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A Queueing Model-Based Experimental Analysis of Mobile-Energy Distribution Stations (M-Eds) for Smart City Urbanization

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ABSTRACT

Smart devices, terminals, energy grids, houses, users, and companies united under one roof have recently grown into smart cities using various technical tools and ways to communicate, process, and exchange information. Urbanization plays a significant part in developing smart cities among the many application services that smart cities offer. Many users/consumers who live in rural areas commute daily to urban areas for jobs, school, and other purposes. There aren't many people there; therefore, building comprehensive smart city services would waste time, money, and resources. However, there is a chance that urbanization may create a small-scale industry for development and a beneficial energy grid for those living in rural areas. Building a completely functional energy grid is also challenging; one must comprehend and determine the parameters before manufacturing. To examine the incoming energy rate from rural areas connected to the primary smart city energy grid, this article presents an efficient Mobile Energy Distribution Substation (M-EDS). Every home's energy inflow rate is assessed, and resources are distributed following the queueing criteria the M-EDS has examined. Two categories—dynamic energy and fixed energy—are used to measure the rate of incoming energy. The suggested mobile energy distribution substation's performance is examined in light of these two evaluations, and its benefits and drawbacks are highlighted.

1. Introduction

The term "smart" in urbanization refers to designing an intelligent service network to improve the quality of life within cities and residents living there by utilizing Information and Communication Technology (ICT) [1]. With ICT, one cannot easily construct a smart city application rather than focusing on the concept of the service and the definition of how the devices should be connected under various lookouts. These lookouts describe the smart city under a widespread view of how it is connected under physical, social, business, and other ICT infrastructure to study the intelligence of these devices operating in the smart city [2]. Also, the supply-demand towards the connection and different functionalities of these devices are noted time-to-time [3].

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Energy flow and optimization are important issues under various application services [1]. The energy grid is key in establishing smart cities in various urban locations to connect and form an energy (electricity) network from producers to consumers via energy grids. These energy grids vary in size and cover an entire city or industry as a closed network [4]. A single energy grid consists of stations, transmissions, and other energy substations to provide clean and safe energy to the smart city's government, private, education, and other commercial sectors.

Over time, users/consumers in rural areas find it difficult to function/operate under a short life span of energy. Since many users settle or travel daily to the city for study and work, the existing rural area gets abandoned without proper maintenance and fear of accepting new technological equipment to improve the infrastructure. Researchers have suggested an optimal solution to upcoming urbanization problems towards smart city development for the past two decades. Energy grids merge non-renewable and renewable energy resources to reduce the environmental problem and provide a clean and eco-friendly system [5-8]. However, much work is needed to develop an effective energy grid in the smart city concerning the technological, economic, and governing background barriers.

1.1 Existing System and its Challenges

The existing energy grid is a super-sized infrastructure covering almost the entire city in a closed loop. The existing system consists of five components, i.e., energy generation, transmission, distribution, transformer, and retail. The energy flow is unidirectional of fixed consumer tariffs typically transmitted/forwarded through a series of stationary energy distribution systems to the appropriate appliances, as depicted in Figure 1.

Energy Generation: The source of energy generated by wind, air, solar, water, or nuclear power as they are kept far away from the civilians to be affected. Each power generator has a price for optimizing the various energy levels that must be synthesized before launching onto the grid [10-11].

Energy Transmission: Once the energy is synthesized, the energy transmission carries the heavy energy load between the cities or transmits to the nearest energy distribution substations for retail usage. Every country has a fixed policy of constructing houses or building industries near the transmission since the energy flow is decimated to a particular radius [12]. Due to the continuous draining of energy in batteries owing to the node activities like overhearing, reception and transmission [17].

