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ScienceDirect
Procedia Computer Science 34 (2014) 559 – 564
Procedia
Computer Science

International Workshop on the Design and Performance of Networks on Chip (DPNoC 2014)

Vehicles–to-Infrastructure Communication Safety Messaging in DSRC

Kenneth Sorle Nwizege[1,]*, Mauro Bottero[2], Shedrack Mmeah[3], Emmanuel D. Nwiwure[4]

[1]Swansea University, Singleton Park, Swansea, SA2 8PP, UK , [2]Independent Consultant, Milan , Italy, [3]Rivers State Polytechnic, Bori, Nigeria, [4]Rivers State Polytechnic, Bori, Nigeria

Abstract

Vehicular communications use either the IEEE 802.11a or IEEE 802.11p wireless standard. With the support of the Dedicated Short Range Communications (DSRC), it has its wide range of applications such as energy efficiency, real-time traffic monitoring, infotainment, congestion control, and road safety. The key challenge in Vehicular communications is how to combat with the high mobility of vehicles due to their varying speed, as they communicate with each other via the Access Point (AP). Vehicles moving at high speeds have short opportunity to share data with each other, and this has to be within the shortest time; else there will be collision. In this paper, we proposed an Adaptive-Context-Aware Rate Selection (ACARS) algorithm, and modelled the mobility of vehicles with speed distribution using context-information. From results obtained, it shows that ACARS is efficient and reliable in delivery of safety messages in vehicles. It performs better using a Constant Speed mobility model, in order to obtain good throughput and low delay. Results also show that vehicles can get reliable messaging from each other via the AP.

Selection and peer-review under responsibility of Conference Program Chairs

Keywords: V2I; Safety messaging; DSRC; ACARS; Context Information; Rate Adaptation; Vehicular Communication; IEEE802.11p; Wireless Networks; Speed; Propagation Environment;

* Corresponding author. Tel.: +447456277377
E-mail address: kennethsorle@yahoo.com, S.K.Nwizege@ieee.org

Selection and peer-review under responsibility of Conference Program Chairs
doi:10.1016/j.procs.2014.07.070

1. Introduction

The recent spread of wireless devices is a motivating factor for more research in the area of wireless and mobile technology. However, the concern for road safety is more challenging since there is daily occurrence of accidents on our roads.

One of the basic challenges in wireless and mobile technology is high mobility, and high data rate due to applications such as vehicular communications, video and voice transmissions. The aim of IEEE 802.11 standard is to provide reliable communication using appropriate protocols, so that reliable and efficient services can be obtained through Quality of Service (QoS).

Our focus is this paper is to design and evaluate a reliable Rate Adaptation Algorithm (RAA) to control the problem of vehicular networks to enhance QoS and provide reliable services through the integration of power control scheme. In order to achieve this, we have modeled ACARS with power control scheme. Reliable messaging in vehicular communications is one of the goals of DSRC. Proper mobility model that will result to efficient system performance need to be properly chosen. We have implemented a constant speed mobility model in this paper, so that vehicles can have reliable and efficient messaging.

The rest of the paper is organized as follows: Section 2 is related works, Section 3 deals with mobility model, while Section 4 evaluates the network and Section 5 analyzes our simulation results. Finally, Section 6 concludes this paper.

2. Related works

Mobility model in vehicular networks is one of the most important factors when dealing with RAA and vehicular communications using any ad-hoc routing protocol. Lots of research has been on mobility model in RAA [9].

Several RAAs such as Adaptive Auto Rate Fallback (AARF)[1], Context-Aware Rate Selection (CARS)[4], SampleRate[2], ONOE[3], Context-Aware Rate Algorithm (CARA)[5], Robust Rate Adaptation Algorithm (RRAA)[7] have been proposed in the literature. However, some implemented mobility, others combined context-information and mobility (CARA, CARS), power control (RRAA), but none of them combined mobility, context-information and power control into rate adaptation scheme.

We have proposed a robust Signal-to-Noise (SNR) rate adaptation algorithm known as Adaptive Context-Aware Rate Selection (ACARS) algorithm with a constant speed mobility model and integration of power management scheme. ACARS algorithm relies on Request-to-Send/Clear-to-Send (RTS/CTS) mechanisms to provide instantaneous receiver-side Signal-to-Interference Ratio (SINR) information to the transmitter [3, 6].

3. Mobility model

Mobility models are used in generating movements of mobile nodes in Ad-Hoc networks. It plays a significant role in determining the protocol performance; hence, it is desirable that these models emulate the movement pattern of targeted real life applications in a reasonable way[22]. Position, speed, and moving direction of nodes are defined by the mobility model during the whole simulation, and change over time. There are several mobility models such as Random walk model, Freeway, Constant Speed, rectangular, RAndomWaypoint, Linear, Circle, Manhattan .

