

Time In Distributed Systems

Pt.1



Hello



Denis Golovachev



SPB



Saint-Petersburg

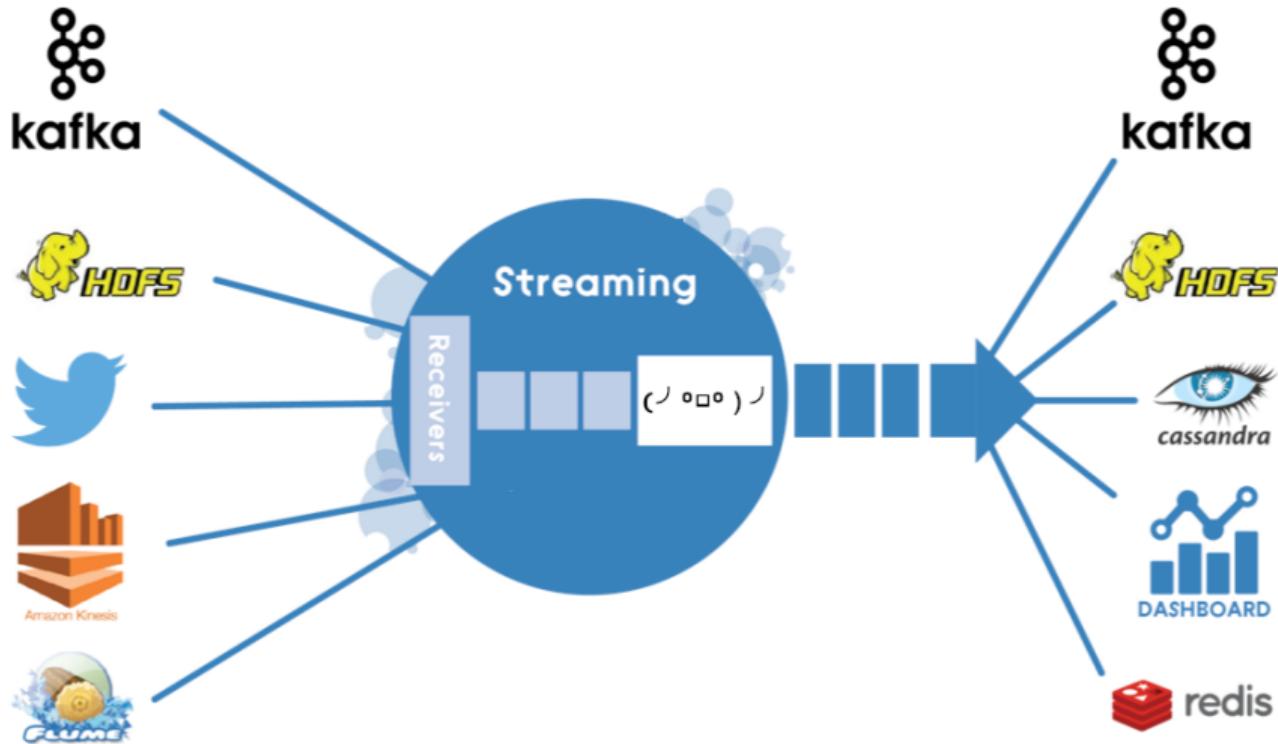




Software Architect



Data Streaming for Big Data







Big Data School





Professor

Boring



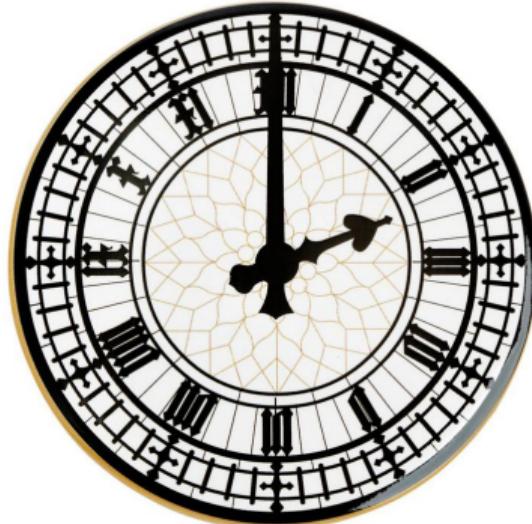
Time



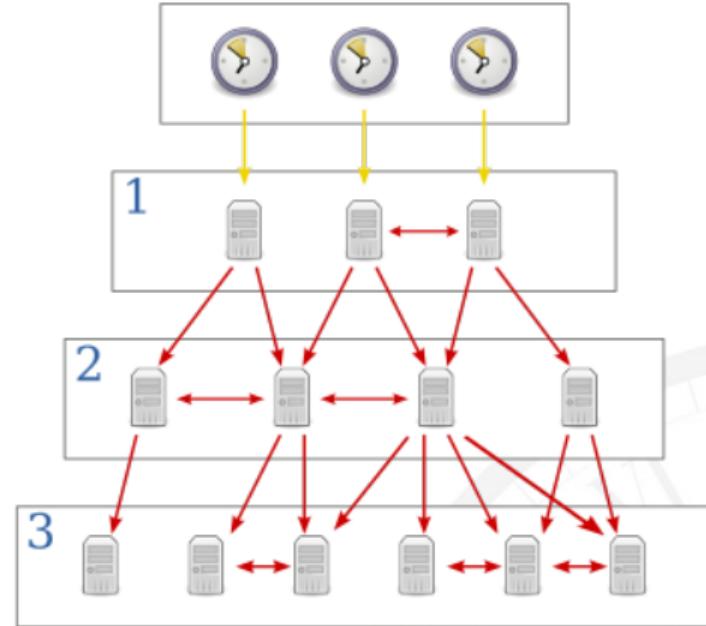
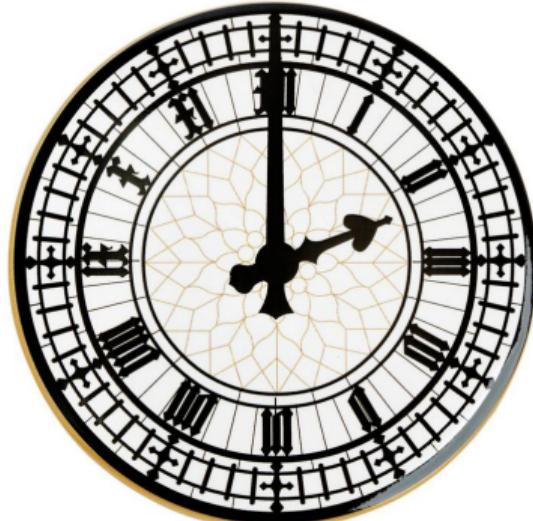
Time



Time



Time



Question

What is time?



Time is ...



MYSTERY SOLVED

Way of arrange the order of events

Time is ...



