Introducing new technologies, innovations, and collaborations in R&E Networking between Africa, Latin America, Europe and the US through new international projects

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Abstract

Geographically distributed sciences often rely on Research and Education Networks (RENs) for data movement. A lower latency REN pathway for data movement between North and South America and South Western Africa is enabled by the collaboration of multiple operators, including Tertiary Education and Research Network of South Africa and South African National Research Network (TENET/SANReN), Brazilian Education and Research Network (RNP), Latin American Cooperation of Advanced Networks (RedCLARA), Internet2, and Florida International University (FIU). These REN operators participate in the AmLight consortium to support the Americas-Africa Lightpaths Express and Protect (AmLight-ExP) project. The goal of AmLight-ExP is to operate and continuously improve production and experimental network connections between the US, South America, and Africa. Geographically distributed sciences in South America and Africa will continue to grow dramatically over the next five years, increasing dependency on advanced cyberinfrastructure and programmable networking.

This article presents recent and developing initiatives for support of Research and Education Networks (RENs), localized within and between Africa and the Americas (North, Central and South). A new REN connection between Brazil and Portugal will soon include Europe via

Portugal. To achieve more direct connections the consortium utilizes high-capacity intercontinental submarine cable systems and terrestrial fiber. The development of the AtlanticWave-SDX 2.0 project, which aims to support research, experimental deployments, prototyping and interoperability testing at international scales is a complementary project to AmLight-ExP. AtlanticWave-SDX is building a distributed intercontinental experimental Software Defined Exchange (SDX) by enhancing Open Exchange Points (OXPs) connected to AmLight.

1. Background

Geographically distributed science in the Americas and Africa is expected to evolve dramatically over the next five years, increasing its dependence on advanced cyberinfrastructure and programmable networking. AmLight [1] leverages nearly two decades of accumulated consortium assets between the United States and Latin America and new long-term infrastructure to Africa, creating a critical cyberinfrastructure that is both sustainable and scalable. The AmLight consortium supports an evolving community-owned set of network assets to operate collaboratively, across North America, Latin America, Africa, and soon Europe. To increase network visibility and improve the services offered to the community, AmLight is deploying a new and highly granular network telemetry solution for at scale per-packet monitoring, real-time troubleshooting, and traffic engineering in a sub-second interval.

The ongoing expansion of RENs in Latin America and their new direct connection to those in Europe are the results of the Bella (Building Europe Link to Latin America) initiative, a consortium of Latin American and European RENs dating from 2016. Bella aims to improve the quality and capacity of connectivity between Latin America and Europe. For the first time a modern, large-scale direct connection between the South American and European RENs, over the newly deployed EllaLink submarine cable [3] between Portugal and Brazil achieves this milestone. The Bella consortium has acquired spectrum on EllaLink, corresponding to 3/8 of the capacity of a fibre pair, for the expected lifetime of the cable (25 years). The consortium is also acquiring spectrum on terrestrial fiber within South America, some of which is provided by the Latin American member RENs, in order to capillarise access to the EllaLink cable, as well as to other international cables to Africa and to the US. Additionally, Bella will deploy a new generation of the RedCLARA regional backbone in South America.

2. Latin American REN: evolution of international connections

RedCLARA is the regional REN in Latin America. Created in 2003 and supported by the European Commission (CE) through the ALICE (2003-7) and ALICE2 (2008-12) projects, it currently connects 11 NRENs from 18 originally targeted countries. The map in Figure 1 shows the internal topology as well as the direct external connections to the USA over AmLight-ExP, with no direct links to other countries/continents in 2017. Since 2018, new transatlantic links to Africa and Europe are removing this limitation.

