Blockchain and AI Powered Smart Grids A Secure and Efficient Energy Management Framework

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Abstract – The monetary gain from an advanced and intelligent electricity substructure that can manage increasing demand is known as a smart grid (SG). Being eco-conscious and conserving energy are key factors. An increase in energy consumption due to both population growth and technological advancements has created serious issues with both environmental sustainability and energy reliability. Applying AI and blockchain technologies to address issues with power control is crucial and noteworthy. Pre-processing data and smart city data with Z-Score normalisation technique to construct power-consumption smart grid. Assign Blockchain technology (a unique method of smartly and securely exchanging and storing order information using the Distributed DAA (Authentication & Authorisation) protocol at a centralized / distributed cloud platform) so as to not only ensure accuracy in data Consistency, but also maintain the confidentiality aspects for a large number of sensitive data an as the use of Distributed DAA (Authentication & Authorisation) protocol will provide confidence in grid applicants. It also combines local feature extraction and global modelling capability that produces an accurate load prediction when CSAM and MSAB are plugged into a Hybrid Attention UNet (named as CMSAMB-UNet) Maybe the smart network can retain the eventual results. An example of a successful user-to-grid communication system is blockchain-based smart energy trading, which allows for real-time demand response and the rapid balancing of electrical load and supply. Last but not least, compared to the current methods, our proposed solution works far better.

Keywords – Smart Grid, Distributed Authentication and Authorization, Channel Besides Spatial Attention Module, Multi-Head Self-Attention Block, Artificial Intelligence, Power Consumption.

I. INTRODUCTION

This will be articulated in green artificial intelligence based renewable energy technologies and hydroelectric power that shape clean circular economy practices in Internet of Robotic and Manufacturing things (IoRt) and cyber-physical production schemes [1]. Other technologies that contribute to this trend include geospatial simulation tools, algorithms for mapping the environment, and smart process planning and management that is assisted by deep learning [2]. Cognitive-radio-based Internet of Things (IoT) networks that employ energy-harvesting technologies and spectrum sensing enhance data fusion and resource allocation in vehicular networks and UAVs. Storage and computation services based on IoT devices and fog nodes are essential in 6G networks, and energy-efficient approaches play a key role in this. By employing fog and edge devices [3], computational processes can be executed with optimal power consumption, resource utilisation, and energy efficiency. In the extended reality environments, 6G Internet of Things (IoT) networks based on fog computing enable autonomous connected vehicles and intelligent automated machines to use energy-efficient approaches through ubiquitous connectivity [6]. The Internet of Energy (IoE) encompasses physical energy, cyber-physical systems, software-based power networks, and distributed renewable resources, all configured by packaged power management tools. Data processing and intelligent measurement infrastructure (smart meters, distributed energy sources and sensors), technologies for transmitting power in real-time, power grids, and control systems [7]. Energy efficiency can be greater by the use of distributed network intelligence, optimal power current, and flexible energy control. Since the energy generated by wireless communication technologies can provide power efficiency, reliability and stability for energy consumption and production, data processing and energy distributed devices [8].

Energy-aware control will be applied to 6G green networks for seamlessly sustainable networks, which will mitigate the power consumed by connected devices and battery-operated mobile terminals [9]. The Sixth Generation Networks evolved around algorithms that serve energy-aware resource pooling, improved power management & signal processing, and greener communication. In reference to this, with advanced communication capability, the usage of eco-friendly green 6G Internet of Things networks may not only increase coverage, but also decrease electrical energy consumption and energy cost [10]. The wireless network system of 6G enables the intelligent of any type of devices IoT devices as applications of large-scale industrial production, where systems and generation of electricity, intelligent traffic control, intelligent transmission and distribution cases. Enable high throughput and energy efficiency with low response time. After the operation and service perspective in sixth-generation IoT communication and energy efficient and aware network systems, virtualisation and complex mobile edge computing technologies can play a significant role towards IoT wireless network scalability [11]. Using spectrum sensing algorithms, problem detection in sensor networks, scheduling of data transmission and energy harvesting works together to maximise performance [4].

With the use of distributed AI and 6G edge computing, industrial wireless sensor networks based on multi-agent systems can reduce energy consumption and cluster sensor nodes for automated equipment operations [12]. 6G industrial machine/devices connectivity, devices operation automation for machine learning tools, clustering of machine learning algorithms, exploration of collaborative networks based on laboratory data-mining techniques [13]. The energy consumption of each node on a wireless network can be reduced through coherent resource allocation on both cloud, edge, and fog computing. More specifically, the utilization of data mining and wireless communication technologies enable enhancements of parameters related to industrial production context traffic congestion, such as energy resource-based network computing efficiency [14]. Distributing network resources more efficiently and reducing traffic congestion are two goals that can be advanced with the help of data fusion technology [5].

