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THE ANALYSIS OF OPTIMISTIC PARALLEL DISCRETE EVENT SIMULATION ALGORITHM ON SMALL-WORLD NETWORKS

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OVERVIEW

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- Optimistic synchronisation algorithm
- The simulation of the algorithms on Small-World networks
- Results: How the underlying topology affects the synchronisation in PDES?

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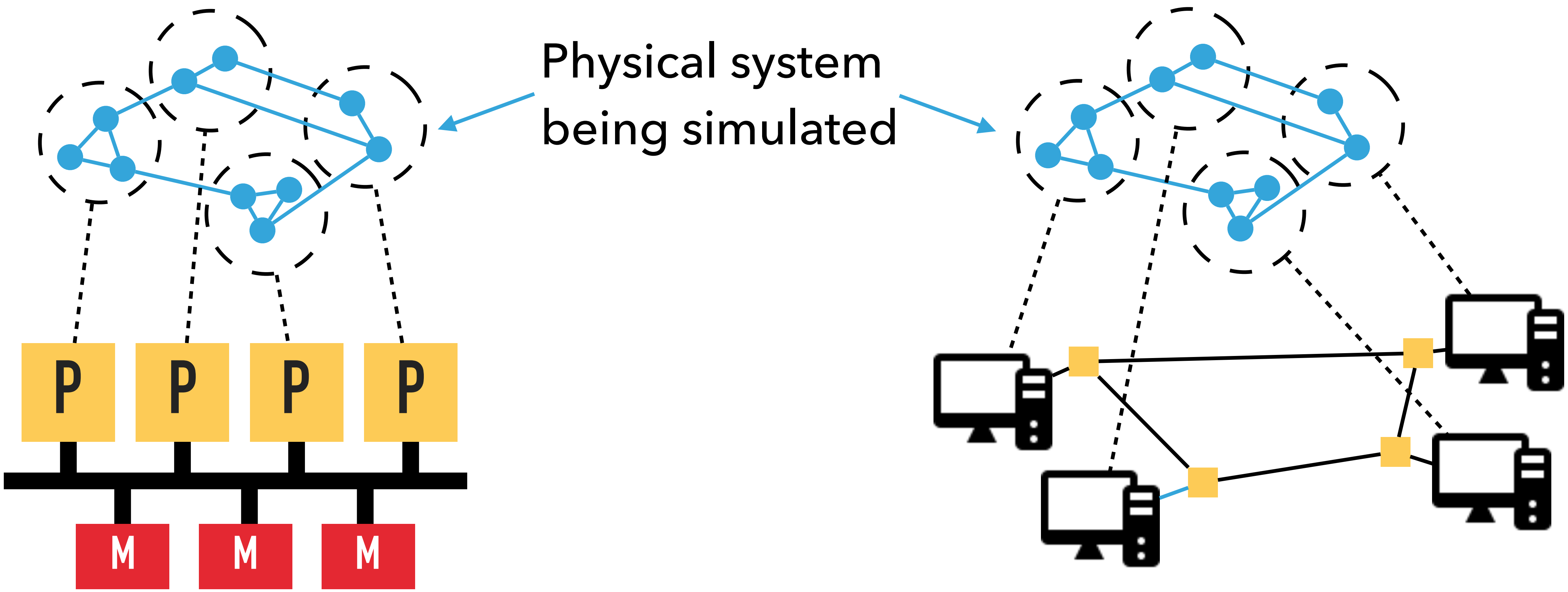
Parallel Discrete Event Simulation is a method of large-scale simulation which allows to execute a single program on a parallel computer.

PARALLEL AND DISTRIBUTED SIMULATION*



Parallel simulation involves the execution of a *single* simulation on a collection of **tightly** coupled processors (e.g. a shared memory multiprocessor)

Distributed simulation involves the execution of a *single* simulation on a collection of **loosely** coupled processors (e.g. PCs interconnected by a LAN or WAN)

**from R.Fujimoto[1]*

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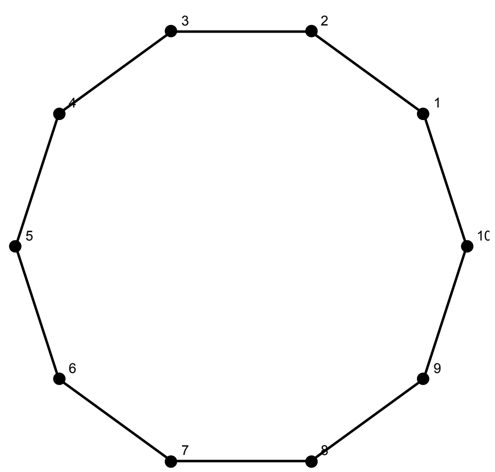
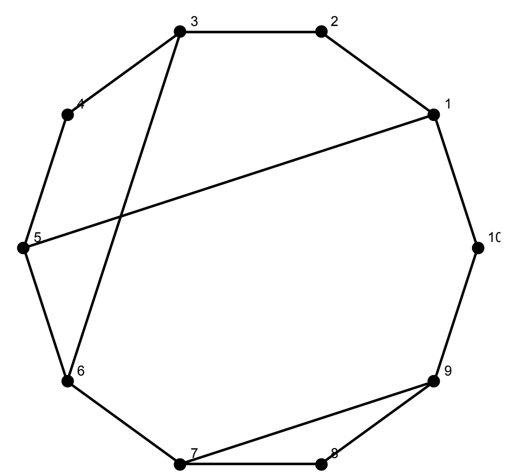
- Changes in subsystems occur at some instant of time and are called **discrete events.**
- To preserve causality between dependent objects some **synchronisation protocol** is used.
- Using the **virtual time concept**.
- Communication between parallel processes goes via timestamped messages.
- No shared memory between subsystems.

UNDERLYING TOPOLOGIES

Regular



Small-World-like [4]



