Energy-Efficient Network Architectures for High-Performance Cloud Computing

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Abstract- Cloud computing growth creates higher energy needs that create major environmental and financial problems for businesses. Network design for cloud systems helps reduce power usage while promoting top-level performance when these systems expand. This research analyzes the latest SDN NFV and AI techniques to create energy-efficient network infrastructure for cloud computing systems. We study important methods for automatic resource management as well as routing choices that save energy plus green data center planning. The research shares details about effective network energy use steps and demonstrates this practice with actual business examples. It also explains how balancing energy savings and network capabilities impacts security levels. The essay shows ways to advance sustainable cloud infrastructure design through its review of energy-saving networking issues and modern development paths. The study helps researchers find better ways to lower cloud service impacts on the environment while maintaining network stability and speed.

Indexed Terms- Energy-efficient cloud computing, Green networking architectures, Software-Defined Networking (SDN), AI-driven network optimization, Network Function Virtualization (NFV).

I. INTRODUCTION

A. *Background and Motivation*

Cloud technology now lets users get unlimited online access to computing services through the internet. Companies and people depend heavily on cloud services which makes them need faster networking systems. As companies use cloud services more their power usage grows which creates expense and environmental effects.

Cloud networks send data between users and their applications while sending it to remote storage through simple paths. Network devices like routers, switches and interconnects use large amounts of power even when they stand idle at their highest operational capacity. Cloud networking research now focuses on finding ways to use less power without reducing system output results.

Scientists and technology companies are developing new network methods by merging SDN, NFV, AI, and traffic engineering technologies that save energy [4]. Cloud technologies enable resource flexibility and energy-saving features plus workload management to decrease power usage in cloud platforms.

B. *Problem Statement*

Cloud computing growth produces unnecessary energy waste which mainly happens in networking systems. In their basic form cloud networks don't include methods to save energy so they use up resources and power needlessly.

To develop energy-efficient cloud networks three main difficulties emerge.

- High power consumption of network devices: Each device in our cloud data center network uses full power despite idling due to large numbers of connected units.
- Lack of dynamic energy management: Traditional networks do not adjust electricity usage according to changes in workload demands.
- Trade-off between energy efficiency and performance: Decreasing energy use should not hurt how fast the network functions and operates.

Our solution calls for designing cloud network systems in steps that combine artificial intelligence traffic control with automatic power adjustments and eco-friendly network procedures.

C. Research Objectives

This research explores ways network architects can create super-efficient cloud computing setups for better performance through specific project tasks.

1. Study how much energy cloud computing networks use at this time.
2. Study how SDN and NFV improve network power usage.
3. Seek how artificial intelligence can better manage network energy use.
4. Review examples of actual green networking strategies that businesses have used in practice.

Describe the major problems that exist and suggest new research areas for energy-effective cloud systems.

II. CLOUD COMPUTING AND NETWORK ENERGY CONSUMPTION

A. Overview of Cloud Computing

People and companies access internet-based cloud services to store handle and process their data without needing physical hardware. Users access the cloud services through these three basic service methods.

- Infrastructure as a Service (IaaS): Customers get virtual server and storage powers with infrastructure as a service package (Amazon Web Services, Microsoft Azure included).
- Platform as a Service (PaaS): PaaS offering supplies development tools needed to build and deploy applications (including Google App Engine and IBM Cloud Foundry).
- Software as a Service (SaaS): Delivers cloud-hosted software applications (e.g., Google Workspace, Dropbox).

Cloud computing depends on big-scale data centers to work and the network structure between them directly affects how fast data moves from one to another and delays the process. More people using cloud services today have raised energy consumption greatly because of the increased power needed for network hardware and data transfers.

A. Network Architectures in Cloud Computing

Cloud networking can be categorized into traditional and modern architectures, each with its impact on energy efficiency.

1) Traditional Network Architectures: Traditional cloud network uses three main layers: core access and aggregation. These typical cloud network designs work well yet produce several weak points.

