DEPLOYING IEEE 1588v2 SYNCHRONIZATION OVER PACKET MICROWAVE NETWORKS

OVERVIEW

Microwave mobile backhaul networks are rapidly evolving to packet networking driven by the evolution to LTE/4G, to support higher rates for mobile data and video applications on an increasing number of smartphones and other mobile multimedia devices. This evolution to packet is also having an impact on how network time distribution, or synchronization, is being implemented as the backhaul network transitions from a synchronized TDM network to an asynchronous Ethernet one.

Precision Time Protocol (PTP), standardized as IEEE 1588v2, is the leading approach for timing delivery over packet networks today and is an ideal match for packet microwave backhaul networks. 1588v2 has become the de-facto standard for packet based timing in the last few years - having been deployed by over 50 major wireless service providers globally. Microwave is the most widely deployed backhaul technology today with greater than 55% of all installed mobile backhaul connections being microwave based[1]. Microwave will continue to dominate the backhaul landscape moving forward as hybrid and packet based microwave continues to displace TDM microwave for the majority of new installs.

There are, however, some unique considerations for deploying 1588v2 over microwave. For example, microwave spans multiple linear and ring based hops in the backhaul and provides much longer distances than the typical 'last mile' connection. Microwave also introduces a variable radio transport path that may impact the available bandwidth under certain weather conditions. These considerations are explored in the paper to provide insight and guidelines on how 1588v2 can be successfully deployed over a microwave backhaul.

MOBILE BACKHAUL EVOLUTION AND THE NEED FOR PACKET TIMING

Mobile base stations, whether CDMA, GSM, W-CDMA, WiMAX or LTE, all rely on some means of being synchronized to a Primary Reference Source (PRS) to maintain and deliver quality service. Without accurate timing in the mobile networks, service quality can be dramatically impaired - resulting in dropped calls, an inability to hand off calls while users are travelling between cell sites, or generally degraded voice quality.

There are three forms of synchronization that may be required in mobile networks: frequency synchronization (or "syntonization"), time synchronization, and phase synchronization. While frequency synchronization is the most common in mobile backhaul today, time and/or phase synchronization will be increasingly required for time/phase critical deployments types e.g. LTE TDD, LTE MBMS and LTE MIMO.

[1] "Mobile Backhaul Equipment and Services Report." Infonetics Research. September 2010.

While timing has traditionally been delivered over TDM very predictably and reliably for years, the migration to packet networks has created a disruption in this reliance, as packet networks are inherently asynchronous. The migration from TDM to Ethernet backhaul "breaks" the timing chain because unlike TDM, packet networks have no inherent mechanism for providing highly accurate synchronization.

There are several approaches to addressing this challenge; the most notable are the use of IEEE 1588v2, Synchronous Ethernet, and GPS. It should also be noted that while TDM and Synchronous Ethernet provide only frequency synchronization (syntonization), 1588v2 and GPS provides frequency and phase/time synchronization.

IEEE 1588v2 OVERVIEW

IEEE Precision Time Protocol (PTP), standardized as IEEE 1588-2008, or more commonly referred to as 1588v2, provides a mechanism for restoring synchronization over Ethernet backhaul networks. It uses time stamped Ethernet packets to synchronize remote network elements such as wireless base stations with a Grandmaster PRS located at the BSC/RNC as illustrated in Figure 1, below.

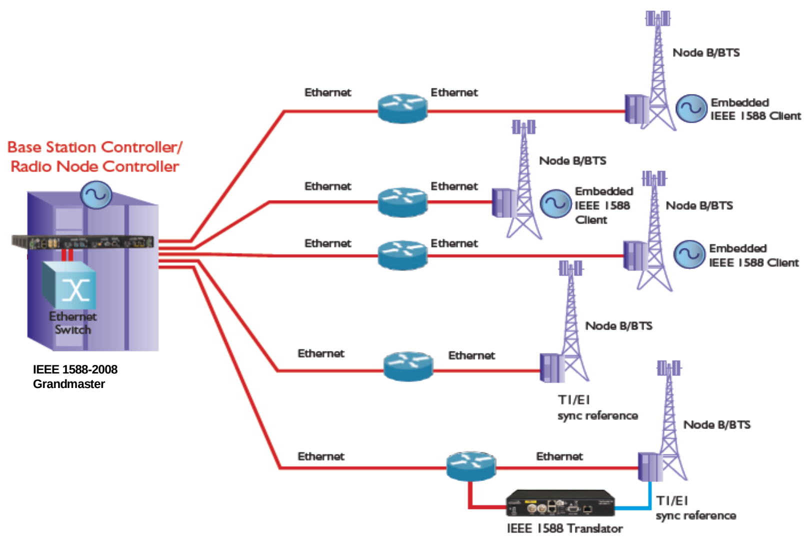

Fig. 1: IEEE-1588v2 Mobile Backhaul Implementation Example

PTP employs a client/server architecture to ensure precise synchronization between PTP Grand Master and the PTP slaves collocated with or embedded in various devices (cell sites) distributed throughout the network.

