

## ADAPTIVE ROUTING SCHEME FOR RELIABLE COMMUNICATION IN VEHICULAR AD-HOC NETWORK (VANET)

Karthikeyini S. SIVASUBRAMANIAN<sup>1\*</sup>, Shankar S. SUBRAMANIAM<sup>2</sup>

<sup>1</sup>Faculty of Faculty of Information and Communication Engineering, Anna University, India

<sup>2</sup>Dept of Computer Science and Engineering, Hindusthan College of Engineering and Technology, India

Received 2 January 2019; revised 4 April 2019, 3 June 2019; accepted date 29 June 2019;  
first published online 5 June 2020

**Abstract.** In a wireless communication system, due to the presence of the surrounding objects, the amplitude of the received signal rapidly changes by reflection, diffraction, and scattering and noise is added to the received signal. This prompts multipath fading and interference, which affects the quality of communication. The proposed Adaptive Routing Scheme (ARS) considers the algorithm Reliable Routing (RR) using Average Bit Error Rate expressed in Nakagami-m fading channel (ABERN-m) to predict the quality of the link, the Energy Efficient Routing (EER) calculates Remaining Battery Energy (RBE) to extend the network lifetime. The Canberra Distance Measure (CDM) is used instead of Euclidean Distance Measure (EDM) to improve the accuracy of distance measurement in mobile nodes. The aim of the proposed scheme is to predict the best optimal path and maintain the consistent path to enhance the Quality of Service (QoS) in real-time communication to improve efficient traffic on the road.

**Keywords:** average bit error rate expressed in Nakagami-m fading channel (ABERN-m), adaptive routing scheme (ARS), energy efficient routing (EER), Canberra distance measure (CDM), Euclidean distance measure (EDM).

### Notations

ABER – average bit error rate;	G-TDMA – generalized time division multiple access;
ABERN-m – average bit error rate expressed in Nakagami-m fading channel;	IETF – internet engineering task force;
ARS – adaptive routing scheme;	IPv6 – internet protocol version 6;
AU – application unit;	ITS – intelligent transportation system;
AWGN – additive white Gaussian noise;	LLC – logical link control;
BPSK – binary phase shift key;	LOS – line of sight;
CCH – control channel;	MAC – medium access control;
CDM – Canberra distance measure;	MGF – moment generating function;
CH – cluster head;	NLOS – no-line-of-sight;
CLAO-TCP – cross layer aware optimization of transfer control protocol;	OBU – on board unit;
CSMA/CA – carrier sense multiple access/collision avoidance;	PDF – probability density function;
DSRC – dedicated short-range communication;	PDR – packet delivery ratio;
EDM – Euclidean distance measure;	PLR – packet loss rate;
EED – end-to-end delay;	QoS – quality of service;
EER – energy efficient routing;	R2R – RSU to RSU;
EU – energy usage;	RBE – remaining battery energy;
FCC – federal communication commission;	RO – routing overhead;
	RR – reliable routing;
	RREP – route reply;

\*Corresponding author. E-mail: [karthikeyinicse@gmail.com](mailto:karthikeyinicse@gmail.com)

- RREQ – route request;
- RSU – road side unit;
- RTS/CTS – request to send/clear to send;
- SCH – service channel;
- SNR – signal to noise ratio;
- SSD-TDMA – spectrum sensing with distributed time division multiple access;
- TCP – transmission control protocol;
- UDP – user datagram protocol;
- VANET – vehicular ad-hoc network;
- V2O – vehicle to others unit;
- V2R – vehicle to RSU;
- V2V – vehicle to vehicle
- WAVE – wireless access in vehicular environment;
- WSA – wireless access in vehicular environment service advertisement;
- WSM – wireless access in vehicular environment short message.

**Introduction**

VANET is a crucial part of ITS. It provides valuable information to assist the driver in order to prevent mishaps and congestion on the road (Sussman, Bronzini 2006). The VANET has a safety application feature, which provides, emergency brake light warning, collision warning, road curve warning and so on. It also has non-safety application, like, navigation, traffic information, and internet access. The DSRC regulation dictated by the US FCC and is designed for 75 MHz transmission capacity and 5.9 GHz data transmission for intelligent transportation application services. The FCC authorized the operation of DSRC spectrum from 5.850 to 5.925 GHz (IEEE Standard 802.11p-2010). This spectrum consists of 5 MHz received as a guard band at the lower end of DSRC spectrum and the remaining 70 MHz is divided into six SCH and one CCH. The channel 178 intended for CCH is utilized for the WSM and WSA, and SCH is utilized for IPv6 packets and WSM. The optional assignment of the 20 MHz for channel 175 and 181 is allocated to critical safety message. These channels are located on either side of Channel 178, which is illustrated in Figures 1 and 2.

