ANALYTICAL TECHNIQUE FOR VISUALIZING BUFFER OVERFLOW ATTACKS COMBINED WITH CODE POINTER INTEGRITY CHECKING

T.E. Akhigbe-Mudu, F. T. Ibharalu, Akinwale A.T

Department of Computer Science, Federal University of Agriculture, Abeokuta, Nigeria

Abstract: *A buffer is a region of physical memory storage that holds a specific amount of data and when that capacity is reached, the data will overflow. A buffer overflow is a condition where in the data transferred to a buffer exceeds the storage capacity. Buffer overflow is susceptible to attacks therefore, creates a necessity for intrusion detection systems. This paper combines code pointer integrity with buffer overflow visualization to address overflows attacks. During monitoring and detection stage, users are requested to introduce some data at a time and when an overflow is detected, the system will process and display appropriate buffer status. Colors are used to represent the different level of operations. A model to analyze the buffer behavior of the random process is derived. The effectiveness of our technique is confirmed through a visualization experiment. Result shows that transmission process is suspended when buffer overflows thus facilitate intrusion analysis.*

Keywords: - *Buffer-overflow, visualization, model and integrity check.*

1.0 INTRODUCTION

In computer science, a buffer is a region of a physical memory storage used temporarily to move data between processes within a computer. Buffers are used for many purposes including: - interconnecting two digital circuits operating at different rates, holding data for later use, allowing timing corrections to be made on a data stream, collecting binary data bits into groups that can then be operated on as a unit, delaying the transition time of a signal in order to allow other operations to occur etc. Buffer has a storage capacity and can only hold a specific amount of data, and when that capacity has been reached, the data has to overflow to somewhere else. A buffer overflow is the condition where in the data transferred to a buffer exceeds the storage capacity of the buffer and some of the data overflows into another buffer, one that the data was not intended to go into [K+12].

The Internet is fast becoming useful in the communication and commercial sectors of our everyday life. This had led to increasing number of attacks designed to infiltrate or disrupt the activities being performed by companies and individuals on the internet. We mean the networks are under constant attack by malicious users, creating a necessity for intrusion detection systems. In this paper the problem of buffer overflow attacks is addressed. Buffer overflow is the result of writing more data into a buffer than the buffer can hold. This happens when a program receives input, and stores the input to a buffer without checking the buffer's boundary [VC12]. Buffer overflow occurs when the aggregate arrival rate exceeds the buffer service rate, causing the buffer to fill and overflow. Buffer overflows have been the most common form of security vulnerability in the recent times. There are many ways that programmers may introduce flaws into programs, such as by failing to limit the size of data written into a buffer (e.g. calling the C/C++ *strcpy* function without checking to see if the source string will fit into the destination buffer), or miscalculating the size or limit of data written into a buffer (e.g. failing to account for the null terminator that will be written to the buffer by a string concatenation function, causing the size to be off by one). Buffer overflow attacks form a substantial portion of all security attacks simply because buffer overflows vulnerabilities are so common and so easy to exploit [AA04]. Buffer overflow vulnerabilities particularly dominate in the class of remote penetration attacks because buffer overflow vulnerability presents the attacker with exactly what they need: - the ability to inject and execute attack code. The injected attack code runs with the privilege of the vulnerability program and allows the attacker to bootstrap whatever other functionality is needed to control the host computer. The overall goal of a buffer overflow attack is to subvert the function of a privileged program so that the attacker can take control of that program and if the program is sufficiently privileged, thence control the host. For an Attack to succeed it needs to accomplish the following tasks: - (1) arrange for suitable code to be available in the program's address space. (2) Get the program to jump to that code, with suitable parameters loaded into register and memory. We categorize buffer overflow attacks in terms of achieving these sub-goals. There are two ways to arrange for the attack code to be in the victim program's address space: - (1) either inject it, or use what is already there. **Inject it**: - the attacker provides a string as input to the program, which the program stores in a buffer. The string contains bytes that are actually native CPU instructions for the platform being attacked. Here the attacker is abusing the victim program's buffers to store the attack code. The attacker does not have to overflow any buffer to do this. It is already there: - often the code to do what the attacker wants is already present in the program's address space [Jaw12, Chi06]. Ways to Cause the Program to Jump to the Attackers' Code: - All of these methods seek to alter the program's control flow so that the program will jump to the attack code. The basic method is to overflow a buffer that has weak or non – existent bounds checking on its input with a goal of corrupting the state of an adjacent part of the program's state, e.g. adjacent pointers. **Activation Records: -** Each time a function is called, it lays down an activation records on the stack that includes, among other things, the return address that the program should jump to when the function exists, i.e. point at the code injected. Attacks that corrupt activation record return addresses overflow automatic variables i.e. buffers local to the function. By corrupting the return address in the activation record, the attacker causes the program to jump to attack code when the victim function returns and dereferences the return address [C+00]. This form of buffer overflow is called a "stack smashing attack".

