INNOVATING COLOSSEO: A DISTR-ACTIVE ARTISTIC PERFORMANCE

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Abstract
For many years now the Italian Research and Education Network (GARR) has been supporting the cultural heritage community by providing advanced network infrastructure and tailored technical solutions that answer its specific requirements.
An example of this strategy is the digital architecture developed for the SITAR territorial system, an online geo-tagged archaeological repository of Rome metropolitan area, which was designed and implemented by the Special Superintendency of Rome.
In 2015, for the first time in history, several Roman monuments of high historical value were interconnected to GARR Network through fiber-optics. This achievement, a landmark in the support of this community, offered the occasion for a challenging endeavor: the setup of a geographically distributed performance leveraging on high-quality R&E network and highlighting the opportunities it can offer to performing arts.
The live performance, a theatrical play specifically designed by the internationally renowned director Giorgio Barberio Corsetti in collaboration with GARR, has leveraged the network to allow HD real-time interaction of actors and musicians located in different locations: three archaeological sites in Rome (Colosseum, the Baths of Diocletian, Crypta Balbi) and a research laboratory, the Frascati National Laboratories of the National Institute of Nuclear Physics (INFN).
Accomplishing what might be called a distr-active (distributed and interactive) performance required careful planning that included the setup of network connections, a very fine tuning of several full-HD streams and the preparation of two sites that used the LoLa software (especially built by GARR in collaboration with the Tartini Music School in Trieste) .

Keywords
Cultural Heritage, WebAIS (Archeological Information System), Performing Arts, LoLa (Low Latency) software, Ultrabroadband

1 GARR and cultural heritage
For many years now, GARR (the Italian Research and Education Network) has been collaborating with the cultural heritage community with the objective of providing advanced network infrastructure and innovative tools for the study, preservation and promotion of cultural heritage assets. This contribution is firstly aimed at facilitating and supporting national and international partnerships involving universities and research institutes that need to share and transmit large amounts of data, and to use applications, such as virtual museums, virtual archaeology, and geographic information systems.
In this framework, GARR and the Special Superintendencies of Rome and Pompei agreed to interconnect several

monuments of high historical and artistic value to the Italian Research and Education Network for the first time in 2015: the Colosseum, Roman Forum and Palatine Hill, Palazzo Massimo, Crypta Balbi, Palazzo Altemps, Baths of Diocletian, and the Pompei Archaeological Area.
This action is part of a strategy aimed at making use of advanced ICT technologies in order to preserve and study the extraordinary cultural heritage of Italy.
An example of this strategy is the SITAR territorial system (Rome Archaeological Information System), an online geo-tagged archaeological repository of Rome metropolitan area, which was designed and implemented by the Special Superintendency of Rome. This repository is aimed at managing the growing data generated by the Superintendency and making them available on a web platform to different user groups (government, local administrations, university and research, education, cultural industry, but also citizens and students).

1.1 SITAR (Geographic Archaeological Information System of Rome)

SITAR is a WebAIS (Archaeological Information System), an instrument to better understand and preserve all archaeological assets, and to help in their contextualization in a historic-topographic framework as well as in the local management of archaeological knowledge.
The system serves multiple needs, from territorial planning to the study and reconstruction of the ancient city of Rome. The aim is also to standardize an enormous amount of information and make it publicly accessible.
In order to do this, it was essential to have an integrated digital infrastructure including a highly available ultra-broadband network and a storage space to preserve a constantly growing amount of data.
SITAR deployment is a good example of technological research applied to archaeology and to knowledge sharing, as inspired by the paradigm of Open Knowledge and Crowdsourcing, which focuses on sharing and reusing already available information.

1.1.1 Hardware and Network Infrastructure

Since the beginning, the technical requirements related to the development of SITAR have emphasized the need for hardware and network infrastructure able to support the implementation of SITAR database, the deployment of web applications and the gradual delivery of new public information services. The digital infrastructure developed for SITAR is composed of: 1) direct fibre optic connection of the SITAR WebAIS to the GARR backbone PoPs, with capacities up to 100Gbps towards the national and international networks; 2) virtual servers residing on physical machines owned and operated by GARR, which will host the new versions of SITAR web applications; 3) repositories for SITAR GeoDB and the digital documents correlated with the logical classes of the Superintendency's information system; 4) services including backup and data restore of the database and web applications, with a dedicated software specifically developed by GARR for the Superintendency.

