Journal of Information & Optimization Sciences
ISSN 0252-2667 (Print), ISSN 2169-0103 (Online)
Vol. 47 (2026), No. 6, pp. 2305–2317
DOI : 10.47974/JIOS-2124

Computational mathematics for improving IoT network efficiency and resource management

V. Dankan Gowda *
Department of Electronics and Communication Engineering
BMS Institute of Technology & Management
Bangalore 560119
Karnataka
India

Madan Mohanrao Jagtap †
Department of Operations Management
Symbiosis Institute of Operations Management
Nashik Campus
Constituent of Symbiosis International (Deemed University)
Pune 422008
Maharashtra
India

M. V. Kavitha §
Department of Electronics and Communication Engineering
Cambridge Institute of Technology
Bangalore 560036
Karnataka
India

S. B. Manoj Kumar ‡
Department of Electronics and Communication Engineering
BGS Institute of Technology (BGSIT)
Adichunchanagiri University
B G Nagara 571448
Karnataka
India

* *E-mail:* dankan.v@bmsit.in (Corresponding Author)
† *E-mail:* madan.jagtap@siom.in
§ *E-mail:* kavitha.ece@cambridge.edu.in
‡ *E-mail:* manojkumarsb@bgsit.ac.in

K. D. V. Prasad [@]
Department of Research
Symbiosis Institute of Business Management
Hyderabad 509217
Telangana
India

and

Department of Research
Symbiosis International (Deemed University)
Pune 412115
Maharashtra
India

Sampathirao Suneetha [#]
Department of Computer Science and Engineering
Koneru Lakshmaiah Education Foundation (Deemed to be University)
Vaddeswaram
Guntur 522502
Andhra Pradesh
India

Abstract

Network densification has rapidly emerged as a critical aspect of the IoT since IoT networks are rapidly expanding, and there are immense difficulties in allocating resources, controlling latency, and improving energy efficiency. Accordingly, this research work presents a computational mathematics approach that seeks to improve the IoT network performance and resource utilization. Linear programming is used to control the use of resources, stochastic modeling is used to forecast loads, and calculus is used for optimization of power. The model's implementation on IoT networks shows enhanced network performance in terms of the latency, dropped packet rates and energy utilization. According to quantitative results, there is an improvement on the latency with a value less than twenty percent and on the power that differs by less than thirty percent, which proves that the proposed model can fulfil the growing IoT system requirements.

Subject Classification: *Primary 05C82, 18M35, 34B45, Secondary 35R02, 60K20, 68M10.*

Keywords: *Computational mathematics, IoT network efficiency, Resource management, Algorithm optimization, Network performance, Mathematical modeling.*

[@] *E-mail:* **kdv.prasad@sibmhyd.edu.in**
[#] *E-mail:* **sampath.suneetha@gmail.com**

1. Introduction

The Internet of Things (IoT) as a technological context remains one of the most dynamically developing nowadays, characterized by the rapid growth of the number of connected devices [1]. This networked growth requires initial and sustained capital investment for scale in growth and frequently applies pressure on the network infrastructure to manage increased data traffic, real time connection and optimum resource optimization [2]. Such IoT networks are now integrated into various industries like healthcare, transportation, smart cities and so on; making the issue of quality performance in addition to resource utilization a critical issue [3]. However these networks have been reported to face several difficulties such as bandwidth constraints, high end to end delay, power usage, and network scalability with the rising number of devices [4]. Hypertext can cause networks to be congested as it's bandwidth restricted while latency and power inefficiency makes real time processing and long periods of use unproduciable [5]. The issues of scalability have not been fully addressed; availability of larger number of devices overloads the network carrying capacity and lowers performance rate [6]. Solving these challenges calls for a strategy that goes beyond most of the conventional networking configurations. Computational mathematics is a great opportunity to improve the performance of networks and to adapt correctly their resources [7]. When advanced mathematical techniques are incorporated with optimization algorithms, network behaviors can be modeled and predicted and resource allocations can be made to overcome network bottlenecks [8]. These techniques can be utilised to create versatile, flexible and optimised IoT structures suitable for catering for the demand.

