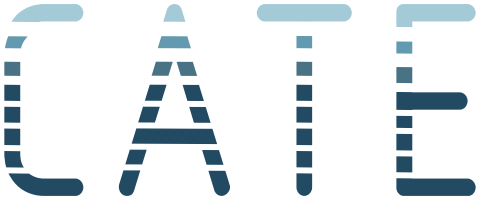

HUMBOLDT-UNIVERSITÄT ZU BERLIN

CATE: An Open and Highly Configurable Framework for Performance Evaluation of Packet Classification Algorithms

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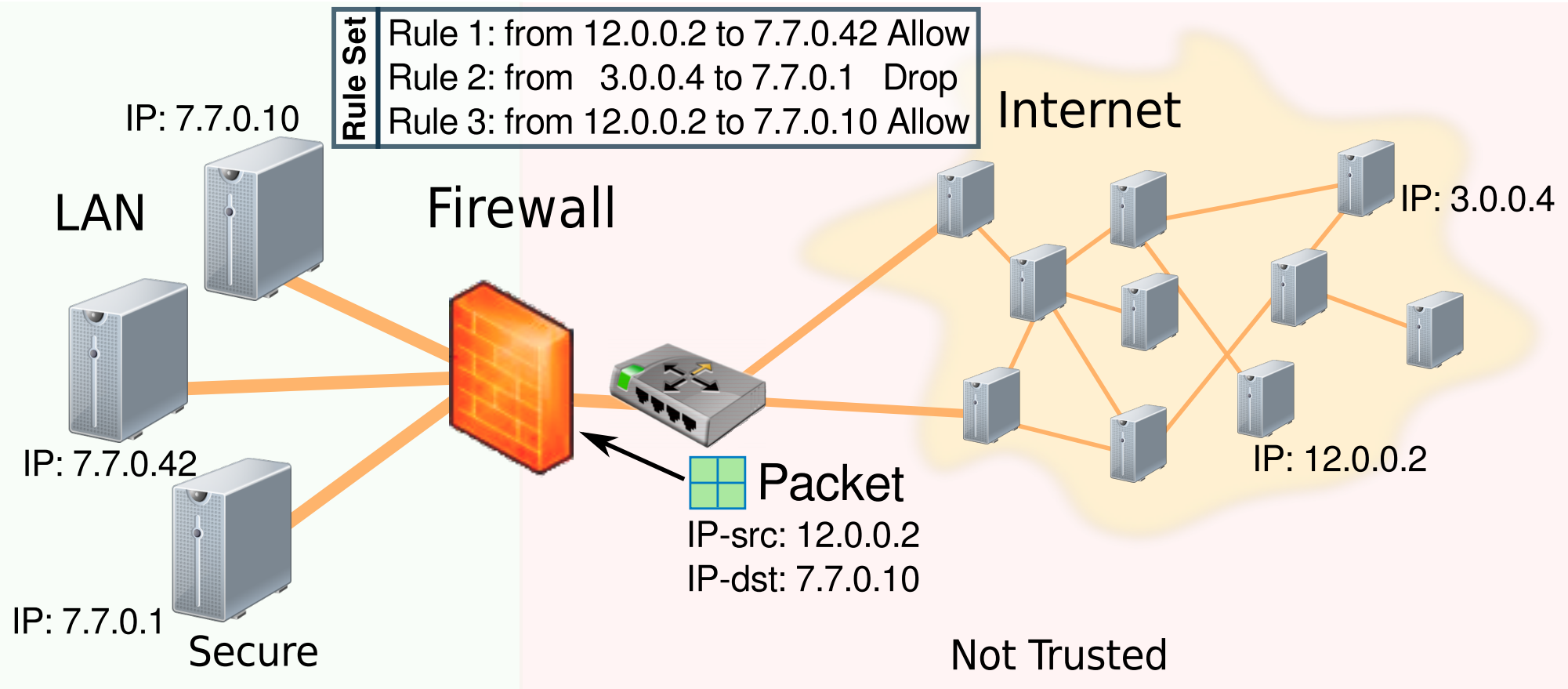
INTRODUCTION

Network packet classification is a crucial task performed in several network applications, such as

- **Firewalls**
- Policy routing
- Traffic measurement and accounting
- Traffic rate limiting
- Intrusion Detection Systems

PACKET FILTERING IN FIREWALLS



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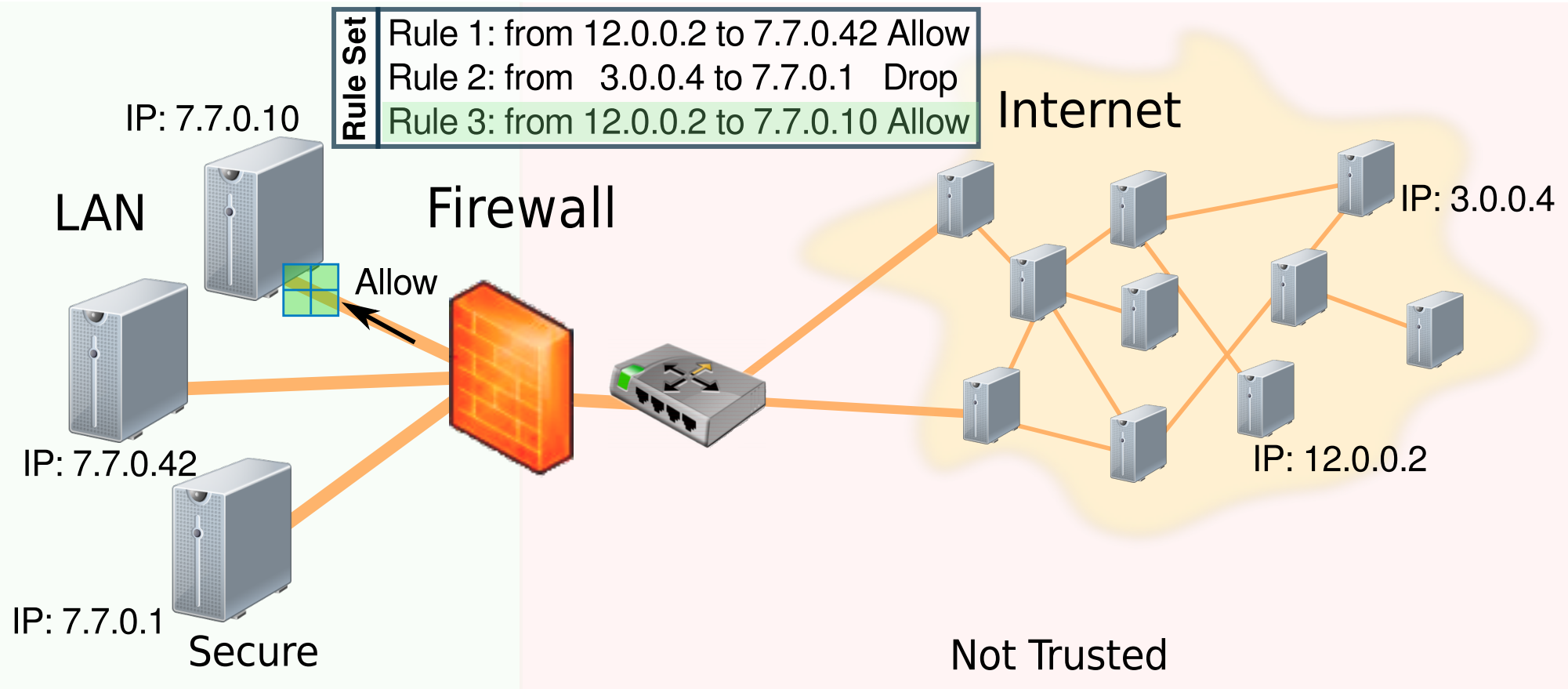

