Enabling Automated Network Services Provisioning for Cloud Based Applications Using Zero Touch Provisioning

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Abstract— **Modern research and education networks need to solve two major tasks: (1) providing seamless access to their users, and (2) support new scientific and collaborative applications that are becoming increasingly complex and dynamic in their scale, use of distributed resources, and required advanced networking services. Rapid deployment and automation of new network services provisioning is becoming difficult in large networks that incorporate different technologies and solutions. The task of providing seamless user experience in typically mobile and dynamically changing collaborative groups generates additional burdens for the configuration phases included in network provisioning. By introducing automation and enabling multipoint auto configuration of network devices, the Zero Touch Provisioning (ZTP) concept emerges as a possible alleviation of the complex network provisioning and infrastructure services deployment process. This paper investigates the characteristics of the ZTP model and discovers how ZTP can be used in order to enhance the services provided by the GEANT network and its associated National Research and Education Networks (NRENs) to the European research and education community. The future solution can be achieved by combining and enriching the existing provisioning models, solutions and practices available from different domains such as wireless networks, (complex) network management and operations services, and cloud based infrastructure services provisioning.**

Automated Network Provisioning, Automated Service Delivery, Cloud Infrastructure Services Provisioning, Network as a Service, Zero Touch Provisioning (ZTP).

I. INTRODUCTION

Adding services to existing networks is placing increased operational stress on network architects and administrators who are already consumed with the tasks of day-to-day management and optimization of their networks [1]. Hence, standing in the first line when it comes to satisfying the clients demands for efficient yet seamless networking, network engineers have turned towards employing and developing solutions that will automate at least part of the daily administration responsibilities like collecting, analyzing, processing performance data and automatically adjusting network configuration parameters.

The concept of automation through integration of network planning, configuration, and optimization into a single, mostly automated process requiring minimal manual intervention is not new. The main objectives of this concept are operational and capital expenditure reductions by diminishing human involvement in network operational tasks, as well as optimization of network capacity, coverage, and service quality. Recently the TeleManagement Forum (TMF) published their definition of the Zero Touch Provisioning (ZTP) concept for network management and operation as a part of their more general Zero-time

Orchestration, Operations and Management (ZOOM) model [2] that is built on top of the currently widely explored SDN (Software Defined Networks) and NFV (Network Functions Virtualization).

Major network vendors are also moving in this direction. One example of an holistic approach to the ZTP definition for networks is provided by Juniper [3], that suggests that the newly connected network devices should be fully configured automatically, in a plug-and-play sort of fashion. ZTP has become part of the services portfolio of a large number of network equipment vendors naming Cisco [4], Juniper [5], and Ciena [6] as just a few that support this trend. In light of these trends, it's even more important to implement ZTP and network automation practices inside NRENs.

GEANT and NRENs are facing increasing demand from their research and education community for delivery of complex distributed infrastructure based services with controlled QoS for scientific applications. This is made even more complex when combined with the demand for a dynamically configured network infrastructure provisioned on-demand that will be used to offer these services. Majority of the currently available and used resources are cloud based and supported by corresponding automated cloud deployment tools. However, these tools do not cover external interconnections to other cloud networks. A number of projects have been addressing multicloud and intercloud network infrastructure delivery, such as GEYSERS [7], CYCLONE [8], and GEANT4 [9]. Some of the aims of these projects are development of corresponding tools and solutions in order to enable connectivity between cloud providers and NRENs or campus networks over the GEANT network infrastructure. Examples include SlipStream [10] for multicloud services deployment, OpenNaaS [11] for intercloud network provisioning, as well as Open Cloud eXchange (OCX) [12] for smooth multi-provider cloud services delivery over the GEANT and NREN infrastructure. However, all of these solutions and components are not integrated into one-infrastructure service provisioning system or platform. Thus, here we investigate whether the ZTP concept could be used as a common base and common framework for building integrated infrastructure services provisioning environment for complex (multi-)cloud based applications.

Nevertheless, one should always keep in mind that this ultimate goal can be seamlessly achieved only by employing ZTP in a vendor-agnostic hybrid approach, combining the possibilities for centralized automation and distributed control of the network elements configuration. As hardware and software continues to be decoupled [13], it's critical to find a way to automate the new operational model. Automation, software defined devices, and bare metal switches are all contributing to a fast-paced and dynamic network environment.

