A New Approach to Network Functions

Aurojit Panda

NEFELI NETWORKS

Current Approach to NFV

Current Approach to NFV

Firewall

Cache

NFs written by experts shipped as VM or container.

Current Approach to NFV

Firewall

Cache

NFs written by experts shipped as VM or container.

```
static int _xbegin(void) {
  int ret = _XBEGIN_STARTED;
  asm volatile(".byte 0xc7,0xf8 ; .long 0"
    : "+a" (ret)
    :: "memory");
    return ret;
}

static void _xend(void) {
   asm volatile(".byte 0x0f,0x01,0xd5"
   ::: “memory");
}
```

FTMB

Stateless

FPGA

AVX-512

TSX

NFs built to target hardware & software features.

Current Approach to NFV

Firewall Cache

NFs written by experts shipped as VM or container.

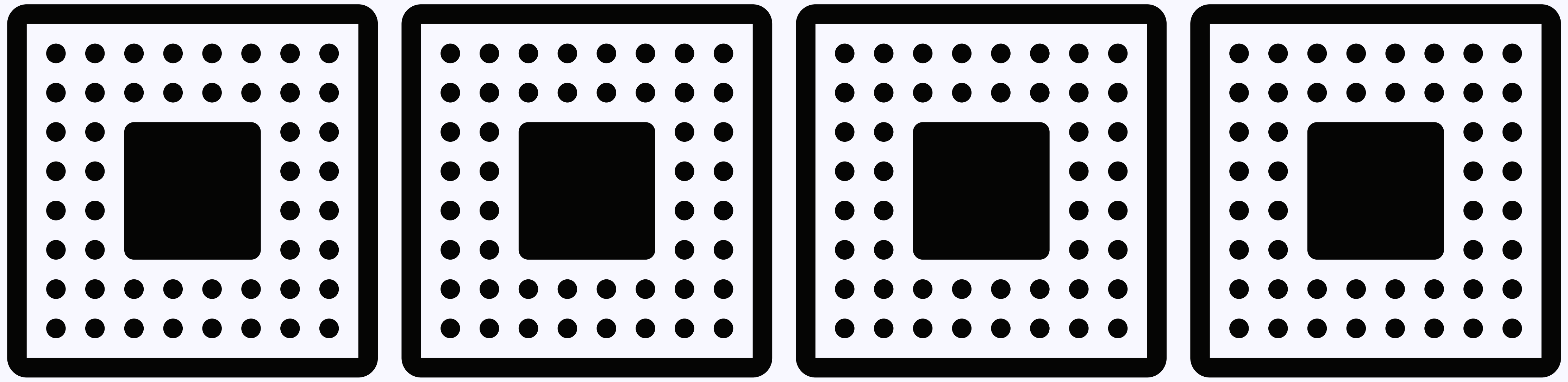
```
static int _xbegin(void) {
  int ret = _XBEGIN_STARTED;
  asm volatile(".byte 0xc7,0xf8 ; .long 0"
    : "+a" (ret)
    :: "memory");
    return ret;
}

static void _xend(void) {
   asm volatile(".byte 0x0f,0x01,0xd5"
   ::: “memory");
}
```

FTMB FPGA AVX-512 Stateless TSX

NFs built to target hardware & software features.

vSwitch Firewall Cache

Executed in VMs or containers for isolation.



Current Approach to NFV

Firewall | Cache

NFs written by experts shipped as VM or container.

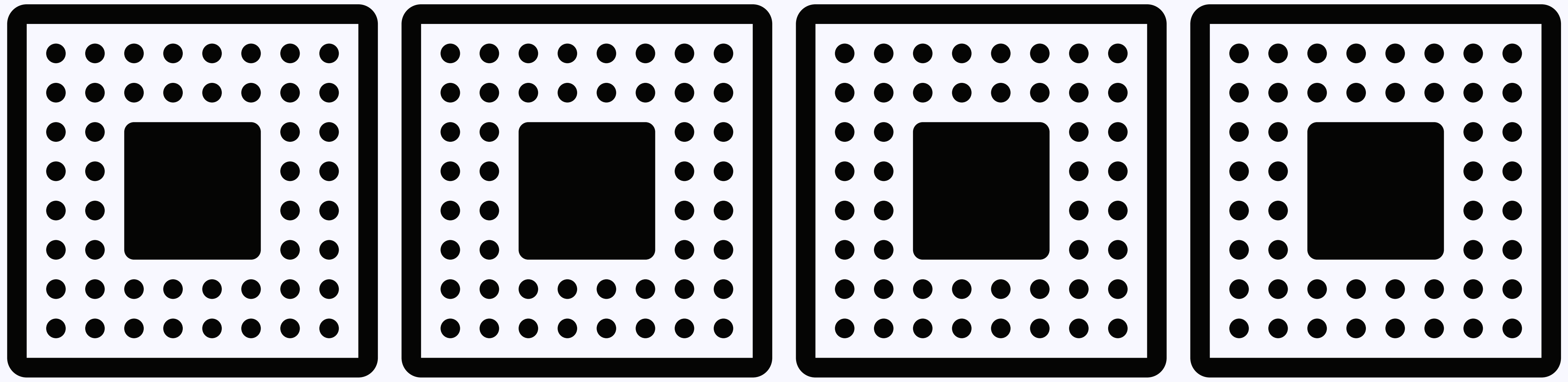
```
static int _xbegin(void) {
  int ret = _XBEGIN_STARTED;
  asm volatile(".byte 0xc7,0xf8 ; .long 0"
    : "+a" (ret)
    :: "memory");
    return ret;
}

static void _xend(void) {
   asm volatile(".byte 0x0f,0x01,0xd5"
   ::: “memory");
}
```

FTMB | Stateless | FPGA | AVX-512 | TSX

NFs built to target hardware & software features.

vSwitch | Firewall | Cache

Executed in VMs or containers for isolation.

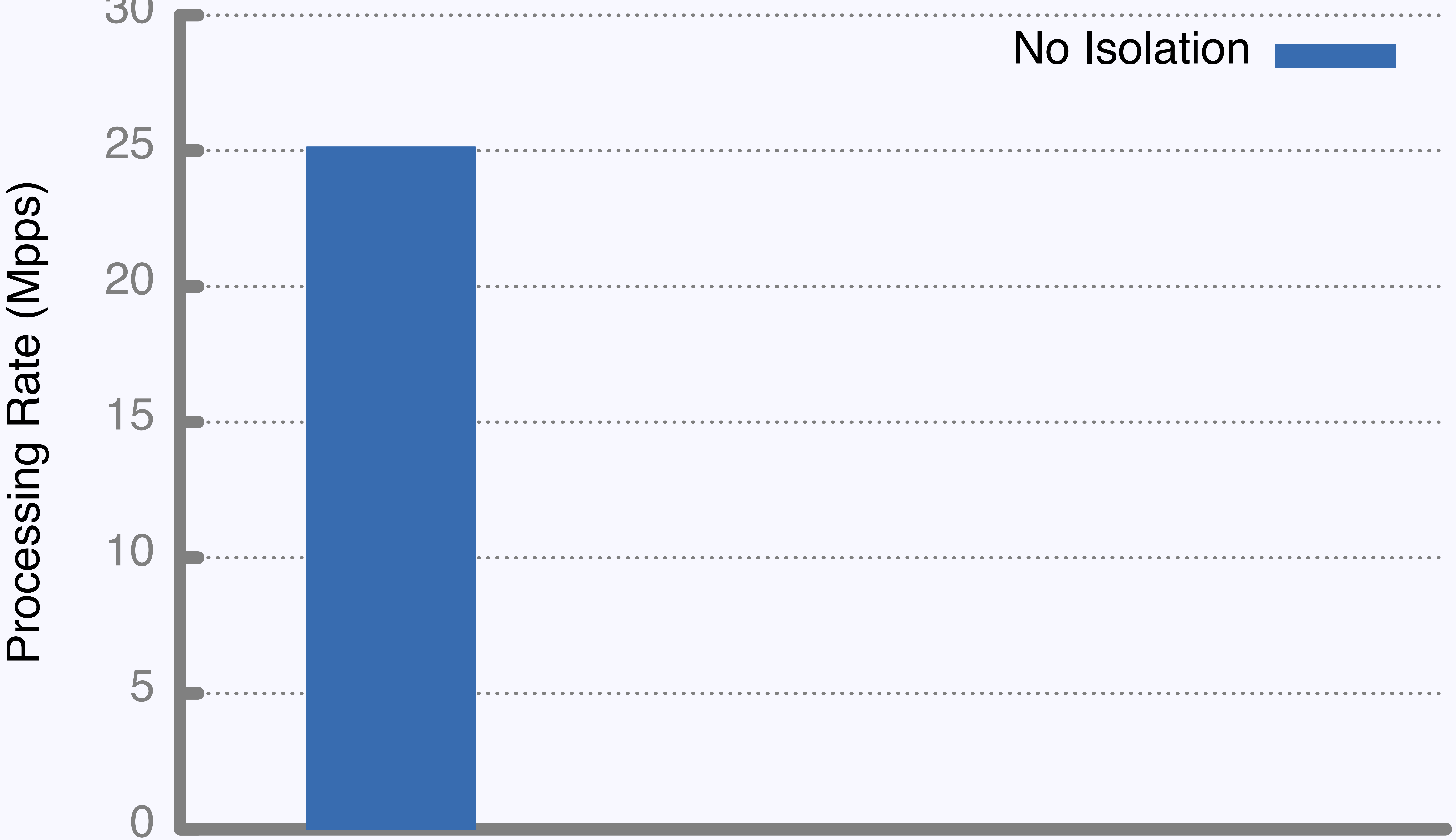


Core placement for performance.

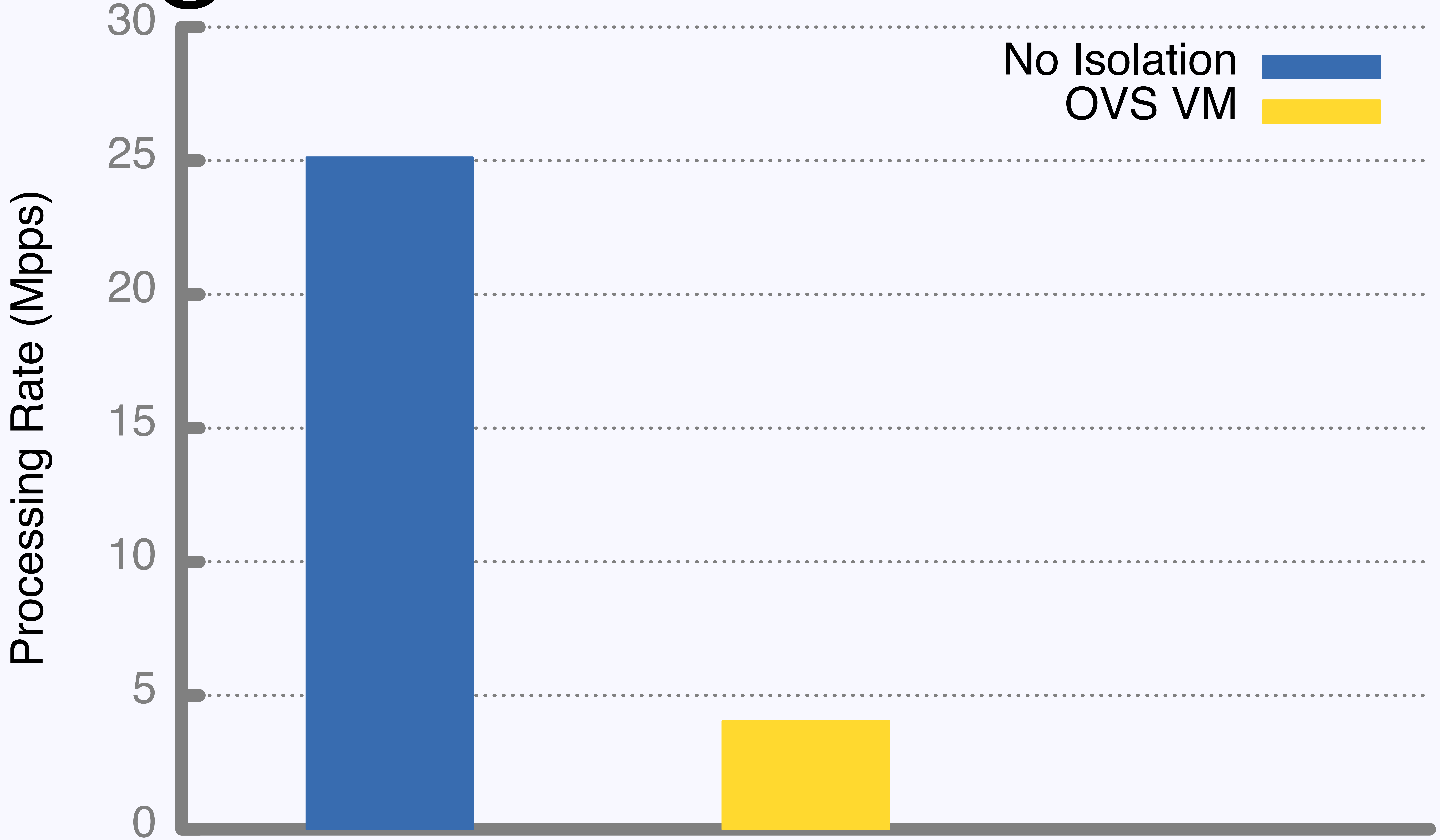
Problems with the Current Approach

- **High overheads** for **isolation** and **chaining**.

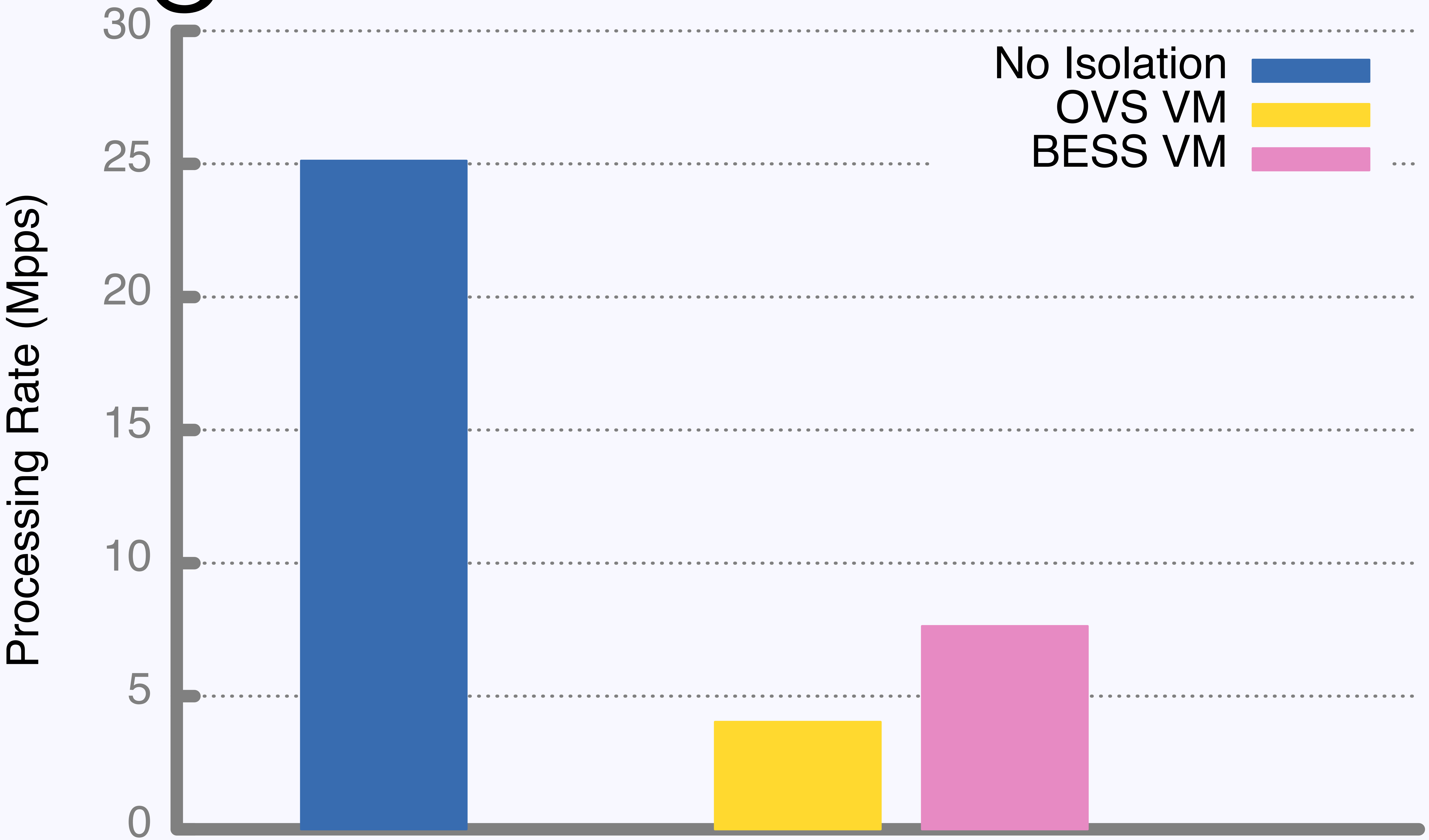
High Overheads for Isolation



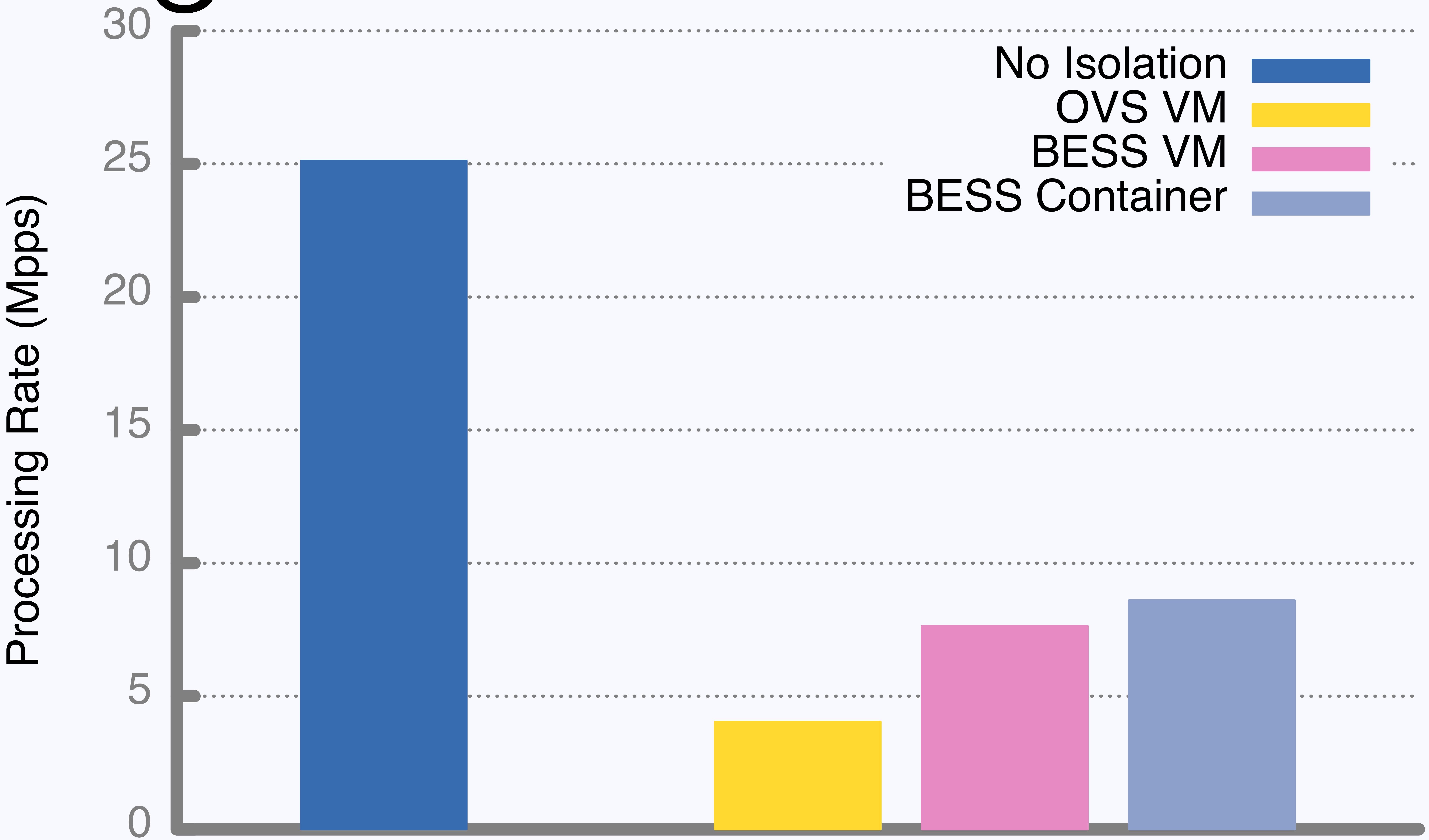
High Overheads for Isolation



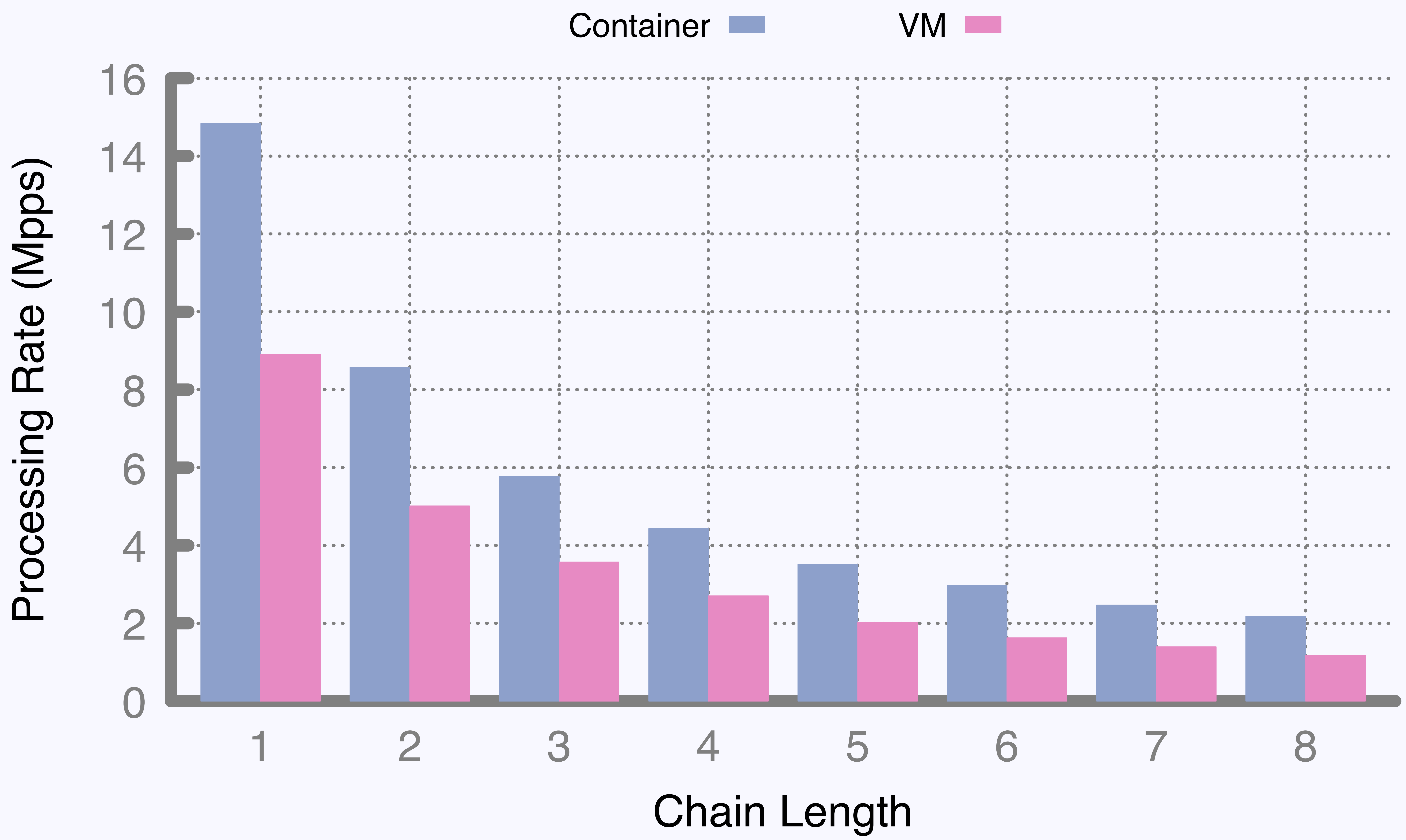
High Overheads for Isolation



High Overheads for Isolation



High Overheads for Chaining



Problems with the Current Approach

- **High overheads** for **isolation** and **chaining**.

- **Hard to write** high-performance network functions.

Hard to Write New NFs

- NFs written in low-level languages, e.g., C or C++.

Hard to Write New NFs

- NFs written in low-level languages, e.g., C or C++.
- Make use of packet processing and I/O libraries like DPDK and netmap.

Hard to Write New NFs

- NFs written in low-level languages, e.g., C or C++.
- Make use of packet processing and I/O libraries like DPDK and netmap.
    - Simplify batched I/O of packets, provide some common data structures.

Hard to Write New NFs

- NFs written in low-level languages, e.g., C or C++.
- Make use of packet processing and I/O libraries like DPDK and netmap.
  - Simplify batched I/O of packets, provide some common data structures.
- **Programmers** responsible for meeting NF **performance requirements**.

Hard to Write New NFs

- NFs written in low-level languages, e.g., C or C++.
- Make use of packet processing and I/O libraries like DPDK and netmap.
    - Simplify batched I/O of packets, provide some common data structures.
- **Programmers** responsible for meeting NF **performance requirements**.
    - Write code to maintain access locality, prevent pipeline stalls, etc.

Hard to Write New NFs

- NFs written in low-level languages, e.g., C or C++.
- Make use of packet processing and I/O libraries like DPDK and netmap.
  - Simplify batched I/O of packets, provide some common data structures.
- **Programmers** responsible for meeting NF **performance requirements**.
  - Write code to maintain access locality, prevent pipeline stalls, etc.
- Result: *Largely written by the same companies that built middleboxes.*

Hard to Write New NFs

- NFs written in low-level languages, e.g., C or C++.
- Make use of packet processing and I/O libraries like DPDK and netmap.
  - Simplify batched I/O of packets, provide some common data structures.
- **Programmers** responsible for meeting NF **performance requirements**.
  - Write code to maintain access locality, prevent pipeline stalls, etc.
- Result: *Largely written by the same companies that built middleboxes.*
  - Hard for **carriers** or **new entrants** to develop NFs, limiting innovation.

Problems with the Current Approach

- **High overheads** for **isolation** and **chaining**.

- **Hard to write** high-performance network functions.

- **Hard to upgrade** existing network functions to utilize new features.

Hard to Upgrade Existing NFs

- Rapidly evolving set of **hardware accelerators** including:

Hard to Upgrade Existing NFs

- Rapidly evolving set of **hardware accelerators** including:
    - For example AVX, transactional memory (TSX), AES-NI, FPGAs, etc.

Hard to Upgrade Existing NFs

- Rapidly evolving set of **hardware accelerators** including:
  - For example AVX, transactional memory (TSX), AES-NI, FPGAs, etc.
- Rapidly evolving software architecture within which NFs are deployed:

Hard to Upgrade Existing NFs

- Rapidly evolving set of **hardware accelerators** including:
  - For example AVX, transactional memory (TSX), AES-NI, FPGAs, etc.
- Rapidly evolving software architecture within which NFs are deployed:
  - State management for fault tolerance/scaling, enhanced scheduling, etc.

Hard to Upgrade Existing NFs

- Rapidly evolving set of **hardware accelerators** including:
  - For example AVX, transactional memory (TSX), AES-NI, FPGAs, etc.
- Rapidly evolving software architecture within which NFs are deployed:
  - State management for fault tolerance/scaling, enhanced scheduling, etc.
- Feature availability dictated by deployment environment, use dictated by vendor.

Hard to Upgrade Existing NFs

- Rapidly evolving set of **hardware accelerators** including:
  - For example AVX, transactional memory (TSX), AES-NI, FPGAs, etc.
- Rapidly evolving software architecture within which NFs are deployed:
  - State management for fault tolerance/scaling, enhanced scheduling, etc.
- Feature availability dictated by deployment environment, use dictated by vendor.
- Result: *Delays before new features are used, increased cost for upgrades.*

Problems with the Current Approach

- **High overheads** for **isolation** and **chaining**.

- **Hard to write** high-performance network functions.

- **Hard to upgrade** existing network functions to utilize new features.

NetBricks Addresses these Problems

What is NetBricks

- A new execution environment and programming framework for NFs.

What is NetBricks

- A new execution environment and programming framework for NFs.

- Up to an order of magnitude better NF performance.

What is NetBricks

- A new execution environment and programming framework for NFs.
- Up to an order of magnitude better NF performance.
- Open source project. Currently developed and maintained by NEFELI NETWORKS

NetBricks Overview

NetBricks Overview

- Compile time type checks with minimal runtime checks for isolation.
  - Same guarantees as existing approaches.
  - Significantly lower overheads for isolation and chaining.

NetBricks Overview

- Compile time type checks with minimal runtime checks for isolation.
    - Same guarantees as existing approaches.
    - Significantly lower overheads for isolation and chaining.
- High-level dataflow model for expressing NF functionality.

NetBricks Overview

- Compile time type checks with minimal runtime checks for isolation.
  - Same guarantees as existing approaches.
  - Significantly lower overheads for isolation and chaining.
- High-level dataflow model for expressing NF functionality.
- NFs built using framework defined operators and user defined functions.

NetBricks Overview

- Compile time type checks with minimal runtime checks for isolation.
  - Same guarantees as existing approaches.
  - Significantly lower overheads for isolation and chaining.
- High-level dataflow model for expressing NF functionality.
- NFs built using framework defined operators and user defined functions.
  - NF can be expressed simply and succinctly.