p=0

0 < p << 1

Vertices - PEs

Edges - dependencies

1. Average shortest path ~ log(N)
2. Clustering coefficient ≈ 0

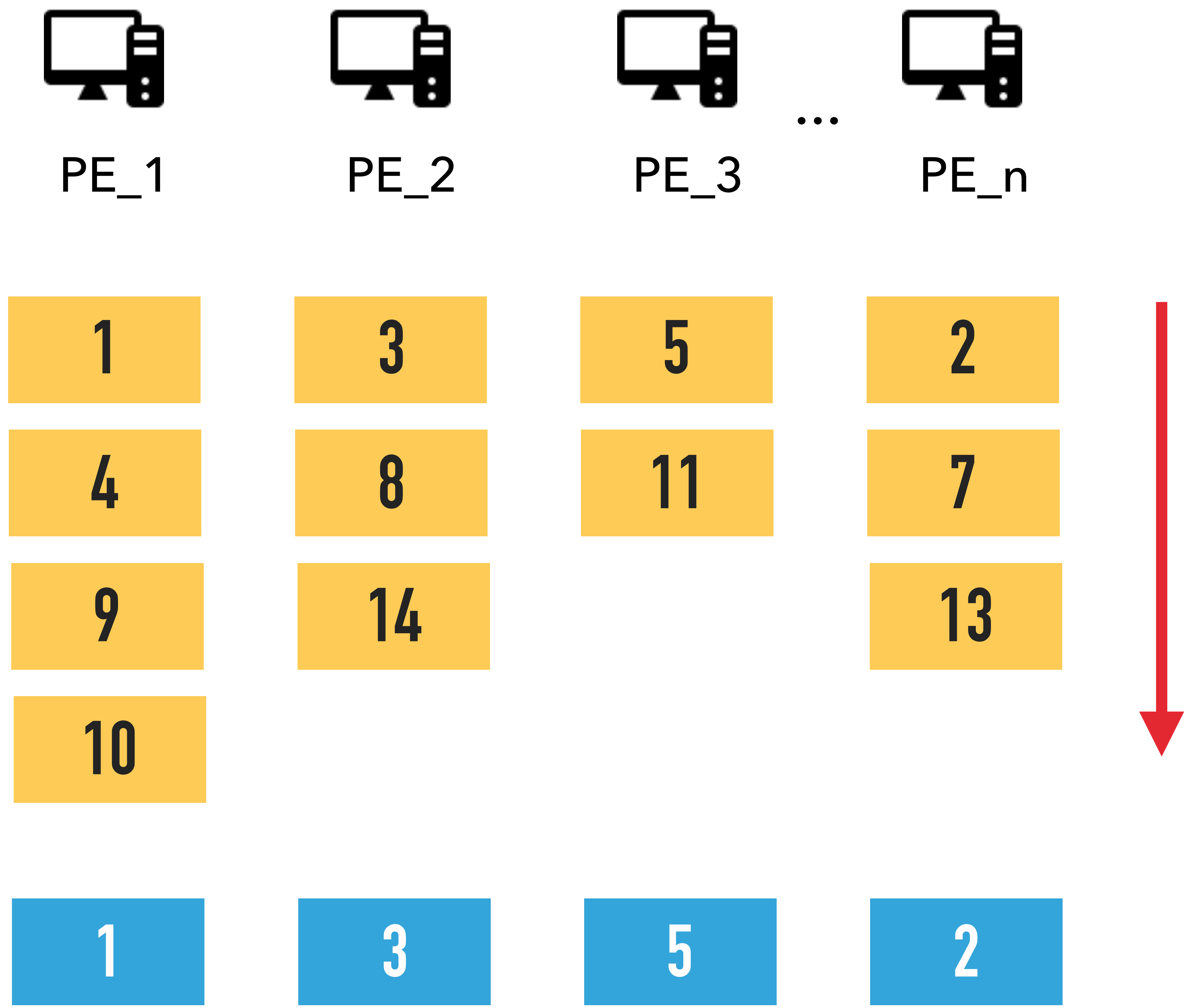
p - concentration of added links

VIRTUAL TIME CONCEPT (AN EXAMPLE)

PE = node/CPU/core/etc.

Lists of events with timestamps

Local virtual time of PEs



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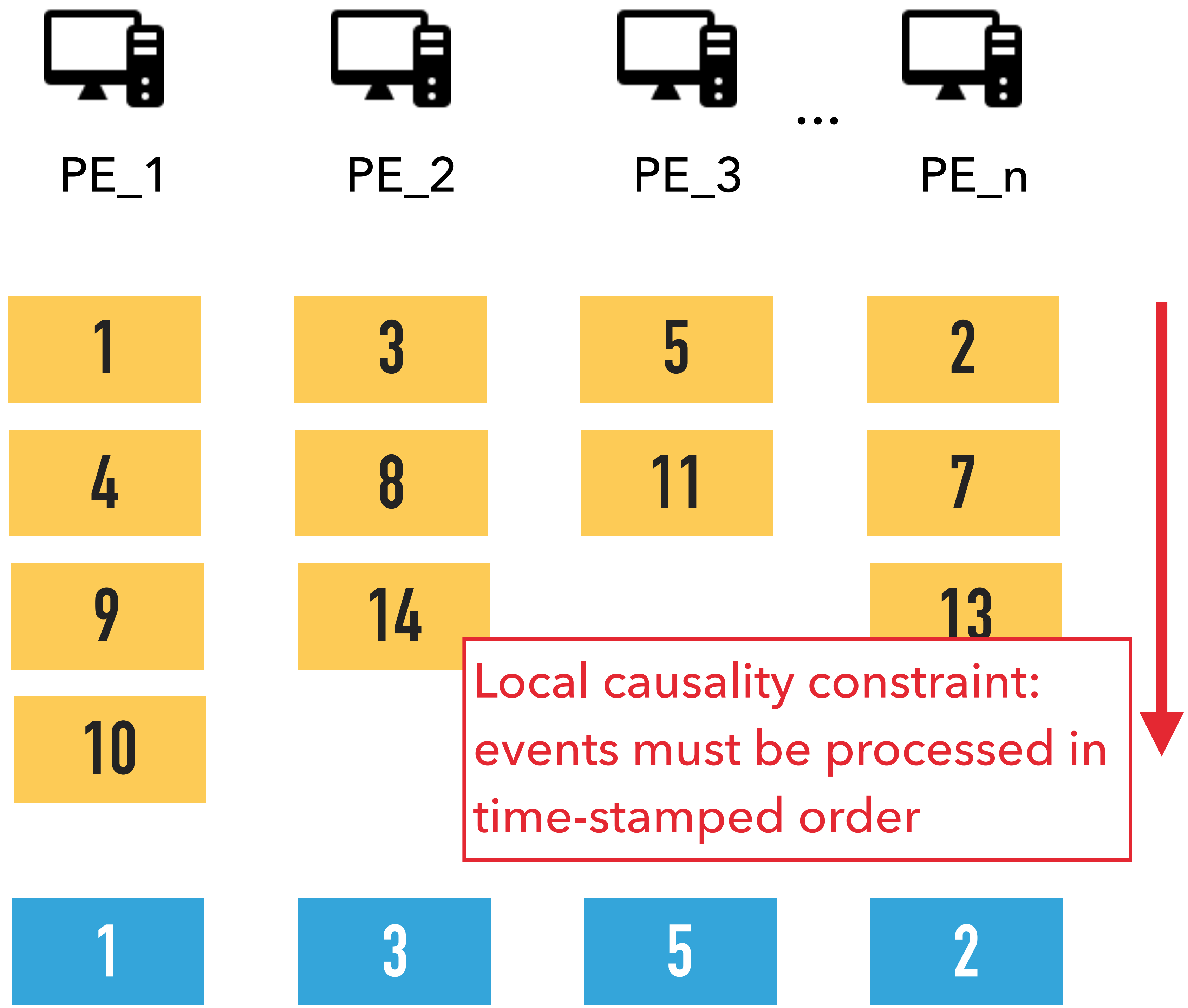

Optimistic algorithm

Allows emergence of causality errors but has a roll-back mechanism. The process, received a message with timestamp lower than its LVT (‘‘from the past’’), rolls-back to the state with lower time. It also sends anti messages to other processes to cancel previously sent messages.

