



A Sustainable Approach Between Satellite and Traditional Broadband Transmission Technologies Based on Green IT

Md. Muktadir Mukto¹, Md. Maiyaz Al Mahmud¹, Md. Ahsan Ahmed¹,
Ikramul Haque¹, Ahmed Wasif Reza¹, and Mohammad Shamsul Arefin^{2,3}✉

¹ Department of Computer Science and Engineering, East West University, Dhaka 1212, Bangladesh

wasif@ewubd.edu

² Department of Computer Science and Engineering, Daffodil International University, Dhaka 1341, Bangladesh

sarefin@cuet.ac.bd

³ Department of Computer Science and Engineering, Chittagong University of Engineering and Technology, Chattogram 4349, Bangladesh

Abstract. Although satellite internet has low performance in the case of data transmission compared to traditional internet services such as broadband internet networks and cellular networks, it may have a low environmental impact as well. Traditional internet services are located on earth so the latency is fairly high. However, if the environmental impact is the only consideration, satellite internet may be a viable option. This research paper tries to analyze this aspect of the internet. Based on green IT which internet service can provide the best and if there is a way to make internet services more efficient? This paper aims to provide as much information regarding this and provide a solution to this. In this paper, a thorough investigation has been conducted to include direct or indirect environmental impact, power consumption, greenhouse emission, building material, etc. A comparative analysis shows if satellite internet can negate the environmental impact of traditional internet services. Based on the study, solutions have been provided for traditional internet services using real-time simulation and machine learning algorithms. The simulation of cabling gives a significant reduction in cable use and the implemented machine learning algorithms in routing devices yield a 30% energy consumption reduction and an almost 25% GHG reduction per month. This paper contributes to the overall process to make the internet greener. This paper can especially help decide which internet service is based on environmental friendliness. This paper can also help internet service providers to reduce costs in connectivity.

Keywords: Environmental impact · Space environment · Terrestrial environment · Green IT · Satellite · Broadband · Cellular network · Greenhouse emission · Power consumption · Machine learning

1 Introduction

Satellites need to be placed in a certain location in outer space from where the satellite will sync with Earth's orbital rotation. This is required to make sure the satellite does not change its initial position and to ensure constant data flow between the satellite and geo-station. As a result, satellites needed to be placed in the geostationary orbit (GEO) [1]. But the distance between the GEO and Earth's surface is very large. Because of this, there occurs a latency in the data flow. On the internet, network latency can cause disturbance in information flow. As the technology for satellites has been improved, now satellites can be located in the medium earth orbit (MEO) and low earth orbit (LEO) which can ensure data flow without any latency. As a result, Satellite Internet is becoming more and more popular among consumers.

In MEO and LEO, the altitude of the satellites from Earth's surface is significantly low compared with the altitude in GEO. As a result, the coverage area for downstream data transmission is also small. So, the number of satellites to be located in LEO or MEO increases to cover more area. To make the data transmission more efficient a new technique is deployed using multiple satellites. This is called a satellite constellation. In a constellation, multiple satellites work as a system rather than working individually. The orbital movement of these satellites is not synced to each other so at any time on any place on the globe, at least one satellite can be seen. In 2013 the first MEO constellation, the O3b constellation, was launched by SES. Modern companies aim to set constellations in the LEO. As the altitude of satellites in LEO is much less than those in MEO, the number of satellites is also very large. In 2021 SpaceX located 1000 satellites in their Starlink constellation [12]. In 2019 Amazon revealed its Kuiper constellation that will contain 3236 satellites [2]. This large number of satellites in a constellation may have a significant impact on Earth or the space environment. As such, this paper provides an overall overview of how satellite constellations, as well as traditional transmission systems, affect the space and Earth environment. The paper discusses the general view on data transmission methods and their environmental consequences. And based on these pieces of information the paper provides modern methods and solutions to tackle the negative environmental impact of these data transmission methods.

The problem this paper addresses is the environmental impact of different internet services on both terrestrial and space environments. The space environment can be considered the environment of our concern as we have reached space. In LEO a large number of satellites can create space debris or space junks [9]. This debris can collide with space crafts or other satellites and create hazardous situations for future space travelers. The satellite space debris can also affect the Earth's environment. Small debris can reach the earth with high velocity by gravitational pull and can spoil the soil in the area of impact. This debris can also emit toxic chemical materials that can be harmful to any living being in that area. So, the environmental effect of satellite constellations is also high, but should we still take the risk?

