

SynCron

Efficient Synchronization Support for Near-Data-Processing Architectures



Christina Giannoula

Nandita Vijaykumar, Nikela Papadopoulou, Vasileios Karakostas
Ivan Fernandez, Juan Gómez Luna, Lois Orosa
Nectarios Koziris, Georgios Goumas, Onur Mutlu

SAFARI



ETH zürich



Executive Summary

Problem:

Synchronization support is **challenging** for NDP systems

Prior schemes are **not suitable** or **efficient** for NDP systems

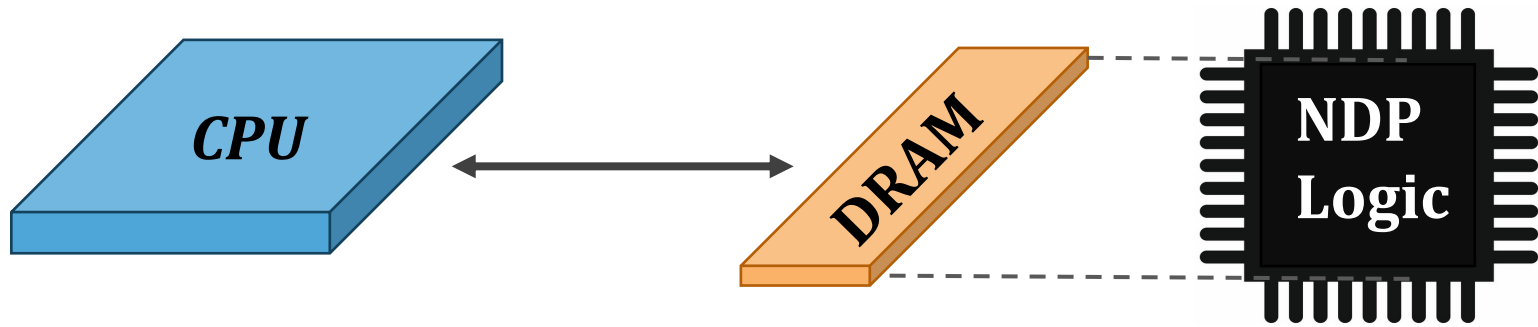
Contribution:

SynCron: the **first end-to-end** synchronization solution for NDP architectures

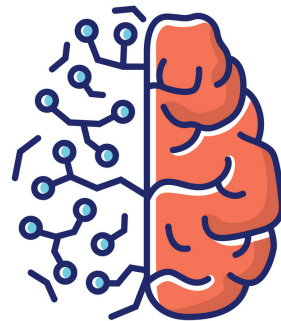
Key Results:

SynCron comes within **9.5%** and **6.2%** of performance and energy of an **Ideal** zero-overhead synchronization scheme

Near-Data-Processing (**NDP**) Systems

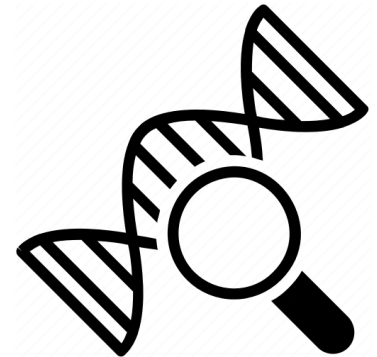
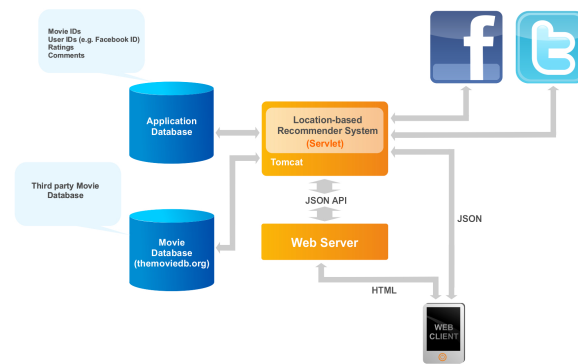


Graph Analytics



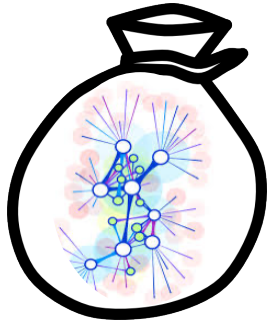
Neural Networks

Recommendation Systems



Bioinformatics

Synchronization is Necessary



Graph Analytics



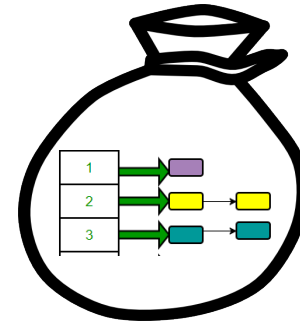
Bioinformatics



Databases



Image Processing



Concurrent Data Structures

Single Source Shortest Path (SSSP)

```
for v in Graph:
  for u in neighbors[v]:
    if distance[v] + edge_weight[v, u] < distance[u]
      lock_acquire(u)
      if distance[v] + edge_weight[v, u] < distance[u]
        distance[u] = distance[v] + edge_weight[v, u]
      lock_release(u)
```

