11-01-2021

# Deliverable D3.4
# International User Support Process and Activities Report

**Deliverable D3.4**

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**Abstract**

This document reports on the International User Support Process and Activities through three use cases, ITER, Belle II and CTAO, which have been chosen to illustrate the activities of WP3 T2 in different fields and involving different services: AAI and network for ITER, end-to-end data transfer optimisation for Belle II, and consulting for CTAO.

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# Executive Summary


This document reports on the user engagement account management activities carried out by the WP3 T2 task of the GN4-3 project during the first two years.

The document introduces the context around the International User Engagement process as it is carried out by the GN4-3 WP3 T2, detailing its driving principles, and the steps that are taken to support specific research communities.

Of the initiatives supported by the task, three specific use cases are reported on, based on their particular interest and representativeness of the task's activities:

- ITER / EUROfusion
- CTAO
- BELLE II

The use cases span very different scientific domains, illustrating the task's effectiveness in engaging with communities that operate in different fields and with different requirements, and in involving different services teams to deliver the most suitable solution. This has resulted in making service offerings available that provide substantial improvements to the user communities: AAI and network for ITER, end-to-end data transfer optimisation for Belle II, and consulting for CTAO.

ITER is the international organisation dedicated to nuclear fusion, currently assembling a tokamak reactor in Cadarache, France. EUROfusion is the European Consortium of Research Institutions on Nuclear Fusion, and collaborates with Fusion4Energy, the EU agency for nuclear fusion, which is one of the main stakeholders of ITER. EUROfusion is in charge - through its partner PSNC - of piloting an Authentication and Authorisation Infrastructure (AAI) solution to ensure seamless integration of services to be accessed by ITER and EUROfusion users.

The Cherenkov Telescope Array Organisation (CTAO) is in charge of building the multi-antenna Cherenkov Telescope Array, which will be hosted at La Palma Canary, Spain (Northern Hemisphere Antenna site) and Cerro Paranal, Chile (Southern Hemisphere Antenna site). CTAO is one of the future international users of the forthcoming BELLA/EllaLink cable system directly interconnecting Europe and Latin America.

Belle II is a High Energy physics experiment using the SuperKEKB asymmetric positron-electron collider, hosted by the KEK laboratory in Tsukuba (Japan). Belle II has a unique capability to measure with unprecedented precision CP-violation physical parameters, and to search for low-mass dark matter and low-mass mediators, also due to the extreme high luminosity of the collider. The experiment has been fully operational since March 2019, when it started recording physics data. Belle II has been

running a number of Network Data Challenge campaigns, focussed on measuring the maximum achievable throughput across the main data centres of the collaboration.

# 1 Introduction

The *Research Engagement* task of the GN4-3 project (WP3 T2), in collaboration with the GÉANT *Research Engagement and Support* team, and with the contribution of all task project partners, has been supporting Research and Education user communities at large. The task is addressing their needs in terms of network and above-the-net services that underpin their distributed computing models, but also facilitates access to the European and Global Research and Education (REN) community and provides consultancy on specific topics (cost analysis, service feasibility, contractual agreements), in agreement with the T2's mission and objectives.

The main goals of the task are to:

- Reach out to existing and potential new user communities to facilitate and extend the use of the GÉANT network and services.
- Act as the 'voice of the customer' within the project to feedback on user needs, and to coordinate service proposals for research communities and their end users.

The task has proactively contacted users communities, and supported them in the definition of their requirements on the network and services stack. For this purpose, the task has established the role of Task Account Manager for each community, international institution or user group. They act as the primary GÉANT contact for the community, gather information on the activities that the users are involved in and their requirements towards the GÉANT services portfolio in the accomplishment of their research objectives.

Account Managers are the means to implement the one-stop shop concept for the research user communities. From solving performance issues between two sites to the development of coordinated Information and Communications Technology (ICT) solutions with multiple e-infrastructures, GÉANT provides dedicated networks and bespoke services covering performance monitoring, data access and security aspects. Although national R&E collaborations are served well by their respective National Research and Education Networks (NRENs), there is a need for central coordination of international projects and their internationally distributed users. The *Research Engagement* task facilitates communication with the NRENs and participating stakeholders to understand their requirements, to collect all necessary technical, operational and financial information, and to present a consolidated and consistent solution for all involved parties. To ensure seamless service implementation and smooth operation, project and operational service management is provided throughout the process.

This deliverable reports on the activities carried out with three large user communities, encompassing their needs at large, and provides a description of the specific work that is carried out with the three selected user groups in this context.

The activities performed to support the ITER/EUROfusion, CTAO and BELLE II user communities are described in detail, highlighting the vision endorsed by the GN4-3 project to support their users in the execution of their scientific mission and tasks.

The document is structured as follows:

Section 2 describes the International User Engagement process that WP3 T2 follows in order to understand the requirements of research organisations and provide them with the support they need.

Section 3 describes the ITER and EUROfusion community, illustrating T2's activities in the field of AAI and networks.

Section 4 describes the Belle II experiment collaboration, illustrating T2's activities in the field of end-to-end data transfer optimisation. Appendix A refers to this section and describes into detail the GÉANT DTN testing facility.

Section 5 describes how T2 has supported the Cherenkov Telescope Array Organisation (CTAO) by providing consultancy.

Section 6 provides a brief summary and offers conclusions on the value of T2's work.

# 2 The GÉANT International User Support Process

International research organisations usually have complex structures, with demanding requirements in terms of providing services, and managing and authorising user access at a global scale to enable seamless access to data, applications and resources. Many large international collaborations, span several e-infrastructure domains, involving sites which are part of existing e-infrastructures, or accessing data from a variety of sources that are connected to multiple computing resources. There is a relevant cross-infrastructural and multi-domain nature in the requirements of many large communities, so that support to end-users requires knowledge, skills and specific know-how regarding services that are available from multiple providers and ways to combine them.

Requirements can span multiple levels of the services stack: network services can range from simple, best-effort IP connectivity to more complex services that provide guaranteed bandwidth between end sites, or traffic separation capabilities, like p2p circuits, VPNs or VRFs. In addition, many communities require above-the-network services, like cloud resources, trust and identity services, and specific advice and consultancy services on relevant topics for the community.

The GÉANT *Research Engagement and Support* team has defined a workflow to accomplish its mission of supporting users and accompanying their transition towards the adoption of advanced networking, cloud, and trust and identity services.

The process comprises the following phases:

1. Requirements gathering: the *Research Engagement* team and relevant service teams discuss the research collaborations' requirements in detail with them. For new collaborations the GEANT Service Portfolio is presented to identify areas of interest. After the areas of interest are identified, an initial list of requirements is compiled.
2. Business Development strategy defines, in collaboration with the relevant GÉANT service teams (network, trust and identity, cloud, etc.), a timeline for designing and delivering a suitable solution for a given user community, based on their requirements .
3. The Design phase involves multiple technical actors from both the research collaboration and the GÉANT service teams, in order to design an architecture that meets the requirements and is compliant with the provisioning model of the services.
4. Once the design is finished, a proposal document is compiled, describing the terms and conditions for the services to be provisioned, Service Level Agreements (SLAs), operational mode for the service, contact information, and, most importantly, the technical proposal itself, which includes the design of the services.

5. Once the proposal is accepted by the research community or the international organisation, the implementation phase can start, where the services are implemented and provisioned by GÉANT and/or the NRENs for the users.
6. Operation and support for the provided service start as soon as the implementation is completed. In this phase, the operational model of the service, as well as monitoring of services and associated SLAs (if agreed) are put in place, and information about the running services is gathered constantly. The control is transferred to the corresponding service teams, which deploy the identified solution according to their workflows.
7. A periodic review of the system and the users' satisfaction is carried out, to gather input for possible service improvement, and define new strategies or requirements, if needed.
8. The various support phases are interconnected by other relevant user engagement flow actions like the renewal of existing services, service termination, the Master Service Agreement definition, and the periodic service review.

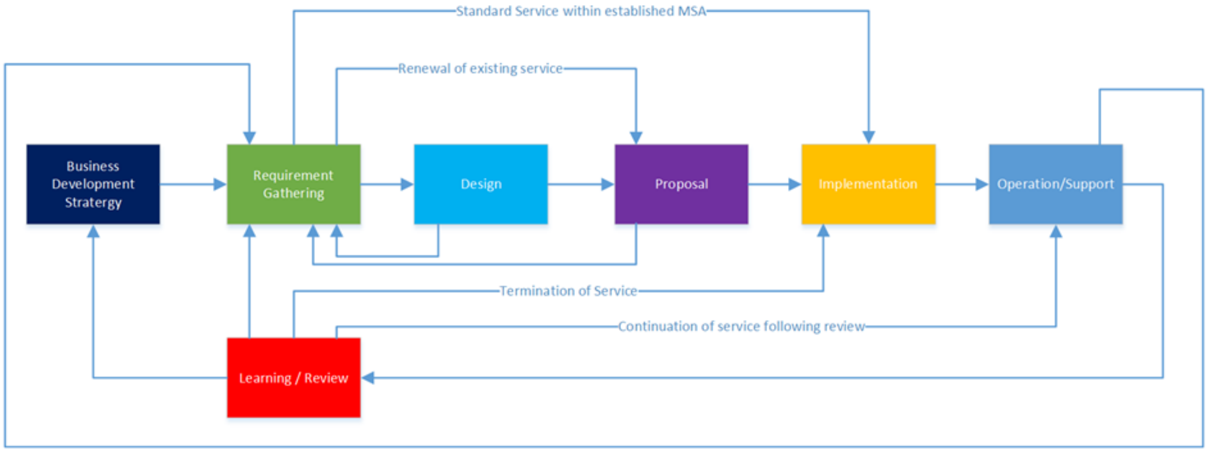


Figure 2.1: The GÉANT User Engagement Process

# 3 ITER/EUROfusion Community

## 3.1 ITER and EUROfusion

This section briefly describes the Nuclear Fusion Community of the international ITER and EUROfusion organisations, and reports on the user engagement process implemented by WP3 Task 2, including specific action points that have been addressed and the result of the support activities.

