

RESEARCH ARTICLE

Particle Swarm Optimization Video Streaming Service in Vehicular Ad-Hoc Networks

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ABSTRACT Owing to the increasing capabilities of mobile devices and the development of mobile communication techniques in vehicular ad hoc networks (VANETs), mobile multimedia services have focused on supporting high Quality of Service (QoS) and Quality of Experience (QoE) for the subscribers in video streaming services. In VANETs, high-quality video streaming services aim to provide subscribers with safety and various infotainment applications. Due to the dynamic topology and frequent connectivity changes in moving vehicles, video streaming services require elastic and continuous vehicle information updates to present interactive real-time views of nontrivial road scenarios. The QoS and QoE are affected due to obstacles, re-location tracking, network traffic, and bandwidth factors that occur due to mobility problems and significantly influence the ability of vehicles with mobility to provide video streaming services. To achieve high QoS and QoE of video streaming services in VANETs, this paper proposes a novel protocol named PSOstreaming based on a particle swarm optimization (PSO) which is one of the mainstream and nature-inspired algorithms for swarm intelligence (SI). PSOstreaming calculates the PSQ score, which is the scoring method of the node in the topology in terms of the data communication capability measurement to analyze and optimize topology information in real-road circumstances. In addition, PSOstreaming utilizes a 3D vector mobility prediction algorithm for the mobility prediction method for the vehicles to address the characteristics of VANETs. In the topology, PSOstreaming defines Global PSO members and Local PSO members to disseminate video packets for video-streaming services to the service requester by computational equations. Experimental results indicate that PSOstreaming achieves high-quality video streaming services with a flexible response to dynamic topology changes and a high frame delivery ratio in terms of QoS and QoE.

INDEX TERMS Swarm intelligence, particle swarm optimization, vehicular ad-hoc networks, video streaming service, 3D-vector mobility support.

I. INTRODUCTION

As the era of advanced development of vehicles and various infotainment content enjoyed in vehicles is approaching, (VANETs) are a very realistic and practical way to meet these needs [1]. In VANETs, vehicles assume the role of network nodes with special characteristics, such as high mobility, self-organization, road pattern restrictions, no energy constraints, and large-scale network sizes. Roadside units (RSUs) are installed near roads, and act as relay nodes owing to their static locations. Vehicles and RSUs can communicate with

each other via dedicated short-range communication (DSRC) technology [2] for vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications [3], [4]. Several projects (e.g., VICS [5], CarTALK 2000 [6], network-on-wheels (NoW)) [7], and industry groups (e.g., Car2Car Communication Consortium [8]) have conducted various studies to establish intelligent transport systems using VANETs. Furthermore, as an important component of smart cities and intelligent transportation systems (ITSs), VANETs have attracted increasing research and real-life communities. Several studies on VANETs have researched various applications, such as special event warnings on the road for safe car driving, emergency notifications for public service, road congestion

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notices for improved driving, and diverse image content commercial advertisements for business and infotainment services [9], [10], [11].

Among the applications of VANETs, video streaming services are currently garnering significant attention for supporting applications, such as video warnings for safe driving and video advertisements for infotainment services. A vehicle can send a video warning file about an accident to the user vehicle from the surrounding and trajectory information. It can also share video clip files advertising nearby stores with neighboring vehicles through a video advertising application. Generally, video files contain large amounts of data depending on their related applications, and have stringent quality of service (QoS) and quality of experience (QoE) requirements. Moreover, VANETs have dynamic topology features owing to intermittent connections and frequent link breakages caused by the high mobility of vehicles on roads.

Accordingly, three challenging issues should be addressed to achieve the QoS and QoE requirements to support video streaming services in VANETs with dynamic topology features and intermittent connections. First, the load-balancing mechanism should be considered to satisfy the high QoS and QoE, and prevent overload of the nodes owing to the extensive video data forwarded to the vehicles. Previous studies on QoS and QoE for video streaming services [12], [13], and [14] have no adaptable load-balancing mechanisms for real-time topology information searches. Second, the vehicle's mobility must be calculated to predict the direction and forward streaming data with less loss data. Vehicles in the topology have high mobility with unpredictable directions and speeds. The research proposed in [15], [16], and [17] adopted a mobility prediction algorithm for video-streaming services in VANETs; however, these protocols cannot be applied to short-term mobility predictions with real-time tracking. Third, data caching should be efficiently conducted to store the video data content on the calculated route until communication is complete. Previous studies [18], [19], [20] have a caching mechanism that does not consider video packet distribution for real-time video streaming services.

Mobile Ad-hoc Networks (MANET) technologies for multimedia data forwarding have recently been proposed in diverse research areas [21], [22]. MANET has a critical energy consumption issue for the multimedia streaming service. The mobile node in MANET has no energy supplies for maintaining the multimedia streaming data forwarding. The energy issue in MANET for the video streaming service is no longer the problem in VANET due to the characteristics of the vehicle. The recently researched multimedia streaming services in MANET are unsuitable for VANET circumstances due to resource calculation differences. The differences in the algorithms and topologies impact the QoS and QoE in the multimedia data forwarding process.

In this paper, we propose a novel protocol named PSOSTreaming to provide video streaming services with supporting QoS and QoE in VANETs by efficiently addressing the three challenging issues. We first adopt Particle swarm

optimization (PSO) algorithm to solve the load-balancing problem in dynamic topology changes. We then formulate short-term mobility predictions to react to the mobility of the vehicle immediately. The dependent long-term mobility prediction algorithm based on the vehicle's trajectory to the destination may cause resource wastage and take time to recover the forwarding route when the user vehicle is off the calculated path. The proposed protocol uses particle swarm optimization information from the topology and the user vehicle's mobility to establish the forwarding path via a 3D mobility short-term prediction algorithm, rather than the long-term predictions researched previously [14], [23], [24]. The long-term prediction algorithms have to use the trajectory of the user vehicle to predict the user vehicle's future location to forward the streaming data. However, using the vehicle's trajectory information to the destination to predict the vehicle's future location cannot immediately handle unexpected circumstances. When the previous studies faced unforeseen circumstances due to the free will of the drivers, the mobility prediction algorithms took more time and more resources to rebuild the data forwarding path to the requested vehicles, which often happens in real road scenarios. Additionally, it constrains the topology resource waste in the streaming services. Otherwise, the short-term mobility prediction in the PSO streaming can avoid the mentioned problems. However, the PSOSTreaming immediately reacts to topology changes because of the service user number, which makes the resource balance of APs in the topology. Owing to the dynamic routing decisions for user vehicles and the closed cooperation of different methods of PSO and 3D mobility prediction, the proposed protocol is capable of adaptively coping with rapid topology changes in real-time video streaming scenarios. The main contributions of this paper are as follows:

- We propose a PSO topology information searching mechanism for APs and calculate the score of APs' resource availability. Compared to previous protocols that search for static availability data by end-to-end routing, the proposed algorithm has flexibility and great adaptability in real-time video streaming. Furthermore, the proposed protocol leads to high load balancing in the topology because all APs organically share their resource information.
- We derive mathematical models for the resource arrangement of APs in the topology before the video streaming service is initiated. The PSO algorithm calculates the scores of all APs in the topology based on resource availability. The aforementioned mathematical models calculate the particle swarm quality information (PSQ) score. The PSQ score continues to update in real time during video streaming. Hence, it recognizes the resource changes owing to the service users in the topology, and updates the live PSQ score for the other service users to create a path and select the global and local PSO members.
- The PSO-based algorithm calculates the topology information based on the PSQ score from the pre-learning

phase. Then, global and local PSO members are selected when the video streaming service is provided to the service requesting user vehicle. The early process of the proposed algorithm mainly comprises candidate derivation and optimal global and local PSO member selection. It also enables collaboration between two member groups for video streaming services.

