ShieldBox

Secure Middleboxes using Shielded Execution

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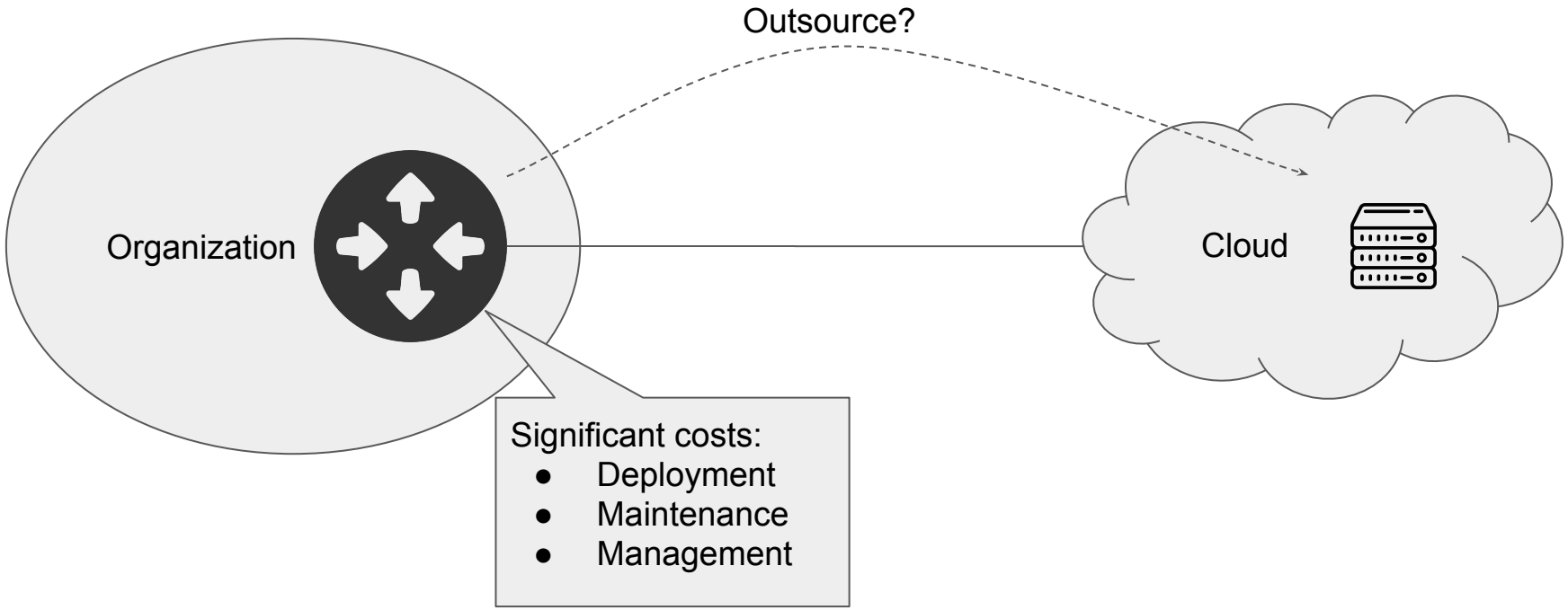
ACM SIGCOMM SOSR 2018

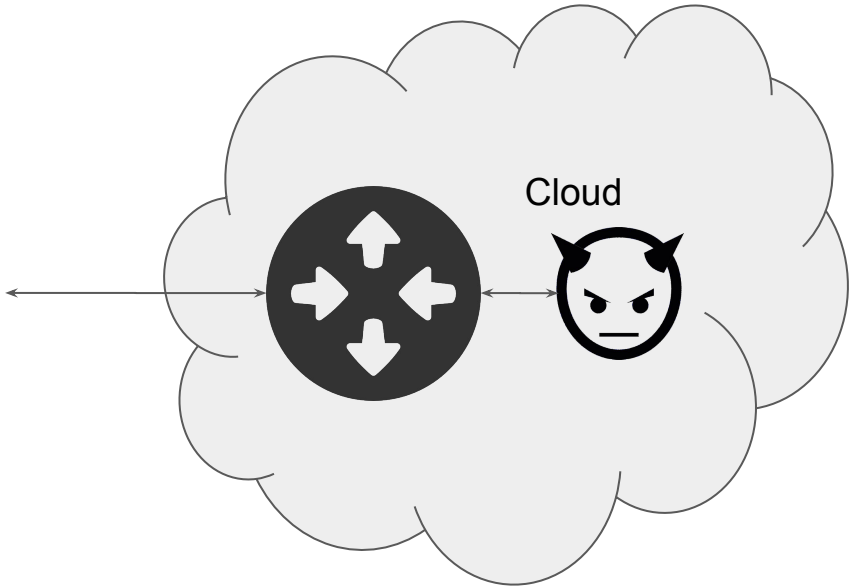
Middleboxes in the Cloud



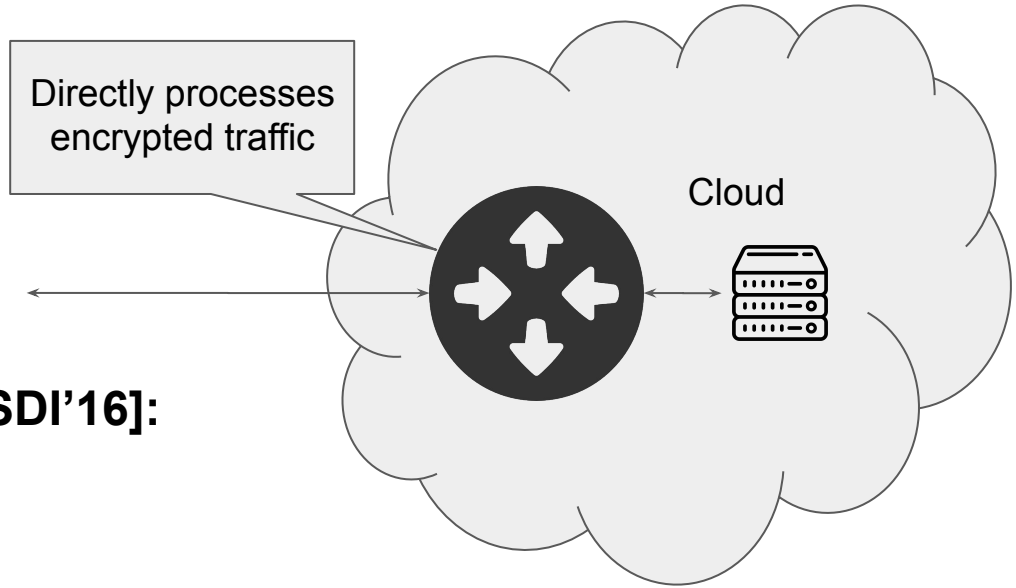
Security Issues

- Cheap computation resources ☺
- NFV advances ☺
- Low trust environment ☹

  - Observe private data
  - Extract encryption keys
  - Learn configuration



State-Of-the-Art Systems



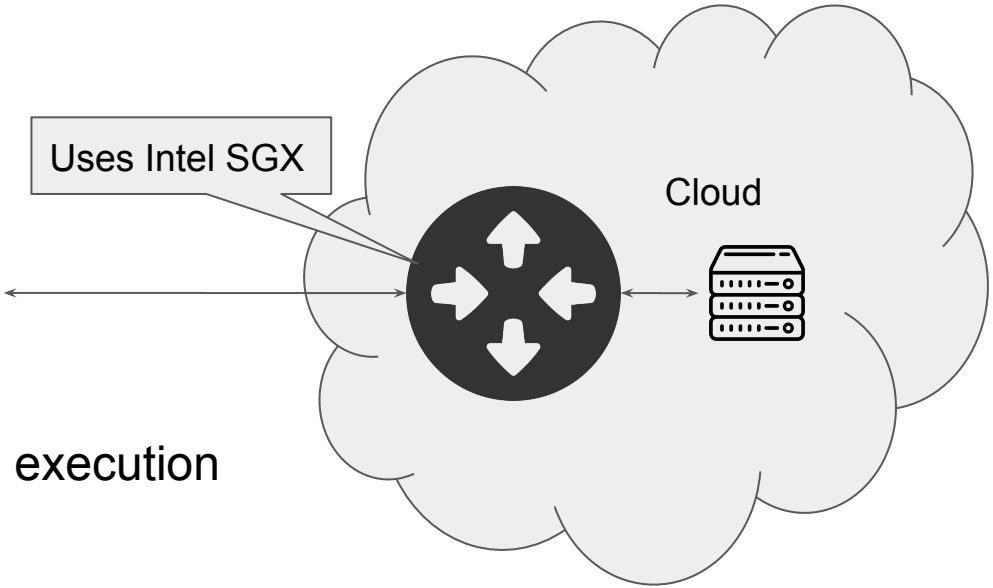
Blindbox [SIGCOMM'15], Embark [NSDI'16]:

- High performance overhead ☹
- Offer limited functionality ☹

Problem Statement

How to securely outsource middleboxes to the untrusted cloud without sacrificing performance while supporting a wide range of NFs?

ShieldBox



ShieldBox:

- Middlebox framework with shielded execution

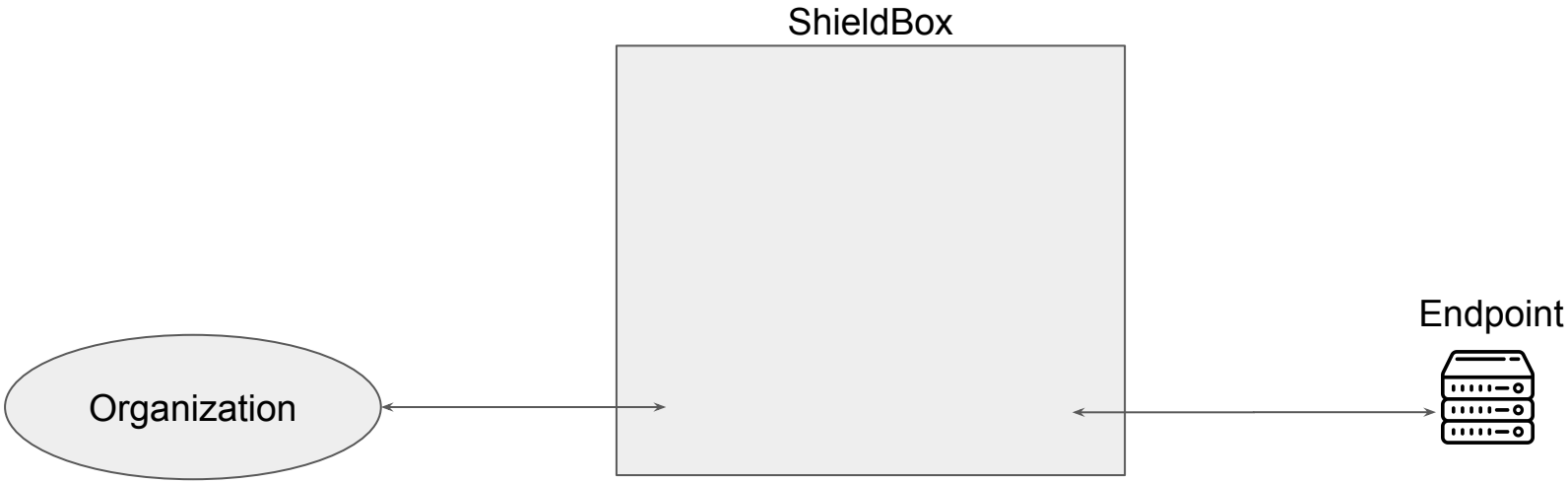
Design Goals

- **Security** - strong confidentiality and integrity guarantees
- **Performance** - near-native throughput and latency
- **Generality** - supports a wide range of NFs
- **Transparency** - portable, configurable, and verifiable architecture

Outline

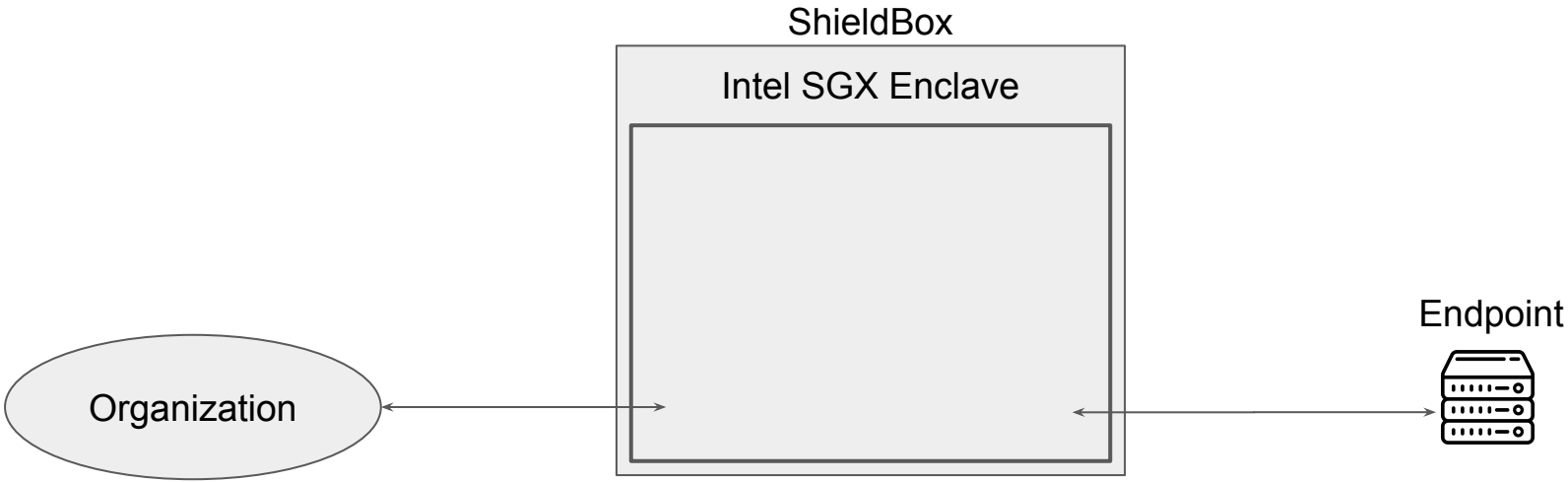
- ~~Motivation~~
- Design
- Evaluation
- Summary

System Overview



	Security	
	Performance	
	Usability	

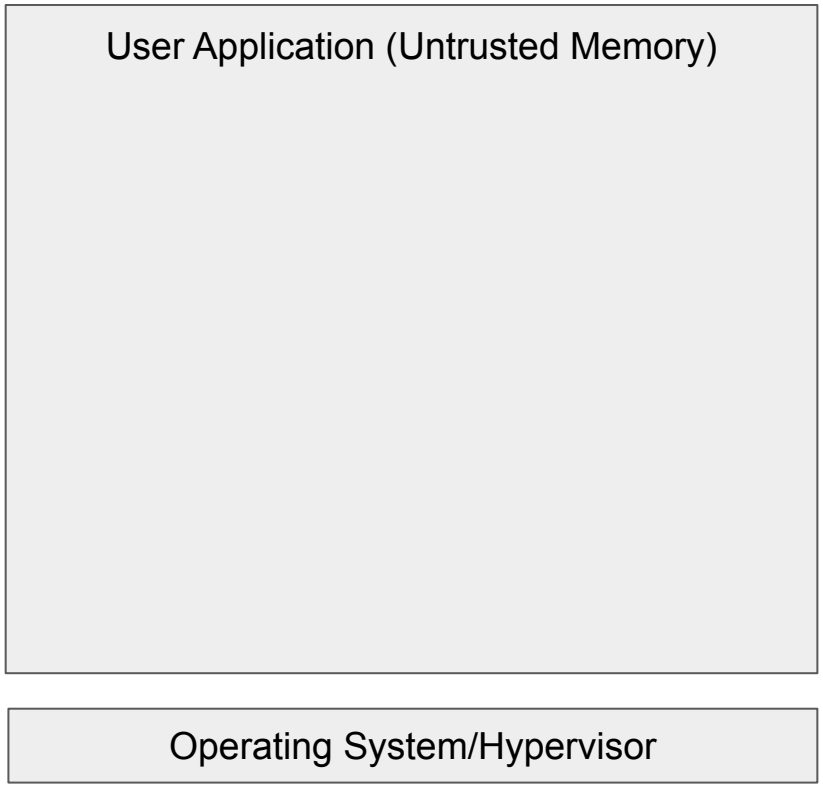
System Overview



✔	Security	Intel SGX
	Performance	
	Usability	

Background: Intel SGX

Intel SGX allows creation and management of **enclaves**.



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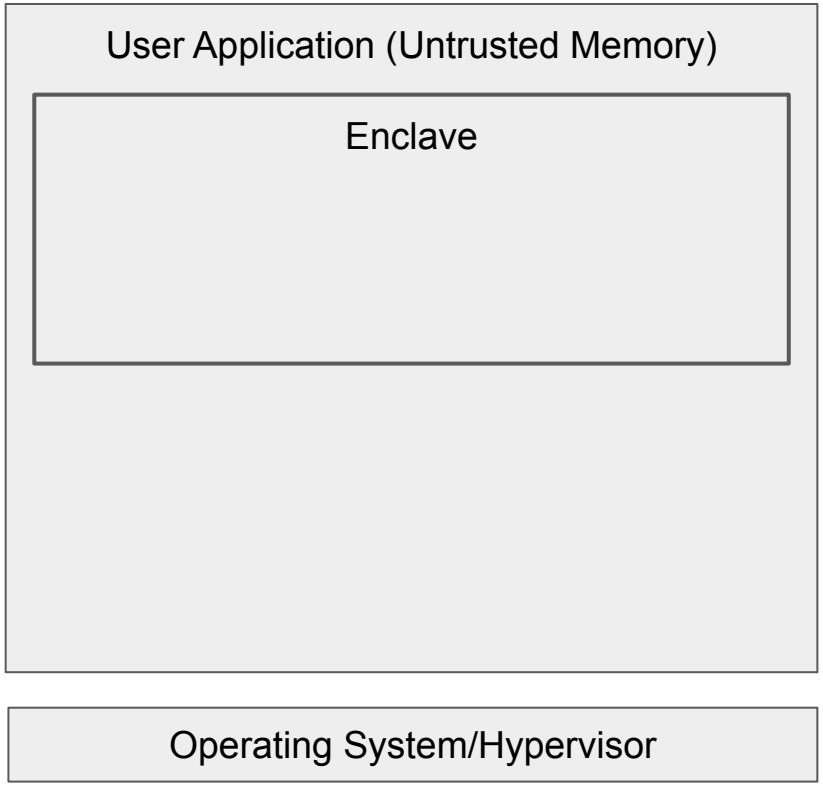

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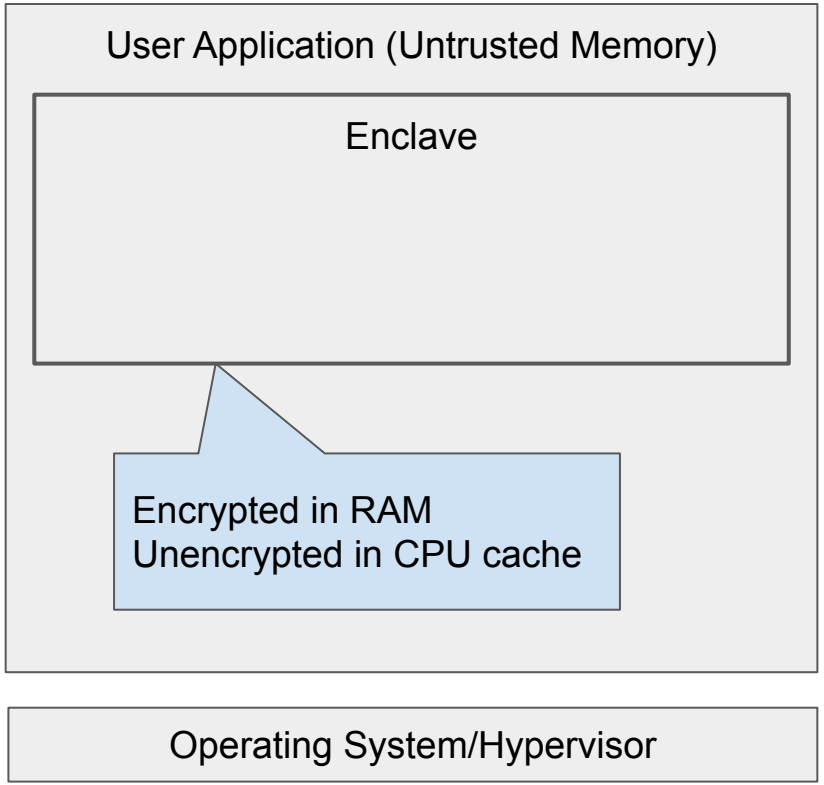

