International Journal of Engineering in Computer Science

E-ISSN: 2663-3590
P-ISSN: 2663-3582
IJECS 2022; 4(1): 01-07
Received: 10-10-2021
Accepted: 04-12-2021

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Development of a mathematical formulation for handover management in heterogeneous network

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DOI: https://doi.org/10.33545/26633582.2022.v4.i1a.57

Abstract
The proposed radio network was described as an unbroken–time Markov chain and generates an effective mathematical expression for state probabilities. However, the proposed model was not stretched to combine both the Poisson and the batched Poisson spectrum types. From the title of the work, in similarity to the study in focus, a set of mathematical equations were also formed for the developed model. On the contrary, the study covers 2g, 3g and 4g respectively at the implementation phase. As a stochastic process, Pareto Positive Stable Distribution (PPSD) based on type 2 fuzzy logic principle was used for control in the handover optimisation decision-making process. About this Thesis, Self-Organized Network (SON) was adopted towards increased Quality of Service (QoS) in Het-Net. Also, as a result of the dynamic nature of the signal, based on fuzzy logic, a self-adaptive (optimizing) model was developed to make an intelligent decision based on the predefined membership function. A Markov-based framework was developed by Guidolin, Pappalardo, Zanella & Zorzi (2015) to model the handover process for the mobile subscriber, while an optimum context-dependent handover criterion was generated. The proposed mathematical model was validated by simulations, comparing the performance of the author's strategy with conservative handover optimization techniques in several scenarios. Lastly, the impact of the handover policy on the subscriber's performance was depicted and how it can enhance the users' capability using context information.

Keywords: Pareto Positive Stable Distribution (PPSD), Quality of Service (QoS), Self-Organized Network (SON)

1. Introduction

Horizontal handover is the movement of homogenous or similar networks (for example, Universal Mobile Telecommunication Service (UMTS to UMTS). Instead, the mobility of different (heterogeneous) systems is known as vertical handover (for example, UMTS to Wireless Local Area Network (WLAN). The optimization of vertical handover involves making optimum use of the vertical handover process by certain criteria, taking into consideration a set of options accessible. Therefore, optimizing integrated cellular networks concerning vertical handover management is the central focus of this research. Vertical handover is a fundamental need in heterogeneous systems allowing mobile cellular networks to constantly exchange information, the next generation of cellular systems must thus continue this process.

States that "vertical handover refers to all procedures carried out so that a mobile terminal may migrate from one mobile provider to another without any connection loss." For instance, roaming in-between cells and operators is facilitated through the cellular network handover mechanism and, as smaller tiny geographic areas are used for increased capacity, the frequency of cell border crossings is increased.

Handover is an important element of mobile networking. The basics here are a mobile subscriber (MS) that provides "best service" to MSs that currently are located within a cell and that has a wireless link to a Base Station Subsystem (BSS). For every active (MS) on the cell, the BSS of a cell executes a radio link. A Mobile Switching Center (MSC) manages one or more BSSs. Apart from any other job, the main responsibility for managing call processing mobility is with the MSC. When an MS moves, in contrast to certain other BSSs, it is somewhat likely that the currently operating BSS can no longer provide sound quality services. The present operator may choose to hand over service to some other active BSS with superior performance or, if necessary, to another active MSC instead of discontinuing the service to the MS. Different call transfer methods were therefore planned and used.

The cheapest handover technique is the one in conventional handover management when the MS relies solely on decision making for handing over.

The MS may then choose an alternative base station when the signal quality or the signal strength received (RSS) falls below a standard threshold. That is, the MS makes the transfer decision. However, conventional handover systems with too much signal overhead are generally fading out with the advent of cognitive radio. The Cognitive Radio technology offers transfer frequency bands, whereas the frequency bandwidth for which a service provider is assigned is defined. Cognitive radio technology offers the possibility to make use of the same network frequency. This is used for longer periods and is known to provide the network resources needed for handover. It is known as Cognitive Radio Handover (CRHO) (Adnan, Zen & Kota, 2013) [1].

Two primary types of handover are available: soft handover and hard handover. The major difference between them is that only one radio connection exists between a Mobile Subscribers (MS) and access points (APs) in the soft handover; whereas in the hard handover, MS may communicate concurrently over an extended period with both old and new access points. This is true for calling traffic. A hard handover is a handover method used with radio networks that require the user's connection to be completely broken with an already existing base station before being switched to a different base station. It is called break before make. Soft handover (otherwise known as make-before-brake) is nevertheless considered for this study because it is quite challenging crossing from one access technology to another.