- A 3D vector mobility prediction mechanism is proposed to predict the mobility of the moving vehicle. This mechanism primarily employs the mobility information of the vehicle, such as the vector direction, speed, and geographical information. Moreover, it immediately reacts to mobility changes caused by the driver's handling. The proposed mobility prediction method provides short-term mobility support and helps maintain the link connection to the user vehicle without trajectory information.

The remainder of this paper is organized as follows. Related works are described in Section II. The proposed protocol is described in detail in Section III. In Section IV, we experimented with simulation in real-road circumstances with Manhattan combined with random mobility of the vehicles and analyzed the simulation results. Finally, Section V concludes the paper.

II. THE RELATED WORKS

The primary purpose of this study is to optimize the routing information of vehicles in the topology, and route video streaming data to a vehicle moving toward its destination according to its geographical information in a VANET. In this section, we review the studies related to the aim of our study. First, we examine studies on multimedia streaming services in VANETs. To satisfy the demands of multimedia streaming services and infotainment applications in VANETs, various routing schemes [25], [26], [27], [28], [29] have been proposed to deliver multimedia streaming data. These studies are based on selecting relaying vehicles to forward distributed streaming data using time scheduling methods for the user vehicle. However, they did not consider QoS and QoE, which are the main factors affecting user satisfaction with video streaming services.

Therefore, several routing protocols that support QoS and QoE mainly have been proposed for multimedia streaming services in VANETs. To support the QoS requirements of multimedia services, Lakas *et al.* [12] proposed CBQoS-Vanet with a bee colony-inspired algorithm that calculates the best routes from a source to destination based on QoS metrics such as bandwidth, end-to-end delay, and jitter. Xing *et al.* [13] proposed a hybrid framework to determine the best delivery strategy and select an optimal path for multimedia data dissemination by considering delivery delay, storage cost, and QoS. To enhance the QoE of video streaming, DQLTV [24] selects forwarding vehicles with the best link quality (transmission success) and link availability (lifetime) using the mobility information of the vehicles. GeoQoE [14] conducts QoE-aware geographic routing for

video streaming, which measures the QoE values (i.e., mean opinion score (MOS)) of neighboring vehicles based on correlated QoE and QoS factors (e.g., packet loss rate, jitter, and delay). Subsequently, it selects the vehicle with the best QoE value as the relay vehicle. Using the mobility information of vehicles, some studies have proposed methods to efficiently support the QoS and QoE of multimedia streaming services in VANETs. The 3MRP method exploits the trajectory information of vehicles as one of the five QoS metrics (distance to destination, vehicle density, trajectory, available bandwidth estimation, and MAC layer losses). Accordingly, 3MRP [15] enables a vehicle to select the best forwarding node for sending video reporting messages to an AP in the city infrastructure to alert emergency services. By exploiting the mobility prediction of vehicles, an adaptive video uploading scheme [16] is proposed to reliably deliver video streaming data from a moving vehicle to a fixed network by selecting the optimal APs and stable relay vehicles. LBP [17] is a prediction window-based video streaming algorithm that adjusts the requested QoE of a video while ensuring that no video stall occurs in vehicles. In addition, the QoS and QoE are supported by vehicular streaming services. To enhance the QoE of video streaming, Pederson *et al.* [18] proposed an algorithm to support adaptive bit rate (ABR) based on video characteristics and efficiently using caching in radio access networks. Yashuang *et al.* [19] proposed a dual time-scale dynamic cache scheme in base stations to support ABR streaming under the condition of high channel variations to achieve high QoS and QoE for video streaming services in VANETs. Zhao *et al.* [20] proposed a scheme to cache OTT multimedia streaming content in future connected RSUs using vehicle mobility prediction. However, existing protocols that support the QoS and QoE of multimedia streaming services only consider static destination vehicles. Moreover, they exploit mobility prediction and caching with the mobility information of normal vehicles on roads instead of the trajectory information of the destination vehicles.

The video streaming service application aims to provide a high-quality infotainment service to the user vehicle. Infotainment enables the smart cars to provide informational and entertainment services, enhancing the experience of drivers and passengers. Video streaming applications in infotainment services are the primary technology to achieve the goal. In recent years, the vehicle infotainment system has captivated significant attention from automobile industries discussed in [30]. For the high-quality media content provided in infotainment services, the services have a topology that minimizes the video file data loss with the minimum delay to the destination vehicle. Independent infotainment service without considering QoS and QoE in the multimedia data forwarding process [30] cause the challenging issues mentioned before in multimedia service in VANETs.

As mentioned previously, the study timeline has pointed out QoS and QoE improvement solutions in the routing process. However, these protocols cause a high error rate and quality decline, owing to the unintended mobility behavior

of the requested vehicles. These challenges arise from two main factors. One is the low refresh rate of the topology information. If the topology information does not reflect the live status, there is a chance that the user vehicles can derive staleness information in the forwarding process. Moreover, the relay AP may have an overloading situation because the user vehicles continue using the same path even though the energy level of the AP in the path has decreased. However, with the rapid development of mobile devices and inter-vehicle systems, the processability of vehicles has increased enough to handle high-cost calculations. This study adopts the concept of artificial intelligence (AI), called swarm intelligence (SI). SI methods are employed in routing, owing to the similarity in the behavior of swarms and routing. SI techniques have provided an optimized solution that ensures flexibility and robustness economically by prior learning.

Several studies have been conducted on VANETs using optimization techniques. Therefore, we classify the SI techniques in VANETs into three categories: ant colony optimization (ACO), bee swarm optimization (BSO), and particle swarm optimization (PSO) [31]. Swarm Intelligence protocols are derived in various application areas. Many studies accept the concept of the SI protocols in VANETs published in the research area. However, in this paper, we categorized the SI protocols for VANETs with video data forwarding in related work. ACO imitates the food exploration behavior of ants. The search for an optimized route for a given task represented in the graph is researched in [32]. The ACO algorithm is based on the ants' behavior when they search for the shortest path between their nests and a food source in the ground. ACO employs a metaheuristic approach. Ants are communal creatures that reside in colonies. Initially, ants randomly go out of the settlement to search for food and discover the shortest route from their territories to the location of the food source. They return to the colony after food discovery using the same path they followed by laying tracks with pheromones. If the other ants in the population find the track with the pheromone, they are likely to select that path for traversing. Thus, the route is strengthened because of the growth in the pheromone deposition by ants.

Di. Caro *et al.* proposed the basic concept of ACO. It is a hybrid and multipath routing protocol that employs ACO techniques called AntHocNet [33]. It initially uses a reactive route setup procedure by broadcasting and unicasting to search for the best route to the destination. Saleem *et al.* proposed a broadcast-based ACO routing protocol called BIOSARP [34]. It employs the biological movement behavior patterns of ants. In the optimal path selection procedure, the data collected from the broadcast are optimized by self-organization to determine the shortest path to the destination to forward the packets. Li *et al.* proposed an adaptive vehicular routing protocol using ACO [35] which is based on route selection techniques, to reduce the minimum delay and overhead for low-rate delivery. BSO is a novel method based on the foraging behavior of honeybee swarms. It uses

different types of bees to optimize the numerical architecture by distinct moving patterns [36].

