Redundant Logic Elimination in Network Functions

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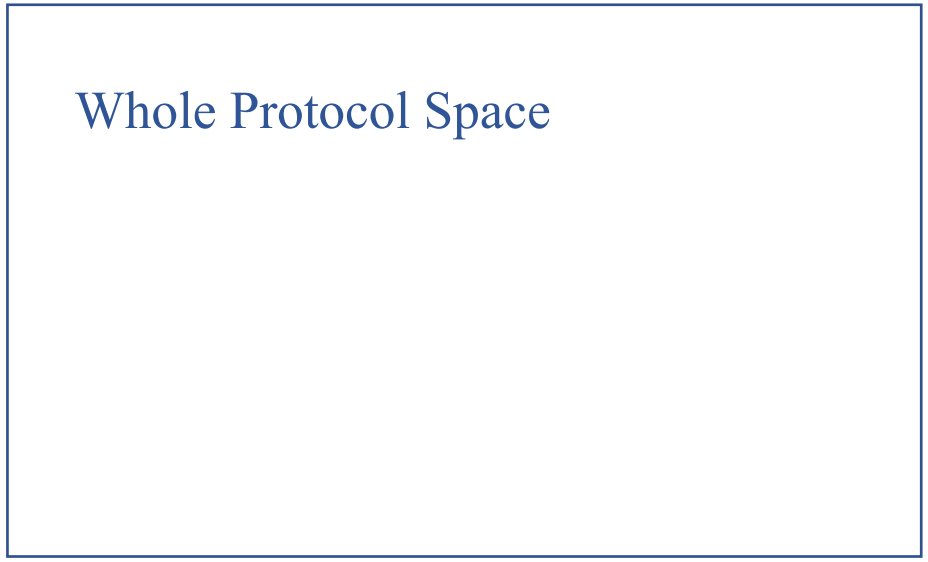
Network Functions: Critical components in network

- Growing impact:
  - Various network scenarios
  - Diverse functions (e.g. , Firewall, NAT, IDS, Load Balancer)

- NF's efficiency in flow processing is critical:
  - Affects network's end-to-end performance in a significant way (e.g., latency accumulation, throughput bottleneck)

Network Functions: Critical components in network

- Mismatch of the protocol space in the development and that in the deployment leads to redundant logic:
  - Covering a large protocol space in development
  - Configuring a subspace of the entire protocol space in deployment



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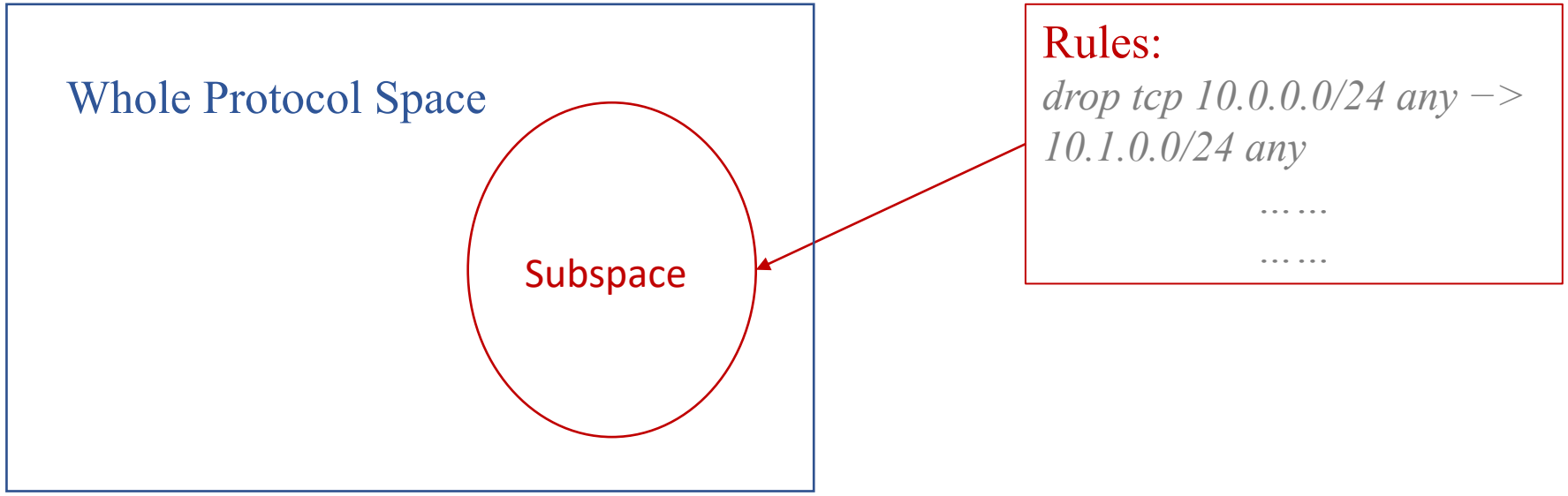

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Goal:

To use compiler techniques to optimize away the redundancy.

Outline

- *Introduction*
- Design Intuition
- NFReducer Implementation
- Preliminary Evaluation
- Conclusion

