Lockdown Rock – The show must go WAN

White Paper - AoIP over WAN with DirectOut Equipment

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DirectOut GmbH

Leipziger Straße 32
09648 Mittweida
Germany

T: +49 3727 5665-100
F: +49 3727 5665-101
www.directout.eu

Introduction

During this period of lockdown for the majority of the countries in the world, network audio and remote production gain even more importance. Many artists and participants of broadcast productions are required to work from home, increasing the demand for high-quality (uncompressed) audio transmission via WAN. In many cases, no dedicated network connections can be used and standard domestic internet connections such as DSL are the only available option.

In this White Paper DirectOut lays out how those may be used with DirectOut's RAVENNA implementation RAV.IO in the PRODIGY.MP and what constraints and prerequisites need to be considered in such a setup.

Scope

- RAVENNA (as well as AES67 and ST2110) was designed to work in a managed or engineered network with predictable behavior. The reliability of DirectOut's RAVENNA implementation has been proven in such networks many times and has also been officially tested as part of the JT-NM Tested Events.
  Link: www.jt-nm.org/jt-nm_tested

- Running RAVENNA on a standard internet connection lacks the predictability of an engineered network and the achievable results will vary a lot, depending on the infrastructure that is available in different places/countries.

- This approach is not meant to be a replacement for products like Zoom, GoToMeeting or Skype. But it offers a way to transmit uncompressed audio over the same connection if a dedicated WAN link is not feasible.

- Extra knowledge about networking is required to connect standard streams, since it is obvious that RAVENNA was not originally designed to be used over standard internet and with domestic ISP, but managed connections.

- The amount of latency and the audio quality is prone to vary due to lots of different conditions (number of places connected, quality of the connections, number of required channels, type and quality of extra routers required, extra video required, presence or absence of a GPS link, etc.) and the end user must be aware of what he can achieve when choosing one of the several options: the more budget and effort is available for the network connections, the higher the quality of the results. The DirectOut hardware is fully ready to offer always the maximum quality and reliability.

The final result can only depend on the strength, the quality, and the speed of the internet connection between the several DirectOut devices.

Quality Levels

We defined several quality levels to categorize the possible circumstances under which a production might use RAVENNA over WAN.

A Private and dedicated layer 1 link with guaranteed bandwidth and GPS linked PTP Grandmaster in each location.

A2 Private and dedicated layer 1 link with guaranteed bandwidth with **no** GPS linked PTP Grandmaster.

B Corporate Internet connection with public IP, guaranteed and symmetrical bandwidth, VPN provided and managed by the ISP, and GPS linked PTP Grandmaster in each location.

B2 Corporate Internet connection with public IP, guaranteed and symmetrical bandwidth, VPN provided and managed by the ISP with **no** GPS linked PTP Grandmaster.

C Home Internet connection with public IP, guaranteed and symmetrical bandwidth, VPN created by the user with dedicated and programmed routers, with GPS linked PTP Grandmaster in each location.

C2 Home Internet connection with public IP, guaranteed and symmetrical bandwidth, VPN created by the user with dedicated and programmed routers, with **no** GPS linked PTP Grandmaster.

D Home Internet connection with public IP, **without** guaranteed and symmetrical bandwidth, VPN created by the user with dedicated and programmed routers, with GPS linked PTP Grandmaster in each location.

D2 Home Internet connection with public IP, **without** guaranteed and symmetrical bandwidth, VPN created by the user with dedicated and programmed routers, with **no** GPS linked PTP Grandmaster.

General Prerequisites and Constraints

Contrary to dedicated links, when using public internet connections, the user has no access to the switches that handle the network packets whatsoever. Each endpoint (i.e. the house connection of the user) has an IP address provided by the ISP. A VPN is required to put all devices in one virtual network and provide accessibility between all nodes.

Depending on the capabilities of the VPN, it might be required to use purely unicast for both PTP and RTP streaming. DirectOut's RAV.IO offers this functionality.

The biggest issue we have to face when using a standard internet connection, is the unpredictable packet jitter. As the bandwidth is not guaranteed, the travel time of the packets will vary a lot.

