POWER CONSUMPTION IN TELECOMMUNICATION NETWORKS OVERVIEW AND REDUCTION STRATEGIES

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ABSTRACT

Base stations in wireless networks and customer premises equipment (such as home gateways) in fixed-line networks are the main sources of power consumption for telecommunication networks, with core network consumption also increasing. Using energy-efficient hardware, optimising network operations through dynamic resource allocation and traffic management, and implementing green technology like sophisticated cooling systems and renewable energy sources are some strategies to lower consumption. Reducing power consumption in telecommunication networks is one of the primary issues facing information and communication technologies in the future. The base stations for wireless access technologies and the home gateways at the customer's location for fixed line access technologies are the main users. But if bit rates rise, the core networks' share may also increase significantly. It was shown that cell zooming algorithms that primarily take client traffic into account can reduce base station power consumption by 14–80%; however, not all research take service quality into account. Base station energy savings of roughly 15% can be attained by striking a balance between energy conservation and service quality. Dynamic network scaling algorithms are more frequently provided in contemporary study, and location management research has been found to be a solution that may help enhance energy-saving strategies and maintain the ideal level of service quality. In this article, we describe the various network types' power usage and talk about ways to lower it.

Keywords: *optical fibres; base stations; mobile communication; power requirement; energy efficiency; passive optical networks.*

INTRODUCTION

Power consumption in telecommunication networks comes from different places, such as data centers, transmission equipment, and base stations. These parts of the network handle tasks like processing information, sending and receiving data, and providing wireless connections. Globally, telecommunication networks use about 1% of the world's total electricity. Mobile networks, in particular, use a lot of power because of base stations and other necessary equipment[1]. On the other hand, fixed broadband networks use a lot of energy because of the devices that end-users use. The amount of power used depends on several factors like how much data is being sent, the technology being used, and the move from older systems to newer ones such as 5G.In the last ten years, there has been a big increase in the focus on environmentally friendly solutions[1]. Especially because of concerns over climate change, every new technology is closely looked at for its environmental impact. This is also true for information and communication technologies, or ICT. It is estimated that ICT is responsible for about 2 to 4% of all carbon emissions worldwide. Most of these emissions, around 40 to 60%, come from the use of equipment[1-2]. By 2020, these emissions could double if nothing is done to reduce them. One sixth of these emissions is because of telecommunication networks. The number of internet users is growing by about 20% each year. In developing countries, this growth is even faster, around 40 to 50%. Because of this, new network setups will be a big part of future telecommunication networks. So, new technologies need to be checked for how much environmental impact they have. ICT is also seen as a tool that could help reduce about 15% of global carbon emissions. For the sector to achieve its goals, it also needs to show that it can reduce its own emissions. The telecommunication sector is very important in modern society because it connects people all over the world, allowing instant communication regardless of where they are[3].

It is also a key part of the global economy's development. In terms of energy use, the electrical systems in telecommunication infrastructure use more than 1% of the world's total electricity[1]. The rollout of next generation mobile networks using 5G technology will increase the electricity demand for telecommunication systems even more. With more competition in the market and lower profits from mobile services, network operators need to make their base station systems more efficient. This helps them get better returns on their investment while keeping the network reliable and ensuring a steady power supply[4].

Optimization in electrical systems for telecommunication can be talked about in terms of using less energy, saving money, making sure the system works well, and being better for the environment. Using less energy means making the base stations use power more efficiently. This can be done by using better radio equipment, using power-saving methods that adjust automatically, and adding renewable energy like solar power[1]. Saving money involves reducing the cost of setting up and running the base station. This is done by choosing the best size and mix of resources based on how much energy costs, how easy it is to get energy, and the existing infrastructure where the base station is located. Good performance means the network works well and stays up for users. Better performance usually costs more money, so it's important to balance performance with cost when optimizing[2]. Being better for the environment means using less energy and adding renewable energy sources to cut down on carbon emissions, helping make telecommunication networks more sustainable. People are studying how much power telecommunication equipment uses [3], [4].

They also look at ways to save energy. Some previous work [5] has looked at using sleep modes to save power, while [6] has focused on making parts of equipment more efficient and managing power better. Now, new ideas or improvements on these methods are being developed. This research creates a mathematical model and looks at ways to best size and set up a system that includes solar panels, batteries, and a diesel generator for a base station that is connected to the grid. The goal is to make the system as cheap as possible to run and build, while making sure the base station never runs out of power[6]. This "100% power availability" means the base station gets a constant and reliable electricity supply so it can keep working without stopping. That means the system must be designed so it can always give the needed power, no matter what's happening with each power source. The results of this research can help network operators make their systems more energy-efficient, cheaper to run, more reliable, and more sustainable[6-7].