Energy Distribution Substations: The EDS is a buffering agent between the energy source and retail consumers. The EDS must clearly define its construction inside the city limit to its higher officials. Since the energy is high-powered, maintenance should be done now and then because the localities gain free energy use without the authority's approval [13-14]. Also, the existing EDS is infrastructure tunnel-based construction to prove energy chances of misfiring or damage as the urban area expands for better smart city development. In general, the capacity of the energy grid is typically measured in terms of electrical power, which is expressed in units such as kilowatts (kW), megawatts (MW), or gigawatts (GW). Larger cities with high population densities and significant energy demands often require grids with capacities ranging from several hundred megawatts to multiple gigawatts. Also, the size of the energy grid is not solely determined, but it may differ according to the installation location in either urban or rural areas.

Transformer: The role of the transformer is to pass the appropriate energy to the appropriate energy holders. It converts the raw energy generated from the source to a proper synchronized energy flow to avoid misfires or decimations.

Retail: A retail can be any of the following holders smart home, government, private, or education sector who seek energy. The users/consumers inside the retail perform their daily duty according to the task assigned. Once again, the retailer must inform their usage amount of energy needed by their higher official. Doing so is prioritized, and the requested energy is granted.

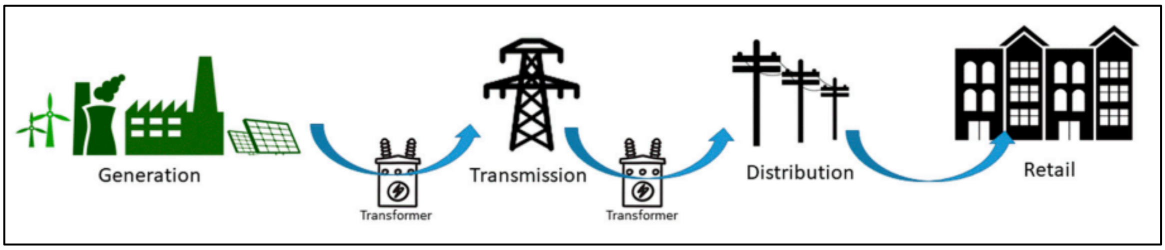

Fig. 1. Stationary Energy Distribution System

The challenges encountered in the existing system are that they are designed only for reading purposes and cannot still provide a clear-cut energy flow from one source to another due to several number interferences [15-16]. Hence, it is impractical to reconstruct further or extend the energy grid to reach the nearest rural areas.

1.2 Proposed Objectives

The primary objectives of the proposed mobile energy distribution substation are listed as follows,

- To construct a dedicated lane for M-EDS to move around at the edge of the urban area to enhance the energy grid coverage to all retail and other small-scale industries in rural areas.
- The M-EDS differentiates the incoming energy request from every individual retail invoked in the smart city application service to provide clean energy between the urban and rural areas.
- To compute the analysis of queueing factors, the M-EDS differentiates the incoming arrival rate of energy into two categories, i.e., dynamic and fixed. The performance of every energy request's processing time analysis is computed, and their merits and demerits are discussed.

This proposed work aims to analyze the incoming energy rate from every retailer based on performance towards the queueing factors used at the energy distribution substations that act as a buffering agent between the main energy of the smart city and smart homes in rural areas.

2. Proposed System

In various energy grid application services, the energy distribution substation is stationary. The energy from the transmission grid is forwarded through multiple transformers constructed around the corresponding energy distribution substation to provide energy to smart homes, retail other industries. This mechanism of constructing multiple transformers leads to overload, and sometimes it gets decimated during energy amplification. Thus, the users/consumers find it difficult to accept such substations operating between the semi-rural or semi-urban areas. To construct an effective energy distribution substation, one needs to understand the basic constraints, such as the location of the transmission grid, the number of transformers needed, and the population number of rural areas to amplify the energy seamlessly and safely.

The proposed system comprises four major components: a smart city power grid, transmission grid, M-EDS network, and transformers. These interconnected components form a closed loop of the amplification energy grid, as depicted in Figure 2.

Smart City Power Grid: The smart city power grid, also called energy source, maintains and organizes the transmission grid, mobile energy distribution substation, transformers, environment awareness, and other subunits operating under the energy source. Also, the energy source monitors the M-EDS movement and correspondingly instructs the needed energy to be distributed to the rural areas.

