Using Complex Networks Metrics to Define 5G Virtual Cells

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Abstract. *The paper presents a vision in tests in 5G networks, fifth generation phones networks, using a ns-3 test environment, addressing their main applications and problems. The objective is to demonstrate the applicability of this new network, to better connect and stability its users. This work searched accomplish tests, to better acknowledge of network and his better applicability.*

1. Introduction

Nowadays, with the fast evolution of technology and its applications, new means of communication that are faster and more efficient in order to connect all people and things are needed. Today's 5G (fifth generation mobile phone networks) networks are seen as the best network for such requirements, given their applications and how they operate. As you look at this new type of network, you can see that it is a faster network that has great connections to Internet of Everything (IoE). With the high level of devices and things connected in 5G network, it turn's into a ultradense network.

The 5G networks will be ultradense network (UDN) and heterogeneous (HetNets). These characteristics generate several challenges such as the ubiquitous wireless broadband connectivity [Carmo et al. 2019]. In 5G UDN, users are connected to radio mast (5G cell site or 5G new radio base station (gNodeB)) through a virtual cell known as V-Cell or VC [Riggio et al. 2014]. However, the virtual cell based on vehicle needs is still an underutilized area [Hung et al. 2019]. It lacks new mechanisms for 5G services improvement, like IoV through 5G vehicle-to-everything (V2X) communications.

This paper presents a new approach to virtual cells formation through a criteria based on user speed and complex network metrics. A software defined network (SDN) controller that previously knows the network topology in its control plane, applies speed rules to the first cells selection by size and range radius. Once this available cells subset is chosen, probabilistic approaches are applied together with greater network knowledge, in particular, the neighbor radio masts of a particular vehicle. The different metrics of radio masts are be analyzed: vertex and betweenness degrees based on complex networks, besides the distance from the vehicle to a radio mast. These metrics are mathematically modeled by probabilistic equations. The results, obtained by the equations, are classified and combined. The combination result indicates the choice decision of an optimized subset of cells that constitutes a virtual cell. Once the best candidate radio masts are chosen, the SDN controller updates the virtual cell.

Some scenarios were simulated with the proposed approach: two different urban scenarios and a freeway one, with variations in the user densities (active vehicles) and with the radio masts available in their topologies. For the evaluation, the number of active virtual cells in common and total radiated power were analyzed and compared with the literature results.

This paper is organized as follows: Section 2 presents the related work; Section 3 presents the proposed approach for virtual cells selection; Section 4 describes the methodology adopted; Section 5 presents the results obtained; and Section 6 discusses the conclusions and propositions for future work.

2. Related Work

The virtual cells allows the creation of an user centered approach. They are several transmission points with an association for each user mobility pattern [Sahin et al. 2017]. The virtual cells are formed by the association of an user with some near transmission points. It is highlighted that TPs should act in a cooperative way and adapt themselves to user mobility. With this, the V-Cell moves as the user moves. A controller is required to dynamically configure and manage the virtual cells, that can be instantiated by the network slice according to specific service requirements. Previous works about virtual cells are summarized in Table 1.

Table 1. Related Work

Work	Brief Description and features
[Riggio et al. 2014]	A view of the design and system architecture of V-Cell is provided.
[Chen et al. 2016]	UE act as access point.
[Behnad and Wang 2017]	Probabilistic formation of small virtual cells by the density of users in the network.
[Liu et al. 2017]	V-Cell is constructed by finding an optimal radius and analyzing the load.
[Gharsallah et al. 2018]	Addresses handover management. In one of its phases, the creation of V-Cells occurs considering cell size and speed of the UE.
[Sahin et al. 2018]	Transmission points of a V-Cell are determined with those that are closest to the center of each user. A dynamic environment was not considered.
[Shi et al. 2018]	The authors adopt a strategy called *K-nearest*, i.e. a UE chooses the k APs closest for V-Cell formation.

