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Seamless Handover in Urban 5G-UAV Systems Using Entropy Weighted Method

Anirudh Sunil Warrier, Saba Al-Rubaye, Dimitrios Panagiotakopoulos, Gokhan Inalhan, Antonios Tsourdos

Abstract**—**The demand for increased data transfer rate and network traffic capacity has given rise to the concept of heterogeneous networks. Heterogeneous networks are wireless networks, consisting of devices using different underlying radio access technologies (RAT). For Unmanned Aerial Vehicles (UAVs) this enhanced data rate and network capacity are even more critical especially in their applications of medicine, delivery missions and military. In an urban heterogeneous network environment, the UAVs must be able switch seamlessly from one base station (BS) to another for maintaining a reliable link. Therefore, seamless handover in such urban environments has become a major challenge. In this paper, a scheme to achieve seamless handover is developed, an algorithm based on Received Signal Strength (RSS) criterion for network selection is used and Entropy Weighted Method (EWM) is implemented for decision making. Seamless handover using EWM decision-making is demonstrated successfully for a UAV moving across fifth generation (5G) and long-term evolution (LTE) networks via a simulation level analysis. Thus, a solution for UAV-5G communication, specifically the mobility challenge in heterogeneous networks is solved and this work could act as step forward in making UAV-5G architecture integration a possibility.

Keywords**—**Air to ground, A2G, fifth generation, 5G, handover, mobility, unmanned aerial vehicle, UAV, urban environments.

I. Introduction

THERE is a growing demand to accelerate the development of intelligent communication systems that can solve the problems of data management, spectrum, handover and ensure high-quality service. 5G is the fifth-generation technical standard [1] for cellular networks and is the successor to 4G networks that primarily provide internet connectivity to cellular users. Like its predecessors, 5G networks are cellular networks, and service areas are divided into small geographic areas called cells. The 5G enabled wireless devices connect to the internet through a local antenna within the cell. The main advantage of 5G networks is that performance parameters such as bandwidth, download speed (up to 10 Gbit/s) are expected to increase to a higher level than previous networks. Due to this increased bandwidth, these new networks not only offer mobile phone services like existing mobile phone networks but will also be used as common internet service providers for laptops and desktop computers, that would eventually lead to applications of Internet of Things (IoT) [2] becoming a reality.

When 5G is used for UAVs Air to Ground (A2G) data links, higher carrier frequencies lead to higher path loss. This means that beamforming and larger antenna arrays need to be placed on both the transmitter and receiver, resulting in higher antenna gains, that offsets the path loss. In [3], a 5G network is envisioned that will be capable, with the help of embedded resources support services such as UAV Non-Orthogonal Access (NOMA), Software Defined Networks (SDN), thus converging the capabilities of communications, computing, and caching.

Heterogeneous networks integrate different telecommunication technologies to use their additional characteristics. Heterogeneous networks allow users to transport the connection between several access points of different types, benefiting from the best customized services depending on their preferences. Furthermore, heterogeneous networks are an important solution to reduce congestion in mobile networks by sharing traffic with other access technologies with higher flows. Due to their rapid and significant deployment, mobile networks will consist of heterogeneous systems managed by different operators and formed of different access networks. [4]. User connections with this heterogeneous network should occur without interruption when the user changes from one network to another. Mobile terminals (UAVs) will be network multi-interfaces that enable them to move transparently from one system to another during communication. Therefore, in this paper, the challenges of global mobility and vertical handovers are addressed.

An algorithm for decision making in vertical handover is presented in this paper. EWM assigns different weights for different network attributes and selects the one with the highest weight. RSS is one key parameter for network selection, and in this algorithm the network with highest RSS is selected. Thus, this work presents a handover scheme to address the mobility problem in heterogeneous networks.

In this paper, Section I introduces 5G UAV networking to provide reliable connectivity. Section II discusses mobility challenges of UAVs using 5G communication, specifically it

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discusses the challenges of mobility in heterogeneous networks. In Section 0, the methodology adopted in this paper is discussed and the proposed solution is introduced. An algorithm is developed based on EWM decision-making and implemented on a simulation level as presented in Section IV. Section V highlights the results and discusses their impact and shows graphs indicating network selection. Section VI concludes the work and discusses future impact

II. UAV Mobility Challenge

In cellular telecommunications, the term handover is the process of transferring an ongoing session from one channel connected to the core network to another channel i.e., by transferring control from one BS to another. When a UAV moves into a different cell while session is in progress, it automatically transfers the session to a new channel. Handover operation not only involves identifying a new BS, but also requires that the data and control signals are allocated to channels within the new BS. The system must provide mobility to the users reliably and without dropping any of their sessions or lose their data. There are two kinds of handover: hard and soft. In a hard handover, the user disconnects from the source cell before connecting to the target cell. In soft handover, the user connects to the target cell before disconnecting it from the source cell. Handover is triggered by different kinds of events that are defined by various characteristics of the serving and the target cells. These events are described in the 3rd Generation Partnership Project (3GPP) Release 15 [1].

