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END-TO-END THROUGHPUT FOR VANET WITH AND WITHOUT CLOUD EFFECT

Raghda Nazar Minihi [1], Haider M. AlSabbagh [2], Hussain Al-Rizzo [3], Alauddin Al-Omary [4]

[1,2] Dept. of Electrical Engineering, College of Engineering, University of Basra, Basrah, Iraq
[1] ragdanazar@yahoo.com, [2] haidermaw@ieee.org

[3] Department of Systems Engineering, College of Engineering and Information Technology,
University of Arkansas at Little Rock, USA
hmalrizzo@ualr.edu

[4] Department of Computer Engineering, College of IT, University of Bahrain, Bahrain
aalomary@uob.edu.bh

Vehicle Ad-hoc network (VANET) have sensing nodes moving with different speeds. The vehicular cloud is a group of vehicles communicating with each other to share the resources provided from the central cloud. The end-to-end throughput for multi-hop wireless network is analysed in this paper using a set of non-linear equations. The interference due to the hidden nodes and the neighbouring nodes is considered into computing the end-to-end throughput. The contention graph is used to clarify the connection among the nodes into the network to find the capacity of the individual links to facilitate estimating the end-to-end throughput. Effect of the cloud on the end-to-end throughput is also illustrated in this paper. The results show that the throughput with employing cloud is lower than that without using the cloud.

Keyword: VANET, vehicular cloud, road side cloud, central cloud, multi-hop wireless network.

1. Introduction

A VANET consists of a number of vehicles that communicate with each other. The vehicles in the transmission range of a specific vehicle act as neighbour nodes and communicate through wireless links. The end-to-end connection between the source and the destination is composed of a number of intermediate vehicles to forward the multi-hop packets to the destination (Raw and Lobiyal, 2012). Multi-hop wireless networks are among the most popular solution to connect the transmitter and receiver when a direct path is unavailable. Recently, the Quality of Service (QoS) for multimedia applications has drawn much attention. The end-to-end throughput for a route must be known to assess the QoS guarantee to the end user. The contention graph can be used to approximately find the end-to-end throughput in an easy manner (Zhao *et al.*, 2011).

In recent years, many researchers have considered integration of cloud computing with vehicular networks. Cloud is a collection of resources that are available at anytime and anywhere to provide the services upon a vehicle's requests. Vehicular Cloud Computing (VCC) is a new paradigm developed from the contention VANETs to share resources in the cloud between vehicles in the Vehicles Cloudlet (VC). The VCC is based on the pay as you go model (Ghafoor *et al.*, 2016). In (Gao *et al.*, 2006) the end-to-end throughput is assessed by employing a set of non-linear equations for multi-hop networks. The hidden nodes problem is taken into account with constant data rate for all links in the route between the transmitter and the receiver. H. Zhao *et. al*. (2011) estimated the end-to-end throughput for the wireless multi-hop route when the data rate is different between the links for the communication route joining the transmitter and the receiver. The throughput and delays results are described in (Raw and Lobiyal, 2012) and used the next hop forwarding method to select the next node to reach the destination. The hierarchical vehicular cloud, the QoS provision model and handover management techniques are reported in (Garai *et al.*, 2015).

In this paper, the end-to-end throughput is investigated for multi-hop VANET networks with and without cloud effect. This network is different from Ad hoc networks as the sensing nodes are vehicles moving with relatively high speeds. Effect of the hidden nodes is considered into our model and the data rate is considered constant for all links in the path between the sender and the receiver.

The reminder of this paper is organized as follows. Scope of the work is described in Section 2. Section 3 presents the system model for the end-to-end throughput along with the results. Section 4 describes the cloud effect on the end-to-end throughput as well as the simulation results. The conclusions are given in Section 5.

2. Scope of the Work

The main scope is to analyse effect of the cloud on the end-to-end throughput. In doing so following tasks are fulfilled:

- The end-to-end throughput for multi-hop wireless network is analysed using a set of non-linear equations.
- The interference due to the hidden nodes and the neighbouring nodes is considered into computing the end-to-end throughput.
- The contention graph is used to clarify the connection among the nodes into the network to find the capacity of the individual links to facilitate estimating the end-to-end throughput.

