How to ensure your Blackburst survives the Introduction of PTP

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Background

Introduction

We have all grown up with Blackburst reference in our facilities and the only change we might have had to manage is the introduction of tri-level sync when facilities started migrating to HD.

The expansion of Blackburst tri-level sync reference systems was relatively simple. Either daisy chain the new device with the loop-through genlock output from an existing device or use a distribution amplifier to split the Blackburst /tri-level sync reference signal. What could be simpler?

Broadcasters are now faced with a new reference: Precision Time Protocol or PTP as we call it. Fortunately, this reference is already being used in other industries like finance, power utilities, telecommunications, and has standards associated with it.

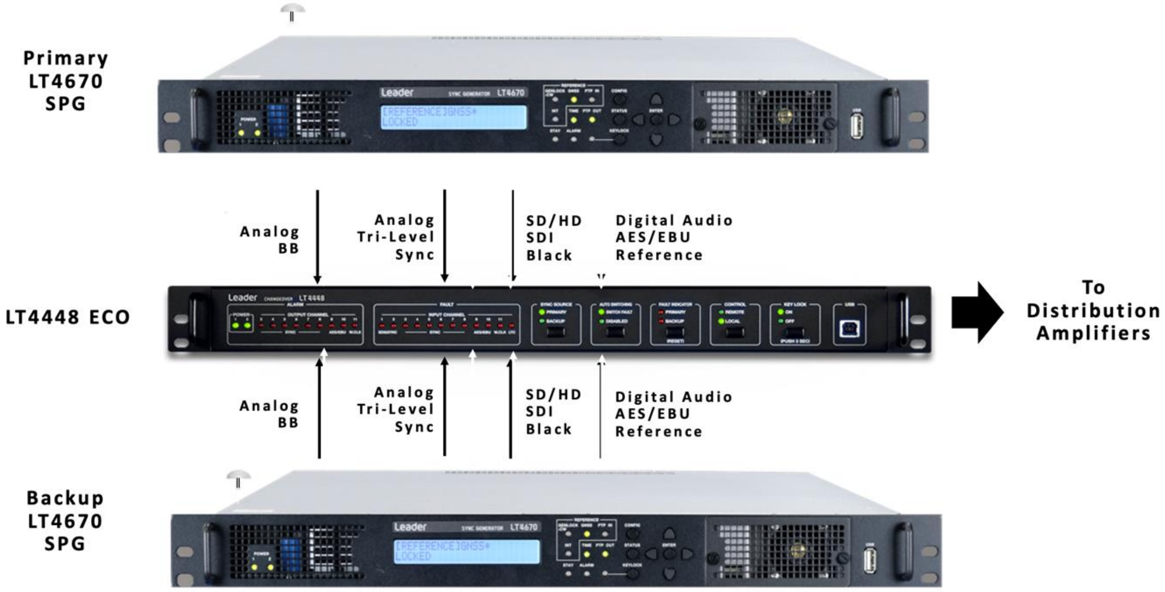
Every industry sector claims to be unique, and the broadcast business is no exception. However, for PTP the broadcast industry is very much unique. The standards authorities have created a broadcast specific profile for PTP and understanding how that profile is applied to the broadcast industry will ensure that your existing SDI infrastructure can integrate with your new video over IP infrastructure without QoS issues being introduced.

In this paper we will discuss the new challenges broadcasters are facing and highlight some of the pitfall that can easily be avoided.

1. Blackburst / Tri-Level Sync

Introduction

Everybody should be more than familiar with a conventional system where we've got a primary sync-pulse generator (SPG), a backup SPG like the Leader LT 4670s's here that feed an Emergency Changeover Unit (ECO) and we take the analog Blackburst, or tri-level sync or HDSDI, and all of that goes out to a set of typically distribution amplifiers that will distribute the house bars, the house reference to the rest of the network.



Dual master reference SPGs are used with an emergency changeover unit (ECO) as shown. The ECO can detect a loss of sync signal at its master input and automatically switch to the back-up input.

Maintaining the sync signal at the output of the ECO prevents a loss of a critical sync signal from affecting timing within the plant.

Synchronization throughout a facility is a critical operation for guaranteed system performance, which is why designing a facility with redundant synchronization provides a complete fault-tolerant, flexible, and robust system.

In many broadcast and post-production facilities, Emergency Changeover units such as Leader's LT4448 are used to automatically switch from one sync source to another upon fault detection in any active source without loss of service within a facility.

The LT4670 can be used in combination with another LT4670 unit to provide a back-up in case of failure of one of the components within the timing system. The LT4448 has eleven user-configurable channels and can be configured to support analogue Blackburst (PAL or NTSC), HD tri-level sync, AES/EBU digital audio, SD-SDI and HD-SDI.

After completing the timing set-up of the whole facility, it is important to save the settings of the Master and Slave SPG.

The LT4670 allows the devices configuration to be saved to a USB memory device. This feature is useful when you want to duplicate LT4670 settings on multiple LT4610/11 devices.

To alleviate further concerns for loss of house timing reference signals, an uninterruptible power supply (UPS) should be incorporated into the system. This prevents power surges or brief loss of power from interrupting the output configurations of the SPG and interfering with the timing settings for the system.

This configuration of a UPS, LT4448 ECO and SPGs ensure peace of mind and could prevent problems if a power failure occurs.

2. Precision Time Protocol (PTP)

Introduction

Precision Time Protocol (PTP) essentially is the Blackburst or tri-level for uncompressed IP video networks. It's an IP protocol that is used to synchronize the clocks throughout an IP network and as we mentioned earlier, it is based on an established standard IEEE1588 that points to a point in time where, if you will, the big bang happened for PTP, which we call the epoch, and the epoch just happens to be 1970-01-01 Time 00:00:00 International Atomic Time (TAI).

So, its time starts there and then we count out in nanoseconds from that point forward, so it's a very, very precise time and we are going to use that instead of a pulse that we use in Blackburst or tri-level. We're going to use time and we're going to put timestamps on packets so that packets happen with that precision clock at points in time.

Now, SMPTE has added some parameters to the IEEE 1588, which is the international standard for PTP because there was nothing in the IEEE 1588 standard that referenced video.

- Provides alignment points for:
  - Analog Standard Definition Television
  - SMPTE ST 318 Ten-Field Sequence Identification
  - Analog High Definition Television
  - Digital High Definition Television
  - Ultra High Definition Television (UHDTV)
  - AES3 Digital Audio
  - SMPTE ST 12-1 Timecode Generation
  - SMPTE ST 309 Date

IEEE 1588 PTP does not have the SMPTE fields
Not all PTP is the same

So, one of the things that we need to do as a video industry is make sure that our devices that we use are aware of the ST 2059 standard that SMPTE used so we don't lose that part of the standard because right now you might not be using it, but there may be some devices that you add to your network that will want that piece.

Then there is the way that we use PTP to deal with a primary clock, which we call the grand master, and a leader clock, which is a standby, like our primary and our backup SPG's that we use going into an ECO, but this is done completely differently.

So, the things that SMPTE added or some things that PTP would have no idea of, parameters for analogue high definition, digital high definition, parameters about AES audio and time code generation and the SMPTE 309 date. So, none of that would be in the standard IEEE 1588 that we dealt with. So those are the pieces that could get lost if you don't have a PTP aware network that knows about the ST 2059 standard.

SMPTE ST2059-2 added some other parameters and did some refinements on other pieces so that we could take things that were in IEEE 1588 and say, "This is how these will be used within the video network."

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SMPTE ST 2059-2

- PTP Profile
- Profile Identification
- Best Master Clock Algorithm (BMCA)
- Management Mechanism
- Path Delay Measurement Mechanism
- PTP Attribute Values
- Follower Clocks
- Clock Physical Requirements
- Node Types Required, Permitted, or Prohibited
- Transport Mechanisms Permitted
- Communication Model
- PTP Option
- Alternate Leader
- Organization Extension TLV Synchronization Metadata Setting Dynamic SM TLV Values

3. What's the difference between NTP and PTP?

One of the unique things about Network Time Protocol (NTP) is NTP is driven by software and anything that's driven by software could be interrupted when you have a service that is requesting something, and you must pause that part of the application to go do another process.

The other thing is NTP only provides millisecond accuracy. PTP provides sub-microsecond accuracy to the end device, so that we have pixel accuracy. And it's set up so that we directly drive it off GPS versus locking onto a NTP server that may be locked onto another server, which eventually hits some form of grand clock source. The grand master within a PTP network pushes time to the receiver or the followers, the receive clocks. With NTP you have to go request that and it's a hold request and it doesn't happen that often. So, it just doesn't have the accuracy or the stability that we need.

Leader

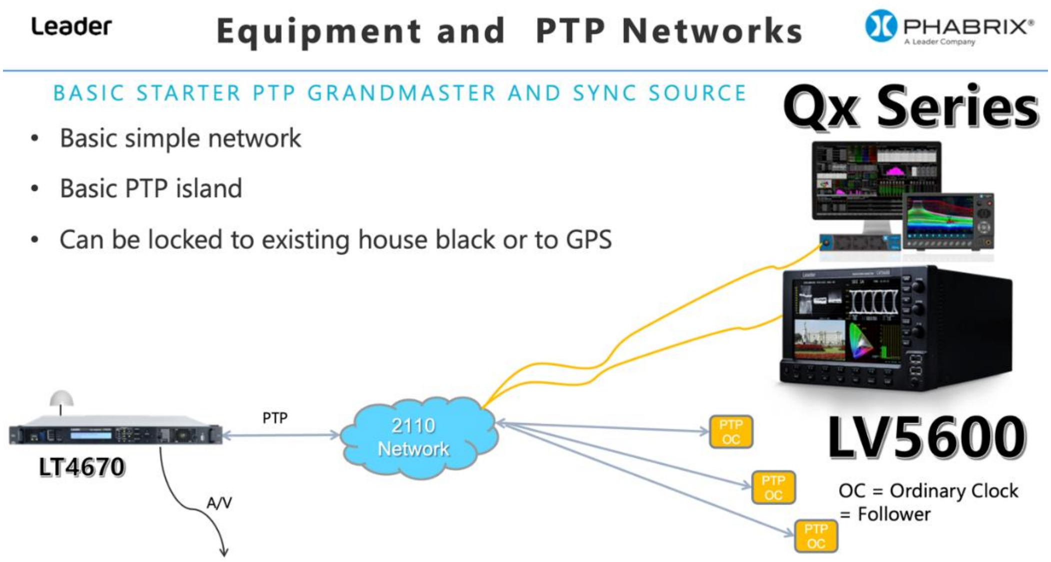
NTP Verses PTP

NTP does not have the accuracy or stability needed for Video networks

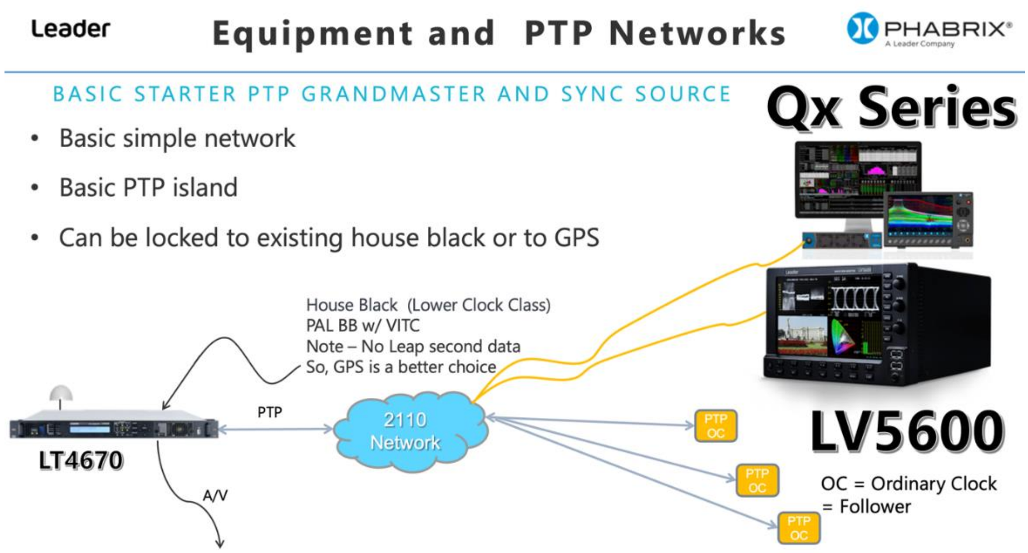
NTP	PTP
NTP provides millisecond accuracy.	PTP provides sub-microsecond accuracy.
Connects over a public WAN to a server that may be connected to another server then to GPS	Connects to a privet network to a PTP server that is normally directly GNSS locked, like GPS
Driven by software Apps	Driven by hardware.
The NTP client can poll over various NTP servers.	The PTP Grandmaster "pushes" time to one or more followers (Receiver Clocks)

4. Implementing PTP to an existing SDI based facility

Most people start off with an isolated network, if you will, because one of the best things you can do is set up a little island, a 'greenfield' where you can set up and learn exactly how everything works.



If you are adding this to an existing network, you can lock your PTP generator to your existing house BLACK. Now, it's a good way to learn how things are going, but it's not the best choice for the long term. For long term, because the clock references off of house BLACK is not nearly as accurate as your house reference if you were to come in off GPS.



