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Article

QoS Aware Multicast Routing Protocol for Video Transmission in Smart Cities

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Abstract: In recent years, Software Defined Networking (SDN) has become an important candidate for communication infrastructure in smart cities. It produces a drastic increase in the need for delivery of video services that are of high resolution, multiview, and large-scale in nature. However, this entity gets easily influenced by heterogeneous behaviour of the user's wireless link features that might reduce the quality of video stream for few or all clients. The development of SDN allows the emergence of new possibilities for complicated controlling of video conferences. Besides, multicast routing protocol with multiple constraints in terms of Quality of Service (QoS) is a Nondeterministic Polynomial time (NP) hard problem which can be solved only with the help of metaheuristic optimization algorithms. With this motivation, the current research paper presents a new Improved Black Widow Optimization with Levy Distribution model (IBWO-LD)-based multicast routing protocol for smart cities. The presented IBWO-LD model aims at minimizing the energy consumption and bandwidth utilization while at the same time accomplish improved quality of video streams that the clients receive. Besides, a priority-based scheduling and classifier model is designed to allocate multicast request based on the type of applications and deadline constraints. A detailed experimental analysis was carried out to ensure the outcomes improved under different aspects. The results from comprehensive comparative analysis highlighted the superiority of the proposed IBWO-LD model over other compared methods.

Keywords: Smart cities; software defined networking; quality of service; video data transmission; multicast routing

1 Introduction

In the past few years, the tremendous growth of smart cities has caused a few serious problems like crime tracking, traffic, and public security. Smart city concept exploits big data analytics and data techniques' sensing to collect human activity data from across the city. It analyzes the information and provides smart services to public applications. Especially, the transformation of infrastructures, services, and buildings with Internet of Things (IoT) technology has gained considerable attention from both industry and academia as shown in Fig. 1 [1]. With the help of sensor nodes, IoT produces large amount of information about smart cities such as traffic, earth vibration, air composition, etc. Amongst these data which demonstrates the realistic efficiency of clustering for gathering, video footage quality, taken by surveillance cameras, has improved widely. As per the literature [2], global video surveillance produces over 560 petabytes of information daily [2]. In smart city applications, video information produced from IoT possesses certain problems. The cameras distributed in modern cities collect video sources from some restricted zones too, even under compromising situations. Particularly, video surveillance content from multiple cameras for the same scene possesses a problem to the application and unified analyses. E.g., three cameras deployed in three consecutive streets with totally different environments. Some of the video surveillance applications such as tracking objects get affected apparently due to tracking of multiple scenarios [3]. When video information is full of unwanted content, then detection or tracking accuracy gets reduced. A reasonable and efficient fusion system can reduce unnecessary information, filter the video data and increase the accuracy of content analysis applications in smart cities.

Figure 1: Application of smart cities

One of the basic criteria to judge a video conference call is its quality of video stream [4]. Usually, this stream is highly sensitive to 5-network states and has rigorous Quality of Service (QoS) necessities like low packet loss, high bandwidth, low end-to-end delay, and so on. Additionally, it is susceptible to heterogeneity of user wireless connection features that might reduce the quality of video stream for all or some users [5]. The conventional networks find it challenging to handle each QoS requirement in real-time settings. In literature, the researchers attempted to develop novel video codecs like Scalable Video Coding (SVC) which splits the video stream into different layers with different qualities. Therefore, this codec is capable of simply adjusting the bit rate of video streams by dropping redundant layers. This framework 20 provides separations between the data plane and control plane of the system [6]. Therefore, it allows a logically-centralized view which enables network management in an effective manner.

The tremendous growth of Software Defined Networking (SDN), with remarkable industrial support, is a great opportunity to perform Internet Protocol (IP) multicast without any difficulties [7]. In fact, it is possible to create and preserve © 2014 IEEE while the material is allowed for personal usage. It is inevitable to obtain authorization for present or future media from IEEE for other purposes including the creation of new collective works, republishing or reprinting the material for promotional/advertising purpose, for redistribution/resale to lists or servers, or reutilization of any copyrighted content of these works, in any other work [8]. Multicast tree between subscribers, its sources and its control applications run on logically-centralized SDN controllers which possess a global network view. SDN possesses programmable features that enable immediate scalability, deployability, updatability, and adaptability traits, which are formerly related to Application-Layer Multicast (ALM), not IP multicast. In this research, an IP multicast application is proposed to run on SDN controller. It also records the subscription activity through a simple northbound interface and illustrates its advantageous performance.

The current research paper presents a novel Improved Black Widow Optimization with Levy Distribution Model (IBWO-LD)-based multicast routing protocol for application in smart cities. The presented IBWO-LD model aims to minimize the energy consumption and bandwidth utilization in accomplishing improved video stream quality in which the client can receive. Besides, a priority based scheduling and classifier model is designed to allocate the multicast request depending upon the type of applications and deadline constraints. A detailed experimental analysis is carried out to ensure the improved outcomes interms of different aspects.

