International Journal of
INTELLIGENT SYSTEMS AND APPLICATIONS IN ENGINEERING

ISSN:2147-6799 www.ijisae.org Original Research Paper

An Optimal Time Constraint Algorithm for Energy Consumption in Hetrogeneous Mobile Networks

Kavin Francis Xavier[1], Geetha Vadnala[2], Gaganpreet Kaur[3], Meena Malik[4], Dr. Shashikant Patil[5], Ram Kishun Lodhi[6*]

Submitted: 11/01/2024 **Revised**: 17/02/2024 **Accepted**: 25/02/2024

Abstract: Ever-increasing information had led to a huge increase in mobile network energy consumption. Recent advancements in heterogeneous mobile networks and ground stations powered by renewable energy are present in the mobile communications sector. In this study, we explore the reasons, problems, and options for addressing the issue of lower electricity costs for these heterogeneous grids. With the variety of issues on traffic and energy consumption, low-cost electricity requires both spatially and temporally the allocation of resource optimization. Then it shows how to merge the improved green power time allocation and the dispersal of space cell traffic into a new approach. A proposed methodology is developed in four phases such as energy forecasting, customer association, green energy reallocation, and optimization. The whole optimization problem is broken down into four sub-problems. The results of the simulation show that the approach we propose may significantly reduce electricity prices.

Keywords: *Heterogeneous Mobile Network; Optimization; Power consumption; Phtotovoltic energy; Spatial cellular traffic*

1. Introduction

With the widespread use of mobile phones & bandwidth-hungry apps, wireless mobile networks had seen substantial growth in traffic. For both industry & academia, many ways to lower the base station's power usage had been investigated. The heterogeneous mobile network (HetNet), comprised of multiple types of base stations with varying transmission strengths & coverage zones, is viewed as one of these [1]. The heterogeneous network design is typified by the extremely dense arrangement of power-efficient small base stations within a large macro-cell. In order to improve loss of path scenarios, smaller base stations are positioned closer to the end users, enabling lower transmission capacity. As a result, Heterogeneous networks with such a highly dense placement of reduced power tiny base stations are thought to consume much less energy than Heterogeneous networks with a reduced power placement of high-energy macro base stations [2].

According to reports, the telecommunications industry is responsible for nearly 2 percent of global CO2 emissions, with that number anticipated to quadruple by 2020. Incorporating certain solar panels, like solar & wind electricity, into current mobile networks had lately been another author's priority to minimize carbon emissions. E-Plus, a German phone operator, had introduced the first generation of green base stations using exclusively wind & solar energy. E-Plus could result in 0 Carbon dioxide emissions if it is not powered by on-grid power [3]. It also allows for Base stations which include solar energy & on-grid power sources.

Network structure in which both macro & pico Base stations were equipped with renewable power collecting equipment & on-grid power. Renewables are substantially less expensive overall than on-grid electricity, but it is even free [4]. As a result, reducing overall power usage without distinguishing between different sources of energy is insufficient. Therefore, because renewable power is becoming more affordable, lowering overall power costs could be similar to lowering Carbon dioxide emissions.

The load distribution of traffic in HCN-HES shows spatially and temporally changes, but so does the renewable power gathering. Consequently, the least cost issue necessitates both geographical and temporal allocation of resources efficiency. The objectives, problems, & methods for power reducing costs inside the HCN-HES are then discussed. We could see that the approach including optimization both in the balancing of spatial traffic and temporal renewable power allotment may acquire the lowest energy price [5]. The comparison indicates that by properly designing an allocation of resources method, it is possible to achieve power reduction in costs. While some conventional technologies, such as user association and base stations used to maximize renewable energy to balance space traffic. It has not been combined with time-based renewable energy allocation. After that, we provide a novel approach that integrates both temporal renewable