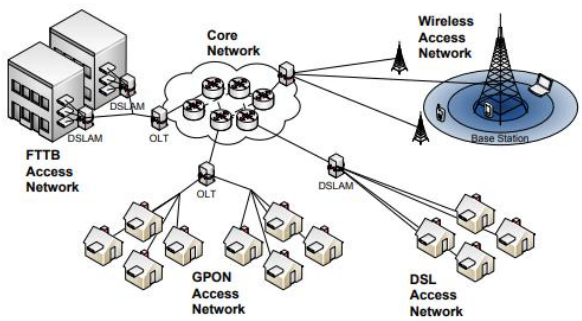

Figure 1: Network Overview

OVERVIEW OF POWER CONSUMPTION

❖ **Wireless Networks:** Base stations, especially the Base Band Unit (BBU) and Remote Radio Unit (RRU), use a lot of power. Cooling these stations also takes up a big part of the energy used[6].

❖ **Fixed-Line Networks:** A lot of energy is used by the devices people have at home.The central office and the network that connects these also use a lot of power.

❖ **Core vs. Access:** The access part of the network, like base stations and home devices, uses more power. However, the core network is using more power now because data rates are getting higher[6].

❖ **Static vs. Dynamic Power:** Even when there is no traffic, the network still uses some basic power. When more people are using the network, the power used goes up. Sources of power consumption [6] .

❖ **Data Centers:** These are important for the network.

❖ They use power for servers, networking tools, and cooling to handle apps, storage, and data processing.

❖ **Transmission Equipment:** Routers, switches, and other systems that send data across the network use energy. How much energy they use depends on how much they're used and how far the data has to travel.

❖ **Base Stations:** For wireless networks, base stations are a big source of power. They help connect mobile phones and IoT devices[6].

❖ **End-User Devices:** In fixed broadband networks, the devices people own, like home routers and other gadgets, use a large amount of the total energy[6].

FACTORS INFLUENCING CONSUMPTION

❖ **Traffic Load:** How much power is used depends on how busy the network is. When more people are using the service and more data is being sent, the power used goes up. The amount of power used can change depending on the time of day and where people are located[7].

❖ **Technology:** Switching from older network types (like 2G and 3G) to newer ones (like 5G) affects how much power is used.

Even though 5G may use less power for each bit of data, the faster speeds and greater capacity can mean more power is used overall because more parts of the network are active[5].

❖ **Architecture:** In mobile networks, the way the Radio Access Network (RAN) is structured, including parts like the Baseband Unit (BBU) and Radio Unit (RU), plays a big role in how much power is used[7].

❖ **Static vs. Dynamic Power:** In real networks, there is always some power being used even when there is no traffic. This is called static power. The aim of making networks more energy efficient is to lower this static power so that the network only uses power when it actually needs to[5].

EFFORTS TO REDUCE CONSUMPTION

❖ **Equipment Upgrades:** One important way to save energy is by replacing old, less efficient equipment with newer, more energy-saving hardware. For example, switching from copper cables to fiber optic cables in fixed access networks can make the system more efficient[8].

❖ **Software and Routing Optimization:** Using energy-saving software, such as the kind found in ZigBee networks, can help by making data routing better and balancing the network's workload, which helps the network last longer[6-8].

❖ **Infrastructure and Operational Changes:** Telecommunications companies are looking for ways to save energy because electricity costs are a big part of their regular expenses[6-8].

NETWORK ARCHITECTURES

Fig. 1 shows the different types of network structures we are looking at. We divide networks into two main groups: access networks and core networks. Access networks are further split into fixed line and wireless types[7].

A. Access Network Structure

The job of access networks is to connect users to the internet.

These networks are often built like a tree, with all users connected to a central office. The traffic from all the users is collected at this central office and sent to the core network. The network branches out through different parts of the tree. The way the tree is built depends on the technology used. The tree can have different levels of data gathering at various points along the way[7].

