Performance analysis of real-time streaming under TCP and UDP in VANET via OMNET

Jun-Li Kuo, Chen-Hua Shih, and Yaw-Chung Chen

***Abstract*—Ad hoc network is composed of mobile nodes without infrastructure. Depending on a hop-by-hop basis of connection, communications between high-mobility nodes are accomplished via cooperative forwarding. Especially, the vehicular ad hoc network (VANET) is a technology that uses moving cars as nodes to create a mobile network or implement vehicle-to-vehicle (V2V) connection. However, the discussion about live streaming or comparative performance in V2V has been lacked so far. We propose a V2V streaming on OMNet platform (VSOP) to build a V2V evaluation of real-time multimedia streaming under TCP/ UDP on VANET. We not only compare TCP and UDP, but also analyze and simulate the routing performance in VANET. The major contribution of proposed scheme is a compared study of protocols for real-time wireless application.**

***Index Terms*—VANET, OMNet, V2V, simulation.**

I. INTRODUCTION

The vehicular ad hoc network (VANET) is a technology that uses moving cars as nodes in a network. VANET can be seen as the extension or inheritance of mobile ad hoc network (MANET). Although VANET is based on MANET, there are several different details between VANET and MANET. (1) Rather than moving at random, vehicles tend to move in an organized fashion and a directive motion. (2) Instead of steady orientation, vehicles usually move at high speed and dynamic velocity. (3) There are intersectional nodes in VANET, because vehicles always move on road and pass through crossroads. The characteristics lead to the special development scenario of VANET.

A vehicle can communicate with other vehicles directly to form the vehicle-to-vehicle (V2V) network. A vehicle also communicates with fixed equipment next to the road, referred to as roadside infrastructure unit to form vehicle-to-infrastructure (V2I) communication. Both V2V and V2I allow vehicles to share safety information about accident prevention, accident investigation or traffic jams. With the development of wireless ad hoc network, multimedia service can also be used in V2V and V2I. The kind of real-time streaming applications must ensure a high quality of service (QoS) to satisfy users.

If VANET is organized by a bottom-up architecture, a network development of VANET must consider network layer and transport layer. VANET may adapt WiFi or WiMax as its network access technology [1] to discuss the implementation and influence [2]. VANET may select one ad hoc routing protocol as its IP routing scheme to discuss the performance evaluation [3]. VANET may use TCP or UDP to deliver data stream. TCP or UDP directly influences the performance of application program and network traffic, however, the related research hasn't be presented so far.

Due to the inheritance of MANET, the routing protocols of VANET are based on ad hoc routing protocols, such as AODV [4] and DSR [5]. However, the routing protocols of MANET aren't always suitable for VANET because of roadway direction and high speed. Therefore, more and more vehicular routing protocols have been published, such as GSR [6], SAR [7], STAR [8], CAR [9], but there is no survey of comparisons. The existing vehicular routing protocols lack the relative works to TCP/ UDP and application.

Therefore, we present a reviewed study to discuss the inter-vehicle traffic in real-time services, such as accident prevention, traffic jam warning, or communication. We propose a V2V streaming on OMNet platform (VSOP) to build a V2V platform and evaluate the performance of real-time multimedia streaming under TCP/ UDP on VANET. We construct a simulation scenario via OMNet++ in the article. The simulation scenario includes GSR and CAR. As a result, the paper can provide a comprehensive comparison to the researchers and designers interested in VANET.

II. RELATED WORKS

A. VANET

With the development of mobile computing, more and more application can be implemented in VANET. IEEE 802.11p and IEEE 1609 standards are also developed now for wireless access in vehicular environments (WAVE). When a vehicle enables the wireless technology, the mobile connection is workable in infrastructure-less environment. The mobile connection includes the service of file sharing, voice communicating, and live streaming, which provide the geographic information, accident prevention, and multimedia entertainment. These applications are often used for improving the driving experience, but they need the real-time distribution to spread date throughout the ad hoc network.

