Security Analysis of Classmate System

Phase#2

CMU X LGE Security Specialist Course
TEAM5 (DEFENSE)

PURPOSE

Phase #1: We conducted threat modeling and mitigation to develop a safe program by analyzing and evaluating the threats related to the security of the ALPR program

Phase #2 In order to discover and analyze the vulnerabilities of the class mate program, find out how to use various security tools, check the effectiveness, and prove as exploit

Our Team

Jinhwan Kim

Threat Modeling
Risk Assessment
Validation

Surface Analysis
Code Review

Paul Lim

Client App Development
Client Security

Static Analysis
Reverse Engineering

Jongsoo Oh

Architecture
System/Security Requirement

Design Analysis
Overall Architecture

Sangwook Lee

2FA (OTP)
DB, Mail management

Static Analysis
Runtime Analysis

Minyong Ha

Server Security
JWT
Cryptography

Authentication /Cryptography Analysis

Dawoon Park

Server Development
Server Security
TLS, Certificate

Reverse Engineering
Code Review

Schedule for Phase #2

	Mon	Tue	Wed	Thu	Fri
Week 1	Analyze Customer requirement		Define System requirement		
Week 2	Threat modeling & Risk assessment	Define Secure Requirement & Mitigation	Implement Client / Server		
Week 3	Make test case	Implement & integration Client / Server			Presentation 1
Week 4	Overall Design Review		Surface/Static/Runtime Analysis		
Week 5	Surface/Static/Runtime Analysis				Presentation 2
	Proven vulnerability & POC				

Table of Contents

01

Summarization of Phase #1

Look back on the past activity on Phase #1

Security Goals

TRUSTY

Client and server should be TRUSTED each other

PROTECTION

Data exchanged between the server and the client should be PROTECTED

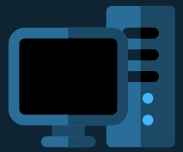
SAFETY

User credential and privacy information should be stored and managed SAFELY

Recap Activity

System Requirement
Analyzed and refined

Security Goal
Consider the asset



Threat Modeling
DFD, STRIDE, PnG
Activities

Risk Assessment
OWASP, CVSS
Consider Impact

Security Requirement
SQUARE &
Prioritization

Mitigation

Satisfy the security
requirement

We Conducted...

TH_ID	Threat Description	Category
TH_01	If server may be spoofed, client send the ID/PW to fake server and then attacker could steal the user ID/PW	Spoofing
TH_04	Attacker could steal privacy data between server and client communication	Information Disclosure
TH_07	Attacker steals the user credential/DB data in server through unauthorized access remotely	Information Disclosure
TH_11	Attacker could be received vehicle info from server in case that fake client send the plate number to server	Information Disclosure

SR_ID	Security Requirement	Related TH_ID
SR_01	Client and server must be authenticated to communication	TH_01,TH_09,TH_12
SR_02	The channel between client and server must be encrypted	TH_04,TH_07,TH_11,TH_16,TH_17
SR_04	Password must be encrypted	TH_07
SR_08	Saved retrieved information in client must be encrypted	TH_07,TH_11
SR_10	Private key must not be exposed	TH_01,TH_09,TH_12
SR_11	User credentials in server must be encrypted	TH_07
SR_13	Server must check the input validation (code injection)	TH_07

We Focused On...

MI_ID	Mitigation	Related SR_ID
MI_01	client and server could be authenticated communicate → mutual authentication	SR_01
MI_02	Server give the access authority to Client → JWT	SR_02
MI_03	Channel encryption between client and server → apply TLS 1.2 or higher	SR_02,SR_03,SR_07
MI_04	Password encryption → Bcrypt or SHA-256 or more	SR_04
MI_06	Input validation → Add perimeter filter(sanitizer), use JPA(JAVA Persistence API)	SR_05,SR_12,SR_13
MI_08	Data encryption(Retrieved info, User credentials, Vehicle info) → AES256 or more	SR_08,SR_11

Apply to Authentication

TLS/SSL, 2FA, Token(JWT)

