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Energy Efficient Business Management System for Improving QoS in Network Model

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Abstract

Assuring the safe and effective operation of a company's technological infrastructure is an essential part of business management. Monitoring, administering, and troubleshooting the many components and systems of the network are all part of the process. Additionally, it is the responsibility of business administrators to find methods to enhance the existing system, as well as to make certain that all resources are distributed in such a manner that their use may be maximized. Management of the business is a key component of the technological infrastructure of any organization, and it is of the utmost importance that it be carried out effectively in order to guarantee a safe and effective operation. It is essential for network operators to discover strategies to improve the energy efficiency of their networks without adversely affecting the quality of service (QoS) for reasons related to both cost and sustainability. In this research, an in-depth analysis of business management techniques for effective resource utilization is presented. This analysis begins with the design of the network and continues all the way through to the delivery of accurate data. An Energy Efficient Network (EEN) must be able to give programmability and flexibility to network infrastructures, as well as the ability to operate networks in a rapid way and provide operators with more control. It is impossible to ignore energy throughout the process of meeting the needs and requirements of network services, especially when taking into consideration the consequences on the long-term viability of both the environment and businesses. Energy efficiency in both current and future networks is the topic of discussion in this research. The findings indicate that energy efficient networks are successful in

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overcoming the present issues that stand in the way of the application of energy efficiency techniques, also the discussed model are effective in addressing some of the obstacles that are encountered by small and medium-sized businesses.

Keywords: Network Efficiency, QoS, Networks, Business Management, ENN.

1 Introduction

1) Business Management

Management is the act of organizing, directing, planning, and managing all aspects of an entity or company in order to achieve the objectives and goals that the firm or organization follows. Controlling all areas of a company, including its finances and operations, as well as its network property, is a part of this responsibility. The following phrases are used in business management in order to enhance the quality of service (QoS) in networking (Km, M., 2017).

Network Virtualization: The technique of merging hardware resources and software resources into a single organizational unit is referred to as network virtualization. A single administrative unit is referred to as a virtual network or virtual network.

Network Resource Management: There is a procedure known as network resource management, which involves the management and allocation of resources for networking operations. Because of the volume of network traffic that is being handled, you have the ability to allocate the resources in a variety of different ways. Through the management and allocation of resources in accordance with the real requirements, you may improve the efficiency of the system when it comes to processing packets (Sreenivasulu 2024).

In order to get optimal performance, network virtualization must be used in conjunction with network resource management. It is possible to give users and systems with the ability to share the hardware and software networking resources in a regulated manner, which result in an increase in the efficiency of the operations involved in virtual networking. When you use network virtualization in conjunction with resource management, you are able to handle flow control, improve the performance of the system, and customize network usage. All of these things are essential in order to achieve virtualization of operating system (OS), application computing, as well as server integration for your organization.

2) ENN

Energy efficiency (EE) improvement has been identified as most significant aims in the Sustainable Development Goals of the United Nations, with the goal of doubling the worldwide rate of progress in EE by the year 2030 (United Nations). The International Energy Agency recommends expanding energy efficiency (EE) as the one of the most significant phases toward achieving energy safety, protecting the environment, also promoting economic development (IEA). On the other hand, the current pace of development is not sufficient to fulfil the two-degree objective by the year 2050, as specified in the Paris Climate Agreement (UNEP DTU). This is something that was noted by the United Nations Environment Program. The Swedish government has set a goal to become carbon neutral by the year 2045 (European Parliament News). Through the use of EE, one of the ways to accomplish such an objective is possible. In Sweden, the industrial sector accounts for 36% of the overall energy consumption (Kanchiralla et al., 2020), and seventeen percent of the total business energy consumption was accounted for by small and medium-sized businesses (SMEs) (Thollander et al., 2019; Camgözlü & Kutlu 2023).

Networks of businesses that have a common interest in EE are referred to as EENs. Through information sharing, capacity development, and the exchange of experiences, EENs are designed to overcome the obstacles that stand in the way of energy efficiency (EE) and achieve the potential for energy savings (OECD 2017). Companies are able to implement energy management systems inside their own walls and observe energy efficiency management systems from a broader viewpoint with information that is easily accessible. The idea of EENs was first introduced in Switzerland in the 1980s, and meanwhile, it has been exported to a variety of nations both inside Europe and outside of it (Schlomann et al., 2016).