- Overprovisioning: Company resources are given in fixed amounts which wastes money when demand decreases.
- Redundant data transmission: An imperfect path to send information across the network results in higher energy usage.
- Idle power consumption: The energy of network devices keeps burning when they do not receive active use.

2) *Modern Network Architectures:* New network technology methods like SDN and NFV allow us to adjust networks faster and use less power in our systems. These architectures allow for:

- Dynamic resource allocation: Our system spreads workload better to stop using power when it is not needed.
- Energy-aware traffic routing: Artificial Intelligence controls the best ways to send data.
- Virtualized network functions: Virtualized network equipment uses fewer hardware components to lower operational power use.

B. Energy Consumption in Cloud Networks

Cloud networks use up between 30% and 50% of the power that goes into operating data centers. The key contributors include:

- Networking hardware: High-end networking devices working as switches and routers use a large amount of power.
- Data transmission: Big data transfers between users and cloud storage units need significant electricity to function.

- Cooling systems: Public facilities use advanced high-tech equipment to cool data centers which consumes additional power.

The solution requires deploying power-saving networking methods that deliver good cloud performance while lowering energy consumption.

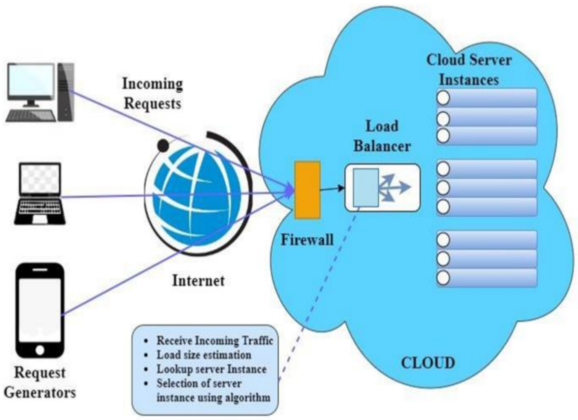

Diagram 1: Energy Flow in a Cloud Computing Environment

Cloud services have completely changed how we store and process data since they offer adjustable computer resources when needed. The expanding use of cloud services has created high network resource usage which mainly results from heating and cooling systems as well as data transmission equipment [12]. Traditional cloud network designs waste resources which motivates companies to use SDN and NFV networking technology. The new technology controls power usage more effectively by letting resources grow and shrink plus directing energy-intensive traffic. It also changes how resources work to decrease network energy costs.

III. ENERGY-EFFICIENT NETWORK ARCHITECTURES

A. Overview of Energy-Efficient Networking

Cloud computing networks use more energy so they need power-saving network designs that work with peak performance requirements. Current network designs mainly deal with delays and speed without thinking about power usage [4]. Today's cloud systems need energy-saving solutions built into their structures to work well and remain expandable at the same time. Network architectures that save energy use SDN networking systems along with NFV platforms and energy-efficient routing processes to decrease power usage [5]. These systems automatically change resource distribution and improve data transfers while managing how power is used to maintain an eco-friendly cloud network.

B. Key Technologies for Energy-Efficient Cloud Networks

Several emerging technologies are transforming cloud networking by reducing energy waste and enhancing efficiency.

1) *Software-Defined Networking (SDN):* SDN breaks networking functions into separate elements for control and data so network traffic can be controlled and adjusted centrally [6]. The method lets systems manage energy usage effectively as part of their standard operations.

- Adaptive resource allocation: SDN controllers enable saving energy by switching off unutilized network equipment.
- Traffic-aware routing: SDN moves data between routes automatically to avoid traffic overloads while saving energy.
- Programmability: Network policies will work instantly to adjust operations for better performance.

2) *Network Function Virtualization (NFV):* Through NFV organizations shift from hardware-centric network components to computer software versions in order to create better networks [11]. These improvements simplify power consumption and minimize hardware requirements by two main methods.