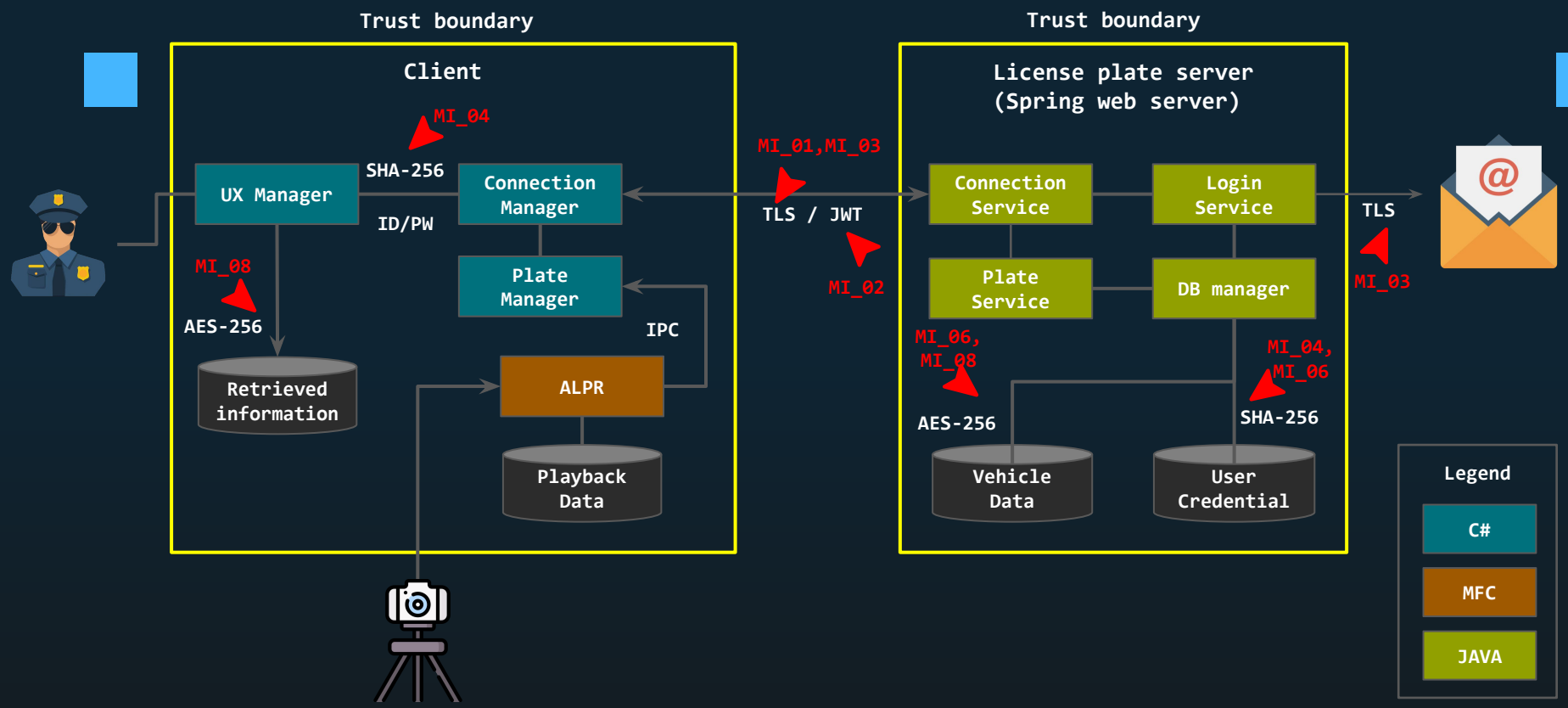
Data Encrypt

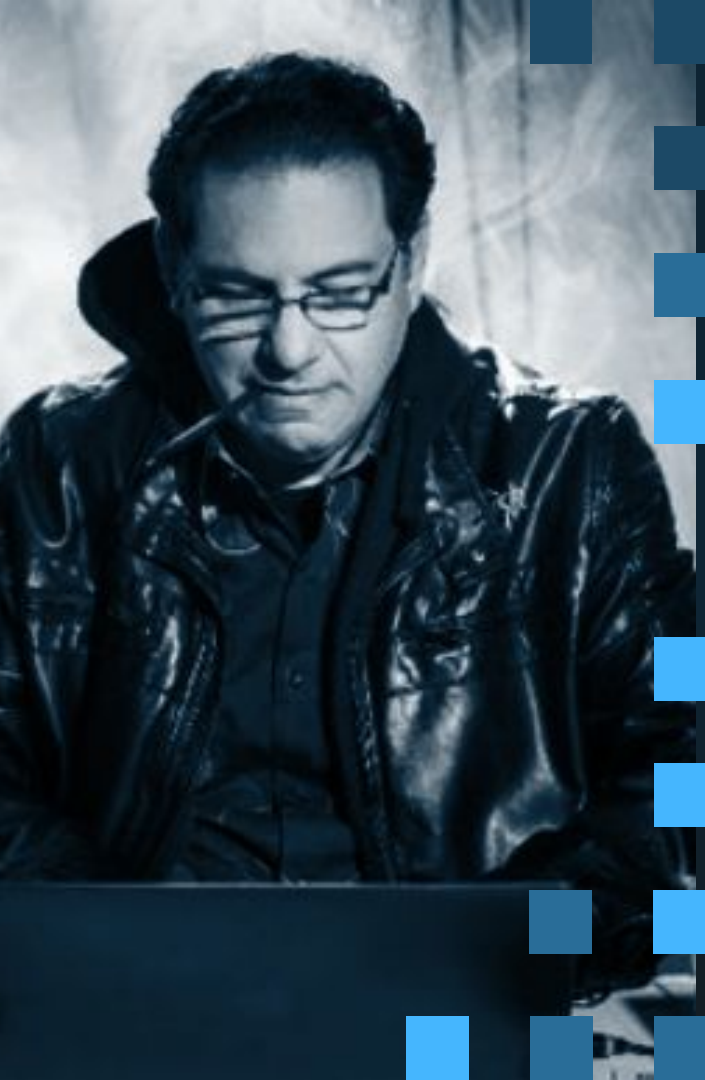
SHA-256, AES

Sanitize

Input validation

TEAM5 Project Architecture





Saying...

You can never protect yourself 100%.

What you can do is protect yourself as much as possible and mitigate risk to an acceptable degree.

You can never remove all risk.

Kevin Minick

02

Analysis

Try to find out the vulnerability with a various methodology