In [Riggio et al. 2014], the authors present virtual cells abstraction so that the resources of heterogeneous cells can compose a single set of resources managed by a controller. In this way, the V-Cell is logically seen as a single macrocell. Each user is associated to a virtual cell with an unique and dedicated identifier, allowing that a zone without handover can be obtainable within a V-Cell.

In [Chen et al. 2016], a new ultra dense network architecture is presented with dynamic grouping of base stations or user equipment (UE) acting as access points, mobility management (virtual cell dynamic adjustments in relation to the UE movement), resources (detection of system capacity), interference (a data flow transmission together with and cooperatively to improve the spectrum efficiency and the quality of experience (QoE)) and security (radio masts authentication and UE in virtual cells).

In [Behnad and Wang 2017], an approach about the small virtual cell for 5G formation is proposed. The ideal density of small virtual cells is obtained in order to increase the network total capacity. The authors present a virtual formation of small cells through the choice of some users by probability, which acts as radio mast and will attend other neighbor users in the network. The number of small cells increases logarithmically with the density of users. The idea is to reduce the connections with the macrocells. It is possible to understand that other features need to be considered, for example, the user speed. A user's overload to attend his/her neighbors and the reward for such task were not exploited in this work, as well the performance gain.

In [de Aguiar and da Silva 2012], it was proposed to study a dinamic linkage model considering three main factors: (i) Connectivity, in wich more connected communities are privileged in choosing links; (ii) Homophilia, connections between communities are more attractive; (iii) metric, linkage is favored due to proximity between comunities. It was analyzed how the behavior of connectivity distribution and dynamic evolution of the network are affected by the metrics, being them: betweenness centrality and density.

The virtual cell design centered on the user is presented by Liu et al. [Liu et al. 2017], based on load (load-aware). The user reference signal received power (RSRP) measurements are sent to a network controller. In the first step, an optimal radius is found by the saturation point of the system average spectral efficiency. Then so, the charge is analyzed. The results demonstrated that the proposed scheme avoids cell congestion and finds a balance between resources and performance.

The 5G UDN and HetNets generate frequent handovers, unwanted, unnecessary (ping-pong effect) and failed handovers and, delay increase in the handover process. Thus, a software defined handover solution (SDHO) for 5G networks is presented by [Gharsallah et al. 2018]. The developed solution is divided into 4 phases: data collection, data processing, V-Cells creation and, handover execution. As a differential, the V-Cells creation considers the cells' size (small, medium or big) depending on the user speed. However, the speeds are not explicit. In this work, the authors implement a software-defined handover management engine (SDHME) and simulate the proposal through the MATLAB, comparing results with the traditional long term evolution (LTE) handover process. However, SDHO is simulated considering the LTE parameters. The authors demonstrate that the presented proposal reduced two metrics: delay rates and handover failure.

Sahin et al. [Sahin et al. 2018] present a V-Cell concept, which can be applied in several V2X use cases where broadcast communications for a group of vehicles occur, for example, cooperative awareness messages (CAMs) and decentralized environment notification messages (DENMs). For this, the authors have adopted the steps of intra-VC optimization (transmission weight selection), power control and admission control. The authors assume that through co-operative beamforming all the TPs in a V-Cell are transmitting the same data in parallel to a vehicle. So there is no intra-VC (V-Cell) interference. However, inter-V interference needs to be considered. A s data symbol of a data flow in a V-Cell is transmitted with a p transmission power and distributed throughout all TPs of the V-Cell according to the w weighting factors. This proposal was evaluated by MATLAB simulations considering LTE systems channel parameters.

