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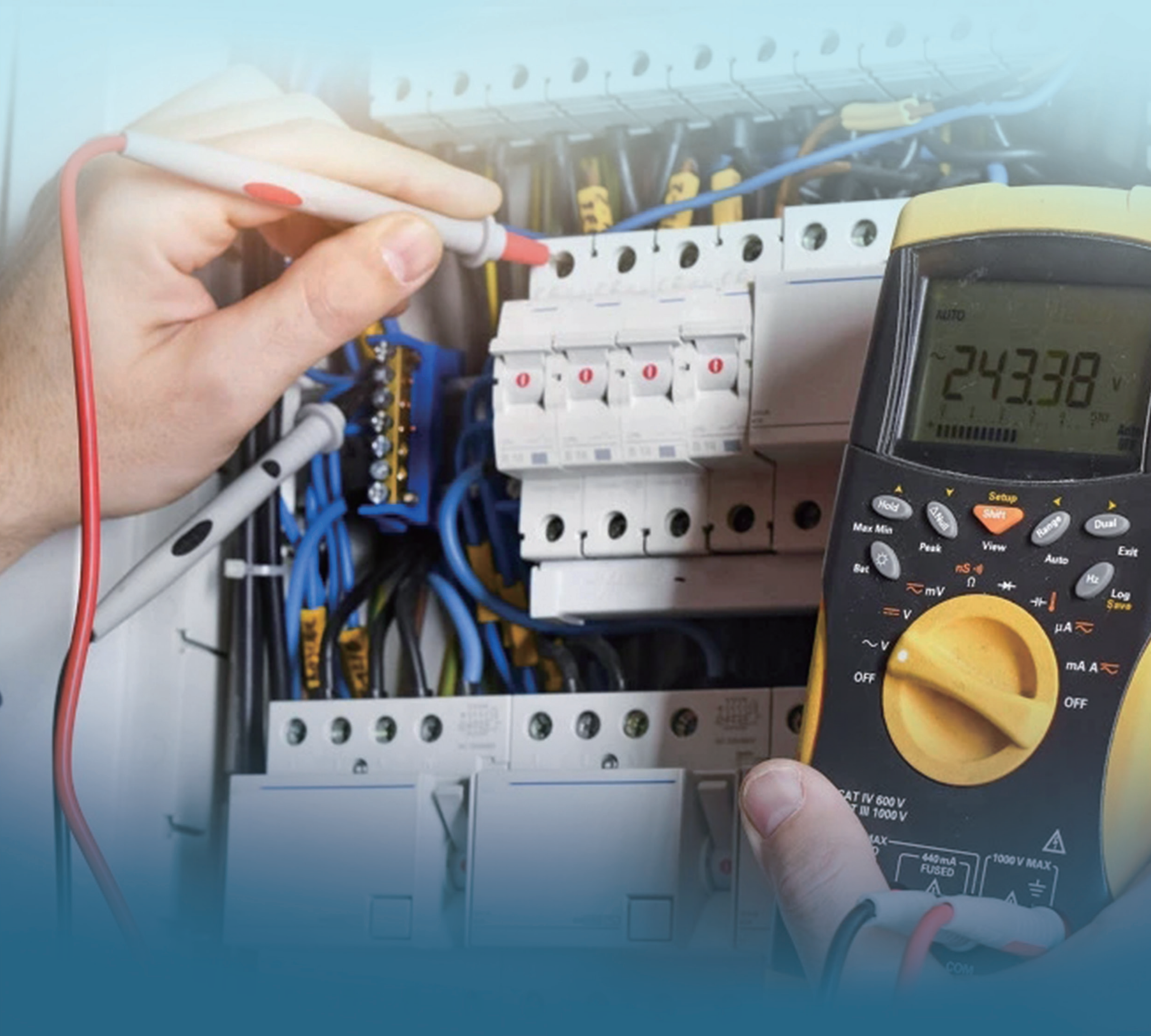

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Volume 3 | Issue 2 | October 2021 | Page1-39
Electrical Science & Engineering

Contents

Editorial

Articles

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ARTICLE

Cyber Security Professionals' Challenges: A Proposed Integrated Platform Solution

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ABSTRACT

As cyber threats and attacks are immensely increasing and broadly spreading catastrophically worldwide, cyber security professionals need to cope up with such a highly demanding environment. Security teams, such as Security operation Centre (SOC), Incident Response (IR) and Threat management teams are the people responsible for dealing with cyber security threats and attacks from detection to containment and preventing future incidents; which encompasses some significant challenges that might impose some limitations to the efficiency and effectiveness of activities cyber security professionals conduct, as these processes are time-consuming. In this paper we propose an integrated platform to help cyber security professionals to proactively manage cyber security threats and emerging incidents by providing an automated functionality that can optimize the workflow. The proposed security platform is supposed to diminish the average time taken by cyber security professionals to respond to cyber incidents with an average of 42%. This study can be used as a preliminary design for such an integrated platform.

1. Introduction

Cyber security threats and attacks have been rising scaringly in the last few years, as a result; the need for a sophisticated approach to collect and trace threat actors has become an essential prerequisite to investigate and counter threats and cyber security incidents [1]. Security Operations Centre (SOC) and Incident Response (IR) teams are required to keep well aligned with the rapidly-evolving cyber threats and attacks or they might find themselves at the verge of being catastrophically exploited.

As attackers tend to reuse similar tactics and almost the same resources across multiple attacks, threat hunting and sharing Cyber Threat Intelligence (CTI) can greatly be beneficial in investigating, mitigating and even defending cyber-attacks [2].

Threat intelligence (TI) can be referred to as a proof-based knowledge, it involves collecting mechanisms, evidences, indicators and actions to be taken for a robust and rapid incident response to form a preventive measure in advance [3]. Threat Intelligence greatly helps cyber security professionals to prevent cyber-attacks and precedingly identify those attacks, which as a result expands the visibility towards the highly-evolving threat landscape [4].

1.1 Indicators of Compromise

Indicators Of Compromise (IOCs) are forensic artifacts that are used to indicate that a system has been compromised or infected with a sort of malware [5]. IOCs are

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composed of a combination of Ips, URLs, domain names and virus signature. Collecting IOCs immensely helps to indicate with a high-level of precision if a system has been compromised or not and then these IOCs are deployed on security tools for the purpose of investigation [6].

There are miscellaneous types of compromise indicators upon which IOCs can be classified, which are: computed, behavioural and atomic indicator respectively [7]. They will be discussed briefly below.

1.1.1 Computed indicators

Mainly developed from materials involved in the incident, an example is the hash of a malicious file.

1.1.2 Behavioural indicators

They combine other indicators in order to create an overall profile of the targeted malicious behaviour. They adopt some behavioural indicators that are observed from individual or collective incident response action against attackers' activities. Such behavioural indicators are often referred to as attacker's tactics, techniques and procedures.

1.1.3 Atomic indicators

They are fragments of data that individually indicate suspicious activity. Fully-Qualified Domain Name (FQDN), IP address or email address is an example. However, atomic indicators need further investigation as they might not necessarily indicate an adversary activity.

1.2 Security Operation Centre (SOC) Team

SOC is primarily a group of security analysts who are required to detect, analyze, respond to, report on and prevent cyber security emerging incidents. Soc teams are likely to deal with data feeds from various sources like Intrusion Detection Systems (IDS), security audit logs and others. In case of emerging incident, there is a process of sorting, categorizing and prioritizing incoming events, which is referred to as triage. Soc team is segmented into tiers as will be described briefly below.

1.2.1 Tier 1 Security Analyst

Monitors alerts and their triage, runs vulnerability scans and escalate incidents to Tier 2 security analyst, known as Triage Specialist.

1.2.2 Tier 2 Security Analyst

Deals with the escalated incidents, influences threat intelligence IOCs, collects data for further investigation and conduct recovery attempts, known as Incident Responder.

1.2.3 Tier 3 Expert Security Analyst

Conducts penetration testing to identify system breaches, validates resilience and fix these vulnerabilities. Known as Threat Hunter.

1.2.4 Tier 4 SOC Manager

Supervises the SOC team activities, manages the escalation process, reviews incident reports and prepares Disaster Recovery (DR) plans.

1.3 Incident Response Team

Is a group of cyber security analysts, who are responsible for planning and responding to cyber threats and attacks, observing system vulnerabilities and developing incident response plan to mitigate the impacts imposed by a threat and remediate it as quickly as possible to keep systems running in an ordinary condition.

1.4 Threat Team

Responsible for proactively looking for and hunting cyber threats by recognizing their potential effect and also figuring out the behaviour adopted by threat actors, so it can facilitate the process of identifying a threat in their environment.

2. Literature Review

Many studies have been conducted regarding cyber security threats, attacks, incident response, mitigation procedures and how to defend cyber-attacks. Security Operation Centre (SOC) teams represent the first line of defence as they are anticipated to detect threats and escalate them to Incident response (IR) teams [8]. Although many researches highlighted SOC, many of them had lacked a thorough overview of the challenges that might face SOC teams as observed from [9,10].

In [11], a survey was conducted to highlight some major areas that SOC teams should focus on to increase the efficiency and effectiveness of security operations. SOC teams perform advanced forensic analysis on artifacts. However, the extent to which they can automate the process of analysis is limited [12].

A major concern for cyber security professionals is the increasingly complicated security environment, as organizations tend to implement cyber security technologies and services from different providers. That adds a considerable difficulty for teams to handle incidents within an acceptable time interval. Also, taking into consideration

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the massive volume of workload that cyber security professionals are confronted with leads to an overwhelm.

Cyber security threats need to speed in action to deal with, but this speed requires vision. This vision is complemented by real-time threat information sharing, which will not only provide a thorough vision for how to react to cyber threats but also anticipating approaches to overcome them [17].

SOC analysts form kind of familiarity with their constituency as well as relevant cyber threats, which in return brings them to a more sophisticated mastery over time. Also, staff attrition can be a mishap and affect the overall performance of SOCs. Hence, it should be diminished as possible.

3. Method

In this paper we intend to highlight the challenges that most of the cyber security professionals face in response to cyber threats and attacks. As they are inclined to extremely rapid response time due to the sensitivity of their environment which might lead to catastrophic impacts if not swiftly contained. Some of the challenges will be discussed below.

3.1 Cyber Security Professionals' Challenges

Cyber security professionals including SOC teams, IR teams and Threat teams are required to identify, analyze and react to cyber security threats using a reliable set of processes and solutions. Hence, there are many challenges that most cyber security professionals face, which are depicted in Figure 1 below.

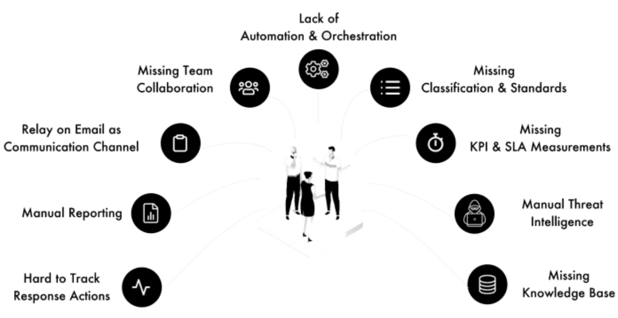

Figure 1. SOC team challenges.

As shown in Figure 1, the challenges that SOC teams confront, which will be discussed briefly as follows:

3.2 Lack of Automation & Orchestration

Cyber security professionals suffer from the difficulty of the process of reporting cases, escalating incidents, collecting IOCs, and imitating attacks. All the previously-mentioned processes are merely hard to conduct and yet time consuming, in an environment that requires rapid actions to be taking to tackle threats and counter cyber-attacks. So, the need for automating and providing a comprehensive platform that rhymes all these processes is crucial.

3.3 Missing Team Collaboration

Having a common workspace that can involve the departments responsible for maintaining cyber security and other departments within an organization or even subsidiaries and third-party entities really counts in keeping well-aligned with security measures.

3.4 Relying on Email as a Communication Channel

Most of cyber-attacks are launched using spamming and phishing emails. So, solely relying on emails as a communication channel between cyber security teams can have catastrophic impacts if it has not been seriously considered.

3.5 Manual Reporting

As it had been discussed above, conducting case reporting manually can be such a frustrating process, yet prone to errors and uncertainty and might even be ambiguous.

3.6 Hard to Track Response Actions

Here the ransomware process will communicate with encryption-key servers in order to retrieve the public key needed for data encryption.

3.7 Missing Classifications and Standards

Standards play a pivotal role in cyber security, as they tend to provide a reference point for every counter-measures that should be taken in response to cyber threats and attacks. Example of cyber security standards include but not limited to National Institute of Standards and Technology (NIST), SANS, International Organization for Standardization (ISO), Information Technology Infrastructure Library (ITIL), Information Systems Audit and Control Association (ISACA) …etc.

3.8 Missing KPI and SLA Measurements

Key Performance Indicator (KPI), Key Risk Indicator (KRI) used to indicate how risky an activity is, Key Change Indicator (KCI) used to understand the effectiveness of risk controls and actions taken to mitigate the impacts emerging from risks [8]. These metrics acknowledge strategic and operational improvements by providing analytical basis for decision making.

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Also, Service-Level Agreement (SLA) is a key factor in guarantee of high-quality services provided by entities involved in the process of maintaining a trustworthy cyber security environment.

3.9 Manual Threat Intelligence

Threat Intelligence is a mandatory factor in defending and pre-empting prospective cyber-attacks. Taking a step ahead and proactively anticipating attacker's targets and strategies would immensely afford a broad vision for preventing and mitigating future attacks and at the same time significantly strengthen security postures [13]. There are many sources available for obtaining threat intelligence ranging from observing one's own systems, public sources or through paid services [14]. Tracing threat intelligence manually would be time consuming and also imposes a burden of analysis for these collected threat intelligence data which is quite ineffective.

3.10 Missing Knowledge Base

Cyber security knowledge base fundamentally highlights the mandatory cyber security necessities needed for every business and also individually. It is also intended to match the detected security pattern and behaviour against a set of common incidents, threats and vulnerabilities to form a robust mitigation approach to confront the detected threat [15]. Not having the adequate knowledge base would result in more susceptible cyber environment.

Taking the previously-mentioned challenges into consideration and how much benefit that can be brought to a design approach for facilitating the work parameters for SOC teams will be such an accommodating contribution for a resilient cyber security environment.

The results of the proposed integrated solution that can be designed to overcome the barriers that confronts cyber security professionals will be discussed thoroughly in the next section.

4. Result

This section describes the proposed solution for bringing together the best methodologies that can incorporate faster detection, reduced response time, resilient threat intelligence, team collaboration, processes integration, automation and visualization to cyber security teams.

The solution aims at speeding up SOC operation and improving SOC team advancement by providing instant team collaboration platform, where it can be integrated with Security Information and Event Management (SIEM) software, that analyzes activities from miscellaneous resources within the organization and collects security artifacts from network infrastructure.

It also involves notifications for emerging threats, which are automatically triggered. The ability to assign tasks and track actions taken as required by providing a flexible workspace that can involve individuals within the same department, from other departments within the organization or can even include subsidiaries and third-parties while maintaining privileges by assigning roles to limit the contribution level of a participant in any processes. Figure 2 shows the workspace that the proposed security platform can provide.

Workflow process

The proposed platform encompasses a sequenced approach for managing security, which are mentioned in brief as follows:

- **Case**

Is the first level of workflow where a case can be initiated according to some predefined anomaly events.

- **Trigger**

Here, SOC analyst recognizes anomaly triggers.

- **Task**

Response actions are assigned to SOC team.

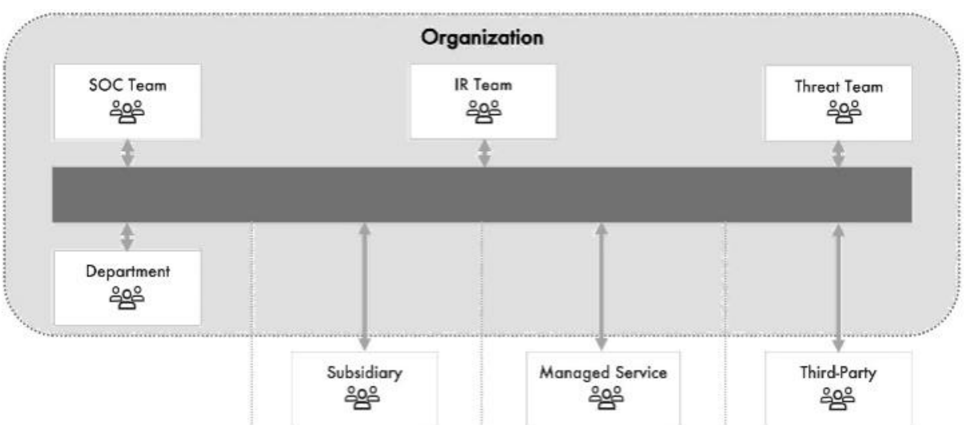

Figure 2. The workspace provided by the proposed platform.

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Considering the people, process and technology (PPT) framework, which refers to the methodology in which the balance between the three components of the framework drives action to achieve organizational efficiency [16]. The proposed platform effectively adopts the PPT framework to bridge the gap imposed by the challenges discussed earlier by providing a holistic view of performance boosting mechanisms that are mandatory for optimum detection, rapid response time, team collaboration, visualization and recommendations for future reference. Figure 3 below depicts the PPT framework insights.

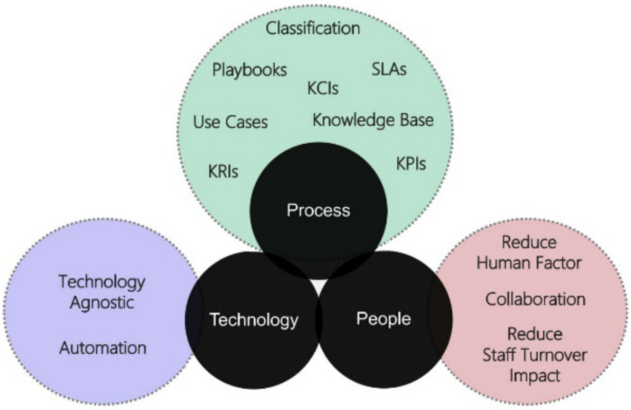

Figure 3. The PPT framework insights.

Our proposed platform will give the full capability to create, assign and fully manage cases and their triage as well as carrying out analytical processes by utilizing the automation technology of Security Orchestration, Automation and Response (SOAR), which allows the collection of data related to cyber threats and respond to cyber security incidents without human interaction.

Also a major contribution of our proposed model is the automation conducted in threat intelligence by automatically checking IOCs in threat intelligence service providers like Virus Total, SHODAN, ALIEN VAULT, Malwarebytes, TaLOS, PAYLOAD SECURITY, ... etc. The operation model is depicted in Figure 4.