### 3.1.1 ITER

ITER [ITER] is the world's largest collaboration on nuclear fusion, whose aim is to assemble and operate a 'tokamak' reactor (see Figure 3.1) to demonstrate an effective energy gain factor of 10.

ITER's stakeholders are the European Union, the United States, India, China, Russia, South Korea, and Japan, each of which hosts a domestic agency for Nuclear Fusion. ITER is currently constructing the tokamak plant site and starting to assemble the reactor in Cadarache, in the South of France.

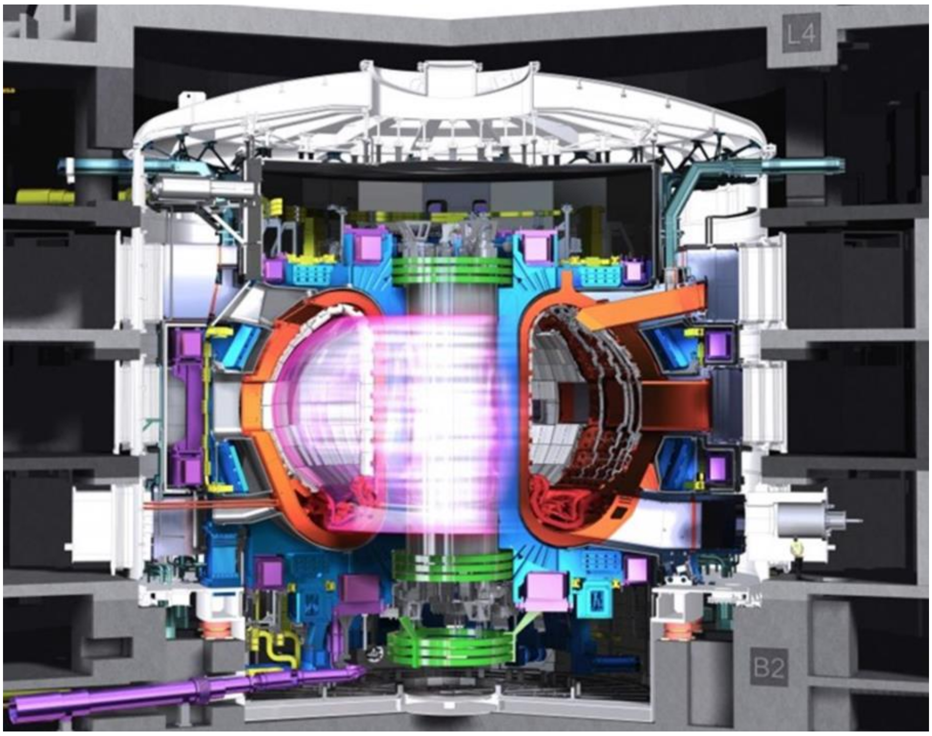


Figure 3.1: The ITER tokamak nuclear fusion reactor

Each one of the seven domestic agencies has the right to request a full replica of the raw data acquired by the machine. This implies a future growing need for high-speed connectivity to many different world locations. Domestic agencies have the right to aggregate the raw data, and to decide individually how they want to use the data and if they want to disseminate it further (tiering).

In addition, EUROfusion, the EU organisation in charge of research and development on nuclear fusion, needs to federate the resources among the scientific laboratories participating in the consortium, and is therefore very interested in Authentication and Authorisation Infrastructures (AAI) which enable seamless and secure access to data for its users. EUROfusion is currently piloting eduTEAMS as an AAI infrastructure to interconnect its sites.

Data is the principal deliverable of the ITER project and its main asset. Securing engineering and scientific data on/off premises is a key project requirement.

ITER presents, therefore, full-stack requirements for GÉANT, featuring world-wide data distribution and federated access services:

- Scientific and plant data must be stored outside of the primary nuclear plant platform.
- Computing resources for data processing must be provided.
- For Disaster Recovery, a separate archive must be provided at a geographically fully-diverse location.

The Scientific Data & Computing Centre (SDCC) will store, secure, process and distribute the vast amount of data produced by the ITER project, while the total scientific data rate is expected to range between 2 and 50 GB/sec, with a total archive capacity of 90 to 2.200 TB/day (the large variability depends on the implementation of the data acquisition technology that will be used, which is still under consideration). Data rates are expected to steadily grow in the various phases of the project, going up to 200 PB/year in 2030, and reaching the exabyte scale around 2035.

Figure 3.2 shows the expected total data growth for ITER in the coming years. The y-axis unit is Terabytes (TB). Numbers are indicative, data amounts could further grow beyond the drafted curve due to possible improvements in the sensitivity of probes and monitoring devices.

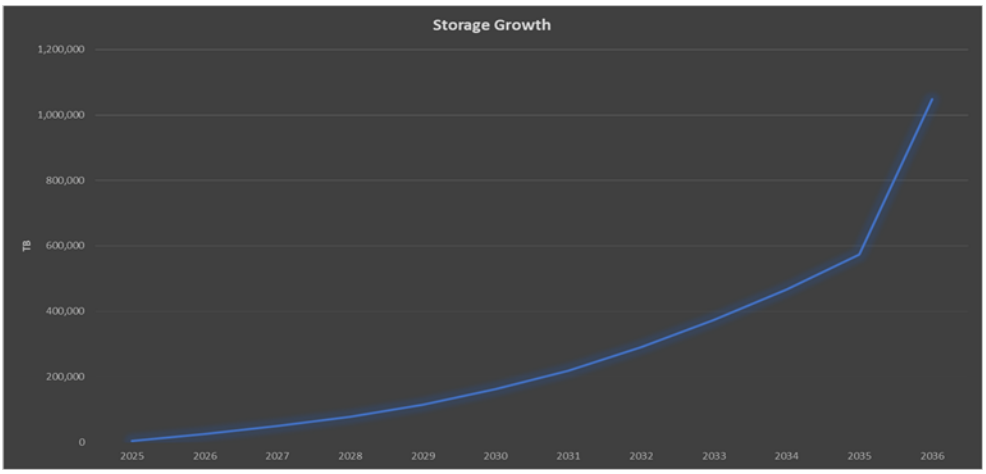


Figure 3.2: Indicative expected growth of the ITER total data sets sizes in the forthcoming years

Table 3.1 reports the ITER collaboration's total expected data production in the coming years, for the various operational stages of the machine (FP = First Plasma phase, PFPO = Pre-Fusion Power Operation phase, FPO = Fusion Power Operation phase).

| Stage | FP 2025 | PFPO-1 2028-30 | PFPO-2 2032-34 | FPO-1 2036 | FPO-2, …,8 | Total |
|---|---|---|---|---|---|---|
| Data (PB) | 0.1-1 | 10-100 | 100-300 | 200-500 | +500 each | 5000 |

Table 3.1: Indicative total sizes of data amounts for ITER in the forthcoming years

Level2 Virtual Private Networks (VPNs), to be established from the ITER SDCC to the domestic agencies, are under consideration for 2021 and later stages. Overall, the network bandwidth requirements are challenging and will grow from the current need for 10 Gb/ from the ITER site, to the current off-site storage location (Denmark), to the need in 2024 for two 200 Gb/s, to the off-site location and several 40 Gb/s flows to remote sites, to end up in 2032 with the need of two 400 Gb/s to the off-site location and several 400 Gb/s links to remote sites.

### 3.1.2 EUROfusion

Within the context of the European Union's EURATOM programme, EUROfusion [EUROfusion] is the organisation that coordinates nuclear fusion Research and Development (R&D) in Europe. Its main goals are to coordinate all research and developments activities on nuclear fusion at the continental level, and to collaborate with the European Union domestic agency for nuclear fusion, fusion4energy [FusEn]. Within this collaboration, EUROfusion contributes to implement nuclear plans to realise nuclear fusion by means of ITER, currently the most outstanding project for relevance and impact.

