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Development of energy-efficient model in long term evolution (LTE) network using optimum network engineering tools

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Abstract
The concept of the heterogeneous network was introduced to meet the demands of the mobile network's traffic flow capacity and data rate. It consists of dissimilar networks with diverse wireless access technologies. By convention, a Mobile Subscriber (MS) may travel and attain the vertical handover by a single criterion vertical handover decision, but, conversely, this may cause ineffective handover, unbalanced system load, and service disruption. This Thesis proposed an enhanced vertical handover optimization using multi-attribute parameters in the heterogeneous network environment consisting of 2G, 3G, Long Term Evolution-Advanced (LTE-A in 4G), and Passive Optical Network (PON). The results for vertical handover such as signal strength, service quality, handover delay, monetary price, user mobility pattern, bandwidth availability and security are linked with this project. These Key Performance Indicators (KPIs) conform with the ITU index to assess the quality of the service of mobile networks (QoS). Examples include network coverage, the integrity of service, retainability of service, availability of network and accessibility of networks. The work only includes 2g, 3g and 4g. It also expands to coverage and capacity, but, for consecutive vertical delivery services request because of time constraints, it does not cover the execution of the Algorithm.

Keywords: Key Performance Index (KPI), Long Term Evolution-Advanced (LTE-A), Mobile Subscriber (MS), Passive Optical Network (PON), Quality of Service (QoS)

1. Introduction

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) (Tan, Chen & Sun, 2020).

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 (Gupta, 2016).

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 (Gupta, 2016).

For example, a WLAN (3g) can connect to the General Packet Radio Service (GPRS)- a 2.5g network, from a higher bandwidth to a lower coverage capacity. Vertical handover is highly demanding and very difficult in heterogeneous cellular networks since the mobile subscriber has to change the preferred network from a different system domain and technologies such as Worldwide Microwave Access Interoperability (WiMAX), Universal Mobile Telecommunications Service (UMTS) and Long-term Evolution (LTE) technologies (Arbain & Kasiran, 2019).

2. Literature Review

The complexity of Network traffic (concerning self-similarity and fractal) was addressed by developing two models using OPNET, based on Pareto. Raw Packet Generator, OPNET, Pareto Distribution, Autocorrelation function and power-law were employed to confirm the presence of fractal traffic on the network. The 80/20 rule implies, 80% output is a result of 20% input. This can be applied to this work to prove that 80% of VHO is generated by only 20% of the handover optimization model for every handover decision. Conversely, a combination of Algorithms would form a model. The complexity of traffic structure can be likened to a Het-Net. A handover is also a form of traffic congestion that must be well managed (Danladi & Vsira, 2017).

Mobility management in the mobile cellular network entails changes in operational environments, sensing the environmental changes and consequently adapting to them (Mwangoka, Marques & Rodriguez, 2020; Osianoh, Muhammad & Barry, 2019) [2].

In the LTE Small-Cell Network load balancing algorithm with adaptive mobility, The overloaded traffic situation in small-cells extends to performance degradation concerning signal strength or capacity and handover success rate. The proposed mobility load-balancing algorithm for this study is adaptive and it is self-organized. In the context of this work, handover is a function of Mobility and coverage and capacity. Adaptation in this work can be enhanced in CRHO or Neuro-fuzzy algorithms (Hassan, Kwon & Jee-Hyeon, 2018) [4].

Handover as a form of congestion is a function of mobility and by extension- coverage and capacity (Liu, Lou, Chen, & Sherali, 2019; Nils, Tim & David, 2016) [5].

3. Methodology

Designing a new network or a modified network is a very challenging task. The designer faces many options and because network components tend to interact in unpredicted ways; simulation allows network designers to best unravel this complexity. In addition, it is more economical to simulate several alternatives than to build many real systems to study.

3.1 Network Simulation Purposes

There are several authentic reasons to do network simulation:

1. Comparison of various options to determine the best.
2. Sensitivity analysis entails selecting a most probable scenario and seeing how modification of some configuration factors affects other performance metrics to pinpoint parameters on which the simulation experiment is most delicate.
3. Forestalling bottlenecks in (2) above can be used to study where traffic jams will occur.
4. Forecasting growth implies finding locations where robust capacity strengthening is required by inducing traffic.
5. Simulation is a widely accepted research method that is used for evaluating network performance. It is mostly used for a very large network with several terminals and services, which would be time-consuming and expensive to implement and evaluate. The use of simulation in networking saves time and helps in controlling the network scale.