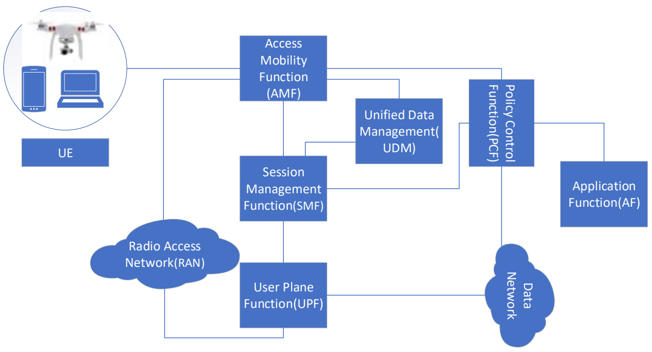

Fig. 1 System Architecture for fifth generation networks

As per ETSI report [5], 5G system architecture consists of Virtualized Network Functions (VNFs), each with their unique functionality, as shown in Fig. 1. In the 5G architecture, Access and Mobility management Function (AMF) receives all connection and session related information from the UAV. Handover happens when the link degrades (falls below threshold) and the mobile terminal (UAV) sends measurement reports, and the network tries to respond with a handover command. The handover command then initiates the process of handover (if necessary). AMF is linked to the Session Management Function (SMF), which contains all information regarding a session and is responsible for transferring session related information from source node to target node, and thus ends the current session and starts a new one. Thus, in a network with different RAT, the mobility feature is essential because UAVs in motion must be able to “roam” throughout the network and connect to the different RATs. Therefore, the provision of continuous service in such networks has become a major problem and, in this paper, it is solved by achieving seamless handover that enables a UAV to provide such a continuous service.

III. Methodology and Proposed Solution

A mobility architecture is designed for urban environments. Urban areas have a higher volume of BSs as they are required to satisfy the cell phone users. The cell phone users may be supported on the 5G network. These same 5G BSs can be used to support the UAV which will make use of a 5G link to communicate with the BSs. Fig. 2 shows a UAV connected with ground 5G BSs while in the urban areas and as it keeps moving away to a rural area where there are no BSs, it switches to a satellite. In this work only the urban environment use-case is considered.

According to the characteristics of the source and target cells, there are two types of handovers defined in 5G; intra RAT and inter RAT. If two networks belong to the different RAT, then the handover is defined as Inter-RAT handover. In this paper we have considered only inter RAT handover. Once a signal level is specified as the minimum usable signal for acceptable link quality at the BS receiver, a slightly stronger signal level is used as a threshold at which a handover is made. The decision to handover or not is taken by the BS based on measurement reports from the UAV. There are multiple measurement items namely, reference signal received power (RSRP), reference signal received quality (RSRQ), Signal to Interference Plus Noise Ratio (SINR) and other ways of periodic as well as event triggered to measure the signal of both serving and neighbour cells. In this paper, we use the RSS as a metric for handover decision.

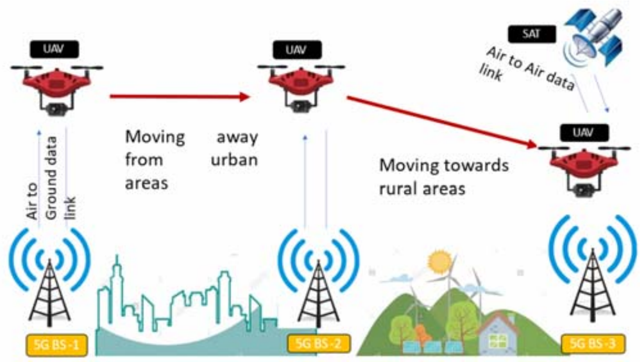

Fig. 2 High level architecture

Different algorithms for decision making have been employed in past, such as Simple Additive Weighted Algorithm (SAW) [6], Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS) [7], Weighted Product Model (WPM) [8].

