A comparative study of generative adversarial networks on domain name generator in botnet malware

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Po-Chun Huang

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4 Botnet

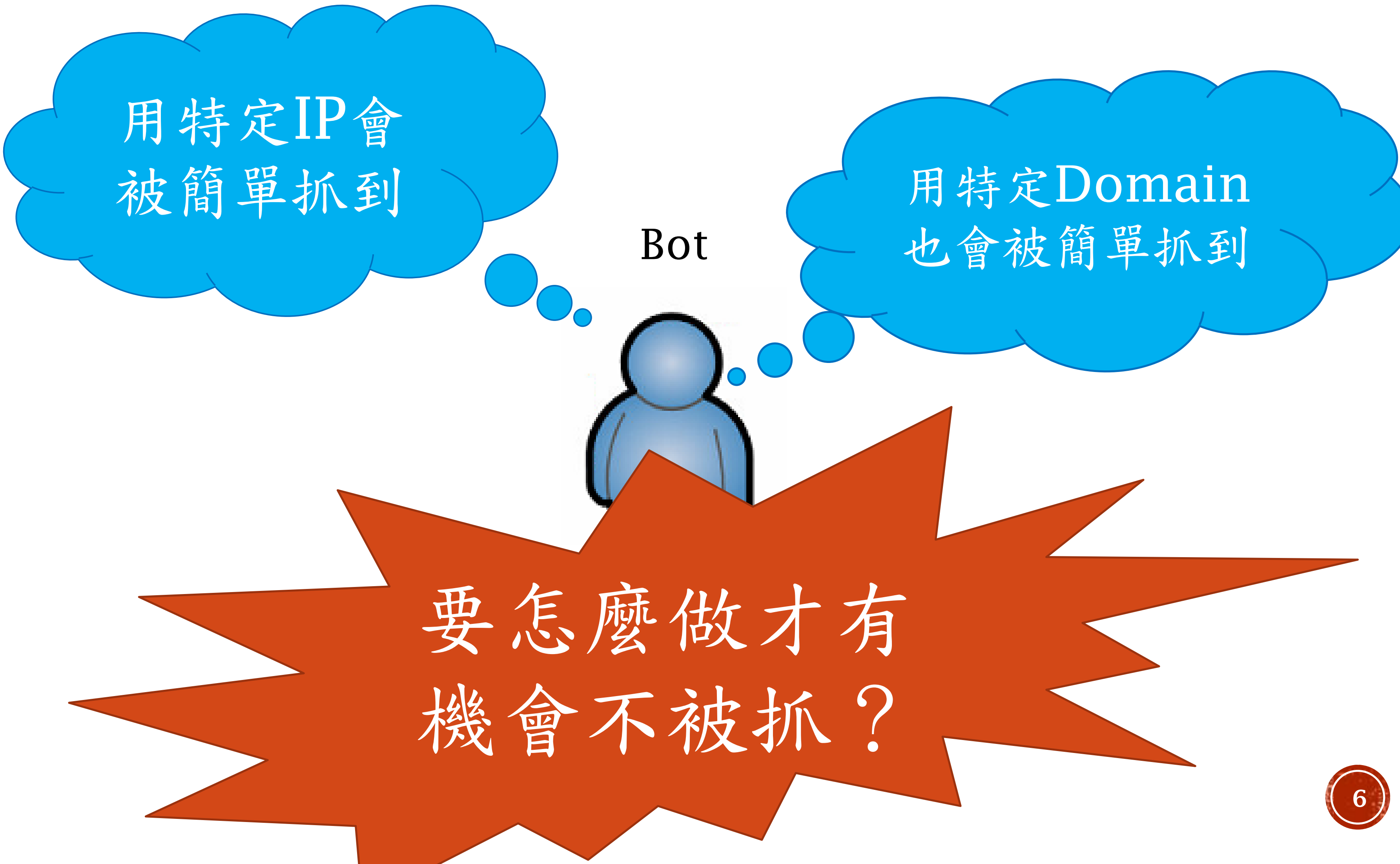
Introduction

Botnet

- Command and Control Server
- Bot

- 以往連接到C&C Server的方法：
  - 特定IP
  - 特定Domain

Botnet



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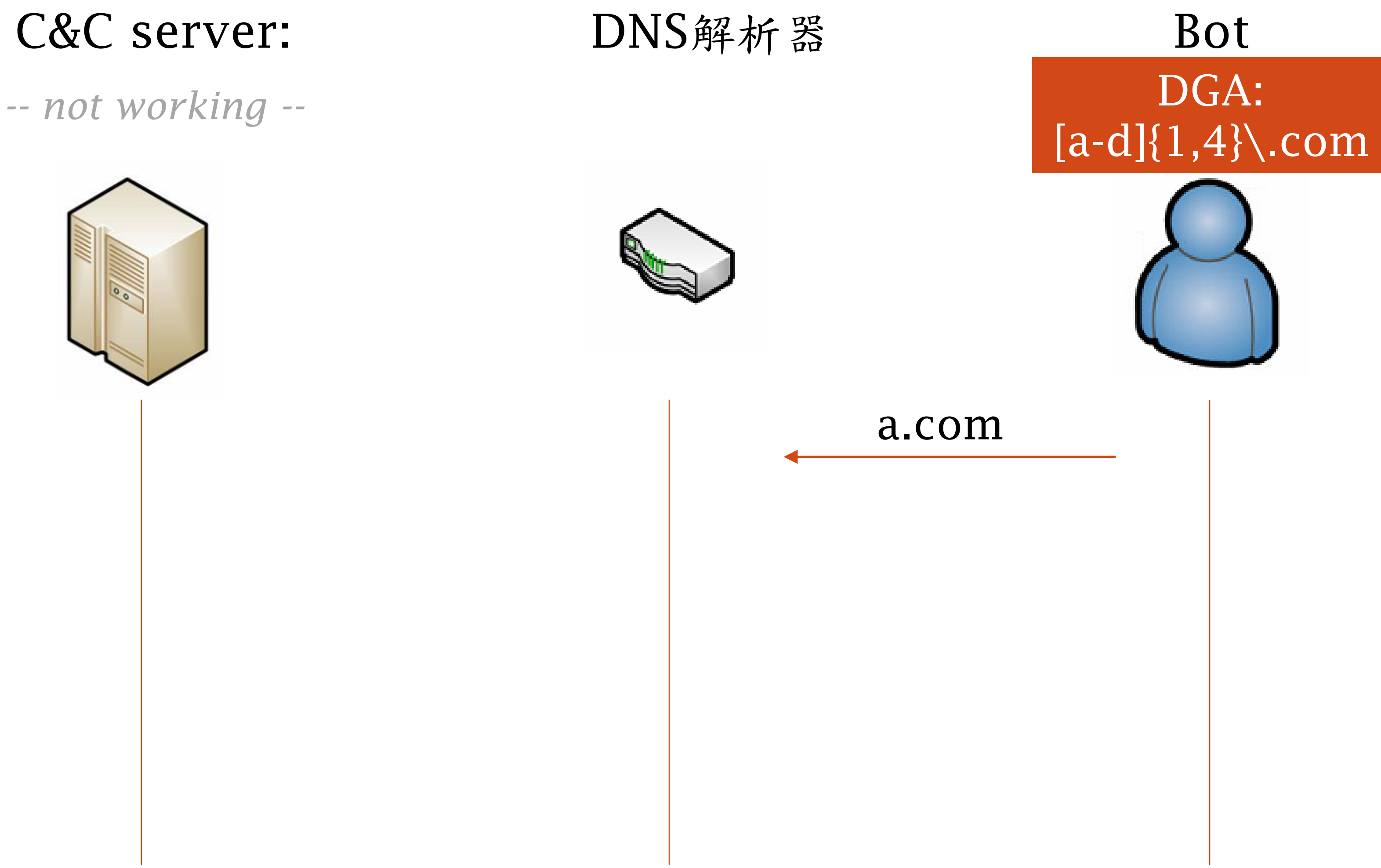
Domain Generation Algorithm (DGA)

