



# TAKING A VIRTUAL MACHINE TOWARDS MANY-CORES

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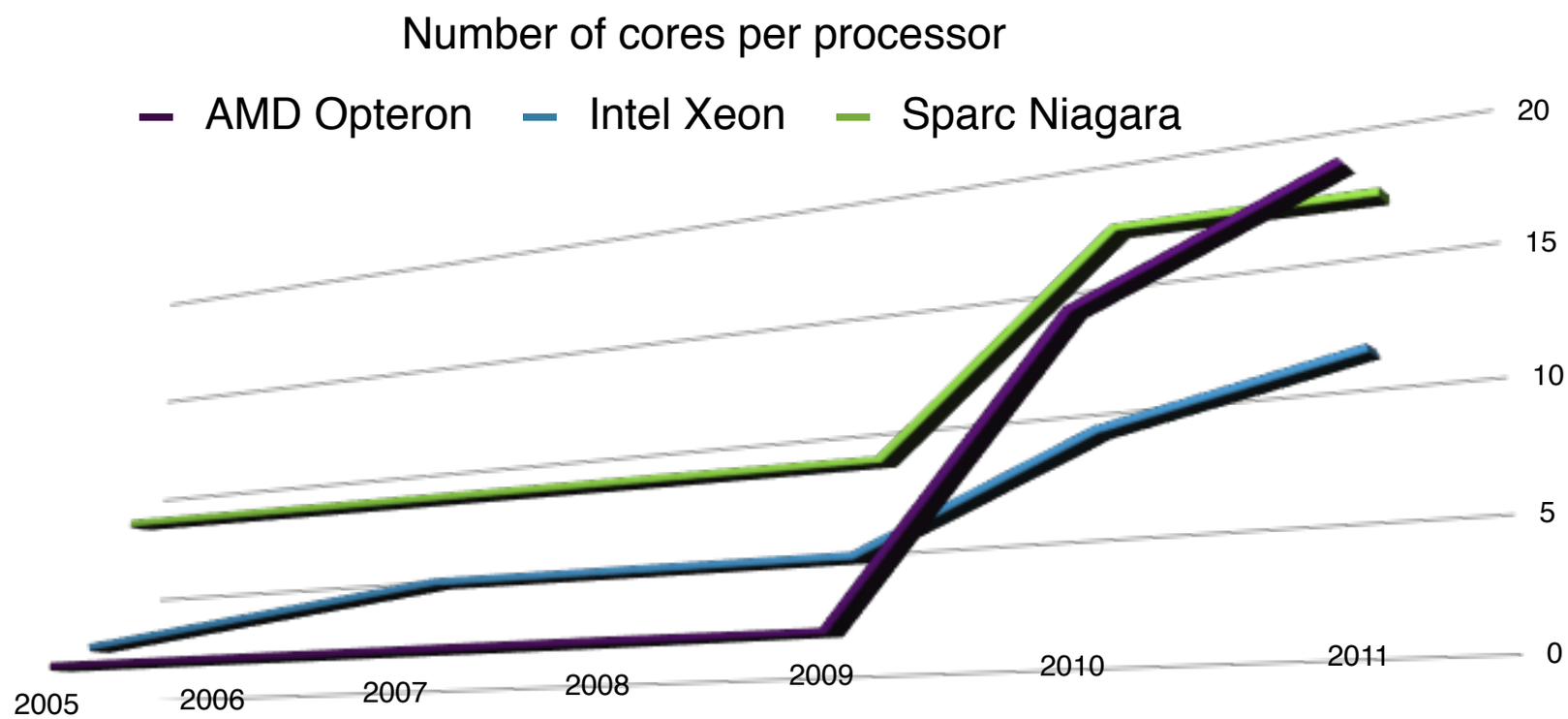
PATRIK NYBLOM - *pan@erlang.org*

# WHAT WE ALL KNOW BY NOW



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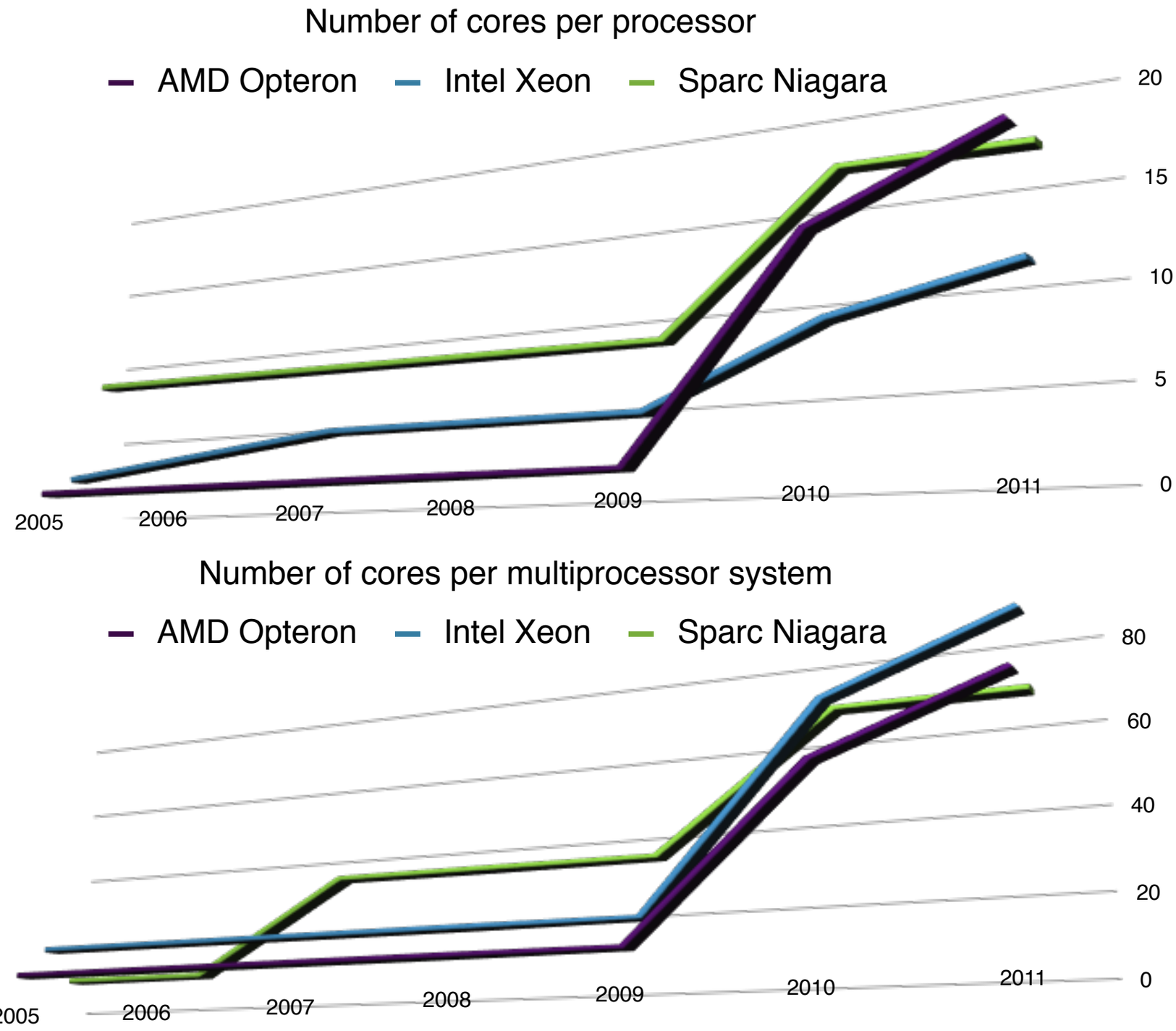

# Resource Contention



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- High level algorithms
  - Server
  - ...



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  - ...
- Software synchronization mechanisms
  - Locks
    - Lock type
    - Lock implementation
  - Lock free data structures
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- Hardware
  - Processor communication
    - Cache line
    - Memory barrier
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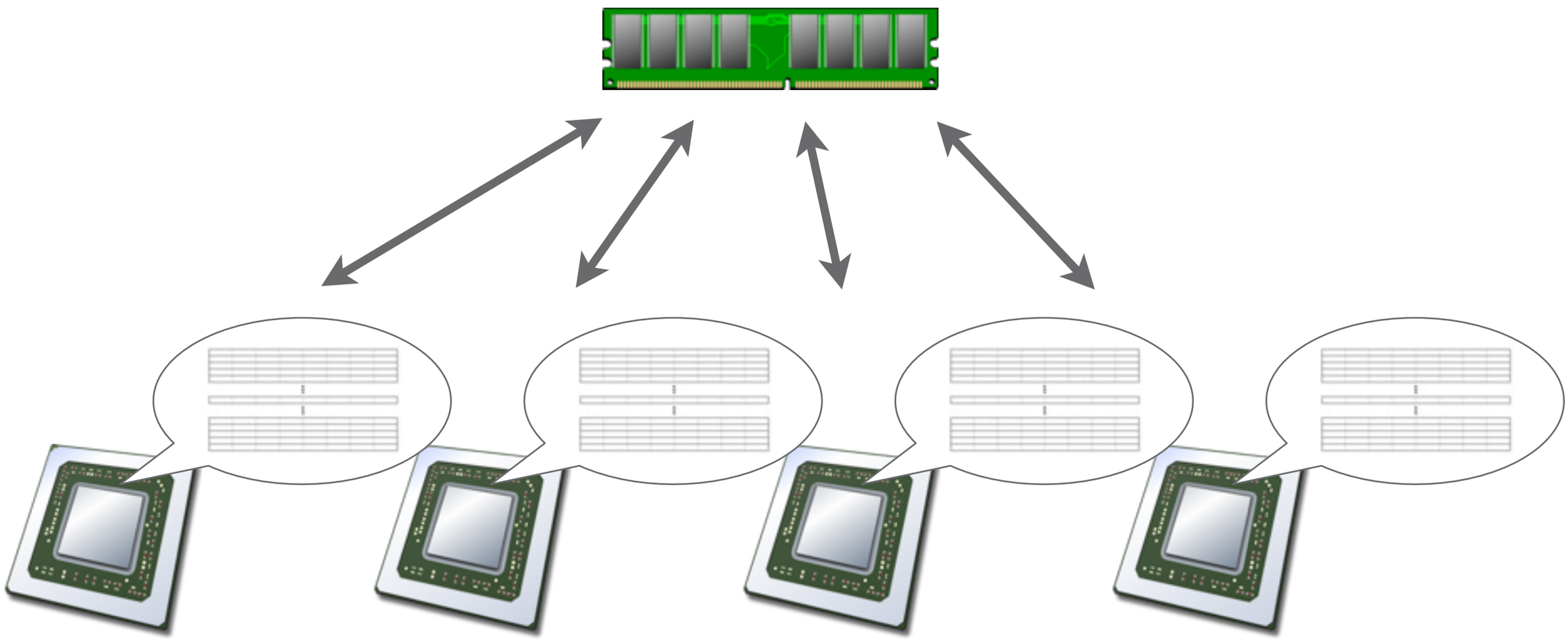
Awareness

# SHARED MEMORY MULTIPROCESSOR SYSTEM



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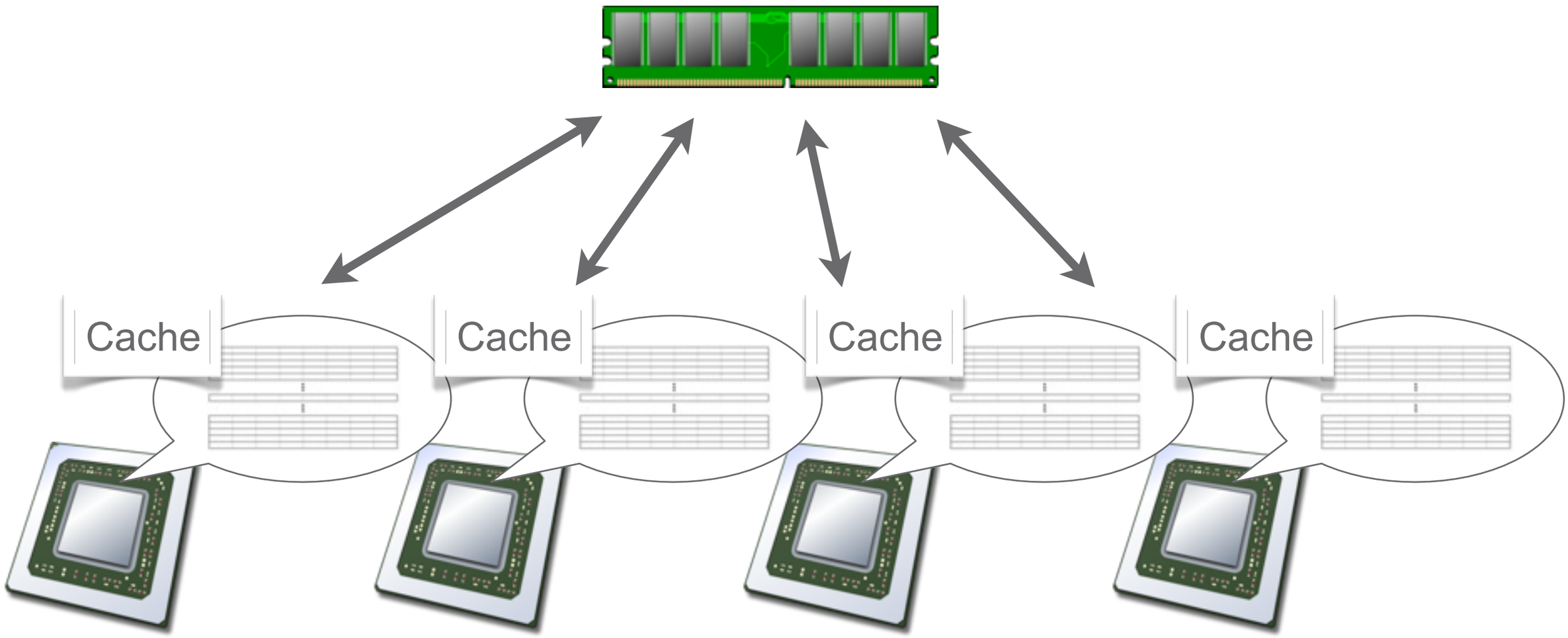
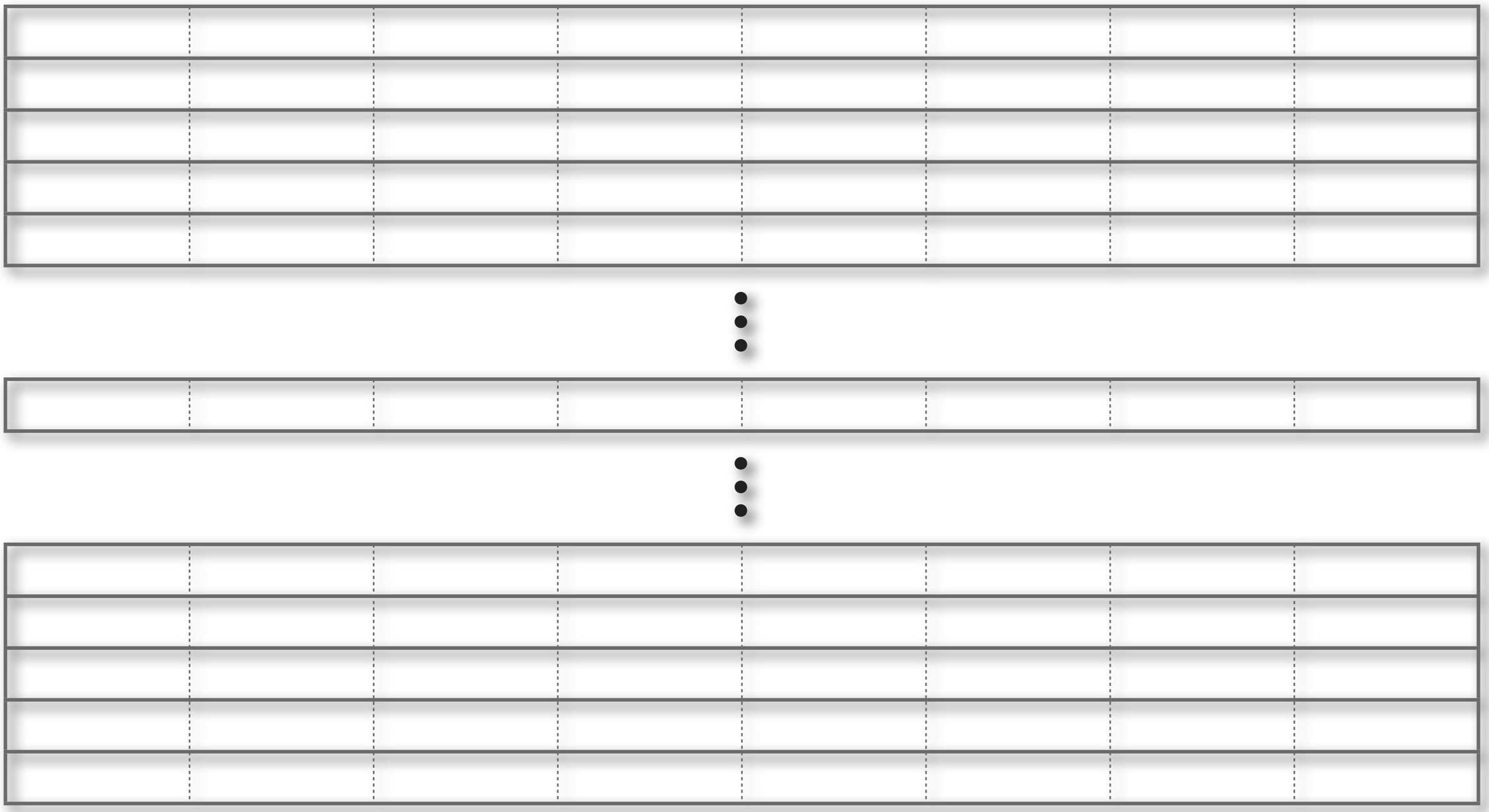


# CACHE



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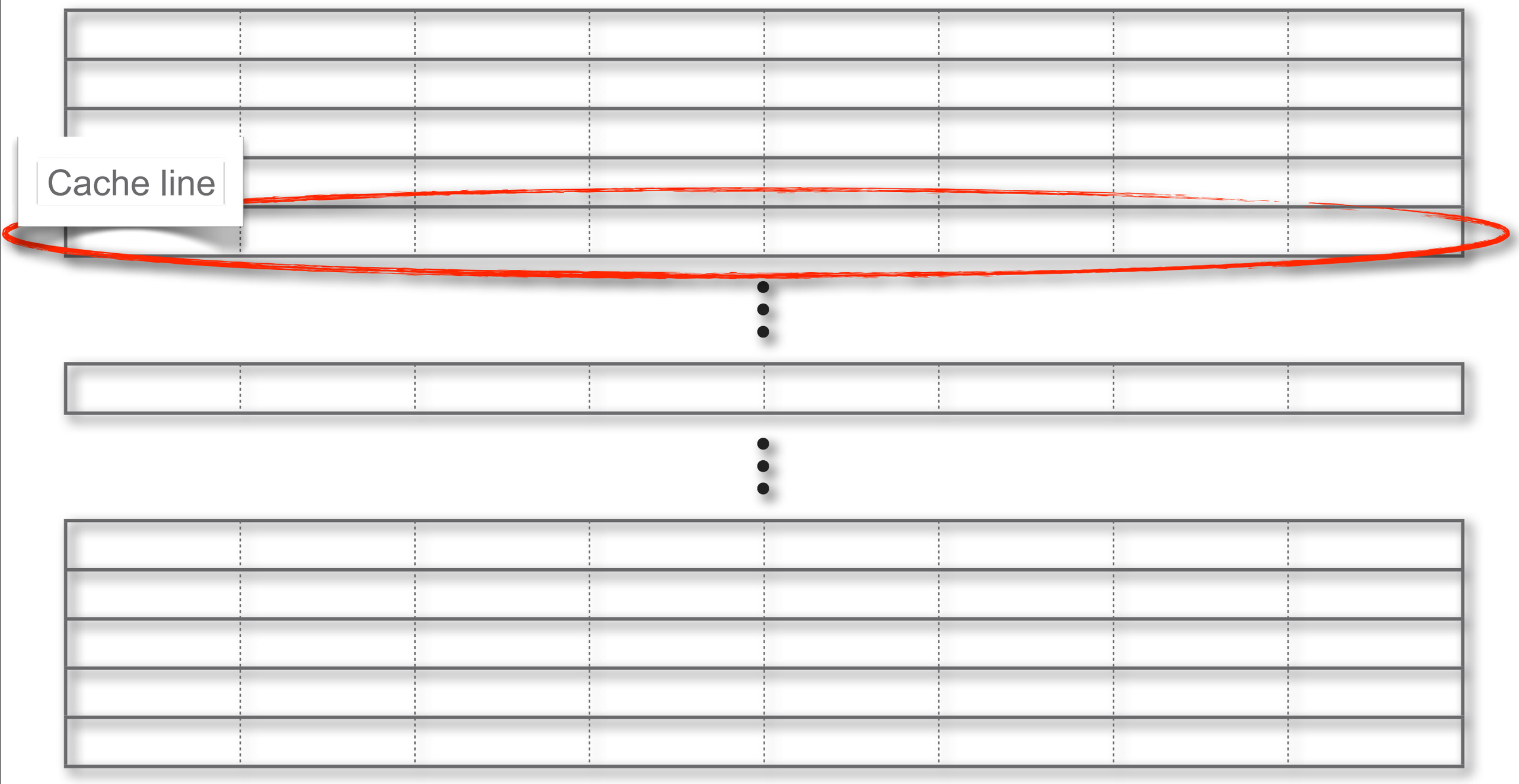