2.0 RELATED WORK

Computer networks complexity has increased lately so also the complexity of defending against cyber attacks. This has caused researchers to develop tools to aid the security analysts to make the data more bearable to sort and understand. More recent research has focused on identifying the threats and impact of attacks to the computer network. Intrusion detection systems (IDS) analyze network traffic for malicious activity [VC12]. When potentially malicious or suspicious activity is detected, alerts are sent to the security analysts. When alerts are generated, analysts must quickly determine whether the activity has any current or future negative impact on the monitored network. [SB12] stated that intrusion detection systems are protective measures such as virtual private networks, authentication mechanisms or encryption techniques are very important to guarantee information security. They help to defend against the various threats to which networks and hosts are exposed to by detecting the actions of attackers or attack tools in a network or host – based manner with misuse or anomaly detection techniques. [A+12] expressed further that IDS should be situation aware in the sense that at any point in time it should know what is going on in its environment regarding attack instances. He made an important step towards this goal by introducing and evaluating a new technique for alert aggregation. [BP12] suggested that alerts that belong to one attack instance must be generated to analyze the ongoing attack instances. Most existing IDS are optimized to detect attacks with high accuracy. However, they still have various disadvantages that have been outline in a number of publications and a lot of work has been done to analyze IDS in order to direct future research [SP12]. Another approach to buffer overflow alert correlation is presented by [SB12], where a weighted attribute - wise similarity operator is used to decide whether to fuse two alerts or not. However, this approach suffers from high number of parameters that need to be set. The similarity operator presented in [KI12] has the same disadvantage – there are lots of parameters that must be set by the user and there is no or only little guidance in order to find good values. In [KI10], another clustering algorithm that is based on attribute- wise similarity measures with user defined parameters is presented. However, a closer look at the parameters setting reveals that the similarity measure, in fact, degenerates according to the source and destination IP addresses and ports of the alerts. The draw backs that arise therefore are the same as those mentioned above. In [Jaw12], three different approaches are presented to fuse alerts. The first group alerts according to their source IP only. The other two approaches are based on different supervised learning techniques. Besides a basic least – square error approach, radial basis function networks and decision in trees are used to decide whether to fuse a new alert with an already existing alert [C+10]. Due to the supervised nature, labeled training data need to be generated which could be quite difficult in case of various attacks instances. Drawback is the large amount of alerts produced.

3.0 METHODOLOGY

The basic idea is to visualize the buffer status during operation with overflow indicator, to prevent buffer overflow attacks. We therefore, combined code pointer integrity checking (CPIC) with buffer overflow alert (BOA) to visualize the buffer during operations. During the detection, users are required to introduce some sizable digits at a time and when an overflow is detected, the system will automatically process the detection result. Colors are used to represent the different levels of operations. The main analytic problem in this case is the determination of the buffer overflow probability. A common feature found in many computer communication systems is that message generation, is usually of a bursty nature. Therefore a model to analyze the buffer behavior during operation is derived, based on the analogy between the buffer occupancy in a discrete time model and the waiting time of M/M/1 queuing system.

3.1 BUFFER BEHAVIOUR MODEL

We assume a situation where we have a concentrating node which receives messages from a number of sources and transmits them over a single aggregate output channel. We clearly have a situation where queue is important – the messages are queued in a buffer for transmission. The streams of messages generated from terminals or data from computers are usually not steady flows: - they are quite often sporadic or bursty [KK77, TS11]. The buffer's capacity and its storage allocation strategy are of great importance for the cost effective design of a computer communication system. Therefore, the analysis of buffer behavior, particularly, of the buffer overflow probability is of considerable importance. Let us consider a discrete time system in which λ_k data units arrive in the kth slot for transmission (or processing). During the same interval μ_k data units will be sent (or processed). We assume that the two processes $\{\lambda_k, \mu_k\}$ are such that the difference $\{\gamma_k\}$ is defined by:

$$\{\gamma_k\} = \lambda_k - \mu_k \qquad 1 \le k < \infty \tag{1}$$

Let L be the size of the buffer capacity. Sometimes the buffer will be completely full and at these times the excess $\{\gamma_k\}$ of arrival over service will be lost and we call this event a buffer overflow [Chy12].
The traffic intensity

$$\rho = \frac{\lambda}{\mu} \tag{2}$$

Following [Ken53] notation, a queue may be specified in the form A/B/C/K/m/Z. Hence A specifies the inter – arrival time distribution, B the service time distribution, C the number of servers, K the system capacity, m the number in the source and Z the queue discipline. The shorter notation is used here: (M/M/1). This is a single server queue distribution model with exponential inter- arrival and service time distribution [Chy12]. We are considering a queue system with an arrival rate λ, service rate μ and a probability $P_t(t)$ of having k – customers (including that being served at time t). In computer communication system, a customer is typically a message, packet, job, transaction etc. It is the unit of operational flow through a queuing system known in the traditional language of queuing theory [CKO11, NM10]. The system is represented by a state diagram (figure 1) where state k corresponds to having k – customers in the system. Movement between the states is by customers arriving (moving to a higher state) or completing service (moving to a lower state). Note also that $\sum P_k = 1$

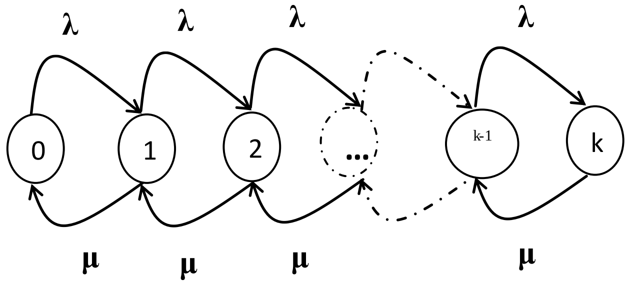

Figure 1: state space diagram

The state S_k corresponds to the queuing system containing K – customers and occurs with a probability P_k. Let's consider first the two states S_0 (empty system) and S_1 (a single customer). The state moves from S_0 to S_1 by a customer arriving and the change occurs with frequency λP_0. Similarly the state moves from S_1 to S_0 by the customer completing service, and the change occurs with frequency μP_1. In equilibrium (steady state) the two must be equal and

$$\lambda P_0 = \mu P_1 \tag{3}$$

Considering **the probabilities of entering and leaving** S_1, we have that

$$\lambda P_0 + \mu P_2 = \mu P_1 + \lambda P_1 \tag{4}$$

But as $\lambda P_0 = \mu P_1$, we have $\lambda P_1 = \mu P_2$
in general,

$$\lambda P_k = \mu P_{k+1} \tag{5}$$

Setting $\rho = \dfrac{\lambda}{\mu}$ and simplifying for P_k, we have

$$P_k = \rho^k P_0 \tag{6}$$

Since the unknown quantities are probabilities, the sum of all probabilities is: $p_0 + p_1 + p_2 + ... = 1$ i.e.

$$\sum_{k=0}^{\infty} \rho^k P_0 = 1 \tag{7}$$

As P_0 is the probability that the system is idle and ρ is the probability that the system is busy, it is clear that

$$P_0 = 1-\rho \tag{8}$$

Using the sum of geometric series, we obtain

$$P_k = (1-\rho)\rho^k \tag{9}$$

The mean number of customers in the system, N is

$$N = \sum_{k=0}^{\infty} kP_k = (1-\rho)\sum_{k=0}^{\infty} K\rho^k \tag{10}$$

Which gives

$$N = \frac{\rho}{1-\rho} \tag{11}$$

As the average number being served is ρ, the average number waiting in the queue is $N-\rho$

i. e. $L_q = \dfrac{\rho}{1-\rho} - \rho$

$$= \frac{\rho^2}{1-\rho} \quad \text{(number in queue)} \tag{12}$$

Applying little's formula, which states that if the N – customers are in the system for an average time T, Then $N = \lambda T$ (Little's formula), the time spent waiting is,

$$W_q = \frac{L_q}{\lambda}$$
$$= \frac{\rho^2}{1-\rho}\left(\frac{1}{\lambda}\right) = \frac{\rho}{1-\rho}\left(\frac{\lambda}{\mu}\right)\left(\frac{1}{\lambda}\right)$$
$$= \left(\frac{\rho}{1-\rho}\right)\left(\frac{1}{\mu}\right) \quad \text{time in queue} \tag{13}$$