5. Discussion

The proposed cyber security integrated platform in this paper is solely intended to facilitate the procedures conducted by SOC teams, starting from creating cases for emerging cyber threats, escalate incidents, responding to those incidents till containment. In addition to team collaboration and tasks assignation.

Having a security system with such capabilities will not only help cyber security professionals to rapidly handle emerging threats or incidents but will also provide a comprehensive cyber security control over an organization and automates some time-consuming procedures which yields to a highly optimized threat and incident management aptitudes and empowers workflow.

The proposed cyber security integrated platform is likely to diminish the time taken by cyber security professionals to detect, report, manage, escalate and mitigate a cyber threat or attack by an average of about 42% as illustrated in Figure 5.

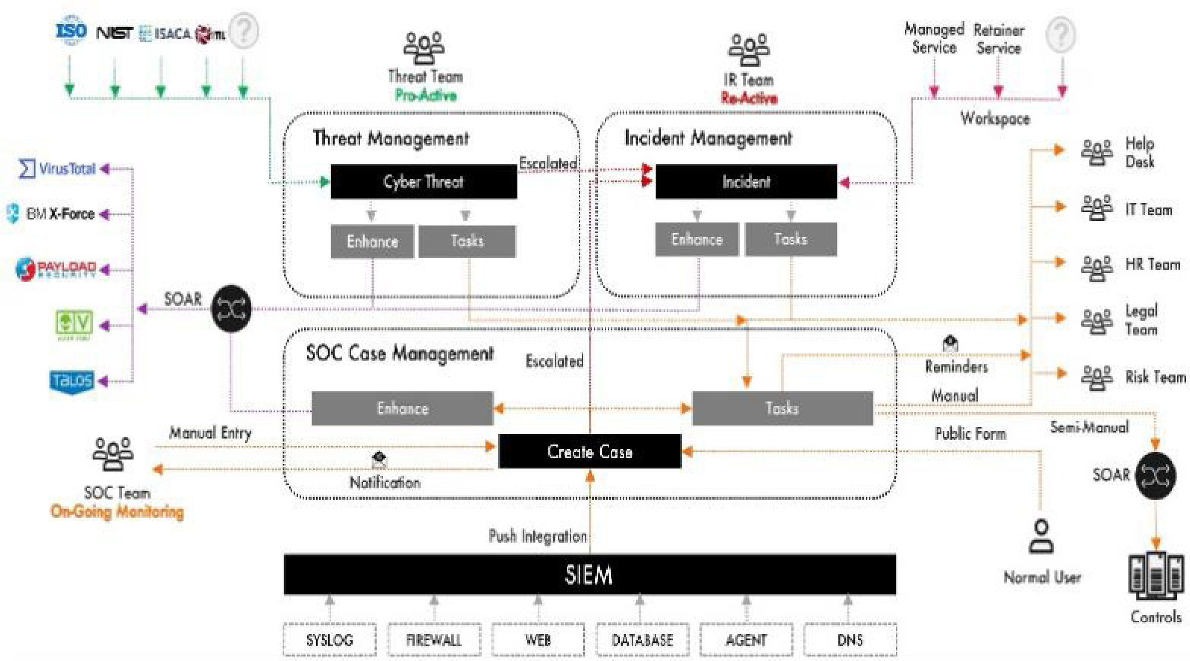

Figure 4. The proposed platform operation model.

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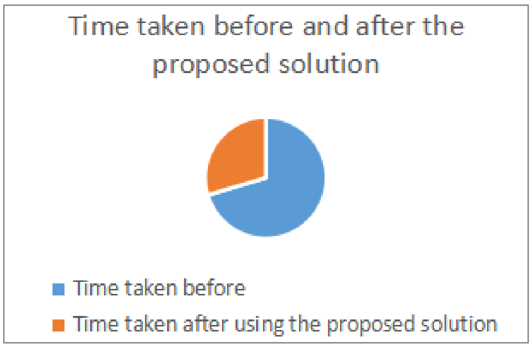

Figure 5. Time taken by cyber security professionals to respond to incidents before and after the proposed solution.

6. Conclusions

In this paper, a comprehensive cyber security platform was proposed to overcome some major challenges that cyber security professionals suffer from, taking into consideration the importance of time as a prominent factor in cyber security environment. Also the sense of automation that empowers cyber security professionals with a fully-rounded set of analytical and holistic view for better response actions.

The results of the proposed platform were quite rewarding as it would minimize the average time needed by cyber security teams to resolve the increasing numbers of cyber threats and attacks by about 42%, which significantly empowers cyber security professionals to keep with such a highly-demanding realm.

It is recommended to conduct further studies to some other challenges and barriers that might degrade or make cyber security teams lag behind. This paper can be considered as a preliminary design for an integrated solution.

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ARTICLE

Representing Increasing Virtual Machine Security Strategy in Cloud Computing Computations

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ABSTRACT

This paper proposes algorithm for Increasing Virtual Machine Security Strategy in Cloud Computing computations. Imbalance between load and energy has been one of the disadvantages of old methods in providing server and hosting, so that if two virtual severs be active on a host and energy load be more on a host, it would allocated the energy of other hosts (virtual host) to itself to stay steady and this option usually leads to hardware overflow errors and users dissatisfaction. This problem has been removed in methods based on cloud processing but not perfectly, therefore, providing an algorithm not only will implement a suitable security background but also it will suitably divide energy consumption and load balancing among virtual severs. The proposed algorithm is compared with several previously proposed Security Strategy including SC-PSSF, PSSF and DEEAC. Comparisons show that the proposed method offers high performance computing, efficiency and consumes lower energy in the network.

1. Introduction

The concept of cloud computing dates back to 1961s. When Professor. John McCarthy one of the founders of AI[1] maintained that one day computing will be organized as a public industry. Then, Douglas F. Parkhill (1966) in his book "The Challenge of Computer Utility" mentioned items like the illusion of unlimited access, elastic computing, representing facilities as public industry privately, governmentally and associatively. But none of the terms used in 1961s, didn't mean the present concept of cloud and it was used verbally as public industry. The idea of galactic computer network or intergalactic computer network which is now called internet expressed in 1969 by J.C.R. Licklider and then it was developed and activated by The ARPANET[2] to let everyone have access to these programs and information throughout this network.

Cloud computing uses the sources at most and includes the highest benefit from the shared sources by server in its planning [1]. A cloud may be like an automation, website and even a Gmail and or it may be infrastructural and based on the rules that you have defined [2]. Previous studies have made so many attempts to defend against co-resident attack which they have proven the strategy of allocating virtual machine with the probability of reducing co-residency [3-5] and it is seen as a process of mapping virtual machines to a physical machine [6]. Yi and colleagues [7] have suggested the strategy of allocating virtual

1 Artificial Intelligence

2 Advanced Research Projects Agency Network

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machine called Personalized Service-Side spam Filtering (PSSF) which not only focuses on security but also it considers the balance between work volume and hosts power consumption. They also control the quality of performing hosts to decrease power consumption. However, benefitting from CPU sources highly influences power consumption [7]. Consequently, the number and the use of CPU must be focused on to reduce power consumption.

Then, a new strategy of allocating virtual machine called selecting the minimum number of virtual machines based on PSSF (SC-PSSF) which reduces power consumption. Finally, SC-PSSF method has been implemented on ns2 software and its efficiency was investigated by the criteria of evaluating resident attack and attack coverage. According to the opinion of cloud server, reducing energy consumption is an important issue. Yi and colleagues [8-10] suggest reducing performing hosts. This matter is considerable that why energy consumption by CPU has allocated 91% of the whole energy consumption in a cloud center to itself. Therefore, CPU consumption is considered as the whole consumption. Clark and colleagues [11-13] suggested that if a host is unemployed, it consumes power around 71% of the whole volume of work.

Considering that some researchers have managed to increase security among process-based virtual servers by PSSF algorithm so far, therefore, besides increasing the level of security of a dedicated server tenants, this study is going to apply load balancing, managing energy level, taking advantage of the nearest neighbor node and network smart monitoring by representing SC-PSSF algorithm besides security.

Two environments have been considered in this study. Dedicated servers based on cloud processing: providing hosting services and dedicated servers based on cloud processing: providing process and computation servers.

In the first method, a dedicated server based on cloud processing has been divided into several virtual servers which is serving host and domain and in the second method; a dedicated server with the same power which has been divided into several virtual severs with the same number as the first method is processing computations and process data. These two servers in this study which naturally tolerate maximum and minimum loads during different times divide load balancing, security and energy consumption and after saving report and observations, the considered algorithm is implemented on both severs and then load balancing and the consumed energy are saved based on the same consumed load and finally they are compared with each other. The purpose is comparison during different times. The current study aims at providing suitable methods to maintain security besides load balancing and suitable energy consumption in virtual servers based on cloud processing.

2. The Suggested Protocol

Sensor infrastructures for setting up cloud servers are among the most important factors to improve lifetime and security. The inserted algorithm will be described in this part of study. There is a supplementary method called HEBM which uses compatible clustering which is known as clustering design. In fact, it is a comparative design whose number of clusters and nodes membership have evolved through time which has been supposed in HEBM-BS. Also it is supposed that BS is is in constant location or far from sensor field. In this state, node may act with special condition (Pch) as CH[10] to tolerate data transfer.

After stimulation and physically setting up network, probable abuses and attacks are prevented using an accurate and smart monitor. Besides these, items existing in basic algorithm also stabilize and as a result secure the network.

3. Performing ns2 Stimulator and Output Diagrams

Stimulation algorithm has several parameters that these parameters have been implemented in different stages. These parameters are created and called one by one after defining initial data and making nodes. They aim at stabilizing network and maintaining data security. This algorithm in the present study has aimed at achieving the following items according to the defined parameters:

a. Maintaining nodes in the range of a well activity;
b. Nodes awareness of neighbor nodes based on energy level and the remained lifetime;
c. Dead nodes fast exit and transferring data related to it to the nearest neighbor node with the most remained energy;
d. Transferring nodes to the nearest and the most active well in the case of disturbance in a well;
e. Maintaining network stability and serving other parts in the case of destruction and or stopping the activity of neighbor wells.

Stimulation Constant Parameters

Routing protocols based on clustering through dividing neighbor nodes into separated clusters and selecting local cluster-heads to combine and send information of each cluster to the base station and trying to consume energy equally by network nodes in the networks of wireless sensor achieve the best efficiency considering increasing lifetime and maintain network coverage compared with other

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routing methods. Various algorithms have been discussed in this part that LEACH, DEEAC and PADCP algorithms are among these ones.

Table 1. the table of defining initial parameters for stimulation

Value	Parameter
200 m × 200	Area
4000 bits	Data pack size
512 bits	Control package size
100/200/…/800	The number of sensor nodes
2 J	Initial energy
(50.50)	The place of base station
87 m	Distance d_0
50nj/bit	

4. Findings

How much energy is remained in the nodes is among the important and exiting parameters in algorithm which not only influence security but also it influences speed and all network infrastructures. This leads to speed loss, security decrease, not managing sources correctly and many other events. The following Figure 1 has defined nodes between 1 and 311 and energy level between 1 and 1611. The algorithm suggested by the study has had suitable performance compared with the bests. It has maintained the remained level around 111 at different levels almost like SC-PSSF almost equal and even when the number of nodes reaches 1611. Each algorithm which has extended output and activity at the beginning of its activity due to low load on nodes shows its weaknesses and the time of network activity increases through time and its activity expands. Fortunately, the suggested algorithm has had trustworthy tolerance in both output and pressure states.

The following Figure 2 has had suitable energy consumption when network lifetime has been investigated from 1 to 711 and it has progressed almost equally with its most serious competitor SC-PSSF.

The number of living nodes has been investigated from 1 to 111 in the following Figure 3 in a 7-number network.

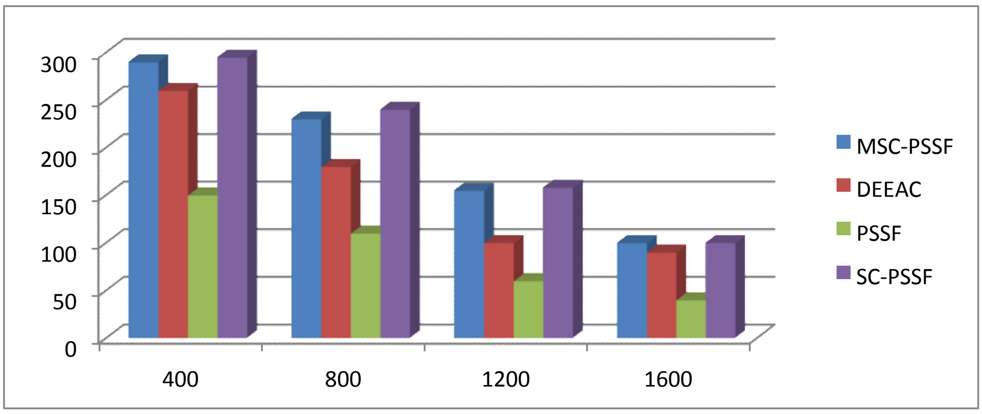

Figure 1. the mean of remained energy

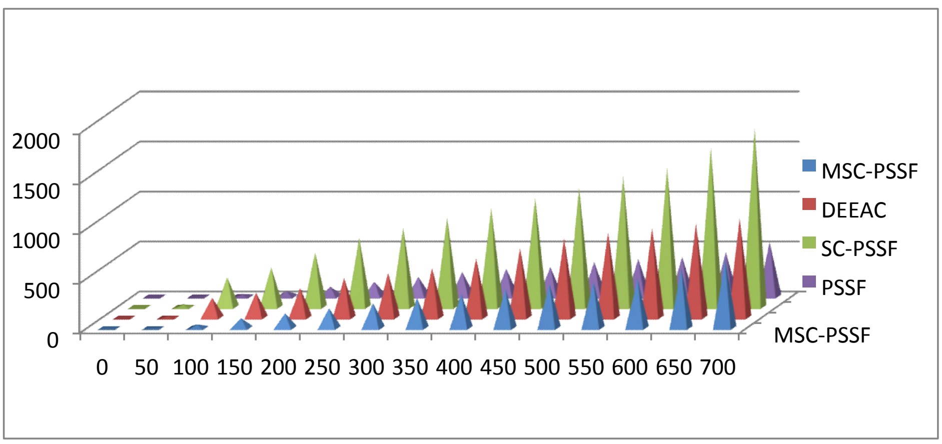

Figure 2. comparing energy consumption

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After PSSF and almost equal to SC-PSSF, the suggested algorithm has had the best performance.

According to the experiences of the other algorithms, the method suggested by this study has ranked second in the following Figure 4. Network lifetime has been regulated from 1 to 711 and stability from 1 to 211 in the Figure 4.

This algorithm has had the least delay after DEEAC algorithm in the Figure 5 based on the number of nodes and sent pack. As a result, such a suitable performance in this algorithm may increase the efficiency to inform base station and observing the fastest momentary reports.

The following Figure 6 has defined 64 to 512 packs

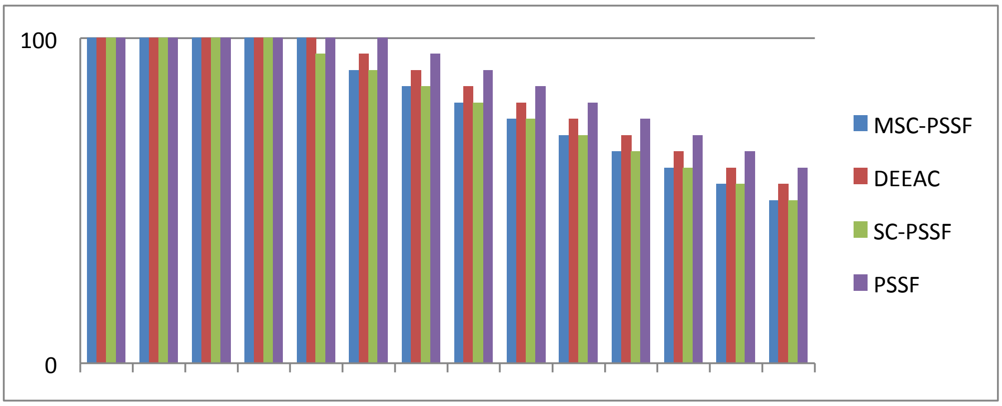

Figure 3. network lifetime (based on the number of living nodes)

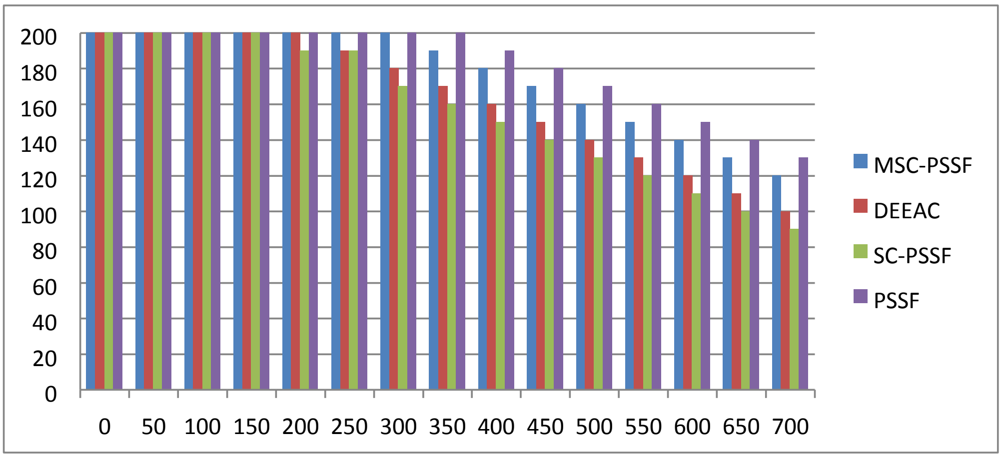

Figure 4. comparing stability and security of network in 111 node scale

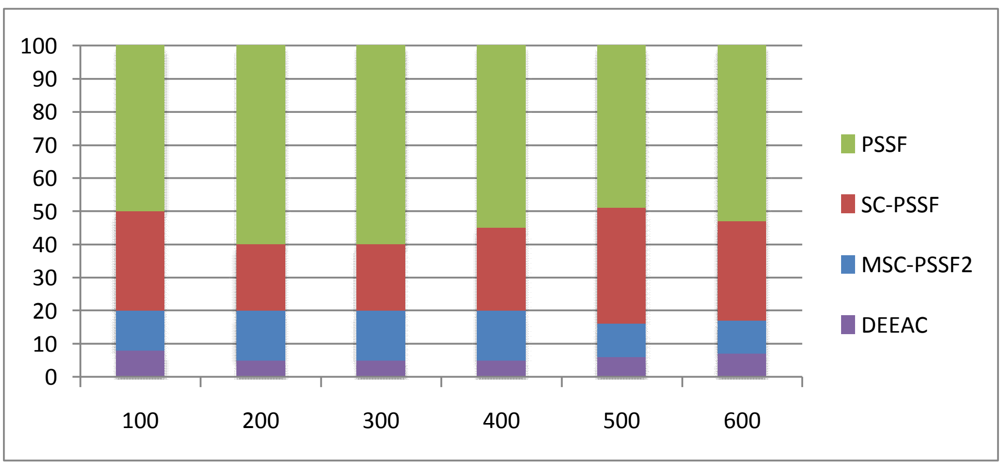

Figure 5. delay in each pack in more nodes scale

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which have been investigated during 1 to 6 seconds.