So, GPS is going to give you the best clock and then your PTP sync generator here, like the LT4670, now can be your source for your Blackburst, tri-level, your test signals, and now your PTP and your Blackburst are all coming off the same clock in your entire network, be it SDI or IP are completely locked to one another.

6. PTP Terms and Definitions

Before we get into how it works too much, let's cover a couple basic terms.

PTP, since it is a clock, there is a hierarchy to these clocks. The clock that your entire is referenced off of is called the **Grandmaster**. It is the ultimate clock source for everything else within your IP domain.

A **Leader** clock is a clock that is either synchronized to the grand master, or is synchronized to GPS, but is not online. It's not the Grandmaster at this point in time, but it's waiting until the Grandmaster falters, it will take over.

A receiver, they're calling the receiver a **Follower** clock. Now these names, you may have heard some other names for all of these, they've gone through and changed the names of what we're calling the clocks now. An ordinary clock or follower is your receiver, and it's following what the Grandmaster is putting out as far as time.

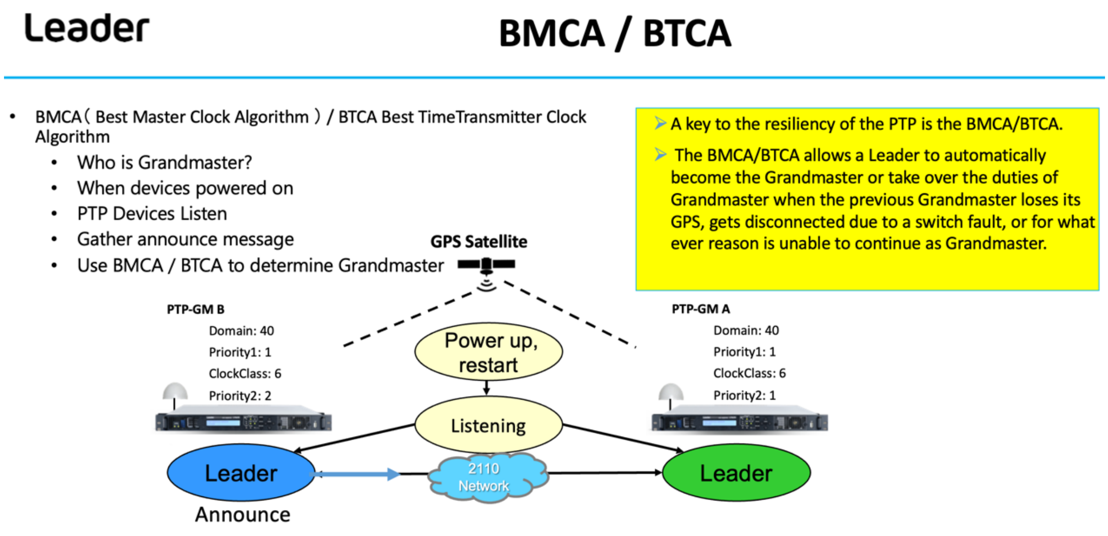
There's also a PTP domain, that is a logical grouping. It is just a grouping of PTP devices. If you happen to have a video PTP source, you can put it in on a specific domain, if you have a AES67 PTP source, you can put it on its own domain. Dante uses PTP. It's going to be on its own domain.

Domains can all be on the same network, but different domain numbers so that they separate each other.

7. Best Master Clock Algorithm (BMCA) / Best TimeTransmitter Clock Algorithm (BTCA)

Unlike the traditional SDI references, that require an Emergency Changeover (ECO) unit, there is no ECO per-say in a PTP network.

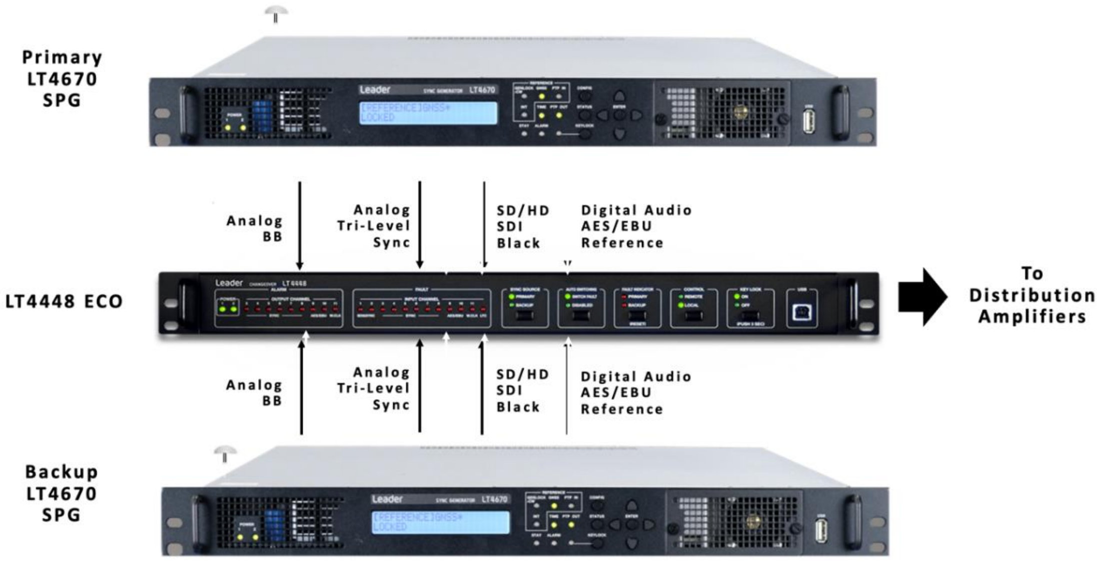
The Grandmaster and the Leader that is set up to be the next in line, communicate with each other through the network and they are sending messages in both directions from the Grandmaster to the follower clocks and the clocks that would be your backup are listening to those messages. There is voting that takes place that sets up who is going to be the Grandmaster and then when something happens, the other PTP generator will take its place. This process is known as the Best Master Clock Algorithm (BMCA) / Best TimeTransmitter Clock Algorithm (BTCA).



The other thing that is unique about PTP is it has a method within it to compensate for the delays in the network, so that the time will be exactly what the time is at the Grandmaster.

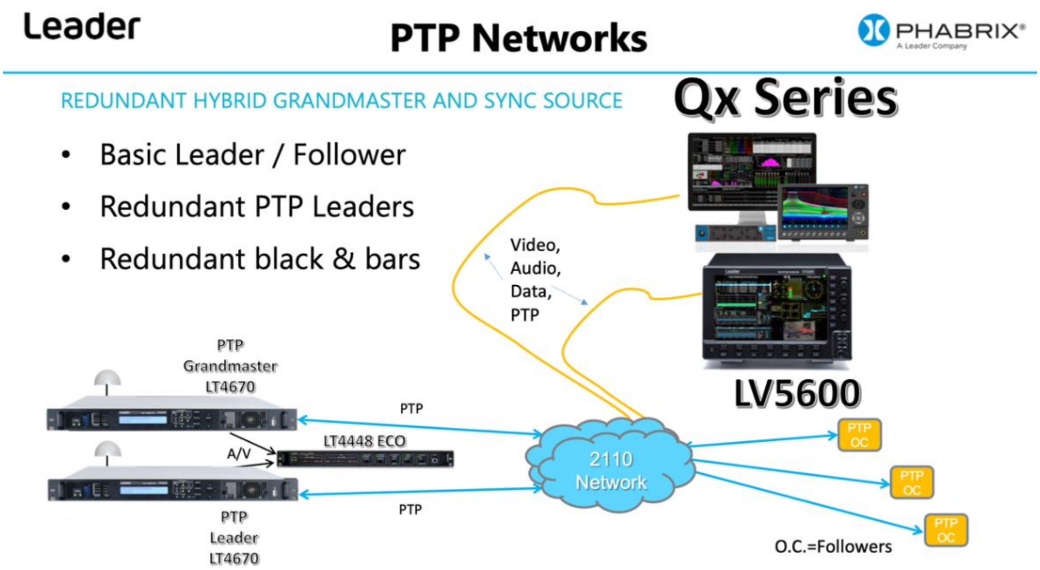
It measures the network delay and subtracts the network delay in the follower so that the follower's time is as close as we can get it to exactly what the Grandmaster's time, and that way we have accurately aligned time.

In a traditional SDI based infrastructure the Primary and Backup SPG are connected to an Emergency Changeover unit.



Then the voting or the decision of who's online is controlled by that ECO, with both units always putting out their signals to the ECO. Then the ECO is normally outputting the primary SPG's signals to the distribution amps, if it falters the ECO switches over to the backup SPG.

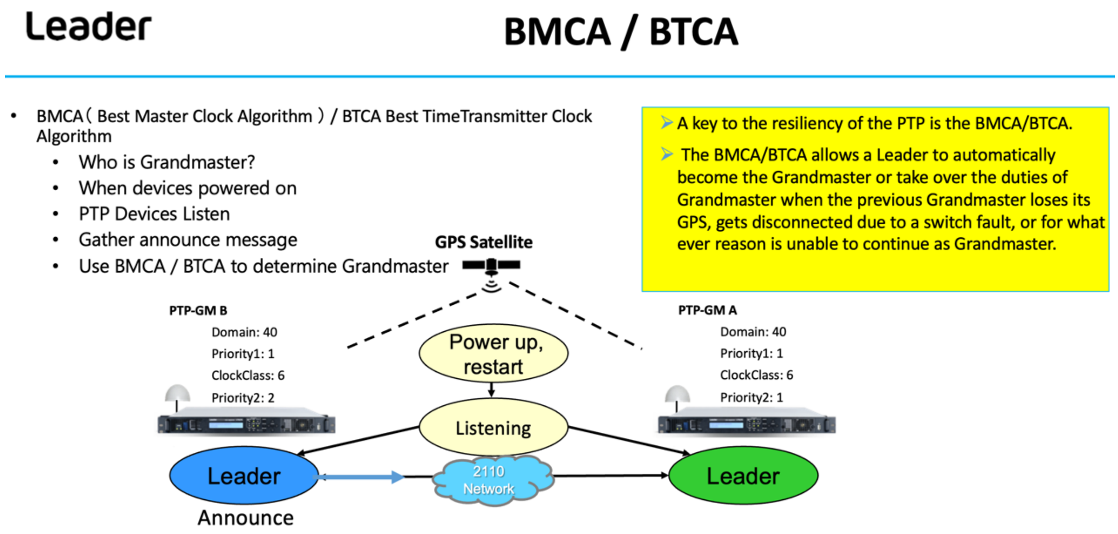
In PTP, the signal comes directly via IP out of that sync pulse generator to the network.



The primary generator is going to be outputting PTP, the secondary generator after the BMCA/BCTA voting takes place will be listening to the primary generator, but it will be also directly attached to the network and ready to go in a moment's notice if something falters in the primary.

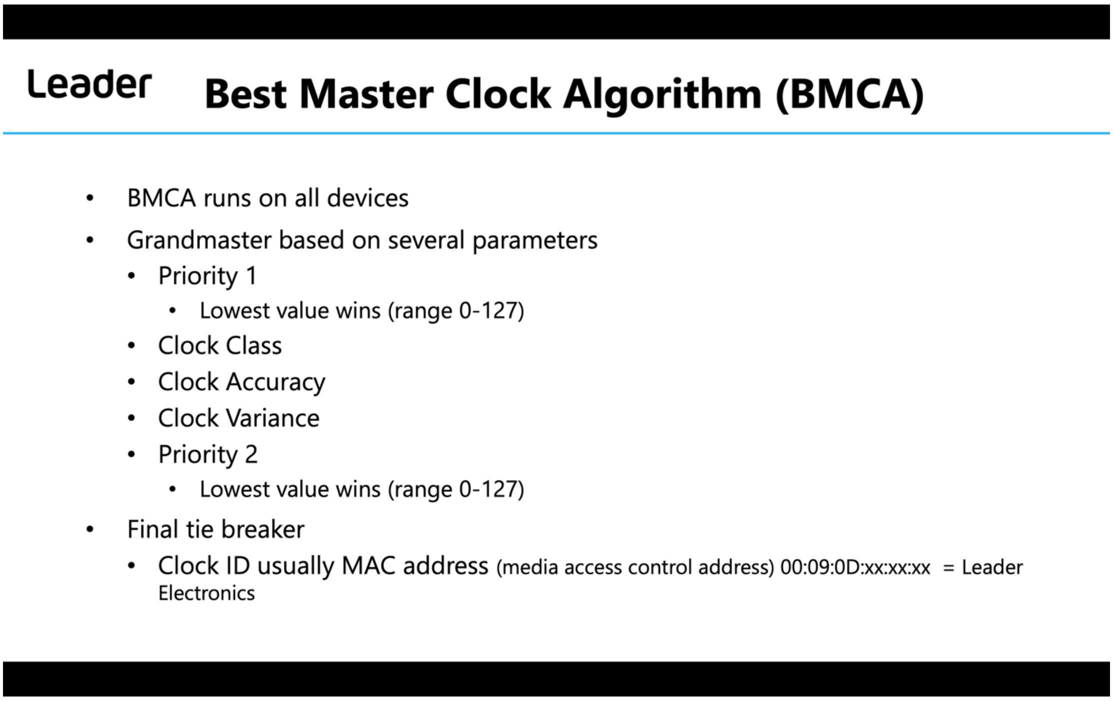
What you end up having is your two SPGs directly linked into your ST 2110 network and they're communicating with each other via that ST 2110 network. You will also have the SDI Audio and the video and all your sync signals going over to your ECO, and then that will go out to your network for all your SDI and Black and Burst needs that you have. This way, the two SPGs are synchronized and are exactly the same.

