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Dedication

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Table of Content:

Academic Journal of Research and Scientific Publishing | Vol 4 | Issue 45
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Crystallites Dimensions and Electrical Conductivity of Solid Carbon Pellets (SCPs) from Date Palm Leaves (Phoenix dactylifera L.)

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Abstract

Solid carbon pellets (SCPs) were prepared from self-adhesive properties of date palm leaves (*Phoenix dactylifera L.*), primary pre-carbonized at low temperature, milled to fine grain, powdered, and pelletized as a grain pellet by applying of (5-21) metric tons of compression load, to carbonization at 1000 ºC. The SCPs produced were analyzed in terms of the volume shrinkage, carbon yield, crystallites dimensions and electrical conductivity of the solid carbon pellets as a function of compression load. The values of the electrical conductivity were further analyzed in terms of percolation theory to estimate the critical density of the SCPs produced. The results show that the volume shrinkage and carbon yield after carbonization were in a range of 54.0-64.8% and 26.98-32.4%, respectively, indicating that the body is physically shrinking to maintain its structural integrity. X-ray diffraction intensity shows that the structures of the SCPs are non-graphitic, and their crystallite dimensions are improved by increasing the compressive load. The d_{002}, L_c and L_a data were found to obey the linear relation of d_{002} versus 1/ L_c and 1/ L_a, as L_c and L_a approach infinity. The electrical conductivity was varied with the compression load and 19 metric tons is a higher value than the others. The critical density of the SCP obtained from the percolation theory was 0.025 g/cm^3.

Keyword: Date palm leaves, grain pellets, carbon pellets, volume shrinkage, carbon yield, crystallite dimensions, electrical property, critical density.

1. Introduction

Carbon materials have attracted great attention in the last decade because of their numerous applications, such as electrical carbon brush (Tang et al., 2005), super capacitor (Pandolfo and Hollenkamp, 2006), electrochemical capacitors (Inagki et al., 2010), catalyst and catalyst support (Lam and Luong, 2014), and double layer capacitors (Arof et al., 2012).Carbon material has been made using a wide range of raw materials: biomass, petroleum coke, rank coals, bio-pitch, bio-oil, polymer in different forms powder, granular and pellets without or with filler reinforcements (Aso et al., 2004; Chunlan et al., 2005; Saeed et al., 2010, Dhyani and Bhaskar, 2018; Zhang et al., 2019; Lu et al., 2020; Wang et al., 2020) The pellet form is particularly useful because it is dense or contains particle sizes closed together in a solid manner. In addition, the shape of pellet form can provide a more fundamental understanding of the physical properties of carbon and the interactions that occur at its surface (Fatima et al., 2022). Several biomass materials have been tested to prepare carbon materials such as shells of mata kucing (*Dimocarpus longan*) fruit (Arof et al., 2012), cellulose (Adinaveen et al., 2016), date palm stones (Ahmed, 2016), oil palm wastes (Rashidi et al., 2017), lignocelluloses (Gonzalez, 2018) and date palm leaves (Fatima et al., 2022), found to be chemically stable in the environment. Frequently, it required careful preparation to improve it is physical and electrical properties and application. For example, the addition of metal material to improve it is electrical and mechanical properties (Kercher and Nagle, 2002; Deraman et al., 2004; Yan et al., 2016).

Characterization of the carbon structure can be made in terms of crystallite dimensions (d_{002}, L_c, and L_a) of the graphitic-like structure that are randomly distributed and oriented throughout the sample. Small graphitic-like structures reflect to disorder a structure which is sensitive to higher porosity content (Benedetti et al., 2018). It is well established in carbon materials that the mechanical properties of the carbon fibers are improved by increasing the crystalline and orientation, by electing a highly oriented precursor and then maintaining the initial high orientation during the carbonization process (Fatima et al., 2022). the electrical conductivity of carbon pellets prepared from oil palm empty bunch increased with the increasing molarities of nitric acid (HNO_3) (Deraman et al., 2002). Additionally, for the petroleum coke and graphite, it has been found the electrical conductivity and bulk density increased with increasing heat treatment temperature (Kim, 2001).

In the present work, the date palm leaves are being used for preparing solid carbon pellets because they're abundant, can be collected in a large amount and have low ash content. Primary, palm leaves were pre-carbonized at low temperature, milled into fine grain powder to improve its self-adhesive properties (Deraman et al., 2004), before being converting into a pellets by applying different compression load without adding any binder The objective of this work is to preparation solid carbon from date palm leaves by compression load, and attempt to establish various relationships between volume shrinkage carbon yields, crystallite size sand electrical conductivity of the solid carbon pellets as a function of compression load. The results of electrical conductivity were analyzed in term of percolation theory the estimate a critical density threshold. An X-ray diffraction programs is also applied to estimate the crystallite dimensions.

2. Material and Methods

Date palm leaves were pre-carbonized at 280 °C in a vacuum chamber for 4 hours, to cause them to shrink and break the date palm leaves microstructure, followed by ball milling for 20 hours milling time to produce a fine grain powder. About 2g of each grain powder was pelletized as a grain pellet by applying of 5, 7, 9, 10, 11, 12, 13, 14, 15, 17, 19 and 21 metric tons of compression load (354.175 x 10^4 N m^{-2}) in a mold of 2.75 cm diameter. These grain pellets were carbonized up to1000 ºC in a nitrogen environment using a multi-step heating profile (VulcanBoxFurnace3-1750). Programmed as1ºC/min from room temperature to 375 ºC where it was held for 1 hour before heating was resumed at 3 ºC/minto 800 ºC and then 5 ºC/min to 1000 ºC, where it was finally held for 5 minutes. Then system was automatically allowed to cool down naturally to room temperature.Then washed thoroughly with hot distilled water to remove the impurity and dried at 100 ºC for 2 hours. Results are given as the average from 5 replicates of each sample and analyzed as a function of compression load (CL) at room temperature. Measurements of the pellets dimensions before and after carbonization were carried out using a micrometer and the bulk density was determined by dividing the weight of the sample with its volume. The percentage of volume shrinkage and the carbon yield was calculated from the volume and the weight of the samples before and after carbonization.

Selected ACP samples were crashed into powder and mixed with KBr and compacted to form thin pellets.

The FTIR spectra were collected using a RFX-65 spectrophotometer capable of a maximum resolution of 0.12 cm^{-1} and equipped with an MCT liquid nitrogen-cooled detector, interferometer, detector and computer software, (model-KVB/Analects, INC). Infrared spectra were collected by using 2 to 5 milligrams (mg) of sample in a potassium bromide (KBr) pellet. The measurement was carried out using the Perkin Elmer System 2000 Fourier Transform Infrared (FTIR) with a pulsed laser carrier and a deutera-tedtriglycine sulfate detector. All the CPs were scanned from 400 to 4000 (cm^{-1}), with averaging 10 scans at 1.0 cm^{-1} intervals with a resolution of 0.25 cm^{-1}.

The XRD diffraction intensity of the CPs was analyzedusing (Bruker Advanced Solution AXS D8) equipment, with Cu K_{α} radiation and 1.5406 Å wavelength (λ). The pellets were scanned at 2θbetween 10º and 60º, with a step size of 0.04°. The diffraction intensity was corrected for the instrumental line broadening (Andrew and Dennis, 2002).Then diffraction intensity profiles recorded were fitted into a symmetrical Gaussian distribution. The crystallite dimensions (L_a, L_c) of the graphite-like crystallites can be calculated from the diffraction intensity using the Sherrier equation (1) and Warren's correction for the instrumental line broadening, by using Trace 1.4 programVarian 5 from Diffraction Technology PTG LTD, Australia. This program refines the intensity of each peak (as a separate variable) smooth the peak shape, as well as subtracts the background line and eliminates the $K\alpha_2$-peak from the diffraction intensity.

$$L_{c,a} = \frac{K\lambda}{\beta_{c,a}\cos\theta} \quad (1)$$

where θ is the scattering angle position, K is a shape factor which is equal to 0.9 for L_c and 1.84 for L_a, $\beta_{c,\,a}$ *is* the width of a reflection at half-height expressed in radians. The relationships between d_{002}, L_c and L_a can be deduced by assuming a well known condition that for large L_a and L_c, ($\frac{1}{L_c}$ and $\frac{1}{L_a}$) approaches zero, then d_{002} versus($\frac{1}{L_c}$ and $\frac{1}{L_a}$) should follow a linear equation given as (Abubaker et al., 2006, Fatima et al., 2022)

$$d_{002} = \alpha_1 + \frac{\alpha_2}{L_a} \quad (2)$$

where α_1 =3.354 Å is the interlayer spacing of pure graphite and α_2 is a constant (e.g., = 9.5 for L_a).

DC electrical conductivity (σ) was measured using the four-point-probe equipment (Keithley Micro-Ohmmeter) and the electrical conductivity (σ) given as:

$$\sigma = \frac{d}{RA} \qquad (3)$$

Where d is the sample thickness, R (Ω) is the electric resistance and A is the area of the sample. First, the carbon samples were polished both sides, second, the electrical conductivity of graphite was used as the standard value to verify the accuracy of the measurement. The obtained results of were analyzed in terms of the percolation theory threshold above critical density (ρ_c) (Chunsheng and Yiu, 2008) given as

$$\sigma \sim (\rho - \rho_c)^t \qquad (4)$$

where ρ is the bulk density, ρ_c is the critical density and τ is the power constant (~2) for the three dimensional. By plotting of log σ versus log (ρ-ρ_c) for ρ>ρ_c for various values of ρc leads in every case to a straight line, with the slope of t.

3. Results and Discussions

3.1. Volume Shrinkage

The palm leavesis the lignocelluloses composed of cellulose, hemicelluloses and lignin as mean products. The weight loss was attributed to lignin and hemicelluloses firstly, decomposed at lower temperature and finally cellulose decomposed reasonably at 360 °C in terms of moisture, tar, and gases, such as H_2, CO_2, CO, and O_2 (Dhyani and Bhaskar, 2018). Table 1, summarized the data of the solid carbon pellets before and after carbonization process. The bulk solid density increased but the apparent density decreased slightly after carbonization despite losing considerable weight and significant volume shrinkage. Similar behavior for carbon pellets from oil palm materials (Deraman et al., 2002) and cotton cellulose (Abubaker et al., 2006).