Therefore, VANET requires the real-time delivery and efficient routing protocol, which are suitable for high dynamics. In order to provide the state-of-the-art architecture, we combine the real-time interaction and V2V communication to discuss the QoS of network traffic. As a result, we focus on the real-time streaming and unicast vehicular routing protocol. In the paper, we only discuss and simulate their route discovery and route execution (loop).

B. Unicast vehicular routing protocols

Geographic source routing (GSR) protocol [6] overcomes the disadvantages of position-based routing algorithm in VANET. GSR uses *distributed planarization algorithm* to graph the

J.L. Kuo works in Information and Communications Research Laboratories, Industrial Technology Research Institute, Taiwan (e-mail: estar.cs95g@nctu.edu.tw).

C.H. Shih works in Chung Shan Institute of Science and Technology, Taiwan (e-mail: shihch@csie.nctu.edu.tw)

Y.C. Chen teaches in Computer Science, National Chiao Tung University, Taiwan (e-mail: ycchen@cs.nctu.edu.tw).

978-1-4799-0846-2/13/$31.00 ©2013 IEEE

local conversion of the connectivity (i.e. *planar graph*), and uses an online routing protocol to operate on planar graphs. Especially in urban areas, the buildings or other radio obstructions restrict the effective routing paths. GSR uses the real map and considers street as the routing path instead of point-to-point link to avoid radio obstruction. Then a routing path (between the source and the destination) is computed using Dijkstra's shortest-path algorithm.

Spatially-aware routing (SAR) protocol [7] is similar with GSR, and it is also a position-based routing protocol. SAR also needs a real map to construct the *spatial model*, which routes packets via the *route list*. Especially in sudden interruption, SAR uses *suspension buffer* to overcome the weaknesses of the recovery strategy in VANET. The suspension buffer is remained until a suitable vehicle arrives in the routing path.

Spatial and traffic aware routing (STAR) protocol [8] is based on SAR, and STAR improves the efficiency of buffered and forwarding packets. STAR uses a *neighbor table* to monitor traffic and predict vehicle density via broadcasting and receiving beacon message. The neighbor table consists of *presence vector* and *persistence vector*, which determine sparse or dense traffic to select the intermediate relay. The neighbor table also indicates network congestion, so STAR derives routing path according to beacon message (including of route-failed alarm) on demand. However, the frequent reforwarding scheme is unsuitable for the high velocity.

Connectivity-aware routing (CAR) protocol [9] is a position-based vehicular routing protocol. CAR uses *velocity vector* and *guard* to construct the logical and temporarily geography, which is maintained via periodic hello beacon. Therefore, CAR doesn't require a map. Every vehicle sends beacon only when staying on routing path, and beacon is piggybacked on forwarded data packet. Velocity vector is considered around a curve or changed course in an intersection, because guard computes the relative coordinates to predict the destination's movement. CAR uses a cache of successful routes between various source and destination pairs to avoid the disconnection. Therefore, every vehicle maintains the established routing paths to avoid the repetition of route discovery. Guards build a virtual infrastructure to provide the street awareness and traffic awareness. When a routing error occurs, CAR uses the buffer mechanism to wait for a routing recovery rather than routing rediscovery.

In summary, GSR considers the V2V characteristics in urban area, but GSR needs a prior street map and considers neither the vehicle density nor vehicular speed. SAR considers the V2V characteristics in recovery mechanism, but SAR needs a prior street map and considers neither the real-time delivery nor vehicular speed. STAR considers the traffic, vehicle density, and network congestion. However, the high vehicular speed and the scalability of beacon messages degrade the performance of STAR. CAR considers the traffic, vehicle density, and recovery mechanism. However, the radio obstructions may lead to the frequency interruptions. In comparison, we summarize the characteristics of GSR, SAR, STAR, and CAR as Table 1 illustrated.