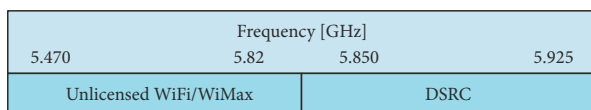


Figure 1. Unlicensed and licensed DSRC band

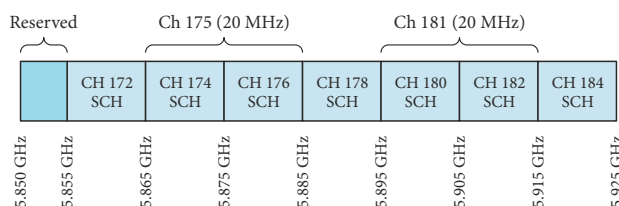


Figure 2. US DSRC band plan

**1. DSRC for VANET**

The IEEE Standard 802.11-2016 has been amended to support DSRC communication. Approved amendments to the IEEE Standard 802.11-2016 referred to as IEEE Standard 802.11p-2010 is used to support WAVES. The MAC sub-layer of the link layer is defined by IEEE 802.11p (Sivasakthi, Suresh 2013). The MAC extension protocol is defined by the IEEE Standard 1609.4-2016, which supports a device to switch among the various DSRC channels allocated by the FCC. The LLC sublayer is defined by the IEEE Standard 802.2-1989. In safety applications, IEEE Standard 1609.3-2016 defines WSM, WSA and protocols for the network and transport. The IEEE Standard 1609.2b-2019 is used for security to encrypt and authenticate the messages. In non-safety applications, IETF defines the TCP or UDP for transport layer services and it defines an IPv6 for network layer services. The non-safety applications run over the internet and DSRC. The safety application developed by the SAE Standard J2735\_201603 application is exemplified in Figure 3.

**1.1. Component of VANET**

DSRC system equipment is an OBU, which has a highly mobile node and a RSU, which is fixed near the roadside. Each vehicle is composed of OBU and an AU, which is connected through a wired or wireless medium (Al-Sultan et al. 2014). There are four types of communication: V2V, V2R, R2R via IEEE Standard 802.11p-2010 and V2O via IEEE Standard 802.11a-1999, IEEE Standard 802.11b-1999 and IEEE Standard IEEE 802.11g-2003. An OBU can communicate with the Internet through RSU or HS and RSU can communicate with the Internet through the gateway (Hartenstein, Laberteaux 2008), which is illustrated in Figure 4.

**1.2. Current issues and challenges in the communication**

Road accidents have become a serious issue due to the increase in the number of vehicles in the recent years, which

Safety application SAE J2735	Non-safety application
Transport and network layer – WSPM	Transport layer – TCP/UDP IETF RFC 793/768
IEEE 1609.3 security IEEE 1609.2	Network layer – IPv6 IETF RFC 2460
LLC sublayer IEEE 802.2	
MAC sublayer extension IEEE 1609.4	
MAC sublayer PHY layer } IEEE 802.11p	

Figure 3. DSRC standard in the US

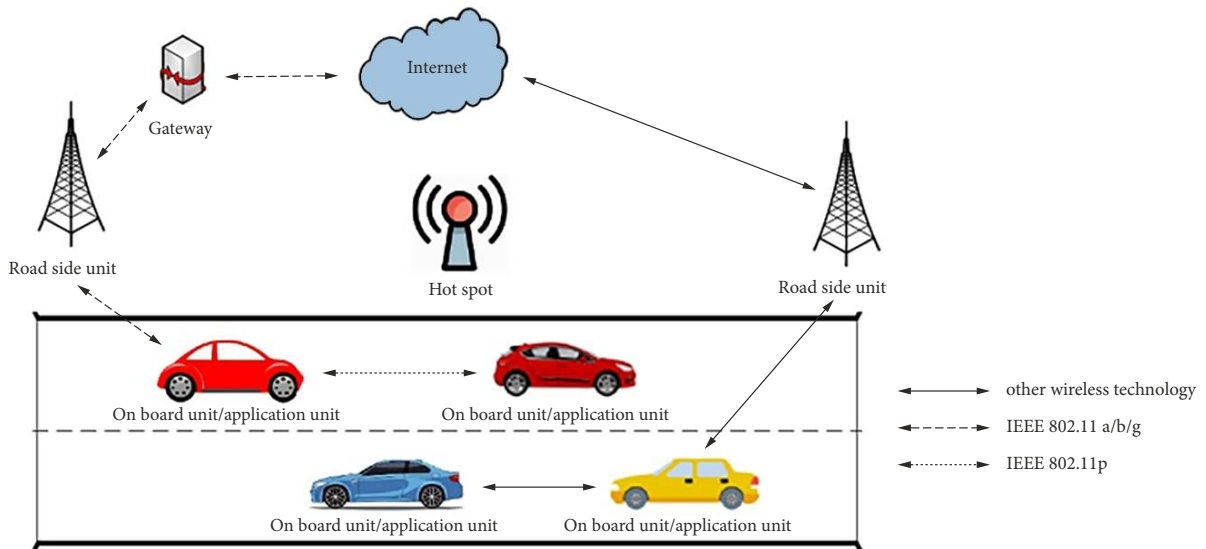


Figure 4. Architecture of VANET

results in loss of human life and property. The emerging technology of vehicular communication system can be more effective in avoiding accidents and traffic congestion. To improve the safety of the passengers travelling on the road and to enhance the traffic efficiency, the ITS provides an application which gives a warning signal such as the condition of the roads, road intersection, collision avoidance, traffic management, toll services, and comfort applications. In VANET, RSUs and vehicles able to communicate through different wireless communications depending on the different applications.

There are some challenging tasks in VANET. First, the network topology is frequently changed and connectivity of nodes is frequently disconnected due to the high mobility nature of VANET. This makes it hard to predict the node position. The dynamic topology nature of the VANET should maintain dynamic routing to improve the quality of communication. Secondly, the realistic communication channel needed to measure the actual received signal strength. Since the vehicles are travelling through different traffic scenario and unpredictable environment, we have to design the realistic communication channel model to cover various types of traffic and environmental conditions. As the ITS safety application must be delivered to the neighbouring vehicles within a time limit, we should well maintain the quality of communication between the vehicles.

