Analyzing downloaded data from road side units

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ABSTRACT

In the context of vehicular networks a map updating application was analyzed, which enables vehicles to download relevant geographic data related to their position. Possible strategies for data sharing are the networks from infrastructure to a vehicle (I2V) and from vehicle to vehicle (V2V). In this study two chunking techniques, the Random Sort Strategy (RSS) and the Network Coding (NC), for the I2V network segment were compared. The study revealed that the distribution of different received chunks is independent of the file size when NC is used; when RSS is used the mean and standard deviation depend on the file size. The authors intend to integrate in a next step these results in the analysis of the V2V network segment.

Keywords: V2V, VANet, map update, network coding, random sort strategy.

RESUMEN

En el contexto de las redes vehiculares, analizamos una aplicación de descarga de mapas, donde cada vehículo descarga datos de mapas relevantes según su posición. Entre las estrategias propuestas está la de utilizar las redes con infraestructura (I2V) además de las redes vehículo a vehículo (V2V). En este trabajo comparamos dos métodos de fragmentación de archivos, para el segmento I2V; los métodos son Random Sort Strategy (RSS) y Network Coding (NC). Encontramos que: cuando se utiliza NC la distribución de los diferentes fragmentos recibidos es independiente del tamaño del archivo. Cuando se utiliza RSS, la media y la desviación estándar dependen del tamaño del archivo. Estos resultados serán utilizados para el análisis del segmento V2V de la red.

Palabras clave: V2V, VANet, actualización de mapas, network coding, random sort strategy.

1. INTRODUCTION

Wireless networks are since their onset used in a wide variety of domains. The vehicular environment is one of them. The most important architecture in this domain is the Wireless Access for Vehicular Environments (WAVE). Vehicular Networks were developed in the United States, and used since 1999. For this application, the Federal Communication Commission (FCC) allocated 75 MHz of spectrum in the 5,9 GHz band to be used by intelligent transportation systems (ITS). This band has been called the Dedicated Short-Range Communications (DSRC), providing communications in specific locations between a vehicle and the roadside. DSRC was dedicated to inter-vehicular communications for the Intelligent Transportation Systems (ITS). In Europe, the European Telecommunications Standards Institute (ETSI) granted in 2008 30 MHz of spectrum in the same band. DSRC was integrated in the 802.11 working group and uses the IEEE 802.11p standard.

A wide variety of applications emerged, some of them using *unicast* (the transmission of sending messages to a single network destination identified by a unique address), others using *multicast* (group communication where information simultaneously is addressed to a group of destined computers). Currently data update applications have been developed allowing upgrading unicast to multicast; facilitating considerably the use of maps in communication.

Maps are increasingly used by several on-board applications such as: GPS, safety applications and Advanced Driver Assistance Systems (ADAS). Those systems convert maps into a powerful tool and considerably help users in decision making. ActMap (ERTICO, 2002) is a European project that develops and proposes mechanisms to deliver incremental map updates. A map update application is a specific download application updating map contents.

Astudillo *et al.* (2010) analyzed a map update application on different technologies, including the 802.11p protocol. The analysis revealed that satellite links are useful communication means for such application; suggesting that the 802.11p could be an alternative way to download maps, or sections of maps for the user/vehicle in a given region. The best measure of performance, in the context of vehicular networks, is to be able to download maps and information directly from the Road Side Unit (RSU) using an I2V (infrastructure to vehicle or vehicle to infrastructure) communication, as shown by Astudillo *et al.* (2012, 2013). Those authors showed in their study the superiority of multicast to unicast. A main limitation is that the high cost of RSU does not permit to install such a system continuous along highways. Consequently, there will be non-covered zones, resulting into intermittent connection between vehicles and infrastructure. A solution to this limitation could be the exchange of data between vehicles (V2V; communication from vehicle to vehicle) in the non-covered zone. The paper examines the performance of downloaded data from infrastructure along the highway.

2. PROBLEM STATEMENT

Figure 1 shows the studied scenario. It considers a straight highway portion. It is assumed that the highway is equipped with some RSUs (Road Side Units). The RSUs behave as access points. Vehicles enter the highway from one side and travel to the other side. Those vehicles use OBUs (On Board Units) to communicate with the infrastructure. Both, RSU and OBU implement the protocol 802.11p. As in real life, the highway is not fully covered with RSUs due to costs.