3. System Model for End-to-End Throughput without Cloud Effect

The link between the communication nodes is assumed identical and half duplex based on the IEEE 802.11 Distributed Coordination Function (DCF) mode. In DCF there are two access modes: basic and RTS/CTS. In this Section, the model for basic excess mode is analysed taking the carrier sensing range as twice of the transmission range for each node. In the basic excess mode for DCF, when a node needs to transmit packets, it must sense the transmission range at first. If the channel is full, this node suspends its transmission and sense the channel after the channel is sensed idle. If the channel is allowed for a specific time, which is the distributed inter frame space (DIFS), the node sets the back-off counter to count down and resumes its sensing cycle. After a node wait DIFS time (i.e. when the counter = 0) it starts transmitting packets to the destination. These packets may either reach the destination or not due to collision with other nodes. After transmitting the packets, the transmitter is set a new back off timer (SIFS is the short inter frame space) to wait for the ACK from the receiver. SIFS timer selects a random value between 0 and CW (Contention Window). The maximum number of retransmitting a packet is set to K, if it reaches K this packet is discarded and restart to check its data queue. The node that has transmission packets takes one of the following three states:

1. The channel idle time is the time that is spent in DCF state,
2. The channel busy time is the time that is spent in deferring state when other nodes are transmitting in the medium, and
3. The time spent in the transmission when the node itself is transmitting its data (Syed and Roh, 2015).

When the attempt is to transmit a packet, back off value is selected from the range (0, CW-1) where CW depends on the number of the unsuccessful transmission of a packet. At the beginning CW = CWmin, and then after each unsuccessful transmission CW = CWmin, where k is the number of the retransmission with a maximum value of K, after K^{th} retransmission, the packet is either successfully transmitted or discarded (Bitam *et al.*, 2015).

3.1. End-to-end throughput model

This section presents the mathematical model for the end-to-end throughput for VANET. The contention graph (Chen *et al*., 2005) may be found from VANET to illustrate the connection between nodes. Therefore, the end-to-end throughput for 802.11 DCF model can be calculated after deriving the channel idle probability and collision probability. The contention graph is used to clarify the connection between nodes and type of connection. In this paper, two types of connection are taken into consideration: hidden node contention and neighbouring contention. The hidden node is a node that is found out of carrier sensing of the sender and may cause a collision with the data send from the sender. The neighbouring connection is found between nodes in the same sensing range of the sender node, and these nodes have packets to be transmitted.

There are three steps to draw the contention graph from the network topology:

1. Generate an undirected graph that shows the connection between specific nodes with its neighbour nodes. The neighbour nodes are the nodes found in the carrier sensing range of the specific node.
2. The contention graph contents the set of nodes (*M*) and active links (*L*) between nodes which is represented by $G = (M, L)$. This graph is found from the undirected graph in the previous step and link the communication nodes (active link).
3. All hidden nodes must be illustrated in the contention graph. Therefore, this graph is represented by $F = (M, L, L')$, where L' is the hidden node effect in the active link.

The end-to-end throughput is (Gao *et al.*, 2006):

$$\mathrm{T}_i = x_i \times (1-\mu_i) \times \frac{\beta_1}{\beta} \times data - rate\,, \tag{1}$$

where x_i is the normalized "self" airtime with the successful and collided transmission time in link i, μ_i is the collision probability of transmission on link i, β is the average packet length (in time slot) = 84.09 (time slot), β_1 is packet payload (in time slot) = 54.55 (time slot), data-rate is the capacity of transmission in the 802.11 protocol, data-rate = 11 Mbps for 802.11b, data-rate = 54 Mbps for 802.11a or data-rate = 20 Mbps for 802.11af (Matsumura *et al.*, 2017). This equation considers two nodes cannot hear each other and has no common neighbour and is not interfere with each other. Therefore, the normalized (self) airtime can be given by:

$$\mathrm{x_i} = (1 - x_i - \sum_{j\in r(i)} x_j + \sum_{m\notin r(n)\cup n;m,n\in r(i)} \frac{x_m x_n}{1-\sum x_c})G(\mu_i)\beta\,, \tag{2}$$

where, $r(i)$ the set of neighbours of link i, x_j is the probability of the channel idle, m and n is the number of the active links between the nodes.