## 2. Related works

Since the transmitted signal in the wireless communication medium is attenuated by reflection, diffraction, and scattering we need a radio propagation model to predict the actual signal strength at the receiver to predict the link quality. In physical layer, to measure the fading effect, the existing large-scale fading model is used to measure the received power. The received power is varying gradually due to signal attenuation cost by the deterministic metrics

of distance, obstacle, and environmental property (Martinez *et al.* 2009). This model ignores the rapid fluctuation of instantaneous received power in small area due to multipath effects. The proposed work considers the challenging task of the randomness of the mobility of the vehicle, and unpredictability of the surrounding environment. We need a small-scale propagation model to measure the signal strength at the receiver within small distance or a lesser time interval.

In the routing process, there are some links which are more reliable than the others and hence they are frequently used to forward many packets. The nodes along the reliable link will be overused without considering the RBE. Since the overused node will consume more energy there are chances of rapid failure of the node, which will degrade the performance of the entire network (Gomez *et al.* 2003). Since all nodes in the network are operated using batteries and the lifetime of nodes depend upon its batteries, the RBE is a critical requirement in wireless ad-hoc network. The sector based energy efficient adaptive routing algorithm (Dhanapal, Visalakshi 2015a, 2015b) finds the RBE of node to avoid the overuse of the node and improve the network lifetime. But, they do not address the transmitted signal attenuated by different fading parameters. In real time applications, all nodes should be continuously alive and reliable to improve the performance of the entire network. The proposed work intends to accomplish higher reliability and maintain the RBE in the routing to improve the QoS over the network.

## 3. Proposed system

The proposed system, ARS addresses three categories. The first category algorithm RR includes the reliability of the node by finding ABER of receiving signal from the transmitted signal by using Nakagami-m fading channel. The existing large-scale communication channel model (Hrovat *et al.* 2014) is used to measure the received sig-

nal strength at a given distance and surrounding environment, which is expressed in the Equation (1):

$$y = x \cdot h + n, \quad (1)$$

where:  $y$  is the received signal strength;  $x$  is the transmitted signal;  $h$  is the path-loss fading effect that attenuates the transmitted signal gradually in wireless medium;  $n$  is the fixed noise added to the transmitted signal.

This propagation model usually predicts the average received signal from the transmitter at a given distance and fixed surrounding environment. Due to the unpredictable mobility of the vehicle and surrounding environment, the small-scale communication model is used. The proposed small-scale communication channel model (Rappaport 2002) used to measure the rapid fluctuation of the signal from the transmitter, which is expressed in the Equation (2):

$$y = x \cdot h_1 + n, \quad (2)$$

where:  $y$  is the received signal of the node;  $x$  is the transmitted signal;  $h_1$  is the multipath fading effect that attenuates the transmitted signal rapidly in the wireless medium;  $n$  is the fixed noise added to the transmitted signal.

This propagation model measures the average received signal in the unpredictable mobility of the vehicle and surrounding environment. The first category algorithm RR calculates the ABERN- $m$  to measure the multipath fading effect is to key out the reliability of path over the network. The second category algorithm EER calculates the energy efficiency of route by finding the RBE of nodes in routing to order to avoid the overuse of node and improve the network lifetime. The third category algorithm CDM is used instead of EDM to measure the accurate distance between the vehicles. The proposed system addresses the requirement of reliable, EER and accurate distance measure to maintain the consistent path in the entire network.

## 4. Information model

### 4.1. RR scheme

In a wireless ad-hoc communication, multipath fading occurs due to delayed, reflected, scattered, and diffracted signal components. Multipath fading is relatively fast and is responsible for the short-term signal variations. The transmitted signal is propagated in multipath fading by surrounding objects (Yacoub *et al.* 2005). The transmitted signal is attenuated by multipath fading effect and noise also added into the received signal. The wireless fading channel coefficient expressed in Equation (3):

$$\begin{aligned} y &= x \cdot h_1 + n; \\ h_1 &= r \cdot \exp(\theta), \end{aligned} \quad (3)$$

where:  $y$  is the received signal in wireless medium;  $x$  is a transmitted signal;  $r$  is the fading channel coefficient;  $\theta$  is an angle which is uniformly distributed on  $[-\pi, \pi]$ ;  $n$  is an AWGN, which is fixed SNR. The received signal strength is attenuated by the fast fading effect such as reflection, refraction and scattering due to surrounding objects.

In Nakagami- $m$  fading channel, different values of  $m$  are used to measure the different fading environments in a small geographical area (Beaulieu, Cheng 2005). PDF of the received signal power for Nakagami- $m$  fading environment in a static wireless system (Govindan *et al.* 2011) is expressed in the Equation (4):

$$\begin{aligned} f_r(r) &= \frac{m^m \cdot r^{m-1}}{\Gamma(m) \cdot \Omega^m} \cdot \exp\left(-\frac{m \cdot r}{\Omega}\right); \\ \frac{1}{2} &\leq m < \infty; \quad 0 \leq r < \infty, \end{aligned} \quad (4)$$

where:  $m$  is the fading parameter;  $r$  is the random variable of instantaneous received signal strength;  $\Omega$  is the average signal power;  $\Gamma(m)$  is an Euler Gamma function.

The parameters  $\Gamma(m)$ ,  $\Omega$  and  $m$  are expressed in Equations (5)–(7).

If  $m$  is integer:

$$\Gamma(m) = (m-1)!; \quad (5)$$

$$\Omega = E[r^2], \quad (6)$$

where:  $r = r_1 + r_2 + \dots + r_N$  that are sample of the received envelop to estimate the fading parameter  $m$ ;  $E[r^2]$  is a average fading power.