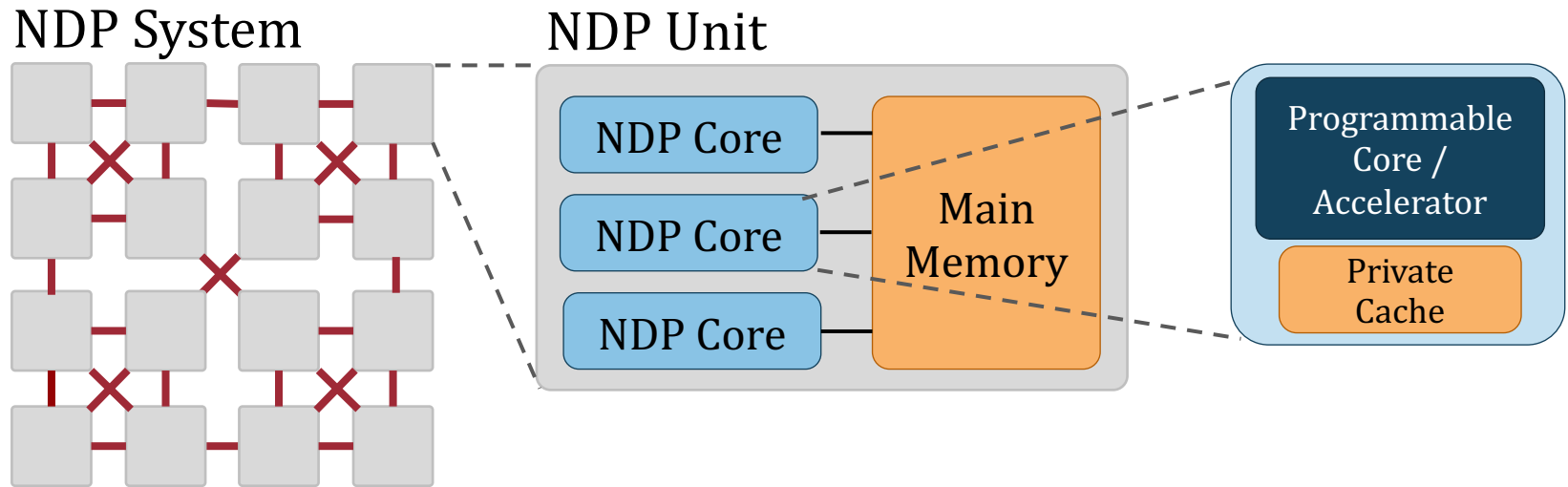
Locks



Barriers



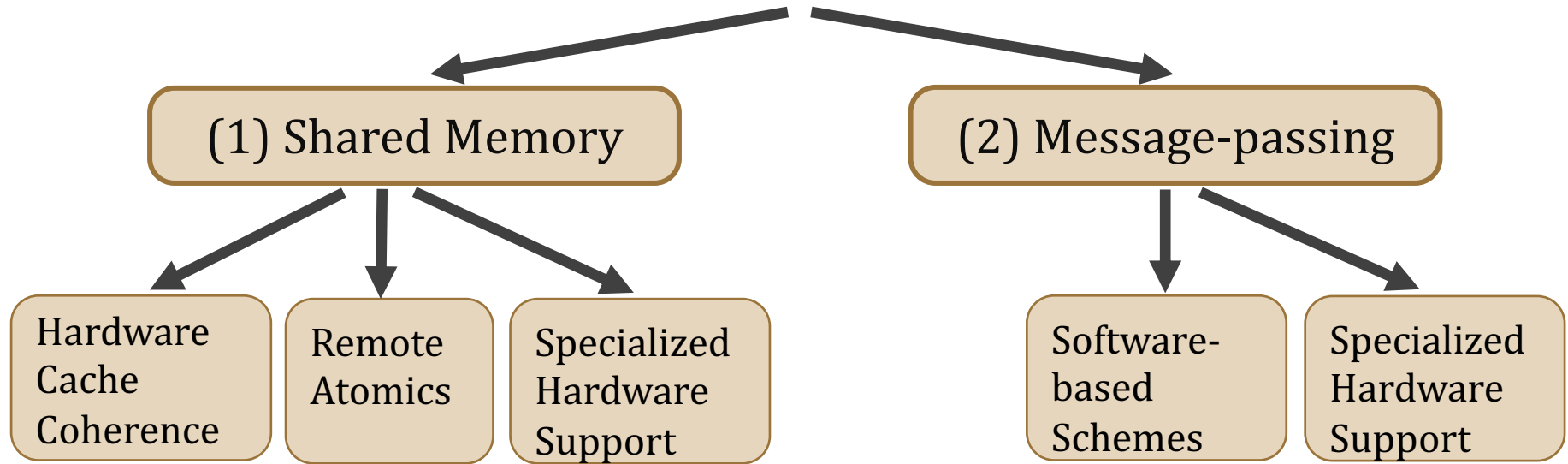
Baseline NDP Architecture



Synchronization **challenges** in NDP systems:

- (1) Lack of hardware cache coherence support
- (2) Expensive communication across NDP units
- (3) Lack of a shared level of cache memory

NDP Synchronization Solution Space



NDP Synchronization Solution Space

(1) Shared Memory

Hardware
Cache
Coherence

Remote
Atomics

Specialized
Hardware
Support

CPUs:

Hierarchical CLH Locks
[EuroPar'06]
Cohort Locks [TOPC'15]
Ticket Locks [TOCS'91] ...

MPPs:

QOLB [ASPLOS'89]

