Green and Sustainable Smart City and role of green Computing: A Survey

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ABSTRACT
The smart city provides several services to its citizens. Among them, communication is one of the essential services. Due to the requirement for a high-quality user experience, it is required to deploy dense cellular base stations. The increasing number of cellular base stations raises the issue of energy preservation and smart power scheduling of the base station. To formulate the solution for this green computing issue first a review of recent techniques of energy preservation has been studied. Based on the conducted review a proactive resource scheduling technique has been proposed and their key components have been discussed. Soon, the formulated solution has been implemented and their influence on power saving has been proposed measure.

Keywords
Data analytics, Green AI, Green Computing, Machine Learning, Smart city.

1. INTRODUCTION
The popularity of smart cities is rising day by day. It is an urban area and utilizes different kinds of technology and sensors for collecting data from the public. The data is collected from citizens, devices, buildings, and assets. The data collected through the city is being used to manage city resources and services. The data has been processed and used to monitor and manage social welfare applications such as traffic and transportation systems, power plants, utilities, water supply, waste management, crime detection, schools, libraries, hospitals, and others [1]. The smart city allows the city administrators to directly interact with people to know what is happening in the city [2]. The smart city enables various services for providing world-class services. Among some essential services are:

1. Green building, Sustainable energy
2. Waste management, Natural resource management, water management
3. Sustainable transportation, Smart education
4. E-government, Smart health, Social responsibility

However managing such a large amount of data, processing, and identifying valuable insights requires to running a huge infrastructure. Additionally requires a significant amount of electric energy. Therefore, the sustainability of smart city is one of the key issues. To achieve sustainable development, the concept of green IT needed to be implemented. Green IT promotes the use of hardware and software applications that consume less or minimum energy. It will also consider recycling to reduce the need for new devices. The ultimate aim is to control and reduce the emission of CO2 and harmful gases by utilizing computational technologies like Machine Learning (ML), Cloud Computing, Big data, and sensors [3]. Therefore, adapting new technologies can minimize the impact on the environment. Additionally, for sustainability balanced growth is necessary [4].

This paper is focused on the study of sustainability in smart cities by preserving electric energy [5]. However, to deal with the energy issues in smart cities several traditional methods as well as advanced computational methods have been applied for power-saving. Among them, ML-based techniques become very popular to minimize power consumption. In this context, ML-based techniques have been formulized as the resource management problem. Additionally, the resource management problems are solved using optimization, prediction, classification, and clustering techniques [6]. ML is used for analyzing the data automatically and obtaining insights for an application. It is a set of algorithms and methods to discover fruitful patterns and trends. The ML is being used in various real-world applications such as medical science, engineering, banking, and others.

The smart cities issues can be solved by using ML because the city has generated and utilized heterogeneous data to maintain connectivity among people, infrastructure, and administration for good governance. In these scenarios, the cellular network has played an essential role. In this paper ML technology and cellular networks have been studied to reduce energy consumption in smart cities. Basically, for providing end-to-end connectivity it is necessary to increase cellular network infrastructure, but due to increasing network infrastructure, the demand of demand of energy has also increased. Additionally, the ideal base stations are also a key reason for power wastage. Therefore, this paper is aimed to provide an understanding of the cellular base station power demand patterns and wastage. In this context, this study includes a review of existing power management techniques in smart cities. Additionally based on review the key issues have been discussed and a relevant solution has been introduced for future design and implementation.

2. LITERATURE REVIEW
Electricity is largely based on non-renewable sources of energy. It is necessary to look for opportunities to save and use it efficiently. To preserve the energy in smart cities many contributions are available, which can provide us guidance about Green and sustainable smart cities. Some essentials are discussed in Table 1 as a summary of the review. The review has been discussed on the basis of research work, key contributions and obtained results or consequences.