To answer this question, we must learn the environmental impacts of traditional internet services, and how efficient they are. Submarine communication cables provide worldwide internet access. Bangladesh has access to two submarine communication cables SEA-ME-WE-4 and SEA-ME-WE-5 through Kuakata and Patuakhali stations. Although submarine communication cables can be considered environment friendly

during a lifetime, the installation, repair, deconstruction, and construction process of these cables can be harmful to the environment. Additionally, the structural components of the cables can also affect the environment. The coating and sheathing of Ethernet coaxial cables can also be harmful to the environment [13]. Resources spent to make these cables and toxic elements emission during this process must also be considered. Additionally, traditional wired internet access may require multiple devices to function, increasing power consumption. Cellular network base stations may be power inefficient [3].

Based on the information mentioned above the research questions can be given as follows:

- Is satellite internet more environment-friendly than traditional internet services?
- Are people (in Bangladesh) ready to accept satellite internet service?
- Can solutions be provided to some environmental-related issues of traditional internet services while we wait for satellite internet to reach the sub-continent market?

Through a comparative analysis, this research paper will try to answer the question of whether satellite internet is worth the risk. To do the comparative analysis we require some information that we can gather by going through some related journals, articles, and papers. A survey has been conducted to learn if people are willing to switch to satellite internet from traditional internet. Their opinion will also be used to evaluate the environmental impact of internet services. That is not all as this paper also provides a solution to energy inefficiency issues in the traditional internet and also provides suggestions to make the internet greener.

The following is a summary of this paper's contributions:

- Comparative analysis of accessibility, data transfer rate, technological innovation, and environmental impact, energy efficiency between traditional wired Ethernet or mobile network and broadband satellite.
- Evaluating the green approach of mentioned broadband transmission technologies.
- Providing additional information on internet services from the consumer's point of view based on the environmental impacts.
- Proposal of the adaptation of the greenest and energy-efficient broadband transmission technology based on the comparative analysis.
- Providing possible solutions to Green IT-related issues of traditional internet access and services.

The remainder of this paper is structured as: Sect. 2 reviews the related work and tries to explain the methods discussed. Section 3 does a comparative analysis of the internet services by the information on environmental impact. The section also discusses whether satellite internet negates any environmental impact caused by traditional internet. A survey is included that explains the consumer's point of view. Some solutions have been provided to make traditional internet and satellite internet more efficient. In Sect. 4 the results are explained and the environmental effects are discussed. While Sect. 5 serves as the conclusion.

2 Literature Review

In [7], the authors Yuan Yang, Mingwei Xu, Dan Wang, and Yu Wang discuss a way to make satellites efficient through energy-efficient routings in satellite networks. The key concept of the paper is that the power consumption can be decreased by reducing DoD (Depth of Discharge) power cells and increasing their lifetime through re-routing. In this article, algorithms are developed based on the location and orientation of a satellite. Then another algorithm is developed for Quality of Service (QoS) included. Overall, the Green-SR algorithm increases battery life by 40% making energy-efficient routing a success. The suggested method in this paper was studied thoroughly to make sense of possible solutions to the environmental impact caused by satellite power generation.

In [13] Jinkyu Lee, Eugene Kim, and Kang G. Shin described power management in the power generation and storage unit of satellites. The management of operational satellite power cells and the initial power cell design are the focus of this study. The study describes the design of a solar panel and battery configurations while autonomously or pre-running all tasks to avoid running out of power. By simulating the algorithms on nano-satellite CubeSat it has been proved that finding the smallest fixed point of SOC power efficiency can be achieved. Also, with a dynamic version execution, orbit sub-period $\delta = 10$ can be achieved, increasing task execution. The mentioned methods and applications in this paper provided a good overview of the ongoing attempt to improve energy efficiency in satellite design.

In [2], Ogutu B. Osoro and Edward J. Oughton explored how to create an open-source modeling framework for evaluating the techno-economic nature of satellite broadband access. The goal of this study is to discuss broadband connectivity. In this paper, the main goal is to find out how much capacity can different LEO broadband constellations also provide what is the maximum capacity per user in various constellations, what is the possible cost per user as the number of subscribers grows and, which regions of the globe are the best candidates for LEO constellations? This technique establishes an engineering-economic framework for a single satellite network, which is centered on LEO in this example. To begin, a supply-side engineering system model that captures a new constellation's capacity and coverage attributes is established. Second, a cost model is developed that may be used to determine the total cost of operating a constellation. The findings show the connectivity benefits and drawbacks of various LEO systems, as well as their practicality. The study required an in-depth look into satellite constellation structure which this paper provided with explanation and interpretation.