The data transmission with cooperative millimeter wave (mmWave) antennas is discussed by Shi et al. [Shi et al. 2018,Shi et al. 2019], which derived integral expressions for the coverage probability and the ergodic capacity of user-centered dense networks. The sensitivity of locks, different distributions of small scale fading (Nakagami, Rayleigh and no fading) and access points cooperation were considered for derivations. One detail is that the APs were supposed to be in line of sight (LOS) since the results demonstrated that the probability of the APs being in LOS increases as the density increases, and tends to be 1. The authors still assume that the APs transmit to the UE with maximum antenna gain via beam alignment and all APs have the same power. The authors consider that the *K-nearest* APs association strategy is more practical than the *K-best* strategy (which considers the power) and thus, there is a lower signaling overload. For the simulations, the authors considered that the APs were distributed within a radius of 100 meters, with a transmission power of 30 dBm, with a frequency band of 73 GHz and a bandwidth of 2 GHz. The authors conclude that the characteristic limited by the communications noise in mmWave is closely related to the APs density and that the APs co-operation provides high coverage performance and capacity gain when the density is low.

3. The Proposed Approach

This section presents the proposed approach, introducing the cell selection rules for vehicle-centric V-Cells formation using the 5G UDN. In the first step, the choice occurs by the speed ranges and the cell size (Subsection 3.1). In the second step, the cells selection is based on complex network metrics (Subsection 3.2). The general scheme of the proposed solution is shown in Fig. 1.

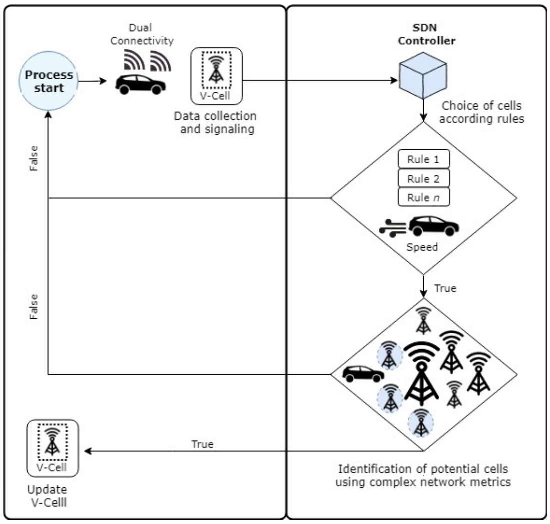

Figure 1. Functional diagram.

In Fig. 1, in order to ensure better QoS for IoV applications and always enable the best connection through the always best connected (ABC) concept, dual connectivity (DC) is indispensable. The vehicle connects to the LTE and to the 5G base stations simultaneously, that is, each vehicle has two interfaces, as shown in Fig. 3. The connection takes place through packet data convergence protocol (PDCP) [Polese et al. 2017].

When a vehicle initially registers itself within the network, we assume that its connection occurs primarily in the 4G macrocell as described in [Zang et al. 2019]. We further assume that the data transmission occurs in a cooperative way at the V-Cell and that all the available radio masts are in the line of sight (LOS), as well as described in [Shi et al. 2018] and [Shi et al. 2019]. An initial virtual cell is instantiated by the matching of all the available radio masts for each vehicle using the k-nearest strategy by its range (up to 300 meters). We further assume that each V-Cell is a network slice for a specific IoV service.

The V-Cell update procedure is shown in Fig. 2. When an IoV service is required or a handover is needed, the first step consists in a SDN controller selecting cells by specific rules. The size of the cells that best suits to the vehicle' speed is an important one. The radio mast in which the vehicle is being serviced is maintained during the update.

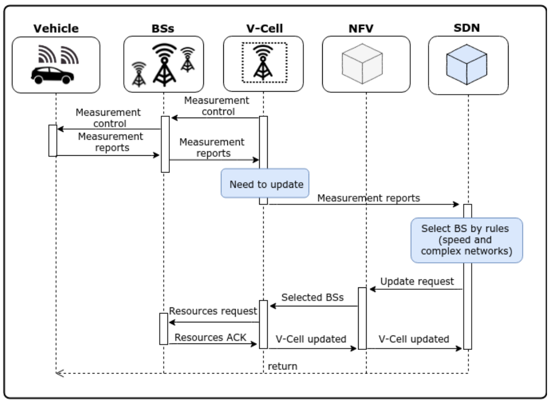

Figure 2. V-Cell update procedure.

