Grid Dynamics

Time In Distributed Systems Pt.1

Hello

Denis Golovachev


Grid
Dynamics

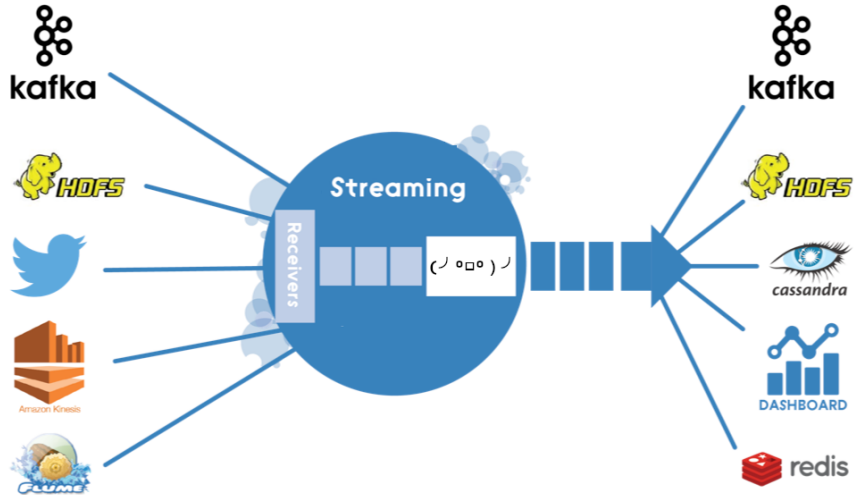
SPB

Saint-Petersburg


BIG
DATA

Software Architect

Data Streaming


kafka
HDFS
Amazon Kinesis
Streaming
Receivers
(ノ ºロº)ノ
kafka
HDFS
cassandra
DASHBOARD
redis


APACHE
kafka


aws


cassandra


APACHE
Spark
TM


APACHE
kafka
Flink
aws
hadoop
cassandra
APACHE
Spark
TM

Big Data School

Big Data School

Professor

Boring


BIG
DATA

Grid Dynamics


I
MY JOB

Time

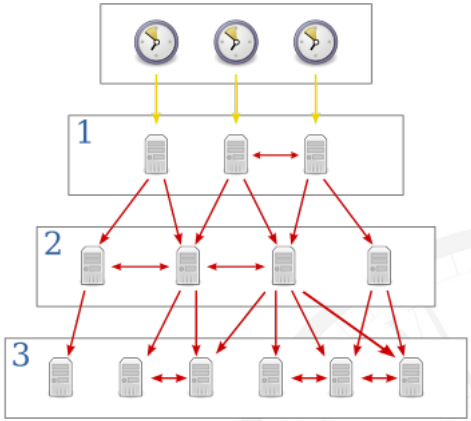
Time


WHAT TIME IS IT?


Joe Klein: Leaderless Democrats
Chile: Portraits of A Disaster
Iraq: The Hopeful Election
Cell Phones: How Safe Is Yours?
Joel Stein: I'd Like to Thank The Academy
TIME
History Maker
How Tom Hanks is redefining America's past
BY DOUGLAS BRINKLEY

Time

Time



Question

What is time?

Time is …

1998 2004 3XXX

MYSTERY SOLVED

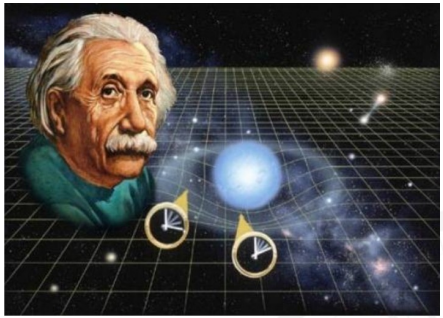
Way of arrange the order of events

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)