3.2 Design of a VHO Model for Multi-Criteria Handover

In this work, an optimization model will be developed to generate algorithms in terms of various equations. Some of the mathematical concepts that support this include but are not limited to the following

1. Laplace transform
2. The probabilistic theory
3. The truth table
4. Permutation and combination
5. Complex number
6. Linear Algebra
7. Set theory
8. Pareto principle

The following also promotes the concept of self-optimization:

1. Application of Maxima and Minima differentiation function
2. Optimization mathematics or mathematical programming- A set of mathematical principles and techniques which comes in handy in numerical or optimization oriented problems in various disciplines including Information technology.

3.3 The Need for a New Model

1. The unstable and dynamic nature of mobile heterogeneous networks in respect to different vertical handover scenarios (based on mobility pattern movement) underscores the necessity for a new model in this study.
2. Phasing out of traditional handover schemes that are RSSI based.
3. The impending deployment of 5G with new requirements such as candidate technology and massive MIMO.
4. Application of the Pareto principle which outranks other distribution techniques, notably- Rayleigh and Poisson distributions in some of the existing QoS models.

3.4 Parameters for Vertical Handover Decision Process

The proposed model for the multi-criteria handover decision will obey the Input-process-output chain rule as depicted in figure 1 below

Network Connection Time
Received Signal Strength
Quality of Service
Handover Latency
User Mobility Pattern
User preferences
Handover Decision
Available Bandwidth
Power Consumption
Monetary Cost
Security

Fig 1: Parameters for vertical handover decision process (Source: Mahmood *et al*, 2013)

3.5 Modelling tool

Microsoft Visio 2003 Edition will be used to model the scenarios

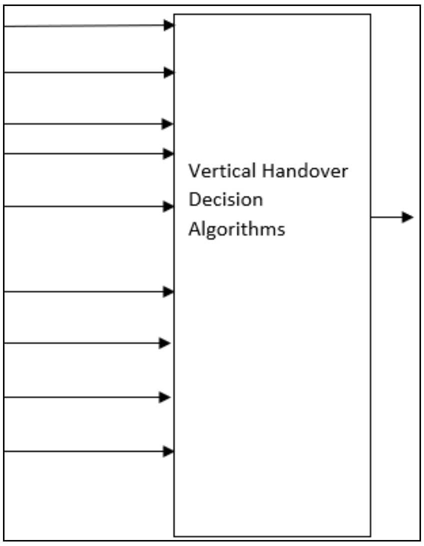


Fig 2: Parameters for Vertical Handover Decision Process

Multi-Attribute Decision Making in the context of this study is a function of several multiple attributes to be considered at various stages involved in the VHO process. For example, to select a target network concerning the cost of network based on Simple Additive Weighing (SAW); having selected the parameters- weight is assigned to it. Thus the cost of the network is given by the summation of all the normalized weighted values of the network

It takes this format:

$$C = \sum_{j=1}^{N} (\text{pi x si, j}) \qquad (1)$$

Where N denotes the number of factors considered, Pi symbolize the weight of the parameter to the i^{th} term, and Si,j represents the value of the i^{th} parameter from the j^{th} term of the target network.

