

**Doctoral thesis** (hereinafter referred to as "thesis"), title of the thesis: HASH-BASED PATTERN MATCHING FOR HIGH-SPEED NETWORKS

**Name of the doctoral student** (hereinafter referred to as "student"), name and surname: TOMÁŠ FUKAČ

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**Name and institution of the reviewer** (full name of the reviewer, full name and country of the institution):

Salvatore Pontarelli, University of Rome – Sapienza, ITALY

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## I. Thesis

### Appropriateness and relevance

This thesis addressed the relevant problem of providing the pattern matching primitives for Intrusion detection systems. In particular the thesis focuses on the scalability issues of the current solutions for high-speed pattern matching. The thesis correctly identifies the bottlenecks of current solutions and proposed a set of solutions to supersede them. The problem taken into account in this thesis is of significant importance in the field of network security and the proposed solutions are interesting and provide an advancement with respect to the state of the art.

### A summary of the contributions of the thesis

The goal of this thesis is to increase the throughput of regular expression pattern matching. The main idea driving the thesis is to pre-filter the incoming network packets with an approximate representation of the regular expressions to analyze. The thesis achieves this goal providing the following contributions:

- i) It proposes a highly scalable hash-based pattern matching architecture amenable for FPGA implementation.
- ii) It develops an algorithm for the fast selection of short strings that provides better pre-filtering of the full regular expression to analyze.
- iii) It optimizes the internal interconnection network providing multiple hash functions in parallel, with the result of an optimization of the FPGA resources.
- iv) It proposes an optimization of the memory resource utilization by reducing the information stored in the hash table used for pre-filtration.

Novelty and significance:

This thesis introduces novel work of a level suitable for a PhD. The solutions introduced are significant and will be an important building block in future research in this field. While the work focuses on pattern matching, there are some architectural optimizations that are also applicable in other fields that make use of hash based data structures. Moreover, these results are practical and can be used by industry in their FPGA-based networking products.

Evaluation of the formal aspects of the thesis:

The formal quality of the thesis is good, and the language level is suitable for a PhD thesis. The thesis is a collection of published peer-reviewed research papers, and as such the organization of the content and the writing style is well suitable to the publication venues, as well as to a papers-based thesis.

Quality of publications

The work included in this thesis was published in several international venues, including IEEE conferences and symposium on both computer networks and FPGA programming. Overall, the student has published four papers, all of them as the lead author. This is good number of publications for a PhD student in this field.

**II. Student's overall achievements**

Overall R&D activities evaluation:

The student's thesis and the results included into it indicate that he is a person with scientific erudition and creative abilities. The results presented in the thesis are both innovative and clever, showing that the student is able to pursue interesting research activities and to provide further research advancements.

Assessment of other characteristics (optional):

The deployment of the presented solutions in Pigasus is an important result since increases the number of rules that can be supported by it. Even more important is the and, most importantly it the use of these solutions for a probe for lawful interception deployed in the Cesnet backbone link. Finally it is worth to be noticed the interest of BrnoLogic in the work presented in this thesis.

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**III. Conclusion**

*Review of a Doctoral Thesis at FIT BUT*

In conclusion, in my opinion, the thesis and the student's achievements until now meet the generally accepted requirements for the award of a PhD academic degree.

The candidate has demonstrated ability to carry out independent research activities and the results are appropriate, relevant and of suitable quality. The research demonstrated novelty and innovation of significance to the field, and there is supporting evidence of the candidate's high-quality level of research.

Rome, 14/10/2024

Signature of the reviewer: