The role and the importance of Interconnection in Gaia-X

Position Paper

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Executive Summary

Interconnection plays an important role in daily enterprise business. Different interconnection services ensure easy multi-cloud setups, network connections on-demand with guarantees and high security standards. Accordingly, it is seen as a fundamental Gaia-X pillar to ensure interoperability and seamless connection among numerous data spaces. In this paper you will learn about the importance of interconnection, and its role. Moreover, a user perspective is elaborated. Finally, the status of interconnection in the technical architecture of Gaia-X is described, introducing an on-hand example for a better understanding. This paper is concluded with our future vision of a federated infrastructure ecosystem.

Introduction

Interconnection is one of the key factors to implement Gaia-X services. Therefore, the aim of this paper is to depict the value added to Gaia-X from a Network & Interconnection perspective and to demonstrate why interconnection is one of the fundamental Gaia-X pillars. We want to show how it can be turned into a powerful and enabling (vision and deployment-wise) asset for Gaia-X. Then, we focus on the perspective and expectations from an end-user point of view. Moreover, we show the current state of the development in the description of interconnection services.

Before describing these points, it is important to give a common background on what interconnection is and how it is used nowadays.

What is an interconnection and its value?

Today's everyday life is mostly digitised, meaning we rely highly on the networking infrastructure assuming that different devices (computers, mobile phones, sensors, etc.) can be connected and/or provide services. While most people are aware of such services, very few are aware of the interconnection and the (inter)networking that are behind the scenes and enable most of the services we are using daily.

Interconnection vs. Networking

These two terms are often confused, so we first try to classify them before going deeper into the topic of interconnection. **Networking** refers to any technical issue aiming to connect different devices, meaning setting up the networks. When we talk about internetworking we usually refer to the Internet, which is a network of different networks.

If we continue with the Internet as an example, different networks normally belong to different entities that are also called Autonomous Systems (ASs), as defined in RFC1930 (https://datatracker.ietf.org/doc/html/rfc1930). The communication between different ASes is performed through the use of the Border Gateway Protocol (BGP) (https://datatracker.ietf.org/doc/html/rfc4271) and the action of connecting different ASes is what we call **interconnection.** That reflects its general definition (so not only related to the computer networks) of a mutual connection between two or more entities that allows the interaction among them. The process of BGP-mediated exchange of data traffic between interconnected ASes is what we call peering.

As we said, the action of connecting different networks is generally termed Interconnection. Various interconnection platforms exist today to support the exchange of digital data, they include Data Centers, and Layer2/3 platforms like Interconnection Fabrics and Internet Exchanges (IXPs). The types of networks served, and the types of services delivered are diverse and include both internet and non-internet (private) services. Collectively the physical and virtual hubs where all types of networks meet to exchange data are perhaps most accurately described as Interconnection Ecosystems.

What are the principles of interconnection?

Interconnection between two different entities is quite simple: a physical connection solves the problem even if the networks are far away.

However, if you need to be connected to more than one network, the number of connections arises accordingly to Metcalfe's Law at (https://en.wikipedia.org/wiki/Metcalfe%27s_law) $(N * (N-1))/2$ where N is the number of networks you want to connect.

