Implementation of Suitcase Lock Security System Using Near Field Communication (NFC) and Global Positioning System (GPS)

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***Abstract*— A key is a tool made of metal to open or fasten a door or object that has a lock by inserting it into the hole in the main key. The lock itself is usually used on doors, suitcases, or other objects that require security. The lock on the suitcase itself still has a slight variation and there are still weaknesses, for example the code lock if you forget it cannot be opened, then the padlock and slot lock if the key is lost cannot be opened and can still be broken into by lockpick. The type of research carried out is included in the type of research and development (Research and Development). So, from these problems, a system will be designed and built that can monitor and maximize security automatically so that user's goods are protected from crime or theft by utilizing Near Field Communication (NFC), Global Positioning System (GPS), Magnetic Sensors and Microcontrollers. This system is made portable, so that it can be used in various goods with certain conditions, for example suitcases. The results of this research are portable lock tools, and applications that can integrate lock tools in real time. From the test results obtained accuracy on the gps key, and the security system can run according to the program.**

***Keywords*— Security, System Key, Key, NFC, GPS.**

I. INTRODUCTION

According to the Big Indonesian Dictionary (KBBI), a key is a tool made of metal to open or fasten a door or object that has a lock by inserting it into the hole in the main key [1]. The lock itself is usually used on doors, suitcases, or other objects that require security. The lock itself has many types, for example on the door there are handle locks, slot locks, padlock locks, and on suitcases there are code locks, slot locks, padlocks.

The lock on the suitcase itself still has slight variations and there are still weaknesses, for example, if you forget the code lock, it cannot be opened, then the padlock and slot lock if the key is lost cannot be opened and can still be broken into by lockpick. From this also the suitcase can be stolen directly and taken, so the whereabouts of the suitcase cannot be known. From these problems, there is a technology that can strengthen its security, namely NFC for the security of opening a suitcase, and GPS for the security of the position of the suitcase.

NFC is one of the newest communication technologies utilizing radio waves which has the advantage of not requiring direct contact when reading NFC tags and NFC tags can store data [2], while GPS is a satellite navigation system designed to provide instantaneous position, speed and time information. all places on earth, and a high degree of accuracy [3][4].

So from the above problems, a system will be designed and built that can monitor and maximize security on the lock automatically so that user's belongings are protected from crime or theft by utilizing Near Field Communication (NFC), Global Positioning System (GPS), Magnetic Sensors and Microcontrollers [5][6]. This system is made portable, so it can be used in various goods with certain conditions, for example suitcases [7]. The way this system works is utilizing NFC as a medium to detect keys that send lock and unlock commands to the lock, then there is an NFC tag that functions as a key that can store the position and date the suitcase was last opened, GPS as a tool that gets latitude and longitude, Magnetic Sensor as a means of detecting the position of open and closed suitcases, and a microcontroller as a translator on the NFC module commands from the user after connecting to a smartphone to make it easier for users to secure and track the whereabouts of luggage bags with the help of Global Positioning System (GPS) [8]-[10].

This tool can be applied to a travel company, one example is the company providing luggage rental for travel. This suitcase lock has advanced security features, by using a contactless NFC key, this suitcase key can also be monitored through an application where this application displays maps, notifications and can also unlock. When a tenant borrows a suitcase, the tenant installs the application to the smartphone, then adds a key to the application by confirming the NFC on the key device, then the key can be monitored through the tenant's smartphone application.

II. METHOD

A. System Diagram Block

The implementation of this system is drawing in diagram block, shown in Fig. 1 below:

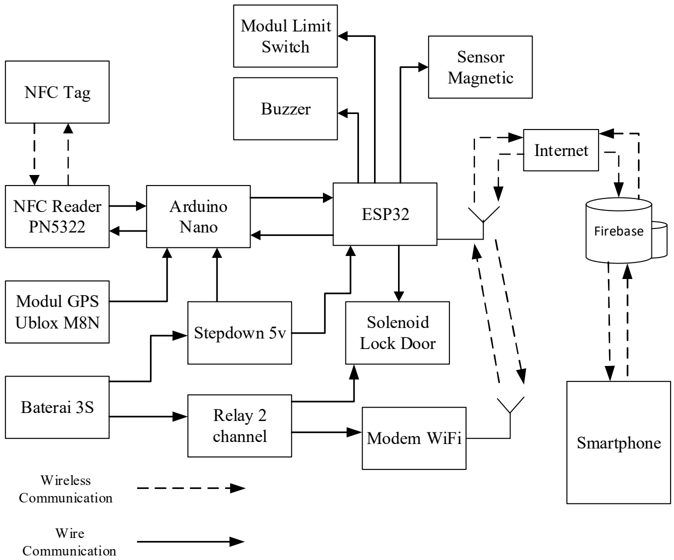


Figure 1. System Diagram Block

Based on Fig. 1, it can be explained that each block includes:

