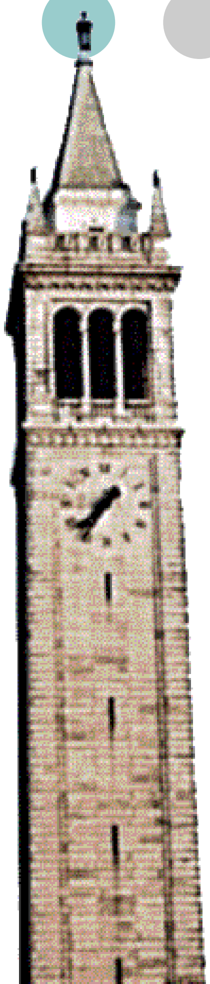


“Whither IEEE 1588?”

John C. Eidson

University of California at Berkeley

eidson@eecs.berkeley.edu

WSTS-San Jose

April 16-18, 2013

Agenda

- A bit of 1588 history (to show the growing influence of telecom on 1588)
- The present situation
  - ICAP
  - PAR for revising IEEE 1588-2008
- Looking forward

But first a disclaimer!

Remarks on the future should be taken with a grain of salt!

But first a disclaimer!

- "It's tough to make predictions, especially about the future." Yogi Berra

1998

But first a disclaimer!

- “It's tough to make predictions, especially about the future.” Yogi Berra
- ~”1588 will never be used in telecom” circa 1998 by a Vice President of Hewlett-Packard (and an engineer by training)

2002

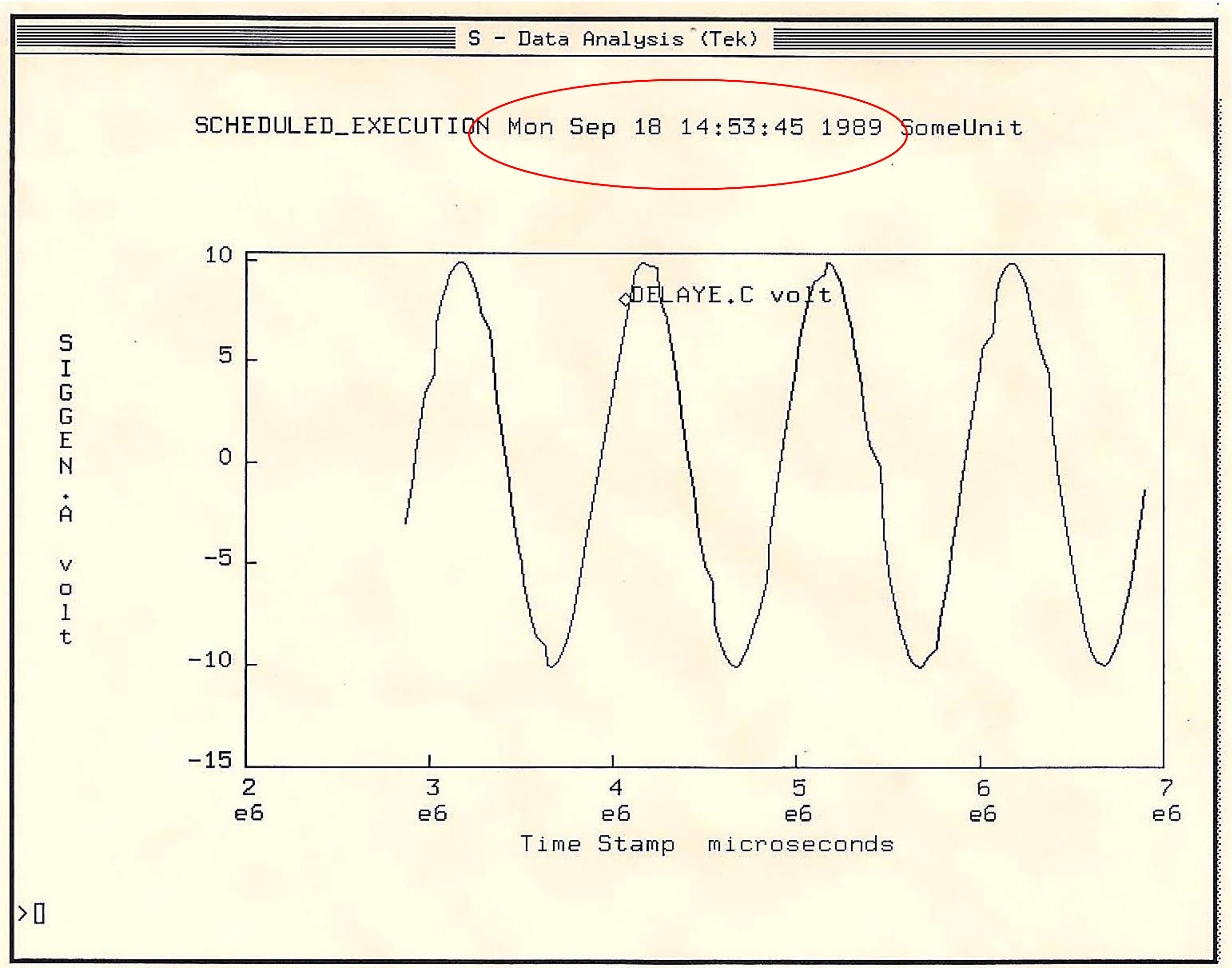
But first a disclaimer!

- “It's tough to make predictions, especially about the future.” Yogi Berra
- ~”1588 will never be used in telecom” circa 1998 by a Vice President of Hewlett-Packard (and an engineer by training)
- ~”this one (1588) smells like a winner” circa 2002 by Catherine Berger (an English major on the IEEE-SA editorial staff)

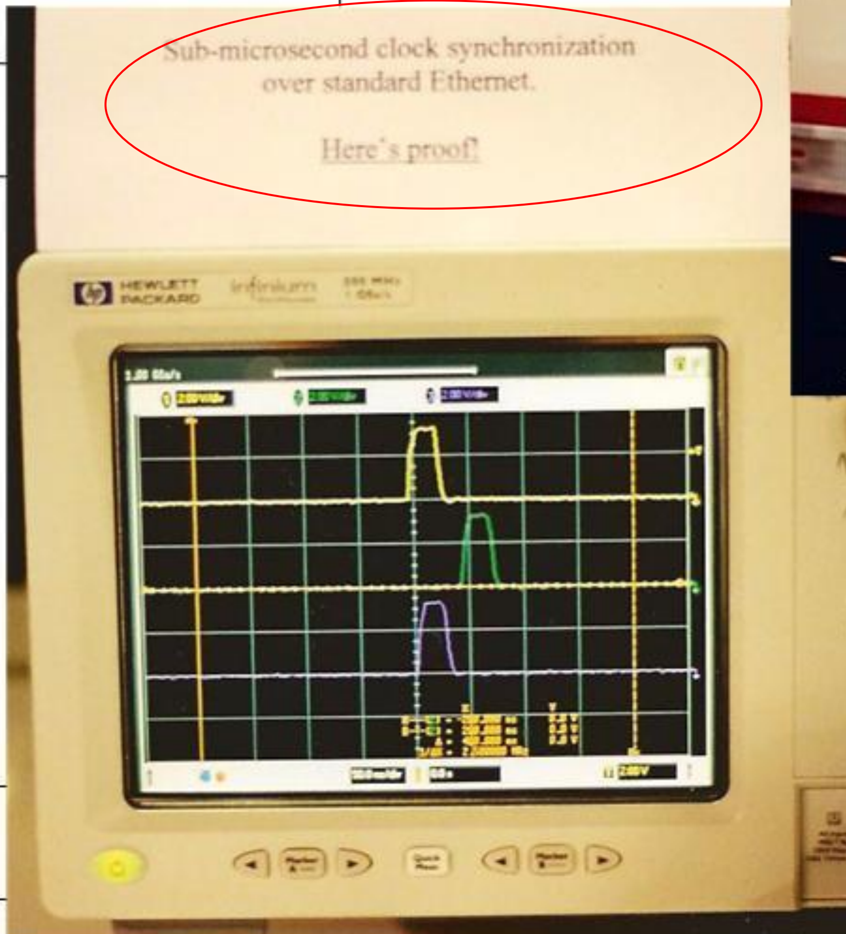
1990s Context

- *1985: NTP by David Mills. ~1-10ms over public networks*
- *1994: GPS fully operational. ~100ns worldwide*
- *1990s:*
  - *Many proprietary network timing protocols in use or under development*
  - *Move away from proprietary networks to Ethernet especially in industrial automation*
  - *NTP not accurate enough for industrial automation*
  - *HP (Agilent) developed prototype for 1588*

