A VHO Scheme for supporting Healthcare Services in 5G Vehicular Cloud Computing Systems

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***Abstract*—Fifth Generation Vehicular Cloud Computing (5G-VCC) systems use heterogeneous network access technologies in order to fulfill the requirements of modern services, including medical services with strict constraints. Therefore, the need for efficient Vertical Handover (VHO) management schemes must be addressed. In this paper, a VHO management scheme for supporting medical services in 5G-VCC systems, is described. It consists of the VHO initiation and the network selection processes, while at the same time, the vehicle's velocity, its current connection type, as well as the status of the onboard patient's health, are considered. Specifically, during the VHO initiation process the necessity to perform handover is evaluated. Subsequently, the network selection process selects the appropriate network alternative considering both medical service requirements and patients' health status. The proposed scheme is applied to a 5G-VCC system which includes Long Term Evolution (LTE) and Worldwide Interoperability Microwave Access (WiMAX) Macrocells and Femtocells, as well as Wireless Access for Vehicular Environment Road Side Units (WAVE RSUs). Performance evaluation shows that the proposed algorithm outperforms existing VHO management schemes.**

I. Introduction

Cloud Computing (CC) [1] and Software Defined Networking (SDN) [2] are considered as the key enabling technologies for the fifth generation (5G) networks. In addition, Vehicular Cloud Computing (VCC), which combines the operating principles of both Vehicular Networks and Cloud computing, has emerged widely, occurring in the further development of the 5G approach. In a typical VCC system, vehicles are equipped with On-Board Units (OBUs) with computational, storage and communication resources. Vehicles communicate with each other, as well as with a Cloud infrastructure through the available Access Networks. The Cloud infrastructure offers vehicular services, including medical services with strict Quality of Service (QoS) requirements. Indicatively, vehicles serve patients with different medical services, including Live Healthcare Video (LVideo) [3], Medical Images (MedImgs) [4], Health Monitoring (HMonitoring) [5] and Clinical Data Transmission (CData) [6] services.

Heterogeneous network access technologies, such as the 3GPP Long Term Evolution (LTE) [7], the Worldwide Interoperability Microwave Access (WiMAX) [8] and the Wireless Access for Vehicular Environment (WAVE) [9], are used for the interconnection between the vehicles and the Cloud infrastructure. Furthermore, the durability and the response latency of the 5G architecture could be improved by applying the operating principles of the Mobile Edge Computing (MEC) [10], resulting to the creation of a Fog infrastructure at the edge of the network. In particular, LTE and WiMAX Base Stations (BSs), as well as WAVE Road Side Units (RSUs) are equipped with additional computational and storage resources and thus they are referred as micro-datacenter BSs (md-BSs) and micro-datacenter RSUs (md-RSUs), respectively.

The vehicles should always obtain connectivity to the best network, in order the requirements of their services to be fulfilled. Therefore, the design of efficient Vertical Handover (VHO) management schemes is required. In general, Multi Attribute Decision Making (MADM) methods are used to select the best alternative among candidate networks given a set of criteria with different importance weights. Widely used methods include the Analytic Hierarchy Process (AHP) [11], the Simple Additive Weighting (SAW) [11] [12], the Fuzzy AHP - SAW (FAS) [13], the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) [14] and the Analytic network process (ANP) [15]. Furthermore, in [16] an algorithm called User Centric Context Aware (UCCA) is proposed. It considers the estimated time that a vehicle will remain connected to its current network, in order to decide whether a VHO must be performed. Accordingly, in [17] a two-step VHO algorithm is proposed. During the first step, the user's current network is evaluated to verify whether it satisfies the minimum requirements of user services. In case the performance of the user's network lies above a predefined threshold, the algorithm progresses to the second step, where network selection is performed using a MADM method. Also, several research studies evaluate network access technologies supporting medical services. Indicatively, in [18] the Adaptive Network Selection for Telecardiology (ANST) method is proposed, which considers the throughput of each candidate network to select the best alternative for supporting telecardiology services. Furthermore, in [19] a network selection algorithm for supporting telecardiology services, is proposed, while in [20] a fuzzy based network selection scheme for supporting healthcare services is described.

This paper describes a VHO management scheme for supporting medical services in 5G-VCC systems, which considers the vehicle's velocity, its current connection type, as well as the health status of onboard patients. Initially, the fact that a vehicle with high velocity will remain for a limited time inside the communication range of a femtocell, is considered. Furthermore, the health status of each patient is evaluated using the Manchester Triage System (MTS) [21] classification system, while at the same time network evaluation criteria such as throughput, delay, jitter, packet loss ratio, service reliability, security and price, are considered. Accordingly, the network evaluation criteria are mapped to patient's health status in a way similar to [20]. Thus, the importance of each criterion is adjusted with respect to the criticality of the medical status of each vehicular user. Following, the VHO initiation and the network selection processes are applied. During the VHO initiation process the vehicle's necessity to perform handover is evaluated, while during the network selection process the appropriate network alternative is selected, considering both medical service requirements and patient's health status.