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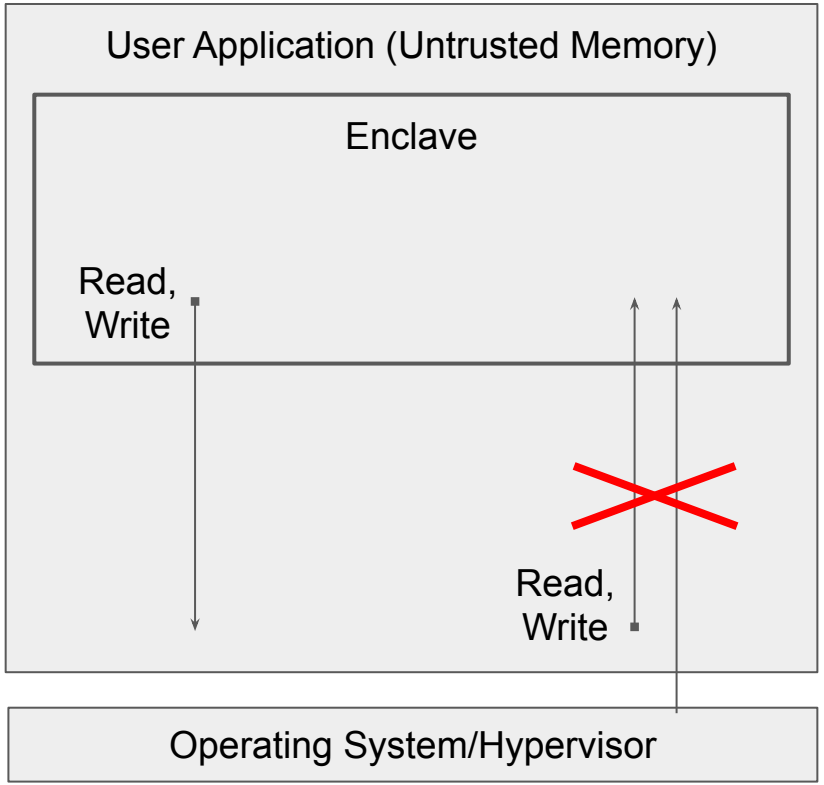

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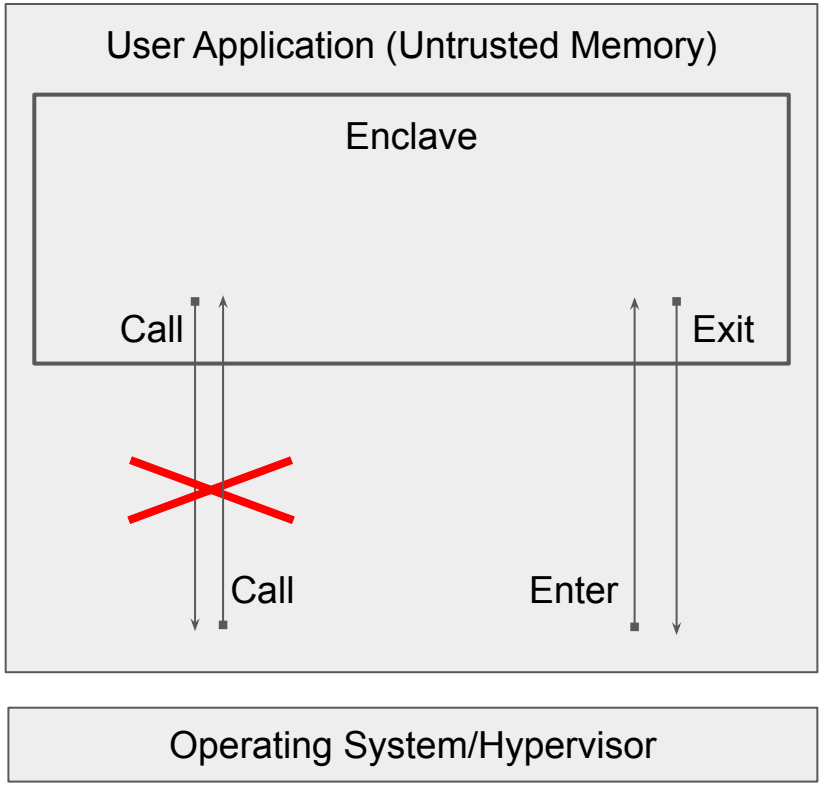

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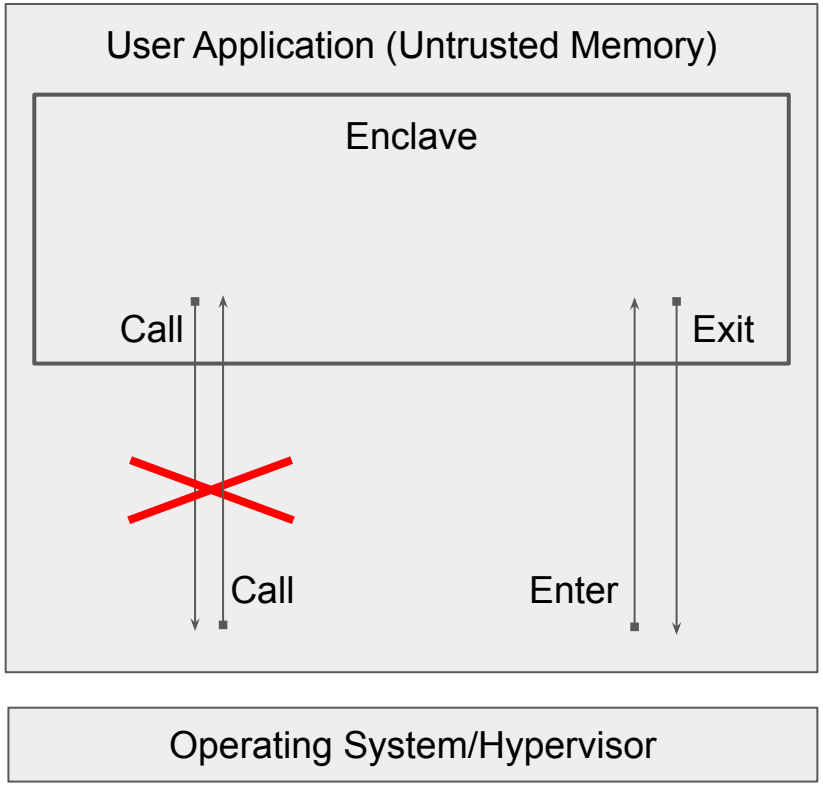

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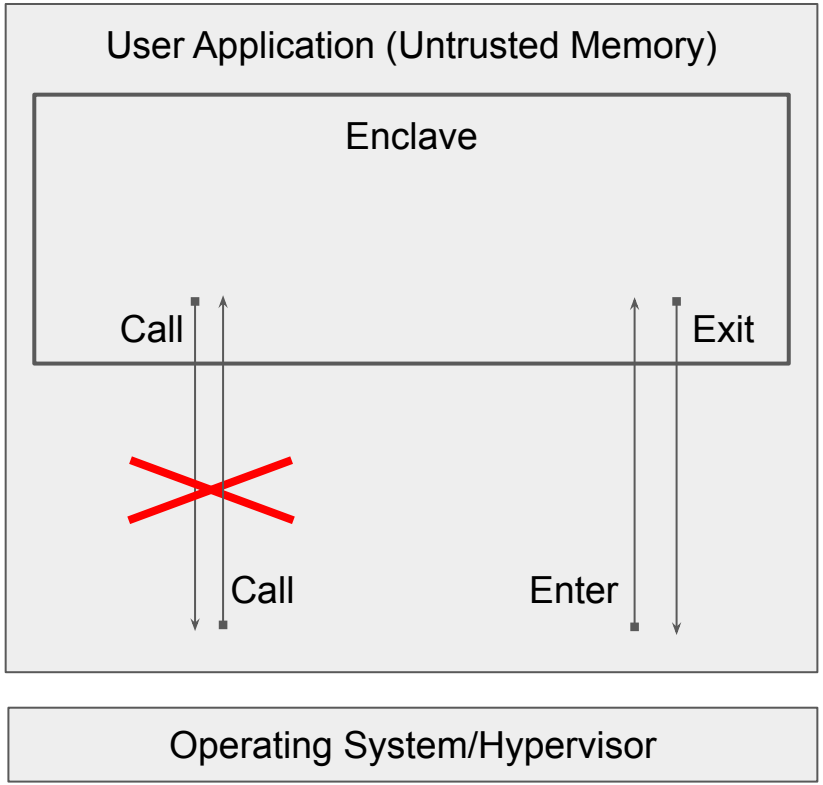
- High overheads for:
  - Secure memory paging
  - Enclave entry/exit



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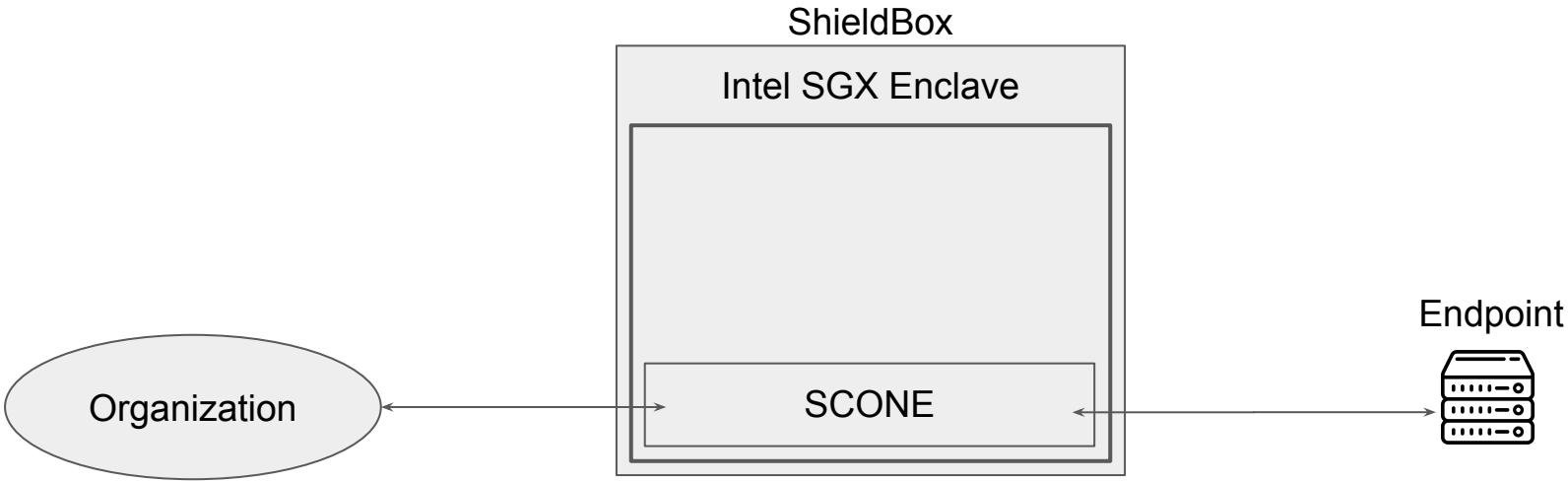

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	Performance	
	Usability	

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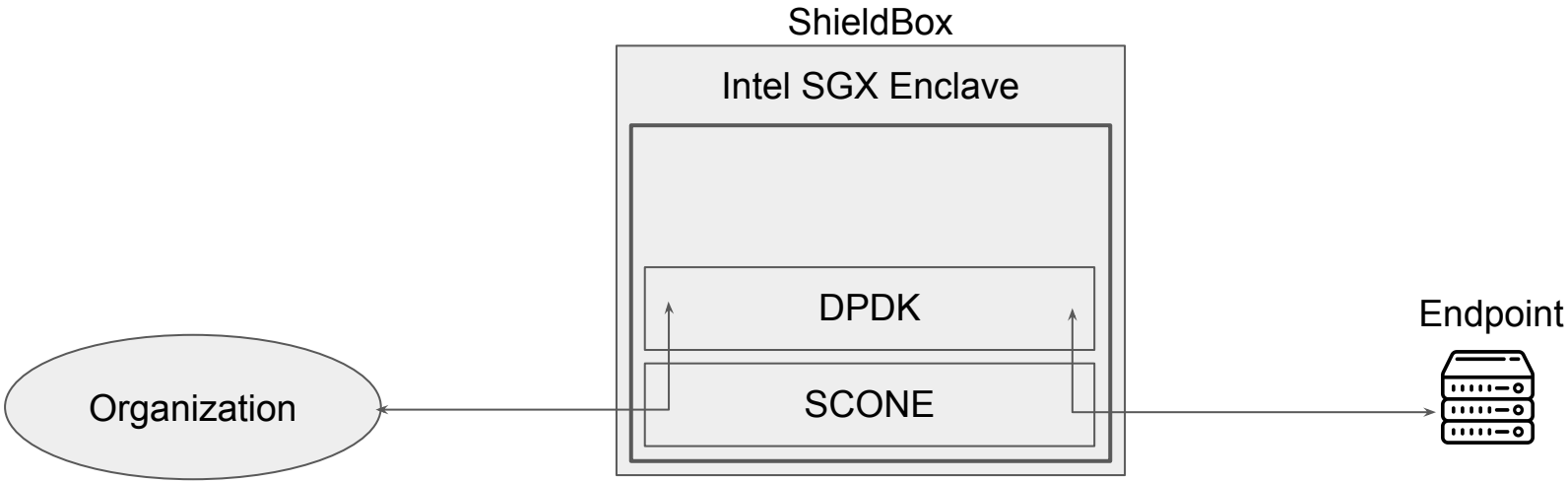

✔	Security	Intel SGX & SCONE [OSDI'16]
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	Usability	

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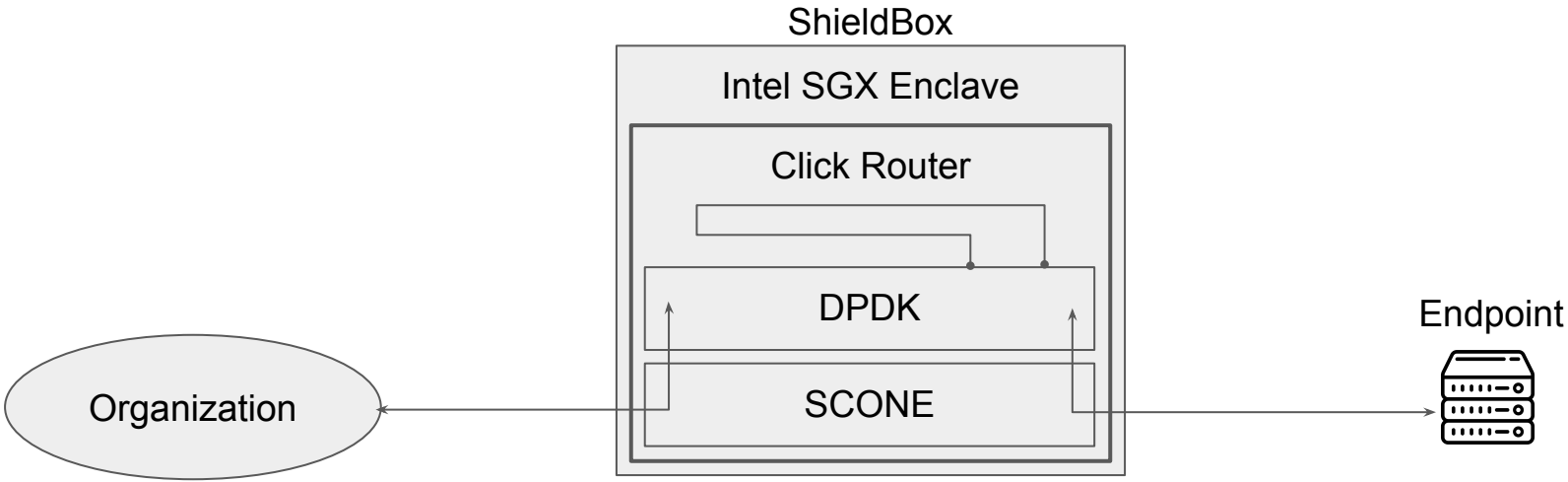

✔	Security	Intel SGX & SCONE [OSDI'16]
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✔	Usability	Click Router [TOCS'00]

Partitioning ShieldBox

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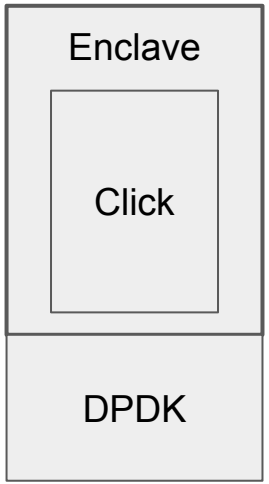

1. DPDK outside - ecalls
   - High overhead ☹
   - Reengineering ☹
   - Reduced TCB ☺

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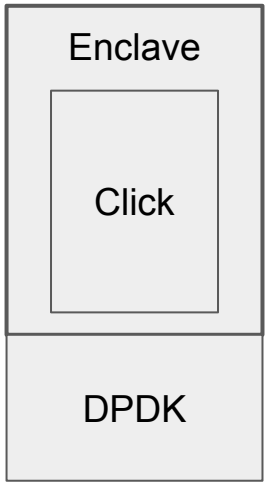

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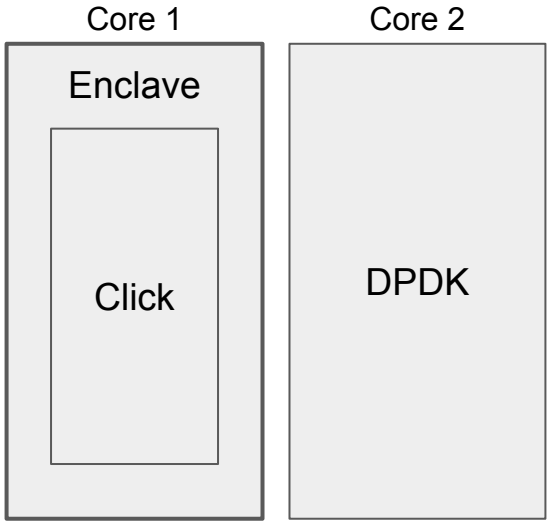
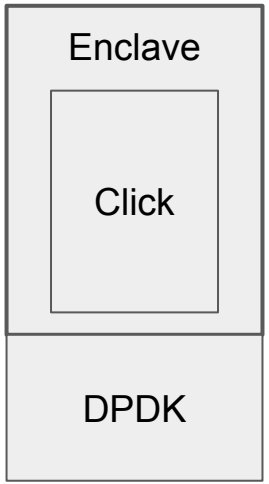