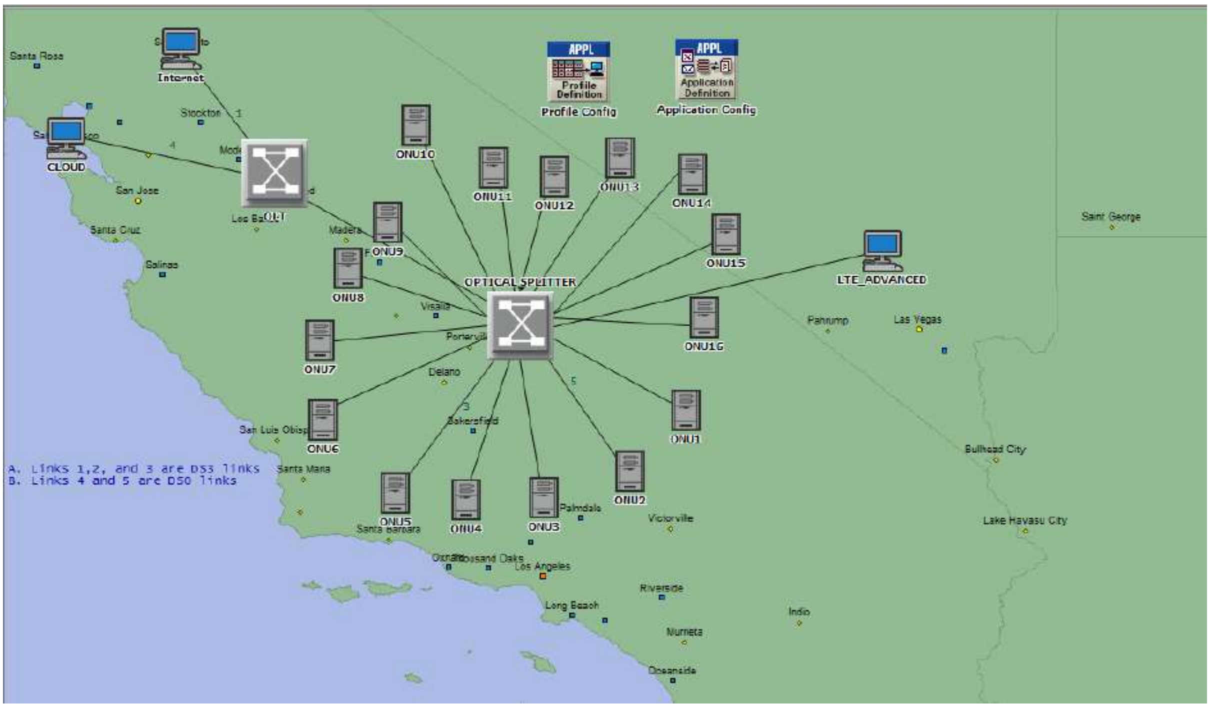
Collection of Data before Simulation

Simulation analysis is valueless if the model does not consider realistic data. Analysts are used to the mantra- "garbage-in-garbage-out" (GIGO) to highlight that if input data is imprecise, the outcomes cannot be accurate. Networking simulation data can never be perfect; however, simulations can give the best result if a mobile operator collects data on its traffic. This includes variations of traffic during daytime and the frequency at which the network fluctuates in seconds. Since simulations generally deal with the future, it is essential to induce network traffic based on its future pattern. Figure 3.2 below depicts a sample network simulation procedure, while figure 3.3 shows the nodes templates using OPNET IT Guru

Start Simulation
Reality versus uncertainty
It is cost-effective to simulate than to build network
Drives
Matching alternatives to choose the best
Case scenario and effect analysis to see the end result if the variable values were modified over time
Antedating challenges
Capacity enhancement to envisage areas where there is need for robusteness
Data collection prior to simulation
Input valid data
Else, GIGO (affects the correctness of the output)
Data gathering on the active network
Predict growth
The Method
By OPNET IT Guru procedure
Label the simulation work space as- clients, switches, servers, routers etc
Map out the topology with communication lines
Setup the nodes and communication links
Add applications to generate network data

Run simulation for a specified period
Study the output for interpretation
Validate simulation experiment
Change parameters to see the effect on other variables
Factoring to know the effect of cost, time etc on performance

Algorithm 5: Network Simulation procedure (Source: Panko, 2009)



Source: Author's Experimental Work

Fig 3: Developed OPNET Model

The Object Pallete tool was used to create various network packet frames. Each Optical Network Unit (ONU) has 16 end-user nodes, one Optical Line Terminal (OLT) node, and 16 ethernet nodes. An Optical Splitter connects all of the ONUs, ranging from one to sixteen nodes. Each ONU's Ethernet nodes were pre-configured (from 1 to 16). They can be installed individually using the Node Model option, and each node is made up of many state machines or process components that can be developed using the Process Model option. To implement distinct programs or algorithms, most state machines require their programming code. Traffic received (bytes/sec), traffic received (packet/sec), traffic sent (bytes/sec), and traffic sent (packet/sec) are the parameter metrics for energy usage.