1.1.2 Identity Federation

In order to facilitate the access to SITAR WebGIS platform, the Superintendency for Rome Archaeological Area has joined the IDEM Federation, the Italian education and research AAI community, and thus EduGain. This was accomplished by means of IDP in the Cloud, the innovative service provided by GARR to ease the process of joining the federation, by delegating to GARR the implementation and configuration of the IDP. The new service delivers a turnkey, pre-configured IDP hosted in GARR Cloud to any organization that requests it, a true identity-as-a-Service (IDaaS) with all the features of an IDEM-federated IDP and with the same guarantees in terms of security and confidentiality of data. The organization thus has the opportunity to have its own Identity Provider with no need for additional servers or dedicated staff for the technical configuration of the service.

2 Innovating Colosseo

In order to celebrate the fibre-optic connection of several Roman monuments managed by the Superintendency for Rome Archaeological Area to GARR Network, a geographically distributed theatre and musical play was organised. The live performance, especially designed by the internationally renowned art director Giorgio Barberio Corsetti, has leveraged the network to allow HD real-time interaction of actors and musicians located in

different areas.
The performance involved three archaeological sites in Rome (Colosseum, the Baths of Diocletian, and Crypta Balbi, which were among the monuments recently interconnected) and a major research facility, the laboratories of the National Institute of Nuclear Physics (INFN) in Frascati, at about 30 km from Rome.
The availability of fibre-optic connection among various locations allowed GARR to extend the benefits of network technology to performing arts, and to accomplish a "distr-active" (distributed and interactive) performance. This event required careful planning, including the setting up of end-to-end network connections, the tuning of streaming service and the preparation of two sites that used LoLa (Low Latency), a program developed by GARR in collaboration with the Tartini Music School in Trieste.
The preliminary survey to define the appropriate technology for the event took about one month of work of the multimedia technicians working in the GARR Netcast Task Force. The originality and complexity of the project and the need to provide a video stream in Full High Definition with an acceptable latency and the necessary flexibility in production, determined the choice of standards live streaming techniques, optimized and perfected through careful tuning of hardware and software resources. The coexistence of different technologies for transmitting audio-visual streams (LoLa - Live streaming) and the mixing into a single product that could be projected in Ultra HD, has required hardware and video production solutions highly attuned with the requirements of a theatrical play and hence of the entire production staff.
One common problem with real-time streaming over low latency/high capacity networks is to reduce response times of client applications, web containers and players, when accessing multimedia content (that means, you want to see on your desktop browser what you see with your eyes in real life: everything is in sync, without time delay).
To do so, GARR did performance tuning at each step of the servers-clients chain:

- OS performance tuning (pert TCP/IP recommendation best practices tuning, processes/context switches minimization, real-time kernel performance tuning);
- streaming server AMS response/delay minimization through configuration tuning (buffer and queues parameters);
- http web container tuning;
- web player optimization; with this configuration we measured streaming visualization delays of almost 0.5 seconds.

On this occasion, the LoLa system was used not only for a distributed musical performance, but also within a more complex theatrical production.

The architecture of the scene provided three levels of dialogue through the network: among the actors, the directors and the musicians.
The operation led to at least three levels of innovation:

1. level of optimization of the technical means
2. level of reconsideration of the directing medium and the role of the director himself
3. level of overcoming the physical location of the actor

From the feedback received by the actors, the medium was considered simple to use and just one test session was sufficient for the use of the platform.

2.1 Artistic performance

Conceived to celebrate the fibre-optic connection of several monuments of the Superintendency for Rome Archaeological Area to the GARR, Network the theatrical play "la nave Argo" (i.e. "Argo") revisits the myth of the Argonauts playing with time and space, reality and virtuality. The real-time of the performance blends with the mythic time in which Jason and the other characters move, and the different spaces in which the actors move

are accommodated in a new “virtual” space, that of the network. Thus, in this new dimension time and space are transformed and take an unconventional, suspended, “risky” form

The performance was played in 4 different locations, the Colosseum, the Crypta Balbi and the Octagonal Hall of Diocletian’s Baths, and INFN Frascati National Laboratories (the oldest research facility in Italy for nuclear and particle physics). The performance had its center in the Octagonal Hall, where the actress playing Europa was the narrative element directing the play and “routing” the live links with the other three locations and the characters in them (Time, the Fury and Jason, playing respectively in INFN National Lab, the Colosseum and Crypta Balbi), visible on a wide screen. These different places became a single stage for the duration of the play, thanks to the network. Actors and musicians interacted in real-time from the different sites with the aid of headphones and monitors, using LoLa, a ultra-high definition audio and video streaming system developed by GARR in collaboration with the Tartini Music Conservatory in Trieste, which can reduce latency virtually to zero (or, more precisely, the propagation time of light in the optic fibers).

