PARALLEL PROCESSING

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3

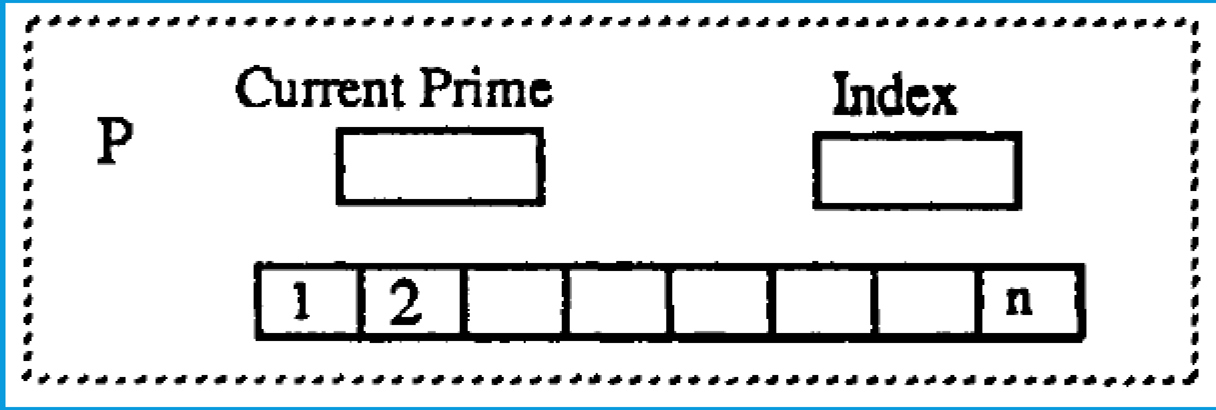
EXAMPLES OF PARALLEL ALGORITHMS

- Sieve algorithm for constructing the list of all prime numbers in the interval [1, n]
  - Initialize X[1]=1, all remaining X[2]..X[n]=0
  - At each step the next unmarked number m in the list is prime and all its multiples are marked none prime beginning with X[m^2]
  - The algorithm stops when $m^2 > n$
  - All unmarked numbers are prime.

EXAMPLES OF PARALLEL ALGORITHMS

2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
m=2																												
2	3		5		7		9		11		13		15		17		19		21		23		25		27		29	
	m=3																											
2	3		5		7				11		13				17		19				23		25				29	
			m=5																									
2	3		5		7				11		13				17		19				23						29	
					m=7																							