This network provides Ethernet communication services to 16 subscribers at a speed of 2.5 Gbps. Time Division Multiple Access (TDMA) was employed to share the medium in the architecture. Between the central office and the neighbourhood, the medium is primarily an optical fibre link. The goal of this section is to reduce power consumption.

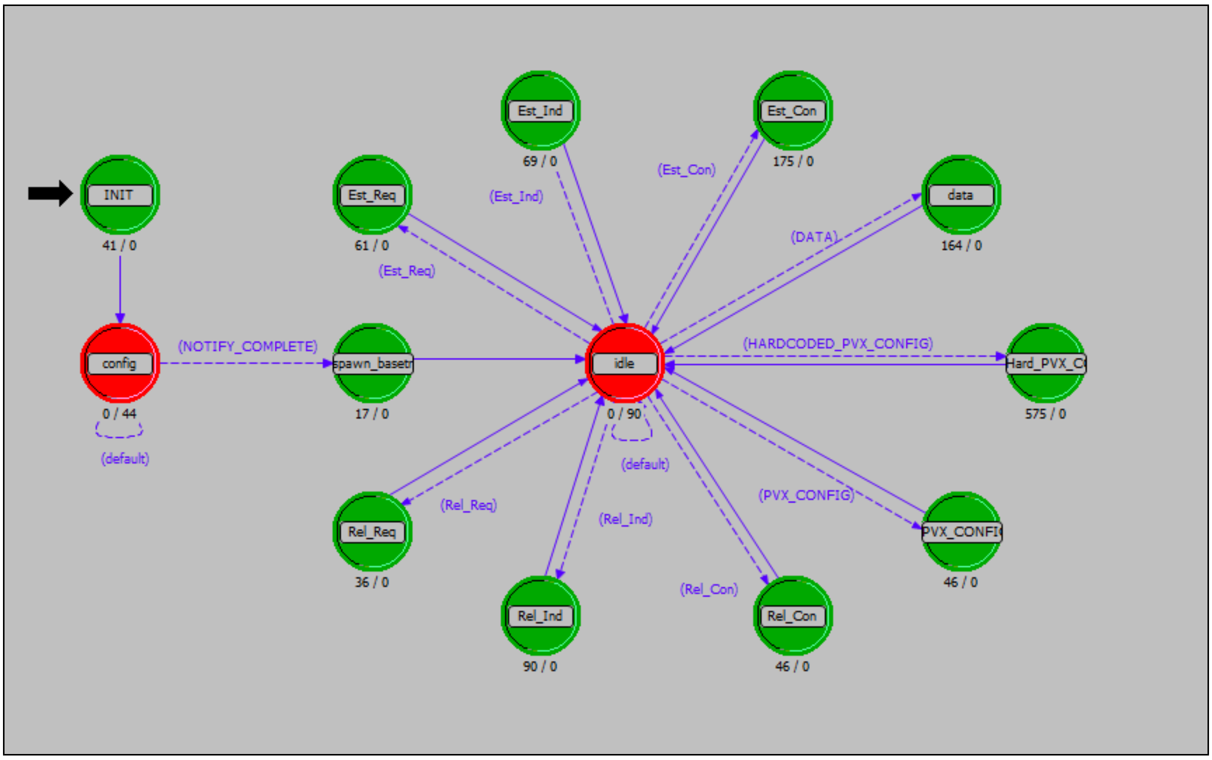


Fig 4: Process of Simulation

Above figure 4 illustrate the simulation process for the model inside the optimum network performance engineering tools (OPNET).

