
    - Tofino

Challenge

- Tofino
  - Programmable Switch[4]
  - SmartNIC[5]
  - …
- Protocol Independent
  - Match anything in any offset of the packet
    - Self-defined protocol
    - Traffic monitoring
    - …
- Content Inspection?

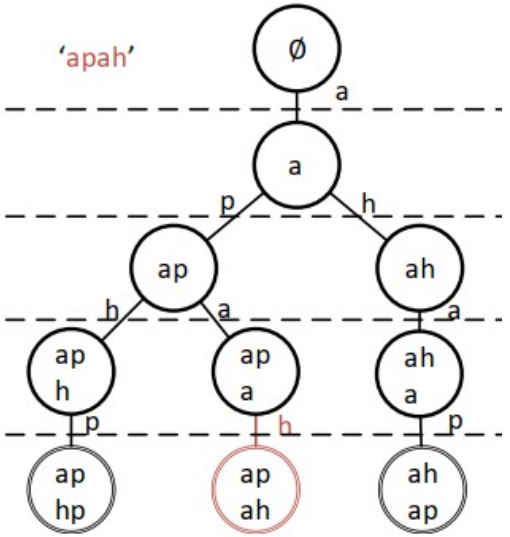
- State Machine
  - Deterministic finite automaton (DFA)



Challenge

- Regex → DFA
  - Regex Compiler
- Intel Hyperscan
  - High performance regex engine
  - Compiler (Regex→DFA)
  - Running time (DFA on CPU)
    - Optimized for CPU

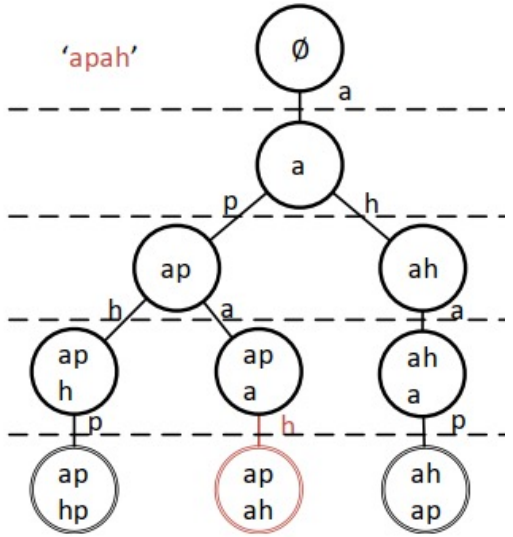
- State Machine
  - Deterministic finite automaton (DFA)



Challenge

- Regex → DFA
  - Regex Compiler
- Intel Hyperscan
  - High performance regex engine
  - Compiler (Regex→DFA)
  - ~~Running time (DFA on CPU)~~
    - ~~Optimized for CPU~~
- DFA→PISA (DFA on Tofino)
  - Limited Memory
    - Several hundred MB

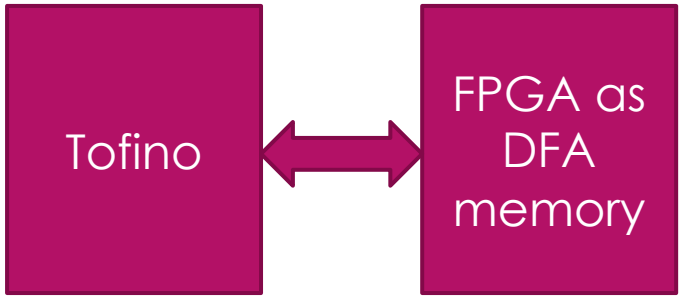
- State Machine
  - Deterministic finite automaton (DFA)



Solution

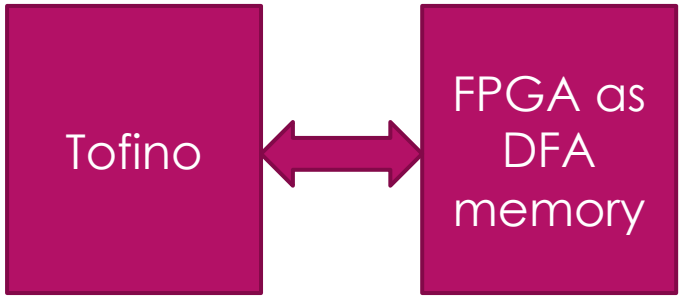
- **Hardware**
- FPGA-based Extended Memory

server-other	string	2118	100%	100%	86837	44460544	EMEM
emerging-trojans	string	9608	100%	100%	412676	211290112	EMEM
emerging-trojans	regex	1496	30%	96%	742765	380295680	EMEM
server-mail	regex	93	91%	95%	3642492	1864955904	EMEM
emerging-pop3	regex	16	100%	100%	34524	17676288	EMEM
community all	string	134	100%	100%	3464	1773568	IMEM
emerging threats all	string	5546	100%	100%	243857	124854784	EMEM
community all	regex	546	54%	84%	3631070	1859107840	EMEM
emerging threats all	regex	5159	32%	90%	2121305	1086108160	EMEM



