To Stream or Not to Stream, is This the Question? Or, How to Stream Laser Shows the Better Way: Video Preview or Raw IDN (ILDA Digital Network) ?

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Abstract — **This demonstration presents different options of streaming laser shows over the Internet. Just like with other cultural or show based happenings, streaming the live event with video and audio transmission seems to be the most obvious option. For the transmission of laser show related data, the International Laser Display Association (ILDA) is working on the novel protocol suite of the ILDA Digital Network (IDN). Although up to now the IDN protocols were primarily used in local network environments, the data transmission over longer distances via the Internet could be feasible as well. Our demo will give some insights on IDN capabilities and will show a prototype setup for Internet streaming of laser shows using IDN.**

I. INTRODUCTION & MAIN MOTIVATION

Current Corona times limit conference and event travelling on a world-wide scale. Since March 2020 and lock down in many countries of the world many events like conferences, trade shows, cultural events, etc. needed to be cancelled on very short notice. To keep people still able to communicate, the use of video conferencing tools significantly increased also in areas where remote conferencing would have never been used before. However, video conferencing often does not offer the same convenience or authenticity for some applications, like live music performances or a play in a theater. Laser shows are widely used for entertainment purposes, both for accompanying other events like a music concert or a product presentation at a trade show, and also for events fully dedicated to the laser shows themselves, e.g. laser show presentations in a planetarium.

One other category of related events is the meeting of hobbyists and/or professionals to exchange ideas, discuss and present hardware and software for laser show activities and also deal with surrounding aspects like artistic issues, laser safety and education, among others. There are regional and national events, such as being organized frequently by individuals of the German LaserFreak community [1] in Germany, and so called "*LEM" events (… Laser Enthusiast's Meeting, e.g. SELEM in the United States, DutchLEM in the Netherlands, UKLEM in Great Britain and others, cf. [2]). The ILDA as the professional business association for the laser industry is hosting an annual conference typically in November for its international membership. At such events, both on hobbyist and also professional level, people meet and one primary goal is to watch and enjoy laser show presentations together in the group.

Due to Corona, several of such events had to be cancelled. E.g. a larger German national LaserFreak meeting for the occasion of the 20th anniversary of the LaserFreak online forum [1] falling together with the 60th anniversary of the invention of the laser had to be cancelled (was May 16, 2020). At extremely short notice with preparation from one to the following day, a spontaneous video conference was held on May 16, 2020 – also showing some laser shows from different participants by simply streaming a video camera capture and audio via microphone or line in. This was acceptable for the spontaneous setup, but could be improved in quality with appropriate preparation and some more sophisticated hardware and software.

The 2020 ILDA conference scheduled for November 20 - 22 is preparing the capabilities and opportunities of having a laser show related conference event in a virtual fashion "via cloud" (or Internet). At the time of finishing this LCN demo proposal for final publication, ILDA envisages presentation of laser shows streamed from the participant's home or office laser studio by common audio + video streaming services.

Our LCN demo will show and compare different ways of showing laser shows in a remote way to different locations in the Internet. This includes a prototype setup for streaming the raw digital data for laser projectors based on IDN protocols between different locations of participants spread all over the Internet.

II. BACKGROUND INFORMATION ON ILDA DIGITAL NETWORK (IDN)

The International Laser Display Association (ILDA) defines the de facto technical standards used in both laser show hardware and software. The analog ILDA Standard Projector (ISP, [3], the connector is also called ISP-DB25) was the relevant specification on how to connect laser control interfaces with laser projectors in a vendor-independent way. Each laser projector was connected to a control-interface by an analog cable with DB25 connectors (25 wires carrying the signals for

X, Y, colors Red, Green, Blue and others), if necessary over long distances.

The ILDA Digital Network (IDN) Stream Specification is a novel standard to transmit laser show artwork in digital data streams [3]. The digital transmission allows for very flexible setups as opposed to the old analog transmission systems. For example, in previous work we have already shown how an IDN software driver can complement existing laser show software to directly generate IDN streams [4]. These are being sent into the local network with destination to an IDN capable laser projector or a suitable IDN-to-analog converter for legacy ILDA controlled laser projectors, the so called DexLogic StageMate ISP, cf. [5]: It can generate the analog laser projector signals for ISP-DB25 from incoming IDN streams. It fully implements the IDN stream specification.

