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Multimedia service utilizing hierarchical fog computing for vehicular networks

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Abstract
This paper focuses on the enhancement of multimedia streaming services for passengers travelling in vehicles. Online media streaming and sharing is popular and has increased tremendously these days whether it is used at home, in the office or while travelling. The millions of internet users accessing media contents consumes a huge bandwidth and can create Internet bottlenecks or traffic congestion. Media traffic like videos flowing from such congested links can introduce even higher delays increasing buffering time. This can bring a bad Quality of Service (QoS) and bad Quality of Experience (QoE) to users. Such degradation is seen even more when streaming requests are sent by clients within mobile nodes like vehicles. To tackle this issue this paper proposes a hierarchical fog computing based multimedia streaming that reduces latency and minimizes Internet bandwidth consumption. A simulation was conducted for the performance evaluation of the proposed architecture and video streaming service was considered for evaluation. The result acquired from the simulation showed that proposed architecture enhances the QoS and brings better QoE to users.

Keywords Vehicular networks · Fog computing · Wireless communication · Internet of things · Performance evaluation

1 Introduction

Although Vehicular Ad-hoc Network (VANET) are similar in concept to that of Mobile Ad-hoc Network (MANET), they are unique from MANETs in their rapid change in topology, their high mobility, and their different kinds of communication environments [7, 25]. Not only are VANETs a solution for road management and safety, they are also a perfect way of making use of the increased number of vehicles on road as useful resources for communication. Currently, vehicles that are employed in VANETs are equipped with many sensors and devices for communication with powerful network capabilities to create an Intelligent

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Transportation System [24]. These smart vehicles use their On-Board Units (OBUs) for direct vehicle to vehicle (V2V) communication if they are under the range of communication. If not, the communication is conducted with the aid of Road Side Units (RSUs) that are placed along roads, parking lots, petrol pumps, or in any favorable places which can be referred to as Vehicle to Roadside Unit (V2R). These days devices like smartphones, tablets, etc., have huge hardware capabilities and thus, can be used for communication with the vehicles creating a Vehicle to Device (V2D) communication. Similarly, communication between vehicles and roadside infrastructure is also possible, creating a Vehicle to Infrastructure (V2I) communication. Such communication between vehicles and other communicating nodes can create an Internet of Things (IOT). This has helped vehicular network to provide various services.

The concept of VANET came out of the desire to create an intelligent transportation system that can ensure road safety, manage traffic congestion with information dissemination. However, these intelligent vehicles are now also considered for their abilities to provide entertainment service to the travelers inside them. These possibilities have also led to competition among transport companies to provide better service to their clients. With development in vehicular infrastructures and wireless technology, it is now possible to provide various Information Technology (IT)-related services to the clients with ease. Apart from simple food and beverage services provided in past days, transport companies are trying to provide more with IT-related services to attract their customers. One of such service could be a multimedia service.

Multimedia services has evolved through time and brought about progress in Internet-based delivery systems. Media streaming and sharing can be taken as an example: media like audio and video has become prominent around the world. Multimedia services like video streaming and sharing have become popular, especially with the emergence of wireless users anytime and anywhere. To cope the demand, smart device manufacturers are working hard to enhance the processing power and hardware capabilities of their devices. Similarly, Internet service providers have continued working a lot to provide heterogeneous network infrastructure. In spite of improvements in device capabilities and network infrastructure, there is still some lag when it comes to the Internet services like media streaming. If video streaming service is taken as an example, the demand for Internet video content is so increasing that it outweighs the rate of hardware and network-side upgrades for the current need. This in turn leads to performance degradation by introducing high latency and delay, and results in low QoS and problems like buffering. The Cisco Visual Networking Index in [11]] states that the global data traffic in 2021 could be 127 times more as compared with the global data traffic in 2005. The popularity of content sharing and streaming via social networking sites or similar sites implies that video streaming, sharing, etc., will dynamically escalate in future. As suggested by the Cisco Visual Networking index [11], most of the bandwidth is shared through internet video streaming and downloads. It also states that by 2021, the video traffic will account for more than 82% of all consumer Internet traffic. Technology is rapidly advancing and this advancement has led the video streaming paradigm much further it was in the old days. Video streaming has evolved from single view to multi-dimensional, multi view, 360-degree view, and more to come. Also, the concept of crowd sourced data has made its way towards the field of video streaming. Huge amounts of video data are flowing from the crowd to the content providers before the video reaches its viewers. This video traffic upsurge will definitely shift to become a serious matter for Internet service and mobile networks. It can severely affect the bandwidth limit of the cellular or many other wireless heterogeneous networks. So, proper mechanisms to solve this issue are immediately needed.

In vehicular networks, there are chances of significant changes in speed and direction, due to which there is change in network topology which leads to instability in connections. The greater the distance between the sending and receiving vehicles, the more hops are used in the data transmission. This increase in hops also eventually increases the transmission delay. Additionally, when the distance between two communicating vehicles increases, there is greater chance of packet drops or link disconnection. We know bandwidth issues, Internet connection speed, unstable connections and location of servers are responsible factors for QoS and QoE. Thus, if multimedia streaming is considered in vehicular networks, all these issues should be properly managed. Hence, we have considered Fog Computing (FC) as a suitable solution for the aforementioned problem. Additionally, the proposed architecture also minimizes the cloud's burden and helps to create an energy efficient network.

In this paper, our main contribution includes:

- Proposing a novel fog computing-based architecture for media streaming in vehicular network.
- Creating bandwidth-efficient network topology.
- Enhancing the QoS and QoE of media streaming in vehicular network.
- Performance evaluation of the proposed architecture.

In this paper, we proposed an architecture for efficient media streaming services in vehicular network. To verify our architecture, we created a simulation environment and used a video stream as media for test data. This paper briefly discusses FC and its relationship with cloud computing in Section 2. Section 3 lists some of the work done for enhancing network quality and providing better media services. Section 3 is followed by Section 4, which describes the different architectures for media service in VANET. Here, we describe the typical cloud based media service and discuss on extending it to the edge-based service by proposing a novel architecture. Performance evaluation is conducted to verify the architecture, so Section 5 describes about the network modelling, its simulation setup and discusses on the performance evaluation. Finally, we come up with our conclusion in Section 6.

2 Fog computing

Since some years cloud computing (CC) has become the most discussed topic. Cloud computing has provided its clients with a safe and secure data storage, where the stored data can be accessed from anywhere and at any time. CC facilitates the client side by providing powerful computing capabilities even in devices with lower configuration and without the availability of huge storage. CC provides the solution for creating virtual networks and provides computing resources with storage features. This advantage of CC has been exploited in vehicular networking, also commonly referred as Vehicular Cloud Computing (VCC) [4, 18, 24]. However, as the network of things continues to rise, bandwidth requirements will also be on the rise. Problems related to scalability due to huge increase in IoT devices can be well handled by CC. However, continuously retrieving and sending data from the cloud can put great stress on the cloud. In addition, an insufficient allocation of bandwidth, network failures or latency can produce unendurable delays. Long distance continuous communication in-between the cloud and the edge network also lead to huge energy consumption. Therefore, to deal with these drawbacks of CC appropriate bandwidth management and model with latency minimized need to be developed. The developed model should be able to cope with the increasing demand while maintaining the QoS. We can see the scenarios are changing, and CC alone will not be able to cope with the upcoming requirements. Therefore, to fill the gaps and extend the reach, FC emerges as the solution.

