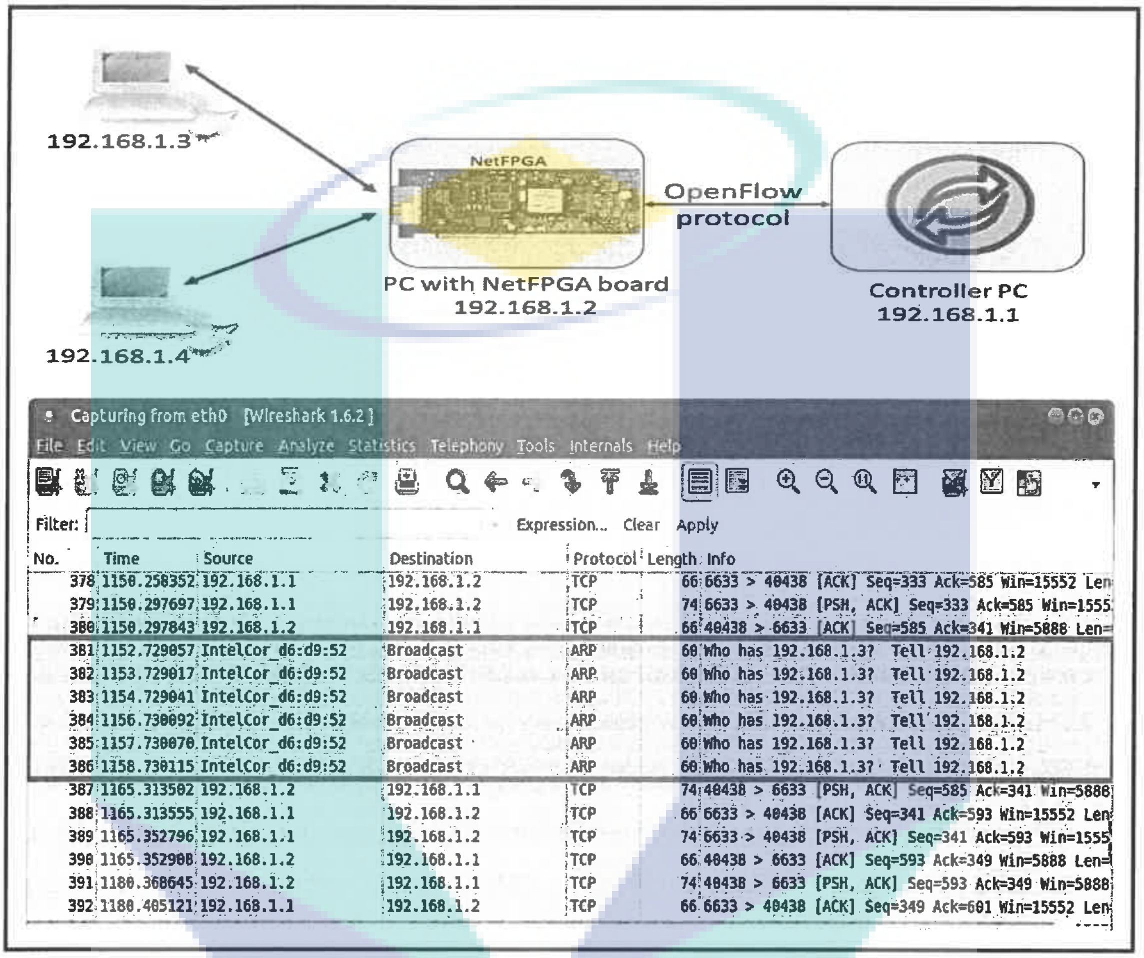
BUKU PROFIL PENYELIDIKAN SKIM GERAN PENYELIDIKAN FUNDAMENTAL (FRGS) FASA 1/204



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  379 1150.297697 192.168.1.1        192.168.1.2   TCP          74 6633 > 40438 [PSH, ACK] Seq=333 Ack=585 Win=1555
  380 1150.297843 192.168.1.2        192.168.1.1   TCP          66 40438 > 6633 [ACK] Seq=585 Ack=341 Win=5888 Len=
  381 1152.729057 IntelCor_d6:d9:52  Broadcast     ARP          60 Who has 192.168.1.3?  Tell 192.168.1.2
  382 1153.729017 IntelCor_d6:d9:52  Broadcast     ARP          60 Who has 192.168.1.3?  Tell 192.168.1.2
  383 1154.729041 IntelCor_d6:d9:52  Broadcast     ARP          60 Who has 192.168.1.3?  Tell 192.168.1.2
  384 1156.730092 IntelCor_d6:d9:52  Broadcast     ARP          60 Who has 192.168.1.3?  Tell 192.168.1.2
  385 1157.730070 IntelCor_d6:d9:52  Broadcast     ARP          60 Who has 192.168.1.3?  Tell 192.168.1.2
  386 1158.730115 IntelCor_d6:d9:52  Broadcast     ARP          60 Who has 192.168.1.3?  Tell 192.168.1.2
  387 1165.313502 192.168.1.2        192.168.1.1   TCP          74 40438 > 6633 [PSH, ACK] Seq=585 Ack=341 Win=5888
  388 1165.313555 192.168.1.1        192.168.1.2   TCP          66 6633 > 40438 [ACK] Seq=341 Ack=593 Win=15552 Len
  389 1165.352796 192.168.1.1        192.168.1.2   TCP          74 6633 > 40438 [PSH, ACK] Seq=341 Ack=593 Win=1555
  390 1165.352908 192.168.1.2        192.168.1.1   TCP          66 40438 > 6633 [ACK] Seq=593 Ack=349 Win=5888 Len=
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A NOVEL DECISION TREE SEARCHING ALGORITHM FOR HIGH SPEED ONLINE TRAFFIC CLASSIFICATION

