MS-CCVN: Multi-Source Content Centric Vehicular Networking

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Abstract —Recently, Content-Centric Networking (CCN) has become an emerging technology in vehicular environments and is called Content Centric Vehicular Networking (CCVN). In this kind of system, the network performance was improved by reducing redundant transmission if the cached contents are popular. However, the volume of the Content Store (CS) is constrained, and much smaller than the generated contents. Moreover, the current capacity vehicular backbone network and bandwidth of the Internet have faced great challenges to cope with constantly increasing vehicular applications. To solve these issues, we propose a novel scheme integrating CCN with Multi-source Mobile Streaming (MS^2) into VANETs model, dubbed MS-CCVN. In this scheme, the caching of each content is not limited to the single server anymore, instead, each content is fragmented and distributed to multiple servers over a large scale network. After experimenting with disjoint multi-paths, various content fragments are coupled at side clients. The results obtained by OPNET Modeler simulation show that the MS-CCVN scheme helps to improve energy efficiency, enhance effective caching, less bottleneck link, shorter round trip time, and offload server traffic in comparison with the original CCN scheme in vehicular environments.

Index Terms—CCN, CCVN, MS^2, VANETs, vehicle cloud computing

I. Introduction

Vehicular ad-hoc Networks (VANET) is one of the important components of intelligent transportation systems to improve the traffic conditions, road safety as well as commercial, entertainment services to drivers. In this network, each vehicle takes on the role of the sender, receiver, and wireless router to broadcast information in wide range communications. In VANET, two kinds of communication are Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) where road site units (RSUs) are deployed along the road and take a role as the access point. From the definition of VANET, a highlight challenge is obvious. Usually, Single-Source Single-Path (SSSP) routing is used between end vehicle and server due to its simplicity. However, facing the sheer volume of rich data applications, the traditional SSSP routing will cause the bandwidth of Internet backbone insufficient to keep up with the Quality of Service (QoS) requirement for a huge number of vehicles. The multisource video stream proposed is robust as compared to distributed solutions to multimedia transport including streaming [1]. Furthermore, routing of streaming services over multiple hops and multiple paths can lead to significant packet losses. The total bits transferred between server side and end user side is not reduced for all above situations.

Today, the types of data traffic are becoming more diverse while the number of vehicles is increasing rapidly. The numerous services are generated and shared by producer and consumer. They pose high requirements for the network bandwidth and data storage while making the Internet transmission congested. At the same time, the requirements of rich multimedia contents continue to increase over time, and the current capacity of vehicle backhaul network and the Internet bandwidth are facing great challenges coping with the practical growing traffic due to the centralized architecture. In relation to the exponential growth of traffic, a skewness of the popularity content characteristic was found. In other words, the large number of end users often queries quite a few most popular contents [2], [3]. In addition, the packets can be lost due to the absence of other vehicles in cooperation with each other, and the arrival of the following vehicles in the accident area is unavoidable in the case of low traffic density. Thus, responding to the packets in a timely fashion is extremely important in this situation.

Furthermore, in V2I communication, wireless nodes are embedded in both vehicles and in the road infrastructure units. The energy consumption of wireless nodes in vehicles is typically not an issue, because it can easily take power from their battery [4]. From viewpoint of the wireless roadside infrastructure as well, the wired power in urban areas are available and affordable. However, deploying RSUs in roadside locations will be difficult to implement due to the following reasons, i.e, *i)* the unavailability of electrical wires especially in rural areas, *ii)* the impossibility of connecting power grids

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connection in many locations, *iii)* the civil engineering and connection cost. Even many nodes are powered by clean energy sources, such as the wind or solar power, which cannot be sustained for a very long time due to low capacity of their storage batteries. Recent works address the energy consumption issue by focusing on energy efficient roadside unit schedule generation, ranging from [5] using variable bit rate (VBR) transmission to [6] switching RSUs group on and off state in order to maintain connectivity while minimizing energy use. However, the quantity and solutions concerned with addressing RSUs energy issue are still limited. In other words, energy consumption of wireless nodes in RSUs is a critical constraint that affects to the reliability and lifetime of VANET substantially.