Table 1 Review summary

Ref.	Domain	Contribution	Results
[7]	Intelligent Street Lighting	Replacement of traditional lighting with LEDs can be used for energy, cost savings and reduces pollution.	The model forecasts not only the number of lamps but also the cost-efficiency in smart cities to understand the demand and supply of energy.
[8]	HALMS	Establish a smarter grid and energy infrastructure is undeniable.	Smart plug that uses IoT for HALMS. It enhances the energy management experience.
[9]	Impact of 5G Technologies on Smart City	Smart plug technologies and the relevant activities and limitations to be overcome.	Concept of Smart Cities and benefits. Describe Services, Applications and role of ICT. Discuss features of 5G and how 5G could be best.
[10]	5G Wireless Networks for Smart Grid	5G provides new business models to the energy providers and improves the way of the utility.	Complete analysis and review of the 5G and its vision regarding smart grid. The user-based analysis in smart grid, and 5G.
[11]	Intelligent Edge Computing for IoT-Based Energy Management	Focused on IoT-based energy management based on edge and reinforcement learning.	Then a software model is proposed. Present an efficient energy scheduling scheme.
[12]	Demanding use case for 5G	Facilitating the deployment of generic MTC Network Function Virtualization and utility-centric Virtual Network Functions.	5G combines i) trusted, scalable, and plug ‘n’ play support ii) mMTC, MTC and xMBB communications with distributed, trusted, secure, scalable and energy-efficient; iii) xMEC to reduce load, increase capacity and reduce delays
[13]	Energy Saving Technology of 5G Base Station	Energy-saving can effect meet the requirements of a 5G ultra-dense BS, and in ultra-dense BS group,	Complexity can also meet system operation, which have a certain degree of practicality, and provide a reference for follow-up.
[14]	Delay-Constrained Energy-Saving Live Migration of VMs	Implement in software and test the optimal minimum-energy SCBM for live VM migration.	1) Complexity is settable online based on target energy 2) minimize network energy consumed 3) quickly react to fading and/or mobility.
[15]	Energy-saving Scheme of 5G Base Station	SCBM is supported by extensive energy versus delay performance comparisons.	BS business data is used to train LSTM, and predict future business. If business is lower than threshold, BS will closed to avoid power waste.
[16]	Green Artificial Intelligence	“Green AI” is enabler of smart city transformation. It offers chance to develop techno centric solutions.	Aim is (1) to highlight the fundamental shortfalls in AI system conceptualization and practice (2) to advocate the need for green AI.
[17]	Data Mining and Machine Learning to Promote Smart Cities	A review regarding DM and ML was adopted. Found articles and VOS-viewer was performed.	29 articles analyzed on DM and ML, and areas that are most engaged. Prediction was common and focused on smart mobility and environment.
[18]	Energy Management in Smart Cities Based on Internet of Things	A new method named HEMaaS is proposed based on a neural network-based Q-learning.	Neural Fitted Q-learning is self-learning and adaptive. It provides agile, flexible, and energy-efficient decision-making system.
[19]	Learning-based Green Workload Placement	Considering online environment of smart city, objective is transferred as an optimization problem.	To minimize energy cost and job completion time, a green workload placement approach is proposed using deep reinforcement learning.
[20]	Machine Learning in WSN	ML as an optimization tool for WSN-IoT nodes. It is first survey of low power consumption.	Results show supervised learning has widely used (61%) as compared to reinforcement learning (27%) and unsupervised learning (12%).
[21]	Smart Traffic Management System	A low-cost future STS to provide better service by deploying traffic updates instantly.	Low-cost vehicle detecting sensors are fixed in middle of the road. IoT is used to attain public traffic data and send it for processing
[22]	Deep learning model for air quality prediction	A deep learning model based on LSTM to predict air quality.	Results show it is promising and can be used in other smart city prediction problems.
[23]	Semantic Framework of IoT for Smart Cities	Framework to integrate IoT with ML, which retrieves and models urban data for certain IoT Apps.	Pollution detection from vehicles and traffic pattern. Results show it is scalable and capable of serving a large number of urban regions.
[24]	ML Technologies for Sustainability	The objective is to analyze the link between Smart Cities, ML techniques, and their applicability.	ML models, techniques, and applications are studied. Areas of sustainability and SDGs discussed. Case study on Andalusian is given.
[25]	Air Quality Prediction in Smart Cities	Covers the revision of the studies related to air pollution prediction using ML algorithms based on sensor data of smart cities.	(1) Apply advanced techniques, (2) China was leading in case study, (3) Matter with 2.5 was target, (4) 41% prediction done for next day, (5) 66% used hourly data, (6) 49% used open data (7) prediction need external factors.

