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GREEN TRAFFIC ENGINEERING : SOLUTION FOR REDUCING ENERGY CONSUMPTION IN SDN NETWORK WITH SEGMENT ROUTING

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ABSTRACT

Thanks to its flexibility of handling and processing due to the separation of control and data planes, The new Software Defined Network (SDN) paradigm has attracted a lot of attention from researchers. On the other hand, energy consumption in ICTs has become an important area of research, given the high energy dissipation due to the manufacture of high-tech equipment and the direct use of electricity. The aim of this study is to improve the energy efficiency of networks by switching off a subset of the links, using an SDN (Software Defined Network) approach.We dynamically adapt the number of network links that are switched on according to the network load.Our solution is based on the Segment Routing protocol, which we will demonstrate that is better than MPLS.The algorithms were implemented and evaluated using the OMNET++ simulator.Experimental results show that the number of links on can be reduced by a very interesting percentage while maintaining a high quality of service and network stability.the proposed solution presents a promising results to address the environmental and energy challenges faced by modern networks.
Keywords: *SDN, Green,Traffic Engineering,Energy saved,Segment Routing*

1. INTRODUCTION

In recent years, studies [1] have shown a shift in the energy footprint of the ICT industry. This increase in energy consumption is caused mainly by the proliferation and widespread use of wireless broadband access, and the massive migration of services to the Cloud. Traditional networking functionality is mainly implemented in one or more switches/routers and application software for the end-user communication process. This represents a difficult task when it comes to programming a large, scalable network. With new technologies such as SDN, the control and data plane are decoupled, centralizing all network intelligence in one place, the SDN controller.

Energy efficiency in SDN can be simplified compared to traditional networks, since the control plane is separated from the data plane, and energy-efficient solutions can be implemented easily in an SDN network [2]. In this paper our contribution is based on optimizing the energy consumed in SDN networks. Software-defined network (SDN) offer operators a new network management paradigm. It consists of a set of SDN switch or v-switches and one or more controllers. A controller provides a global view of a network. It helps an operator to optimize network performance, such as maximum link utilization and energy savings, where the bandwidth of current networks can satisfy both peak and off-peak traffic demands [3].

[4,5] study the problem of optimizing energy in SDN by rerouting traffic, using a routing protocol offering poor quality of service. Celenlioglu [6] focuses on SDN using MPLS as a data transport protocol based on label switching, which is introduced at the entrance to the MPLS network and removed at its exit. Assefa [7] proposes to replace under-utilized links with the next shortest path, and with the next path in the direction of the maximum link utility. All these studies address network energy saving using the idle method. [7,8] present a overview of different energy-efficient methods in SDN networks and carried out a comparative study to demonstrate the usefulness of this method over others.

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This article's main idea is to turn off under-utilized link to save energy consumed by the network, since even during peak consumption, links are rarely used beyond 50% of their capacity [9]. The use of routing protocols can only be used to implement fairly basic rules based only on the destination address, and do not offer advanced traffic engineering capabilities. Unlike other solutions which implement MPLS or dynamic variation of IP metrics to reroute traffic, in this paper, we use Segment Routing SR managed by an SDN controller. We adopted Multi-controller architecture to improve traffic rerouting [10]. To calculate the new traffic routes, algorithms are set up to manage the entire network traffic.

The rest of the paper is structured as follows. Section 2 present related works. Section 3 describes in detail the advantages of Segment Routing over MPLS, especially in SDN networks. Section 4 introduces the proposed algorithm. Section 5 provides the simulation results and discussion, while Section 6 concludes the paper and offers suggestions on future researches.

2. RELATED WORK

The traffic approach in SDN is inspired by the fact that many network elements are under-utilized, given the redundancy of network paths. The idea is to set these components to standby when no packets need to be transmitted, in order to save energy. This technique is known as Linksleeping LS [11]. Energy efficient techniques utilize the approach of sleeping or turning off unused switches or links when the traffic volume is low and turn them on when the traffific volume increases.