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FRGS Field: Technology and Engineering

METHODOLOGY

Research methodology represents the basis behind a research study as it dictates the selection of methods for data collection and analysis, as well as the perspective applied for analysis interpretation. As such, this section describes and discusses the research methodology employed in both designing and evaluating a novel decision tree searching algorithm for high speed online traffic classification

Figure 1 illustrates a well-defined methodological research operational framework of the study, which consist of the following primary procedures: data collecting, data preprocessing, features extraction, classification model and output. The system are placed before an edge router or a campus gateway. Therefore, all the transmitted and received packets passed through the classifier as shown in Figure 2.

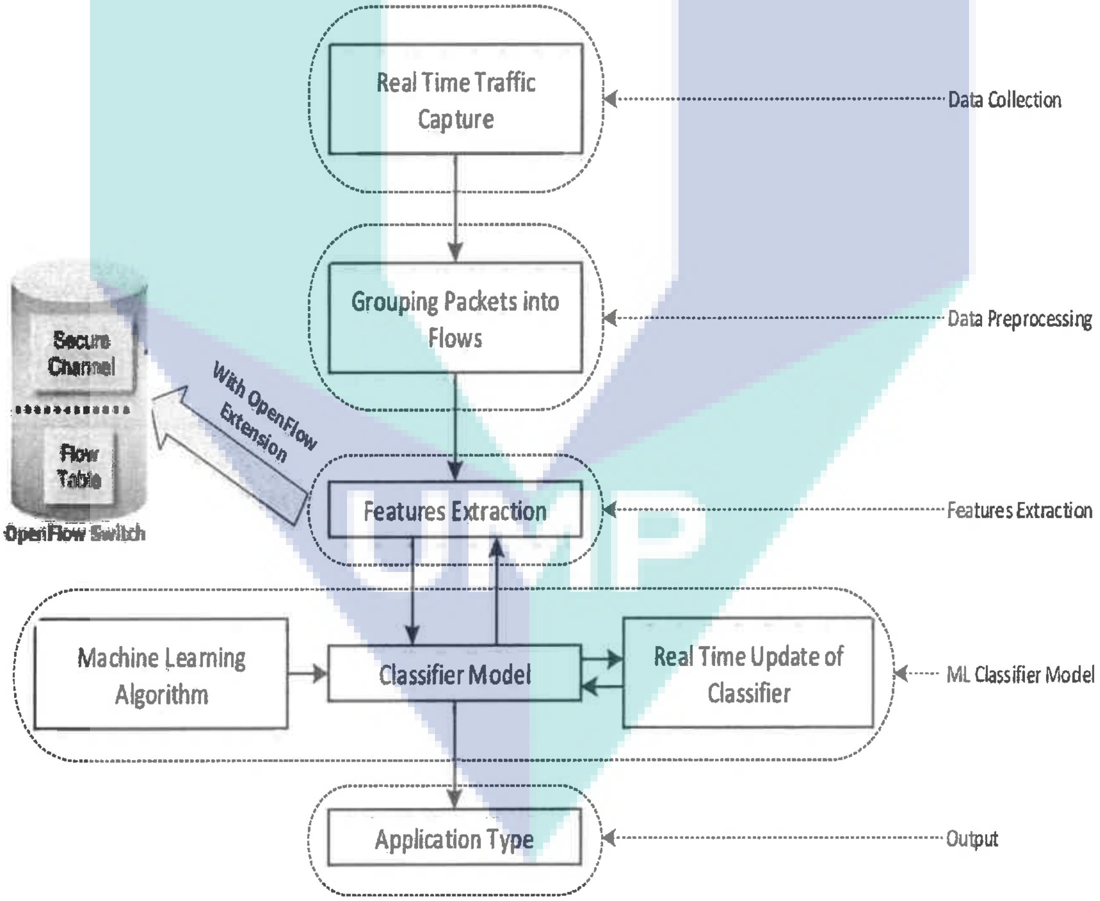

Figure 1 Proposed Framework for Online Traffic Classification Based on Machine Learning

paths existed in the design. The first path shows that the Ethernet packets are received by NetFPGA board through the 1G Ethernet ports and going through all the pipeline stages, then transmitted back to the network through the same Ethernet ports. For the second path, at the moment the packets are captured by the NetFPGA Feature Extraction Module, the packets are duplicated to undergo flow demultiplexing, feature extraction and transfer mechanism. Transfer mechanism will generate features packets for each valid flow and lastly these feature packets being transmitted to host PC through PCI bus. A Python script is run on host PC to capture these feature packets and to convert them to readable format for C++ classification.

