REGISTER LEVEL SORT ALGORITHM ON MULTI-CORE SIMD PROCESSORS

Xiaochen Tian, Kamil Rocki and Reiji Suda
The University of Tokyo
Suda Lab

Xeon Phi and AVX-512

- Xeon Phi:
  - 60 cores. 240 threads with Hyperthreading.
  - AVX-512 supported

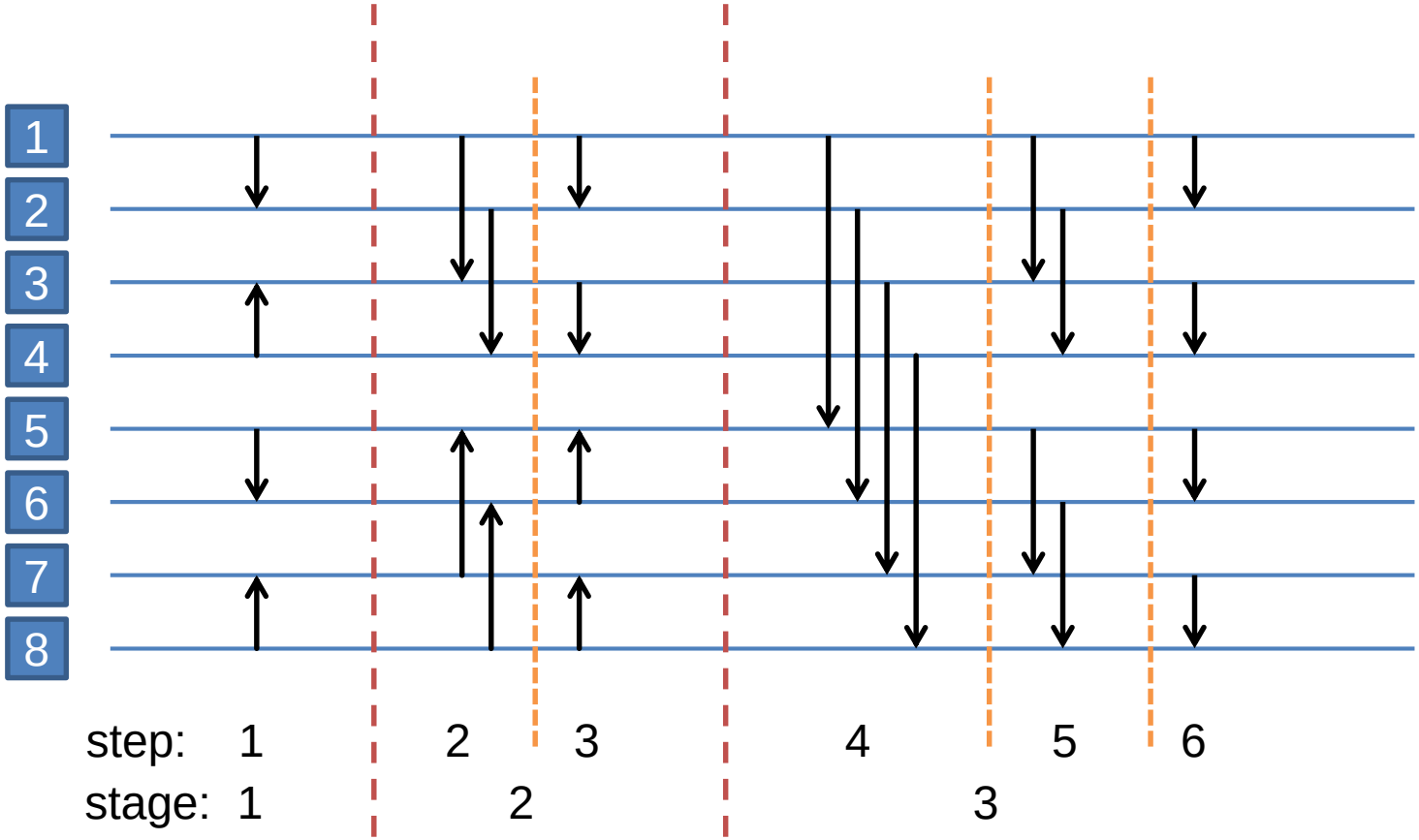
- SSE
  - Operates on 128-bit wide registers, SIMD execution
  - For example, 4 integer operation or 2 double precision
- AVX
  - 256-bit registers
- AVX-512
  - 512-bit registers