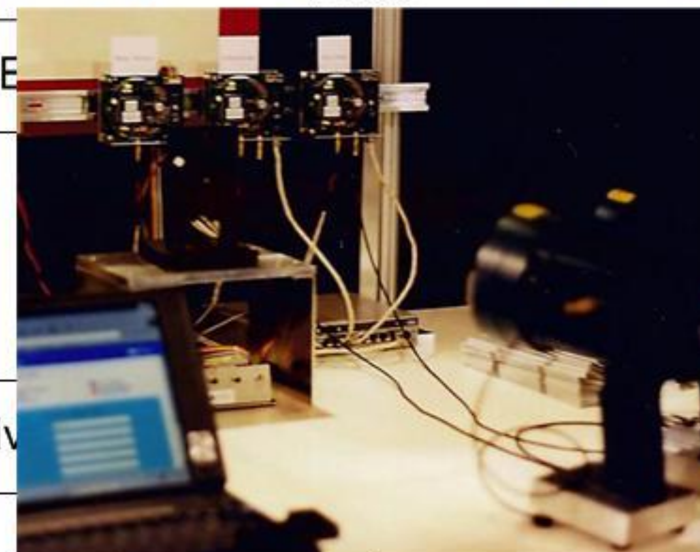
Early work at Hewlett Packard



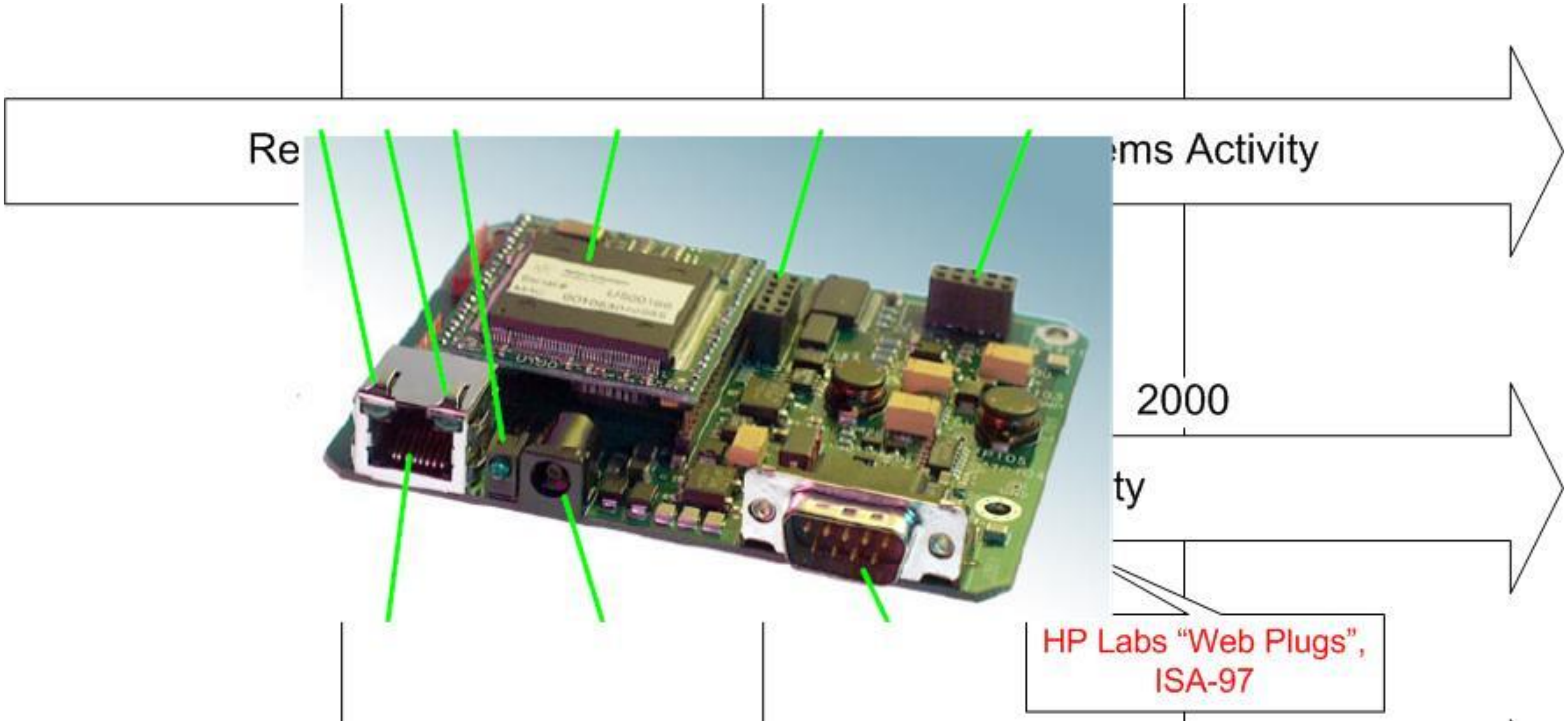
ISA-1997


Sub-microsecond clock synchronization
over standard Ethernet.
Here's proof!
HEWLETT PACKARD


Yellow Strobe
Blue Strobe



ISA-1997



Prototype Boundary Clock

Re

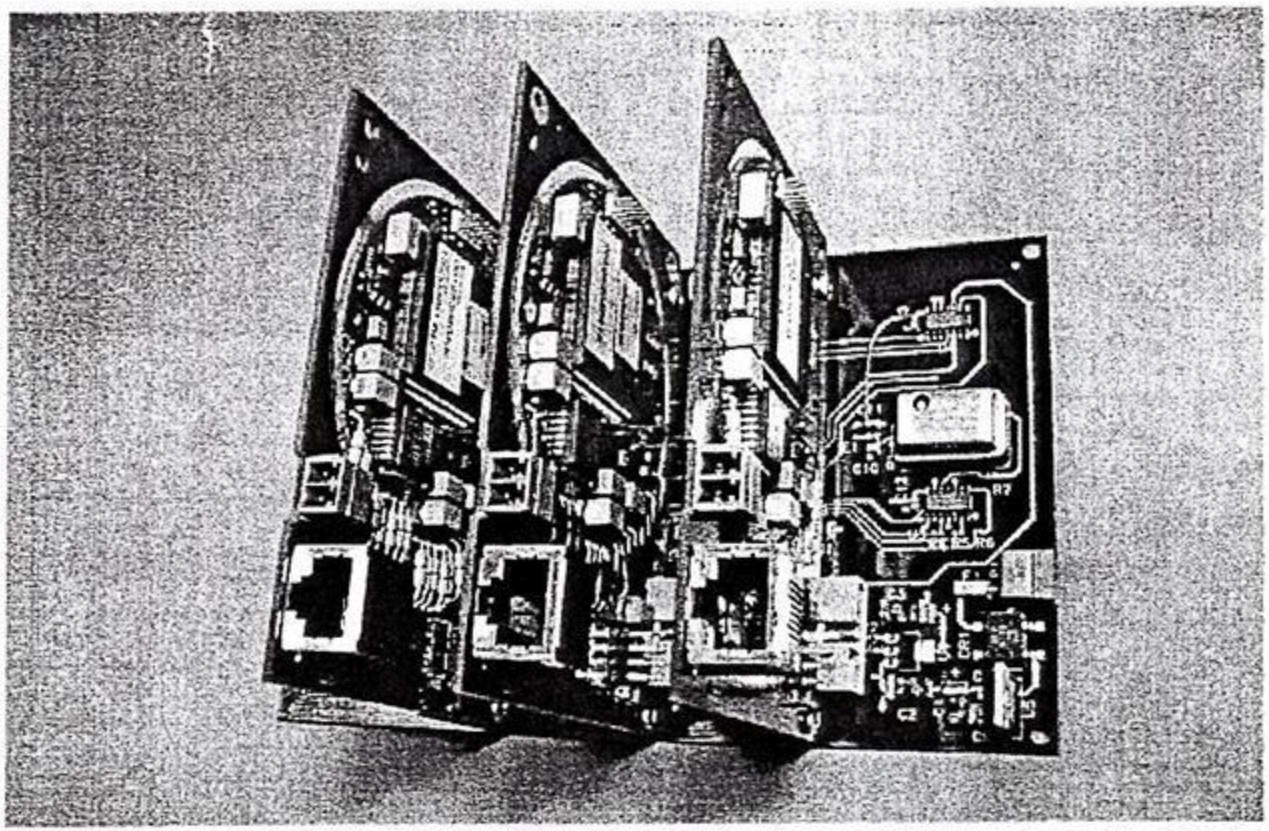


Figure 11: Prototype boundary clock with three Ethernet ports

JCE 12/11/02

Evolution of IEEE 1588
(V1: PAR June 18, 2001, published Nov 2002)