EUROfusion, in its role of coordinating body for research on nuclear fusion, is a fundamental key actor for ITER. Currently, 30 research organisations and universities from 26 European Union member states, plus Switzerland and the Ukraine, take part in the EUROfusion consortium. Overall, more than 150 European laboratories are involved in the implementation of the EUROfusion work plans, in various domains of science, engineering and information technology. Fusion Physics is also a Competence Centre in the EOSC-hub, focussing on data management and data transfer, as well as spanning data access services, provided by several e-infrastructures.

Within EUROfusion, PSNC is working in the Core Programming Team, and is in charge of the design and demonstration of a scalable, secure Authentication and Authorisation Infrastructure for the EUROfusion collaboration. In this context, GÉANT started a collaboration with PSNC on an AAI pilot based on the eduTEAMS proxy service, the GÉANT flagship Trust and Identity service to support Research Collaborations, managing virtual organisations often spanning different e-infrastructures.

## 3.2 Community Requirements

Requirements gathering has been carried out with ITER for the network and with EUROfusion for the Authentication and Authorisation Infrastructure. The first in-depth discussions took place from spring 2019 to early 2020, where the needs of ITER and EUROfusion, in terms of network requirements and AAI infrastructure, were identified.

### 3.2.1 Network Requirements

ITER presented two main network requirements to GÉANT and the NRENs:

- The need for a dedicated 10 Gbps connection from the ITER site in France (Cadarache) and the Japanese site of IFERC, located in Rokkasho.
- The need to support the raw data backup process from Cadarache (France) to a data centre in Ballerup (Denmark), where storage resources are being provided.

#### 3.2.1.1 *Remote Experimentation Use Case*

A relevant use case to be supported by ITER is the possibility to remotely perform experimental activities on the tokamak reactor operating in Japan, while designing, planning and carrying out experimental tasks. This requires 10Gb dedicated connectivity from the ITER plant site in Cadarache to the experimental site at the International Fusion Energy Research Centre (IFERC) in Rokkasho, Japan.

#### 3.2.1.2 *Raw Data Backup Use Case*

ITER requires a dedicated 10G capacity link from Cadarache, where the Scientific Data Computing Centre for the tokamak plant data is located, to the ITER Secondary Data Centre in Ballerup, Denmark, hosted by InterXion.

This use case, as currently foreseen by the SDCC prototype Data Management Overview, is shown in Figure 3.3.

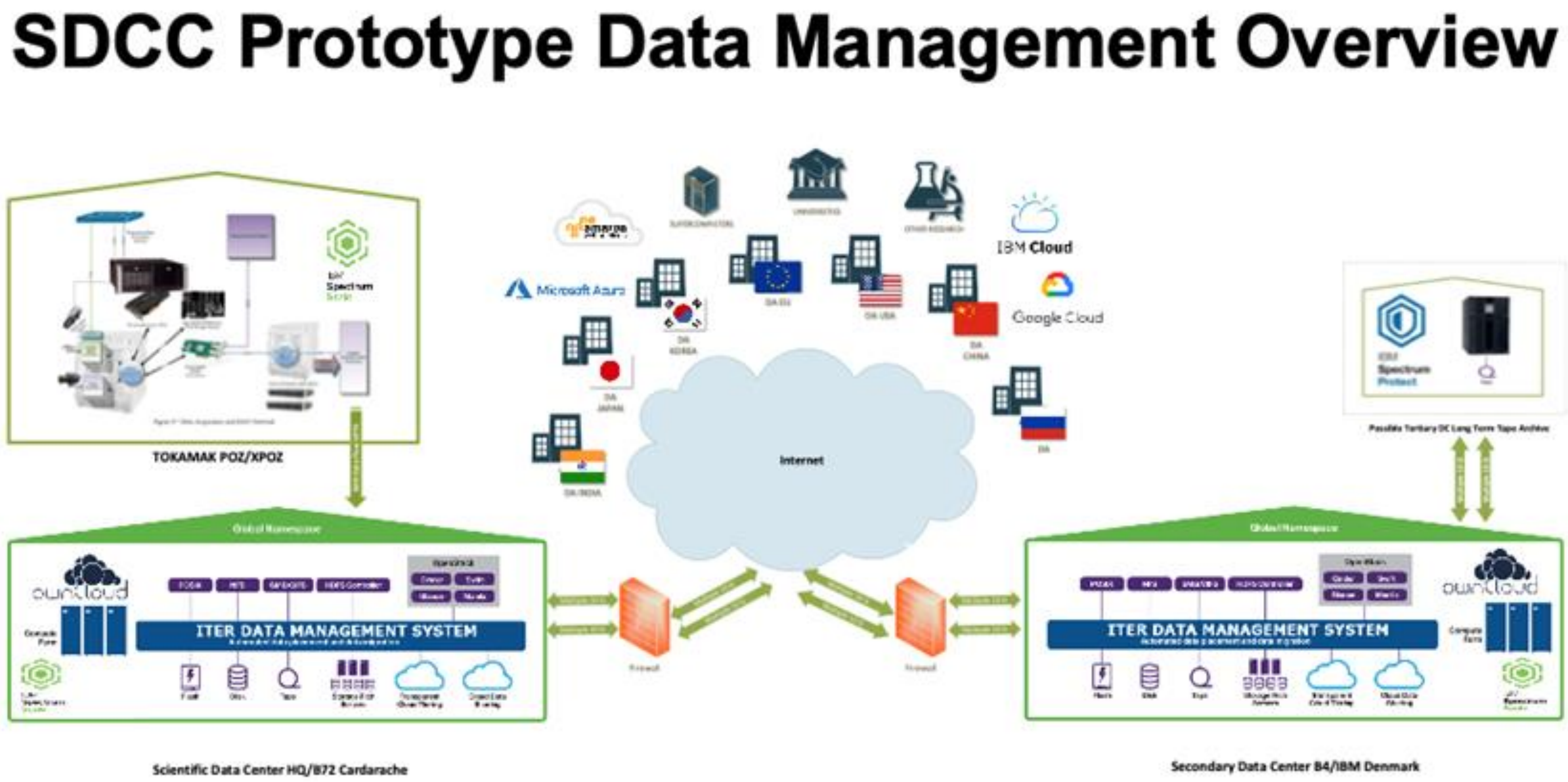


Figure 3.3: The ITER distributed Data Management involving DCs in France and Denmark (courtesy of ITER)

ITER is willing to work on a solution including two parallel circuits to carry out the data backup using the GÉANT and NRENs backbone (Cadarache – Grenoble – Geneva – GÉANT Point of Presence (PoP)) and the backbone of a commercial provider, InterXion.

### Backup via InterXion backbone

To ensure backup via the InterXion backbone, ITER requested RENATER to provide a 10G link from Cadarache to their Marseille 1 PoP, to then reach the second PoP in Marseille and connect to the InterXion backbone there, in order to transport data from Marseille to Ballerup, Denmark.

### Backup via GÉANT backbone

GÉANT is coordinating the implementation of a Layer 2 (L2) peer-to-peer (P2P) circuit crossing multiple network domains with partner NRENs (RENATER for France, DeiC and NORDUnet for Denmark). This is provided on the GÉANT backbone via the GÉANT+ service.

At the time of writing, this activity is in progress, with GÉANT acting as the Single Point of Contact (SPOC) for ITER, to ensure the link will become operational in 2021.

## 3.2.2 AAI Requirements

The discussions with EUROfusion, carried out with the eduTEAMS team, focussed on the possible improvements to the approach they were using for authentication and authorisation. Overall, the main EUROfusion requirements for AAI that were identified are:

- Adopt federated authentication at the community-level to allow global single-sign-on for EUROfusion users, moving away from a fragmented AAI managed at the individual site level.
- For the above purpose, it appeared immediately that the community needed support in spawning identity providers, in order to enable the creation of a federated AAI.
- Establish a EUROfusion Virtual Organisation, spanning several sites and domains, to manage users' profiles and authorisations to access community services.
- Define a community user identifier to generate an EUROfusion identity for users and authorise them, based on a set of specific attributes (eduPerson schema).
- Adopt an Authentication and Authorisation for Research and Collaboration (AARC) Blueprint-compliant AAI architecture, to be able to interoperate globally and to benefit from the adoption of standards.
- Interface Active Directory as the identity management system to the SAML2 identity provider to be able to onboard individual lab users to federated access credentials.
- Spawn local identity providers to make individual site identities available for accessing federated community services.
- Port community services to the federated AAI approach, making them available to Virtual Organisation (VO) users.

The EUROfusion laboratories involved in the pilot were:

- CEA (France)
- UKAEA (UK)
- PSNC (coordinator, Poland)
- GARCHING (Germany)

## 3.3 GÉANT Support for Network Services

GÉANT provisioned a dedicated GÉANT Plus circuit on the GÉANT backbone, from Geneva to Amsterdam, where peerings with RENATER and SINET are in place, respectively.

RENATER is responsible for the link from the GEANT PoP in Geneva to the French end site in Cadarache, while SINET manages the link from the SINET PoP in Amsterdam to the end-site in Japan.

The path from Europe to Japan, in particular, makes use of the interconnection of 100Gbps between the GÉANT network and the Japanese Science Information Network (SINET), operated by the National Institute of Informatics (NII), upgraded in March 2019 from the previous 20Gbps link landing in London.