Bastien Taormina, Juan Balde, Andrew Wants, Gérard Thouzeau, Morgane Lejarta, Nicolas Desroyf, and Antoine Carlierb, the authors of [6], wanted to see what was known about the possible environmental consequences of Submarine Power Cables (SPC) throughout the installation, commissioning, and decommissioning phases. Ideologically, the study aimed to examine the impact of undersea power cables on the marine environment, as well as to identify knowledge gaps in current studies on marine life protection and make recommendations for monitoring and mitigating these environmental consequences. To generate a bibliographic database, a literature search was conducted utilizing online databases and internet search engines (Web of Science, Science Direct, Google Scholar, ResearchGate). Because there are few published studies on the subject,

corporate or government reports, and environmental impact assessments are also considered knowledge-gathering. Finally, discovered knowledge gaps regarding the protection of the maritime environment from SPCs, and made recommendations to lessen SPCs' impact on marine life. The SPCs can have an impact on the environment by the formation of electromagnetic fields and creating an artificial reef. The information provided here can be used to describe the environmental impacts of submarine power cables that have similar structures to submarine transmission cables.

In [5], X. Zeng, M. Liang, H. Liu, Y. Ren, and R. Yang propose the monitoring system of distribution running based on Broadband Power Line Communication, introduce the constitution of hardware and software in detail, and discuss the functions and characteristics of this system. So, a system is needed to monitor and manage the running states of electric meters and transformers in real-time. Optical fibers have been installed at 35 kV transformer substations by city power supply bureaus. The general public network PSTN, GPRS wireless mode, and power line carrier are presently the most regularly used communication modalities. Broadband Power Line Communication is a type of communication technology that employs the Medium Voltage (MV) and Low Voltage (LV) distribution networks as the communication medium for data, voice, and real-time picture transfer. It is a synthesized system with power management and burden control, an essential technological means for achieving power grid distribution and electric burden management, as well as allowing electric utilities to enter the market to promote social and economic advantages. The paper provides an overview of a monitoring system for electric generation and data transmission. The knowledge provided here is highlighted in the comparative analysis to make sense of modern attempts at energy-efficient power distribution.

In [4], J. Baliga, K. Hinton, and R. S. Tucker proposed a network-based model for estimating internet power usage, which includes the core, metro, and access networks. The authors estimate that the internet consumes around 1% of overall electricity usage in broadband-enabled nations. Estimating overall internet and network power usage is required to find out possible solutions to reduce power consumption. The access network, the metro network, and the network core are the three main portions of a typical Internet Service Provider's (ISP) network. A passive splitter at the curb-side combines the signal from numerous homes into a single fiber that is directly linked to one of ten edge nodes, reducing the number of fibers necessary to connect each home to one of the edge nodes. Core routers are designed to scale with future expansion and are often designed to handle double the present peak demand. They calculate the power usage based on a peak access rate of 100 Mb/s, an average access rate of 30 Mb/s, and household size of two people with an average capita energy use of one kW in OECD nations. The internet accounts for 1% of overall electricity use. The paper acts as a base source of information for the methodologies described in the research.

3 Methods and Procedures

In this section, at first, we do a comparative analysis between satellite Internet and traditional Internet services such as wired cable networks and cellular networks. Then a survey has been conducted to gather more information and to summarize the consumer's

perspective. Afterward, some proposed methods have been provided to make traditional internet services more sustainable. The survey is in sub-section B and the proposed methods are provided in sub-section C.

3.1 Comparative Analysis

While doing this analysis we give more priority to the environmental impacts of these internet services. Aspects such as power consumption, CO₂ emission, hazardous chemical emission, and effect on animal behavior and health are considered.

Environmental Impact of Submarine Communication Cable: Modern cables include optic fibers that can be used for the internet and telephone. Recent studies show that during the operational lifetime the submarine communication cables have significantly less effect on marine life except in benthic communities [6]. Submarine communication cables are usually laid deep under the ocean buried or laid on top of the ocean bed. The lower levels of a body of water contain the benthic species as well as micro and macro-organisms. Because of the installation of these cables in their habitats, these species can be dislocated. As the cable takes a narrow space this effect can be minimal [6]. The other large species can also be affected during the installation, repair, or deconstruction time. During this period, the equipment and technologies used for this task may create very large noise. In the ocean and sea some marine species such as whales, and turtles are very sensitive to noise. It can interfere with their communication and disrupt migration, feeding, and breeding.

The submarine communication cable is composed of Polyethylene - Coating, Mylar tape, Steel wire, Aluminum water barrier, Polycarbonate, Copper and aluminum tube, Petroleum jelly, and Optical fiber.