C. *Aided routing protocols*

Besides ad hoc routing protocols, there are several aided routing protocols used for improving the performance of vehicular scenario. These aided routing protocols often focus on the route optimization rather than the route discovery or route execution. For example, trust and reputation infrastructure-based proposal (TRIP) [10] apply trust and reputation management techniques in VANET.

Table 1: The comparison of unicast vehicular routing protocols

	GSR	SAR	STAR	CAR
The requirement of prior map	☑	☑	☑	☐
The requirement of route discovery	☑	☑	☑	☑
The requirement of periodic beacon	☐	☐	☑	☑
The consideration of velocity and density	☐	☐	☑	☑
The consideration of route recovery	☐	☑	☑	☑

Passive clustering aided routing (PassCAR) protocol [11] is a passive clustering aided routing protocol to enhance routing performance in the one-way multi-lane highway scenario. The main goal of PassCAR is to determine suitable participants for constructing a stable and reliable cluster structure during the route discovery phase. Each node determines the priority to compete for a participant via the special election strategy based on metrics such as node degree, expected transmission count, and link lifetime.

PassCAR not only increases the successful probability of route discovery, but also selects more suitable nodes to participate in the created cluster structure. This well-constructed cluster structure significantly improves the packet delivery ratio and achieves a higher network throughput due to its preference for reliable, stable, and durable routing paths.

Reliable inter-vehicular routing (RIVER) protocol [12] is an aided passive routing protocol to improve real-time and reliable interaction. The main goal of RIVER is to avoid link failure and network congestion. Each node determines the *reliability rating* to select a reliable route via sharing *street information* based on metrics such as response time and throughput.

RIVER not only monitors real-time interaction to increase the throughput, but also selects a reliable route to avoid forwarding starvation. Although the high density of vehicle traffic leads to high overhead, RIVER provides the high throughput in the high density of vehicle traffic. When traffic is highly dynamic, the real-time interaction still recalculates the reliable routing path.

III. THE PROPOSED SCHEME

A. *System overview*

In order to evaluate the packet-level performance, we design a bottom-up architecture of the proposed scheme, and design four modules which are based on the network stack. As Figure 1 illustrated, MAC layer adopts the module of WiFi ad hoc model, routing layer adopts GSR/ CAR module, transport layer adopts TCP/ UDP module, application layer adopts live streaming module.[1]

- MAC layer: IEEE 802.11 wireless network is operated in the implementation of ad hoc network. We adopt the IEEE 802.11b as the network protocol due to its maturity. We also consider the IEEE 802.11p due to its vehicular

[1] The module is the term of OMNet, and it means a block of software.

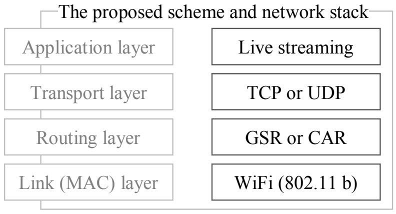

Figure 1: The proposed scheme and network stack

characteristics. When a WiFi adapter switches to ad hoc mode, WiFi Direct [13] or WiFi P2P [14] can be implemented in the ad hoc network.

- Routing layer: The vehicular routing protocols are used to design ad hoc route. We compare GSR with CAR under TCP or UDP. GSR needs a prior map, but CAR doesn't. GSR rediscovers route and reestablishes the routing path, but CAR recovers the established route when the routing path is broken. As Table 1 illustrated, the characteristics of GSR is most different from the ones of CAR, so we select GSR and CAR to simulate the performance of VANET.
- Transport layer: TCP or UDP is used to design the end-to-end connection. We compare TCP with UDP under real-time multimedia delivery. TCP usually has high fairness and high continuity, and UDP usually has high throughput in the wireless network.
- Application layer: The socket programming is used to design the real-time multimedia applications.