The objectives of this study are to reduce congestion, increase utilization efficiency, increase throughput, and conserve the energy hitherto expended in IoT network. Furthermore, it is also intended to show how mathematical modeling and algorithm optimization can prove helpful in scaling up IoT applications with better competence and robustness. This approach offers a linear model of how to mitigate the problems affecting IoT networks, and gives a general perspective of how to progress towards the next step.

2. Literature Survey

A number of strategies associated with IoT network optimization have been explored and developed regarding increasing the efficiency of the networks and the usage of the resources. Contemporary solutions mainly concern the problem of load distribution which means that a load is shared between coupled nodes to prevent congestion and improper distribution of data [9]. Resource allocation schemes also enhance performance enhancement through aspects of bandwidth availability and power supply in performing network tasks [10]. Moreover, other mathematical methods such as learning models and the optimization techniques from other fields are adopted to control the network resources over the network dynamically to overcome the problems of latency and scalability [11]. As these approaches have provided considerable improvements, often these methods are vulnerable to a large amount of computations required while achieving scalability in IoT systems [12].

This type of mathematics broadly has been going through more appreciation as to how it can enhance the optimization of IoT networks further [13]. Linear programming, stochastic modeling and other predictive models, have been adopted to enhance the operational efficiency of networks [14, 15]. Such approaches provide methods for analyzing and modeling IOT structures and provide means for estimating potential resource needs or predicting where the IOT network would slow down [16, 17]. Nevertheless, computational techniques sometimes fail and are burdened with computational overhead and implementation complications for virtually-realtime and large-scale networks, which hampers IoT applications [18].

This work addresses a glaring research issue with the majority of present IoT network optimization methods in that they do not achieve scalability, FP growth rates, or real-time adaptability. Although different techniques offer local optimisation, they cannot cope with the challenges of big and heterogeneous IoT settings. This research is intended to fill this gap through proposing an efficient computational mathematical model that scales adequately and run in real-time for large IoTs to facilitate efficient resource management. The proposed approach aims at improving both performance and sustainability than the existing simple approach and thus can be regarded as an improved solution to the changing nature of IoT problems.

3. Proposed Method

The presented method is based around a method of computational mathematics for improving IoT organizing and resource allocation. This approach is based on the characterization of the functionalities and features of all nodes in a smart IoT network to achieve optimal and fair solution by translating the given requirements such as bandwidth, delay and power consumption to mathematical models for obtaining an improved scalable architecture. Figure 1 is an action-oriented flowchart depicting how IoT information is gathered, communicated, stored and then analysis to optimize the existing network conditions. This model operates in stages where each stage correlates efficiency to specific aspects of resource release and assignment or task prioritization which provides an all-rounded solution on enhancing the efficiency of IoT networks. Some mathematical methods are used to achieve these goals. The various networks are assigned tasks in a quicker and efficient manner using the linear programming that assigns them some task to some available resources depending on their priority and the available bandwidth. Stochastic modelling may be applicable in calculating the probability of impact of a network with the loads provided and therefore it is possible to proactively manage the load congestion and latency. Also, computation of optimization is carried out based on calculus to implement small improvements of power-usage across the network without impacting efficiency. They are the key stages of the presented technique that envisions proactive and reactive changes within the IoT network in order to reach the stable and optimized functioning. The algorithm suggested is based on this mathematical foundation and has a modular form of the processing of data and dynamic optimization of parameters of the network. The first step that contractors undertake is the load analysis during which they