Snort IDS Code(Simplified)

```
1  /* One example Snort rule:
2  drop tcp 10.0.0.0/24 any -> 10.1.0.0/24 any
3  */
4  struct {
5      unsigned long sip, dip;
6      unsigned short sport, dport;
7      ...
8  } net;
9  void main() {
10     LoadRules();
11     while(1) {
12         pkt = ... // get a packet
13         DecodeEthPkt(pkt); // decode a packet
14         ApplyRules(); // match rules
15 } }
16 void DecodeEthPkt(u_char *pkt) {
17     DecodeIPPkt(pkt);
18 }
19 void DecodeIPPkt(u_char *pkt) {
20     net.dip = ...
21     net.sip = ...
22     net.protocol = ...
23     log(net.sip, net.dip, net.protocol);
24     if (net.protocol == TCP)
25         DecodeTCPPkt(pkt);
26     else if(net.protocol == UDP)
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Parsing

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Parsing → Match

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Parsing → Match → Action

Type-I Redundancy: Unused layer parsing

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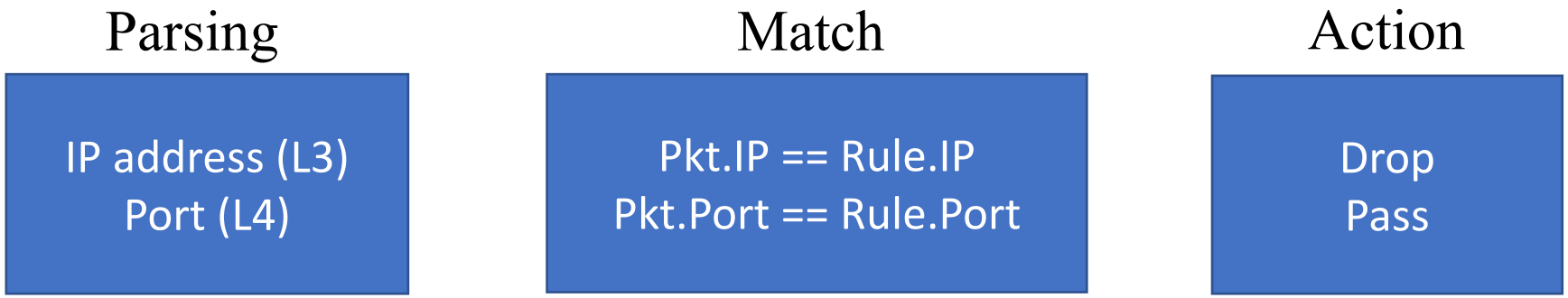

