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1 Enterprise Credential Spear-phishing Attack 2 Detection

3

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14 **Abstract:**

15 The latest report by Kaspersky on email Spam and targeted Phishing attacks, by percentage,
16 highlights the need of an urgent solution. Attachment-driven Spear-phishing struggles to succeed
17 against many email providers' malware-filtration systems, which proactively check emails for
18 malicious software. In this paper, we provided a solution that can detect targeted Spear-phishing
19 attacks based on required similarities in the specific domain which it has been targeted. The strategy
20 is to figure out whether the domain is genuine or a forgery, which is to be evaluated by multi novel
21 grading algorithms. Therefore, this research addresses targeted attacks on specific organisations by
22 presenting a new enterprise solution. This detection system focuses on domain names, which tend
23 to be registered domain names trusted by the victims. The results from this investigation show that
24 this detection system has proven its ability to reduce email phishing attacks significantly.

25 **Keywords:** Spear-phishing, phishing attacks, phishing detection, anti-phishing

26

27 1. Introduction

28 Neutralising the threat of phishing for cybersecurity is not easy; over the years, the
29 attacks have exponentially gained sophistication, adapting to the ever-more stringent
30 parameters and new techniques applied by anti-phishing strategists [1], [2]. By using a variety
31 of social engineering methods and hoodwinking web-surfers, phishing poses a risk to the
32 cyber-security of users, often extracting crucial, confidential information using these

33 methods [3]. Even web-surfers who are not naïve to the risk of phishing can still be vulnerable to
34 these attacks [4], because their ability to discern between legitimate and illegitimate pages may be
35 confounded by a false web page that is designed by phishers to accurately emulate the features of the
36 legitimate site it is imitating.

37 In the last half of 2014, the anti-phishing working report discovered 132,972 unique phishing
38 attacks between July and December, globally [5]. The industries which are most likely to come under
39 attack are e-commerce, banks, and money transfer companies, for an obvious reason- these promise
40 the most lucrative reward for phishers. The following top-tier domains were utilised by 75% of
41 phishing pages: .net, .cf, .pw, .tk, and .com.

42 The report also found that during the given time period, the median uptime for phishing sites
43 (i.e. uptime) increased to 10 hours and 6 minutes. In 2015's first three quarters, the financial service
44 sector and banking sector ceased to be the most vulnerable sector, falling into third and second place
45 respectively. Evidently, attackers began to prioritise Internet Service Providers (ISPs) during this
46 time-frame, with them taking first place as the most commonly targeted industry sector [6].

47 The reason for this change of tactic becomes clear when we consider the opportunities ISP
48 accounts offer phishers for gleaning confidential information such as credit card and identification
49 data [7]. Once gained, this personal information can even be utilised for further phishing endeavors;
50 for example, attackers are able to use hacked accounts to send spam mail. The Business Email
51 Compromise (BEC) fraud of 2015 exemplifies a serious case where a successful phishing attack cost
52 industries large amounts of money [6]; with the use of Spear-phishing methods, the phishers were
53 able to dupe their targets into making transfers and fraudulent transactions. Blacklisting, as
54 previously mentioned, is commonly used to guard users against phishing. Often, these mechanisms
55 are embedded within web browsers as plug-ins which perform a check on every URL and operate on
56 the basis of phishing identification measures which include user votes. This then alerts users of the
57 malicious nature of pages they are trying to visit when a domain appears in the blacklist and blocks
58 the connection to protect them. Some examples of this type of anti-phishing plug-in are as follows:

59 Google-safe browsing for Firefox [8], phishing filter for Internet Explorer [9]. The blacklist, though,
60 needs to be constantly updated for these measures to be effective, and the update process is often not
61 as speedy as it needs to be, especially considering the fact that many phishing websites typically have
62 short life-spans, with up-times of only a few hours.

63 Our approach is designed to detect Spear-phishing attacks by analysing the sender domain
64 name. Ransom-ware attack is categorised as drive-by-download attacks and it is beyond the scope of
65 this paper as we have focused on targeted attacks.

66 This paper is organized as follows. Overviews of existing literature is presented in Section 2.
67 Section 3 presents the proposed method which is divided into two subsections. The results obtained
68 from the proposed method is presented in Section 4. Section 5 reveals some related discussions and
69 comparisons with existing methods. The paper ends with complete collusion based on the outcomes
70 of the presented method.

71 **2. Background**

72 Spear-phishing refers to an attack targeted specifically against a group, organisation or
73 individual [10], [11]. This method has grown in popularity [12], superseding that of more
74 conventional techniques like random and mass email phishing. The reason for this is that Spear-
75 phishing has a far higher success rate than the other, more generalised methods [12]. This is because
76 the content of the phishing email is tailored to the receiver, therefore it is less likely to arouse
77 suspicion.

78 Spear-phishing is much more successful because people generally trust communications which
79 come from entities whom they already hold an account with or are familiar with [13]. Phishing sites
80 that imitate organisations which users have previously interacted within their legitimate forms are
81 less likely to arouse suspicion and cause them to check the authenticity closely. Some phishers even
82 impersonate specific users' friends [14] or colleagues [15] to ensure a higher success rate. Phishers
83 can, for instance, contact a staff member in an organisation whilst pretending to be a colleague from

84 another department, who for legitimate-seeming reasons asks the victim to respond with important
85 login details or open malicious attachments.

86 This technique can yield great success and lead to entire data networks being compromised in
87 an institution [16]. This is the preferred method for phishers carrying out what is described as an
88 Advanced Persistent Threat (APT) attack [17], which is an attack targeted at a specific organization,
89 with specific goals. The personalised nature of Spear-phishing makes it an ideal means of attaining
90 this goal. APT attacks are typically carried out over a long time, and care is taken to avoid drawing
91 any attention to the infiltration before the set objectives are achieved. Making use of malware or zero-
92 day vulnerability exploits, phishers launch APT attacks in order to achieve goals such as sabotage or
93 espionage [18].

94 To create personalised Spear-phishing emails, it is first necessary to obtain some data about the
95 target. One means of achieving this is browser sniffing [14], which is a technique of “sniffing” out the
96 websites that a target has visited by viewing access times for certain cache cookies, DNS caching, and
97 URL [19]. If access time for a certain DNS lookup or URL is brief, this is evidence that the user has
98 accessed the website before, since a DNS cache already exists for the DNS entry, or the browser has
99 created a cache for quick access to the site. Cache cookies also allow phishers to monitor which sites
100 are frequently accessed by their victims. This enables the development of a personally targeted attack
101 which draws on what the phisher knows to be the victim’s established network of interests and
102 affiliations. This sniffing technique can be deployed by embedding JavaScript containing malware
103 into websites, web-ads, HTML emails, or search engine optimisation, and sending links to these in
104 emails [20]. Once installed, the malware will report back to the phisher all of the victim’s access times,
105 allowing a personalised attack to be devised.