1) NFC Tag is a card that contains ID and data. Its function is used as the id of the user who opened the suitcase and saves the time and location of the last time the suitcase was opened.
2) NFC Reader is used to read NFC Tags and write down the time and location of the last time you opened the suitcase or the output result.
3) Arduino Nano as a data retrieval control from the NFC Reader PN532 which is communicated/sent to the ESP32.
4) The UBLOX NEO-M8N GPS module is used to get latitude and longitude locations.
5) ESP32 as control of data retrieval from arduino nano, limit switch module, magnetic sensor, buzzer control and control of Solenoid door lock in opening and closing, and also as a data sender to the firebase database.
6) A WiFi modem is used to provide a connection to the ESP32 so that it can connect to the database.
7) Firebase is used to store output data from ESP32 such as latitude and longitude, and also stores account data from applications on Smartphones.
8) Smartphone is used as a container of applications, the application displays warnings and to control the microcontroller to enable and disable security mode.
9) Solenoid door lock is a remote door locking mechanism that locks or unlocks via an electromagnetic solenoid. Its function is used as a lock on the suitcase, which will open if the NFC Tag matches the one in the Arduino program.
10) Buzzer is a component that can emit a 'Beep' sound which is used as an alarm.
11) Magnetic Sensor is a component that is used to determine the condition of the suitcase lid is open or closed.
12) The Limit Switch module is a component that is used as an indicator for the condition of the suitcase being closed and open.
13) 3s battery is a series of batteries that have 3 pieces or 3 slots that have a total power supply of 12 volts.
14) Stepdown 5v is a module or component that has a function to lower the voltage, where the voltage is lowered from 12v to 5v.
15) Relay 2 channel is a relay module that has two relays, the relay itself has a function to control the flow of electricity to the connected components.

B. System Flowchart

How the security system works is shown in Fig. 2 below:

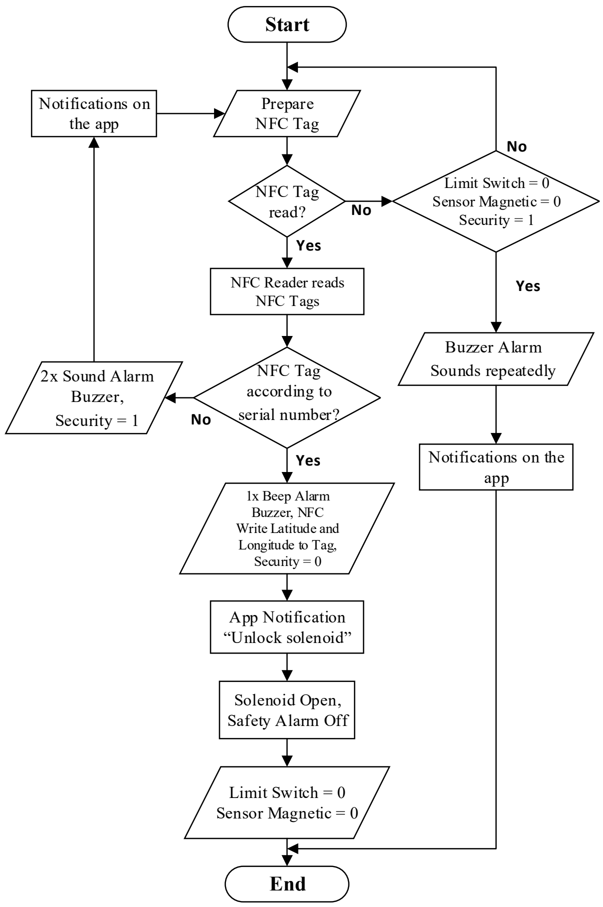


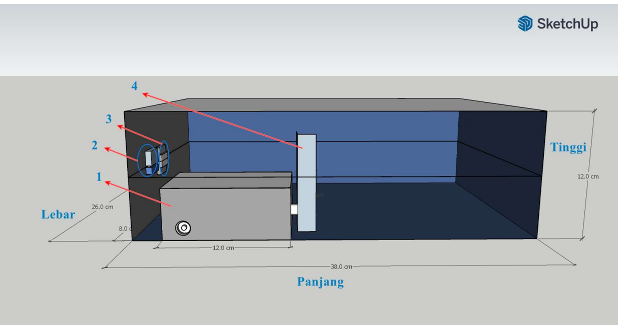
Figure 2. Flowchart Open Security Key

Setting up the NFC Tag to the side of the suitcase that contains the NFC Reader, where if it is not within reach of the NFC Reader, the NFC Reader will not read it but when it is within reach, the NFC Reader will read it. When the NFC Tag is read, the serial number of the NFC Tag will be checked [11][12]. If it doesn't match, the buzzer will light up twice, and a notification will be sent to the application as an incorrect NFC Tag notification [13]. Then if the serial number of the NFC Tag matches, the buzzer will sound 1x, the NFC will write the latitude and longitude data ordered to the NFC Tag. Then there will be an incoming notification on the application as a marker for the lock to be opened, then the solenoid will light up (open) so that the lock can be opened.

When the NFC Tag is not read but the lock condition on the limit switch is 'false', the magnetic sensor is 'true' and the security is '1' then the buzzer will sound repeatedly and a notification will be sent to the lock application. The alarm will go off if the NFC Reader gets an NFC Tag that matches the serial number.

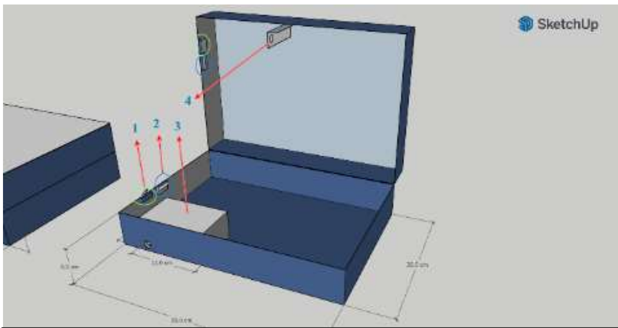
C. Mechanical Design

The mechanical design is made with the aim of describing the mechanical design that will be implemented in the research. The following figures are the mechanical design of the system that will be used in the research:



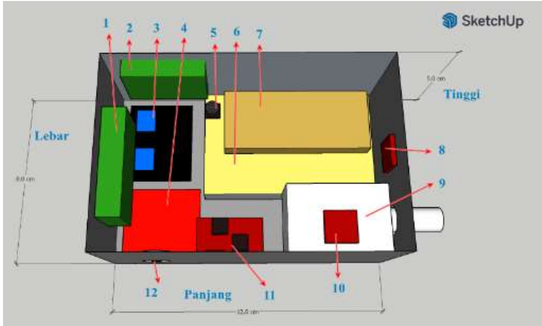
Description :
1. Box Kontrol
2. Limit Switch
3. Magnetic sensor
4. Kev Slot Custom (Modification)

Figure 3. Mechanical Design of Front View Suitcase Implementation



Description :
1. Limit Switch
2. Magnetic Sensor
3. Box Kontrol
4. Key Slot Custom (Modification)

Figure 4. Mechanical Design of Suitcase Implementation Side view is open



Description :
1. ESP32
2. Arduino Nano
3. Modul Relay 2 Channel
4. PN532 (NFC)
5. Buzzer
6. Battery 12V
7. Modem WiFi
8. GPS Module
9. Solenoid Door Lock
10. GPS Antena
11. Step Up (XL6009)
12. Pin Chager

Figure 5. Mechanical Design of Control Box

The picture above is a mechanical design that shows the security system implemented in the suitcase and seen from the outside. ESP32 as controller is placed in a green box next to the box [14][15]. The solenoid functions to lock the suitcase so as to provide double security in the suitcase, and until there is a command to open it from the microcontroller. The NFC Reader is placed in the middle of an open suitcase when the suitcase is open, which functions to detect the NFC tag used to open the lock.