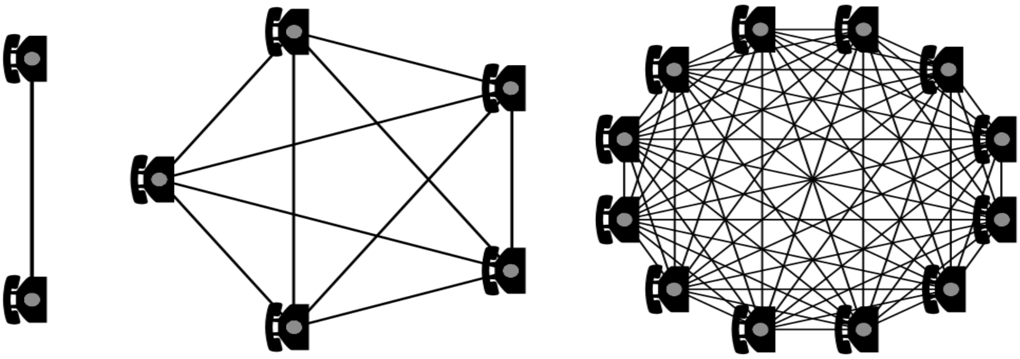

Figure 1: Complexity of connection with the increased number of networks. (Source: https://en.wikipedia.org/wiki/Metcalfe%27s_law)

So, the first step to have a cheaper interconnection is performing it in a common colocation space, thus reducing the cost of having many geographical (and expensive) circuits. The best solution is, if the owner of the colocation space is not involved in the same business as the networks that wants to interconnect, thus providing neutrality. They're normally called (carrier) neutral colocation sites and interconnection are performed with physical fiber cross-connects.

With the increase of the desired or potential interconnections, the interconnection can be achieved through a Layer 2 network. For example, this would be a Layer 2 MPLS-based service, like VPLS or EVPN that facilitates interconnection between networks. This may be achieved by players that operate such Layer 2 networks and are often referred to as Exchanges. The most common example is provided by Internet Exchange Points (IXPs), whose best definition is available on the Euro-IX page https://www.euro-ix.net/en/forixps/.

At its core, an IXP is essentially one or more physical locations containing interconnected switches that move traffic between the different connected networks (generally referred to as *members* in an IXP context). The network is referred to as the *IXP LAN, IX-fabric* or *peering LAN*.

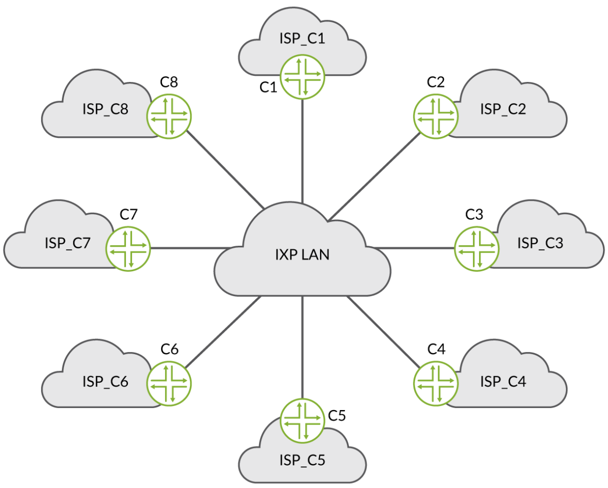

Figure 2: IXP LAN example (Source https://www.juniper.net/documentation/en_US/day-one-books/topics/topic-map/internet-exchange-point-overview.html)

It could be said that the goal of an IXP is to reduce the portion of traffic an ISP will deliver via their upstream transit providers, thereby, amongst other things, potentially reducing the average per-bit delivery cost of traffic. Furthermore, the increased number of available paths improves routing efficiency and fault tolerance. Additionally, goals could be reducing latency, providing shorter network paths, and increasing or providing redundancy.

Due to the cost reduction in port switches many networks apply a mixed approach with both Public Peering (on IXPs) and Private Peering (with cross-connects in colocation facilities or private VLANs on Layer2 fabric).

Interconnection evolution

Nowadays, different services (not only the open Internet) can be reached through interconnection; the most important is the access to public clouds (AWS, Azure, GCloud, etc.). Instead of accessing it through the Internet on Layer 3 it can be done via Layer 2 ensuring the performance and security requirements that are key features to allow enterprises to switch from on-premises resources to cloud services. These services are more frequently offered in both colocation facilities or within IXPs.