The fading parameter  $m$  defines the severity of fading in the communication channel (Tepedelenlioglu, Gao 2005):

$$m = \frac{\Omega^2}{E \cdot (r^2 - \Omega)^2}. \quad (7)$$

To improve the simplicity of the Equation (4), it can be written in MGF (Simon, Alouini 2002, 2008), which is expressed in Equation (8):

$$M_r(-s) = \left(1 - \frac{s \cdot \Omega}{m}\right)^{-m}, \quad s > 0. \quad (8)$$

Due to the unpredictability of mobility and the surrounding environment, the proposed work considers probabilistic model that is Nakagami- $m$  propagation model. This method is used to measure the received signal strength in multipath condition in order to measure the performance of the network. The Nakagami- $m$  fading channel, shape parameter  $m$  is easily configurable and covers different fading environmental conditions in the mobile ad-hoc wireless medium (Tarique, Hasan 2011). When the value of  $m = 1$ , it becomes a Rayleigh distribution, which has NLOS between sender and receiver. When  $m = 1/2$  it becomes a one-sided Gaussian distribution. The fading effect of signal amplitude is more severe than a Rayleigh distribution when  $m < 1$ . When  $m > 1$ , the fading effect is less severe than Rayleigh fading. Nakagami- $m$  distribution closely approximates the Rician distribution when  $m = 1$ . The Nakagami and Rician distributions can be mapped to each other by the fading shape parameter  $m$  and Rician  $k$  factor. The value of  $m$  applied to the Nakagami- $m$  distribution, which is used to measure. The below Equation (9) indicates the different fading environments

such as one-sided Gaussian, Rayleigh, and Rician distributions (Tiwari *et al.* 2009), when assigning different values of  $m$  in Nakagami- $m$  distribution:

$$m = \begin{cases} \frac{1}{2}, & \text{one-sided Gaussian distribution;} \\ 1, & \text{Rayleigh distribution, NLOS;} \\ > 1, & \text{Rician distribution, } m = \frac{(k+1)^2}{(2 \cdot k+1)}, k = \frac{\sqrt{m^2 - m}}{m - \sqrt{m^2 - m}}, \text{ LOS;} \\ \infty, & \text{no fading occurred.} \end{cases} \quad (9)$$

The performance of the receiver in the dynamic wireless system is measured by the parameter called ABER, which is defined as the ratio of the number of wrong bits per second to the number of total bits transmitted per second. Since the distance between transmitter and sender is a random variable, ABER in ABERN- $m$  is an important performance metric in measuring the quality of links (Craig 1991) which is expressed in Equation (10):

$$AVG_{BER} = \int_0^{\infty} p_e(r) \cdot f_r(r) dr, \quad (10)$$

where:  $AVG_{BER}$  is average bit error rate;  $p_e(r)$  is a fixed SNR (a probability of error symbol represented in AWGN);  $f_r(r)$  is an instantaneous SNR.

It is represented in a Gaussian Q-function (Lever 1998). The probability of error of AWGN channel is expressed in Equation (11):

$$p_e(r) = Q(a) = \frac{1}{\pi} \cdot \int_0^{\frac{\pi}{2}} \exp\left(-\frac{a^2}{2 \cdot \sin^2 \theta}\right) d\theta, a \geq 0. \quad (11)$$

Information of bits is modulated prior to the transmission over the channel. Where  $a$  is a constant, which depend on the specific modulation combination. One of the digital modulation formats BPSK used. The probability of bit error for BPSK modulation (Goldsmith 2005) in AWGN channel is expressed in Equation (12):

$$p_e(r) = Q(a) = Q(\sqrt{2 \cdot r}) = \frac{1}{\pi} \cdot \int_0^{\frac{\pi}{2}} \exp\left(-\frac{r}{\sin^2 \theta}\right) d\theta, x \geq 0. \quad (12)$$

By substituting the Equation (12) in the Equation (10), we arrive at Equations (13) and (14):

$$AVG_{BER} = \int_0^{\infty} \frac{1}{\pi} \cdot \int_0^{\frac{\pi}{2}} \exp\left(-\frac{r}{\sin^2 \theta}\right) d\theta f_r(r) dr; \quad (13)$$

$$AVG_{BER} = \frac{1}{\pi} \cdot \int_0^{\frac{\pi}{2}} \left( \int_0^{\infty} \exp\left(-\frac{r}{\sin^2 \theta}\right) f_r(r) dr \right) d\theta. \quad (14)$$

The inner integral in the form of Laplace transform in the Equation (14) can be written as MGF, which is expressed in Equation (15):

$$AVG_{BER} = \frac{1}{\pi} \cdot \int_0^{\frac{\pi}{2}} M_r\left(-\frac{1}{\sin^2 \theta}\right) d\theta, \quad (15)$$

where:  $M_r\left(-\frac{1}{\sin^2 \theta}\right)$  is MGF of instantaneous fading channel.

By substituting the Equation (8) in Equation (15), the result is in Equation (16):

$$AVG_{BER} = \frac{1}{\pi} \cdot \int_0^{\frac{\pi}{2}} \left(1 + \frac{\Omega}{m \cdot \sin^2 \theta}\right)^{-m} d\theta, \quad (16)$$

when:  $m=1$  the ABER in Rayleigh fading channel (Simon, Alouini 2002, 2008) is expressed in Equation (17):

$$AVG_{BER} = \frac{1}{2} \cdot \left(1 - \sqrt{\frac{\Omega}{m + \Omega}}\right). \quad (17)$$

