Distributed Systems

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Objectives

- To discuss the concept of clock synchronization (NTP).
- To introduce Lamport's logical (scalar) clock and discuss its properties.
- To introduce Vector clock and discuss its properties.

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Difficulty with Physical Clock

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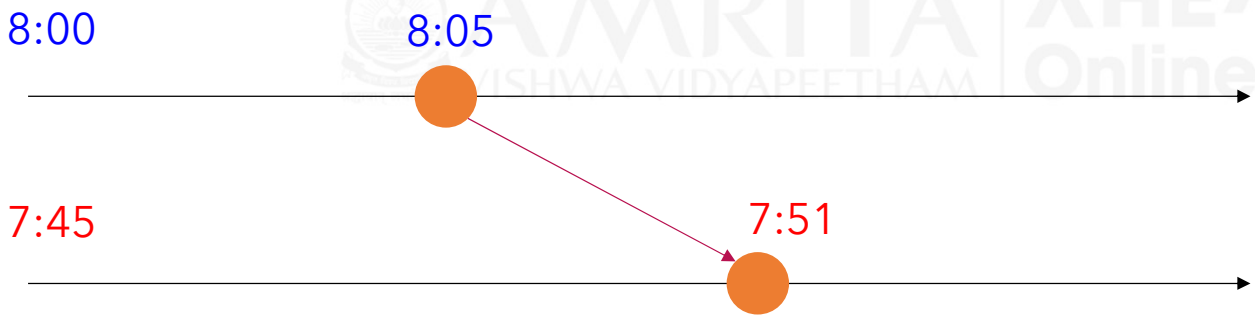
Two system clocks may not be in perfect sync or run in unison.

- P1 sends a message m to P2 at time t
- P2 receives m at time < t (why would this happen??)

P2's clock is behind P1



- Debugging and troubleshooting can be very challenging.
- You need to know the order of events that happened.

Solution 1: Synchronize clock

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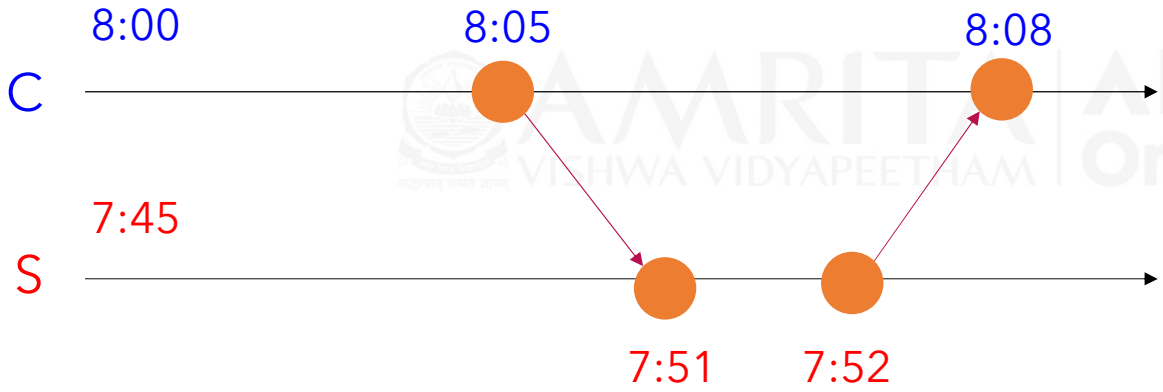
- Network Time Protocol (NTP)