Average time in the system,

$$W = \frac{N}{\lambda} = \frac{\rho}{1-\rho}\left(\frac{1}{\lambda}\right) \tag{14}$$

Multiplying by $\mu, W = \dfrac{1}{\mu-\lambda}$ (15)

For the finite buffer case, we denote the buffer occupancy sequence by {b$_k$ }, and defined as,

$$b_k = \begin{cases} b_{k-1} + C_k \le 0 \\ b_k + C_k \quad 0 \le b_{k-1} + c_k \le L \\ L \le b_{k-1} + c_k \end{cases} \tag{16}$$

And compare it with $\{\chi_k\}$ defined as,

$$\chi_k = \max\{0, \chi_{k-1} + c_k\} \tag{17}$$
$$b_1 = \min\{L, \max\{0, c_1\}\} \le \max\{0, c_1\} = \chi_1 \tag{18}$$

We assume that $b_k \le \chi_k$ for some k, then for k+1:

$$b_{k+1} = \begin{cases} \min\left\{L, \max\left\{0, b_k + C_{k+1}\right\}\right\} \\ \le \min\{L, \max\{0, \chi_k + c_{k+1}\}\} \\ \le \max\{0, \chi_k + c_{k+1}\} = \chi_{k+1}\} \end{cases} \tag{19}$$

Thus we have shown by mathematical induction that
$b_k \le \chi_k \qquad \forall$ k

Since the maximum value that b_k can take is L, it follows that,

$$P\{b_k = L\} \le P\{\chi_k \ge L\} \quad \text{For all k} \tag{20}$$

Let us denote the distribution of the random variables b_k and χ_k in the limit as $k \to \infty$ by $P_L(n)$ and $P_\infty(n)$ respectively.
Then equation (20) becomes,

$$P_L(L) \le \sum_{n=L}^{\infty} P_\infty(n) = F_x(L-1) \tag{21}$$

Where F_x is the distribution function of x.
Solving for the upper bound, the probability of buffer capacity L is full,

$$P_L(L) \le B_{z_0}^{-(L-1)} \le B_{Z_0}^{*\,-(L-1)} \tag{22}$$

Where B_{z_0} the root of the characteristic equations determined by the input and output statistics.
The quantity $P_{overflow}(L)$ is therefore defined as,

$$P_{overflow}(L) = \frac{offeredload - carriedload}{offeredload}$$
$$= \frac{\gamma_k}{E(\lambda_k)} \tag{23}$$

Where (γ_k) is the expected amount of data lost per time in slot k and this upholds equation (1).

3.2 Implementation

We combine the tasks of monitoring and detecting buffer overflow into one unique system interface. As shown in figure 2, our interface is composed of three windows:- buffer topology windows (bottom middle), and target window (right) and history window (top left). The topology window visualizes the current buffer topology, where users can interact with the topology with several routines tasks. The target window lists the different level of the buffer during operation with overflow indicator. We also collect information of each level of buffer operation for analysis, such as traffic history :- (buffer density, inbound and out bound). To handle buffer overflow attacks in real time environment, we need to integrate user interaction with our buffer overrun detection and visualization methods. During the detection, the users are only required to introduce some sizable digits at a time and when an overflow is detected, the system will automatically process the detection result. Colors are used to represent the different level of operations – red indicating a possible overflow, blue color indicates active behavior of the buffer and yellow color indicates passive behavior of the buffer [S+10]. The top left locates the history window, bottom left includes parameter window and topology interaction window and the right lists the information of the potential buffer state.

