

# Simulation of a Mathematical Model Minimizing Energy Consumption in SDN Type Networks

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## Abstract

Several works by the authors have shown that energy consumption in communication networks does not only depend on the traffic load but on all connected equipment in the network. We have contributed a new mathematical model and a new energy saving strategy with Software Defined Network (SDN) technology [1]. Our Model solution is based on the Modified SPRING Protocol (MSP). In this paper, we simulated our work and compared it to that of the authors [2] and [3]. The OMNET++ simulator was used for our work. Thus, the results of the simulations gave a delay that tends to zero, a packet loss of the order of 10% and a constant jitter of 4% better than the previous authors.

## Keywords

SPRING, Protocol, Simulator, OMNET++, Graph, Mathematical Model

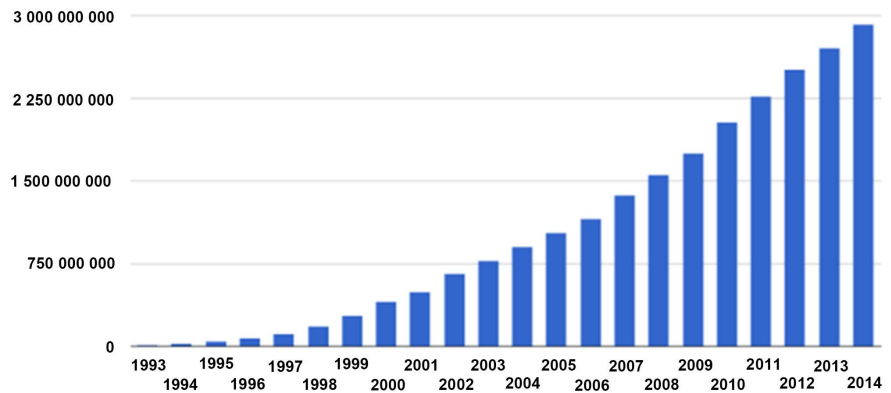
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## 1. Introduction

In Wael Zouaoui's thesis, which was defended on January 15, 2016, the authors showed that, following recent advances in the technological fields, the energy bill has continued to grow. This is due to the interconnections of computer equipment. These devices are increasingly bulky with high computing power (see **Figure 1**).

In our previous work accepted for publication in [1], we mentioned the authors of [5] and [6]. In this work, a study has shown that ICTs alone consume 2% to 10% of global consumption [5] and a consumption of 6 Twh/an to USA in hubs, Switch, Routers [6]. It was necessary to find a mathematical model that is able to minimize the consumption of energy.

We have proposed a mathematical model that minimizes energy and its relevance has been shown by an algebraic resolution. In this paper, we will



**Figure 1.** Number of global users [4].

simulate our approach proposal. The work will consist in presenting in Section 2 the previous works. Section 3 will present our mathematical model and its constraints (delay, packet loss and jitter) in which we will explain our algorithmic approach. We present in Section 4 the results of our simulations. In Section 5, we will compare our work with that of previous authors. The conclusion will come in Section 6.

## 2. Previous Work

In this section, we present the results of the simulations of different authors on energy consumption in SDN networks.

Several simulation works have been processed in the optimization of energy consumption in communication networks. This is the case for citing the authors [2] and [3]. In [2], the authors used a software approach based on an automatic On/Off control system to enable and disable router links. This is a test-bed that has been done in conventional networks. The authors chose in their network topology paths supported by the Cognitive Packet Network (CPN) protocol. It has been found that non-protocol defined routes are not degraded. The results of their approach gave 10% to 20% extinction of energy-saving links with QoS degradation (see figures below). These works of the authors, we reproduced them [2] (Figure 2).