Then, up to three radio mast are identified in the selection process. If no potential cells are identified, the algorithm returns to its initial state. If potential cells are selected, the V-Cell is updated. Finally, it is emphasized that the main processing is performed in the controller. In this way, vehicle energy expenditure and signaling costs are minimized as the core of the operations is performed by the controller.

3.1. Speed Rules

In order to ensure good service experience to any user or vehicle, specific rules about the cell size that best match with the vehicle's speed were created. These rules are presented in Table 2. We consider the following sizes for the best case: small cells (picocells) for speeds between 0 and 30 km/h; medium cells (microcells) for speeds between 31 and 120 km/h; and big cells (macrocells) for extremely high speeds (between 121 and 500 km/h).

Table 2. V-Cell Rules to Speed Ranges

V-Cell	Low speed 0-30 km/h	High speed 31-120 km/h	Very high speed 121-500 km/h
1st option	Small size cell	Medium size cell	Big size cell
2nd option	Medium size cell	Big size cell	Medium size cell
3rd option	Big size cell	Small size cell	Small size cell

If it is not possible to allocate according to the size of the cell, in the worst case, it is applied the second or the third option according to the topological network availability, that is previously known by the SDN controller through its control plane. Fig. 3 illustrates the application of V-Cell instances according to vehicle speeds in a 5G UDN network topology.

As in [Sahin et al. 2018], we assume that all instantiated V-Cells are network slices for each IoV application or specific vehicles, and the resources are shared by different V-Cells. This means that each vehicle has its own V-Cell, distinct from other vehicles and

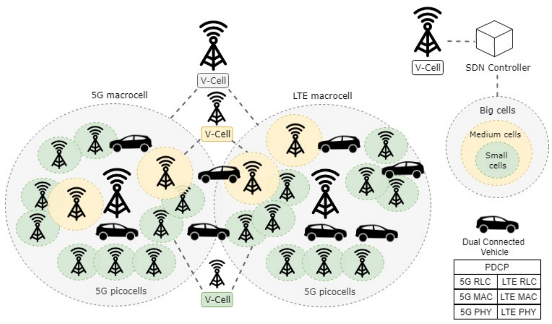

Figure 3. Proposed macrodiversity solution in 5G UDN.

thus n V-Cells are instantiated by the SDN controller, even for broadcasting use cases. Each user or vehicle is unique in the network, even if a group has the same radio masts in common in a subset of n V-Cells, due to the network dynamics, V-Cells are updated independently of the broadcast communication that is still received by the group.

3.2. Use of complex networks to the cell selection

The identification phase of candidate cells to update the 5G UDN network virtual cell is performed by adopting complex network metrics. They are based on the importance of a base station (BS) in the network (we assume up to three potential candidate cells if available in the topology) and the position of the user or vehicle.

Studies show that the complex network metrics help in the solution of diverse problems in vehicular networks [Rezende et al. 2011, Lousada et al. 2019]. Thus, the present work combined probabilistic approaches together with a better network knowledge, in particular, the neighboring base stations of a user or vehicle. Once the three best base stations or candidate cells of the vehicle-specific V-Cell are chosen by a probabilistic calculation, the update of the V-Cell is performed.

Each user or vehicle maintains a table of contextual knowledge of its neighboring base stations as well its neighboring vehicles, which allows it to choose the best radio mast in terms of both proximity and available network resources. The following metrics are used:

- BS degree: the BS's that have a high degree are the most active in the network. The higher is the cell degree, the smaller is its probability to be chosen as a candidate cell.
- Betweenness: it is the centrality of intermediation, one of the most interesting measures, because it indicates the most influential nodes within the network. It can also be seen as the entity's capacity to make connections with other entities or groups. The higher it is, the smaller is the probability to be chosen as a candidate cell.
- Vehicle distance to BS: the position of the vehicle in the network is one of the main factors to choose or not the potential candidate cell. Thus, the smaller it is, the higher is the possibility to be chosen as a candidate cell.