OPTIMISTIC SYNCHRONISATION

PE = node/CPU/core/etc.

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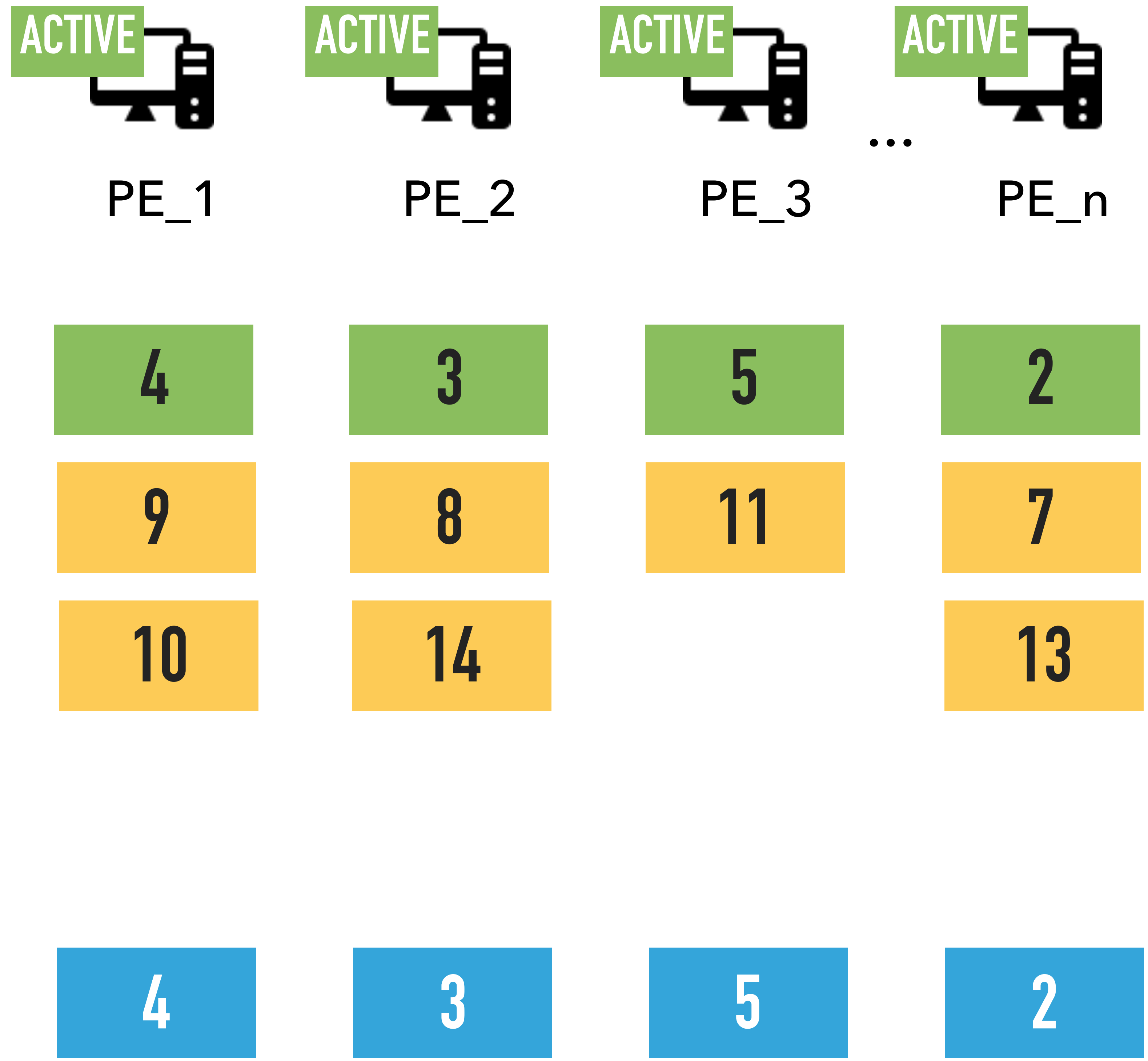
Local virtual time of PEs



OPTIMISTIC SYNCHRONISATION

PE = node/CPU/core/etc.

	PE_1	PE_2	PE_3	...	PE_n
Status	ACTIVE	ACTIVE	ACTIVE		ACTIVE
Lists of events with timestamps	9	8	11		7
	10	14			13
Local virtual time of PEs	9	8	11		7