[1]*M/S Muscat Engineering Consultancy Pvt. Ltd, Trichy-620001, Tamil Nadu, India. fkavin@gmaiil.com*
[2]*Department of CSE, Madanapalle Institute of Technology & Science, Andhra Pradesh, India, geethav@mits.ac.in*
[3]*Chitkara University Institute of Engineering and Technology, Chitkara University Punjab, India, drgaganpreetcse@gmail.com*
[4]*University Centre for Research & Development,Chandigarh University, Punjab, India. meenamlk@gmail.com*
[5]*Department of CSE, Atlas SkillTech University, Mumbai, India, sspatil999@gmail.com*
[6]*Department of Applied Science, Symbiosis Institute of Technology [SIT], Symbiosis International (Deemed University) [SIU], Lavale, Pune-412115, Maharashtra, India*
ramkishun.lodhi@gmail.com
Corresponding Author Email: ramkishun.lodhi@gmail.com

power allotment and the geographical distribution of cellular traffic. In a model, compare our proposed solution to 2 peer methods, one of which is an approach without allocation of resources optimization while the other is a technique with spatial domain optimization alone, to show its potential for large power reducing costs. Moreover, for realistic network operations, its dispersed variant with minor efficiency decrease is rather simple to construct.

2. Related Works

Our framework incorporates a HetNet with 2 kinds of Base stations: macro & pico, with macro BSs spanning a greater region, and pico Base stations within macrocells spanning a smaller space (Figure 1).

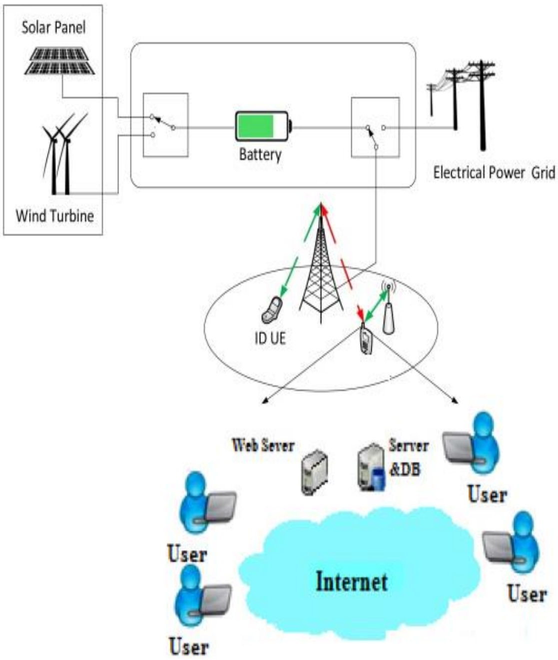

Fig 1: Structure of Heterogeneous Mobile Network Using Hybrid Energy Providers

Due to the accessibility of renewable radiation and the high efficiency of industrial photovoltaic (PV) panels, solar energy is rated the most suitable of all renewable power options [6]. They concentrate on PV innovation as a source of renewable power in this paper due to the space constraints, but most of the discussion that follows applies to other power sources as well [7]. The energy consumption of a pico Base station is magnitudes lower than that of normal macro Base stations due to infrastructure variations between the two. As a result, a macro Base station must be provided with a bigger PV panel & a higher storage cell capacity to ensure proper operation [8].

2.1 Materials and Methods

Renewable electricity production could have both temporal and spatial variations in general. Solar energy production, e.g., is influenced by a variety of elements like temp, sunshine intensity, and the placement of a solar module [9]. Hybrid power generation, which combines power from an electric grid with a renewable power harvester, had lately emerged as a viable alternative. The hybrid-powered Base stations are equipped with both grid-connected & stand-alone renewable energy production. Whenever the realistic energy demand surpasses the renewable power storage, solar energy could be used to decrease on-grid energy usage [10]. Alternatively, depending on the traffic load & renewable power storage, they could switch between different energies at various time intervals [11]. As a result, switching strategies must be properly constructed to favor the use of renewable power.

Even though the solar generation process is reliant on the position of Photovoltaic panels & weather conditions, realistic observations may be utilized to construct a predictive model that could be utilized to direct hybrid-powered Base station processes [12]. We utilize the PVWatts model for forecasting hourly solar power production in Bangalore in this post. The average solar energy generation pattern is presented based on observed information of a typical day, with energy storage rates collected every 10 mins. We can observe that power generation begins at 7 a.m., increases to around 1 p.m, maximum at around 1 p.m, and then ceases around 6 p.m. during sunset. Although weather variables affect charging rates, the general charging pattern is consistent across days [13].

In the European program ERATH [14], an energy usage model was presented to quantify every Base station's energy use. The user's information transmission transmits energy from its linked Base station

$$a = \frac{e \tan(\beta + \beta_a)}{\cot\rho + \tan(\beta + \beta_a)} \quad (1)$$

$$b = \frac{e \tan \beta_b}{\cot\rho + \tan(\beta + \beta_a)} \quad (2)$$

is the Base station's dynamic power usage when it becomes active, as a result of signal analysis, wave voltage blocks, and other factors. And Asleep is the energy usage when the Base station has been in sleep mode & no customer is connected to it.

