Measurement: Sensors 27 (2023) 100740

Contents lists available at ScienceDirect

Measurement: Sensors

journal homepage: www.sciencedirect.com/journal/measurement-sensors

A novel framework for optimizing the edge network node for wearable devices

Mude Sreenivasulu [a,*], J. Ashok [b], Rakesh Kumar Godi [c], Pydimarri Padmaja [d], Puneet Kumar Aggarwal [e], Dhiraj Kapila [f]

[a] Department of ECE, Samskruti College of Engineering and Technology, Hyderabad, TS, India
[b] Department of Electronic and Communication Engineering, V.S.B. Engineering College, Karur, Tamil Nadu, India
[c] Department of IT, CVR College of Engineering, Hyderabad, JNTUH Hyderabad, India
[d] Department of Electronics and Communication Engineering, Teegala Krishna Reddy Engineering College, Meerpet, Hyderabad, 500097, India
[e] Department of Information Technology, ABES Engineering College, Ghaziabad, Uttar Pradesh, India
[f] Department of Computer Science & Engineering, Lovely Professional University, Phagwara, Punjab, India

ARTICLE INFO

Keywords:
Internet of things
Edge computing
Wearables device
Optimization
Performance measures

ABSTRACT

The Multi-access edge computing (MEC) server would provide context-aware capabilities. When edge computing uses high-quality computing performance to supplement edge applications with vast IoT-based data services, substantial constraints are placed on the collaboration of edge nodes. Conversely to cloud computing, situational circumstances in the edge network are more complicated. In this paper, we provide a novel Edge Network (EDN) optimization (EDN-Opt) to boost the efficiency of edge computing jobs. In particular, we initially specify the parameters for cooperative assessment through the Internet of Things (IoT). Furthermore, the effectiveness of the proposed architecture is shown using real datasets collected from elderly individuals and various activity trackers. A comprehensive study on QoC intended with EDN is used to assess collaboration effectiveness. The cooperative optimization method developed provides improved efficiency To assess the effectiveness of EDN optimization, the discrepancy between the proposed equivalent and the real equivalent is examined. Investigation in this sector analyses several practical cases. The Spearman rank correlation factor is +1 or −1 when a perfect monotonic association is attained with no identifying data. The examination of this article demonstrates that trials show that our proposed edge cooperation optimization technique can quickly assess the EDN and then provide information on the collaborative relationship's replacement occurrences that can help the EDN's design.

1. Introduction

Edge computing offers greater safety and confidentiality than conventional cloud computing. Three key designs for the evolution of edge computing have already been put forth: cloudlets, fog computing, and mobile edge computing [1–3]. Particularly, the MEC design has drawn a lot of interest from academics and businesses. The equipment doing computationally heavy activities is increasingly shifted from the cloud to the edges since the cloudlets paradigm was first proposed in 2009 when edge computing considerably enhances customer service [4].

The supervision of edge services and the interaction for both edge devices present new possibilities and problems with the advent of a diverse range of edge software packages [5]. In other terms, the optimization of assignment collaboration in edge computing designs must take the volatility of the edge surroundings into concern [5]. There is no universal method to assess and optimize edge collaboration, and the majority of the efforts that are currently available are restricted to a specific job. Our inspiration is mostly drawn from the collaborative analysis and improvement of activities [6]. We believe that there are many parallels between the assessment and enhancement of teamwork in sports leagues and edge computing [7]. The assessment of a person's commitment to a sporting event has subsequently been the subject of numerous intriguing publications.

Individual efforts may be further assessed in their work [8]. By rating their deliveries, soccer players can determine how much they contribute to opportunity production. Another research focuses on collective efficiency and decision-making [9]. Both the group and player aspects of decision-making are explored in their study. One of the most valuable

* Corresponding author.
E-mail address: srinivasmude1980@gmail.com (M. Sreenivasulu).

https://doi.org/10.1016/j.measen.2023.100740
Received 26 December 2022; Received in revised form 6 February 2023; Accepted 2 March 2023
Available online 6 March 2023