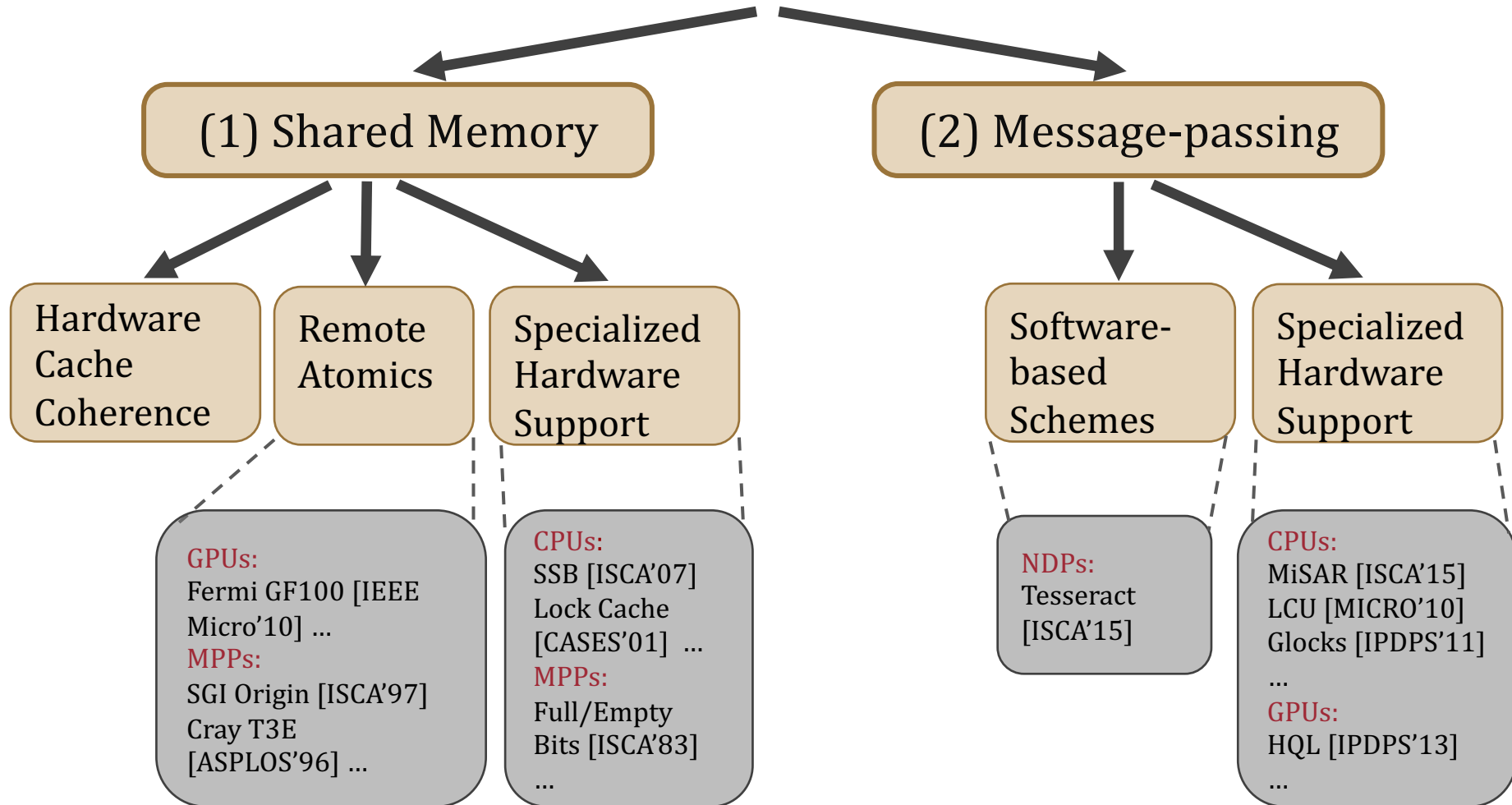
(2) Message-passing

Software-
based
Schemes

Specialized
Hardware
Support

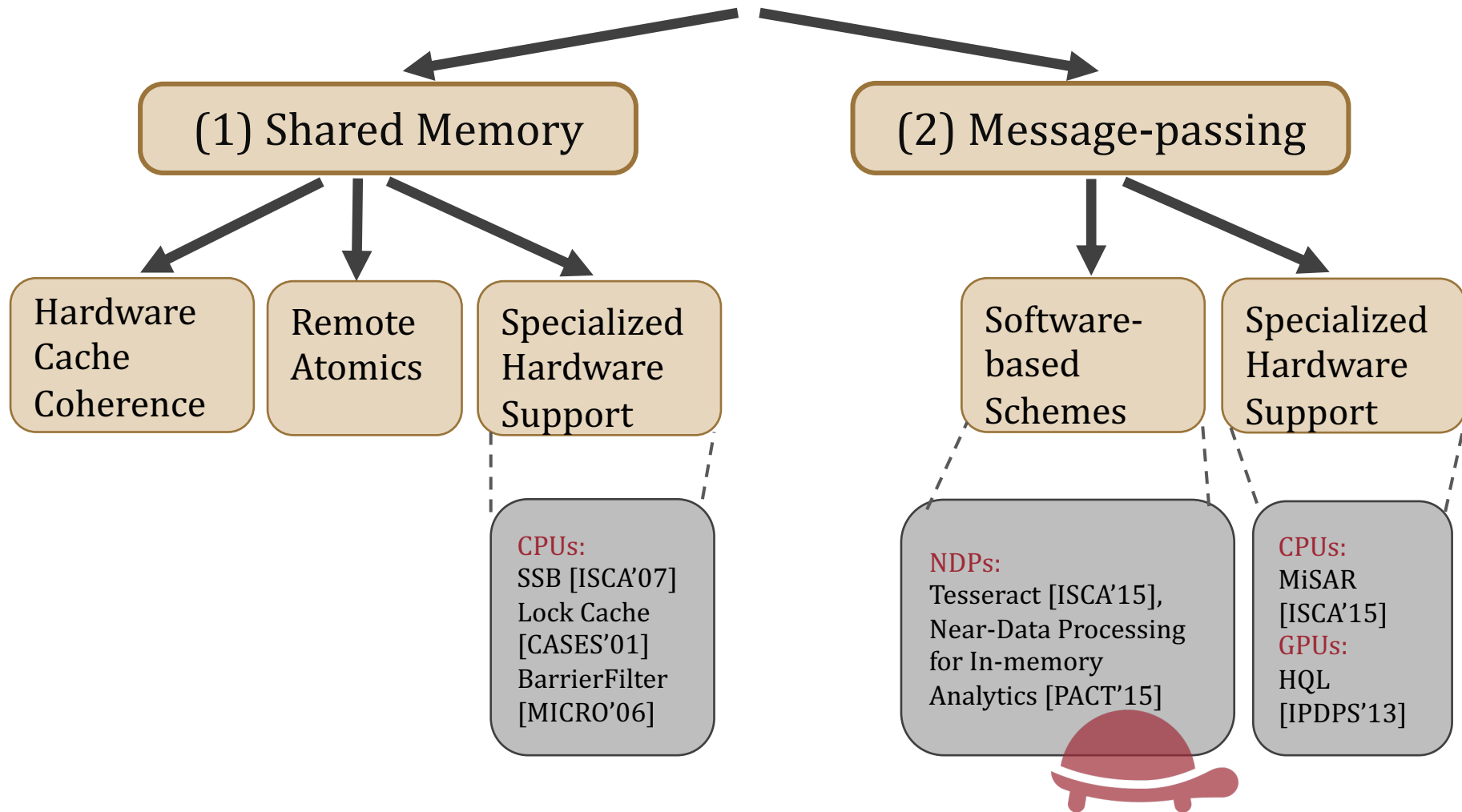
Lack of hardware cache coherence support