3.1. Constant speed mobility model

In the ConstSpeed mobility model, vehicles can move along a lane with constant speed to a randomly chosen target, and when the target is reached, it randomly selects a new one. With this model, vehicles select their speeds uniformly over this range as shown in equation (1). Initial positions of vehicles are generated randomly in MATLAB called $Pos_{old.}$

$$v = [\overline{V} \text{ x } 0.75, \overline{V} \text{ x } 1.25]\text{km/h} \quad (1)$$

$$Pos_{new} = Pos_{old} + v \times t \quad (2)$$

$$d= \left| Pos_{new} - Pos_{AP} \ldots + Pos_{nnew} - Pos_{nAP} \right| \quad (3)$$

where, **v** is speed, **t** is time, **d** is distance between each node and the AP, Pos_{new} is the vehicles' new position**,** Pos_{AP} is the position of the AP, **n** is the total number of vehicles, Pos_{nnew} is the new position for **nth** number of vehicles, Pos_{nAP} is the position for **nth** number of AP , and $\overline{V}$ is average speed of vehicles. $\overline{V}$ of 55 km/h was used for the different number of vehicles by using this range . The distance **d** between vehicles and Access Point (AP) or Road Side Unit (RSU) determine which vehicle is in communication range or out of range. Parameters used in this simulation are listed in Table I.

4. Evaluation

This section considers the integration of power control scheme into ACARS. With this integration into ACARS and existing RAA, we can evaluate the optimization process of power management in various rate selection schemes.

4.1. Network Analysis

We configured and simulated using a Vehicle-to-Vehicle (V21) network, reason is that the Vehicle-to-Vehicle (V2V) network is complicated to handle in this case, which will be considered for future research. Figure 1 is a V2I network, and Figure 2 is network setup used in this paper.

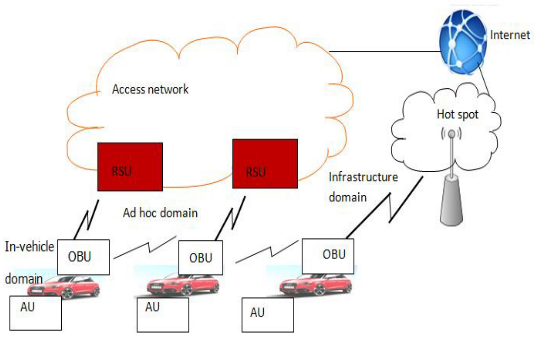

Fig. 1. Vehicle-to-infrastructure network.

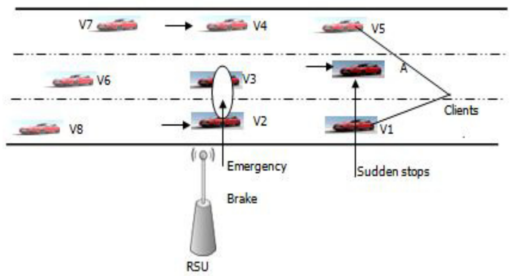

Fig.2. Network setup.

4.1.2. *ACARS implementation*

This algorithm is implemented with power control. Other existing RAAs concentrate on mobility model and power control separately, and not the combination of both [2,12, 13, 21].

Algorithm 1 is a summary of ACARS implementation. The two key functions in this algorithm are $\mathbf{E_C}$ and $\mathbf{E_H}$. $\mathbf{E_C}$ uses context-information (ctx) as input parameter and helps to implement line 9 of Algorithm 1 which is Packet Error Rate (PER) $\overleftarrow{\mathbf{P}}$. $\mathbf{E_H}$ uses past transmission statistics for each bit-rate. $\boldsymbol{\alpha}$ indicates when to give priority to either **ctx** or $\mathbf{E_H}$, **S** is the speed normalizer, **v** is the speed of the vehicles, $\forall$ is average retries, $\overrightarrow{\mathbf{V_{mob}}}$ is mobility function that uses input parameters for ctx, **a** is chosen as 0.03 for averaging the number of errors blocks, $\boldsymbol{\partial}$ is rate, $\overrightarrow{\mathbf{TV}}$ is transmitting vehicles, $\overrightarrow{\mathbf{C_R}}$ is communication range (300m), and $\mathbf{X_{max}}$ is length of the road. To estimate SNR to the Physical (PHY) layer, this algorithm uses $\boldsymbol{\tau}$ from the look up table for Bit-Error Rate (BER) generated for each node. The goal of Algorithm 1 is to return the best rate to be chosen for transmission.