Transmission Grid: In modern energy grid applications, the transmission grid acts as a backbone network across the urban areas connecting to all the nearest mobile energy distribution substations in the environment. Based on the energy needed, a single transmission grid allocates two or more energy amplification to the corresponding mobile energy distribution substations or even directly to the corresponding transformer near the rural areas.

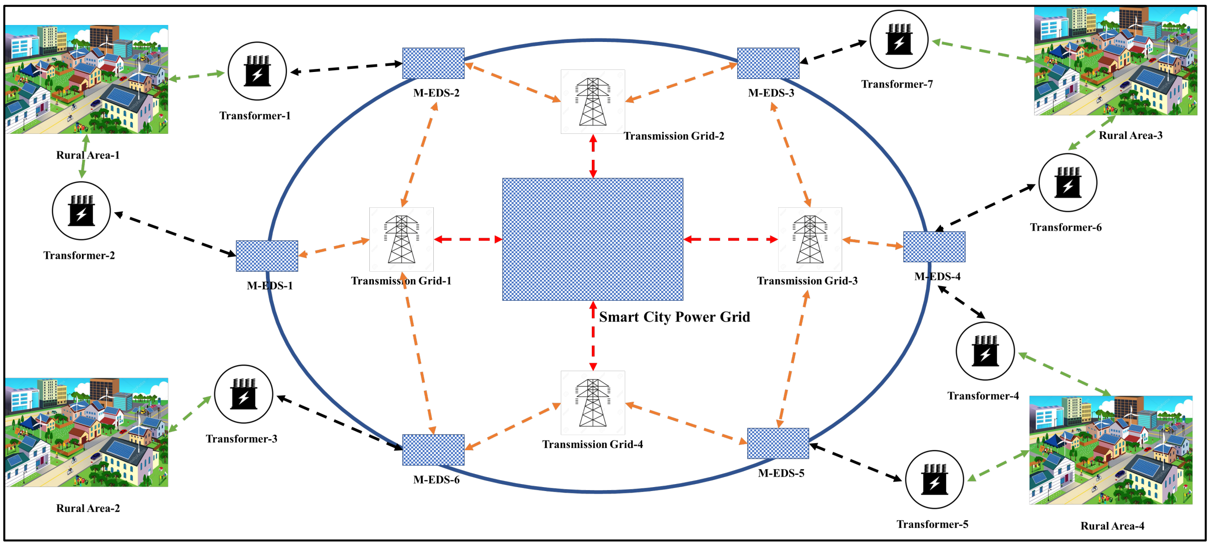

Fig. 2. Proposed Application Scenario

M-EDS Network: The intended purpose of the M-EDS network is to form an intermediate buffer agent between the transmission grid and the transformers in rural areas. A single M-EDS network consists of multiple mobile energy distribution substations that can either be stationary or move along the dedicated lane constructed by the smart city. The M-EDS are embedded with smart request/response functionality where rural retailers can request more energy transmission for their usages. Also, the M-EDS can process the requested energy and provide the necessary energy amplified to their corresponding transformers.

Transformers: The operation of transformers in energy grid applications is very similar to the existing system, where the energy is stored, amplified, and synchronized with the raw energy received by the corresponding source and converted to the proper energy flow to avoid misfires and decimations.

3. Working Process of M-EDS

The M-EDS receives energy requests from various service backgrounds separately maintained and queued in an array or storage file in the energy aggregation stage. The energy request to various backgrounds is represented in a binary code format where each code is a special resource allocation with a fixed time limit. The energy request is exchanged among the M-EDS, and the necessary energy flow is allocated to the nearest transformer to amplify in the rural area. Once the energy requested is aggregated from rural areas based on the incoming energy rate, the E-MDS notifies the classifier and analyzes the queuing factors described in Pseudocode 1.

Pseudocode 1 explains the working procedure to classify the energy request from rural retailers [9]. The same pseudocode with an enhanced version of request classification is included and tested for our M-EDS energy service. Table 1 illustrates the list of notations used in Pseudocode 1.