## 4.2. Enhancement of network life time

The main objective of routing to discover EER, which will prolong the lifetime of the network based on the weight of the RBE (Toh 2001) along with the reliable link. The RBE of node  $n_i$  at time  $t$  is expressed in Equation (18):

$$RBE_{n,t} = \text{initial energy} - \text{consumed energy}. \quad (18)$$

Weight of RBE is inversely proportional to the remaining energy of the batteries. The weight of the remaining energy of node calculated at different times, which is expressed in the Equation (19):

$$W_i(RBE_{n,t}) = \frac{1}{RBE_{n,t}}. \quad (19)$$

Let  $\alpha$  be the threshold value of the ABER of a node and  $\beta$  be a threshold value of the weight of remaining battery power of a node. We consider the set of nodes that have the threshold value of the ABER and the threshold power of batteries to find the optimal path. The sum of the life span of intermediate nodes on the optimal path is expressed in Equation (20):

$$W_i(\text{optimal path } j) = \sum_{j=0}^n W_i(RBE_{n,t}). \quad (20)$$

The maximum life span of the path is considered as a minimum value of the total weight of the all the paths and is expressed in Equation (21):

$$\text{Best}_{\text{optimal path } j} = \min(W_i(\text{optimal path } j)). \quad (21)$$

where: ‘min’ is a function, which selects the minimum total weight of path to prolong the lifetime of the path.

The graph  $G$  contains set of path  $j$  and set of node  $n_i$  in path  $j$ . There are three paths  $p_1, p_2, p_3$  from source to destination. As per Equation (19) total weight of optimal path  $w(p_1)$  is 70,  $w(p_2)$  is 40 and  $w(p_3)$  is 40. According to the Equation (21) the best optimal path  $p_2$  is selected for forward the packet from source to destination. If all the paths have the same total weight of the battery, the best optimal path is selected based on hop count, which is illustrated in the Figure 5.

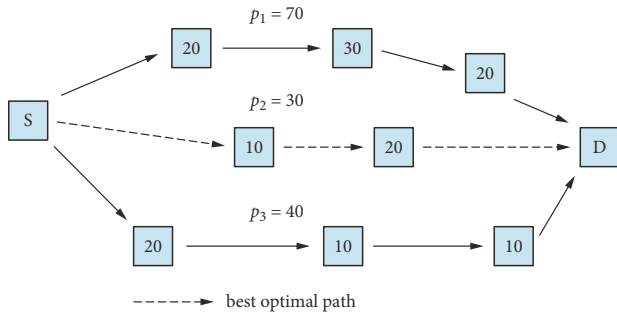


Figure 5. Best optimal path selection

Vehicles	Coordinates of vehicles		
V1	1	1	1
V2	1	1	0
V3	2	2	2
V4	10	10	10
V5	11	11	11
V6	10	5	0

Figure 6. Coordinates of vehicles in the area

### 4.3. Accuracy improvement by CDM

The ITS is a novel technologies in the field of communication. To avoid the congestion on the road and to improve the traffic efficiency, it provides through the safety application such as route information, dangerous road conditions, safety overtake warning, accident sites information and emergency vehicle warning. Assume that an ambulance has to carry an injured person from the accident site to the hospital for emergency treatment. In such a scenario, the ambulance is allowed to break road rules like crossing the road when the traffic light is red or exceeding speed limit in order to reach the destinations in the right time. The ambulance broadcasts this emergency message to its neighbouring vehicle on the road to avoid mishaps and enable it to reach the destination at the earliest. The driver of the neighbouring vehicle will take timely action by receiving the emergency information. Each vehicle needs to find the neighbouring vehicle to disseminate the message. The distance measure metric must satisfy the following four conditions (Xu, Wunsch 2005):

- 1) distance between two coordinate must be non-negative, i.e.  $distance(x_i, x_j) > 0$  for all  $x_i, x_j$ ;
- 2) if  $distance(x_i, x_j) = 0$ , the two points are identical, i.e.  $x_i = x_j$ ;
- 3)  $distance(x_i, x_j) = distance(x_j, x_i)$ ;
- 4) distance measure must satisfy the triangular inequality, i.e.  $distance(x_i, x_k) \leq distance(x_i, x_j) + distance(x_j, x_k)$ .

The Euclidean distance satisfies the above metric condition so this EDM is metric. The coordinates of pair of object is calculated by using the formula of Euclidean distance is expressed in Equation (22). The example of coordinates of vehicles defined in Figure 6.

$$Distance_{Euclidean} = \sqrt{\sum_{k=1}^n (x_{jk} - y_{jk})^2}. \quad (22)$$

The Bray–Curtis distance or Sørensen distance is semi metric, which is not satisfying the triangle inequality property. The drawback of this measure is undefined if both coordinates near to zero value (Bray, Curtis 1957). The proposed Canberra distance which used to measure the distance in mobile node (Lance, Williams 1966) is an extended version of Manhattan or City block distance.

The CDM method examines the sum of series of fractional difference between the coordination of pairs of objects. The CDM is defined if both coordinate near zero value (Jain, Dubes 1988). The CDM is defined in Equation (23):

$$Distance_{Canberra(i, j)} = \frac{1}{n} \cdot \sum_{k=1}^n \left| \frac{x_{jk} - y_{jk}}{x_{jk} + y_{jk}} \right|. \quad (23)$$

The time complexity of both Euclidean distance and CDM are  $O(n)$  in linear time, but the Canberra distance has more accuracy in measuring the distance of the mobile objects than Euclidean distance (Shirkhorshidi *et al.* 2015), which is defined in Table 1.

The Euclidean measure indicates the distance between the vehicles V1 and V3 is same as between V4 and V5. Since the CDM indicates the distance between the vehicles V1 and V3 is not same as between V4 and V5, this analysis indicates that the CDM is more sensitive for values closer to the origin.

### 4.4. Proposed ARS RREQ format

In the route selection process, among the available routes, the source node selects the best optimal path based on the weighted estimation of ABER and remaining battery capacity. The RREQ format of the proposed ARS protocol is shown in the Figure 7.