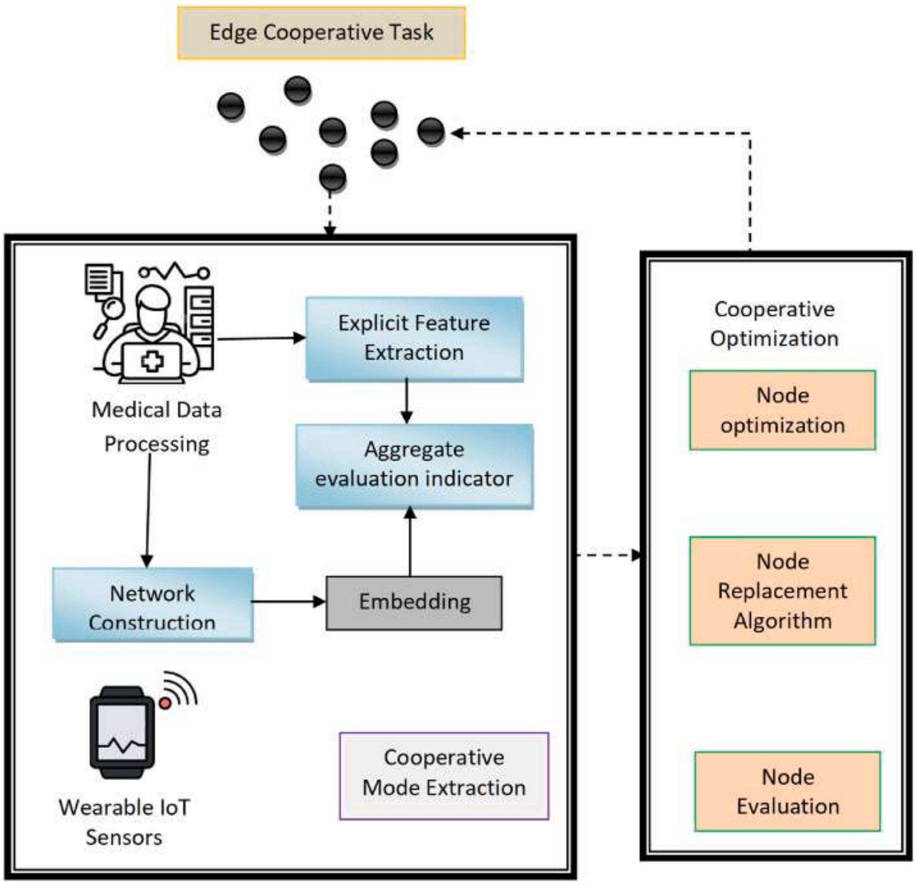

Fig. 1. The proposed architecture.

player techniques, a novel optimization technique, takes into consideration the objectives of both the group and the individual performances [10]. We look into this issue from the perspective of the conventional network because teamwork in competitive activities and node interaction in edge computing generally have such a network model.

2. Related works

In the feature space, data interpretation can be done using these variables. Learning network representations often has two benefits: initially, they may be used to rebuild the actual network model, and subsequently, they can be used to assist in the prediction of network data [11,12]. Matrix factorization, stochastic paths, and deep neural networks are the three groups into which detection techniques are decomposed. Building a relationship matrix between the networks and then using a matrix decomposition procedure to derive the network representation vector are the two phases that are generally used in matrix factorization-based approaches [13]. The objective behind random walk-based approaches is to match vertices to phrases in natural language processing. In contrast perspective, a neural network-based technique defines the network using a function learning approach appropriate for adapting non-linear features.

As a result of several edge computing environments, new possibilities, and problems are presented by edge resource collaboration and management throughout edge nodes [14]. Enabling activity collaboration will enable the development of the edge computing framework that focuses on the volatility of the edge environment. Previous research offers several strategies for this approach [15]. Peer-to-peer offloading is carried out in the IoV architecture by implementing a roadside device and encouraging heuristics computation and artificial intelligence, which permits the storage and transmission of resources near autonomous sensors [16]. With the contribution of this model, the overall system latency has been reduced spectacularly. Several scholars have tackled the collaborative storage problem in films with variable bit rates [17]. With the use of a heuristic algorithm, the computing workload allocation in multi-hop cooperative communications is maximized by repeated job scheduling.

When investigating the possibilities of IoT, edge devices use the edge computing prototype to guarantee secrecy and speed up latency [18]. Due to the restricted computing capacity at endpoint gadgets, energy savings in mobile devices are achieved by offloading some or all computation time from the MEC terminals to the internet [19]. Regardless of the widespread adoption of edge computing technologies, this method is still applied. The facial detection technology in mobile phones, and edge devices, and their processing power are fully utilized [20]. By continuous data collected about the final consumer and concluding as a result via edge devices, the MEC server would provide context-aware capabilities. When edge computing uses high-quality computing performance to supplement edge applications with vast IoT-based data services, substantial constraints are placed on the collaboration of edge nodes and peripherals [21].

The data is immediately sent to the centralized, uniform cloud database in the event of cloud computing, where it is processed and stored. After receiving and reviewing the collected data, the central server will determine whether any action is necessary and send its response back to the device. Even though the entire procedure usually takes under a second, there may be times when the response is interrupted or delayed. This could occur as a result of a network issue, a shaky internet connection, or just the fact that the data center is too far away from the device. Decentralizing data handling is the main goal of edge computing. This results in several benefits over the conventional cloud. Some of the advantages are.

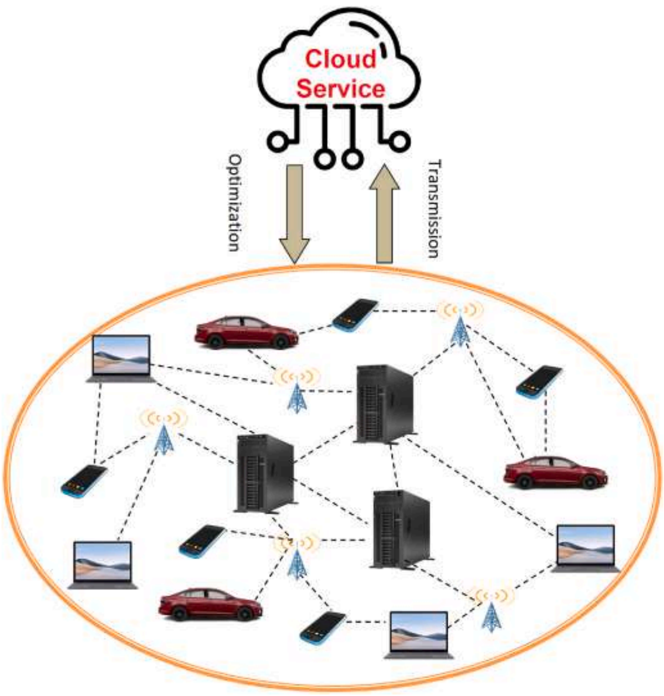

Fig. 2. Edges communication.