In the first case, the service is offered through an SDN fabric that allows a network to have multiple and flexible access (in terms of capacity and duration) to different cloud resources. The fabric can be operated by the same colocation company or by one or more of its customers. In the second case, the IXP fabric is SDN compliant and integrates such services in addition to traditional interconnection services.

Gaia-X added value from a network & interconnection perspective

The Gaia-X vision is articulated in the creation of two ecosystems, data and infrastructure, integrated by federation services (aka three pillars). This to enable portability, exchange and sovereignty of services and data between providers; opening the European Data Market for competitiveness and ultimately fostering growth and social equality. This vision will be turned into reality only if all three pillars are realised. To this extent, it is worth highlighting that control over infrastructure will be the key to sovereignty.

At the infrastructure level, the final goal is to set a standard that can be adopted by the market. Therefore, the target is not an academic framework to forcibly integrate different infrastructures and services, but the resulting federated ecosystem should be competitive towards consolidated public cloud providers, to foster a real open market of data & infrastructure services. This can happen only if the cost, performance, and ease of use of the infrastructure pillar of Gaia-X are comparable to (or better than) the existing solutions. The cost factor is difficult to address, although it has been proven that interconnection exchanges provide the most cost-effective solution when scale comes into play, i.e., with the growth of the number of connections (multiple destinations for each source) and increased bandwidth. It is also quite simple to demonstrate that a properly designed and instantiated network/interconnection element will guarantee the performance of the overall federated service. This is valid for both cloud/edge infrastructures and between end-users and cloud/edge.

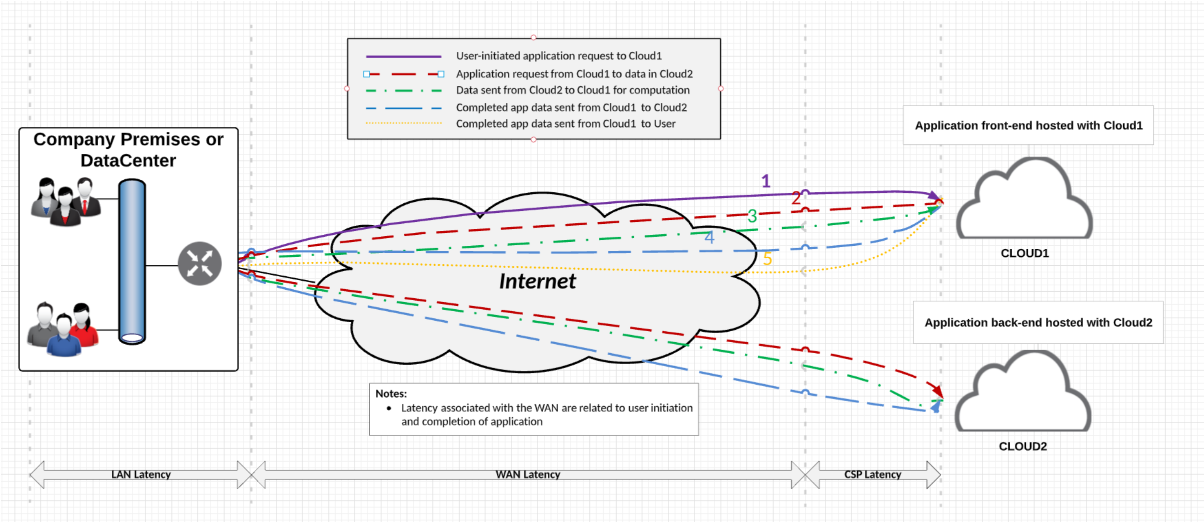

*Figure 3: Multi Cloud Data Sharing **without** Interconnection.*

Technically speaking, a Cloud or Edge service exposed to the user is always a composition of network, compute and storage services. Compute and storage always require network services to be consumed by the user. Even in the case of Platform or Application services (which abstract the underpinning Network, Compute and Storage services), the network is key to permit the user to connect to the services. This becomes exceedingly critical when the different components of the services have to be provided by different players (service providers), for instance, computing and storage provided by different infrastructure, or in other cases combining different applications running on separate infrastructures (same datacenter by different providers, same city/metro, same country in different locations, different countries, different regions...).

