Communication-Based Mapping Using Shared Pages

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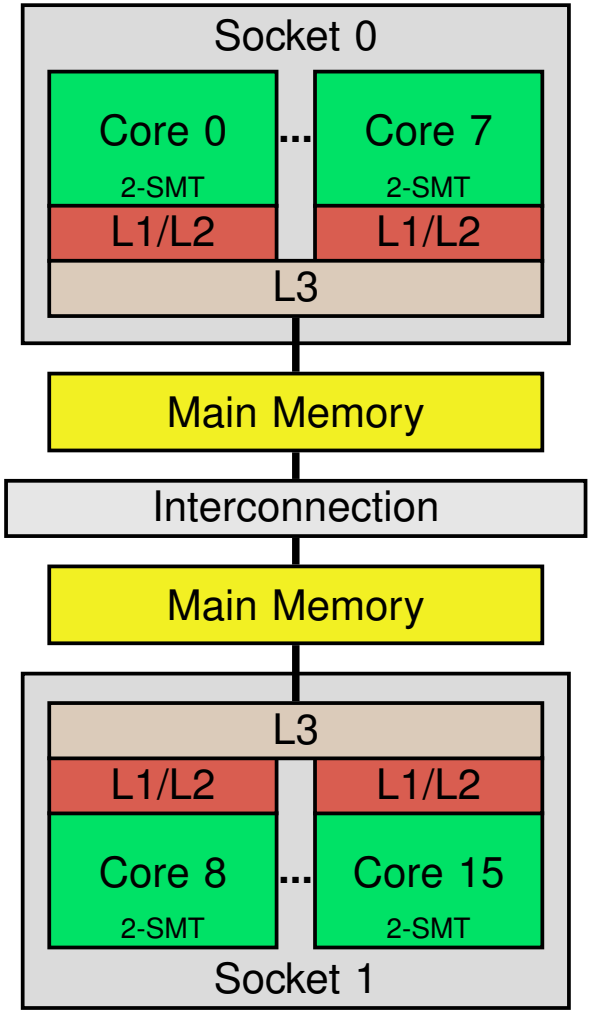

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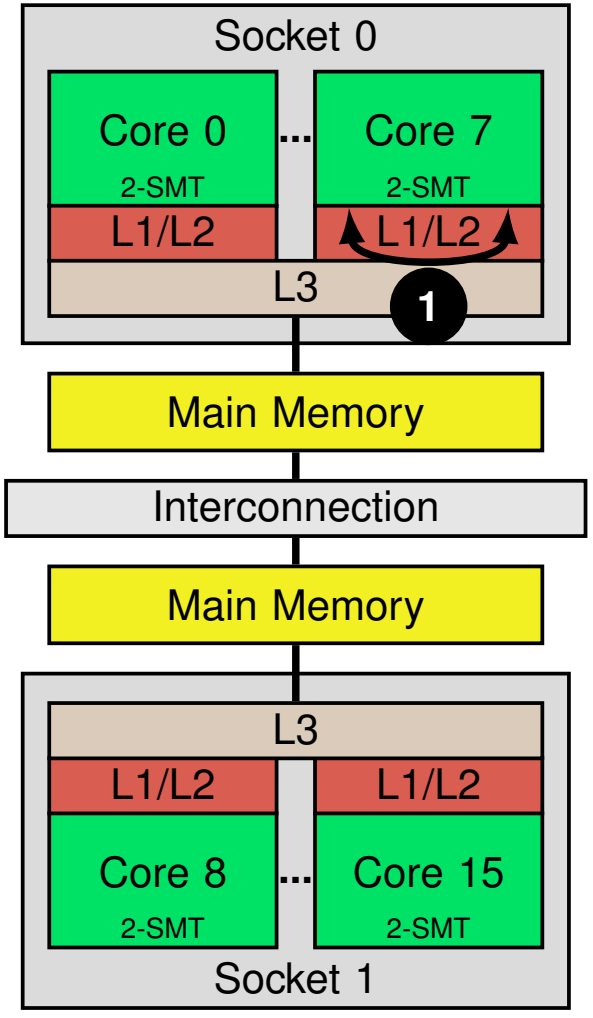

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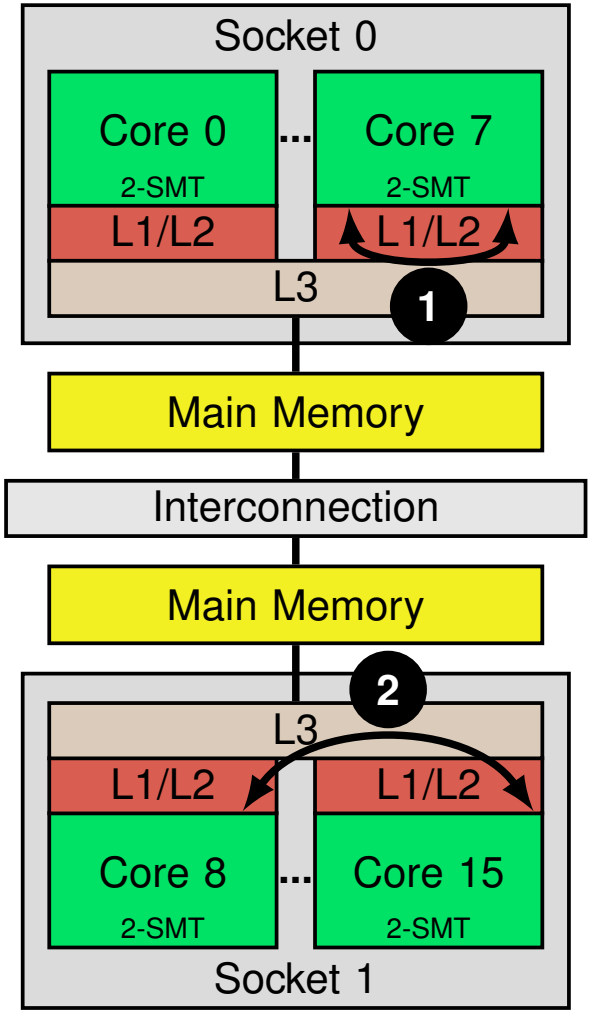

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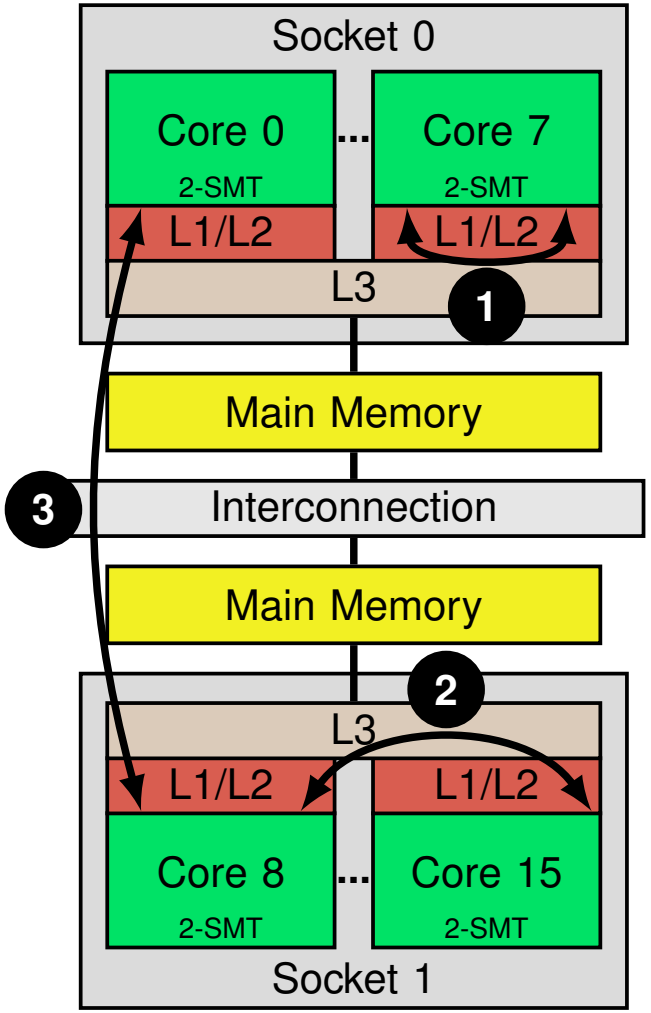

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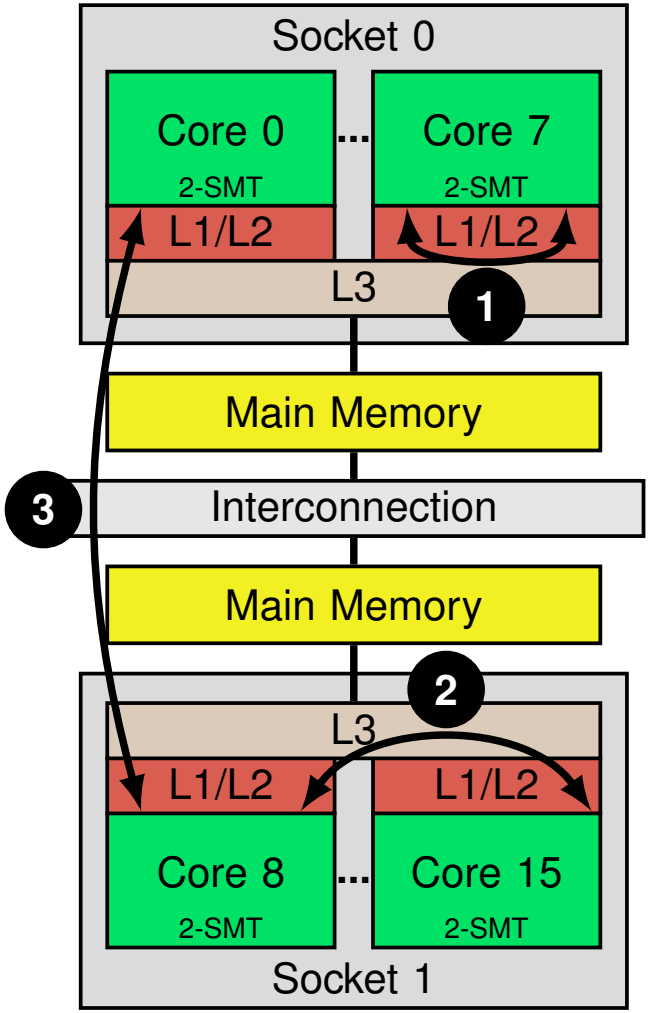

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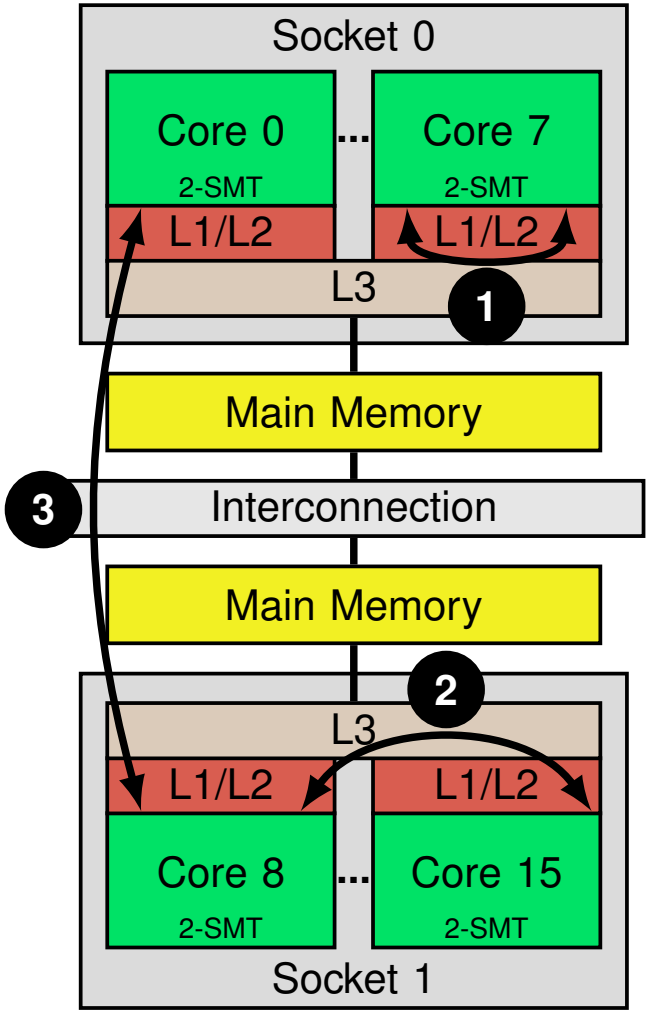