NetBricks Overview

- Compile time type checks with minimal runtime checks for isolation.
  - Same guarantees as existing approaches.
  - Significantly lower overheads for isolation and chaining.
- High-level dataflow model for expressing NF functionality.
- NFs built using framework defined operators and user defined functions.
  - NF can be expressed simply and succinctly.
  - Operator provided by framework, simplify NF upgrades.

NetBricks Overview

- Compile time type checks with minimal runtime checks for isolation.
  - Same guarantees as existing approaches.
  - Significantly lower overheads for isolation and chaining.

Execution Environment

- High-level dataflow model for expressing NF functionality.
- NFs built using framework defined operators and user defined functions.
  - NF can be expressed simply and succinctly.
  - Operator provided by framework, simplify NF upgrades.

Programming Framework

NetBricks: Execution Environment

Execution Environment Requirements

- **Execution environment** must satisfy three requirements

Execution Environment Requirements

- **Execution environment** must satisfy three requirements
    - Performance: Process packets at line rate.

Execution Environment Requirements

- **Execution environment** must satisfy three requirements
  - Performance: Process packets at line rate.
  - Consolidation: Maximize number of NFs that can be consolidated.

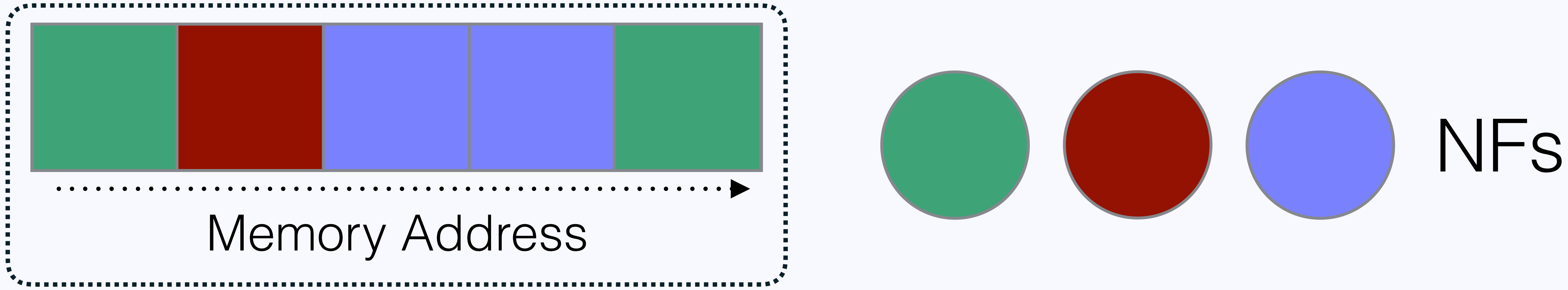
Execution Environment Requirements

- **Execution environment** must satisfy three requirements
  - Performance: Process packets at line rate.
  - Consolidation: Maximize number of NFs that can be consolidated.
  - Isolation: Ensure NFs do not affect each other

Isolation

Isolation

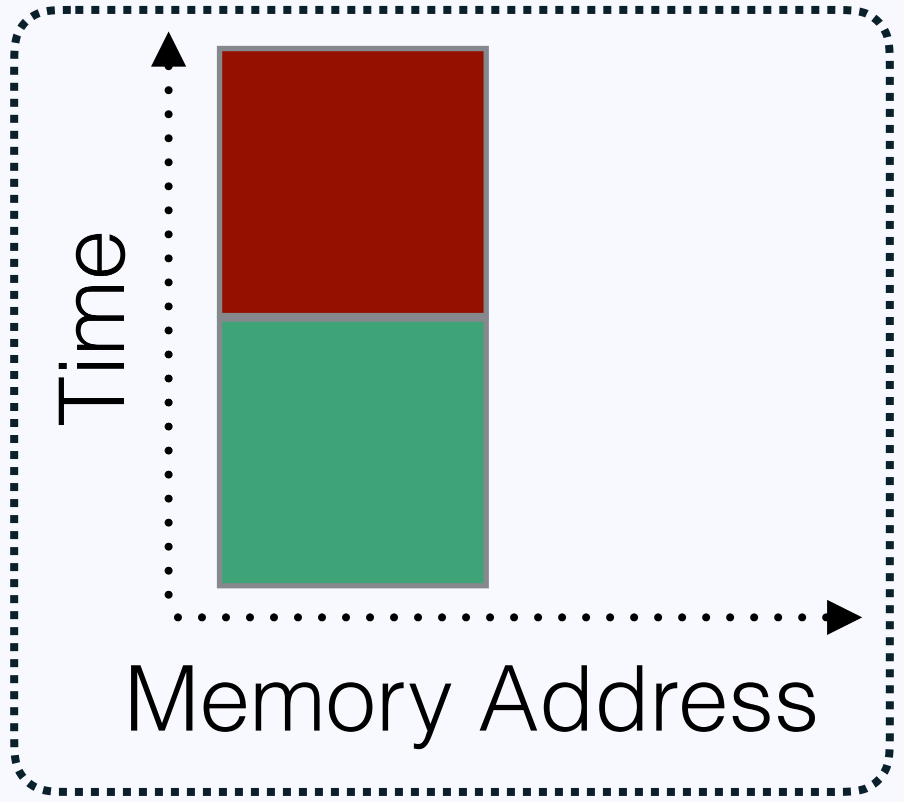
- **Memory Isolation**: Partition memory spatially between NFs.

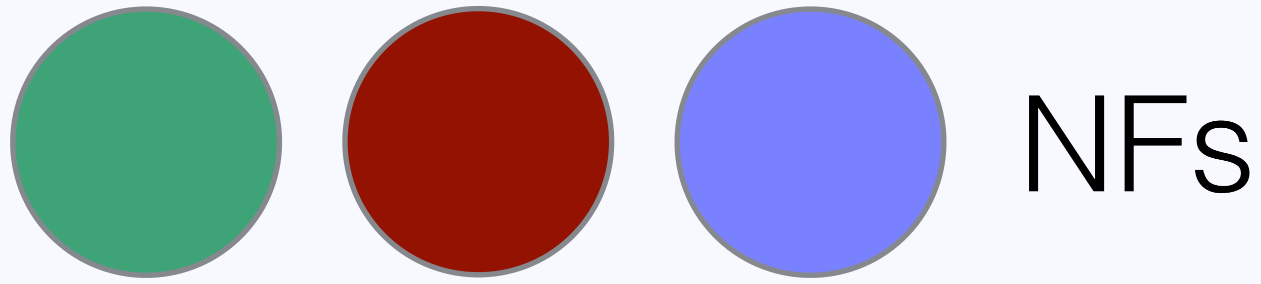


Isolation

- **Memory Isolation**: Partition memory spatially between NFs.

- **Packet Isolation**: Partition packet memory temporally between NFs.





Isolation

- **Memory Isolation**: Partition memory spatially between NFs.
- **Packet Isolation**: Partition packet memory temporally between NFs.
- **Performance Isolation**: One NF does not affect another's performance.

Isolation

- **Memory Isolation**: Partition memory spatially between NFs.

- **Packet Isolation**: Partition packet memory temporally between NFs.

- **Performance Isolation**: One NF does not affect another's performance.
    - Ongoing work: Partition **last level cache**.

Why Isolation?

- Enables **consolidation** in NFV deployments.

Why Isolation?

- Enables **consolidation** in NFV deployments.
  - NFs can be run by different **tenants**, built by different **vendors**.

Why Isolation?

- Enables **consolidation** in NFV deployments.
  - NFs can be run by different **tenants**, built by different **vendors**.
- Enables **consolidation** for NFs like SSL proxies that have **secrets**.

Why Isolation?

- Enables **consolidation** in NFV deployments.
  - NFs can be run by different **tenants**, built by different **vendors**.
- Enables **consolidation** for NFs like SSL proxies that have **secrets**.
  - Isolation is a building block for protecting secrets in applications.

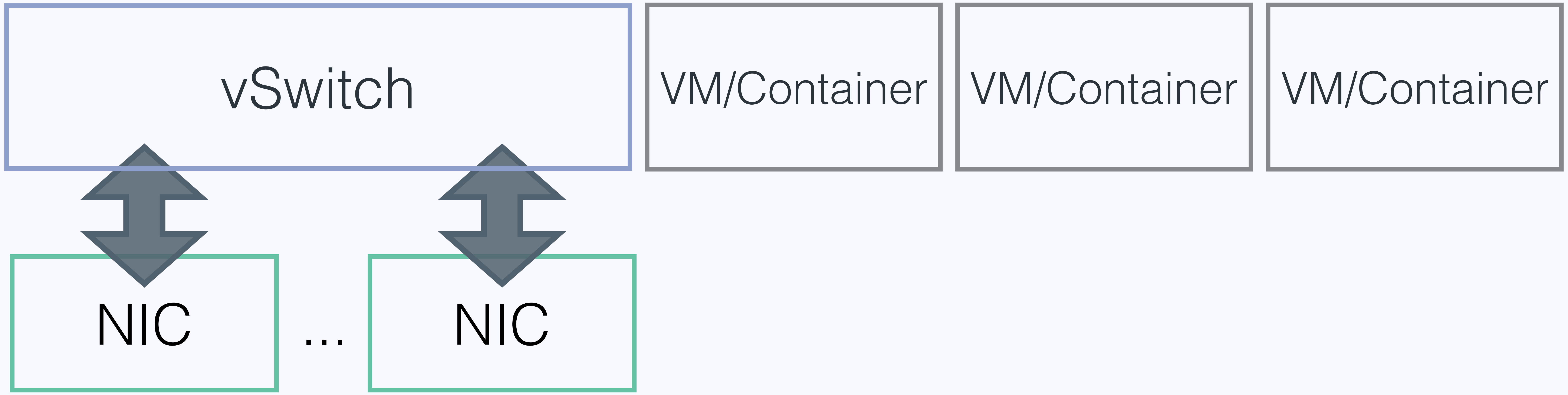
Why Isolation?

- Enables **consolidation** in NFV deployments.
    - NFs can be run by different **tenants**, built by different **vendors**.
- Enables **consolidation** for NFs like SSL proxies that have **secrets**.
    - Isolation is a building block for protecting secrets in applications.
- **Simplifies programming**: don't need to worry about other **programs** and **NFs**.

Why Isolation?

- Enables **consolidation** in NFV deployments.
    - NFs can be run by different **tenants**, built by different **vendors**.
- Enables **consolidation** for NFs like SSL proxies that have **secrets**.
    - Isolation is a building block for protecting secrets in applications.
- **Simplifies programming**: don’t need to worry about other **programs** and **NFs**.
    - Lack of isolation between drivers is a major cause of crashes in OSes.

