Enhancing Energy Efficiency and Data Security in Smart City Grids Using Bio-Inspired Algorithms and Blockchain Technology

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Abstract – One of the primary problems in the context of modernizing ways in "smart cities is the energy efficiency and data security of smart grids. Wireless sensor networks and improved metering infrastructures enable intelligent energy system management, turning traditional towns into "smart communities." This article proposes a smart city energy paradigm in which prosumer community's network energy-independent households to generate, consume, and share clean energy on a decentralized trading platform using blockchain technology and a smart Microgrid. Smart Microgrid enable this. A smart Microgrid-based smart city energy concept is also proposed. Wireless sensor nodes that manage a lot of network data increased the grid network's efficiency and stability. The sensors' energy quickly runs out due to the long communication distances between nodes and the base station, shortening the network's lifespan. Thus, bio-inspired algorithms were presented to improve routing by finding the shortest path throughout the network. This improved cluster head selection, energy usage, and network longevity. It was accomplished by learning about the best practices for solving a problem in biological systems and then implementing those practices in the realm of communication. This all-inclusive approach utilizes particle swarm optimization and a genetic algorithm to find the best answer rapidly and efficiently to any problem".

Keywords – Microgrid, Meta Heuristic Algorithms, Wireless Sensor Network, Particle Swarm Optimization, Advanced Metering Infrastructure, Blockchain, Ethereum.

I. INTRODUCTION

Smart cities are utopian communities where residents enjoy superior amenities and government services thanks to an emphasis on cutting-edge technology. Combining ICT with IoT can dramatically enhance city operations. In order to improve people's quality of life, urban life in smart cities have to adapt to a number of new circumstances over the years. "Despite smart cities' high energy consumption, new improvements in smart grids and the emergence of smart communities have substantially improved the quality of power [1-3]".

Smart grids are malleable power networks that make use of technology that allow for two-way communication in order to make energy usage more secure, effective, and environmentally friendly. With the help of information and communication technology, data collected from sensor networks, wearables, and Internet of Things (IoT) devices located all over a city may be gathered and analyzed [4,5].

Microgrids are an important use case for smart grids since they increase the grid's reliability and resilience. These are localized grids that can function independently or in conjunction with a larger system. "Microgrids are designed to function independently from the main utility network, or "mother grid," during power outages or other disruptions". A wide array of dispersed energy sources is connected to one another through a network that is both directed and highly efficient (solar panels, wind turbines, micro turbines, etc.). It can considerably increase the efficiency of the system that delivers energy by lowering the prices of capacity while also reducing energy losses that occur during transmission and distribution. The ability to generate and distribute electricity locally and meet energy needs in sparsely populated areas is made possible by this technology [6].

As a result of the worldwide increase in energy consumption, a new category of electricity users known as "prosumers" has emerged. These individuals can generate and use power from renewable sources, distributing the excess energy to other users or selling it back to the grid. Smart microgrids make this possible through their incorporation of features including advanced metering infrastructure (AMI), bidirectional communication technologies, automated distribution, and grid-wide monitoring and control. "A wireless sensor network, also known as a WSN, is a self-configured network of sensors that is used to monitor different environmental factors in real time, such as pressure, temperature, humidity, motion, and so on. The data collected by these sensors is known as wireless sensor data. Sensor nodes are utilized extensively in many different fields, including smart grids, healthcare, the military, surveillance, the industrial sector, agriculture, transportation, and logistics, etc. Network lifetime maximization is a serious problem in WSNs because of the limited power available in nodes and the great distances that must be traversed for communication, necessitating the use of specific optimization approaches to cut down on unnecessary data replication and power consumption [7-9]".

Since WSNs communicate over an open channel, such as the internet, privacy and security have become key concerns due to the large amounts of sensitive information being handled. Furthermore, due to the restricted power supply and processing resources of the sensor nodes, the systems can only be secured up to a particular range [10]. For the most part centralized infrastructure security solutions have been developed. Centralized control has various problems, including a lack of security that leaves the system open to illegal data manipulation and the participation of intermediaries and third parties, which drives up operational and transactional expenses. Blockchain technology could provide digital energy records that are instantly accessible, secure, and unchangeable [11]. These data might also be updated in real time. This article presents a blockchain-based smart microgrid that may be used in conjunction with blockchain technology to improve the capabilities of an intelligent community's citizen residences in terms of energy distribution. Data loss is avoided, and the system's energy efficiency and lifespan are both improved. These algorithms can tackle complex issues with ease because they mimic the tactics adopted by biological systems [12].

Information sent over a network can be transmitted securely thanks to blockchain technology, which also protects user privacy. In this study, the primary emphasis is placed on the use of this technology to peer-to-peer energy trading in microgrids. This type of trading makes it possible for prosumers to sell any excess energy economically and openly they produce to other families in the neighborhood. A blockchain-based system is created, allowing residents to buy power from their utility companies directly with cryptocurrency and keep decentralized energy transaction records in the blockchain.

II. MATERIALS AND METHODS

Literature Review

"The wireless sensor network, abbreviated as WSN, has attracted a significant amount of interest from the business world as well as the academic community". To solve some of the most urgent problems that arise in WSNs, a great number of algorithms have been devised. The wide variety of applications for WSNs as well as the potential pitfalls of smart grids are covered in this article. Protocols for providing quality of service QoS, conserving power, making the most of available bandwidth, and ensuring safe routing in WSN are all described.

In this section, we provide several metaheuristic algorithms used to optimize various features of WSNs, with the goal of yielding sufficiently good solutions under reasonable time limits. In, we propose using a firefly-based method to achieve WSN node clustering and optimize packet delivery ratio and network longevity. A brand novel approach for exact node localization in WSNs is called the salp swarm algorithm, and it was inspired by natural phenomena. "It combines the ant colony optimization (ACO) with the harmonic search algorithm (HSA) to discover the ideal cluster head that has the shortest routing path possible. An algorithm serves as the foundation for a proposed method of routing that is more energy efficient [13].

In this section, we describe and analyses the various routing protocols used in WSN, focusing on their performance, limitations, and security flaws. An overview of the state of the art in multipath routing techniques, including a discussion of the primary difficulties and proposed directions for the field, is provided. For those interested in learning more about the benefits and cons of various routing protocols, this article serves as a guide. In, we describe an enhanced genetic algorithm technique that boosts the efficiency with which mobile agents locate the quickest path through the sensor network [14]. To ensure that the entire monitored region is covered and that the lifespan of the network is maximized, heterogeneous WSNs use a hybrid GA that combines greedy initialization with bidirectional mutation operation. The methods of clustering and routing are unified into a single chromosome in the genetic algorithm-based clustering and routing described in this study, which increases the network's energy efficiency. The optimal load distribution attained in this work reduces cluster head energy consumption on average. Each sensor node's estimated DOA (direction-of-arrival) from numerous sources in a three-dimensional area is classified using a genetic algorithm (GA). Without compromising the precision of the estimation, this strategy has the potential to significantly reduce the computing burden. To solve the challenge of optimally deploying nodes in WSNs while considering topology, environment, application requirements, and designer preferences, a multi-objective GA is proposed.

In, a particle swarm optimization PSO approach is given for the purpose of extending the life of networks by first clustering the nodes of the network into groups and then selecting a leader for each of those groups. By integrating the PSO with a multi-hop routing protocol in a WSN, it is possible to produce uneven dynamic clustering in the network. Because of this, the distribution of clusters can vary in a dynamic manner in reaction to the failure of individual nodes.