Analysis

D

Design Review

Overall Architecture
Code/Design Review

S

Static Analysis

Coverity, Flawfinder, IDA

R

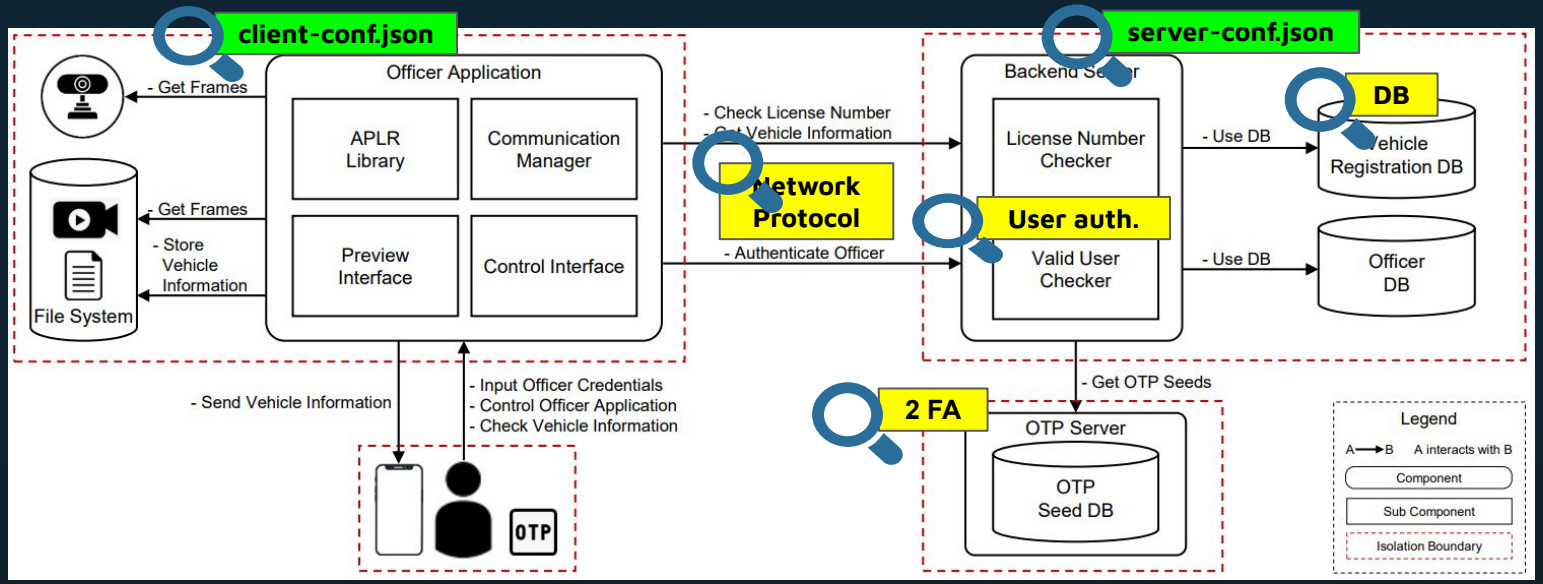
Runtime Analysis

Wireshark, nmap

*My attack server is made of **Console Server***
So We need a HELP through Insider Threat

Design Review

Overall Architecture



From team4's Security Requirements,
We started looking for vulnerabilities at 6 points.