The working process of mobile energy distribution substations is divided into four stages: request energy aggregation, energy classifier, resource allocation, and energy amplification. At first, the M-EDS are set and deployed in the urban environment moving in a uniform direction and speed. Depending upon the energy application service, the M-EDS moves in a pre-defined waypoint to provide coverage and enhance the energy flow to all the transformers in the rural areas. Before providing the needed energy, the M-EDS communicates to the nearest transmission grid and acquires the energy needed to be distributed. The internal working architecture of E-MDS is shown in Figure 3.

Table 1
List of Notations Used in Pseudocode 1

Notations	Definitions
T_{ID}	*Transformer-ID*
T_L	*Time Limit*
TS	*TimeStamp*
E_REQ_L	*Energy Request from Transformers*
C_{CODE}	*Classifier Code from Energy Request*
$CM\text{-}EDS_i$	*Current M-EDS node*
E_Classifier	*Energy Classifier*
Req_Type	*Energy Request Type*
REQ_{ACCESS}	*Request Access for Energy Request*
$RM_{[0]}$	*Response Message with Null Value/Invalid Request*
$RM_{[Ser\_Msg]}$	*Response Message with Service*
SER_{IR}	*Service Information Request*
RES_{PRO}	*Resource Provider*
$Source_{Trans.Grid}$	*Source Transmission Grid*

Upon aggregating the energy requests, the CM-EDSi extracts the following parameters for the service information request based on their transformer-ID (TID), timestamp (TS), and request-type (Req-Type) demanding to access the needed energy for the retailer's purposes. The energy aggregator shows different energy requests from different retailers in the architecture diagram. To avoid confusion with the requested category, we have shown it in different patterns and service allocation is the database of the retailers category and delivery them the required energy level at the needed time. Once the classification is completed, the energy request is forwarded to the service allocation to obtain the needed energy to be serviced. The resource allocation in the M-EDS holds the list of energy to be provided by various retailers. It provides access and acquires the most recent updates from various energy requests indicated by the rural areas.

If the requested energy is available and matches the resource allocation, a response message and the energy request are ready for energy amplification. Once the energy is acquired, the M-EDS uses a fixed time limit used as a reference for transmitting the energy flow to the appropriate transformer in the rural area. Finally, the M-EDS updates its internal database and notifies other nearest M-EDS to avoid redundant energy transmission.