With the growth of the data volumes that needs to be exchanged between different entities and/or produced in one domain (entity) and consumed (computed, augmented) in another domain, the criticality and the effectiveness of a real interconnection strategy becomes evident. As shown in the picture, a consumer needs to run a service in Cloud1, which uses the data from Cloud2 to provide results back to the consumers IT/DataCenter. In a traditional cloud connectivity architecture over the Internet, all the communications will go between the "consumer" IT datacenter and the two Clouds, adding an unnecessary cycle of latency.

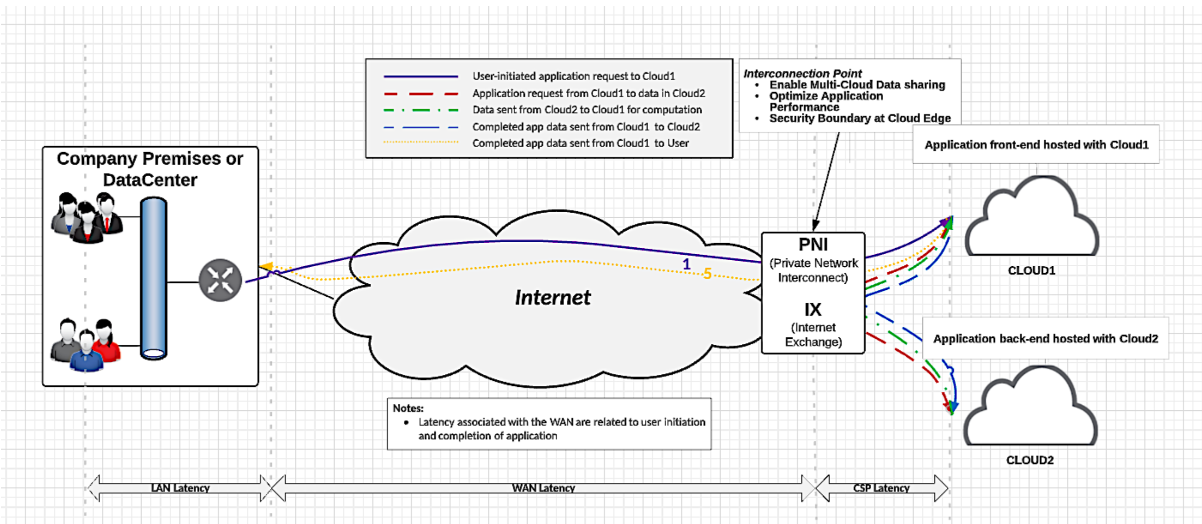

*Figure 4: Multi Cloud Data Sharing **with** Interconnection.*

This determines an implicit and underlying key requirement, which, if properly met, will determine the success of the whole initiative: Interconnection between many diverse players meeting their privacy, security, and performance needs.

Interconnection as a fundamental Gaia-X pillar

On one hand, the growing diffusion of the cloud is progressively changing the technological and business models for service demand and supply, making software-enabled flexibility, scalability, and composition the biggest trend and driver in every application domain.

On the other hand, Europe is not the leader in the cloud market. Instead, this is dominated by a few private players, which implies the lack of digital sovereignty and the risk of a total technological and business lock-in. This limits competitiveness, growth, and social equality. In addition, cloud adoption by enterprises in the EU is very low (around 36%), which sets both a challenge and an opportunity.