Slaves remain synchronized with their masters by continuously exchanging time stamped packets with them, thereby compensating for the latency and resulting packet delay variation (PDV) incurred within the packet-based network. A high level of accuracy is ensured by utilizing PHY-based hardware time stamping of each packet. An illustration of the message exchange that takes place between a1588v2 grandmaster/ server and its respective slaves is shown in Figure 2.

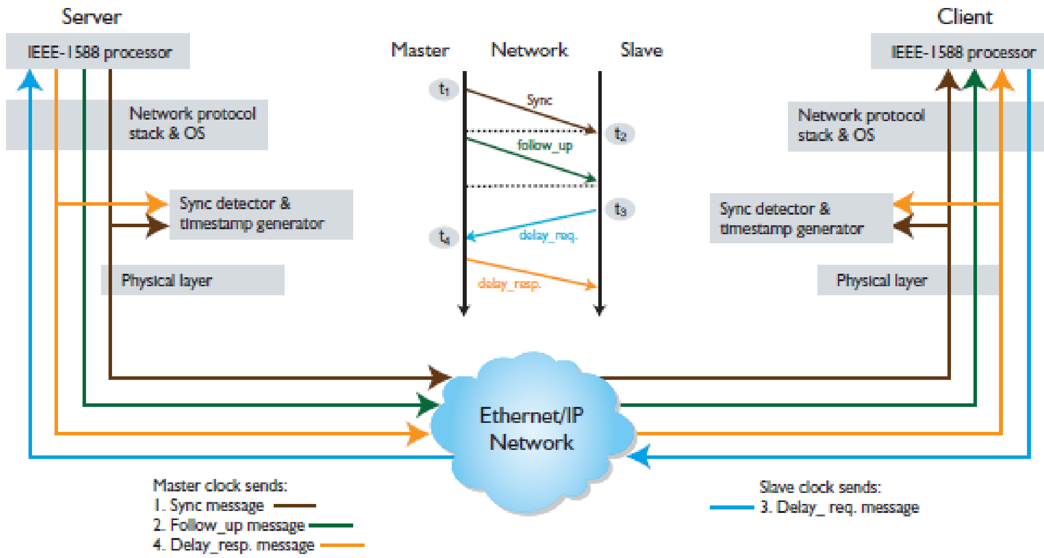

Fig. 2: IEEE-1588v2 Client-Server Messaging

Operators can overlay 1588v2 timing over a hybrid combination of microwave, copper and packet optical backhaul networks - essentially "bookending" the 1588v2 at packet entry and exit points. In this approach, networks deploy a small number of 1588v2 master clocks in their core or aggregation hubs. These then communicate to slave clocks either at the cell site, or embedded in the base station itself; optional boundary or transparent clocks may also be used to extend the range of the 1588v2 network when needed. In this 'unaware' state, networks do not have to rely on underlying physical network to support highly accurate clocking at all node points, but do have to ensure their transport quality meets the requirements for supporting PTP timing.

History of IEEE 1588 Enhancements

IEEE1588v1 was originally ratified in 2002. Version 1 was intended to provide precise synchronozation for data-only LANs, for applications such as industrial factory automation.

IEEE 1588v2, which was ratified in 2008, significantly broadened the scope of the protocol to include WAN applications such as synchronization of telecommunications networks carrying data, voice and video traffic. IEEE 1588v2 added the following feature enhancements:

- New message types and formats
- More message rate choices
- Unicast Communication
- Fault Tolerance
- Alternative timescales
- Transparent clocks
- On the fly timestamps
- Additional Profiles
- Security Features

PACKET MICROWAVE AND UNIQUE NETWORKING CONSIDERATIONS

Advanced packet microwave systems provide the ability to support multiple modes of operation over an unlicensed or licensed radio frequency (RF) for transporting various traffic types, providing programmable mechanisms to carry a mix of TDM, TDM + Ethernet or all Ethernet backhaul. Microwave easily delivers up to 400Mbps transport in a single RF channel and can also support multi-Gbps transport with advanced techniques including link aggregation, cross-polarization, and various compression techniques.