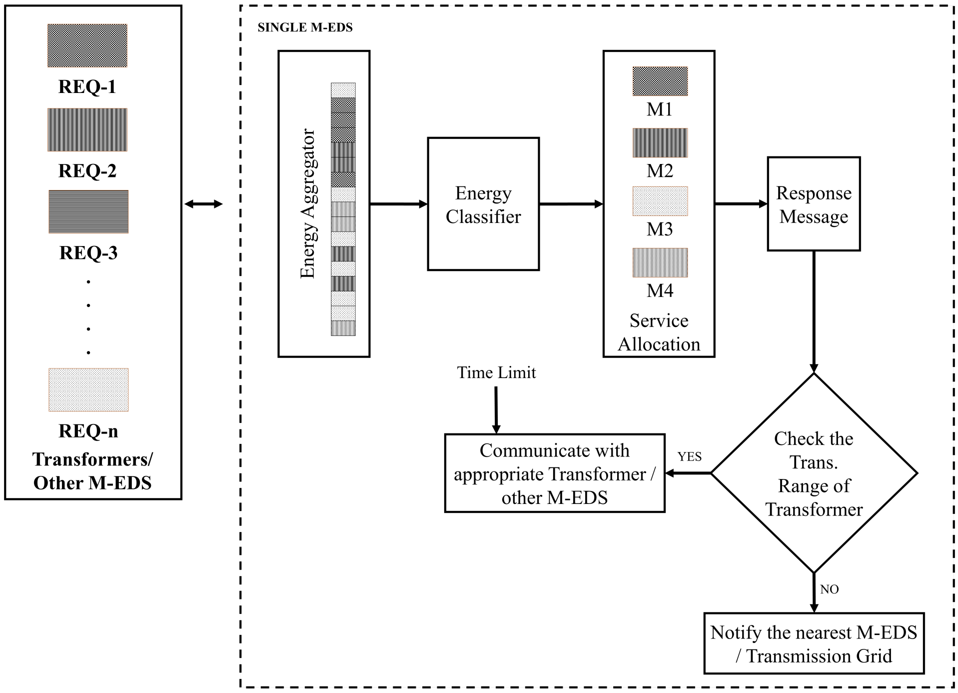

Fig. 3. Architecture of M-EDS

Suppose the requested energy is not available with the corresponding M-EDS. The information is relayed to the transmission grid as secondary support to achieve the requested energy after trying a threshold number of intermediate M-EDSs. Suppose the requested energy is not available in both SourceTrans.Grid and CM-EDSi, the corresponding CM-EDSi returns the null value/invalid response message to the requested transformer.

Pseudocode 1: *Classification of Energy Requests in M-EDS*
Input: Transmission of Energy Request (E_REQ_L) to M-EDS.
Output: Transmission of Energy flow to the appropriate transformer.
BEGIN
Initialize $CM\text{-}EDS_i$, SER_{IR}, E_REQ_L, E_Classifier, T_{ID}, TS, Req_Type, REQ_{ACCESS}, C_{CODE}, RES_{PRO}, $RM_{[Ser\_Msg]}$, $RM_{[0]}$ $Source_{Trans.Grid}$
Loop
$CM\text{-}EDS_i \longleftarrow$ **Aggregate**: E_REQ_L [SER_1, SER_2, SER_3....SERn]
E_Classifier $\longleftarrow$ **Extract**: SER_n [T_{ID}, TS, Req_Type]
$REQ_{ACCESS} \longleftarrow$ **E_Classifier**: Compare (SER_n, C_{CODE})
Search $CM\text{-}EDS_i$ (RES_{PRO}) $\longleftarrow$ REQ_{ACCESS}
if ($SER_n == RES_{PRO}$) **then**
$CM\text{-}EDS_i \longleftarrow$ **return** SER_n ($RM_{[TID, TS, Req\_Type, Ser\_Msg]}$, T_L)
elseif (SER_n != RES_{PRO}) **then**
$Source_{Trans.Grid} \longleftarrow$ **return** $CM\text{-}EDS_i$: Transmit SER_n **else**
$CM\text{-}EDS_i \longleftarrow$ **return** SER_n ($RM_{[NID, TS, Req\_Type, 0]}$, T_L)
end if
Update $RES_{PRO} \longleftarrow CM\text{-}EDS_i$ (SER_N, $RM_{[Ser\_Msg]}$ || $RM_{[0]}$)
End Loop
END

4. Role of M/M/1 Queueing Model

Queuing theory is a mathematical method to analyze the arrival, service, and departure requests estimated over the communication link between two or more stakeholders. With the help of queueing theory, the response service/message is scheduled to communicate with the appropriate stakeholder in time. The queuing theory remains valuable for understanding waiting lines, predicting system performance, and optimizing service systems. However, it is crucial to use queuing models judiciously and complement them with real-world observations and considerations to ensure accurate and effective analysis. To differentiate the incoming flow of energy rate among the E-MDS network, the M/M/1 queueing model is used under two categories of energy rates, i.e., dynamic and fixed energy rates.

Dynamic and fixed energy rates refer to different pricing models for electricity consumption. Dynamic energy rates reflect the actual cost of generating and delivering electricity at different times. They aim to incentivize consumers to shift their electricity usage to off-peak hours when the demand and costs are lower. This pricing model encourages load balancing and can help reduce peak demand and the strain on the energy grid. Fixed energy rates provide simplicity and predictability for consumers, as they can budget their energy expenses more easily since the rate remains constant throughout the day. However, this pricing model does not reflect the fluctuating electricity generation costs and may not incentivize consumers to modify their energy usage patterns to align with periods of lower demand. The choice between dynamic and fixed energy rates depends on various factors, including individual consumer preferences, the ability to adjust energy consumption patterns, the potential for cost savings during off-peak hours, and the utility company's availability and structure of rate plans.