Particle Swarm Optimization (PSO) [37] is a metaheuristic SI technique that uses a stochastic population and achieves optimization. PSO adopts real-life social behavior of diverse animals, such as fish schooling and birds flocking while performing the movement for food search. The PSO concept analyzes the physical movements of an individual in a swarm, where each particle is guided by its own best position and that of the entire swarm. Therefore, the individual particles in PSO work properly in group movement situations such as VANETs. PSO also has high adaptability in various network environments in VANETs. In VANETs with video streaming, multiple characteristics users are excited in the topology. The users have different network features in their network devices. Therefore, the devices participating in the network service have to use optimized different algorithms to forward the requested data to the destination. PSO is adaptive algorithm that can optimize the network status of the nodes adapted using a metaheuristic technique. PSO algorithm satisfies the dynamic topology challenge issues in VANETs due to the reason mentioned [38].

The proposed protocol uses the Particle Swarm Optimization (PSO), which is the most suitable algorithm compared with others in the diverse circumstances in VANETs. The proposed protocol aims at two primary goals. The first is topology load balancing using a Particle Swarm Optimization algorithm, and the second is vehicle video streaming service using a 3D vector mobility prediction algorithm and video data caching mechanism. The mentioned techniques for the video streaming service in VANETs lead low delay in data forwarding time and minimize the data loss in terms of the diverse conditions. The mentioned previous research in VANET for video streaming services and multimedia protocols has struggled the challenge issues in VANETs discussed before. In the next section, we describe the two main techniques of the proposed protocol to solve the challenge issues in VANET streaming service.

III. THE PROPOSED PROTOCOL

In this section, we present the proposed protocol, PSOstreaming for supporting video streaming services in VANETs. First, we explain the network model and the overview of our protocol. Subsequently, we describe in detail of the process of PSOstreaming in time order.

A. NETWORK MODEL AND PROTOCOL OVERVIEW

By leveraging mobile vehicle technologies, video streaming services have been developed for the various multimedia protocols mentioned in communication technologies. However, the main challenges of video streaming services are the highly dynamic topology, extensive coverage challenge, and intensely varying density of VANETs. To address these challenges, any video-streaming solution must comply with certain QoS and QoE requirements. With this satisfying condition, the proposed protocol has a prelearning phase to

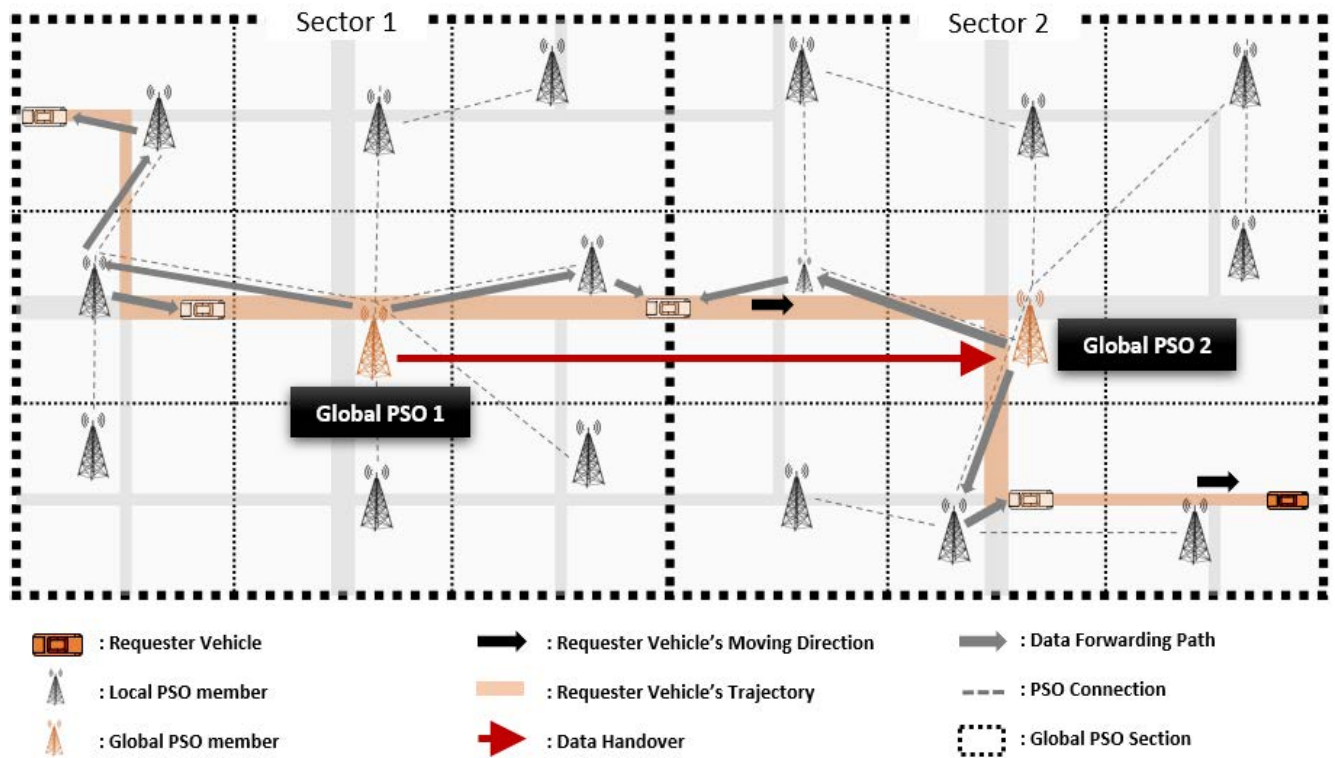


FIGURE 1. The protocol overview of PSostreaming: a requester vehicle receives video streaming data through the data forwarding path from a Global PSO member and Local PSO members in the section where it locates during moving on its trajectory.

analyze the overall topology status with AP conditions, to determine the best particle swarm optimization path. The proposed scheme aims to support dynamic topology changes under real-life road conditions. The AP status analysis process is activated only once before the path selection. The aforementioned challenging issues occur with time flows, owing to the large amount of multimedia data and load balancing. However, the proposed protocol has a PSO pre-learning phase to support real-time changes in the AP status in terms of bandwidth, energy consumption, and number of subscribers. As a result of the prelearning phases, all APs in the topology share their conditions and information for data forwarding. Consequently, this leads to making the path to the user vehicle and dealing with the unsuspected changes on the roads easier. Before the scenario, a numerical integration of all communication APs is required to reduce the overall delay. Each AP maintains an updated status value called the particle swarm quality (PSQ), based on a connection performance test with neighboring APs from the pre-learning phase. The connection performance test is an activated-robustness PSO algorithm with its neighbor.

Figure 1 illustrates the overview of the PSostreaming using the situation on the road with two sectors. The first process of the proposed protocol is finding the requester vehicle and the request content data in the topology. The request packet has been generated from the requester vehicle

to the nearest AP on the topology. Then, the request packet is forwarded to the global PSO member already selected for the video streaming service. The response packet is sent back to the first requester vehicle using the same path the request packet used. The first request packet has the information of the vehicle and the request content data identification, which uses for searching from the backbone server for the video streaming service.

The proposed protocol can be divided into PSQ measurement, PSO group decision, 3D vector mobility prediction, and link connection with the delivery process. In the PSQ measurement phase, the PSQ value is estimated, which unifies the resource status and availability of the APs in all topology areas. Furthermore, using PSO, the proposed protocol indicates how to maintain the real-time data of the APs. In the PSO group decision phase, every AP gets its own invested roles following the basic concept of PSO. The roles comprise global and local PSOs. In the 3D vector mobility prediction phase, the proposed protocol employs a short-term mobility prediction model to manage the unsuspected mobility changes of the vehicles. This mobility prediction compensates for the defect of a long-term mobility prediction model based on the trajectory of the vehicles. In the link connection with the delivery process, a one-hop link is connected along with the selected end node and requested vehicle. It utilizes the 3D vector mobility prediction algorithm for a seamless

link connection between the last and flowing link connection times of the PSO groups and request vehicles. Thus, the proposed protocol conducts the aforementioned phase in sequence, to provide a high-packet data content service through communication between the requested vehicle and PSO group members.