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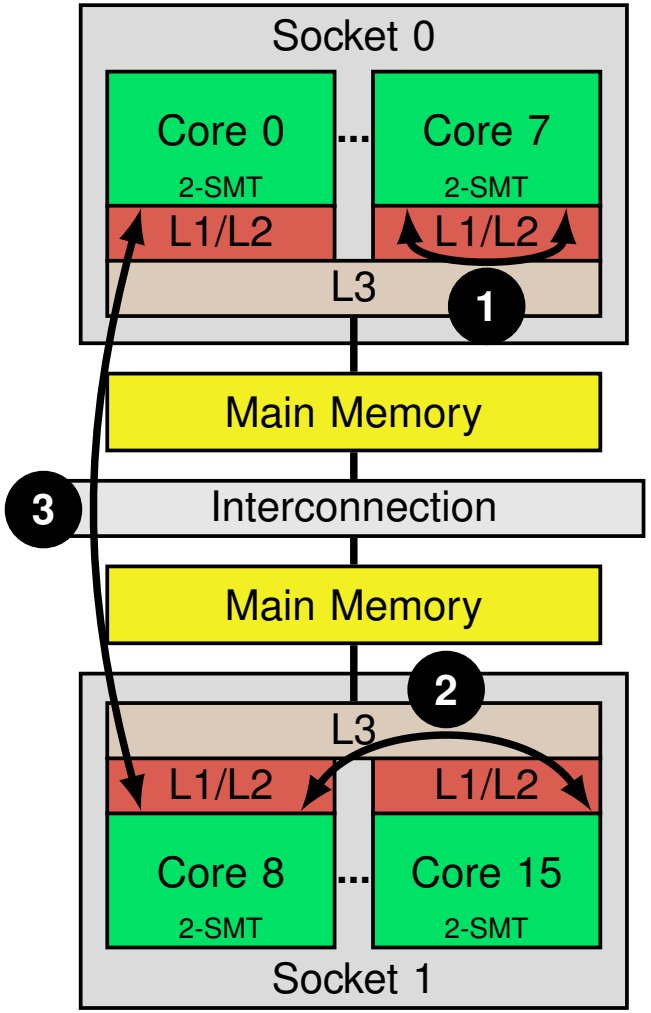

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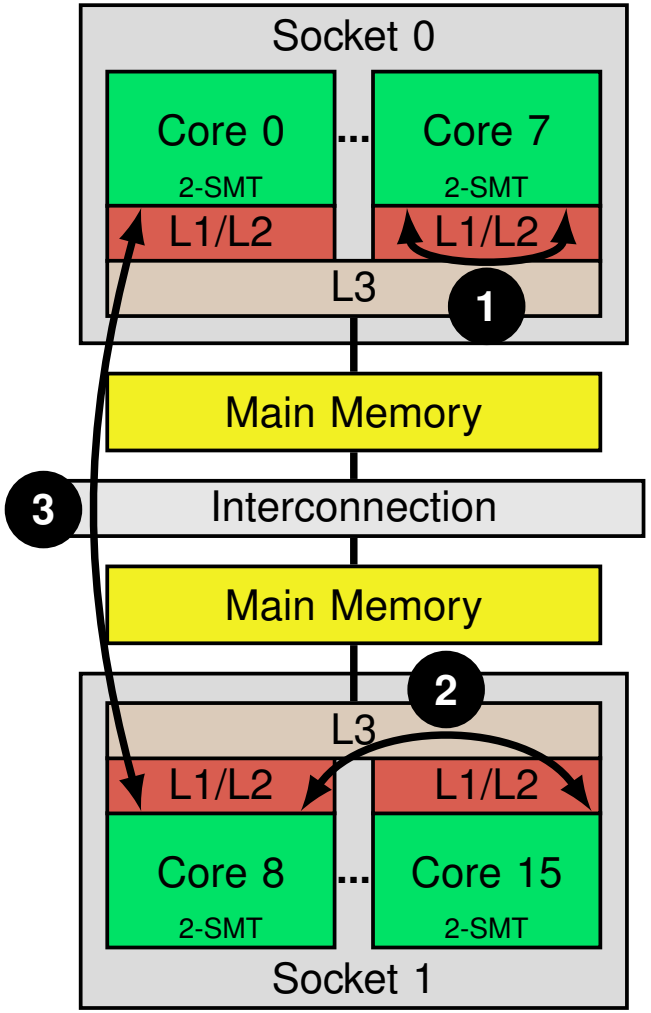

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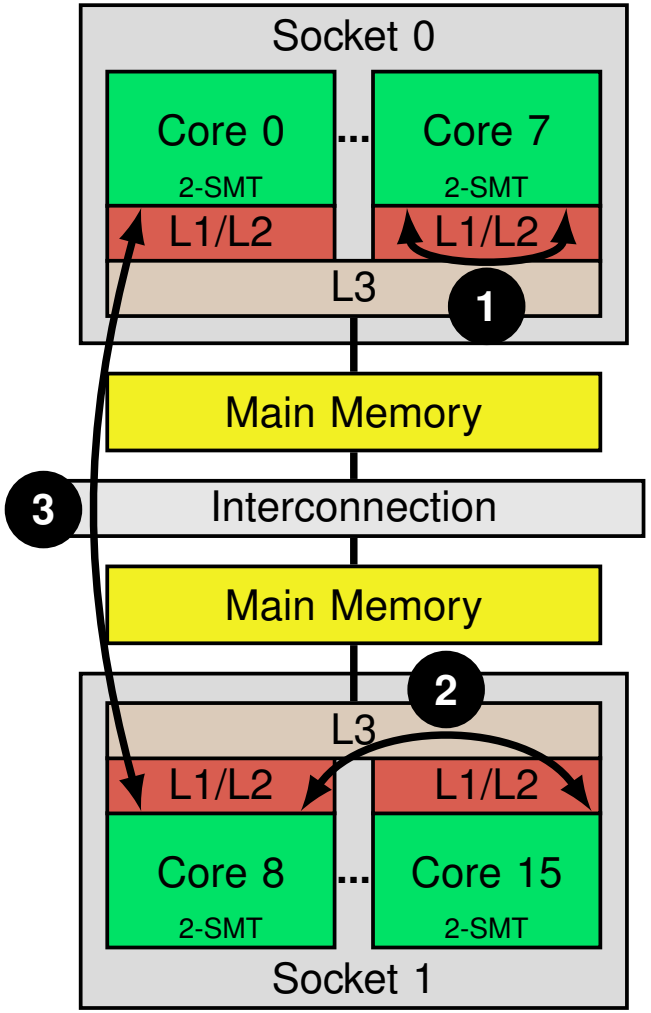
  - Increase locality of memory accesses



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- Previous work:
  - Memory traces (high overhead)
  - Hardware statistics (imprecise, hardware dependent)
  - Modifying runtime libraries (only for a subset of applications)

Our proposal:

SPCD: Shared Pages Communication Detection

Use virtual memory for detection

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- Two parts:
  1. **Detect Communication**
  2. Map threads to hardware topology

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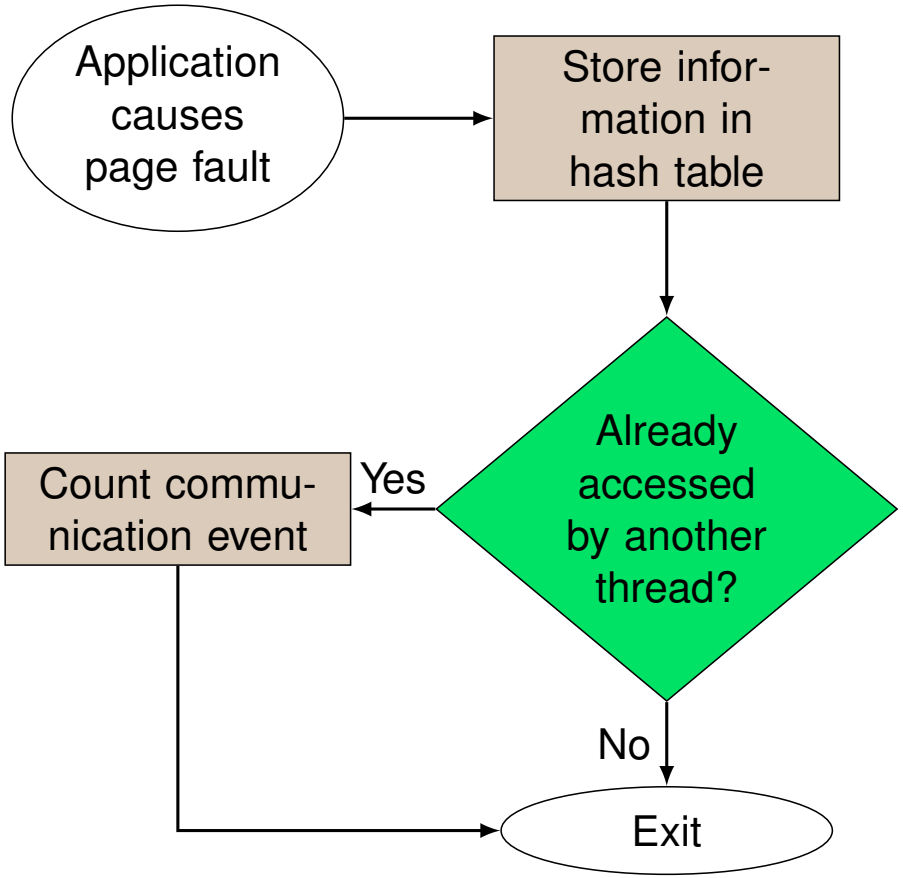
- **Analyze memory access behavior by observing page faults**
  - Store information about them (address, thread ID)
  - Page faults with the same address: *communication event*
- Granularity of detection is configurable
  - Divide address space into *memory regions*



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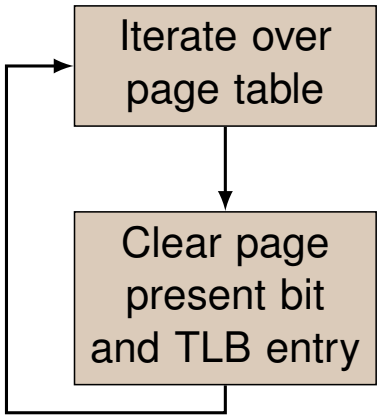

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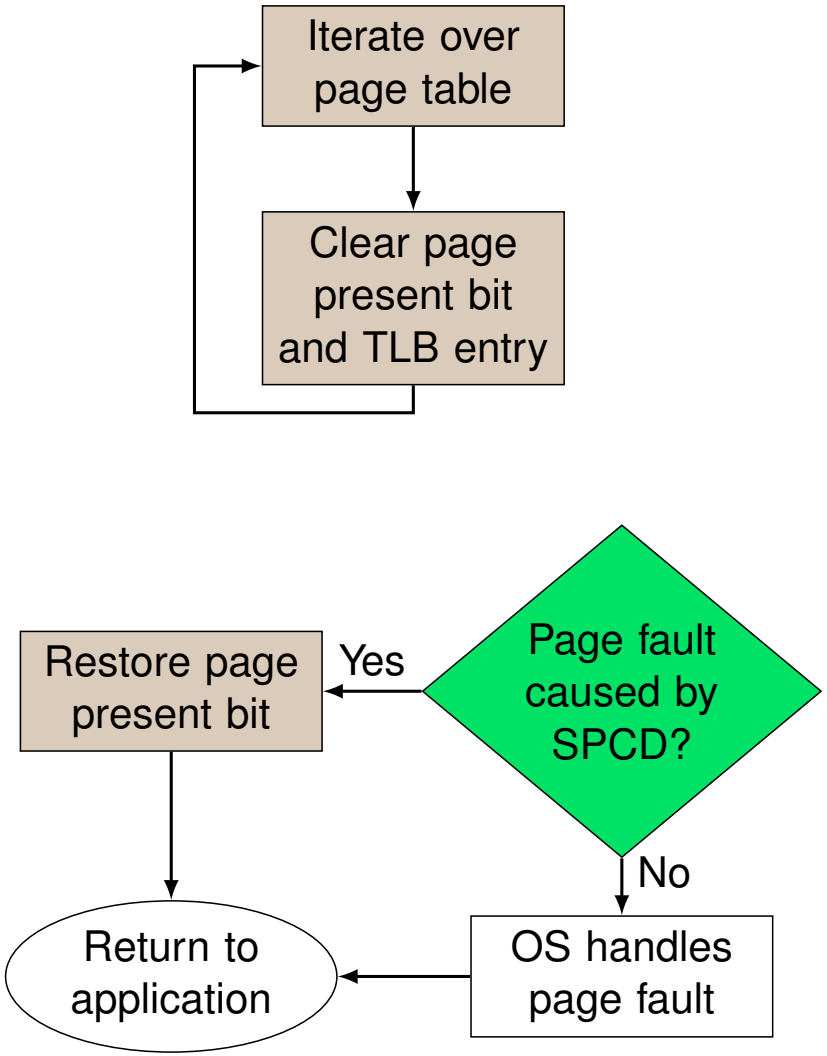
- **Insert additional page faults in the application**
- Page faults can be resolved with a low overhead