Figure 2 showed that disabling some routers at instants 100 s, 300 s, 500 s, 700 s caused a delay. This is due to the fact that each time the links or routers are shut down, the CPN routing protocol looks for new favorable paths. And these paths being the shortest paths (instants 200 s, 400 s, 600 s) are quickly saturated. Only long paths are borrowed. Some packages are lost. In the authors' experience, the packets use in their header the extinction strategy based on the Cognitive Packet Network (CPN) protocol. Routers have become mere rest areas or roads for future destinations. This is where packages with experience look for favorable destinations. During shutdown, packets in the queue are destroyed (Figure 3).

While packages take time to find a way, some of them are lost. Because these have already reached the number of jumps to be made in the network (30 jumps

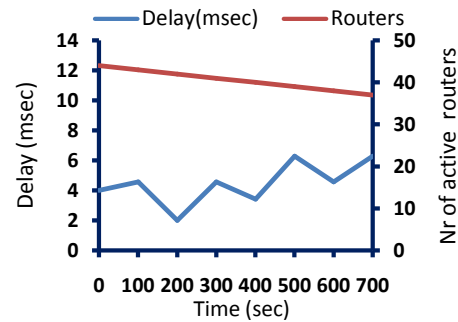


Figure 2. Delay-first experience.

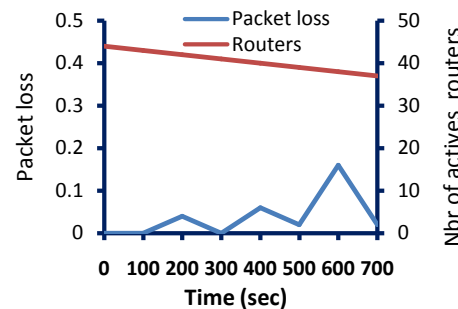


Figure 3. Packet loss-first experience.

maximum) beyond, the packets are destroyed to allow others to make their way. The successive extinction of the routers or the maximum number of links increases the delay due to congestion in the network thus causing packet losses that reach 20% (Figure 4).

Here, the jitter does not vary. The delay follows the same rhythm. Its value is constant of 0.08 (or 8%). We present now the simulations of the work of the authors of [3]. In [3], the authors proposed a software approach using the SPRING protocol to turn off links when they are not used. Their approach shows in the simulations that it was possible to turn off 44% of the links to save energy that we present below through captures:

Figure 5 simulations Results in Germany 50 (top) and Giant (bottom) networks [3]

In this work [3], we report their results on three points:

- ✓ **Impact on the network load:** it creates an additional cost of 18.56%. The paths on which packets are routed are not the shortest. But this extra cost is quickly canceled when the links are lit (Figure 5(a) and Figure 5(c)).
- ✓ **Impact on end-to-end delay:** the increase was 37% with Germany 50 while in most cases it is 20%.
- ✓ **Impact on packet loss:** no loss of packets with the algorithm used by the authors based on the Spring Protocol.

We used the idea of the authors of [3] to improve the work of the authors [2]. Our approach is software. It allowed us to disable the maximum of routers ports. Ports are disabled for adjacent routers. It is better than those of the previous

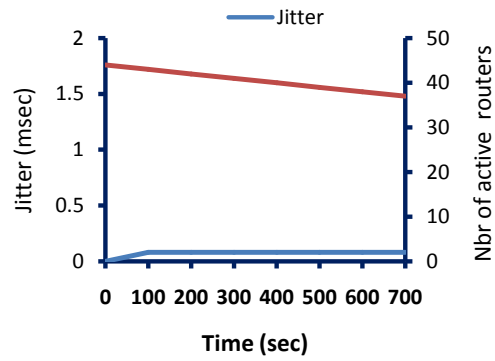


Figure 4. Jitter-first experience.