Let x_c is the common neighbouring for node i, therefore the collision probability and general formula of the collision probability can be found, respectively from

$$\mu_\mathrm{i} = \frac{\alpha x_i}{1-\sum x_c}\,, \tag{3}$$

$$G(\mu) = \frac{1+\mu+\mu^2+\mu^3 ... + \mu^k}{b_0 + \mu b_1 + \mu^2 b_2 + \mu^3 b_3 ... + \mu^k b_k}\,, \tag{4}$$

where, b_k is the back off duration at the kth packet retransmission (in time slot) and $b_0 = 16$ in the 802.11 protocol. Whenever, $CW = 2k$ CWmin, therefore, $b_1 = 32$, $b_2 = 64$ … $b_6 = 1024$ due to retransmission limit (= 7 in this paper, i.e. $k = 6$) (Gao *et al.*, 2006), and α is the data packet transmission time:

$$\alpha = \frac{\mathrm{packet}}{\mathrm{DIFS} + packet + SIFS + ACK}\,, \tag{5}$$

DIFS is the Distributed Inter Frame Space (*DIFS* = 50 µs), *SIFS* is the Short Inter Frame Space (*SIFS* = 10 µs), *ACK* is the Acknowledgment (*ACK* = 38 bytes), packets = 1500 bytes.

3.2. The network topology and end-to-end throughput

The network topology shown in Figure 1 consists of six active links. The link connects the source with the destination. Each of these nodes has a transmission range which is represented by a circle with radius R = 50 m. The node may sense each of the neighbouring nodes found in the transmission range (i.e. the node 'S' is sensed the 'A, B' nodes). The source (S) is connected to the destination (D) through (A, D, C) nodes that are represented as router nodes. Throughput of this topology may be found from the following steps:

Step 1: the undirected graph of this network is shown in Figure 2. The source node (S) is connected to the node A, node B due to these nodes are found in the carrier sensing range of node S. They are the neighbours of node S. The graph in Figure 2 can be completed in the same manner.

Step 2: generate the contention graph by converting the active links in path 1: link 1, link 2, link 3 and link 4 to nodes as shown in Figure 3. Node 1 represents link1 which is connected to node 2 and node 3 since any transmission in these links can be sensed by the sender (S in this case) of link 1.

Step 3: all the hidden nodes must be represented in the contention graph. From the undirected graph in Figure 2, it is clear that the transmission from node C can be heard by the receiver of link1 (node A) but cannot be heard by the sender of the link1 (node S). Therefore, this node is called hidden node and may cause a collision in node 1, hence node 1 and node 4 must be connected in direct dot line, as shown in Figure 4.

