Huge pages impact analysis on high-speed network packet capture in the Linux kernel

Master's thesis

Computer and Information Engineering

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Introduction

Scenario

Packet capture

- traffic analysis
- network monitoring

Requirements

- high-speed
- low packet loss rate

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10–40 Gigabit Ethernet

The Linux kernel

Linux is an **open-source** operating system.

Frameworks for high-performance packet capture:

- **PFQ**
- **Intel DPDK**
- **PF_RING ZC**

PFQ Framework

PFQ I/O

- highly optimized for **multi-core** architecture
- RX and TX **line-rate on 10-Gbit links**
- user-kernel memory-mapped buffer backed with **Huge Pages**

Translation Lookaside Buffer

Virtual memory:

- software-controlled set of memory addresses
- data **protection** and **control** among processes

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$\rightarrow$ cache for resolved addresses:

Translation Lookaside Buffer

Not always enough to save CPU clocks:

- TLB miss event

Huge pages

How to reduce the CPU cycles spent for translations?

- fewer translations $\rightarrow$ fewer CPU cycles
- **wider address range** for each TLB entry
- the same number of TLB entry covers **more addresses**
- more likely TLB **hits** events

Huge pages

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Huge Pages

4K → 2M

Linux support for huge pages

Transparent Huge Pages

- **on-demand** allocation
- without user awareness

Really available?