The horizontal handover is a conventional call transfer in the same technology of the connection layer, a typical example of this is the machine-to-machine (M2M) communication. Horizontal handover is triggered when a mobile subscriber moves within homogeneous network technology under the same mobile operator. For example, a mobile user roaming within the coverage of their provider's network will have to switch in-between cellular towers as they travel within and outside of the range of different towers.

The Node B is a telecommunications terminal in a specific mobile telecommunication system, that adheres to the UMTS standard. It provides the connection between cell phones and the wider radio (cellular) network. UMTS is the leading third-generation (3G) standard, whereas, the Node B relates to a Base Transceiver Station (BTS) in the Global System of Mobile Communication (GSM).

Soft handover refers to the transfer of call between two segments of the same cell of a NodeB. This is called make before the break; whereas, softer handover takes place between two cells comprising of different NodeB. There are two categories of softer (horizontal) handover, namely- intra Radio Network Controller (RNC) and Inter RNC handover. Intra-cell handover is a soft handover that occurs when a user is moving within a cell to change the channel to mitigate inter-channel interference in the same BS. On the other hand, inter-cell handover is a type of hard handover that triggers when a subscriber moves to an adjacent cell and communication is transferred from one BS to another.

Vertical handover can further be categorized into upward vertical handover and downward vertical handover. By convention, an MS with high mobility has a low tendency of travelling in a low coverage network. This process of handing over from a lower coverage network to a higher coverage network is called upward vertical handover. Generally, this takes place when an MS moves out of a segment of the network with higher bandwidth but lower coverage and moves to a lower bandwidth but higher coverage network. A typical example is when subscribers travel from a low coverage network like WLAN (3G) and move into a higher coverage network like Long Term Evolution (LTE) which is a 4G network. This process of linking to a lower coverage from a higher coverage network is called downward vertical handover. For this type of handover, the link needs to be restructured so that higher bandwidth can be consumed.

Vertical Handover Optimisation (VHO) parameters include- Resource Availability (R. A.), Received Signal Strength Indicator (RSSI), Power consumption, Quality of Service (QoS), Handover latency, network connection time, monetary cost, User preferences, security and user mobility pattern. Despite the integration of Heterogeneous Networks, Handover management is still an issue for both academia and mobile telecommunication industries.

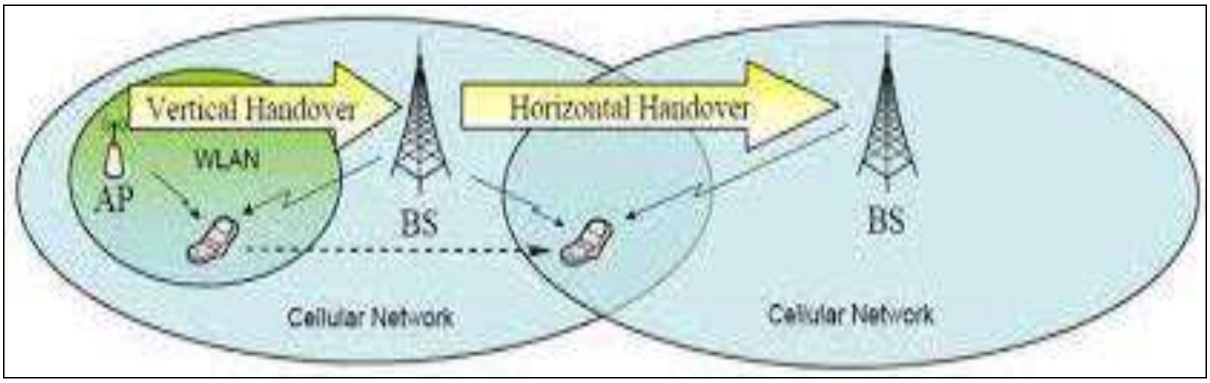

Fig 1: Optimization of coverage and handover in a heterogeneous network (Almoshabi & Elalem, 2019) [13]