Mobile traffic is highly diverse in terms of both time & space [15]. The following is an e.g., of a regularly utilized peak & off-peak design. The peak & off-peak periods of mobile traffic are distinguished by their temporal behaviors. The top hours are 10 a.m. – 6 p.m., while the off-peak hours were 1 a.m. – 5 a.m. The number of customers in a given period could be modeled as uniformly distributed with an average value derived from past data. Figure 2 shows an example of a mobile traffic pattern.

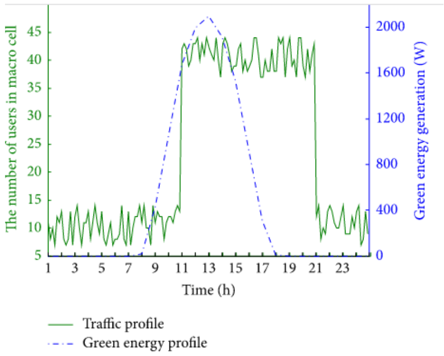

Fig 2: Observation of Energy Collected and Mobile Traffic Patterns

2.2 Cost Minimization in HCN-HES

With an exemplary scenario, they first describe the incentives for power reducing cost, then analyze the problems & review the techniques to fix this issue. The bulk of a mobile network's operating costs are determined by the energy usage price of base stations, as was previously mentioned [16]. When HetNet is implemented, a client may be in the coverage areas of multiple Base stations simultaneously. Customers can choose a Base station with a lesser transmitted power without sacrificing their service requirements thanks to this [17]. As a result, with HCN-HCS, cutting back on power consumption alone isn't always enough; in some circumstances, increasing the use of renewable energy is better because it produces goods at a lower cost and emits fewer greenhouse gases [18]. Utilizing as much saved solar energy as possible inside the present RCTL15, on either hand, may not have been a viable approach, as newly created renewable power might not be sufficient to fulfill the traffic load in the following RCTL15. Analyze a basic network situation with two neighboring Base stations, Base Station 1 and Base station S2, & 2 sequential RCTL15s, RCTL151 & RCTL152, to demonstrate the viability of power reducing cost. In RCTL15 1, the network had 8 customers: from user1 to user 8 whereas in RCTL15 2, in addition to the current option 3, a new customer, a user4, enters the network. They used a simple unit price of 1 for on-grid power & 0 for renewable power [19-20].

A "no optimization" technique is depicted in Figure 3. User 1 & user 2 were linked to Base station 1 in RCTL15 1 & utilized 2 & 3 units of energy from it, accordingly. User 4 is connected to Base Stations 2 & uses one unit of electricity. Base Station 1 & Base Station 2 in RCTL15 1 can, of course, also be powered by renewable power. After RCTL15 1, Base Station 1 & Base Station 2 have 3 - 7 units of renewable power storage, correspondingly. The new user 4 at RCTL15 2 is linked to Base station 1 and uses 3 units of energy. Overall energy consumption rises to 8 units, which is more than Base station 1 renewable energy store of 3 units. As a result, Base Station 1 must be supplied by on-grid electricity & uses 8 units. As a result, the overall energy price of 2 RCTL15 comes to 8 units.