To facilitate efficient data transfer at low cost and in a short amount of time, we provide a route optimization method based on a genetic algorithm (GA). As a result, sensor nodes can save a lot of power, making the network more efficient and lasting longer [15].

In addition to extending the lifespan of nodes, this approach improves data security as well. Since WSNs rely on the energy internet for communication, it is imperative that privacy and security measures be taken to protect users' personal information and their energy systems. When it comes to upgrading to blockchain technology, several industries, including electricity, energy, electrical network, and smart grid, take center stage. Articles from mostly discuss how blockchain technology can be used in the energy industry. In this paper, we present a future scenario for a blockchain-powered, interconnected microgrid that makes efficient use of a power grid. The energy efficiency and power quality of a power system may both be improved with the application of blockchain technology. A paper makes recommendations for the application of the technology in the field of electric power systems. This article examines the significance of blockchain technology in this sector, as well as its present and future applications". The article highlights notable projects currently underway in the domain of applying blockchain technology to the electrical industry. "In this paper, we describe how blockchain technology might be used to facilitate the creation of energy communities, where prosumers can trade energy with one another.

In, the idea of creating a grid for a smart city that is made up of several different hybrid micro grids is presented. In this article, we look at the present state of the art regarding the issues regarding the safety of blockchain-based smart cities. The combination of blockchain technology and devices connected to the internet of things makes it possible to implement intelligent metering as well as billing for an electrical grid.

This is explored in relation to the application of blockchain technology in the microgrid sector. In this article, we compare the bandwidth needs of several microgrid architectures and describe how a central blockchain-controlled system with advanced metering technologies could work. When comparing a blockchain-based solution to one based on advanced metering techniques, it is discovered that the latter requires roughly 10 times as much bandwidth. In, we propose a comprehensive investigation into the myriad difficulties inherent in putting into practice blockchain-based P2P microgrid networks. Using hybrid blockchain technology, which allows the consumer and prosumer to share a safe space for energy exchange, this article provides a solution to the problem of wasted energy in a microgrid. Using blockchain technology, the smart grid and a smart contract can carry out a smart transaction. Blockchain technology is used to solve a microgrid design issue for a real-time demand response initiative in. To locate and identify renewable power units with variable pricing, a fuzzy optimization strategy is given. Based on the data collected, the Vietnam region has had profitable growth of 1.68% and increased consumer satisfaction of 2.61%. An application of blockchain technology to microgrid energy forecasting, emphasizing cost-effectiveness and minimum power loss".

Background Study

Particle Swarm Optimization

In 1995, "James Kennedy and Russell Eberhart were the ones who initially conceived up the concept of the particle swarm optimization (PSO). PSO is an acronym for "population-based metaheuristic optimization." It helps to find the optimal solution to an optimization issue by simulating the behavior of a group of animals, such as a flock of birds or a school of fish [16]". **Fig 1** shows an optimization technique based on a swarm of particles (particle swarm optimization, or PSO).

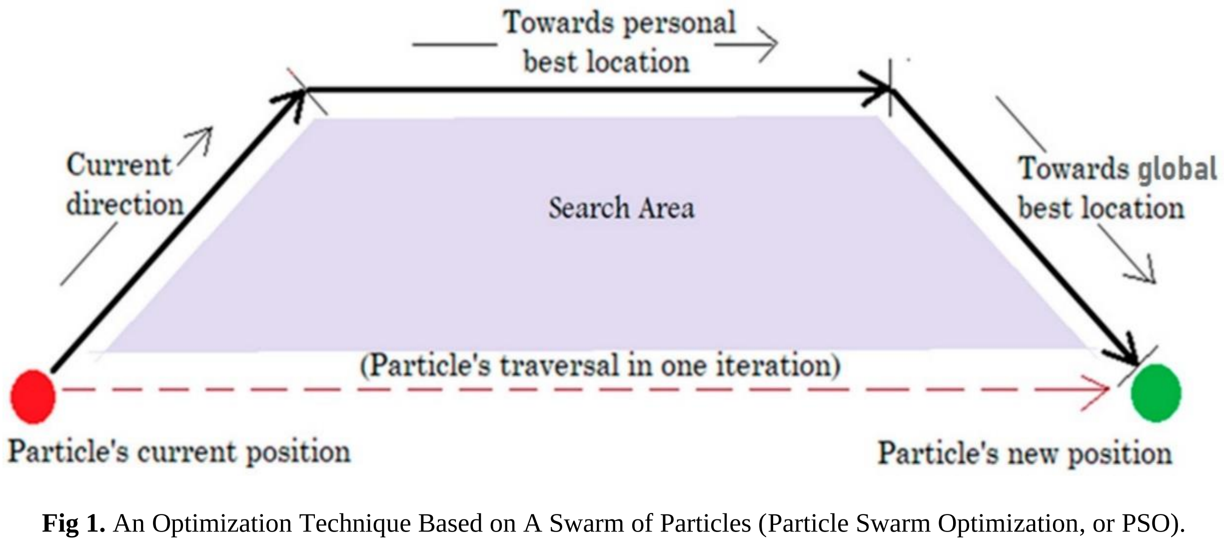

Fig 1. An Optimization Technique Based on A Swarm of Particles (Particle Swarm Optimization, or PSO).

Using the following equation, we can calculate the new position and velocity of the particle:

$$\overrightarrow{Pv_t^{i+1}} = \overrightarrow{Pv} + \overrightarrow{Vp_t^{i+1}} \quad (1)$$

$$\overrightarrow{Vp_t^{i+1}} = \vartheta Vp_t^{i+1} + a1r1\left(\overrightarrow{mbest} - \overrightarrow{Pv_t^{i+1}}\right) + a2r2\left(\overrightarrow{mbest} - \overrightarrow{Pv_t^{i+1}}\right) \quad (2)$$

Where,
i = iteration number
Pv = Position Vector
Vp = particle velocity of the t th value
a1,a2 = Acceleration coefficient
r1,r2 – Random components

$$a1r1\left(\overrightarrow{mbest} - \overrightarrow{Pv_t^{i+1}}\right) - cognitive\ component$$
$$a2r2\left(\overrightarrow{mbest} - \overrightarrow{Pv_t^{i+1}}\right) - social\ component$$

Genetic Algorithm

In 1992, “John Henry Holland came up with the idea for what is now known as the genetic algorithm (GA), which is one of the earliest examples of evolutionary algorithms. The process of natural selection, also referred to as "survival of the fittest," was a significant contributor to the development of this idea. The Darwinian theory of evolution, which outlines the process through which living things have developed biologically over time, serves as the foundation for this notion. As can be seen in **Fig 2**, each chromosome in the genetic algorithm stands in for a potential solution, and the collection of chromosomes together represents the population. Genes, a genetic representation of potential solutions, are used in conjunction with an objective function, called a fitness function, to solve optimization problems utilizing the GA [17]. The fitness function takes an array of bits or a bit string representing a gene and returns a value that indicates the degree to which that gene's products are useful in solving the problem at hand.