The GÉANT-SINET interconnection in Amsterdam is part of the deployment of NII's globe-spanning ring of 100 Gbps links from Tokyo to Los Angeles, across to New York, on to Amsterdam and from there back to Tokyo. The international connectivity for SINET is shown in Figure 3.4.


Figure 3.4: SINET international connectivity development (before / after 1 March 2019)

Following the completion of the setup of the new GÉANT Plus circuit from Amsterdam to Geneva, CACTI monitoring of the circuit was implemented in June 2020, and Figure 3.5 shows the traffic on the GÉANT router interfaces in Geneva and Amsterdam, respectively.

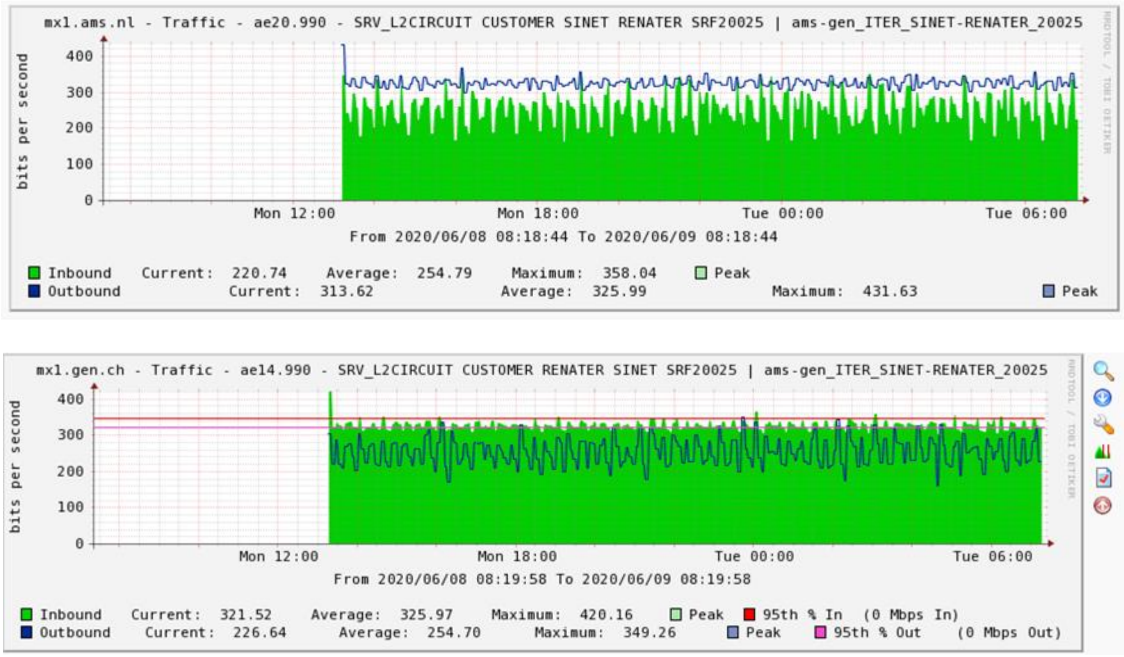


Figure 3.5: The CACTI traffic monitoring for the GÉANT plus circuit for ITER in AMS (above) and GVA (below)

## 3.4 GÉANT Support for ITER/EUROfusion AAI

### 3.4.1 Opportunity for Change

Before the introduction of the new AAI model, each of the EUROfusion sites implemented its identity management (IdM) for the services they provide to the community. The result is that a user willing to access a service (Service A) offered by Site A, has to register at the IdM of Site A to get an account that can be used just for the service or services provided by Site A. If the user wants to access a service from Site B, they have to repeat the registration process to get another account in Site B.

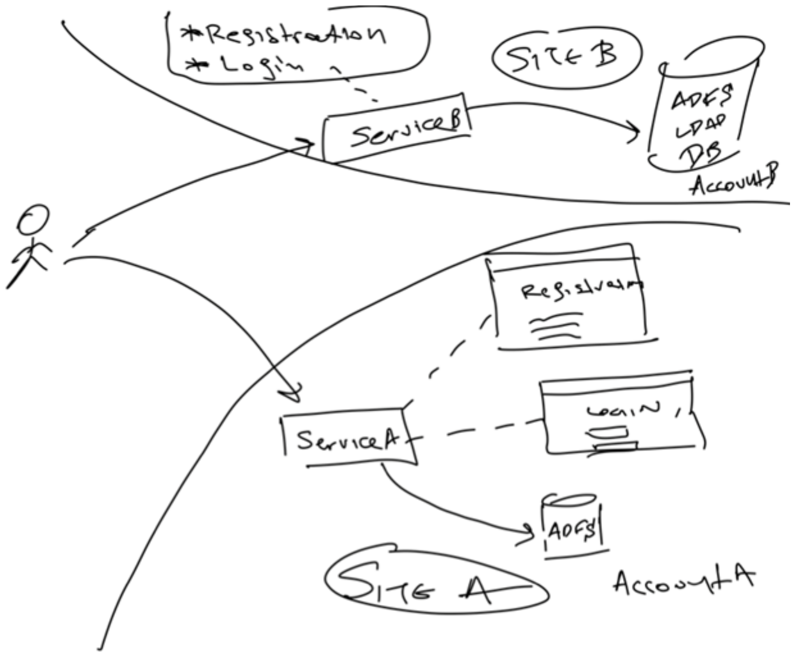


Figure 3.6: The fragmented EUROfusion AAI before using eduTEAMS

As the number of sites and services increases, so does the complexity. A user, before the introduction of the new AAI architecture based on the eduTEAMS service, had to manage and remember a number of credentials for the services they were using, and of course transferring data and resources across sites/services becomes increasingly complex as that number grows.

The users that the EUROfusion project supports had to rely upon a number of different systems to perform the daily tasks of their research work. These systems were not integrated in a homogeneous way with regards to trust and identity, resulting in a situation where accessing the systems proved inefficient and time-consuming.

### 3.4.2 Identified Solutions

The key enabling factor for a scalable and secure AAI architecture is the eduTEAMS Virtual Organisation Management service, implementing the standard AARC Blueprint Architecture for AAI.

eduTEAMS makes it possible to manage all users in an international collaboration with one system, providing VO and users management at scale, in a site-independent fashion.

To enable the use of the eduTEAMS proxy, the creation of identity providers was required. Two solutions have been successfully exploited for this purpose:

- Spawning of SAML Identity providers.
- Instantiation of KeyCloak [Key] as OIDC/OAuth2 Provider (OP) for integration of eduTEAMS via its Identity Hub component.

## 3.5 AAI Pilot with EUROfusion

After the eduTEAMS team assessed the requirements and designed a solution to address them, the deployment of the pilot was started in collaboration with PSNC in Poland. The pilot included the instantiation of the eduTEAMS proxy and related services dedicated to the EUROfusion community.

The task carried out preliminary work to support the spawning of identity providers, since the pilot involved labs in the EUROfusion community which were not already equipped with their own identity provider.

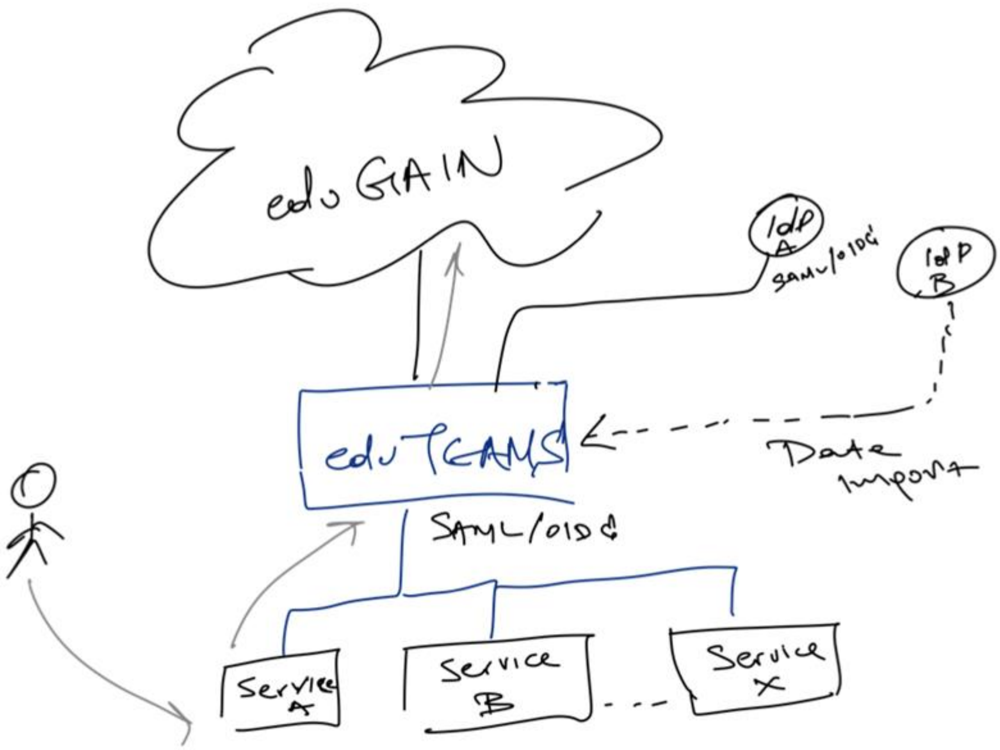


Figure 3.7: EUROfusion AAI after the adoption of federated AAI via the eduTEAMS service

Some of the benefits of the adoption of this new AAI architecture based on the eduTEAMS service are:

- A user can authenticate at one identity provider and access all the services that are available to the EUROfusion community.
- All services in EUROfusion receive the same consistent information about the user, including the community user identifier, which is the same for all services.
- Users can share data and resources across services, as they are uniquely and consistently identified.