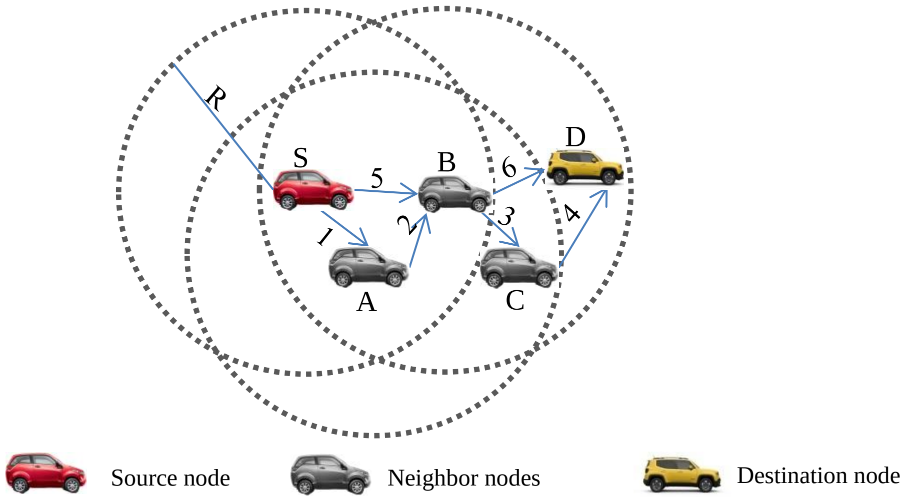

Figure 1. Network topology with four active links

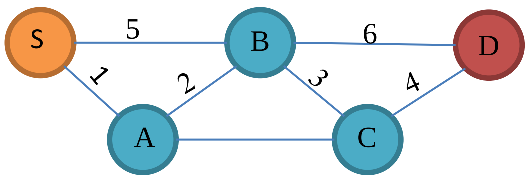

Figure 2. Undirected graph

There are four links in this path with different capacity of each link. Therefore, the capacity for each link must be found and the end-to-end throughput of this path is the minimum capacity of these links. Figure 4 shows one hidden node (node 4), so the collision probability μ_1 of link 1 is found from Eq.6.

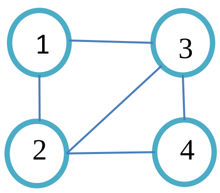

Figure 3. Contention graph

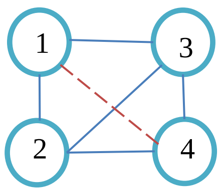

Figure 4. Hidden nodes in contention graph

System of equations (1-5) are used to evaluate the throughput for each link in path 1 (shown in Fig. 4) and found the following equations:

$$\mu_1 = \frac{\alpha x_4}{1 - x_2 - x_3}, \tag{6}$$

$$x_1 = (1 - x_1 - x_2 - x_3) G(\mu_1) \beta \,, \tag{7}$$

$$x_2 = (1 - x_1 - x_2 - x_3 - x_4 + \frac{x_1 x_4}{1 - x_2 - x_3}) G(0) \beta \,, \tag{8}$$

$$x_3 = (1 - x_1 - x_2 - x_3 - x_4 + \frac{x_1 x_4}{1 - x_2 - x_3}) G(0) \beta \,, \tag{9}$$

$$x_4 = (1 - x_2 - x_3 - x_4) G(0) \beta \,. \tag{10}$$

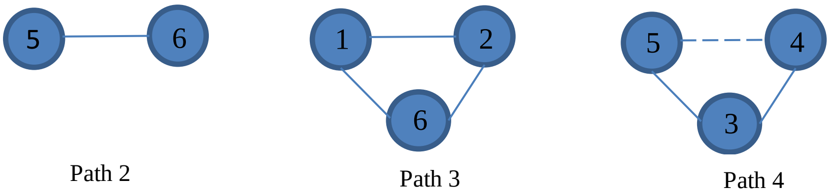

Figure 5. Contention graph for three possible connection paths

There are other paths can be connected the source and the destination. The contention graph for these paths is shown in Figure 5.

Table1. The capacity equations for 3 paths

Path 2	**Path 3**	**Path 4**
$x_5 = (1 - x_5 - x_6) G(0) \beta$	$x_1 = (1 - x_1 - x_2 - x_6) G(0) \beta$	$x_5 = (1 - x_3 - x_5 + \frac{x_5 x_4}{1 - x_3}) G(\mu_2) \beta$
$x_6 = (1 - x_6 - x_5) G(0) \beta$	$x_2 = (1 - x_1 - x_2 - x_6) G(0) \beta$	$x_4 = (1 - x_3 - x_4) G(0) \beta$
	$x_6 = (1 - x_1 - x_2 - x_6) G(0) \beta$	$x_3 = (1 - x_3 - x_4 - x_5) G(0) \beta$

If data-rate = 11 Mbps, the capacity for each of the four links in path 1 is equal to T_1 = 0.19 Mbps, T_2 = 2.2 Mbps, T_3 = 1.2 Mbps, and T_4 = 3 Mbps. For path 2, T_1 = T_2 = 3.4 Mbps. For path 3, T_1 = T_2 = T_3 = 2.3 Mbps. Path 4, T_1 = 0.4 Mbps, T_2 = 4.4 Mbps, T_3 = 2.5 Mbps. Therefore, the end-to-end throughput for path 1 = 0.19 Mbps, path 2 = 3.4 Mbps, path 3 = 2.3 Mbps and path 4 = 0.4 Mbps.

