Service-based Interface Selection Scheme for V2V Network Communication

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***Abstract*—Increasingly, the automotive industry creates solutions for smart cars. These devices need to have effective communication between them, and this is growing the demand for C-ITS (*Cooperative Intelligent Transport Systems*) solutions. However, the current telecommunication infrastructure may not support this demand soon. One option to minimize this problem is use multiples networks and select the best infrastructure available even before to starting the communication. This work presents the SISS (*Service-based Interface Selection Scheme*) algorithm that aims to select the best network option for each new connection, taking the service requirements into account. We present simulation results to show the effectiveness of the proposed iterative SISS approach.**

***Index Terms*—C-ITS, V2V, Network Communication, Interface Selection, multiples networks, TOPSIS, SISS.**

I. Introduction

The automotive industry is constantly making efforts to improve services and solutions for smart cars. Data traffic in vehicular networks is expected to increase with the new applications for connected cars. DSRC (Dedicated Short-range Communications Services) and mobile networks surely promising to facilitate vehicular communications, the increasing traffic on vehicular networks will probably overload the capacity of channel resources of these radios networks in a long term [1]. Nevertheless, current architectures cannot meet the latency requirements of ITS applications in highly congested and mobile environments [2]. The future aim of autonomous driving forces current networking architectures further to their limits with hard real-time requirements [3].

An alternative solution to deal with the growing amount of data traffic is using multiples networks, which has been explored by the research community recently. The idea is motivated by the fact that commercial devices nowadays are usually equipped with multiple types of network interfaces (e.g., DSRC, Wi-fi and cellular), each of which has different characteristics concerning signal propagation, data rates, and costs. Moreover, some new studies in wireless communication using different technologies like millimeter wave, visible light, and TV white space bands would also promise to be widely deployed in vehicles communication.

The main goal of the future networking is to keep all the radios devices available, and active and dynamically select the suitable interface to transmit their data packets according to the vehicles context (e.g., channel load, road condition, distance between the vehicles and requirements of service) to improve the communication performance. The different features of the radios, in combination with an intelligent decision maker for network selection, makes it possible to complement the limitations of each type of channel, improving flexibility and reliability of wireless communications systems [1].

In this paper, a new service-based interface selection scheme is introduced to improve data communication using multiples networks, where each new connection solicitation will select the best network option available at that moment which can meet the constraints and requirements.

The obtained simulation results prove that using this selection algorithm we can better take advantage of the total bandwidth offered at one point. We organized the paper as follows, the first section introduces the importance of the research area, while in section 2 the most important related works are over viewed; in section 3 we explain how the selection algorithm works and we show the simulation results. Finally, we conclude this paper with analyses of this work and acknowledgment.

II. Related work

With the rapid development of wireless technologies, the trend of the next-generation network is the integration of heterogeneous networks. Though a place may be overlapped by several networks, that hardly will substitute each other regarding their differences in coverage, system throughput, quality of service (QoS) and mobility support [4]. Service performance in a heterogeneous IP wireless network environment requires the selection of an optimal access network. Selection of a non-optimal network can cause disagreeable effects such as higher costs or poor service experience. Different factors influence network selection in such environment, and a complete solution to solve this kind of problem are not available yet[5]. Most researches are focused on single access network selection algorithms, but to support seamless mobility and provide a better quality of service in heterogeneous wireless networks, this work proposes a network selection algorithm, where each new connection solicitation and each host can communicate with more than one network simultaneously. For example, suppose that exists one connection in progress, and we need to transmit other information, but the requirements of this new solicitation does not fit with the network that you already are using. Then, we should choose other network interface available that time to transmit the new connection solicitation.