The volume shrinkage of the carbon pellets decreases with increasing compression load and becomes saturated at a higher CL.

This indicates that the compression load in the grain powder has an intrinsic tendency to reduce the volume shrinkage of the carbon pellets during the carbonization process due to squealing the particle size together in a solid manner.

3.2. Carbon Yields

Table 1 show the total yield of the carbonization process decrease at lowered load and further fluctuated at higher compression loads in a range of 26.98-32.4%, which is found similar to those of biomass olive stones treated with phosphoric acid (Yakout and Sharaf El-Deen, 20016). 5 metric tons of compression loads is exhibit a higher yield than the others.

Table 1: Metric Tons, Thickness (T_1, T_2), Diameter (D_1, D_2), bulk Density (ρ_1,ρ_2), volume shrinkage % and carbon yield % of the solid carbon pellets, before and after Carbonization

Grain Pellets				Solid Carbon Pellets				
Metric Tons	T_1 (mm)	D_1 (mm)	ρ_1 (g/cm^3)	T_2 (mm)	D_2 (mm)	ρ_2 (g/cm^3)	VolumeShrinkage %	Carbon Yield %
05	0.275	2.707	1.2439	1.99	19.60	1.063	64.8	32.40
07	0.264	2.716	1.3452	1.82	19.57	1.072	54.6	27.29
09	0.258	2.717	1.408	1.77	19.51	1.124	54.0	26.98
10	0.253	2.712	1.4669	1.79	19.45	1.212	59.3	29.66
11	0.251	2.703	1.4954	1.81	19.37	1.222	60.9	30.45
13	0.25	2.707	1.5051	1.80	19.37	1.293	63.7	31.87
14	0.248	2.71	1.5278	1.79	19.38	1.256	61.3	30.63
15	0.247	2.704	1.5436	1.77	19.34	1.281	61.0	30.48
16	0.246	2.714	1.5505	1.79	19.41	1.244	60.8	30.38
17	0.245	2.71	1.5654	1.77	19.38	1.298	61.9	30.95
19	0.244	2.712	1.5771	1.79	19.39	1.323	64.6	32.28
21	0.244	2.709	1.5789	1.77	19.37	1.276	60.8	30.41
SIG-K						1.540		
a								31-36.8

Note: SIG-K (Sigradur K) (Deraman et al. 2002) [a]is the carbon from the olive stones (Yakout and Sharaf-Ei-Deen 2016).

3.3. FTIR

For the SCPs treated from 5 to 21 metric tons of load, the spectra showed a broad band at 1652 cm-1 due to C=C stretching by the aromatic rings (Jia and Aik 1999) or it may be caused by the C=O stretching vibration of carboxyl or carbonyl groups. The band at 2950 cm-1 represents -CH stretching in the olefins or acetylene rings. For KOH treatment above 10 CLM, the FT-IR transmission spectra did not show any stretching band. Possibly, the carbon samples had a more amorphous structure, increasing the bond angle sufficiently to have had bands in slightly different positions from those in the crystalline phase. Otherwise, it reflects a homogenous structure in the carbon grain particles when it was prepared by a higher CL.

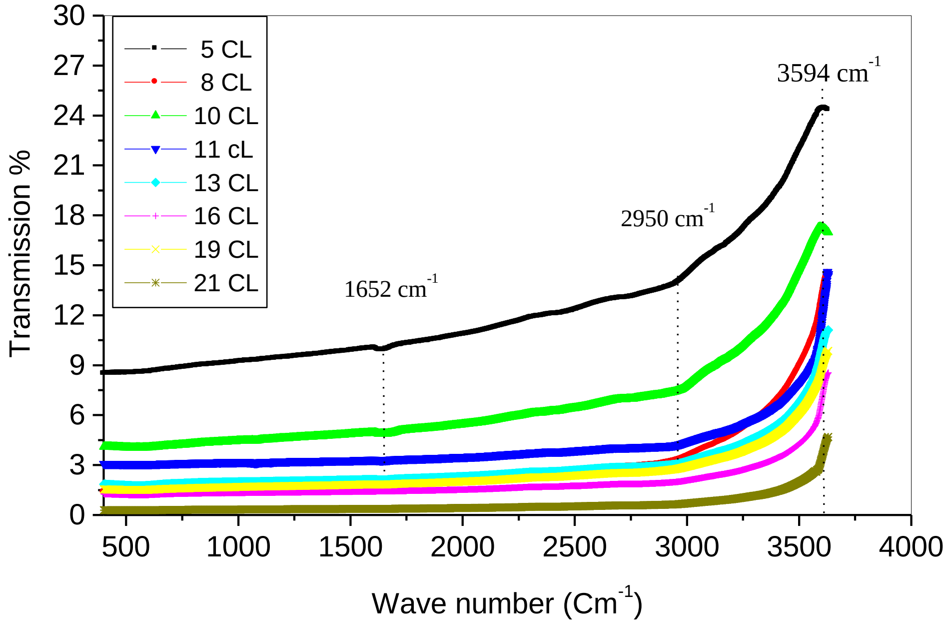

Figure 1: FTIR D of the solid carbon pellets

3.4. X-Ray Diffraction and Crystallite Dimensions

Figure 2 shows the X-ray diffraction of SCP contains two broad diffused at (002) and (100) peaks in roughly the same position as the peaks of pure graphite, results in a non-graphitic carbon structure (Song et al., 2011; Kristin et al., 2014). Similar observations have been shown on carbon -based petroleum coke (Lu et al., 2010). The order in the crystal is usually both positional and oriented, in that the molecules are constrained both to occupy specific sites in the lattice and to orientate their molecular axes in specific directions.

The diffraction intensity has been corrected to the background line, and instrumental boarding, and then fitted into the Lorentz distribution curve, as shown in Figure 3. As the diffraction profile overlaps and consists of four broad incomes peak, i.e., (002), (100) and (004), located at approximately 24.2°, 43.59°, and 52.0° diffraction angles, respectively. After correction, the diffraction intensity and Bragg's peaks were the same as in a graphite-like structure, and the layer separation was slightly further apart than in a graphite structure as shown in Figure 3.

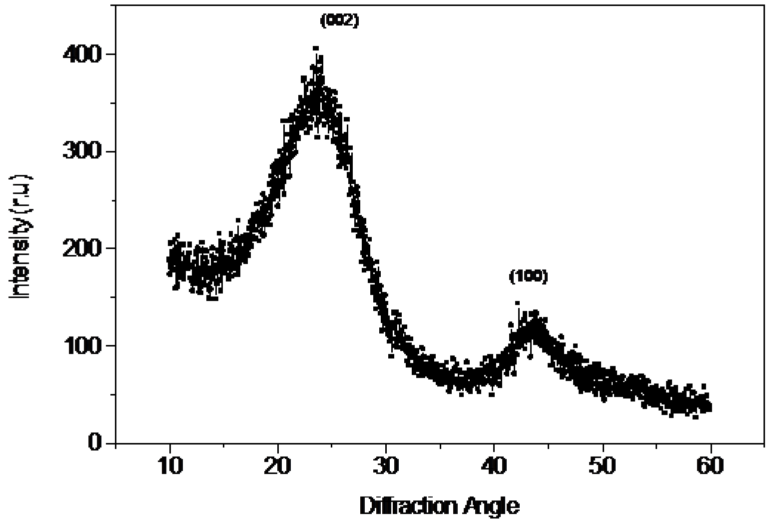

Figure 2: XRD intensity of solid carbon pellets

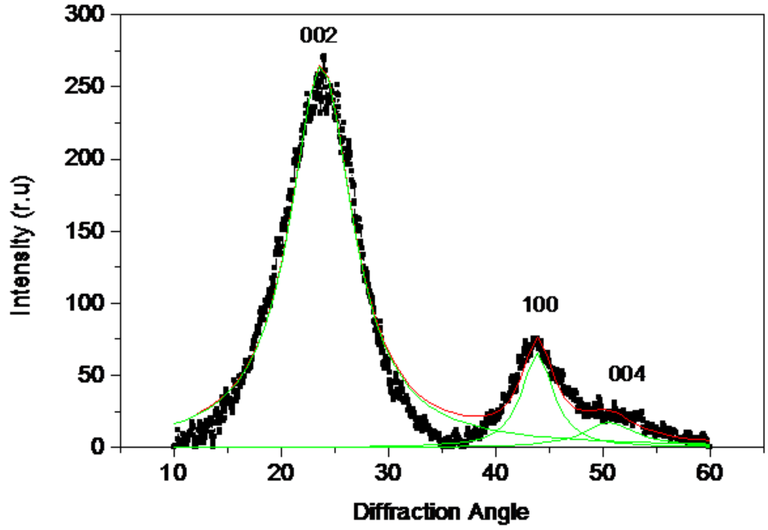

Figure 3: XRD intensity corrected to background line and fitted to Lorentz distribution curve

The d_{002} spacing of the carbon pellets produced is larger than that of graphite (i.e., d_{002} = 3.354 Å), reflecting the lower ordered structure. Also, d_{002} decreased with increasing compression load, indicating that a higher pressure gives a more crystalline structure as a consequence of the decreasing decrease in the d_{002}spacing of the SCPs produced as shown in Figure 4 and Table 2. The result also showed that both the L_c and L_a increased rapidly with increasing compression load from 5 to 12 metric tons of compression load, indicating an improved crystalline structure in the SCPs. Therefore, 16 tons of load gave the highest values of L_c and L_a, indicating that this pressure was sufficient for pelletizing grain powder. Above 16 metric tons, the values fluctuated, probably due to stress behavior at a higher compression load used for the pelletizing (Figure 5). This finding indicates that the compression load used for the pelletizing improved the crystalline dimensions of the SCPs produced.

From the data in Table 2, the values of d_{002}, L_c and L_a were compared to those of carbon made from phenanthrene and carbon from polyvinyl chloride (PVC) (Aso et al., 2004), carbonized at the same temperature, i.e., 1000 ºC. The values of L_c and d_{002} are in good agreement but L_a is lower than the values reported previously (Aso et al., 2004). The crystallite parameters of carbon samples, i.e. (d_{002}, L_c and L_a) were observed to increase with increasing CL.