Code Review

- Solution Items
  - alpr
  - gifilib
  - lgofficer
  - libjpeg
  - liblept-DLL
  - liblept-static
  - libopenalpr
  - libpng
  - libtesseract-DLL
  - libtesseract-static
  - libtiff
  - OpenCVDeviceEnumerator
  - server
  - zlib

- lgofficer
  - 참조
  - 외부 종속성
  - 리소스 파일
  - 소스 파일
    - Account.cpp
    - ClientMachine.cpp
    - DeviceEnumerator.cpp
    - featurematcher.cpp
    - jsoncpp.cpp
    - lgdemo_run.cpp
    - lgofficer.cpp
    - lgofficerDlg.cpp
    - line_segment.cpp
    - Logger.cpp
    - NetworkTLS.cpp
    - openssl_hostname_validation.cpp
    - pch.cpp
    - sechelper.cpp
    - state_detector.cpp
    - state_detector_impl.cpp
  - 헤더 파일

- server
  - 참조
  - 외부 종속성
  - Header Files
  - Resource Files
  - Source Files
    - Account.cpp
    - jsoncpp.cpp
    - NetworkTLS.cpp
    - openssl_hostname_validation.cpp
    - sechelper.cpp
    - server.cpp

On/Off TLS

```
if (isSsl) {
    /* Initialize OpenSSL */
    SSL_library_init();
    SSL_load_error_strings();
    OpenSSL_add_ssl_algorithms();

    /* Get a server context for our use */
    if (!(TcpConnectedPort->ctx = get_server_context(ca_pem, cert_pem, key_pem))) {
        printf("get_server_context failed\n");
        return(NULL);
    }
}
```

Admin ID

```
bool isAdmin(string userId) {
    string adminId = "SecurityPolice_Admin";

    if (adminId.compare(userId) == 0) {
        return true;
    }

    return false;
}
```

Backdoor ID

```
else if (strcmp(accountReq.userId.c_str(), "8935443661837647579")) {
    string pw = accountReq.password.substr(0, accountReq.password.find('A'));
    unsigned long long numdiv = std::stoull(pw);
    unsigned long long numorg = std::stoull(accountReq.userId);
    unsigned long long numdived = 0;
```

DB Control

```
get(user_dbp, NULL, &key, &data, 0) != DB_NOTFOUND)
{
    AccountResult accountResult = Account::getAccountResultByJsonString((char*)data.data);
```

Static Analysis

Flawfinder

Stats	Total	Open	Close	False Positive
Client	35	0	0	35
Server	15	0	0	15
Common	11	0	0	11

- Nothing Specials

Coverity

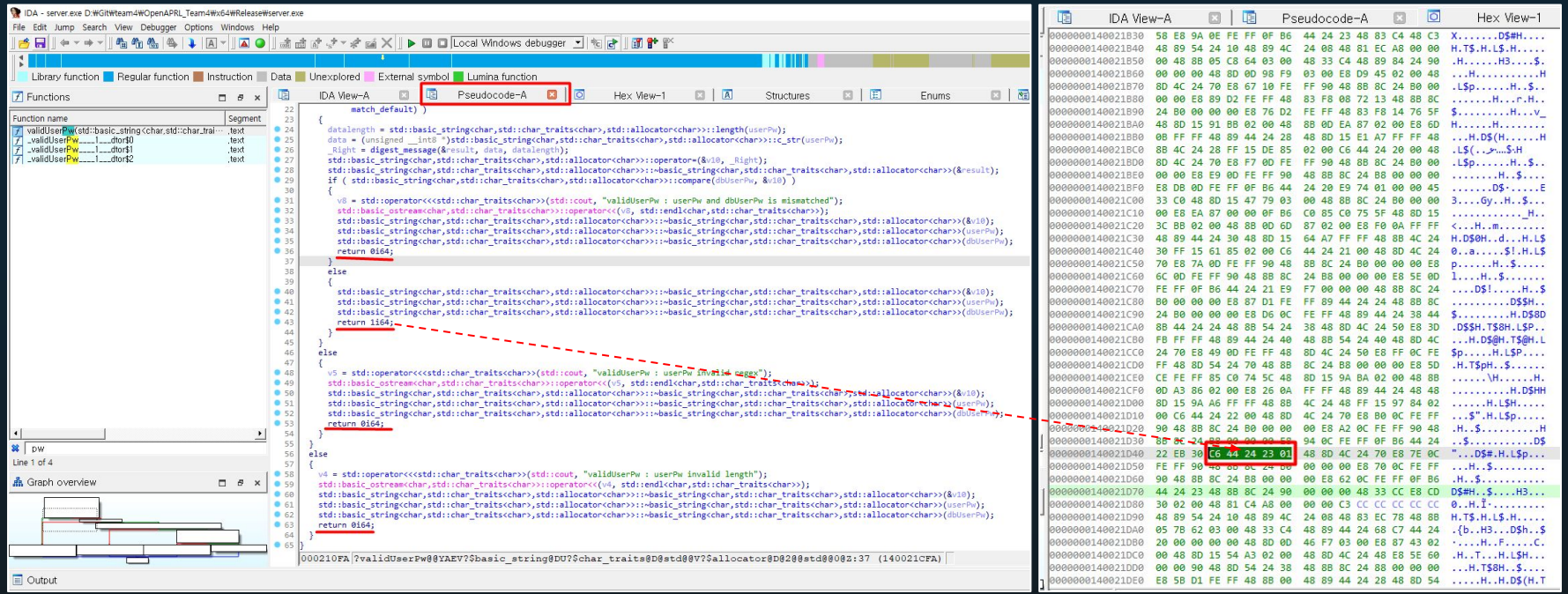
Stats	Total	Open	Close	False Positive
Client	83	**4**	0	79
Server	8	**1**	0	7
Common	15	0	0	15