2. DPDK outside - sibling core
   - Overhead in some cases ☹
   - Reengineering ☹
   - Reduced TCB ☺

Partitioning ShieldBox



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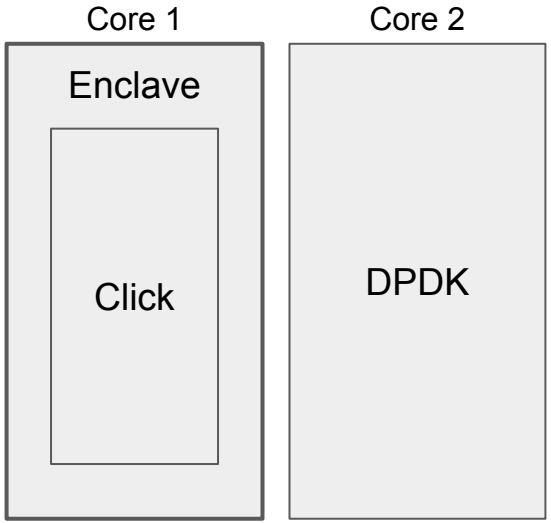

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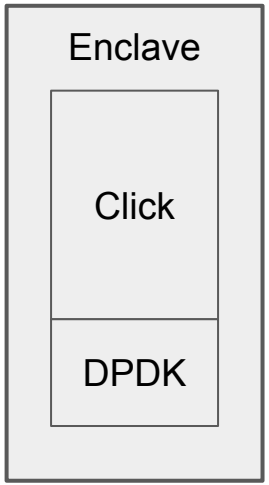
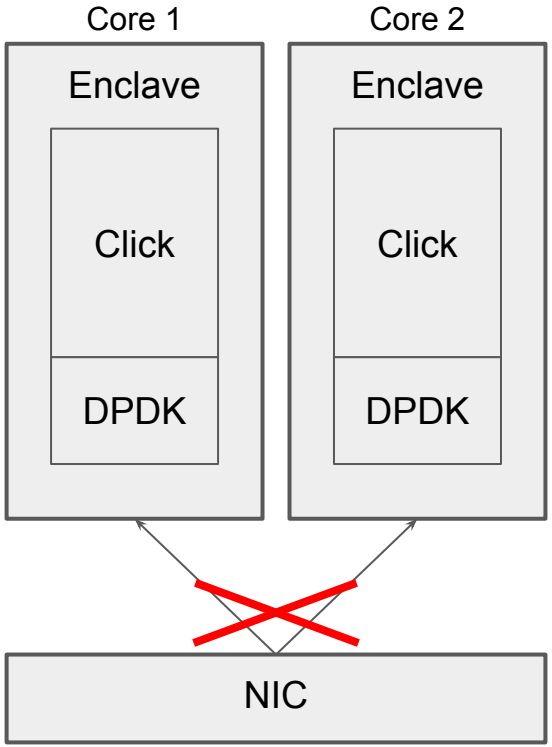


3. DPDK inside enclave
   - Low overhead ☺
   - No reengineering ☺
   - Increased TCB ☹

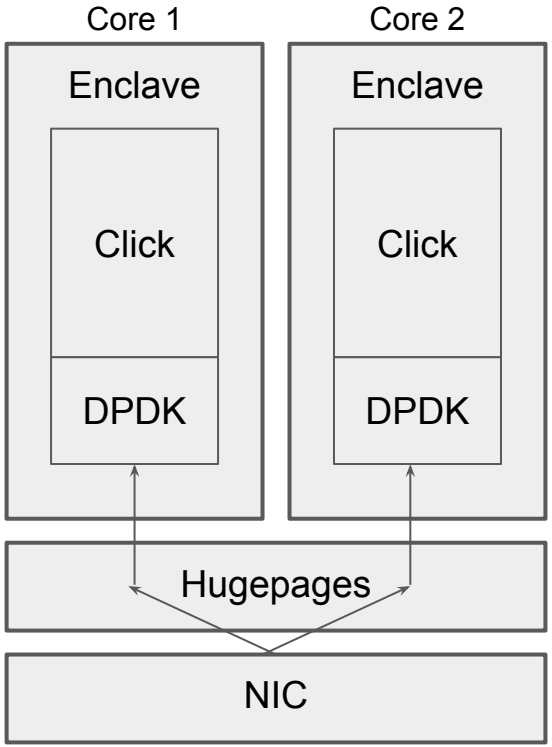
Partitioning ShieldBox - DPDK

- NIC can’t deliver packets directly to enclave.



Partitioning ShieldBox - DPDK

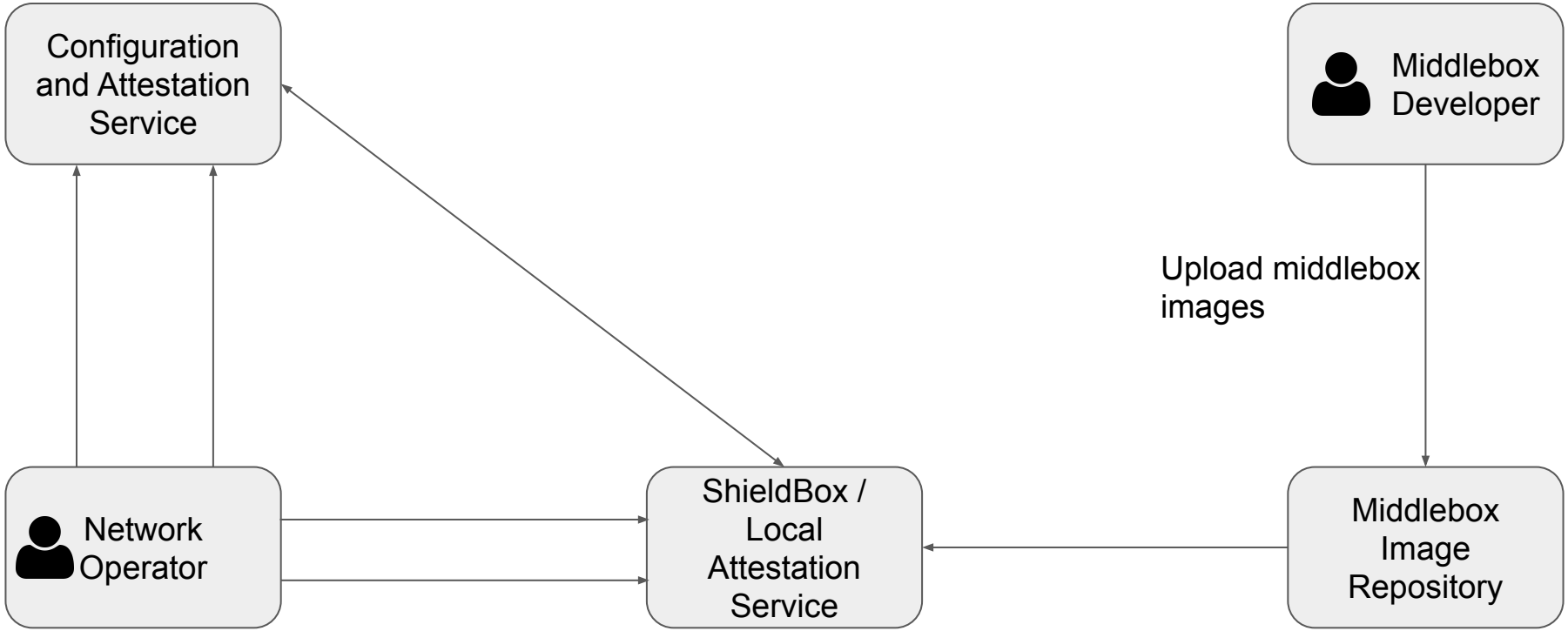
- NIC can’t deliver packets directly to enclave:
  - Allocate hugepage memory outside
  - Packets and mbufs delivered to hugepages



ShieldBox Features

- **Security**
  - Iago Attack Protection
  - New Elements
  - Remote Attestation and Configuration System
- **Performance**
  - On-NIC Time Source
  - Optimizations over standard Click
- **Features**
  - Middlebox State Persistence
  - Network Function Chaining
  - New Elements

System Workflow with Remote Attestation



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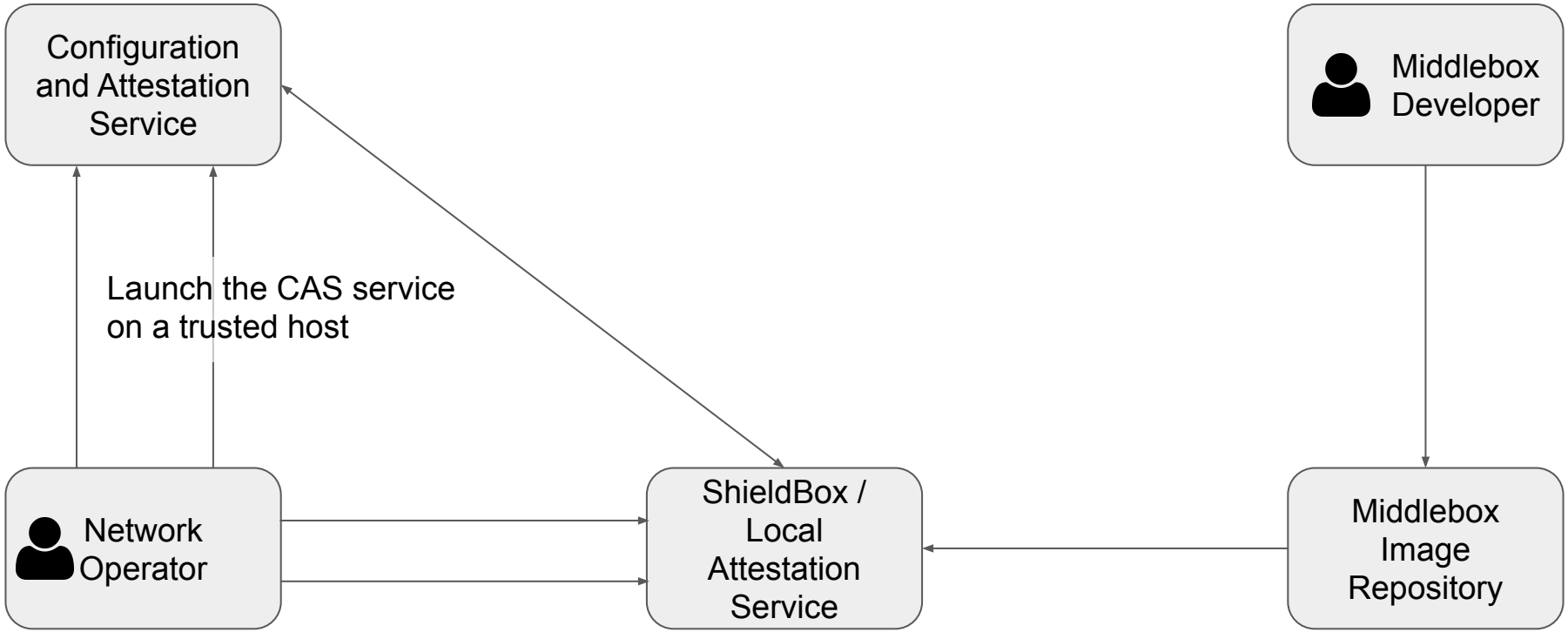

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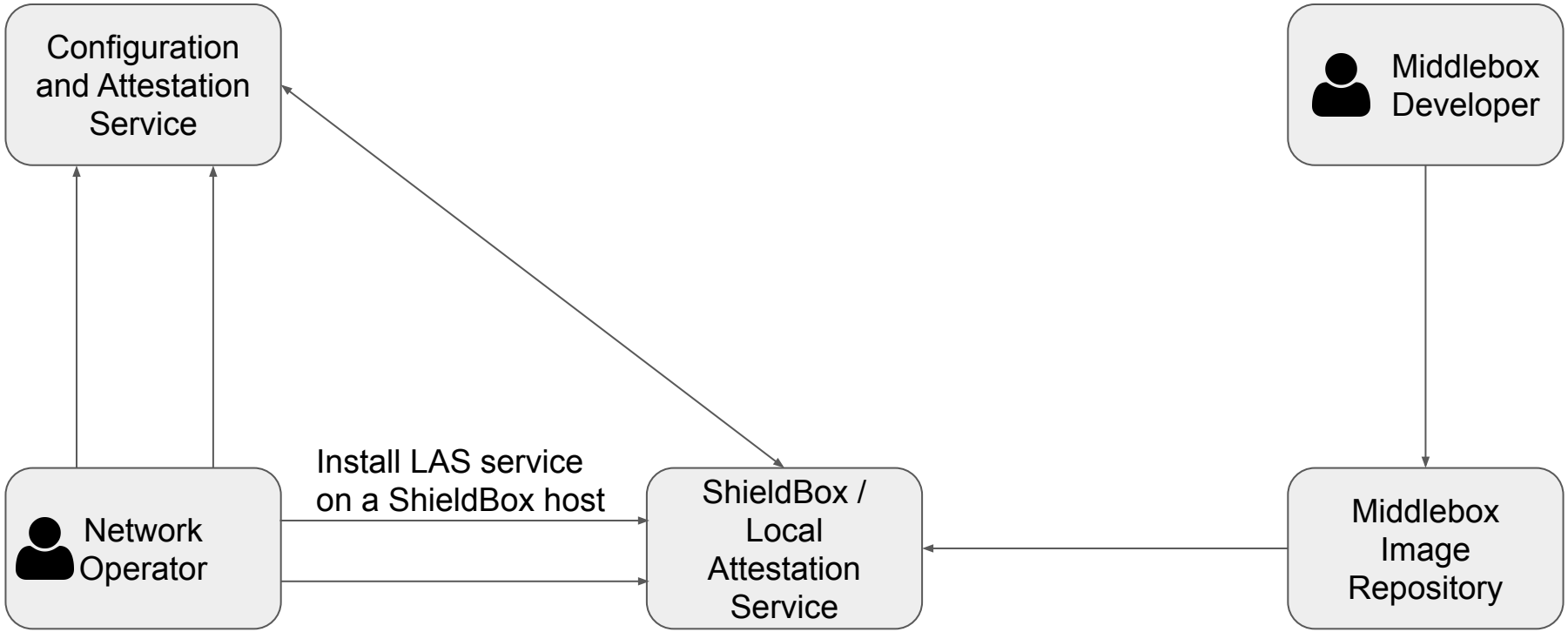

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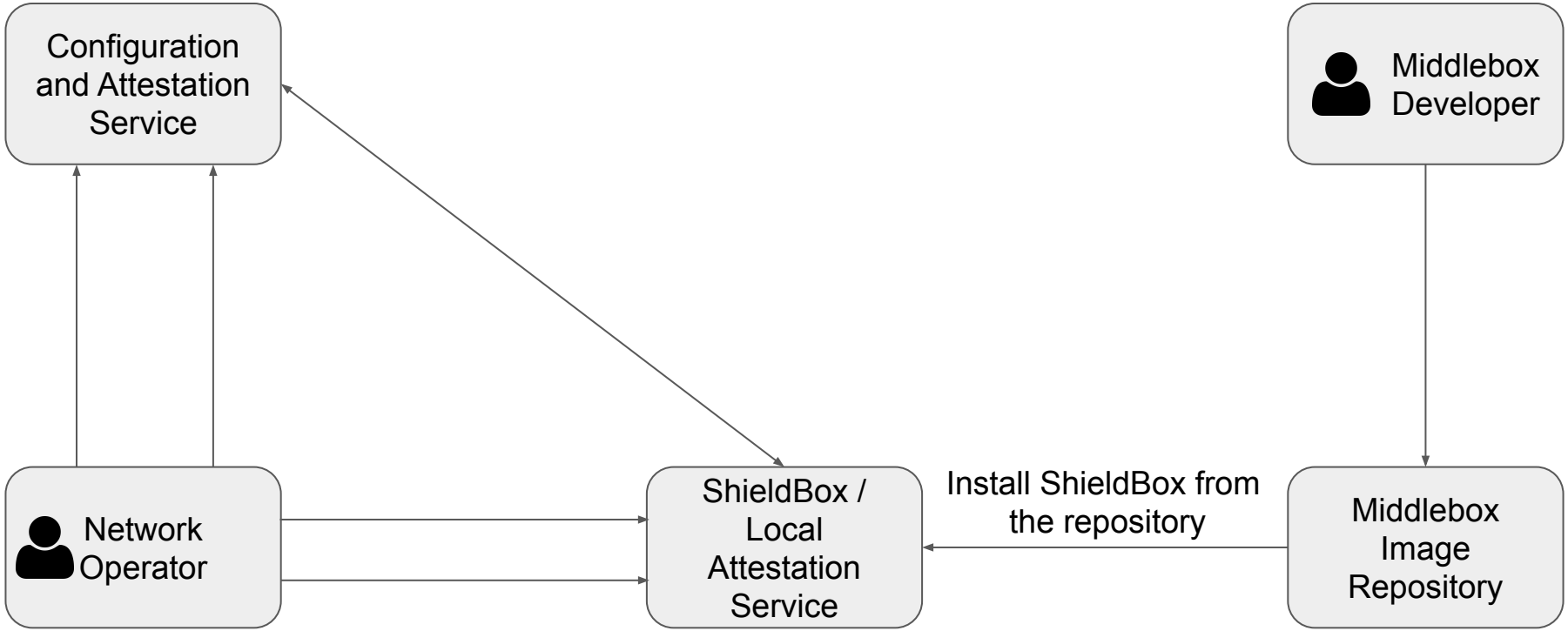

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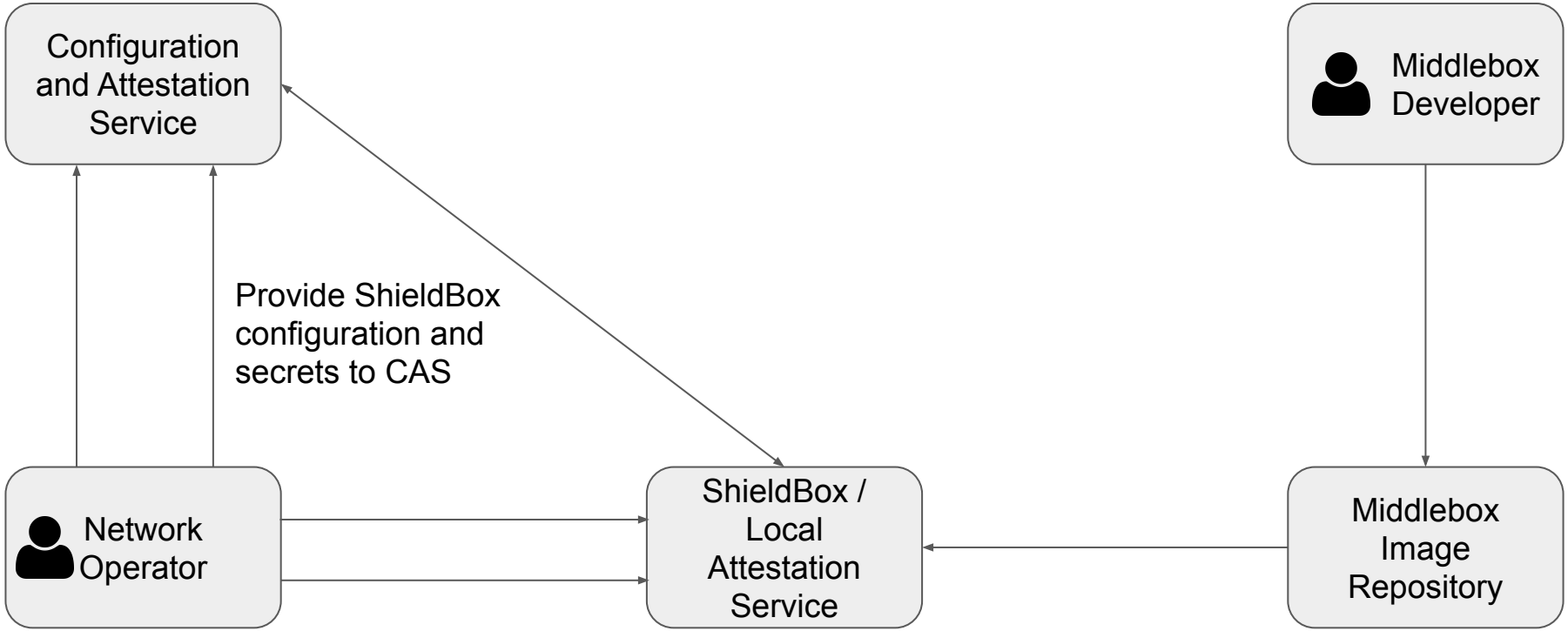