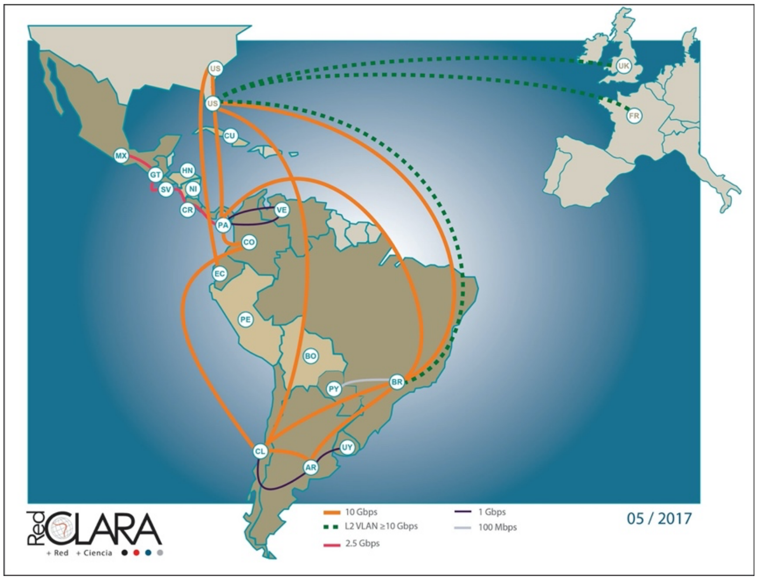

Figure 1. International connections of RedClara in 2017

Since 2018, 3 new transatlantic submarine cables have been laid from Fortaleza in Brazil. In 2018 the SACS (to Angola) [5] and SAIL [6] (to Cameroon), and in 2021 the EllaLink to Portugal, with landings in Africa (Cape Verde, Mauretania, and Morocco). These links provide increased opportunities for cooperation with African R&E communities. RedCLARA has already signed a cooperation agreement with UbuntuNet Alliance to foster and expand South and East Africa's collaboration opportunities. Together with the Bella Project, this provides a significant network, augmenting cooperation opportunities between Europe, the USA, Latin America, and Africa.

The BELLA Initiative

Ever since the beginnings of RedCLARA in 2004, it was clear that other direct international R&E connections should be made to the neighboring continents of Europe and Africa. After a feasibility study in 2010-12, the EC published a call for connecting LA to Europe and launched the BELLA programme with GÉANT, RedCLARA, and EU and LA NRENs in 2016. The major problem was to find a commercial company interested in laying a new direct cable between Europe and South America and offering acceptable terms for R&E use. The company selected by open call was Ellalink. Ellalink signed a contract in 2018 with RedCLARA, GÉANT and 9 national RENs (5 from Europe and 4 from South America) to provide 3/8 of the spectrum (45 x 33.3 GHz optical channels, each of which capable of supporting at least 100 Gb/s) on a fibre pair between Sines, Portugal, and Fortaleza, Brazil, for the lifetime of the cable (estimated in 25 years).

In March 2021, the 6000 km transatlantic part of EllaLink was completed, and service is expected be provided from June 2021. This project is called Bella-S (S-submarine) and is being complemented by the rebuilding of corresponding network infrastructure in South America – the Bella-T project – a new release of RedCLARA including scalable capacity links of Nx100Gb/s.

Figure 2. The main transatlantic route of the EllaLink cable between Sines, Portugal, and Fortaleza, Brazil

The delivery of Nx100G connectivity using the new EllaLink cable (Brazil-Portugal) in 2021 also provides Nx100G connectivity between Europe and several NRENs in South America (initially Brazil, Chile, Colombia and Ecuador). Global Exchange Points (GXPs) in Fortaleza and São Paulo provide support for traffic to Africa via SACS and the US via Amlight ExP. RedCLARA's high-capacity intercontinental access for Latin American NRENs is shown in Figure 3.