III. RESULTS AND DISCUSSION

A. Results of the PN532 NFC Distance Testing The PN532 NFC

Distance Testing aims to determine the module's sensitivity level in reading and writing to the NFC Tag. This test is carried out by bringing the NFC Tag closer to the PN532 and measuring the distance with the help of a ruler, where the measurement is divided into two different conditions, namely without barriers and with barriers. The results of the test can be seen in table.

TABLE I
TEST RESULT FOR NFC PN532

Experiment	Distance	Results without barriers	Results with barriers
1	0 cm	Can be read and written	Can be read and written
2	1 cm	Can be read and written	Can be read and written
3	2 cm	Can be read and written	Can be read and written
4	3 cm	Can be read and written	Can be read and written
5	4 cm	Can be read and written	Can be read and written
6	5 cm	Unreadable and written	Unreadable and written

From the test results that have been obtained, there are 6 tests with a distance of 0cm, 1cm, 2cm, 3cm, 4cm and 5cm. The data that has been obtained from the test results by measuring the reading distance between the tag and the NFC reader with the PN532 module, it can be concluded from these results that the farthest reading distance is 4cm without a barrier, and 4cm with a barrier. The barrier used has a thickness of 0.5 cm, so that it is found that the barrier can also affect the readings on PN532, the thicker the barrier, the shorter the reading distance of PN532.

B. GPS Accuracy Test Results This GPS

Test aims to determine the accuracy level of the Neo Ublox M8N module on the device. For this GPS test, it compares with the GPS that is on the smartphone by using the "GPS Test" application. In this test, 11 sample points were taken in the Malang area. The results of the GPS test can be seen in the following table.

TABLE II
GPS ACCURACY TEST RESULTS

No.	Result		Difference
	Ublox Neo M8N	**GPS Test**	
1	Latitude: -7.956022 Longitude: 112.613815	Latitude: -7.956135 Longitude: 112.61384	Lat: -0.000113 Long: 0.000025
2	Latitude: -7.996722 Longitude: 112.619544	Latitude: -7.996767 Longitude: 112.619485	Lat: -0.000045 Long: -0.000059
3	Latitude: -8.031949 Longitude: 112.626754	Latitude: -8.031962 Longitude: 112.626722	Lat: -0.000013 Long: -0.000032
4	Latitude: -8.079061 Longitude: 112.639709	Latitude: -8.079065 Longitude: 112.639722	Lat: -0.000004 Long: 0.000013
5	Latitude: -8.152908 Longitude: 112.694480	Latitude: -8.152909 Longitude: 112.694503	Lat: -0.000001 Long: 0.000023
6	Latitude: -8.018704 Longitude: 112.643569	Latitude: -8.018769 Longitude: 112.643620	Lat: -0.000065 Long: 0.000051
7	Latitude: -7.967292 Longitude: 112.682289	Latitude: -7.967280 Longitude: 112.682256	Lat: 0.000012 Long: -0.000033
8	Latitude: -7.936872 Longitude: 112.649612	Latitude: -7.936895 Longitude: 112.649699	Lat: -0.000023 Long: 0.000087
9	Latitude: -7.891458 Longitude: 112.667716	Latitude: -7.891399 Longitude: 112.667628	Lat: 0.000059 Long: -0.000088
10	Latitude: -7.835304 Longitude: 112.697319	Latitude: -7.835302 Longitude: 112.697290	Lat: 0.000002 Long: -0.000029
11	Latitude: -7.944999 Longitude: 112.617195	Latitude: -7.944978 Longitude: 112.617198	Lat: 0.000021 Long: 0.000003
		Average Difference	Lat: -0.000015 Long: -0.000004

From the data obtained from GPS retrieval at 11 locations, the average value of the difference in all data at latitude is-0.000015 and at longitude is 0.000004. From this value, the difference between the GPS on the device and the smartphone can be obtained using the "Euclidean Formula" formula. This formula can be seen as follows.