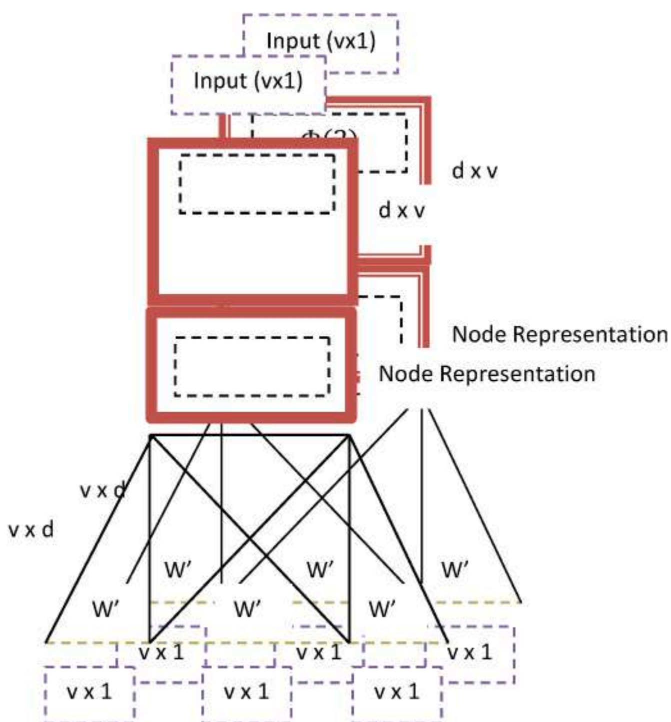

Fig. 3. The network node context.

- Higher data security
- Better performance of the app
- Lower operating expenses
- Unlimited scalability

The Multi-access edge computing (MEC) server in edge computing uses high-quality computing performance to supplement with vast IoT-based data services. Cloud computing in the edge network is more complicated. The work relevant to reduce the complication in MEC was

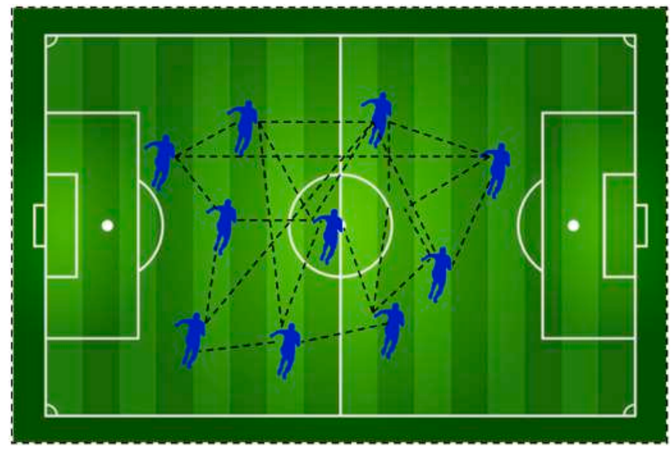

Fig. 4. Sample dataset chosen.

not been properly addressed. In particular, specifying the parameters for cooperative assessment through the Internet of Things (IoT) is a challenging task for the researcher. Propose an optimization method developed is expected to provide improved efficiency.

3. Methodologies

Parameters are presented initially, followed by a summary of our system. Furthermore, every element is provided along with a detailed overview.

- The problem of constrained capacities, such as node computational power, has always persisted in edge networks. An EDN in this setting signifies the degree of collaboration among edge nodes over a specific period.
- To acquire low-dimensional vertices descriptions in an EDN, a network description technique is used.
- We use the level of collaboration among nodes to describe a node's collaborative state.

Depending on this, binary structures and ternary structures are used to categorize the collaborative partnerships between the nodes in the EDN. In a binary structure, nodes have only one set of positive connections [22]. In this paper, ternary structures are defined as three vertices with significant interaction between every set of nodes. Although the versatility of the binary structure provides benefits the triangle motif has a greater value while dealing with significant jobs.

The EDN-Opt system is split into three sections. The first component involves creating an EDN, and the other involves using the network description technique to create a low-dimensional description of the connections in the EDN. We initially define the collaborative form of nodes in the third section. After that, we assess the connections and improve our system. Fig. 1 depicts the framework features.

As an illustration, edge network jobs use fewer computational resources than regular activities require. Additionally, networks in edge cooperative tasks are typically unique from one another. Functions, computational capabilities, resources, and other characteristics are instances. Because nodes vary from one another, it is challenging to accurately manage every node's condition to maximize collaboration. In Fig. 2, an overall EDN instance is displayed.