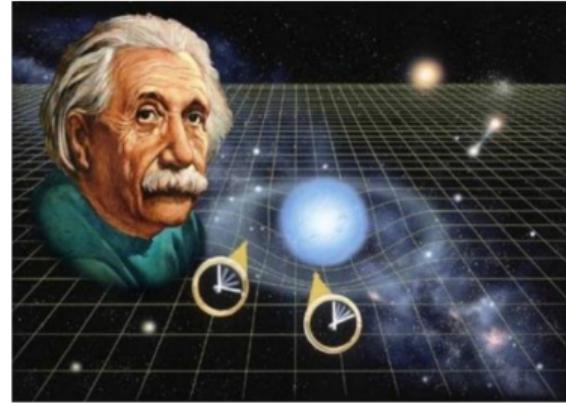
1998

2004

3XXX

MYSTERY SOLVED

Way of arrange the order of events



Another dimension

Definition of time

Compact and robust definition of time has proved to be remarkably tricky and elusive.

- What clocks measure (attr. to physicists Albert Einstein, Donald Ivey, and others)
- What prevents everything from happening at once (physicist John Wheeler and others)
- A linear continuum of instants (philosopher Adolf Grünbaum)

Religion



Wikipedia

In Zurvanism, Zurvan was perceived as the god of infinite time and space and was aka ("one", "alone").

Time is ...

Time is something we deal with every day, and something that everyone thinks they **understand**



Game time!

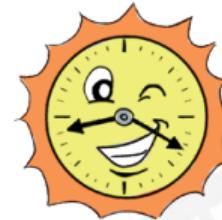
Round 1

There are always
24 hours in a day

Round 1

There are always
24 hours in a day

Daylight saving time



*Daylight Saving
Time Begins*

Round 2

There are always
60 seconds in a minute

Round 2

There are always
60 seconds in a minute

Leap Second



COURAGEOUSCHRISTIANFATHER.COM

Round 3

A month not always
ends in the same year it started

Round 3

A month not always
ends in the same year it started

- Fiscal year
- Chinese Year



Round 4

Month could have
less than 20 days

Round 4

Month could have
less than 20 days

September 1752 had
19 days in British
Empire



Everyone's do it wrong!?







Red Hat Bugzilla – Bug 479765

[Home](#) [New](#) [Search](#) [My Links](#) [Help](#)**Bug 479765 - Leap second message can hang the kernel****Status:** CLOSED ERRATA**Alias:** None**Product:** Red Hat Enterprise Linux 5**Component:** kernel **Sub Component:** [\(Show other bugs\)](#)**Version:** 5.2**Hardware:** All Linux**Priority:** high**Severity:** medium**Target Milestone:** rc**Target Release:** --**Assignee:** Prarit Bhargava**QA Contact:** Red Hat Kernel QE team**Docs Contact:****URL:****Whiteboard:****Keywords:** Reopened, ZStream**Duplicates (1):** 800289 [\(view as bug list\)](#)**Depends On:****Blocks:** 1300182 483701 485920 801794**TreeView+ depends on / blocked****Reported:** 2009-01-12 22:31 UTC by Chris Adams**Modified:** 2018-11-28 20:21 UTC [\(History\)](#)**CC List:** 15 users [\(show\)](#)**Fixed In Version:****Doc Type:** Bug Fix**Doc Text:****Clone Of:****Environment:****Last Closed:** 2009-09-02 08:33:56 UTC**Dependent Products:**

Java Code

```
public class ThreadSleep {  
  
    public static void main(String[] args) throws InterruptedException {  
        long start = System.currentTimeMillis();  
        Thread.sleep(2000);  
        System.out.println("Sleep time in ms = "+(System.currentTimeMillis()-  
start));  
  
    }  
  
}
```



Oracle Technology Network > Java > Java SE > Community > Bug Database

JDK-6900441 : PlatformEvent.park(millis) on Linux could still be affected by changes to the time-of-day clock

Type: Bug

Priority: P3

Submitted: 2009-11-11

Component: hotspot

Status: Closed

Updated: 2015-11-27

Sub-Component: runtime

Resolution: Fixed

Resolved: 2013-09-24

Affected Version: e5.0u21,hs24,hs25,6,6u29,7

OS: linux,linux_ubuntu

CPU: generic,x86,ppc

Versions (Unresolved/Resolved/Fixed)

JDK 6	JDK 7	JDK 8	Other
6u71 Fixed	7u60 Fixed	8 b109 Fixed	hs25 Fixed

Related Reports

Duplicate : [JDK-8024036](#) - Thread.sleep(long) is not immune to system time shifts with Linux kernel 3.7.10Duplicate : [JDK-7139684](#) - ScheduledExecutorService doesn't schedules correctly if sys time drifts backRelates : [JDK-8029453](#) - java/util/concurrent/locks/ReentrantLock/TimeoutLockLoops.java failed by timeoutRelates : [JDK-8024036](#) - Thread.sleep(long) is not immune to system time shifts with Linux kernel 3.7.10Relates : [JDK-8144167](#) - [OS_X] ConditionObject#awaitNanos waits too long if system clock is turned backRelates : [JDK-6546236](#) - Thread.interrupt() of Thread.sleep() can be lost on Solaris due to race with signal handlerRelates : [JDK-6311057](#) - Java Thread.sleep(timeout) is influenced by changes to System time on Linux

Description

This is a continuation of 6311057 which only partially "fixed" the problem because Linux itself is operating incorrectly in this area. I have it on good authority that "The futex wait implementation is historically wrong." and that "I think with newer kernel/glibc combinations it will be correct."

The real fix here is to change the pthread_cond so that it is associated with the monotonic clock (pthread_condattr_setclock(CLOCK_MONOTONIC) - and with pthread_cond_init being passed the attr object) and to calculate the absolute time as "millis from now" on the monotonic clock. This will make the PlatformEvent::park(millis) code immune to changes in the time-of-day clock.

Distributed environment



Mathias Verraes

@mathiasverraes

Follow



There are only two hard problems in distributed systems: 2. Exactly-once delivery
1. Guaranteed order of messages 2. Exactly-once delivery