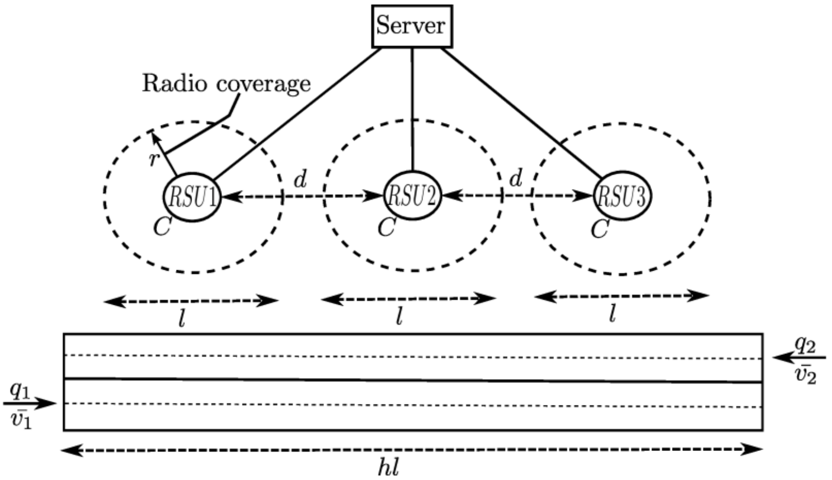

Figure 1. Schematic outline of the discontinuous configuration along a highway.

If the highway is not fully covered, vehicles have intermittent connection with the infrastructure (Fig. 2), but also with other vehicles. Vehicles driving in the same direction have less intermittence than with vehicles riding in the opposite direction. The intermittence time is given by the vehicles' speed and traffic density in both directions.

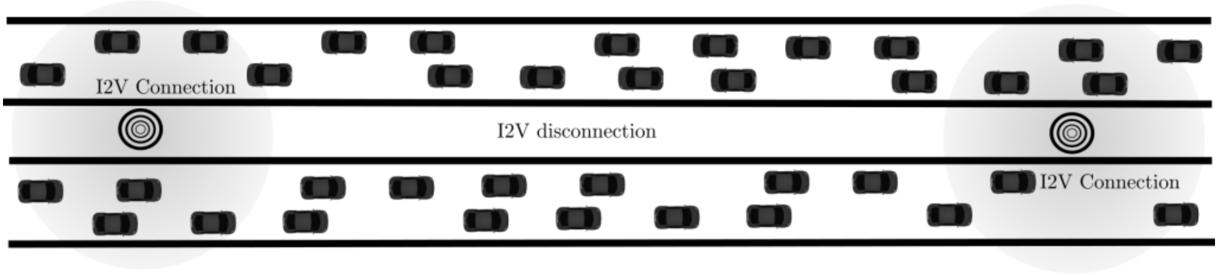

Figure 2. The scenario of intermittence.

Traditionally, an application server provides the vehicles with a map, or any other useful geographic data. To this end, a map is split into numerous chunks of constant size, each chunks being sent in a single packet. The transmission of large files is affected by the intermittency. For example, if OBUs do not succeed in capturing the entire file from the current RSU, they must wait for the next RSU. However, OBUs can also use the V2V communication system to exchange missing chunks. Figure 3 illustrates that if the four OBUs exchanged their chunks, after a few exchanges, all OBUs would get the complete file. To exchange chunks of files, OBUs may use different strategies. However, before exchanging information from vehicle to vehicle it is essential to known the quality and performance of the downloaded data from the RSU. Based on the performance of the downloaded data an optimized strategy to exchange data from vehicle to vehicle can be proposed.

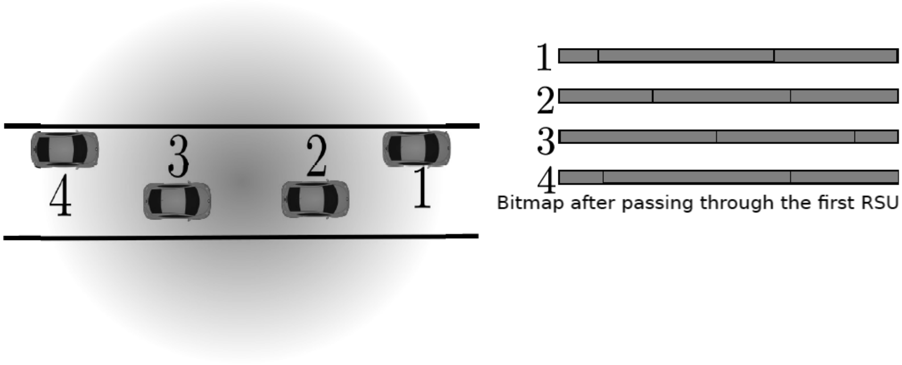

Figure 3. Downloading a file.

