G.W.A.T.T.

New Bell Labs application able to measure the impact of technologies like SDN & NFV on network energy consumption

WHITE PAPER

Increased energy consumption is a key challenge for the Information and Communications Technologies (ICT) industry. Network energy bills represent more than 10 percent of operators' operational expenses. With the advent of the Internet of Things era, and the inexorable consumption of video and cloud services promising to drive massively increased traffic across networks, it is even more important for operators to have a complete view of the energy impact of different technology and architectural evolution options.

G.W.A.T.T. (Global "What if" Analyzer of NeTwork Energy ConsumpTion) has been built to allow operators and industry stakeholders to better understand these challenges. This application visualizes the current and future communication networks and forecasts key trends in energy consumption, energy efficiency, cost and carbon emissions based on a wide variety of traffic growth scenarios and technology evolution choices. It is intended as a mind-sharing tool to grasp the importance of the energy challenge and how innovation and new technologies can help address these issues in the future.

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EXECUTIVE SUMMARY

The explosion of the Internet traffic volume resulting from both the worldwide broadband subscriber base extension and the increasing number and diversity of available applications and services require a relentless deployment of new technologies and infrastructures to deliver the expected user-experience. At the same time, it also raises the issue of the energy consumption and energy cost of the Internet and more generally of the Information and Communication Technologies (ICT). The increasing energy consumption is becoming one of the key challenges for the ICT industry and it is only expected to grow in importance. In order to deploy and support future data communication networks in an economic and sustainable way, service and content providers need to address the energy consumption of their networks as one of their top priorities.

In order to help the ICT industry and its associated stakeholders fully understand this challenge, the industrial research arm of Alcatel-Lucent, Bell Labs developed the easy-to-use **G.W.A.T.T. — Global 'What if' Analyzer of NeTwork Energy ConsumpTion** application. This application visualizes the energy challenges of current and future communication networks and forecasts key trends in energy consumption, energy efficiency, cost and carbon emissions based on a wide variety of traffic growth scenarios and technology evolution choices. It is intended as a mind-sharing tool to grasp the importance of the energy challenge and how innovation and new technologies can help address these issues in the future.

G.W.A.T.T. provides an end-to-end view of how much power is consumed at each point in the network, including the home and enterprise networks, the wireless and fixed access networks, the metro, edge and core backbone networks and the service core and data centers. This global perspective allows users of G.W.A.T.T. to quickly identify 'hot spots' in a network where most of the energy is consumed. It also provides a way to identify the impact of different technologies in making the network more energy efficient. The application was developed as part of Alcatel-Lucent's commitment to dramatically reduce the energy consumption and operational costs of next-generation communication networks while supporting the dramatic growth in data traffic. This white paper introduces the G.W.A.T.T. application and focuses on the basic features to highlight the energy consumption, energy cost and carbon emissions of current networks. It also emphasizes that new technologies not only provide more advanced features (such as mobile broadband everywhere, higher throughputs and reduced latency, greater network flexibility and management and more sophisticated applications) but that they also have a strong positive impact on the Internet energy consumption.

G.W.A.T.T. is publicly available on the Internet on the following link **G.W.A.T.T.**

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INTRODUCTION

The rapid adoption of smart phones and tablets is driving up daily Internet traffic dramatically, and forecasts indicate that it will increase up to 85 times by 2017 compared to 2010. The Web population is expected to grow from 2.3 billion in 2012 to 3.6 billion people by 2017, or half of the world's population. By 2017 more than 5 trillion gigabytes of data will pass through the global communications network every year; this is the equivalent of everyone on the planet tweeting non-stop for more than 100 years. Cloud services and applications provide users around the globe with on-demand computing, storage, and software services that can be accessed from any location and any device. This dramatic traffic explosion, especially from mobile devices, requires ever-increasing resources at the network infrastructure level as well as in the data centers. According to several sources [6], the Internet, if it were a country, would be ranked as the sixth largest in terms of its energy demand and the ICT sector as a whole would be ranked as the fifth largest. To be economically viable and sustainable, the ICT stakeholders (telecommunication operators, service providers, content providers, equipment manufacturers, etc.) need to control their operational expenditure. In particular they need to control and limit the increasing percentage of their operational expenses attributed to the energy consumption.

In order to understand the scope of the challenge and the opportunities to address it, several questions should be raised:

- What is the overall energy consumption of the Internet and the telecommunication networks?
- Where is most of the energy consumed in the end-to-end network today?
- How much does it cost to power the network?
- What is the carbon footprint of the network?
- How much energy is consumed by wireless networks? By fixed access networks? By data centers?
- What is the impact of traffic growth and new applications and services on the energy consumption of current networks?
- How will the network's energy consumption evolve based on technology evolution over the next several years?
- What is the overall impact of specific technologies? How much energy can be saved? What are the economic and environmental benefits of these technologies?
- What is the impact of current energy-related research efforts? How should the research ideas be prioritized and which products should be developed for maximum benefit?

Fortunately there are answers to these questions. Bell Labs developed the G.W.A.T.T. tool specifically to address these questions and summarize the answers in an easy-to-use and intuitive application.

G.W.A.T.T. (Global 'What if' Analyzer of NeTwork Energy ConsumpTion) is intended to support the ICT and telecommunication stakeholders, decision makers and generally interested users in their understanding of the energy challenge, the impact of traffic growth and the impact of new technologies being developed and deployed. G.W.A.T.T. provides a view of the total energy consumption of communication networks, the relative energy consumption and hot spots in different network domains and the global and relative impact of different technology evolutions. G.W.A.T.T. was designed as a broad mind sharing tool to measure, understand and cope with the energy evolution of the Internet in order to facilitate a sustainable evolution of it in the coming decade. It is relevant for a broad spectrum of people: from telecommunication strategists and decision makers that need to have a high-level perspective on technology impacts to guide investments and strategic decisions; to the general public and interested consumers that want to get a grasp of the issues at hand.