9:40 PM - 14 Aug 2015

7,192 Retweets 5,632 Likes



70

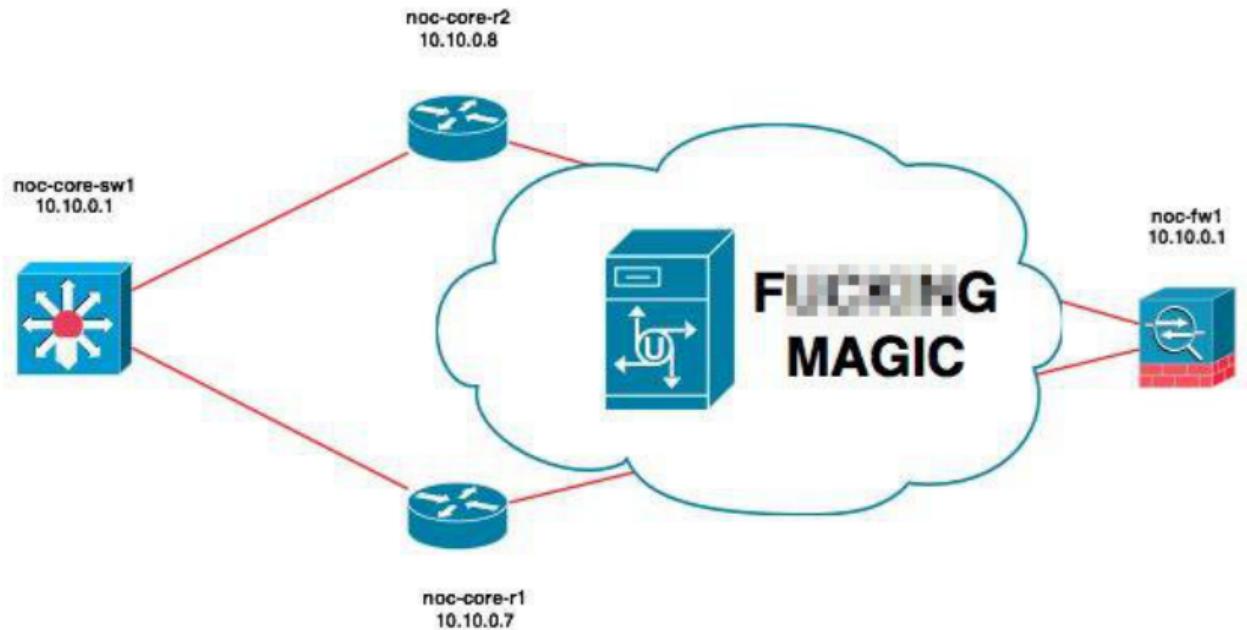


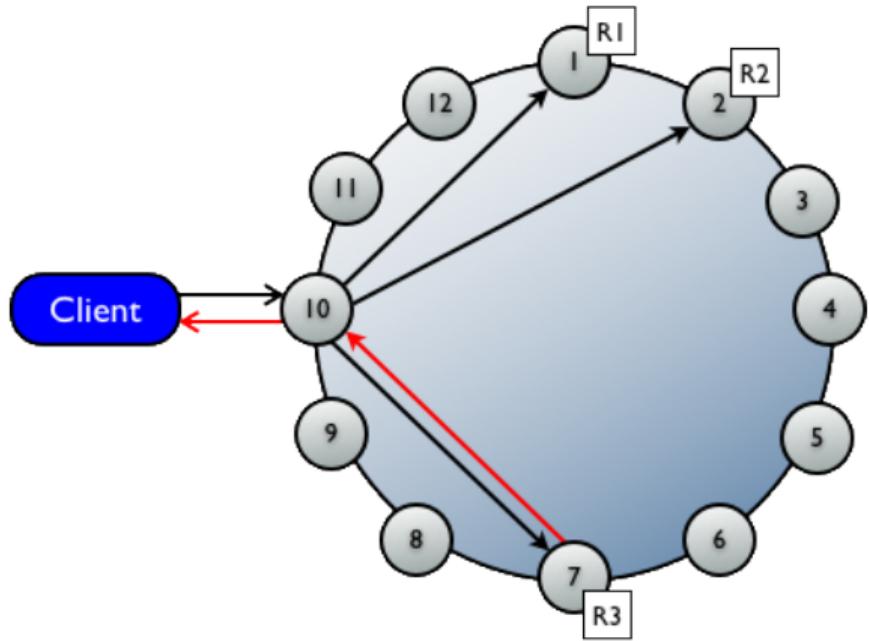
7.2K



5.6K







- Peer to Peer Database
 - Masterless Architecture
- its difficult to reason about events in this system

I am the Law and Order



Needed to establish the order of events that have occurred in the system or when they will occur in the future

Order in Chaos

- Maintain consistency
- Build reliable systems
- Mutual exclusions
- Debug [Resumption of execution]

Common Clock

We can reliably define

- simultaneous: all events that happen between clock ticks

Common Clock

We can reliably define

- simultaneous: all events that happen between clock ticks
- before: an event that happens in a previous clock tick
- after: an event that happens in a subsequent clock tick

Distributed Systems

Synchronization in distributed systems is **hard**

- **No shared memory**
- **No common clock**

Wall Clock

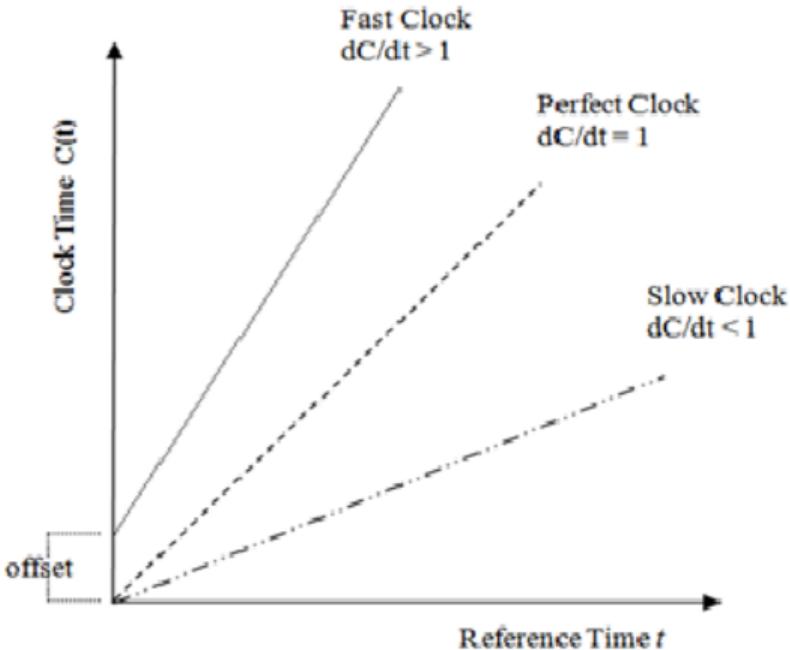
Let's use 'Wall Clocks' and NTP!?



When kept under tension the quartz crystal oscillates at a well-defined frequency

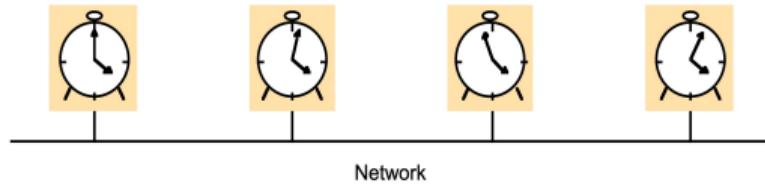
Clock Drift

We can't have perfect clocks



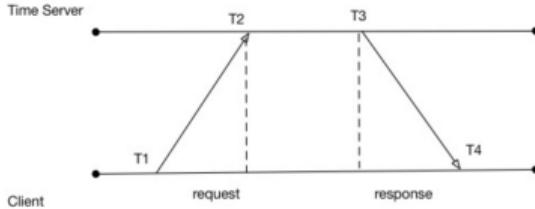
Ordinary clocks drift by about 1 sec in 10 days

Clock Skew



Skew: the difference between the times on two clocks (at any instant)

I'm running NTP. I'm good



The challenge with this approach is that there is a delay in the transmission from the time server to the client receiving the time update
This **delay is not constant for all requests**. Some request may be faster and others slower

I'm running NTP. I'm good

600000 events per second

I'm running NTP. I'm good

$1 / 600000 = 0.0000016 \dots$ microsecond?