3. SYSTEM MODEL

NS3 is used as simulation tool to evaluate the behavior of the downloaded data. This section provides a description of the simulated model.

3.1. Mobility model

The length of the analyzed highway, possessing two lanes in both directions, is twenty-four kilometers. The IDM/MOBIL model is used (Arbabi and Weigle, 2010; Treiber, 2010). The entry rate of vehicles is set at $\lambda = 0{,}4\ veh/s$. The speed of a vehicle at the entrance to the highway follows a normal distribution with mean $\mu = 36\ m/s$ and a standard deviation of $\sigma_\mu = 1 m/s$.

3.2. Network topology

The typology of the general scenario is depicted in Fig. 4. The areas covered by a RSU alternate with “white” areas where V2V communication is used. The size of these “white” areas is variable depending on the density of RSUs.

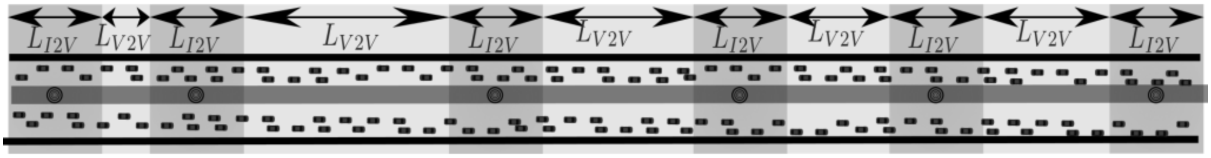

Figure 4. V2V as complement of I2V.

Figure 5 shows the simulated scenario, which is characterized by two RSUs covered zones of six kilometers at each end of the highway section. Three RSUs, equally spaced, are placed in each zone. V2V communications are not considered in the infrastructure covered areas. The portion in Fig. 5 represented by the distance L is twelve kilometers long. In that portion V2V communication is considered; of which the performance is subject of future research. Although, the ideal situation would be studying the entire topology, the complete simulation will be very demanding in memory and computation time, and therefore the simulation is proceed in two stages.

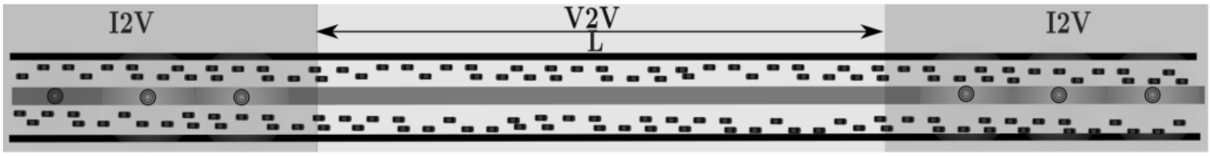

Figure 5. Simplified scenario with one long white area.

In a first simulation campaign, using only I2V communications, traces of the OBUs available to the output of a highway section were detected, and the correlation between the received chunks by the neighbor's vehicles analyzed. In future research, the results of this article will be used to analyze the performance of the V2V communications as a function of the received chunks from the infrastructure. In the current study the traces obtained from previous studies (Astudillo *et al.*, 2013; Astudillo *et al.*, 2014) were analyzed. The first study used Sort Strategies (SS), and the second Network Coding (NC). Specifically, we use the Random Sort Strategies (RSS) which seems to be the best from the results obtained in Astudillo *et al.* (2013).

Each trace belonging to an OBU contains a sequence of identifiers of chunks $T = \{t_0, \dots, t_{\chi-1}\}$ where χ is the number of different chunks received by an OBU. For traces from the simulation with RSS; the number of possible identifiers is equal to the number of chunks of the file (see Astudillo *et al.*, 2013). For traces from simulation with NC; t_i ranges between 0 and $2\beta - 1$, where $\beta = 32$ represents the number of bits used to generate the seed (see Astudillo *et al.*, 2014). For NC only the linearly independent chunks are kept.