The performance was designed by the director Giorgio Barberio Corsetti and GARR, both from the artistic and from the technological point of view.

Figure 1 - Distance of locations involved in Innovating Colosseo (as the crow flies)

Figure 2 - Distance of locations involved in Innovating Colosseo (as the crow flies)

2.2 Technical Setup

The design and technical implementation of "la nave Argo" required about 2 months and involved 6 to 10 people depending on the development phase. The adopted technical solutions are shaped around three drivers: ease of use, transparency and flexibility. This was needed in order to tackle the different locations' peculiarities, the difficulties related to the work plan and to the availability of some of the sites, not to mention the challenges related to artistic choices. Thus, the design of the play and its technical setup was an ongoing effort that involved both the artistic and technical crew and was heavily affected by the implementation requirements, especially:

- managing a large number of real-time full HD audio and video feeds,
- reducing latency due to coding-decoding and buffering
- ensuring audio quality
- tackling the logistic difficulties to work simultaneously on different sets.

As previously mentioned, the Octagonal Hall was the centre of the narrative and it also hosted the event's audience. From the implementation perspective, this hall was also central as it became the technical hub of the system. The complex hw/sw system implemented was capable of receiving 5 audio and video streaming feeds, 4 of which 1080P and the fifth, related to the LoLa system, in standard definition. The latter was only used for the musicians' interaction and for the audio of the musical instruments. The Full-HD streaming feeds came from different locations: 2 came from the Colosseum and INFN National Laboratories, while the other 2 came from cameras set in the Hall. The material from Crypta Balbi was actually not live, as the script foresaw that the character would enter the Octagonal Hall at the end of the play. These 4 streaming feeds were sent to a dedicated hardware and mixed by a program, which sent them to the 3 projectors in the Hall. The streaming server was also remotely located, in a fifth location (i.e. GARR headquarter).
The streaming feeds were all traditional live streams in Full HD; for the remote streams, the buffering was suppressed in order to minimize any possible delay, the streaming underwent three levels of optimization:

- At the SO level, the TCP/IP was optimized and a fine performance tuning was carried out, eliminating all non-necessary processes which could slow down the system;
- At the application level, the buffering on Adobe MS was reduced to a minimum;
- At the output level, the buffering was also minimized though a tailored configuration of the JW player.

Of course, the almost complete elimination of buffering made the quality and timeliness of the stream

completely dependent on the network level, which was only possible because of the high quality of the network infrastructure implemented.
In addition, remote locations had completely different environmental factors to be tackled such as ground noise, distances and work conditions and separate live streaming stations, cameras, microphones had to be installed at each of them.
Finally, some artistic requirements needed to be taken into account in order to insert in the performance also some musicians, who were not initially planned. In order to ensure a very-high audio quality, an especially developed system was adopted for this audio stream, the LoLA system.

2.2.1 LoLa system

The LOw LAtency audio visual streaming system (LOLA) is a program designed and developed by GARR and the Tartini Music School of Trieste. Lola enables musicians that are located thousands km away to play together in real-time, as if they were in the same room.
The technical details of this software are:

- encoding/decoding delay (one way) of less than 10 ms
- One-way time of less than 10 ms every 1000 km on high-performance networks
- Reduced variance in delay (Jitter)
- Round-trip time of approx. 60 m
- Dedicated hardware e software such as:
    - Professional ASIO capture cards and drivers
    - Uncompressed audio e video so as to reduce codification
    - Industrial cameras
    - High-speed monitor
    - Buffering elimination
    - Broadband (min. 1 Gbps)

2.2.2 Challenges & Solutions

The peculiar setting of the play was composed of three distinct locations where actors and musicians performed and interacted with each other by means of monitors and projectors; and one location where the audience was sitting.
The audience was attending the play at the Diocletian Bath, where 3 full HD film projectors allowed one group of actors to interact with the others who were in the other sites.
This geographical distribution of actors and musicians together with the need to ensure their real-time interaction with high-quality video and audio standards resulted in several technical challenges for the team.