Through the use of energy-efficient data transmission mechanisms, big data clustering and coordination, and the ability to share spectrum, mobile devices powered by IoT sensors and powered by deep learning technologies [15] can mould energy and battery lifecycle management and monitoring in a way that promotes environmental sustainability. Mitigating energy consumption is achieved by the integration based 6G automation [16]. By utilising multi-agent deep reinforcement learning, decentralised and leading to a decrease in computing complexity and energy consumption [17].

An innovative power management system that leverages communication and internet technology is known as a smart grid (SG). A lot of people are interested in it because of the stable, efficient, and long-lasting manner it manages power. To improve the efficiency and dependability of energy management, smart grids use cutting-edge technology in the areas of sensor measurement, equipment, control methods, and decision support systems [18]. Additionally, smart grids provide bidirectional connections between energy producers and consumers; this feature distinguishes smart grids from traditional power grids, as it enables users and power grids to exchange information in both directions. A plethora of data sources, including citywide sensor networks, smart technology, and IoT devices, contribute significantly. The data is collected and analysed using information and communication technology. Individuals and communities alike will be able to generate and utilise renewable energy sources via this intelligent network. Additional energy can be stored for use at a later time. Because it is dependable, self-repairing, and reduces costs in energy generation, transportation, and smart city transformation, smart grid technology comes highly recommended.

Motivations and Objectives

The obstacles to widespread use of blockchain technology in smart grid-based power consumption prediction models include the computational complexity of handling large-scale data, the inability to distribute data transmission, and the lack of a long-term forecasting basis. Both user-to-user communication and data interchange along a transmission path are susceptible to limitations.

- Computational complexity as a result of big data: Dealing with big data in a precise input data manner leads to computational complexity. It does not have access to big data and only uses small data sets.
- The system's inability to provide completely distributed control is primarily due to centralised formulation. Because of a lack of distributed processing capacity or because of a clever system that assigns work to other nodes in the network. Its lack of distributability raises concerns about its scalability, flexibility, and resilience.
- The main drawback is that it is only applicable to short-term, one-step forecasting and not to long-term predictions. This constraint makes it difficult to generate long-term predictions. It must be highly complicated data that defies

accurate prediction. A big flaw in its applicability and scalability is that it is too specialised to be useful for long-term prediction.
- Constrained communication: For end-user communication, constrained communication can be both intelligent and complicated. The communication line is affected by system overhead, delays, and resource consumption, and it has difficulties communicating computational resources.
- Protocols and routes of transmission: Problems may arise as a result of assumptions about bandwidth, technical dynamics, and the impact of latency on transmission paths and telecommunication standards.

Research Contributions

In order to increase performance safely, this strategy employs optimisation techniques in a smart grid-smart manner with the primary objective of predicting smart city-based power consumption using blockchain knowledge in addition artificial intelligence. Listed below are the other aims of this study:
- Power consumption data is used to pre-process and normalise smart grid data.
- Pre-processed data can have important features extracted from it.
- Using extracted features, it is possible to transmit data securely to blockchain technology in the cloud.
- An endeavour to predict how much power smart cities will use and then use that data to store it on smart grids.
- One shown and stored consequence of the smart grid is the capability to communicate with end users.

II. RELATED WORKS

In this research, Hakiri et al., [19] add a three-pronged contribution to the corpus of knowledge on the foregoing specifically in the context of distributed IoT systems under the kot of blockchain termed the secure and decentralised, effective architecture of WANs. First, with the integration of Blockchain-SDN component which increased trustworthiness and adaptability, it improves IoT networks QoS. Second, it deliver the architecture of smart contract in traditional IoT to control IoT data and quarantine suspicious IoT node and decrease bad traffic. Third, we need to model a new Proof-of-Authority (PoA) consensus algorithm to get the agreement among the edge enabled IoT nodes of the blockchain framework to verify that the IoT edge devices are available and these steps lead to get the infinite confidence for the complete smart IoT systems. As compared to the classical proof-of-work (PoW) & the experimental results show that SDN apply to the blockchain system greatly improves the performance, latency reduces up to 68%, transaction throughput improves to 87%, energy saving improves to 45%.