Rest of the paper is planned as follows. Section 2 offers literature review while Section 3 introduces the proposed model. Section 4 details about the results of the analysis, while Section 5 draws the conclusion for the study.

2 Related Works

Naeem et al. [9] employed an iterative low-complexity probabilistic evolutionary technique to schedule video cameras so as to maximize the throughput in Video Camera Sensor Networks (VCSN) for IoT systems. Video camera scheduling-in-VCSN is a combinatorial optimization problem to increase throughput while the difficulty in computation increases gradually with increasing number of video cameras. Doan et al. [10] provided a scalable IoT video data analytics application for smart cities to end users, who can take advantage of scalability in both data processing as well as storage power to perform analysis on complex/large datasets. This algorithm offers data analytics environment and suite in which the researchers and developers could develop scalable analytical applications and services. Edge or cloud-based automatic video analysis methods process a massive number of video streams. In these methods, the fundamental structure could scale according to the number of camera devices and is easier to incorporate analytical applications.

Pan et al. [11] addressed the problem by presenting Machine Learning (ML) based Bitrate Estimation (MBE) algorithm for parsing bitrate data from IP packet level. Next, the transmission modes were recognized in this method based on the traffic features of some earlier packets. Then, the resolutions and bitrates of Dynamic Adaptive Streaming and Hypertext Transfer Protocol (HTTP) Live Streaming over HTTP modes were recognized based on the features present in video chunks. Calavia et al. [12] introduced a smart video surveillance method which can detect and classify abnormal and alarming scenarios by investigating object movements. This architecture is developed to mitigate transmission and video processing tasks, thereby enabling a massive number of cameras is positioned on the network. This phenomenon makes it appropriate for its utilization as a ‘combined security and safety solution’ in smart city. Alarm detection can be implemented based on the parameters of their trajectories and object movement. Further, it is also implemented by ontologies and semantic reasoning.

Sodhro et al. [13] proposed two algorithms namely, Delay-tolerant Streaming Algorithm (DSA) and Hybrid Adoptive Bandwidth and Power Algorithm (HABPA) by adapting stored video stream in the name of ‘StarWarsIV’. In addition, a new framework was also presented for smart city schemes. Hossain et al. [14] designed a cloud-enabled architecture for a secure video transmission in which the mobile users have limited capacity. However, the user is empowered to share video easily, without compromising on its quality and integrity. In the presented architecture, when videos are taken using smart phones, a key frame is identified. This key frame can be identified with the help of Genetic Algorithm (GA) model. A Discrete Wavelet Transform (DWT)-based watermarking method is utilized for inserting the watermark into key frame. A 2-layer protection system-based error correcting code is employed as an identity/signature of a person to create the watermark i.e., insert in the videos to protect it from attacks/distortion and transmission loss.

Jin et al. [15] developed a sequence for scheduling strategies and optimization algorithms-based Unmanned Aerial Vehicles (UAV) clusters. Initially, a complete device coverage network is created with the help of UAV clusters in heterogeneous transmission environments of smart cities. Kang et al. [16] projected a cooperative method for mobile networks which could utilize local memory space and upload bandwidth to release the computation loads for streaming servers. Initially, a statistical distribution of the device’s lifecycle is established vigorously, according to the analyses of departure and random arrival of mobile users. Tian et al. [17] suggested a Block-level Background Modelling (BBM) method for assisting long-term reference architecture for effective video surveillance coding. Also, a rate-distortion optimization system for surveillance source (SRDO) is presented for improving the performance of coding.

3 The Proposed Model

3.1 Assumptions Made

Once the video conference is set for a group of users, then the individuals are named as participants. A participant plays the role of a sender as well as receiver of video streams simultaneously from each of the remaining participants. Consider that a participant is interconnected to every node that belongs to the network whereas many other participants are also interconnected to similar nodes. The participant is assumed to be wirelessly connected to their nodes through 4G cellular technologies like Long Term Evolution (LTE). All the network nodes offer SDN switching function as well as wireless accessing function (like eNode-B). Since the network is an SDN-assisted one, consider that every node within the network contains OpenFlow switches and has the ability to interact with SDN controllers i.e., accountable for call management. Each switch is capable of adapting Scalable Video Coding (SVC) stream by dropping redundant layers on the path.

SVC stream is generally controlled in layers based on base layers. Consider that SVC layer consists of base layer L1, and three improved layers such as L2, L3, and L4. But this process could be generalized easily to any number of layers. Furthermore, a provided layer is utilized, once each low layer is received. All the participants accept the maximum number of layers that can be accepted by its downlink ability. The participant obtains low video quality when using the base layer.

In video conference, the best possible bitrate, allowed by access connection bandwidth, is suggested to achieve an improved Quality of Experience (QoE). Thus, during a video call, all the participants send the highest bitrate streams allowed by other receivers. Then, this stream gets degraded (viz., highest layer is dropped) to adapt according to the participant with least downlink bandwidth capability [18]. After determining the channel condition and network topology with SDN global view, it becomes easy to find the location of switches, where there is a need for degrading the SVC stream.