Considering the challenges mentioned above, it is critical to design an effective method of saving bandwidth, offload server traffic, efficient data storage, as well as reducing energy consumption. To address these problems, Vehicular Cloud Computing (VCC) has proven to be the great benefits for VANET in term of processing, data storage, and networking [7], [8]. Reduced bandwidth and efficient data storage are becoming very crucial to improve road safety and passenger comfort. To enhance data storage capability, VCC can be implemented by moving all data and services from local to remote cloud servers, while leverages the already available resources on vehicles. However, VCC is still in the early stages of development, which faces great challenges including existing cloud computing problems. In addition, to alleviate the bandwidth problems concerning with the skewness of popularity content, CCN is proposed to effectively disseminate the popular data content to a huge number of vehicles [9]-[11]. To maximize the probability of sharing with minimal upstream bandwidth demand (e.g. RSUs or sensors update traffic conditions) and lowest downstream latency, routers/gateways should keep all arrived contents as long as possible. Furthermore, reducing traffic load by in-network caching can lead to enhance the VANET performance with higher energy efficiency and toward the evolution of the "green" VANET. Effective caching is one of the most important aspects of the CCN performance. While several papers focus on the performance of replacement decision and replacement policy, an associate fashion between caches is a better solution than a single cache due to constrained cache size.

A multi-source mobile streaming (MS^2) architecture is proposed to further alleviate the impact of network congestion on mobile streaming services, by using sufficiently the available network resources through an effective rate allocation scheme among multiple sources. Additionally, this rate allocation scheme can collaborate to stream the same content in a complementary manner [12]. In this paper, following MS^2 architecture and inheriting the principle of the CCN, we integrated the MS^2 architecture with the CCN to enhance the performance of VANET model, dulled by Multi-Source Content-Centric Vehicular Networking (MS-CCVN). The contribution of the paper is as follows. We first evaluate the energy efficiency in MS-CCVN model. Then evaluate the benefits brought for VANET in term of utilization in the case of bottleneck links, effective caching, shorter round trip time, and overloading server by comparing different scenarios: with typical single-source CCN connection and with Multi-source CCN connections.

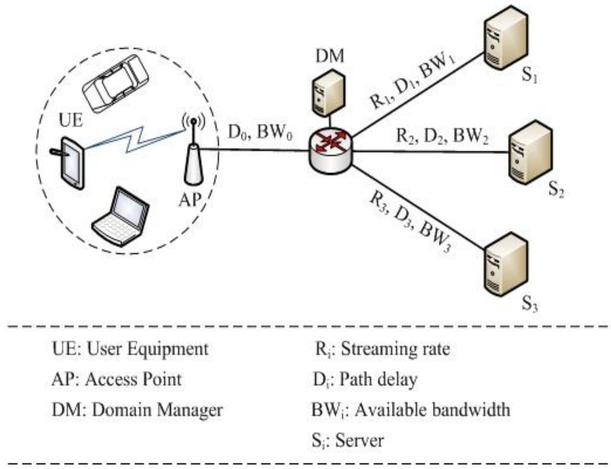

Fig. 1. Simplified MS^2 model with three servers

The remainder of this paper is structured as follows. Section II highlights some of the related studies that pertain to content-centric networking, cloud computing. Section III describes MS^2 model operation and MS-CCVN network architecture, and evaluation and discussion the results in Section IV. Finally, the paper is concluded in Section V.

II. BACKGROUND AND RELATED WORK

A. CCN: Overview

In the past, streaming serves were done from nearby nodes or routers. CCN was developed to perform efficient streaming based on smart caching of popular content near the requesting users. The CCN model presented a simple but effective communication. In CCN, two types of packets are envisioned to identify a content, which is typical hierarchical and human readable. They are called Interest Packets (IntPk) and Data Packets (DataPk). CCN nodes maintain three data structures: Forwarding Information Base (FIB), Pending Interest Table (PIT) and Content Store (CS). Once a CCN node receives an IntPk, it looks up to CS. If an appropriate content is found, the DataPk will be sent for a request, otherwise, the IntPk will be checked in PIT. PIT keeps track of unsatisfied IntPks. After PIT creates a new entry for an unsatisfied IntPk, the IntPk is forwarded to upstream towards a potential content source based on FIB's information. A returned DataPk will be sent to downstream and stored on CS. In general, a content is cached at routers for a certain time. When the "caching" deadline expires, the content is removed to cope with the limited size of content storage. When CS is about to get full or receive a new content, it stores the new content according to the underlying replacement policy to leave space for the new content. Least recently used (LRU), least frequently used (LFU) and first in first out (FIFO) are few notable examples of replacement policies for CCN.