HugeTLB filesystem

- **pre-allocated** pages
- **application awareness**

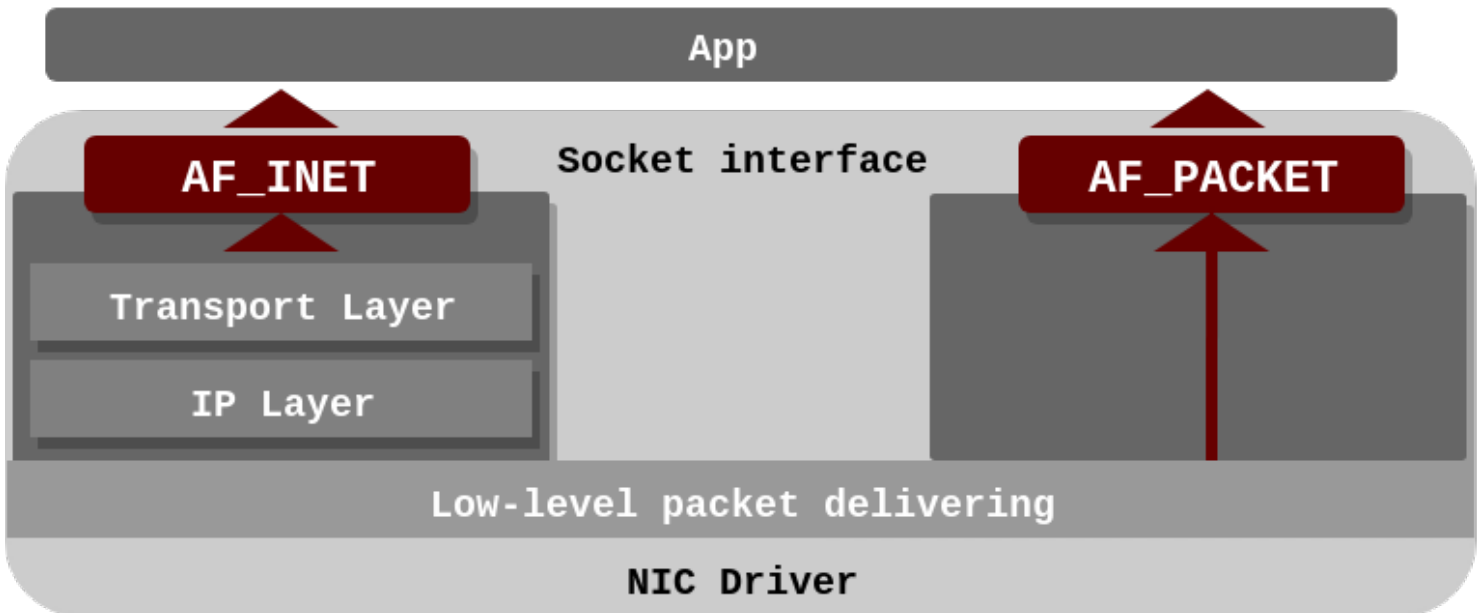
Not *transparent!*

Problem analysis

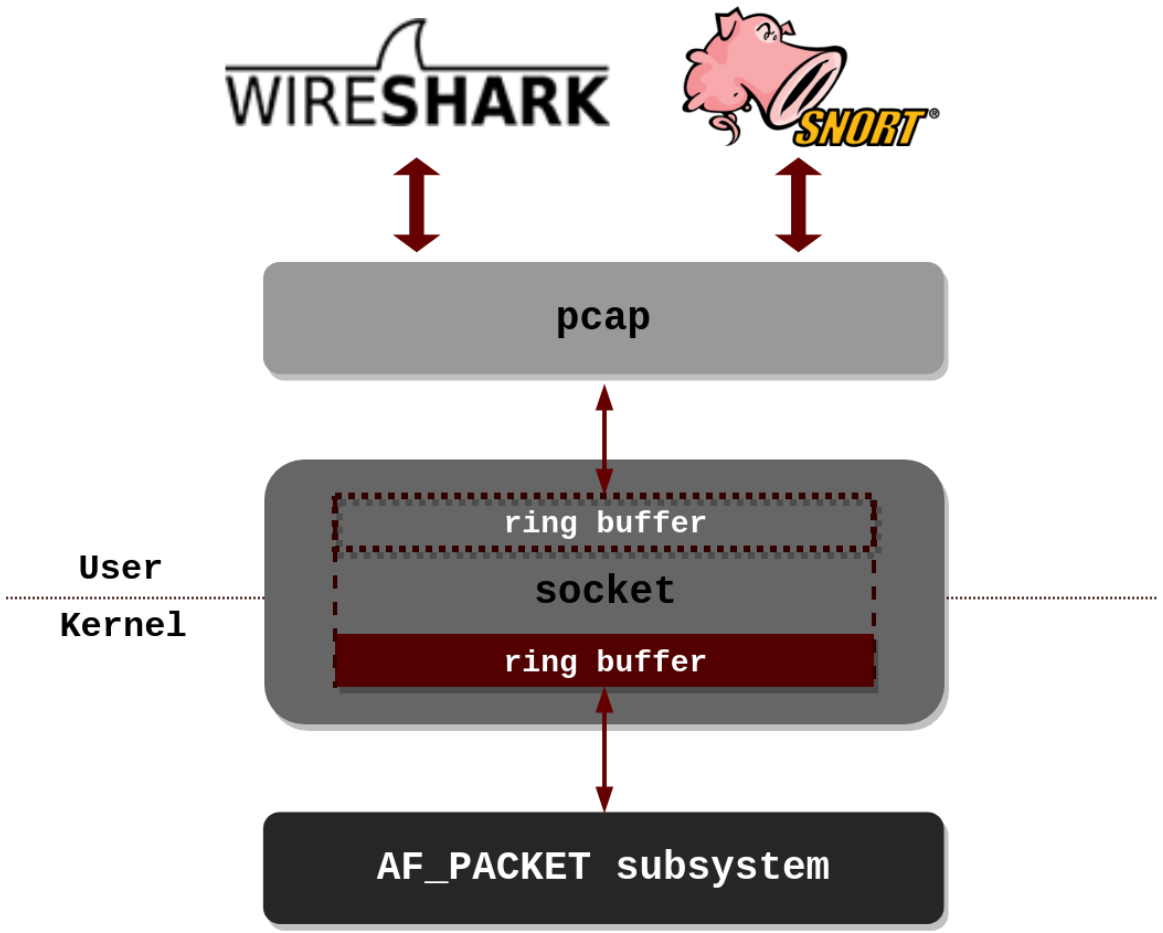
The AF_PACKET kernel subsystem

The `AF_PACKET` implements the networking domain of the raw sockets:

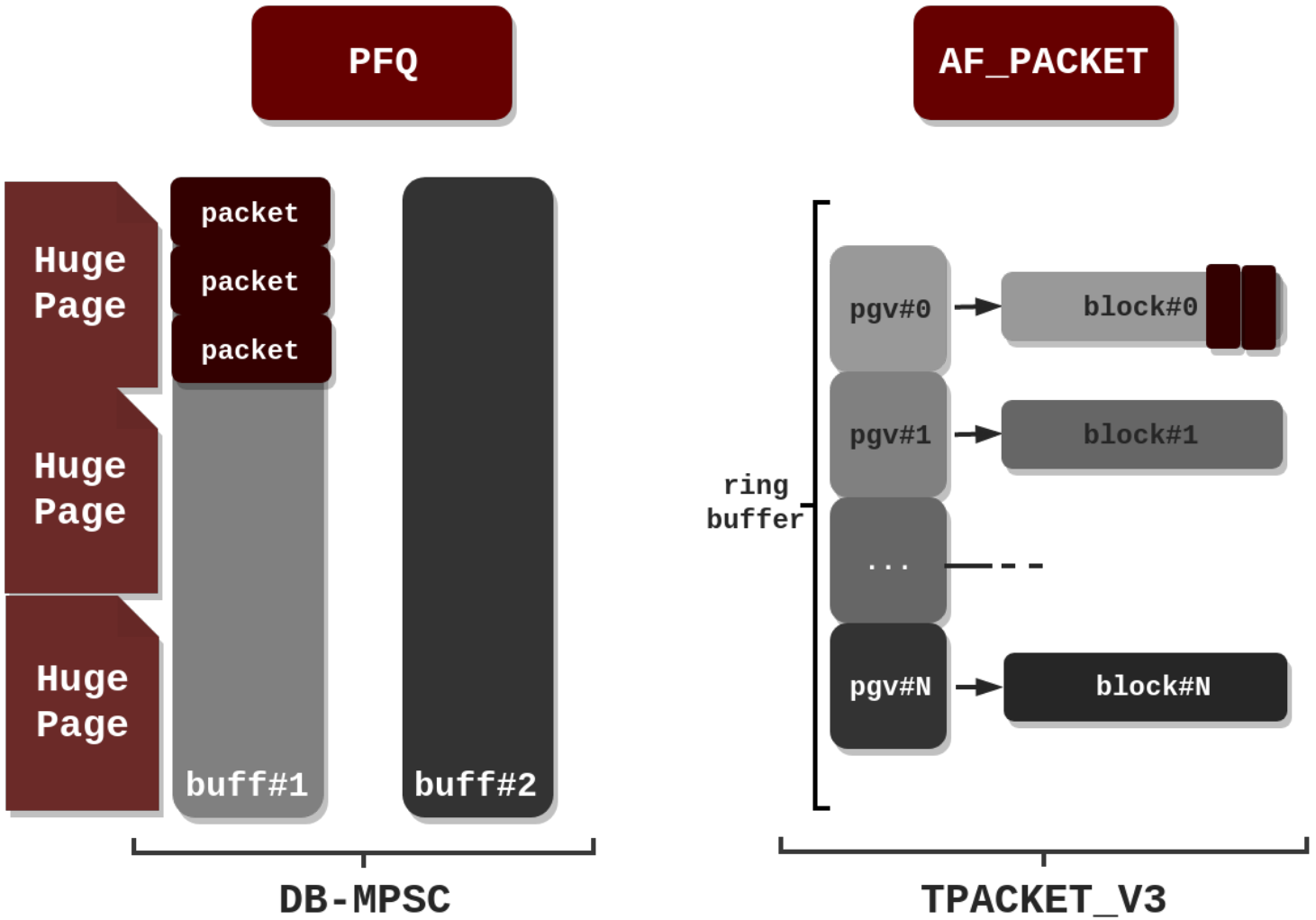
- low-level access to the network interface



Traffic analysis in Linux



PFQ vs AF_PACKET



PFQ vs AF_PACKET

Premises:

- the Linux kernel **does not use Huge Pages** in the buffer reception
- PFQ that optimizes the packet capture **uses Huge Pages**