The remainder of the paper is as follows: Section II describes the proposed scheme, while Section III presents the simulation setup and the evaluation results. Finally, section IV concludes the discussed work.

II. THE PROPOSED VHO MANAGEMENT SCHEME

During the entire vehicle movement, its velocity, as well as its current connection type (ctype), are monitored. More specifically, in a way similar to [22], the following states are defined (Figure 1):

- *If* $velocity > 30kmh$ *and* $ctype = femtocell$*:* Since the vehicle will remain for a limited time inside the femtocell coverage, the VHO initiation process is bypassed and network selection is executed, while no femtocells are considered as alternatives.
- *If* $velocity > 30kmh$ *and* $ctype \neq femtocelll$*:* The VHO initiation will be executed, while no femtocells are considered as alternatives.
- *If* $velocity \leq 30kmh$*:* The VHO initiation will be executed, while all the available networks will be considered as alternatives.

Interval Valued Trapezoidal Fuzzy Numbers (IVTFN) [23] are used in both VHO initiation and network selection processes. In particular, an IVTFN can be represented as: $\tilde{a} = [\tilde{a}^L, \tilde{a}^U] = [(a_1^L, a_2^L, a_3^L, a_4^L, v^L), (a_1^U, a_2^U, a_3^U, a_4^U, v^U))]$ where: $0 \leq a_1^L \leq a_2^L \leq a_3^L \leq a_4^L \leq 1$, $0 \leq a_1^U \leq a_2^U \leq a_3^U \leq a_4^U \leq 1$, $0 \leq v^L \leq v^U \leq 1$ and $\tilde{a}^L \subset \tilde{a}^U$. Furthermore, the corresponding Membership Functions (MFs) are created using the Equalized Universe Method (EUM) [24] [25]. Specifically, the EUM method creates MFs in such a way that their centroids to be equally spaced along a predefined domain of values. The values of each i^{th} MF are calculated using formula 1, where U_{min} and U_{max} are the minimum and maximum value of the domain and c is the count of the MFs.

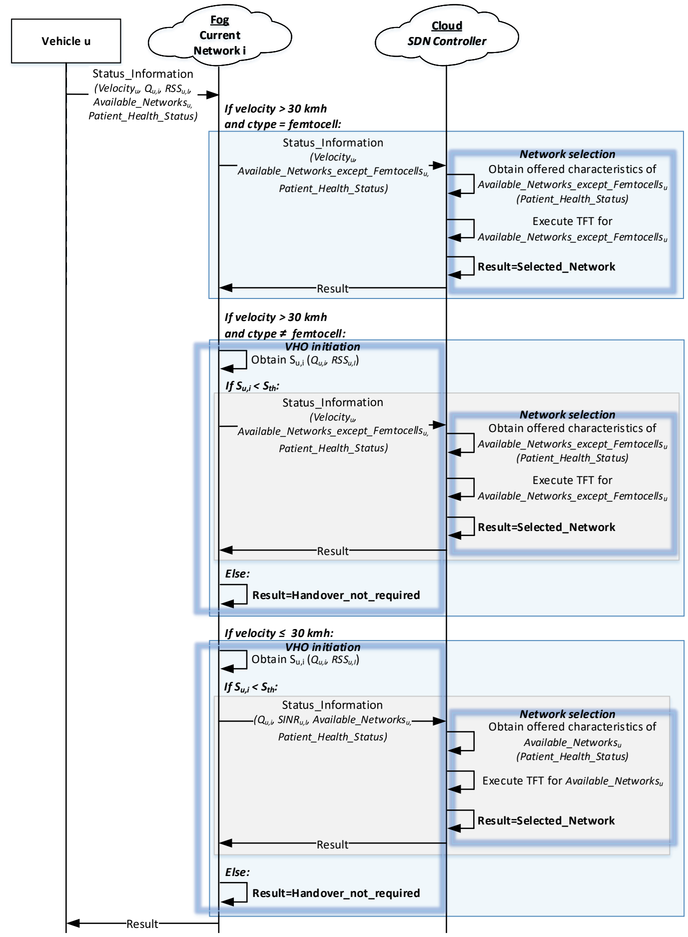

Fig. 1. The proposed methodology.

