ISSN 1330-3651 (Print), ISSN 1848-6339 (Online)
https://doi.org/10.17559/TV-20240902001960
Original scientific paper

Adaptive Energy Efficient Routing for Video Transmission in Wireless Multimedia Sensor Network Using Greedy Algorithm

V. RANJITH*, C. YAASHUWANTH, K. PRATHIBANANDHI, T. JAYASANKAR

Abstract: Wireless sensor networks (WSNs) are distributed systems that present unique challenges compared to centralized networks, particularly in terms of energy consumption, service quality, and data delivery efficiency. Recent advancements in wireless multimedia sensor networks have facilitated applications such as video transmission via affordable mobile devices and cameras. However, these applications often suffer from issues related to end-to-end delay and bandwidth limitations. To address these challenges, this paper introduces a novel algorithm named the Predicted Transmission Count Delay Greedy Algorithm (PTC-DGA), designed to enhance the performance of WSNs under such constraints. Unlike the traditional Direct Diffusion-Based Algorithm (DDBA), which is data-centric and fails to adequately address delays, bandwidth limitations, throughput, and energy consumption, the PTC-DGA algorithm offers a robust solution by optimizing network quality, latency, and throughput. A key innovation of PTC-DGA is the integration of a Look-Ahead Algorithm to predict the cost of current sub-paths, thereby selecting the sub-path with the lowest predicted cost as the next cross point. This approach significantly improves the accuracy and robustness of sub-path selection. The effectiveness of the proposed PTC-DGA algorithm is validated through comparative analysis with the DDBA, using both tabulated results and graphical representations. The findings demonstrate that PTC-DGA not only addresses the limitations of DDBA but also provides substantial improvements in network performance metrics, including reduced delay, enhanced bandwidth utilization, and improved throughput.

Keywords: bandwidth optimization; end-to-end delay; network performance metrics; predicted transmission count delay greedy algorithm (PTC-DGA); wireless sensor networks (WSNs)

1 INTRODUCTION

The development of Wireless Sensor Networks (WSNs) has dramatically assisted various industries, including those concerned with surveillance, remote monitoring and control, target tracking, environmental monitoring, disaster relief, agriculture, and more [1]. In light of the increasing demand for wireless multimedia networks (WMSNs), it is of the utmost importance to develop a routing protocol that considers the Quality of Service (QoS) requirements that must be met. This protocol should have as its primary objective the reduction of network latency as well as the consumption of power [2]. Wireless multimedia sensor networks (WMSNs) place a premium on energy efficiency because of the resource limitations inherent to the networks themselves and the ever-increasing demand for efficient data transmission. Because of the meteoric rise in popularity of multimedia applications such as live video streaming, innovative strategies have emerged to cut down on energy consumption while maintaining the same level of timely and reliable video content transmission [3]. Monitoring the environment, public safety, and medical care are just some of the many areas that can benefit from utilizing these networks [4].

The objective is to reduce energy consumption while maintaining the same level of quality and timeliness in the delivery of video data [5]. Batteries are a common source of power for the sensors; however, due to their limited capacity, careful management is required to ensure the network's longevity and the continuous transmission of data [6]. The Predicted Transmission Count Delay Greedy Algorithm (PTC-DGA) that has been proposed is an example of significant progress made toward these goals. The proposed system is intended to improve the efficiency of video data transmission in Wireless Multimedia Sensor Networks (WMSNs) by accurately predicting the necessary transmission count for ensuring reliable video delivery [7].

2 RELATED WORKS

Research into Wireless Sensor Networks, also known as WSN, has primarily concentrated on questions concerning the network's durability and the amount of energy it requires. The Low Energy Adaptive Cluster hierarchy, abbreviated as LEACH, is a hierarchical routing protocol designed specifically for a node distribution that can potentially be chaotic [8]. It combines the phases of initialization and steady-state operation in order to lower the overall power consumption of the network. The network's performance is degraded when the LEACH algorithm uses a random selection process for cluster heads (CHs), as this has been observed [9]. Compared to the LEACH protocol, the Centralized LEACH (LEACH-C) algorithm demonstrates an improved selection of Cluster Heads (CHs) by using previously acquired information regarding the energy and location of nodes. LEACH-E employs a modification of the algorithm known as the minimum spanning tree to select the nodes that will act as Cluster Heads (CHs) [10].