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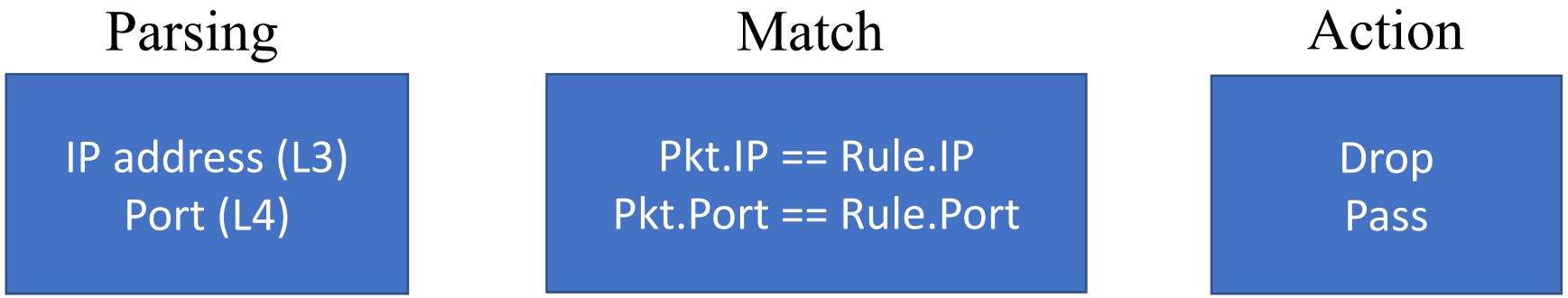

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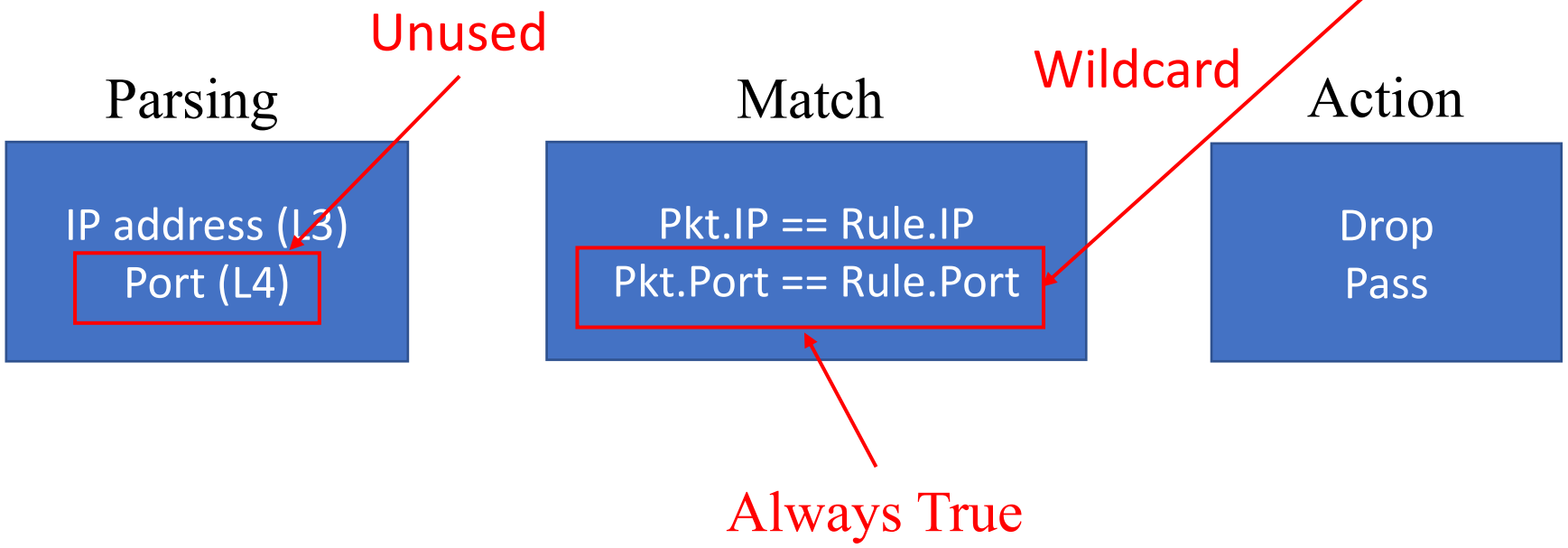

Type-I Redundancy: Method to Solve

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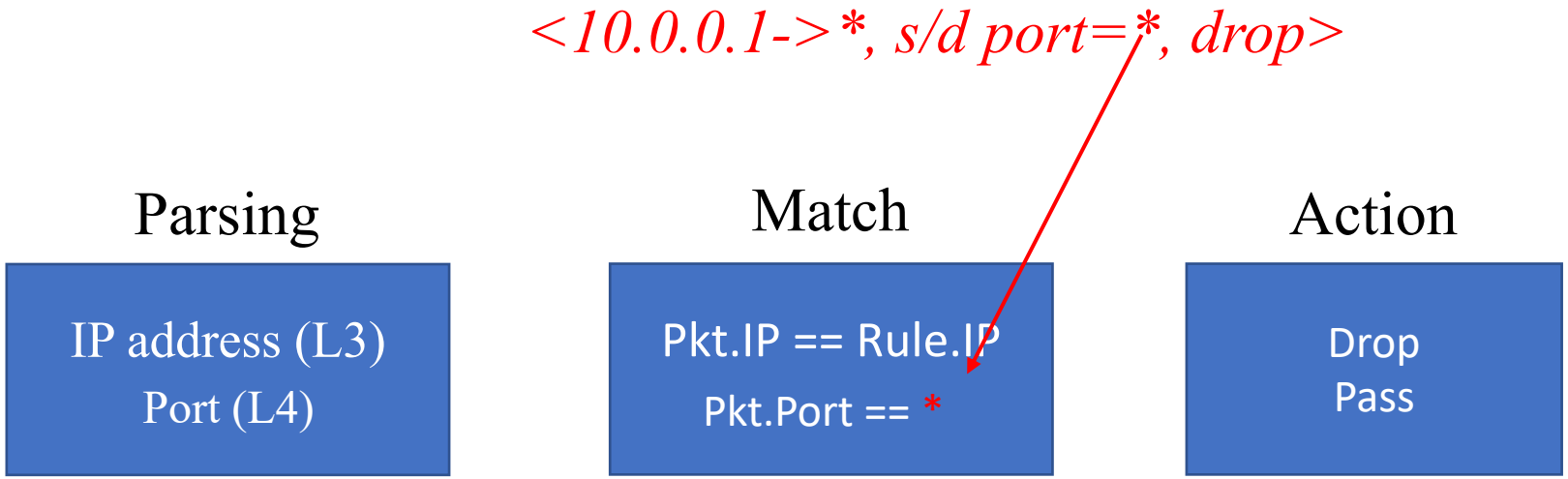

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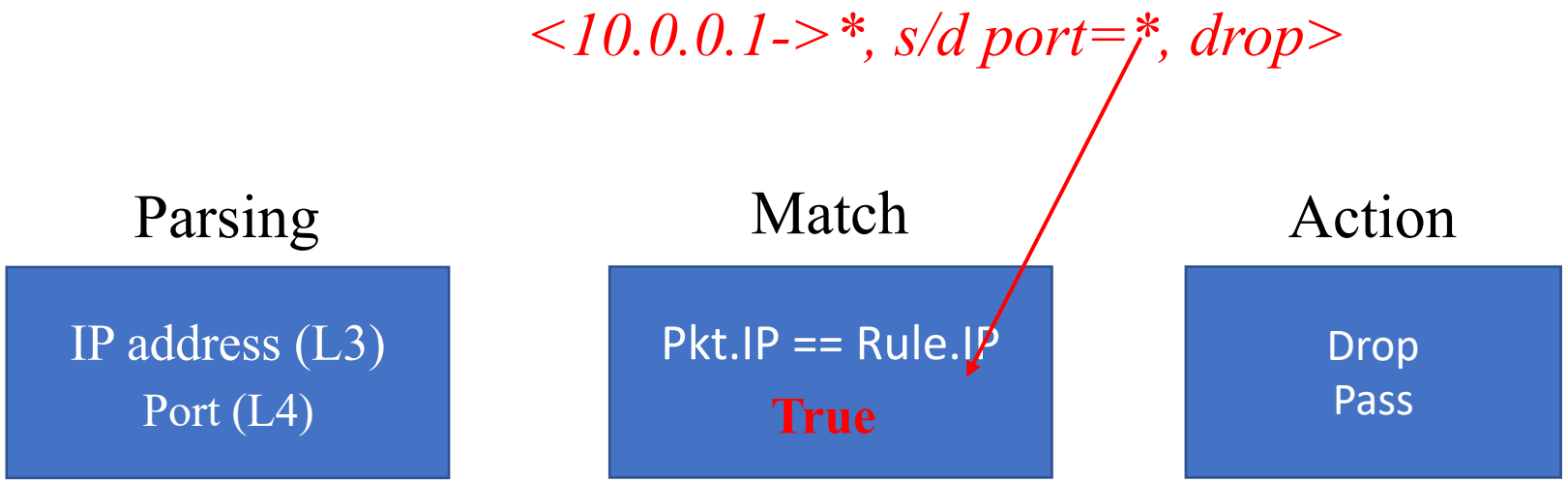

Type-I Redundancy: Method to Solve

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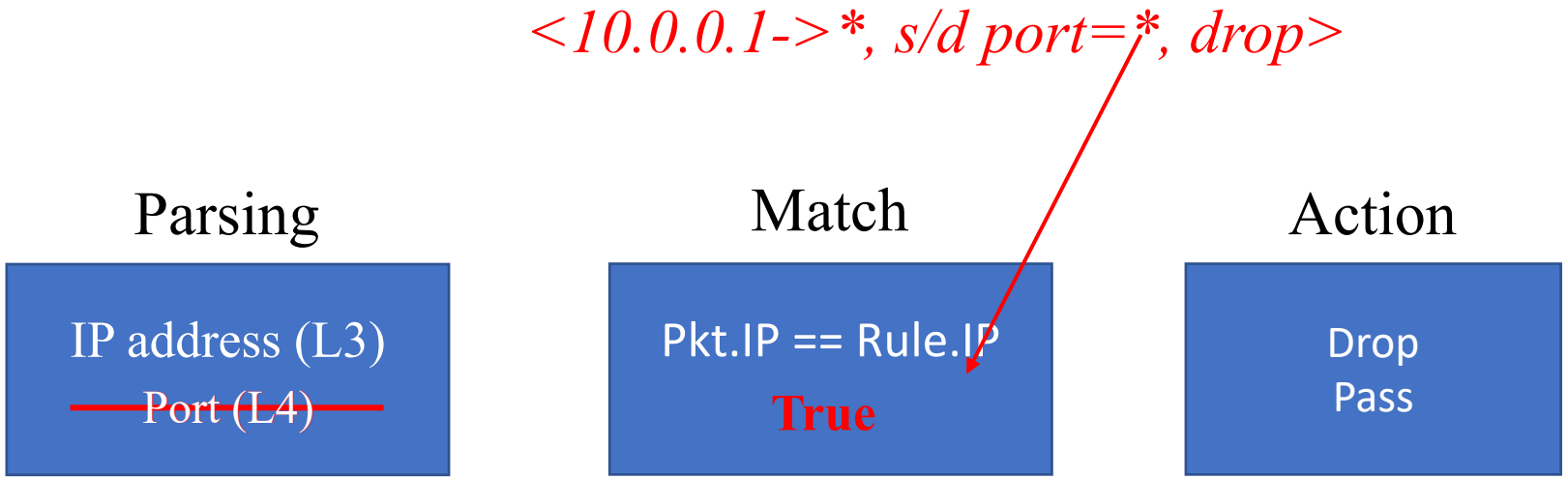
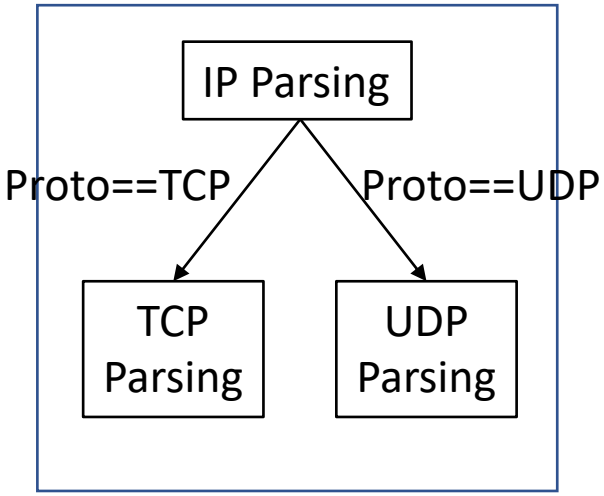


Type-II Redundancy: Unused Protocol (Branch) Parsing

- Branches in Parse and Match

If NF processes TCP packets only, E.g., <10.0.0.0/24, tcp, 80, drop>



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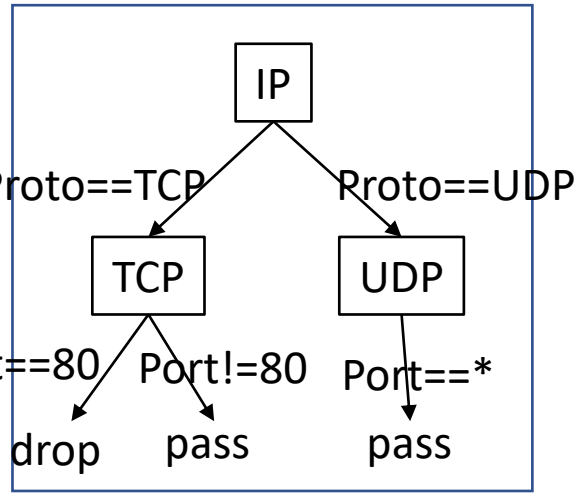

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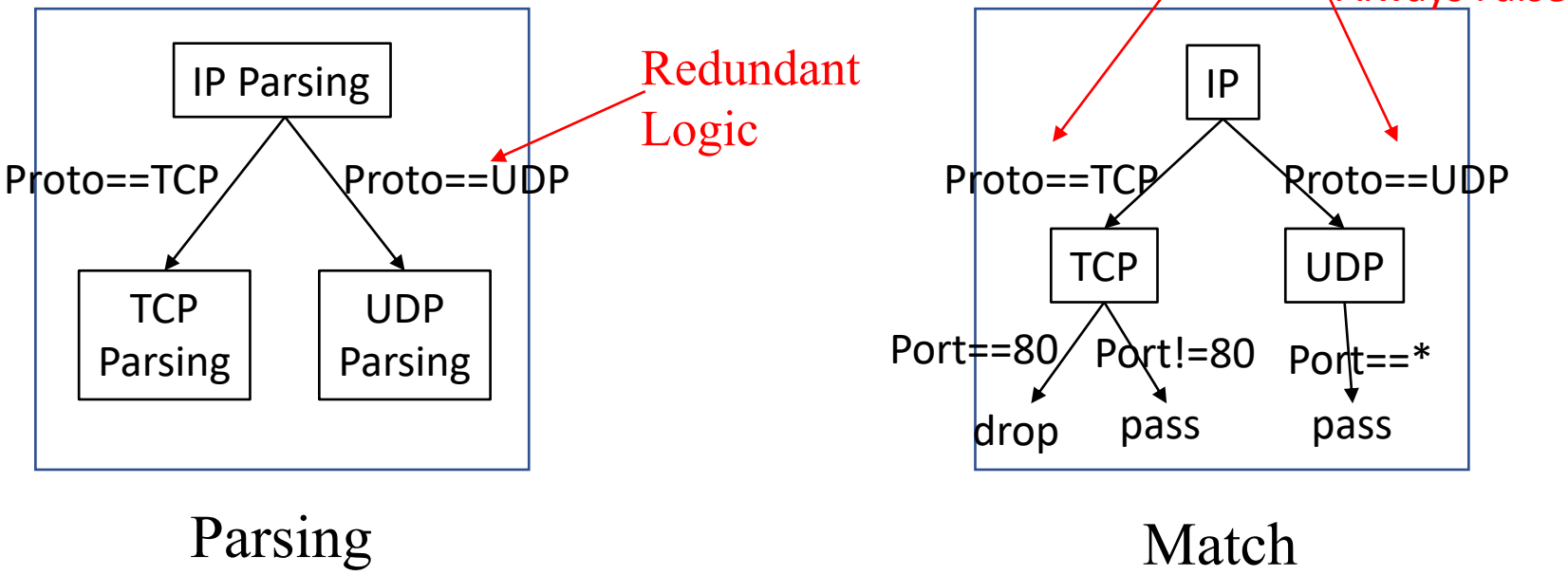

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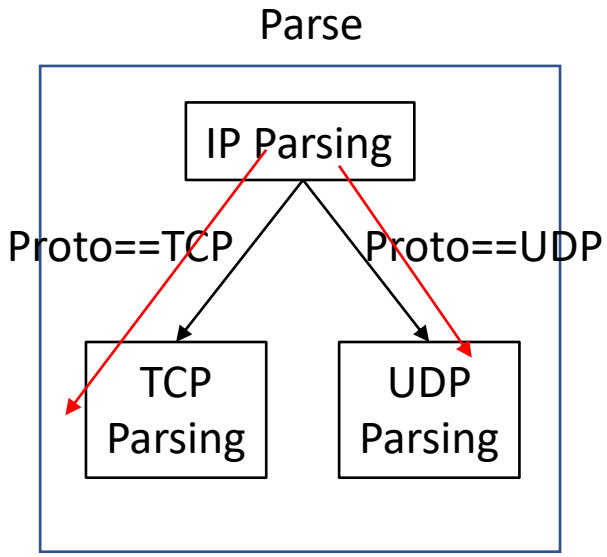

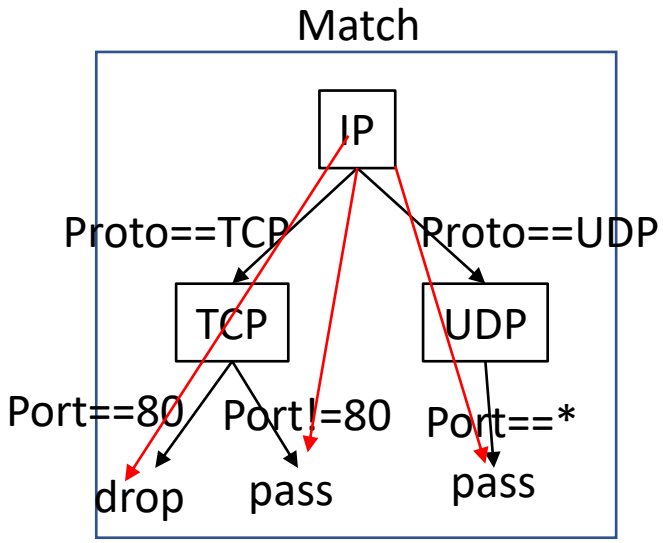

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- Extract Feasible Execution Path