This method is implemented in SDN controllers to set up a video conferencing call and build a multi-cast tree from all participants (transmitter) to each other (receiver). It is based on the assumption given herewith.

- Each SVC layer belongs to the video stream released by one sender and it follows a similar path. There is a single tree for each layer of the provided video streams. As the adaption is executed in fundamental network, few branches of the tree might bring a subset of layer.
- SDN controllers know the network's comprehensive topology, positions of the participant, and their accessible downlink and uplink accessing bandwidth.
- Some SDN switches may degrade (viz., drops high quality layer) SVC streams.

3.2 Design of Multicast Routing Protocol

At this stage, IBWO-LD technique is designed for multicast routing for the purpose of video data transmission in smart cities. BWO stimulates the metaheuristic techniques and is currently used in resolving difficult numerical optimization issues. BWO is assumed to be a part of evolutionary techniques, owing to its operator. BWOA components are same as that of GA, the most essential evolutionary technique. Like every other evolutionary technique, BWO too has few conditions that mimic the procedures found in natural evolution like mutation, reproduction, and selection. These conditional variations differentiates BWO from other evolutionary techniques. BWO is inspired from strange mating behaviour of black widow spider. Further, this technique has few variances against evolutionary techniques and is utilized in achieving optimum efficiency upon difficult issues. BWOA is simulated as the natural chosen Darwin model and is determined as descent with alteration, idea of altering species in time, and generation of novel ones. BWO avoids local optimum entity and delivers rapid convergence owing to which the algorithm is obtained through optimum techniques and can resolve different kinds of optimization issues. With a number of local optima in place, BWO keeps a balance between exploration and exploitation stages. Fig. 2 exhibits the block diagram of BWO system. A detailed explanation for the essential steps in BWO are explained herewith.

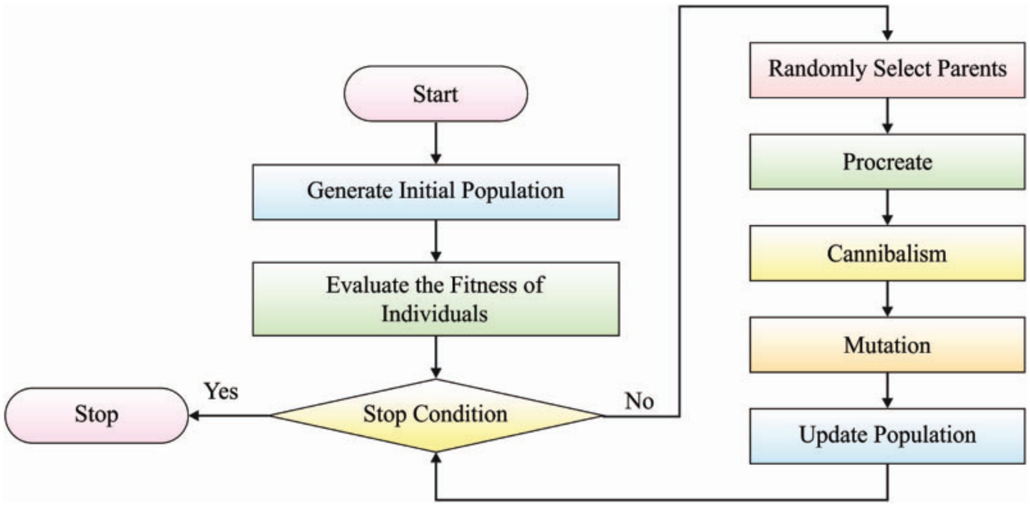

Figure 2: Flowchart of BWO

Step 1: Initialization

During this phase, the population contains a few number of widows sized N, where all the widows are demonstrated as an array of $1 \times N_{var}$ signifying the solution for the issue. This array is determined as $widow = (x_1, x_2, \ldots, x_{N_{var}})$, where N_{var} refers to dimensions of the optimized issue. Besides, N_{var} refers to the determined amount of threshold values which are required and can be attained by this technique and finally x_i implies the ith candidate solution.

The fitness of widow is estimated using fitness function (FF) i.e., f of all the widows of the set $(x_1, x_2, \ldots, x_{N_{var}})$. Next, $fitness = f(widow)$ is demonstrated as follows; $fitness = f(x_1, x_2, \ldots, x_{N_{var}})$. In the presented technique, f is replaced by FF Otsu in Eq. (8) or Kapur Eq. (14). Optimization procedure is started using an arbitrarily-initialized population of spiders from a matrix sized, $N_pop \times N_var$. Afterward, a pairs of parents is chosen arbitrarily to implement the production step. Then, the mating procedure occurs in which the male black widow is consumed by female during mating or after mating is over [19].