Introduction

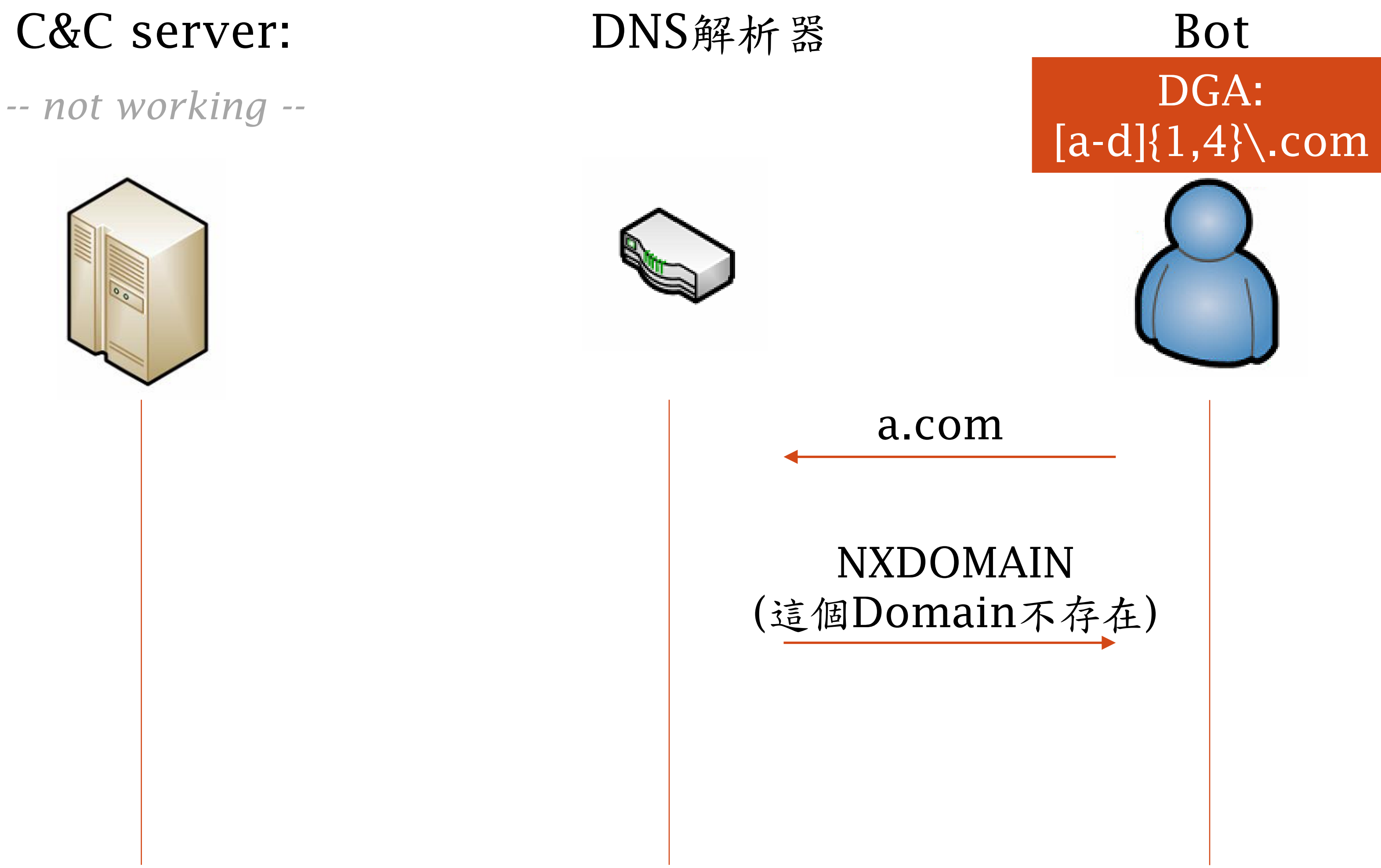
Domain Generation Algorithm

未發動攻擊時

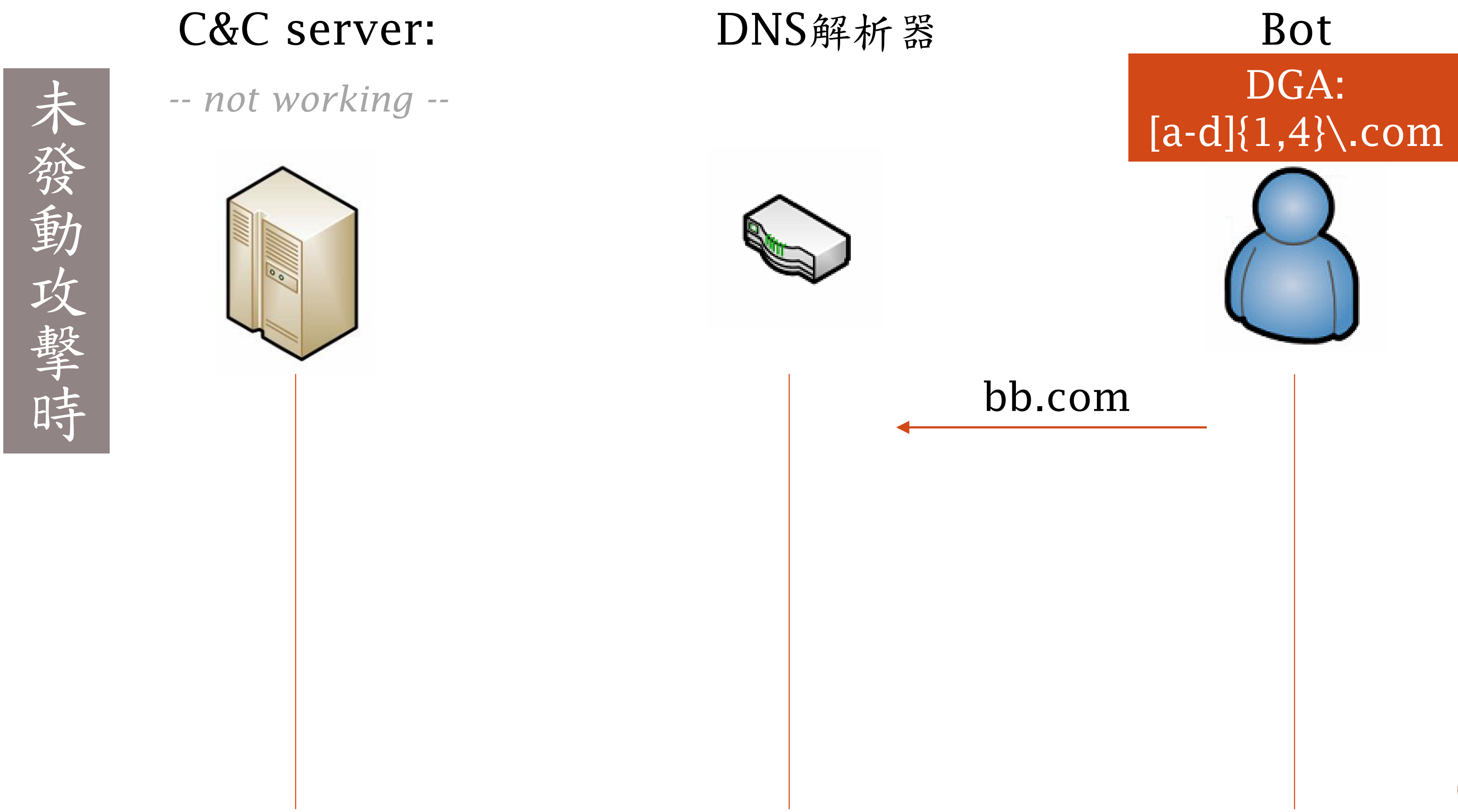


Domain Generation Algorithm

未發動攻擊時



Domain Generation Algorithm



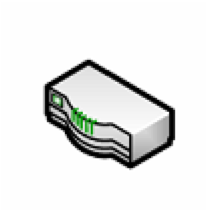
Domain Generation Algorithm

未發動攻擊時

C&C server:

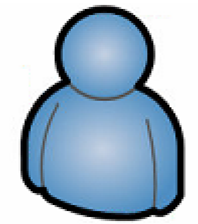
-- not working --

DNS解析器



Bot

DGA:
[a-d]{1,4}\.com

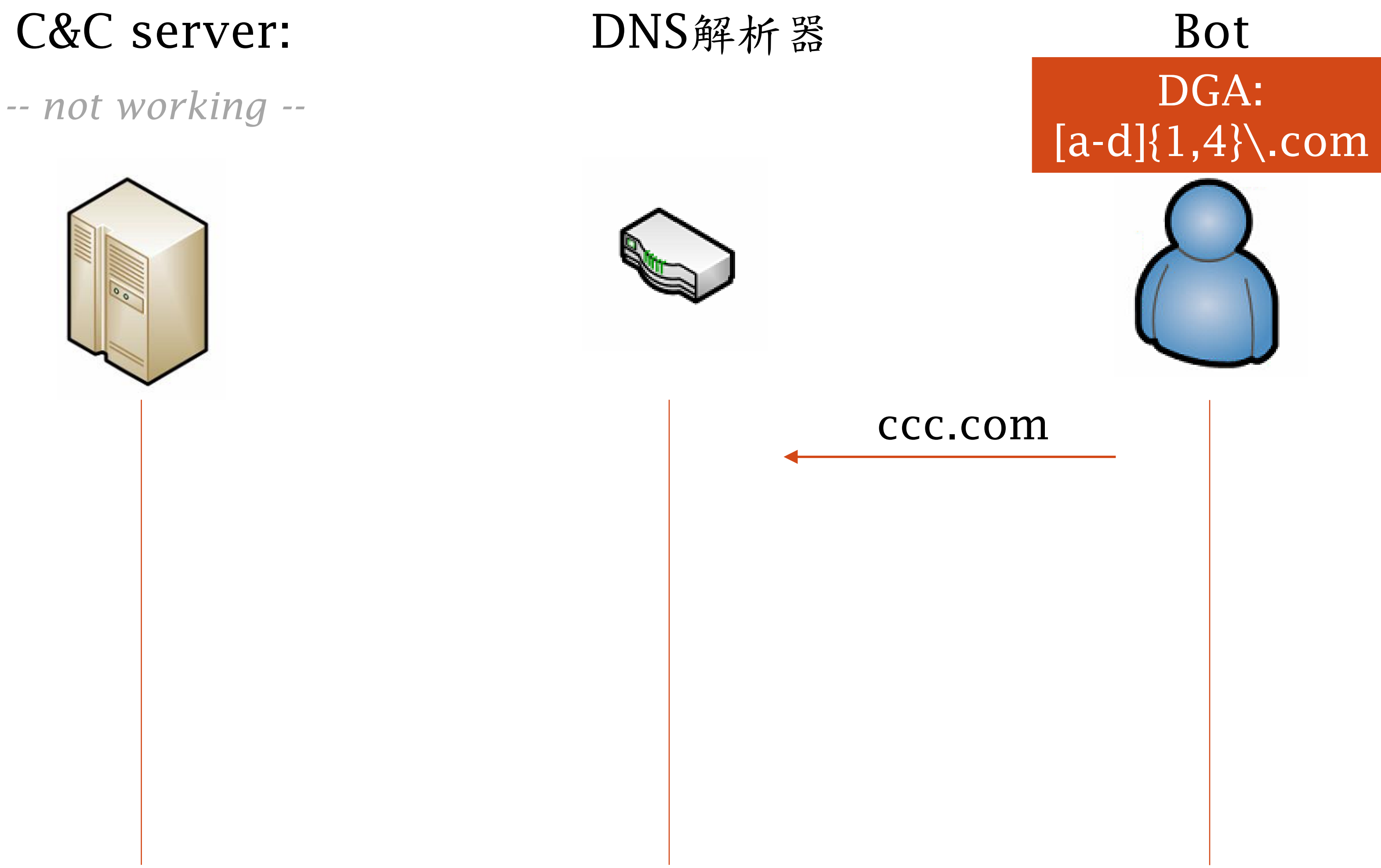


bb.com

NXDOMAIN

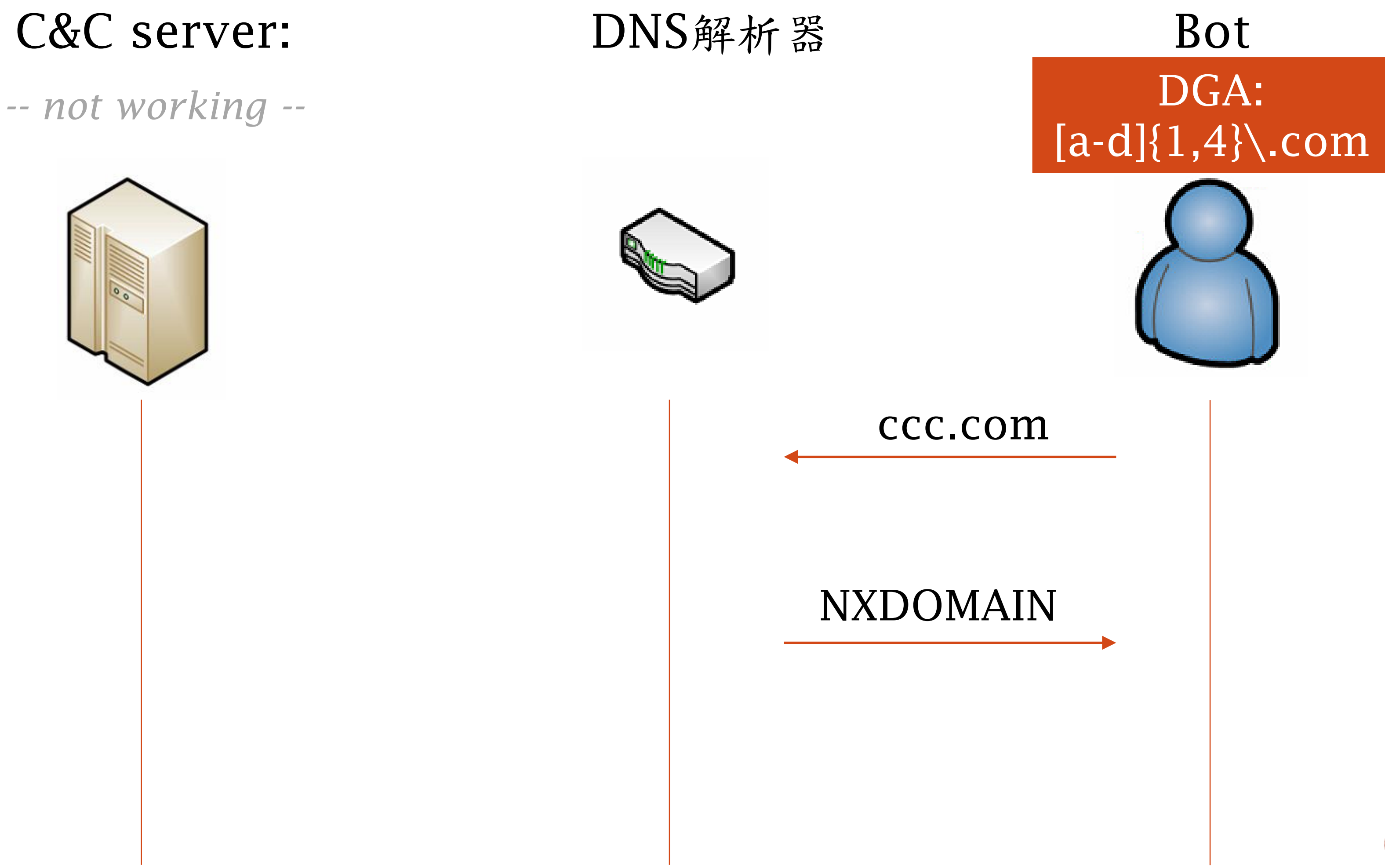
Domain Generation Algorithm

未發動攻擊時



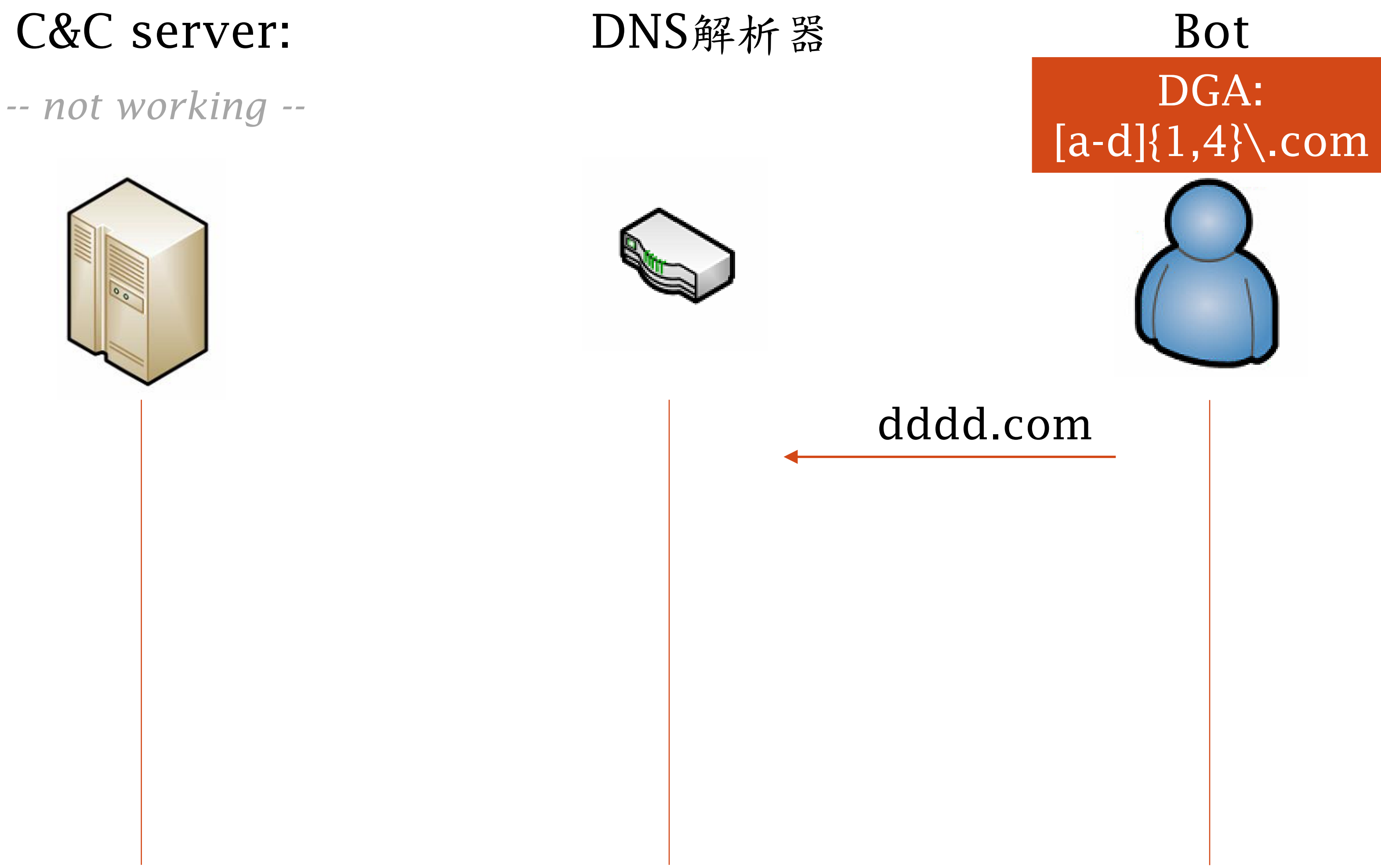
Domain Generation Algorithm

未發動攻擊時



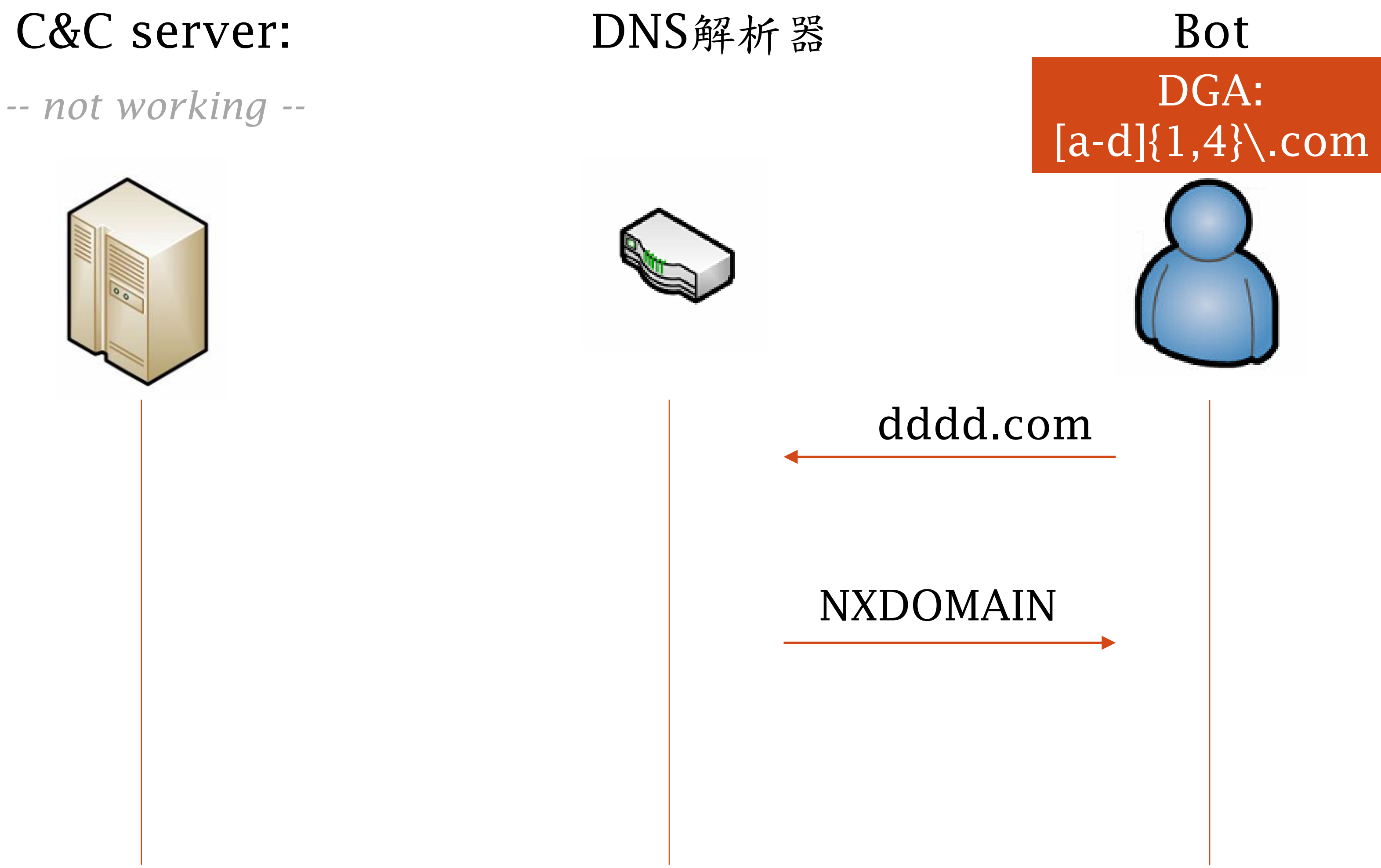
Domain Generation Algorithm

未發動攻擊時