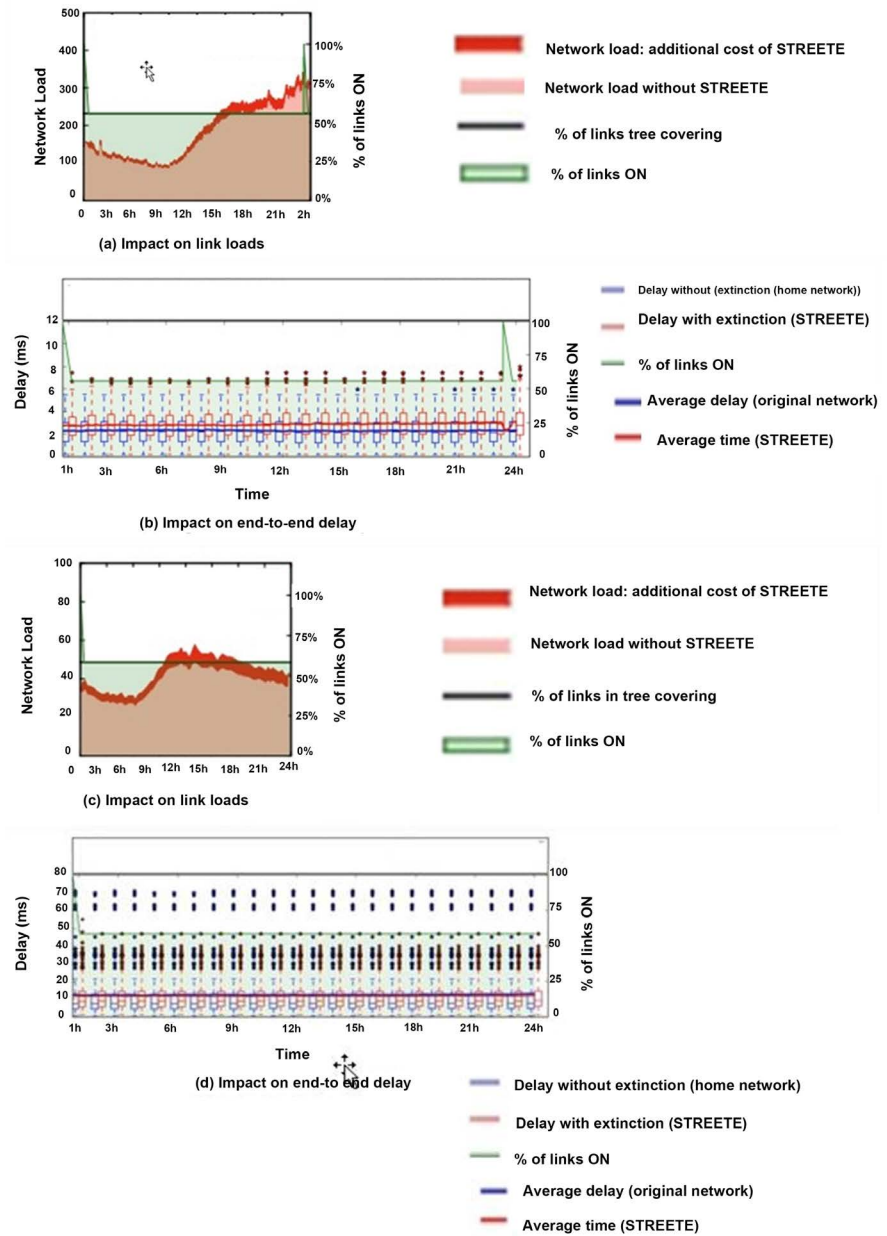


Figure 5. Simulations results in Germany 50 (top) and giant (bottom) networks [3].

ones. Because it offers us a double saving of energy saving (in ports and links). Our simulations will demonstrate them. Well before we remember our mathematical model and then follow our simulations.

### 3. Model Presentation

In this section, we present our mathematical model under constraint of delay, packet loss and jitter. We showed the principle of the extinction of the ports of the routers by our Modified SPRING Protocol [3] on a tree covering minimum weight.