IEEE 1588-2002 Committee Members (all 13 of them)

Scott Carter	*Jack Kusters*
John Eidson	*Judah Levine*
Richard Hambly	***Anatoly Moldovansky***
Bruce Hamilton	*Stephen Smith*
Steve Jennings	*Joe White*
William Kneifel	*Stan Woods*
Jurgen Knopke	

-*Industrial Automation*	*31%*
-*Test and Measurement*	*46%*
-*Timing Community*	*23%*

1588-2002: 144 Pages, IP/UDP only, no options

Evolution of IEEE 1588
(V2: PAR April 2005, published July 2008)

IEEE 1588-2008 Committee Members (all 50 of them)

Galina Antonova
Doug Arnold
Sivaram Balasubramanian
P. Stephan Bedrosian
Stewart Bryant
Chris Calley
George Claseman
Ron Cohen
Robert Cubbage
Ian Dobson
John Eidson
Tom Farley
John Fischer
John Fleck
Georg Gaderer
Geoffrey M. Garner
Michael Gerstenberger
Franz-Josef Götz
Bruce Hamilton
Kenneth Hann
Ken Harris
Jim Innis
Joel Keller
Jacob Kornerup
Kang Lee
John MacKay
Dirk S. Mohl
Anatoly Moldovansky
Laurent Montini
Paul Myers
Karen F. O'Donoghue
Jonathon D. Paul
Stephen Peterson
Antti Pietilainen
William E. Powell
Markus Renz
Silvana Rodrigues
David Roe
David Rosselot
Stephan Schüler
Markus Seehofer
Mark Shepard
Veselin Skendzic
Dave Tonks
Richard Tse
Aljosa Vrancic
Hans Weibel
Ludwig Winkel
Taylor Wray
Gabriel Zigelboim

-Industrial Automation 8% (31%) *- Military 4% (0%)* *- Power 6% (0%)*
-Telecommunications 42% (0%) *-Test and Measurement 28% (46%)*
-Timing Community 2% (23%)

1588-2008: 269 Pages, 6 transport maps, ~9 options

Evolution of IEEE 1588

(revision of 2008: PAR to be submitted in May 2013)

IEEE 1588-201? Committee Members (all 135 of them)

FIELD 201? % 2008% 2002%

- *Academia …………………..14.0% …..0………0*
- *Financial ……………………..0.8% ……..0………0*
- *General ……………………....16.5% …..0………0*
- *Industrial Automation …….....9.9% … .8………31*
- *Military ………………………3.3% … .4………0*
- *Power ………………………..3.3% ..... .6………0*
- *Telecommunications ………..47.9% …..42……...0*
- *Test and Measurement …….2.6% ……28…….46*
- *Timing Community …………1.7% …… 2………23*

1588-201?: ??? Pages, ? transport maps, ~? options

Workshops & Symposia on IEEE 1588 (both plug-fest and technical program)

- 2003- NIST workshop (Gaithersburg, MD) (GE, BCs, TCs, telecom shows up!)
- 2004- NIST workshop (Gaithersburg, MD) (major telecom presentation)
- 2005- NIST workshop (Zurich Univ Applied Sciences, Winterthur, CH)
- 2006- NIST workshop (Gaithersburg, MD)
- 2007- ISPCS (Austrian Academy of Science, Vienna) (glorious)
- 2008- ISPCS (Univ Michigan, Ann Arbor, MI)
- 2009- ISPCS (Univ of Brescia, Brescia, IT)
- 2010- ISPCS (IOL, Portsmouth, NH)
- 2011- ISPCS (Tech Univ Munich, Munich, DE)
- 2012- ISPCS (San Francisco, CA) (telecom and power rule!)
- 2013- ISPCS (Ostwestfalen-Lippe University of Applied Sciences, Lemgo, DE)
- 2014- ISPCS (Austin, TX)

2003 1588 NIST workshop TOC

(v1 published Nov.2002)

Glen Algie at the 2003 1588 NIST workshop- the beginning of 1588 telecom

IEEE1588 proposal for Metro Ethernet Enterprise Solutions

IEEE1588 Sept 24 2003 workshop presentation

Glenn Algie
Nortel Networks, Wireless Technology Labs
Sept 24 2003

NORTEL NETWORKS

Why IEEE1588 Enhancements ?

Problem Statement:

- Transition is now occurring from Circuit to Packet in the Metro
- Ethernet edges are replacing the Traditional E1/T1 circuit demarcation (803.3ah)

- **Timing sensitive services that used the Circuit/Sonet/SDH timing references can't transition to Ethernet edge without a packet based Precision timing reference. New timing sensitive packet based services are also emerging.**

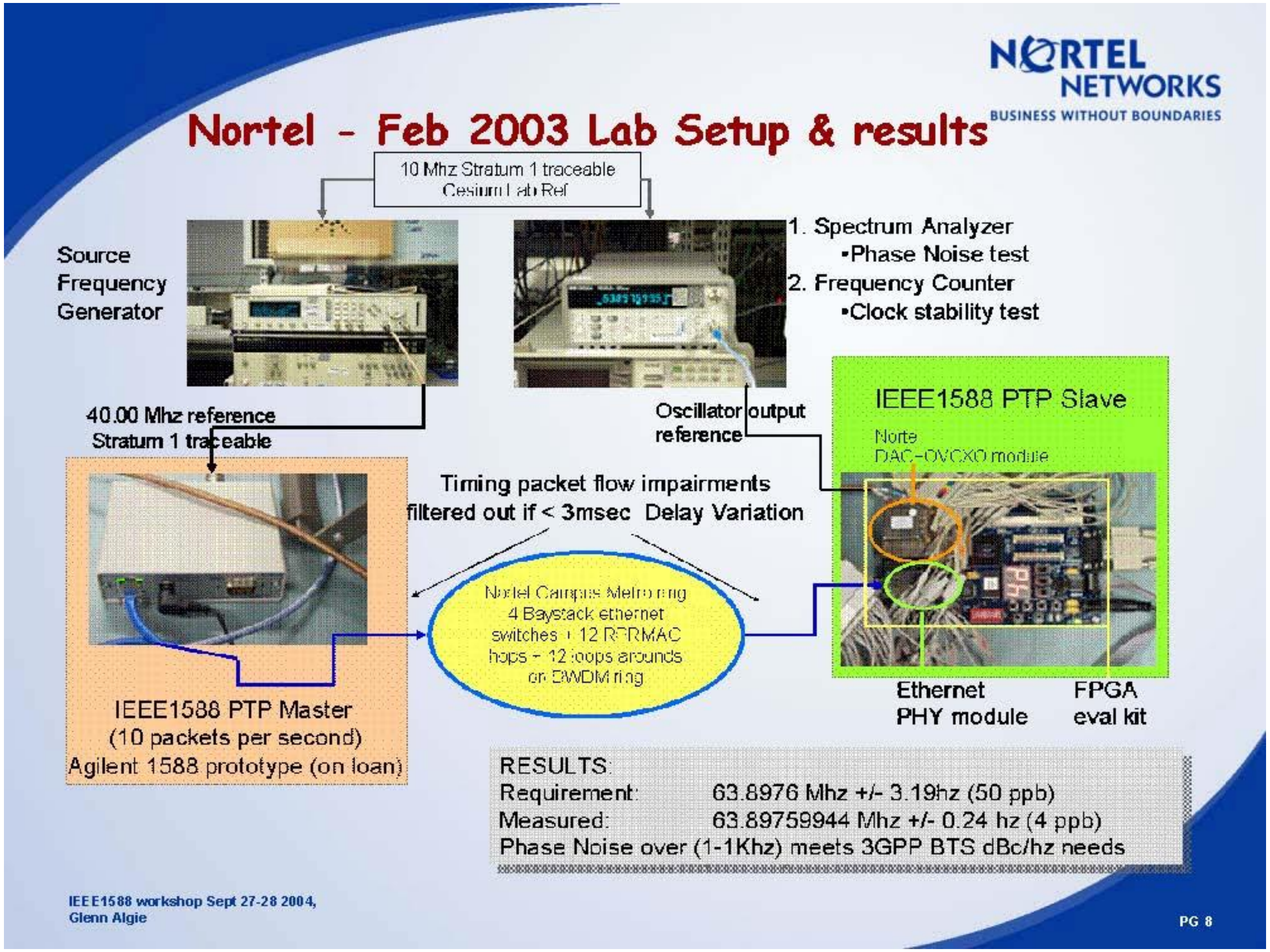
Solution Proposed:

- **NORTEL NETWORKS proposes that IEEE1588 be adapted for this need. Positioned as a Precision timing service over Metro Ethernet demarcations into Enterprise VPN (Virtual Private Network).**
- **Slight enhancements to the IEEE1588 Standard are proposed here for these Metro applications.**
- **1588 timing payloads are extensible to any frame/cell transport.**
- **Does not replace NTP. Interworking is expected.**

IEEE1588 enables timing sensitive end services on Enterprise VPNs to utilize Metro Ethernet Solutions

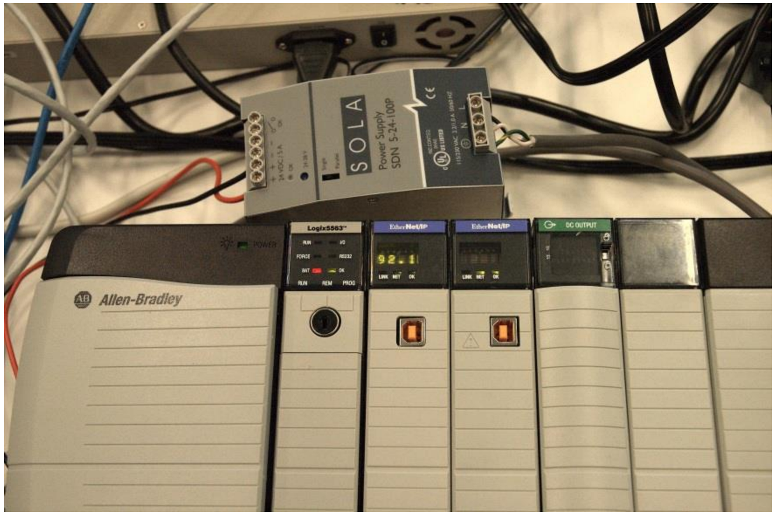
NORTEL NETWORKS

Glen Algie at the 2004 1588 NIST workshop



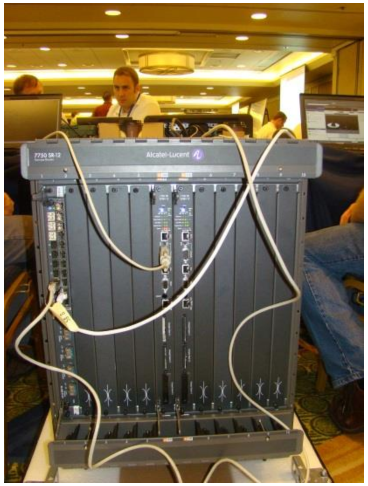
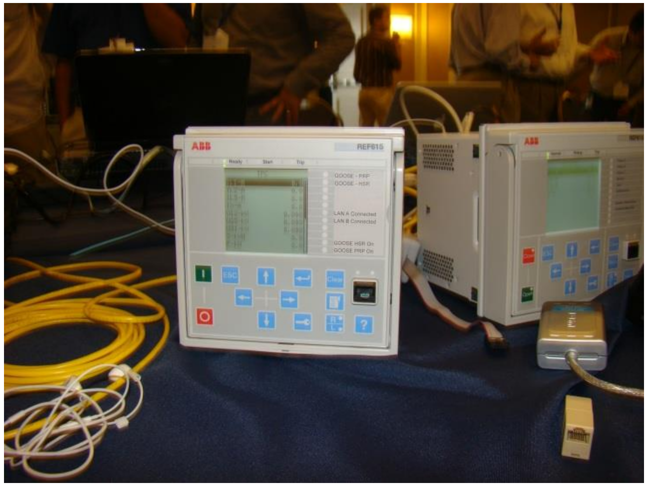
2005 Workshop in Winterthur

(plug-fest and social event)



2007 Workshop in Vienna (technical venue and social event)

2012 Workshop in San Francisco (plug-fest and social event)



The Present Situation:
Is there anything left to do?

- Security concerns
- Fault tolerance, redundancy and holdover
- Relationship of 1588 domains & other time/frequency distribution mechanisms, e.g. GPS, SyncE, NTP
- Higher accuracy and precision
- Manage the asymmetry problem!
- Management and measurement
- **Resolve fiefdoms issues vis–à–vis IETF, ITU-T, 1588, 802.1as, SAE AS6802…**
- Make sure all this stuff works together (plug-fest, testing)
- **New ways to use time and frequency**

The Present Situation: IEEE Conformity Assessment Program

- **ICAP fully integrated into IEEE SA as of January, 2013**
  - Governance provided by ICAP Steering Committee and ICAP Conformity Assessment Policy
  - First ICAP conformity assessment program to cover IEEE 1588 Telecom Profile based on IEEE 1588-2008 and ITU G.8265.1 for frequency synchronization
- **Formation of ICAP IEEE 1588 for Telecom Profile program**
  - New technical committee under ICAP to continue work accomplished by the IEEE 1588 Conformity Alliance and Committee of Experts
  - ICAP concludes lab agreement with Iometrix
- **Goals of ICAP conformity assessment program for IEEE 1588**
  - Align commercial implementations to PTP standards through an IEEE-ICAP sanctioned testing process
  - Drive adoption of 'IEEE-compliant' products and services in the telecom industry

What (if anything) will the current p1588 revision process accomplish?

Based on the PAR written at the April 2-3 p1588 study group meeting:

- Collaborate with 802 to:
  - Generate layer models (formalize future enhancements)
  - Generate interfaces for needed signals (e.g. 802.3bf)
  - Define mapping details to other transports
  - Settle the 802.1Q issue
- Liaison with IETF, ITU-T, 802, C37.238,…

What (if anything) will the current p1588 revision process accomplish?

Based on the PAR written at the April 2-3 p1588 study group meeting:

- Security (verify identity of grandmaster?)
- High accuracy (CERN White Rabbit technology)
- Multiple paths/masters
- Standard MIB (there are 3 or 4 in use now)
- Fix known (and maybe some unknown) editorial and technical errors
- Maintain backward compatibility with 1588-2008

Who is leading the revision of 1588

- Co-Chairs: Doug Arnold, John Eidson
- Vice-chair: Hans Weibel
- Secretary: Silvana Rodrigues
- Editor: John MacKay

Looking Forward
New ways to use time and frequency

Distrib Comput (1993) 6:211–219

DISTRIBUTED COMPUTING

Practical uses of synchronized clocks in distributed systems*

Barbara Liskov

MIT Laboratory for Computer Science, Cambridge, MA 02139, USA

Received June 1991 / Accepted January 1993

Barbara Liskov received her B.A. in mathematics from the University of California at Berkeley and her M.S. and Ph.D. in computer science from Stanford University. She is currently a member of the faculty at the Massachusetts Institute of Technology, where she is NEC Professor of Software Science and Engineering. Her research and teaching interests include programming languages, programming methodology, distributed computing, and parallel computing. Her work on data abstraction

algorithms that make use of synchronized clocks and analyzes h

Key word
clocks – D

1 Introduc

Synchronized clocks are quickly becoming a reality in distributed systems. For example, the network time pro-

At-most-once messaging,
Authentication tickets in Kerberos
Cache consistency
Atomicity
Commit windows

- Examine the messages to identify those that could be avoided by using timestamps. Or,
- Where message exchange is reduced by maintaining state save storage by using timestamps as a garbage collection technique.