Comparison Sorting on Xeon Phi

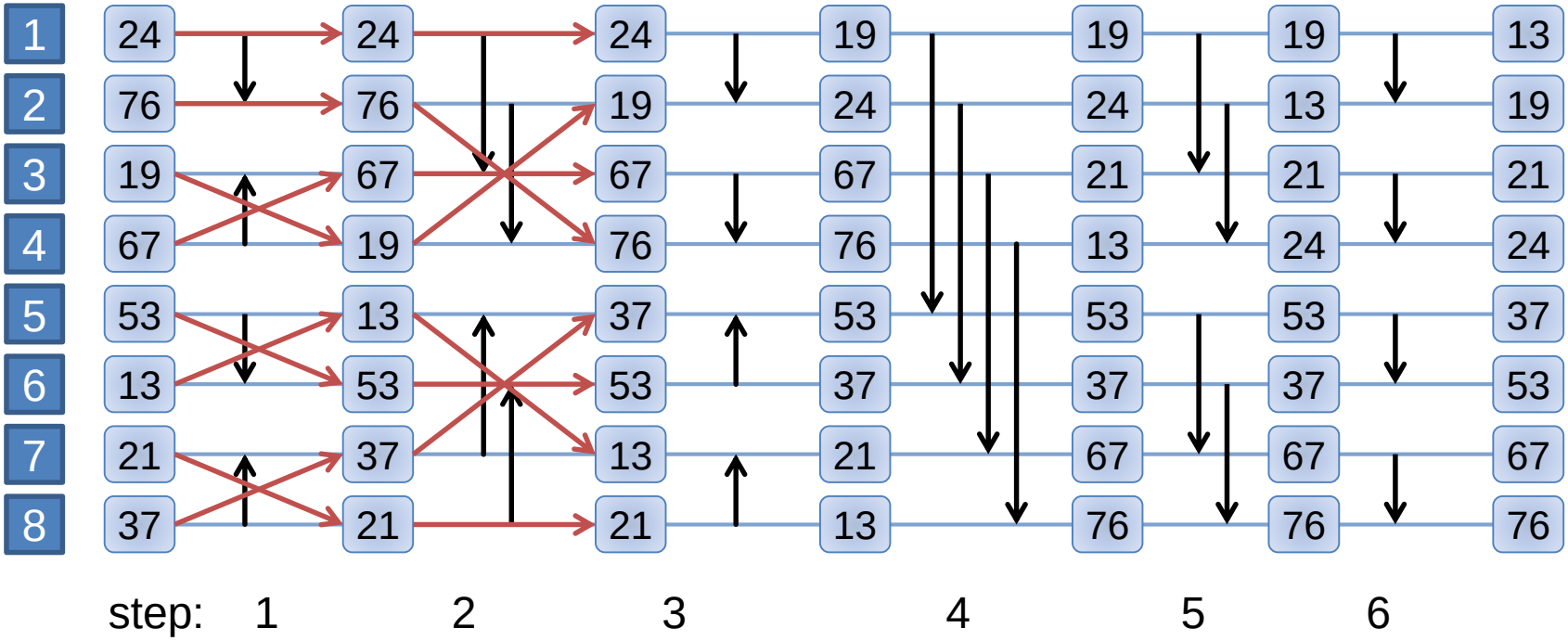
- Purpose:
  - Utilize 60 cores
  - Utilize AVX-512
- Challenge:
  - Restriction of Memory Accessing.(explained at next slide)
- Proposed Algorithm:
  - based on Bitonic Merge Sorting work
  - 2 register method
  - 1 register method