Step 2: Procreate

During procreation phase, an array named alpha α is generated by a widow array which is composed of arbitrary values. Afterward, the offspring is created by utilizing α. In Eq. (1), x_1 and x_2 represent the parents and y_1 and y_2 demonstrate the offspring. The crossover outcome is estimated and saved.

$$y_1 = \alpha \times x_1 + (1 - \alpha) \times x_2 \textit{ and } y_2 = \alpha \times x_2 + (1 - \alpha) \times x_1 \tag{1}$$

Step 3: Cannibalism

Different cannibalism behaviours have been reported earlier such as sibling cannibalism, sexual cannibalism, and a frequently-observed cannibalism in which baby spider eats its mother. After the implementation of cannibalism process, a novel population is estimated and saved based on the variable named pop2.

Step 4: Mutation

The procedure of mutation gets completed by the arbitrary-chosen *Mutepop* number of individuals in the mutated population. All the solutions are selected arbitrarily with connections containing two elements of array. Then, the mutation is implemented after which a novel population is estimated and saved from the novel population i.e., $pop3$. Eventually, a novel population is reached after the migration of $pop3$ and $pop2$ and is sorted out for returning an optimum widow of threshold value with N_{var} dimension. Algorithm 1 illustrates the pseudocode for BWO.

Algorithm 1: Black Widow Optimization algorithm

Initialize: Maximal amount of iterations, rate of Cannibalism, rate of mutation, Rate of procreating;
while *Stop condition not met* do
for $i = 1$ to nr do
Arbitrarily choose 2 solutions as parents in pop1.
Create D children utilizing in Eq. (1).
Destroy father.
According to the rate of cannibalism, destroy any children (currently attained solutions).
Store the residual solutions into pop2.
end for
According to the mutation rate, compute the amount of mutation children nm.
for $i = 1$ to nr do
Choose the solution in pop1.
Arbitrarily Mutate single chromosome of solution and create a novel solutions.
Store a novel one as to pop2.
end for
Upgrade $pop = pop2 + pop3$.
Return the optimum solution.
Returning the optimum solution in pop.
end while

To enhance the performance of BWO technique, IBWO-LD technique is derived by integrating Levy flight concept.

Levy Flight concept was first presented by the French mathematician named Paul Levy, in 1937. Different kinds of natural and artificial phenomena have been defined based on Levy statistics. LF is assumed to be a class of stochastic non-Gaussian walks in which the step length value is assigned based on Levy stable distributions. It is determined as follows.

$$Levy(\beta) \sim u = t^{-1-\beta},\ 0 < \beta \leq 2 \tag{2}$$

β signifies the vital Levy index for changing the stability. Levy arbitrary amount is estimated using the formula given below.

$$Levy(\beta) \sim \frac{\varphi \times \mu}{|\mathrm{v}|^{1/\beta}} \tag{3}$$

where μ & v signify the regular distribution, Γ demonstrates the normal Gamma function i.e., $\beta = 1.5$, & φ are given as follows.

$$\varphi = \left[\frac{\Gamma(1+\beta) \times \sin\left(\pi \times \frac{\beta}{2}\right)}{\Gamma\left(\left(\frac{1+\beta}{2}\right) \times \beta \times 2^{\frac{\beta-1}{2}}\right)}\right]^{\frac{1}{\beta}}. \quad (4)$$

To attain a trade-off between the exploitation and exploration abilities of metaheuristic technique, LF method is utilized. It also upgrades the location of search agents and is determined as follows.

$$X_i^{levy} = X_i + r \oplus levy(\beta) \quad (5)$$

where X_i^{levy} represents the novel position of ith search agent, X_i afterward upgrading and r defines the arbitrary vector between 0 and 1 and $\oplus$ signifies the dot product (entry wise multiplication).

During this case, the purpose of the proposed model is to send the information sized M in source to target the vehicles at minimal energy cost, without compromising on the deadline and bandwidth constraints. The issue is otherwise known to be Mixed Integer Programming (MIP) and is determined as follows.

Objective:

$$\min \sum_{i \in V} \sum_{j \in V} e_{ij} f_{ij}, \quad (6)$$

Subject to

$$\sum_{fkw(i)} f_{ij} = M, i = s \quad (7)$$

$$\sum_{j \in N(i)} f_{ji} = M, \forall i \in T \quad (8)$$

$$\lambda_{ij} + \lambda_{ji} \leq 1, \ \forall i, \ j \in V \quad (9)$$

$$f_{ij} \leq \lambda_{ij} b_{ij}, \ \forall i,j \in V, \quad (10)$$

$$\sum_{j \in N(i)} f_{ji} \geq f_{ik}, \forall i, k \in V, \quad (11)$$

$$d_j \geq (d_i + g_{ij} + q_i + (f_{ij}/b_{ij})) - ((1-\lambda_{ij})^* L), \ \forall j \in V, \ i \in N(j), \quad (12)$$

$$q_i = 0, \ \forall i \in \{s \cup T\} \quad (13)$$

$$d_i = 0, \ i = s \quad (14)$$

$$d_i \leq \theta, \ \forall i \in T, \quad (15)$$

$$f_{ij} \geq 0, \ \forall i,j \in V, \quad (16)$$

$$\lambda_{ij} \in \{0, 1\}, \ \forall i, \ j \in V \quad (17)$$

The objective function (6) is to minimize the utilization of energy in multi-casting data, sized M in source to destination [20].

