



Arhitecturi Paralele

Abordări probleme paralele

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Elemente preluate din cursul Prof. Ciprian Dobre



FACULTATEA DE
**AUTOMATICĂ ȘI
CALCULATOARE**





Rank Sort

9	4	2	7	6	5	6	1
---	---	---	---	---	---	---	---

1	2	4	5	6	6	7	9
---	---	---	---	---	---	---	---

Rank Sort

9	4	2	7	3	5	6	1
---	---	---	---	---	---	---	---

How many numbers are smaller than me?

How many numbers are smaller than me?

How many numbers are smaller than me?

How many numbers are smaller than me?

How many numbers are smaller than me?

How many numbers are smaller than me?

How many numbers are smaller than me?

How many numbers are smaller than me?

Rank Sort

9	4	2	7	3	5	6	1
---	---	---	---	---	---	---	---

0

How many numbers are smaller than me?

How many numbers are smaller than me?

How many numbers are smaller than me?

How many numbers are smaller than me?

How many numbers are smaller than me?

How many numbers are smaller than me?

How many numbers are smaller than me?

Rank Sort

9	4	2	7	3	5	6	1
---	---	---	---	---	---	---	---

0

5

How many numbers are smaller than me?

How many numbers are smaller than me?

How many numbers are smaller than me?

How many numbers are smaller than me?

How many numbers are smaller than me?

How many numbers are smaller than me?

Rank Sort

9	4	2	7	3	5	6	1
---	---	---	---	---	---	---	---

0

5

4

How many numbers are smaller than me?

How many numbers are smaller than me?

How many numbers are smaller than me?

How many numbers are smaller than me?

How many numbers are smaller than me?

Rank Sort

9	4	2	7	3	5	6	1
---	---	---	---	---	---	---	---

0

5

4

2

How many numbers are smaller than me?

How many numbers are smaller than me?

How many numbers are smaller than me?

How many numbers are smaller than me?

Rank Sort

9	4	2	7	3	5	6	1
---	---	---	---	---	---	---	---

0

5

4

2

6

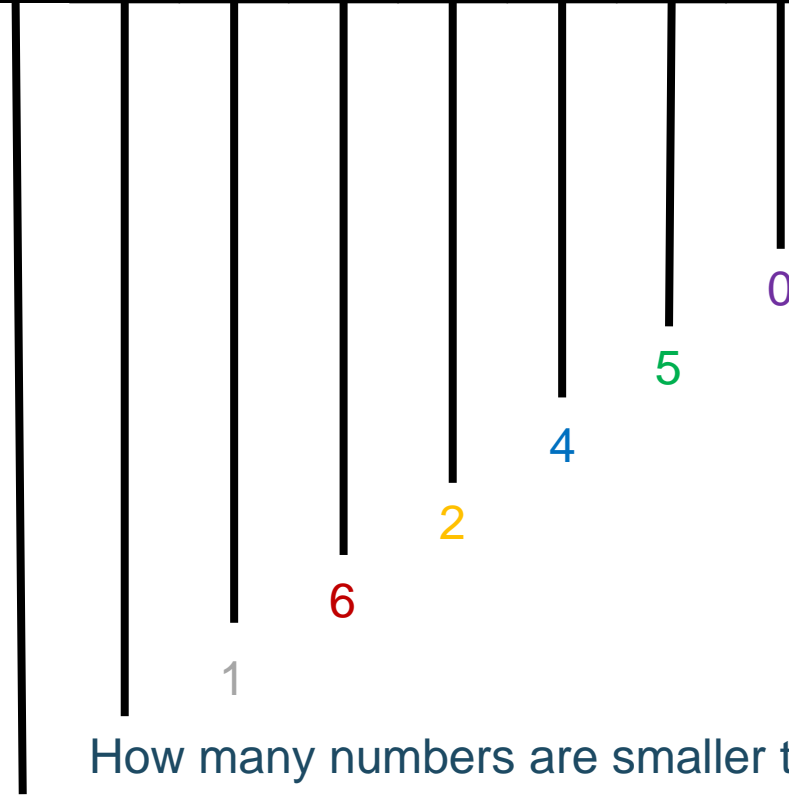
How many numbers are smaller than me?

How many numbers are smaller than me?

How many numbers are smaller than me?

Rank Sort

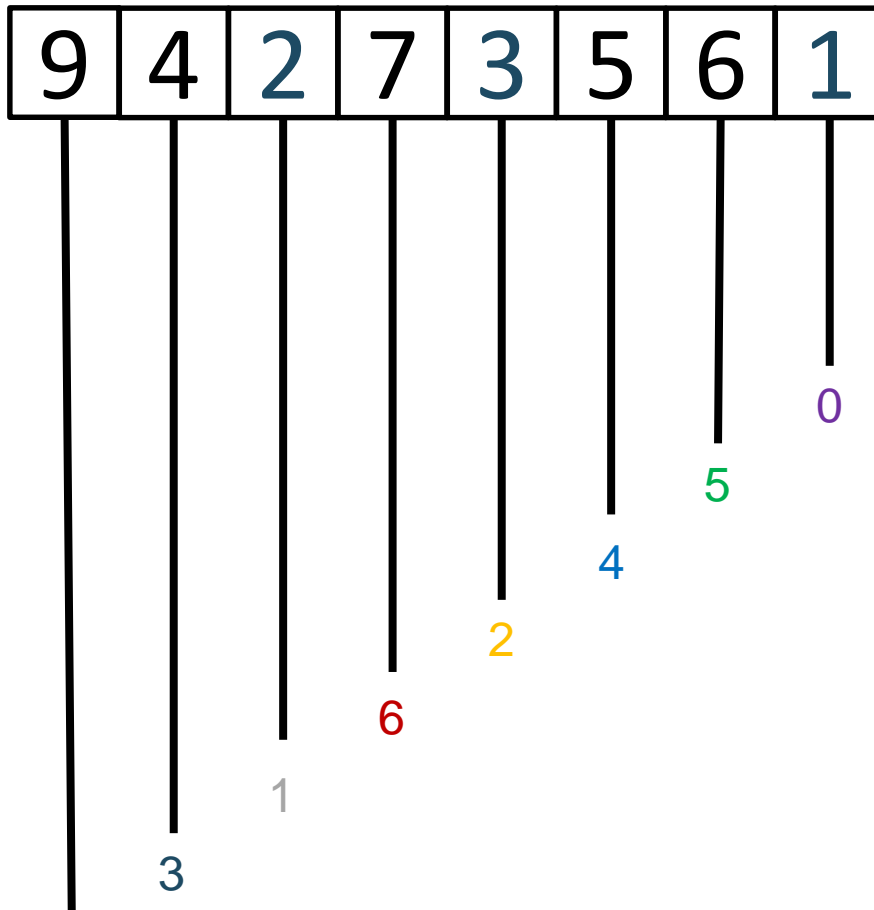
9	4	2	7	3	5	6	1
---	---	---	---	---	---	---	---



How many numbers are smaller than me?

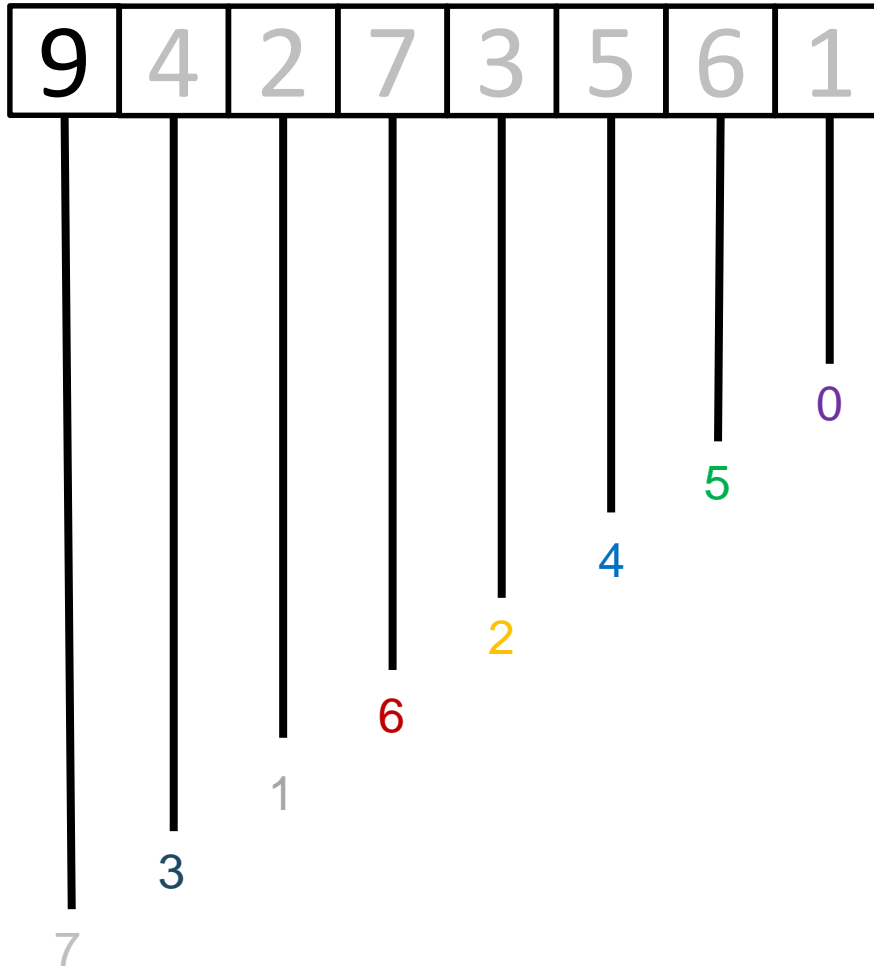
How many numbers are smaller than me?

Rank Sort



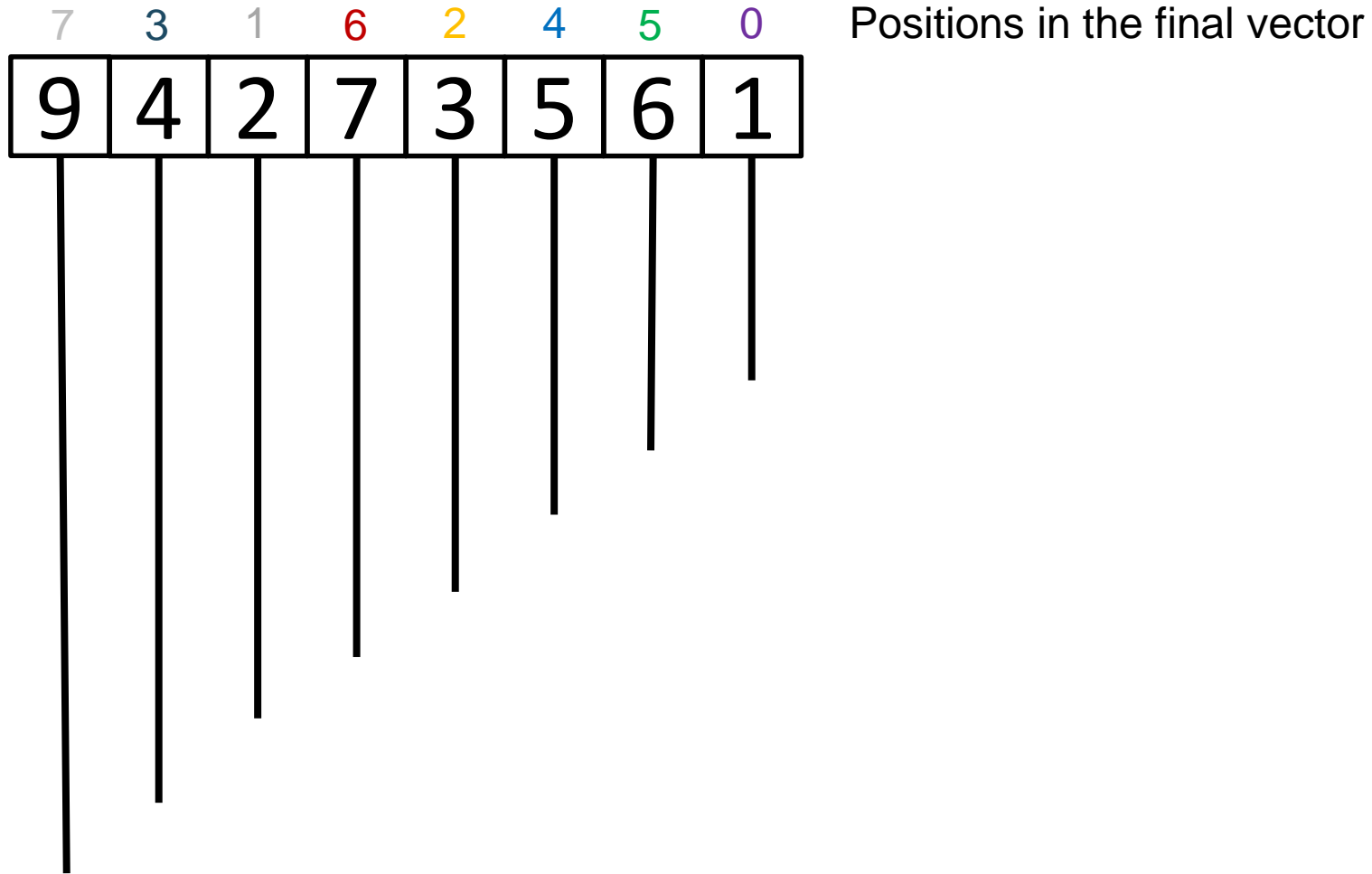
How many numbers are smaller than me?