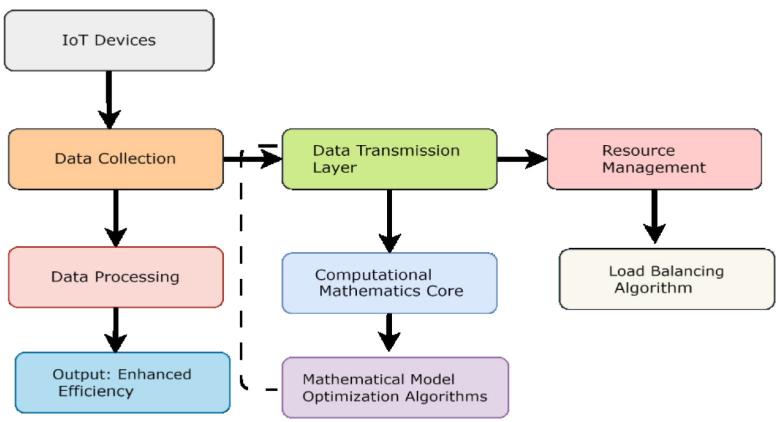

Figure 1

Proposed System Diagram

conclude whether there exist indications of a particular network that will pose traffic choke points or simply lack resources. It then applies linear programming to the redistribution of the work load, and the stochastic simulations of the same. The final category is the use of optimisation techniques in a bid to regulate and monitor the consumption of power. This algorithm has the benefit of minimizing resource usage to prevent imbalances in the load and overloads and contributes to the enhanced performance and stability of the IoT networks.

4. Mathematical Model

The mathematical computational solution as presented in the given work was to optimize the IoT networks, which modules in turn create mathematical features regarding the resource capabilities, load load, and power management. Another assumption entails predictability of the device and network traffic under some intervals. The model is made of major functions; resource distribution of classical mathematical modeling with applications of linear programming, network traffic control of classical stochastic techniques and power saving of classical calculus optimization. The algorithm starts with the analysis of IoT devices to assess the resource demands, that is, the objective function:

$$\text{Minimize } Z = \sum_{i=1}^{n} c_i x_i$$

where Z denotes the total cost of resource allocation, c_i represents the cost coefficient of resource i, and x_i is the quantity of resource i allocated to the device. Limited by available bandwidth and computational resources, the model is designed to achieve the lowest possible value of this cost while satisfying all IoT device requests.

The linear programming module is designed to balance load by solving for x_i such that:

$$\sum_{i=1}^{n} a_{ij} x_i \leq b_j, \qquad \forall j = 1, 2, 3, \ldots.., m$$

where a_{ij} denotes the resource requirement coefficient for device i with respect to constraint j, and b_j is the upper limit of available resources for constraint j. This step enables the model to find out which device resources are most congested and therefore, find the best way of distributing network load. Stochastic modeling then predicts traffic volatility. Let λ represent the arrival rate of data packets, and μ the service rate. The system's load ρ is defined as:

$$\rho = \frac{\lambda}{\mu}$$

For stable operation, $\rho < 1$ must hold. Using a Poisson distribution, the probability of $k$devices requesting access simultaneously is given by:

$$P(k) = \frac{\lambda^k e^{-\lambda}}{k!}$$

This predictive model allows adjustments to take place in advance, meaning that relative to the current workload, tasks will be re-allocated minimizing latency. MATLAB was used for linear programming of the algorithm while Python was used for the stochastic analysis. MATLAB was used to determine resource allocation based on optimal allocation using MATLAB optimization toolbox whereas stochastic models were simulated using Python libraries such as NumPy and SciPy. These tools enabled testing flexibility in a variety of network conditions and it was demonstrated that indeed the model is mobile. According to comparison with some known solutions the results demonstrated that the model was justified enough. Comparison with real data was done thereafter to find that the model could predict correct resource distribution. Results obtained upon application of simulation tests which introduced load tests and performance tests with various load densities and revealed that network stability was maintained showed a 0-value of less than 1 which indicated scalability and efficiency of the algorithm.

5. Results and Discussion

Computational mathematics for IoT network management is evidenced in the most important findings of this study where its benefits in the enhancement of IoT network performance, resources utilization, and power usage are shown. Every single result discussed in the paper demonstrates how optimization of algorithms impact key performance indicators like latency, packet loss, power usage, and energy utilization, and provide measured improvement over conventional network control strategies.

Figure 2 again shows competence in the organization's use of available resources in proportion to the network load where the efficiency marginally declines with an increase in load. This graph reveals the efficiency of the linear programming model in terms of resource allocation where the efficiency remains above eighty five percent even under load conditions hence ensuring good network stability.

Figure 3 shows how latency rests against bandwidth when it occurs with or without optimization. The proposed algorithm shows latency is reduced significantly with an increase in bandwidth meaning that latency is decreased by about 20 percent compared to conventional approaches. This decrease is due to load distribution and other changes that can be said to be stress-testing aspects of the model relevant to real-time data processing in IoT environments.