2. Literature review

2.1 The Pareto principle (The 80/20 Rule)

The Pareto principle is frequently used as a directing tool in research analysis and solutions; this also applies to optimization techniques for network resources. It is also relevant in root cause analysis. The 80/20 rule can be understood as 20% effort yielding 80% results or 80% of time expended returning 20% of results. The principal was named after Wilfried Fritz Pareto who was born into the family of Vilfredo Federico Damaso Pareto on July 15, 1848, in Italy. He was trained as well as being an engineer, sociologist, economist, and political scientist. His work on income distribution and the decisions of people was crucial to economics. He pioneered the idea of Pareto efficiency and contributed to the knowledge expansion of the microeconomics field. He was the first philosopher to ascertain that income, resources or network distribution Also known as the power-law probability distribution, the following distribution obeys a Pareto distribution. The 80/20 rule is a concept that highlights the significance of the irrelevant many and the importance of the crucial few. That is, it concentrates more on the vital few aspects of a problem.

2.2 Applications of Pareto principle in Vertical Handover Optimization

For this work, the principle is applied to:

I. Control vertical handover optimization
II. Develop a solution (the optimization model was developed based on Pareto Positive Stable Distribution)
III. Manage time and other network resources: Timeliness in the vertical handover process is of the essence and the Pareto principle is applied as a time management technique.

In summary, in Pareto principle:

i. relative few of the contributors account for the main part of the effect. The most important parameters were combined to attain the accurate and optimal result.
ii. it is important to find patterns that depict the highest concentration of enhancement (optimization) abilities in the fewest number of remedies.
iii. if one way of stratifying the data does not result in a vital few, it is critical to re-stratify the data by other factors until the vital few are established. Pareto entails that a small number of effects are answerable for the vast majority of the outcome.

Visual method for splitting the vital few from the valuable many form consensus on our top precedence, and therefore sets the stage for action. Pareto is appropriate in prioritizing problems, analyzing symptoms and finding root causes. It is a suitable time management tool (because 20% of the time or other resources can be invested to return 80% result.

2.3 Cognitive Radio

The cognitive radio, which can think, is characterized as a radio that thinks. Researchers' inability to adhere to a unified definition of CR has been caused by the inconsistencies of thought processes. The FCC defines the CR as a radio that can alter its settings according to its interaction with its surroundings, whereas the ITU describes it as a system or radio that detects its environment and adjusts to it, changing dynamically and autonomously.

Cognitive Radio has helped promote spectrum use by distinguishing between main and secondary users. The technology can operate inside several authorized frequencies, including government entities and mobile operators; it can also function in some frequency bands that do not need permission. License holders are the main users, with their private channels, while secondary users are unlicensed users who have access to the channels given to the prime users. The cognitive radio network architecture is shown in figure 2. The secondary user plans to utilize opportunistic strategies to access the current signal and avoid interference from the main user. After selecting a preferred channel that is free of all other users, the secondary user utilizes the channel without permission until a new user arrives. The primary aim of CR is to get the most out of spectral holes.