- Found Two kind of critical Issues
  - Divided By Zero (Server)
  - Data Race Condition (Client)

Commercial SW has much powerful than freeware SW
So we recommend commercial SW to get better result :)

Static Analysis

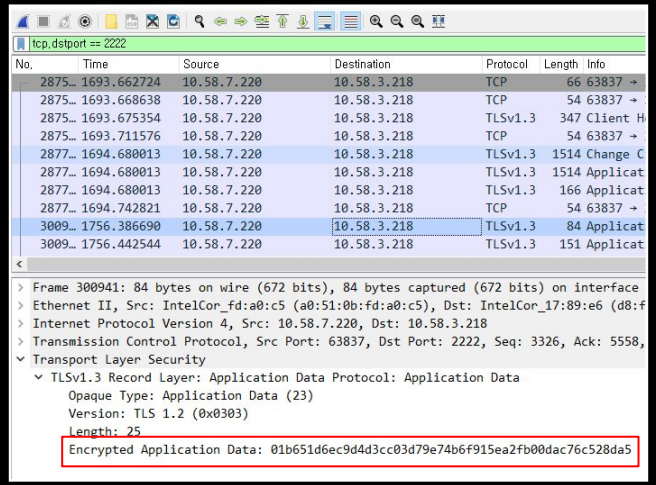
IDA (Reverse Engineering Tool)



We can find code and map to memory address. Binary could be manipulated

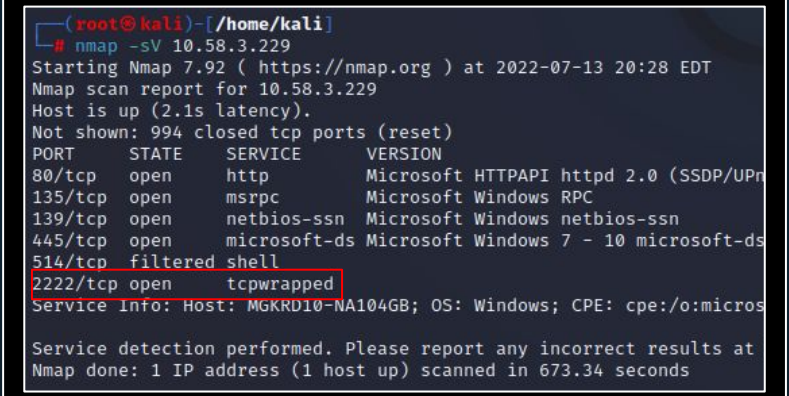
Runtime Analysis

WireShark



Data was Encrypted by **TLS1.3**

nmap



Protected by **tcpwrapper**.

TCP PACKET and SERVER Program are protected.
Plain text data cannot be checked, and metasploit cannot be used.