The feature extraction is the top level module which inserted into NetFPGA reference pipeline in between Output Port Look Up and Output Queues modules. To make the hardware design match with the aforementioned top level view of flow-based traffic classification stages (packet capture, flow demultiplexing, feature extraction and classification), the top level module is structured as in Figure 4. The submodules inside feature extraction module are packet capture, flow demultiplexing, feature extractor, inactive flow detector, UDP flow generator and arbiter. The functions of each submodules are summarized in Table 1

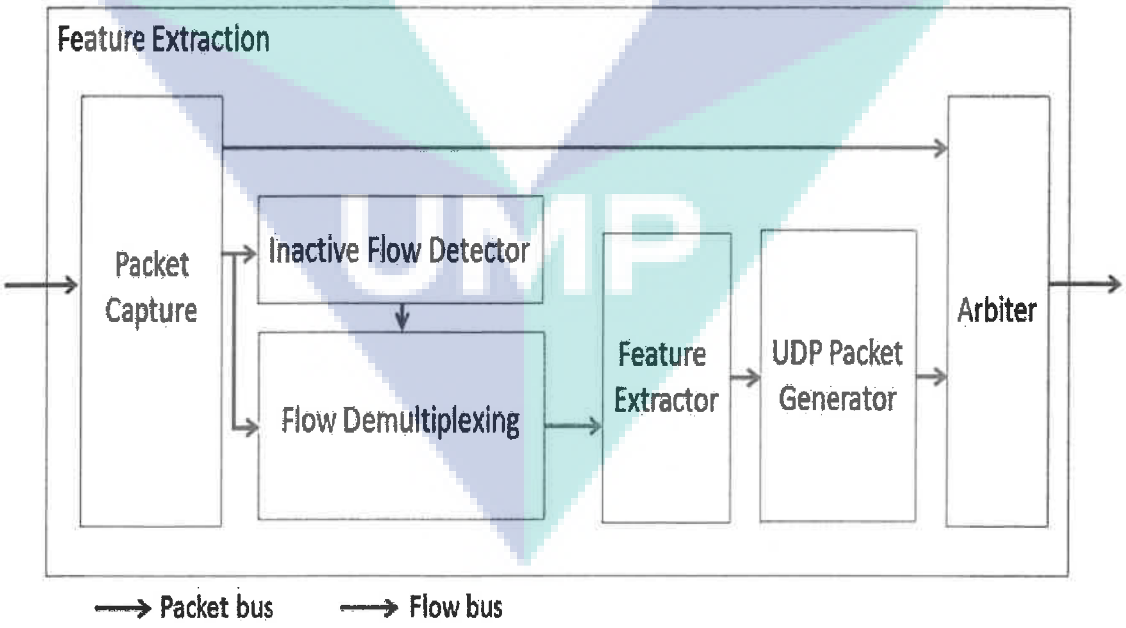

Figure 4 Feature Extraction Module

The interface between the hardware feature extraction module and software classification and incremental learning module are constructed using Python build-in library, Scapy. The feature packets are sniffed and according to its format as shown in Figure 5, five feature parameters located in data field could be extracted and written to a text file. The classification sytem read inputs from text file, thus flow features have to be reconstruct into readable format and written to a text file. This software classifier predict class for each input flows. In order to determine its accuracy, the actual class for each flow must be known. This semi-supervised incremental learning classification subsystem is targeted to classify five classes of network traffic which are Web, mail, P2P (peer-to-peer), Skype and MSN (Windows Live Messenger).

An experiment has been setup to measure performance of NetFPGA hardware system. Simulation is done on feature extraction hardware module to measure its processing time. On the other hand, a case study is done to measure the performance of software classification system by using an available network traffic data sets with associated ground truth as input data

LITERATURE REVIEW

The evolution of the Internet has induced various multimedia applications (such as Skype, IPTV, etc.) to emerge and gain rapidly popularity. It becomes a vital issue for Internet Service Providers (ISPs) to identify the application types of traffic carried on their networks. Classifying network traffic is the foundation for applying the appropriate QoS feature to that traffic, such as traffic shaping and traffic policing, enabling one to allocate network resources to deliver optimal performance for specific type of traffic. The research field of network traffic classification gains sustained attention while more and more applications emerge on the Internet. Many applications often use obfuscation techniques such as encrypted data transmission, changing or randomly selected ports to prevent detection [1]. The increased capacity and availability provided by broadband connections have led to more complex behaviors arising from various emerging applications and services, inevitably imposing restrictions on the practical deployment of traffic classification system. These challenges include acquisition of ground truth for network applications, quick extraction of flow features, identification of flows containing changing user behavior patterns and various data characteristics.

of memory accesses may be needed for branching decision. Since the authors have not implemented their design on FPGA, the actual performance results are unclear. Note that the number of memory accesses for each packet to traverse the decision tree is varying and highly depends on the data set. This makes it difficult to pipeline the tree traversal to achieve high throughput.

FINDINGS

1. The proposed system design utilizes less than 30% of the NetFPGA resources compared to the switch design and able to achieve maximum frequency of 86.34MHz

2. Processing time of the feature extraction component is measured in ModelSim simulation by using minimum and maximum Ethernet packet length of 64 and 1518 bytes as input packet. For minimuman packet length, it takes 58 clock cycles (which correspond to 0.646*us*) to complete the packet capture, flow demultiplexing and feature extraction stages, whereas for maximum packet length, it takes 223 clock cycles (which correspond to 1.784*us*), approximately fourfold processing time as compared with the minimum packet length. The processing time could be further improved by increasing the clock frequency, and in this case clock frequency for 1G NetFPGA platform is 125MHz

3. The experiment is setup for a period of 100s, and bandwidth is measured for every one-second interval. The proposed NetFPGA hardware system is able to achieve cumulative bandwidth of 939Mbps without packet loss

4. The results show that the proposed design is feasible to be implemented for online traffic stream classification due to its high throughput and high classification accuracy.