"Fog computing", sometimes also referred to as fogging or fog networking was devised by Cisco in 2012 [3]. FC performs similarly to CC but brings CC in direct reach of the edge user from multi hop to single hop. A simple FC architecture is depicted in Fig. 1. FC has come up as a solution for providing users a cloud service at the network edge or at the place where data is generated. Hence, it is also often termed "descendent cloud". The transformation of cloud towards single hop client-server distance has led FC towards having a more secured and lower latency network. In other words, it can be said that FC extends the functionality of clouds to a new level by providing additional benefits of lower latency, lower delay jitter, better security, location awareness, mobility support, etc. These features of fogging enable it to make the network much more efficient if it is deployed alongside with cloud. The world is moving towards being smart (smart cities, smart factory, etc.) by making use of IoT. IoT devices are deployed at the edge network and the features hosted by FC can be best suited for handling the massive data that they generate. In an FC based network, most of the data are managed at the edge which minimizes cloud burden by lowering data exchange with the cloud and conserves the network bandwidth. Since it possesses such qualities, the application of FC with no doubt can be the best choice for building smart networks like smart cities, smart factories, smart health, and smart vehicular

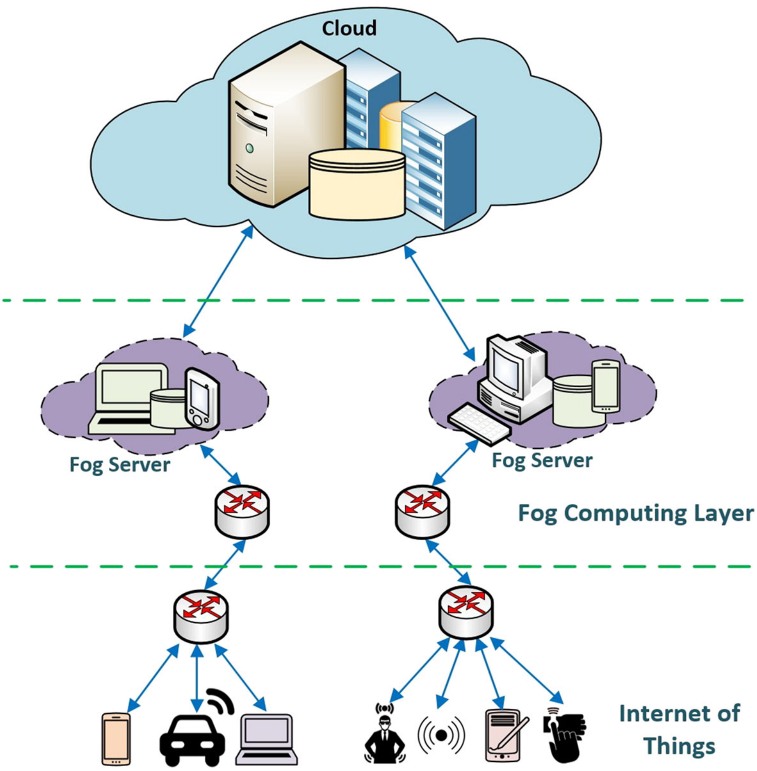

Fig. 1 Fog Computing architecture

networks. Apart from smart networks, the application of FC is also thought to produce promising results for future wireless technology like 5G [19].

The FC network comprises "Fog nodes" which can be created with devices that have little computing capability, network connectivity or storage. These fog nodes are easily deployable and can interact with edge users, collect data and sometimes are even able to process data. They collaborate with edge users to achieve certain tasks of communication management and storage. The fog server can store readings from different IoT devices, and sensors and store local information such as information about shop, hotels, availability of parking spaces, maps, media content information like videos and audios, etc. For example, in our case we considered media content and used video data for streaming from the fog server to the clients in our performance evaluation.

In Fig. 1 we can see that the edge users are connected with the fog servers so the data generated from the edge can be sent to the fog server and vice versa. We can also see that the fog server is able to communicate with the cloud and acts as the middle man between the cloud and the edge users if needed. Cloud roles comes into play only if the fog servers are not able to fulfill or serve the request of the edge user. This reduces the cloud burden and its advantage can be greatly felt when there are thousands of data generating nodes at the edge. Since most of the requests from the edge are handled by FC, it also helps save Internet bandwidth. In addition, as explained earlier, the ability to minimize latency has led FC to be used for developing a QoS aware network. So, having such capabilities, there is no doubt that FC can be a good companion for IoT that generates huge amount of data. In short, we can say that utilizing FC alongside the CC can be a good choice while developing a smart and intelligent network.

3 Related work

Multimedia sharing and streaming service have become very popular, so much of research has been carried out for enhancing the multimedia services. Different architectures and prototypes have been proposed for media streaming in the existing literatures. This section presents some of the related works that were conducted recently on related topics. J.M. Batalla et al. in [1] proposed method for increasing efficiency in media streaming for smart cities. In this work, the author considers using multipath transmission of high quality media stream and the collaboration of a neighboring device. In this proposed method, the more sub streams that reach the receiver the better is the QoE. Research work by F. Wang et al. in [23] suggested cloud assisted media streaming. Based on their results, they claimed their work is able to minimize the cost of system deployment along with satisfactory rate and latency. Study for minimizing packet loss rate was done by W.E. Liang et al. in [15] by exploiting Software Defined Networking. They stated that their algorithm lowered the packet loss rate by more than 10 percent. Work on minimizing delay and creating a loss resilient network for media streaming was carried out in [21] by A.M. Sheikh et al. In this work researchers exploited network coding and distributed scheduling for their work. When they compared their work with the random push scheme method, they were able to get better media quality in terms of playback delay, bandwidth consumption. Q. Jiang et al. in [14] carried out work on streaming media transmission over cognitive radio. They conducted their experiment under a dynamic environment and considered energy-efficient adaptive transmission. They utilized an ARC scheme and receive buffer as an aid to achieve energy efficiency and better QoS. In [28] authors H. Zhou et al. proposed a WhiteFi infostation for maximizing throughput in vehicular media streaming services. With the additional introduction of a location aware scheduling scheme in their proposed system they were able to get the desired results for both cases of delay tolerant and delay sensitive network. G. Ma et al. in [16] researched on user's content request pattern considering various user behaviors. From the research, it was deduced that joint caching strategies have a great impact on enhancing the performance of video content delivery. After designing an efficient caching strategy their result showed better performance as expected. B.W. Chen et al. in [5] reviews video broadcasting and transmission technologies. It also discusses various coding methodologies, QoE modelling, compression efficiency and flexible transmission system. Authors also created a typical model that enables various features for improving the overall receiving quality of heterogeneous devices during video broadcasting. C.M. Huang et al researchedon k-hop fleet based cooperative streaming for vehicular network and proposed it in [9]. In the proposed scheme, the requester coordinates with helpers in the range to download the requested video. Their proposed scheme showed increased peak signal to noise ratio with smooth video playback. In [26], E. Yaacoub et al. proposed a cooperative clustering of moving vehicles as an approach for data dissemination. They used LTE to send data to a distant cluster head which then finally multicast the video data to the vehicles within its cluster via IEEE 802.11p. Authors compared their method with a non-collaborative method and found their approach performed better in terms of both QoS and QoE. Authors, A. Mammeri et al. proposed a converter model in [17] exploiting erasure coding that adapts the old Real Time Transport Protocol (RTP) to make it favorable for VANET. Their method showed improvement in packet loss but with some additional delays. Work on enhancing the visual quality and smooth playback of video streaming in vehicular networks was conducted by L. Sun et al. in [22]. They employed an auction based channel allocation method in their proposed model. They considered playback and visual quality for their test, and their test results showed that their algorithm was able to outperform the existing ones.