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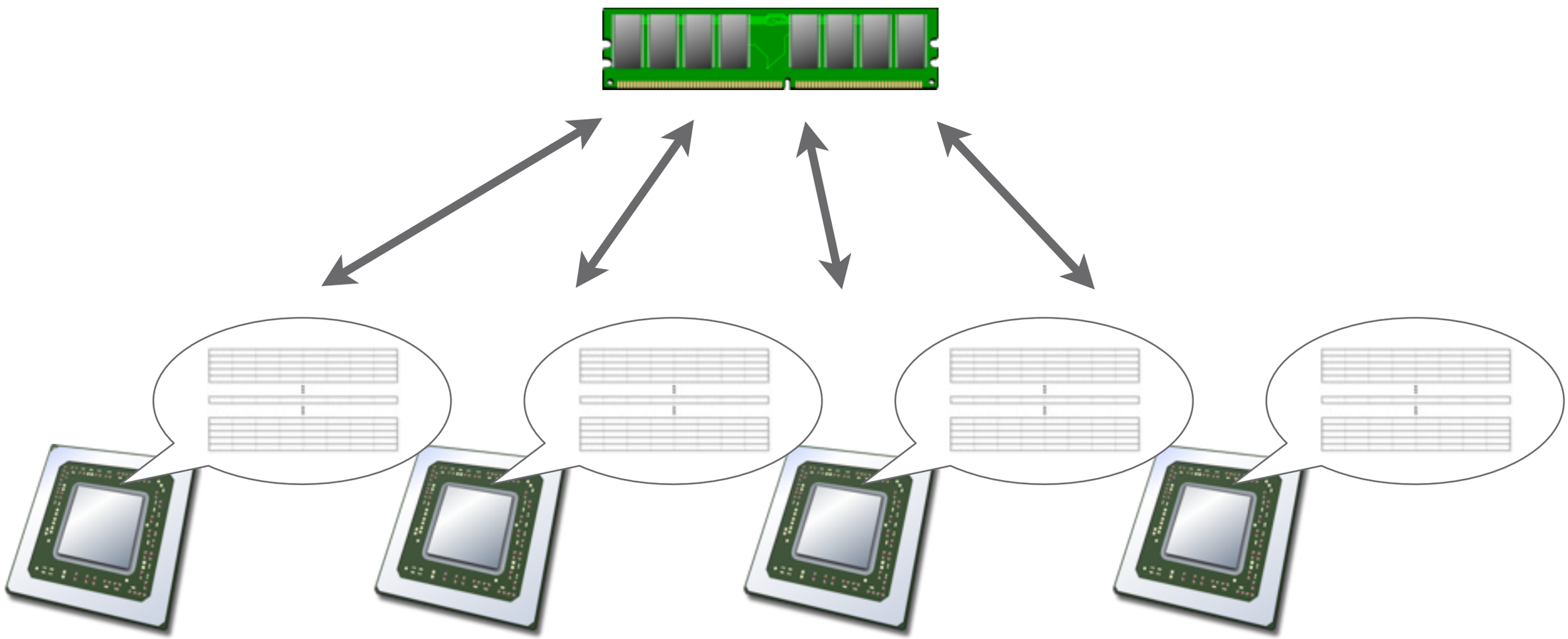

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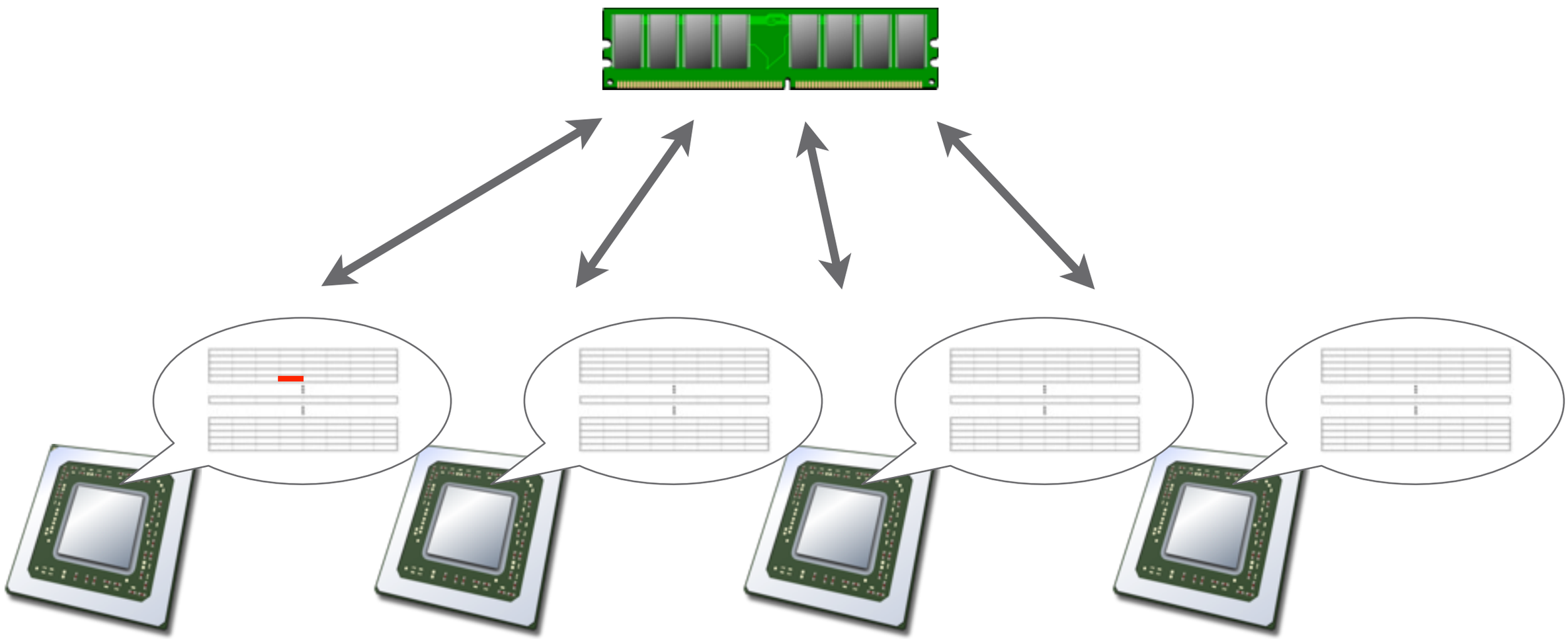

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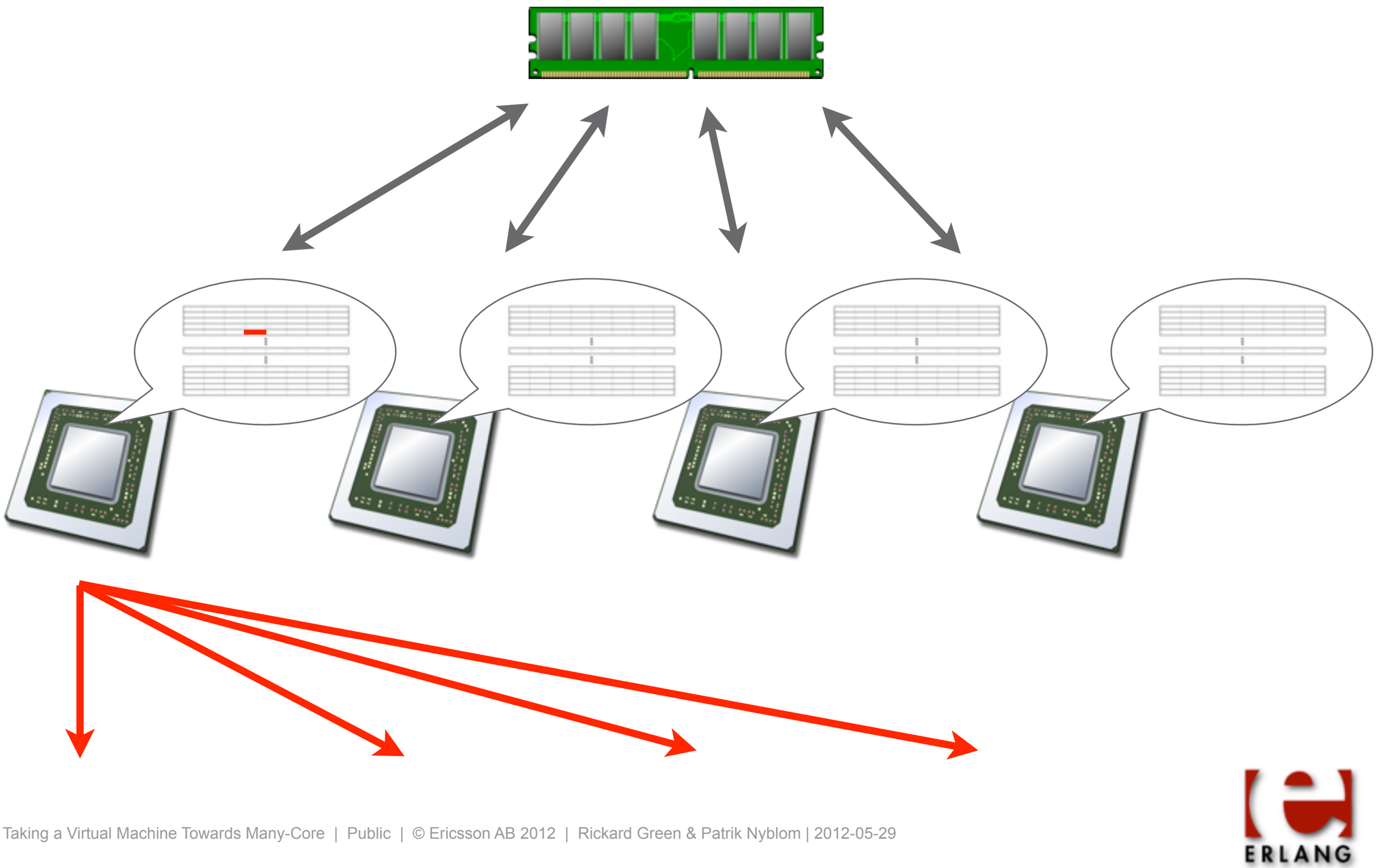

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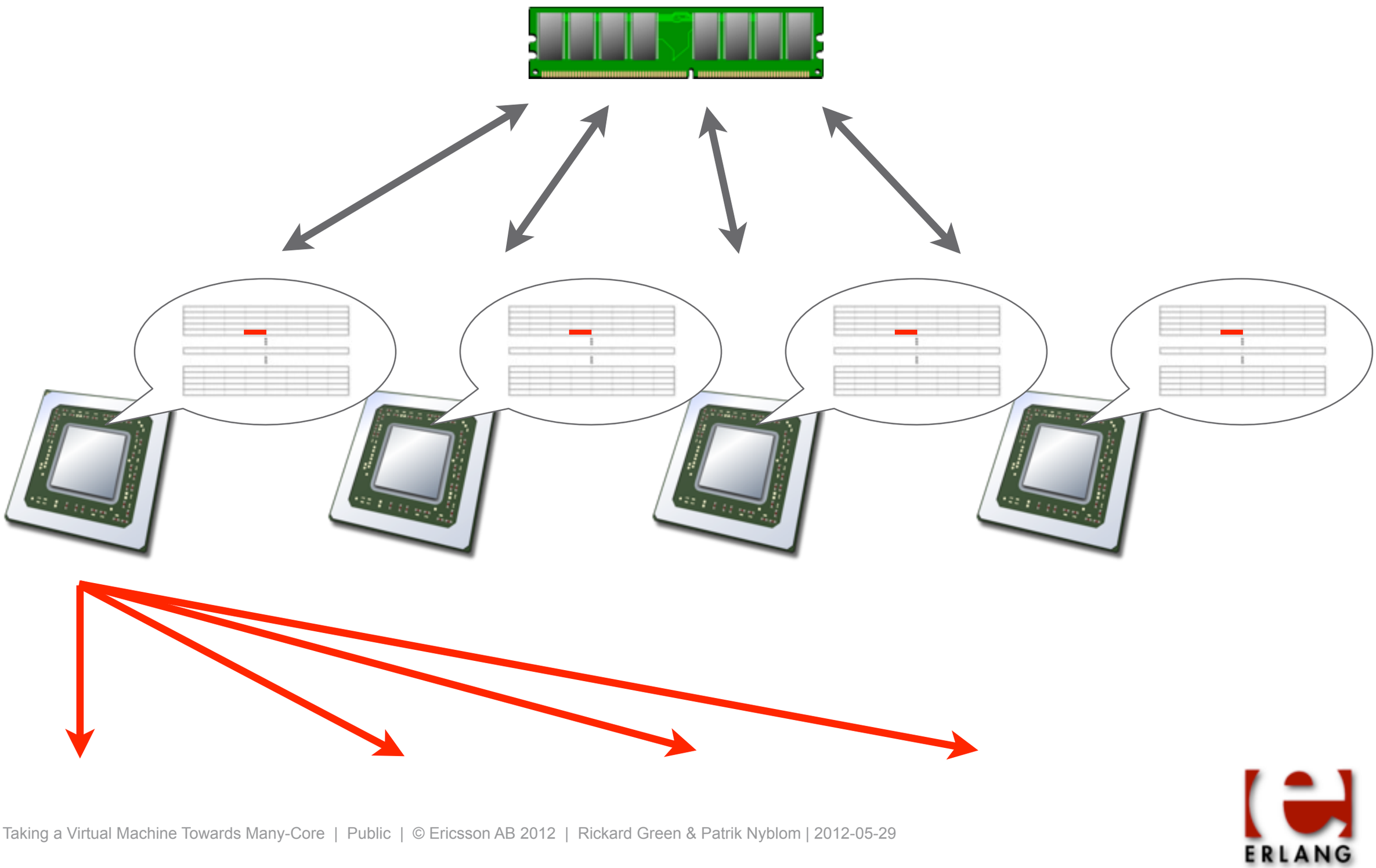

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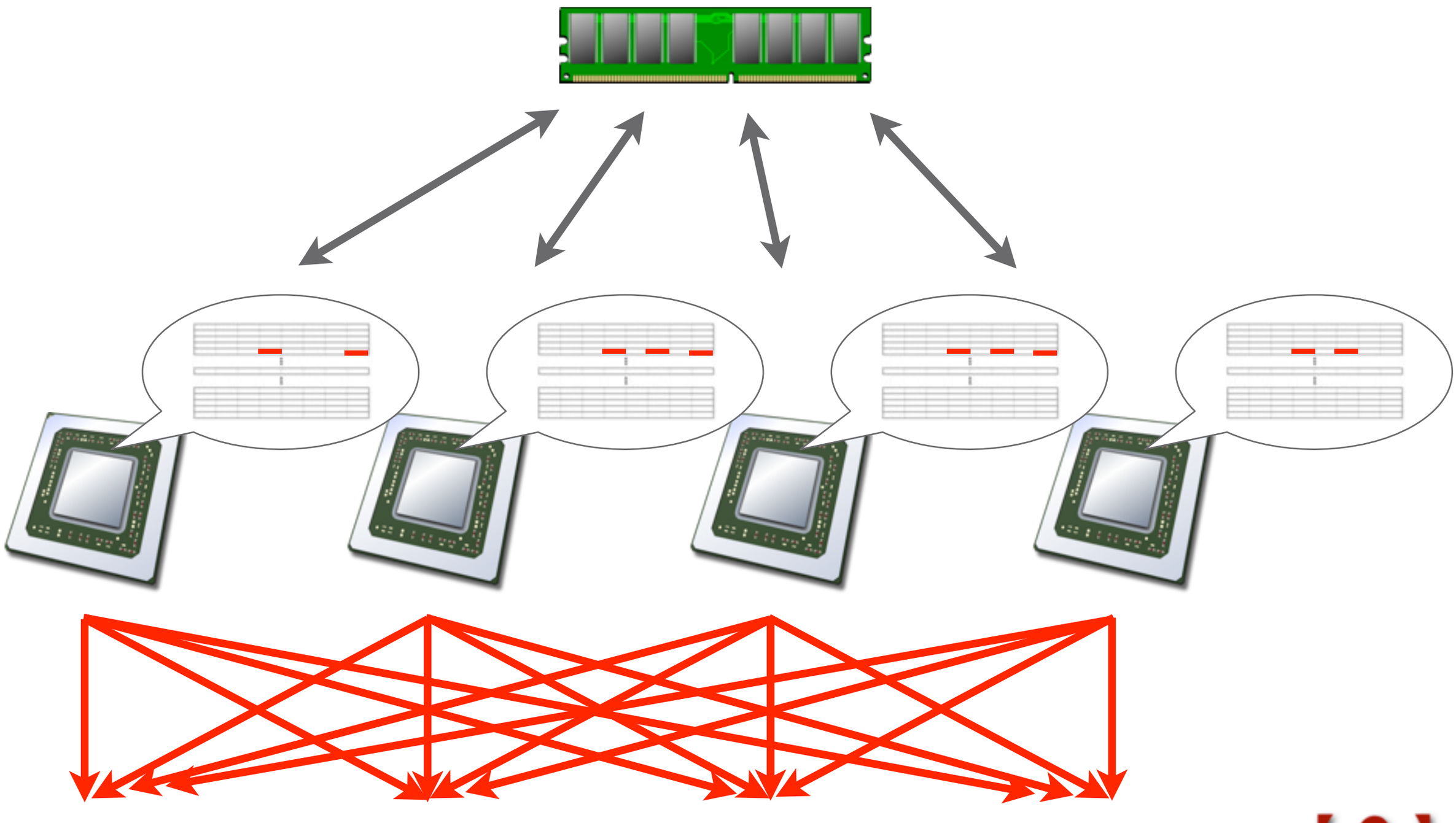

# TABLE ELEMENT LOOKUP

- Read-lock table
- Lookup element
- Increment element reference count
- Read-unlock table
- Operate on element
- Decrease element reference count
  - Release if reference count reached zero
- Deletion of element
  - Remove from table
  - Decrease reference count and release if it reached zero

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  - Add number of schedulers to element reference count
  - Decrement reference count once for lost table reference
  - Schedule “confirm deletion jobs” on all schedulers
  - Each scheduler decrease reference count and release if it reached zero



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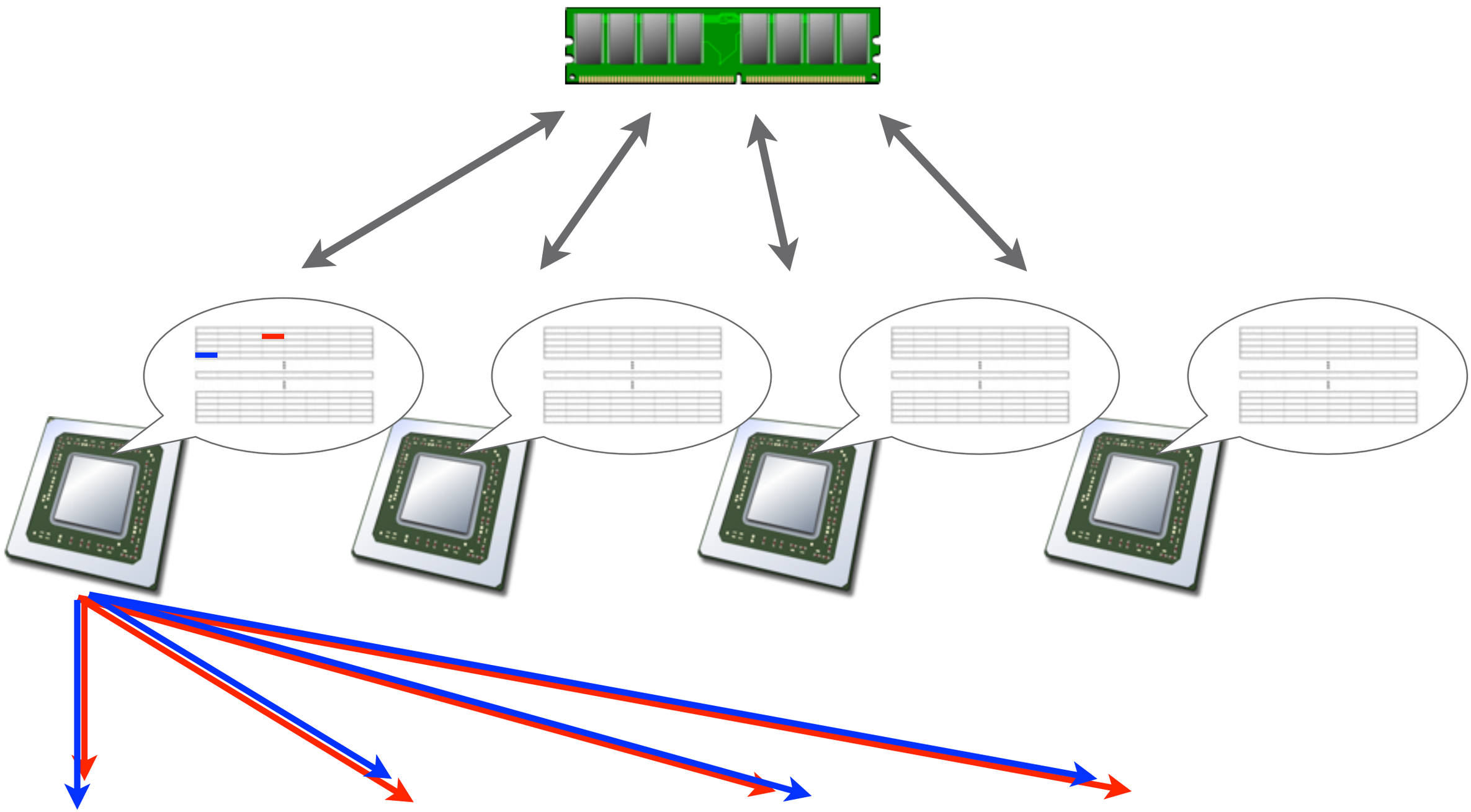
# ORDER OF MEMORY OPERATIONS