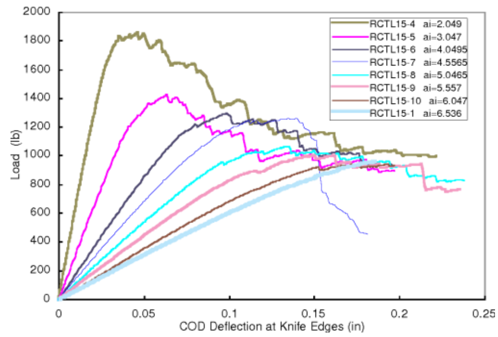

Fig 3: Possibility of Energy Costs Reduction at Knife Edges on 8 Slots

Optimization of the spatial traffic balancing technique is depicted in Figure 3. The network activity in RCTL15 1 is identical to that described before. In RCTL15 2, BS1's renewable power storage is insufficient to service 3 users: user 1, user 2, & user 4, while user 1 & user 4 are farther away from Base Station 2 to be served by Base Station 2 [21]. To maximize spatial traffic balancing, Base Station 1 decreases the coverage area & offloads user 2 to Base Station 2. As an outcome, Base Station 1 requires 5 units of on-grid electricity to run on. In addition, Users 2 and 3 can both be served by base station 2's renewable energy supply [22]. The combined cost of energy of the 2-time frames is 5 units, and less than the "no optimization" option. Assume they could predict base station 1 traffic growth in the next RCTL15. They could start by allocating some renewable power between the two RCTL15s & reserving extra renewable power in RCTL15 2 for Base Station 1 energy need [23]. Assume they distribute 3 units of renewable power to Base station 1 in RCTL15s 1 & 5 units of renewable power to Base station 2. As a result, in RCTL15 1, Base station 1 limits its coverage area & off-loads user2 to Base station 2 to only utilize the renewable power allotted to it. Both Base stations could be fueled by renewable power because Base station 2 available renewable power is adequate to sustain either user 2 & user3. In RCTL15 2, they assign 6 units of renewable power to Base station 1 and 4 units of renewable power to Base station 2. To equalize the spatial traffic dispersion, User 2 is still linked to Base station 2. As a result, both Base station1 and Base station 2 can run on renewable power, and the overall energy price of 2-time RCTL15s was zero [24]. In comparison to the previous two solutions, they can see that by carefully designing an allocation of resources method, could not only traffic dispersion be managed, and also renewable power use could be optimized, resulting in lower energy costs [25].

3 Proposed Methodology

Depending on the sample case above, they may deduce that every Base Stations' energy cost is affected not only by its linked customers but also by its renewable power allocation. As a result, our objective is to find single user-Base Station association matrices and a renewable power allotment vector that lessens power charges while still meeting network QoS benchmarks.

$$R(a,\sigma) = \sum_{j=1}^{m} \sigma_j(a) R_j(\sigma) \quad (3)$$

$$\beta_a = tan^{-1}\left(\frac{f_a}{m}\right) \quad (4)$$

$$\beta_b = tan^{-1}\left(\frac{f_b}{m}\right) \quad (5)$$

The maximal transmission energy budget for every Base station is a limitation. Constraint C4 states that the amount of green energy allocated to each Base Station cannot exceed the sum of its cumulative renewable power and the amount of power generated in the current RCTL15. Constraint c5 demonstrates that renewable power has a lessen unit price than on-grid electricity.

Solar energy-aware consumer association, Base station sleeping, & combined renewable power allotment & spatial traffic balancing techniques are among the techniques designed to approach the price reduction issue from various aspects.

Solar Energy-Aware: In [26], they proposed renewable power-aware consumer association techniques for an HCN-HES that minimize overall power expense while ensuring customers' data rate needs. That has two levels of optimization: The first is to minimize overall power consumption across all Base stations by obtaining an initial consumer association strategy that prevents later customer re-association from lowering overall energy consumption. Because the energy requirement for every Base station must not perfectly fit the renewable power storage, the second step involves adjusting certain user-Base Station associations to ensure that renewable power storage is fully utilized across all Base stations. Base stations with much more residual renewable power, in particular, must serve more customers who have been previously linked with Base stations supplied by on-grid electricity, as long as renewable power is still available. Even though, these techniques only consider energy reduction in costs in one RCTL15, ignoring the dynamics of customer traffic & renewable power charging inside the temporal domain.

As previously stated, the power price minimization challenge in an HCN-HES includes both spatially and temporally allocation of resources optimization due to the diversity of traffic patterns & charging processes. Additionally, optimization inside one domain is inter-leaved including optimization in another domain, making this a difficult challenge to tackle. On the one side, based on past data, could apply an estimation method to forecast traffic & power arrival processes. It could find an optimum solution like all uncertainty is erased as long as such forecasts are right. These predictions, on either side, might not perfectly match the real traffic & power distribution. As a result, they might need to make certain allocation of resource adjustments based on the current scenario. As a result of these factors, our proposed approach includes both off-line & online methods.

The overall energy reduction problem, renewable power allotment issue, consumer association problem, & renewable power reallocation problem are all sub-problems of the energy least cost issue. As a result, our solution is divided into four phases, each of which addresses one of the sub-problems. The User association & green energy reallocation algorithms are online methods that run for each RCTL15 & are based on real-world mobile traffic & renewable power allocations.