We can see from the literature review that many methods been proposed for enhancing the video streaming quality. We can also see that due to the high mobility in vehicular environment, smooth video streaming is harder to achieve. Existing work on media streaming has focused on delay, bandwidth consumption, smooth playback, visual quality, energy efficiency etc. However, most of the works were CC oriented and were not mostly focused on multiple performance parameters. On the other hand, our proposed architecture for video streaming utilizes the hierarchical FC approach shifting the totally CC dependent network to edge reachable. This helps in maximizing the QoS and QoE. Also, by reducing the workload to cloud the proposed method maximizes Internet bandwidth and minimizes energy consumption.

4 Architecture for media service in VANET

4.1 Cloud based media service

The typical approach of cloud based media services is shown in Fig. 2. In the typical cloud based approach media are stored in the cloud. If users in vehicle requests some media, the request passes to the content provider via the Internet. The network provider in Fig. 2 acts as an Internet gateway to connect the vehicles and the content provider. RSU helps in vehicular communication by allowing vehicles to infrastructure (V2I) communication when they are in each other's range. If not, multi-hop vehicle to vehicle (V2V) based communication is used. We can see that the only way to access those media stored in cloud is via the Internet.

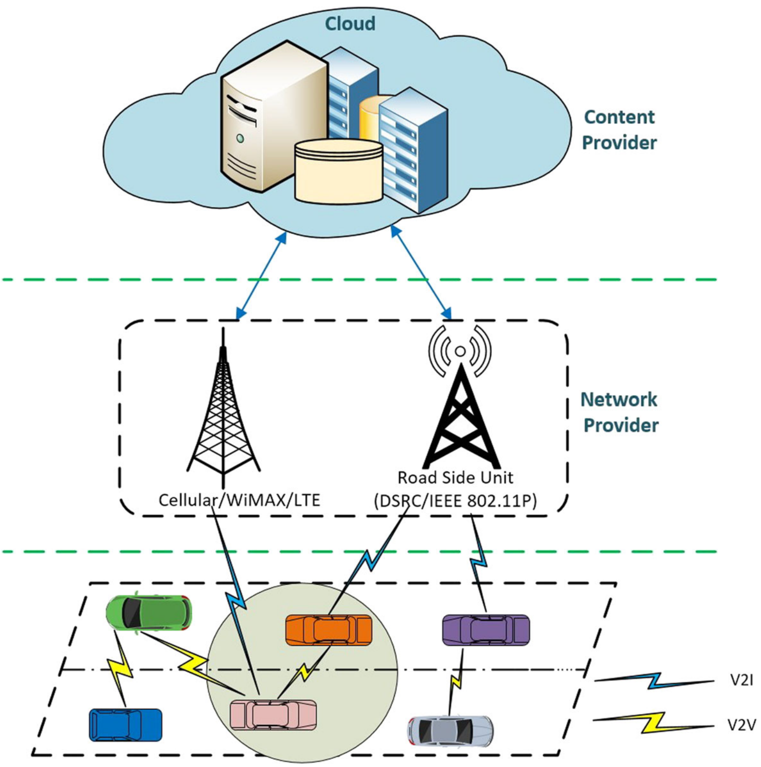

Fig. 2 Typical cloud based media service for vehicular network

Due to the reliance on the Internet, the streaming quality of medias like audio or video stored in the cloud is greatly affected by the Internet connection. The QoS and QoE deteriorates highly if the Internet connection is slow or interrupted. Also, as discussed earlier, the huge shipping distance of data between server and client via Internet can introduce significant delays and energy consumption.

4.2 Hierarchical fog assisted media service

Thousands of media contents are requested every day and hundreds of requested contents are similar. Many similar contents are requested from users who are in the same region or the nearby regions. We can take the top 100 songs or some frequently accessed promotional video of the region, etc., as an example. If such contents are requested from users of the same region or nearby regions then it can be just another unwanted burden on the cloud and can be considered misuse of the Internet bandwidth. Hence, if such content can be cached or stored locally to the users then it can have multifaceted benefits as explained earlier. This novel way of utilizing FC for media services for an Intelligent Transportation System (ITS) can be a great choice.

The proposed FC assisted media service for vehicular networks is shown in Fig. 3. The architecture is based on hierarchical FC. The concept of "Hierarchical Fog Computing" is that, it enhances the capability of traditional fog computing approach if it needs to be utilized in smart vehicular network. There are thousands of vehicles and the cost increases

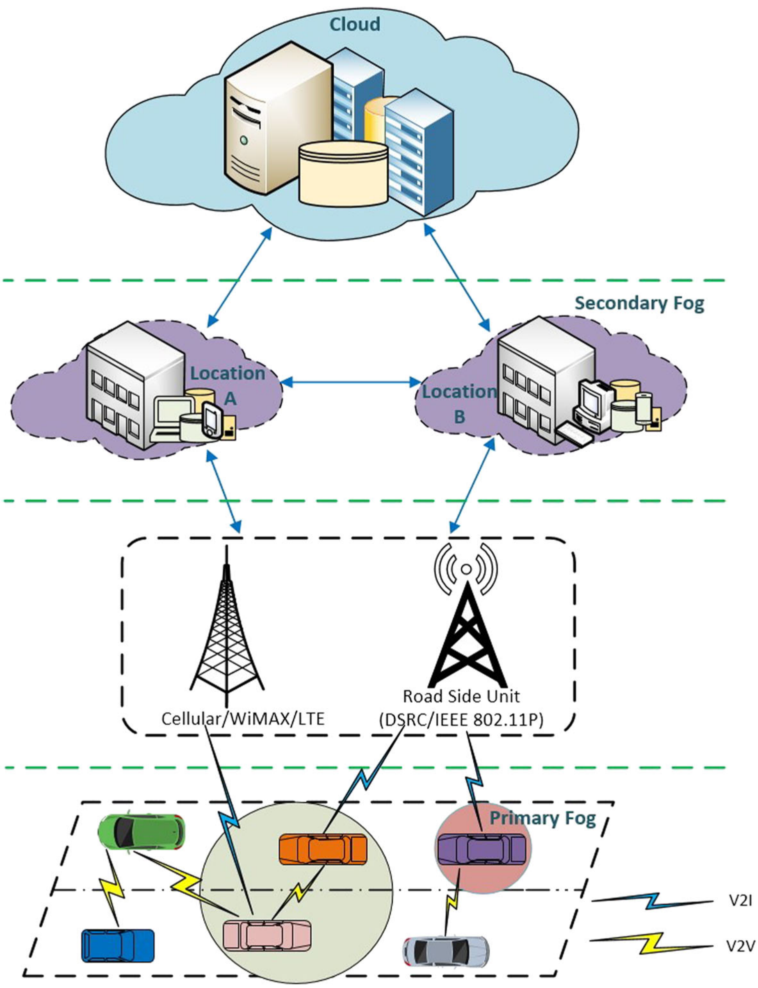

Fig. 3 Proposed hierarchical fog assisted media services for vehicular network

based on its functionality and features. More advanced the vehicle's system is, the higher will be the cost. Also, equipping vehicle with complete intelligence requires heavy algorithms, huge knowledgebase; and for it, the peripherals incorporated in vehicles like storage, OBUs should be much more powerful, which can maximize cost and resource requirement drastically. Thus, as a solution of this problem, the concept of Primary Fog and Secondary Fog has been introduced in the paper, which works in a hierarchical structure.