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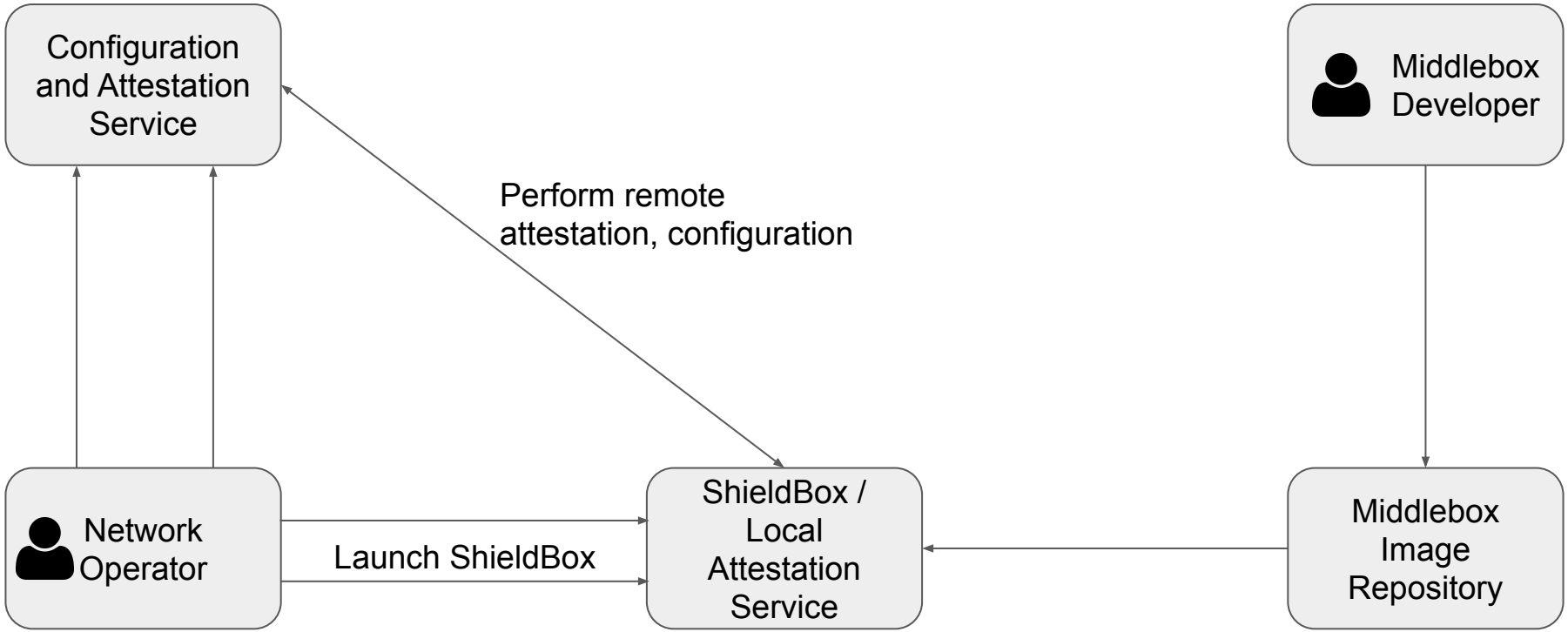
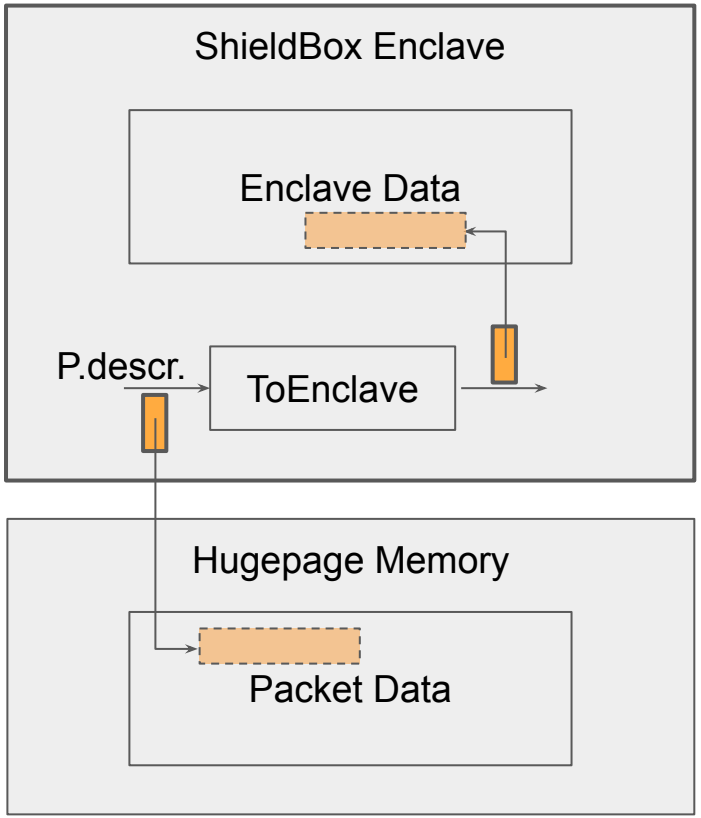


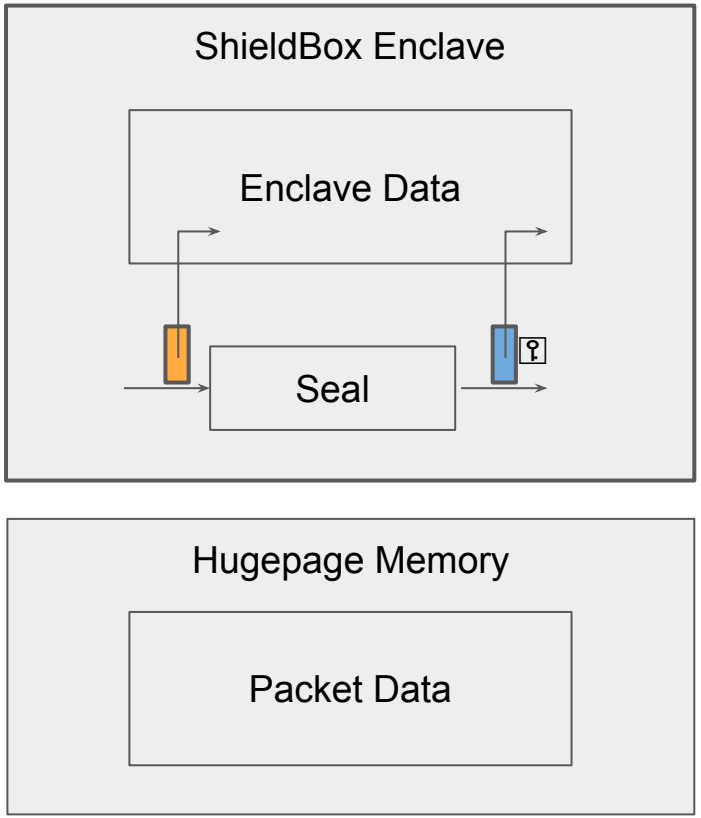
New Elements

- ToEnclave:
  - Copies packet data into enclave



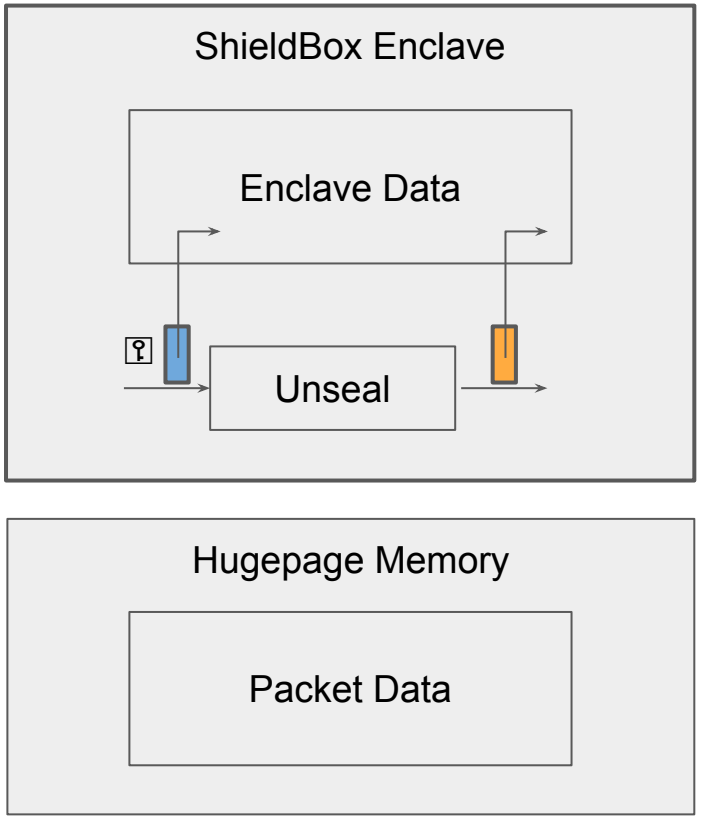
New Elements

- ToEnclave:
  - Copies packet data into enclave
- Seal:
  - Encrypts packet using AES-GCM



New Elements

- ToEnclave:
  - Copies packet data into enclave
- Seal:
  - Encrypts packet using AES-GCM
- Unseal:
  - Decrypts an AES-GCM encrypted packet



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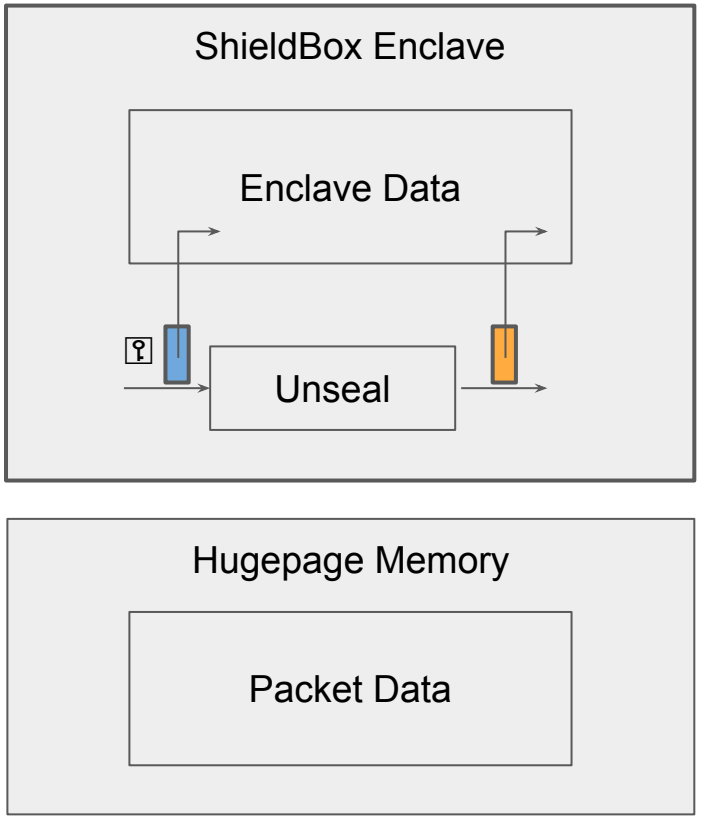
- Unseal:
  - Decrypts an AES-GCM encrypted packet
- HyperScan, DPDKRing, StateFile:
  - See paper!



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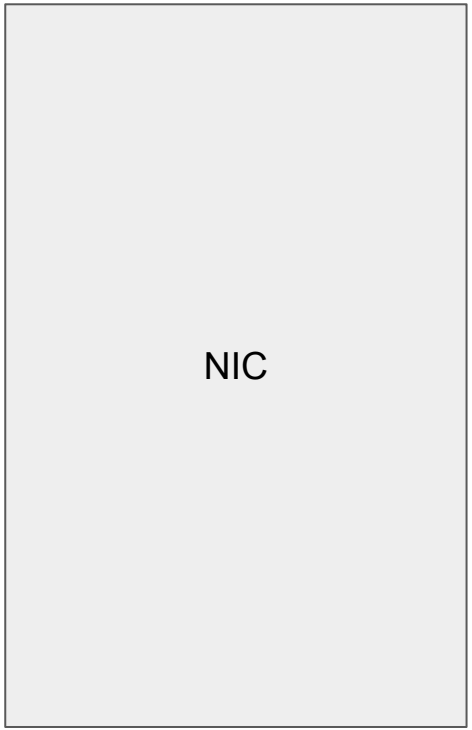

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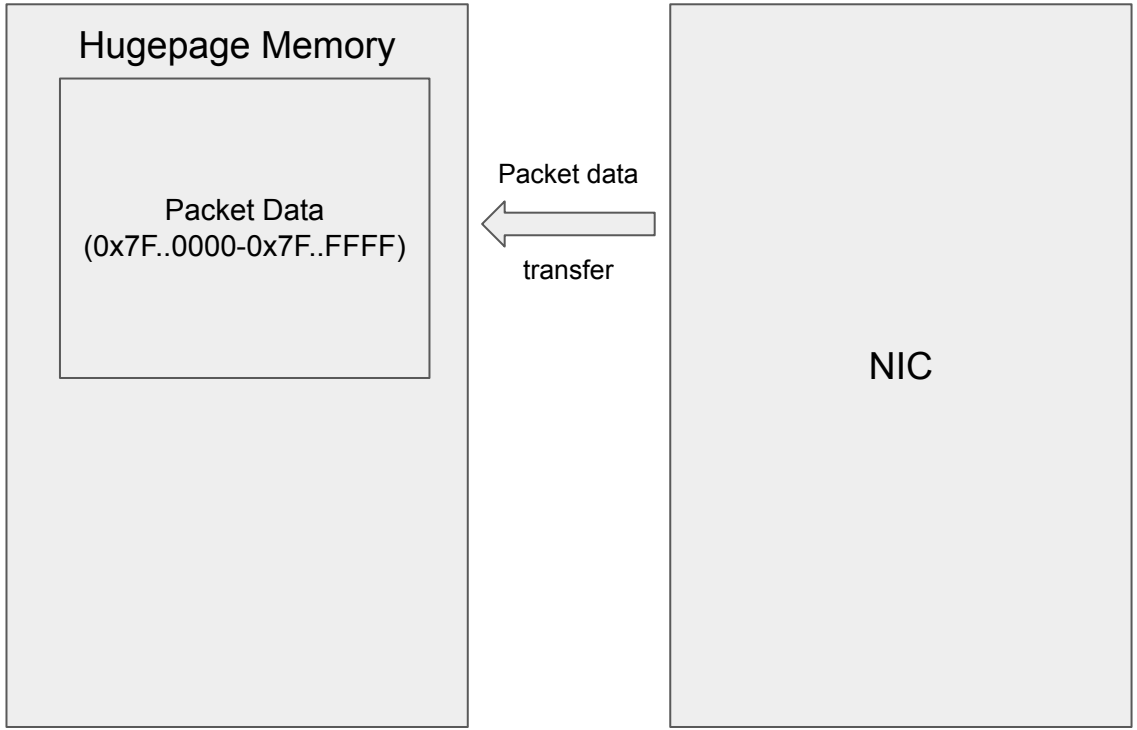

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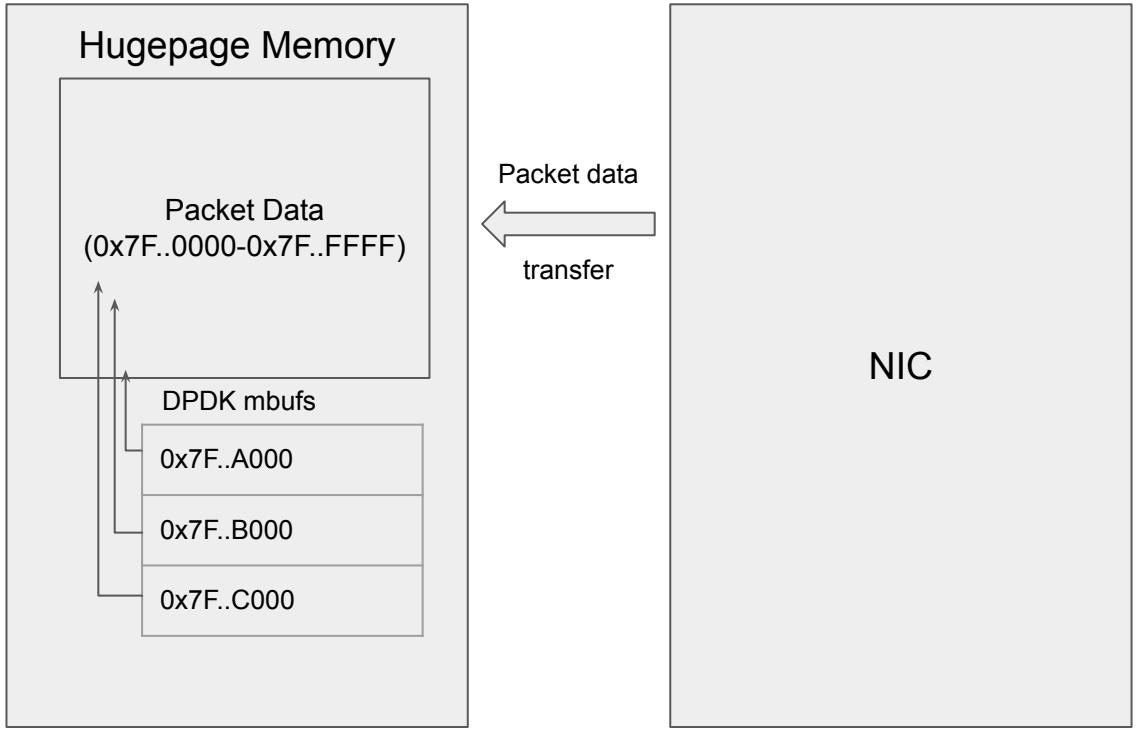