In their study, (Paramonova et al., 2014) conducted a survey of the existing networks in Sweden and stressed the need of developing qualitative and quantitative assessment methodologies for industrial EARs. In addition to this, the research proposed the establishment of a collective standard approach to the operation as well as the assessment of business EENs (Paramonova et al., 2014). ENERGIG was the initial local pilot program in Sweden that was based on scientific data and participated in the EEN project. It was sponsored by the European Regional Development Fund in addition to local partners. (Johansson et al., 2017) It was operational from 2014 to 2019 and consisted of a total of 44 enterprises that were distributed throughout seven networks.

3) Concept of Energy Efficiency Network

There are three stages that are involved in the operation of LEEN networks: the commencement phase, the energy evaluation phase, and the network operation phase. A presentation of the LEEN idea is made during the initiation phase, which also includes the entire network operations as well as formation of network contracts in order to provide the groundwork for the formal launch of the EEN networks. For the purpose of achieving the efficiency goals, the energy evaluation phase includes the energy saving identification, the inspection of the site, and the preparation of first saving reports. Monitoring the results of LEEN networks is the last step, and it will be accomplished by site inspections, lectures on various issues related to energy efficiency, the presentation of measures that have been implemented, and a general sharing of experiences. (Schlomann et al., 2016).

2 Review of Literature

As a result of the introduction of EENs in Switzerland, businesses have been able to build networks and engage with one another (OECD 2017). Zurich was the location where the initial Swiss network, known as "Energy Model Zurich," was developed as a collaborative effort to increase energy efficiency and energy savings (OECD 2017). Within a short period of time, this network was able to reach a large amount of energy-saving potential (OECD 2017). Its goal was to assist the private sector in lowering its energy consumption and CO_2 emissions. After few years, comparable EENs were implemented in Germany (Schlomann et al., 2016). The Learning Energy Efficiency Network (LEEN) is a network that was established with the intention of building a business management system to illustrate the advantages of energy efficiency networks (EENs). This network consisted of thirty pilot networks (Rohde et al., 2015). Through the implementation of LEEN standards, the project was expanded to include a great number of other networks (Schlomann et al., 2016) (Schlomann et al., 2016). When asked about their experiences with the German "30 Pilot Networks," the most of the members thought that the advantages they received from the ENN network were either high, that the amount of time needed was very low, also they obtained relationships that they utilized outside of the network (Rohde et al., 2015). It is hard to get enterprises to engage in the network program, and it takes 3 to 4 working days to convince one organization to join (Durand et al., 2018). This is despite the fact that the experience of the German

EENs demonstrates that it is very hard to attract organizations to participate. Both the EENs and the person who is doing the recruitment are quite important in terms of their credibility. It was stated that 50 percent of the motivations to join a network were due to personal relationships with the network operator/moderator or consulting engineer (Durand et al., 2018). Conducted a survey to analyze regional EENs in order to determine whether or not EENs have a good influence on members. The results of the study revealed that the component that was most valued by the participants in the network was the participation in the sharing of experiences (Chassein et al., 2018). It was essential to have unified objectives for energy efficiency and carbon dioxide reductions in order to make energy efficiency a higher priority in businesses and to persuade upper management to make investments (Jochem & Gruber 2007). Utilizing a two-stage computational prototype, which was implemented in (Jiménez-Carrión et al., 2023), resulted in an increase in the efficiency of the network. In the first step, the difficult computational issue is taken into consideration, and in the second stage, the process of resource allocation is carried out. On the basis of the NOMA model, the most effective method for resource allocation has been proposed in (Bouhamed, 2023). In order to reduce the number of resources that are wasted in dynamic networks, the same algorithm has been used for both the uplink and downlink processes.

3 Energy Efficiency in Network Infrastructure

ENN networking is used to identify attempts to minimize greenhouse gas emissions in network structure. This concept is based on the environmental standpoint. Additionally, there are various points of view, including those that are engineering, regulatory, and economic in nature. The latter is described as a system that may simultaneously reduce the amount of energy that is used in the process of executing a task while keeping the same level of performance (Bianzino et al., 2010). In order to take into account, the environmental and economic impacts of the approaches or tactics that are being employed, we primarily take into consideration the engineering viewpoint. Figure 1 describes the factors of ENN networks.