Decentralised energy generation through the use of a nester, or energy sharing without the involvement of a third party, has been suggested by Kavin and Jayakumar [20]. In order to facilitate effective power transfer between prosumers and consumers and to guarantee power sharing between buyers and sellers, decentralised blockchain technology is utilised. Reducing and regulating energy use is a part of energy management. In distributed power generation, blockchain technology is crucial for many reasons, including power-sharing (solar besides wind), price fixing, monitoring energy transactions, and peer-to-peer power-sharing. In t renewable energy production, these are the tasks carried out by blockchain technology. The use of blockchain technology in solar power generation has the potential to influence the power producing system. The distributed ledger is the central component of blockchain technology that records and tracks all distribution system transactions in order to enhance the transmission system's overall efficiency. Another essential feature in blockchain technology is the smart contract. This contract is issued to buyers and sellers to confirm their agreement before commencing any energy transaction. This can help to prevent external interference, and delays. Most power arbitrages happen in the solar or thermal system (PV cells can detect the maximum power via blockchain). Blockchain technology is transforming energy management systems which will increase energy efficiency, improve energy utilisation, and reduce costs.

Babaei et al., [21] put forward four models for optimisation. This process starts with carefully solving three optimisation models based on the concepts of risk aversion, justice, and weighted sum. Then, based on these models, a multi-objective optimisation model based on the PMCG approach is built. This framework facilitates the ranking and scoring of different renewable energy sources, which assists in making sound decisions. We demonstrate through a case study that there is great potential for fusion of blockchain energy. In the first phase, our models — which are based on concepts of risk, optimisation and justice — propose goals for this next stage. The proposed method offers decision makers and supply chain managers a diverse set of analytical tools.

They addressed the issue of efficiently and securely contributing to building energy smart city communities, whilst rapidly advancing the attainment of UN Sustainability Development Goals (SDGs) especially SDGs 11 and 13, embracing Blockchain technologies [22]. The major aspects of a proposed framework are: (1) a blockchain platform, (2) predictable digital twin platform (3) API and (4) building energy model. It also supports an energy billing function based on digital money and smart contracts on the blockchain platform with pre-set price tiers and feed-in tariffs. Through the use of a digital twin platform, users are able to communicate and view physical assets in an interactive manner. Both platforms can be easily connected through APIs. If real usage deviates from ideal values, the Digital Twin platform will notify system members based on the simulation results given into it via the Building Energy Model, which functions as a forecast tool. Using an apartment block as a case study, to show that the suggested structure can operate.

Green Sharding (GS), planned by Luo et al., [23], reduces power consumption for Practical Byzantine consensus. In order to prevent nodes in a wireless blockchain network from being involved in a global consensus, the GS uses their geographical position to assign them to certain shards. In the meanwhile, to suggest a way to estimate energy consumption after sharding, which will simplify the computation of energy consumption in blockchain networks. To also give the best algorithm for selecting committee nodes (CNs), which can further reduce the GS-based committee consensus's energy usage. Finally, to model and examine the GS response to terahertz (THz) and millimetre wave (mmWave) signals, two potential 6G communication scenarios. With a minimal inaccuracy of only 0.11% and an energy consumption reduction of 99.76%, the simulation results demonstrate that the GS is successful.

III. PROPOSED METHODOLOGY

Improving network performance, efficiency, and reliability through the use intelligence and blockchain methods is the recommended method for anticipating power consumption in smart city smart grids. The suggested architecture is shown in **Fig 1** as an overall picture. This can be incorporated into the following process flow:

- Collecting besides pre-processing data
- Extraction of features
- Transmission and storage through blockchain
- Prediction based on demand
- Strategy for smart grid communication

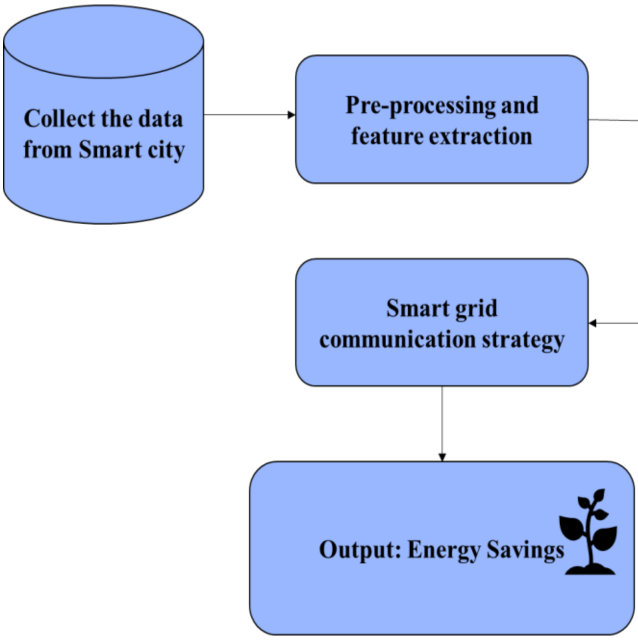

Fig 1. Workflow of The Research Model.