# ORDER OF MEMORY OPERATIONS

c1 = c2 = 1

| Thread 1 | Thread 2 |
|---|---|
| Store(c1, 0) | Store(c2, 0) |
| r1 = Load(c2) | r2 = Load(c1) |

| r1 | r2 |
|---|---|



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| 0 | 0 |
| 0 | 1 |
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# ORDER OF MEMORY OPERATIONS

c1 = c2 = 1

| Thread 1 | Thread 2 |
|---|---|
| Store(c1, 0) | Store(c2, 0) |
| MemoryBarrier | MemoryBarrier |
| r1 = Load(c2) | r2 = Load(c1) |

| r1 | r2 |
|---|---|
| 0 | 0 |
| 0 | 1 |
| 1 | 0 |

# HARDWARE MEMORY BARRIERS

- Hardware architectures
  - Very different ordering guarantees
    - x86 - quite strict
    - ...
    - alpha - very relaxed
  - Hardware memory barriers
    - Tools for enforcing ordering
    - Expensive
    - Architecture dependent
    - Sometimes lightweight versions exist



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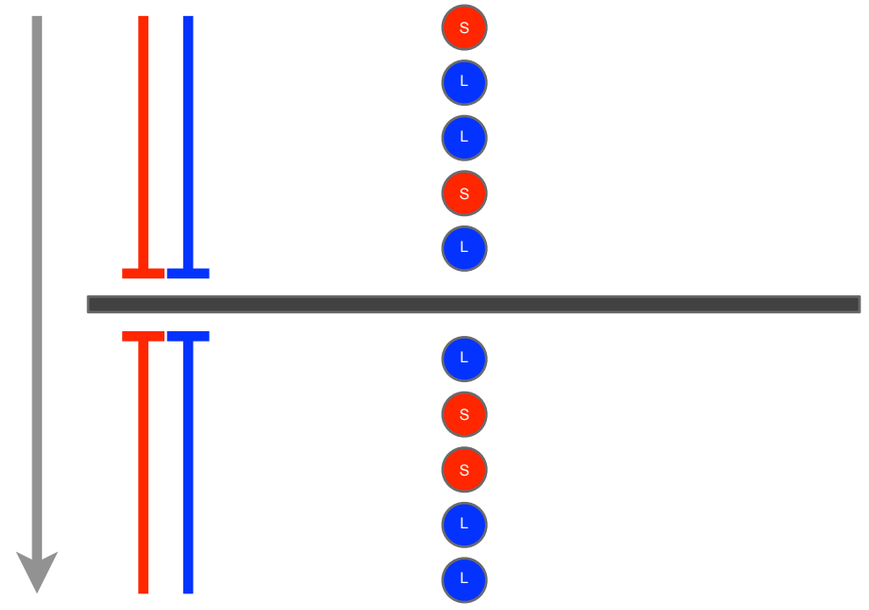

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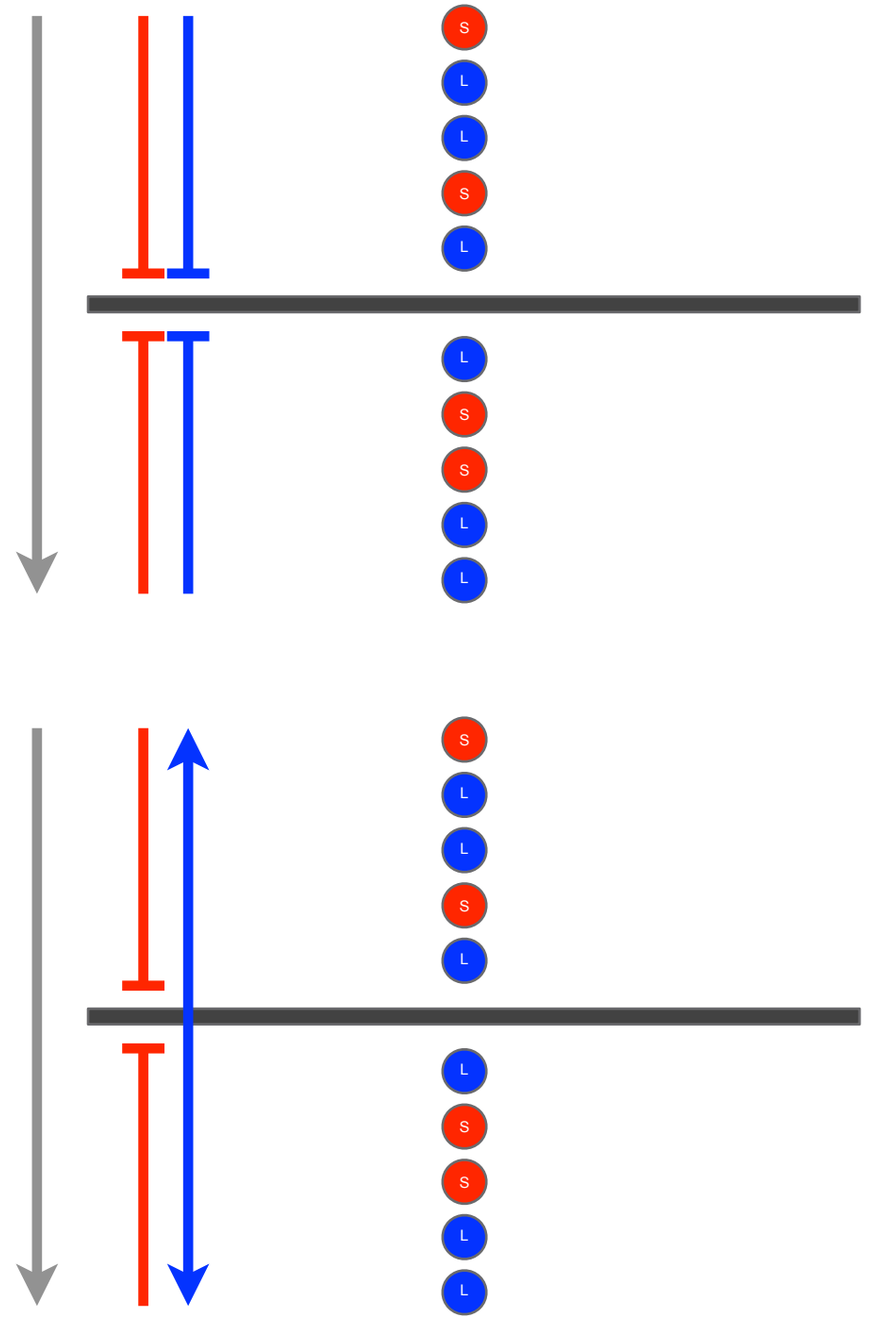

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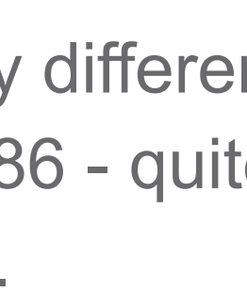

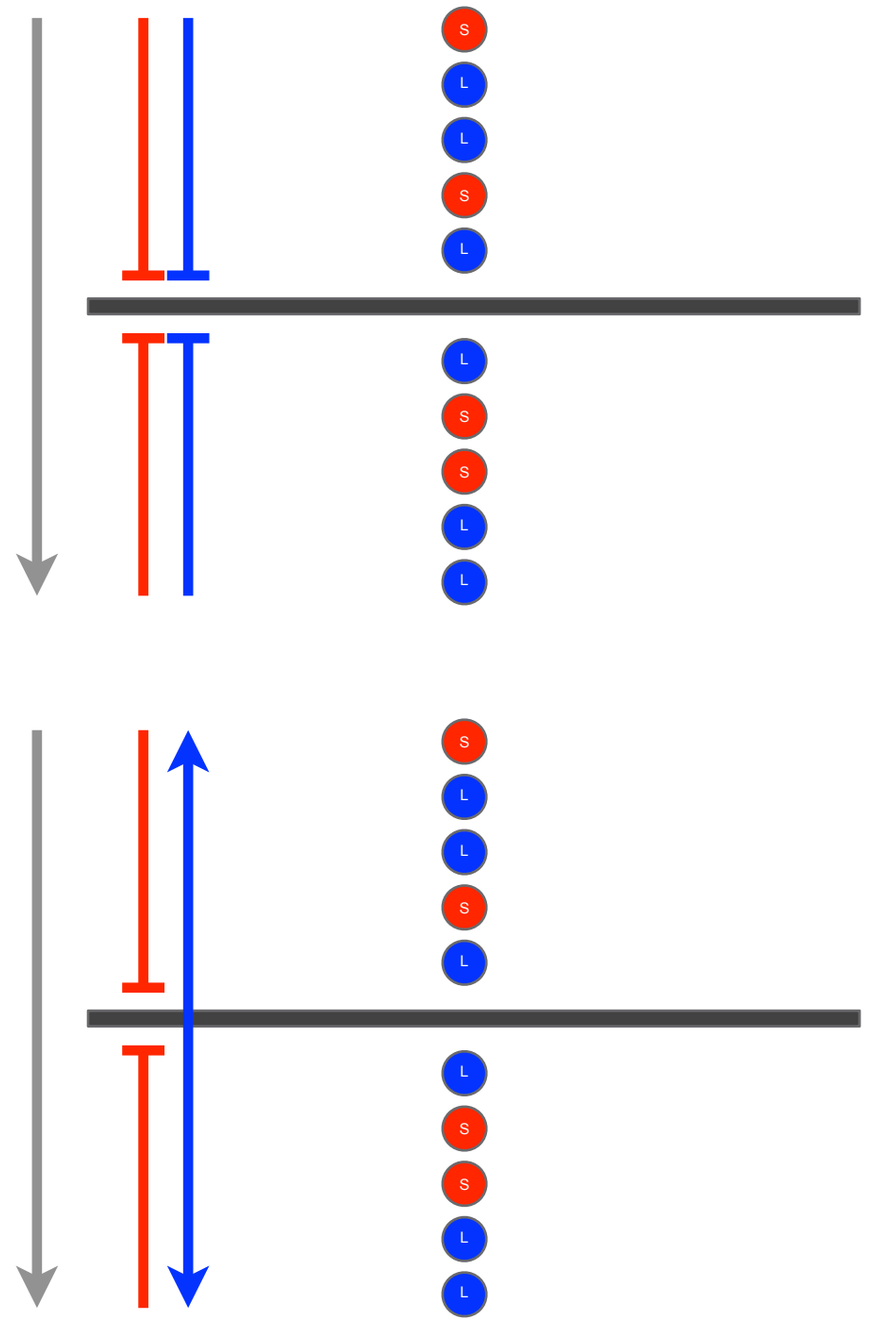

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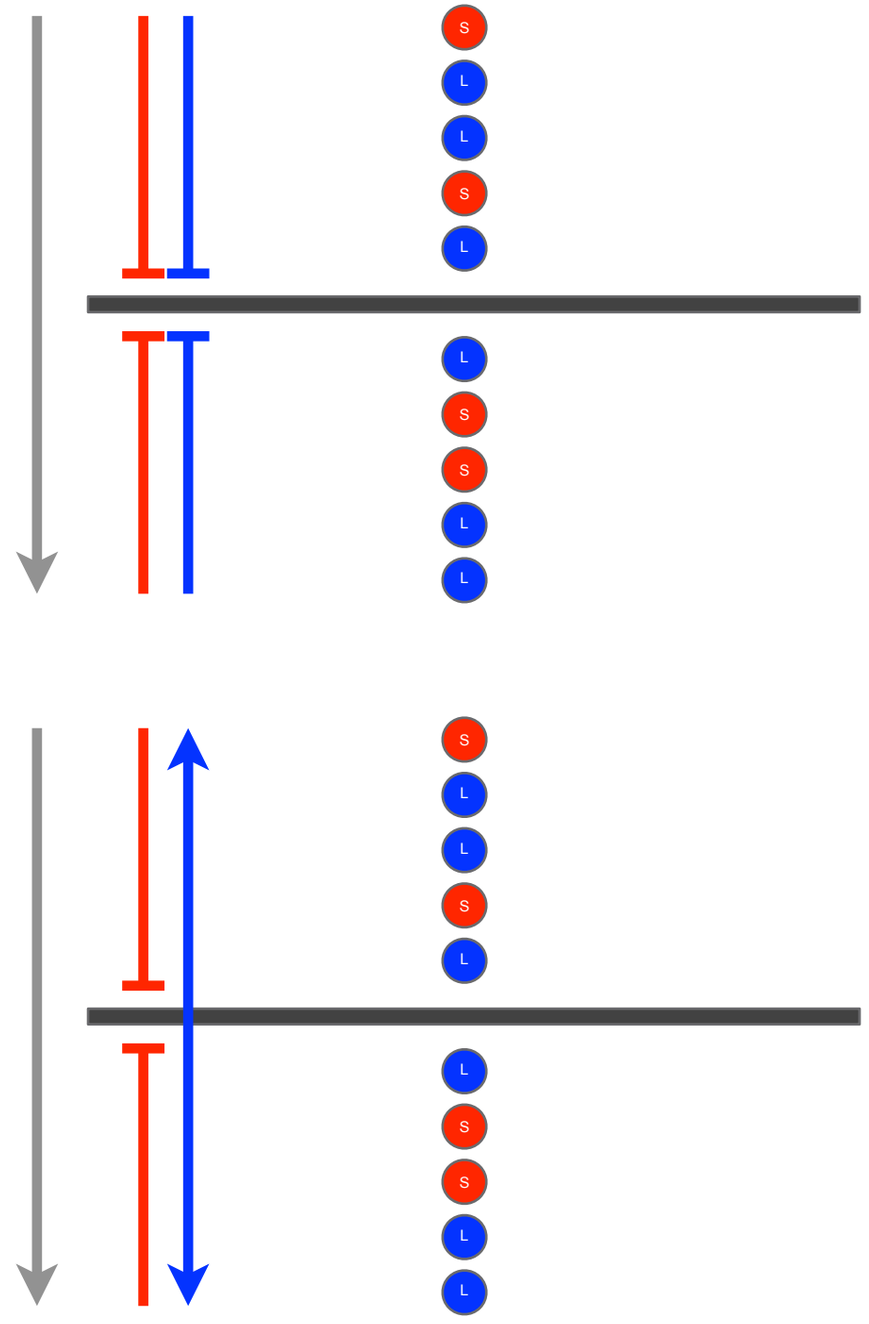


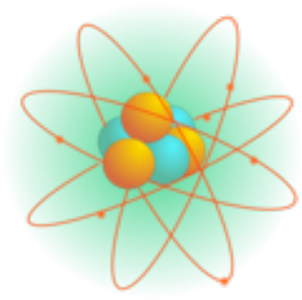



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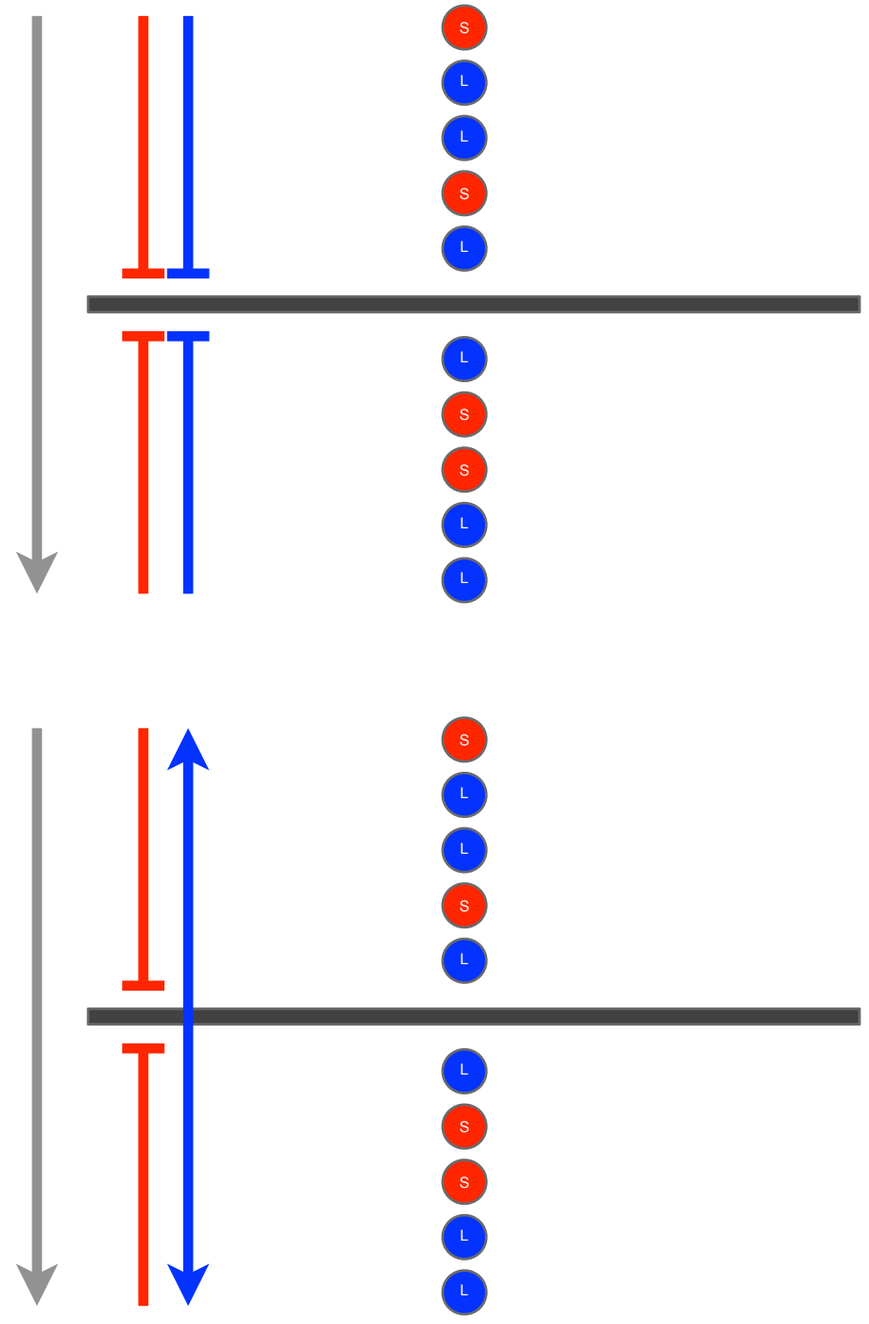


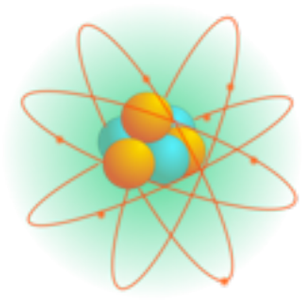




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# OLD ATOMIC API

ethr_atomic_init()
ethr_atomic_set()
ethr_atomic_read()
ethr_atomic_inc()
ethr_atomic_dec()
ethr_atomic_add()
ethr_atomic_inc_read_mb()
ethr_atomic_dec_read_mb()
ethr_atomic_add_read_mb()
ethr_atomic_read_bor_mb()
ethr_atomic_read_band_mb()
ethr_atomic_xchg_mb()
ethr_atomic_cmpxchg_mb()

# OLD ATOMIC API

## Word size

ethr_atomic_init()
ethr_atomic_set()
ethr_atomic_read()
ethr_atomic_inc()
ethr_atomic_dec()
ethr_atomic_add()
ethr_atomic_inc_read_mb()
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ethr_atomic_read_band_mb()
ethr_atomic_xchg_mb()
ethr_atomic_cmpxchg_mb()



# ATOMIC API R15



# ATOMIC API R15

## 32-bit

ethr_atomic32_init()
ethr_atomic32_set()
ethr_atomic32_read()
ethr_atomic32_inc_read()
ethr_atomic32_dec_read()
ethr_atomic32_inc()
ethr_atomic32_dec()
ethr_atomic32_add_read()
ethr_atomic32_add()
ethr_atomic32_read_bor()
ethr_atomic32_read_band()
ethr_atomic32_xchg()
ethr_atomic32_cmpxchg()
ethr_atomic32_init_mb()
ethr_atomic32_set_mb()
ethr_atomic32_read_mb()
ethr_atomic32_inc_read_mb()
ethr_atomic32_dec_read_mb()
ethr_atomic32_inc_mb()
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ethr_atomic32_add_read_mb()
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ethr_atomic32_xchg_mb()
ethr_atomic32_cmpxchg_mb()
ethr_atomic32_init_acqb()
ethr_atomic32_set_acqb()
ethr_atomic32_read_acqb()
ethr_atomic32_inc_read_acqb()
ethr_atomic32_dec_read_acqb()
ethr_atomic32_inc_acqb()
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ethr_atomic32_add_read_acqb()
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ethr_atomic32_read_bor_acqb()
ethr_atomic32_read_band_acqb()
ethr_atomic32_xchg_acqb()
ethr_atomic32_cmpxchg_acqb()
ethr_atomic32_init_relb()
ethr_atomic32_set_relb()
ethr_atomic32_read_relb()
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ethr_atomic32_read_bor_relb()
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ethr_atomic32_xchg_relb()
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ethr_atomic32_init_ddrb()
ethr_atomic32_set_ddrb()
ethr_atomic32_read_ddrb()
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ethr_atomic32_read_band_rb()
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ethr_atomic32_cmpxchg_rb()
ethr_atomic32_init_wb()
ethr_atomic32_set_wb()
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ethr_atomic_read_bor_wb()
ethr_atomic_read_band_wb()
ethr_atomic_xchg_wb()
ethr_atomic_cmpxchg_wb()