Two ddos and backdoor methods are among the most important attacks which have targeted virtual and even main hosts during recent years. These two methods are usually used in targeting information theft and turning off servers to disturb network efficiency. This study focuses on DDoS attacks. These attacks are usually contemporary and the attacking IP class is finally recognized by firewall and the attacking IPs are blocked before connecting to server. But when firewall is going to identify IP class, this is network which has activated its state by stability and optimality.

The algorithm suggested by this study has had suitable performance in the competition among dead nodes at the beginning, middle and the end of time and since it manages fast displacement of living nodes with the dying ones, it has minimized this possibility due to energy managed consumption.

It is surprising but one of the important parameters during attack is the suitable location of well to manage the motion of nodes. The only factor which may be effective is algorithm correct definition from nodes activity. After PSSF, this algorithm has shown the best performance besides SC-PSSG.

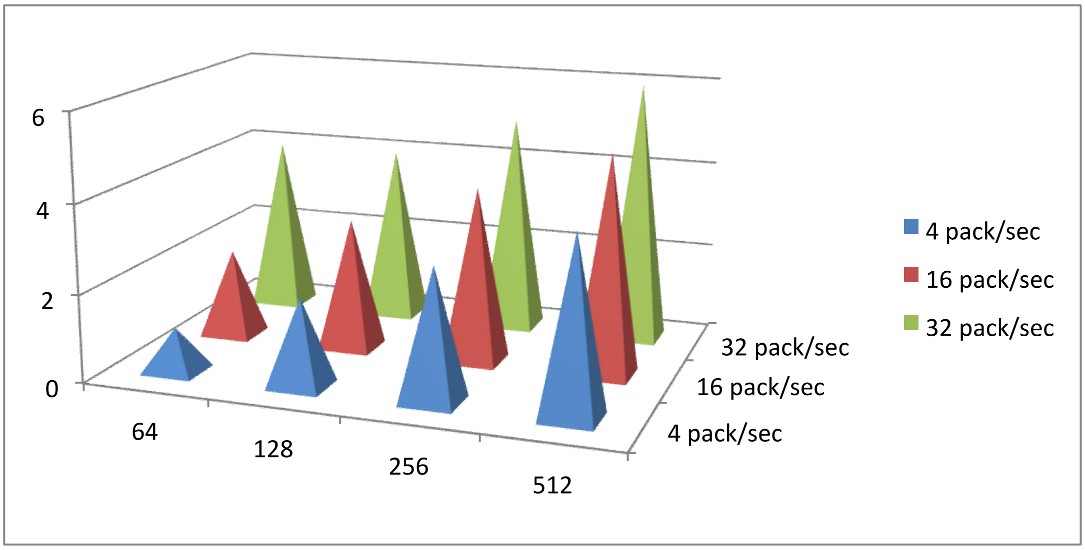

Figure 6. transfer time with packs different values (data).

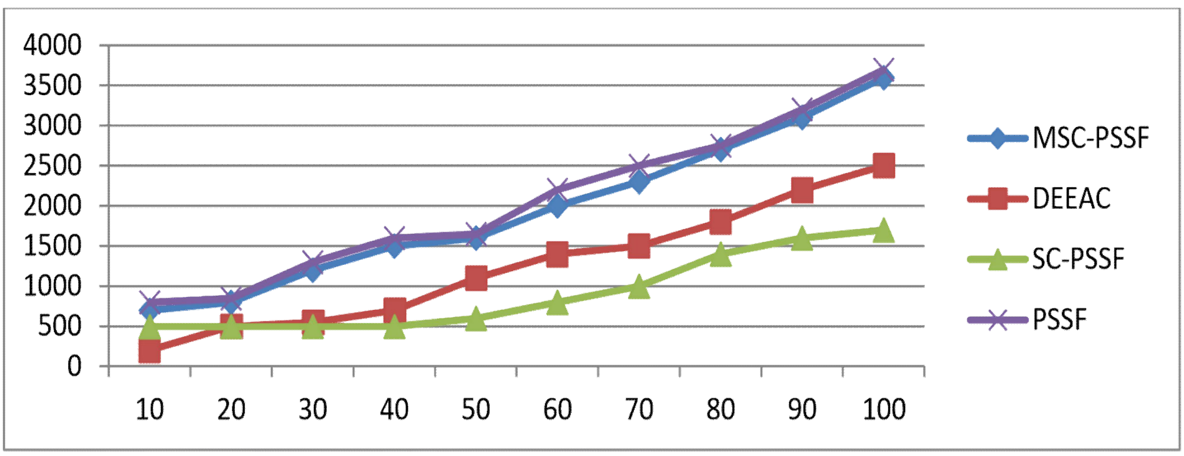

Figure 7. the percent of network dead nodes based on stimulating DDoS attacks

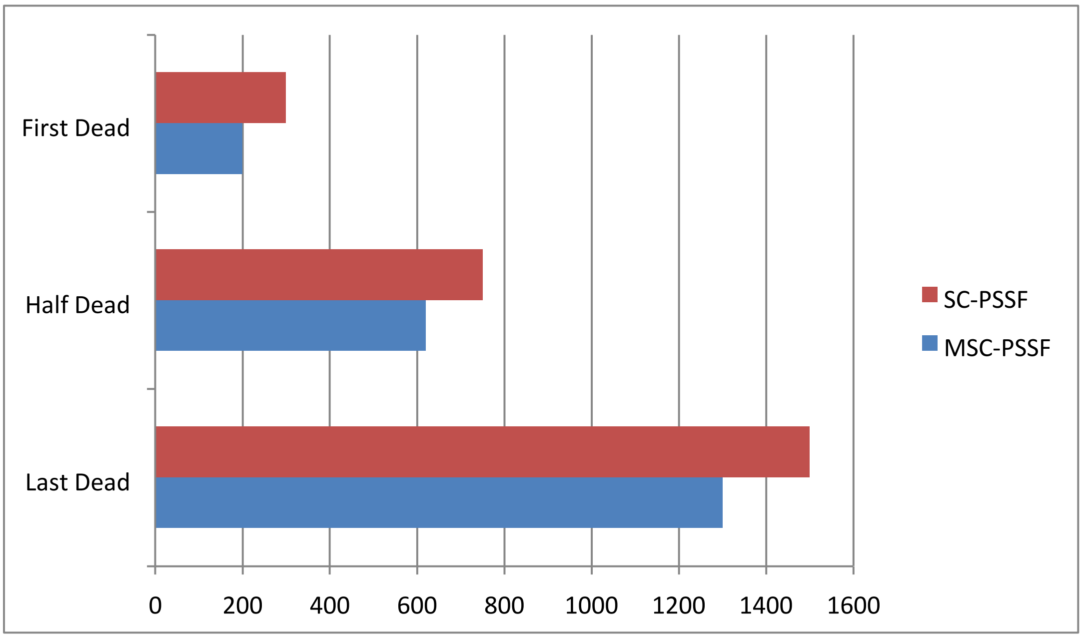

Figure 8. competition among dead nodes at the beginning, middle and the end

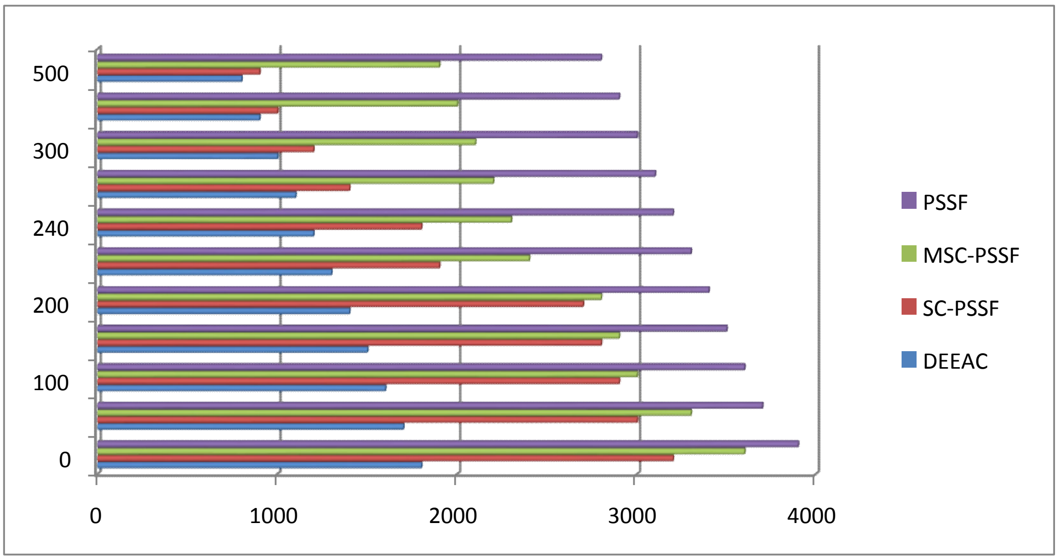

Figure 9. the location of well against normal time and under network attack.

5. The Time of Performing Insertion Transactions during Processing High Performance System

Transaction performed in this study constantly using one order in two types of server and performance time shown in multithreading and rounded form based on second. This trend is done when software like Billing is pressing server. Also, traditional servers are turned off and reset in doing a part of test due to load increase.

The results are juxtaposed with each other and compared in the following diagram. It is obvious that virtual servers based on cloud token have more suitable performance rather than traditional servers.

The Figure 13 is related to comparing the time of searching in two common and cloud servers. Unlike orders like insertion, removal and or updating, much difference is observed in searching. New algorithms, tokening and query banks based on cloud server have made messaging platforms and social networks have activity in massive volume of stable data and with high speed.

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Table 2. the time of performing recording order in physical server with diagram

The time of performance/ rounded	The number of records	The type of action	Row
5 sec	111.111	Insertion	1
8 sec	211.111	Insertion	2
11sec	311.111	Insertion	3
12 sec	411.1111	Insertion	4
13 sec	511.111	Insertion	5
16 sec	611.111	Insertion	6
18 sec	711.111	Insertion	7
19 sec	811.111	Insertion	8
21 sec	911.111	Insertion	9
23 sec	1111.111	Insertion	11

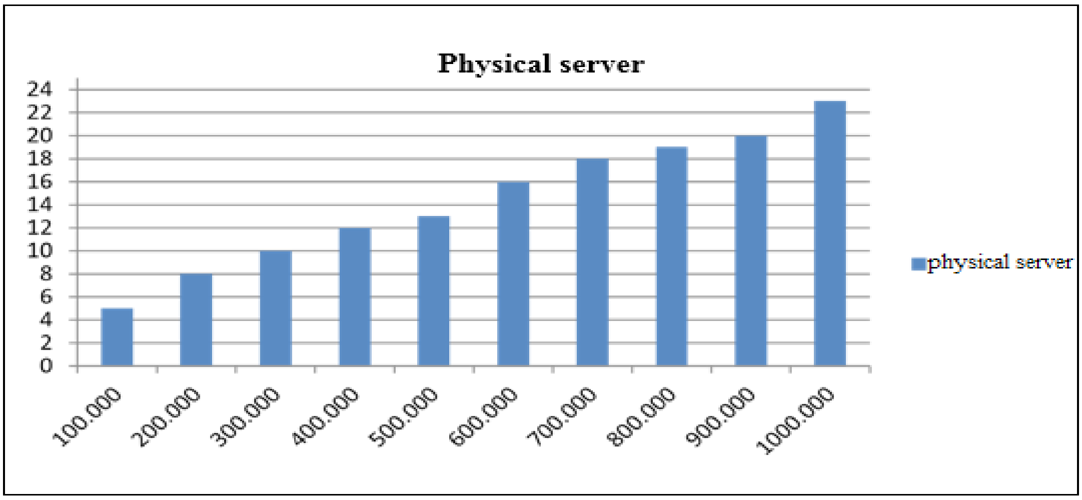

Figure 10. Physical server.

Table 3. the time of performing recording order in cloud server with diagram.

The time of performance/ rounded	The number of records	The type of action	Row
2 sec	111.111	Insertion	1
4 sec	211.111	Insertion	2
5 sec	311.111	Insertion	3
6 sec	411.1111	Insertion	4
8 sec	511.111	Insertion	5
9 sec	611.111	Insertion	6
11 sec	711.111	Insertion	7
12 sec	811.111	Insertion	8
14 sec	911.111	Insertion	9
15 sec	1111.111	Insertion	11

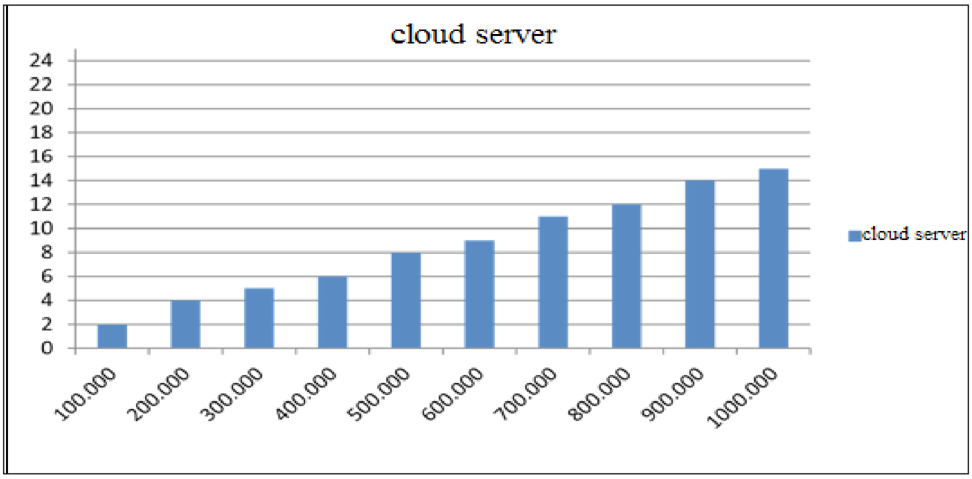

Figure 11. Cloud server.

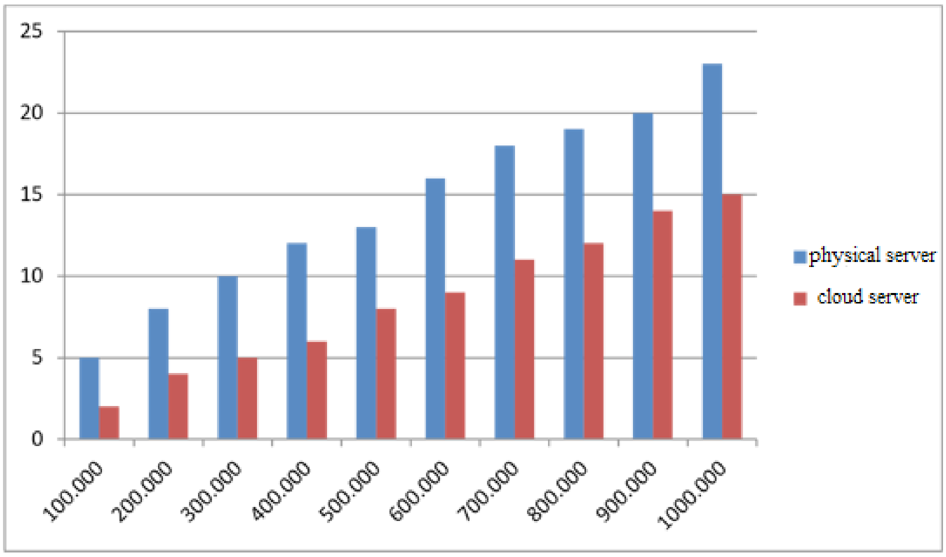

Figure 12. comparing physical server and cloud server in insertion transactions

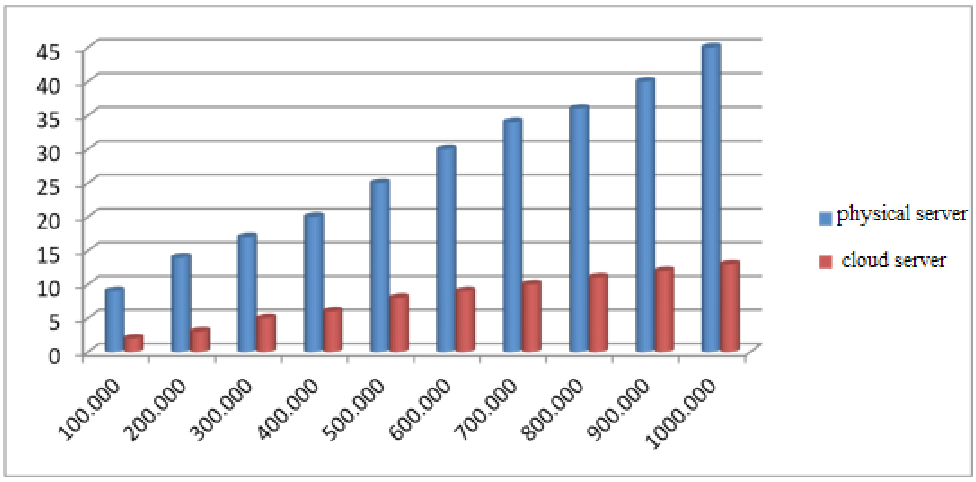

Figure 13. comparing physical server and cloud server in searching.

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6. Conclusions

Making a cloud processing platform is easy as far as one of its sources is common. Although making a scalable, reusable and developed cloud processing architecture for sharing all types of sources still faces with obstacles. No matter what you want, cloud processing will finally work for you. If you cannot perfectly use cloud processing service, but you have a part of it. You can save your data during the least possible time in the servers instead of your hard disc. Although, we are still cautious about our personal information, the number of people who save their personal information in servers accessible from internet is increasing. Millions of people upload their personal information including emails, images and even their working data in the third party company like Google. A main reason for not using web-based programs is that you do not control it. Using a web-based program may be as dangerous as a dedicated program. Do your works with your PC by the program which give you freedom of action.