B. Module design

In the proposed scheme, we consider the V2V connection and the performance of real-time multimedia delivery. We build the V2V platform (VSOP) and implement the network modules to monitor the flow of packets. Based on OMNet [15], we design application module, network module, routing module, and WiFi module in the vehicular node as Figure 2 illustrated.

INET [16] provides the module of IEEE 802.11b protocol, including of the behavior of mobile node. And MF (Mobility Framework) module [17] provides the module of management of wireless channels in IEEE 802.11b protocol and WiFi ad hoc network. Therefore, we fetch the part of INET and MF to implement the proposed WiFi module.

INETMANET [18] provides the modules of ad hoc routing protocols, such as DSR and AODV. We modify DSR module to implement GSR module due to the source routing similarity. And we modify AODV module to implement CAR module, because both AODV and CAR adopt an on-demand route and periodical alive (hello) beacons. Because INETMANET is well compatible with INET, we implement the proposed routing module based on INETMANET, instead of creating a new routing module.[2]

INET [16] also provides the modules of IP routing table, TCP, and UDP. Both TCP and UDP support IP headers, data transfer, and application-level flow. TCP and UDP modules are well-organized and provide useful application programming interfaces, thus we directly use the application programming interfaces to implement the proposed network

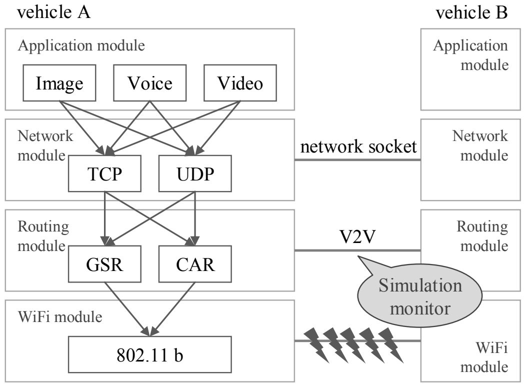

Figure 2: The modules and interfaces of proposed scheme (VSOP)

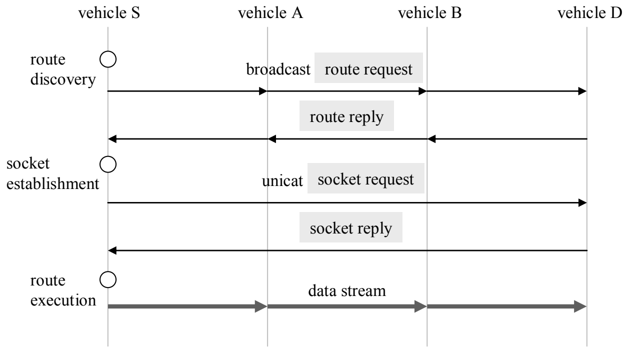

Figure 3: The message flow

module. TCP/ UDP connection doesn't consider the intermediate vehicle, but GSR/ CAR route must consider the intermediate vehicle.

The data formats of image, voice, and video are provided in the proposed application module. We consider the multimedia delivery in packet level, and set a *simulation monitor* to observe the V2V connection. When a vehicle triggers the real-time streaming, the simulation monitor logs the packets on routing path, and then we analyze the QoS of network traffic.

C. Message flow

The proposed VSOP establishes a V2V connection as Figure 3 illustrated. In Figure 3 as an example, vehicle S is the source, vehicle D is the destination, vehicles A and B are intermediate vehicles.

1. The source executes route discovery for connecting to the destination.
2. The source broadcasts *Route Request Message* in VANET, and waits for *Route Reply Message*.
3. When receiving *Route Reply Message*, the source establishes a point-to-point connection via network socket.
4. The source starts route execution for transmitting real-time packets to the destination.

IV. ANALYSIS

We use the mathematical theory to analyze the packet success ratio. The *packet success ratio* means the ratio of the packets received by destination to the packets sent by source. As Figure 4 illustrated, the Markov chains is used to analyze the average performance, and the notations in the analysis are defined as Table 2 illustrated.