Zero touch services are promoted as versatile and flexible so that a plethora of specific needs and service provisioning can be effectuated. They can be deployed in many NREN networks for various specific reasons that seem to converge toward network optimization, higher quality of experience (QoE), and better operational efficiencies.

The main goals of this paper is to position the zero touch trends within the everyday networking tasks and service provisioning of the NRENs and their interconnections aiming to leverage the zero touch potential in order to enhance the services offered to the end-clients (not just in the sense of seamless wireless connections but also in deploying more advanced services) and explore the possibilities for developing new services that can be efficiently provisioned using the zero touch approach.

The rest of the paper is organizes as follows: In Section II zero touch provisioning is introduced and its benefits and capabilities compared to the traditional approach are presented. The wireless networking use case is considered additionally being somewhat more specific in its design and influence on the user experience. Section III goes one step further with the zero touch concept discussing the benefits of zero touch orchestration that leverages the benefits of zero touch on a full end-to-end path throughout the network, while Section IV introduces the concept of higher level service provisioning for true zero touch user experience offered via the zero touch connectivity as a service that can be integrated with different application layer services. Finally, Section V concludes the paper.

II. ZERO TOUCH PROVISIONING

At its core, ZTP is an automation solution that's designed to reduce errors and save time when network administrators need to bring new infrastructure online.

The process of ZTP has its roots in the process of automated server deployment, which is a typical treat that is part of the IT world ever since the first Linux servers [14]. Rather than using command-line interfaces (CLI) to configure systems one at a time, administrators can use automation tools to roll out the operating system software, patches and packages on new servers automatically. Advanced scripting capabilities also allow administrators to tailor the boot configuration of these systems with profiles for specific applications.

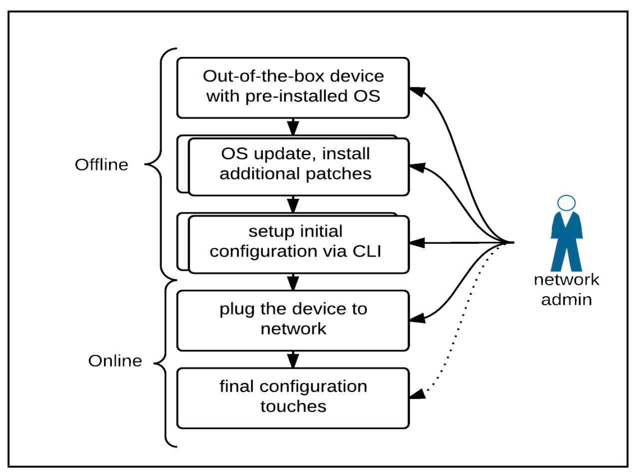

Figure 1. Process flow of the traditional new network device provisioning

A. *Traditional network provisioning*

Network devices have traditionally been managed via the CLI. For an example, switches are traditionally coupled with pre-loaded proprietary network operating systems. Network technicians use CLI or the manufacturers own tools to provision the device, a process that can be broken down into the following basic steps, see Fig. 1:

1) The new switch already has a pre-installed OS to help bootstrap the device. When first removed from the box, the device is kept offline while the administrator checks the operating system version and makes any updates - patches, bug fixes, or any new feature updates as necessary.

2) An initial configuration is made to establish basic network connectivity. This includes parameters such as administrator and user authentication information, the management IP address and default gateway, basic network services (DHCP, NTP, etc). The processes of enabling the chosen L2 and L3 network protocols are also examples of the bootstrap process.

Once the initial OS and configuration has been verified, the device can be installed into the environment (racked and cabled), where further customized configuration can be made (either locally via the console or using a remote access protocol). These final configurations are specific to the application and location within the network.

B. *The ZTP approach*

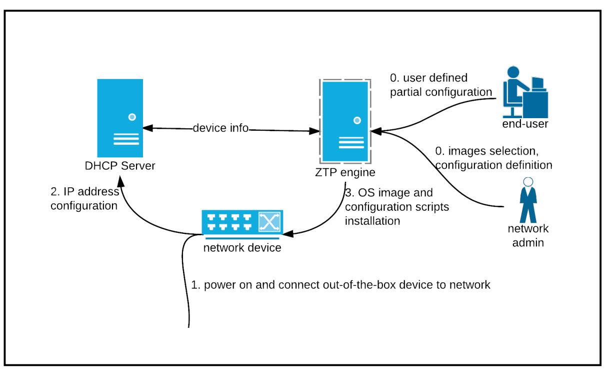

Figure 2. Steps included in the ZTP process when connecting a new device to the network

With ZTP, the administrator receives the hardware and the first thing they do is to physically install the device – rack and cable the switch. Once the switch is powered on, it uses standard network protocols to fetch everything it needs for provisioning. The process usually includes the following steps (with small variations depending on the vendor), see Fig. 2:

1) Power on the device and connect it to the network immediately.