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A. Related works on interface selection

Cellular systems provide users mobility, however, with high cost and the possibility of becoming congested, also is a single point of failure. Alternatives wireless networks should be adopted as a complementary service to support high bandwidth and low cost in congested urban areas. In [6], they work with a different mechanism of selection to integrated 3G and wireless LAN networks. The proposed network selection combines the Analytic Hierarchy Process and GRA (Grey Relational Analysis), another type of MADM (Multi-Attribute Decision Making) techniques.

In paper [1], they propose an intelligent interface selection mechanism, tailored to hybrid vehicle-to-vehicle communications. They introduce an approach of hierarchical decision making, in which a remote central server loosely controls interface selection by vehicles. The server provides a recommended interface selection strategy, which is based on the statistical previous knowledge about road and network conditions. In this paper, we focus on V2V (Vehicle to Vehicle) communication, assuming that vehicles can select independent and dynamic different options of network radio to transmit their information. A cooperative transmission algorithm using Fuzzy QoS gateway selection was proposed in [7]. They use vehicular ad hoc Long Term Evolution Advanced (LTE Advanced) with hybrid network architecture that elects a gateway to connect the source vehicle to the infrastructure under the scope of vehicle-to-infrastructure (V2I) communications, that means, a different scenario.

B. MADM

Various algorithm approaches have been proposed for ranking of candidate networks, with MADM being one of the most promising classes of techniques. These techniques are based on a deterministic approximation and have been broadly used in operations for decision making where the results impact several factors. In [4], they proposed a selection algorithm with parallel transmission based on MADM. In the algorithm, they first determine all available wireless networks and consider every subset of these networks as a network scheme. Then they get aggregation attributes of every scheme and define the alternative network schemes. Finally, they build the decision matrix of multiple attributes and determine the optimal scheme by using GRA. There are several applications for MADM, such as the simple additive weighting (SAW), the technique for order preference by similarity to an ideal solution (TOPSIS), analytical hierarchy process (AHP), data envelopment analysis (DEA) and so on [8], [9] and [10]. The grey system theory proposed by [11] has been widely applied to various fields [12]. It has been proven to be useful for dealing with weak, incomplete, and uncertain information [13].

C. TOPSIS

The TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) is a kind of MADM approach. In paper [5] they apply TOPSIS to the problem of network selection. The causes of ranking abnormalities in TOPSIS were analyzed and 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, was proposed. Their approach iterative applies TOPSIS to the problem, removing the bottom candidate network after each iteration. Simulation results show that proposed algorithm could improve the throughput of the connections solicitations and reduce the price-cost per bit. By this reason, we choose this technique modification to implement our selection scheme propose. How the algorithm works and its equations will be demonstrated in the next session.

III. Service-based Interface Selection Scheme (SISS)

In this session we propose a service-based network selection algorithm that relies on a modified TOPSIS method. The algorithm comprises five steps that we will describe and then summarize it with the proposed algorithm. We assume, in this work, that the vehicles are equipped with four types of network interfaces, UMTS 3G, LTE 4G, DSRC 802.11p and Wi-Fi 802.11n; and these interfaces can be active simultaneously.

In the beginning, 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. The constraints defined in this simulation environment follows:

- If the car is in movement, drop the Wi-Fi option because of the short communication range and the mobility restriction characteristic;
- If over 1 km distance, drop the 802.11p option (distance range limit of the standard);
- If the network choice does not support the requirements (e.g., bandwidth), drop this option and rerun the algorithm; if there is no other network option, drop the connection;
- If there is just one option, and this network meets the connection requirements, it is unnecessary to run the algorithm, it will choose the unique network available;
- If there is no network available, or if the networks available will not support the requirements, drop the connection.

After that, we use the modified approach of TOPSIS algorithm proposed in [14], that is represented in Figure 1.

For the network selection dilemma, the following is a representative set of attributes that are considered in the decision-making process:

- Cost of Byte (*CB*): Shows the relative transport cost of the access network. It should be considered factors such as the use of the spectrum and roaming agreement.
- Bandwidth (*TB*): How much bandwidth is available on the wireless access link.
- Allowed Bandwidth (*AB*): Indicates the bandwidth allowed per users basis.