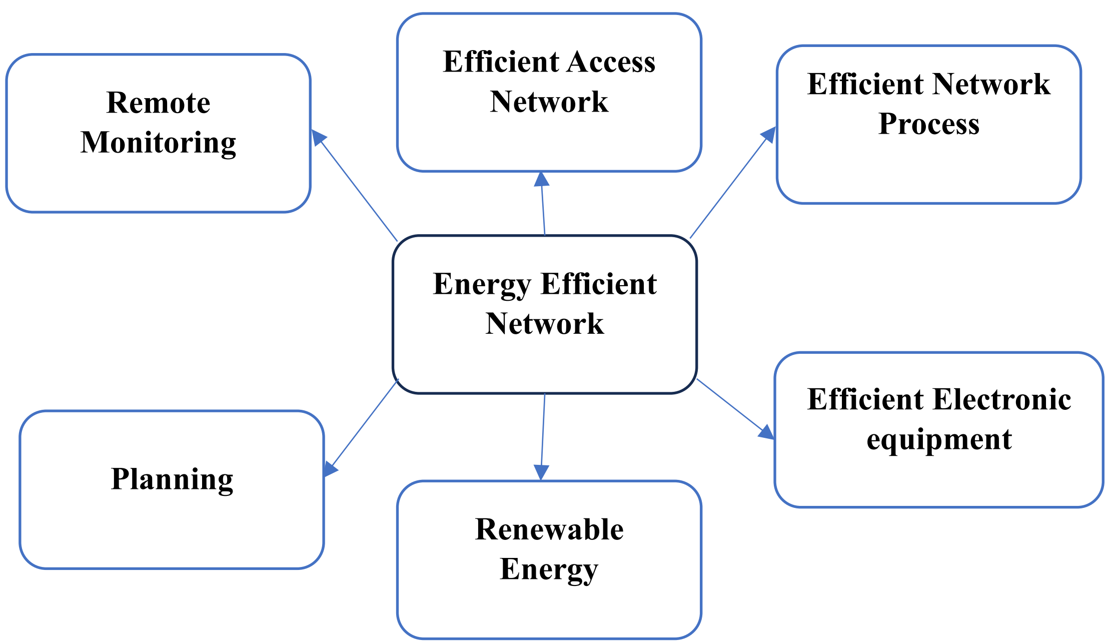

Figure 1: Factors Influences in Energy Efficient Network

1) Contributing Factors to ENN

There are four fundamental components of network architecture— namely, network wired and wireless networks—that influence energy consumption. These components include Hosts, network devices, network architecture, and Services. (Maaloul et al., 2018; Bianzino et al., 2010; Buzzi et al., 2016).

Hosts: Computers or other kinds of hardware are the clients of network services offered by network application. Examples of network applications include servers located in the cloud or edge DCs, as well as smartphones or Internet of Things devices that are linked to access networks at the edge network. On account of the fact that these end systems are mostly generated from computer systems, the region in which they are located is seen as being well-developed (Maaloul, et al., 2018). Hardware and software, for example operating systems and applications, are both components of hosts that are responsible for energy consumption and have an impact on the amount of energy that is used. End systems in wireless networks may be anything from computers and mobile phones to tablets and Internet of Things devices, as well as other appliances.

Network Device: Network devices are the second most frequent donors to the network infrastructure, after networked hosts as the most common contributors. In the context of a network, these components have an impact on the energy consumption profile for each situation that involves a different number of devices (Maaloul, et al., 2018). The number of active ports, the protocols that are enabled, and the amount of traffic are all characteristics that are uniquely associated with each and every device, including network switches and routers. Network functions, which are specialized network devices designed to support certain applications, would also fall under this category. When it comes to wireless networks, and 5G in particular, base stations and radio frequency transceivers are regarded to be the most energy-consuming components (López-Pérez et al., 2022). In a manner similar to that of networked hosts, enhancements for "greening" network devices or nodes are accessible via both hardware and software developments.

Network Architecture: The architecture of the network is a component of the design of the network and includes the devices that make up the network as well as the manner in which they are linked and configured. Core, metro or transit, and access networks are the three domains when discussing network architecture (Maaloul, et al., 2018). Each of these domains is associated with network topology and has scalability issues to take into account. There is a correlation between the use of optical fibres as the medium and the consumption of energy in both core and transport networks. On the other hand, access networks are often in the form of wirelessly connected networks.

Services: The consumption of network energy is not only affected by the design, hosts, and devices, but also by the services that are provided by the network. It is important to take into consideration the protocols and traffic characteristics of the apps. In addition, these services have an impact on the energy consumption of the network infrastructure. This impact is dependent upon the features of the various applications (such as routing, TE, security, and multimedia), as well as the manner in which these programs used the physical network resources in order to offer services to end systems or users.