$$MF_i = \begin{cases} \begin{cases} a_{i,1}^U = a_{i,2}^U - \frac{U_{max} - U_{min}}{4 \cdot (c-1)} \\ a_{i,1}^L = a_{i,1}^U \cdot (u^L / u^U) \end{cases} \\ \begin{cases} a_{i,2}^U = (U_{min} + \frac{U_{max} - U_{min}}{c-1} \cdot (i-1)) - \frac{U_{max} - U_{min}}{2 \cdot (c-1)} \\ a_{i,2}^L = a_{i,2}^U \cdot (u^L / u^U) \end{cases} \\ \begin{cases} a_{i,3}^U = (U_{min} + \frac{U_{max} - U_{min}}{c-1} \cdot (i-1)) + \frac{U_{max} - U_{min}}{2 \cdot (c-1)} \\ a_{i,4}^L = a_{i,3}^U \cdot (u^L / u^U) \end{cases} \\ \begin{cases} a_{i,4}^U = a_{i,3}^U + \frac{U_{max} - U_{min}}{4 \cdot (c-1)} \\ a_{i,5}^L = a_{i,4}^U \cdot (u^L / u^U) \end{cases} \end{cases} \quad (1)$$

A. VHO initiation

The satisfaction grade $S_{u,i}$ of vehicle u from its current network i, is defined. Whenever the $S_{u,i}$ becomes less than a predefined S_{th} threshold, the network selection is executed. More specifically, the $S_{u,i}$ is estimated as a function of the $RSS_{u,i}$ and $Q_{u,i}$ parameters, using the Mamdani Fuzzy Inference System (FIS) described in [26]. $RSS_{u,i}$ represents the Received Signal Strength (RSS) of vehicle u from its current network i. Accordingly, $Q_{u,i}$ represents the quality of vehicle's u services, offered from its current network i. Specifically, $Q_{u,i}$ is calculated using formula 2, where N represents the number of the parameters considered and K the number of the available services. Also, $th_{u,i,k}$, $d_{u,i,k}$, $j_{u,i,k}$ and $pl_{u,i,k}$ represent the throughput, the delay, the jitter and the packet loss ratio respectively, obtained by user u for the service

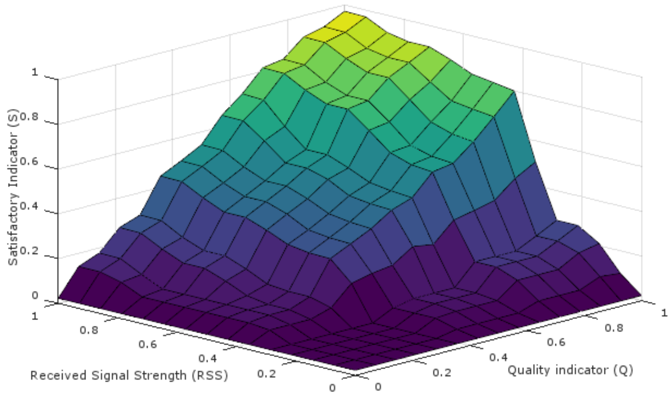

Fig. 2. The S values range as obtained using the FIS.

k. Furthermore, the $w_{th,k}$, $w_{d,k}$,$w_{j,k}$ and $w_{p,kl}$ represent the weights of the aforementioned parameters, estimated using the Trapezoidal Fuzzy Analytic Network Process (TF-ANP) [27] method. Table I presents the linguistic terms, which are created using the EUM method and used for the TF-ANP pairwise comparisons.

TABLE I
THE LINGUSTIC TERMS THAT USED FOR CRITERIA PAIRWISE COMPARISONS.

Linguistic term	Interval-valued trapezoidal fuzzy number
Equally Important (EI)	[(0.0, 0.0, 0.2, 0.25, 0.8), (0.0, 0.02, 0.18, 0.22, 1.0)]
Moderately More Important (MMI)	[(0.15, 0.2, 0.4, 0.45, 0.8), (0.18, 0.22, 0.38, 0.42, 1.0)]
Strongly More Important (SMI)	[(0.35, 0.4, 0.6, 0.65, 0.8), (0.38, 0.42, 0.58, 0.62, 1.0)]
Very Strongly More Important (VSMI)	[(0.55, 0.6, 0.8, 0.85, 0.8), (0.58, 0.62, 0.78, 0.82, 1.0)]
Extremely More Important (EMI)	[(0.75, 0.8, 1.0, 1.0, 0.8), (0.78, 0.82, 0.98, 1.0, 1.0)]

$$Q_{u,i} = \Big(\sum_{k=1}^{K} \big((w_{th,k} \cdot th_{u,i,k} + w_{d,k} \cdot \frac{1}{d_{u,i,k}} + w_{j,k} \cdot \frac{1}{j_{u,i,k}} + w_{pl,k} \cdot \frac{1}{pl_{u,i,k}})/N \big) \Big) / K \quad (2)$$

Both $RSS_{u,i}$ and $Q_{u,i}$ are normalized in order to have values within the range [0, 1].