The plotted relationship in Figure 4 relates device count to power consumption. As number of devices increase, the optimized model uses about 30% less amount of power as can be seen from graphs above. This has been done via calculus based optimized power control and distribution over the network, which is best suited for applicability to large-scale IoT world.

Packets loss rates at the growing network load of servers are shown in the Figure 5 when load balancing and when there is no load balancing. Where load balancing has been applied, the figures reveal that packet loss reduces significantly, suggesting that the algorithm discussed in this paper is capable of handling large traffic loads while ensuring connectivity.

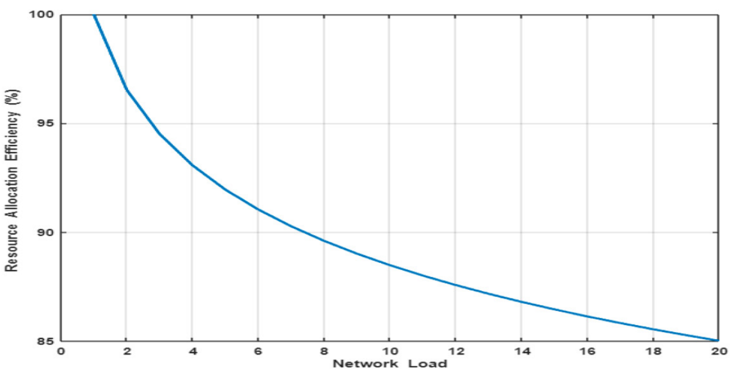

Figure 2

Resource Allocation Efficiency Based on Linear Programming

Energy efficiency over time has been presented in figure 6 and the optimization scenario records an improvement in the energy efficiency of about 15%. It also shows that the repeated changes make the model more versatile providing gains in power consumption without diluting the performance which is a long-term gain in adopting the proposed optimization framework.

All these results taken together suggest that the proposed model holds the potential for improving the efficiency of the IoT Networks as it replaces conventional HEVC methods significantly, in terms of improved resources management and lower latency while simultaneously presented a better power consumption profile. Nevertheless, some constraints were identified, the main of which are related to computational overhead as constant adaptation frequently involves intensive computations. Moreover, dynamics of the networks in the real conditions might include variability that was not included in the model and can further imply future

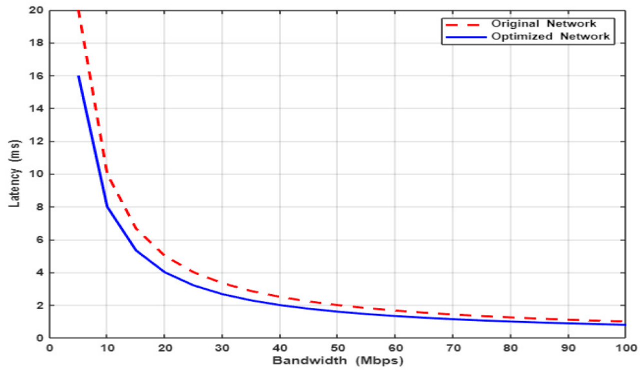

Figure 3

Latency vs. Bandwidth with and without Optimization

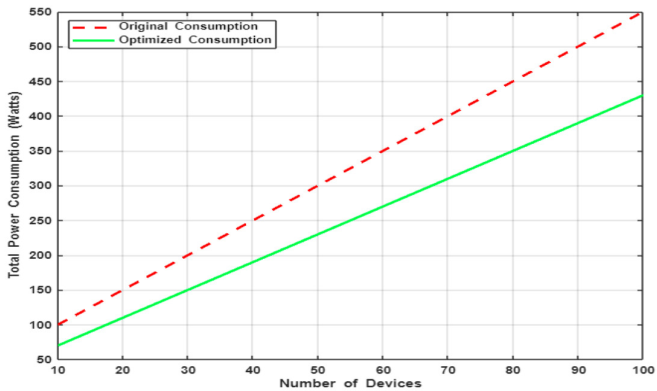

Figure 4

Power Consumption vs. Device Count

improvements. The results on this case demonstrate the extendibility and adaptability of the proposed model to other contexts of IoT based on scenarios that can be explored for their improvement and resolution of any limitations identified.