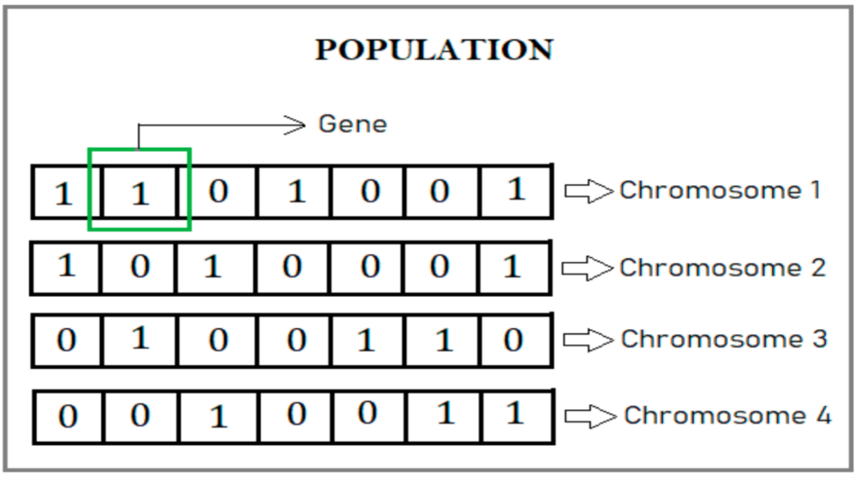

Fig 2. Representation of a Group of Chromosomes in a Population.

Each solution in the initial population is produced at random and then subjected to four genetic operators—selection, crossover, mutation, and elitism—with a predetermined probability. The genetic information of two parents can be combined by a process known as crossover or recombination”. This involves the exchange of genes before and after a randomly selected point in each generation. The crossover frequency (Pc) of a population can be determined by using the population's possibility of crossing over. In order to simulate the process of natural selection by employing a roulette wheel mechanism, the first step is to create a random number within the range [0, 1].

Small, random shifts in a chromosome's genetic code can provide novel traits to a community and expand its genetic diversity. It also aids in keeping the GA from settling on a solution too quickly. Genetic mutations that reduce the proportion of optimal solutions are gradually weeded out by natural selection and genetic crossover as the population evolves. The pace at which a gene mutation occurs in a population is referred to as the mutation rate. This rate allows beneficial characteristics to be maintained and passed on to subsequent generations without being altered. In order to compute the mutation rate, we make use of the crossover and mutation operators. Additionally, elitism is utilized in order to preserve a minuscule portion of the most superior members (elites) of a population. The elitism ratio (Er) is used to calculate the percentage of top performers, which can then be put to use in the next generation's solution improvement via selection, recombination, and mutation. A genetic algorithm uses evolutionary mechanisms to improve the population's fitness over time.

Blockchain Technology

A “blockchain is a type of database that is known for its high level of security, inability to be altered, and decentralized nature. Transactional data is saved in an encrypted form in the form of blocks, and it does so in a block-by-block method. This is done in a decentralized manner. A new block is added to the distributed ledger whenever a user conducts a transaction that is then verified by the network. As seen in **Fig 3**, these blocks are connected using cryptographic hashing. Blockchain's primary benefit is that it is a decentralized system operating as a layer on top of the internet; this decreases the need for expensive servers, does away with middlemen and third parties, and gives systems greater independence while also bolstering their data integrity and security.

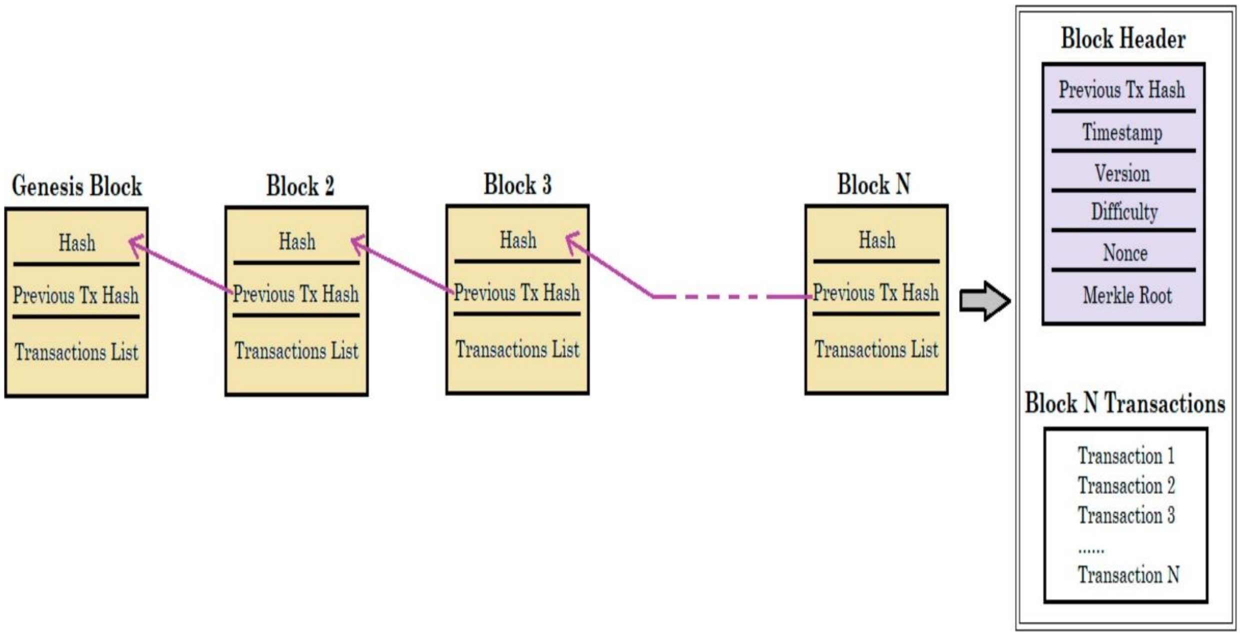

Fig 3. Block Structure.

For maximum security, blockchain implementations of encryption use 256-bit hashing algorithms like SHA-256 for Bitcoin and ETHash for Ethereum cryptocurrency. To modify the information, attackers would need a lot of computational power to crack all the encryptions, as shown in **Fig 3**, because each block carries the unique transaction hash of the previous block. Each participant in a blockchain network is assigned a pair of keys—a public and private key—that together function as a digital signature, allowing them to conduct transactions and access encrypted data. The node level is another area where blockchain excels in providing security. In a distributed ledger system, such as a blockchain, each node is a computer that contributes to the network. One of the most well-known and successful blockchain-based systems is Ethereum, which was developed by Vitalik Buterin in 2015 and is available to the public as open-source software. Before adding transactions to the blockchain, miners verify their authenticity by solving the proof-of-work (PoW) consensus mechanism. This ensures that the transactions are valid. It supports smart contract capabilities. Smart contracts are computer programs that, once deployed on the Ethereum blockchain, cannot be altered and are only activated when a certain set of instructions or conditions are met. These programs are typically implemented in the Solidity programming language. Decentralized apps (dApps) can be developed and deployed on the Ethereum blockchain, with control vested in the underlying smart contract [18]. Therefore, the entire application is automated, and all transactions are checked and validated by the system without the need for human participation.

As of the last check, one ether (ETH), Ethereum's decentralized digital currency, was worth 123,743.91 Indian rupees. It is used to deploy smart contracts, power decentralized applications, and handle all financial transactions on a peer-to-peer network. To reward miners for the time and energy they spend verifying and validating transactions, a smaller unit of the Ethereum token called "Gas" (1 Gwei = 10^9 ETH) is used to fuel the process of adding a block to the public ledger. Because of this, blockchain technology may perform computations without requiring faith from any of its participants”.