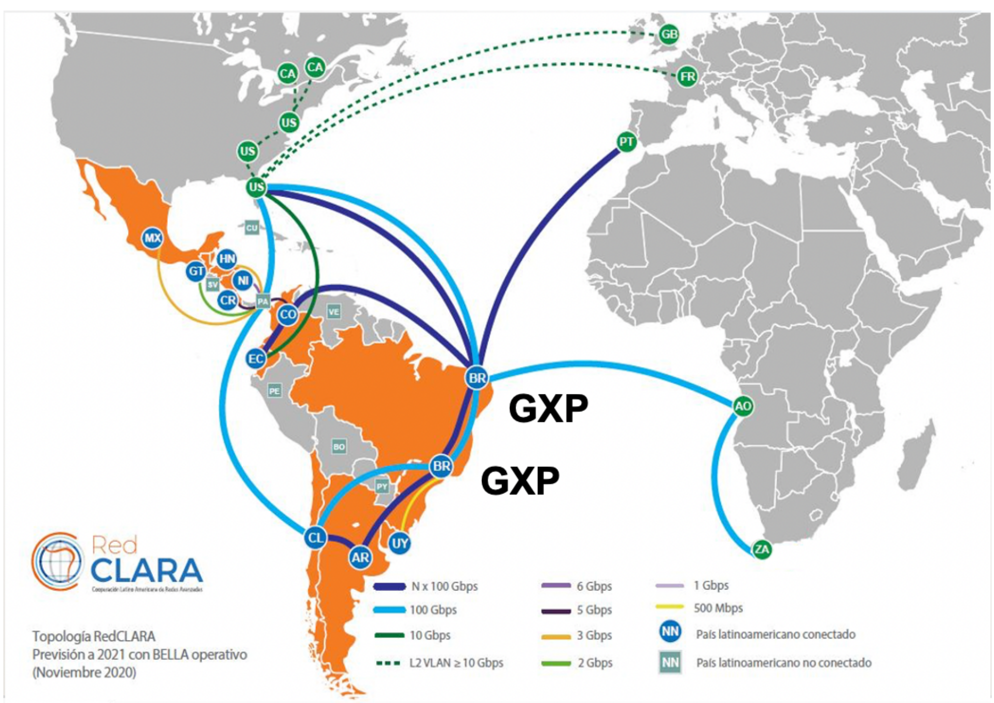

Figure 3. RedCLARA high-capacity intercontinental access for Latin American NRENs in 2021

3. South Africa National Research and Educational Networks (SA NREN)

The Tertiary Education and Research Network of South Africa (TENET) [7] and South African National Research Network (SANReN) [8] jointly form the South Africa NREN. SANReN is a business unit inside the South African CSIR's National Integrated Cyberinfrastructure System (NICIS). It is responsible for the design, acquisition, and roll-out of national and international capacity for the South Africa NREN and the development and incubation of advanced services. TENET operates the SANReN, which is a key component of the South African government's National Integrated Cyberinfrastructure System (NICIS), alongside the Centre for High-Performance Computing (CHPC) and the Data-Intensive Research Initiative of South Africa (DIRISA).

TENET was created in 2000 as a non-profit company. Membership is primarily universities (all 26) and research institutions but serves a much broader constituency (TVET Colleges and School Networks) and is funded through cost recovery from beneficiary Institutions. TENET operates the network deployed by SANReN but also deploys some network functions and components and delivers services.

SANReN was created in 2006 as a business unit in the Council for Scientific and Industrial Research, and it is funded through a State grant (Department of Science and Technology). SANReN designs, acquires, and implements networks and network components, from metro to international level and develops and incubates services.