## Double word size

ethr_dw_atomic_init()
ethr_dw_atomic_set()
ethr_dw_atomic_read()
ethr_dw_atomic_cmpxchg()
ethr_dw_atomic_init_mb()
ethr_dw_atomic_set_mb()
ethr_dw_atomic_read_mb()
ethr_dw_atomic_cmpxchg_mb()
ethr_dw_atomic_init_acqb()
ethr_dw_atomic_set_acqb()
ethr_dw_atomic_read_acqb()
ethr_dw_atomic_cmpxchg_acqb()
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ethr_dw_atomic_read_rb()
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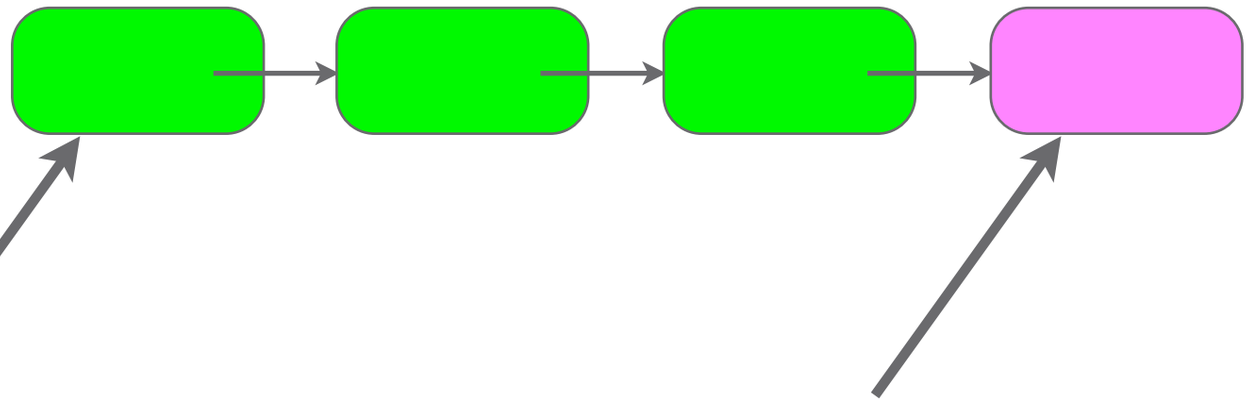
ethr_dw_atomic_init_wb()
ethr_dw_atomic_set_wb()
ethr_dw_atomic_read_wb()
ethr_dw_atomic_cmpxchg_wb()



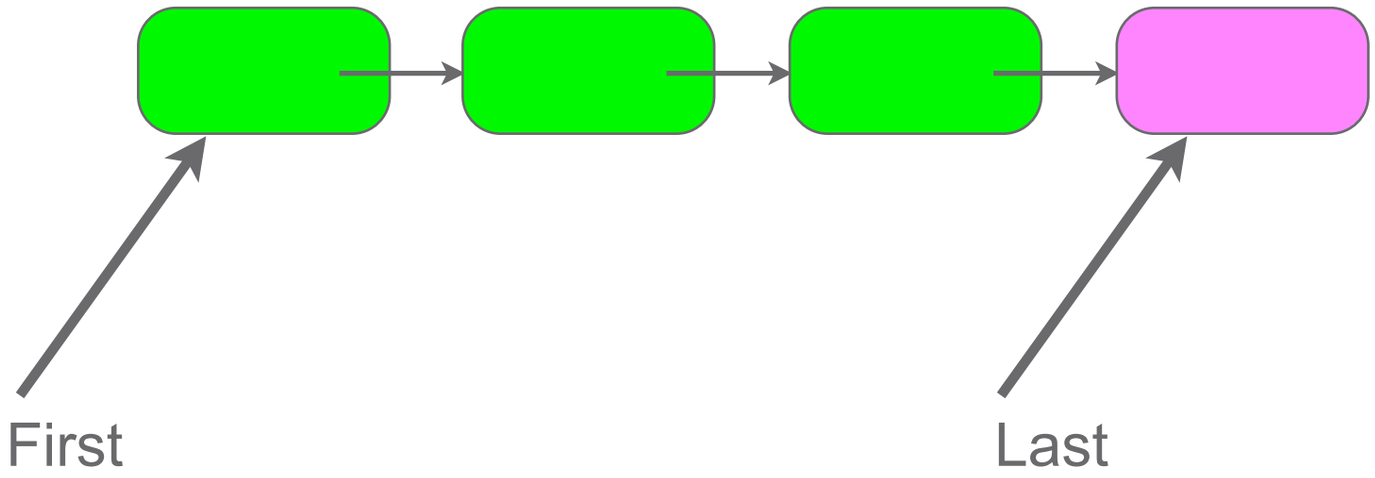
# LOCKED QUEUE



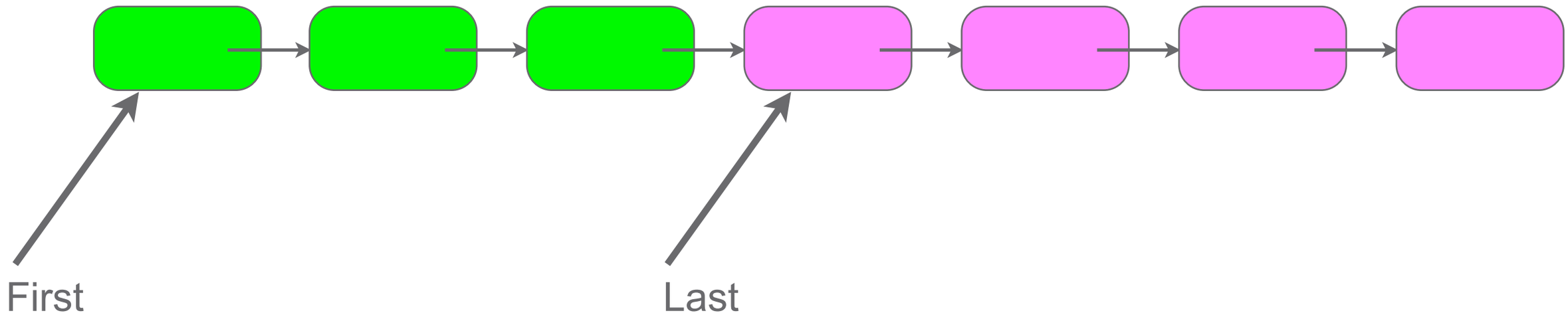
First

Last

# LOCK FREE QUEUE



# LOCK FREE QUEUE



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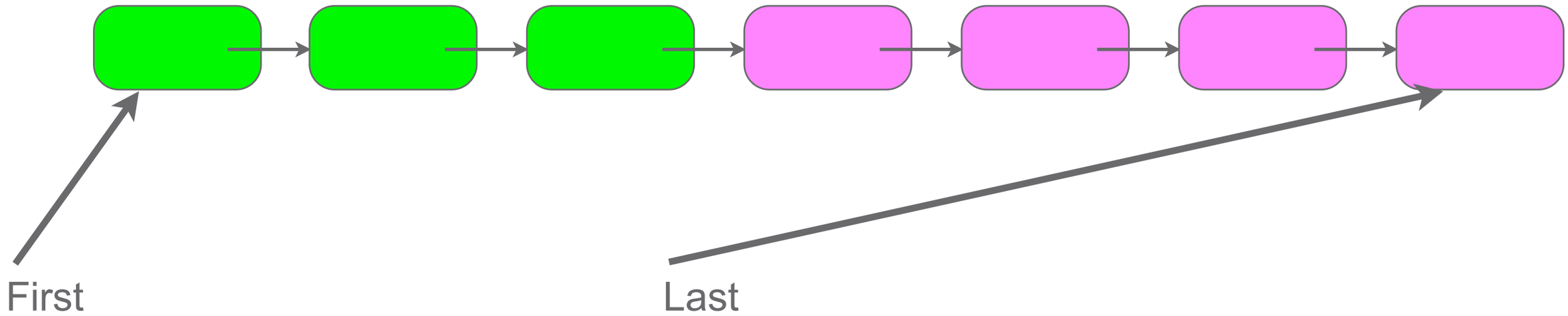
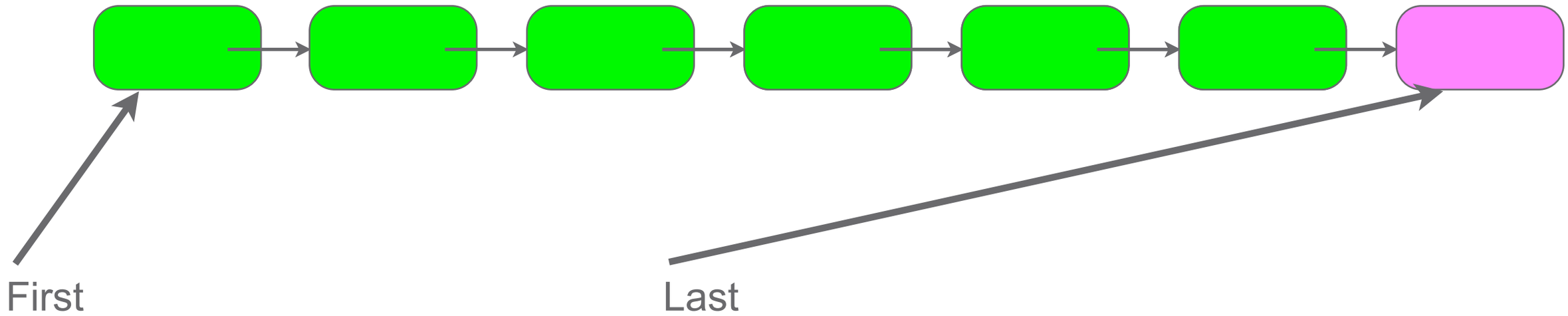
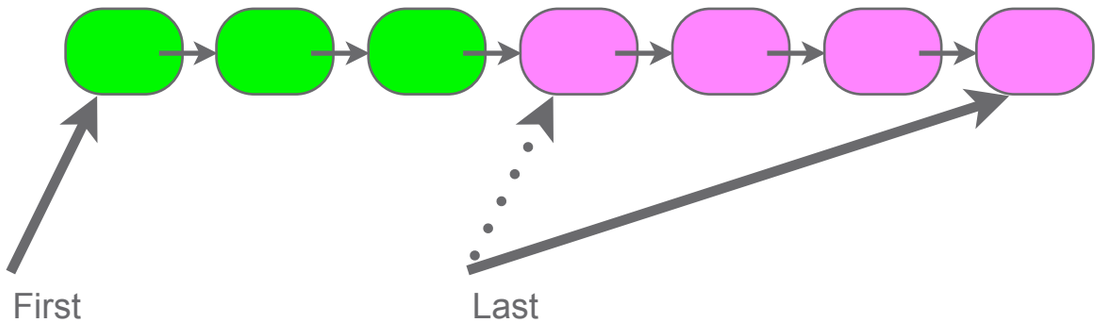


# LOCK FREE QUEUE



# THREAD PROGRESS

- We want a mechanism that can be used in order to determine when all “interesting” threads
  - have at least once returned to the event loop code
  - have at least once executed a full memory barrier
  - will see all modifications I have made
- Interesting threads are “managed”:
  - We know about all of them
  - They do not hang
  - They will always return to a certain point
  - Typically - the schedulers and a few other threads

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- Unmanaged threads need to be taken care of by other means

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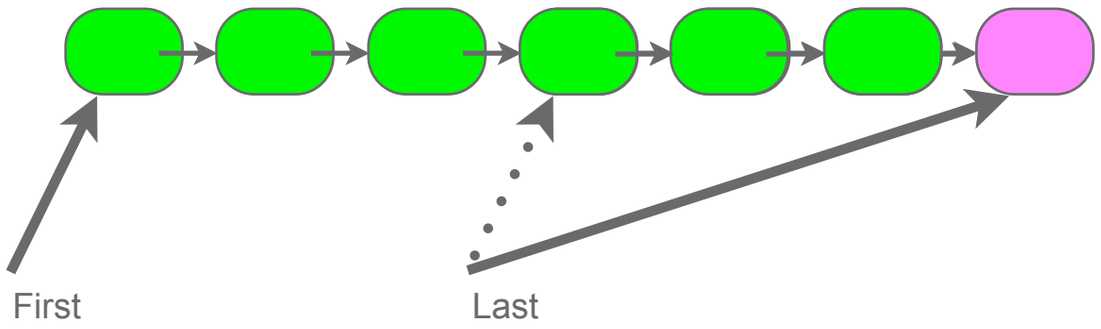


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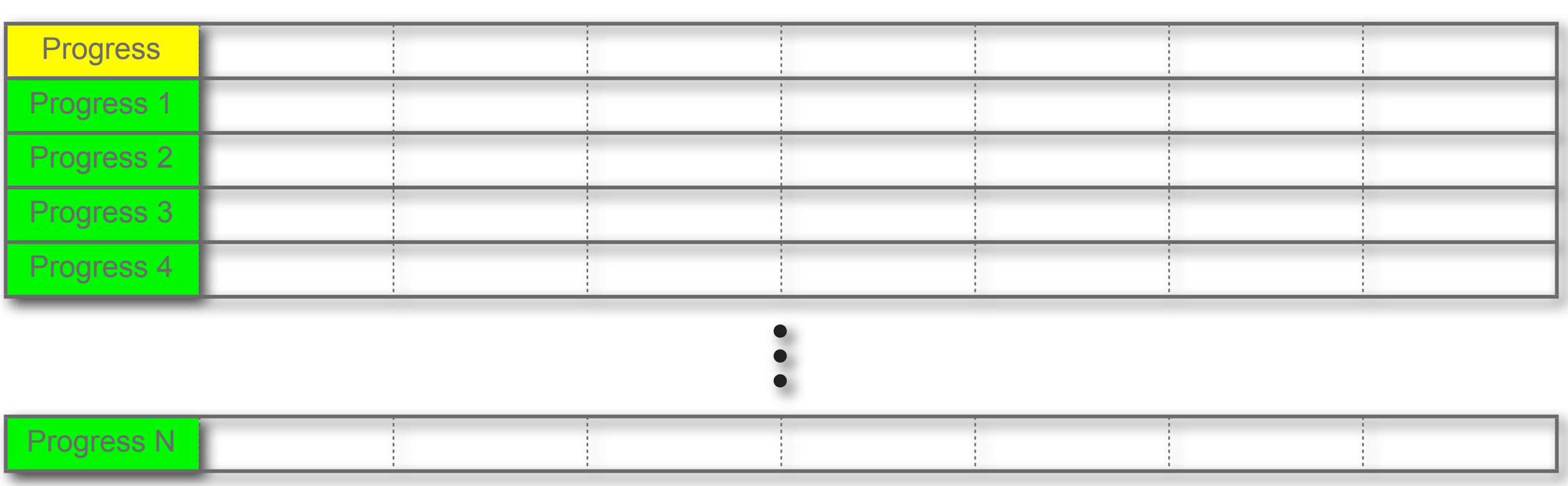
# THREAD PROGRESS

- Master thread coordinates
- Thread progress communicated via thread specific cache lines



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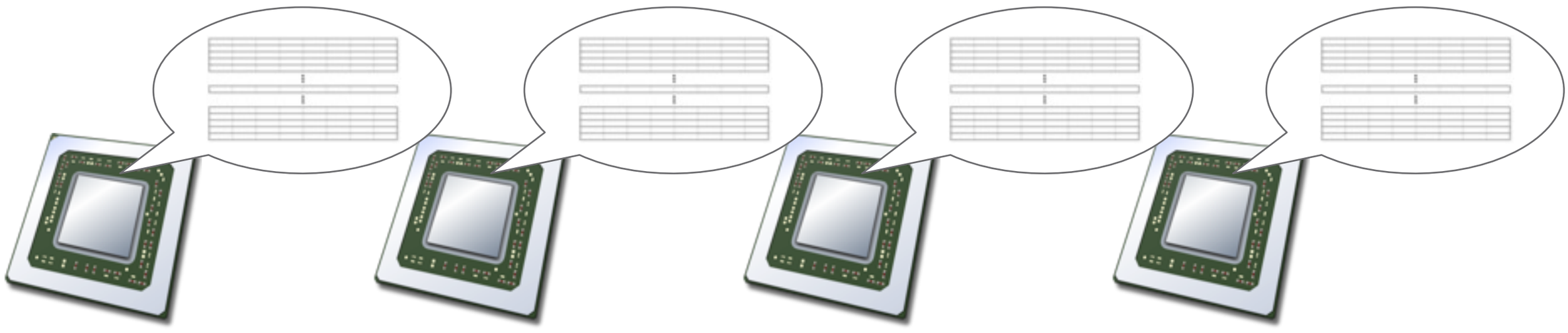
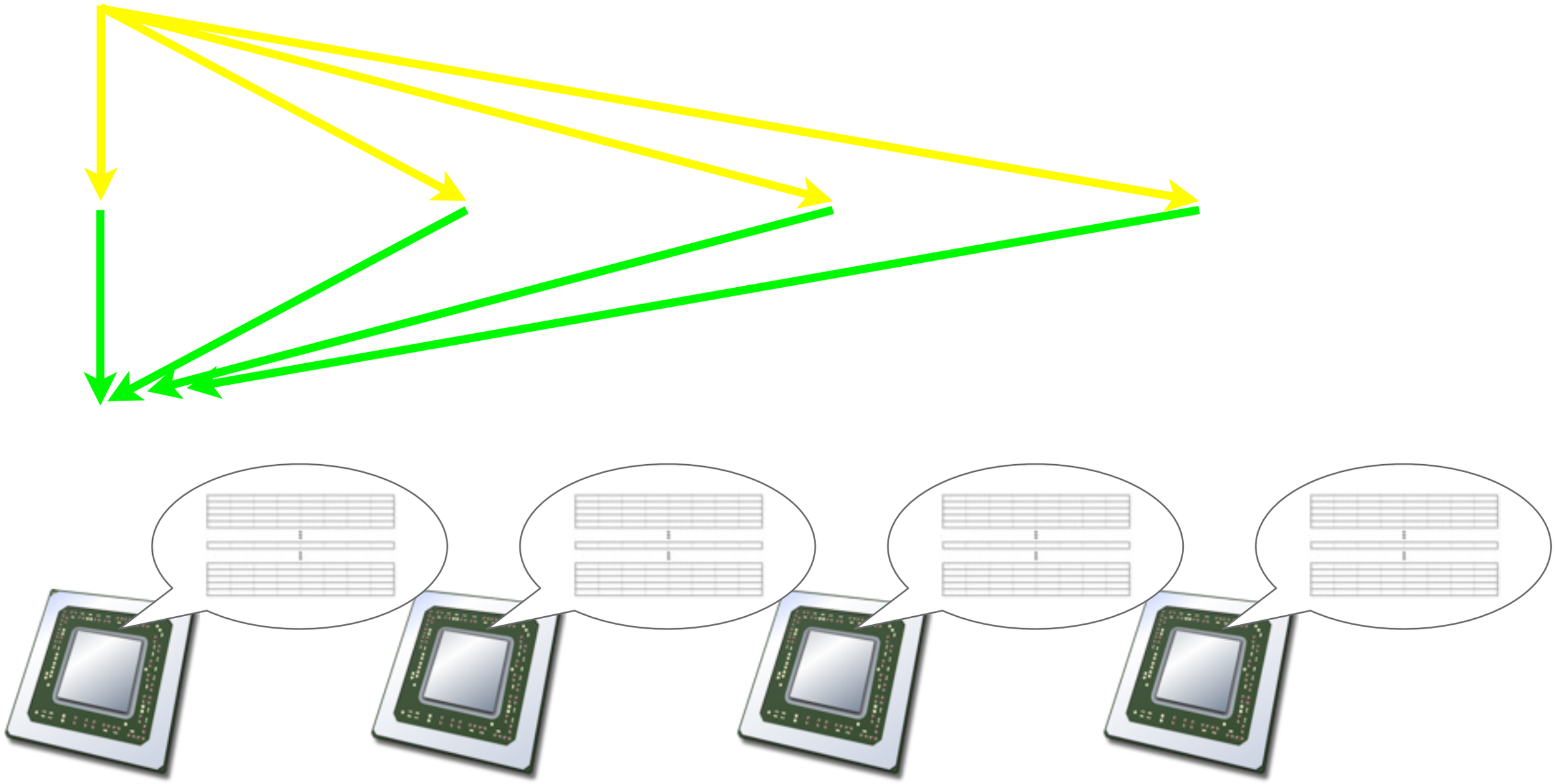
# THREAD PROGRESS

