Preemptive Network Selection for V2V Communication

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***Abstract*—A key aspect to fill the demand for intelligent and connected vehicle solutions in C-ITS (*Cooperative Intelligent Transport Systems*), is to improve the network communication technologies existing nowadays. The actual radio network technologies may not support this future demand. One option to minimize this problem is to use extra information, like navigation GPS route, and use intelligent algorithms to choose the better infrastructure. In this paper we will show our proposed SISS algorithm and compare with TOPSIS algorithm to select network, using and not using the GPS route data, applying the requirements of different applications in the network selection. We present simulation results to show the differences of the proposed approach.**

***Keywords*—C-ITS; GPS Route; Interface Selection; Network Communication; SISS; TOPSIS; V2V.**

I. Introduction

This work claims to address the use of GPS information, available in the car navigation applications, to predict and select the best network infrastructure in C-ITS (Cooperative Intelligent Transport Systems) communication. The cellular infrastructure offers handoff technique, and studies has already been developed to optimize it for vehicular networks [1]. Therefore, the problem of mobility in the Network layer still. The IP Protocol does not offer mobility native. A major effort is being made in the academic community and industry to best develop mobility headers in IPv6 [2] but it will take time for it to be fully implemented. Our work aims to meet this need, being a transition mechanism, while the complete implementation of IPv6 mobility is not ready for vehicular communication. The main consideration of our work is that we analyze the constraints and the requirements of each connection that will be transmitted, by making the connection source choose the best network alternative available, without relying only on the choice of the operator, relieving the work in the service provider.

II. Related work

Two distinct types of networks for C-ITS applications exists for now. The conventional cellular networks, along with the next generation 5G and the DSRC (Dedicated Short Range Communications) IEEE 802.11p network, specially developed for ITS data exchange [3]. Although, the 5G network brings many innovations and solutions in data communication [4], we must not forget that it shares this access with many other applications. There is also the challenge of cost and redundancy. That is why our work is important since we assume that vehicles can use any network available and it is up to the source system to manage and choose the best network alternative. The following we will describe the important topics related to this work.

A. C-ITS Networks

It is necessary to identify how different networks can meet the applications requirements, allowing the use of several radio networks by the same source. The authors of [5] identify the strength and weaknesses of each technology and identified which technology is more suitable for witch networking scenario, they tested two of the most viable communication standards IEEE 802.11p and LTE (long-term evolution). They compared both standards in terms of delay, reliability, scalability, and mobility support in different application requirements. The results are that IEEE 802.11p offers acceptable performance for sparse network topologies with limited mobility support. LTE meets most of the application requirements in terms of reliability, scalability, and mobility support; however, it is challenging to get stringent delay requirements in the presence of higher cellular network traffic load. Studies of [6] shows cases in V2V (Vehicle-to-Vehicle) services in 3GPP (3rd Generation Partnership Project) and the standardization of LTE to meet the V2V requirements. They also discuss the challenges and detailed design aspects in cellular networks. They analyzed V2V services and possible 5G future solutions. As with all technological innovation, we assume in our work we will have a smooth transition of technology. When installing the 5G and IEEE 802.11p networks for communication of the C-ITS vehicles, the 4G and 3G networks will still be available. We consider the 5G, 4G, 3G and 802.11q networks with different configuration parameters, such as the bandwidth, jitter, latency, distance limit for communication and the cost of each access, for the network selection algorithms. Also, this is necessary even for reasons of transition, redundancy and backup. Work [7] affirm that the high node mobility in V2V can cause frequent network topology changes and fragmentation, and V2V are susceptible to vehicle density variations from time-to-time throughout a day. This imposes new challenges in maintaining connections between vehicular nodes.

The length of the connected link and its lifetime between network nodes are critical issues that determine the performance of the network. They conclude that the communication link length and lifetime is essential for designing efficient communication that support different application requirements in V2V. The paper [4] they investigate current vehicular networking architectures and their evolution towards the 5G era. The main driving force behind vehicular networking is to increase safety, with several other applications exploiting this system for traffic efficiency and multimedia services. They affirm that the current architectures can not meet the latency requirements of C-ITS (Cooperative Intelligent Transport Systems) improving significantly the performance of the networks.