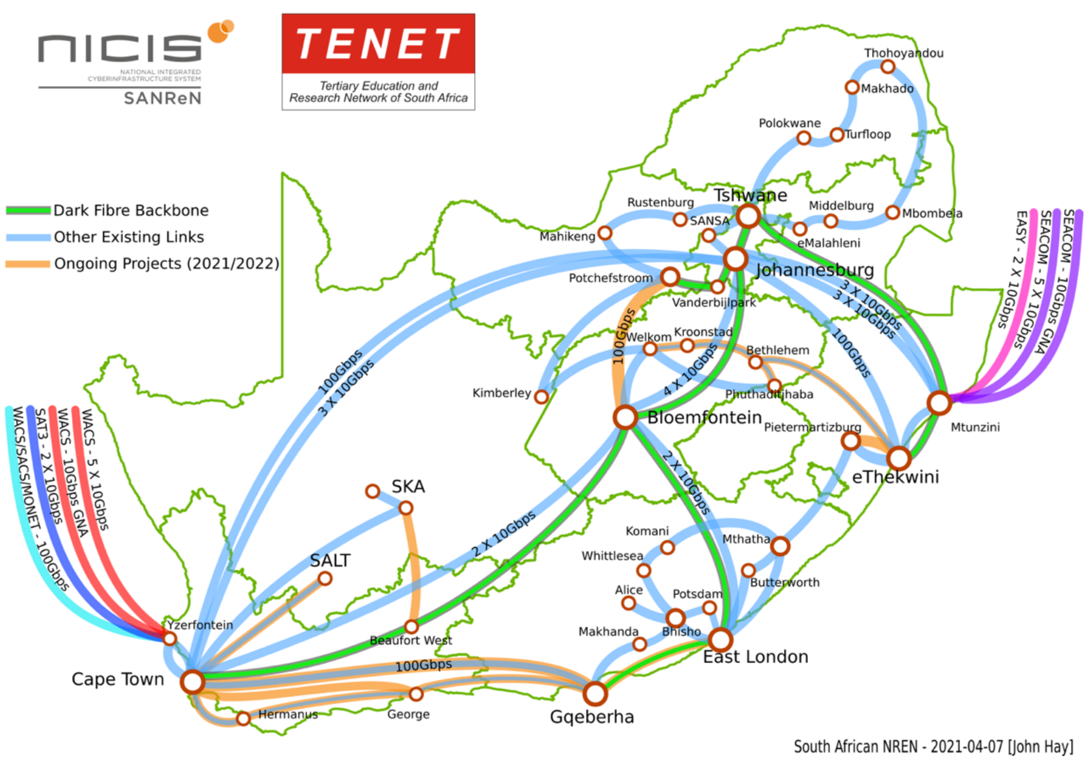

Figure 4. South Africa NREN Map

The SA NREN has steadily been implementing backbone enhancements to support current and future research and education activities (Figure 4). These enhancements include deploying a national DWDM backbone, upgrading national and international gateway routers, consolidation of international 10G links, and participating in international collaborations.

The SA NREN national DWDM backbone is a 96 channel (gridless and directionless) optical line system. DWDM terminal equipment provides 100G network links on long haul segments and 200G within metros. The system is ready for 400G/600G/800G transport. Additionally, seven SA NREN national and international gateway routers have been upgraded to medium-density 100G devices. The consolidation of 10G international links into single 100G carriers over WACS and SEACOM paths will completes this phase of enhancements to provide 100G transport links throughout the network backbone.

International collaborations include establishing South Africa Open Exchange One (ZAOXI) in Cape Town, AMPATH SACS-WACS 100G trans-Atlantic link to South America and setting up interconnections via the AMPATH GXP Miami. Interconnects are set up with ANSP, CANARIE, CSTNET, Internet2, and RedClara. A link between Cape Town and AARNet is in planning. Enabling a US IP transit service at AMPATH has reduced the latency between Southern Africa and North/South America.

Future international collaboration plans include:

- enabling ZAOXI for Atlantic-Wave SDX integration,
- upgrading DTN and PerfSONAR nodes to 100G capable devices, and
- working closely with WACREN to enable their ZAOXI presence.

4. AmLight-ExP

AmLight leverages nearly two decades of accumulating consortium assets between the United States and Latin America and new long-term infrastructure to Africa, creating a critical digital infrastructure enabling confident research through sustainable and scalable connectivity. The community supports the following specific assets enabling AmLight-ExP [9] to operate collaboratively:

- Multiple channels of a spectrum between Boca Raton to Fortaleza to São Paulo (through **2032)**
- Channel of a spectrum between Fortaleza to Luanda (through **2034)**
- A community-supported long-term 100Gbps self-managed lease, renewable indefinitely between Miami, San Juan, Fortaleza, Sao Paulo, Buenos Aires, Santiago, Panama, and back to Miami available (through **2035)**
- Terrestrial fiber through the BELLA-T project interconnecting Santiago and Buenos Aires, Bogota and Panama City, as well as other critical city pairs throughout Latin America (through **2030)**
- A new connection in the next several years from Fortaleza to Lisbon through the **BELLA-S** Project for the life of the cable (approximately **2050**)
- Capacity on the **WACS** cable system for the life of the cable interconnecting Luanda to Cape Town (approximately **2035**)

5. New Technologies

AmLight In-Band Network Telemetry (INT)

AmLight will support In-Band Network Telemetry (INT) [10] and streaming telemetry. INT is a framework designed to allow the collection and reporting of network state, by the Data Plane, without requiring intervention or work by the Control Plane. In the INT architectural model, packets contain header fields that are interpreted as “telemetry instructions” by network devices. These instructions tell an INT-capable device what state to collect and write into the packet as it transits the network. INT traffic sources (applications, end-host networking stacks, hypervisors, NICs, etc.) can embed the instructions either in normal data packets or in special probe packets. Similarly, INT traffic sinks retrieve (and optionally report) the collected results of these instructions, allowing the traffic sinks to monitor the exact data plane state that the packets “observed” while being forwarded.