Therefore, **it is necessary to design, develop and implement governance, technical and business models that are aimed at restoring digital sovereignty, fostering adoption and innovation. In addition, the market must be made accessible to a large and diverse set of players, therefore allowing fair and healthy competition.**

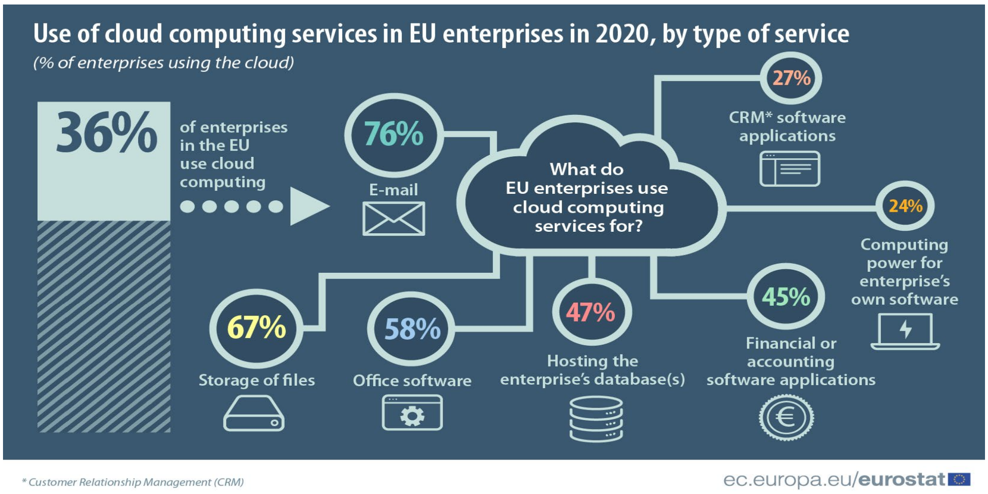

Figure 5: Cloud computing overview in EU.

Given the current market structure, the emergence of single players capable of carving out relevant niches is hardly conceivable, which might even slow down the cloud adoption of SMEs. Therefore, a totally different approach is required, which unavoidably leads towards a collaborative and federated model that, as an added value, might be more tailored to the fragmented and diversified European market structure.

Indeed, a federated approach might fundamentally resolve the single-owner dominance issue, enabling a distributed and balanced governance, which might refresh the egalitarian promise of the Internet, while also meeting the emergent need for closed groups and dedicated resources for critical applications. In addition, this would foster a more vibrant market, allowing for a healthy distribution of wealth, which generally increases the economic and social robustness and cohesion in the long term for the participants in the related ecosystem.

Seen as a promising answer to the described challenges, Gaia-X is based on the vision and promise of a federated, open, transparent, and secure digital ecosystem aimed at enabling and fostering a growing, efficient and effective data and services exchange at a European level. Therefore, Federated Data and Infrastructure Ecosystems appear to be the conceptual and practical core fabric of the technological and business structure required for the deployment of the Gaia-X vision. This sets secure, performing and privacy-preserving Interconnections between many diverse players as a key requirement for the success of the whole initiative.

On the other hand, the absence of a flexible, performing, and reliable Interconnection fabric either will prevent the establishment of a multi-stakeholder federated system or it will set it back to a fragmented or oligopolistic system, failing to deliver the disruptive Gaia-X vision.

Aligned with the intention of Gaia-X to reuse and leverage what is already available, low hanging fruits in regard to interconnection options at European (and beyond) scale are available. Indeed, a potential interconnection fabric would be easily accessible and could be switched on when requested: the IXPs and other ‘neutral colocation points’, distributed throughout Europe, could be federated and connected on demand, being compliant with the emerging Gaia-X architecture and policies. This would give the option to create dedicated or Internet-driven connection paths, which could be considered as the network fabric requested by all kinds of applications. Including the most privacy, performance, and security sensitive ones, and needed in order to be a viable alternative or complement to the current solutions offered by the dominant (non-European) players.