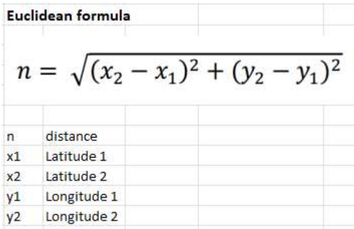


Figure 6. Euclidean Formula [2]

From this formula, adjustments need to be made to determine the distance value on the average difference that has been obtained. The results of the calculations using the formula are obtained as follows.

$$n = \sqrt{(lat\ Difference)^2 + (long\ Difference)^2} \quad (1)$$

$$= \sqrt{(-0.000015)^2 + (0.000004)^2}$$

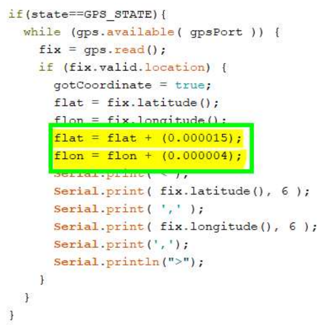
$$= 0.001728136\ km$$

$$= 1.7281356\ m$$

So from the average value of the difference, using the Haversine formula, the average distance between the device and the smartphone is 1,728 meters.

C. GPS Calibration Test Results This GPS

This GPS Calibration test aims to determine the level of accuracy of the Neo Ublox M8N module on the device after adjusting the coding to the accuracy results. The procedure for this test on the tool is given a calibration code which can be seen in Fig. 7.



```
if(state==GPS_STATE){
  while (gps.available( gpsPort )) {
    fix = gps.read();
    if (fix.valid.location) {
      gotCoordinate = true;
      flat = fix.latitude();
      flon = fix.longitude();
      flat = flat + (0.000015);
      flon = flon + (0.000004);
      Serial.print( '<' );
      Serial.print( fix.latitude(), 6 );
      Serial.print( ',' );
      Serial.print( fix.longitude(), 6 );
      Serial.print(',');
      Serial.println(">");
    }
  }
}
```

Figure 7. Calibration GPS Code

Then compare it with the GPS on the smartphone using the "GPS Test" application. In this test, 11 sample points were taken in the Malang area. The results of the GPS test can be seen in the following table:

TABLE III
GPS CALIBRATION TEST RESULTS

No.	Result		Difference
	Ublox Neo M8N	**GPS Test**	
1	Latitude: -7.956058 Longitude: 112.614006	Latitude: -7.956212 Longitude: 112.613964	Lat: 0.000154 Long: 0.000042
2	Latitude: -7.996768 Longitude: 112.619537	Latitude: -7.996758 Longitude: 112.619565	Lat: 0.000010 Long: 0.000028
3	Latitude: -8.031965 Longitude: 112.626792	Latitude: -8.032056 Longitude: 112.626719	Lat: -0.000091 Long: -0.000073
4	Latitude: -8.079030 Longitude: 112.639717	Latitude: -8.079027 Longitude: 112.639762	Lat: 0.000003 Long: 0.000045
5	Latitude: -8.153138 Longitude: 112.694488	Latitude: -8.153141 Longitude: 112.694589	Lat: -0.000003 Long: 0.000101
6	Latitude: -8.018696 Longitude: 112.643508	Latitude: -8.018727 Longitude: 112.643571	Lat: -0.000031 Long: 0.000063
7	Latitude: -7.967387 Longitude: 112.682960	Latitude: -7.967377 Longitude: 112.682972	Lat: 0.000010 Long: 0.000012
8	Latitude: -7.936873 Longitude: 112.649589	Latitude: -7.936877 Longitude: 112.649491	Lat: -0.000004 Long: -0.000098
9	Latitude: -7.891571 Longitude: 112.667549	Latitude: -7.891604 Longitude: 112.667581	Lat: -0.000033 Long: 0.000032
10	Latitude: -7.835189 Longitude: 112.697219	Latitude: -7.835245 Longitude: 112.697224	Lat: -0.000056 Long: 0.000005
11	Latitude: -7.945003 Longitude: 112.617164	Latitude: -7.945022 Longitude: 112.617146	Lat: -0.000019 Long: -0.000018
		Average Difference	Lat: -0.000033 Long: 0.000005

From the GPS calibration data at 11 locations, the average value of the difference in all data at latitude is -0.000033 and at longitude is 0.000005. From this value, it can be obtained the distance difference between the GPS on the device and the smartphone using the "Euclidean Formula" formula which can be seen in the accuracy test.