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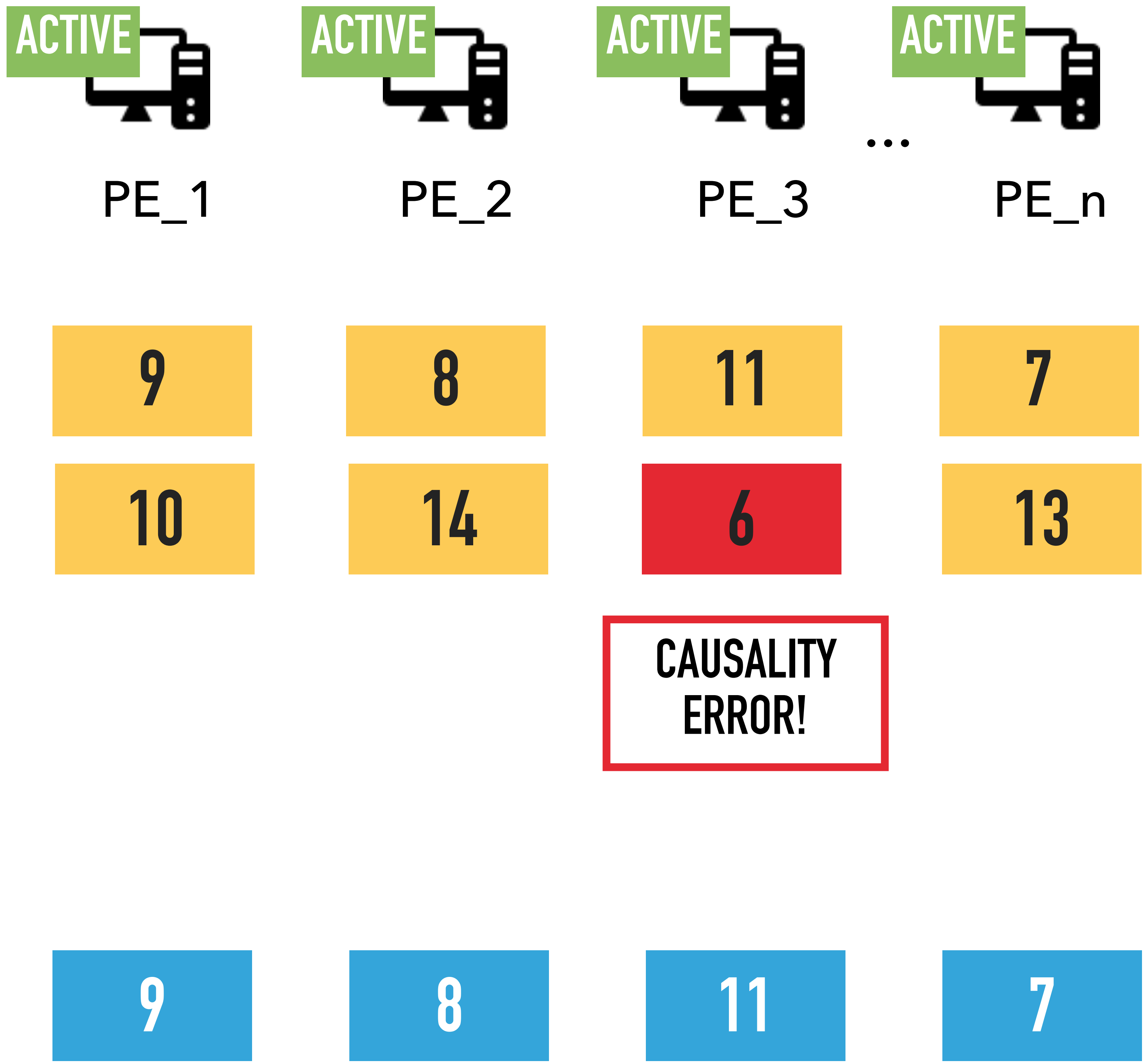
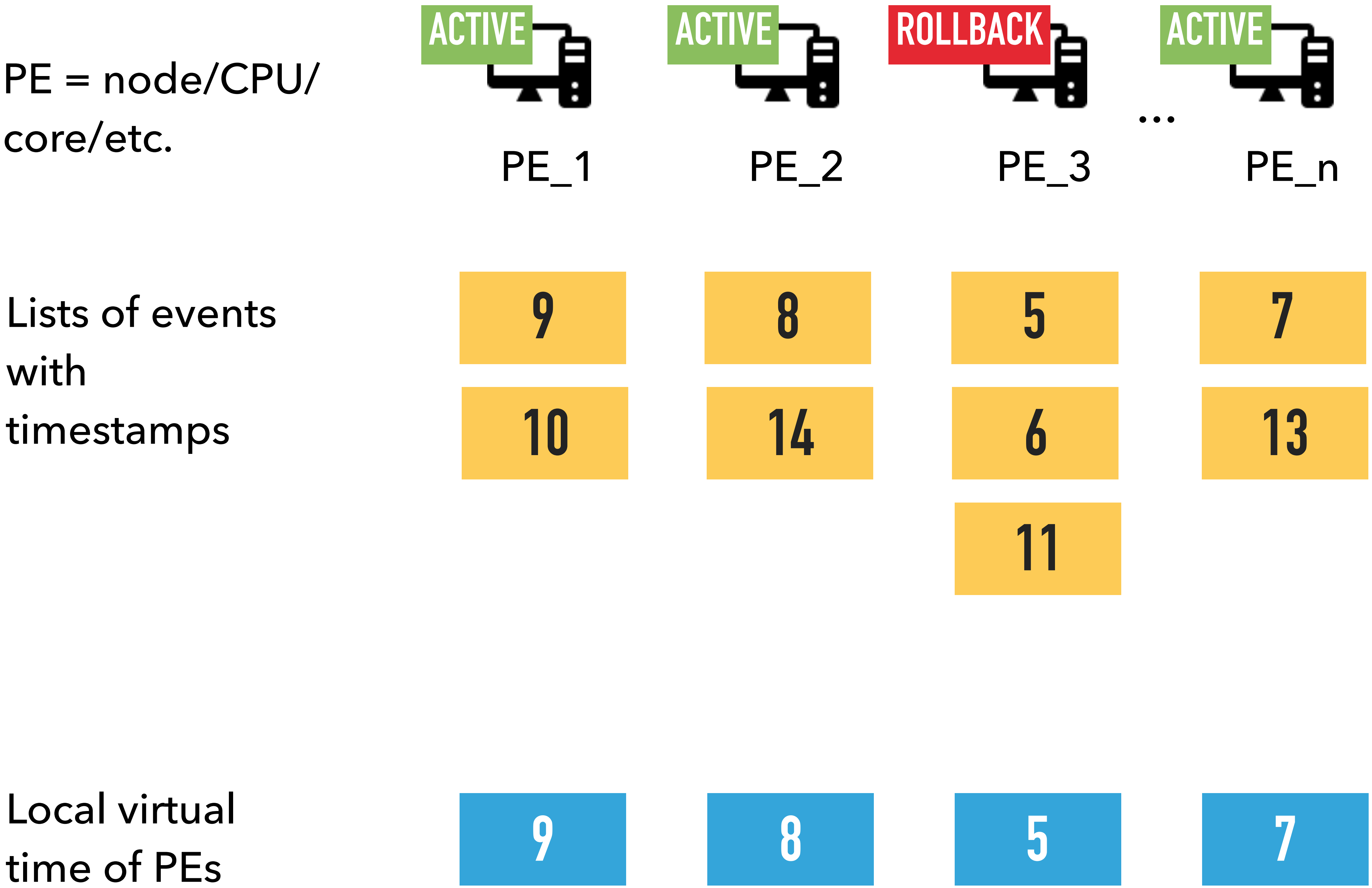