In type field, the bits 012 are used for precedence; bits 345 are used for type of service. Flag G is indicating whether RREP should be unicast to the destination IP address. Flag D indicates whether destination responding to the RREQ. Identification is a number to identify all fragments of the original IP packet. The hop count is the number of hops by which the message is carried from the source address to the destination address.

### 5. ARS

Finding the best optimal path from source to destination based on the ABERN-m fading channels, the remaining energy of batteries, and by calculating the accurate distance:

- 1) where  $d$  is a distance,  $d = (d_0, d_1)$ ,  $d_0 = 80$  m,  $d_1 = 200$  m, ABER threshold  $0 \leq \alpha \leq 0.3$  (Das *et al.* 2016), RBE threshold value  $\beta$  is 12V; the distance between the pair of coordinate is calculated by CDM;

Table 1. Distance between the vehicles measured by Euclidean and Canberra metrics

EDM	V1	V2	V3	V4	V5	Distance between V1 and V3	Distance between V4 and V5
V1	0	1	1.732	15.588	17.321	1.732	1.733
V2	1	0	2.449	16.186	17.916	1.499	1.73
V3	1.732	2.449	0	13.856	15.588	1.732	1.732
V4	15.588	16.186	13.856	0	1.732	1.732	1.732
V5	17.321	17.916	15.588	1.732	0	1.733	1.732
V6	9.899	9.849	8.775	11.180	12.570	1.125	1.39
CDM	V1	V2	V3	V4	V5	Distance between V1 and V3	Distance between V4 and V5
V1	0	1.000	1.000	2.455	2.500	1.000	0.045
V2	1.000	0	1.667	2.636	2.667	0.667	0.031
V3	1.000	1.667	0	2.000	2.077	1.000	0.077
V4	2.455	2.636	2.000	0	0.143	0.455	0.143
V5	2.500	2.667	2.077	0.143	0	0.423	0.143
V6	2.485	1.485	2.095	1.333	1.423	0.39	0.09

Type	G	D	Identification		Hop count
RREQ ID		ABER		Remaining battery capacity	
Destination address					
Destination sequence number					
Source address					
Source sequence number					

Figure 7. RREQ format of ARS protocol

$$2) \text{Distance}_{\text{Canberra}}(x_i, x_j) = \frac{1}{n} \cdot \sum_{k=1}^n \frac{|x_{ik} - x_{jk}|}{|x_{ik} + x_{jk}|},$$

where:  $x_{ik}, x_{jk}$  are the pair of coordinates of the objects;

$$3) \text{AVG}_{\text{BER}} = \frac{1}{2} \cdot \left( 1 - \sqrt{\frac{\Omega}{m + \Omega}} \right);$$

4) if distance(sender, receiver)  $\leq d_0$  then  $m = 1.5$ ;  $\Omega = E(r)^2 = 2 \cdot \sigma^2$ ;

$$\text{AVG}_{\text{BER}(\leq d_{0,m})} = \frac{1}{2} \cdot \left( 1 - \sqrt{\frac{\Omega}{m + \Omega}} \right),$$

else

5) if distance (sender, receiver)  $> d_0$  and distance (sender, receiver)  $\leq d_1$  then  $m = 0.75$ ;

$$\text{AVG}_{\text{BER}(d_0 \leq d_{1,m})} = \frac{1}{2} \cdot \left( 1 - \sqrt{\frac{\Omega}{m + \Omega}} \right),$$

else

6) if distance (sender, receiver)  $> d_1$  then  $m = 0.5$ ;

$$\text{AVG}_{\text{BER}( > d_{1,m})} = \frac{1}{2} \cdot \left( 1 - \sqrt{\frac{\Omega}{m + \Omega}} \right),$$

7) Endif;

8)  $RBE_{n_i t}$  = initial energy – consumed energy, where  $RBE_{n_i t}$  is a RBE of node  $n_i$  at a time  $t$ ;

$$9) w_i(RBE_{n_i t}) = \frac{1}{RBE_{n_i t}},$$

weight of the RBE is inversely proportional to the RBE;

10) if  $\text{AVG}_{\text{BER}(d,m)} \geq \alpha$  and  $w_i(RBE_{n_i t}) \geq \beta$ , then

11) select the optimal forwarding node, otherwise discard the node;

$$12) W_i(\text{optimal path } j) = \sum_{j=0}^n W_i(RBE_{n_i t});$$

$$13) \text{Best}_{\text{optimal path } j} = \min(W_i(\text{optimal path } j));$$

14) if  $\text{Best}_{\text{optimal path}} > 1$  then

15) thus, the shortest path is selected among the best optimal path.

## 6. Simulation results

In ITS safety application, there is not much delay in communicating between the vehicles in the network. In CSMA/CA, the node first listens to the channel through the RTS/CTS packets into the channel. If the channel is free, node directly transmits the packet, otherwise it waits for random back off time. If two or more nodes sense the channel free, this causes the hidden terminal problem that increases the collision at the denser territory (Nguyen *et al.* 2013). Based on the collision, the random back off value is selected which causes unbounded delay, reduces the throughput, consumes additional energy and it finally reduces the throughput of network (Bilstrup *et al.* 2010). The G-TDMA schedules the time slot for vehicle in a centralized manner by CH or RSU (Almalag *et al.* 2012). It reduces the hidden terminal problem and collision in the two-way traffic, but it increases the overhead of cluster formation, CH selection and CH maintenance in the highly dynamic nature of the network. However, it does not overcome the merges collision issue in two-way traffic (Omar *et al.* 2013). The SSD-TDMA identifies the license free channel and assign available spectrum to the spectrum