[2] We modify the ad hoc routing protocols (DSR and AODV) to implement vehicular routing protocols (GSR and CAR) in the proposed routing module.

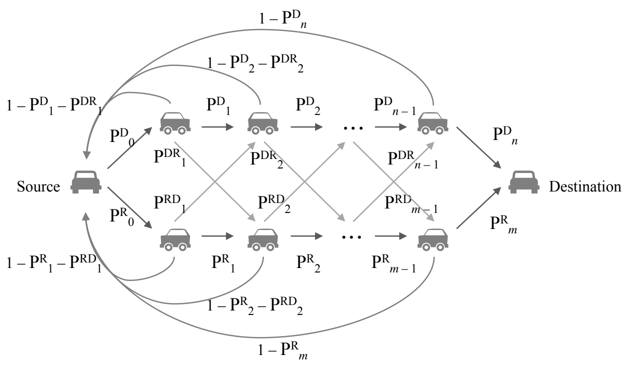

Figure 4: Markov chains of bidirectional scenario

Table 2: The notations in the analysis

Notation	Description
n	The number of vehicles in the direction of source toward destination
m	The number of vehicles in the direction of destination toward source
P	The probability of successful packet propagation
P^D_i	The probability of successful packet propagation in i-th vehicle toward the same direction of source
P^R_i	The probability of successful packet propagation in i-th vehicle toward the reverse of source
P^{DR}_i	The probability of successful packet propagation in i-th vehicle in the direction of source to the reverse of source
P^{RD}_i	The probability of successful packet propagation in i-th vehicle in the reverse of source to the direction of source

If intermediate vehicle forwards or routes a packet along the direction to destination, the packet success ratio of direction is the multiplication of all P^D_i.

$$P_D = \prod P^D_i \ (0 \le i \le n) \tag{1}$$

On the same concept, the packet success ratio of reverse is the multiplication of all P^R_i.

$$P_R = \prod P^R_i \ (0 \le i \le m) \tag{2}$$

When an intermediate vehicle forwards or routes a packet to another intermediate vehicle in the different direction, k directional vehicles and other reverse vehicles are selected to derive a routing path, and packet success ratio is based on P_D.

$$P_{DR} = C^n_k \, (P^D_i)^k \, (P^R_i)^{m-k} \tag{3}$$

When $k = 0$, i.e. there is no directional vehicle in the successful forwarding path, the Equation (3) $P_{DR} = C^n_0 \, (P^D_i)^0 \, (P^R_i)^m = (P^R_i)^m = \prod P^R_i \ (0 \le i \le m) = P_R$. On the same concept, the packet success ratio can be based on P_R.

$$P_{RD} = C^m_k \, (P^R_i)^k \, (P^D_i)^{n-k} \tag{4}$$

When $k = 0$, i.e. there is no reverse vehicle in the successful forwarding path, the Equation (4) $P_{RD} = C^m_0 \, (P^R_i)^0 \, (P^D_i)^n = (P^D_i)^n = \prod P^D_i \ (0 \le i \le n) = P_D$.

However, the exchange of directions must be considered. After the source forwards someone packet successfully with probability P^D_0 or P^R_0, the intermediate vehicles forward it to reverse with probability P^{DR}_i or P^{RD}_i. There may be zero, one, or many exchanges of directions in the packet route, and the total exchanges is denoted as a, let b be the symmetry of a. In essence, $b = a$, or $b = a - 1$, thus the packet success ratio can be derived from P_{DR}. $P_{DR}(k, a)$ is the probability function of k directional way and a exchanges based on P_{DR}.

$$\begin{aligned} P_{DR}(k, a) &= \text{directional forwarding AND exchanged forwarding} \\ &= C^n_k \, (P^D_i)^k \, (P^R_i)^{m-k} \times C^a_b \, (P^{DR}_i)^a \, (P^{RD}_i)^{a-b} \end{aligned} \tag{5}$$

On the same concept, $P_{RD}(k, a)$ can be based on P_{RD}.