Then we have the ECO that's going to output the SDI and Black signals, now on the PTP side the two LT4670 SPG's will communicate through the network with each other.



If we take a very simplistic view, we've got two sync generators that are outputting PTP on a ST 2110 network, when they power up, they start listening and they will send announced messages saying what their status is, what their lock status is, along with several pieces of information about their configurations to each other.

This voting is called the Best Master Clock Algorithm (BMCA) and it will then decide because both units will run that BMCA and via that BMCA one of the units will be selected as the Grandmaster.



With Priority1 and 2 the lowest number wins and the one unit that you want to be your primary clock will become the Grandmaster. The secondary clock will be the clock, and waiting will be the leader that will be there if the Grandmaster happens to fail.

Priority1, it's a numeric value that is used as part of BMCA voting to determine who the Grandmaster will be, it will have a numerical value between 0 and 127. In practices both generators should have the exact same Priority1, so that they are set to the same voting plane.

The next parameter is Clock Class, Clock Accuracy, and the Clock Variance, which is basically how good is your signal that is locking the SPG to its reference, like GPS. This is going to be the quality and accuracy of the clock that you are locked to.

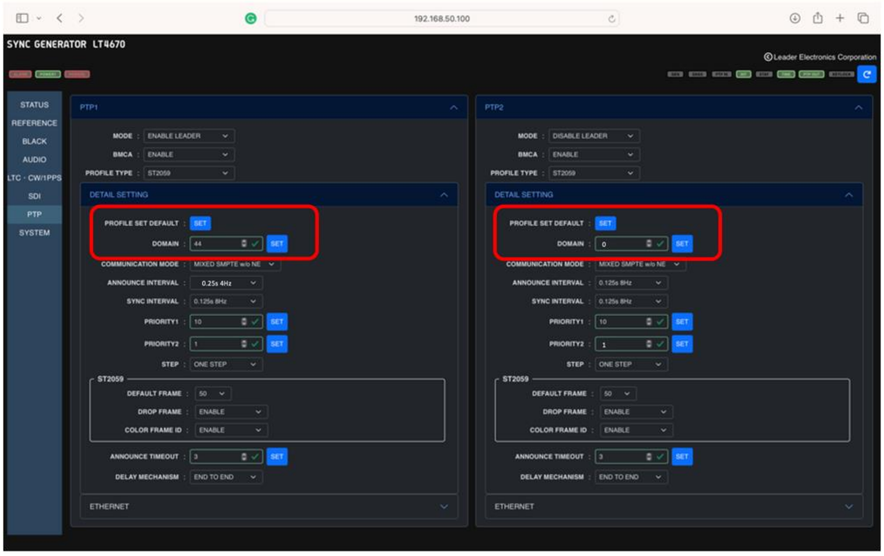
Priority 2 is used to set up the hierarchy if both units have the same Priority1 and both are locked to the same reference source. Who's going to be the Grandmaster? Who's going to be the leader? There is basically no limit (127 of them) to the number of SPG's you can have stacked in your system.

If you set both Priority1 and Priority2 the same, there's got to be something that's going to break that tie. The MAC address is the tie breaker, but that puts who's going to be your Grandmaster out of your control. The Grandmaster's going to be the SPG that's got the lowest MAC address, so you really want to set up Priority2, so that you are in absolute control of this.

You also have the ability within your sync pulse generator to set what domain PTP is going to be on.

PTP Domains are used for multiple PTP services simultaneously within one network (see section 10. PTP Domains for more detail.)

PTP Settings - Domains



8. Clock Class

Clock Class is the quality of the clock, and it's based on what you are locked to.

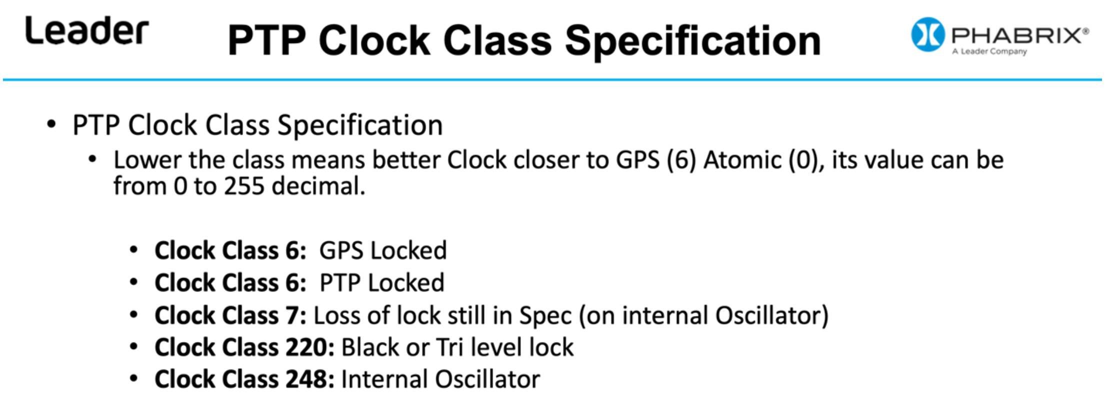
If you are Clock Class 0, that means you are the atomic clock, the absolute source of time.

In the case of GPS locked devices, the best Clock Class you can have is Clock Class 6, which means that you are either GPS locked, or you are locked to PTP, which is GPS locked. Your time of day of off the epoch is perfectly locked.

If we lose lock and you go onto the SPG's internal oscillator, the internal oscillator will maintain time, but we can't be Clock Class 6 anymore, so we drop to Clock Class 7 hold over. This is telling us that "Yes, we had a solid lock, my time is set to the epoch and my internal clock is stable enough to hold that time for a given period.

Once that time has elapsed, based on the quality of the internal oscillator, which is an oven-controlled oscillator, the Clock Class will drop to Clock Class 248. This is telling us that "I'm on internal oscillator now and the epoch time will not be absolutely perfect."

If you lock to Blackburst or Tri-Level, you will be Clock Class 220. This is telling us that "I'm not locked to GPS; however, I am locked to a stable clock."



It's best to lock your network to a GPS reference source once you add PTP to your facility. Black or Tri level do not have the time base or accuracy to keep PTP time the same as GPS time.

The Leader LV5600W / LV7600W "True Hybrid' IP and SDI waveform monitors have the ability to analysis these parameters, to enable you to monitor the status of your PTP reference sources.

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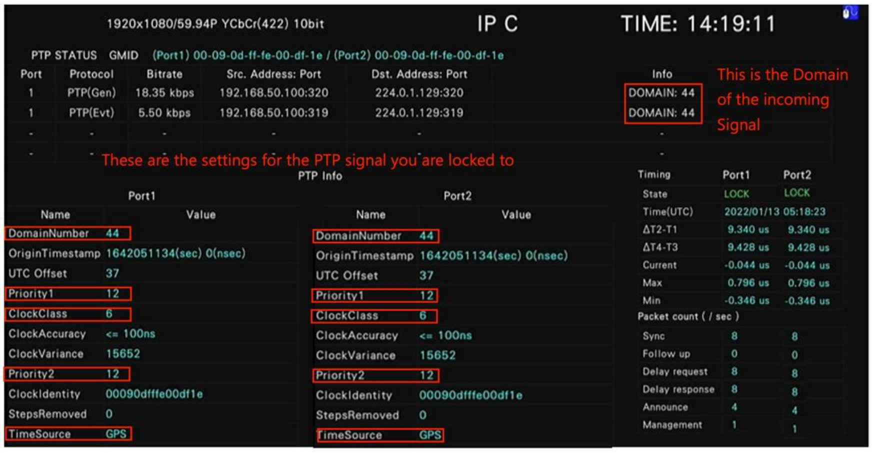
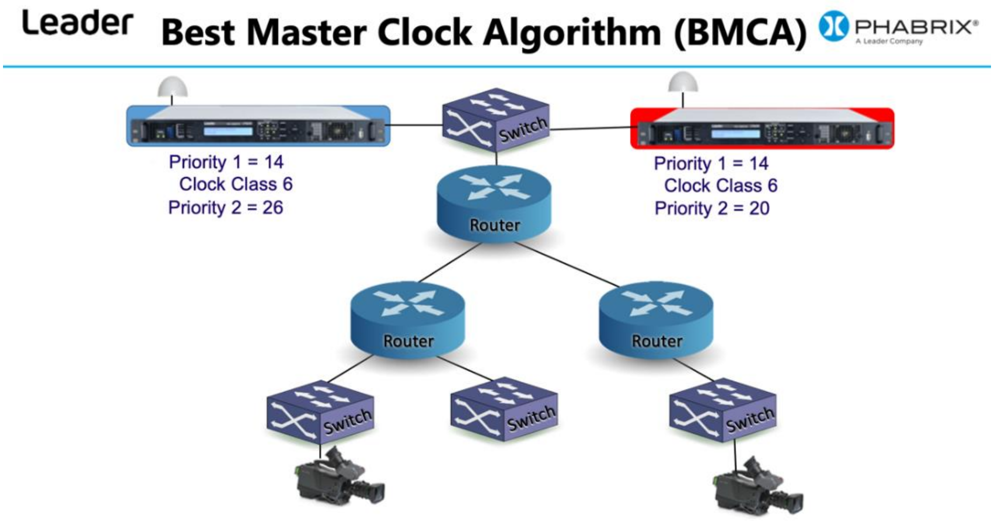
Best Master Clock Algorithm



STATUS -> F.2 SDI/IP ANALYSIS ->F.4 IP -> F.1 IP MEAS -> F.2 PTP ->F.1 INFO

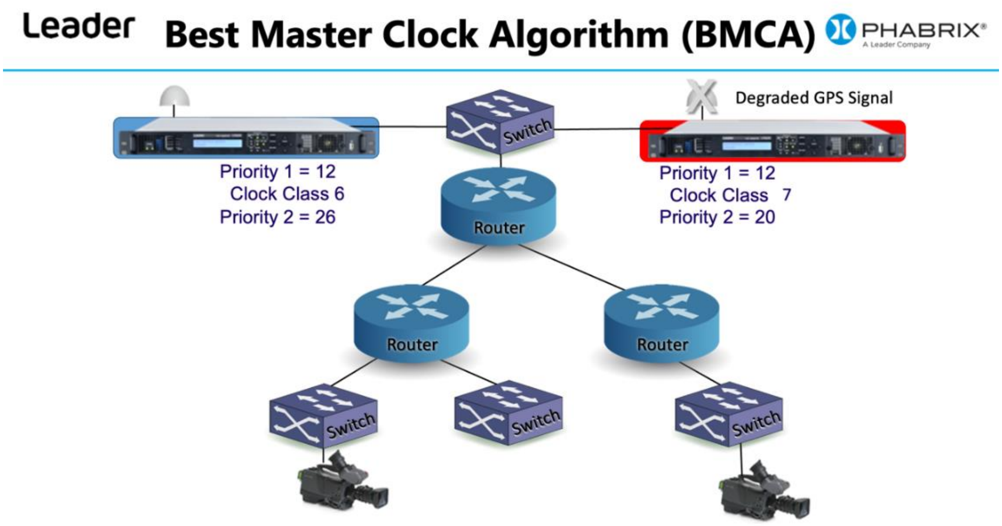
9. Examples of BCMA/BTCA

Can you identify which SPG the BMCA/BTCA will identify as the Grandmaster?



Answer: The network on the right, the red network is the grand master because its Priority 2 (20) is lower than the Priority 2 (26) on the blue network. They both have the same Priority 1, same Clock Class, so it gets down to the voting of Priority 2. The BMCA says that unit on the right will be our Grandmaster.

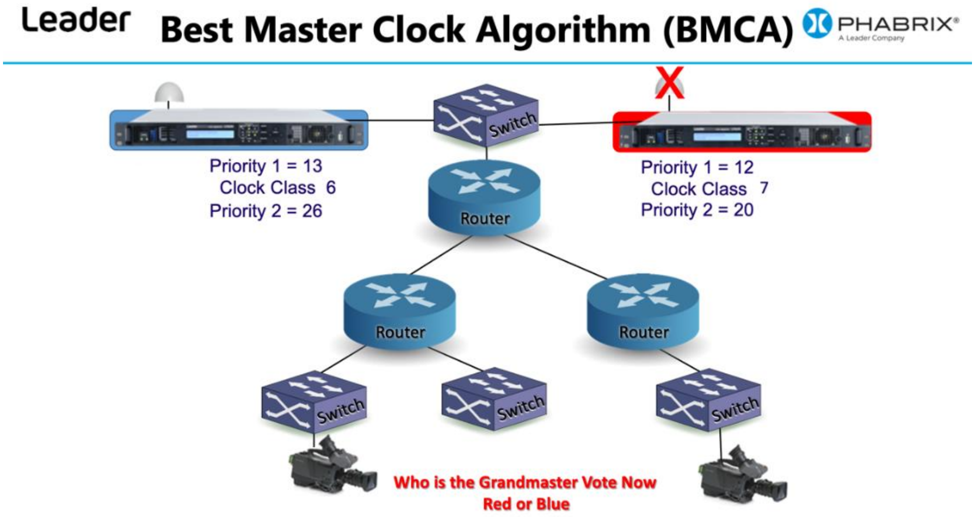
Example #2



Answer: The unit on the left, the blue network is now the Grandmaster because the clock class sits between Priority 1 and Priority 2 and it's going to be the determining factor. It overrides Priority 2 because it's above Priority 2. Since the unit on the right went to clock class 7, and the unit on the left is still at class 6, it's going to take over and become the Grandmaster.