`

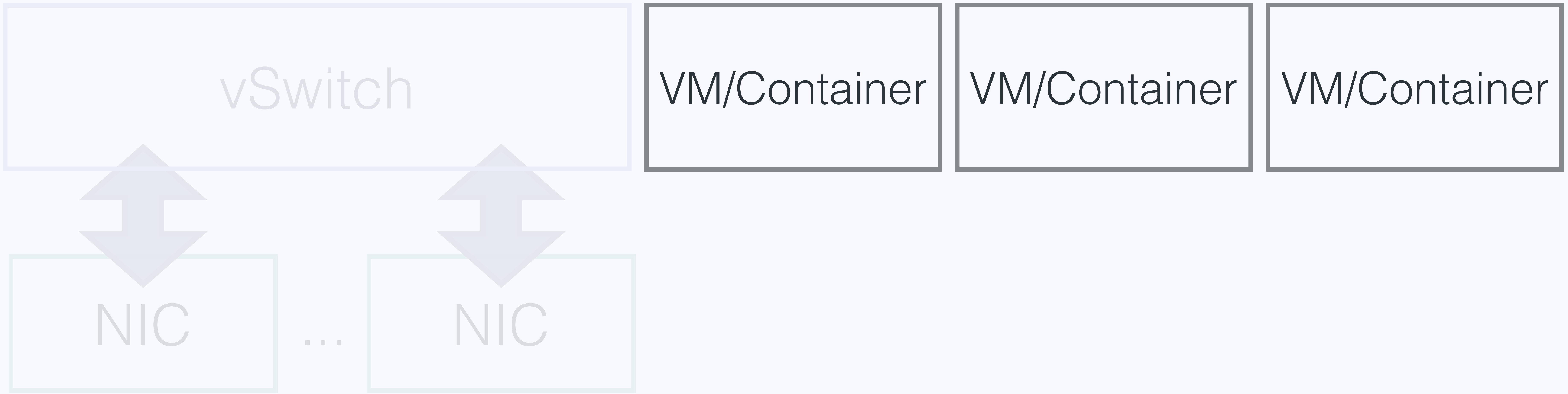


Memory Isolation

Packet Isolation

Performance

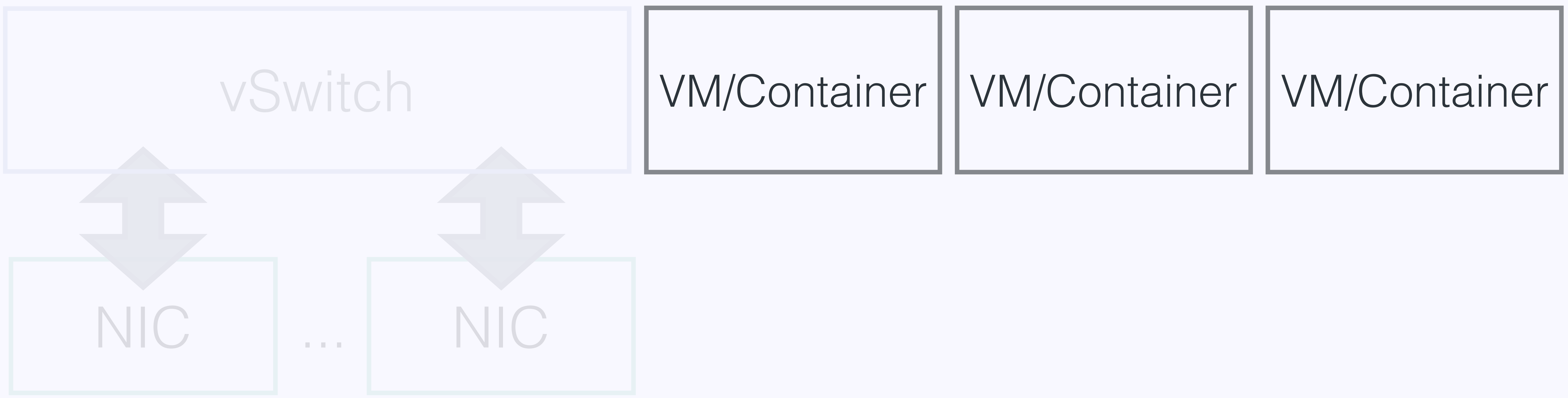
`



Memory Isolation

Packet Isolation

Performance

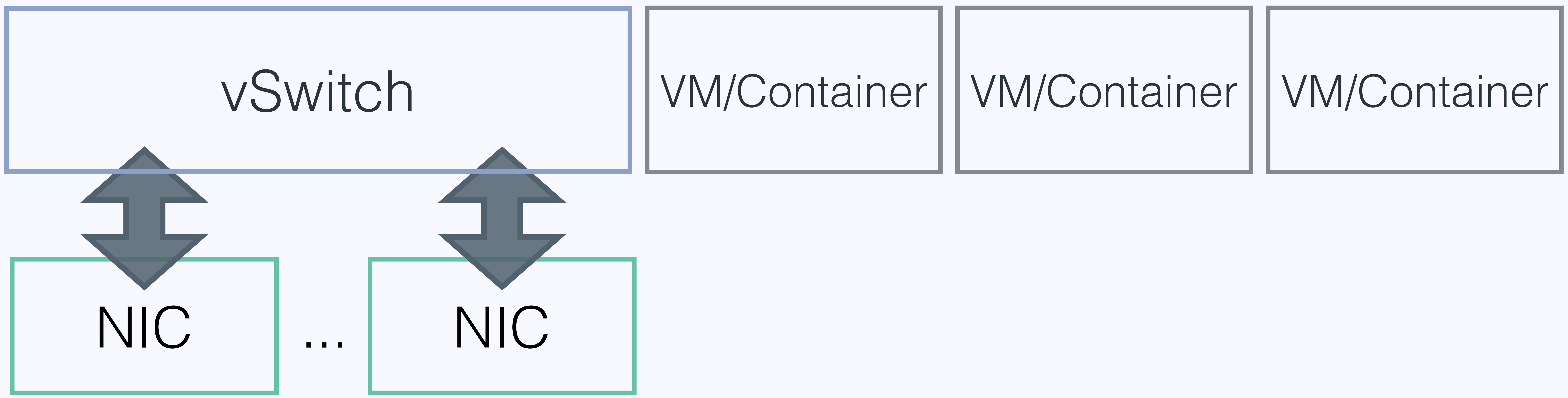


✔Memory Isolation

Packet Isolation

Performance

`

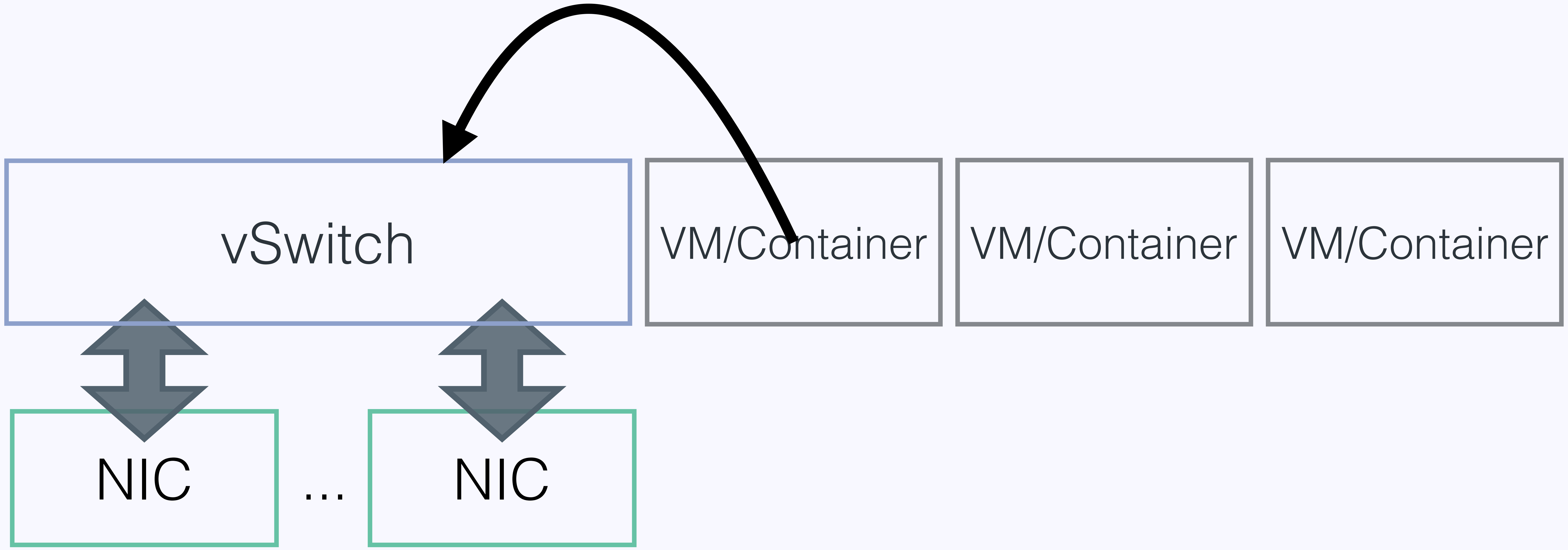


✔Memory Isolation

Packet Isolation

Performance

`

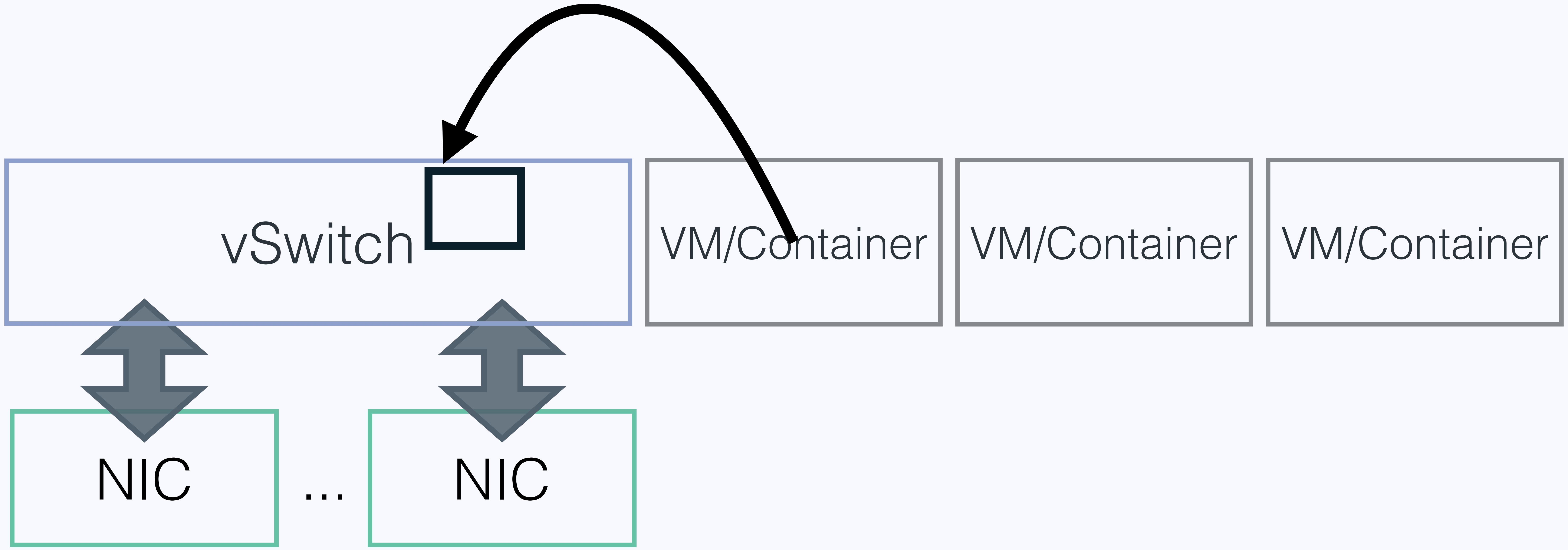


✔Memory Isolation

Packet Isolation

Performance

`

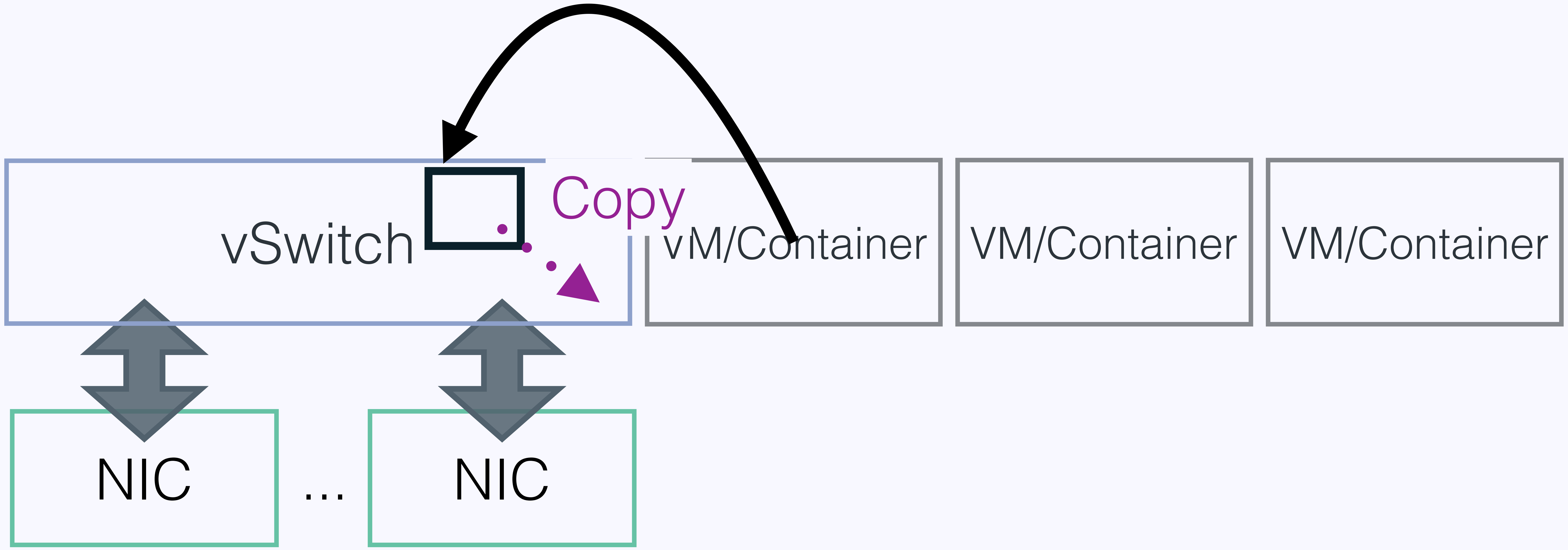


✔ Memory Isolation

Packet Isolation

Performance

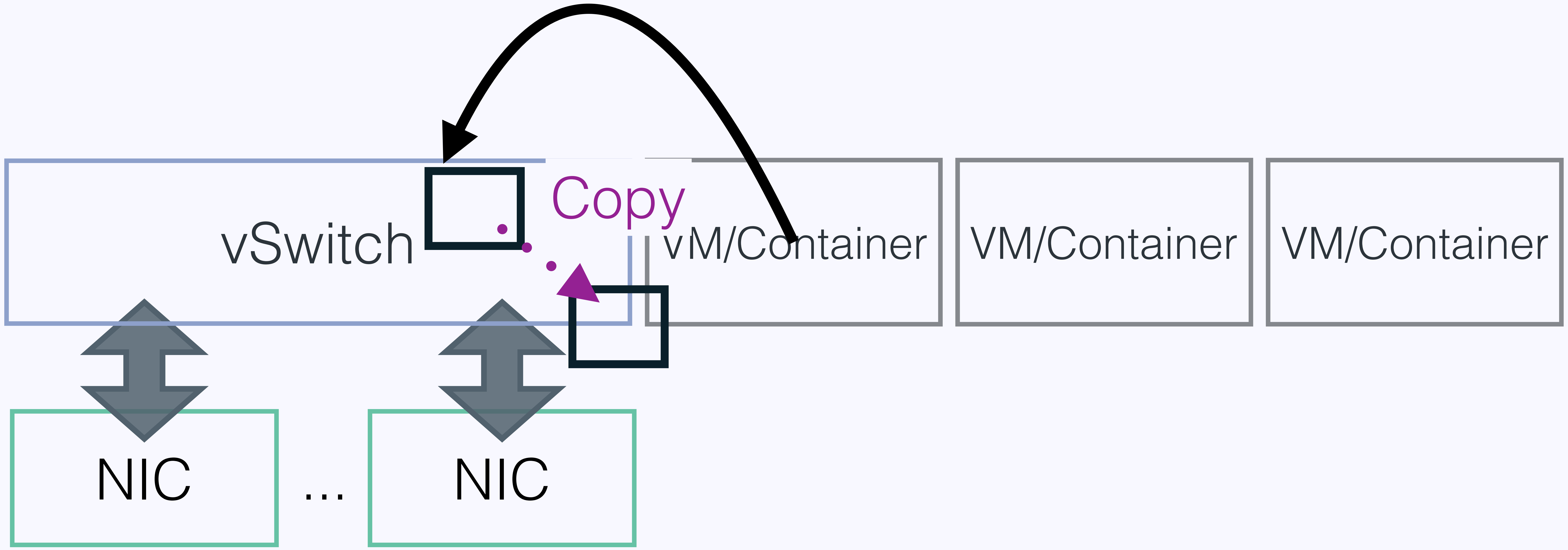
`



✔Memory Isolation

Packet Isolation

Performance

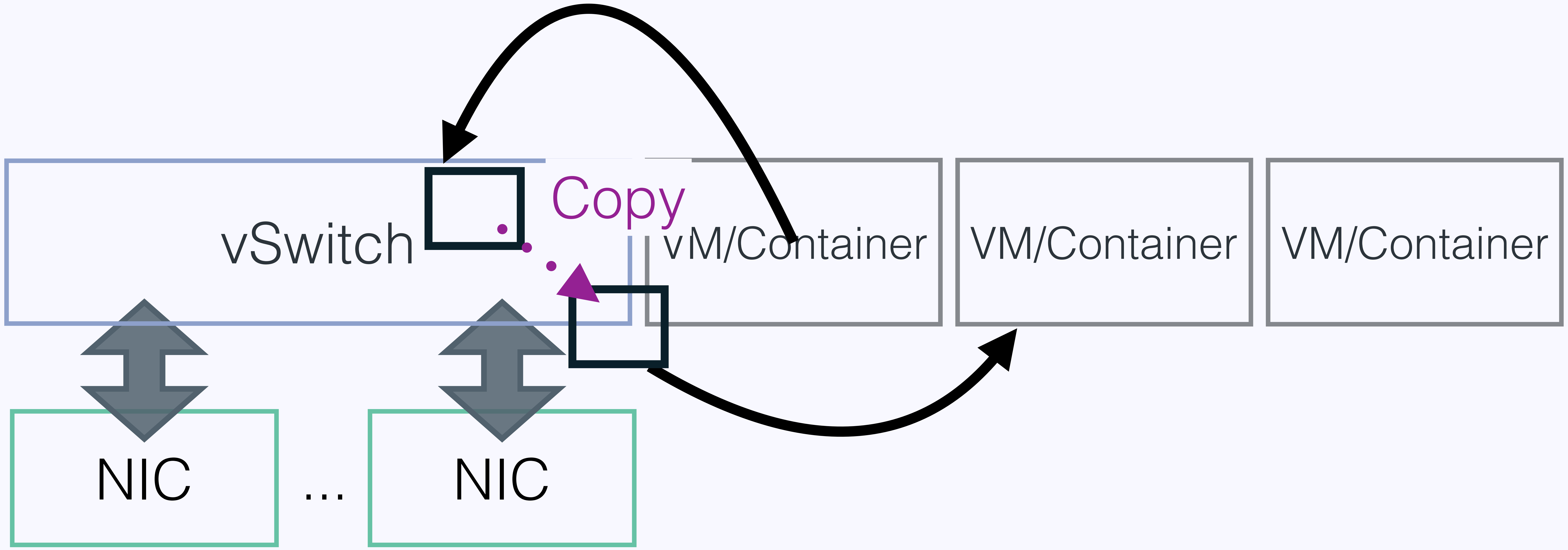


✔Memory Isolation

Packet Isolation

Performance

`

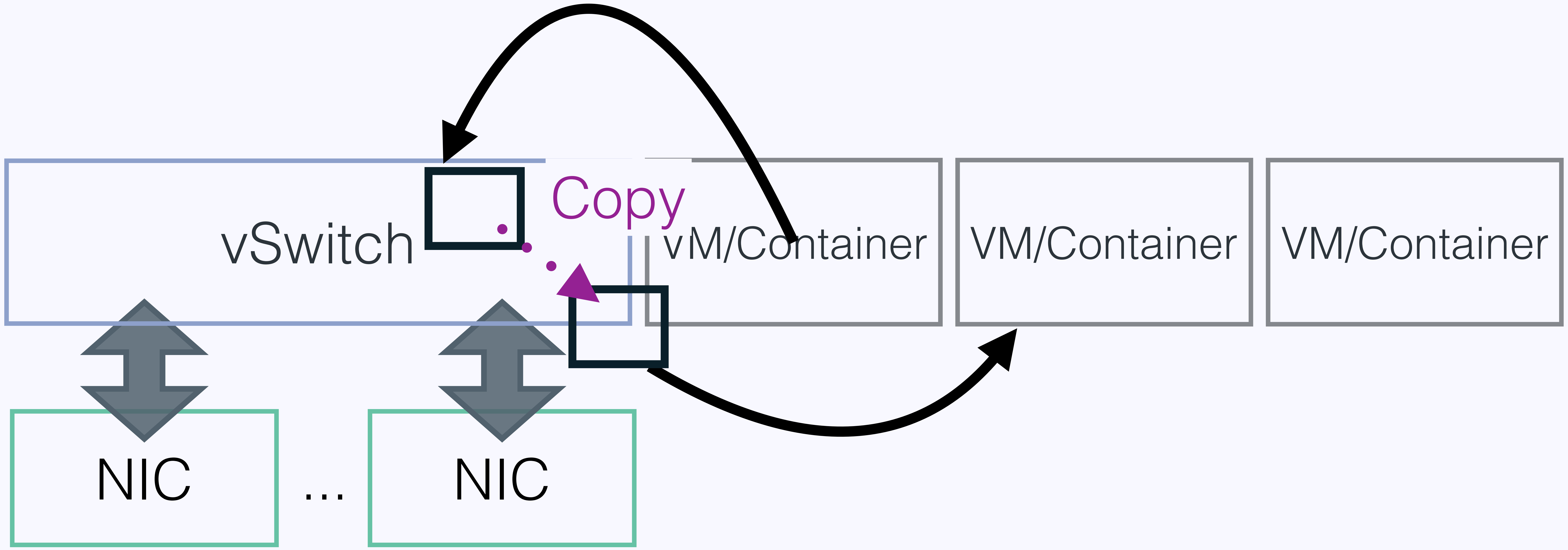


✔Memory Isolation

Packet Isolation

Performance

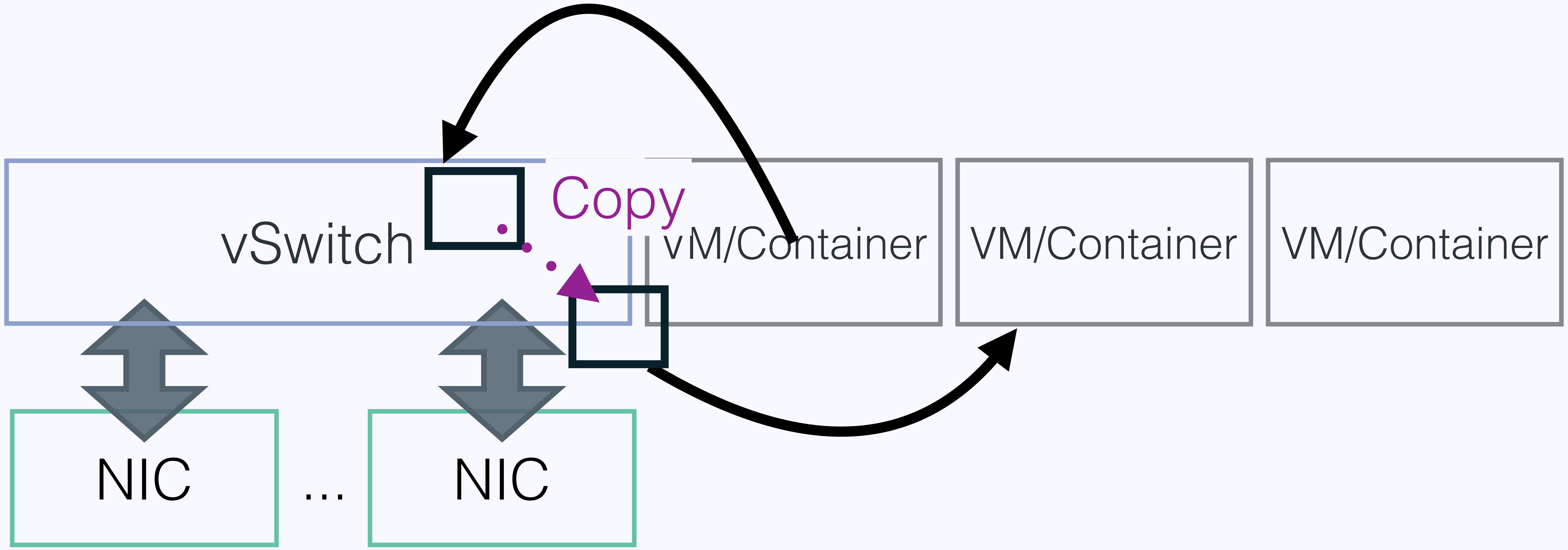
`



✔Memory Isolation

✔ Packet Isolation

Performance

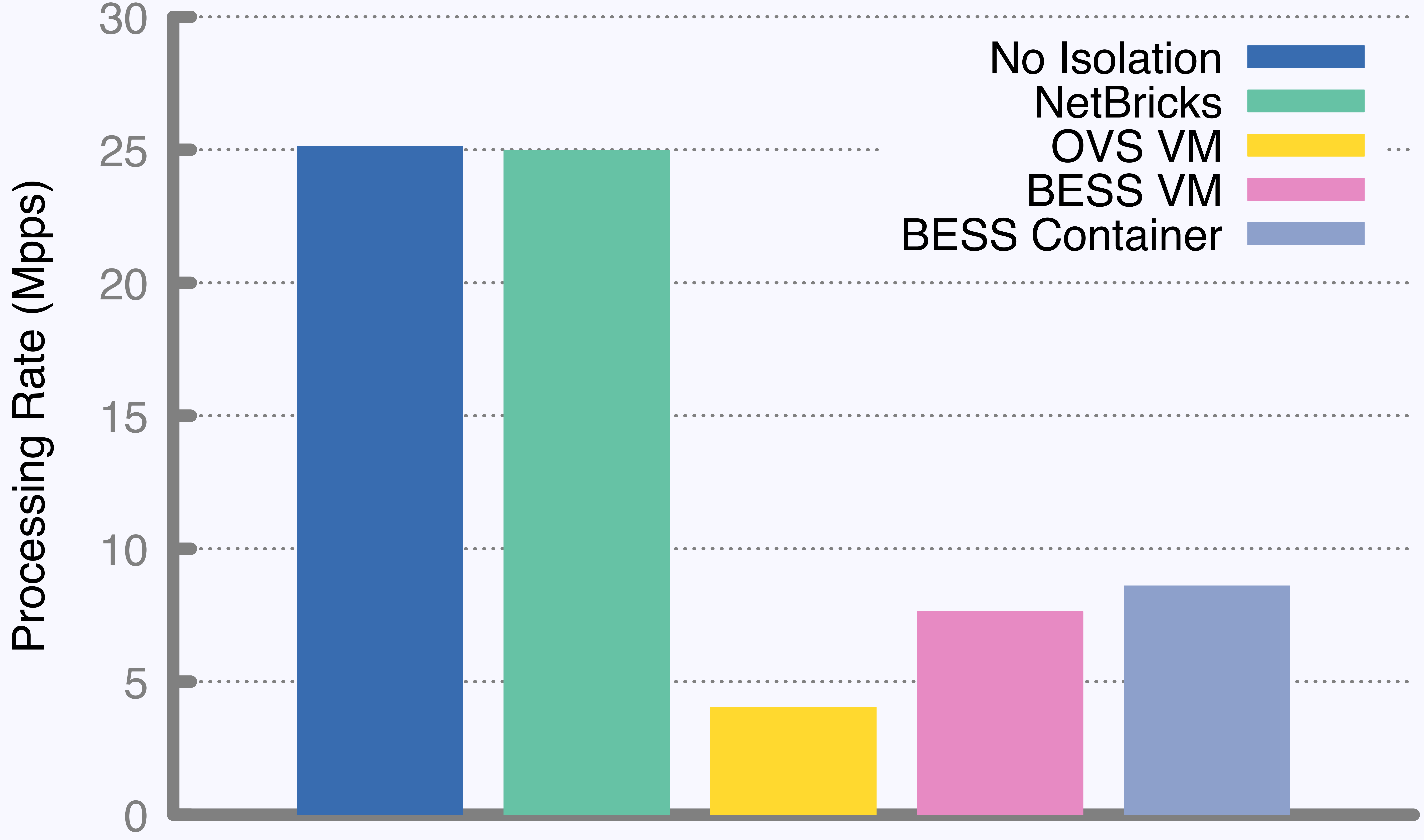


✔ Memory Isolation

✔ Packet Isolation

✗ Performance

NetBricks: Low Overhead Isolation



NetBricks: Key Insight

- **Runtime mechanisms** too expensive for NFV workloads.

NetBricks: Key Insight

- **Runtime mechanisms** too expensive for NFV workloads.
    - Process a packet approximately every 100ns (10 **MPPS**) or faster.

NetBricks: Key Insight

- **Runtime mechanisms** too expensive for NFV workloads.
  - Process a packet approximately every 100ns (10 **MPPS**) or faster.
- Must rely on **static** compile-time checks for **isolation**.

Memory Isolation at Compile Time

- Types and runtime checks can provide **memory isolation** within a process.

Memory Isolation at Compile Time

- Types and runtime checks can provide **memory isolation** within a process.
  - Check isolation almost entirely at compile time, limited runtime overhead.

Memory Isolation at Compile Time

- Types and runtime checks can provide **memory isolation** within a process.
    - Check isolation almost entirely at compile time, limited runtime overhead.
- Built on **Rust** - **type checks**, **bound checks**, **no garbage collection**.

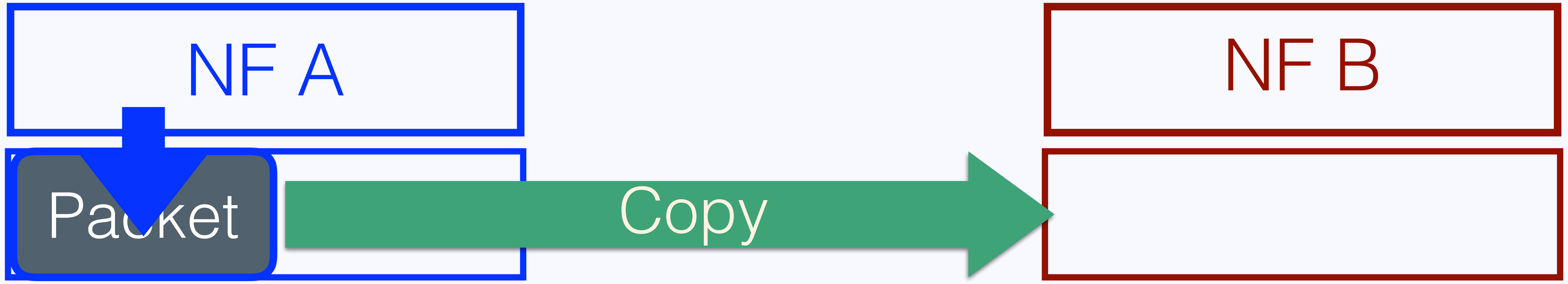
Memory Isolation at Compile Time

- Types and runtime checks can provide **memory isolation** within a process.
  - Check isolation almost entirely at compile time, limited runtime overhead.
- Built on **Rust** - **type checks**, **bound checks**, **no garbage collection**.
- Framework **designed** to meet the rest of the **memory isolation requirements**.

Approaches to Packet Isolation

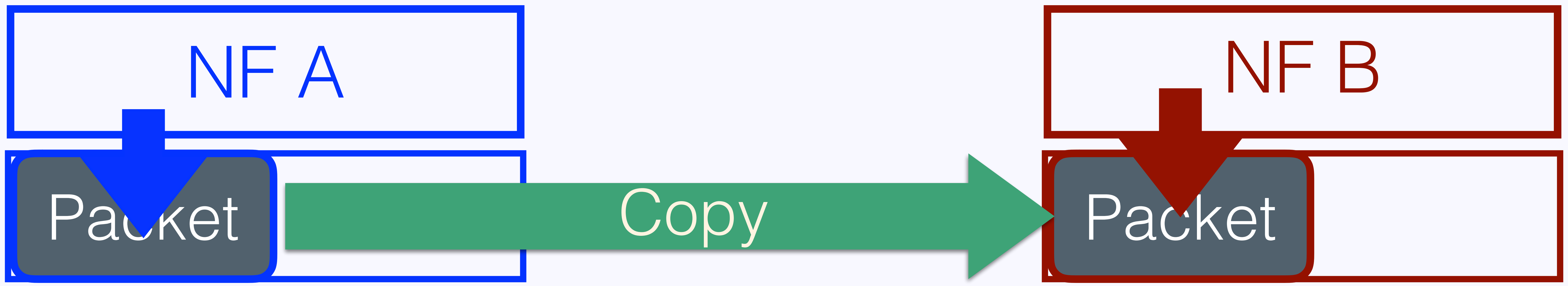
- Packets are passed between **network functions** - memory isolation insufficient.
- Existing approaches convert this **temporal problem** to a **spatial one**.
  - **Copy packets** from one packet space to another.

Approaches to Packet Isolation



- Packets are passed between **network functions** - memory isolation insufficient.
- Existing approaches convert this **temporal problem** to a **spatial one**.
  - **Copy packets** from one packet space to another.

Approaches to Packet Isolation



- Packets are passed between **network functions** - memory isolation insufficient.
- Existing approaches convert this **temporal problem** to a **spatial one**.
  - **Copy packets** from one packet space to another.

Linear Types: Packet Isolation at Compile Time

- Solution: Use **linear types** (1990s) for isolation.

Linear Types: Packet Isolation at Compile Time

- Solution: Use **linear types** (1990s) for isolation.
- Syntax marks argument that are **moved**.

```
fn consume(a: Packet) {
    // Work with packet.
}
```

Linear Types: Packet Isolation at Compile Time

- Solution: Use **linear types** (1990s) for isolation.
- Syntax marks argument that are **moved**.
  - **Argument** moved during calls.

```
fn consume(a: Packet) {
    // Work with packet.
}

// pkt is a packet
consume(pkt);
```

Linear Types: Packet Isolation at Compile Time

- Solution: Use **linear types** (1990s) for isolation.
- Syntax marks argument that are **moved**.
    - **Argument** moved during calls.
        - Ownership is transferred to callee.

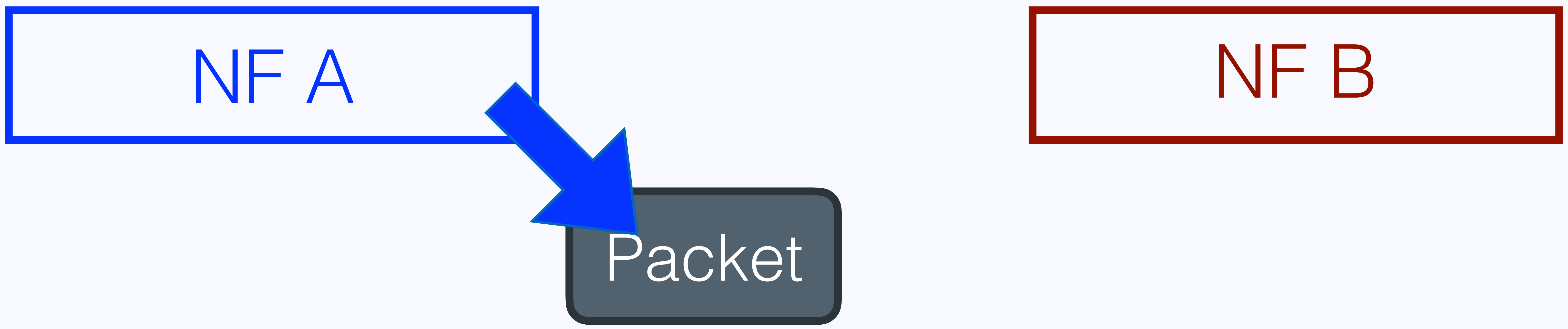
```
fn consume(a: Packet) {
    // Work with packet.
}

// pkt is a packet
consume(pkt);
```

Linear Types: Packet Isolation at Compile Time

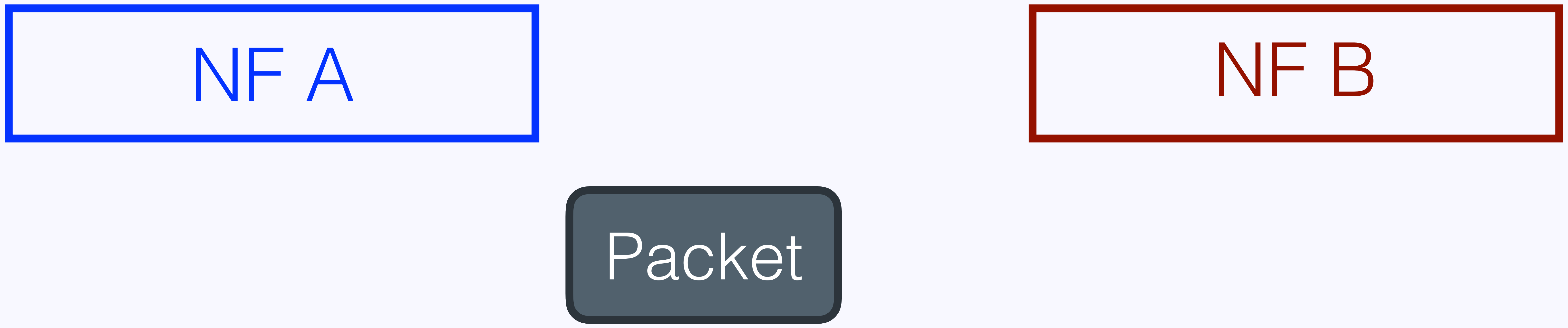
- Solution: Use **linear types** (1990s) for isolation.
- Syntax marks argument that are **moved**.
  - **Argument** moved during calls.
    - Ownership is transferred to callee.
  - **Moved variables** can not be reused.

```
fn consume(a: Packet) {
    // Work with packet.
}

// pkt is a packet
consume(pkt);

pkt.set_length(200);
```

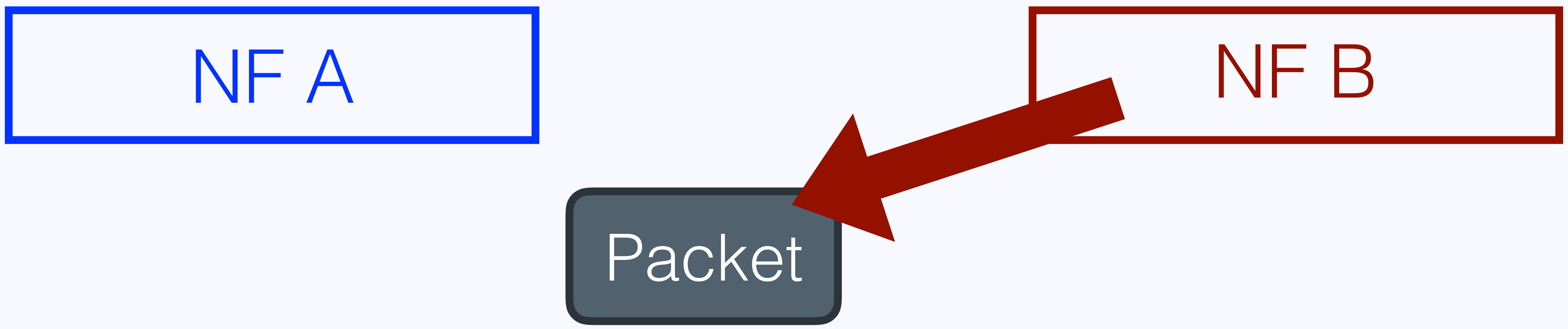
NetBricks: Packet Isolation



NetBricks: Packet Isolation



NetBricks: Packet Isolation



NetBricks: Packet Isolation

NetBricks: Packet Isolation

- Linear types implemented by **Rust** for concurrency.

NetBricks: Packet Isolation

- Linear types implemented by **Rust** for concurrency.
- **NetBricks operators** consumes packet reference.

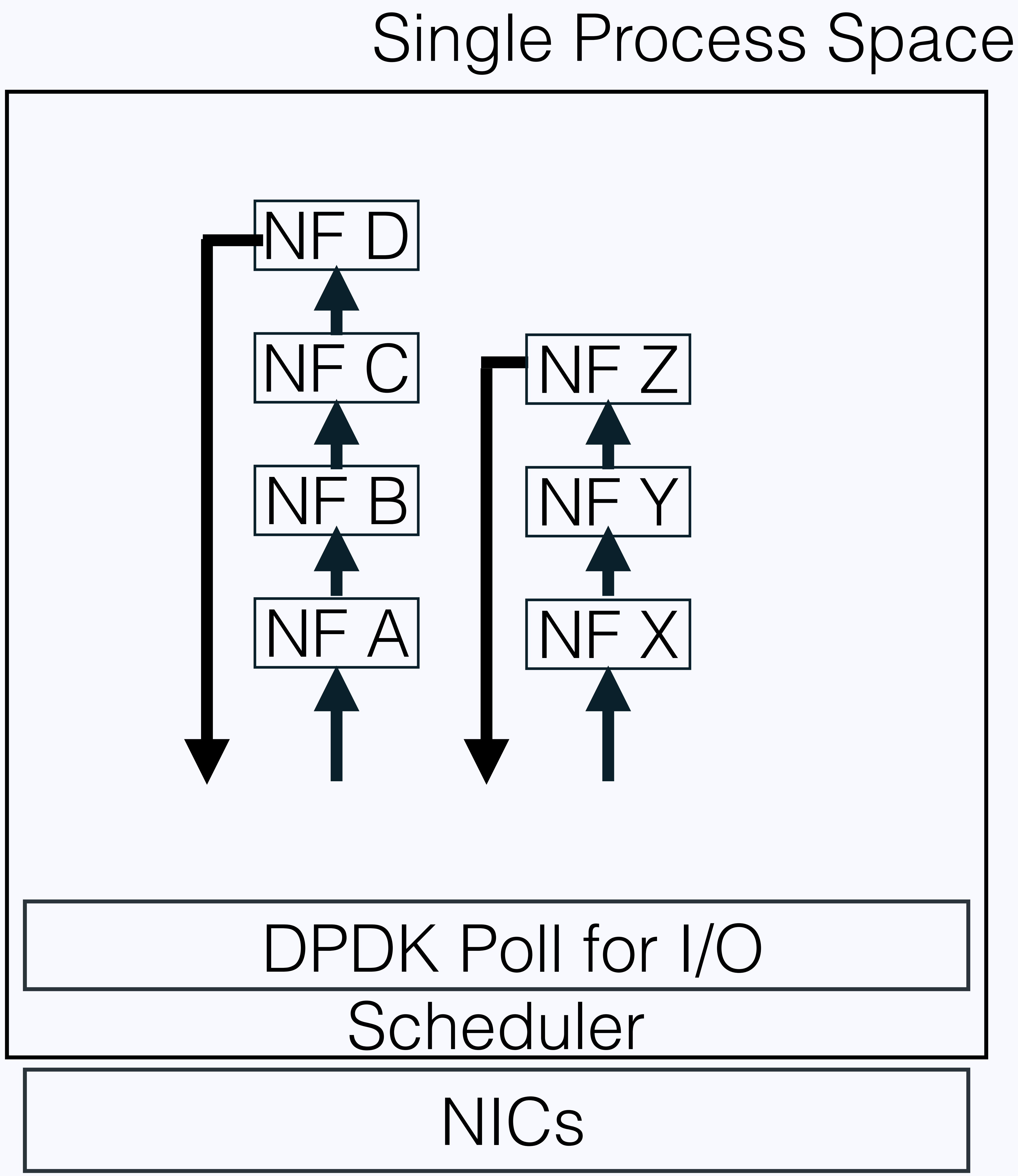
NetBricks: Packet Isolation

- Linear types implemented by **Rust** for concurrency.
- **NetBricks operators** consumes packet reference.
- API is designed so that **safe** code can never learn packet buffer address.

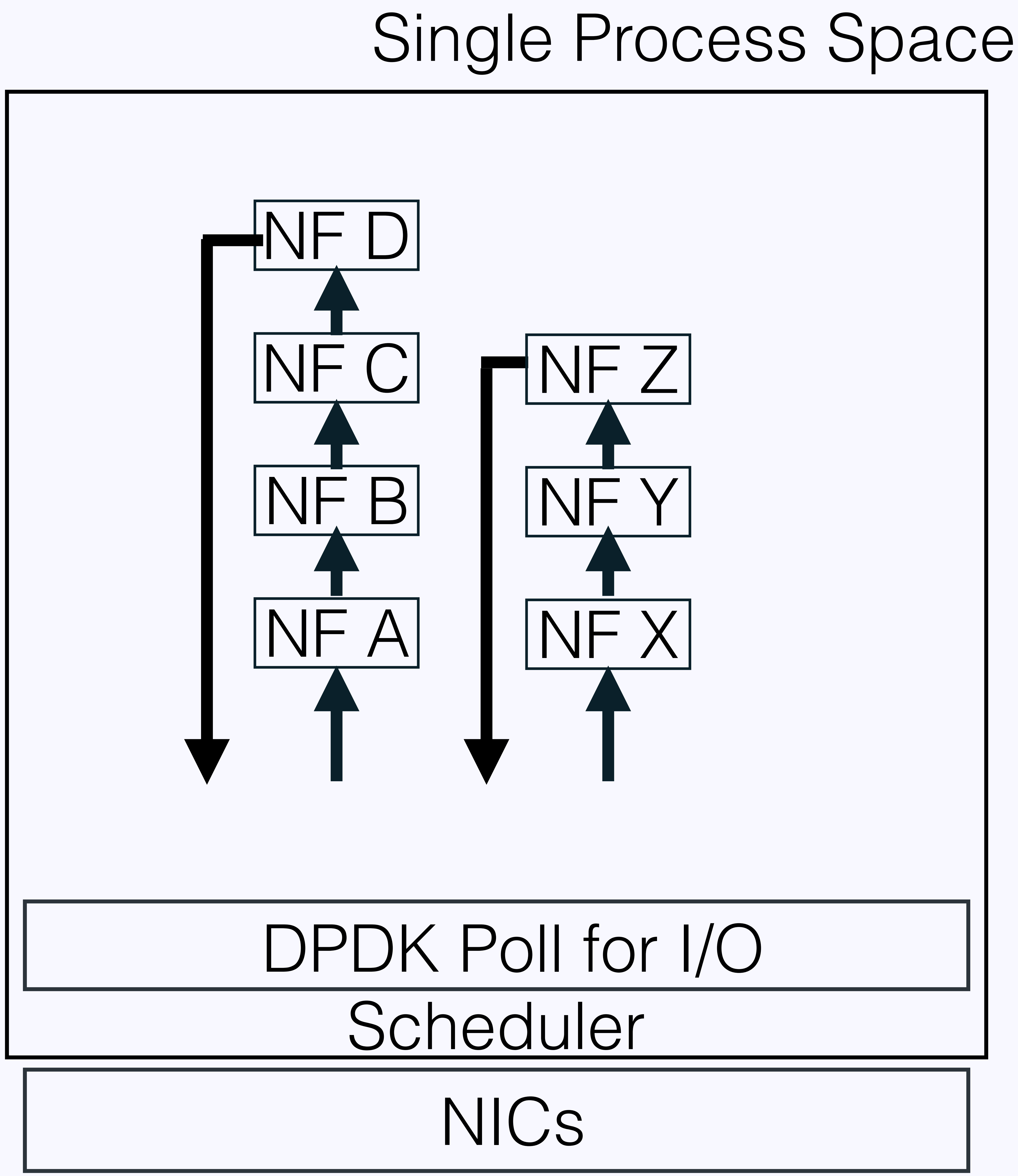
NetBricks: Packet Isolation

- Linear types implemented by **Rust** for concurrency.
- **NetBricks operators** consumes packet reference.
- API is designed so that **safe** code can never learn packet buffer address.
- Assuming compiler is sound - packet isolation is guaranteed.