106 **3. PROPOSED METHOD**

107 *3.1 Attack Taxonomy*

108 Spearfishing differs from attacks which use software and protocol weaknesses and technical
109 vulnerabilities to infiltrate machines. The engineering that goes into a Spear-phishing attack can be

110 described as social rather than technical. Spear-phishing entails sending specially designed emails
111 which are bespoke to the victim, intended to hoodwink victims into carrying out an action which
112 benefits the predator. Due to the nature of the attack, very little technical knowledge is necessary on
113 the part of the attacker. Unlike other types of phishing, Spear-phishing does not prey on the
114 functional vulnerabilities of machines and software but rather relies on the gullibility of users, which
115 means attacks are difficult to deflect through automated technical defense systems.

116 The relatively high success rate of Spear-phishing results from the fact that emails are easy to
117 spoof and the considerable time attackers invest in creating emails designed specifically for a
118 particular victim. Hence, as of yet, effective measures or tools for identifying or defending against
119 Spear-phishing do not exist.

120 whilst Spear-phishing emails are made bespoke to victims with particularly valuable
121 information, capabilities, or access to resources. The attacks are designed with a very specific aim in
122 mind, which makes it possible to tailor every detail in such a way as to increase convincingness.

123 Phishers are forced to carry out expensive zero-day exploits in order to succeed against
124 meticulous technical defense systems. Conversely, the barriers set up against credential Spear-
125 phishing are very low; phishers need only to cleverly construct a bespoke email and host a spoof
126 website in order to hoodwink their victims.

127 To hoodwink targets into performing actions on behalf of the phisher, Spear-phishing emails
128 must instill trustworthiness by a demonstration of authority or legitimacy. Usually, this is attained
129 by impersonating trusted entities who are already known to the target. Then, the phisher
130 impersonating the authority figure will ask the target to carry out an action which benefits the
131 phisher, such as transferring funds or breaching sensitive data.

132 *3.2 Threat Model*

133 In this work, we specifically focus on an “Enterprise Credential Spear-phishing” threat model,
134 where the attacker tries to fool a targeted enterprise’s victim into revealing their credentials.

135 In the tests that we did on the Liverpool John Moores University email system, we found that
136 the attacker can bypass detection by changing one character of a legitimate domain name. In this test,
137 we register the domain "ljmuac.uk". The only difference between our registered domain name and
138 the legitimate Liverpool John Moores University domain name "ljmu.ac.uk" is that ours has one less
139 full stop or dot. As shown in Figure 1, we sent an email from
140 **dontreply@ljmu.ac.uk**<dontreply@ljmuac.uk>.

141



from: **dontreply@ljmu.ac.uk** <dontreply@ljmuac.uk>
to: y.k.alhamad@ljmu.ac.uk
date: Oct 3, 2018, 12:35 PM
subject: Status Report
mailed-by: ljmuac.uk

142
143 **Figure 1: Registered domain name**

144 In our threat model, the real email is xxx@ljmu.ac.uk, where "xxx" can be any name such as
145 dontreply, ITHelpDesk, or even a person's name.

146 The adversary can send arbitrary emails to the victim and convince the recipient to click on URLs
147 embedded in the adversary's email (Figure 2). To impersonate a trusted entity, the attacker may set
148 any of the email header fields to arbitrary values.



149
150 **Figure 2: Send email to user**

151
152 This paper is focused on attacks which entail masquerading as a trusted entity, with the payload
153 being a link to a credential harvesting phishing page.

154 Figure 2 shows an email we sent to LJMU students, informing them of strange internet traffic
155 originating from their computers, and telling them that there appears to have been a small outbreak
156 of viruses that may have spread across the network. We reassure the user that we are attempting to
157 remove these infections, however, the user must change their password immediately. Then, the user

158 is asked to click on a link. The link redirects the user to a cloned website where we present a cloned
159 version of a legitimate website.

160 To gain more trust, we placed “https://myaccount.ljmu.ac.uk/” over the hyperlink text which
161 sends users to our cloned website “https://myaccount.ljmu.ac.uk/”.

162 We asked 50 different people (40 students and 10 staff) to read the email and click on the link.
163 Once they read it and opened the link, we asked if they noticed anything wrong with the email and
164 the page. Only 2 people (1 student and 1 staff member) noticed that firstly, the sender of the email is
165 not Liverpool John Moores University, and none of them spotted that the web page they browsed is
166 a cloned version of a legitimate page

167 As shown in Figure 3, we were able to obtain user usernames and passwords. Once the user
168 clicks on the login button, they are redirected to the legitimate address, which in this case is
169 “http://stureg.ljmu.ac.uk”, and they think that they might have inputted their username and
170 password incorrectly without even realising that their username and password has been stolen.
171 Therefore, this Spear-phishing attack was successful in stealing the victim login credentials.

```
[*] WE GOT A HIT! Printing the output:
PARAM: __LASTFOCUS=
PARAM: detail_ToolkitScriptManager1_HiddenField=
PARAM: __EVENTTARGET=
PARAM: __EVENTARGUMENT=
PARAM: __VIEWSTATE=/wEPDwUKMTYwMTg1OTk4N2QYQAQYeX19Db250cm9ec1JlcXVpcm
PARAM: __VIEWSTATEGENERATOR=C2EF9ABB
PARAM: __EVENTVALIDATION=/wEdRAUSFPGL8W2NaR9Tmh3oBF0Eyh1HDN25acBMNcp5
POSSIBLE USERNAME FIELD FOUND: ct100$detail$tbUsername=test
POSSIBLE PASSWORD FIELD FOUND: ct100$detail$tbPassword=test
PARAM: ct100$detail$btnSubmit=Log+On
[*] WHEN YOU'RE FINISHED, HIT CONTROL-C TO GENERATE A REPORT.
```

172
173

Figure 3: Sniffed username and password

174 During our test phase, we successfully bypassed the email protection that the university put in
175 place to protect users. A dialogue was established with the university IT department, to find out what
176 types of protection they employ and how they tackle phishing attacks.

177 Unfortunately, they had no idea what we were talking about. There is a difference between spam
178 and phishing emails. Spam emails can be phishing emails, but Spear-phishing emails cannot be spam
179 and will bypass the spam scoring system if the attacker crafts the email carefully. Therefore, the
180 “Trend Micro Email Protection” system is impractical in guarding against Spear-phishing attacks on

181 Liverpool John Moores University staff or students, as demonstrated by the fact that we successfully
182 launched a Spear-phishing attack and bypassed the detection system.

183 During the literature review phase, we could not find any solution that tackles “Enterprise
184 Credential Spear-phishing”, where attackers carefully plan attacks. These types of attacks normally
185 deploy by the following steps:

186 **Step 1: Identifying the victim:** At the beginning of each phishing attack, an attacker needs to find a target.
187 Since Spear-phishing is a targeted attack, the attacker must specifically identify the victim.

188 **Step 2: Gathering information about victim:** Once the attacker identifies the victim, they need to gather
189 intel about the victim using search engines or social networks such as name, location, place of work,
190 close friends, favourite brands, and favourite things to do.

191 **Step 3: Choosing techniques:** Based on the information gathered from the previous step, now the attacker
192 will choose their attack techniques. In our threat model, the attacker has chosen Spear-phishing,
193 typosquatting and credential harvesting.

194 **Step 4: Preparing tools:** Based on techniques selected in step 3, the attacker now prepares the tools that are
195 suited to the planned attack.