Algorithm 1 The adaptive context-aware rate selection algorithm
Function: ACARS_GetRate
Output: ∂
Input : ctx, α, P_L
1. Compute τ from the BER table
p(n,:) = polyfit (SNR (∇,1),
2: $E_C = \varphi . E_C \overrightarrow{TV}$,
3: Determine E_H using
4: $E_H = \varphi . E_H (\overrightarrow{TV})$
5: Compute E_C
6: $\varphi . E_C (\overrightarrow{TV},)$ = min (1, exp (polyval (P_{TX}, SNR)
7: Compute E_H using
8: $\varphi . E_H (\overrightarrow{TV}, \partial (\overrightarrow{TV},) = \varphi . E_H (\overrightarrow{TV}, \partial(\overrightarrow{TV})$ x (1-a) + τ **x** a
9: Compute $\overleftarrow{P}$ using
$\overleftarrow{P}$= E_C. α +(1- φ. α) **x** E_H
∀= (N. $\overleftarrow{P}$^{(N+1)}- (N+1). $\overleftarrow{P}$^ (N+1)) /(1- $\overleftarrow{P}$) + N. $\overleftarrow{P}$^N)
10: Thr = ∂ (∀. (1- $\overleftarrow{P}$^N)^/ρ
11: Select ∂
12: IF Thr $> Thr_{max}$
13: $Best_{Rate} \leftarrow$ bit-rate
14: $Thr_{max} \leftarrow$ Thr
15: ENDIF.

4.1.3. *Propagation Environment*

To implement power control scheme for RAAs, we studied the effect of propagation phenomena, with path loss exponent and shadowing deviation. These effects take place in different locations, as vehicles move from one location to the other, resulting to different propagation effects in different environments. Due to imperfect propagation environment, in practice, it is not exactly the inverse square. The distance between sender and receiver gives a high correlation between signal level and error rate as this affects the number of transmitted packets to be received[8, 10]. Equations 4-6) gives a summary of power control integrated into the ACARS algorithm.

Our simulation results show that propagation phenomena affect rate changes in vehicular communications.

$$g_{(t)} = g_{p(t)} + g_{s(t)} + g_{m(t)} \quad (4)$$

$$P_{rx} = P_{tx} - g_t \quad (5)$$

$$\text{RSS} = P_{rx} - P_{noise} \quad (6)$$

where g_t is power gain, $g_{p(t)}$ is path loss, $g_{s(t)}$ is shadowing and $g_{m(t)}$ is multipath fading while RSS is the received signal strength.

5. Analyses of simulation results

In this section, we will analyze the results obtained from simulated RAAs using MATLAB. We will also discuss the results obtained from various rate adaptation schemes, and evaluate their performance to show the impact of speed in RAAs.

Table 1. Configuration parameters.

Parameters (Units)	Values
PHY and MAC Protocol	802.11p
Frequency (GHz)	5.89
Number of iteration	4
Normalized Transmit Power (mW)	40,50
Noise Power (dBm)	-90
ϒ (Path Loss exponent, Urban area cellular radio)	2.0, 2.7-3.5
σ (dB)	6-8
Data rate (Mbps)	3, 4.5, 6,9,12,24,27

5.1. *Network setting*

In this simulation model, all vehicles act as clients. We use a fixed base station as server which is similar to what is obtained in cities and highways having road-side units (e.g., kiosks and cafes) with wireless services. Our scenario consists of a road of length **1000 m** with multiple lanes. The base station is located at the middle of the road. Table I shows the simulation parameters, path loss exponent and shadowing deviation.

5.1.2. *Rate selection*

From algorithm 1, $\mathbf{E_H}$ uses an Exponentially Weighted Moving Average (EWMA) of past transmission statistics of each bit-rate , while $\mathbf{E_C}$ uses context- information, which is represented by the variable **ctx**. The weight **α** determines when to give preference to the context -information or to the EWMA. **α** is assigned based on the vehicle speed. When speed is zero, there is no opportunity for doing any prediction of link quality using context-information, hence EWMA is given preference, but when vehicle speed is high, context- information is given preference. More precisely, $\boldsymbol{\alpha = max\,(0, min(1,\, v/S))}$. We select speed normalizer, **S** = 30 (metres per second) as the best value, which corresponds to a vehicle speed of about 65 miles per hour.

The algorithm calculates estimated throughput for each bit-rate and selects the bit-rate that it predicts will provide the most throughput. **N** is the maximum number of retransmissions, and ∀ computes the average number of retransmissions. $\boldsymbol{\rho}$ is the weight that signifies the penalty given to unsuccessful packet transmission [2].

5.1.3. *Results and discussions*

SampleRate has better performance than all other RAAs as the vehicles select their speed according to range set from the network configuration. From Figure 3, AARF did not perform well as compared to ACARS, MODIFIEDCARS and ONOE.

ACARS performs better than all other rate selection algorithms from Figure 4. Observation shows that SampleRate drops its transmission rate frequently than AARF and has the worst performance in this scenario. MODIFIEDCARS did not perform well especially as the speed of the vehicles increase.