The results of the calculations using the formula are obtained as follows.

$$n = \sqrt{(lat\ Difference)^2 + (long\ Difference)^2} \quad (2)$$
$$= \sqrt{(0.000033)^2 + (0.000005)^2}$$
$$= 0.003715454\ km$$
$$= 3.715454\ m$$

So from the average value of the difference, using the Haversine formula, the average distance between the device and the smartphone after calibration is 3,715 meters, so it is found that the results of this calibration have not been able to add to the accuracy of the previous accuracy results.

D. Testing Results of Security System Unlocking NFC Locks

At this stage the researcher has tested the reading of the NFC tag card on the key that can open the Solenoid door lock by testing the NFC tag card on the NFC reader one by one to get data as a result of testing the key security system whether it is as expected. Therefore, the NFC test was carried out on the key with the serial number "TcAvYzez" so that the solenoid was open, so that the following data results were obtained.

TABLE IV
OPEN SECURITY KEY TEST RESULTS

NFC Tag ID	Serial Number	Format	Relay Modul	Solenoid door Lock	Buzzer
B4:CF:96:4E	TcAvYzez	NDEF	ON	ON	1x Beep
79:1C:04:E4	Blank	NDEF	OFF	OFF	2x Beep
C4:9E:A6:4E	MpxtRS7R	NDEF	OFF	OFF	2x Beep
3A:CD:B3:9D	Blank	Non-NDEF	OFF	OFF	No Sound

In the table above, it can be seen the results of testing the NFC component against the Solenoid door lock and getting the appropriate data, namely if the NFC tag is affixed on the registered NFC reader, the relay module will light up and the Solenoid door lock will open and the buzzer will light up once, while for NFC tags that have not been registered on the NFC reader, they will still be readable but the relay module will not turn on and the buzzer will light up twice.

E. Security System Test Results with Scenarios

In testing the security system with this scenario, it is done to be able to show that this security system can run according to the program and logic. There are two scenarios carried out, the first is the scenario at the airport. The procedure in this test, the owner has added the suitcase id in the application, and the suitcase is connected to the internet.

This scenario tells of the owner who will travel to the airport, the owner performs check-in cabin procedures to the airport according to existing procedures. When the owner is on the plane, the owner monitors the suitcase through the application to make sure the suitcase is in the correct aircraft baggage. In this scenario, it was carried out in the Malang State Polytechnic, where the Graha Polinema building was the airport, where I was boarding the owner's house, and in front of the Army building as a plane.

From this scenario, at the beginning the owner was preparing the items to be taken to the airport and put in the suitcase. From this, it means that you will get the initial gps location in the owner's home environment. These results can be seen in the following image.

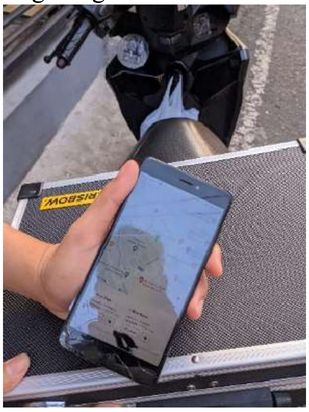


Figure 8. Owner's starting location

Next the owner travels from home to the airport. When the owner is at the airport, the owner ensures the location on the application where the location on the suitcase where the owner can be monitored is appropriate. These results can be seen in the following image.

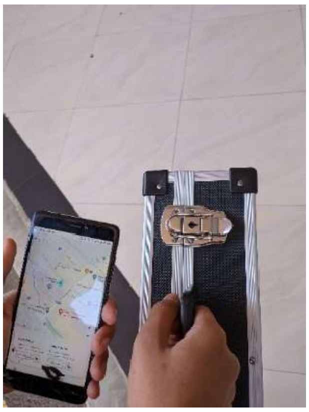


Figure 9. Owner checks the location of the suitcase

After making sure that the luggage security runs smoothly, the owner then checks in, and checks the suitcase into the trunk. When registering, the contents of the suitcase will be checked and ensured that it complies with the requirements at the airport. When opening the suitcase, the appropriate NFC Tag is required to open it and will display a notification. The results of the process of opening the suitcase can be seen in the following image.

After checking the luggage will be taken to the aircraft trunk. The owner waits in the boarding, while waiting for the owner to monitor the journey of the suitcase to the plane's baggage through the application, the results can be seen in the following image.