Data Collection and Pre-Processing

In a smart city, data on power use can be retrieved from a smart grid, with the data being automatically generated by the grid. Information pertaining to smart infrastructure, electrical meters, street lights, transportation, industries, zones (including homes, businesses, and hotels), and leisure and entertainment areas [24]. It is recommended to pre-process the acquired data in order to eliminate uncertainties such as duplicates, noise, and missing values. Using the Z-Score, the normalisation can be accomplished. After normalisation, data points are scaled to their appropriate ranges and can be quite quantitative. The collected data can be transformed by converting the values to a scale with one standard deviation and zero average. In order to convert ρ to ρ′, calculate:

$$\rho' = \frac{\rho - \bar{H}}{a_H} \tag{1}$$

By calculating the standard deviation of each data point from the mean, the Z-score normalises the data. A positive or negative value could be represented by the z-score, which is calculated from deviation.

Transmission and Storage Using Blockchain

Transmitting and storing feature-extracted data on the cloud is possible with blockchain technology. Securely transmit data to a centralised platform using blockchain technology—a distributed authentication and authorisation protocol that ensures data applicants.

Decentralized Authentication

Secure connections are provided via the proposed decentralised authentication protocol using blockchain technology. The two main parts of it are signing up and logging in. Login and registration are the two parts of our authentication process.

Registration Process

Users initially assign themselves a cryptographic public key (PK) to use as their identity key. After the user specifies a distinct username, they associate this identifying key with this binding and submit it to a blockchain. Consumers initiate an identification transaction following the registration process.

Login Process

In order to validate their identity, users must private key into the service application. The user's secret key is used to sign a login request that is sent to the service provider. The supplier executes relevant smart contracts and queries the blockchain for identification data after evaluating the login request. A date, public key, username, and signature are all part of the authentication request that the user receives. In order to authenticate themselves, the user generates a signature using the provided parameters and then returns it. After receiving a user's login credentials and data, the service provider checks them to determine whether to authorise or refuse the login.

Smart Contract Design

Transferring transactions to registration and searching for resources or identity blockchain are both made possible by smart contracts. The Query Data function is used to retrieve identity data, while the Send Transactions function is used to send it to the blockchain. Smart contracts streamline authentication by controlling interactions between users and providers and allocating access to blockchain data.

Implementation Steps

In order to complete the registration procedure, one must first generate registration data, sign that data using cryptographic keys, and then send registration requests to the blockchain. The rest of it looks up addresses, validates tokens for account approving, and approves or refuses the user's access to their account based on whether or not they are verified. The just-furnished protocol employs blockchain technology to provide users with authenticated connections in a smart grid scheme, offering secure and decentralised verification. Details including unique user's Name, Identity, and Private key (PK).

Decentralized Authorization

It allows arbitrary resource(s) owner(s) to register it/them to Blockchain without much hassle using Register Resource method. The Authorisation process is shown in **Fig 3**. Steps it suggests include time frames:

Data Preparation

To register a resource, its owner needs to gather some information. This information consists of the resource properties, such as the file owner's unique AccountId, as well as the public key.

Signing the Data

Usually, the owner signs the composed data, usually UserResource, Public Key, with his own private key. This signature validates that the registration request is authentic and has not been tampered with in any way.

Submission to The Blockchain

In a transaction, the signed document and relevant information are often sent to the blockchain via a smart contract-oriented resource registration mechanism. This information is stored in a ledger, and the process of recording information is transparent and permanent due to the use of blockchain technology.

Verification

After the transaction is completed the blockchain will raise an event to announce whether the registration was successful or not. This event is confirmed by the system to determine whether or not the resource registration process has succeeded or there were errors.

Outcome

Once registered, resource will be securely stored on the blockchain and needful users will be able to access and make use afterwards. Fix registration problems Only by ensuring the integrity of the registration mechanism can we ensure that everything that happens is the necessary way to set up problems that may arise during registration.

The Register Resource procedure essentially guarantees decentralised authorisation and control over resource access as it allows resource owners to archive the resource on the trusted blockchain privately and makes it publicly accessible. Resource owners can create resources in the blockchain by using Register Resource method.

The suggested protocol enables smart grid systems to perform resource authorisation and identity verification by integrating the immutable ledger qualities and decentralised authentication of blockchain architectures that are ideal for power systems with a specific blockchain methodology.

