Demonstration of Bandwidth Demand and Jitter Properties of a Software Sender/Scheduler for the (proposed) ILDA Digital Network

Matthias Frank
University of Bonn
Institute of Computer Science 4 / Laser & Light Lab
Friedrich-Ebert-Allee 144, D-53113 Bonn, Germany
matthew@cs.uni-bonn.de
http://lll.net.cs.uni-bonn.de/

***Abstract* — this demo proposal presents continued work of the Laser & Light Lab at the Institute of Computer Science 4 of the University of Bonn based on earlier LCN demo presentations and on proposed standardization work of the International Laser Display Association (ILDA). The ILDA has started to work on defining a possible standard and protocol for digital transmission of laser projection/picture data over a local network, so-called (proposed) IDN – ILDA Digital Network. The Laser & Light Lab got involved into a proof-of-concept implementation of a software-based sending side of IDN, interoperable with DexLogic StageMate ISP [1], an FPGA-based hardware receiver implementing the (proposed) IDN protocol.**

The demo presents a setup with professional/commercial laser show software, supplemented with our software library for IDN, operating over 100 Mbit/s and Gigabit-Ethernet to a set of IDN-receivers. We will illustrate the bandwidth demand for real-time streaming of laser data (e.g. overloading a 100 Mbit/s link) together with jitter properties. The indirect interplay of sender and receiver(s) plays an important role in this application scenario.

Keywords – IP-based network control; Laser projection; Local area networks; Multimedia & real-time streaming; Scheduling

I. INTRODUCTION & MOTIVATION

Some relevant basic information on laser show systems and their relation to the topic area of computer networks have been given in the LCN 2011 and LCN 2009 demo papers of the same author, see [2] + [3]. Laser show systems can be considered to be among the most visible applications of lasers and probably the most entertaining ones. Introductory information on how laser shows work can be found in [4].

Relevant for the network related aspects of our demonstration are the following three types of elements that are needed to run a laser show system:

- A computer, running the laser show software, that is able to control one or more laser projectors
- One or more laser control interfaces, each controlling one laser projector
- One or more laser projectors, each projecting colorful beam or screen effects coming from a single laser beam redirected in X- and Y-orientation (examples see [4])

To connect these elements, there are several standards that are in use. The typical way to connect a computer with the laser control interface(s) is via USB (Universal Serial Bus) or over a TCP/UDP/IP based local area network.

The connection between a laser control interface and the laser projector typically is done according to the so called ILDA Standard Projector (ISP). The ISP [5] is one of the relevant standards of the ILDA, the majority of commercially available laser projectors offer an ILDA ISP-DB25 input. The ISP defines some hardware configuration, among others the ISP-DB25, a DB25 connector and signal specification for the cable connection between an ILDA-compatible laser projector and a laser control interface. The ISP-DB25 contains the X- and Y-signals used by the laser projector to generate a laser picture by (mechanical) redirection of the laser beam. It also contains color-signals, e.g. red, green and blue for a three-color laser projector (also six color channels are common for high-end laser projection systems).

It has to be noted that the ISP connection uses analogue signals, generated in the laser control interface, received by the electronics of the laser projector to directly control the X-Y-scanning systems and the laser modules for each color. Between the laser control interfaces and each laser projector an individual DB25 cable is needed. If a laser control interface is connected to the computer with USB, the ISP-DB25 may have significant lengths of several 10's or 100's of meters, depending on the overall scenario and topology of the laser show setup (fixed installation in a music hall or discotheque, live installation at a rock/pop concert in a huge venue like sports arena, and others). The analogue cabling quickly becomes subject to interference (signal level distortion, ground loops …) which may significantly degrade the laser show projection quality.

Another option of connecting the computer to the laser control interface(s) is via a local network. The development of this concept already started some years ago, commercial products on this became available in recent years (e.g. the so called NetLase interface, manufactured by [8] for own integration into a laser projector; the "Infinity ShowLaser" projector manufactured by [7], the Pangolin QM2000.NET [9], or Moncha.NET [10] – among others).

The advantage of a laser system set-up with network-based control is the digital transmission of the relevant data over longer distances. The physical network technology might be Ethernet or Wireless LAN, the Internet Protocol family with IP and TCP or UDP most probably is used as protocol suite for OSI layers 3 and 4. The laser control interface typically still is connected to the laser projector via the ISP-DB25, but as the control interface is closely located to the laser projector (or integrated into), the lengths of the (analogue) cable/connection is short and therefore interference issues are minimal.

Unfortunately, this concept of digital transmission of laser projection data is currently only available in proprietary solutions of commercial products. At least some of the vendors offer a documented library API to allow own laser show software to control the respective laser control interface via the network. But the protocol used between the software library and the laser interface is not documented. Other solutions are fully closed and by intention the operation from specific laser show software is only possible with a (network-controlled) laser control interface coming from the same vendor.