B. PARTICLE SWARM QUALITY (PSQ) INFORMATION

In previous studies, a timeline was used. A recent study [23] considered live-streaming services with extensive multimedia data and mobility support for vehicles. However, other studies on existing node information measurements are unsuitable for live video streaming services because of the low reflection rate of real-time node scenarios. Real-time resource availability information is crucial for live multimedia streaming support, to estimate the optimal forwarding path to a requested vehicle with high QoS, QoE, and load balancing. The PSQ score is an indicator of the network efficiency of the APs based on the PSO algorithm, which affects the user QoS and QoE of the overall topology. However, previous node information measurements primarily measure AP availability in statistical circumstances. Therefore, it is difficult to continuously measure the change in the capability of APs in a live vehicle movement situation where mobility changes continuously. The proposed protocol provides a solution to the challenges of the pre-learning process of PSO. In the pre-learning process, the selected global PSO members discover paths to each location and share the resource information of their local PSO members. When the user vehicle requests multimedia data, global PSO members compute adaptive PSQ scores depending on the requested geographical location of the vehicle using pre-learning data. The equation for the PSQ score measurement is as follows:

$$U_{net} = \frac{B}{N_{User}} \quad (1)$$

$$PSQ_{score} = \frac{1}{\sqrt{\frac{1}{N} \sum_{k=1}^N (y_k - y_{kd})^2}} * (H(1 - E) \frac{1}{U_{net}}) \quad (2)$$

In the equation 1 and 2, where y_k denotes the output corresponding to the k th particle input, y_{kd} is the desired particle output of the k -th sample, and N is the number of pre-learning samples. H represents the performance of a node in the case of hardware, and it ranges from 1 – 10 based on the response time and hardware availability measurements. A single-packet transmission test can calculate the hardware score in the communication range of the destination vehicle without any obstacles. B is the bandwidth of the AP, and bandwidth usage is calculated by the number N_{Users} of users that connect the AP to receive video chunks. E represents the error rates due to the geographic features and network topology of the node. U_{Net} represents the real-time network usage. The interaction of the network topology with neighbors, traffic information, and source data size defines the

real-time network usage. Based on these factors, the PSQ score can be calculated using the following equation.

C. PSO PRE-LEARNING

In standard PSO, diverse particles distributed in the field are gathered in groups around the best particles as the iteration progresses. The particle swarm optimization algorithm assumes that a group of animals searches for their goals, such as food and destinations. However, not all animals in a group ensure their distance and location from the goal because they are unaware of the specific coordinates or geographical locations of the goal. The fastest way to find a goal is to search for the area around the animals closest to the goal. In PSO, each particle has a direction for optimal particles and searches for the communication area to determine the best particles. In the learning phase, APs are the particles in the particle swarm optimization algorithm.

Moreover, in the proposed protocol, the topology is divided into several sectors to distinguish the area and choose a global PSO member in the sector. APs compute their PSQ score and share the score with their neighbors to determine the best global PSO member in the sector. A group of n APs is broadcast in a divided sector-search space. Each AP in the search process considers its search history and the best score within the group of other APs, and position changes are based on this. The position of the APs, score, and location of the best AP changes according to the following equation in the standard PSO algorithm:

$$S_i(k + 1) = \omega S_i(k) + c_1 rand() (P_i - X_i(k)) + c_2 rand() (P_g - X_i(k)) \quad (3)$$

$$X_i(k + 1) = X_i(k) + S_i(k + 1) \quad (4)$$

In the equation 3 and 4, where X_i is the position vector of the i -th AP and S_i is the PSQ score of the AP. Consider P_i as the best position of the i -th AP during its search process in the communication range, and P_g as the position of the best global PSO member during the current search in the sector. ω determines the current communication speed of the AP to its neighbors. c_1 and c_2 are learning factors that make the AP have the process of self-summary and learning to the best of the sector, and determine the location of the best position of the global PSO member in the sector. $rand()$ is a random number distributed within $[0,1]$. The communication speed of the AP is limited to the maximum range S_{max} .

$$D_N = \frac{1}{1 + E(N)} \quad (5)$$

$$E(N) = \frac{1}{N} \sum_{j=1}^{Score} E_j(N) \quad (6)$$

$$E_{j(N)} = \sum_{i=1}^N -p_{ij} \log p_{ij} \quad (7)$$

In the equations 5, 6, and 7, p_{ij} is the probability that the j th bit is sign 1 in N APs. $E(N)$ denotes the average entropy

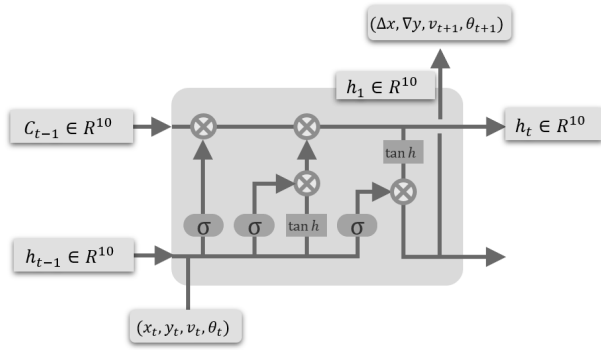


FIGURE 2. 3D vector mobility prediction architecture.

of the sector. $E_{j(N)}$ is the entropy of N APs in the jth bit. D_N represents AP density, which is the resource strength of the sector, $D_N \in (0,1)$. According to the computation of the resource strength of the sector, when $D_N = 1$, the sector that services the video data streaming has qualified QoS and QoE for the user vehicle.

D. GLOBAL PSO GROUP DECISION

PSO prelearning is performed before a request event occurs. Sectors are selected in the pre-learning phase, and one of the APs located in the optimal regional location in the sector promotes the global PSO member. The service district is divided into several sectors depending on the void-area range and number of APs and user vehicles. Global PSO members are selected according to the optimal regional location among the APs in the topology. The optimal regional location is where global PSO members are located. Each global PSO member is one of the APs in the optimal regional location, covering each sector within the communication range, and is connected to the backbone content network. Furthermore, the selected APs in each sector communicate to share the information collected from the sector. When an event occurs, they receive content data from the backbone network for streaming services.

E. 3-DIMENSION VECTOR MOBILITY PREDICTION

The 3D vector algorithm in the proposed protocol predicts vehicle mobility. Using the localization device in the vehicle, such as GPS, the proposed protocol indicates the vehicle’s location at time t+1, utilizing the vehicle’s information at times t-1 and t. Figure 2 shows the 3D vector mobility prediction architecture. The role of 3D vector mobility prediction is to predict the next 10 minutes mobility patterns from the vehicle’s trajectory vector direction information in the past 5 minutes. To solve the prediction problem of the moving vehicle in the PSO streaming, the main factors of the architecture are explained in the following equations.

$$N_t^P = (x_t, y_t, v_t^x, v_t^y) \tag{8}$$

$$v_t^x = vt \cos \theta_t, v_t^y = v_t \sin \theta_t \tag{9}$$

$$O_t^P = (\Delta x, \Delta y, \Delta v^x, \Delta v^y) \tag{10}$$

$$L^i = \sum_{t=5}^{10} |N_{t+1}^i - \hat{N}_{t+1}^i| \tag{11}$$

N_t^P represents the mobility prediction results from the equation 8. Where x_t denotes the vehicle’s latitude when the time t, where y_t denotes the vehicle’s longitude when the time t. v_t^x denotes the vector prediction factor that gives the location information for the moving vehicle. O_t^P represents the position changes of the moving vehicle due to the vector position changes in time t. Where L^i denotes next 10 minutes location information prediction results using previous 5 minutes vector direction information from the mobility prediction architecture. Using the PSO optimization algorithm, the PSOstreaming minimize the change value θ for better performance in delay and data loss.