Based on the Mamdani FIS, the MF_{RSS}, MF_Q, MF_S membership functions are defined, indicating the linguistic terms and the corresponding IVTFNs for the fuzzy representation of the $RSS_{u,i}$, $Q_{u,i}$ and $S_{u,i}$ respectively (Table II). These membership functions are equally distributed inside the domain $[U_{min}, U_{max}]$ = [0, 1] according to the EUM method. Subsequently, the satisfaction chart presented in figure 2 is constructed using the Mamdani FIS [26]. The chart contains the entire possible values of $S_{u,i}$ as a function of the entire possible values of $RSS_{u,i}$ and $Q_{u,i}$. Indicatively, when the $RSS_{u,i}$ and $Q_{u,i}$ values are too low, the produced $S_{u,i}$ value is too low as well. On the contrary, when the $RSS_{u,i}$ and $Q_{u,i}$ values are close to 1, the produced $S_{u,i}$ value is also high, indicating that the user is fully satisfied. Furthermore, when only one of the $RSS_{u,i}$ or the $Q_{u,i}$ values is close to 0, the user satisfaction is in quite low levels.

TABLE II
LINGUISTIC TERMS AND THE CORRESPONDING INTERVAL-VALUED TRAPEZOIDAL FUZZY NUMBERS USED FOR $RSS_{u,i}$, $Q_{u,i}$ AND $S_{u,i}$.

$RSS_{u,i}$ **membership functions.**	
Linguistic term	**Interval-valued trapezoidal fuzzy number**
Too Bad (TB)	[(0.0, 0.0, 0.1, 0.15, 0.8), (0.0, 0.0, 0.12, 0.18, 1.0)]
Bad (B)	[(0.1, 0.15, 0.35, 0.4, 0.8), (0.06, 0.12, 0.37, 0.43, 1.0)]
Enough (EN)	[(0.35, 0.4, 0.6, 0.65, 0.8), (0.31, 0.37, 0.62, 0.68, 1.0)]
More than Enough (ME)	[(0.6, 0.65, 0.85, 0.9, 0.8), (0.56, 0.62, 0.87, 0.93, 1.0)]
Excellent (EX)	[(0.85, 0.9, 1.0, 1.0, 0.8), (0.81, 0.87, 1.0, 1.0, 1.0)]
$Q_{u,i}$ **membership functions.**	
Linguistic term	**Interval-valued trapezoidal fuzzy number**
Absolutely Poor (AP)	[(0.0, 0.0, 0.05, 0.07, 0.8), (0.0, 0.0, 0.06, 0.09, 1.0)]
Very Poor (VP)	[(0.05, 0.07, 0.17, 0.2, 0.8), (0.03, 0.06, 0.18, 0.21, 1.0)]
Poor (P)	[(0.17, 0.2, 0.3, 0.32, 0.8), (0.15, 0.18, 0.31, 0.34, 1.0)]
Medium Poor (MP)	[(0.3, 0.32, 0.42, 0.45, 0.8), (0.28, 0.31, 0.43, 0.46, 1.0)]
Medium (M)	[(0.42, 0.45, 0.55, 0.57, 0.8), (0.4, 0.43, 0.56, 0.59, 1.0)]
Medium Good (MG)	[(0.55, 0.57, 0.67, 0.7, 0.8), (0.53, 0.56, 0.68, 0.71, 1.0)]
Good (G)	[(0.67, 0.7, 0.8, 0.82, 0.8), (0.65, 0.68, 0.81, 0.84, 1.0)]
Very Good (VG)	[(0.8, 0.82, 0.92, 0.95, 0.8), (0.78, 0.81, 0.93, 0.96, 1.0)]
Absolutely Good (AG)	[(0.92, 0.95, 1.0, 1.0, 0.8), (0.9, 0.93, 1.0, 1.0, 1.0)]
$S_{u,i}$ **membership functions.**	
Linguistic term	**Interval-valued trapezoidal fuzzy number**
Absolute Unsatisfactory (AU)	[(0.0, 0.0, 0.03, 0.05, 0.8), (0.0, 0.0, 0.04, 0.06, 1.0)]
Very Unsatisfactory (VU)	[(0.03, 0.05, 0.12, 0.14, 0.8), (0.02, 0.04, 0.13, 0.15, 1.0)]
Unsatisfactory (U)	[(0.12, 0.14, 0.21, 0.23, 0.8), (0.11, 0.13, 0.22, 0.25, 1.0)]
Slightly Unsatisfactory (SU)	[(0.21, 0.23, 0.3, 0.32, 0.8), (0.2, 0.22, 0.31, 0.34, 1.0)]
Less than Acceptable (LA)	[(0.3, 0.32, 0.4, 0.41, 0.8), (0.29, 0.31, 0.4, 0.43, 1.0)]
Slightly Acceptable (SA)	[(0.4, 0.41, 0.49, 0.5, 0.8), (0.38, 0.4, 0.5, 0.52, 1.0)]
Acceptable (A)	[(0.49, 0.5, 0.58, 0.6, 0.8), (0.47, 0.5, 0.59, 0.61, 1.0)]
More than Acceptable (MA)	[(0.58, 0.6, 0.67, 0.69, 0.8), (0.56, 0.59, 0.68, 0.7, 1.0)]
Slightly Satisfactory (SS)	[(0.67, 0.69, 0.76, 0.78, 0.8), (0.65, 0.68, 0.77, 0.79, 1.0)]
Satisfactory (S)	[(0.76, 0.78, 0.85, 0.87, 0.8), (0.75, 0.77, 0.86, 0.88, 1.0)]
Very Satisfactory (VS)	[(0.85, 0.87, 0.94, 0.96, 0.8), (0.84, 0.86, 0.95, 0.97, 1.0)]
Absolute Satisfactory (AS)	[(0.94, 0.96, 1.0, 1.0, 0.8), (0.93, 0.95, 1.0, 1.0, 1.0)]