Demand-Based Prediction

One way to forecast how much power a smart city will use is via a smart grid. Using a state-of-the-art deep learning classical, it makes predictions.

Overview

In light of the power consumption measurements, a CMSAMB-UNet based attention network that incorporates both global and local factors is proposed.

General Organisation of The Proposed CMSAMB-UNet

The partitioning of input data has seen heavy use of U-Net and variants in the past few years. It is possible for UNet's convolution layers to incorrectly classify pixels due to the acquisition of redundant information. Also, taking advantage of global interaction isn't a good fit for UNet's small convolution kernels limited receptive fields. The proposed network, CMSAMB-UNet, solves these issues by enhancing the original UNet with hybrid attention, which combines local and global attention processes.

The CMSAMB-UNet keeps UNet's essential parts running with Resnet50 [25] as its backbone. F eat $i(i = 1, 2, 3, 4, 5)$, which is the encoder's description of the five steps that the returned feature maps from Resnet50 go through, the decoder's feature maps are also defined as upi, where i ranges from 1 to 4. F eat1 and f eat2 use CSAM early on to better using local focus and filter out all semantic features except for the important ones before skipping connections. Combining f eat4 and f eat5, which are activated to build high resolution feature maps, via MSAB, and adding MSAB replicates far-reaching dependencies for the latter stages of the CNN backbone based on the global attention. At long last, the decoder generates the pixel-level disease segmentation output.

Backbone

When it comes to remote sensing photos, Resnet does a fantastic job with target detection and semantic segmentation. Resnet is based on framework, and instead of using an underlying mapping F(x), it uses stacked layers F(x) + x to accommodate residual mappings, which are trained element-by-element using rapid connections. Resnet can potentially learn more detailed features without gradient deterioration by increasing the network's depth using this framework's shortcut connection.

Considering the training complexity and parameter count, feature extraction is carried out in this work using Resnet50. **Table 1** displays the structural breakdown of the Resnet50 backbone.

CSAM

Recognisable and accurate feature representations are vital for segmentation with high accuracy. Nevertheless, CNNs may illustration of data by extracting repeating features, especially in the early stages. An approach to selecting features is thus necessary for feature extraction. With CSAM, the projected CMSAMB-UNet in the early stages of developing the encoder, the emphasis was on channel attention and augmentation in complex input data scenes. Here is a way to summarise CSAM's overall evolution using an input map of qualities x:

Table 1. The Resnet50 Construction Utilised in Paper

Layer Name	Operator	Output Name	Output Size	Output Dimension
Conv1	7X7 Conv, stride=2, padding=3	$feat_1$	256X256	64
Conv2x	3x3 pool, stride=2 $\begin{bmatrix} 1X1\ Conv \\ 3X3\ Conc \\ 1X1\ Conv \end{bmatrix} \times 3$	$feat_2$	128X128	64
Conv3x	$\begin{bmatrix} 1X1\ Conv \\ 3X3\ Conc \\ 1X1\ Conv \end{bmatrix} \times 3$	$feat_3$	64X64	512
Conv4x	$\begin{bmatrix} 1X1\ Conv \\ 3X3\ Conc \\ 1X1\ Conv \end{bmatrix} \times 3$	$feat_4$	32X32	1024
Conv5x	$\begin{bmatrix} 1X1\ Conv \\ 3X3\ Conc \\ 1X1\ Conv \end{bmatrix} \times 3$	$feat_5$	16X16	2048

$$y = M_s(M_c(x) \otimes (M_x(x) \otimes x)) \quad (2)$$

$$M_c = \mathrm{sigmoid}\left[\mathrm{mlp}\left(x_{avgpool}\right) + \mathrm{mlp}(x_{maxpool})\right] \quad (3)$$

$$M_s = \mathrm{sigmoid}\left[\mathrm{conv}(\mathrm{concat}(x_{avgpool}, x_{maxpool}))\right] \quad (4)$$

In which Mc stands for channel attention and M_s for spatial attention-, and y is the highlighted feature map developed activation maps following a sigmoid function, where ⊎ indicates multiplication by elements, map stands for a convolution layer, besides represents a multi-layer perceptron. Feature maps using CSAM selectively highlight important aspects in the channel and spatial dimensions, with an emphasis on bodies of water and a suppression of irrelevant parts.