3.3. *Application description*

The paradigm used is the "client-server", which is centralized. The proposed application is based on push technology. This choice was made because the contents are potentially intended for all vehicles. The use of query messages to request updates from vehicles compromise the application's scalability (huge amount of requests). Server sends the file when a new update is produced; OBU does not have to ask for an update. The server sends the file's chunks using RSS or NC. Both this transfer modes were evaluated.

Random Sort Strategies (RSS): The server will indefinitely send the file as a sequence of N chunks, $C_1, \dots, C_N$. The order in which the chunks are sent through a given RSU r is given by a permutation $\sigma_r: \{1 \dots N\} \rightarrow \{1 \dots N\}$.

Network Coding (NC): Let us define= $(c_1, \dots, c_N)$, $C_i \in \boldsymbol{F}_q$ a set of coefficients from the Galois field $\boldsymbol{F}_q$ where $q = 2\gamma$. Applying classical Network Coding techniques (Ahlswede *et al.*, 2000; Li *et al.*, 2003), enables the encoding of block B as a linear combination of the original chunks C_i:

$$B = \sum_{i=0}^{n} (c_i . C_i) \qquad (1)$$

Please note that C_i has to be seen here as a vector whose coefficients are in $\boldsymbol{F}_q$ (with bit packing, and potential padding with null values if the number of bits is not a multiple of γ). The number of dimensions of this vector is thus $d = L/\gamma$ where L is the bit length of the chunk, and γ is the number of bits of each coefficient.

A vehicle will be able to build the file as soon as it has received N blocks B_1 ... B_N that are linearly independent. These blocks and their associated coefficients build a system of N equations (such as Eq. 1) with N unknowns C_1 ... C_N. This system being linearly independent, the original chunks C_i can be computed. To build these linear equations, the receiver needs to know all the coefficients C_i for each block B. If the blocks have the coefficients included as overhead, this would lead to large overheads for large files. Each coefficient vector can be seen as $N \cdot \gamma$ bits, potentially hundreds of bytes, depending on the file size. For that reason another process was applied for the building of each block.

In the applied alternative process generates the server randomly a seed $s \in [0 \cdots 2\alpha]$ where α is the number of bits of the seed, assuming $\alpha = 32$. The N coefficients $c_{1,} \dots, c_N$ are built using the PRNG technique as defined in Payne *et al.* (1969). As far as $C_i \in \boldsymbol{F}_q$ and assuming that $\gamma \leq \alpha$, C_i can be built with the γ less significant bits of the PRNG results. The encoded block B_s is then computed using Eq. (1).

4. SIMULATION RESULTS AND ANALYSIS

The correlation between the chunks received by OBUs from the infrastructure was analyzed. In the case of RSS, each OBU received a number of different chunks (χ). Figure 6 shows that the number is well approximated by a normal distribution. The plotted PDF is the normal distribution with the same mean μ_χ and standard deviation than the simulations. μ_χ and σ_χ depend on the file size, as we can see in Fig. 7. Note that the standard deviation is low.

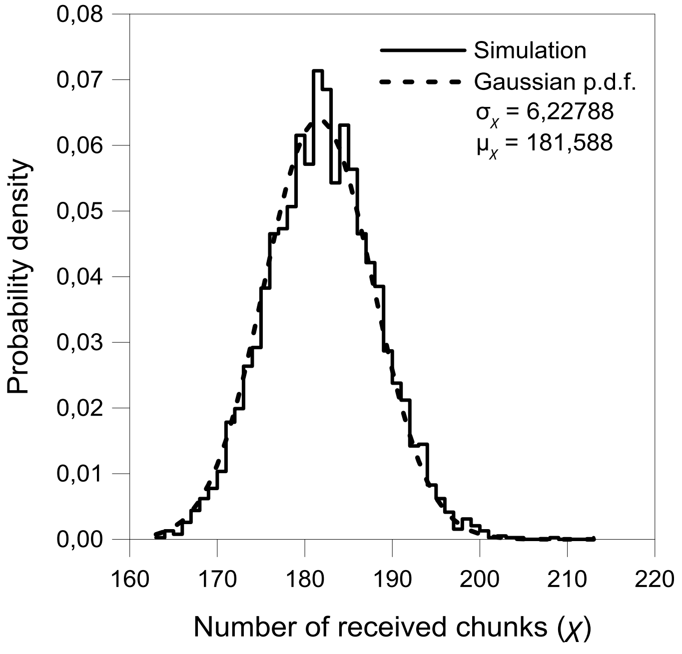

Figure 6. Probability density of the number of received chunks (using RSS).