B. Network selection

The network selection is performed using the Trapezoidal Fuzzy Topsis (TFT) [28] algorithm, which accomplishes the ranking of the candidate networks. IVTFNs [23] are used for the representation of both criteria values and their importance weights, while at the same time, the corresponding MFs, created using the EUM method (Table II), are considered. Additionally, the TF-ANP method is applied in order to estimate the decision weights per service type and patient health status, considering the ANP network model proposed in [28]. The criteria used include throughput, delay, jitter, packet loss, price, service reliability and security.

III. SIMULATION SETUP AND RESULTS

In our experiments, we consider a 5G-VCC system consisting of a Fog and a Cloud infrastructure (figure 3), while the Network Simulator 3 (NS3) simulator [29] is used for the simulation setup. The Fog infrastructure includes a number of LTE and WiMAX Macrocells and Femtocells, as well as of WAVE RSUs, with additional computational and storage resources (Table III). Additionally, the Cloud infrastructure includes a set of Virtual Machines (VMs) providing medical services such as LVideo, MedImgs, HMonitoring and CData. Furthermore, a Software Defined Network (SDN) controller provides centralized control of the entire system.

The case where 10 vehicles with patients are moving inside the 5G-VCC environment is considered (Table IV). Each vehicle needs to be connected to a network which satisfies the requirements of its services and at the same time comply with its patient health status. The health status of each patient is evaluated using the Manchester Triage System (MTS) [21] healthcare classification system, which defines 5

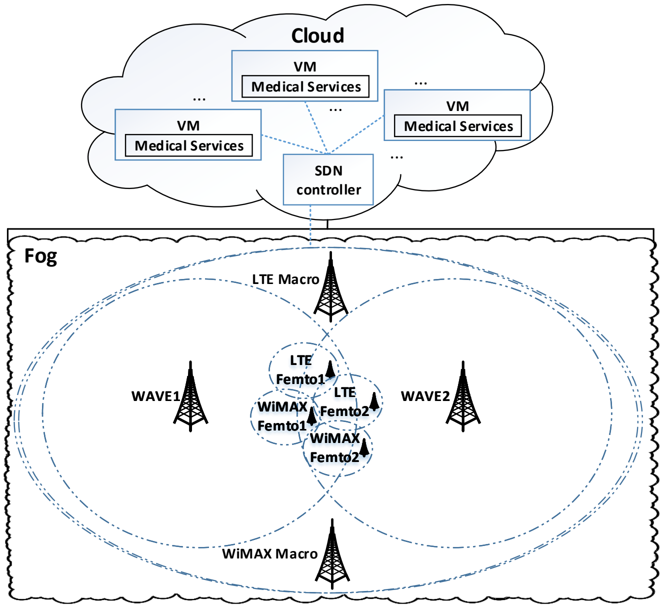

Fig. 3. The simulated topology.