196 **Step 5: Register domain(s):** In this step, the attacker will register a domain name designed to establish the
197 victim’s trust. For example, for a victim working in a company with the web address *www.abcd*
198 *ef.co.uk.*, the attacker will register a domain name similar to that with 1 or 2 characters different, e.g.
199 *www.abcedcf.co.uk.*

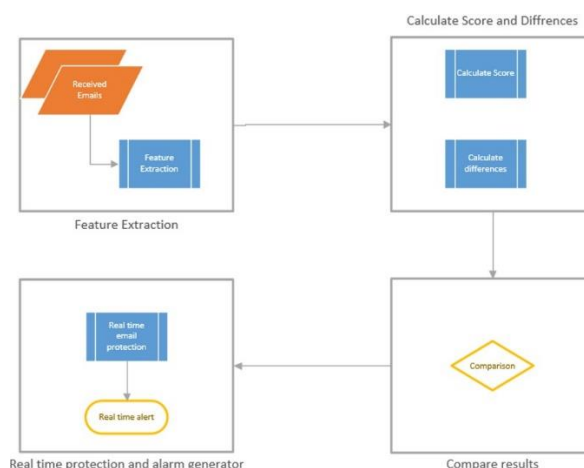
200 **Step 6: Craft email template:** To gain more trust, the attacker must construct an email template carefully.
201 Once a victim cannot identify anything suspicious in a spoofed email, 99% of their trust is
202 established.

203 **Step 7: Clone targeted website:** Because of the nature of the techniques chosen, the attacker needs to clone
204 the targeted website that he wants to send to the victim in order to extract their credentials.

205 **Step 8: Send email**

206 **Step 9: Credentials Obtained**

207 Therefore, to tackle this type of attack, we proposed a solution that can detect an “Enterprise
208 Credential Spear-phishing” attack, where the attacker uses a similar domain name to gain the victim’s
209 trust and to trap the victim into the attack. The proposed solution, at a high level, has four stages as
210 illustrated in Figure 4.



212

Figure 4: Overview of the proposed protection system

213

As shown in Figure 4, the first process is feature extraction, then the extracted features are

214

processed to calculate scores and differences. These two processes are the most important parts of

215

our proposed solution. Once the scores and differences are calculated, the result will be compared

216

with the database and threshold values. If there is a match, an alert is created and the email is

217

quarantined for further investigation.

218

3.2.1 Feature Extraction

219

In this process, the proposed system extracts the following features from the received email

221

domain: **Count number of characters** (Cnoc), **Count number of unique characters** (Cnouc), **Count**

222

number of dots (Cnod), **Count number of numeric values** (Cnonv), **Count number of hyphens**

223

(Cnoh), **Extract domain extension after** (Ede), **Count number of character before the first dot** (Cnocb

224

f d), **Incoming mail IP address** (INi p), **Valid IP address** (VI P), **Similar characters place** (SCP),

225

Similar domain name (Sdomain), **Number of common characters** (NCC), **Similar domain name**

226

length (SDNL)

227

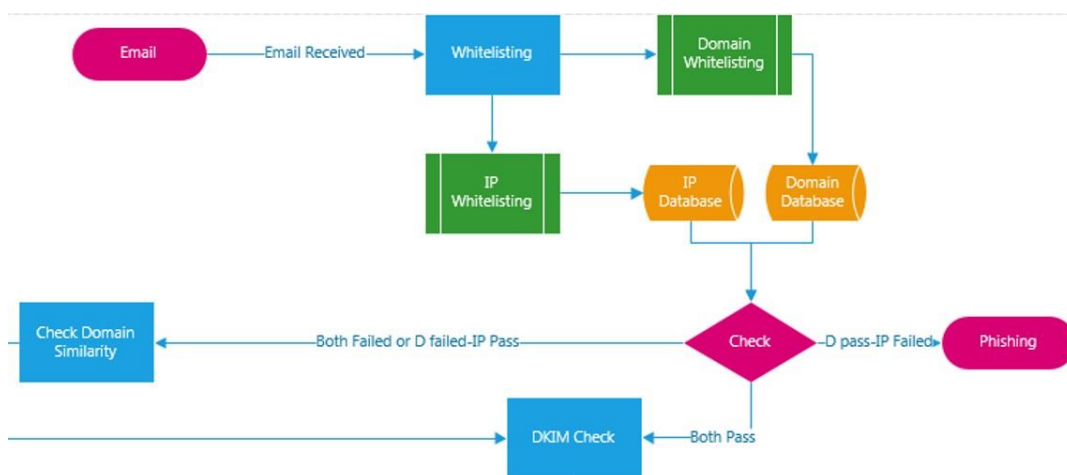
As shown in Figure 5, the proposed solution starts to work once the email is received by the

228

system. At the first stage, the email domain is whitelisted through the first process, which is the

229

“whitelisting” process.



230

Figure 5: Whitelisting processes

231

This process has two sub-processes to check whether the incoming email can be whitelisted or

232

233

not. The first sub-process is to check the domain against a valid domain database. This process will

234 check if the incoming email domain name (i.e. ljmu.ac.uk) exists in the domain database. Then, the
235 next sub-process will check the sender IP address (i.e. 1.1.1.1) against the IP database to see if the
236 sender IP address exists in that database.

237 Afterward, the results are compared to make a decision about the email. In the “Check” process,
238 the system will mark the email as phishing if the domain name is the same (result pass), but the IP
239 address is different (result fail). This means an attacker is trying to spoof a valid domain name to
240 send the phishing attack, but the IP address is not similar to the valid IPs.

241 If both checks fail, then the email is forwarded to another process, which is “Check Domain
242 Similarity”. This is because neither the domain nor the IP is valid.

243 If the domain check result is failed but the IP address is valid, the email is still sent to the “Check
244 Domain Similarity” process again for further examination. If both the domain and IP pass, the
245 proposed solution sends the email to another process named “DKIM and SPF” checker.

246 3.2.2 Algorithm 1: Whitelisting

247 In this part, we propose an algorithm for whitelisting the incoming email domain name. The
248 proposed algorithm has two parts, “Function Domain Whitelisting” and “Function IP address
249 Whitelisting”.

250 **Function Domain Whitelisting**

251 This function whitelists the domain name using the valid domain database, where IN_{domain} is
252 the incoming email domain name and V_{domain} is a whitelisted domain in the valid domain database.