B. Related Work

Recently, CCN has been studied in VANET by leveraging its advantages in popular content distribution, which provides a promising solution in the future. Some existing works have been discussed as network paradigm to support typical application in data collection and dissemination. In [13], a system collecting data from mobiles based on named data was explored to collect information from vehicles for monitoring and detected problems. Moreover, data packets from vehicles were attached with device's signature and encrypted using public key before delivery to the Internet. The CCN architecture was applied in [4]: RSUs play the role of consumers by broadcasting Interest and collecting information from vehicles acting as the provider. The work in [14] also discussed the advantages of named-data approach in V2V and V2I communication. Similarly, a simple traffic information dissemination application in V2V was proposed and evaluated by leverage CCN for efficient Interest and Data broadcasting [15]. Instead of simulation tools, in [16] the advantages of CCN for vehicular environments were evaluated in real implementations. In [17], the redundant links among nodes in CCN paradigm were beneficially exploited by applying network coding techniques to improve content dissemination in VANETs. In [18] the robust forwarder selection (RUFS) scheme was to mitigate the interest flooding problems. In RUFS, each vehicle was allowed to exchange the list of satisfied interest with neighbors. All neighbors stored this information in their Neighbors Satisfied List (NSL), which helps to rank the vehicles before forwarding any interest.

So far, most of the works applying CCN principles for data dissemination in VANET has focused on either to improve forwarding routines or naming and transport design [19], [20], while only a few of them interested in the effective caching. In [21], caching decision and replacement policies were performed to store the data content effectively, in which four policies were compared and evaluated in term of hitting rate and offloading server. With the same cache size, PT-Sharing and PT-LRU helped to enhance the effectiveness of caching and offload total server traffic better than Least-Recently-Used (LRU) and Least Frequently Used (LFU) schemes in comparison respectively.

Besides, ICN has been recognized as an enabling networking technology for an emerging paradigm in VANETs, namely VCC. Actually, VCC is another form of Mobile Cloud Computing (MCC) [22], which commences from a conventional cloud-computing model. The network access does not only utilizes the unlimited computing resources on the Internet but also store/download contents from the Internet. To reduce bandwidth, enhance data storage and lessen time-spent to respond the contents from Internet cloud, VCC leveraged the processing and storage of vehicles where they are in off state (e.g. in parking lots or other waiting states), dubbed vehicular cloudlet [23], [24]. Two different types of vehicular cloudlet can be defined, i.e., mobile and static which vehicle state in mobility and off state, respectively. While vehicles in mobile vehicular cloudlet that act as data ferrying service, vehicles in static vehicular cloudlet act as storage system.

Similarly, the extension of VCC model has proposed by integrating new computing resource installed on vehicles (called temporary cloud) [25]. Thus, it does not only helps vehicular drivers to access computing resource using both stationary and mobile nodes but also provide support to other users. As a result, it can reap different computing function such as processing, storage, and bandwidth. However, this extension model leads to raising more challenges and issues that remain to be addressed in future works, i.e, *i)* how to effectively communicate and coordinate between permanent and temporary sub-models, *ii)* how to raise privacy and security, and *iii)* how to improve resource allocation and sharing to reduce response time. Therefore, it is not easy to build applications on top of VCC networking.

III. A Basic MS^2 Model and MS-CCVN Model

A. A Basic MS^2 Model

The basic MS^2 architecture, along with its supporting mechanisms, was described in details in [12]. Fig. 1 depicts the considered MS^2 model topology, which involves three media servers servicing a number of the end users through a single Access Point (AP). Whilst in the envisioned topology, consideration was made in the case of video streaming through a single access point. It shall also be stressed out that multimedia streaming via different paths and different access points shall be possible [26]. The topology consists of three uncorrelated paths from the servers to the gateway traversing a number of routers and gateways. As detailed in [12], MS^2 operations follow a number of steps. The MS^2 architecture comprises also a domain manager or a Decision Maker (DM) that carries out the overall service management. Effectively, DM sends a request information packet to server[i] with i = 1;2;3; and receives some reply information packets from server[i].

The path delay (D_i) from server[i] to DM is calculated referring to the inter-arrival times of two adjacent arriving packets from server[i]. The available bandwidth (BW_i) of the bottleneck link between DM and server[i] is then estimated from the ratio of the information packet size to the path delay. Using all the links to the servers, DM calculates the values of the following parameters for each server[i] [12]:

- Streaming rate (R_i);
- Number of packets (P^i_v) to be sent during the monitoring period (δ);

- Data packet inter-transmission times (Δ_i);
- The time to commence the transmission (τ_i);

Finally, the two parameters R_i and τ_i are communicated to server[i] that calculates, as elaborated in details in [12]. When a user desires to view a content video, it sends an IntPk to DM. DM selects, following the certain logic, the servers to be involved in the delivery of the content and communicates to them the parameters R_i and τ_i. Based on the path delay (D_i) from each of these servers to DM, and subsequently, on the computed values of τ_i, Δ_i and P^i_v, the servers schedule the delivery of DataPks packets to the end user. Hereby, the packets of the same content will arrive in order at user without high jitter, and most importantly without duplicate packets that could drain up the battery lifetime of the end user [12].