I'm running NTP. I'm good

Protocol	Media	Sync Accuracy
NTP	Ethernet	50-100 milliseconds
IRIG-B	Coaxial	1-10 microseconds
PTP	Ethernet	20-100 nanoseconds

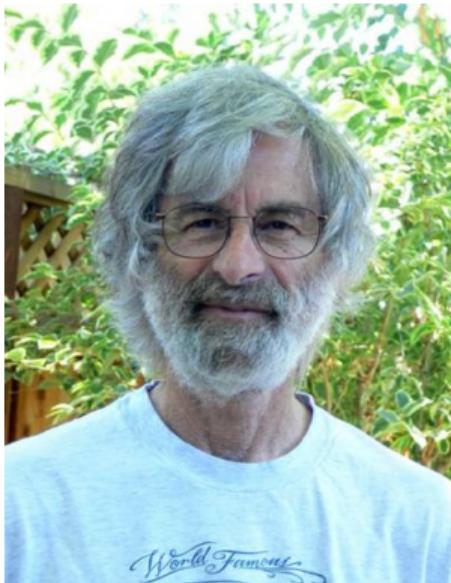
* Choosing the correct Time Synchronization Protocol and incorporating the 1756-TIME module into your Application
By: Josh Matson

Boom!



Correction of time does not mean that all machines agree on time, it just means they are much **closer to each other on average**

Leslie Lamport



Lamport, L. (1978). "Time, clocks, and the ordering of events in a distributed system"

- The important contribution of Lamport is that in a distributed system, **clocks need not be synchronized absolutely**
- It is **not important** that all **processes agree on what the actual time is, but that they agree on the order in which events occur**
- Happens Before

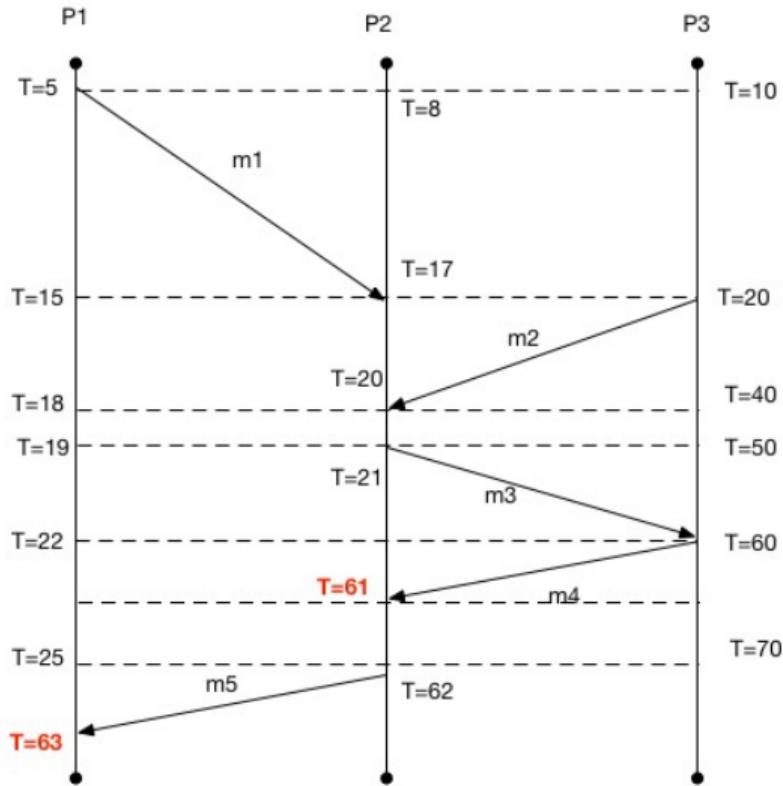
Happens Before

The relation ' \rightarrow ' on the set of events of a system is a smallest relation satisfying three conditions

- If a and b are events **in the same process**, and a comes before b , then $a \rightarrow b$
- If a is the sending of a message by one process and b is the receipt of the same message by another process, then $a \rightarrow b$
- Transitive. If $a \rightarrow b$ and $b \rightarrow c$ then $a \rightarrow c$. Two distinct events a and b are said to be concurrent if $a \not\rightarrow b$ and $b \not\rightarrow a$

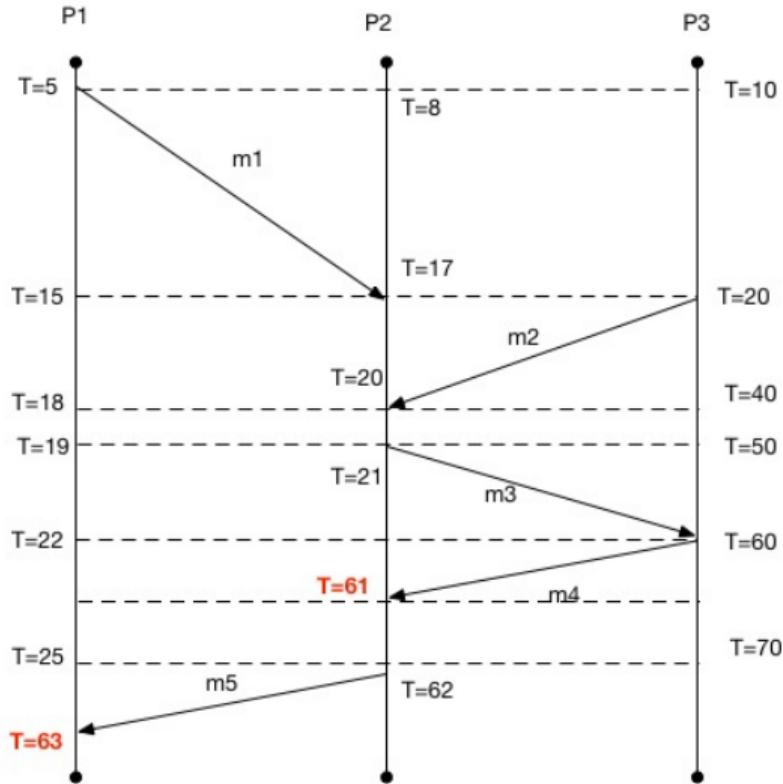
If $a \rightarrow b$ happens between **two process**, and events x and y occur on another set of processes and these two sets of processes don't exchange messages then: we cannot say whether $x \rightarrow y$ or $y \rightarrow x$ from the perspective of the first set of processes outcome