CONCLUSION

The proposed design on NetFPGA is able to perform packet capture, flow demultiplexing, feature extraction and transfer features to host PC on online traffic data without packet loss at bandwidth of 939Mbps. The feature extraction hardware module with low processing time

Beamformer, *International Journal of Computing, Communications & Instrumentation Engg. (IJCCIE)*, Vol. 3, Issue 1, pp 89-95

HUMAN CAPITAL DEVELOPMENT

One (1) PhD Students

Muhideen Abbas Al-doori, "An Efficient Algorithm for Respiratory Rate Extraction Based on A Novel Photoplethysmography Sensor Probe Design and Hybrid Processing of Adaptive Filter and Wavelet Transform". 2017.

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SENARAI DAFTAR HARTA MODAL DI BAWAH DANA PENYELIDIKAN FUNDAMENTAL KEMENTERIAN PENDIDIKAN TINGGI (FRGS)

BIL	IPT	JENIS GERAN (FRGS/ERGS/LRGS/PRGS/NRGS/RAGS/RACE/TRGS)	FASA (CONTOH 1/2014)	TAJUK PROJEK PENYELIDIKAN	NAMA KETUA	NAMA ASET	BILANGAN UNIT	NO SIRI PENDAFTARAN	TARIKH PEROLEHAN	HARGA PEROLEHAN ASAL (RM)
1	UMP	FRGS	1/2014	A Novel Decision Tree Searching Algorithm for High Speed Online Traffic Classification	Dr. Izzeldin Ibrahim Mohamed Abdelaziz	NetFPGA Card	FTKEE	D495182	06/07/2015	4,198.00
2						PC (NetEon)		KMA2209429	06/07/2015	5,290.00
3						PC (Dell)		9C0L862	06/07/2015	4,680.00
4						LED Monitor		ETK9E03452019	06/07/2015	1,190.00
5						Notebook		FTK1000-PB101(R)-1711-0012-00001	29/11/2017	3,650.00
						Printer (HP)		FTK1000-PB101(R)-1711-0012-00001	29/11/2017	515

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Evaluating the Impact of SNOIs on SINR and Beampattern of MVDR Adaptive Beamforming Algorithm

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Abstract

Minimum Variance Distortionless Response (MVDR) is basically a unity gain adaptive beamformer which is suffered from performance degradation due to the presence of interference and noise. Also, MVDR is sensitive to errors such as the steering vector errors, and the nulling level. MVDR combined with a Linear Antenna Array (LAA) is used to acquire desired signals and suppress the interference and noise. This paper examines the impact of the number of interference sources and the mainlobe accuracy by using Signal to Interference plus Noise Ratio (SINR) and array beampattern as two different Figure-of-Merits to measure the performance of the MVDR beamformer with a fixed number of array elements (L). The findings of this study indicate that the MVDR successfully form a nulls to L-1 nonlook signal with average SINR of 49.31 dB. Also, the MVDR provides accurate mainlobe with a small change to the real user direction when the SNOIs are bigger than array elements. The proposed method was found to perform better than some existing techniques. Based on this analysis, the beampattern not heavily relies on the number of unwanted source. Moreover, the SINR strongly depends on the number of SNOIs and the nulling level.

Keywords: Beamforming, Linear Antenna Array, Minimum Variance Distortionless Response, SINR, Smart Antenna

1. Introduction

Currently, the mobile cellular networks are experiencing a massive evolution of data traffic, because of multimedia and internet applications that are used by a vast number of devices such as smartphones, mobile PC and tablets[1,2]. Most beamforming techniques have been considered for use at the Base Station (BS) since antenna arrays are not feasible at mobile terminals due to space limitations[3].

The Long Term Evolution (LTE), as introduced by the 3rd Generation Partnership Project (3GPP), is an extremely flexible radio interface, the first LTE deployment was in 2011. LTE is the evolution of 3GPP Universal Mobile Telecommunication System (UMTS) towards an all-IP network to ensure the competitiveness of UMTS for the next ten years and beyond. LTE was developed in Release 8 and 9 of the 3GPP specification. Maravedis, anticipates that 3 LTE–TDD and 59 LTE–FDD networks will be running worldwide by the end of 2011. By 2016, there will be 305 million LTE subscribers, which means about 44 million (14%) will be LTE–TDD clients and the remaining 261 million (86%) will be LTE–FDD[4]. With the increasing trend of he number of subscribers and demand for different services in wireless systems, there are always requirements for better coverage, higher data rate, improved spectrum efficiency and reduced operating cost. To fulfill this requirement, beamforming technique is able to focus the array antenna pattern into a particular direction and thereby enhances the desired signal power.

Interference is one of the significant obstacles in the wirel-ess networks. It can be caused by other users or by the signal itself[5]. The signal can interfere with itself

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*Author for correspondence

an isolation from the null, and by rejecting interference presented on the array system. Whereas no complete assessment of the SINR and the beampattern as a function of all the above mentioned parameters. The analysis of the MVDR in this work is carried out in three different scenarios where the MVDR performance is assessed with two important metrics; SINR and beampattern. This investigation not only helps to better figure out the MVDR beamformer, but also helps to form a better array system in real-world application. The remainder of this paper is organized as follows. In Section 2, MVDR beamformer based on linear antenna array design method with the signal propagation model is described. The simulation results and performance analysis are provided in Section 3. Finally, in Section 4, the paper's conclusions and summary of MVDR performance are described.