2) The device will send a DHCP query and get an assigned IP address that will enable network connectivity and management.

3) The DHCP server will also provide the device with information on how to contact the ZT engine (one or several, usually TFTP, servers) in order to get:

a) the right operating system image, and

b) receive and activate the right configuration file based on the application profile.

Of course, this means that the device proper operating system image and specific configurations need to be decided upon and defined at the heart of the ZT control (i.e. the ZT engine) prior to connecting the new device to the network.

Another possibility that greatly influences the increased ZT capability for interconnectivity and process automation is the ability for the desired configuration to be supplied to the ZT engine via an intuitive web based interface. This opens up the possibility for allowing (at least partial) end-user control of the network devices. This feature is very important since it holds the potential to allow the end-users exercise control over the network infrastructure when requiring a specific service. It would be, however, a lot more beneficial if this type of remote configuration is automatically triggered with the request of the service, hiding the unnecessary details from the end-user. Yet, in order to provide this solution across network domains a full orchestration of the network provisioning needs to be achieved as it is discussed in the next section.

Different vendors have slightly different implementations of the above-described general approach. For an example, the Cisco Networking Services Zero Touch feature [4] provides a zero touch deployment solution where the device contacts a Cisco Networking Services configuration engine to retrieve its full configuration automatically. This capability is made possible through a single generic bootstrap configuration file common across all service provider end customers subscribing to the services. Within the Cisco Networking Services framework, customers can create this generic bootstrap configuration without device-specific or network-specific information. The Cisco Dynamic Host Control Protocol (DHCP) Zero Touch feature enables a device to retrieve configuration files from the remote DHCP server during initial deployment with no end-user intervention.

Using Zero Touch Provisioning (ZTP) capabilities available in Juniper Networks [5], a new device has its port configuration and its IP address automatically provisioned based on the requirements of its location. When a switch is connected to the network and powered up with its factory default configuration, the ZTP process on the switch downloads the appropriate software as well as the configuration file for the device. The basic ZTP process provides a standard configuration file based on the type of device. The second phase is device-specific, taking advantage of Juniper Networks built-in automation capabilities. During the second phase, the device automatically installs a device-specific configuration based on its location. The device gets a specific configuration based on where the device is plugged into the network. If this device is removed and another device gets plugged in at this location, that device gets the same specific configuration irrespective of the MAC address or serial number of the device.

Furthermore, one of the essentials of the zero touch approach is the ability to do this initial bootstrapping and configuration in a secure manner. This topic has been investigated lately, resulting with several different solutions and Internet drafts. One example is the technique for establishing a secure NETCONF connection between a newly deployed IP-based device, configured with just its factory default settings, and its rightful owner's network management system (NMS) given in [15].

It is straightforward to conclude that all NRENs can benefit by implementing the ZTP approach, thus reducing the time for provisioning new equipment, but also for updating and adjusting the already deployed devices and network services that run on top of them. The largest benefits can be seen within the network operation center (NOC) during their daily routine business, as well as the possibility for an unmanned network setup and configuration for different NREN clients, e.g. remote setting up new devices on the premises of schools or research facilities using zero touch. Another large potential use case is ZTP for the eduroam service, which is discussed in the next subsection.

C. Zero Touch for seamless wireless connectivity

The eduroam service [16] is one of GEANT's greatest success stories, adopted by all of its members and many of their immediate clients. The eduroam service provides federated WiFi connectivity for all educational and research staff members of the NREN clients no matter their location inside the GEANT network. However, in order to provide this seamless experience to the end-user a substantial effort needs to be made by every local network administrator in order to setup the eduroam wireless network across all access points and wireless controllers across the coverage area.

The traditional approach includes a supervised multi step configuration network (APs, controllers, underlying L2/L3 infrastructure), thus inherently requiring a high level of expertise. Whenever the coverage area expands, additional access points come to life and the configuration process needs to be repeated all over again. Expansion of eduroam coverage outside the university campus into the smaller organizations like schools and colleges is thus inhibited. The ZTP approach has potential to at least somewhat alleviate this setup (see Fig. 3), while also reducing the need for technical support from the local network admins. Similar attempts are being made within NREN communities [17].