Additionally, the frequently used abbreviations and their full forms are reported in Table 2. These keywords are being used in further discussion. Additionally, help to understand the terminology of the conducted review.

Table 2 Abbreviations

Keyword	Full form
BS	Base station
LSTM	Long Short Term Memory
HEMaaS	Home Energy Management as a Service
WSN	Wireless Sensor Networks
DM	data mining
IoT	Internet of Things
mMTC	massive Machine Type Communications
xMBB	Extended Massive BroadBand
xMEC	extended Mobile Edge Computing
SCBM	settable-complexity bandwidth manager
SDGs	Sustainable Development Goals
HALMS	Hybrid Appliance Load Monitoring System

According to the studied literature, the replacement of traditional devices and the employment of new computational technologies may help in understanding the pattern of energy demand and supply. The key understanding of the energy demand pattern will help to manage the resources and also minimize the demand as well as the wastage of energy. However, the entire ecosystem of energy demand and supply involves different computational technologies such as data collection, processing, decision-making, and information distribution. Sensors, cellular networks, wireless sensor networks, machine learning, big data, data analytics, and cloud computing are the common technologies, which are applied now in these to support and serve in different real-world applications. Additionally, these techniques and methods are also now being employed for preserving these non-renewable resources.

As a conclusion, the utilization of advanced computing technology and maximizing the service quality needs a balance to maintain. At the same time, it is also necessary to optimize the utilization of service technologies to minimize their resource consumption. Therefore the proposed work has keenly focused on studying how we can effectively make use of these methodologies for improving urban life. Additionally, enhances them to accomplish a sustainable, energy-efficient, and green lifestyle. However, in smart cities, there are many services and technologies, which may be enhanced by the utilization of optimization techniques. Among them, cellular network-based power demand and wastage prevention are the main aims of the proposed study.

3. KEY OBJECTIVES

The smart city is running on several services to support a luxurious and easy life. In these services, the communication technology is playing an essential role. That is used to collect, distribute, and process the data in different kinds of ways. These technologies are now engaged with ML, cloud computing, and Software. But to serve better to the smart city we need to increase the density of the communication network. The increasing communication infrastructure has also increased the energy demand additionally the ideal cellular infrastructure will also increase the power wastage. Therefore, it is essential to optimize and enhance the power utilization and waste of power in cellular network infrastructure. In this context, to preserve the energy the following key objectives are established.

1. **Investigation of recent power-saving strategies:** A review of recent methods and techniques has been carried out for power-saving and optimization in smart city. The investigation is focused on techniques that are developed based on ML. Using this study we are also trying to identify the ML algorithms, features and datasets used.
2. **Provide understanding of the power requirement of network Base stations:** The power consumption of a base station is mainly decided based on the peak traffic load on base station. But the traffic is variable with the time. Therefore, the aim is to analyze the patterns and trends of the traffic to understand the power demand.
3. **Analysis of network base station's traffic behavior:** The traffic demand in different areas of smart city is changing with the time. The traffic behavior and power demand of bases stations is changing with the mobility and time. Therefore, the aim is to analyze the traffic behavior with mobility and with the time.
4. **Design a method to predict the traffic demand of the network base stations:** The aim is to design a predictive ML technique to efficiently and accurately predict the base station load and power demand.
5. **Design an energy efficient cellular base station scheduling technique:** In this phase the predictive ML model is extended to prepare a power demand schedule according to the future traffic load.

Optimal energy utilization and prevention of energy wastage are the two sides of the same problem. In case a system utilizes the power optimally then it automatically prevents the wastage of energy. Additionally, the power demand can also depend on many different internal and external factors. Therefore, besides the above-discussed objectives, there are more tasks have been included to enhance power utilization for smart city communication infrastructure. However, energy preservation and management is a wide domain of study, research, and development, but we can initiate with a limited scope of the energy demand understanding and their management.