The first level of fog server is deployed inside the vehicle. It is shown as "primary fog" in Fig. 3. As the primary fog (PF) is inside the vehicle, its capacity will not be as huge as that of the SF. Hence, PF contains only the media that is mostly accessed in that locality or the route. Let's take an example of public buses: they travel on the same designated route every day. So, the PF in such buses will hold the media that is popular in the location where it travels. It can be media like top 20 songs, top 20 videos or some frequently accessed medias like video advertisements, etc.

The second level of the fog servers are in some specific centers near the area of the requesting vehicles. This is shown as "secondary fog" in Fig. 3. One city or region can have more than one secondary fog (SF). These SFs within same city/region are treated as one cluster. These SFs within the same cluster are interconnected with each other via some high-speed direct connectivity and can share their resources. However, the cluster of SFs in one city/region has no direct connectivity with the SF cluster in another city. In simple words, only the SFs within the same cluster are inter-connected and can work co-operatively. If the requested media in not available in all the SFs within the same cluster, the media is requested to the cloud.

SFs will have much huger capacity than PFs and can store much more data. Every SF stores/caches the content that is requested from the client within their service area. As, SFs within same clusters are interconnected, SF works in a cooperative way for providing the requested content and maximizes the probability of content availability. This further minimizes intervention involving the cloud.

In SF, there is an Intelligent System (IS) that is running Recommendation System (RS) and Machine Learning (ML) algorithms. IS helps in filtering the contents from huge available contents. RS or recommendation engine is a system that analyzes the information acquired to provide suggestions for something (In our case, checking hit rates and recommending to store/delete) that a client (Passenger in our case) might be interested in. It is itself not a ML technique but it deploys ML techniques like Content Based Recommendation (CBR), Collaborative Filtering (CF), etc. IS uses RS for recommending media in PF, and ML for content analysis and storage optimization in SF, which is discussed in Sections 4.2.2 and 4.2.3. This scenario is shown in Fig. 4. With IS enriched, SF can cache/store and delete media based on the hits, number of access or content popularity. With the help of IS, the SF is also able to identify the most frequently accessed content and highly rated contents. This helps in deciding which media content need to be sent to the PF and which should just be kept at the SF. The most frequently accessed contents are identified by the SF and are cached in the PF. The process of content recommendation to PF is discussed in 4.2.3. Similarly, all the highly rated content or the contents that has the probability of being requested in the future are stored in SF. This application of RS also helps to make efficient and optimum use of the storage.

4.2.1 Proposed system's work flow

The proposed system is a hierarchical FC approach. The task for serving the client's media request is carried out in a hierarchical manner. The request is attempted to be served by the server in the first level, followed by the others next up in the hierarchy. This makes the PF the first candidate for serving the request. However, if PF becomes incapable, the server at an upper level of hierarchy is responsible, for which SF is the candidate. SFs in the same cluster work together to accomplish the task that is serving the PF request. Figure 5, shows the flowchart of the proposed system's work process.

The flowchart in Fig. 5 assumes that the client is authenticated to access the PF's contents. When the client travelling in a vehicle requests media, the request is first sent to the PF that is inside the vehicle. The content requested is then searched inside the PF and, if available, directly provided. If the content is not available in the PF, then PF forwards the request to the SF, which is just some kilometers away from the PF. As explained earlier, the SF contains content with high popularity or those which are likely to be requested in the given region. Thus, this makes it a high chance that the requested media be served from the SF. However, in the worst-case scenario or if the requested content is not popular and is

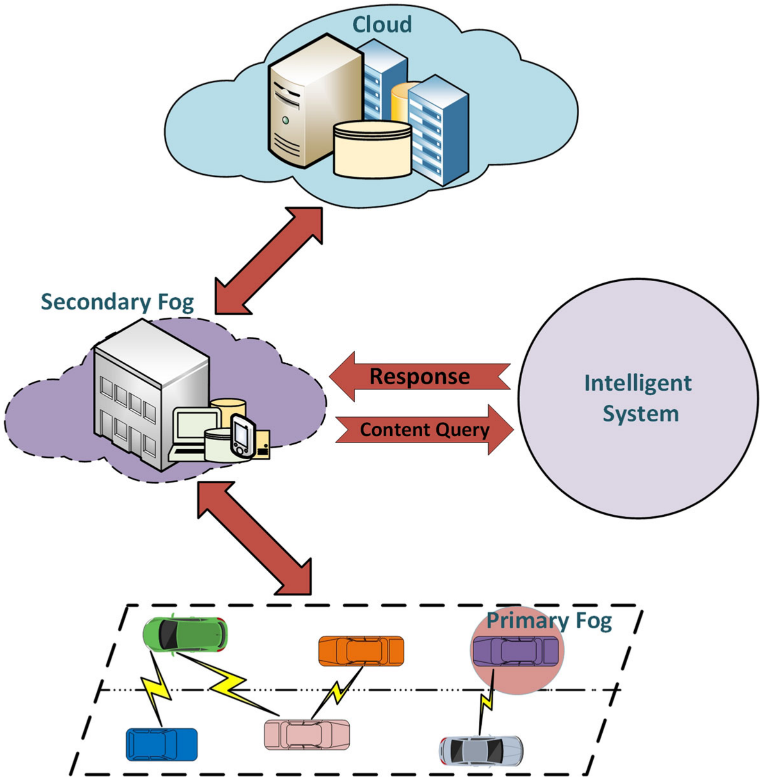

Fig. 4 Estimation of content popularity

unavailable in the SF the cloud assistance comes into the play. The SF becomes the requester of the content and enquires about the content's availability in the cloud. If it is available in the cloud, the SF performs two tasks. Firstly, the content is sent to the PF from where the requesting client is served. Secondly, the content is cached for further analysis by its RS section, which is discussed in 4.2.2. However, if the requested content is not even available in the cloud, the requesting client in the vehicle is provided with a content unavailability message.

4.2.2 Content analysis procedure

When the SF receives content from the cloud, apart from forwarding the contents to the PF, it should analyze the contents as well since storage are always limited. It should analyze content to find whether it is suitable to be cached or not. The RS employed in SF is responsible for finding the suitability of the content based on their popularity.

As shown in Fig. 6, to find the content popularity, the IS in the SF analyzes the received content by checking whether the same contents has been requested to the other SFs in its cluster or not. It assumes that, if there is a record of the same content being requested in other SFs as well, there is a high chance that it will be requested again in the future. Hence, the SF regards such content as popular and caches them. On the other hand, if the contents are not found to be popular, it simply deletes them but keeps the record of the contents for

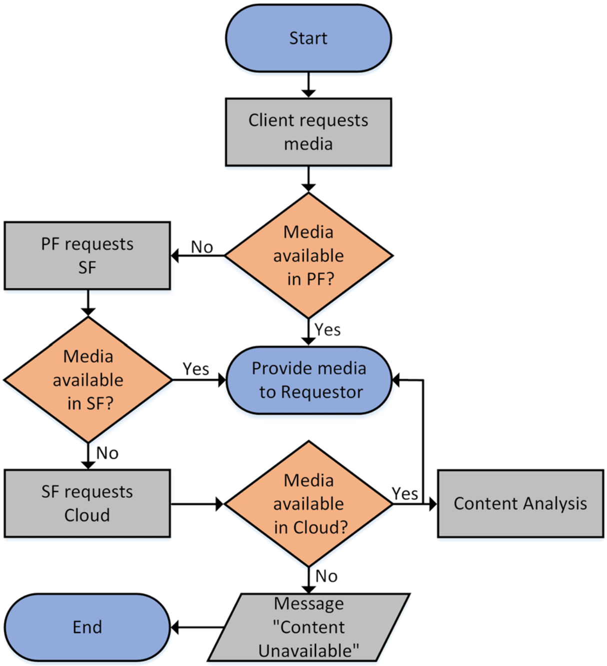

Fig. 5 Flowchart for providing media service

future popularity analysis. If any contents are received from the cloud in the future, this recorded information is used as a knowledgebase to identify if that content was accessed in the past and was popular back then. If it was popular back in the past, it will be cached.