Bitonic Merge Sorting Network

- Numbers in the box represent the indices of elements

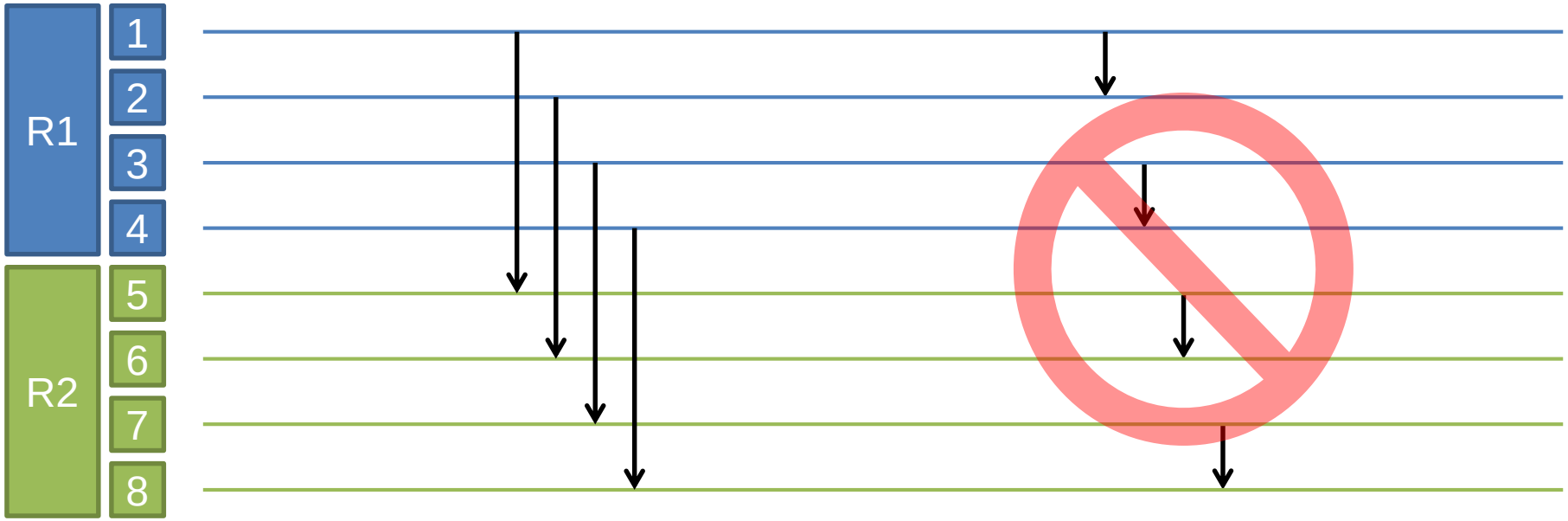


Example of Bitonic Merge Sort



Restriction of Memory Accessing

- R1, R2 are two registers




```
R1' = _m512_min_epi32(R1,R2);
R2' = _m512_max_epi32(R1,R2);
```

comparison between elements in the same register is invalid!

Restriction of Memory Accessing

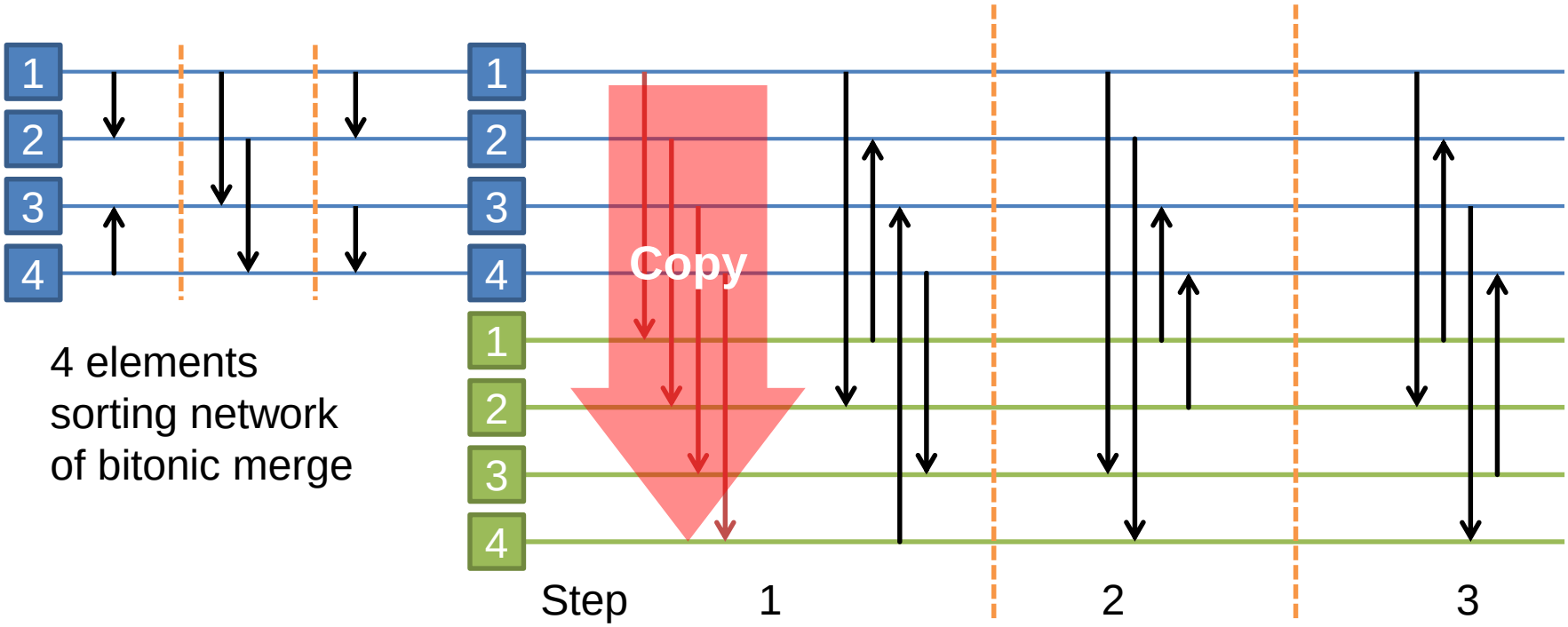
- Permutation and mask instruction

```
R2 = _mm512_shuffle_epi32(R2,<2 1 3 4>);
R1' = _mm512_min_epi32(R1,R2);
R2' = _mm512_max_epi32(R1,R2);
```

```
R1' = _mm512_mask_min_epi32
    (R1,0b1010,R1,R2);
R2' = _mm512_mask_max_epi32
    (R2,0b0101,R1,R2);
R1' = _mm512_mask_max_epi32
    (R1,0b0101,R1,R2);
R2' = _mm512_mask_min_epi32
    (R2,0b1010,R1,R2);
```