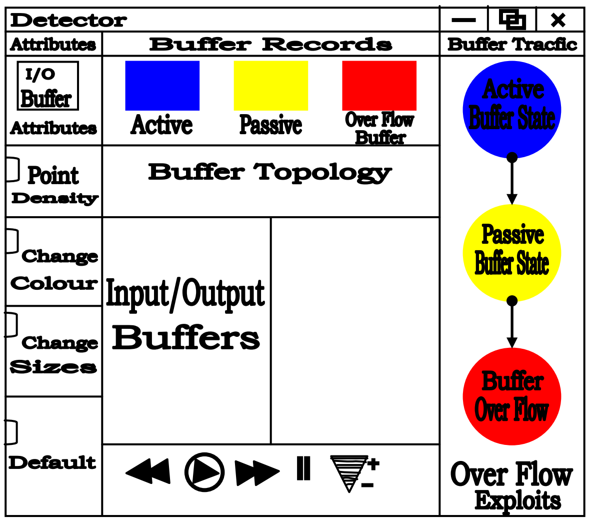

Figure 2: Buffer overflows detection

4.0 EVALUATION

In our sample evaluation, we combine the task of monitoring and detecting buffer overflow into one unique interface. Our basic idea is to visualize the buffer status during transmission to prevent buffer overflow. We Create tcp client socket in connecting to server and this is shown in our algorithms (figure 3a and 3b). The main loop of the algorithms, generate the data to send (here we generate random text using a user defined functions). It converts the data to send to array of bytes and check if the bytes to be sent are greater than the buffer size (step 8) and (step 8.1) of the buffer algorithms. Colors are used to represent the different level of operations – red indicating a possible buffer overflow, blue color indicates active behavior of the buffer and yellow color indicates passive behavior of the buffer. When buffer is overflowing, the transmission is suspended till the buffer queue is eased out. The sent data is displayed on the client output window and increases the number of sent packets by 1. The received data is displayed on the server output window and increases the received packets by 1. A sample run of these algorithms is displayed in figure 4(a) and 4(b) respectively.

<u>BUFFER MONITOR ALGORITHM: CLIENT</u>

```
Step 1: Obtain server IP and port number
    1.1 Create a variable to hold the server IP address
    1.2 Create tcp client socket to use in connecting to server.
    1.3 Declare and initialize variables: Sent, Vs=0; Received, Vr=0; Discarded, Ds=0
Step 2: Connect to the tcp server using the tcp client
Step 3: Generate the data to send (Here we generate random texts using a user defined functions our data)
Step 4: Compute the checksum of the data to send
Step 5: Make the checksum value a 10-digit string by padding 0s to the beginning of the value if the number of digits of the computed value is less than 10.
Step 6: Append the 10-digit checksum value to the beginning of the generated data to be sent
Step 7: Convert the data to send to array of bytes.
Step 8: Check if the byte to be sent is greater than the buffer size.
    8.1 If packet size > buffer size discard packet. Set Ds=Ds+1
        Else Send byte data to server
Step 9: Display appropriate buffer indicator. Yellow when it is passive, Blue when active and Red when packet has been discarded.
Step 10: Display sent data on the client output window and increase the number of sent packets by 1
    10.1 Set Vs=Vs+1
    10.2 Wait for response from server. Server is of the format CHECKSUM#ACK
Step 11: Receive response from server
    11.1 Check if received message ends with the string #ACK
    11.2 If message ends with #ACK, get the checksum by replacing #ACK in the received message with empty string
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        11.3  Display received data on the server
              output window and increase the number of
              received packets by 1.
              Set Vr=Vr+1
Step 12: Close tcp client socket
Step 13: End
```

Figure 3a: Buffer monitor algorithm- Client

PACKET COUNTER ALGORITHM: SERVER

```
Step 1: Obtain IP and port number
        1.1  Create a variable to hold the server
             IP address
        1.2  Create tcp listener to use in listening
             to connection from clients.
        1.3  Create tcp socket to use in receiving
             data/sending response to client
While (server is still running)
Begin
Step 2: Initialize tcp listener
Step 3: Start listening for connection at a specific
        port (5002 used for this implementation)
Step 4: Initialize the receiving buffer. Buffer size
        used is 8192 bytes
Step 5: Tcp socket accepts an incoming connection
Step 6: Read the received message from the buffer
        and convert it to characters.
Step 7: Store the converted message in a string variable
Step 8: Extract the first 10 digits which is the
        checksum value and store in a variable chk
Step 9: Extract the main message from position 11 to
        the end and store in variable msg
Step 10: Compute the checksum value for the
         message stored in msg and store in variable
         chksum. Pad up the checksum value with 0s
         to make it a 10-digit string
Step 11: Compare the value of chk(received
         checksum) and chksum(computed checksum)
Step 12: If (chk = chksum)
              12.1  Display the received message
                    on the standard output device
              12.2  Send an acknowledgement
                    message with the format
                    chksum#ACK to the client
        Step 13: Close tcp socket
        Step 14: Close tcp listener
End While
Step 15: End
```

Figure 3b: Buffer overflows Algorithms - server

4.1 Experimental Result

In order to merit the simulation model, appropriate statistical methods are essentially required to validate and verify the simulation results.