scarcity area in order to overcome the spectrum deficiency in an urban scenario (Sivaganesan, Karthikeyini 2015). It assigns the slot in a distributed way to avoid collision and to avoid the wastage of bandwidth in two-way unbalanced traffic scenario (Cabric *et al.* 2006). The drawback of the SSD-TDMA method does not consider the RR in an unpredictable traffic. CLAO-TCP measures the received signal strength by using deterministic methods to predict the reliable node. It assigns the time slot in distributed ways based on message generation time within the communication range by using directional antennas (Shakkottai *et al.* 2003). This is to avoid the path loss and collision in early stage and to avoid the TCP unnecessary movement to the slow-start. The drawback of the CLAO-TCP method does not consider the signal propagation in unpredictable scenario of environmental condition. The proposed ARS analysis the ABERN-m of node to improve the reliable communication in an unpredictable environment condition. It predicts the residual battery energy of the node to extend the network lifetime and thereby avoid the overuse of the node. It also uses the accurate distance measure method to find out the distance between the vehicles. The NS2 simulation shows the execution of the proposed ARS evaluated by different performance metrics such as energy consumption, RO, PDR, PLR and EED listed in Table 2. The performance of the proposed system ARS is better than the existing approaches of CSMA/CA, G-TDMA, SSD-TDMA, and CLAO-TCP by *Network Simulator NS2 version 2.34*. The simulation parameters are listed in Table 3.

### 6.1. EU

Performance metric EU measures the energy consumed when the packet is transferred from source to destination in the network. The  $x$ -axis in the graph represents the speed of vehicle [m/s]. The  $y$ -axis in the graph represents the EU [J]. The EU of CSMA/CA is 45 J at 100 m/s, G-TDMA is 40 J at 100 m/s, SSD-TDMA is 37 J at 100 m/s, and CLAO-TCP is 29 J at 100 m/s. The proposed approach ARS is 25 J at 100 m/s. The graph proves that the EU of the proposed approach ARS is lesser than the EU of the existing methods and its performance is better than the existing approaches as seen in Figure 8.

Table 2. Performance metrics

No	Performance metrics	Formula
1.	EU	$= \frac{\text{consumed energy}}{\text{speed of vehicle}}$
2.	Delay	$= \text{packet departure time} - \text{packet arrival time}$
3.	Packet deliver ratio	$= \frac{\text{number of packets received}}{\text{number of packet sent}} \cdot 100$
4.	Control overhead	$= \frac{\text{number of control route request} + \text{number of route reply}}{\text{total control packet sent}}$
5.	PLR	$= \text{number of packet sent} - \text{number of packets received}$

Table 3. Simulation parameters

Parameters	Value
Simulation time	60 s
Transmission range	250 m
Number of channels	7
Number of vehicles	100
RSU	6
Base station	1
ABER $\alpha$	$0 \leq \alpha \leq 0.3$
Residual battery weight $\beta$	12V
Channel data rate	3 mb/s
Packet size	512 bytes

### 6.2. RO

The RO is measured by the number of control packets required from source to destination in the network. The  $x$ -axis in the graph represents the speed of vehicle [m/s] and the  $y$ -axis in the graph represents the control overhead [bytes]. The RO of CSMA/CA is 8.3 bytes at 100 m/s, G-TDMA is 7.2 bytes at 100 m/s, SSD-TDMA is 6.7 bytes at 100 m/s, and CLAO-TCP is 3.9 bytes at 100 m/s. The proposed approach ARS is 3.2 bytes at 100 /s. The graph proves that the RO of the proposed approach ARS is lesser than the RO of the existing methods and its performance is better than the existing methods as seen in Figure 9.

### 6.3. PDR

The PDR is measured by the ratio of total number of receiving packets to the total number of sending packets from source to destination in the network. The  $x$ -axis in the graph represents the speed of vehicles in meters per second and the  $y$ -axis in the graph represents the packet received in bytes. The PDR of CSMA/CA is 76% at 100 m/s, G-TDMA is 79% at 100 m/s, SSD-TDMA is 80% at 100 m/s and CLAO-TCP is 83% at 100 m/s. The PDR of the proposed approach ARS is 85% at 100 m/s. The graph proves that the PDR of the proposed approach ARS is more than the PDR of the existing methods and its performance is better than the existing methods as seen in Figure 10.