G.W.A.T.T. is very unique in its capabilities and approach. There are many publicly available sites on the Internet that provide data on the traffic forecast and traffic evolution such as the CISCO VNI [7] or GeSI [3]. We are, however, not aware of any tools or applications that visualize an end-to-end network and its energy consumption while allowing the user to dynamically explore different evolution scenarios and evaluate their impact on a worldwide or regional basis.

THE ENERGY CHALLENGE

The energy consumption of telecommunication networks (including operator networks, office networks and customer premises equipment) has already grown significantly to reach 350 TWh worldwide in 2012 [1]. The network energy bill can represent more than 10% of the operational expense of telecommunication service providers in mature countries and even up to 40-50% in some developing countries [8], [9] and [10]. In the mature countries, the Internet made up close to 10% of the region's overall energy consumption in 2013. In some countries, the telecommunications operators are the largest consumers of electricity with overall energy bills of several hundred million dollars and Euros.

The worldwide electricity power of the ICT was around 109 GW, which represents 6% of the world electricity consumption in 2013. Note that 1GW represents the energy production of an average typical nuclear power plant. Of these 109 GW, Figure 1 shows that the devices consumed about 39 GW with the largest amount by far being consumed by personal computers (36.9 GW). Smart phones and mobile phones on the other hand consume 0.6 GW each, whereas printers represent 0.9 GW and tablets 0.2 GW. Since tablets and smart phones are more energy efficient than laptops and desktops and since they will be even more widely used in the future (as replacements of laptops and desktops), the global devices energy consumption is unlikely to grow in the coming years. This trend is expected despite the fact there is a growing number of broadband connected users and devices.

Looking at a total lifecycle analysis, up to 80% of the overall energy and carbon footprint of the ICT devices is related to the manufacturing process and the so-called embedded energy footprint. The actual energy consumption of the devices is quite small (0.2GW for tablets and 0.6 GW for smartphones). Therefore, given the rapid replacement cycles of the mobile devices, the main sustainability challenge for the devices is to find efficient manufacturing processes incorporating reuse and recycling of valuable natural resources. From a consumer perspective, the most important feature is the battery lifetime rather than the actual total energy consumption. Of course lower power devices along with more efficient batteries will be able to extend the energy autonomy of the devices. Different solutions for powering the devices are being studied, including the use of renewable energy sources and local energy harvesting, which look quite promising [2]. One should, however, note that the predicted wide deployment of machine-to-machine (M2M) communication and the Internet of Things (IoT) might impact the percentage of the devices in the ICT energy footprint. Nevertheless the current understanding is that the Internet of Things will rather impact the data traffic and related services in the Internet and consequently the energy consumption of the Internet and networking infrastructure itself.

After looking at the devices, let's turn our attention to the network infrastructure itself as shown in Figure 2. Of the 109 GW of total ICT power, the remaining 69 GW represent the share of the infrastructure equipment. This power is distributed as follows:

- 9.5 GW for the home and enterprise network
- 21.2 GW for the access network including the wireless and fixed access network
- 37.1 GW for the service core and data center
- 1.6 GW for the metro, edge and core network domains.

Figure 1. Power Consumption of Devices

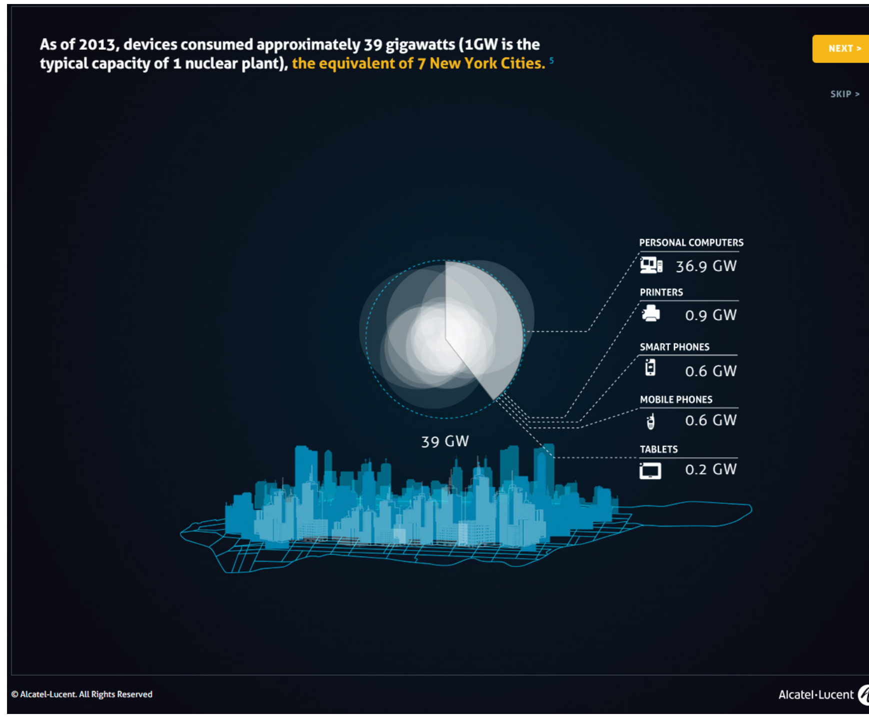
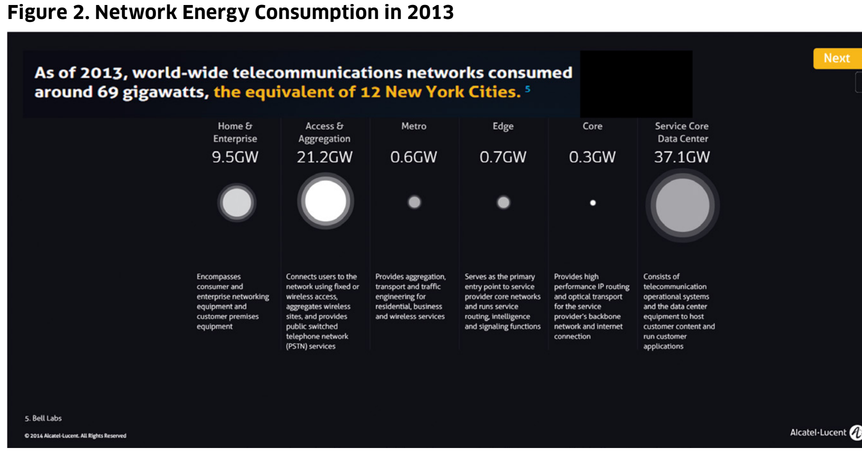