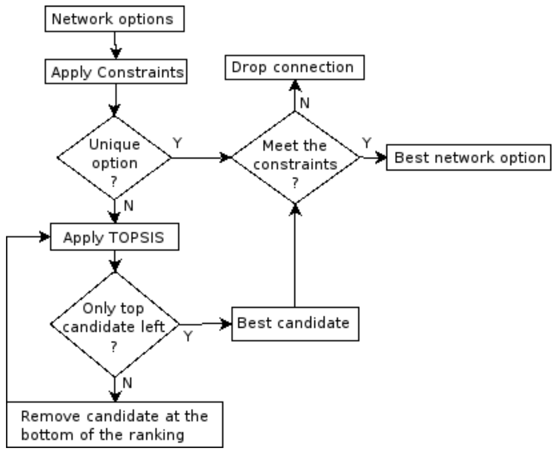

Fig. 1. Decision making process in an iterative approach

- Utilization (U): Provides a measure of current utilization of the wireless link.
- Delay (D:) Gives the average packet delay within the access system. It is not the end-to-end delay.
- Jitter (J): Measures the average delay variations within the access system.
- Packet Loss (L): The average packet loss rate within the access system. It can be expressed in packet loss probability.

There is i network alternatives to be considered in the selection process. We can represent the NW_i networks to be considered in the selection process in the form of a matrix, using the attributes above, as follows:

$$NW_i = \begin{bmatrix} CB_1 & TB_1 & AB_1 & U_1 & D_1 & J_1 & L_1 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ CB_N & TB_N & AB_N & U_N & D_N & J_N & L_N \end{bmatrix}$$

The TOPSIS algorithm modification comprises these steps used in [14]:

- The value for each of the attribute in matrix *NW* is normalized, to ensure accuracy in the selection algorithm. We use column normalized matrix technique, in the equation 1 each column is represented as C.

$$(C_{norm})_i = \frac{C_i}{\sqrt{\sum_{i=1}^{N} C_i^2}} \tag{1}$$

- The importance of each of the attributes involved in the decision about network selection is determined and adjusted accordingly with the weights (w), as represented in equation 2.

$$(C_{update})_i = (C_{norm})_i * w \tag{2}$$

- The best and worst values for each of the attribute are determined. Depending on the attribute, the best value can be the maximum or the minimum value. For example, in the case of the network utilization attribute, the best value will be the lowest and the worst value the highest. For the case of an attribute related to the allowed bandwidth, however, the best value will be the highest and the worst value the lowest.
- For each access network under consideration, the measures of closeness/separation S, for the best and worst cases, are calculated using Euclidean distances.
- For each of the access networks under consideration (represented by a row in matrix *NW*), its level of preference P is based on the relative closeness to the best and separation from the worst solutions. The preference value P as shown below represents a hyperbolic curve known as an indifference curve. The term indifference curve means that a decision maker would give equal preference to any of the alternatives on the same indifference curve (i.e., with the same value of P).
- The access network with the highest P value is selected.

Assignment of Attribute Weights (w) - The assignment of weights to different parameters in the algorithm plays a key role in network selection. It is proposed that the assignment of these weights be based on interpreting the requirements of the requested application as equation 3.