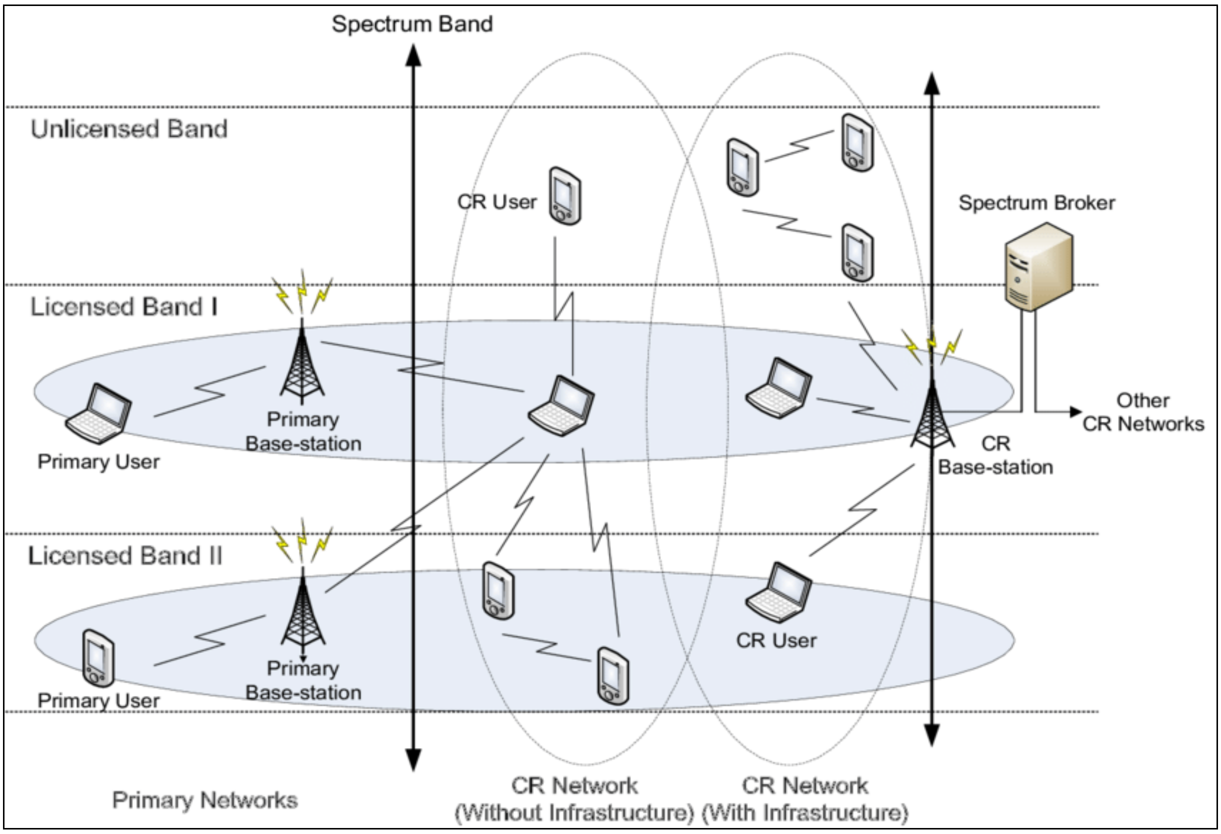

Fig 2: Cognitive Radio Network Architecture (Li, 2010)

2.4 Handover in Cognitive Radio Networks

In a CR network, main and secondary users manage Handover requests. The primary user's request for Handover is because of the drop in the quality of the communication channel and the return of the primary user; the secondary user's request for Handover is because of the restoration of the primary user, the communication channel's drop in quality, and the existence of a communication channel with improved quality. The channel distribution system in the CR network influences the quality of service provision and optimum spectrum use, along with delivery success or successful delivery. Here are the conditions for cognitive radio handover:

1. If the inter-handover time is higher than the threshold, then.
2. If the number of handover requests is low
3. If the traffic volume is below the threshold, the need rate for handover is lowered.

Cognitive Radio is the key to active use and opportunist access to the frequency spectrum. The capacity to sense the environment and conformity with the present environmental settings are included in the features of Cognitive Radio Networks. The use of CR was first discussed by J. Mitolla, and Akyildiz and others who studied its application in the cellular networks of future generations.

2.5 Dynamic Spectrum allocation in cellular networks

As was said before, the mobile network's spectrum distribution was expected to be static. This implies that fixed channel (frequency) assignments are given to each of the cluster cells, but alternative users in the same cluster's cells do not utilize the channels. If a user moves from one cell to another in the same cluster, he conducts a handover, but when the new cell and all its channels are full, the connection is severed. However, in other places in the cluster, it's conceivable that an empty channel (frequency) will occur. That means if the routing of those channels is more likely to congest the cell, this instantiation is incapable of having any kind of communication disruption. Therefore, a good deal of study has been done to address this problem. In reality, the central point of the research is the spectrum's shifting distribution. When it comes to a cellular network, reuse of channels does not occur since any interference in the cell is minimal and, thus, may be considered a noise.

3. Methodology

Develop Q-learning Algorithm Formulation for vertical handover

A decision model for handover using fuzzy logic was developed

Adaptive Hysteresis Fuzzy Logic Model for Vertical Handover

Membership Function for vertical handover management in mobile cellular heterogeneous networks

Fuzzy rules for vertical handover management in mobile cellular heterogeneous networks

4. Result and disscusion

Result Based on a mathematical relationship between handover and energy.