In access networks, we have two main types: fixed line and wireless. Fixed line networks use wires to connect users to the network. There are three main technologies used today. The first is Digital Subscriber Line (DSL), which uses old telephone wires made of copper. There are different versions of DSL, each with different speed limits and max distance. The most known versions are ADSL and VDSL. ADSL is for slower speeds, while VDSL offers much higher speeds[8].

Another technology is coaxial cables, which are used with the DOCSIS standard.These networks often start from old TV networks. Recently, optical technologies are becoming more common. These are already used in parts of the network that need much higher speeds. Currently, optical technologies are being used closer to users, either through a direct link (point-to-point), an active splitter (active star), or a passive splitter (passive optical network). Depending on the speed and the amount of traffic, different technologies can be used together in the access network. When using VDSL, only optical technologies can handle the gathered traffic[9].

So, cable access networks use an optical backbone and are called Hybrid Fibre Coax (HFC). Optical networks can also be connected to VDSL devices, like FTTB (fibre to the building), FTTC (fibre to the cabinet), or FTTH (fibre to the home), which is full optical access. In this analysis, we will focus on optical and DSL technologies. Traffic in the access network is unpredictable and varies a lot. However, the equipment used has a power use that doesn't change much over time. So, when looking at power use, we'll consider power per user[7].

ADSL used to be the main way people connected to the internet, with downstream speeds from 8 Mbps to 24 Mbps and upstream speeds around 1 Mbps. The range of ADSL can be up to 5.5 km, but the slower the speed, the farther it can reach. This allows more users to be connected in the first part of the network. Because of this large number of users, the power used by the backhaul part of the network per user is very low. VDSL, on the other hand, uses a wider range of frequencies, giving faster speeds but with a shorter reach[7-9].

This means the first part of the network is closer to the user, requiring a larger backhaul network. That makes the backhaul use more noticeable in terms of power. Optical fibre offers both higher speeds and longer reach. A single fibre can go up to 10 Gbps with a range of 10 to 20 km. However, these high speeds are not needed for one user. So, point-to-point connections are mostly used in the backhaul to collect traffic[7]. In star and PON (Passive Optical Network) setups, the capacity is shared among many users. Common split ratios are 32 (up to 20 km) and 64 (up to 10 km). GPON (Gigabit PON) is the most commonly used standard. Right now, optical line terminals (OLTs) usually handle between 4 and 72 fibre connections. In wireless access networks, users connect via radio signals to a base station. The base station is then connected to the central office through a backhaul network. There are different wireless technologies with different transmission power, frequency, and methods, leading to different speeds for users. At the user's location, the access network connects to customer premise equipment[9].

For fixed lines, this is usually a home gateway that links to other devices like computers or set-top boxes. For wireless, the equipment can be a mobile phone, a Wi-Fi card in a laptop, or a home gateway. For wireless technologies, we use the general term 'mobile station'[10].

B. Core Network Architecture

Access networks group users in a specific area together. To connect these areas, core networks are used. A core network includes several core nodes that are linked using wavelength-division multiplexed (WDM) optical fiber cables. These connections are often arranged in a mesh or ring layout[7]. Today, core networks usually combine multiple layers of different technologies stacked on top of each other, like IP-over-ATM-over-SDH, as shown in Figure 2(a). However, there's a growing movement towards more uniform network designs where IP is directly sent over WDM links, as shown in Figure 2(b). Based on this trend, we will focus on the latter design. At a high level, core nodes are optical-electrical-optical based. This means that all optical traffic is converted into an electronic signal and processed by the node, whether the traffic is ended at that node or not[78]. Typically, a node has multiple WDM transmit and receive cards, also called transponders or transceivers, connected to an IP router. The IP router can then connect to multiple access routers. WDM fiber links carry multiple wavelengths, with each one usually having a capacity of 10 Gbps or 40 Gbps. It's common to have 40 to 80 wavelengths on a single fiber. Optical amplifiers are needed every 80 km or so to compensate for signal loss. Because the maximum distance a light signal can travel is limited, usually between 1000 and 4000 km depending on the speed and technology, long-distance links need to regenerate the optical signal[7].