NDP Synchronization Solution Space



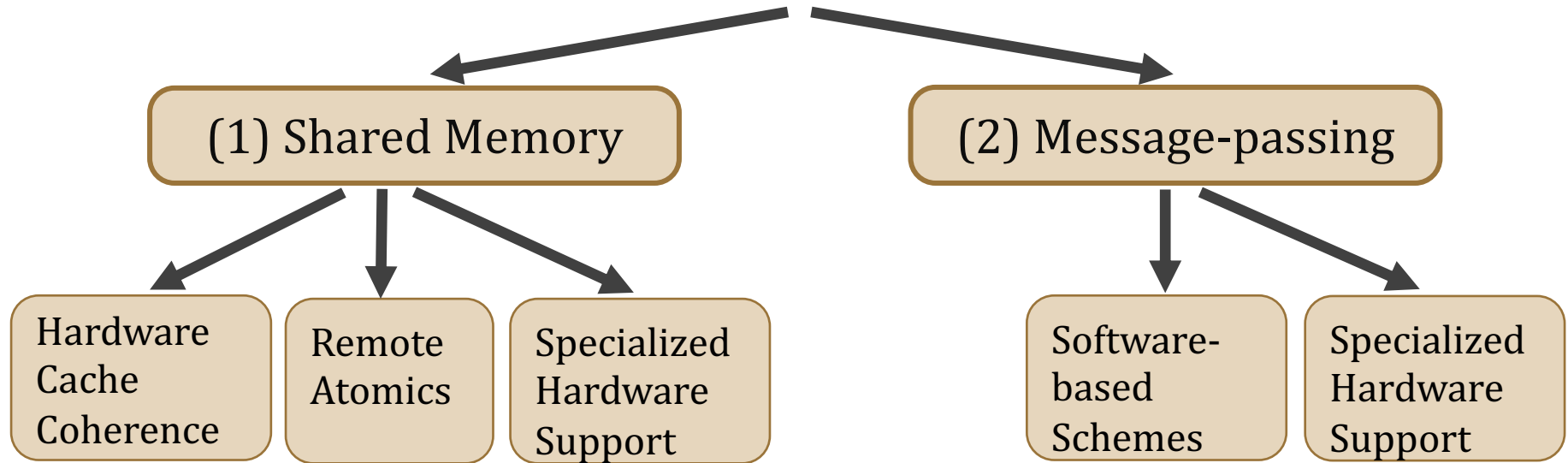
Expensive communication across NDP units

NDP Synchronization Solution Space



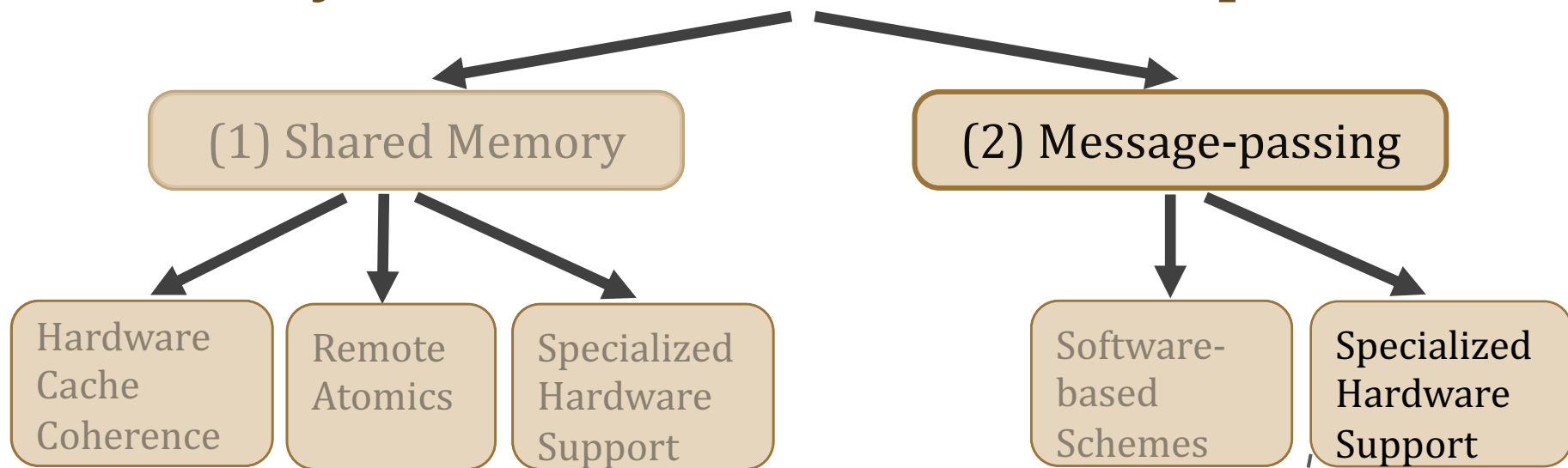
Lack of a shared level of cache memory

NDP Synchronization Solution Space



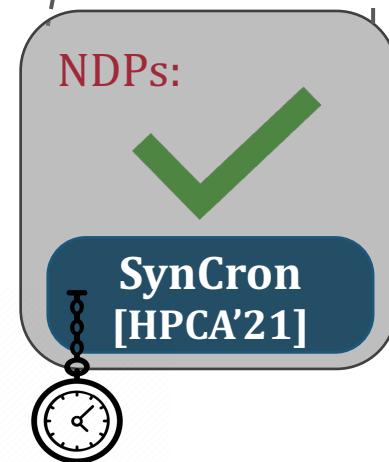
Prior schemes are *not suitable or efficient* for NDP systems