Based on the studies mentioned above, the advantages of CCN and MS^2 can simultaneously be applied to VANET model to enhance QoS, dubbed multi-source content-centric vehicular networking that will be presented in detail in the later domain.

B. MS-CCVN Model

Having described the operation of the MS^2 architecture with its principal components, we now present on how the MS^2 can be integrated with CCN strategy into VANET model to further improve its performance.

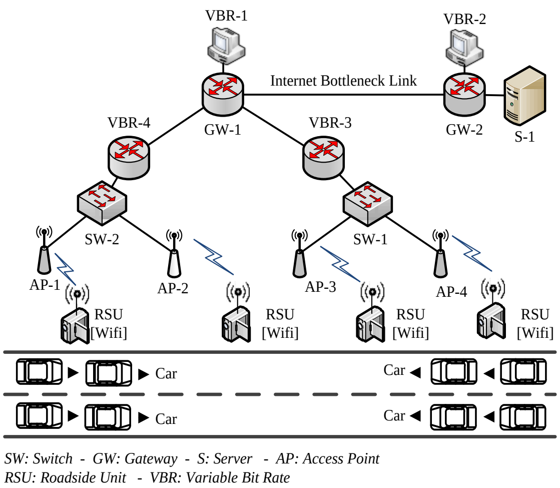

Fig. 2. A typical single-source CCN

In this kind of model, CCN processing modules are integrated into all network elements, such as the gateway/router, WiFi-access point, RSU, and DM. With every intention to consider a typical Internet network topology, a typical single-source CCN model simulation topology as shown in Fig. 2. As seen in Fig. 2, the link between gateway GW-1 and GW-2 is the bottleneck link (e.g. 6 Mbps). Because of the bottleneck link, some of the packets can be dropped and cannot reach the vehicle during the network traffic congestion time. The vehicle maintains time-out to resend the request for packet loss.

Moreover, to simulate a realistic background traffic, variable bit rate (VBR) with different shapes is also considered between GW-1 and GW-2, generated by VBR-1 and VBR-2, respectively. The VBR is combined with two shapes of network traffic at the same time by using (1), e.g. *Uniform (a;b) + Poisson(x;λ)* s, for inter-transmission packets.

$$R_{VBR}=\left[R_{uniform(a,b)}+R_{poission(x,\lambda)}\right]=\frac{2}{a+b}+\frac{1}{\lambda} \tag{1}$$

$$E\left[R_{VBR}\right]=PkSize\times R_{VBR} \tag{2}$$

where R_{VBR} is the traffic generated by Variable Bit Rate (VBR), *PkSize* is the packet size, the average background traffic ($E\left[R_{VBR}\right]$) is calculated by (2). For practical reasons, the background traffic to avoid congestion that satisfies with the MS^2 condition. The case of SSSP, the streaming rates should not surpass the accessible bandwidth along each Path[i] (BW_i) [12], as shown in (3).

$$BW_i > n_V\cdot R_i + R_{VBR} \qquad 1\le i\le n_S \tag{3}$$

where R_i is the streaming rate of the path [i], n_S and n_V donate the number of server and vehicle, respectively.

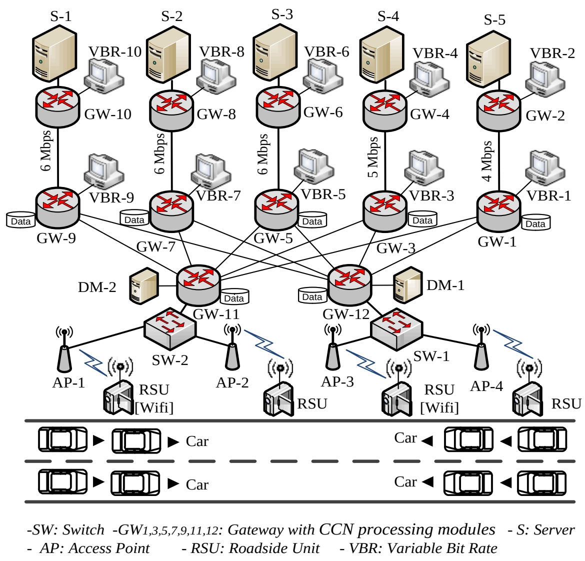

Fig. 3. MS-CCVN model with five-server distribution

Fig. 3 shows the proposed model simulation topology, which includes five servers. The topology consists of five uncorrelated paths from the servers to the gateway traversing a number of routers/gateways. The VBRs setup is similar to the single-source CCN scheme. The simulation network includes two wireless domains. All vehicles within the radio range of AP-1 and AP-2 are managed by DM-1. Similarly, vehicles, connected to AP-3 and AP-4, are handled by DM-2. In the case of non-congestion condition, the link utilization on each path can be computed as follows.

$$BW_i > (1-H_i)\cdot n_V\cdot R_i + R_{VBR} \tag{4}$$

$$U_{Link[i]}=\frac{(1-H_i)\cdot n_V\cdot R_i+R_{VBR}}{BW_i}=\frac{(1-H_i)\cdot n_V\cdot\left(\frac{BW_i}{\sum_i^{n_s}BW_i}\cdot R_p\right)+R_{VBR}}{BW_i} \tag{5}$$

The hitting rate is defined as the percentage of access to data found in the cache. Hence, we denote H_i is the hitting rate obtained on each path from the server to the vehicle. R_p represents the vehicle play rate with the assumption that average R_p of all vehicles are similar.