A simplified form of wireless ZTP is offered by the big wireless equipment vendors, such as Aruba [18], by the means of remote access points that receive their configurations automatically without any need to configure them from the controller itself (i.e. in this scenario, the remote access points are the new network device discussed in the previous subsection). There are now controller-less solutions that are based on one dynamically elected access point to automatically distribute the network configuration to the rest of the access points in the wireless network (e.g. Aruba Instant [18]).

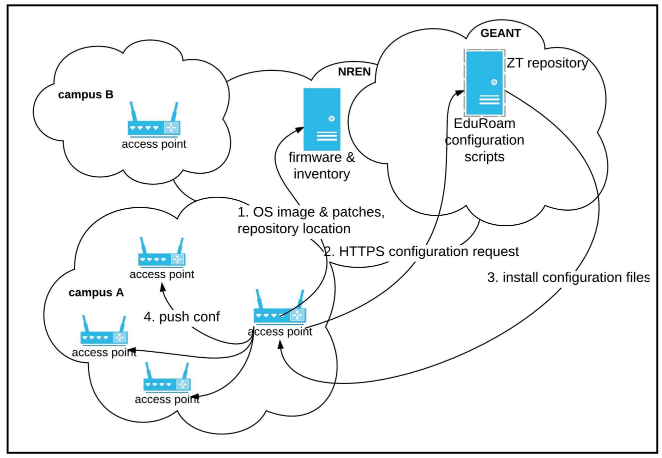

Figure 3. Possible zero touch provisioning for eduroam configuration inside NREN clients networks

However, care must be taken that the largest problem for the successful implementation of this solution is the huge diversification of the networking equipment available at the NRENs and their clients. Thus, it seems that in order to have a wireless ZTP on the GEANT level, or at least on the level of a single NREN, there is a rising need for an integrated multi-vendor solution.

From a complex multi-cloud service provisioning point of view, this zero touch wireless scenario faces a number of the same problems. Lessons must be learnt from it, especially regarding the way the seamless wireless service usage is offered to the end-clients that need to have zero knowledge on the background processes for provisioning this service, and on the problem of vendor and procedure diversification that is also present among cloud providers.

III. NETWORK AUTOMATION AND ORCHESTRATION

The initial bootstrapping and configuration of network devices that enables zero-touch provisioning of new additions in the network is just the first step in the zero touch concept.

One step beyond the single network device, is the automatic deployment of network management that allows for: device discovery, SNMP management, alarm management and event logging, network wide upgrades and rollback. It also allows centralized representation of the distributed network state that provides a single point of integration and network wide visibility and analytics. All of these features can be added via partial customization of the initial configuration files during the stage of zero touch provisioning, after which the newly added devices will be automatically added to the list of managed devices within the network management system (NMS) and all relevant management information will be pushed/pulled.

Leveraging the possibility for a centralized representation of the distributed network, the zero touch concept can be further expanded in order to include network wide orchestration. This opens up the possibilities for deployment of advanced services across the complete network domain such as seamless mobility, load balancing or quality of service.

The zero touch orchestration can actually be seen as an enabler of the self-organizing networks (SON). In this way the inherent complexity of deploying and managing a feature-rich network (WAN in many NREN cases) can be simplified with the tasks of underlying configuration and monitoring handled automatically. In order to provide this, zero touch orchestration needs to have the abilities to decide on the best network wide configuration according to the current traffic flow and clients requests from the network.

This zero touch framework is expected to provide rapid deployment, while enabling high availability and advanced features like performance based routing. In other words, it provides the means for achieving the ultimate QoE for all users within the community. By adopting the zero touch orchestration approach the NRENs would turn their network into agile dynamic environments that can instantly respond to the traffic pattern changes and user demands put on it.

For an example, one of the main existing GEANT services that can benefit from this approach is seamless mobility across the extended eduroam areas composed of different domains administered by different entities (operators), where users don't have to re-initiate their connections while moving from one eduroam domain to the other.

A. Network automation for seamless mobility

Another use case in the NRENs wireless networks that has a great potential is the current trend towards WiFi and 3G/4G mobile convergence.

ZTP and, even more globally speaking, SONs are already in place in a number of mobile operators greatly alleviating the transitioning process of 3G to 4G [19]. Current effort is nevertheless based on the single-operator network scenarios.