Example



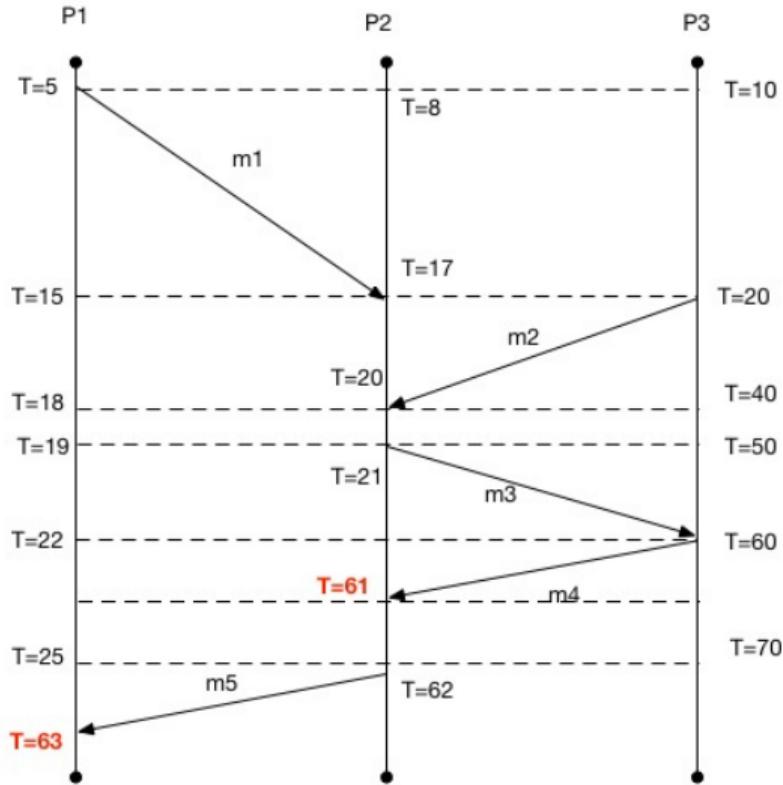
- When a message is transmitted from $P_1 \rightarrow P_2$, P_1 will encode the send time into the message

Example



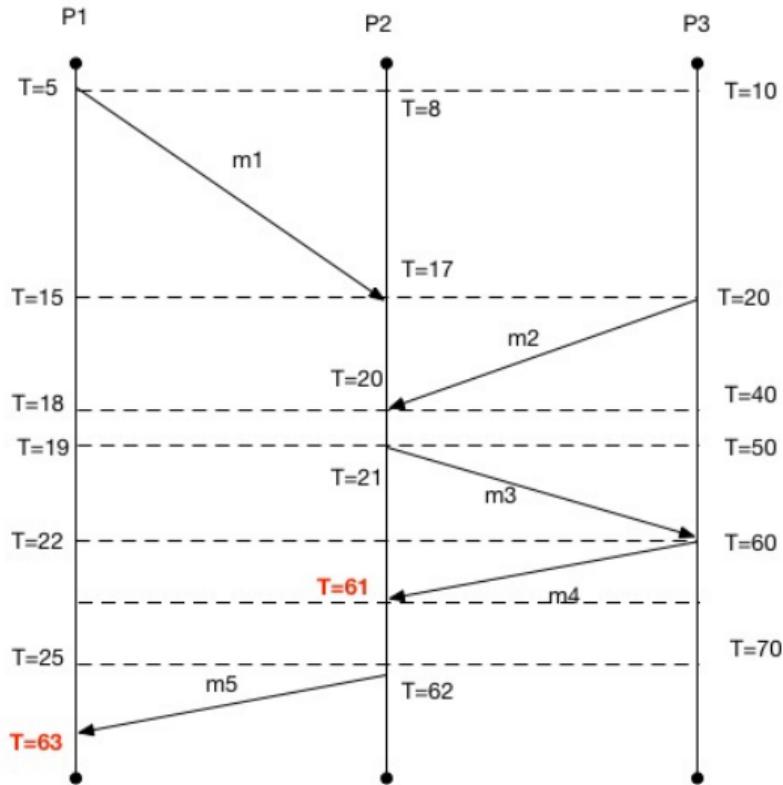
- When a message is transmitted from $P1 \rightarrow P2$, $P1$ will encode the send time into the message
- When $P2$ receives the message, it will record the time of receipt

Example



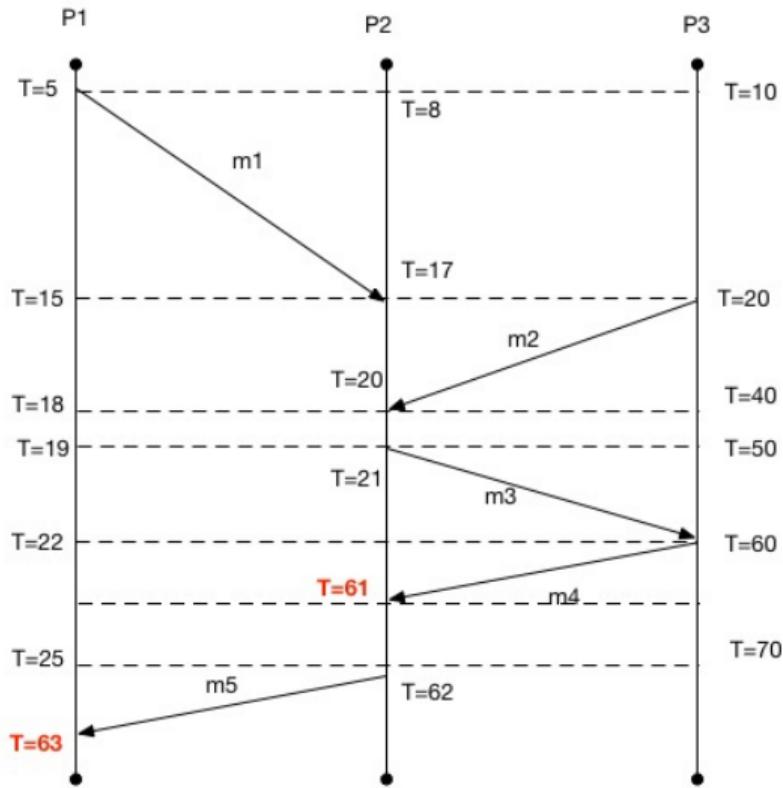
- When a message is transmitted from $P1 \rightarrow P2$, $P1$ will encode the send time into the message
- When $P2$ receives the message, it will record the time of receipt
- If the time at $P2$ is already greater than the send time, then no action is required for $P2$

Example



- When a message is transmitted from $P1 \rightarrow P2$, $P1$ will encode the send time into the message
- When $P2$ receives the message, it will record the time of receipt
- If the time at $P2$ is already greater than the send time, then no action is required for $P2$
- If $P2$ discovers that the time of receipt is before the send time, $P2$ will update its software clock to be one greater than the send time

Example

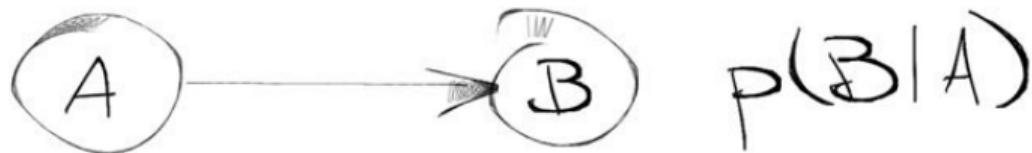


- When a message is transmitted from $P_1 \rightarrow P_2$, P_1 will encode the send time into the message
- When P_2 receives the message, it will record the time of receipt
- If the time at P_2 is already greater than the send time, then no action is required for P_2
- If P_2 discovers that the time of receipt is before the send time, P_2 will update its software clock to be one greater than the send time
- “happens-before” relationship is preserved with this actions

Lamport Clocks Limitations

With Lamport's clocks nothing can be said about **the actual time** of a
and b.