- Network optimisation
  All selected locations were already interconnected with fibre-optics to GARR. The Colosseum and the Baths of Diocletian are interconnected though 1Gbps fibre link each, while the INFN National Laboratories is interconnected through a 10Gbps dark fiber. However, the stage was not always in proximity of the network termination (an average distance from GARR equipment being about 300mt), so local links had to be put in place in order to offer real end-to-end capacity to the audio and video streaming. A fifth site in Rome was also involved, i.e. the GARR headquarter, where the streaming server receiving and transmitting the streams was.

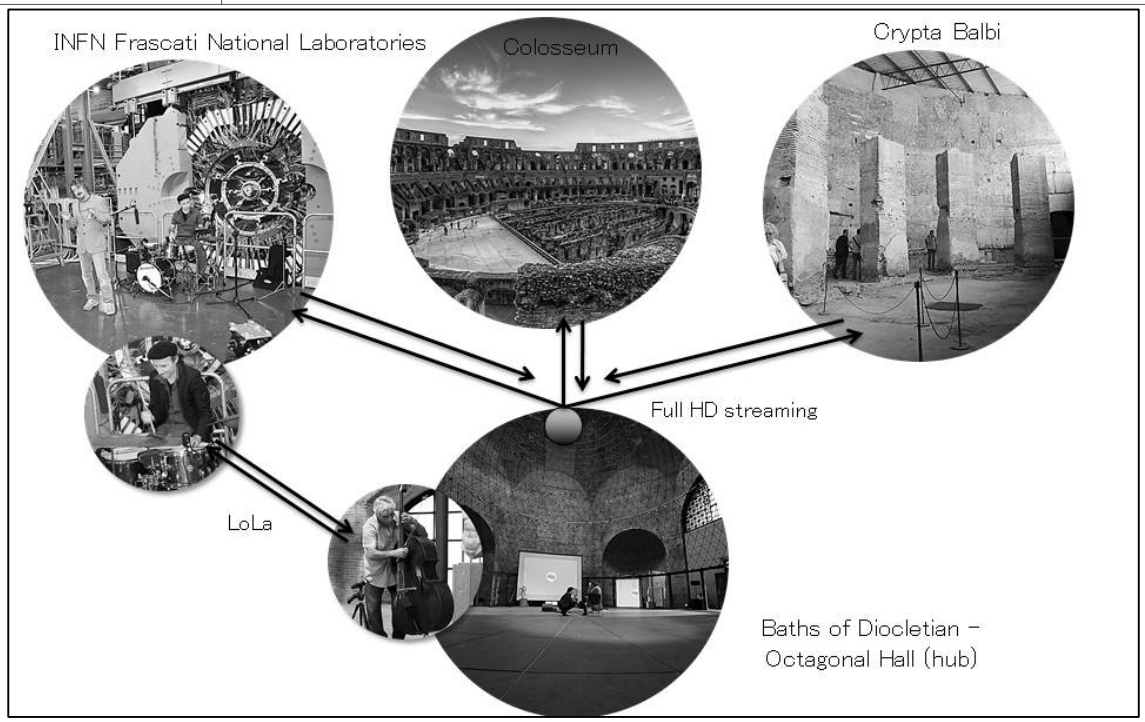

Figure 3 - Audio and video system

In order to avoid risks of throughput limitations due to the edge routers, it was decided to route the traffic directly at the level of the geographic network: each end site was interconnected with a 3750X switch and all the routing was done on GARR infrastructural Pops. This solution, together with adjustments made at the SW level resulted in a delay of less than 1 second, which is acceptable in order to ensure a flawless, natural interaction among actors and musicians.