We think about the nodes' function. The function of nodes is implied in their connection with one another. To construct a network, we initially identify base stations and wearable technology as comparable nodes in the network and handle them similarly. Subsequently, the records of node connections for the activities. Algorithm 1 outlines the procedure.

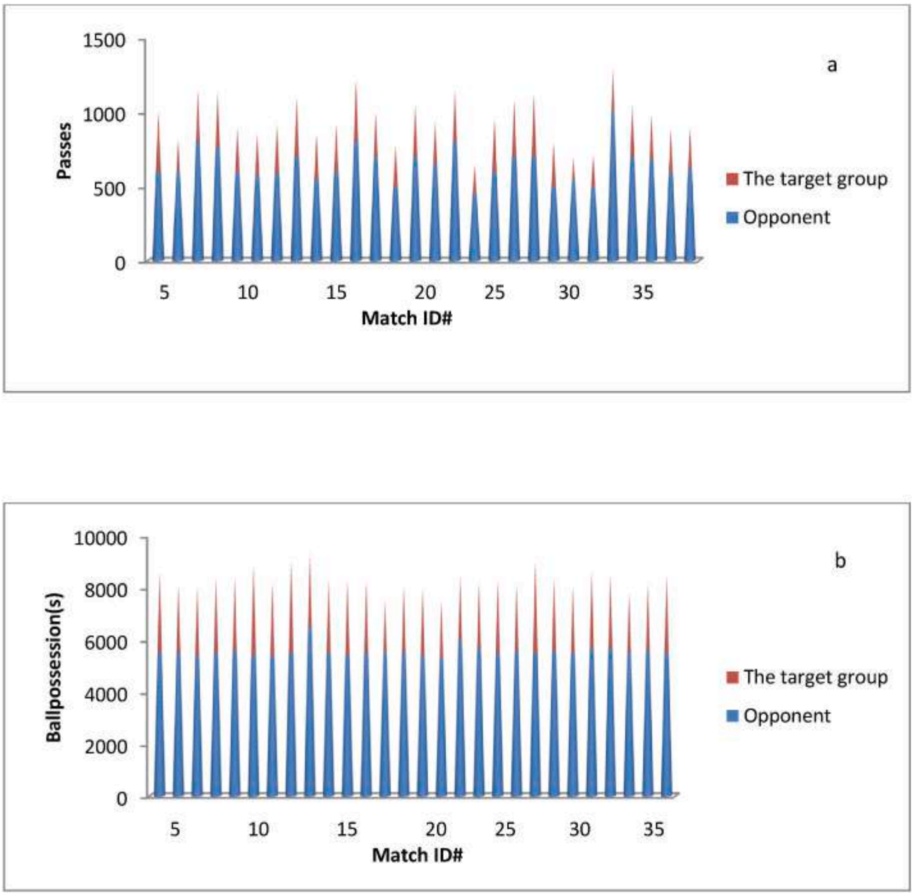

Fig. 5. Position of all ball.

Table 1
Comparison based on Correlation Metrics.

Indicator	PCC	SRCC	CS
QoC (ours)	**0.7010**	**0.9985**	0.9110
PS (mean)	0.0568	−0.0176	0.9433
PS (var)	0.3128	−17.8048	**0.9565**
Pezzali Score	0.0890	0.9829	0.6556

3.1. Mode extraction

The deep walk uses the random walk method to create node segments of a certain duration t. Therefore, in an Edge Network (EDN) optimization (EDN-Opt), these patterns are seen as being comparable to phrases. The following nodes in the series are chosen during the random walk process with the frequency of pi,j provided by

$$p_{x,y} = \frac{w_{x,y}}{\sum_{k \in N_x} w_{x,k}} \tag{1}$$

Skip-gram language method is constructed with node patterns as an input document to develop low-dimensional descriptions of edges.

$$max \frac{1}{N} \sum_{x=1} \sum_{-w \le y \le w, y \ne 0} log \;\; log\, p\left(v_{x+y} \middle| v_x\right) \tag{2}$$

Computational complexity expense is required to optimize this objective [23]. To estimate the optimization of the optimization problem, negative sampling is performed.

$$- \sum_{y=0, y \ne w}^{2w} \Phi(x - w + y).\Phi(x) + \sum_{k=1}^{|v|} exp\{\Phi(k).\Phi(x)\} \tag{3}$$

A strong cooperative paradigm exists among nodes with proximity. On the other hand, there is not much cooperation between nodes with huge distances [24]. By defining the collaboration intensity criteria c, we may discriminate across strong and inadequate collaborative links among nodes. Only the effects of intense collaboration within the EDN are covered in this section shown in Fig. 3. In a cooperative network, it has been found that high collaboration displays a more centralized collaborative design [25].