Figure 2. Network Energy Consumption in 2013



It is important to notice that the fastest growing domains in terms of energy consumption of the Internet infrastructure are the mobile access and the data centers domains. In contrast to the devices, smart phones and tablets, the energy consumption during the use phase of the infrastructure equipment is the dominant factor (between 70% and 80%) of the overall energy consumption. It is therefore evident that the major challenge with the largest immediate impact is the reduction of the in-use energy consumption of the equipment. Other aspects such as manufacturing, deployment, removal and recycling remain important nevertheless, but we have chosen to focus G.W.A.T.T. on the dominant component at this time.

The energy consumption of the ICT infrastructure (telecommunication networks and data centers) is clearly already an issue today; and an issue that will only become more important over the next decade. ICT is also facing another challenge: as stated in the SMARTer 2020 report from GeSI [3], ICT is a powerful technology enabler with the potential to reduce the global greenhouse gas emissions of other industry sectors (such as transportation, agriculture, healthcare or education) by a significant 9.1 gigatons in 2020, which represents 16.5% of the world's greenhouse gas emissions. This requires of course greater use of ICT technologies in all domains of human activities. To achieve this in a sustainable way, ICT has to become more energy efficient itself to support the further increase in traffic in the communication and computing networks.

The issue of network energy consumption is global and affects all service providers, operators and content providers, albeit in possibly different ways and different levels of severity.

- In mature countries, service providers are mostly concerned with the rising cost of their energy bills and their overall operational expense. They also have to cope with some technical challenges that have a direct impact on network deployments and capital investments. These include for example the heat dissipation and floor space required for hosting a growing and energy consuming/dissipating infrastructure. Thermal densities are starting to become limiting factors in the design, development and deployment of network equipment. In addition, the ongoing migration of traffic from fixed access networks to mobile access networks, which are more energy hungry by nature, further compounds this challenge.
- In emerging countries that rely on increased broadband access to sustain their economic development, the issue is not only the energy cost but also the access to reliable and stable energy sources. Very often, such access cannot be guaranteed because of a poor or even completely absent power grid. A commonly used solution to provide energy autonomous network elements (such as radio base stations) relies on the extensive use of diesel generators. This solution, however, has several major drawbacks, including the cost of the diesel fuel, the degraded quality of service because of the poor reliability of diesel generators, the cost of logistics to refuel the sites, etc. Hybrid or solar/wind powered solutions are starting to be deployed. More wide-spread deployment requires further improvements in the solar cell efficiency, higher density batteries, a reduced total cost of ownership of the system as well as more energy efficient network elements to make such solutions practical and economically viable at large scale.

The energy challenge has of course been recognized by the ICT sector for several years now and increasing attention has been paid to improve the energy efficiency of network equipment. Generally, the energy efficiency of network equipments has improved by 10% to 20% year over year and continues to do so. New technologies are coming to market that are more energy efficient than previous generations: for example LTE versus 2G or 3G, VDSL2 versus ADSL, latest GPON technologies.

Although this puts ICT among the fastest evolving technology sectors, an even greater energy efficiency improvement rate is needed to keep pace with the data traffic explosion. This is the reason why ICT has numerous research programs such as GreenTouch™ [4] to generate more disruptive research efforts. For instance, the GreenTouch consortium aims at providing a portfolio of technologies, architectures and solutions that can improve by a factor of 1000 the energy efficiency of telecommunication networks in 2020 with respect to the 2010 baseline. The EARTH project [5] is another early example of a dedicated research effort to improve the energy efficiency of wireless communication networks.