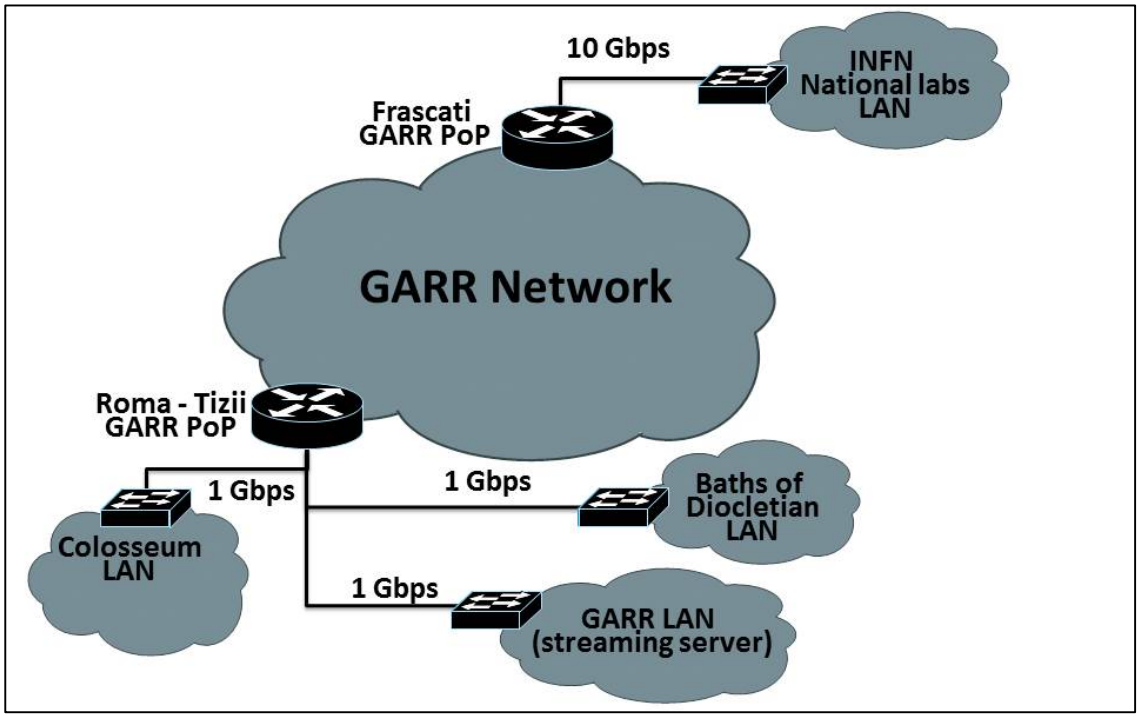

Figure 4 - Network structure

- Use of different systems to broadcast video and audio (LoLA vs Streaming)

  While actors were video and audio connected via streaming, the two musicians were connected with LoLA (LOw LAtency audiovisual streaming system). In order to avoid delays or interference between the two systems, the successful solution was to use LoLA only for the audio transmission.

- Convergence of Video streaming

  A previously mentioned, the challenge was the interaction of these different video sources and it was solved with a high-performance equipment (MacPro). The complex hw/sw system implemented for the event was capable of receiving 5 audio and video streaming feeds, 4 of which 1080P and the one in standard definition. These streaming feeds came from different locations: 2 came from the Colosseum and INFN National Laboratories, while the other 2 came from cameras set in the Hall. The material from Crypta Balbi was actually not live, as the script foresaw that the character would enter the Octagonal Hall at the end of the play. The 4 full HD streaming feeds were sent to a dedicated hardware and mixed by a program, which sent them to the 3 projectors in the Hall. In order to minimise any possible delay, the buffering on the streaming service was reduced to a minimum, which was only possible because of the high quality of the network infrastructure used.

- Specific environmental conditions

  Each location had specific environmental conditions and factors that needed to be addressed by the team. One of the most outstanding examples was the ground noise of the particles accelerator at the INFN National Laboratories and the very need to shut it down in order to allow musicians and technicians to operate within the facility in safe conditions.
  In addition, the bad weather conditions obliged the team to move most of the IT equipment in the Colosseum into a sheltered area.
  Also, the underground structure of the Crypta Balbi was a real challenge for the team, as the network connection only reached the ground level and an extension to the underground would have affected the good quality of the transmission.

3 Future Perspectives

The contribution of the GARR network in the digital humanities is twofold: the development of research applications and the ability to support activities in the field of performing arts.
For the first aspect, SITAR has among its next targets the inclusion of as many people as possible both in the construction of a participatory knowledge, and in its dissemination to all potential users of the cultural content platform. The database and the wealth of information held will be critical to integrating 3D models and reconstructions within the service itself.
The access to WebAIS with federated identities is still at the planning stage and it will be possible thanks to the participation to the IDEM Federation and eduGAIN. On the one hand, WebAIS as SP will be available from anywhere in the world thanks to eduGAIN, on the other hand, the Superintendency has put in place its own IDP to have its own federated identities.