253 **Function IP address Whitelisting**

254 This function whitelists the sender IP address(Figure 6) using the valid IP address database, where IN_{IP} is the
255 sender IP address and V_{IP} is the whitelisted IP address in the valid IP address database.

```
Received: from [127.0.1.1] ([167.99.81.250])  
by smtp.gmail.com with ESMTPSA id 125-v6sm9501157wmr.2:  
for <h.kolivand@ljmu.ac.uk>  
(version=TLS1_2 cipher=ECDHE-RSA-AES128-GCM-SHA256 bit:  
Mon 03 Dec 2018 06:27:44 -0800 (PST))
```

256

257

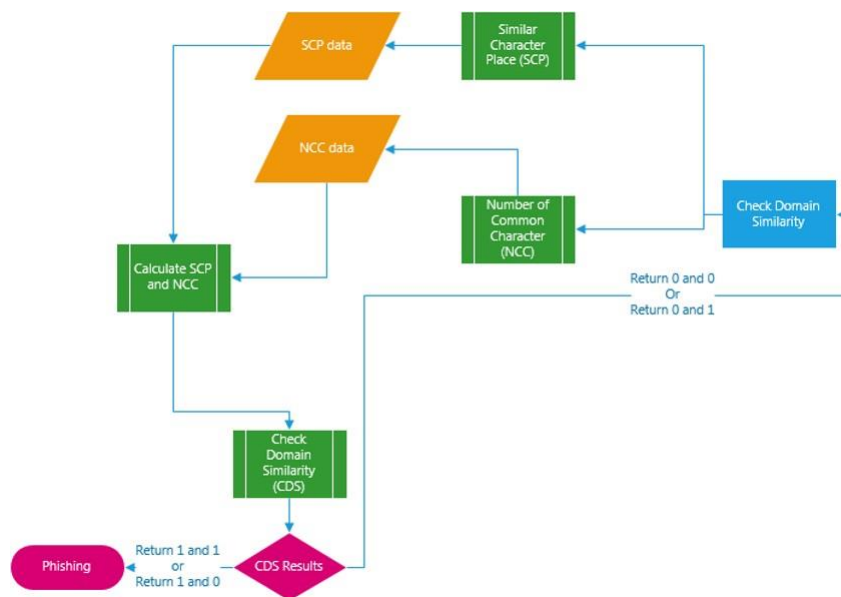
Figure 6: Send IP address

258 Once an email is received, the process starts to work by checking and validating two factors. The
 259 first factor is the domain name and the second one is the sender IP address. If the result is pass, then
 260 the email is valid and moves to the next layer of processing, which is the Domain Keys Identified
 261 Mail (DKIM) and Sender Policy Framework (SPF).

262 This is because if INdomain = Vdomain, then it means the sender domain is the same as the
 263 domain in the whitelisted database. To avoid address spoofing, we check the sender IP address
 264 against the valid IP address. If INI P = VI P then it means the email was sent from one of the trusted
 265 domains. In this case, we send the email for future checks to the DKIM and SPF process. If both fail,
 266 then the email is sent to the next function, "Check Domain Similarity".

267 *3.2.3 Algorithm 2: Check Domain Similarity*

268 This process starts to work by evaluating the incoming email domain name. As shown in Figure
 269 7, this process has two sub-processes, Similar Character Place (SCP) and Number of Common
 270 Characters (NCC).



271
 272 **Figure 7:** Check domain similarity process

273 Similar Character Place (SCP) looks for common character placements between incoming the
 274 email domain name and valid domain addresses. In theory, this will help to prevent attack techniques
 275 such as "Typo squatting". In "Typo squatting", attackers use a similar domain to a legitimate domain.

276 For example, an attacker might use “ljmuac.uk” as the email domain name to send an email to the
277 victim, which is close to “ljmu.ac.uk”.

278 To achieve this, we proposed an algorithm named “Similar Character Place (SCP)” to find
279 similar character placements in both domains. If the “SCP” is more than the threshold value, it is
280 given a “1” score, if it is less the score is “0”. The threshold value is half of the valid domain name.

281 As an extra security precaution, we proposed another algorithm named “Number of Common
282 Character”. This sub-process counts the number of common characters in both domains, minimising
283 the risk of the attacker evading detection. The idea behind this is that normally, attackers use words
284 similar to a target address. For example, an attacker might send an email from “insatgarm.com”,
285 trying to pretend that the email is from “instagram.com”. This domain has eight common characters
286 with the domain “Instagram.com”. As with SCP, if the threshold is met, then the system gives a score
287 of “1”, and if it is not met then the score is “0”. The threshold value for this process is one-third of the
288 number of characters in the valid domain address.

289 Once both Similar Character Place and Number of Common Character are calculated based on
290 the following presented algorithms:

```
291 Function Similar Character Place (SCP) () {  
292     def1: Find SCP  
293     Read From ( $V_{domain}$ )  
294     Input  $IN_{domain}$   
295     String [] $SP1$ ;  
296     String [] $SP2$ ;  
297     Counter Index = 0;  
298     For  $I = 1$  to  $V_{domain}.length[]$   
299         For  $J = 1$  to  $IN_{domain}.length[]$   
300             IF  $V_{domain}[I] = IN_{domain}[J]$   
301                  $SP1.append(I)$ ;  
302             }  
303 Function Number of Common Character (NCC) () {  
304     def2: Find NCC  
305      $s1 = set(Read\ From\ Database(V_{domain}))$ ;  
306      $s2 = set(Input\ IN_{domain})$ ;  
307      $common_{char} = s1 \& s2$ ;
```

```

308         remove_dots = ([s.strip('.') for s in s2])
309         IF len(common_char) < ' 1':
310             return (list(set(s1).intersection(remove_dots)))
311         else:
312             return 0
313     }

```

314 Then the result is forwarded to another sub-process called “Check Domain Similarity”. If the result
315 of both is “1”, then the incoming email is classified as “Phishing”. This is because the proposed sub-
316 processes, Similar Character Place and Number of Common Character, detected a high chance of
317 similarity to the valid domain; therefore, the email is marked as phishing.

318 If the Similar Character Place score is “1” and the Number of Common Character score is “0”,
319 again the proposed system has detected a high chance of the incoming email having a Similar
320 Character Place to the valid email.

321 If one of the SCP or both of them return “0”, then the domain will forward the email to DKIM
322 for further examination of the domain.

323 **DKIM and SPF Process** 324

325 This process was designed and added as an extra layer of security to make sure that the emails
326 reaching users are 99% clean and valid.

327 Once an email is received, first the process checks the Domain Keys Identified Mail (DKIM) with
328 a public DNS server. Once the result comes back from the Public DNS Server, the next process checks
329 the Sender Policy Framework (SPF) with a Public DNS Server to hinder the ability of attackers to send
330 email spoofing a domain name, as shown in Figure 8.

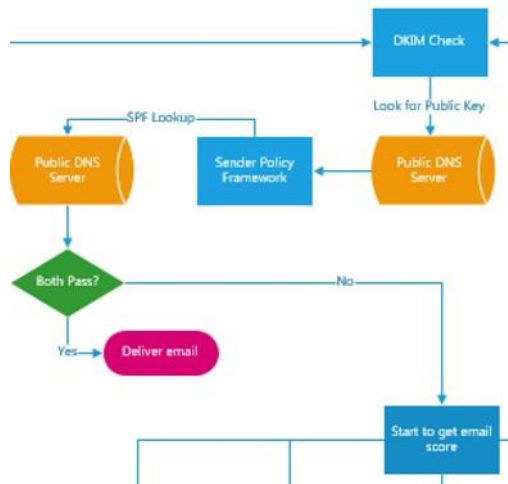


Figure 8: DKIM and SPF process

331

332

333

If both the DKIM and SPF check pass, then the system will deliver the email. This is because,

334

after the previous processes and this one, the proposed system believes that the email is 99.9% clean.

335

However, if both of the checks or one of them failed, then an extra layer of filtering and checks are

336

put in place to make sure that the email sender is legitimate.