Reset clock to 8:08 – 00:15 = 7:53



$$\frac{(7:51 - 8:05) + (7:52 - 8:08)}{2}$$

$$\frac{-14 + (-16)}{2}$$

$$\frac{-30}{2}$$

$$-15$$

Solution 1: Synchronize clock

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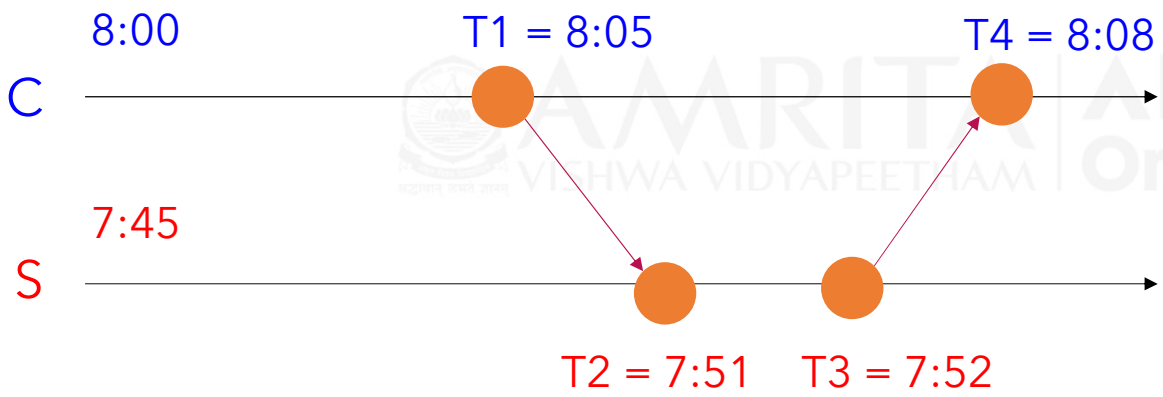
- Network Time Protocol (NTP)



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Let's generalize this

Solution 1: Synchronize clock

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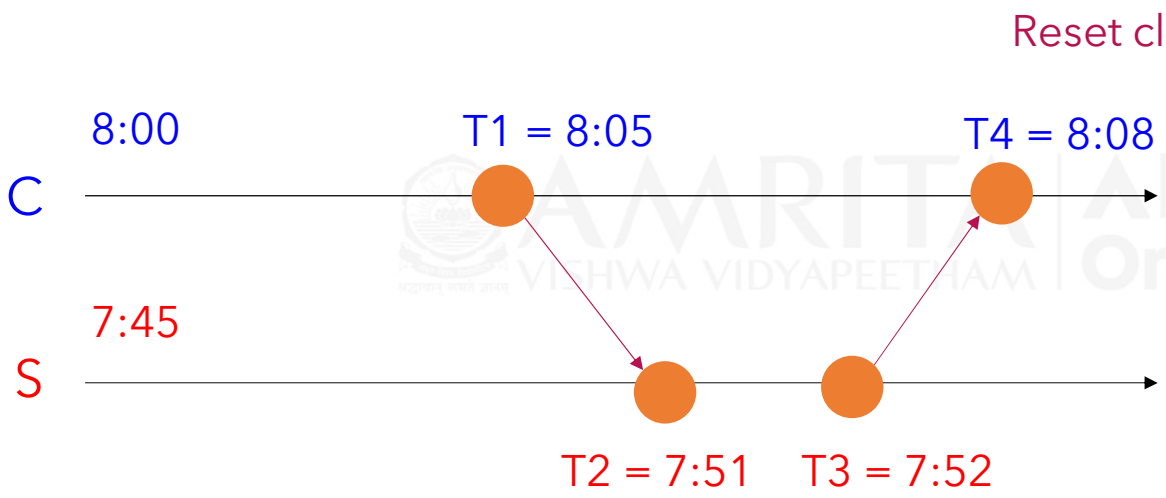
- Network Time Protocol (NTP)



$$\frac{(T2 - T1) + (T3 - T4)}{2}$$

Clock offset θ

What happens in case of irregular transmit delays?

Clocks tend to drift over time

Let's generalize this

Solution 2: Logical clock

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- Maintain a separate logical clock (like counter)
- Adjust the clock whenever necessary.

