Proposed Cost-effective Model for Migration from a 2G to 3G Mobile Backhaul and Analyzed Solutions for Synchronization

Hamza Kadir, Md. Rejwanur Rashid Mojumdar, Numair Muhammad Fadlullah, Arif Md. Waliullah Bhuiyan, and Mohammad Arif Saber

***Abstract*—The evolution of the cellular networks leaves enterprises to determine how to manage today's mobility solutions as well as future plans. Now for all of the 2G mobile backhauls, the 3G networks are the next step in the quest for speed and increase in bandwidth to provide support for more demanding multimedia applications and other next generation services. A major challenge is in the transmission backhaul of these networks. In this pursuit of migration, there is always a trade-off between merits and costs of several technical options. To address these issues, this Paper explores the possible options of the road to migration of a mobile telephony backhaul network from a traditional second generation circuit switched network, which will meet the ever growing high bandwidth demands of the subscribers, keeping in mind about the optimized benefit to cost efficiency of such a massive transformation. New challenges such as synchronization will also arise in such a migration which will be required to be dealt with in an innovative way. Solutions to such challenges will also be suggested in our proposed model.**

***Index Terms*—NGN backhaul, PBB-TE, MPLS-TP, sync E, IEEE 1588, synchronization in carrier ethernet**

I. Introduction

Annual traffic has grown by 10 or even 100 times in the last decade. At the end of 2008, the number of mobile subscribers topped 3.5 billion and projections show that it will reach 5 billion in just a few years in the world. By 2013, 300 million new fixed broadband users will be added, doubling today's total. In coming years, there will be higher demand for massive amounts of data services, and thus the data capacity will have to grow immensely. This will allow endless services based on IP and higher bandwidth such as "3 Screen" (TV, PC and mobile handset) convergence and always-on networking.

[1] There will be demand for such services which will enable us to control and monitor our home appliances remotely. Regardless of these possibilities, telecom operator companies have a big challenge in their hand in terms of cost and also time. The most cost effective way needs to be chosen for this massive migration to a mobile backhaul of a Next Generation Network from a Second Generation / EDGE phase, especially for companies in the third world countries. The biggest change will occur in the transmission backhaul of the network in order to support and manage the massive traffic demands in a proper way. It is required to have deep insight of the possible technologies and roads to this migration. So in a comparative basis, we will focus on our possible options of the next technology of choice such as PBB-TE and T-MPLS/MPLS-TP. We will see that there is a synchronization challenge which needs to be dealt more delicately than before as we shall move to a packet based solution from a dedicated circuit based technology. On a comparative basis considering merits and demerits, we will choose the best techniques of the above for our proposed model architecture for the converged network which shall meet the requirements.

II. Existing 2G Mobile Backhaul and Its Problem

The widely accepted and implemented methods in the transmission for the 2G networks are PDH and SDH/SONET, which consists of pre-defined dedicated PCM/E1 routes for the Mobile Backhaul. Even though this was sufficient up to the past demands of services like voice calls, short message service and Wireless Application Protocol based services, it is not an efficient method when there is such a huge growth in bandwidth requirements in the NGN networks for data services. We need flexibility to pack more traffic more efficiently into the network, also maintaining the desired quality of service. Packet switching network technologies are well-known of its utilization efficiency by load balancing and openness by reachability. The most widely accepted packet based technique, Ethernet, is a connectionless technology which is good for data traffic. But, Voice Calls and Video services are jitter-intolerant applications, where "five nines" (99.999%) level reliability is a necessity. So our solution needs to have the quality of service of connection-oriented techniques but also needs to have the good features (such as cost-effectiveness, flexibility and expandability) of a packet based network. Therefore, we shall move to a connection oriented Ethernet with improved reliability and simplified management.

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III. The Way Forward – Carrier Grade Ethernet

A number of groups including IEEE, IEETF, ITU and MEF have worked on standardizing CET techniques to finally develop the most acceptable method in terms of profit to cost ratio, feasibility, features and other advantages. A few of such technologies are PBB-TE and T-MPLS/MPLS-TP which are designed to replace a SONET/SDH layer directly by their network functions.