4 Energy Consumption Models

In this section, we will discuss the challenges that arise with ENN wired and wireless networks, as well as the recommended solutions. The paper discusses the method of packet processing, as well as traffic-aware intelligent cell site design and cross-layering network planning approaches.

1) Packet Processing

The processing of packets occurs in the forwarding engine, which accounts for a significant amount of the total energy usage of a switch device. The packet header is read and checked by the forwarding engine before the packet is sent forward. Because of this, the amount of energy that is used by the forwarding engine is substantially dependent on the quantity of data packets than the length of the packets. But, the majority of the data on the network at the moment exhibits relatively short packet lengths. Taking into consideration a network packet length distribution (Caida), 70% percent of the total packets are control packets that are twenty bytes or forty bytes in length. Although they only use a little portion of the network's capacity, these packets control the switching timings. In a network environment with a high bit error rate (BER), the maximum transmission unit (MTU) is intended to lower the rate of packet loss; however, a small MTU might increase the amount of energy that is used during the packet processing operation. A clean environment as well as a low enough bit error rate (BER) are supported by the existing high-quality network. Therefore, it is possible to raise MTU while still maintaining an acceptable BER. Within the context of this idea, the packet burst approach has the potential to be a very exciting strategy for green packet processing. The process of combining many short-length packets that are all headed to the same destination into a single long-length packet and attaching a single header to the burst packet is known as packet burst. The amount of energy that is used during the processing of packets is lowered by a factor of N when the number of packets that make up a burst packet is N. Figure 2. provides a description of the numerical study of the energy consumption experienced by the reference router. The NSFNET topology model and the tera-scale router reference, which has a consumption of 10 nJ/bit, are both taken into consideration here (Tucker et al., 2009).

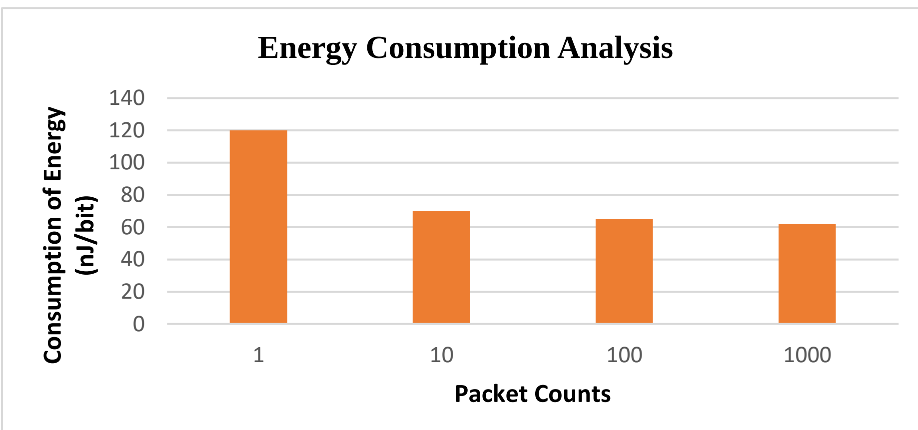

Figure 2: Analysis on Consumption of Energy on Various Packet Size

2) Cross Layering Network Planning

In order to create an IP-over-WDM network that is more energy efficient, we examine cross-layering network planning. It is necessary to give adequate consideration to the IP-over-WDM architecture since it is a practical method. There is an IP router that is part of the IP layer, also we assume that the energy consumption of the router is the same as in the previous section (Tucker 2009). Path-based circuit switching is the method that our model proposes for the transmission of data in a WDM network. For the purpose of switching function, wavelength division multiplexing (WDM) incorporates an optical cross connector (OXC), an erbium-doped fibre amplifier (EDFA), and a wavelength convertor (WC) to resolve wavelength conflict. In simple terms, the energy consumption of switching elements in optical devices is much lower rather than the electrical components. When nano-watts scale passive-medium optical components are taken into consideration, the amount of energy that is used by OXC is insignificant. Our assumption is that the wavelength conversion process for WC uses 4W, whereas the EDFA process uses 8W. At intervals of 80 kilometres, EDFA is deployed.