4.2.3 Content recommendation procedure

Another task that needs to be carried out by the SF is to identify the contents that need to be cached/stored in the PF. As explained earlier, the PF is placed inside the vehicle and has limited resources like processing capabilities and storage. Hence, the SF decides whether the contents should be cached/stored in the PF as well.

The procedure of recommending contents to the PF is illustrated as a flowchart in Fig. 7. In this process, the IS in the SF checks the frequency at which the same content is requested from the PF in its closest proximity. In the IS, some content access frequency is defined that is regarded to be cacheable. Hence, the content recommendation algorithm running in IS of SF is continuously checking for the defined condition. If the provided condition is met the content is recommended to PF for caching/storing. If the condition is not met the content is only cached in SF and further action is taken using content analysis procedure discussed in 4.2.2.

5 Network modelling and setup

In this section, we discuss the performance evaluation of our proposed hierarchical fog computing based architecture. The simulation environment we created was used to test

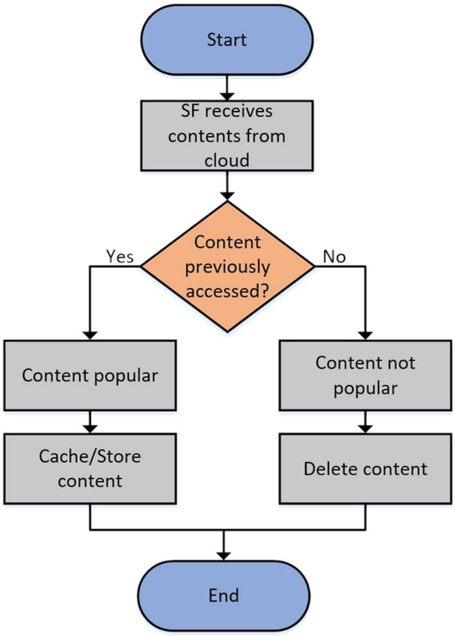

Fig. 6 Flowchart for analysis of contents from cloud

and check the feasibility of our proposed architecture considering QoS and QoE in media streaming service. We considered video data as the media content for our experimentation. The scope of this paper is to maximize the QoS and QoE during media streaming. Hence, the IS in the SF for optimum storage usage is not considered during the simulation. Connectivity in vehicles are affected by various parameters like speed of vehicles, transmission range of vehicles, road traffic, etc [27] and were considered in the simulation too, which is further explained in the following sections. In the simulation, the WiMAX BS is considered stationary and it is also assumed that there is no obstacle between the Line of Sight (LoS) of the vehicle and the RSU.

For the performance evaluation of our proposed architecture, we created a simulation environment for cloud based media streaming service. Similarly, a simulation environment for a hierarchical fog-based media streaming service was also created. Various simulation scenarios were created to compare the network performance between these two architectures. These scenarios are discussed in Section 5.1 below.

5.1 Simulation setup

Simulation was conducted on OPNET. The terrain considered was the area around Kumoh National Institute of Technology, Gumi, South Korea which is an urban city. Simulation environment consisted eighteen scenarios. Firstly, four basic scenarios were created: media service from cloud (C2V), media service from SF (SF2V), media service from PF (PF2V) and media service in between vehicles via PF (V2V). In these scenarios, the mobility of vehicle was not considered. However, while simulating vehicular networks, it is crucial to also consider mobility. Hence, the first four basic scenarios were duplicated, but the vehicles were provided mobility this time. Again, from the C2V scenario, a further 10 network scenarios were created with different server location. The C2V network scenario created

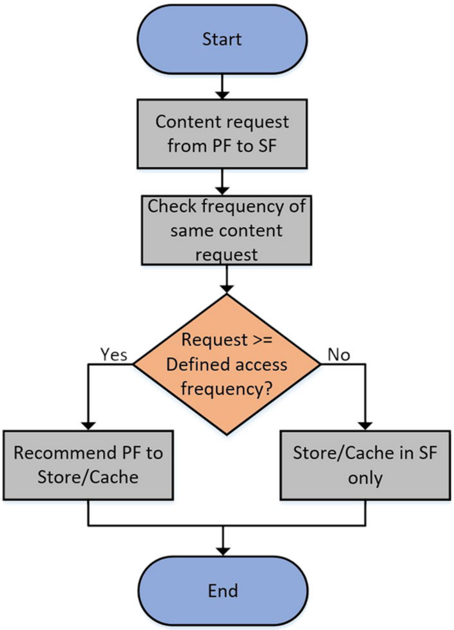

Fig. 7 Flowchart for recommending contents to PF

for the simulation is the representation of the network architecture described in Section 4.1 and is depicted in Fig. 2. In every C2V scenario, the server location was different, so the distances of the cloud servers from the client locations were also varied. This was done to identify the best cloud server for providing media to the client in the vehicle. For the network performance of the C2V scenario with the proposed architecture, the C2V scenario with the best network performance was chosen. For generating the multimedia traffic, the default high-resolution video streaming parameters provided by the OPNET were chosen.

The basic topology created for simulation is shown in Fig. 8. In the figure, the SF is placed inside the Sec_Fog and the PF is placed inside Vehicle A and Vehicle B. The PF in the vehicles communicate with the SF via RSUs, implemented via a WiMAX enabled base station (BS) and represented as BS 1 and BS 2 in Fig. 8. Table 1 shows the basic essential parameters of the RSU in our simulation model.

The RSUs are connected to the SF and the SF with the backhaul network with the DS3 line and with a link capacity of 44.736 Mbps. Each vehicle is equipped with WiMAX receiving and transmitting capabilities. This enabled the task of data transmission from the SF to the PF, vehicle to infrastructure (RSU) and vehicle to vehicle with ease. The vehicles have WiMAX to Wireless LAN (WLAN) enabled wireless access points (AP) for enabling Wi-Fi clients to send and receive data from the PF. The vehicular network in the simulation was created considering public vehicles in the city area. Therefore, HATA propagation model (Okumura Hata model) with hata model [2, 20] for large city was chosen for the terrain profile in the simulation.

The transmission of data from the PF to the client is via Wi-Fi and we know that the Wi-Fi performance is affected by the distance between source and the destination. Considering this factor, the size of the vehicle was designed depicting a public bus in the real-life scenario, with a width of 2.59 m and a length of 12.9 m. We considered two vehicles in the simulation, and each vehicle was assigned with 40 clients, making it total number of