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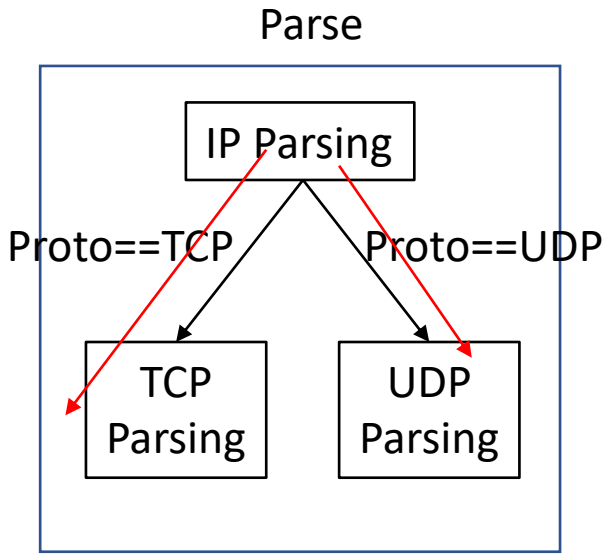

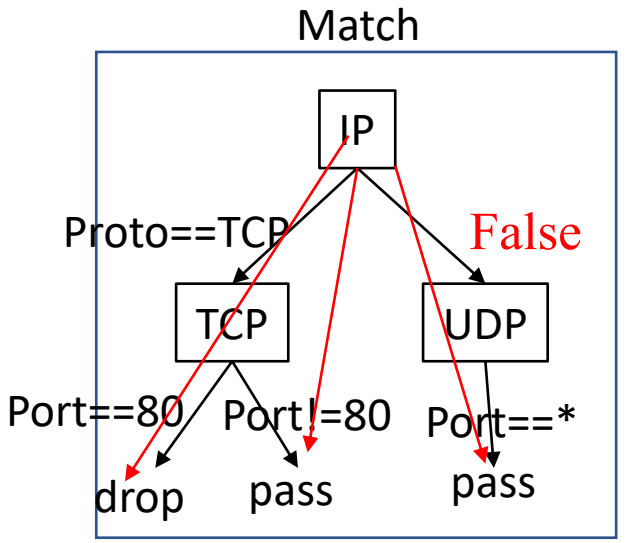

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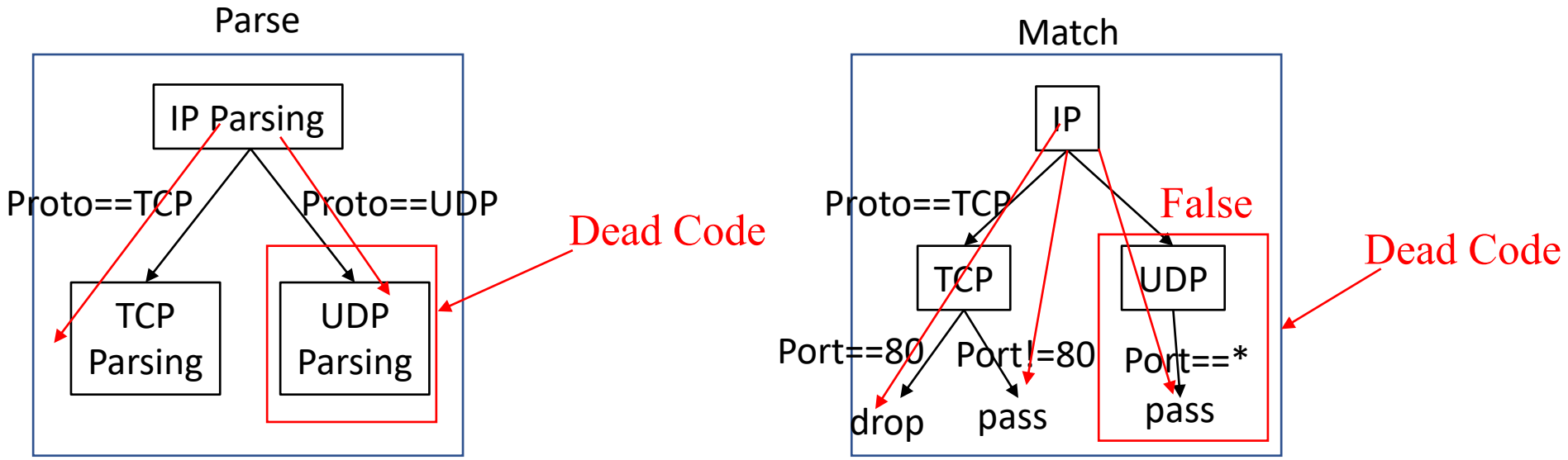

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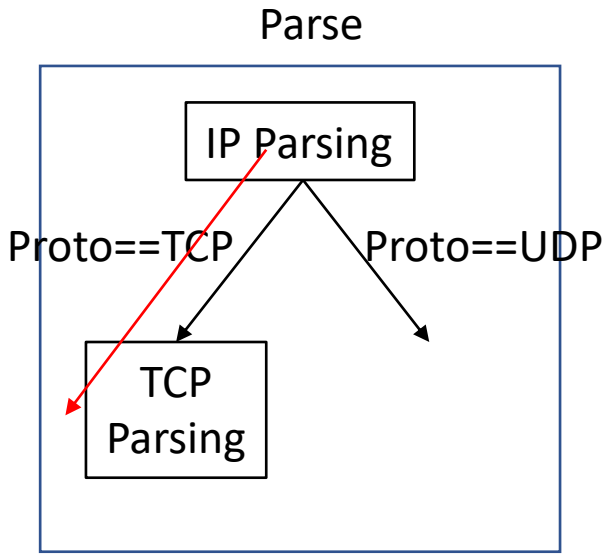
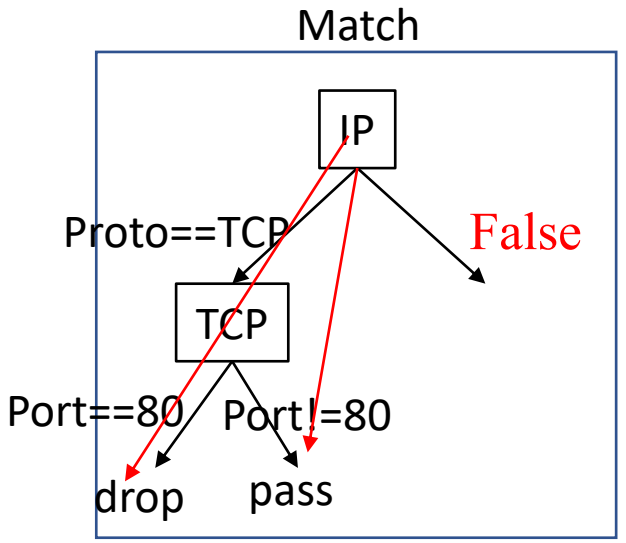
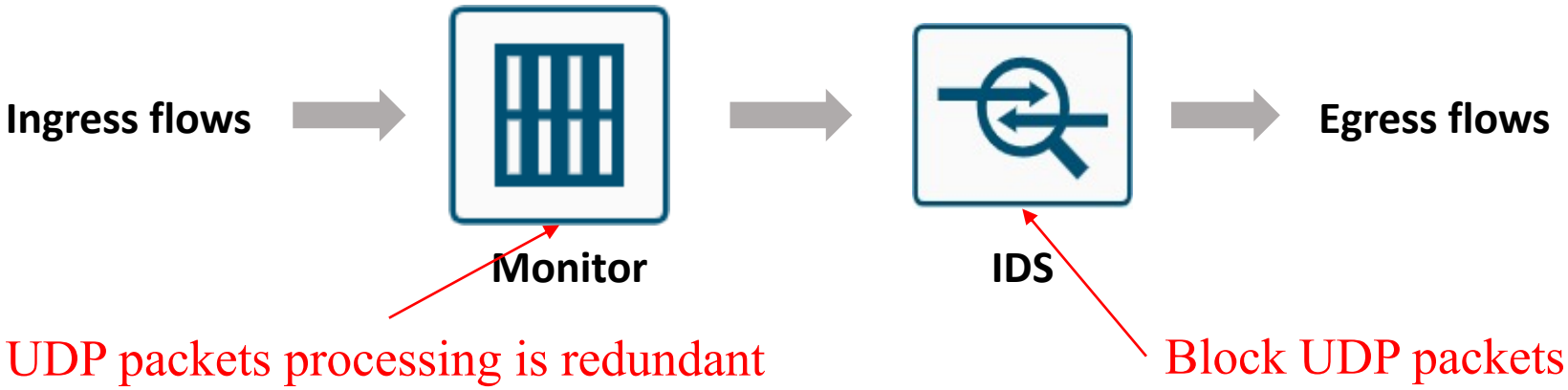




Type-III Redundancy: Cross-NF Redundancy

- If a monitor deployed before an IDS instance who blocks UDP packets, all the parsing and counting for UDP packets in the monitor is redundant.



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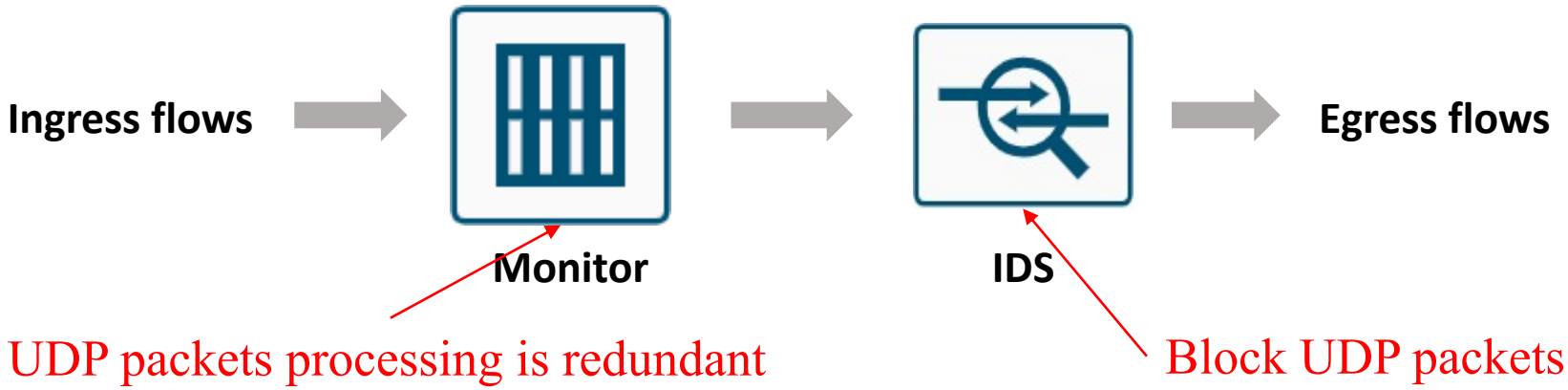

- *Method to Solve:*
  - Consolidate
  - Eliminate *type-I* and *type-II* redundancy
  - Decompose

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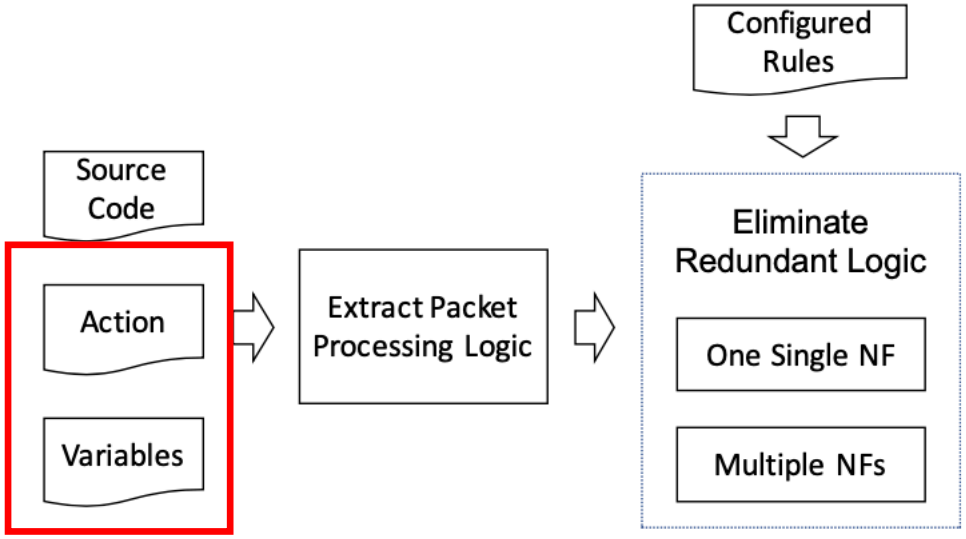
NFReducer Architecture



The architecture of NFReducer

- Labeling Critical Variables and Actions

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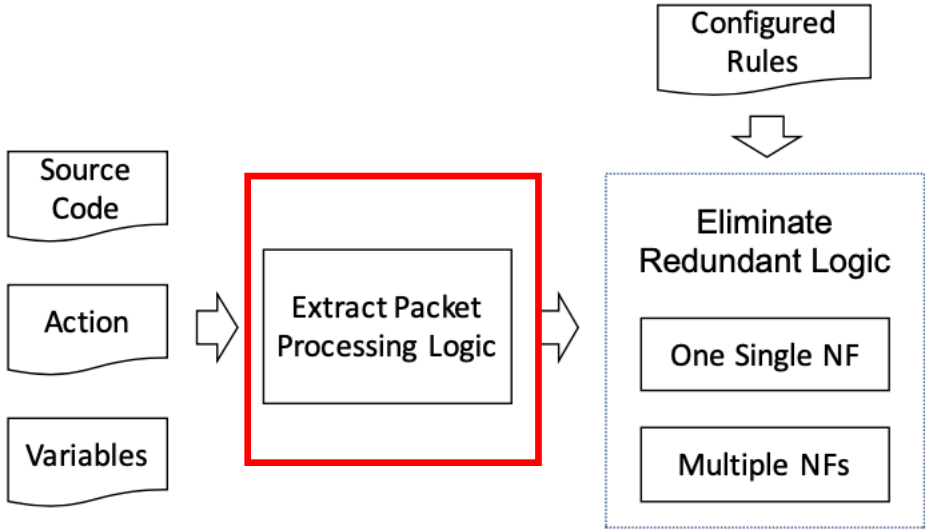