1 Register Method

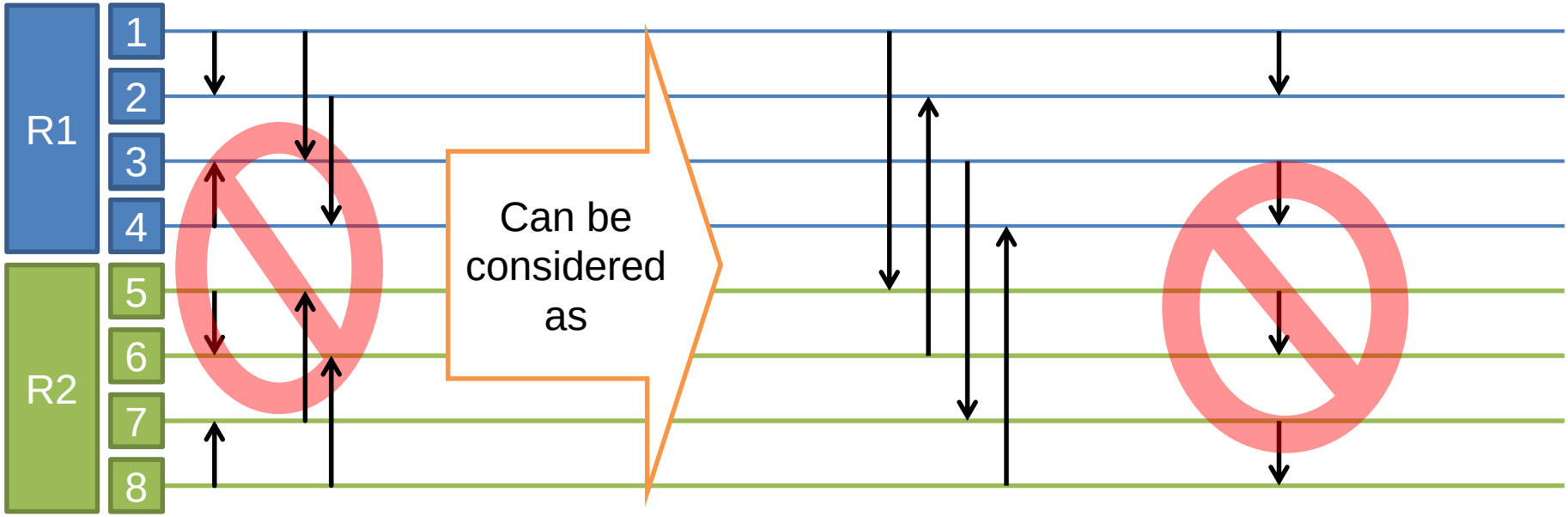
- Sort K elements, K : the length instruction
- Idea: copy R1 to R2 so that comparison becomes valid