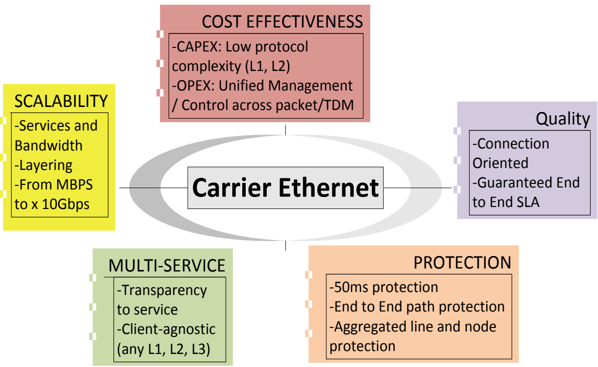

Fig. 1. Features of Carrier Ethernet [2]

Fig 1 shows the salient features of Carrier Ethernet, the major reasons behind our decision to move to a Carrier Ethernet solution to meet our requirements.

A. *Candidates for the NGN Backhaul:*

1) Provider Backbone Bridges (PBB):

This is a set of protocols which creates an architecture which provides packet switched and connection-oriented transmission / interconnection between a customer's routers over a provider's transmission network. The identity of the customer's network is maintained by individually pre-defined VLANs. This can be deployed to allow multiple customers' traffic to pass through a provider's transmission network without losing their individual identities. This technique has gone through multiple standardization stages by IEEE and finally evolved to Provider Backbone Bridges –Traffic Engineering IEEE 802.1 Qay-2009.

2) Multi-Protocol Label Switching:

This is a connection - oriented packet transport technique well-known to the telecom operators for at least a decade. This is a mechanism which provides interconnections between distant nodes creating virtual links using MPLS-Labels. It adds one or more labels (a label stack) to incoming traffic. The switching of these MPLS-labeled packets is done only by a look-up into the labels, instead of looking further into it or into the IP table. This label switching is faster than the routing table in a traditional Ethernet switch. T-MPLS has been derived from MPLS for applying it to the transport networks. It has been developed by adopting some features from SDH and removing some features from MPLS which are irrelevant to the transport networks. It is said to operate in layer 2.5 in the OSI layer. It is also cheaper than layer 3. Later the standardization bodies started working on MPLS-TP which is also targeted for the transport layer but is more interoperable with MPLS.

B. *Performance Comparison between PBB-Te and MPLS/T-MPLS*

For convenience, we want to focus on the comparative performance study of the upcoming technologies and avoid the technical details. Let's refer to the following results taken from an extensive experiment conducted in [3].

1) Delay Profile

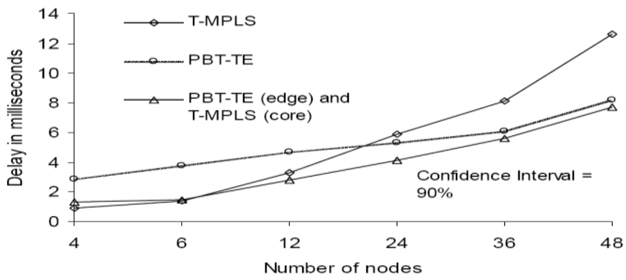

Fig. 2.Delay for T-MPLS and PBB-TE [3]

From Fig 2, we can see that PBB-TE performs better for lower node counts thus lower load. But as the node counts / load increases T-MPLS has out-performs. So T-MPLS is more suited to massive traffic rather than PBB-TE.

2) Scalability

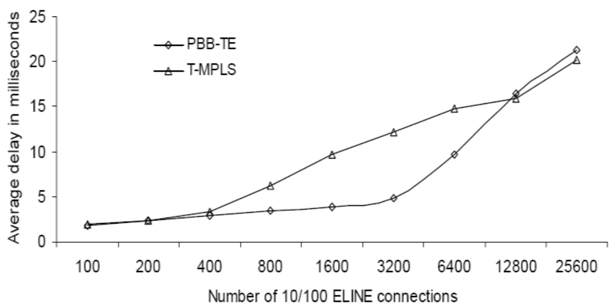

Fig. 3.Scalability for T-MPLS and PBB-TE [3]

From Fig 3, PBB-TE allows better scalability than T-MPLS at low to medium loads. The hierarchical structure of labels (B-tags, C-Tags and S-tags) could be the main reason behind this.