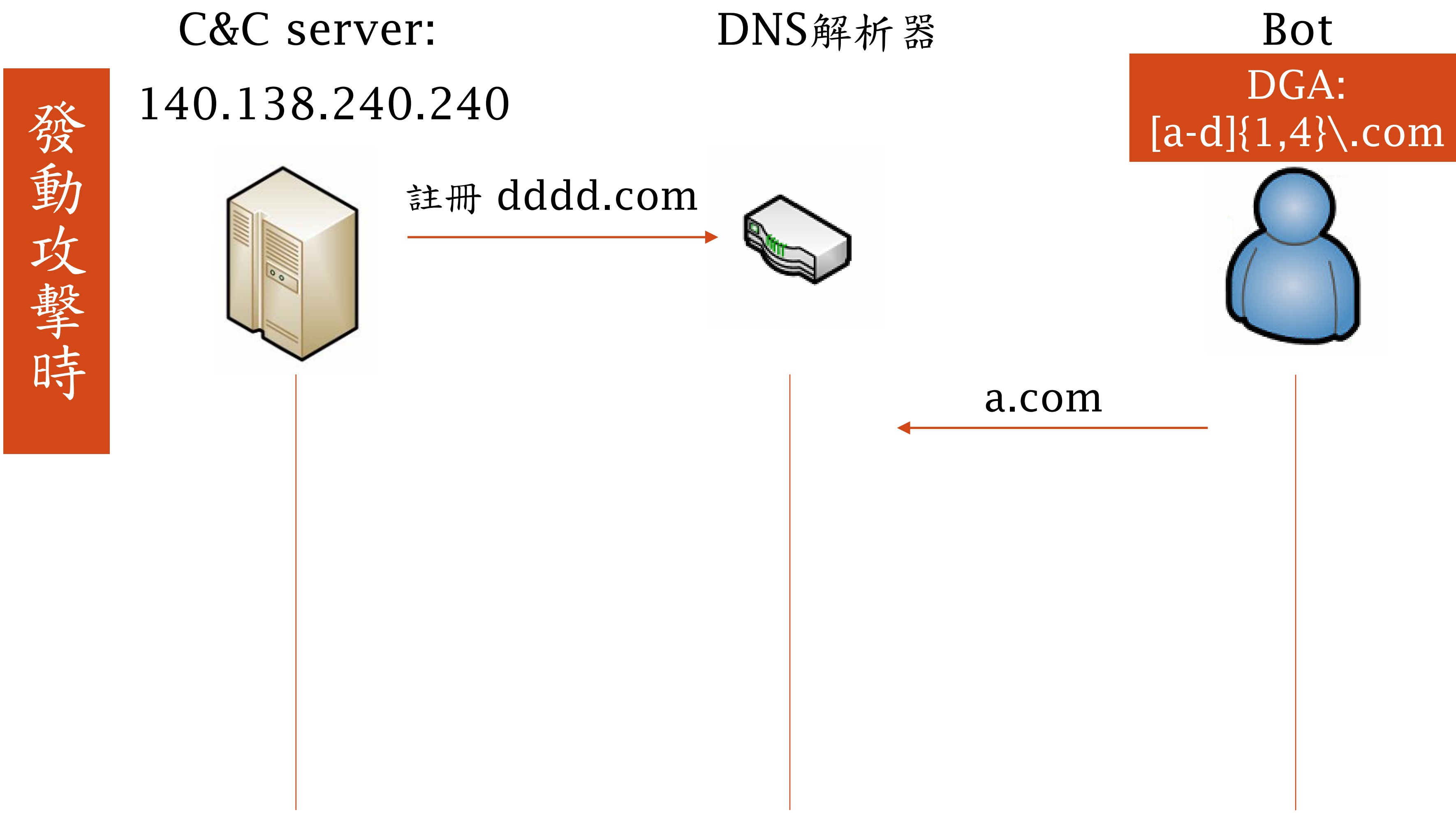


Domain Generation Algorithm

未發動攻擊時



Domain Generation Algorithm



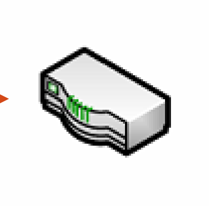
Domain Generation Algorithm

發動攻擊時

C&C server:
140.138.240.240

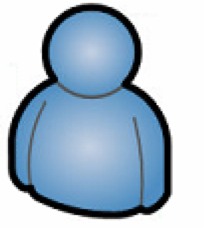
註冊 dddd.com

DNS解析器



Bot

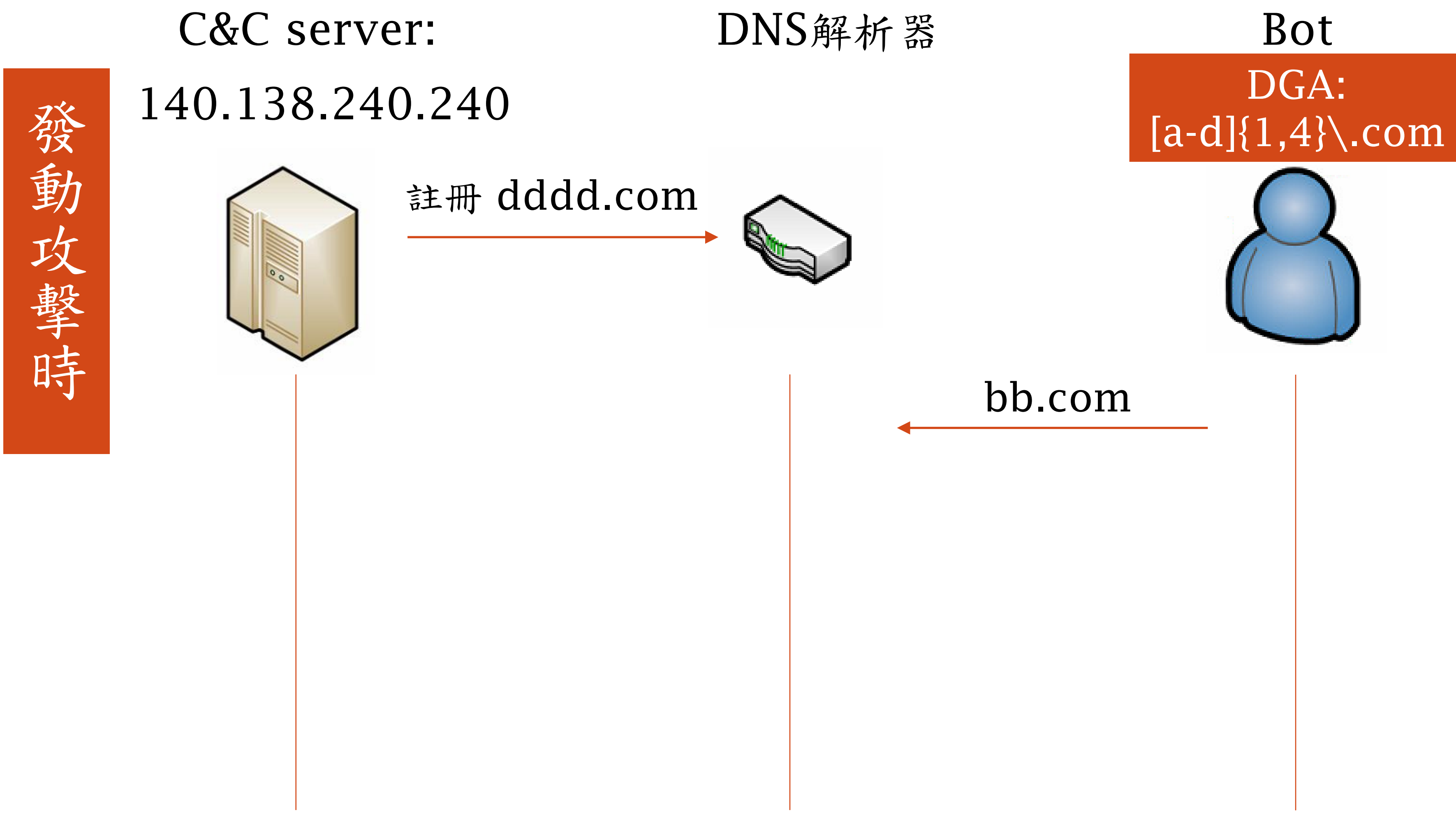
DGA:
[a-d]{1,4}\.com



a.com

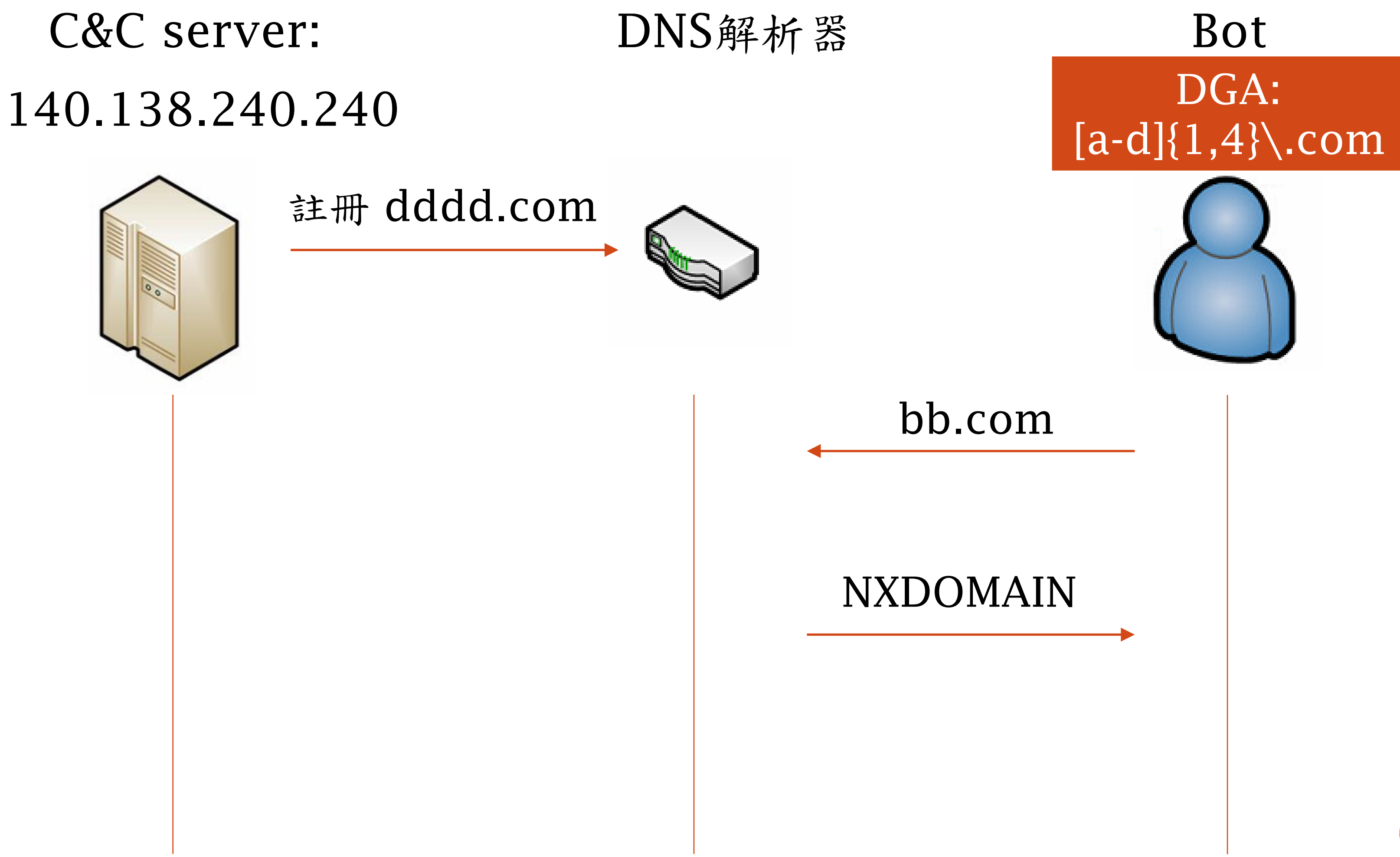
NXDOMAIN
(這個Domain不存在)