Indeed, access to neutral points would instantly make the interconnection between the many (big and small) players in the public and private sector practical, which would otherwise not be conceivable (as regards to viability and efficiency) in a peer-to-peer architecture. For the moment there are couple of factors that prevents all the players to connect to an IXP. For example:

1. Knowledge about IXP's existence. If your business isn't primarily in the interconnection-business you either don't know what an IXP is, or the rest of your organisation won't agree to your business-case since they lack the proper understanding.

2. Technical knowledge in the organisation isn't sophisticated enough. Many organisations don’t have their own AS and don't have the knowledge in their company on how to setup and run their own AS.

User perspective and expectations

From a business point of view, data sovereignty and no vendor lock-in are valuable sources of value and clear selling propositions.

However, the user world is dominated by risk management:

- from a legal point of view, European companies are obliged to comply with the GDPR, however no official certification exists. As a consequence, it could happen that a consumer does business with a non-compliant provider, and it is associated with possible fines.
- from an operational point of view, there are risks of ransomware attacks and the like, with the associated effects on the business reputation and operational shortages for the company.

One approach that has gained wide acceptance in recent years is the zero-trust approach. This approach implies that by default, the outside world is hostile to us, and we adopt a protectionist attitude. The final outcome is that moving data from one company to the other is:

- Difficult to establish. To get the permissions to interconnect, many approvals are needed and the interconnection solutions are quite complex, with many checkpoints in between.
- Of low performance. Due to these checkpoints with the associated inspections and shields that introduce significant delays.
- Expensive. Given that all the gear required to implement the above checkpoints, inspections and controls are expensive, and the associated procedures are complex and intensive, whichrequire a highly qualified human workforce.

What do we require to overcome these encumberments? The best approach is to work inside trusted chains, made of 'trusted by default' organisations, like:

- Trusted end-user organisations
- Trusted Cloud Service Providers (maybe the end-user organisation acting as a cloud service provider as well)
- Trusted Interconnection and Networking Service Providers that connect the above organisations.

This could be accomplished via a mix of elements, like:

- Creating labelling schemes that brings in trustfulness for organisations
- Introducing new elements that provide enhanced security, and therefore more trust, without the associated drawbacks of the current building blocks, like zero trust approaches.

Concerning Interconnection, one such new building block is private connections that are closed to the public Internet.

Development status of interconnection in Gaia-X technical architecture

To this point, we have defined Interconnection as one of four fundamental resources in Gaia-X. Moreover, following the idea of the OSI model, we have introduced three layers that interconnection can consist of. These are a physical medium (L1), Connection (L2) and a Route (L3). For the detailed attributes that describe each of these elements, refer to the latest release of the Architecture Document (https://gaia-x.eu/sites/default/files/2022-01/Gaia-X_Architecture_Document_2112.pdf).

Recently, we have modeled a scenario of Bare-Metal-as-a-Service (found in https://gitlab.com/gaia-x/gaia-x-community/gaia-x-self-descriptions/-/blob/master/documentation/sd-tutorial/bare_metal_service_offering.md). To implement it, every element in this use case needs a self-description (a machine-readable file with the description of a specific element via attributes). Let's say a company wants to offer a Bare Metal as a Service (BMaaS) in the Gaia-X Federated Catalogue. BMaaS consists of four CPU Nodes with certain configurations. All these hardware nodes have a dual-port network interface card (NIC) of type 10GBase-T standard. Interconnection connects two NICs. They are referred to as Networking Device 1 (ND1) and Networking Device 2 (ND2) as shown in Fig.6. Note that one node can have multiple NIC elements and each of those can be connected via the interconnection. This is work in progress and attributes are being revised.

The following diagram shows the self-descriptions of a network configuration. We do not include the bare metal node description, as it is not relevant for the networking part. The Interconnection element itself consists of three elements being physical medium, connection,and a route, indicated in green below.