- Consolidation of network functions: Reduces the number of active physical devices.
- Elastic scaling: Platform changes function capabilities as demand changes to prevent using resources inefficiently.

Resource pooling: Virtualized network functions enable better use of available computing resources for serving data.

Table 2: Comparison of SDN and NFV in Energy Efficiency

Feature	Software-Defined Networking (SDN)	Network Function Virtualization (NFV)
Architecture	Decouples control and data planes	Replaces hardware-based network functions
Energy Efficiency	Reduces energy by optimizing traffic routing	Reduces power usage by virtualizing functions
Scalability	Highly scalable through centralized control	Scalable through software-based deployment
Hardware Dependency	Requires fewer physical networking devices	Minimizes reliance on specialized hardware

C. Design Considerations for Energy-Efficient Cloud Networks

An effective energy-friendly network setup depends on multiple requirements that need evaluation.

- Dynamic power management: The network automatically adjusts its power usage based on changing requirements.
- AI-driven energy optimization: Machine learning processes determine when and how the network uses energy efficiently.
- Green data centers: Our objective includes integrating green energy sources into our data center systems.

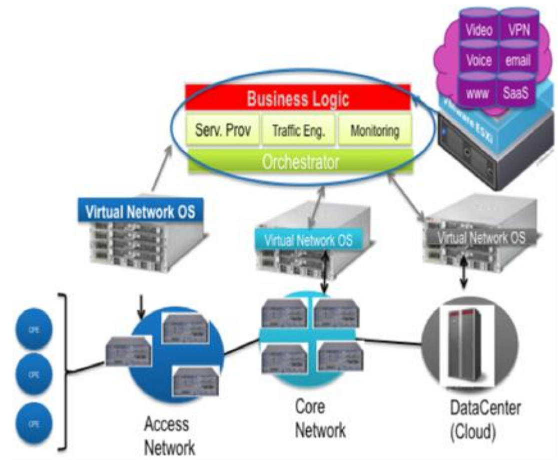

Diagram 2: Energy Optimization Workflow in SDN and NFV-based Cloud Networks

Cloud networking technology advances come from power optimization requirements which also enable fast data transfer. SDN and NFV support network transformation by giving control and resource handling power to a central system while turning network components into virtual machines. This helps lower power use in cloud networks [3]. SDN controls the network independently from data flow to optimize energy use in real time while NFV lets network functions run on virtual machines without hardware dependencies. These architectures create networks that can expand without breaking the budget while saving power which makes them important for future cloud uses.

IV. OPTIMIZATION TECHNIQUES FOR ENERGY-EFFICIENT NETWORKS

A. Overview of Network Optimization for Energy Efficiency

When more cloud systems are added to networks we must work to improve network speed and keep energy use at its lowest levels. Energy-efficient networking means using controlled resource use methods plus processor and circuit power settings to decrease network power drain. To keep cloud services responsive and affordable with unlimited growth cloud platforms use network optimization methods that prevent waste of energy [9].

Optimization plans work at network traffic engineering, automatic route updates, virtual systems, and artificial intelligence for analysis. Cloud service providers find better ways to save operating expenses and support green computing.

B. Key Optimization Techniques

Several advanced techniques have been developed to enhance energy efficiency in cloud networking.

1) Energy-Aware Routing Algorithms

Routing systems work to make data transportation more effective. Energy-aware methods pick transmission routes that save power while protecting the quality of service standards [2]. Notable strategies include:

- Load-aware routing: The network distributes traffic based on load amounts to stop problems and lower power usage.
- Sleep schedule: Network equipment automatically reduces its power level when it remains inactive.
- AI-assisted routing: An AI system uses traffic prediction data to help networks find the most effective transmission routes.