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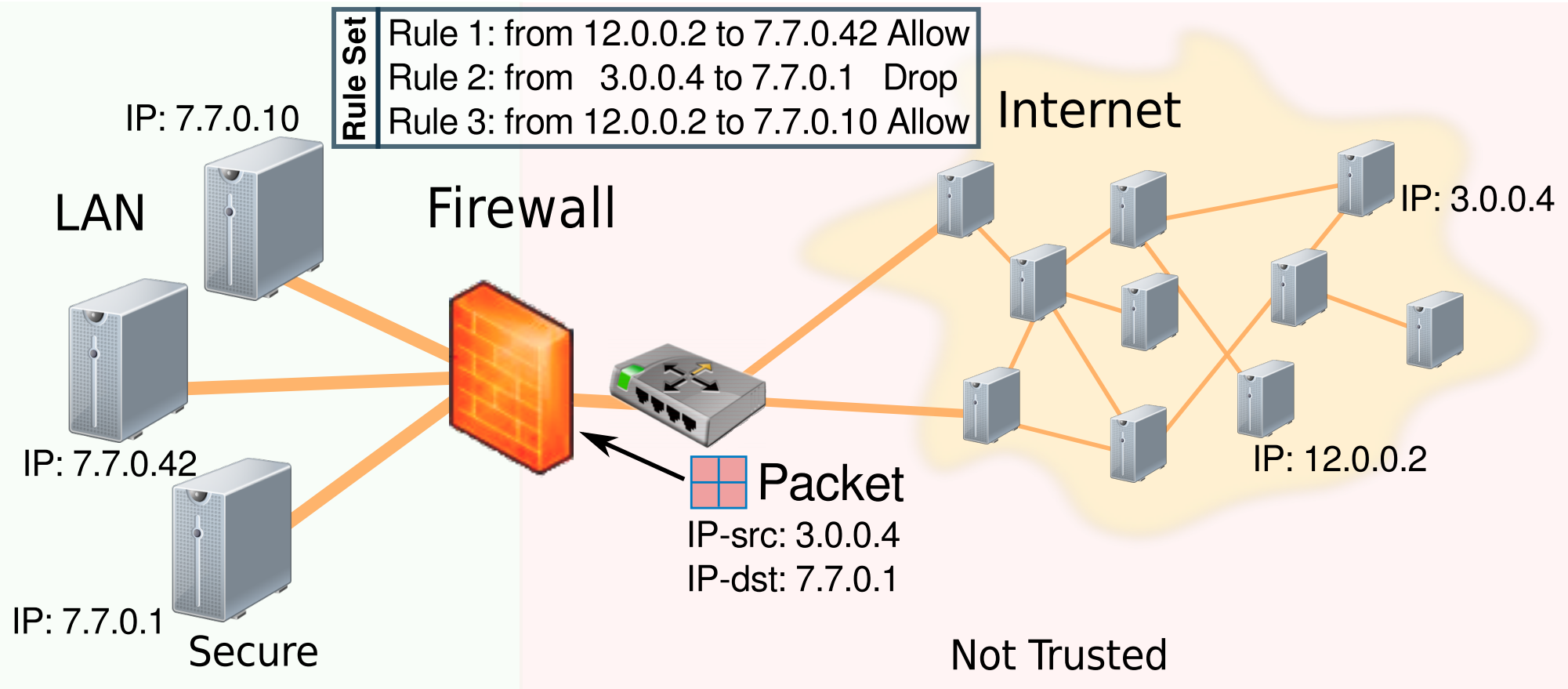

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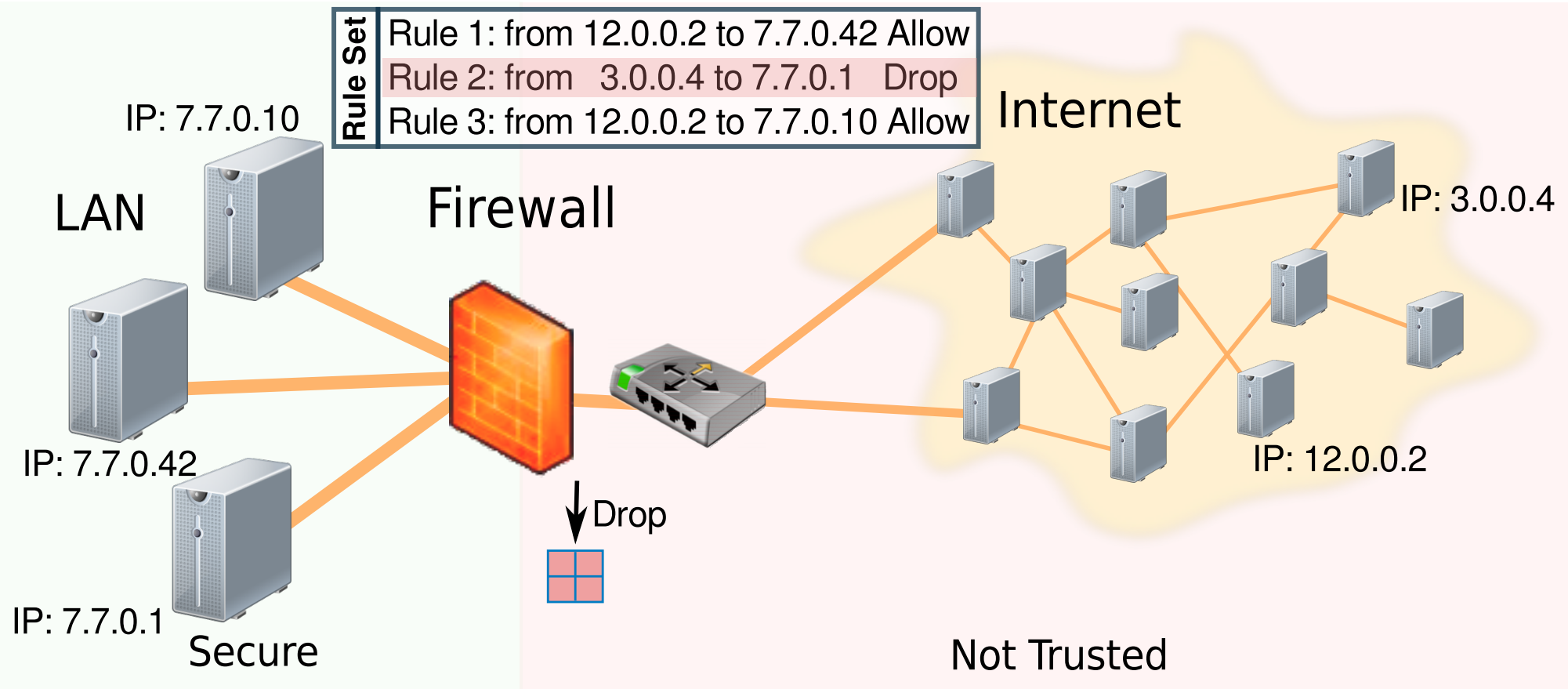