The pre-stage phase of the IBLEACH protocol is defined as occurring prior to the setup phase and the steady state phase. The network's overall energy footprint will be cut down, which is the goal. According to the suggestion made by the researcher, live video could be transmitted through the use of wireless sensor networks that are powered by Zigbee technologies. The quality of the video that is sent over a Zigbee network has been successfully improved thanks to optimization efforts [11]. Quality of Service (QoS) can be analyzed in Wireless Sensor Networks (WSNs) utilizing the transmission of video packets. The time that elapses in a Wireless Sensor Network (WSN) between the transmission of two sensor reports can range from a few minutes to several days. The transmission of video content utilizes its own distinct frequency band, which presents fresh challenges for the underlying protocol stack, particularly at the Media Access Control (MAC) layer. It has been demonstrated that Time-

Synchronized Channel Hopping (TSCH), a MAC technology that the IEEE802.15.4e working group is currently standardizing, can be utilized to transmit video by demonstrating that it satisfies these requirements.

Tiny autonomous robots can be used to place video-enabled sensors inside a building that has been damaged due to an earthquake. This technological intervention aims to improve the efficiency with which rescue workers can survey the rubble and evaluate the likelihood that any survivors are still present. This will allow for a more accurate assessment of the situation [12]. In this section, we will elaborate on related literature covering various topics, ranging from the physical layers to the application layers. The primary focus of research efforts is the development of daughter cards with video capabilities that can be easily inserted into existing wireless motte devices. Numerous experimental studies have concluded that single-hop communication or higher-throughput radio technologies such as IEEE802.11 are the superior options. This research seems to be the first attempt at demonstrating multi-hop video communication within a low-power network that is based on IEEE 802.15.4. The method of MAC protocol currently in use is known as Time Division Multiple Access (TDMA). In order to reduce the detrimental effects of external interference and multi-path fading, the Time Synchronized Channel Hopping (TSCH) method is utilized in conjunction with the channel hopping technique [13]. Establishing a route that uses multiple hops significantly impacts the delivery of multimedia streams. The identified drawbacks of the existing methodologies while performing the video transmission are as follows.

- The existing method transmits data in the indiscriminate fashion to all the neighboring nodes, resulting in redundancy in transmission. This redundancy consumes and creates wastage of excessive of energy.
- The existing energy concentrating on the energy saving aspects, ignores the delay or data loss concern, leading to the data retransmission. This retransmission indirectly consumes excessive energy for video transmission.

To overcome these concerns, the proposed work of Predicted Transmission Count Delay Greedy Algorithm was introduced such as to perform the video transmission with minimal energy consumption.

3 PROPOSED WORK

A novel algorithm, namely Predicted Transmission Count Delay Greedy Algorithm, has been proposed in the proposed method. This algorithm can estimate the interference, increasing the throughput and reducing the delay during the sending and receiving videos in multi-hop wireless sensor networks.

A. Centralized direct diffusion algorithm

The centralized direct diffusion algorithm finds the best path for transmitting the data packets among all the available routes. The sink node does the processing of this algorithm. The data packet prediction information can be obtained during the packet flooding.

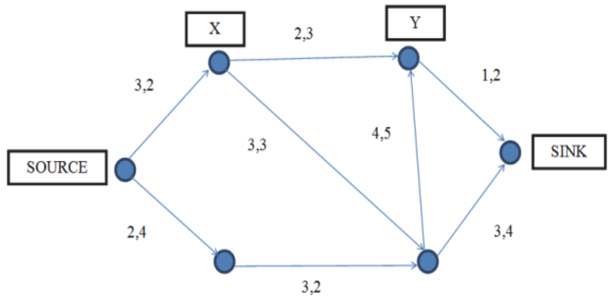

Figure 1 Route selection of centralized direct diffusion algorithm

Fig. 1 shows a network with six different nodes. Arrow marks indicate the routes from one node to the other with their respective metrics. The cost of the metric from the sender to the destination point is minimum through the route SOURCE → X → Y → SINK. Hence, the algorithm will choose this path to transmit the packets.

The drawback of the centralized direct diffusion algorithm is that it cannot be used in the real time environment because of two major reasons. The first reason is that this algorithm has no global trace recordings, and it is data-centric. The second reason is that, in real-time, wireless sensor networks might contain an enormous number of nodes. The memory required for the direct diffusion algorithm will be more, whereas the memory of the nodes in the wireless sensor networks would be less.