NetBricks Runtime Architecture

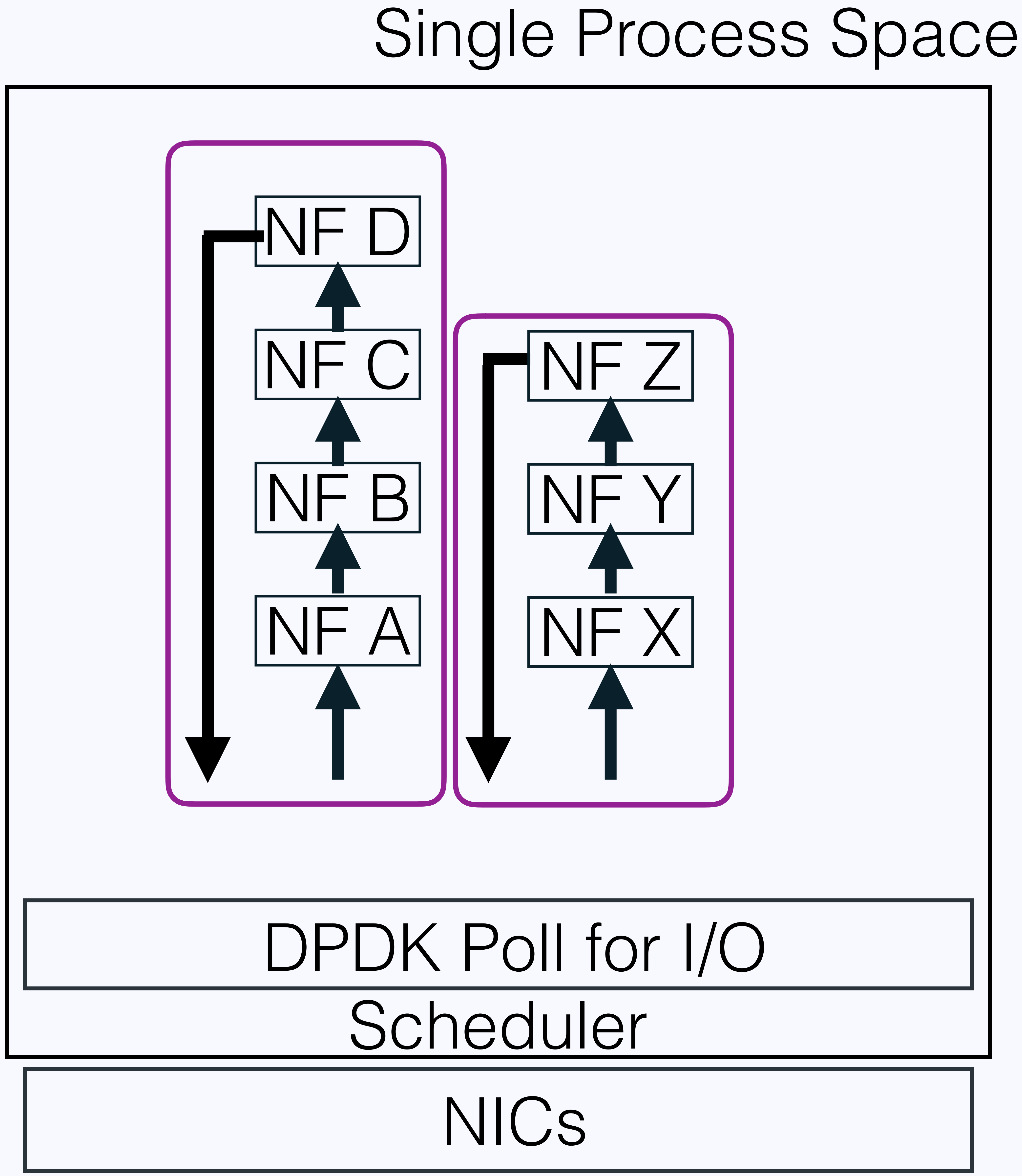


NetBricks Runtime Architecture



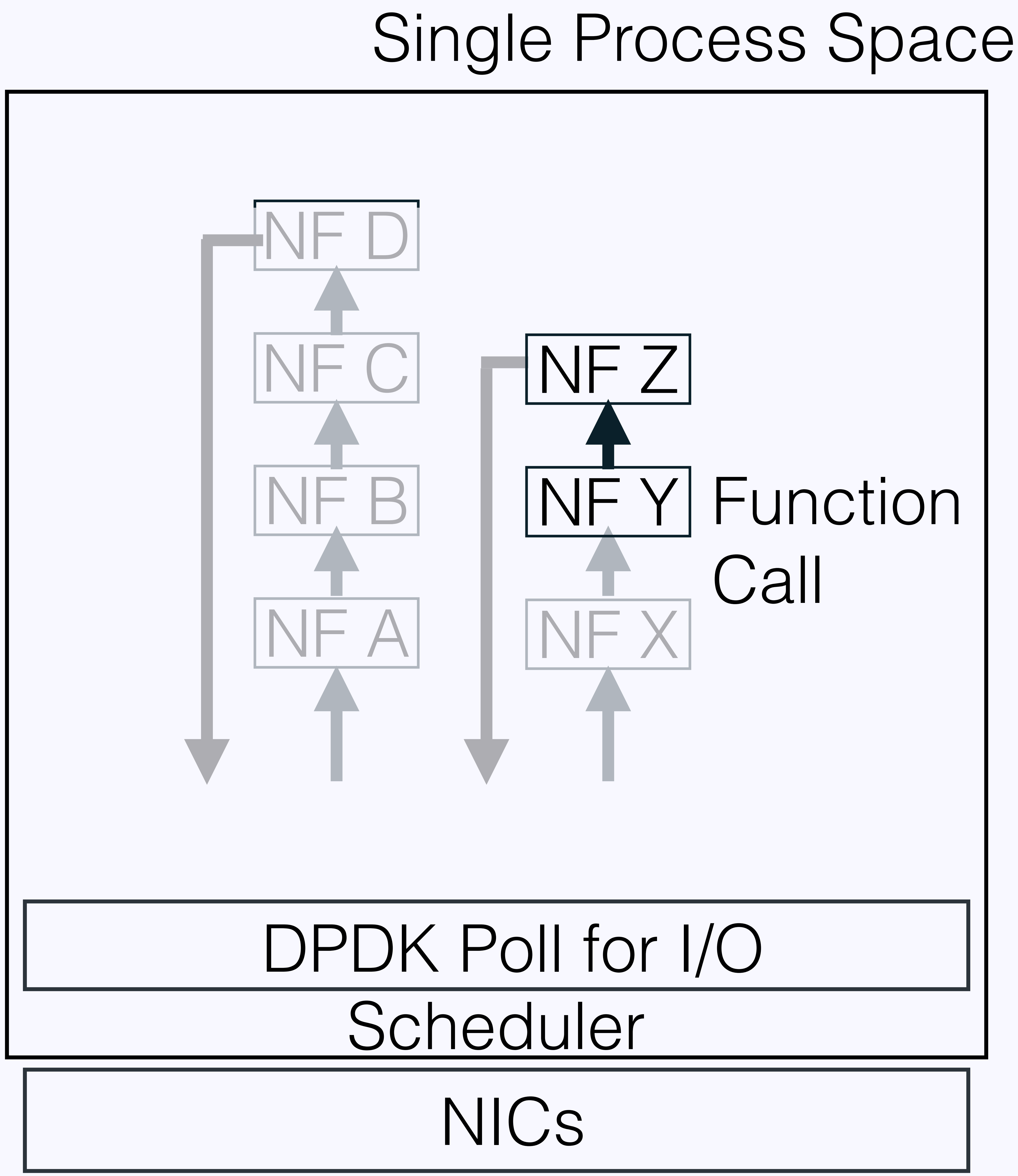
DPDK: Fast packet I/O.

NetBricks Runtime Architecture

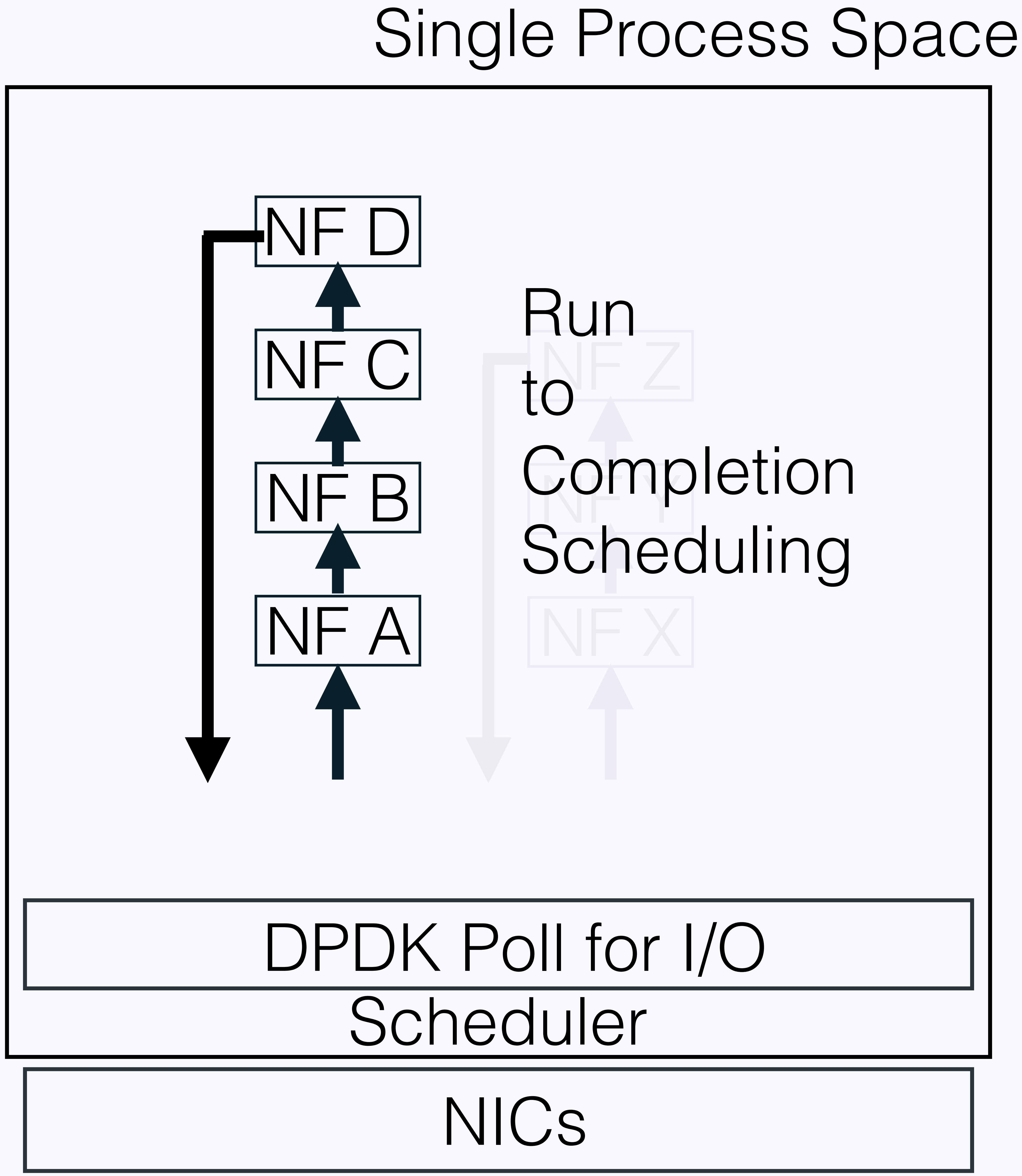


NF Chains: Units of scheduling

NetBricks Runtime Architecture

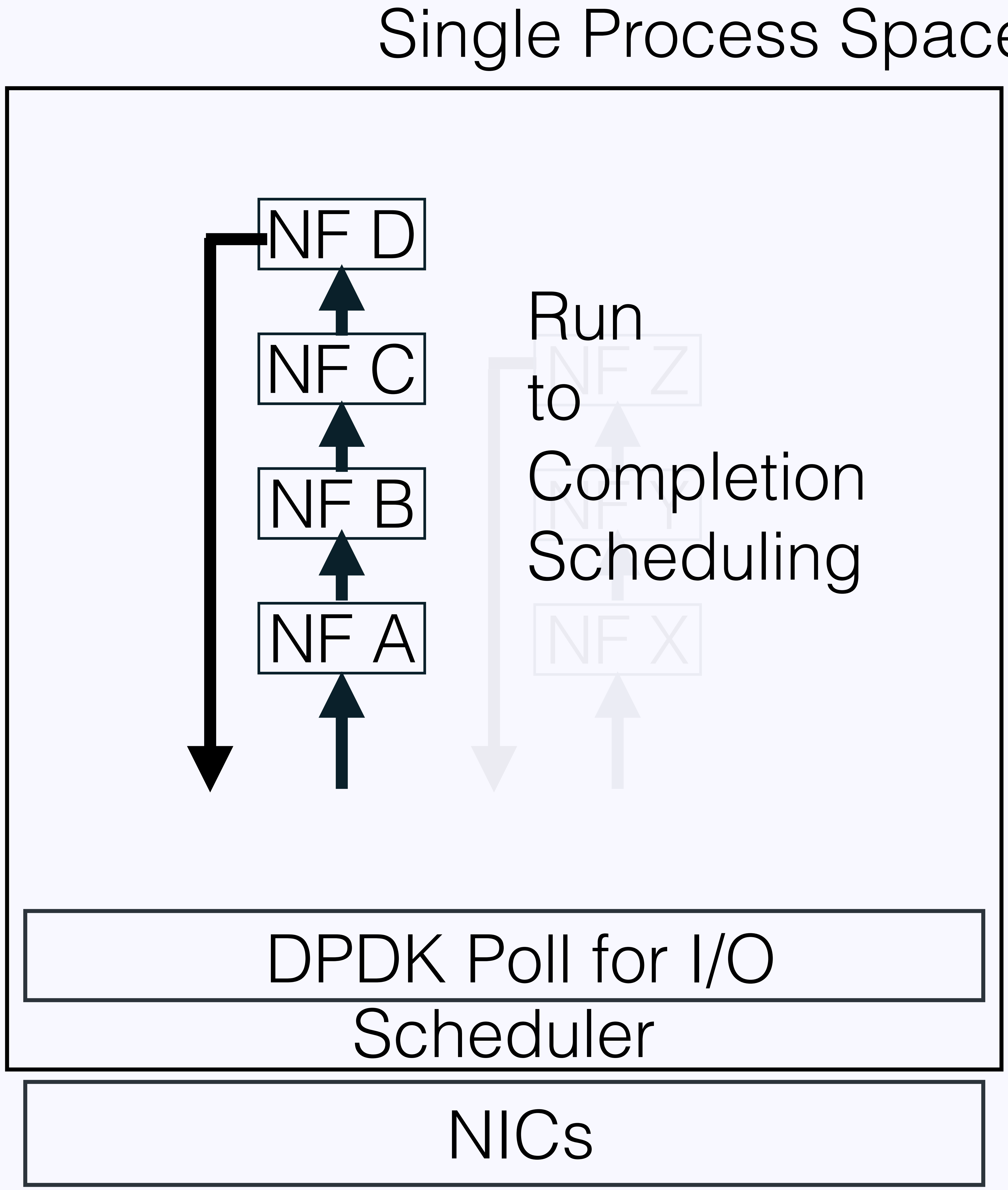


NetBricks Runtime Architecture



-Do not preempt NF chain.

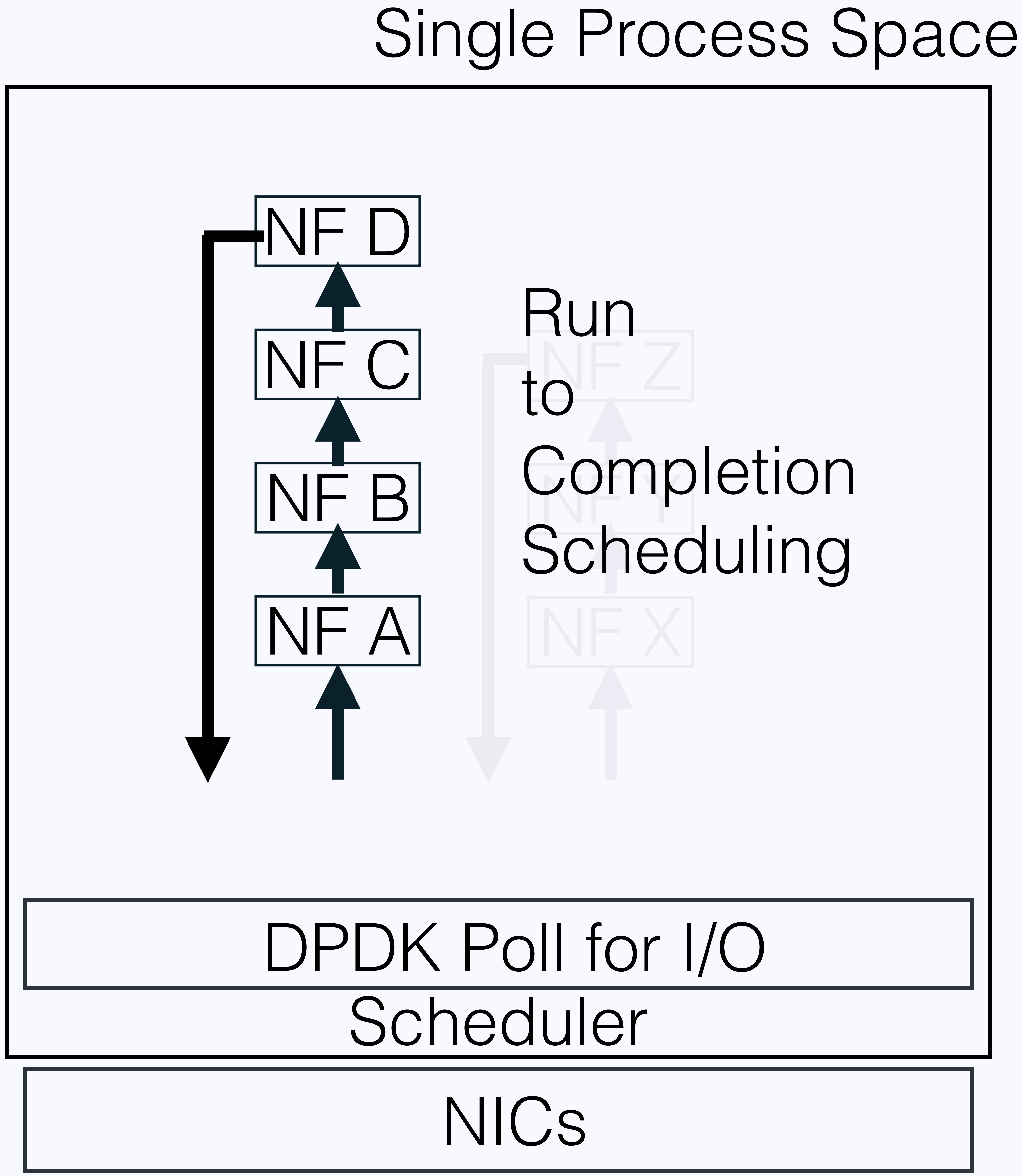
NetBricks Runtime Architecture



-Do not preempt NF chain.

-Reduces number of packets in-flight.

NetBricks Runtime Architecture

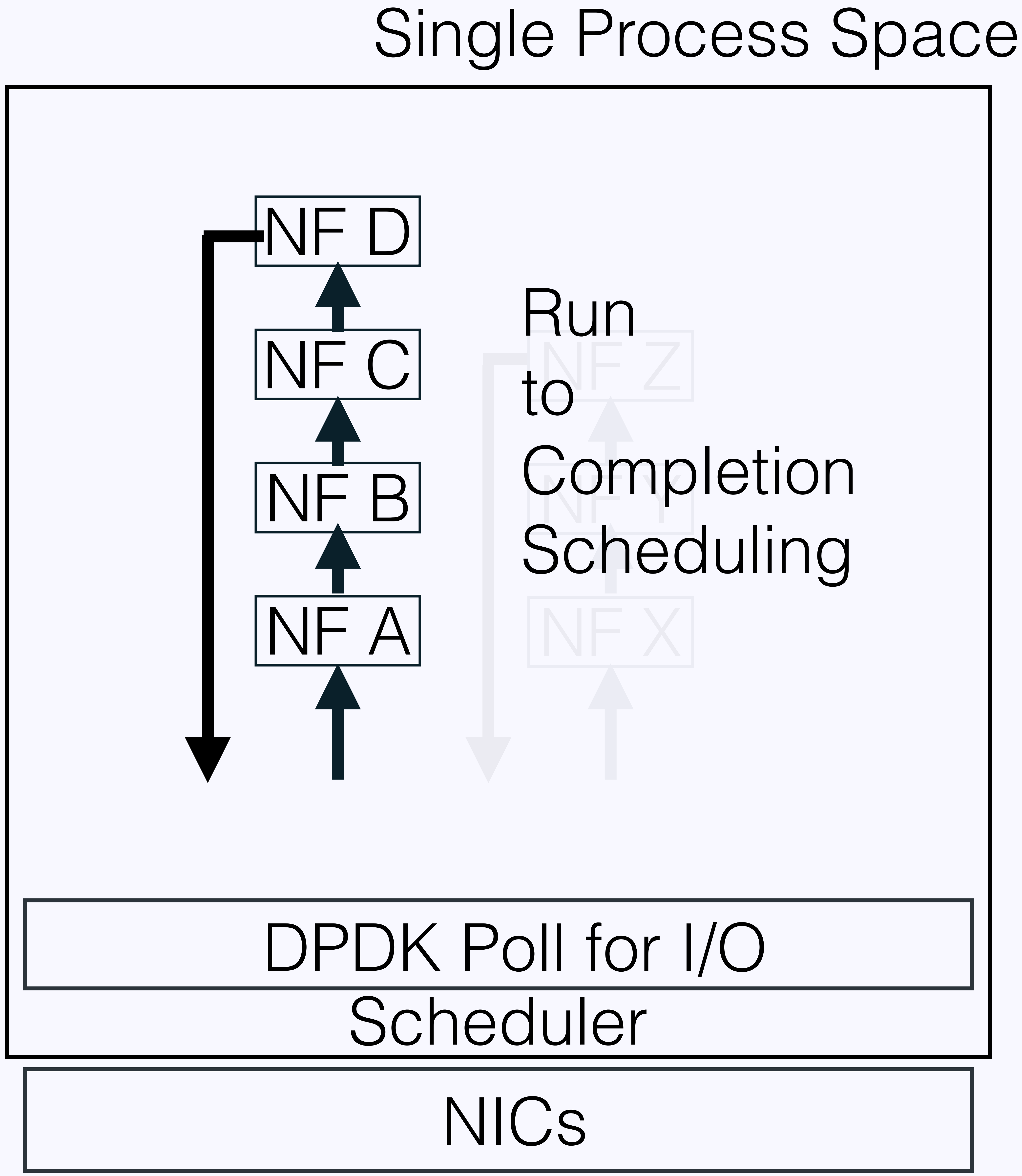


-Do not preempt NF chain.

-Reduces number of packets in-flight.

-Reduces working set size.

NetBricks Runtime Architecture



-Do not preempt NF chain.

-Reduces number of packets in-flight.

-Reduces working set size.

-Preemption points added using queues

Benefits of Software Isolation

- Provides low overhead **memory** and **packet isolation**.

Benefits of Software Isolation

- Provides low overhead **memory** and **packet isolation**.
- Improved **consolidation**: multiple NFs can share a core.

Benefits of Software Isolation

- Provides low overhead **memory** and **packet isolation**.
- Improved **consolidation**: multiple NFs can share a core.
  - **Context switch** (~1μs) vs **function call** to NF (~ few cycles = few ns).

Benefits of Software Isolation

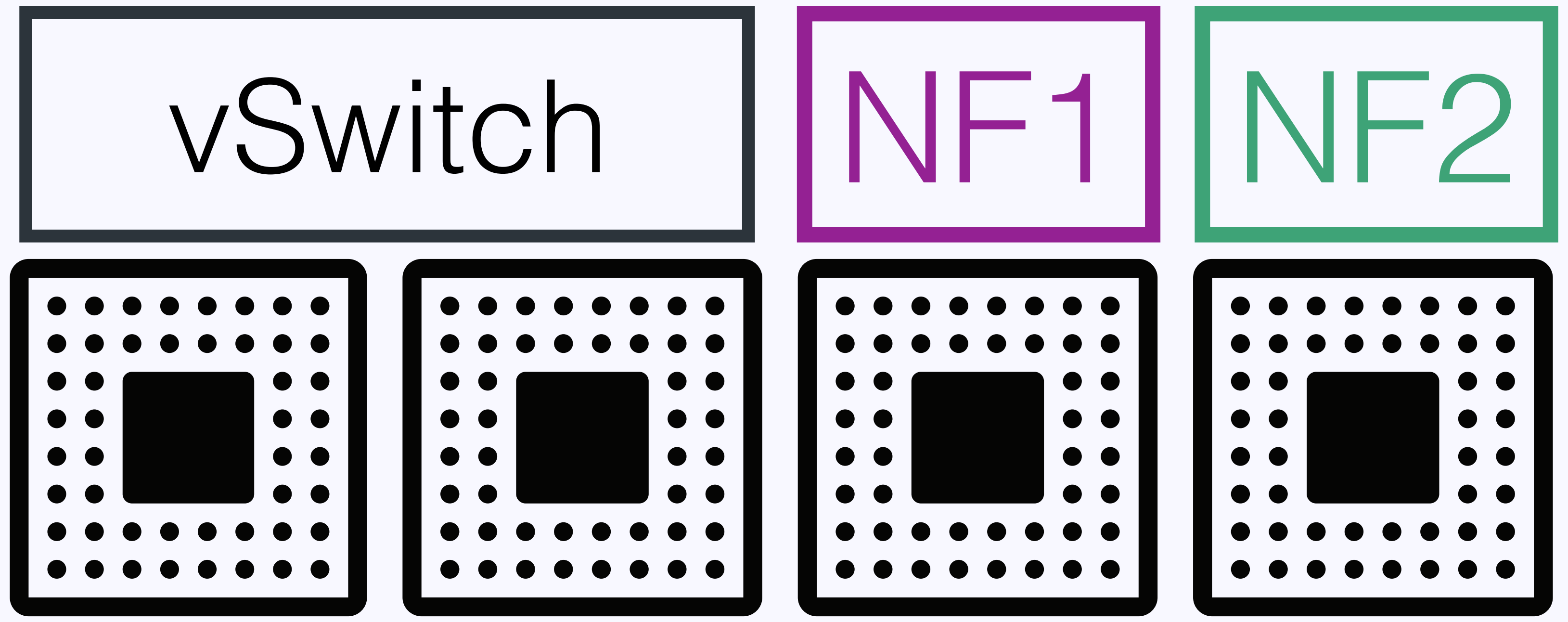
- Provides low overhead **memory** and **packet isolation**.
- Improved **consolidation**: multiple NFs can share a core.
  - **Context switch** (~1µs) vs **function call** to NF (~ few cycles = few ns).
- Reduce **memory** and **cache pressure**.

Benefits of Software Isolation

- Provides low overhead **memory** and **packet isolation**.
- Improved **consolidation**: multiple NFs can share a core.
  - **Context switch** (~1μs) vs **function call** to NF (~ few cycles = few ns).
- Reduce **memory** and **cache pressure**.
  - Zero copy I/O => do not need to copy packets around.