The energy consumption estimation method uses cellular traffic spatially and temporally characteristics to calculate an approximate annual energy consumption pattern for every Base station. They employ the closest association strategy to get a minimum overall energy usage provided a single instance of customer dispersal, whereby each consumer is associated with its closest Base station. To acquire the estimated average energy usage profile for every Base station for each RCTL15, the energy consumption estimation algorithm must be run numerous times. If this isn't the situation, the green energy allocation method will decrease past time RCTL15 allocations in allocating the needed renewable power to the present time RCTL15.

There are two stages to the centralized User association method. It is frequently hard to collect all network data & coordinate between various Base stations inside an HCN-HES. Then, they present a low-complexity dispersed User association algorithm that provides a multiplicative path gain biasing factor to every Base station for each lot, allowing additional consumers to be off-loaded to the Base station with enough renewable power:

$$B(a,\sigma) = \beta\cos\theta\ R(a,\sigma)f(\sigma) + \alpha\frac{E(\emptyset)H(X,Y,Z)W(\theta,m)}{\cos\theta}D(\sigma)\ (6)$$

Depending on the green energy reallocation algorithm adjusts the renewable power allotment vector. It's worth noting that the amount of renewable energy consumed might differ from the amount allotted for each RCTL15. The green energy reallocation algorithm redistributes the excess renewable power into the subsequent RCTL15s by the previously allocated renewable power quota for every upcoming RCTL15.

3.1 Limitations

The overall electricity price was based on the power usage of every BS and the power source used throughout the period, as shown further under Chapter 3.1. The energy usage of every base station is determined by how bandwidth was distributed across several base stations in a single terminal. The electric power was determined by every base station's power usage and renewable power collection. Renewable collection, and from the other side, was related to the charging process of self BS all through time. As a consequence, the subject of reducing electricity prices presents momentous hurdles for integrative planning for both the spatial-spectral domains and Spatial Traffic Balancing. According to a higher available bandwidth of micro base stations than tiny BSs, in a Hornet having the smooth installation of tiny base stations inside the service of micro base stations, an unequal network congestion allocation was items utilized even without any adequate congestion matching method in the spatial structure. Still, not only all the energy usage of every base station and the accessible coal power should indeed be considered in optimizing power use in HCN-HES. The accessible renewable power across various BSs might demonstrate variability during a given period. To maximize the amount of renewable power available in each space, the energy consumption between different BSs must be optimised based on the renewable power allotted to each HPBS. The base stations that were allocated significantly more renewable power were reserved so they could accommodate more customers while still operating at full capacity.

Renewable Management on a Time Scales. On only one side, the renewable power produced in one period would never be used in subsequent periods for every unique HP-base station. But at the other side, because the amount of renewable power obtainable for a one-time frame would be established by the amount of clean power created in that prime time and the amount of renewable power from the last several spaces, inordinate use of renewable power in the existing vacant spot would then outcome in a prospective shortfall of clean power generation. As an outcome, every HP-base station's renewable power distribution over multiple periods must be adjusted in an attempt to optimize its long-term efficiency. In such a Timeframe, Clean Energy Planning Solely on a single hand, the sustainable energy generated during a period would not be used in the following durations for every individual HP-base station.

However, since the quantity of clean energy available power for a specific timeframe has been affected by the quantity of smooth energy generated during that network television and the quantity of wind energy out from previous some many rooms, excessive the using solar electricity in the current bench position might result in a potential spotless power generation funding gap. As a result, the renewable energy allocation of each HP-base station should be changed throughout numerous periods to maximize its lengthy performance.

4 Result And Discussion

A multiple different communication modem with 7 micro units and 4 tiny units equitably spread within every mobile terminal was considered. Most BSs have used both on and solar panels, having varying prices of solar power collecting. The connection weights, and variables, are listed in Table 1. Used the Pewits methodology to anticipate daily average solar power production in Bangalore City for said renewable power able to charge concept. The time features for user traffic could be described as two various stages, according to the survey data in [27]: overall high season and off time. Its number of customers was spread evenly together around a median rate of 40 users during the high season, and 10 users during the off-peak time. Moreover, Smartphone browsers were spread equally throughout the system in the feature space. Solar power production pattern and a traffic information graph, respectively. A standard closest connection method and the greatest renewable power utilization method are compared to the proposed policies.