B. GPS route

To analyze the performance gain when we know the route that the vehicle will follow, we will use the route information available by the GPS applications used in the cars navigation that implement C-ITS applications. We will use this information to calculate the maximum distance expected between the two cars communication. How this information is used, will be explained in the simulation section. Route selection algorithms, already use route source information and Cartesian position according to [8]. TBF (Trajectory-based Forwarding) algorithm combines source routing and position forwarding for ad hoc networks. The source node selects the route or trajectory to the destination. Unlike traditional source routing, they base the forwarding decisions in TBF on the relationship to the trajectory. They select the vehicle with the shortest expected data delivery delay as the next relay node. Safety applications are the most important motivating applications for V2V. In such applications, it should provide information to all surrounding vehicles, requiring a broadcast forwarding protocol. Traditional broadcasting techniques as flooding, seriously suffer from broadcast storm problem where a large amount of bandwidth is consumed by many retransmissions. When node density is high, this leads to numerous collisions and high channel contention overhead. Most of research activities in broadcast forwarding algorithms propose new ideas to this problem.

III. Network Selection

To select the best network to transmit the data packet, we select two algorithms to make the comparison and show the efficiency when already has the information of the route that the driver intends to use. This does not mean that the driver can not change his route. If he does, this route transition interval may be vulnerable to loss of performance in data transmission. We do not take account this transition in this work. Our work uses two network selection algorithms. TOPSIS is known for the work of [9] and the other SISS presented in [10]. Next, we will present the functionality of the algorithms.

A. TOPSIS

The TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) is a kind of MADM (Multiple-Attribute Decision-Making) implementation. In paper [11] they apply TOPSIS to the problem of network selection. And they proposed an improvement to the algorithm as applied to the question of network selection where only the top ranking alternatives are considered essential for decision making. Their approach iterative applies TOPSIS to the problem, removing the bottom candidate network after each iteration. The TOPSIS algorithm can be visualized in Figure 1.

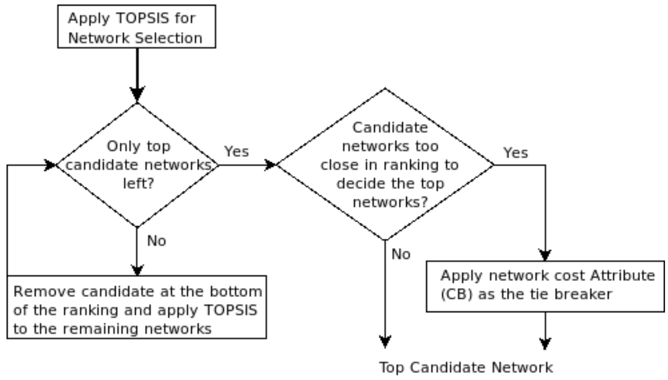

Fig. 1. TOPSIS decision making process [11]

IV. SISS

We propose a new SISS (Service-based Interface Selection Scheme) algorithm, which is a modification of the TOPSIS algorithm, optimized to V2V communication. The algorithm follows the steps: Before we run the network selection algorithm; we define constraints and requirements that each new connection have and rearrange the matrix of the network status with updated values. The values that can change in the simulation are *Total Bandwidth*, *Allowed Bandwidth* and *Utilization* parameters that will be describe ahead. We can visualize the SISS algorithm in Figure 2.

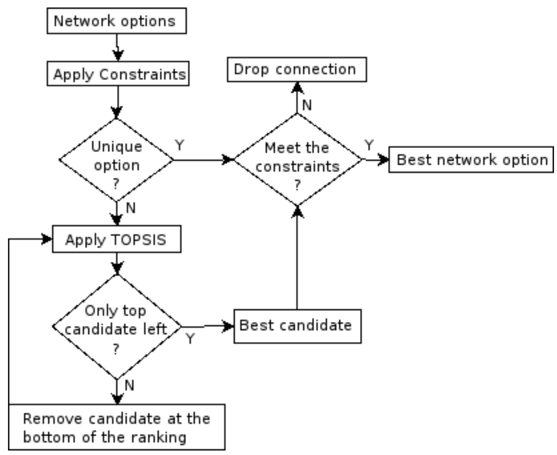

Fig. 2. SISS decision-making process [10]