3.2. Optimization

To accomplish a function in the EDN, a variety of node categories might have to work well together. Based on this, we investigate node traits to gauge their capacity for cooperation. Inherently, all cooperating edge nodes share the following three traits: activity allocation T, interface rate I, and collaboration mode selection Mnode. The collaboration inclination is easily calculated using Mnode = τ3 τ2. The proportion of node connections to all network interactions over time t is known as the interface rate I. As a result, the formulation for the interface rate Ii of each particular node vi is as follows:

$$X_x = T \frac{\sum_{e_{x,y} \in E} w_{x,y}}{t} \tag{4}$$

Activity participation T is also directly tied to specific functions. We can determine how related every set of vectors is by adding these three characteristics to every component. Specific nodes are therefore

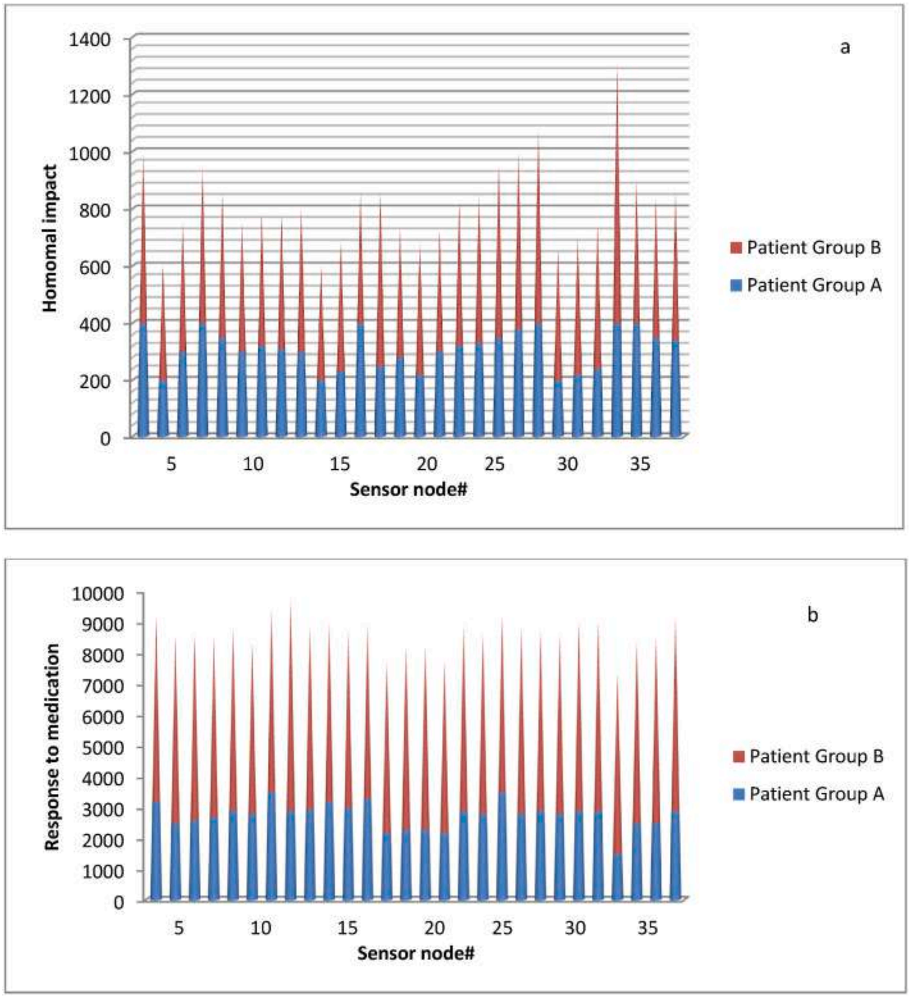

Fig. 6. Data visualization.

successfully examined as a result.

For instance, network variations have an impact on collaboration, making it inappropriate to assess the QoC while disregarding this disruption. From the macro perspective of the EDN (MEDN), it would seem that the network's inclination for a large-scale cooperative mode would represent the influence of elements like network variations. When exterior environmental effects Ψare considered, the QoC is also constrained. For the reasons outlined over, we suggest an all-encompassing cooperative quality model termed QoC, which is as follows:

$$QoC = \frac{(M_{ECN})^{\mu} \times \Omega}{\Psi} \tag{5}$$

where the variable that determines whether the cooperative approach is preferred is called μ. Two parameters are task-specific. They are Ω and Ψ. The number of connections (QoC) efficiently counts the degree of system collaboration involving edge nodes. We demonstrate the deployment of QoC to special issues in the method procedure.

3.3. Optimization of edge cooperation

Nodes typically collaborate with other nodes that are comparable to them. As an illustration, 80% of the nodes that collaborate with the data transfer node perform data transmission, and 20% of the nodes perform various functions. Consequently, the node's preferred cooperative method Mnode can also be thought of as a measure of how similarly the node functions. In the edge collaboration activity, we discover that Mnode and MEDN are considerably enhanced, and the efficiency of the network activity is substantially enhanced, when the same nodes with inadequate characteristics are replaced or redundant comparable nodes are reduced. As a result, we search the Mnode for networks that the system can optimize. We employ DPCA to first execute density-based clustering on topological data to increase the Mnode indices.