Aluminum mining, refining, and smelting can be very harmful to the environment and human health. Additionally, aluminum is toxic for fishes with gills. It causes osmoregulatory failure in marine species. It also accumulates in plants. In high-density copper becomes toxic and can affect the metabolic processes of microorganisms in marine environments.

Environmental Impact of Ethernet Cables: Ethernet cables are twisted pair cables that use copper as a core element. High levels of copper concentration can be harmful to the environment and any living being. Copper can be released in large concentrations during cable manufacturing. When copper is discharged into the environment, it generally binds to organic matter particles and does not decompose. The other material used in Ethernet cables is PVC coating. Polyvinyl Chloride (PVC) is halogen-based. In a fire, halogen-containing plastics release hydrogen chloride, a poisonous gas that forms hydrochloric acid when it comes in contact with water. So, PVC is bad for the environment. Also, one of the components of PVC is Chlorine. Chlorine is a toxic element and also a building block of CFC gas that damages the ozone layer.

Environmental Impact of the Cellular Network: The current 5G network uses 10-mm waves [11]. Millimeter waves make space for a network connection that increases energy consumption. To transmit these waves small cells are used. Small cells are miniature

cells that can be placed anywhere. As the millimeter wavelength is very small any solid object can disrupt transmission. So, large amounts of small cells must be placed at short distances. Millimeter waves can also affect the ecosystem. 5G network towers that transmit millimeter waves can harm animals coexisting with humans [8].

MIMO antennas which are used for signal linking alone consume 1000 watts of energy per sector. Additional power is required for other base station operations. The energy consumption contributed has increased because of this.

Environmental Impact of Satellite Internet Services: The satellite can send signals to base stations and it distributes the internet service to the clients [10]. Based on the service provider's choice, the internet can then be distributed to clients through cable or RF networks. No cable is needed to transmit data to the gateway, base station, or gateway [16].

Although satellites do not directly affect Earth's environment, we cannot say they are entirely environmentally friendly. Satellites can have a great impact on the space environment, especially in LEO and MEO where large numbers of constellations are set or are planned to be set. The first concern is the space debris created from these satellites. A satellite that has reached the end of its lifecycle can turn into space debris if not retrieved. Additionally, if any parts of the satellite get damaged and get separated from the satellite from a meteor or other collision, it can become space debris. Too much space debris can hamper future space travel or can damage any devices or technologies in its orbital area. According to Aaron Boley, assistant professor at the University of British Columbia in Canada, at least 2.2 tons of dead satellites are expected to enter Earth's atmosphere per day with the launch of the first generation of Starlink constellations containing a large number of the satellite. The satellites are mostly made of Aluminum [9]. LEO orbital space is closest to the Earth and gravitational pull somewhat exists there. Because of this the space debris gradually loses altitude to a certain point and starts to burn up. Burned-up defunct satellites or space debris can leave behind toxic chemicals that can damage Earth's atmosphere, especially the Ozone layer. Re-entering dead Aluminum satellites can also damage the Ozone layer. We know that the damage to the Ozone layer is temporary and the layer in the stratosphere has good regeneration. But as the number of satellites in LEO is increasing the concern remains.

3.2 Consumer's Point of View

A survey was conducted on satellite internet services. The participants were asked certain questions based on the environmental impacts of satellite internet and traditional internet services. Among 50 participants 90% replied positively in the first question where they were asked if they are environmentally aware (Fig. 1).

45% replied positively when they were asked if they want to take satellite internet services after learning about environmental impacts. 55% of the participants cared more about the marine environment or terrestrial environment rather than the space environment (Fig. 2).

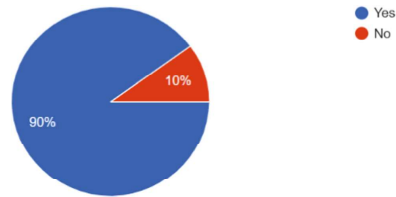


Fig. 1. Environment awareness among participants

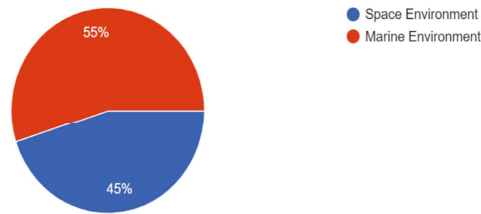


Fig. 2. Which environment people care for the most

3.3 Proposed Methods to Make Broadband Internet Sustainable

In this research paper, some solutions (Figs. 3 and 4) and suggestions were provided to make these services as efficient as possible.