For the network selection problem, the following is the set of attributes we consider in the decision-making process: Cost of Byte (*CB*), Bandwidth (*TB*), Allowed Bandwidth (*AB*), Utilization (U), Delay (D), Jitter (J), Packet Loss (L). There is i network alternatives we can consider in the selection process. We can represent the NW_i networks in the selection process in the form of a matrix, using the attributes above:

$$NW_i = \begin{bmatrix} CB_i & TB_i & AB_i & U_i & D_i & J_i & L_i \end{bmatrix}$$

We assume that the main applications that will be used in C-ITS communications are: v2v data (safety applications, etc), and also the regular data types on the internet as data (web and file access), video and voice. We describe the weights (w) of different attributes for common types of applications next.

- Data - A regular web application requires a low QoS service, delay, jitter, and packet loss is small. The total bandwidth and allowed bandwidth are therefore less critical, but it considers the transport cost significant.

- V2V packets - It is a low bandwidth signal used for C-ITS connections. But require the highest QoS and no loss. There are applications described in [12], that would allow the use of the high-level QoS independent of the cost in the network.

- VoIP - A low bandwidth application sensitive to delay and jitter but can resist packet loss. Total and bandwidth are not issues. It prefers low usage for the selected network since there is a correlation between utilization with jitter and delay.

- Video - Multimedia applications, for example streaming demands a higher bandwidth than VoIP. The bandwidth, transport cost, and current utilization are the fundamental characteristic. It is less exposed to delay and jitter than VoIP. Now we will describe the simulation environment.

A. Simulation

To simulate the connection attempts between the moving vehicles, we used road traffic simulator SUMO (Simulation of Urban Mobility) [13] to generate the random communication between the vehicles present in the simulation. The simulation lasted 10^3 seconds, and the vehicles uses randomly chosen routes. To generate the connection requests, we follow the pattern described in table I, randomly chosen and uniformly distributed in the total simulation time, between the cars (hosts) that wherein the simulation in that same period. The time for each connection also was randomly chosen. We use different connection times, this means that the connections start and end a random time, simulating a real environment, but always trying to override the capacity of the total bandwidth available.

TABLE I. DATA TYPE

Connection Type	Bit rate (Mbps)
v2v	0.5
data	8
video	10
voice	1

To analyze the use of the interactive SISS approach, we considered four networks in our simulation. Table II presents a snapshot of attribute values for these networks at the time of network selection, and this value can change for each new scenario.

TABLE II. ATTRIBUTE FOR THE CANDIDATE NETWORKS

	CB (%)	TB (mbps)	AB (mbps)	U (%)	D (ms)	J (ms)	L (10^{-6})
5G	100	40	0.2	0	400	50	100
4G	30	100	5	0	100	20	15
3G	100	50	2	0	100	15	15
802.11p	40	100	5	0	150	30	20

We represent the weights used in our simulation in Table III. This illustrates the importance rate of each parameter in the algorithm when selecting the best network.

TABLE III. WEIGHTS

	CB	TB	AB	U	D	J	L
w_{data}	0.25	0.2	0.2	0.2	0.05	0.05	0.05
w_{v2v}	0	0	0	0.1	0.4	0.4	0.1
w_{video}	0.2	0.1	0.1	0.1	0.2	0.2	0.1
w_{voice}	0.2	0	0.1	0	0.3	0.3	0.1

The system updates the utilization value $U(\%)$ of the networks in each new interaction. An essential step in the efficiency of the proposed algorithm in this work is the definition of the constraints and restrictions that each new connection will put before choosing the best network. In this simulation, we used two approaches. One simulation uses the route information, and we calculated the maximum distance between the vehicles. We identify this parameter as MD (maximum distance). And in the other simulation, that does not use the route information, we only use the initial position of the vehicles and we calculate the initial distance, identified as SD (start distance). In our experiments we use the Euclidean distance calculation 1.

$$SD = \sqrt{(X_{car1} - X_{car2})^2 + (Y_{car1} - Y_{car2})^2} \quad (1)$$

The maximum distance is called MD equation 2. We get the maximum value of the distance between the transmission time.

$$MD = max(\sqrt{(X_{car1} - X_{car2})^2 + (Y_{car1} - Y_{car2})^2}) \quad (2)$$

Next we will analyze the achieved results.