$$P_{RD}(k, a) = C^m_k \, (P^R_i)^k \, (P^D_i)^{n-k} \times C^a_b \, (P^{RD}_i)^a \, (P^{DR}_i)^{a-b} \tag{6}$$

Therefore, for all i, a generic formula that represents the packet success ratio in bidirectional route denoted as $P(k, a)$ is derived from $P_{DR}(k, a)$ and $P_{RD}(k, a)$, which is based on $0 \le i$ and $k \le \max\{n, m\}$.

$$\begin{aligned} P(k, a) &= \textstyle\sum_k \sum_a P_{DR}(k, a), \text{ when } n \ge m \\ &\text{or } \textstyle\sum_k \sum_a P_{RD}(k, a), \text{ when } n < m \end{aligned} \tag{7}$$

Let E[ ] be the function of expected value, which means the number of transmissions. If the retransmission is not considered, the expected number of successful route from source to destination can be simplified.

$$E[P(k, a)] = 1 / P^{\min\{n, m\}} \tag{8}$$

If the retransmission is considered, let j-th vehicle be the failure forwarding node, and the packet success ratio is denoted as $P(j)$.

$$\begin{aligned} P(j) &= (\text{Before } j \text{ successful transmission}) \text{ AND} \\ &\quad (j \text{ failure forwarding}) \text{ AND} \\ &\quad (\text{retransmission from source}) \\ &= P(k_t, a_t) \times (1 - P^D_j - P^{DR}_j) \times P(k, a) \end{aligned} \tag{9}$$

In Equation (9), t means the times of retransmissions. If j-th vehicle is driven in reverse, $(1 - P^R_j - P^{RD}_j)$ replaces $(1 - P^D_j - P^{DR}_j)$. However, t and j are variables.

$$P = (\textstyle\prod_t P(k_t, a_t) \, (1 - P^D_j - P^{DR}_j)) \times P(k, a) \tag{10}$$

When $\min\{n, m\}$ is very large, t approaches E[P]. We use the recursive function to compute the packet success ratio as the ideal value in the simulation results.

V. Results

A. Simulation scenario

VSOP is based on OMNet++ [15], which constructs a simulation to measure the integrated performance of TCP/ UDP of GSR/ CAR in packet level. The simulation needs a map to simulate VANET as Figure 5 illustrated. The map considers a ring road with bidirectional directions, and the central zone is a radio obstruction. We use INET [16] to implement the simulated map.

In the simulation, we refer to IEEE 802.11b and IEEE 802.11p simultaneously. The radio propagation range for each vehicle is 300 meters and channel capacity is 2 Mbits/s. The simulation randomly selects the source and destination vehicles, and considers the unicast V2V communication. There are multiple V2V communications in the same time, and channel follows CTS/ RTS mechanism to avoid the packet collision.

In OMNet, the probability of a successful transmission is depended on the relative velocity of two vehicles. When the absolute value of relative velocity is high, the probability of a successful transmission is low. The number of vehicles is 150, and the velocity of mobile vehicle is 15 m/s initially. 100 simulation runs per setup for each scenario and collected data is averaged over those runs.