Microwave backhaul is usually deployed in multiple hops from the aggregation point to a cell site, up to ten hops or more in some cases. Also, microwave topologies may consist of a mix of linear, ring and hub and spoke deployments. Unfortunately, the more hops added introduces more packet transmission delay and delay variation over the Ethernet microwave backhaul, the amount of which is proportional to the number of hops. Proper design and engineering is required to ensure these requirements can be met.

Adaptive coding and modulation (ACM) is a unique attribute of microwave transport that allows the effective throughput of the microwave link to be changed to accommodate radio path fading typically due to weather changes. If bandwidth is reduced as a result of AM, it is critical that advanced traffic and QoS mgmt. techniques be applied to ensure that 1588v2 traffic (timestamps) are prioritized and not impacted by AM changes.

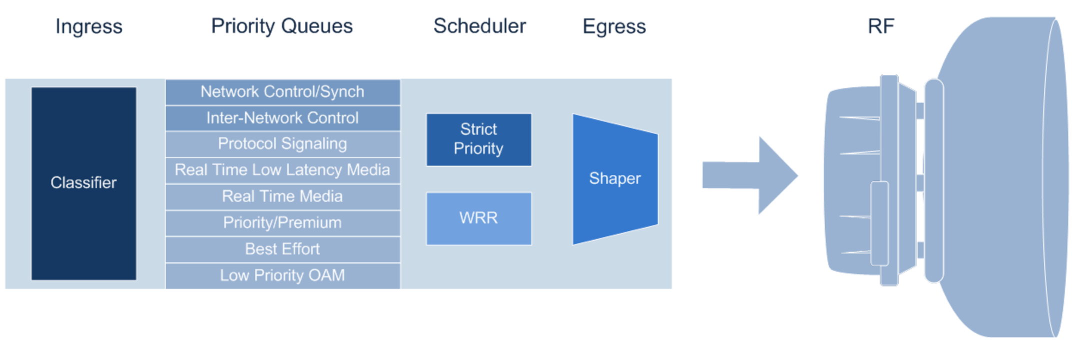

Fig. 3: Example of Microwave Traffic/QoS Management

Adaptive Coding and Modulation (ACM)

Advanced microwave networks are now available with adaptive coding and modulation ACM) mechanisms that can apply different modulations, e.g. QPSK, 64-QAM, 256-QAM etc., to deliver the highest available capacity across a radio path based on network conditions at a particular point in time.

TYPICAL 1588v2 OVER MICROWAVE DEPLOYMENT SCENARIOS

MULTI-HOP LINEAR BACKHAUL NETWORK

Multi-hop linear backhaul is the most common microwave backhaul topology deployed today. It consists of a chain of microwave nodes connected back to back between the last cell site, containing the 1588v2 slave clock, and the aggregation site, hosting the grandmaster/boundary clock. For simplicity reasons, what is not shown in the diagram is that each intermediary node could also support additional cell sites with their own slave clocks, but the same principles would apply to these sites.

Some of the key deployment considerations for these types of configurations are:

- Maintain an end to end delay between 100-500uS per link
- Use the highest modulation and highest channel bandwidth available on the microwave radios - ensure this is maintained even under various ACM states. ACM in conjunction with QoS can be applied, but ensure that synchronization traffic receives the highest priority in any ACM state
- Ensure consistent traffic management (QoS policy, scheduling, shaping etc.) handling across the entire radio network and within each microwave node
- Boundary clocks might be required if target end to end delay is excessive for services demanding sub-microsecond phase requirements.

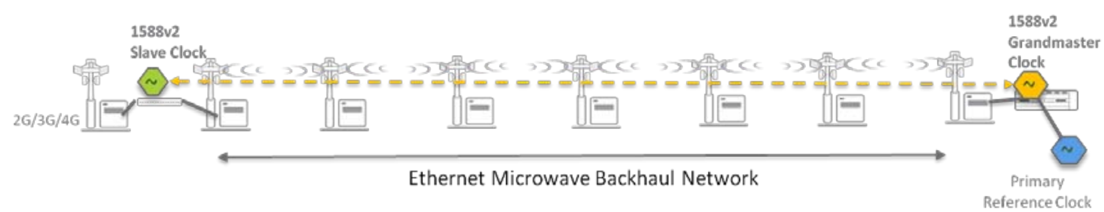

Fig. 4: Multi-Hop Linear Network Showing "bookend" Timing

RING-BASED BACKHAUL NETWORK

Deployments of ring based microwave backhaul are growing in number due to the additional protection benefits provided by resilient ring architectures. Advanced microwave ring systems can be designed to support fiber like 50ms protection for high availability networking.