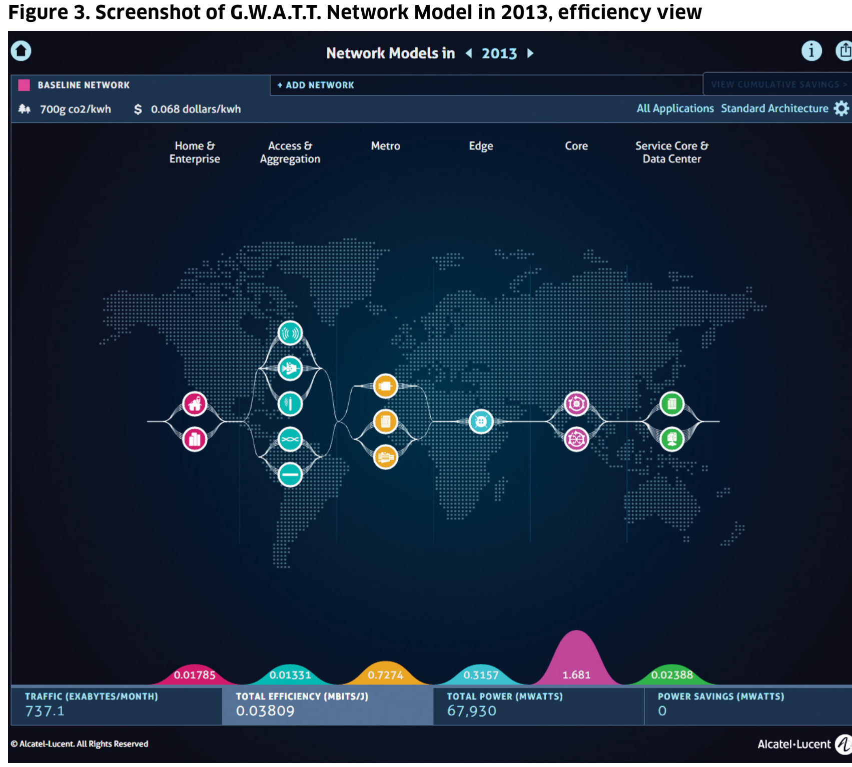
G.W.A.T.T. PRESENTATION AND USE

In order to help the ICT community understand this challenge and visualize the various ways of coping with it, the G.W.A.T.T. tool shows a five year forecast of the network infrastructure energy consumption using a wide variety of traffic growth scenarios and technology evolution choices. G.W.A.T.T. provides an end-to-end view of how much power is used each year and at each point and subdomain in the network. Thanks to G.W.A.T.T. the user quickly identifies 'hot spots' in the network where most of the energy is consumed and how this could be mitigated through technology evolutions to make the overall network more energy efficient.

Figure 3 shows the Network Model screen where the user is able to pick and choose network domains and technologies and test their corresponding energy consumption. In the shown screenshot, G.W.A.T.T. displays the baseline data for the reference year of 2013. For each network domains (Home & Enterprise, Access & Aggregation, Metro, Edge, Core and Service Core and Data Centers), the technology subdomains are shown in the colored circles. By clicking on these colored circles, the user is able to select different technologies and test their impact. At the bottom of the screen, the results are displayed through bell curves with the colors matching those of the network domains above. In particular these bell curves display respectively:

- The traffic data according to the user selection (worldwide or regional) expressed in exabytes per month
- The network efficiency expressed in megabits/Joules
- The total power consumed by the network expressed in megawatts and
- The power savings when a new technology is selected (in this case 0 since we are on the baseline display and no technology has been selected).

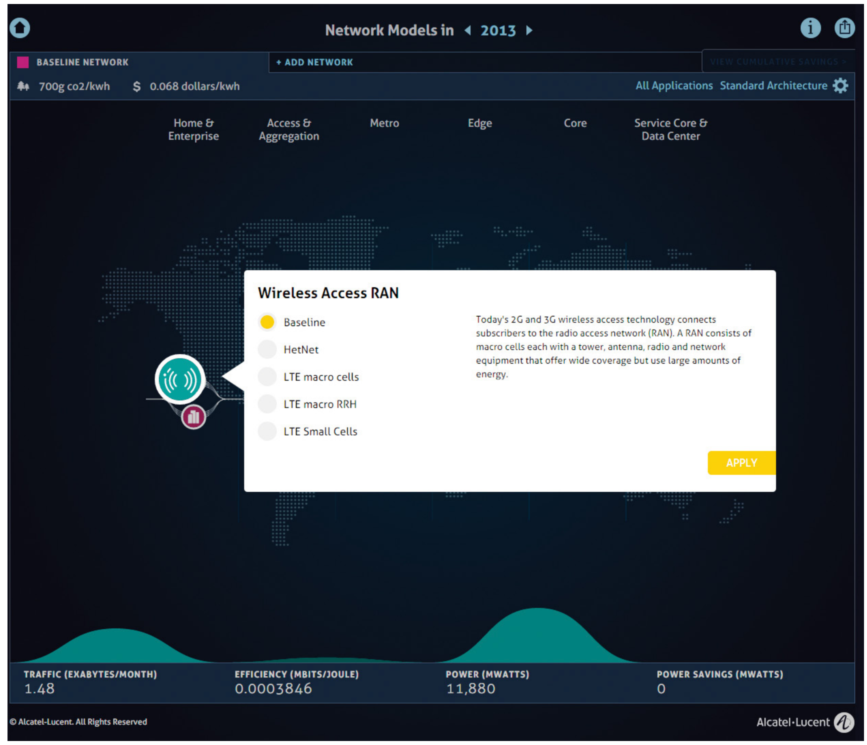
Figure 3. Screenshot of G.W.A.T.T. Network Model in 2013, efficiency view



The user can toggle between Traffic, Efficiency, Power and Power savings views. Figure 3 represents the efficiency view as an example.