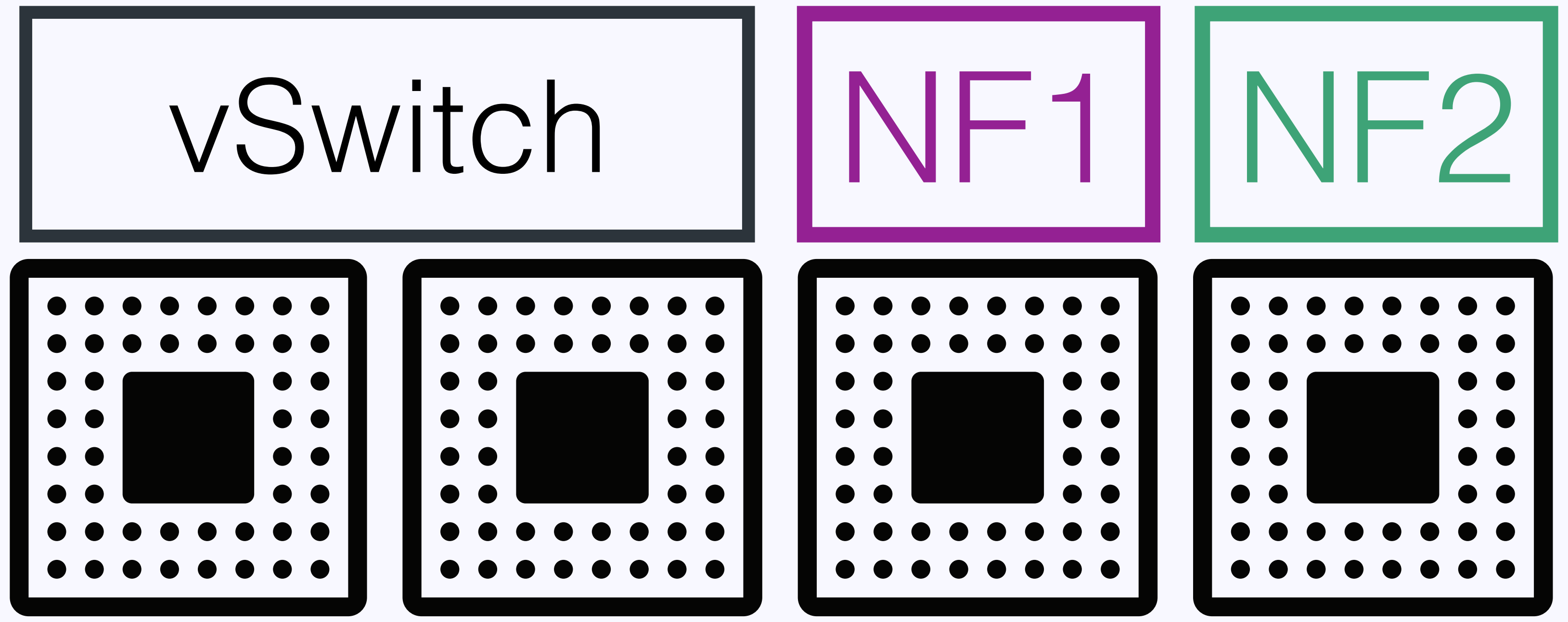
Evaluation Setup

VM/Container

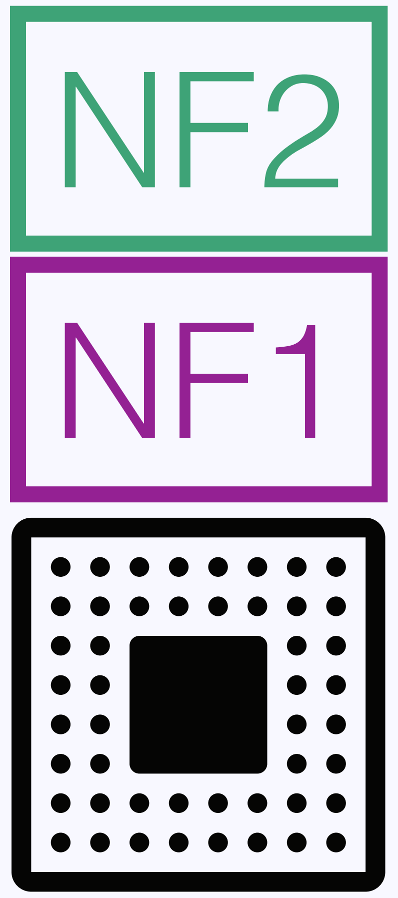


Evaluation Setup

VM/Container

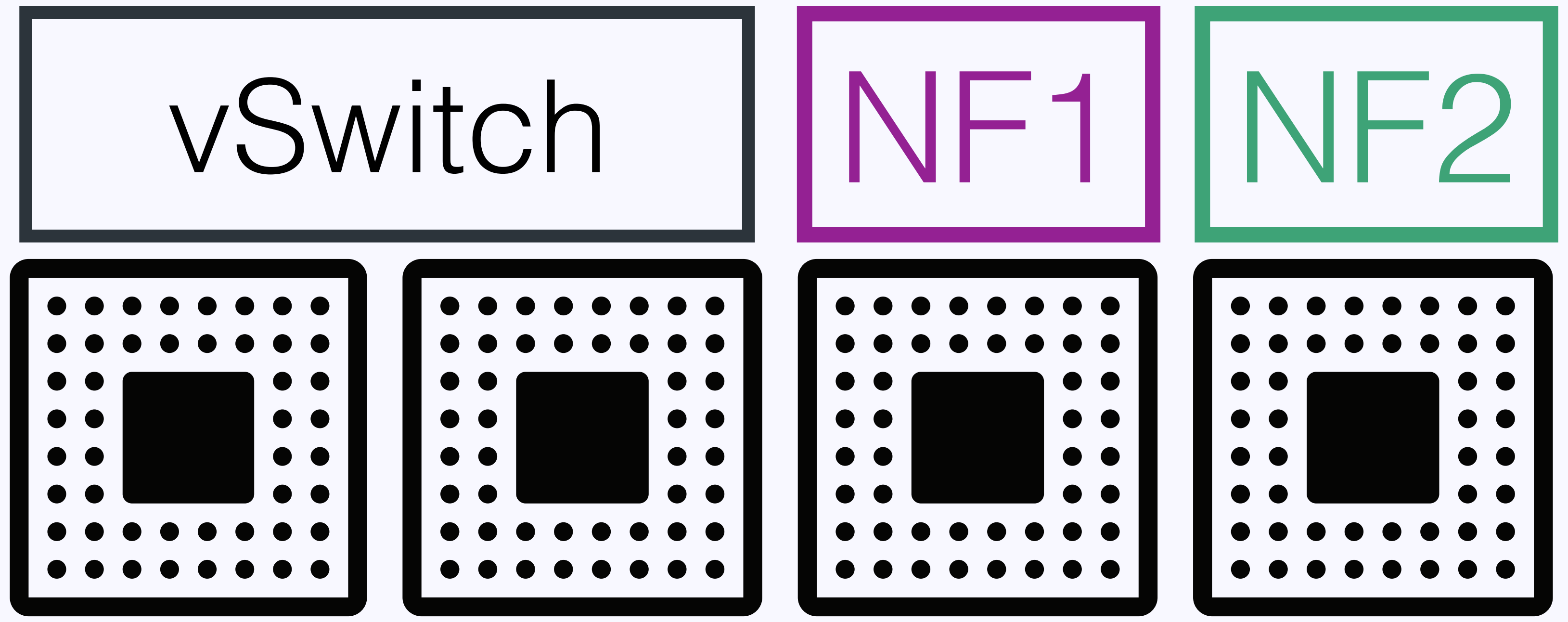


NetBricks

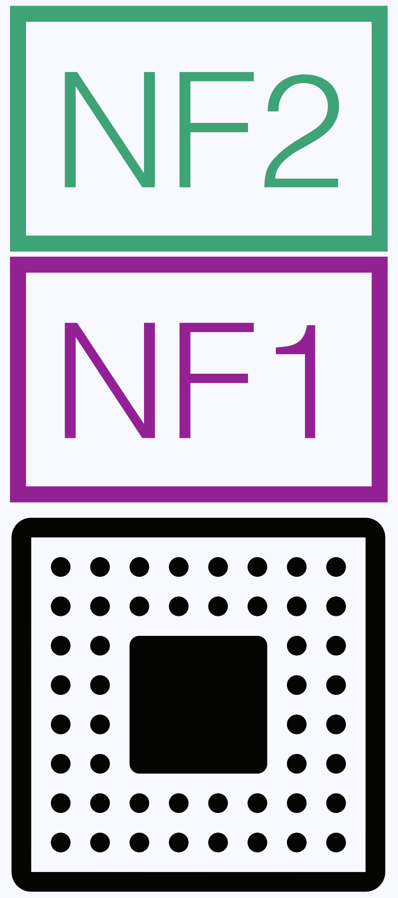


Evaluation Setup

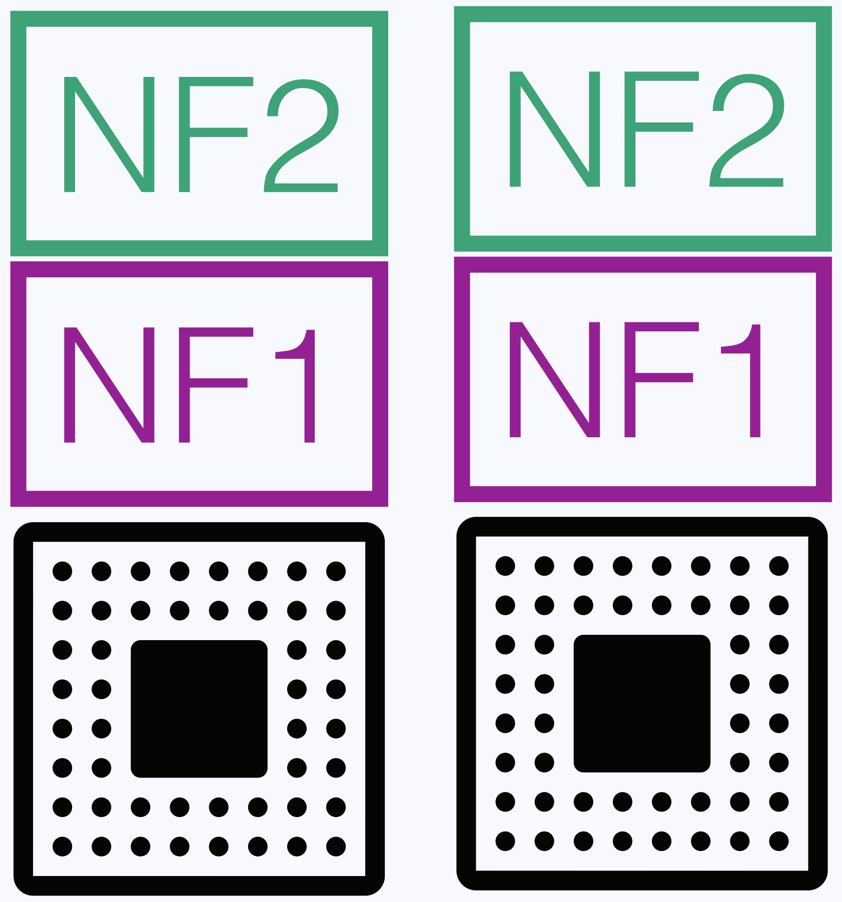
VM/Container



NetBricks

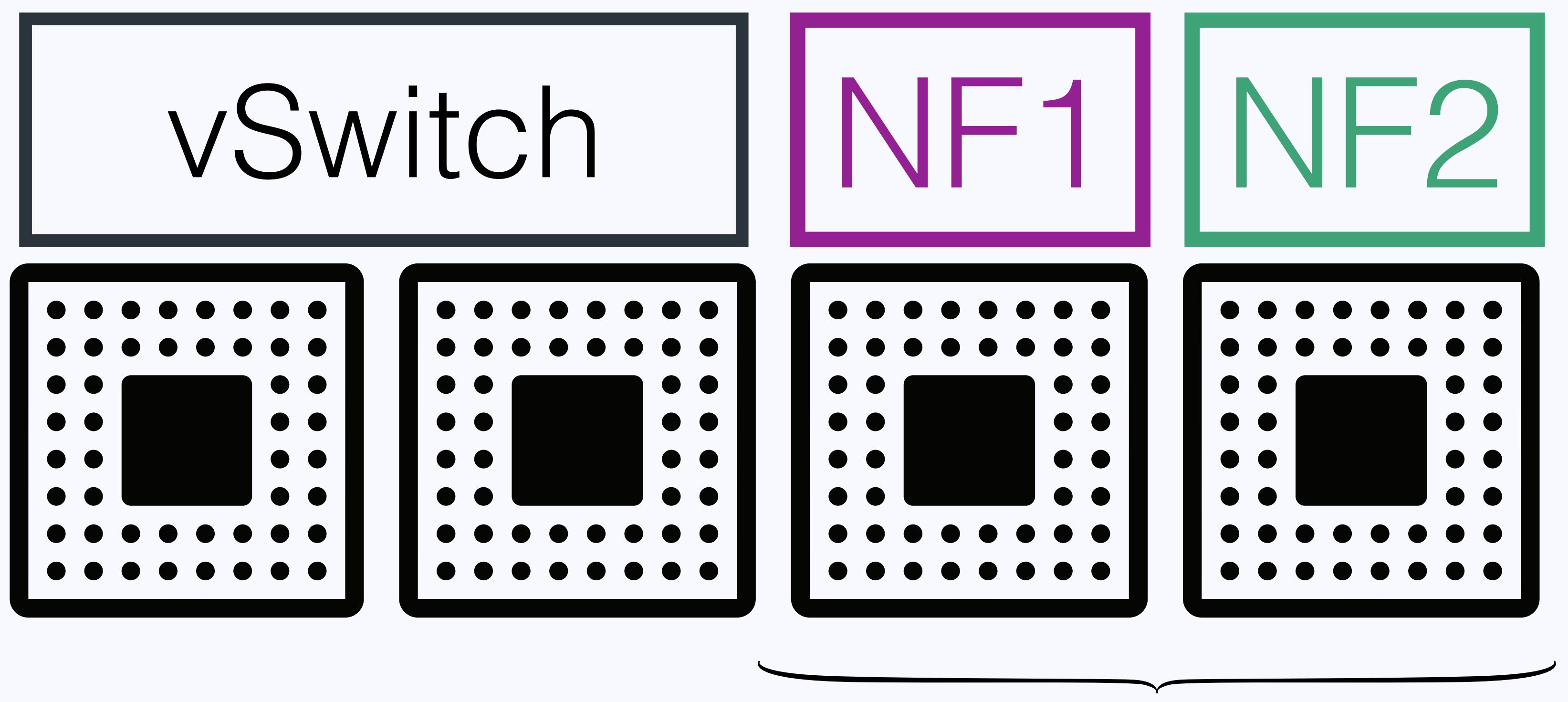


NetBricks Multicore

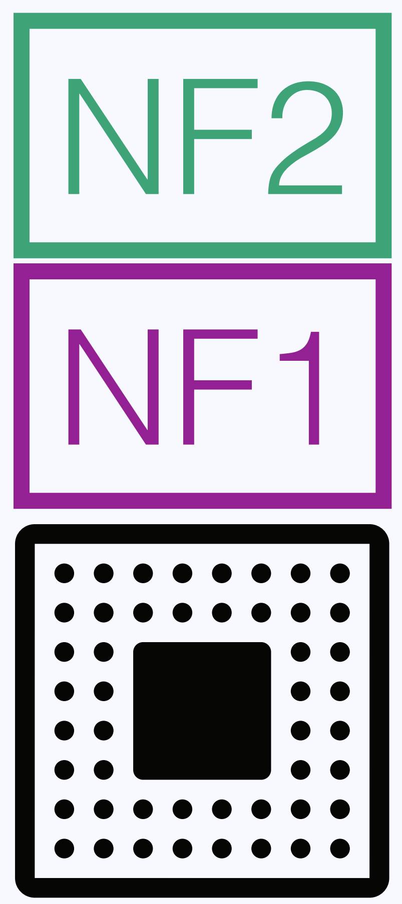


Evaluation Setup

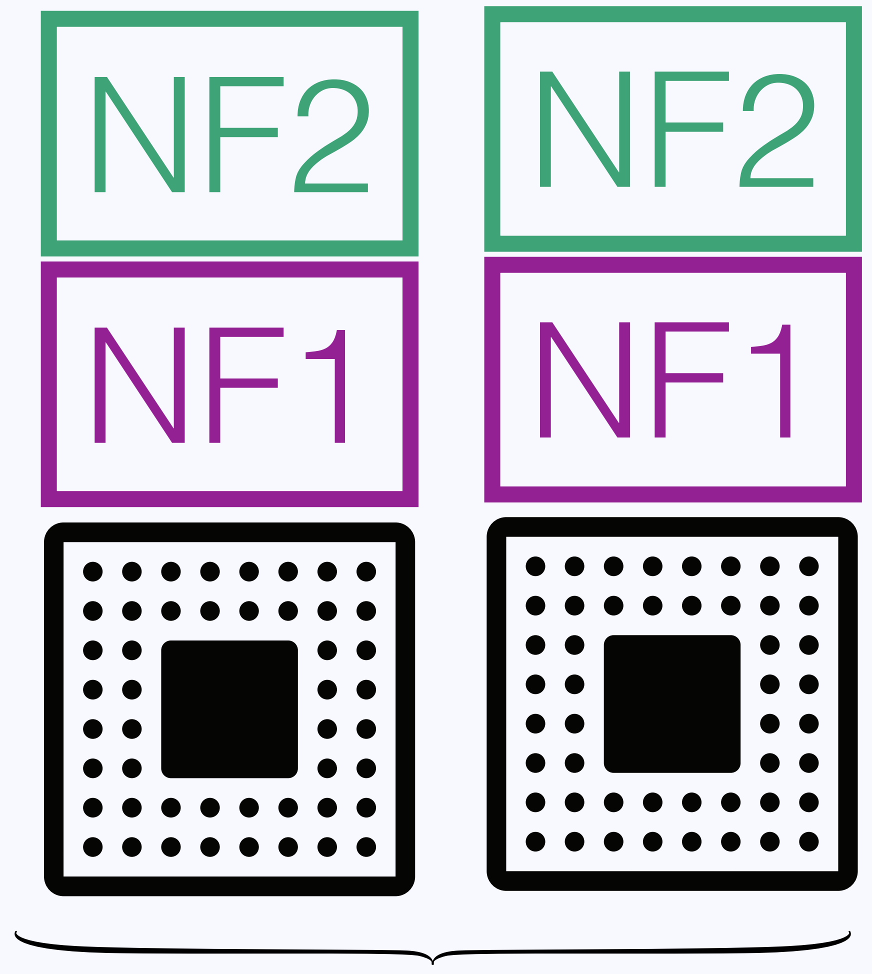
VM/Container



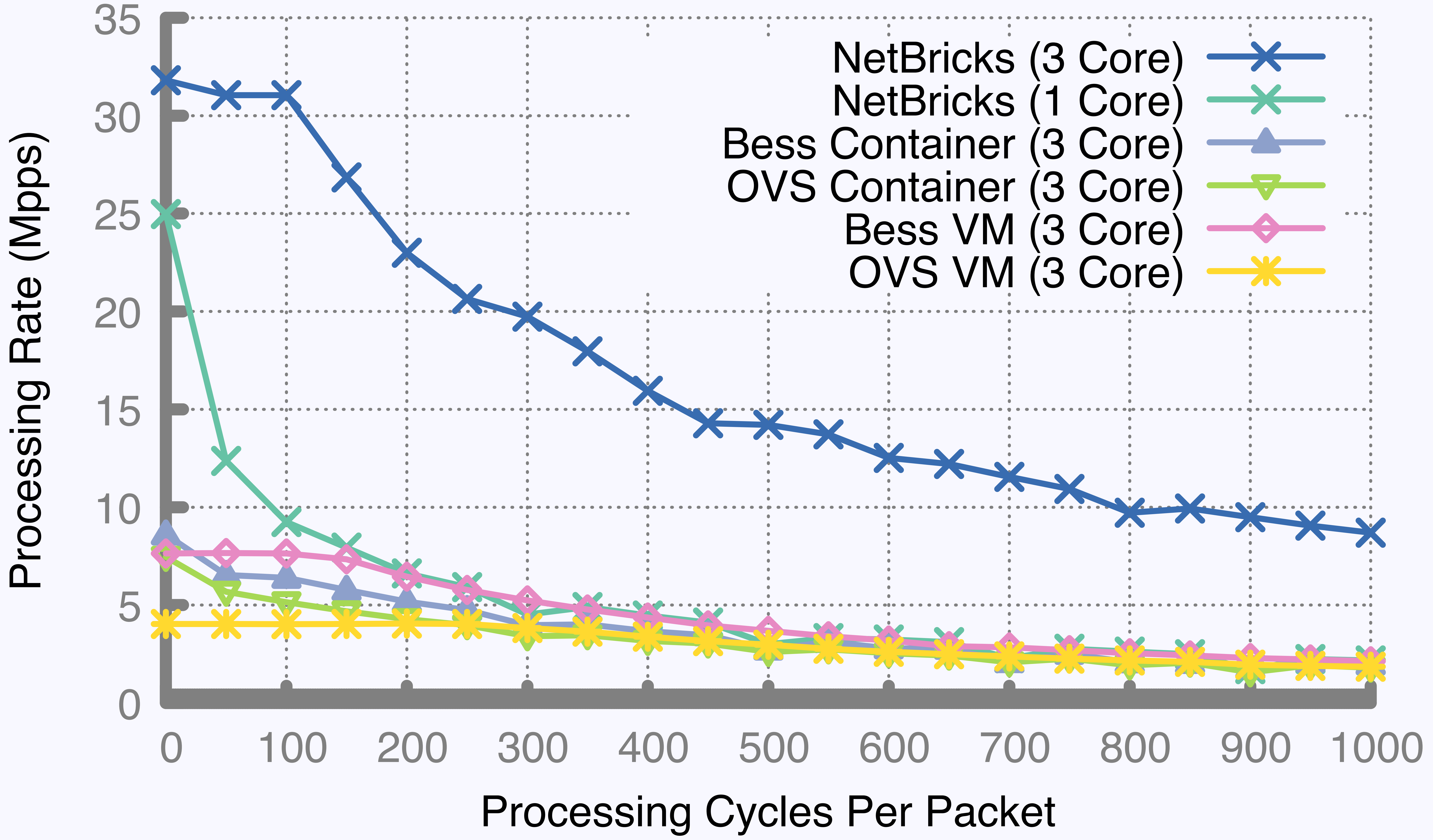
NetBricks



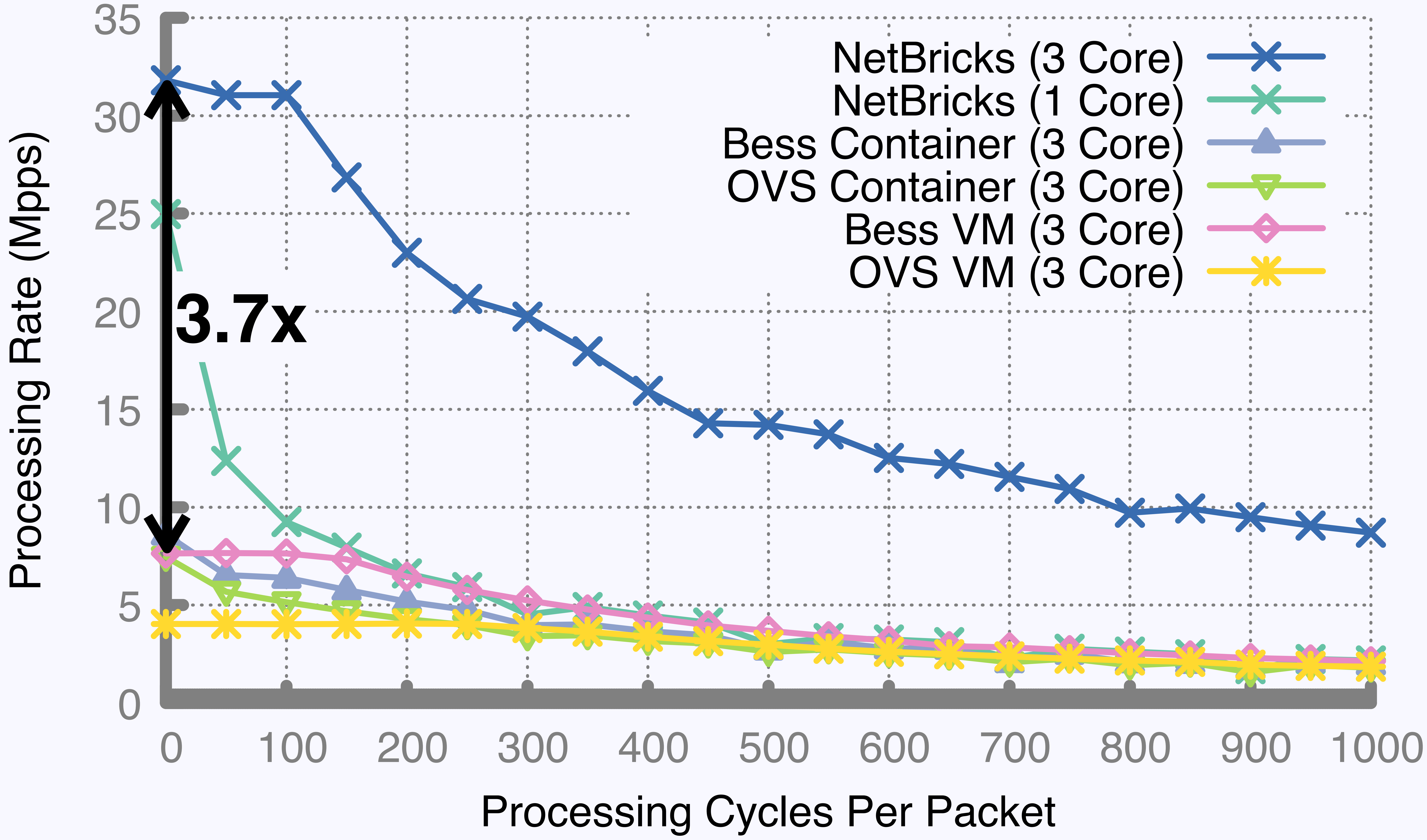
NetBricks Multicore



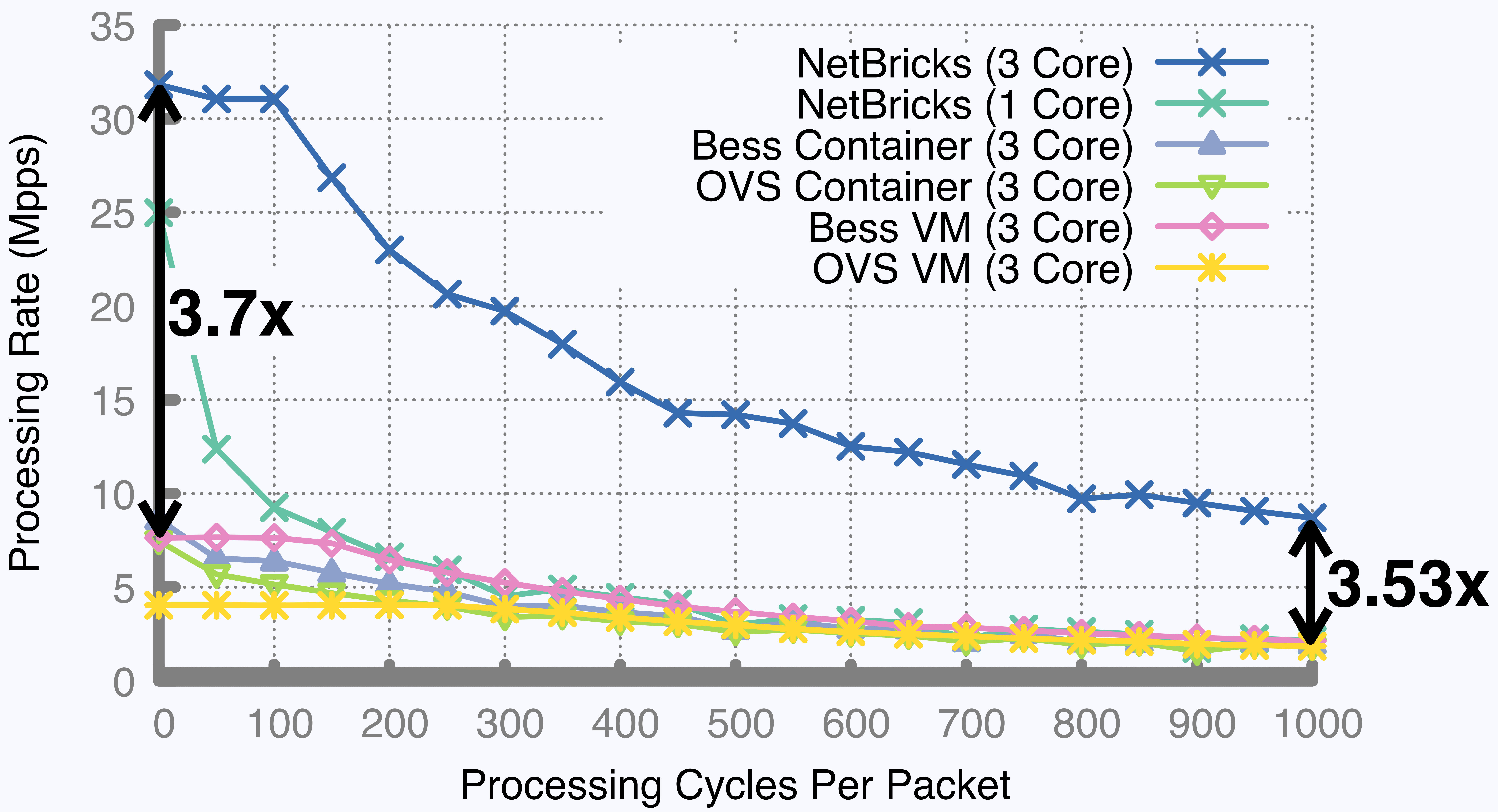
NetBricks: More Efficient



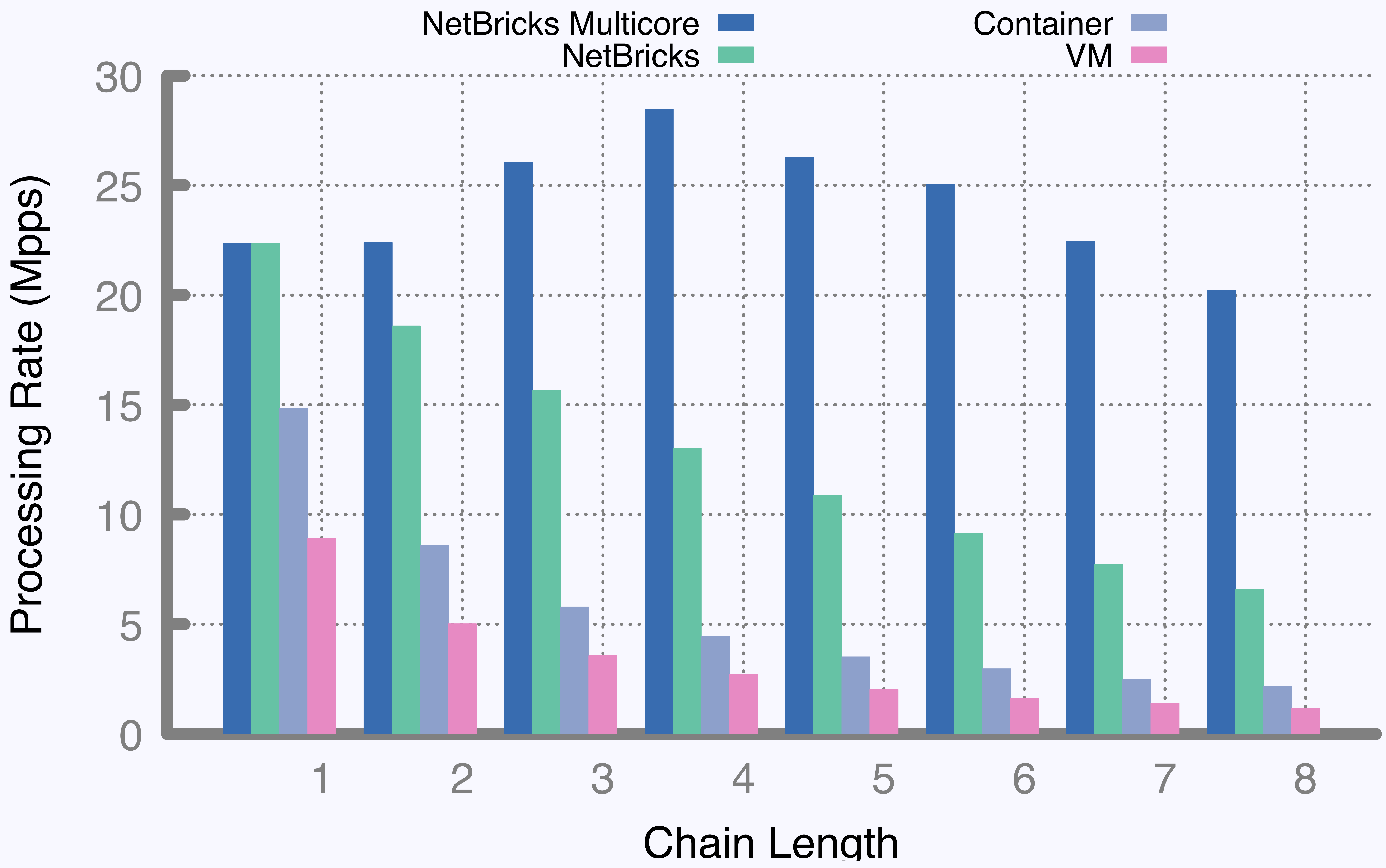
NetBricks: More Efficient



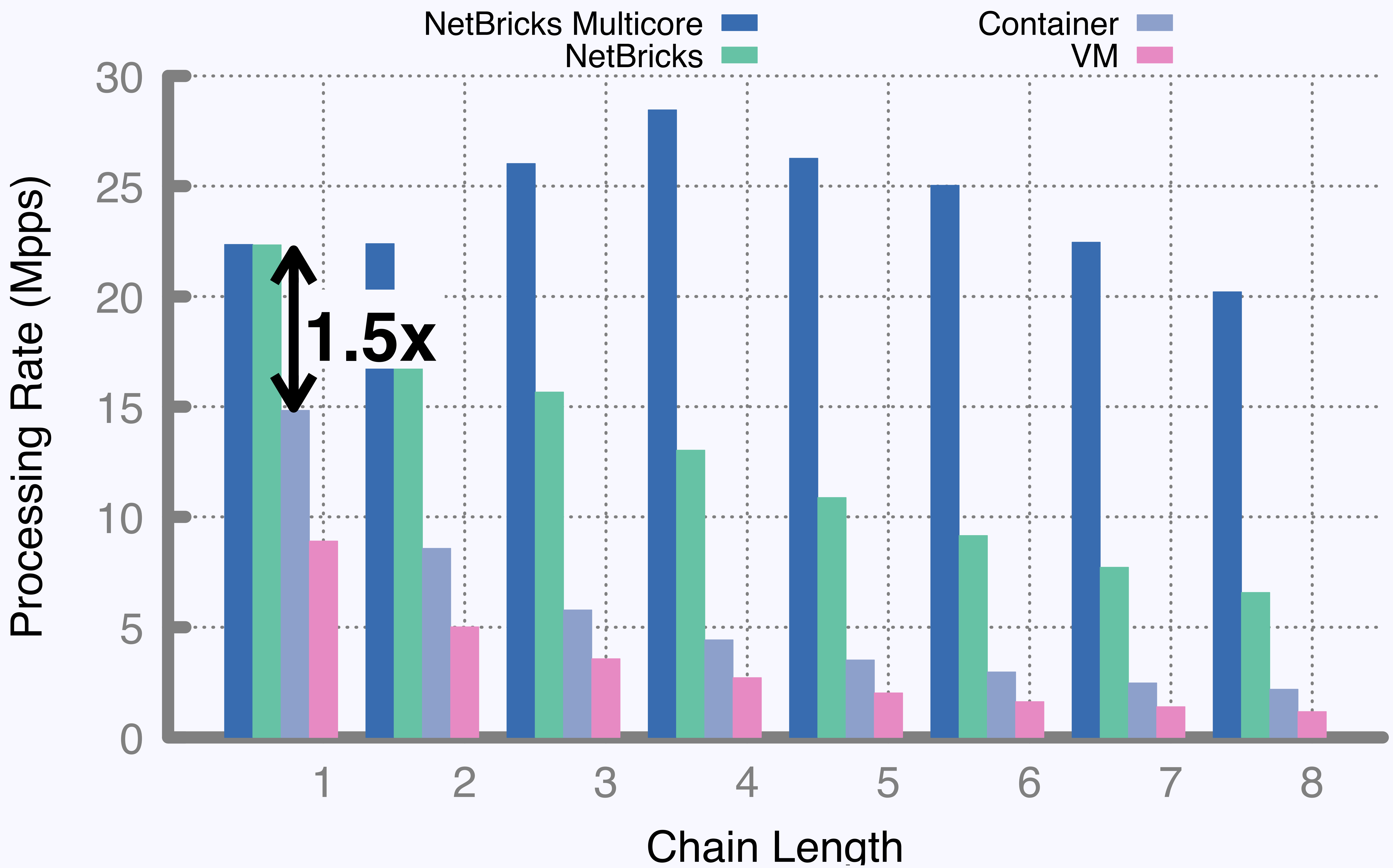
NetBricks: More Efficient



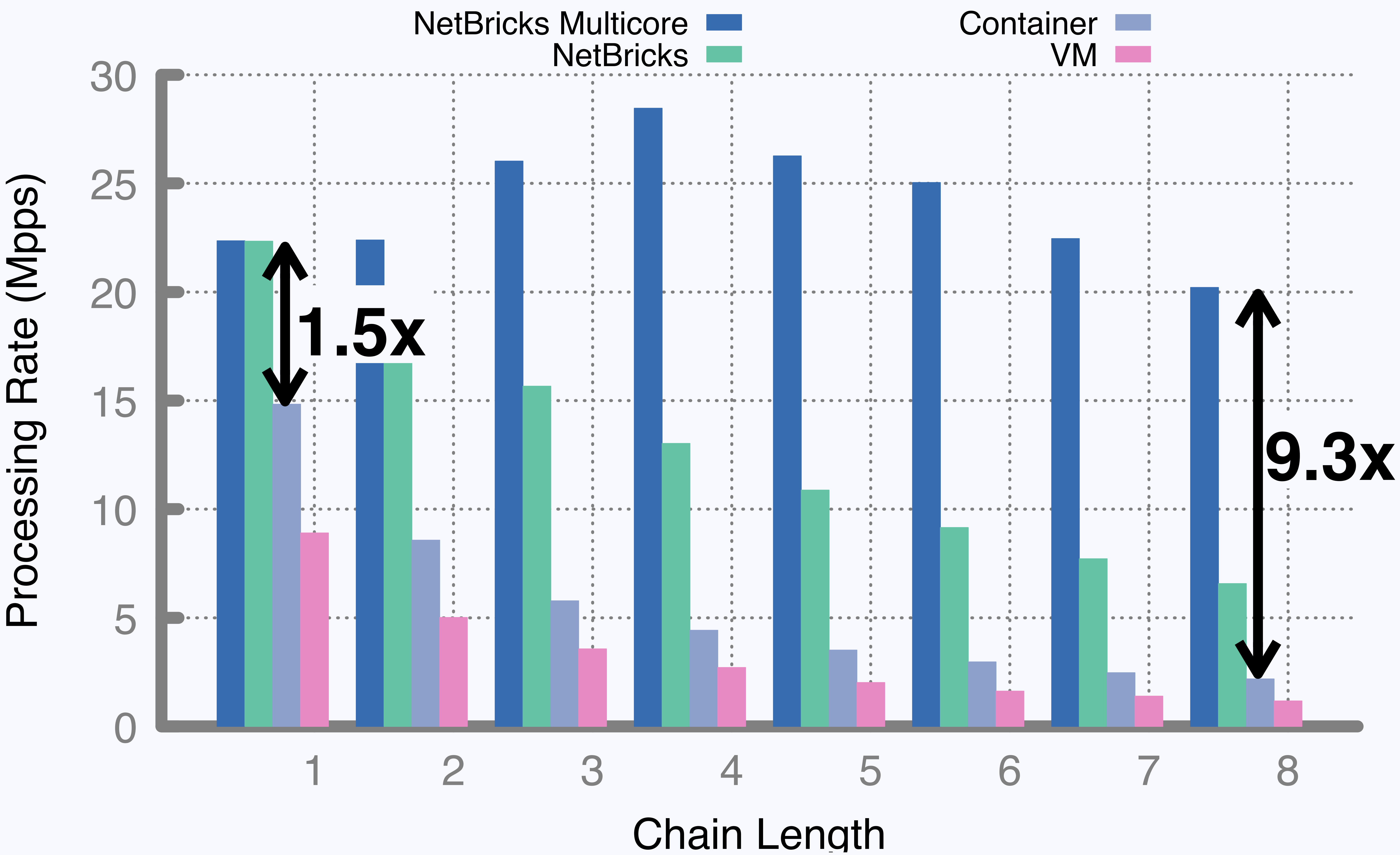
Scaling with Chain Length



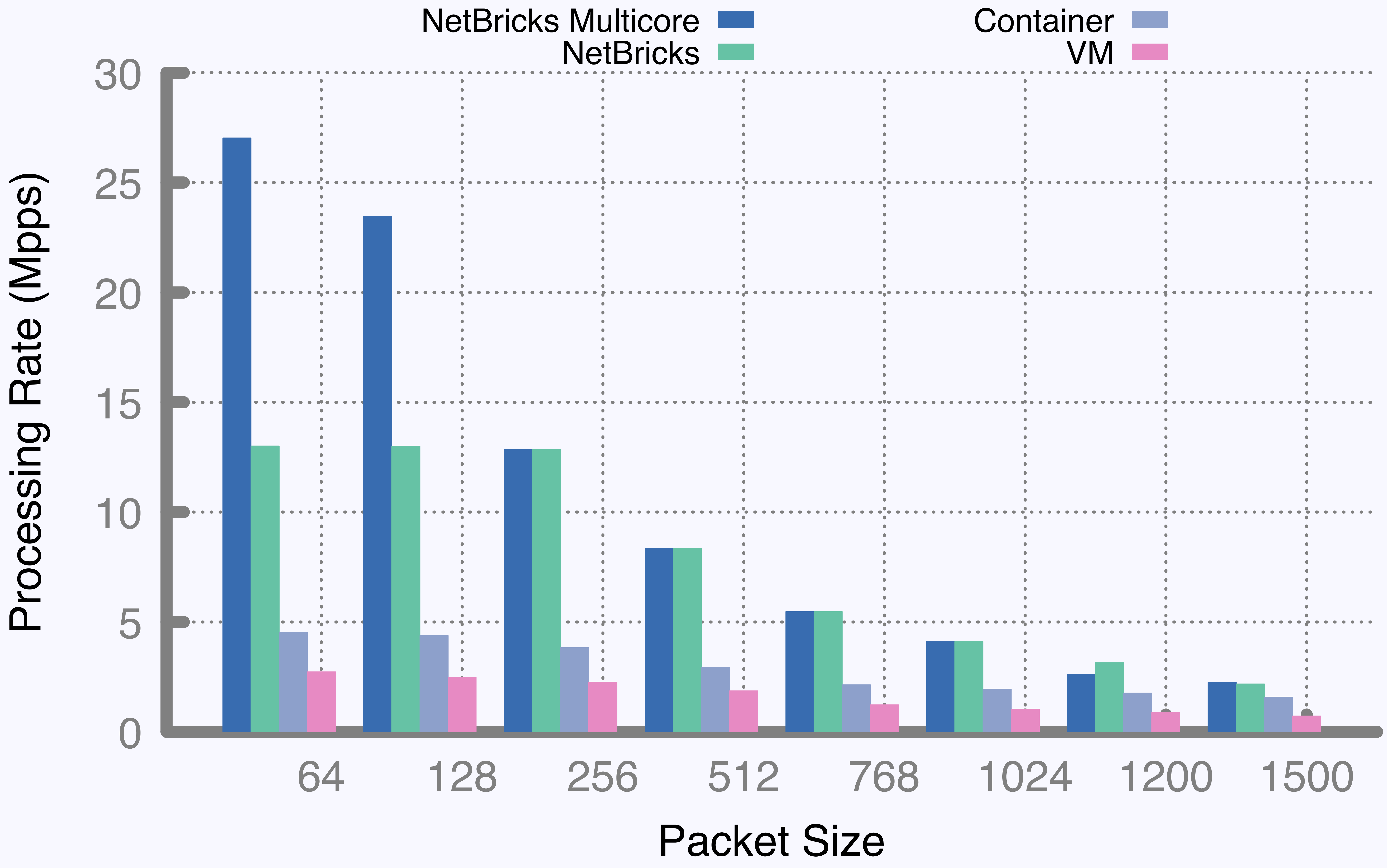
Scaling with Chain Length



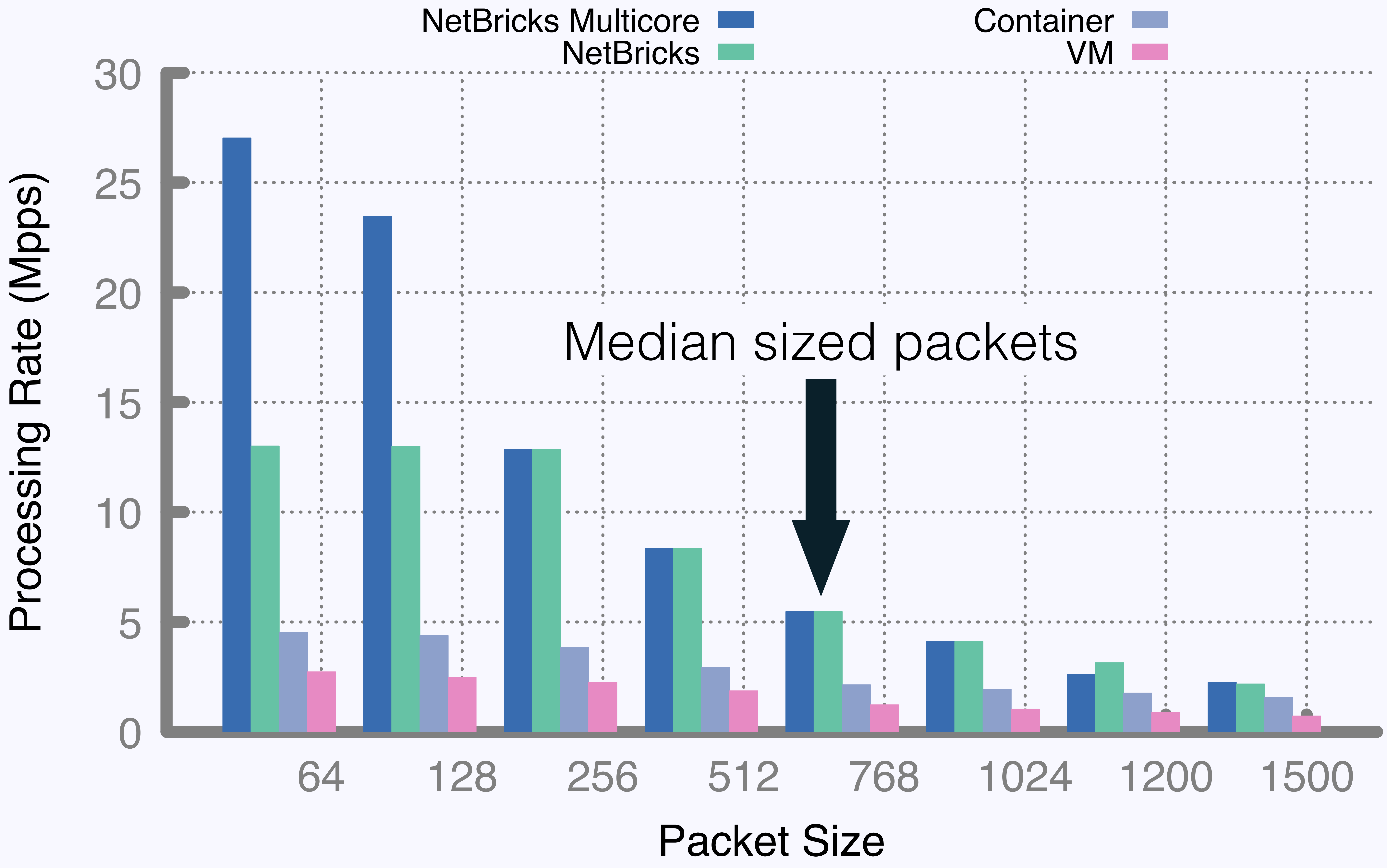
Scaling with Chain Length



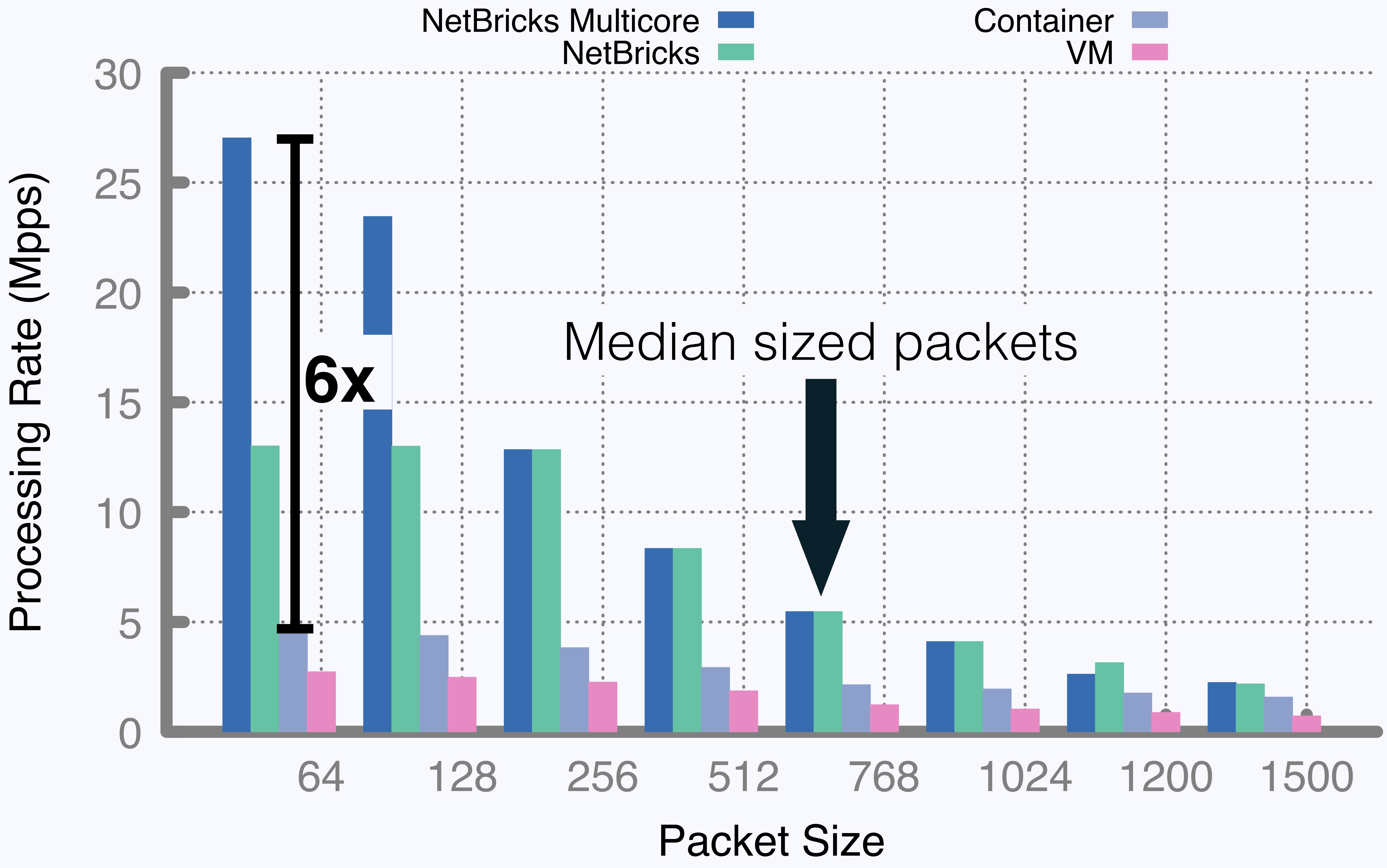
Effect of Increasing Packet Size



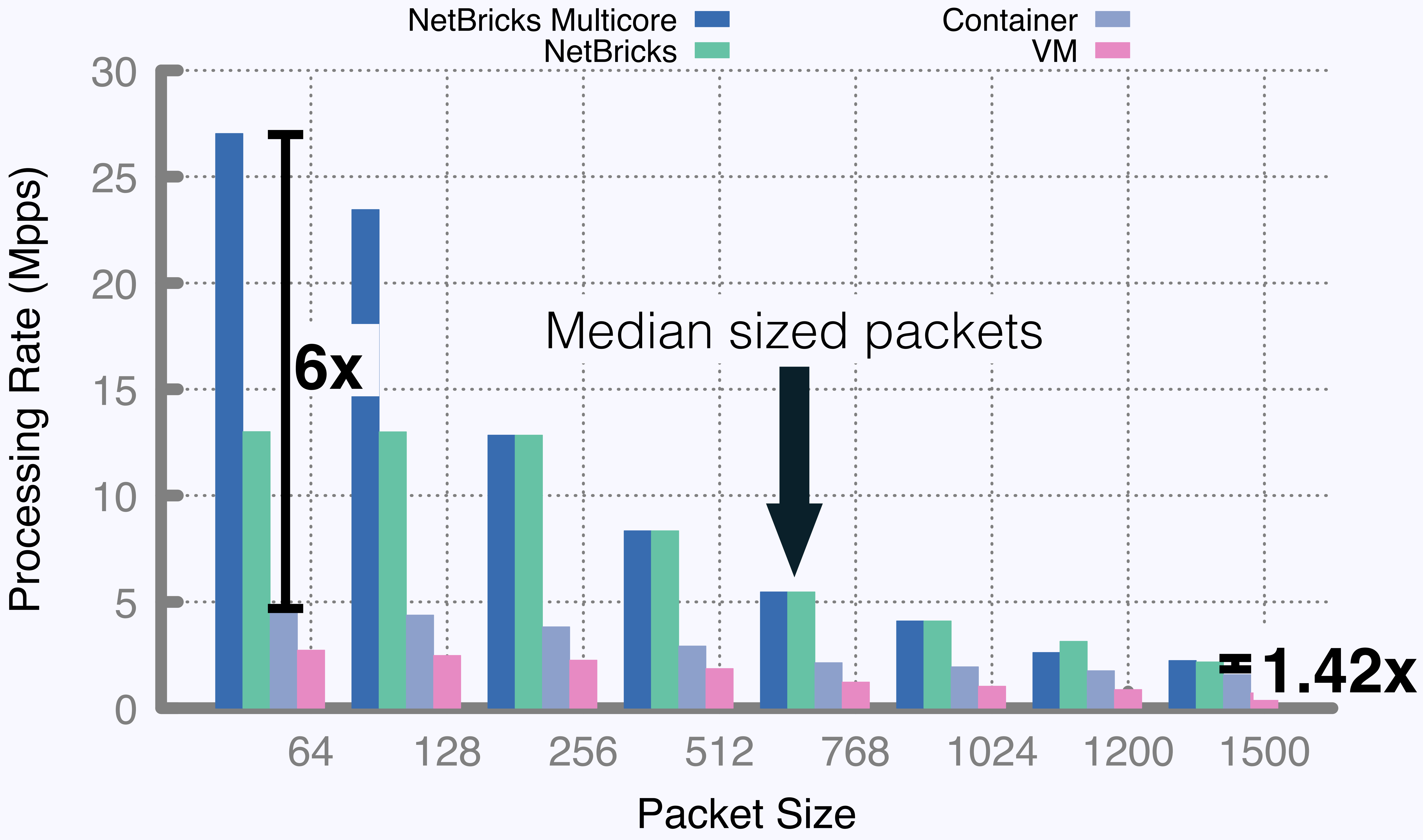
Effect of Increasing Packet Size



Effect of Increasing Packet Size



Effect of Increasing Packet Size



NetBricks: Programming Environment

NetBricks Approach

- Write NFs using a **compact set of abstractions** provided by the framework.

NetBricks Approach

- Write NFs using a **compact set of abstractions** provided by the framework.
  - Safe mechanisms whose **performance** is **comparable** to native code.

NetBricks Approach

- Write NFs using a **compact set of abstractions** provided by the framework.
  - Safe mechanisms whose **performance** is **comparable** to native code.