In the ring topology shown below, cell sites are located at each ring node and contain their own 1588v2 slave clock, while the aggregation site hosts the grandmaster/ boundary clock.

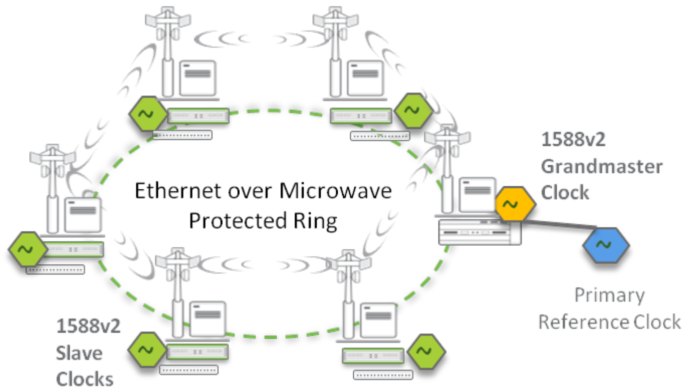

Fig. 5: Ring-based Backhaul Network with Grandmaster and Slave Clocking

In addition to the linear considerations previously given, there are a few other ones that come into play when deploying 1588v2 over microwave rings:

- Implement a carrier class ring protection switching mechanism e.g. <50ms protection switching. Protection mechanisms with long convergence times e.g. RSTP, are not recommended since the long length of time to converge may terminate the 1588v2 session
- Carefully engineer for the maximum ring path delay for the worst case re-route scenario i.e. the delay will vary depending on where on the ring the break occurs and how many hops the protection re-route takes around the protected path

SUMMARY OF TECHNICAL RECOMMENDATIONS FOR DEPLOYING 1588v2 OVER A MICROWAVE SYSTEM

In addition to the network considerations above, a few specific technical recommendations should be considered when implementing a microwave system to support 1588v2 backhaul:

- Implement a nodal microwave system that can provide a common switch supporting multiple radio paths simultaneously
- When implementing QoS to prioritize 1588v2 traffic over Ethernet, 802.1p support is recommended on systems that provides multiple-queues (4 minimum, but 8 preferred)
- Recommended to segregate 1588v2 into a distinct VLAN using 802.1q VLAN tagging, or 802.1ad (QinQ)
- Recommend implementing a traffic management scheduler that supports Strict and weighted round robin (WRR) queuing, or a hybrid combination of the two is preferred, ensuring that 1588v2 traffic is assigned a Strict priority

Some other recommended 'rules of thumb' for designing the optimal IEEE 1588v2 over microwave solution are summarized in the table below:

Network Link Speed	Maximum Network Traffic Loading	Maximum Intermittent Congestion	Recommended QoS Priority Setting for 1588v2 Packets	Recommended Hop Count between Grandmaster and Slaves*
Gigabit Ethernet	80% Average	100% load for less than 100s	Highest Priority available	Frequency Only (10 Hops); Time/Phase (5 Hops)

*Recommended hop counts may be exceeded by deploying transparent or boundary clocks between the 1588 Grandmaster and slaves

In summary, properly designed and engineered microwave backhaul networks with linear, ring or other topologies can be effectively deployed to support 1588v2 transport, and can be effective even at very high utilization levels.

SUMMARY

Microwave backhaul and IEEE 1588v2 are a combination of technologies that work well together. Both are field-proven solutions – microwave in over 55% or all backhaul deployments and 1588v2 deployed in well over 50 live networks around the globe today. As mobile backhaul networks evolve towards all-IP and Ethernet becomes the dominant transport media, 1588v2 over microwave will continue to grow as a viable option for mobile backhaul synchronization.

However, each network has its own specific design requirements which must be thoroughly tested and properly engineered to ensure optimal performance over maximum traffic loading and all corner case conditions.

Aviat and Symmetricom have joined forces to test and validate that both 1588v2 and packet microwave technologies can work harmoniously and can meet your synchronization requirements today and well in to the future.

REFERENCES

IEEE 1588-2008 - IEEE Standards for a Precision Clock Synchronization Protocol for Network Measurement and Control Systems. 2008.