Assuming the nodes as vehicles are moving in velocity of 50 km/h, the relation between throughput and the data rate (end-to-end) is given in Figure 6. It is obvious that the shortest path (i.e. path 2) has highest throughput from the longest path (i.e. path 1). The performance of this network increases when the packets passes through the shortest path.

The relationship between the throughput and the separation between the transmitter and the receiver vehicles is shown in Figure 7. When the receiver if found in the coverage range of the transmitter the system would work with high level of throughput, however, when the receiver being out of the coverage range the transmitter start searching some intermediate nodes (relay) for reaching the target receiver. This would enhance suppression of the throughput.

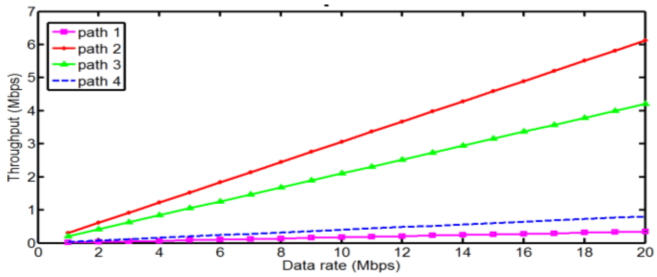

Figure 6. Throughput as a function to data rate

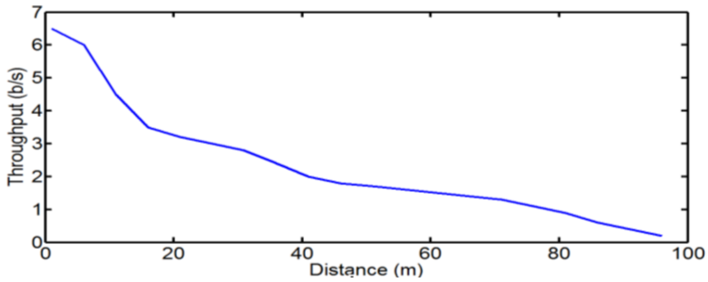

Figure 7. End-to-End Throughput

4. End-to-End Throughput with Cloud Effect

Cloud architecture in VANET can be divided into three interacting layers: central cloud (CC), roadside unit cloudlet (R-Cloudlet) and vehicular cloudlet (V-Cloudlet).

Central cloud: The CC is the basic cloud that has multi servers to execute the required services from vehicles and used to store the massive data. The vehicles in the V-Cloudlet interact with the CC via R-Cloudlet (Gao *et al.*, 2016).

Roadside Cloudlet: The R-Cloudlet is the local cloud that contains a set of neighbouring RSUs to preamble the cloud services to the vehicles found in the radio range of this RSU. When the vehicle needs to service the request, it may select the closer R-Cloudlet to connect it to the cloud. The RSU Controller (RC) may create the virtual resources (virtual machine (VM)) according to the vehicle's request. When the vehicle moves out of the radio range of the current R-Cloudlet services, the vehicle needs to connect with the nearby R-Cloudlet. Consequently, the VM is migrated to the new R-Cloudlet to continue the cloud service. If the connection between the vehicles and R-Cloudlet is totally interrupted, the VM is migrated to the CC. When the vehicle reconnects to the new R-Cloudlet, the VM migrates to its vehicles (Yao *et al.*, 2015).

Vehicular-Cloudlet: The set of vehicles are connecting over a tree to form a V-Cloudlet. The neighbour vehicles are connecting in a tree topology to create local cloud (V-Cloudlet), and these vehicles select each other to share their communication and computational resources in the tree. IEEE 802.11p link is used in the V2V connection while 4G access network is used in the V2I connection. The vehicle that is found in the root of a tree is called Tree Controller (TC) that is represented as a gateway to the R-Cloudlet from vehicles (Garai *et al.*, 2015).

Figure 8 shows the three types cloud connection. The sender (S) can be transmit data to the receiver (D) via five paths.

Path 1: link1- link10- link9.
Path 2: link2- link3- link10- link9.
Path 3: link2- link4- link5- link10- link9.
Path 4: link1- link10- link7- link8.
Path 5: link2- link3- link10- link7- link8.

The contention graph for these paths is shown in Figure 9. The contention graph shows the connection between nodes founds in the same transmission range as well as the hidden nodes.