Both hop-by-hop routing (HHR) and traffic grooming are being considered as potential candidates for the technology that will be used to route packets. In HHR, the IP router is responsible for terminating the packet at each hop. It is not necessary to have the WC for the HHR scheme since the IP router has the ability to alter wavelength. Wavelength contentions are addressed at the wavelength control (WC) at the wavelength division multiplexing (WDM) layer on the traffic grooming side. Therefore, in the process of traffic grooming, only the IP routers connected from the source to destination to handle the packet, and the packet is delivered inside the light path. This allows us to investigate the distinction between energy minimized routing and traffic minimized routing by simulating both of these types of routing. The simulation is carried out using CPLEX1 using the integer linear programming (ILP) technique.

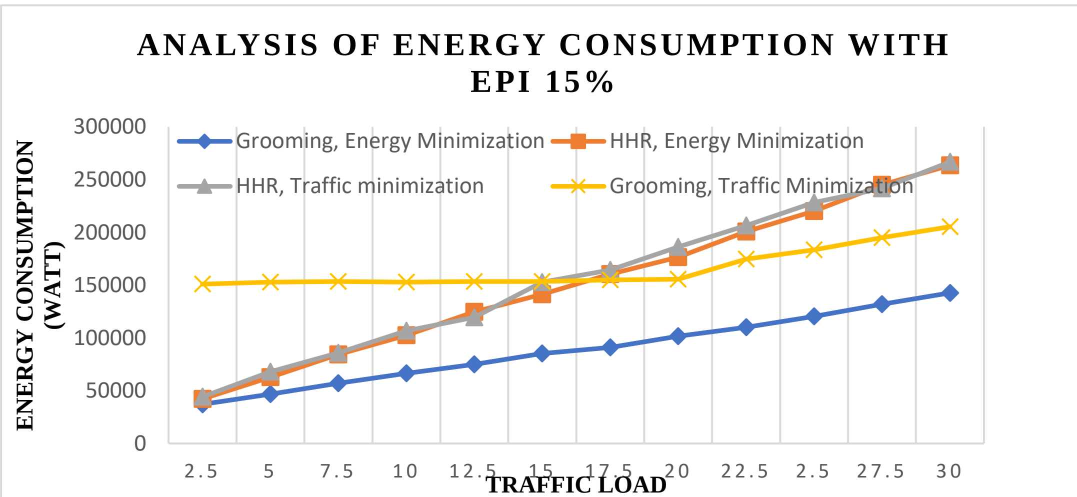

Figure 3: Analysis of Energy Consumption With 15% EPI

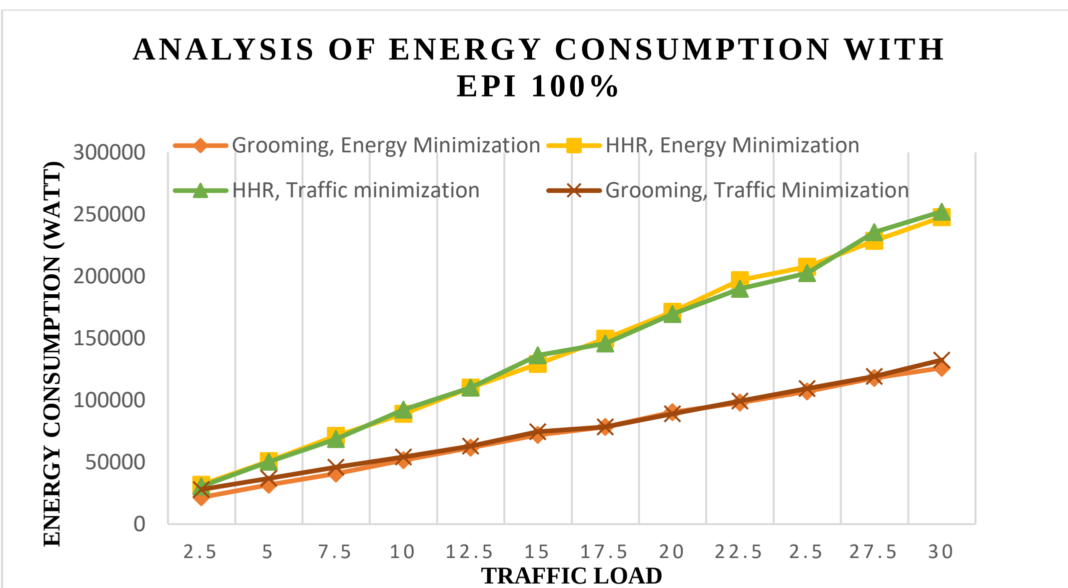

Figure 4: Analysis of Energy Consumption With 15% EPI

There is a very significant finding that may be found in Figure 3 and Figure 4. The traffic load has a significant impact on the amount of energy that is used by high EPI equipment. As a result, when EPI is large, the energy consumption of energy minimized routing is nearly identical to that of traffic minimized routing. Also, both EPIs demonstrate improved energy efficiency when it comes to traffic grooming. A significant amount of energy consumption may be saved by energy reduction and traffic grooming in very low EPI cases. Consequently, energy reduction routing is necessary for low EPI equipment, such as current devices, because of this requirement.