Causality

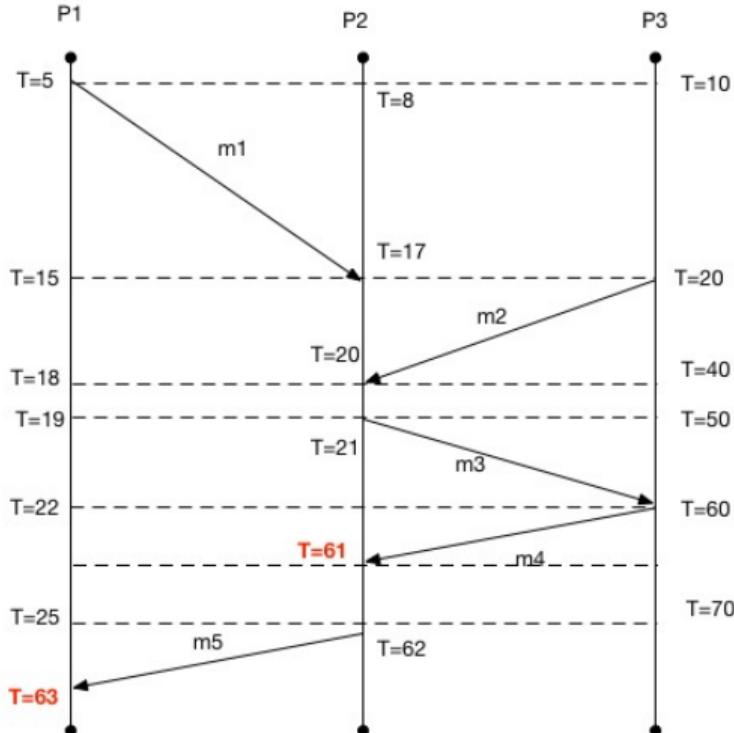


Causal relations

An example of a causal relation and its representation in a graph.

Credits: C. Giarmatzi

Who did when?



- $m_1 \rightarrow m_3?$
- $m_2 \rightarrow m_3?$

Vector Clocks

Vector Clocks

by Colin Fidge and Friedemann Mattern in 1988

Vector Clocks

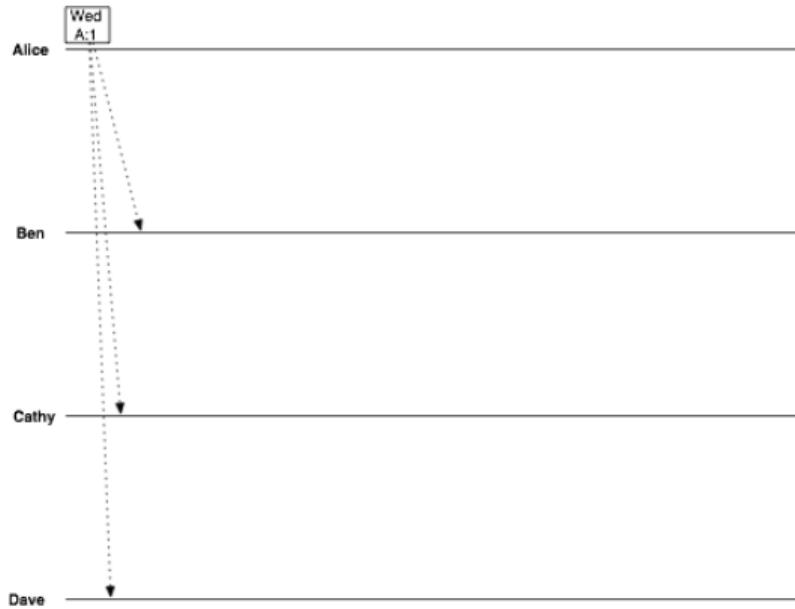
- A vector clock of a system of N processes is **an array/vector** of N logical clocks, **one clock per process**
- A vector clock $VC(a)$ is assigned to an event a
- If $VC(a) < VC(b)$ for events a and b , then event a is known to causally precede b

Robbery

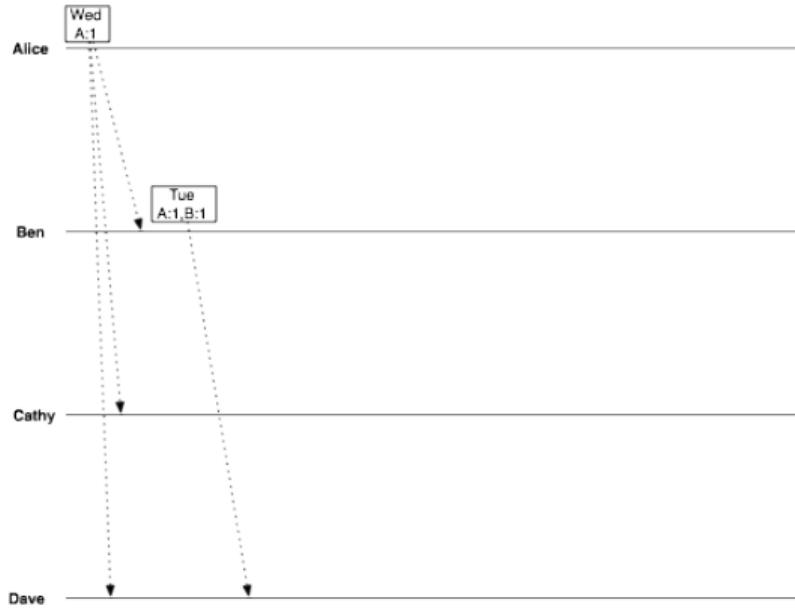


Alice, Ben, Cathy, and Dave want to rob a bank

- They could send P2P messages
- No leader



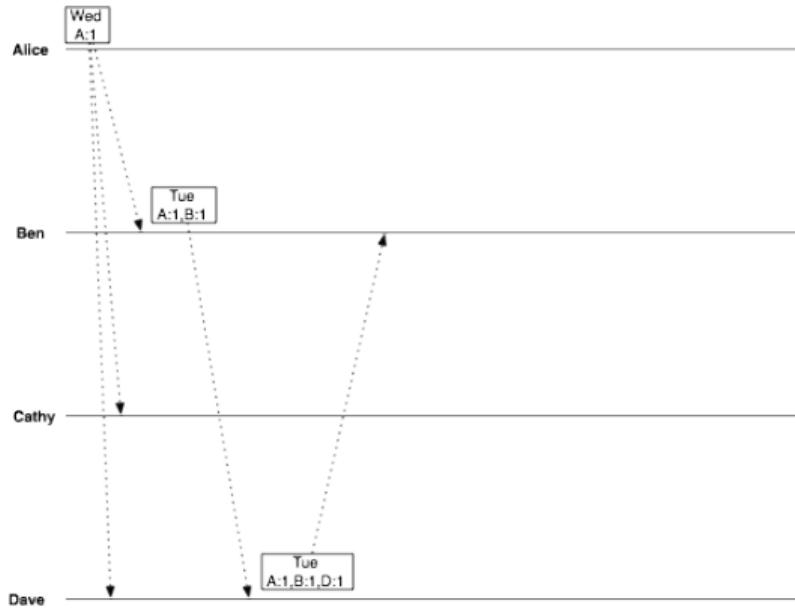
```
date = Wednesday  
vclock = Alice:1
```