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

Daylight saving time

There are always 24 hours in a day

Round 2

There are 60 seconds in a minute

There are 60 seconds in a minute

Leap Second

Round 3

A month always ends in the same year it started

Round 3

A month always ends in the same year it started

- Fiscal year/calendar
- Chinese Year

Month could have less than 20 days

Round 4

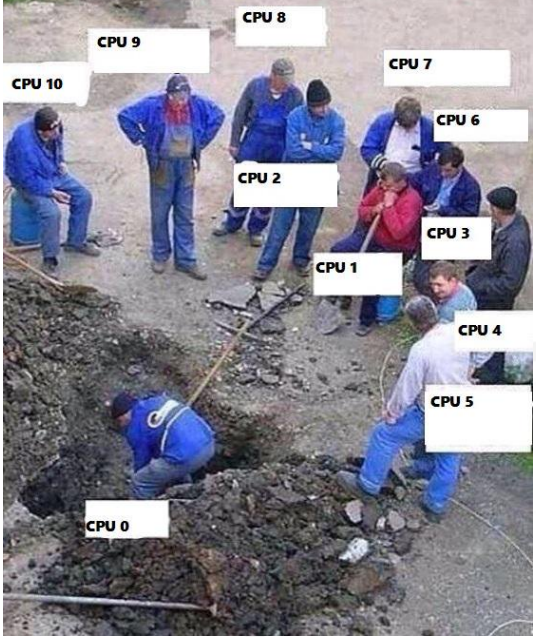
Month could have less than 20 days

September 1752 had 19 days in British Empire

Everyone's do it wrong!


SERVER DOWN?
ALIENS
HISTORY.COM
memecrunch.com


SERVER DOWN?
ALIENS
HISTORY.COM
memecrunch.com


CPU 8
CPU 9
CPU 7
CPU 10
CPU 6
CPU 2
CPU 3
CPU 1
CPU 4
CPU 5
CPU 0

Bug 479765 - Leap second message can hang the kernel

Status: CLOSED ERRATA
Alias: None
Product: Red Hat Enterprise Linux 5
Component: kernel
Sub Component: Type a sub-component na (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 Java Bug Database

Search

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
Component: hotspot
Sub-Component: runtime
Affected Version: e5.0u21,hs24,hs25,6,6u29,7

Priority: P3
Status: Closed
Resolution: Fixed
OS: linux,linux_ubuntu
CPU: generic,x86,ppc

Submitted: 2009-11-11
Updated: 2015-11-27
Resolved: 2013-09-24

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

Description

Distributed environment

Mathias Verraes
@mathiasverraes

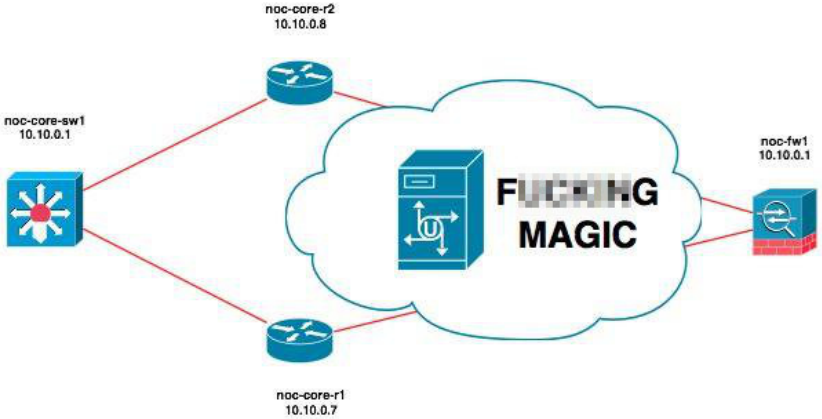
Follow

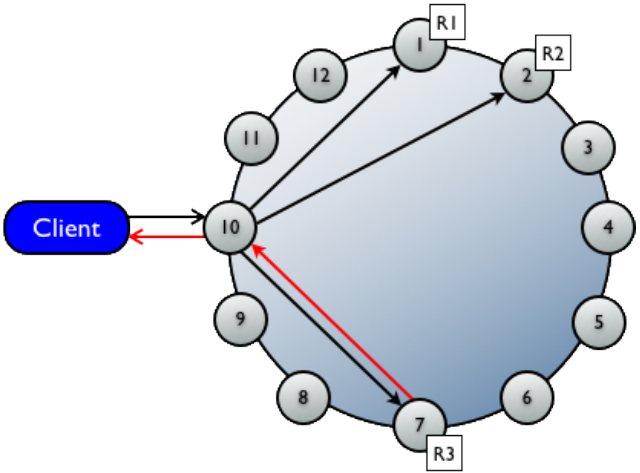
There are only two hard problems in distributed systems: 2. Exactly-once delivery 1. Guaranteed order of messages 2. Exactly-once delivery

