Entropy Weighted Method Handover for 5G-UAV Systems in Urban Environments

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Abstract— **The demand for increased data transfer rate and network traffic capacity has given rise to the concept of heterogenous networks. Heterogeneous networks are wireless networks, consisting of devices using different underlying radio access technologies (RAT). In an urban heterogeneous network environment, Unmanned Aerial Vehicles (UAVs) must be able switch seamlessly from one base station to another for maintaining a reliable link. Therefore, seamless handover in such environments have become a major challenge. In this paper, a novel scheme to achieve seamless handover is developed, an algorithm based on Received Signal Strength (RSS) criterion for network selection is used and Entropy Weighted Property (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— ***Unmanned aerial vehicle (UAV); fifth generation (5G); mobility, handover; air to ground (A2G), urban environment.***

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 networks, and service areas are divided into small geographic areas called cells. The cell's 5G 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 (Gbit/s)) are expected to increase to a much 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 are also used as common internet service providers for laptops and desktop computers, that would eventually lead to applications of Internet of Things (IoT) [2] become a reality.
When the 5G is used for Unmanned Aerial Vehicle (UAV) A2G (Air to Ground) data links, higher carrier frequencies lead to higher path loss. This means that beam formation 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 service such as UAV Non-Orthogonal Access (NOMA), Software Defined Networks (SDN), thus converging the capabilities of communications, computing, and caching.
The term heterogeneous networks come from the integration of different telecommunication technologies with the aim of using their additional characteristics. Because of heterogeneous networks, users can transport the connection between several access points of different types, benefitting from the best customized services depending on their preferences. Moreover, heterogeneous networks represent an important solution for decreasing congestion on mobile networks by sharing traffic with other access technologies with higher flows. Because of their fast and significant deployment, mobile networks will consist of a set of heterogeneous systems, managed by different operators, and formed of distinct access networks [4]. All the user connections with this heterogeneous network should occur without interruption and without degradation in service when the user changes from one network to another. In this context, mobile terminals will be network multi-interfaces, which enables them to move from one system to another transparently during communication. In this paper, therefore, challenges of global mobility and vertical handover are addressed.

A novel algorithm for decision making in vertical handover is presented in this paper. Entropy Weight Method (EWM) assigns different weights for different network attributes and selects the one with the highest weight. Received Signal Strength (RSS) is one key parameter for network selection, and in this algorithm the network with highest RSS is selected. Thus, this work presents a new 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 discusses the challenges of mobility in heterogeneous networks. In Section III the methodology adopted in this paper is discussed and the proposed solution is introduced. An algorithm is developed based on entropy weight method 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 call or data session from one channel connected to the core network to another channel. 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 base station, but also requires that the data and control signals be allocated to channels within the new base station. The system must provide mobility to the users reliably and without dropping any of their sessions or lose their data. There are two types of handovers, hard and soft. In 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 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 summarized in [1]. As per ETSI report [5], 5G system architecture consists of Virtualized Network Functions (VNFs), each with their unique functionality, as shown in **Fig. 1** the 5G architecture diagram out of which the 5G Core Access and Mobility management Function (AMF) receives all connection and session related information from the UAV. In 5G, 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 new session an starts a new one.

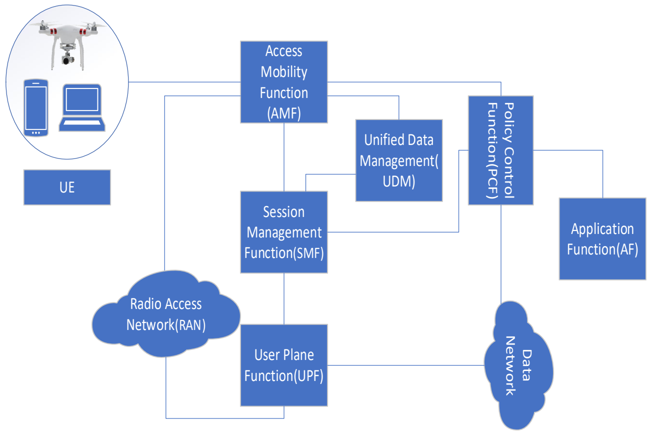

Fig. 1 System Architecture for fifth generation networks

Thus, in a network with different radio access technologies, the mobility feature is essential because UAVs in motion must be able to "roam" throughout the network and connect to the different radio access technologies. Therefore, the provision of continuous service in such networks has become a major concern and, in this paper, it is tried to be 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 base stations as they are required to satisfy the cell phone users. The cell phone users may be supported on the 5G network. These same 5G base stations can be used to support the UAV which will make use of a 5G link to communicate with the base stations. **Fig. 2** shows a UAV connected with ground 5G stations while in the urban areas and as it keeps moving away to a rural area where there are no base stations 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 base station 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 base station based on measurement reports from the UAV. There are multiple measurement items namely, reference signal received power, reference signal received quality, Signal to Interference Plus Noise Ratio (SINR) and multiple ways periodic and event triggered to measure the signal quality of the serving cell and neighbor cells.