The probability of the candidate cell selection, called *pS*, is calculated by the product of the probability associated with the BS degree (*pBSdegr*) and the probability associated with the betweenness (*pBetw*), divided by the vehicle distance to BS (*distVehBS*), formulated by the equation (1):

$$pS = \frac{pBSdegr \times pBetw}{distVehBS} \tag{1}$$

For the selection of candidate cells, it is interesting to choose radio masts that have a lower grade value. For the *pBSdegr* calculation of a particular BS, it is necessary for the BS to know the degree of the vertex of all its BS neighbors and vehicles connected. This value is maintained and updated in its neighbors' table. The *pBSdegr* calculation is given by 1 (one) minus the division between its vertex degree (*vDeg*), obtained by counting the number of vehicles and radio masts reachable (this information is kept in the neighbors table of the BS itself), and the sum of the vertex degrees of its neighbors (*VDegNeig*), as shown in equation (2).

$$pBSdegr = 1 - \frac{vDeg}{VDegNeig} \tag{2}$$

Following the same reason as the previous metric, for the selection of the candidate cells, it is interesting the radio masts choosing that have a lower betweenness value. The normalized betweenness calculation (in undirected graphs), to measure the BS importance, is shown in the equation (3), where g_{st} is the shortest path from source (*s*) to destination (*t*), and n^i_{st} is the shortest path from "*s*" to "*t*" passing through "*i*".

$$pBetw = \frac{1}{\frac{(N-1)\times(N-2)}{2}} \sum_{s \neq i \neq t} \frac{n^i_{st}}{g_{st}} \tag{3}$$

As the differential of this work, this step suggests the adoption of complex network metrics to assist the choice of radio masts that will constitute virtual cells. Thus, we aim to improve the efficiency of the radio resource use, and the current service or IoV service user experience, especially in ultra-dense networks, such as 5G.

As proposal to creation of a virtual cell a algorithm was proposed to create a virtual cell as show in VirtualCell algortithm.

Algorithm 1 VirtualCell

```
Input: range = range[targetCell
Input: allBetwenessMetrics = CalculateAllBetwenessMetrics()
Input: allDistanceMetrics = CalculateAllDistanceMetrics()
Input: allDensityMetrics = CalculateAllDensityMetrics()
Input: nodesChoice[]
for aux = 0; aux ¡ 10; aux ++ do
    Input: smallerBetweness=MaxDoubleValue
    Input: chosen = -1
    for aux2 = 0; aux2 ¡ numberOfCells; aux2 ++ do
        if allBetwenessMetrics[aux2] ¡ smallerBetweness then
            chosen = aux2
    allBetwenessMetrics[chosen]=MaxDoubleValue nodesChoice[chosen] ++
    Input: smallerDistance=MaxDoubleValue
    Input: chosen = -1
    for aux2 = 0; aux2 ¡ numberOfCells; aux2 ++ do
        if allDistanceMetrics[aux2] ¡ smallerDistance then
            chosen = aux2
    allDistanceMetrics[chosen]=MaxDoubleValue nodesChoice[chosen] ++
    Input: smallerDensity = MaxDoubleValue
    Input: chosen = -1
    for aux2 = 0; aux2 ¡ numberOfCells; aux2 ++ do
        if allDensityMetrics[aux2] ¡ smallerDensity then
            chosen = aux2
    allDensityMetrics[chosen]=MaxDoubleValue nodesChoice[chosen] ++
```

The proposed algorithm after calculated all metrics, already presented, for each metric the best value acquired by each cell is added in ”nodesChoice” array. The ”nodesChoice” array is a control variable to know for all metrics what is the bests cells at all. The idea of this algorithm is that the best cell chosen was the cell who all metrics appoint as the best. At the end of this algorithm is time to pick the 3 best cells chose and create a virtualCell. After many tries and multiple evaluations, was understanded of ten is the best number to ”For” usage because of response time of algorithm.