So that's how this BMCA/BTCA works. It's a tiered voting system.

Example #3



Answer: The network on the right, the red network is the Grandmaster, even though it's lost its GPS reference source. The unit on the right is Priority1 of 12. The unit on the left is Priority1 of 13.

Since Priority1 is the highest voting and it's above the Clock Class, even though the Clock Class dropped to 7, which is the holdover condition, it still says, "I am the unit you are going to stay locked to."

And this is why you need to make the Clock Classes at Priority1's exactly the same, otherwise you will not switch to your backup on a loss of GPS.

This is one of the reasons why when you build your network and you get two SPG running and you have them running on your network, you need to test your failover BMCA not only by removing the PTP off of the switch, but you also need to make it fail over by taking off the GPS signal because they're two different things that both need to be tested.

One is a complete absence of PTP, the other an absence of GPS reference source. Changing from Clock Class 6 to Clock Class 7, where the unit on the left is still clock class 6, you would expect the system to fail over to that unit, but the Priority 1 value stops the Grandmaster status from being transferred.

10. PTP Domains

PTP Domains are used for multiple PTP services simultaneously within one network

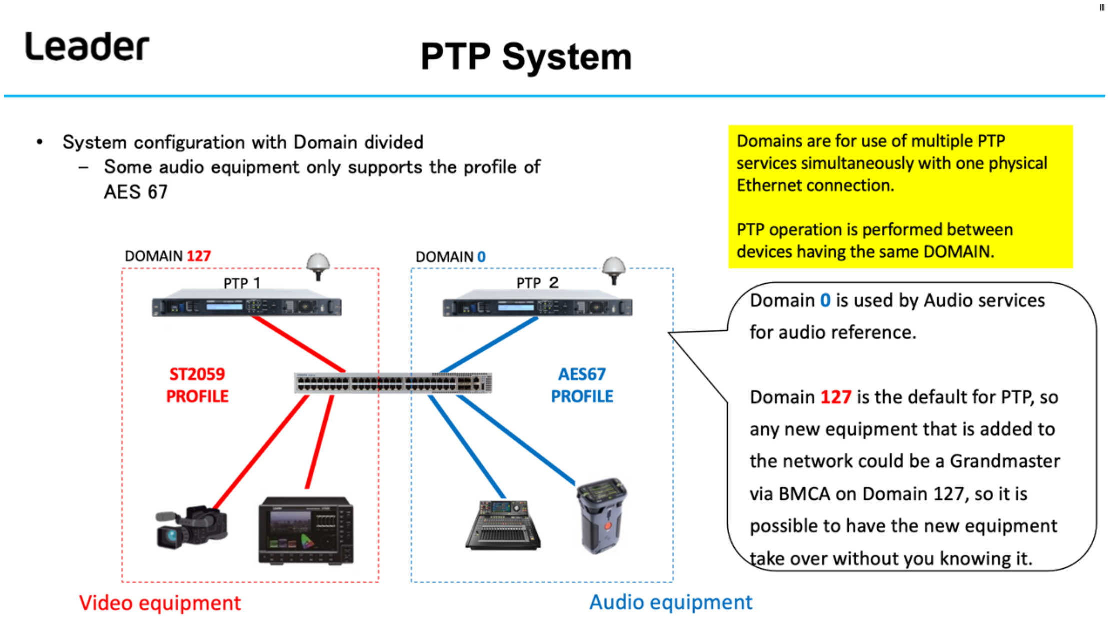
PTP Domain numbering can range from 0 to 127.

There are two domains that you really want to stay away from when you set your network up. The first of these is the default domain 127.

You don't want to leave it on domain 127 because that's the default, every device that's added to your network that may have the potential of being a Grandmaster, is going to come in with that domain value.

The other domain is domain 0, and domain 0 is used by audio services and typically, you don't want to have two things on the same domain.

If you have put in an audio system or Dante or anybody else, they typically will run on domain 0, so you want to leave domain 0 open for audio devices in case you are on the same network topology, and you are running your audio network along with your video network, which is perfectly fine to do.



If a new device is added to the network and their Priority1 now happens to be lower than the Priority1 you selected, they will take over and become the Grandmaster. So, you do don't want a new device that's added to your network to be a rogue and somehow take over as You want to be in control of that, so we recommend that you change it to some other value. It doesn't matter what the value is.

Our Leader demonstration systems use domain 44, just so anything else that we put on the network, isn't going to take over because the chances are astronomical that it's going to be set to 44 when we turn around and do this.

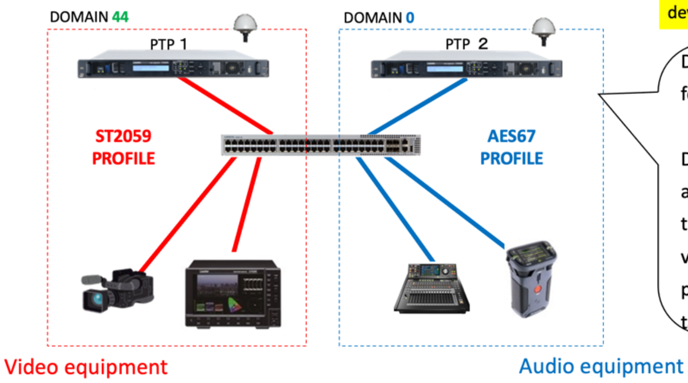
Leader

PTP System

- System configuration with Domain divided
  - Some audio equipment only supports the profile of AES 67

Domains are for use of multiple PTP services simultaneously with one physical Ethernet connection.

PTP operation is performed between devices having the same DOMAIN.



Domain 0 is used by Audio services for audio reference.

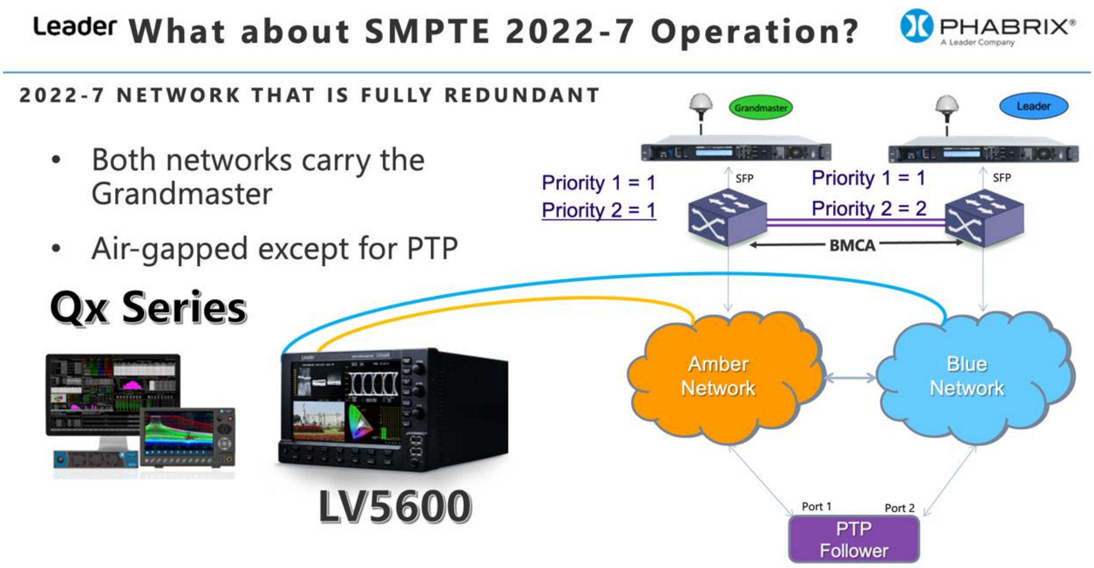
Domain 127 is the default for PTP, so any new equipment that is added to the network could be a Grandmaster via BMCA on Domain 127, so it is possible to have the new equipment take over without you knowing it.

11. PTP and SMPTE 2022-7

In a SMPTE 2022-7 network, what you have is two complete independent networks that have the same data on them.

In the diagram below there is a connection between the amber and blue networks, even though you want them to be 100% air gap networks as far as your video, audio and anc data is concerned. There needs to be a PTP connection between those two networks so the BMCA between the two SPG generators will take place.

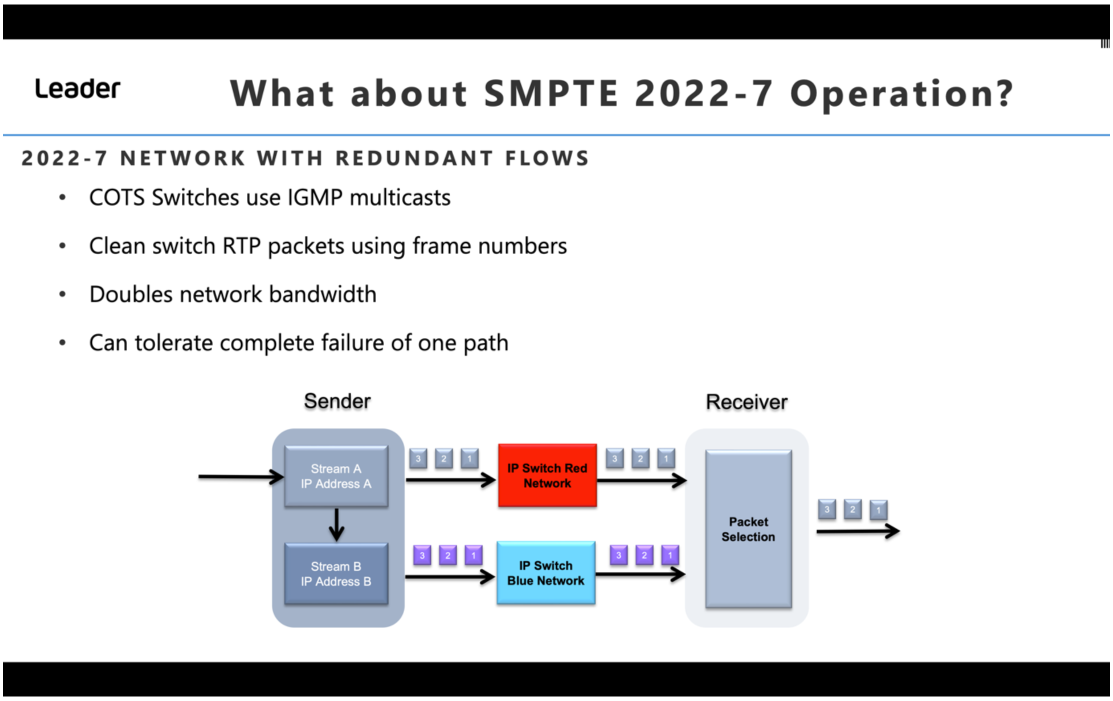
What will happen in this case is, the generator on the amber network happens to be the Grandmaster because of its Priority 2 (20), so it's PTP will go across that link and both the amber and the blue will have the same PTP source coming down to the follower so that way you have complete failover that you are getting your PTP and you're getting the same PTP on the Amber network as you are getting on the Blue network.



There are many different ways to do this interconnection between the two networks and that depends upon your network topology. You may not want to do it at the network level, you may want to actually move it up and do it closer to the sync generators, but that just depends upon how you do your individual topology.

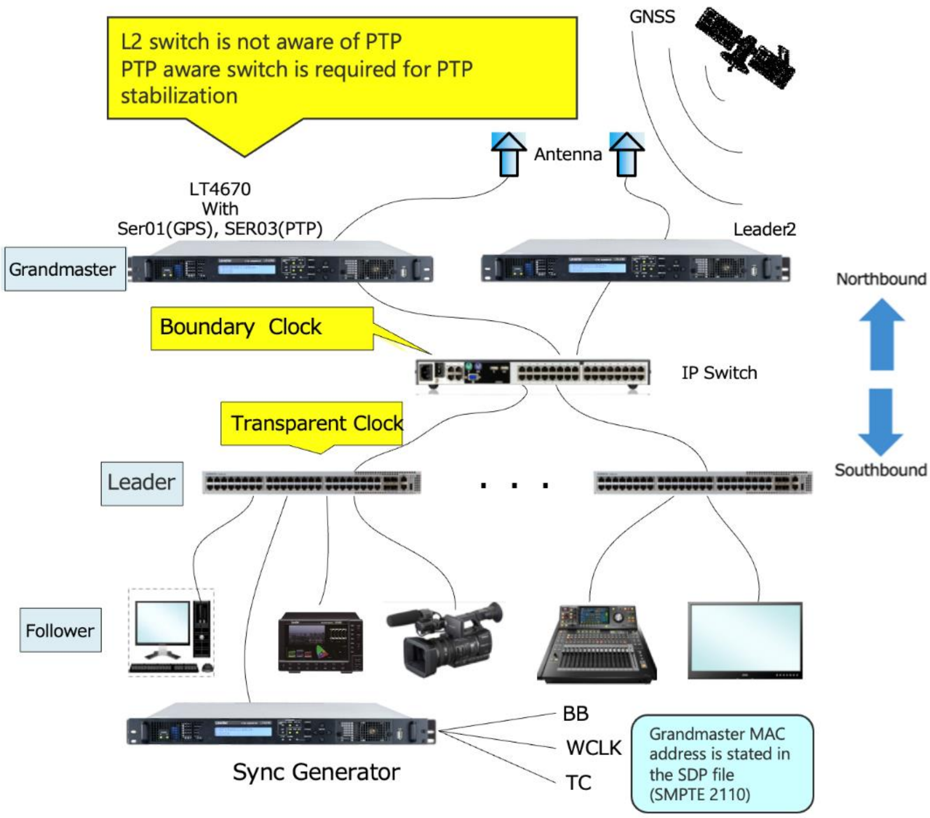
The SMPTE 2022-7 provides IP streams with a redundant path from source to destination. Initially, broadcasters deployed SMPTE 2022-7 architectures, because they were concerned that drop packets over the IP networks, would result in Quality of Service (QoS) issues.