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ARTICLE

Finding Non-liner Register on Binary M-Sequence Generating Binary Multiplication Sequence

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ABSTRACT

In the current time there is an important problem that is for a received linear or nonlinear binary sequence $\{z_n\}$ how we can find the nonlinear feedback shift register and its linear equivalent which generate this sequence. The linear orthogonal sequences, special M-Sequences, play a big role in these methods for solving this problem. In the current research trying give illuminations about the methods which are very useful for solving this problem under short sequences, and study these methods for finding the nonlinear feedback shift register of a multiplication sequence and its linear equivalent feedback shift register of a received multiplication binary sequence$\{z_n\}$ where the multiplication on *h* degrees of a binary linear sequence $\{a_n\}$, or finding the equivalent linear feedback shift register of $\{z_n\}$, where the sequence $\{z_n\}$of the form M-sequence, and these methods are very effectively. We can extend these methods for the large sequences using programming and modern computers with large memory.

1. Introduction

Sloane, N.J.A., discuses that the multiplication binary sequence $\{zn\}$ on *h* degrees of $\{an\}$ which has the *r* complexity the *r* complexity, the complexity of {zn} can't be exceeded;

$$_rN_h=\binom{r}{1}+\binom{r}{2}+\ldots+\binom{r}{h}. \quad (1)$$ [1-2]

Al Cheikha A. H., & Mokayes D., studied the construction of the multiplication Mp-sequences and their complexities, periods, and the lengths of the linear equivalents of these multiplication sequences, where the multiplication will be on one Mp-sequence or on more than one binary sequence [3-8].

Al Cheikha A. H., & Omar Ebtisam Haj, studied the construction of the multiplication binary M-sequences, Mp-Sequences and their reciprocal sequences and their complexities, periods, and the lengths of the linear equivalents of these multiplication sequences, where the multiplication will be on one Mp-sequence or on more than one binary sequence [9].

Al Cheikha A. H., studied the construction of the multiplication binary M-sequences and their complexities, periods, and the lengths of the linear equivalents of these multiplication sequences, where the multiplication will be on one Mp-sequence or on more than one binary sequence [10-14].

Orthogonal Sequences are used widely in the systems communication channels as in the forward links for mixing the information on connection and as in the backward

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links of these channels to sift this information which transmitted and the receivers get the information in a correct form, especially in the pilot channels, the Sync channels, and the Traffic channel [14-18].

In current article we try to solve the problem; we received the binary sequence $\{z_n\}$, where $\{z_n\}$ is a linear or nonlinear binary sequence then how we can find the basic original binary sequence $\{an\}$ which is under the multiplication operation and the multiplication operation lead to the sequence $\{zn\}$.

It is the inverse problem of finding the sequence $\{z_n\}$ where $\{an\}$ is known.

2. Research Method and Materials

2.1 M- Linear Recurring Sequences

The sequence $\{sn\}$ of the form

$$s_{n+k} = \eta_{k-1}s_{n+k-1} + \eta_{k-2}s_{n+k-2} + \ldots + \eta_0 s_n + \eta; \eta \,\&\, \eta_i \in F_2\,, i = 0,1,\ldots,k-1 \quad or \quad s_{n+k} = \sum_{i=0}^{k-1}\eta_i s_{n+i} + \eta \tag{2}$$

where, $\eta, \eta_0, \eta_1, \ldots, \eta_{k-1}$ are in the field $F_2=\{0,1\}$ and k is a positive integer is called a binary linear recurring sequence of complexity or order k, *if* $\eta = 0$ then the sequence is called a homogeneous linear recurring sequence (H.L.R.S), in other case the sequence is called non-homogeneous linear homogeneous sequence, the vector $(s_0, s_1, \ldots, s_{k-1})$ is called the initial vector and the characteristic equation of the sequence is;

$$f(x) = x^k + \eta_{k-1}x^{k-1} + \ldots + \eta_1 x + \eta_0 \tag{3}$$

We are limited in our article to η_0=1 and the all sequences are binary.

2.2 Definitions and Theorems

Definition 1.

The ultimately sequence $s_0, s_1, \ldots$ in F_2 with the smallest natural number $r\neq0$ is called periodic with the period r *iff*:

$s_{n+r} = s_n$; $n = 0, 1, \ldots$ [2-5]

Definition 2.

The linear register of a linear sequence is a linear feedback shift register with only addition circuits and the number in its output in the impulse n equal to the general term of the sequence $\{an\}$ and the register denoted as LFSR [3].

Definition 3.

The complement of the binary vector $X = (x_1, x_2, \ldots, x_n)$, $x_i \in F_2$ is the vector $\overline{X} = (\overline{x_1}, \overline{x_2}, \ldots, \overline{x_n})$, where:

$$\overline{x_i} = \begin{cases} 1 & if \quad x_i = 0 \\ 0 & if \quad x_i = 1 \end{cases} \tag{4}$$ [3,5-8]

Definition 4.

Suppose $x = (x_0, x_1, \ldots, x_{n-1})$ and $y = (y_0, y_1, \ldots, y_{n-1})$ are two binary vectors of the length n on F_2. The coefficient of correlations function of x and y, denoted by Rx,y, is

$$R_{x,y} = \sum_{i=0}^{n-1}(-1)^{x_i + y_i} \tag{5}$$

Where $xi + yi$ is computed *mod* 2. It is equal to the number of agreements components minus the number of disagreements corresponding to components or if $x_i, y_i \in \{1, -1\}$ (usually, replacing in binary vectors x and y each "1" by "1*= -1" and each "0" by "0* = 1") then

$$R_{x,y} = \sum_{i=0}^{n-1} x_i^* y_j^* \tag{6}$$ [2-10]

Definition 5.

The two binary vectors $x = (x_0, x_1, \ldots, x_{n-1})$ and $y = (y_0, y_1, \ldots, y_{n-1})$ are orthogonal iff;

$$\left|R_{x,y}\right| \le 1 \tag{7}$$ [11-13]

Definition 6.

The set G, where $G = \{X; X = (x_0, x_1, \ldots, x_{n-1}), x_i \in F_2, i = 0,1,\ldots,n-1\}$ is orthogonal iff the following two conditions are satisfied:

$$1.\ \forall X \in G, \left|\sum_{i=0}^{n-1} x_i^*\right| \le 1,\ or\ \left|R_{x,0}\right| \le 1. \tag{8}$$

$$2.\ \forall X, Y \in G(X \ne Y), \left|\sum_{i=0}^{n-1} x_i^* y_i^*\right| \le 1\ or\ \left|R_{x,y}\right| \le 1. \tag{9}$$

That is, the absolute value of "the number of agreements minus the number of disagreements" is less than or equals one [6,9].

Definition 7. (Euler function φ).

$\varphi(n)$ is the number of the all-natural numbers that are relatively prime with n [11-14].

Definition 8.

Inverse problem: Finding the sequence $\{an\}$ which $\{zn\}$ is a linear or multiplication sequence on it and it is one of the issues at present and it requires a solutions [10].

Theorem 9.

If $g(x)$ is a characteristic prime polynomial of the (H. L. R. S.), $s_0, s_1, \ldots$ of degree k, and α is a root of $g(x)$ in any splitting field of F_2 then the general term of this sequence is:

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$$s_n = \sum_{i=1}^{k} C_i \left(\alpha^{2^{i-1}} \right)^n \qquad (10)\ [6,12]$$

Theorem10.

The number of irreducible polynomials in $F_q(x)$ of degree m and order e is $\varphi(e)/m$, if $e \geq 2$, when m is the order of q by mod e, and equal to 2 if $m = e = 1$, and equal to zero elsewhere [8,14-18].

* The study here is limited to the finite fields of the form F_{2^k}, then the period of M-Sequence is of the form $r = 2^k - 1$.

3. Results and Discussion

Strategies finding the origin nonlinear feedback shift register and linear equivalent for nonlinear sequences.

Our strategies here as the method of the factorization natural number to their prime factors and If the origin feedback shift register of the sequence $\{z_n\}$ is a linear or nonlinear then we can accomplished it as the following:

1) If the period of the sequence $\{z_n\}$is of the form $r = 2k$-1 and the set of all periodic permutations of one period of the sequence $\{z_n\}$is orthogonal then the sequence $\{z_n\}$is a M-Sequence and their feedback shift register is a linear, its characteristic polynomial is comfortable with a prime polynomial of degree k, and we can find it through the first k terms of the sequence $\{z_n\}$ by finding the coefficients of the characteristic equation using the recurrent sequence;

$$z_{n+k} + \lambda_{k-1} z_{n+k-1} + \ldots + \lambda_1 z_{n+1} + z_n = 0 \qquad (11)$$

In other cases, if $r = 2k$-1 and the set of all periodic permutations of one period of the sequence $\{z_n\}$ is not orthogonal then we can go to the second step which we can make it by one of the two following strategies namely 2 or 3;

2) We find the origin sequence binary recurring M-Sequence $\{an\}$ with the complexity k and the initial vector $\alpha_0, \alpha_1, \ldots, \alpha k\text{-}_1$ (and the best try; $\alpha_0, \alpha_1, \ldots, \alpha k\text{-}_1 = z_0, z_1, \ldots, zk\text{-}_1$ respectively), the number of degrees h (where $h = 2,3,..,k$ starting with 2 until we come to the sequence $\{z_n\}$or by inverse starting with $h = k$ until we come to the sequence $\{z_n\}$) and the terms (which they are under the multiplication operation) are sufficient for finding the nonlinear feedback shift register which will be generate the nonlinear sequence $\{z_n\}$.

The value h is one value between 2 and k and we need take the all prime polynomials of degree k and for each of them we will try, one by one, give h the values from 2 to k until we get the comfortable prime polynomial, h and the terms under the multiplication operation of the sequence$\{an\}$ will give us the sequence $\{z_n\}$, after that we can find the general term of the sequence $\{z_n\}$which will define the length of the linear equivalent and through element the sequence $\{z_n\}$by solving one algebraic linear system.

3) If the period of the sequence $\{z_n\}$ is of the form $r = 2k$-1 or divides it and the set of all periodic permutations of one period of the sequence $\{z_n\}$ is not orthogonal then the sequence $\{z_n\}$is nonlinear, not M-Sequence and their equivalent linear feedback shift register comfortable with the first m terms in the sequence $\{z_n\}$, we can find the coefficients of the characteristic equation of the equivalent linear feedback shift register as following;

$$x^m + \mu_{m-1} x^{m-1} + \ldots + \mu_1 x + 1 = 0 \qquad (12)$$

of the recurrent sequence;

$$y_{m+k} + \mu_{k-1} y_{m+k-1} + \ldots + \mu_1 y_{m+1} + y_m = 0 \qquad (13)$$

Where m is one value between $\binom{k}{1} + \binom{k}{2}$ and ${}_kN_k = \binom{k}{1} + \binom{k}{2} + \ldots + \binom{k}{k} = \sum_{i=1}^{k} \binom{k}{i}$ starting through $m = \binom{k}{1} + \binom{k}{2}$ until we coming (and maybe with some shifting of the indexes) to the sequence $\{yn\} = \{z_n\}$ or by inverse starting with h = until (and maybe with some shifting of the indexes) we coming to the sequence $\{yn\} = \{z_n\}$), thus, we can go to finding the equivalent feedback shift register generating the sequence $\{z_n\}$ specially, m the complexity of the equivalent linear register of the sequence $\{z_n\}$.

Finding h: As very known that $m \leq \binom{k}{1} + \ldots + \binom{k}{h} = {}_kN_h$ then h is larger than or equal to j where j is the smallest natural number for $m \leq \binom{k}{1} + \ldots + \binom{k}{j} = {}_kN_j$ and if $m = \binom{k}{1} + \binom{k}{2}$ then h = 2 or 3.

Usually, $h = j$ or j+1. We will try solve some problems through the two strategies 2 and 3.

Example 1.

Suppose the following sequence $\{sn\}$;

0 1 0 0 1 1 0 1 0 1 1 1 1 0 0, 0 1 0 0 1 1 0 1 0 1 0 0 1 1 0, … (14)

We can look that the sequence is a periodic sequence with the period $r = 2^4 - 1 = 15$, here k = 4, and the set of the all cyclic permutations of one period is $S = \{ m_0, m_1, \ldots, m_{14}\}$ is;

$m_0 =$ 0 1 0 0 1 1 0 1 0 1 1 1 1 0 0

$xm_1 =$ 0 0 1 0 0 1 1 0 1 0 1 1 1 1 0

$m_2 =$ 0 0 0 1 0 0 1 1 0 1 0 1 1 1 1
$m3 =$ 1 0 0 0 1 0 0 1 1 0 1 0 1 1 1
$m4 =$ 1 1 0 0 0 1 0 0 1 1 0 1 0 1 1
$m5 =$ 1 1 1 0 0 0 1 0 0 1 1 0 1 0 1
$m6 =$ 1 1 1 1 0 0 0 1 0 0 1 1 0 1 0
$m7 =$ 0 1 1 1 1 0 0 0 1 0 0 1 1 0 1
$m_8 =$ 1 0 1 1 1 1 0 0 0 1 0 0 1 1 0
$m_9 =$ 0 1 0 1 1 1 1 0 0 0 1 0 0 1 1
$m_{10} =$ 1 0 1 0 1 1 1 1 0 0 0 1 0 0 1
$m_{11} =$ 1 1 0 1 0 1 1 1 1 0 0 0 1 0 0
$m_{12} =$ 0 1 1 0 1 0 1 1 1 1 0 0 0 1 0
$m_{13} =$ 0 0 1 1 0 1 0 1 1 1 1 0 0 0 1
$m_{14} =$ 1 0 0 1 1 0 1 0 1 1 1 1 0 0 0

we can check that each m_i, $i = 0,1,\ldots, 14$ has 8 of the "1" and 7 of the "0" and $m_i + m_j \in S, mod\ 2$, for example;

$m_2 + m_9 = 010011010111100 = m_0$

Thus, S is an orthogonal set.

There are to ways for finding the linear shift register of the sequence;

First way:

There are only tow prime polynomials of degree 4 are; $f(x) = x^4 + x + 1$ and its reciprocal $g(x) = x^4 + x^3 + 1$ and we will check each of them if can be generate this sequence (with some shift of the indexes).

a) For the prime polynomial $g(x) = x^4 + x^3 + 1$ which corresponding with the recurrent sequence $y_{n+4} + y_{n+3} + y_n = 0$ or $y_{n+4} = y_{n+3} + y_n$ and their comfortable linear shift register for the first initial vector(0 1 1 0)is the following;

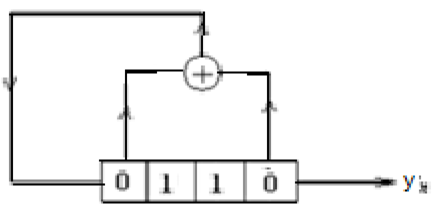

Figure 1. Linear feedback shift register with 4 complexity over F_2

This feedback shift register generates the following periodic sequence;

0 1 1 0 0 1 0 0 0 1 1 1 1 0 1, 0 1 1 0 0 1 0 0 0 1 1 1 1 0 1 (15)

And we can see that this sequence is not the same of received sequence.

b) For the prime polynomial $f(x) = x^4 + x + 1$ which corresponding with the recurrent sequence $y_{n+4} + y_{n+1} + y_n = 0$ or $y_{n+4} = y_{n+1} + y_n$ and their comfortable linear shift register for the first initial vector(0 1 1 0)is the following;

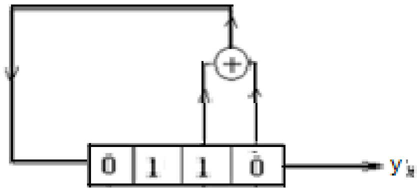

Figure 2. Linear feedback shift register with 4 complexity over F_2

This feedback shift register generates the following periodic sequence;

0 1 1 0 1 0 1 1 1 1 0 0 0 1 0 0 1 1 0 1 0 1 1 1 1 0 0 0 1 0… (16)

And we can see that this sequence is the same of the received sequence with shift of the index by 14.

Second way:

Suppose the characteristic equation is of the form; $x^4 + \alpha_3 x^3 + \alpha_2 x^2 + \alpha_1 x + 1 = 0$ and the recurrent formula is the following;

$y_{n+4} + \alpha_3 y_{n+3} + \alpha_2 y_{n+2} + \alpha_1 y_{n+1} + 1 y_n = 0$, and $y_0 = 0$, $y_1 = 1$, $y_2 = 0$, $y_3 = 0$, $y_4 = 1$, $y_5 = 1$, $y_6 = 0$, $y_7 = 1$. Thus;

$$for\ n = 0 \Rightarrow y_4 + \alpha_3 y_3 + \alpha_2 y_2 + \alpha_1 y_1 + 1 y_0 = 0$$

$$for\ n = 1 \Rightarrow y_5 + \alpha_3 y_4 + \alpha_2 y_3 + \alpha_1 y_2 + 1 y_1 = 0$$

$$for\ n = 2 \Rightarrow y_6 + \alpha_3 y_5 + \alpha_2 y_4 + \alpha_1 y_3 + 1 y_2 = 0$$

$$for\ n = 3 \Rightarrow y_7 + \alpha_3 y_6 + \alpha_2 y_5 + \alpha_3 y_4 + 1 y_3 = 0$$

From the first three equations we have; $\alpha_3 = 0, \alpha_2 = 0, \alpha_1 = 1$ and the characteristic equation is $x^4 + x + 1 = 0$ and the recurrent equation is; $y_{n+4} + y_{n+1} + y_n = 0$ and it is the same what we get in the first way.

Example 2.

Given the following received periodic sequence $\{z_n\}$;

0 0 1 0 1 0 1 1 0 0 0 0 0 0 0, 0 0 1 0 1 0 1 1….. (17)

The period of the sequence is $r = 2^4 - 1 = 15$ and as showing is not orthogonal that is the sequence $\{z_n\}$ is nonlinear sequence and we need find the nonlinear feedback shift register and the linear equivalent which generates it that are; origin sequence $\{a_n\}$, the terms of it which they are under the multiplication operation, finding h the number of these terms which under the multiplication operations, and the linear equivalent to the nonlinear register.

There are only two prime polynomials of degree 4 they are; $g(x) = x^4 + x^3 + 1$ and $f(x) = x^4 + x + 1$.

We will study the nonlinear sequences generated by given nonlinear feedback shift register corresponding to the polynomials under the multiplication operation on two degrees, three degrees, and four degrees for each of them one by one.

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First step.

For the first polynomial $g(x) = x^4 + x^3 + 1$ and the origin sequence $\{a_n\}$ generated with the characteristic polynomial $g(x)$, the initial vector (0010) and the sequence is under the multiplication operation.