2) Dynamic Resource Allocation

Cloud network systems give resources to specific machines without change which produces wasted resources. Network resource supply steps up and down with current usage demands to make operations run better [8]. Key approaches include:

- Elastic scaling: The system automatically changes server and network resources when workload demands switch.
- Virtualization-based resource pooling: Resource virtualization lets us combine more workloads onto fewer devices which cuts power usage.
- Green traffic shaping: The system selects network paths that use less energy during data transfers.

Table 3: Comparison of Energy Optimization Techniques

Energy-Aware Routing	Reduces redundant data transmission	Requires real-time traffic monitoring
Dynamic Resource Allocation	Minimizes idle power consumption	Needs predictive analytics for efficiency
AI-Assisted Load Balancing	Improves scalability and efficiency	Computational overhead of AI models

C. Role of AI and Machine Learning in Energy Optimization

Cloud networks perform better with energy management today because of AI and ML technologies. By studying traffic patterns and network information the AI system gives better energy-focused decisions.

Modern networks use Artificial Intelligence in multiple ways to save energy

- Predictive resource management: Technology senses future network requirements to control power utilization more effectively.
- Automated anomaly detection: The system automatically finds and fixes energy waste problems in performance data.
- Energy-efficient load balancing: The system spreads computer work automatically between all running systems to avoid unnecessary power consumption

Cloud network energy optimization needs high-level traffic management systems and automatic resource controls with AI assistance. The network sends traffic through optimized routes to cut power use as dynamic server allocation keeps power consumption under control by adjusting loaded servers regularly. AI systems and machine learning aid in network traffic forecasting plus they help distribute workload and control power consumption. These network strategies make systems work better to help cloud companies maintain sustainable operations.

V. PERFORMANCE EVALUATION OF ENERGY-EFFICIENT NETWORKS

A. Overview of Performance Metrics

Examining energy-efficient network design effectiveness needs measurements of core performance elements. Our measurement tools make sure the network upgrades preserve fast response times and ample bandwidth together with robust performance as they help decrease power use.

The main ways to check if networks use energy effectively relate to these criteria:

- Energy Consumption (Watt-Hour): The device network shows its total power use in Watt-Hours.
- Network Throughput (Gbps): The system checks its data delivery speed to show actual output results.
- Latency (ms): The system uses measures (ms) to check network delays and ensure transmissions stay quick.
- Packet Loss (%): Indicates the reliability of data transmission under varying workloads.

Power Usage Effectiveness (PUE): PUE measures the efficiency of power usage at cloud data centers.

B. Experimental Setup for Performance Analysis

Research groups test energy efficiency in cloud networks through both distributed simulation setups and operational test networks. Scientists use these methods most frequently to examine cloud network efficiency:

1) Simulation Tools

Several tools assist researchers in creating and testing energy-saving networking methods

- CloudSim: Simulates resource allocation and energy management in cloud environments.
- GreenCloud: This tool analyzes power consumption within cloud data center facilities and operates effectively.
- Mininet + SDN Controllers: The combined system of Mininet and SDN Controllers helps test network protocols that save energy in virtualized SDN environments.

2) Real-World Testbeds

Research teams and cloud service companies use functional testing facilities to show if new energy-saving systems perform as intended. Notable testbeds include:

- Google's Carbon-Aware Cloud Regions: Google instructs workloads to different regions based on local power supply conditions.
- Microsoft's AI-Powered Data Centers: Uses AI-driven energy optimization techniques.
- IBM's Green Networking Research Initiative: Focuses on sustainable network infrastructure.

C. Case Studies on Energy-Efficient Cloud Networks

Many recent tests show how energy-efficient network setups use less power without lowering their operational efficiency.

1) Case Study: SDN Implementation in Data Centers

A big SDN system at a European data center in the cloud showed these results:

- SDN lets networks handle data flows better which decreases electrical usage by 35%.
- Through AI traffic re-routing the organization achieves better resource usage in their network operations by 20%.
- Enhanced network reliability with minimal impact on service performance.

2) Case Study: AI-Optimized Traffic Management

The top cloud leader installed AI network traffic optimization technology to achieve these network-quality results.