A more recent shot at “Practical uses of synchronized clocks in distributed systems”

The NITRD National Workshop on The New Clockwork for Time-Critical Cyber-Physical Systems

October 25-27, 2012 | Hyatt Regency Baltimore

- 18 papers from academia covering: transportation, power distribution, telecom, military, medical, wireless…
- Concern over GPS spoofing and wire line hacking
- Mostly doing things better rather than new techniques
- Scaling in system size and complexity is an issue

Scaling issues => distributed, networked, time-based systems?

Complexity:
- Data acquisition
- Complex machinery
- Finance
- …

Spatial extent:
- Power grid
- Telecom
- Transportation
- Telesurgery
- …

Photo courtesy of Veselin Skendzic

Some examples and what we can learn from them.

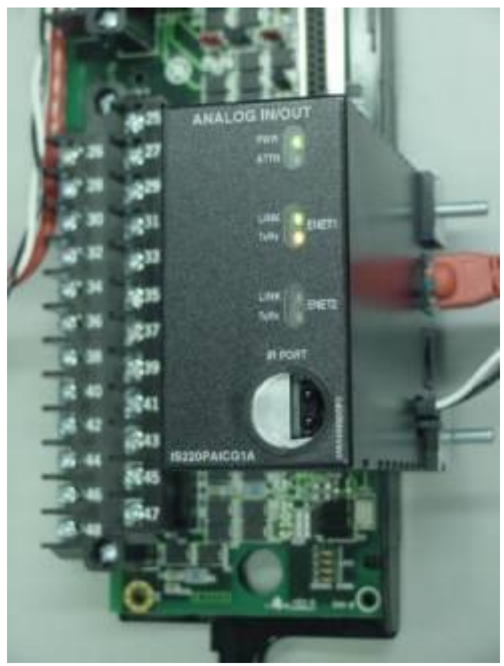
- Some are in use today, some are proposed
- Time provided by some combination of NTP, GPS, 1588 and proprietary
- They use time <u>mostly in traditional ways</u>
- Most require ubiquitous time
- Demonstrate a wide range of required accuracy and precision
- How will all of this affect telecom?

Some of the examples provide hints of non-traditional uses of time

- Replacement of messages with timestamps
- Timestamps to save bandwidth
- Timestamps in memory management
- Timestamps to reduce wiring
- Timestamps to simplify calibration
- Timestamps to alleviate latency and/or jitter
- Reasoning about order =>reasoning about time
- Timestamps vis–à–vis execution time
- …

Power system applications

GE uses 1588 in the Mark™VIe control system for large generators, turbines, wind farms, and other DCS applications. (reduce wiring, save bandwidth, manage complexity and scaling)

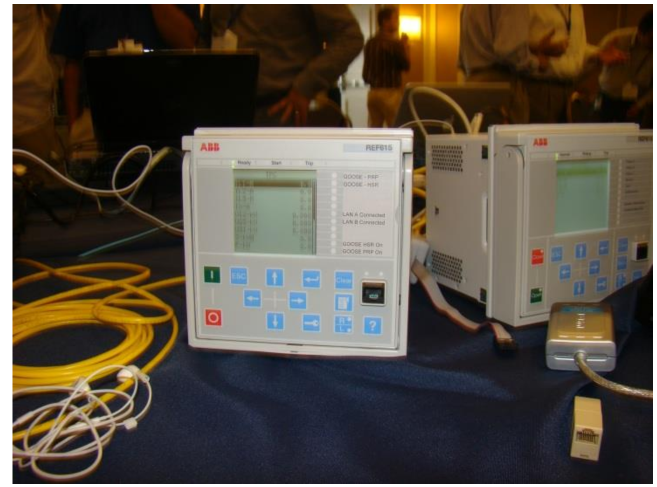


Courtesy of General Electric

Finance
high speed trading => 1588-based
(alleviate some latency & jitter issues)

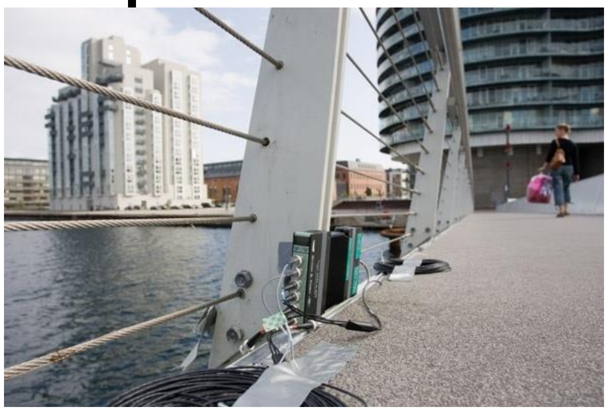
Power distribution
(in process, GPS and 1588, C37.238)

Photo courtesy of Veselin Skendzic



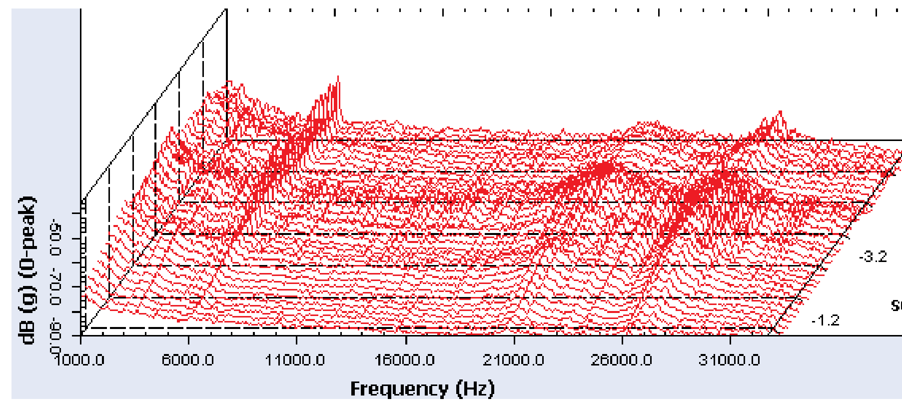
(alleviate some latency,
jitter and complexity issues)

Data Acquisition:
Sound, vibration,…, machine condition monitoring



Courtesy Brüel & Kjaer

Acquisition devices with 1588 clock, ~ 1 µs



Courtesy Crystal Instruments

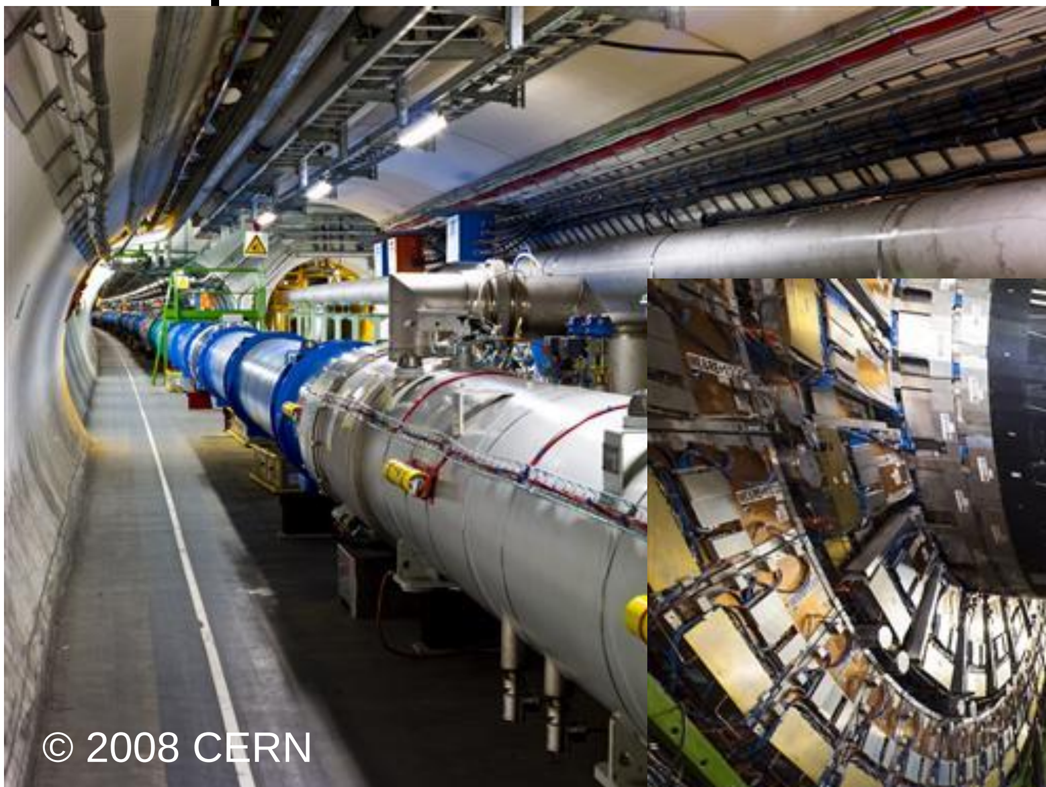
Photograph by Alan D. Monyelle, USN, 5/23/02