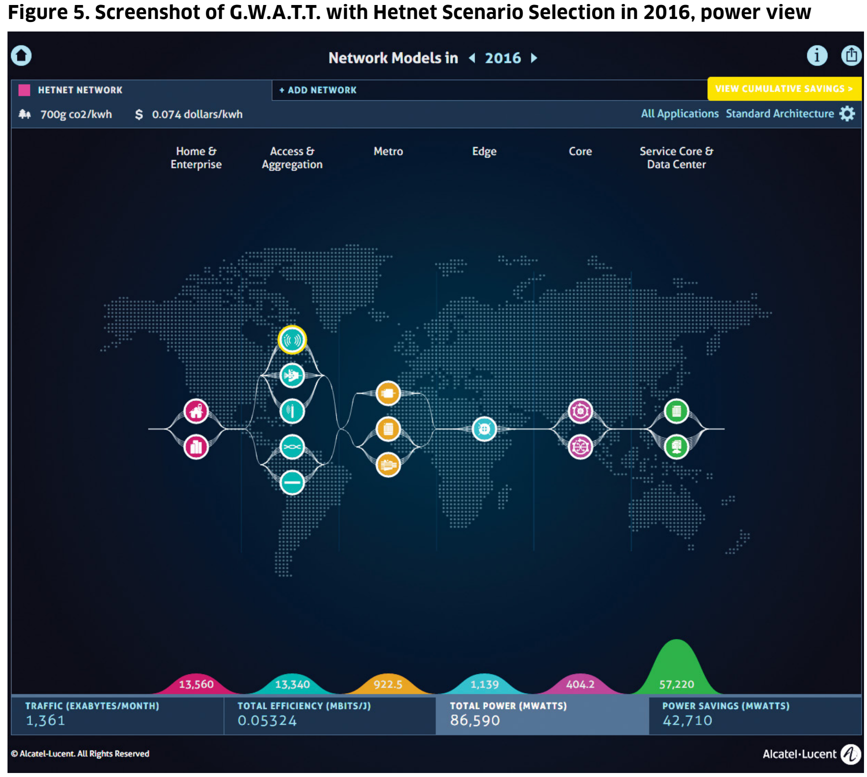
When a specific network subdomain is selected, the display changes to focus on the specific subdomain traffic, energy efficiency and power data. It also provides the user with a selection of technologies to test for their associated energy consumption. For instance, in Figure 4 the user has chosen to select the wireless radio access network domain.

Figure 4. Network Subdomain Selection



Going further, the user can select different reference years and technologies. For example, in Figure 5, the year 2016 was chosen together with the wireless access HetNet technology. The overall power of the network is displayed (86.590 GW) along with the savings generated in 2016 by the HetNet technology with respect to the 2G/3G baseline. In this particular use case, the power savings are 42.71GW (on a worldwide basis).

Figure 5. Screenshot of G.W.A.T.T. with Hetnet Scenario Selection in 2016, power view

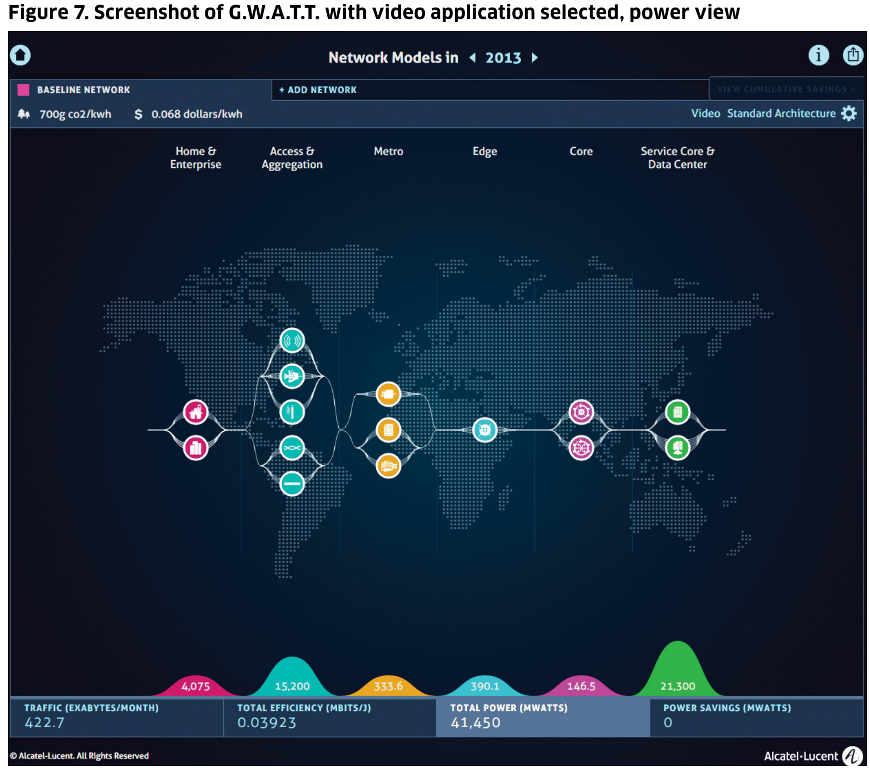


G.W.A.T.T. also provides application oriented views. In Figure 6, the user has selected the video application. G.W.A.T.T displays the data for the video application in 2013 (traffic per network domains, efficiency, power consumed by the video application worldwide). Since the traffic tab was selected, the bell curves display the traffic data for each network domains. In addition to the video application, the user can also select online gaming or consumer/business web browsing, file sharing or video transmission.