$$\sum w_{[CB,TB,AB,U,D,J,L]} = 1 \tag{3}$$

We assume that the main applications that will be used in C-ITS communications are: data (browsing and file transfer), emergency signals (safety applications), voice and video. The relative importance of different attributes for common types of applications is described below. Data - A Web browsing application requires a low QoS service; the importance of utilization, delay, jitter, and packet loss is small. It does not need a guaranteed bandwidth because of the type of the traffic patterns. With statistical traffic multiplexing for such traffic, wireless networks can deliver a consistent customer experience even at lower average data rates. The total bandwidth and allowed bandwidth are therefore less critical, but the transport cost is considered significant. Emergency packets - It is a low bandwidth signal used for e-Safety communication. Requires the highest QoS and no loss. It can transport warnings signal of traffic, stops, collision, pedestrian crossing, accident, speed, work zone and so on. There are some e-Safety applications described in [15], that would allow the use of the high-level QoS independent of the transport cost in the network. VoIP - Also a low bandwidth application that is very sensitive to delay and jitter but can resist some packet loss. The cost factor is supposed to be trivial because of low bandwidth usage. Also, because of low bandwidth specifications, total and available bandwidth are not issues. It is preferred to have low usage for the selected network, since there is a correlation between utilization with jitter and delay. Video - Multimedia service application, like streaming demands a higher bandwidth than VoIP. Consequently, the available bandwidth, transport cost, and current utilization are the fundamental characteristic. It is less exposed to delay and jitter than VoIP because of the ability to buffer data before playback, but influence to packet loss is similar to VoIP.

The main consideration of our proposed work is that we analyze the constraints and the requirements of each new connection that will be transmitted, by making the connection source choose the best network alternative currently available, without relying exclusively on the choice of the operator, relieving the work of the service provider. Finally, we can represent the SISS in Algorithm III.

Algorithm 1 Steps of the SISS algorithm:

Input: Available network options
Output: Network chosen

Step 1 :
1: Define weights of the attributes
2: Define the constraints
3: Filter interfaces (constraints)
Step 2 :
4: Select interface using TOPSIS Algorithm
Step 3 :
5: Verify if the interface selected meet the constraints
6: IF NOT Discard the interface selected
7: REPEAT Step 2
Step 4 :
8: IF The interface selected meet the constraints
9: Choose this network option
10: Finish the algorithm
Step 5 :
11: IF Any interface meet the constraints
12: Drop the connection
13: Finish the algorithm
END of algorithm.

For comparison and performance of the proposed algorithm, we used the sum of all bandwidth capacities on simulation, and we called *Aggregate_Bandwidth* in equation 3:

$$Aggregate\_Bandwidth = \sum_{i=1}^{N} CB_i \quad (4)$$

Now we will describe the simulation and the obtained results.

IV. Evaluation of the SISS method

A. Simulation

In order to simulate the communication attempts between the moving vehicles road traffic simulator SUMO [16] and python programming language was used. We use a usual square with four intersections with four traffic lights in each intersection to simulate one typical environment, as shown in Figure 2. The simulation lasted 180 seconds, and the vehicles use randomly chosen routes. To generate the connection requests, the pattern described in table I was followed, randomly chosen and uniformly distributed in the total simulation time, between the cars (hosts) that wherein the simulation in that same period. Moreover, the time for each connection also was randomly chosen. Different connection times are used, this means that the connections start and end at random, simulating a real environment, but always trying to override the capacity of the total bandwidth available.

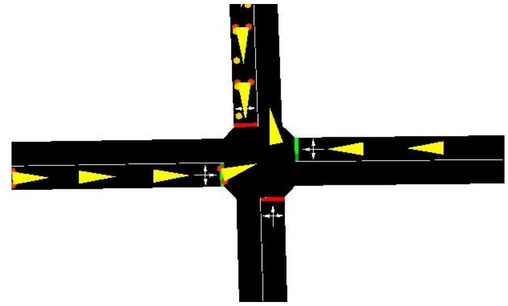

Fig. 2. Sumo Simulation

TABLE I
Data type connection requested

Connection Type	Bit rate (Mbps)
emergency	0.1
data	5
video	5
voice	0.2

To analyze the use of the interactive SISS approach, these four networks were considered in our simulation. Table II presents a snapshot of attribute values for these networks at the time of network selection, and these values can change for each new scenario. The weights used in our simulation is represented in Table III. This represents the importance rate of each parameter in the algorithm that is taken into account when selecting the best available network.