3) Service Provisioning

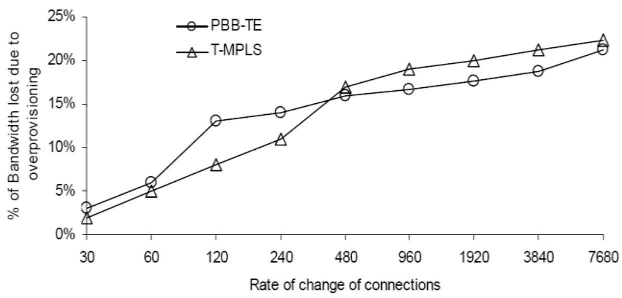

Fig. 4.Service provisionting using T-MPLS and PBB-TE [3]

As seen in Fig 4, increase in provisioned bandwidth for services is somewhat proportional to the rate of change of connections. The difference between the performances of these two techniques is at most 8-10% at before the rate of change reaches the total number of ELINEs in the network. When the rate of change reaches saturation, the performance these two techniques are somewhat similar.

C. *Operational Cost Comparison between PBB-Te and MPLS/T-MPLS*

PBB-TE is expected to be 30-40% cheaper than its competitor technology T-MPLS networks with identical features and capabilities. [4] But MPLS based techniques for transport networks might be more preferred in a telecom network because of MPLS has been familiar in the core networks over a decade. So the T-MPLS should be easier to deploy. On the other hand, Operation and Maintenance (OAM) functionalities such as fault management, performance monitoring, connectivity fault management and link layer discovery are required for both technologies. For deploying OAM in TMPLS, skilled labor is required because T-MPLS and MPLS boxes are not automatically interoperable with each other and requires specific configuration at each box. Although MPLS-TP is being standardized to overcome this interoperability between a transport layer MPLS technique and the core MPLS technique, but the PBB-TE frames can be treated transparently by its switches. So, OAM in PBB-TE is simpler and cheaper.

D. *Comparison Summary*

None of the above technologies are better than the other. They are best suited to particular network environments and situations independently and separately based on their performance and compatibility, thus migration cost. In summary from above analysis, it is clear that T-MPLS is more suited to the core networks with higher traffic and PBB-TE is more scalable towards the other end of the transmission network. Also, for dynamic traffic like the metro / access, PBB-TE out-performs T-MPLS. It is also visible that the difference between the two in terms of performance might be less than significant. MPLS based techniques have also better standardization that PBB based techniques. Again, considering cost, PBB-TE has the upper hand. We shall go for a network architecture where PBB-TE and MPLS based technologies coincide separately in different parts of the transmission network according to their suitability.

IV. Synchronization in Mobile Backhaul

Synchronization in a telecom network is very sensitive because its slight deviation directly affects mobile hand-offs and causes call drops or poor voice quality. In a legacy TDM based network, synchronization clocks are required at both source and destination nodes. But, there is inherit synchronization characteristics as they have synchronization bits in the frame structure itself. In contrast to that, a packet based network does not carry synchronization information. The TDM based networks are of deterministic nature where in a packet based network, the route is selected based on certain situations at hand at that certain moment in the network. Packet based transmissions are also of burst characteristics. They might be dropped and required to be retransmitted. In an NGN network, five nines (99.999%) reliability will also be required by video services (Video Calls, TV, online streaming etc) along with voice services. So as we move to the Carrier Ethernet solution, we shall have to provide a solution for synchronization from a different approach so that it supports the sub-microsecond levels of synchronization in timing and frequency required by the mobile base stations. [5]

A. *Options for Synchronization:*

We will discuss two main options for synchronization.