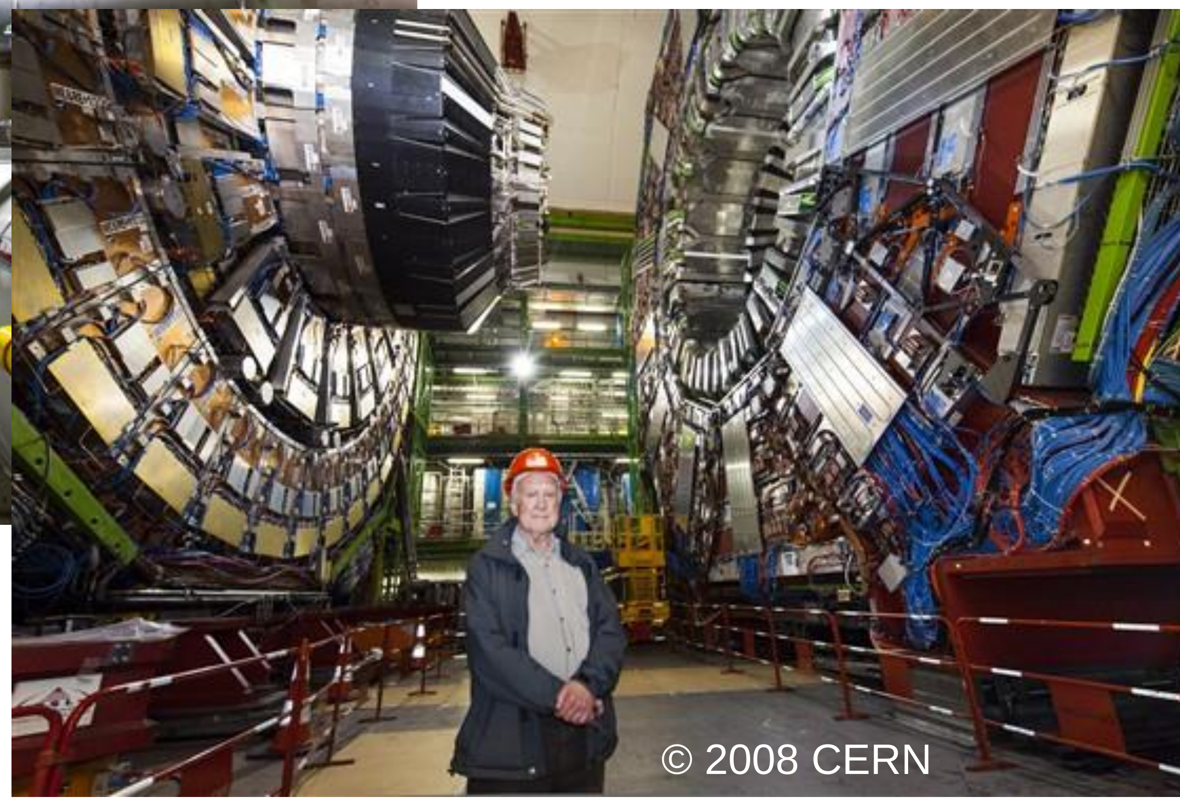
(alleviate some latency, jitter, complexity and calibration issues)

Telesurgery

(still pretty much local but there is a lot of interest in telesurgery)

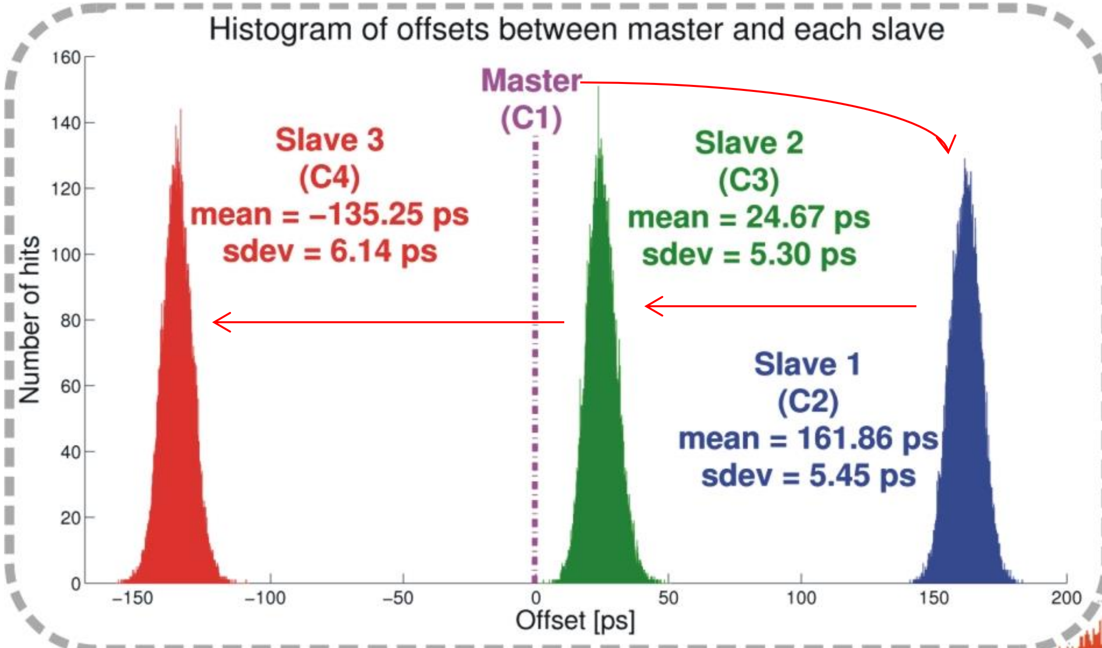
Scientific applications
(e.g. LHC at CERN)





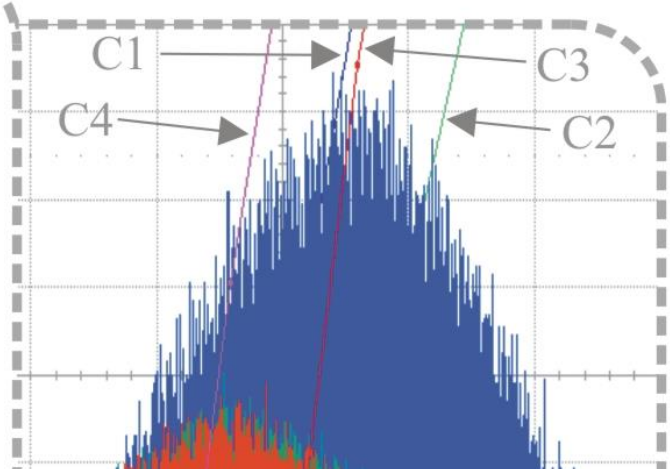
(alleviate some latency, jitter, complexity and calibration issues)

CERN White Rabbit Performance: Sub-nanosecond synchronization error over three 5km fiber optic links!