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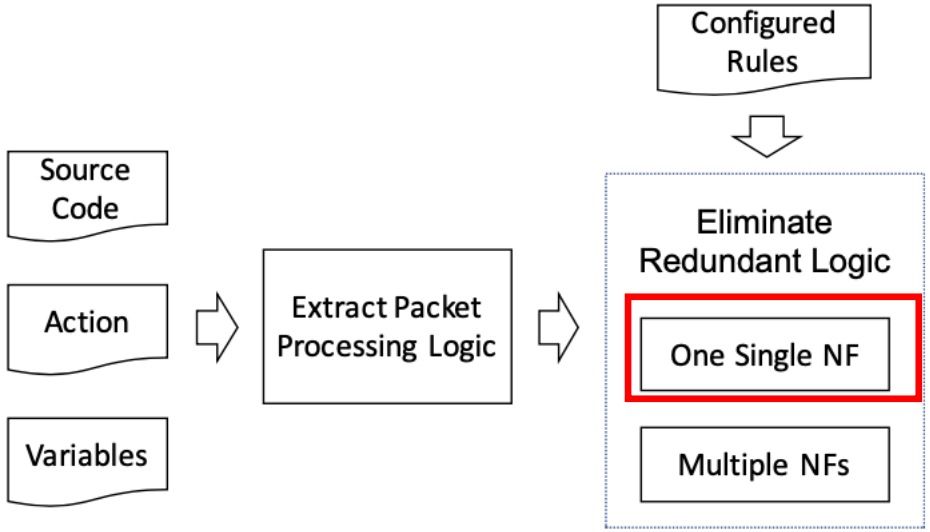

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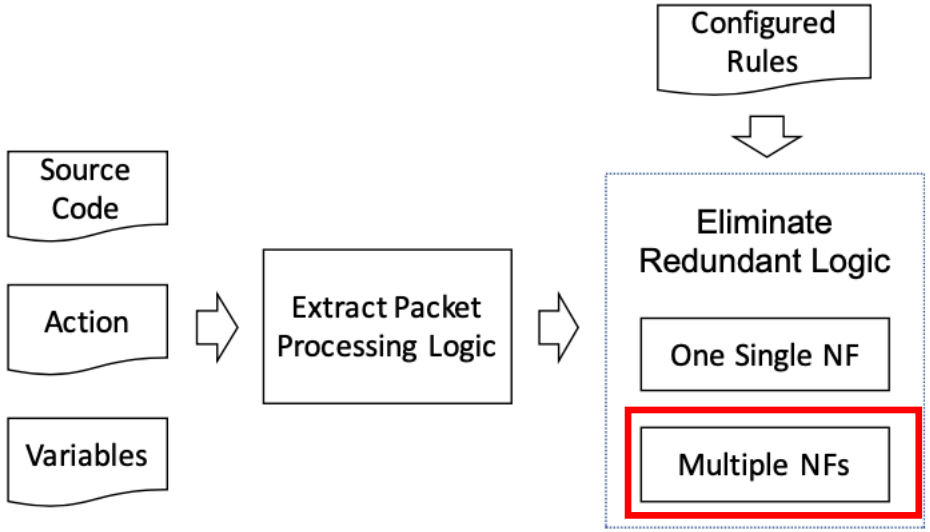

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- Labeling Critical Variables and Actions
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- Individual NF Optimization
- Cross-NF Optimization

NFReducer Architecture

- Labeling Critical Variables and Actions
  - Critical Variables
    - Packet Variables: Holding the packet raw data.
    - State Variables: Maintaining the NF states. (e.g., counter)
    - Config Variables: Maintaining the config info. (e.g., rules)
  - NF Actions:
    - External Actions (e.g., replying, forward, drop packets)
    - Internal Actions (e.g., updating state variables)

NFReducer Architecture

- Labeling Critical Variables and Actions

- Extracting Packet Processing Logic
  - Removing functionalities unrelated to packet processing (e.g., log).
  - Facilitate the compiler techniques applied later (e.g., symbolic execution).