- Access policies, users and groups can be managed from a central location, the EUROfusion AAI with the ability to delegate to part of the management to authorised users.

## 3.6 Results and Impact

The main results of the complete change of approach in the management of the EUROfusion AAI, moving away from the previously fragmented and scattered scenario, are the fundamental benefits of a federated identity management infrastructure, for example:

- EUROFusion users can use one identity and access all the services that are available to the EUROfusion community.
- All services in EUROfusion receive consistent information about the user, including the community user identifier.
- Compliance with standards, and adoption of community-developed best practices (such the AARC Blueprint Architecture), enable the integration with international infrastructures such as eduGAIN and potentially the European Open Science Cloud.
- Users can share data and resources across services as long as they are uniquely and consistently identified via the EUROfusion AAI.
- Access policies, users and groups can be managed from a central location, the EUROfusion AAI, with the ability to delegate part of the management to authorised users.
- Security and privacy have been addressed by applying best practices.

## 3.7 Future Plans

The EUROfusion pilot will continue in the forthcoming months, pursuing additional integration of new community services and relevant EUROfusion sites.

# 4 Belle II

This section presents the activities carried out by the WP3 Task2 Research Engagement team in support of the Belle II experiment collaboration.

## 4.1 The Belle II Experiment

Belle II [BELLE] is a particle physics experiment designed to study the properties of B mesons (heavy particles containing a bottom quark). It is the first experiment designed to explore new physics beyond the standard model of particle physics. The Belle II project has a unique positioning, investigating asymmetries between matter and antimatter using a special particle called B meson. Ronald Kotulak, writing for the Chicago Tribune, called the particle 'bizarre' and stated that the meson 'may open the door to a new era of physics' with its proven interactions with the 'spooky realm of antimatter' [Kotulak].

Belle-II could then provide fundamental information about why we do not find antimatter around us, or the imbalance between matter and antimatter.

From 1998 to 2010 KEK, the Japanese High-Energy Accelerator Research Organisation operated KEKB, a record-breaking collider aimed to investigate B mesons. B mesons are very special, because they spontaneously transform into their own antiparticle and back.

KEKB was designed to support specific energy levels so that large numbers of B meson were produced. The facility was, therefore, also known as a the 'B factory'. The SuperKEKB accelerator, a major upgrade of KEKB, is designed to achieve a peak density of collisions (otherwise called 'luminosity') a factor of forty times higher than the previous KEKB. The Belle II experiment (Figure 4.1) is designed to record data at SuperKEKB and investigate matter-antimatter asymmetries using the B mesons.

The two B-factory experiments (Belle at KEKB, BaBar at PEPII) observed the first evidence for CP violation (matter-antimatter asymmetries) in the B meson sector in 2001. These results demonstrated that Kobayashi’s and Maskawa's hypothesis for the origin of the CP violation was correct and provided the experimental foundation for their 2008 Nobel Prize in Physics. In June 2020, SuperKEKB, the new e+e- collider, achieved a new instantaneous luminosity world record.

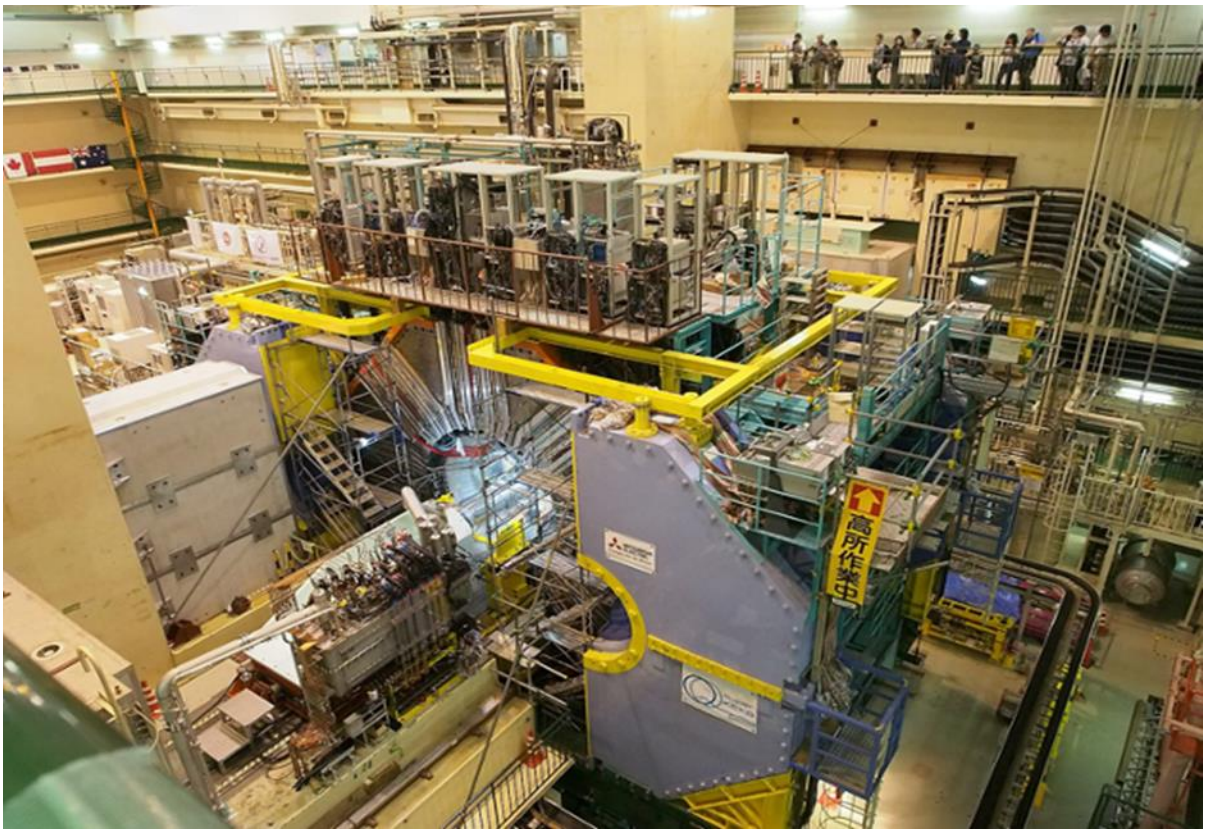


Figure 4.1: The Belle II detector at SuperKEKB (source: Wikipedia)

## 4.2 Community Requirements

The Belle II collaboration needs to transfer large amounts of data over the network from Asia to Europe and to the U.S., given the worldwide distribution of members research institutions which are stakeholders in the experiment. The GN4-3 WP3 Task2 team is in a position to offer support for the optimisation, tuning and planning of these data transfers. This is the main requirement expressed by the collaboration during the interactions with GÉANT. Figure 4.2 indicates the data transfer sizes required by the experiment.

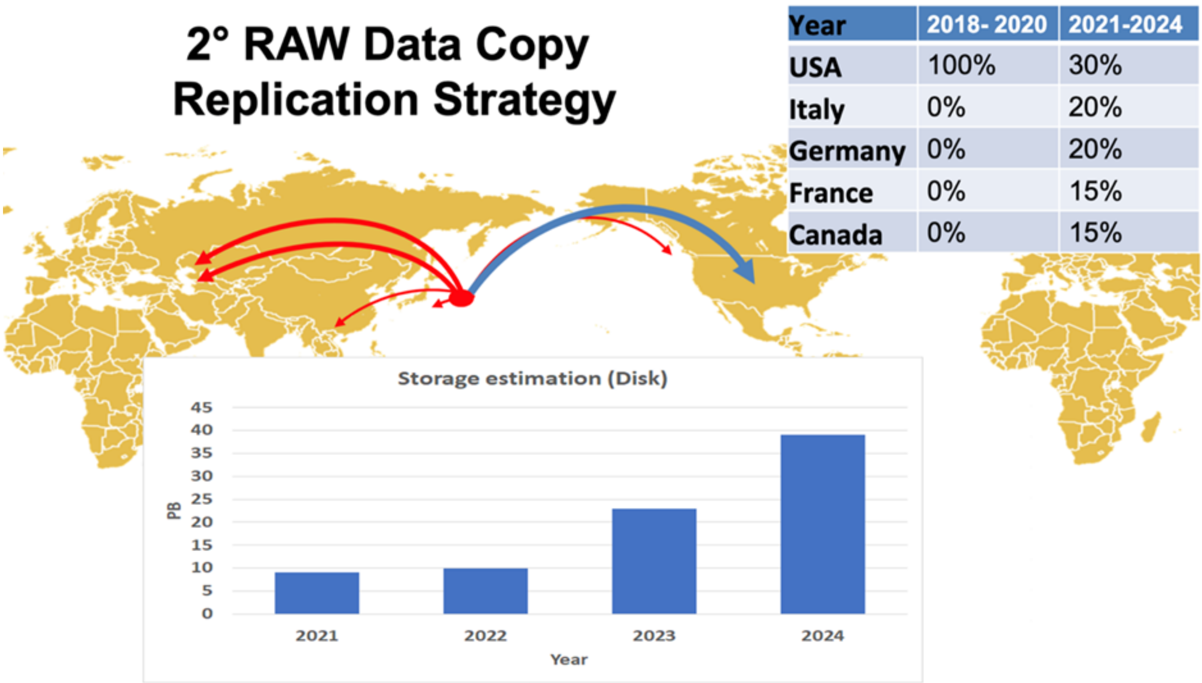


Figure 4.2: Raw data replication strategy for BELLE-II (courtesy of S. Pardi/INFN)