Meanwhile the ILDA has started discussion on network-based laser projection within its technical committee and in the annual ILDA conference. Mid- to long-term goal might be to develop another open ILDA standard for digital transmission of laser projection data over packet oriented networks to allow different types of laser show software and different types of laser projection systems to interact (working title "IDN – ILDA Digital Network").

The Laser & Light Lab [6] of the Institute of Computer Science 4 at the University of Bonn (in the following short "Uni-Bonn-LLL") builds on conceptual and programming experience in networked environments for laser show projections systems, as was already presented with the LCN 2009 and LCN 2011 demos [2] and [3]. Currently, Uni-Bonn-LLL as a non-profit ILDA member contributes to the IDN development and proof-of-concept implementations.

The following subsections shortly outline the basics of IDN, our contribution to IDN prototyping and describe the practical demonstration envisaged for the LCN 2014 conference in September 2014.

II. IDN BASICS

The current (proposed) version of IDN has been developed by ILDA member company DexLogic [1]. Based on long-time experience on development of laser projector control boards and interfaces, DexLogic defined the protocol for IDN (header and data unit formats, behavior of peer endpoints …). "*IDN (under development) is planned as a standard for the transmission of laser, DMX512, audio and other sources across packet oriented network links*" (cited from [1]).

Furthermore, DexLogic has developed the so called StageFeed ISP and StageMate ISP hardware: StageFeed is a network sender (FPGA-based), digitizing the (analogue) ILDA ISP-DB25 signals (several channels) and sending this digital data over an Ethernet based network according to the (proposed) IDN. The StageMate is the network receiver, receiving according to the (proposed) IDN and generating the respective analogue signals for the ILDA ISP-DB25. The StageMate typically will be located very close to a laser projector (or integrated into). The typical scenario for operating a pair of StageFeed and StageMate is a **cable replacement of the analogue ILDA cable over long distances**. Multiplexing of several connections over a single network link is possible.

Another IDN scenario directly arises from our categorization of network elements as given in the introduction/motivation section: The computer running the **laser show software could directly generate data packets according to the IDN protocol and send these packets to one (or more) StageMate ISP** (one for each laser projector used in the setup). This scenario requires appropriate capabilities of the laser show software (e.g. a library attached to it) to generate the packet stream. The development of a software based sending side of the IDN protocol is main subject of work of Uni-Bonn-LLL.

A third IDN scenario has to be mentioned: The StageFeed ISP(s) can be used to **digitize the output of one (or several) laser control interfaces and send the digital stream to recording software**. A complete (multi-projector) laser show could be digitally recorded and could be played back (with StageMate ISPs) independently from the original laser show software. The same feature in the (analogue) ILDA world was prominently accomplished by the ADAT recording. This IDN recording scenario is not subject to our current interest and therefore will not be further discussed.

Finally, it has to be noted that the (proposed) IDN protocol has not yet been published. Draft/preliminary versions are available to ILDA members or other partners interested to work with or contribute to the IDN project.

Our implementation of the software-based sending side of IDN **started early in 2013**. DexLogic provided a prototype of the StageMate ISP (network receiver) together with a preliminary draft description of the IDN protocol. In the cable replacement scenario with a pair of StageFeed/StageMate ISPs, the basic operation of the IDN protocol is in streaming mode: The StageFeed ISP has a multi-channel analogue digital converter (ADC) operating with a sampling frequency of 100 kHz. The ADC converts a total of 10 channels (ILDA X, Y signal, typical color signals R,G,B, and additional optional channels, e.g. for 6 color operation). 100 samples will be sent in a single UDP packet, 1000 packets will be sent per second (with an inter packet time of 1 ms), summing up to a total bandwidth of about 12.5 Mbit/s including IDN, UDP, IP and Ethernet header overhead.

The streaming mode equals typical real-time communication with a constant bitrate usage of the communication channel. The IDN header contains timestamp information for a sample chunk and duration information for the sampling playback on the receiving StageMate ISP, e.g. duration of 1000 µs for 100 samples equals the sampling rate of 100 kHz. The FPGA and digital analogue converter (DAC) on the receiving side are able to work with a maximum sampling frequency of 250 kHz (which is more than sufficient for high-end laser projection systems).

Some challenges arise when the sample stream (or UDP sample chunk stream) should be directly sent from laser show software. The FPGA-based implementation in the StageFeed ISP is a highly optimized implementation focusing on the necessary functions for sample ADC and IDN protocol processing (including a UDP/IP protocol stack and Ethernet NIC). Implementing the sending side in a (software) library, attached to laser show software on a COTS computer raises several challenging issues on the performance of the implementation and the overall system:

- Efficiency and performance of the laser show software (generating the laser picture data)
- Efficiency and performance of the IDN sending protocol software (library), including a scheduler for timely delivery of IDN sample chunk UDP packets
- Performance of the operating system (Windows, Linux), in particular the protocol stack to send out the real-time stream of UDP packets
- Overall performance possibly influenced by other applications, background services, GUI operations, etc.