NFReducer Architecture

- Labeling Critical Variables and Actions
- Extracting Packet Processing Logic
- Individual NF Optimization
  - Apply Configs
  - Extract Paths
  - Constant Folding and Propagation
  - Check Path Feasibility
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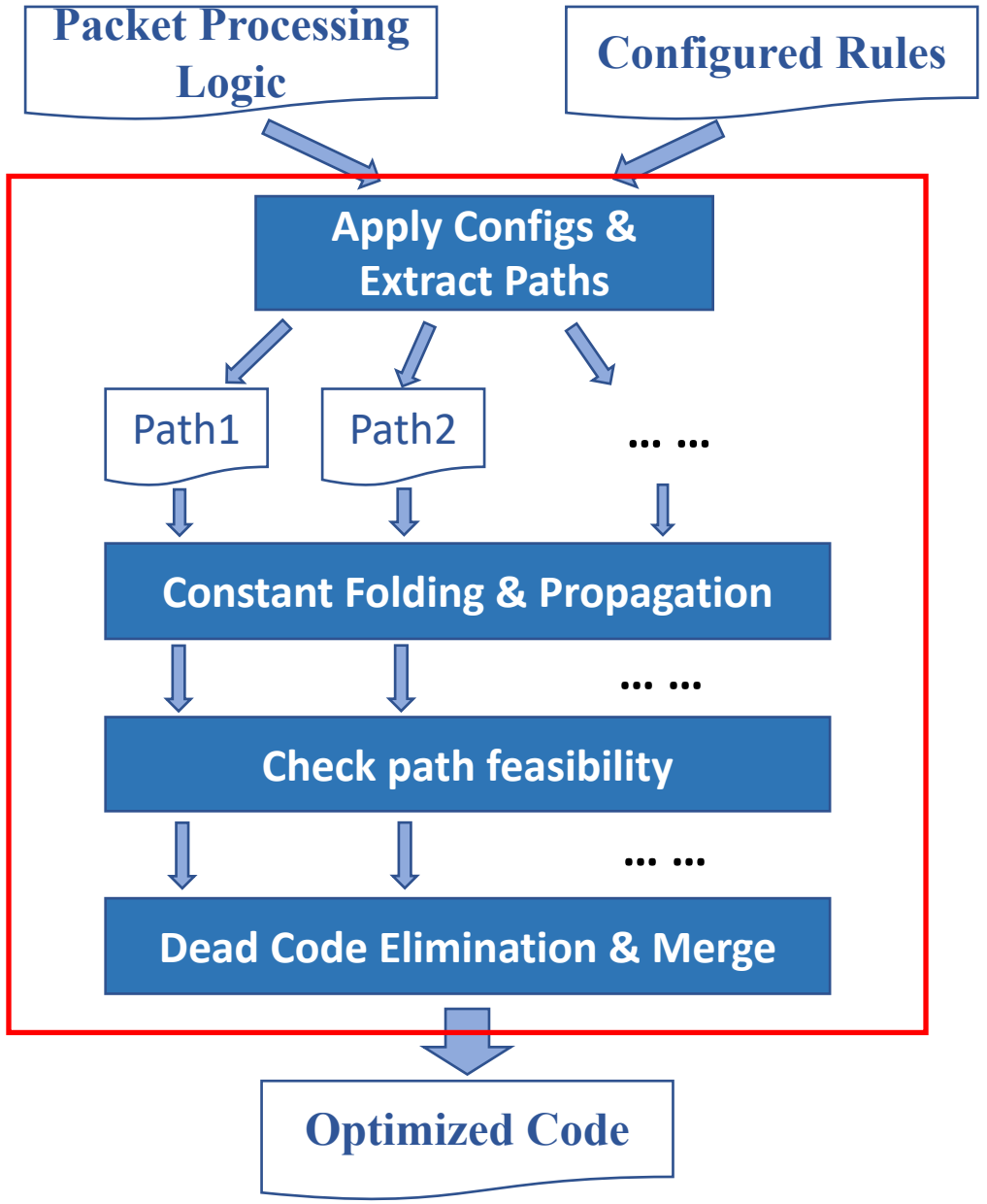
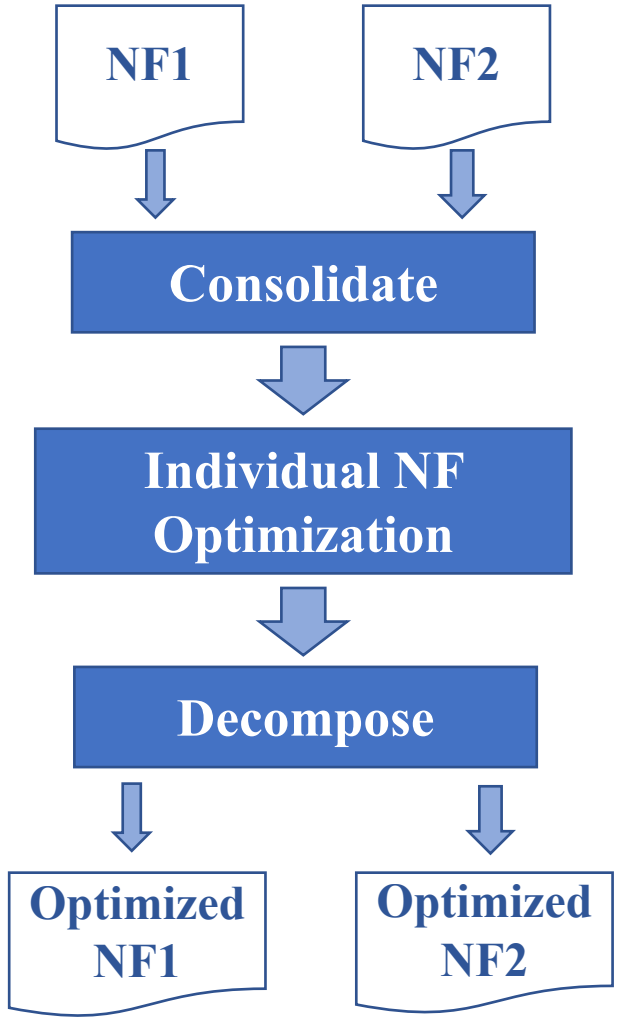
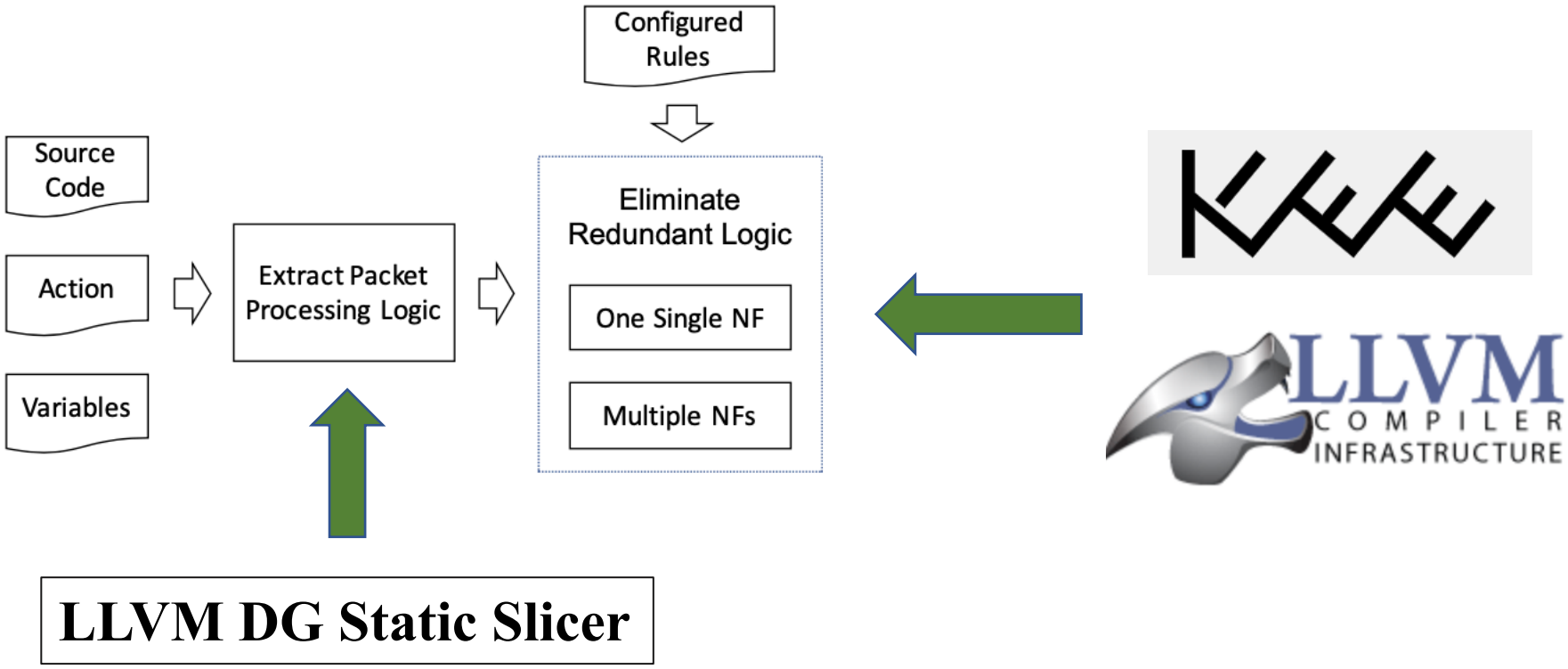


NFReducer Architecture

- Labeling Critical Variables and Actions
- Extracting Packet Processing Logic
- Individual NF Optimization
- Cross-NF Optimization
  - Preliminary discussion on the optimization of different NF chain execution models.



Implementation



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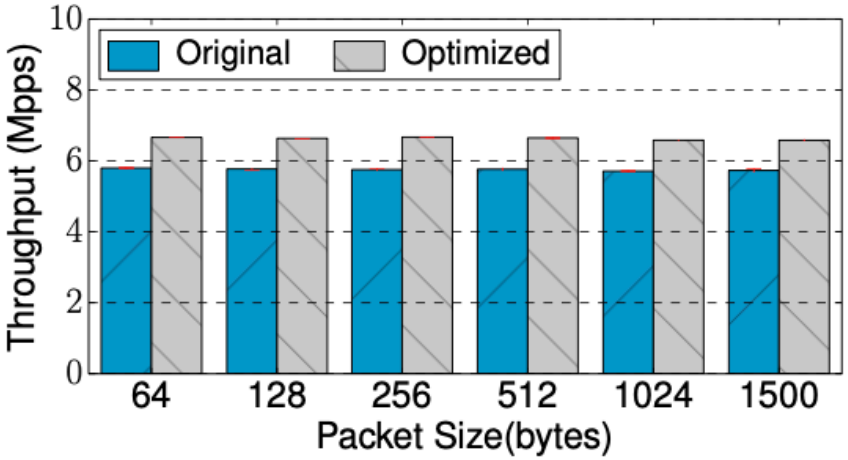

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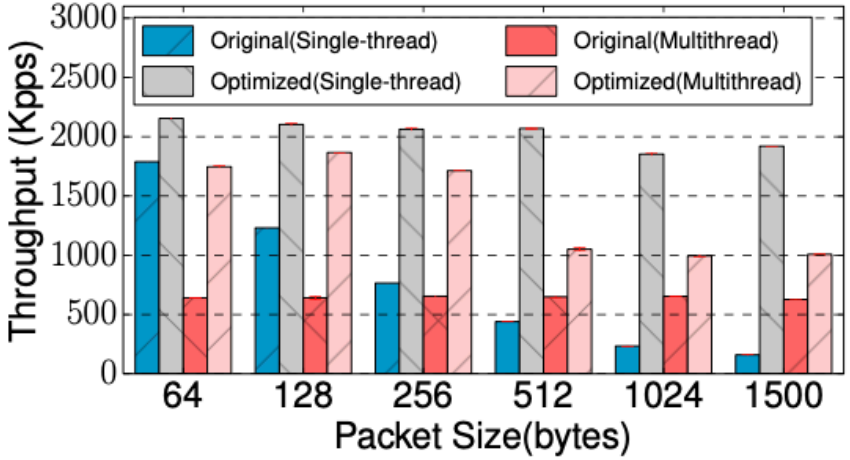

Throughput of Suricata

- Setting: Configured with layer-3 rules.
- Increase by nearly 15% for Snort and by 15% to 10X for Suricata (single thread).
- Suricata is more significant
  - inspects packets deeper in payload than Snort.