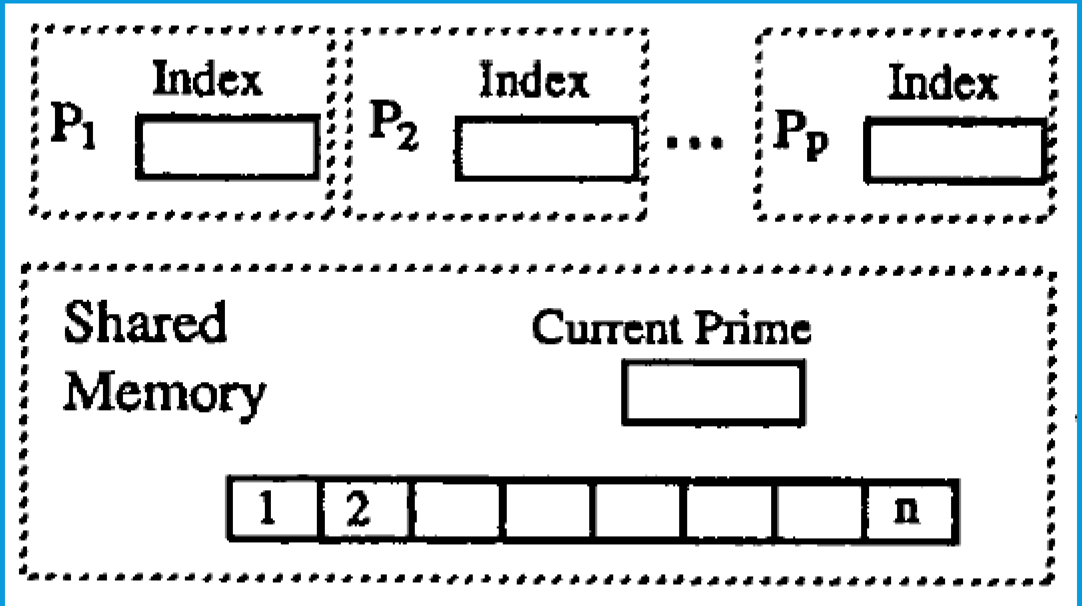
EXAMPLES OF PARALLEL ALGORITHMS



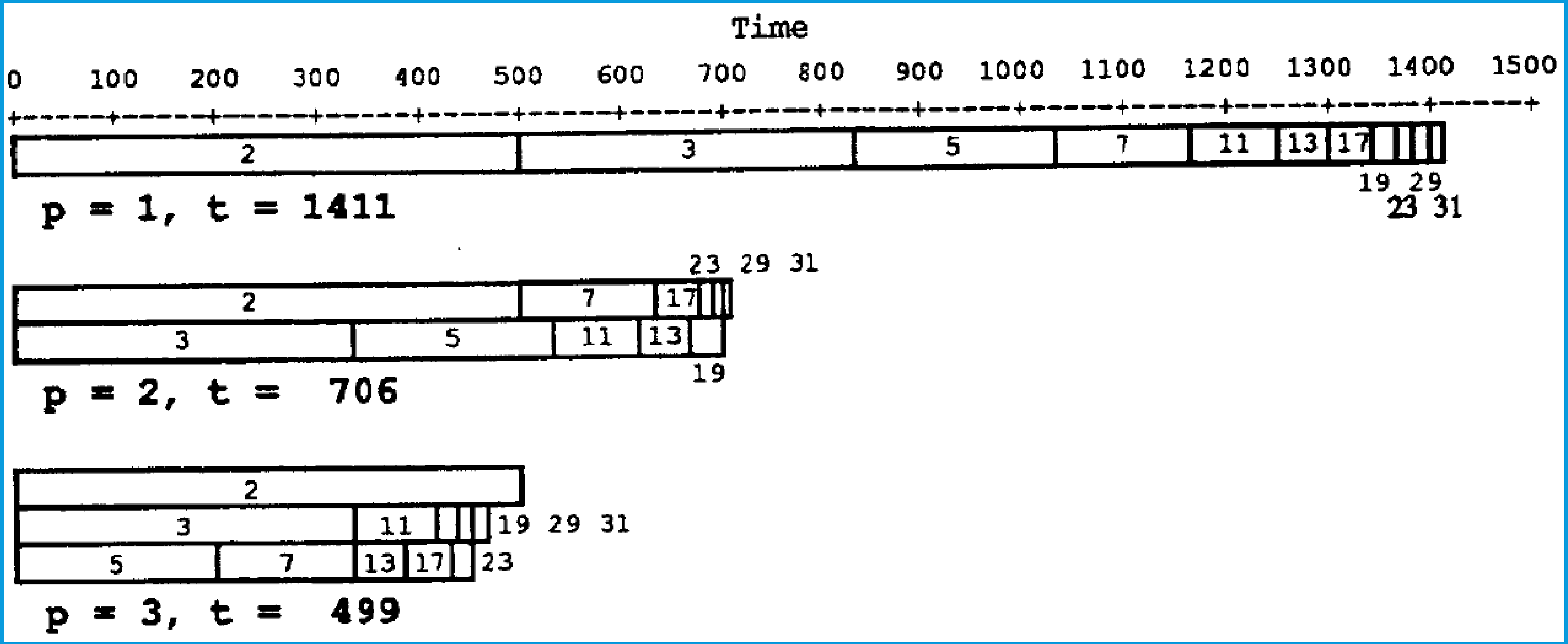
EXAMPLES OF PARALLEL ALGORITHMS

- Shared memory parallel algorithm
  - Shared current_prime, list _of_numbers
  - Index is local to each processor
  - An idle processor check the shared memory for the next prime *m* and updates the current_prime accordingly.
  - Using its local index , mark the multiples of *m*