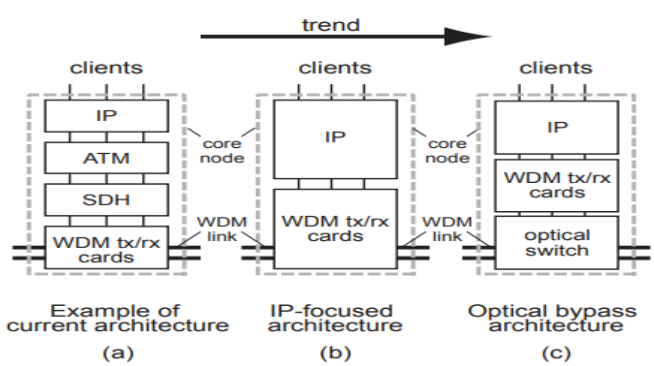

Figure 2. Core Network Node Architecture

POWER CONSUMPTION IN TELECOMMUNICATION NETWORKS

ICT uses various electronic equipment and technologies that are common in today's society. Figure shows the power usage of different ICT sectors, and it is seen that almost 50% of this, including server operations, comes from telecommunication networks. These networks can be mobile networks, local area networks (LANs), or fixed line networks. Fixed line and mobile networks have big differences when it comes to power use [1]. In fixed line networks, more than 70% of total power is used by users, while only 30% is used by the operator's operational expenses (OPEX). In mobile networks, 10% of the power is used by users, and 90% is used by the operator's OPEX. If we ignore the core network, fixed line networks lose a lot of energy due to cable transmission, routing, and broadband access. Mobile networks, on the other hand, use a lot of energy for base station operations. Figure 2 shows how power is divided among different network functions. In terms of overall network performance, energy use is higher in the access part of the network and in data centers that manage information. Backbone and aggregation networks have lower energy needs [6]. This shows that an energy-efficient network should focus on smart and efficient access methods and efficient data handling by data centers. The main functions of a network include data regeneration, transportation, storage, routing, switching, and processing [7]. Figure 2 shows the power consumption of these functions, and it can be seen that most energy is used for routing/switching, data regeneration, and data processing. Both communication protocols and electronic devices are responsible for this high energy use, which creates challenges for more advanced transport methods, cooling switches or servers, and reducing unnecessary data transfers. A good example of energy efficiency in electronic equipment for these functions is shown in Table 1.

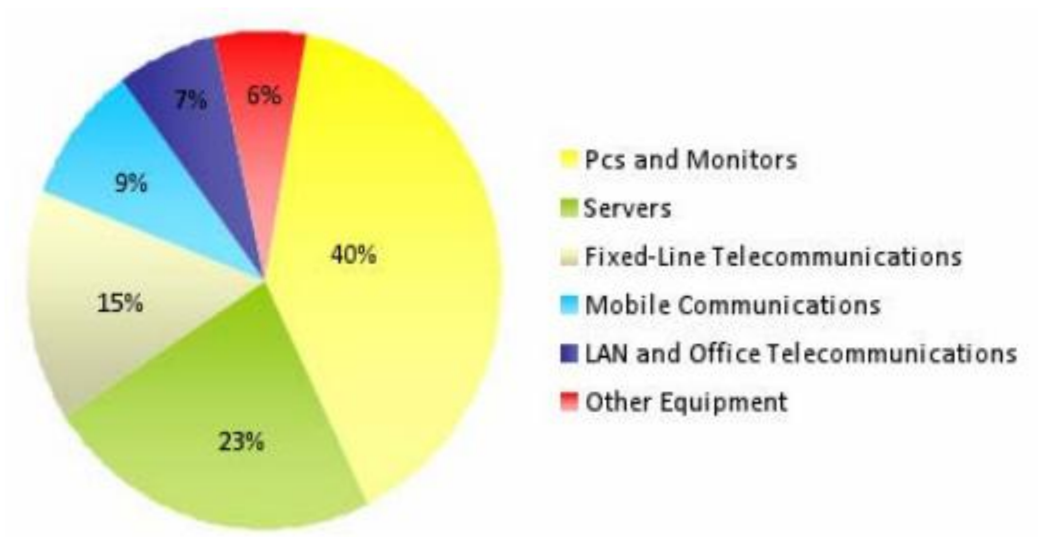

Figure 3: Energy consumption in ICT sectors [1].