Table 2: Crystallites parameters (L_c, L_a, d_{002}) and the electric conductivity of the SCPs

Metric Tons	**L_c (Å)**	**L_a (Å)**	**d_{002} (Å)**	**σ (Ω. m)$^{-1}$ X 10^5**
05	15.5	27.14	3.70	0.172
07	16.3	27.94	3.69	0.174
09	17.3	29.69	3.67	0.184
10	17.9	30.65	3.66	0.202
11	17.1	29.69	3.67	0.204
13	16.3	27.94	3.69	0.219
14	17.9	30.65	3.66	0.211
15	16.8	28.79	3.68	0.216
16	18.0	31.67	3.65	0.208
17	16.3	27.94	3.69	0.220

19	17.4	30.65	3.66	0.225
21	16.1	29.69	3.67	0.215
PVC-1000	16.0			-
AC-Type H		32	3.60	-
AC		27.57	3.70	
graphite		-		1

Note: PVC-1000 is for carbon precursor Polyvinyl chloride (PVC) (Aso et al. 2004) carbonized up to 1000 ºC. Activated carbon (AC) from cotton cellulose (Abubaker et al., 2006), AC-Type H is the commercial activated carbon (Saeed et al., 2014)

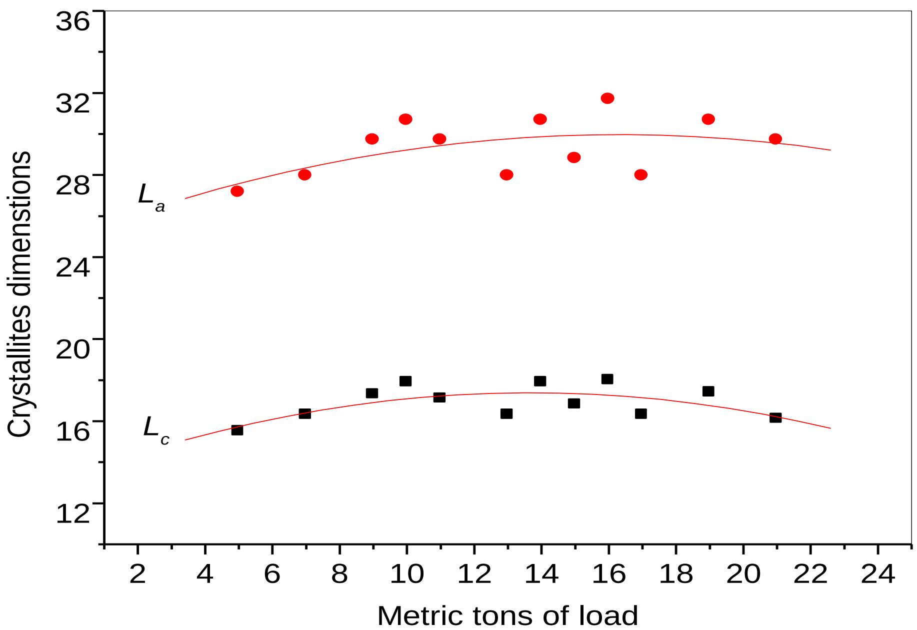

Figure 4: crystallites dimensions (L_a and L_c) versus CL

Our analysis of the d_{002} versus L_c and L_a was also found that obeyed the linear relation of d_{002} versus 1/ L_c and 1/ L_a, where d_{002} approached the value for pure graphite as L_a approaches infinity as shown in Figures 4 and 5. The linear equations are given as the following:

$$d_{002} = 3.342 + \frac{5.62}{L_c} \tag{5}$$

$$d_{002} = 3.354 + \frac{9.8}{L_a} \tag{6}$$

This linear correlation indicated that an improvement in the crystallite dimension occur simultaneously with the increase of L_a.

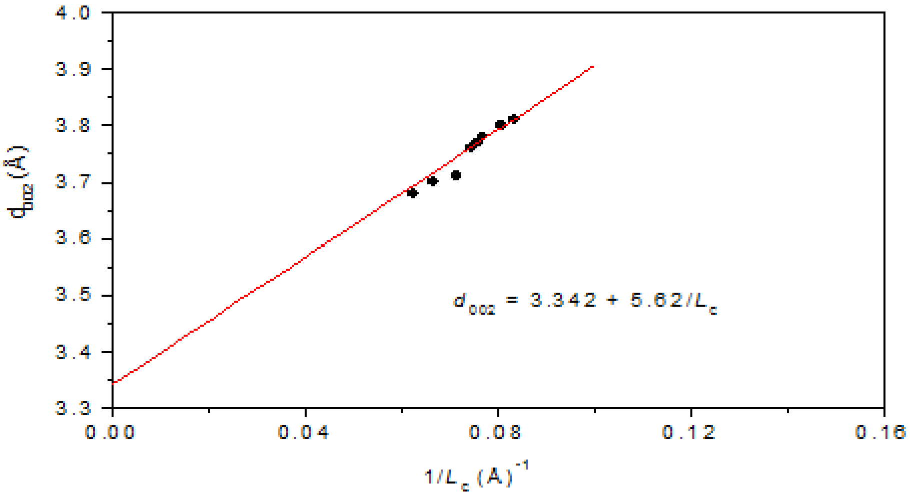

Figure 5: d_{002} versus $1/L_c$

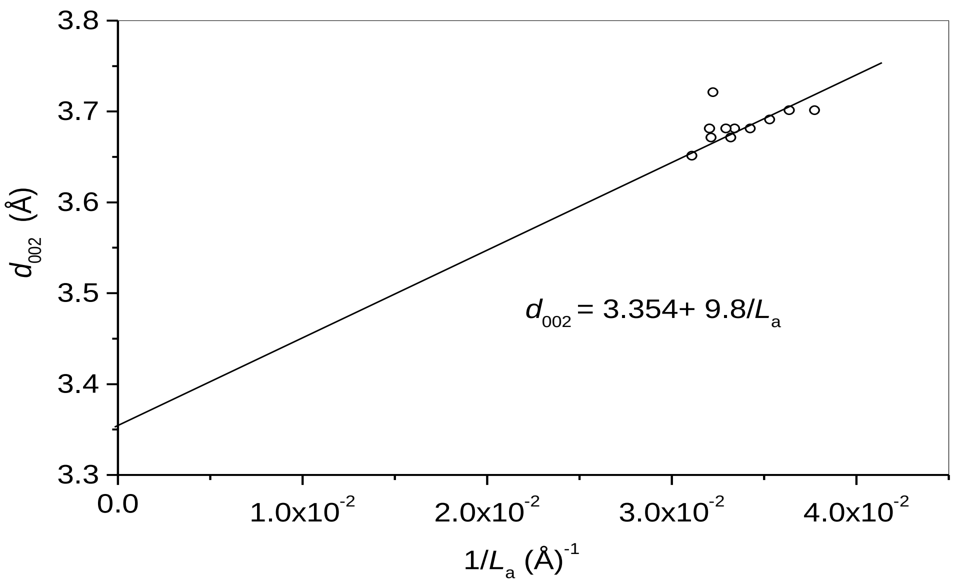

Figure 6: d_{002} versus $1/L_a$

3.5. Electrical Conductivity

The plot of electrical conductivity of the SCPs versus compression load is shown in Figure 6. The data in this figure show that the electrical conductivity of carbon pellets slightly increased with the increase of compression and exhibited its higher value at 19 tons pressure and then decreased. The increases in electrical conductivity are expected due to an improvement in its microstructure or preferred orientation. The electrical conductivity of the SCPs is less than that of a standard value of (SIG-K). This can be explained by the fact that during carbonization the volatile component is the interlayer's distance and pore size of the CPs, which reduces the amount of solid to conduct electrons. Or it's probably because of volatile organic matter microcrystalline, and more or less hydrated in organics substance (ash) may be considered as an insulating material.

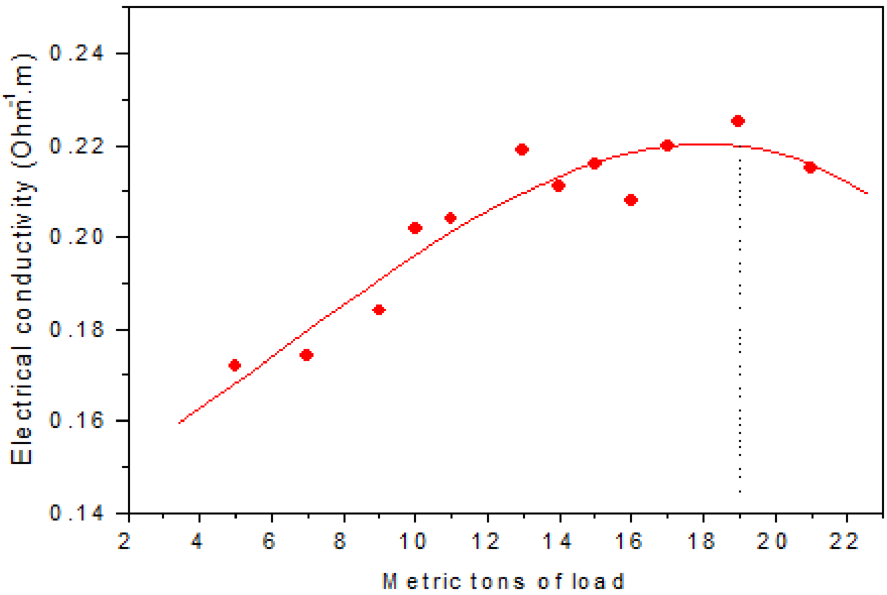

Figure 7: Electrical conductivity versus CL

3.6. Percolation Theory

The electrical conductivity is based on percolation theory, corresponding to the ACPs whose densities are located above its critical density ($\rho > \rho c$) by fitting log σ versus log ($\rho - \rho c$). This fitting was made by varying the values of ρc until the best linear curve fit is obtained, with the slope of 1.21 which is lower than the accepted universal value of t ~ 2 (Chunsheng and Yiu, 2008).