To add all cells at a virtual Cell is very important to analyse the type of cell the previous algorithm has chosed. As presented before the choosen of virtual cell has to follow a rule based on the speed of the car. The range variable is used to know what is the velocity of actual user. At the end tho choose the virtual cell he first tries at his rules and if he can't choose one good cell he tries another rule or in other words he's change the range variable and tries others cells. The PickingCellsToVirtualCell algorithm is this create of a virtual Cell.

Algorithm 2 PickingCellsToVirtualCell

```
Input: VirtualCells[3]
Input: end = 1
Input: insert = 0
repeat
    end = 1 Input: index = -1
    Input: biggest = -1
    for aux = 0; aux ¡ numberOfCells; aux ++ do
        if nodesChoice[aux] ¿ biggest then
            //Dealign with smallest Cells if range == 1 then
                if !smallestCells(aux) then
                    biggest = nodesChoice[aux] index = aux
                else
                    break
            //Dealing with medium cells
            range == 2 if !mediumCells(aux) then
                biggest = nodesChoice[aux] index = aux
            else
                break
            else
                if !biggestells(aux) then
                    biggest = nodesChoice[aux] index = aux
                else
                    break
    if index != -1 then
        VirtualCells[insert] = index biggest = 0 nodesChoice[index] = 0 //cant chose this
          cell again
    else
        biggest = 0 if range == 1 then
            range == 2
        range == 2 range == 3 else
            range == 1
    end == 1 //Not fill all VirtualCells for aux = 0; aux ¡ 3;aux ++ do
        if VirtualCells[aux] == -1 then
            end = 0 break
until end == 0;
```

4. Evaluation Methodology

The proposed approach was tested using the ns-3 network discrete event simulator which was designed to simulate different technologies and scenarios. Several works in the literature use the ns-3 and their modules, such as LTE-EPC network simulator (LENA) and ns3-mmWave. In this work, the ns3-mmWave and the OFSwitch13 modules (OpenFlow 1.3 module for ns-3) were used. The OFSwitch13 allows the inclusion of a SDN controller in the scenarios. The traffic model was created through the simulation of urban mobility (SUMO) and the scenarios were evaluated with a confidence interval of 95% for 10 simulation trials. The assumed scenarios are presented in Table 3.

Table 3. Simulation Scenarios

Parameters	Scenario I Urban	Scenario II Urban	Scenario III Freeway
Network area	4 lanes for 3.5m each, 2 lanes in each direction (grid with 1000m x 1000m)	4 lanes for 3.5m each, 2 lanes in each direction (grid with 250m x 433m)	6 lanes for 4m each, 3 in each direction (2000m)
Active vehicles	25, 75, 125 and 250 vehicles	25, 75, 125 and 250 vehicles	25, 75, 125 and 250 vehicles
Vehicle densities	117, 351, 585 and 1171 veh/km^2	117, 351, 585 and 1171 veh/km^2	117, 351, 585 and 1171 veh/km^2
Speed (random)	15, 30 and 60 km/h	15, 30 and 60 km/h	70, 140 and 300 km/h
Position	Poisson process	Poisson process	Poisson process
Spacing	2.5 s	2.5 s	2.5 s
Macrocells	2	2	2
Microcells	8	4	3
Picocells	40, 90, 140 and 190	21	10

The physical base stations or radio masts were distributed in the following way: in scenario I, based on [Sahin et al. 2018], the radio masts were randomly distributed, as the vehicles were randomly positioned; in scenario II, 25 radio masts were positioned in 2 macrocells so that 4 microcells form the center of the grid and 21 picocells are in each corner of the grid; in scenario III, based on [Zang et al. 2019], radio masts are randomly placed within macrocells having a radius of 500 meters each. In scenario I, for the analysis purpose of the transmission point density impact, the number of picocells were increased considering the same network area.