The study of [9] compares the above mentioned and other methods and outlines their advantages and disadvantages. Thus, considering the disadvantages of the previous methods, we suggest an algorithm for decision making.

In [10], EWM is used to develop an effective decision-making algorithm for source water site selection. This same approach has been adopted in this paper to develop a decision-making algorithm for handovers. A MATLAB simulation set up is used to illustrate the seamless handover procedure between the two types of networks viz. 5G and LTE. Network is selected based on RSS and results are visualized in the form of two plots, one that shows the seamless transition (signal strength vs. time) and the other time the UAV remains in each network before switching to the other one.

A. Air-Ground Connectivity for Urban Environments

This scenario is modelled for urban environments where usually, there are adequate BSs to support the UAVs and as such can be integrated with the already existing cellular network. A high-level architecture depicting this scenario is shown in Fig. 3, where two UAVs are moving in a cellular network and are shown to switch between BS, the first one from A to B and the second one from C to D. A received signal parameter (such as RSS) from the UAV will be constantly measured and monitored by the BS. If it is higher than the threshold in an urban area, the drone will continue using the BS for communication. However, if the threshold is not met then handover is initiated. A decision is made using one of the decision algorithms (EWM). Event B2 from [1] is triggered when a primary serving cell becomes worse than the defined threshold for that cell, while a neighbour inter-RAT cell becomes better than their threshold. This triggers inter-RAT mobility procedures. Primary serving cell transmits lower RSS signal. The target cell provided adequate coverage, this is ensured by Inter-system neighbour cell measurements.

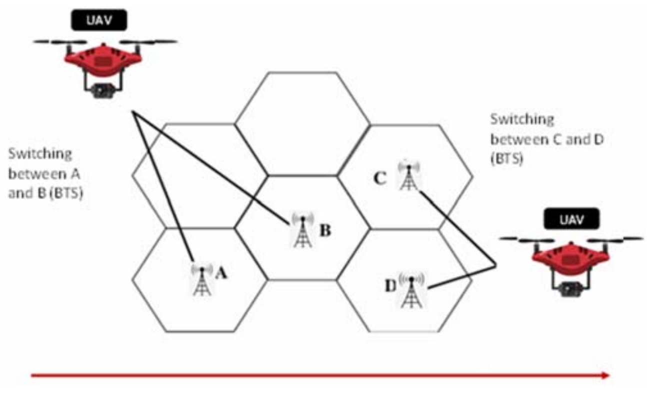

Fig. 3 UAV Mobility in Urban Area

A UAV is moving across an urban area through different cells. As it moves, it will constantly need to change BSs by 'handing over'. A signal parameter is measured. The measurement reports are constantly exchanged between BS and the UAV. The data flow from UAV via a source BS to the data plane of the 5G Core, i.e., User Plane Function (UPF). Radio Resource Control (RRC) signalling is employed to continuously measure and report on signal quality. This phase is known as handover initiation. A threshold is set for this parameter, which is determined to be slightly higher than the minimum acceptable signal. If the signal parameter is higher than the threshold, then the system goes back to the monitoring phase. Should it be less than the threshold, the handover procedures are initiated. The decision to handover or not is made using a decision algorithm. This is the decision phase.

Next, the UAV control is transferred from source BS to target BS. The UAV connects with the target BS to commence the switching process. After the handover is performed, a new route is defined and UAV's context is released to the new BS by the AMF. Context refers to all data and control signals that are associated with the UAV. A path switch request is made from the target BS to the AMF and once acknowledged, the data can flow from the UAV through that target BS and on to the prescribed UPF. This completion of the handover is termed as the execution phase.

We see that only after checking the signal parameter and ensuring that it is more than the threshold, the handover request is initiated.

The three stages of handover can therefore be summarized as follows:

(i) Initiation

Fig. 4 shows the initiation procedure where the UAV is currently connected to a 5G BS as explained in the previous section.

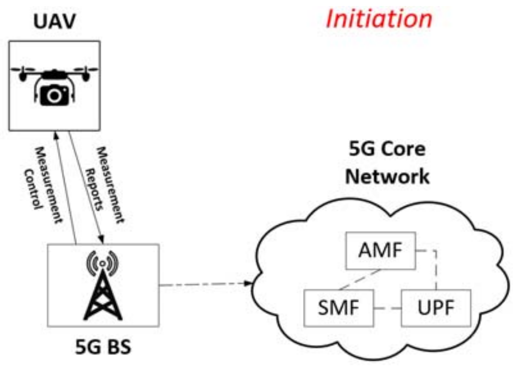

Fig. 4 Handover Initiation for UAV

(ii) Decision Phase

The BS then, based on the value (i.e., if it is lower than the threshold) uses a decision algorithm to make the handover decision. If a handover is needed, then the source BS sends a handover request signal (RQ) to the target BS. The RQ signal consists of information that identifies UE and associated protocols which will enable the UE to be 'admitted' to a new BS. The target BS understanding the need for handover sends back an acknowledgment signal (ACK). Fig. 5 represents the decision, where the UAV waits for the ACK signal to execute the handover.