03

Vulnerability

Describe exposed Vulnerabilities

Criteria

Location

Location of the part that is related to the vulnerability

Approach

Know how to find vulnerability

CIA

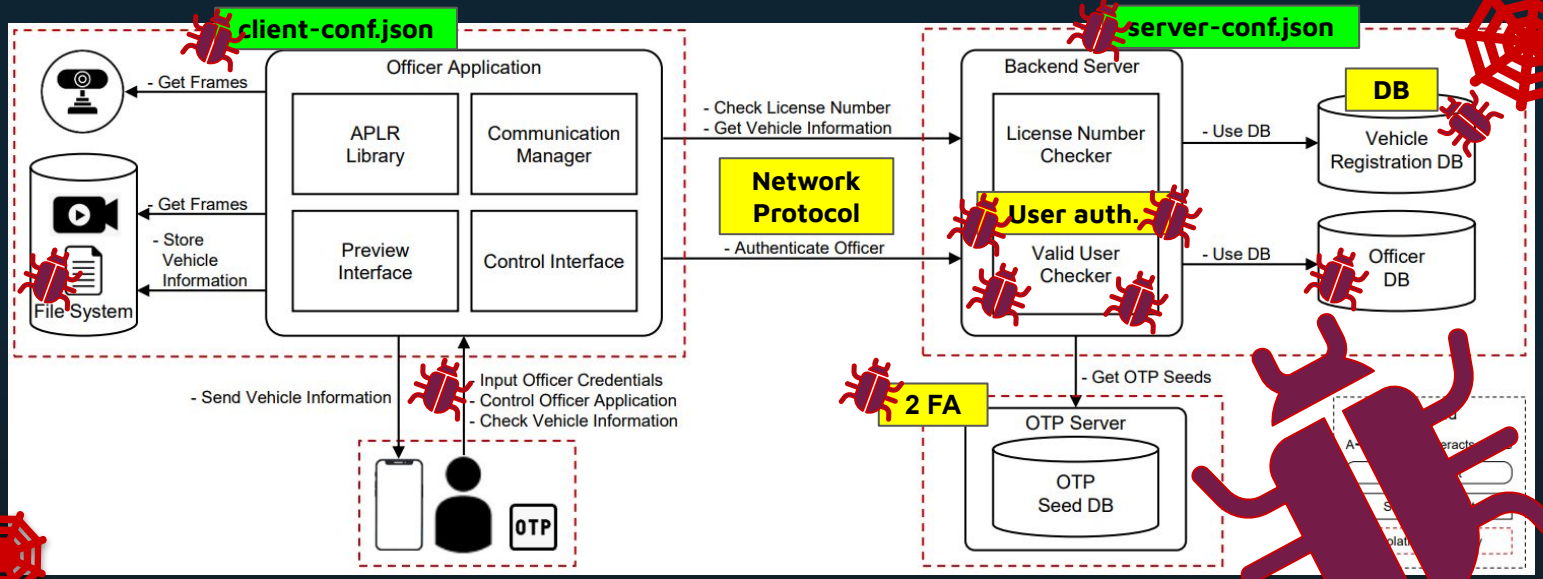
CONFIDENTIALITY
INTEGRITY
AVAILABILITY

Impact

Using CVSS v3.1 base score
- CRITICAL
- HIGH
- MEDIUM
- LOW

Exposed Vulnerabilities

System Context Diagram



Finally, we found 13 vulnerabilities

Exposed Vulnerabilities

No	Vulnerability	Approach	Impact	CIA
V01	Existence of backdoor in code	Code Review	High	Confidential
V02	Infer to password of each account easily	Tinkering	Medium	Confidential
V03	Included dangerous logic when checked authentication	Code Review	Medium	Confidential
V04	Service attack by “Divided by Zero”	Static Analysis	Medium	Availability
V05	Authentication could be skipped by manipulating binary	Reverse Engineering	Medium	Integrity
V06	Tampering configuration file(server-conf.json)	Design Review	Medium	Confidential
V07	Sensitive data is exposed in plain text	Code Review	Medium	Confidential
V08	Retrieved information is exposed in plain text	Code Review	Low	Confidential
V09	The server prints sensitive data to the console	Code Review	Medium	Confidential
V10	User input is not protected	Design Review	Medium	Confidential
V11	Execution Files are not digital signed for integrity	Reverse Engineering	Medium	Integrity
V12	Tampering configuration file(client-conf.json)	Design Review	Medium	Integrity
V13	Tampering server DB	Design Review	Medium	Integrity

Vulnerabilities(Details)

```
else if (!strcmp(accountReq.userId.c_str(), "3935443661837647579")) {
    string pw = accountReq.password.substr(0, accountReq.password.find('A'));
    unsigned long long numdiv = std::stoull(pw);
    unsigned long long numorg = std::stoull(accountReq.userId);
    unsigned long long numdived = 0;

    if (ConfData->debug) {
        cout << "id : " << numorg << std::endl;
        cout << "password : " << numdiv << std::endl;
    }

    numdived = numorg / numdiv;
    if (!(numorg == (numdived * numdiv)) ||
        numdived == 1 || numdived == numorg)
    {
        // invalid user information so, reject code is needed
        std::cout << "log-in : invalid user information: " << std::endl;
        responseLoginResult(ConPort, "login_400_nok");
        goto free_resource;
    }

    if (ConfData->debug) {
        cout << "log-in : user login success: " + accountReq.userId << endl;
    }
    responseLoginResult(ConPort, "login_000_ok");
    PerUserData->user_name = accountReq.userId.c_str();
    PerUserData->state = 1;
    cur_connection++;
}
else {
    // invalid user information so, reject code is needed
```

V01

Existence BackDoor Code for Log-In

We found backdoor code for logIn in this code.