Our model was obtained using the convexity theorem. Thus, the objective function obtained is:

$$\min(f(n(t), t)) = \min \left( \sum_{i \in n(t)} ((C_{ch} + Cp) - (a\ell(t) + b)) + \sum_{i, j \in n(t)} f(k(i, j, t)) \right) \quad (1)$$

Under Constraint of:

$$\begin{aligned} q(f(t), R(F(t), n(t), k(t), t)) \leq Q(f(t)), \forall f(t) \in F(t) \text{ and:} \\ \sum f(t) \leq C_{i,j} \forall f(t) \in F(t) \text{ and } \text{Max} \ell(t) < \lambda_{\max} \\ k \in \{0, 1\} \end{aligned}$$

When the routers are turned on, only one port on each router is activated and the (n-1) others are turned off. The packets have at least one path on each router. This approach will influence the delay of transmission unlike that of the authors [2] and [3]. So we define our delay based on the number of disabled ports called  $D\ell(t)$ . Our delay will be obtained from the data of the work of [2].

So, we have:

$$D\ell(t) = \frac{\text{Delay}_n}{\text{Max} \ell(t)} \quad (2)$$

where  $D\ell(t)$ : delay when  $\ell(t)$  ports are disabled.

$\text{Delay}_n$ : Normal delay (value obtained from those of [2]).

$\text{Max} \ell(t)$ : Maximum number of ports off on each router.

- **The ratings: (Table 1)**

We have found our mathematical model which minimizes, so we present our simulations on the basis of our Modified SPRING Protocol (MSP).

### 4. Our Simulation Results

Our extinction principle approach by Modified SPRING protocol are described in our algorithms and simulation results are presented in **Algorithm 1** and **Algorithm 2**.

**Algorithm 1.** Centralized SDN: <Reroute And Router Off>.

Data: List-of-Ports: [(0-4), (2-6)..] and the news/\* Supplied by <Select Portsto Off> and Compute New Routes> respectively

- 1) Begin
- 2) The controller gives all adjacent nodes the new routes to use for the virtual paths;
- 3) The controller sees the network as a whole and informs neighboring routers to turn off all enabled ports except one;

**Continued**

- 4) Routers 0.1.3... send an (ACK) to the controller after the task is executed;
- 5) The SDN controller identifies the lit ports and turns off the others;
- 6) All routers apply the change to the forward tables for redirection by other ports;
- 7) Nodes 0, 1, 2... stop sending IGP packets;
- 8) Ports (0 - 1, 2 - 5...) stop and enter sleep mode to be turned off;

**Algorithm 2.** Main loop.

- 1) While energy efficient traffic engineering is active do
- 2) Initialization of the selected ports to the number of lit ports;
- 3) If new roads and all ports are on then
- 4) <turn off the links to avoid circuits>;
- 5) List of ports  $\leftarrow$  list of links;
- 6) If the new routes (all ports turned on) then
- 7) <Reroute And Router Off> (List-Of-Ports);

**Table 1.** Summary of the ratings.

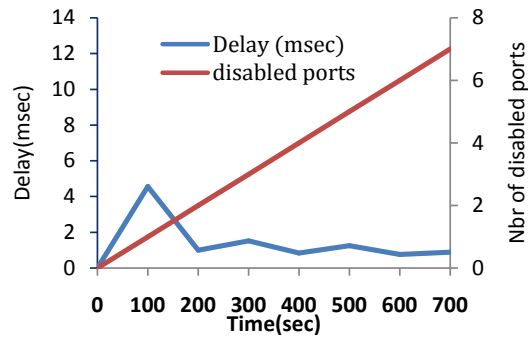
$f(n(t), t)$	Power consumption in the subnet
$\lambda_{\max}$	Total number of ports on a router
$C_i$	Overall energy of the router
$a^\ell(t) + b$	Gain of energy obtained during the deactivation of the ports
$f(k(i, j, t))$	The state of ports in sub-networks at time $t$
$q$	Quality of service perceived by the user
$F(t)$	Set of all requests at the moment $t$
$f_{s,p}(t) \in F(t)$	Observed request of a user at the instant $t$ from a point $s$ to a $p$ .
$R(F(t))$	Routing of all requests at time $t$ (see the routing algorithm).
$n(t) \subseteq N(t)$	The subnet included in the network at time $t$
$Q(f(t))$	Quality of service set to not exceeded for all requests observed.
$D^\ell(t)$	delay when $\ell(t)$ ports are disabled
Delay <sub>n</sub>	Normal delay
Max $\ell(t)$	Maximum number of ports off on each router

We have the results of our simulations and a comparative study of these results with the previous ones based on our algorithmic approach in OMNET ++ has been done (see **Figure 6**).