  - Abstractions implement **micro-optimizations** to achieve performance.

NetBricks Approach

- Write NFs using a **compact set of abstractions** provided by the framework.
  - Safe mechanisms whose **performance** is **comparable** to native code.
  - Abstractions implement **micro-optimizations** to achieve performance.
- **User defined functions (UDFs)** provide flexibility.

NetBricks Approach

- Write NFs using a **compact set of abstractions** provided by the framework.
  - Safe mechanisms whose **performance** is **comparable** to native code.
  - Abstractions implement **micro-optimizations** to achieve performance.
- **User defined functions (UDFs)** provide flexibility.
  - Insight: customization is largely orthogonal to performance

NetBricks Approach

- Write NFs using a **compact set of abstractions** provided by the framework.
  - Safe mechanisms whose **performance** is **comparable** to native code.
  - Abstractions implement **micro-optimizations** to achieve performance.
- **User defined functions (UDFs)** provide flexibility.
  - Insight: customization is largely orthogonal to performance
- Framework can implement **global optimization**.

Abstractions

Packet Processing
- Parse/Deparse
- Transform
- Filter

Control Flow
- Group By
- Shuffle
- Merge

Byte Stream
- Window
- Packetize

State
- Lookup Tables
- LPM Tables

Abstractions

Packet Processing	
Parse/Deparse	Header
Transform	UDF
Filter	UDF

Control Flow	
Group By	UDF
Shuffle	UDF
Merge	

Byte Stream	
Window	UDF
Packetize	UDF

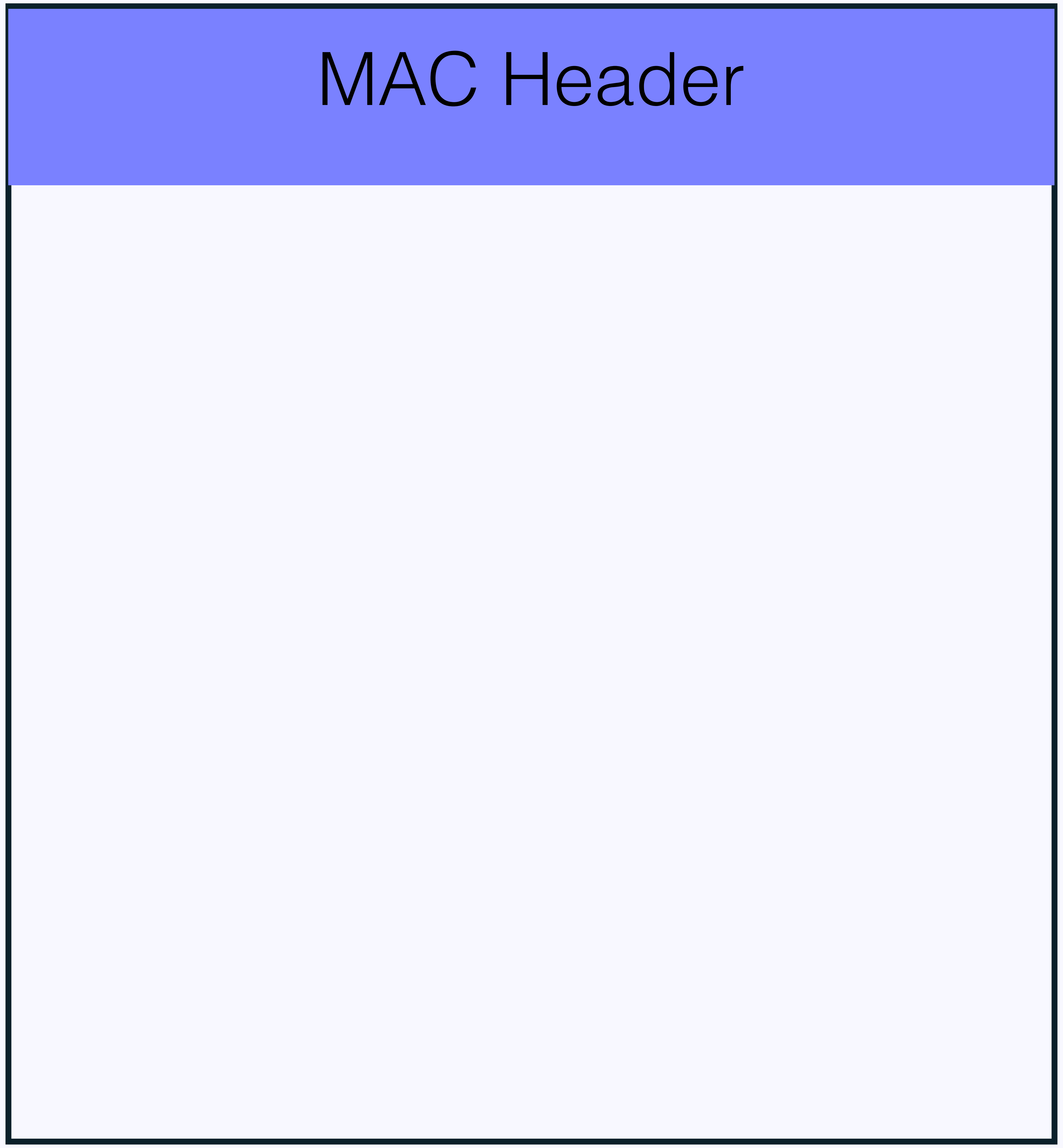
State	
Lookup Tables	Consistency
LPM Tables	

Abstractions and UDFs

```
...
.parse::<MacHeader>()
.parse::<IpHeader>()
.parse::<TcpHeader>()
.filter(|pkt| {
    f(pkt.header().src_port())
})
```