(iii) Execution

The ACK signal consists of information that would enable the UAV to synchronize with the new BS. SN Status is then transferred so that packets can be transmitted to the new BS. The UAV then detaches from the old cell and synchronizes with the new cell and delivers the packets to the target BS. The handover is then confirmed by the UAV sending a confirm signal to the target BS. A path request signal is sent from the target BS to the AMF. The AMF switches the data links through the User Plane Functions. It then returns an ACK and the UAV switches to the target BS. The UAV context is finally released, and the handover is executed. This is shown in Fig. 6.

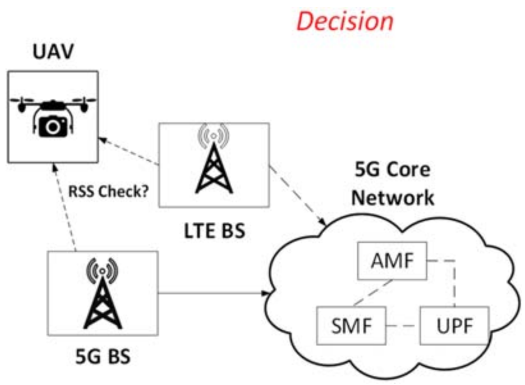

Fig. 5 Handover Decision for UAV

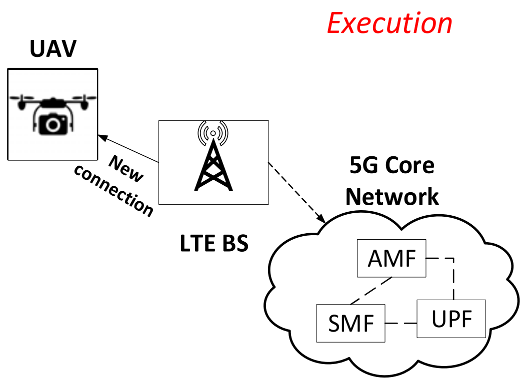

Fig. 6 Handover Execution for UAV

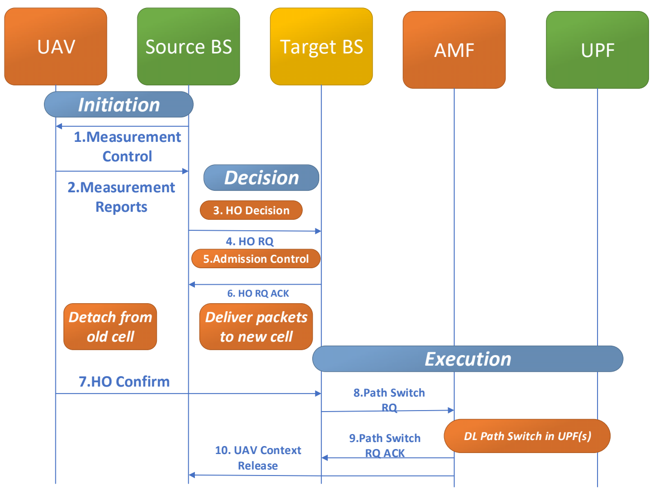

Fig. 7 Sequence Diagram for handover in urban areas

It can be summarized that in this proposed mobility scheme the handover will take place in three steps: (i) initiation, where measurement monitoring and reporting takes place, (ii) decision making, where an algorithm is employed to decide whether a handover is required or not, and (iii) execution, which carries out the handover and transfers complete control to the target BS. The sequential flow through the three stages is represented in Fig. 7 as a sequence diagram.

IV. EWM for Decision Making

Based on the disadvantages of the existing methods outlined in [9], in this paper an algorithm is presented for decision making.

The EWM evaluates a value by measuring its degree of differentiation. This method calculates the indicator's information entropy and uses the degree of difference in the indicator to measure the effective information and indicator weight contained in known data. The greater the degree of dispersion of the measured value, the greater the degree to which the index varies; thus, more information can be derived. Moreover, a higher weight should be assigned to the index, and vice versa [10].

m indicators and n samples are set in the evaluation, and the value of the ith indicator measured in the jth sample is recorded as xij in this method.