Wang et al [4] study the problem of energy optimization in SDN through traffic re-routing, in a similar way to the Green-TE approach, by formulating a programmable integer model putting the under-utilized elements (idle) in sum under the constraints of link utilization and packet delay. Two algorithms are proposed to solve this problem: alternative greedy algorithm and global greedy algorithm. Same authors in [5], define energy-efficient routing to optimize control and data traffic in SDN, this approach adds a control traffic constraint to the traditional energy-saving routing problem statement, They propose a heuristic algorithm using dynamic weighting to compute the energy-sensitive routing path.

But their equations are still too complex to solve using the usual optimisation techniques.[11]

Celenlioglu [6] focuses on SDN with MPLS. The work assumes that a set of MPLS paths are pre-calculated (pre-established) and installed. The controller performs admission control. The authors propose an algorithm for placing flows on active paths that aggregates traffic in order to put equipment in standby mode, as well as an algorithm for distributing the load of congested paths over several flows.The challenge is to decide which path combinations can be actively used to ensure that the maximum number of switches are in standby mode. To solve this equation the PLSP Selection Algorithm (PSA) is used, which takes into account both the capacity and energy consumption of each PLSP when activating or deactivating PLSPs (Pre-established Label Switching Paths), MPLS is used for large-scale networks.

[6] chose to work with MPLS but, in our solution we use Segment Routing.We demonstrate, in section 3 and section 5 experimentation and results, that it is more better than [6].

Assefa [12] propose replacing underutilized links with the next shortest path, and the next path in the direction of the maximum link utility. They introduce an IP formulation for traffic- and energy-sensitive routing problems, based on link utility information, and evaluate the algorithms using real-time low, medium and high traffic volume traces and network topologies.but they only manage to save 30% of the energy consumed, whereas our work achieves up to 50% of the energy saved.

In [13], the proposed algorithm allows the controller to configure remote routes and link rates by updating network device flow tables and setting port rates. This algorithm approximately solves the following SDN routing problem: given the network topology, a set of data flows and their traffic demands, the discrete operating rates available from each link, searches for the integral routing path of the data flows and the operating rates of all links that minimize network energy consumption.

A more recent Green-TE approach using SR-based SDN is [24]. It is based on an algorithm that removes the least used link from the topology. In addition, it is guaranteed that a previously defined upper limit for the MLU is not exceeded. Before a link is removed, a centralized SDN controller calculates the respective SR configurations to release that link from traffic. All this is done in an automated and dynamic way, where the SDN controller constantly monitors the network and cuts the links when possible. But this solution has not proven a scalability of the network to demonstrate its stability.

Table 1: Comparative Table Of The State Of The Art And Our Solution By %Energy Saved And Complexity Of The Algorithm And Protocol

	Complexity/Protocol	% energy
[4]	Yes	Not defined
[5]	no	Not defined
[6]	No/MPLS	46%
[12]	NO	30%
[13]	Yes/MPLS	Up to 50%
[24]	Yes/Segment Routing	Not defined
Our solution	No/SegmentRouting	Up to 50%

3. SEGMENT ROUTING AND MPLS

MPLS-TE was necessary to achieve a higher level of traffic management, but its complexity and lack of scalability limit its use. Segment Routing, a standardized architecture within the IETF SPRING group, offers an innovative and simple approach to traffic engineering [14,15-16], and to network programming while resisting the scaling factor. Organizations are increasingly adopting this architecture. The use of MPLS as the initial data plane has accelerated implementations and deployments. The transition to Segment Routing becomes easier as no additional protocols are required [17][25]. Ongoing work on IPv6 (SRv6) [18] will increase the number of uses, since it will be possible to program any IP architecture using the same principles.

SR use the same label switching concept as MPLS, and can use the MPLS data plan without modification. However, the control plane requires a complete overhaul. For example, labels called Segment Identifiers (SIDs) have a global scope, unlike MPLS where their scope is local.

- ✓ A nodal identifier is unique for the entire network and identifies a node (a, b, c, ..., h).
- ✓ An adjacency identifier is local to a node and identifies an outgoing interface : in the case of node b, outgoing interfaces are identified by L1, L2, L3, L4 and L5). Unlike MPLS, label distribution is done using an IGP extension rather than special protocols (LDP/RSVP-TE). Once the network has been discovered, sending a packet to node a using the shortest path boils down to adding the label a to its header.

However, it is possible to manage traffic more precisely:

- ✓ By adding the header [b, L1], node h forces the packet to go to node a using the L1 link (Figure 2).
- ✓ In Figure 3, if h wants to send a packet to a via f, it will add the header [f, a]. The packet will then take the shortest path to f, then continue to a.