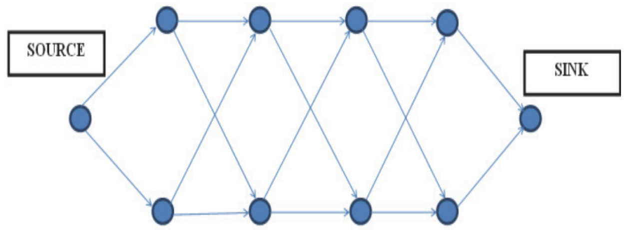

Figure 2 Worst-case scenario of the centralized direct diffusion algorithm

Fig. 2 shows the worst-case scenario of the direct diffusion algorithm. The memory required for this network will be infinite. The number of routes will be $O(C^m)$. Here, C is a constant, and m is the number of nodes. To overcome the drawbacks of this algorithm, a heuristic algorithm has been developed in the proposed method, so called predicted transmission count delay greedy algorithm.

B. Predicted transmission count delay greedy algorithm (PTC-DGA)

In the Predicted transmission count delay greedy algorithm, the sub path through which the information is received is being recorded. The next hop can be done only by the flow with the best sub path.

The proposed algorithm reduces the time complexity during the data transmission from the source to the sink, and at the same time, it also minimizes the memory space required. Due to the absence of the solution property of optimization, this algorithm, however, cannot find the best route. This algorithm can be further enhanced by using the look-ahead algorithm.

C. Look ahead algorithm for performance improvement of PTC-DGA

The look-ahead algorithm is employed to predict the cost of the present sub-path. Distribution of the information related to the transmission takes place between the nodes as the video data moves from the sender point to the destination point. The sharing of the transmission information [14] from one node to its neighbors is done in N hops, N being a positive integer. It is assumed that the change in the delay changes from hop to hop. The cost of the path is determined. The accuracy and the robustness in selecting the sub-path can be done using the look-ahead algorithm. The algorithm for the PTC-GDA is illustrated in Tab. 1.

Table 1 Algorithm for look ahead of PTC-DGA

Algorithm: Look ahead of performance improvement of PTC-DGA
Input: Threshold Delay (D_{th}) Output: Path Selection (P_S) Processes: 1: Initialize the threshold delay (D_{th}) 2: Predict the transmission count: $TC_p = \frac{1}{T_S}$ // T_s is the successful transmission count 3: Determine the expected delay: $D_e = D_p(i,j) + D_t(i,j) + D_q(i,j)$ // D_e is the expected delay, D_p is the processing delay, D_t is the transmission delay and D_q is the queuing delay. 4: Determine the optimal path: $P_s = \alpha TC_p + \beta D_e$ 5: Look ahead optimization: $P_s(Opt) = \arg\min Score(P_s)$ 6: End process

D. Transmission Path reinforcement

Fig. 3 shows the nodal diagram of avoiding transmission path reinforcement. The node A first tried to access the link to the node C. When B tries to access C at the same time, C will decline B as it is considered as a message that is old. B then receives a negative response (NEG-RES) message from C.

After receiving the negative response message, B deletes that entry in its local table and looks for another entry, say D.

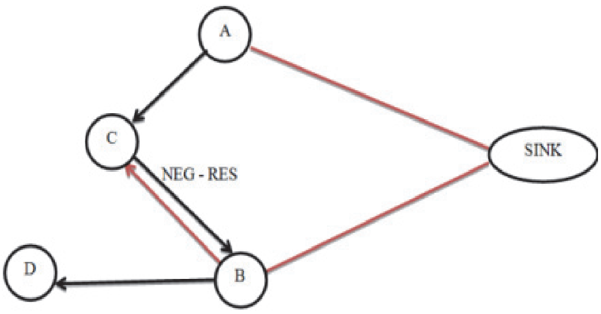

Figure 3 Avoiding transmission path reinforcement Avoiding loops during transmission

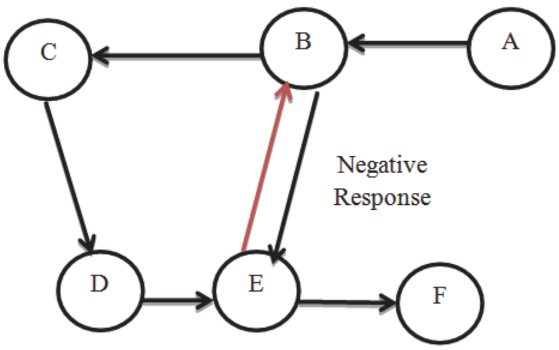

Figure 4 Nodal diagram of avoiding loops during transmission

Fig. 4 depicts the nodal diagram of avoiding loops during transmission. When a node receives a negative response from one node and finds the next candidate, it must track the delivery of data so that the data packets can arrive before the deadline.