NDP Synchronization Solution Space

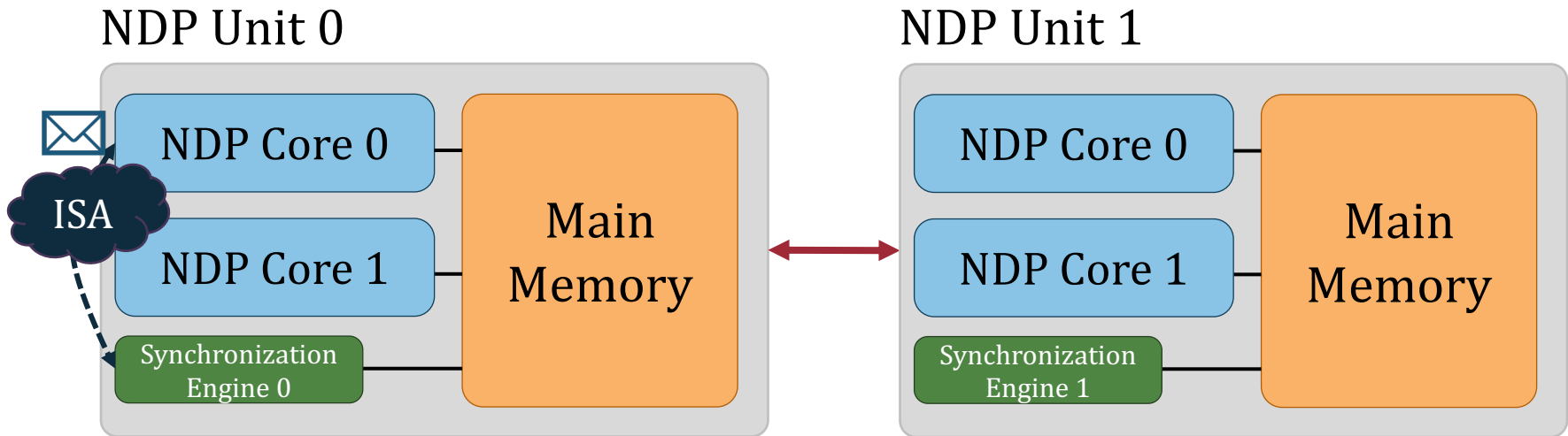


SynCron's Key Techniques:

1. **Hardware support** for synchronization acceleration
2. **Direct buffering** of synchronization variables
3. **Hierarchical** message-passing **communication**
4. Integrated hardware-only **overflow management**



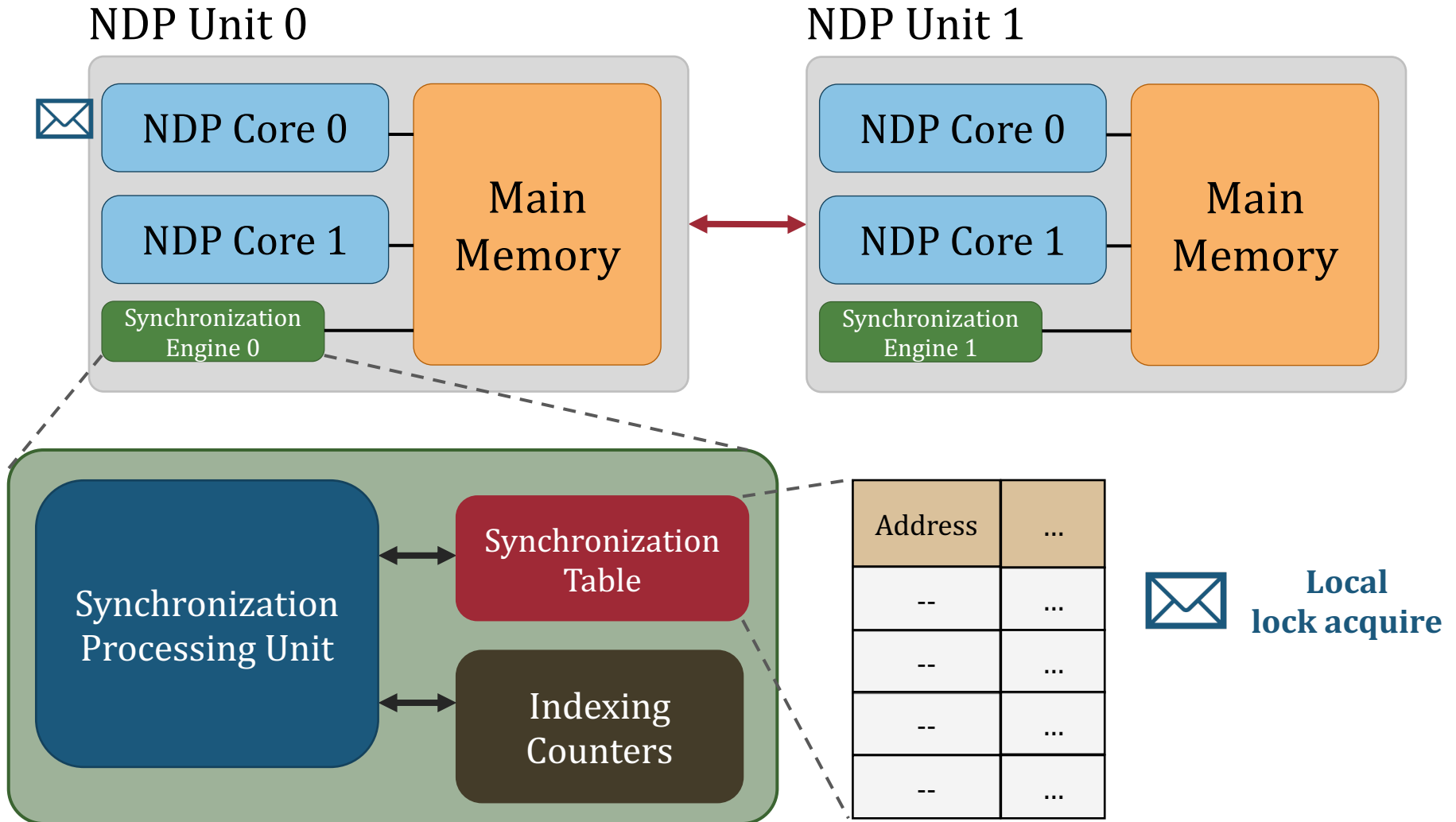
1. Hardware Synchronization Support



**Local
lock acquire**

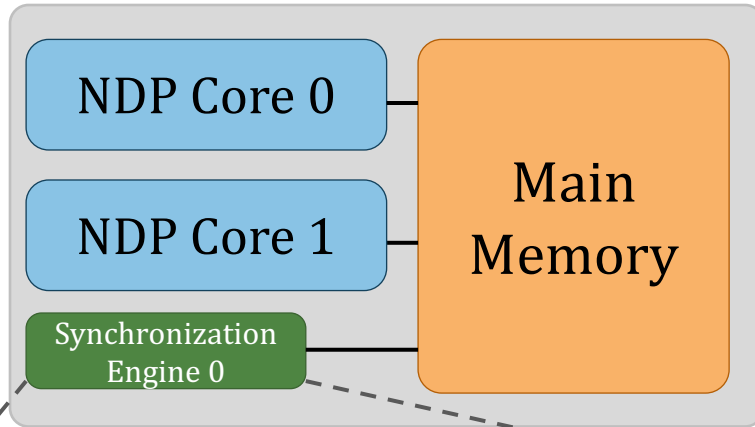
- ✓ **No Complex Cache Coherence Protocols**
- ✓ **No Expensive Atomic Operations**
- ✓ **Low Hardware Cost**