Segment Routing is the ideal choice for dynamic rerouting, both with SDN and independently.

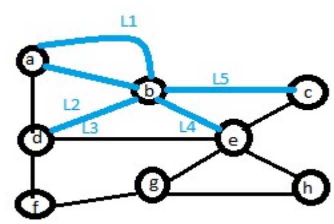

Figure 1:Segment identifier

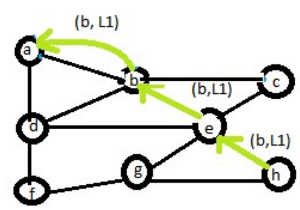

Figure 2: Forced passage through a link

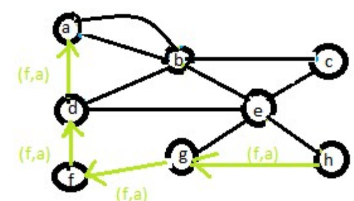

Figure 3 : Forced passage through a node.

4. PROPOSED ALGORITHM

It is clear from the previous overview that a large number of studies have been carried out on the subject of energy saving in SDN networks, particularly in terms of traffic management and the rerouting of flows between the various network devices, and the use of low-energy modes. Data rerouting techniques on alternative routes to reduce the load on links are possible, as ISPs are over-dimensioning and making networks more redundant in order to cope with consumption peaks and to offer a high quality of service. However, even during peak periods, links are rarely operated at over 50% of capacity [19].

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In this paper, we address the energy consumption issue by changing the state of the router ports at each link end. Once a link is no longer required to transfer data, the components are set to standby mode, and returned to operational mode when required: link on, link off. We assume that switching off a link corresponds to turning off a part of the integrated circuit, for example for a :

100 Gbps = 2 (135 + 150) = 570 W (1)

10 Gbps = 2 (10 + 50) = 120 W (2)

Figure 4 shows variation of link energy consumption according to speed.

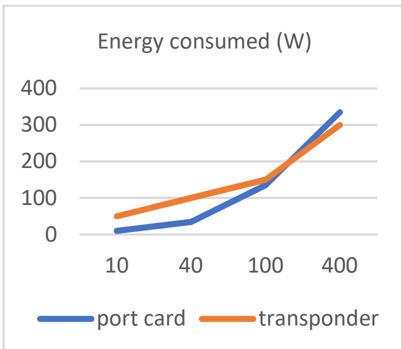

Figure 4 : Router port consumption according to port speed (Gbps)

There is a significant increase in the energy saved when port speeds increase.

The proposed solution can be divided into 3 steps:

- ✓ Select the links to be switched on or off.
- ✓ Re-route paths according to ON/OFF links.
- ✓ Send newly calculated routes to network devices to switch links on or off.

The main algorithm can be described as shown in the following flow chart (Figure 5) :

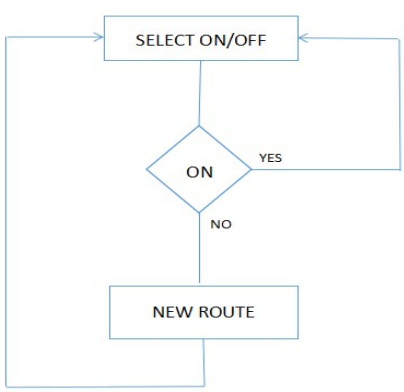

Figure 5 : Main algorithm flowchart

The main objective is not to lose connectivity. In the distributed case, nodes must synchronize to avoid turning off a link that could break the connectivity constraint. In the centralized version, if no network failure occurs, this risk does not exist [10].

4.1 Select ON/OFF

We implement a policy based on deleting less congested links, since this approach is the commonly used in the literature for evaluating results. This step consists in classifying links according to their current transmission rate, and then disabling the nodes that transmit the lowest amount of data. The challenge is not to lose connectivity even when links are deactivated.

Regarding link reactivation, we search for the utilization of the most-used node, and if its load is greater than 75%, all links are reactivated and the shortest paths are recalculated. Figure 6 below shows the flowchart of the ON/OFF link selection algorithm, which outputs a list of links that will be switched on or off.