Solution

- **Hardware**
- FPGA-based Extended Memory
  - Utilized in Tofino-based load balance solution
  - Existing→Too large [6]



- **Software**
- Sub-ruleset
  - SQL-injection/Cross-site script
    - Over 70%
  - Tokenization
    - Modsecurity/libinjection
  - **‘ and 1=1**
  - **s & 1 o 1**
  - **(quote) (and) (num) (oper) (num)**
- SQL DFA tokenization states
  - Based on Hyperscan compiler
  - Only 9000+ states
  - (less then 8MB)

Solution

- **Hardware**
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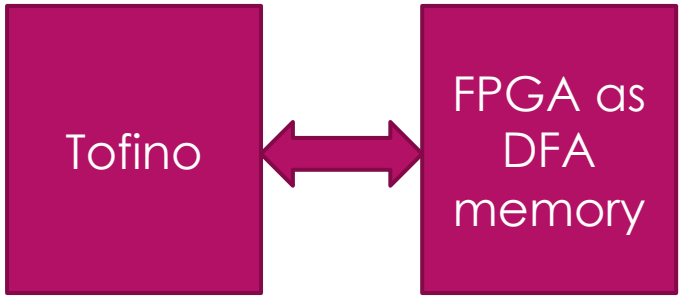
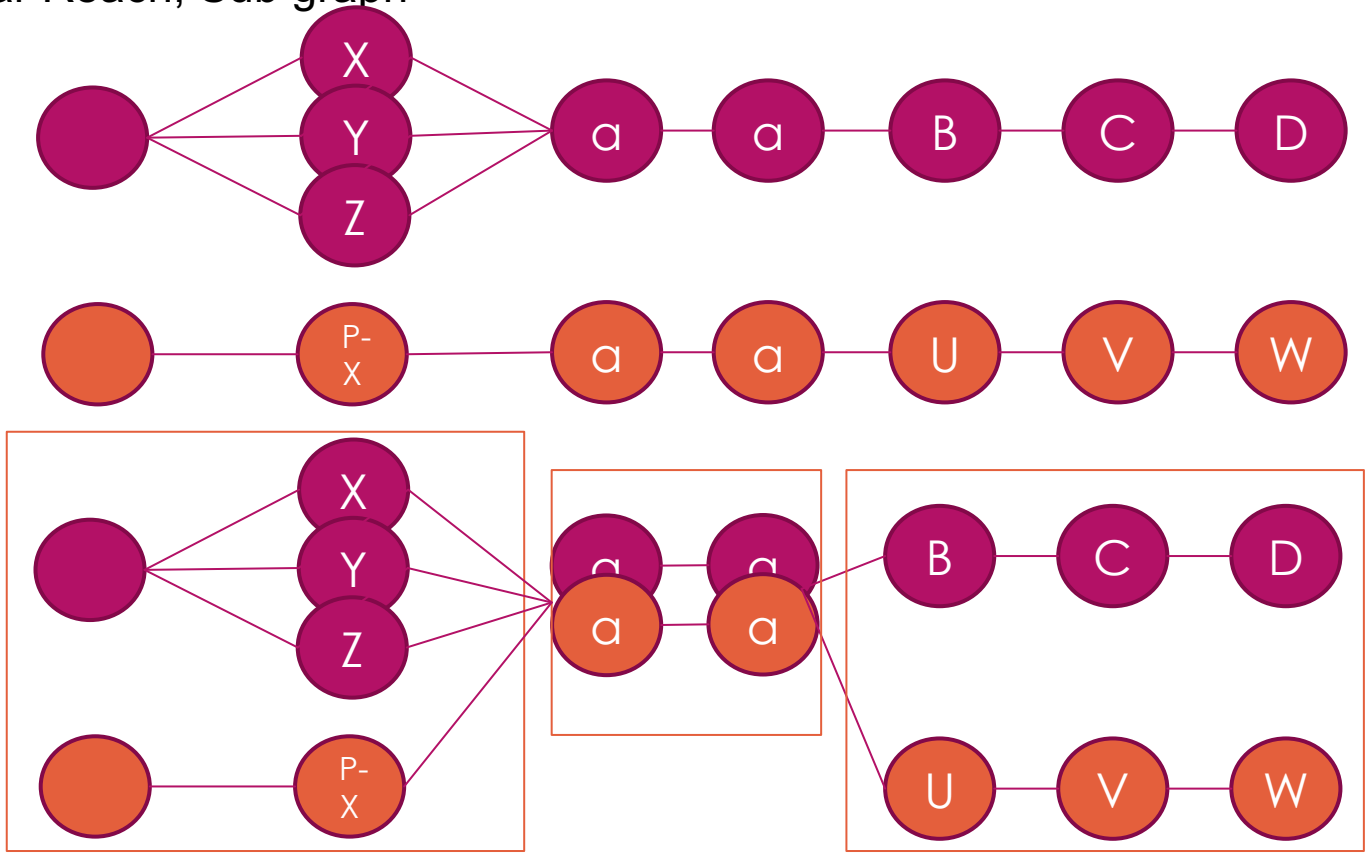