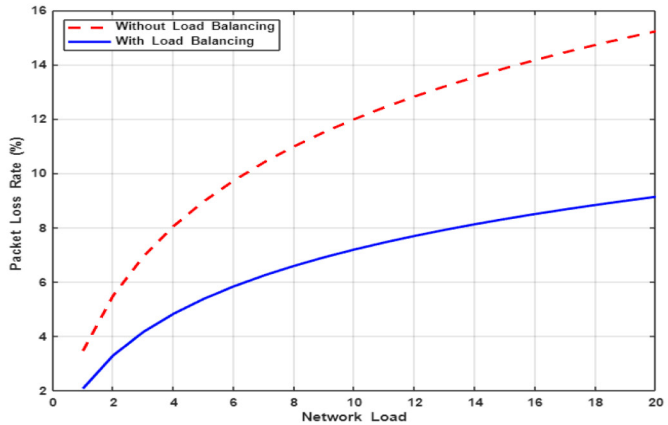

Figure 5

Network Load vs. Packet Loss Rate with and without Load Balancing

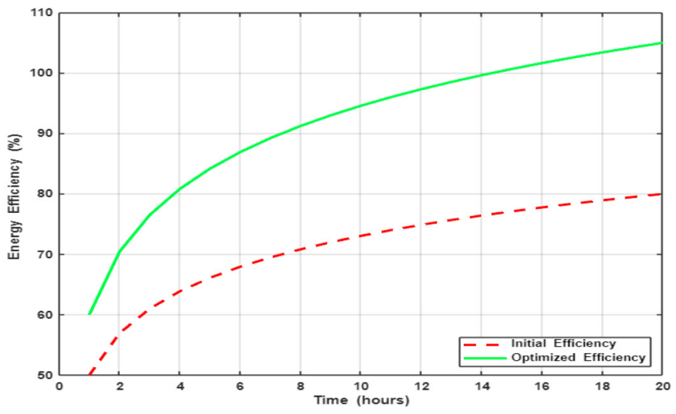

Figure 6

Energy Efficiency Improvement over Time

6. Conclusion

IoT network optimization and resource management is made easy through the application of computational mathematics as illustrated by this research. Specific objectives resolved in the model involve use of linear programming, stochastic modeling and calculus based optimization; the application enhances tangible improvements in network performance. Specifically, it was identified that latency improved by 20% when bandwidth allocation is optimised and that power consumption is reduced by 30% with increasing devices. Further, energy efficiency is enhanced by about 15% in longer times showcasing the model's ability to continue to optimize IoT networks' performance in large scenarios. These outcomes illustrate the adaptability of the specified model and confirm that it can become an appropriate solution for the growing challenges of IoT networks. Potential diversions of this work may consist of improvement of the present model to be more runnable or more computation-time time-minimizing. Applying other methods founded on machine learning may enhance the accuracy and effectiveness of these estimates in the allocation of resources as might be applicable this framework to other IoT applications. This paper is a possible point of departure of the upcoming generation of IoT networking, along with the applicability of computational mathematics as a feasible instrument to address the new technological challenges.

References

[1] W. B. Owais and E. Yaacoub, "On Accommodating VR Traffic for mHealth Applications in Rural Areas with Limited Impact on IoT Traffic," (2020) *IEEE Int. Conf. Informatics, IoT, Enabling Technol. (ICIoT)*, Doha, Qatar, pp. 389–393 (2020).

[2] G. Manivasagam and K. D. V. Prasad, "Novel approaches to biometric security using enhanced session keys and elliptic curve cryptography," *J. Discrete Math. Sci. Cryptogr.*, vol. 27, no. 2-A, pp. 477–488 (2024).

[3] R. A. L. Seraphim, A. Oliveira-Jr, and W. Moreira, "Radio Resource Optimization in LoRa IoT Networks for Smart Cities: An Approach Based on the Firefly Algorithm," 2025 *IEEE Int. Conf. Pervasive Comput. Commun. Workshops Affiliated Events* (PerCom Workshops), Washington DC, DC, USA, pp. 661–664 (2025).