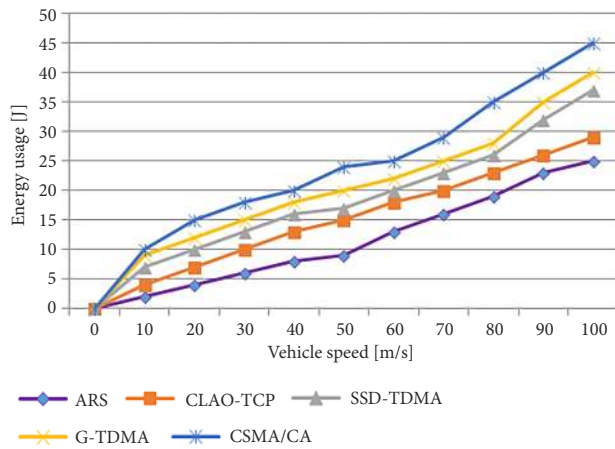


Figure 8. EU

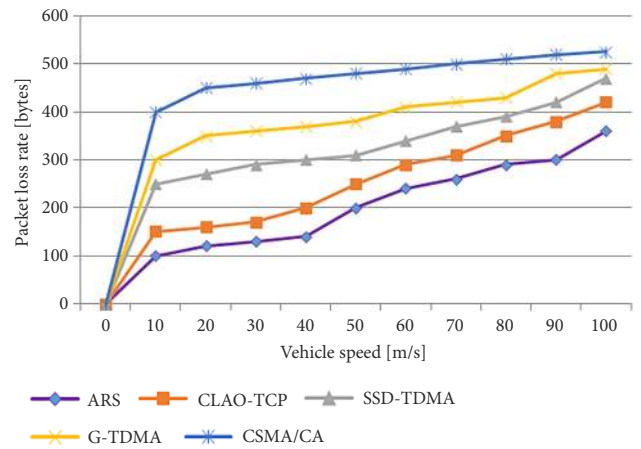


Figure 11. PLR

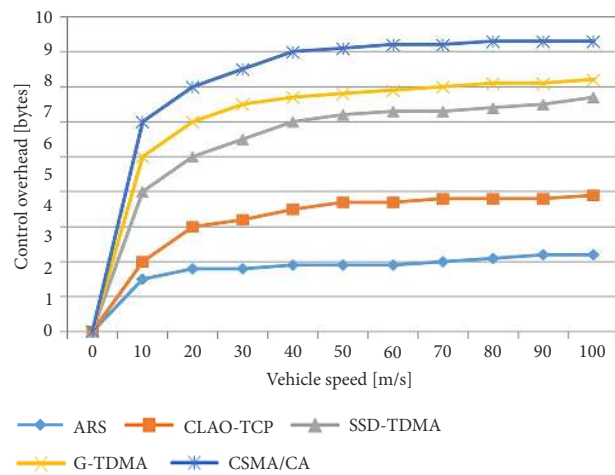


Figure 9. RO

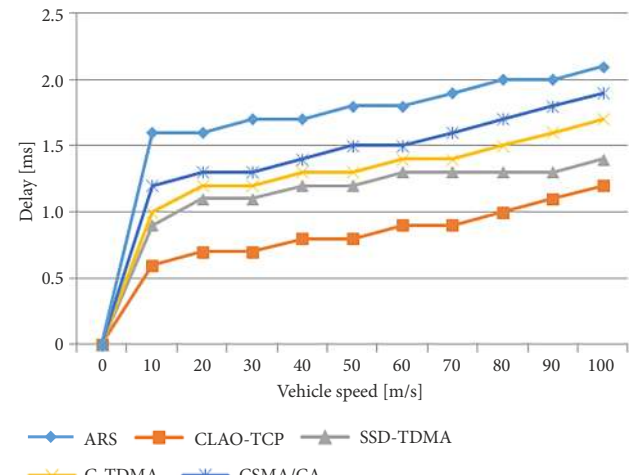


Figure 12. EED

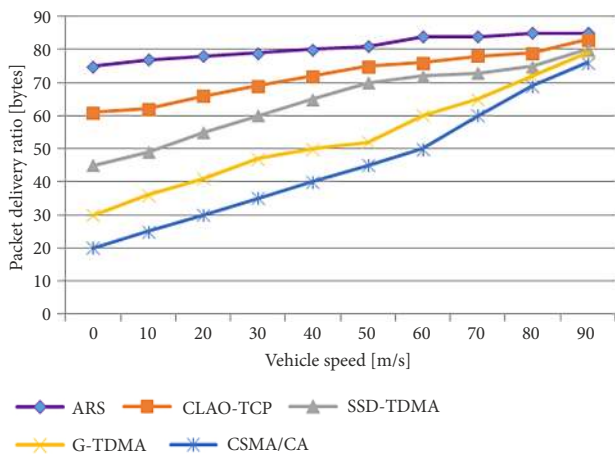


Figure 10. PDR

### 6.4. PLR

The PLR is measured by the difference between the number of packets sent and number of packets received from source to destination in the network. The *x*-axis in the graph represents the speed of vehicle in meters per second

and the *y*-axis in the graph represents the PLR [packets]. The PLR of CSMA/CA is 525 packets at 100 m/s, G-TDMA is 490 packets at 100 m/s, SSD-TDMA is 470 packets at 100 m/s and CLAO-TCP is 420 packets at 100 m/s. The PLR of the proposed approach ARS is 360 packets at 100 m/s. The graph proves that PLR of the proposed approach ARS is lesser than the PLR of the existing methods and its performance is better than the existing methods as seen in Figure 11.

### 6.5. EED

The EED is measured by the time taken for the packets to transfer from source to destination in the network. The *x*-axis in the graph represents the speed of vehicles in meters per second and the *y*-axis in the graph represents the delay [ms]. The EED of CSMA/CA is 2.1 ms at 100 m/s, G-TDMA is 1.9 ms at 100 m/s, SSD-TDMA is 1.7 ms at 100 m/s and CLAO-TCP is 1.4 ms at 100 m/s. The EED of the proposed approach of ARS is 1.2 ms at 100 m/s. The graph proves that the EED of the proposed approach of ARS is less than the existing methods and its performance is better than the existing methods as seen in Figure 12.

## Conclusions

Vehicles within the network are responsible to send the information from source to the destination.

The received signal strength should be of adequate strength to have a good quality of communication and it should be energy efficient to boost the network lifetime.

The proposed ARS considers the ABERN-m fading for a forwarding node to ensure the quality of communication in mobile nodes. It considers EER to calculate the remaining battery capacity of nodes to enhance the network lifetime, and CDM used to measure the accurate distance between mobile nodes.

The performance metrics of the proposed scheme ARS are analysed by *Network Simulator NS2 version 2.34*. The proposed scheme ARS proves to be more efficient than the existing schemes.

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