Despite these challenges, it was possible to implement a library that is able to accept laser picture frames via API function calls, a common way for laser show software to interact with a laser control interface. Our library implements a scheduler which generates the sample stream for IDN that is needed to periodically project the laser picture.

In **November 2013**, the first prototype of the software-based IDN sender was demonstrated at the annual ILDA conference (at that stage, it was Linux-based). In **March 2014**, a standalone Windows library implementation attached to a commercial laser show software system was completed and later was presented to the public at a popular German national laser user-group meeting.

III. Scope and Significance of the Demo

The proposed demo for LCN 2014 will present a setup with professional/commercial laser show software, supplemented with our software library for IDN, on a Windows system. With 100 kHz sample streaming, the data rate for controlling a single laser projector is about 12.5 Mbit/s. In the current version, the library can dynamically adapt to sampling frequencies of up to 200 kHz (when needed by the laser show software, equaling about 25 Mbit/s network load). For a set of several streams for more than one laser projector, it is easily understood that a single Ethernet link of 100 Mbit/s is quickly overloaded.

The demonstration will show the bandwidth demand in the IDN streaming scenario, while also looking at the jitter observed on the receiving side. Main contributor to delay and jitter is the sending computer (cf. discussion in section II), rather than the Ethernet network, as this is operated in full-duplex switched mode.

In the lab at Uni-Bonn-LLL, delay/jitter caused by the scheduler and/or performance limits of the sending computer can easily been observed from distortion in the laser projection. Furthermore, a log output from the StageMate ISP via a serial interface can frequently report on the system status and will indicate buffer underruns, if these occur. Additionally, dummy receivers implemented in software can collect data and present histograms of packet inter-arrival times. The latter two will be demonstrated at LCN 2014, as it probably is not possible to bring a laser projector to the demo in Edmonton.

Both a 100 Mbit/s and a Gigabit Ethernet link will be used in the demonstration. The first will likely have the bottleneck on the link, depending on the number of active IDN streams and the sampling frequency (and corresponding data rate). For a Gigabit link, the bottleneck will rather be on the sending computer, where the number of IDN streams need to be handled by the laser show software and the operating system including the network protocol stack. StageMate ISP buffer status log and dummy receiver inter arrival times histograms will illustrate the performance.

IV. Acknowledgements

The author wants to thank the student Simon Ofner of University of Bonn, who spent considerable time in 2013 working for a Diploma seminar and Diploma lab on the IDN prototype library implementation, continuing the work with some topics of scientific worth in his Diploma thesis in 2014.

Furthermore, special thanks go to Dirk Apitz from Dexlogic Karlsruhe, who provided early IDN protocol descriptions as well as all necessary StageMate ISP hardware that we needed to perform the lab measurements and do the demonstration at LCN 2014 in Edmonton.

It is intended to publish an extended version of the demo material as a University of Bonn technical report, summarizing the most important results and findings of the experiments performed with our software library for IDN.

References

[1] DexLogic Hardware and Software Solutions (ILDA member), Karlsruhe, Germany, http://dexlogic.com (last accessed June 24, 2014)

[2] Matthias Frank, An Experimental Architecture of IP-based Network Control of Laser Show Projection Systems, IEEE LCN 2011 demo publication, Bonn, October 2011, http://www.ieeelcn.org/prior/LCN36/lcn36demos.html (last accessed June 24, 2014)

[3] Matthias Frank, Network based real-time control of a laser show projection system, IEEE LCN 2009 demo publication, Zurich, October 2009, http://www.ieeelcn.org/prior/LCN34/lcn34demos.html (last accessed June 24, 2014)

[4] Laser F/X International, How Laser Shows Work - Introduction, http://www.laserfx.com/Works/IndexWorks.html (last accessed June 24, 2014)

[5] ILDA – International Laser Display Association, Orlando/Florida, USA, http://www.laserist.org (last accessed June 24, 2014)

[6] Laser & Light Lab, Insitute of Computer Science 4 (ILDA member), University of Bonn, Germany, http://lll.net.cs.uni-bonn.de/ (last accessed June 24, 2014)

[7] MediaLas Electronics GmbH (ILDA member), Balingen, Germany, http://www.medialas-showlaser.de/ (last accessed June 24, 2014)

[8] Müller Elektronik (ILDA member), Spaichingen, Germany, http://www.jmlaser.com/ (last accessed June 24, 2014)

[9] Pangolin Laser Systems (ILDA member), Orlando/Florida, USA, QM2000.NET: Network-connectable laser controller http://www.pangolin.com/LD2000/QM2000NET.htm (last accessed June 24, 2014)

[10] Showtacle (ILDA member), Bratislava, Slovakia, Moncha.NET http://www.showtacle.com/products/moncha-net (last accessed June 24, 2014)