4 elements sorting network of 1 Register Method

2 Register Method: Conflict Situation

- Sort $2K$ elements
- Data are loaded into R1 and R2

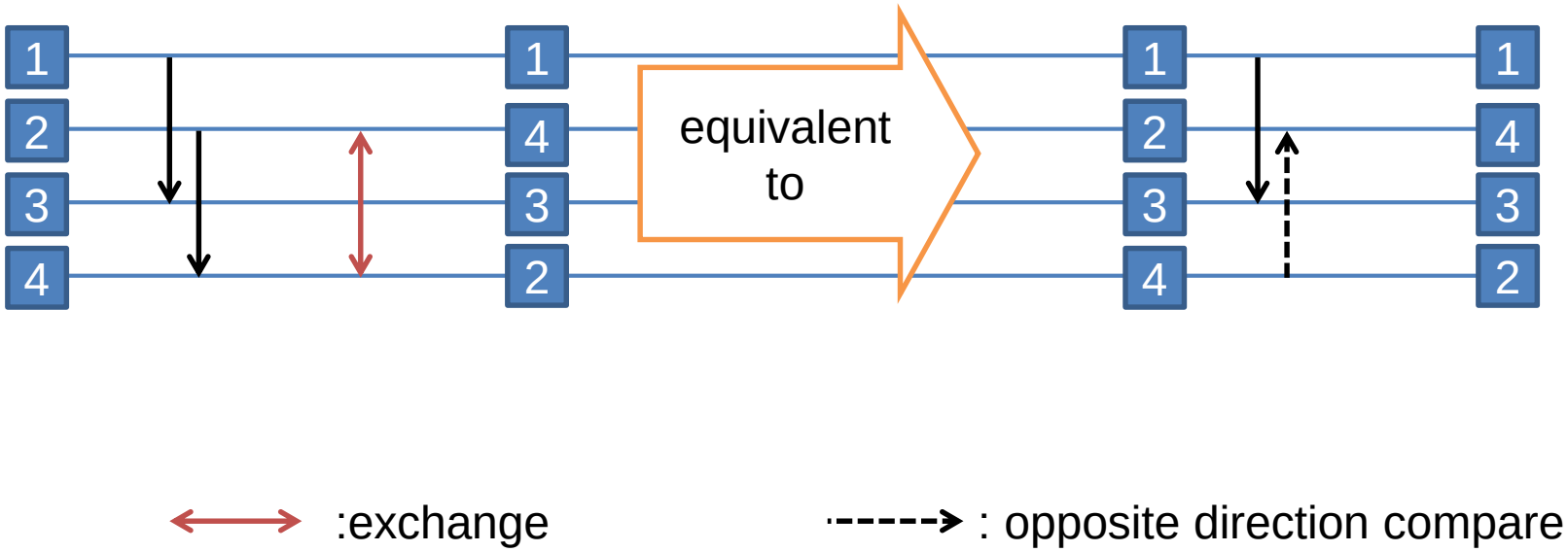


Step 1 2(invalid)