Ben suggests Tuesday

`date = Tuesday`

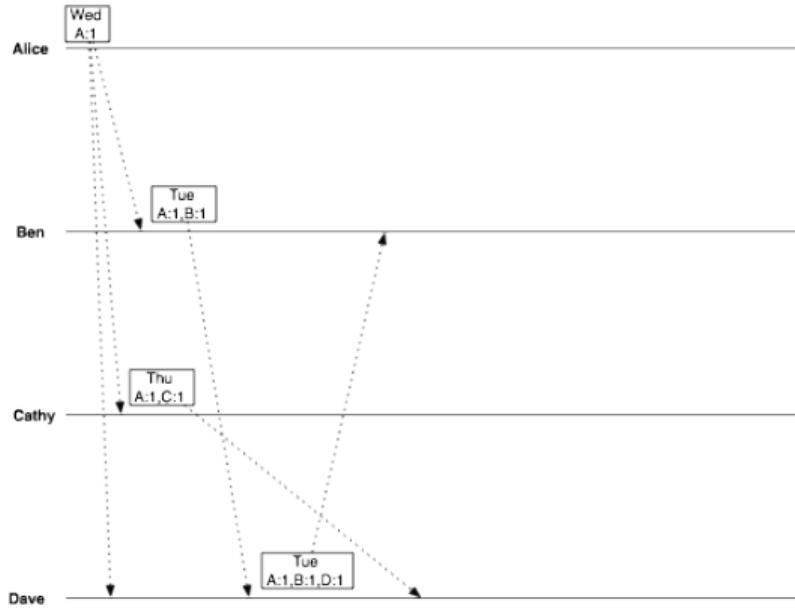
`vclock = Alice:1, Ben:1`



Dave replies, confirming Tuesday

`date = Tuesday`

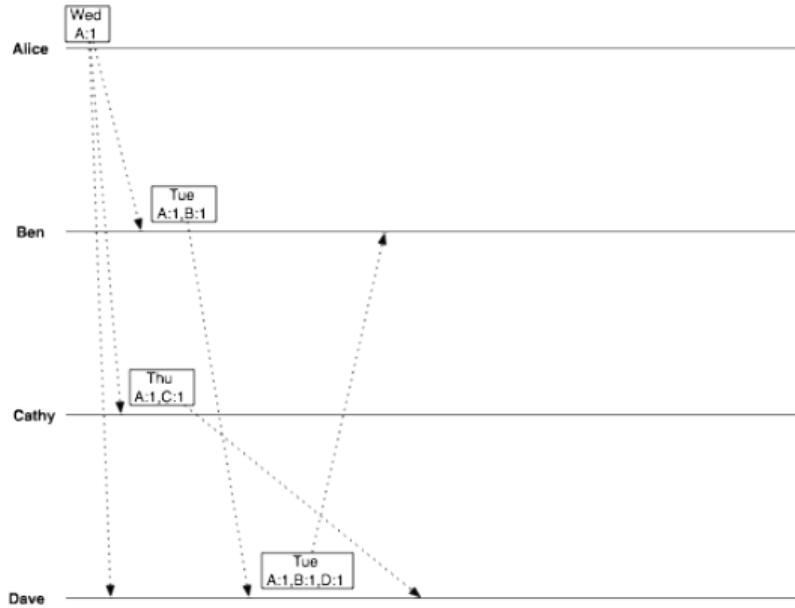
`vclock = Alice:1, Ben:1, Dave:1`



Then Cathy joins, suggesting Thursday

`date = Thursday`

`vclock = Alice:1, Cathy:1`



Dave has two conflicting objects

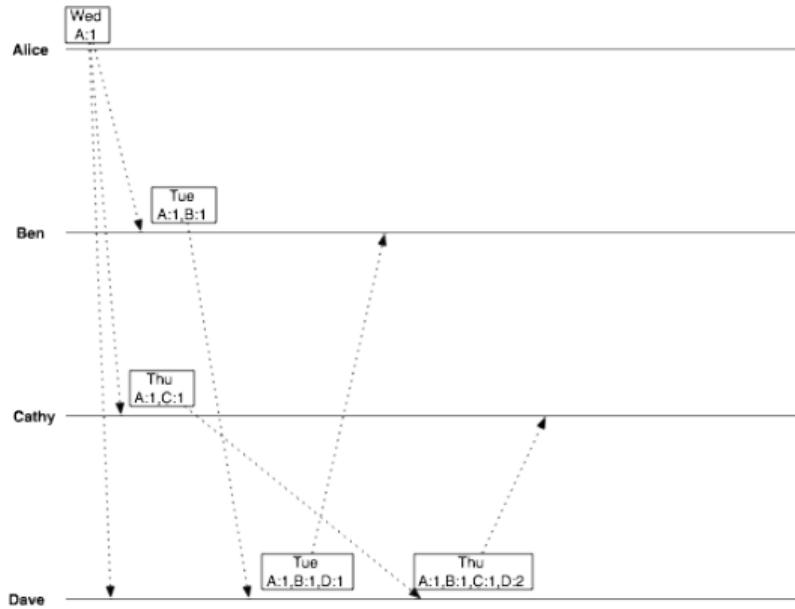
`date = Tuesday`

`vclock = Alice:1, Ben:1, Dave:1`

and

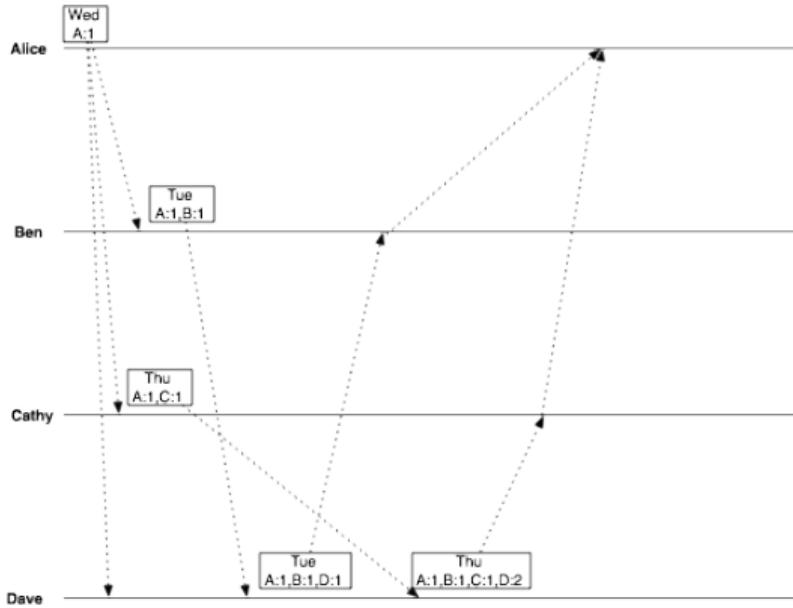
`date = Thursday`

`vclock = Alice:1, Cathy:1`



Dave's a reasonable guy, and chooses Thursday.
So he sends this value back to Cathy

```
date = Thursday
vclock = Alice:1, Ben:1, Cathy:1,
          Dave:2
```