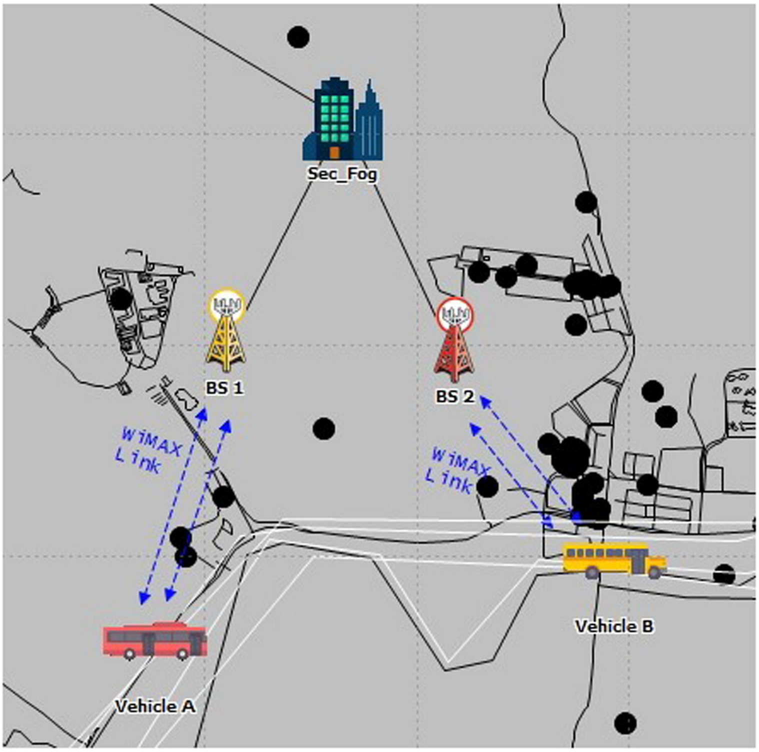

Fig. 8 Basic simulation model

80 clients altogether. The performance of the network is usually good in non-stressed light network condition. So, we did performance evaluation of the proposed architecture in a congested environment. For, this we made all the passengers in the bus to request media simultaneously from the beginning of the simulation. Hence, the media request, which was the video stream in our case was requested simultaneously from the beginning of the simulation to stress the network condition. As the clients requesting the media are inside the

Table 1 Parameters of Road Side Unit (RSU)

Parameter	Value	Note
Physical layer	IEEE 802.16e	WiMAX
Physical layer profile	OFDM	N/A
Antenna gain	15	dBi
Minimum power density	− 110	dBm/subchannel
Maximum power density	− 60	dBm/subchannel
BS Transmission (Tx) power	10	W
Link bandwidth	20	MHz
Data rate	10	Mbps
Number of transmitters	SISO	N/A

vehicle, their distance from the wireless access point (AP) can only vary within this area. For the mobility, a custom trajectory was defined. Part of the trajectory is shown by white lines in Fig. 8. The speed of vehicles was made to vary from 40 km/hr to 60 km/hr and was limited within 40 km/hr to 60 km/hr. This limitation was kept to relate the speed of vehicles in real life scenario in case of urban environment. For the signals that are being received at the vehicle, the path loss parameter was set to "Vehicular Environment" based on the details provided in ITU's white paper in [13]. Some of the basic parameters used for simulation is shown in Table 2:

5.2 Performance evaluation

After creating the simulation test bed, we conducted performance evaluation on the created network scenarios. The simulation was run for 40 minutes with a simulation seed of 128. Since our major concern was QoS and QoE, we considered End-to-End Delay (E2ED), Packet Delay Variation (PDV), Packet Loss, and Visual Mean Opinion Score as performance evaluation parameters. As discussed in Section 5.1, while the vehicles move, they can be stationary sometimes, so performance evaluation was done for both cases of vehicles: mobile and stationary.

5.2.1 End-to-End Delay (E2ED)

For the generation of packets, we have 3 sources (the PF, the SF and the cloud) in our simulation. These sources change based on the simulation scenario. Hence, the time taken for the packet to be transmitted from these sources to the requesting client (inside the vehicle) is termed as E2ED.

Table 2 Basic simulation parameters

Parameter	Value	Note
Physical layer	IEEE 802.16e	WiMAX
BS Tx power	10	W
Mobile station (MS) Tx Power	3	W
BS antenna gain	15	dBi
MS antenna gain	10	dBi
Data rate	10	Mbps
Antenna type	Omni-directional	Horizontal
Link bandwidth	20	MHz
Modulation scheme	QPSK	Model
Path loss parameter	Vehicular Environment	ITU
Number of RSUs	2	BS
Number of vehicle	2	MS
Number of clients/vehicle	40	Client
Total no. of clients	80	Client
Simulation seeds	128	random
Simulation time	40	minutes
WLAN physical characteristics	802.11g	Wi-Fi

Figure 9 shows the E2ED comparison of all four mobility considered network scenarios with respect to simulation time in the x-axis. We can see from the graph that all of the 3-proposed network models video streaming is showing better performances than the typical C2V network scenario. From the figure, we can also see that the proposed PF2V is showing the best performance, and the C2V is showing the worst based on E2ED. Similar result is seen for network scenarios in which mobility is not considered. We can also see from Figs. 9 and 10 that the delay is more less when the vehicle is stationary.

5.2.2 Packet Delay Variation (PDV)

PDV, also referred as IP packet delay variation or jitter is the variation of packet arrival at the destination. According to IETF in [6], if a pair of packets is selected within two measurement points in a packet stream, the difference in one-way-delay of these selected pair of packets is referred to as PDV. The PDV was also analyzed in the simulation for all four scenarios, considering both mobile and stationary vehicle states. In addition of being a QoS parameter, it is also an important parameter of QoE metrics. The PDV has a negative correlation with the users' video perception; the greater the PDV, the lower the quality of visual perception [10].

Figure 11 above illustrates the mobility considered scenario while Fig. 12 compares the PDV when mobility is not considered. Looking at Fig. 11, we can easily note that the C2V has the highest PDV, whereas the PDV in PF2V and V2V are negligible when compared to C2V. We also see that, although SF2V has higher delays than PF2V and V2V, it still has lower PDV than the C2V. Again, from Fig. 12, we can see the same result pattern as it was in the case of mobility with the only difference in the PDV values, which are lower in all cases.

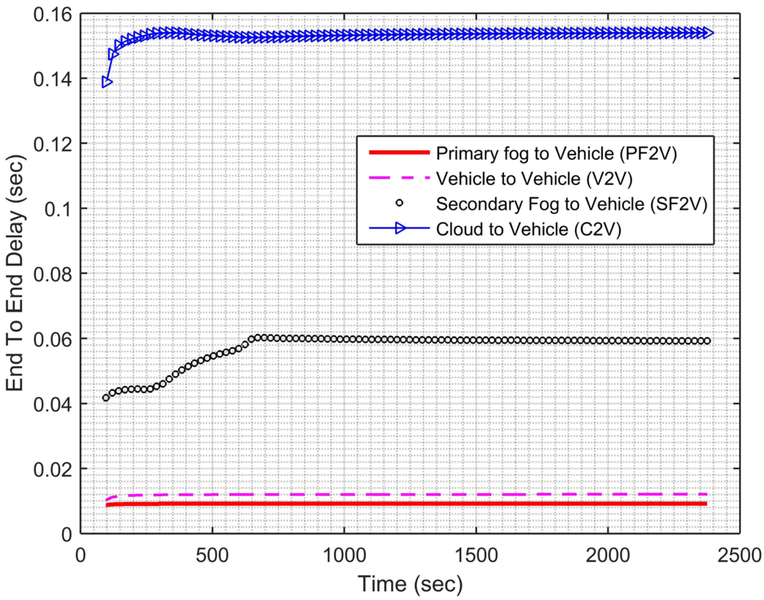

Fig. 9 Average E2ED with respect to simulation time (mobility considered)