- **Software**
- RuleTailor (WIP)
  - Full snort rule set is too large
  - Decreasing the number of DFA states
    - Longest-prefix-based:
      - abc,abcde,abcfg:A
      - abf,abg:B
      - abc*:A
      - ab*:B
    - Non-prefix-based
      - (X|Y|Z)aaBCD: A
      - (P-X)aaUVW: A
      - *aa*: A
      - Graph-based compression
  - Intel Hyperscan Compile time
    - DFA Compression

Solution

- RuleTailor
  - Innovative from Intel Hyperscan
  - Graph Computation
    - Char Reach, Sub graph



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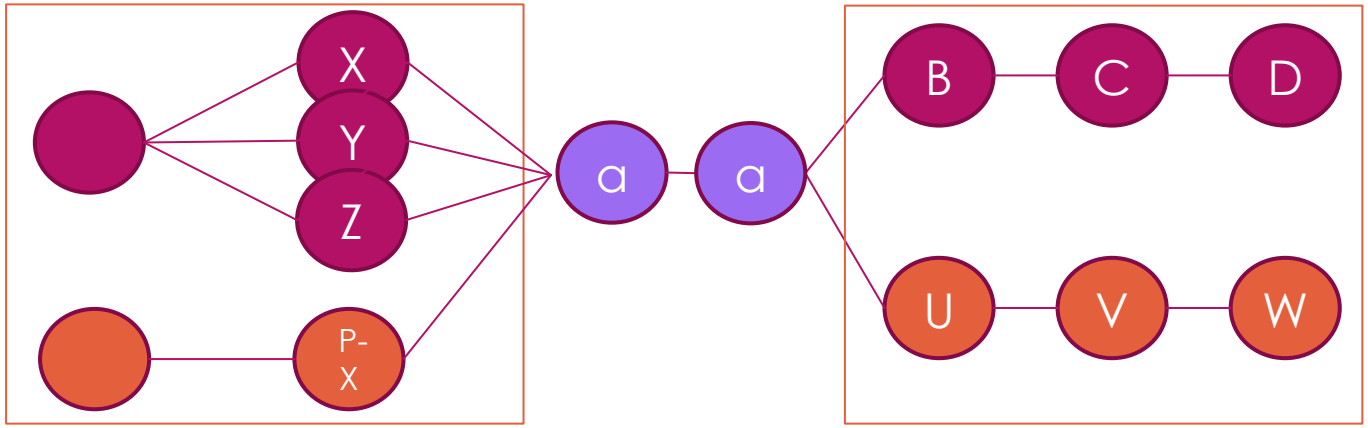