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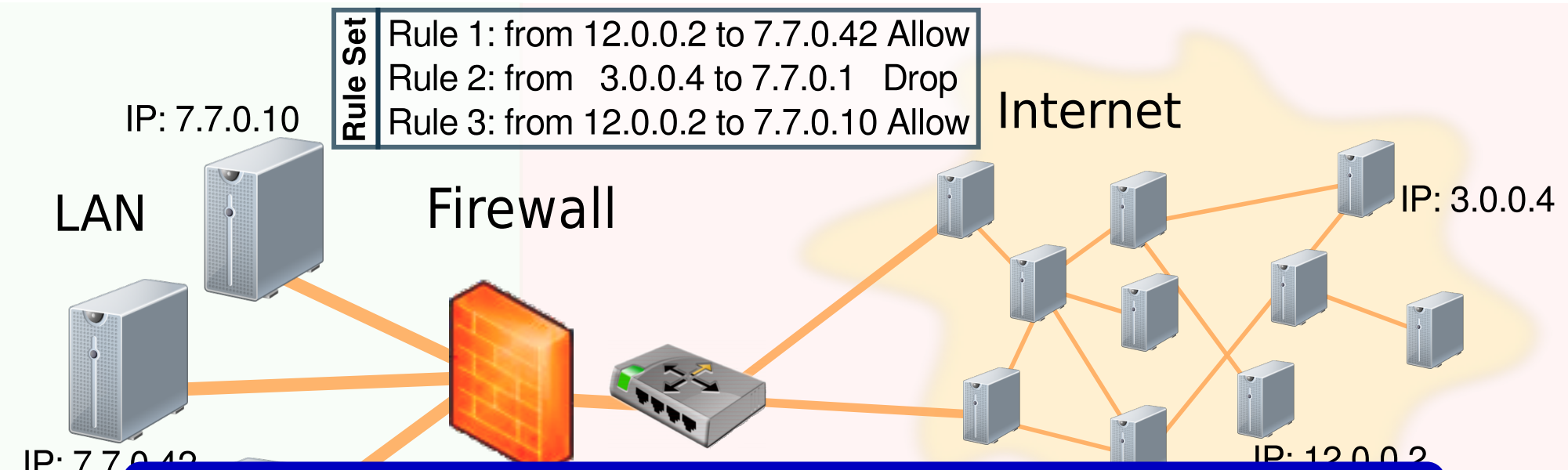
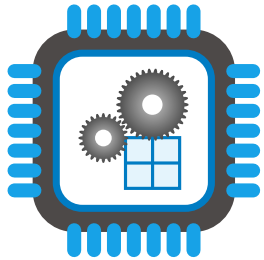


Packet Classification

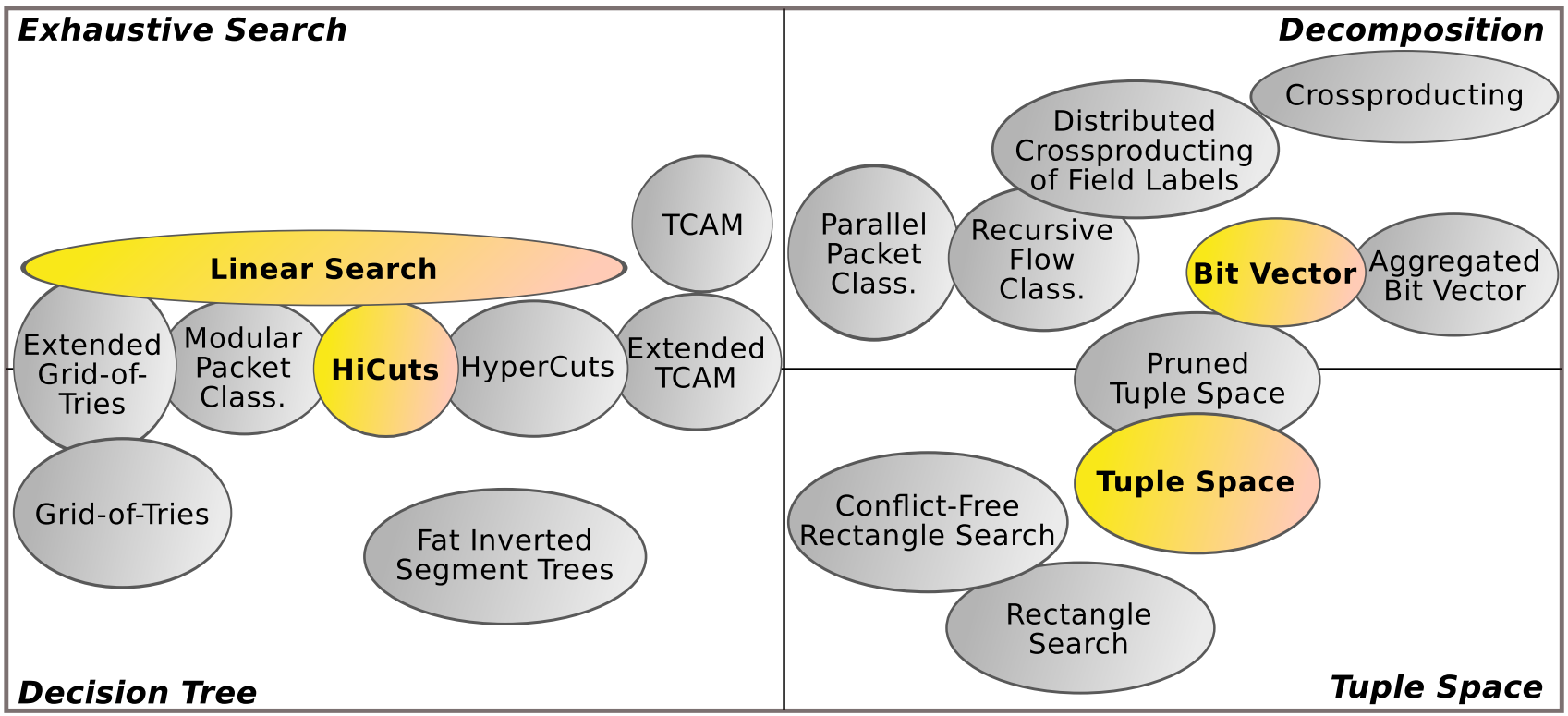
For each incoming packet find the highest priority matching rule in a rule set and apply its associated action.