Time ticks only when an event happens

If recv time (m) < send time (m)
Reset clock at receiver

Basic Terms

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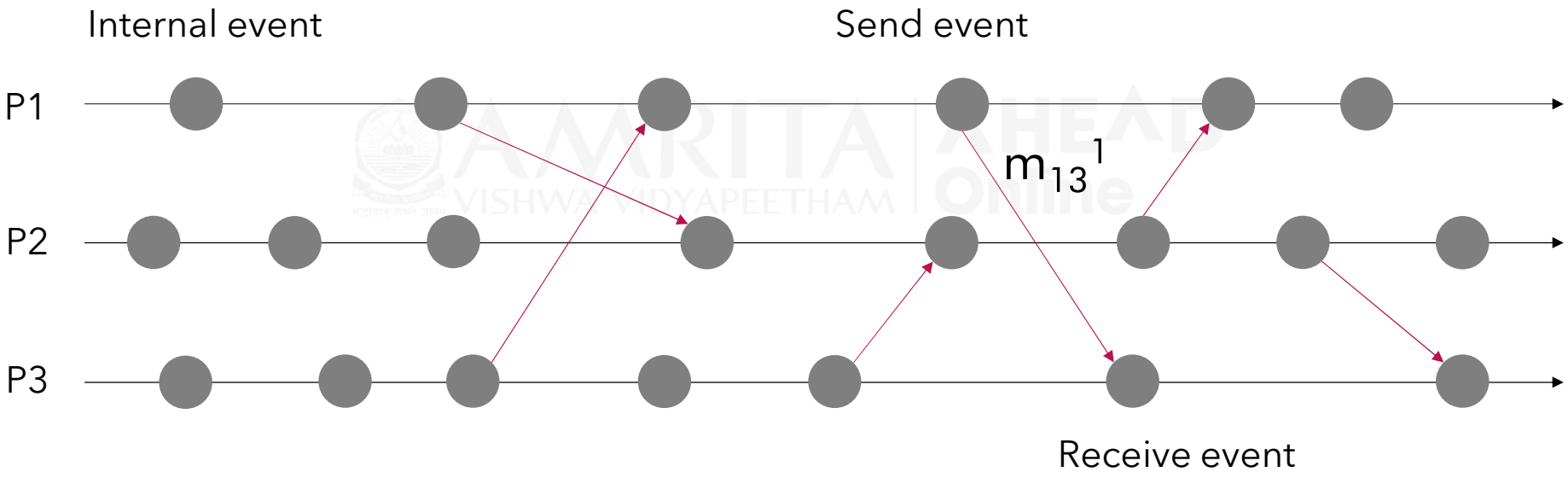
- Space-Time diagram, Events, Sender, Receiver, Messages, 'happens before' relation.



Space-Time Diagram

m_{ij}^{k} k^{th} message from Pi to Pj

Lamport's Scalar Clock

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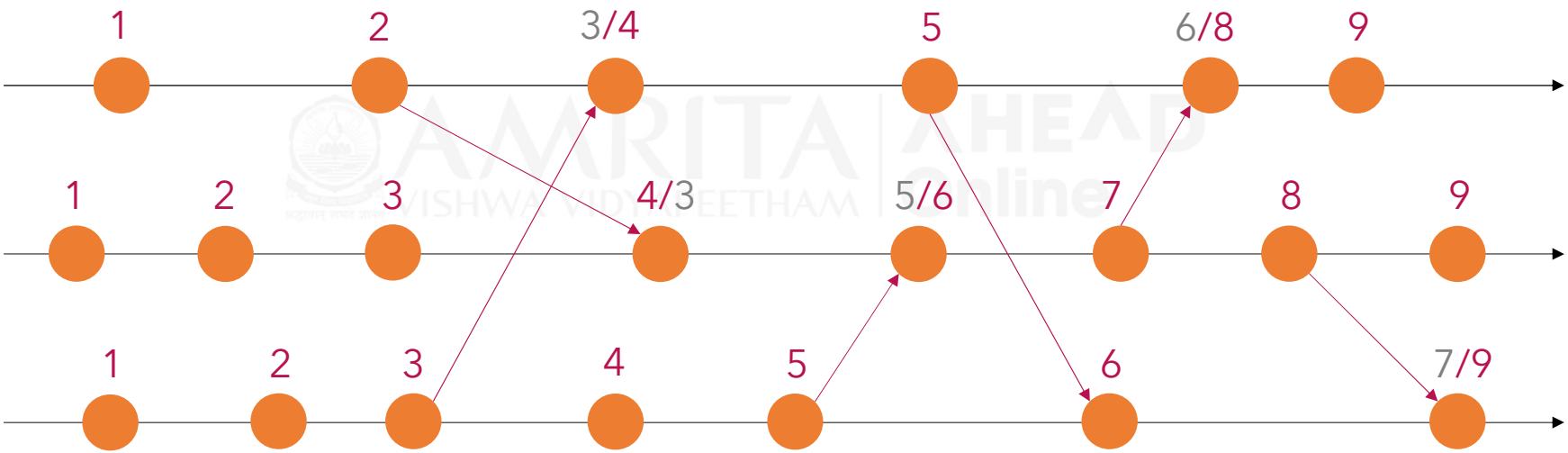
- Consider the space-time diagram of 3 processes and the events given below.



