ACM Highlights

- **Learning Center** tools for professional development: [http://learning.acm.org](http://learning.acm.org)
  - 1,400+ trusted technical books and videos by O’Reilly, Morgan Kaufmann, etc.
  - Online training toward top vendor certifications (CEH, Cisco, CISSP, CompTIA, PMI, etc.)
  - Learning Webinars from thought leaders and top practitioner
  - **ACM Tech Packs** (annotated bibliographies compiled by subject experts)
  - Podcast interviews with innovators and award winners

- Popular publications:
  - Flagship *Communications of the ACM (CACM)* magazine: [http://cacm.acm.org/](http://cacm.acm.org/)
  - **ACM Queue** magazine for practitioners: [http://queue.acm.org/](http://queue.acm.org/)

- **ACM Digital Library**, the world’s most comprehensive database of computing literature: [http://dl.acm.org](http://dl.acm.org).

- International **conferences** that draw leading experts on a broad spectrum of computing topics: [http://www.acm.org/conferences](http://www.acm.org/conferences).

- Prestigious awards, including the **ACM A.M. Turing** and Infosys: [http://awards.acm.org/](http://awards.acm.org/)

- And much more...[http://www.acm.org](http://www.acm.org).
What Time Is It?
A Guide to Time for Software Developers
George Neville-Neil
Time is an Illusion

- Created by people for people
- Provides ordering to the day
- Necessary for basic, human, communication
A Brief History of…

- Seasons
- Months
- Days
- Hours
- Minutes
- Seconds
Finer grains

- 1 second
- 1,000 milliseconds
- 1,000,000 microseconds
- 1,000,000,000 nanoseconds
How do I use time?

- In my programs?
- In deployed systems?
- Time is pervasive
- Most systems are distributed systems
Programming with Time

- Takes time to get time
  - gettimeofday(2)
  - Traditional
    - clock_gettime(2)
  - Finer grained controls
What's wrong with computer time?

- Cheap Crystals
- Systems run hot and cold
- Age of crystals
- Workload effects
- Harder than you (or your management) might think
Technology always makes things better

1990  2000  2010  2020

Regular watches

Smart watches

Brief, glorious period in which our wrists were free
Can you see it?
How bad is it?

- Offset starts at 0,0
- 23:00-01:00 (2 hours)
- 15ms behind
- Typical behavior
Who cares about a little wander?

- Debugging distributed systems
- Reconciling on-line transactions
- Robots and Automation
- Power Grids
- Cellular Networks
When is a second not a second?

- Syntonization is not synchronization
- Frequency inputs to massage the clock
  - Pulse Per Second (1PPS)
- Other frequencies available, at a cost
What is your tolerance?

- Financial Transactions
  - FINRA: 1 second (for now)
- Robot Arm
- Powerline
  - 1/50th or 1/60th of a second
- Cellular Networks
Solutions?

- Better crystals
  - Not on commodity hardware
- Add on cards
  - Expensive for large deployments
- Ask a better clock
  - Current state of the art
Ask a better clock

• A clock with a better crystal exists
• Clients synchronize to the better clock
• Complications
Basic Theory of Operation

- Stratum
- Time Transfer
- Ask, “What time is it?”
- Measure and correct for network propagation time
- Steer the local clock
Network Time Protocol (NTP)

- V3 RFC 1305 (1992)
- V4 RFC 5905 (2010)
- Internet Based Timekeeping
- Client/server model
- Default polling is once per 64 seconds
- Can take hours to synchronize
Some Definitions

- Synchronization
  - My neighbor and I know it is 3pm
- Syntonization
  - The duration of a second is one second
- Network Jitter
  - Variance in network latency
- Grand Master
  - The better clock
Time in the Cloud
What?!

- Default NTP config
- Polling 50 times per day
- +/- 5ms
Precision Time Protocol (PTP)

- LAN Environment
- Multicast
- Better than 1usec accuracy with software only
- Hardware Support Available
How did you do that?

- Graph includes 24 hours
- Hundreds of measurements per hour
- Median 300ns
- +/- 30usec around 0
- Client is pure software
- Master is a Meinberg M600
PTP in Packets

DELAY RESPONSE

DELAY REQUEST

GM

Slave
Slave
Slave
Slave

SYNC

FOLLOWUP
Sources of jitter

- Routers
- Switches
- Links
- Electronic Noise
- Software
Where does the time go?

- NIC Interrupts
- Packet Buffering
- OS Scheduling
- Software Stack
<table>
<thead>
<tr>
<th>Daemon</th>
<th>gettimeofday()</th>
</tr>
</thead>
<tbody>
<tr>
<td>Socket</td>
<td></td>
</tr>
<tr>
<td>UDP</td>
<td>SO_BINTIME</td>
</tr>
<tr>
<td>IP</td>
<td>PCAP/BPF Time</td>
</tr>
<tr>
<td>Ethernet</td>
<td>Hardware Timestamp</td>
</tr>
</tbody>
</table>

Where does the time go?
For my next trick...

- Every packet has a sequence number
- All packets are multicast
- All hosts see the packets “at the same time”

Alas… 16 bit sequence number
Inter Host Quality

- For each SYNC record the system time
- Post process files
- Show the offset between hosts
- Included in PTPd (Quality File)
PTPd

- BSD Licensed
- Supports IEEE-1588v2
- Interoperates with NTPd
- http://ptpd.sf.net
The Leap Second

- Adjustment based on astronomical measurement

- Periodically adds a second to the clock
  - 23:59:60

- Can occur at the end of any month
  - But usually June or December
Questions about this webcast? learning@acm.org

ACM Learning Webinars (on-demand archive): http://learning.acm.org/webinar

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