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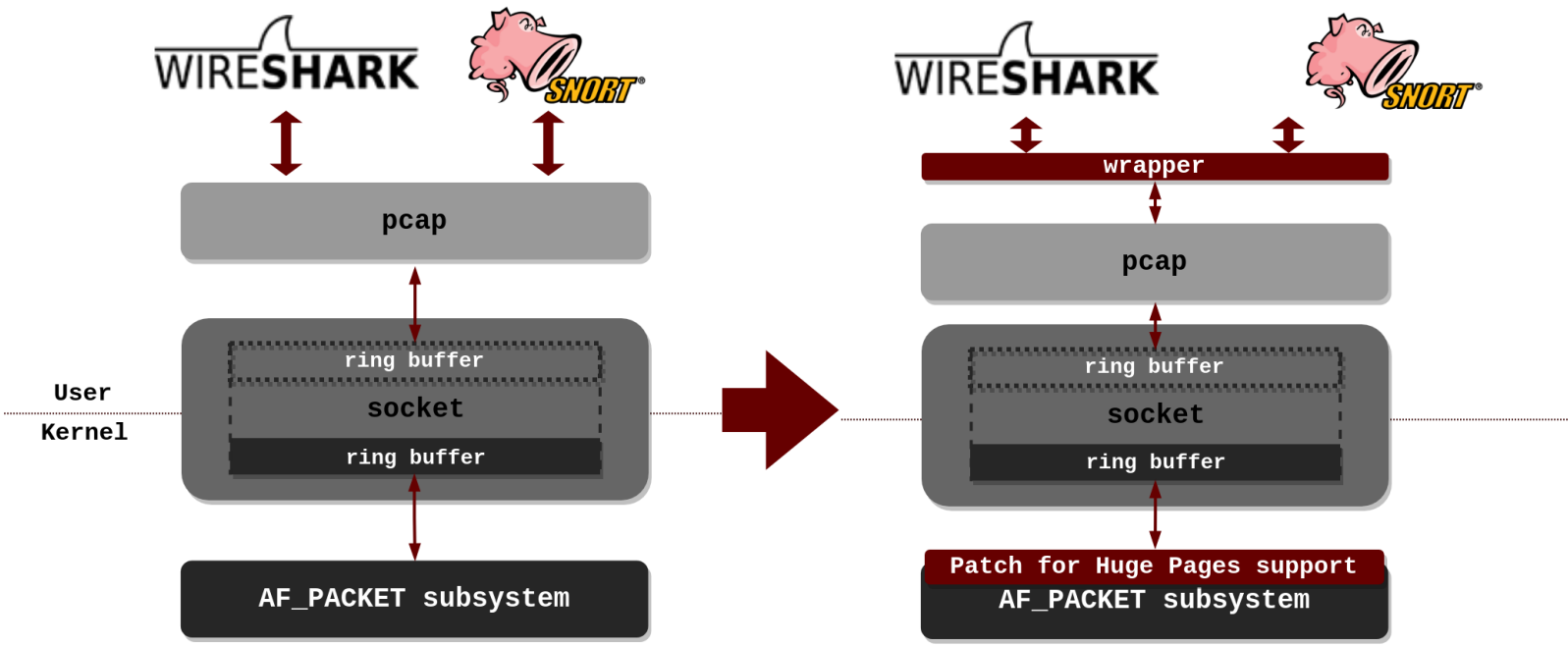
Our question

Can make sense introducing a buffer allocation backed with the Huge Pages in the AF_PACKET domain?

Proposed solution

Our solution



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  - `pcap`

Current block allocation policy

Attempts of block allocation in order of preference:

1. physically contiguous **direct** memory request
2. only virtually contiguous memory request
3. physically contiguous forced memory request

New block allocation policies

One allocation policy among the following can be forced:

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If not specified, the original allocation policy is performed.

Integration with the `pcap` library

Making cascaded modifications to a library is a costly operation.

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- using **environment variables** to transfer not supported information

No need to recompile the pcap library!

Results

Test environment - sender side

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- rate at 10 Gb/s

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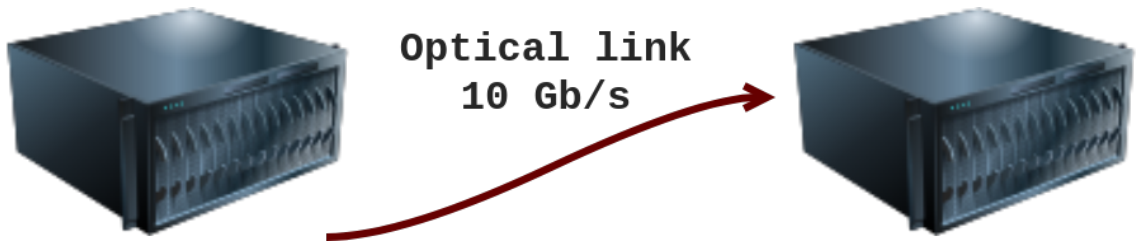
- variable delay factor every 100 packets
  - 1000 multiplications repeated for *delay factor* times
  - buffer overloading to simulate traffic analysis peaks
- statistics computed on 10 runs for each configuration