OPNET Modeller 14.5 was used to design the essential data units, nodes, and linkages for simulations. The most essential characteristics of both methods of allocation are contained in

OLT, CT, and ONU units. The procedure step for the optimum energy consumption includes the following steps

a. Profile Configuration

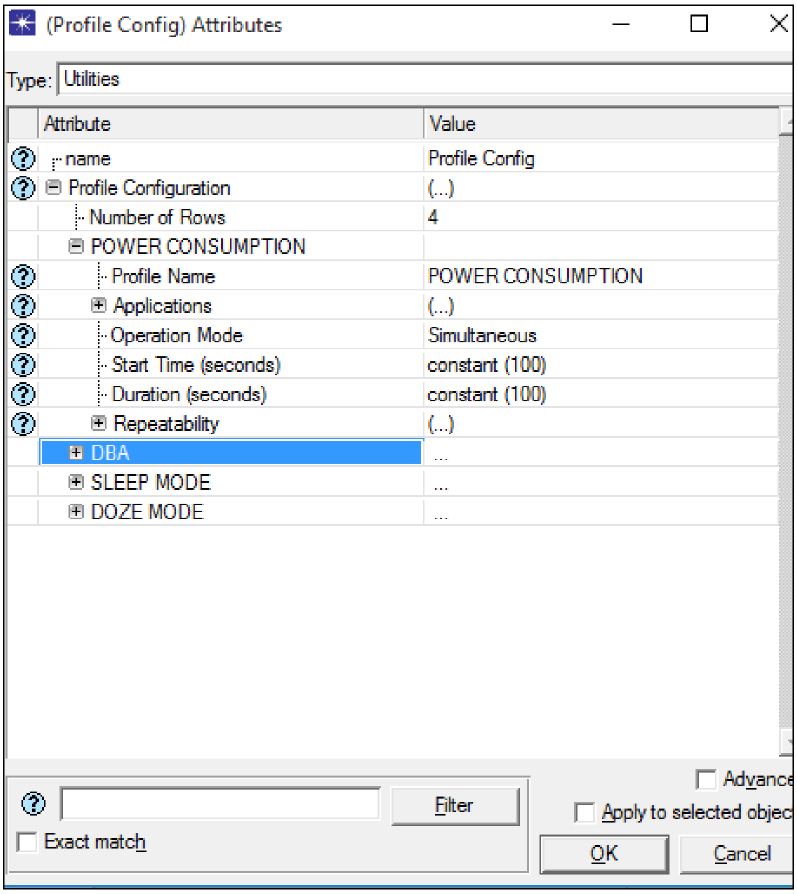