Table 1. Characteristics and Attributes of the Network

Characteristics	Attributes
The radius of Macrocell	500 meter
Bandwidth	15 MHZ

Max Power Transmit	45 dBm
Power of Static	125 W
Sleep Power	50W
Dynamic Power of Slope	3.8
Loss of Path	135
Noise power in Thermal	-135 dBm
Interval of Time	500s

Figure 4(a) shows the overall power price throughout a single workday. The on-grid power, and renewable power costs, were fixed at 1 & 0, correspondingly. These methodologies use considerably less power than another two methods, especially during high periods. It's because, unlike some others, the proposed methods optimize renewable power distribution in the video sequence relies on empirical renewable power charging and cellular vehicle movement.

Moreover, to use the proposed modeling method and the actual customer allocation, they maximize renewable electricity utilization within every session. The spread method outperforms the centralized approach by a little margin. That's because, in comparison to the centralized one as well repeated connection refinement within every seat, it could also properly utilize the allotted renewable power by merely choosing a biasing value for every BS. The section is intended) shows overall power consumption throughout a 10 operating period. It's also not surprising that perhaps the overall power expenditures of the 4 methods arise as the working proceeds to the next phase. Following 4 days, the overall power requirement of their data available was nearly identical to that of the centralized approach. That's because the spread method could utilize greater renewable power produced over the past days.

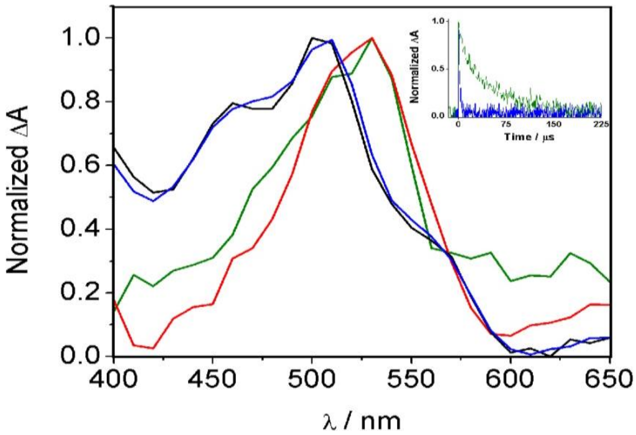

Fig 4. (a) overall power cost of various load times in a single day; (b) overall electricity price throughout a 10-day operational time. 1 and 0 λ.

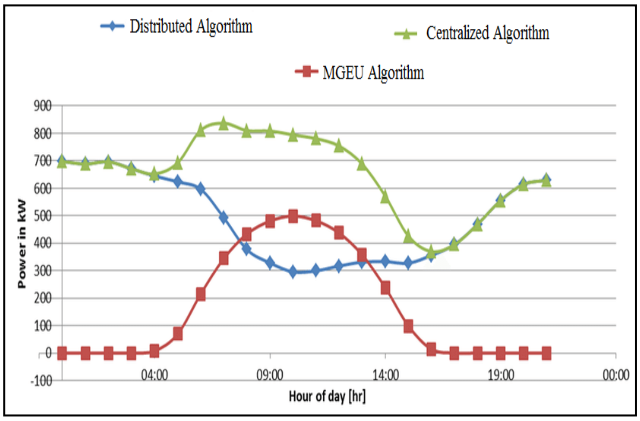

Fig 5. Comparison of proposed algorithm with a distributed and centralized algorithm

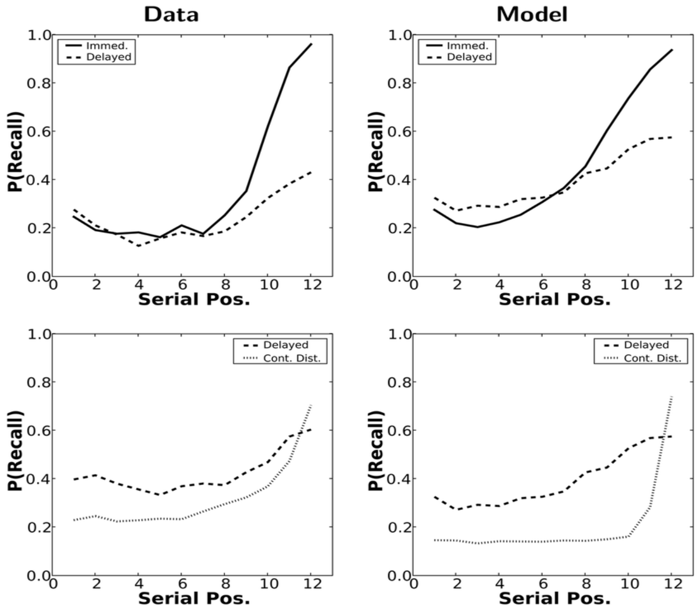

Fig 6. Comparison of the optimized algorithm with an existing delayed system based on recall and precision