One benefit of SMPTE ST 2022-7 is the ability to carry out maintenance on the networks, without impacting the performance of the IP networks. In SDI based systems, software and firmware update were few and far between and normally implemented to fix software bugs. In the IP world, software and firmware update go together with security patches and ask anybody who has deployed an IP system about the frequency of ‘critical-security’ software and firmware updates.



12. PTP System – Terms and Definitions

For those not familiar with IP systems, they come with a whole new language, that unless you're from the telco or IP Engineering world, you're not going to be familiar with these new terms and definitions.



We have already talked about the **Grandmaster**, the ultimate clock and then you have your **Leader clock**, that will be the second clock waiting based on Priority 2, to take over. The follower happens to be receivers, anything that's receiving the PTP information and using that as sync is a follower.

Then we have the PTP aware switch, a PTP aware switch is a switch that participates in the exchange of time using the PTP protocol as either "boundary clocks" or "transparent clocks" and does not exclude those packets, so they are an extension to the management messages that are going on and we want to pass through the switch.

Next, we have a **Boundary clock**. A **Boundary clock** is kind of unique in that it is a follower from the north, i.e. from the sync generator coming to it and it becomes a follower of that sync generator, but it becomes a leader for all of the devices below it. And it's a separation between what's happening with the PTP generator and what's happening below it, the reason for this is to limit the PTP traffic going back to the grand master. So PTP is very verbose and if you put too many followers on a network, you can have PTP congestion and you start dropping the messages.

This allows you to have a much wider network and the **Boundary clock** then will become the sync source for everybody below it. And those **Boundary clocks** are all locked to the clock above it. A **Transparent clock** is a clock that looks at the PTP timestamp coming in, it looks at the PTP timestamp that's going to be going out, and it puts any correction factor in the PTP message that says, "My input was this time. My output was this time. So, it spent this much time inside of me." It's a correction number.

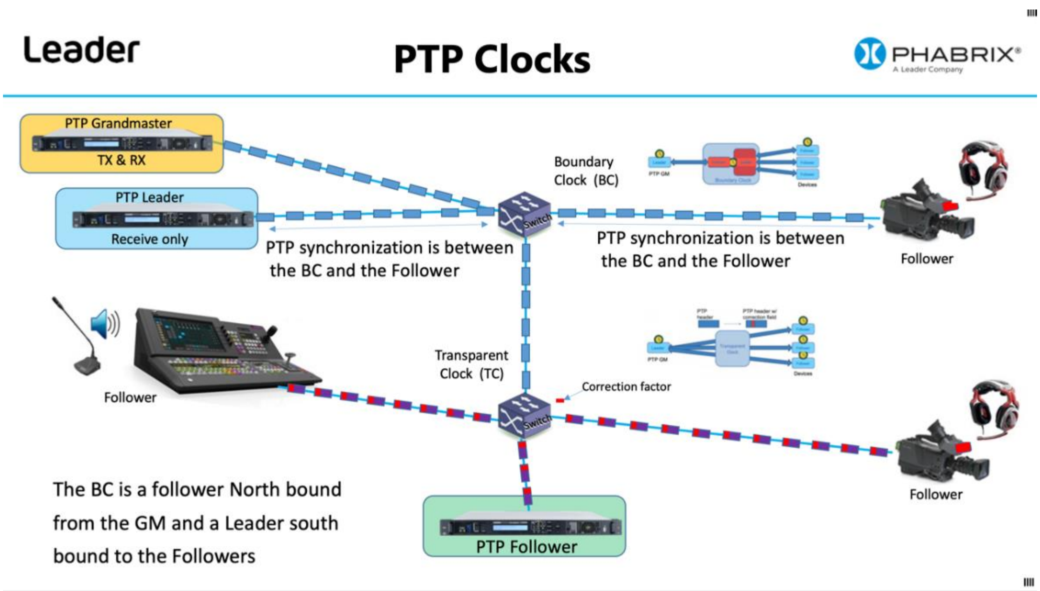
So, let's take a more detailed look and use SDI reference terminology to explain how these IP reference systems operate.

If we look at this as a simple line drawing, we have the LT4610 PTP generator, outputting PTP messages, in this case into a **Boundary Clock** switch. The **Boundary Clock** switch to a degree is like a re-clocking Distribution Amplifier, accept there is a separation between northbound and southbound traffic. It is a receiver like a re-clocking Distribution Amplifier on its input, but it's a brand new PTP source on the output.

The **Boundary Clock** is going to be a follower from the northbound PTP traffic, but it is going to be a generator of PTP traffic southbound to everything that is plugged into it on the receive side, and it recreates brand new PTP messages, so any inbound PTP messages don't go beyond that switch.

The **Boundary Clock** switch will have PTP messages going up to the grand master, but the switcher, the camera and another PTP generator as a follower, will not have direct messages back to the grand master, but they will be locked to the grand master's exact time.

A **Transparent Clock** behaves similar to a normal fan out Distribution Amplifier where it passes through the PTP signal. The **Transparent Clock** does give you that fan out, but it also gives you a correction field that details the amount of time that it took for the PTP message to get through the switch.



If we look at this in terms of a real simple line drawing here, we've got the PTP generator, outputting PTP messages, in this case into a **Boundary Clock**. The **Boundary Clock** is going to be a follower from the northbound traffic, but it is going to be a generator of PTP southbound to everything that is plugged into it on the receive side, and it recreates brand new PTP messages.

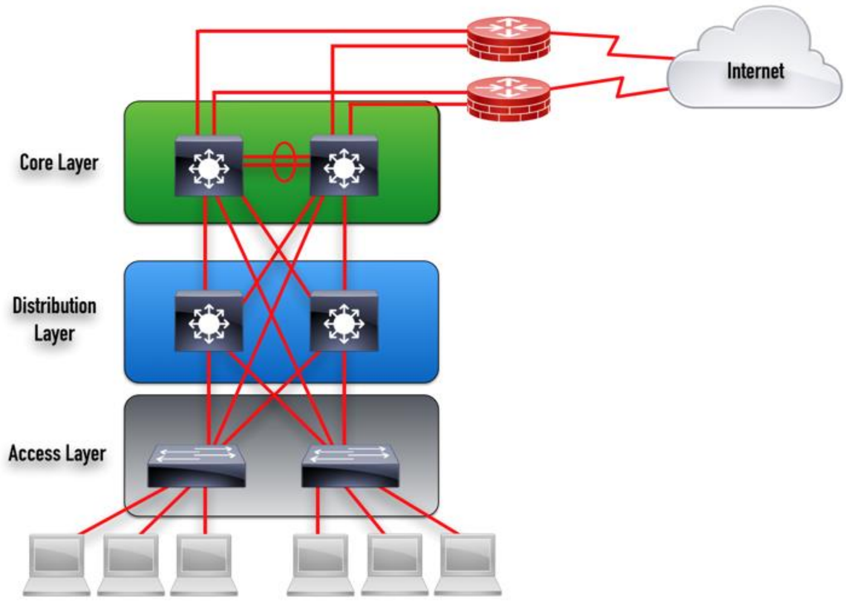
The **Boundary Clock** switch will have PTP messages going up to the **Grandmaster**, but any device southbound, will not have direct messages back to the **Grandmaster**, but they will be locked to the **Grandmaster's** exact time.

Southbound of the **Boundary Clock** switch is the **Transparent Clock** switches, messages will pass through that **Transparent Clock,** and they will have a correction field added to it, so **Followers** like cameras, switchers (audio / video), waveform monitors are correctly timed.

You may have also notice on the second PTP generator, it's not generating PTP, it's just listening to what's going on and looking at those announce messages and making sure all devices are doing what they should.

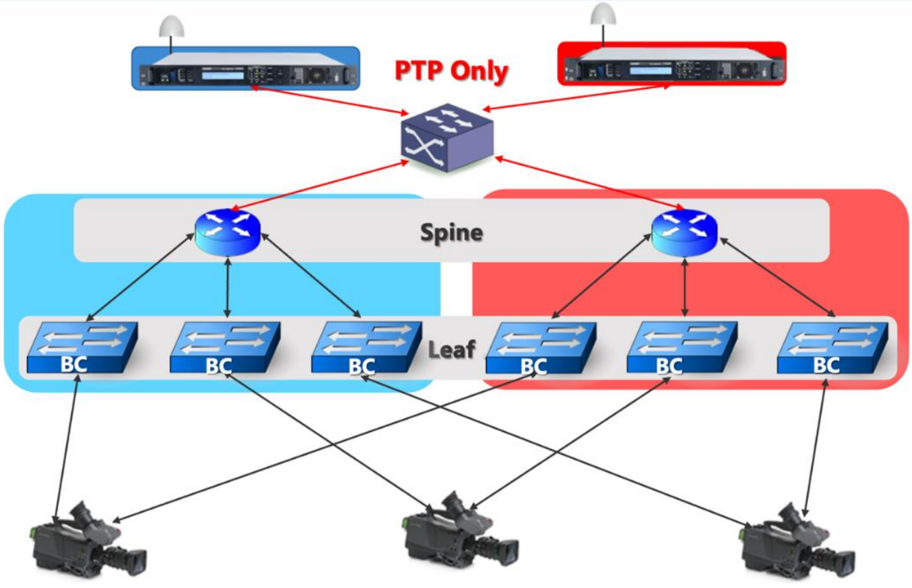
13. Network Topology

Data centers traditionally use a three-tier topology, but broadcasters prefer leaf and spine topologies, does the network topology affect the PTP architecture?



A typical data center type topology might look something like this, where you've got layered switches and you've got multiple interconnections for route tables where if something's congested, the access layer could go all the way up to the core layer if it had to, or to a distribution layer just based on traffic, it can take different routes.

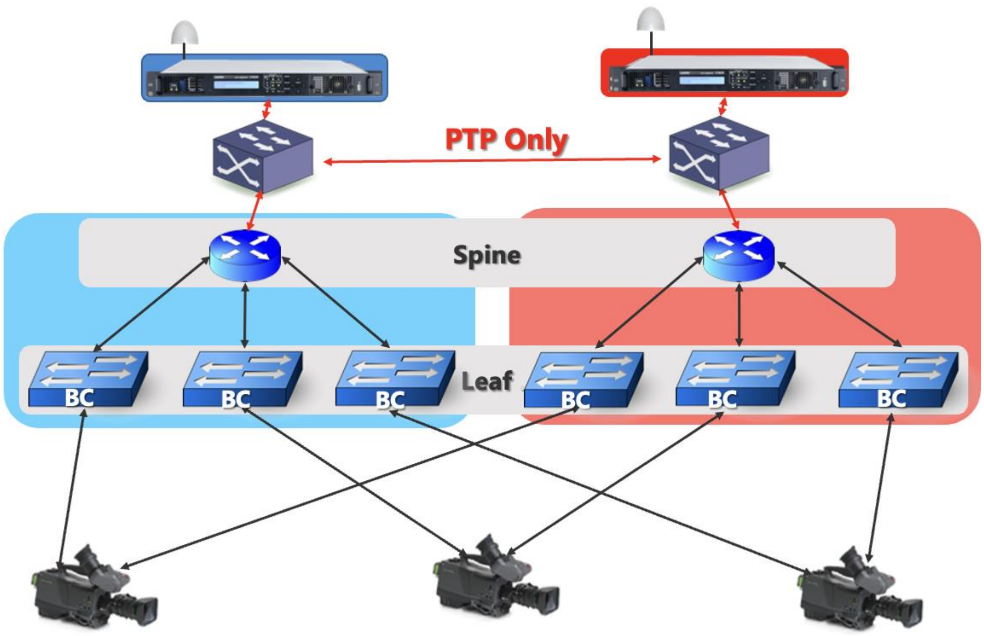
We can't have that happen in a PTP network. A PTP network, the transmit direction and the received direction must be the same path. PTP is based on a symmetrical network. You don't want a delay in one direction from a switch to be greater than a delay in the other direction.