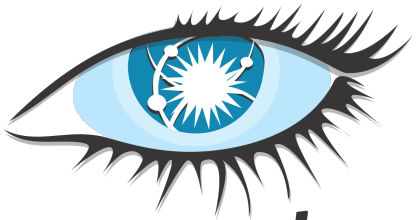
9:40 PM - 14 Aug 2015

7,192 Retweets **5,632** Likes

70 7.2K 5.6K


noc-core-r2
10.10.0.8
noc-core-sw1
10.10.0.1
noc-fw1
10.10.0.1
MAGIC
noc-core-r1
10.10.0.7





cassandra

- 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

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

Synchronization in distributed systems is **hard**

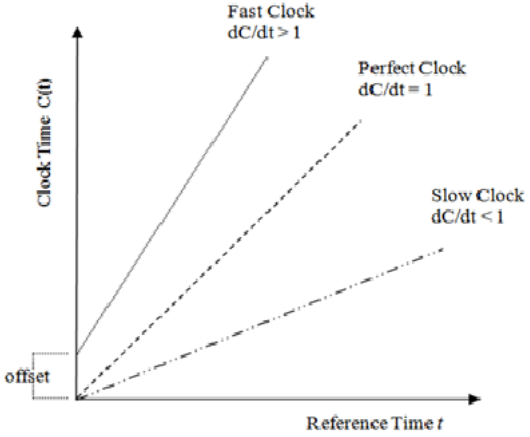
- **No shared memory**
- **No common clock**

Let’s use ’Wall Clocks’ and NTP!?

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

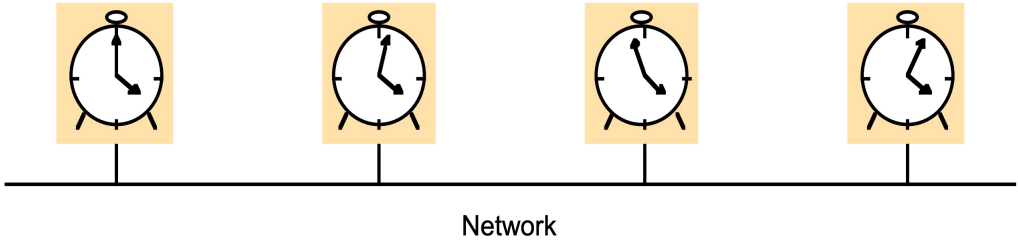
Clock Drift

We can’t have perfect clocks



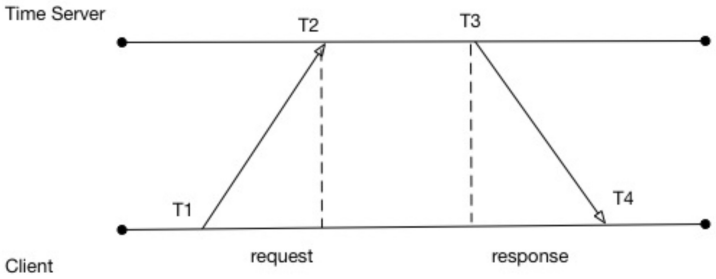
Ordinary clocks drift by about 1 sec in 10 days

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 ... microsecond?

I'm running NTP. I'm good

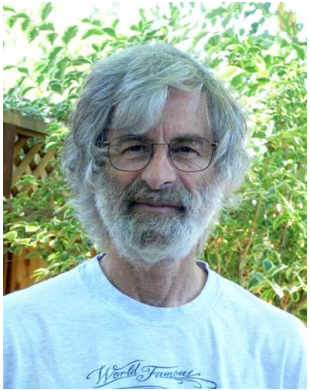
Protocol	Media	Sync Accuracy
NTP	Ethernet	50-100 milliseconds
IRIG-B	Coaxial	1-10 microseconds
PTP	Ethernet	20-100 nanoseconds