MSAB

Segmentation cannot proceed without precise pixel-level predictions. Resolving the uncertainties of local pixel prediction requires consideration of both fine-grained features and long-range relationships. To improve tiny regional segmentation, intrinsic correlations between pixels in big-scene photos are useful. Convolutional neural networks (CNNs) are great at analysing local neighbourhoods, but they fail miserably when it comes to capturing latent contextual connections in large datasets. Incorporating MSAB into the last stages of the encoder based on self-attention allows it to replicate the long-range interactions. By combining the data of n heads for self-attention, the MHSA, of the MSAB, is able to imprisonment the numerous intricate interactions. Next, 1×1 convolution is used to alter the size of the produced feature maps.

With the assumption that x is a good example of feature, MSAB provides a feature map of the output.

$$y = \mathrm{concat}(y_1, y_2, \dots, y_n) \quad (5)$$

And each head's specific calculating process is providing by

$$y_i = \mathrm{softmax}\left(\frac{Q.K^T}{\sqrt{d_i}}\right).V \quad (6)$$

$$Q = W_q x, K = W_k x, V = W_v x \quad (7)$$

Where *yi* characterises the head's map, *di* = *d*/*n* shows how much focus there is on the brain. A trainable 1 × 1 convolution produces three separate matrices: Q, K, and V.W_q, W_k and *Wv* symbolise the input x times the keys, values, and queries. The proposed optimisation self-attention using formula (6). In order to get the global contextual information-containing attention ratings, the normalisation of attention mappings follows the pd i and SoftMax functions. Finally, the outcome generated by assigning a value to V based on the attention ratings. Positional embedding is applied input feature x of the MHSA layer. With n brains processing data concurrently, the MHSA layer might pick up on the more nuanced global context. Our approach reduces the computational complexity of MHSA by building MSAB with a total of four heads and three MHSA layers. In the last stage of the encoding process, long-range dependencies are captured by merging high-resolution feature maps of the input data with global attention maps of different stages. Using MSAB, these maps are generated from features in that order.

IV. RESULTS AND DISCUSSION

Analyses and evaluations of the proposed study plan's experiments are presented in this part. There are three parts to this section: Research summaries, comparative analyses, and a simulation study.

Simulation Setup

Python 3.96 is used to model the suggested research approach. All the necessary details for the proposed method are laid out by this effective instrument. Research for the proposed model was conducted using Python's deep learning toolbox and Google Colab. The 8 GB RAM NVIDIA Quadro P4000 was utilised as the GPU for testing and training purposes. Our assessment process makes use of a 10-fold cross-validation technique, which involves splitting the benchmark datasets into a training set besides a test set. This allows us to assess the performance of the suggested models. Several hyper-parameters need to be set in order for the suggested architecture to be employed throughout the prediction process. To accomplish the best possible architecture performance, this is necessary. Epochs, learning rate, dropout, and batch size are these hyper-parameters.

Validation Analysis of Proposed Classical with Existing Procedures

Table 2 and 3 mentions the validation analysis of proposed classical with existing procedures in terms of diverse metrics.

Experimental Analysis demonstrates that the to Proposed modelto achieves the highest to accuracy (0.972) to, to precision (0.96) to, to recall (0.966) to, and to F1-score (0.97) to, outperforming existing techniques. To U-Net (0.950) and Mobile Net (0.941) follow closely, showing strong performance in classification but slightly lower recall values. To

MLPNN (0.914) and DNN (0.90) to exhibit comparatively lower metrics, indicating that deep neural network-based methods benefit from more sophisticated architectures. The results confirm that to proposed model to effectively balance precision and recall, leading to superior overall performance.

Table 2. Experimental Investigation of Proposed Classical with Existing Techniques

Model	Accuracy	Precision	Recall	F1-score
DNN	0.90	0.92	0.90	0.91
MLPNN	0.914	0.91	0.91	0.92
MobileNet	0.941	0.93	0.936	0.94
U-Net	0.950	0.95	0.951	0.95
Proposed	0.972	0.96	0.966	0.97

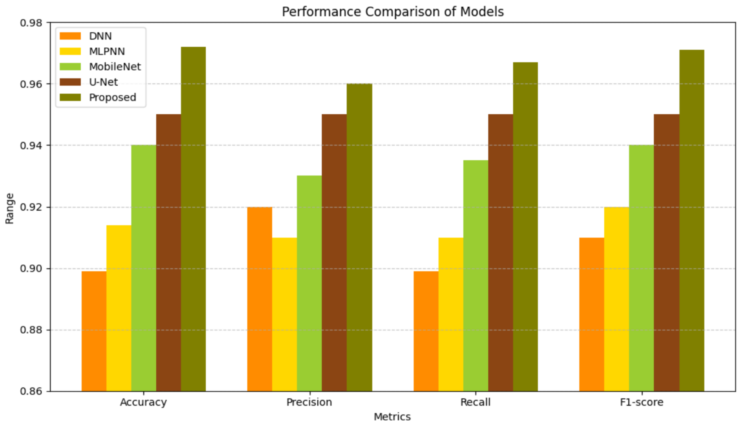

Fig 2. Graphical Description of Projected Classical with Existing Procedures.