1) Option 1: Synchronous Ethernet (Synch E):

Traditional Ethernet was intended for transmission of asynchronous data traffic and there was no need to pass the synchronization signal from the source to the destination. As a matter of fact, the old 10-Mbit/s (10Base-T) Ethernet cannot pass the synchronization signal over the physical layer interface because the 10Base-T transmitter stops sending pulses during idle periods—it sends a single pulse every 16 ms to notify its presence to the receiving end. [6]

Synchronous Ethernet provides a mechanism to transfer frequency over the Ethernet physical layer. An external source such as a network clock is used to trace the frequency over this layer. As such, the Ethernet link may be used and considered part of the synchronization network. Synchronous Ethernet must “fit” within the general architecture of an Ethernet network. To make use of its ability to transfer timing, Synchronous Ethernet must also fit within the general architecture of synchronization networks [7].

2) Option 2: IEEE 1588:

IEEE 1588 is standard for a Precision Clock Synchronization Protocol for Networked Measurement and Control systems. The standard defines a Precision Time Protocol (PTP) designed to synchronize real-time clocks in a distributed system.

There are 2 types of clocks in IEEE 1588, masters and slaves. A clock in a terminating device is known as an ordinary clock, a clock in a transmission component like an Ethernet Switch as a boundary clock. A master which is controlled ideally by a radio clock or a GPS receiver synchronizes the respective slaves connected to it. [8] This process involves a message transaction between the master and slave where the precise moments of transmit and receive are measured — preferably at the hardware level. Messages containing current time information are adjusted to account for their path delay, therefore providing a more accurate representation of the time information conveyed. [9]

B. *Comparison between Synchronization Options*

Synchronization network performance may vary with varying traffic or network impairments (i.e. packet delay variation), if IEEE 1588v2 is deployed because this technology is network load dependant; whereas G.8261-Synchronous Ethernet gains the advantage, being network load independent. However, IEEE 1588v2 is able to deliver both ToD and Time synchronization, where Synchronous Ethernet is able to deliver only time synchronization. It should be noted that for GSM network, only frequency synchronization is required. IEEE 1588v2 works on Layer 2 and not hop dependant (Edge to Edge) whereas Synchronous Ethernet works on the physical layer (Layer 1) is hop dependant.

V. Synchronization Solution for Different Network Scenario

TDM to IP migration is not a precipitous process and there would be an intermediate period when IP and TDM would co-exist. Considering this issue, two scenarios could arise; segmented IP network with SDH backhaul and end to end IP network.

A. IP at Access with SDH Backhaul

In case of a mixed network consisting both IP and SDH equipments, Synchronous Ethernet will not be an efficient solution. The problem with Synchronous Ethernet is that it requires all the network nodes to be Sync E capable. Each node in Sync Ethernet network should recover and distribute the clock from reference PRC, which would not be possible for the SDH equipments. To overcome this challenge IEEE 1588v2 needs to be used. To implement IEEE 1588v2, slave clocks will need to be installed at the Node B/RNC sites if the function is not built within the Node B/RNC equipment.

B. E2E IP Network

In case of E2E IP network, it would be possible to implement Synchronous Ethernet. Multivendor environment would be a consideration factor here because all the equipments would need to be Sync E enabled. The better approach would be to implement IEEE 1588v2. The IEEE 1588v2 offers the capability to deliver phase and frequency and it works for most of network traffic profile, disturbances and disruption. The short coming of IEEE 1588v2, that is the dependency on traffic load can be solved by careful synchronization network planning.

C. Summary of Synchronization:

Mobile base-stations need a highly accurate timing signal that has to be shared across the entire network in order to ensure a continuous high quality of service. Based on the discussion above, we propose IEEE1588v2 in our model of a future converged network.