For modelling the power consumption of each component the following equations were used:

$$P(r) = (1 + a)(r/R)P_{active} + (1 - (1 + a)r/R)P_{sleep}$$

$$P_{sleep} = b\, P_{active}$$

with

$P(r)$: Average electricity usage as a subscriber rate function. The first term counts the amount of time while the component is active, the second is sleeping.

P_{active}: Energy usage if the component transfers complete data (active state),

P_{sleep} : Power consumption in the sleep saving mode of the component,

b: Proportional factor in estimating idle power as an active power percentage,

r: Average subscriber rate (we modelled upstream 50 Mbit/s and upstream 10 Mbit/s)

R: Max. component rate (e.g. downstream 2.5 Gbit/s and upstream 1.25 Gbit/s in EPON, 1 Gbit/s in particular user rate processing blocks)

a: Superficial (a ratio of listening state to total sleep cycle plus a preamble time for synchronizing the component).

Thanks to the increased average rate of access, the integration between EPON and LTE may enhance the energy efficiency of the access network. However, with comparable MCSs FIBRE has better SNR than LTE, resulting in lower data rates for LTE.

Differences in split ratios, FBS range, diffusion factor and modulation scheme affect the electricity consumption and energy efficiency of the integrated access network when taking into account parameters changes. The increasing split ratio may decrease the overall energy consumption of the network and enhance energy efficiency by improving equipment sharing. In addition, a longer FBS range may decrease overall energy usage and also boost energy efficiency considerably. However, it is necessary to take cautious action so that the greater range does not impair the signal quality. On the other hand, a change in the broadcasting parameters does not have a significant difference in both total energy consumption and efficiency and has the smallest effect on overall energy consumption.

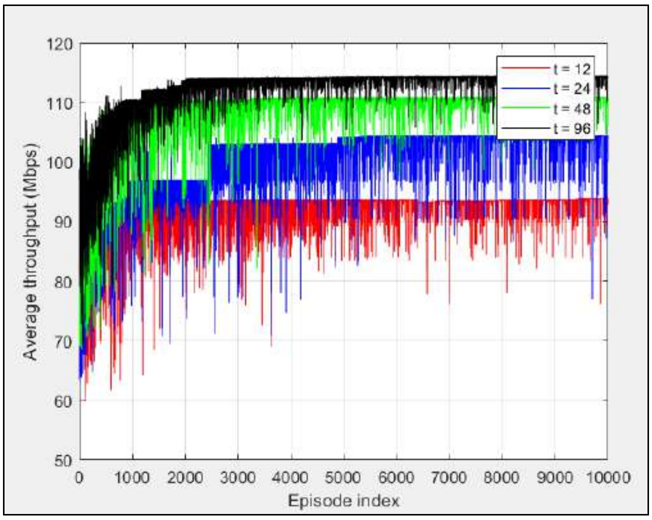

Fig 3: Average throughput for Vertical Handover based on Signal Level

Figure 3 shows the average throughput for vertical handover on signal level. Multimodal MTs may now transition between WLAN and cellular networks in real-time and choose their preferred network. MTs need effective vertical handover (VH) algorithms to utilize the heterogeneity of the wireless environment. From figure 3 above, the best average throughput was 114Mbps

Q-learning handover

%% Create reward matrix for limiting the possible actions at each state (TTT combination)

% We have 9 possible actions:

%

% Increase TTT_LV by a single level: (i+1)

% Decrease TTT_LV by a single level: (i-1)

% Increase TTT_VL by a single level: (i-n)

% Decrease TTT_VL by a single level: (i+n)

% Increase both TTT_LV and TTT_VL by a single level: (i+n+1)

% Decrease both TTT_LV and TTT_VL by a single level: (i-n-1)

% Increase TTT_LV and decrease TTT_VL by a single level: (i-n+1)

% Increase TTT_VL and decrease TTT_LV by a single level: (i+n-1)