First 2 steps of Bitonic merge sort

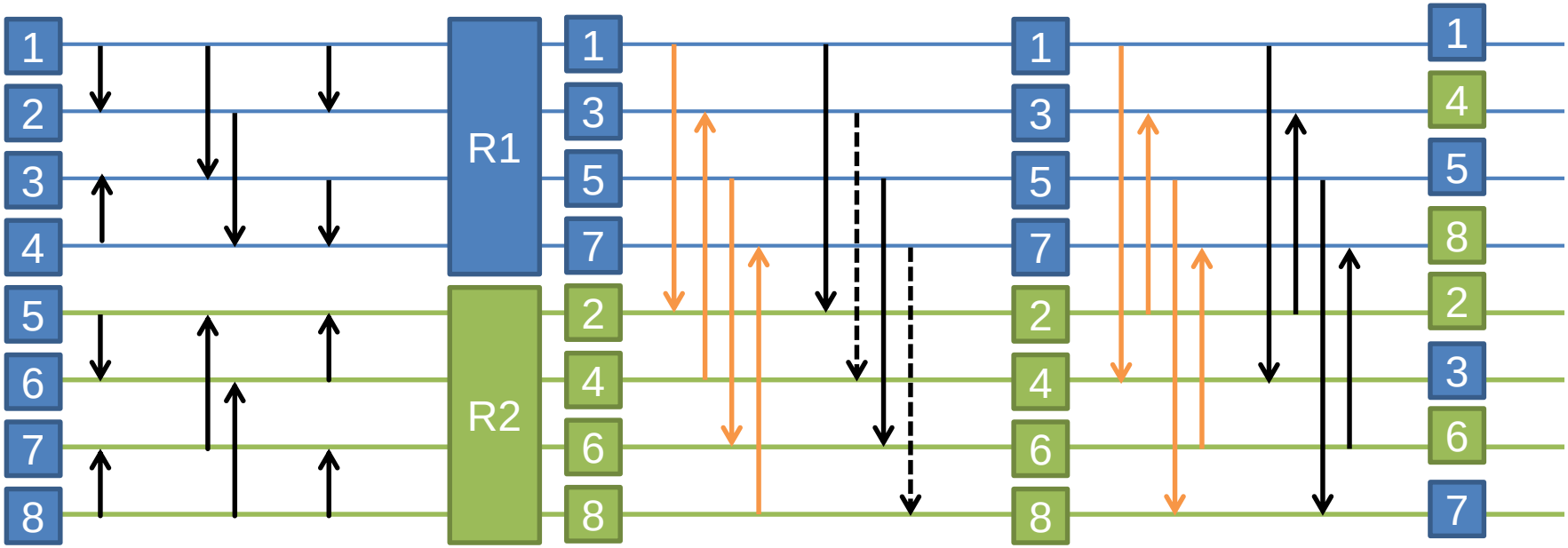
Compare and Exchange

- Exchange: exchange two positions' data
- Compare + Exchange = opposite direction compare



2 Register Method: Solution of Conflict

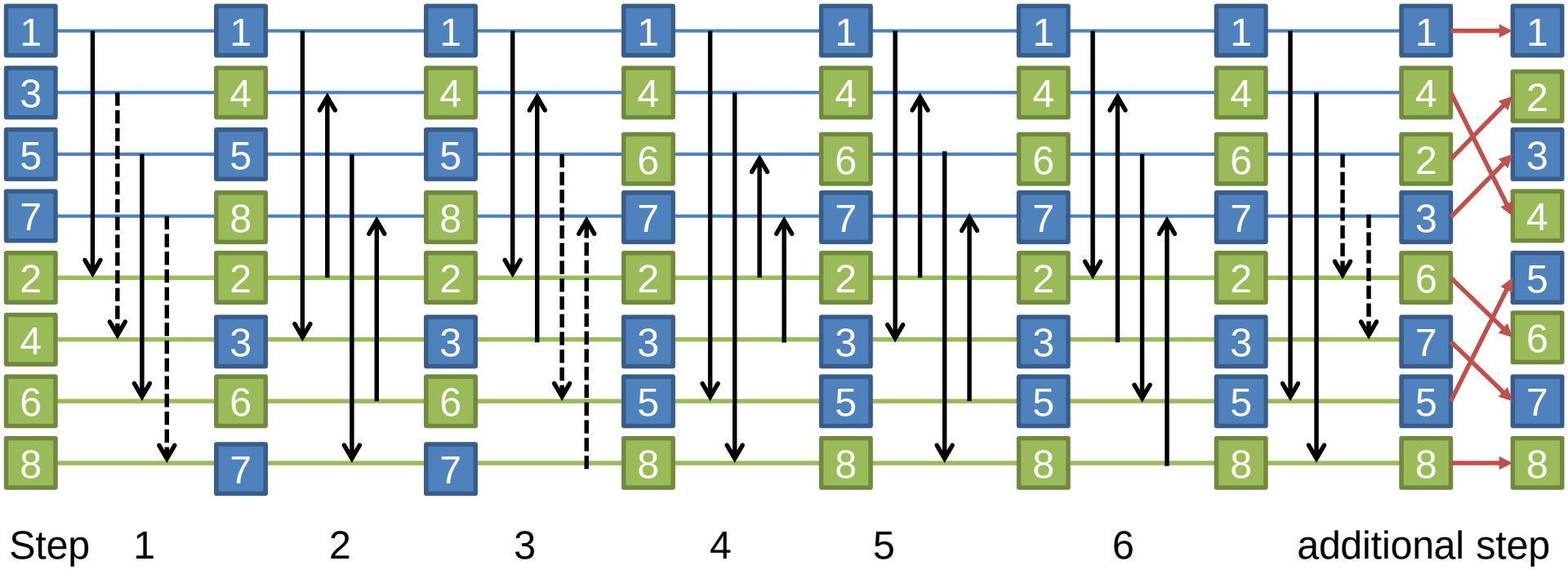
- Look one step ahead.
- Exchange the position and prepare for next step.