III. PROPOSED WORK

A proposal for a smart energy community has been offered; according to this model, “a coalition of neighboring prosumers would be formed on the basis of an agreed-upon sharing mechanism. This paradigm, which also makes use of a decentralized energy network and storage technologies, is built on the foundation of energy-independent households as its primary component. The intelligent administration of the microgrid is made possible by a wireless sensor network and an advanced metering infrastructure, both of which monitor the generation, transmission, and consumption of power in real time respectively. **Fig 4** shows the concept of a "smart energy community." modern metering infrastructure is called "AMI.".

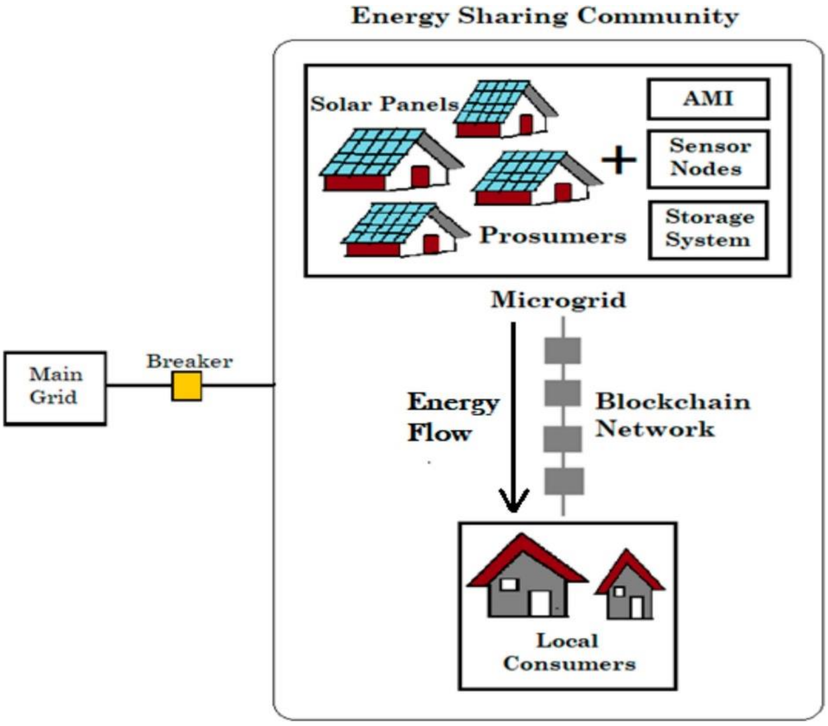

Fig 4. The Concept of a "Smart Energy Community." Modern Metering Infrastructure is Called "AMI.".

Based on their net energy profiles at different times, prosumers can switch between selling to the microgrid and buying from the grid. Prosumers can, for instance, purchase electricity from other prosumers in the network if their own power generation is insufficient to meet their load demand. To further encourage the use of renewable energy sources, prosumers can receive a feed-in tariff if they sell their excess energy to the utility grid. The amount of energy produced daily by PV prosumers sets the rate at which energy is distributed among the homes. Taking prosumers' adaptability in energy use into account, energy prices will be set considering supply and demand, economic cost, and regulatory constraints. The smart contract manages the prosumers' energy supply in the community and oversees energy sharing activities, considering the energy pricing agreed upon by all prosumers. This mechanism for trading energy directly between individuals or households reduces the burden on the utility grid while maximizing the usage of power generated by decentralized sources of energy.

The solution that is being proposed considers a sophisticated metering infrastructure that is based on blockchain technology. This infrastructure is made up of several sensor nodes that collect data regarding energy use from the smart meters that have been put in all the homes. The distributed ledger technology of blockchain is utilized to safely record transactions and data to facilitate power consumption monitoring for the objectives of analysis and decentralized management of energy systems. It also allows for encrypted communication between the blockchain and its authorized users (the prosumers and customers in this example). **Fig 5** shows AMI based blockchain; DCC, which is data and control center.

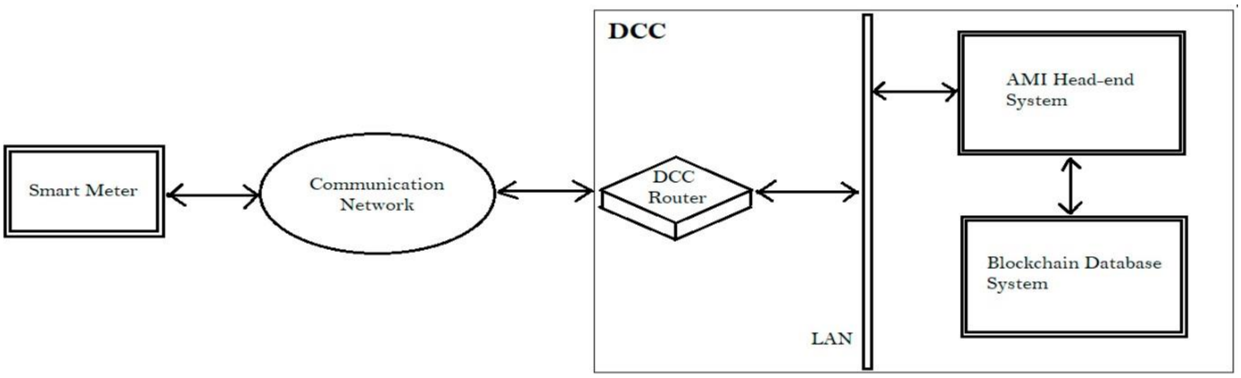

Fig 5. AMI Based Blockchain; DCC, which is Data and Control Center.

An optimization strategy has been proposed as a means of achieving optimal results in the selection of cluster heads and the utilizations of resources in network routing. This not only boosts the performance of the network but also increases its lifetime, both of which are key constraints when it comes to the construction of a sensor network. Our plan for a smart city is based on the utilization of a wireless sensor network for the purpose of monitoring the energy infrastructure and disseminating information regarding this monitoring in real time. At first, the sensor nodes are scattered throughout a certain area, each with its own limited source of power. Because it is connected to the power grid from outside the sensing region, the power supply at the base station is virtually limitless. After deployment, it is assumed that all WSN nodes, with the exception of the sink node, are left unattended by the system. This is the strategy that we have advised. The information that is gathered by these nodes is then sent, at regular intervals, to the people who are supposed to receive it. These nodes are grouped together into clusters for the purpose of reducing power consumption, and the most capable node in each cluster is given the role of serving as the cluster head (CH)". **Fig 6** shows formation of clusters and finding the best routes.