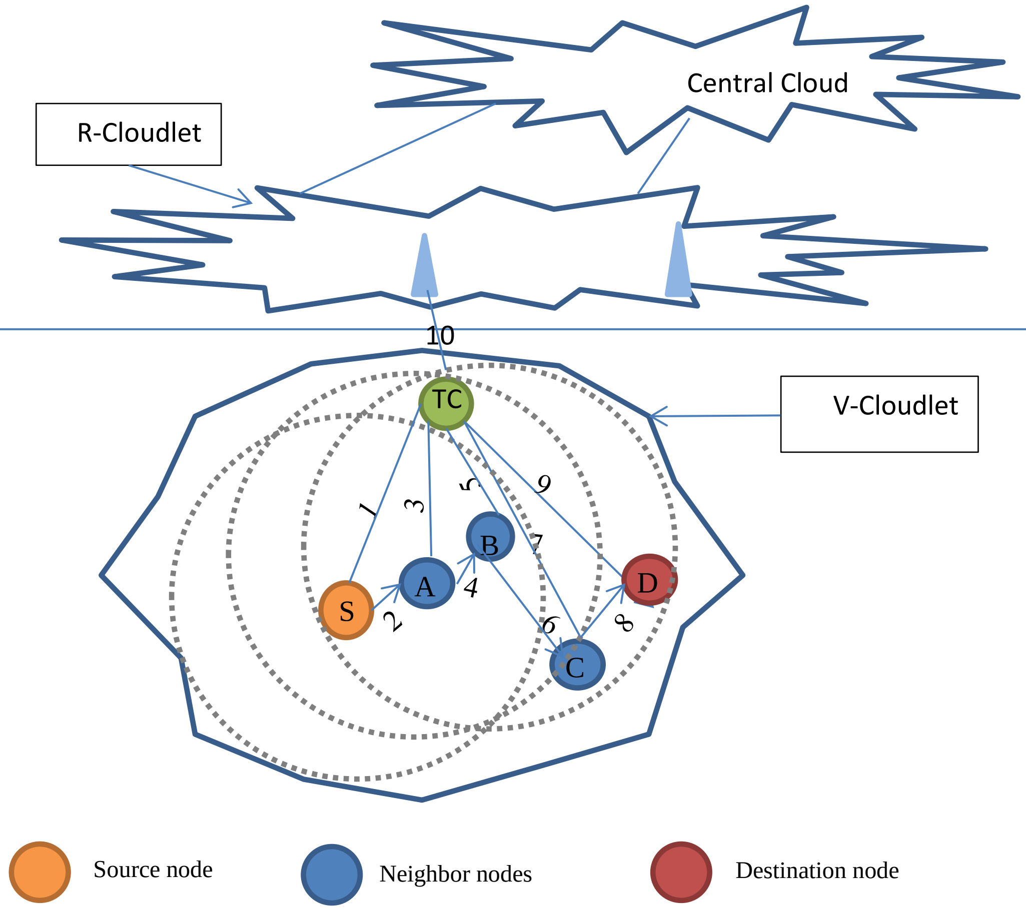

Figure 8. Network topology with cloud effect

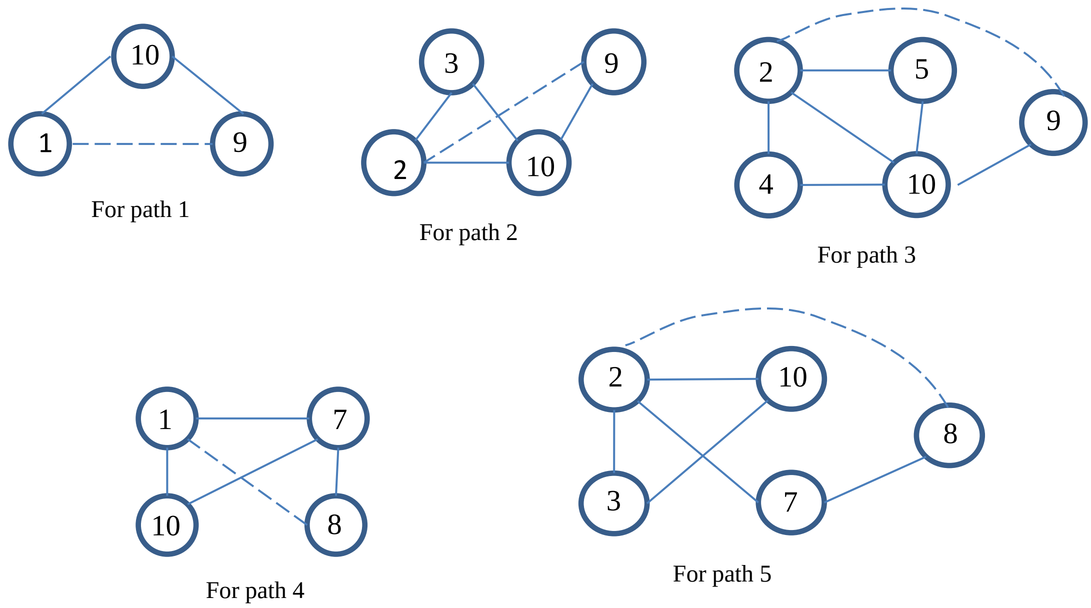

Figure 9. Contention graph for four paths

The end-to-end throughput for these links depending on Eqs. (1 - 5) are detailed in Tables 2 - 6 below.

Table 2. Throughput for each links in path 1

Link	Link capacity equation	Link capacity (Mbps)
Link 1	$x_1 = (1 - x_1 - x_{10})G(\mu_1)\beta$	0.3
Link 9	$x_9 = (1 - x_9 - x_{10})G(0)\beta$	3.7
Link 10	$x_{10} = (1 - x_1 - x_9 - x_{10} + \frac{x_1 x_9}{1 - x_{10}})G(0)\beta$	3.9

Table 3. Throughput capacity for each links in path 2

Link	Link capacity equation	Link capacity (Mbps)
Link 2	$x_2 = (1 - x_2 - x_4 - x_5 - x_{10})G(\mu_2)\beta$	0.15
Link 3	$x_3 = (1 - x_2 - x_3 - x_{10})G(0)\beta$	5.2
Link 9	$x_9 = (1 - x_9 - x_{10})G(0)\beta$	5.2
Link 10	$x_{10} = (1 - x_2 - x_3 - x_9 + \frac{x_2 x_9}{1 - x_{10}} + \frac{x_3 x_9}{1 - x_{10}})G(0)\beta$	0.15