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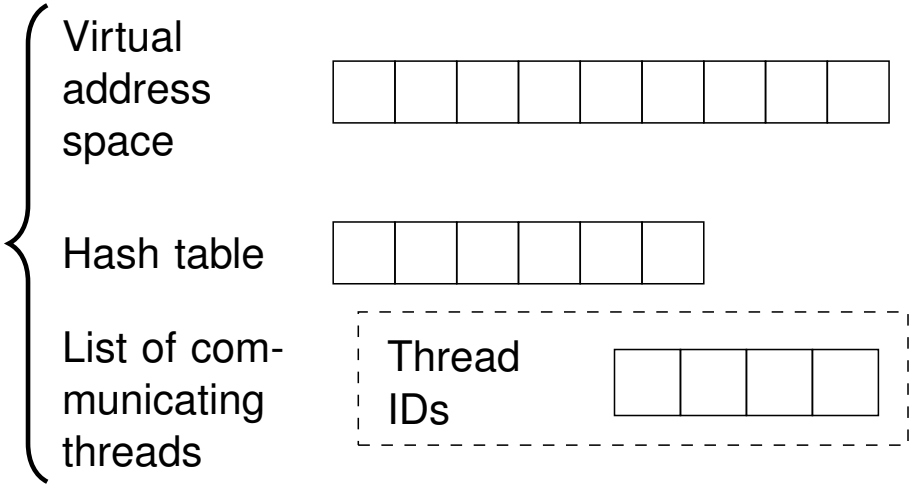

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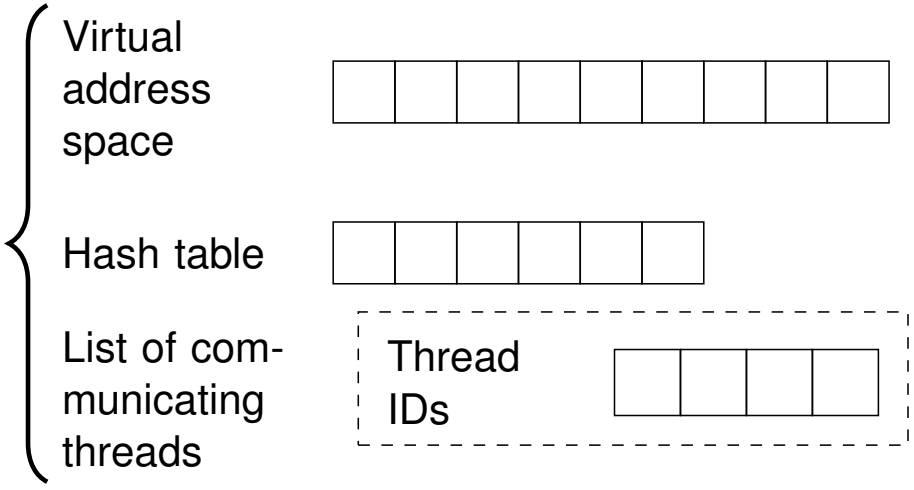

- Store communication events in communication matrix

3	8	5	2	
2	3	1		2
1	4		1	5
0		4	3	8
	0	1	2	3

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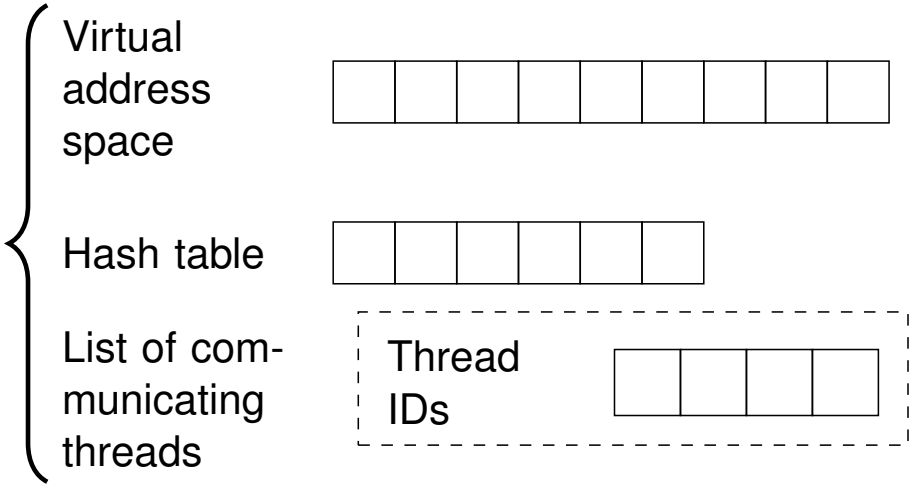

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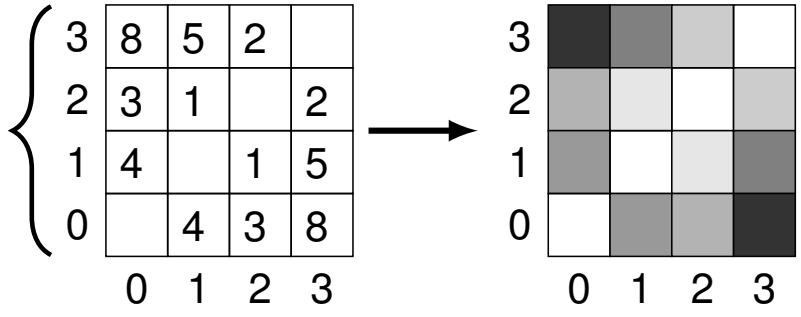
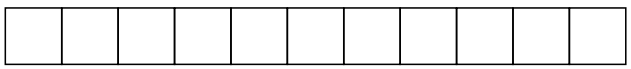
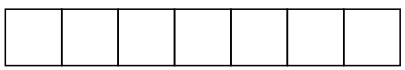


SPCD: EXAMPLE

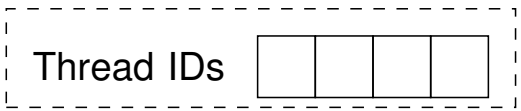
Virtual address space



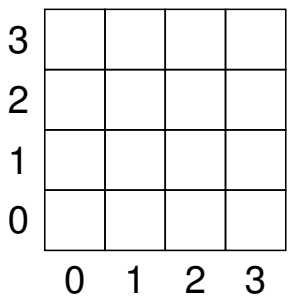
Hash table



List of communicating threads



Communication matrix



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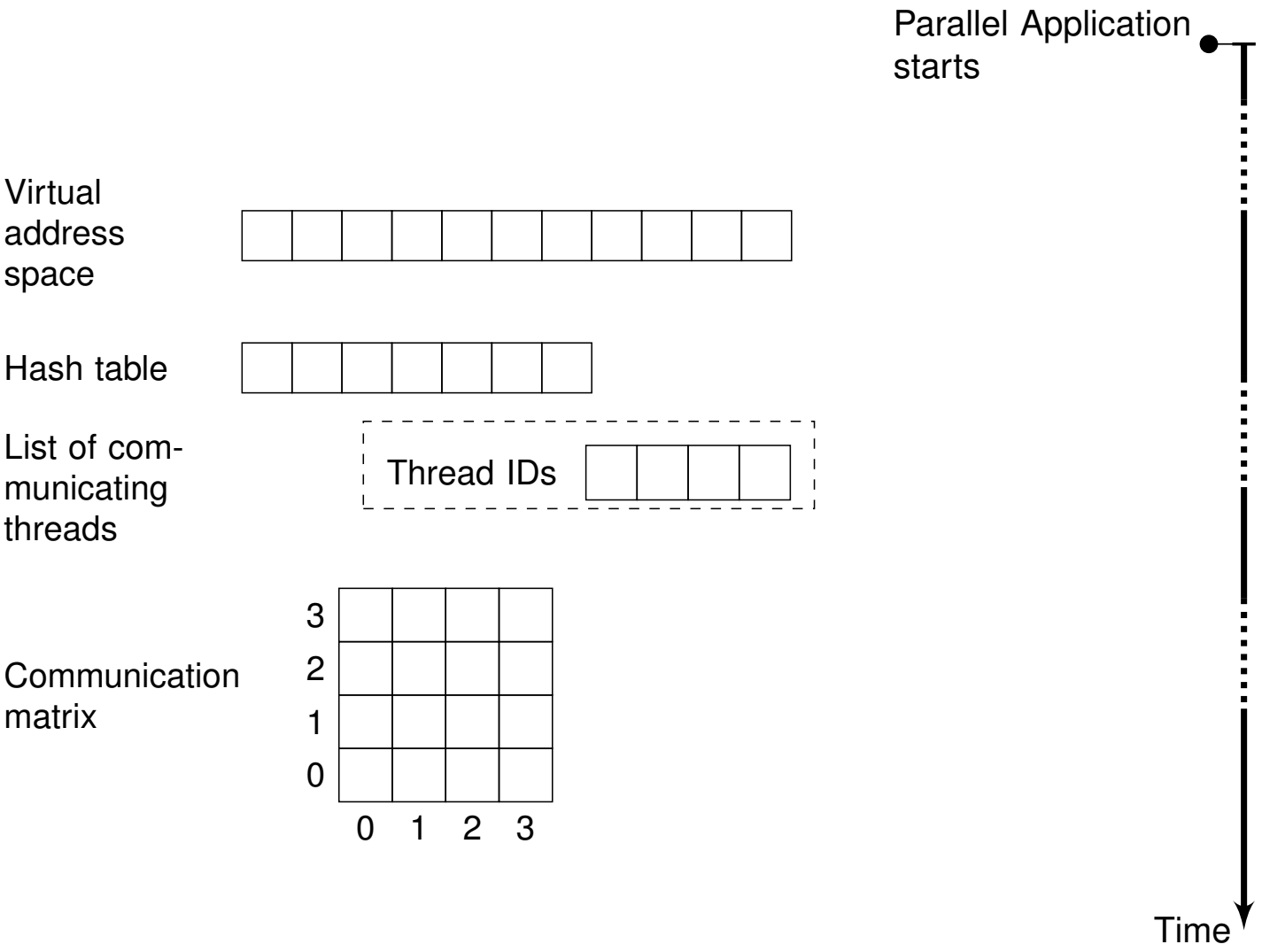

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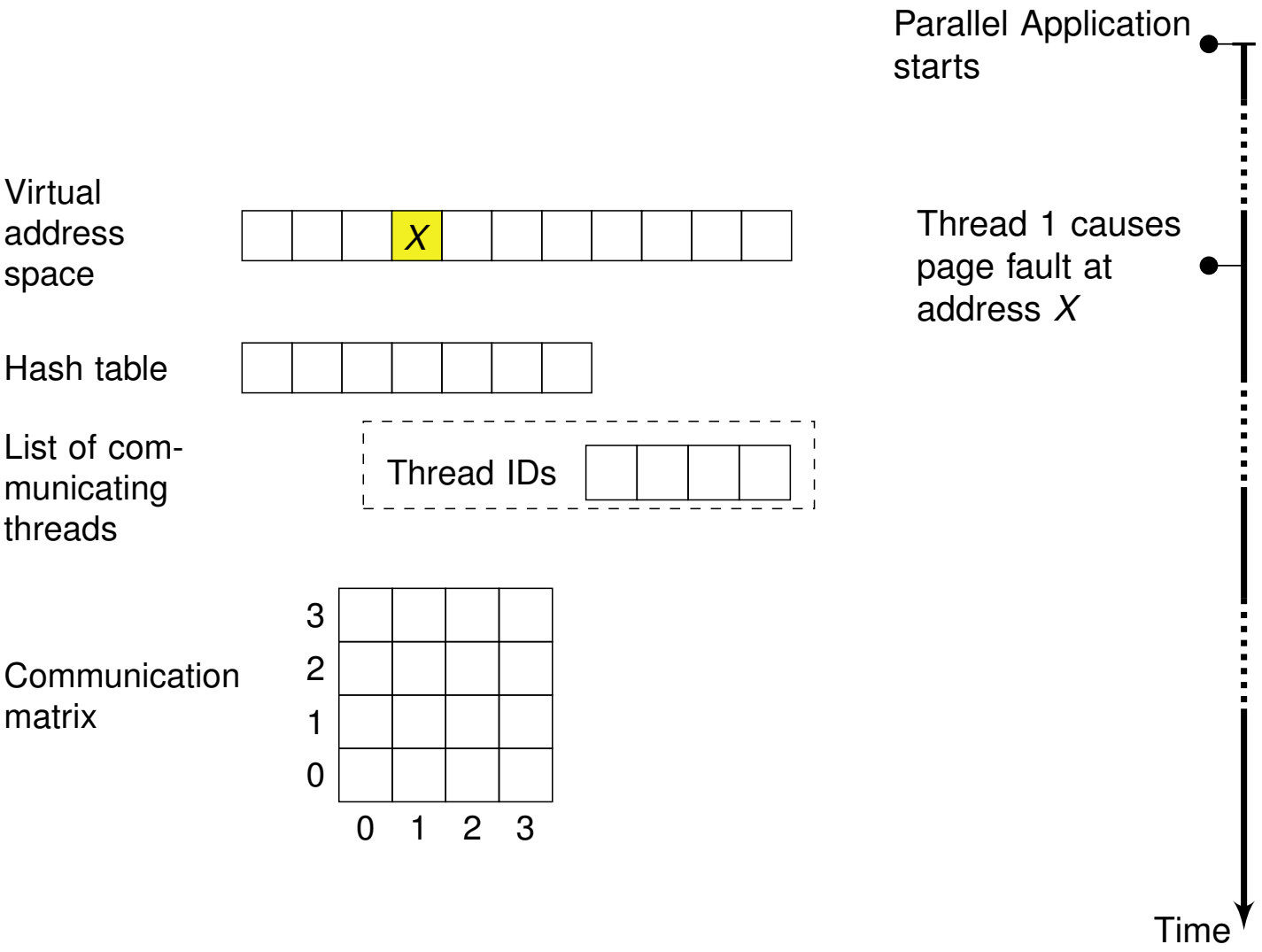