CHALLENGING REQUIREMENTS



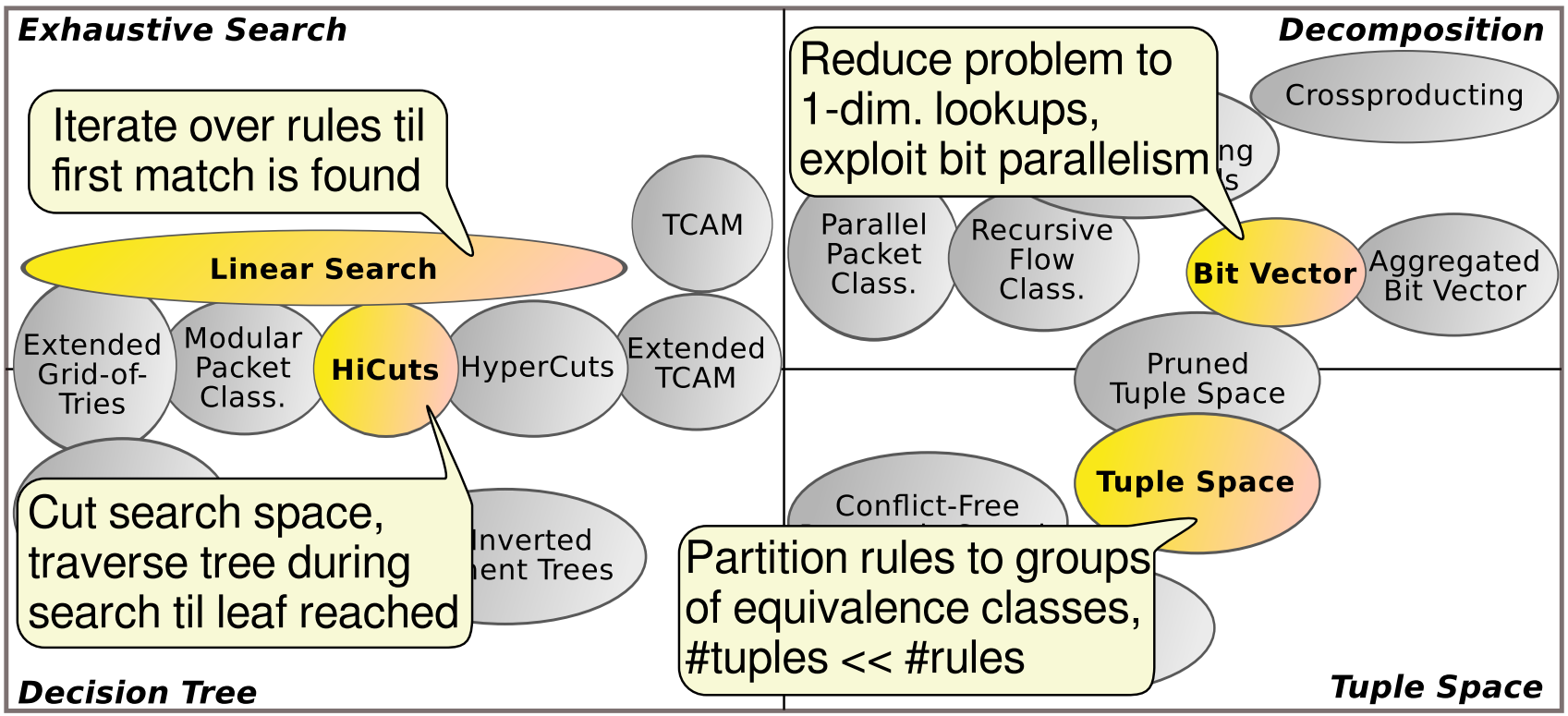
- Classifying at line speed:
  - For 40 Gbit/s: 125 millions IP-packets per second (with 40 Bytes each)
  - Time to classify and forward each packet is only **8 ns**
  - Main memory access time is **5 to 60 ns**
- Operate at the leading edge of today's hardware technology
- **Efficient packet classification is essential.**

CLASSIFICATION ALGORITHMS



Based on Taylor, David E. "Survey and taxonomy of packet classification techniques." ACM Computing Surveys (CSUR) 37.3 (2005): 238-275.

CLASSIFICATION ALGORITHMS



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PROBLEM STATEMENT

- Plenty of classification algorithms with different properties
- Differences in classification performance and memory footprint
- Comparisons problematic, as no integrative framework exists

Main Questions

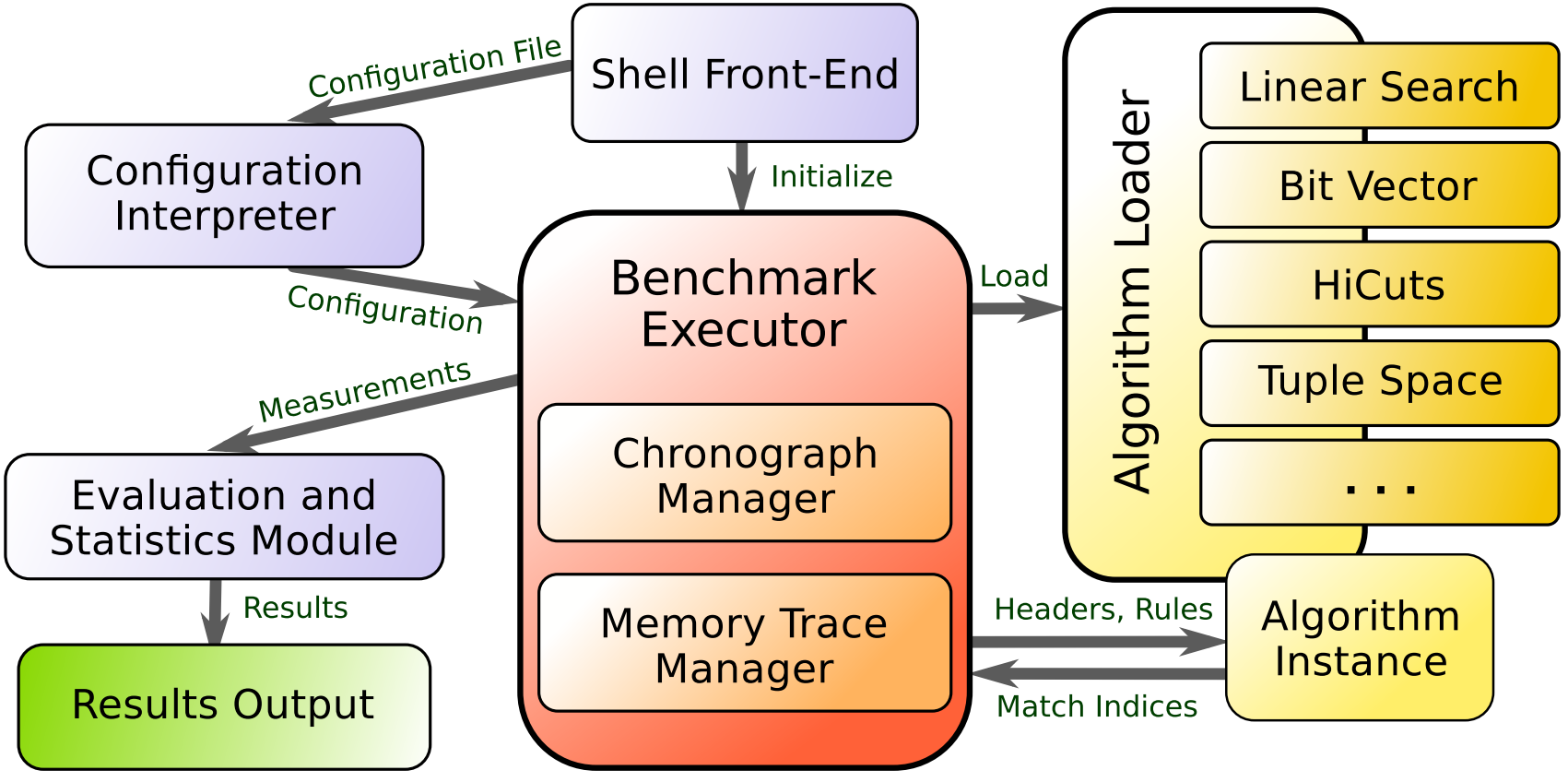
- **For developers**: Which classification algorithm is best suited for a certain application?
- **For researchers**: How to compare a new algorithm to already existing classification algorithms?