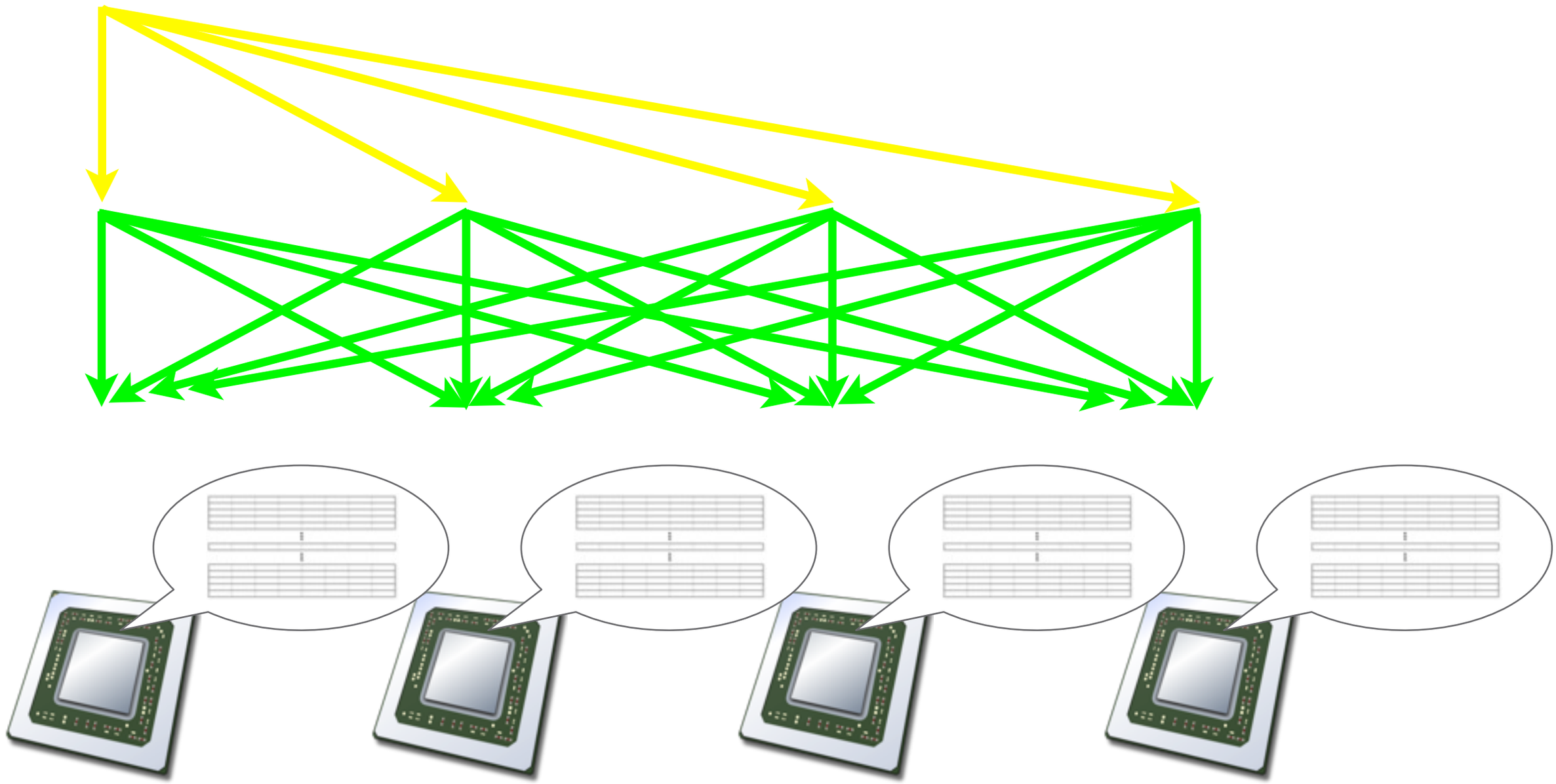




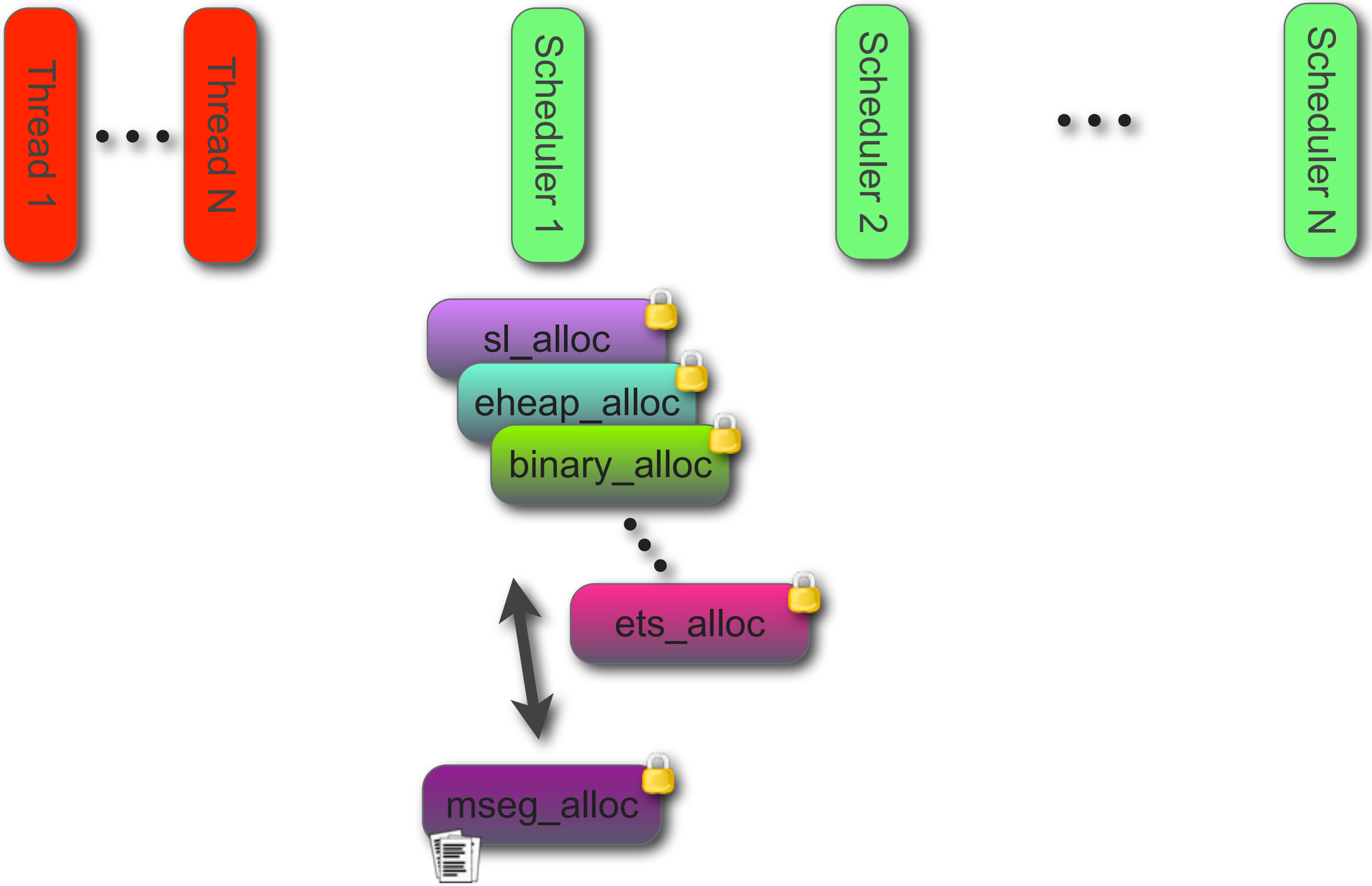
# THREAD PROGRESS



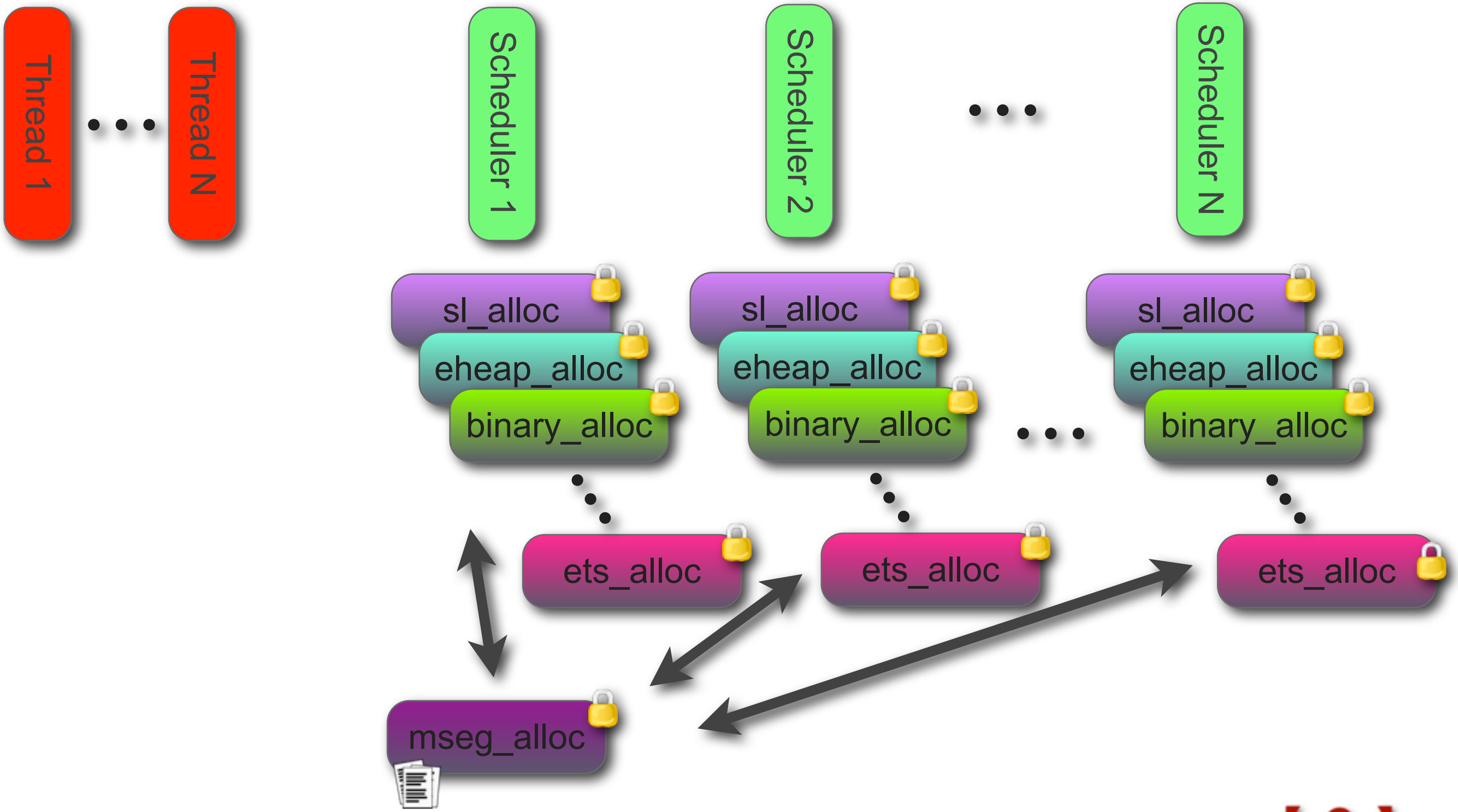
# THREAD PROGRESS



# MEMORY ALLOCATORS R11B



# MEMORY ALLOCATORS R12B-1



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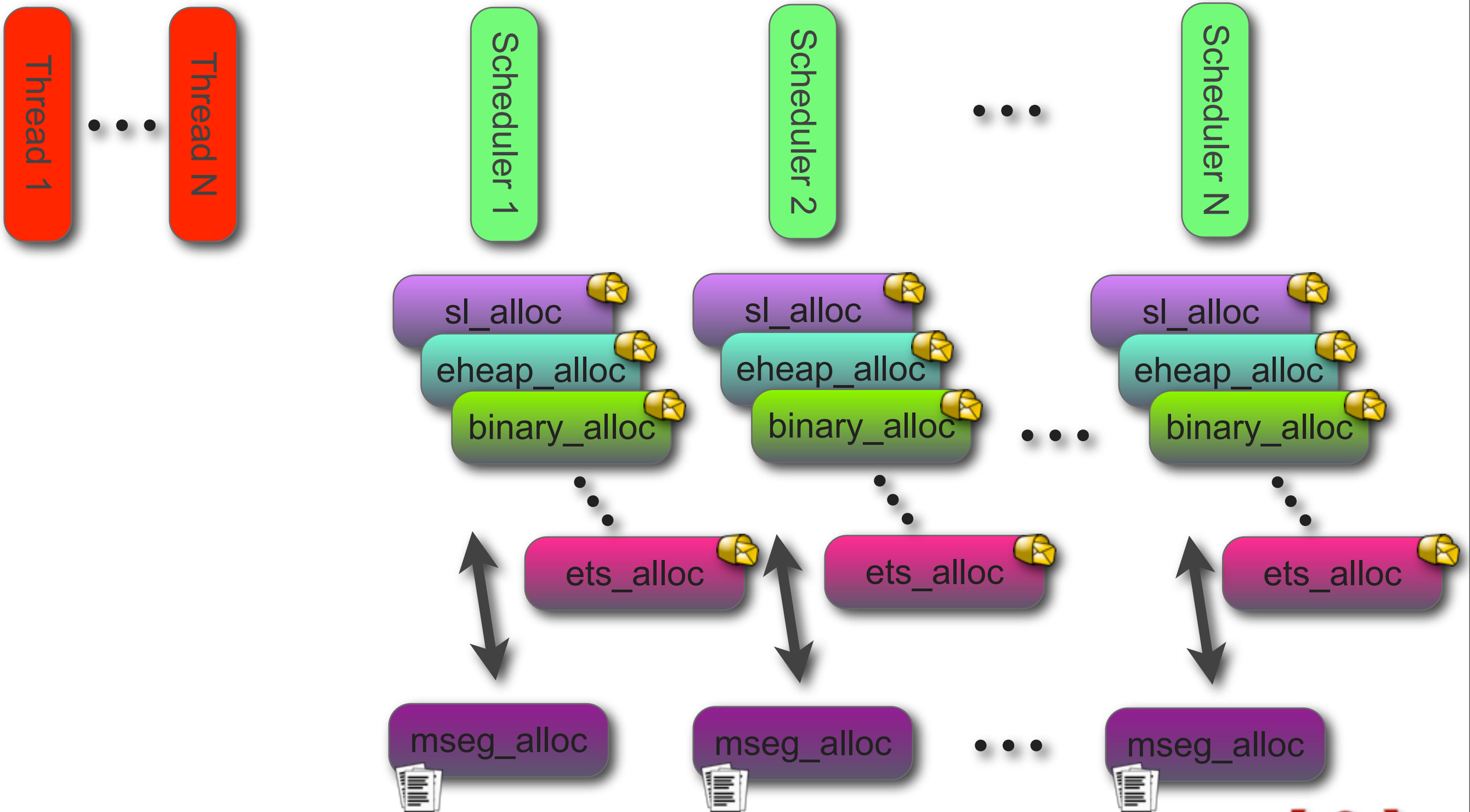
# MEMORY ALLOCATORS R15B



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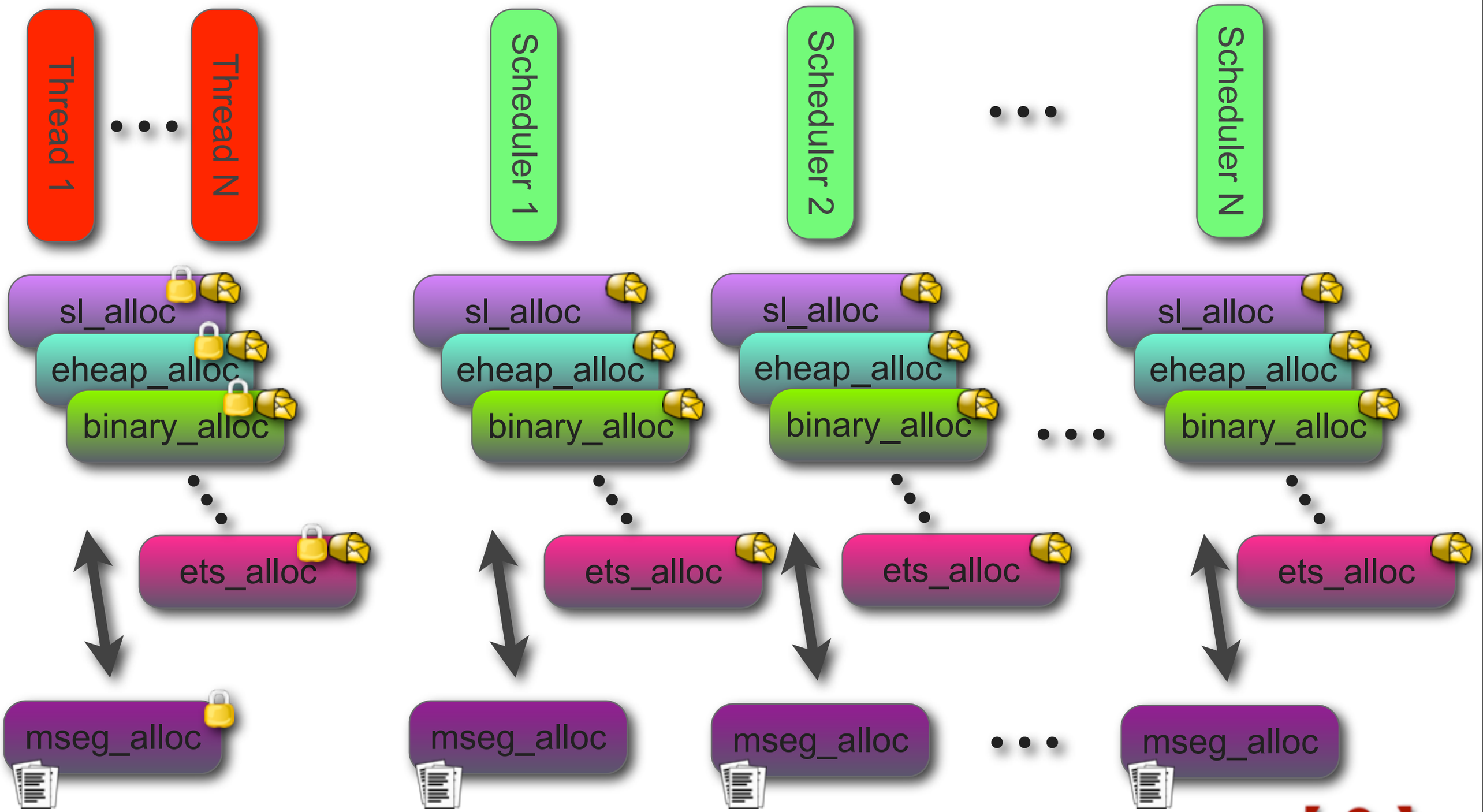
# MEMORY ALLOCATORS R15B



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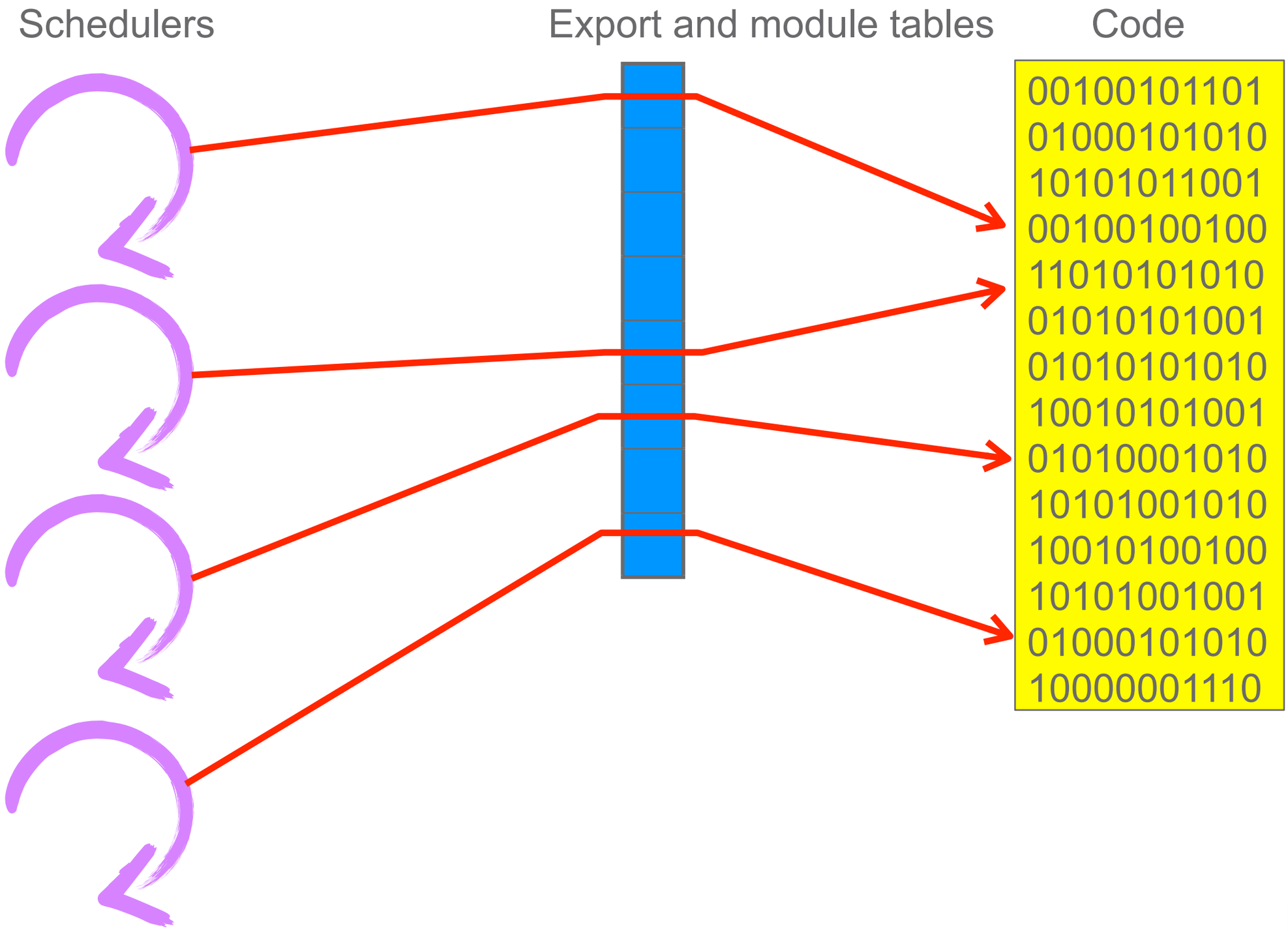
# CODE-LOADING R11-R15