In the above figure, A has already sequentially reinforced B, C, D and E. When E tries to access the route to B, B responds negatively to E. So, the next candidate, F is reinforced by E after receiving the negative response signal from B. Only one packet can be reinforced by a standard diffusion algorithm. However, the packets are discarded when there is a loop, and the source will receive no packet.

4 RESULT AND DISCUSSION

The parameters selected for the proposed Predicted Transmission Count Delay Greedy Algorithm (PTC-DGA) are the transmission probability which is essential for the balanced performance between the energy efficiency and delay sensitivity. The parameters impacting on the proposed algorithm are the energy consumption, delay and the stability of the overall path. To implement the proposed work, a Wireless Sensor Network with 100 nodes is spread over 1000 × 1000 m coverage area. The nodes were deployed in random and the transmission energy is of 1 unit per packet sent. The reception energy is of 0.5 units per packet received and 0.2 units for processing energy per packet. Tab. 2 provides the throughput of PTC-DGA and DDBA with different network sizes, and Fig. 5 shows the graphical representation of the throughput of PTC-DGA and DDBA with different network sizes.

Table 2 Throughput of PTC-DGA and DDBA with different sizes of the network

S. No	Size of the network	Throughput (packets per second)	
		PTC-DGA	DDBA
1.	50	39.71	38.71
2.	100	39.42	37.63
3.	150	39.56	37.50
4.	200	39.61	37.42
5.	250	39.52	37.34
6.	300	39.48	36.50

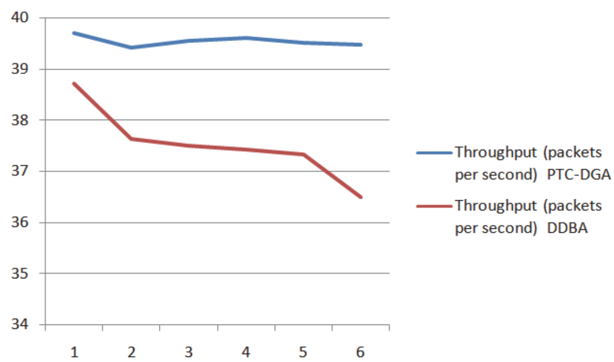

Figure 5 Graphical representation of throughput of PTC-DGA and DDBA with different sizes of the network

Tab. 3 gives the delay in the delivery of packets with PTC-DGA and DDBA with different sizes [15] of the network and figure 6 gives the graphical representation of the end-to-end delay of PTC-DGA and DDBA with different network sizes.

Table 3 Network size

S. No	Size of the network	End-to-end delay	
		PTC-DGA	DDBA
1.	50	25.21	84.23
2.	100	30.14	84.66
3.	150	30.23	100.51
4.	200	31.51	110.35
5.	250	44.62	115.34
6.	300	52.43	150.21

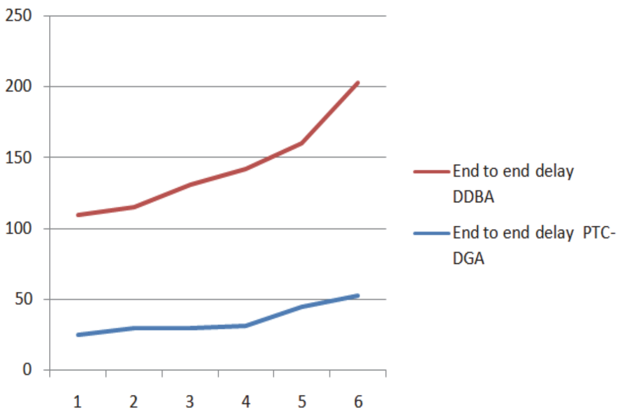

Figure 6 End-to-end delay of PTC-DGA and DDBA with different sizes of the network

Tab. 4 gives the throughput of PTC-DGA and DDBA concerning the rate of error of the outgoing channel, and Fig. 7 depicts the graphical representation of the throughput of PTC-DGA and DDBA concerning the rate of error of the outgoing channel.