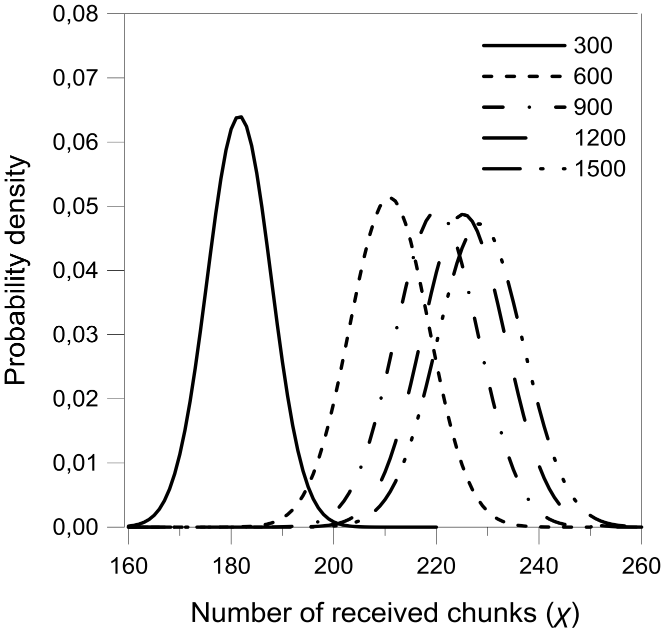

Figure 7. Normal distribution as a function of the file size (using RSS).

Equation (2) is used to measure the bitmap similarity between an OBU and its neighbors, calculated at the end of the RSU coverage. Ω is estimated from the traces.

$$\Omega(j) = \sum_{i=0}^{N} \left[\frac{\frac{(|\mathrm{T}^{\mathrm{i}} \cap \mathrm{T}^{\mathrm{i+j}}|)}{(|T^{i} \cup T^{i+j}|)}}{\mathrm{N}} \right] \tag{2}$$

where T^{i} is the set of received chunks from the reference vehicle and T^{i+j} the set of received chunks by its j^{th} nearest in front neighbor ($j > 0$) or behind neighbor ($j < 0$). Figure 8 shows Ω as a function of $j \epsilon \{-3, -2, -1, 1, 2, 3\}$; so it corresponds to the six nearest OBUs going out of coverage (three vehicles in front and three vehicles behind).

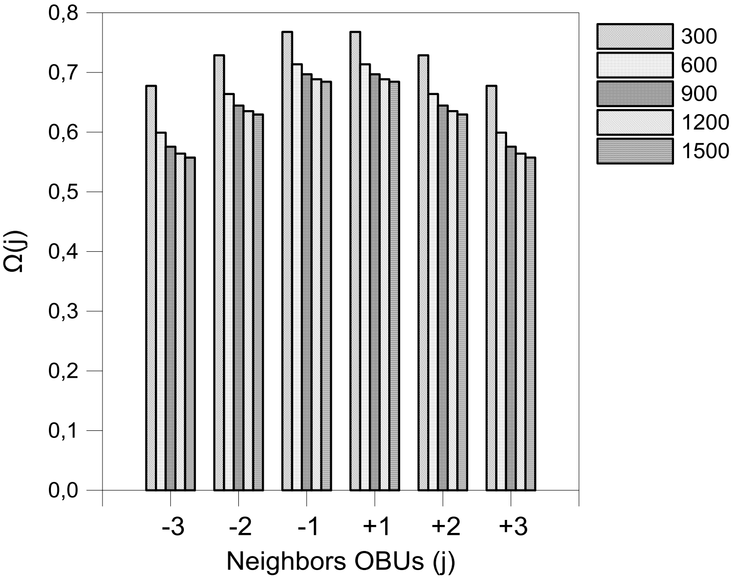

Figure 8. Bitmap's similarity index between nearest neighbors OBUs flowing in the same direction (using RSS).