Figure 5 shows the sum of power assessment of the financial various process, and pricing rates, it means whenever the contract sum rate was greater than 5, the classification approaches produce a substantially lower overall power cost than the MGEU and closest connection methods. But the product cost ratio rises, and the overall power cost lowers. It obtains the largest power cost savings whenever the unit price of organic solar power that was, the solar power, would be zero. When contrasted to the close connection method, the power usage gains of the local and remote algorithms were 65.72 percent and 71.24 percent, correspondingly shown in Figure 6.

5 Conclusions

Looked into the power cost-cutting potential using HCN-HES under this study. New model concerns, and practical problems, had arisen as a result of the fact because together portable mobility and solar power exhibit time and geographical variations in a quit system. It explored certain methodologies and developed a novel wealth distribution method to improve spatially congestion mixing and time renewable power equilibrium. When contrasted to two competing methods, proposed modeling results that it improved scheme was more successful in terms of reduction.

References

[1] Borah, J., & Bora, J. (2020). Dynamic and location-based power allocation mechanism for inter-cell interference mitigation in 5G heterogeneous cellular network. International Journal of Communication Systems, 33(15), e4548.

[2] Arif, M., Wyne, S., Navaie, K., Nawaz, S. J., & Alvi, S. H. (2020). Decoupled downlink and uplink access for aerial terrestrial heterogeneous cellular networks. IEEE Access, 8, 111172-111185.

[3] Rushdi, A. M. A., Hassan, A. K., & Moinuddin, M. (2020). System reliability analysis of small-cell deployment in heterogeneous cellular networks. Telecommunication Systems, 73, 371-381.

[4] Buvana, M., Loheswaran, K., Madhavi, K., Ponnusamy, S., Behura, A., & Jayavadivel, R. (2021). Improved Resource management and utilization based on a fog-cloud computing system with IoT incorporated with Classifier systems. Microprocessors and Microsystems, 103815.

[5] Rani, S., Ahmed, S. H., & Rastogi, R. (2020). Dynamic clustering approach based on wireless sensor networks genetic algorithm for IoT applications. Wireless Networks, 26, 2307-2316.

[6] Abdel-Basset, M., Mohamed, R., Mirjalili, S., Chakrabortty, R. K., & Ryan, M. J. (2020). Solar photovoltaic parameter estimation using an improved equilibrium optimizer. Solar Energy, 209, 694-708.

[7] Kaur, G., Bharathiraja, N., Murugesan, S., Pradeepa, K., & Sudhakar, G. (2023, February). A Security model with efficient AES and Security Performance Trade-off Analysis of Cryptography Systems with Cloud Computing. In 2023 Fifth International Conference on Electrical, Computer and Communication Technologies (ICECCT) (pp. 01-08). IEEE.

[8] M. Malik and M. Sharma, "Implementation of Energy Constraints of S-MAC Protocol," in *Proceedings of the 2018 7th International Conference on Reliability, Infocom Technologies and Optimization (Trends and Future Directions) (ICRITO)*, pp. 1–7, Noida, India, August 2018.

[9] Kalpana, V., Mishra, D. K., Chanthirasekaran, K., Haldorai, A., Nath, S. S., & Saraswat, B. K. (2022). On reducing energy cost consumption in

heterogeneous cellular networks using optimal time constraint algorithm. Optik, 270, 170008.

[10] Vasconcelos Sampaio, P. G., Aguirre Gonzalez, M. O., Monteiro de Vasconcelos, R., Santos, M. A. T. D., Jacome Vidal, P. D. C., Pereira, J. P. P., & Santi, E. (2020). Prospecting technologies for photovoltaic solar energy: Overview of its technical-commercial viability. International Journal of Energy Research, 44(2), 651-668.

[11] Wang, B., Yang, Q., Yang, L. T., & Zhu, C. (2017). On minimizing energy consumption cost in green heterogeneous wireless networks. Computer Networks, 129, 522-535.