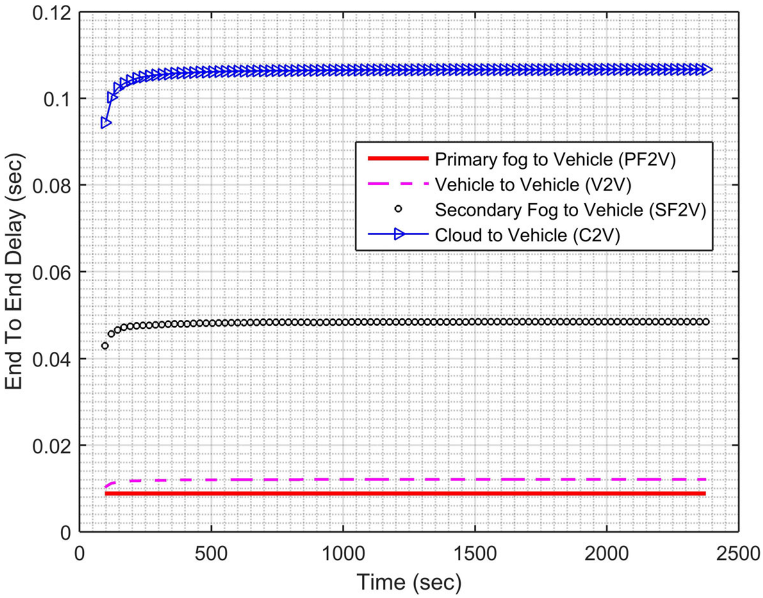

Fig. 10 Average E2ED with respect to simulation time (mobility not considered)

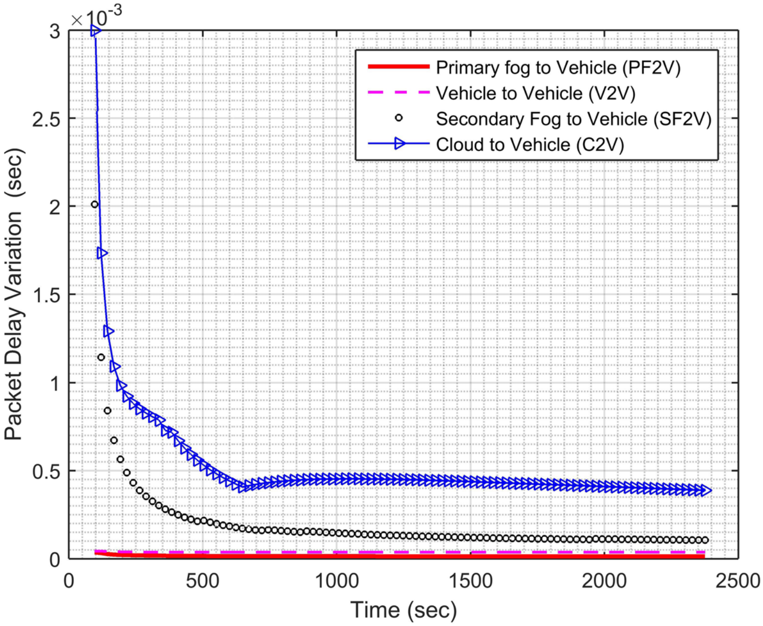

Fig. 11 Average PDV with respect to simulation time (mobility considered)

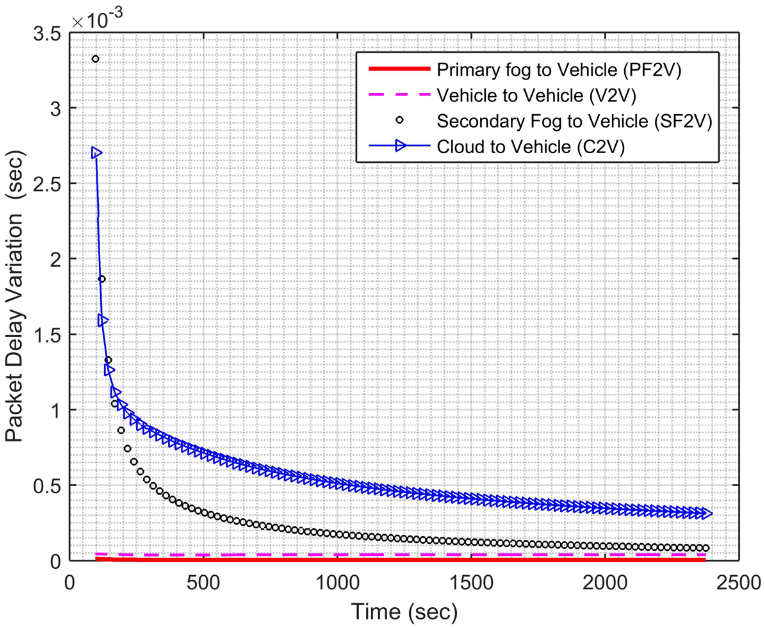

Fig. 12 Average PDV with respect to simulation time (mobility not considered)

5.2.3 Packet loss

When the transmitted packet is unable to reach its destination, the packet is regarded as lost, and this is referred to as packet loss (PL). For smooth streaming, both video and audio have their own packet loss requirements. Cisco specifies that the loss should not be more than 5 percent if QoS needs to be addressed in case of video streaming.

Figure 13 shows the percentage of packet loss when the vehicle is mobile. As described earlier, all clients requested the video content simultaneously to check and compare the network performance in congested environment. We know that, the greater the congestion, the more likely that the packet will be lost. However, we can see from Fig. 13 that although the vehicle is mobile and the network is congested the PF is not affected much and the PL is still in the considerable range.

In case of network scenarios with no mobility, in Fig. 14 we can see that the percentage of PL when video is streamed from PF is similar to that in the mobility considered scenario. This is because, the PF is placed inside the vehicle so it has negligible effect on the PL even when the vehicle is mobile. However, we are seeing this negligible amount of PL in both cases even when the passenger's request is being served from the primary fog. This is because, as discussed in Subsection 5.1, we evaluated the network performance with maximum network load from beginning of the simulation to make a fair performance evaluation. Finally, seeing the PL trend in Figs. 13 and 14, we can also deduce that the proposed network architecture is performing better even in the mobile environment.

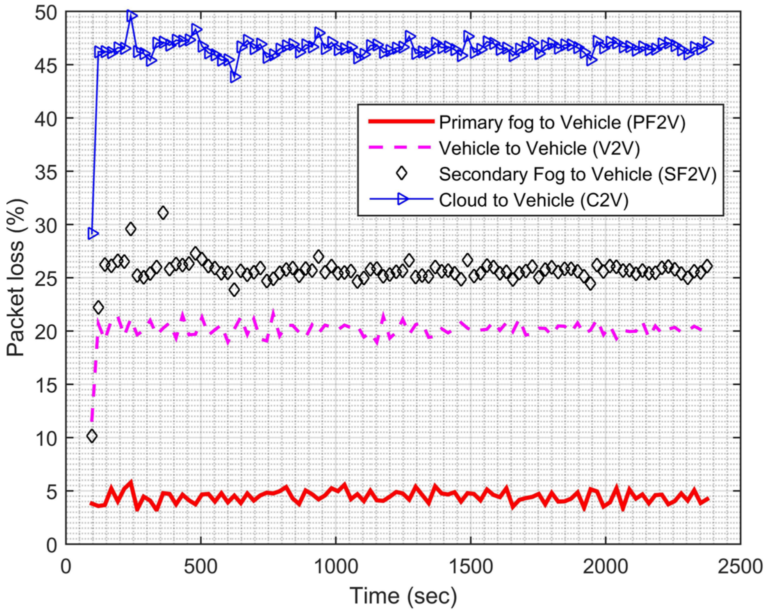

Fig. 13 Percentage of Packet Loss with respect to simulation time (mobility considered)