EXAMPLES OF PARALLEL ALGORITHMS



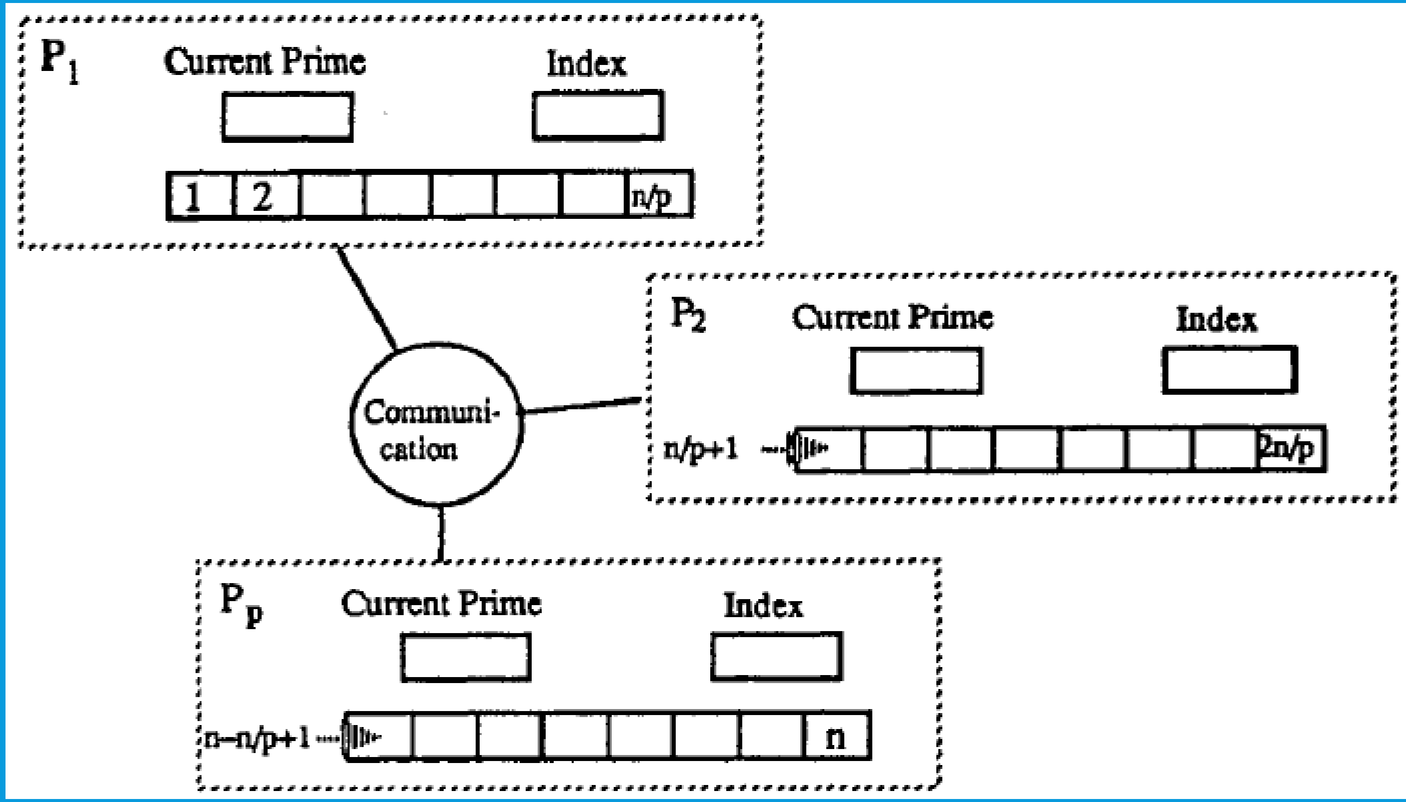
EXAMPLES OF PARALLEL ALGORITHMS



EXAMPLES OF PARALLEL ALGORITHMS

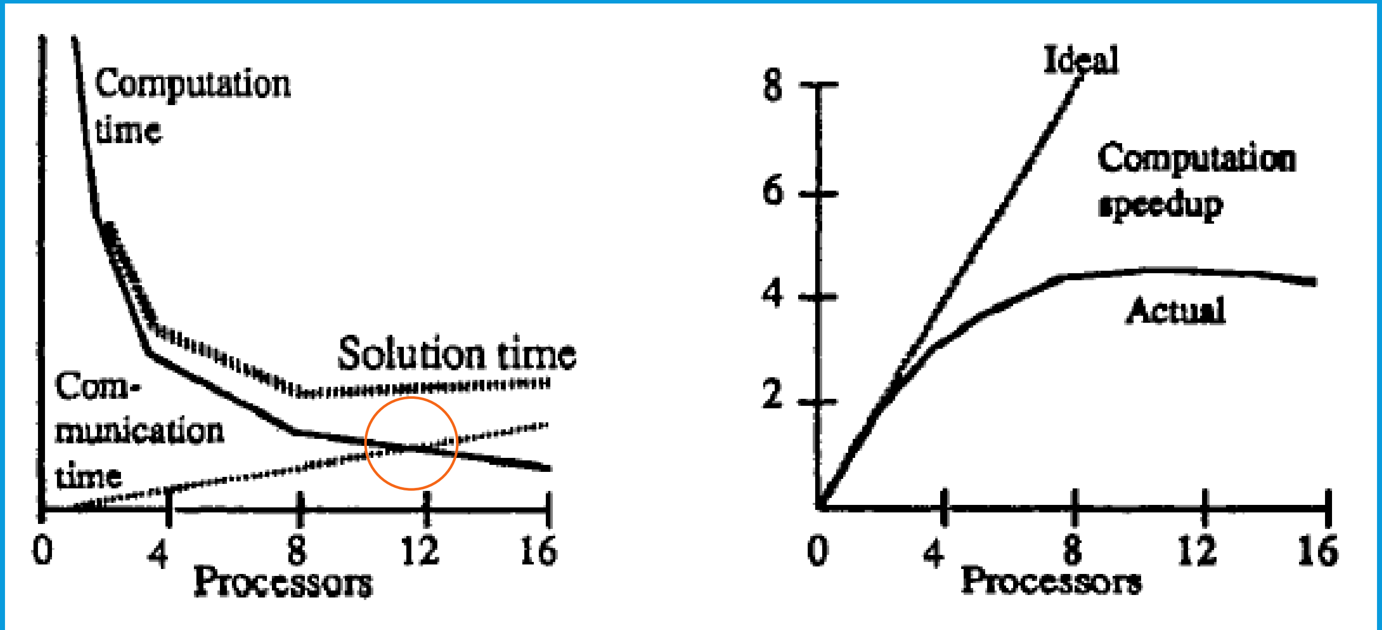
- Data Parallel Approach.
- *p* is the number of processors.
- The bit-vector representing the *n* integers is divided into *p* equal-length segments.
- The condition here is $p < \sqrt{n}$ to make sure all prime numbers are in the first segment.
- The first processor *p1* will work as coordinator. It find the next prime and broadcast it to all other processors to mark the multiples as not prime.
- **The total time = communication time + computation time.**
- **Communication time** is time spent on transmitting the selected primes to all processors.
- **Computation time** is time spent by each processor marking their sub lists.