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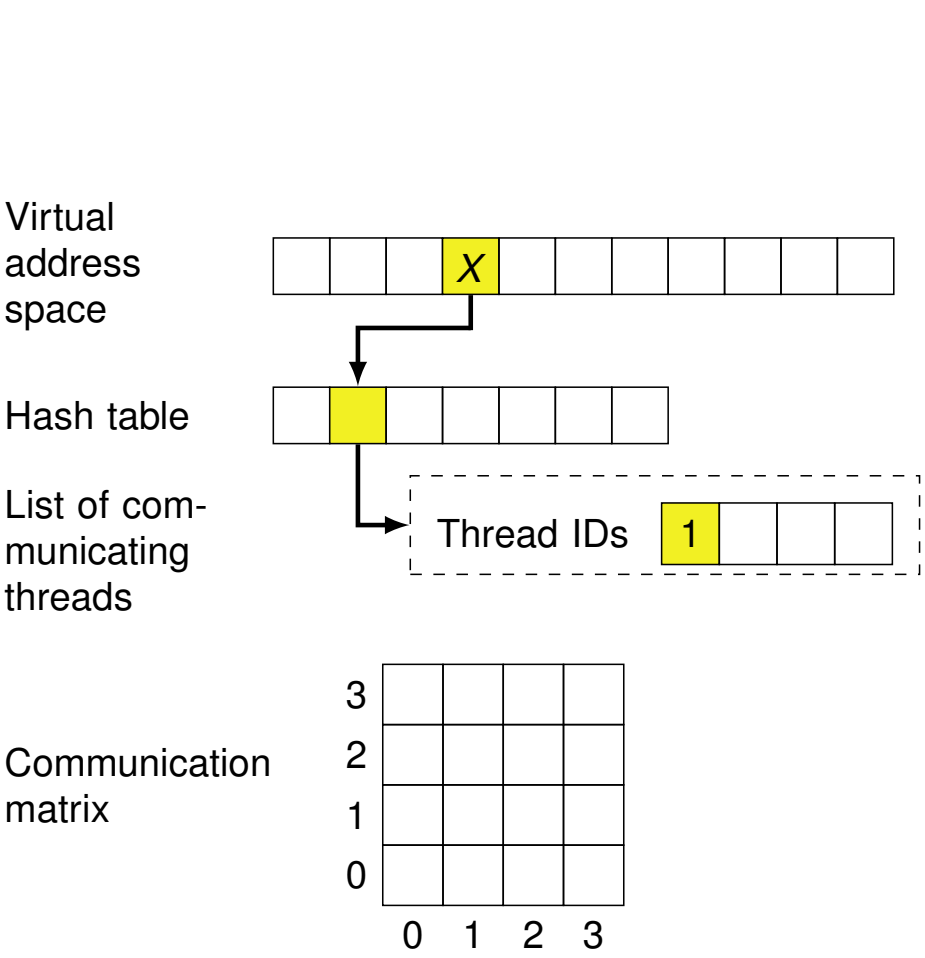

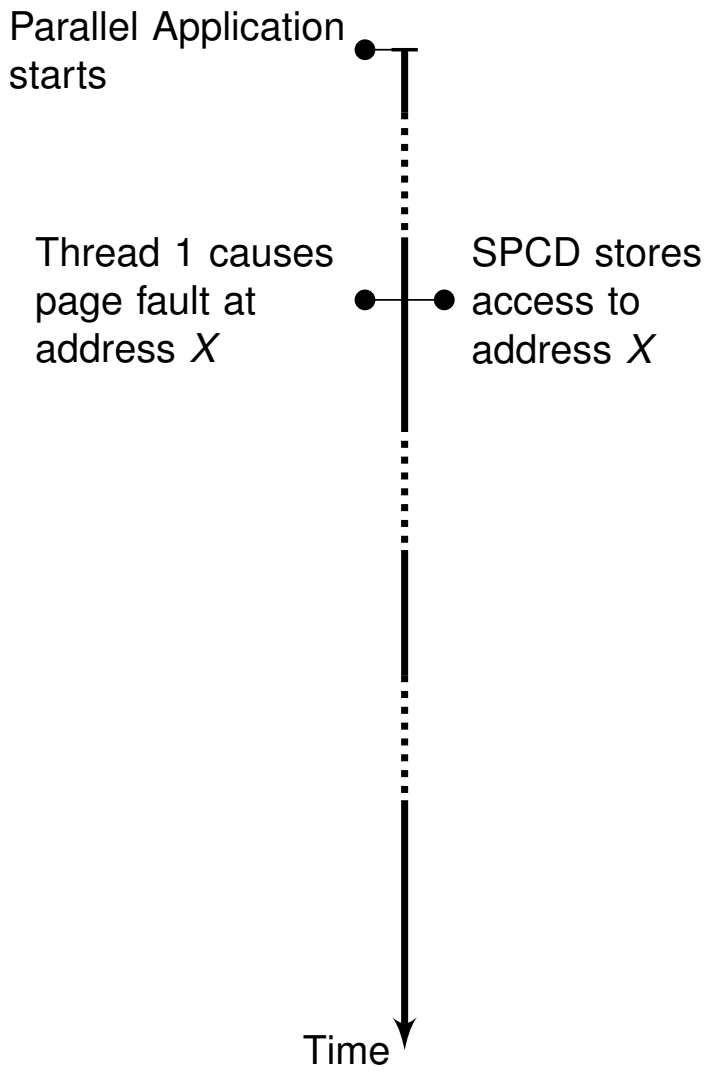

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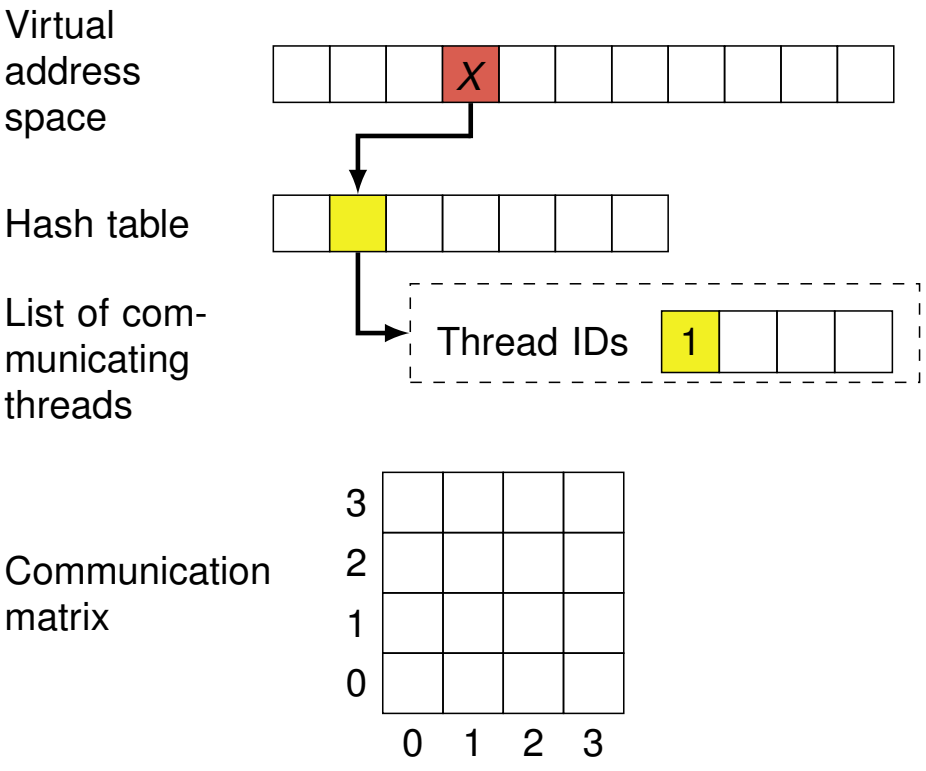