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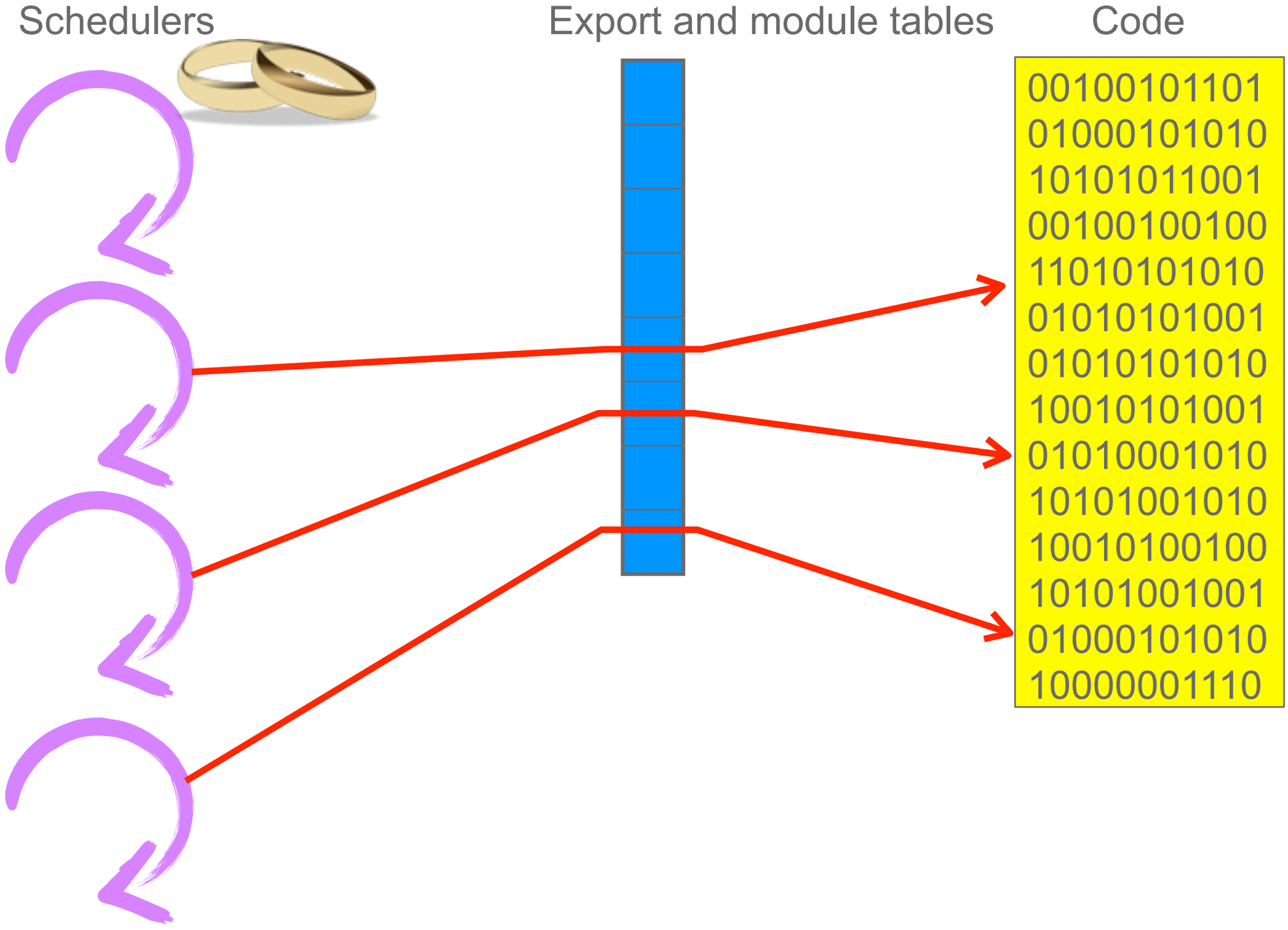

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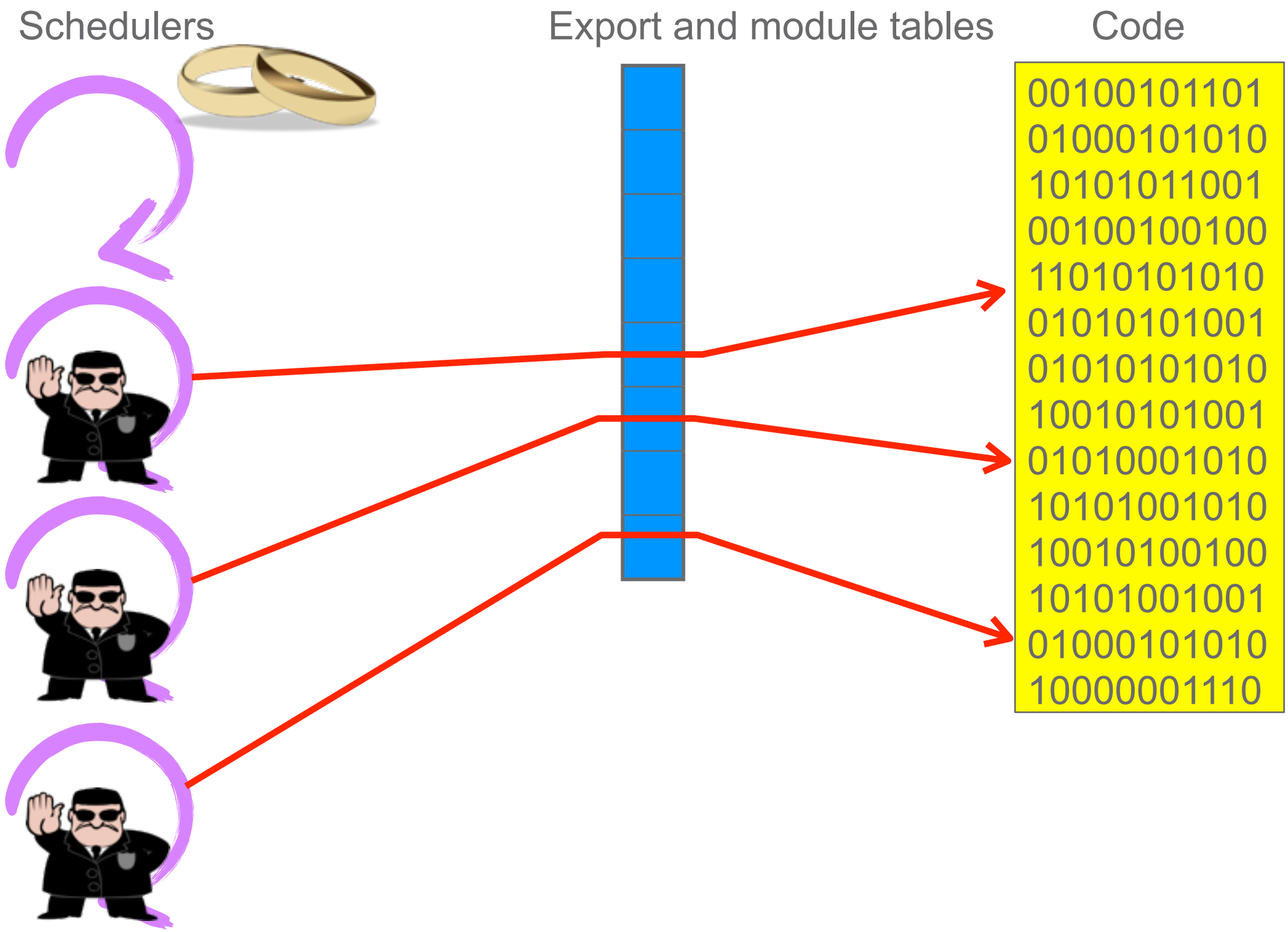
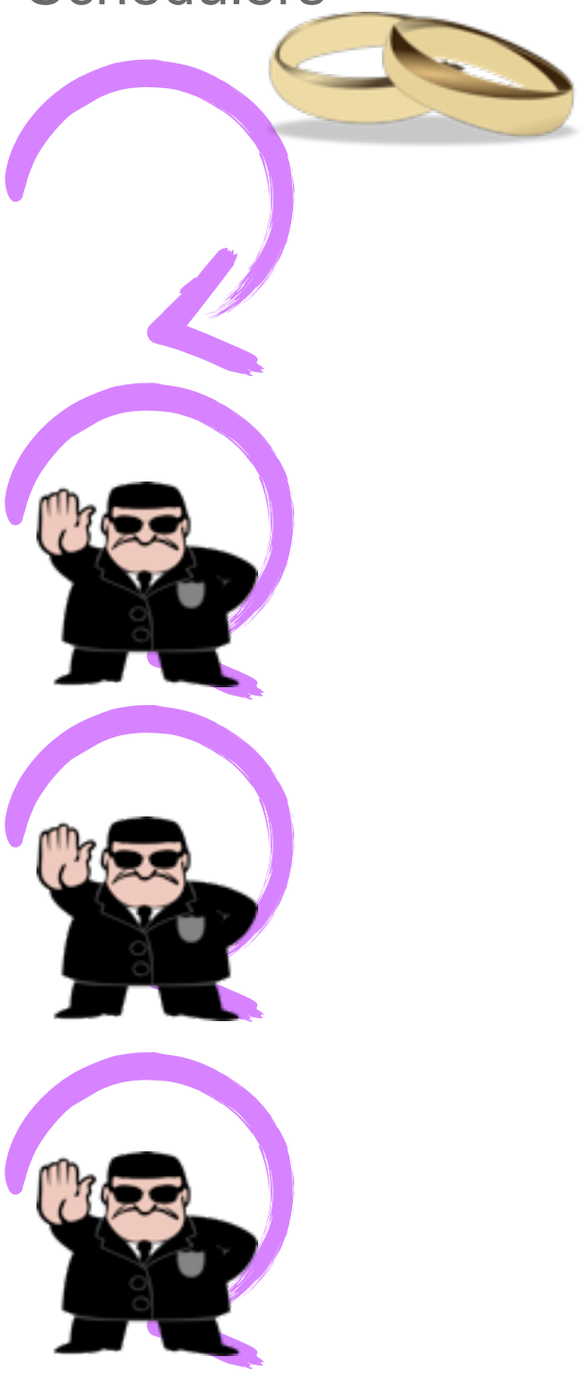
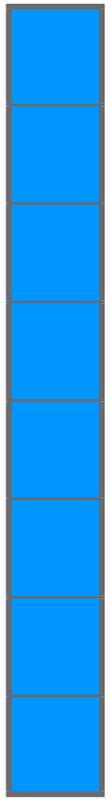


# CODE-LOADING R11-R15

Schedulers



Export and module tables

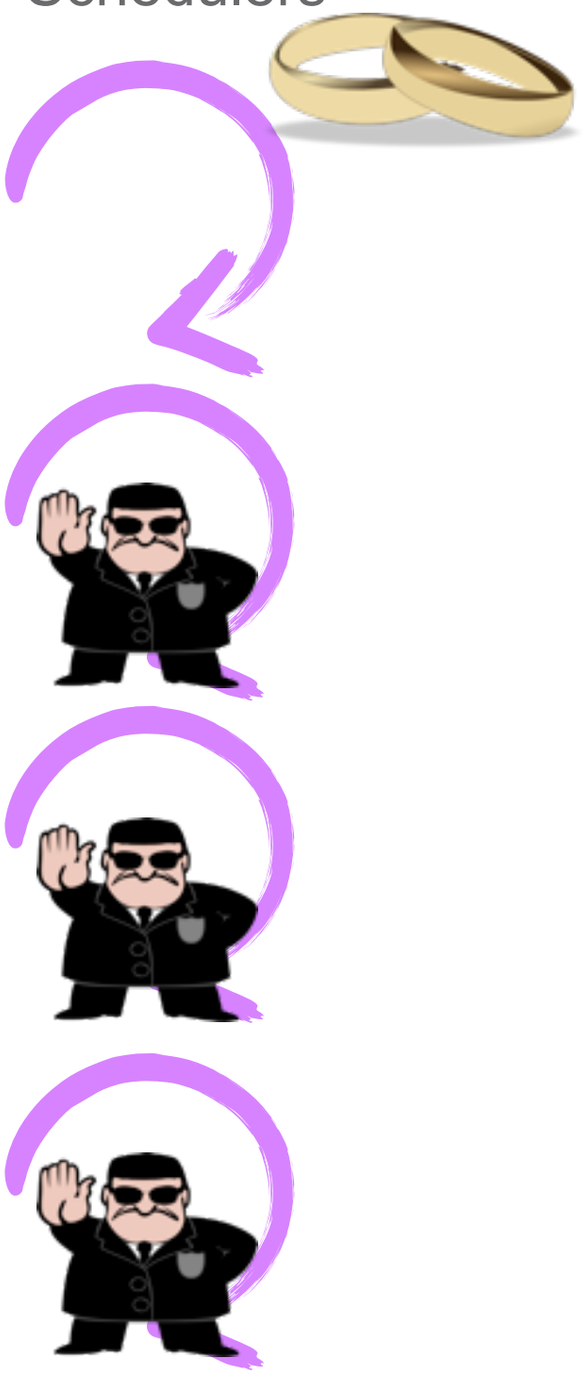


Code

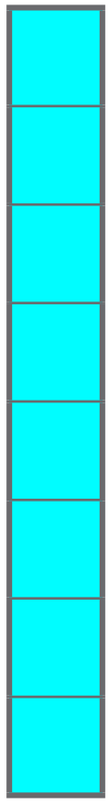
```
00100101101
01000101010
10101011001
00100100100
11010101010
01010101001
01010101010
10010101001
01010001010
10101001010
10010100100
10101001001
01000101010
10000001110
```

# CODE-LOADING R11-R15

Schedulers



Export and module tables



Code

```
00100101101
01000101010
10101011001
00100100100
11010101010
01010101001
01010101010
10010101001
01010001010
10101001010
10010100100
10101001001
01000101010
10000001110
```



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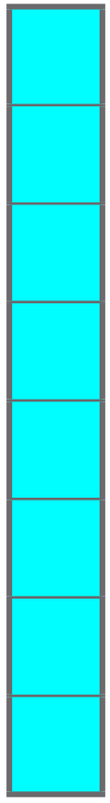
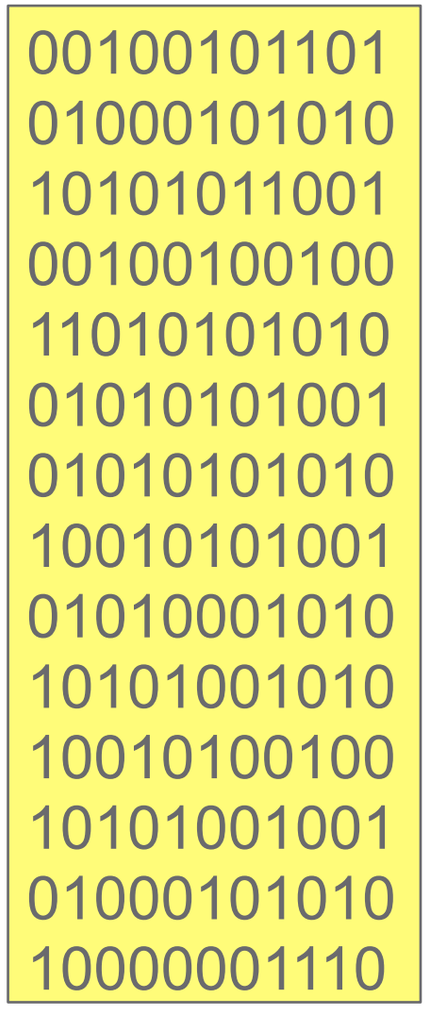
# CODE-LOADING R11-R15

Schedulers

Export and module tables



Code



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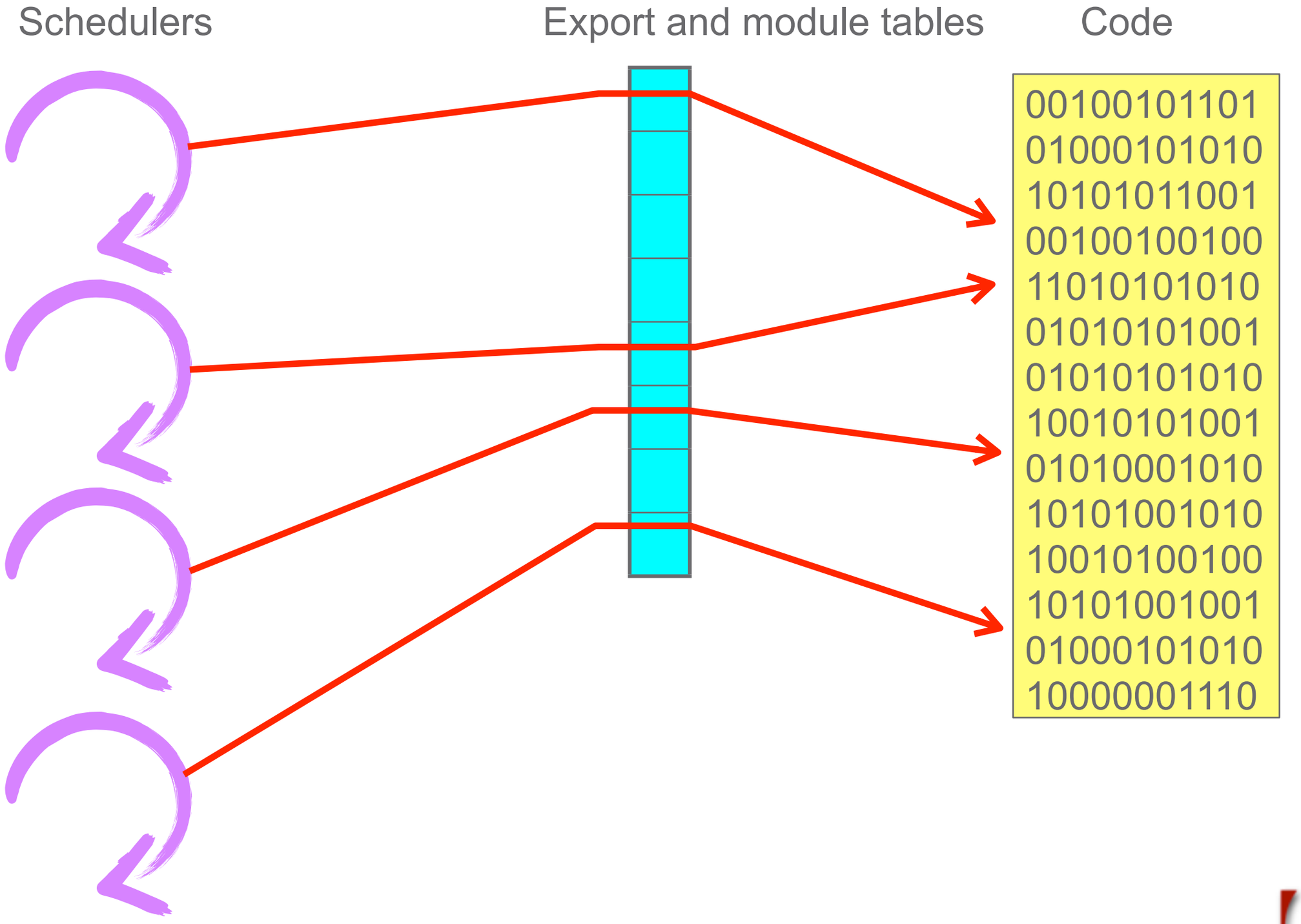
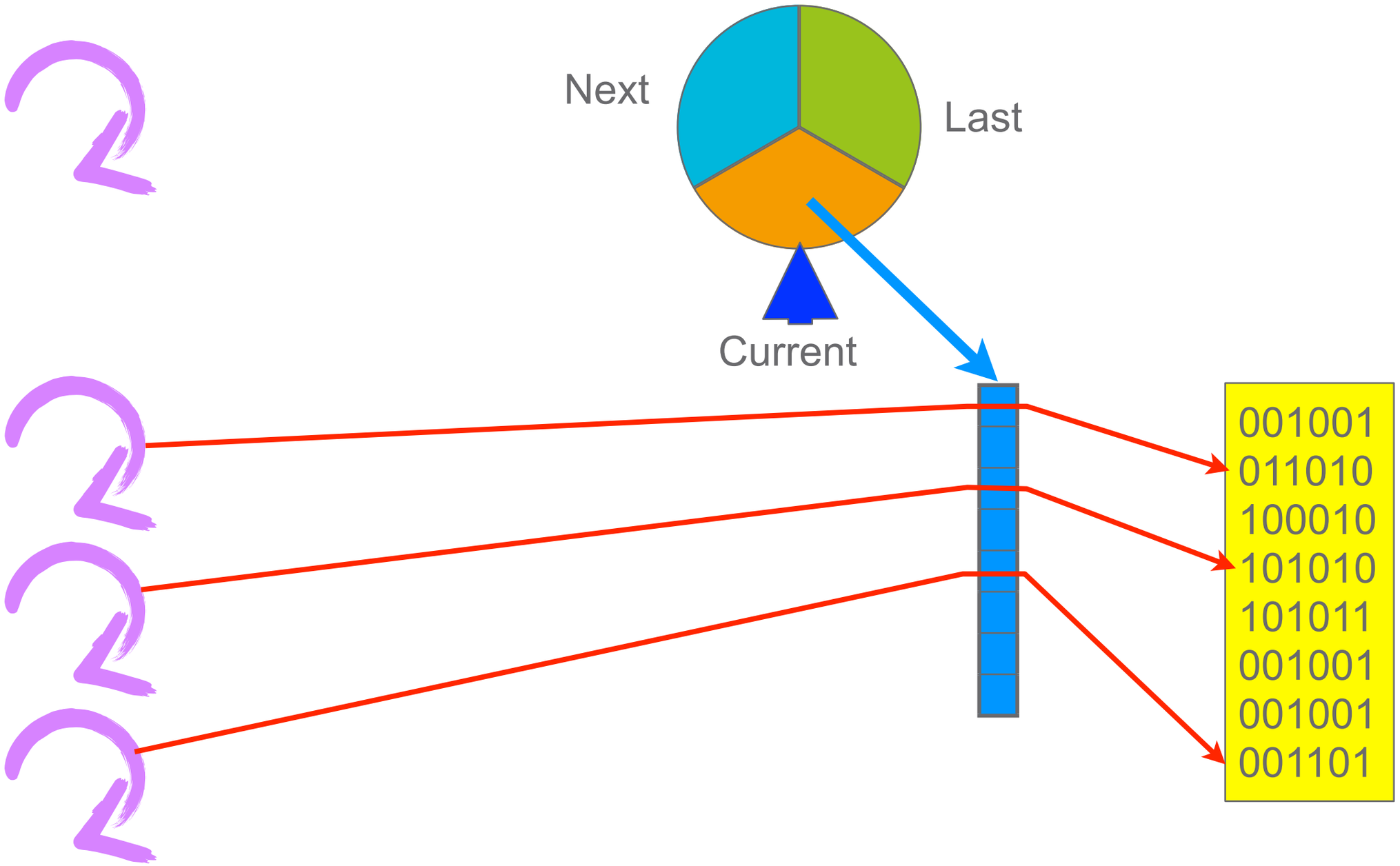