Figure 6. Screenshot of G.W.A.T.T. with video application selected, traffic view

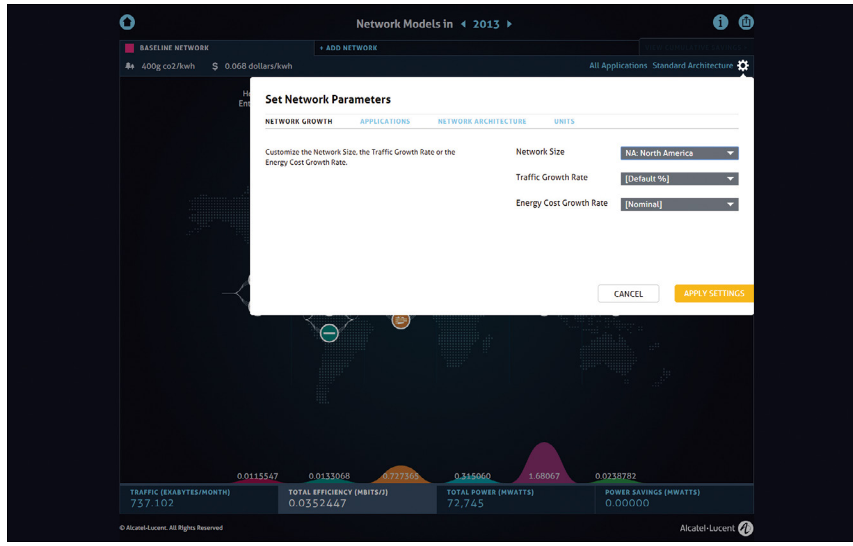
Figure 7 shows the same video application view with the power tab selected. The bell curves now display the power consumed by each subdomain while supporting the global traffic coming from video applications alone.

Figure 7. Screenshot of G.W.A.T.T. with video application selected, power view



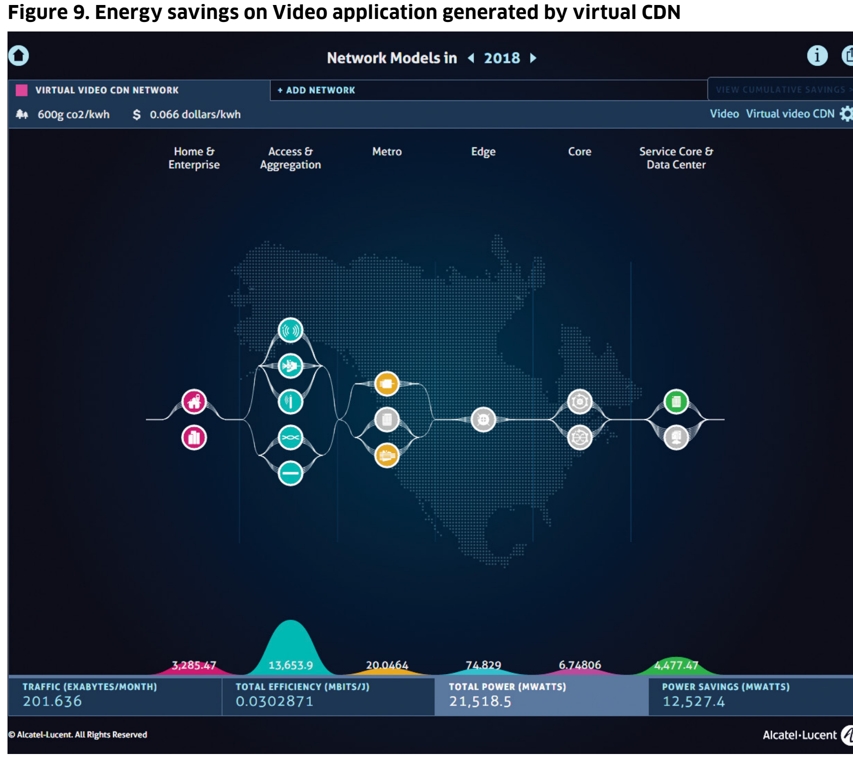
G.W.A.T.T allows the selection of a wide range of network parameters. Figure 8 shows the application settings menu in which the user can make the following selections. First the user can choose the geographical region of interest; in the shown screenshot, the selected network is the North American network. Secondly the user can select different annual traffic growth rates other than the nominal traffic growth based on extrapolated traffic projections. Similarly the user can also select different annual increases in the unit energy cost. The other tabs allow the selection of different application scenarios (as the video example quoted in Figure 7), various network architecture variants such as SDN/NFV transformations and finally the units that will be used to display the network data (energy cost, efficiency, power and power savings).

Figure 8. Screenshot of G.W.A.T.T. network parameters menu



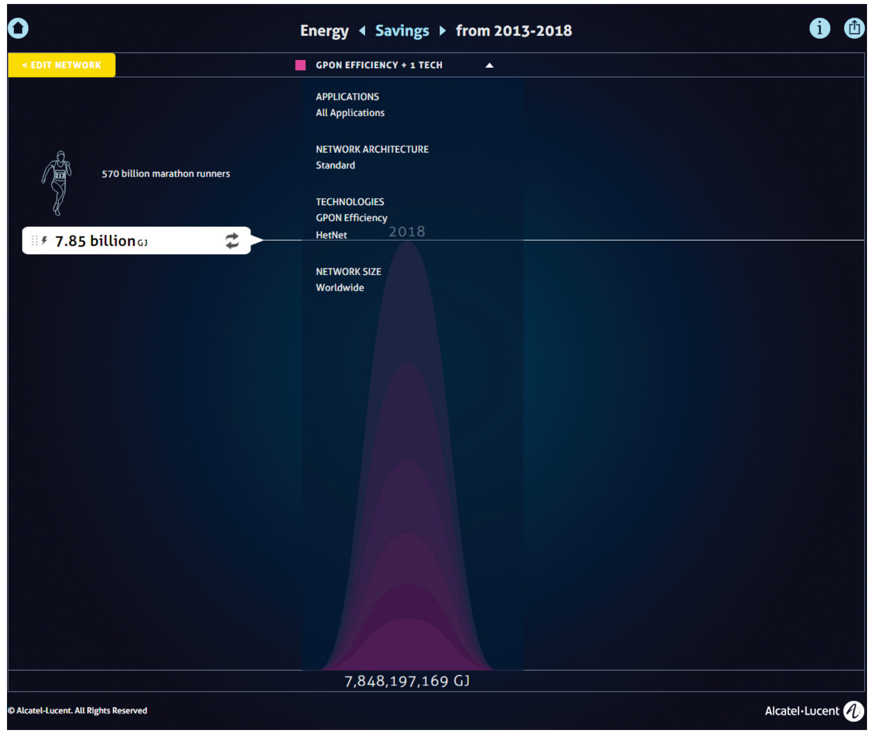
G.W.A.T.T. visualizes the impact of SDN/NFV transformations. Figure 9 illustrates the case where the user wants to assess the impact of a virtual Content Delivery Network architecture on the energy cost of the video application for the North America Region. The Video traffic data for the NAR region has been selected and then the virtual CDN network transformation has been applied resulting in savings of around 12.5 GW.