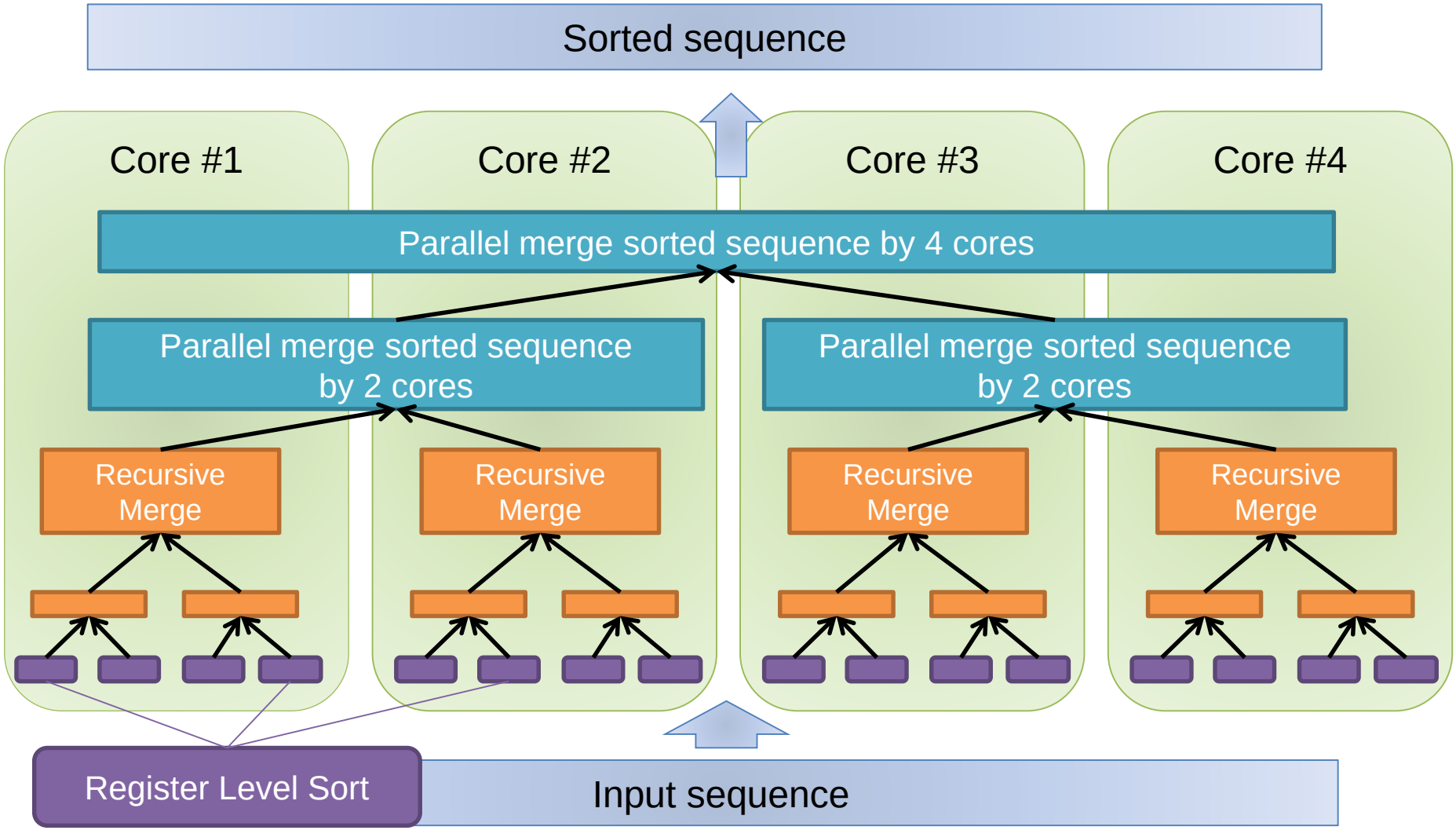
:old direction :actual direction :opposite direction compare

2 Register Method Sorting Network

- Sort network of 8 elements.
- Red line represents permutation.
- Dashed line means opposite direction compare.