Table 4 presents the adopted simulation parameters, based on 5G V2X ecosystem [Storck and Duarte-Figueiredo 2019]. The 3GPP mmWave channel model was used to perform the initial connection of the active vehicle to the radio mast using mmWave communications and considering the parameters of frequency, bandwidth, number of sub-bands, channel conditions and fading. The Round Robin scheduling was used.

The number of active V-Cells in common and the total radiated power (TRP) were used as the metrics to evaluate the probabilistic approach proposed. Each simulated vehi-

Table 4. Simulation parameters

Parameter	Value	Description
channel	mmWave3gpp	Channel model
frequency	28 GHz	Supported Frequency
bandwith	1 GHz	Bandwidth
numSubbands	72	Number of sub-bands
subbandWidth	13.89 MHz	Width of the sub-band (MHz)
propagation	mmWave3gpp	Propagation model
losCondition	true	Channel conditions
shadowing	true	Fading
enableBuildings	true	Consider obstacles
macScheduler	Round-Robin	Scheduler class
harqEnabled	true	Enable HARQ
harqProcesses	100	HARQ for DL and UL
rlcAmEnabled	true	RLC-AM enabled
packetSize	1446 Bytes	Package/Segment Size

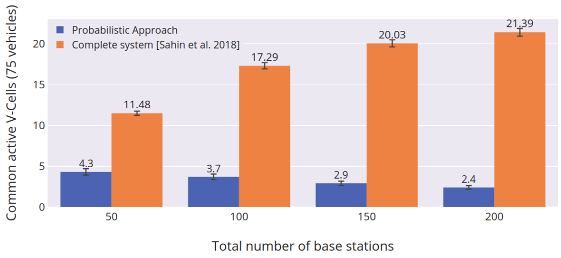

Figure 4. Impact of the total number of radio masts with number of common active V-Cells vs. the maximum number of served hotspots by V-Cells and 75 vehicles.

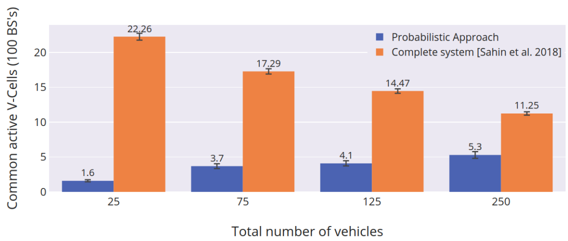

Figure 5. Impact of the number of vehicles with number of common active V-Cells vs. the maximum number of served hotspots by V-Cells and 100 radio masts.

cle had its own V-Cell. For comparison purposes, we check the average number of active V-Cells that share the same radio masts. In other words, vehicles that have one V-Cell equal to another one at a given time in the simulation and, we compare with the maximum number of the served hotspots (HSs) by V-Cells of [Sahin et al. 2018]. In [Sahin et al. 2018], the TRP is the sum of all power distributed by all virtual cells in the system. Each V-Cell thereby distributes its signal with power p_k dBm over different transmission points by using the weight vector w_k and the total distributed signal has power p_k. The maximum output power per TP used is 26 dBm. In [Huo et al. 2017], the maximum output effective isotropic radiated power for the 28 GHz band is 43 dBm.

5. Results

The simulation results are presented and analyzed in this section.

5.1. Active V-Cells in common

This subsection presents the impact analysis regarding the increase of density considering the same network area for V-Cells formation. Fig. 4 shows, through the y-axis, the average common active V-Cells for each 5G UDN network density variation (50, 100, 150, and 200 radio masts) by the x-axis in the scenario I with 75 active vehicles in the network. Fig. 5 shows, through the y-axis, the average common active V-Cells for each vehicle density variation (25, 75, 125, and 250) by the x-axis in scenario I with 100 radio masts.