The intercept at the y-axis is 1.23, and the fitting value of ρc was found to be 0.025 g cm^{-3}, which represents the percolation threshold (critical density) for SCPs produced. This value is half of the percolation threshold of the graphite backbone (i.e., 0.05 g cm^{-3}) measured by Celzard et al., (2002). As follows from Table 2, the percolation theory was found to have a good correlation with the bulk density of the carbon samples, and it was interpreted by the increase in the bulk density of the carbon samples above 0.025 g cm^{-3}.

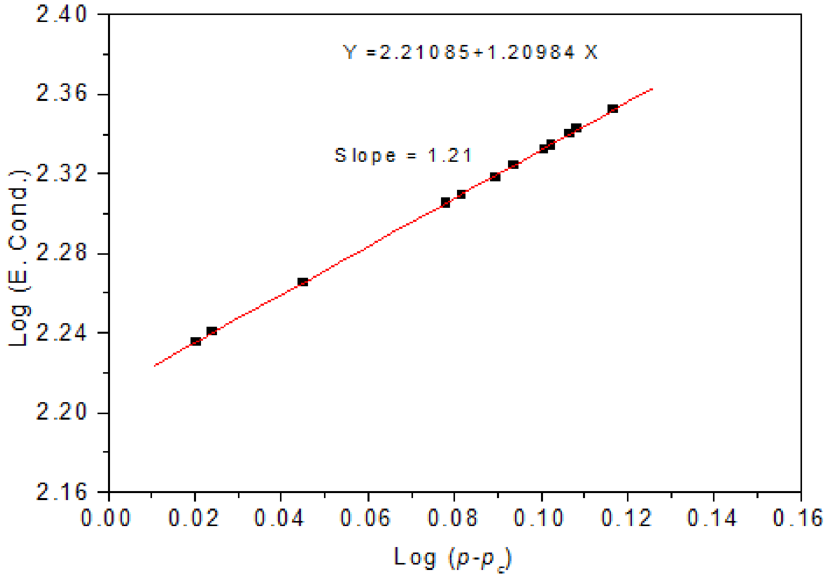

Figure 8: log (E. cond.) versus log (p-p_c)

Table 3: bulk density (p), electrical conductivity (σ), Log (σ) and Log (p-pc)

p (g/cm^3)	$\sigma(\Omega.cm)^{-1}$	Log (σ)	Log(P-P_c)
1.063	172	1.2355	0.0204
1.072	174	1.2406	0.0241
1.124	184	1.2648	0.0449
1.212	202	1.3054	0.0781
1.222	204	1.3096	0.0817
1.293	219	1.3404	0.1065
1.256	211	1.3243	0.0938
1.281	216	1.3345	0.1024
1.244	208	1.3181	0.0896

1.298	220	1.34242	0.10823
1.323	225	1.35218	0.11661
1.276	215	1.33244	0.10072

4. Conclusion

The volume shrinkage and carbon yield reasonably varied with the compression load. FTIR data above 9 metric tons of compression pressures did not show any absorption band indicated non-carbon components had been released, forming a solid sample with a uniform structure. The crystallite dimensions of the carbon pellets (d_{002}, L_c and L_a) were observed to increase and decrease with increasing compression load. Also, increasing compression load increases the electrical conductivity of the carbon pellets produced, up to 19 metric tons of compression load. Justifying, thatan improvement in the inter-particle bonding,and more free carriers are created due to sequels the particle size together in asolid manner. The percolation theory found that 0.025 g/cm^3 is the critical density of the solid carbon pellets produced.

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Implementation of Hub, Switch and Load Balancer Scenarios in a Software-Defined Datacenter Network

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Abstract:

Software-Defined Networking (SDN) is a networking design approach, which separates the data plane from the control plane, providing the network with certain benefits due to centralized programmatic control. SDN provides a centralized view and enables management of the entire network. It offers flexibility in configuration, reduces time to deploy, provides automation and facilitates building a network without requiring the knowledge of any vendor-specific software/hardware. SDN offers the datacenter network benefits such as improving traffic and security management as well as providing a scalable infrastructure. Load balancing enhances the performance of the network by distributing traffic among servers and therefore preventing congestion and server underutilization. This paper aims to explore SDN and test its implementation and demonstrate how to implement its concepts within a datacenter network. The experiment considers the datacenter network implemented in Sudan University of Science and Technology as a case study. The edited network topology is made up of a Demilitarize Zone (DMZ) having three servers, a Local Area Network (LAN) and a main switch. The Hub, Switch and Load balancer scenarios are implemented using Mininet emulator.

In addition, the three scenarios are tested using external devices and analyzed using Wireshark. Moreover, the connectivity of HTTP and FTP is verified.

Keywords: Control Plane, Data plane, Load Balancer, Network Programmability, Software-Defined Networking.

1. Introduction

Software-Defined Networking (SDN) is a recent architectural approach that improves and simplifies network processes by combining interaction such as provisioning and messaging among applications, services and devices, whether they are real or virtualized. SDN is deployed by employing a logically centralized control point in charge of coordination and management of communication between applications and network elements that require interaction with each other. In addition, the controller recognizes and identifies network processes. The controller then reveals network functions and processes through application-friendly and bidirectional programmatic interfaces 0(Feamster et al., 2013) .

SDN allows the deployment of devices from different vendors in a flexible manner. Employing standard protocols instead of vendor proprietary protocols enhances the flexibility of the network in terms of interoperability between access, distribution and core layers that consist of different vendors, the price factor in purchasing the devices and support.

2. Research Objectives:

The objectives of this research are to:

1. Propose a load balancer for SDN-based datacenter networks.
2. Testing the load balancer under the Hub, Switch and Load balancer scenarios using both emulation and external devices.
3. Testing the connectivity of HTTP and FTP services in the SDN network.

3. Research Importance:

Datacenter networks are designed for satisfying the data transmission demand of densely interconnected hosts in the datacenter, so the adaptation of load balancing methods became common and important. However, the requirement of load balancing routing in datacenter networks cannot be fully satisfied by traditional approaches.

4. Related Work:

A number of studies on SDN have been proposed (Mahjoub, 2015), (Körner , 2015) (Salih et al., 2014) (Ghaarinejad, 2015). The project Event-Driven Network Control Using Software-Defined Networking explored SDN as an emerging paradigm and tested its implementation in dynamic network environments (Mahjoub, 2015). It also highlighted the problem of dynamic networks in terms of configurability and the need to look at SDN as an approach or architecture to not only simplify the network but also make it more reactive to the requirements of workload and services placed on the network. The work in (Körner , 2015) dealt with the question of how datacenter networks could benefit from the integration of SDN in terms of network primitives, load balancing, Quality-of-Service (QoS) overlays and forwarding and firewalls. It also introduced innovative concepts to realize the usual ingress datacenter network service chain. The authors of (Salih et al., 2014) took advantages of SDN and implemented a remote configuration of Virtual Local Area Network (VLAN) from a single controlling point. The case study was to balance the load between multiple VLANs when one of them is overloaded. The work in (Ghaarinejad, 2015) emphasized the need for an SDN load balancer. In traditional networking, the IP address is used to split traffic among servers. Therefore, the traffic is not equally split, causing congestion and utilization problems. The problem was solved using SDN and three different load balancing policies were developed: Round-Robin, Random and Load-Based.

The algorithm proposed in (Chakravarthy & Amutha, 2019) balances traffic load in data center networks by selecting the best paths to route data flows. Paths are evaluated based on: byte rate, packet count, forward rate and transmission duration. Experimental results proved that the algorithm relieved network congestion due to load balancing which lead to reducing latency. The load balancer implemented in (Aguilar & Batista, 2019) employed three algorithms: random, round robin and least bandwidth. Results showed that the performance of the three algorithms is similar, maintaining acceptable response time. A SDN Multiple Controller Load-Balancing Strategy Based on Response Time (SMCLBRT) was proposed in (Cui et al., 2018) considering the trade-off between load balancing and switch migration among controllers.

The evaluation revealed that switch migration could be performed ahead of time to offload congested controllers while keeping the number of migrating switches minimum.

The load balancing problem was addressed in (Sufiev et al., 2019) by dynamically reassigning switches among controller clusters. Simulation results indicated a fivefold improvement of dynamic clustering over static clustering. Another study attempted to manage load balancing in hierarchical networks by distributing traffic flows among different paths in the network (Sitota, 2021). The proposed load balancing algorithm transmits traffic on the path having the least cost considering throughput and delay. Simulation results proved that the proposed algorithm reduced congestion while improving resource utilization. The authors of (Mulya et al., 2019) used ant colony optimization for load balancing in a SDN network. A simulation was developed to evaluate completion time, throughput and traffic load. Attained results showed that the ant colony optimization resulted in higher throughput compared to round robin while ensuring even distribution of CPU utilization.

5. Software-Defined Networking:

The Open Networking Foundation (ONF) has formulated the definition of Software-Defined Networking (SDN) as an innovative network architecture that separates network control from forwarding and that it is directly programmable (ONF, 2012). According to this definition, SDN is characterized by two properties; the separation of the control plane and data plane and enabling programmability of the control plane. It is worth mentioning that these two features are not new to network architecture, however, SDN offers both features with higher programmability, flexibility and control.

5.1. SDN Architecture

Fig.1 depicts the SDN architecture. As the figure shows, there are three different layers (Xia et al., 2015):

1) ***Application Layer****:* Provides several services and applications like access control, intrusion detection and prevention system (IDS/IPS), in addition to load balancers.
2) ***Control-plane Layer***: Includes a logically-centralized SDN controller, which maintains a global view of the network that takes requests through clearly defined Application Programming Interfaces (APIs) from the application layer and performs management and monitoring of network devices via standard protocols.
3) ***Data-plane Layer***: Also known as infrastructure layer, this layer provides with hardware components used for forwarding such as switches and routers.