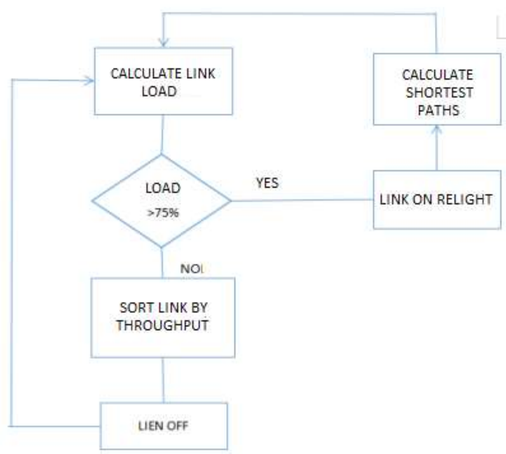

Figure 6 : Select ON/OFF flow chart

4.2 New_Route

In a traditional infrastructure, the network may not be able to route all flows when selected links are down. Each node doesn't always have to recalculate the shortest paths through the network, since congestion can still occur: congestion can occur even when a link is active, for example if it is one of the shortest paths for a large network.

The introduction of SDN technology into the network is very promising, and solves the above problem as long as the SDN controller has global knowledge of network traffic, and knows the

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bandwidth used between all ends : the traffic matrix is taken from [20].

Flow statistics should be collected by the SDN switches in the routing area. It should be noted that in this step, the algorithm can also calculate alternative paths. A technique is implemented to calculate the shortest path between each pair of network nodes and to test the ability to route all data without congestion. The calculation equation for the shortest path is as follows:

$$V \cdot (E + V \cdot \log V) \quad (3)$$

E : The number of links

V : The number of nodes.

This calculation is quite complicated, however, it can be optimized using optimization techniques [21], and using Dijkstra's algorithm at node level.

4.3 Main Algorithm:

The main algorithm of our solution which includes Select ON/OFF and New-Route is the following :

Inputs: list of links (output of SELECT ON/OFF algorithm)
BEGIN:
1.New path provided by the controller
2.Request to switch off links
3.Sends ACK acknowledgements to controllers
4.Controller sends broadcast request
5.Update routing tables and create new routes
6.The nodes in question stop sending initialization messages.
7.Links enter standby mode

This solution is cost-effective compared to distributed solutions, because in the distributed version, nodes have to synchronize to avoid a link going out and breaking the connectivity constraint. In a centralized network using SDN, this issue does not exist.

5. EXPERIMENTATION AND RESULTS

To simulate the networks, we used the omnet++ 5.5.1 simulator refering to Pratap [23] and Inet 3.6.6. Figure 7,8 present the simulated network topologies (Geant and Germany 50) are real topologies taken from topology zoo [22], for each network we simulated one day of use.

SR simplifies the control plane used in MPLS by removing RSVP. However, similar to the MPLS data plane, the traffic source uses predefined labels or segments for a particular flow along a path or part of a path.

Figures 9 and 10 show the average network throughput with mpls and with SR. Network throughput is defined as the amount of bandwidth that is successfully delivered based on the total amount of requested bandwidth arriving on the network. Throughput results are very promising using SR.

A higher rejection rate results in less link utilization because most requests are not routed.It is clearly demonstrated that the average throughput as a function of the number of responses for a network using SR is higher than that using MPLS, so the use of SR in an energy-efficient SDN network will be beneficial.