Instead of going to laser projectors directly, the so called IDN-Switcher can redirect and replicate IDN streams so that multiple IDN producers can be "mapped" conveniently to a certain number of laser projectors [6].

Furthermore, the transmitted IDN streams can easily be received and analyzed to help with testing and debugging of laser show systems. For this purpose, we have developed the IDN-Toolbox, which is able to display the received IDN stream data on a 2D computer screen [7]. With a different software, a more authentic approach on virtual laser show visualization from IDN streams using virtual reality (VR) headsets is possible: Using a VR headset, the user can move around in a virtual room with several virtual laser projectors and watch laser show artwork generated by typical laser show software. Even without a VR headset connected, the user will see a 3D preview on the computer screen and is able to use keyboard controls to move around in the virtual show room. The so called IDN-Laser-VR software has been presented in [8].

All these heterogeneous elements of IDN are depicted in Figure 1, the IDN producers (generating IDN streams) on the left hand side, the IDN consumers on the right hand side and the IDN-Switcher at center bottom.
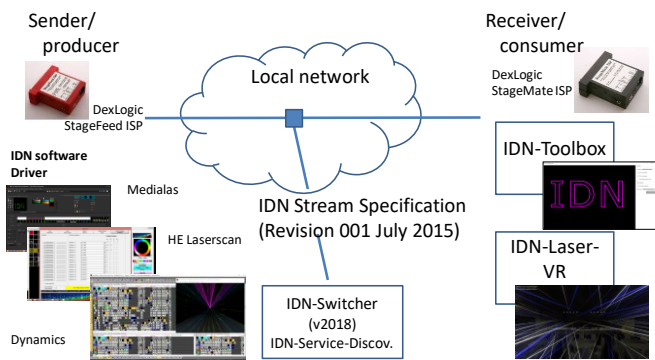

Figure 1. **IDN Producers and Consumers.**

It is also important to understand the content of the IDN streams. The so-called IDN channel messages contain a sequence of laser projector samples each with values for X and Y coordinates and at least three colors, red, green and blue. A laser projector as IDN consumer would use these sample values to generate the control signals of X and Y mirrors for laser

beam deflection and the color signals (R, G, B) for control of multi-color laser modules. The sample sequence describes the laser projection in a vector-oriented style, similar to probably known from "connect the dots" puzzles.

The IDN laser projector service has two modes, the discrete graphic mode, and the continuous graphic mode. In discrete graphic mode (aka "frame mode"), the IDN channel message contains an arbitrary number of frame samples. Typically, the discrete graphic mode frame samples are generated in a laser show software system, which is the original source of the laser show artwork. The frame with all of its laser samples will be continuously projected and repeated, if no new IDN channel message arrives at the IDN consumer. An example of a full laser graphics frame can be seen in Figure 2.

Figure 2. **Preview of IDN laser data in IDN-Toolbox (2D).**

In the continuous graphic mode (aka "wave mode", an IDN channel message carries a certain number of laser projector wave samples, which is part of an uninterrupted sequence of samples representing a waveform. Preceding and successive IDN channel messages contain other parts of the sample sequence and the integrity of the overall uninterrupted sample sequence can be verified by a sequence number and a (relative) timestamp field in the IDN channel message headers. This is also called "wave mode".

A typical application of the IDN wave mode is the use of analog to digital converters to connect to legacy laser show systems that are not able to directly generate IDN streams from the software. Here, an IDN converter (like the DexLogic StageFeed ISP, [5]) is connected to the ILDA ISP-DB25 analog output of the laser show system, one IDN converter for each laser projector, each generating a digital waveform of all laser control signals like the above mentioned X, Y, colors R, G, and B. The IDN stream specification requires a minimum sample frequency of 100 kHz for the representation of the laser control signals of ISP DB-25 in an appropriate quality. In terms of IDN wave channel messages carried in UDP datagrams, this equals a gross data rate of about 12 Mbit/s for the IDN stream for each laser projector.

In current implementations and use cases of IDN, typical local network technologies like Ethernet or Wireless LAN are used. Typically, all IDN producers and consumers (in particular laser projectors) were located on one site and the network

performance in a LAN with Gigabit/s data rate, negligible end-to-end delay and considerably low jitter was basically not limited.