Using the equations 9, 10, and 11, the proposed protocol can predict the mobility of vehicles in the topology in a short time. The predicted data of all vehicles are then forwarded to the AP in the communication range; hence, the AP collects and manages mobility data from all vehicles within its range. All mobility information of the vehicles in the sector is superintended in real time because the APs containing the vehicle’s mobility information forward the information to global PSO members.

F. CONTENT REQUEST

When a live streaming service is requested, the first process is to choose a local PSO member, where the AP has the highest PSQ score in the requested vehicle’s communication range. The selected AP then forwards the requested packet to the global PSO member in its sector. The global PSO member downloads the requested content and determines the optimal path to the local PSO member connecting the requested vehicle, using pre-learning phase information. The optimal path to the first local PSO member follows the PSQ score to reach its destination. From the pre-learning data by particle swarm optimization, the global PSO member recognizes the PSQ scores of every AP in the topology within the communication range. Following the direction of the route that requested the used packet, the global PSO member sets the discovery route table to the first local PSO member using the pre-learning topology information. The requested content data are forwarded based on the calculated path to the local PSO member, and mobility support according to the user vehicle’s mobility is described in the following local PSO group decision.

G. LOCAL PSO GROUP DECISION

Figure 3 shows the operation of local PSO members in a section. After the Global PSO members have selected in the sectors, the Local PSO selection algorithm is processed to help the streaming data forward to the requested vehicle. The local PSO member candidates are the random AP in the sector with a high PSQ score to the requested vehicle to serve the high QoS and QoE in the streaming services. The first local PSO member is selected, and the mobility information

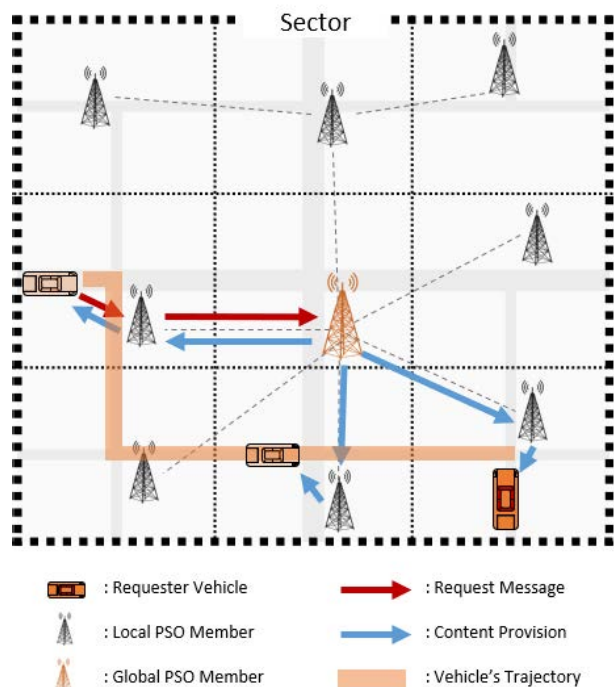


FIGURE 3. The operation of local PSO members in a section: a requester vehicle receives video streaming data from the local PSO member with which it connects during moving in the section.

of the vehicle is calculated using a three-dimensional vector algorithm to predict the mobility of the user vehicle. The first local PSO member estimates the following $t+1$ location of the vehicle using a prediction algorithm. If the first local PSO member repeats the process, then the requested vehicle eventually reaches the end of its communication range. Therefore, the first local PSO member initiates a search for other local PSO members to create a group that contains the live-streaming service. The following local PSO member candidates must satisfy several conditions: overlapping the communication range with the first local PSO member, positioning on the predicted route of the requested vehicle, and meeting with minimum communication time to forward content data. The minimum communication time is calculated using the link connection time of the requested vehicle, data transmission speed, and resource-efficient factor α , depending on the PSQ. The equation for minimum communication time is as follows: According to these conditions, the first local PSO member prioritizes the following local PSO member candidates: the highest priority member is the next local PSO member, which contains the link connection from the first local PSO member and receives the content data from the route used by the first PSO member. The mentioned process for searching the local PSO member is repeated until the transmission to the requested vehicle ends.

H. GLOBAL PSO HANDOVER

As shown in Fig. 1, when the requested vehicle escapes from the first sector where the vehicle is located initially, the

proposed protocol initiates the handover process to the other global PSO member which belongs to the following sector where the vehicle is located. The handover process begins when the local PSO member recognizes that the sector of the next local PSO member does not match. The previous local PSO member connects the link to the next local PSO member in the next sector and completes the received content data from the global PSO member. After the content data are forwarded to the next sector, the new local PSO member will be the first local PSO member in the next sector. The new member sends a packet that includes the progress of the content file transmission and data request of a new global PSO member. The new global PSO member receives the requested packet, then forwards the content data using the PSQ score and follows the local PSO decision process.

IV. PERFORMANCE EVALUATION

In this section, we experiment with the proposed protocol in various simulation environments and analyze the performance of PSO streaming, compared with different SI protocols [38], [39], [40] and the previous streaming protocol [23]. BSOGR [39] has represented Bee Swarm Optimization in VANETs using a fuzzy algorithm for data forwarding. PSOR [38] has described Particle Swarm Optimization in VANETs using an opportunistic routing algorithm for data forwarding. AQRV [40] has represented the Ant Colony Optimization algorithm in VANET using adaptive QoS-based routing. The comparison protocols for performance evaluation are for VANETs with single data transmission. The recent works of the video streaming service using Swarm Intelligence in VANETs have not been considered due to the computing resource problem in the previous. However, the network devices in the vehicle and the access points get improved enough to compute the swarm intelligence protocols for optimization recently. This paper proves how properly the proposed protocol shows better results in video streaming services using the Swarm intelligence called PSO compared with other SI protocols with the previous video streaming services. To better explain the results of the proposed and compare protocols, we assume that the SI protocols have a pre-learning task to recognize the topology information, such as the number of vehicles in the topology the number of intersections in the map times. We set this assumption because the SI protocols require time to predict the random mobility of vehicles in the topology to develop their algorithms. Otherwise, CLONE does not have time for pre-learning because it has no SI algorithms.

A. SIMULATION PARAMETERS

In our simulation experiments, the 802.11p standard for ad hoc network QoS was derived. Network Simulator 3 (NS-3) was utilized to generate vehicle mobility, geographical information, and topology information. The simulation area was set to 3000 m × 3000 m, comprising 32 intersections and 27 one-lane road segments. The maximum number of vehicles in the topology was 100, and the maximum

TABLE 1. Simulation parameters.

