Practical Approach to Backhaul Timing Solutions and Challenges

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The Juniper Mobile Backhaul Solution comprises:

- Juniper BX 7000 Multi-Access Gateway
- Juniper M-series Aggregation Site Gateway with Circuit Emulation PICs
- Juniper MX-series for metro backhaul aggregation
- JUNOScope IP Services Manager with extensions for mobile backhaul
Challenges (Circuit to Packet Migration)

- **Why Migrate TDM/ATM Circuit to Packet?**
  - Cost saving (Packet solutions costs fraction of Circuit Based solution)
  - Scalability (Mobile network offering multimedia & broadband services)

- **Why we need Time or Phase Synchronization?**
  - Base station clock needs to be within certain limit of central radio controller to insure glitch free hand-over between different base stations.
  - TDD (time division multiplex) requires both frequency and phase/time synchronization to reference clock.
  - FDD (frequency division multiplex) requires only frequency synchronization to reference clock.
Challenges (Circuit to Packet Migration)

What is the requirement?

- **Time Sync**
  - WCDMA TDD system:
    - (50ppb frequency sync and time/phase within +/- 1.25us between ref and BTS)
    - +/- 2.5 us between base stations
    - CDMA2000: +/- 3us time/phase alignment
  - WiMAX
    - < +/- 2.5us
  - WCDMA and GSM: FDD system
    - +/- 50ppb frequency and no specific time/phase requirement
    - +/- 100ppb for Fête Cell

**Bottom Line**

- Timing frequency and phase plays a critical role in Mobile Network and loss of synch leads to
  - Disruption in service and bad user quality of experience (Upset Customer, revenue loss)
  - Wastage of precious frequency spectrum
Migration of TDM/ATM based synchronous mobile backhaul to Asynchronous Packet based Network creates need for “Synchronization”
Sync Solution options

- What are the options currently available or in work
  - Currently available
    - GPS receiver on each cell site
    - Adaptive Clock Recovery (ACR)
  - Being worked in partnership with Service Providers and their partners (Standard bodies, Networking Equipment and Silicon Providers)
    - IEEE 1588 v2 / NTP
    - Sync Ethernet
GPS Sync Solution (details) (Option#1)

- **GPS**
  - **Value**
    - Provides Accurate frequency and Time (UTC) time traceable to a Stratum 1 PRC
    - Predominant solution in the US
      - Reluctance to adopt globally due to US DoD sponsorship
    - Others - Glonass, Galileo
  - **Cons**
    - Costly due to cost of receiver, local high quality Oscillator required for holdover
    - Antenna requires visibility to Sky (may not be feasible in certain Cell site location.
    - *Satellite failure modes produces signals with large errors*
      - *Receiver Autonomous Integrity Monitoring (RAIM) should compare all satellite signals and discard errors*
    - Jamming: Intentional and non Intentional
  - It’s a costly solution but provides high quality PRC Sync in normal conditions.
Adaptive Clock Recovery (Option#2)

- Packet based in-band Sync
  - Clock is reconstructed using the packet interarrival rate
  - Adaptive Clocking Provides the line timing
  - Goal of ACR algorithm is to match Ingress Clock Frequency to Egress Frequency and maintain G.823 MTIE mask.
  - ACR algorithm implementations are proprietary
  - Requires Tuning to a particular network traffic profile

- ACR runs into issues during:-
  - During significant packet-loss in Network
  - PDV is significant band/range or long tail
  - Path delay changes due to network reconfiguration or restoration
ACR (Does it work?)

GPS Receiver for PRC

E1/0

default

172.28.113.193
lo0-44,432

GPS Reference
Clock for TX and
Jitter/Wander

JDSU

172.28.113.89

BX7000 #1

172.28.113.126
lo0-2.1.1.102

GE-1/0/1

11.1.1.1/30

Agilent N2X for G.8261
Profile traffic injection and
terminations

BX7000 #2

172.28.113.127
lo0-13.1.1.102

GE-1/0/2

11.1.1.1/30

ACR Solution setup (SP_Lab)
Findings

- **ACR**
  - It does work for the most of the cases
  - It can handle most of the network disturbances

- **Is it the solution to Packet based backhaul Network?**
  - Yes in certain scenarios

- **What to look for in ACR based solution:-**
  - During significant packet-loss in Network (Algorithm Dependent)
  - PDV is significant (Add high priority QoS for ACR based backhaul traffic)
  - Path delay changes due to network reconfiguration or restoration (Algorithm dependent)
ACR with 30% Steady Network Utilization

Analysis range: [0, 89680] s
Sample rate: 1/s

TDEV: N/12 - rec. 0.172

Comment: 10/03/2008 12:14:56.000
ACR with 30% Steady Network Utilization

TIE data from 08.09.23 12:34:23.000 to 08.09.30 13:29:10.000

Samples: 89681

Time [s] Marker Drift rate
0 89680 53741 -8.1E-12 ppm/s
114.18 -199.74 -46.36

Sample rate: 1 / s
Frequency offset: -4.1E-8 ppm

Comment: 10/03/2008 12:13:41.000
ACR with QoS on PW + 90% BE Traffic
ACR with QoS on PW + 90% BE Traffic
Solution Validation (Does it work?)