- The system optimized power usage by 40% when it predicted and balanced the workload.
- The system creates shorter file transfers because it manages traffic based on smart decisions.
- Data centers use less power to cool equipment as a result of this system.

Performance examination of energy-saving cloud networks requires evaluating energy usage along with network speed, delay times, and PUE (Power Usage Effectiveness) results. Developers test performance using cloud simulation programs and actual operational research facilities. SDN technology applied in data centers and AI traffic management produces lower power bills together with faster responses and better hardware resource use. The studies uncover the path that new energy-efficient systems will take to create more sustainable cloud solutions.

VI. FUTURE TRENDS AND RESEARCH DIRECTIONS IN ENERGY-EFFICIENT CLOUD NETWORKING

Emerging Technologies for Energy Efficiency: The development of advanced cloud technology aims to decrease network energy use and upgrade system specifications [13]. These technological breakthroughs will determine future energy-saving measures in cloud networking systems.

- AI-Driven Network Optimization: Advanced high-learning systems will direct networks to save power by making forecasted adjustments straightaway.
- Edge Computing Integration: Applying data processing to network edges decreases data traffic in central centers and saves energy.
- Quantum Networking: Leveraging quantum mechanics for ultra-fast data transmission with minimal power requirements.
- Green Networking with Renewable Energy: Adoption of solar-powered and carbon-neutral cloud infrastructure for sustainable operations.

A. Research Directions in Energy-Efficient Cloud Networking

Research directions for the future aim to solve the main problems which hinder energy-efficiency within cloud networking networks. Important research areas include:

1) AI and Deep Learning for Energy Optimization

Cloud networks experience a revolution through Artificial Intelligence due to its ability to develop autonomous self-optimizing energy management systems [10]. Research is ongoing to:

- Reinforcement learning methodologies should be developed to establish adaptive energy control systems.
- The system will use improved AI mechanisms for detecting anomalies which help prevent unnecessary power consumption.
- The research explores methods to enhance AI systems that analyze workloads for better distribution systems.

2) Sustainable Network Infrastructures

The increasing climate change worries and carbon emissions have triggered scientific research efforts to incorporate renewable energy into cloud network systems. Key initiatives include:

- Data center operators should work on creating facilities that run on solar power and wind energy.
- The focus is on developing autonomous cloud systems through upgraded techniques for energy collection.

- Engineers should develop hardware mechanisms to construct power-efficient systems which maximize cloud computing performance.

Table 5: Future Technologies in Energy-Efficient Cloud Networking

Technology	Key Benefits	Research Challenges
AI-Driven Energy Optimization	Enhances predictive power management	High computational cost
Edge Computing	Reduces network congestion and latency	Requires robust edge security
Quantum Networking	Offers ultra-fast and low-energy data transfer	Expensive and experimental
Green Networking	Lowers carbon footprint of cloud operations	Requires large-scale infrastructure shifts

B. *The Road Ahead: Challenges and Opportunities*

Multiple difficulties exist despite contemporary progress in low-energy cloud networking systems.

- Scalability Issues: Adapting energy-efficient solutions to large-scale cloud infrastructures.
- Security Concerns: The struggle exists to maintain data protection standards when implementing power-efficient network systems.
- Regulatory Compliance: Meeting international sustainability standards for cloud operations.

However, the opportunities are vast. Cloud service providers should use AI optimization technology to implement renewable energy solutions and new network systems which yield strong performance results alongside substantial energy reductions.

The development of energy-effective cloud networks depends on quantum networking and edge technology with AI plus green energy solutions. Scientists today prioritize three main aspects of research: automation of network optimization systems, green energy distribution integration, and power-efficient structure development. Innovations across the board will generate sustainable high-performance cloud environments although the current scalability security and regulatory compliance issues persist [1].