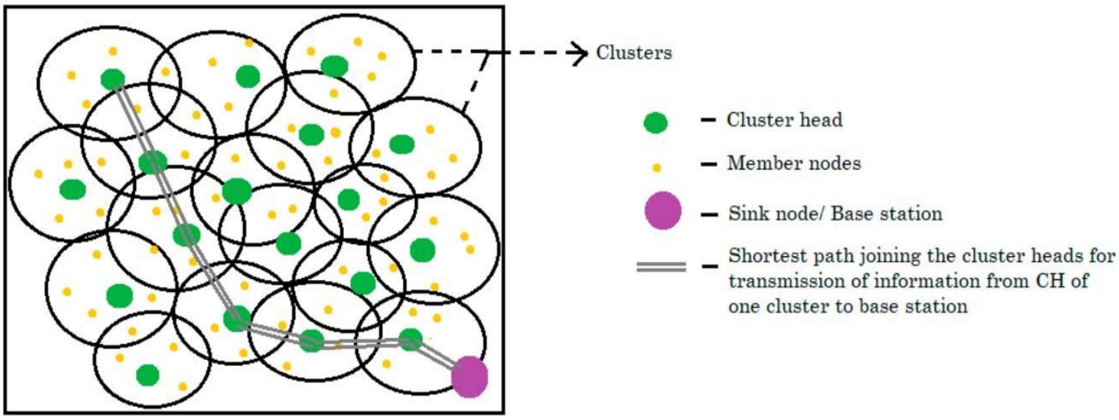

Fig 6. Formation of Clusters and Finding the Best Routes. CH Stands for Cluster Head.

Each network node can perform the duties of a sensor and a group leader. "The cluster nodes each provide their data to the CH, which then processes the data and forwards it on to the base station either directly or by going through a number of CHs. This is done in order to reduce the expenses of communication as well as the energy that are associated with sending and receiving data". The PSO algorithm is utilized by the recommended method in order to select the CH in the most effective and economical use of available resources manner. Consequently, the cost function can be represented as follows:

$$Cost\ function, Cf = p \times Ed + q \times Re + r \times Db \tag{3}$$

Where,

p,q,r – constants (p=q=0.40; r=0.21)

Ed – Euclidean distance (average distances from one node to another node in a cluster)

Re – Total residual energy ($\frac{Residual\ Energy\ of\ the\ alive\ node}{Residual\ energy\ of\ the\ node\ in\ consideration}$)

Db – Base station Distance

The "objective is to minimize the cost function in order to find the ideal location of the cluster head. This site should have the highest possible residual energy and should be as close as possible to the base station and the member nodes. *The following is a list of the steps that are involved in the PSO algorithm:*

- The beginning state of a collection of particles, including their positions, velocities, and residual energies;
- PSO parameters consist of the following: the size of the swarm, the number of iterations, the inertia weight, personal acceleration coefficients, and social acceleration coefficients;
- The calculation of the cost function for each particle;
- The determination of the best location for the individual and for the entire system;
- The updating of the position, velocity, and amount of energy lost for each particle after each iteration
- Finding the particle that has the lowest value of the cost function the head of the cluster on each iteration;"
- Continue to repeat steps 3 to 6 until all of the nodes have gone inactive.

The quickest path that travels from the origin node to the destination node, connecting a group of sensor nodes along the way and only making a single stop at each node. It was successful in achieving this goal by making use of the evolutionary algorithm to determine the route with the shortest distance between each individual sensor node. In doing so, we were able to achieve our goal.

In a space with only two dimensions, the evolutionary algorithm works to determine which of two possible routes between two points is the shortest. The technique employs the Euclidean distance that exists between each pair of consecutive nodes in order to determine whether or not it is fit to be used as a fitness function. The several possible solutions, or chromosomes, each reflect a different way of approaching the problem at hand:

- The beginning of the population;

- The determination of the fitness level of each chromosome;
- The use of a roulette wheel mechanism to choose the best chromosomes to serve as parents for the next generation;
- The crossover of parent chromosomes;
- The mutation of chromosomes;
- The determination of the fitness level of each chromosome in the newly created population;
- The continuation of steps 3 to 6 until the shortest path is found.

We can regulate community-based energy trading by keeping tabs on residential energy use in urban areas once wireless sensor networks have been optimized for this purpose. "In our approach, prosumers use solar panels and batteries to generate and store sustainable energy, which they then sell to nearby consumers via a peer-to-peer (P2P) energy trading platform. To facilitate the sale and purchase of clean energy between households without the need for a middleman, a blockchain-based web application driven by smart contracts is developed. It makes the Ethereum blockchain network available to authorized users and distributes a copy of the ledger to each node in the network. Consequently, the AMI and distributed ledger features of the blockchain enable secure communication between energy suppliers and purchasers using a decentralized keyless signing system".

Consumers in a given area can use the blockchain web app as a proof-of-concept for decentralized trade systems by paying prosumers in Ether for energy. **Fig 7** shows a prototype of this web application.

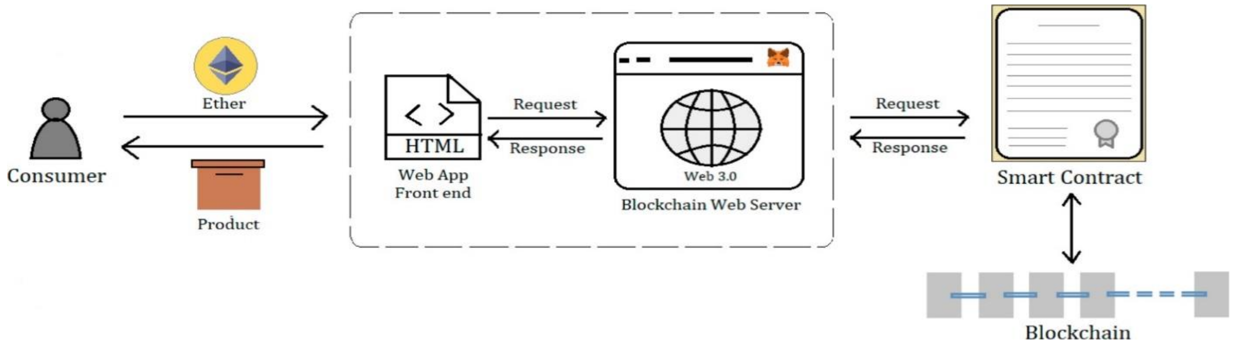

Fig 7. Model for Blockchain-Based Web Applications.

The web app's user interface (UI) is designed with an interactive HTML5 and React library of JavaScript front end. Using the web3.js package, a website may be built that communicates with the Ethereum blockchain. The Solidity programming language is used to generate the smart contract, which is then deployed on the Ethereum network. Without having to spend any actual cash, we were able to develop a prototype web application for decentralized applications (dApps). The programs known as "Ganache" is responsible for spawning and hosting a virtual Ethereum node on our computer. The user interface of Ganache features a list of accounts, each of which has a separate public and private key in addition to a balance of one hundred ether. In the context of the web app, these accounts function as the prosumer and consumer Ethereum accounts. **Fig 8** shows Ganache console.