Figure 10. Checking luggage contents at the airport

Figure 11. Check the location of the suitcase in luggage

From the test results, it was found that the suitcase security system in terms of opening the lock with the appropriate NFC Tag can run, and the application can monitor the location of the lock on the suitcase when it is in the aircraft trunk.

F. Testing Application Quality of Service (QoS) to Firebase

This test aims to obtain the values of the parameters tested, namely delay, and packet loss. Packet Loss and Delay measured are the result of communication between the smartphone application and the firebase database. This test data retrieval on a smartphone uses the "tPacketCapture" application which has a function to track running data, which is then stored in the ".pcap" format which can be opened using the "Wireshark" software on a PC/laptop. The connection used during this test uses a home WiFi connection.

1) This delay test aims to determine the length of time the data is received or from firebase to the application. This test can be taken by getting the firebase ip, then filtering to wireshark, then taking 10 data samples that contain "Time delta from previous". In the following table are the results of the delay measurements that have been carried out, there are 10 samples shown in the following table.

2) From the results of taking 10 data delay samples, the average delay is 0.07995 seconds or 79.95ms, which is included in the good category according to ITU-T G.114. The

smaller the delay, the better the quality of a data transmission because there will be no information delay.

TABLE V
DELAY RESULTS

No.	Source	Destination	Delay (s)
1	35.186.236.207	10.8.0.1	0.086275
2	35.186.236.207	10.8.0.1	0.050529
3	35.186.236.207	10.8.0.1	0.090208
4	35.186.236.207	10.8.0.1	0.050542
5	35.186.236.207	10.8.0.1	0.253206
6	35.186.236.207	10.8.0.1	0.066424
7	35.186.236.207	10.8.0.1	0.050626
8	35.186.236.207	10.8.0.1	0.050562
9	35.186.236.207	10.8.0.1	0.050601
10	35.186.236.207	10.8.0.1	0.050529
		Average delay (s)	0.07995

3) This packet loss test aims to find out data packets that are lost during the process of sending or receiving data from firebase. This test can be taken by getting the firebase ip, then filtering to wireshark, then taking 10 sample data then selecting statistics, then capturing file properties so that it looks like the following picture.

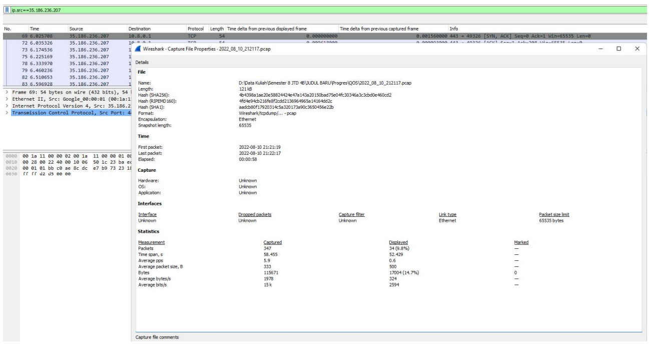


Figure 12. Packets Loss Pickup

From the picture above, the results of testing the number of packets that were successfully sent were 347 and the packets that were not successfully received by the server were 34. So that the packets that were successfully received by the server were 313 packets. To calculate the packet loss value, use the following formula.

$$Packet\ Loss = \frac{(Data\ packet\ sent - Data\ packet\ Recived)}{(Data\ packet\ Recived)} \quad (3)$$

$$= \frac{(347-3\quad)}{(347)} \times 100\%$$

$$= 0.097982 \times 100\%$$

$$= 9.7982\%$$

In the above calculation, the packet loss value is 9%. The packet loss value includes values that are in the moderate range according to ITU-T G.114.

IV. CONCLUSION

Based on the background, problem formulation, planning and implementation, it can be concluded from this research that the results of the accuracy of the neo ublox m8n gps have better accuracy than the gps on the smartphone which has an average difference of ±5 meters. The results from the NFC reader to read registered and unregistered cards are very accurate and the buzzer sounds according to the condition of the card, so there are no errors when reading NFC tags that have not been registered or have different formatting. The alarm buzzer, limit switch and magnetic sensor on the security lock system work well according to the settings in the programming and have a delay of less than 1 second. The internet connection required by esp32 must use a stable connection so that there is no obstacle in monitoring the key location and if you want to get notifications on smartphone applications without obstacles.