Domain Generation Algorithm

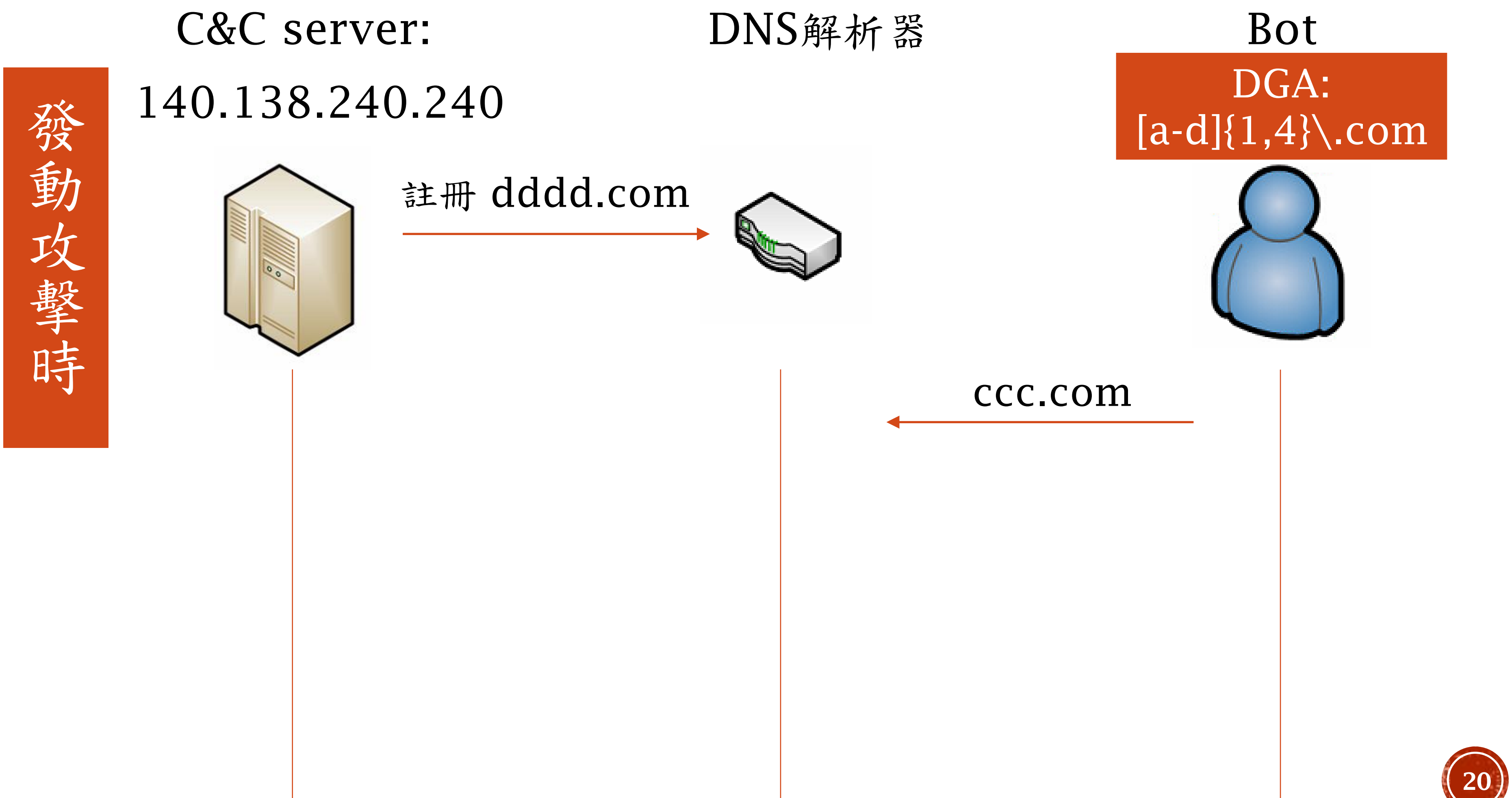


Domain Generation Algorithm

發動攻擊時

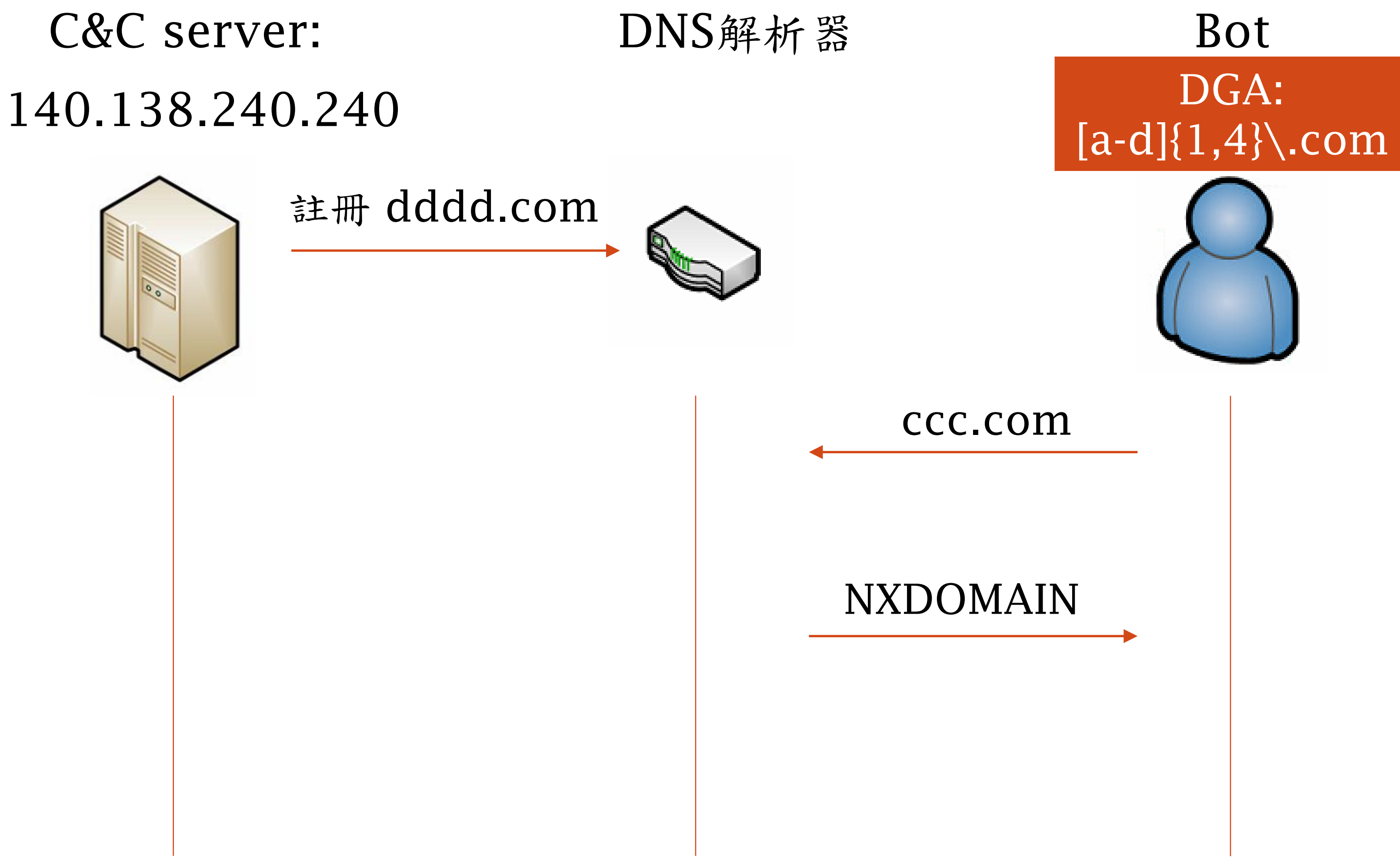


Domain Generation Algorithm

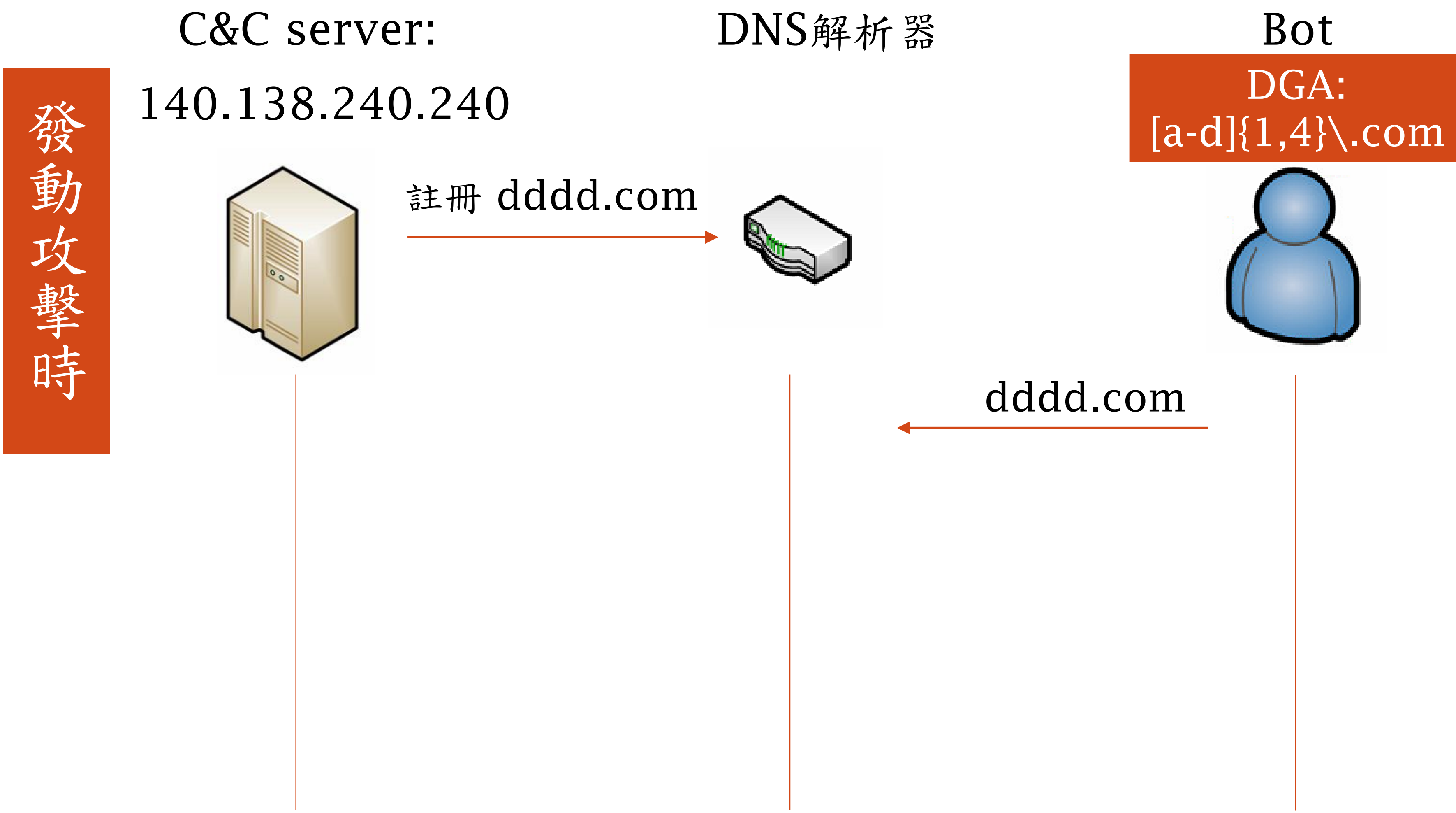


Domain Generation Algorithm

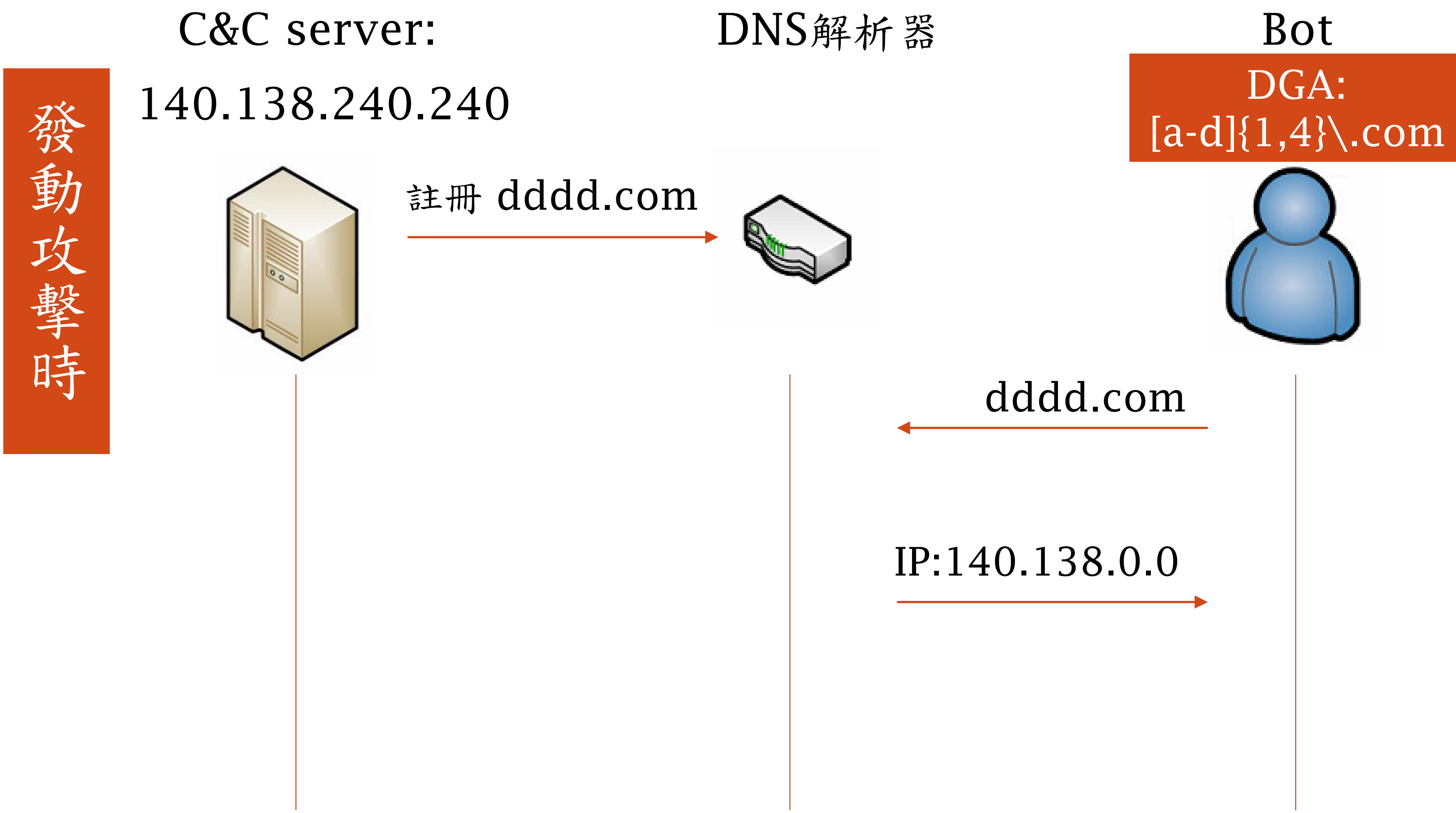
發動攻擊時



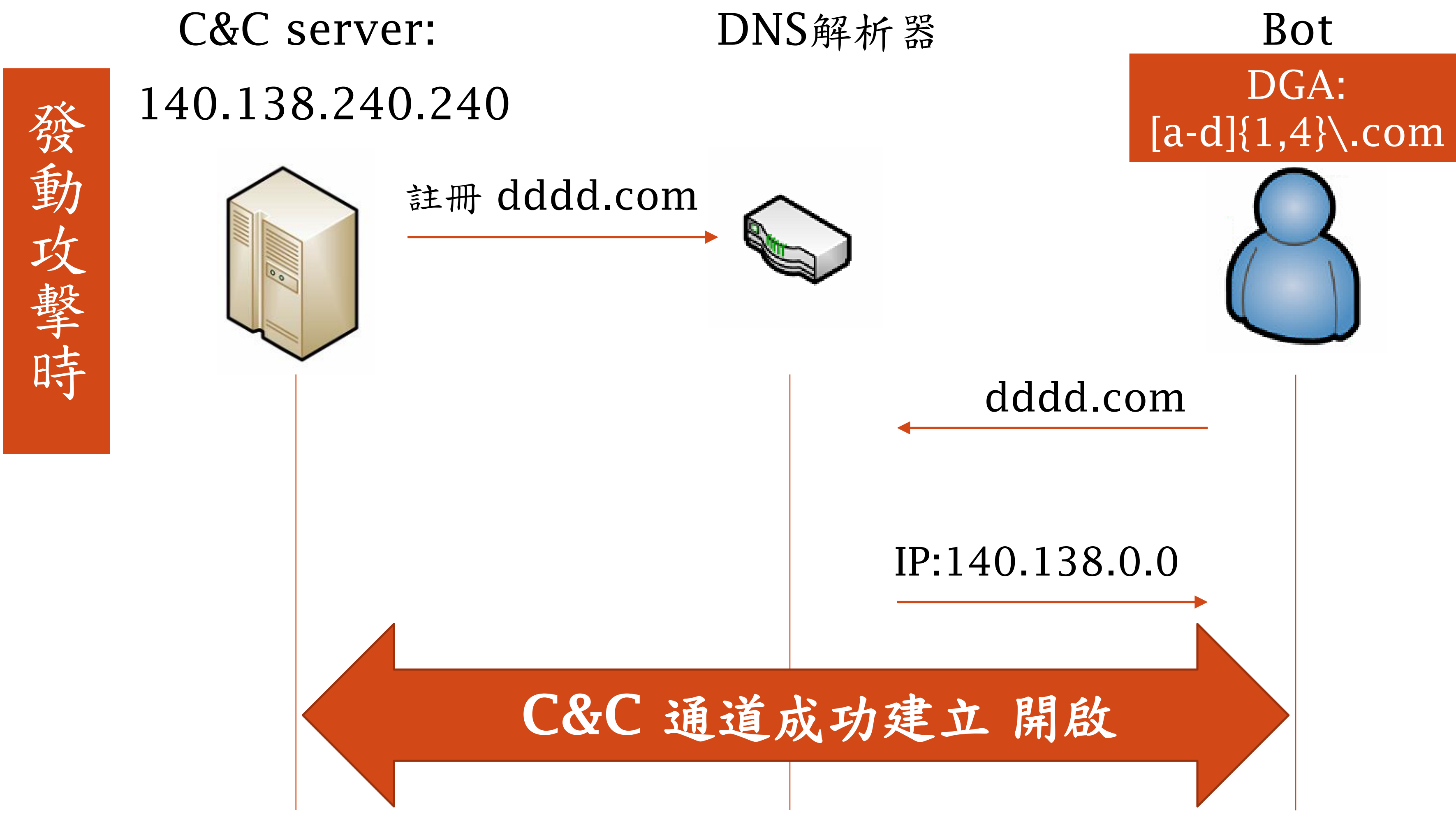
Domain Generation Algorithm



Domain Generation Algorithm



Domain Generation Algorithm



Domain Generation Algorithm