# CODE-LOADING R16



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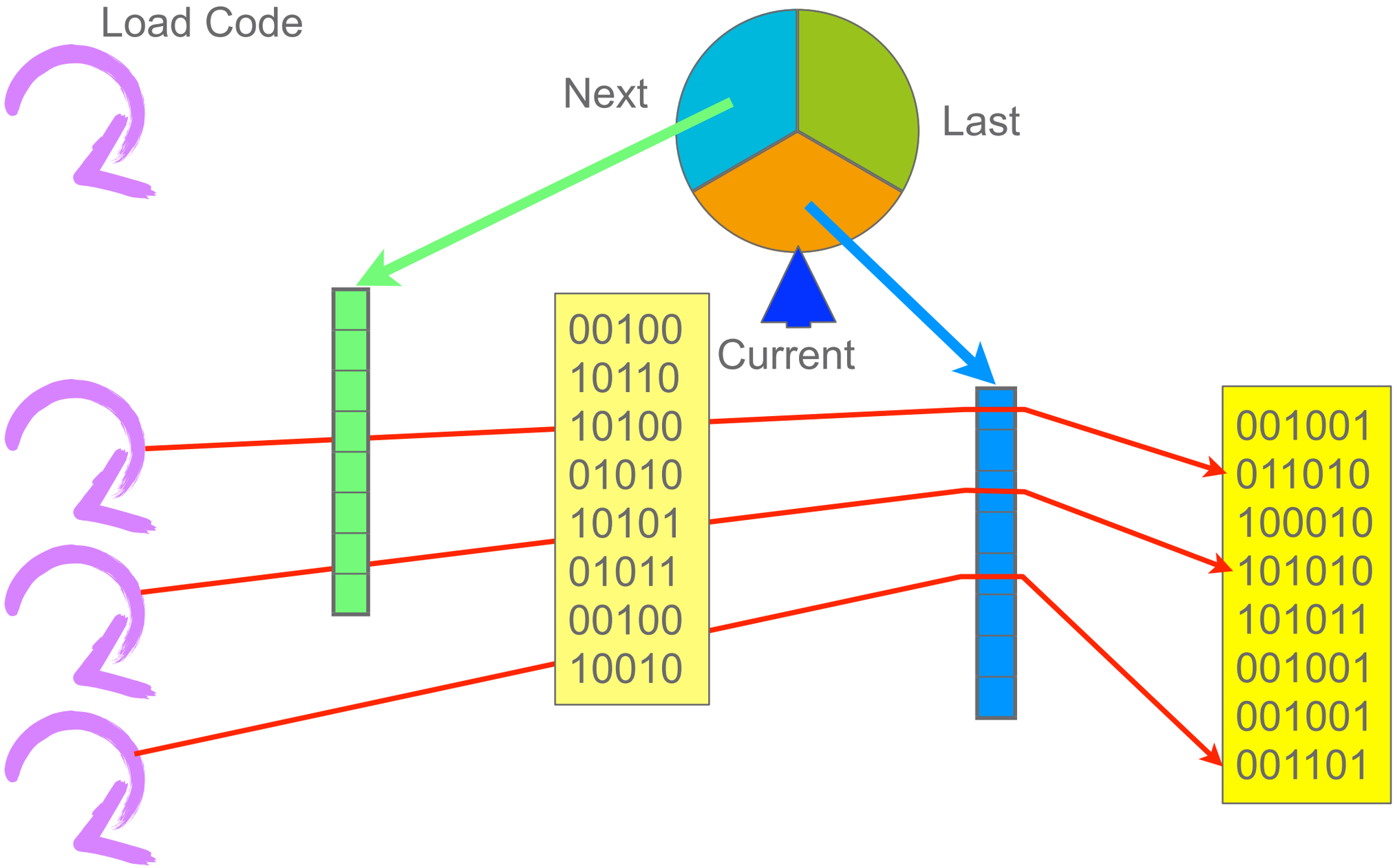

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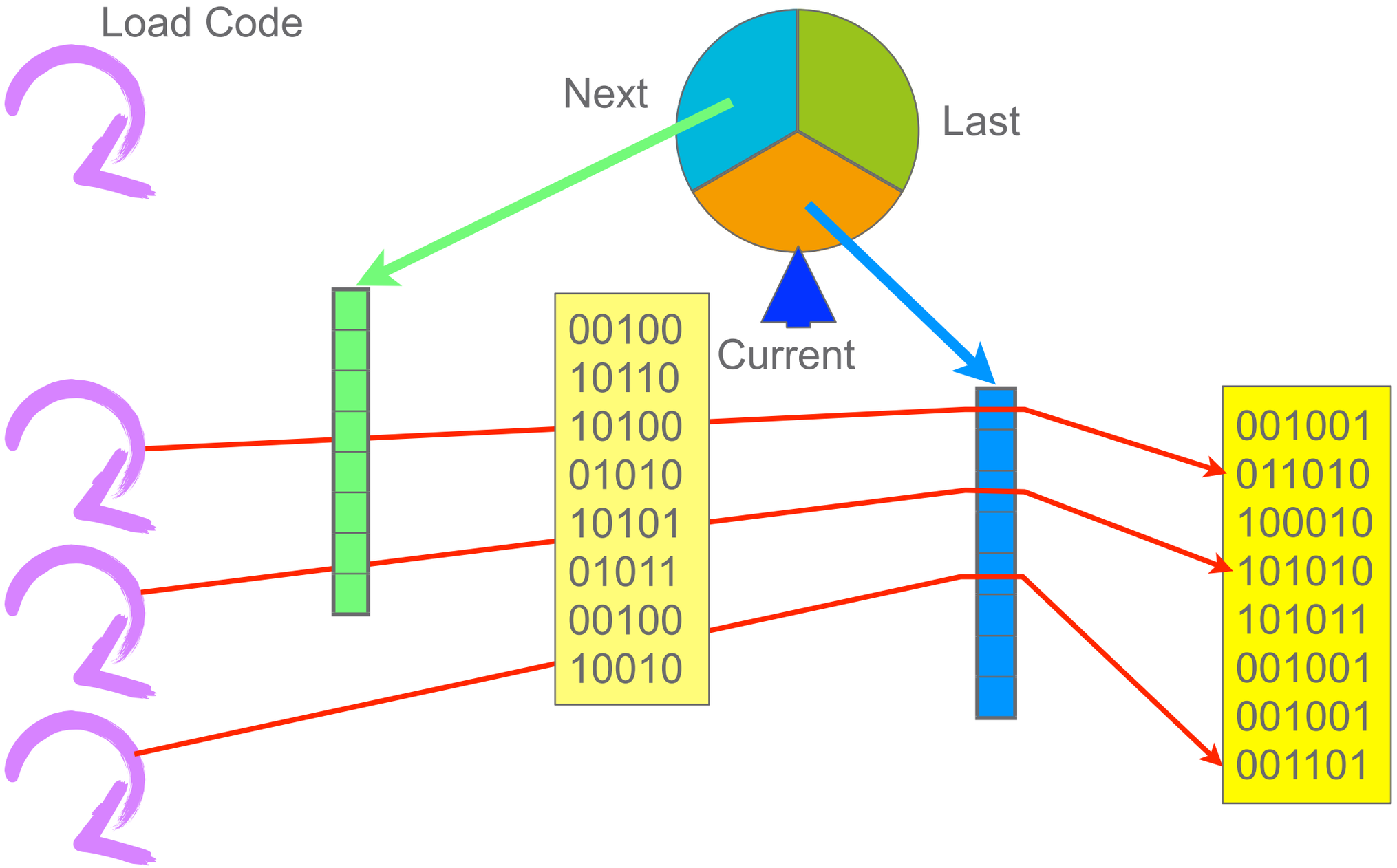

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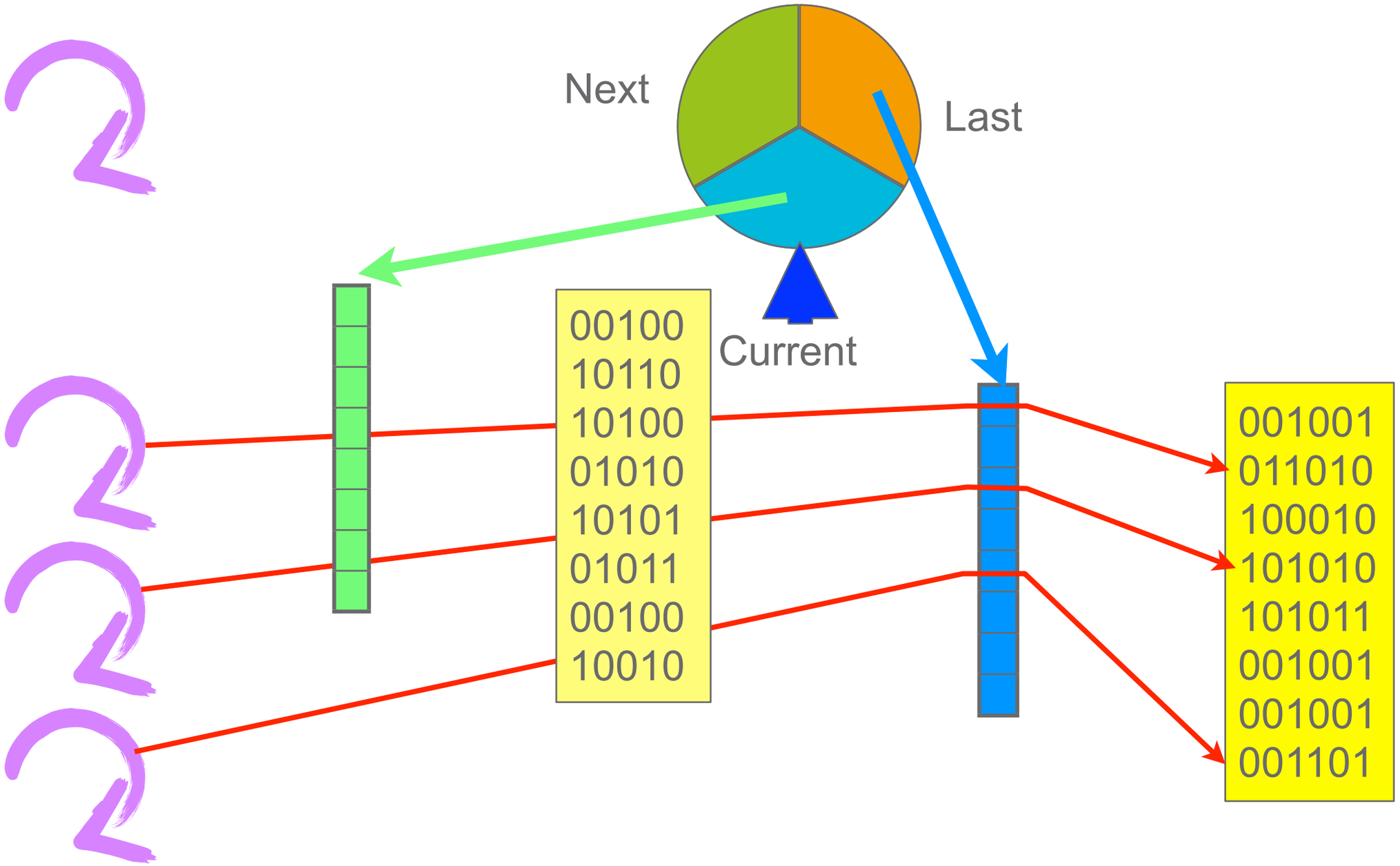

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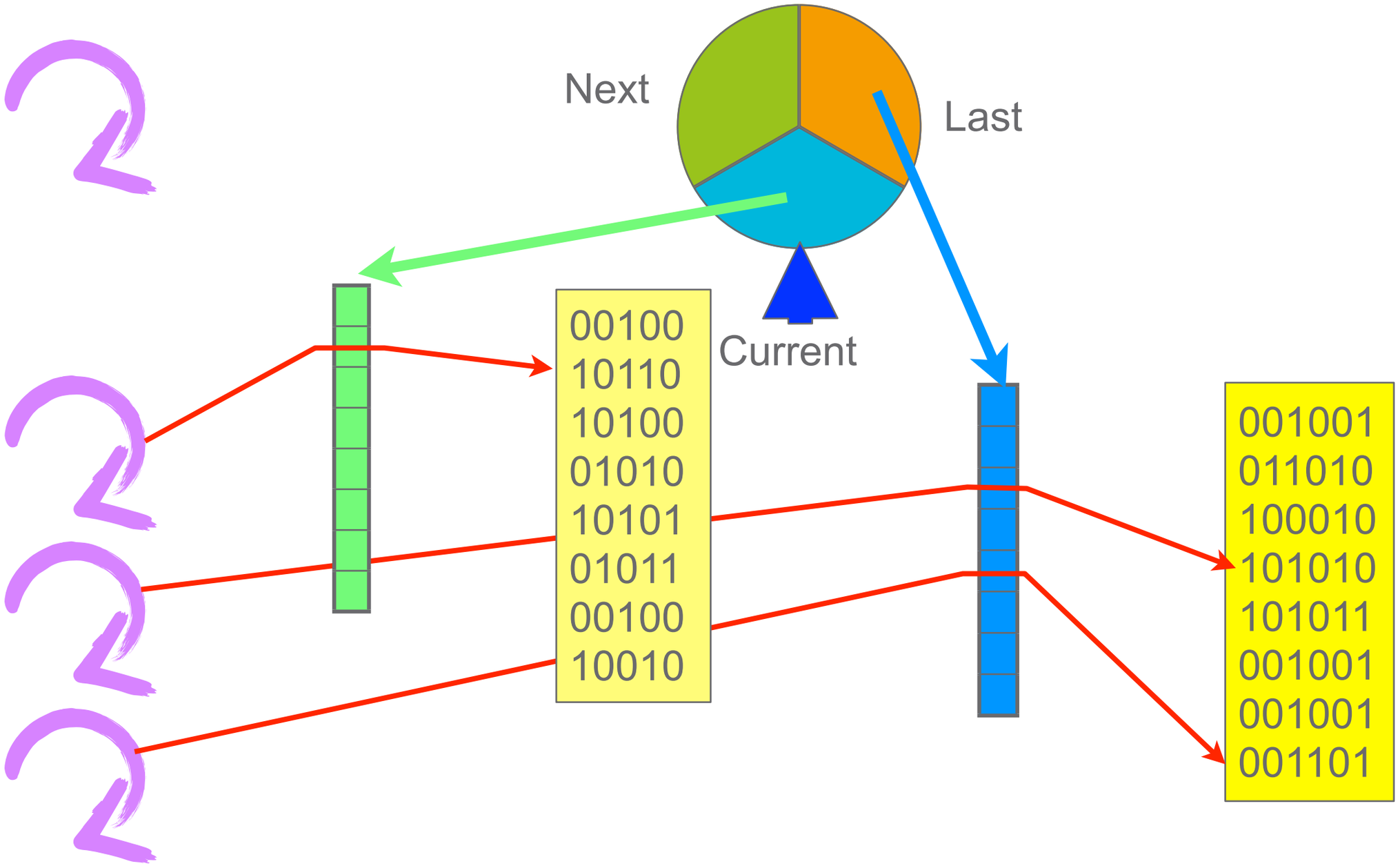

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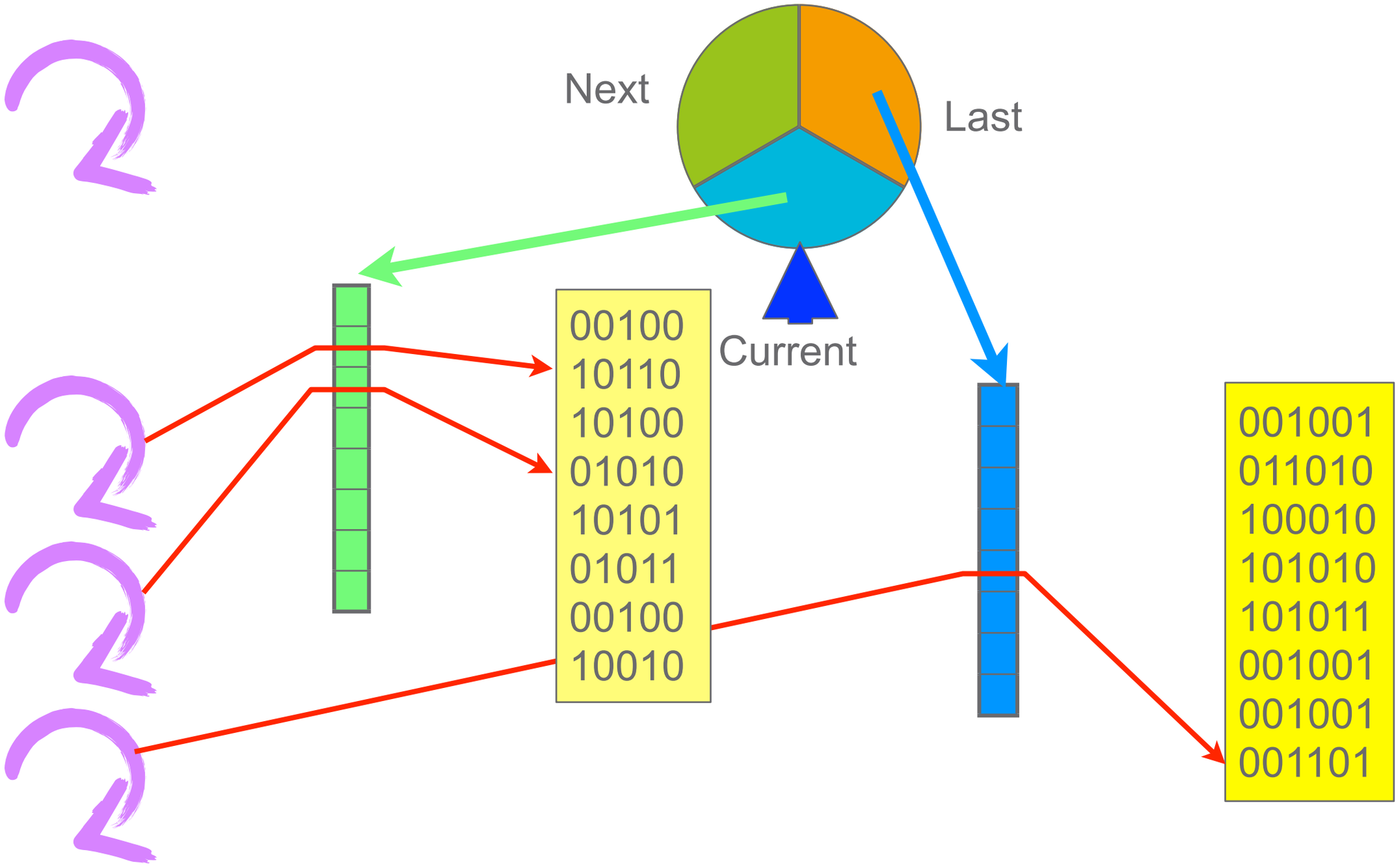