% No change to the current values of TTT_LV and TTT_VL: i

% 24 equal-length periods

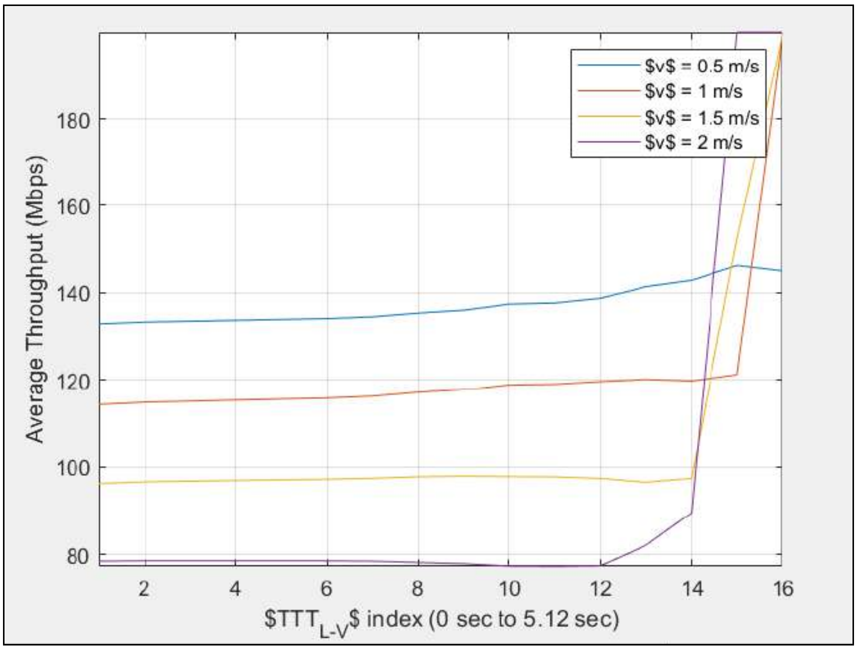

Fig 4: Average throughput on Vertical Handover based on one base station

Figure 4 above show the throughput on vertical handover when one base station is used. The best average throughput based on the iteration was 200Mbps at 14sec.

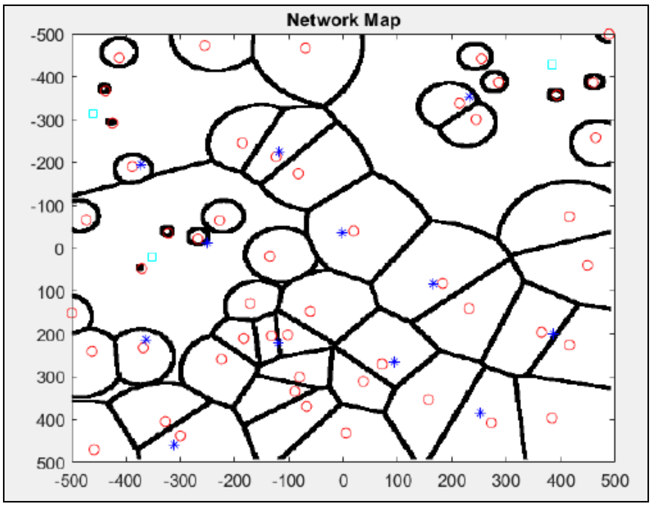

Fig 5: Network Map for vertical handover management in mobile cellular heterogeneous networks After applying Q-learning Algorithm

Figure 5 shows the result of the vertical handover management after the learning algorithm was applied. The network map for various signals was shown. There is improvements in the mobility models. These developments are less to certain circumstances and thus do not provide support in generic mobility.

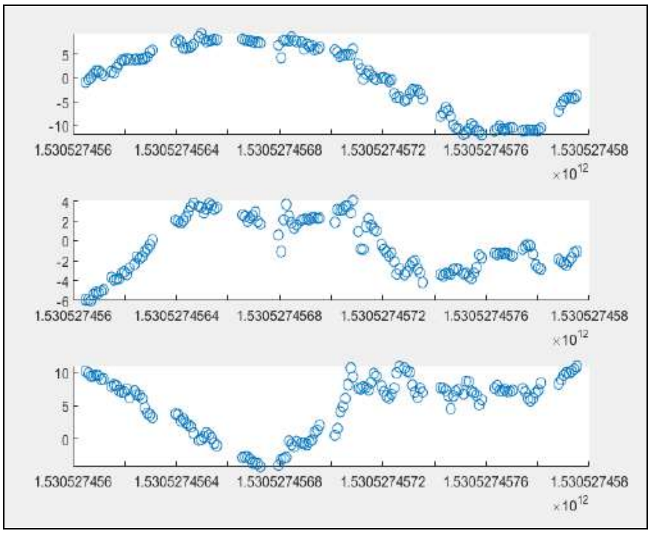

Fig 6: Noise Filter before Handover

Figure 6 shows the signal generated for noise filter before handover. The signal level was not properly segmented