2. Direct Buffering of Variables

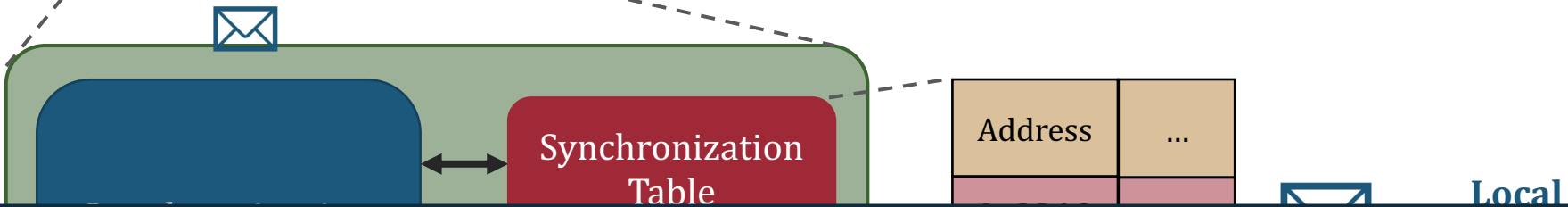
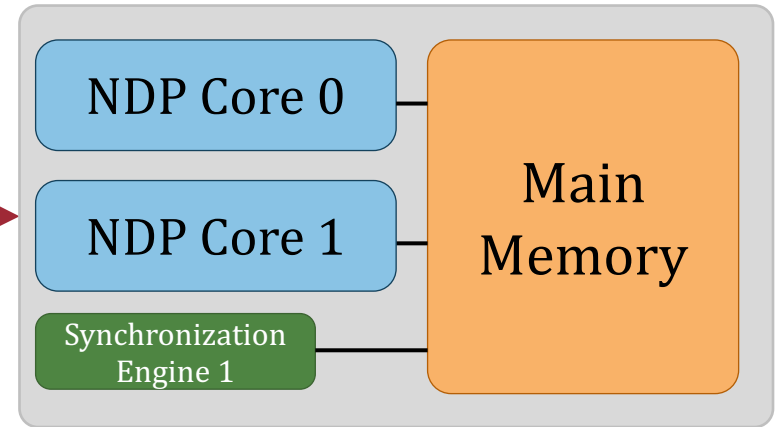


2. Direct Buffering of Variables

NDP Unit 0



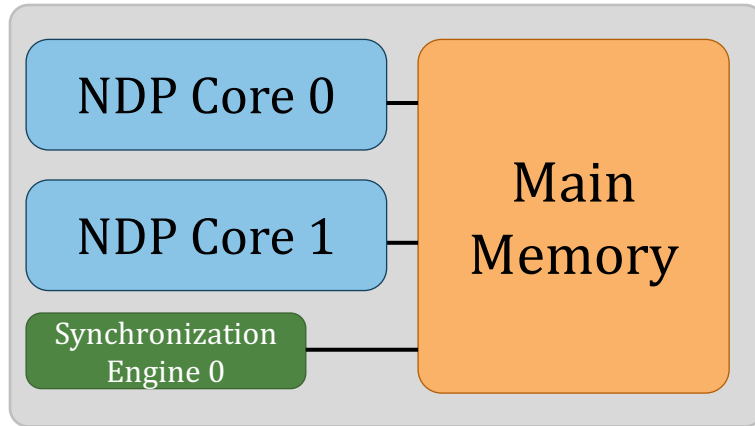
NDP Unit 1



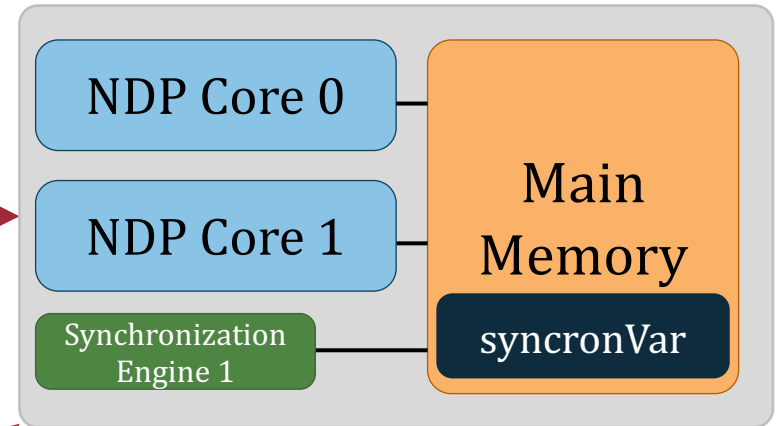
- ✓ No Costly Memory Accesses
- ✓ Low Latency