[12] Savitch, S. L., Bauer, T. M., Alvarez, N. H., Johnson, A. P., Yeo, T. P., Lavu, H., ... & Cowan, S. W. (2020). The pathway to low outlier status in venous thromboembolism events: an analysis of pancreatic surgery in the National Surgical Quality Improvement Program. Journal of Pancreatic Cancer, 6(1), 55-63.

[13] Shankar, G., Kaur, G., & Gill, S. K. (2023). Security and Privacy Challenges in IoT System Resolving Using Blockchain Technology. In Convergence of IoT, Blockchain, and Computational Intelligence in Smart Cities (pp. 136-161). CRC Press.

[14] Veltmann, C., Winter, S., Duncker, D., Jungbauer, C. G., Wäßnig, N. K., Geller, J. C., ... & Klein, H. U. (2021). Protected risk stratification with the wearable cardioverter-defibrillator: results from the WEARIT-II-EUROPE registry. Clinical Research in Cardiology, 110, 102-113.

[15] Erath, K., Ingram, J., Moschkovich, J., & Prediger, S. (2021). Designing and enacting instruction that enhances language for mathematics learning: A review of the state of development and research. ZDM–Mathematics Education, 53, 245-262.

[16] Kumar, A., Sharma, S., Goyal, N., Singh, A., Cheng, X., & Singh, P. (2021). Secure and energy-efficient smart building architecture with emerging technology IoT. Computer Communications, 176, 207-217.

[17] Khawam, K., Lahoud, S., El Helou, M., Martin, S., & Gang, F. (2020). Coordinated framework for spectrum allocation and user association in 5G HetNets with mmWave. IEEE Transactions on Mobile Computing, 21(4), 1226-1243.

[18] Nagu, B., Arjunan, T., Bangare, M. L., Karuppaiah, P., Kaur, G., & Bhatt, M. W. (2023). Ultra-low latency communication technology for Augmented Reality application in mobile periphery computing. Paladyn, Journal of Behavioral Robotics, 14(1), 20220112.

[19] Anand, M., Antonidoss, A., Balamanigandan, R., Rahmath Nisha, S., Gurunathan, K., & Bharathiraja, N. (2021). Resourceful Routing Algorithm for Mobile Ad-Hoc Network to Enhance Energy Utilization. Wireless Personal Communications, 1-20.

[20] M. Malik and M. Sharma, "Design and analysis of energy efficient MAC protocol for wireless sensor networks", *Int J Eng Adv Technol (IJEAT)*, vol. 8, no. 3, pp. 690-696, 2019..

[21] Xue, Q., Sun, Y., Wang, J., Feng, G., Yan, L., & Ma, S. (2021). User-centric association in ultra-dense mmWave networks via deep reinforcement learning. IEEE Communications Letters, 25(11), 3594-3598.

[22] Su, C., Ye, F., Cong, S., & Tian, Y. (2020, July). Difference Based Matching Algorithm for User Association Problem in Ultra-Dense Heterogeneous Networks. In 2020 IEEE USNC-CNC-URSI North American Radio Science Meeting (Joint with AP-S Symposium) (pp. 81-82). IEEE.

[23] Thiagarajah, S. P., Alias, M. Y., Tan, W. N., & Mahmud, A. (2020, November). Capacity optimised user association in planned small cell deployment for heterogeneous wireless networks. In 2020 IEEE 5th International Symposium on Telecommunication Technologies (ISTT) (pp. 123-128). IEEE.

[24] Bouaziz, A., Saddoud, A., Fourati, L. C., & Chaouchi, H. (2021, June). Adaptive V2X user selection and resource allocation for ultra-dense 5G HetNet network. In 2021 International Wireless Communications and Mobile Computing (IWCMC) (pp. 1454-1459). IEEE.

[25] Swami, P., Bhatia, V., Vuppala, S., & Ratnarajah, T. (2020). User fairness in NOMA-HetNet using optimized power allocation and time slotting. IEEE Systems Journal, 15(1), 1005-1014.

[26] Fan, Q., & Ansari, N. (2016, April). Green energy aware user association in heterogeneous networks. In 2016 IEEE wireless communications and networking conference (pp. 1-6). IEEE.

[27] Xu, C., Zheng, G., & Tang, L. (2020). Energy-aware user association for NOMA-based mobile edge computing using matching-coalition game. IEEE Access, 8, 61943-61955.