Rank Sort

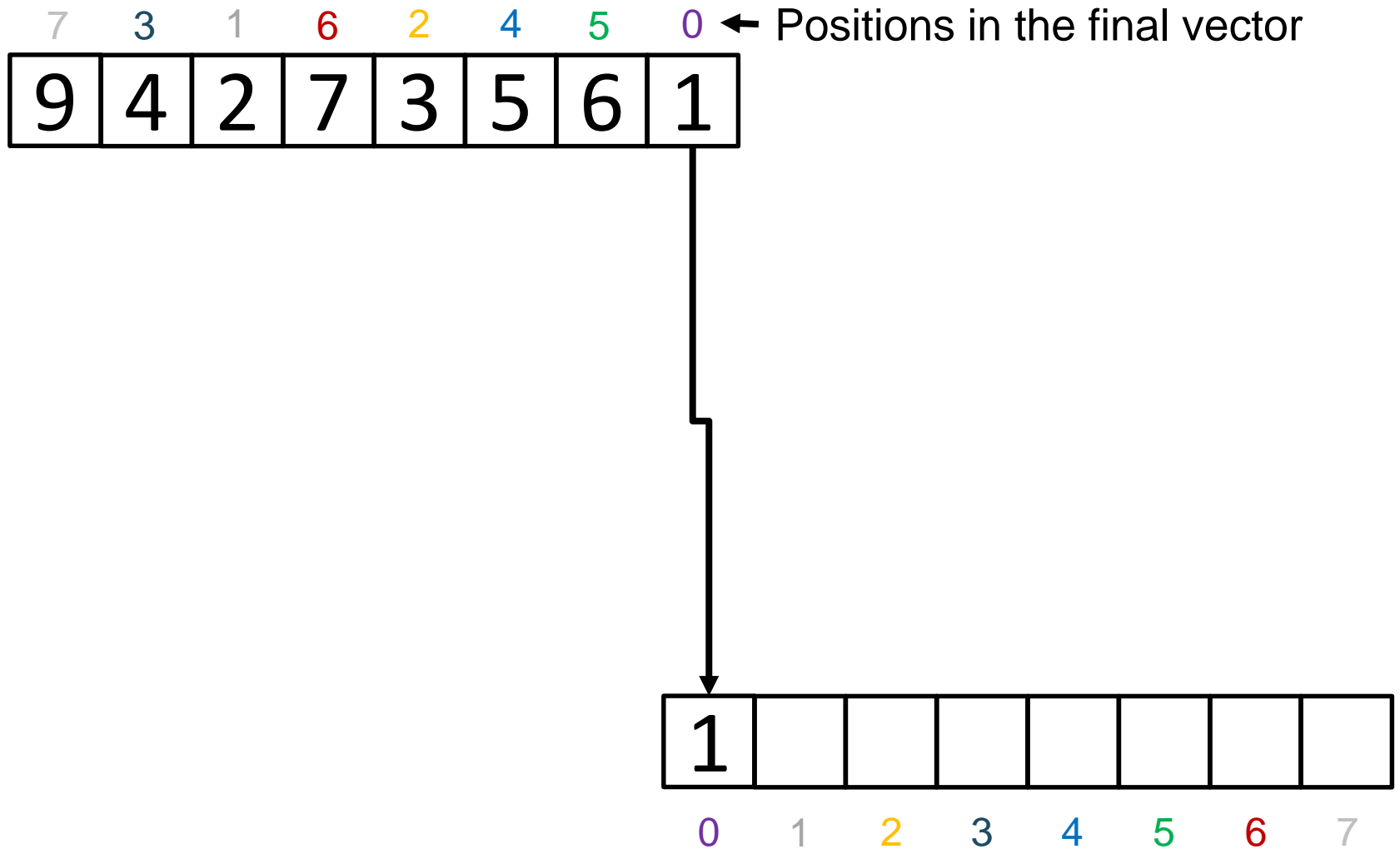




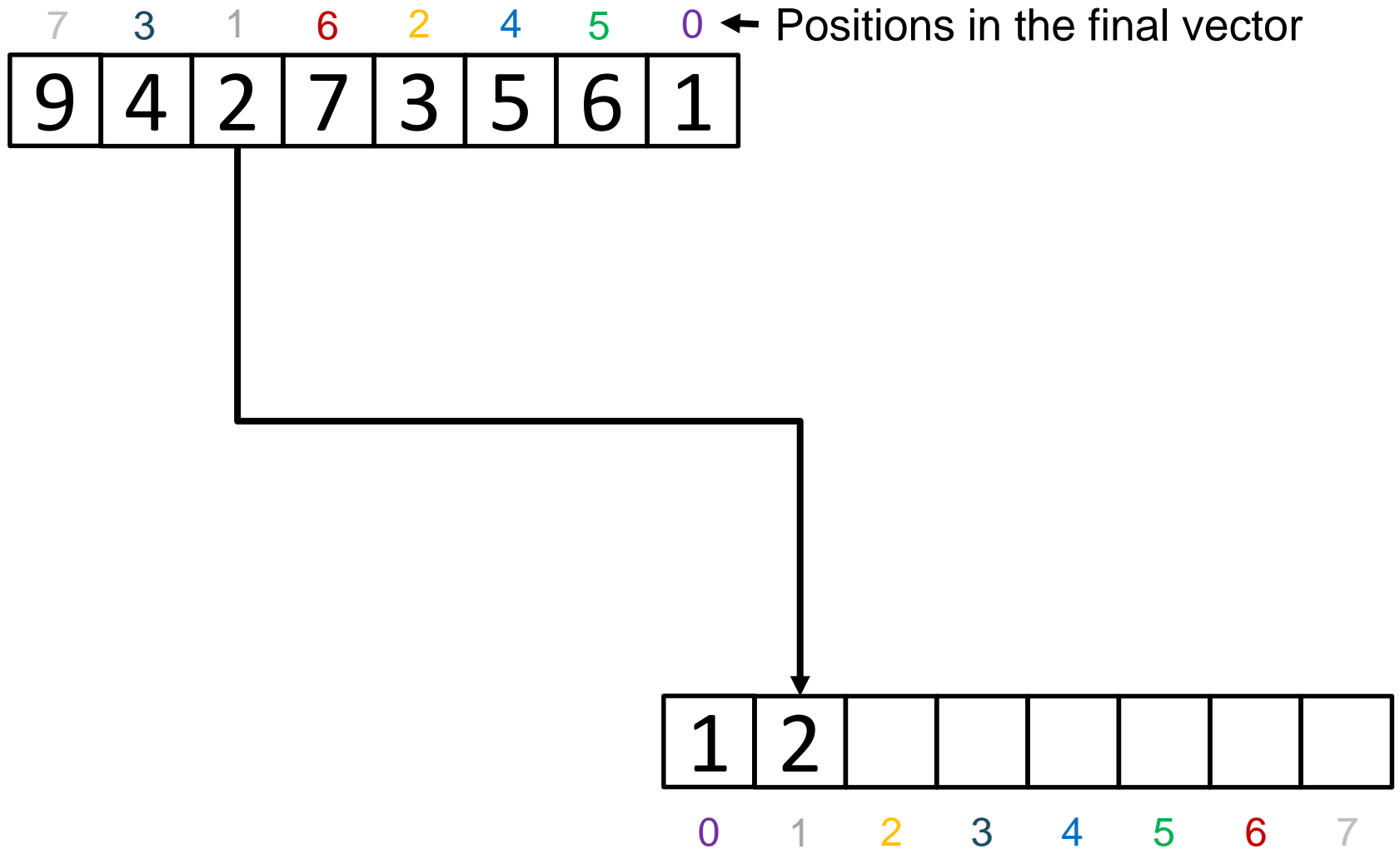
Rank Sort



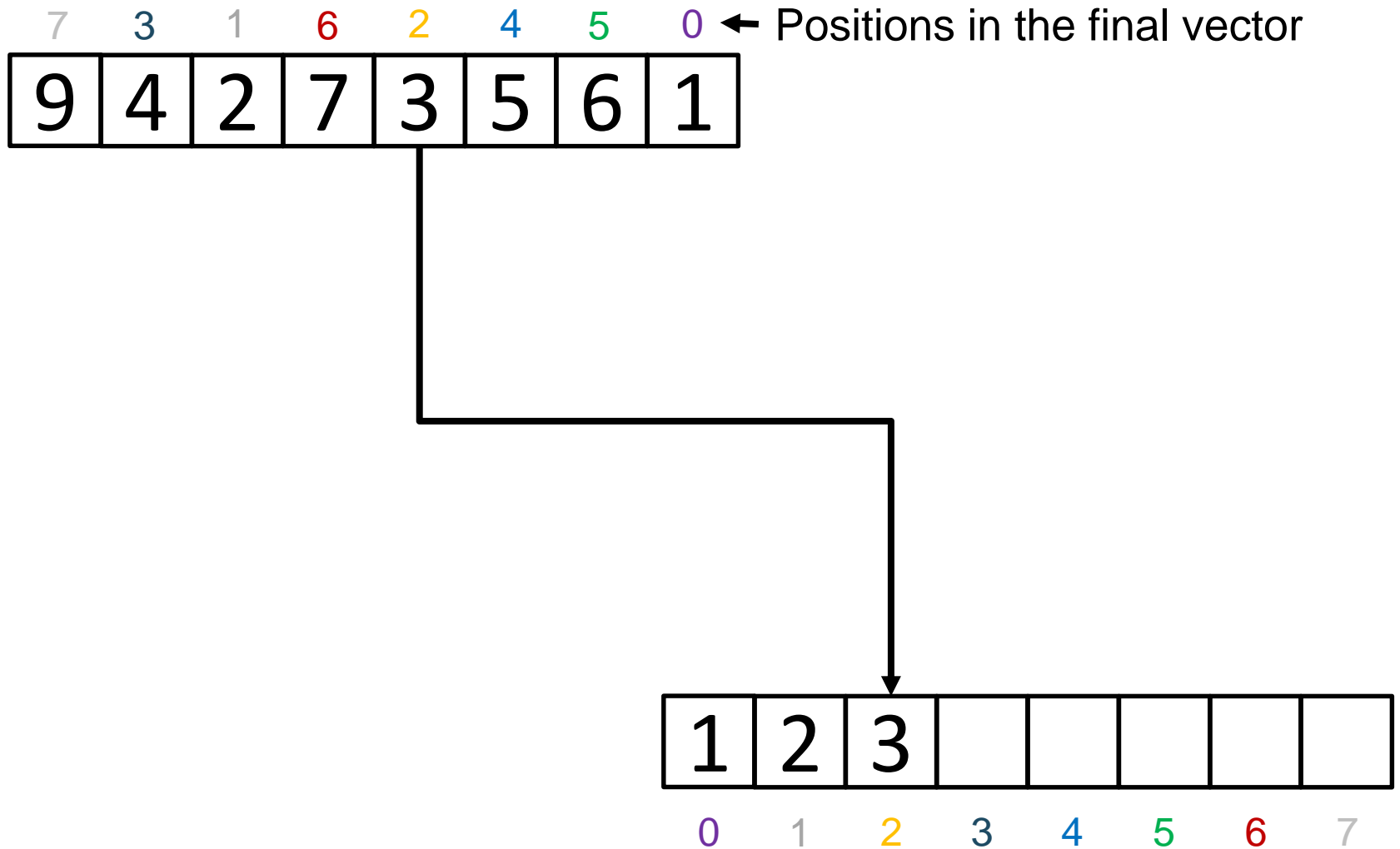
Rank Sort



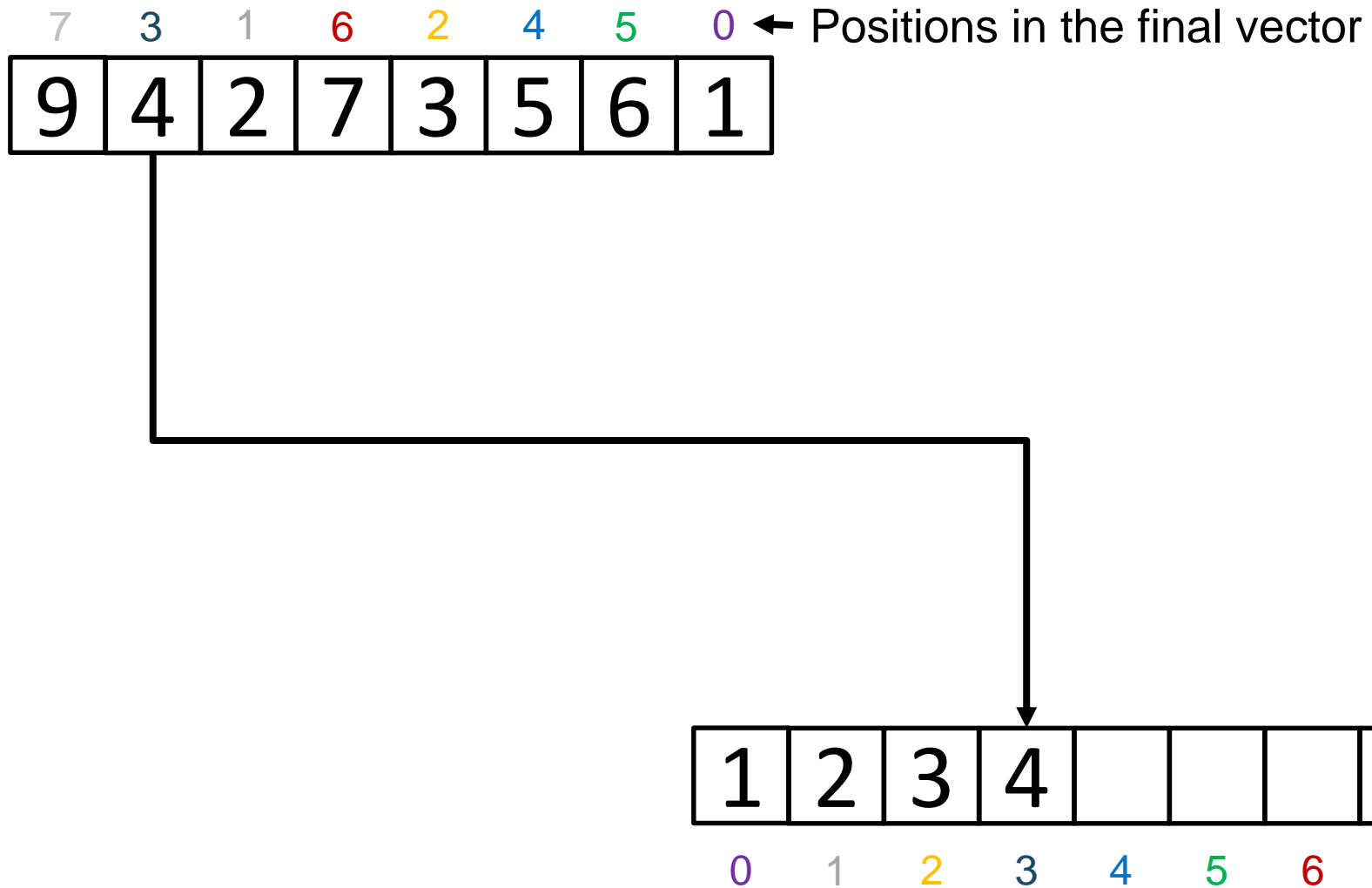
Rank Sort



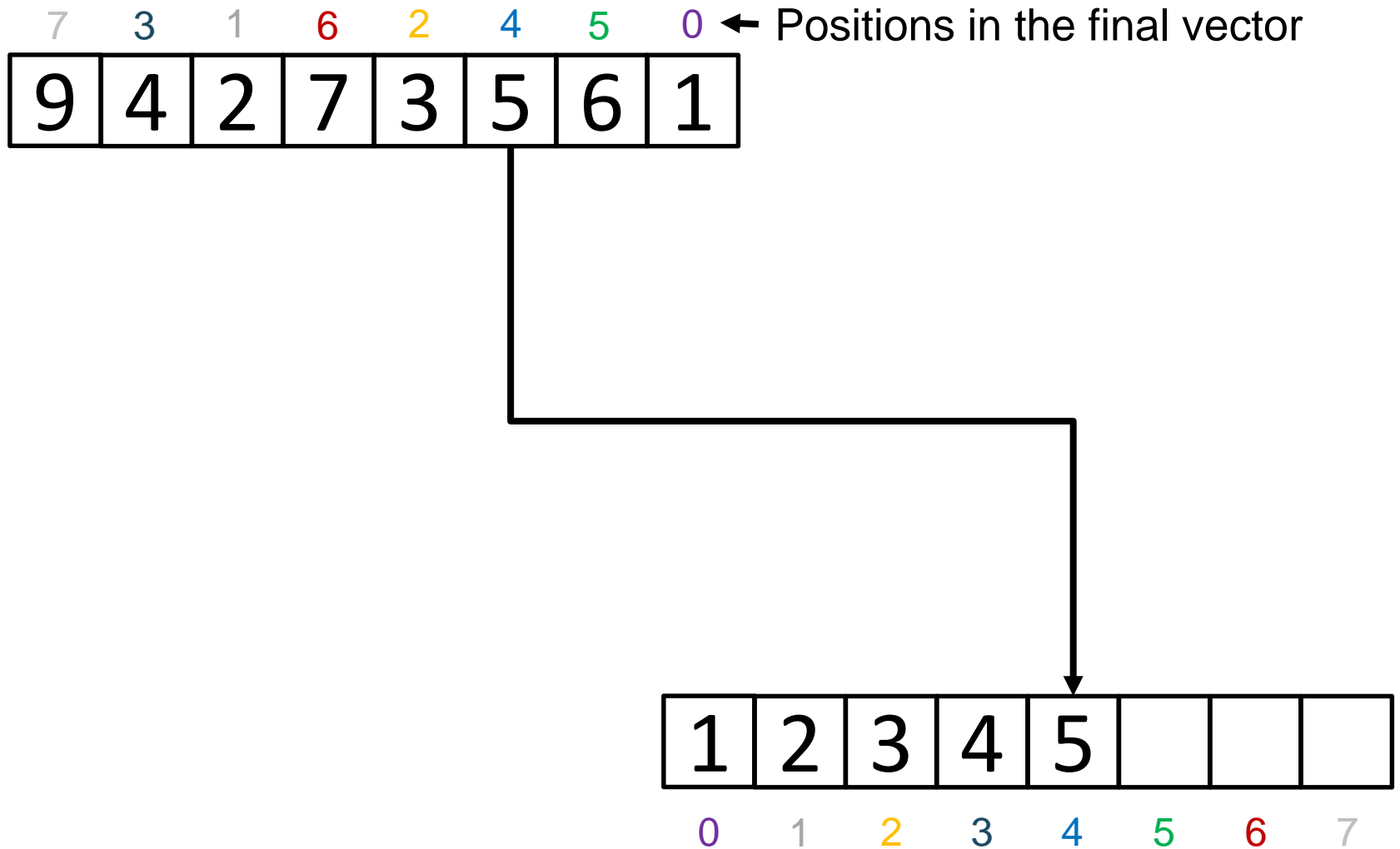
Rank Sort



Rank Sort

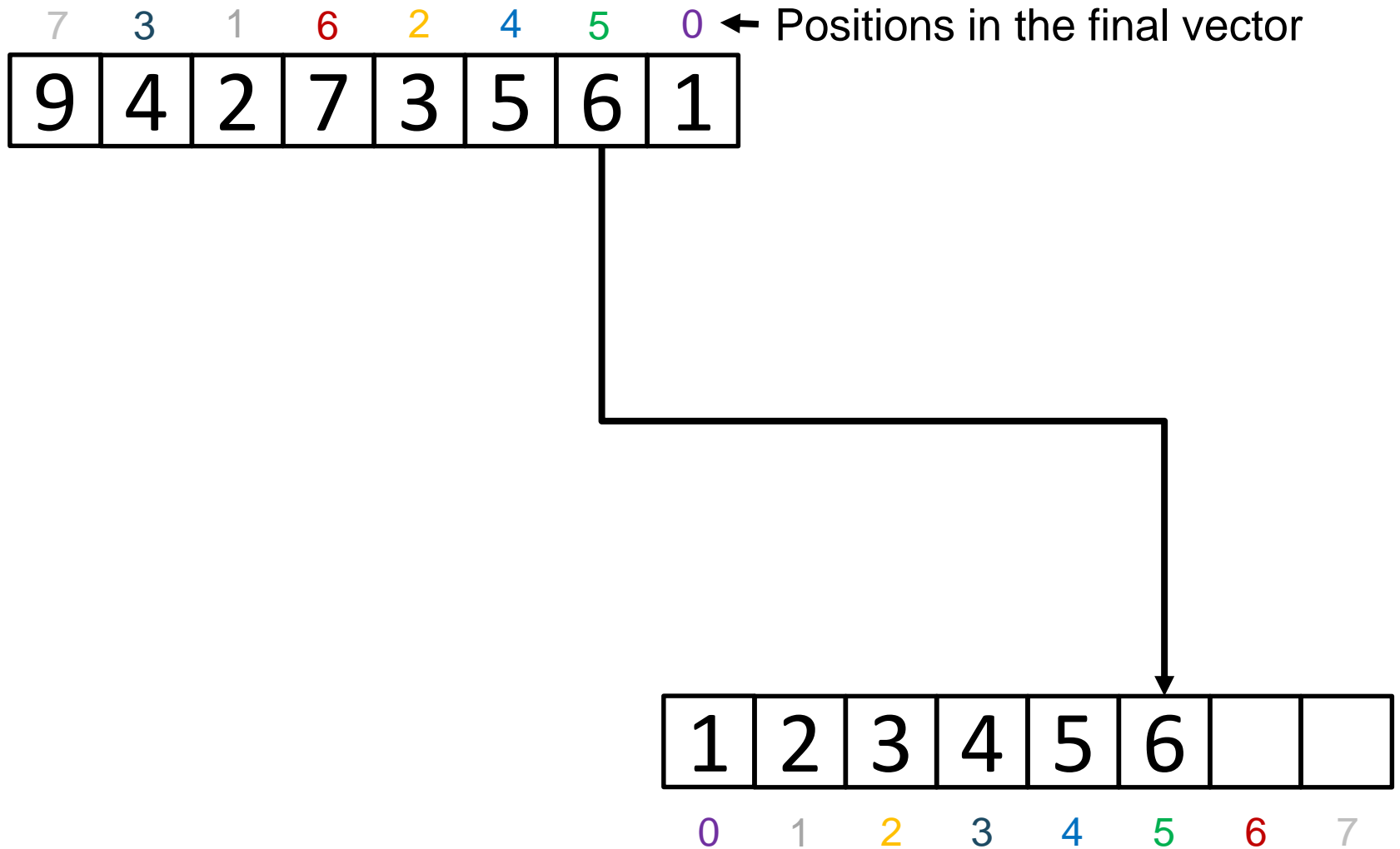


Rank Sort

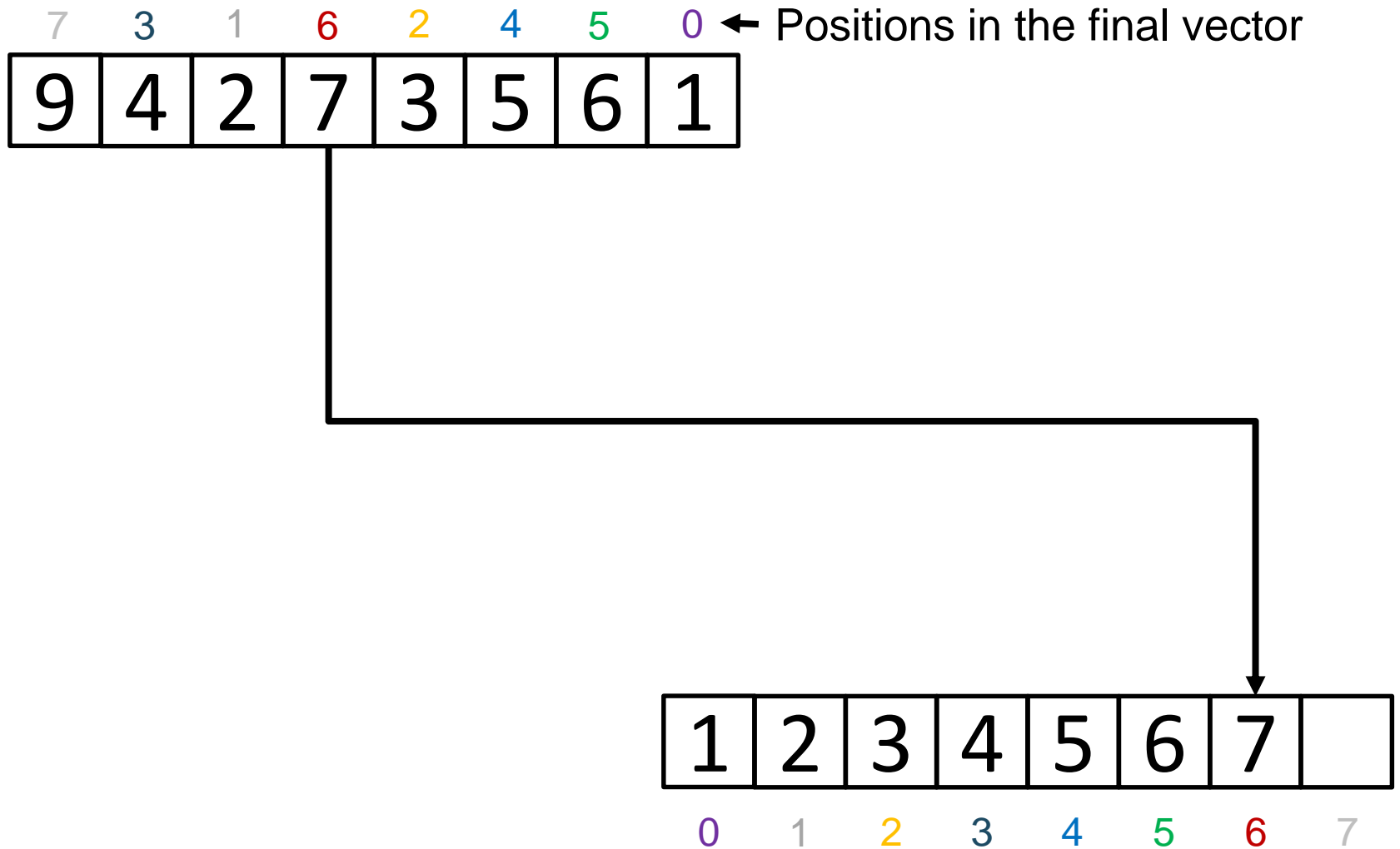




Rank Sort

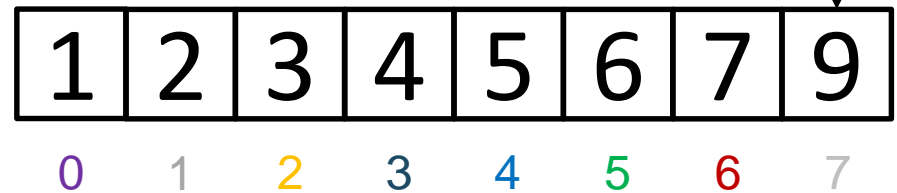
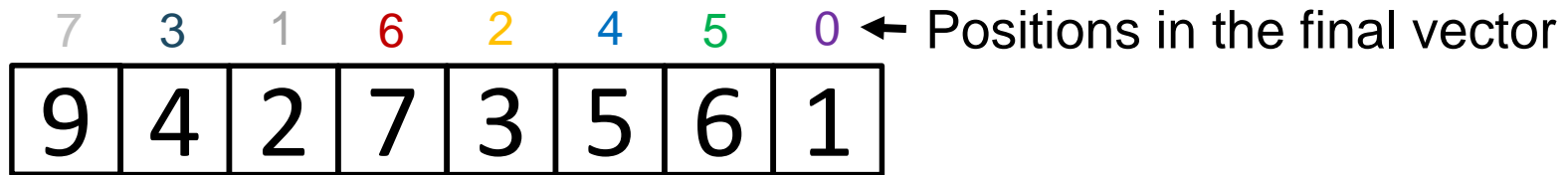


Rank Sort





Rank Sort





Parallel Rank Sort

9	4	2	7	6	5	6	1
---	---	---	---	---	---	---	---

1	2	4	5	6	6	7	9
---	---	---	---	---	---	---	---

Parallel Rank Sort

9	4	2	7	3	5	6	1
---	---	---	---	---	---	---	---

All question can be answered in parallel

How many numbers are smaller than me?

How many numbers are smaller than me?

How many numbers are smaller than me?

How many numbers are smaller than me?

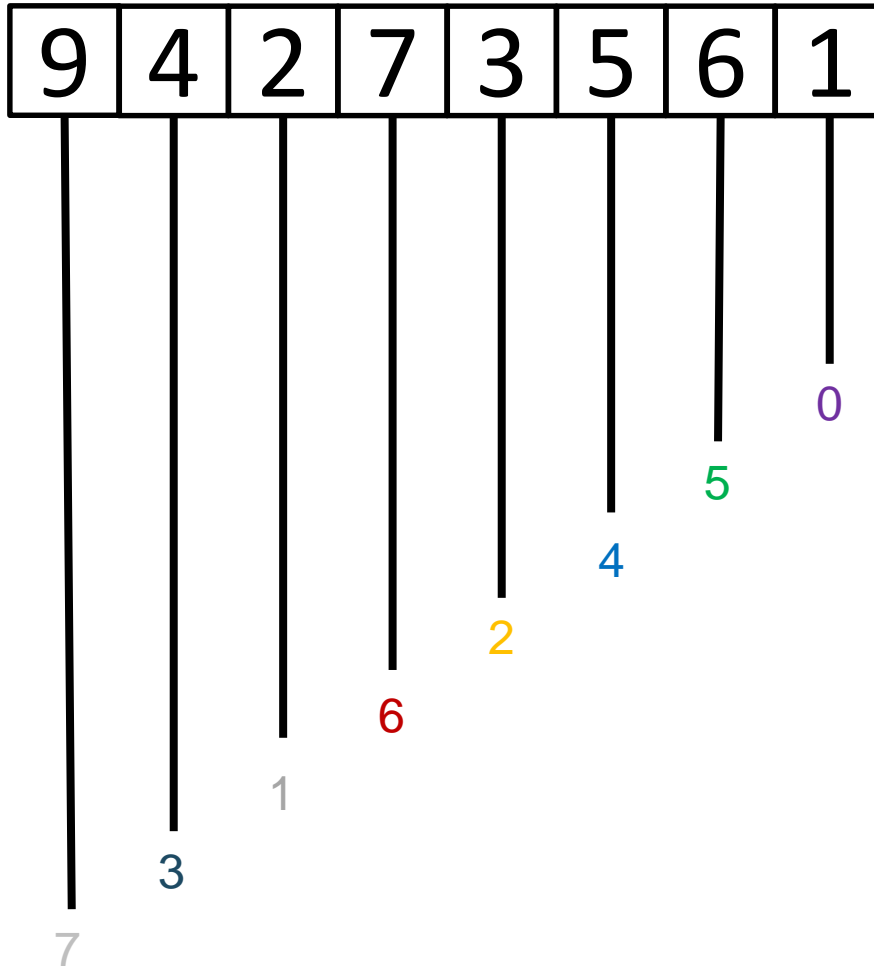
How many numbers are smaller than me?

How many numbers are smaller than me?