Several constraints are taken into account from the chosen optimum multicast path. Following is the list of constraints used.

- 1st constraint (7): The overall amount of information sent by the source vehicle is equivalent to M.
- 2nd constraint (8): The overall amount of information is provided by the most number of target vehicles is equivalent to M.
- 3rd constraint (9): If the flow is sent in node i to j, the flow cannot enter node j to i. This constraint is utilized to avoid the loops.
- 4th constraint (10): Data flow gets transmitted from node i to j which is lesser than or equivalent to residual bandwidth of the connection in node i to j.
- 5th constraint (11): The in-between nodes cannot be taken as the message targets. So, it can be transmitted to an adjacent node once it is received. But, the maximum amount of information transferred from in-between node to every neighboring node is lesser than or equivalent to the amount of data received.
- 6th constraint (12): As the message is separated into distinct packets, all the packets arrive in a distinct path from transmitter node to i node. The delay for total number of messages to reach the node i is equivalent to the maximal delay of packets from the path that leads to node i when data is sent to i. Besides, these delays contain the Queuing Delay (QD) and propagation delay. The QD of $i(q_i)$ node implies the average QD from i node. All the set nodes calculate their average QD regularly (all the 4 s). Afterward, it transmits q_i values to local controllers that upgrade their data and transmits the values to SDN controllers. During these constraints, $(1 - \lambda_{ij}) * L$ is utilized to explain that the deadline constraints are calculated for the nodes, i as well as j, if the flow is from i to j nodes. Else, $(1 - \lambda_{ij}) = 1$, therefore $d_j \geq d_i + g_{ij} + q_i + (f_{ij}/b_{ij})$ remains ineffective.
- 7th constraint (13): There is no QD from both source and target vehicles
- 8th constraint (14): As the message is established from the source nodes initially, the delay for the messages to reach the node is continuously equivalent to 0.
- 9th constraint (15): The delay of messages could not surpass the deadline.
- 10th constraint (16): The dataflow in some nodes to further ones is not ever negative because when the data could not be sent between two nodes, their volume becomes equivalent to 0; else it can be superior to 0.
- Last constraint (17): Based on these constraints, the variable λ_{ij} gets the value one, when the data is sent from node i to j. Else, their value is zero.

3.3 Design of Priority Based Scheduling and Classification Model

This protocol makes use of priority-based scheduling and application-based classification algorithm to reduce the cost and accomplish QoS needs.

The Closest Fixed Node $F^t_{(i)}$: This is a fixed node with minimal delay using ith vehicle at time t and is represented as $F^t_{(i)}$. As per (18), the nearby fixed node transmitted from j to vehicle i at time t is defined by regular transmission of beacon packet. The fixed nodes that respond to this packet with minimal delay is considered as a nearer one. The respond time to this packet through fixed node is based on traffic load and distance of this node.

$$F^t_{(i)} = \arg\min_{j \in N} d^t_{i,j} \tag{18}$$

Here, N represents a group of fixed nodes and $d_{i,j}^{t}$ denotes the delay at the j^{th} fixed node while i^{th} vehicle at time t.

Local Controller C_i: All the groups of (N_i) fixed nodes are connected to individual local controllers which is represented as C_i in which $i \in \{1, 2, \ldots, Q\}$ and Q denotes the amount of local controller.

Where, θ signifies deadline limitation, T indicates the group of destination vehicle, M represents the output of EEMSFV which denotes multi-cast tree and Π denotes data size.

Usually, distinct multi-cast session requests are raised towards the controllers (SDN/local controllers) which must serve these requests, according to their priority. Initially, the controller categorizes the request on the basis of every group of same application type and is queued in a certain format. In current study, four application types are considered that denote the type of vehicle i.e., normal, police, firefighting, and ambulance vehicles. Next, the request inside all the queues is scheduled according to the priority. The priority of the vehicle can be defined based on deadline limitation in which the request with low deadline limitation takes the higher priority.

After high priority requests are computed, the controllers select individual requests at a time, according to the priorities from the head of this queue. After that, the multi-cast tree is built for it. Such priorities are defined according to two criteria given herewith.

Application Type: Distinct application types have different priorities. In current work, several values have been allocated to all the application types for representing their priority. The value 14 represents the priority for normal, firefighting, ambulance, and police applications, correspondingly.

Deadline Constraint: Usually, multi-cast requests with minimal deadline limitation have high priority.