Table 4 Throughput of PTC-DGA and DDBA concerning the rate of error of the outgoing channel

S. No	Rate of error	Throughput (packets per second)	
		PTC-DGA	DDBA
1.	0.2	39.74	39.02
2.	0.3	39.82	38.21
3.	0.4	39.23	36.82
4.	0.5	38.14	35.04
5.	0.6	39.00	31.95
6.	0.7	40.23	33.62

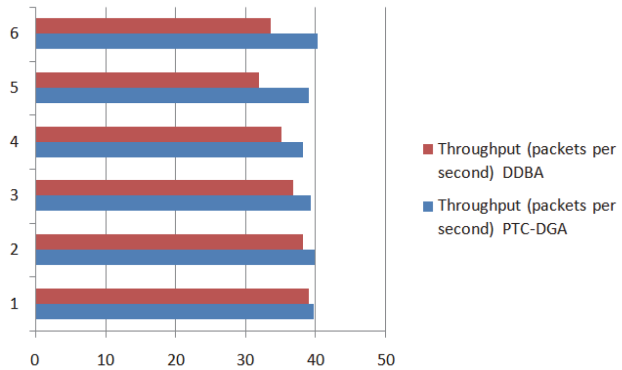

Figure 7 Throughput of PTC-DGA and DDBA concerning rate of error of the outgoing channel

Tab. 5 gives the delay in the delivery of packets with PTC-DGA and DDBA concerning the rate of error of the outgoing channel, and Fig. 8 gives the graphical representation of the delay [16] in the delivery of packets [17] with PTC-DGA and DDBA concerning rate of error of the outgoing channel.

Table 5 End-to-end delay of PTC-DGA and DDBA for the rate of error of the outgoing channel

S. No	Rate of error	End-to-end delay	
		PTC-DGA	DDBA
1.	0.2	25.62	87.95
2.	0.3	30.31	88.68
3.	0.4	27.42	100.21
4.	0.5	32.55	80.54
5.	0.6	31.32	85.32
6.	0.7	20.24	75.21

Tab. 6 gives the efficient output of PTC-DGA and DDBA concerning traffic rates.

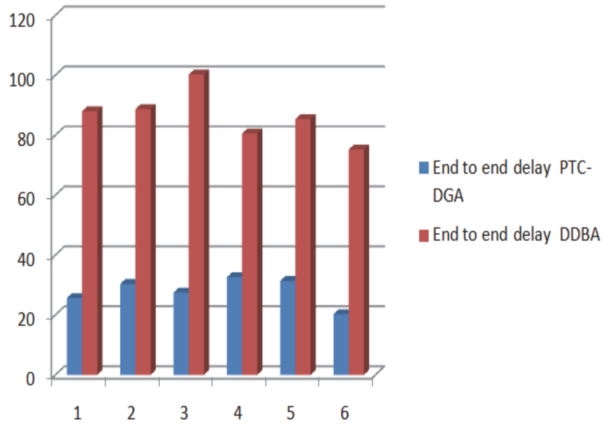

Figure 8 End to End delay of PTC-DGA and DDBA concerning rate of error of the outgoing channel

Table 6 Throughput of PTC-DGA and DDBA concerning rates of traffic

S. No	Traffic rate (packets per second)	Throughput (packets per second)	
		PTC-DGA	DDBA
1.	60	57	56
2.	80	74	68
3.	100	85	75
4.	120	87	66
5.	140	92	65
6.	160	78	64

The efficient output in packets per second of PTC-DGA is 87 when the traffic rate in one second is 120 data units, and the efficient output in packets per second of PTC-DGA is 66 when the traffic rate [18] in one second is 60 data units. Fig. 9 gives the graphical representation of the throughput of PTC-DGA and DDBA concerning traffic rates. The efficient output of PTC-DGA is 57 when the traffic rate is 60 packets per second, and the efficient output of PTC-DGA is 56 when the traffic rate is 60.