4. PROBLEM STATEMENT AND FORMULATION

The proposed work is mainly focused on understanding energy demand and optimization of energy utilization in cellular base stations. In this context, the concept of proactive resource management and scheduling has been adopted. Proactive resource management has proven its benefits towards managing the resources in many real-world complexities such as in VM migration, resource management, and also managing businesses. Therefore, proactive management has become a successful model for demand-specific resource supply. Additionally, that helps to enhance the ways for better utilization of available resources and decrease the wastage of resources. The basic concept of proactive resource management is demonstrated in Figure 1.

According to the described basic proactive resource management technique, ML algorithms are needed to apply historical resource demand patterns and predict the possible resource demand. When the resource demand requested has met with the resource demand than supply the resource required. Therefore, if we accurately predict and organize the possible resources according to increasing and decreasing demand, then we can better manage and preserve the resources. Additionally, with the limited amount of resources, we can enhance the productivity and execution cost of any resource infrastructure.

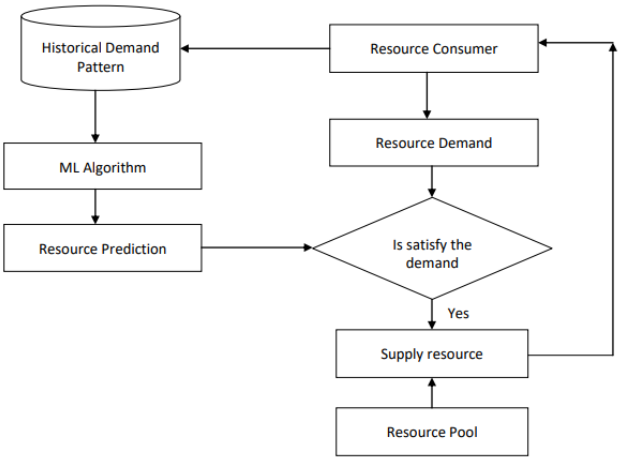

Figure 1 proactive resource management

Thus, the proposed work is motivated to apply this proactive resource management technique to enhance the power demand of cellular base stations. According to the proactive resource methodology, it is required to utilize ML techniques for predicting future resource demand. In our case, we can follow the following steps to find a solution:

1. First, we need to predict the possible future traffic demand of the cellular base station for next one hour, day, week or month, because the traffic demand of a base station is directly proportional to energy demand of base station.
2. Further, based on the power demand we need a decision making function which decide whether we need to increase the power and whether not.
3. Next, we need to predict the possible amount of power to increase or decrease.
4. Finally based on these parameters the resource has been managed.

In order to clear understanding the proposed concept let we have a historical dataset of cellular traffic demand say D. Additionally, we required a predictive ML algorithm, which can predict the future traffic demand T.

$$T = predict(D) \dots\dots\dots\dots (1)$$

Where, T is predicted traffic demand, $predict$ is a trained ML algorithm, D is the historical traffic pattern.

Here, according to our assumption traffic demand in proportional to energy demand E:

$$T \to E \dots\dots\dots\dots . (2)$$

After that we need to formulate the energy demand based on traffic demand. Thus, the required energy demand is given by ΔE. Next, we need a decision function is required to decide whether the required demand in increasing or decreasing based on historical samples. Based on this function, the decision made can be given as:

$$I = f(E, \Delta E) = \begin{cases} if\ E + \Delta E > C_E \\ if\ E + \Delta E \leq C_E \end{cases} \dots\dots (3)$$

Where, C_E is the current energy supply, and I is the amount of power need to increase.

5. KEY COMPONENT OF THE REQUIRED MODEL

The model presented in the last section aims to reduce energy consumption based on the proactive scheduling technique. The basic formulation of the required model has also been discussed previously. In this section, we are discussing the key components of the proposed model. The basic concept of the proposed model is given in Figure 2.