In the area of the performing arts, demonstrating the use the fibre connection as a means to support artistic expression gives way to new forms of collaboration with the community in this area, and across the academic and research spectrum to explore new frontiers and create real distributed artistic laboratories. In the short term, the GARR experience will be an incentive for national and international communities, in the first place with the dissemination of these results. In the long run, for the design and implementation of a user-friendly platform that can enable interested parties that do not have the technical expertise and resources, and can likewise catalyse issues and knowledge base and create a community and working groups.

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Biographies

Edoardo Angelucci with more than 5 years experience as hardware IT specialist, actually working as system administrator at GARR, with main tasks focusing on multimedia service events support,
customer support and desktop hardware and software management.
He has also background skills in h.323 and SIP protocols, multimedia systems, videostreaming protocols and applications.

Alex Barchiesi is a creative physicist with a PhD in Particle physics, researcher at European Organization for Nuclear Research (CERN ATLAS experiment), associate professor of new media art and informatics at Art Academy of Rome, associate professor and senior researcher at EPFL Computer Science department. His artistic work has been presented around Europe including in IRCAM centre Pompidou Paris and Auditorium Parco della Musica in Rome and received international awards. Invited researcher of the Planetary Collegium and member of GARR.

Andrea De Tommasi is a GIS-expert and actually serves as member of the system-design workgroup within the SITAR Project launched since 2007 by the Special Superintendency for the Colosseum, the National Museum and the Archaeological Heritage of Rome, for the digitalization of the complex knowledge related to the rich archaeological heritage of the Rome territory.
Particularly, he deals with the design and evolution of the SITAR data model and the logic architecture of the Archaeological Information System, with a particular research interest in the integration of the SITAR web platform with other knowledge management systems, through resilient networking environments such as GARR-X.

Bruno Nati has a degree in Multimedia and Audiovisual Communication Technologies. He started in 2002 to deal with educational technology and production of media content for schools. Since 2008, he deals with web communication for the GARR. He participates in the implementation of projects and provision of e-learning training, production of multimedia educational content and tutoring. His interest in educational technology has led him to work on techniques of live streaming and broadcast audiovisuals for GARR and user community events.
Bruno builds and manages many GARR web channels and he takes care of production and post-production of content and audiovisual products.

Mirella Serlorenzi graduated and specialized in Medieval Archaeology. She studied large urban excavations of Rome Crypta Balbi and the Palatine.
Since 2007, she directs and coordinates the SITAR project (Geographic Information System Archaeological Rome) of the Superintendency for the Colosseum, the Roman National Museum and the Archaeological Area of Rome, for the realization of the first online archaeological Land Registry of the City. She is currently Director of the National Museum of Rome - Crypta Balbi.
Mirella is scientific director and coordinator of important archaeological excavations in Rome.
She participates actively in working groups of European projects: Ariadne, "Atlas des techniques de construction dans le monde romain" AREA (Archives of European Archaeology).

Sabrina Tomassini is an expert in network infrastructure design and she joined GARR in 2007 as Senior Network Engineer. She is part of the Network Planning and Engineering team, that collects the user community

requests for connectivity and plans technical solutions to implement them. In the position, Sabrina is currently following initiatives connected to Humanities and Cultural Heritage communities. She is also involved in GARR member and partner relations.

Cristiano Valli actually works as system administrator at GARR, with main task focus on infrastructure service consolidation and cloud operation management. With more than 10 years as IT system engineer, has also background skills in application development (OpenGL satellite mission simulator) & security system integration (RSA/FoxT SSO/PKI two-factor authentication systems).

Giancarlo Viola was born in Cosenza in 1971. After attending high school in Calabria, he moved to Pisa to attend the School of Telecommunications Engineering, where he graduated in 2001. He began his career in 2002 with Infotel Italy company, where he worked for two years as a IP network technician. In 2003 he arrives at Ericsson, where he held the position of IP Network designer for four years. Currently he is a Senior Network Engineer at GARR, where he works since 2007.

Carlo Volpe works, since 2007, in the External Relations and Communications Office at GARR, the Italian Research and Education Network that provides ultrabroadband connectivity to the community of education, research and culture.
He handles institutional communication and activities of relationships with users. He looks after the aspects of media relations, concept and the layout of graphic information materials, web and editorial content, corporate and institutional events.