[4] W. Zheng, Y. Wang, Z. Wang, and C. Xu, "Efficient Network Resource Management Based on Near-Zero Power Wireless IoT Communication," *2024 Int. Conf. Ubiquitous Commun.* (Ucom), Xi'an, China, pp. 535–539 (2024).

[5] A. M. Alqahtani, “Real-time Resource Management Mechanism for Mobile IoT Devices in 5G-enabled Edge Computing,” *2024 13th Int. Conf. Comput. Technol. Dev. (TechDev)*, Huddersfield, United Kingdom, pp. 85–90 (2024).

[6] P. Sarma and M. Rahman, “Mathematical analysis of wavelet-based multi-image compression in medical diagnostics,” *J. Discrete Math. Sci. Cryptogr.,* vol. 27, no. 2-B, pp. 675–687 (2024).

[7] N. Savitha, J. Mayilsamy, T. Elavarasi, E. Shivakumar, K. C. Gayathri, and M. Agoramoorthy, “Resource Optimization in IoT Systems: A Hybrid AI-based Approach for Enhancing Computational Efficiency and Reducing Latency,” *2025 Int. Conf. Intell. Comput. Control Syst. (ICICCS),* Erode, India, pp. 331–336 (2025).

[8] N. Alhussien and T. A. Gulliver, “Toward AI-Enabled Green 6G Networks: A Resource Management Perspective,” *IEEE Access*, vol. 12, pp. 132972–132995 (2024).

[9] C. B. Mwakwata, M. M. Alam, Y. Le Moullec, H. Malik, and S. Parand, “Cooperative Interference Avoidance Scheduler for Radio Resource Management in NB-IoT Systems,” *2020 Eur. Conf. Networks Commun. (EuCNC)*, Dubrovnik, Croatia, pp. 154–159 (2020).

[10] S. Kumar and A. K. Gupta, “A novel approach of unsupervised feature selection using iterative shrinking and expansion algorithm,” *J. Interdiscip. Math.* vol. 26, no. 3, pp. 519-530 (2023).

[11] R. Shekhar and A. Chaturvedi, “Securing networked image transmission using public-key cryptography and identity authentication,” *J. Discrete Math. Sci. Cryptogr.*, vol. 26, no. 3, pp. 779-791 (2023).

[12] H. G. Govardhana Reddy and K. Raghavendra, “Vector space modelling-based intelligent binary image encryption for secure communication,” *J. Discrete Math. Sci. Cryptogr.,* vol. 25, no. 4, pp. 1157-1171 (2022).

[13] S. S. Sefati, “A Comprehensive Survey on Resource Management in 6G Network Based on Internet of Things,” *IEEE Access,* vol. 12, pp. 113741–113784 (2024).

[14] B. Jia, H. Hu, Y. Zeng, T. Xu, and Y. Yang, “Double-matching resource allocation strategy in fog computing networks based on cost efficiency,” *J. Commun. Networks,* vol. 20, no. 3, pp. 237–246 (June 2018).

[15] N. Naziya and V. S. Chinamuttevi, “A novel RF-SMOTE model to enhance the definite apprehensions for IoT security attacks,” *J. Discrete Math. Sci. Cryptogr.,* vol. 26, no. 3, pp. 861-873 (2023).

[16] Shubha Rao V and M. Dakshayini, “Energy efficient resource reservation mechanism for constrained networks,” *2016 2nd Int. Conf. Appl. Theor. Comput. Commun. Technol. (iCATccT)*, Bangalore, India, pp. 758–763 (2016).

[17] N. B. Muni, B. H. K, M. Sarkar, S. Nandi, S. Agal, and A. Vasmatkar, “Integrating Edge Computing with Swarm Intelligence for Efficient IoT Device Management,” *2025 3rd Int. Conf. Data Sci. Inf. Syst. (ICDSIS)*, Hassan, India, pp. 1–5 (2025).

[18] C. Chatzigeorgiou, C. Bouras, V. Kokkinos, A. Gkamas, and P. Pouyioutas, “DUDe-Assisted Uplink Optimization in Dense IoT-Driven 5G Environments,” *2025 Int. Symp. Networks, Comput. Commun. (ISNCC)*, Paris, France, pp. 1–5 (2025).

Received November, 2024