Test machines



Packet generator

- CPU: Intel® Xeon E5
- NIC: Intel® 82599ES

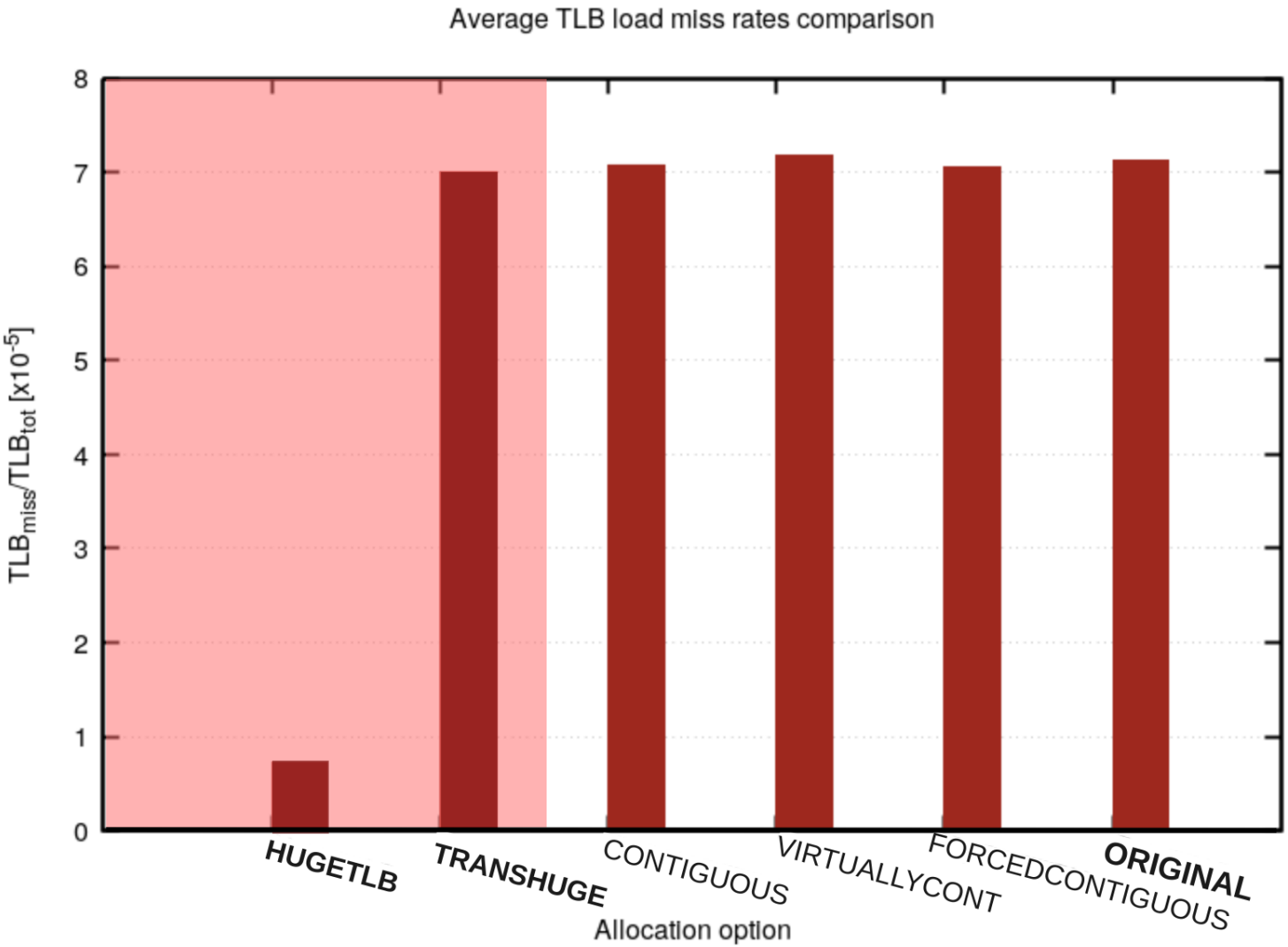
Packet receiver

- CPU: Intel® Xeon E5
- NIC: Intel® X710

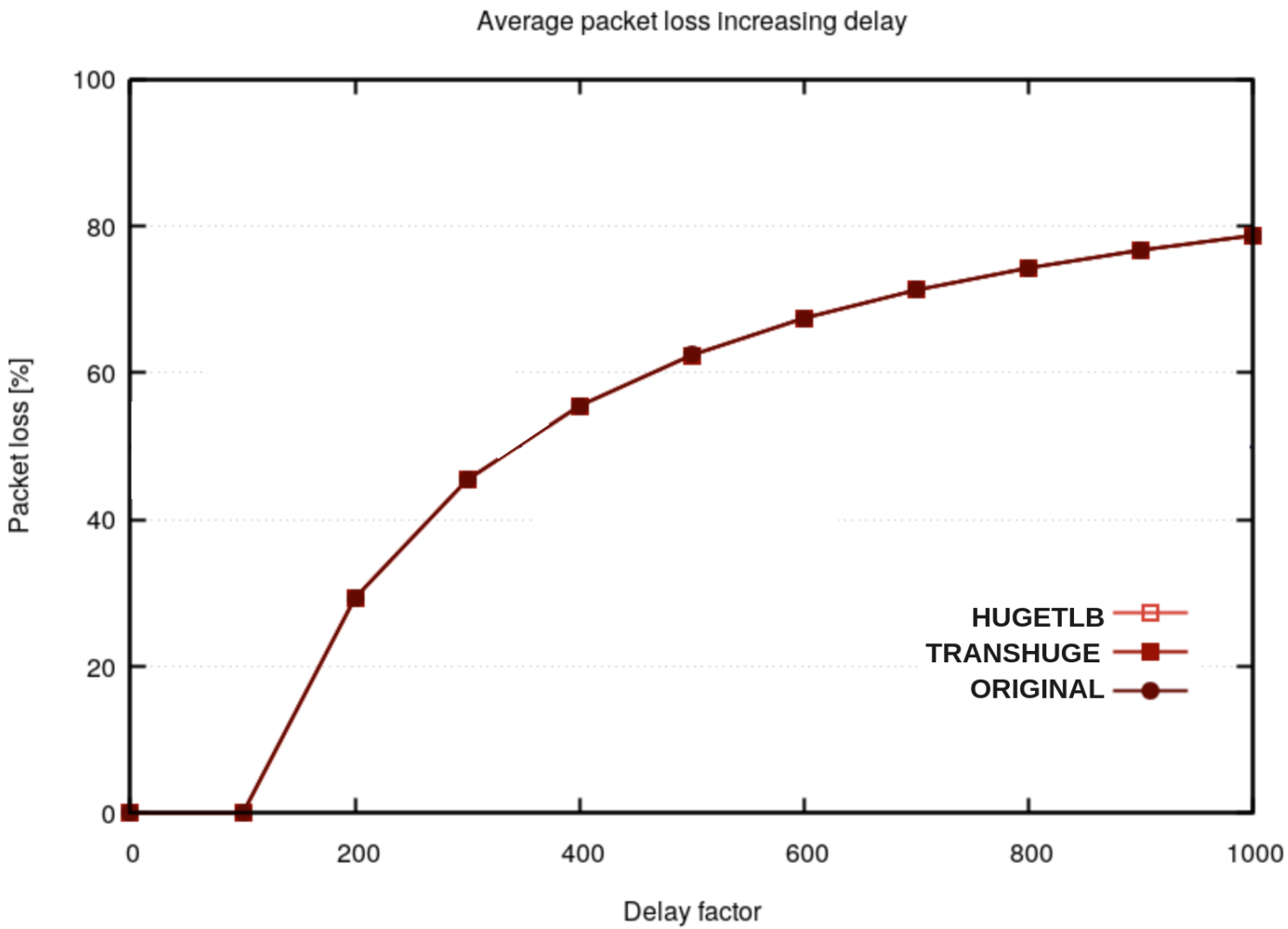
Performance measurements

- **Performance Measurement Unit** provides hardware-based counters
- **perf** tool analyser to measure events:
  - **CPU cycles**
  - **TLB accesses**
  - **TLB misses**
- **Time Stamp Counter** register
  - **CPU cycles** counter in Intel x86

TLB load miss rates



Packet loss



Conclusions

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Impact analysis of two new allocation policies based on **huge pages**:

- **compatibility** with widespread applications
- effective **improvement** in terms of TLB miss rates
- **no gain** in terms of packet loss rate

Thank You for listening!

Laura Trivelloni