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COST 2100 TD(08) 453
Wrocław, Poland
2008/Febr/6-8

SOURCE: Department of Telecommunications,
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Performance Analysis of Outdoor IEEE 802.11 WLAN with Mobile Sensors/Vehicles

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PERFORMANCE ANALYSIS OF OUTDOOR IEEE 802.11 WLAN WITH MOBILE SENSORS/VEHICLES

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ABSTRACT

In this report, the preliminary results concerning the application of IEEE 802.11 protocol to a transmission between a base station and mobile vehicles are presented. In analysed scenarios, mobile vehicles are in the range of a base station only during the limited period of time, inversely proportional to their velocities. The simulation results of the achieved throughputs are introduced. The possible applications to wireless sensor networks, as well as to vehicular networks are discussed.

KEYWORDS

Traffic & Mobility Modelling and Prediction, Unlicensed Mobile Access, Wireless Sensor Networks

INTRODUCTION

The IEEE 802.11 standard [1,2] has become an extremely popular communication protocol. As its WLAN cards are nearly pervasive, they will probably become a standard equipment on board of any kind of car. The possible applications are manifold. Drivers could exchange a variety of information with base stations (access points) located along the roads, concerning the weather, traffic conditions, local infrastructure (shops, petrol stations, hospitals, etc.) or just to connect Internet. On the other hand, base stations could gather some traffic information from sensors mounted on vehicles' boards. This document is motivated by the research concerning the analysis of the performance of IEEE 802.11 protocol as a method for multiple access of moving vehicles connecting to a single base station (BS). The main issue addressed in this report is the low efficiency of 802.11 protocol when moving vehicles are in the BS range through the limited short period of time. Presented research results are rather preliminary, however, they show the way to find the potential problem's solution.

ANALYSED SCENARIO

In the considered scenario, there are multiple vehicles (mobile nodes) equipped with wireless transceivers driving along a motorway. The vehicles are moving with the same velocity and the same intervals between them. All the mobile nodes are going to connect and send a data using TCP protocol to a BS located near the motorway (Fig. 1). They must compete with others to gain the access to the radio channel and send their data. They are in BS range only during a limited period of time, inversely proportional to their velocity. The access to the channel is realised at the carrier frequency of 2.45 GHz using IEEE 802.11 protocol with collision avoidance scheme and employing RTS/CTS (Request To Send/Clear To Send) mechanism.

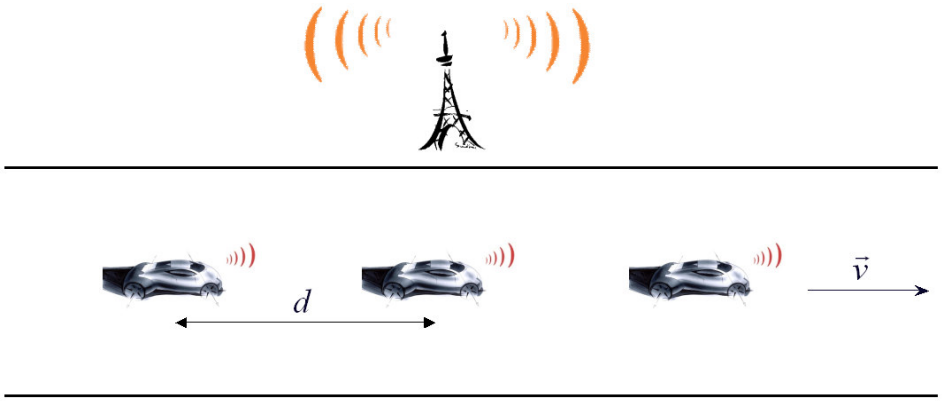

Fig.1. The analysed scenario: the vehicles are moving with the velocity v with a distance between two of them equal to d.

SIMULATION METHODOLOGY

All the simulations were performed with the ns-2 network simulator. It was assumed that the base station and all the vehicles were equipped with identical Cisco Aironet 802.11g WLAN cards with transmit power equal to 13 dBm and receiver sensitivity equal to –71 dBm. The BS antennas as well as the antennas of all the vehicles were omni-directional. The antenna height was 1.5 m for the vehicles and 5 m for BS.

There are 3 parameters that characterise the movement of vehicles on the motorway: traffic intensity i (in cars per time unit), their average velocity v and the average distance between vehicles d. These parameters are tied together by a simple equation:

$$v = i \cdot d \,. \tag{1}$$

The data throughput in 802.11 protocol is strictly dependent on how many other mobile nodes are contending for the wireless medium. Thus, the average distance d appears to be critical for the protocol performance. This is why the simulation results are presented below as a function of v and i with $d = const$.