B. Results and Analysis

Each new connection request, the host would transmit the data on the network where the host already is connected at the time of the request, making no selection, letting the service provider make the best route choice and QoS for the user. Using our intelligent network selection scheme, from now on, with the restrictions and requirements that the service requesting access require, it is possible to choose the best network option available. To show the effectiveness of the algorithm proposed, we run eight simulations, with 500 to 4000 random solicitations of data, voice, video and v2v signal, as described on the simulation chapter.

Now it is possible to analyze in the graphs that applying the MD/SD techniques in each connection, and then, apply the network selection algorithm, we have more efficient use of the sum of the total bandwidth by all the networks available to the users in the congestion environment, that is after 1000 connections. Figure 3 we can observe the bandwidth when applied the SISS and TOPSIS techniques with the MD/SD approach.

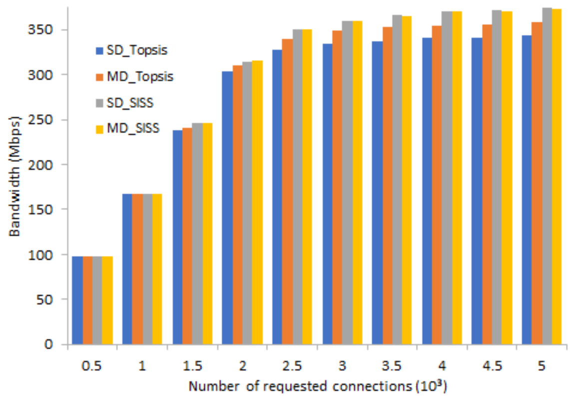

Fig. 3. TOPSIS/SISS(MD/SD) Bandwidth utilization

Despite of the minimal difference in the average band utilization of the SISS algorithm between MD and SD parameters, seen in Figure 3, it is possible to guarantee the effectiveness in Figure 4, when we show the drop packet.

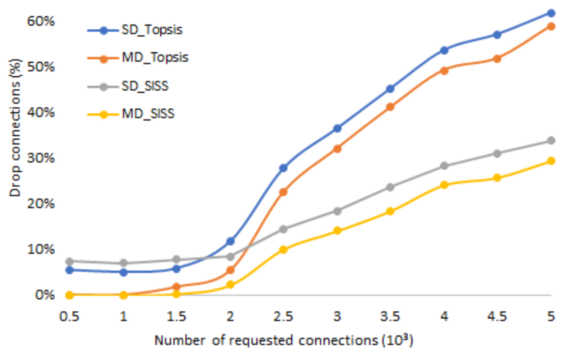

Fig. 4. TOPSIS/SISS(MD/SD) Drop connections

It is possible to see the differences between the TOPSIS and SISS algorithm, specially after 2000 connections. And the difference of the MD / SD parameter in each algorithm is visible. In Table IV we can measure the difference of discarded packets, when applied the MD parameter in each algorithm.

TABLE IV. EFFICIENCY

	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5
TOPSIS	5%	5%	4%	6%	5%	4%	4%	4%	5%	3%
SISS	7%	7%	8%	6%	4%	4%	5%	4%	5%	4%

Therefore, we can prove the effectiveness and improvement of data communication when using information external to the network environment, in this case, we use GPS route information, and not just jitter, latency and bandwidth, which are common parameters in the subject of communication networks .

V. CONCLUSION

The current radio network technologies may not support the demand of C-ITS applications in the future. So, it is necessary to use different techniques to meet the demands of this kind of data communication.

The aim of this research is to address the use of navigation GPS system, to predict and select the best network infrastructure. This technique can be a transition solution, while the complete implementation of mobility in the network layer is not ready. Doing this, we relieve the work in the service provider, and the source of the information can choose the best network option which meet the requirements of the application. We presented and analyzed the two techniques MD and SD and we show the gain when we use more than network parameters to select the network.

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