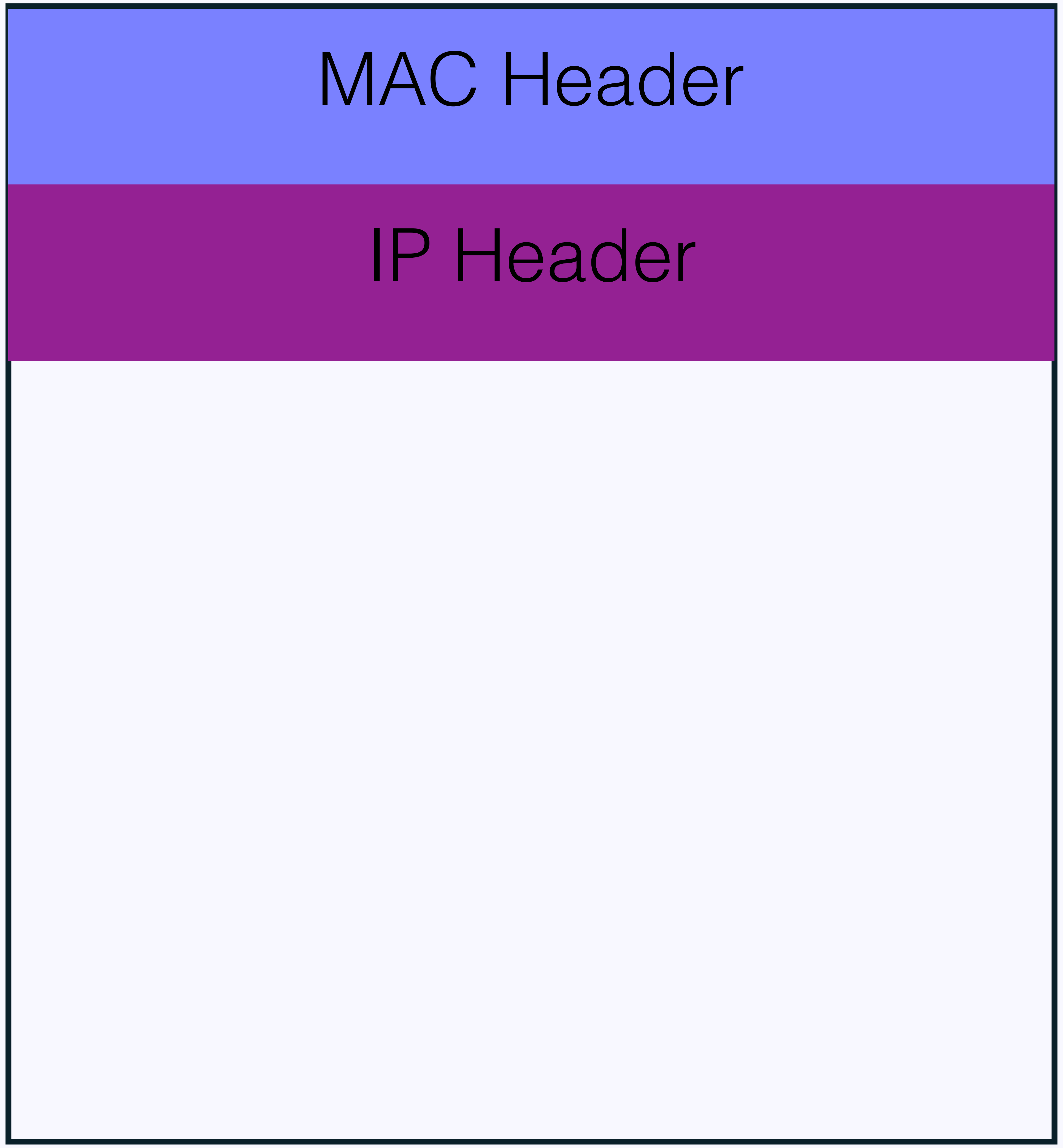
Abstractions and UDFs

```
...
 .parse::<MacHeader>()
 .parse::<IpHeader>()
 .parse::<TcpHeader>()
 .filter(|pkt| {
     f(pkt.header().src_port())
 })
```



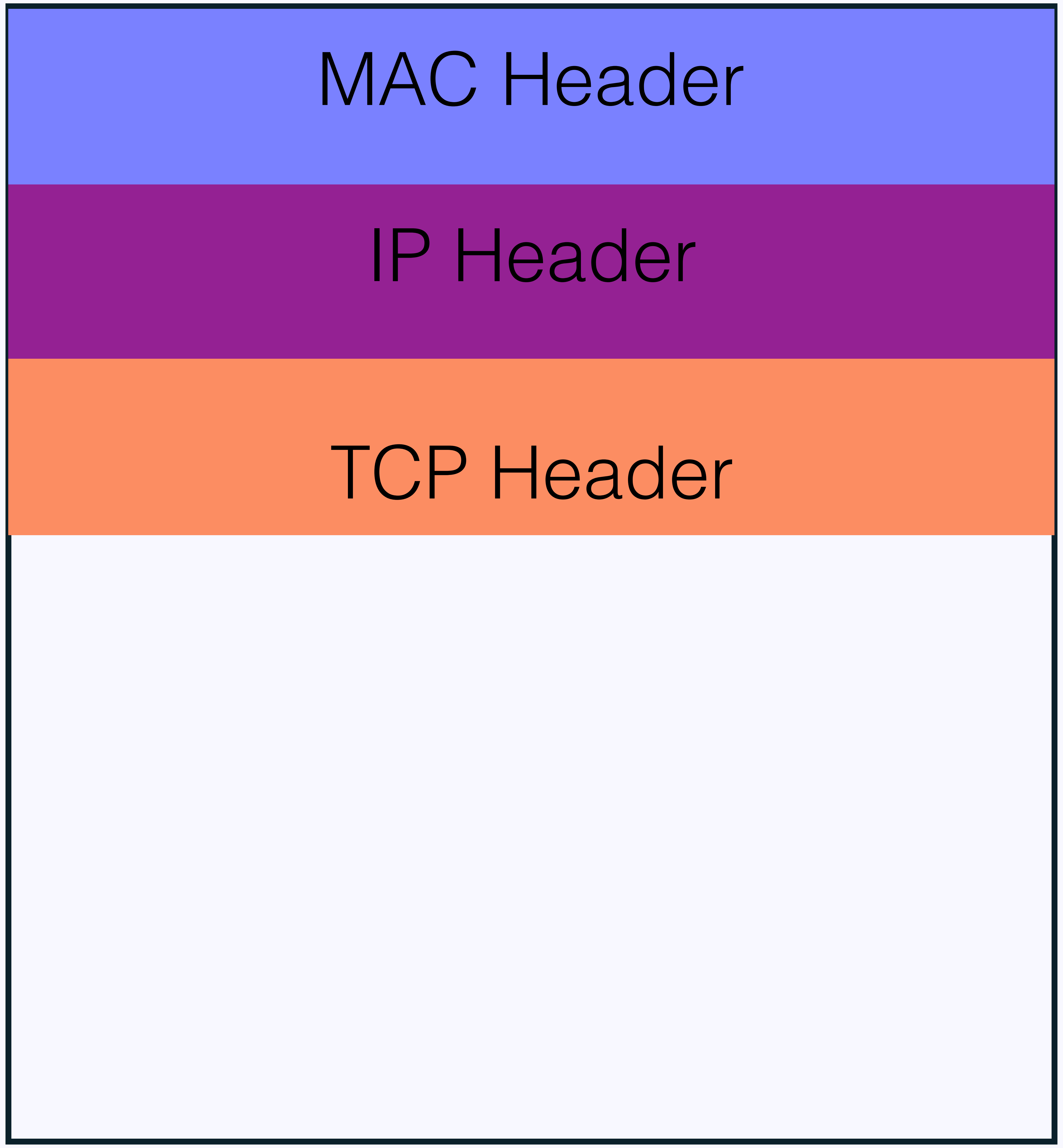
Abstractions and UDFs

```
...
 .parse::<MacHeader>()
 .parse::<IpHeader>()
 .parse::<TcpHeader>()
 .filter(|pkt| {
     f(pkt.header().src_port())
  })
```



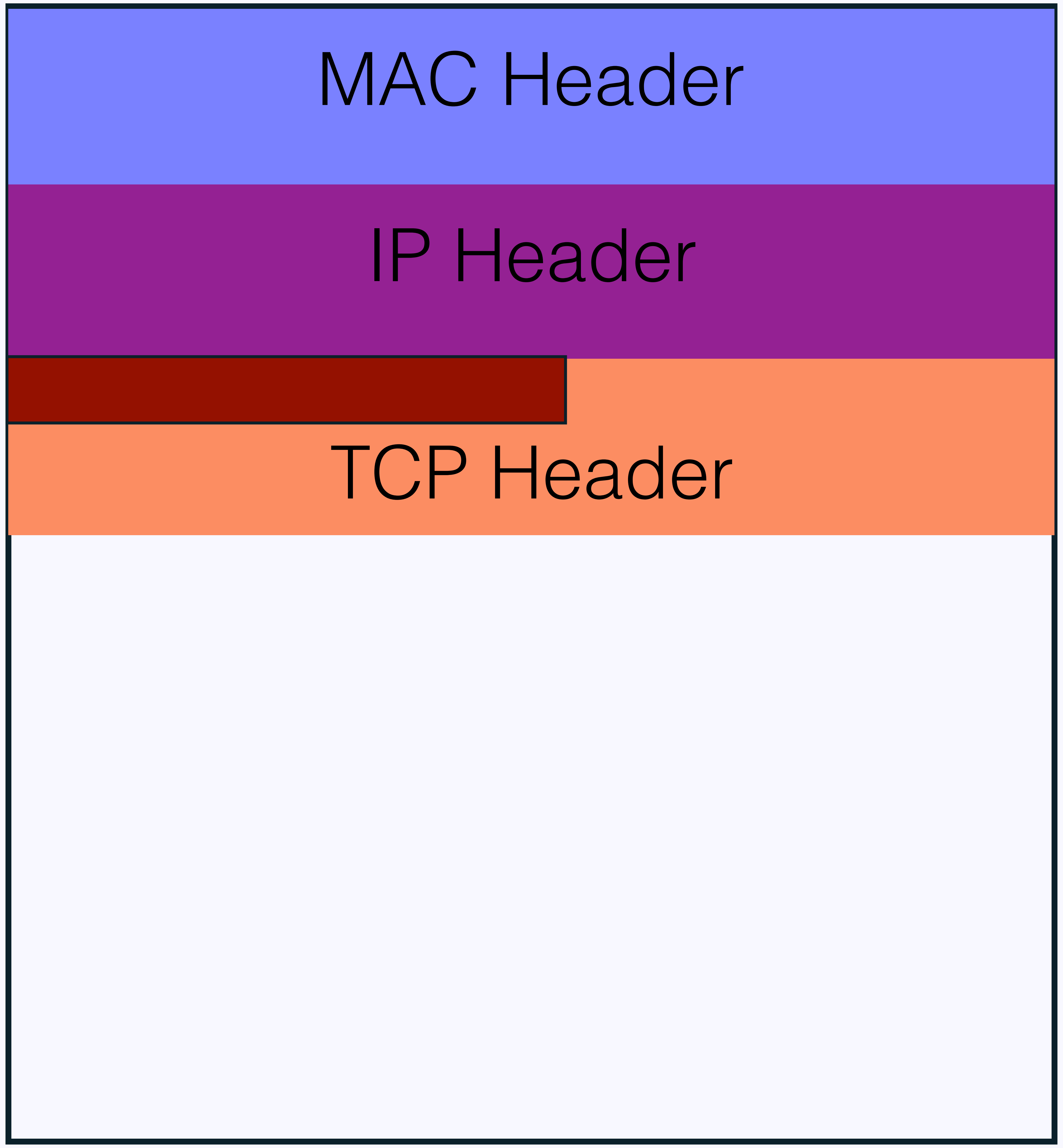
Abstractions and UDFs

```
...
 .parse::<MacHeader>()
 .parse::<IpHeader>()
 .parse::<TcpHeader>()
 .filter(|pkt| {
     f(pkt.header().src_port())
  })
```



Abstractions and UDFs

```
...
 .parse::<MacHeader>()
 .parse::<IpHeader>()
 .parse::<TcpHeader>()
 .filter(|pkt| {
     f(pkt.header().src_port())
  })
```



Example NF: Maglev

- **Maglev**: Load balancer from Google (NSDI’16).

Example NF: Maglev

- **Maglev**: Load balancer from Google (NSDI'16).
- Main contribution: a **novel consistent hashing algorithm.**

Example NF: Maglev

- **Maglev**: Load balancer from Google (NSDI'16).
- Main contribution: a **novel consistent hashing algorithm.**
  - Most of the work in common optimization: batching, scaling cross core.

Example NF: Maglev

- **Maglev**: Load balancer from Google (NSDI'16).
- Main contribution: a **novel consistent hashing algorithm.**
    - Most of the work in common optimization: batching, scaling cross core.
- NetBricks implementation: **105 lines, 2 hours of time**.

Example NF: Maglev

- **Maglev**: Load balancer from Google (NSDI'16).
- Main contribution: a **novel consistent hashing algorithm.**
    - Most of the work in common optimization: batching, scaling cross core.
- NetBricks implementation: **105 lines, 2 hours of time**.
- NetBricks performance (1 core): **9.2 MPPS**

Example NF: Maglev

- **Maglev**: Load balancer from Google (NSDI'16).
- Main contribution: a **novel consistent hashing algorithm.**
  - Most of the work in common optimization: batching, scaling cross core.
- NetBricks implementation: **105 lines, 2 hours of time**.
- NetBricks performance (1 core): **9.2 MPPS**
  - Reported: **2.6 MPPS**

Example NF: Evolved Packet Core

- **EPC**: A common NF used in cellular data processing.

Example NF: Evolved Packet Core

- **EPC**: A common NF used in cellular data processing.
- Made by **collaborators** at Berkeley - changes EPC architecture.

Example NF: Evolved Packet Core

- **EPC**: A common NF used in cellular data processing.
- Made by **collaborators** at Berkeley - changes EPC architecture.
- Approximately **2,054** lines of code vs **80,000** for **OpenAirInterface**.

Example NF: Evolved Packet Core

- **EPC**: A common NF used in cellular data processing.
- Made by **collaborators** at Berkeley - changes EPC architecture.
- Approximately **2,054** lines of code vs **80,000** for **OpenAirInterface**.
- 10x better performance than **OpenAirInterface**.

Example NF: Evolved Packet Core

- **EPC**: A common NF used in cellular data processing.
- Made by **collaborators** at Berkeley - changes EPC architecture.
- Approximately **2,054** lines of code vs **80,000** for **OpenAirInterface**.
- 10x better performance than **OpenAirInterface**.
- More than **5x** better than commercial **EPCs** based on DPDK.

Upgrading NFs through abstractions

Upgrading NFs through abstractions

Warning: Future work ahead.

Abstractions Enable Upgrades

- Assumed to be the **most complex part** of the code.

Abstractions Enable Upgrades

- Assumed to be the **most complex part** of the code.
  - **Developed** and **provided** by the framework not by NF developer.

Abstractions Enable Upgrades

- Assumed to be the **most complex part** of the code.
  - **Developed** and **provided** by the framework not by NF developer.
- Upgrade strategy: Implement **multiple versions** of each abstraction.

Abstractions Enable Upgrades

- Assumed to be the **most complex part** of the code.
  - **Developed** and **provided** by the framework not by NF developer.
- Upgrade strategy: Implement **multiple versions** of each abstraction.
  - Each version **targets specific hardware feature** or software architecture.

Abstractions Enable Upgrades

- Assumed to be the **most complex part** of the code.
  - **Developed** and **provided** by the framework not by NF developer.
- Upgrade strategy: Implement **multiple versions** of each abstraction.
  - Each version **targets specific hardware feature** or software architecture.
- Choose which version to use at deployment time.

Abstractions Enable Upgrades

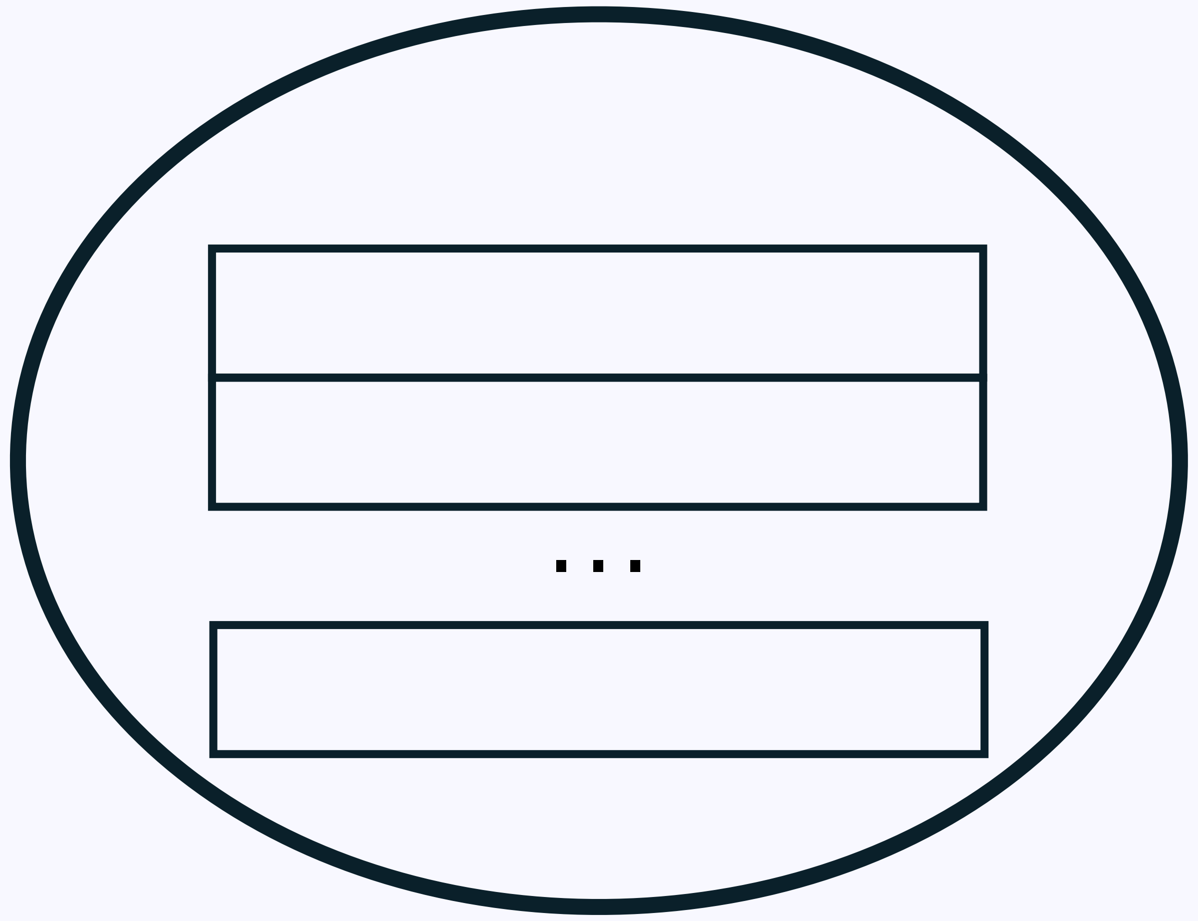
- Assumed to be the **most complex part** of the code.
  - **Developed** and **provided** by the framework not by NF developer.
- Upgrade strategy: Implement **multiple versions** of each abstraction.
  - Each version **targets specific hardware feature** or software architecture.
- Choose which version to use at deployment time.
  - Choice depends on what is supported, and resource scheduling.

Upgrading Abstractions: Stateless NFs

Lookup Table (Current)

Upgrading Abstractions: Stateless NFs

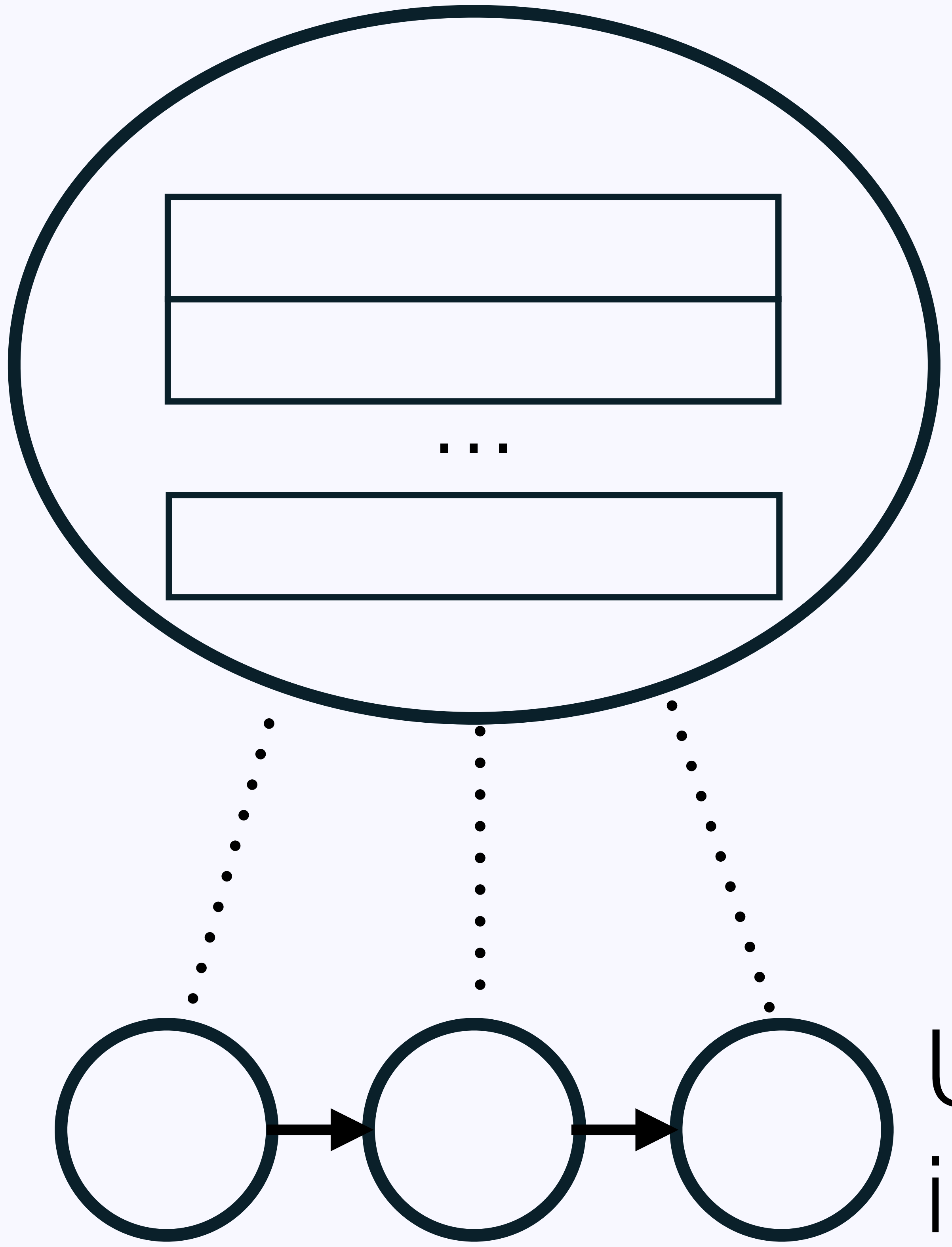
Lookup Table (Current)



Abstraction
backed
by local
memory

Upgrading Abstractions: Stateless NFs

Lookup Table (Current)

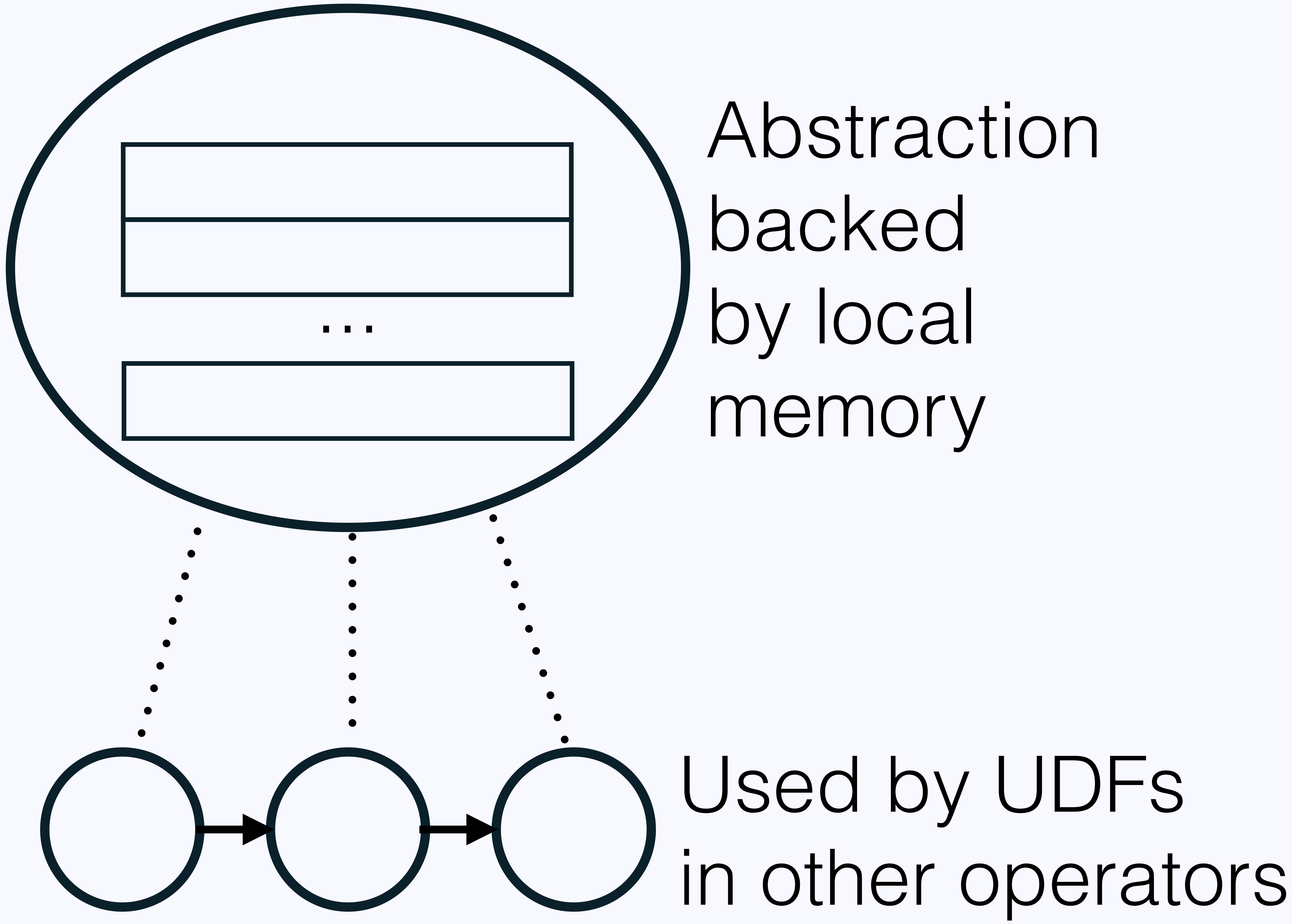


Abstraction backed by local memory

Used by UDFs in other operators

Upgrading Abstractions: Stateless NFs

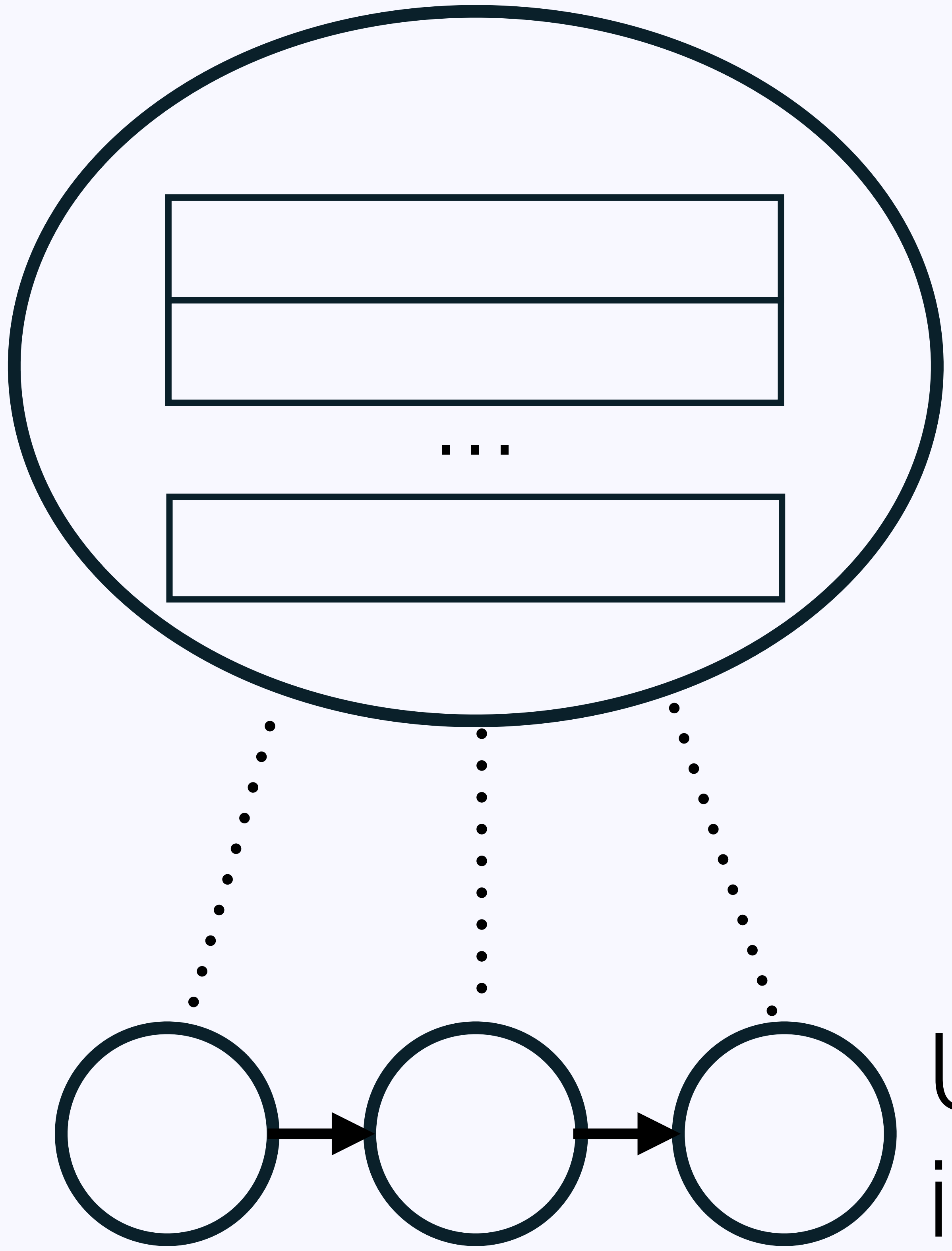
Lookup Table (Current)