Classification
Algorithm
Testing
Environment

CLASSIFICATION ALGORITHM TESTING ENVIRONMENT

- Framework for benchmarking algorithms' software implementations
- Measured values: time durations and memory usage
- Implemented in C++, runnable on many targets
- Highly customizable with Lua as configuration language
- Uses white box classification algorithms

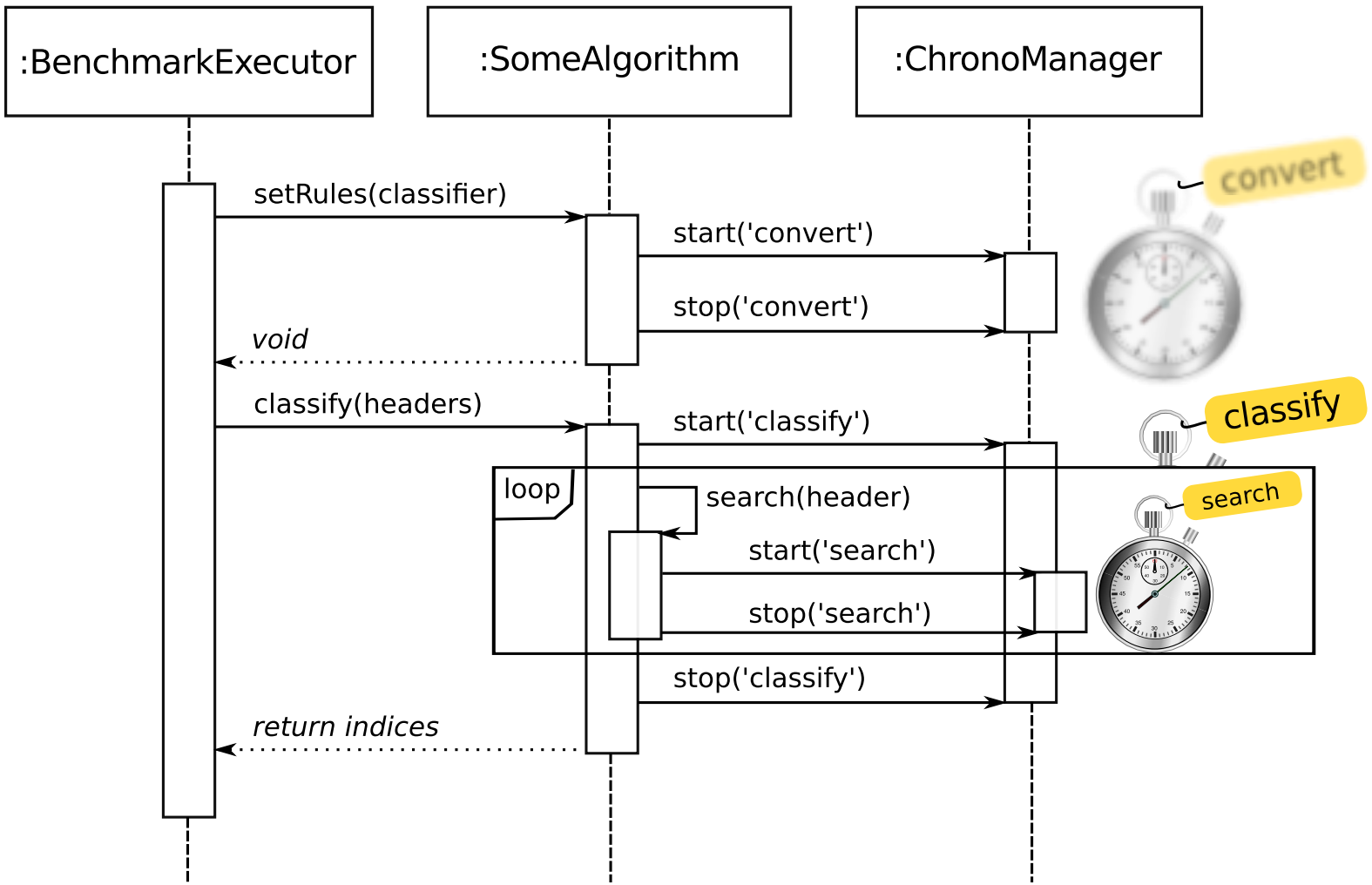
SOFTWARE ARCHITECTURE



MEASURING PERFORMANCE

- Take time duration(s)
- Compare benchmarks:
  equal workload – different time durations
- Important aspects: control and granularity

MEASURING PERFORMANCE



MEASURING MEMORY USAGE

- Goal: Precisely trace memory allocations and memory accesses (byte granularity)
- High-level programming languages provide an abstraction of memory management
- In C++, memory information can be acquired implicitly by the `sizeof`-operator

MEASURING MEMORY USAGE

- Realized by code-instrumentation
- Utilization of class inheritance and C++ template techniques
- Arbitrary data types can be regarded, e. g.
  - `int val;` ⇒ `MemTrace<int> val;`
  - `Stack st;` ⇒ `MemTrace<Stack> st;`
- Tracing memory usage imposes overhead on measured time durations

Evaluation

EVALUATION HIGHLIGHTS

1. Analyze probe effect (overhead by memory tracing)
2. Compare algorithms' performance for varying #rules
3. Effect of different rule set structures on classification performance
4. Vary field structure of packet headers