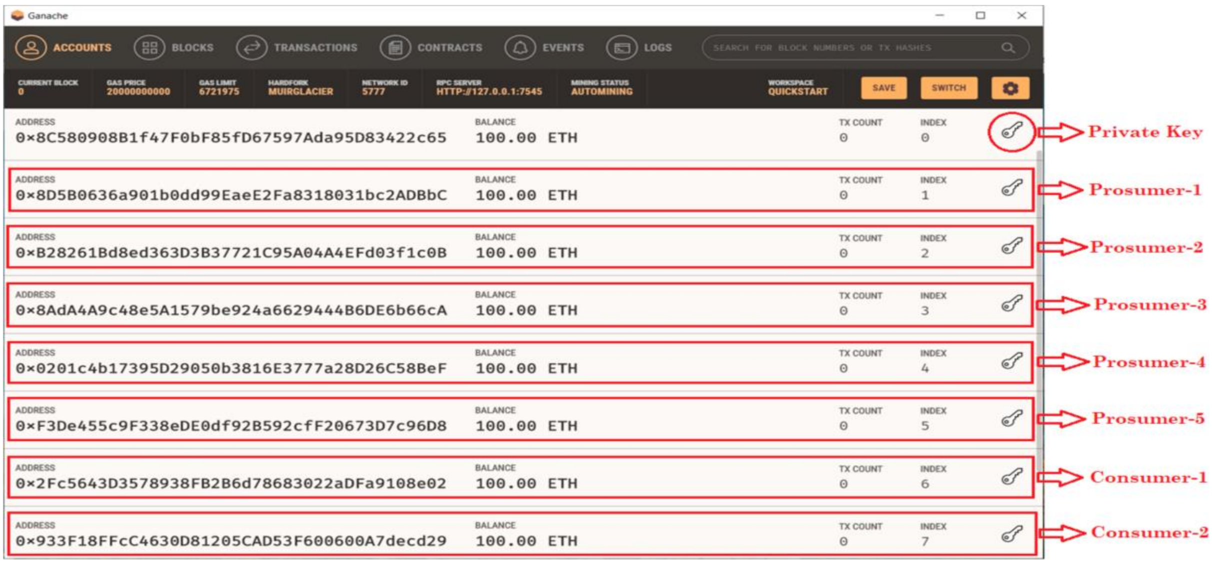

Fig 8. Ganache Console.

The term "MetaMask" refers to an extension for web browsers that provides a connection between standard web browsers and the Ethereum blockchain. When a user wants to import their Ganache account into their MataMask wallet, they need their private key to do so. To connect to our local, simulated cryptocurrency, the Main Ethereum Network in MetaMask is configured to use Localhost:7545 as the network address.

IV. RESULTS

In this "section, the experimental setup and the various parameters of the suggested procedure are discussed, and the results of those discussions are also demonstrated. The MATLAB 2020b environment is used to carry out the implementation of the suggested technique for WSN optimization. The PSO method for the optimal selection of a cluster head on a machine that has an Intel Core i5 processor running at 2.71 GHz and 8 gigabytes of random-access memory (RAM). This is carried out on a personal computer that is equipped with a hard drive that is 8 gigabytes in capacity and memory that is also 8 gigabytes in size:

Maximum number of iterations allowed is 30, swarm size is 10, inertia coefficient is 0.9, personal acceleration coefficient is 2, social acceleration coefficient is also 2, and maximum number of iterations allowed is 30. The initial energy of a node is equal to 45 units, and the position of the base station on the graph is equal to (40, 40)".

The change in the inertia coefficient from 0.9 to 0.3 takes place during the course of 30 cycles. The search landscape is traversed by the particles while concurrently the goal function is optimized in order to zero in on the most favorable site for the cluster head. **Fig 9** depicts the final state of the optimization process, where the optimal particle and its associated cost function value have been calculated. The cluster leader is the node that has the lowest distance to the base station, the most immediate neighbors, and the maximum residual energy. This node is also the one that is located closest to the ideal placement of the best particle.

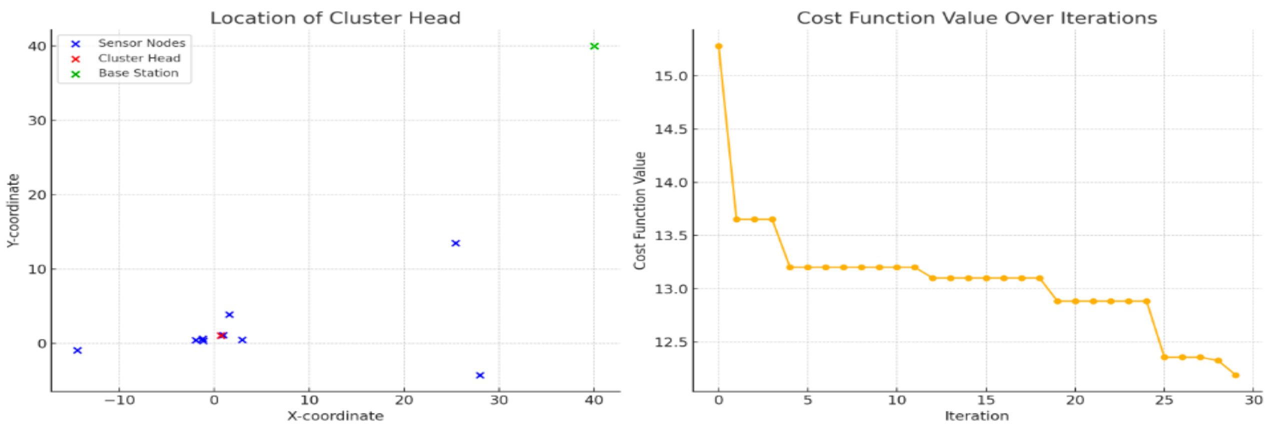

Fig 9. The Location of The CH and The Value of The Cost Function That Corresponds to It.

The overall amount of energy that is consumed by the nodes that are still alive steadily declines with each round, as shown in **Fig 10**. This is because the transmission of data causes the cluster head nodes as well as the non-cluster head nodes to lose some of their stored energy.

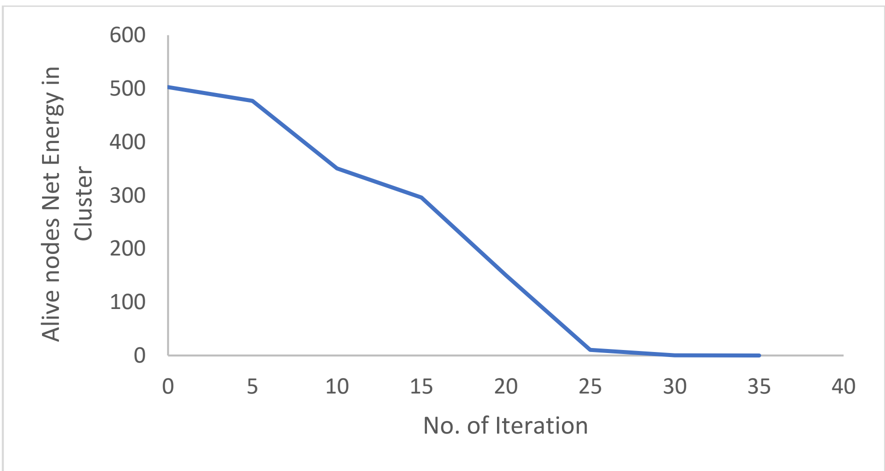

Fig 10. PSO Iterations Decrease Total Residual Energy of Living Nodes.

The PSO algorithm that has been suggested selects a cluster head node in an energy-efficient manner, which has the potential to increase the amount of network monitoring and to lengthen the lifespan of the network. The reason for this is because the non-uniform clustering technique utilized by the EEUC ultimately results in the untimely demise of cluster head nodes that are situated both very far away and very close to the sink node.

For the purpose of facilitating a quicker exchange of data and connecting all of the CH nodes to the base station, an ideal path is constructed. In order to search the network for the route that covers the shortest distance, the genetic algorithm is utilized. As seen in **Fig 11**, The first thing that needs to be done in order to put this strategy into action is to arbitrarily place a group of twenty sensor nodes on a square unit area that is 50 X 50. It is assumed that all of the nodes, with the exception of the final node, are cluster heads.