To prove the impact of CCN on MS^2, original MS^2 architecture is considered in the case of congestion (not satisfies equation 1) but avoided in MS-CCVN model (satisfies equation 4). Thus, BW_i has to satisfy (6).

$$n_V \cdot R_i + R_{VBR} \geq BW_i > (1 - H_i) \cdot n_V \cdot R_i + R_{VBR} \tag{6}$$

In the network shown in Fig. 3, caching contents are deployed at edge gateways (GW-1; GW-3; GW-5; GW-7; GW-9) and all the WiFi-access point (AP) for simulation schemes. Edge caching is of vital importance for the CCN, which becomes more efficient with intelligent caching at edge routers/gateways, AP, and RSUs. In other words, the data content become less efficient when caching location is further away from the end-users [27] [28]. By caching, some of the popular data contents are accessed from nearby caches, and bypassing bottleneck links. For this reason, the average data delay of the packet is significantly reduced. To evaluate the spreading of requirement bandwidth through multi-source and disjoint multi-paths, some of the assessment metrics (such as bottleneck link utilization, hitting rate, offloading server and RSUs traffic, and server responding delay) are used in the simulation.

Furthermore, the general equation is based on total energy consumption (E) to evaluate energy efficiency as in (7) [29] [30], which is considered in this model. Dividing (7) by the time t, the power consumption (P) can be formulated into a linear equation as in (8).

$$E = (e + b \cdot r \cdot t) + C = t \cdot (a + b \cdot r) + C \tag{7}$$

$$P = \alpha \cdot r + \beta \tag{8}$$

where e is energy consumption per unit time, r is data rate *(Mbps)* and C is a constant value, b is the energy consumption rate for data (*Joule/Mbytes)*, α is power consumption per unit time (*mW/Mbps*), β (*mW*) is the base power. According to the power model data transfer, these parameters (α and β) are calculated specifically as [31]. Equation (8) illustrates that the power consumption is linear to the data rate. Therefore, an assessment of energy efficiency of RSU is easy to achieve based on the offloading RSU traffic (data rate r) in comparison among variety multiple sources, which is evaluated in detail in the next section.

Fig. 4 shows the main operation for MS-CCVN in the general case of server [i]. First, server [i] sends a root's name advertisement to CCN nodes and DM. CCN nodes will add this root's name into their forwarding information base (FIB), and then forward it to their neighbors. All CCN nodes will then update to the new root's name by broadcasting periodically from the servers. DM acts as CCN node but without pending interest table (PIT) and content ctore (CS). When DM receives an IntPk from a vehicle, DM just use its FIB to forward the IntPk to the nearest CCN node.

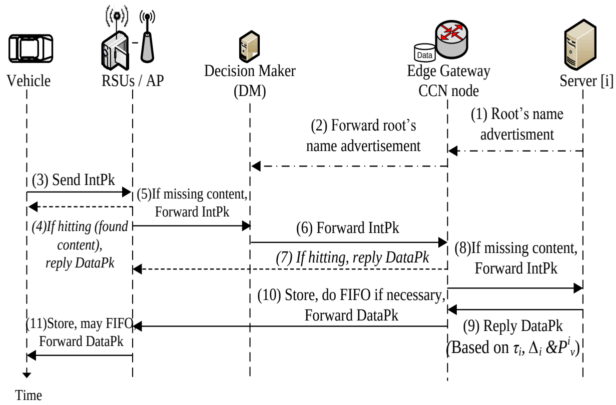

Fig. 4. MS-CCVN flowchart with server [i]

IV. Simulation and Results

This section presents numerical results that illustrate the validity of the proposed model in section 3.2. Hereafter, the simulation setup is described, and then analysis and evaluation of the results obtained.