The origin sequence $\{a_n\}$ which has $g(x)$ as a characteristic polynomial and satisfies the recurrent formula $a_{n+4} + a_{n+3} + a_n = 0$ is orthogonal and periodic with the period $r = 2^4\text{-}1=15$ and is showing in the Figure 3;

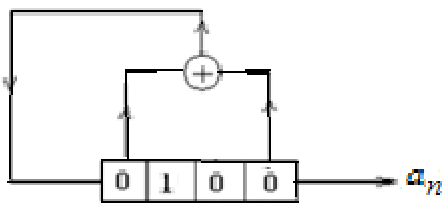

Figure 3. Linear feedback shift register with 4 complexity over F_2

And it is;

0 0 1 0 0 0 1 1 1 1 0 1 0 1 1, 0 0 1 0 0 0 1 1……. (18)

Suppose $u_n^{(i,j)}$ is the nonlinear sequence generated under the multiplication operation on the tow degrees i and j of the feedback shift register, and we have $h = 2$;

$u_n^{(0,1)}$ = 0 0 0 0 0 0 1 1 1 0 0 0 0 1 0 0 0 0 0 0 0 1…..

$u_n^{(0,2)}$ = 0 0 0 0 0 0 1 1 0 1 0 1 0 0 0 0 0 0 0 …..

$u_n^{(0,3)}$ = 0 0 0 0 0 0 1 0 0 1 0 0 1 0 0 1 0 0 0 ……

$u_n^{(1,2)}$ = 0 0 0 0 0 1 1 1 0 0 0 0 1 0 0 0 0 0 0 0 …..

$u_n^{(1,3)}$ = 0 0 0 0 0 0 1 1 0 1 0 0 0 0 0 0 0 0 0 0 …..

$u_n^{(2,3)}$ =0 0 0 0 1 1 10 0 0 0 1 0 0 0 0 0 0 0 0 ……

Thus, no any of the previously sequences is equal to the sequence $\{z_n\}$.

Second step.

For the polynomial $f(x) = x^4 + x + 1$ the origin sequence $\{b_n\}$ generated with the characteristic function $f(x)$ and has the initial vector (0010) and the sequence is under the multiplication operation.

The origin sequence $\{b_n\}$ which has $f(x)$ as a characteristic polynomial and satisfies the recurrent formula

$b_{n+4} + b_{n+1} + b_n = 0$ is orthogonal and periodic with the period $r = 2^4\text{-}1=15$ and is showing in the Figure 4;

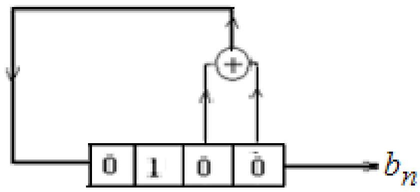

Figure 4. Linear feedback shift register generating the sequence $\{b_n\}$

And it is;

0 0 1 0 0 1 1 0 1 0 1 1 1 1 0, 0 0 1 0 0 1 1 0 1 0……. (19)

Suppose $w_n^{(i,j)}$ is the nonlinear sequence generated under the multiplication operation on the tow cells i and j of the feedback shift register, and we have $h = 2$;

$w_n^{(0,1)}$ = 0 0 0 0 0 1 0 0 0 0 1 1 1 0 0…..

$w_n^{(0,2)}$ = 0 0 0 0 0 0 1 0 1 0 1 1 0 0 0…..

Thus, we can see that $w_n^{(0,2)}$ is a permutation of $\{z_n\}$ by 4 cyclic and the sequence is a nonlinear sequence over two degrees which are the first and the third degrees of the linear shift register of the sequence $\{b_n\}$ and Figure 5 showing the nonlinear feedback shift register for the sequence;

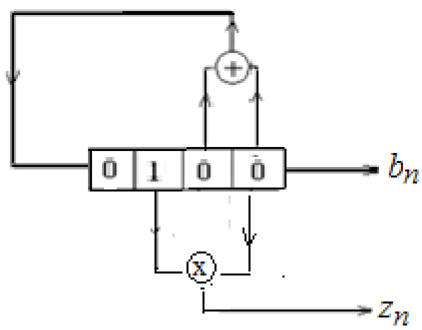

Figure 5. Nonlinear feedback shift register generating the sequence $\{z_n\}$

We can find the linear equivalent of the sequence by other way through the sequence $\{b_n\}$as following;

The sequence $\{b_n\}$satisfies the recurrent formula $b_{n+4} + b_{n+1} + b_n = 0$ *or* $b_{n+4} = b_{n+1} + b_n$ and its characteristic equation is $x^4 + x + 1 = 0$ and $f(x) = x^4 + x + 1$ is a prime polynomial, if β is a root of the characteristic equation then the roots of the characteristic equation (in F_2^4) are $\beta, \beta^2, \beta^4, \beta^8$ and the general solution of the characteristic equation which that is the general term of the sequence $\{bn\}$is;

$$b_n = A_1\beta^n + A_2\beta^{2n} + A_3\beta^{4n} + A_4\beta^{8n}$$ or

$$b_n = A_1\beta^n + A_2\beta^{2n} + A_3(\beta+1)^n + A_4(\beta^2+1)^n$$

The elements of the $F_2{}^4$ are;

$$F_{2^4} = \{0,\beta,\beta^2,\beta^3,\beta^4=\beta+1,\beta^5=\beta^2+\beta,\beta^6=\beta^3+\beta^2,\\ \beta^7=\beta^3+\beta+1,\beta^8=\beta^2+1,\beta^9=\beta^3+\beta,\beta^{10}=\beta^2+\beta+1,\\ \beta^{11}=\beta^3+\beta^2+\beta,\beta^{12}=\beta^3+\beta^2+\beta+1,\beta^{13}=\beta^3+\beta^2+1,\\ \beta^{14}=\beta^3+1,\beta^{15}=1\} \quad (20)$$

The sequence $\{b_n\}$ is periodic with the period $r=2^4-1=15$ and;

$$n=0 \Rightarrow A_1+A_2+A_3+A_4=0\\ n=1 \Rightarrow A_1\beta+A_2\alpha^2+A_3\beta^4+A_4\beta^8=0\\ n=2 \Rightarrow A_1\beta^2+A_2\beta^4+A_3\beta^8+A_4\beta^{16}=1\\ n=3 \Rightarrow A_1\beta^3+A_2\beta^6+A_3\beta^{12}+A_4\beta^{24}=0$$

or

$$n=0 \Rightarrow A_1+A_2+A_3+A_4=0\\ n=1 \Rightarrow A_1\beta+A_2\beta^2+A_3\beta^4+A_4\beta^8=0\\ n=2 \Rightarrow A_1\beta^2+A_2\beta^4+A_3\beta^8+A_4\beta=1\\ n=3 \Rightarrow A_1\beta^3+A_2\beta^6+A_3\beta^{12}+A_4\beta^9=0$$

Solving this system of equations we have;

$$A_1=\beta, A_2=\beta^2, A_3=\beta^4, A_4=\beta^8$$

Thus, the general term of the sequence $\{bn\}$ is;

$$b_n = \beta.\beta^n + \beta^2.\beta^{2n} + \beta^4.\beta^{4n} + \beta^8.\beta^{8n} \quad (21)$$

and $\{b_n\}$ is a M-Sequence with period $2^4-1=15$, and one period with its cyclic permutations form an orthogonal set;

0 0 1 0 0 1 1 0 1 0 1 1 1 1 0, 0 0 1 0 0 1 0 0……. (22)

Suppose the sequence $\{zn\}$ is a multiplication sequence on two degrees of $\{bn\}$, b_n and bn_{+2} of the sequence $\{bn\}$ as is showing in Figure 5, then;

$$z_n = b_n.b_{n+2}$$

$$b_{n+2} = \left(\beta^3\beta^n + \beta^6\beta^{2n} + \beta^{12}\beta^{4n} + \beta^9\beta^{8n}\right)$$

Or;

$$z_n = \left(\beta.\beta^n + \beta^2.\beta^{2n} + \beta^4.\beta^{4n} + \beta^8.\beta^{8n}\right)\\ \left(\beta^3\beta^n + \beta^6\beta^{2n} + \beta^{12}\beta^{4n} + \beta^9\beta^{8n}\right)$$

Or;

$$z_n = \beta^2\beta^n + \beta^4\beta^{2n} + \beta^{13}\beta^{3n} + \beta^8\beta^{4n} +\\ \beta^5\beta^{5n} + \beta^{11}\beta^{6n} + \beta^{16}\beta^{8n} + \beta^{14}\beta^{9n} +\\ \beta^{10}\beta^{10n} + \beta^7.\beta^{12n} \quad (23)$$

Thus, the zeros of the characteristic polynomial of the sequence $\{zn\}$ are;

$$\beta^n, \beta^{2n}, \beta^{3n}, \beta^{4n}, \beta^{5n}, \beta^{6n}, \beta^{8n}, \beta^{9n}, \beta^{10n}, \beta^{12n}$$

The characteristic polynomial of the sequence $\{zn\}$ is finding through the formula;

$$h(x) = (x-\beta^n)(x-\beta^{2n}).....(x-\beta^{12n}) \quad (24)$$

Thus, the characteristic equation of the sequence $\{zn\}$ is;

$$(x-\beta^n)(x-\beta^{2n}).....(x-{}^{12n}) = 0 \quad (25)$$

We can verify that;

$$\beta^n.\beta^{2n}.....\beta^{12n} = \beta^{60n} = 1$$

And;

$$h(x) = x^{10}+x^8+x^5+x^4+x^2+x+1 \quad (26)$$

And the characteristic equation for the equivalent of the nonlinear sequence s;

$$x^{10}+x^8+x^5+x^4+x^2+x+1=0 \quad (27)$$

The equivalent feedback shift register is showing in the following Figure 6;

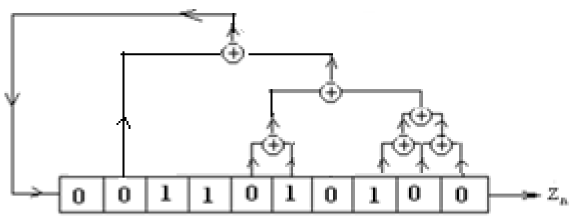

Figure 6. The equivalent linear feedback register generating the sequence $\{z_n\}$

Or, the characteristic equation can be written as;

$$((x-\beta^5)(x-\beta^{10}))((x-\beta)(x-\beta^2)(x-\beta^4)(x-\beta^8))\\ ((x-\beta^3)(x-\beta^6)(x-\beta^9)(x-\beta^{12}))=0 \quad (28)$$

$$(x^2+x+1)(x^4+x+1)(x^4+x^3+x^2+x+1)=0 \quad (29)$$

The subsequence as result of the characteristic equation x^2+x+1 is periodic with the period $2^2-1=4$, x^4+x+1 and $x^4+x^3+x^2+x+1$, each of them is prime with the period $2^4-1=15$, Thus the sequence $\{zn\}$, as a result of the characteristic equation $x^{10}+x^8+x^5+x^4+x^2+x+1=0$, is periodic with the period $2^4-1=15$, the same period of the sequence $\{bn\}$, and the sequence $\{zn\}$ defined by the recurring formula

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$$z_{n+10} + z_{n+8} + z_{n+5} + z_{n+4} + z_{n+2} + z_{n+1} + z_n = 0 \quad (30)$$

And it is;

0 0 1 0 1 0 1 1 0 0 0 0 0 0 0, 0 0 1 0 1 0 1 1, 0 0 1 0 1 0 1 1 0 0 0 0 0 0 0, 0 0 1 0 1 0 1 1….. (31)

Thus, the sequence reached its maximum length;

$$\binom{4}{1} + \binom{4}{2} = 4 + \frac{4(4-1)}{2} = 10 \quad (32)$$

Or;

The length of the linear equivalent of the nonlinear sequence $\{z_n\}$ is $m = \binom{4}{1} + \binom{4}{2} = 10$.

The characteristic equation of the linear equivalent shift register is of the form;

$$\begin{aligned} &x^{10} + \mu_9 x^9 + \mu_8 x^8 + \mu_7 x^7 + \mu_6 x^6 + \mu_5 x^5 + \mu_4 x^4 \\ &+ \mu_3 x^3 + \mu_2 x^2 + \mu_1 x + 1 = 0 \end{aligned} \quad (33)$$

Or from the recurrent formula;

$$\begin{aligned} &z_{n+10} + \mu_9 z_{n+9} + \mu_8 z_{n+8} + \mu_7 z_{n+7} + \mu_6 z_{n+6} + \mu_5 z_{n+5} \\ &+ \mu_4 z_{n+4} + \mu_3 z_{n+3} + \mu_2 z_{n+2} + \mu_1 z_{n+1} + z_n = 0 \end{aligned} \quad (34)$$

We need solve system of 9 equations (or we can take more equations if it is need) using the terms of the sequence $\{z_n\}$ and the previously characteristic equation that are for $n = 0, 1, \ldots, 8$ as following;

For $n = 0 \rightarrow$ $z_{10} + \mu_9 z_9 + \mu_8 z_8 + \mu_7 z_7 + \mu_6 z_6 + \mu_5 z_5 + \mu_4 z_4 + \mu_3 z_3 + \mu_2 z_2 + \mu_1 z_1 + z_0 = 0$

For $n = 1 \rightarrow$ $z_{11} + \mu_9 z_{10} + \mu_8 z_9 + \mu_7 z_8 + \mu_6 z_7 + \mu_5 z_6 + \mu_4 z_5 + \mu_3 z_4 + \mu_2 z_3 + \mu_1 z_2 + z_1 = 0$

For $n = 2 \rightarrow$ $z_{12} + \mu_9 z_{11} + \mu_8 z_{10} + \mu_7 z_9 + \mu_6 z_8 + \mu_5 z_7 + \mu_4 z_6 + \mu_3 z_5 + \mu_2 z_4 + \mu_1 z_3 + z_2 = 0$

For $n = 3 \rightarrow$ $z_{13} + \mu_9 z_{12} + \mu_8 z_{11} + \mu_7 z_{10} + \mu_6 z_9 + \mu_5 z_8 + \mu_4 z_7 + \mu_3 z_6 + \mu_2 z_5 + \mu_1 z_4 + z_3 = 0$

For $n = 4 \rightarrow$ $z_{14} + \mu_9 z_{13} + \mu_8 z_{12} + \mu_7 z_{11} + \mu_6 z_{10} + \mu_5 z_9 + \mu_4 z_8 + \mu_3 z_7 + \mu_2 z_6 + \mu_1 z_5 + z_4 = 0$

For $n = 5 \rightarrow$ $z_{15} + \mu_9 z_{14} + \mu_8 z_{13} + \mu_7 z_{12} + \mu_6 z_{11} + \mu_5 z_{10} + \mu_4 z_9 + \mu_3 z_8 + \mu_2 z_7 + \mu_1 z_6 + z_5 = 0$

For $n = 6 \rightarrow$ $z_{16} + \mu_9 z_{15} + \mu_8 z_{14} + \mu_7 z_{13} + \mu_6 z_{12} + \mu_5 z_{11} + \mu_4 z_{10} + \mu_3 z_9 + \mu_2 z_8 + \mu_1 z_7 + z_6 = 0$

For $n = 7 \rightarrow$ $z_{17} + \mu_9 z_{16} + \mu_8 z_{15} + \mu_7 z_{14} + \mu_6 z_{13} + \mu_5 z_{12} + \mu_4 z_{11} + \mu_3 z_{10} + \mu_2 z_9 + \mu_1 z_8 + z_7 = 0$

For $n = 8 \rightarrow$ $z_{18} + \mu_9 z_{17} + \mu_8 z_{16} + \mu_7 z_{15} + \mu_6 z_{14} + \mu_5 z_{13} + \mu_4 z_{12} + \mu_3 z_{11} + \mu_2 z_{10} + \mu_1 z_9 + z_8 = 0$

For $n = 9 \rightarrow$ $z_{19} + \mu_9 z_{18} + \mu_8 z_{17} + \mu_7 z_{16} + \mu_6 z_{15} + \mu_5 z_{14} + \mu_4 z_{13} + \mu_3 z_{12} + \mu_2 z_{11} + \mu_1 z_{10} + z_9 = 0$

Solving these equations we have;

$$\begin{aligned} &\mu_9 = 0, \mu_8 = 1, \mu_7 = \mu_6 = 0, \mu_5 = \mu_4 = 1, \\ &\mu_3 = 0, \mu_2 = \mu_1 = 1 \end{aligned} \quad (35)$$

Thus, the equivalent linear shift register as showing previosly in the Figure 6.

Example 3.

Given the following received periodic sequence $\{z_n\}$;

000001000010000, 000001000010000….. (36)

The period of the sequence is 2^4-1 = 15 and as showing is not orthogonal t. e. is nonlinear sequence and we need find the nonlinear feedback shift register which generates it and the linear equivalent to it that are; origin sequence $\{a_n\}$, the terms of it which they are under the multiplication operation, finding h the number of these terms, and the linear equivalent to the nonlinear shift register.

There are to prime polynomials of degree 4 they are; $g(x) = x^4 + x^3 + 1$ and $f(x) = x^4 + x + 1$.

We will study the nonlinear sequences generated by given nonlinear feedback shift register corresponding to the polynomials under the multiplication operation on four degrees and there are only one sequence for each of the prime polynomial, after that three degrees and there are only 4 sequences for each of the prime polynomial, and after that for two degrees for each of them one by one.

First step.

For the polynomial $g(x) = x^4 + x^3 + 1$ and the origin sequence $\{a_n\}$ generated with the characteristic function $g(x)$ and has the initial vector (0010) and the sequence is under the multiplication operation.

The origin sequence $\{a_n\}$ which has $g(x)$ as a characteristic polynomial and satisfies the recurrent formula $a_{n+4} + a_{n+3} + a_n = 0$ is orthogonal and periodic with the period 2^4-1=15 and is showing in the Figure 7;

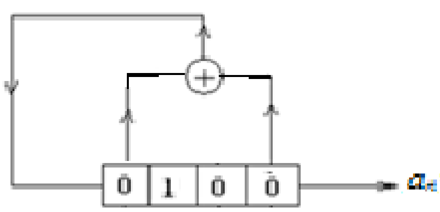

Figure 7. Linear feedback shift register with 4 complexity over F_2

And it is;

001000111101011,001000111101011……. (37)

Thus the nonlinear sequence which as a result of multiplication on all degrees of the linear shift register in the Figure 7 is;

0 0 0 0 0 0 1 0 1 0 0 1 0 0 1, 0 0 0 0 0 0 1 0 1 0 0 (38)

And it is not the same sequence $\{z_n\}$.

Second step.

For the polynomial $f(x) = x^4 + x + 1$ and the origin sequence $\{b_n\}$ generated with the characteristic function $f(x)$ and has the initial vector (0010) and the sequence is under the multiplication operation.