B. Simulation scenario

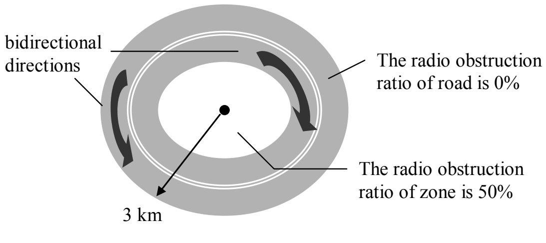

Figure 5: The simulation map

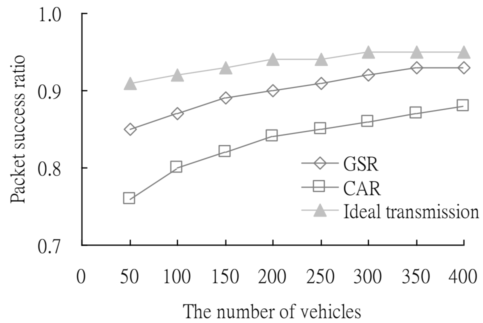

Figure 6: Packet success ratio by network size

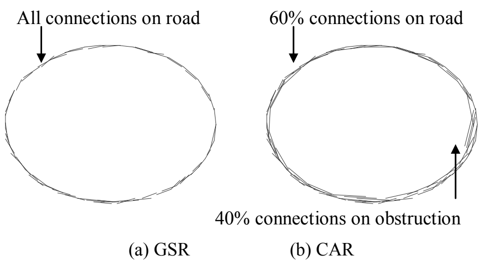

Figure 7: Obstructive connections in CAR

We use the packet success ratio to evaluate the performance of GSR and CAR. Let P be the ideal packet success ratio in Equation (10), in which P^D is 0.99, P^R is 0.97, P^{RD} is 0.97, and P^{RD} is 0.95. As Figure 6 illustrated, the packet success ratio is increasing with the network size, i.e. the number of vehicles or mobile nodes. Because there are connections through the obstructive zone, CAR has the low packet success ratio. Because GSR has the prior map, the connections are established along the road. GSR avoids the obstructive zone and has the high packet success ratio as Figure 7 illustrated.

Because V2V connection is based on hop-by-hop scheme, the intermediate hops are reselected when arriving or departing. When velocity or moving speed is high, the routing path is changed dynamically. As Figure 8 illustrated, the packet success ratio is decreasing with the velocity, because the route rediscovery or recovery happens frequently. CAR algorithm considers velocity and recovery, but GSR doesn't, so CAR is better than GSR when velocity is high.

Figure 9 illustrates the throughput of real-time data streaming via TCP or UDP. In mobility scenario, the timeout and congestion often happen in TCP. There are some connections over obstructive zone in CAR, and the obstructive connections provide additional throughput.

VI. CONCLUSION

In the paper, we present a VANET platform to analyze V2V

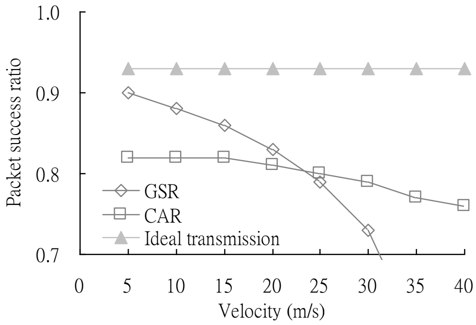

Figure 8: Packet success ratio by velocity

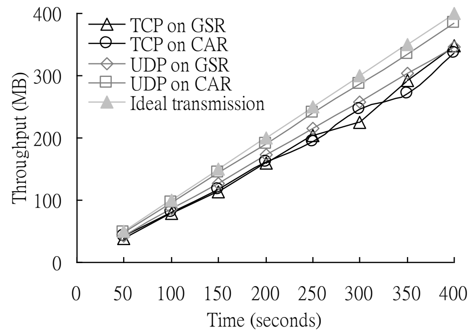

Figure 9: TCP vs. UDP by throughput

connection. The proposed scheme, V2V streaming on OMNet platform (VSOP), integrates WiFi, vehicular routing protocol, and TCP/ UDP to provide the evaluation of real-time service on VANET. VSOP is based on OMNet simulator and constructs a bottom-up architecture to perform scalability and mobility. Depending on the mathematical analysis and simulation results, VSOP can be demonstrated to be workable. VSOP also provides a consideration of TCP/ UDP and GSR/ CAR, and the simulation results guide the selection of protocol for someone given application.

REFERENCES

[1] T.M. Fernández-Caramés, M. González-López, and L. Castedo. *Mobile WiMAX for vehicular applications: Performance evaluation and comparison against IEEE 802.11p/a*. Computer Networks, 2011.