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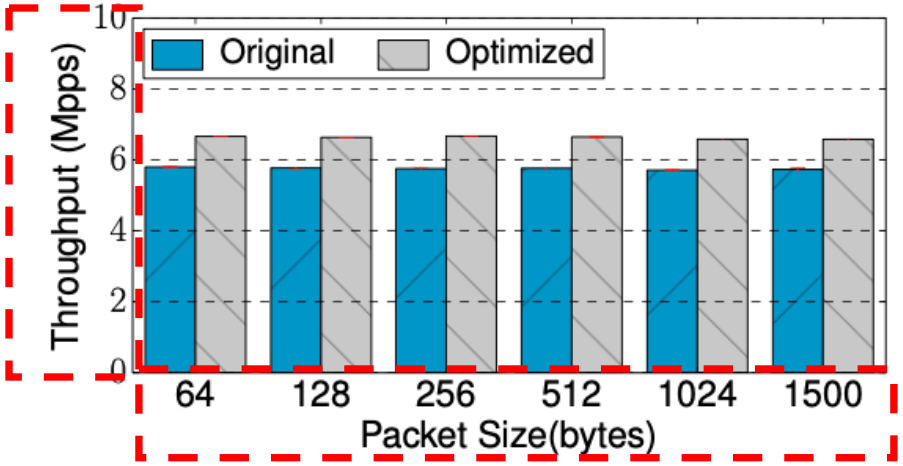

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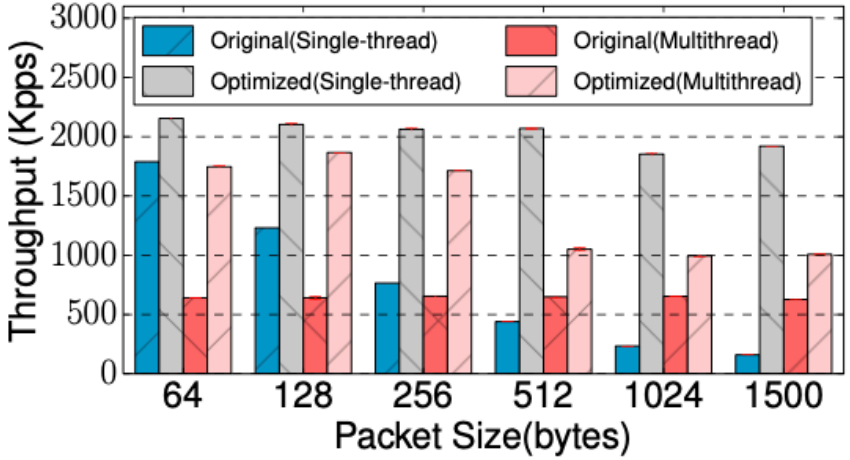

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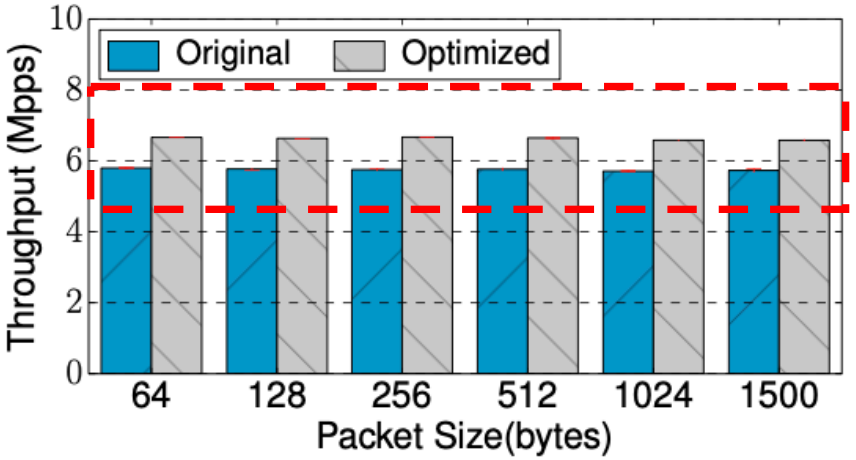
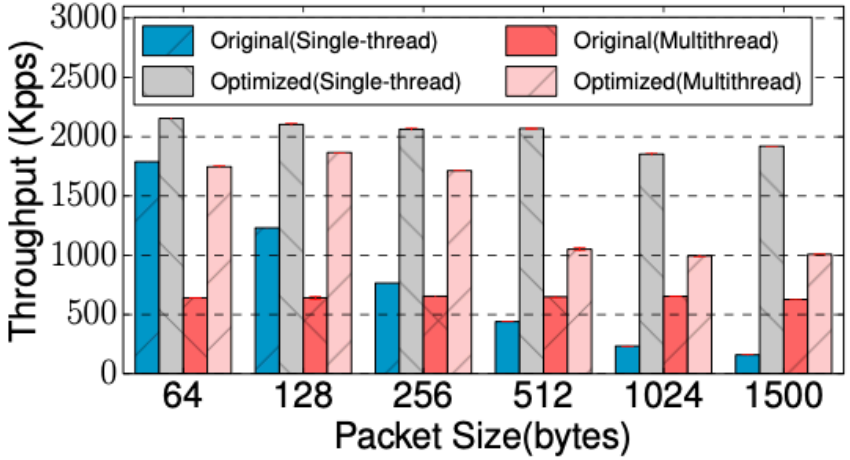


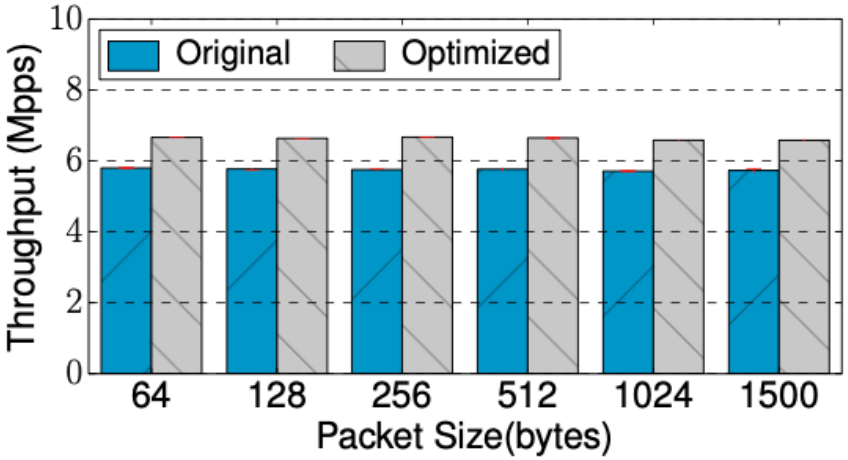
Throughput of Snort



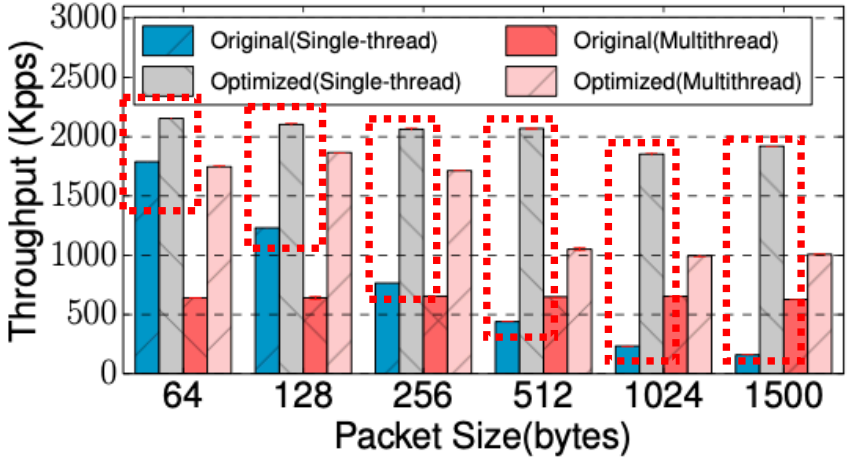
Throughput of Suricata

- Setting: Configured with layer-3 rules.
- Increase by nearly 15% for Snort and by 15% to 10X for Suricata (single thread).
- Suricata is more significant
  - inspects packets deeper in payload than Snort.

Evaluation: Eliminating Type-I Redundancy



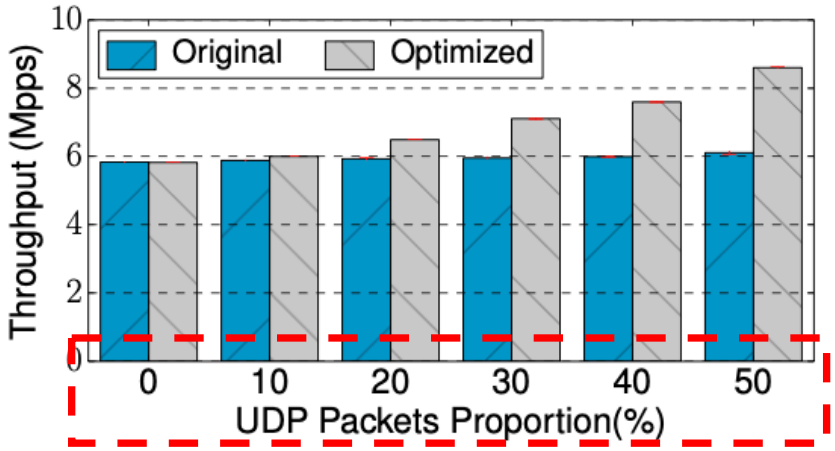
Throughput of Snort



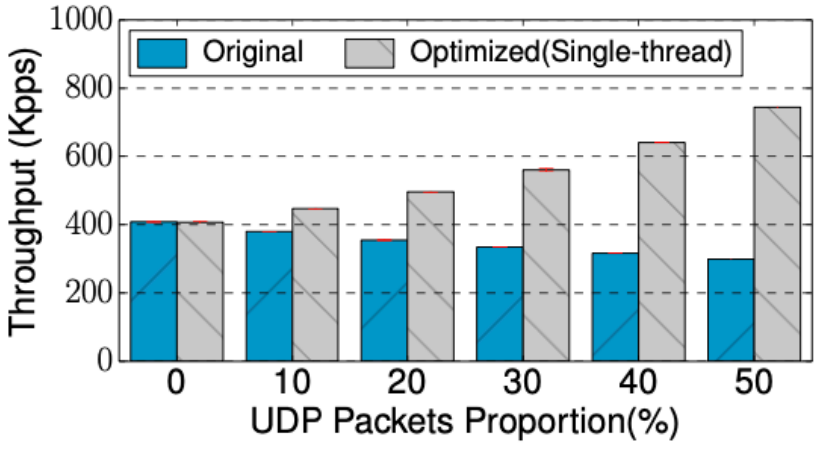
Throughput of Suricata

- Setting: Configured with layer-3 rules.
- Increase by nearly 15% for Snort and by 15% to 10X for Suricata (single thread).
- Suricata is more significant
  - inspects packets deeper in payload than Snort.

Evaluation: Eliminating Type-II Redundancy



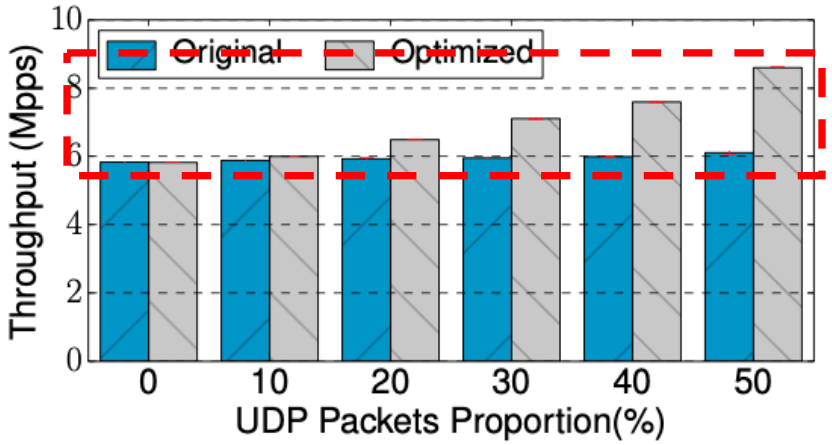
Throughput of Snort



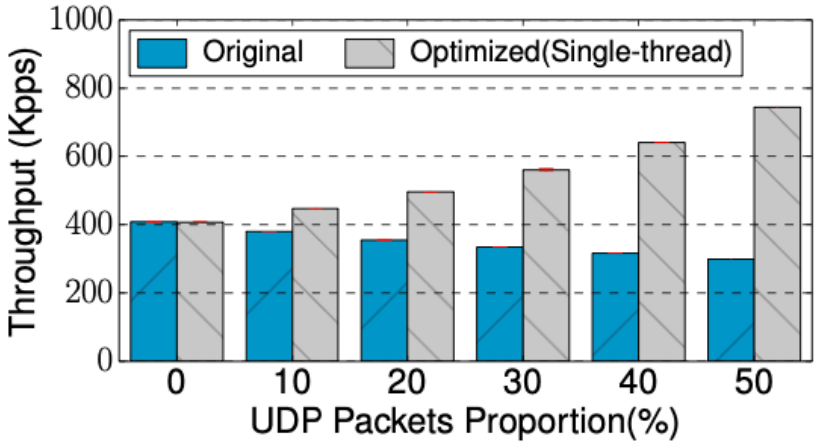
Throughput of Suricata

- Setting: Configured with TCP rules only.