Validation of Proposed Blockchain Model on Different Samples

Table 3 and **Fig 3, 4, 5, and 6** presents the experimental investigation of projected blockchain classical with different samples in terms of various metrics.

Table 3. Analysis of Proposed Blockchain Model

No of samples	**Latency**	Throughput	**Response time (s)**	Energy Consumption (J)
100	0.894	0.90	0.892	0.896
200	0.883	0.916	0.87	0.883
300	0.894	0.928	0.88	0.874
400	0.887	0.941	0.86	0.869
500	0.904	0.969	0.85	0.845

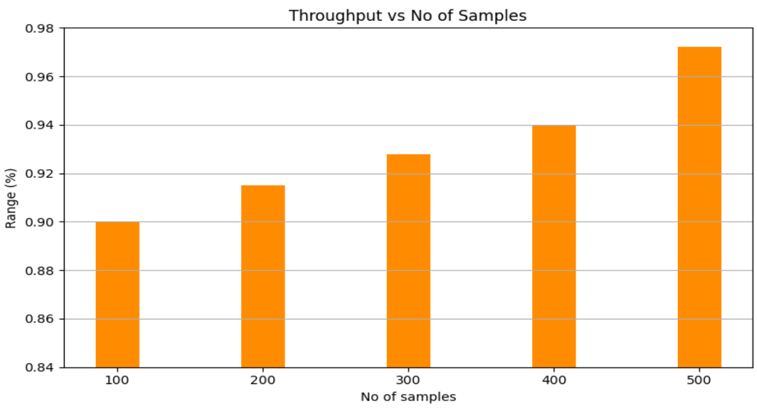

Fig 3. Visual Analysis of Throughput.

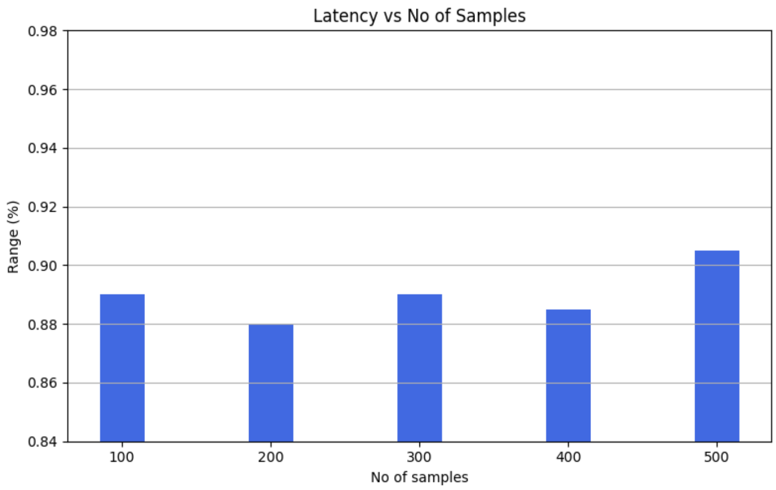

Fig 4. Visual Analysis of Latency.

The Analysis of the Proposed Blockchain Model highlights its performance across different sample sizes. As the number of samples increases from to 100 to 500 to, to latency to remains stable, fluctuating slightly around to 0.88–0.90, indicating efficient processing times. To Throughput improves progressively from 0.90 to 0.969 to, demonstrating enhanced transaction handling capability. To Response time decreases from 0.892s to 0.85s, suggesting that the model efficiently scales with larger sample sizes. To Energy consumption also reduces from 0.896J to 0.845J, reflecting optimized computational resource utilization. These results confirm that to Proposed Blockchain Model to maintain high efficiency, scalability, and energy effectiveness.

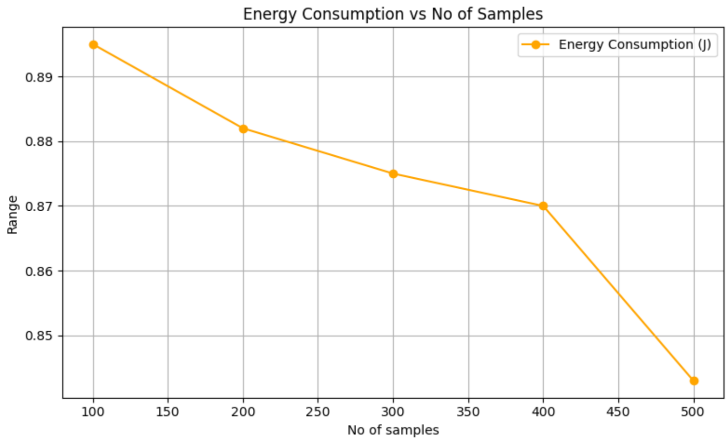

Fig 5. Analysis of Energy Consumption.