- GPS Receiver
- Master Timing Source based on GPS reference
- JDSU ANT20 with GPS Referenced Clock for Transmit and Jitter/Wander reference
- IP/MPLS Network (5- to-16 Hops)
- Agilent N2X Network Traffic Emulations
- Adaptive Clock Recovery
Synchronous Ethernet (Option#3)

- Similar to SONET/SDH/PDH Clock is distributed using the bit-stream embedded in PHY Layer
- A reference timing signal traceable to a PRC is embedded into the Ethernet Switch/Router using an external clock port
- OAMPDUs can be used to pass synchronization status message
- The Ethernet PHY recovers the clock signal from the “bit stream” at the physical layer
- Sync Ethernet only delivers the frequency not the phase
- Network load does not impact Clock
Synchronous Ethernet Concept

- **PRC Clock is embedded in PHY layer**
  - Receiver PHY Generates the clock signal from “bit stream”
  - Just like SONET/SDH PLL
- **Each Node in Sync Ethernet Network should recover and distribute the Clock from reference PRC**
- **Performance is independent of Network Traffic Profile since Clock is carried at PHY layer**
Synchronous Ethernet

- Standards based – G.8261
- Can be deployed with SONET/SDH based network in Phases
- Deliver frequency at high accuracy tractable to PRC
- Sync Ethernet does not deliver the Phase
- Sync Ethernet Capable network elements is needed at each node to maintain the synchronization
IEEE 1588v2 (Option#4)

- Packet based out-of-band synchronization
  - Clock info is distributed using dedicated timing packets between Master and Slave (Master-Slaves)
  - Synchronizations packet do no depend on Network traffic (Always exchanges between Master and Slaves even when there is no traffic data)
  - Virtually independent of the physical media and can flow over low-speed twisted-pair, high-speed optical fiber or wireless links.
  - Delivers both frequency and Phase i.e. it can be used for FDD and TDD system timing solutions
IEEE 1588v2 (Option#4)

- 1588 Grandmaster connected to a PRC source, communicates with 1588 slaves via the PTP protocol messages over PSN network to achieve synchronization for both frequency and time.
- Employs a two-way methodology, where packets are exchanged bi-directionally between the clock masters and slaves.
- It can be used for any pure packet-based network, hence providing synchronization for future backhaul networks to be deployed by mobile operators.
- High resiliency due IP/MPLS network resiliency.
- The IEEE 1588v2 packets are fully Ethernet and IP standards compliant and backward compatible with all existing Ethernet and IP routing and switching equipment.
IEEE 1588v2 (Does it Work?)

GrandMaster
IP Address 11.1.17.25/30

GPS
CLOCK
SOURCE

CERN C-2000
Precision Time
Protocol Server

Slave
IP Address 11.1.17.9/30

Feb/GE conversion

Oversubscription w/wo QoS

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1588v2 Validation:
Network disturbance load with 80% for 1 hour after the clock recovery and stabilization period of 900 sec. Master with 32 Sync Packets/s (it did meet the G.8261 requirement)
1588v2 Validation:

Sudden large, and persistent changes in network load. It demonstrates stability on sudden large changes in network conditions, and wander performance in the presence of low frequency PDV.
Starting with network disturbance load at 80% for 1 hour, drop to 20% for an hour, increase back to 80% for an hour, drop back to 20% for an hour, increase back to 80% for an hour, drop back to 20% for an hour.
1588v2 Validation:
Temporary network outages and restoration for varying amounts of time to demonstrates
ability to survive network outages and to recover on restoration. MTIE over the 1000 s
interruption will largely be governed by the quality of the local oscillator not indicative of the
quality of the clock recovery process.
Starting with 40% of network disturbance load after a stabilization period removed network
connection for 10 s, then restored, Allowed a stabilization period and then repeated with
network interruptions of 100 seconds.
1588v2 Validation:

Temporary network congestion and restoration for varying amounts of time. It demonstrates ability to survive temporary congestion in the packet network.

Starting with 40% of network disturbance load after a stabilization period increasing network disturbance load to 100% (inducing severe delays and packet loss) for 10 s, then restoring it. Allowing a stabilization period for the clock recovery process to stabilize and then Repeat with a congestion period of 100 s.
1588v2 Validation:

Changing the number of Routers from 6 to 4 causing a step change in packet network delay. This test was started with 40% of network disturbance load after a stabilization period according to re-routing the network to bypass two Routers and again allowing a stabilization for the clock recovery process to stabilize, and then restoring the original path. Done through changing the link matrix.
IEEE 1588v2

- 1588v2 algorithms have got much better over time
- Most of the 1588v2 algorithm assume bell curve PDV distribution if PDV does not match these assumption, they get wacky i.e. do not meet the G.8261 MTIE and TDEV mask
- Asymmetric traffic profile also posses the challenge to the algorithms
- 1588v2 can handle bursty, constant load, on/off, routing range, network outage, network congestion traffic well but watch out for overload/long ramp.
- QoS provides the needed protection in overload condition as long as overload traffic is BE and PTP traffic is classified as AF or EF in IP Network.
Conclusions

- The IEEE 1588v2 offers the capability to deliver phase and frequency and it works for most of network traffic profile, disturbances and disruption but there are corner cases, which need algorithm improvements.

- Sync Ethernet can be used for delivering the frequency for Mobile backhaul solutions. It requires Sync E capable node to deliver and redistribute the clock.

- Sync E and 1588v2 can be used in conjunction to deliver high accuracy clock based on network architecture

- ACR can be solution for certain network Architecture (QoS makes a huge difference)
THANK YOU!

Q & A