## 4.3 GÉANT Support for Belle II

Transferring large amounts of data (several PBs per year) across big distances requires special software tools, and powerful and reliable networks. The GÉANT Data Transfer Nodes (DTNs), dedicated high-power devices located in strategic European locations (London and Paris), have been identified as the optimal tools to analyse, test and provide support to the intercontinental high-bandwidth data transfers that the Belle II experiment will need to rely upon.

### 4.3.1 Opportunity for Change

The Belle II experiment plans to accumulate more than 100PB of data (including experimental data and simulations) in total. In particular, according to the current estimation, it will collect more than 12PB of experimental data per year at the maximum luminosity, and the data will be processed using a worldwide distributed computing infrastructure.

A second copy of the unprocessed experimental data (raw data) will be stored in the USA until 2020, then, from 2021 onwards, will also be distributed in Italy, Germany, Canada and France.

Network capabilities and specialised data transfer tools are, therefore, crucial elements to the success of Belle II, and, at the moment, its infrastructure is based on two main pillars:

- SINET 100G Global Ring – a 100Gb/s connection between the Japanese Tier-0 KEKCC to USA and Europe.

- LHCONE – Connecting the largest Belle II computing sites that are providing more than 80% of the total computing power and storage resources.

In addition, thanks to an agreement reached between WLCG Tier-1 sites in 2017, Belle II can use the LHCOPN links for the internal traffic among those data centres.

### 4.3.2 Identified Solution

Moving petabytes of data across the network requires careful planning and specialised tools. Downloading 1 PB with a home internet connection (10Mb/s) would take 65 years. Using a 100 Gb/s connection, which is not unusual in the R&E network community, it will take less than a day. Research and education networks are, therefore, crucial to support experiments like Belle II, where large amounts of data have to be shared across a widespread international community.

For several years, Belle II has run systematic Network Data Challenge campaigns, focussed on measuring the maximum achievable throughput over the available links connecting KEK to the main data centres of the collaboration. This class of test consists of a set of end-to-end data transfers using grid the Storage Resource Manage (SRM) protocol.

The Belle II networking team used the DTNs provided by GÉANT during the last part of the 2019 Network Data Challenge Campaign, to measure the network bandwidth and speed, free from local site effects (i.e. grid protocol, file system speed, LAN configuration, etc.), and to validate data transfer methods and protocols.

In addition to the provision of time slots and support on the GÉANT DTNs in London, the Task has been liaising with the researchers to recreate in the GÉANT DTN testing devices the same software and computing environment used by the storage system of Belle II, and then run detailed measurements with them to assess the quality of the data transfer.

## 4.4 Results and Impact

Belle II used the GÉANT DTN in London, through its 100 Gbps network interface, as a European end point for its intercontinental data tests.

The Belle II experiment Tier-0 is located at the KEK Central Computing system (KEKCC), Tsukuba (Japan), where the data storage server is connected to the SINET network through 4x10Gbps access ports. KEKCC provides computing and storage resources for KEK research projects and the Belle II collaboration is one of its largest user group. SINET is the largest NREN in Japan, with a multiple-100Gbps backbone covering all Japanese prefectures, managed by the National Institute of Informatics (Chiyoda-ku, Tokyo, Japan).

The tests were carried out in the direction from Japan to EU, mimicking the same path the experiment data will follow, in particular to send a second copy of the original data (raw data) from Japan to the research centres in Europe.

The Round Trip Time (RTT) measured between the two sites over the 100Gbps international link provided by SINET was 161 ms.


Figure 4.3: Test Scenario

Figure 4.4 shows the results obtained using 10 and 20 iperf3 sessions, respectively, with 16 parallel streams each. In particular, the graphs show that the Belle II collaboration was able to reach a maximum peak of 37 Gbps saturating over 92% of the total bandwidth (40 Gb being the bottleneck) with 10 concurrent flows.

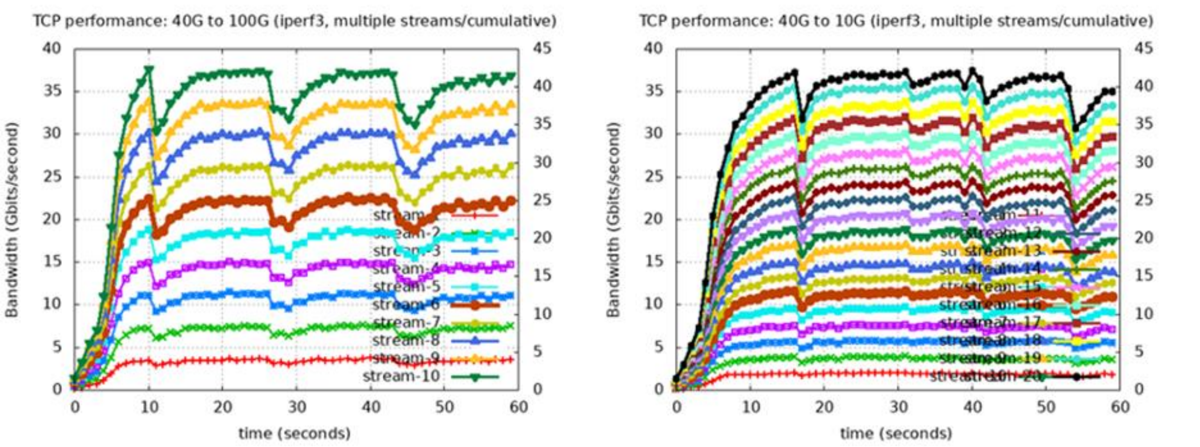


Figure 4.4: Iperf3 performances

The graphs in Figure 4.4 show the performances achieved with iperf3, each line represents the contribution of a single transfer to the total band. The plots were generated using a python script collection, written by the collaboration.

These results confirmed that the throughput achievable using the international R&E network infrastructure would satisfy the requirements of the distributed computing model of the Belle II experiment, allowing a seamless transfer of the raw data from Japan to Europe.

## 4.5 Future Plans

GÉANT continues to work with the Belle II collaboration to perform more network tests between Japan and Europe, for example, evaluating the connection between international data centres (Tier 1), part of the Belle II collaboration.

In addition, the researchers are planning to use the GÉANT DTN nodes for the Jennifer2 Project [Jennifer], the Japanese and European Network for Neutrino and Intensity Frontier Experimental Research, funded under the Horizon2020 program of the European Union as a Marie Curie Action of the RISE program, under Grant n.822070.

The JENNIFER2 project is based on research programs at experimental facilities located in Japan, including accelerator produced neutrinos (T2K and Hyper-K collaborations), cosmic neutrinos detection (Hyper-K collaboration), and a high luminosity electron-positron collider (Belle II experiment at SUPERKEKB), where very rare processes can be observed, aiming to jointly investigate the quark and lepton flavour structure of the particle physics.

JENNIFER2 fosters the collaboration of European scientists with the Japanese research community in all experimental issues, and specific knowledge sharing among different experiments is pursued in the field of photon detection, computing, real time and remote controls, data analysis algorithms, and theory calculations. This will allow to build up synergies on key technologies and research methodologies, as well as on dissemination and outreach.

# 5 CTAO

This section reports on the activities carried out to support the Cherenkov Telescope Array Organisation (CTAO). This activity has been carried out with the support of REN partners in South America and Europe.

## 5.1 The CTA Organisation

The Cherenkov Telescope Array is a global initiative to build the world's largest and most sensitive high-energy gamma-ray observatory in the world, with tens of antennas planned across two sites: one in the Northern hemisphere, on the island of La Palma, Spain, and the other in the Southern hemisphere, in the Atacama desert near Paranal, in Chile.