Table 4. Throughput capacity for each links in path 3

Link	Link capacity equation	Link capacity (Mbps)
Link 2	$x_2 = (1 - x_2 - x_{3-} x_{10})G(\mu_1)\beta$	0.004
Link 4	$x_4 = (1 - x_2 - x_4 - x_{10})G(0)\beta$	1.6
Link 5	$x_5 = (1 - x_2 - x_5 - x_{10})G(0)\beta$	1.6
Link 9	$x_9 = (1 - x_9 - x_{10})G(0)\beta$	1.6
Link 10	$x_{10} = (1 - x_2 - x_4 - x_5 - x_9 - x_{10} + \frac{x_2 x_9}{1 - x_{10}} + \frac{x_4 x_5}{1 - x_{10} - x_2} + \frac{x_4 x_9}{1 - x_{10}} + \frac{x_5 x_9}{1 - x_{10}})G(0)\beta$	5.2

Table 5. Throughput capacity for each links in path 4

Link	Link capacity equation	Link capacity (Mbps)
Link 1	$x_1 = (1 - x_1 - x_7 - x_{10})G(\mu_2)\beta$	0.04
Link 7	$x_7 = (1 - x_1 - x_7 - x_8 - x_{10} + \frac{x_1 x_8}{1 - x_7} + \frac{x_8 x_{10}}{1 - x_7})G(0)\beta$	7.4
Link 8	$x_8 = (1 - x_7 - x_8)G(0)\beta$	2.2
Link 10	$x_{10} = (1 - x_1 - x_7 - x_{10})G(0)\beta$	2.2