Internet Cable Re-routing. In many regions twisted pair cables are used for broadband internet connection. Internet service providers who use this cable usually give internet access to clients individually. What this means is for every individual client at least one cable is used to link the client to internet access. If we imagine a 5 storied building with 2 sections on each floor and internet service providers want to give access to all of the sections then 10 cables of varying sizes will be required to cover both sections on each floor. Not to mention this also increases the number of devices and power consumption.

A solution to this issue can be by using a fiber optic cable. Fiber optic connections use a fast-traveling light pulse to convey data. The light traverses through glass fiber. An extra joint box can be used in the building which can route multiple cables. In this case, multiple cables do not need to be routed from internet access. Only one cable links the joint box to internet access and additional routing is done via the joint box. It is much more efficient as less cable is used and also fiber optics are made of glass fiber which is very eco-friendly while twisted pairs are made of copper which can be toxic in organic material. Through the fiber cables, an ONU transforms optical signals into electrical signals. In this case, the number of devices may increase. So now we discuss how we can make these routing devices such as ONU and routers to be more energy efficient.

Data Transmission Detection. Routing devices such as Wi-Fi routers and ONU can consume much power if they are not switched off when not in use. People forget to switch off these devices when they go outside or when they go to sleep. If the power consumption of these devices during this time is lessened then much power can be

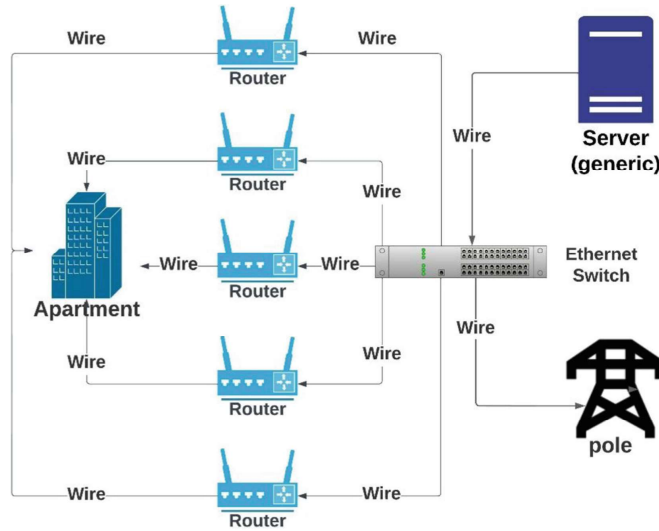


Fig. 3. Congested wired ethernet connection

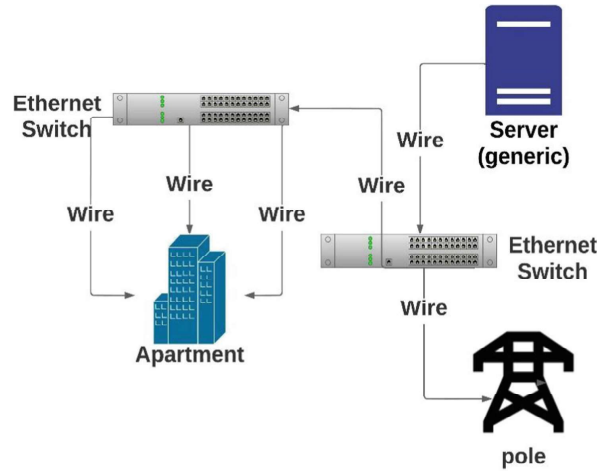


Fig. 4. Efficient wired ethernet connection

saved. In this paper, a smart router ML has been proposed. By using machine learning this functionality will compute average transmission upstream and downstream rates for a specific amount of time.

$$\text{Avg T} = \frac{\sum_{s=0}^n t_s}{n} \tag{1}$$

In the above Eq. 1, the average transmission rate Avg T has been calculated within a given number of times. t_s Denotes the upstream and downstream transmission rate and

n is the number of transmissions in a given amount of time. The transmission rate is computed every second. The summation of upstream and downstream transmission rates in every second divided by the number of transmission rates for the given time gives us the average transmission rate. Calculating this average value for a long time will train the system. After the system is trained by the generated data it can automatically detect the absence of user activity and trigger sleep mode or completely switch off. Let us consider an example where the time interval is 10 min. So, $n = 600, s$ for an average calculated for every second. Let us assume in any part of the day the average transmission rate has been calculated to be less than 10 kbps for 10 min then the device will switch to sleep mode. Here 10 kbps is the defined threshold value. The system will try to detect if the average data transmission rate exceeds the threshold value for another 10 min or not. If it does not exceed then the device will determine there are no user activities and switch off. The sample dataset is listed in Table 1.