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 available network. Now we will analyze the obtained results.

B. Results and Analysis

Generally, with 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, without making any 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 at that time. To demonstrate the effectiveness of the algorithm proposed, we run five simulations, with 150 to 550 random solicitations of data, voice, video and emergency signal, as described on the simulation chapter. With this, it is possible to analyze in the graphs that applying the restriction 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.

TABLE II
INITIAL ATTRIBUTE VALUES FOR THE CANDIDATE NETWORKS

	CB		TB		AB		U		D		J		L	
	(%)	norm	(mbps)	norm	(mbps)	norm	(%)	norm	(ms)	norm	(ms)	norm	(10ˆ6)	norm
Ntwk#1 UMTS	100	0.53	40	0.14	0.2	0.02	0	0	400	0.53	50	0.43	100	0.67
Ntwk#2 LTE	30	0.16	100	0.34	5	0.41	0	0	100	0.13	20	0.17	15	0.10
Ntwk#3 802.11p	40	0.21	50	0.17	2	0.16	0	0	100	0.13	15	0.13	15	0.10
Ntwk#4 801.11n	20	0.11	100	0.34	5	0.41	0	0	150	0.20	30	0.26	20	0.13

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_emergency	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

Figures 3 and 4 we can observe the results in successful connections and fewer drop connections when applied the SISS technique instead of run the TOPSIS algorithm.

It is possible to confirm that SISS has 16.86% more effectiveness in successful connections.

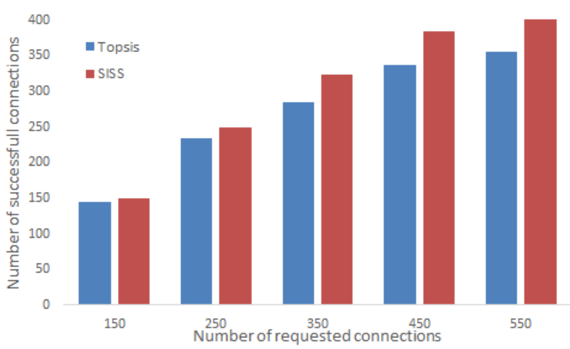

Fig. 3. TOPSIS x SISS successful connections

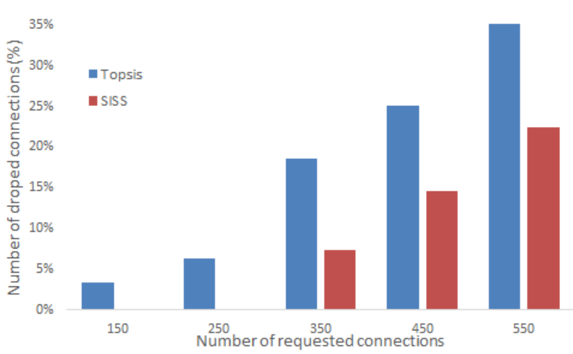

Fig. 4. TOPSIS x SISS Drop connections

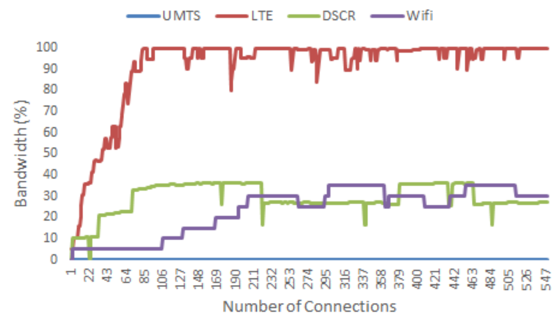

Fig. 5. TOPSIS connections per Interface

We can verify in Figures 5 and 6 the bandwidth utilization of each interface per connection of the two algorithms selections.