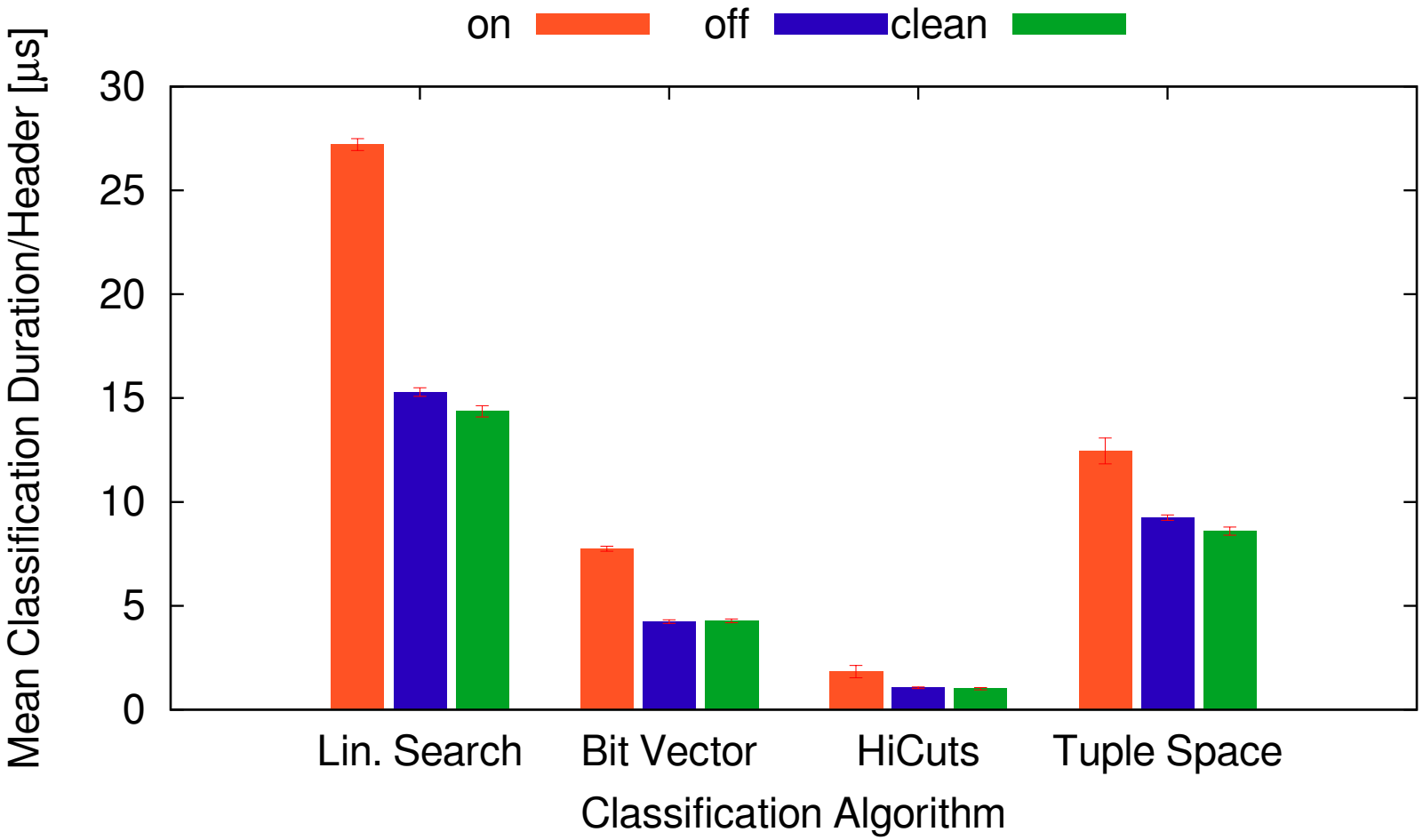
SYSTEM SETUP

- 2.27 GHz Intel i5 M430, single core, Linux 3.13
- Virtual Machine (32 bit) with 1024 MB RAM
- Synthetic *ClassBench* rules and 100K headers
- Measurements of time durations were repeated 8 times and arithmetic mean was taken.

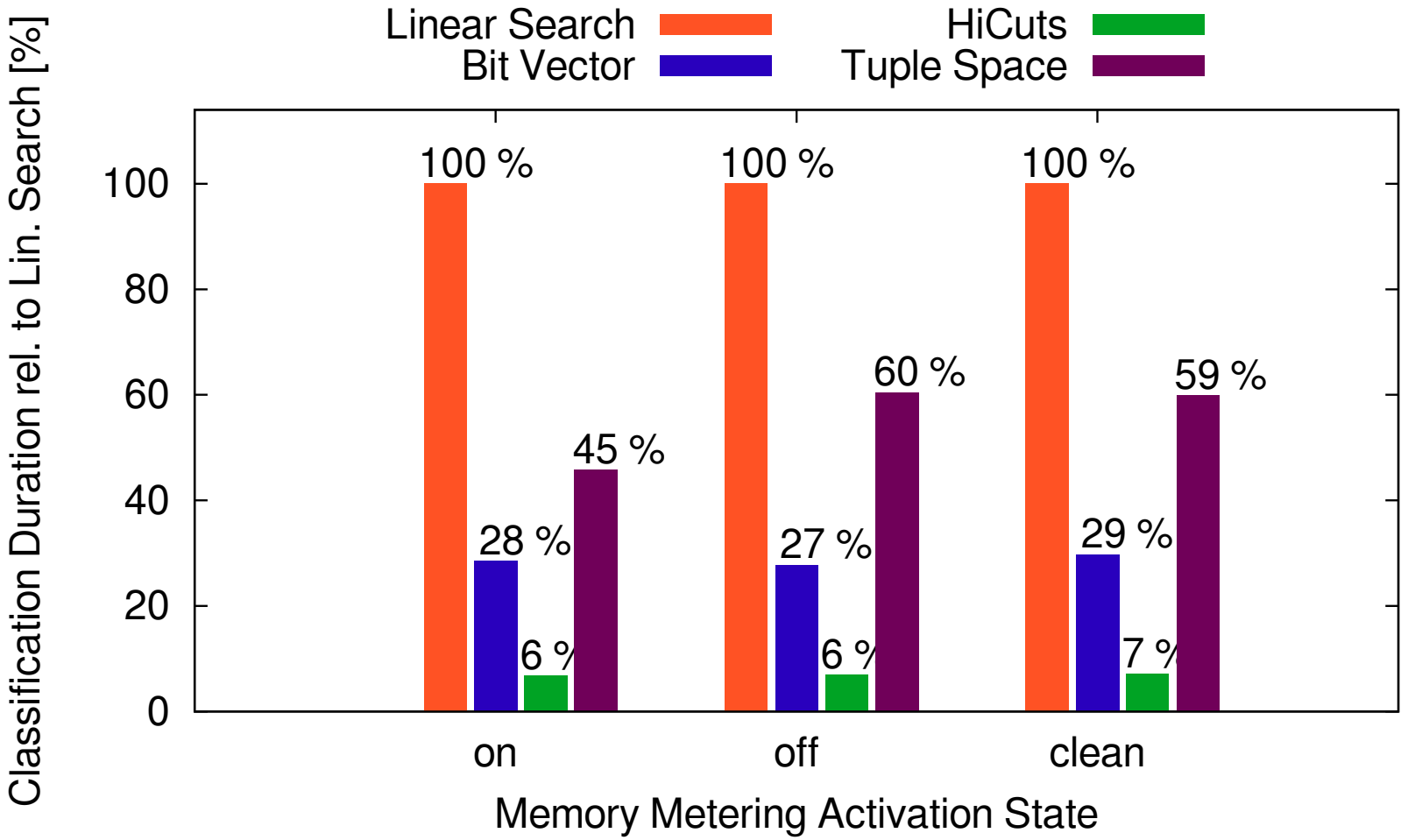
ANALYZING PROBE EFFECT

- Measure time durations in three operation modes:
  - enabled: memory allocations and accesses are traced during time measurements
  - disabled: memory usage tracing is disabled by preprocessor directive
  - cleaned: code-instrumentations are removed manually from code