Table 2 illustrates some queuing factors over the E-MDS network's M/M/1 queuing model as the equation derived from [9]. Upon computing these queuing factors, the E-MDS cross-verifies with its recent update with the time limit value from its internal database and decides whether to process. Suppose the corresponding E-MDS takes more time to process or realizes that the requested stakeholder moves out of sight. In that case, it intimates and relays the response message to the nearest E-MDS to provide the actual service to the appropriate stakeholder in the rural area.

Table 2
Queuing Parameters over M/M/1 Model

Parameters	Equations
E-MDS Utilization	$\rho = \frac{\lambda}{\mu}$
E-MDS Idle State	$P_0 = 1 - \rho$
Length of the System	$L_S = \frac{\lambda}{\mu - \lambda}$
Length of the Queue	$L_Q = \frac{\lambda^2}{\mu(\mu - \lambda)}$
Waiting Time in the System	$W_S = \frac{1}{\mu - \lambda}$
Waiting Time in the Queue	$W_Q = \frac{\lambda}{\mu(\mu - \lambda)}$
Processing time analysis	$Processing\ Time\ (PT) = \frac{W_S}{W_Q}$

5. Experimental Setup

The mobile-energy distribution substations are tested under two test cases of energy request arrivals, i.e., dynamic and fixed, alongside which the request classification and queuing factors are computed time-to-time. Upon experimenting with these two test cases, the M-EDS identifies the demanding service from the transformers based on the energy request concerning its queuing factors.

5.1 Computation Analysis under Dynamic Arrival Rate

The incoming arrival rate (λ) of energy packet requests depends on the transformers located at various locations in rural areas. The service rate (µ) is set to a maximum threshold value of X depending on the service demand and environmental conditions (Urban or Rural). Tables 3 and 4 represent the numerical dataset collected in measuring the queuing factors from the M-EDS under dynamic arrival rate with two different service rates, µ1 and µ2.

Table 3
Queuing analysis of M-EDS-1 under dynamic arrival rate with µ1 =1000/sec

Retailers	Queuing Factors							
	(λ/sec)	(ρ) (%)	(P_0) (%)	(L_S)	(L_Q)	(W_S) (sec)	(W_Q) (sec)	(PT)(Energy
1	20	0.02	0.98	0.02	0	3.67	0.07	50
2	880	0.88	0.12	7.333	6.453	30	26.4	1.14
3	790	0.79	0.21	3.762	2.972	17.14	13.54	1.27
4	140	0.14	0.86	0.163	0.023	4.19	0.59	7.14
5	520	0.52	0.48	1.083	0.563	7.5	3.9	1.92
6	440	0.44	0.56	0.786	0.346	6.43	2.83	2.27
7	70	0.07	0.93	0.075	0.005	3.87	0.27	14.29
8	580	0.58	0.42	1.381	0.801	8.57	4.97	1.72
9	560	0.56	0.44	1.273	0.713	8.18	4.58	1.79
10	820	0.82	0.18	4.556	3.736	20	16.4	1.22

Table 4
Queuing analysis of M-EDS-2 under dynamic arrival rate with µ1 =1000/sec

Retailers	Queuing Factors							
	(λ/sec)	(ρ) (%)	(P_0) (%)	(L_S)	(L_Q)	(W_S) (sec)	(W_Q) (sec)	(PT) (Energy/sec)
1	900	0.9	0.1	9	8.1	36	32.4	1.11
2	20	0.02	0.98	0.02	0	3.67	0.07	50
3	880	0.88	0.12	7.333	6.453	30	26.4	1.14
4	790	0.79	0.21	3.762	2.972	17.14	13.54	1.27
5	140	0.14	0.86	0.163	0.023	4.19	0.59	7.14
6	520	0.52	0.48	1.083	0.563	7.5	3.9	1.92
7	490	0.49	0.51	0.961	0.471	7.06	3.46	2.04
8	200	0.2	0.8	0.25	0.05	4.5	0.9	5
9	300	0.3	0.7	0.429	0.129	5.14	1.54	3.33
10	570	0.57	0.43	1.326	0.756	8.37	4.77	1.75

At the service rate µ2, the same arrival rate value from M-EDS-1 and M-EDS-2 is tested with the service rate µ2 = 2000/sec, which follows the same routine principle in measuring the queuing factors as shown in Tables 5 and 6. Since the E-MDS are mobile, the queuing factors among them vary time-to-time.