Adopting Sateless Abstraction

Upgrading Abstractions: Stateless NFs

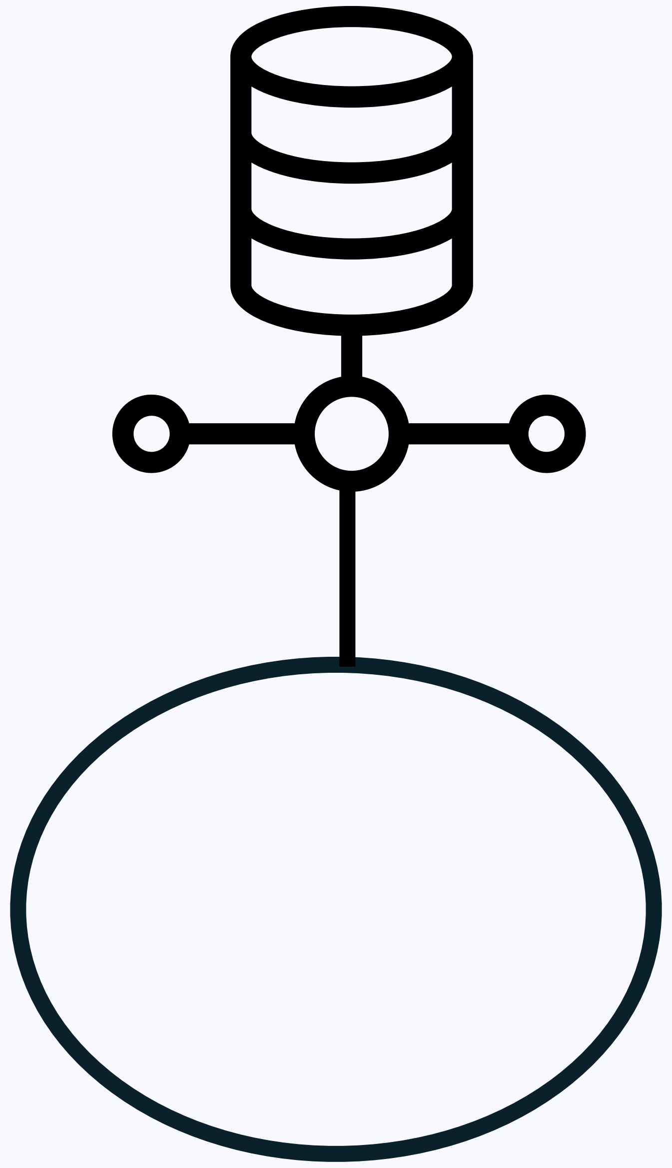
Lookup Table (Current)



Abstraction
backed
by local
memory

Used by UDFs
in other operators

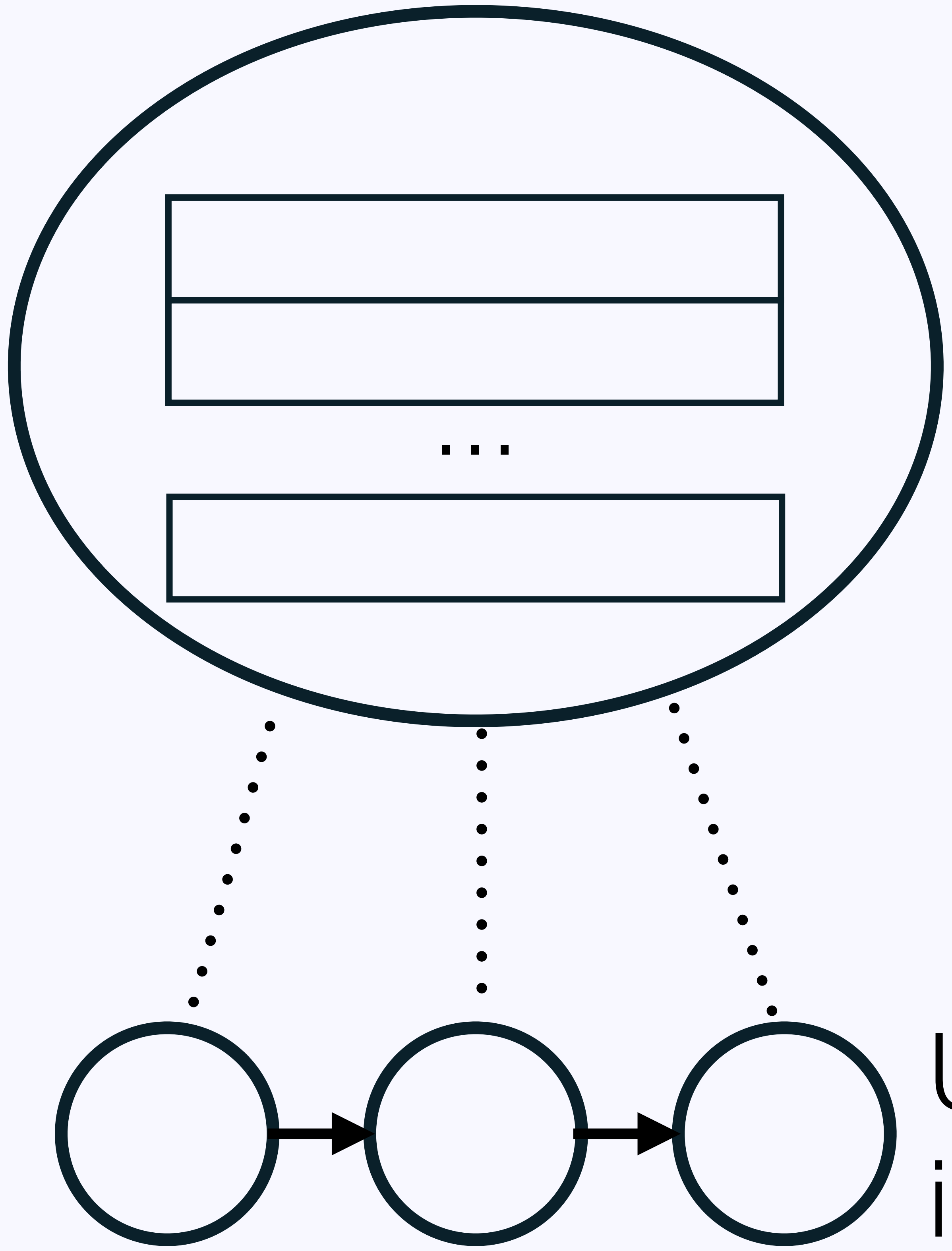
Adopting Sateless Abstraction



Abstraction
backed
by remote
KV-store

Upgrading Abstractions: Stateless NFs

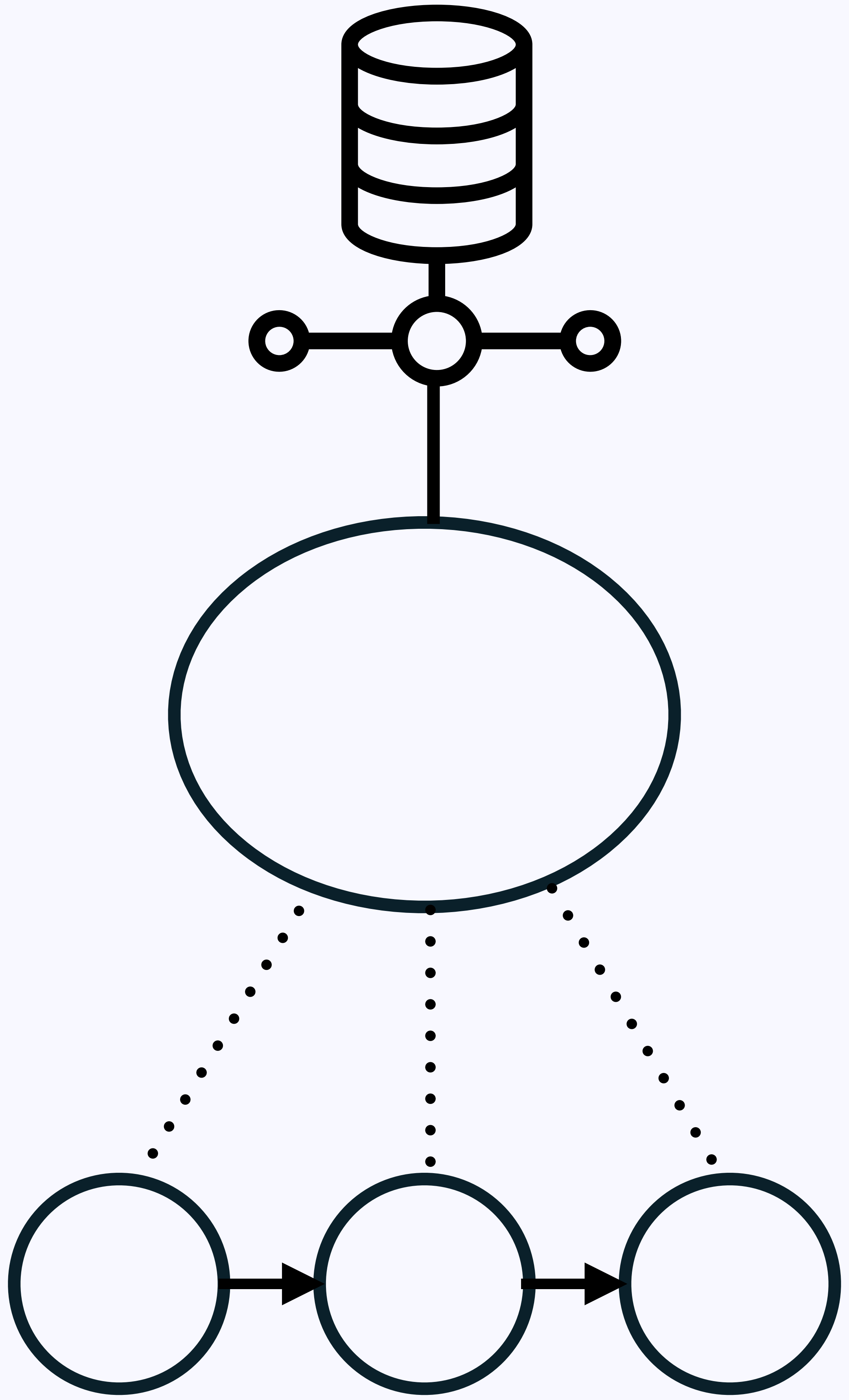
Lookup Table (Current)



Abstraction backed by local memory

Used by UDFs in other operators

Adopting Sateless Abstraction

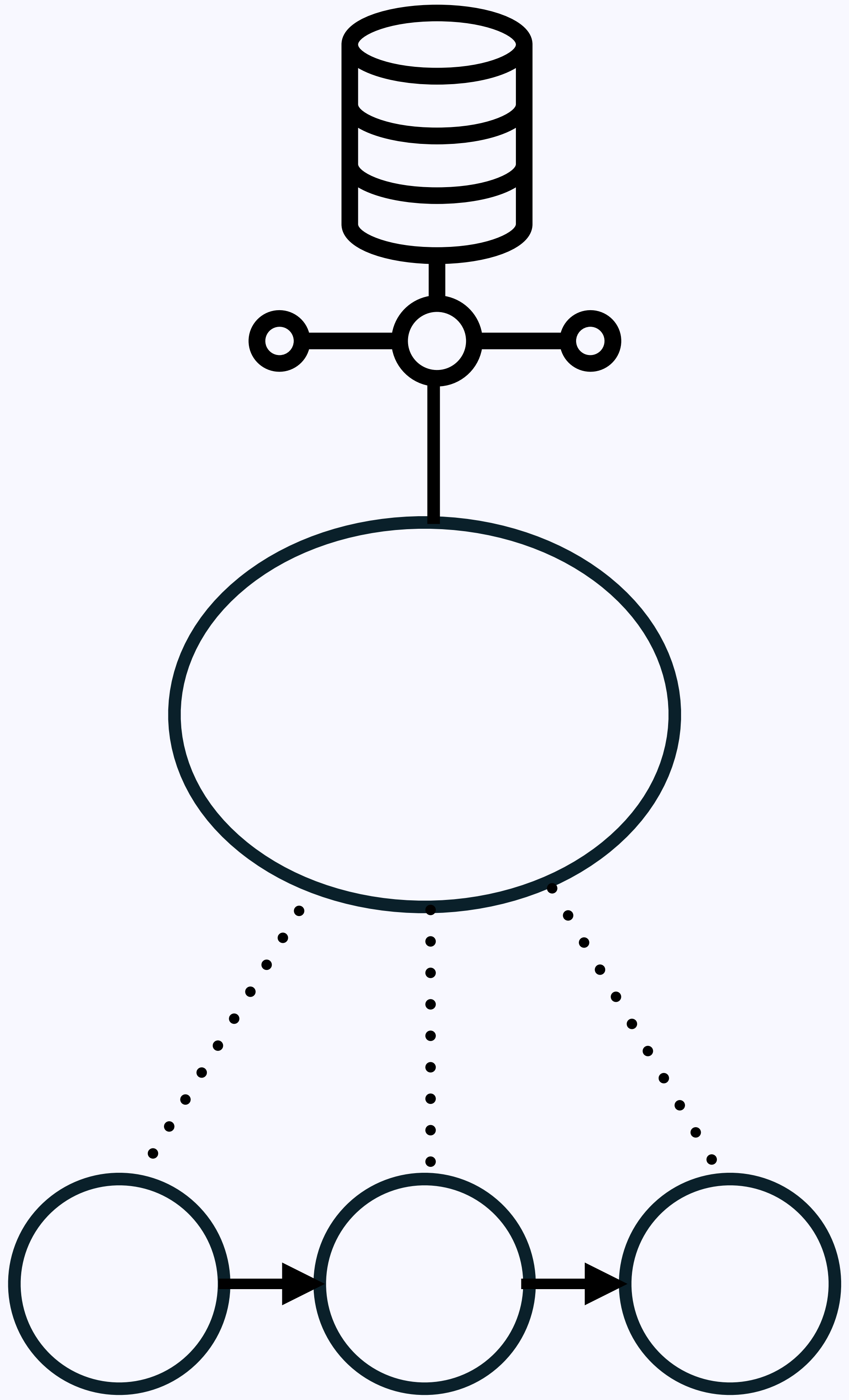


Abstraction backed by remote KV-store

UDFs remain unchanged.

Upgrading Abstractions: Stateless NFs

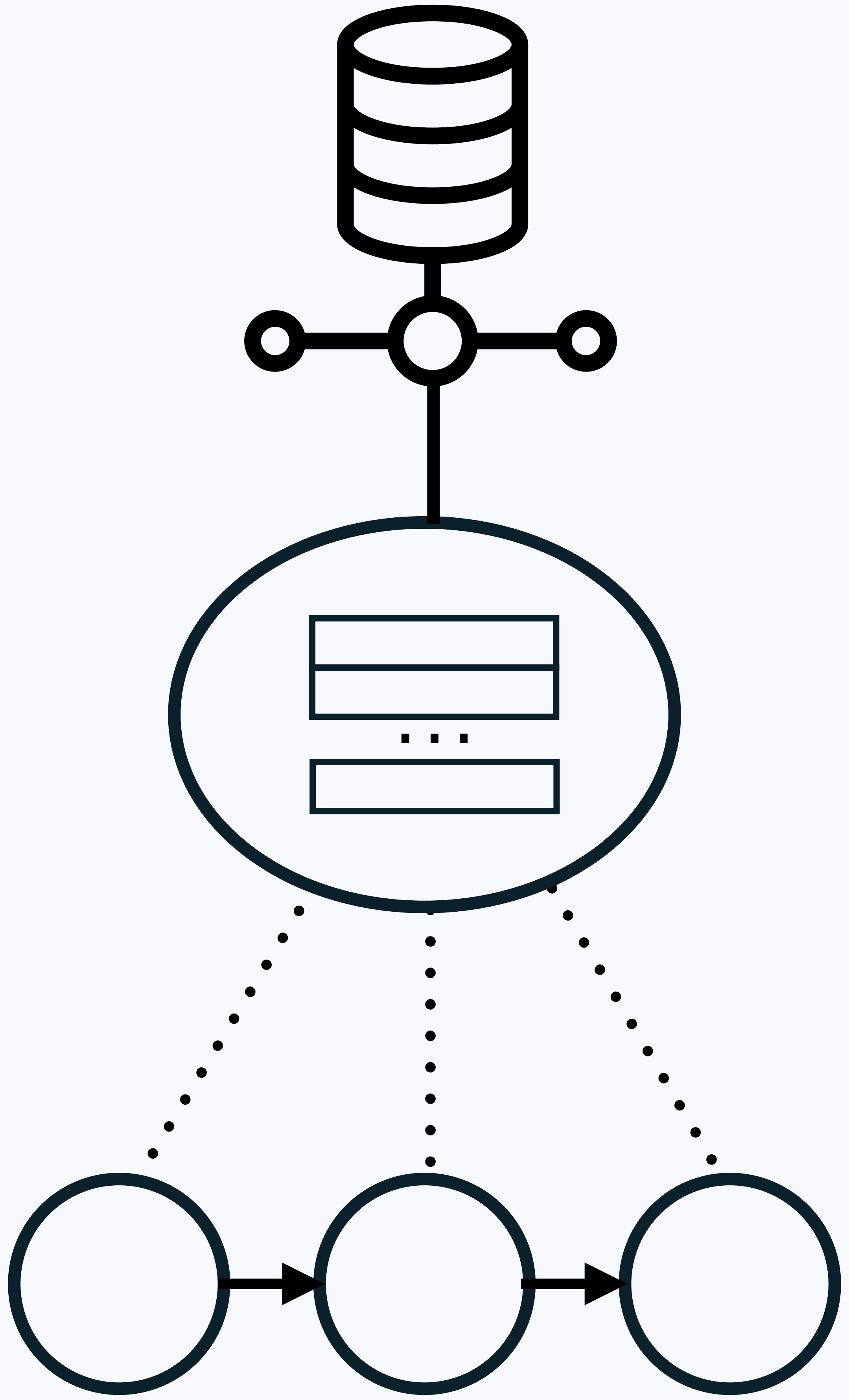
Adopting Sateless Abstraction



Abstraction backed by remote KV-store

UDFs remain unchanged.

Adopting Stateless and Caching



Use consistency requirements to implement local caching.

UDFs remain unchanged.

Upgrading Abstractions: Stateless NFs

Adopting Sateless Abstraction

Adopting Stateless and Caching

Adopting new features requires **no changes** to NF code.

ency
s to

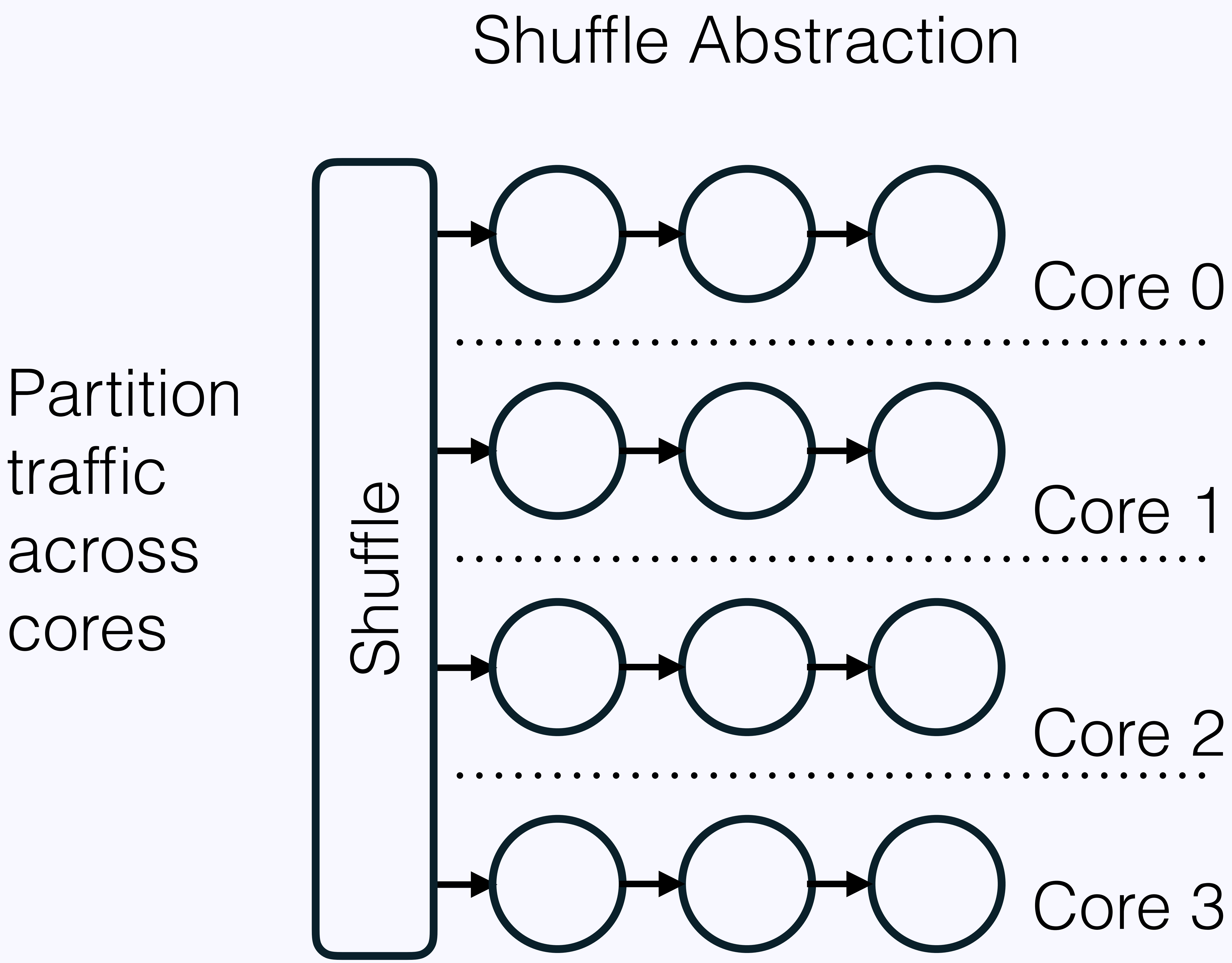
g.

Becomes a **policy decision** made by **deployment.**

UDFs remain
unchanged.

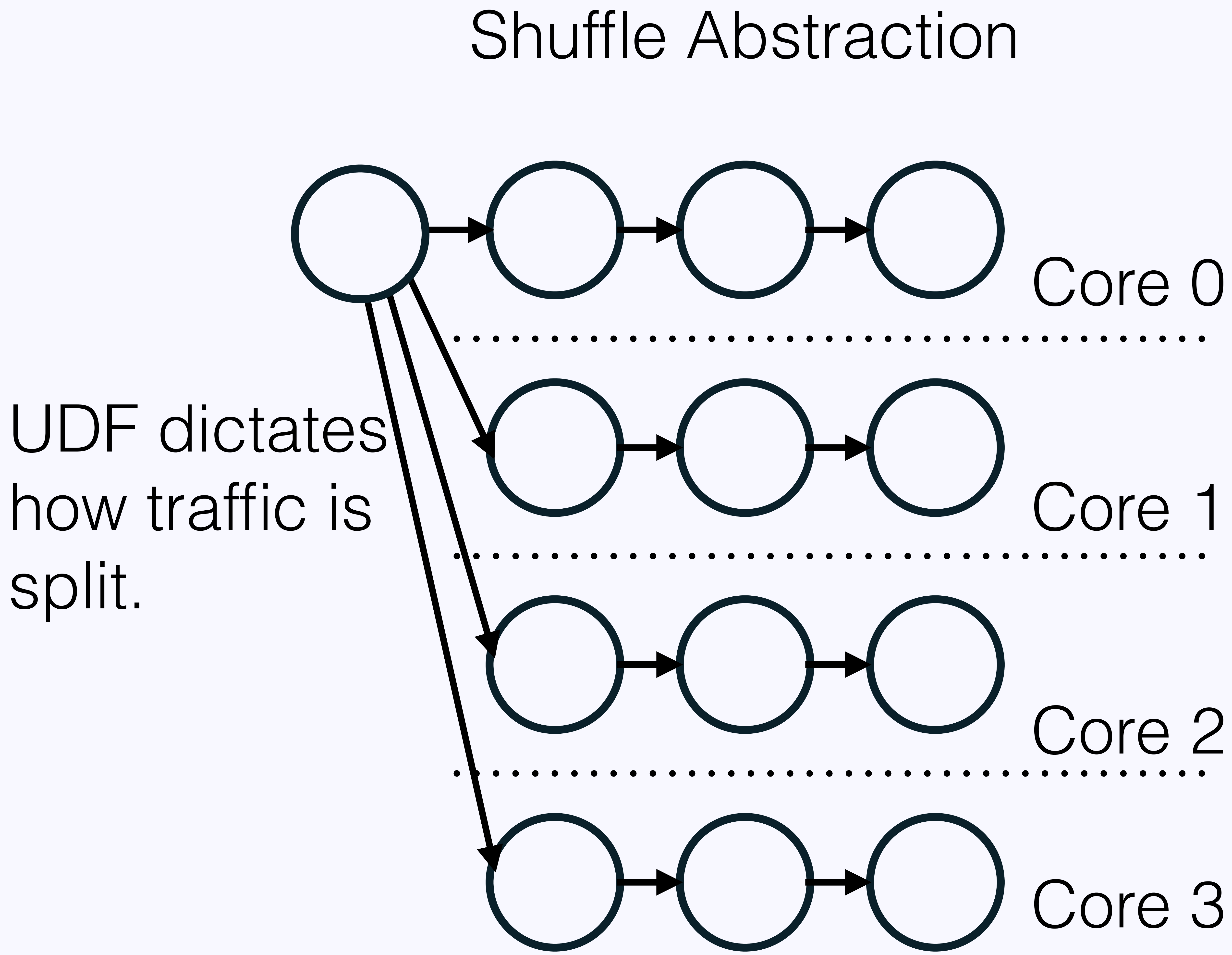
UDFs remain
unchanged.

Upgrading Abstractions: Shuffles as RSS



- For many UDFs can implement on NIC.
  - Using receive side scaling (RSS).
- RSS can be used when shuffling by
  - TCP 5-tuple
  - Masked parts of the IP header.
- Currently implemented.
  - Significant performance benefits.

Upgrading Abstractions: Shuffles as RSS



- For many UDFs can implement on NIC.
  - Using receive side scaling (RSS).
- RSS can be used when shuffling by
  - TCP 5-tuple
  - Masked parts of the IP header.
- Currently implemented.
  - Significant performance benefits.

Upgrading Abstractions: Challenges

- Compilations: How to **compile UDFs** on offload hardware?

Upgrading Abstractions: Challenges

- Compilations: How to **compile UDFs** on offload hardware?
  - Everything is compiled through LLVM. Supports large number of backends.

Upgrading Abstractions: Challenges

- Compilations: How to **compile UDFs** on offload hardware?
  - Everything is compiled through LLVM. Supports large number of backends.
  - Expectation: Get UDFs in LLVM IR form and retarget as appropriate.

Upgrading Abstractions: Challenges

- Compilations: How to **compile UDFs** on offload hardware?
    - Everything is compiled through LLVM. Supports large number of backends.
    - Expectation: Get UDFs in LLVM IR form and retarget as appropriate.
- Using Offloads Across NFs: How to share resources or compose, etc.

Upgrading Abstractions: Challenges

- Compilations: How to **compile UDFs** on offload hardware?
  - Everything is compiled through LLVM. Supports large number of backends.
  - Expectation: Get UDFs in LLVM IR form and retarget as appropriate.
- Using Offloads Across NFs: How to share resources or compose, etc.
  - Example: How to shuffle in chained NFs? Who gets to use an FPGA?

Upgrading Abstractions: Challenges

- Compilations: How to **compile UDFs** on offload hardware?
  - Everything is compiled through LLVM. Supports large number of backends.
  - Expectation: Get UDFs in LLVM IR form and retarget as appropriate.
- Using Offloads Across NFs: How to share resources or compose, etc.
  - Example: How to shuffle in chained NFs? Who gets to use an FPGA?
  - Relying on resource allocation policy to help with these questions.

Conclusion

- NetBricks is a new NF development and execution platform.

Conclusion

- NetBricks is a new NF development and execution platform.
- Addresses three challenges in today's environments.

Conclusion

- NetBricks is a new NF development and execution platform.
- Addresses three challenges in today's environments.
  - Providing isolation without overheads.

Conclusion

- NetBricks is a new NF development and execution platform.
- Addresses three challenges in today's environments.
    - Providing isolation without overheads.
    - Simplifying NF development.

Conclusion

- NetBricks is a new NF development and execution platform.
- Addresses three challenges in today's environments.
    - Providing isolation without overheads.
    - Simplifying NF development.
    - Enabling NFs to take advantage of hardware and software improvements.

Conclusion

- NetBricks is a new NF development and execution platform.
- Addresses three challenges in today's environments.
    - Providing isolation without overheads.
    - Simplifying NF development.
    - Enabling NFs to take advantage of hardware and software improvements.
- NetBricks is open sources, available at http://netbricks.io/