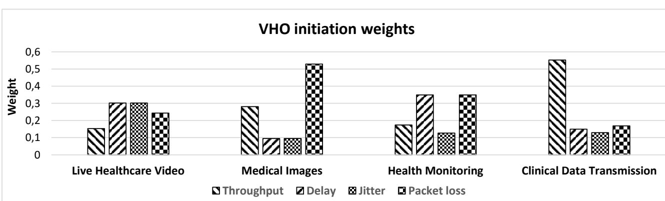

Fig. 4. Criteria weights per service for the VHO initiation.

health statuses, called Non-Urgent, Standard, Urgent, Very-Urgent and Immediate. The Non-Urgent status has the lower risk about patient's life, while the Immediate status has the higher one. Table IV presents the services of each vehicle, as well as the MTS classification of the corresponding patient.

A. VHO initiation

Figure 4 depicts the estimated VHO initiation weights for each service, including Live Healthcare Video (LVideo), Medical Images (MedImgs), Health Monitoring (HMonitoring) and Clinical Data Transmission (CData), which are proportional to the corresponding service constraints, obtained from the TF-ANP method.

The minimum acceptable values for RSS_{MTS} and Q_{MTS} per MTS patient health status, as well as the evaluated $S_{th,MTS}$ thresholds, obtained from the Mamdani satisfaction chart, are presented in tableV. Similarly, the $RSS_{u,i}$ and the $Q_{u,i}$ are obtained and inserted as inputs to the Mamdani satisfaction chart, in order the $S_{u,i}$ satisfaction grade of vehicle u from its current network i to be estimated. Accordingly, table VI presents the VHO initiation results based on each vehicle's velocity, connection type, as well as the respective estimated $S_{u,i}$ and $S_{th,MTS}$ values. As it can be observed, the VHO initiation process is ignored for the vehicle 3, due to the fact that it moves with high velocity while at the same time it is connected to a femtocell. Furthermore, vehicle 5 will not handover to another network, while at the same time, the rest of vehicles will proceed to the network selection.

TABLE III
THE AVAILABLE NETWORKS.

Service	Network	Throughput	Delay	Jitter	Packet Loss	Service Reliability	Security	Price
Live Healthcare Video (LVideo)	LTE Macro	AG (9.5 Mbps)	AG (45 ms)	AG (25 ms)	VG (10^{-4})	VG	AG	G
	LTE Femto 1	MP (8 Mbps)	MG (60 ms)	VG (35 ms)	AG (10^{-5})	AG	VG	AP
	LTE Femto 2	G (9 Mbps)	VG (50 ms)	AG (25 ms)	AG (10^{-5})	VG	G	MG
	WiMAX Macro	MP (8 Mbps)	M (65 ms)	MG (45 ms)	G (10^{-3})	G	G	MP
	WiMAX Femto 1	G (9 Mbps)	G (55 ms)	VG (35 ms)	VG (10^{-4})	G	G	M
	WiMAX Femto 2	MG (8.5 Mbps)	MG (60 ms)	AG (30 ms)	VG (10^{-4})	G	MG	AG
	WAVE 1	MG (8.5 Mbps)	MG (60 ms)	G (40 ms)	AG (10^{-5})	MG	VG	MP
	WAVE 2	MP (8 Mbps)	MP (70 ms)	MG (45 ms)	AG (10^{-5})	MG	G	P
Medical Images (MedImgs)	LTE Macro	VG (9 Mbps)	VG (55 ms)	AG (35 ms)	AG (10^{-7})	VG	AG	AP
	LTE Femto 1	M (8 Mbps)	G (60 ms)	VG (40 ms)	VG (10^{-6})	AG	VG	G
	LTE Femto 2	G (8.5 Mbps)	G (60 ms)	VG (40 ms)	AG (10^{-7})	VG	G	MP
	WiMAX Macro	M (8 Mbps)	G (60 ms)	MG (50 ms)	VG (10^{-6})	G	G	M
	WiMAX Femto 1	M (8 Mbps)	MG (65 ms)	AG (35 ms)	AG (10^{-7})	G	G	VG
	WiMAX Femto 2	MG (8.2 Mbps)	M (70 ms)	VG (40 ms)	AG (10^{-7})	MG	M	M
	WAVE 1	VG (9 Mbps)	AG (50 ms)	VG (40 ms)	AG (10^{-7})	MG	VG	G
	WAVE 2	G (8.7 Mbps)	VG (55 ms)	G (45 ms)	AG (10^{-7})	MG	G	MP
Health Monitoring (HMonitoring)	LTE Macro	G (290 Kbps)	MG (40 ms)	VG (25 ms)	AG (10^{-4})	VG	AG	VG
	LTE Femto 1	VG (300 Kbps)	AG (25 ms)	AG (15 ms)	VG (10^{-3})	AG	VG	P
	LTE Femto 2	AG (305 Kbps)	AG (25 ms)	VG (22 ms)	VG (10^{-3})	G	G	AG
	WiMAX Macro	G (290 Kbps)	AG (26 ms)	G (30 ms)	VG (10^{-3})	AG	VG	VP
	WiMAX Femto 1	VG (300 Kbps)	MG (40 ms)	VG (23 ms)	AG (10^{-4})	VG	AG	G
	WiMAX Femto 2	MG (282 Kbps)	MG (39 ms)	VG (25 ms)	VG (10^{-3})	G	G	AP
	WAVE 1	MG (280 Kbps)	MG (40 ms)	G (30 ms)	VG (10^{-3})	MG	MG	M
	WAVE 2	M (270 Kbps)	M (45 ms)	MG (35 ms)	VG (10^{-3})	MG	MG	MP
Clinical Data Transmission (CData)	LTE Macro	MG (2.5 Mbps)	M (190ms)	G (90 ms)	VG (10^{-4})	VG	AG	MP
	LTE Femto 1	AG (3.2 Mbps)	AG (150ms)	AG (80 ms)	AG (10^{-5})	AG	VG	G
	LTE Femto 2	VG (3 Mbps)	G (170ms)	M (100ms)	AG (10^{-5})	VG	G	MG
	WiMAX Macro	G (2.8 Mbps)	M (190ms)	M (100ms)	AG (10^{-5})	MG	M	MP
	WiMAX Femto 1	M (2.3 Mbps)	MP (200ms)	MG (95 ms)	VG (10^{-4})	G	G	VG
	WiMAX Femto 2	MG (2.5 Mbps)	M (190ms)	M (100ms)	AG (10^{-5})	M	M	M
	WAVE 1	AG (3.2 Mbps)	G (170ms)	G (90 ms)	AG (10^{-5})	MG	MG	P
	WAVE 2	G (2.8 Mbps)	M (190ms)	AG (80 ms)	AG (10^{-5})	MG	G	G