Table 5
Queuing analysis of M-EDS-1 under dynamic arrival rate with µ2 = 2000/sec

Retailers	**Queuing Factors**							
	(λ/sec)	**(ρ) (%)**	**(P_0) (%)**	**(L_S)**	**(L_Q)**	**(W_S) (sec)**	**(W_Q) (sec)**	**(PT) (Energy/sec)**
1	20	0.01	0.99	0.01	0	1.82	0.02	100
2	880	0.44	0.56	0.786	0.346	3.21	1.41	2.27
3	790	0.395	0.605	0.653	0.258	2.98	1.18	2.53
4	140	0.07	0.93	0.075	0.005	1.94	0.14	14.29
5	520	0.26	0.74	0.351	0.091	2.43	0.63	3.85
6	440	0.22	0.78	0.282	0.062	2.31	0.51	4.55
7	70	0.035	0.965	0.036	0.001	1.87	0.07	28.57
8	580	0.29	0.71	0.408	0.118	2.54	0.74	3.45
9	560	0.28	0.72	0.389	0.109	2.5	0.7	3.57
10	820	0.41	0.59	0.695	0.285	3.05	1.25	2.44

Table 6
Queuing analysis of M-EDS-2 under dynamic arrival rate with µ2 = 2000/sec

Retailers	**Queuing Factors**							
	(λ/sec)	**(ρ) (%)**	**(P_0) (%)**	**(L_S)**	**(L_Q)**	**(W_S) (sec)**	**(W_Q) (sec)**	**(PT) (Energy/sec)**
1	900	0.45	0.55	0.818	0.368	3.27	1.47	2.22
2	20	0.01	0.99	0.01	0	1.82	0.02	100
3	880	0.44	0.56	0.786	0.346	3.21	1.41	2.27
4	790	0.395	0.605	0.653	0.258	2.98	1.18	2.53
5	140	0.07	0.93	0.075	0.005	1.94	0.14	14.29
6	520	0.26	0.74	0.351	0.091	2.43	0.63	3.85
7	490	0.245	0.755	0.325	0.08	2.38	0.58	4.08
8	200	0.1	0.9	0.111	0.011	2	0.2	10
9	300	0.15	0.85	0.176	0.026	2.12	0.32	6.67
10	570	0.285	0.715	0.399	0.114	2.52	0.72	3.51

The merit of the above test case is that the service rate is set to a maximum threshold of µ1 and µ2, to which the E-MDS can receive a range between 0 to N-1 energy requests from the retailers for every time interval Ti. From the computed values, the M-EDS computes its average server utilization concerning its reference index as a checker and decides whether the corresponding M-EDS can provide the essential service requested by stakeholders in time. There is also an alternative working process of the M-EDS to provide the actual service to the requested stakeholders, i.e., without computing the average server utilization. However, the alternative mechanism can expect a drastic measure of resource provisioning needed to process the energy request now and then, leading to this scenario's demerit using a dynamic arrival rate.

5.2 Computation Analysis under Fixed Arrival Rate

The incoming arrival rate (λ) acquires a pre-defined amount of energy requests from the retailers. The service rate (μ) is dynamic if the M-EDS takes more time to process the energy request. In contrast to the dynamic arrival rate, Tables 7 and 8 represent the overall numerical analysis measured from the queuing factors under the retailer's fixed arrival rate of energy requests.