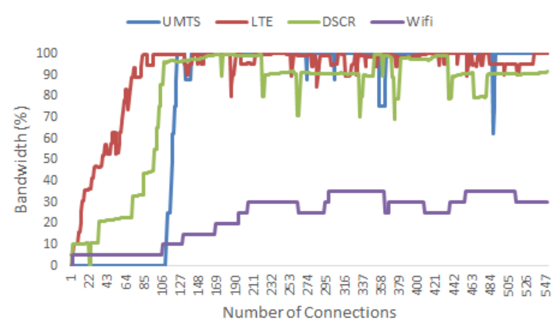

Fig. 6. SISS connections per Interface

Figure 7 shows the difference between successful and discarded connections between the TOPSIS and SISS algorithms, distributed among different types of data used in the simulation. As a positive sign, we do not have emergency signal discarded.

In Figure 8, we can compare how the different types of data were distributed between the different networks. All emergency connections were successful, so it was not placed on the comparative chart.

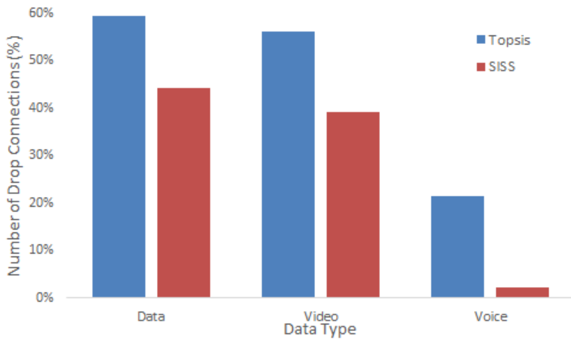

Fig. 7. TOPSIS x SISS Drop connections per Data type

We also have better use of the aggregate bandwidth. Figure 9 shows the aggregate bandwidth utilization with the 550 solicitations of randomly uniform distributed connections.

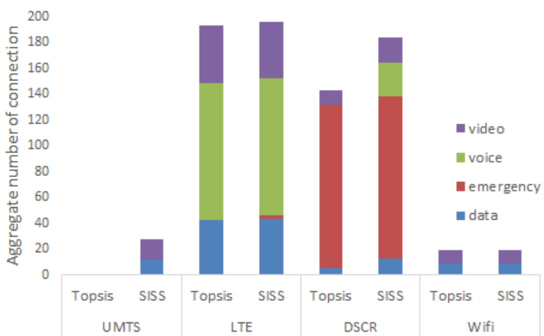

Fig. 8. TOPSIS x SISS Data type per Network

In a congestion simulation, SISS reach 220.1 Mbps, and only 143.5 Mbps using TOPSIS algorithm, this can represent 34.8% of the effectiveness of the SISS algorithm.

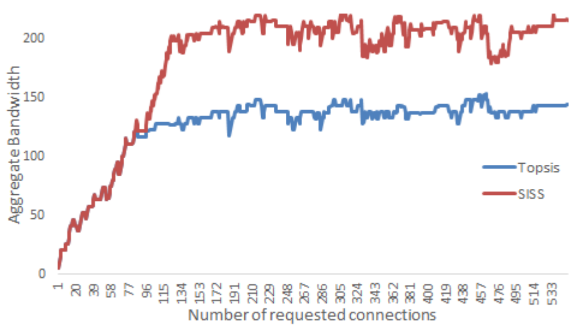

Fig. 9. TOPSIS x SISS Aggregate Bandwidth

V. Conclusion

The next generation of mobile communications systems in C-ITS systems should work together to give the impression of unlimited data capacity, impressive speeds, and excellent efficiency compared to currents networks. Also, these services would also require guaranteed performance. One way to get an improvement in our future infrastructure is to use multiples networks and apply intelligence when choosing the best available network at that particular moment. Decentralizing the control of service operators a bit and giving more flexibility when deciding which interface the application will use, to have a better guarantee of success of the connection. As a result, the users and systems could have a perception of the unlimited bandwidth available for their applications; this is the main implication of our proposed work. These characteristics will enable new types of applications such as connected vehicles, which are at the moment unfeasible due to constraints such as latency or capacity limitations of current vehicular communication systems. The future connected vehicles will lead to fewer accidents and improve fuel efficiency as vast volumes of data can be covered up in the cloud and provide real-time information to numerous vehicles. Wideband connectivity will enable system updates, driving software, and support next-generation applications. In the access network, current technologies should be optimized and cooperate with the new kinds of network radios access [3].