3) Cell Site Planning

The user demand-based dynamic BS on/off mechanism is theoretically introduced in this section. Given that the quantity of power is reduced exponentially with increasing distance, the combined design of tiny cells in a cellular network has the potential to significantly reduce the amount of energy that is used. When there are fewer people using the system, the energy efficiency is going to be quite low. Therefore, a strategy that employs user-demand adaptive BS cell on/off is necessary in order to provide an energy-efficient BS management system.

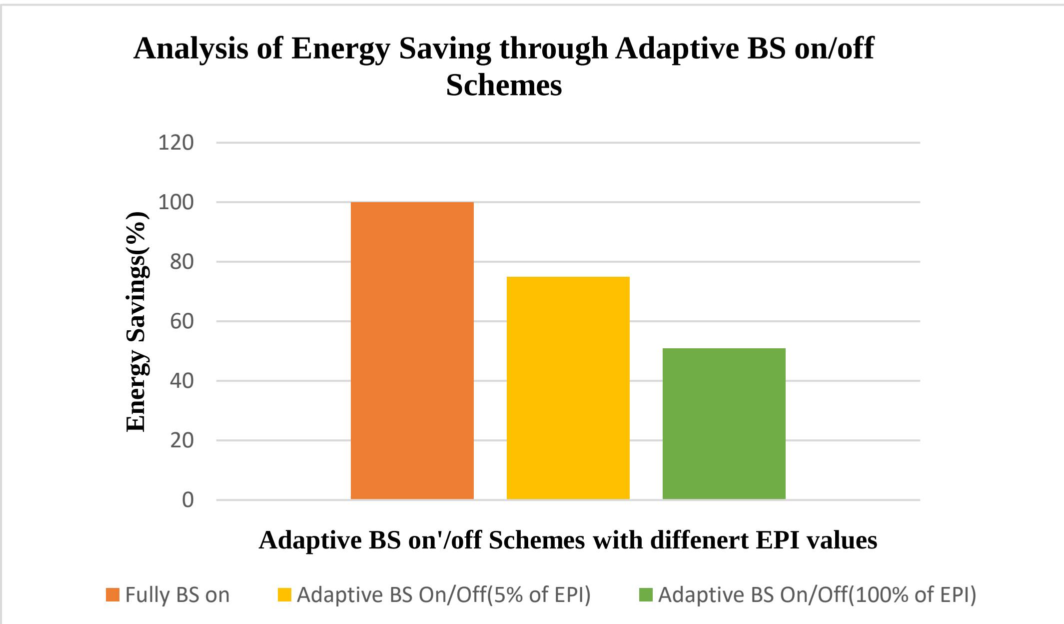

Figure 5: Analysis of energy saving with different EPI values

Figure 5. illustrates the amount of energy that may be saved by the manipulation of the on/off switch for the BS. Through a method of uniform distribution, we create users. For the purpose of simulation, we make use of the daily traffic pattern found in (Lorincz et al., 2010), and we sample it every four hours. In comparison to the completely BS on scheme, the adaptive BS on/off system is able to achieve a significant reduction in energy consumption. Additionally, a high EPI of each individual BS contributes to the successful achievement of network energy efficiency.

5 Conclusion

Over the last several years, energy efficient research in networking has emerged as one of the most important categories of research. The purpose of this paper is to demonstrate the relevance of energy-conscious networking by predicting the future energy consumption in network management. In order to achieve energy-aware core networking, it is necessary to take into account both the packet routing strategy and the optical packet technology. A very high level of energy efficiency may be achieved on the wireless side with the use of intelligent power management for inter-cell optimization. In order to successfully design both wired and wireless networks for ENN, it is essential to give EPI a particularly thorough consideration.

Organizations are able to detect and rectify performance issues via the use of business management procedures before these issues become problematic for users. Businesses are able to improve their networks for maximum efficiency and guarantee that consumers have a great experience on a constant basis if they analyze traffic and use trends.

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