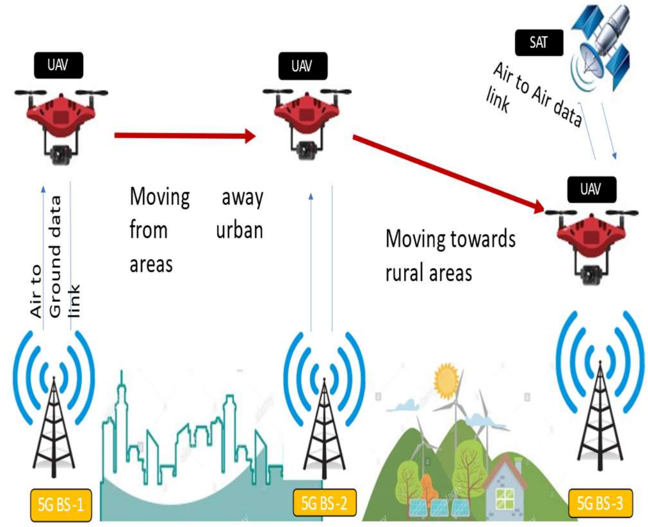

Fig. 2 High level architecture

In [6] entropy weighted method 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 base stations 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 Received Signal Strength (RSS)) from the UAV will be constantly measured and monitored by the base station. If higher than the threshold in an urban area, the drone will continue using the base station for communication. However, if the threshold is not met then handover is initiated. A decision is made using one of the decision algorithms (Entropy Weighted Method). Event B2 from [1] is triggered when a primary serving cell becomes worse than the defined threshold for that cell, while a neighbor inter-RAT cell becomes better than their threshold. This can be used to trigger inter-RAT mobility procedures when the primary serving cell becomes weak. Inter-system neighbor cell measurements are used to ensure that the target cell provides adequate coverage.

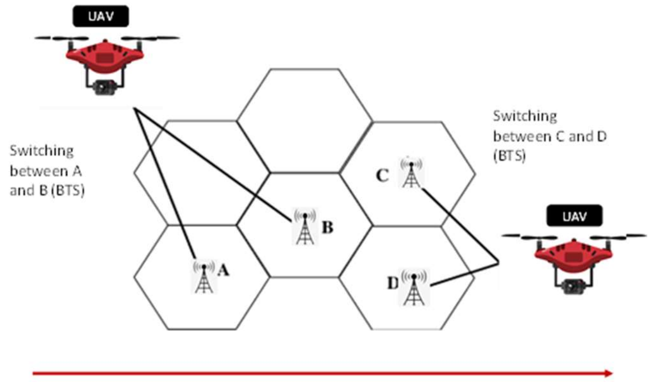

Fig. 3 UAV Mobility in Urban Area

In **Fig. 3** a UAV is moving across an urban area through different cells. As it moves, it will constantly need to change base stations (BS) by 'handing over'. A signal parameter is measured. The measurement reports are constantly exchanged between BS and the UAV. The data flows from UAV via a source BS to the data plane of the 5G Core, i.e., UPF. Radio Resource Control (RRC) signaling 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. After which handover is carried out and the UAV control changes from one BS to another BS. The UAV connects with the target BS to commence the switching process. After the handover is performed a new route is defined the tunnels are moved across to the target BS and UAV's context 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, is the handover request initiated.

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

(i) Initiation

Measurement reports are constantly exchanged between BS and the UAV and thus it is monitored. The data flows from UAV via a source BS to the data plane of the 5G Core, i.e., the User Plane Function (UPF). Radio Resource Control (RRC) signaling is employed to continuously measure and report on signal quality.

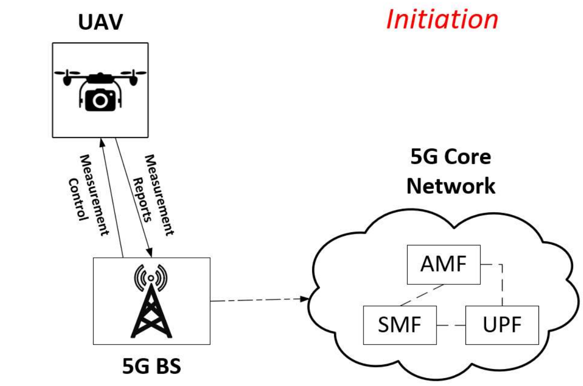

Fig. 4 Handover Initiation for UAV

(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 BS. The target BS understanding the need for handover sends back an acknowledgment signal (ACK).