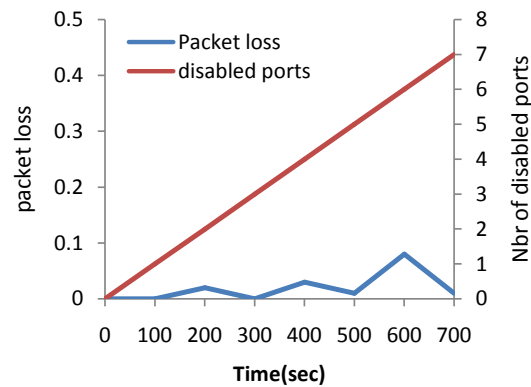
In this diagram, as we disable the ports of the routers, the delay decreases or even tends to zero. This is explained by our approach. There is at least one port on, thus establishing a link between different routers avoiding the waste of time finding a path (**Figure 7**).

**Figure 7** is the consequence of that (**Figure 6**). The delay decreases, resulting in a decrease in packet loss (relatively low). In our case, it is 10% (**Figure 7**).

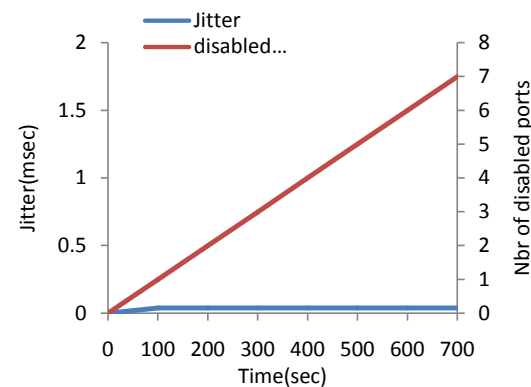
Jitter, in our case it decreased doubly 0.04 (**Figure 8**) contrary to 0.08 of the authors of [2].



**Figure 6.** Delay based on the number of disabled ports.



**Figure 7.** Loss of package based on the number of disabled ports.



**Figure 8.** Jitter based on the number of ports disabled.

Given these results, a comparison of our model with that of the authors cited in our work is necessary.

## 5. Performance Evaluation

In this section, we compare our results with those of the authors cited in this paper.

We find that the results of the authors [3] are much better than that of the authors [2]. We recall that the authors of [2] worked in classical networks. The

efficiency in the work of [3] lies in the importance of SDN technology. The fact that the SDN has a global view of the network facilitates the definition of effective rules. The use of the SPRING algorithm with SDN allowed the authors of [3] to obtain better results. Our view of the different figures, is still interesting than the previous two. Our Modified SPRING Protocol (MSP) -based approach minimizes energy with good quality of service (QoS) in terms of delay, packet loss and jitter. We achieved better packet forwarding times with less congestion, thus minimizing losses. Just like the authors of [3], we can also say that the loss of packets in our simulations are the same. We cannot minimize without degradation. It (packet loss) is 20% in [3], [2] and 10% in ours. Our delay is much better than previous authors.

## 6. Conclusions

We simulated our mathematical model with the OMNET++ simulator. The results show that the ports of the routers, when deactivated according to our energy saving strategy, have a good quality of service (QoS) in terms of delay that tends to zero, packet loss of the order of 10% and constant jitter of 4%.

The quality of service degradation can be related to several factors: network connectivity difficult at times, over-provisioning of the network causing configuration rules and correct routing problems. Because the size of the memory (TCAM) in which the rules used by SDN devices are stored is small. This orientation is interesting and could be developed in our future work. The advent of SDN by the programmability thus brings flexibility and good results in the management of the network.

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## Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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