Properties of Scalar clock

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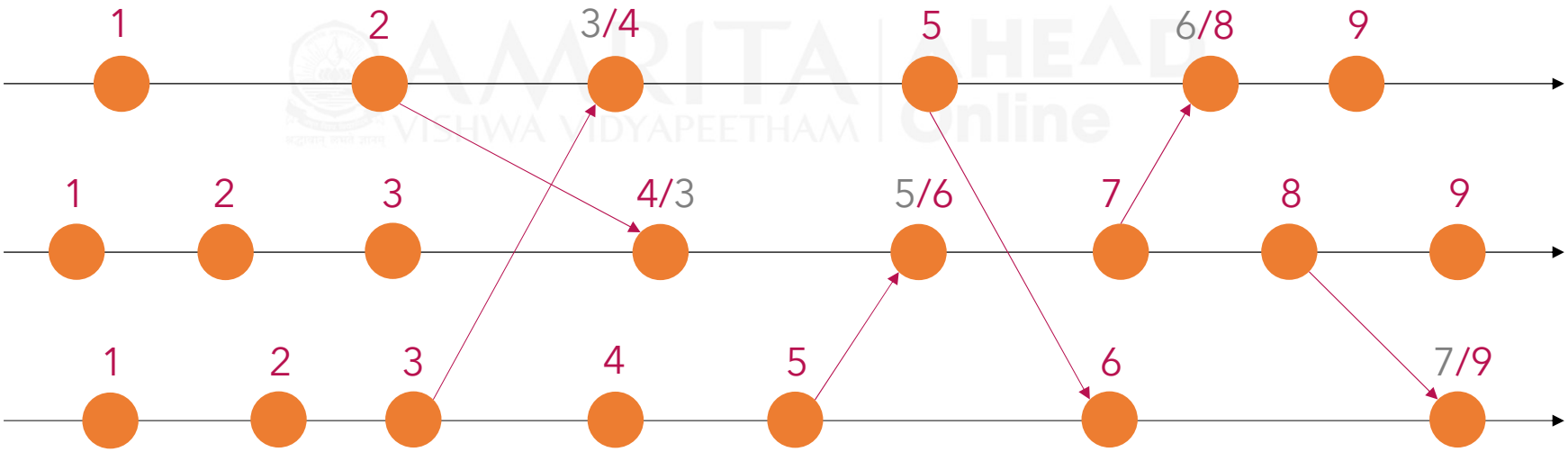
- Consistency Property: ei → ej ➔ C(ei) < C(ej)
- Not strongly consistent: C(ei) < C(ej) ⇏ ei → ej
- Total ordering



Vector Clock

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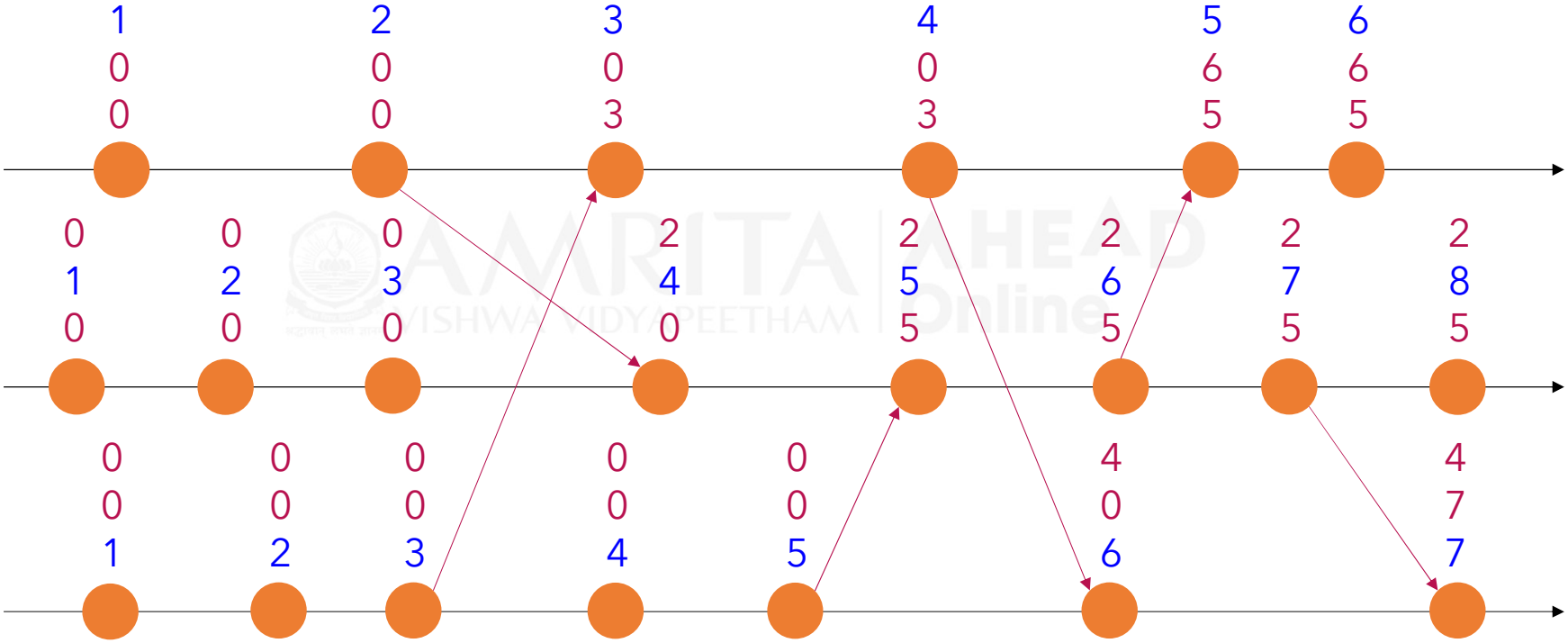
- Consider the space-time diagram of 3 processes.