References

[1] T. Higuchi and O. Altintas, "Interface selection in hybrid V2V communications: A hierarchical approach," *IEEE Vehicular Networking Conference, VNC*, vol. 2018-Janua, 2018.

[2] S. Chen, J. Hu, Y. Shi, Y. Peng, J. Fang, R. Zhao, and L. Zhao, "Vehicle-to-Everything (v2x) Services Supported by LTE-Based Systems and 5G," *IEEE Communications Standards Magazine*, vol. 1, pp. 70–76, 2017.

[3] K. Katsaros and M. Dianati, *5G Mobile Communications*. Cham: Springer International Publishing, 2017.

[4] L. N. Zhang and Q. Zhu, "A Network Selection Algorithm with Parallel Transmission Based on MADM," *Applied Mechanics and Materials*, vol. 556-562, 2014.

[5] F. Bari and V. Leung, "Automated network selection in a heterogeneous wireless network environment," *IEEE Network*, vol. 21, no. 1, 2007.

[6] Q. Song and A. Jamalipour, "Quality of service provisioning in wireless LAN/UMTS integrated systems using analytic hierarchy process and grey relational analysis," *IEEE Global Telecommunications Conference Workshops, 2004. GlobeCom Workshops 2004.*, 2004.

[7] G. E. M. Zhioua, N. Tabbane, H. Labiod, and S. Tabbane, "A fuzzy multi-metric QoS-balancing gateway selection algorithm in a clustered VANET to LTE advanced hybrid cellular network," *IEEE Transactions on Vehicular Technology*, vol. 64, no. 2, 2015.

[8] K. P. Yoon and C.-L. Hwang, *Multiple attribute decision making: an introduction*. Sage publications, 1995, vol. 104.

[9] T. Yang, M.-C. Chen, and C.-C. Hung, "Multiple attribute decision-making methods for the dynamic operator allocation problem," *Mathematics and computers in simulation*, vol. 73, no. 5, 2007.

[10] T. Yang and C.-C. Hung, "Multiple-attribute decision making methods for plant layout design problem," *Robotics and computer-integrated manufacturing*, vol. 23, no. 1, pp. 126–137, 2007.

[11] J.-L. Deng *et al.*, "Control problems of grey systems." *Sys. & Contr. Lett.*, vol. 1, no. 5, 1982.

[12] C.-T. Lin, C.-W. Chang, and C.-B. Chen, "The worst ill-conditioned silicon wafer slicing machine detected by using grey relational analysis," *The International Journal of Advanced Manufacturing Technology*, vol. 31, no. 3-4, 2006.

[13] Y. Kuo, T. Yang, and G. W. Huang, "The use of grey relational analysis in solving multiple attribute decision-making problems," *Computers and Industrial Engineering*, vol. 55, no. 1, 2008.

[14] F. Bari and V. Leung, "Multi-attribute network selection by iterative TOPSIS for heterogeneous wireless access," *2007 4th IEEE Consumer Communications and Networking Conference, CCNC 2007*, 2007.

[15] P. M. Khilar and S. K. Bhoi, "Vehicular communication: a survey," *IET Networks*, vol. 3, no. 3, 2014.

[16] M. Behrisch, L. Bieker, J. Erdmann, and D. Krajzewicz, "Sumo–simulation of urban mobility," in *International Conference on Advances in System Simulation (SIMUL 2011), Barcelona, Spain*, vol. 42, 2011.