Here is the algorithm for Avg T calculation:

```

Avg T ()
1  N = User Defined (n)      /* Time of Average Data Transmission
2  Avg T = 0                  /* Initial Average Data Transmission Rate
3  For i = 1 to N
4      Avg T = Avg T + ti    /* ti = Data Transmission Rate per Second
5  Print Avg T
6  Stop

```

Table 1. Sample data transmission dataset

Time-hour	Time-min	Data-transmission up (kbps)	Data-transmission up (10 min avg)	Data-transmission down (kbps)	Data-transmission down (10 min avg)	Target
10	15	600	10050	600	7000	1
10	25	550	1150	600	25000	1
10	35	0	0	0	0	0
10	45	0	0	0	0	0
10	55	0	0	0	0	0
11	05	500	3500	650	3500	1

The above image shows the first few rows of the dataset. Here the target values 0 and 1 define the user activity. Value 0 indicates there is no user activity and value 1 indicates there is user activity. After the train, the system can determine the target value for a given time in a day.

Algorithm to determine target Value:

Target Value (Avg T)

```

1  threshold = User Defined      /* threshold = Data Transmission Rate
                                Threshold To Determine the Target Value
2  if threshold < Avg T         /* Avg T = Average Data Transmission Rate
3      target = 1                /* target 1 means user active
4  else
5      target = 0                /* target 0 means user not active

```

Satellite Power Cell Management [7]. We know that satellites use renewable solar energy as their main energy source. Solar energy is collected by solar panels and battery cells are used as energy storage. But the main environmental impact comes from the dead satellite. Dead satellites turn into space debris and affect space and Earth's environment in the ways which are mentioned above. So, the best way to reduce the environmental impact of satellites is by increasing their longevity. Although some issues cannot be fixed such as meteor and debris collision and permanent damage, what can be done is to increase longevity by making energy-efficient battery cells. Battery cells deplete when they are in use. To make energy power cells more energy-efficient and energy-efficient, satellite routing was proposed.

Satellite power cell life cycles can be increased by decreasing DoD (Depth of Discharge). The LEO constellation is like a cluster of satellites linked together. They don't need to send signals to ground stations at the same time. So, at any time, some satellites can stay idle. The satellite router can detect transmission rate and based on that can switch to sleep mode which can reduce satellite power consumption and reduce DoD discharge. This can increase the battery life cycle by 40%. Another proposed method is to optimize the state of charge (SOC) of power cells to a fixed value.

4 Results

The first method we have suggested can reduce the use of cable in certain cases. For example, let us consider a 3-storied building with a 3.5-m floor height and distance from an electric pole is 10 m. In this case, if there is a client on every floor and the ISP individually provides service with one cable stretched from the pole then the cable requirement would be $(30 + 36) = 66$ m given the distance between two apartments is 2 m. If we put a switch on the roof of a building to connect all the clients then the cable requirement would be $(10 + 3.5 + 3.5 + 7 + 7 + 10.5 + 10.5) = 52$ m given the number of apartments on each floor is 2. So, we save $(66 - 52) = 14$ m of cables. It makes the internet excess more efficient and also reduces the cost of cables.

In the second method discussed it was suggested to use machine learning algorithms in routing devices to determine user activity and trigger sleep mode and power off. Here the accuracy of the machine learning model can show how successful the systems will be in detecting user activity through transmission rate. A customized model was made for this purpose. Using different parameter tuning options, the model performance was evaluated and the best result was selected.

Table 2. Accuracy of different models

Model	Hyperparameter detail	Accuracy
Logistic Regression (C = 1.5, intercept_scaling = 10, l1_ratio = 1, max_iter = 10000, multi_class = 'ovr', penalty = 'elasticnet', random_state = 42, solver = 'saga')	C = 1.5 parameter indicates the large margin of misclassification max_iter = number of maximum iterations multi_class = 'OvR' a binary classification scheme Elastic NET that includes L1 and L2 penalties solver Saga includes an L1 penalty	80%
Support Vector Machine (C = 1.25, break_ties = True, cache_size = 20, coef0 = 10.0, degree = 2, random_state = 42, shrinking = False)	break_ties = true. Model break ties according to confidence database cache size = 20 coef0 a kernel function = 10 NO temporary elimination of variables	80%
Linear Support Vector Classifier (C = 10, dual = False, random_state = 42, tol = 0.1)	dual problem optimization tolerance for stopping = 0.1	60%
Random Forest Classifier	(default)	80%

From Table 2, we can see the system will be able to detect user activity with 80% accuracy. Given the dataset will be way larger when in practical use and the system will get more data to train, the accuracy will also increase. Now that we have seen how accurately the system will work, let us see how energy efficient the system will be.