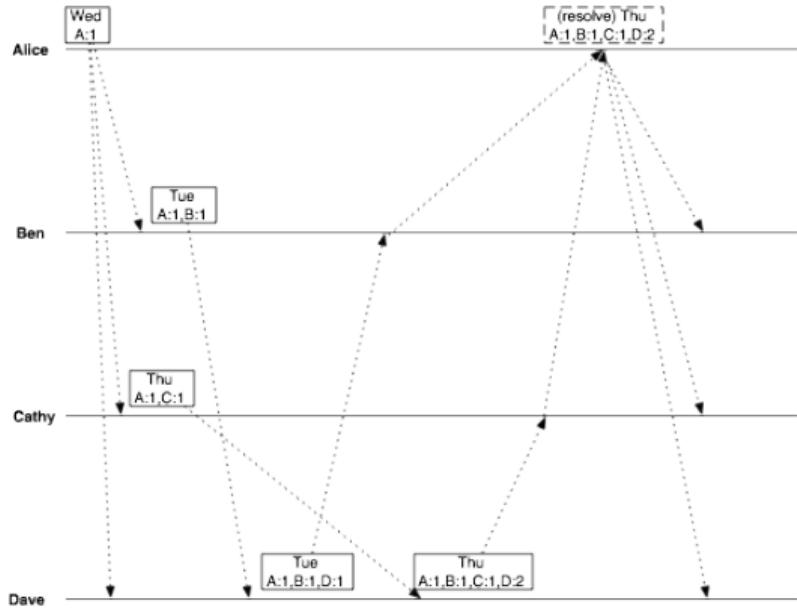


When Alice asks Ben and Cathy for the latest decision, the replies she receives are, from Ben

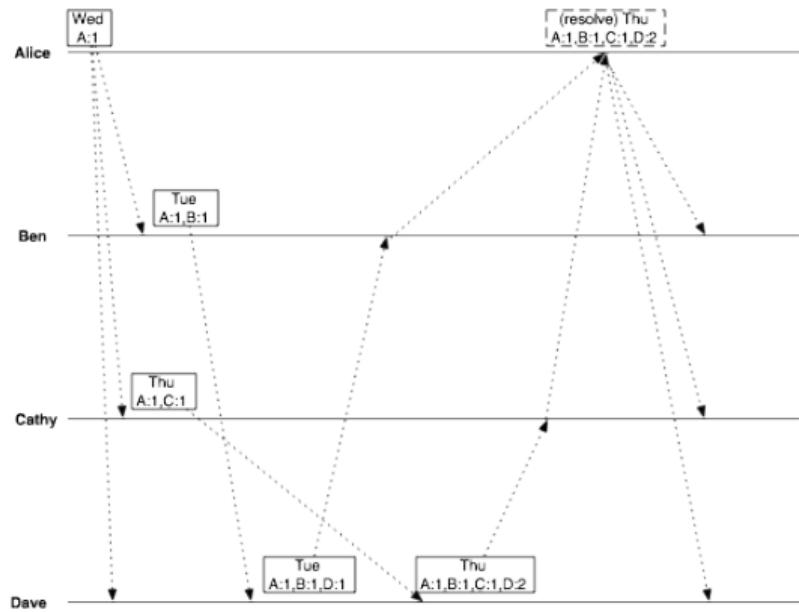
```
date = Tuesday
vclock = Alice:1, Ben:1, Dave:1
```

From Cathy and Dave

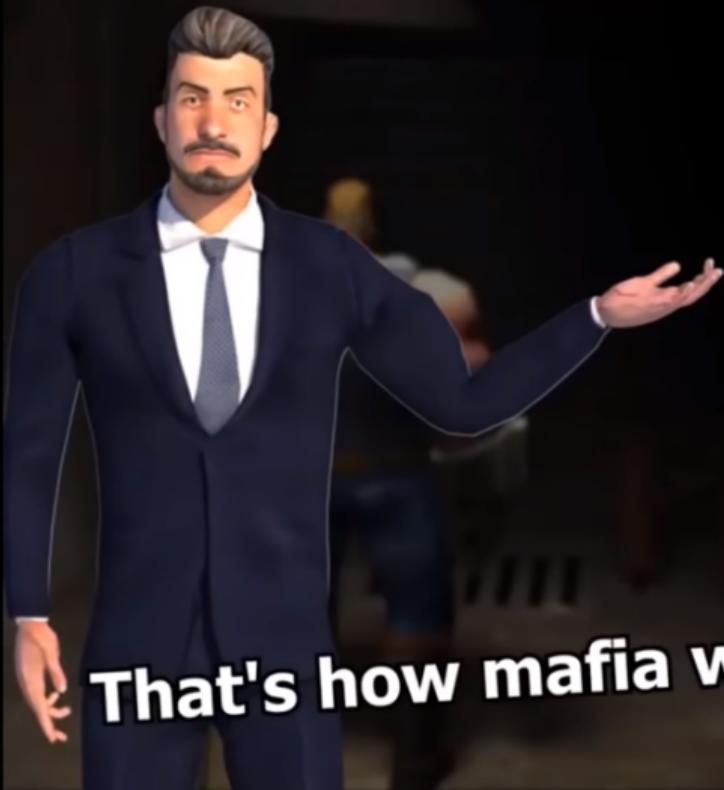
```
date = Thursday
vclock = Alice:1, Ben:1, Cathy:1,
Dave:2
```



All Alice has to do is show Ben the vector clock from Cathy's message, and Ben will know that he has been overruled.



Done. Everybody's in sync



That's how mafia works

So, What!?

So... What Did We Get Out Of All of This?

Review

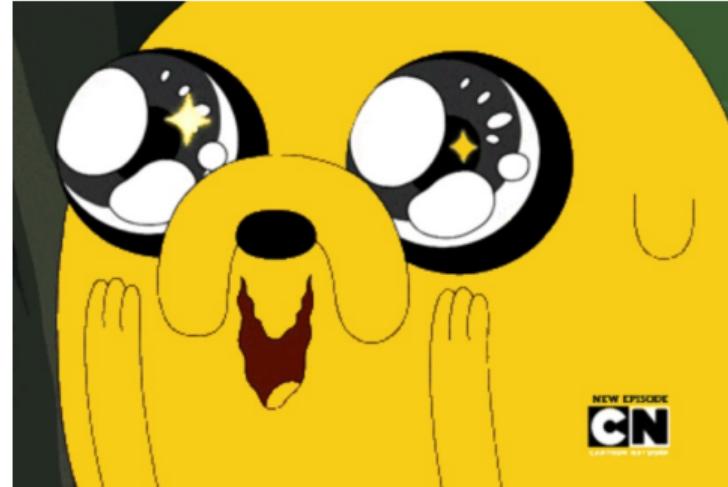
- Physical Clocks - hard to keep synchronized
- Logical clocks - can provide some notion of relative events occurrence
- Lamport's logical time
 - happened before defines causal relation
 - this clocks don't capture causality
 - total ordering relation
- Vector Clocks
 - captures causality
 - have a component for each process in the system
 - slow and grow

So many things to tell you

- GPS Clocks
- Atomic Clocks in Google Spanner Database
- UTC, TAI, TCG and TCB coordinate time standards
- Why do clocks run clockwise?
- Why there were no December 30 in Samoa?

Thank you! That was Algebraic! Questions?

- Thank
- You
- For
- Your
- Time



NEW EPISODE
CN
Cartoon Network



Thank you!