337

Step 1: Read "DKIM" and "SPF" from DNS Domain Check with Public DNS Server to see if SPF record is valid and authorised

338

Retrieve Public Key with Public DNS Server to verify sender key

339

340

Step 2: IF Both Pass = yes => Deliver Email

341

Step 3: IF Both Pass = No => Check Domain Similarity IF either of them pass = NO => Check Domain

342

Similarity Domain Keys Identified Mail (DKIM): is a protocol used by email systems to verify the

343

sender and integrity of a message and prove that spammers did not modify an incoming message

344

while in transit.

345

The DKIM key is used by recipient mail servers to decrypt the message's signature and compare

346

it against the domain DNS record. If the values match, then it will prove that the message is authentic

347

and unaltered in transit, therefore, not forged or altered.

348

Sender Policy Framework (SPF): SPF prevents spammers or attackers from sending emails with

349

a spoofed domain name as the sender. SPF adds IP addresses to a list of servers that are authorised

350

to send email from your domain. It verifies that messages sent from your domains originated from

351

the listed server, which reduces the amount of backscatter that you receive.

352

An example of received email by Gmail with DKIM and SPF results is shown in Figure 9.

```
dkim=pass header.i=@ljmuac.uk header.s=default header.b=dFP3P197;  
spf=pass (google.com: domain of dontreply@ljmuac.uk designates 10
```

Figure 9: Example from received email by Gmail

353
354
355

356 **Complimentary Filtering and Checks**

357 In this process, we used an existing solution which was designed to prevent spam emails,
358 because we believe that the same system to prevent spam can be used in conjunction with the
359 proposed method to increase the detection rate.

360 If the results of DKIM and SPF failed, then the incoming email is forwarded to this process. This
361 process has five sub-processes. An incoming email is passed to each of these five sub-processes for
362 further checks. Each of these sub-processes has a scoring limit, which if exceeded, will categorise the
363 email as phishing. Each filter below contributes to a SPAM/Phishing scoring. If the received email
364 returns a total score greater than the “Pre-defined Scoring Limit”, then the message will be blocked.
365 Compared to the Bayesian option, the Hidden Markov Model (HMM) produces results that are more
366 exact.

367 **Step 1: Check with RBL Filter**

368 This filter extracts the sender IP address from the email header and checks it with the configured
369 RBL one at a time. If the check returns a positive result, it means the sender IP address is listed by
370 one of the RBL servers and a spam score equal to the RBL server’s assigned confidence level is
371 assigned to the email.

372 **Calculate Score:**

373 *IF Pre-defined Score Exceed = No => Send to Total Pre- defined Score*

374 *IF Pre-defined Score Exceed = Yes => Label Email as Phishing*

375 **Step 2: Check Bayesian Filter**

376 This scoring filter adds to a message’s score if contains specific words, and when it exceeds a
377 pre-defined score, it categorises the message as phishing/spam. An example is “Share Password”,
378 which would surely give a high score.

379 **Calculate Score:**

380 *IF Pre-defined Score Exceed = No => Send to Total Pre- defined Score*

381 *IF Pre-defined Score Exceed = Yes => Label Email as Phishing*

382 **Step 3: HMM Filter Calculate Score:**

383 *IF Pre-defined Score Exceed = No => Send to Total Pre- defined Score*

384 *IF Pre-defined Score Exceed = Yes => Label Email as Phishing*

385 **Step 4: Suspicious HELO Calculate Score:**

386 *IF Pre-defined Score Exceed = No => Send to Total Pre- defined Score*

387 *IF Pre-defined Score Exceed = Yes => Label Email as Phishing*

388 **Step 5: Invalid HELO Calculate Score:**

389 *IF Pre-defined Score Exceed = No => Send to Total Pre- defined Score*

390 *IF Pre-defined Score Exceed = Yes => Label Email as Phishing*

391 **4. Test and results**

392 This chapter has two parts, which provide an evaluation of the proposed solution and the
393 awareness-training framework by performing different tests. The first part covers the proposed
394 technical solution, which we call ECSPAD (Enterprise Credential Spear-phishing Attack Detection)
395 and the second part covers the evolution of the proposed awareness- training framework. At the end
396 of the tests, by comparing the results, we have validated that the proposed solutions achieved the
397 main aim of this paper, which is to develop a solution that can detect an Enterprise Credential Spear-
398 phishing Attack. The other aim of this paper is to develop an awareness-training framework for the
399 state of Qatar, to train users to reduce the impact of phishing attacks. There is a proverb saying,
400 "Prevention is better than a cure".

401 **ECSPAD – (Enterprise Credential Spear-phishing Attack Detection)**

402 **Test – ljmu.ac.uk**

403 In this part, we performed a series of tests to evaluate the proposed method. In Table 1, we have
404 a valid domain name set to "ljmu.ac.uk". The Similar Character Place (SCP) Threshold Value and
405 Number of Common Characters (NCC) are calculated based on the valid domain name.

406 TABLE 1 SCP and NCC for ljmu.ac.uk

<u>Valid Domain</u>	<u>Ljmu.ac.uk</u>
SCP Threshold value	2
<u>NCC Threshold value</u>	2

407 Once the SCP and NCC Threshold value was calculated, we then used the domain "ljmuac.uk"
408 as the phishing domain name. As the results show in Table 2, we assume that the attacker registered
409 the domains to perform the "Credential Spear-phishing Attack" by choosing the same domains as
410 the victim domain name.

411 Once an email is received from "user@ljmuac.uk", the proposed system starts to work. In the
412 beginning, the system extracts the following features from an incoming email domain name.

413 **TABLE 2**
414 **RESULT OF THE PROPOSED METHOD**

<u>Incoming email domain</u>	<u>Classified as Phishing?</u>
<u>ljmuac.uk</u>	<u>Yes</u>
<u>Ljmu.acuk</u>	<u>Yes</u>
<u>Limu.a.c.uk</u>	<u>Yes</u>
<u>Ljm.ac.uk</u>	<u>Yes</u>
<u>Ljmuu.a.c.u.k</u>	<u>Yes</u>
<u>Ljmuacuk</u>	<u>Yes</u>

415

416 **Valid Domain = LJMU.AC.UK**

417 **Incoming mail Domain = LJMUAC.UK**

418 **Step 1: Whitelist domain:** Verify if the incoming email domain name is the same as the valid
419 domain name.

420 **Step 2: Whitelist IP:** Verify if the incoming email IP is the same as the valid IP.

421

422 The result for this process will be "fail" as "INi p 192.168.1.11" is not the same as "Vi p =

423 192.168.1.10"

424 of Common Characters extracted from "Step4" and it will compare to TVNCC (threshold value)

425 which is calculated previously. Because both "Step1" and "Step2" result came back as "fail", the email

426 will forward to the next step to perform further examinations.

427 **Step 3: Find Similar Character Place (SCP):** Find similar character places between Vdomain and
428 INdomain. As shown in Figure 10 (top), the SCP between Vdomain and INdomain is just 4
429 characters. The result of this process is "4".