How many numbers are smaller than me?

How many numbers are smaller than me?

Parallel Rank Sort



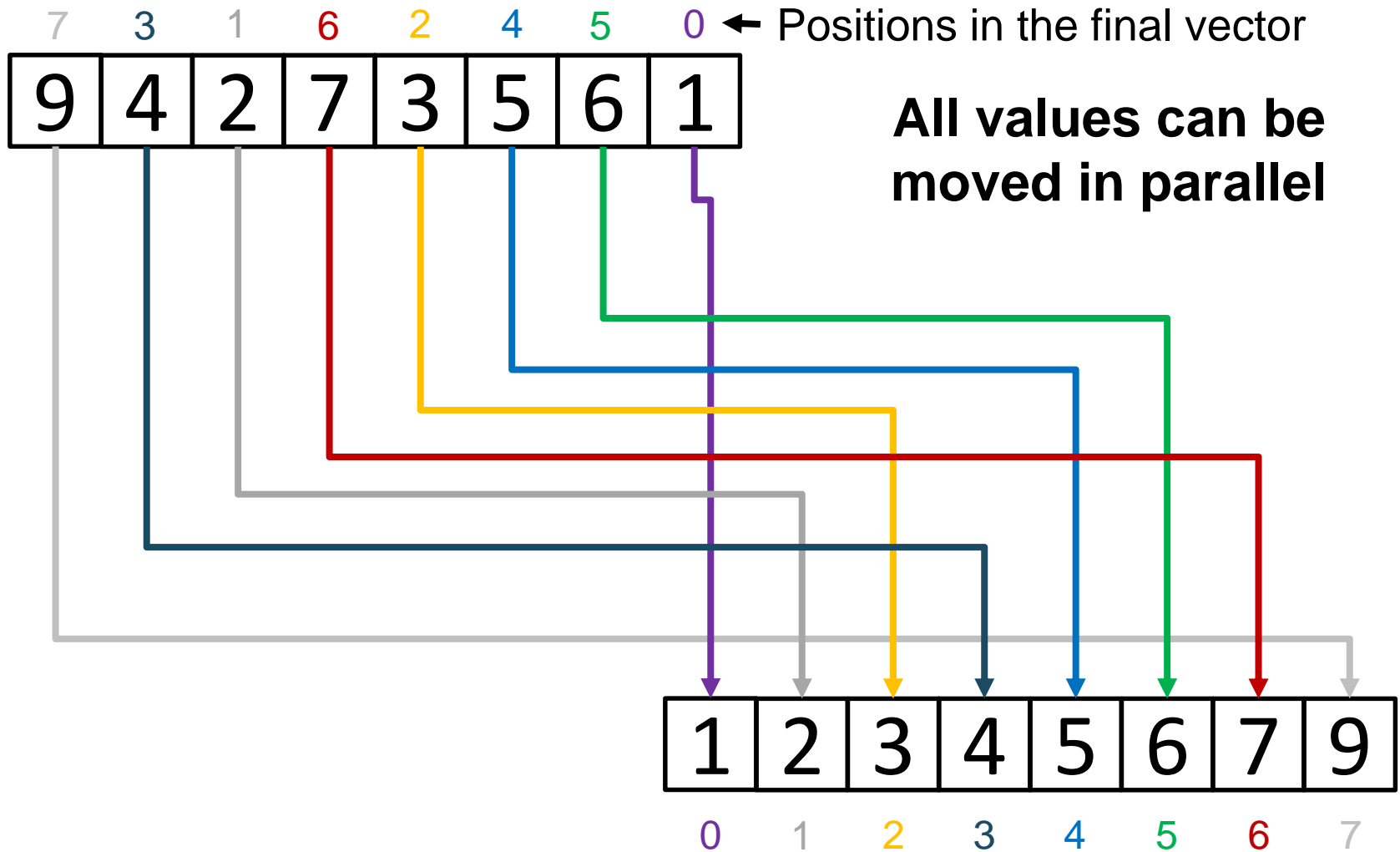
All question can be answered in parallel



Parallel Rank Sort



Parallel Rank Sort







Binary Search

Searching for 3

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1	2	3	5	5	6	6	7	7	7	8	8	9	9	9



Binary Search

Searching for **3**

Interest area **0** **15**

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1	2	3	5	5	6	6	7	7	7	8	8	9	9	9



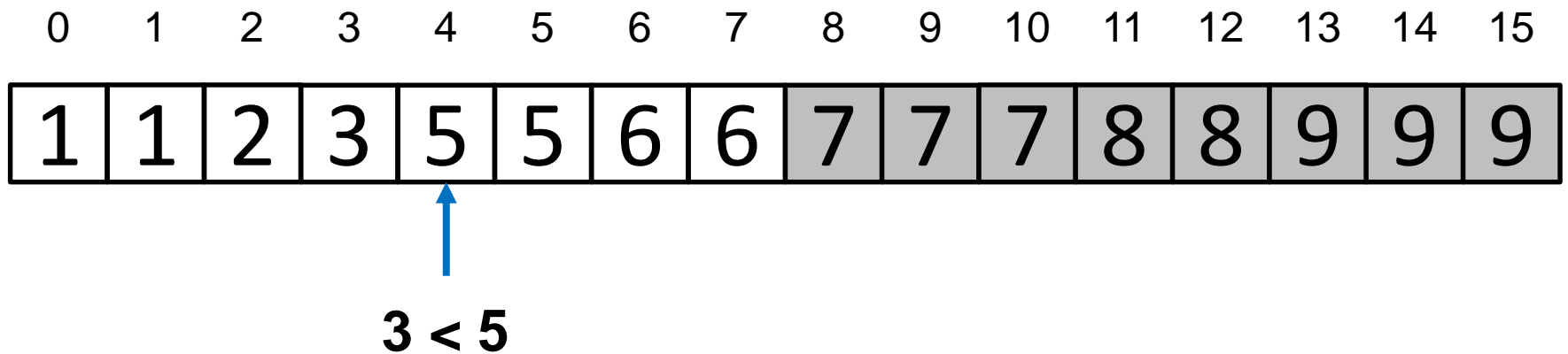
$3 < 7$



Binary Search

Searching for **3**

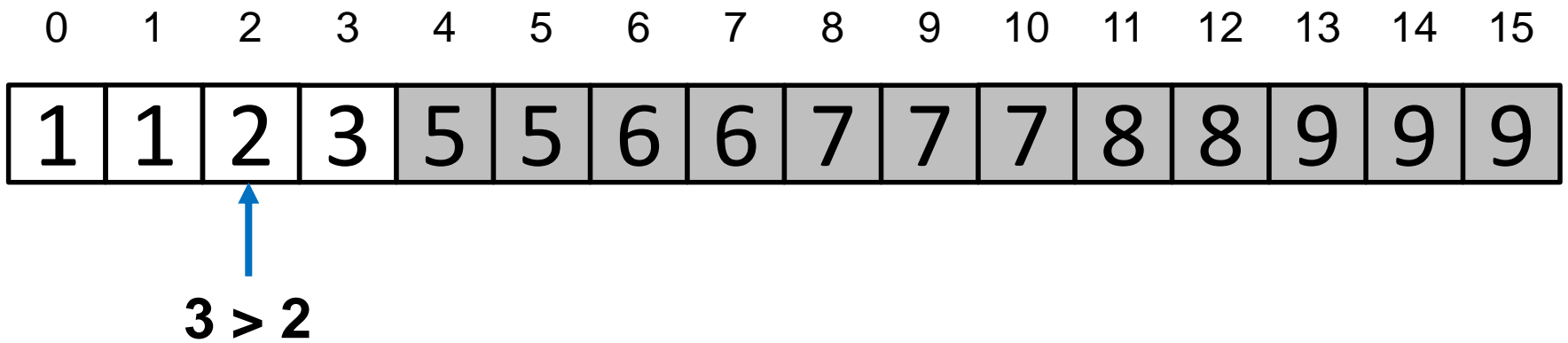
Interest area **0** **7**



Binary Search

Searching for 3

Interest area 0 3




Binary Search

Searching for 3

Interest area 3 3

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1	2	3	5	5	6	6	7	7	7	8	8	9	9	9


3 = 3
end

$O(\log_2(n))$ time



Parallel Search

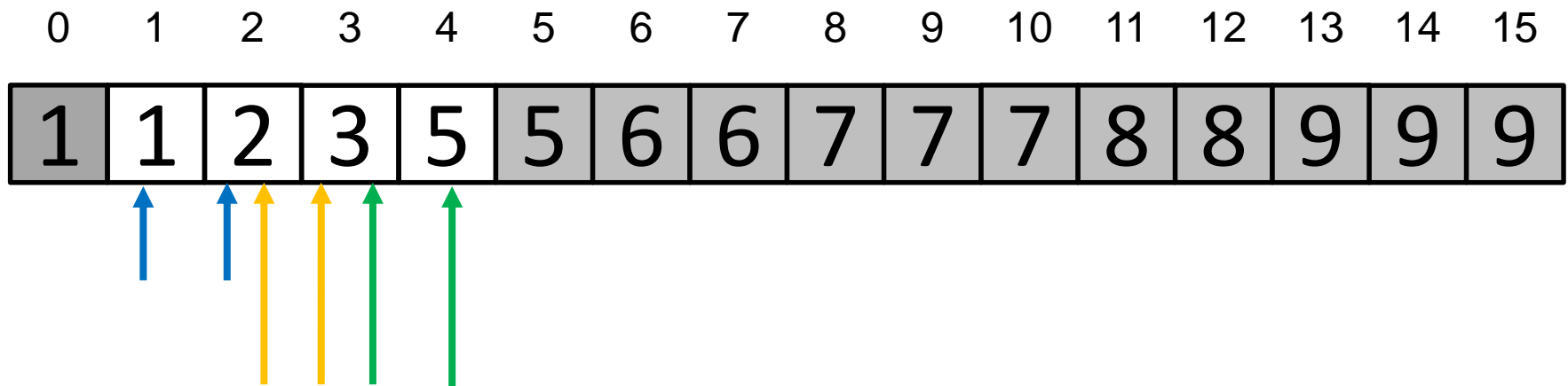
Searching for 3

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1	2	3	5	5	6	6	7	7	7	8	8	9	9	9