Table 1: Power Efficiency Of Telecommunication Equipments [7]

Equipment	*Power Efficiency (W/Gbps)*
Router	40
IP Switch	25
Transport TDM	80
ATM Switch	80

For mobile networks, one of the main factors that affect how much power the network uses is how the site is set up, which includes the base station equipment [5, 8]. In the last part of Figure 2, there's a breakdown showing the total power used by the whole site and by the base station itself. It's clear that the biggest part of the energy goes towards cooling the equipment and running the base station. Monitoring and lighting use very little energy, but when it comes to backhaul, it's not clear how much energy is used, and it depends on what kind of connections are used—like fiber or cable. Inside the base stations, the high energy use is mainly because of the feeders (which send out radio waves), the RF conversion units and power amplifiers, the signal processing units, and other electronic equipment such as climate control and support systems[5, 8]. In the next part of the paper, some existing research projects in this area are looked at, and different ways to improve the network's energy efficiency are suggested.

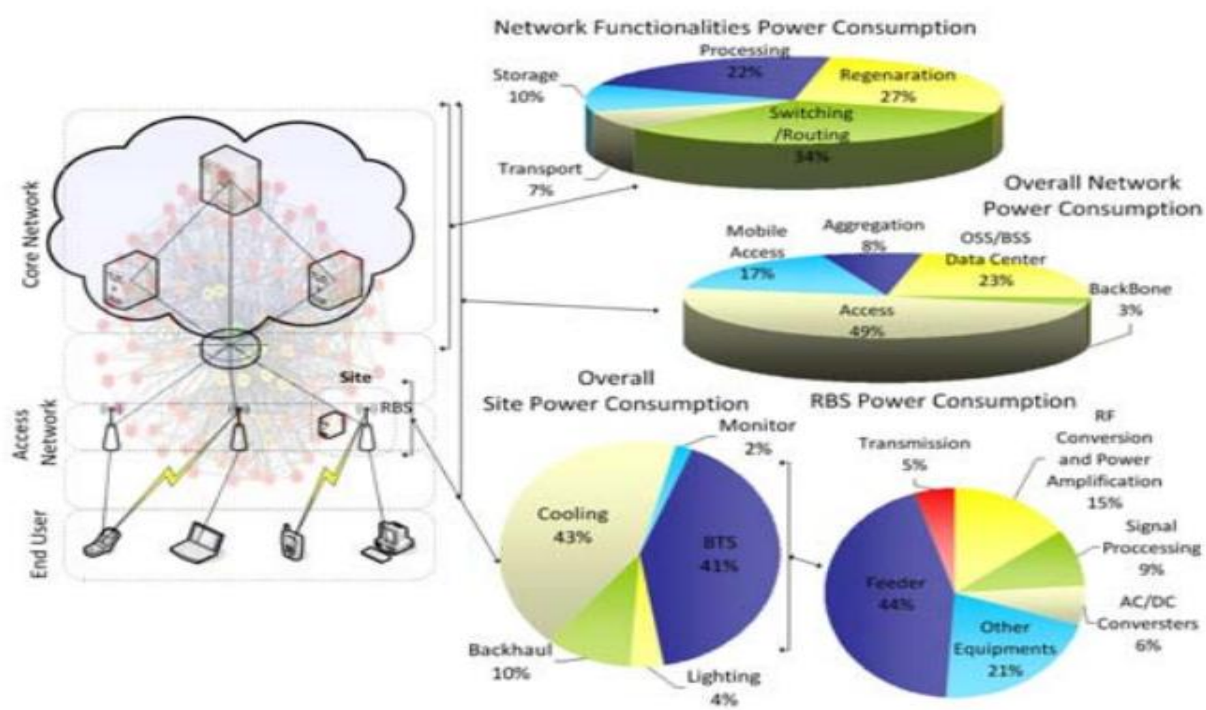

Fig. 2. Power consumption in different layers of the network.

CONCLUSION

The number of people using the internet is growing quickly, and these users are asking for higher quality services that need more data. At the same time, there is a need to cut down on the environmental impact of ICT. Saving energy in telecom networks is now a big challenge. New technologies can help use less power, but when designing these, it's important to focus on using as little power as possible. This includes turning off parts of the system when they're not needed, lowering the workload on the network, and making sure that network parts use power efficiently. Right now, most of the energy used comes from the customer's side. In fixed-line networks, the biggest energy user is the home gateway, which can be made more efficient with simple changes. In wireless networks, the main energy user is the base station. In fixed-line networks, making energy savings is harder because the network structure is like a tree. But moving towards fully optical networks can help save a lot of energy. In wireless networks, there are still many ways to save energy. In the core part of the network, energy use is currently low. However, as more data is sent through these networks, it's still good to find ways to save energy here too.

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