APPLICATION BRIEF

Symmetricom®

NGN SERIES

Synchronization for Next Generation Networks

Advances in Backhaul Synchronization - Maximizing ROI

Table of Contents

Abstract

Wireless backhaul is shifting away from traditional TDM (T1/E1) to Ethernet IP-based backhaul. Cost is the key motivator as mobile operators need to scale economically with growing bandwidth demands. An increase in the number of mobile users per base station and their increased use of data services are combining to create this demand. Packet-based backhaul has clearly emerged as the optimal solution, but this change takes away the TDM backhaul which served as a reliable frequency source. This major challenge needs to be overcome as timing and synchronization discontinuities are created by this shift to packet-based backhaul. This paper discusses the timing and synchronization technologies that address the challenges in moving from TDM to IP-based backhaul including IEEE 1588 Version 2 Precision Time Protocol (PTP), free-running atomic clocks (rubidium oscillators) and GPS based timing solutions as well as the various advantages and disadvantages of each.

Introduction

Wireless backhaul is shifting away from traditional TDM (T1/E1) to Ethernet IP-based backhaul. Cost is the key motivator as mobile operators need to scale economically with growing bandwidth

Mobile networks were designed to carry voice traffic over Time Division Multiplexed (TDM) networks. To support this, E1 and T1 circuits were used for backhaul transport from the Base Station Controller (BSC) to base stations (BTSs). SONET/SDH networks were used to transport voice traffic between BSCs Mobile Switching Centers (MSCs). Introduction of 2.5G mobile networks brought with it data services. This challenged the backhaul network to evolve and accommodate increased data traffic. Infrastructure used to cater to this demand included Frame Relay, ATM, and IP.

Today, the backhaul network is being overwhelmed by the rapid increase in bandwidth demand. New 3G (HSDPA, EV-DO) and 4G (LTE, UMB, and WiMax) mobile technologies offer greater flexibility to activate new data intensive services. While this drives up the demand for data, the average revenue per bit is steadily decreasing owing to market forces. Therefore, the operational costs associated with traditional backhaul methods are rising faster than the revenue generated by the new data services (see Figure 1).

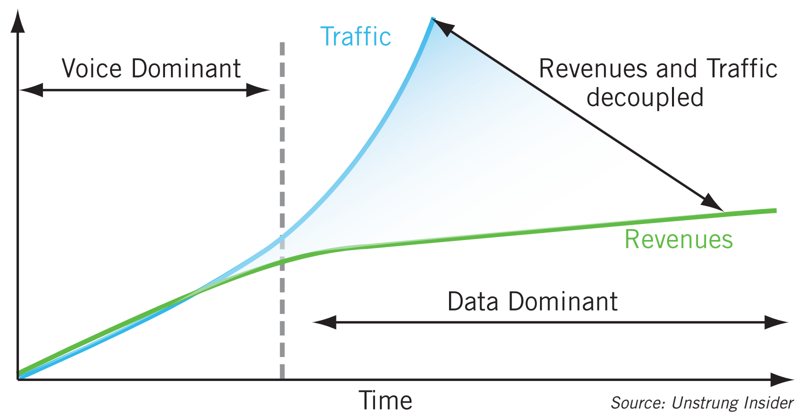

FIG 1 Traffic and Revenue evolution with time

Mobile operators must therefore reduce their costs (especially per-bit cost) of data transport in the backhaul network while continuing to ensure voice quality, maintain carrier-grade Operations, Administration and Maintenance (OAM), and provide circuit-like resilience. Although advanced Ethernet technology provides a solution to these backhaul problems, a shift to Ethernet impacts the operation of the base stations in GSM and UMTS networks, and a full solution must mitigate this impact.

This aggressive transition from tried-and-true TDM to next-generation Ethernet is fraught with technical and operational challenges, but essential for operators to thrive. This transition has to be managed while maintaining quality of services in order to minimize subscriber churn.

In this paper we examine the business challenges that the service and transport providers face to deliver to the ever higher bandwidth demands placed on the backhaul infrastructure. We will focus on the issue of frequency and time synchronization. Synchronization is essential for the air interfaces on the mobile radios to function properly, and is significantly impacted by any transition away from traditional TDM backhaul to Ethernet backhaul.