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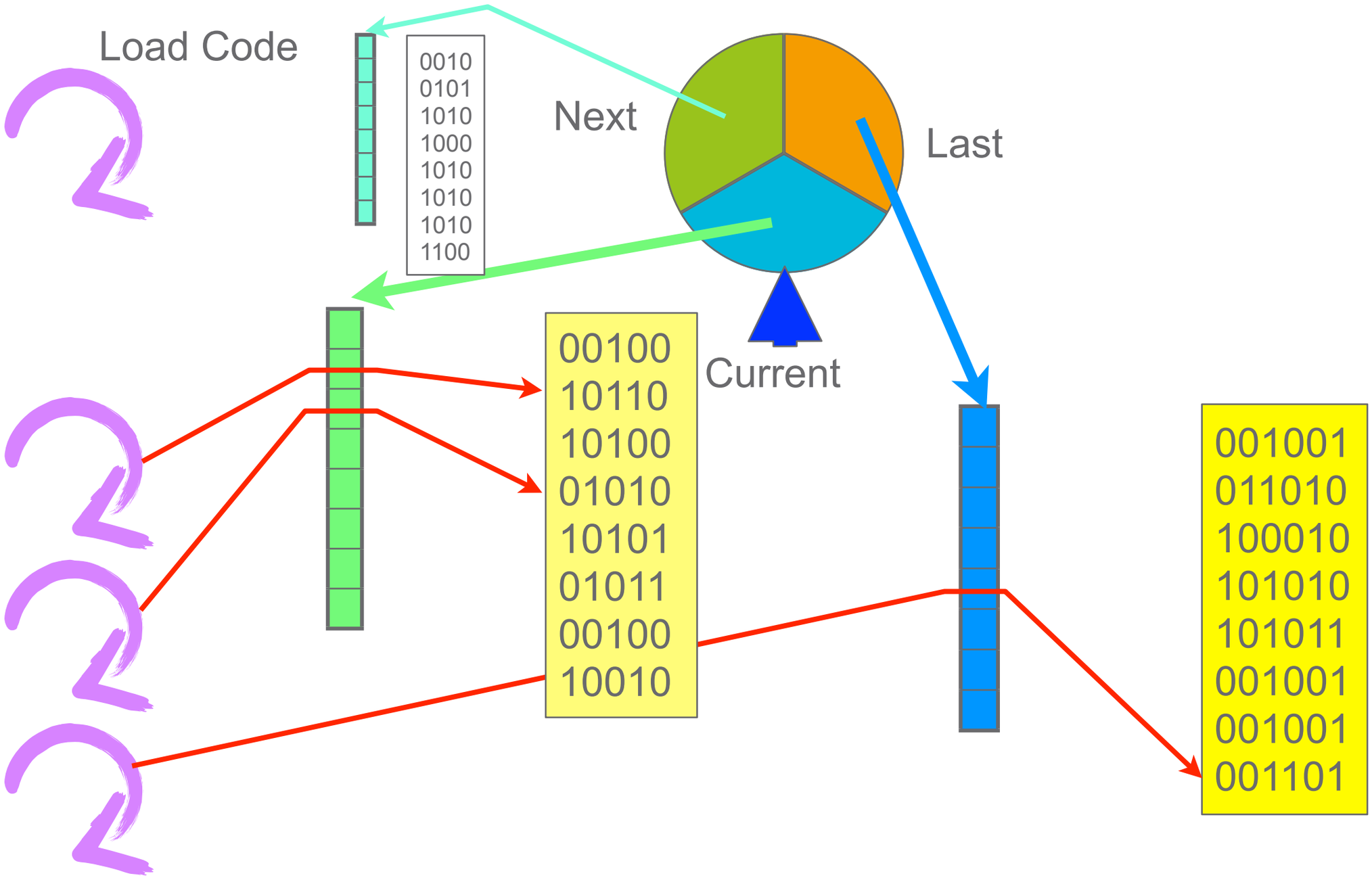




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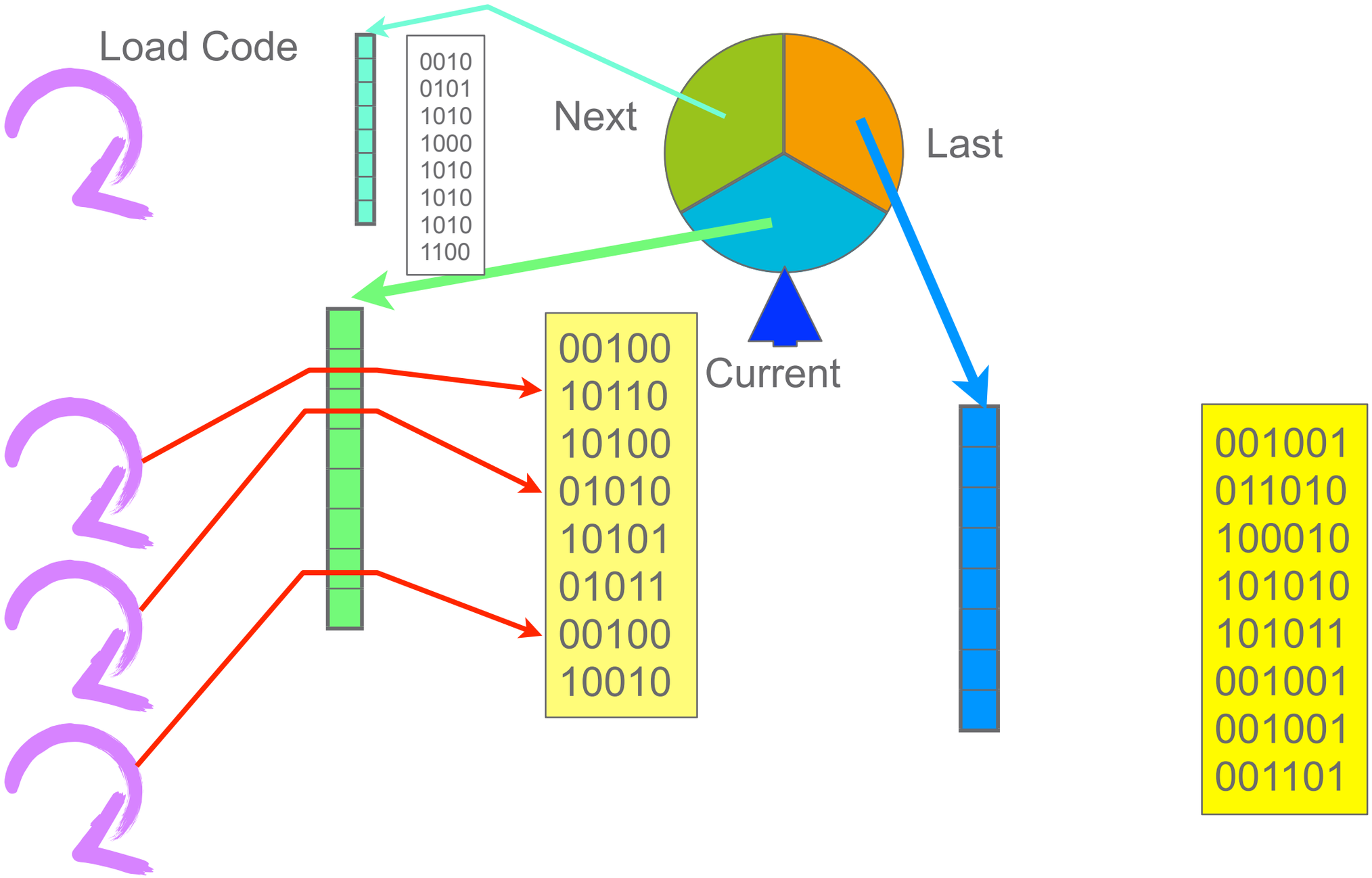




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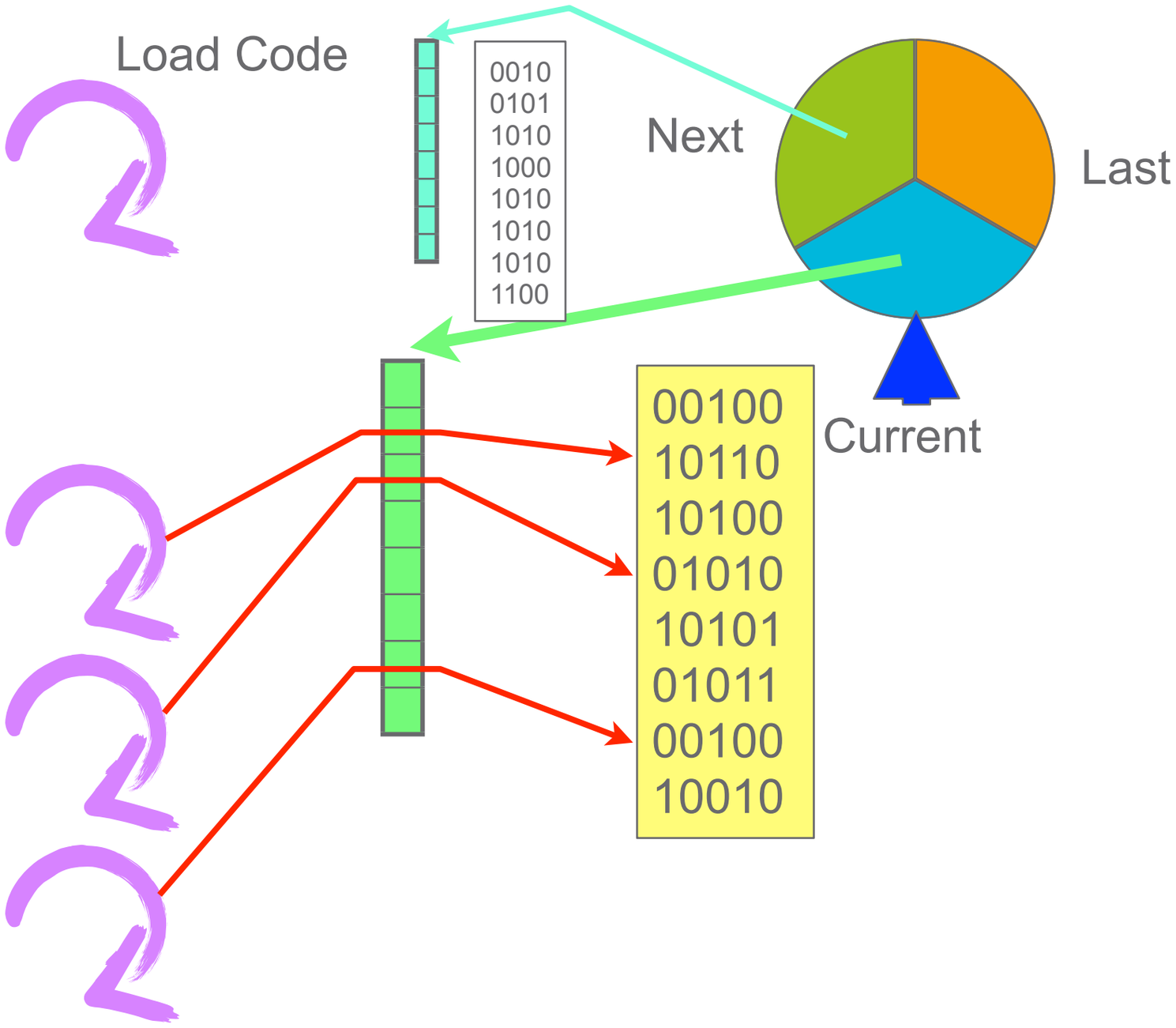

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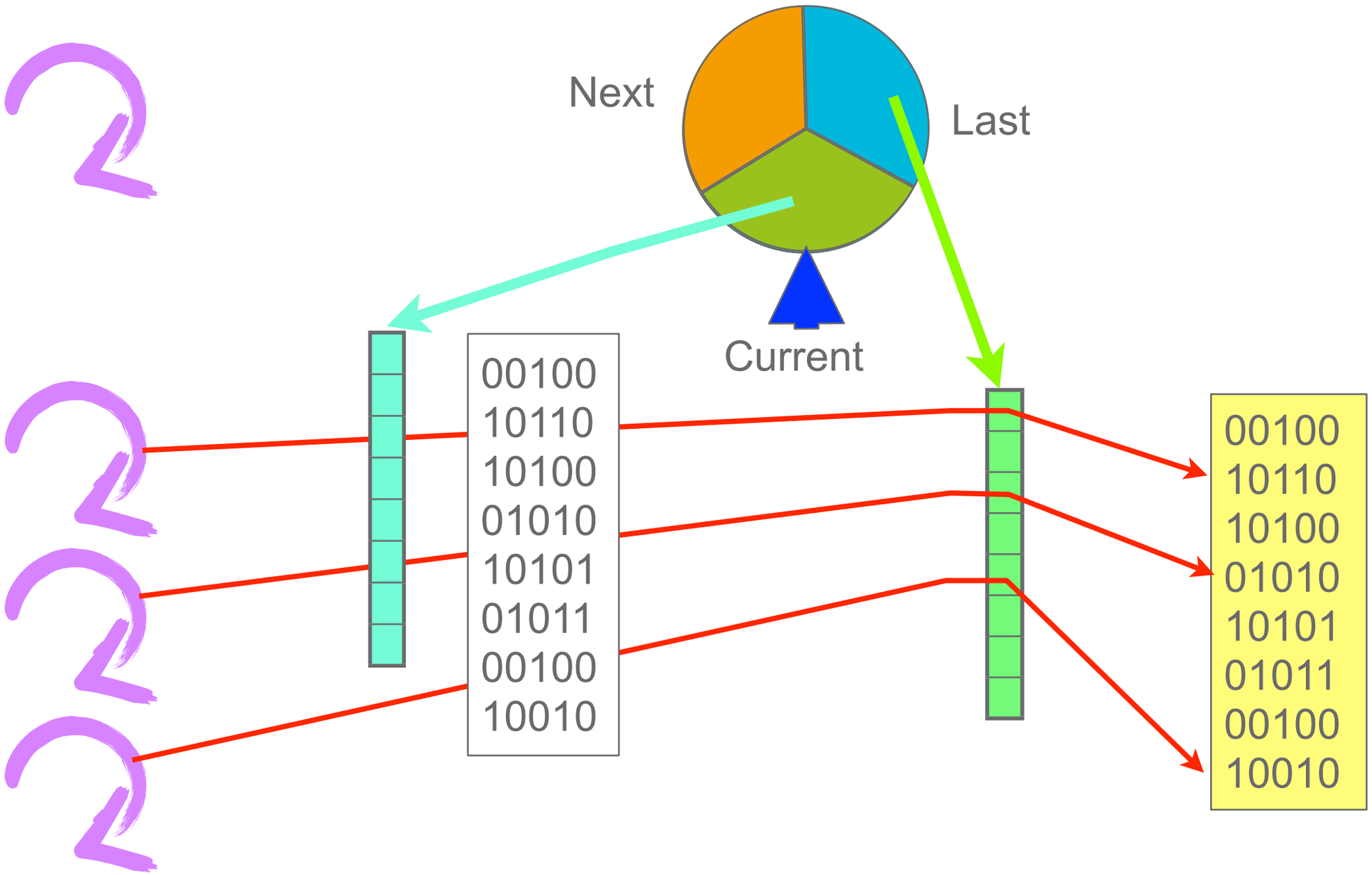

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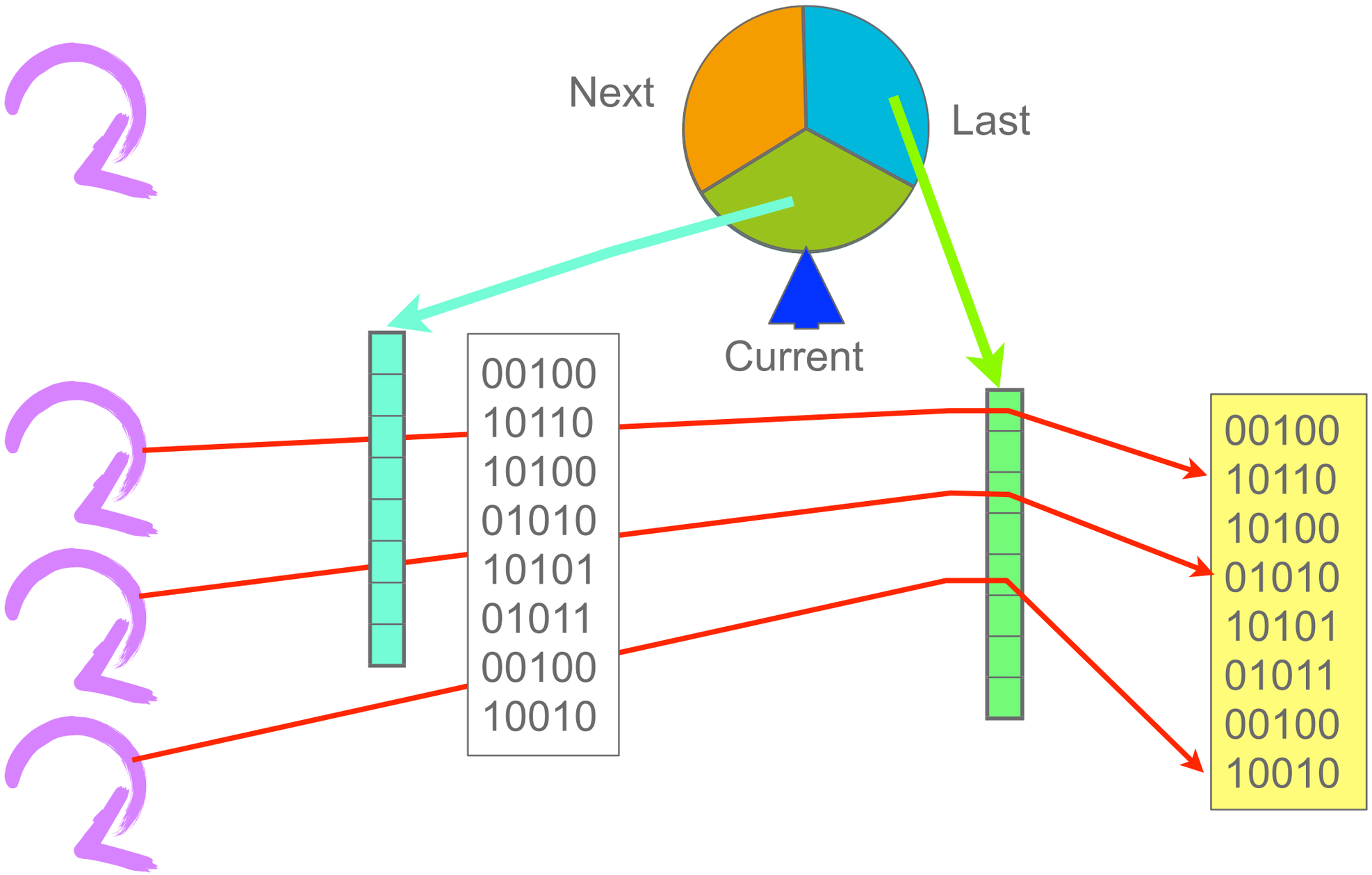

# RECIPES

- Divide or multiply resources
  - Separate memory
  - Separate cache-lines
- Asynchronously schedule work
  - Delayed dealloc
- Only involve relevant parties
  - Fine-grained synchronization
  - Lock-free queues
  - Reader optimized RW-Locks
- Postpone until possible
  - Thread progress
    - Lock-free queues
    - Code loading
  - Table cleanup



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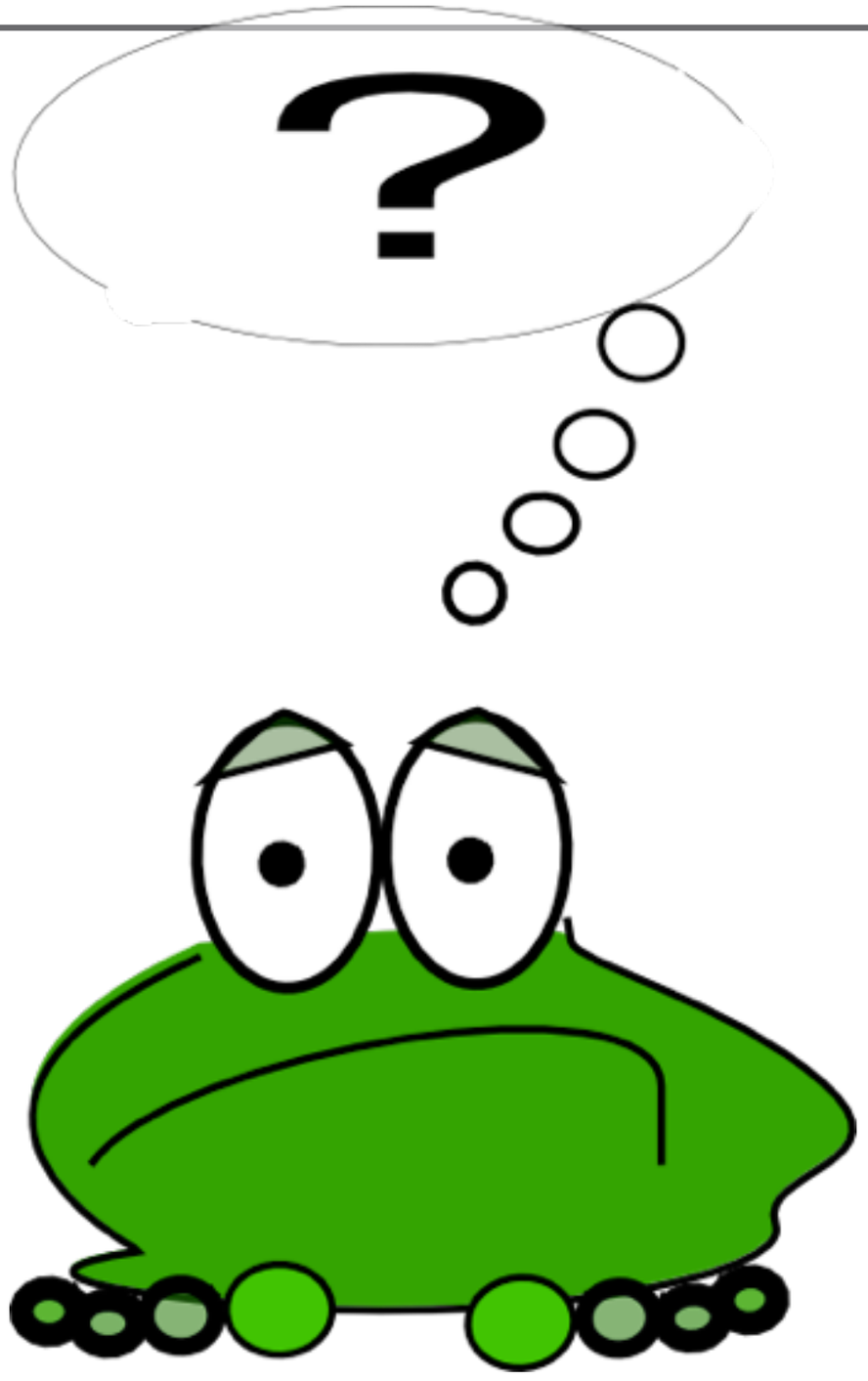
# QUESTIONS?



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