Parallel Search

Searching for 3

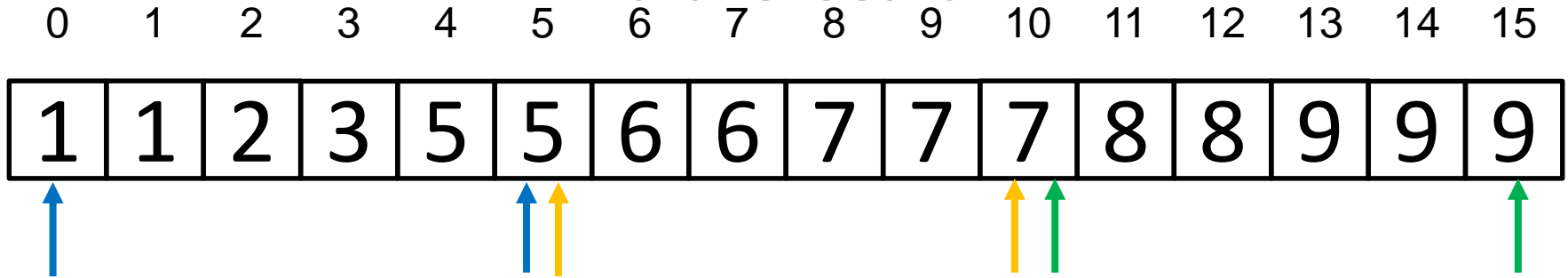
Interest area 1 4



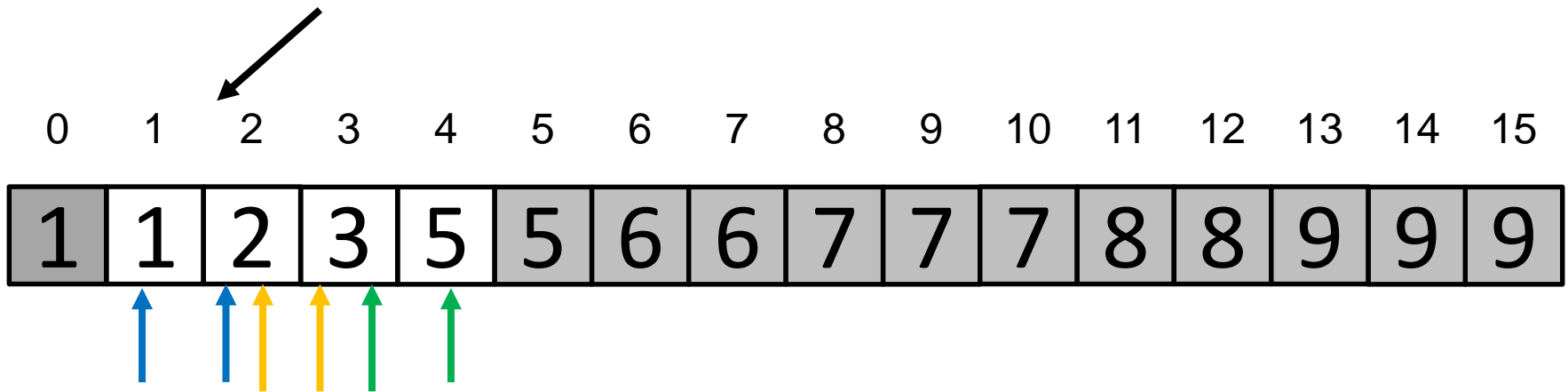
I found the element

I found the element

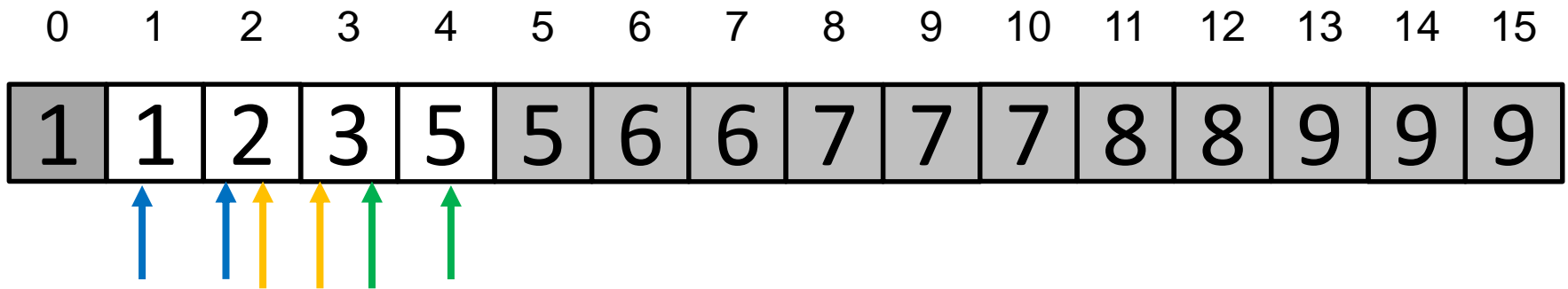
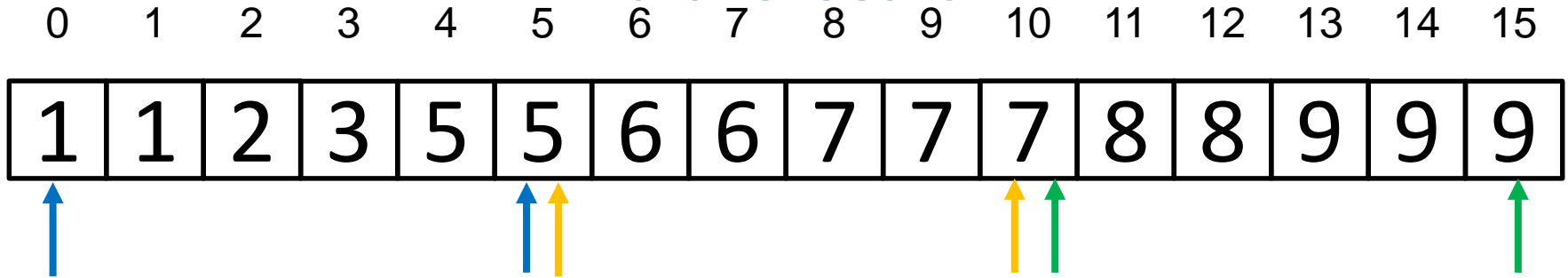
Parallel Search



Operations can **NOT** be executed in parallel



Parallel Search



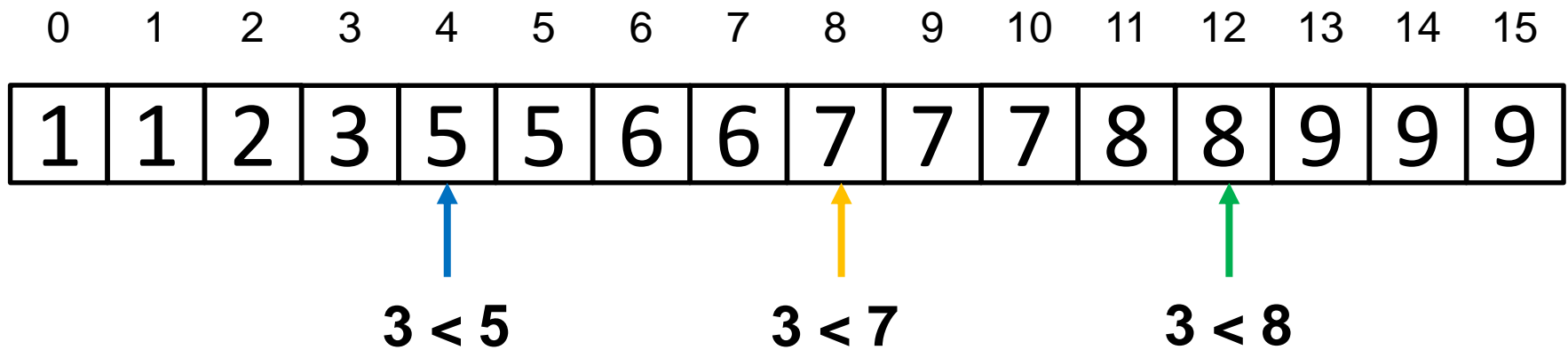


Parallel Search – solution 2 (fewer threads)

Parallel Search – solution 2 (fewer threads)

Searching for **3**

Interest area **0** **15**



Operations can be executed in parallel

Parallel Search

Searching for 3

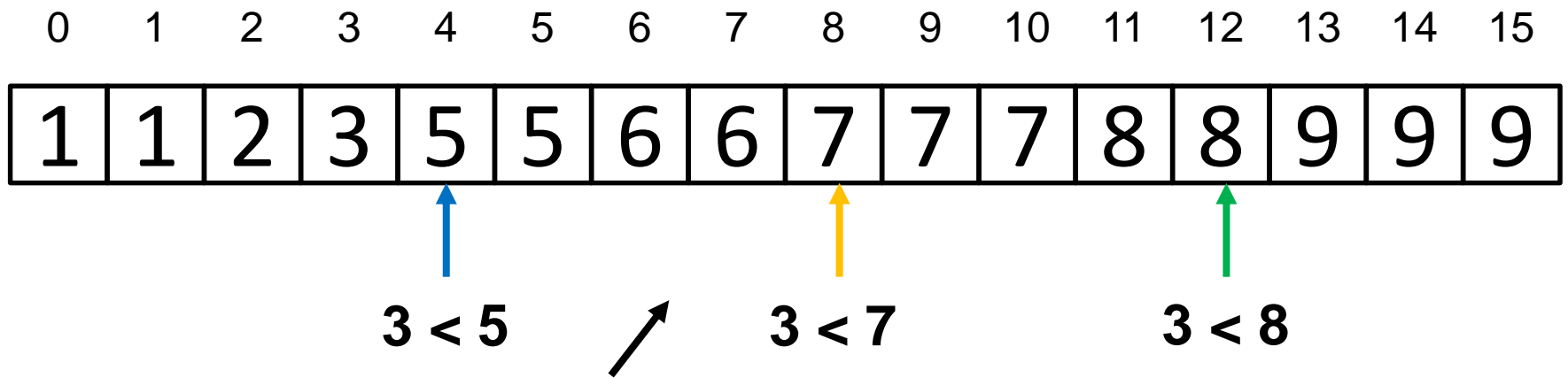
Interest area 0 3

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1	2	3	5	5	6	6	7	7	7	8	8	9	9	9

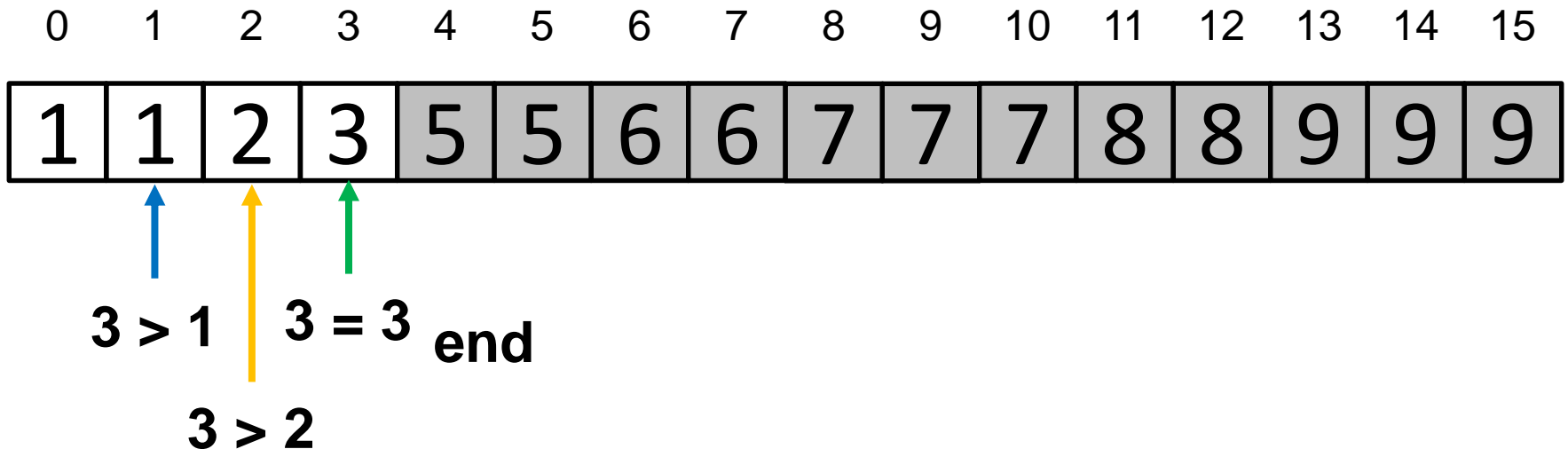
$3 > 1$
 $3 > 2$
 $3 = 3$ end

$O(\log_p(n))$ time

Parallel Search



Operations can **NOT** be executed in parallel



Parallel Search

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1	2	3	5	5	6	6	7	7	7	8	8	9	9	9



$3 < 5$



$3 < 7$



$3 < 8$



0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1	2	3	5	5	6	6	7	7	7	8	8	9	9	9



$3 > 1$



$3 > 2$

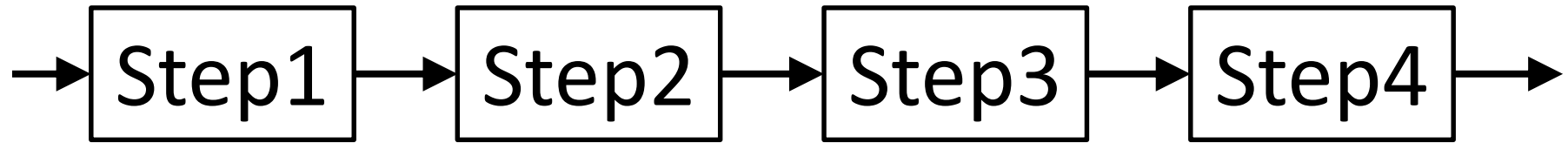


$3 = 3$



Pipeline

- CPU Instruction pipeline
- Graphics pipeline
- Various algorithms



Un pas poate fi executat de:

- thread
- process
- element hardware

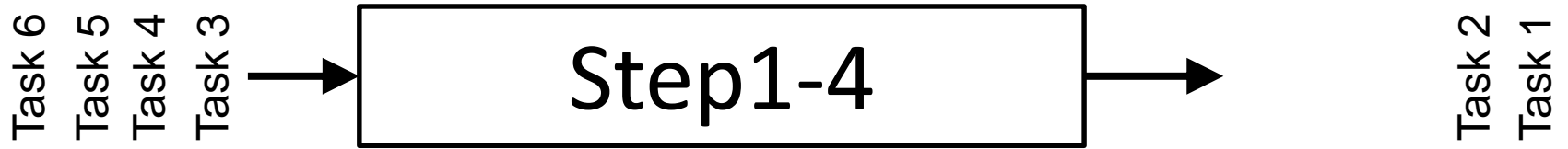
Without Pipeline



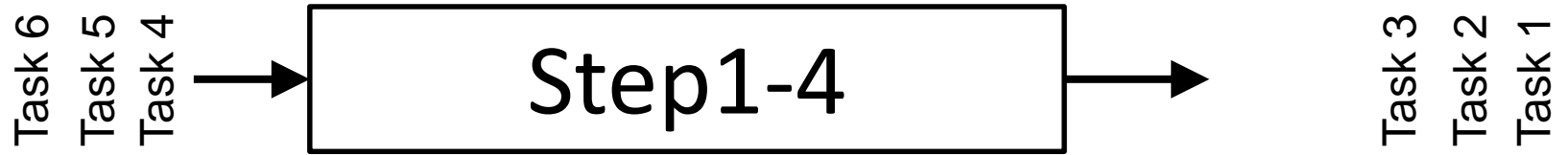
Without Pipeline



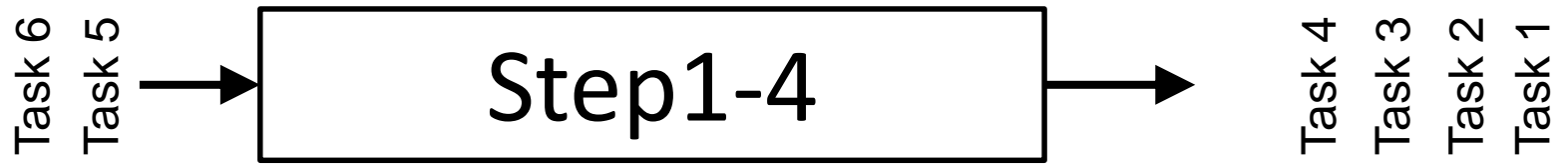
Without Pipeline



Without Pipeline



Without Pipeline



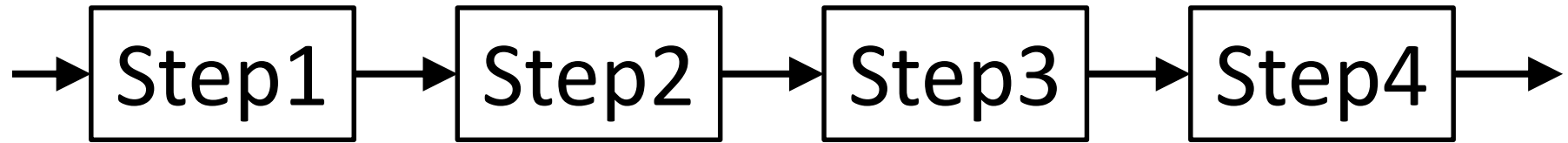
Without Pipeline



$$total_execution_time = task_execution_time * number_of_tasks$$

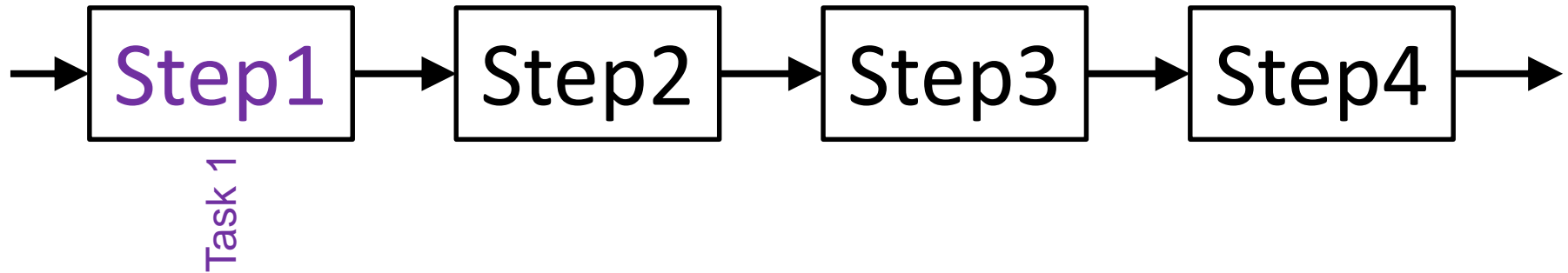
Pipeline

Task 6
Task 5
Task 4
Task 3
Task 2
Task 1



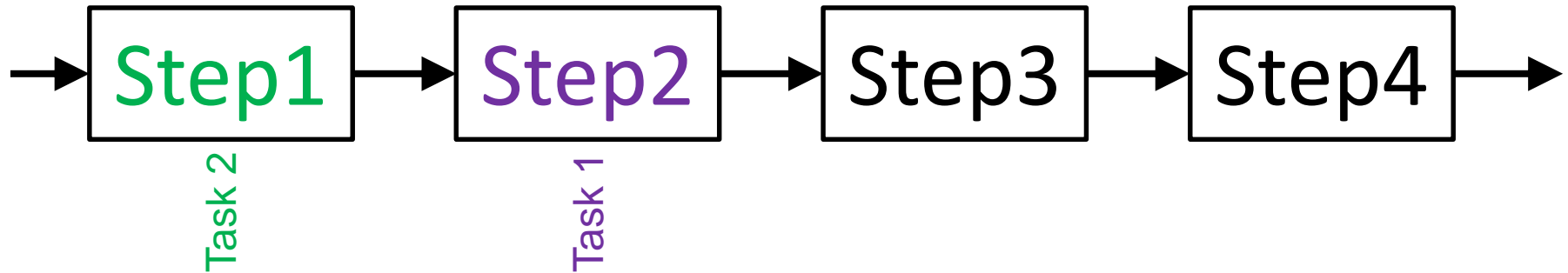
Pipeline

Task 6
Task 5
Task 4
Task 3
Task 2



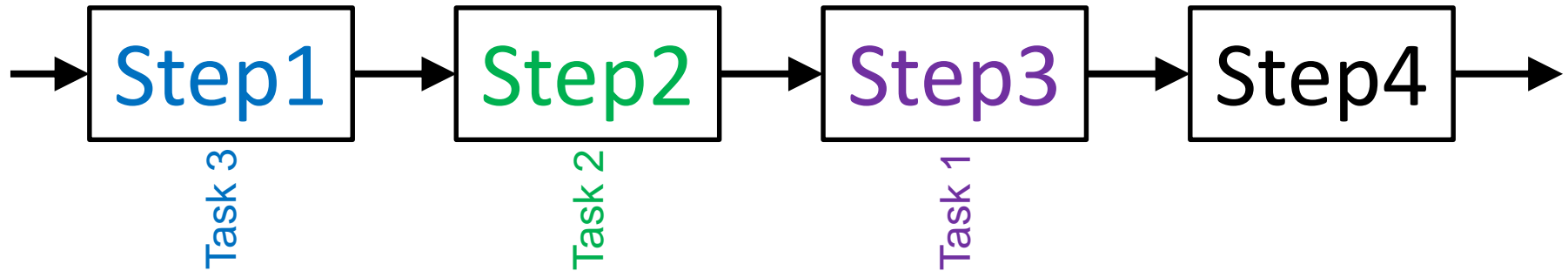
Pipeline

Task 6
Task 5
Task 4
Task 3



Pipeline

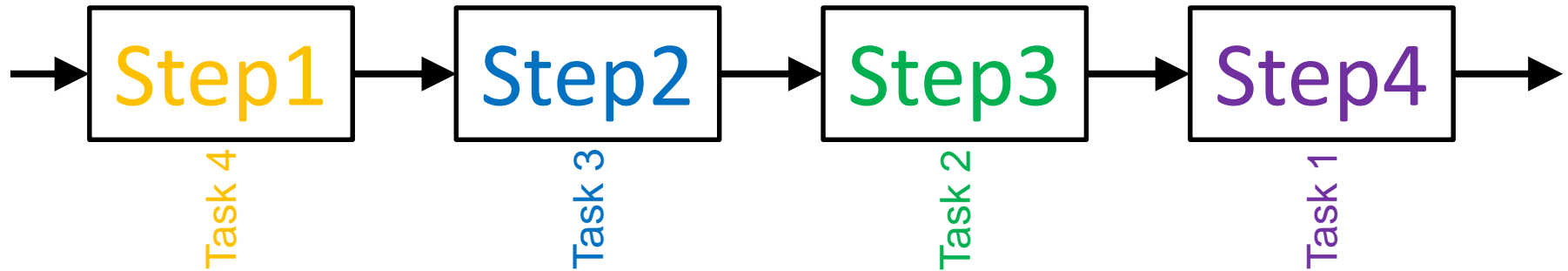
Task 6
Task 5
Task 4



Pipeline

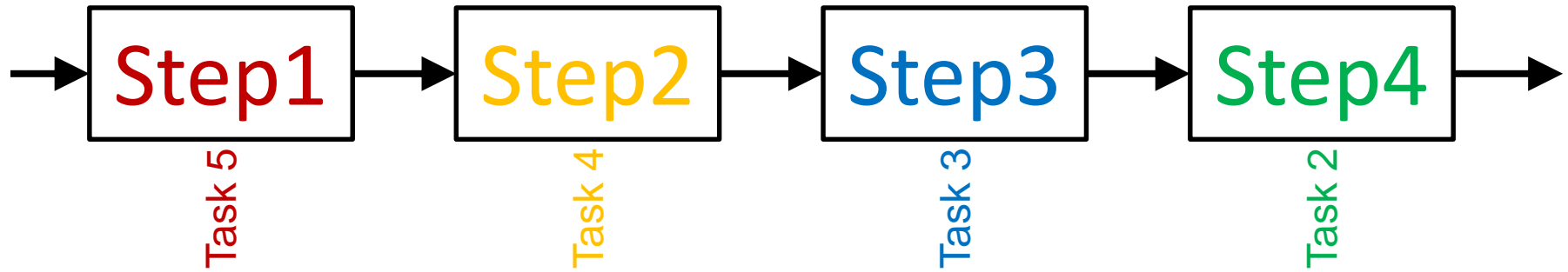
Task 6

Task 5



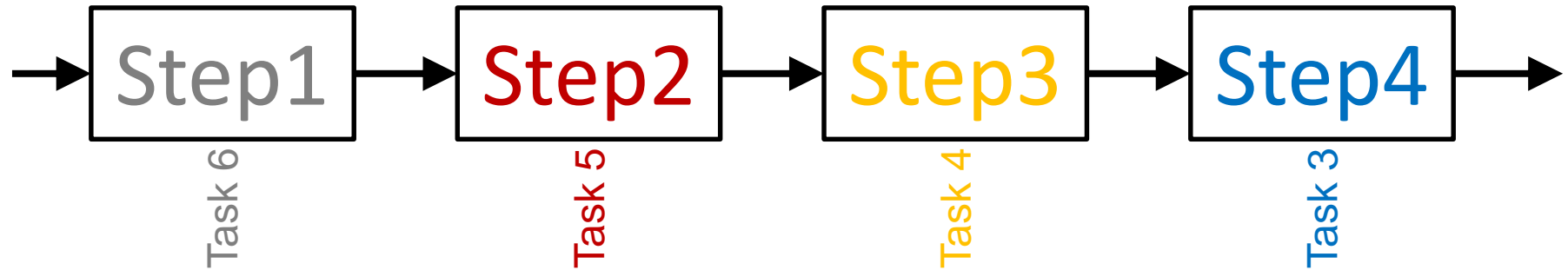
Pipeline

Task 6



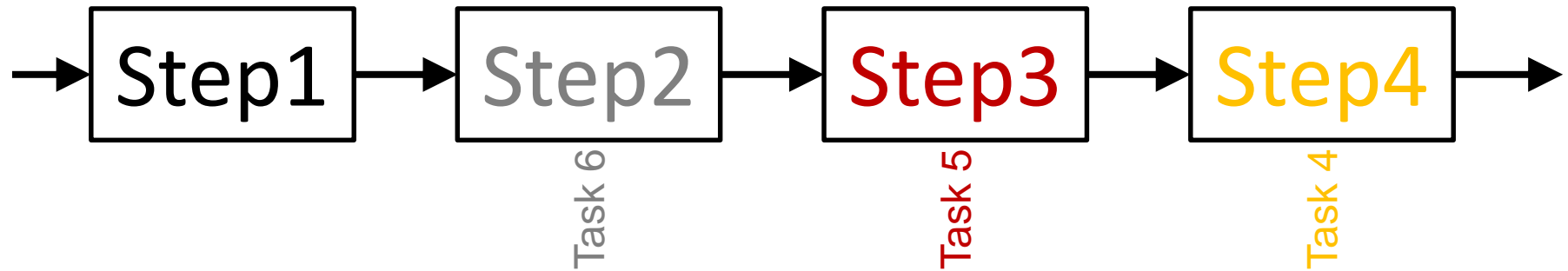
Task 1

Pipeline



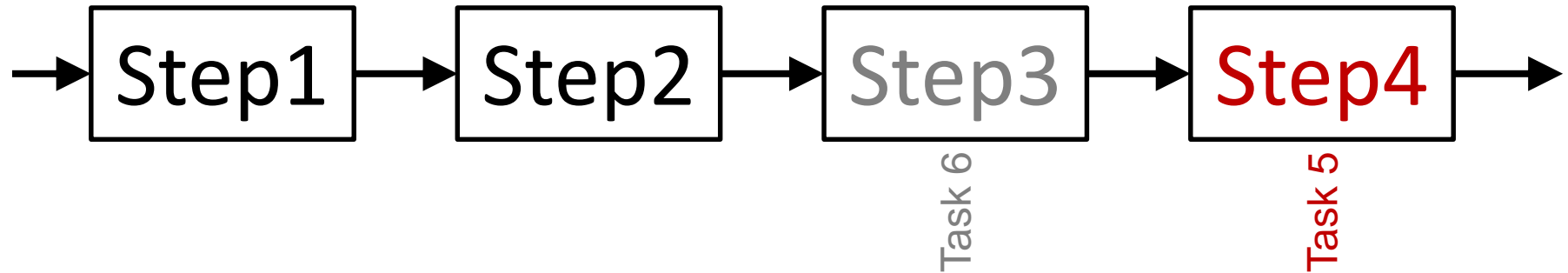
Task 2
Task 1

Pipeline



Task 3
Task 2
Task 1

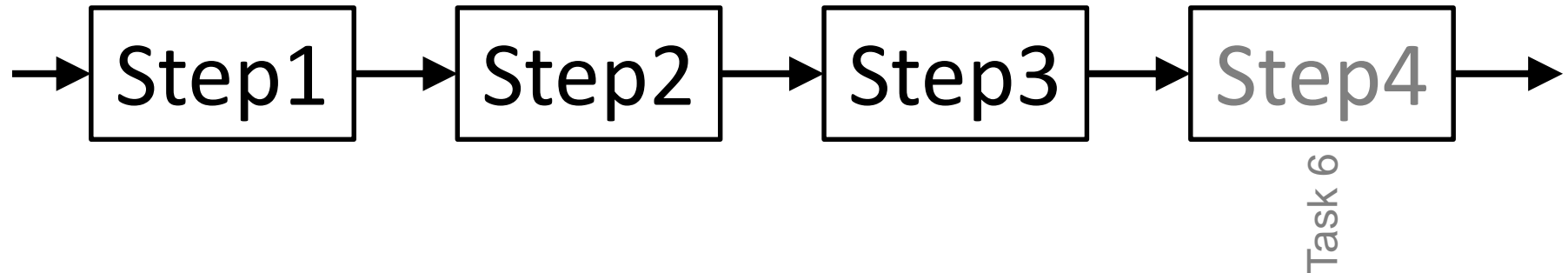
Pipeline



Task 4
Task 3
Task 2
Task 1

Pipeline

Ideal: $step_execution_time = \frac{task_execution_time}{number_of_steps}$



După $number_of_steps$ tascuri:

$total_execution_time = number_of_tasks * step_execution_time$

Un task se termină la fiecare “step tick”

Task 5
Task 4
Task 3
Task 2
Task 1



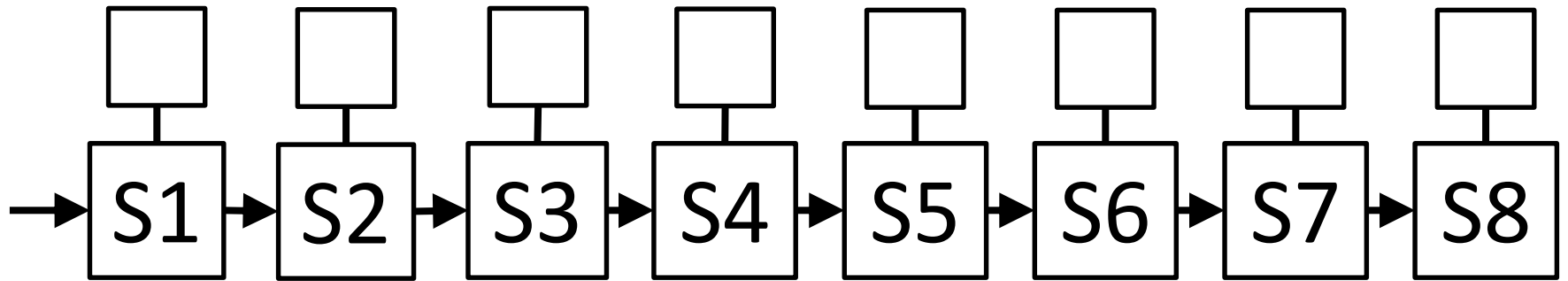


Sorting

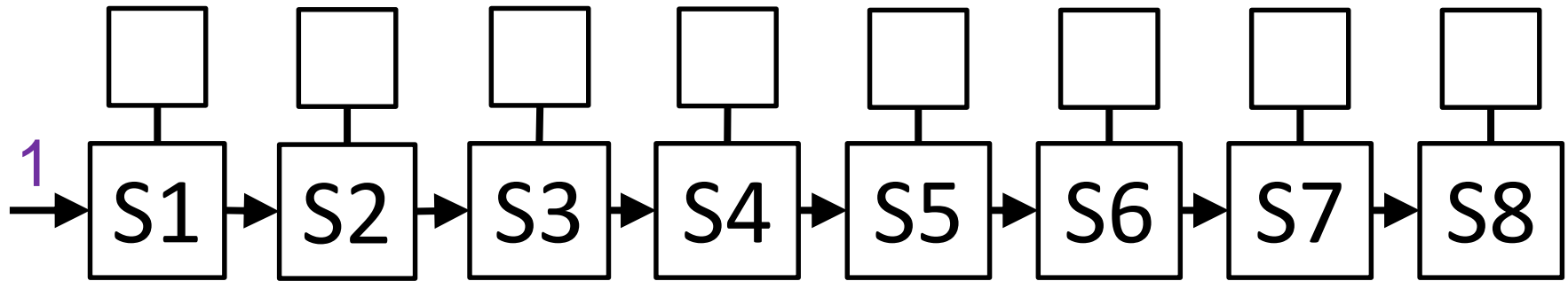
9	4	2	7	6	5	6	1
---	---	---	---	---	---	---	---