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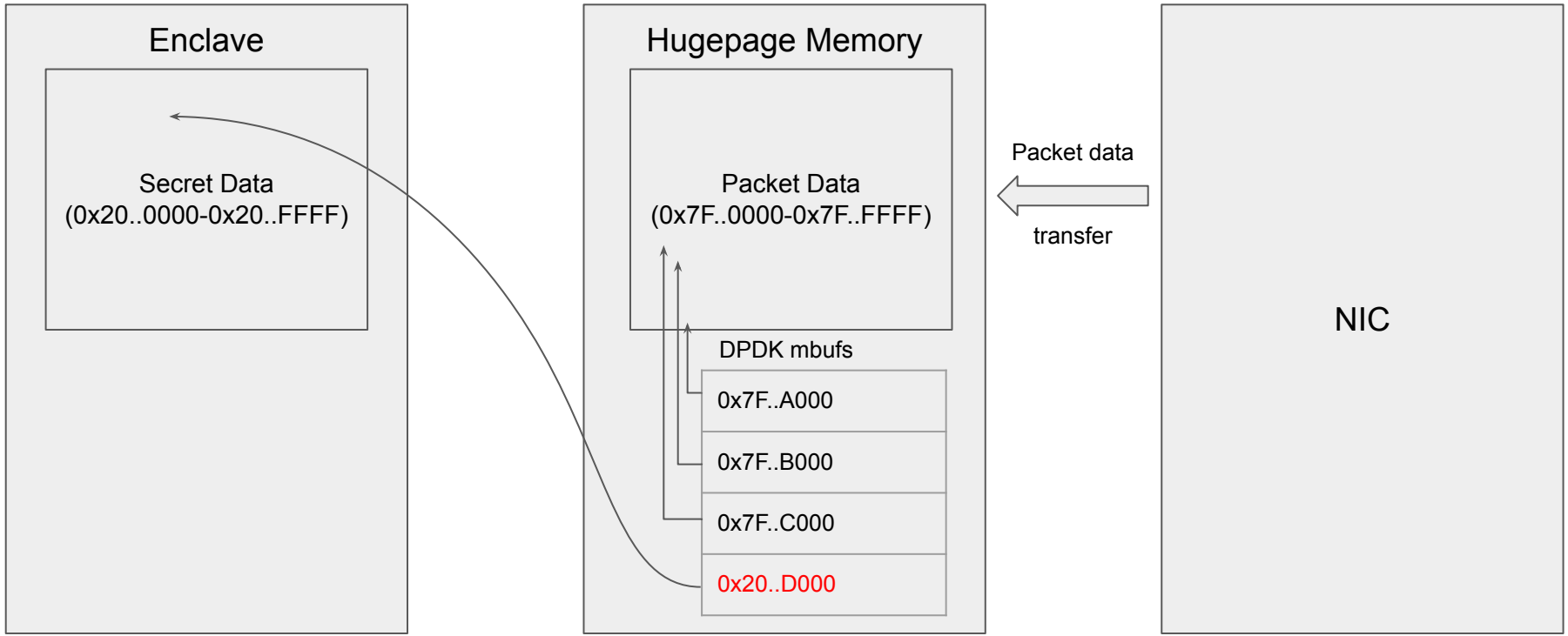

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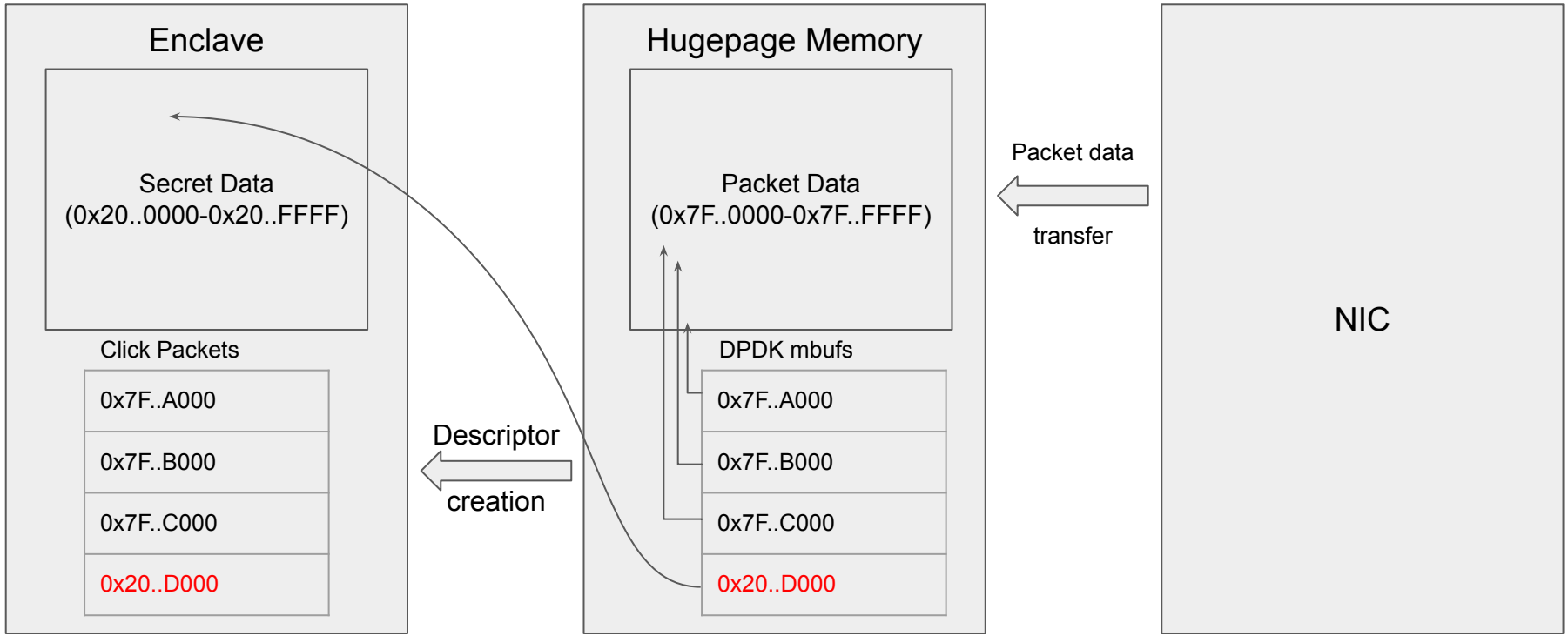

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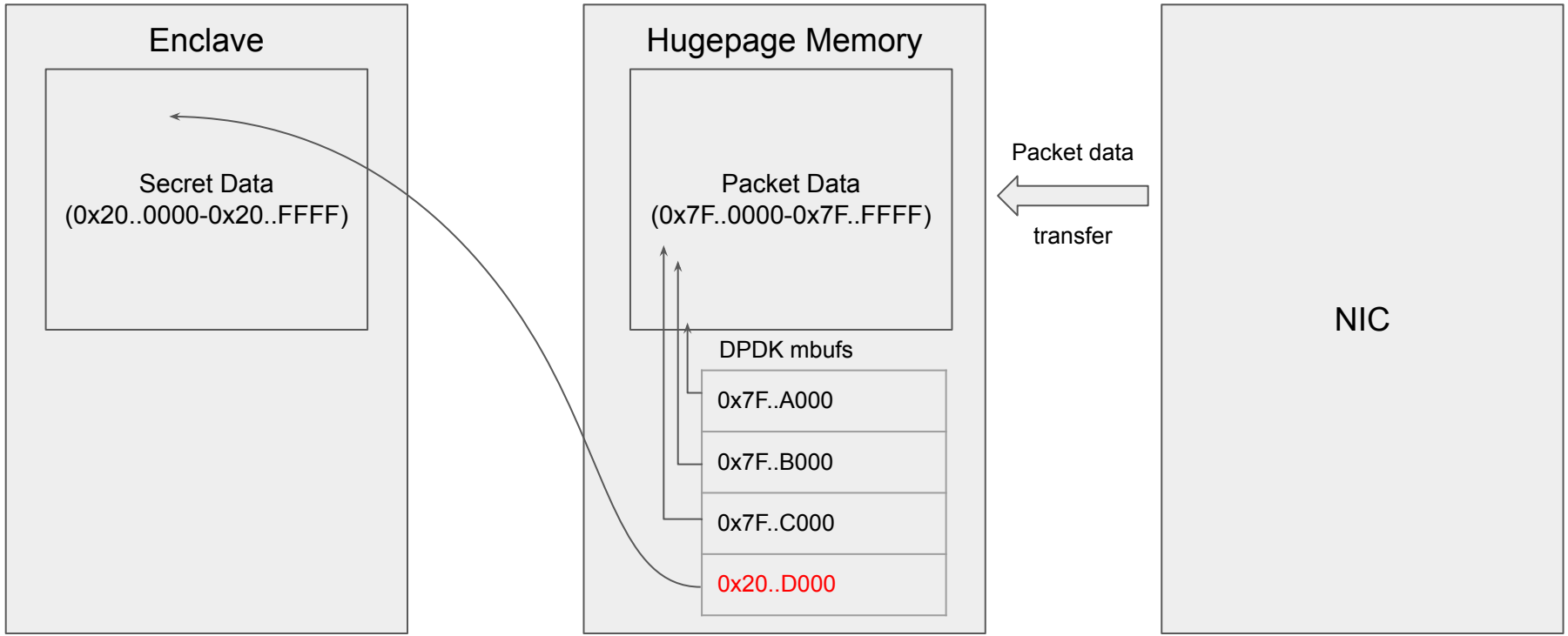

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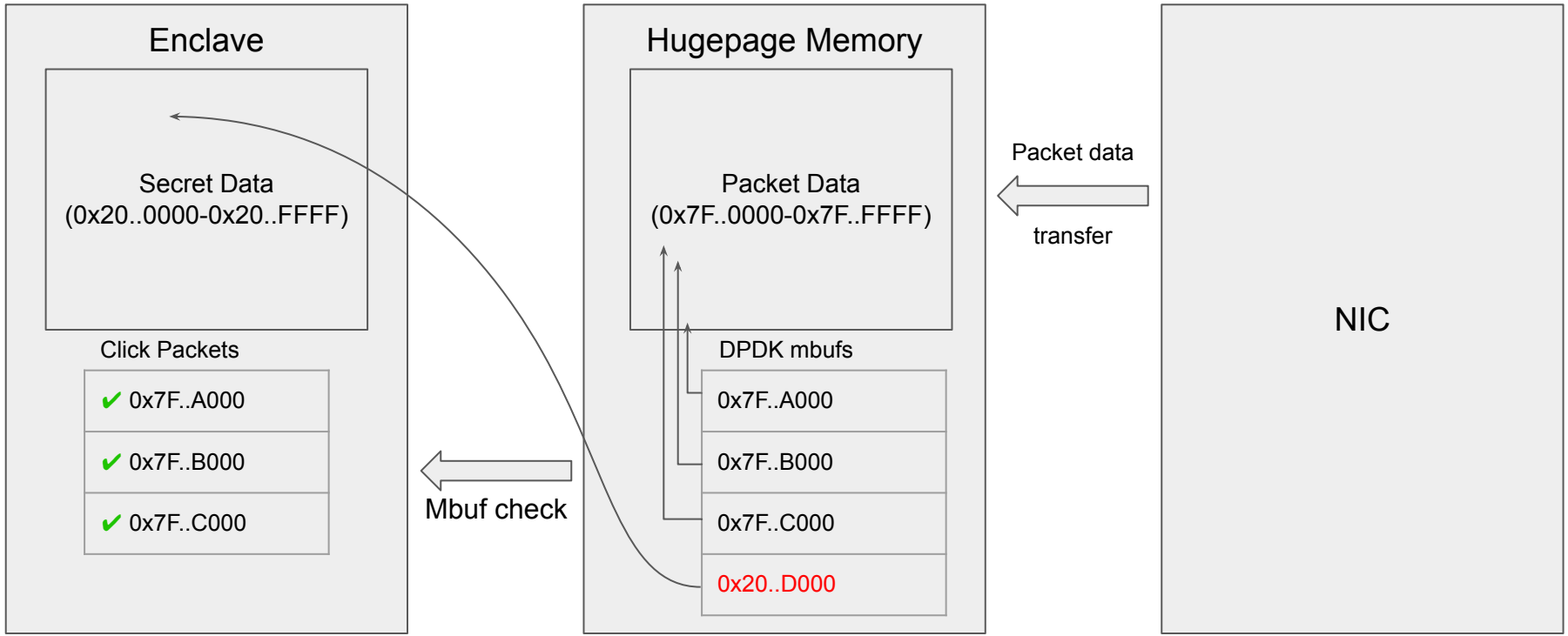

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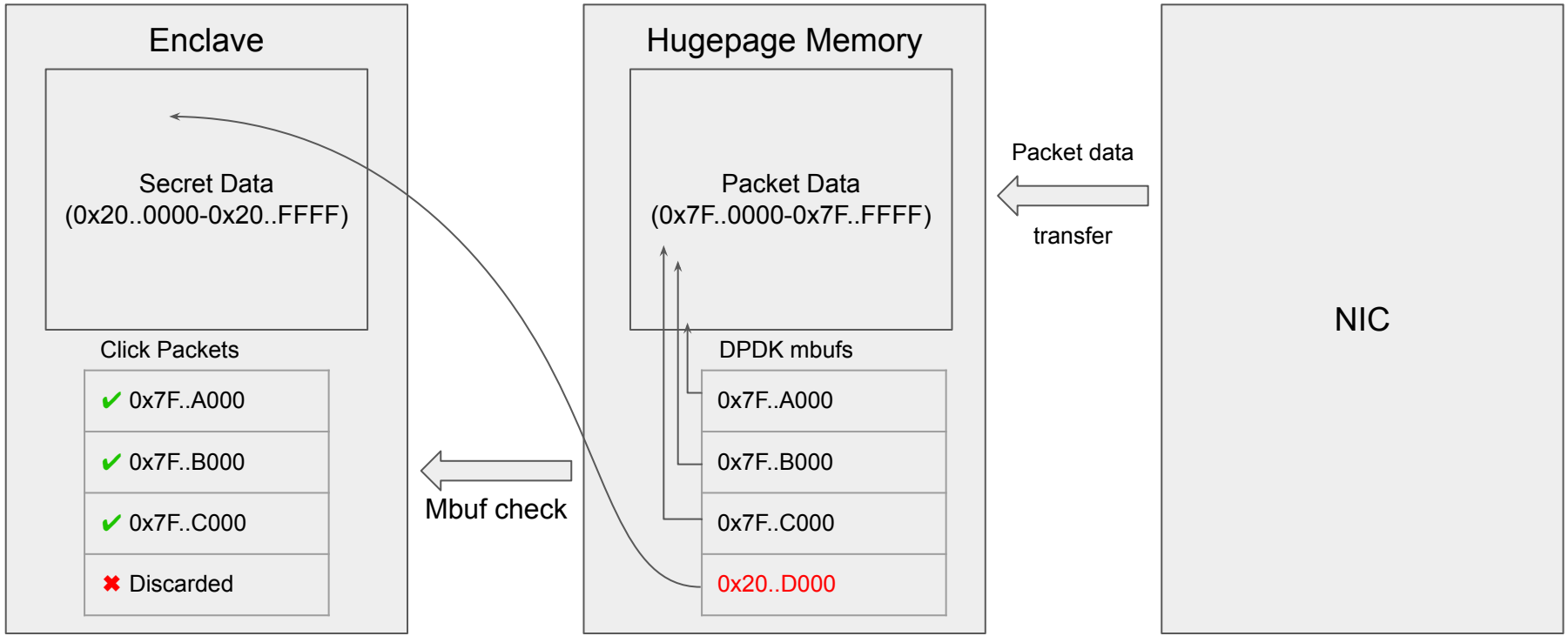
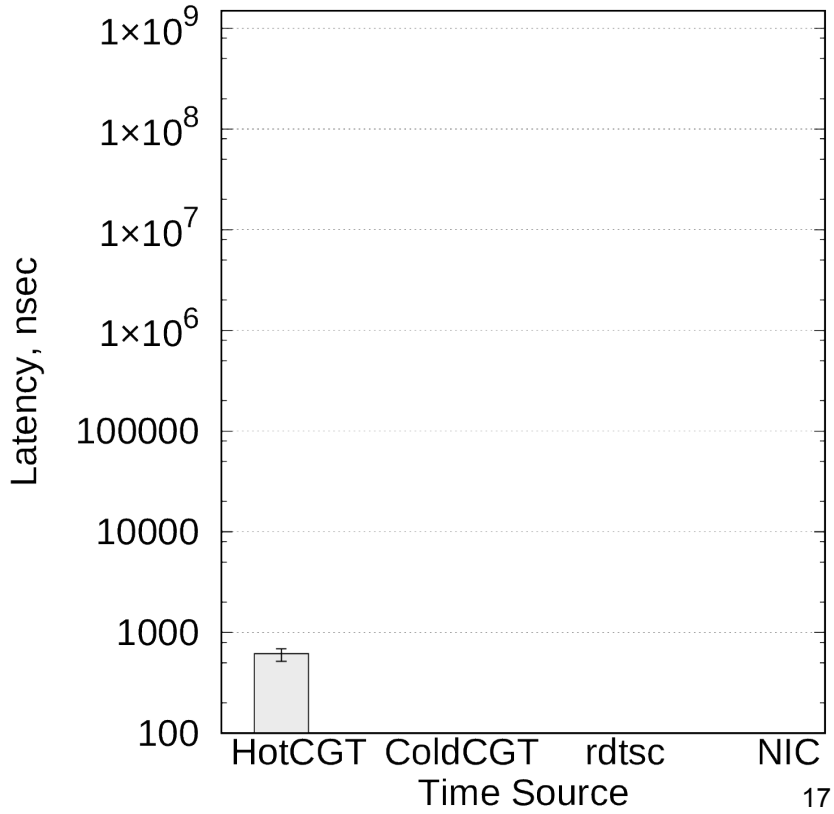


On-NIC Time Source

- `clock_gettime`
  - Hot sthread: reduce performance



On-NIC Time Source

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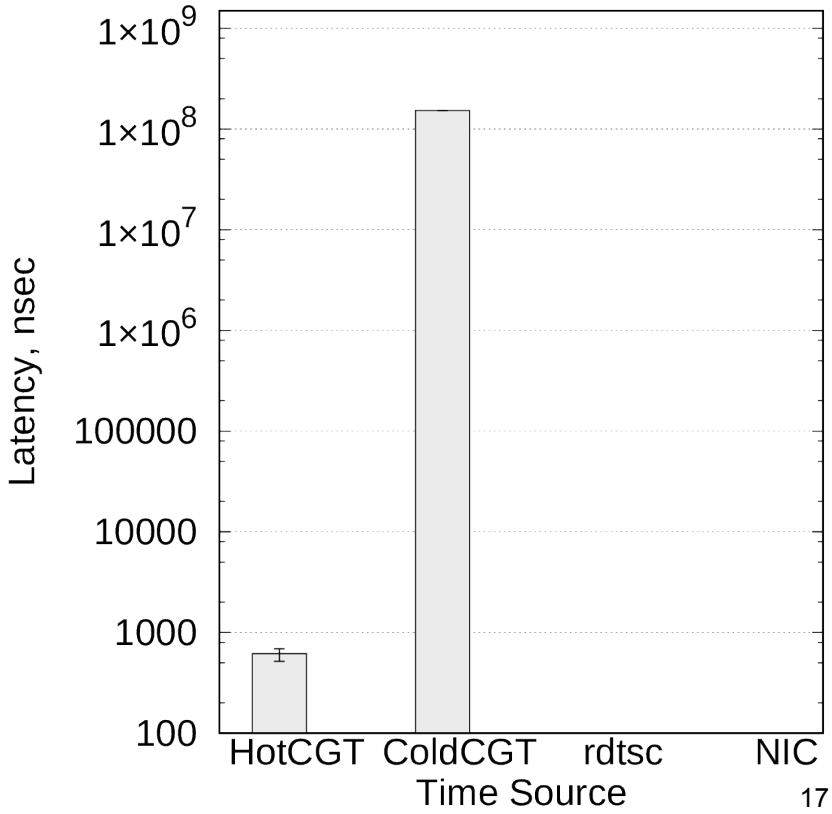

