

Synchronizing 2G/3G Base Stations as Backhaul Networks Transition to Ethernet

TimeProvider 500 Translator can solve the :
accumulated jitter problems of multi-hop :
Ethernet backhaul networks. :



Accumulated Jitter and Packet Delay Variation

Discussions about the core technical issue described in this paper often make reference to “jitter variation”, or “high jitter networks”, or “exceeding the jitter buffer handling limit”. More accurately, the problem is Packet Delay Variation (PDV) which represents the change in latency from packet to packet. Packet delay itself has no effect on the accuracy of the clock; constant delay would cause a fixed offset. However, variable delay causes a varying estimate of the offset. PDV is caused by the network elements such switches or routers, the physical network layer and even the topology of the network. It increases with the number of hops, and tends to be correlated to network load. If the amount of traffic in the network increases, the delay variation is also likely to increase.

The variation in delay from packet to packet through the network induces noise in the PTP client’s perception of the time at the master. That is, packet delay variation can result in variation in the time calculations that are based on timestamps in the PTP packets. The performance of the client is affected by both the magnitude of this variation, and how effective the client is at removing this noise. A client designed with a high quality reference oscillator and advanced algorithms will effectively filter this noise, or “accumulated jitter”, allowing the frequency of the signal to the base station to remain within specification for synchronization requirements.

Introduction

Mobile operators are deploying Ethernet backhaul networks to support 4G/LTE mobile technologies and meet customer demand for more bandwidth for a multitude of voice, video and data applications. The transition to Ethernet backhaul creates both a technical and economic challenge of providing precise synchronization for the existing 2G and 3G infrastructure that remains in service. This paper addresses this challenge and looks at alternative solutions.

The Problem

Ethernet networks can economically scale to meet the bandwidth demands of 4G/LTE deployments as well as backhaul the existing 2G/3G traffic. Despite its many benefits, the shift to Ethernet backhaul removes the TDM layer that inherently supplied a synchronization signal to the base stations that met their requirements.

The core technical problem is that the accumulated jitter from packet delay variation of a multihop Ethernet network can move synchronization performance of Ethernet access devices (usually a gateway switch or router) outside of the acceptable level. Non-conforming synchronization may result in dropped calls and failure to meet customer SLAs. Operators must find an affordable solution to meet the synchronization requirements of the 2G/3G

base stations using the packet networks to fully realize the economic benefits of Ethernet backhaul. The GSM and UMTS requirement for frequency accuracy at the transport interface is 16 parts per billion (ppb).

The Alternatives

A common approach to preserving sync for the 2G/3G mobile equipment is to continue to use existing T1/E1 connections (figure 1). However, serving a base station site with both TDM and Ethernet means continued monthly expense for the circuits and ongoing maintenance of the equipment.

Using the Ethernet network to deliver TDM services for the 2G/3G base stations is another alternative. Pseudowire and circuit emulation services provide the standard T1/E1 interfaces required by the 2G/3G base stations. Unfortunately real world networks have shown that with the accumulated delay variation over multiple hops, typical PWE3/CES implementations cannot reliably deliver the frequency synchronization performance required by the 2G/3G base station equipment.

Another alternative is to use native Ethernet without circuit emulation. IEEE 1588-2008 Precision Time Protocol (PTP) is a standard developed to deliver IP-based synchronization for packet-based communications networks. PTP has gained wide acceptance in mobile networks

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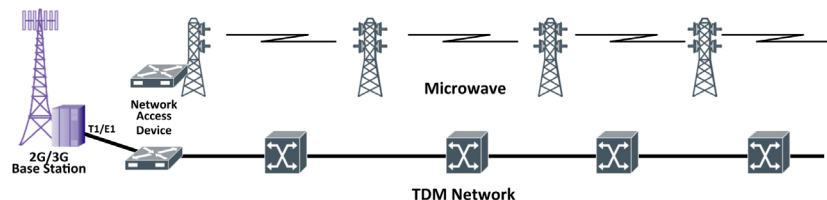


Figure 1. Common 2G/3G backhaul alternatives

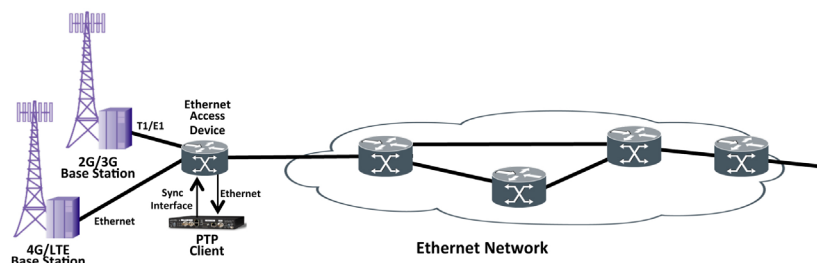


Figure 2. 4G/LTE and bandwidth growth drive the backhaul to Ethernet

worldwide as the primary synchronization mechanism to deliver timing over Ethernet backhaul to the cell site. Ethernet access devices often have embedded PTP clients or other frequency synchronization implementations. But multihop Ethernet network performance often does not allow these solutions to consistently meet the 16 ppb specification required by 2G/3G base stations.