Observations show from Figure 3-6, that mobility affects the performance of various RAAs. From these figures, ACARS performs better than the other rate schemes with SampleRate having the worst performance among all. One of the reasons may be that the algorithm is struggling with mobility issue, since it was not originally designed with mobility concept. Since varying channel condition affects all other schemes, it affects the performance of various RAAs. ACARS out- performs all other RAAs at about a speed of 70 km/h.

We can observe from Figures 3-6, that ACARS out-performs the other rate selection algorithms, but having fluctuations as the speed of the vehicles increase. In the case of shadowing, when the inter-node distance increases, the reception probability drops because, the transmitting node is far away from the receiver at that point. From these figures, speed of the vehicles affect the distance, hence it affects the reception of signals. SampleRate could not perform as the other RAAs in this channel condition, reason may be the in-ability to adapt to the fast variation of propagation phenomena and vehicle speeds. In its implementation, it tries to limit the minimum duration between successive rate changes to be at least 2 seconds; this affects its overall performance. MODIFIEDCARS also did not perform very well as compared to AARF, ACARS and ONOE.

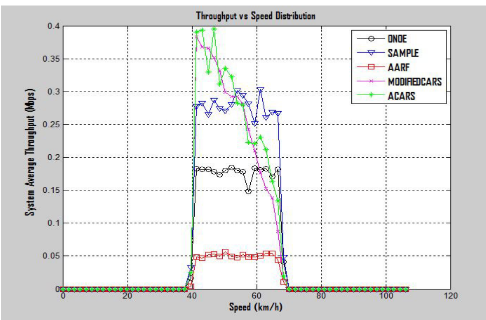

Fig. 3. Average system throughput vs speed, (fading & CommRange) .

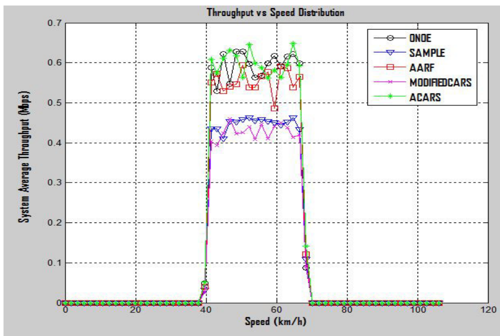

Fig. 4. Average system throughput vs speed (fading,NoCommRange).

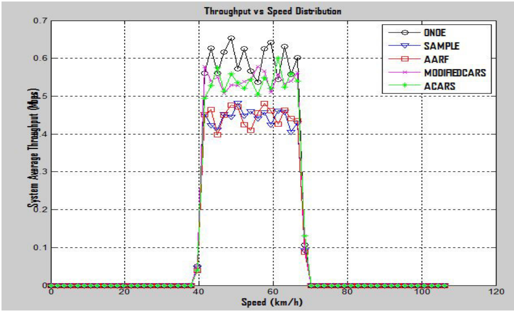

Fig. 5.Average system throughput vs speed for (Nofading, NoCommRange).

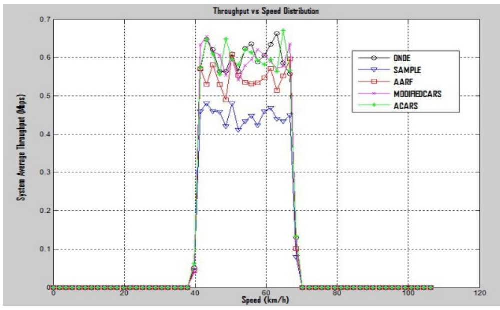

Fig.6. Average system throughput vs speed (Nofading, CommRange).

From our simulations, we have evaluated the impact of speed on various RAAs. Results show that, ACARS performs better than all other RAAs as a SNR-based RAA, since it can estimate SNR faster to the PHY layer.

One of our key contributions in this paper is the implementation of a SNR-based rate adaptation algorithm. ACARS, that can estimate SNR at the PHY layer for effect packet delivery in vehicular communications. ACARS performance makes it suitable for data transfer of safety messages, collision avoidance, congestion control, energy efficiency.

6. Conclusion and future work

We can critically evaluate these analyses to say that, ACARS will be suitable for a good range of environments; this means that vehicles will be able to maintain good performance, despite the different locations they are that is affected by propagation phenomena. Interestingly is that, it can perform indoor, outdoor and urban areas.

In the future, we will evaluate the impact of ACARS on other environments and also consider other context-information such weather condition, traffic signs, tunnel effect. We will also like to evaluate this algorithm in a V2V network and also try another simulation platform such as OMNeT++, NS2.

Acknowledgements

This research was supported by Education Trust Fund (ETF) through the Rivers State Polytechnic, Nigeria.

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