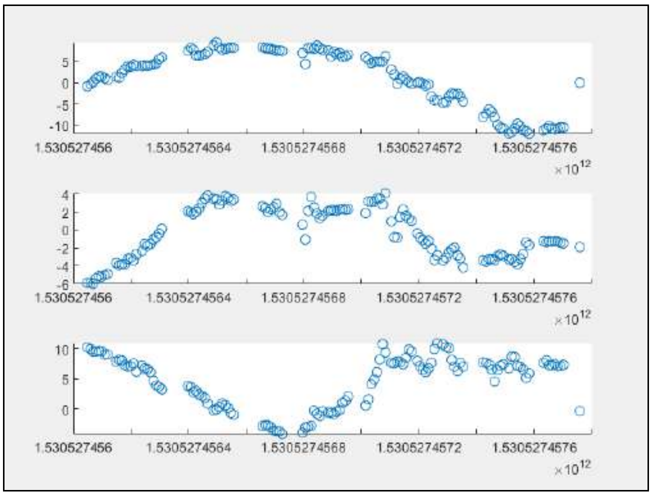

Fig 7: Noise Filter after Handover

Figure 7 shows the noise filter after handover. The signal level was segmented and resuce noise level

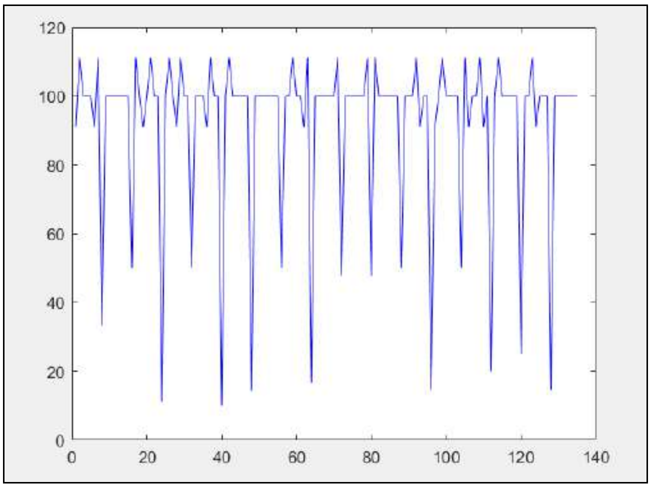

Fig 8: Spectrum sensing before handover

Figure 8 shows the effect of handover on spectrum sensing. This lower the call quality of the heterogenous network. The signal level attenuate bove the threshold level from 120 to 138db.

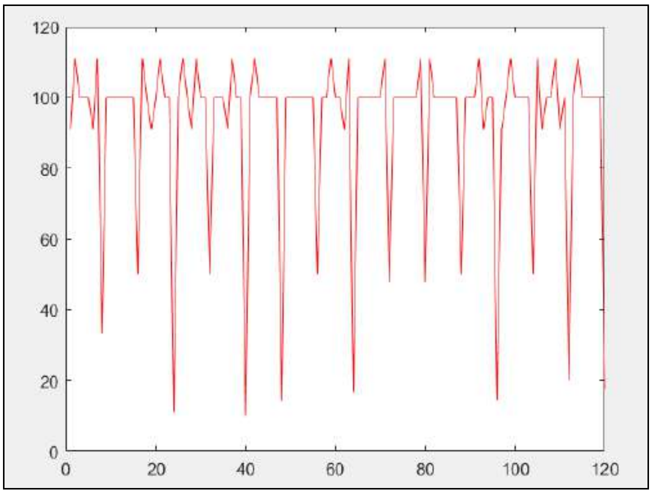

Fig 9: Spectrum Sensing after Handover

Figure 9 shows the spectrum sensing afetr handover. There is improvement os noise signal level from 138db to 120db. Handover was be used to avoid the termination of call when user signal travel from cell to another in Mobile Network.

5. Conclusion

A collection of algorithms based on established key performance indicators for handover optimisation (KPI). This involves creating a new class of coupled Vertical Handover optimization algorithms based on a well-defined Fuzzy MCDM logic to provide a scalable, adaptable and flexible HetNet technology. The use of discrete data has also helped to quantify and analyze discrete optimization factors for vertical handover.

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