Figure 9. Energy savings on Video application generated by virtual CDN



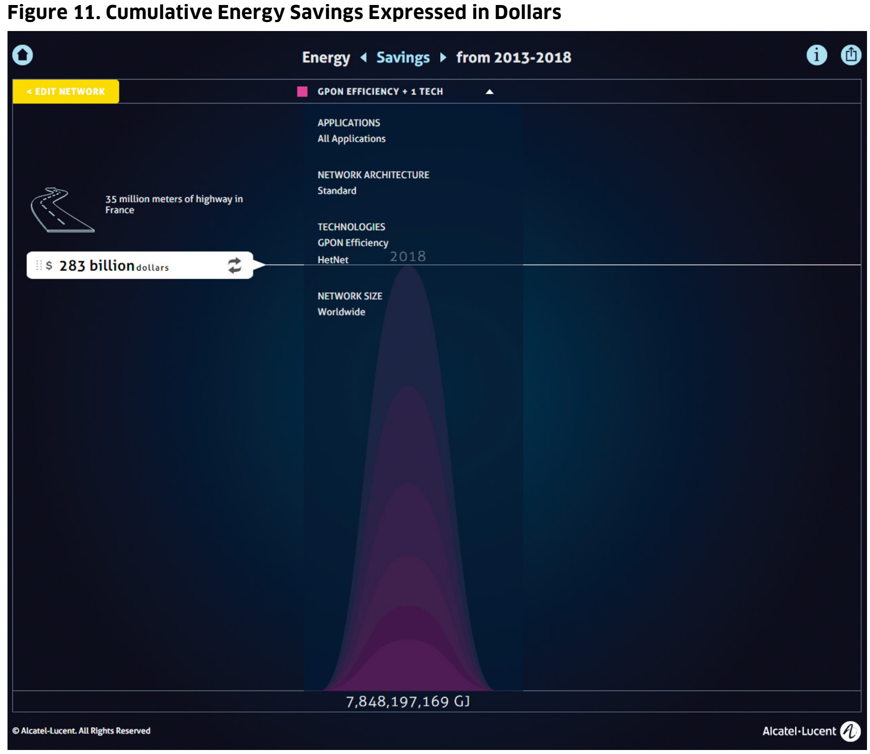
G.W.A.T.T. also provides various views on the impact of one or several technology choices. For instance, in Figure 10, G.W.A.T.T. shows the cumulated savings over six years generated by a worldwide deployment of HetNet and advanced GPON technologies (which in this use case add up to 7.84 billion of Gigajoules.)

Figure 10. Cumulative Energy Savings Expressed in Joules



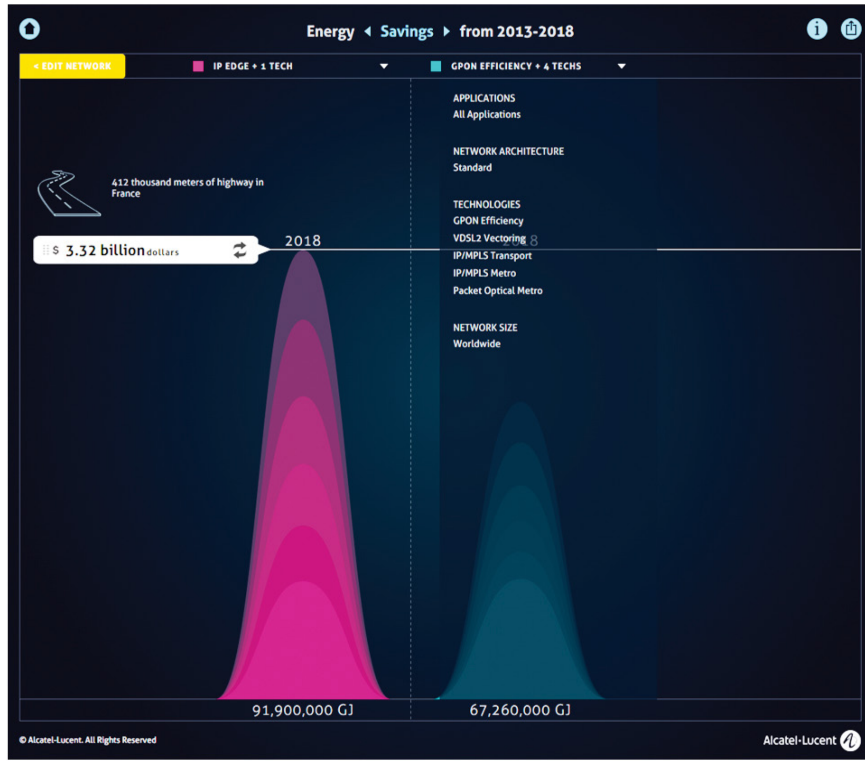
The projected savings can be displayed in different units. In addition to the energy savings, Figure 11 presents the same savings expressed in currency, which for this use case is shown to be $283 billion over the same six year period. G.W.A.T.T. proposes prize comparisons expressed in terms of easy-to-understand real-world analogies such as high speed trains, stadiums, coal power plants or dishwasher cycles.