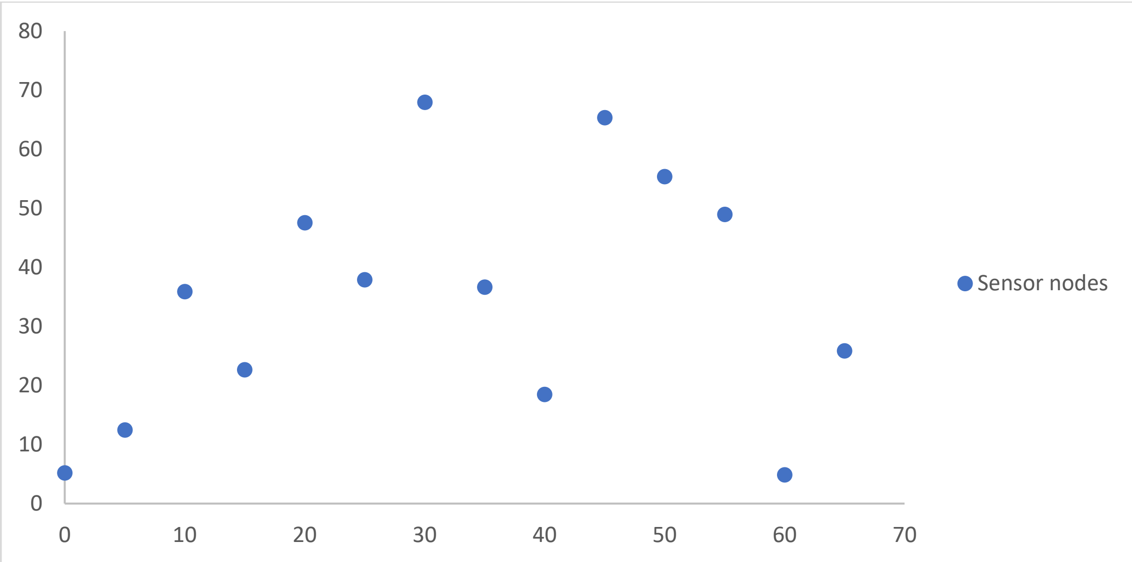

Fig 11. Locations of The Various Sensor Nodes.

Regarding The Suggested Algorithm, The Following Parameter Values are Taken into Consideration

The population is estimated to be 75, and there have been 100 generations, with Mutation rate of 0.04 and Crossover rate of 0.78. The algorithm determines which path through the network takes the least amount of time, as depicted in **Fig 12**, and it enhances the quality of each particular solution with each new generation. It generates sequences of new populations by employing operators such as selection, crossover, and mutation in order to carry out its functions.

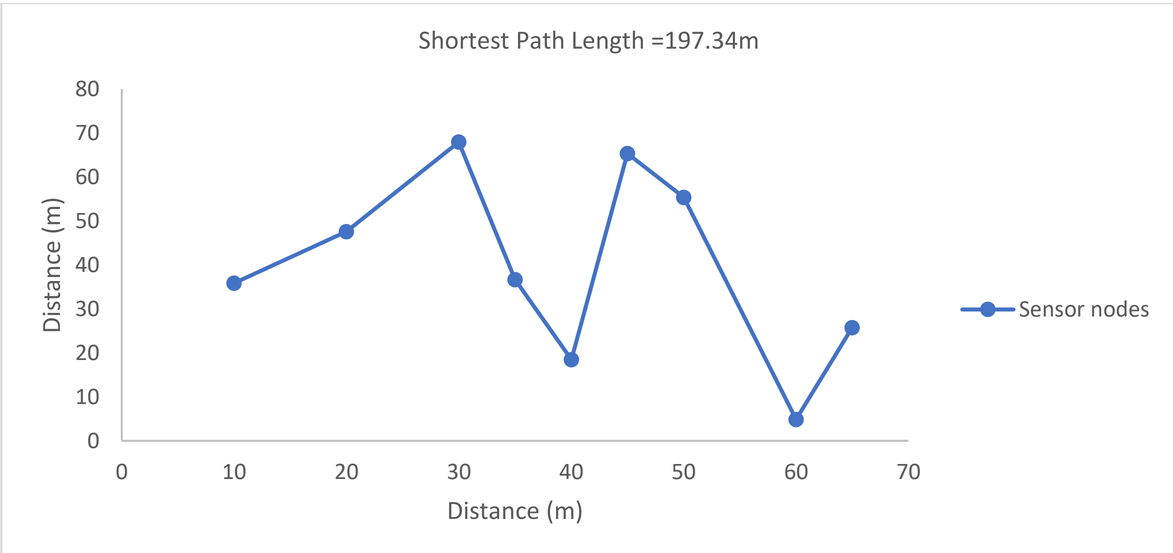

Fig 12. Genetic Algorithm Shortest Path (GA).

In only 86 generations, the GA was able to locate the best route, which was 174.27 meters in length. The effectiveness of this approach can be observed by referring to the graph of path length vs generation number that is presented in **Fig 13**.

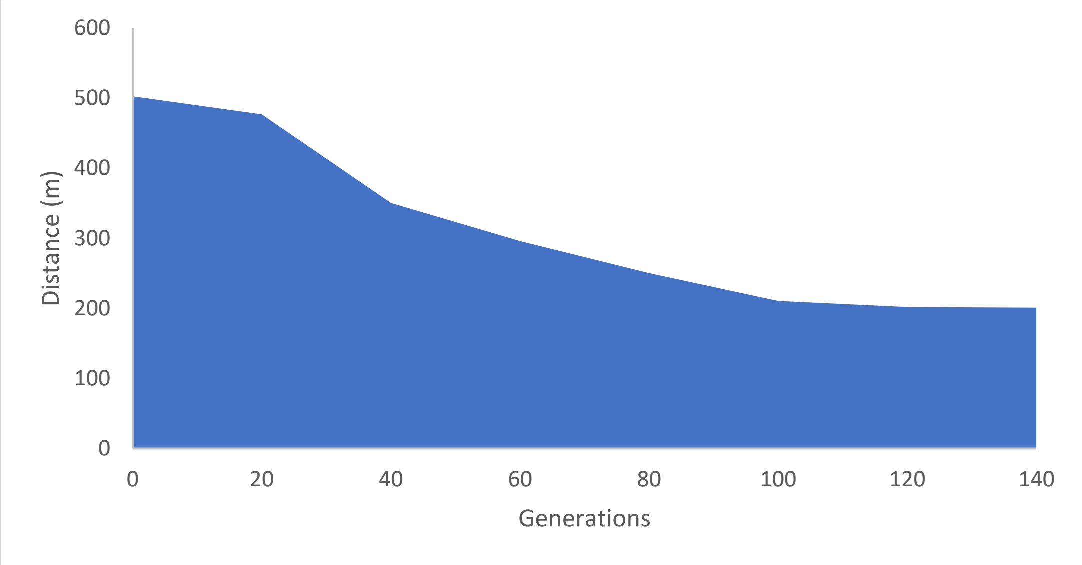

Fig 13. A graph depicting distance versus generation.

When wireless sensor networks are optimized, a blockchain-based web app can be used to facilitate P2P energy trade between individual households in real time. **Table 1** displays our web application's user interface. In this scenario, it is expected that a single PV prosumer can generate 38 kW-h of energy on an ideal day with 5 hours of direct sunlight. An average American home uses 29 kilowatt hours (kWh) of energy per day in 2019, with the average cost per kWh around $0.14 (or 0.0000938 ETH) according to a survey by the US Energy Information Administration (EIA). This online software generates energy prices and supplies based on the data provided and our assumptions.