EXAMPLES OF PARALLEL ALGORITHMS



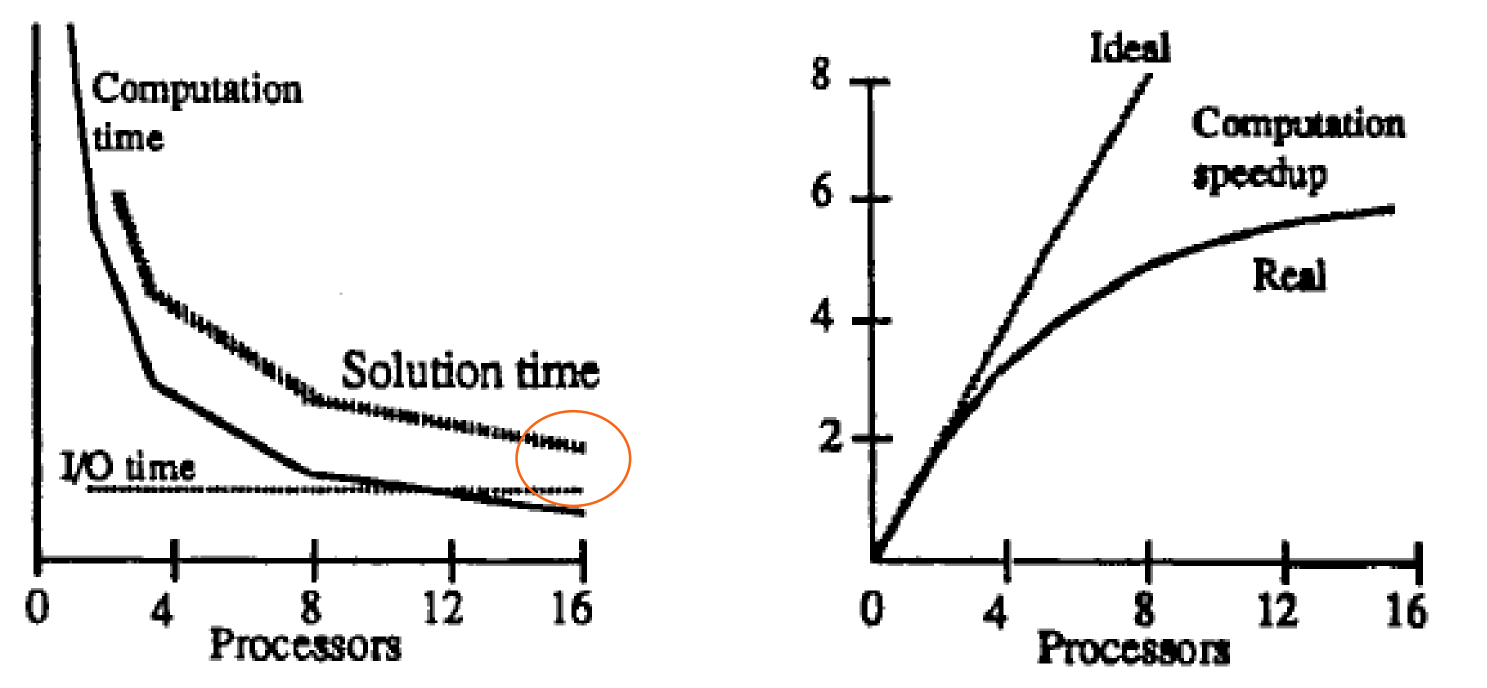
EXAMPLES OF PARALLEL ALGORITHMS

Effect of communication time



EXAMPLES OF PARALLEL ALGORITHMS

Effect of constant I/O Time

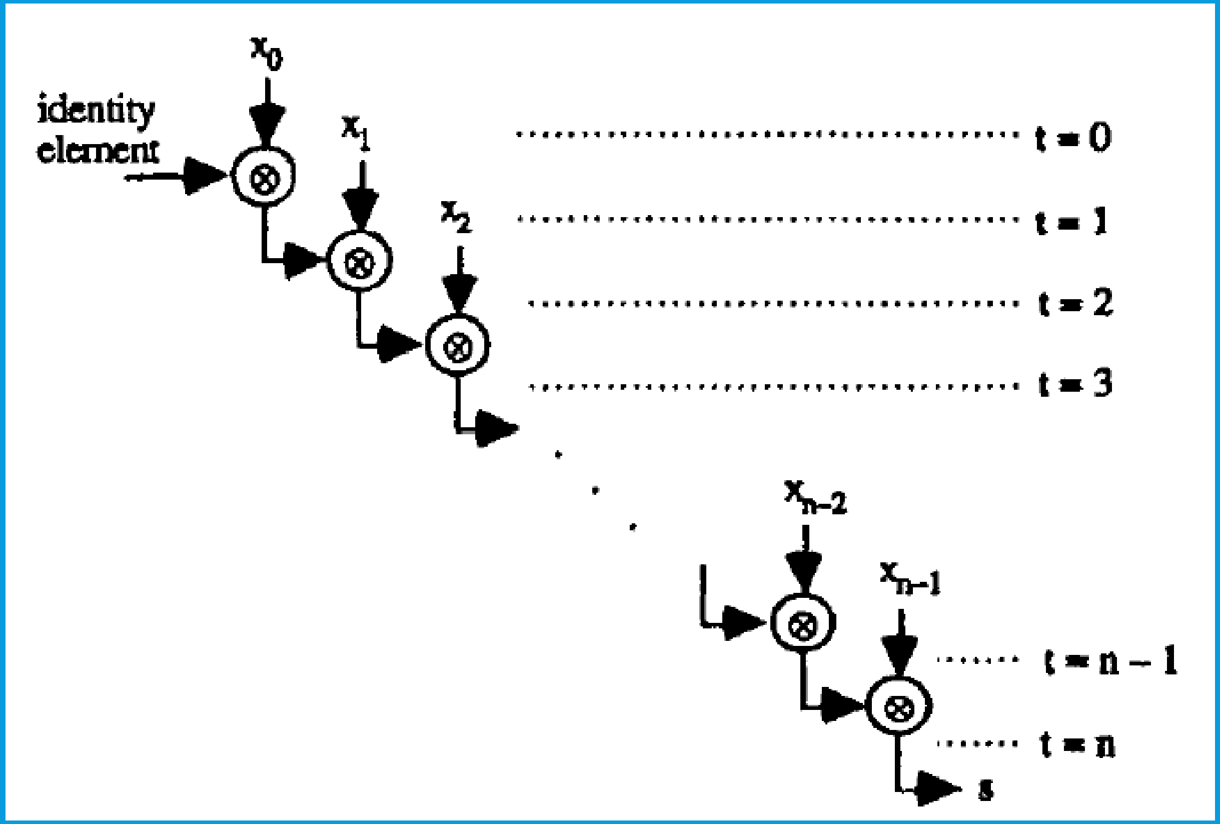


EXAMPLES OF SIMPLE COMPUTATIONS

- Semigroup computation (reduction or fan-in)
- Let $\otimes$ be an associative binary operator; i.e., $(x \otimes y) \otimes z = x \otimes (y \otimes z)$ for all $x, y, z \in S$. A semigroup is simply a pair $(S, \otimes)$, where S is a set of elements on which $\otimes$ is defined.
- Given a list of n values $x_0, x_1, \ldots, x_{n-1}$, compute $x_0 \otimes x_1 \otimes \ldots \otimes x_{n-1}$
- Common examples for the operator $\otimes$ include $+$, $\times$, $\wedge$, $\vee$, $\oplus$, $\cap$, $\cup$, max, min.
- The parallel algorithm can compute chunks of the expression using any partitioning scheme.
- The chunks must be combined in left-to-right order.