III. Subject of the LCN demo

In the light of Corona limitations, the question came up whether the streaming of IDN digital data between remote locations would be feasible to allow IDN producers on one location to interact with IDN consumers on remote locations, even over longer distances via the Internet.

In the Laser & Light Lab of the Institute of Computer Science 4 at the University of Bonn (in the following short "UBN-LLL") we will prepare a full local IDN network setup with laser show software, the IDN-Switcher and several laser projectors. As a reference, a video and audio feed via a YouTube live channel will be set up, demonstrating the common way of streaming a camera view of an event with lasers to LCN demo participants.

To demonstrate the IDN data transmission over the Internet, the concept of virtual private networks (VPN) will be applied: A VPN server (based on OpenVPN protocols) will be prepared to allow connection from remote computers via the Internet. All connected computers will see an additional (virtual) network interface with private IP address and will be virtually connected. This virtual LAN allows for local network broadcast which is needed by some of the IDN protocols and would not be possible over the Internet without VPN.

One dedicated computer in the UBN-LLL LAN will additionally be integrated into the IDN VPN. It will execute the IDN-Switcher which will be able to map and replicate IDN streams to the lab network with real lasers and the IDN VPN.

External computers (from LCN demo participants) will be able to connect to the IDN VPN, will then receive IDN streams with the sample data for laser projection and can use our software IDN-Toolbox or IDN-Laser-VR to visualize the laser data stream in 2D or 3D preview on the computer screen in real-time (even without a VR headset, or real laser projector). The tools can be used to compare the visualization of received IDN streams at their own location with the video/audio feed via the live YouTube stream.
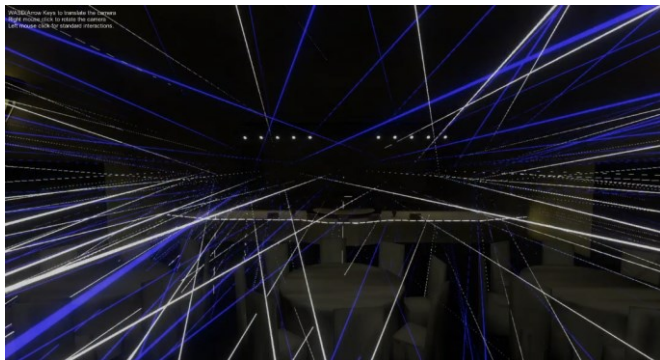

Figure 3. **Preview of IDN laser data in IDN-Laser-VR (3D).**

Figure 2 already showed an example of laser graphics projection taken from a screenshot of the IDN-Toolbox and Figure 3 shows the IDN-Laser-VR visualization of laser beam effects in mid-air when using artificial haze or fog.

The intended scenario allows for different levels of participant interaction for the LCN 2020 demo:

- "Passive" – just watch the demo presentation live in the conference stream

- "Medium Active" – also watch the YouTube live stream with video from the real laser setup and audio/music coming from the UBN-LLL

- "Fully Active" – as above, and additionally get the own computer integrated in our IDN VPN

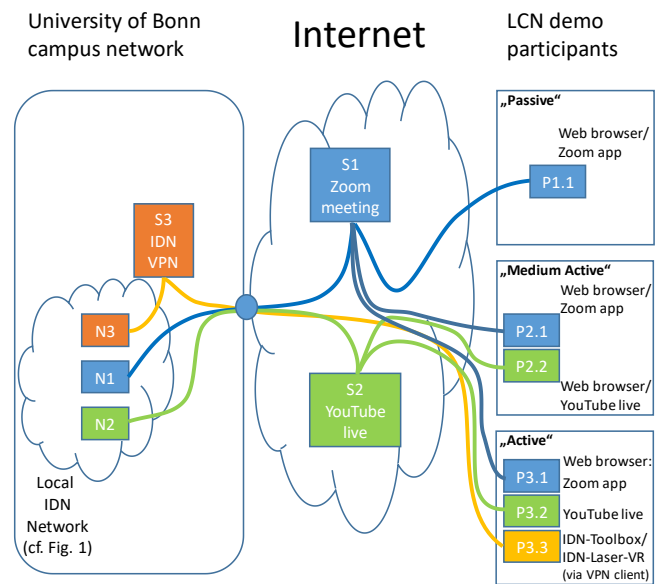Figure 4 shows the overall demo system/network architecture illustration.