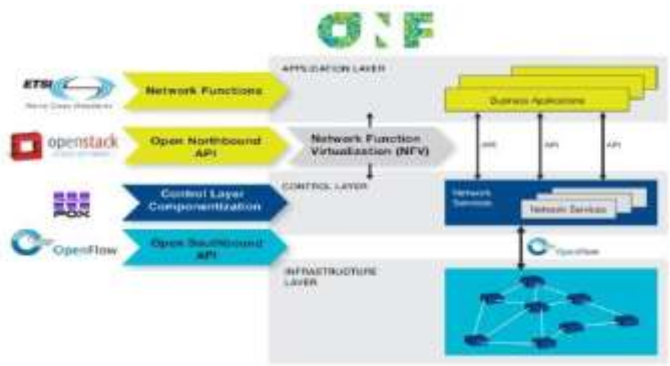

Fig.1. The Open SDN Architecture

5.2. SDN Controllers

SDN controllers differ in their basic architecture and programming model in addition to other concepts. Finding the ideal controller for a specific situation is influenced by many factors including the choice of programming language which can sometimes affect performance and the learning curve of the controller. Other factors include user base and community support. Moreover, the choice of controller should consider the Southbound and Northbound interfaces (policy layer).

There are several popular SDN controllers implemented in different languages offering a wide variety of services. The most well know controllers are summarized in TABLE **1**.

TABLE 1 SUMMARY OF PROPERTIES OF FAMOUS CONTROLLERS

	NOX	**POX**	**Ryu**	**Floodlight**	**OpenDay Light**
Language	C++	Python	Python	Java	Java
Performance	Fast	Slow	Slow	Fast	Fast
Distributed	No	No	Yes	Yes	Yes
OpenFlow version	1.0	1.0	1.0, 1.1, 1.3, 1.4	1.0	1.0, 1.3
Learning Curve	Moderate	Easy	Moderate	Steep	Steep

5.3. Load Balancing

Today's Internet experiences high traffic that could lead to server congestion if not managed in a controlled manner. Load balancing is the mechanism of distributing traffic among servers with the purpose of offloading them leading to improved performance. It is achieved using Application Delivery Controllers (ADCs) which direct traffic to a set of servers hosting the same target application. Load balancing ensures a stable, falt-tolarent network with improved performance (Ghosh & Manoranjitham, 2018).

As illustrated in Fig.2, the load balancer device resides between the clients and the set of servers. It accepts incoming traffic and distributes it to servers using a load balancing algorithm. This reduces the load on each server. In the case of a server failure, the load balancer redirects packets to other responsive servers.

A load balancing algorithm defines the method that is used to select the server to which each client request is forwarded. Load balancing algorithms differ in the criteria they use for this selection. The most famous load balancing algorithms are (Load Balancing Algorithms, 2021):

1. The Least Connection Method
2. The Round Robin Method
3. Weighted Round Robin
4. Fastest Response

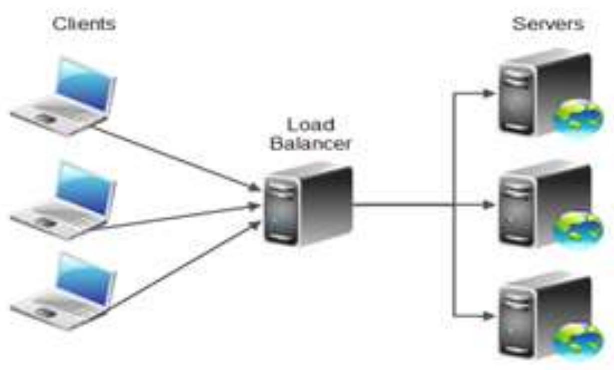

Fig.2. Load Balancer

5.4. SDN for Datacenters

A datacenter is a centralized repository, either physical or virtual. It employs many host servers and networking devices that process requests. In addition, it interconnects hosts to other hosts in the network or to the public Internet. Requests made to a datacenter range from web content serving, email and distributed computation to many cloud-based applications. It simultaneously provides many applications associated with a publicly visible IP address. Fig.3 shows the hierarchical topology of a datacenter network.

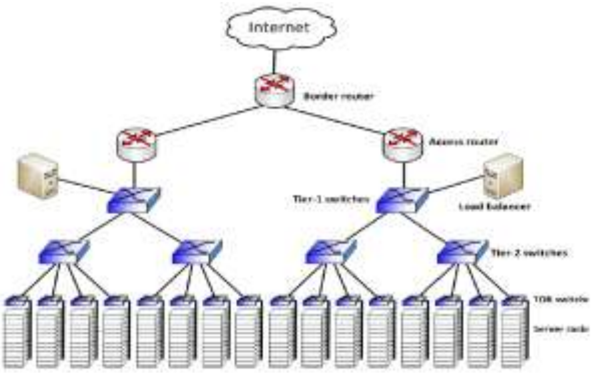

Fig.3. The Hierarchical Topology of a Datacenter Network

6. The SDN Design and Emulation Environment

6.1. Network Topology

In this study, Sudan University of Science and Technology (SUST) datacenter network topology was selected to implement SDN.

SUST network contains one main core switch connecting the LAN network with the Demilitarize Zone (DMZ) area. Inside the DMZ there is one server with multiple services provided to the network as shown in Fig.4. This topology was edited in order to give a clear implementation of SDN concepts and to meet load balancing main expectation which is distributing traffic to more than one server. The edited topology contains three basic legs: The DMZ area which contains three servers, LAN and the main switch.

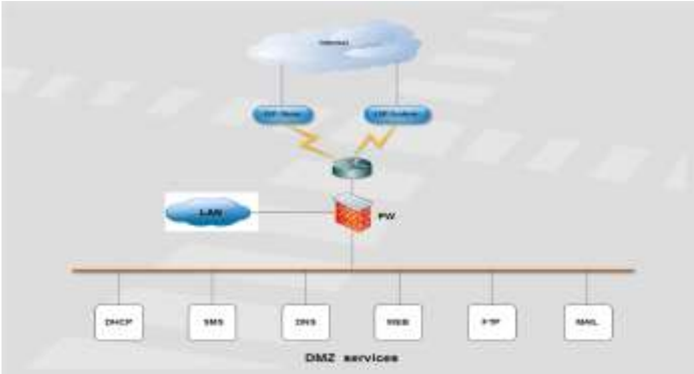

Fig.4. SUST Datacenter Network Topology

6.2. The Emulation Environment

Mininet emulator (Mininet Overview, 2019) was chosen for this experiment because it combines many of the best features of emulators, hardware testbeds and simulators. Compared to full system virtualization-based approaches, Mininet:

- Boots faster: seconds instead of minutes.
- Scales larger: hundreds of hosts and switches vs. single digits.
- Provides more bandwidth: typically, 2 Gbps total bandwidth on modest hardware.
- Easily installed: a prepackaged Virtual Machine (VM) that runs on VMware or VirtualBox for Mac/Win/Linux is available with OpenFlow v1.0 tools already installed.

Compared to hardware test beds, Mininet is inexpensive, always available and quickly reconfigurable and restartable. Compared to simulators, Mininet runs real, unmodified code including application code, OS kernel code and control plane code (both OpenFlow controller code and Open vSwitch code).

6.3. Controller Scenarios

According to TABLE 1, there are many SDN controllers available to implement OpenFlow protocol to control OpenFlow devices and act as the aggregated control plane. The comparison between these controllers led to choosing POX as the SDN controller in this work.

In the considered topology there is one Open vSwitch (OVS) to direct traffic to the servers. And so, the controller will manage the switch to work as desired. Three scenarios are implemented and tested on the OVS in the network:

1) Hub:

A hub is a common connection point for devices in a network and contains multiple ports. When a packet arrives at one port, it is copied to the other ports so that all segments of the LAN can see all packets.

2) Switch:

A switch manages the flow of data across a network by transmitting a received network packet only to one or more devices for which the packet is intended. Each network device connected to a switch can be identified by its network address, allowing the switch to regulate the flow of traffic.

3) Load Balancer:

In this paper, the load balancer implements the round robin algorithm. The Round-Robin algorithm is one of the simplest methods for distributing client requests over a group of servers. The round-robin load balancer forwards a client request to the first server in the list of servers, and then to the second server, and so on all the way to the last server in the server list. When it reaches the end of the list, the load balancer returns to the first server in the list, and the process continues. The main benefit of round-robin load balancer is that it is extremely simple to implement.

7. SDN Implementation

Using Mininet, the datacenter network topology is implemented and the configuration which is pushed on the virtual switch by the controller became simple and independent of the vendor and operating system. The controller is developed using Python and implemented on Ubuntu Operating System. Using the Python program running on the controller, the configuration could be changed to match any vendor.

Information was needed to evaluate the time required to implement a hardware-based hub, switch and load balancer in addition to software-based hub, switch and load balancer. The time required to deploy an orthodox hardware load balancer varies depending on a number of factors such as the efficiency of the engineer, the availability of the site and the urgency of the requirement. The methodology utilized in this work was completely based on experience of professional graduate students instead of industry experts.

After collecting the data using the above research methodology, the software-based hub, switch and load balancer were implemented using the following strategies:

7.1. Emulation

First, the virtual network topology was implemented using the GUI version of Mininet (Miniedit). The test topology was configured to have a total of five hosts: three servers and two clients connected to the Open vSwitch. The hosts were made to start with a dynamically assigned but easily readable IP and MAC addresses. The Open vSwitch was configured to connect to the remote POX controller on a TCP socket and communicate using the OpenFlow protocol. When the POX controller is started it opens a GUI interface that was developed using C# to manage the hub, switch and load balancer scenarios. The controller thereby implements their functionality in the SDN.

Second, the three servers were configured as Web Servers and port 80 was opened to listen to HTTP GET Requests. Meanwhile, the remaining two hosts were configured as clients which generate traffic to the servers. The three scenarios work as follows:

1) *Hub*: the Open vSwitch listens to all incoming packets and broadcasts them to all hosts.
2) *Switch*: the Open vSwitch listens to all incoming packets and forwards them to their given destination.
3) *Load Balancer*: the Open vSwitch listens to all incoming packets and selects a server to create a new session. The server is selected in a round-robin fashion for every session. The algorithm uses the OpenFlow libraries to listen and forward the packets while POX controller libraries are used to read and modify packets.

7.2. External Devices

In addition to implementing the SDN in an emulation environment, the network was connected to external devices and the connectivity of the implementation was tested. Three real servers are connected to the emulator through external interfaces, and the connectivity of HTTP and FTP services were verified using Wireshark.

8. SDN Testing and Verification

This section demonstrates the testing and verification of the SDN network. It shows the different scenarios implemented using the Mininet emulator and external devices.