OPTIMISTIC SYNCHRONISATION

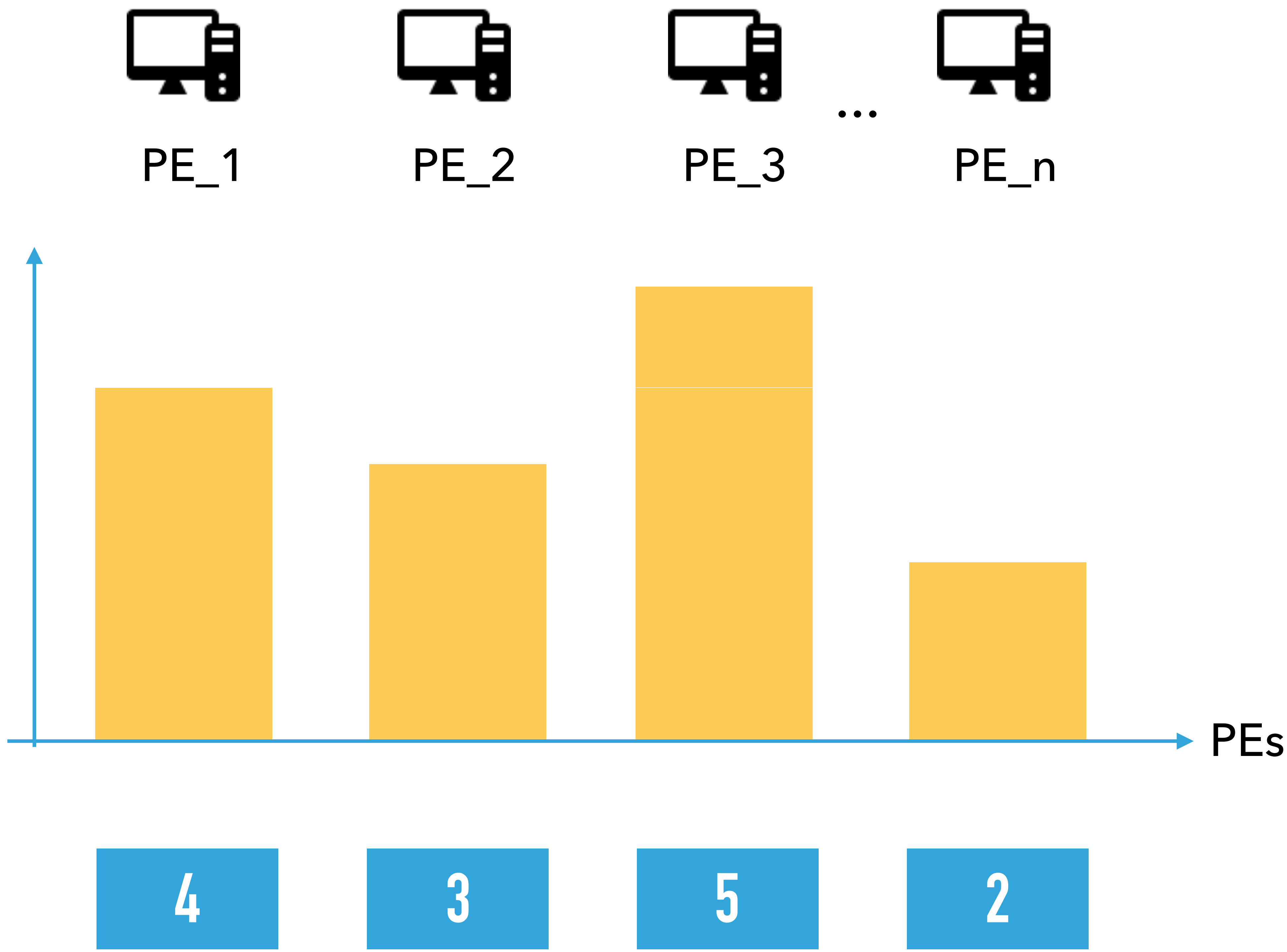


THE CONCEPT OF VIRTUAL TIMES (EXAMPLE)

PE = node/CPU/core/etc.

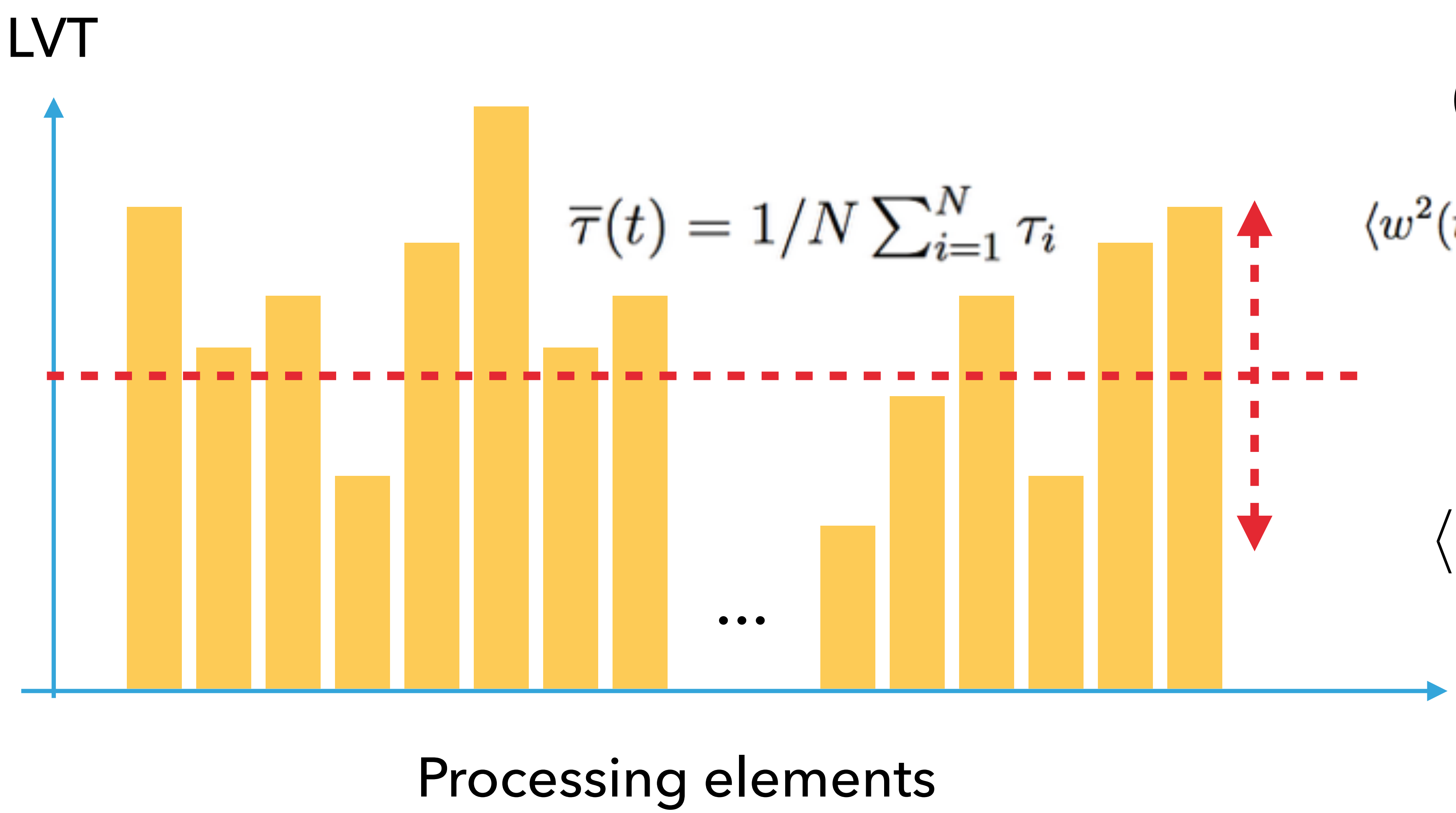
Local virtual time profile

Local virtual time of PEs



THE OBJECT OF THE RESEARCH

We study the scalability properties of **Optimistic** synchronisation algorithm on small-world communicational network.