3. Hierarchical Communication

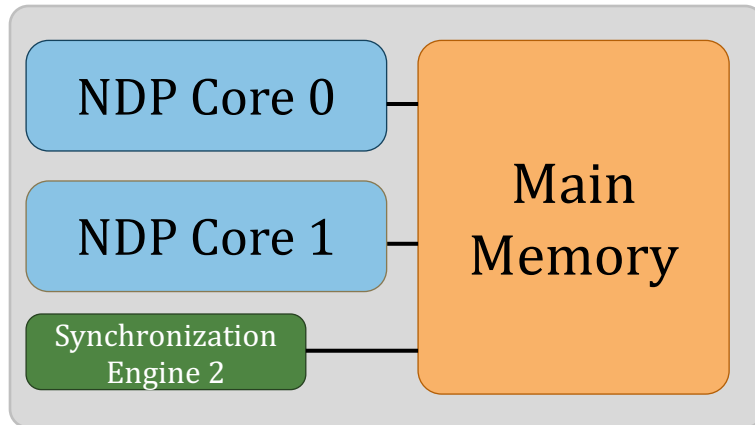
NDP Unit 0



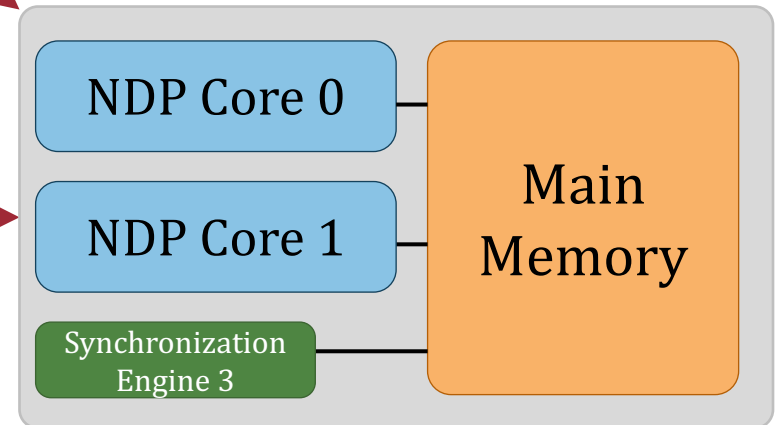
NDP Unit 1



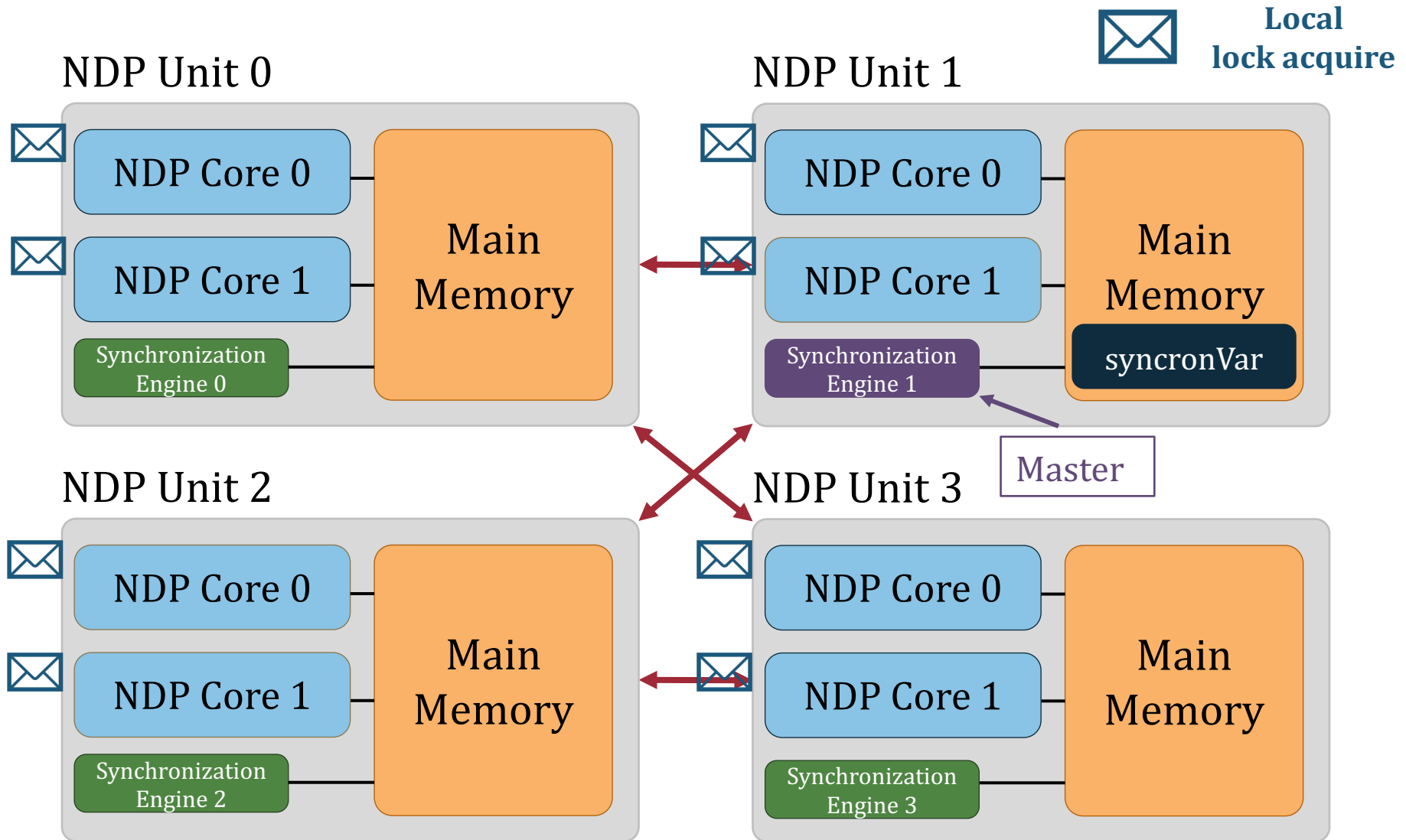
NDP Unit 2



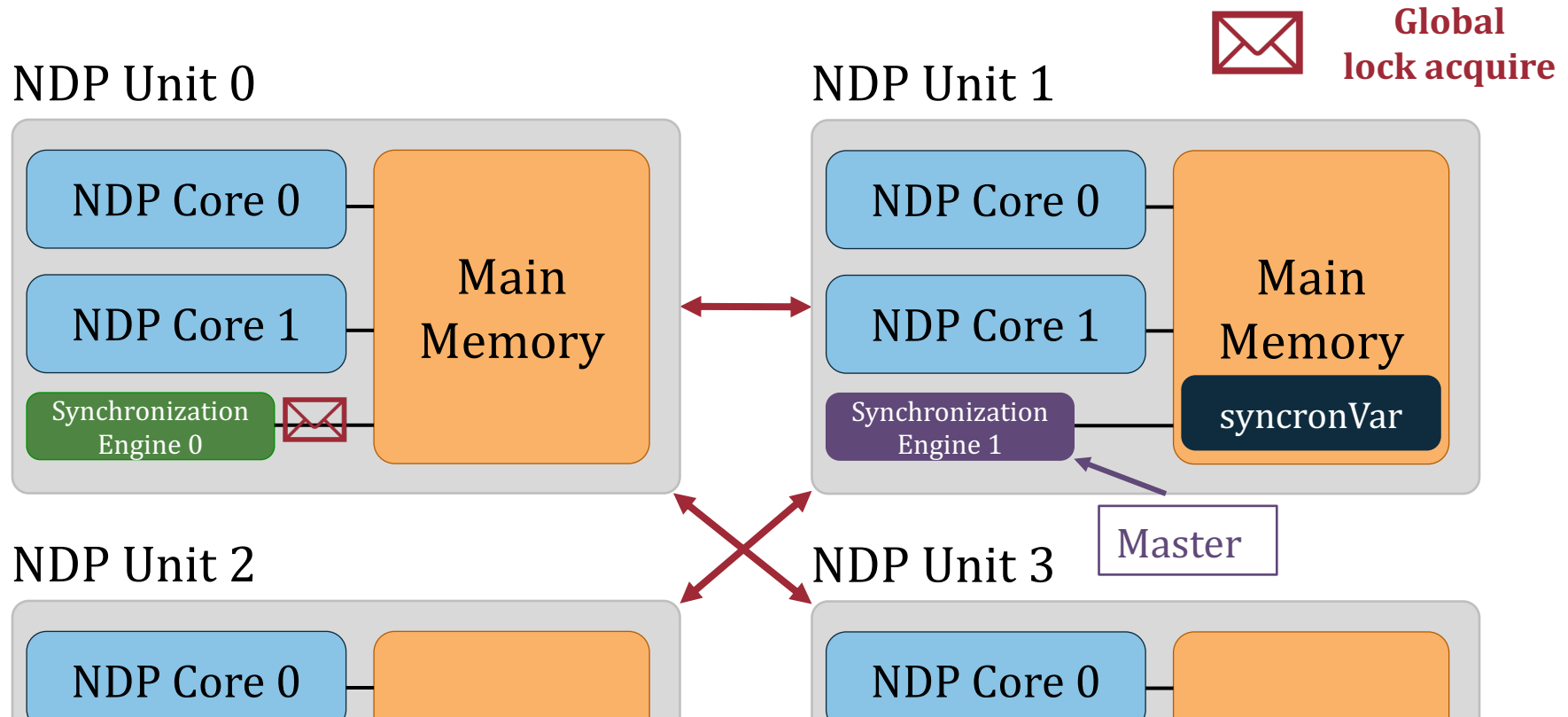
NDP Unit 3



3. Hierarchical Communication



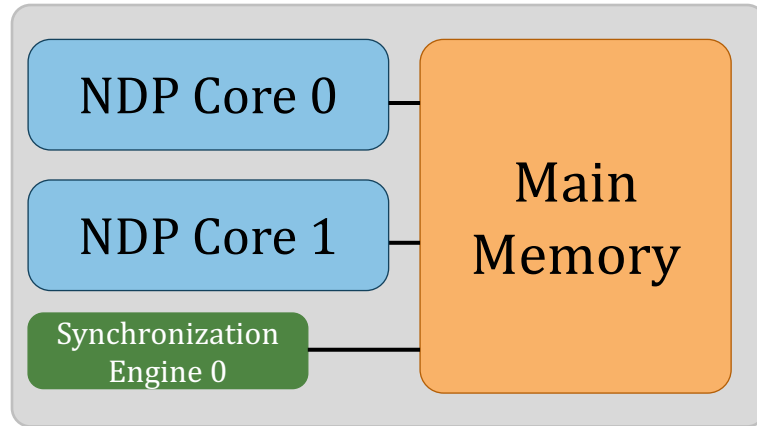
3. Hierarchical Communication



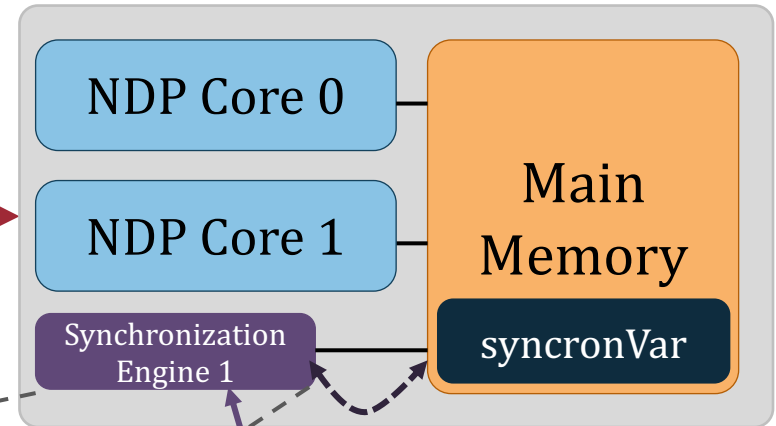
✓ Minimize Expensive Traffic

4. Integrated Overflow Management

NDP Unit 0



NDP Unit 1



Master

Fully Occupied

Address	...
0x2340	

- ✓ Low Performance Degradation
- ✓ High Programming Ease

SynCron

The first end-to-end synchronization solution for NDP architectures

SynCron's **Benefits**:

1. High System Performance
2. Low Hardware Cost

SynCron comes within 9.5% and 6.2% of performance and energy of **Ideal zero-overhead synchronization**

SynCron

Efficient Synchronization Support for Near-Data-Processing Architectures



Christina Giannoula

Nandita Vijaykumar, Nikela Papadopoulou, Vasileios Karakostas
Ivan Fernandez, Juan Gómez Luna, Lois Orosa
Nectarios Koziris, Georgios Goumas, Onur Mutlu

SAFARI



ETH zürich