Next, the fitness value of all the requests is calculated. The requests with the least values are considered as high priority and are elected using the controllers. The fitness values are calculated as follows.

$$Fitness_i = A_i + \theta_i \tag{19}$$

In which $Fitness_i$ signifies the fitness values of request, i. A_i and θ_i represent the standardized value of application types and the deadline limitation of request i, correspondingly.

$$P_i > P_j \text{ if } fitness_i < fitness_j \tag{20}$$

Here, P_i & P_j represent the priority of i and j requests correspondingly.

4 Performance Validation

The current section discusses the results achieved from performance analysis of IBWO-LD technique against other techniques under different aspects.

Tab. 1 and Fig. 3 shows the results from average bandwidth analysis accomplished by IBWO-LD technique and other techniques under varying number of participants. The results show that the proposed IBWO-LD algorithm generated improved performance with maximal average bandwidth compared to other techniques. For instance, with 3 participants, IBWO-LD technique resulted in an increased average bandwidth of 54 Mbps, whereas unicast (UNI), Shortest Path Tree (SPT), Minimizing Spanning Tree (MST), ALM, and Multiple Control Unit (MCU) techniques gained low average bandwidth values such as 47, 48, 43, 46, and 50 Mbps respectively. At the same time, with 12 participants, IBWO-LD technique gained a high average bandwidth of 817 Mbps, whereas UNI, SPT, MST, ALM, and MCU techniques attained reduced average bandwidth values such as 780, 420, 410, 630, and 740 Mbps respectively.

Table 1: Average bandwidth analysis results of IBWO-LD model against existing approaches

Average bandwidth (Mbps)						
Number of participants	UNI	SPT	MST	ALM	MCU	IBWO-LD
3	47	48	43	46	50	54
6	195	120	110	150	197	257
9	420	280	260	350	410	461
12	780	420	410	630	740	817

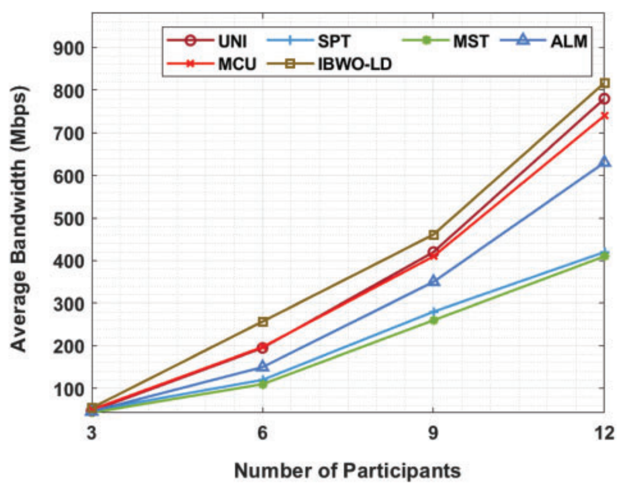

Figure 3: Average bandwidth analysis results of IBWO-LD technique under varying number of participants

A brief Average End to End Delay (AETED) analysis was conducted between IBWO-LD and other existing techniques and the results are shown in Tab. 2 and Fig. 4. The results point out that the proposed IBWO-LD technique accomplished effective outcomes with least AETED. For instance, with MS = 5, IBWO-LD technique obtained effective outcomes with least AETED value of 0.15 s, whereas MABC, CVLMS, and EEMSFC techniques attained maximum AETED values such as 0.50, 0.40, and 0.20 s respectively. Besides, with MS = 25, IBWO-LD method attained effective outcomes with least AETED value i.e., 0.50 s, whereas MABC, CVLMS, and EEMSFC techniques attained the maximum AETED values such as 1.50, 1.40, and 0.60 s correspondingly.

Table 2: AETED analysis results of IBWO-LD model against existing approaches

Number of multicast session (MS)	AETED (s)			
	MABC	CVLMS	EEMSFV	IBWO-LD
5	0.50	0.40	0.20	0.15
10	0.62	0.50	0.25	0.20
15	0.90	0.62	0.38	0.35
20	1.18	0.90	0.42	0.40
25	1.50	1.40	0.60	0.50