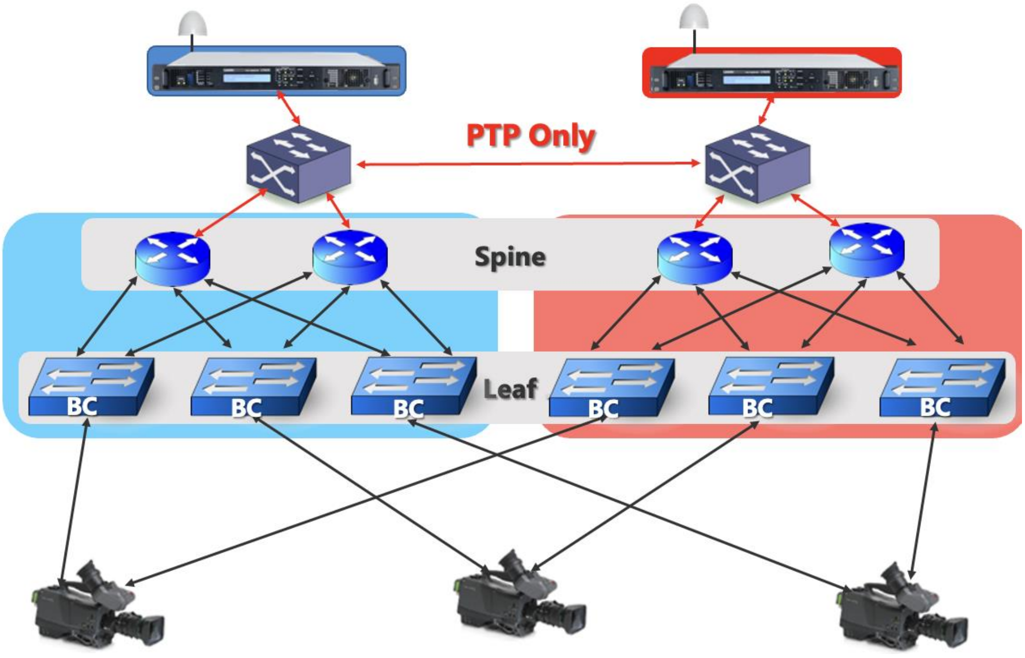
A Leaf and Spine is much easier to manage if you need to grow your network.

Here we've got our red and blue networks, they're going into a switch to distribute PTP to both networks and also that switch now allows you to receive PTP if you have other devices that just need PTP sync.

But now the rest of those networks are 100% air gapped from each other and the path to get from one device to another device is only Boundary Clock, Spine, Boundary Clock. It never goes beyond that, no matter where you happen to be going. It works very nicely from that standpoint.



Some architectures may want separate distributions for their PTP so you could put in two conventional switches for the PTP messages and then make a PTP only pipe (Virtual Local Area Network VLAN) between those two switches so that the BMCA can take place. Or you could do this at the spine level. The advantage of doing it above the spine level, is that if something happens to your network, you aren't relying on that network, the spine, to convey the PTP messages across.

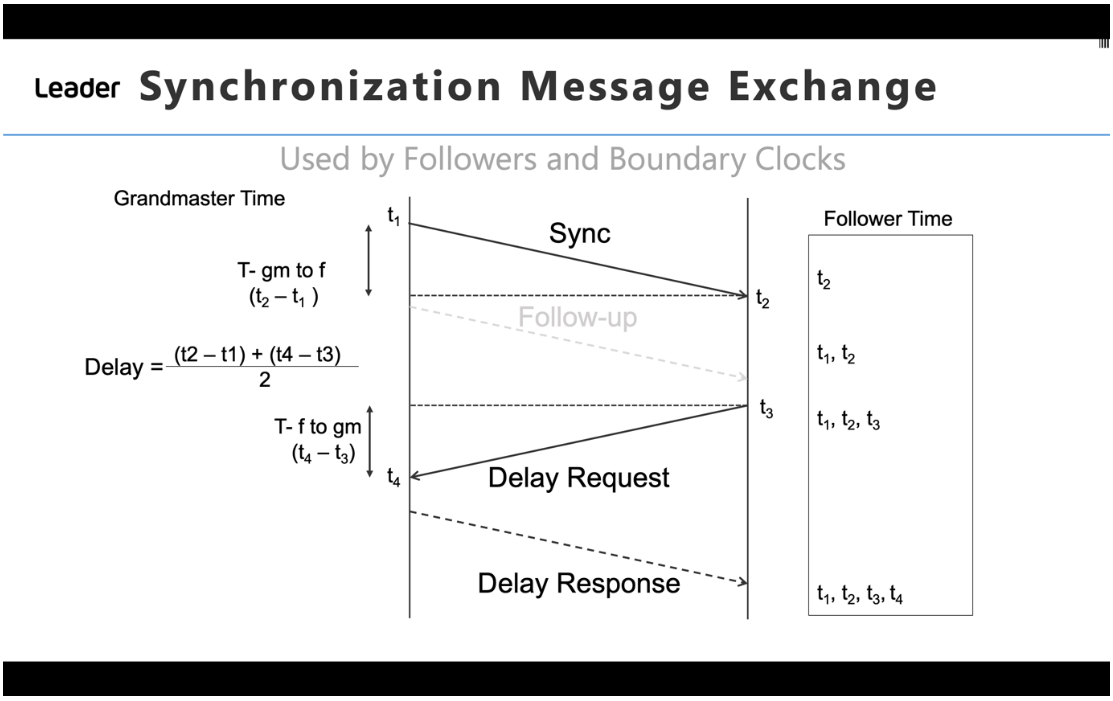


If you need more bandwidth, all you have to do is add more spines and the traffic is still boundary clock or leaf to spine, back to leaf, no matter where you're going, but it just increases your network bandwidth. If you need more followers, more nodes, you just add more boundary clocks, more Leaf's and the Leaf's then connect to the existing spines that you have.

So, it's very easy to grow these types of networks.

14. PTP Topology

Earlier in this paper we mentioned that PTP can calculate the equivalent of the propagation delay through the switches and networks. This is part of the **Best Master Clock Algorithm (BMCA) as** part of the announced messages, the sync messages and delay requests and delay responses.



The announced message basically asks devices on the network, what is their Priority 1, Priority 2, CLOCK class etc. and those messages are sent out to the whole world.

Then we have a **Sync** message. The **Sync** message is the Grandmaster's time to the network, now all of the followers will now send back a **Delay Request**, which is their time going back to the Grandmaster. The Grandmaster then will again respond with its time back to the follower in the form of a **Delay Response**.

Now the follower knows what the Grandmaster's time is, so the follower now has **T1**, which is the Grandmaster's time, the follower also has **T2**, which is his own time. The follower is going to send that at **T3** at some other point in time, back to the Grandmaster.

So now the Grandmaster knows what the follower's time is, and he knows what its own time is and then the Grandmaster is going to send a **Delay response**, which again is Grandmaster time and the follower will now have what the original time was, what the follower time was, what the time was when the follower sent his time back to the Grandmaster, and the Grandmaster's new time on the response.

If you take **T2** minus **T1**, that gives the **Delay Time** from the Grandmaster to the follower (receiver) and if you take **T4** minus **T3**, it gives the delay time going back from the follower (receiver) to the Grandmaster. So **T2** minus **T1** is the delay of the Grandmaster's time to the follower and **T4** minus **T3** is the follower's **Delay Time** that it took to get back to the Grandmaster.

$$\text{Delay} = \frac{(t2 - t1) + (t4 - t3)}{2}$$

So, when you take those **Delay Time** measurements, add them together, divide them by two, now you've got a two to one of the delay going forward and the delay coming backwards. That's why it's so important to have a network that is symmetrical, and the follower will take those T1 times and that's what they will use to synchronize themselves.

The followers are not going to instantaneously synchronize to T1 time, because they are clocks, they have to phase lock loop. Also, you don't want to shock your network all of a sudden, so if you lost GPS and now you're getting GPS again, it's going to walk slowly back to that time so that your network doesn't do like some of our old Blackburst networks used to do, a 360□ spin when we go through a GPS switch.

ΔT2-T1	8.168 us
ΔT4-T3	8.428 us
Current	8.298 us
Max	8.862 us
Min	8.224 us

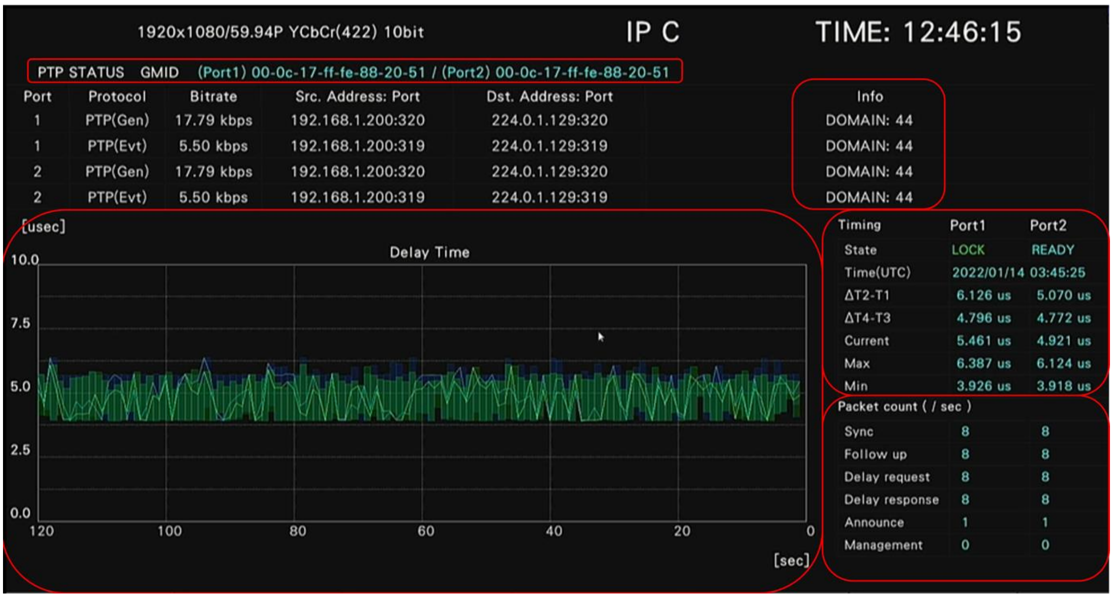
Test and measurement waveform monitors will give you that ΔT2-T1 time, the ΔT4-T3 time. You can also see that the two numbers (ΔT2-T1 = 8.168μs and ΔT4-T3 = 8.428μs) are very similar to each other, indicating that the delay through the network is symmetrical.

Typically, the T2-T1 Grandmaster to the follower will be slightly higher than the T4-T3, due to the PTP competing with all the Video and Audio traffic. If this value gets too high, then it can indicate that you're Network is starting to be bogged down, and you may need to look at the amount of traffic on this leg.

If the **Delay Time** measurements are not similar, then your network is not symmetrical and can be visualized as a highway that has heavy traffic in one direction and is clear in the opposite.

△T2-T1 △T4-T3

Let's now take a look in a bit more detail at the PTP information that's available on a Leader waveform monitor display.



At the very top of the display **PTP STATUS GMID** details which Grandmaster each port is connected to, the MAC Address of the Grandmaster is displayed.

We can see the messaging coming in on Port 1 and Port 2 from the PTP generator, along with the domain that is being used.

We also have a graph of that delay time in one second buckets. This is the amount of delay, min and max within a one second bucket and then you see those buckets move across and you can see the graph of those buckets. This graph can be scaled from 120 seconds to 72 hours, depending on the duration of time you wish to monitor.

To the right of the **Delay Time** graph, you can see the real-time ΔT2-T1, ΔT4-T3, current, min, and max.

In this case, ΔT2-T1 is a little larger than the ΔT4-T3 time, so you need to be careful about that because that means that the video network is being stressed, that it's taking more time to get from the PTP generator to the follower than it is from the follower back to the PTP generator.

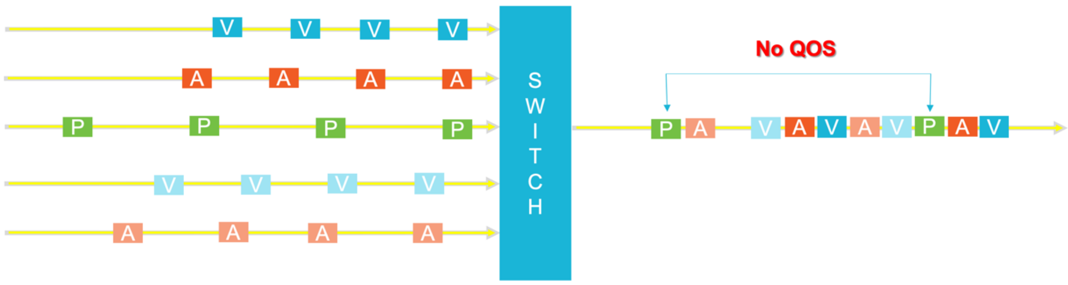
The messages from the PTP generator to the follower are going with all the traffic so this suggests that the switch architecture that we are currently going through, if this stays like this and gets bigger and bigger, that the network is starting to get congested and you need to start looking at why, maybe I need more bandwidth in my network, that it's starting to slow down my PTP messages, and then you can see all of the message rates, how many times a second each one of these messages are actually being sent.