Table 1. Metamask's Web App UI.

P2P Energy Trading System				
Sell Clean Energy				
Energy Price in ETH				
Sell				
Energy Purchase & Sale Record				
#	Electricity Supplier	Price in Eth	Public Key of Buyer	
1	Prosumer1	0.14 Eth	0 X 3Dg4587efackdf89d0923402	Buy
2	Prosumer2	0.36 Eth	0 X 2DeRFH679rjL234345DKJHYT	Sold

By entering the cost of the electricity, they generate in the appropriate field and pressing the "sell" button, prosumers can profit from the sale of renewable energy. The smart contract is written in such a way that it prevents sellers from buying their own energy. Users will be taken to their respective MetaMask wallets in order to validate their Ether payments generated by the interaction with smart contracts. When the Ethers have been successfully moved from the buyer's account to the seller's, a block containing the transaction data will be created and uploaded to the Ganache blockchain. This will happen once the transfer has been completed successfully. **Table 2** shows all energy purchases and sales are recorded by the web app.

Table 2. All Energy Purchases and Sales Are Recorded by The Web App.

P2P Energy Trading System				
Sell Clean Energy				
Energy Price in ETH				
Sell				
Energy Purchase & Sale Record				
#	Electricity Supplier	Price in Eth	Public Key of Buyer	
1	Prosumer1	0.34 Eth	0 X 2Fd59G568H54Gl4589d0923402	Buy
2	Prosumer2	0.76 Eth	0 X 1FGHGK8765EWL234345DKJHYT	Sold
3	Prosumer3	0.43 Eth	0 X 45YTVJITE678JHFD	Sold

As shown in **Table 3**, each block in the Ganache blockchain contains a list of transactions that were recently processed. This method allows us to save transaction records in a safe place, which is useful for later auditing purposes.

Table 3. Encrypted 256-Bit Transaction Hash Blocks.

Current Block 21	**Gas Price 200000000**	**Gas Limit 456789**	**MURGLACIER**	**Network ID 52345**	**RPC Server http://145.0.0.1.34**	**Status Automining**	**Workspace Quick start**
TX HASH 0 X 2Fd59G568H54Gl4589d0923402e3587FGH78549							Contract Call
FROM ADDRESS 0 X 2Fd59G5FGH78549589d092			TO CONTACT ADDRESS 0 X FGH78549567FG3421KJefh987			Gas Speed 45678	Value 344567780000
TX HASH 0 X 1GFd59Ge569GH32LKI0923402e3587FGH78549							Contract Call
FROM ADDRESS 0 X 1Gj578766eGHT567Kj4532788E			TO CONTACT ADDRESS 0 X 2Fg56781KJefh987GH56			Gas Speed 23819	Value 2300000000

If the proposed model is implemented on a public blockchain network like the "Kovan test network," users would be able to use their web browsers to pay with actual Ethers for grid energy transactions. Alternately, we can deploy the model on a private blockchain.

V. DISCUSSION

Both the “Genetic Algorithm (GA) and the Particle Swarm Optimization Process (PSO) are examples of approaches that can be utilized in order to locate the local optimal solution to a specific optimization issue. Both the genetic algorithm (GA) and the particle swarm optimization (PSO) start with a population of random solutions, explore and exploit the search space using parameters that are predetermined, and estimate the global optimal solution for a particular optimization problem”. This is evident from the fact that both begin with the same steps described above. Each algorithm's performance is highly sensitive to the values chosen for its control parameters, which change depending on the type of problem being solved. Due to the potential for excessively long computation times, our suggested technique recommends keeping the GA's population size relatively small. Protecting the population's diversity is crucial for delaying the onset of convergence. “Because of this, it's important to keep the mutation rate low so that GA may continue to converge while searching in and around the potential regions identified by the crossover operator. Furthermore, the PSO's global and local searchability can be fine-tuned by setting the starting and terminal inertia weights to optimal levels. Further, the process may be aborted before a viable solution is found if the acceleration constants c1 and c2 are set too low, while setting them too high may cause the acceleration to be too great and the particles to move too quickly throughout the search area. As a result, for particles to have smooth trajectories, the sum of c1 and c2 must be kept below or equal to 4. As a result, it is important to carefully adjust the parameters of these stochastic algorithms. The evolutionary algorithm may not provide the best answers for difficult situations, despite being simple to implement and requiring fewer processing resources. The PSO technique is suitable for low-latency applications due to its simplicity, efficiency, and robustness; yet it is computationally expensive due to its large memory requirements. These constraints provide a starting point for future work on improving data aggregation and transmission in diverse sensor networks and extending their lifetime.

According to the research that is going to be conducted on the use of blockchain technology in smart grid applications, a decentralized energy trading platform offers data that is secure and unchangeable, as well as transactions that cannot be tampered with. Smart contracts in this system make it possible to have an efficient and uncomplicated end-to-end power supply by automatically confirming and recording any trades that are carried out in the blockchain. Without the need for middlemen, it opens the door for prosumers to take an active role in the energy market and gives consumers more control over their transactions. The immaturity of the technology and the infancy of blockchain-based projects, however, impede its optimal application. Therefore, future work can concentrate on improving the scalability of the blockchain, developing incentive mechanisms for adopting blockchain-based applications, boosting decentralized power generation, and making this technology financially viable.”

VI. CONCLUSION

The primary objective of a “"smart city" is to raise the living standards of urbanites by optimizing resource use and cutting down on wasteful energy consumption and associated expenditures. The study presents a decentralized and efficient energy paradigm for smart cities. In a decentralized energy trading system, the study focuses on prosumer energy sharing and the optimization of wireless sensor networks as two key components of the smart grid. Energy-efficient routing in a wireless sensor network can be built using a bio-inspired strategy that incorporates particle swarm optimization and the genetic algorithm. Combining the two approaches allows for the execution of this strategy. Sensor nodes' power consumption can be drastically reduced with this strategy, extending the useful life of the network. Finding the shortest path connecting the cluster heads in the network for the purpose of data transmission aids in timely data distribution all the way to the base station. Blockchain technology ensures the security of communication networks and the confidentiality of massive amounts of data when used in conjunction with a smart grid. Blockchains with smart contracts can facilitate the use of consensus-based security for energy transactions. The proposed peer-to-peer energy trading system not only promotes the use of renewable energy sources in microgrids, but also aids in making sure that energy is used in an eco-friendly way."

CRediT Author Statement

The authors confirm contribution to the paper as follows:
Conceptualization: Mahamoodkhan Pathan, Rameshkumar J; **Methodology:** Rameshkumar J and Chintalapudi V Suresh; **Software:** Mahamoodkhan Pathan; **Data Curation:** Mahamoodkhan Pathan, Rameshkumar J and Chintalapudi V Suresh; **Writing- Original Draft Preparation:** Rameshkumar J and Chintalapudi V Suresh; **Visualization:** Mahamoodkhan Pathan, Rameshkumar J and Chintalapudi V Suresh; **Investigation:** Mahamoodkhan Pathan; **Supervision:** Mahamoodkhan Pathan, Rameshkumar J and Chintalapudi V Suresh; **Validation:** Rameshkumar J and Chintalapudi V Suresh; **Writing- Reviewing and Editing:** Mahamoodkhan Pathan; 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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