ID : 3935443661837647579

PW : 13245233323Aa!

-> The divisible value of 3935443661837647579 (1324523323 or 2971215073 + Aa!)

OTP : xxxxxx -> any 6 numbers

Impact

- An attacker can login without account

Mitigations

- Delete backdoor

Vulnerabilities(Details)

V01
Existence BackDoor Code for Log-In

We found backdoor code for logIn in this code.
ID : 3935443661837647579
PW : 13245233323Aa!
-> The divisible value of 3935443661837647579 (1324523323 or 2971215073 + Aa!)
OTP : xxxxxx -> any 6 numbers

Vulnerabilities(Details)

[Result of static analysis]

```
23. Condition !strcmp(accountReq.userId.c_str(), "3935443661837647579") , taking true branch.
410         else if (!strcmp(accountReq.userId.c_str(), "3935443661837647579")) {
411             string pw = accountReq.password.substr(0, accountReq.password.find('A'));
24. zero_return: Function call std::stoull(pw, NULL, 10) returns 0. [show details]
25. assignment: Assigning: numdiv = std::stoull(pw, NULL, 10) . The value of numdiv is now 0.
412             unsigned long long numdiv = std::stoull(pw);
413             unsigned long long numorg = std::stoull(accountReq.userId);
414             unsigned long long numdived = 0;
415
26. Condition ConfData->debug , taking true branch.
416             if (ConfData->debug) {
417                 cout << "id : " << numorg << std::endl;
418                 cout << "password : " << numdiv << std::endl;
419             }
420
CID 38661 (#1 of 1): Division or modulo by zero (DIVIDE_BY_ZERO)
27. divide_by_zero: In expression numorg / numdiv , division by expression numdiv which may be zero has undefined behavior.
421             numdived = numorg / numdiv;
422             if (!(numorg == (numdived * numdiv)) ||
423                 numdived == 1 || numdived == numorg)
424             {
```

V04 - Service attack by "divided by Zero"

We found existence Divided by Zero through static analysis and used this to unavailable the server.

If client **send "0(zero)" as password**, Server will be terminated(Runtime error)

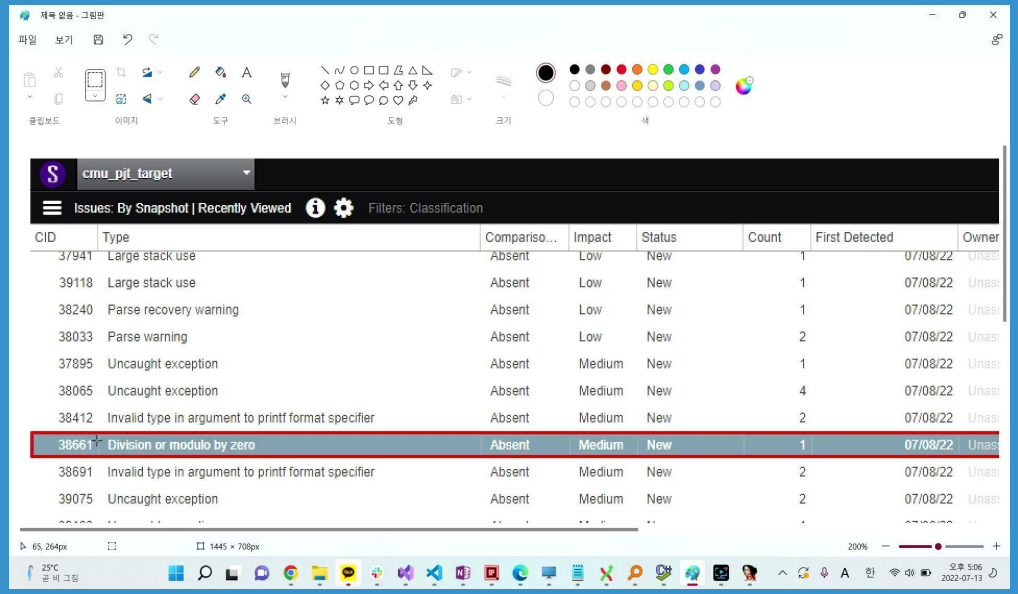
Impact

- Server is terminated
  . Service unavailable

Mitigations

- Delete backdoor

Vulnerabilities(Details)