A. Simulation Setup

TABLE I: Simulation Parameters

Packet types	Information	32 B
	Interest (IntPk)	32 B
	Data (DataPk)	1 KB
Vehicle	Buffer size	100 Pks
	Play rate	100 Pk/s
	Wireless interface	802.11g@54 Mbps
	DataPk time-out	0.6 s
	Start time	50+Uniform(0,10) s
	Stop time	2000s
DM/Server	Monitoring time interval	0.3 s
Bottleneck links	Single server	6 Mbps
	Two servers	5; 6 Mbps
	Three servers	4; 5; 6Mbps
	Four servers	4; 5; 6; 6 Mbps
	Five servers	4; 5; 6; 6; 6 Mbps
Other links	GW-GW	OC-24
	Other links	1000BaseX
Content	Data size	200 DataPk / 2 s
	Popularity characteristic	Pareto(104;102)
Content Store (CS)	Relative cache size	0.025;0.05;0.1;0.15; 0.2
	Replacement policy	FIFO

The proposed model is implemented by using the OPNET Modeler 16.0. Actually, typical vehicle speed of about 40-80 km/h. However, a simulation of a slow movement in traffic explosion scenario was setup. Thus, eight vehicles divided into two groups move slowly in two directions with 5 km/h speed that request different contents from a single server via a single path. Four RSUs are deployed for 1 kilometer of road, whereas both RSUs and vehicles are equipped wireless node that operated under IEEE802.11g standard. Every vehicle requires seamless data streaming with a constant rate of 800Kbps. Vehicles send randomly the requested content around the 50th second after the start of the simulation, e.g. 50+Uniform (0; 10)s. Data are streamed from the data server (S-1) and finally received by CCN processors. After executing underlying data caching/replacement policies, CCN processors supply requesting vehicles with requested data content when available at CCN nodes.

In this paper, FIFO replacement policy was applied to achieve the benefits of CCN. The performance of five schemes for different relative cache sizes were evaluated, which presented the percentage of a cache size over a catalog size as shown in Table III. To make different quality of experiment (QoE) between the single-source scheme and multi-source scheme, a bottleneck link between server side and client side was setup. All VBRs are initiated at the 10th second after the start of the simulation and it is maintained until the end of the simulation. Table I lists the rest of the simulation parameters.

B. *Simulation Result*

According to the simulation setup in the previous section, simulations scenarios are performed to validate the effectiveness of our proposed approach in comparison with variety of multi-source detailed hereafter.

Fig. 5 (a) and Fig. 5 (b) show the vehicles would receive similar data results while the impact of a number of server distribution on the RSU load is different. In single source CCN scheme, all DataPks are fetched from CCN nodes, passing through bottleneck link through single-path. The bottleneck link utilization still reaches its maximum at congestion events. As a result, the delivery delay of DataPks increases and packet loss is unavoidable, and the RSU traffic load is higher than variety multi-source. In Fig. 5(c), the effective offloading RSUs traffic is achieved (e.g. reach to 72.47 percent in the case of five servers in comparison with single-source). These results are calculated based on the final state data rate in Fig. 5 (a) and (8). From this assessment, it was realized that MS-CCVN contributes a significant portion of the energy efficiency, which is not only for RSUs but also for other nodes (e.g. infrastructure wireless nodes and servers), to advance to the “green” VANET in future.