The origin sequence $\{b_n\}$ which has $f(x)$ as a characteristic polynomial and satisfies the recurrent formula $b_{n+4} + b_{n+1} + b_n = 0$ is orthogonal and periodic with the period 2^4-1=15 and is showing in the Figure 8;

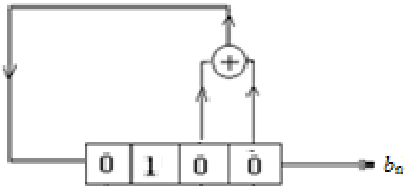

Figure 8. Linear feedback shift register generating the sequence $\{b_n\}$

And it is;

0 0 1 0 0 1 1 0 1 0 1 1 1 1 0, 0 0 1 0 0 1 1 0 1 0 1 1 1 1 0……. (39)

Thus the nonlinear sequence which as a result of multiplication on all cells of the linear shift register in the Figure 7 is;

0 0 1 0 0 1 0 0 1 0 1 0 0 0 0 0 0 0 1 0 0, 1 0 0 1 0 0 0 0 1 0 1 0 0 (40)

And it is not the same sequence $\{z_n\}$.

Third step.

We will go for finding $u_n^{(i,j,k)}$ and $w_n^{(i,j,k)}$ the nonlinear sequences over three cells of the sequences $\{a_n\}$ and $\{b_n\}$respectively which are in the previously first step one by one and we have the following;

$a)\, u_n^{(0,1,2)} =$ 0 0 0 0 0 0 1 1 0 0 0 0 0 0 0, 0 0 01 1 0 0 0 0 0 0 0 …

$w_n^{(0,1,2)} =$ 0 0 0 0 0 0 0 0 0 0 1 1 0 0 0, 0 0 0 0 0 0 0 0 0 0 0 1 1…

And both of $u_n^{(0,1,2)}$ & $w_n^{(0,1,2)}$ is not the same sequence $\{z_n\}$.

$b)\, u_n^{(0,1,3)} =$ 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0, 0 0 0 0 1 0 0 0 0 0 0 0 …

$w_n^{(0,1,3)} =$ 0 0 0 0 0 1 0 0 0 0 1 0 0 0 0, 0 0 0 0 0 1 0 0 0 0 1 0 0 0 0 0 0 …

We can see that $u_n^{(0,1,3)}$ is not the same $\{z_n\}$ but the sequence $w_n^{(0,1,3)}$ is the same and the following nonlinear shift register generates the sequence $\{z_n\}$;

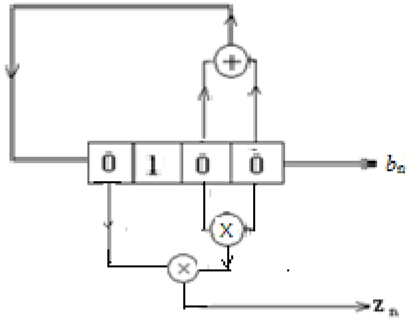

Figure 9. Nonlinear feedback shift register generating the sequence $\{z_n\}$

From (20);

$$b_n = \beta.\beta^n + \beta^2.\beta^{2n} + \beta^4.\beta^{4n} + \beta^8.\beta^{8n}$$

$$b_{n+1} = \beta^2.\beta^n + \beta^4.\beta^{2n} + \beta^8.\beta^{4n} + \beta.\beta^{8n}$$

$$b_{n+3} = \left(\beta^4\beta^n + \beta^8\beta^{2n} + \beta\beta^{4n} + \beta^2\beta^{8n}\right)$$

$$z_n = b_n.b_{n+1}.b_{n+3}$$

$$z_n = (\beta.\beta^n + \beta^2.\beta^{2n} + \beta^4.\beta^{4n} + \beta^8.\beta^{8n}).$$
$$(\beta^2.\beta^n + \beta^4.\beta^{2n} + \beta^8.\beta^{4n} + \beta.\beta^{8n}.$$
$$(\beta^5\beta^n + \beta^{10}\beta^{2n} + \beta^5\beta^{4n} + \beta\beta^{8n}$$

Or;

$$z_n = \beta^n + \beta^{2n} + \beta^{4n} + \beta^8\beta^{5n} + \beta^{7n} + \beta^{8n} + \beta^{10} + \beta^{11n} + \beta^{13n} + \beta^{14n} \quad (41)$$

Thus;

The zeros of the characteristic polynomial of the sequence $\{zn\}$are;

$$\beta^n, \beta^{2n}, \beta^{4n}, \beta^{5n}, \beta^{7n}, \beta^{8n}, \beta^{10}, \beta^{11n}, \beta^{13n}, \beta^{14n} \quad (42)$$

The characteristic polynomial of the sequence $\{zn\}$ is finding through the formula;

$$f(x) = (x - \beta^n)(x - \beta^{2n}) \,.....\, (x - \beta^{14n}) \quad (43)$$

Thus, the characteristic equation of the sequence $\{zn\}$is;

$$(x - \beta^n)(x - \beta^{2n}) \,.....\, (x - \beta^{14n}) = 0 \quad (44)$$

We can verify that;

$$\beta.\beta^2.\beta^4.\beta^5.\beta^7.\beta^8.\beta^{10}.\beta^{11}.\beta^{13}.\beta^{14n} = \beta^{75} = 1 \quad (45)$$

And the characteristic equation of the sequence $\{zn\}$is ;

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$$((x-\beta^5)(x-\beta^{10}))((x-\beta)(x-\beta^2)(x-\beta^4)(x-\beta^8))$$
$$((x-\beta^7)(x-\beta^{11})(x-\beta^{13})(x-\beta^{14}))=0 \quad (46)$$

Or;

$$x^{10}+x^5+1=0 \quad (47)$$

And the characteristic function of the linear equivalent of the nonlinear sequence $\{z_n\}$ is;

$$f(x)=x^{10}+x^5+1 \quad (48)$$

The linear equivalent feedback shift register of $\{z_n\}$ is showing in the following Figure 10;

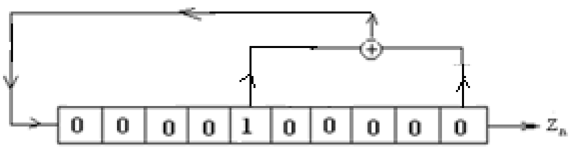

Figure 10. The equivalent linear feedback register generating sequence $\{z_n\}$

Or by inverse, we define the equivalent linear register, after that we define *h* the number of terms which are under the multiplication operation and after that we define the basic sequence which is under under the multiplication operation, namely as following;

The length of the linear equivalent of the nonlinear sequence $\{z_n\}$ is $h=\binom{4}{1}+\binom{4}{2}=10$.

The characteristic equation of the linear equivalent shift register is of the form;

$$x^{10}+\mu_9x^9+\mu_8x^8+\mu_7x^7+\mu_6x^6+\mu_5x^5+\mu_4x^4$$
$$+\mu_3x^3+\mu_2x^2+\mu_1x+1=0 \quad (49)$$

Or from the recurrent formula;

$$z_{n+10}+\mu_9z_{n+9}+\mu_8z_{n+8}+\mu_7z_{n+7}+\mu_6z_{n+6}+\mu_5z_{n+5}$$
$$+\mu_4z_{n+4}+\mu_3z_{n+3}+\mu_2z_{n+2}+\mu_1z_{n+1}+z_n=0$$

We need solve system of 9 equations (or we can take more equations if it is need) using the terms of the sequence $\{z_n\}$and the previously characteristic equation that are for n = 0,1, ….,8 as following;

For $n = 0 \rightarrow$ $z_{10}+\mu_9z_9+\mu_8z_8+\mu_7z_7+\mu_6z_6+\mu_5z_5+\mu_4z_4$
$+\mu_3z_3+\mu_2z_2+\mu_1z_1+z_0=0$

For $n = 1 \rightarrow$ $z_{11}+\mu_9z_{10}+\mu_8z_9+\mu_7z_8+\mu_6z_7+\mu_5z_6+\mu_4z_5$
$+\mu_3z_4+\mu_2z_3+\mu_1z_2+z_1=0$

For $n = 2 \rightarrow$ $z_{12}+\mu_9z_{11}+\mu_8z_{10}+\mu_7z_9+\mu_6z_8+\mu_5z_7+\mu_4z_6$
$+\mu_3z_5+\mu_2z_4+\mu_1z_3+z_2=0$

For $n = 3 \rightarrow$ $z_{13}+\mu_9z_{12}+\mu_8z_{11}+\mu_7z_{10}+\mu_6z_9+\mu_5z_8+\mu_4z$
$+\mu_3z_6+\mu_2z_5+\mu_1z_4+z_3=0$

For $n = 4 \rightarrow$ $z_{14}+\mu_9z_{13}+\mu_8z_{12}+\mu_7z_{11}+\mu_6z_{10}+\mu_5z_9+\mu_4z$
$+\mu_3z_7+\mu_2z_6+\mu_1z_5+z_4=0$

For $n = 5 \rightarrow$ $z_{15}+\mu_9z_{14}+\mu_8z_{13}+\mu_7z_{12}+\mu_6z_{11}+\mu_5z_{10}+\mu_4$
$+\mu_3z_8+\mu_2z_7+\mu_1z_6+z_5=0$

For $n = 6 \rightarrow$ $z_{16}+\mu_9z_{15}+\mu_8z_{14}+\mu_7z_{13}+\mu_6z_{12}+\mu_5z_{11}+\mu_4$
$+\mu_3z_9+\mu_2z_8+\mu_1z_7+z_6=0$

For $n = 7 \rightarrow$ $z_{17}+\mu_9z_{16}+\mu_8z_{15}+\mu_7z_{14}+\mu_6z_{13}+\mu_5z_{12}+\mu_4$
$+\mu_3z_{10}+\mu_2z_9+\mu_1z_8+z_7=0$

For $n = 8 \rightarrow$ $z_{18}+\mu_9z_{17}+\mu_8z_{16}+\mu_7z_{15}+\mu_6z_{14}+\mu_5z_{13}+\mu_4$
$+\mu_3z_{11}+\mu_2z_{10}+\mu_1z_9+z_8=0$

For $n = 9 \rightarrow$ $z_{19}+\mu_9z_{18}+\mu_8z_{17}+\mu_7z_{16}+\mu_6z_{15}+\mu_5z_{14}+\mu_4$
$+\mu_3z_{12}+\mu_2z_{11}+\mu_1z_{10}+z_9=0$

Solving these equations we have;

$$\mu_9=\mu_8=\mu_7=\mu_6=\mu_4=\mu_3=0,\mu_5=1 \quad (50)$$

And the characteristic equation is;

$$x^{10}+\ x^5++1=0 \quad (51)$$

Or;

$$(x^2+x+1)(x^4+x+1)(x^4+x^3+1)=0 \quad (52)$$

Or, the recurrent formula of the sequence $\{z_n\}$ is;

$$z_{n+10}+z_{n+5}++z_n=0 \quad (53)$$

We can check that the recurrent sequence generates the same nonlinear sequence $\{z_n\}$.

Thus, the equivalent linear shift register as showing in the previously Figure 10.

From the length of the equivalent linear shift register, which equal to 10 we can guess that the nonlinear shift register has the length 4 (4 degrees) and;

$$\binom{4}{1}+\binom{4}{2}=10\ \&\binom{4}{1}+\binom{4}{2}+\binom{4}{3}=14 \quad (54)$$

Thus, h =2 or 3 and we can go to the first step for finding the exactly the degree of multiplication operation h.

4. Conclusions

1) If the received sequence $\{z_n\}$ is orthogonal and periodic with the period $r = 2k$-1 then the sequence is linear and has linear shift feedback register with the complexity (length) equal to k and we can find the linear feedback shift register using the initial vector (α_0, α_1, … ,αk-$_1$ = z_0, z_1, … ,zk-$_1$).

2) If $\{z_n\}$is periodic with the period $2k$ -1, the linear equivalent of sequence $\{z_n\}$ has the length;

$$_{r}N_2 = \binom{r}{1} + \binom{r}{2} = r + \frac{r(r-1)}{2}$$

and then the set of all cyclic permutations of one period of $\{z_n\}$is not an orthogonal set then $\{z_n\}$is multiplication on only two degrees of recurring sequence $\{an\}$ and the characteristic polynomial of the sequence $\{an\}$ is prime polynomial of degree *k*.

3) If the multiplication sequence $\{z_n\}$ is periodic with the period 2*k* -1 or divide it and the linear equivalent register of $\{z_n\}$ has the complexity *m* where $m \leq {}_kN_t$ (*t* is the latest natural for the inequality is true) then $h \geq t$ (*h* is the number of terms of the original recurring sequence $\{an\}$ which are under the multiplication operation) and the characteristic polynomial of the sequence $\{an\}$is prime polynomial of degree *k*. Thus from the period of $\{z_n\}$ we can define *k* the degree of the characteristic polynomial of the original sequence $\{a_n\}$ and then from the length of the linear equivalent of $\{z_n\}$ we can define *h* the number of terms from $\{z_n\}$ which are under the multiplication operation.

4) If the multiplication sequence $\{z_n\}$ is periodic with the period 2*k* -1 or divide it then we can define *k* the degree of

characteristic polynomial of the sequence $\{an\}$which is a prime polynomial and after that we can define the original sequence $\{an\}$and the terms of it which are under the multiplication operation that is we can define *h* then through these terms we can define *m* the complexity of linear equivalent register of the multiplication sequence $\{z_n\}$. Thus from the period of $\{z_n\}$ we can define *k* the degree of the characteristic polynomial of the original sequence $\{a_n\}$ and then from k we can define *h* the number of the terms which are under the multiplication operation after that we can find m the complexity of linear equivalent of the sequence $\{z_n\}$.

5) Knowing he construction of the nonlinear register of the original sequence $\{a_n\}$ giving us all codes (or commands) which sending through it and how we can to influence it.

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Appendix 1.

List of the primitive polynomials on F_2^n

x^2 + x^1 + 1
x^3 + x^1 + 1
x^4 + x^1 + 1
x^5 + x^2 + 1
x^5 + x^4 + x^2 + x^1 + 1
x^5 + x^4 + x^3 + x^2 + 1
x^6 + x^1 + 1
x^6 + x^5 + x^2 + x^1 + 1
x^6 + x^5 + x^3 + x^2 + 1
x^7 + x^1 + 1
x^7 + x^3 + 1
x^7 + x^3 + x^2 + x^1 + 1
x^7 + x^4 + x^3 + x^2 + 1
x^7 + x^5 + x^4 + x^3 + x^2 + x^1 + 1
x^7 + x^6 + x^3 + x^1 + 1
x^7 + x^6 + x^4 + x^2 + 1
x^7 + x^6 + x^5 + x^2 + 1
x^7 + x^6 + x^5 + x^4 + x^2 + x^1 + 1
x^8 + x^4 + x^3 + x^2 + 1
x^8 + x^5 + x^3 + x^1 + 1
x^8 + x^6 + x^4 + x^3 + x^2 + x^1 + 1
x^8 + x^6 + x^5 + x^1 + 1
x^8 + x^6 + x^5 + x^2 + 1
x^8 + x^6 + x^5 + x^3 + 1
x^8 + x^7 + x^6 + x^1 + 1
x^8 + x^7 + x^6 + x^5 + x^2 + x^1 + 1
x^9 + x^4 + 1
x^9 + x^5 + x^3 + x^2 + 1
x^9 + x^6 + x^4 + x^3 + 1
x^9 + x^6 + x^5 + x^3 + x^2 + x^1 + 1
x^9 + x^6 + x^5 + x^4 + x^2 + x^1 + 1
x^9 + x^7 + x^6 + x^4 + x^3 + x^1 + 1
x^9 + x^8 + x^4 + x^1 + 1
x^9 + x^8 + x^5 + x^4 + 1
x^9 + x^8 + x^6 + x^5 + 1
x^9 + x^8 + x^6 + x^5 + x^3 + x^1 + 1
x^9 + x^8 + x^7 + x^2 + 1
x^9 + x^8 + x^7 + x^3 + x^2 + x^1 + 1
x^9 + x^8 + x^7 + x^6 + x^5 + x^1 + 1
x^9 + x^8 + x^7 + x^6 + x^5 + x^3 + 1
x^10 + x^3 + 1
x^10 + x^4 + x^3 + x^1 + 1
x^10 + x^6 + x^5 + x^3 + x^2 + x^1 + 1
x^10 + x^8 + x^3 + x^2 + 1
x^10 + x^8 + x^4 + x^3 + 1
x^10 + x^8 + x^5 + x^1 + 1
x^10 + x^8 + x^5 + x^4 + 1
x^10 + x^8 + x^7 + x^6 + x^5 + x^2 + 1
x^10 + x^8 + x^7 + x^6 + x^5 + x^4 + x^3 + x^1 + 1
x^10 + x^9 + x^4 + x^1 + 1
x^10 + x^9 + x^6 + x^5 + x^4 + x^3 + x^2 + x^1 + 1
x^10 + x^9 + x^8 + x^6 + x^3 + x^2 + 1
x^10 + x^9 + x^8 + x^6 + x^5 + x^1 + 1
x^10 + x^9 + x^8 + x^7 + x^6 + x^5 + x^4 + x^3 + 1

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EDITORIAL

The Development and Creation of Intelligent Systems in the Next One Hundred Years

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Today the intelligent systems are technological implemented as advanced machines [1] which have high perception, interaction and response to the real world being in much cases an extension of the reality, anticipating events, intertwining remote events, saving life and predicting preferences of human been [2,3] through of robust programming and electronic systems with high performance, optimization and design in operations where are required machines with an strong and complete interacting with the environment [2]; environment which also goes increasing until; in the very near future, to the ends of the Universe.

Likewise, much of these systemic problems and automatized process require more research in the artificial intelligence and advanced computing, even in the quantum context where all logical and praxio-logical process must be realized under M-sequences as alternative in the pseudorandomnian context, although in the quantum context are extended in the domain of the energy states.

The information security problems require increasingly the development of machine learning in security strategies [4], where the election of information in the cloud computing computations or the remote collaborative work can establish intelligent technologies-teams that can struggle to develop adequate security strategies with the multitude of devices on ever-expanding corporate networks, for example in a technological firms [5] or international enterprises and industry. Protecting investments is critical for business survival and growth, yet IoT security presents unique challenges [8].

From a point of view on the technical devices and technical details in programming, the key factors that have contributed to the growth of the intelligent systems are the development of an exponential growth of processor speed and memory capacity, increasing its memory to operative sequences more complex, as well as algorithmic advances. Likewise the intelligent systems include in the expertise research the development factory automation, assistive robotics, medical care where in this case the artificial intelligence and biomedical sciences require a joint work to preservation of life [6,7]. Also in education and academic remote work, the intelligent systems are of great importance, for example in the last pandemic situation has

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been evident this work form as an good work form and could be implemented now as an alternative more useful to collaborative work in academia, scientific research and even in ambit of medical remote treatments [4,7] where now exist some examples in Germany, United Kingdom, for example, where is performed surgery. Newly in the security systems will be relevant the development of intelligent systems in military applications, biometrics and remote surveillance and saving [6,8]. The speed of reaction to a sinister or dangerous events must be done in immediately and of form optimal. Here for example, integrated systems with platforms that can to reduce the average time taken by cyber security professionals to respond to cyber incidents.