1. width of the profile (=desynchronisation)

$$\langle w^2(t) \rangle = \langle \frac{1}{N} \sum_{i=1}^{N} [\tau_i(t) - \overline{\tau}(t)]^2 \rangle$$

2. speed of the profile (=utilization)

$$\langle u(t) \rangle = \langle \tau_i(t) - \tau_i(t-1) \rangle_i$$

THE MODEL OF EVOLUTION OF THE LOCAL VIRTUAL TIME PROFILE

Set parameters N, M, p, b
Create small-world graph with pN random long-range links.
for $t = 0..M$ **do**
    for $i = 0..N$ **do** $\tau_i(t) += \eta_i$
    k = Poisson(b)
    for $j = 1..kN$ **do**
        Choose random PE_m
        Choose random neighbour of PE_m PE_r
        If $\tau_m(t) > \tau_r(t)$ then $\tau_m(t) = \tau_r(t)$
    Calculate observables.

$$\langle w^2(t)\rangle = \langle \frac{1}{N}\sum_{i=1}^{N}[\tau_i(t) - \overline{\tau}(t)]^2\rangle$$

$$\langle u(t)\rangle = \langle \tau_i(t) - \tau_i(t-1)\rangle_i$$

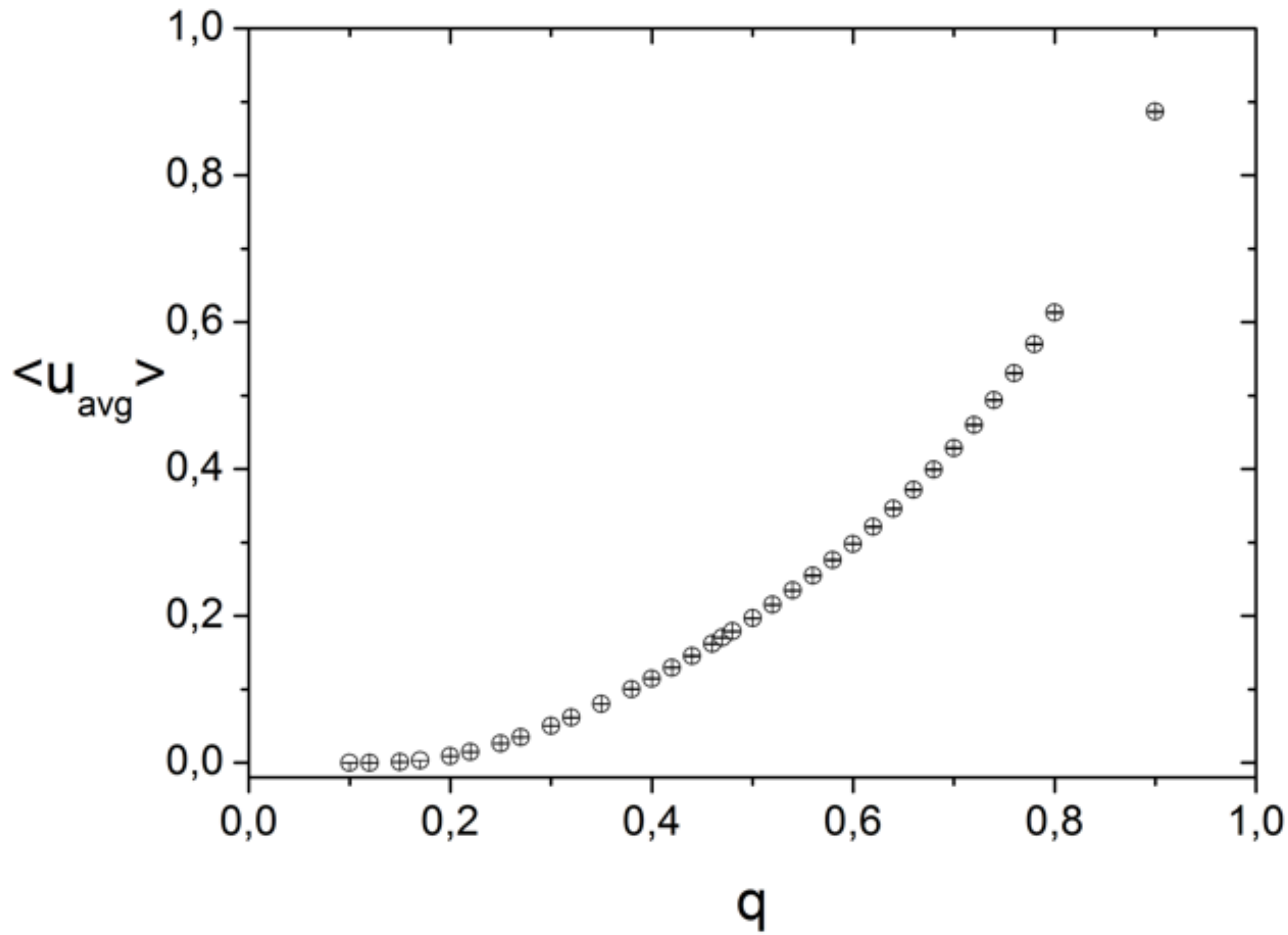
RESULT#1: AVERAGE SPEED

The parameter (progress rate):

$$q = \frac{1}{1+b}$$

where b is a mean avalanche length (the number of PEs, which rolled back during one simulation step)