Figure 4. **LCN demo system/network architecture illustration.**

The conference organizers provide a video conferencing platform for demo presenters, presumably a Zoom meeting (server S1 somewhere in the Internet). All demo participants join the Zoom session (P1.1, P2.1, P3.1) and a computer in the local IDN network (node N1) will be the source of audio, video/screen sharing for the demo presentation.

Furthermore, another computer (node N2) will feed an audio + video stream to a YouTube live server (S2). Demo participants can easily access the live channel on their web browser (P2.2 and P3.2, in addition to the Zoom meeting).

The IDN VPN server is operated inside the University campus network. The node N3 in the local IDN network executes a VPN client and also the IDN-Switcher (cf. section II). The IDN-Switcher thus has access to two network interfaces and is able to replicate IDN streams coming from IDN producers and map these streams to both IDN consumers

in the local IDN network (mainly the real laser projectors) and also the IDN visualization software running on a computer of an LCN demo participant. P3 in Figure 4 is a participant who also connects to the IDN VPN server S3 and executes either the IDN-Toolbox or the IDN-Laser-VR (P3.3).

For those interested in the "Fully Active" option, a web page will be provided giving detailed information on what to prepare: The installation of a Windows OpenVPN client, the configuration for the IDN VPN and starting the IDN visualization software will take about 5 to 10 minutes. It is possible to execute all components on the same computer (incl. conference stream and YouTube feed). However, preferably at least a second monitor or even a second computer might be helpful.

IV.   CONCLUSION AND FUTURE WORK

In the demo preparation phase we used an external OpenVPN server outside the network of University of Bonn to make realistic experiments between distinct locations in the Internet, namely the University network, the VPN server operated in Southern/East Germany and additionally the private home network of the author via a public Internet provider. The preliminary results looked promising.

For the demo execution phase, the OpenVPN server will be operated at the University of Bonn. Thus, the UBN-LLL and the IDN VPN server are very close together (cf. Figure 4 N3 and S3) and the performance of streaming IDN data over the Internet is mainly dominated by the Internet connection of each demo participant and the provider connection and peering to the DE-CIX router in Frankfurt (which is the Internet exchange router with the German universities' network DFN).

An issue not yet covered is the streaming of audio together with the IDN data streams via the IDN VPN. For the LCN demo, the audio for pre-programmed laser shows synchronized to music will come via the YouTube live channel (or the conference stream) and may not be in perfect synchronization to the laser display. For future applications of IDN streaming via the Internet, the synchronized audio transmission needs to be kept in mind and could possibly be integrated into the IDN streams.

Furthermore, the OpenVPN server can either be configured to operate the VPN tunnel via TCP or via UDP (or even both in parallel and the connecting client can choose the appropriate OpenVPN profile). Concerning the streaming of IDN data it has to be noted that current IDN implementations are using UDP to carry the IDN channel messages. In the IDN frame mode, a delay or even loss of a UDP datagram (carrying an IDN channel message with a full frame of laser graphics) would only lead to a loss of smoothness in the animation of a frame sequence (just like losing full frames of an MPEG video stream). In the IDN wave mode, a loss or delay of a subset of stream samples (i.e. a part of the continuous stream of laser samples) would lead to outages of the laser projection. This would be noticeable to the spectator, just like missing audio sample chunks in a live audio feed would be annoyingly observed by a listener. Using a VPN tunnel with TCP would provide reliability at the cost of speed/delay because packet retransmission will pile up subsequent IDN channel messages until a packet loss has been recovered. Follow-up activities may evaluate the performance differences between TCP or UDP tunnels in the IDN streaming scenario, in particular with real laser projectors.

For professional users with IDN consumer hardware (and real laser projectors) it would be possible to use another instance of the IDN-Switcher at the remote site to map and redirect IDN streams to real IDN laser projectors in the local network on that side. This option may be further evaluated in view of the (virtual) ILDA conference starting Nov. 20, 2020, or also follow-up activities in the future.

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