430 **Step 4: Find Number Common Character (NCC)**

431 The result from this step is shown in Figure 10(middle), and the result of this process is "7".

432 **Step 5: SCP and NCC Calculation**

433 To calculate the SCP, we propose the following algorithm which the results is shown in Figure
434 10(buttom).

435 *def 3: Calculate SCP*

436 *IF RSC ≥ PTVSC P Then:*

437 *Return 1*

438 *Else:*

439 *Return 0*

440

441

```
Valid Domain: ljmu.ac.uk
Incoming Email Domain: ljmuac.uk

l ----- l
j ----- j
m ----- m
u ----- u
.         a
a         c
c         .
.         u
u         k

Similar Character Place: ['l', 'j', 'm', 'u']
```

442

```
Valid Domain: ljmu.ac.uk
Incoming Email Domain: ljmuac.uk

Common Characters: ['a', 'c', 'k', 'j', 'm', 'l', 'u']
Number Common Characters: 7
```

443

```
Valid Domain: ljmu.ac.uk
Incoming Email Domain: ljmuac.uk
Calculate SCP result: 1
```

444

Figure 10: (top): SCP result, **(middle):** NCC result, **(bottom):** Calculate SCP result

445

We need to calculate the TVsc p. The TVsc p is half of the length of the valid domain name (Sdomain = ljmu). Therefore, TVsc p is "2". Based on the result from "Step 3" which is "4", the result of Calculate SCP is "1".

448

Now, it is time for the NCC calculation process to begin. The following algorithm has been proposed, where RNCC is the Number of Common Characters that were extracted from "Step4", and is compared to the TVNCC (threshold value) which was calculated previously.

451

def 4: Calculate NCC

452

IF RNCC ≥ TV NCC Then:

453

Return 1

454

Else:

455

Return 0

456

The RNCC is "7", and the TVNCC is "2". Therefore, the result of this should be "1", as the Number of Common Characters is greater than the threshold value.

458

Step 6: Check Domain Similarity

460

Based on the results from previous processes, the domain is now classified as Phishing, Suspected as Phishing, or send to the next step, which is DKIM and SPF check. Based on the results, the proposed system classified the email as phishing, because the SCP score is "1", the NCC score is "1", and the proposed algorithm calculated a high similarity between the incoming domain name and the valid domain name. Table 3 shows the results of the tests we did with different domains that we registered for the presented Spear-phishing targeted attack.

466

467

TABLE 3
VALID DOMAIN EXTRACTED FEATURES

468

469

Feature Name	Ljmu.ac.uk	Ljmuac.uk	INSTAGRAM.COM	insatgarm.com	ALPINA.QA	ALPNIA.QA
VCnoc	10	9	13	13	9	9
VCnouc	7	7	10	10	6	6
VDomain	ljmu.ac.uk	ljmuac.uk	instagram.com	insatgarm.com	alpina.qa	alpnia.qa
SDomain	ljmu	ljmuac	instagram	insatgarm	alpina	alpnia
VCnod	2	1	1	1	1	1
VCnonv	0	0	0	0	0	0
VCnoh	0	0	0	0	0	0
VEde	ac.uk	ac.uk	com	com	qa	qa

VCnocab f d	4	6	9	9	6	6
Vi p	192.168.1.10	192.168.1.11	192.168.12.100	192.168.15.15	192.168.20.100	192.168.22.100

470

471 Table 4 shows that the only detection system that detected all of the tests is the proposed
 472 method. However, from the result, we can see that the Gmail email server detection was able
 473 to detect our “Instagram.com” phishing attack and the motc.gov.qa was able to detect the
 474 attack that we sent from our registered domain “motcgv.qa”.

475

476

477

478

TABLE 4
 TARGETED SPEAR-PHISHING ATTACK TEST RESULTS

Domain	TrendMicro	Outlook	Gmail	Yahoo	Live	ESCPTAD
ljmuac.uk	pass	pass	pass	pass	pass	detected
instagram.com	pass	pass	detected	pass	pass	detected
motcgv.qa	pass	pass	pass	pass	pass	detected
<u>alpina.qa</u>	pass	pass	pass	pass	pass	detected

479

480

481 5 Discussion

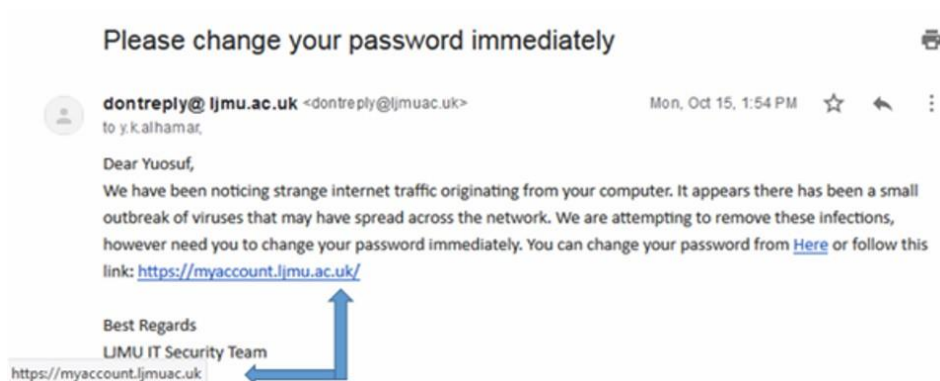
482 In this part, we made a comparison between the results of ECSPAD and other enterprise
 483 solutions and research solutions. Because the nature of the attack is targeted, and the victim will be
 484 selective rather than mass email sending, we performed a target test rather than analysing a database
 485 to find the phishing. Based on the conducted research, we could not find any solution exactly
 486 designed for Credential Spear-phishing attacks.

487 Liverpool John Moores University uses TrendMicro Email Security as the enterprise approach
 488 to provide a secure environment for email. As mentioned by TrendMicro on their website, “A good
 489 technique for hunting and detecting suspicious domains is to also use a similar modus that
 490 cybercriminals typically employ: patterns. DNS data (i.e., a passive system of record of DNS
 491 resolution data), for instance, provides information security professionals and system administrators
 492 insight on how a particular domain changes over time. Not only does this help them correlate
 493 indicators of compromise, but also provides the context needed for identifying related or additional
 494 suspicious domains. Domain registration information also helps unmask a cybercriminal’s

495 infrastructure by correlating a specific suspicious domain to others registered using similar
496 information.”

497 Trend Micro InterScan Messaging Security claims that it can stop email threats in the cloud with
498 global threat intelligence, identify targeted email attacks, social engineering attacks, and identify
499 targeted attack emails by correlating email components such as the header, body, and network
500 routing. Our research proves that those claims are not valid, at least for Enterprise Credential Spear-
501 phishing attacks, by comparing the results of an email sent to a user in Liverpool John Moores
502 University with TrendMicro as their email security system versus ECSPAD.

503 As shown in Figure 11, an email was sent to users saying “Please change your password
504 immediately”. In the content, we asked users to change their password due to strange internet traffic
505 originating from their computers.



506
507

Figure 11: Targeted Spear-phishing email

508 Then we asked them to follow a link to reset their password. As shown in Figure 12, the
509 embedded TrendMicro email security system has a feature named “Unknown URL protection” that
510 blocks emails with malicious URLs before delivery and re-checks URL safety when a user clicks on
511 it.