Figure 11. Cumulative Energy Savings Expressed in Dollars



G.W.A.T.T. allows the comparison of various combinations of scenarios and technologies. Figure 12 illustrates this feature through an example comparing the energy savings generated by an upgrade of the Edge and Core domains with an upgrade of the Fixed Access and Metro domains. It is important for service providers to first understand what the hot spots of their networks are in terms of energy consumption and then secondly to select the combinations of technology changes/upgrades that will best address their energy costs. For instance Figure 11 clearly demonstrates that, in this hypothetical case, an upgrade of the edge and core routing elements has a stronger impact on the energy consumption than an upgrade of the fixed access and metro networks. Such information is very important and relevant for prioritizing technology upgrades and making strategic investment decisions.

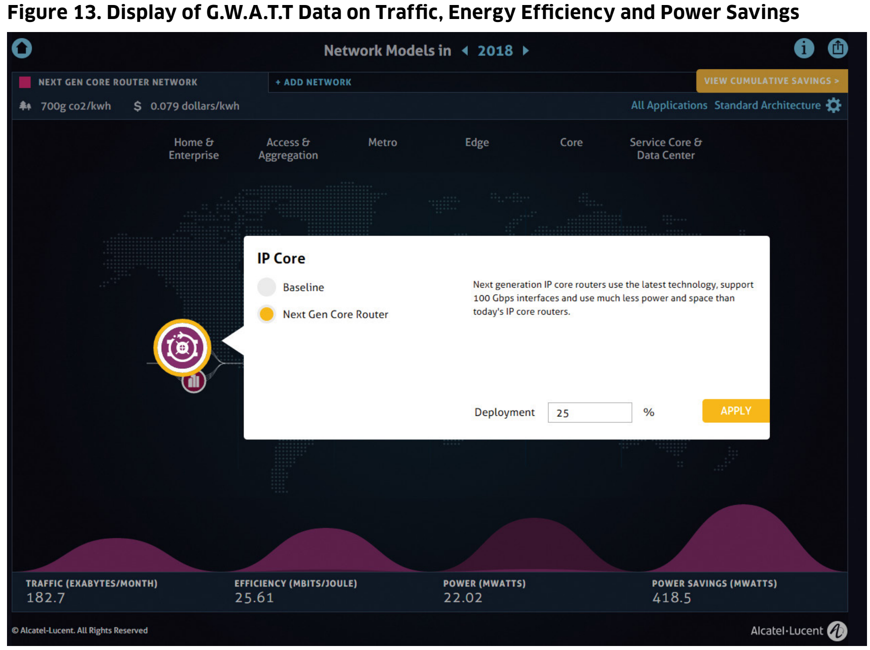
Figure 12. Comparison of upgrade scenarios



G.W.A.T.T. MODELING

The energy consumption models and scenarios used in G.W.A.T.T. are based on traffic forecasts and network modeling results coming from various sources: public data, results from Bell Labs modeling and other independent consortia including **GreenTouch**[4] and the **Global e-Sustainability Initiative (GeSI)**[3].

Figure 13. Display of G.W.A.T.T Data on Traffic, Energy Efficiency and Power Savings



G.W.A.T.T is not a detailed network planning and dimensioning tool. We have instead adopted a statistical approach in order to provide an end to end view of the network infrastructure and its energy consumption according to traffic forecast and averaged efficiency of the networks elements. In particular the energy efficiency and power consumption values used are industry averages and generally representative of current technologies without being specific to any one particular vendor or service provider network.

G.W.A.T.T is based on three models:

- A traffic data model. For each subdomain of the network, we use a traffic volume expressed in exabytes/month. For instance in Figure 12, the traffic associated to the IP Edge network subdomain is displayed on the bottom left bell curve and represents 128.4 exabytes/month.
- A network element efficiency model. An efficiency expressed in megabits/joules is associated with each subdomain. For instance in Figure 9, it can be seen that the efficiency is 0.4338 megabits/joules for the IP Edge network subdomain. We also see that the overall power of this subdomain resulting from the traffic and efficiency data is of 913.5 MW.
- From the traffic and efficiency data and the underlying network model, G.W.A.T.T. computes the total end-to-end network power (expressed in mega watts), consumption (in gigajoules), energy cost (in €, $ and ¥) and greenhouse gas emissions (expressed in gigatons of CO_2 equivalent). For instance, in Figure 13, we see that the deployment at a 25% rate of the next generation core router technology provides 418.5 MW savings in 2018 with respect to the baseline as shown in the bottom right bell curve.

CONCLUSION AND NEXT STEPS

Over time, Bell Labs/Alcatel-Lucent will continue to expand the capabilities of G.W.A.T.T., refining its modeling capabilities, adding new network scenarios and including future technologies and architectures currently being investigated by Bell Labs Research. We are also partnering with the **GreenTouch**™ consortium [4] to design a dedicated G.W.A.T.T. site that will incorporate the consortium's advanced results. Finally we are actively engaging with service content providers and operators to design dedicated versions of G.W.A.T.T. that correspond to their specific data models and network efficiency data.

Bell Labs has designed G.W.A.T.T. as a mind sharing tool to help the ICT stakeholders understand the key energy challenge of ICT triggered by the data traffic explosion. G.W.A.T.T. also measures how the deployment of current and future technologies positively impacts this energy footprint. We will regularly update the tool to reflect the latest state of the art in term of traffic evolution forecast and networking and communication technological advances. Bell Labs also encourages partnerships with other actors of the ICT industry to further enrich the data models being used.

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