4. Experiments

To test our architecture, we creatively choose the sports collaboration system based on players' wearable sensors for tests. We primarily present the chosen dataset in this article. Then, we contrast the collaboration network's performance measures with those of other systems. The node substitute occurrences in the actual dataset are then appropriately analyzed. Based on this, we demonstrate the usefulness of the conceptual framework. The player network is a system created using individuals as vertices and the value of links is determined by the volume of interactions among players. Fig. 4 displays a basic diagram.

It includes information on 59 271 game events and 23 429 transfers made by 366 players. Interactions among players can involve passing, scoring, and other activities. We choose the dataset's deliveries and ball possession for illustration. There seems to be a significant association between the patterns of ball control and the number of deliveries, as illustrated in Fig. 5.

4.1. Optimization of the EDN

In practice, a network assessment indication can be used to

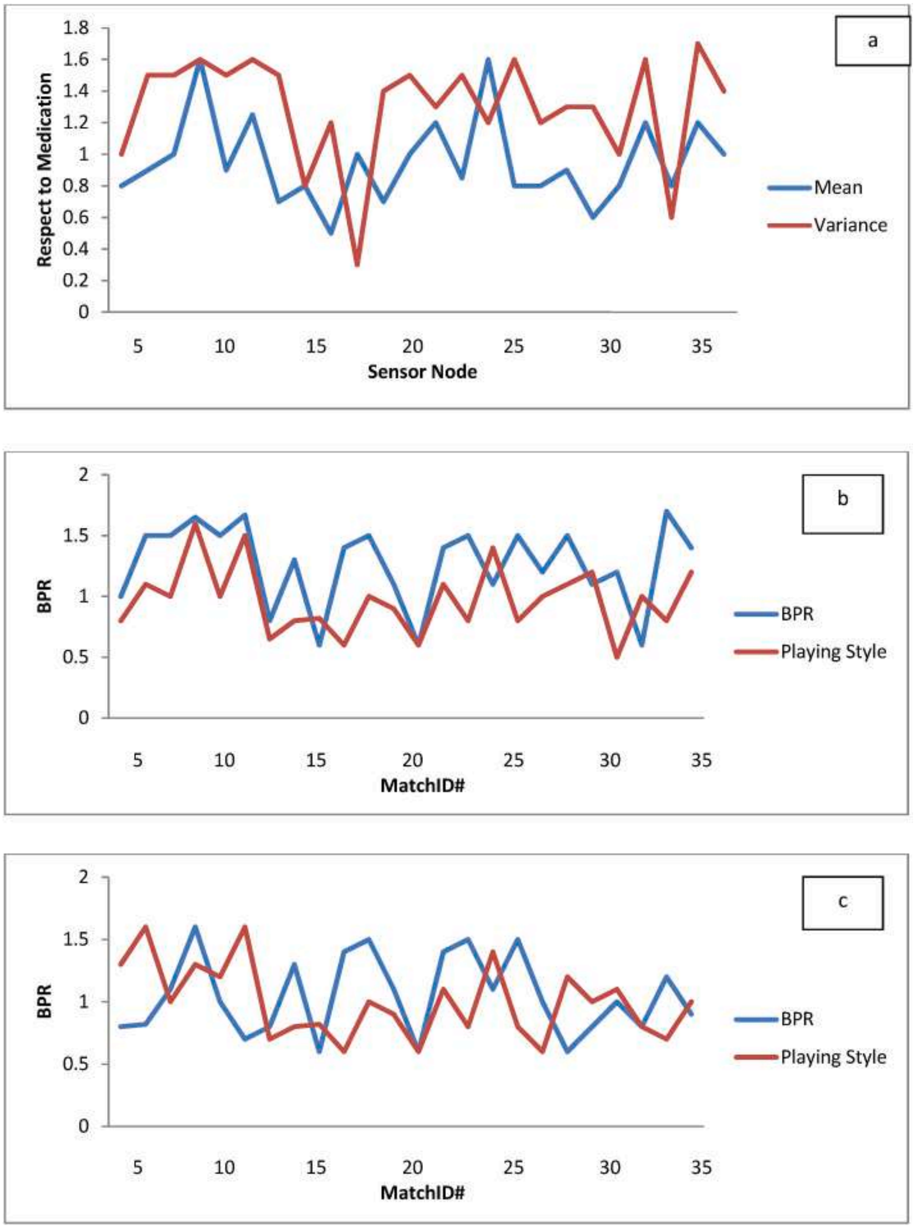

Fig. 7. Comparison based on mean and variance.

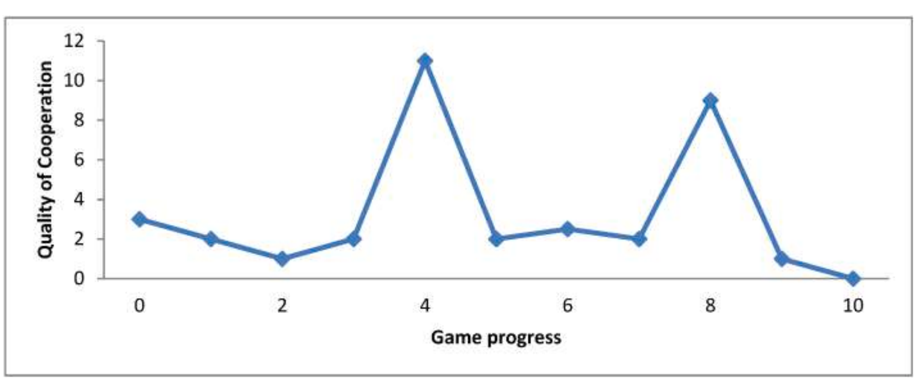

Fig. 8. Time stages of QoC.