The INT architectural model is intentionally generic and hence can enable a number of interesting high-level applications, such as network troubleshooting L1 traceroute, microburst detection, packet history (a.k.a. postcards), trajectory sampling; advanced congestion control; advanced routing, for instance, utilization-aware routing; and network data-plane verification.

AmLight In-band Network Telemetry (INT) aims to leverage new programmable network devices on the AmLight ExP network, provide highly granular network telemetry, enable at-scale per-packet monitoring to enable real-time troubleshooting and traffic engineering in a sub-second interval.

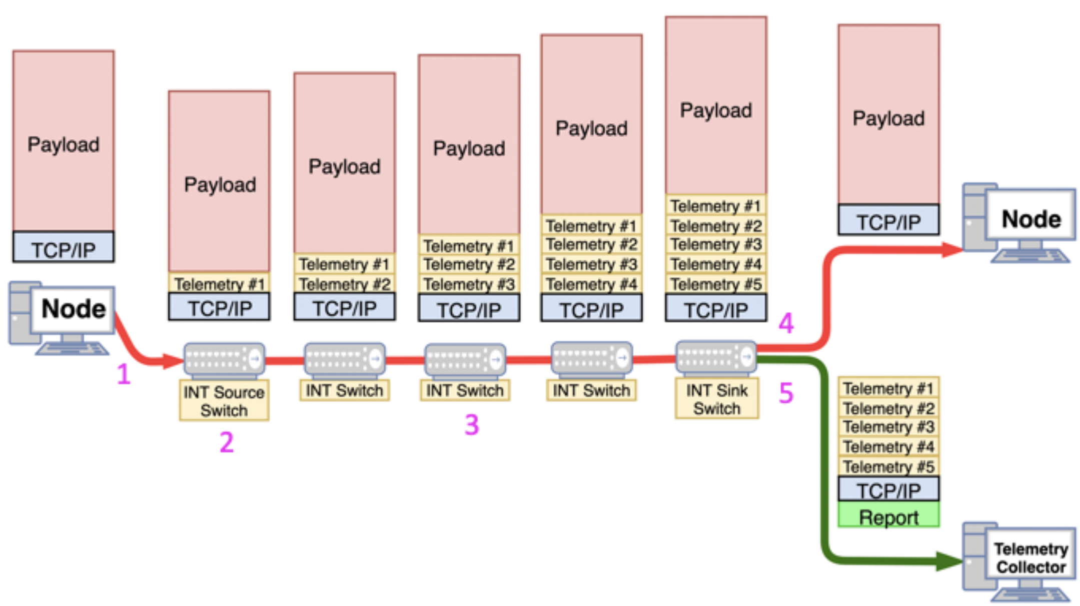

Figure 5. In-band network telemetry process

The process of INT, as shown in Figure 5, includes 1) User sends a TCP or UDP packet unaware of INT, 2) First switch (INT Source Switch) pushes an INT header + metadata, 3) Every INT switch pushes its metadata Non-INT switches just ignore INT content, 4) Last switch (INT Sink

Switch) extracts the telemetry and forwards original packet to a user, and 5) Last switch (INT Sink Switch) forwards the 1:1 telemetry report to the Telemetry Collector.

AtlanticWave-SDX 2.0

To improve the management and operation of all resources made available by the AmLight consortium members, including links and computing and storage resources, the AtlanticWave-SDX 2.0 project was created. The AtlanticWave-SDX 2.0 project [11] aims to support research, experimental deployments, prototyping, and interoperability testing, at international scales. Atlantic-Wave SDX 2.0 goals include building a distributed intercontinental experimental SDX by leveraging Open Exchange Points (OXPs) [12] in the US, Chile, Brazil, and South Africa. The project also includes collaboration with the Open Science Grid (OSG) [13] and Pegasus workflow management system [14].

As shown in Figure 6, AtlanticWave-SDX 2.0 architecture includes closed-loop orchestration, dynamic provisioning of Layer3 services, integration with other orchestrators (e.g., SENSE [15], AutoGOLE [16], and FABRIC [17]), compute and storage integration, integration with science applications by exporting topology information, and network management tools (e.g., inventory, monitoring, debugging, SDX configuration, telemetry).