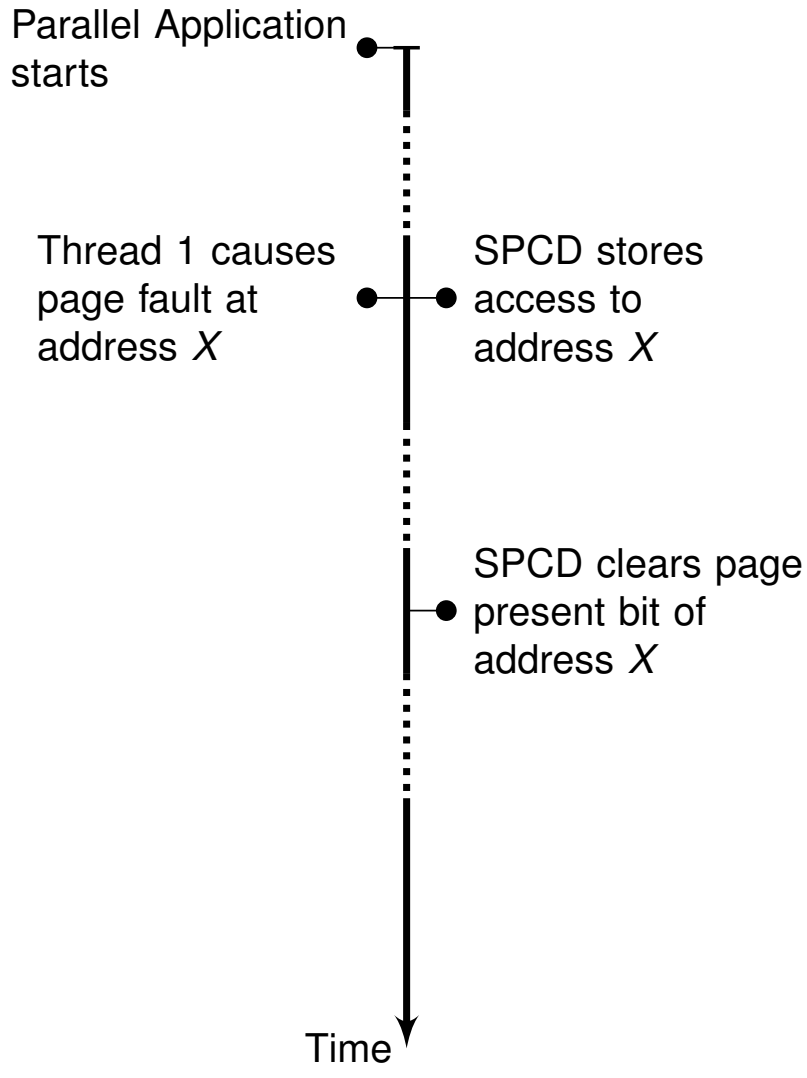

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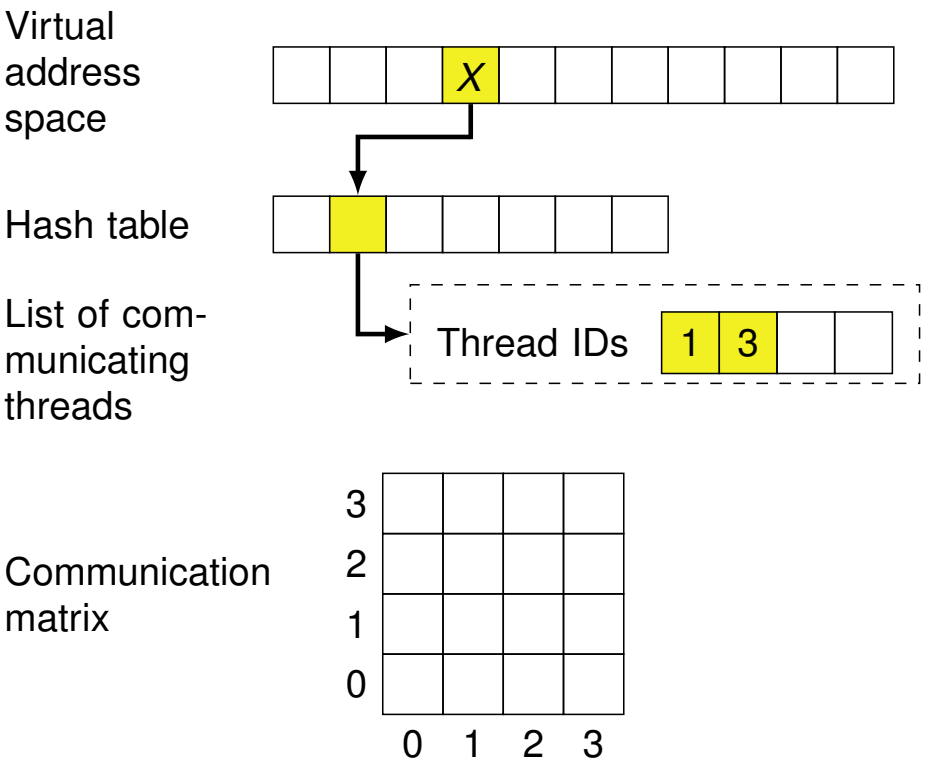

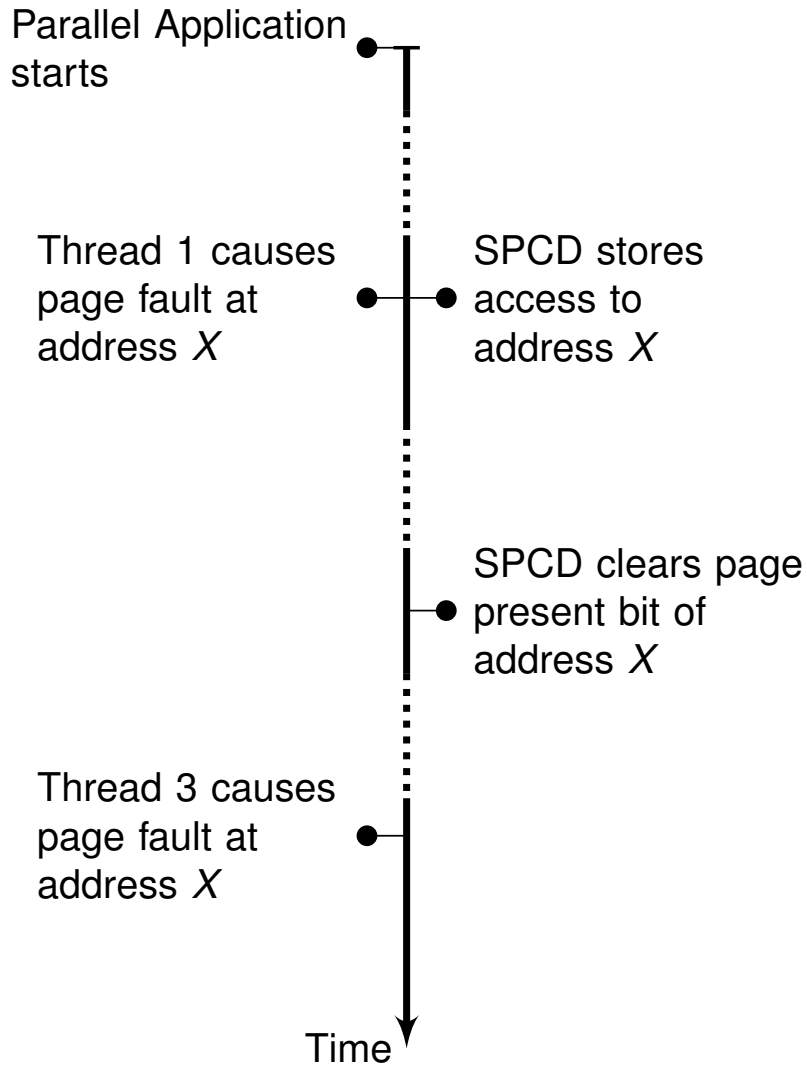

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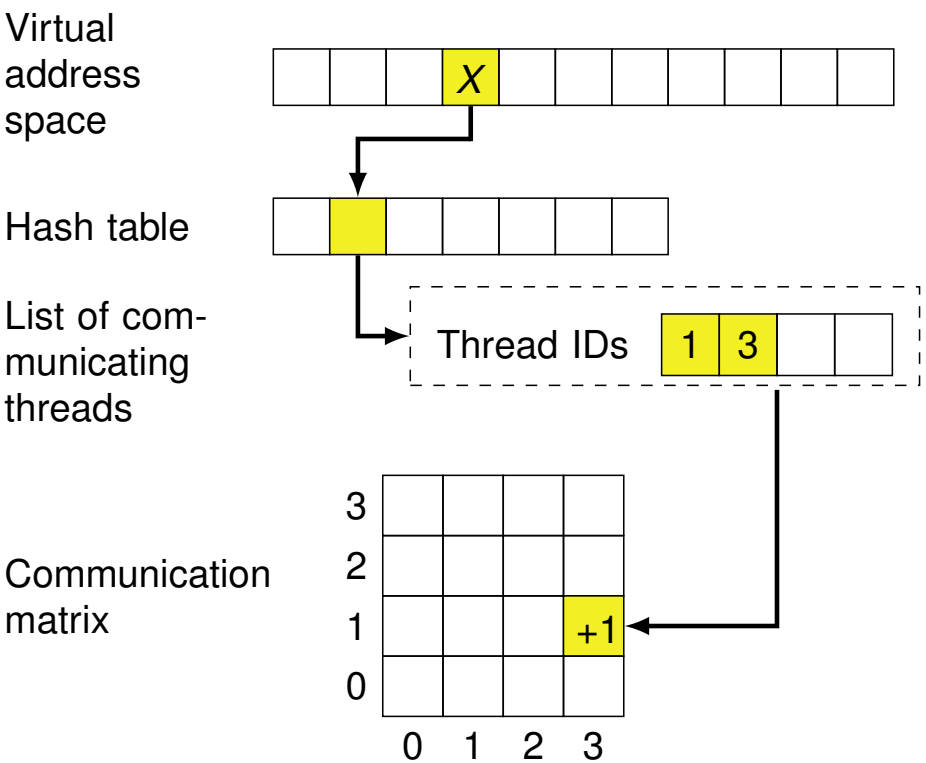

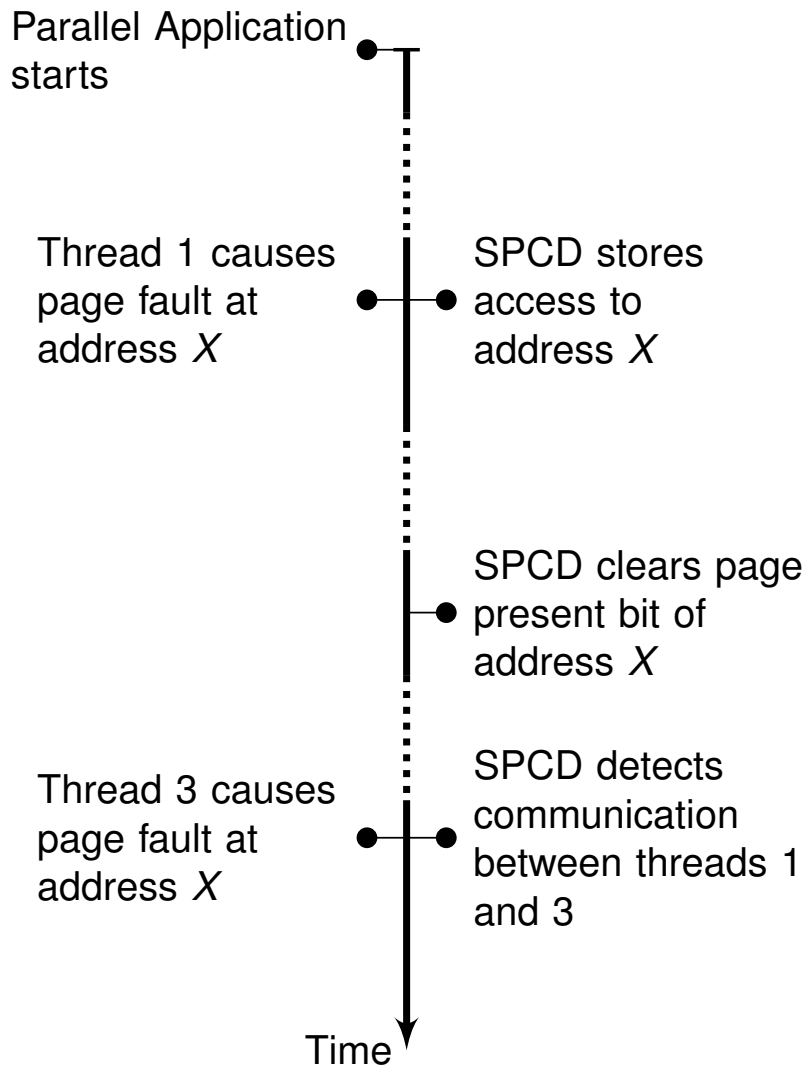

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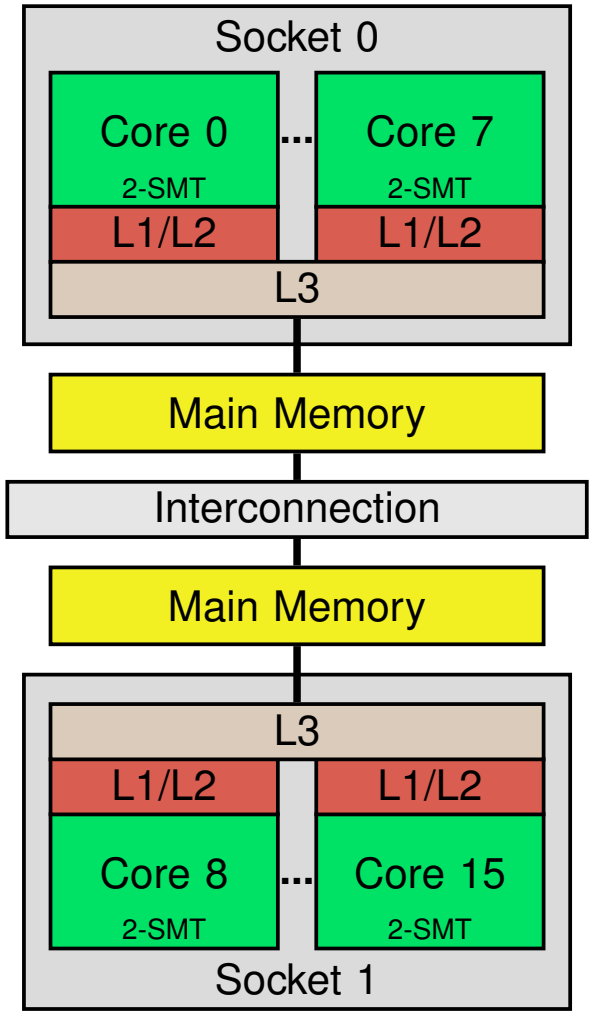