The Backhaul Bottleneck Challenge

The mobile industry is growing at an aggressive pace. There will be 3.6 billion handsets by 2010, growing from 2.5 billion in 2006. The number of backhaul connections will grow even faster to accommodate this to 3.3 million by 2009 from 2.3 million in 2006 (see Figure 2).

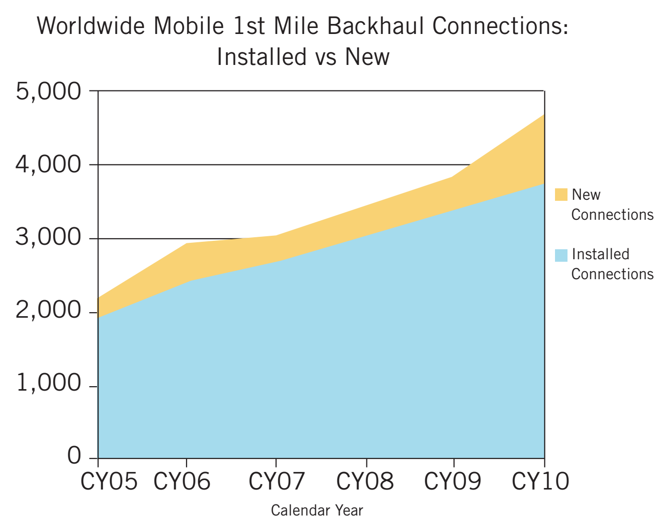

FIG 2 Growth in Base Stations (source: Infonetics Research)

Most towers now have more than one mobile operator's base stations at the same site. The amount of data that each base station will demand to support services to their customers will increase several fold (see Figure 2). Mobile operators now estimate their backhaul transport costs to be a third of their total expenses. As data demand increases, this cost is set to increase dramatically, leading to an untenable business model. The mobile operators need a way to cater to this increased demand in a cost effective and efficient way, and keep their operational expenses in control at the same time. This problem becomes especially acute in the face of slow growth in Average Revenue Per User (ARPU).

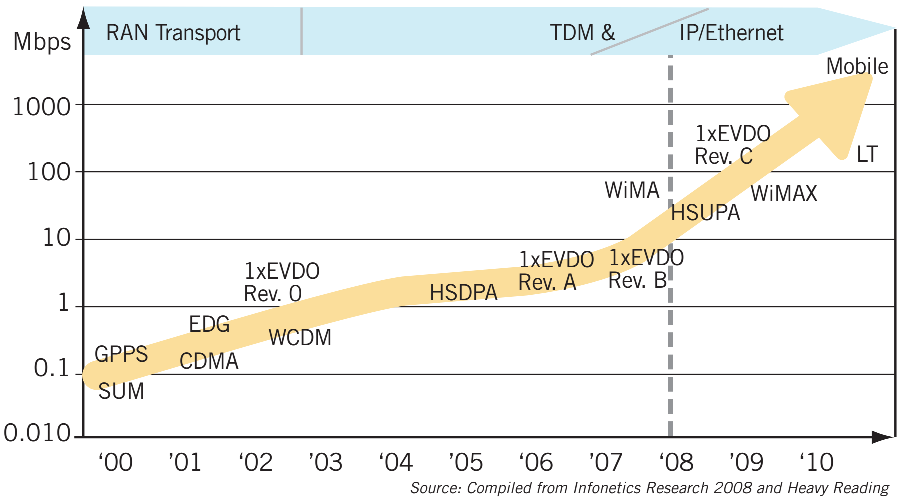

FIG 3 Ramping data demand

All this imply that the mobile operators will need to invest to increase their network coverage, cater to more mobile subscribers, and build infrastructure to support more data intensive services (by supporting more bandwidth demanded per handset), while at the same time find more efficient ways to do this.

It is clear that several trends have converged to drive traffic from the base station to the user handsets:

- More mobile users
- Denser packing of subscribers in the same areas (more subscribers per base stations)
- Subscribers using more broadband services
- Improved capacity at the air interface

These trends indicate that packet based infrastructure is the only way to solve this backhaul problem, which will only get more acute with the transition to bandwidth hungry 4G networks.

The Economic Equation

The key motivator in this and any such transition is cost. The backhaul infrastructure is under pressure to scale economically. Operators do not want to add a T1 or E1 line when there is increased demand for bandwidth. The ARPU is growing slowly, and yet catering to the demand forces the operator to linearly increase their operational expenses (OPEX) in the face of declining revenue per bit. Clearly, a model for backhaul where the cost per bit is steadily decreasing, is called for, and this is only possible through packet (Ethernet) based backhaul.