* 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

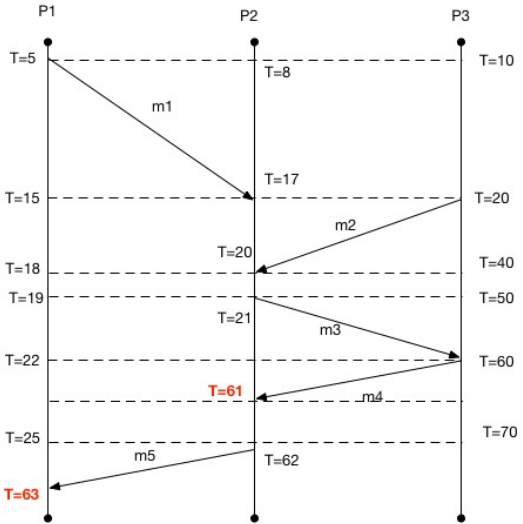
Happens Before

The relation '→' 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 $b \not\rightarrow a$

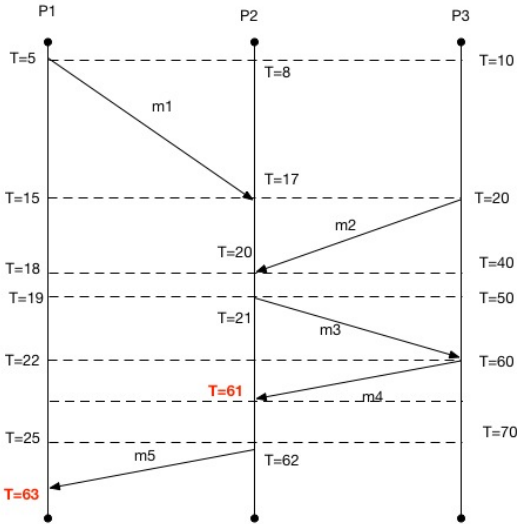
If $a \rightarrow b$ happens between **two process**, and events x and y occur on another set of processes and these two sets of processes don't exchange messages then:
we cannot say whether $x \rightarrow y$ or $y \rightarrow x$ from the perspective of the first set of processes outcome

Example



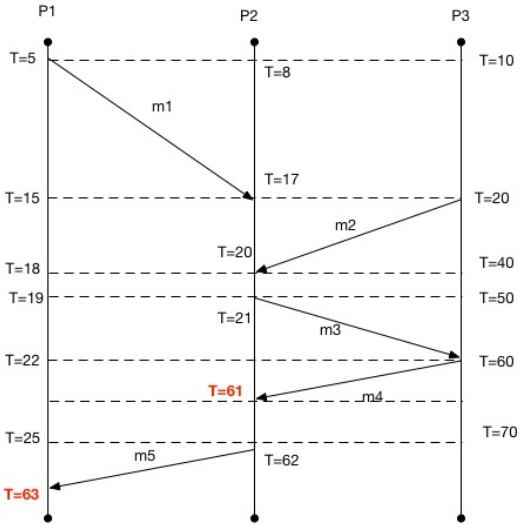
- When a message is transmitted from $P1 \rightarrow P2$, $P1$ will encode the send time into the message

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
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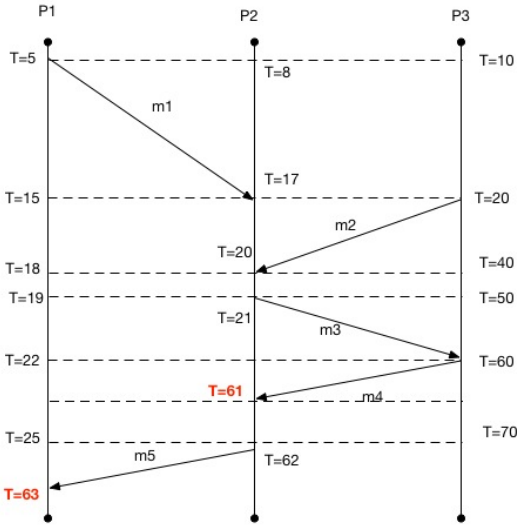
Example