In GEANT's case a new set of network automation tools is required for multi-vendor, multi-operator heterogeneous radio access networks (HRAN) in order to expose the true zero-touch, zero-human-intervention network for R&E community. In this way, having setup a ZTP system for WiFi eduroam provisioning, the convergence of the wireless mobile access becomes far easier task from the point of view of configuration of the wireless equipment (access points or RAN LTE equipment).

B. Network automation for datacentres and cloud based application

Scale and complexity of modern cloud datacenters and applications that are deployed and run on clouds provide another use case and motivation for the described zero touch orchestration approach. Beneficially, network provisioning as part of the cloud infrastructure can use the same cloud deployment automation tools as used for computer resources provisioning.

Investigating the vendors for this type of use cases, we can identify an interesting solution provided by Big Switch networks that leverage bare metal SDN fabric with an software defined network (SDN) software layer in order to provide ready to deploy hyperscale network solutions [20]. Another strong example is the Glue Intelligent Engine with central policy based orchestration being part of the Cisco Gluware SDN based software stack [21].

IV. Zero Touch Network as a Service

The rising use of cloud services and network virtualization has a great impact on the future development of the NREN networks and services they provide. With the expanding usage of bandwidth hungry, low latency cloud based applications, the clients' key demands steadily turn towards on-demand, assured, cloud-centric network services.

In order to answer this growing need, NRENs need to strive for changes towards virtual network management that will enable agile delivery of new, dynamic, on-demand services with rapid new service and technology operationalization that will have performance and security guarantees.

Since the cloud service providers can potentially be accessed from within a different NREN than the one where the client resides, the question of orchestrated delivery of automated connectivity as a service across multiple network domains and multiple internal multi-technology networks arises [7].

The zero touch paradigm in this use case scenario translates into enabling the client with connectivity-on-demand service: self-chosen type of connectivity and higher level services, accompanied by service elasticity and possible change of service characteristics during the connectivity lifetime.

Thus, the ultimate challenge for the zero touch approach in GEANT is the implementation of a service/network configuration solution that allows service continuity with no service impact during service creation/modification/removal automating the network engineers' configuration changes.

In this scenario, see Fig. 4, the NRENs' end-users ask for a seamless experience for all connectivity towards possibly multiple cloud service providers (CSPs), including those within the NREN reach and those that can be reached across GEANT. The service should be setup in a matter of minutes, and a continuous delivery status and performance monitoring should be available to the client. The SLAs provided to the client needs to be monitored proactively in order for the client to be able to verify that there are consistent performance guarantees across all involved domains.

The NREN (or GEANT) acting as a connectivity provider needs to expose on-demand self-service ordering for all available CSPs with a fully orchestrated operations solution and integration between internal partners and the CSPs end points.

In order to provide automatic service ordering, design, testing and activation of network services, this scenario requires an implementation of API integration together with a seamless integration between the higher layer service access points and the (possibly SDN based) controllers and the network function virtualization (NFV) based orchestration. The programmable NFV infrastructure is a must in order to provide rapid instantiation of new services. Also, the solution needs to provide insurance for the quality