8.1. Emulation Results

In the following we demonstrate the results of the hub, switch and load balancer scenarios, obtained from the Mininet environment.

1) The Hub Scenario

Error! Reference source not found. shows the results obtained from Wireshark packet analyzer, and as shown, the request from h4 to server 1 is broadcasted to all nodes in the datacenter.

2) The Switch Scenario

Fig.6 shows the results obtained from Wireshark under the switch scenario. As can be seen, the packets are exchanged between the source h4 and the destination server 2 only.

3) Load Balancer Scenario

Under the load balancer scenario, the operator of the network will pass a list of IP servers. A debug message that notifies if all servers are up or if there is a problem is also sent. When h4 requests the service in the load balancer scenario, the traffic is randomly directed to one of the servers. If there is another request from the same client or another client, the traffic is directed to the next server in the list using round-robin fashion for every session. This is shown in Fig.7.

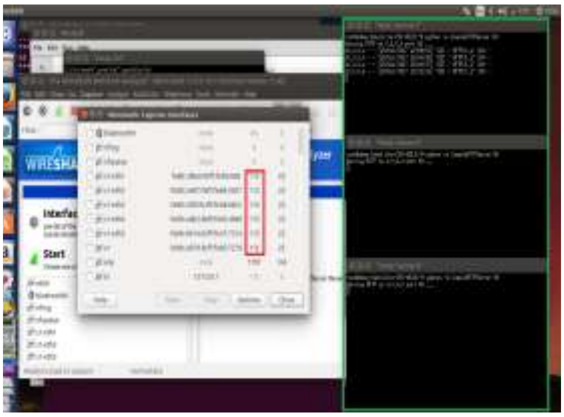

Fig.5. Broadcasting of Packets in the Hub Scenario using Emulator

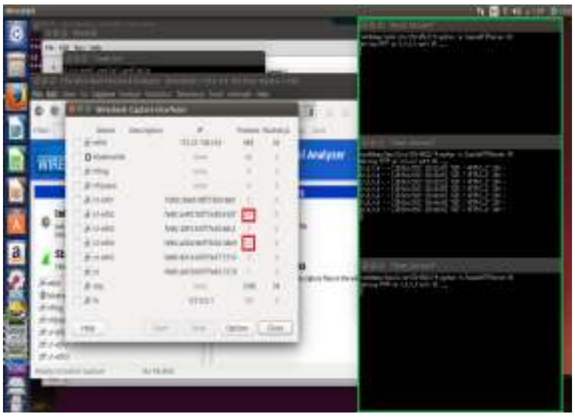

Fig.6. Exchange of Packets in the Switch Scenario using Emulator

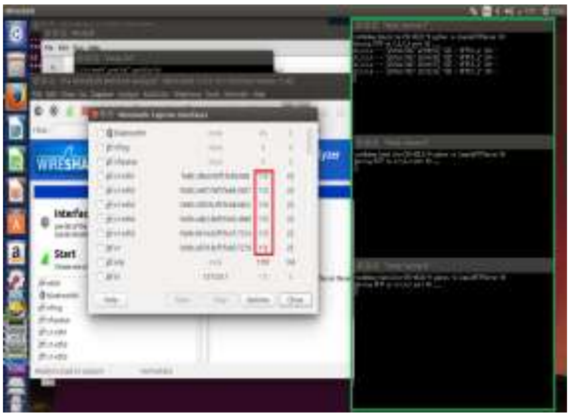

Fig.7. Traffic Distribution Among Servers using Emulator

Fig.8. Broadcasting of Packets in the Hub Scenario using External Devices

8.2. External Devices Results

Here, the results obtained by testing the Hub, Switch, HTTP, FTP and load balancer connectivity using external devices are demonstrated. The three IP addresses for the three servers are (10.0.0.10, 10.0.0.20 and 10.0.0.30), and for the two clients (10.0.0.5 and 10.0.0.6).

1) Hub Connectivity

To verify the connectivity of the topology using a Programmable Hub, successful Internal Control Message Protocol (ICMP) echo and echo reply messages (ICMP ping) are sent between the nodes. To verify that the hub mechanism is working, it can be seen in Wireshark that there is a broadcast of ICMP packets inside the topology as shown in Fig.8.

2) Switch Connectivity

Fig.9 verifies the connectivity of the topology using a Programmable Switch. Successful ICMP echo and echo reply messages (ICMP ping) are sent between the nodes. Only the source and destination of the ICMP request exchange packets between them. This validates the success of the switch mechanism.

3) HTTP Connectivity

A simple test is made from the physical host to the server by opening a web browser in the host and typing http://www.sustech.com. The HTTP protocol is also verified from Wireshark as Fig.10 shows.

4) FTP Connectivity

The File Transfer Protocol (FTP) can also be verified from the web browser of the physical host or Wireshark which provides a better resolution that shows the source IP and the destination IP as can be seen in Fig.11

5) Load Balancer

In the load balancer scenario, the received traffic can be seen as depicted in Fig.12. In this scenario client 10.0.0.6 requested HTTP service. The response in the first time came from server 10.0.0.20 and in the second time from server 10.0.0.10, consistent with the load balancing mechanism.

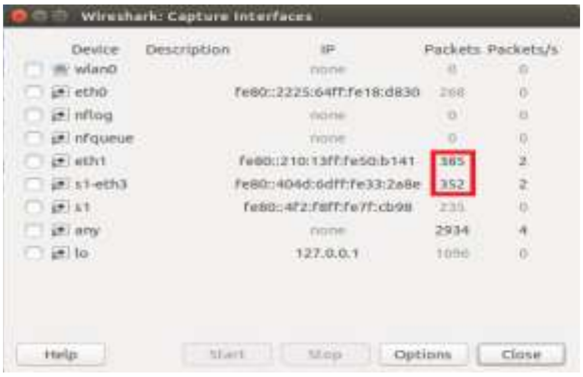

Fig.9. Source and Destination Exchange Packets in the Switch Scenario using External Devices

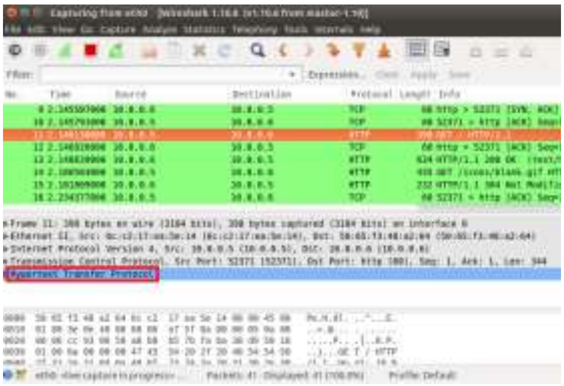

Fig.10. Exchanging of HTTP Packets using External Devices

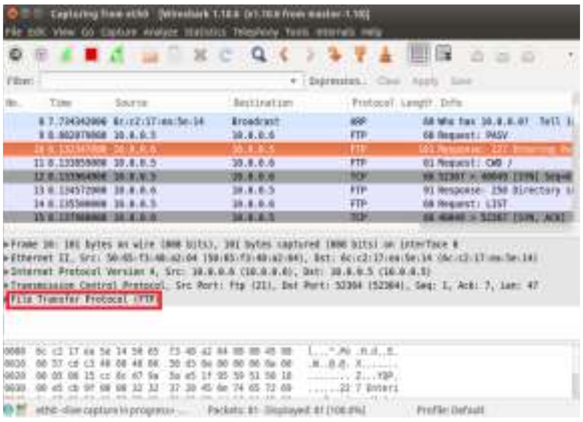

Fig.11. Exchanging of FTP Packets

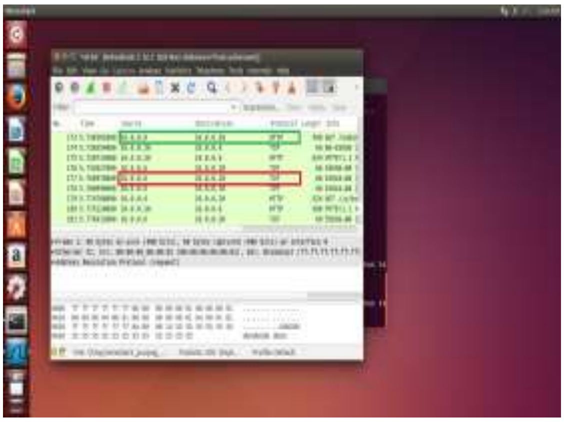

Fig.12. Distributing of Traffic Among Servers

9. Conclusions

This paper has explored and implemented the SDN approach on a datacenter network using both emulation and external devices. Three common scenarios of datacenter server options were successfully implemented: Hub, Switch and Load Balancer, where the software-based nature helped reduce the cost of implementation.

The work is vendor independent because it relies on open standards which provide flexibility in configuration and deployment by allowing the company to install the software on any white-box or OpenFlow supported device. Thus, significantly reducing the time required to deploy new services when compared to a traditional network.

For future work we plan employing other controllers other than POX to identify the controller type that improves the performance of the datacenter network under different topologies and traffic. Another possible improvement is to add a redundant controller to the network to achieve lossless, low delay performance and higher availability. In addition, the controller can be modified to implement different load balancing algorithms including Weighted Round Robin and IP-based Hashing and evaluate their performance under different traffic conditions.

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The Future of Cybersecurity Workforce Development

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Abstract

This paper will discuss the future of cybersecurity workforce development. Cybersecurity is a field that is increasingly becoming important in today's workplaces. Considering the rapid growth of technology, it is expected that the field of cybersecurity will change significantly in the future. As such, preparedness is needed to ensure that the future cybersecurity workforce is not hindered by a lack of training, resources, or technical expertise. The personality traits of a cybersecurity professional should be evaluated before the assumption of a given occupation to ensure that this professional is the best fit and possesses all skills, values, and values required for that post. Teamwork should be integral in future workforce development because, according to the current trend in different industries, being a team player is essential. Lastly, cybersecurity professionals should be trained to observe ethics and civic duty by being loyal to their employers. They should also prioritize continued learning because the cyber domain is ever-changing and requires flexibility and adjustment. This paper will first explore the cyber environment and highlight some of the challenges currently facing the area. Next, the most fundamental skills needed for the furtherance of this field will be covered. One area that will be the paper's focus will be the importance of social skills. The article will finally provide an overview of some of the anticipated changes that will take place in the area of cybersecurity workforce development.