15. Quality of Service

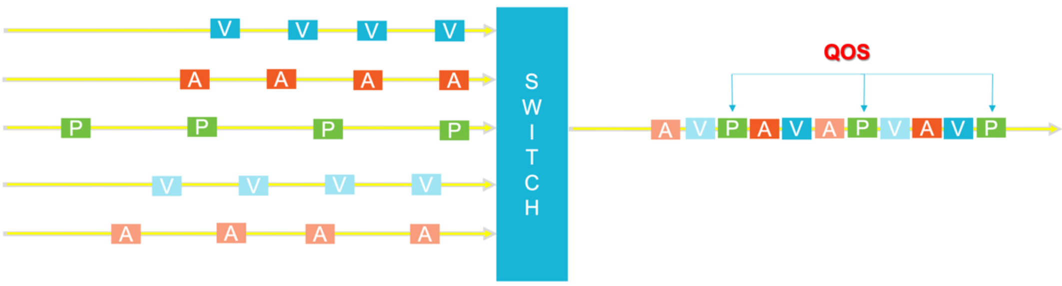
We hear a lot about quality-of-service settings on network switches, can we use the QoS for SMPTE ST2110 and PTP?

We can use QoS for parts of the network. You don't want to use QoS for the video or for the audio because they are the main flows, and every packet then would try to be the best packet possible, and the switch will get bogged down trying to manage every packet.

QoS needs to be set so only a specific flow that isn't necessarily the main flow through the switch would have the QoS on it. If you were to set the video or audio as QoS, you'd overload the CPU in the switch. So, what you want to set for QoS is the most important thing, which in this case is PTP. If you look at the graph below, the PTP is getting moved because of the audio and video and just because of the random output that the switch has as far as its decision making on which packets come out first.



So PTP has been spaced way back, but if you apply QoS to PTP, it's going to now have priority over the video and audio, and it will be able to be placed exactly where it needs to be.

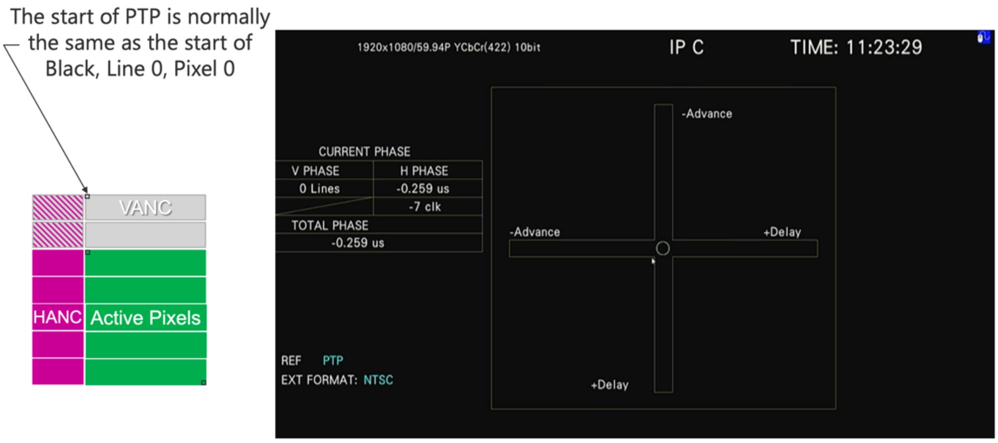


The Leader LT4610 uses that differentiated service code point 46, which sets the PTP as the highest priority going through that switch so that you don't have that issue.

16. PTP timing in relation to Video

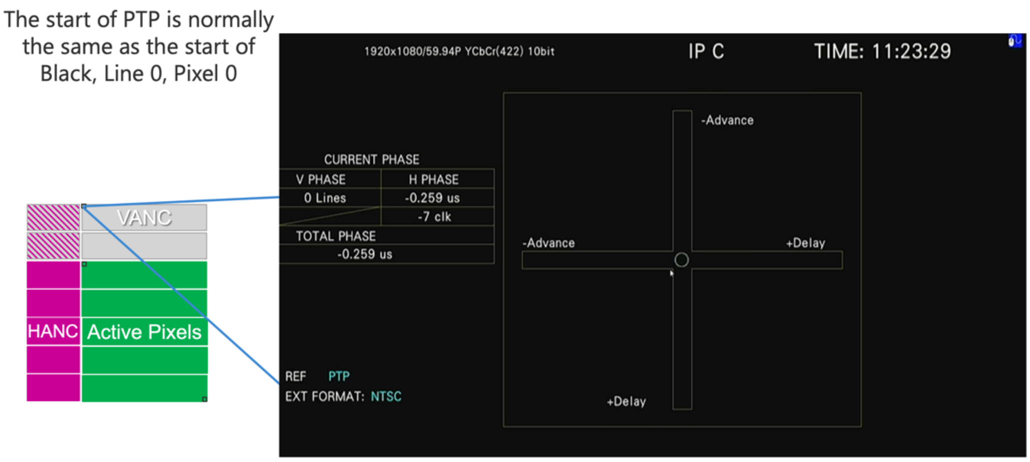
SMPTE ST2110 standard specifies real time RTP based transport of uncompressed active video essence over IP networks. So, unlike SDI video, ST2110-20 results in both a vertical and horizontal phase offset.

The thing that we need to look at is where is PTP relationship to BLACK and then what is the active video relationship to PTP and BLACK? So PTP starts typically at the same exact point where BLACK starts, it's going to be at line zero, pixel zero all the way up the top of the Vertical Blanking.



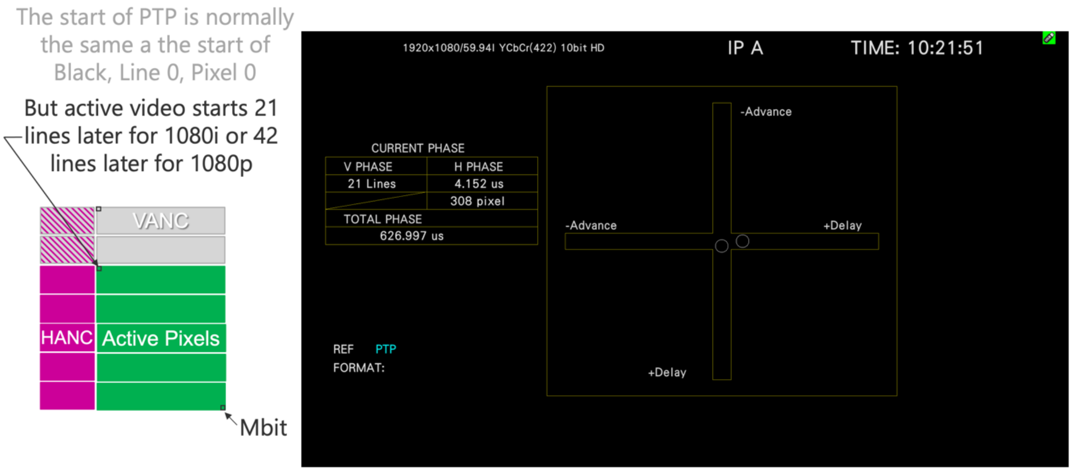
STATUS -> F.2 SDI/IP ANALYSIS ->F.2 EXT REF PHASE -> F.1 REF SELECT PTP-BB

You need the ability to look at where is my PTP is relative to my Black and Burst and it should be almost zero by zero. Now, there's always going to be a fractional horizontal offset, but it should start on line zero and be really, really close to starting exactly where Black and Burst starts. as seen in the figure here.



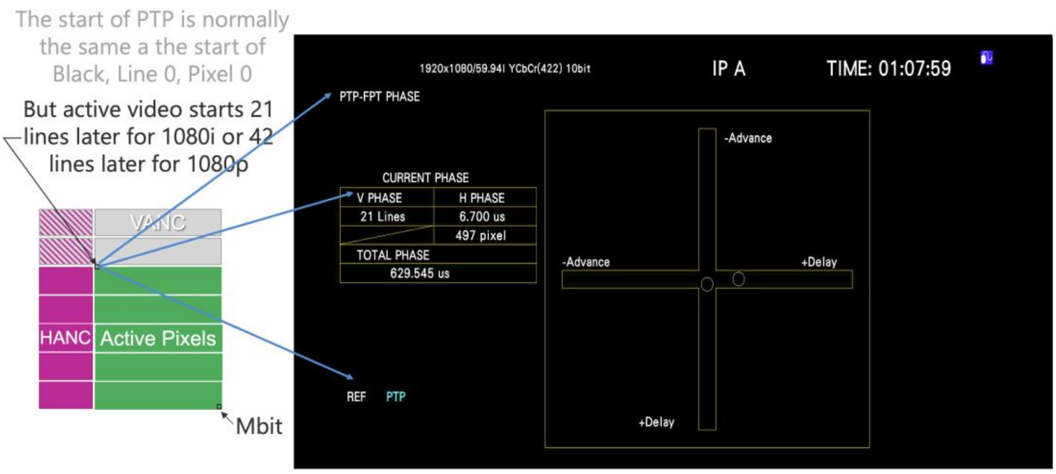
STATUS -> F.2 SDI/IP ANALYSIS ->F.2 EXT REF PHASE -> F.1 REF SELECT PTP-BB

Now, the other subject we look at is that normally the video is going to start later, offset from both the horizontal and vertical. So, the actual first pixel of the active video starts 21 lines later for 1080i or 42 lines later for 1080p and this can be monitored by comparing the PTP-RTP.



STATUS -> F.2 SDI/IP ANALYSIS ->F.2 EXT REF PHASE -> F.1 REF SELECT PTP-RTP

Or by monitoring the 1st Packet Arrival Time.

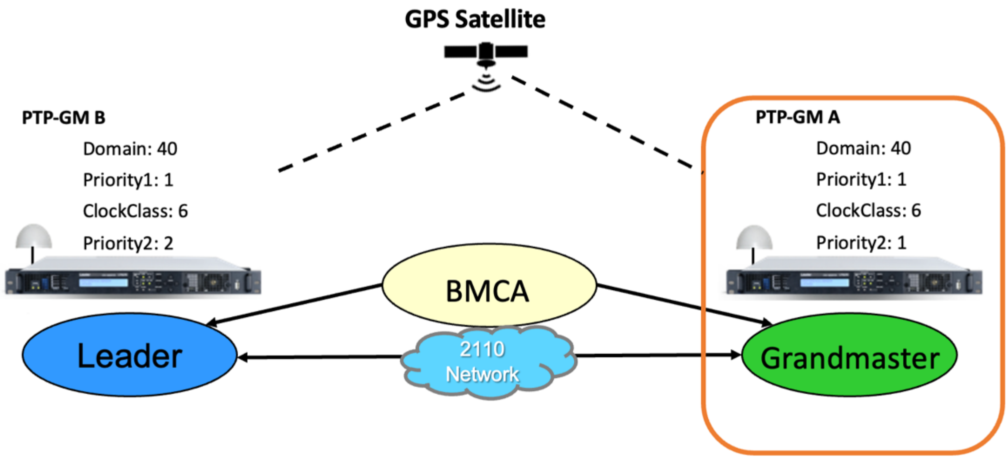


STATUS -> SDI/IP -> F.2 EXT REF PHASE -> REF SELECT PTP-FPT

We really want the video to be in lockstep with SDI because let's face it, in this world you're going to have some SDI at different places within your facility and ST2110 is what we're moving into, but it's going to be a gradual migration. So, we want to make sure that just like aligning cameras or any other source, that the two are linked to each other and at the same offset.

17. PTP reference relationship with GPS reference

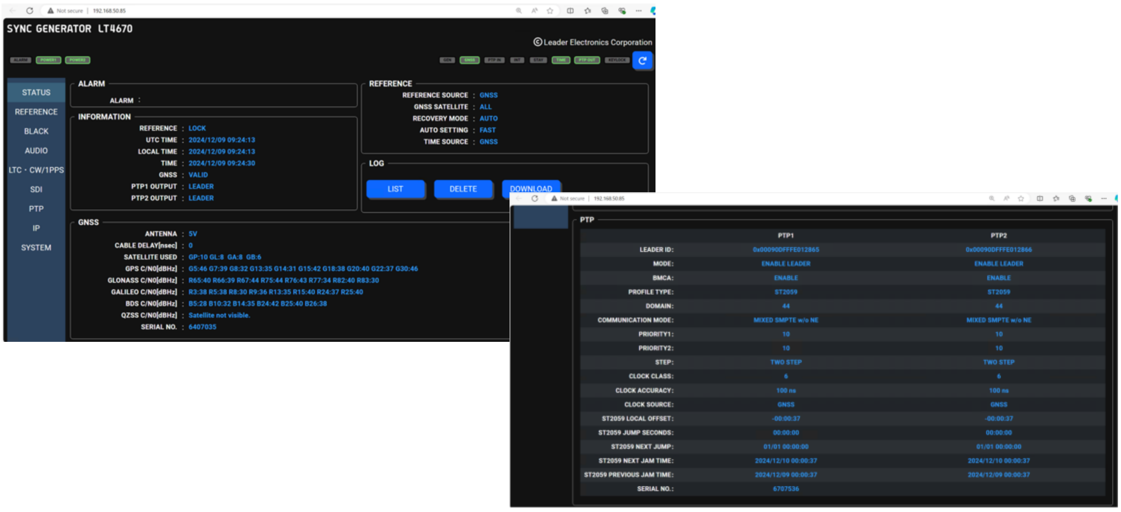
Previously we mentioned that the Best Master Clock Algorithm and how it is used to ensure resilient PTP reference.