One way to achieve this is by using a statistical technique and determines the precision of our model. Let X be the number of repeated independent trials and the measure of probability, P(x), associated with our x – variable is determined by x's relative position with respect to the mean and standard deviation of the distribution. A binomial variable is discrete, whereas the normal random variable is continuous, therefore, we use a histogram to illustrate that the area of each bar over the value of x has an area equal to the probability (figure 5). The addition and / or subtraction of (0.5) to the x – value involved is commonly referred to as the continuity correction factor [Jon76]. It becomes our method for converting from a discrete to a continuous variable. Now let's look at a normal distribution and the probability representation therein. We first need a normal distribution with a mean and standard deviation, mean, $\mu = np$, $\sigma = \sqrt{npq}$ and the number of trials, n is 8. Therefore, $\mu = 4$, $\sigma = 1.4$ and the key to working with normal distribution is the standard score, $\mathbf{Z} = \frac{x-\mu}{\sigma}$

Recall that one of the basic properties of probability is that the sum of all probabilities is exactly 1.0. Since the area under the normal curve must be exactly one unit, then the area under the curve to the right of the mean is exactly $\frac{1}{2}$ unit, and to the left, it is also $\frac{1}{2}$ unit.

P(0.5 < $\mathbf{Z}$<1.5) = $P\left(\frac{0.5-4}{1.4}\right) \not\leq \mathbf{Z} \angle P\left(\frac{1.5-4}{1.4}\right)$
= 0.04

P (1.5 <Z < 2.5) = 0.17, P (2.5 < Z < 3.5) = 0.34
P (3.5 < Z < 4.5) = 0, P (4.5< Z < 5.5) = 0.31
P (5.5 < Z < 6.5) = 0.16, P (6.5 < Z < 7.5) = 0.04
P (7.5 < Z < 8.5) = 0.01