REFERENCES

[1] Kaswanto, “Arti Kata Kunci,” Kaswanto Blog, 3 Juni 2020. [Online], Tersedia: https://kaswanto.staff.ipb.ac.id/arti-kata-kunci/. [Diakses 10 Maret 2021].

[2] Zulhelmi, dan R. Nandika, “Perancangan Kunci Pintu Menggunakan NFC Ring dan Password Logger Berbasis Arduino Mega 2560,” Sigma Teknika, Vol. 1, No 2, Hal. 139-148, November 2018.

[3] A. S. Djamar, S. R.U.A Sompie, dan M. D. Putro, “Implementasi Teknologi NFC Untuk Akses Pintu Masuk dan Keluar,” E-Journal Teknik Informatika, Vol. 11, No. 1, 2017.

[4] R. Tulloh, D. N. Ramadan, S. Hadiyoso, Rohmattullah, dan Zikra Rahmana, “Fuel Truck Tracking for Real-Time Monitoring System Using GPS and Raspberry-Pi,” Proceedings of the 1st International Conference on Electronics, Biomedical Engineering, and Health Informatics, Hal. 29-42, Oktober 2021.

[5] F. H. Wijaya, “Iot Sistem Keamanan Pintu Rumah Menggunakan E-Ktp Sebagai Rfid Tag Dan Kontrol Android Berbasis Mikrokontroler,” Thesis, Universitas 17 Agustus 1945 Surabaya.

[6] A. Diamanis, Y. D. Y. Rindengan, dan D. K. Manembu, “NFC (Near Field Communication) Based Attendance Management at GMIM Imanuel Bahu,” Jurnal Teknik Informatika, Vol.17, No. 1, hal. 83-92, Januari 2022.

[7] W. Puspitasari and H. Y. Perdana R, "Real-Time Monitoring and Automated Control of Greenhouse Using Wireless Sensor Network: Design and Implementation," 2018 International Seminar on Research of Information Technology and Intelligent Systems (ISRITI), 2018, pp. 362-366, doi: 10.1109/ISRITI.2018.8864377.

[8] Ikasl, Suherman, dan Sumiati, “Perancangan Sistem Kendali Otomatisasi On-Off Lampu Berbasis Arduino dan Borland Delphi,” Seminar Nasional Rekayasa Teknologi Informasi, Hal 117-123, November 2018.

[9] R. H. Yoga Perdana, N. Hidayati, A. W. Yulianto, V. Al Hadid Firdaus, N. N. Sari and D. Suprianto, "Jig Detection Using Scanning Method Base On Internet Of Things For Smart Learning Factory," 2020 IEEE International IOT, Electronics and Mechatronics Conference (IEMTRONICS), 2020, pp. 1-5.

[10] A. Jufri, “Rancang Bangun dan Implementasi Kunci Pintu Elektronik Menggunakan Arduino dan Android,” Jurnal STT STIKMA Internasional, Vol. 7, No. 1, Hal. 40-51, 2016.

[11] D. Mawaddah dan I. D. Fatmaningtyas, “Perancangan Aplikasi Audio Sederhana Dengan Android Studio,” Jurnal Mahasiswa Bina Insani, Vol. 5, No. 2, Februari 2021.

[12] B. Saputro, “Manajemen Penelitian Pengembangan (Research & Development),” Yogyakarta: Aswaja Pressindo, 2018.

[13] R. H. Y. Perdana, H. Hudiono and A. F. N. Luqmani, "Water Leak Detection and Shut-Off System on Water Distribution Pipe Network Using Wireless Sensor Network," 2019 International Conference on Advanced Mechatronics, Intelligent Manufacture and Industrial Automation (ICAMIMIA), 2019, pp. 297-301, doi: 10.1109/ICAMIMIA47173.2019.9223386.

[14] I.Y. Ishak, M.B. Othman, R. Talib, dan M.A. Ilyas, “Students paperwork tracking system (SPATRASE),” AIP Conference Proceedings, 020012 (2017).

[15] M. H. Mushaddiq, R. Munadi, dan A. I. Irawan, “Implementasi Near Field Communication (Nfc) Pada Smartphone Untuk Pengamanan Ruangan Server,” e-Proceeding of Engineering, Vol.6, No.2, Hal 4054-4061, Agustus 2019.