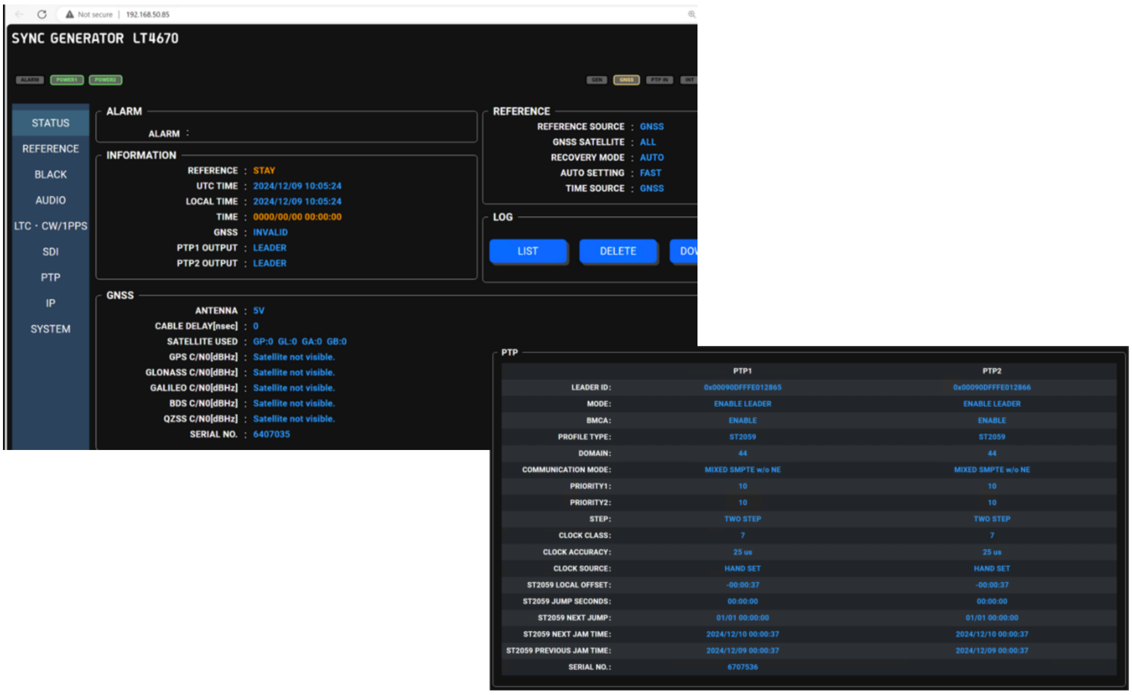
But what happens to PTP resilience if the GPS reference source is unreliable, as PTP is based upon IEEE-1588 and this standard requires PTP generators to locked to GPS?

Loss of GPS reference can happen from time to time, especially with OB trucks, a number of venues are now locating the OB truck compound underneath the stadium or sheltered from direct line-of-sight to the GPS satellites.

In a normal condition, it would be exactly like what we show here. You'd be looking at a perfect lock, lots of satellites, good signal level, you'd be **PTP CLOCK class** 6.

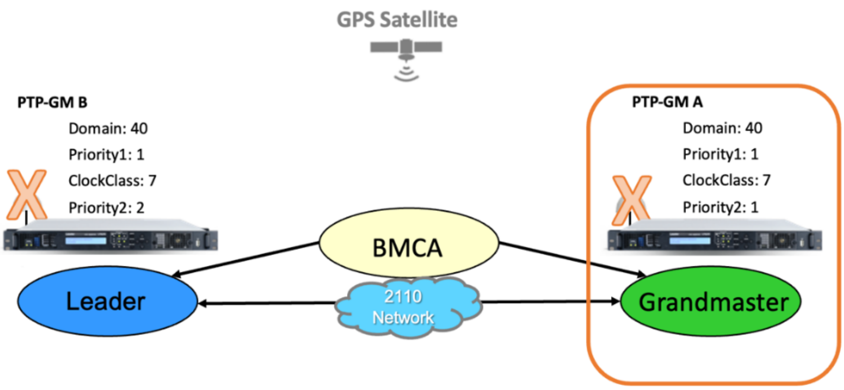


If however the GPS reference is unreliable and the LT4610’s loses connection to the GPS satellite reference then the LT4610’s Genlock Status will change from **LOCKED (GPS)** to **STAY IN SYNC** and the **PTP CLOCK Class** with change to 7 (Hold Over).



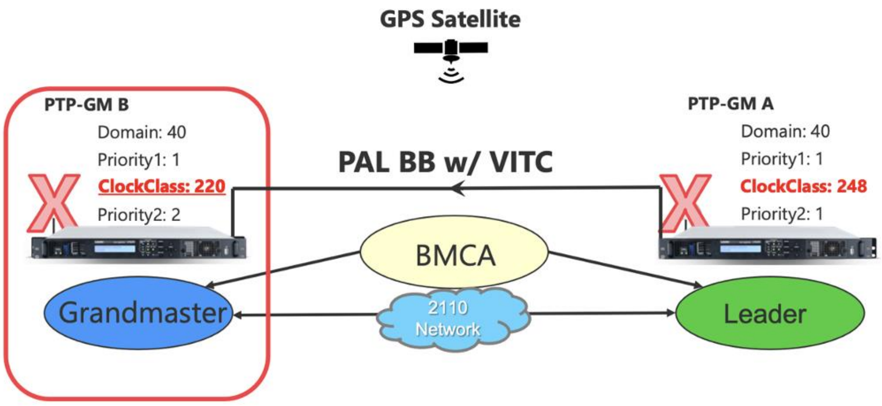
Let’s be clear, the switching between PTP CLOCK Class 6 and 7 will not cause any issue to the PTP reference and will have no impact upon systems that are using the PTP reference, the transition from PTP CLOCK Class 6 to 7 will appear seamless to them.

One of the things that we need to consider about this design here is when we lose GPS, there needs to be a link, especially for trucks, between the two generators, to be able to provide sync and lock the two generators, because normally they'd be locked to GPS.



Without GPS, PTP-GM A and PTP GM-B are no longer linked together.

When GPS is lost, both LT4670's are going to go into free run state and the last thing you want is the two PTP sources in free run and not absolutely phase and frequency locked with each other, counting time down in the microsecond, nanosecond range. So, we need to add something to lock these.



One potential solution is to interconnect the two LT4670's with a PAL BB w/VITC. The time source from **LT4670 PTP-GM B** is used to lock **LT4670 PTP-GM A** and those two LT4670's will now be absolutely perfectly in lockstep when GPS is lost.

Leader recommends for operational environments with unreliable GPS connections to configure the LT4670's with two pre-set configurations.

1. For reliable GPS
2. For No GPS which uses PAL BB w/VITC as reference

Pre-set #1 should be the power up pre-set for both LT4670's and then pre-set #2 can be recalled if GPS connection cannot be established.

NOTE : Prior to the loss of GPS reference, **LT4670 PTP-GM A** was the Grandmaster, but now it's going to be sending PAL BB w/VITC reference, so we have a time-based lock on the **LT4670 PTP-GM B** however, **LT4670 PTP-GM A** is running on an internal oscillator, so it's ClockClass is going to be 248 and as **LT4670 PTP-GM A** is locked to **LT4670 PTP-GM B**, its ClockClass is going to be 220.

NOTE : The Leader **LT4670 PAL BB** W/VITC output only supports SMPTE 12M-1, which means that only the hours, minutes and seconds information is available. If day, month, and year information is required then PTP should be used instead of PAL BB W/VITC as a reference source.

So, this will result in the Grandmaster switching from **LT4670 PTP-GM A** to **LT4670 PTP-GM B.**

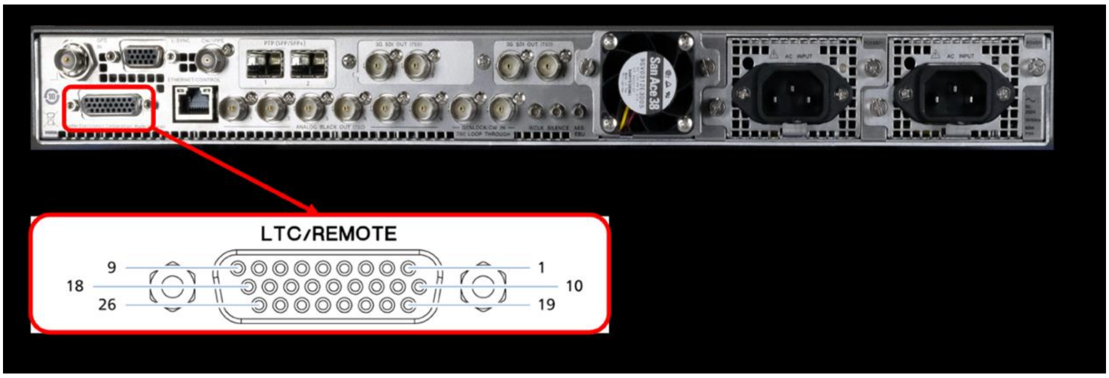
18. Ensuring PTP & BB/TLS come from the same SPG

For facilities that are using the LT4670's to provide both BB and PTP reference sources to both the SDI and IP infrastructure, the switching of the Grandmaster by the BMCA from **LT4670 GM-PTP A** to **LT4670 GM-PTP B** or the forced changeover of BB by the switching of the LT4448 Emergency Changeover unit, will result in the BB reference and PTP reference coming from different LT4670's and creating potential issues.

To overcome this issue, Leader recommends configuring the LT4670's as follows.

Blackburst failure resulting in BCMA switching PTP Grandmaster.

The LT4670 features on the rear panel an LTC Signal I/O and Remote Control 26 pin D-Sub connectors.



You can use PRESET1 to PRESET4 to recall pre-sets 0 to 9 on the LT4670.

Pin No.	I/O	Pin Name
1	I	LTC+
2	-	GND
3	O	LTC1+
4	O	LTC2+
5	O	LTC3+
6	-	GND
7	O	ALARM1
8	O	ALARM2
9	-	RESERVED
10	I	LTC-
11	-	GND
12	O	LTC1-
13	O	LTC2-
14	O	LTC3-
15	-	GND
16	-	RESERVED
17	-	RESERVED
18	-	OPEN
19	-	SHIELD GND
20	I	PRESET1
21	I	PRESET2
22	I	PRESET3
23	I	PRESET4
24	-	GND
25	-	RESERVED
26	-	SHIELD GND

Preset Numbers	23p	22p	21p	20p
	PRESET4	PRESET3	PRESET2	PRESET1
0	H	H	H	L
1	H	H	L	H
2	H	H	L	L
3	H	L	H	H
4	H	L	H	L
5	H	L	L	H
6	H	L	L	L
7	L	H	H	H
8	L	H	H	L
9	L	H	L	H

As the Best Master Clock Algorithm (BCMA) is used to select the Grandmaster, if we build a pre-set with a lower PRIORITY 2 value, when a BB/TLS failure occurs, the LT4448 can trigger an alarm that triggers a pre-set recall on the LT4670, so the BMCA switches the Grandmaster.

PRIORITY1 : 10
CLOCK CLASS : 6
PRIORITY2 : 10

PRIORITY1 : 10
CLOCK CLASS : 6
PRIORITY2 : 9

The LT4670 presets are binary and the LT4448 outputs will be High when selected and low when not selected.

So, to trigger a switch, use Pin 3 to switch on, it will go low when not primary.

If you want Auto return use pin 4 to call the Normal operation when the SPG is switched back to Primary. (You may want to control that manually.)

Use Preset 0, 1, 3, 7 these are all single low recalls.

See table below

3	SYNC SOURCE (PRIMARY)	O	Transmits a high-level signal when SYNC SOURCE is set to PRIMARY.
4	SYNC SOURCE (BACKUP)	O	Transmits a high-level signal when SYNC SOURCE is set to BACKUP.

Make Preset 0 or 1 the power on Normal Preset, Make Preset 3 the switch Preset

Pin 3 of the LT4448 to Pin 22 (preset #3) to switch and Pin 9 of the LT4448 to Pin 24 of the LT4670 (GND)

Recalling Presets

You can use PRESET1 to PRESET4 to recall presets 0 to 9.
Apply L according to the table below.

Table 6-5 | Recalling presets

Preset Numbers	23p	22p	21p	20p
	PRESET4	PRESET3	PRESET2	PRESET1
0	H	H	H	L
1	H	H	L	H
2	H	H	L	L
3	H	L	H	H
4	H	L	H	L
5	H	L	L	H
6	H	L	L	L
7	L	H	H	H
8	L	H	H	L
9	L	H	L	H

BCMA PTP Grandmaster switching resulting in LT4448 switching from Primary to Backup LT4670.

The LT4670 features the ability to turn BMCA Linkage ON and OFF.

If you set the BLACK1 LINKED TO PTP1, the Black #6 output is stopped in linkage with BMCA of the selected PTP.

Once the black output is stopped, this will trigger the LT4448 Emergency Changeover unit to switch from the Primary LT4670 to the backup LT4670, so the BB reference signal follows the PTP.

Leader

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