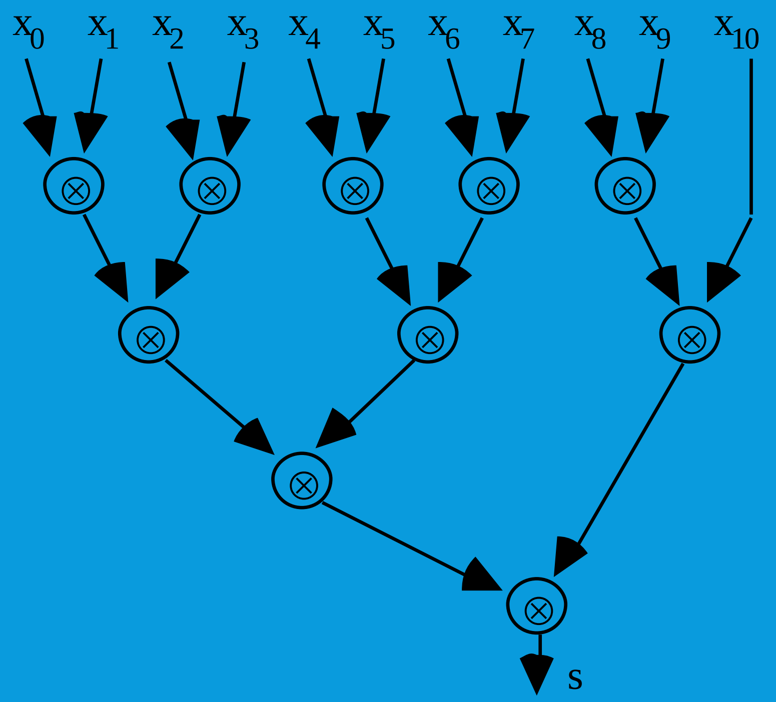
EXAMPLES OF SIMPLE COMPUTATIONS

Semi-group computation on one processor



EXAMPLES OF SIMPLE COMPUTATIONS

Semi-group parallel computation



EXAMPLES OF SIMPLE COMPUTATIONS

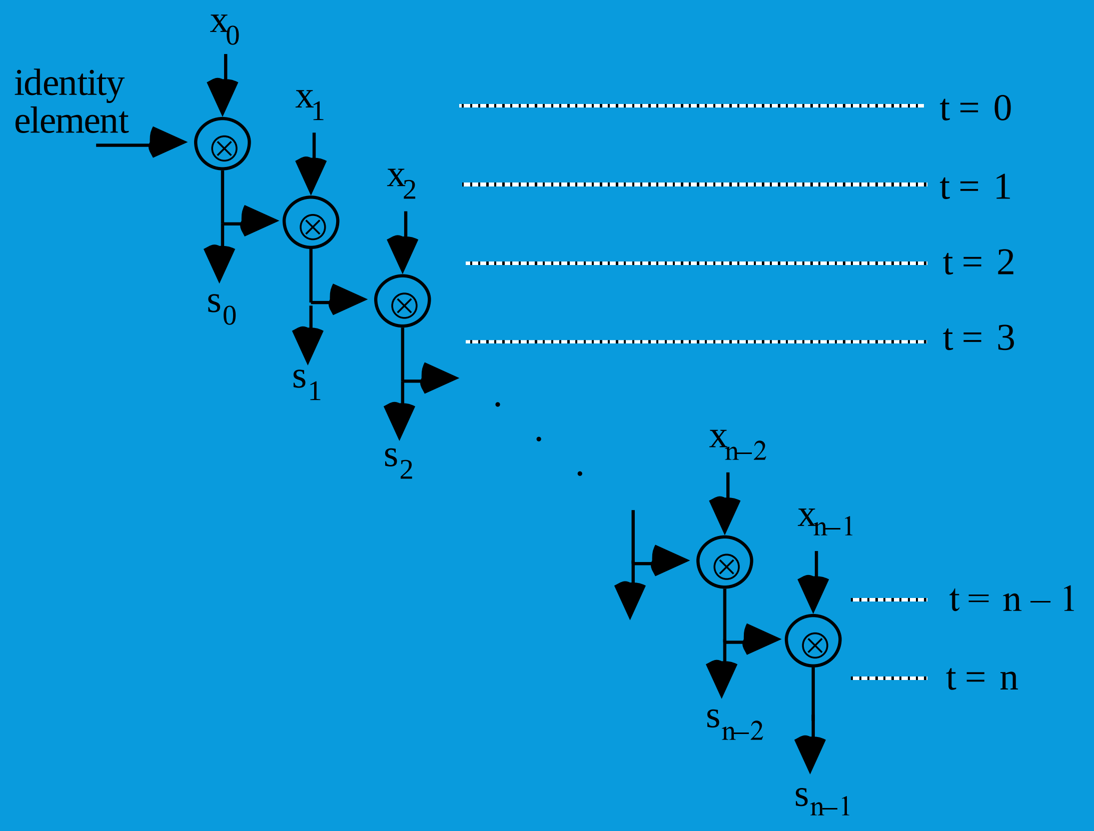
- Prefix Sum

i =	0	1	2	3	4	5	6	7	8	9
A[ ] =	3	5	2	-4	6	10	4	-5	3	2

i =	0	1	2	3	4	5	6	7	8	9
A[ ] =	3	8	10	6	12	22	26	21	24	26

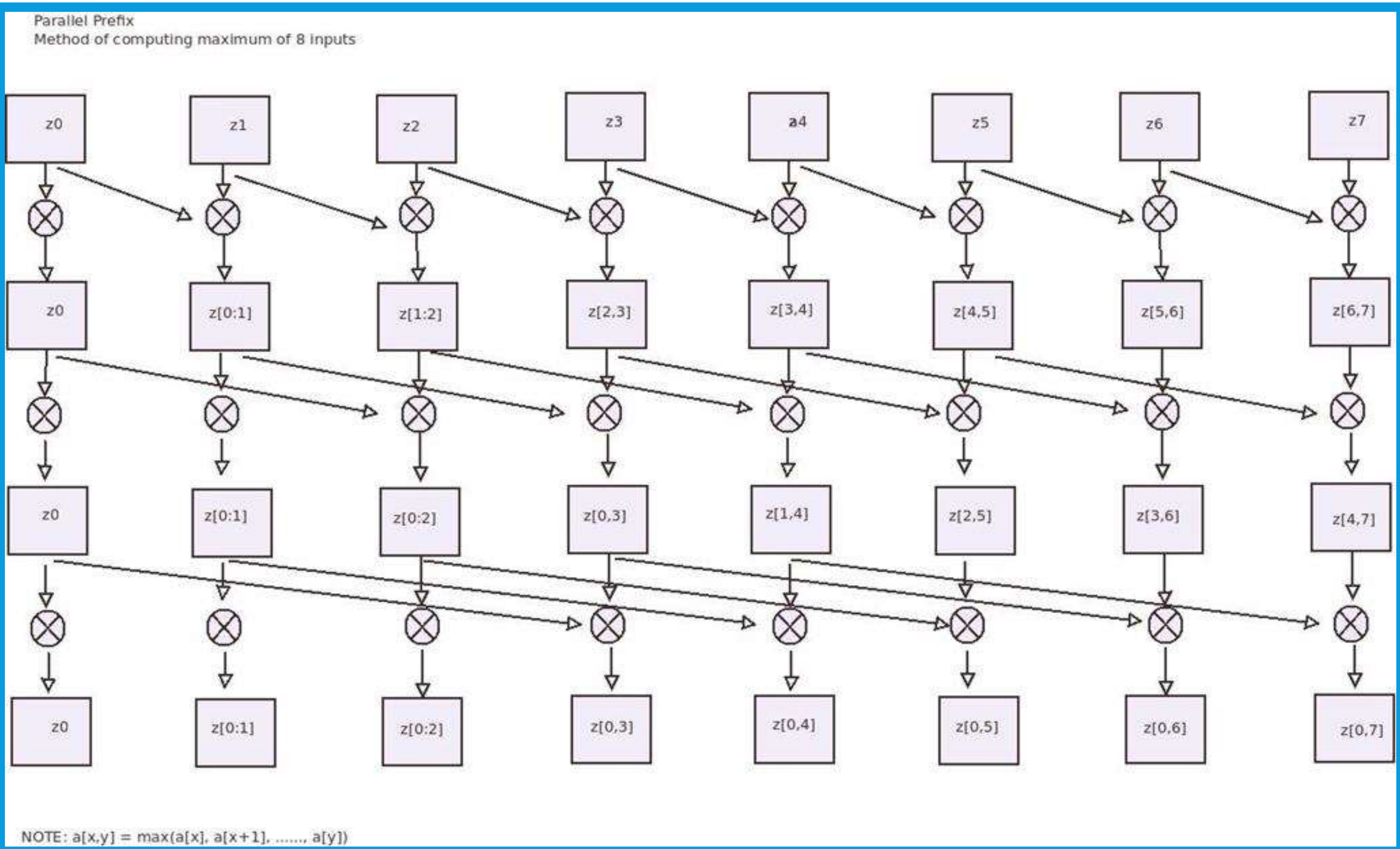
EXAMPLES OF SIMPLE COMPUTATIONS

- Parallel prefix



EXAMPLES OF SIMPLE COMPUTATIONS

- Parallel prefix



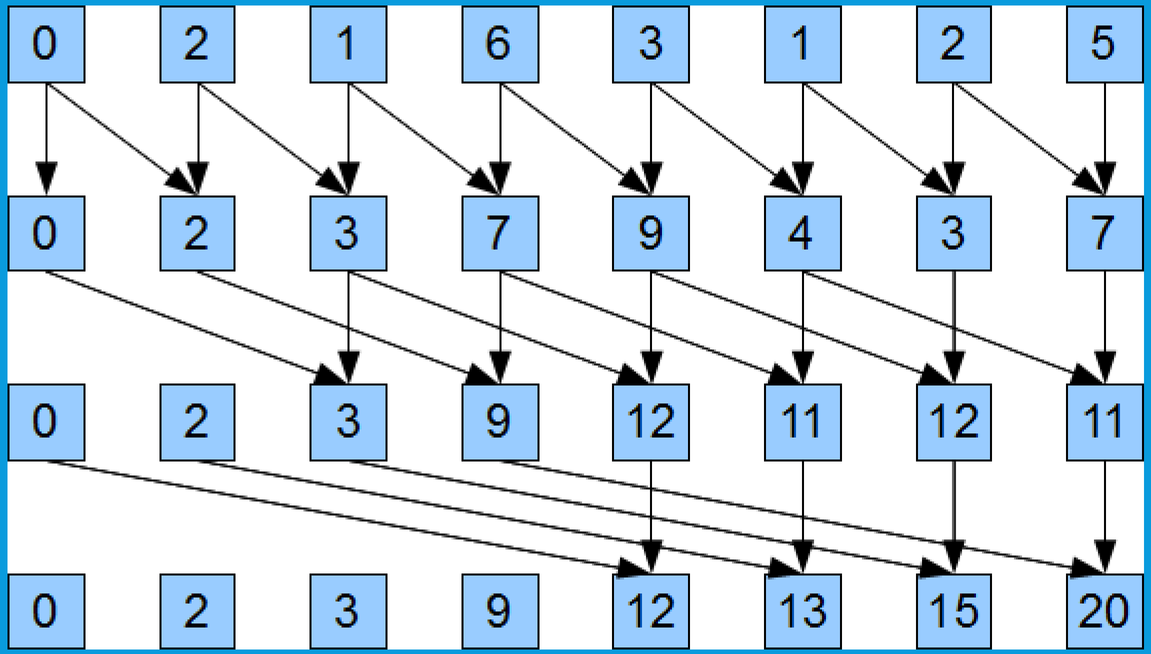
EXAMPLES OF SIMPLE COMPUTATIONS

- Parallel prefix

```
for d = 0 to log n - 1 do
    for i = 0 to n - 1 by 2^(d+1) do in parallel
        a[i + 2^(d+1) - 1] := a[i + 2^d - 1] + a[i + 2^(d+1) - 1]
```