For the applied density, an OBU has about 70% of common chunks with its two nearest neighbors. Further, Ω decreases in function of the file size. While OBUs are farther, they have fewer chunks in common. It should be noted that the measurements were taken after the vehicles left the I2V coverage area. Moreover, neighboring input are not necessarily the same at the output due to the mobility model. This is one reason why the slope of bitmap difference between j and $j+1$ is not very marked, as shown in Fig. 8.

Figure 9 depicts the results if NC is used instead of RSS, revealing that the distribution of the different received chunks is independent of the file size. It is noticed that the mean and variance of the number of received messages are functions only of the number of crossed RSUs. Figure 10 shows, regardless file size, that the similarity index is the same. This index is a function of proximity between adjacent OBUs.

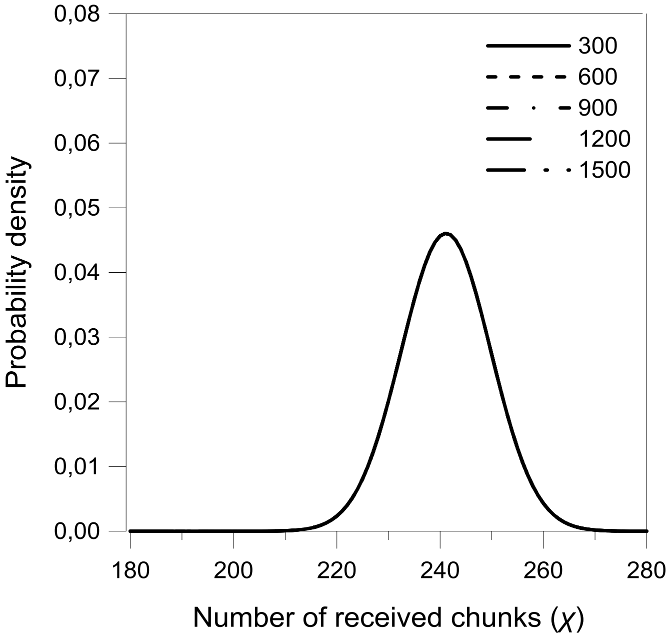

Figure 9. Normal distribution in function of the file size (using NC).

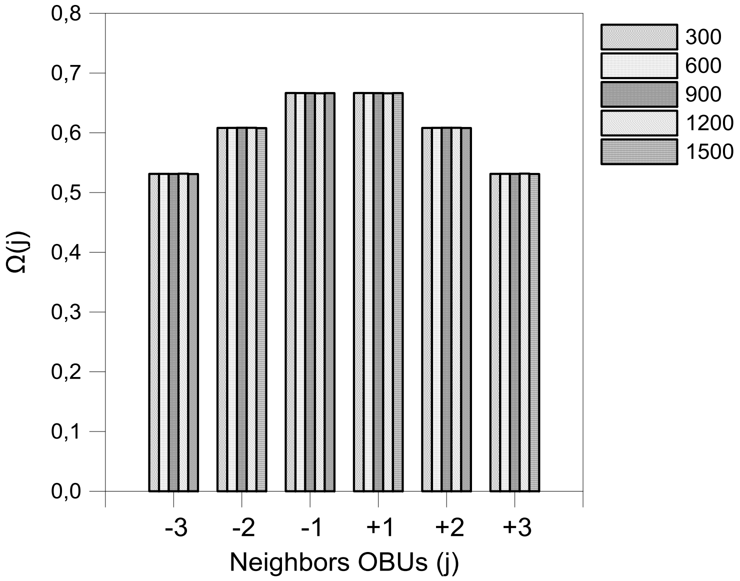

Figure 10. Bitmap's similarity index between nearest neighbors OBUs flowing in the same direction (using NC).

5. CONCLUSIONS

Results reveal that when using NC vehicles receive more chunks than using RSS. Moreover, the number of received chunks when using NC is only a function of the number of crossed RSUs; while using RSS the number of received chunks additionally depends on the file size.

The problem on the V2V communications using NC is the identification of chunks; because the chunks' identifiers are given by a random number generated at the server. Those identifiers have $\beta = 32$ bits. To exchange chunks using NC, vehicles need to send the list of identifiers. The bigger the file, the larger will be the list to be exchanged. The identifier of the chunk for the case of V2V communications using RSS is the chunk's position into file. To exchange chunks, vehicles can send a bitmap of their missing chunks. Next, the obtained results can be used to analyze the best way to exchange chunks between vehicles using V2V communications.

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