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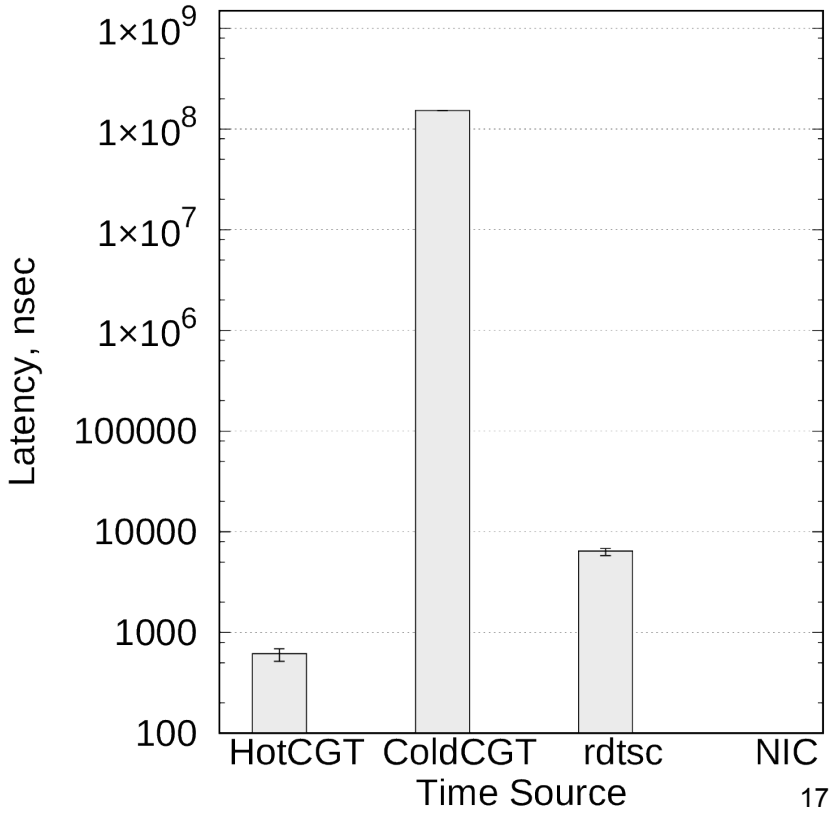
  - Causes enclave exit
  - Performance loss due to TLB flush



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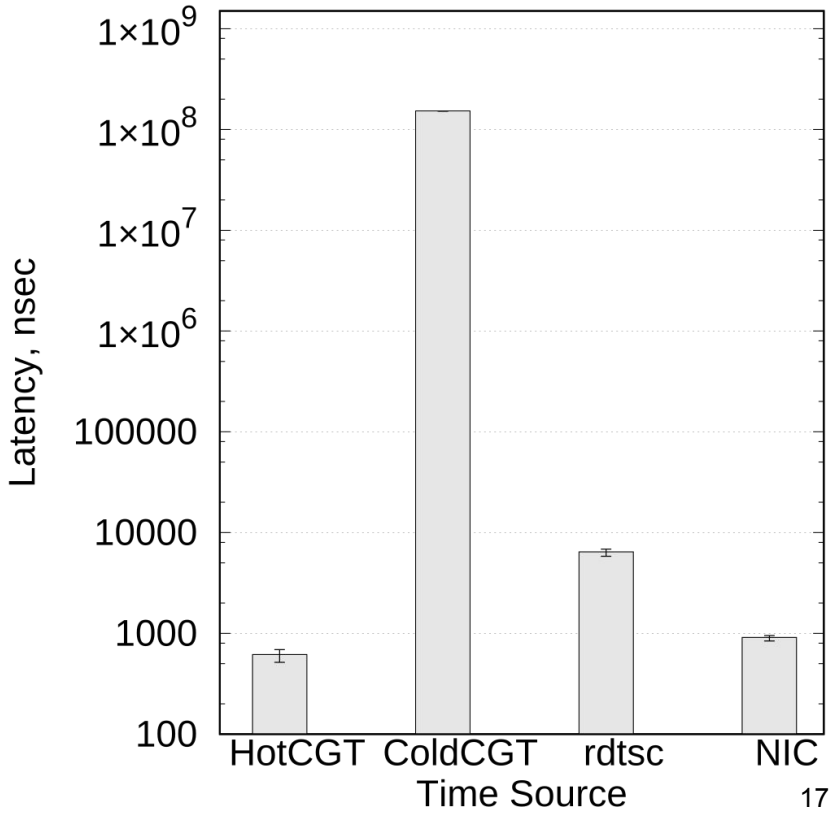
- On-NIC Timer
  - Acceptable performance



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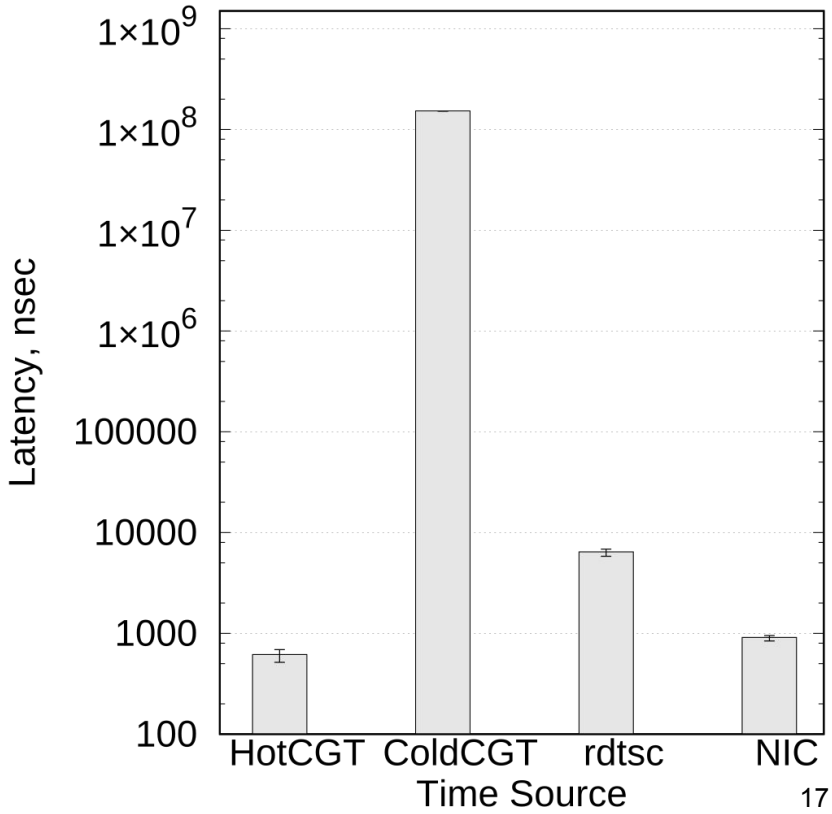
  - Acceptable performance

All of these time sources are untrusted.



Outline

- ~~Motivation~~
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- Summary

Evaluation

- What is the throughput and latency of our system?
- What is the influence of ToEnclave element on the performance?
- Other questions: see in the paper.

Throughput: Router Use Case

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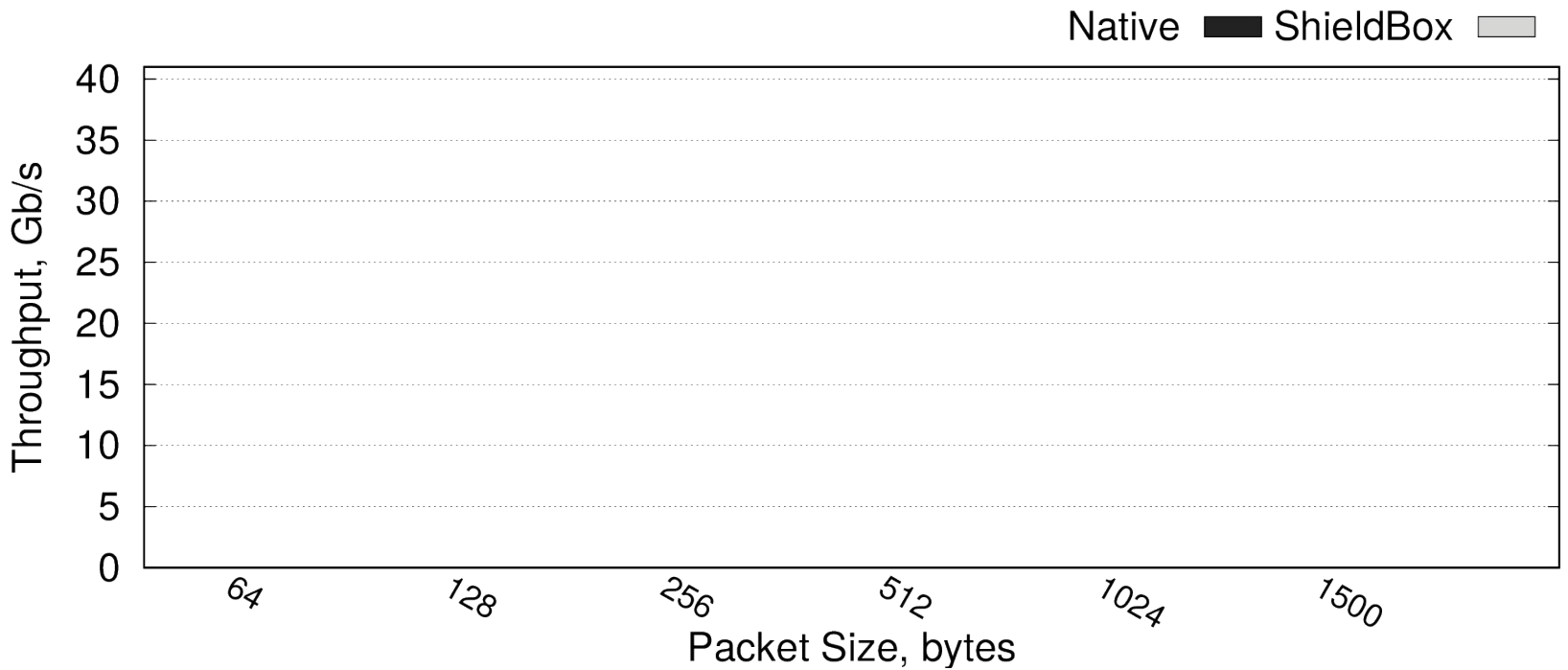
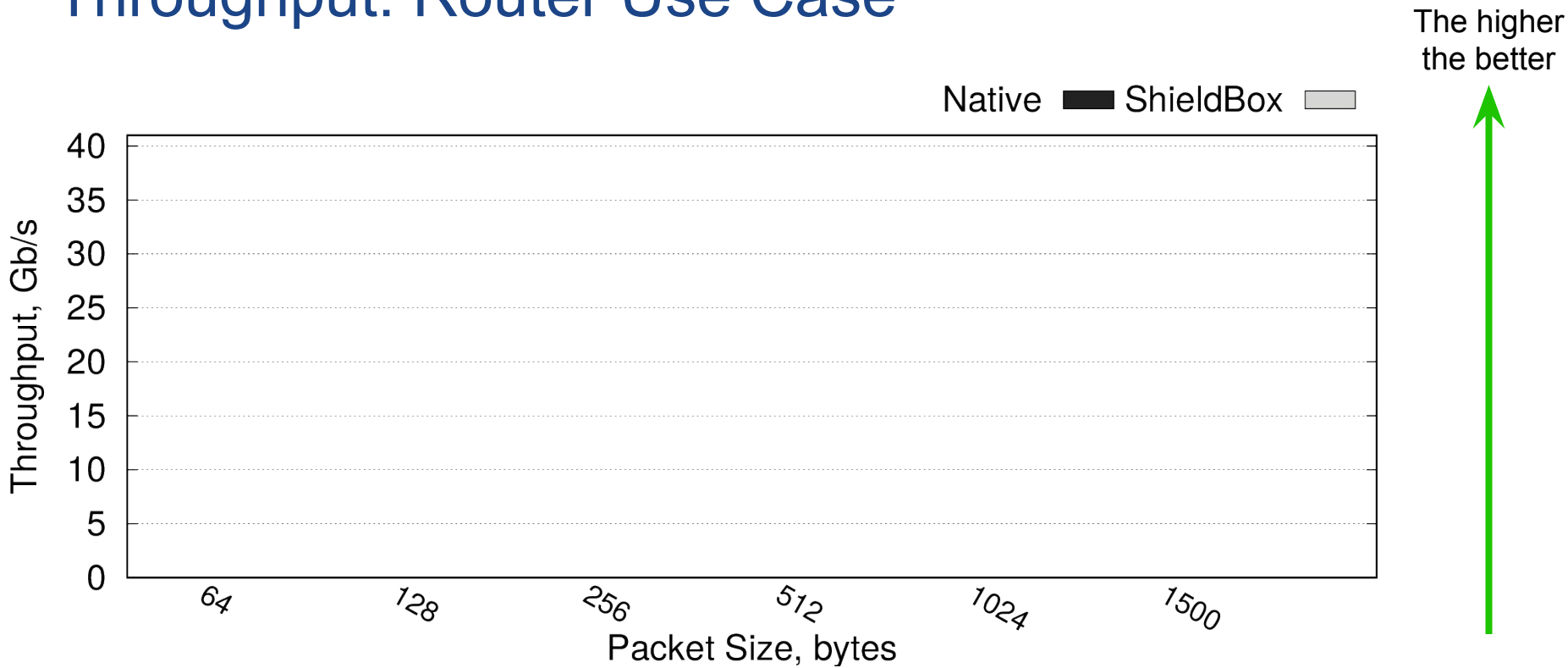


Throughput: Router Use Case



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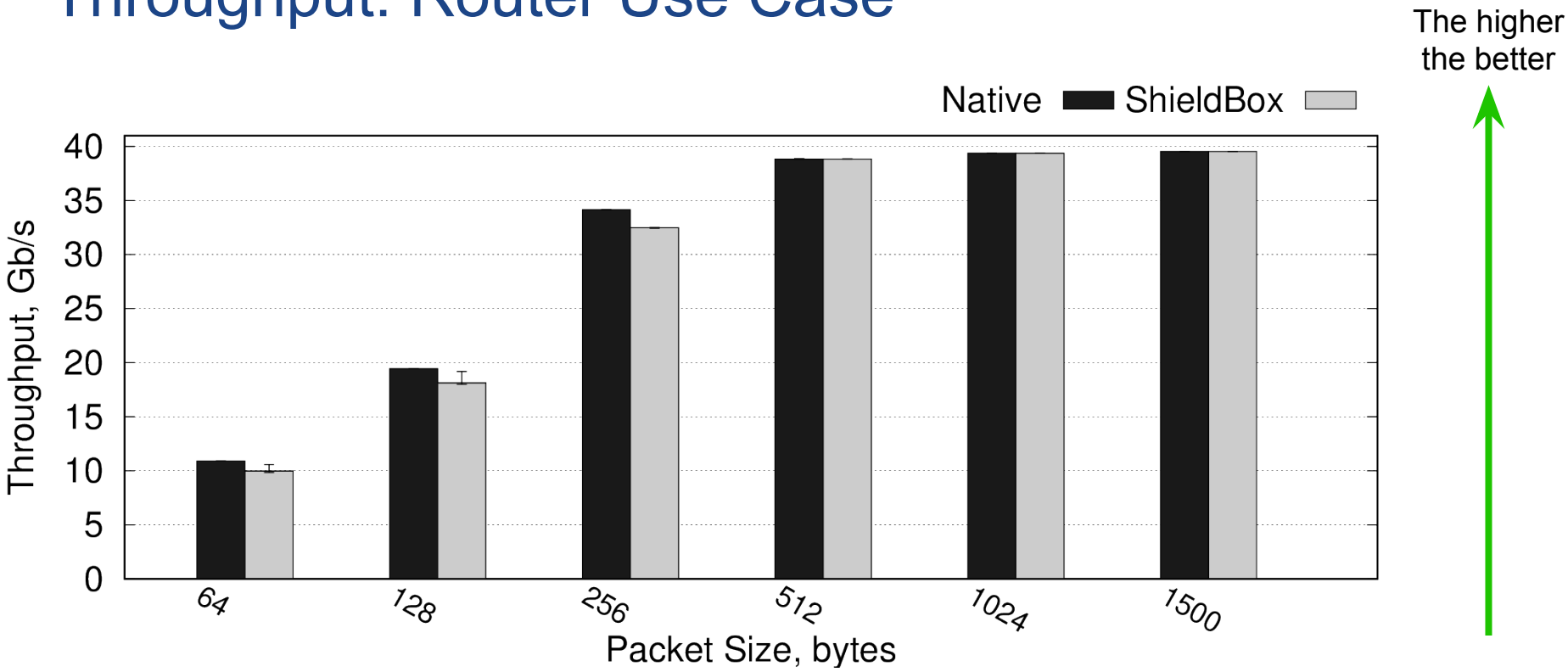

Line rate at most common packet size

Latency: Router Use Case

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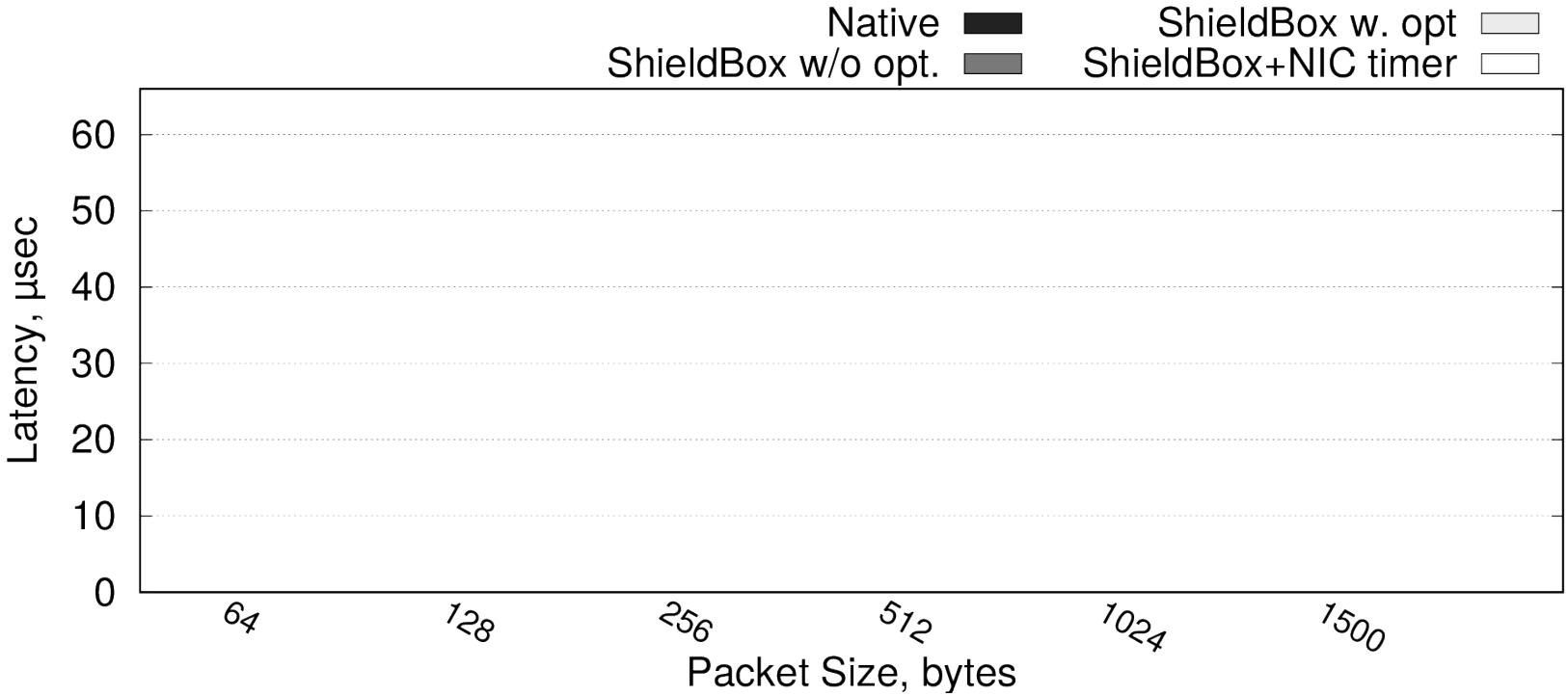