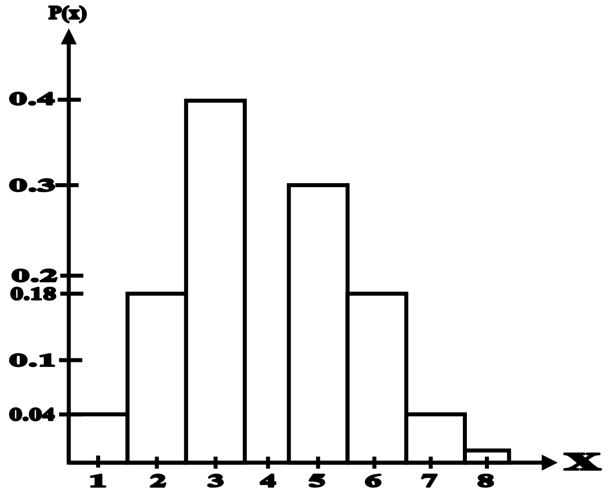
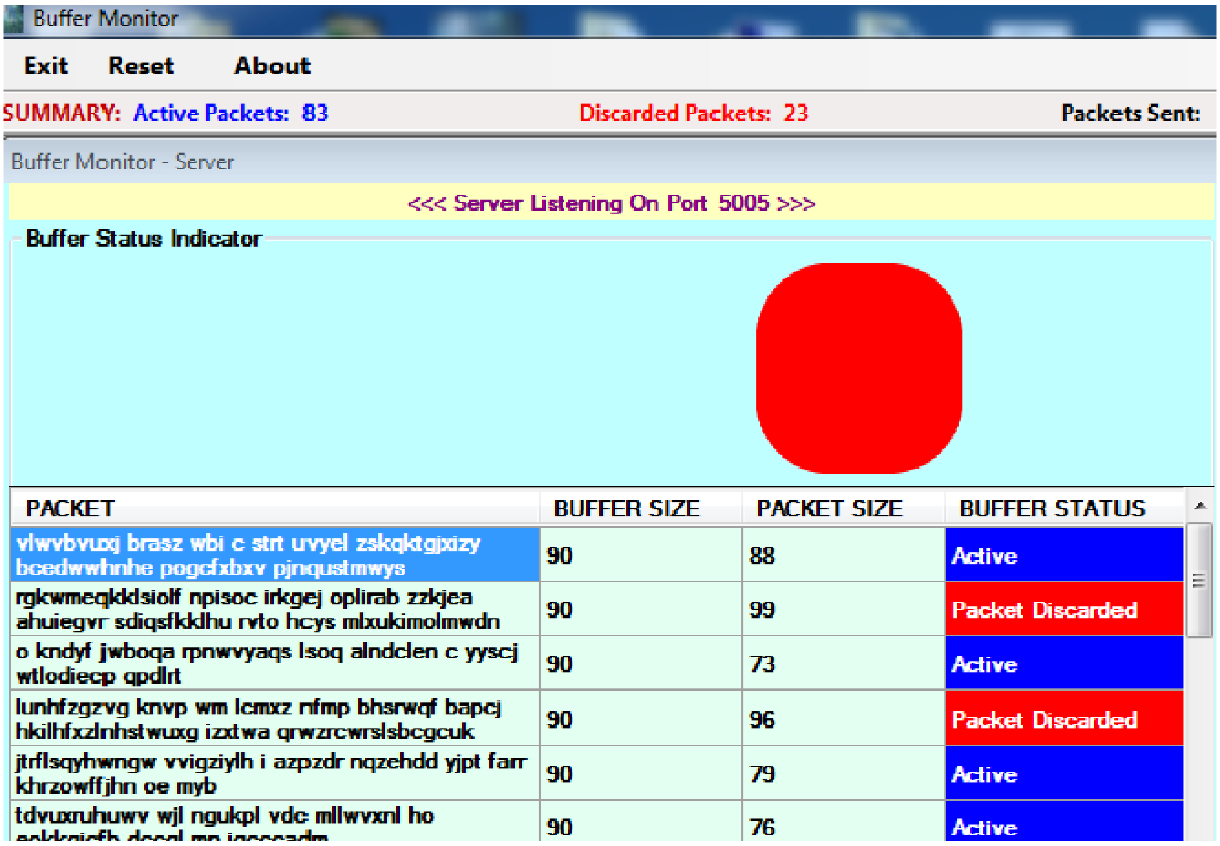


Figure 5: Histogram showing the detection accuracy

Result obtained shows that suspending transmission when buffer overflows greatly reduces the chance of buffer overflow attacks while preserving the functionality and performance of the systems. Thus improving the effectiveness of intrusion response