determine whether the EDN is optimal. In the meanwhile, a significant part of the EDN's efficiency involves player substitution. For instance, removing network nodes with weak interaction capabilities might significantly increase effectiveness. Therefore, using our system, we can identify the players that are proposed for substitution in every game. In addition, we see as players are changed throughout a game. We examine the assessment measures modification to demonstrate the efficiency of the optimization activity in the EDN by evaluating the reliability and variance between both the proposed and realistic substitution. This portion of the research focuses on investigating a collection of common instances.

5. Performance and discussion

Furthermore, analyses and experimental data demonstrate the value of this approach.

The genuine dataset chosen for the study is shown initially in Table 1. Additionally, a comparison of the collaboration network evaluation measures with the other systems that are already in use is accomplished. Finally, an assessment of node replacement occurrences from the actual dataset is carried out. Based on these findings, the effectiveness of the proposed methodology is demonstrated. The degree of efficiency of the EDN is assessed using a network evaluation indication. Based on the modification of the assessment indication about the data collected by the medical sensors, the effectiveness of optimization of the proposed methodology is confirmed. EDN optimization also aims to replace any network nodes with a minimal level of interaction. In consequence, this increases overall effectiveness. After receiving the suggestion to repair a given node, the exact update is carried out, and the efficiency of the system is further examined. To assess the effectiveness of EDN optimization, the discrepancy between the proposed equivalent and the real equivalent is examined. Investigation in this sector analyses several practical cases. Fig. 6 depicts the visual modeling process of the physiological influence identified by the sensor network and the reaction to the treatment of two multiple users.

For the use of assessing baseline metrics and a cooperative assessment indication focused on quality of care (QoC), subsamples from a variety of portable sensor devices are collected from older persons. The exact value serves to indicate the degree of the correlation. The Spearman's Rank Correlation Ratio can be used to calculate the rank correlation between any 2 factors. A monotonic expression is used to analyze the relationship between variables. The Spearman rank correlation factor is $+1$ or -1 when a perfect monotonic association is attained with no identifying data. The baseline and QoC indications are compared with the treatment response in Fig. 7 in respect of average and variation.

We choose a common scenario and examine the variations in QoC to illustrate the efficacy of our proposed edge cooperation optimization technique. Nine timeframes, every with 60 passes, make up a single game. The conversion occurrence occurs during stages 4 and 5, and this choice is incompatible with the outcomes of the cooperative optimization technique we've proposed. The dotted box in Fig. 8 depicts this comparable decline in QoC. On the other hand, stage 7's replacement is in line with our suggestions, and QoC rises, as indicated by the clear box. The examination of this article demonstrates that trials show that our proposed edge cooperation optimization technique can quickly assess the EDN and then provide information on the collaborative relationship's replacement occurrences that can help the EDN's design.

6. Conclusion

In this study, an optimization framework for EDN is presented. The collaborative nodes retrieved and the EDN description is presented mostly on the premise of network representation learning. According to the EDN collaborative method requirements, a comprehensive measurement known as QoC is used in EDN to assess collaboration effectiveness. Through the use of a cooperative optimization method developed in this research, EDN efficiency is also enhanced. The experiment part utilizes information from wearable medical sensors to demonstrate the framework's effectiveness. Based on a research study, the edge cooperative optimization algorithm's viability is therefore confirmed. The datasets will be increased in the next, and the framework's performance will be further optimized.

CRediT authorship contribution statement

Mude Sreenivasulu: Supervision, Writing – review & editing. **J. Ashok:** Writing – original draft, preparation. **Rakesh Kumar Godi:** Conceptualization. **Pydimarri Padmaja:** Methodology. **Puneet Kumar Aggarwal:** Data curation. **Dhiraj Kapila:** Data Validation, Validation, Data curation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

