Conservatorio di musica Giuseppe Tartini Trieste

Consortium GARR

LOLA (Low Latency) Project

Enabling remote real time musical performances over advanced networks

Project Description

LOLA project aims to enable real time musical performances where musicians are physically located in remote sites, connected by advanced network services, like the ones provided by the NRENs and GEANT and other International backbones.

The project motivation comes directly from musicians who are currently engaged into many geographically distributed activities (Concerts, MasterClasses, Teaching, Recording Sessions, etc.) which requires them a lot of travel and results in a big time waste.

LOLA provides a tool which permit musicians to perform many more reharshals before a concert, for example, giving them much more time to refine the performance before they join together for the event; they can engage in MasterClasses teaching students around the world even when they are located in distant sites, including the ability to perform together with the student during the lesson, and enabling many more students to participate without the need of travel; they can take part in recording sessions without the need to travel to the recording studio, etc.

But LOLA provides also the ability to perform real concerts for the public, with distributed performers, and distributed audience, too. It thus opens a new fully unexplored performance scenario, with new challenges and new opportunities.

LOLA is a project developed by Conservatorio di Musica Giuseppe Tartini from Trieste (Italy) in collaboration with GARR, the Italian Research and Academic Network, and was conceived in 2005 after a demonstration of the first intercontinental viola MasterClass between the GARR National User's Conference in Pisa (Italy), and the New World Symphony music academy in Miami (USA).

Apart from the Conservatorio Tartini site, which is connected to GARR backbone on a dark fiber, with a dedicated 1G lambda reserved for LOLA, provided by the Trieste Research Metropolitan Optical Network "Lightnet", the other remote site involved has been the IRCAM site in Paris, connected to

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RENATER also at 1Gb (general use). Other sites are on the way to participate in a wider experimentation of LOLA around European NRENs and Internet2.

The project research and development team is composed by Massimo Parovel (Conservatrio Tartini Director and project supervisor), Paolo Pachini (project coordinator), Carlo Drioli (software development), Nicola Buso (audio engineering, musical advice and testing) from Conservatorio Tartini, and Claudio Allocchio (network engineering and testing) from GARR; Teresa Trevisan and Flavio Zaccaria (piano duo and piano teachers at Conservatorio Tartini) are the project field testers and music consultants, providing user's experience feedback and setting the user's requirements.

Technical Challenges and Network Requirements

The big initial challenge for LOLA was to create audio/video CODECs with a very low latency: existing CODECs were far beyond the acceptable latency of 60ms (round trip time – RTT), which is the limit where human perception starts to detect a delay in sound and video. This study required a lot of investigation and field testing of different hardware and software solutions; most of existing developments, indeed, were optimized for non real time operations (recording) or for broadcasting (non interactive). Also the networking CODECs approach was conceived for slow, unreliable networks, resulting in higher latency, too.

The solution was identified by applying to audio/video conferencing device designed for high speed robotic and industrial processing control, re-writing from scratch both the camera and audio control software. The networking packet drivers were also greatly re-engineered, focusing on a different target network: fast, reliable and bandwidth over provisioned.

As a consequence, LOLA asks for a high set of end-to-end network features:

- Bandwidth: LOLA sends uncompressed audio/video data, grabbing them from the hardware and sending to the remote site over the network totally unprocessed. The amount of data sent depends on camera resolution, frame rate, and pixel depth: a 640x480 pixels, black & white, 30fps, 2x44100 24bit audio (minimal configuration) requires 94Mbps end-to-end; the color version, 60fps, is over

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500Mbps, and increases even more with higher video resolutions and audio multi-channels.