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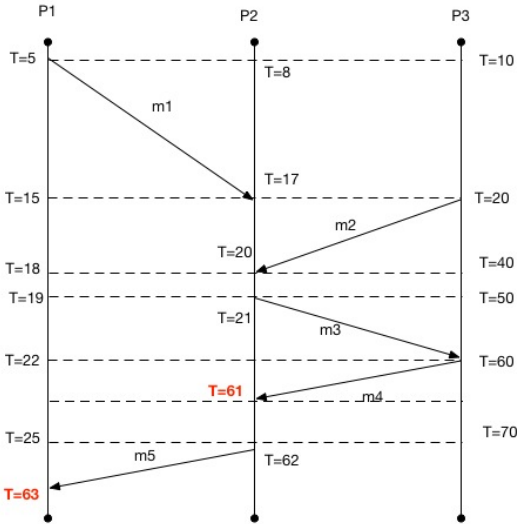
Example



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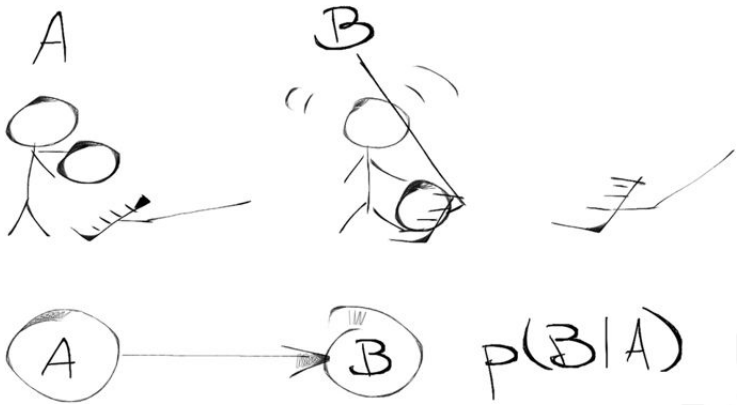
- If $P2$ discovers that the time of receipt is before the send time, $P2$ will update its software clock to be one greater than the send time
- “happens-before” relationship is preserved with this actions

Lamport Clocks Limitations

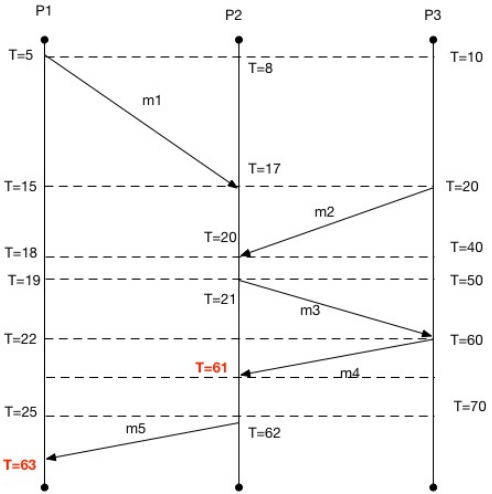
With Lamport's clocks nothing can be said about **the actual time** of a and b.

Causality



Causal relations
An example of a causal relation and its representation in a graph.
Credits: C. Giarmatzi

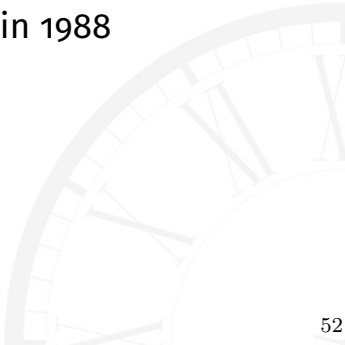
Who did when?



- $m1 \rightarrow m3$?
- $m2 \rightarrow m3$?