Standardizing the measured values is the first step. The standardized value of the ith index in the jth sample is denoted as pij, and its calculation method is as follows:

$$p_{ij} = \frac{x_{ij}}{\sum_{j=1}^{n} x_{ij}} \tag{1}$$

In the EWM, the entropy value E_i of the ith index is defined as:

$$E_i = -\frac{\sum_{j=1}^{n} p_{ij} . \ln p_{ij}}{\ln n} \tag{2}$$

When using the EWM, $p_{ij}. \, ln \, p_{ij} = 0$ is generally set when pij = 0 for the ease of calculation.

The range of Ei is [0, 1]. The larger Ei, the greater the degree of differentiation of index I, and more information can be obtained. Thus, a higher weight was allocated. Therefore, in the EWM, the calculation method of weight ωi is determined by:

$$\omega_i = \frac{1-E_i}{\sum_{i=1}^{m} 1-E_i} \tag{3}$$

With respect to this work, the RSS is considered as the indicator for different types of networks and consequently used as a decision-making factor for switching of network. The UAV moves across two different networks viz. 5G and LTE in an urban environment.

In the algorithm: BS and UAV co-ordinate as arguments to various functions are used to calculate path loss, RSS, weight property entropy. It first checks whether the network is in 5G or LTE network and once the network is determined, the RSS from both networks is calculated. Then depending on the respective RSS value, a handover is carried out to the network

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with higher RSS.

Algorithm 1: Weighted Property Entropy for decision making
Input: 5G_BS_co-ordinate; LTE_BS_co-ordinate; UAV_co-ordinate.
Output: RSS_5G; RSS_LTE.
1: Set UAV_co-ordinate, 5G_BS_co-ordinate and LTE_BS_co-ordinate.
2: Assign UAV_speed
3: Determine if UAV is_in_5G or is_in_LTE
4: Change net_state to 0 or 1
5: Compute RSS using calculate_RSS (UAV_co-ordinate, s) where s=LTE, 5G.
6: if in past network then
7: handoff_clock=0
8: else handoff_clock=1
9: Plot RSS vs time
10: Plot mark of the network vs time

Co-ordinates for both the BSs and the UAV along with the UAV speed are set. In next step, using function "is_in_5G_coverage" or "is_in_ LTE_coverage" the current state of the UAV is determined. Once the current state is defined a net state variable is either set (1) or reset (0) depending on which network the UAV is currently in. After this the RSS from both serving networks are calculated using calculate_RSS function. After the RSS is measured, it is checked which network has higher value and that network is selected, i.e., handover is performed. After the decision is made, if the UAV is still in the past network, then a clock signal "handoff_clock" is reset (0) else if handover is performed and the UAV is in the new network then "handoff_clock is set (1). After this, two graphs are plotted, viz. RSS vs time and mark of the network vs time.

The following functions are used in this model:

- *calculate_path_loss:* calculates the free space path loss using the formula derived from Friis Transmission formula [11]:

$$FSPL = 32.44 + 20\log_{10}\frac{d}{1000} + 20\log_{10}\frac{f}{10^6} \quad (4)$$

- *calculate_RSS:* calculates RSS using UAV co-ordinates and switch case variable for determining the type of network. It uses the following formula:

$$RSS = P_{tx} + G_{tx} + G_{rx} - FSPL - k \quad (5)$$

where RSS: received signal strength; P_{tx}: Transmitted Power. It is assumed to be 38 dBm for 5G and 24 dBm for LTE [12]; G_{tx}: Transmitter Antenna Gain, assumed to be unity i.e., 0 dB; G_{rx}: Receiver Antenna Gain, also assumed to be unity; k: slow fading margin, assumed to be 8dB [13]; FSPL: Free space path Loss as obtained from (4).

- *is_in_5G_coverage and is_in_LTE_coverage:* Checks which network UAV is in, based on its co-ordinates.
- *calculate_weight_property_entropy:* Assigns weights and performs decision making process.

V. Results and Analysis

The UAV moves across two different networks viz. 5G and LTE in an urban environment. A MATLAB simulation set up is used to illustrate the seamless handover procedure between the two networks. Network selection is based on the strength of the received signal and the decision to handover is formulated using EWM. The parameters used in this simulation are summarized in TABLE I.