PROPAGATION MODEL

According to the analysed scenario, the radio propagation channel model appropriate for rural environment should be applied. To the best of authors'

knowledge, there is no such well known and popularly used channel model for 2.45 GHz. In [3], D. Laselva *et all* propose a model which can be used in this case. The model is based on the measurements campaign for 2.45 GHz rural radio channels conducted in Oulu (Finland) during the WINNER project. For the distances between 100 and 400 m, the propagation loss can be estimated as:

$$PL = 38.3 + 21.1 \cdot \log(r) \text{ [dB]}, \tag{2}$$

with a shadow fading standard deviation equal to 2.9 dB.

This model was used to calculate the maximal range where the mobile nodes can communicate with the base station. For the WLAN card parameters mentioned above, this range equals to 146.5 m in average. More precisely, it is deviated by the signal fading according to the shadow fading deviation. For comparison, if two-ray propagation model [4] was used (where the path loss exponent is equal to 2 or 4 with a threshold calculated on the basis of the wavelength and antenna heights), the range was 154.5 m.

The channel is assumed to be narrowband. For each transmitted packet, the received power is calculated and compared with the receiver sensitivity. Consequently, a simple decision is taken: to accept or drop the packet.

SIMULATION RESULTS

In Fig. 2, the average data throughput between BS and mobile nodes is presented. The distance between two consecutive vehicles is 50 m, so each mobile node contends for the wireless medium with 5 other nodes, in average. The throughput is shown as a function of vehicles' velocity v. For $d = const$, v is proportional to i, so Fig. 2 can be also interpreted as a function of traffic intensity.

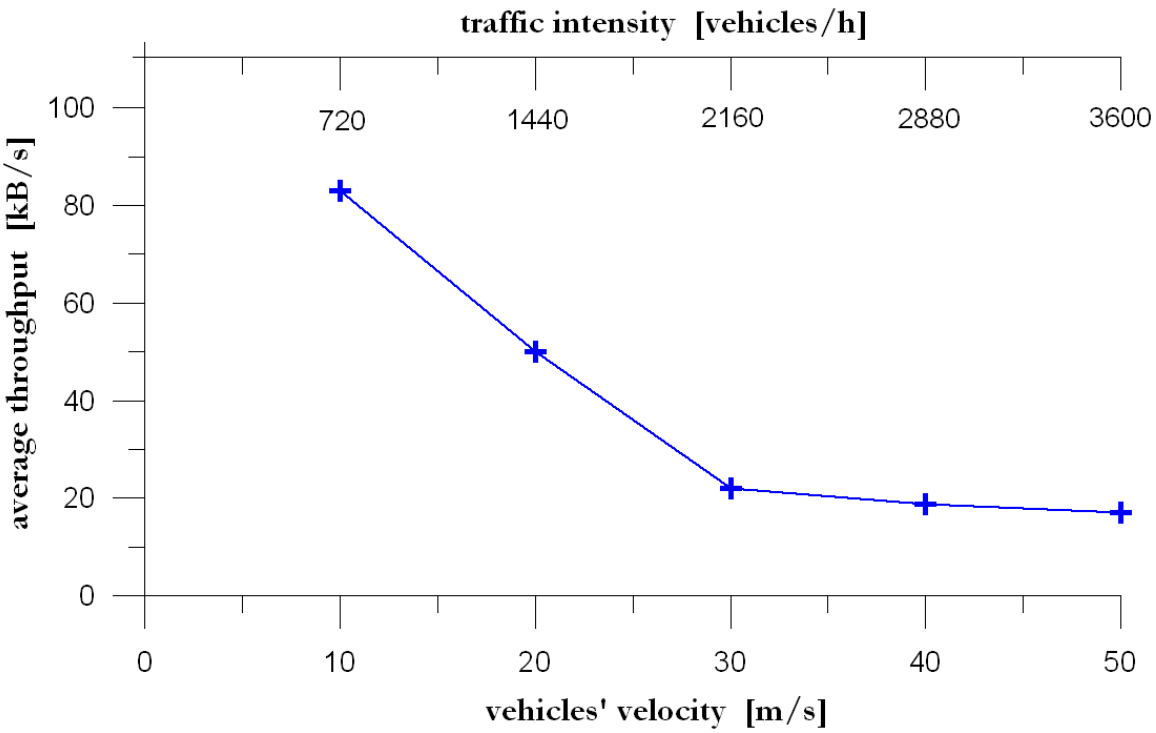

Fig. 2. The average throughput as a function of vehicles' velocity.
The interval between two consecutive cars is equal to 50 m.

The data throughput presented in Fig. 2 can be compared with the case where there is only a single vehicle on a road. Additional simulations showed that for a single vehicle the throughput could exceed 300 kB/s, independently on the vehicle's speed.