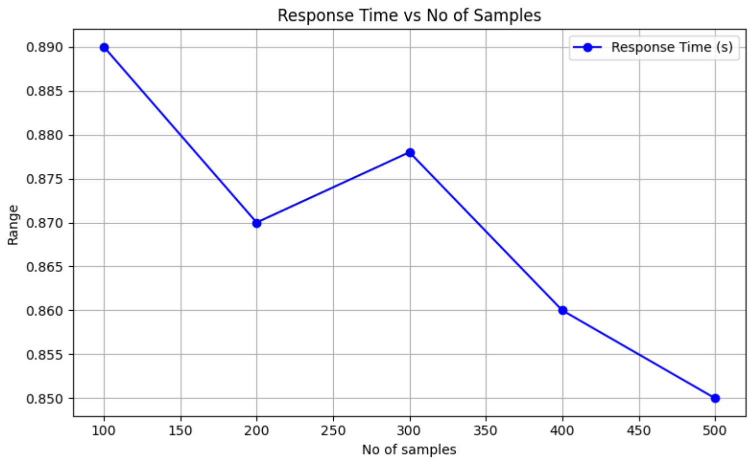

Fig 6. Analysis of Response Time.

V. CONCLUSION

In the first stage of the suggested technique, data preprocessing, to build a smart grid besides collect data from the smart grid's real-time data. Using Z-Score Normalisation, the redundancy are removed during the pre-processing. After that, the data that has been collected will be sent securely using Distributed Authentication and Authorisation (DAA) protocol to guarantee privacy besides honesty of data. After that, it will be kept on a cloud-based blockchain. To ensure precise load forecasting, to next execute a demand-based prediction utilising a CMSAMB-UNet. Building a trustworthy, low-latency communication network is the next step in smart grid communiqué. This is made possible through blockchain-based smart energy trading at Greenbridge. Enables task-oriented real-time load and supply balancing through a communication mode. Lastly but not least, for the validation of the methodology as well as the system testing with different traits of performance measures. The following validation report of assumed work is brought on the basis of diversity of execution metrics profiles which includes quantity samples accuracy Metrics, time spent Metrics vs consumption of energy, average latency Metrics vs and quantity of samples, throughput Metrics vs time and response time vs quantity of samples. Researchers will find solutions to smart grid latency and real-time data processing using blockchain to optimize edge computing. This solution maintains edge devices synchronized with the blockchain enabling secure and efficient data exchange. If indeed that will translate to real ground performance and scale will require some real app.

CRediT Author Statement

The authors confirm contribution to the paper as follows:

Conceptualization: Sarala P Adhau, Rajesh Kumar T, Kalpana V, Vemula jasmine Sowmya, Suguna M and Jebakumar Immanuel D; **Methodology:** Sarala P Adhau, Rajesh Kumar T and Kalpana V; **Software:** Vemula jasmine Sowmya, Suguna M and Jebakumar Immanuel D; **Data Curation:** Sarala P Adhau, Rajesh Kumar T, Kalpana V, Vemula jasmine Sowmya, Suguna M and Jebakumar Immanuel D; **Writing- Original Draft Preparation:** Vemula jasmine Sowmya, Suguna M and Jebakumar Immanuel D; **Visualization:** Sarala P Adhau, Rajesh Kumar T and Kalpana V; **Investigation:** Sarala P Adhau, Rajesh Kumar T, Kalpana V, Vemula jasmine Sowmya, Sugua M and Jebakumar Immanuel D; **Supervision:** Sarala P Adhau, Rajesh Kumar T and Kalpana V; **Validation:** Vemula jasmine Sowmya, Suguna M and Jebakumar Immanuel D; **Writing- Reviewing and Editing:** Sarala P Adhau, Rajesh Kumar T, Kalpana V, Vemula jasmine Sowmya, Suguna M and Jebakumar Immanuel D; All authors reviewed the results and approved the final version of the manuscript.

Data Availability

No data was used to support this study.

Conflicts of Interests

The author(s) declare(s) that they have no conflicts of interest.

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Competing Interests

There are no competing interests

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