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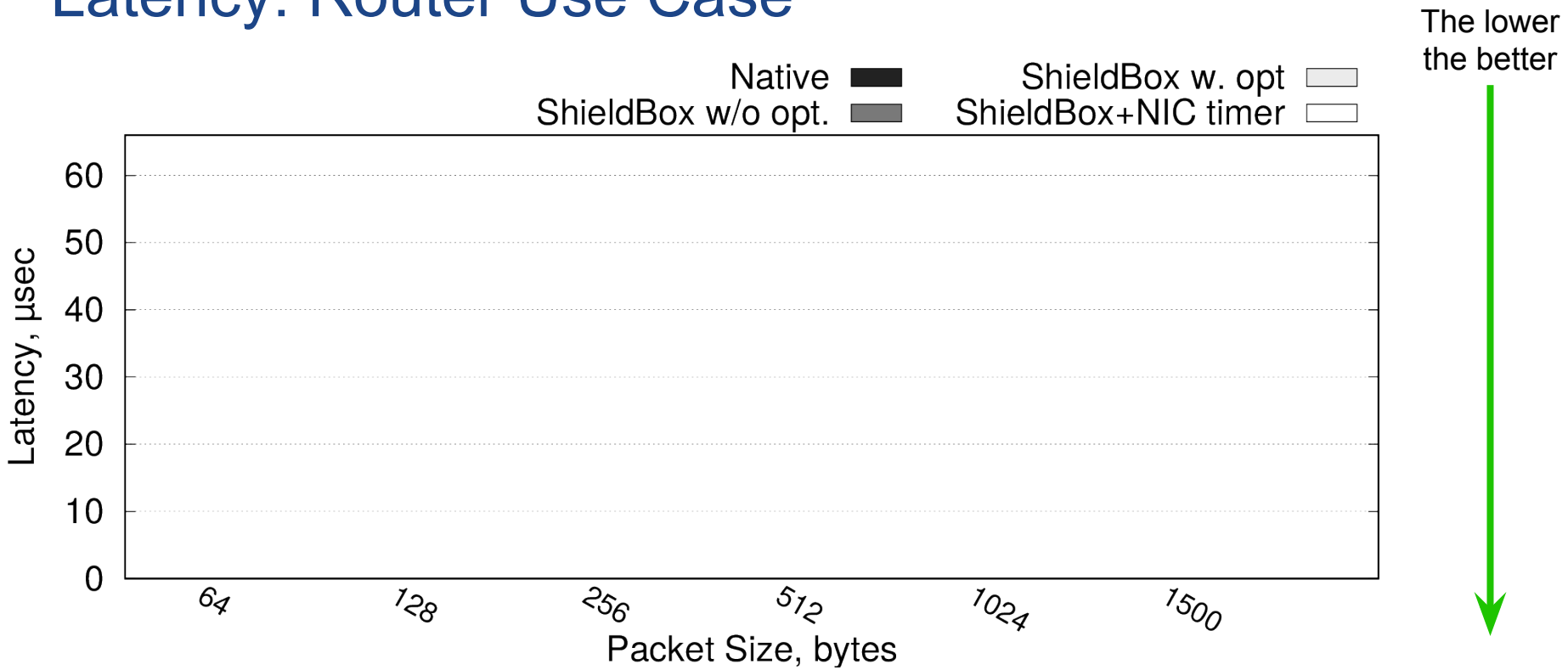

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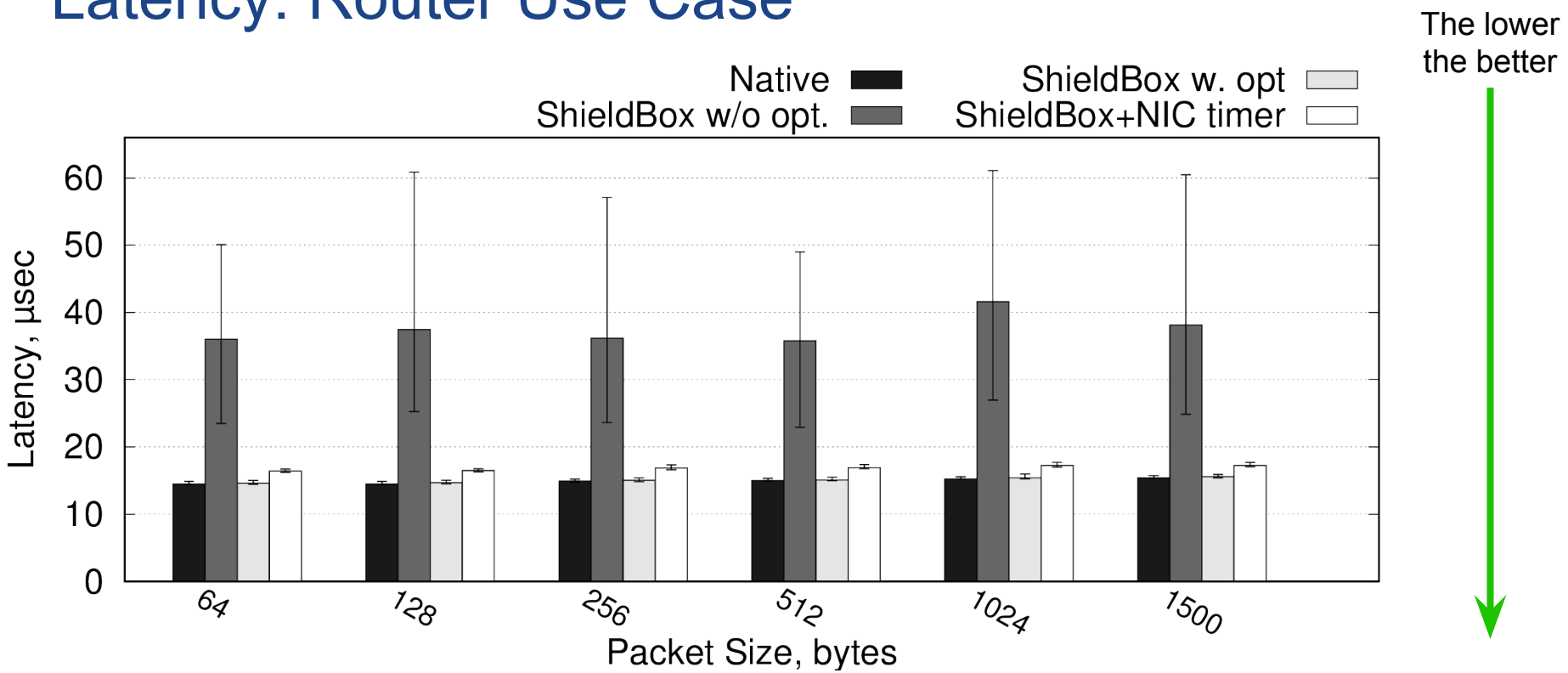
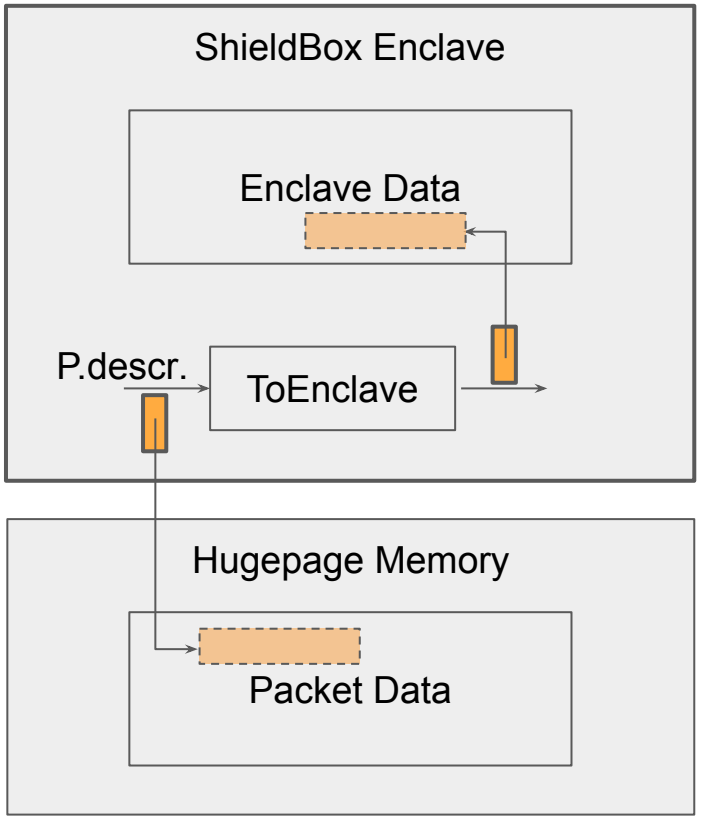


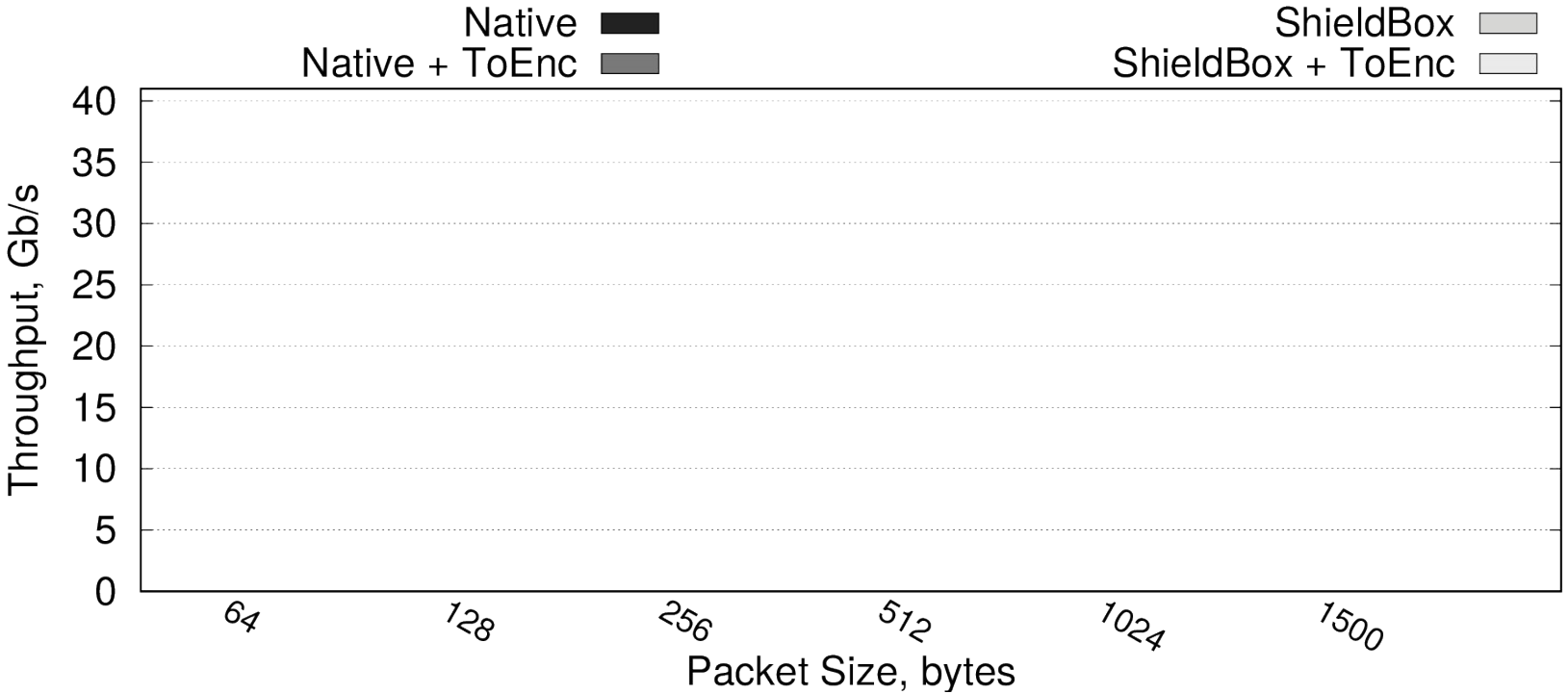
Optimizations bring latency to native level

ToEnclave Influence: EtherMirror

- Cheap NF→ worst-case example



ToEnclave Influence: EtherMirror



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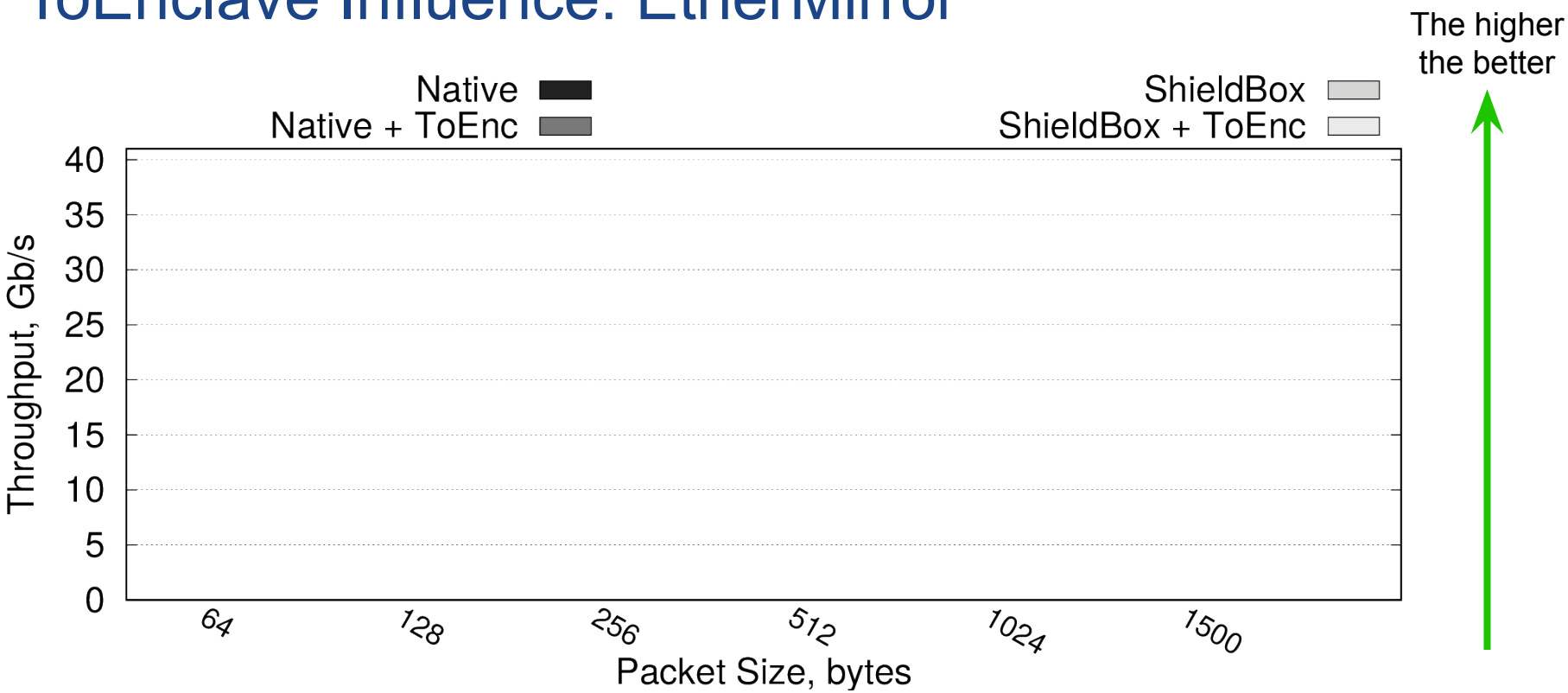

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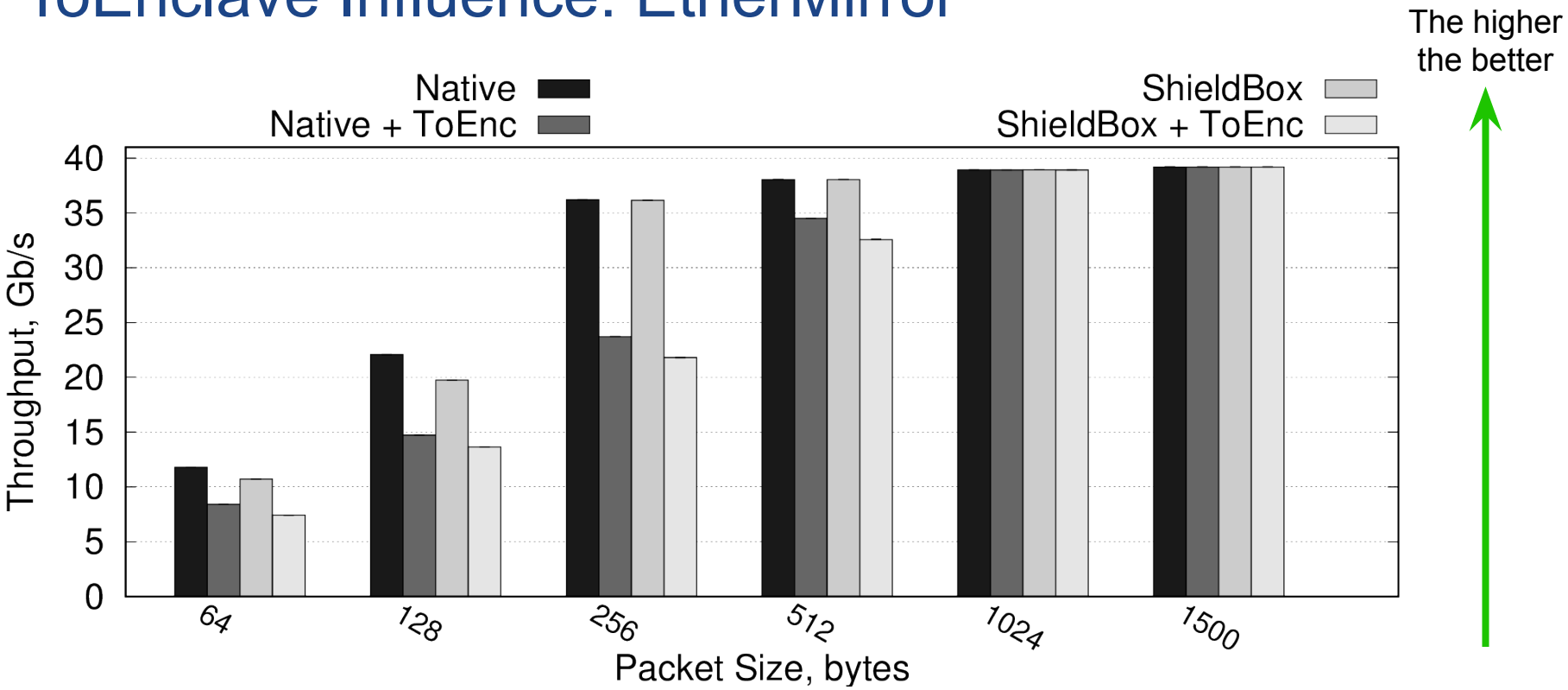

~15% throughput reduction due to the extra memory copy

Outline

- ~~Motivation~~
- ~~Design~~
- ~~Evaluation~~
- Summary

Summary

- Cloud:
  - Abundant computational resources ☺
  - Limited trust to platform ☹

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  - Abundant computational resources ☺
  - Limited trust to platform ☹

- TEEs allow construction of middleboxes in the cloud:
  - Achieve end-to-end trust
  - Flexible frameworks for NF construction available

Summary

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  - Line rate with typical Network Functions by using DPDK
  - Minimal overhead from ToEnclave element

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Thank You!