- Reliability: video, and especially audio, badly tolerate data loss. LOLA does not implement any data loss recovery feature to save time, thus the network must provide a very reliable 0 packet loss performance for hours.
- Stability: as LOLA does not buffer audio/video information (even if it can use some buffers, to adapt to less optimal conditions), network jitter must be very stable (<3ms at 30fps, <6ms at 60fps).
- Routing: LOLA can work both at layer 2 (Ethernet circuit) and layer 3 (routed IP). As any hop, especially at layer 3, introduces latency, the network path shall minimize hops. When available, end-to end layer 2 or layer 1 optical circuits (lambdas) should be used, and they become a requirements at the high configuration settings; at minimal configuration LOLA can run on shared IP circuits.
- QoS: LOLA is able to use DIFFSERV when available, to get better network perormances.
- Security features: any “action” on network packets introduces latency; thus firewalls, packet filters, etc. shall be avoided on the end-to-end path.
- NAT: also NAT introduces latency, and shall be avoided.
- Geographical paths: the longest is the physical patch end-to-end, the largest is the network latency (a rule-of-the-thumb states ~ 1ms per 100Km on current multi-Gigabit-style NRENs and backbones). Current NRENs and backbones do not (yet) consider “shortest geographical path” as a critical parameter in design. LOLA requires this to be considered, too.

The above considerations clearly show that only advanced NRENs and backbones (GEANT, Internet2, etc.) can satisfy LOLA requirements. Indeed, the challenge to further reduce latency is now on the network side (shortest path, faster electronics, circuits-on-demand, etc.).

The LOLA session between Trieste and Paris at the Network Performing Arts Production Workshop in November 2010 was done crossing the Conservatorio Tartini LAN, the Trieste Lightnet Metropolitan Optical Network, the GARR backbone, GEANT, the RENATER backbone, the IRCAM 1Gbps last mile and the IRCAM LAN.