Table 7
Queuing analysis of M-EDS under Fixed arrival rate with μ1 = 1000/sec

Retailers	Queuing Factors							
	(λ/sec)	(ρ) (%)	(P_0) (%)	(L_S)	(L_Q)	(W_S) (sec)	(W_Q) (sec)	(PT) (Energy/sec)
1	450	0.45	0.55	0.818	0.368	6.55	2.95	2.22
2	450	0.45	0.55	0.818	0.368	6.55	2.95	2.22
3	450	0.45	0.55	0.818	0.368	6.55	2.95	2.22
4	450	0.45	0.55	0.818	0.368	6.55	2.95	2.22
5	450	0.45	0.55	0.818	0.368	6.55	2.95	2.22
6	450	0.45	0.55	0.818	0.368	6.55	2.95	2.22
7	450	0.45	0.55	0.818	0.368	6.55	2.95	2.22
8	450	0.45	0.55	0.818	0.368	6.55	2.95	2.22
9	450	0.45	0.55	0.818	0.368	6.55	2.95	2.22
10	450	0.45	0.55	0.818	0.368	6.55	2.95	2.22

Table 8
Queuing analysis of M-EDS under Fixed arrival rate with μ2 = 2000/sec

Retailers	Queuing Factors							
	(λ/sec)	(ρ) (%)	(P_0) (%)	(L_S)	(L_Q)	(W_S) (sec)	(W_Q) (sec)	(PT) (Energy/sec)
1	450	0.225	0.775	0.29	0.065	2.32	0.52	4.44
2	450	0.225	0.775	0.29	0.065	2.32	0.52	4.44
3	450	0.225	0.775	0.29	0.065	2.32	0.52	4.44
4	450	0.225	0.775	0.29	0.065	2.32	0.52	4.44
5	450	0.225	0.775	0.29	0.065	2.32	0.52	4.44
6	450	0.225	0.775	0.29	0.065	2.32	0.52	4.44
7	450	0.225	0.775	0.29	0.065	2.32	0.52	4.44
8	450	0.225	0.775	0.29	0.065	2.32	0.52	4.44
9	450	0.225	0.775	0.29	0.065	2.32	0.52	4.44
10	450	0.225	0.775	0.29	0.065	2.32	0.52	4.44

The merit of this approach is that the incoming arrival rate of energy requests is set to a minimum threshold. The M-EDS can provide adequate data on the retailer's location in processing the requested energy. Like the dynamic arrival rate approach, the M-EDS work in two ways: deciding whether the M-EDS can provide the actual service to the retailer, i.e., by computing the requested energy based on the average server utilization or without average server utilization. Either way, this approach's demerit is that the requested energy lacks data priority due to substantial data contention from multiple retailers leading the response service or message to be buffer overfilled or decimate one another.

6. Conclusion and Future Enhancements

In this paper, we have proposed a mobile energy distribution substation (M-EDS) with a dedicated lane constructed at the edge of the smart city to enhance coverage and synthesize the energy flow of transmission between the city and rural areas. The architecture of M-EDS consists of four stages; request energy aggregation, energy classifier, resource allocation, and energy amplification. Before providing the needed energy, the M-EDS communicates to the nearest transmission grid and acquires the energy needed to be distributed. The incoming energy rate is measured under two categories, i.e., dynamic and fixed energy. Based on these two analyses, the performance of the proposed mobile energy distribution substation is analyzed, and the merits and demerits are discussed.

In dynamic arrival rate, the service rate is set to a maximum threshold of µ1 and µ2, to which the E-MDS can receive a range between 0 to N-1 energy requests from the retailers for every time interval Ti. However, this mechanism of dynamic arrival rate can expect a drastic measure of resource provisioning needed to process the energy request now and then.

The incoming arrival rate of energy requests is set to a minimum threshold in a fixed arrival rate. The M-EDS can provide adequate data on the retailer's location in processing the requested energy. However, this mechanism lacks data priority due to substantial data contention from multiple retailers leading the response service or message to be buffer overfilled or decimate one another.

The mobile energy distribution substation can further be improved in the following ways for future enhancements. Firstly, the mobile energy distribution substation be tested in a real-time environment, where the experimental analysis's pros and cons are identified. Secondly, the mobile energy distribution substation embeds various security aspects of authentication and other key exchange cryptography mechanism for service access to avoid unnecessary resource allocation and queuing processes.

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