2. System Model and MVDR Beamforming

In this section, the mathematical formulation of the design model for adaptive beamforming will be presented in detail. Consider a single cell with *L* elements antenna array. Let there be *S* wanted signal sources and *I* interference sources spreading on same the frequency channel at the same time. The algorithm starts by creating a real life signal model. A number of plane waves are considered from *K* narrowband sources impinging from various angles (θ, φ). The impinging radio frequency signal reaches into antenna array from far field to the array geometry of Linear Antenna Arrays (LAAs). A block diagram of the antenna array using DOA and BF process is shown in Figure 1. As displayed in this figure 1, after the signals are received by antenna arrays consisting of the wanted user signal, the interference source, and the noise, the first part is to estimate the direction of the arrival of the *S* signal and *I* signals using a well-known algorithm developed by capon, named MVDR spectrum estimator, to find the DOA angles of several sources. However, the MVDR estimator algorithm wants information of the number of sources. With the known direction of the source, then the second part is applied by using MVDR ABF technique that places a straight beam to *S* signal and placing nulls in the direction of *I* signals. Each signal is multiplied by adaptable complex weights and then summed to form the system output.

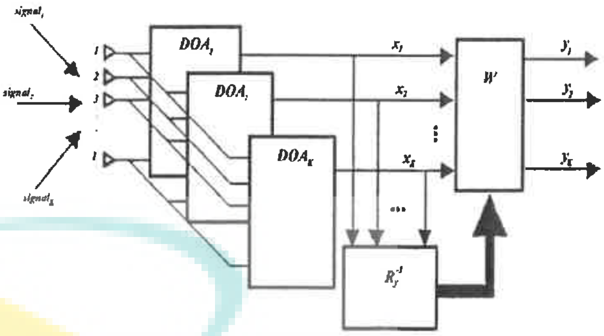

Figure 1. A smart antenna array system using DoA and beamforming process.

The total composite signals received by an adaptive antenna array at time index, t, become:

$$x_T(t) = \sum_{s=1}^{S} x_s(t) + \sum_{i=1}^{I} x_i(t) + x_n \tag{1}$$

$$= \sum_{s=1}^{S} x_s(t)\,a(\theta_s) + \sum_{i=1}^{I} x_i(t)\,a(\theta_i) + x_n \tag{2}$$

Where $x_T(t) \in C^{K\times L}$, $x_s(t)$, $x_i(t)$, $x_n(t)$, denote the desired signal, interference signal and noise added from White Gaussian noise, respectively. The unwanted signal consists of $x_i(t)+x_n(t)$ and *I* is the number of interferences, the desired angle and interference direction of arrival angles are θ_s and θ_i , $i=1,2....,I$, respectively. $a(\theta_s)$ denote the steering vector or array response for wanted signal while $a(\theta_i)$ refers to the interference signal steering vector or array response to the unwanted signal.

Steering vector is a complex vector $\in C^{L\times K}$ containing responses of all elements of the array to a narrowband source of unit power depending on the incident angle, which is given by[20]:

$$a(\theta_{s,i}) = \begin{bmatrix} 1 \\ e^{-jqd\sin\theta_{s,i}} \\ e^{-jq\,2d\sin\theta_{s,i}} \\ \vdots \\ e^{-jq\,(L-1)d\sin\theta_{s,i}} \end{bmatrix} \tag{3}$$

Where j is the imaginary unit, (i.e., $j^2 = -1$), *d* is the spacing between elements and *q* is the wave number given as:

$$q = \frac{2\pi}{\lambda} \tag{4}$$

This method reduces the contribution of the unwanted signal by minimizing the power of output noise and interference and ensuring the power of useful signal equals to 1 (constant) in the direction of useful signal $w^H a(\theta_s)=1$. By using Lagrange multiplier, the MVDR weight vector that gives the solution for the above equation as per the following formula[23]:

$$w_{\mathrm{MVDR}} = \frac{R_y^{-1} a(\theta_s)}{a^H(\theta_s) R_y^{-1} a(\theta_s)} \tag{22}$$

Inserting Equation (22) into Equation (12), the output of MVDR is given by;

$$\begin{aligned} y(t) &= w^H(t)\, x_T(t) \\ &= w^H a(\theta_s)\, x_s(t) + w^H x_i(t)\, a(\theta_i) + w^H x_n \\ &= x_s(t) + w^H x_i(t)\, a(\theta_i) + w^H x_n \end{aligned} \tag{23}$$

The output signal power of the array as a function of the DOA estimation, using optimum weight vector from MVDR beamforming method[24], it is given by MVDR spatial spectrum for angle of arrival estimated by detecting the peaks in this angular spectrum as[25]:

$$P_{MVDR}(\theta) = \frac{1}{a^H(\theta_s) R_y^{-1} a(\theta_s)} \tag{24}$$

Finally, the SINR is defined as the ratio of the desired signal power divided by the undesired signal power:

$$SINR = \frac{\mathrm{E}\{|y_s(t)|^2\}}{\mathrm{E}\{|y_{i+n}(t)|^2\}} = \frac{w^H R_s w}{w^H R_{i+n} w} \tag{25}$$