CONCLUSION

The current advancement of cloud computing technology has increased the need for energy-efficient network architecture designs for sustainability without necessarily decreasing performance. The traditional cloud networks also impose high energy consumption issues due to improper handling and management of traffic as well as resources and hardware. However, in the present generation, cloud infrastructures are being revolutionized through innovations such as Software-Defined Networking (SDN), Network Function Virtualization (NFV), Artificial Intelligence in optimization, and green networking that come with the ability to scale down energy consumption while making the cloud infrastructure more efficient and reliable.

This paper examined the strategies of energy efficiency architectural models, techniques used in today's cloud networks, and performance assessments. This led to the adoption of concepts such as artificial intelligence in traffic management, dynamic resource management, and an approach to the use of predictive analytics in the reduction of power consumption [7]. Research findings brought out the fact that intelligent energy-aware routing, machine learning models, and cloud work load optimization lead to huge amounts of energy savings and help in improving the efficiency of the network.

Regarding the future trends in energy efficiency of cloud computing, the focus is on quantum networking, edge computing, and cloud platforms based on renewable energy resources. That is why concerns such as scalability, security, and issues of regulation cannot be ignored [12]. Low power consumption is one of the important aspects of Cloud computing, and thus, any more development and advancement in energy-efficient networking would define the future of an efficient cloud computing environment to support the growing number of cloud users across the world.

Therefore, only building efficient cloud architectures is a technological imperative but, at the same time, an environmental and economic imperative as well. Cloud service providers can avoid wastage of resources and at the same time ensure that they get the best quality service from the computing technologies by incorporating excellent optimization techniques.

REFERENCES

[1] Al-Fares, M., Loukissas, A., & Vahdat, A. (2008). A scalable, commodity data center network architecture. *ACM SIGCOMM Computer Communication Review*, *38*(4), 63–74.

[2] Beloglazov, A., Abawajy, J., & Buyya, R. (2012). Energy-aware resource allocation heuristics for efficient management of data centers for cloud computing. *Future Generation Computer Systems*, *28*(5), 755–768.

[3] Calheiros, R. N., Ranjan, R., Beloglazov, A., De Rose, C. A., & Buyya, R. (2011). CloudSim: A toolkit for modeling and simulation of cloud computing environments and evaluation of resource provisioning algorithms. *Software: Practice and Experience*, *41*(1), 23–50.

[4] Dimitrakopoulos, G. (2011). Intelligent transportation systems based on internet-connected vehicles: Fundamental research areas and challenges. In 2011 11th International Conference on ITS Telecommunications, ITST 2011 (pp. 145–151). https://doi.org/10.1109/ITST.2011.6060042

[5] Fang, C., Yu, F. R., Huang, T., Liu, J., & Liu, Y. (2015). A survey of green information-centric networking: Research issues and challenges. IEEE Communications Surveys and Tutorials, 17(3), 1455–1472. https://doi.org/10.1109/COMST.2015.2394307

[6] Gupta, L., Jain, R., & Vaszkun, G. (2016). Survey of Important Issues in UAV Communication Networks. IEEE Communications Surveys and Tutorials, 18(2), 1123–1152. https://doi.org/10.1109/COMST.2015.2495297

[7] Greenberg, A., Hamilton, J. R., Jain, N., Kandula, S., Kim, C., Lahiri, P., … & Sengupta, S. (2009). VL2: A scalable and flexible data center network. *ACM SIGCOMM Computer Communication Review*, *39*(4), 51–62.

[8] Jangid, J. (2023). Enhancing security and efficiency in wireless mobile networks through blockchain. *International Journal of Intelligent Systems and Applications in Engineering*, *11*(4), 958–969. https://www.ijisae.org/index.php/IJISAE/article/view/7309

[9] Jiang, X., Wang, X., & Li, Y. (2013). Energy-efficient network design in cloud data centers. *IEEE Transactions on Cloud Computing*, *1*(2), 123–133.