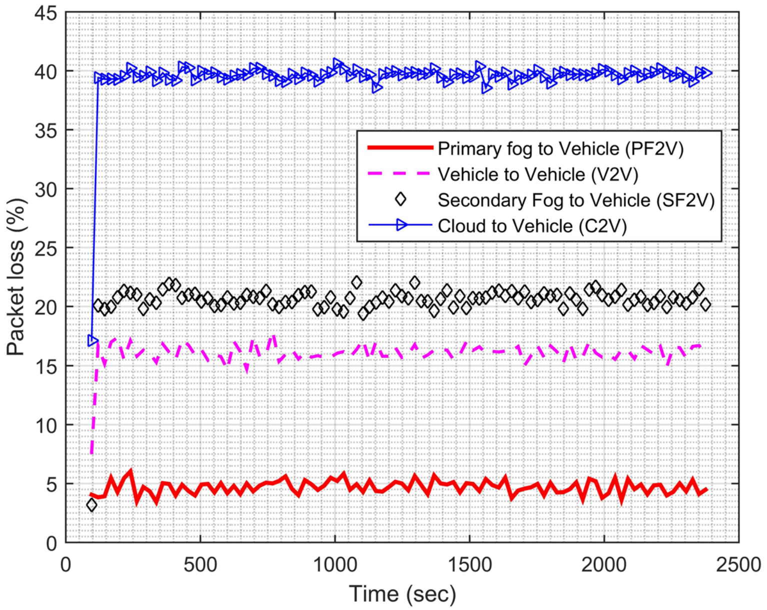

Fig. 14 Percentage of Packet Loss with respect to simulation time (mobility not considered)

5.2.4 Visual mean opinion score

This is a standard measure developed as a subjective parameter for measuring the users' perception of the audio/video. In our case we used it as a measure to identify the clients' perceptions of the videos while receiving them from the cloud, the SF and the PF. This "Visual Mean Opinion Score" was borrowed from the Mean Opinion Score parameters developed for voice [8] by ITU. For simplicity, we are representing this derived Visual Mean Opinion Score as "MoS" in our manuscript. Mean Opinion Score is subjective and hard to measure so, ITU has come up with the E-Model standard [12], with R-value or transmission rating factor as an output.

$$R = Ro - Is - Id - Ie + A \tag{1}$$

Where, signal to noise ratio is represented as *Ro*, *Is* represents the combination of simultaneously occurring impairments, *Id* is the impairments induced by delays, *Ie* denotes the equipment impairment factor caused by packet loss and the low bit codecs and finally, *A* is the advantage factor for compensating the loss if users are benefitted with some other medium of access.

To evaluate users' perception of the video, we created a testbed environment assuming the ideal situation. We allocated a single client with enough bandwidth to keep R with the highest value. From the experimentation, we obtained a visual MoS of 4, which we used as a mark point to represent the best user perception, and similarly, 1 as the worst visual experience.

Figure 15 shows the user perception of the video quality for different scenarios. We can see that the client getting service through the C2V scenario have very low visual perception. Although the clients' perceptions of the streamed video quality are not so good in case of

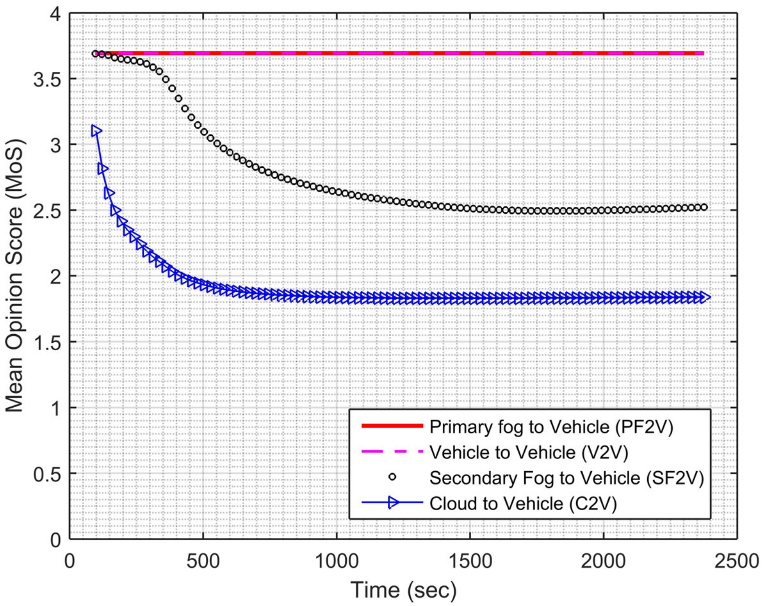

Fig. 15 MoS with respect to simulation time (mobility considered)

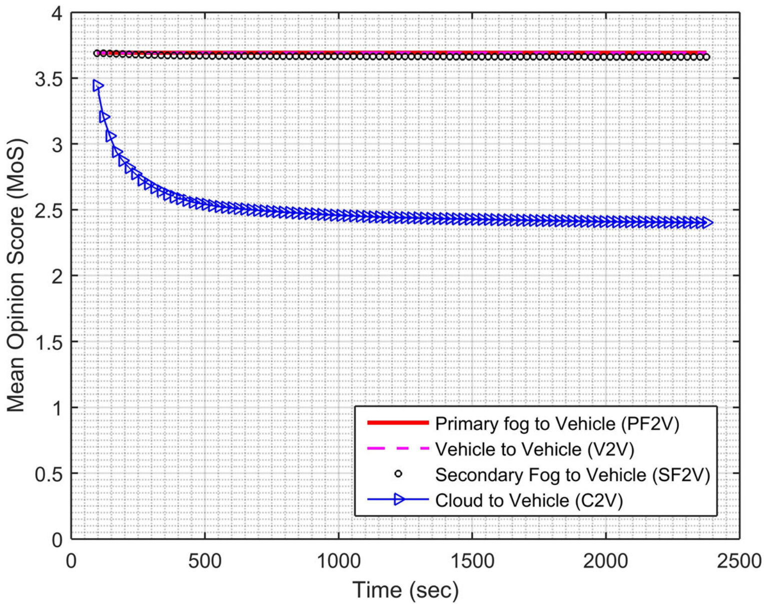

Fig. 16 MoS with respect to simulation time (mobility not considered)

SF2V, it is higher than that of C2V. However, we can see the MoS score is nearly the highest when the client is getting service from PF2V and V2V.

Similarly, in Fig. 16 we can see that when mobility is not considered, even the clients getting service from SF2V are well satisfied and are getting nearly the same visual perception as in the case of PF2V and V2V.

6 Conclusion

In this paper, we have proposed novel architecture for multimedia streaming utilizing hierarchical fog computing. In case of media streaming services, and specially the audio and video streaming, QoS and QoE play a vital role, so the architecture focused on efficient bandwidth utilization, maximizing QoS and clients' QoE. For efficient bandwidth utilization, the architecture targets the minimal involvement of the cloud for serving the clients' requests for media. As the cloud service or C2V, is not at the edge, it's service was considered as the worst-case scenario because it induces more delays during transmission. On the other hand, the secondary and primary fog stations located at edge were considered the better and best-case scenario respectively. The Simulation model of the proposed architecture was created on OPNET to validate the hypothesis and to check the reliability of architecture. Performance evaluation was done based on E2ED, PDV, packet loss, and MoS, and video streaming service was considered for the test. The evaluation showed that serving clients from PF and SF enhanced the QoS and clients' visual perception. Hence, it is seen that extending C2V to the edges making use of the proposed architecture can significantly enhance the network performance in terms of Internet bandwidth efficiency, QoS and QoE. Performance evaluation is also an important tool to identify whether the proposed architecture is deployable in real world or not; and as seen from the performance evaluation, our model showed very promising results. Thus, this proposed architecture can be followed to build a real-world network to cope with the future challenges in providing seamless high-quality media services to the clients using vehicular networks.

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