Properties of Vector Clock

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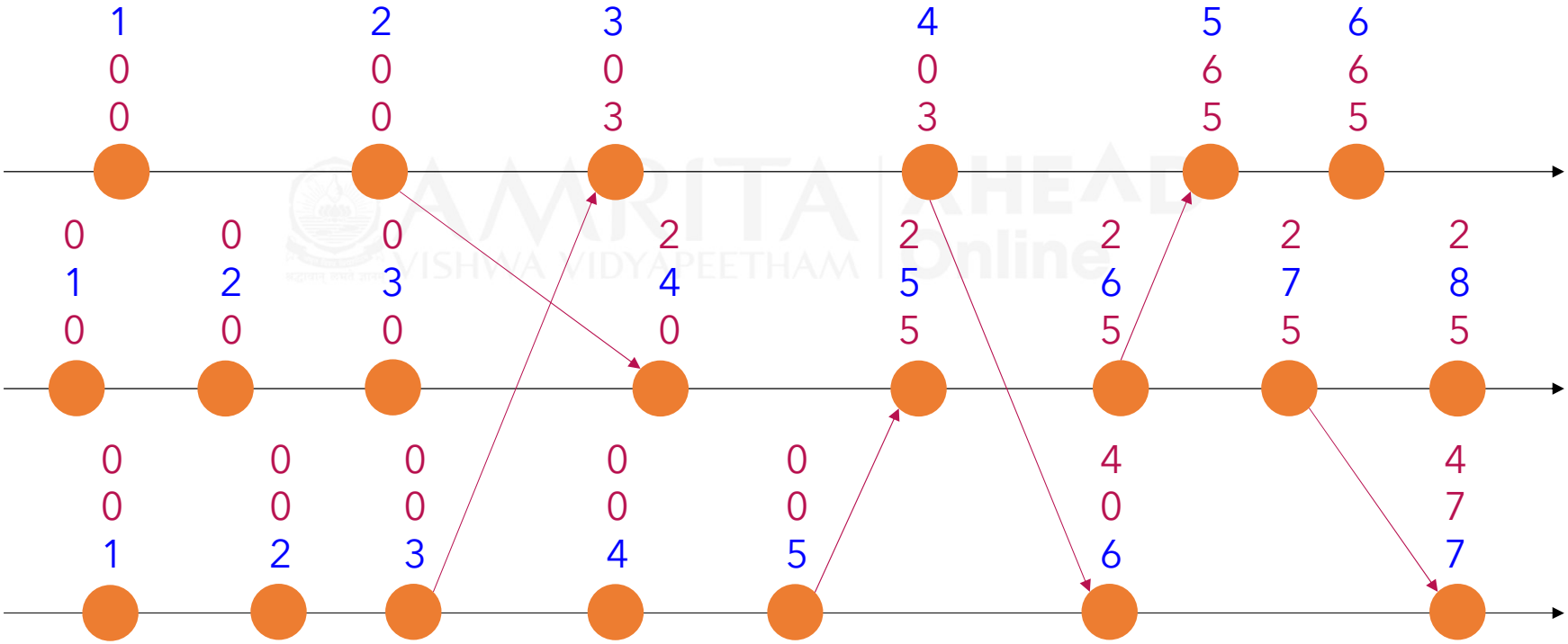
- Strong clock consistency: (1) ei → ej ⇔ C(ei) < C(ej) and (2) ei || ej ⇔C(ei) || C(ej)



Summary

- We discussed NTP, Scalar and Vector clocks.