Let us consider a router of 12V and 1.5 A. The power consumption of the router will be 18 W/h. Another routing device is used in fiber optic cable which is an ONU (Optical network unit). This is a consumer end device and it also can consume energy. Now let us consider an ONU of 12V and 1.25 A. The power consumption of the ONU will be 15 W/h. If both of these devices are turned on for 24 h then power consumption per day would be 432 W for the router and 360 W for ONU. If we consider the power consumption for one month then the power consumption becomes 12960 W or 12.96 kW for the router and 10800 W or 10.8 kW for ONU. According to the US energy information administration, for 1 kW energy consumption, 0.385 kg of carbon is emitted. So, from the both devices $(23.76 * 0.385) = 9.15$ kg carbon emitted per month [14].

Now we consider the same devices but this time the suggested machine learning algorithms were implemented. Using machine learning the user activity is detected through data transmission rate and the devices are switched to sleep mode for 3 h and kept powered off for 5 h. So, for 16 h the devices are kept operational. In this case, the power consumption per day would be $(5 * 3 + 18 * 16) = 303$ W for the router given power consumption during sleep mode is 5 W. In the same way, power consumption per day for ONU would be $(4 * 3 + 16 * 15) = 252$ W of power consumption during sleep mode is 4 W. So, the consumption of both devices combined per day is 555 W. Without

the algorithm implemented, the consumption was 792 W per day. Power saved = $(792 - 555) = 237$ W per day. And monthly power consumed by both devices is 16650 W or 16.65 kW. Power saved per month = $(23.76 - 16.65) = 7.11$ kW. So, carbon emission reduced = $(7.11 * 0.385) = 2.74$ kg. Power consumption and carbon emission before and after implementing the proposed method, as presented in Table 3.

Table 3. Power consumption and carbon emission before and after implementing the proposed method

Device	Time length	Power consumption	Carbon emission
Router	1 day	432 W	0.167 kg
	1 month	12.96 kW	4.99 kg
Router (Using ML)	1 day	303 W	0.117 kg
	1 month	9.09 kW	3.49 kg
ONU	1 day	360 W	0.139 kg
	1 month	10.8 kW	4.16 kg
ONU (Using ML)	1 day	237 W	0.091 kg
	1 month	7.56 kW	2.91 kg

5 Conclusion

From the comparative analysis, it has been observed that both traditional internet services and satellite internet service have their share of environmental impact. Most of the environmental impacts come not during the operational phase but during the construction, deconstruction, or repair phase. After the introduction of the 5G network, cellular networks have become the main concern for the green internet. Although satellites can minimize various environmental impacts of traditional internet services in terrestrial environments, they can very affect the space environment. From the survey, we learned that people are more concerned about the marine environment than the space environment. Although we need to care for both environments. Satellites can be a good alternative if latency is ignored. A coexistence among the internet services can be beneficial as well as it can negate each other's environmental impact. In conclusion, the paper -

- Provides a broader view of the different data transmission systems and how they have an impact on the environment.
- Provides a comparative analysis of different data transmission systems based on the environmental impact and user preferences.
- Provides methods and solutions that can contribute to energy efficiency, cost reduction, and green internet.

The proposed method 1, Internet Cable Re-routing can be used by individual users and ISPs to reduce cable usage and reduce environmental impacts from the cable elements. This also helps to reduce the cost of cables. The Data Transmission Detection system can be implemented in any wireless routing device to save much energy and reduce power consumption. Individual users can use these smart devices to reduce energy costs and data leaks.

In this paper, the suggested method can be used in traditional internet services. For satellite internet services a proper suggestion could not be provided because of the lack of knowledge in this field. This can be considered a limitation of this paper. However, a proper overview of suggested solutions for energy efficiency in satellites has been provided.