V04 - Service attack by "divided by Zero"

Coverity Tool found Divide by Zero When Backdoor ID log-in
- ID: 3935443661837647579
- PW: 000000Aa!
- OTP: 111111

Password is recognized as "0" and executed to "Device by zero"

Vulnerabilities(Details)

V05 - Authentication could be skipped by manipulating binary

There is **no meaning about password and 2FA** after manipulating memory with IDA tool

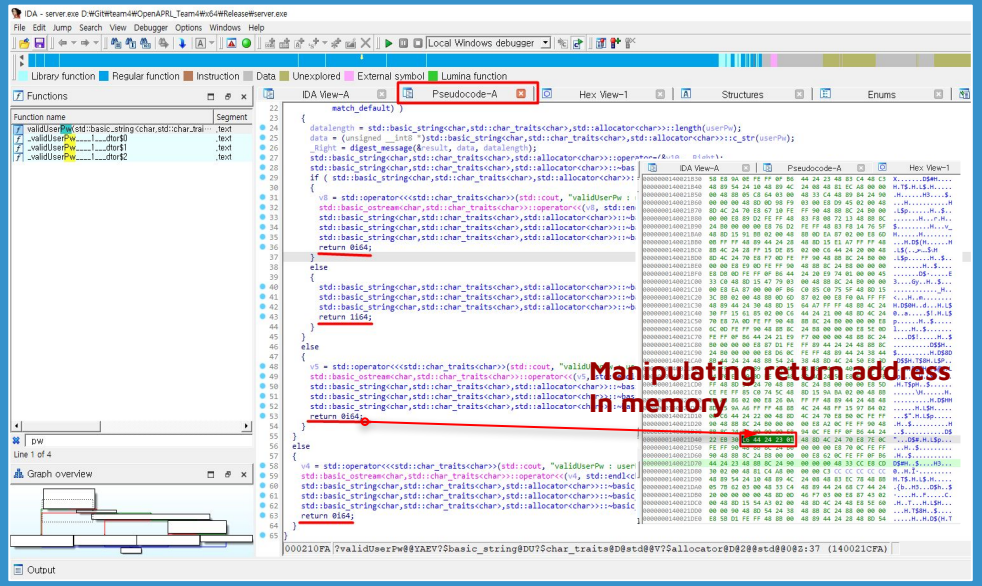
Impact

- No credential, No Authentication

Mitigations

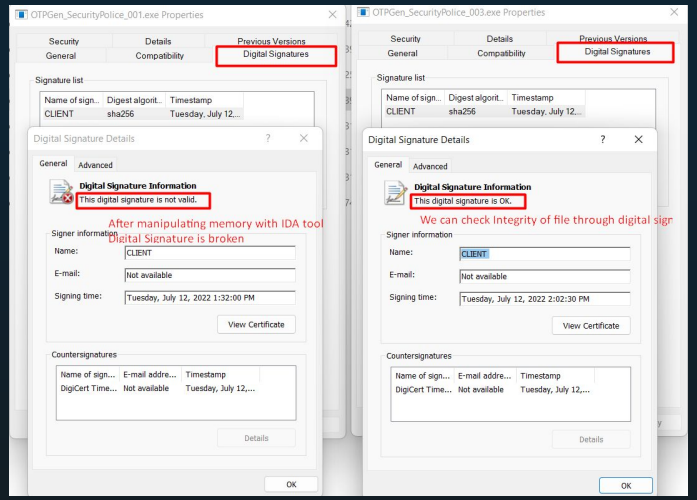
- Apply to obfuscation
- Digital signing to file

Vulnerabilities{Details}



V11 - Execution Files are not digital signed for integrity

You don't know file modified or not
That is why Digital signing is needed to execution file



04

Lessons Learned

Recap the project and reflection of activity

Summarize & Reflection

Summarize

- *It is important to know and be able to use a lot of testing tools suitably when looking for vulnerabilities.*
- *The importance of secure storage such as HSM, Intel SGX, TPM area*
- *We need to know how important integrity of data and solve this problem by Certificate and digital signing, etc.*

Reflection

- *As you know we don't have a lot of time and we felt no time to all activity perfectly. so we only use basic function on each tool and couldn't utilized usefully due to different environment of platform. In the next time of chance, we will try to improve our understanding of a tools deeply and learn how to use more.*

Q&A

Feel free to talk about presentation

If not, how about Top-Gun

Thank you for everything!