EXAMPLES OF SIMPLE COMPUTATIONS

- Parallel prefix
- simultaneously evaluating all of the prefixes of the expression.



EXAMPLES OF SIMPLE COMPUTATIONS

- Packet Routing :
  - A packet resides on processor i and need to be sent to processor j .
  - The packet may need to pass through intermediate processor.
  - The problem is complicated when a processor has more than one packet to be routed at the same time.
  - One-to One communication.

EXAMPLES OF SIMPLE COMPUTATIONS

- Broadcast:
  - Disseminate the value a to all processors as fast as possible.
  - One-to-all communication.
- Multicast:
  - Disseminate the value a to some processors.
  - One-to-many.

EXAMPLES OF SIMPLE COMPUTATIONS

Sorting:

Given a list of values x1, x2, …, xn rearrange the values such that

$$x1, x2, \dots, xi, xj, \dots, xn \ where \ xi \leq xj \ for \ all \ i \ and \ j$$

In our examples we will sort records based on key value, we will just sort the keys.

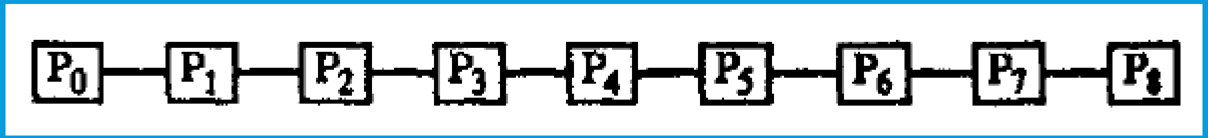
EXAMPLES OF PARALLEL ARCHITECTURE

- D the diameter is the longest of the shortest distances between any two processors.
- d is the maximum node degree the number of links at each processor.

- Some simple architectures:
  1. Linear array of processors
  2. Binary tree of processors
  3. Two-dimensional mesh of processors
  4. Multiple processors with shared variables

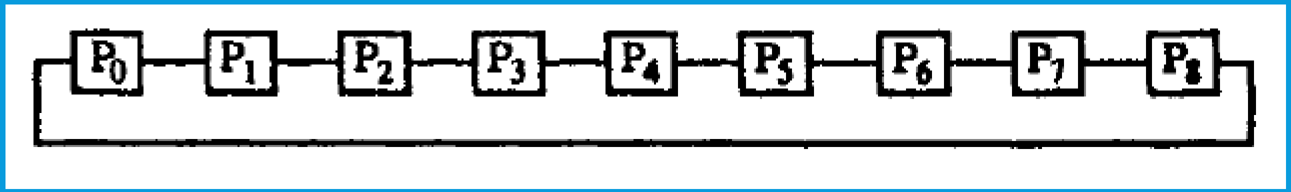
EXAMPLES OF PARALLEL ARCHITECTURE

- Linear array of processors
- The diameter of linear array of *p*-processors is D=*p*-1
- The maximum node degree (number of links) d=2.