Matlab plot of collected data

Oscilloscope screenshot



Measure	P1:skew(C1,C2)	P2:skew(C1,C3)	P3:skew(C1,C4)
value	176 ps	42 ps	-117 ps
mean	161.86 ps	24.67 ps	-135.25 ps
min	141 ps	3 ps	-846 ps
max	183 ps	48 ps	-109 ps
sdev	5.45 ps	5.30 ps	6.14 ps

Maciej Lipinski, et.al., ISPCS 2011, Munich

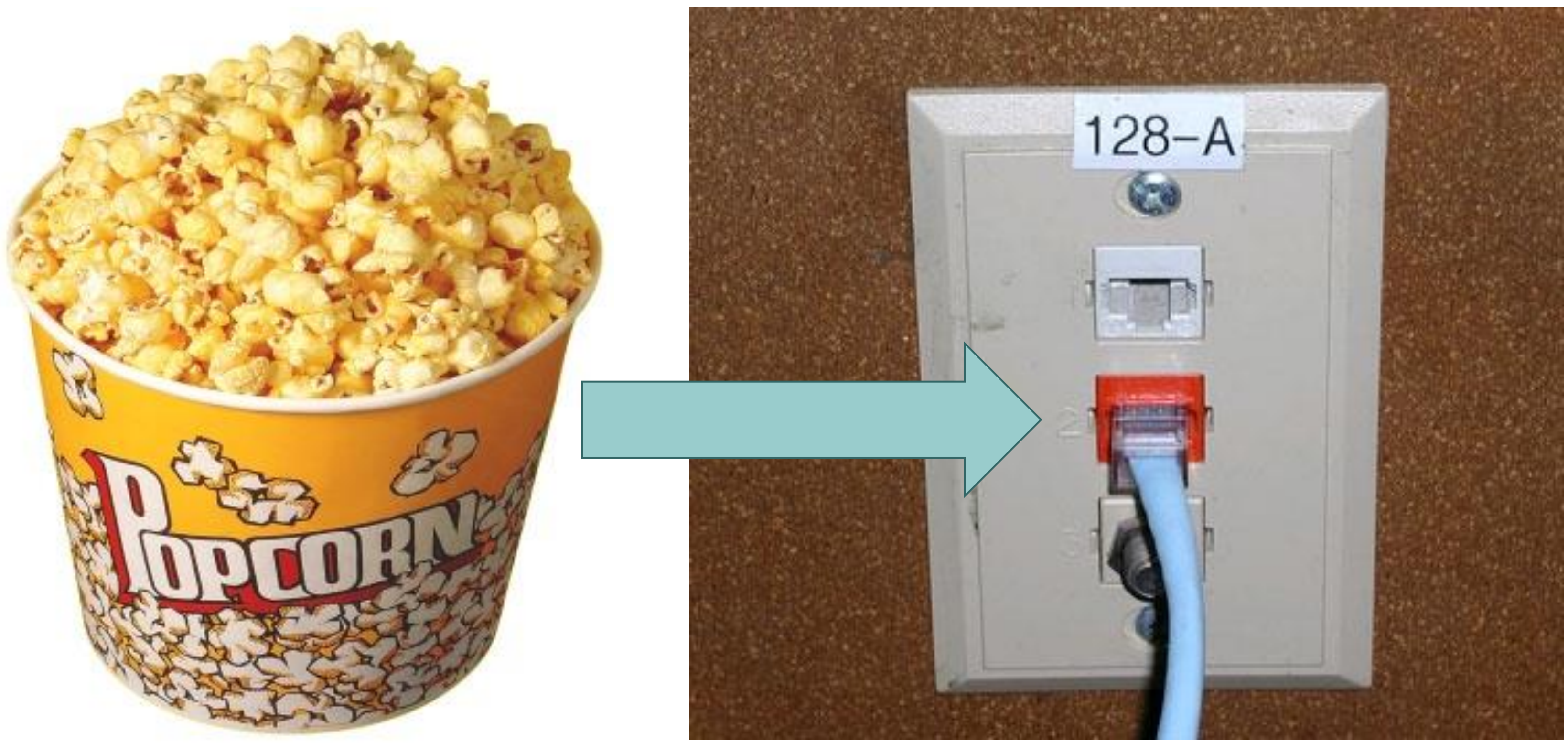
A guess (maybe even a certainty)

- Users will demand accurate, precise, robust, ubiquitous time
- Users are going to try running their own 1588 domains over the public internet.
- **<u>It will not be satisfactory</u>** (no on-path support)

How will this affect telecom sync and operators?

(so far you have thought about 1588 primarily for telecom purposes)

What if we brought back popcorn?



"At the next tick of the 1588 clock the time will be:
2013-04-17 15:35:02.010234 ± 1μs TAI
(or for a few more $/month ±10ns)"

My guess is-

- Result in more deployment of distributed applications
- More robust timing based on redundancy between GPS, wire line (NTP and 1588), and
- **<u>New innovative ways of using time by customers you have never heard of</u>**

hints

Example of an innovative use of time!

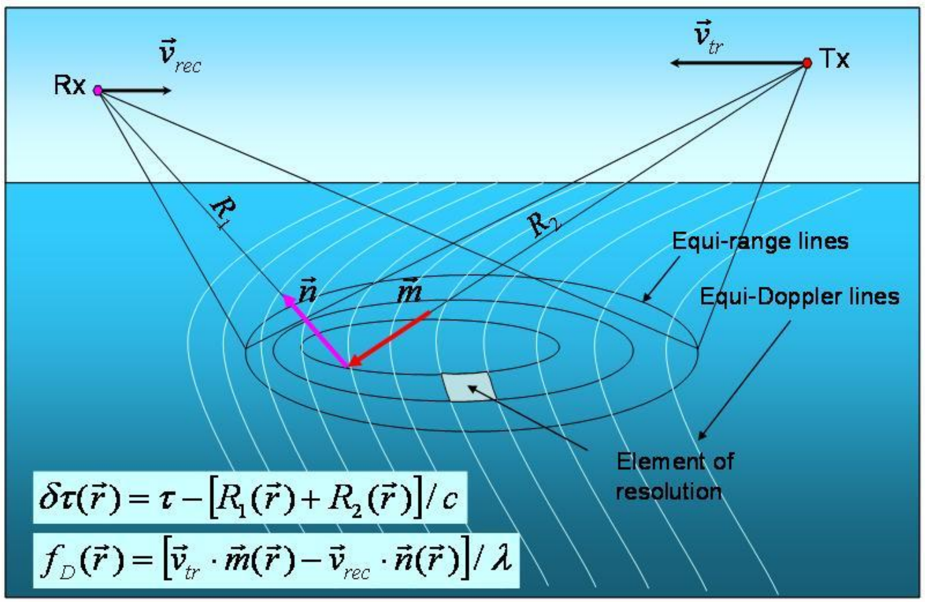
Key is to "Transform commit order reasoning to timestamp order reasoning",

Wilson Hsieh at OSDI 2012

http://research.google.com/archive/spanner.html

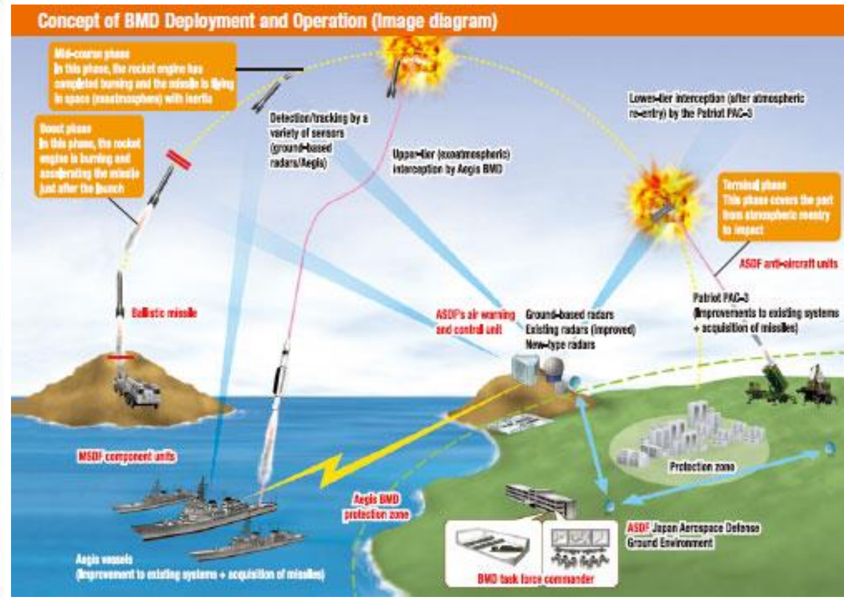
Military-aerospace applications
(courtesy of Boris Gelfand- Lockheed Martin)