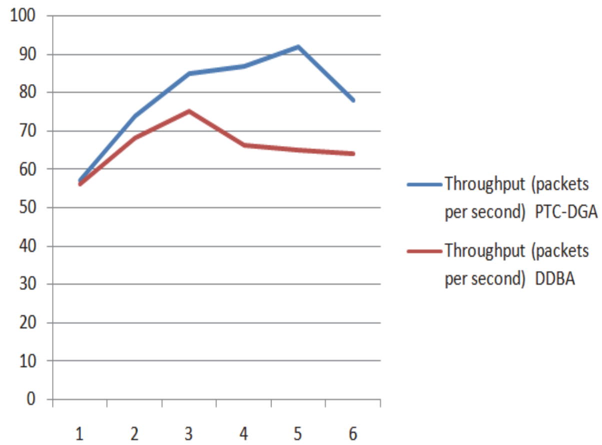

Figure 9 Graphical representation of throughput of PTC-DGA and DDBA with respect to rates of traffic

The efficient output of PTC-DGA is 92 when the traffic rate in one second is 140 data units, and the efficient output of PTC-DGA is 65 when the traffic rate in one second is 60 data units. The efficient output of PTC-DGA is 78 when the traffic rate in one second is 160 data units, and the efficient output of PTC-DGA is 64 when the traffic rate in one second is 60 data units. For larger networks, despite using the proposed work, it experiences increase in delay and may limit the performance. In this case, formation of clustering will make the performance to persist at the same better level at par with the presented method.

5 CONCLUSIONS

The development of wireless multimedia sensor networks has led to the development of mobile phones and cameras that cost less. However, during video data transmission, these devices face issues related to energy, bandwidth, throughput and end-to-end delay. The existing direct diffusion algorithm does not satisfy the requirements of the wireless sensor networks. This work has put forth a novel algorithm called Predicted Transmission Count Delay Greedy Algorithm (PTC-DGA). The proposed algorithm improves the efficient output, delay during packet transmission and bandwidth during video transmission. The performance of the proposed algorithm has been improved using the carry look ahead algorithm. The results have been graphically depicted, and the proposed algorithm is observed to have provided better performance. The performance of the proposed work shall further be enhanced for robustness, adaptability and data security by using fuzzy based routing solutions and advanced encryption algorithms.

6 REFERENCES

[1] Shah, S. L., Abbas, Z. H., Abbas, G., Muhammad, F., Hussien, A., & Baker, T. (2023). An Innovative Clustering Hierarchical Protocol for Data Collection from Remote Wireless Sensor Networks Based Internet of Things Applications. *Sensors (Basel)*, *23*(12), 5728. https://doi.org/10.3390/s23125728

[2] Balakrishnan, S. & Vinoth Kumar, K., (2023). Hybrid Sine-Cosine Black Widow Spider Optimization based Route Selection Protocol for Multihop Communication in IoT Assisted WSN. *Technical Gazette*, *30*(4), 1159-1165. https://doi.org/10.17559/TV-20230201000306

[3] Anuradha, D., Subramani, N., Khalaf, O. I., Alotaibi, Y., Alghamdi, S., & Rajagopal, M. (2022). Chaotic Search-and-Rescue-Optimization-Based Multi-Hop Data Transmission Protocol for Underwater Wireless Sensor Networks. *Sensors (Basel)*, *22*(8), 2867. https://doi.org/10.3390/s22082867

[4] Haider, S. K., Jiang, A., Almogren, A., Rehman, A. U., Ahmed, A., Khan, W. U., & Hamam, H. (2021). Energy Efficient UAV Flight Path Model for Cluster Head Selection in Next-Generation Wireless Sensor Networks. *Sensors (Basel)*, *21*(24), 8445. https://doi.org/10.3390%2Fs21248445

[5] Feng, Q., Chu, S. C., Pan, J. S., Wu, J., & Pan, T. S. (2022). Energy-Efficient Clustering Mechanism of Routing Protocol for Heterogeneous Wireless Sensor Network Based on Bamboo Forest Growth Optimizer. *Entropy (Basel)*, *24*(7), 980. https://doi.org/10.3390/e24070980

[6] Liu, Z., Wang, Y., Feng, F., Liu, Y., Li, Z., & Shan, Y. (2023). A DDoS Detection Method Based on Feature Engineering and Machine Learning in Software-Defined Networks. *Sensors (Basel)*, *23*(13), 6176. https://doi.org/10.3390%2Fs23136176