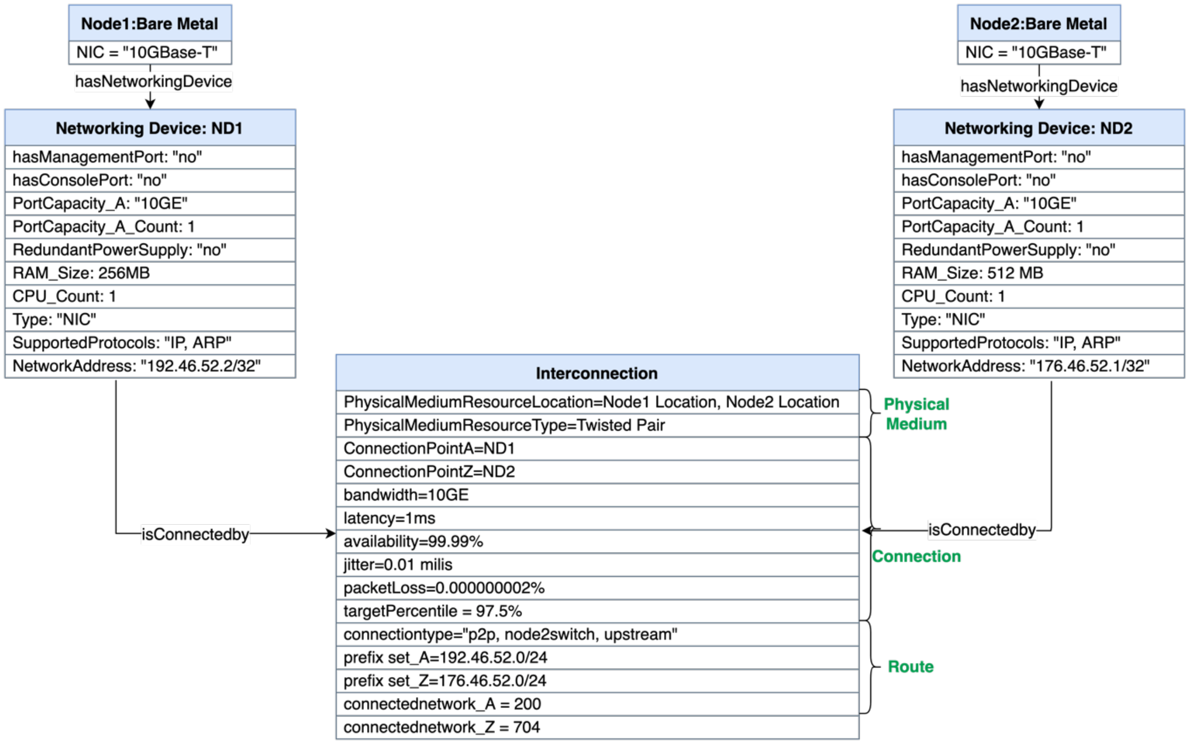

Figure 6: Example of interconnection for two nodes.

Vision of a Federated Infrastructure Ecosystem

The success of Gaia-X depends on the underlying infrastructure. Numerous Gaia-X use cases with critical applications can't rely on the best-effort Internet. However, in order to withstand the competition with hyperscalers, providers should join forces and develop common standards and APIs to enable the Federated Infrastructure. Our vision of such an Ecosystem is depicted below. This approach would ensure a dynamic provisioning of networking resources, SLA guarantees over the cascade of different providers and an increased value of using Gaia-X conforming providers.