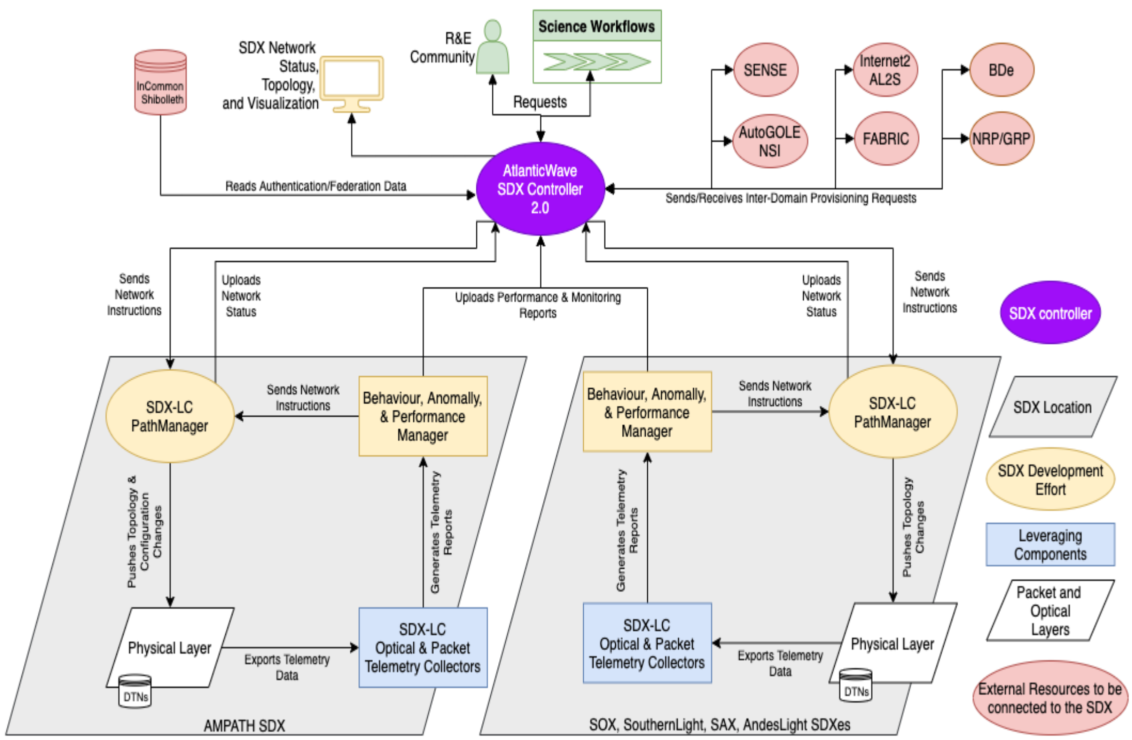

Figure 6. AtlanticWave-SDX 2.0 architecture

A primary motivation for the development of the AtlanticWave-SDX 2.0 is facilitating the use of the network for domain scientists and science applications for Distributed High Throughput Computing (dHTC) (e.g., OSG, High Energy Physics Information Exchange (HEPiX) [18], Pegasus), real-time high-availability applications (e.g., Vera Rubin Observatory [19], MeerKAT [20], SKA [21], HERA [22], PAPER [23]), international research testbeds (e.g., FABRIC, HEPiX), and bulk data transfer applications (e.g., BigData Express [2]). For example, The MeerKAT 64-antenna array radio telescope is a precursor to the SKA and will merge into the SKA1. SKA high-frequency dishes will produce ten times the current global internet traffic.

6. Conclusion

In conclusion the 2020's will experience remarkable expansion of Research and Education Networking between the Americas, Africa, and Europe through consortium efforts and new high-capacity submarine cable systems in the South Atlantic. Concurrently, the science drivers of astro-physics, high-energy physics, genomics, epidemiology, and others are performed internationally in multiple locations and require the RENs for smart data movement empowering rapid analysis and ever-increasing rates of discovery. These breakthroughs are made possible by the investment of the National Science Foundation (NSF) in the U.S. and Ministry of Science, Technology and Innovations (MCTI) in Brazil, FAPESP in Sao Paulo, Brazil, National Research Foundation (NRF) in South Africa, and the European Commission in Europe. Furthermore, technology advances in software defined networking and high-performance computing coupled with extraordinary submarine cable buildouts and the cooperation and collaboration of the companies laying the cable has created a renaissance of R&E networking.

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