Parameter	Value
Simulated network field	3000m × 3000m
Intersections number	32
one-lane road segments	27
AP numbers	Up to 200 (Random position)
Vehicle numbers	UP to 100 (Random mobility)
Vehicle Density	30 percent to 70 percent
Communication range	200m to 800m
MAC protocol	802.11p
Mobility model	Manhattan random mobility
Video Resolution	480p, 720p, 1080p
Video Frame rate	30 Fps
Vehicle speed	30Km/h to 70Km/h
Simulation time	600s
Simulation reputation for average data	30
Simulation Method	NS-3 (Network Simulator-3)

AP number was 200, where the vehicles moved randomly at speeds between 30 km/h and 70 km/h. Vehicle density is defined as 30 – 70 percent of the maximum number of vehicles in the topology. We used a random mobility model combined with the Manhattan mobility model for vehicle mobility in the experiment. To obtain more realistic results from the experiment, we employed three different video resolution, 480p, 720p, and 1080p. Each video resolution had a different file size, but counted the same frames per second (30Fps). The overall simulation time without pre-learning was 600s. We ignored the delay in the topology setting time for the overall delay estimation. We repeated each simulation 30 times to obtain the average data from the experimental results. The remaining simulation parameters are presented in Table 1.

B. QoS PARAMETERS

QoS is a video content quality measurement based on user experience. QoS parameters can be categorized as opportunities to provide high-performance video-streaming services. To maximize the QoS experienced by the user, several parameters—bandwidth media, control of jitter and controlled period, and decreased packet loss—must be considered and tuned. In our simulations, end-to-end delay and packet delivery ratios based on the jitter and packet loss results while forwarding the video content data were considered as QoS parameters. As aforementioned about QoE, if video streaming does not consider QoS in packet forwarding, the protocol will encounter crucial problems in the transfer and routing process of voice and video quality.

C. QoE PARAMETERS

The perceived video quality is measured using two commonly used QoE parameters: MOS and peak signal-to-noise ratio (PSNR). PSNR is the standard metric for measuring objective video quality. This parameter is expressed as a function of the mean standard error between the original and received video frames. If a video frame experiences either transmission or overdue loss, it is considered to be dropped and concealed

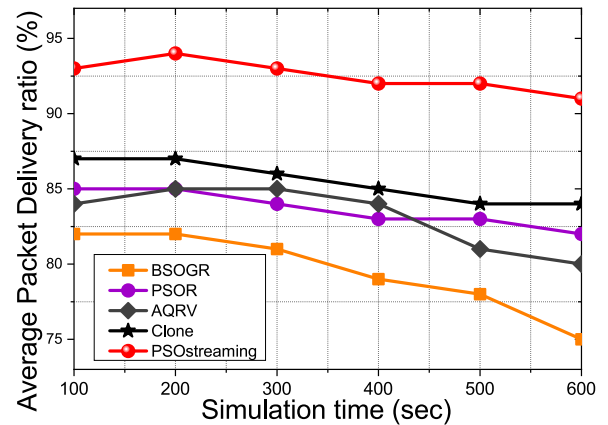


FIGURE 4. Average packet delivery ratio for simulation time.

by copying the payload from the last received frame before it. The metric SSIM is utilized as an image/video metric to measure the received frame quality based on its structural, luminance, and contrast similarity. SSIM, measured using MSU tools, improves the MOS and PSNR metrics by revealing the perceived quality of the received video sequences. The SSIM differs from the PSNR because it approximates structural distortion, instead of pixel-by-pixel errors, to evaluate useful information for the human eye.

D. SIMULATION RESULTS

Figure 4 illustrates the Average Packet Delivery Ratio (APDR) in overall simulation time. During the overall simulation time in 600s with the 720p packet sending rate, the CLONE streaming protocol and other SI protocols indicate different result patterns in the graph. The graph's average data indicate different SI protocol results during the 30 different random positions of the APs and vehicles from the simulation. As the simulation maintains, each SI protocol shows other weak points. AQRV uses ant colony optimization (ACO), which only uses the first searched path to the user vehicle for transmission until the path has a lower level than the other path they find. Although the first path is much longer than the different paths they find later, ant colony optimization in root selection of the video streaming service only chooses the first path for transmission and initiates the data forwarding. If the first path has a low energy level than the other path they find, they move the forwarding path to another path. AQRV is based on the ACO method in SI. Therefore, AQRV takes several hops in data forwarding for video streaming because the large packet size of the data in the transmission costs a lot. Hence, AQRV has to keep changing the path to the user vehicle. It leads to multiple hops and gives a disadvantage to PDR. BSOGR indicates the lowest result in PDR because it does not consider the used path in the data forwarding. BSOGR abandons the used path to the user vehicle when the energy level gets lower, and never considers the used path even though it recovers from the low energy level. Hence, BSOGR cannot choose diverse options for the

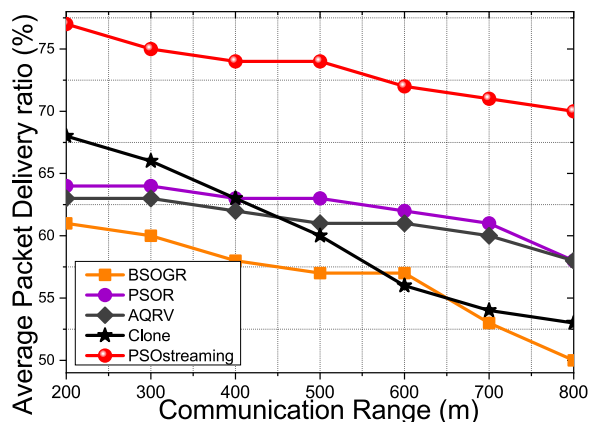


FIGURE 5. Average packet delivery ratio for communication range.

forwarding path when the time increases. PSOR adopts a particle swarm optimization algorithm as the proposed protocol. However, it does not consider a large packet transmission like the video streaming service. Although PSOR discovers the same forwarding path as the proposed protocol, the PSOR has no mobility support for moving vehicles. There is no suitable transmission way for video streaming data delivery to the user vehicle. The aforementioned challenge leads low APDR from the results. CLONE supports the video streaming service with mobility support and caching mechanism for the user vehicle to discover the path. However, CLONE has long-term mobility support based on the trajectory of the vehicle. In a random mobility scenario in the simulation background, unpredictable mobility of the vehicle that is not in the trajectory information leads to a high packet loss, affecting the decrement of delivery ratio. However, the proposed protocol has a short-term mobility model called the 3D vector mobility support, which handles the unpredictable behavior of the vehicle, and PSQ searching phase supports the load balancing no matter how the time goes. Over the simulation, the proposed protocol keeps changing the low energy AP to the high energy AP for QoS and QoE based on the PSQ score. The video streaming data forwarding consumes high energy of the AP in the topology. The comparison protocols in the simulation do not have the adaptive data forwarding path and AP selection algorithm due to the energy consumption over time. Therefore, the mentioned mechanism with particle swarm optimization in the proposed protocol leads to a high PDR no matter the simulation time.