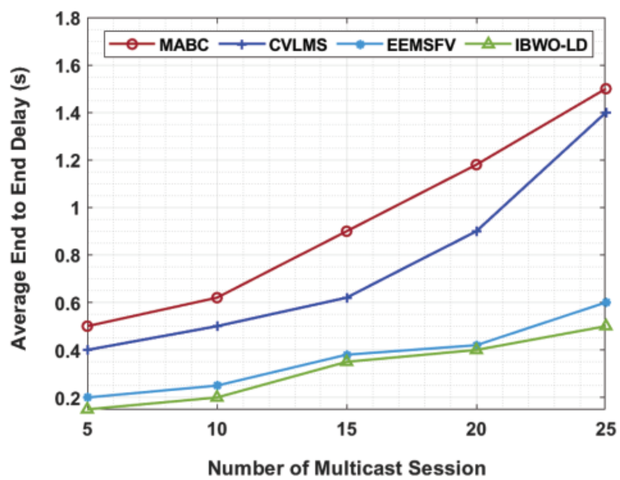

Figure 4: AETED analysis results of IBWO-LD techniques under varying MS

Tab. 3 and Fig. 5 shows the results for Successfully Transmitted Ratio (STR) analysis accomplished by the proposed IBWO-LD technique against other techniques under varying number of Multicast Session. The outcomes demonstrate that the proposed IBWO-LD method produced high performance with maximum STR compared to other techniques. For instance, MS = 5, IBWO-LD technique produced an increased STR of 0.99, whereas Modified Artificial Bee Colony (MABC), Collaborative Vehicle Location Management Service (CVLMS), and Energy Efficient Multicast routing protocol based on SDN and Fog computing for Vehicular networks (EEMSFV) techniques achieved low STR values such as 0.87, 0.93, and 0.98 correspondingly. Also, with 25 participants, IBWO-LD technique gained a high STR of 0.94, whereas MABC, CVLMS, and EEMSFV methods attained low STR values such as 0.21, 0.60, and 0.94 correspondingly.

A detailed Packet Loss Ratio (PLR) analysis was conducted between IBWO-LD and existing methods and the results are shown in Tab. 4 and Fig. 6. The results infer that the presented IBWO-LD technique accomplished effective outcomes with minimal PLR. For instance, with MS = 5, IBWO-LD technique achieved an effectual outcome with the least PLR of 0.07, whereas MABC, CVLMS, and EEMSFC techniques accomplished maximum PLR values such as 0.20, 0.15, and 0.08 correspondingly. In addition, with MS = 25, IBWO-LD system obtained effective outcomes with the least PLR of 0.15, whereas MABC, CVLMS, and EEMSFC techniques attained the maximum PLR values such as 0.75, 0.60, and 0.15 respectively.

Table 3: STR analysis results of IBWO-LD model against existing approaches

Number of multicast session	STR			
	MABC	CVLMS	EEMSFV	IBWO-LD
5	0.87	0.93	0.98	0.99
10	0.80	0.91	0.97	0.98
15	0.68	0.82	0.96	0.97
20	0.50	0.84	0.94	0.96
25	0.21	0.60	0.92	0.94

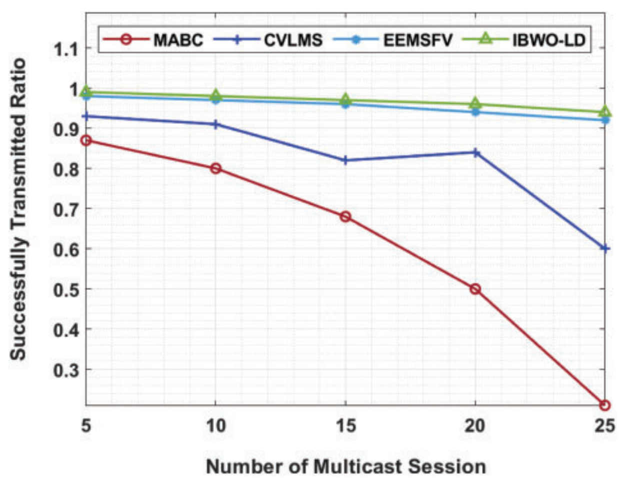

Figure 5: STR analysis of IBWO-LD techniques under varying MS

Table 4: PLR analysis results of IBWO-LD model against existing approaches

Number of multicast session	PLR			
	MABC	CVLMS	EEMSFV	IBWO-LD
5	0.20	0.15	0.08	0.07
10	0.25	0.21	0.10	0.08
15	0.35	0.28	0.10	0.07
20	0.58	0.37	0.11	0.08
25	0.75	0.60	0.15	0.15

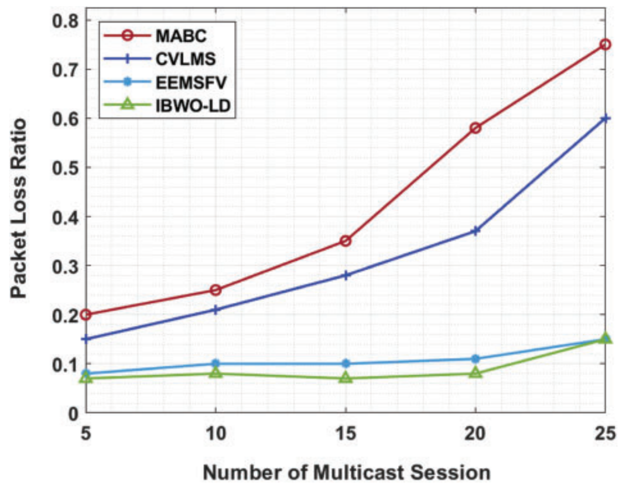

Figure 6: PLR analysis of IBWO-LD techniques under varying MS

A brief Normalized Overhead Load (NOL) analysis was conducted between IBWO-LD and existing methods and the results are shown in Tab. 5 and Fig. 7. The results infer that the proposed IBWO-LD technique accomplished effective outcomes with minimal NOL. For instance, with MS = 5, the proposed IBWO-LD methodology reached effective outcomes with a decreased NOL of 15, whereas MABC, CVLMS, and EEMSFC techniques attained maximum NOL values such as 35, 28 s, and 20 respectively. Likewise, with MS = 25, IBWO-LD technique obtained effective outcomes with the least NOL of 50, whereas MABC, CVLMS, and EEMSFC techniques achieved the maximal NOL values such as 135, 100, and 58 correspondingly.