- 隨手寫的式子：[a-d]{1,4}\.com

  → 就已經可以產生340種網域名稱了

Domain Generation Algorithm

- 現實中Botnet的DGA更加複雜
- 一天就可以產生成千上萬個網域名稱

    → 太多可疑對象，防禦方難以防禦

    → DNS供應商

    → 網路管理員

- 雖然有成千上萬的網域名稱，但是只有一個或少數幾個才會被真正註冊作為惡意伺服器

    → 攻擊方所付出的代價卻很低廉

Literature Review

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Purpose

Introduction

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Deep Learning

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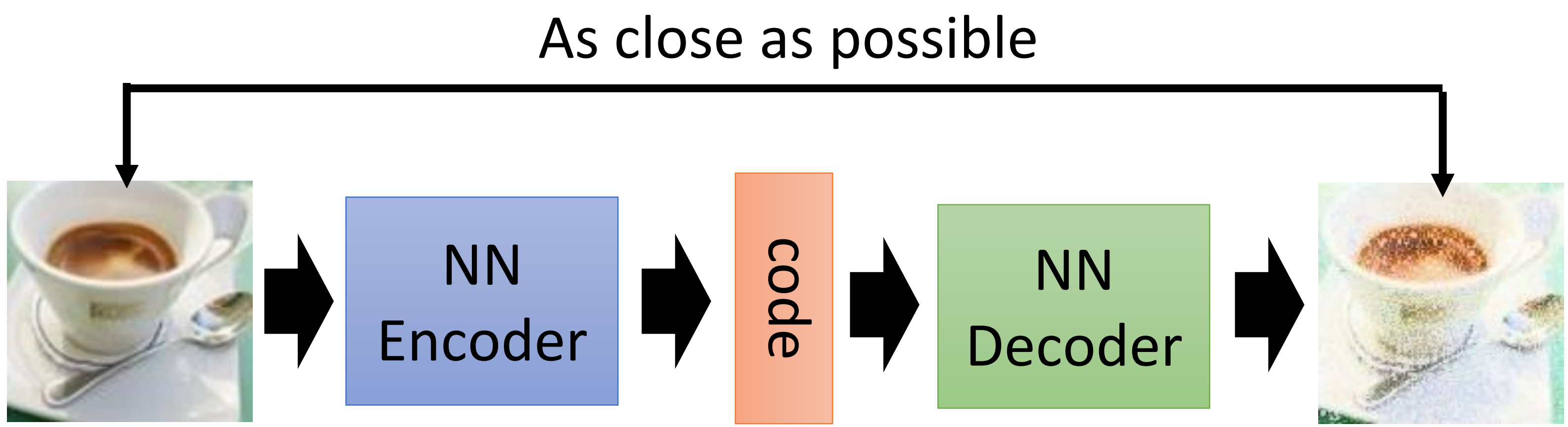