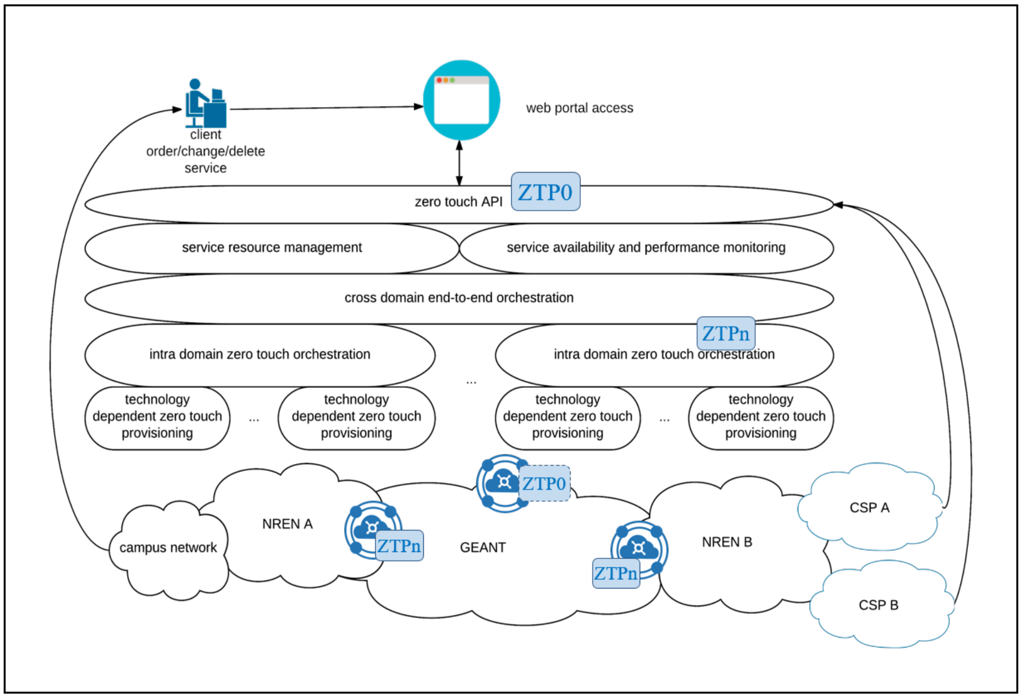

Figure 4. Zero touch cross-domain provisioning of cloud services via GEANT and NRENs

of service and satisfaction of the requirements in the agreed SLAs for the end-to-end network connectivity. On the other hand, this requires secure APIs for cross-domain exchange of performance information, together with service assurance applications, as well as, service integrity checks.

One possible direction towards the development of the solution for this use case can be drawn from the ZOOM project pushed by TMF and other companies [22] that aims to provide zero touch network as a service solution. This project is greatly supported by the MEF community [1].

V. ZTP Infrastructure Components

Implementing and operating ZTP services in a distributed multi-provider and multi-domain environment will require dedicated infrastructure that supports distributed control over the large scale services and resources deployment that in many case requires complex workflow execution that defines both the sequence of resource deployment, activation and adjustment to local environments (that will depend on the current state of the provider resources) and requires resources interaction.

In developing consistent model for ZTP enabled complex multi-cloud/intercloud applications over GEANT and NRENs network infrastructure we plan to reuse cloud experience gained with a number of large scale services deployment and extend it with the ZTP enabled network services control as given in Figure 4. Increasing proliferation of SDN and NFV at all levels of the network infrastructure will help make the usage of cloud automation tools easy.

Configuration management and orchestration tools have been used for cloud server deployment automation for a long time [24] including the most popular tools such as Puppet, Chef and Ansible [25], however their network configuration capabilities allow only intra-cloud network configuration.

A good example of fusion between cloud originated technologies and SDN is the recent development of the Network Automation and Programmability Abstraction Layer with Multivendor support (NAPALM) system by [26] that implements a common set of functions to interact with different network Operating Systems using a unified API. NAPALM supports several methods to connect to the devices, to manipulate configuration or to retrieve data and uses Ansible [27] to configure network devices as programmable devices. Ansible has benefits against other tools for network deployment and management as it does not require a node agent and runs all process over SSH what simplifies its use for configuring network devices from multiple vendors.

Network connectivity provisioning in multi-cloud environment will require dedicated infrastructure components intra-domain and inter-domain ZTP configuration servers to enable automated service provisioning over already established multi-domain/multi-NREN network infrastructure. Such servers can be naturally co-located with or integrated with the Open Cloud eXchange (OCX) [28] that is being developed by GEANT4 project . The OCX's role is to provide connectivity and network information exchange point for cloud services delivery from cloud data centers to user locations in NRENs and campuses (see Figure 4). In this case the OCX Marketplace will simplify API exchange between user applications and multiple involved CSPs and network providers.

VI. Conclusion

Deploying new services to users faster is the key to gaining competitive advantage. With the fully automated server virtualization in the cloud world, it's become critical to automate the network processes by using discussed here Zero Touch network provisioning concept and extend it to automated provisioning of the whole cloud based applications infrastructure.

Towards this goal, this paper aimed at presenting the possibilities for automated network services provisioning as part of more general distributed cloud based applications using the Zero Touch Provisioning concept.

There are a number of use cases within the NRENs networks that can greatly benefit from employing the zero touch paradigm. In order to respond to this challenge, GEANT needs to develop the means for providing zero touch connectivity as a service that will enable automatic set up of on-demand connectivity between multiple locations and resources comprising user applications and collaborative environment.

However, implementation of zero touch approach and scenarios typical for R&E community will require additional research and development of a common platform and a number of components to make this working in heterogeneous multi-provider and multi-vendor environment that can be easily adapted to the specific environment of each NREN and integrate with the existing equipment.

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