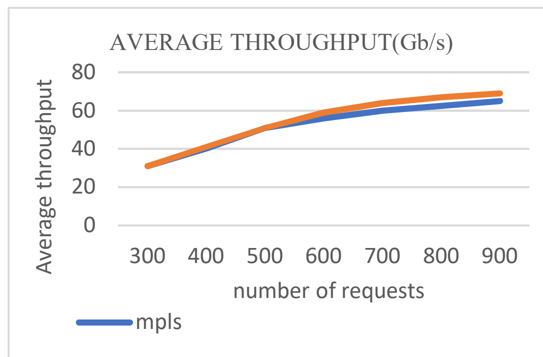

Figure 9 : Average Throughput in Gb/s

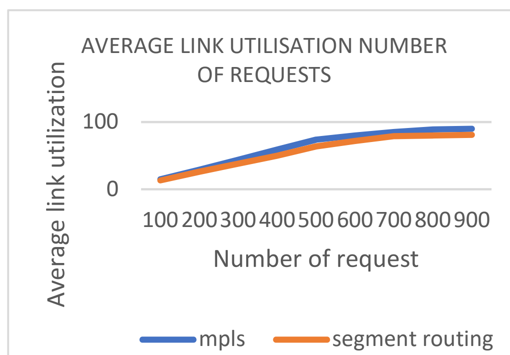

Figure 10 : Average Link Utilisation

Figures 11 and 12 present network load variation based on time over 24 hours and percentage of activated links when applying the algorithm and without it. Rerouting data over paths considered not to be the shortest leads to additional costs in terms of network load. The additional cost of our solution is illustrated in Figures 9 and 10, with a maximum value of around 17%. Despite this overhead, the network converges. Even if the links

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are deactivated, there is no great influence on network connectivity.

For the energy section, we calculate the percentage of deactivated links, using a mathematical formula to determine the percentage of energy saved. The percentage corresponds to the number of deactivated links/total number of links.

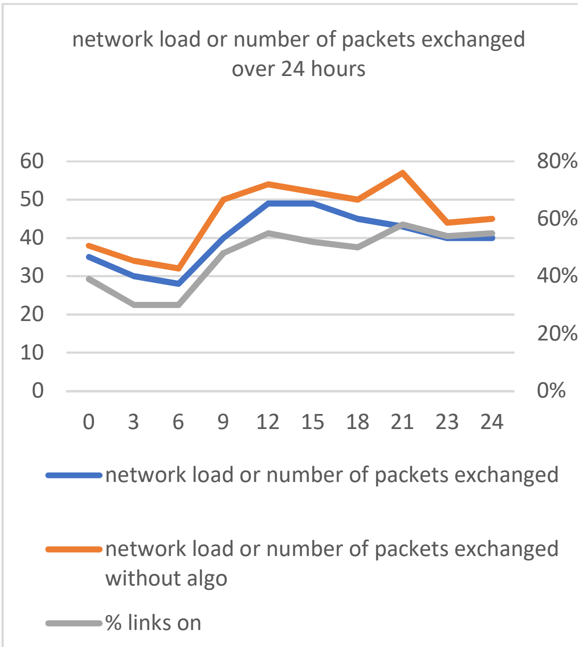

Figure 11 : Network load in Geant network

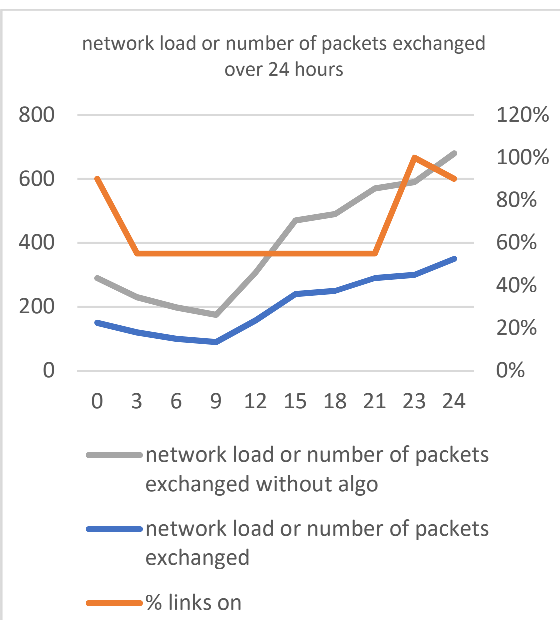

Figure 12 : Network load in Germany 50 network

On the Germany 50 network (Figure 13), we can see that from 3 a.m. to 9 p.m. the number of links switched off remains stable, so that for most of the day 45% of the links are switched off, which also represents 45% of the energy saved.
On Figure 14, which represents the Géant network from 3am to 11pm, the average number of links switched off is 50%.

Figures 13 and 14 clearly show that during peak hours the percentage of links switched off is almost constant, which means that energy consumption is also constant and can be saved by up to 50% for the 2 network topologies studied.

The proposed solution guarantees connectivity even when network load increases, which explains the stability applied to real-life core networks such as Germany50 and Géant. The generic nature of the approach means that it can be progressively improved by simply modifying the component algorithms.