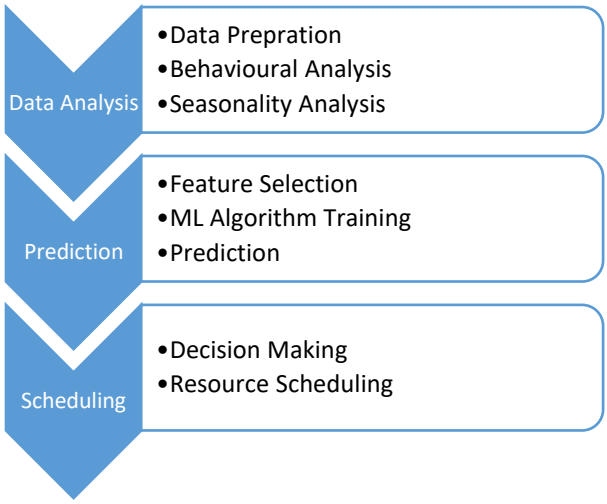

Figure 2 Layers of the proposed Green Computing Model

The proposed system has composed with three layers to accomplish the following task:

5.1 Data analysis

The data analysis includes the following sub tasks:

1. **Data preparation:** This phase is responsible for data preprocessing, transformation and scaling to standardize the learning dataset
2. **Behavioral analysis:** The data has been taken from the Kaggle, which consist of data of multiple base stations. Therefore, the behavioral similarity and dissimilarity of cellular network base stations has been identified. It is essential to understand the time based variations of the traffic pattern.
3. **Seasonality analysis:** seasonal variation of network traffic is needed to identify to understand the cycle traffic pattern and trends to formulate the appropriate predictive model, which provides more accurate prediction for the specific time interval.

5.2 Prediction

The prediction module involves the following three components:

1. **Feature selection:** Analyzing the key features from the training data is an essential part of ML. this process help to reduce the time requirement and also the space complexity of a ML algorithm for training. Therefore, appropriate feature selection techniques have been employed for identifying the valuable features.
2. **ML algorithm training:** The extracted features have used to train the ML algorithm. After training the algorithm has able to predict the consequences based on the input parameters.
3. **Prediction:** In this presented work we need an accurate predictive algorithm. Because the entire system's quality of service has completely depends on the prediction of possible future traffic demand.

5.3 Scheduling

This section delivers the following two consequences:

1. **Decision making:** The consequences of the previous phase in form of prediction are making use for utilizing with a decision making function. This decision making

algorithm used for providing decision to increase or decrease the amount of energy, which is required by the proposed active system.

2. **Resource scheduling:** However, it is also obtained from the decision making function. The consequences of decision making function can also be recognize the schedule when to increase or decrease the power.

6. CONCLUSION

The aim of the proposed work is highly motivated by the study described in [15]. In this article, the authors are trying to discuss the increase and energy wastage issue of cellular base stations. Based on a similar hypothesis the proposed work has been planned and described in this paper. First, we have collected and reviewed the recent power-saving techniques in smart city infrastructure. Therefore, some articles from Google Scholar have been collected and reviewed. Next, a proactive concept of resource management has been explained. Based on the studied resource management technique the key research problem has been formulated. Additionally based on the formulated problem the solution steps have been identified and explained with a possible solution model. The presented work aims to discuss how to analyze and predict the traffic pattern of a cellular base station. Additionally, traffic patterns have been formulated as the power demand in base stations. Shortly, this discussed conceptual model and solution have been implemented to accomplish a proactive power management technique for cellular base stations using machine learning techniques.

7. REFERENCES

[1] S. Daniel, M. A. Doran, “geoSmartCity: geomatics contribution to the Smart City”, The Proceedings of the 14th Annual International Conference on Digital Government Research, June 17–20, 2013, Quebec City, QC, Canada. ACM.

[2] R. Lea, M. Blackstock, “Smart Cities: an IoT-centric Approach”, IWWISS '14, September 01 - 02 2014, Saint Etienne, France, ACM.

[3] A. Naim, “New Trends in Business Process Management: Applications of Green Information Technologies”, British Journal of Environmental Studies, 1(1): 12-23, 08 Oct. 2021.

[4] G. P. Hancke, B. de Carvalho e Silva, G. P. Hancke Jr., “The Role of Advanced Sensing in Smart Cities”, Sensors 2013, 13, 393-425.