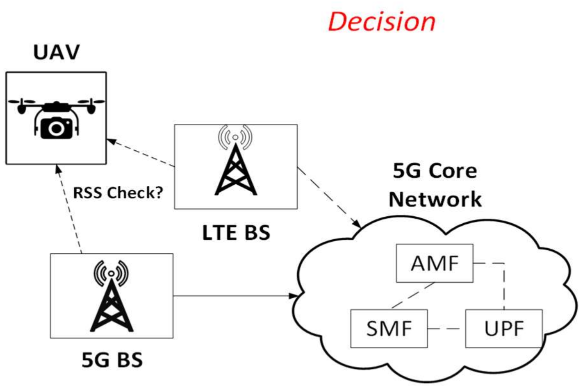

Fig. 5 Handover Decision for UAV

(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 now 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 acknowledgement signal and the UAV switches to the target BS. The UAV context is finally released, and the handover is executed.

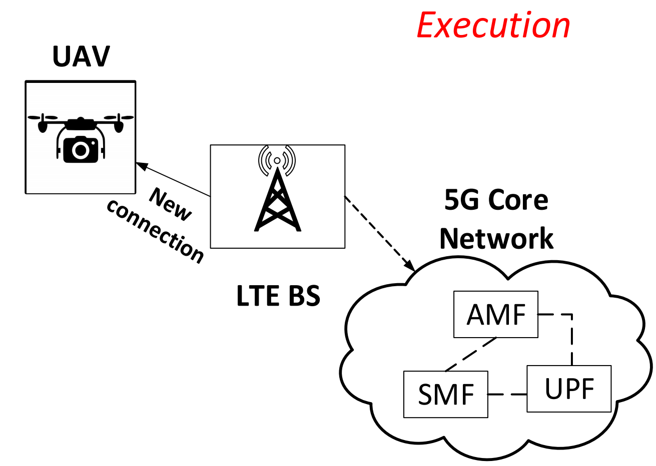

Fig. 6 Handover Execution for UAV

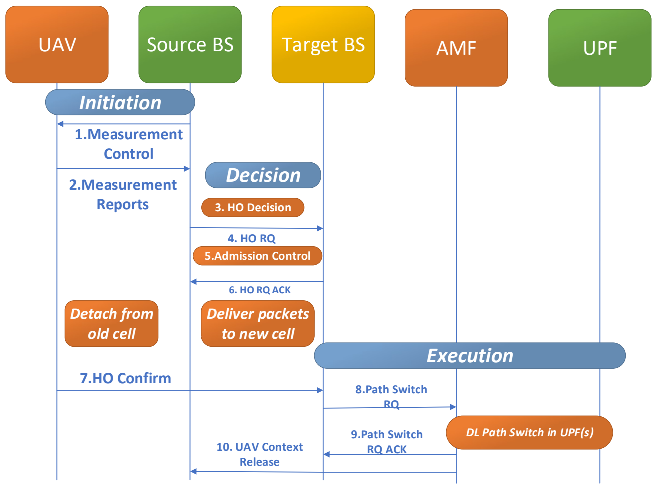

Fig. 7 Sequence Diagram for handover in urban areas

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. 6 as a sequence diagram

IV. ENTROPY WEIGHTED METHOD(EWM) FOR DECISION MAKING

The EWM evaluates value by measuring the degree of differentiation. The method calculates the information entropy of the indicator and use the degree of difference of the indicator to measure the effective information and indicator weight contained in the known data. The higher the degree of dispersion of the measured value, higher the degree to which the index varies thus more information can be derived. Moreover, higher weight should be given to the index, and vice versa [6]

In this method, m indicators and n samples are set in the evaluation, and the measured value of the i^{th} indicator in the j^{th} sample is recorded as x_{ij}.

The first step is the standardization of measured values. The standardized value of the ith index in the jth sample is denoted as p_{ij}, and its calculation method is as follows:

$$p_{ij} = \frac{x_{ij}}{\sum_{j=1}^{n} x_{ij}} \quad \textbf{(1)}$$

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

$$E_i = -\frac{\sum_{j=1}^{n} p_{ij}.\ln p_{ij}}{\ln n} \quad \textbf{(2)}$$

In the actual evaluation using the EWM $p_{ij}.ln\, p_{ij} = 0$ is generally set when $p_{ij} = 0$ for the convenience of calculation.