The electrical and electronic world will require deep research and innovative development accord with the obtained intelligent systems in advanced sensors and transducers [9,10], these last with unlimited energy capacity to permanent functioning in all necessary processes in anyway and anywhere. New branches and extensions of electronics and electrical sciences, as the photonics and spintronics will be necessaries in the next years with the accelerated development of intelligent systems in a new dynamics where the communications will require more effectiveness and efficiency, even in quantum communication [9], where this last is starting with new referents in information theory, (QED) quantum electrodynamics and new materials with the nanotechnology implementations [11,12]. In the searching of the more speed computers superconducting materials will be fundamentals and also semi-conductor materials in processes of the energy interchange on the base of the spintronic devices, which will require spin interactions to move singular particles as new information objects in supercomputers to special and advanced effects in the Universe [13].

Finally, the engineering in all fronts will be vital in the survival of the human race, having more preponderance the digital systems, electronics and electrical sciences, because we must care our natural environment with clean energies, and save the Earth.

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ARTICLE

Performance Assessment of Motorized Solar Photovoltaic Louvers System Using PVSYST Software

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ABSTRACT

In the realm of technological market penetration of solar photovoltaic louvers (PVL) addressing environmental difficulties and the industrial revolution, a new avenue of renewable energy is introduced. Moreover, solar energy exploitation through building façades was addressed through motorized solar photovoltaic louvers (MPVL). On the other hand, proponents exalted the benefits of MPVL overlooking the typical analyses. In this communication, we attempted to perform a thorough industrial system evaluation of the MPVL. This communication presents a methodology to validate the industrial claims about MPVL devices and their economic efficiency and the insight on how geographical location influences their utilization and augment their potential benefits. This task is carried out by evaluating the extent of solar energy that can be harvested using solar photovoltaic system (PVSYST) software and investigating whether existing product claims are associated with MPVL are feasible in different locations. The performance and operational losses (temperature, internal network, power electronics) were evaluated. To design and assess the performance of different configurations based on the geographical analogy, simulation tools were successfully carried out based on different topographical locations. Based on these findings, various factors affect the employment of MPVL such as geographical and weather conditions, solar irradiation, and installation efficiency. tt is assumed that we successfully shed light and provided insights into the complexity associated with MPVL.

1. Introduction

As fossil fuel dependency over the years increased paralleled with its severe environmental consequences, alternative energy resources had received grave attention [1]. Most countries are considering solar energy as a primary candidate for harnessing alternative sources of energy. The overall energy that can be obtained from the sun is 1.8 x 10^{11} MW which is more than enough on the human required energy consumption [2]. These abundant clean energy can be directly harnessed through numerous techniques such as thermal and photovoltaic (PV) energy harvesting. Among these technological advances, PV is favored due to its propagation addressing the clean energy resource dilemma by utilizing abundant solar energy by directly capturing solar irradiation and converting it instantaneously to electrical energy. Currently, this technology is already industrially utilized providing clean

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energy [3,4]. Likewise, technological advances regarding renewable energy are still in peril, recent evolution of smart devices transformed the traditional solar cells into a structural-functional segment through the incorporation of this technology into the louvers system. Considering the performance and aesthetics that consumers seek for their homes. The demand for advancement gives triggered the development of solar photovoltaic louvers (PVL) which serve as an energy harvesting system that simultaneously acts as a solar shading system. PVL acts like venetian blinds that block a compelling amount of solar radiation from entering the building's window reducing the cooling operating cost. The rising popularity of PVL applications can be attributed to their suitability for newly developed zero energy and zero-carbon building design, as well as their ability to help reach benchmarks defined by building energy labels [5,6].

Traditional PV is situated in a fixed angular stature concerning the sun's optimal irradiation but this design creates a shadowed area between the blind slits. This leads to a reduction in the PVL efficiency and its energy harvesting capability. Therefore, manipulation of the angular stature of the PVL considering the sun direction to harvest the optimal solar radiation is considered. Formative development was employed to progressively utilize the abundant solar irradiation through the incorporation of sun-tracking ability on PVL or motorized solar photovoltaic louvers (MPVL). The smaller dimension of PVL compared to the traditional PV system enables PVL the liberty to do the necessary angular movement to track the sun and gather the optimum energy at a given time. This will allow a maximal depth of inflow of solar light to the PV module [7,8].

Despite the progress made from a technology point of view, implementing MPVL remains non-trivial from a technical standpoint, and validating the claims regarding this technology is still imperative. Therefore, a need to provide standard analyses to quantify the total power generated from the MPVL systems with the optimized behaviors and functionality [5]. Economic advantage is often overlooked in cost analyses regarding the efficiency trade-off of the proposed technology, energy generation requires significant investment in infrastructure and energy operating costs that could potentially not be recovered by insufficient power generation. Hence, an evaluation of solar MPVL electricity production and consumption was thoroughly scrutinized. Few would dispute this view, but the magnitudes of these effects have not been systematically quantified. The MPVL commercial product information in conjunction with the theoretical photovoltaic system analysis was thoroughly scrutinized to estimate the potential savings of this technology. In this paper, we use PVSYST software to assess the MPVL feasibility relative to the industrially available products [9]. The comparative power production of theoretical and commercial solar MPVL allows us to discuss the economics of solar MPVL power generating efficiency, with the consideration of operational factors such as the energy cost to drive the sun tracking ability of the system [10]. To clarify where this research fits in the debate, we presented the basic approach to valuing solar PVL power using PVSYST software to analyze the MPVL power generation. The economic feasibility and viability of MPVL solar harvesting implementation relative to geographical location were mainly aimed on the simulation. By analyzing the energy production, performance ratio, efficiency, and cost to determine the optimal location feasibility.

2. Experimental

Accurate simulation of the MPVL devices requires integrated energy simulation tools to properly evaluate and analyze the PVL electricity production. The methodology presented in this paper is a step up from the existing work that had applied a fully parametric PVL model to evaluate both daylighting and energy-related parameters to validate its flexibility for commercial or residential projects. The PVsyst simulation tool was used to validate the effect of geographical topology on energy harvesting efficiency. PVsyst is a simulation software was designed to calculate the necessary data for the operation of a PV system. This software provides the probable energy generation of a specified system which is used for the design and configuration of the PV system. The generated information is based on the scaled simulation which is highly influenced by the topology site of the PV system. Results may consist of several simulations variables that can be presented at monthly, daily, or hourly rates. The simulation can also predict the flaw in the design through system and collection losses [2]. The overall research goal is to provide a guide in building and applying PVL. The idea is to provide insights on the transcribed PVL limitations with the symmetrical features and attempt to maximize solar energy by system adopting the configuration from the combination of different geometrical locations.

3. Results and Discussion

3.1 Geographical and Location Correlation on Solar Energy Harvesting of MPVL

PV infrastructure become rampant these past few years as a part of the green energy transition. Progressive development of the PV system garnered the employment

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of MPVL intending to optimize the solar harvesting capability. This led to the design modification to track the sun through the angular movement of sectioned PV grid. This will allow optimum energy harvesting capability. And PVsyst software was utilized to determine the effectiveness of this advancement relative to topographical location. All figures were generated through the simulation measurements on three different locations. Demonstrated in Figure 1 is a visual representation of the simulation design. The panels are programmed to track the sun movement following the peak of solar radiation through single-axis orientation. It is well understood that the location greatly affects the power generation in terms of PV systems which is highly influenced by the location weather. This confirms the power harvesting feasibility of a certain location. In this research work, PVSYST software was used to simulate the energy harvesting capability of MPVL on different locations (Seoul, Cairo, and New York) in a daily setting in a year.

All the figures, tables are depicted here in the paper are generated during the simulation process. As this paper represents the computational modeling, we present our simulated results of a small system MPVL, all measurements are based on different scenarios at different cities Seoul, Cairo, and New York. Temporal efficiency and energy harvesting capacity of MPVL depending on the location variation can be realized [11]. The azimuth is varied from 0 to 90°, the incident solar energy radiation was tracked by the MPVL system ensuring a perpendicular sunlight projection. Modifying the azimuth angle any time of the day and month of the year. Due to the elliptical sun path on the celestial sphere, different solar heights can be observed at different locations on earth [12]. Evaluation of the power transmission capacity through PVSYST software is demonstrated. Shown in Figure 2 a-c is the sun path on different locations (Seoul, Cairo, and New York). The graph depicts the attenuation of solar light diffusivity with relative shading loss parametric relative to the angular orientation of the MPVL. It can be discerned that Cairo demonstrated a higher solar height followed by Seoul and lastly New York. This can be correlated to the locational advantage of Cairo being situated in the middle latitude of the equator. The solar path demonstrated the same trend in Cairo having wider solar attenuation, the wider asymptotic azimuthal projection starting from 10-14 h. On the other hand, Seoul demonstrated a narrower solar path which can be correlated to the lower sun height which leads to lower solar attenuation [8]. The solar path of New York was found to be the lowest among the three locations attributable to the reduction of radiation transmission and locational constraints [11]. To meteorological and incident energy of the investigated locations were elaborated through the interpretation of global horizontal irradiation (GlobHor) and diffuse irradiation (DiffHor) as presented in Tables 4, 8, and 12. Presenting the overall global incident energy (GlobHor and DiffHor) on the collection plane of Seoul (1,183 and 756 KWh/m^2), Cairo (1,891 and 826 KWh/m^2), and New York (1,429 and 677 KWh/m^2), confirming that Cairo has the highest incident energy compared to Seoul and New York. It can be concluded solar energy transmission and harvesting are highly dependent on location which gravely affects the utilization of MPVL in specific areas [5].

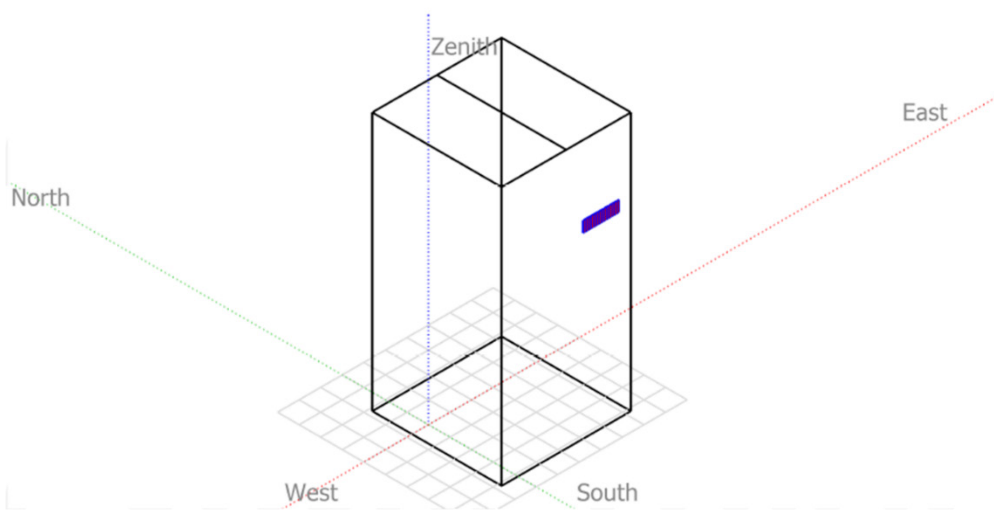

Figure 1. The perspective of the PV field and surrounding shading scene.

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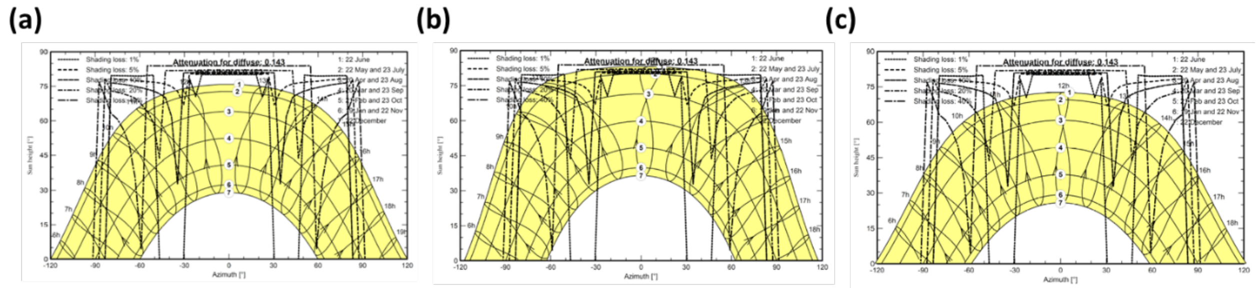

Figure 2. Sun path in (a) Seoul, (b) Cairo and (c) New York

3.2 Performance Analysis

It has been valued that onsite PV power generation offers an advantage through clean energy harvesting. The incremental modification had been developed infusing functionality on the PV system through seamless infusion on the existing infrastructure through MPVL. Like any other power-generating infrastructure, MPVL requires a significant amount of investment. Evaluation of the efficiency and economic advantage is imperative. Therefore, PVSYST software was utilized to build a systematic simulation. PVSYST software has been chosen due to its accuracy, simplistic operation, and diverse functions, it provides daylighting analysis, solar radiation, and harvesting performance. All the results presented are achieved through the design simulation. The simulation produces monthly data for one year. The setting for the analysis are as follows: tracking axis 0-90°, rotating phi limits -60-60°. Performance assessments of MPVL on different locations were thoroughly scrutinized. Comparison of the data sets simulated from three different locations has been conducted and summarized in Figure 3 a-f and Table 12. These data will serve as a representation of the actual installation of MPVL panels taking to account the fluctuation in the solar radiation [13]. This data is also particular on the losses and effect of orientation, operation, obstructions, and other factors that affect the efficiency of solar MPVL. The energy production has a monthly increment with substantial variation relative to geographical location as discussed earlier. Monthly energy production fluctuation is also observed reflecting the weather change throughout the year, with Cairo having the most linear yearly energy production accounting for the limited weather fluctuation in the area. Seoul has a sharp drop in energy yield in the middle of the year due to seasonal weather transitions. And New York has an almost plateau monthly energy output. The monthly trend influence the yearly power generation with Seoul having 1,704 kWh/year, Cairo 2,281 kWh/year, and New York 2,276 kWh/year. The performance ratio (PR) of the MPVL is the ratio of the final PV system yield (Y_f) and the reference yield (Y_r) as referred on equation 1 [2]. It can be noticed that even though Cairo demonstrated a higher energy harvesting probability compared to New York based on the earlier assessment their yearly energy output is almost the same. Rendering a performance ratio of 0.578, 0.492, and 0.550 (Seoul, Cairo, and New York) in each location leaving Cairo the lowest energy conversion. This can be ascribed to the collection loss in Cairo due to the location's thermal effect disseminating a massive amount of energy during solar harvesting compromising the efficiency of the system. Even though Seoul was placed on the lower solar irradiation and yearly power generation among the three cities, it garnered the highest performance ratio due to its low energy collection loss. The two categories of PV energy losses are collection loss and system loss. The system losses are fairly average throughout the year and not influenced by the location, attributed to an anavoidabale system limitation of partial shading. On the other hand, collection loss affects the efficiency of the system the most which can be described as energy loss in wiring and voltage intolerance [14]. Influence by the month of the year and highly confide in the locational situation which can be ascribed on the effect of the regional weather conditions. The results shown in the tables for each location present the detailed calculation of energy production and variables that govern the energy losses.

$$PR = \frac{Y_f}{Y_r} \quad (1)$$

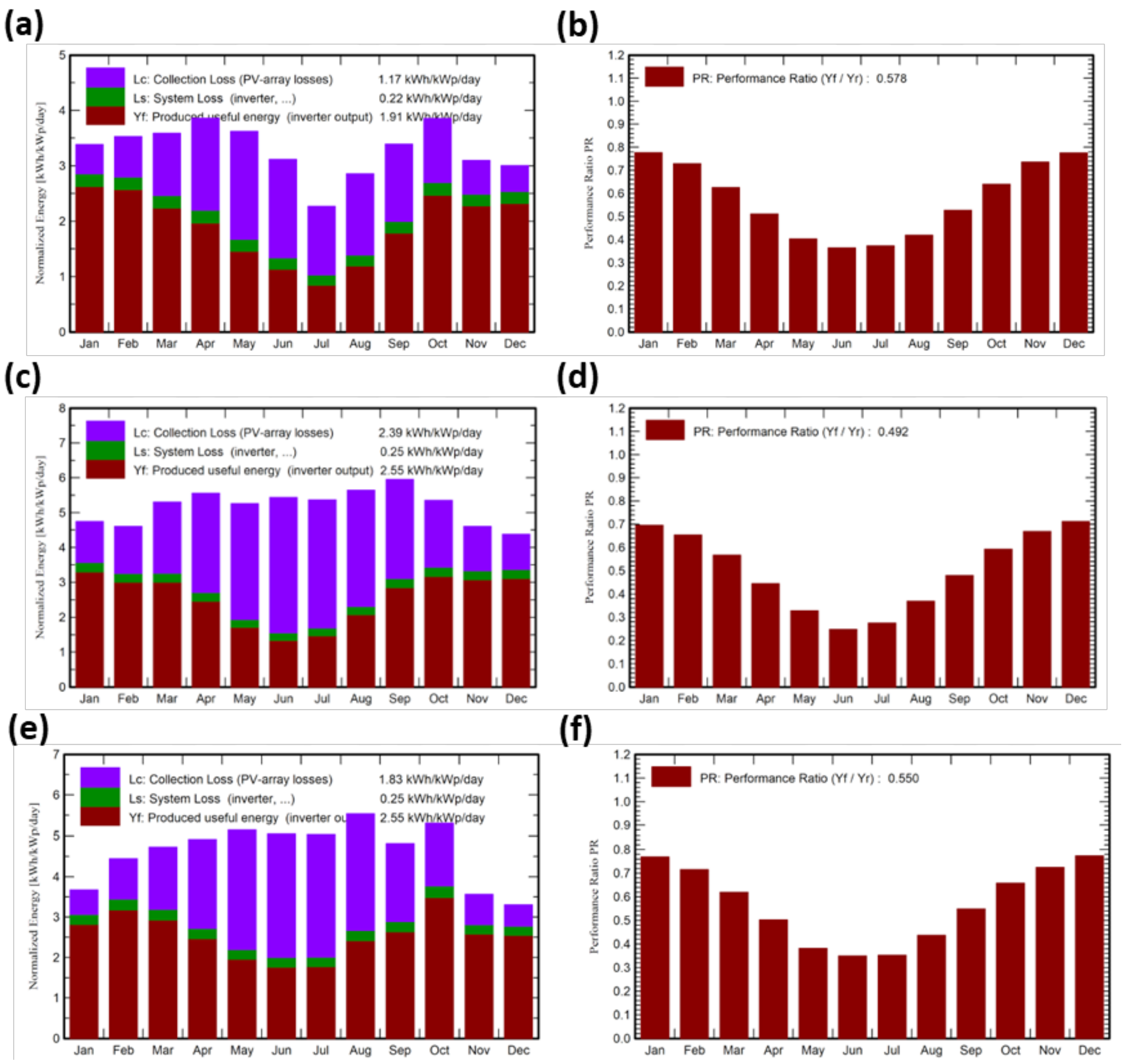

Figure 3. Monthly normalized energy production and performance ratio in (a-b)Seoul, (c-d) Cairo, and (e-f) New York.