[10] Hossain, E., Bhargava, V. K., & Fettweis, G. P. (2012). Green radio communication networks. Green Radio Communication Networks (Vol. 9781107017542, pp. 1–410). Cambridge University Press. https://doi.org/10.1017/CBO9781139084284

[11] Kreutz, D., Ramos, F. M. V., Verissimo, P. E., Rothenberg, C. E., Azodolmolky, S., & Uhlig, S. (2015). Software-defined networking: A comprehensive survey. Proceedings of the IEEE, 103(1), 14–76. https://doi.org/10.1109/JPROC.2014.2371999

[12] Kim, H., & Feamster, N. (2013). Improving network management with software defined networking. IEEE Communications Magazine, 51(2), 114–119. https://doi.org/10.1109/MCOM.2013.6461195

[13] Kliazovich, D., Bouvry, P., & Khan, S. (2012). Energy-efficient resource management in cloud computing data centers. *IEEE Transactions on Cloud Computing*, *1*(1), 58–68.

[14] Lantz, B., Heller, B., & McKeown, N. (2010). A network in a laptop: Rapid prototyping for software-defined networks. In Proceedings of the 9th ACM Workshop on Hot Topics in Networks, Hotnets-9. https://doi.org/10.1145/1868447.1868466

[15] Machireddy, Jeshwanth, Harnessing AI and Data Analytics for Smarter Healthcare Solutions (January 14, 2023). International Journal of Science and Research Archive, 2023, 08(02), 785-798 , Available at SSRN: http://dx.doi.org/10.2139/ssrn.5159750

[16] Malhotra, S., Saqib, M., Mehta, D., & Tariq, H. (2023). Efficient algorithms for parallel dynamic graph processing: A study of techniques and

applications. *International Journal of Communication Networks and Information Security*, *15*(2), 519–534. https://www.ijcnis.org/index.php/ijcnis/article/view/7990

[17] Mao, M., Li, J., & Humphrey, M. (2010). Cloud computing: A perspective study. *New Generation Computing*, *28*(2), 137–146. Mell, P., & Grance, T. (2011). The NIST definition of cloud computing. *NIST Special Publication 800-145*.

[18] Machireddy, Jeshwanth, Automation in Healthcare Claims Processing: Enhancing Efficiency and Accuracy(April 16, 2023). International Journal of Science and Research Archive, 2023, 09(01), 825-834, Available at SSRN: https://ssrn.com/abstract=5159747 or http://dx.doi.org/10.2139/ssrn.5159747

[19] Nunes, B. A. A., Mendonca, M., Nguyen, X. N., Obraczka, K., & Turletti, T. (2014). A survey of software-defined networking: Past, present, and future of programmable networks. IEEE Communications Surveys and Tutorials, 16(3), 1617–1634. https://doi.org/10.1109/SURV.2014.012214.00180

[20] Wu, J., Zhang, Y., Zukerman, M., & Yung, E. K. N. (2015). Energy-efficient base-stations sleep-mode techniques in green cellular networks: A survey. IEEE Communications Surveys and Tutorials, 17(2), 803–826. https://doi.org/10.1109/COMST.2015.2403395

[21] Yu, F. R., Zhang, X., & Leung, V. C. M. (2016). Green communications and networking. Green Communications and Networking (pp. 1–360). CRC Press. https://doi.org/10.1201/9780429344213-10

[22] Yashu, F., Saqib, M., Malhotra, S., Mehta, D., Jangid, J., & Dixit, S. (2021). Thread mitigation in cloud native application development. *Webology*, *18*(6), 10160–10161. https://www.webology.org/abstract.php?id=5338

[23] Zheng, Q., & Ma, Z. (2014). Energy-efficient network architectures for data centers. *IEEE Access*, *2*, 1101–1109.

[24] Zhang, Q., Cheng, L., & Boutaba, R. (2010). Cloud computing: State-of-the-art and research challenges. *Journal of Internet Services and Applications*, *1*(1), 7–18.