Funding

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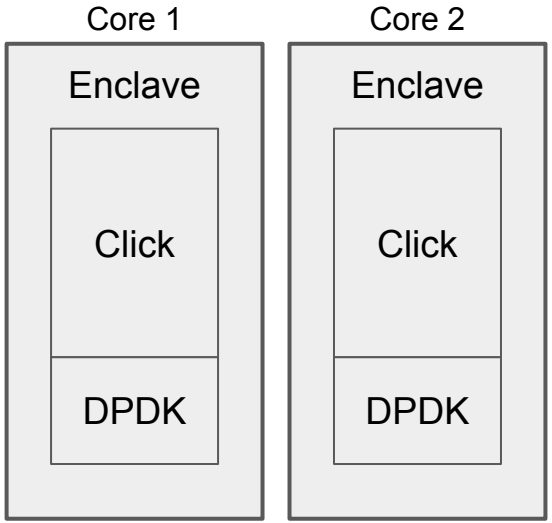
Design Challenges

- Modern middleboxes are expected to run at line speeds (10-40Gb/s)
- Overheads of 10x from asynchronous system call interface
- High impact on latency without optimizations (2-3x)
- SGX applications require a partitioning scheme

ShieldBox TCB

Trusted Computing Base:

- Click code and data
- DPDK code and non-hugepages data
- SCONE



ShieldBox: Security, Deployment, Limitations

Security:

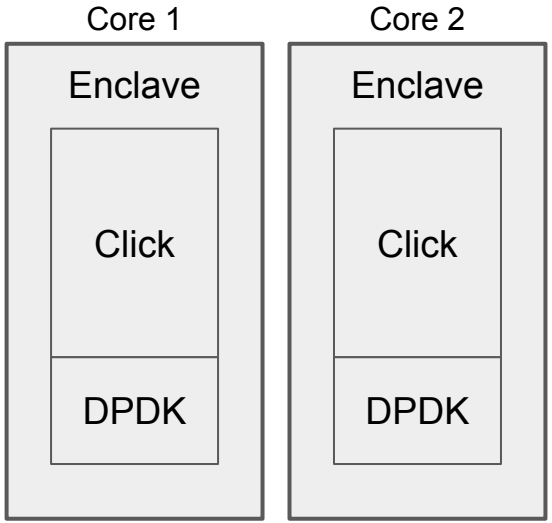
- Confidentiality for data inside enclave
- Integrity for data and processing functions

Deployment scenarios:

- Out of scope
- see APLOMB [SIGCOMM'12]

Limitations:

- No flow reassembly



Outline

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DPDK and SGX Interaction

DPDK Initialization:

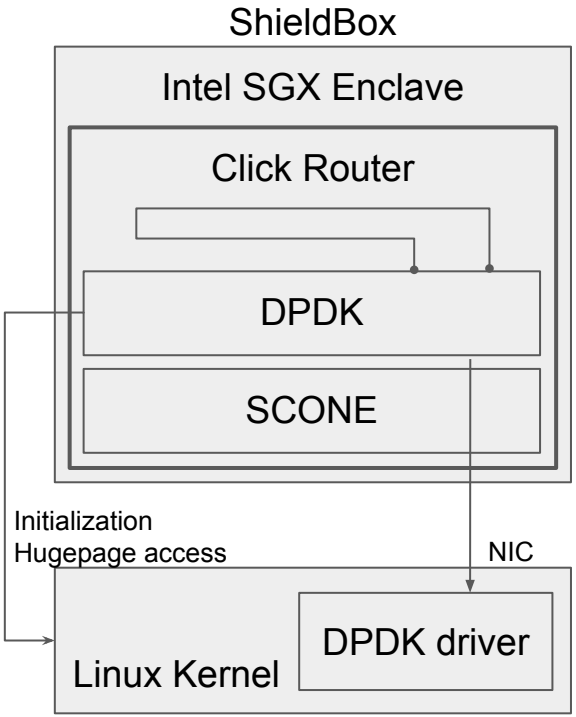
- SCONE system calls
- Minor patching for SCONE musl-libc

Obtaining huge pages:

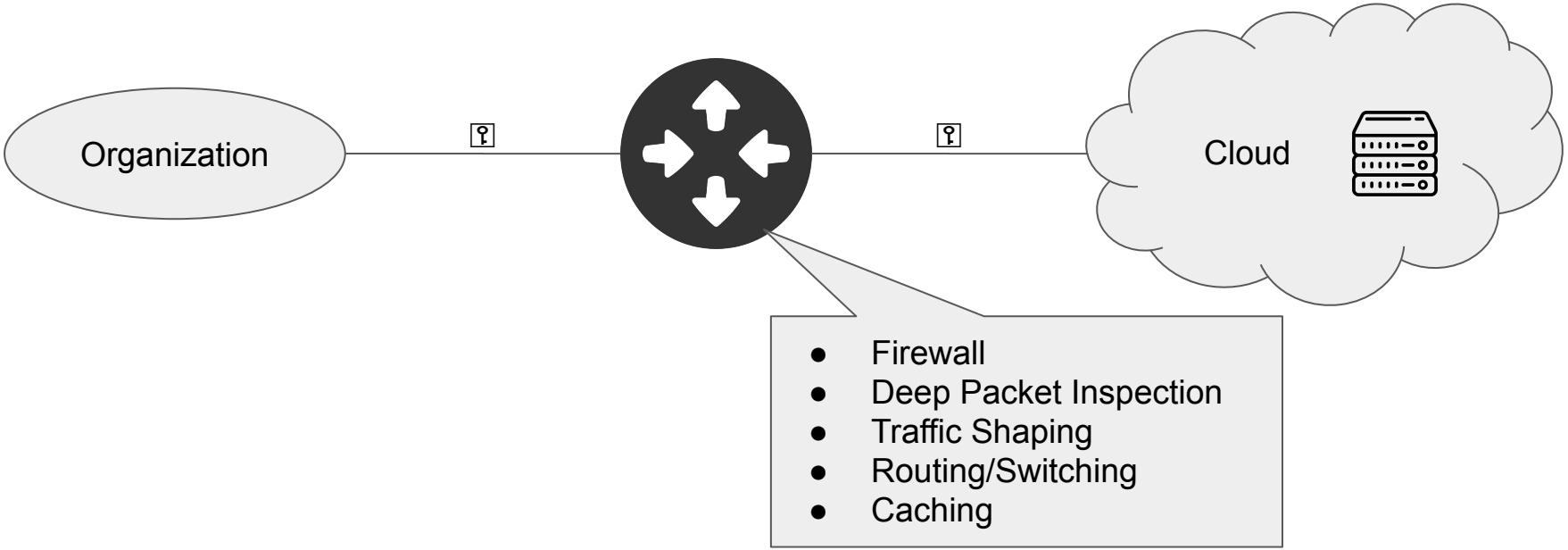
- Directly, with disabled FS shielding

NIC access:

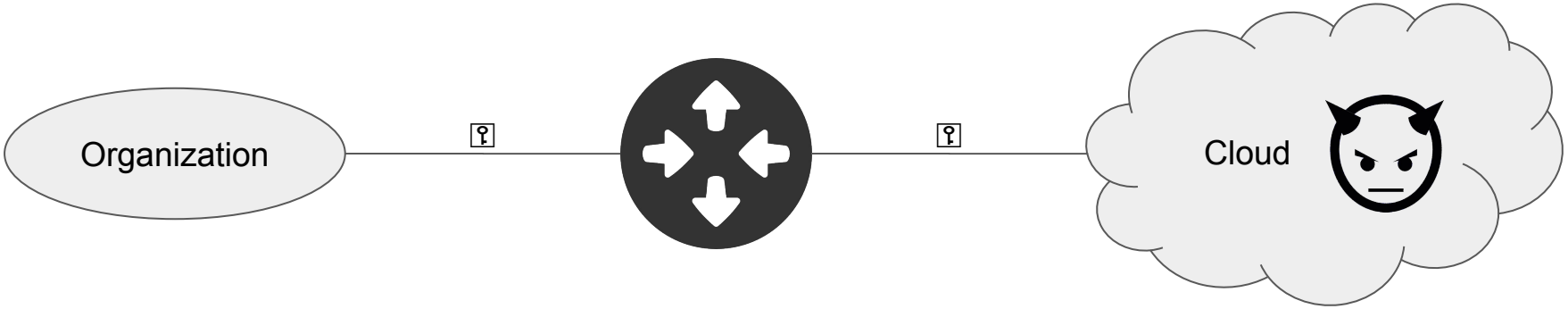
- Standard DPDK driver, disabled FS shielding



Middleboxes in the cloud



Security issues

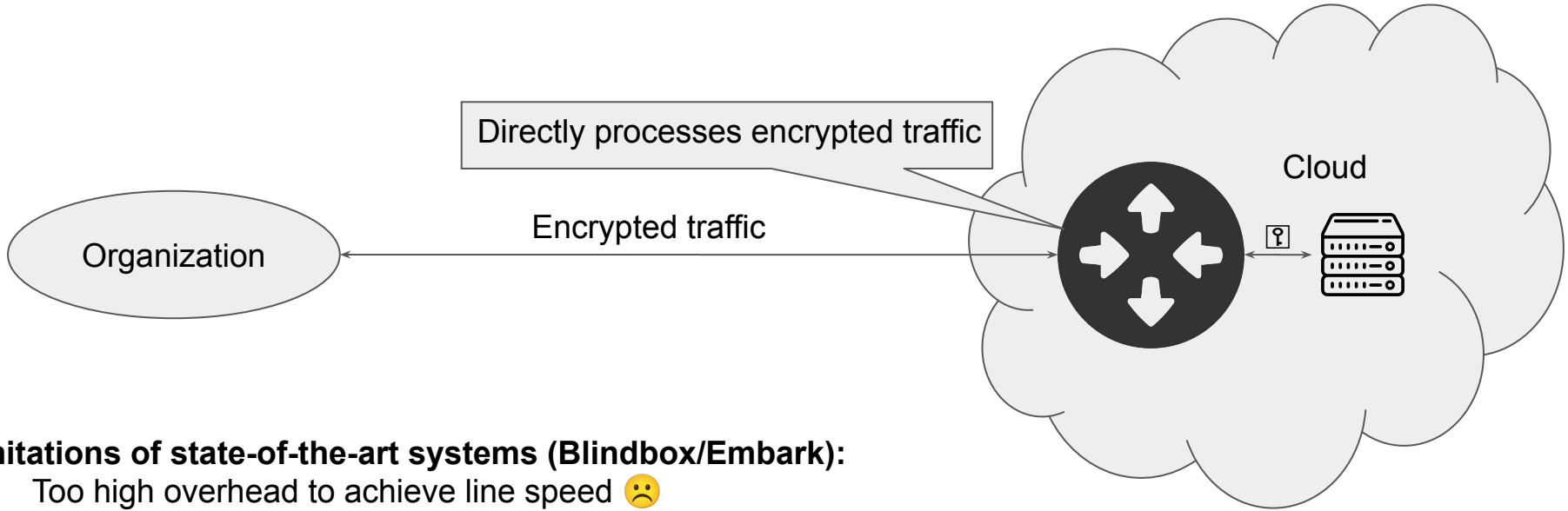


Already use cloud for computations ☺
Higher trust requirements for NFs ☹

Cheap computation resources ☺
Economy of scale ☺
Low trust environment ☹

- Observe private data
- Extract encryption keys
- Learn configuration

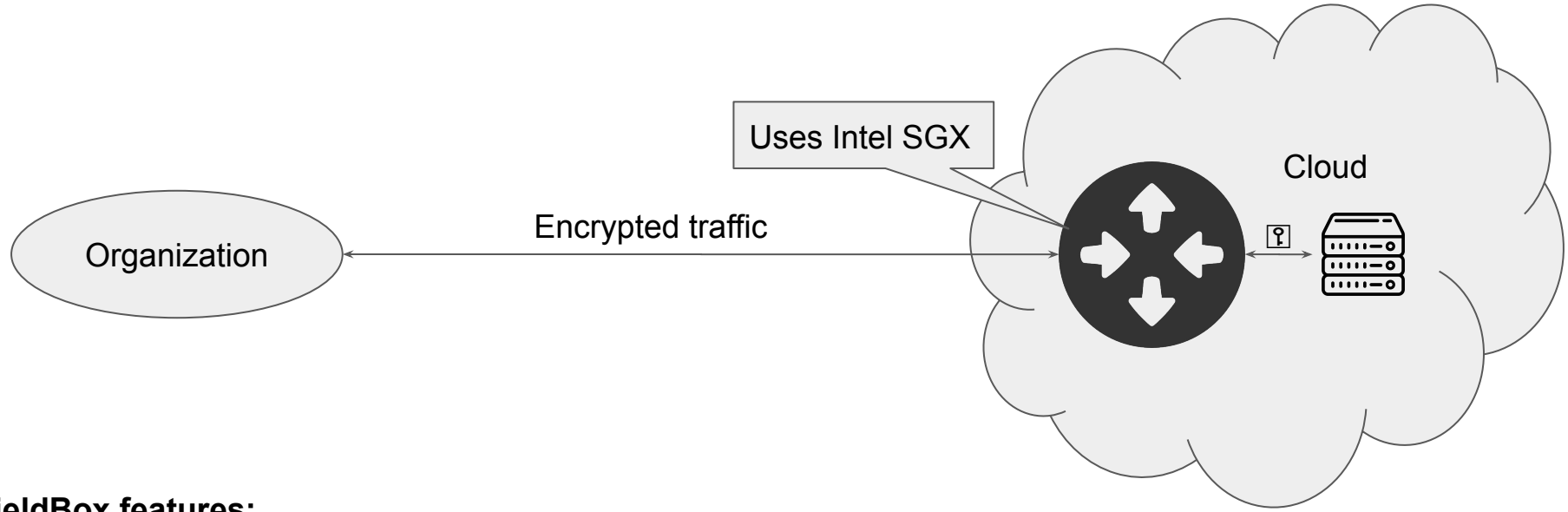
State-of-the-art



Limitations of state-of-the-art systems (Blindbox/Embark):

- Too high overhead to achieve line speed ☹
- Long communication session setup time ☹
- Require protocol modifications ☹
- Offer limited functionality ☹

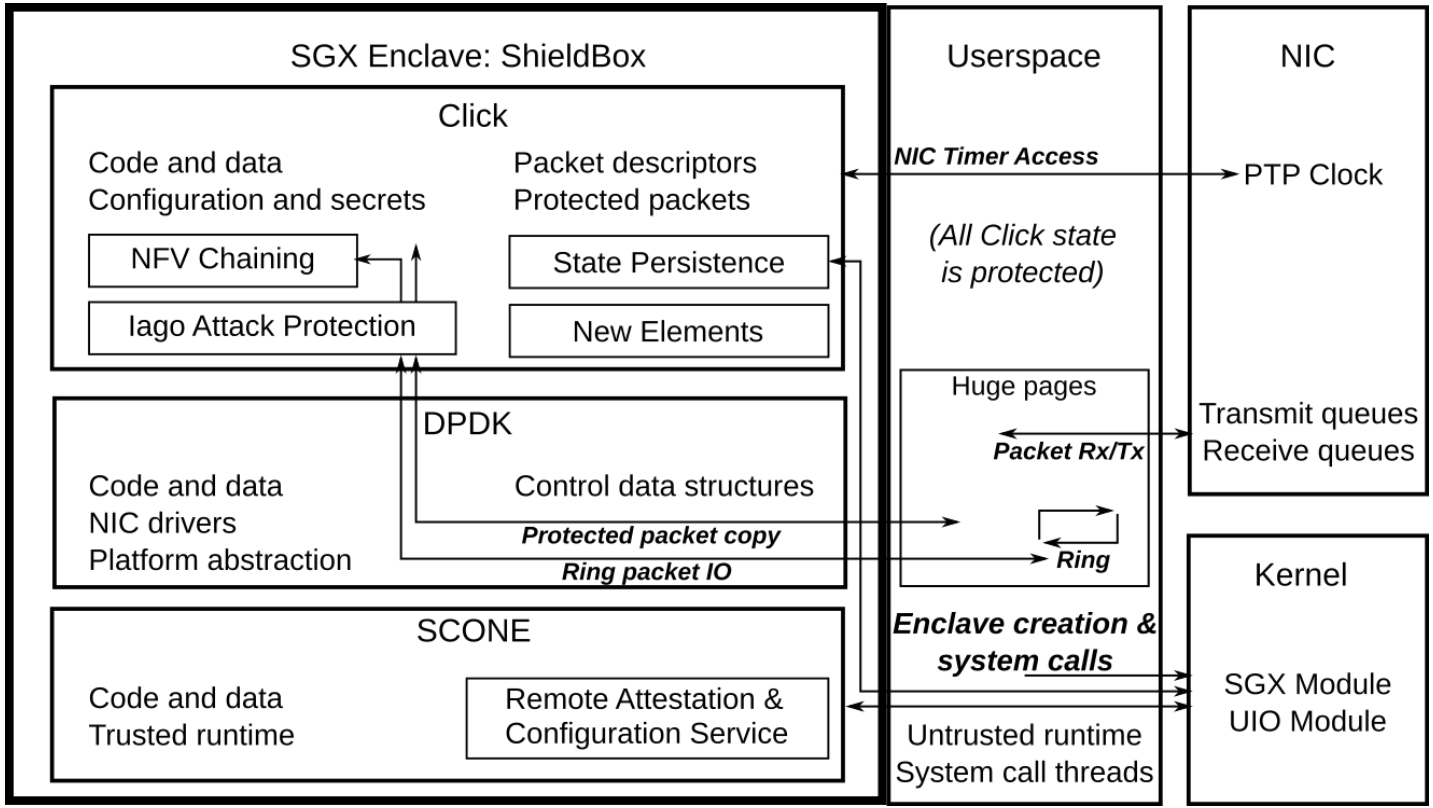
ShieldBox



ShieldBox features:

- Middlebox framework with shielded execution

System overview



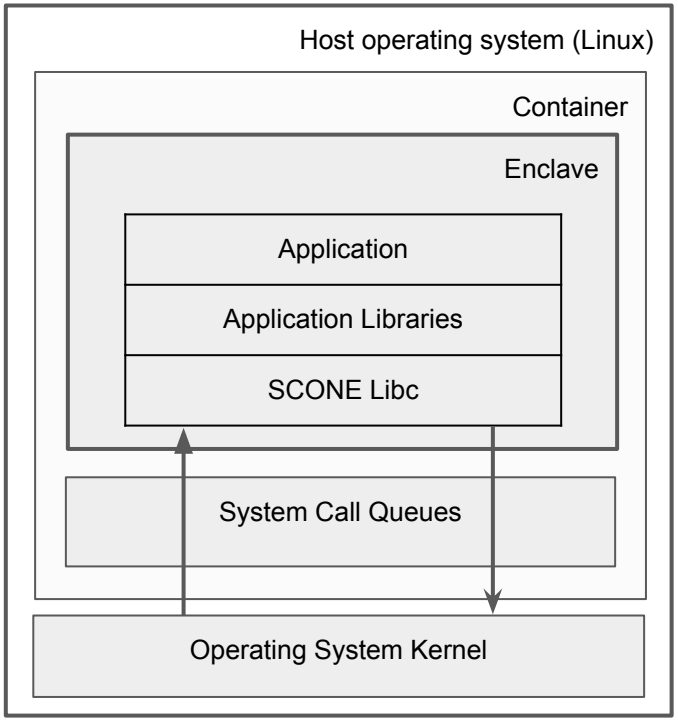
SCONE

Secure **Con**tainer Framework

Runs unmodified POSIX applications inside enclave:

- Memory management
- System calls
- Userspace threading

Provides remote attestation and configuration service.



Usage Scenarios

Developer writes a Click program and distributes it to ShieldBox via CAS

- High-level, easy-to-use API

When necessary Click element is missing, developer to ShieldBox via C++ API

- Low-level, flexible API

Operator can monitor the operation of the system using ControlSocket

Evaluation Setup

System Under Test (ShieldBox):

- Intel Xeon E3-1270 v5 (3.6 GHz, 4 cores, 8 HT)
- 32GB RAM

Load Generator:

- Intel Xeon D-1540 (2 GHz, 8 cores, 16 HT)
- 32GB RAM

Connection: Intel XL710 40Gb NIC between the machines