Vector Clocks

by Colin Fidge and Friedemann Mattern in 1988



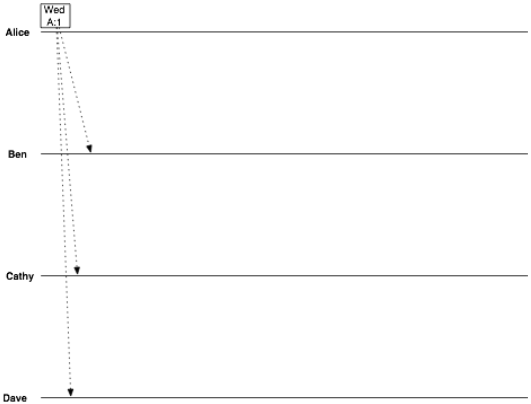
Vector Clocks

- 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

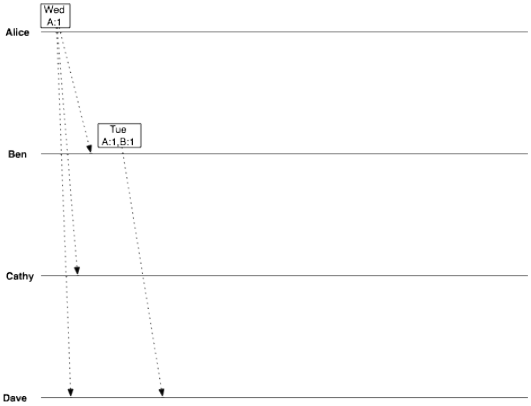
Robbery

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

- They could send P2P messages
- No leader

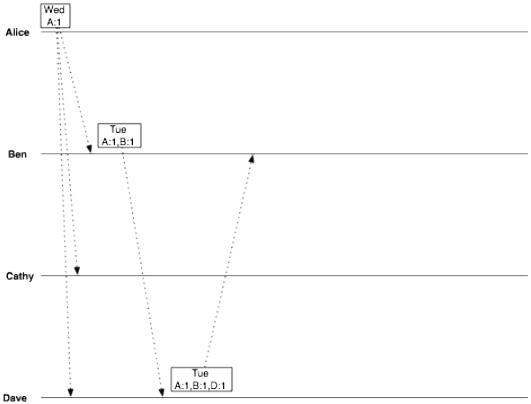



```
date = Wednesday
vclock = Alice:1
```



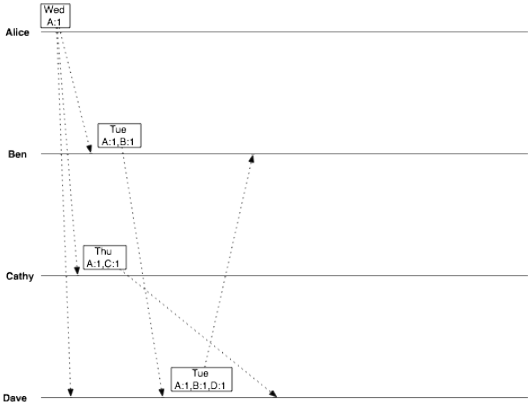
Ben suggests Tuesday

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



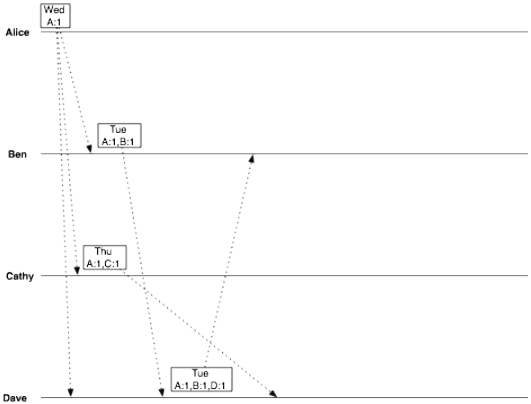
Dave replies, confirming Tuesday

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



Then Cathy joins, suggesting Thursday

```
date = Thursday
vclock = Alice:1, Cathy:1
```

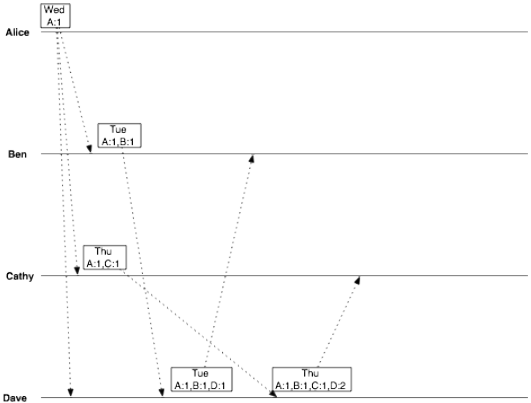


Dave has two conflicting objects

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

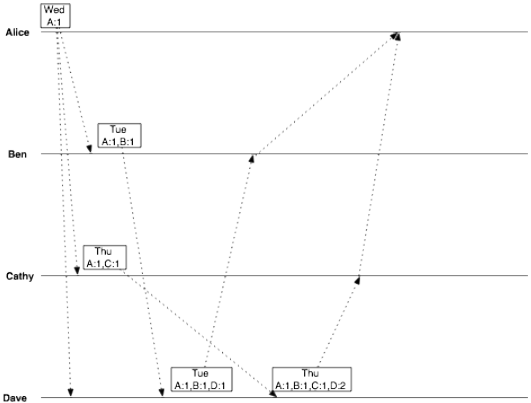
and

```
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
```