1	2	4	5	6	6	7	9
---	---	---	---	---	---	---	---

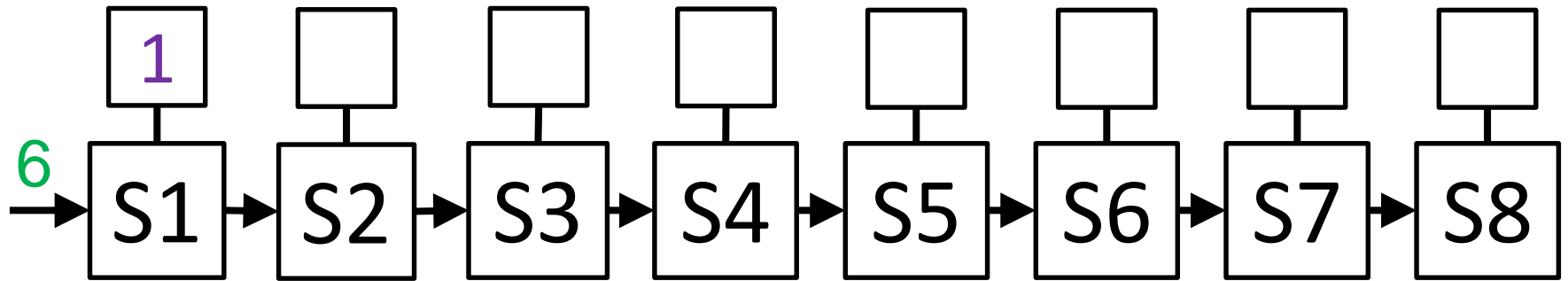
Sorting with pipeline



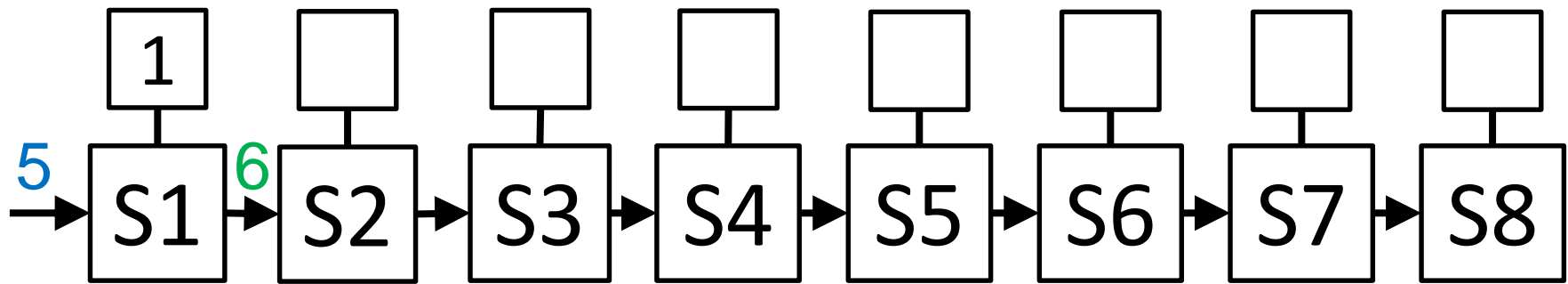
Sorting with pipeline



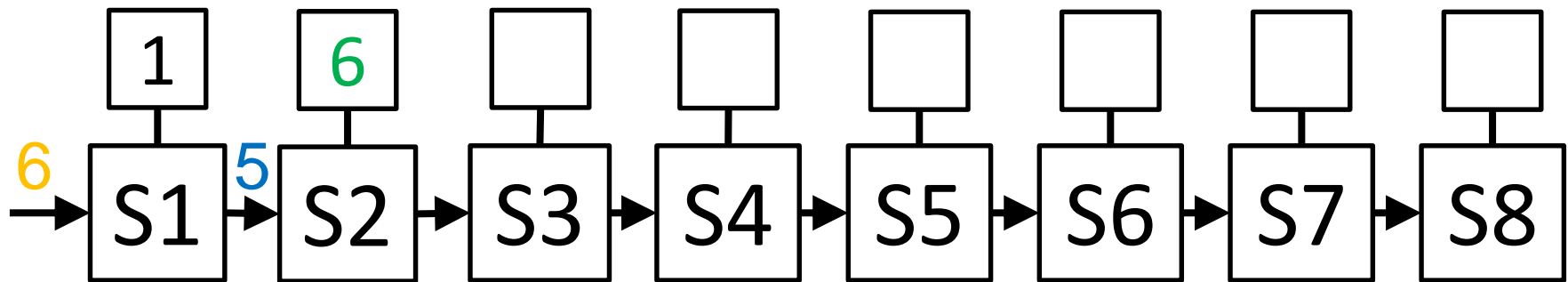
Sorting with pipeline



Sorting with pipeline

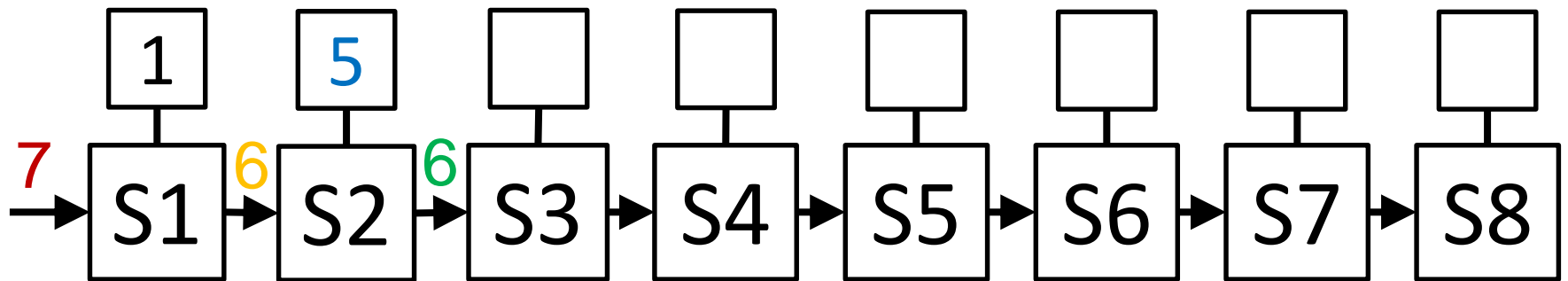


Sorting with pipeline



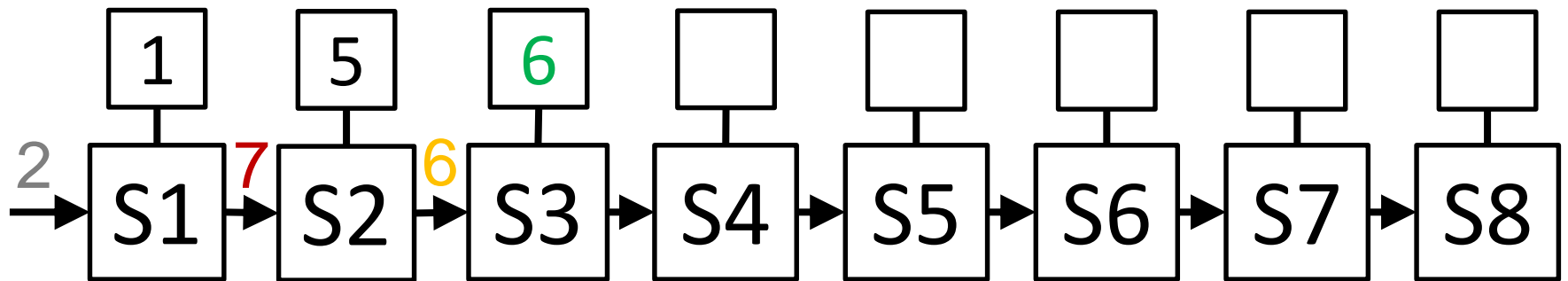
Sorting with pipeline

9	4	2
---	---	---



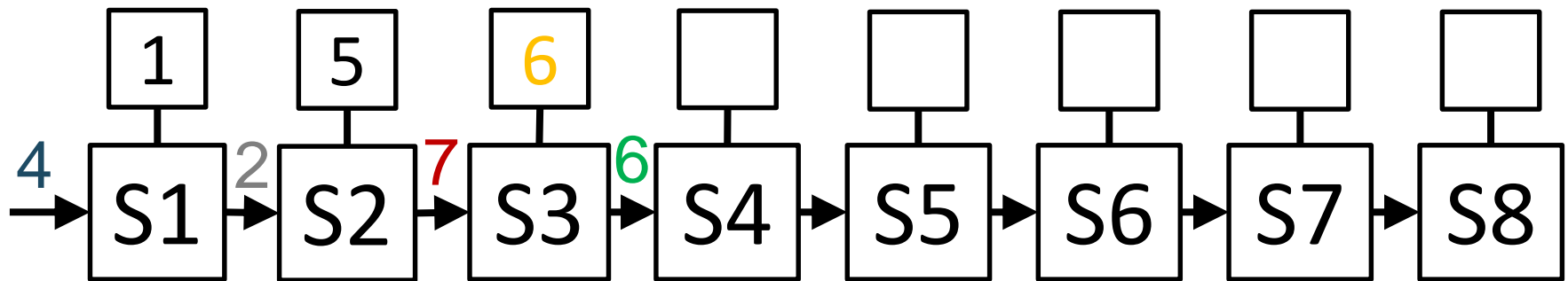
Sorting with pipeline

9	4
---	---

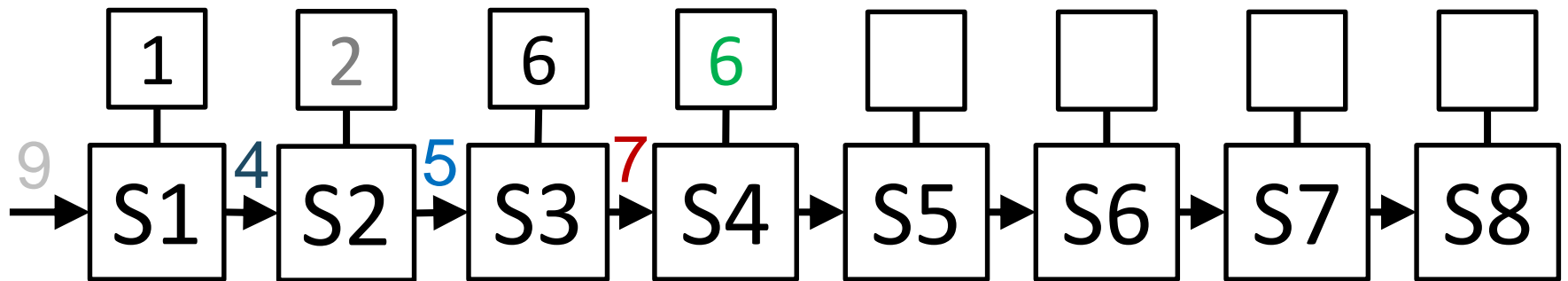


Sorting with pipeline

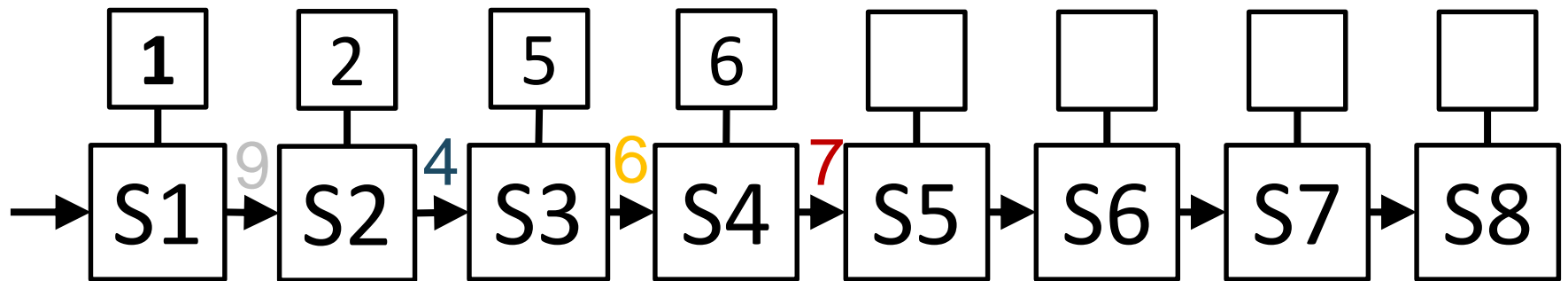
9



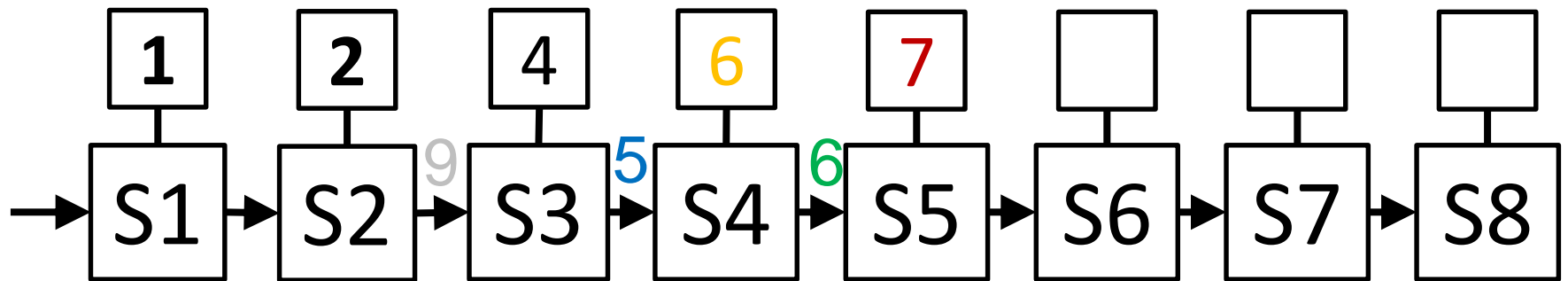
Sorting with pipeline



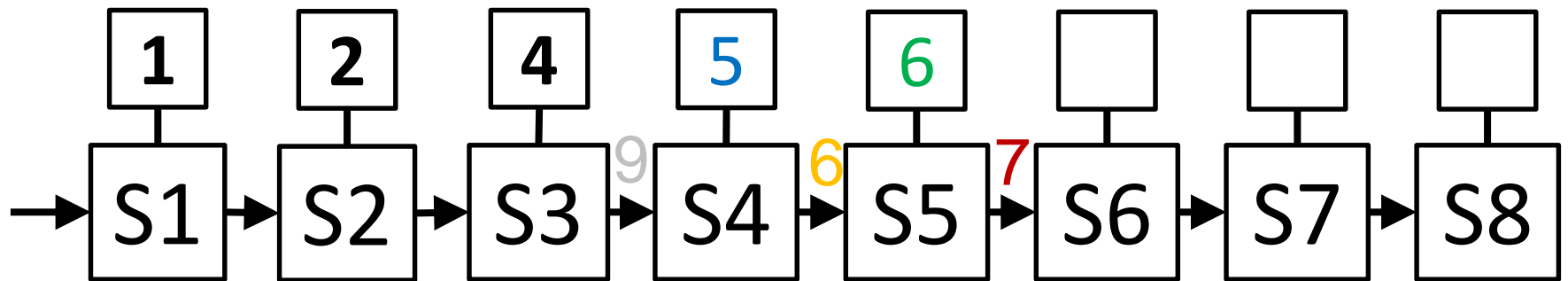
Sorting with pipeline



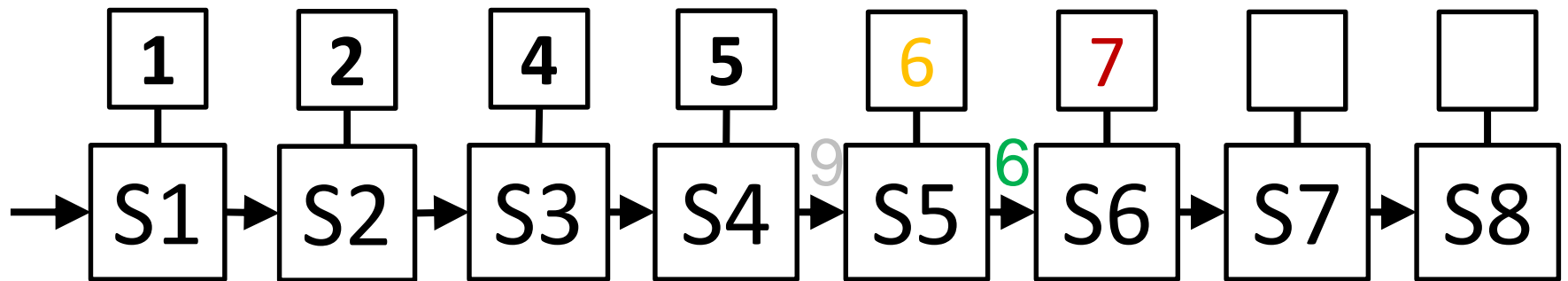
Sorting with pipeline



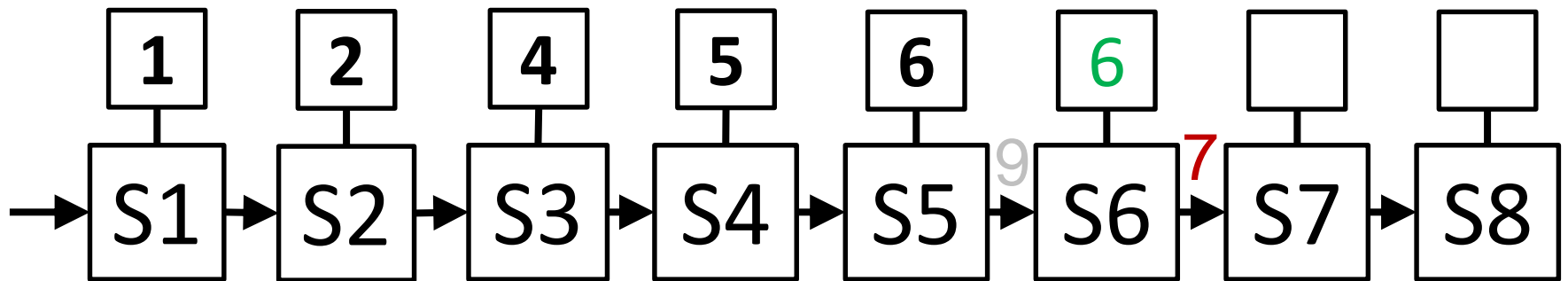
Sorting with pipeline



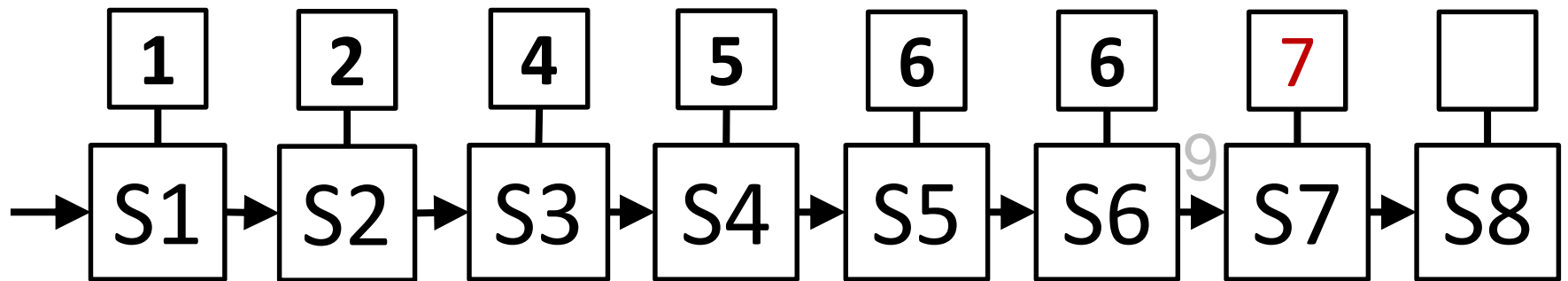
Sorting with pipeline



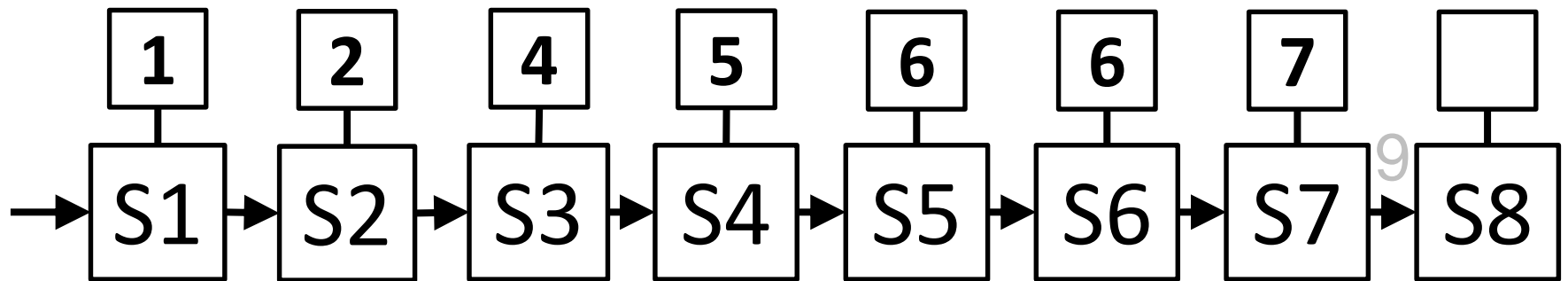
Sorting with pipeline



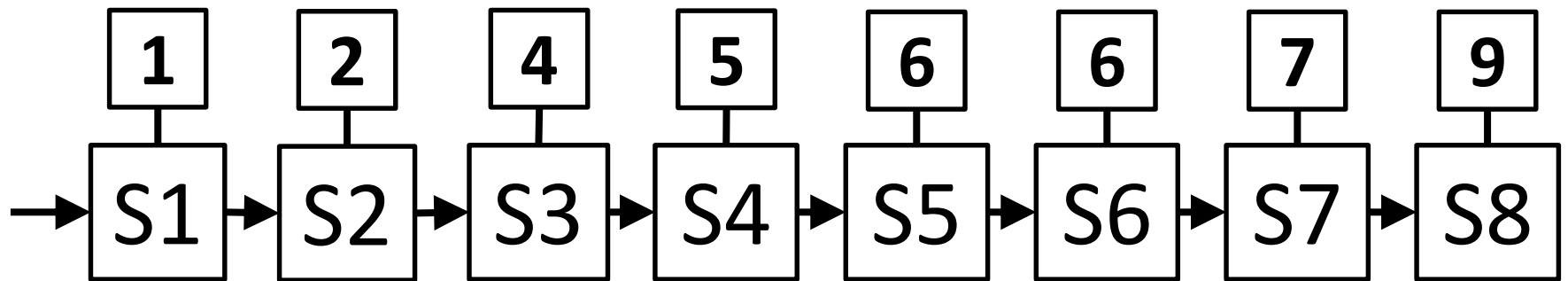
Sorting with pipeline



Sorting with pipeline



Sorting with pipeline



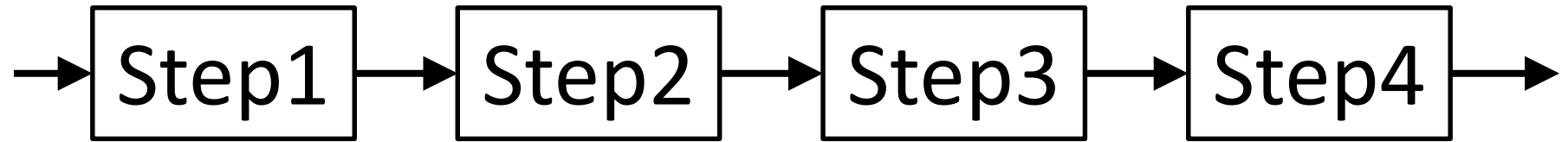




Polynomial

$$P(x) = \sum_{i=0}^n a_i x^i = a_0 x^0 + a_1 x^1 + a_2 x^2 + \cdots + a_{n-1} x^{n-1} + a_n x^n, n \geq 0$$