References

1. Voelsen, D.: Internet from Space, 3rd edn. Daniel Voelsen, German (2021)
2. Osoro, O.B., Oughton, E.J.: A techno-economic framework for satellite networks applied to low earth orbit constellations: assessing Starlink, OneWeb and Kuiper. *IEEE Access* **9**, 141611–141625 (2021). <https://doi.org/10.1109/access.2021.3119634>
3. Sikdar, B.: A study of the environmental impact of wired and wireless local area network access. *IEEE Trans. Consum. Electron.* **59**(1), 85–92 (2013). <https://doi.org/10.1109/TCE.2013.6490245>
4. Baliga, J., Hinton, K., Tucker, R.S.: Energy consumption of the Internet. In: Joint International Conference on the Optical Internet and the 32nd Australian Conference on Optical Fibre Technology, COIN-ACOFT 2007, pp. 1–3 (2007). <https://doi.org/10.1109/COINAC-OFT.2007.4519173>
5. Zeng, X., Liang, M., Liu, H., Ren, Y., Yang, R.: Monitoring system of distribution running states based on broadband power line communication. In: 2006 International Conference on Power System Technology, pp. 1–6 (2006). <https://doi.org/10.1109/ICPST.2006.321424>
6. Taormina, B., et al.: A review of potential impacts of submarine power cables on the marine environment: knowledge gaps, recommendations, and future directions. *Renew. Sustain. Energy Rev.* **96**, 380–391 (2018). <https://doi.org/10.1016/j.rser.2018.07.026>
7. Yang, Y., Xu, M., Wang, D., Wang, Y.: Towards energy-efficient routing in satellite networks. *IEEE J. Sel. Areas Commun.* **34**(12), 3869–3886 (2016). <https://doi.org/10.1109/JSAC.2016.2611860>
8. Abrol, A., Jha, R.K.: Power optimization in 5G networks: a step towards green communication. *IEEE Access* **4**, 1355–1374 (2016). <https://doi.org/10.1109/ACCESS.2016.2549641>
9. Boley, A.C., Byers, M.: Satellite mega-constellations create risks in Low Earth Orbit, the atmosphere, and on Earth. *Sci. Rep.* **11**, 10642 (2021). <https://doi.org/10.1038/s41598-021-89909-7>
10. Gadze, J., Aboagye, S., Agyekum, K.: Real time traffic base station power consumption model for telcos in Ghana. *Int. J. Comput. Sci. Telecommun.* **7**(5), 6–13 (2016). <https://www.ijcst.org/Volume7/Issue5.html>
11. Lyras, N.K., Kourogorgas, C.I., Panagopoulos, A.D.: Energy-efficient broadband satellite communication systems design at frequencies above 10 GHz. Tu-sofia. bg. http://rcvt.tu-sofia.bg/CEMA2016_2.pdf.G
12. Space.com. SpaceX Falcon 9 rocket launches 60 new Starlink satellites, nails its 2nd drone ship landing at sea (2022). <https://www.space.com/spacex-starlink-28-rocket-launch-and-landing-success>. Accessed 22 Jan 2022

13. Lee, J., Kim, E., Shin, K.G.: Design and management of satellite power systems. In: 2013 IEEE 34th Real-Time Systems Symposium, pp. 97–106 (2013). <https://doi.org/10.1109/RTSS.2013.18>
14. Gomez, K., Riggio, R., Rasheed, T., Granelli, F.: Analysing the energy consumption behavior of WiFi networks. In: 2011 IEEE Online Conference on Green Communications, pp. 98–104 (2011). <https://doi.org/10.1109/GreenCom.2011.6082515>
15. Yanovsky, M., Gorbenko, A., Kharchenko, V.: Adaptive WiFi systems: principles of design and application support. In: The International Conference on Digital Technologies, pp. 203–206 (2013). <https://doi.org/10.1109/DT.2013.6566312>
16. Wei, T., Feng, W., Chen, Y., Wang, C., Ge, N., Lu, J.: Hybrid satellite-terrestrial communication networks for the maritime internet of things: key technologies, opportunities, and challenges. *IEEE Internet Things J.* **8**(11), 8910–8934 (2021)
17. Yang, J., et al.: Achieving broadband RCS reduction using carbon fiber-connected composite via scattering mechanism. *Compos. Sci. Technol.* **200**, 108410 (2020). <https://doi.org/10.1016/j.compscitech.2020.108410>
18. Alagoz, F., Gur, G.: Energy efficiency and satellite networking: a holistic overview. *Proc. IEEE* **99**(11), 1954–1979 (2011). <https://doi.org/10.1109/jproc.2011.2165192>
19. Jurdana, I., Ivče, R., Glažar, D.: Submarine optical cables: impact on the marine environment. In: Proceedings ELMAR 2014, pp. 1–4 (2014). <https://doi.org/10.1109/ELMAR.2014.6923320>
20. Kim, J.U., Lee, S., Kang, S.J., Kim, T.: Materials and design of nanostructured broadband light absorbers for advanced light-to-heat conversion. *Nanoscale* **10**(46), 21555–21574 (2018). <https://doi.org/10.1039/c8nr06024j>
21. Goh, S.T., Zekavat, S.A.: Space-based solar power via LEO satellite networks: synchronization efficiency analysis. In: 2013 IEEE Aerospace Conference, pp. 1–9 (2013). <https://doi.org/10.1109/AERO.2013.6497319>
22. Krause Perin, J.: Spectrally and Power Efficient Optical Communication Systems (2018)

AQ2