Fig 5: Profile Configuration

b. Application Configuration

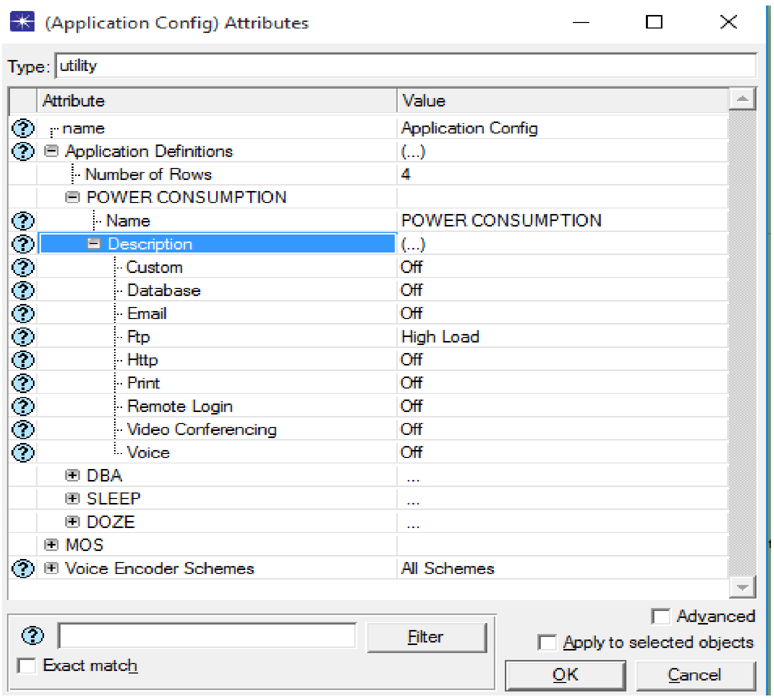


Fig 6: Application Configuration

4. Result

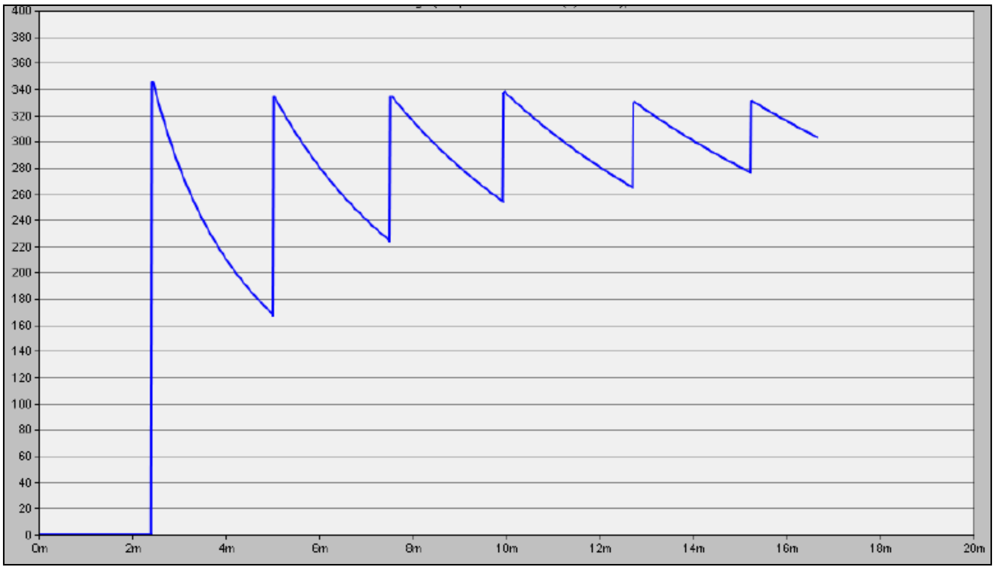


Fig 7: Energy Consumption In Traffic Received (BYTES/SEC)

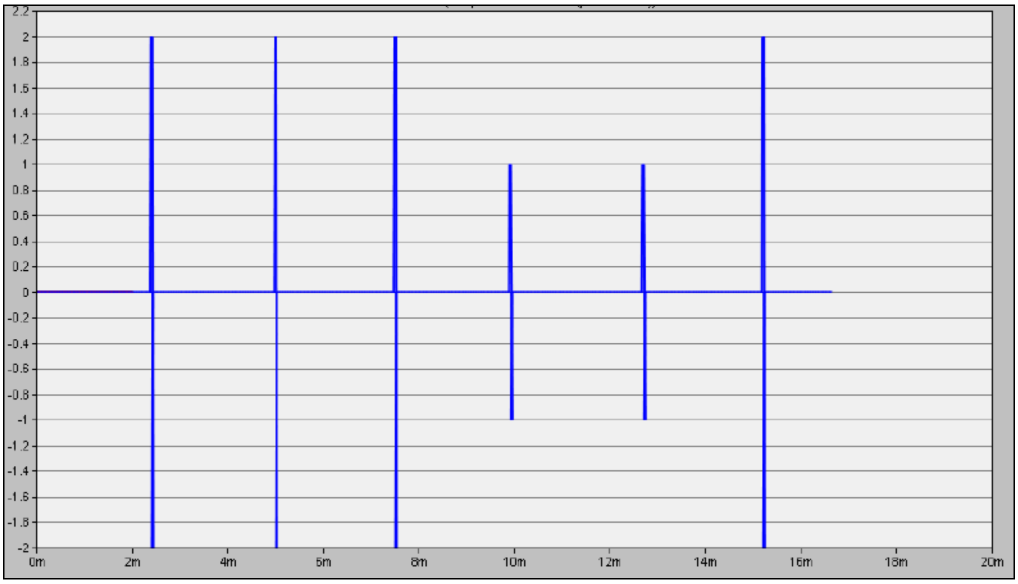


Fig 8: Energy Consumption In Traffic Received (BYTES/SEC)