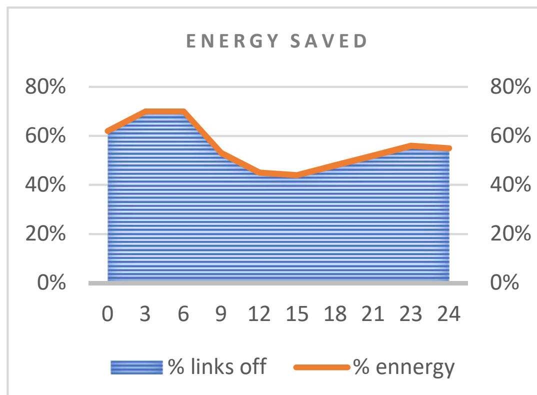

Figure 13: Percentage of energy saved and links switched off as a function of time (Géant network)

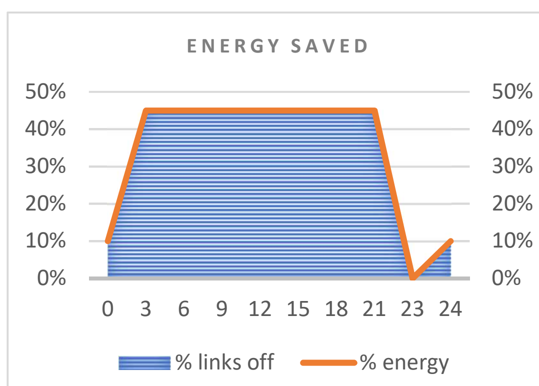

Figure 14: Percentage of energy saved and links switched off as a function of time (Germany 50 network)

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6. CONCLUSION AND PERSPECTIVE

In this article, we presented a new technique for traffic engineering designed to save energy consumed by SDN networks based on Segement Routing protocol. The aim is to reduce the energy consumption of ICTs while maintaining network quality of service. We used the OMNET++ simulator to simulate differents approaches for traffic management and flow rerouting in SDN networks, we compare network results using SR and MPLS. Results show that SR gives better performance than MPLS for the different scenarios.

Our solution is stable respecting connectivity and applied on real networks.

This study opens up a number of interesting prospects for future research into energy saving in SDN networks :1) Extension to other topologies to assess its robustness and effectiveness in a variety of network environments.2) Integration of other metrics such as latency, response time and quality of service for overall network optimisation.3) Managing the mobility of SDN networks and studying how to adapt our solution to effectively manage the mobility of connected devices.

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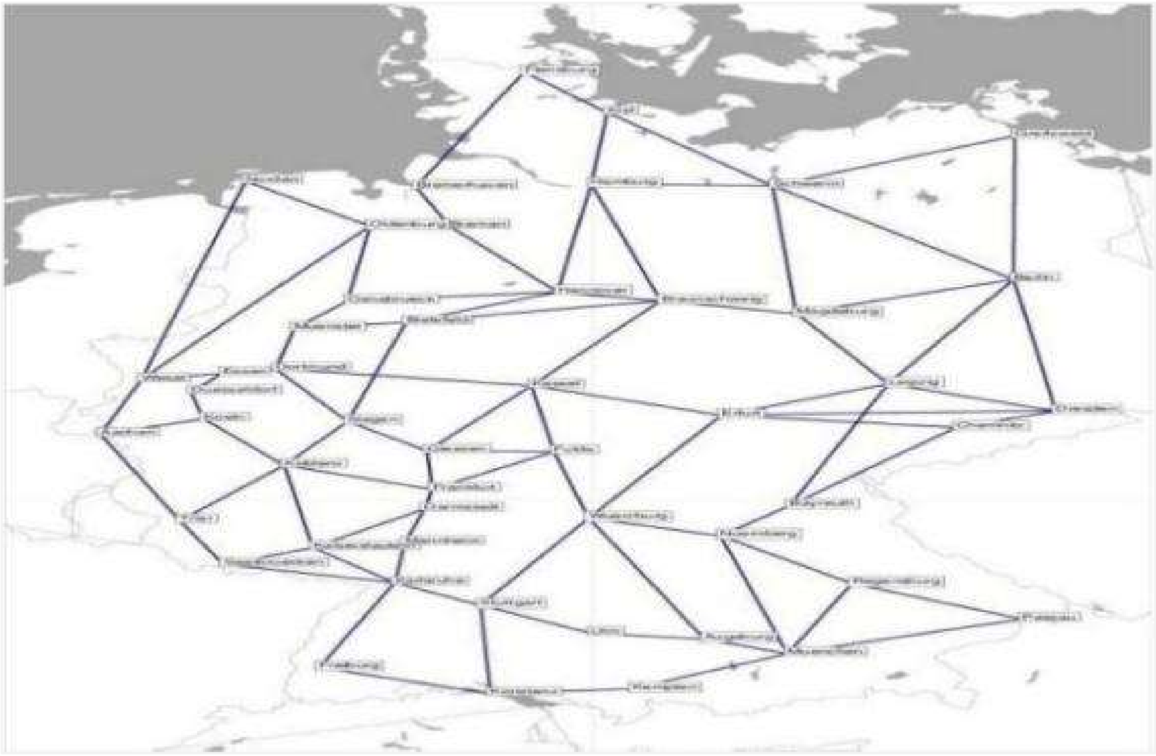