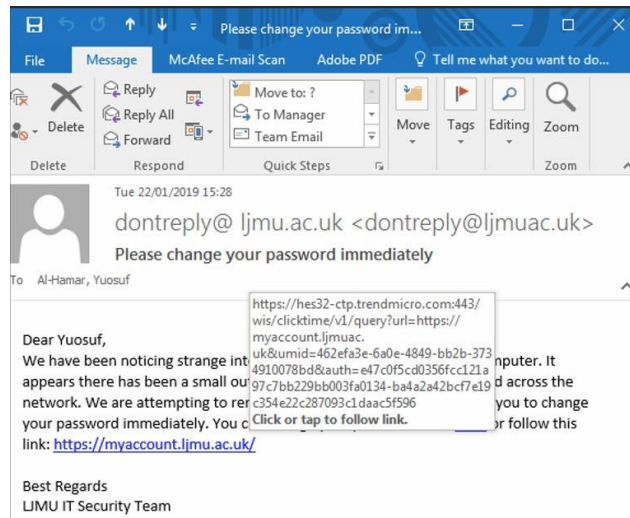


Figure 12: TrendMicro security email analysis

Once we clicked on the URL, the TrendMicro cloud threat intelligence system analysed the URL and opened it without any warning or block as shown in Figure 13.

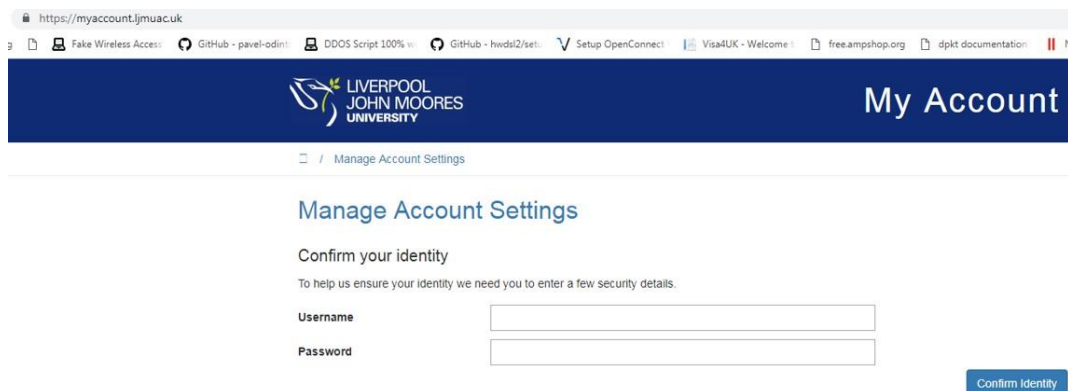


Figure 13: Cloned website

For the proposed test, we used the test username “ljmu” and password “password” on the cloned website to get user credential details (Figure 14).

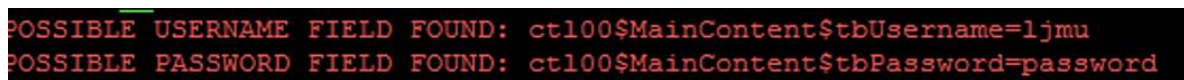


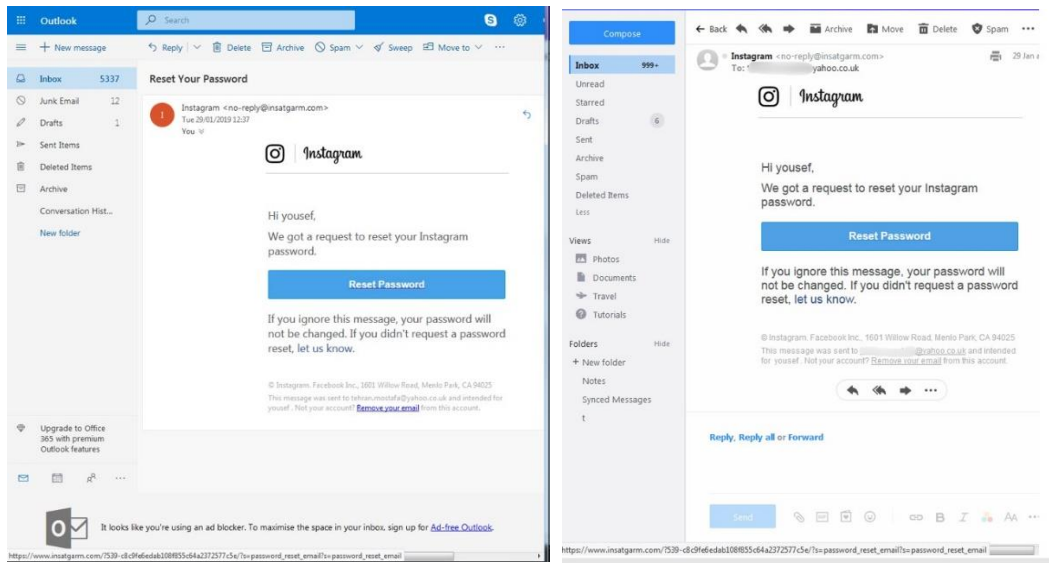
Figure 14: User credential

In this test, we registered a new domain, “insatgarm.com”, to attack Instagram users. This domain has been carefully chosen, as it is very similar to the original domain name, which is “Instagram.com”.

529 We sent an email to Instagram users to reset their password. The emails asked the user to click
530 on a link to go to a password reset page.

531 As shown in Figure 15(left), the email successfully bypassed the Microsoft Email Phishing
532 Detection system. As shown in Figure 15(right), it also successfully bypassed the Yahoo Email
533 Phishing Detection system. Therefore, the user would receive this email as a genuine email.

534



535

536

537

Figure 15: (left) Instagram phishing to live, (right): Instagram phishing email to yahoo

538 However, as shown in Figure 16(left), Gmail detected the email that was sent to our victim. By
539 doing further tests and analysis, we found that Gmail uses content analysis; therefore, it found
540 “Instagram” in the content and classified the email as phishing. As has been shown in Figure
541 16(right), we cloned Instagram’s main page on our host to get the victim's usernames and passwords.

542

543

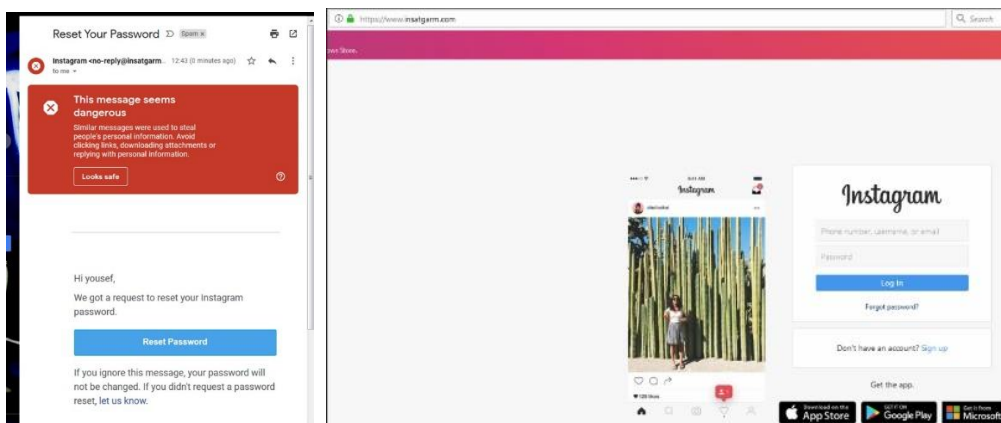


Figure 16: (left) Instagram phishing to Gmail, (right): Cloned Instagram page

544 **6. Conclusion**

545 This paper presents a real-world example of targeted Spear-phishing attacks, where attackers
546 use a mixture of different techniques such as Spear-phishing, Typosquatting, and Credential
547 harvesting to bypass detection and perform successful attacks.