TABLE I
System Parameters

Parameter	5G	LTE
Frequency	6 GHz	2.5 GHz
BS Co-ordinates	[0,0]	[600,0]
UAV Speed	19 m/s	19 m/s
Initial measured RSS	-84.46 dBm	-105.67 dBm

The analysis for seamless handover is simulated using RSS selection criteria based on an EWM decision model. A graph is plotted: time vs. RSS showing the change between 5G and LTE networks. In Fig. 8, we see that when the RSS falls below the set threshold, it switches to the LTE network. Similarly, when the RSS for the LTE network degrades below threshold it switches back to 5G. The UAV is initially in the 5G network and records RSS of about -84 dBm and falls steadily. After 20 s, the LTE network RSS starts measuring at -106 dBm slowly increasing. At about the 40 s mark, the RSS is decreasing for 5G and increasing for LTE. At -98 dBm the UAV switches to the LTE network. The RSS in LTE increases up to -88 dBm in a 6 s time frame, suffers a brief period of outage and then starts falling. After 71 s, the RSS from 5G becomes more than that of LTE and the UAV switches back to 5G which now has RSS of -102 dBm.

To further illustrate the seamless handover another graph is plotted where we could see that the UAV switches seamlessly from 5G to LTE and then back to 5G. This graph is shown in Fig. 9.

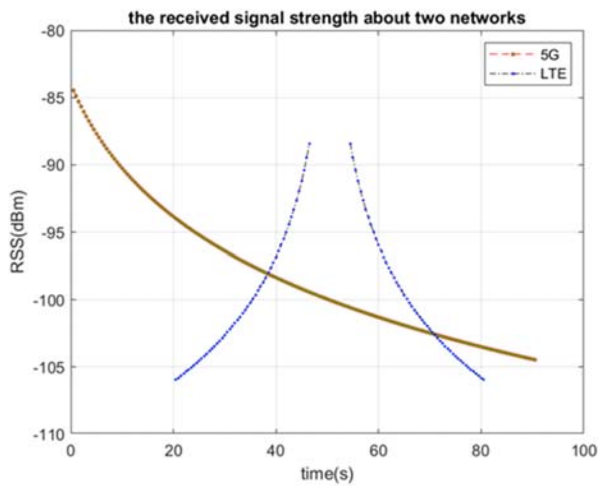

Fig. 8 RSS switching between 5G and LTE networks

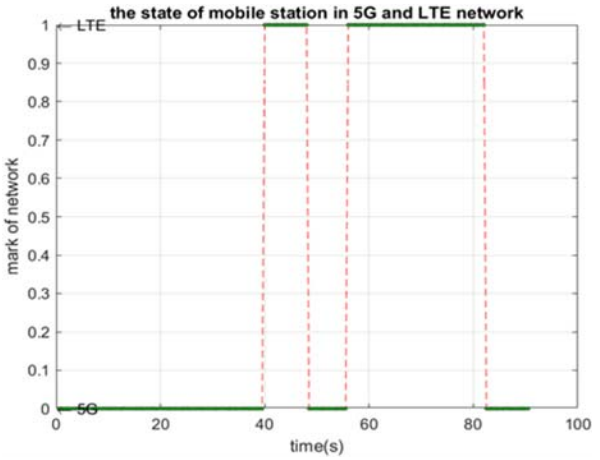

Fig. 9 Switching between 5G and LTE

As already explained above, the UAV stays in 5G network for 40 s and then switches to LTE stays there for 18.5 s and goes back to 5G. After another 7 s at 55.5 s mark, it switches back to LTE stays there for 26 more seconds and then goes back to 5G.

VI. Conclusion

The UAVs must communicate with the ground station continuously to maintain data flow. One of the key parameters which would affect the implementation of UAV-5G integrated architecture is its mobility model. In this paper, mobility architectures for integrating UAV with 5G communication architecture is achieved by developing a mobility algorithm that enables seamless handover in urban environments. A simulation level analysis is carried out illustrating seamless handover of a UAV between 5G and LTE networks. The selection is based on RSS where the decision making is implemented using EWM. The results are plotted graphically which show that switching is carried out seamlessly. Therefore, EWM which has been previously used for water site selection has been successfully implemented for network selection decision in this paper. Thus, UAV communication specifically the mobility problem in the 5G architecture aimed to cover urban environments to provide continuous and uninterrupted service with the proper mobility architecture is demonstrated on a simulation level successfully and the work could act as a step forward in making UAV-5G architecture integration is possibility.

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