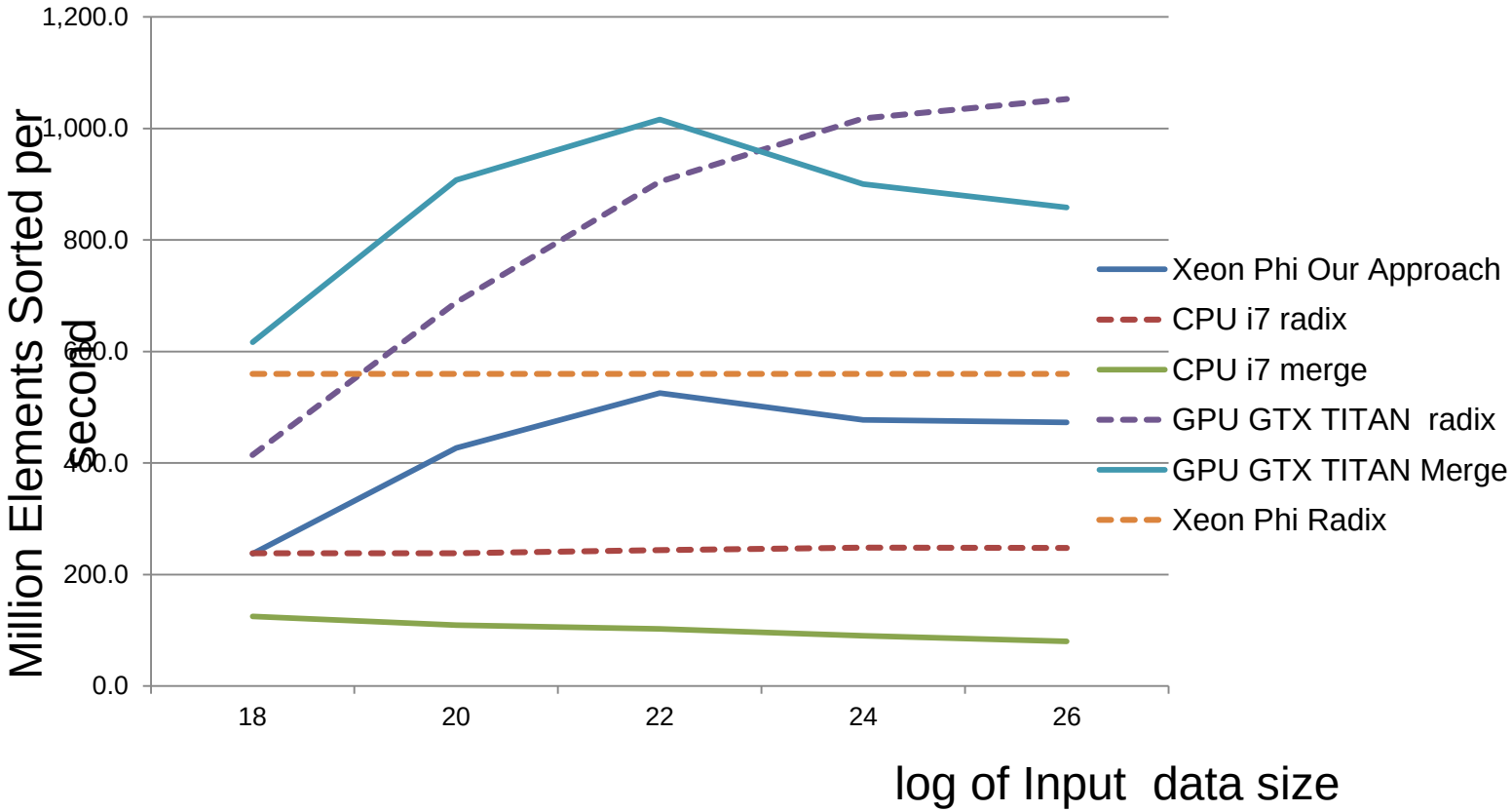


Whole diagram of the algorithm



Performance

- Experiment on Xeon Phi 5100
- AVX-512 contributes 3.7 times speed up.



Conclusion

- Proposed two register level sort:
  - 1 register method
  - 2 register method

- An parallel sort implementation on Xeon Phi

- Q&A