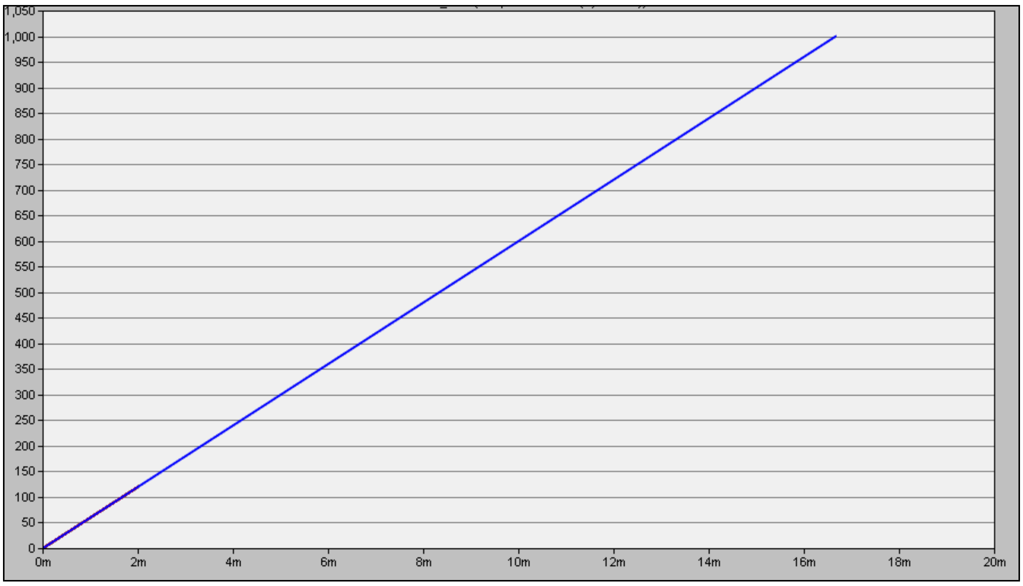


Fig 9: Energy Consumption In Traffic Sent (Bytes/SEC)

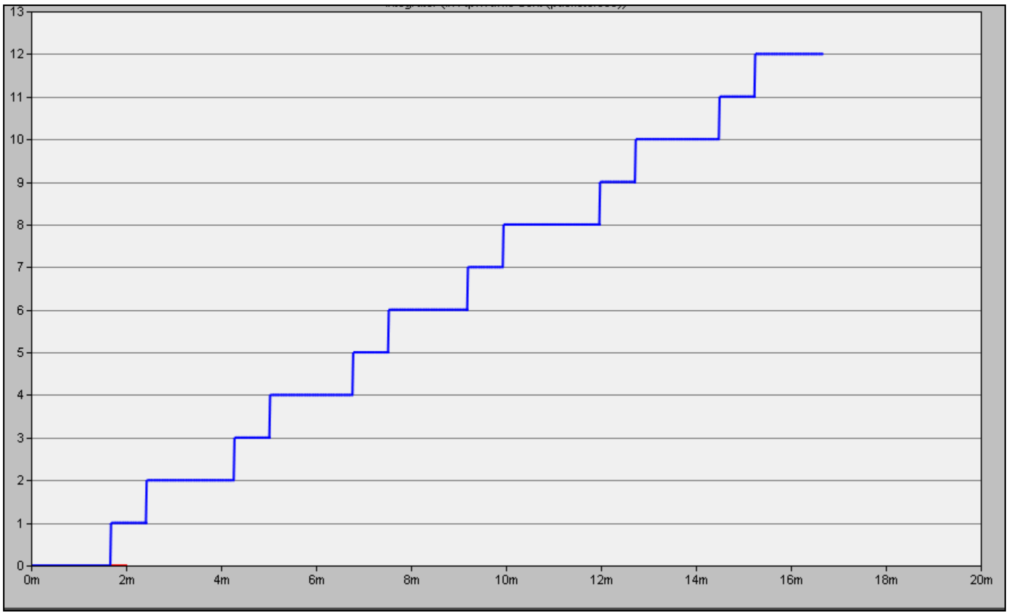


Fig 10: Energy Consumption In Traffic Sent (Packets/SEC)

5. Conclusion

Optimizing the vertical transfer is a mobility function. For the further development of a vertical optimization process, an enhanced optimization model was also developed to provide the HV process for the typical self-organizing network in terms of learning, adaptation and decision-making, based on various algorithms for different vertical hobby scenarios.

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