3. Simulation Results and Analysis

In this study, the performance of the proposed MVDR beamformer method is presented, and illustrative for the array of L linear antenna elements configuration is arranged along some axis added to the beamformer system at the cellular Base Station (BS). The array receives signals from different spatially separated users. The received signal consists of the intended signal, co-channel interference, and a random noise component. To increase the output power of the desired signal and reduce the power of Co-channel interference and noise, beamforming is employed at the BS. The antenna array elements separated by inter-element spacing, d, at carrier frequency (*Fc*) of 2.6 GHz, which is the spectrum band allocated to LTE operators in Malaysia[26]. To measure the performance of the MVDR algorithm for ABF applications with varying number of SNOIs, nulling accuracy to the interference source. The goal is to analyze the effects of intefereing signals to achieve the best beamforming capabilities that form the mainbeam in the wanted direction and null in the directions of interference with highest output SINR.

The incident fields are assumed to impinge from the direction angles $\theta_s = 0°$ and $\theta_i = \{1, 2, \ldots, L+1\}$ in the azimuth plane $(-\pi/2 < \theta < \pi/2)$. Throughout the simulations, the array is illuminated by uncorrelated sources of equally power levels. Three different scenarios are considered, and the simulation parameters setting in this study is shown in Table 1.

Table 1. Key simulation parameters of MVDR beamformer

Key System Parameters	Values
Array antenna configuration	LAA
Antenna type	Isotropic
Carrier frequency (Fc)	2.6 GHz
Beam scanning range	±90° (Azimuth)
Number of element (L)	8
Element spacing (d)	λ/2
# SOI	1
# SNOIs	1 : 9
SNR [dB]	10
INR [dB]	10
Snapshots (ns)	250

3.1 The First Scenario

Using multiple antennas at the BS can reduce the effects of co-channel interference, multipath fading, and background noise. Many BF algorithms have been devised to cancel interference sources that appear in the cellular system. MVDR algorithm can null the interferences without any distortion to the real user path.

The first simulation scenario reveals the results calculated by considering the distance between array elements set to be $d=0.5\lambda$ with Signal to Noise Ratio (SNR) = Interference to Noise Ratio (INR) = 10 dB and number of data sample = 250. Figures 2 and 3 illustrates a typical 2D MVDR beampa-ttern plot displayed in a rectangular and polar coordinates, Uniform LAA with $L = 8$ elements, the additive noise is modeled as a complex zero mean white Gaussian noise. Four interfering sources are assumed to have DOAs (θ_i) at ±15° and ±30° respectively.

sors increases, the mean cost of design increases due to the increasing number of RF modules, A/D converters, and other components. This causes the operational power consumption to increase as well.

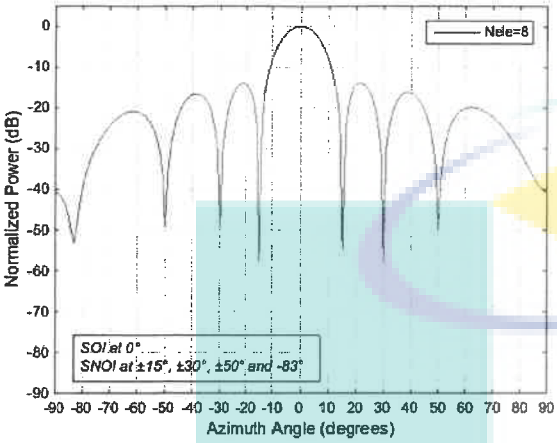

Figure 4. Line plot – beampattern analysis of MVDR with L = 8, d = λ/2 and SNOIs = 7.

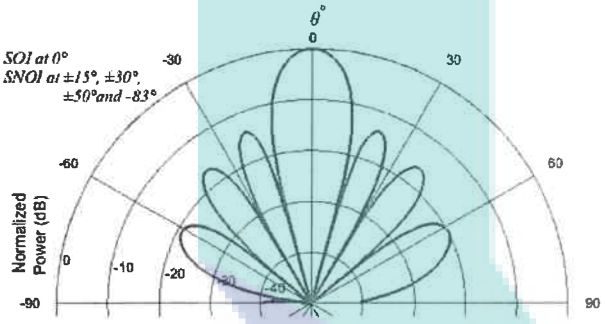

Figure 5. Polar plot – beampattern analysis of MVDR with L= 8, d = λ/2 and SNOIs = 7.

3.3 The Third Scenario

This scenario is done to show how MVDR beamformer deal with interference source in case of having SNOIs > L on the performance of MVDR for a desired user at θ_s = 0° and nine interference signals (θ_i) at ±15°, ±30°, ±50°, 60° and ±80° with L = 8, d = λ/2. Figure 6 and 7 displays the antenna patterns steered to real user source angle with the interference signal > L, it gives the output beampattern with seven nulls due to the antenna array able to provide a null of L-1 with one degree of freedom. It can be seen that the MVDR shows null at direction ±15°, ±30°, ±50°, 80° with output SINR equal to 22.1 dB with mainlobe shape is unaffected as depicted in Table 4. In this manner, MVDR beamformer found to cancel L-1 interference source. In short, reducing the effect of interference arriving outside the mainlobe. This interference reduction increases the capacity of the communication systems. Pattern nulling at specific directions suppresses the interference from other sources located at these directions.