The range of entropy value E_i is [0, 1]. The larger the E_i is, the greater the differentiation degree of index I is, and more information can be derived. Hence, higher weight should be given to the index. Therefore, in the EWM, the calculation method of weight ω_I,

$$\omega_i = \frac{1 - E_i}{\sum_{i=1}^{m} (1 - E_i)} \quad \textbf{(3)}$$

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: Base station and UAV co-ordinates as arguments to various functions are used to calculate slow fading, 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 with the 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: Compute RSS using calculate (UAV_co-ordinate, s) where s=LTE, 5G.
5: Change net_state to 0 or 1
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

The following algorithm outlines the decision-making process using the weighted entropy method and makes use of base station and UAV co-ordinates as arguments to various functions.

Functions used:

i. calculate_slow_fading: Calculates slow fading using UAV co-ordinates
ii. calculate_RSS: Calculates received signal strength using UAV co-ordinates and switch case variable for determining the type of network
iii. is_in_5G_coverage and is_in_LTE_coverage: To check which network UAV is in
iv. calculate_weight_property_entropy: To assign weights and perform decision making process.
v. is_network_performance_meet: calculate the network performance and simultaneously calculate the weight of each property

By taking the UAV and base station co-ordinates as arguments to the functions mentioned above those parameters are calculated. In the main algorithm UAV speed is specified to be a constant and then using functions (ii) above it is determined which network the UAV is in initially. After that is determined (in this simulation it is 5G network initially), the RSS for the UAV is calculated, followed by measuring the RSS from the neighbouring network (LTE). If it is found that 5G has higher RSS, then it continues to stay in 5G, a clock signal is reset. On other hand if LTE has a higher RSS, then the handover must take place. The UAV's net state value is changed now to reflect its switch to LTE and the clock signal is set. The measurement process starts again in the new network and continues, so that the UAV always receives the best signal strength.
A graph is plotted for RSS against time, which shows the switch. A second one is plotted that represents the time spent by the UAV in each network.

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 Entropy Weighted Method (EWM). The parameters used in this simulation is summarized in **Table 1**

Table 1 System parameters

Parameter	5G	LTE
Frequency	6 GHz	2.5 GHz
Base station 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 entropy weighted method decision model. A graph is plotted showing time vs RSS showing the change between 5G and LTE networks. A graph is plotted between time against the RSS. In Fig. **8** we see that as soon as the RSS falls below the set threshold for the 5G network it switches to the LTE network and 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 40 s mark, decreasing RSS of 5G and increasing that of 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 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 the **Fig. 8**

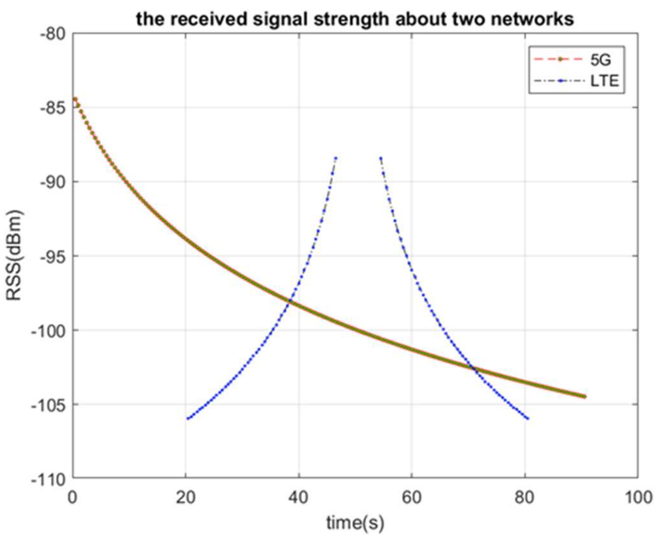

Fig. 8 Received Signal Strength switching between 5G and LTE networks

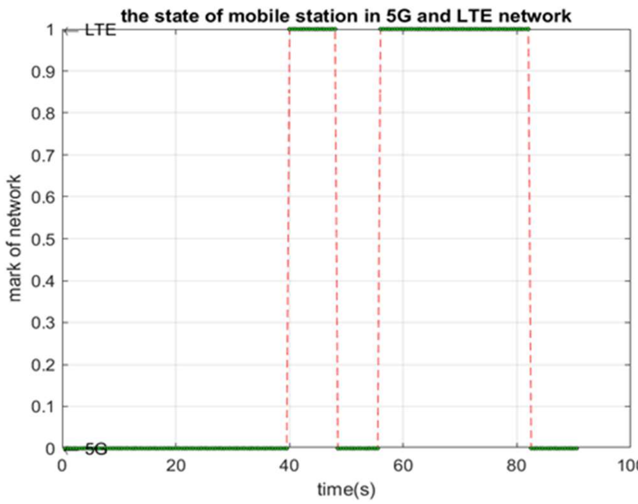

Fig. 9 Switching between 5G and LTE

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 continuous flow of data. 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 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 entropy weight method (EWM). The results are plotted graphically which shows that switching can be 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 a is possibility.

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