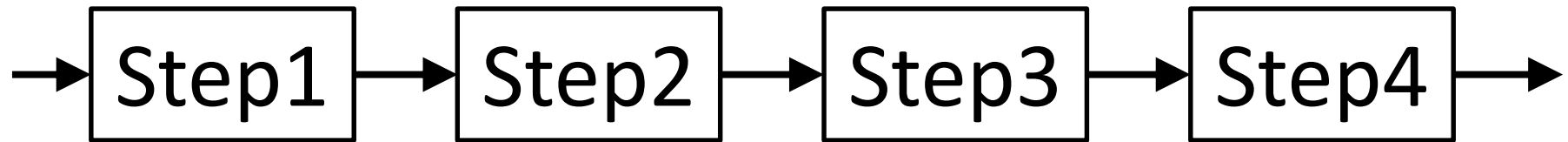
Pipeline



Polynomial calculation + Pipeline

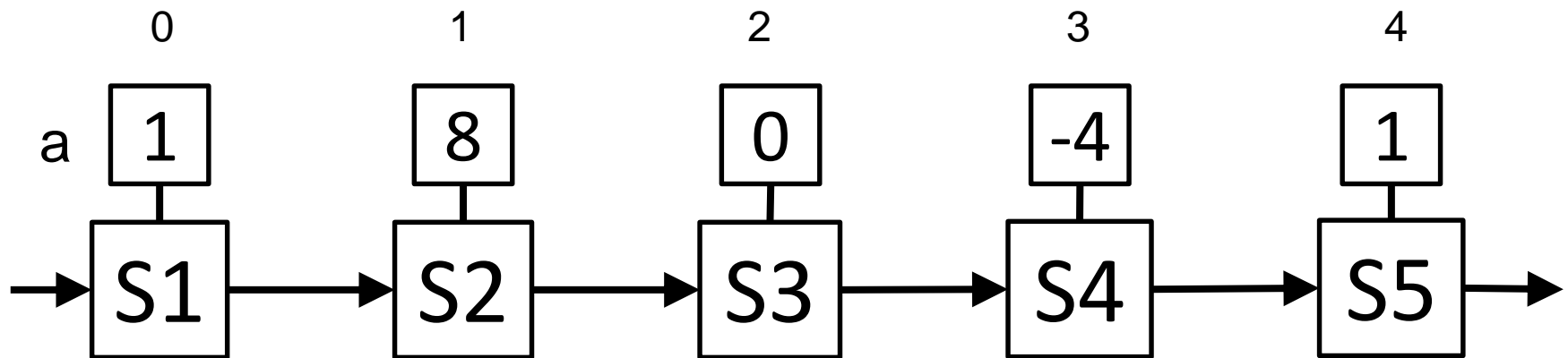
$$P(x) = 1 + 8x + (-4)x^3 + x^4$$

	0	1	2	3	4
a	1	8	0	-4	1



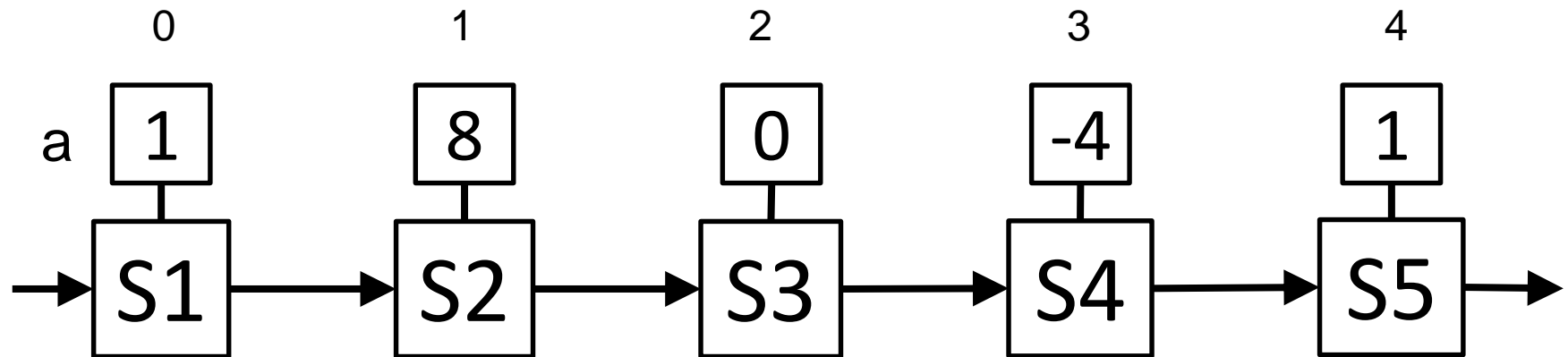
Polynomial calculation + Pipeline

$$P(x) = 1 + 8x + (-4)x^3 + x^4$$



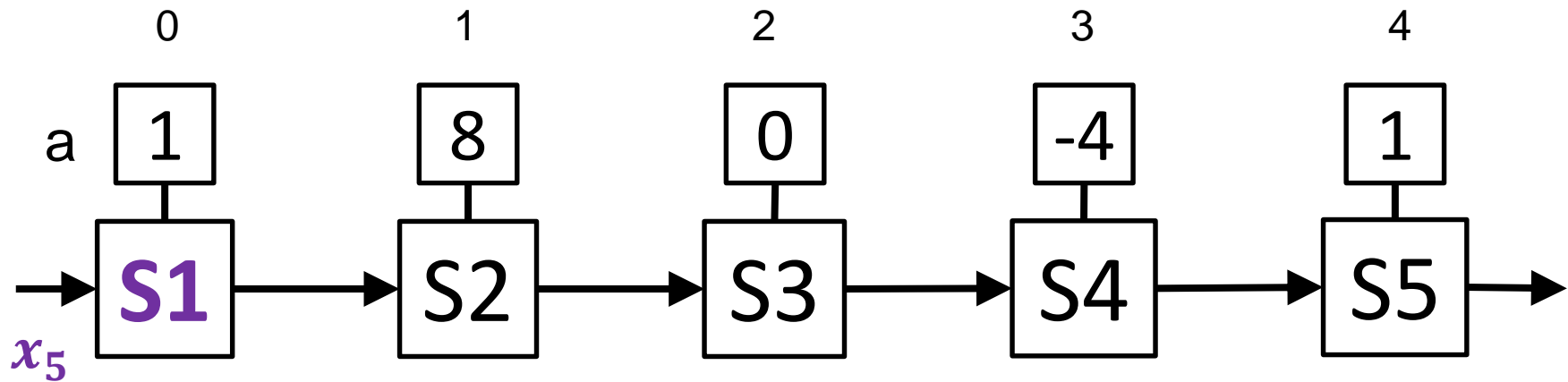
Polynomial calculation + Pipeline

x_1 x_2 x_3 x_4 x_5



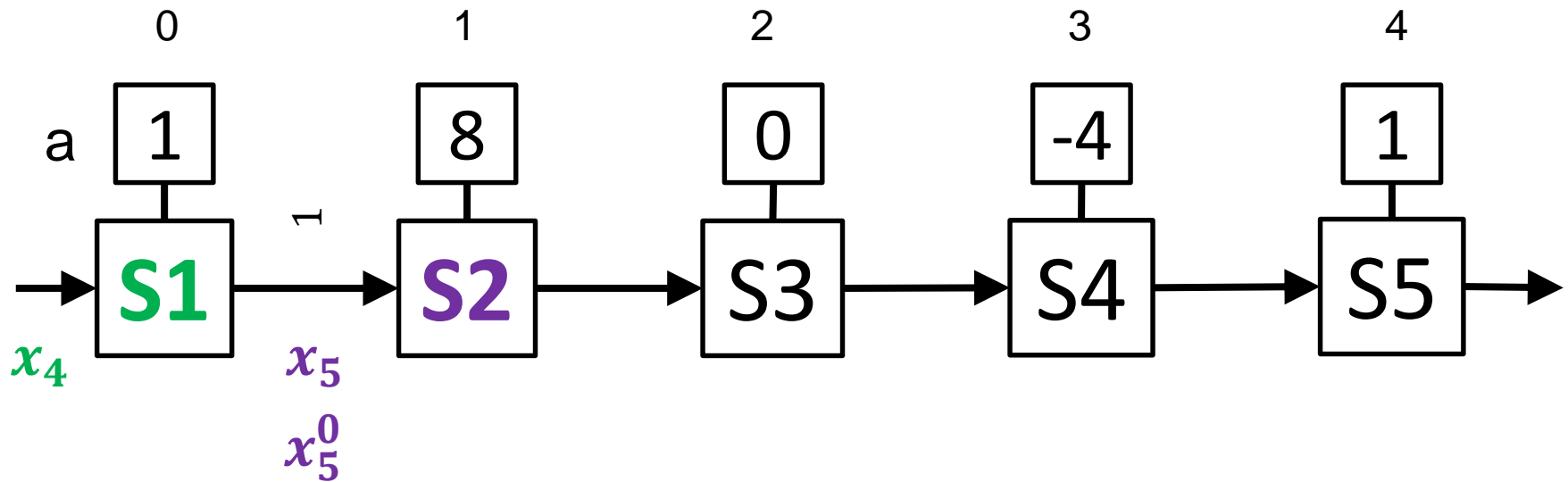
Polynomial calculation + Pipeline

x_1 x_2 x_3 x_4



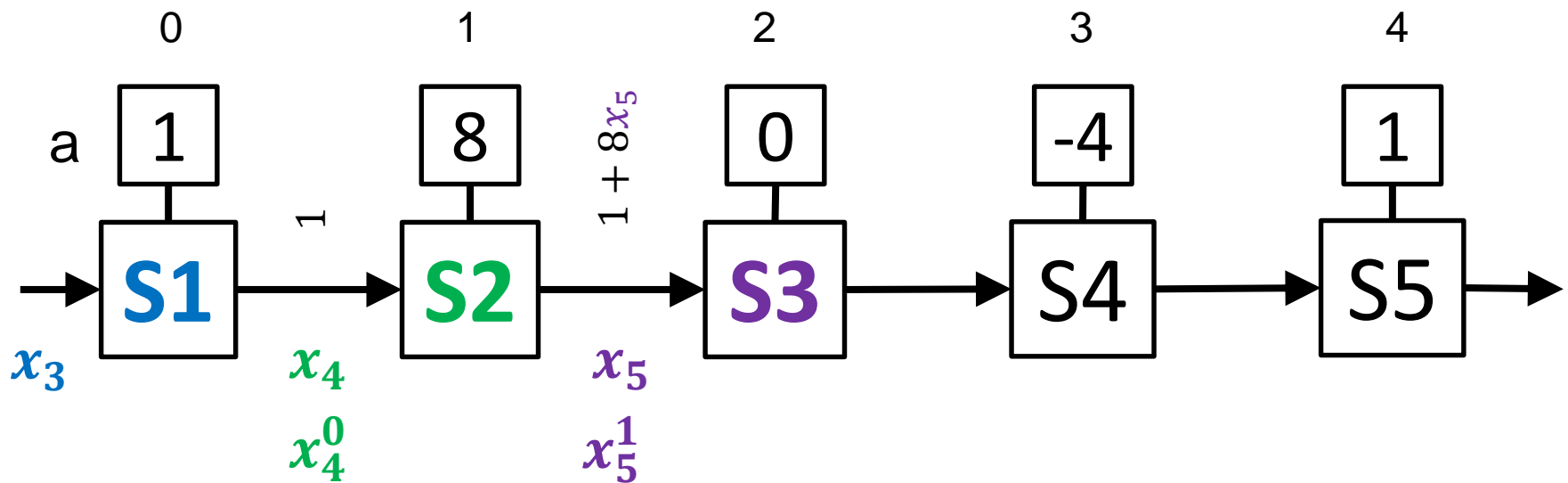
Polynomial calculation + Pipeline

x_1 x_2 x_3



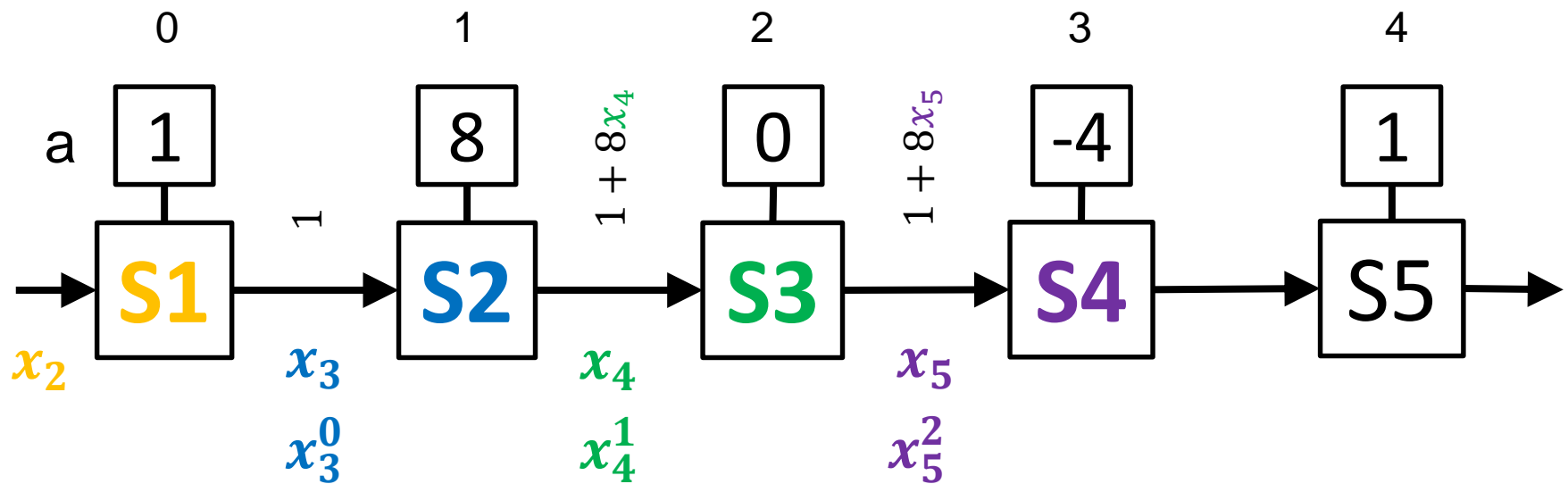
Polynomial calculation + Pipeline

x_1 x_2

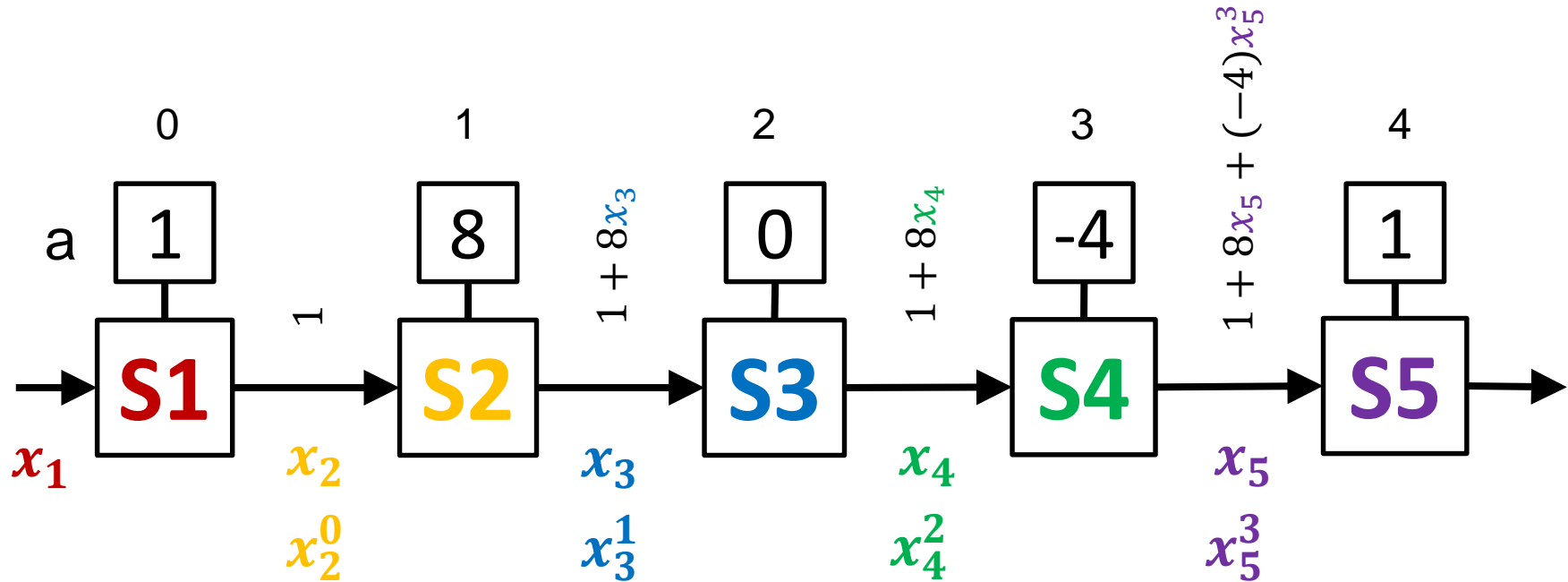


Polynomial calculation + Pipeline

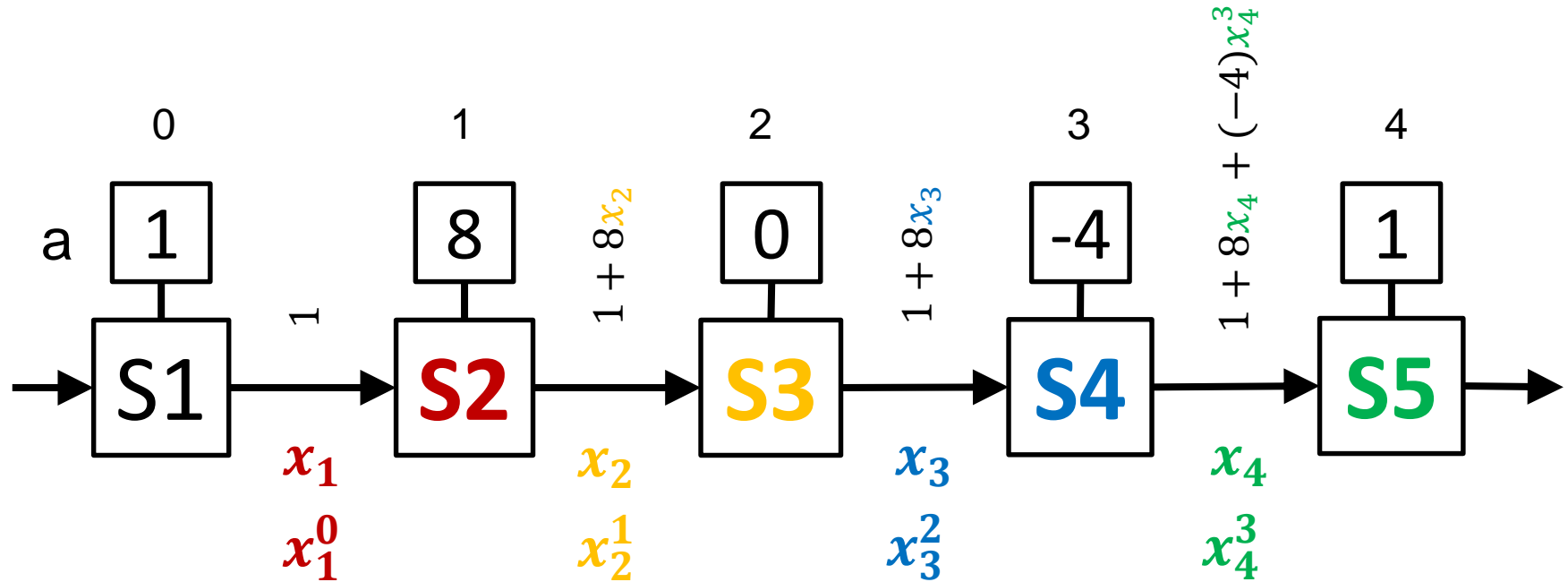