[2] Z. Zhang, A. Boukerche, and H. Ramadan. *Design and evaluation of a fast MAC layer handoff management scheme for WiFi-based multichannel Vehicular Mesh Networks*. Journal of Network and Computer Applications, 2013.

[3] Y.H. Ho, A.H. Ho, and K.A. Hua. *Routing protocols for inter-vehicular networks: A comparative study in high-mobility and large obstacles environments*. Computer Communications, 2008.

[4] C. Perkins and E. Royer. *Ad hoc On-demand Distance Vector Routing*. IEEE Workshop on Mobile Computing Systems and Applications, 1999.

[5] D.B. Johnson, D.A. Maltz and J. Broch. *DSR: the dynamic source routing protocol for multi-hop wireless ad hoc networks*, Ad Hoc Networking, 2001.

[6] C. Lochert, H. Hartenstein, J. Tian, H. Füßler, D. Hermann, and M. Mauve. *A routing strategy for vehicular ad hoc networks in city environments*. IEEE Intelligent Vehicles Symposium, 2003.

[7] J. Tian, L. Han, K. Rothermel, and C. Cseh. *Spatially aware packet routing for mobile ad hoc inter-vehicle radio networks*. IEEE Intelligent Transportation Systems, 2003.

[8] F. Giudici and E. Pagani. *Spatial and traffic-aware routing (STAR) for vehicular systems*. High Performance Computing and Communications, 2005.

[9] V. Naumov and T. Gross. *Connectivity-aware routing (CAR) in vehicular ad-hoc networks*. IEEE International Conference on Computer Communications, 2007.

[10] F.G. Mármol and G.M. Pérez. *TRIP, a trust and reputation infrastructure-based proposal for vehicular ad hoc networks*. Journal of Network and Computer, 2012.

[11] S.S. Wang and Y.S. Lin. *PassCAR: A passive clustering aided routing protocol for vehicular ad hoc networks*. Computer Communications, 2013.

[12] J. Bernsen and D. Manivannan. *RIVER: A reliable inter-vehicular routing protocol for vehicular ad hoc networks*. Computer Networks, 2012.

[13] D. Camps-Mur, X. Pérez-Costa, and S. Sallent-Ribes. *Designing energy efficient access points with wi-fi direct*. Computer Networks, 2011.

[14] G. Kbar, W. Mansoor, and A. Naim. *Voice over IP mobile telephony using WiFi P2P*. International Conference on Wireless and Mobile Communications, 2010.

[15] *OMNET++ 4.0*. http://www.omnetpp.org.

[16] *INET Framework*. http://inet.omnetpp.org.

[17] *Mobility Framework for OMNeT++*. http://mobility-fw.sourceforge.net/hp/index.html.

[18] *INETMANET Framework*. https://github.com/inetmanet/inetmanet.

Jun-Li Kuo works in Information and Communications Research Laboratories, Industrial Technology Research Institute, Hsinchu, Taiwan. He received his Ph.D. in Computer Science from National Chiao Tung University, Hsinchu, Taiwan in 2013. His research interests include peer-to-peer network, wireless multimedia, ad-hoc network, and clouding computing.

Chen-Hua Shih works in Chung Shan Institute of Science and Technology, Taoyuan, Taiwan. He received his Ph.D. in Computer Science from National Chiao Tung University, Hsinchu, Taiwan in 2012. His research interests include peer-to-peer network, QoS, mobile IP, wireless networks, and network protocols.

Yaw-Chung Chen received his Ph.D. degree from Northwestern University, Evanston, Illinois, USA. In 1986 he joined AT & T Bell Laboratories, where he worked on various exploratory projects. He is currently a professor in the Department of Computer Science, National Chiao Tung University, Hsinchu, Taiwan. His research interests include Internet Protocols, fast mobility management, P2P systems and green computing.