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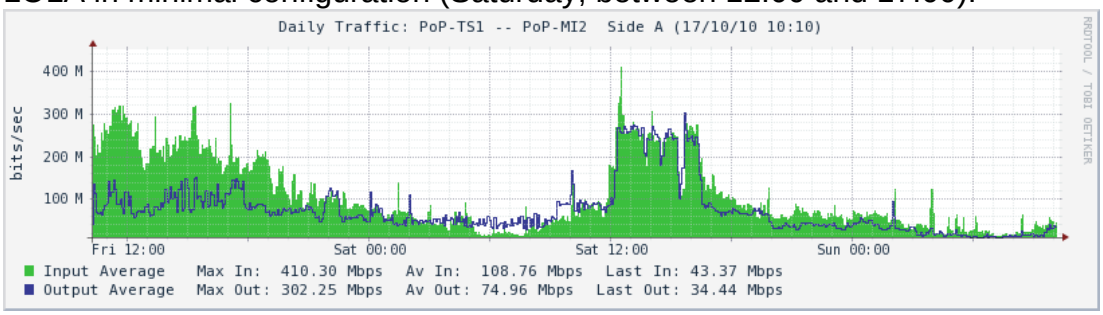
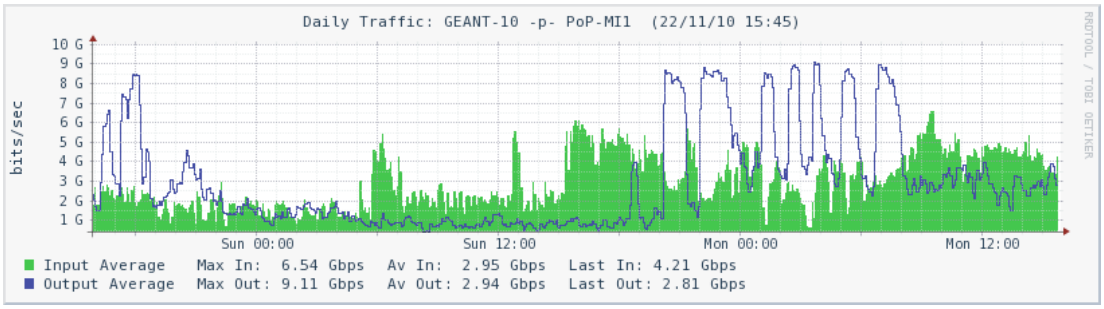
allocchio@BG-Tartini> traceroute 129.102.1.197
traceroute to 129.102.1.197 (129.102.1.197), 30 hops max, 40 byte packets
 1  ru-afamtart-rc-ts1.ts1.garr.net (193.206.142.145)  1.709 ms  1.094 ms  1.211 ms
 2  rc-ts1-rt-mi2.mi2.garr.net (193.206.134.205)  10.464 ms  10.283 ms  10.038 ms
 3  rt-mi2-rt1-mi1.mi1.garr.net (193.206.134.189)  10.141 ms  10.311 ms  10.351 ms
 4  garr.rt1.mil.it.geant2.net (62.40.124.129)  10.178 ms  10.302 ms  10.279 ms
 5  as0.rt1.gen.ch.geant2.net (62.40.112.33)  18.182 ms  17.663 ms  17.814 ms
 6  so-3-0-0.rt1.par.fr.geant2.net (62.40.112.30)  26.510 ms  26.558 ms  26.833 ms
 7  renater-gw.rt1.par.fr.geant2.net (62.40.124.70)  27.073 ms  38.517 ms  27.319 ms
 8   te0-0-0-0-paris2-rtr-001.noc.renater.fr (193.51.189.6)   27.656 ms   27.509 ms
27.522 ms
     MPLS Label=16128 CoS=0 TTL=255 S=1
 9  * * *
10  ircam-vl374-te1-4-paris2-rtr-021.noc.renater.fr (193.51.182.9)  27.430 ms  27.645
ms  27.261 ms
11  gw-dmz.rezo.ircam.fr (129.102.254.6)  27.673 ms  27.564 ms  27.586 ms
```

Here is the network use (GARR backbone between Trieste and Milan), with LOLA in minimal configuration (Saturday, between 12:00 and 17:00):



Apart from the technical issues above, during some of the tests it became clear that current GEANT backbone can run into bandwidth allocation conflicts for different applications. Here is another traffic graph showing LHC data transfers competing with LOLA streaming data, over the GARR-GEANT access link (Monday):



Thus, LOLA also required some bandwidth reservation (1Gbps) / traffic shaping in order to sustain its network requirements.

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Musical requirements and challenges

LOLA aims to reproduce the remote presence (audio and video) of the musician on the remote site, but at the same time is must be minimally invasive of the environment where the musicians perform. Thus, technically is requires a very careful sound capturing and reproduction system (surround); when reproducing the remote instrument, the biggest challenge is to make it sound as a real acoustic instrument being played there, together with the real instruments on site. Also the presence, “look and feel” of the sound image of the remote musician must fit into the local environment “as if he/she was there”, from the expected position, the expected size, etc. The technical installations shall also be “transparent” to the environment (one of the existing challenges is that video cables cannot be too long to work at the required low latency for example).

Another musical challenge is the sound environment where musicians play together; they always adapt their interpretation to the sound ambience (reverberation, echos, volume, etc.) of the site where they are. When merging together two (or more) sites with LOLA, we create a totally new mixed environment, where sound (but also spatial) response in one site must keep into consideration also the situation on the other(s) site(s).

The more experiment we do with LOLA, the more new challenges and opportunities are discovered.

The future – work in progress

LOLA is work in progress, and also its requirements on the network are evolving. Even if it can run in minimal configuration on shared production networks like the NRENs and GEANT, it is an evident potential customer of bandwidth on demand and circuit on demand services, as it can easily have a schedule for reharshals, concerts, MasterClasses, etc. even without a permanent dedicated network infrastructure. Using the LOLA system will more and more ask for optimized geographical and network paths between sites, too. As current development with color, higher resolutions in images and sound (multi-channels) goes into production, also the network requirements will consequently increase.

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Other fields of application

LOLA can be used in any other environment where real time audio/video collaboration and presence is required: from other performing arts (dance, theater, etc) to medical applications (remote control of equipment), to remote audio/video data collections where real time is essential… and who knows the rest…

Production

Conservatorio di musica G. Tartini - Trieste

Implementation

Paolo Pachini: general coordination
Carlo Drioli: programming
Nicola Buso: testing and musical advice
Claudio Allocchio (Consortium GARR): testing and networking advice
Massimo Parovel: conception and supervision