Table 6. Throughput capacity for each links in path 5

Link	Link capacity equation	Link capacity (Mbps)
Link 2	$x_2 = (1 - x_2 - x_3 - x_7 - x_{10} + \frac{x_3 x_7}{1 - x_2} + \frac{x_{10} x_7}{1 - x_2})G(\mu_2)\beta$	0.03
Link 3	$x_3 = (1 - x_2 - x_3 - x_{10})G(0)\beta$	3.3
Link 7	$x_7 = (1 - x_2 - x_7 - x_8 + \frac{x_2 x_8}{1 - x_7})G(0)\beta$	3.3
Link 8	$x_8 = (1 - x_7 - x_8)G(0)\beta$	3.3
Link 10	$x_{10} = (1 - x_2 - x_3 - x_{10})G(0)\beta$	3.4

Where,

$$\mu_1 = \frac{\alpha x_9}{1 - x_{10}},$$

$$\mu_2 = \frac{\alpha x_8}{1 - x_7}.$$

From Table 2, capacity of link 1 is the minimum, therefore the end-to-end throughput for path 1 = 0.3 Mbps. For path 2, path 3, path 4, and path 5, the end-to-end throughput = 0.15 Mbps, 0.004 Mbps, 0,04 Mbps, 0.03 Mbps as listed in Table 3, Table 4, Table 5, and Table 6, respectively. Considering the nodes in Figure 6 as vehicles moving at 50 km/h. Figure 10 shows the comparison between throughputs for all paths that may route the data to the destination. Comparing the throughput for the shortest path with that for the longest path, the value with the shortest path is superior to that with the longest path. The shortest path may not be always better than the longest path, but this result is revealed from analysing this network.

Comparison of the results in Figure 7 with that in Figure 11, the throughput based on the cloud is lower than throughput without using cloud. In this case, the transmitted data is sent to the R-Cloudlet and may be to the CC and then to the destination, therefore the distance between the transmitter and the receiver as well as the time are increased which, as a result, turn to decrease amount of the throughput.

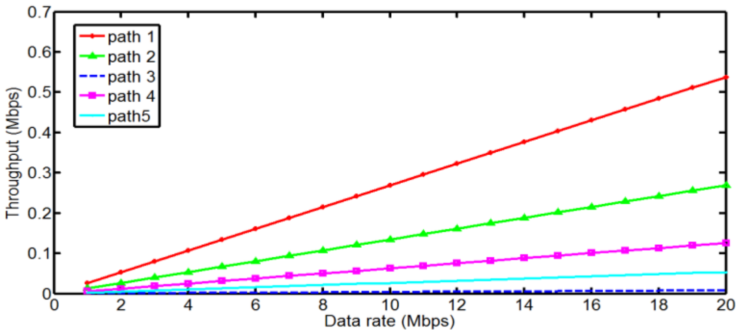

Figure 10. Throughput with data rate for five paths

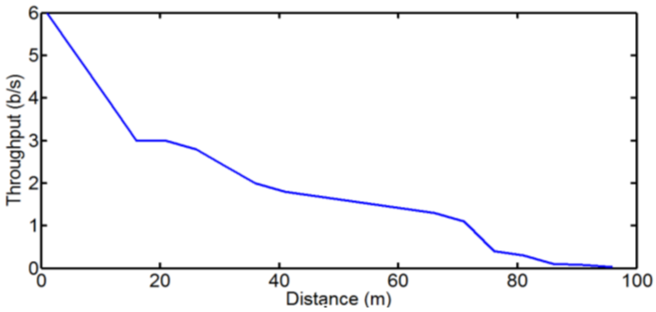

Figure 11. End-to-End Throughput based on cloud

5. Conclusions

In this paper, the end-to-end throughput in multi-hop VANET network is analysed. The connection between the source and the destination may require intermediate nodes to relay the transmitted data. Therefore, there are multi-paths between the communication sides to transfer data.

The analysed VANET network results show that the shortest path has the highest throughput (i.e. good performance). As the transmission data rate increases, the throughput is enhanced. The vehicles may need to transmit the data to the cloud to be ready for request of other vehicles which request data from the cloud. This increases the distance of data transmission between the transmitter and the receiver. Therefore, the throughput decreases as comparing it with the same network that does not use cloud for relaying the data. As a future work, the presented work is to be validated by implementing a prototype and get practical throughput. This will help to compare the simulated results by real measured value and enhance our contribution in the VANET field.

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