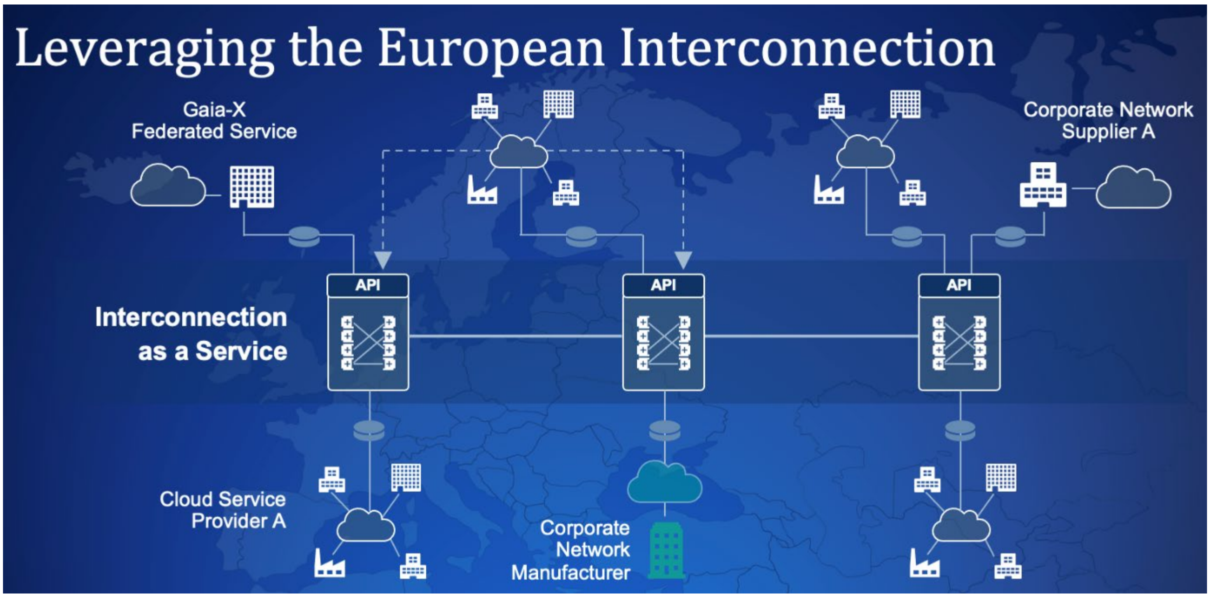

Figure 7: Vision of European Federated Interconnection Ecosystem

There are two initiatives that follow the idea of such a federated approach:

Structura-X, a lighthouse project for European cloud infrastructure endeavors to enable existing Cloud Service and Infrastructure Providers (CSP) data and infrastructure services to be Gaia-X certifiable. The goal is to create an ecosystem of independent CSPs, orchestrated by a shared layer of federation certification and labeling services based on Distributed Ledger Technology (DLT). The success will be measured through a set of Minimal Viable Products (MVPs), which shall be fully portable and interoperable between different CSPs and certified by Gaia-X or a delegated certification authority. (https://gaia-x.eu/news/gaia-x-making-stride-navigating-digital-transformation-its-lighthouse-projects-targeting)

Tellus, the Gaia-X Innovation Cluster is developing a Gaia-X compliant interconnection platform and is compiling examples of critical use cases from businesses and industries, whose requirements on the Internet infrastructure in terms of latency, bandwidth, security, resilience, growth, and monitoring go significantly beyond the current economic and technical framework. This involves connecting various cloud platforms – both to each other and to third parties – via DE-CIX and Internet service providers (ISPs) to give users choice and flexibility, and thus digital sovereignty. The goal is to use integrated software instances and homogeneous interfaces to set up and deploy a Gaia-X network infrastructure across provider boundaries that runs independently of the standard Internet and yet is supported by its infrastructure. This enables the linking of the many users and providers of federated cloud services such as AI applications, data storage and collaboration tools. (https://www.de-cix.net/en/about-de-cix/media/press-releases/de-cix-receives-subsidy-from-the-german-federal-ministry-of-economics)

Conclusion

This paper gave an extensive overview about interconnection and its importance in Gaia-X. We have demonstrated numerous advantages it has and how Gaia-X would benefit from exploiting interconnection platforms. This is also validated from the user's point of view. We strongly recommend to further explore and develop this topic in the context of Gaia-X technical architecture. Moreover, more attention should be devoted to the real-world implementations and prototyping.