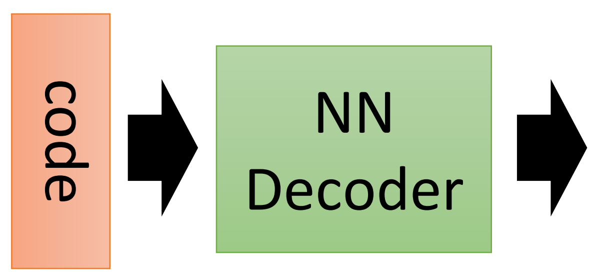
Deep Learning

AUTO-ENCODER

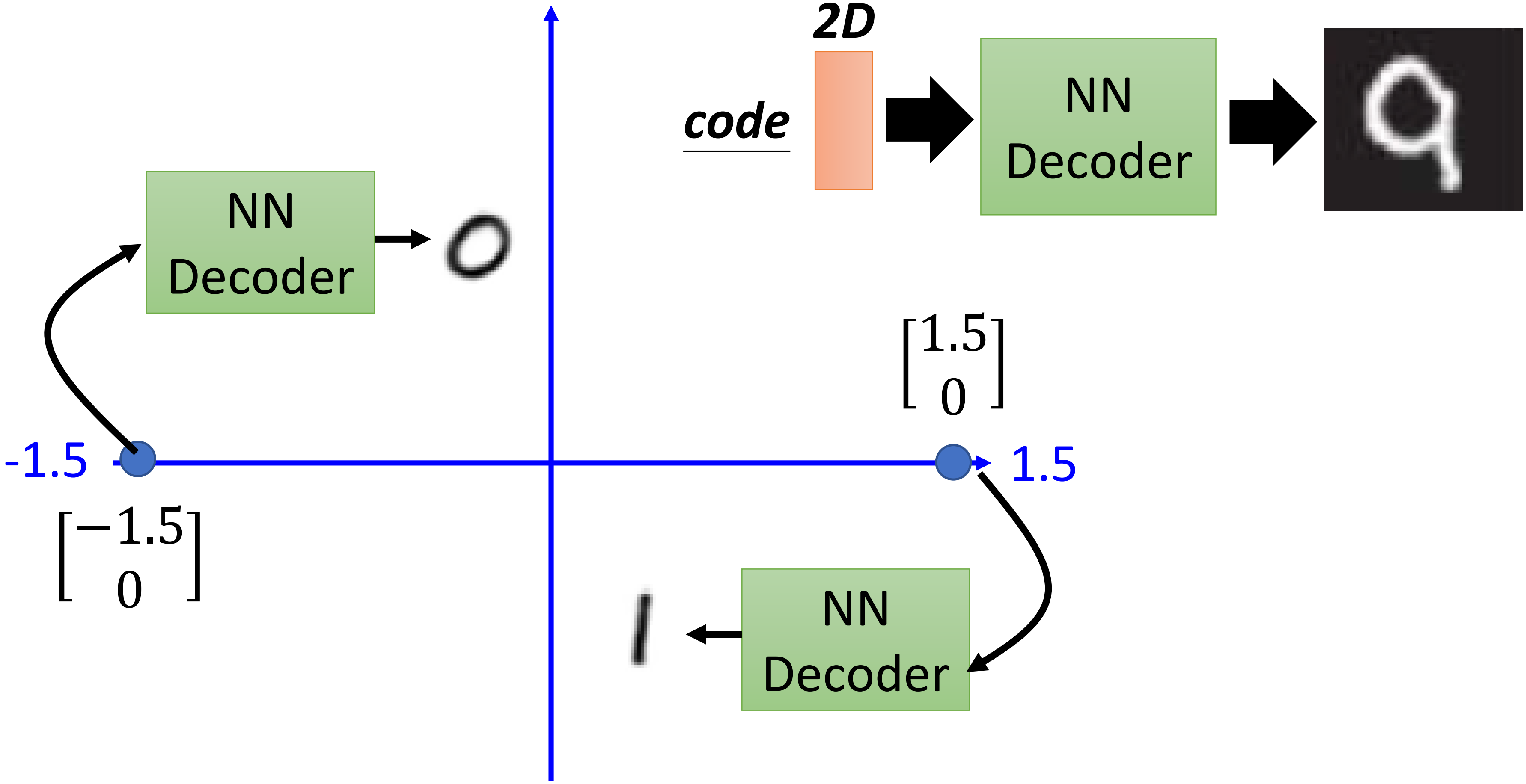


Randomly generate a vector as code



From Hung-yi Lee, "Generative Adversarial Network/Basic Idea/Machine Learning and having it deep and structured (2017,Spring)"
http://speech.ee.ntu.edu.tw/~tlkagk/courses_MLDS17.html

AUTO-ENCODER



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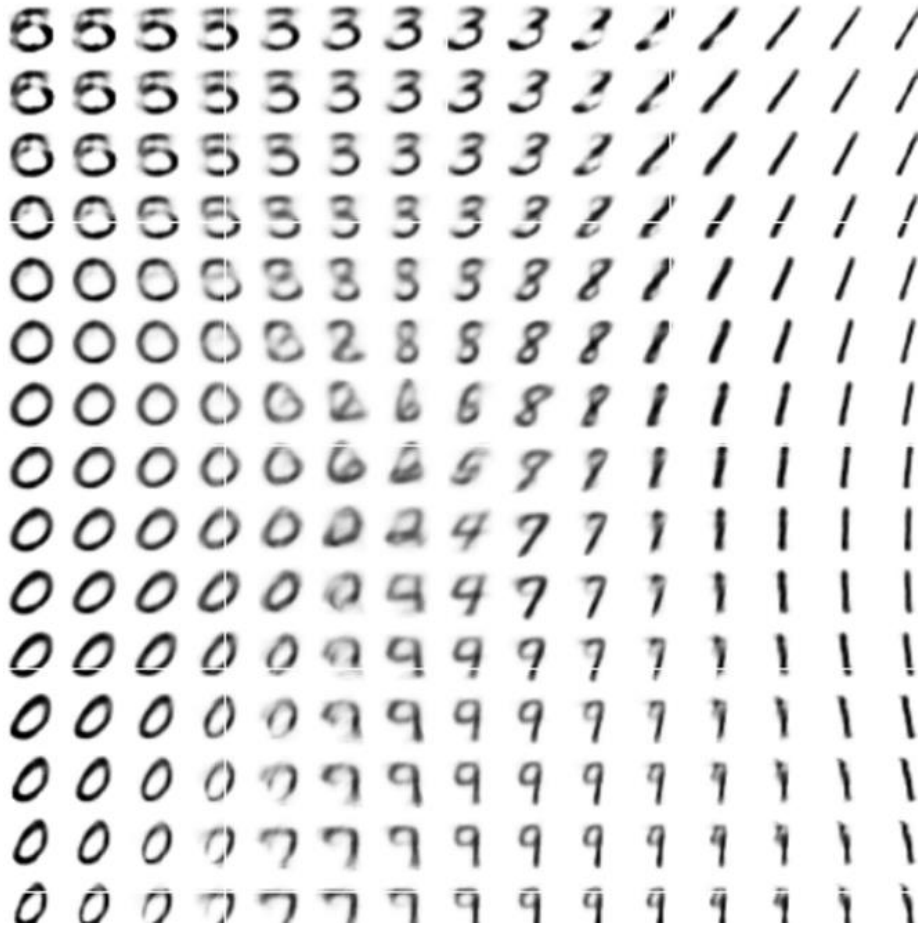

