Examples of Time Transport

Michel Ouellette
Technical Advisor
Huawei Technologies Co., Ltd.
Outline

- LTE-Advanced Time Synchronization Examples
- Time Distribution over Packet Transport Network
- Latest Field Trials
- Performance Results & Voice/Data Service Results
- Summary
LTE-Advanced
Network Synchronization Overview

- **Network Based Synchronization Error**
  (frequency and/or time)

- **Over-the-Air Synchronization Error**

3GPP TR36.814 defines further advancements for LTE

- LTE / LTE-A phase/time specs are beyond current GSM/UMTS frequency specs (50ppb) imposing further requirements on the transport network
Radio transmissions from multiple base stations radiate at the same time (spatial multiplexing), giving better cell edge performance and higher data rates.

- Broadcast service on the air interface
- Accurate time synchronization required at base station (GPS, IEEE1588-time, etc.) for aligning radio transmissions

\[\text{Time difference} = \max\{t_0-(\Delta_1+t_1), t_0-(\Delta_2+t_2)\} \leq x \text{ \(\mu\)sec}\]

*Illustrative example
Relay used to improve the coverage of high data rates sites, temporary network deployment, coverage in new areas, etc.

The relay node (RN) is wirelessly connected to radio-access network via a donor cell (eNB).

The UE may need to get timing info from RN over the air, and where the RN also obtains timing over the air from the donor eNB.

Some relay nodes have stringent time alignment such as Example 2

- RN nodes might be equipped with GPS or is synchronized via the radio interface
- Donor eNB might be equipped with GPS or is synchronized via IEEE1588-time

*Illustrative example
Field Trial Topology
City-Wide Time Distribution, Joint with China Mobile

Requirement at NodeB: < ± 1.5μsec of cumulative time error
Field Trial Setup
Time Distribution

- One Core 10GE ring with 6 Access GE ring
  - Approximately 75 nodes, covering one city, multi-vendor equipment

- Two Time Reference Sources
  - Dual mode GPS/Beidou receivers, connected to packet transport nodes via Gigabit Ethernet interface (running IEEE1588) or direct 1PPS+ToD interface

- Packet Transport Nodes
  - IEEE1588 Boundary Clock & Best-Master Clock Algorithm. IEEE1588 terminated in each port, 10GE & GE timestamping (similar in spirit to 802.3bf architecture)
  - Synchronous Ethernet & ESMC channel for frequency distribution
  - IEEE1588 time and SyncE frequency reference chain are congruent
  - Fiber asymmetry compensated section-by-section

- NodeB base stations
  - Receive time synchronization from Fast Ethernet interface (running IEEE1588) or direct 1PPS+ToD coaxial input.
  - NodeB can output 1PPS interface for measurement purposes

- Traffic
  - PTN carries real voice/data services

- Measurement equipment
  - TimeAcc 1PPS+ToD analyzer, call quality drive test tool and voice call generator

- Test Scenarios
  - Long term cumulative time error performance
  - Time Reference protection switch, PTN protection switch
  - BMCA master-slave hierarchy, SyncE reference switch
  - Quality of voice/data service, handoff and call completion
Delay compensation of every single element is necessary

**Scenario 1:** BITS uses 1PPS+ToD to provide time to packet transport, and BTS uses IEEE1588 FE to recover time

Result: Acceptable performance

**Scenario 2:** BITS uses 1PPS+ToD to provide time to packet transport, and BTS uses 1PPS+ToD interface to recover time

Results: NodeB not capable of compensating (at the time of the trial) for 1PPS+ToD coaxial cable delay and internal delay
Performance Results

Long term Cumulative Time Error (36 hours)

Long-term cumulative time error < ± 1.5usec
Voice/Data Quality Results

- Drive tests
  - Between NodeBs supporting IEEE1588 time sync
  - Between NodeBs supporting IEEE1588 and NodeBs supporting GPS

- Voice/Data Services under test & Handoff performance
  - AMR voice, VP and PS384 (various wireless codecs)
  - Eg., AMR traffic: 100-seconds call with 10-seconds interval
  - Drive speed: 40 – 60km/hour

  - Successful handoff ratio between adjacent base stations: 100%
  - Call completion ratio: 100%
  - Average voice MOS (mean opinion score): 3.46

Drive test routes
Summary

- Accurate Phase/Time distribution over large-scale Packet Transport Network is progressing within Q13, primarily serving wireless radio interfaces requirements.

- Various Field Trials
  - IEEE1588 distribution over Packet Transport Network
  - IEEE1588 distribution over Optical Transport Network

- Field trials using Boundary Clocks & Best Master Clock show good results
  - Cumulative time error < ±1.5 usec for TD-SCDMA NodeB
  - Packet impairments: reference switch, protection switch
  - Good voice & data quality of service
  - Successful handoff and call completion

- Additional references:
  - C599, ZTE/CMCC, Geneva, October 2009
  - WD29, Huawei/CMCC, Lannion, December 2009
  - C1065, ZTE/Huawei/CMCC/CATR, Geneva, June 2010
  - C1064/65, ZTE/CMCC/CATR, Geneva, June 2010
Additional Slides

- Additional performance results
  - Time distribution via IEEE1588
  - Frequency distribution Synchronous Ethernet
- Boundary Clock
Trial Results

- 2 time synchronization reference chains
- A chain consists of 15 nodes
- Each node implements IEEE1588 (for time) and Synchronous Ethernet (for frequency)
- Default Best Master_Clock Algorithm used to establish Master-Slave hierarchy and electing new GrandMaster during failure
- GM1 is the initial GrandMaster of the network
- 1PPS signal (cumulative time error) and 2.048MHz signal (time interval error) used for time and frequency measurements

M: Master port
S: Slave port (only 1 per switch)
P: Passive port
GM: GrandMaster

Diagram:
- Chain #1: 52 km
- Chain #2: 43 km
- 1PPS signal (cumulative time error)
- 2.048MHz signal (time interval error)
- GPS reference
- Time Tester
Frequency and Time Results
Performance of two Boundary Clocks connected via single GE link

Frequency (SyncE)

± 3 nsec on 2.048MHz output

~10^-11 frequency offset

→ PRC traceable results

Time (IEEE1588)

± 2 nsec 1PPS pk-to-pk jitter

+ 3 nsec static time error due in part to fiber asymmetry
Frequency and Time Results
Protection scenario from Chain#1 to Chain#2

- Master failure done by disconnecting 1PPS interface/cable from GM1
- Master2 is the new GrandMaster, produced by BMCA & the exchange of Announce messages. Time is distributed through Chain #2

RESULT:
- Chain #1 Time error performance: ±15 nsec
- Chain #2 Time error performance: ±20 nsec
- Protection Switch from Chain 1 → 2 (~60 nsec)
- Phase Transient (~80 nsec)

Results demonstrate the robustness and performance when using IEEE1588 node-by-node time synchronization
Boundary Clock System

Boundary Clock is similar in concept to current SDH/SONET/SyncE synchronization system (deal with time and not just frequency)