Table 5: NOL analysis of IBWO-LD model with existing approaches

Number of multicast session	NOL			
	MABC	CVLMS	EEMSFV	IBWO-LD
5	35	28	20	15
10	45	35	24	20
15	65	53	30	25
20	98	78	42	35
25	135	100	58	50

A comparative Multicast Energy Consumption (MEC) analysis was conducted between the proposed IBWO-LD against existing techniques and the results are shown in Tab. 6 and Fig. 8. The results showcase that the proposed IBWO-LD approach accomplished effective outcomes with the least MEC. For samples, with MS = 5, the proposed IBWO-LD technique has obtained effective outcomes with the least MEC of 285 Joules, whereas MABC, CVLMJOULES, and EEMSFC methods reached maximal MEC values such as 1250, 1049, and 586 Joules respectively. Besides, with MS = 25, IBWO-LD method obtained effective outcomes with the least MEC of 2819 Joules, whereas MABC, CVLMJOULES, and EEMSFC techniques attained the maximal MEC values namely, 5998, 5414, and 3885 Joules correspondingly.

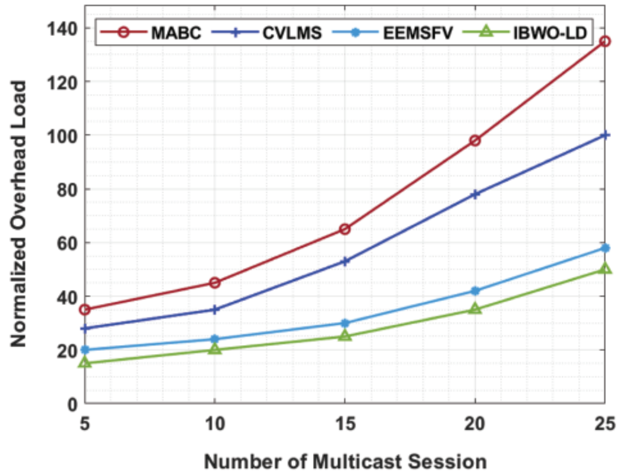

Figure 7: NOL analysis of IBWO-LD techniques under varying MS

Table 6: MEC analysis results of the proposed model

Number of multicast session	MEC (in Joules)			
	MABC	CVLMS	EEMSFV	IBWO-LD
5	1250	1049	586	285
10	2015	1673	828	425
15	2880	2477	1250	808
20	3966	3785	2296	1512
25	5998	5414	3885	2819

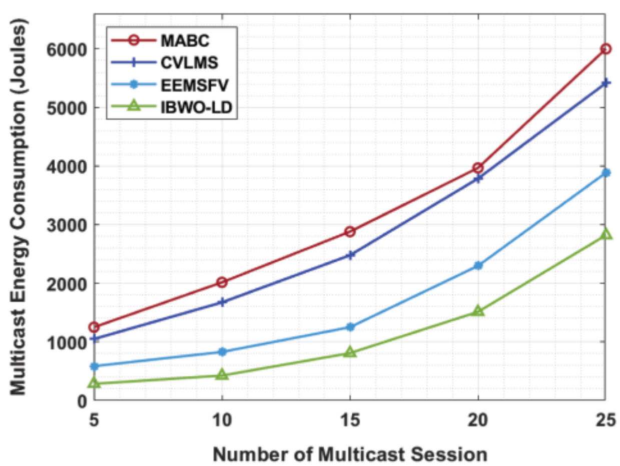

Figure 8: MEC analysis of IBWO-LD techniques under varying MS

5 Conclusion

Multicast routing protocol with multiple QoS constraints is an NP hard problem. It can only be solved with the help of metaheuristic optimization algorithms. In this background, the current study presented an effective IBWO-LD based multicast routing protocol for smart cities. The presented IBWO-LD model aims at minimizing energy consumption as well as bandwidth utilization, while improved video stream quality is to be accomplished for client end. Besides, a priority-based scheduling and classifier model is designed to allocate multicast request based on the type of applications and deadline constraints. A thorough experimental analysis was conducted to guarantee the improved outcomes under different aspects. The comprehensive comparative analysis results highlighted the superiority of the proposed IBWO-LD model over other compared approaches. As a part of future scope, IBWO-LD technique can be implemented in real-time scenarios and its performance can be fine-tuned.

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