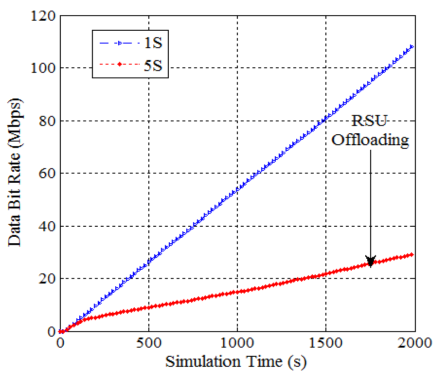

Fig. 5 (a). Total traffic sent by RSUs

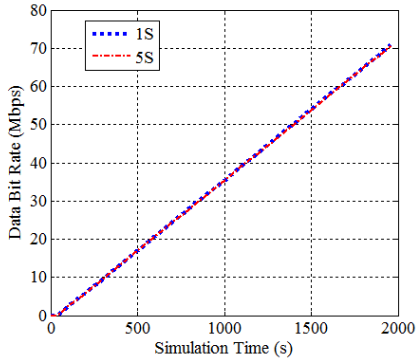

Fig. 5 (b). Total traffic received by vehicle

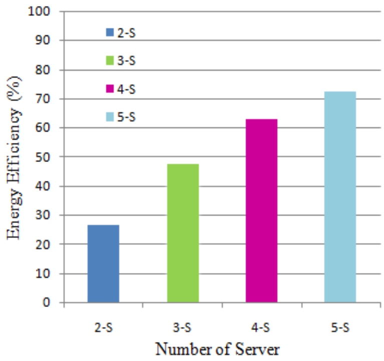

Fig. 5 (c). Offloading RSUs traffic

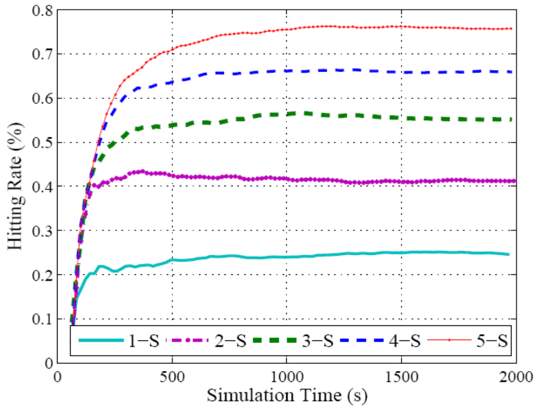

Fig. 6. Hitting rate on the 6Mbps bottleneck link

Fig. 6 compares performance amongst different multi-source schemes when the relative cache size is set to 0.1. In Fig. 6, the obtained simulation results show that a better hitting rate can be achieved when increasing the number of server distribution. When the higher number of server distribution is explored, resulting lower data packets are delivered to each routing path and infrequent replacements of data packets at caches. Thus, the hitting rate is increased in association with the number servers 1,2,3,4, and 5, respectively. From the figure, it becomes apparent that this increase in the hitting rate is not linear to increase in the number of servers. Thus, the figure demonstrates the effective caching by an associate of fashion between caches in MS-CCVN that is a better solution than a single cache in single source CCN scheme.

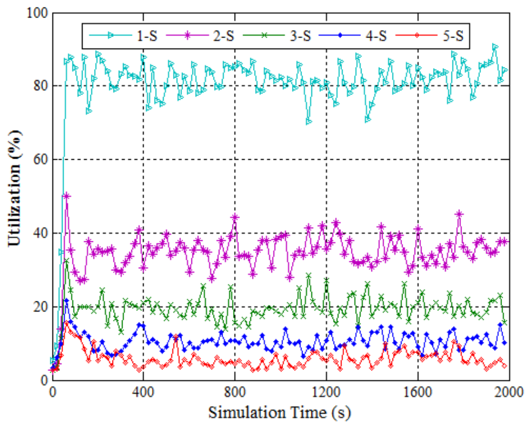

Fig. 7. Bottleneck links utilization

Fig. 7 compares the utilization bandwidth (*BW*) on the 6Mbps bottleneck link under variety multi-source. In the typical single-source CCN scheme, the single-path utilization often reaches its maximum resulting in congestion. By leveraging the concept of MS^2, the content delivery is distributed among several servers, e.g. 2, 3, 4, and 5 servers, respectively, with disjoint routing paths to the vehicle. Thus, the BW requirement on routing paths is reduced quickly, associated with the number of servers. For this reason, the MS-CCVN model not only uses less BW requirement from the bottleneck links but also improves the utilization free BW of the entire network. We check consistency between results from the derived mathematical model and the simulations. In the case of Uniform *(0.002; 0.02) + Poisson(0.02)* s, the VBR is approximately 0.75Mbps based on (1), (2). From Fig. 6, the final state hitting rate (H_i) (at 2000 seconds simulation for 1,2,3,4 and 5 servers) reaches 0.25, 0.41, 0.55, 0.66 and 0.76 respectively. Based on (5), we compute the average bottleneck links utilization: $U_{Link} \simeq$ 80% in the single-source CCN scheme, and $U_{Link} \simeq$ 34.3, 19.2, 10.4, and 5.7% in the MS-CCVN with 2, 3, 4 and 5 servers respectively. In a comparison of the obtained values and the OPNET simulation results in Fig. 7, it was observed that they are approximate values, demonstrating the accuracy of our mathematical model and validating our simulation setup. This result can be explained by the fact that, the hitting rate is increased in association with the number of servers while the cache size is not changed, which causes to reduce the bottleneck links utilization that is illustrated in Fig. 6 and (5). Therefore, the effectiveness of multiple sources in term of bottleneck links is achieved substantially instead of the approach by increasing the cache size in a typical single source CCN scheme.

Fig. 8 presents the impact of the number of server distribution on the total servers load. In CCN strategy, instead of sending all the IntPks to the origin servers, CCN nodes act as surrogates to original servers and the cached contents are responded to the end users, and then offloading the server load. If CCN nodes perform higher hitting rate, lower requested traffic is fetched to servers, and then higher percentage of offloading traffic is achieved. Obviously, in the Fig. 8, the total responding data bit rate sent by servers is reduced in association with the number of servers 1, 2, 3, 4, and 5, respectively.