Figure 7 : Germany 50 network

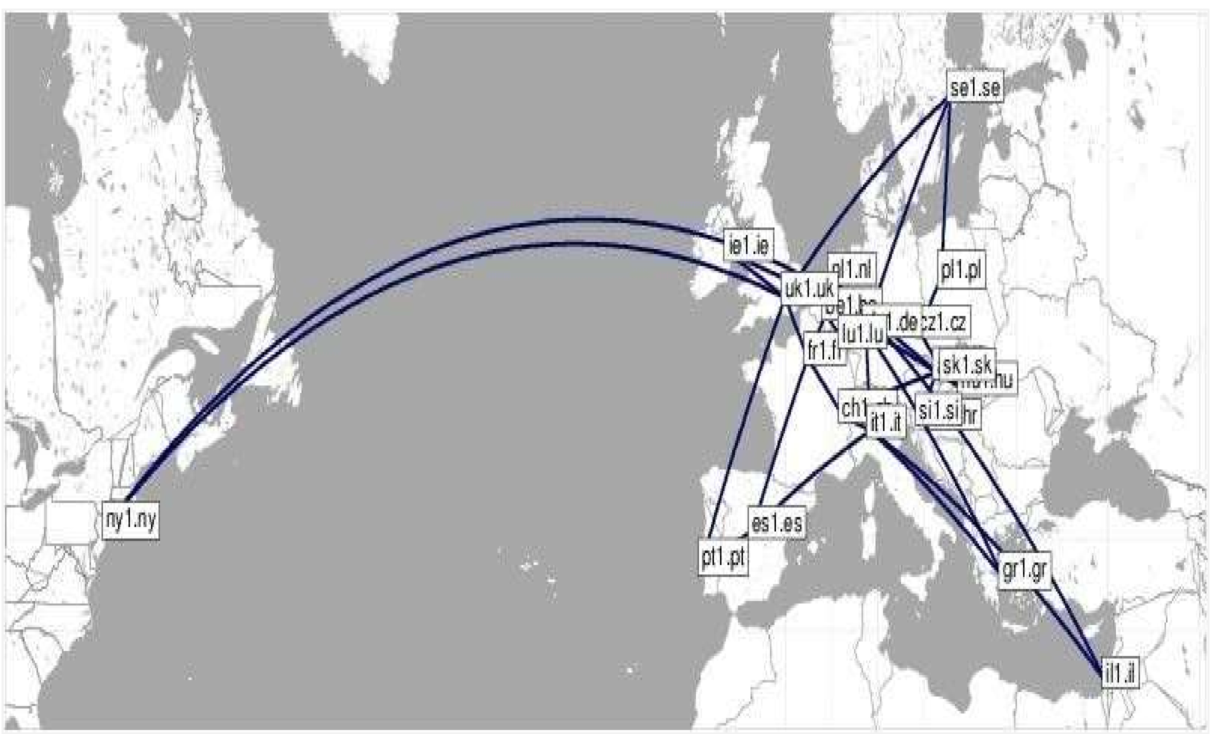

Figure 8 : Geant Network