Figure 5 illustrates the average packet delivery ratio depending on the communication range when the density of the AP and vehicle change. As observed in the mechanism of the three SI protocols and CLONE, the BSOGR illustrates the lowest APDR graph from the figure because it does not make use of the path to the user vehicle once used, even though the used path gets recovered. When the communication range gets increased, BSOGR has a task to broadcast and search several paths to the user vehicle. Then the used path is abandoned. Eventually, the short path cannot be used

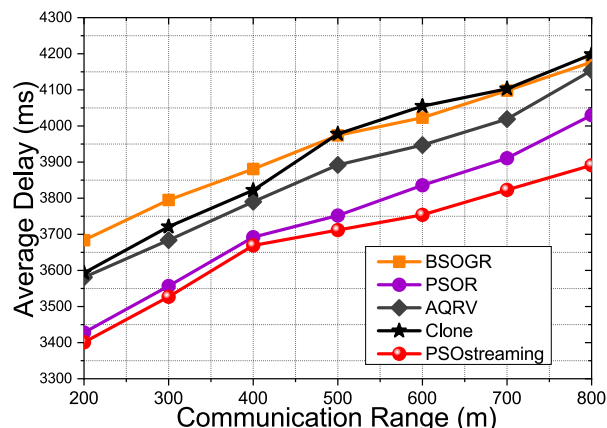


FIGURE 6. Average delay for communication range.

because the short path to the user vehicle is abandoned. AQRV and PSOR illustrate a similar graph because the two mechanisms derive similar topology searching techniques. However, CLONE indicates a better performance than other SI protocols in the 300 m communication range, but the results are reserved after the 400 m communication range. The reasons for the results can be explained as two reasons: If the density in the communication range gets low, CLONE requires several hops to forward the streaming data to the user vehicle, and it is difficult to determine the excellent condition of nodes in low density and takes much time to search and get a response about the near neighbor information. The proposed protocol can handle the mentioned weak points for the other protocols. PSQ searching technique helps to determine high-quality APs for streaming forwarding to the user vehicle. Even in a low density and large communication range, the proposed protocol can realize the minimum time for video streaming transmission owing to the pre-learning of the topology information. Moreover, the other three SI protocols do not have any short-term mobility support to react to the mobility changes on the roads. Therefore, other SI protocols have trouble with supporting the unexpected mobility changes in the communication.

Figure 6 illustrates the average delay depending on communication range change and density changes. The proposed protocol indicates the optimal delay in the graph. Although the three SI protocols had pre-learning time to figure out the topology information, the three SI protocols do not have a large data transmission way for video streaming services. The mentioned SI protocols have trouble with supporting video streaming services from moving vehicles. Only single packet techniques are included in the protocols. These challenges lead to high packet failure, thereby increasing processing recovery mode. CLONE has trouble handling the short-term mobility changes owing to the random mobility that is not based on the vehicle's trajectory. The vehicles on real-road keep altering the direction and speed while in motion. Even if they have trajectory information, the calculated direction sometimes has to be changed by unpredictable

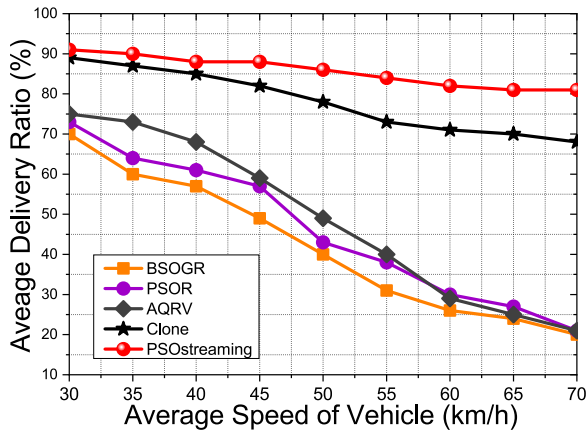


FIGURE 7. Average delivery ratio for average speed of the vehicle.

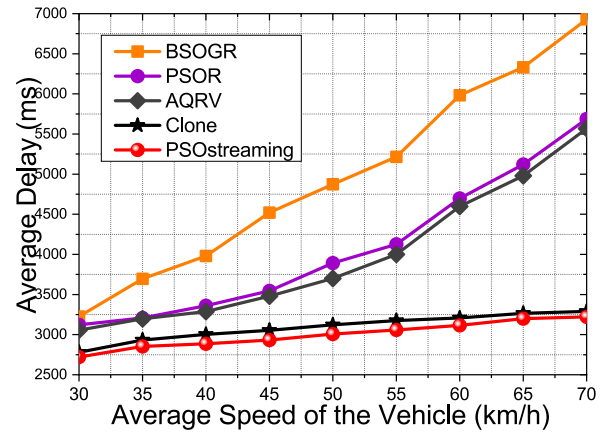


FIGURE 8. Average delay for average speed of the vehicle.

factors depending on the road circumstances. CLONE uses several resources to recreate CLONE APs, link connection, and the path to the user vehicle. It leads to a high average delay. However, the proposed protocol has short-term mobility support and global and local members to help recreate the fixed path to the user vehicle. It decreases the delay of the overall protocol in diverse circumstances in density and communication range.

Figure 7 illustrates the ADR depending on the average speed of the vehicles from 30 km/h to 70 km/h. The experiments of the graph were simulated 30 times in every five increments of the vehicle speed with a random density score. As the graph illustrates, the SI protocols without video streaming service and mobility of the vehicle supports, the average delivery ratio results are not good enough to service the video streaming to the user vehicle. It is difficult to handle the large video packet in a real-time streaming service with a single packet forwarding mechanism. Moreover, searching and linking the moving vehicle in a live video streaming service is necessary for tracking and link connection methods. The proposed protocol uses 3D vector mobility support to track the user vehicle moving on the road. Moreover, the data-link connection mechanism to moving vehicles is also utilized in the proposed protocol. Therefore, the proposed protocol indicates better results in vehicle speed and road density changes.

Figure 8 illustrates the average delay depending on the average speed of the vehicles on the road. As mentioned in the description of Figure 4, BSOGR is not suitable for video streaming services even though it has an SI technique for data packet forwarding to reduce the number of fuzzy rules. The other two SI protocols, AQRV and PSOR indicate similar results. The two protocols estimate the vehicle's route by searching the intersection that the user vehicle passed through. Therefore, when the vehicle is moving and receiving the large video packet, the compared SI protocols lose the video streaming packets from tracking the user vehicle. It leads to high re-transmission requests to the server and delays more in finding the moving vehicle in which

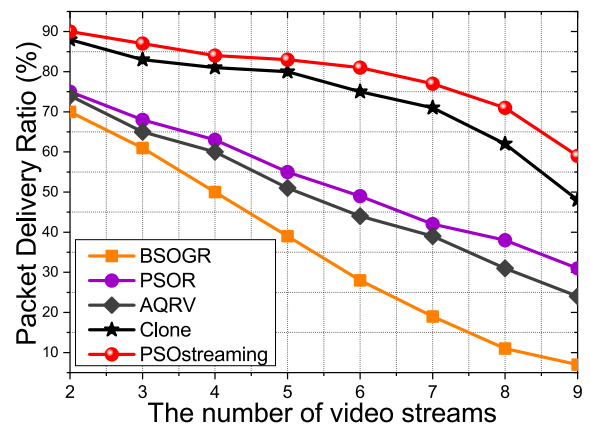


FIGURE 9. Packet delivery ratio for the number of video streams.

intersection the user vehicle is located. CLONE has link connection, mobility support, and caching process to support the video streaming service. Therefore, the results indicate a better performance than other SI protocols. However, the proposed protocol utilizes the 3D vector mobility support. Therefore, the proposed protocol does not need a re-searching message to find the user vehicle moving on the road. The proposed protocol contains the link with the user vehicle, owing to the PSQ information with PSO data from the pre-learning phase. It takes a low failure probability to link the connection with the user vehicle. Hence, the proposed protocol indicates the best results in average delay time.