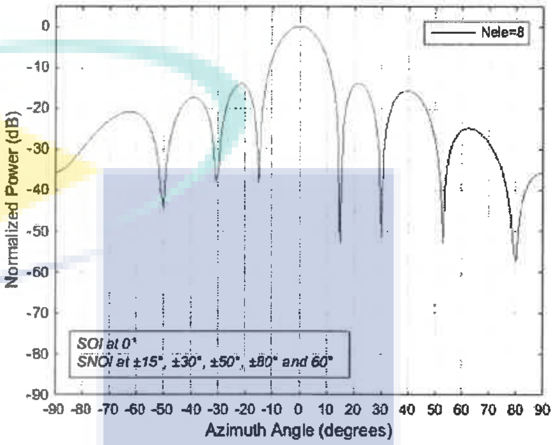

Figure 6. Line plot – beampattern analysis of MVDR with L = 8, d = λ/2 and SNOIs = 9.

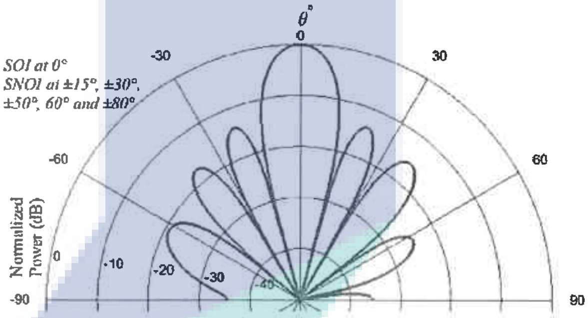

Figure 7. Polar plot – beampattern analysis of MVDR with L = 8, d = λ/2 and SNOIs = 9.

Table 4. MVDR performance analysis for SOI at 0° and SNOIs at ±15°, ±30°, ±50°, 60 ° and ±80°

w MVDR	θ_s shift	PSL [dB]	Null [dB]	SINR [dB]
0.1092+0.0002i 0.1330+0.0026i 0.1201+0.0029i 0.1372-0.0067i 0.1372+0.0070i 0.1204-0.0047i 0.1333-0.0018i 0.1095+0.0004i	-0.005	14.3	-57.1	22.1

The graph in Figure 8 compares the SINR of the MVDR beamformer for various interference sources at a given background noise starting from I = 1 and

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The Impact of Noise Label on Beampattern and SINR of MVDR Beamformer

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Abstract**—**Minimum Variance Distortionless Response (MVDR) is basically a unity gain adaptive beamformer which is suffered from performance degradation due to the presence of interference and noise. Also, MVDR is sensitive to errors such as the steering vector errors, and the nulling level. MVDR combined with a linear antenna array (LAA) is used to acquire desired signals and suppress the interference and noise. This paper examines the impact of the noise variance label (σn2) and the number of interference sources by using Signal to Interference plus Noise Ratio (SINR) and array beampattern as two different Figure-of-Merits to measure the performance of the MVDR beamformer with a fixed number of array elements (L). The findings of this study indicate that the MVDR have successfully placed nulls in the nonlook angle with average SINR of 99.6, 49.6, 24.9 dB dB for σn2.of -50, 0, 50 dB, respectively. Also, the MVDR provides accurate majorlobe to the real user direction, even the σn2 are bigger than desired signal power. The proposed method was found to perform better than some existing techniques. Based on this analysis, the beampattern is not heavily relies on the σn2. Moreover, the SINR strongly depends on the σn2 and the number of SNOIs.

Keywords**—**Beamforming, Linear antenna array, Minimum variance distortionless response, SINR, Smart antenna.

I. INTRODUCTION

CURRENTLY, the mobile cellular networks are experiencing a massive evolution of data traffic, because of multi-media and internet applications that are used by a vast number of devices such as smartphones, mobile PC and tablets [1], [2]. Most beamforming techniques have been considered for use at the base station (BS) since antenna arrays are not feasible at mobile terminals due to space limitations [3]. The Long Term Evolution (LTE), as introduced by the 3rd Generation Partnership Project (3GPP), is an extremely flexible radio interface, the first LTE deployment was in 2011. LTE is the evolution of 3GPP Universal Mobile Telecommunication System (UMTS) towards an all-IP network to ensure the competitiveness of UMTS for the next ten years and beyond. LTE was developed in Release 8 and 9 of the 3GPP specification. Maravedis, anticipates that 3 LTE–TDD and 59 LTE–FDD networks will be running worldwide by the end of 2011. By 2016, there will be 305 million LTE subscribers, which means about 44 million (14%) will be LTE–TDD clients and the remaining 261 million (86%) will be LTE–FDD [4].

Interference is one of the significant obstacles in the wireless networks. It can be caused by other users or by the signal itself [5]. The signal can interfere with itself due to multipath components, where the signal is gathere-d with another version of the signal that is delayed because of another propagation path [6]. The fundamental pr-inciple of the Adaptive beamforming (ABF) algorithm is to track the statistics of the surrounding interference and noise field as well as adaptively placing nulls that decrease dramatically the interference and noise under the restriction that the look angle is not distorted at the beamformer's output [7]. The basic idea of the Minimum Va-riance Distortionless Response (MVDR) algorithm is to estimate the beamforming excitation coefficients in an adaptive way by minimizing the variance of the residual interference and noise whilst enforcing a set of linear constraints to ensure that the real user signal are not distorted [7].