B. Network selection

The decision weights per service and patient health status are obtained from the TF-ANP method, as presented in figure 5. As illustrated the weights are proportional to the constraints of each service as well as to the patient health status. In particular, in Live Healthcare Video the weights for the delay and jitter criteria are more important than throughput. On the contrary, in the Clinical Data Transmission case the delay and jitter criteria obtain low values. Furthermore, the price criterion obtains high values for the Non-Urgent health status, while its values are minimized in case of the Immediate health status. Subsequently, the TFT algorithm selects the best network

TABLE IV
THE SIMULATED VEHICLES.

Vehicle	Velocity	Medical Services	Patient Health Status	Current Network (RSS)	Candidate Networks	Next process
1	20 kmh	LVideo	Urgent	WAVE 2 (-80 dBm)	All	VHO initiation
2	15 kmh	MedImgs	Immediate	WiMAX Femto 2 (-75 dBm)	All	VHO initiation
3	40 kmh	HMonitoring	Very urgent	WiMAX Femto 1 (-65 dBm)	All except femtocells	Network selection
4	25 kmh	CData	Standard	WAVE 1 (-94 dBm)	All	VHO initiation
5	80 kmh	LVideo & HMonitoring	Non urgent	LTE Macro (-63 dBm)	All except femtocells	VHO initiation
6	20 kmh	MedImgs & HMonitoring	Standard	WAVE 2 (-88 dBm)	All	VHO initiation
7	5 kmh	MedImgs & CData	Urgent	LTE Femto 1 (-95 dBm)	All	VHO initiation
8	60 kmh	LVideo & CData	Immediate	WiMAX Macro (-89 dBm)	All except femtocells	VHO initiation
9	10 kmh	HMonitoring & CData	Standard	WiMAX Femto 2 (-80 dBm)	All	VHO initiation
10	35 kmh	LVideo & MedImgs & HMonitoring	Very urgent	WAVE 1 (-92 dBm)	All except femtocells	VHO initiation

TABLE V
THE RSS_{MTS}, Q_{MTS} AND $S_{th,MTS}$ THRESHOLDS PER PATIENT HEALTH STATUS.

MTS classification	RSS_{MTS}	Q_{MTS}	$S_{th,MTS}$
Non-Urgent	0.5	0.5	0.35768
Standard	0.6	0.6	0.48583
Urgent	0.7	0.7	0.67242
Very-Urgent	0.8	0.8	0.75838
Immediate	0.9	0.9	0.87452

for each vehicle considering the vehicle service requirements (Table IV).