[5] M. Jayachandran, Ch. R. Reddy, S. k. Padmanaban, A. H. Milyani, “Operational planning steps in smart electric power delivery system”, Sci. Rep.,11, 17250, 2021

[6] O. Shurdi, L. Ruci, A. Biberaj, G. Mesi, “5G Energy Efficiency Overview”, European Scientific Journal, Vol.17, No.3, January 2021

[7] N. K. Suryadevara, G. R. Biswal, “Smart Plugs: Paradigms and Applications in the Smart City-and-Smart Grid”, Energies, 12, 1957, 2019

[8] S. K. Rao, R. Prasad, “Impact of 5G Technologies on Smart City Implementation”, Wireless Pers Commun, 100, 161–176, 2018

[9] R. S. Sofana, T. Dragi˘cevi´c, P. Siano, S. R. S. Prabaharan, “Future Generation 5G Wireless Networks for Smart Grid: A Comprehensive Review”, Energies, 12, 2140, 2019

[10] Y. Liu, C. Yang, L. Jiang, S. Xie, Y. Zhang, “Intelligent Edge Computing for IoT-Based Energy Management in Smart Cities”, IEEE Network, 2019

[11] H. C. Leligou, T. Zahariadis, L. Sarakis, E. Tsampasis, A. Voulkidis, T. E. Velivassaki, “Smart Grid: a demanding use case for 5G technologies”, IEEE International Conference on Pervasive Computing and Communications Workshops, 2018

[12] K. C. Chang, K. C. Chu, H. C. Wang, Y. C. Lin, J. S. Pan, “Energy Saving Technology of 5G Base Station Based on Internet of Things Collaborative Control”, IEEE Access, Vol 8, 2020.

[13] E. Baccarelli, M. Scarpiniti, A. Momenzadeh, “Fog-Supported Delay-Constrained Energy-Saving Live Migration of VMs Over MultiPath TCP/IP 5G Connections”, IEEE Access, Vol 6, 2018.

[14] Y. Wang, “Energy-saving Scheme of 5G Base Station Based on LSTM Neural Network”, 2nd International Conference on Applied Physics and Computing, Journal of Physics: Conference Series, 2083, 032026, 2021

[15] T. Yigitcanlar, R. Mehmood, J. M. Corchado, “Green Artificial Intelligence: Towards an Efficient, Sustainable and Equitable Technology for Smart Cities and Futures”, Sustainability, 13, 8952, 2021

[16] J. T. deSouza, A. C. deFrancisco, C. M. Piekarski, G. F. doPrado, “Data Mining and Machine Learning to Promote Smart Cities: A Systematic Review from 2000 to 2018”, Sustainability, 11, 1077, 2019

[17] C. Mahapatra, A. K. Moharana, V. C. M. Leung, “Energy Management in Smart Cities Based on Internet of Things: Peak Demand Reduction and Energy Savings”, Sensors, 17, 2812, 2017

[18] Q. Zhou, Y. Sun, H. Lu, K. Wang, “Learning-based Green Workload Placement for Energy Internet in Smart Cities”, Jour. of Mod. Pow. Sys. and Clean Energy, Vol. 10, No. 1, Jan. 2022

[19] H. Sharma, A. Haque, F. Blaabjerg, “Machine Learning in Wireless Sensor Networks for Smart Cities: A Survey”, Electronics, 10, 1012, 2021

[20] A. Sharif, J. Li, M. Khalil, R. Kumar, M. I. Sharif, A. Sharif, “Internet of Things- Smart Traffic Management System For Smart Cities Using Big Data Analytics”, IEEE, 2017

[21] İ. Kok, M. U. Şisek, S. Özdemir, “A deep learning model for air quality prediction in smart cities”, IEEE International Conference on Big Data (BIGDATA), 2017

[22] N. Zhang, H. Chen, X. Chen, J. Chen, “Semantic Framework of Internet of Things for Smart Cities: Case Studies”, Sensors, 16, 1501, 2016

[23] A. D. L. Heras, A. L. Sendra, F. Z. Polo, “Machine Learning Technologies for Sustainability in Smart Cities in the Post-COVID Era”, Sustainability, 12, 9320, 2020

[24] D. Iskandaryan, F. Ramos, S. Trilles, “Air Quality Prediction in Smart Cities Using Machine Learning Technologies Based on Sensor Data: A Review”, Appl. Sci., 10, 2401, 2020

[25] M. Dey, S. P. Rana, S. Dudley, “A Case Study Based Approach for Remote Fault Detection Using Multi-Level Machine Learning in A Smart Building”, Smart Cities, 3, 401–419, 2020