Table 1. Normalized performance coefficients of MPVL system yielded in Seoul simulation.

	Yr kWh/m²/day	Lc ratio	Ya kWh/kWp/day	Ls ratio	Yf kWh/kWp/day	Lcr ratio	Lsr ratio	PR ratio
January	3.39	0.525	2.86	0.231	2.63	0.155	0.068	0.777
February	3.53	0.727	2.80	0.229	2.57	0.206	0.065	0.729
March	3.58	1.118	2.47	0.224	2.24	0.312	0.063	0.626
April	3.86	1.661	2.20	0.227	1.97	0.430	0.059	0.511
May	3.62	1.947	1.68	0.216	1.46	0.537	0.060	0.403
June	3.11	1.771	1.34	0.207	1.14	0.569	0.067	0.365
July	2.27	1.235	1.03	0.186	0.85	0.545	0.082	0.373
August	2.85	1.459	1.39	0.199	1.20	0.511	0.070	0.419
September	3.39	1.397	2.00	0.210	1.79	0.412	0.062	0.527
October	3.86	1.154	2.70	0.233	2.47	0.299	0.060	0.640
November	3.10	0.607	2.49	0.211	2.28	0.196	0.068	0.736
December	3.00	0.460	2.54	0.214	2.33	0.153	0.071	0.775
Year	3.29	1.173	2.12	0.215	1.91	0.356	0.065	0.578

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Table 2. Meteo and incident energy of 1 M^2 PV system in Seoul.

	GlobHor kWh/m²	DiffHor kWh/m²	T_Amb °C	WindVel m/s	GlobInc kWh/m²	DifSInc kWh/m²	Alb_Inc kWh/m²	DifS_GI ratio
January	62.6	34.84	-2.26	2.6	104.9	14.34	6.25	0.000
February	77.1	47.85	0.32	2.7	98.7	18.41	7.68	0.000
March	107.0	67.40	5.58	3.0	111.1	25.08	10.67	0.000
April	130.1	81.67	12.04	2.9	115.8	29.28	12.98	0.000
May	145.0	91.27	17.56	2.6	112.3	32.45	14.48	0.000
June	132.6	89.15	21.38	2.4	93.4	31.57	13.22	0.000
July	101.5	72.85	24.36	2.4	70.3	27.08	10.12	0.000
August	110.2	75.81	25.14	2.4	88.5	27.96	10.99	0.000
September	104.7	67.61	20.53	2.1	101.8	25.27	10.43	0.000
October	95.3	55.39	14.65	2.1	119.5	21.47	9.51	0.000
November	62.6	39.76	6.77	2.4	92.9	15.78	6.23	0.000
December	54.1	32.27	-0.07	2.5	93.0	13.32	5.40	0.000
Year	1183.0	755.88	12.23	2.5	1202.5	282.00	117.95	0.000

Table 3. Detailed system losses of the MPVL simulation in Seoul.

	ModQual kWh	MisLoss kWh	OhmLoss kWh	EArrMPP kWh	InvLoss kWh
January	-1.698	4.694	1.614	217.2	17.52
February	-1.499	4.145	1.223	192.0	15.68
March	-1.462	4.042	1.087	187.4	17.02
April	-1.261	3.487	0.805	161.7	16.70
May	-0.991	2.740	0.479	127.2	16.41
June	-0.768	2.124	0.314	98.7	15.25
July	-0.611	1.689	0.250	78.5	14.15
August	-0.825	2.281	0.438	105.9	15.08
September	-1.145	3.166	0.808	146.8	15.40
October	-1.604	4.434	1.460	205.3	17.71
November	-1.430	3.954	1.288	183.0	15.53
December	-1.508	4.169	1.383	193.0	16.27
Year	-14.803	40.925	11.148	1896.7	192.71

Table 4. Balances and main results of MPVL system yielded in Seoul simulation.

	Yr kWh/m²/day	Lc ratio	Ya kWh/kWp/day	Ls ratio	Yf kWh/kWp/day	Lcr ratio	Lsr ratio	PR ratio
January	3.39	0.525	2.86	0.231	2.63	0.155	0.068	0.777
February	3.53	0.727	2.80	0.229	2.57	0.206	0.065	0.729
March	3.58	1.118	2.47	0.224	2.24	0.312	0.063	0.626
April	3.86	1.661	2.20	0.227	1.97	0.430	0.059	0.511
May	3.62	1.947	1.68	0.216	1.46	0.537	0.060	0.403
June	3.11	1.771	1.34	0.207	1.14	0.569	0.067	0.365
July	2.27	1.235	1.03	0.186	0.85	0.545	0.082	0.373
August	2.85	1.459	1.39	0.199	1.20	0.511	0.070	0.419
September	3.39	1.397	2.00	0.210	1.79	0.412	0.062	0.527
October	3.86	1.154	2.70	0.233	2.47	0.299	0.060	0.640
November	3.10	0.607	2.49	0.211	2.28	0.196	0.068	0.736
December	3.00	0.460	2.54	0.214	2.33	0.153	0.071	0.775
Year	3.29	1.173	2.12	0.215	1.91	0.356	0.065	0.578

Table 5. Normalized performance coefficients of MPVL system yielded in Cairo simulation.

	Yr kWh/m²/day	Lc ratio	Ya kWh/kWp/day	Ls ratio	Yf kWh/kWp/day	Lcr ratio	Lsr ratio	PR ratio
January	4.75	1.167	3.58	0.274	3.31	0.246	0.058	0.696
February	4.60	1.342	3.26	0.252	3.01	0.291	0.055	0.654
March	5.31	2.039	3.27	0.260	3.01	0.384	0.049	0.567
April	5.56	2.845	2.72	0.250	2.47	0.512	0.045	0.444
May	5.26	3.312	1.94	0.222	1.72	0.630	0.042	0.327
June	5.43	3.874	1.56	0.220	1.34	0.713	0.041	0.247
July	5.37	3.673	1.69	0.217	1.48	0.684	0.040	0.275
August	5.65	3.335	2.31	0.232	2.08	0.591	0.041	0.368
September	5.95	2.835	3.12	0.260	2.86	0.476	0.044	0.480
October	5.35	1.911	3.44	0.265	3.17	0.357	0.050	0.593
November	4.61	1.267	3.34	0.258	3.08	0.275	0.056	0.669
December	4.38	1.005	3.38	0.258	3.12	0.229	0.059	0.712
Year	5.19	2.389	2.80	0.247	2.55	0.461	0.048	0.492

Table 6. Meteo and incident energy of 1 M^2 PV system in Cairo.

	GlobHor kWh/m²	DiffHor kWh/m²	T_Amb °C	WindVel m/s	GlobInc kWh/m²	DifSInc kWh/m²	Alb_Inc kWh/m²	DifS_GI ratio
January	94.6	44.65	14.06	3.5	147.2	18.22	9.46	0.000
February	106.7	58.95	15.73	3.7	128.9	22.13	10.65	0.000
March	157.7	74.60	18.86	4.2	164.5	26.89	15.74	0.000
April	186.7	85.05	21.89	4.3	166.9	28.85	18.65	0.000
May	213.8	92.53	26.09	4.2	162.9	30.11	21.34	0.000
June	219.4	86.03	28.40	4.0	163.0	27.92	21.92	0.000
July	220.1	83.33	29.84	3.6	166.4	27.31	21.97	0.000
August	200.9	83.85	29.93	3.5	175.1	28.30	20.06	0.000
September	170.2	68.40	27.75	3.6	178.5	24.78	17.01	0.000
October	135.9	61.55	24.76	3.4	165.8	23.38	13.57	0.000
November	98.4	45.13	19.95	3.0	138.2	18.11	9.82	0.000
December	86.8	41.71	15.97	3.3	135.8	16.95	8.64	0.000
Year	1891.3	825.79	22.81	3.7	1893.2	292.95	188.83	0.000

Table 7. Detailed system losses of the MPVL simulation in Cairo.

	ModQual kWh	MisLoss kWh	OhmLoss kWh	EArrMPP kWh	InvLoss kWh
January	-2.128	5.883	2.328	271.9	20.82
February	-1.749	4.835	1.586	223.8	17.30
March	-1.939	5.361	1.699	248.2	19.74
April	-1.558	4.306	1.061	199.7	18.35
May	-1.149	3.178	0.584	147.6	16.87
June	-0.893	2.468	0.368	114.7	16.18
July	-1.002	2.771	0.467	128.7	16.50
August	-1.369	3.785	0.848	175.6	17.62
September	-1.789	4.945	1.507	229.0	19.09
October	-2.042	5.646	2.060	261.1	20.14
November	-1.921	5.311	2.222	245.4	18.94
December	-2.007	5.549	2.288	256.4	19.57
Year	-19.546	54.037	17.017	2502.1	221.10

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Table 8. Balances and main results of MPVL system yielded in Cairo simulation.

	GlobHor	DiffHor	T_Amb	GlobInc	GlobEff	EArray	E_Grid	PR
	kWh/m²	kWh/m²	°C	kWh/m²	kWh/m²	kWh	kWh	ratio
January	94.6	44.65	14.06	147.2	121.8	271.9	251.1	0.696
February	106.7	58.95	15.73	128.9	99.6	223.8	206.5	0.654
March	157.7	74.60	18.86	164.5	111.8	248.2	228.5	0.567
April	186.7	85.05	21.89	166.9	90.5	199.7	181.3	0.444
May	213.8	92.53	26.09	162.9	68.0	147.6	130.7	0.327
June	219.4	86.03	28.40	163.0	53.6	114.7	98.5	0.247
July	220.1	83.33	29.84	166.4	60.4	128.7	112.2	0.275
August	200.9	83.85	29.93	175.1	82.2	175.6	158.0	0.368
September	170.2	68.40	27.75	178.5	106.9	229.0	209.9	0.480
October	135.9	61.55	24.76	165.8	121.5	261.1	241.0	0.593
November	98.4	45.13	19.95	138.2	113.2	245.4	226.4	0.669
December	86.8	41.71	15.97	135.8	116.1	256.4	236.8	0.712
Year	1891.3	825.79	22.81	1893.2	1145.4	2502.1	2281.0	0.492

Table 9. Normalized performance coefficients of the MPVL system yielded in New York simulation.

	Yr	Lc	Ya	Ls	Yf	Lcr	Lsr	PR
	kWh/m²/day	ratio	kWh/kWp/day	ratio	kWh/kWp/day	ratio	ratio	ratio
January	3.67	0.596	3.07	0.250	2.82	0.162	0.068	0.769
February	4.45	0.995	3.45	0.271	3.18	0.224	0.061	0.715
March	4.73	1.536	3.19	0.264	2.93	0.325	0.056	0.619
April	4.91	2.193	2.72	0.253	2.47	0.446	0.052	0.502
May	5.13	2.933	2.20	0.243	1.96	0.571	0.047	0.381
June	5.06	3.048	2.01	0.240	1.77	0.603	0.047	0.350
July	5.04	3.030	2.01	0.236	1.77	0.601	0.047	0.352
August	5.54	2.867	2.67	0.253	2.42	0.518	0.046	0.437
September	4.81	1.923	2.89	0.253	2.64	0.400	0.053	0.548
October	5.30	1.531	3.77	0.287	3.49	0.289	0.054	0.657
November	3.56	0.743	2.82	0.235	2.58	0.209	0.066	0.725
December	3.30	0.525	2.77	0.225	2.55	0.159	0.068	0.773
Year	4.63	1.832	2.80	0.251	2.54	0.396	0.054	0.550

Table 10. Meteo and incident energy of 1 M^2 PV system in New York.

	GlobHor	DiffHor	T_Amb	WindVel	GlobInc	DifSInc	Alb_Inc	DifS_GI
	kWh/m²	kWh/m²	°C	m/s	kWh/m²	kWh/m²	kWh/m²	ratio
January	56.3	23.45	0.36	3.6	113.7	10.43	5.59	0.000
February	74.7	33.16	1.39	3.7	124.5	13.94	7.44	0.000
March	113.5	52.21	5.97	3.7	146.6	20.68	11.31	0.000
April	142.1	70.36	11.61	3.4	147.3	26.38	14.18	0.000
May	174.2	87.37	16.77	2.8	159.2	31.54	17.41	0.000
June	179.6	90.18	21.47	2.6	151.7	31.73	17.94	0.000
July	176.1	82.91	24.42	2.5	156.3	29.96	17.60	0.000
August	170.4	75.53	24.05	2.3	171.7	27.78	17.01	0.000
September	125.3	62.63	19.84	2.5	144.4	23.86	12.50	0.000
October	106.6	44.45	13.80	2.8	164.4	18.24	10.64	0.000
November	59.5	28.95	8.78	3.1	106.9	12.26	5.92	0.000
December	51.1	25.41	3.20	3.5	102.3	10.86	5.08	0.000
Year	1429.3	676.60	12.70	3.0	1688.8	257.66	142.62	0.000

Table 11. Detailed system losses of the MPVL simulation in New York.

	ModQual kWh	MisLoss kWh	OhmLoss kWh	EArrMPP kWh	InvLoss kWh
January	-1.829	5.055	2.304	233.4	18.99
February	-1.852	5.120	1.994	236.7	18.57
March	-1.895	5.240	1.836	242.4	20.03
April	-1.560	4.312	1.232	199.8	18.60
May	-1.303	3.603	0.760	167.2	18.48
June	-1.149	3.178	0.614	147.5	17.65
July	-1.191	3.292	0.706	152.7	17.96
August	-1.583	4.378	1.212	202.9	19.22
September	-1.660	4.590	1.530	212.4	18.63
October	-2.243	6.201	2.525	286.6	21.82
November	-1.623	4.487	1.926	207.3	17.30
December	-1.650	4.561	1.931	210.7	17.08
Year	-19.538	54.014	18.569	2499.5	224.32

Table 12. Balances and main results of MPVL system yielded in New York simulation.

	GlobHor kWh/m²	DiffHor kWh/m²	T_Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray kWh	E_Grid kWh	PR ratio
January	56.3	23.45	0.36	113.7	100.0	233.4	214.4	0.769
February	74.7	33.16	1.39	124.5	100.6	236.7	218.1	0.715
March	113.5	52.21	5.97	146.6	104.3	242.4	222.4	0.619
April	142.1	70.36	11.61	147.3	87.5	199.8	181.2	0.502
May	174.2	87.37	16.77	159.2	74.2	167.2	148.7	0.381
June	179.6	90.18	21.47	151.7	66.6	147.5	129.9	0.350
July	176.1	82.91	24.42	156.3	70.1	152.7	134.8	0.352
August	170.4	75.53	24.05	171.7	93.0	202.9	183.6	0.437
September	125.3	62.63	19.84	144.4	96.5	212.4	193.8	0.548
October	106.6	44.45	13.80	164.4	128.2	286.6	264.7	0.657
November	59.5	28.95	8.78	106.9	91.5	207.3	190.0	0.725
December	51.1	25.41	3.20	102.3	91.4	210.7	193.6	0.773
Year	1429.3	676.60	12.70	1688.8	1104.0	2499.5	2275.2	0.550

3.3 Factors Affecting the MPVL Utilization

According to the results discussed, the topological location impacts the feasibility of MPVL. Not only relying on the solar potential of each cities, there are other governing factors plays in the economic standpoint of MPVL such as panel type, compounding material, capacity, inflation rate and country's policies. The policies in various countries are highly dependent on the countries financial capability to support subsidies, tax policies, monetary policies and price policies. Some countries leading the efforts to switch and adopt renewable energy by implementing different policies such as; feed-in tariffs, tendering, net metering and fiscal incentives. Nevertheless, renewable energy expanding support leads to the deployment of large scale projects. Feed-in tariffs are the most commonly used form of legislative support to the renewable power sector, MPVL utilization maybe favoured on one country than the other, some countries provide more promising opportunities. Such countries optimized the renewable energy policy and renewable energy developments to yield a clear solution to decrease CO_2 emissions. Results confirmed the substantial difference between economic performance on subsidies and non subsidies energy consumption. Financial support is important on building these system. The high initial cost of MPVL discourage people on replacing traditional energy sources from fossil fuel and adopting this green energy alternative sources. Deployment of various policies have been recognized all over the world which culminated a positive growth on the MPVL infrastructures all over the world. However, to make MPVL available as an option in everyone all over the world, the following policies are highly recommended.

- Energy price reform that provides consumers loans for purchasing of MPVL.
- Reduction on fossil fuel subsides, since these policies hinders the deployment and development of MPVL.
- Tax exemption on producers and consumers of green energy.

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- Deployment of MPVL in commercial sector.
- Structural change on the sector that holds a more decisive role on energy production. Tax increase might be considered on fossil fuel produce energy.
- Strategically positioning the MPVL structures on places with long sun hours.
- Public education regarding the importance of replacing fossil fuel based energy with green energy.

These strategies must be employed by the governmental institution decreasing the friction on green energy utilization and fulfilling the responsibility of reducing carbon imprint and fossil fuel based energy. The deployment of MPVL provided an alternative and functional solution. Overall, high installation cost, limited knowledge and lack of governmental subsidy still limits the rampant utilization of MPVL.

4. Conclusions

This article aimed to validate the proposed performance of the MPVL using PVSYST software to design a solar harvesting simulation demonstrated in different geographical locations (Seoul, Cairo, and New York). The findings of the analysis were thoroughly scrutinized to demonstrate the feasibility of MPVL on the exploitation of solar energy on a multi-domain façade. The results also supported the assumption that advanced simulation tools can be used to standardize façade configurations, efficient MPVL system is designed for a grid-connected environment using PVsyst software. The designed MPVL simulation confirmed the viability of installing testing solar harvesting in different topological locations. These findings can be used to validate and will set a basis for MPVL construction feasibility. The analysis not only validated the MPVL configuration but also clear the tradeoffs that affect the energy harvesting efficiency.

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