CTA will be the foremost global observatory for very high-energy gamma-ray astronomy over the next three decades, and will be the first ground-based gamma-ray astronomy observatory open to the world-wide astronomical and particle physics communities. CTA will address some of the greatest mysteries in astrophysics, detecting gamma rays with an unprecedented sensitivity and expanding the cosmic source catalogue tenfold. CTA is a unique, ambitious large-scale infrastructure that will expand observations up to a region of the spectrum that has never been observed, opening an entirely new window to our Universe.

## 5.2 Community Requirements

The main requirement expressed by the CTAO organisation was technical and financial advice to assess the cost to connect their two sites to a set of relevant data centres in Europe. In particular, CTAO needed to update and refine their distributed computing model, aiming to optimise data transfers and reduce cost. One of the key factors in the global connectivity scenario is the forthcoming availability of the BELLA/EllaLink cable directly connecting Europe and Latin America: one of the requests from CTAO, in addition to a description of the connectivity options for each of their sites, was to quantify the benefits (in terms of available link capacity and reduction of costs) of the introduction of BELLA in connectivity from Chile to Europe.

A connectivity costs analysis document has been produced for CTAO, describing the terrestrial connectivity solutions, transatlantic links, last mile connectivity at the two end-sites and at the indicated data centres in Europe.

### 5.2.1 The CTA Southern Hemisphere Array

The Southern Antenna Site of CTA [CTA] is in the Paranal region, in the South of Chile, close to the two Paranal and Armazones scientific sites that are currently used for other astronomical instruments, and are already provisioned with connectivity established by the EU-funded EVALSO project. The site is less than 10 km southeast of the European Southern Observatory's (ESO) existing Paranal Observatory in the Atacama Desert in Chile, which is considered one of the driest and most isolated regions on Earth – a paradise for stargazers.

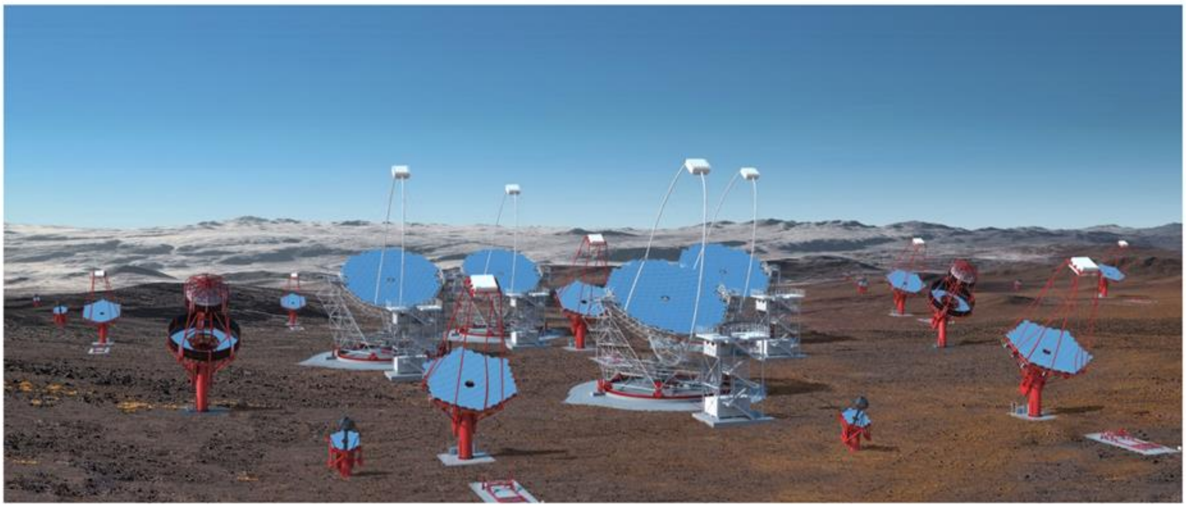

Figure 5.1: CTA Southern Hemisphere Site (rendering)- source: CTAO web site

### 5.2.2 The CTA Northern Hemisphere Array

The CTA Northern Antenna site in Spain is the Roque de los Muchachos observatory, on La Palma island, which is part of the Canary Islands. RedIRIS has two PoPs in La Palma, one close to the cable landing point and the other on the observatory site. The connectivity between Roque de Los Muchachos and any RedIRIS PoP in the peninsula is based on dark fibre, and lit with equipment that supports 10Gbps lambdas. RedIRIS is, therefore, capable to provide multiple 10Gbps links, if required.

In 2020 RedIRIS will start the renewal of all optical equipment, supporting 100Gbps wavelengths.

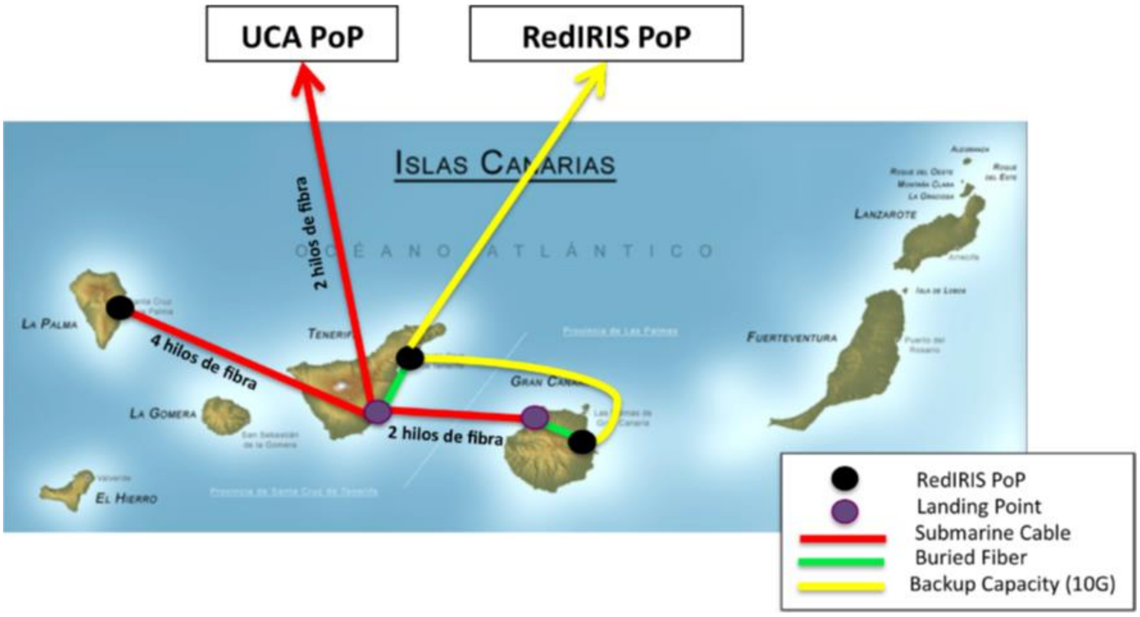


Figure 5.2: Layout of fibre infrastructure in the Canarias Islands

Figure 5.3 shows the local network for the Instituto Astronomico de Canarias, including the fibre interconnection among the sites in the Canary Islands:


Figure 5.3: IAC Network on the Canarias Islands

The local IACNET network interconnects the observatories and antenna sites to the IAC headquarters, which are then connected via fibre to the RedIRIS PoP.

## 5.3 The Cost Analysis Document

The final outcome of the support activity to CTAO is represented by a connectivity cost analysis document provided to the CTAO organisation, detailing the costs and link capacities for connecting the two antenna sites to the data centres in Europe.

Upon request from the CTAO organisation GÉANT has provided a cost analysis document of a study aimed at drafting estimates for the costs that CTAO will be facing to provide the required connectivity from the antenna sites to Europe.

The document is meant to help CTAO to define their distributed computing model, and to assess the connectivity of the European sites involved in it.

Further information is available in the *Cherenkov Telescopic Array Connectivity Assessment Information update on connectivity possibilities for Cherenkov Telescopic Array sites: Chile and Spain cost* analysis document, and may be made available on request [CTAInput].

## 5.4 Connectivity Information for the Southern Antenna Site

The Southern Antenna Site of CTA is in the Paranal region, in the South of Chile, close to the two Paranal and Armazones scientific sites that are currently used for other astronomical instruments, and are already provisioned with connectivity established by the EU-funded EVALSO project.

Further information is available in the *Cherenkov Telescopic Array Connectivity Assessment Information update on connectivity possibilities for Cherenkov Telescopic Array sites: Chile and Spain cost* analysis document, and may be made available on request [CTAInput].

# 6 Conclusions

This document has presented an extensive insight into the activities of GN4-3 WP3 T2 in supporting international research communities, including the process behind the engagement and support actions. The role of the International User Support function is to leverage the services and synergies of the European NREN community with the purpose of enabling and facilitating science and education, in Europe and globally, to the highest possible extent, but also to strengthen the value proposition of the GÉANT community towards the user communities.

The three use cases reported in the document, ITER, Belle II and CTAO, have been chosen to illustrate the activities of WP3 T2 in different fields and involving different services: AAI and network for ITER, end-to-end data transfer optimisation for Belle II, and consulting for CTAO.

For each use case, the document has highlighted the positive impact of the support activity, describing how the user experience has improved due to the contributions from the GÉANT team. The document has also shown how the process of creating value has relied on the involvement of the NRENs (both European and non-European), and the collaborative approach that the GÉANT Research Engagement team pursues and promotes.