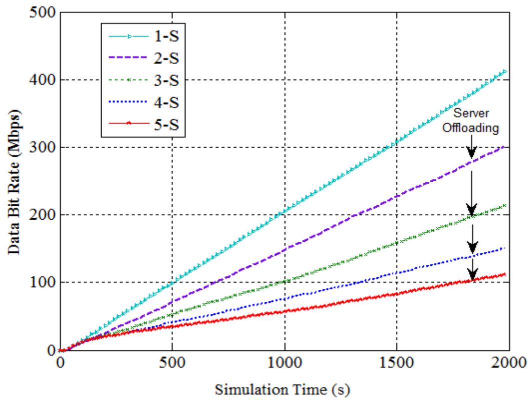

Fig. 8. Sum of servers traffic

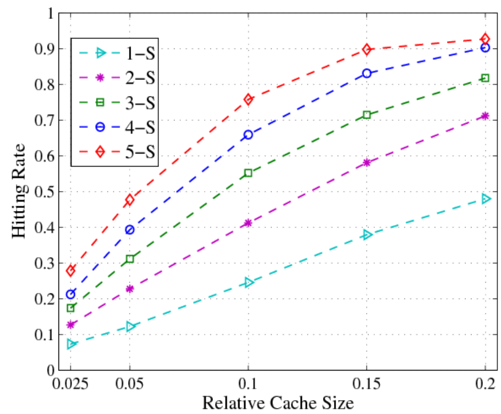

Fig. 9. Final state of multi-source schemes for varying relative cache size

Fig. 9 further compared the five schemes different relative cache sizes. From this figure, it was realized that higher number of server distribution exhibit always higher hitting rate in all situations. Furthermore, the figure reveals two important observations. First, when the relative cache size is too small (e.g. 0.025), the increasing number of servers have few benefits to improve the hitting rate. Second, when the relative cache size is large enough (e.g. 0.2), a high number of server distribution (e.g. 5) is not necessary because the hitting rate is just a slight improvement. Thus, there is a trade-off between cache volume, number of servers and performance, and there is consequently the need to retrieve a suitable value of cache size and servers. This trade-off is an important factor for cost-effectiveness in VANET.

Fig. 10 presents the total time elapsed since a vehicle issues an IntPk requesting a data till it receives the first DataPk of the data. In addition, the relative cache size is set to 0.1 as default in this scheme. As shown in the Fig. 10, in the typical single source CCN scheme, many DataPks need to be fetched from the single server, passing through bottleneck link due to low hitting rate on the single CCN node. At the congestion time, the delivery delay of DataPks increases, highly dynamic and some packets losses occur. Hence, the responding delay in the single-source CCN scheme is always higher and varying than the multi-source scheme (e.g. with 2 servers and 5 servers), and that is during the entire simulation time. Obviously, in the MS-CCVN scheme, when the desired content is cached at several CCN nodes located on disjoint multi-paths to the vehicle, an entire available cache size increases along with the number of data paths (or the number of server distribution). For this reason, popular content can be accessed immediately from nearby nodes with negligible delay. Otherwise, unpopular data take a delay of transmission through bottleneck links with congestion avoidant.

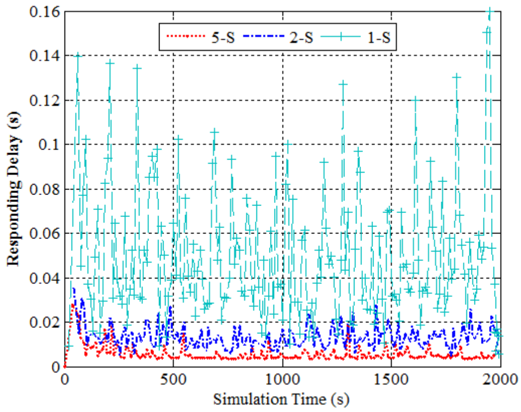

Fig. 10. Server responding delay at the vehicle

V. Conclusions

In this paper, recent MS^2 architecture to improve the CCN performance in vehicular environment has been presented. The resultant architecture, dubbed by MS-CCVN, reduce RSUs energy consumption, efficiently distributes contents available to vehicles and improves the utilization of the overall free bandwidth through disjoin multi-path. This helps in avoiding the access to popular content from far away servers along paths that could be congested. The performance of MS-CCVN was evaluated through computer simulation and compared against the typical single-source CCVN. The obtained results illustrate the effectiveness of MS-CCVN with a different number of server distribution schemes. Additionally, simulation results on data playback quality such as delay and jitter stability illustrate that MS-CCVN could outperform the typical single-source CCVN in utilizing overall network resources more efficiently. As for future work, we plan to improve MS-CCVN by addressing more in detail the smart caching issues as well as the predictive available bandwidth forms.

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