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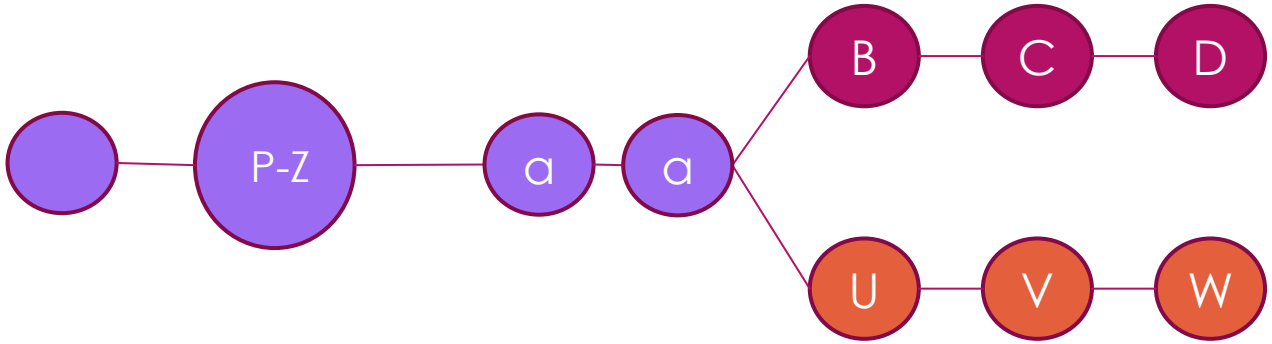
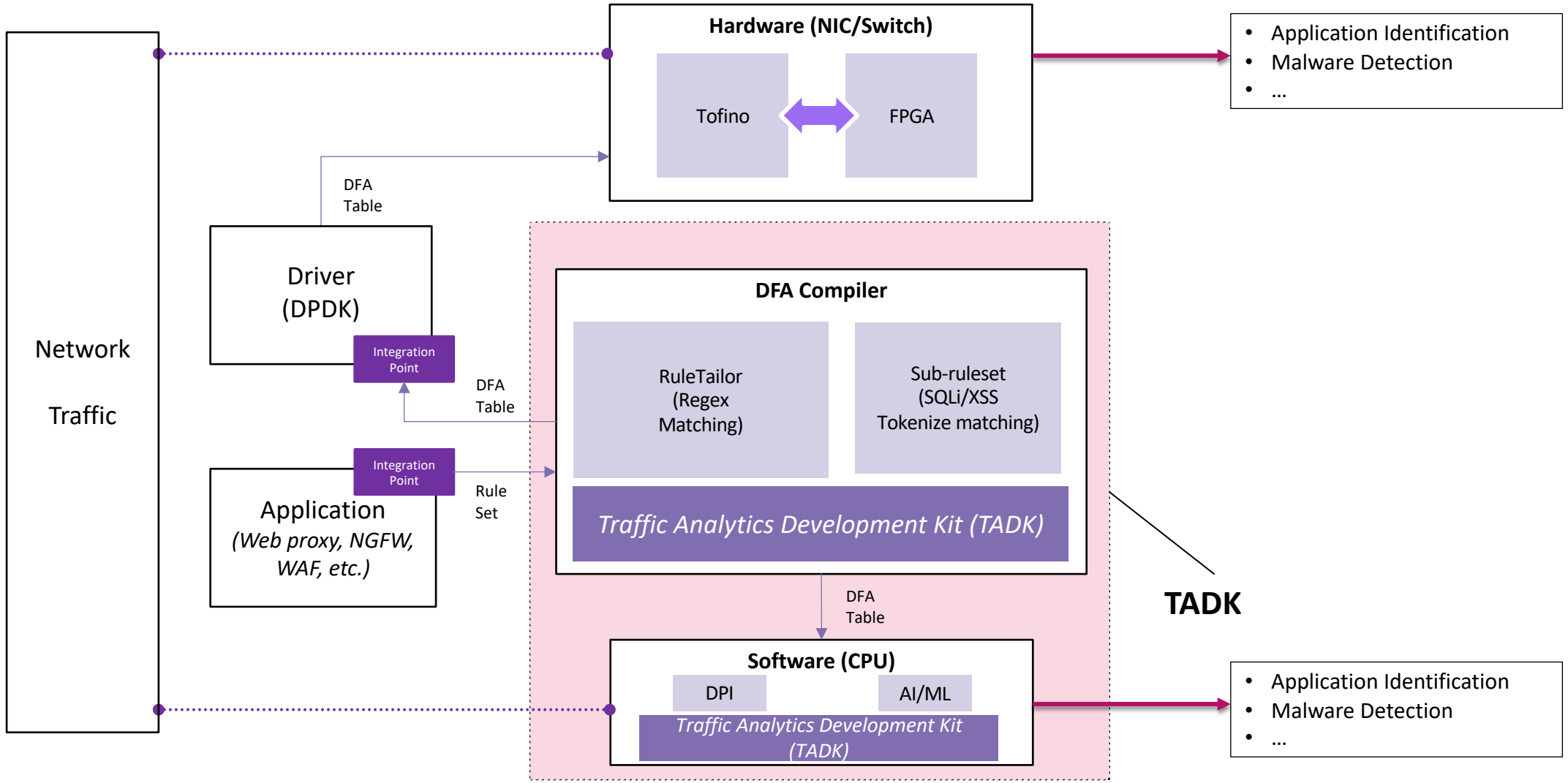


Solution


Hardware (NIC/Switch)
Tofino
FPGA
Application Identification
Malware Detection
…
DFA Table
Driver (DPDK)
Integration Point
Network Traffic
DFA Compiler
RuleTailor (Regex Matching)
Sub-ruleset (SQLi/XSS Tokenize matching)
Traffic Analytics Development Kit (TADK)
DFA Table
Integration Point
Application (Web proxy, NGFW, WAF, etc.)
Rule Set
TADK
DFA Table
Software (CPU)
DPI
AI/ML
Traffic Analytics Development Kit (TADK)
Application Identification
Malware Detection
…

Acknowledgement

- Network Application Team
  - Ying Wang, Wenjun Zhu, Xiahui Yu, Chenmin Sun,
- Hongjun Ni, Xiang Wang, Weigang Li, Baoqian Li, Haitao Kang
- Intel Barefoot Team
  - Robert Soule, Changhoon Kim

Reference & QA

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