Keywords: Cybersecurity, Workforce, Future, Social, Skills.

1. Introduction

According to the current trends in the digital world, people who work in the cyber domain require diverse skills and knowledge to handle all situations professionally and successfully. With the recent technological advancements in different sectors and fields, cybersecurity workforce development is expected to be altered. In this case, other aspects will be integrated to fill various gaps in the current cybersecurity workforce. All the workforce development in this field will also require the inclusion of contemporary elements. The cyber domain is complex, which presents a unique challenge in developing a holistic and skilled workforce. Cybersecurity is a current field because it has not existed for an extended period, and this implies that there needs to be more information has been developed regarding the different aspects it entails. In this case, people emphasize essential technical skills and ignore organizational and social skills, which are critical for success in all settings (Dawson, 2018). In the future, it is expected that the development of the workforce in this field will put more emphasis on social and organizational skills because they dictate the outcomes of different occurrences in different settings. The future development of the cybersecurity workforce will include more positions to ensure that all critical aspects are well covered and addressed.

This workforce will be developed so that all members are systemic thinkers and have strong communication abilities. They will also have an intense yearning to learn more and be team players. They will be expected to have a strong sense of civic duty and should have balanced social and technical skills. These skills are essential because the cyber domain is a vast multi-disciplinary field comprised of different disciplines, such as engineering, computer science, economics, law, and psychology. Therefore, the workforce in this field must possess diverse skills that entail more than dealing with online devices. The cyber domain is critical because, in the modern world, it impacts different facets critical for human beings ranging from electricity to transportation networks used by people every day. In this case, the cybersecurity workforce plays a huge role in supporting and defending these networks. It is critical to ensure that they receive the best development so that they can be able to deal with cyberattacks effectively (Dill, 2018). There is a need for more cybersecurity workers regarding the number of posts available for these workers.

Figure 1: Gap in the cybersecurity workforce in the market

There is also a gap in the cyber domain and the skills necessary for a future workforce in this field. It is critical to examine this gap and evaluate different ways to address it to ensure that the cybersecurity workforce possesses all skills and knowledge essential in the future cyber domain.

2. Literature Review

Understanding the specific roles and responsibilities in any field is one of the most critical factors that can help shape the organization of a company's workforce. It is a fact that different people, especially cyber professionals, are different. However, it is the responsibility of every organization to ensure that all these individuals fit in an organization. Organizations should thus embrace systems aimed at developing their cybersecurity workforce and ensure that continuous learning processes are maintained in the long run. Technical expertise will undoubtedly be integral to a better cybersecurity landscape (Wang, 2019). It is a fact that this field is in its infancy, and much academic work remains undone. However, it is expanding rapidly, requiring advanced research critical to understanding these aspects. In this case, it is critical to understand what makes a proficient cyber professional and how to recruit such a worker.

It should also be noted that the fact that cybersecurity is an integral part of national security means that the defense forces are expected to be directly involved in the development of the systems and personnel that form the cybersecurity network.

Cyber Domain

According to Dawson (2018), the cyber domain is divided into three layers: social, physical, and logical. The physical layer includes the infrastructure and hardware that support different networks. The logical layer comprises different logical devices that are linked to a network. Examples of hardware that support the logical layer include Digital Cross-Connect Systems, Central Office switches, and Main Distribution Frames. The social layer comprises all cognitive aspects of different personas interacting within a network. Currently and in the past, people have been concentrating on logical and physical layers and ignoring the social layer because it is not connected to cybersecurity directly. In the future, the social layer will be given a higher consideration because people have different human interactions in different layers that make the cyber domain unique (Blair, 2019). Understanding these diverse human interactions is critical because they are the source of vulnerabilities on different networks. Therefore, the future of cybersecurity development, in-depth knowledge, and skills in human interactions will be emphasized. Also, advanced training in developing technologies such as Artificial Intelligence and quantum computing should be incorporated to ensure that the future workforce can handle such systems easily and manage them effectively.

NICCS Structure

The National Initiative for Cybersecurity Careers and Studies (NICCS) has a cybersecurity framework that provides information about the work roles of different people in the cybersecurity workforce. There are over 31 specialty areas and about 1000 types of skills and abilities (National Initiative for Cybersecurity Careers and Studies, 2020). However, these acting roles are based on traditional information technology. They maintain and operate roles, including security analysts, system administrators, and knowledge management. The govern and oversee roles include cyber law, education, policy development, and managerial roles. The defend and protect roles include network defenders and cyber analysts. The major challenge with NICCS role training programs is that less than ten skills include social skills and teamwork training. Therefore, as much as the advancement of technical skills training is essential, it is critical to incorporate different aspects related to the social fit of cybersecurity training.

One of the most critical aspects that NICCS should consider in the future is to develop talent based on the different traits of trainees (Thomson, 2018). According to past cyberattacks, it was discovered that human behavior was exploited, and therefore social factors should be incorporated into future cybersecurity workforce development. The framework provided by NICCS includes a wide array of skills, knowledge, and abilities that form the training program's crust. The organization collaborates with various learning institutions to ensure these skills are passed to as many trainees as possible. However, many colleges need to align with the set curricula, and these limitations threaten the qualities needed in a cybersecurity workforce.

Challenges Facing the Current Development Framework

The main problem with the current training programs is that they emphasize electrical engineering and technical skills. Social skills should be prioritized because the skills and knowledge developed are essential in developing effective teams. They are also crucial because they ensure greater fidelity in developing a holistic cybersecurity workforce. In this case, it is essential to define the right organizational environment to ensure that an effective cybersecurity workforce is produced. The current structure of different institutions that offer different programs needs to be completed because they need to offer comprehensive training in work roles and attributes (Mailloux, 2018). A changing work environment characterizes the cyber domain, and the needed skills are also changing. In this case, introducing motivational and social metrics is essential to ensure that cyber professionals can overcome various challenges related to several social factors.

3. Analysis

Different studies have concluded that more than technical knowledge for cyber professionals is required because a lack of social skills leaves a security, retention, and knowledge gap. Therefore, a significant gap exists in the current NICCS framework, which needs to be completed because there is a need for a cyber-professional with communication skills efficient in making savvy decisions and managing other members in an organization. With the current technological advancement and development of the number of cyberattacks, cybersecurity should be prioritized so that different members of an organization are trained or have essential information in this field. Studies and research papers that have been done in the past have yet to cover cybersecurity professionals' organizational and social fit. It is also critical to ensure that cybersecurity professionals receive continuous education because supplemental education ensures

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they remain proficient. In the future, there should be different programs designed so that cybersecurity professionals receive supplemental education after a particular period. The future of cybersecurity workforce development should prioritize on-the-job training and mentorship because the cyber domain keeps experiencing different changes (Sharevski et al., 2018). This requires cybersecurity professionals to keep updating their knowledge and skills in dealing with new technologies.

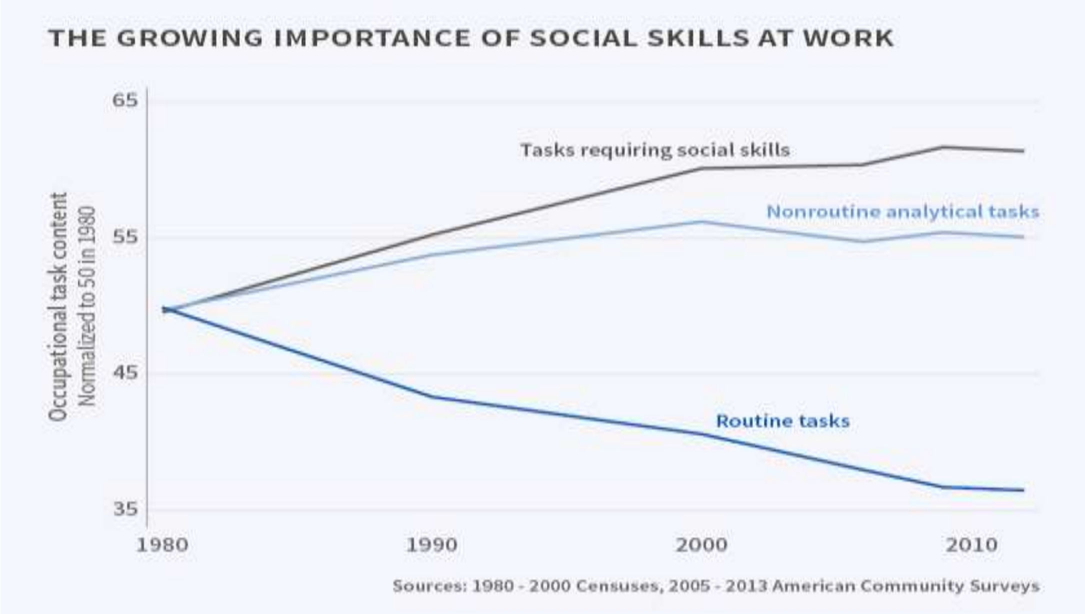

Figure 2: Need for social skills in cybersecurity

Importance of Social Skills

The nature of cybersecurity work is complex, and professional cybersecurity needs to be trained to work in teams. This is important in different organizations because different teams require diverse talents. In the private sector, the cybersecurity department only comprises a small number of workers. A cybersecurity worker must have ample knowledge and skills to ensure that different areas are covered and safeguarded. Distribution of expertise is critical in cybersecurity, and corporations should be keen to observe this aspect in their cybersecurity teams. The current demands in the cyber domain require a holistic team of professionals with diverse knowledge in different areas. Therefore, future cybersecurity workforce development programs should prioritize developing high skills related to teamwork and collaboration (Dawson, 2018). The social aspect of the cyber domain is clinical, and the current systems have neglected this aspect.

In this case, the future program should account for social and technical skills to achieve excellence and true creativity. The complexity of the cyber domain is a significant problem that cybersecurity professionals face, and it is critical to address this problem in the future. People from other departments that do not deal with cybersecurity aspects have difficulty dealing with the language used in this field. This requires changing the entire educational system, where cybersecurity is introduced as a standard unit in different courses.