Figure 6 compares the results of the proposed scheme with the ones obtained using the ANST [18], the FAS [13], the UCCA [16] and the Two-step [17] VHO management schemes. In this figure, for each vehicle the current network as well as the target network connection estimated by each of the five schemes are presented. Additionally, the TFT ranking of each network is given. From the obtained results it is clear that the proposed algorithm outperforms the existing schemes since it selects as target networks for vehicles the ones with the best TFT ranks. In contrast, for the target networks selected by the ANST and UCCA algorithms high TFT ranks are obtained only for four vehicles, whereas the rest of the algorithms perform worse. Also, in special cases where the velocity of vehicles is high (eg. for vehicles 3, 8 and 10) the proposed scheme considers only the wide coverage candidate networks as alternatives avoiding the handovers to femtocell networks.

TABLE VI
VHO INITIATION RESULTS.

Vehicle	$RSS_{u,i}$	$Q_{u,i}$	$S_{u,i}$	$S_{th,MTS}$	VHO required
1	0.540541	0.733822	0.54232	0.67242	Yes
2	0.675676	0.935882	0.85552	0.87452	Yes
3	-	-	-	-	Yes (due to high velocity)
4	0.162162	0.968061	0.23509	0.48583	Yes
5	1.000000	0.795331	0.84589	0.35768	No
6	0.324324	0.699189	0.22980	0.48583	Yes
7	0.135135	0.732698	0.13617	0.67242	Yes
8	0.297297	0.690775	0.14245	0.87452	Yes
9	0.540541	0.658957	0.47013	0.48583	Yes
10	0.216216	0.753302	0.17768	0.75838	Yes

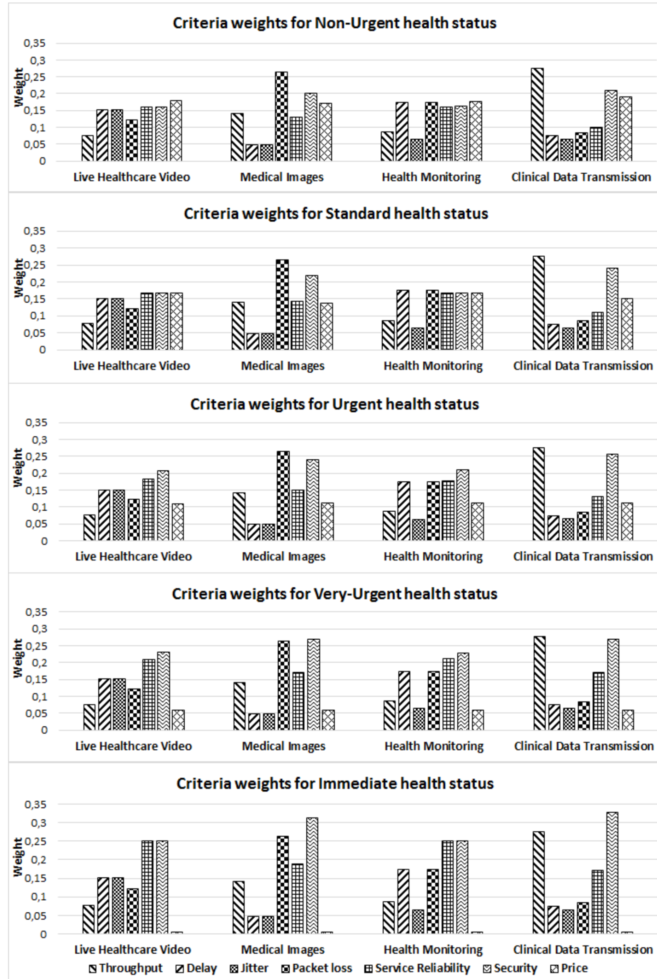

Fig. 5. Criteria weights per service and patient health status for the Network Selection.

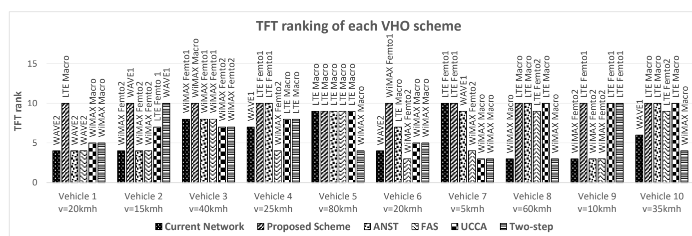

Fig. 6. Proposed VHO management scheme's results.

IV. CONCLUSION

This paper proposes a VHO management scheme for supporting medical services in 5G-VCC systems. The discussed scheme consists of the VHO initiation and the network selection processes. The vehicle's velocity, its current connection type, as well as the status of patient's health, are considered. Specifically, during the VHO initiation process the necessity to perform handover is evaluated and, subsequently, the network selection process selects the appropriate network alternative. The proposed scheme is applied to a 5G-VCC system. Performance evaluation showed that the proposed scheme outperforms existing network selection methods by satisfying multiple groups of criteria and medical services per user.

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