$$u = u_0(q - q_c)^\nu$$



RESULT#1: AVERAGE SPEED FITTING

DIRECTED PERCOLATION UNIVERSALITY CLASS

$$\nu = 1.733847(6)$$

The phase transition takes place at

$$q_c = 0.189(2)$$

for the RSOS model

and

$$q_c = 0.233(1)$$

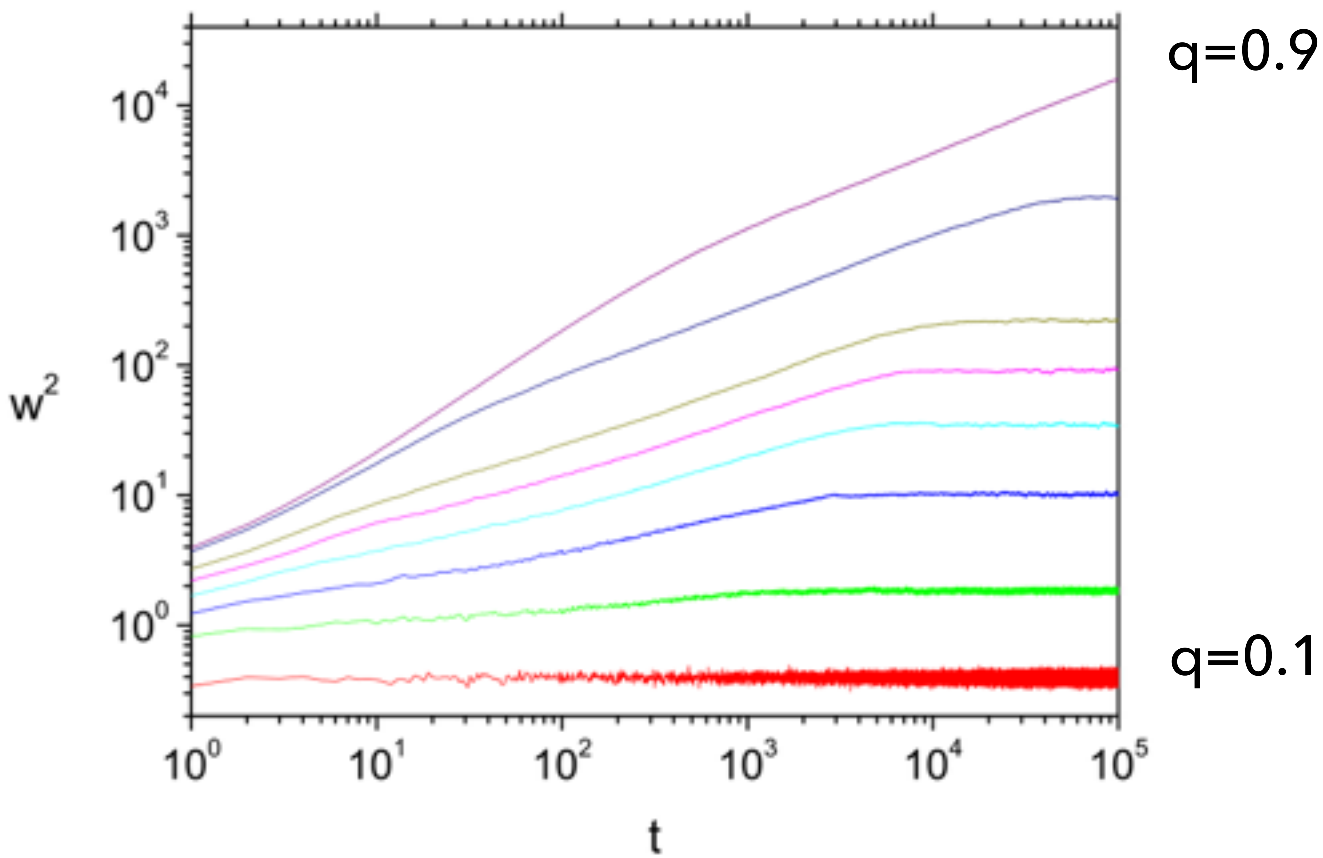
for the unrestricted model

$$u = u_0(q - q_c)^\nu$$

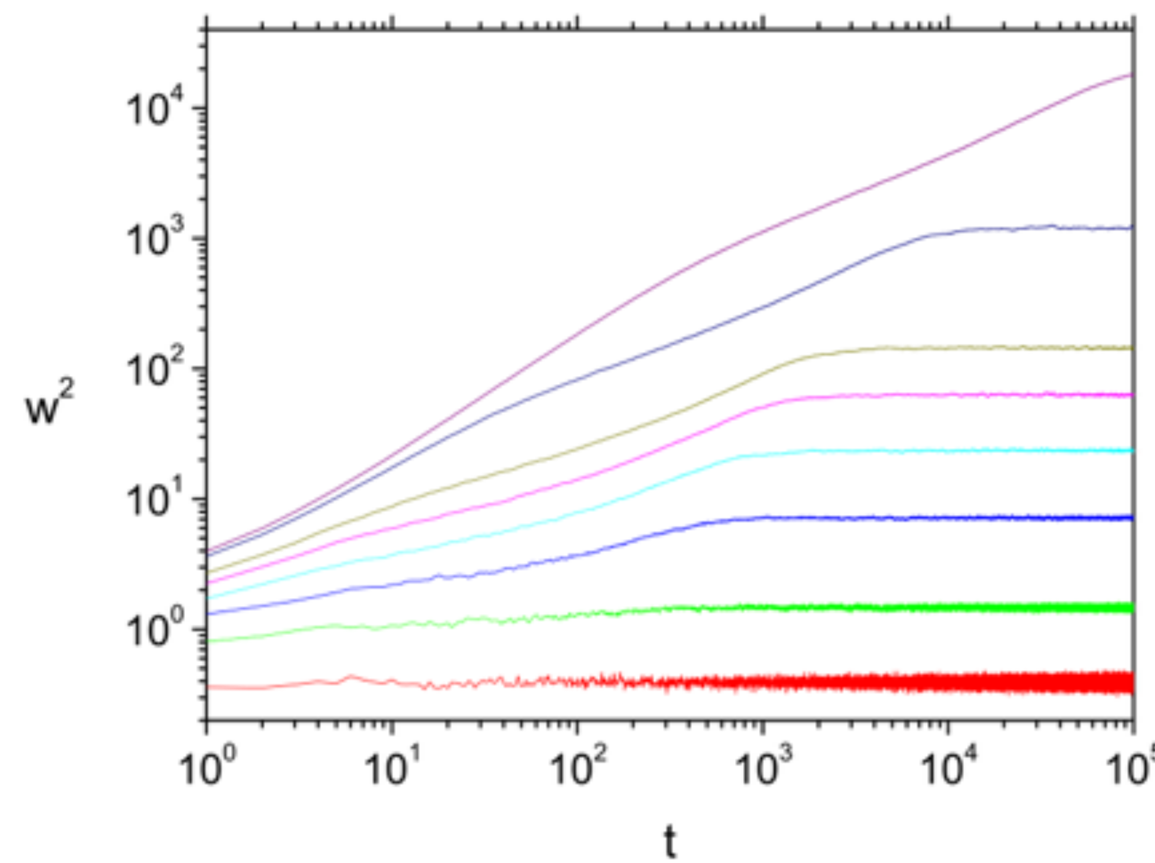
p	u_0	q_c	v
0	1,093(5)	0,143(1)	1,66(1)
0,001	1,126(9)	0,149(3)	1,69(2)
0,01	1,165(8)	0,166(2)	1,70(1)
0,05	1,27(1)	0,202(2)	1,74(2)
0,1	1,38(1)	0,224(2)	1,79(1)
0,2	1,54(2)	0,249(3)	1,88(2)