There is yet another economic factor for GSM and UMTS base stations (and Node Bs). The TDM lines are a reliable source of frequency, since the frequency in the T1 / E1 lines is traceable to a Primary Reference Source. GSM / UMTS base stations are required to maintain 0.05 parts per million to the nominal frequency. In legacy networks, the radios at the base stations were synchronized by deriving a stable frequency from the T1 / E1 backhaul. The transition to IP based backhaul (such as Ethernet based) impacts synchronization delivery to the base station, and a different solution to cater to that need for synchronization (at the base station) is essential.

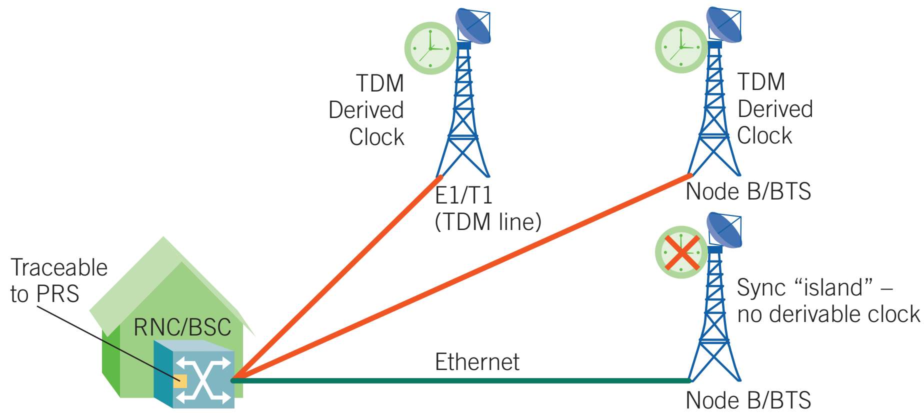

FIG 4 Sync Islands from transition away from TDM backhaul

The challenges are different for transport (backhaul) providers and the mobile operators. In most markets, the backhaul provider and the mobile operator are separate entities.

The backhaul providers sell economical backhaul solutions to the base station sites, where more than one mobile operator's base station may be located. Mobile operators buy these backhaul services, and they may insist on getting synchronization from a specific, traceable source.

For wireless operators, the key considerations are cost (lower OPEX and CAPEX), and a technically viable solution that does not impact their ability to support the handset operations from that base station.

Synchronization Solutions

At present, the two technologies used for synchronization at base stations are GPS based timing (for CDMA and CDMA 2000 base stations) and TDM line based timing (for GSM and UMTS base stations). Newer 4G technologies such as mobile WiMAX (802.16e) and LTE (Long Term Evolution from 3GPP) have stricter phase synchronization requirements that seem to imply that GPS based timing would be the only viable option. Synchronization requirements for different mobile technologies are summarized in Table 1.

Wireless requirement category	Frequency	Phase (System specific time)	Global Time
GSM / UMTS	Carrier frequency shall hold between +/- 5x10-8; for air interface only	Not Applicable	E911 location & services: target to within 20m; accuracy of the time stamping translates directly to position location and likewise its error Other applications & services requiring time of day (sub-second accuracy sufficient)
CDMA / CDMA 2000	Achievement of alignment error sufficient	Time alignment error must be less than 10 µs	
WiMAX	Achievement of alignment error sufficient	Time alignment error must be between 5-15 µs (depends on guard band width)	
LTE	Achievement of alignment error sufficient	Time alignment error less than 3-5 µs ... standards are being finalized	

TABLE 1: Synchronization requirements in different mobile technologies

Both technologies have their disadvantages. GPS, while delivering very precise timing and frequency, is expensive to deploy. TDM lines are being eliminated as a result of market pressures (as discussed in this paper).

The new technologies under consideration include IEEE 1588 based systems in the network, high precision free running atomic clocks (rubidium) at the base stations, Synchronous Ethernet and Adaptive clock recovery from Circuit Emulation.

Each of these technologies has their advantages and disadvantages; these are summarized in Table 1. IEEE 1588 v2 (PTP) has emerged as the technology with the greatest promise to solve this problem. It is also the favored solution by base station vendors, since it enables them to keep their equipment costs low.