ANALYZING PROBE EFFECT



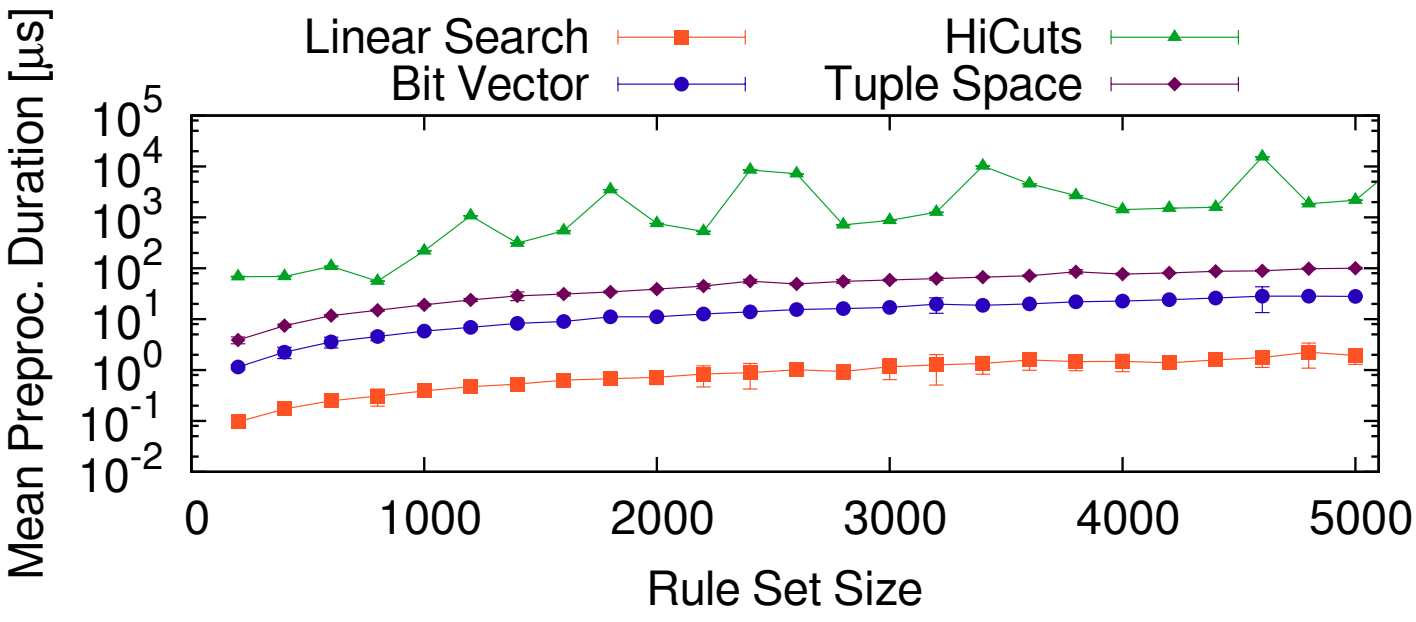
ANALYZING PROBE EFFECT

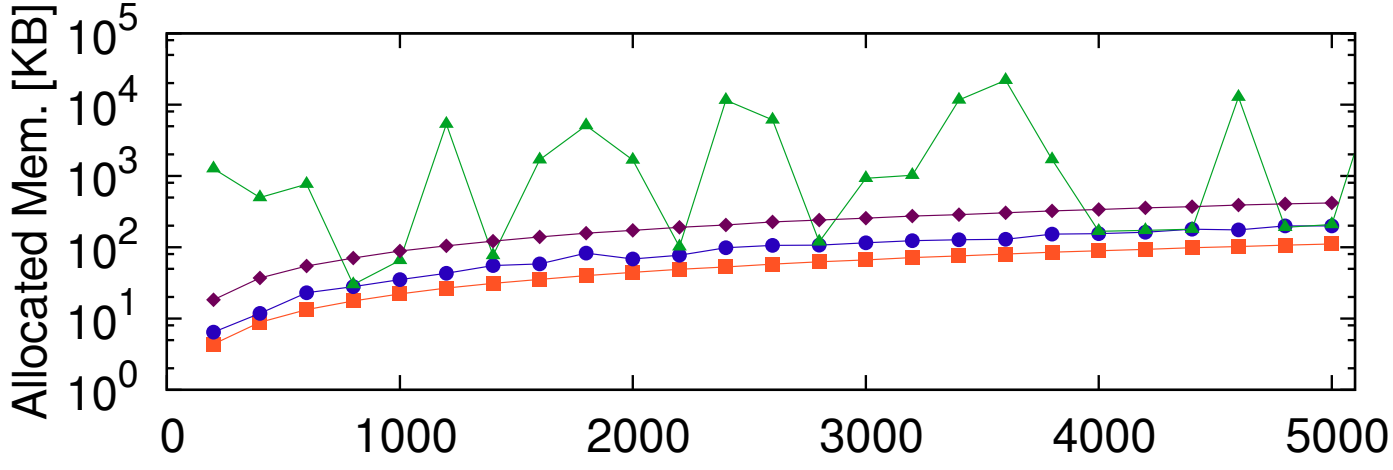


VARIATION OF RULES

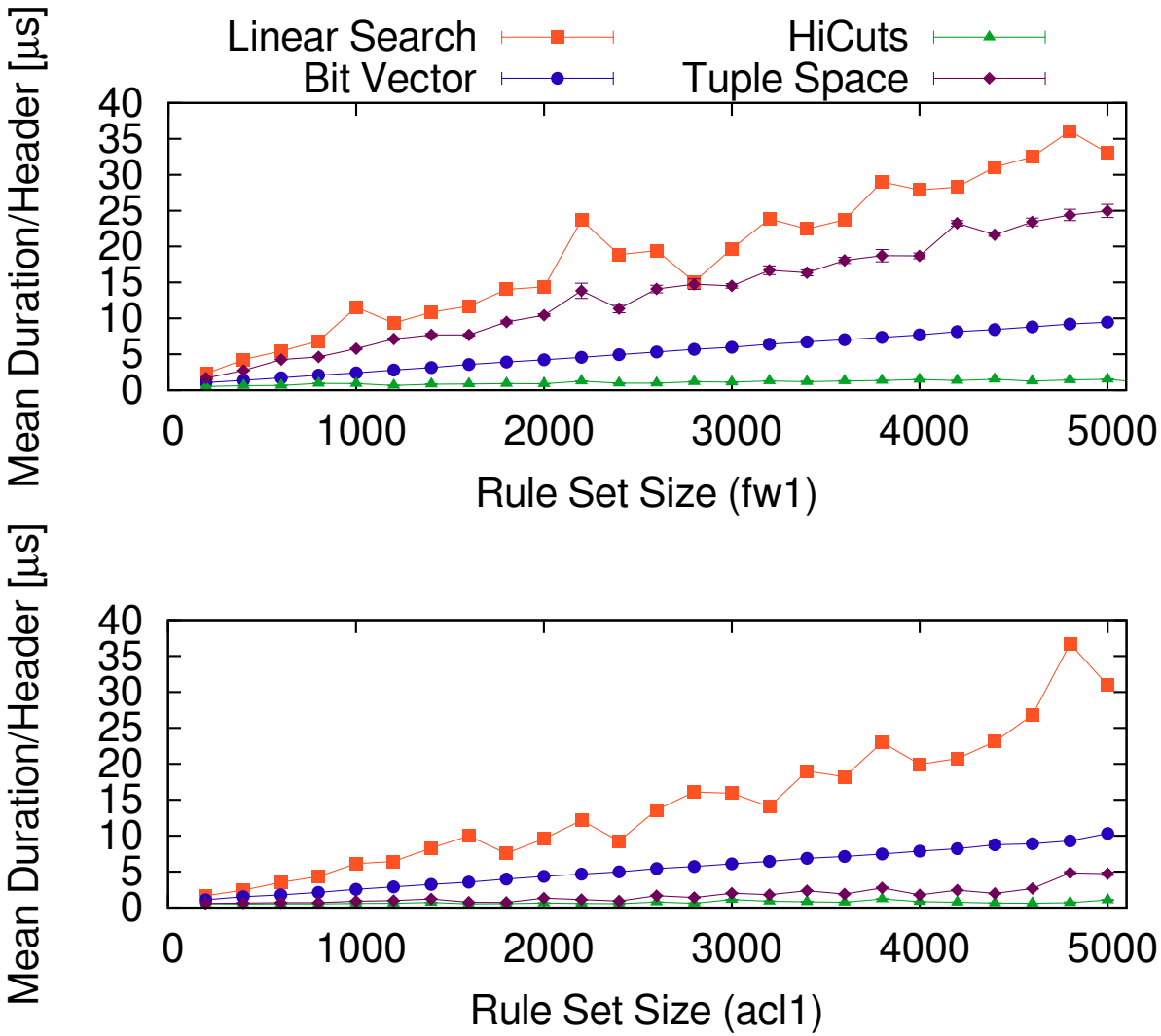
- Vary number of rules (200, 400, 600, ..., 5000)
- Use common 5-tuple: (32 bit, 32 bit, 8 bit, 16 bit, 16 bit)
- Observe performance during preprocessing and classification stages
- Compare performance for rule sets with different structure

VARIATION OF RULES - PREPROCESSING





VARIATION OF RULES - CLASSIFICATION

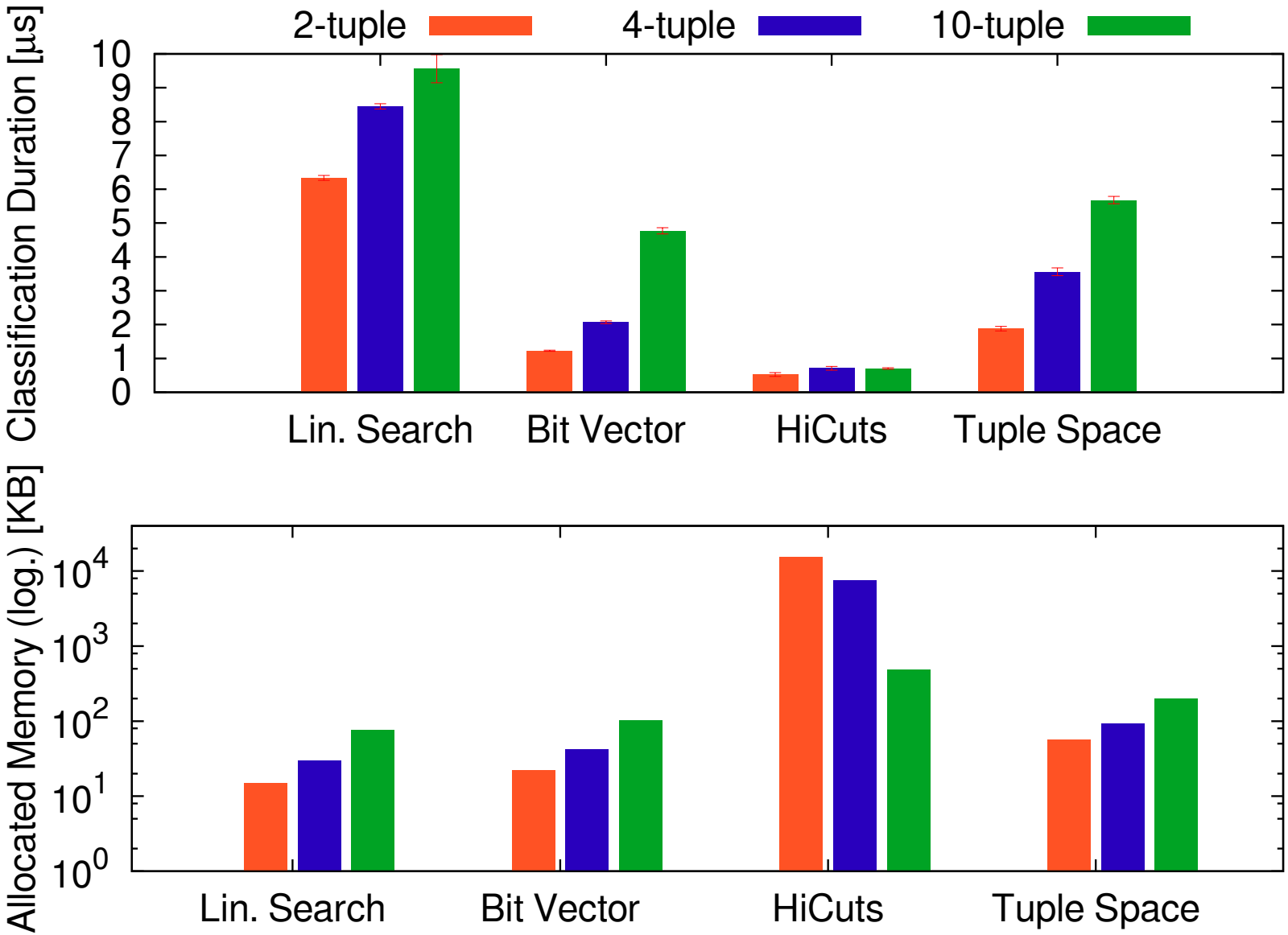


e. g., `fw1_4000`: 449 wildcard checks, `acl1_4000`: 22 wildcard checks

VARYING FIELD STRUCTURE

- Vary tuple size (2, 4, 10 fields), each field is 32 bit
- Expectations:
  - Increasing tuple size should not affect HiCuts' classification performance
  - Allocated memory should increase with increasing tuple size for all algorithms

VARYING FIELD STRUCTURE



Conclusions

RESULTS AND CONCLUSIONS

- CATE provides an integrative measurement environment for practical implementations.
- Probe effect does not change time duration relations between algorithms.
- Classification algorithms can show unexpected characteristics for specific applications.
  - Memory allocation for HiCuts' data structure is highly fluctuating.
  - Tuple Space Search performance depends on rule structure.
  - Increasing header fields can result in less memory allocation by HiCuts.

RESULTS AND CONCLUSIONS

- CATE provides an integrative measurement environment for practical implementations.

Open Access to CATE

Checkout CATE @github:

`http://gusew.github.io/cate`

structure.

- Increasing header fields can result in less memory allocation by HiCuts.