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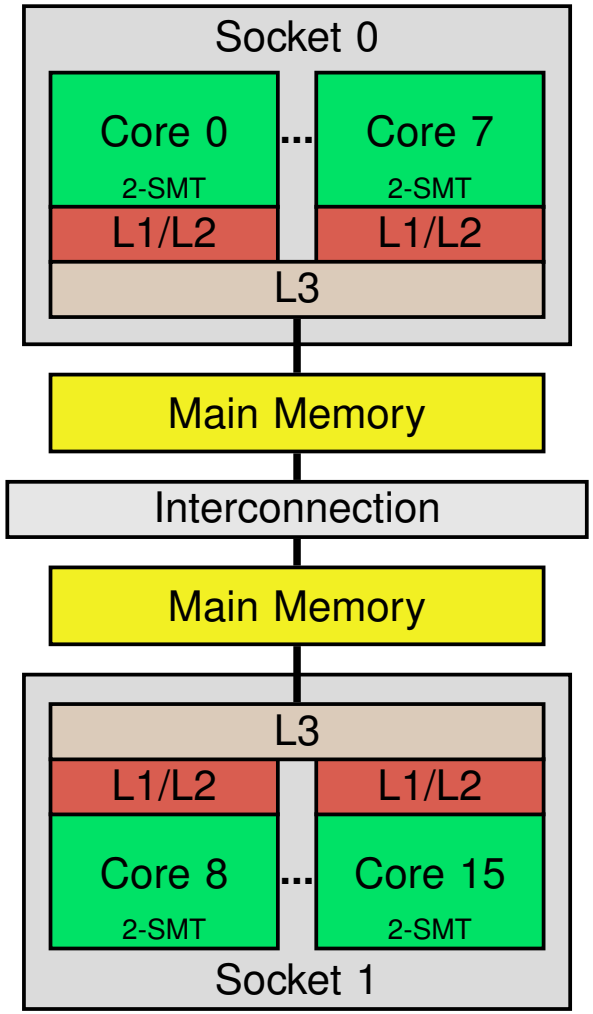

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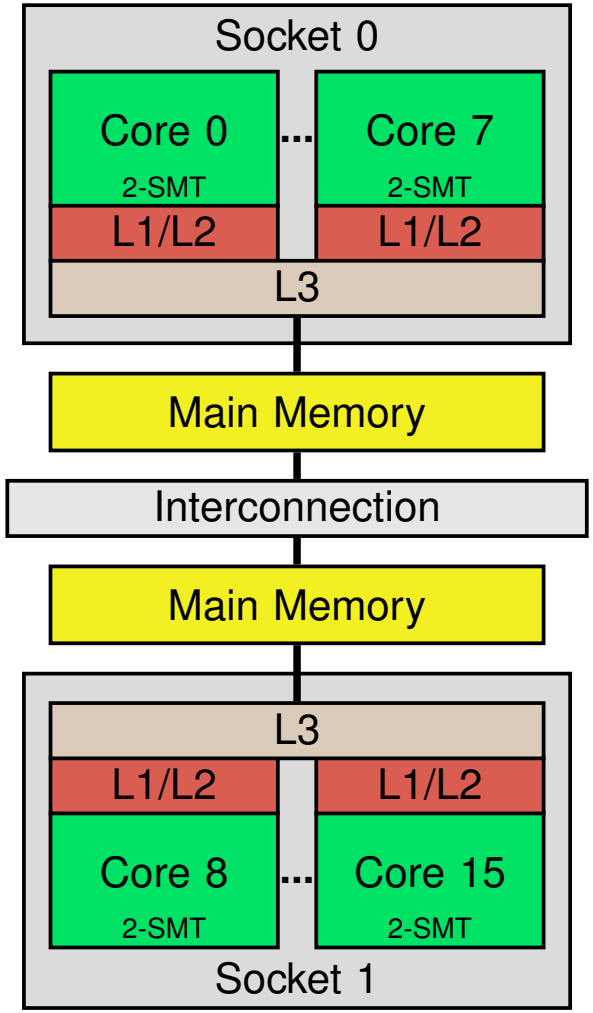

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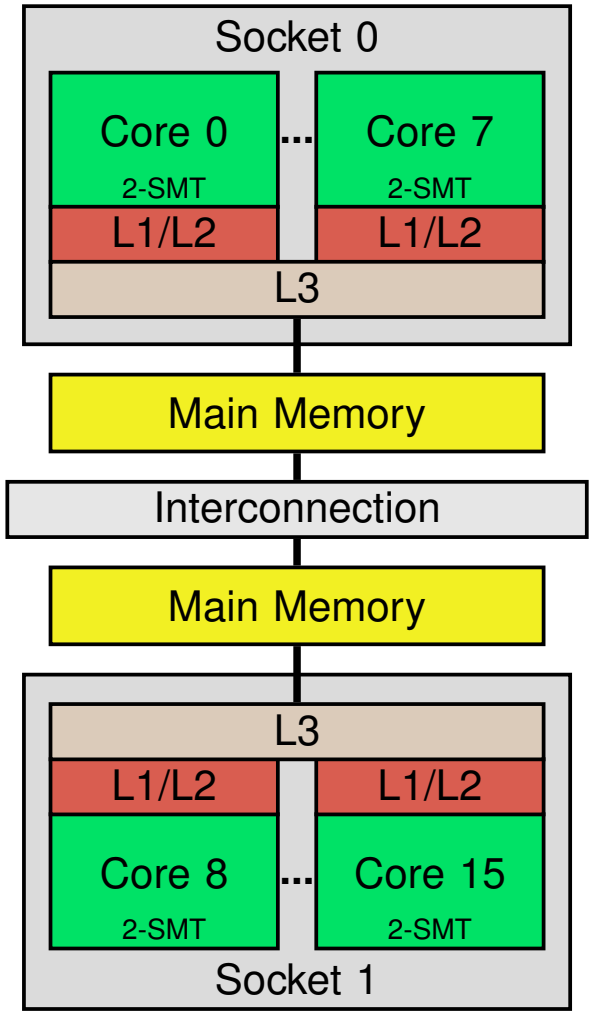
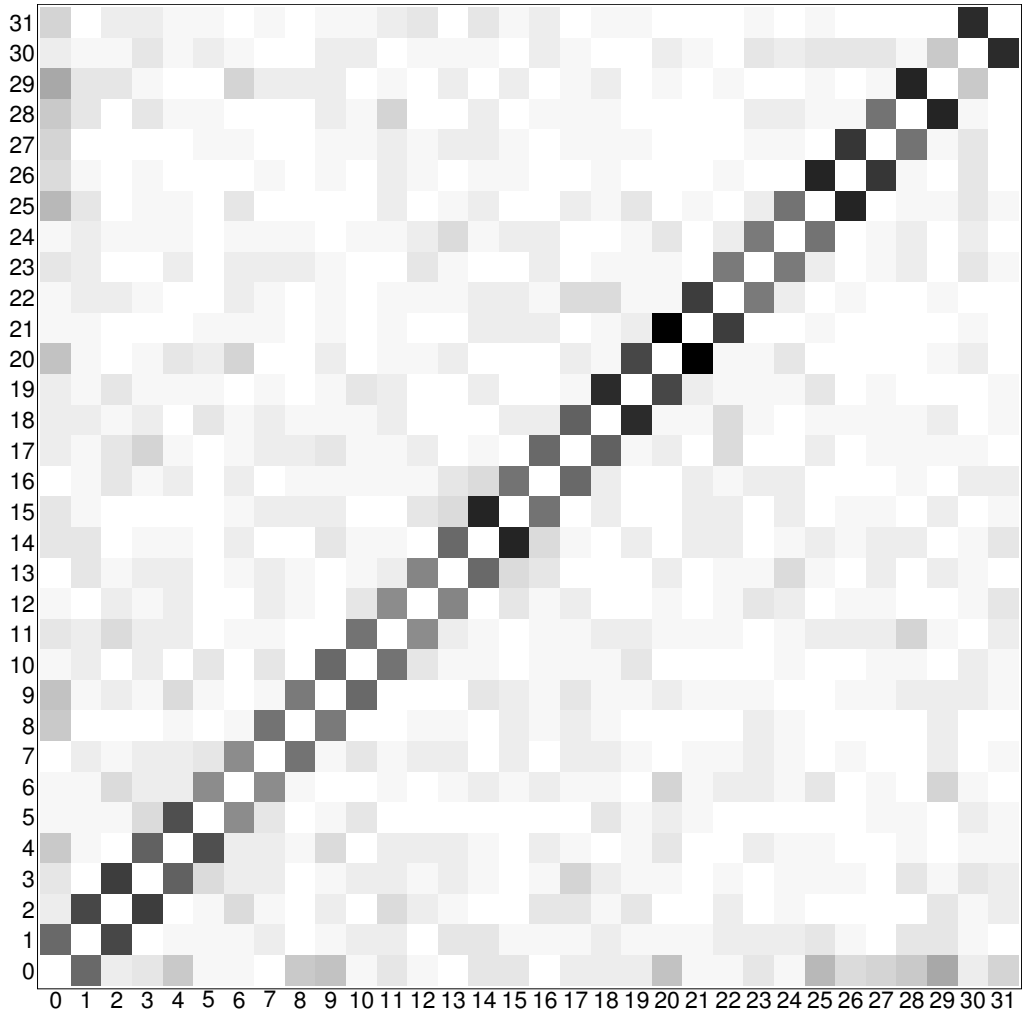
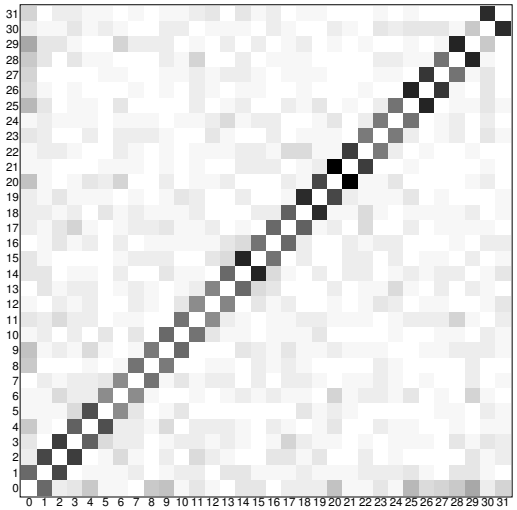
  - Granularity: 512 Bytes
  - Additional page faults: ~10%



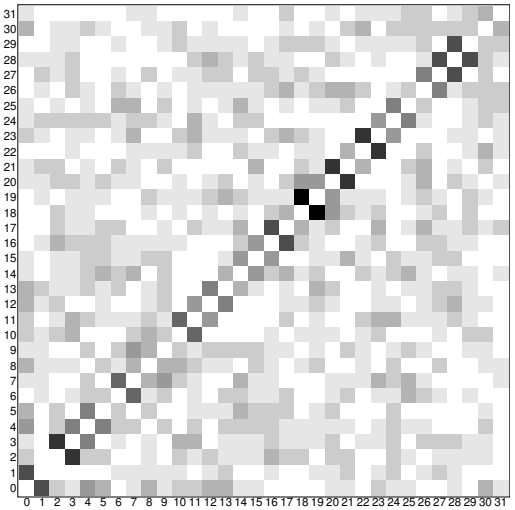
COMMUNICATION PATTERN – BT



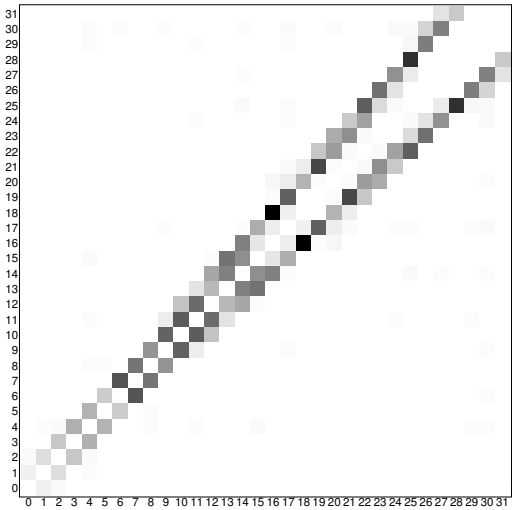
COMMUNICATION PATTERNS – BT, LU, MG, SP, UA