x_1



Polynomial calculation + Pipeline

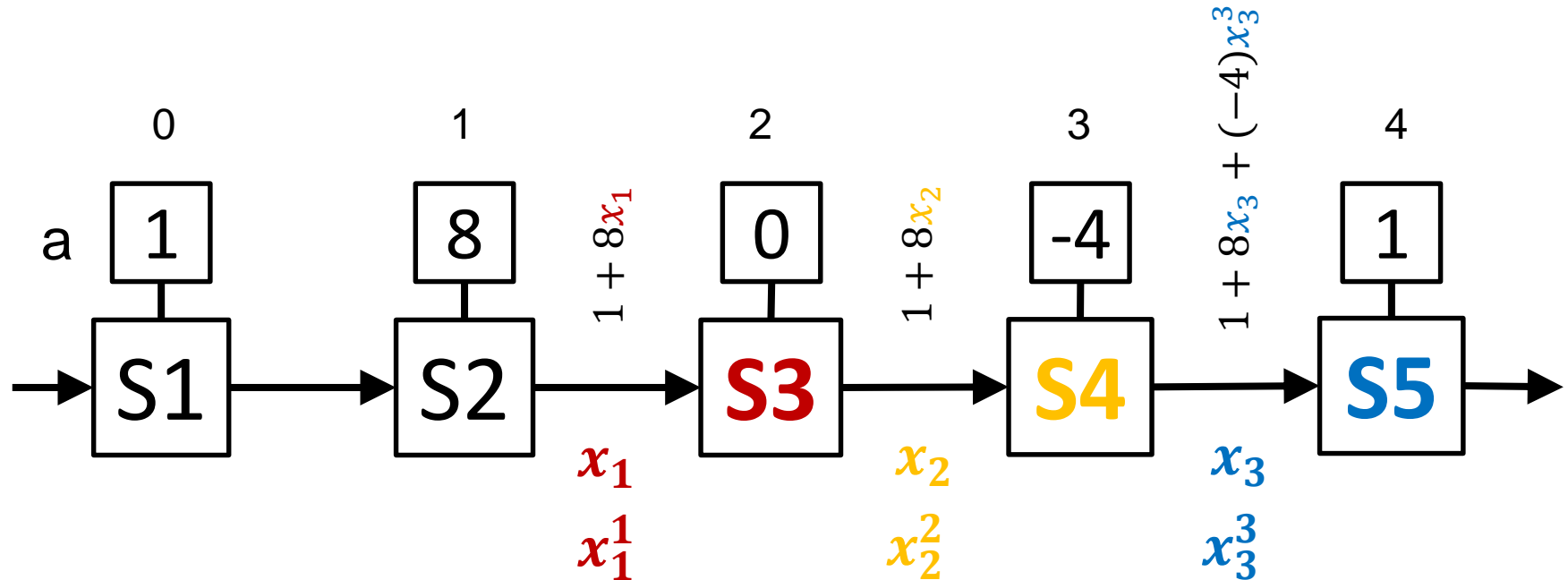


Polynomial calculation + Pipeline



$$1 + 8x_5 + (-4)x_5^3 + x_5^4$$

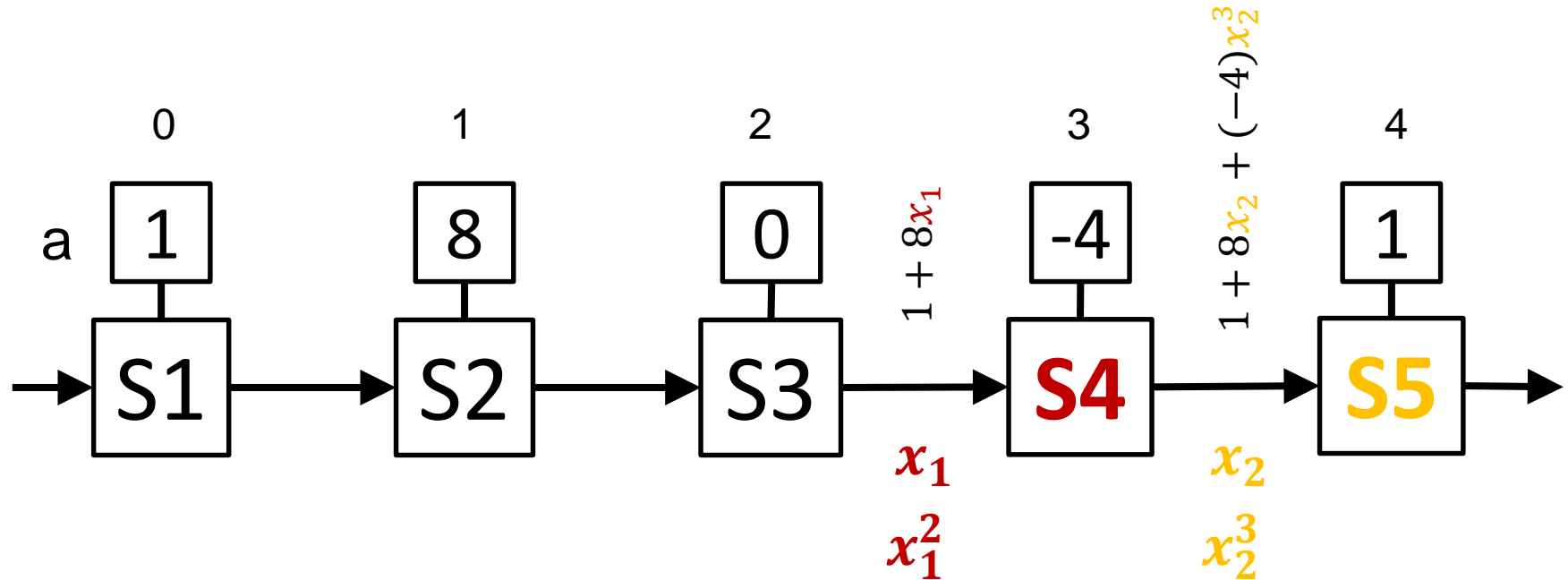
Polynomial calculation + Pipeline



$$1 + 8x_4 + (-4)x_4^3 + x_4^4$$

$$1 + 8x_5 + (-4)x_5^3 + x_5^4$$

Polynomial calculation + Pipeline

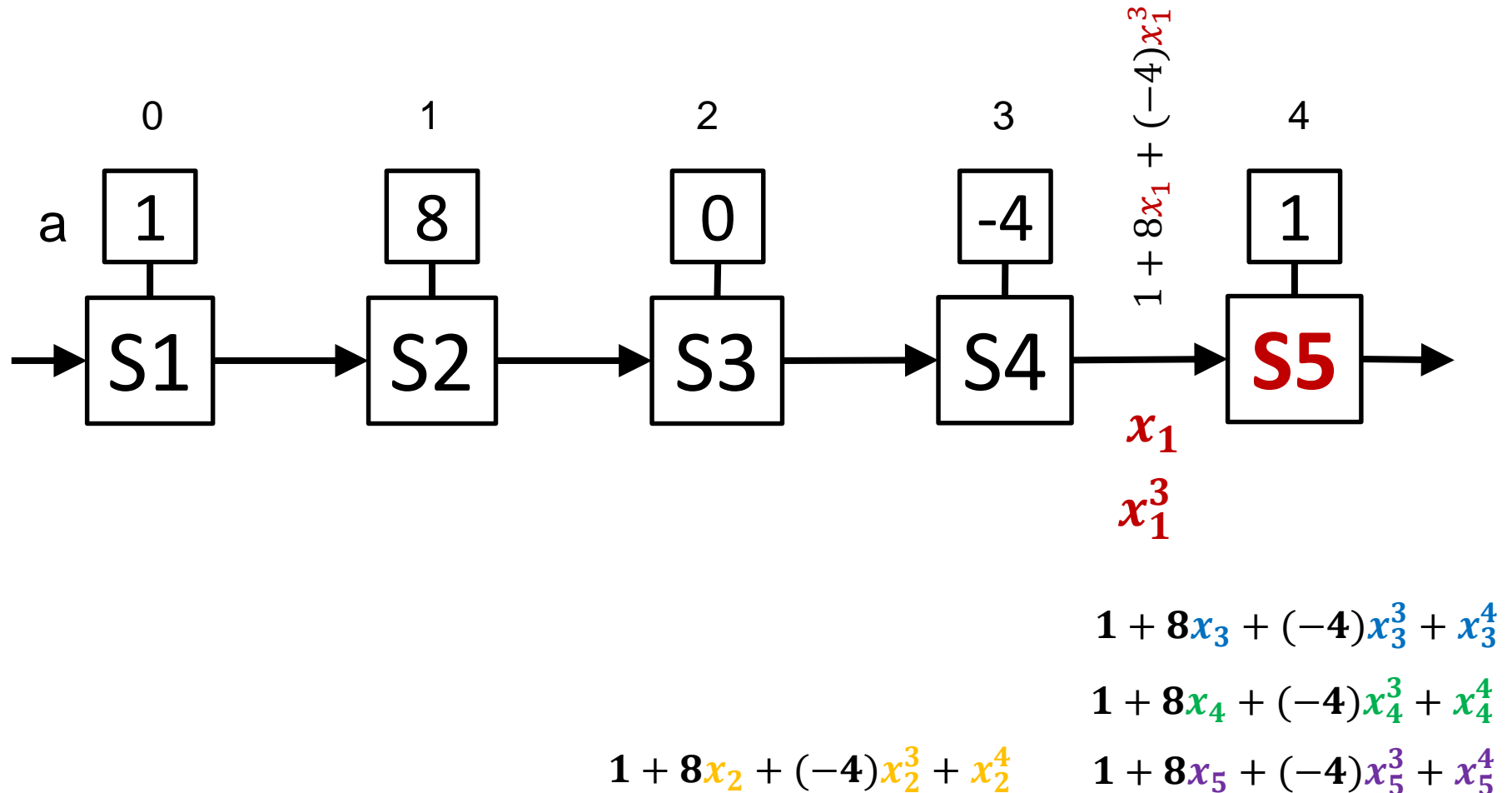


$$1 + 8x_3 + (-4)x_3^3 + x_3^4$$

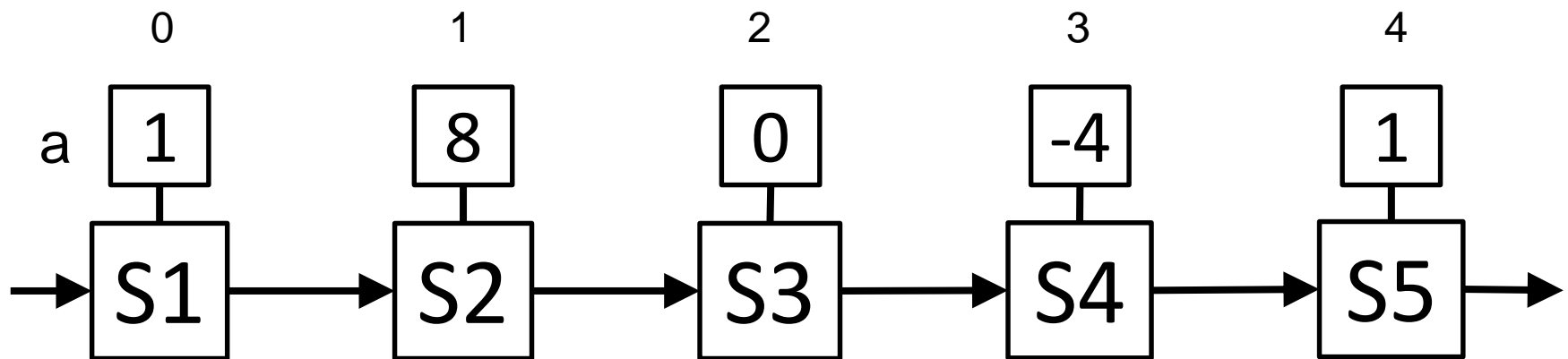
$$1 + 8x_4 + (-4)x_4^3 + x_4^4$$

$$1 + 8x_5 + (-4)x_5^3 + x_5^4$$

Polynomial calculation + Pipeline



Polynomial calculation + Pipeline



$$1 + 8x_1 + (-4)x_1^3 + x_1^4$$

$$1 + 8x_2 + (-4)x_2^3 + x_2^4$$

$$1 + 8x_3 + (-4)x_3^3 + x_3^4$$

$$1 + 8x_4 + (-4)x_4^3 + x_4^4$$

$$1 + 8x_5 + (-4)x_5^3 + x_5^4$$