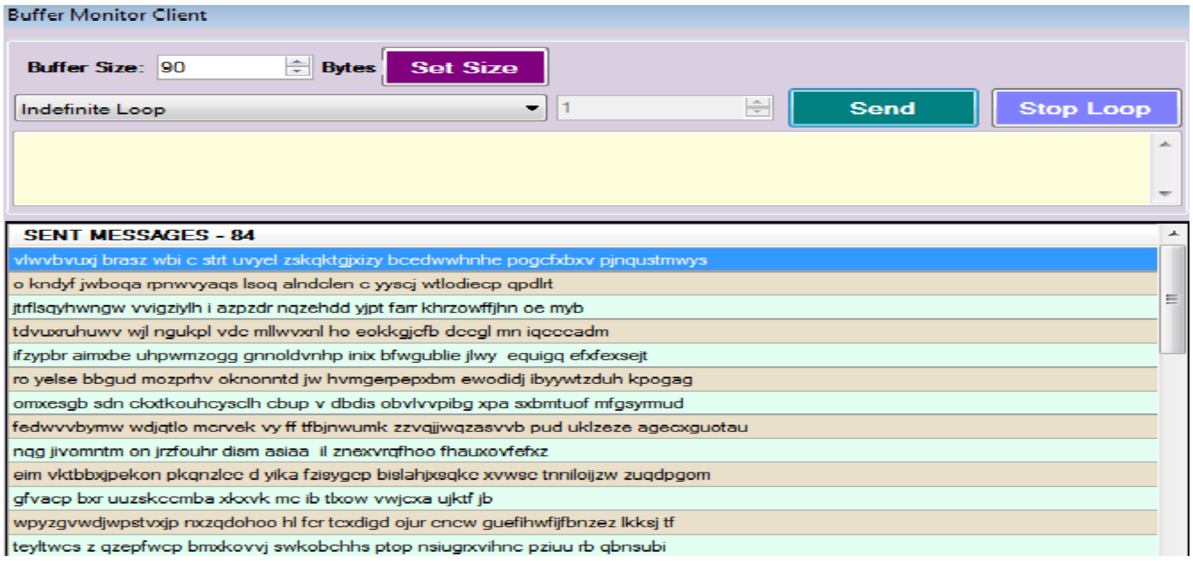


SUMMARY: Active Packets: 83 Discarded Packets: 23 Packets Sent:

<<< Server Listening On Port 5005 >>>

PACKET	BUFFER SIZE	PACKET SIZE	BUFFER STATUS
vlwvbvuxj brasz wbi c strt uvyel zskqktgjxizy bcedwwhnhe pogcfxbxv pjnqustmwys	90	88	Active
rgkwmeqkkdsiolf npisoc irkgej oplirab zzkjea ahuiegvr sdiqsfkkdhu rvto hcys mlxukimolmwdn	90	99	Packet Discarded
o kndyf jwboqa rpnwvyaqs lsoq alndclen c yyscj wtlodiecp qpdlrt	90	73	Active
lunhfzgzvg knvp wm lcmxz nfmp bhsrwqf bapcj hkilhfxzlnhstwuxg izxtwa qrwzrcwrslsbcgcuk	90	96	Packet Discarded
jtrflsqyhwngw vvigziylh i azpzdr nqzehdd yjpt farr khrzowffjhn oe myb	90	79	Active
tdvuxruhuwv wjl ngukpl vdc mllwvxnl ho	90	76	Active

Figure 4(a) showing a sample run from the algorithm



SENT MESSAGES - 84

```
vlwvbvuxj brasz wbi c strt uvyel zskqktgjxizy bcedwwhnhe pogcfxbxv pjnqustmwys
o kndyf jwboqa rpnwvyaqs lsoq alndclen c yyscj wtlodiecp qpdlrt
jtrflsqyhwngw vvigziylh i azpzdr nqzehdd yjpt farr khrzowffjhn oe myb
tdvuxruhuwv wjl ngukpl vdc mllwvxnl ho eokkgjcfb dccgl mn iqcccadm
ifzypbr aimxbe uhpwmzogg gnnoldvnhp inix bfwgublie jlwy  equigq efxfexsejt
ro yelse bbgud mozprhv oknonntd jw hvmgerpepxbm ewodidj ibyywtzduh kpogag
omxesgb sdn ckxtkouhcysclh cbup v dbdis obvlvvpibg xpa sxbmtuof mfgsyrmud
fedwvvbymw wdjqtlo mcrvek vy ff tfbjnwumk zzvqjjwqzasvvb pud uklzeze agecxguotau
nqg jivomntm on jrzfouhr dism asiaa  il znexvrqfhoo fhauxovfefxz
eim vktbbxjpekon pkqnzlcc d yika fzisygcp bislahjxsqkc xvwsc tnniloijzw zuqdpgom
gfvacp bxr uuzskccmba xkxvk mc ib tlxow vwjcxa ujktf jb
wpyzgvwdjwpstvxjp rxzqdohoo hl fcr tcxdigd ojur cncw guefihwfijfbnzez lkksj tf
teyltwcs z qzepfwcp bmxkovvj swkobchhs ptop nsiugrxvihnc pziuu rb qbnsubi
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Figure 4(b) showing a sample run from the algorithm

5.0 CONCLUSION

This paper presents an analytical technique for visualizing buffer overflow attacks. Buffer overflow occurs when the aggregate arrival rate exceeds the buffer service rate, causing the buffer to fill and overflow. Buffer overflow is susceptible to attacks and as such creates a necessity for intrusion detection systems. We therefore, combined code pointer integrity checking with buffer overflow visualization to monitor and visualize the buffer status during transmission with overflow indicator. Our technique is an intuitive mechanism to suspend transmission during overflow and resume transmission when the buffer queue eases out. Thereby reduces the chance of buffer overflow attacks while preserving the functionality and performance of the existing systems. The effectiveness of our technique is confirmed through a visualization experiment thus facilitate intrusion analysis.

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