[7] Evans, S. J., Clift, M. J., Singh, N., de Oliveira Mallia, J., Burgum, M., Wills, J. W., Wilkinson, T. S., Jenkins, G. J., & Doak, S. H. (2017). Critical review of the current and future challenges associated with advanced in vitro systems towards the study of nanoparticle (secondary) genotoxicity. *Mutagenesis*, *32*(1), 233-241. https://doi.org/10.1093/mutage/gew054

[8] Shi, P., Ye, T., Wang, Y., Zhou, T., Xu, W., Du, J., Wang, J., Li, N., Huang, C., Liu, L., Chen, B., Su, Y., Fang, W., Wang, M., Hu, X., Wu, J., He, C., Zhang, Q., Ye, Q., Jaeger, C., & Okada, N. (2020). Disaster Risk Science: A Geographical Perspective and a Research Framework. *International Journal of Disaster Risk Science*, *11*(4), 426-40. https://doi.org/10.1007%2Fs13753-020-00296-5

[9] Adnan, M., Iqbal, J., Waheed, A., Amin, N. U., Zareei, M., Umer, A., & Mohamed, E. M. (2021). Towards the Design of Efficient and Secure Architecture for Software-Defined Vehicular Networks. *Sensors (Basel)*, *21*(11), 3902. https://doi.org/10.3390/s21113902

[10] Li, C., Chen, Y., & Zhao, H. (2023). Frequency hopping signal detection based on optimized generalized S transform and ResNet. *Mathematical Biosciences and Engineering*, *20*(7), 12843-12863. https://doi.org/10.3934/mbe.2023573

[11] Anusuya Devi, V. & Kalaivani, V. (2023). Enhanced BB84 quantum cryptography protocol for secure communication in wireless body sensor networks for medical applications. *Personal and Ubiquitous Computing*, *27*(3), 875-885. https://doi.org/10.1007/s00779-021-01546-z

[12] Wu, M. T. (2019). Reducing inverse quantization numbers in intra frame for video transcoding architectures. *PLoS One*, *14*(5), e0215131. https://doi.org/10.1371/journal.pone.0215131

[13] Silvestre-Blanes, J., Sempere-Payá, V., & Albero-Albero, T. (2020). Smart Sensor Architectures for Multimedia Sensing in IoMT. *Sensors (Basel)*, *20*(5), 1400. https://doi.org/10.3390/s20051400

[14] P. D and S. K, (2021). A Strong Authentication For Fortifying Wireless Healthcare Sensor Network Using Elliptical Curve Cryptography. *2021 IEEE Mysore Sub Section International Conference (MysuruCon)*.

[15] Vinoth Kumar, K., Jayasankar, T., Eswaramoorthy, V., & Nivedhitha, V. (2020). SDARP: Security based Data Aware Routing Protocol for Ad hoc Sensor Networks. *International Journal of Intelligent Networks*, *1*(2020), 36-42. https://doi.org/10.1016/j.ijin.2020.05.005

[16] Priya, G. L. & Ghosh, D. (202). An Effectual Video Compression Scheme for WVSNs Based on Block Compressive Sensing. *IEEE Transactions on Network Science and Engineering*, *11*(2), 1542-1552.

[17] Yuan, Y. et al. (2024). Joint Optimization of QoE and Fairness for Adaptive Video Streaming in Heterogeneous Mobile Environments. *IEEE/ACM Transactions on Networking*, *32*(1), 50-64.

[18] Adhikari, S., Alsadoon, A., Bekhit, M., Jerew, O. D., Siddiqi, M., & Ali, A. (2024). Optimizing Real-Time Video Transmission for Surgical Tele-Education through ERV Algorithm. *IEEE Access*, *12*, 98707-98722.

Contact information:

V. RANJITH, Assistant Professor
(Corresponding author)
Department of Information Technology,
Sri Venkateswara College of Engineering, Chennai

Dr. C. YAASHUWANTH, Professor
Department of Information Technology,
Sri Venkateswara College of Engineering, Chennai

Dr. K. PRATHIBANANDHI, Associate Professor
Department of Electrical and Electronics Engineering,
Sri Sai Ram Engineering College, Chennai.

Dr .T. JAYASANKAR, Assistant Professor
Department of Electrical and Electronics Engineering,
University College of Engineering (BIT Campus),
Anna University Tiruchirappalli
E-mail: jayasankar@aubit.edu.in