# Appendix A The GÉANT DTN Testing Facility

Two Data Transfer Nodes (DTNs) were set up in the GÉANT network (see Figure A.1), specifically at the London1 (Telecity, Harbour Exchange, London) and the Paris PoPs, with 10 Gb/s and 100 Gb/s network interfaces and a Linux (Fedora 23) operating system. The aim was to support the international scientific community which required trusted data transfer beacons, to measure, assess, evaluate and perform experiments with specialised data transfer applications and protocols.

The GÉANT DTNs were installed and managed by the Research Engagement and Support team and tuned according to the most recent recommendations from the network card manufacturer Mellanox (Mellanox Ethernet Performance Tuning Guide) and the ESNet Fasterdata website (ESnet Fasterdata 100G tuning website).

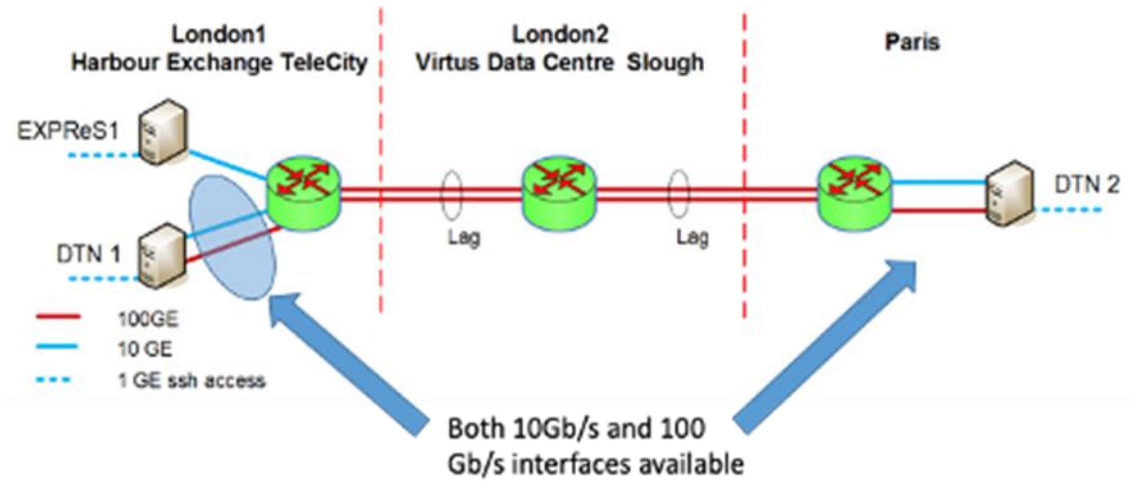


Figure A.1: The AARC Blueprint Architecture for interoperable AAIs

## A.1 Available Data Moving Tools

The DTNs have been equipped with a selection of open-source data transfer tools that large-scale distributed research projects are already using for efficient, high-speed data transfers. In particular GridFTP and FDT have been chosen because they were well-known within the scientific GÉANT community.

### A.1.1 GridFTP

GridFTP [Grid] is a high-performance, secure, reliable data transfer protocol optimised for high-bandwidth, wide-area networks. It is an extension of the File Transfer Protocol (FTP) designed for grid computing. The GridFTP protocol was developed and formally defined within the GridFTP working group of the Open Grid Forum. There are multiple implementations of the protocol; the most widely used is that provided by the Globus Toolkit.

The aim of GridFTP is to provide a more reliable and high-performance file transfer than the standard FTP, enabling a more efficient transmission of very large files. GridFTP is used extensively within large science projects such as the Large Hadron Collider, and by many supercomputer centres and other scientific facilities. One of the characteristics of GridFTP is the use of simultaneous TCP streams, optimising the use of the available bandwidth. Files can be downloaded in pieces simultaneously from multiple sources; or even in separate parallel streams from the same source. Striped and interleaved transfers, again either from multiple or single sources, allow further speed increases.

Another addition to the standard FTP protocol is the support of partial retransmission. Although FTP can resume an interrupted file transfer from a specific point in a file, it does not support the transmission of only a certain portion of a file, while GridFTP allows just a subset of a file to be sent. Such a feature is useful in applications where only small sections of a very large data file are required for processing (for example, processing data from a science experiment repository, a traditional use of Grid technology). In addition, GridFTP provides a fault-tolerant implementation of FTP, to handle network unavailability and server problems. For example, data transfers can also be automatically restarted if a problem occurs.

Finally, the underlying TCP connection in FTP has several settings such as window size and buffer size. Expert users can manually set those parameters, otherwise GridFTP could allow automatic negotiation of these settings to provide optimal transfer speeds and reliability (optimal settings are likely to be different with large files and for large groups of files).

### A.1.2 FDT

FDT [FDT] is an application for Efficient Data Transfers which is capable of reading and writing at disk speed over wide area networks. FDT is based on standard TCP, written in Java, and controlled through a Command Line Interface (CLI). Binaries are available for all major platforms and easy to use.

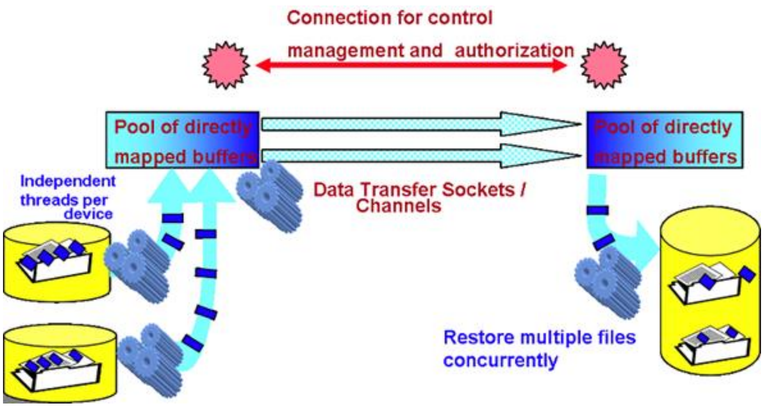


Figure A.2: FDT block diagram (from the official FDT website)

FDT is based on an asynchronous, flexible multithreaded system, and uses the capabilities of the Java NIO libraries. The main features of FDT indicated in the block diagram of Figure A.2 are:

- Streams a dataset (list of files) continuously, using a managed pool of buffers through one or more TCP sockets.
- Uses independent threads to read and write on each physical device.
- Transfers data in parallel on multiple TCP streams, when necessary.
- Uses appropriate-sized buffers for disk I/O and for the network.
- Restores the files from buffers asynchronously.
- Resumes a file transfer session without loss, when needed.

FDT can be used to stream a large set of files across the network, so that a large dataset composed of thousands of files can be sent or received at full speed, without the network transfer restarting between files.

## A.2 Network Testing Tools

### A.2.1 udpmon

UDP achievable throughput and packet loss tests can be performed using udpmon. udpmon is a client-server network testing software that sends streams of carefully spaced UDP frames from a requesting node to a responding one. It is able to measure:

- UDP achievable throughput as a function of the time between sending packets and the packet size.
- Packet loss rate and loss distribution.
- Packet re-order rate and re-order distributions.
- Inter-packet jitter.
- Relative 1-way delay.
- The CPU load on local & remote nodes (user and kernel mode).

- The statistics for the network devices on local & remote nodes.

### A.2.2 iperf and iperf3

Memory-to-memory TCP Achievable Throughput can be measured using iperf [iperf] and iperf3. iperf3 also provides the number of TCP segments that were re-transmitted.

# References


| | |
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| **[thiss.io]** | https://thiss.io/ |

# Glossary

| | |
|---|---|
| **AAI** | Authentication and Authorisation Infrastructure |
| **AARC** | Authentication and Authorisation for Research and Collaboration |
| **CLI** | Command Line Interface |
| **CoCo** | Common Objects in Context |
| **DS** | Discovery Service |
| **DTN** | Data Transfer Node |
| **FTP** | File Transfer Protocol |
| **GDPR** | General Data Protection Regulation |
| **ICT** | Information and Communications Technology |
| **IdM** | Identity Management |
| **IdP** | Identity Provider |
| **IFERC** | International Fusion Energy Research Centre |
| **L** | Layer |
| **MDS** | Metadata Service |
| **MMS** | Membership Management Service |
| **NREN** | National Research and Education Network |
| **P2P** | Peer to Peer |
| **PoP** | Point of Presence |
| **R&D** | Research and Development |
| **REN** | Research and Education |
| **RTT** | Round Trip Time |
| **SAML** | Security Assertion Mark-up Language |
| **SDCC** | Scientific Data & Computing Centre |
| **SLA** | Service Level Agreement |
| **SIRTFI** | Security Incident Response Trust Framework for Federated Identity |
| **SP** | Service Provider |
| **SRM** | Storage Resource Manage |
| **T** | Task |
| **TB** | Terabytes |
| **TCP** | Transmission Control Protocol |
| **VO** | Virtual Organisation |
| **VPN** | Virtual Private Network |
| **WP** | Work Package |