GPS antennas and receivers deployed at base station sites will meet the synchronization specification requirements for 2G/3G and 4G/LTE. However, the cost of equipment (receiver, antenna, cable, etc.) and installation for carrier grade GPS may run as much as \$3,000 to \$4,000 per site in the U.S.; so it is not economically attractive to install a GPS receiver at every cell site. Less expensive GPS antenna/receivers are available, but they generally are not carrier grade designs with an oscillator and the needed interfaces. Another concern is that GPS is subject to interference from jamming and spoofing as well as occasional solar flare-ups and intermittent path fades. In addition, GPS may not be suitable for deployment in locations where satellite signals are partially blocked.

The Solution

Low cost IEEE 1588-2008 PTP clients incorporating a high quality crystal oscillator and advanced timing algorithms can supply a sync interface to the Ethernet access device that enables it provide a T1/E1 connection to the base stations that complies with

their timing specifications. As indicated in figure 2, this approach allows the Ethernet network to carry all of the backhaul traffic, eliminating the need for legacy T1/E1 backhaul and avoiding deployment of GPS antennas and receivers.

PTP utilizes clocks configured in point-to-multipoint configuration. Master clocks can be standalone devices or cards installed in existing synchronization distribution equipment such as Building Integrated Timing Supply (BITS) and Synchronization Supply Unit (SSU) systems located in master switching centers. Slaves are installed in remote locations either as embedded clients in carrier network elements or standalone devices. Master clocks send messages to its slaves to initiate synchronization. Each slave then responds to synchronize itself with the master. Incoming and outgoing PTP packets are time-stamped at the start of the frame of the corresponding Ethernet packet. The protocol is used to calculate the offset and network delay between time stamps, apply filtering and smoothing, and adjust the slave clock phase and frequency. This sequence is repeated throughout the network to pass very accurate time and frequency synchronization. Standalone clients designed with a high quality reference oscillator and timing algorithms that monitor and adapt to packet delay variations are better able to fine tune the frequency where multiple hops between the master location and the slave result in high accumulated jitter.

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With T1/E1 monthly costs ranging from \$60 to \$160 month per circuit in the US, and even higher internationally, a PTP client can return its investment in less than 6 months. The PTP client also requires far lower capital investment and operating expenses than a GPS receiver with its associated cable runs and antenna. As a network based solution the PTP client is not subject to the vulnerabilities and deployment limitations of GPS solutions. Consequently, carriers using standalone PTP clients are able to leverage their investment in Ethernet backhaul, originally driven by the 4G/LTE transition, to ensure service continuity for the 2G/3G network while eliminating the costs of the legacy connections. This efficient, easy-to-deploy solution operates within the overall sync and timing architecture of the Ethernet and 4G/LTE networks, so it is easy to integrate into the end-to-end management, performance monitoring and operational practices that are already in place.

Implementation

The amount of accumulated jitter from packet delay variation in a multihop network is dependent upon a variety of factors, including the type of transport technology that is employed, such as fiber optics or microwave technology. A further complication is that many mobile network operators lease backhaul services from other carriers which are subject to varying quality and availability.

These factors could make the operational implementation of the recommended solution a complicated subject. Knowing when and where to deploy it could involve truck rolls with test equipment to gather PDV data, complete an analysis and make a decision. The cost of making the decision could be higher than the cost of the solution. Since standalone PTP clients are relatively inexpensive and easy to install, some carriers have taken a very practical approach. To be certain their services will be supported and to avoid a complicated planning process, they follow a very simple rule: if there are more than three hops, they install a standalone PTP client.

Conclusion

A high performance PTP client provides a synchronization solution for 2G/3G networks that are being served by Ethernet backhaul. It satisfies the technical requirements of the legacy equipment and supports the operator's SLAs while lowering legacy network backhaul costs, fully leveraging the Ethernet backhaul investment and operating within the existing Ethernet/IP network and Operations and Maintenance requirements.