Bistatic Radar



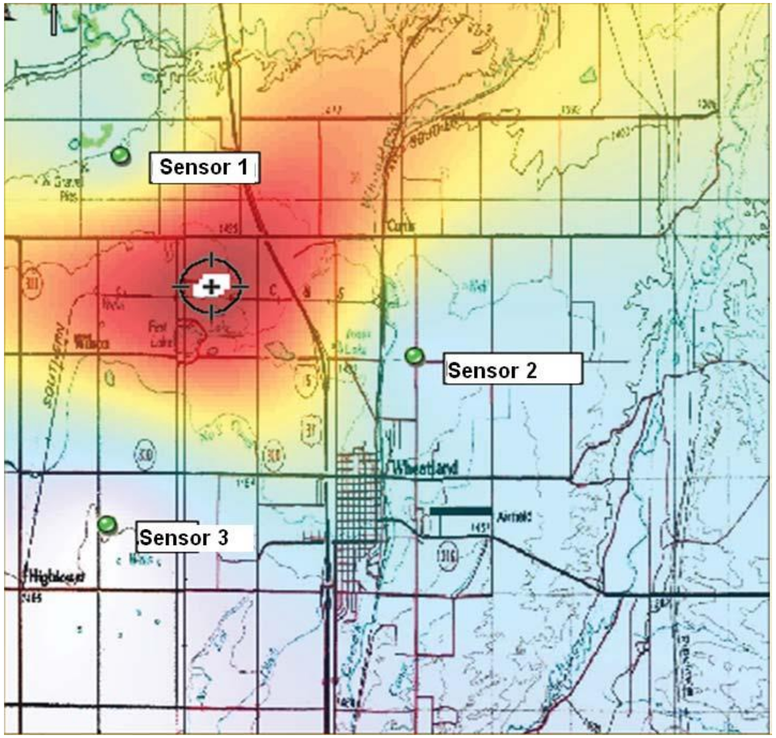
Bistatic is very timing dependant; estimates indicate **sub-ns need**.

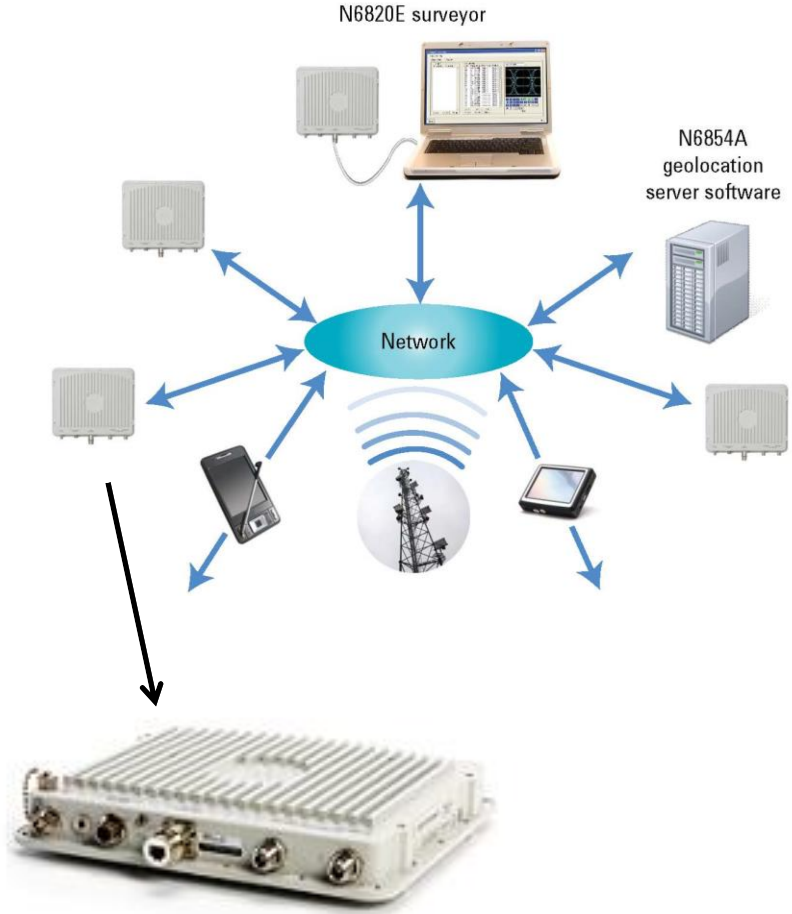
Aegis/BMD



Key requirement is a shared frame of time reference and position at a very high degree of accuracy. Relative ship position, pitch, yaw, roll, all need to be accounted for on a per-waveform (pulse train) basis.

Trilateration
(courtesy of Agilent Technologies)

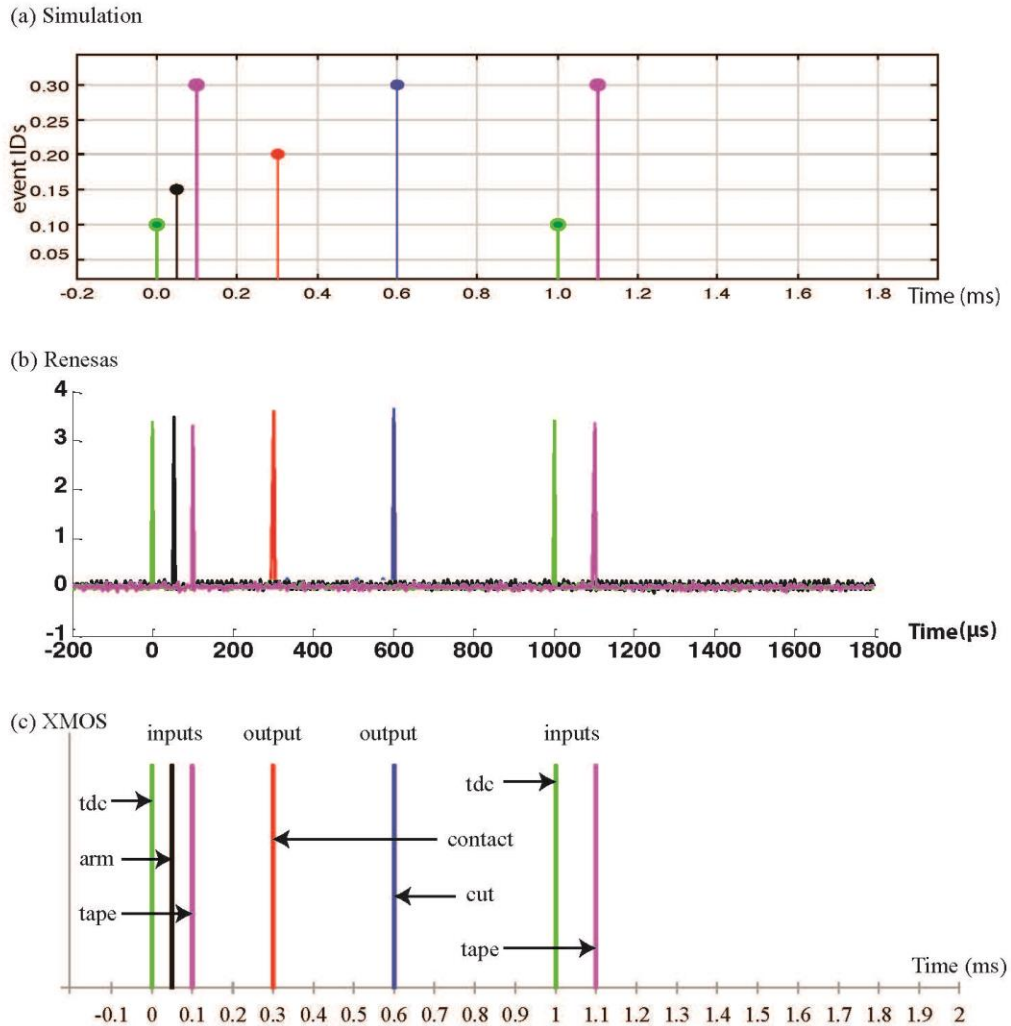




Embedded systems- especially distributed systems.

Designers should be able to design, simulate, and code generate for multiple targets with guaranteed timing!

http://chess.eecs.berkeley.edu/ptides/



The Swarm at the Edge of the Cloud

(courtesy Edward Lee: http://www.eecs.berkeley.edu/bears/)

(**http://www.terraswarm.org/index.html**)

Funding: DARPA and industry partners, including Applied Materials, GLOBALFOUNDRIES, IBM, Intel Corporation, Micron Technology, Raytheon, Texas Instruments, and United Technologies.

[J. Rabaey, ASPDAC'08]

Conclusions

- We have only scratched the surface of time-based applications
- GPS, NTP and 1588 will jointly and separately play key roles
- We can expect many more innovative uses of time and of high accuracy time
- Ubiquity is key- time must be a service not an application domain function
- **Telecom industry has a KEYSTONE role to play to enable timing capabilities and opportunities for your customers**

Thank You