An IEEE 1588 solution requires the base station to have IEEE 1588 client. Alternatively, for base stations already operating with T1 / E1 lines a 'translator' function could act as the client and 'translate' to a T1 / E1 timing signal that the base station could use for its timing (see Figure 5).

Technology & use today	Mechanism used	Advantages	Disadvantages	Commentary & market adoption
GPS (used for CDMA and WiMAX BTSs)	GPS provides highly accurate timing. Used	Accurate, precise, proven	Higher costs for installation and maintenance	Not favored as a solution (owing to complexity, OPEX and effort)
TDM Line Timing (used in GSM & UMTS base stations)	Cost effective (free) & proven in GSM and UMTS	Cost effective (free), proven & simple to implement	On its way out with the shift away from TDM backhaul	Carriers moving away from TDM lines owing to other reasons
Adaptive Clock Recovery (Circuit Emulation)	Clock is distributed over the packet n/w as a TDM stream	Simple transition from legacy infrastructure	Proprietary algorithms & requires vendor devices at both ends	Move towards a more standard / open approach
Synchronous Ethernet	Uses physical layer of Ethernet transport	Almost like TDM based timing distribution	Will require infrastructure upgrade right out to the base station	CAPEX to implement high
IEEE 1588 (PTP) v2	Packet based frequency & time distribution	Cost effective, open standard	Network-wide deployment needed with client-server architecture	New technology, but most NEMs favorite as it is cheapest for the BTS
High Precision Atomic Clock (rubidium)	The oscillator at the base station provides a stable frequency from installation and turn-on	Free-run, no dependency; proven technology	Higher initial capital outlay	Now economically viable – different approach

TABLE 2: Comparison of timing technologies for base stations

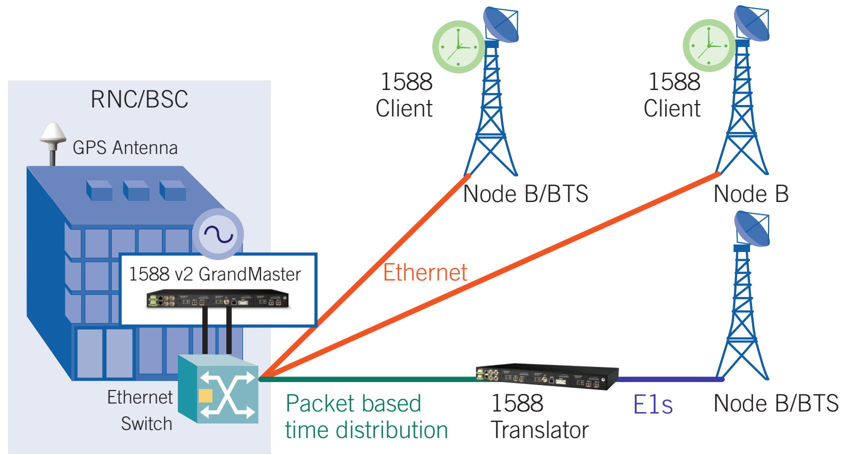

FIG 5 Sync Islands from transition away from TDM backhaul

Summary

Market economics in the mobile wireless segment is driving the mobile operators to look for more efficient and scalable backhaul technologies. It is clear that they will need to transition their existing T1 / E1 based backhaul approach to IP (Ethernet) based backhaul. While today, some operators have already started to deploy hybrid solutions that utilize Ethernet for the data part of their backhaul traffic, leaving TDM lines to backhaul voice traffic, this approach does not allow them to fully realize the potential efficiencies and cost savings of IP based backhaul. A transition to packet based backhaul will cause discontinuities in the ability of the infrastructure to provide synchronization (frequency and time), and this problem needs to be solved. Of the several solutions available, the market is clearly betting on IEEE 1588 v2 to solve this problem and enable them to gain significant efficiencies and scalability

More Background Reading on PTP

Please refer to these other White Papers produced by Symmetricom.

1. *"Deployment of Precision Time Protocol for Synchronization of GSM and UMTS Basestations"*, Symmetricom white paper, May 2008
2. *"Best Practices for IEEE 1588/PTP Network Deployment"*, Symmetricom white paper, May 2008

Symmetricom®

SYMMETRICOM, INC.
2300 Orchard Parkway
San Jose, California
95131-1017
tel: 408.433.0910
fax: 408.428.7896
info@symmetricom.com
www.symmetricom.com