VI. Proposed Cost-Effective Model Architecture

Based on the above discussions, we propose a model probable architecture of a converged network, which consists of a Multi Vendor / Multi Technology environment. Any approach of this migration must also bridge the gap between existing legacy TDM phase and the NGN phase in terms of as much as possible compatibility (specified in details by the standardization bodies) and cost-effectiveness. Each transport technique can fit certain scenario respectively, and they could be used in different network layers (access / aggregation / core) as shown in Fig 5. [10]

We followed the following grounds in our proposed model:

a. T-MPLS – Telecom networks have been familiar with MPLS in the core networks for almost a decade now. So T-MPLS is our most preferred technique to be applied to as many parts of our transport network as possible keeping in mind the cost factor. As T-MPLS has been derived from MPLS by excluding irrelevant features to be better suited to the transport networks, it will be applied to the Access and Metro networks in our proposed model. This will be applied to those parts of Access and Metro where there is heavier traffic congestion than average.

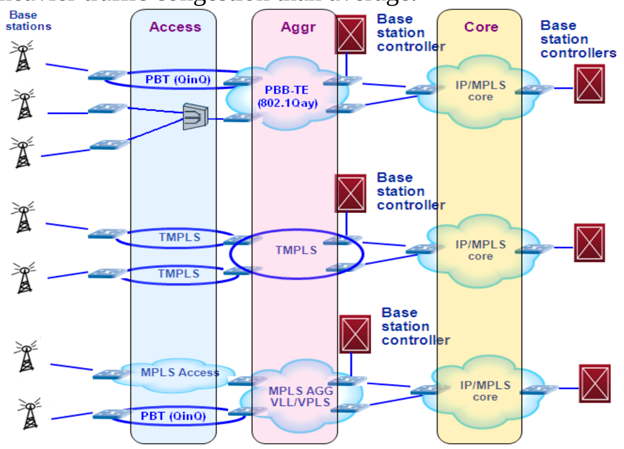

Fig. 5. Model mobile backhaul architecture.

b. PBB-TE: This technique performs better than MPLS in the Access and the Aggregation layer, and is quite cheaper than layer 3 or even MPLS as mentioned earlier. But it is an Ethernet based technique which is comparatively new for a telecom network. Version of PBB with Q-in-Q is preferred for access networks where there is high number of independent services to be identified separately by VLAN tag in VLAD tag technique. PBB-TE may be deployed in the aggregation layer.

c. IP/MPLS – MPLS has been in the core networks in most telecom networks for quite a while already. It has been designed to be compatible to Packet over SONET/SDH, and as it is best suited to heavy traffic. So in our model, it will be implemented in the core networks.

To be noted, both Provider Backbone Bridges related standards and T-MPLS may reside in the Access and Metro / Aggregation networks in an NGN telecom backhaul depending on certain requirements and conditions.

A typical 2G Network may also require as mandatory the following features in its transmission in order to migrate to a 3G Network,

- VLAN tagging (IEEE 802.1q)
- Multiple Spanning Tree Protocol (IEEE 802.1s)
- Rapid Spanning Tree Protocol (IEEE 802.1w)
- Provider Bridging, QinQ (IEEE 802.1ad)
- Link Aggregation (IEEE 802.3ad)
- Ethernet ONM (IEEE 802.3ah and IEEE 802.1ag)
- For synchronization: IEEE 1588v2 client
- Ethernet Ring Protection (ITU-T G.8032)
- Adaptive Modulation

VII. Conclusion

It is evident in recent years how growths of smart phones and dongle users have driven the telecom networks in terms of data services. New core networks and mobile base station techniques along with new radio coverage techniques have been developed to meet these demands. But if there is not enough high capacity pipes with appropriate inherit intelligence; the new users of these services will only end up being disappointed, affecting business of the telecom operators greatly. The migration of a total circuit switched TDM network to the next generation network in terms of mobile backhaul is a gradual process rather than a sudden one. Our proposed model for a converged network consists of MPLS and PBB based technologies placed in appropriate sections of the mobile backhaul depending on its suitability, and we suggest IEEE 15588v2 as the solution to its synchronization demand. Consistent and reliable synchronization will be a demand for quality assurance, network performance, and seamless interoperability across the network and service infrastructure and customer premise equipments. With time, it has been noticed that cost increase and revenue growth decoupled and desisted from being proportional as we moved to a data driven market. So our solutions must be cost-effective in every step we take. They must be scalable and flexible as customer demands will be very dynamic and clever deployment will be required in certain environments.

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