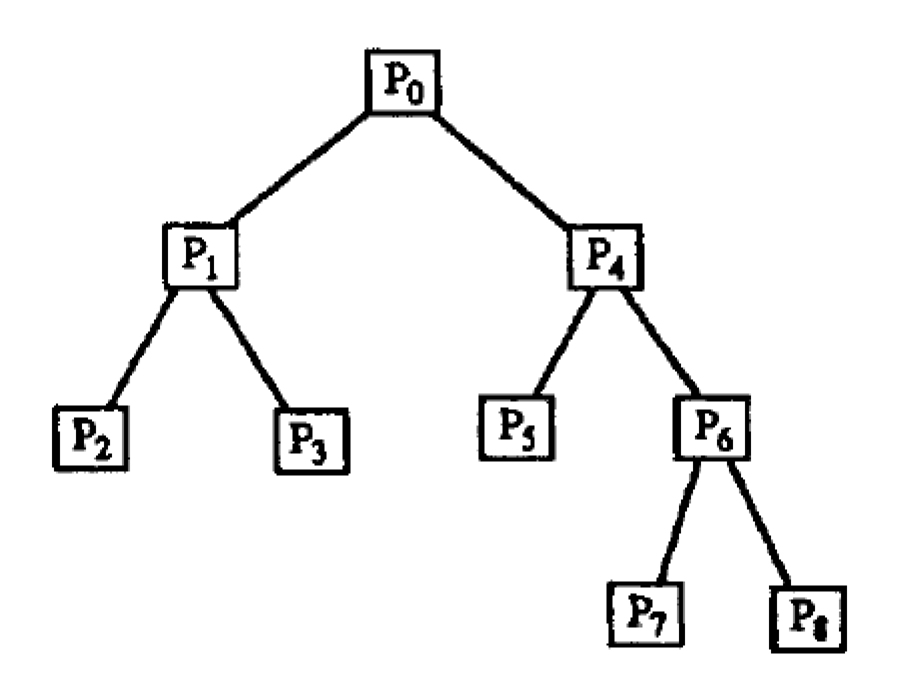
EXAMPLES OF PARALLEL ARCHITECTURE

- The ring linear array of processors
- The diameter of linear array of *p*-processors is D=$\left\lfloor \frac{p}{2} \right\rfloor$
- The maximum node degree (number of links) d=2.



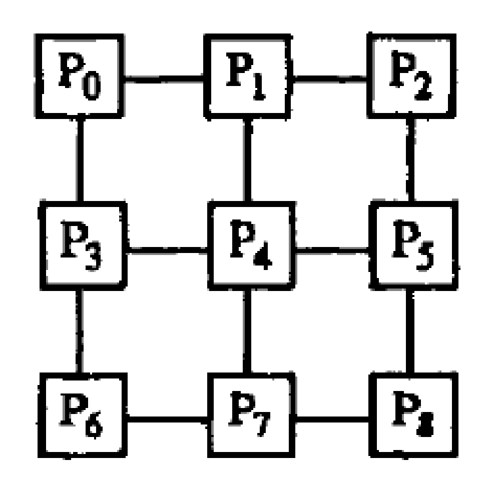
EXAMPLES OF PARALLEL ARCHITECTURE

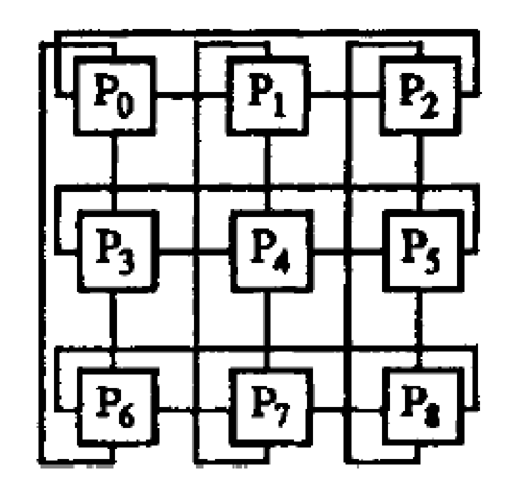
- Binary tree of processors (the tree is balanced the leaf levels differ by at most 1)
- The diameter of binary tree of p-processors is $D=2\lfloor \log p \rfloor$ and the degree d=3



EXAMPLES OF PARALLEL ARCHITECTURE

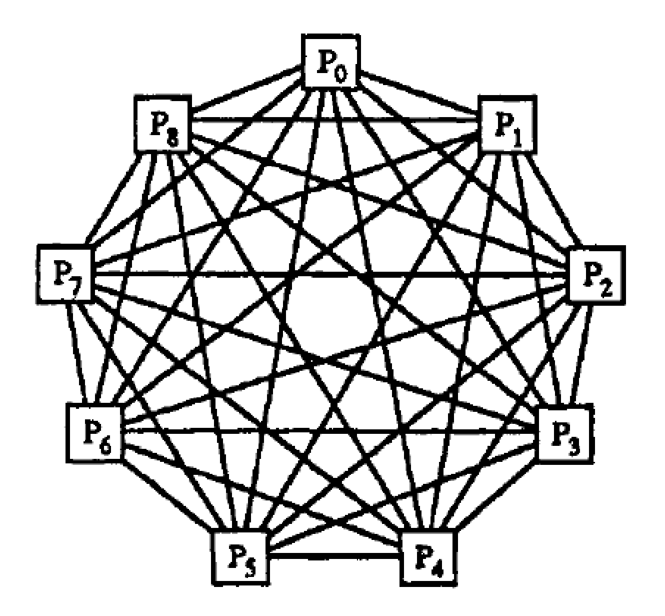
- 2D mesh of processors
- The diameter of 2D mesh of p-processors is D=$2\sqrt{p}$ -2 and d=4
- What about tours?





EXAMPLES OF PARALLEL ARCHITECTURE

- Shared memory can be represented as complete graph.
- The diameter of shared memory multiprocessor is D=1 and d=p-1
- Think about the cost?



EXAMPLES OF PARALLEL ARCHITECTURE

- We will see how to implement some of the simple computations on the simple types of architectures.