RESULT#2: AVERAGE WIDTH

Regular lattice



Small-world network, p=0.01



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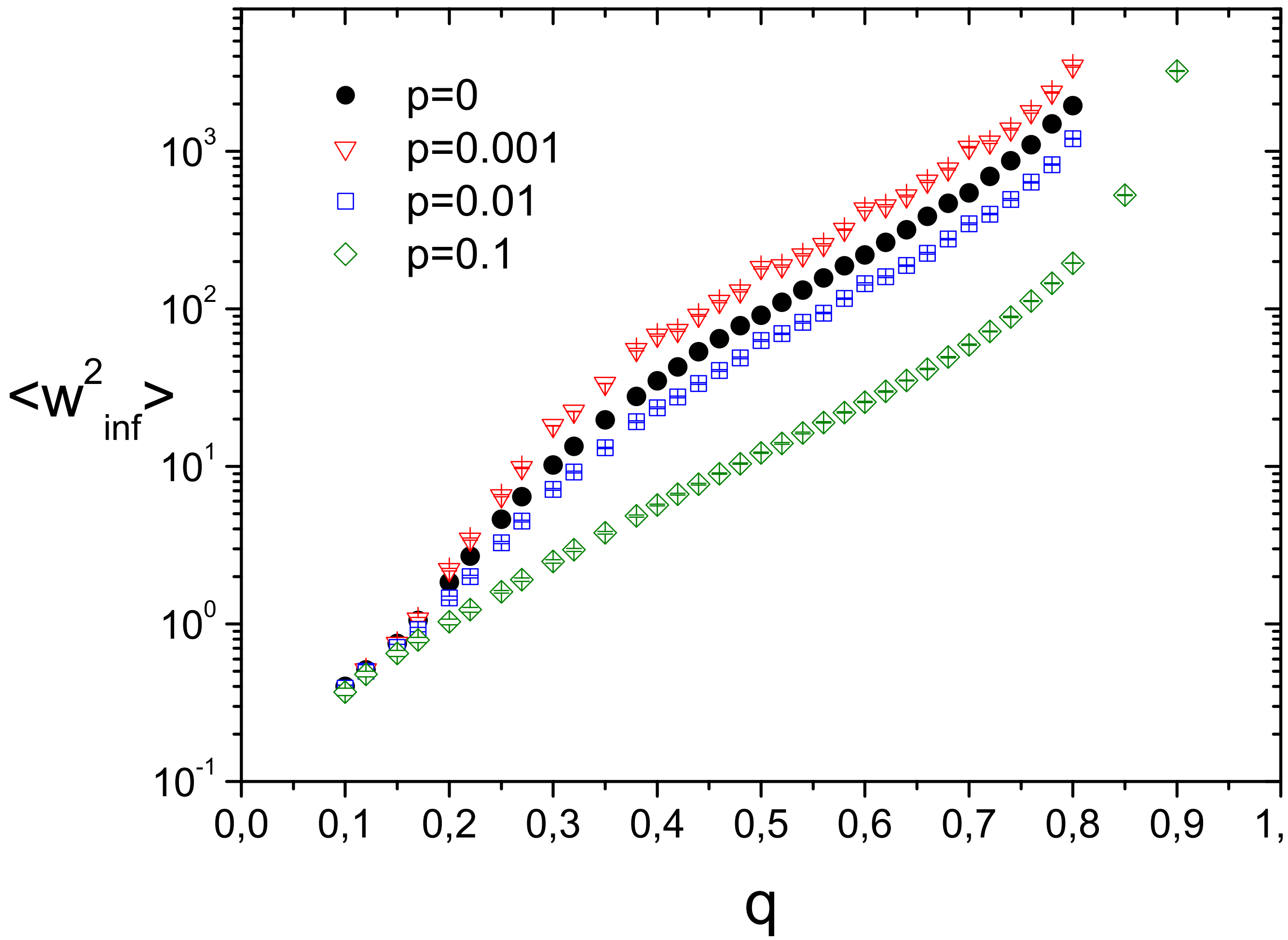

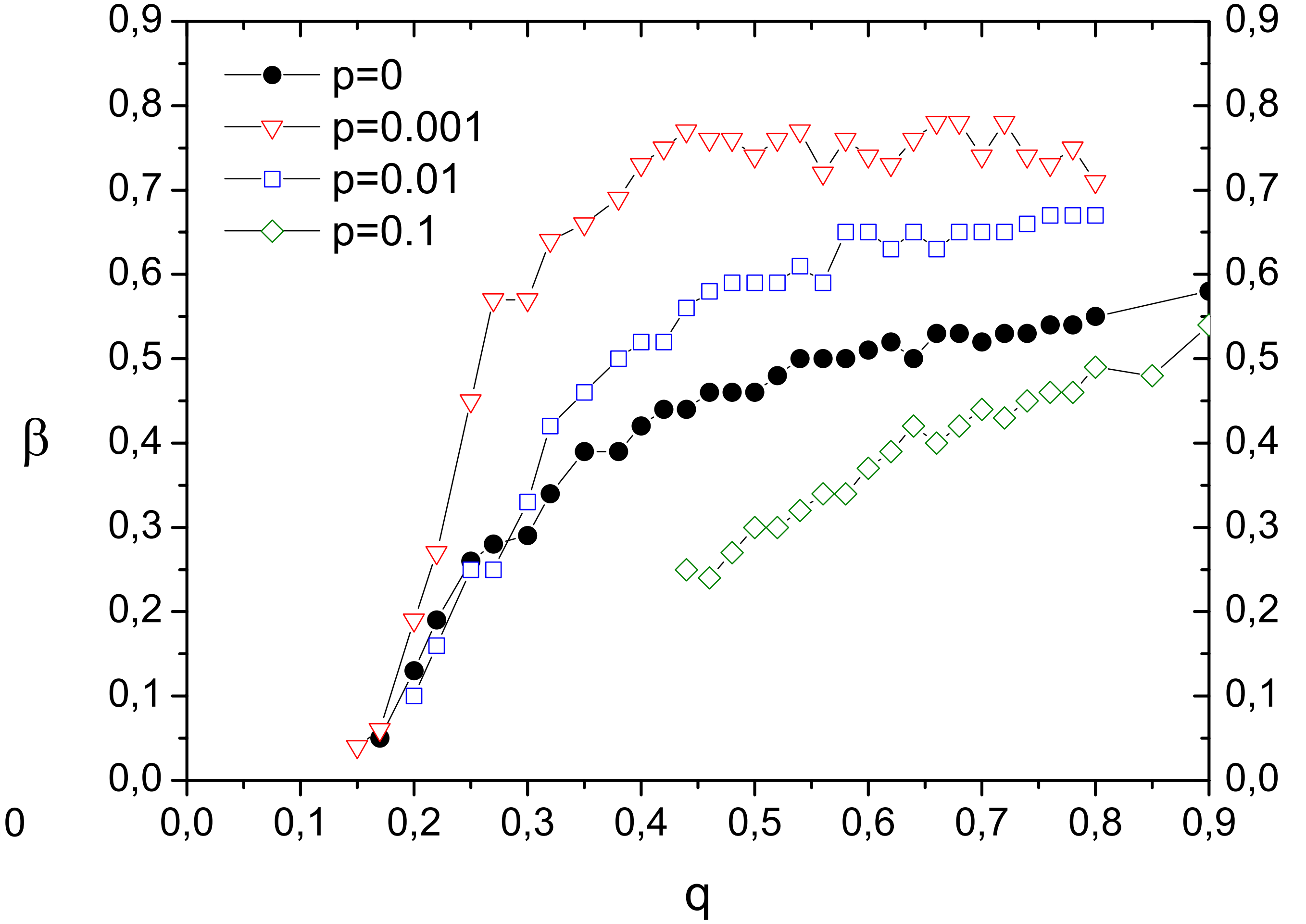

CONCLUSION:

- **We built the model of local virtual time profile growth in optimistic PDES**
- **The average speed of the profile behaves as:** $u = u_0(q - q_c)^v$
- **The model belongs to DP universality class**
- **The behaviour of the average width does not change with the topology, i.e. it saturates after some time.**

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