References

[1] N. Chen, T. Qiu, L. Zhao, X. Zhou, H. Ning, Edge intelligent networking optimization for the Internet of things in a smart city, IEEE Wireless Commun. 28 (2) (2021) 26–31.
[2] M.S. Bali, K. Gupta, D. Koundal, A. Zaguia, S. Mahajan, A.K. Pandit, A smart architectural framework for symmetrical data offloading in IoT, Symmetry 13 (10) (2021) 1889.
[3] A.I. Jehangiri, T. Maqsood, Z. Ahmad, A.I. Umar, J. Shuja, E. Alanazi, W. Alasmary, Mobility-aware computational offloading in mobile edge networks: a survey, Cluster Comput. 24 (4) (2021) 2735–2756.
[4] K. Balamurugan, T.P. Latchoumi, T.P. Ezhilarasi, Wearables to improve efficiency, productivity, and safety of operations, in: InSmart Manufacturing Technologies for Industry, 4.0, CRC Press, 2022, pp. 75–90.
[5] A. Naouri, H. Wu, N.A. Nouri, S. Dhelim, H. Ning, A novel framework for mobile-edge computing by optimizing task offloading, IEEE Internet Things J. 8 (16) (2021) 13065–13076.
[6] A.A. Mutlag, M.K.A. Ghani, M.A. Mohammed, A healthcare resource management optimization framework for ECG biomedical sensors, in: InEfficient Data Handling for Massive Internet of Medical Things, Springer, Cham, 2021, pp. 229–244.
[7] L. Heng, G. Yin, X. Zhao, Energy-aware cloud-edge service placement approaches in the Internet of Things communications, Int. J. Commun. Syst. 35 (1) (2022) e4899.
[8] T.P. Latchoumi, R. Swathi, P. Vidyasri, K. Balamurugan, Develop new algorithm to improve safety on WMSN in health disease monitoring, in: 2022 International Mobile and Embedded Technology Conference (MECON), IEEE, 2022, March, pp. 357–362.
[9] S.A. ElRahman, A.S. Alluhaidan, Blockchain technology and IoT-edge framework for sharing healthcare services, Soft Comput. 25 (21) (2021) 13753–13777.
[10] K.T. Putra, H.C. Chen, M.R. Ogiela, C.L. Chou, C.E. Weng, Z.Y. Shae, Federated compressed learning edge computing framework with ensuring data privacy for PM2. 5 prediction in smart city sensing applications, Sensors 21 (13) (2021) 4586.
[11] K. Ramasamy, M.H. Anisi, A. Jindal, E2DA: energy efficient data aggregation and end-to-end security in 3D reconfigurable WSN, IEEE Trans. Green Commun. Netw. 6 (2) (2021) 787–798.
[12] K. Tripathi, S. Agarwal, Energy efficient clustering scheme to improve the lifespan of WSN, in: 2021 9th International Conference on Reliability, Infocom Technologies and Optimization (Trends and Future Directions)(ICRITO), IEEE, 2021, September, pp. 1–5.
[13] M. Monica, P. Sivakumar, S.J. Isac, K. Ranjitha, PMSG based WECS: control techniques, MPPT methods and control strategies for standalone battery integrated system, in: AIP Conference Proceedings, 2405, AIP Publishing LLC, 2022, April, 040013, 1.
[14] Z. Shahbazi, Y.C. Byun, Improving transactional data system based on an edge computing–blockchain–machine learning integrated framework, Processes 9 (1) (2021) 92.
[15] B.J. Chelliah, T.P. Latchoumi, A. Senthilselvi, Analysis of demand forecasting of agriculture using machine learning algorithm, Environ. Dev. Sustain. (2022) 1–17.
[16] P. Garikapati, K. Balamurugan, T.P. Latchoumi, K-means partitioning approach to predict the error observations in small datasets, Int. J. Comput. Aided Eng. Technol. 17 (4) (2022) 412–430.

[17] H.A. Muqeet, H.M. Munir, H. Javed, M. Shahzad, M. Jamil, J.M. Guerrero, An energy management system of campus microgrids: state-of-the-art and future challenges, Energies 14 (20) (2021) 6525.

[18] T. Nasir, S.S.H. Bukhari, S. Raza, H.M. Munir, M. Abrar, K.L. Bhatti, R. Masroor, Recent challenges and methodologies in smart grid demand side management: state-of-the-art literature review, Math. Probl Eng. (2021), 2021.

[19] L. Fei, M. Shahzad, F. Abbas, H.A. Muqeet, M.M. Hussain, L. Bin, Optimal energy management system of IoT-enabled large building considering electric vehicle scheduling, distributed resources, and demand response schemes, Sensors 22 (19) (2022) 7448.

[20] A. Gaurav, B.B. Gupta, P.K. Panigrahi, A comprehensive survey on machine learning approaches for malware detection in IoT-based enterprise information system, Enterprise Inf. Syst. (2022) 1–25.

[21] D.N. Molokomme, A.J. Onumanyi, A.M. Abu-Mahfouz, Edge intelligence in Smart Grids: a survey on architectures, offloading models, cyber security measures, and challenges, J. Sens. Actuator Netw. 11 (3) (2022) 47.

[22] M.A. Al Rakib, M.M. Rahman, M.A. Rahman, S. Chakraborty, M.A.S. Shawon, F. I. Abbas, IoT based controlling of power grid, Eur. J. Eng. Technol. Res. 6 (6) (2021) 54–57.

[23] M.Y. Arafat, S. Pan, E. Bak, Distributed Energy-Efficient Clustering and Routing for Wearable IoT Enabled Wireless Body Area Networks, IEEE Access, 2023.

[24] F. Su, M. Chen, Z. Sun, T. Xin, D. Bu, Y. Chen, An Interpretable Deep Learning Optimized Wearable Daily Monitoring System for Parkinson's Disease Patients, 2023.

[25] J. Kim, P. Kantharaju, H. Yi, M. Jacobson, H. Jeong, H. Kim, W.H. Yeo, Soft wearable flexible bioelectronics integrated with an ankle-foot exoskeleton for estimation of metabolic costs and physical effort, npj Flexible Electron. 7 (1) (2023) 3.