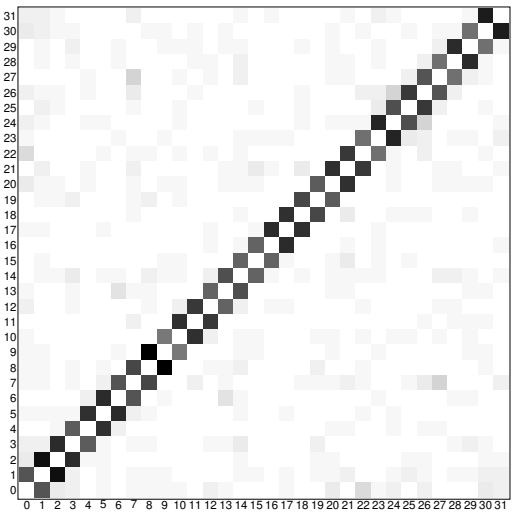
BT



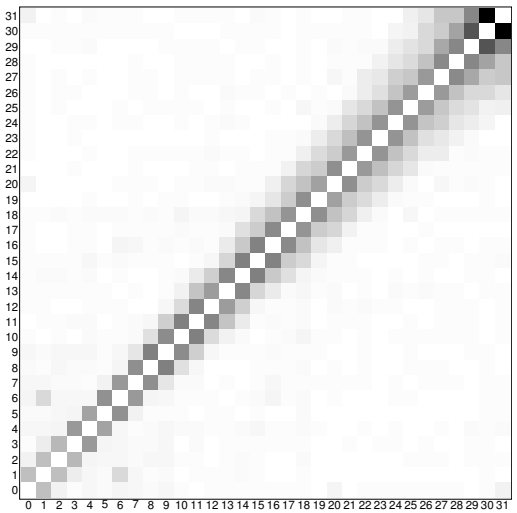
LU



MG

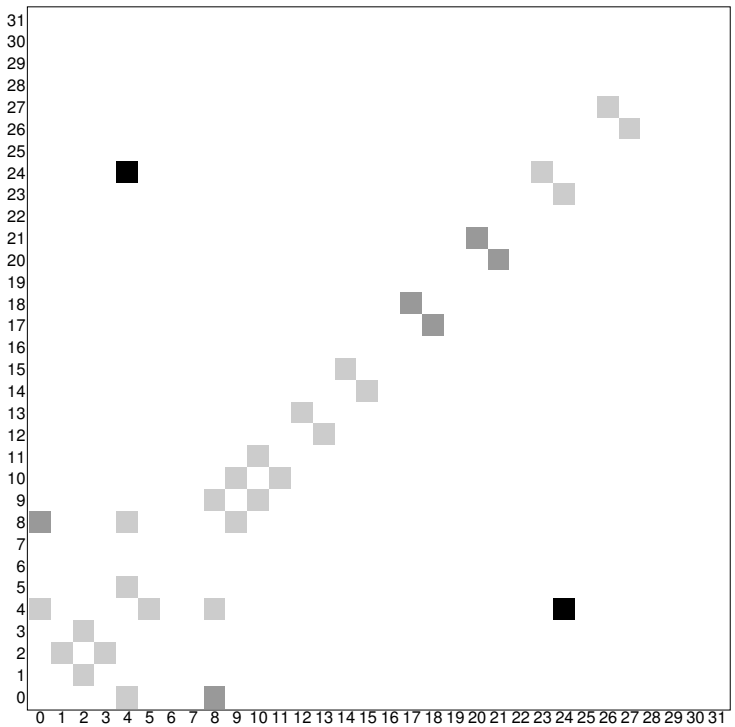


SP

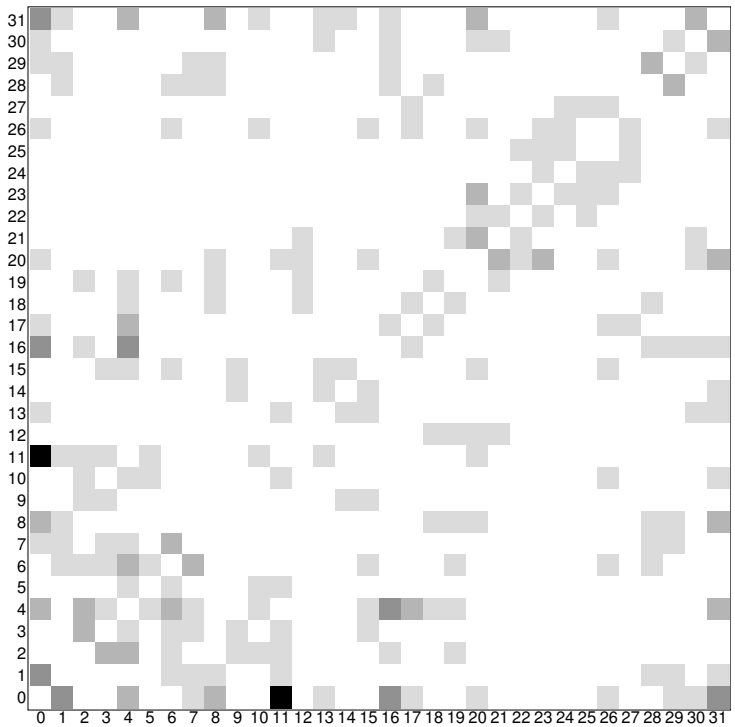


UA

COMMUNICATION PATTERNS – CG, DC

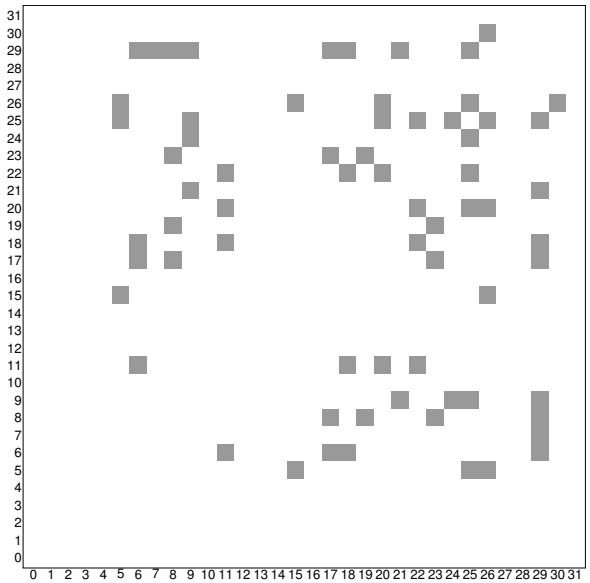


CG

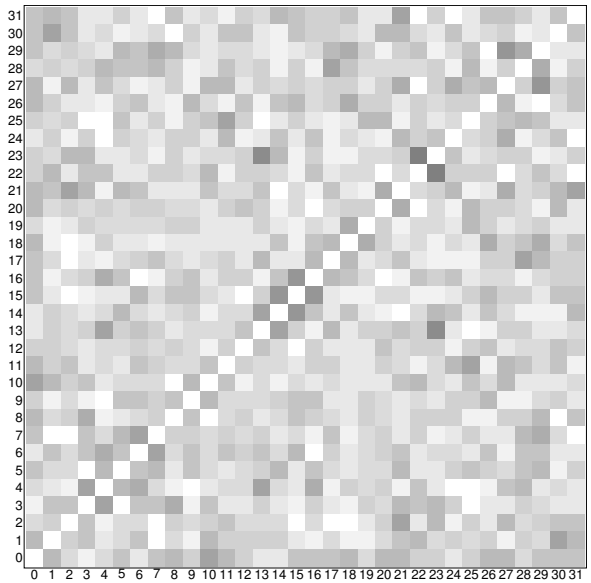


DC

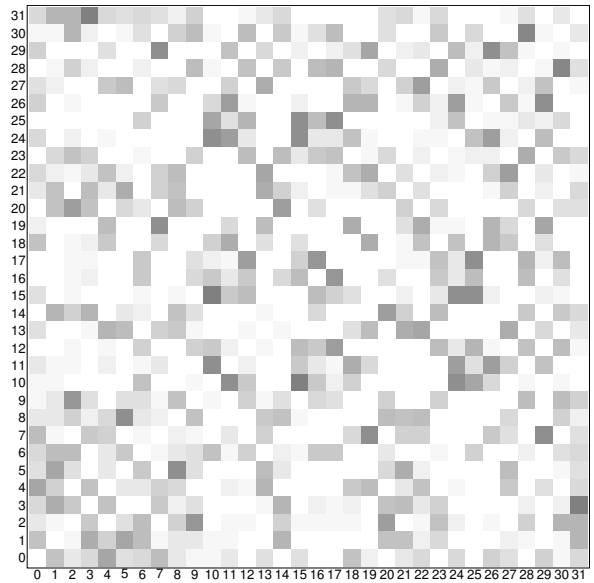
COMMUNICATION PATTERNS – EP, FT, IS



EP



FT



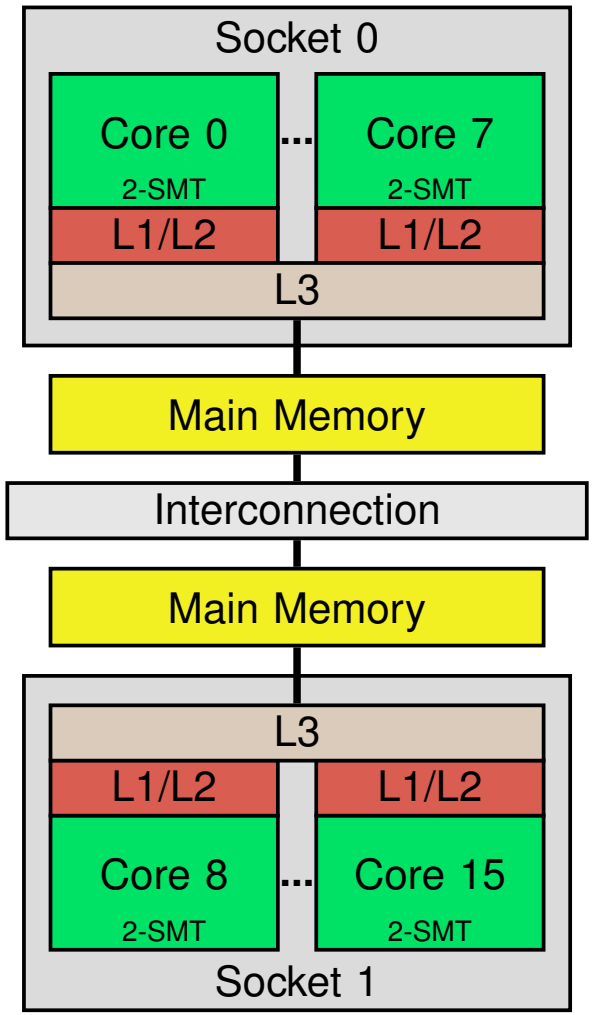
IS

COMMUNICATION PATTERNS – SUMMARY

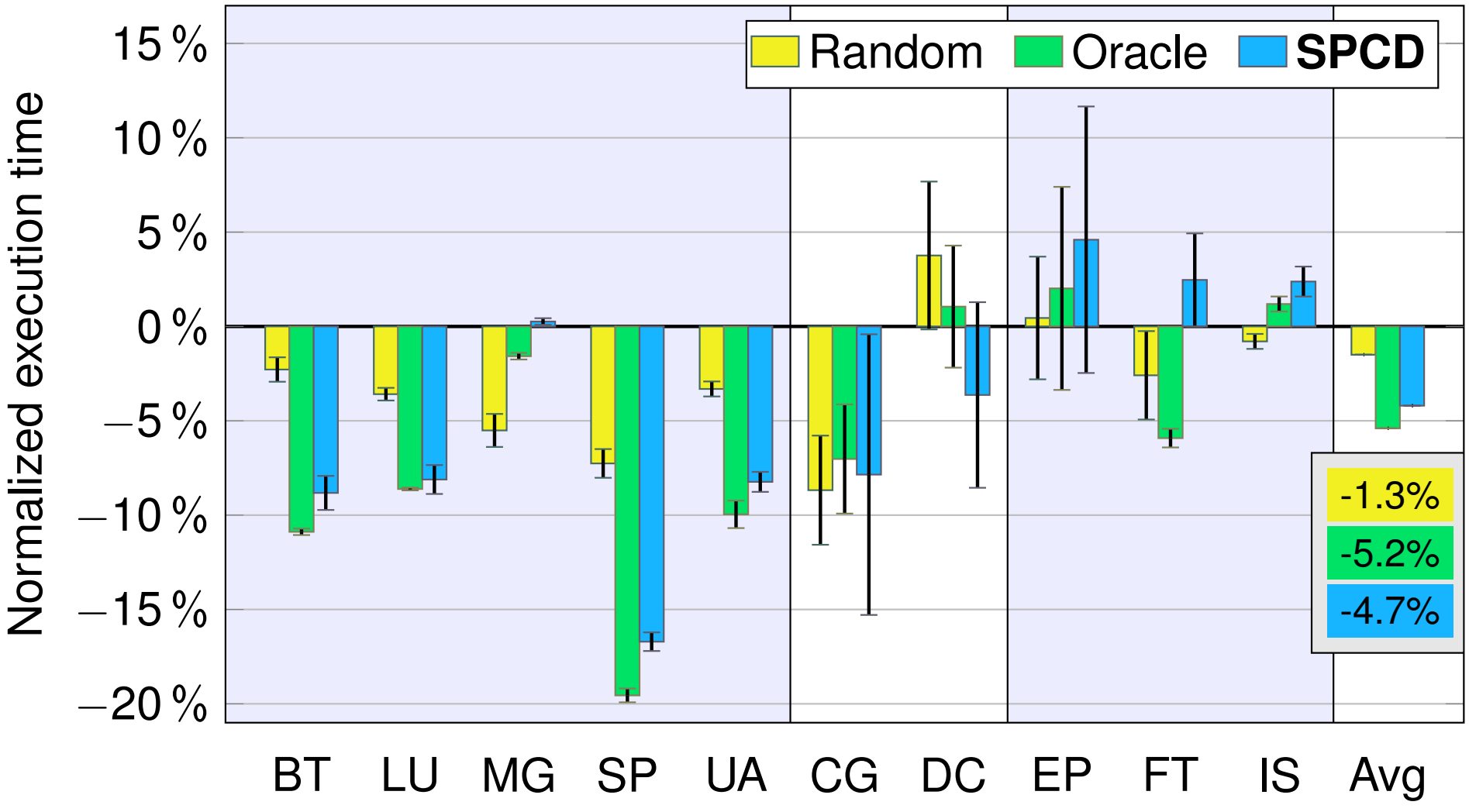
- All patterns detected correctly
- 3 groups
  1. Structured pattern, nearest neighbors: BT, LU, MG, SP, UA
  2. Slightly structured pattern, nearest neighbors: CG, DC
  3. Unstructured pattern, all-to-all: EP, FT, IS
- Expect performance improvements for structured patterns