Two reasons for the relatively low throughput in analysed scenario can be pointed. First one is rather straightforward: because of possible packet collisions or necessary connection establishing procedures, IEEE 802.11 protocol is not effective when multiple mobile nodes need to contend for the medium during very short period of time. The second reason concerns routing protocols. The mobile nodes must be aware of the fact that they have entered into BS range. They can use short routing messages to check the connectivity with the base station. However, in the worst case, a mobile node could enter into BS range just after checking the connectivity and, in consequence, is wasting much of time.

The protocol performance can be improved by increasing the frequency of routing messages. In the scenario discussed above, the maximum update period of routing messages was equal to 15 s. The shortening of this period to 5 s will effect in significant increasing of the average throughput, in same cases more than two times – it is shown in Fig. 3. Such a solution can be appropriate when radio transceivers on vehicles' boards have reasonable energy supplies. Otherwise, e.g. when BS is communicating with small vehicle sensors equipped with limited batteries, frequent routing messages can consume the energy needed for data transmission.

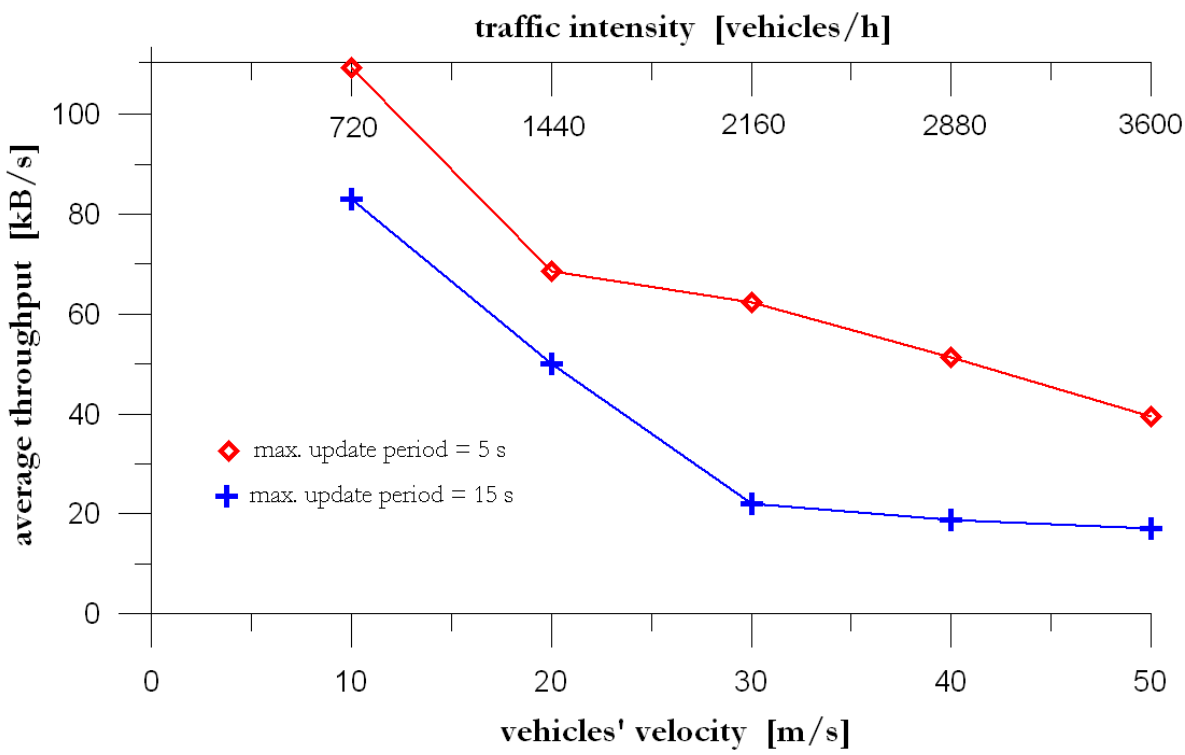

Fig. 3. The average throughput as a function of vehicles' velocity ($d = 50\text{m}$). Maximum period between routing update messages is equal to 5 s (red line) or 15 s (blue line).

CONCLUSIONS

The scenario of moving vehicles connecting with a base station by IEEE 802.11 protocol was considered in this article. The performance of the protocol was analysed with ns-2 network simulator. It was shown that the achieved data throughput increased with the frequency of routing messages exchanged between the mobile nodes and the base station.

The results presented in this document are preliminary and the considered scenario is rather simplistic. It is planned to continue the research using more realistic scenarios and conducting exhaustive simulations under different traffic patterns, channel characterisations and mobility models. The analysis should be also extended on different network layer protocols and frequency bands.

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