548 To detect and combat such attacks, a multi-layered method, called ECSPAD (Enterprise
549 Credential Spear-phishing Attack Credential), is presented in this chapter which has provided
550 multiple-layered algorithms for the complex task. The presented method was developed specifically
551 to detect “Enterprise Targeted Spear-phishing Attacks”, where attackers select their targets and
552 launch personalised attacks to harvest personal information from social networks.

553 Our research displays the results of our original study on how well users and email hosts can
554 detect and prevent spear-phishing attacks. We spoof an email, claiming to be from Instagram, while
555 changing one letter, which our research showed is common phishing technique, to evaluate the
556 relative success of ECSPAD. The results were then compared to existing Spear-phishing defense
557 methods, especially LJMU’s Trend Micro, which failed to capture our spoofed email. Our results were
558 also compared to popular web hosts’ defense mechanisms. A successful Spear-phishing attack on the
559 Liverpool John Moores University email system could be a catastrophic event potentially leading to
560 credential theft, identity theft, Malware download, and Ransomware attack. The attack method
561 proposed in this paper showed how an enterprise security system like TrendMicro could be
562 vulnerable to Spear-phishing attacks. The proposed method can be used to detect whaling attacks
563 when attackers use a similar domain name to bypass the email security system and gain the target’s
564 trust.

565 This study's goal is to design a solution that can detect a targeted attack based on the domain it
566 has used. Our research has shown that the success rate of SpearPhishing/whaling attack when
567 attackers use a similar domain is significantly high, therefore we worked to provide a solution that
568 can overcome this issue, and our tests showed that the current email security system and email
569 providers are vulnerable to such attacks.

570 The enterprise email phishing detection system has been tested successfully both in the UK, and
571 Qatar. We continuously sent those emails on 4 months intervals from Oct 2018, with an average of 10
572 emails per month. The last test was carried out on 22/01/2019, which clearly shows that the
573 TrendMicro intelligence security system is unable to even determine the pattern of these attacks,
574 while ECSPAD did successfully detect them.

575 Our investigation show ECSPAD performs an excellent detection result as compared to five
576 standard and widely used email system (built-in with Phishing Detection Mechanism).

577 **Conflicts of Interest:** We confirm that there is no conflict of interest for this paper.

578 Reference

- 579 [1] A. G. Mishra and B.B., "Hybrid solution to detect and filter zero-day phishing attacks," 8 2014, pp.
580 373–379.
- 581 [2] K. Parsons, A. McCormac, M. Pattinson, M. J. Butavicius, and C., "The design of phishing studies:
582 Challenges for researchers," *Computers & Security*, vol. 52, pp. 194–206, 2015.
- 583 [3] A. Almomani, B. B. Gupta, S. Atawneh, A. A. Meulenberg, and E., "A survey of phishing email
584 filtering techniques," *IEEE communications surveys &*, vol. 15, no. 4, pp. 2070–2090, 2013.
- 585 [4] S. Sheng, B. Magnien, P. Kumaraguru, A. Acquisti, L. F. Cranor, J. N. Hong, and E., "Anti-phishing
586 phil: the design and evaluation of a game that teaches people not to fall for phish," 7 2007, pp. 88–99.
- 587 [5] "APWG report available at," Accessed, vol. 30, 11 2015. [Online]. Available:
588 [http://www.antiphishing.org/download/document/
589 245/APWG_Global_Phishing_Report_2H_2014.pdf](http://www.antiphishing.org/download/document/245/APWG_Global_Phishing_Report_2H_2014.pdf).
- 590 [6] "APWG Q1-Q3 2015 Report available." [Online]. Available: [http:](http://www.antiphishing.org/download/document/245/APWG_Global_Phishing_Report_2H_2014.pdf)
- 591 [7] R. M. Saad, A. Almomani, A. Altaher, B. M. Gupta, and S., "ICMPv6 flood attack detection using
592 DENFIS algorithms," *Indian Journal of Science and Technology*, vol. 7, no. 2, pp. 168–173, 2014.
- 593 [8] E. Alomari, S. Manickam, B. B. Gupta, P. A. Singh, and M., Design, deployment and use of HTTP-
594 based botnet (HBB) testbed. *IEEE*, 2 2014.
- 595 [9] F. Schneider, N. Provos, R. Moll, M. Chew, and B. Rakowski, "Phishing protection design
596 documentation," 2007. [Online]. Available: https://wiki.mozilla.org/Phishing_Protection
- 597 [10] N. P. Singh, "Online frauds in banks with phishing," *The Journal of Internet Banking and
598 Commerce*, vol. 12, no. 2, pp. 1–27, 1970.
- 599 [11] K. Krombholz, H. Hobel, M. W. Huber, and E., "Advanced social engineering attacks," *Journal
600 of Information Security and applications*, vol. 22, pp. 113–122, 2015.
- 601 [12] F. S. Rietta, "Application layer intrusion detection for SQL injection," 3 2006, pp. 531–536.
- 602 [13] J. S. Downs, M. C. Holbrook, and L.F., "Decision strategies and susceptibility to phishing," 7
603 2006, pp. 79–90.
- 604 [14] T. N. Jagatic, N. A. Johnson, M. M. Jakobsson, and F., "Social phishing," *Communications of the
605 ACM*, vol. 50, no. 10, pp. 94–100, 2007.
- 606 [15] T. Halevi, N. N. Memon, and O., "Spear-phishing in the wild: A real- world study of personality,
607 phishing self-efficacy and vulnerability to spear-phishing attacks," 2015.
- 608 [16] A. Elledge, *Phishing: An analysis of a growing threat*. GIAC Security Essentials Certification.
609 GSEC) Practical, SANS Institute, 2007.
- 610 [17] T. Micro, "Spear-phishingemail: Most favored APT attack bait. Research Paper . Trend Micro
611 Incorporated," 2012. "Symantec," Symantec Corporation, 2011.
- 612 [18] E. S. Felten and M.A., "Timing attacks on web privacy," 11 2000, pp. 25–32.

613 [19] E. E. Bursztein and V., "Internet-wide efforts to fight email phishing are working. Google
614 Security Blog, [https://security,](https://security.googleblog.com/2013/12/internet-wide-efforts-to-fight-email.html)" 2013, googleblog. com/2013/12/internet-wide-efforts-to-fight-email.
615 html.

616 [20] D. P. Patil and J.B., "Survey on malicious web pages detection tech- niques," International Journal
617 of U-and E-service, Science and Tech- nology, vol. 8, no. 5, pp. 195–206, 2015

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