METHODOLOGY: PERFORMANCE AND ENERGY

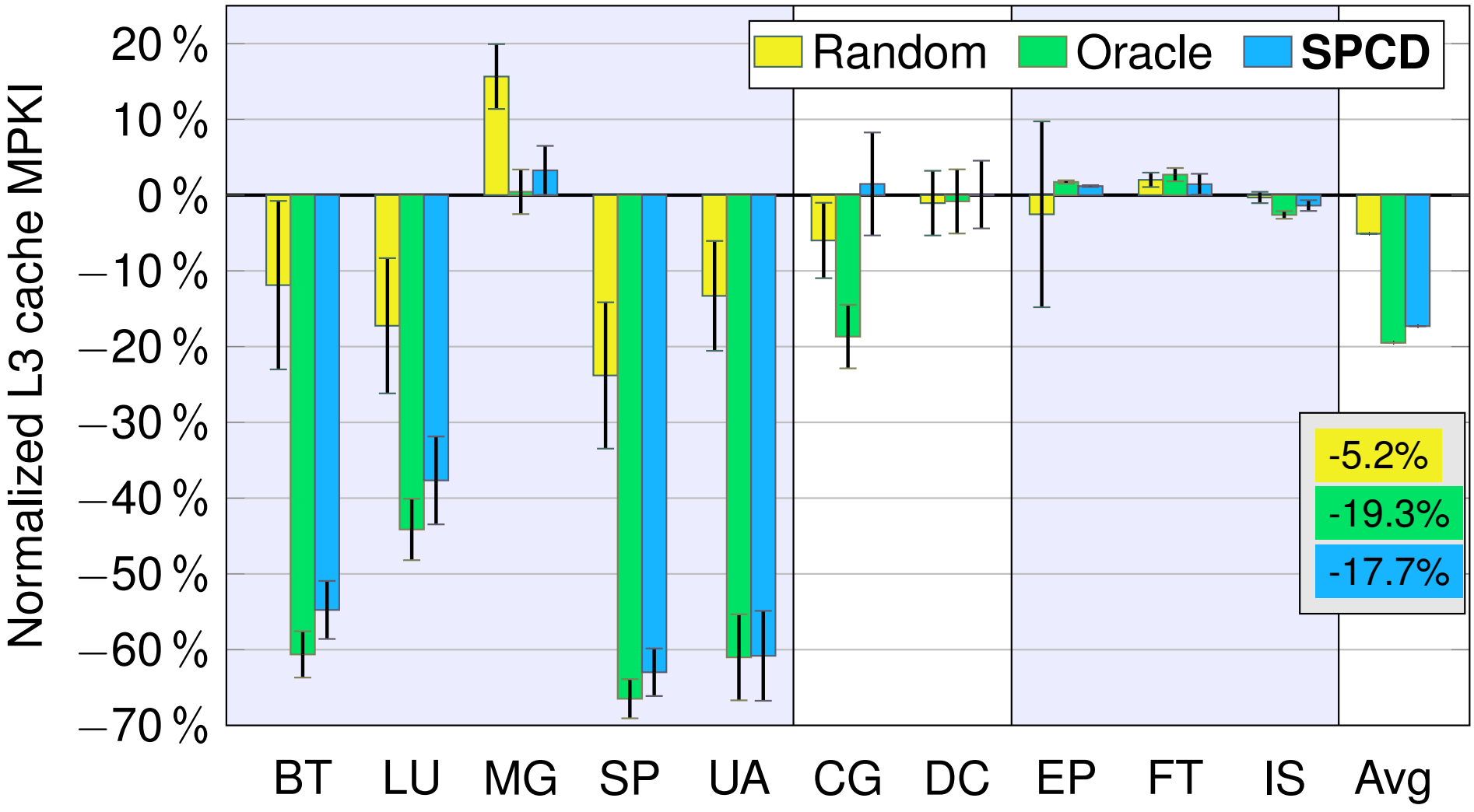
- Same machine, benchmarks, SPCD configuration as before
- **Online mapping of threads to cores using Edmonds' graph matching, minimizing communication costs**
- Compare SPCD to
  - Operating system (baseline)
  - Random static mapping
  - Oracle mapping
- Measure execution time, cache misses and processor energy consumption (using SandyBridge RAPL counters)



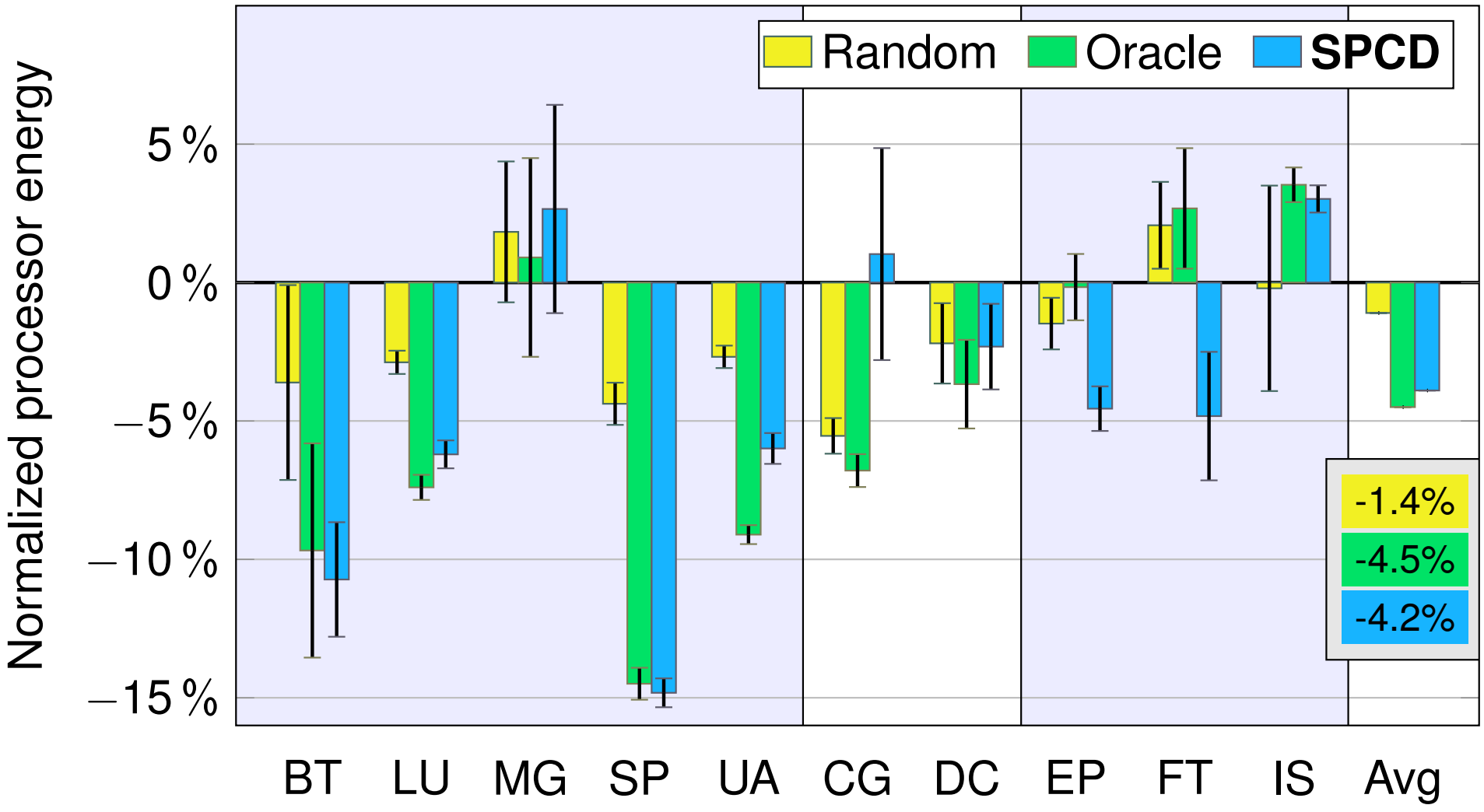
RESULTS – EXECUTION TIME



RESULTS – L3 CACHE MPKI



RESULTS – PROCESSOR ENERGY PER INSTRUCTION



RESULTS – OVERHEAD

- Sources of overhead:
  - Communication detection (+ additional page faults)
  - Mapping

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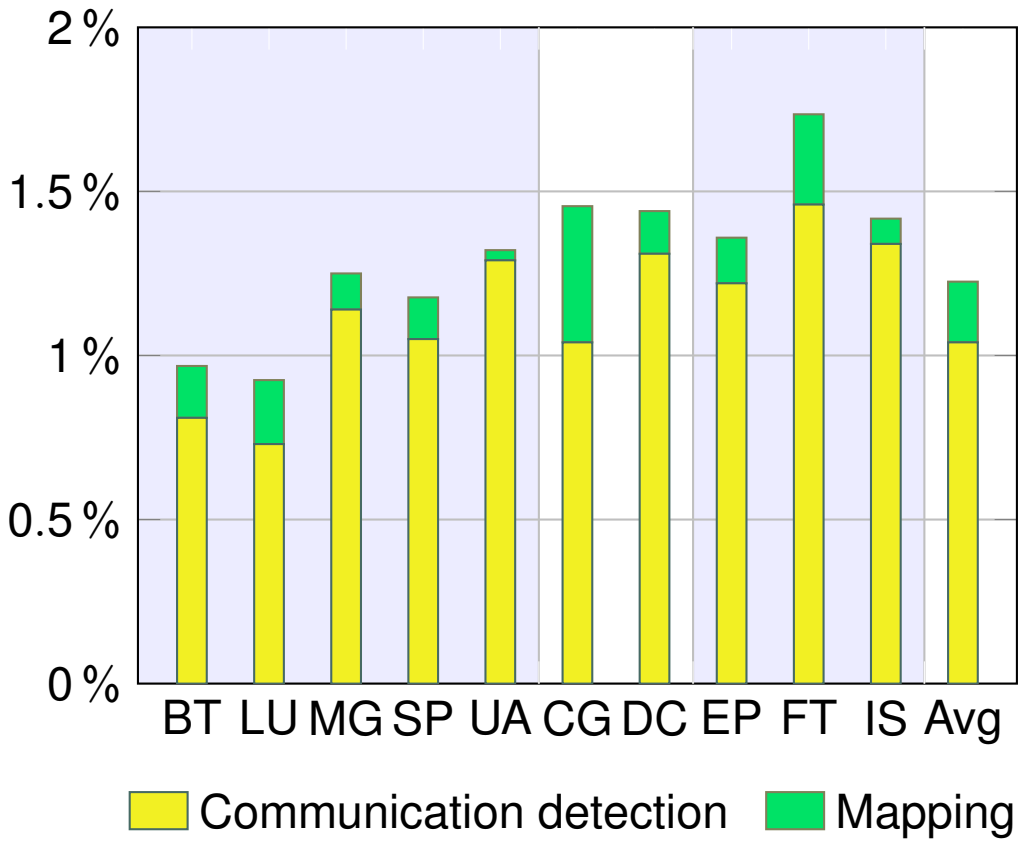

CONCLUSIONS

- **Page faults of a parallel application can be used to analyze its memory access behavior**
- SPCD: kernel-based mechanism to detect inter-thread communication
  - Low overhead
  - No need to modify applications or support libraries
  - Provide detection and migration during execution of the application, no prior knowledge required
- Results
  - Improve performance by up to 16.7% (avg 4.7%)
  - Reduce energy consumption by up to 14.7% (avg 5.2%)

Download: `http://inf.ufrgs.br/~mdiener`

Communication-Based Mapping Using Shared Pages

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