PTP

In networks with PTP-aware switches the PTP quality is extremely good. PTP-Jitter is exceptionally low (below 1µs) and the synchronization between two devices is as accurate as with an AES11 compliant word clock sync.

When using public internet connections, no PTP-aware switches are available. It is preferable to use GPS-synchronized Grandmasters in every location in this case. PTP messages must be blocked between locations in this case[1].

If no GPS-synchronized Grandmasters can be used, the PTP messages have to be distributed inside the VPN over the connection that is available. As a result, the PTP-Jitter will increase significantly. DirectOut's RAV.IO offers a set of **Jitter filters** that can be applied in such cases. By that the devices are still able to synchronize to a remote PTP Grandmaster even if the packet jitter is high.

Streaming

The RTP packets also suffer from packet jitter. The solution here is to use a big input buffer in the receiving device. Buffer sizes of several 100 milliseconds can accommodate a huge packet jitter. This increases the stream delay, of course. However, for (real-time) monitoring a stream with low latency should be used where sporadic packet loss is accepted. This is crucial to make the artists feel well when they perform together. To save bandwidth, 16 Bit Audio encoding can be used for the monitoring streams. Still, depending on the available internet connection, the achievable stream delay for the monitoring stream might not meet the expectations of the musicians. This needs to be tested on a per-case basis.

Even with large packet buffers it may happen that packets just get lost during their travel through the internet. Neither RAVENNA nor AES67 or ST2110 implement the possibility to re-transmit packets, so this is an error which cannot be recovered.

[1] Blocking PTP is only required if the Grandmaster sends multicast PTP packets.

To minimize the impact of such packet losses it is a good practice not to use the highest packet time available for a stream. Smaller packet times increase the required bandwidth, but a medium value will offer a good trade-off between bandwidth and the number of samples lost if a packet gets dropped.

Of course, the most effective instrument against lost samples is using **redundant streams**. With DirectOut's RAV.IO you can set up both unicast and multicast streams redundantly to address this issue and improve the reliability of the transmission significantly.

Results

Depending on the infrastructure that is available, different quality levels can be achieved. In any case the net bandwidth provided by the internet link is the limiting factor.

All levels that make use of "Home Internet" connections must be considered a "workaround" for situations where no other option can be chosen. The audio transmission is much better than any conference app that uses compression, but this solution cannot be considered professional as long as the quality of the connection is not professional as well.

In particular, the quality levels offer possibilities as follows:

Level D2

This is the "worst case scenario" but at the same time the one that will be available in most places with little additional effort. Nothing is guaranteed regarding the transmission link. Thus, only a few audio channels can be submitted to leave sufficient "headroom" in case the bandwidth fluctuates. Be aware that the bandwidth of the connection might be asymmetrical (i.e. 100 MBit/s download, 20 MBit/s upload).

Heavy filtering of the PTP sync will ensure synchronization. However, the resulting clock will most probably not be stable enough to synchronize external hardware. Internal SRCs in the PRODIGY.MP fix this situation. Audio signals coming from different locations might not be completely phase accurate.

Level D

The GPS-linked Grandmaster now ensures phase accuracy. Still the streaming packets require a lot of buffering to cope with fluctuating bandwidth. But due to the accurate timestamps the resulting audio signals will all be aligned among the locations involved. The number of channels needs to be reduced to keep enough "headroom" in case the bandwidth is reduced sporadically.

Level C2

In this case a higher channel count might be achievable as the bandwidth is guaranteed and one can rely on bandwidth calculations for the streaming. Phase accuracy will suffer from PTP jitter.

Level C

Again, the GPS-linked Grandmaster improves the phase accuracy. PTP Jitter filters are not required.

Level B and B2

The difference to the other Levels is the VPN being provided by the ISP. A powerful implementation and professional management of the VPN can be expected. As with the other levels a GPS-linked Grandmaster is preferable. Level B can be considered for professional productions.

Level A and A2

Those can be used for professional applications. All parts of the link are configurable by the user or provided with guaranteed and predictable behavior by a service provider. Layer A is preferable due to better PTP conditions.