Although in [Sahin et al. 2018] vehicle speeds were not specified and the authors adopted LTE network operating standards, the base values presented for comparison with our proposal are higher. However, this means that in practice, the number of vehicles that can be regrouped in the same active V-Cell is much smaller than that reported by [Sahin et al. 2018] and depends on several factors. Therefore, we conclude based mainly on the

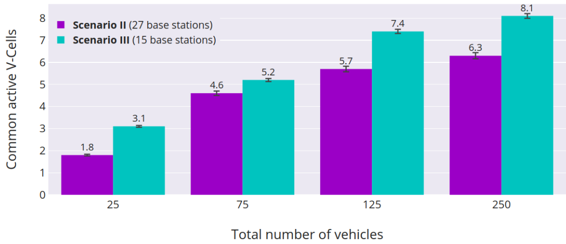

Figure 6. Impact of the number of vehicles with number of common active V-Cells in urban and freeway scenarios.

dynamic mobility of vehicles associated with high speeds, the instantiation of virtual cells by each vehicle is the best approach to be adopted in IoV.

Also, to evaluate our proposal in a highly mobile and dynamic network environment, we have tested our proposal with a distinct urban scenario configuration (scenario II with 27 radio masts) and also in a freeway scenario (scenario III with 15 radio masts), as shown in Section **??**, both considering 25, 75, 125 and 250 active vehicles in the network, that is, a vehicle density corresponding to 117, 351, 585 and 1171 veh/km^2. Fig. 6 shows the average active V-Cells in common for each one of the two scenarios.

5.2. Total radiated power

In this subsection, the average radiated power is analyzed and compared with [Sahin et al. 2018] according to the density of the 5G UDN network in scenario I. Fig. 7 shows, through the y-axis, the TRP in dBm for each 5G UDN network density variation (50, 100, 150, and 200 radio masts) by the x-axis in scenario I with 75 active vehicles in the network. The radiated power is important to analyze environmental problems involving 5G networks

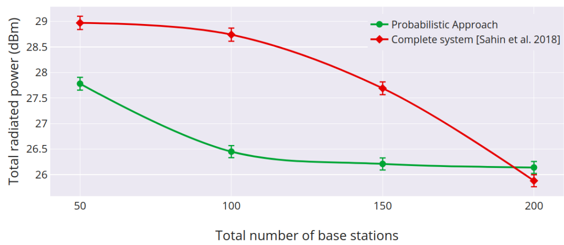

Figure 7. Impact of the number of base stations with total radiated power [dBm] and 75 active vehicles.

Sahin et al. [Sahin et al. 2018] concluded that the as HSs are associated with closer TPs, less attenuation is experienced in transmissions, hence, a less transmit power becomes sufficient. Comparatively, our proposal can save 4.22% of the network energy. This occurs mainly because the V-Cells are created only for active vehicles considering that each V-Cell is a network slice for a particular vehicle, or service together with the application of our proposed approach.

6. Conclusions

The 5G UDN virtual cells management requires approaches that guarantee the services offered by the network. The intense mobility and the network dynamic make the process complex and challenging. With this paper proposed approach, the 5G communication aspects (through measurement reports) and the dynamic changes in the network topology are detected by a controller and taken into account for virtual cell instantiation (independent for each vehicle). Besides it, using complex network metrics, the approach connects each vehicle to the most available radio masts, or in other words, those that are least congested, since the service is provided without compromising quality. In this way, a network balancing is also performed.

The proposal developed makes a more assertive decision for V-Cell management. It was demonstrated by the rate of active V-Cells in common. Among the employed techniques, the choosing of radio masts adopting vehicle speed rules and cells' size, combined with the probability of choosing through complex network metrics, manages the virtual cells for each vehicle. The V-cells management based on complex network metrics proposed in this paper was good choice as the results have shown. As future works, simulations with other scenarios will be conducted, as well as the evolution of the proposed approach employing recent techniques to overcome frequent handovers.

As future proposed works, is propose a genetic algorithm to choose a virtual cell using machine learning and other techniques to learn with the network and always pick the best cells.

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