From Hung-yi Lee, "Generative Adversarial Network/Basic Idea/Machine Learning and having it deep and structured (2017,Spring)"
http://speech.ee.ntu.edu.tw/~tlkagk/courses_MLDS17.html

Generative Adversarial Networks (GAN)

Deep Learning

ALGORITHM

Algorithm 1 Minibatch stochastic gradient descent training of generative adversarial nets. The number of steps to apply to the discriminator, k, is a hyperparameter. We used $k = 1$, the least expensive option, in our experiments.

for number of training iterations **do**
  for k steps **do**
  - Sample minibatch of m noise samples $\{\boldsymbol{z}^{(1)}, \dots, \boldsymbol{z}^{(m)}\}$ from noise prior $p_g(\boldsymbol{z})$.
  - Sample minibatch of m examples $\{\boldsymbol{x}^{(1)}, \dots, \boldsymbol{x}^{(m)}\}$ from data generating distribution $p_{\text{data}}(\boldsymbol{x})$.
  - Update the discriminator by ascending its stochastic gradient:

$$\nabla_{\theta_d} \frac{1}{m} \sum_{i=1}^{m} \left[\log D\left(\boldsymbol{x}^{(i)}\right) + \log\left(1 - D\left(G\left(\boldsymbol{z}^{(i)}\right)\right)\right)\right].$$

  end for
  - Sample minibatch of m noise samples $\{\boldsymbol{z}^{(1)}, \dots, \boldsymbol{z}^{(m)}\}$ from noise prior $p_g(\boldsymbol{z})$.
  - Update the generator by descending its stochastic gradient:

$$\nabla_{\theta_g} \frac{1}{m} \sum_{i=1}^{m} \log\left(1 - D\left(G\left(\boldsymbol{z}^{(i)}\right)\right)\right).$$

end for

The gradient-based updates can use any standard gradient-based learning rule. We used momentum in our experiments.

From "Generative Adversarial Networks"
https://arxiv.org/abs/1406.2661

Wasserstein GAN (WGAN)

Deep Learning

ALGORITHM

Algorithm 1 WGAN, our proposed algorithm. All experiments in the paper used the default values $\alpha = 0.00005$, $c = 0.01$, $m = 64$, $n_{\text{critic}} = 5$.

Require: : α, the learning rate. c, the clipping parameter. m, the batch size. n_{critic}, the number of iterations of the critic per generator iteration.
Require: : w_0, initial critic parameters. θ_0, initial generator's parameters.

while θ has not converged **do**
  for $t = 0, \ldots, n_{\text{critic}}$ **do**
    Sample $\{x^{(i)}\}_{i=1}^m \sim \mathbb{P}_r$ a batch from the real data.
    Sample $\{z^{(i)}\}_{i=1}^m \sim p(z)$ a batch of prior samples.
    $g_w \leftarrow \nabla_w \left[\frac{1}{m}\sum_{i=1}^m f_w(x^{(i)}) - \frac{1}{m}\sum_{i=1}^m f_w(g_\theta(z^{(i)}))\right]$
    $w \leftarrow w + \alpha \cdot \text{RMSProp}(w, g_w)$
    $w \leftarrow \text{clip}(w, -c, c)$
  end for
  Sample $\{z^{(i)}\}_{i=1}^m \sim p(z)$ a batch of prior samples.
  $g_\theta \leftarrow -\nabla_\theta \frac{1}{m}\sum_{i=1}^m f_w(g_\theta(z^{(i)}))$
  $\theta \leftarrow \theta - \alpha \cdot \text{RMSProp}(\theta, g_\theta)$
end while

From "Wasserstein GAN"
https://arxiv.org/abs/1701.07875

Improved Wasserstein GAN (WGAN-GP)

Deep Learning

ALGORITHM

Algorithm 1 WGAN with gradient penalty. We use default values of $\lambda = 10$, $n_{\text{critic}} = 5$, $\alpha = 0.0001$, $\beta_1 = 0$, $\beta_2 = 0.9$.

Require: The gradient penalty coefficient λ, the number of critic iterations per generator iteration n_{critic}, the batch size m, Adam hyperparameters α, β_1, β_2.
Require: initial critic parameters w_0, initial generator parameters θ_0.

```
while θ has not converged do
    for t = 1, ..., n_critic do
        for i = 1, ..., m do
            Sample real data x ~ P_r, latent variable z ~ p(z), a random number ε ~ U[0, 1].
            x̃ ← G_θ(z)
            x̂ ← εx + (1 − ε)x̃
            L^(i) ← D_w(x̃) − D_w(x) + λ(‖∇_x̂ D_w(x̂)‖_2 − 1)^2
        end for
        w ← Adam(∇_w (1/m) Σ_{i=1}^m L^(i), w, α, β_1, β_2)
    end for
    Sample a batch of latent variables {z^(i)}_{i=1}^m ~ p(z).
    θ ← Adam(∇_θ (1/m) Σ_{i=1}^m −D_w(G_θ(z)), θ, α, β_1, β_2)
end while
```

From "Improved Training of Wasserstein GANs"
https://arxiv.org/abs/1704.00028

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Requirement

MATERIALS AND METHODS

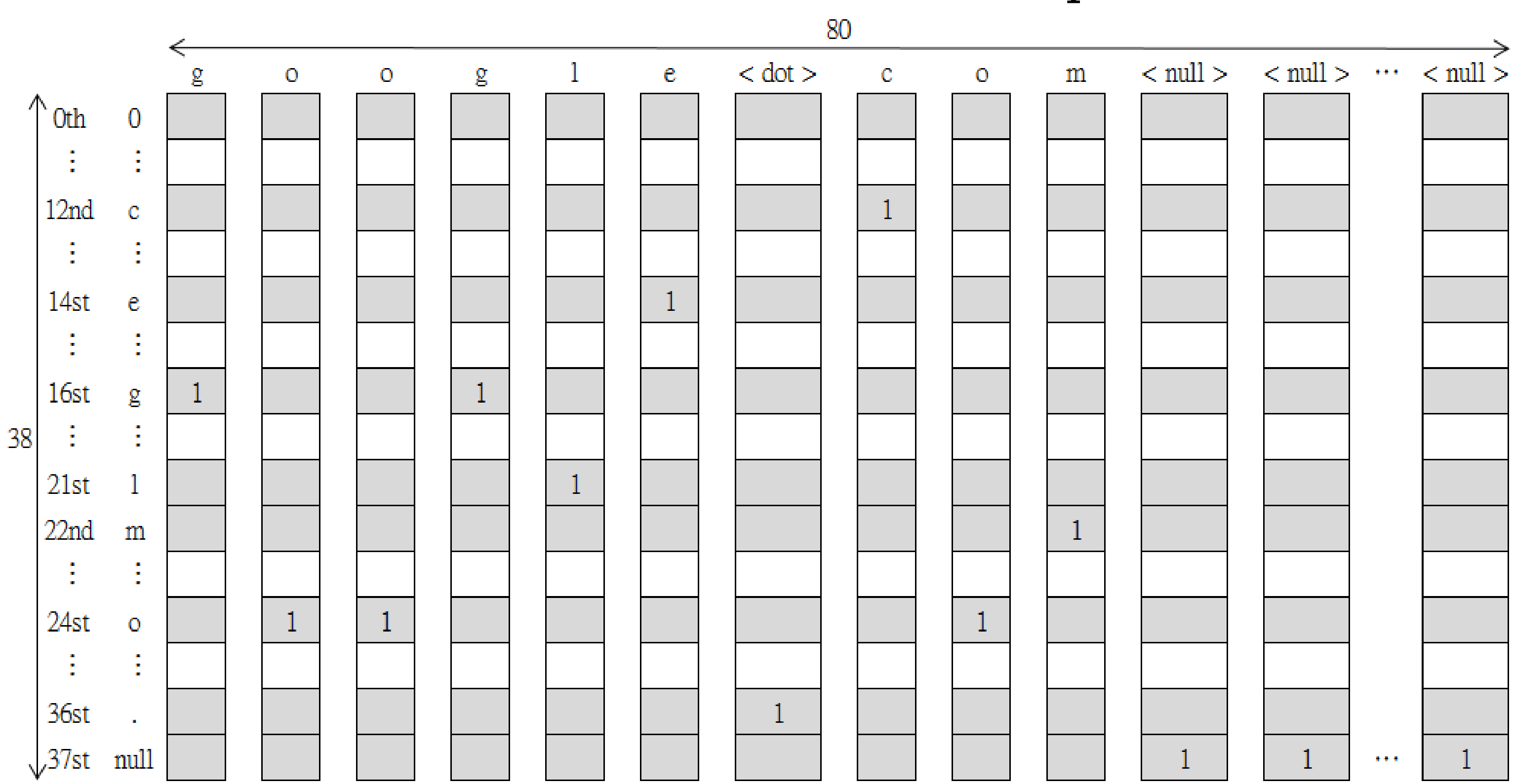
REQUIREMENT

- Q: Where is my training data?
- A: From Alexa Top 1-million sites.

	A	B
1	1	google.com
2	2	youtube.com
3	3	facebook.com
4	4	baidu.com
5	5	yahoo.com
6	6	wikipedia.org
7	7	amazon.com
8	8	twitter.com
9	9	qq.com
10	10	google.co.in
11	11	live.com
12	12	taobao.com
13	13	bing.com
14	14	google.co.jp
15	15	msn.com
16	16	yahoo.co.jp
17	17	linkedin.com
18	18	sina.com.cn
19	19	weibo.com
20	20	vk.com
21	21	instagram.com
22	22	google.ru
23	23	yandex.ru
24	24	google.de
25	25	hao123.com
26	26	ebay.com
27	27	reddit.com
28	28	google.co.uk
29	29	amazon.co.jp
30	30	t.co
31	31	google.com.br
32	32	mail.ru
33	33	google.fr
34	34	pinterest.com
35	35	netflix.com

REQUIREMENT

- Q: How to use this data?
- A: I deal these domain names as 38x80 pictures.



REQUIREMENT

- Because we don’t have the “code”. We have to train an Auto-encoder model.