The authors in [8] proposed an enhanced model of MVDR algorithm by replace the position of the reference element in steering vector to be in the central of the array and the number of elements must be odd. Simulation results show that modified MVDR has a realistic behavior especially for detecting the incoming signals direction and outperforms the conventional MVDR. One of the popular approaches to improve the classic Capon beamfor-mer in the presence of finite sample effect and steering vector errors is the diagonal loading, which was studied by [9]. The idea behind diagonal loading is to adapt a covariance matrix by adding a displacement value to the diagonal elements of the estimated covariance matrix. Nevertheless, how to select an appropriate diagonal loadi-ng level is a challenging task. [10] mentioned that the element spacing must be d ≤ λ/2 to prevent spatial aliasin-g. In [11], the author presents a comparative study of MVDR algorithm and LMS algorithm, where results show that LMS is the better performer. The SINR maximization is another criterion employed in the joint transmitter and receiver beamforming algorithms [12], [13], [14]. In an analysis of [15], the mixing of differential algorithm based LAA is applied to deepen nulls and lower side lobe levels (SLLs) in the unwanted direction, and they fou-nd the max null depth of -63 dB by using 20 element. The statistic numerical algorithm was proposed to obtain the requirement for the amplitude and phase error of multibeam active phased array antenna [16]. The radiation beampattern is simulated from the value of the random amplitude and phase errors of phase shifter. From the results, it is found that the only way to meet the requirement of the sidelobe level is to use digital

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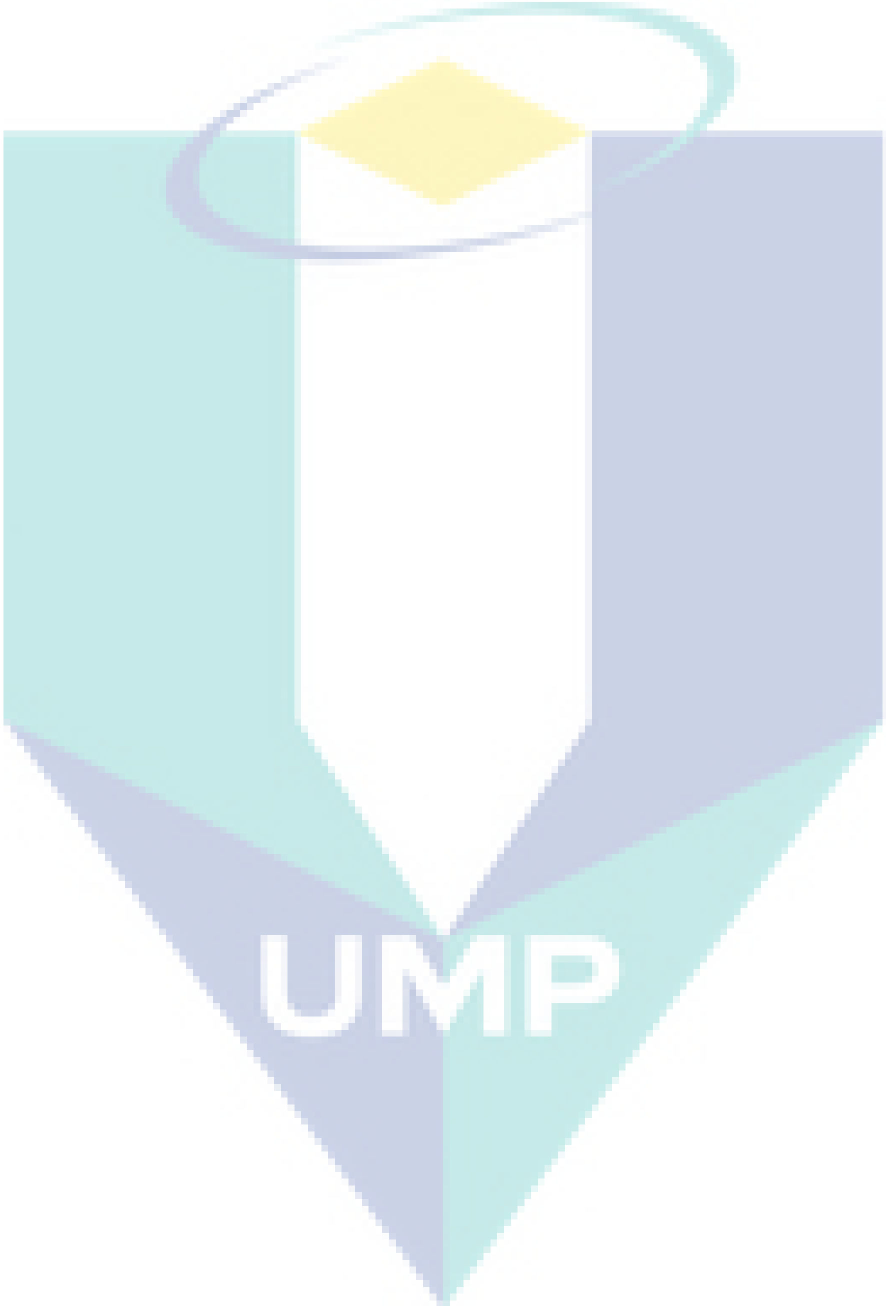
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