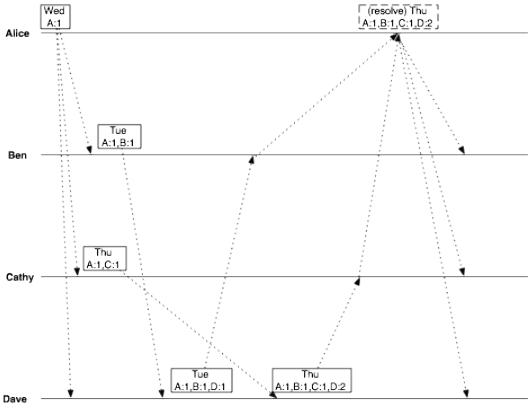


When Alice asks Ben and Cathy for the latest decision, the replies she receives are, from Ben

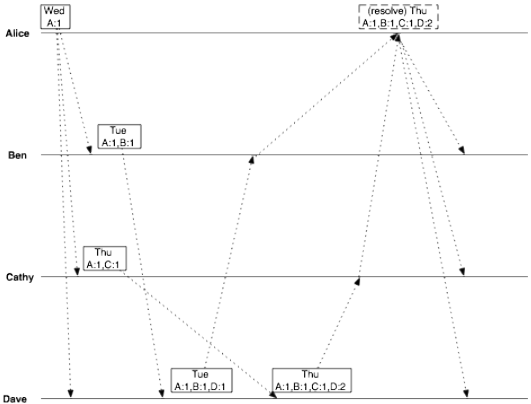
```
date = Tuesday
vclock = Alice:1, Ben:1, Dave:1
```

From Cathy and Dave

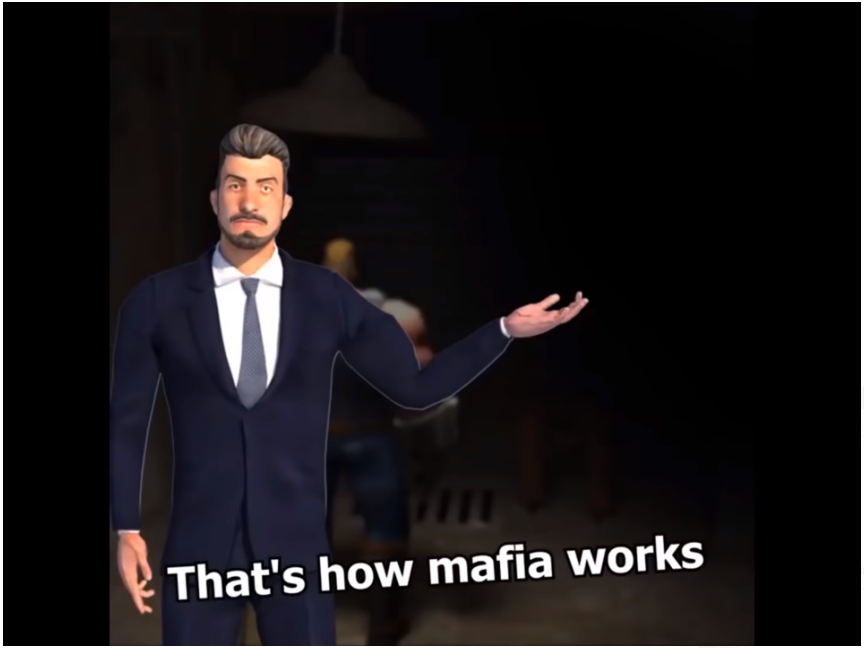
```
date = Thursday
vclock = Alice:1, Ben:1, Cathy:1,
    Dave:2
```



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