Figure 9 illustrates the packet delivery ratio depending on the number of video streams. When the user requests the video streaming services at once to the same AP, the availability of the AP that requested the service from several users decreases. A live video streaming service is required to have a load balancing mechanism to handle the overload circumstance to prevent the issue. BSOGR shows the low level of the packet delivery ratio that it abandons the used path if the energy level gets low. Moreover, there is no load balancing mechanism in the protocol. AQRV and PSOR also do

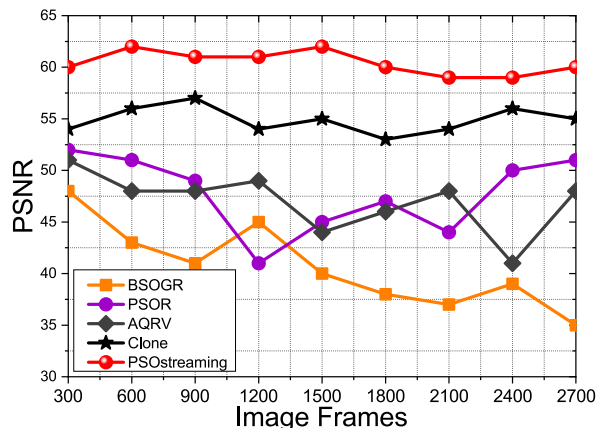


FIGURE 10. PSNR for image frames.

not support the load balancing for the topology energy level. CLONE has CNQI metric to search the topology information before the transmission starts, and during the transmission, CLONE updates the topology information using the CNQI metric. It supports load balancing and handles the overload circumstances during the video streaming data transmission. However, the CNQI metric leads to high delay than the proposed PSQ mechanism because of the pre-learning. In the pre-learning phase, the proposed protocol calculates the PSQ score of the APs in the topology and estimates the optimal path to the destination that will be chosen. Therefore, PSQ minimizes the delay in searching the other path or other AP with better conditions than the used one. However, CLONE has to broadcast the neighbor nodes nearby to determine the other node to cooperate with the video streaming service.

Figure 10 illustrates the PSNR depending on the forwarding image frames. PSNR is the standard metric for measuring objective video quality, and is expressed as a function of the mean standard error between the original and received video frames. Image frame increment means an increment of the file size for the transmission. If the file size increases, the resource consumption of the APs that participate in the data transmission increases as well. It causes the QoS and QoE decrement in video streaming transmission. In the figure 10, the data indicate the same order of compared protocols with PSOstreaming in APDR results. BSOGR, PSOR, and AQRV are not suitable protocols for the video streaming service; however, CLONE and PSOstreaming have processes for video streaming services in data transmission. Therefore the graph illustrates the results of the performance. Although BSOGR, PSOR, and AQRV have the SI algorithm for the optimal path to the destination, diverse processes to help the video streaming transmission, such as mobility support, packet distribution, and link connection algorithm, PSOstreaming indicates better results than CLONE owing to the mobility prediction algorithm difference. Long-term mobility prediction of CLONE takes more hop counts and delay than the short-term mobility prediction in PSOstreaming, and this leads a better PSNR result.

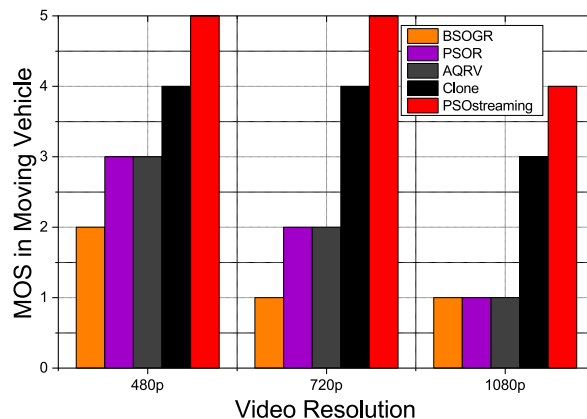


FIGURE 11. MOS in mobility depending on the video file resolution.

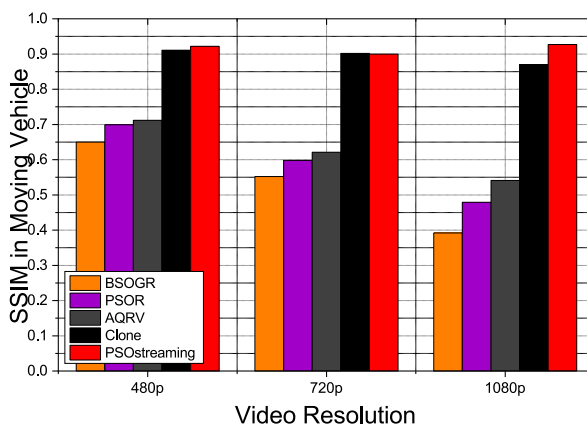


FIGURE 12. SSIM in mobility depending on the video file resolution.

Figure 11 and 12 illustrate the MOS and SSIM results depending on the video file size in transmission. MOS and SSIM results indicate the QoE experience of users. SSIM results indicate the similarity of visual image quality based on the QoE with human eyes. Moreover, SSIM does not consider a numeric error between the original and transferred video files. MOS values have been graded based on user experienced quality. MOS has been measured by the “MSU Video Quality Measurement Tool.” Both MOS and SSIM results mean high user QoE from the human eyes. In addition, it is affected by the mobility prediction method of the video streaming services. BSOGR, PSOR, and AQRV optimize the route to the destination for video streaming transmission, but do not support the mobility of the user vehicle. Therefore, the three compared protocols indicate lower QoE results than CLONE and PSOstreaming. CLONE has a long-term mobility prediction algorithm based on the trajectory of the vehicle. The mobility data based on the vehicle’s trajectory may not react to the vehicle’s unexpected mobility changes; therefore, the unexpected mobility changes lead to the re-transmission of the streaming video file. Because of the re-transmission, the user QoE gets decreased, and it is critical for the video streaming service. PSO streaming has a 3D vector mobility

prediction algorithm to correspond to the autonomy of the user vehicle. This short-term prediction algorithm can react to any unexpected mobility change circumstances in video streaming transmission. Therefore, PSostreaming indicates better results in terms of QoE factors, such as MOS and SSIM.

V. CONCLUSION

In this study, we proposed PSostreaming, a video streaming service scheme based on a particle swarm optimization algorithm. The proposed protocol has a topology analysis algorithm called PSQ, which is based on PSO. The proposed scheme searched for an optimal path depending on the location and provided the best route to the destination. Sectors were selected as a result of the topology analysis, and one of the APs located in the optimal regional location in the sector was proposed to the global PSO member. Following the selection of global PSO members, PSostreaming selected other local PSO members who participated in video data streaming transmission. The proposed adopted a 3D vector mobility prediction algorithm, which provided short-term mobility prediction, making PSostreaming unconcerned about the trajectory information of the vehicle and supported the autonomy and free will of the user drivers. The route using global PSO members and local PSO members for the user vehicle is always changeable because load balancing is maintained for user QoE and QoS. Because of the PSO algorithms in gathering the topology information, global PSO members, and local PSO member selection, the load balancing for APs in the topology indicated better results than other compared protocols. PSostreaming improved the topology information analysis algorithm compared with other SI protocols, AQRV, BSOGR, and PSOR. Therefore, PSostreaming exhibited 20% better results in the overall experiments. Moreover, compared with CLONE, PSostreaming yielded better results in mobility prediction using a 3D vector mobility prediction algorithm. Hence, the simulation results indicated 5% to 10% improvements compared with the other protocols.

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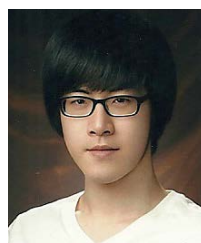
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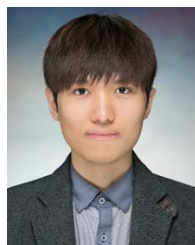


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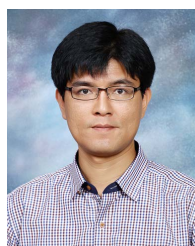
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