Cybersecurity Needs

Currently, organizations are characterized by tightening budgets, and they cannot hire a cybersecurity team and have to work with an individual. According to Swarovski et al. (2018), this is a serious issue because some organizations do not understand their cybersecurity needs. Therefore, as much as teamwork is emphasized, it is critical to ensure that individual cybersecurity professionals can handle essential aspects related to the overall requirements of a small organization. Another area that needs to be addressed in the future is developing an ethical code that will ensure that cybersecurity professionals follow different directives that ensure that an organization's networks and information are safeguarded from exploitation (Sharevski et al., 2018). Cybersecurity professionals should be trained to create and maintain high levels of trust with their organizations and employers. This is critical because cybersecurity professionals remain the highest threat to organizational data if their loyalty is divided. Therefore, future cybersecurity workforce development should prioritize the development of values and technical skills. The value system is critical and should be encoded in law to ensure that cybersecurity professionals have a high moral standing related to duty obligation and law adherence. The relationship between cybersecurity professionals and organizational management should be based on the assumption that these professionals will conduct their obligations in good faith.

Current Trends in the Cyber Domain

Top organizations around the globe ensure that their top management has ample technical knowledge and takes measures necessary to assess how managers are performing. There is no doubt that, in the future, it will be imperative to develop robust cybersecurity workforces that will be able to address the constantly emerging cyber issues. There will be many people whose cybersecurity skills will need to be substantially improved. The training capacity for various professions related to cybersecurity needs to be broadened.

It will be essential to encourage higher learning institutions to take this opportunity and explore ways to offer such courses to their students. Not all cybersecurity professionals fit in an organization, and it is critical to train these professionals to deal with diverse situations and work environments. In this case, the inclusion of social skills in training is essential because it enables cybersecurity professionals to fit in different work environments and to remain trustworthy and reliable (Crumpler, 2019). Cybersecurity professionals seek to work for organizations that fit their values, skills, and knowledge because they have yet to be trained or equipped with social skills. As much as cybersecurity professionals seek job satisfaction, they should be trained to deal with different aspects of the organizational culture of diverse organizations. For example, cybersecurity employed in a hospital should have diverse skills to deal with the complexities associated with such an organization.

4. Discussion

In the future, cybersecurity should be trained to deal with situational dynamics within different organizations. Cybersecurity professionals need help adjusting and blending into different organizations because they need to possess the required social skills. The Big Five Personality traits model is one of the tools used to determine a person's aspects. It can identify cybersecurity professionals who can thrive in different settings. Therefore, understanding the cyber domain is essential because it helps identify the occupational classifications that individuals fit in perfectly according to their personality traits. In the future, it is critical to have a program that helps cybersecurity professionals identify the area they fit best before specializing in different areas. This will ensure that cybersecurity professionals specialize in areas that fit their traits and where they can produce optimal results (Caulkins et al., 2016). The other aspect that should be addressed is the emerging roles in the cyber domain, which is experiencing continuous change. The future cybersecurity workforce development should be shaped by the predicted organizational work based on the technological advancement expected shortly. Cybersecurity professionals are facing a huge challenge related to a need for more content comprehension because there are aspects they need to understand because they were not present in their training. To address this issue, it is critical for the current and future training programs to entail the content of different cybersecurity issues that are expected to be experienced shortly.

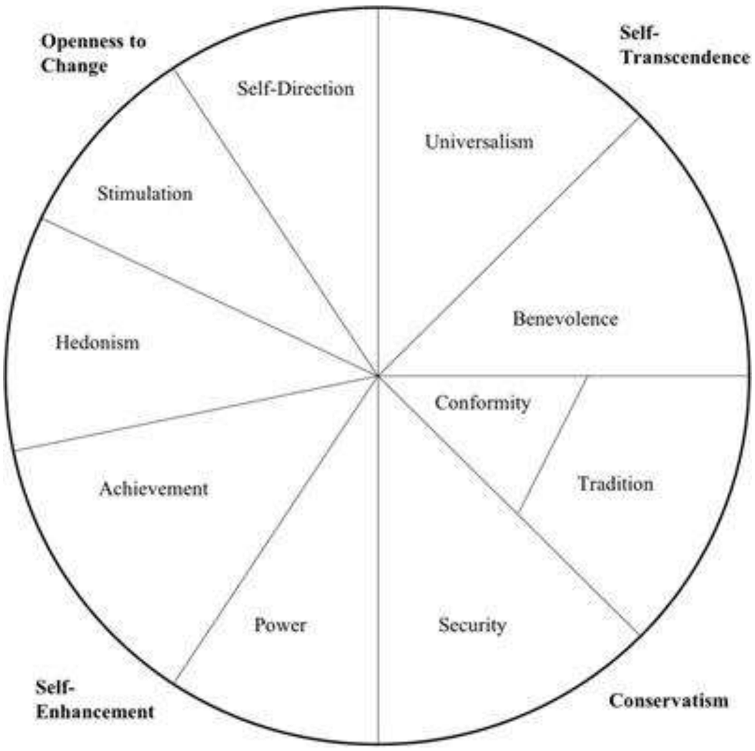

Figure 3: Social skills needed in cybersecurity

Incorporation of Social Skills and Teamwork

As stated, it is critical to understand the cyber domain, and future cybersecurity workforce development should encompass all relevant aspects of the current cyber domain. Also, cybersecurity professionals should be trained on how to strengthen their predictive power because cybersecurity requires vigilant people who can predict potential attacks and threats. These professionals should also have the skills necessary to offer valuable insights, which should also be related to the occupational interest of trainees. The future of the cyber domain requires systemic thinkers, and the development of these professionals should ensure that they can link the interconnections between different elements effectively (McDuffie, 2014). They should also be able to deal with the cyber domain as a system of structures by applying mental agility and the current conceptual framework. Being a team player is essential for a cybersecurity professional, and it requires him/her to have excellent skills required in a cyber-team. The future is founded on working in teams, and the objective will be to establish a team that produces high performance.

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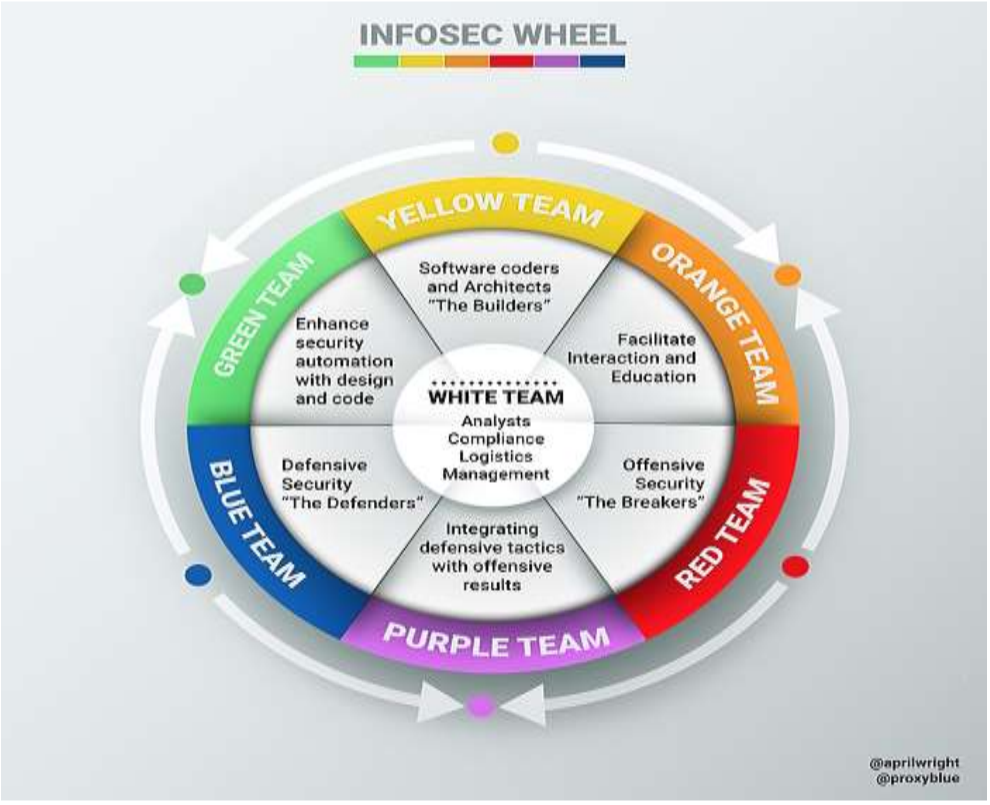

Figure 4: Teamwork in cybersecurity

5. Conclusion

The future of cybersecurity workforce development depends on different aspects that make the current development programs ineffective. One of the issues that have been found critical is the inclusion of social skills in the development of this workforce. Social skills are critical in the same way as technical skills are because cybersecurity professionals work in an environment where human aspects contribute to the outcomes of different tasks. Social skills training is needed to complete the current training programs offered by NICCS, and they should be incorporated in the future. Future security workforce development should encompass training in emerging technologies applied by different organizations, such as quantum computing and AI. The personality traits of a cybersecurity professional should be evaluated before the assumption of a given occupation to ensure that this professional is the best fit and possesses all skills, values, and values required for that post. Teamwork should be integral in future workforce development because, according to the current trend in different industries, being a team player is essential. Lastly, cybersecurity professionals should be trained to observe ethics and civic duty by being loyal to their employers. They should also prioritize continued learning because the cyber domain is ever-changing and requires flexibility and adjustment.

6. Glossary

Cyber domain: This is a global realm within the information landscape where interdependent networks of information and data are found.

***The physical layer*:** The infrastructure and hardware that support different networks.

***The logical layer*:** Comprises different logical devices that are linked to a network.

The social layer*:* Comprises all cognitive aspects of different personas interacting within a network.

***NICCS*:** National Initiative For Cybersecurity Careers And Studies

7. Academic Integrity Statement

The independent pursuit of information and knowledge is an essential part of education. I also acknowledge that academic integrity is an integral part of the code of conduct of our university. Therefore, I have committed myself to upholding this code, and as such, all the work presented in this paper is my own, and I have given credit where due, with proper citations and referencing.

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