- The larger proportion of UDP packets, the larger performance gain.
- 40% performance gain for Snort and 2.5× for Suricata

Evaluation: Eliminating Type-II Redundancy



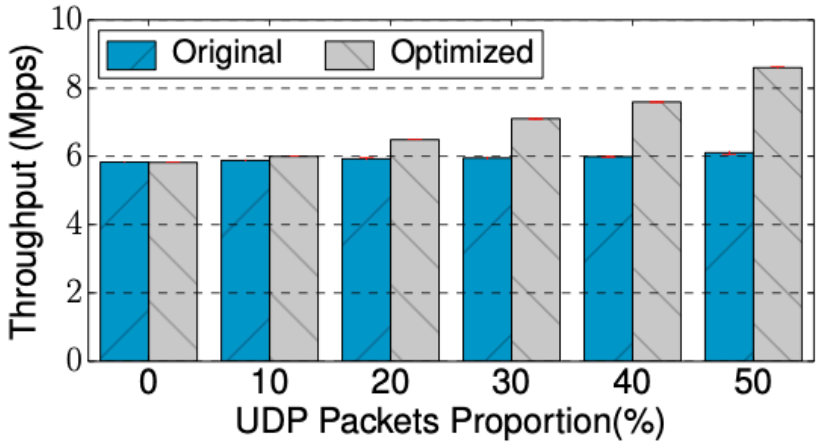
Throughput of Snort



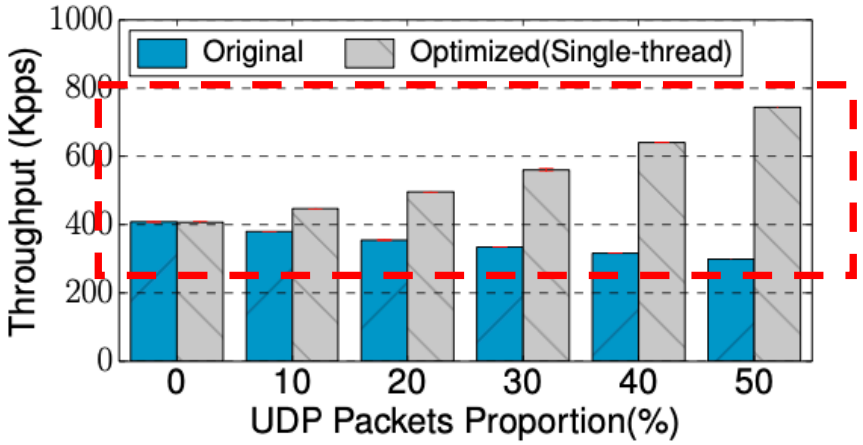
Throughput of Suricata

- Setting: Configured with TCP rules only.
- The larger proportion of UDP packets, the larger performance gain.
- 40% performance gain for Snort and 2.5× for Suricata

Evaluation: Eliminating Type-II Redundancy



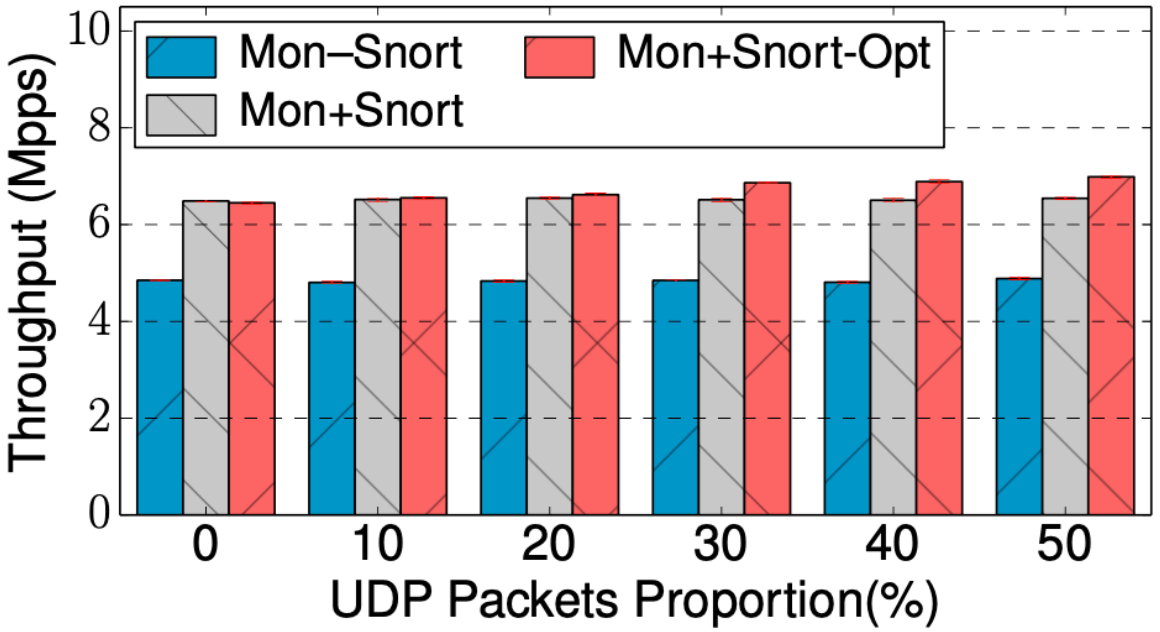
Throughput of Snort



Throughput of Suricata

- Setting: Configured with TCP rules only.
- The larger proportion of UDP packets, the larger performance gain.
- 40% performance gain for Snort and 2.5× for Suricata

Evaluation: Eliminating Type-III Redundancy

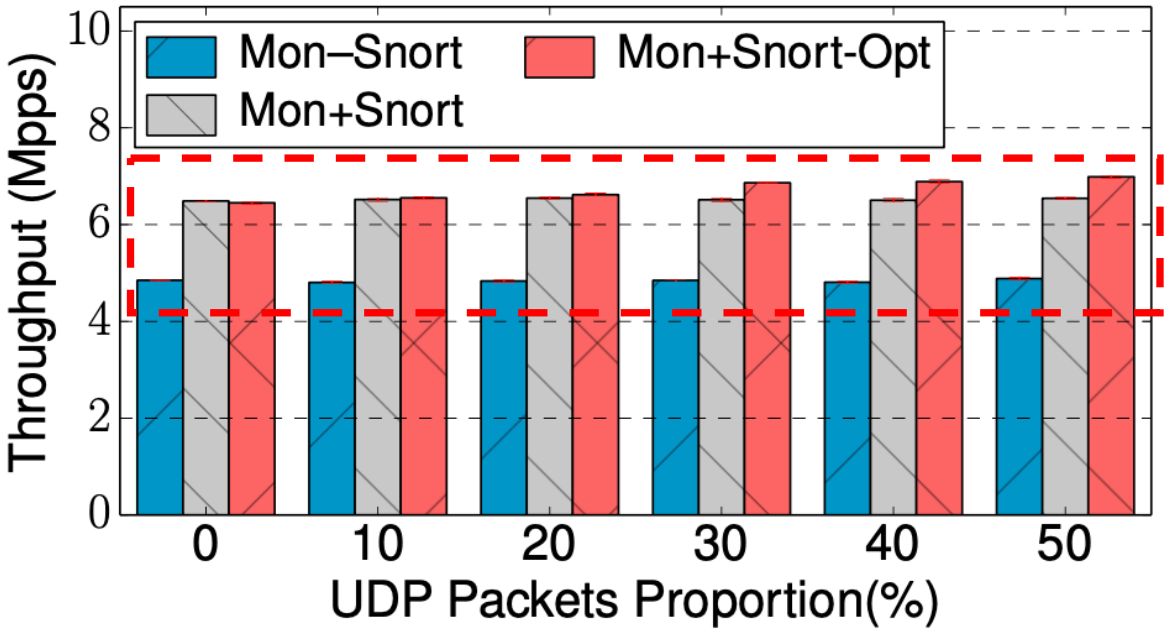


- Setting:
  - Mon—Snort: executed in two processes
  - Mon+Snort: consolidated
  - Mon+Snort-Opt: consolidated and optimized
  - Configured with TCP rules only for Snort

- Consolidation and Redundancy Elimination help improve:
  - By more than 30%

- Performance gain increases as the UDP proportion increases.

Evaluation: Eliminating Type-III Redundancy



- Setting:
  - Mon—Snort: executed in two processes
  - Mon+Snort: consolidated
  - Mon+Snort-Opt: consolidated and optimized
  - Configured with TCP rules only for Snort

- Consolidation and Redundancy Elimination help improve:
  - By more than 30%

- Performance gain increases as the UDP proportion increases.

Evaluation: Overhead

- Labeling Variables and Actions manually:
  - Operator-involved
  - Once for an NF
- Extracting the packet processing logic:
  - 7.2s for Snort and 1.2s for Suricata
- Eliminating Redundancy:
  - 26.8s for Snort and 83.6s for Suricata (mainly cost by symbolic execution).
- Rebuilding:
  - 0.126s for Snort and 2.753s for Suricata

Conclusion

- Show the existence of the redundant logic in NF programs
- Propose NFReducer to eliminate the redundancy.
  - Takes user labeled information
  - Applies compiler techniques
- Performance gain and overhead of the two example NFs.

- In future, we will:
  - Complete and automate the whole workflow process further.
  - Apply NFReducer to more NFs.
  - Make complete tests on NFReducer.