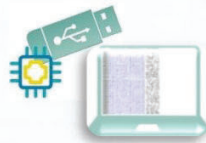# FEAST

To overcome the loopholes of existing tools, FEAST introduces an automated novel framework to improve the security assessment and analysis of embedded devices.

1. Firmware binary extraction using EEPROM programmer.

2. Security Assessment and Analysis of extracted firmware.

3. Report Generation of the findings.

Product by NCSAEL

NCSAEL's prime emphasis is to Design and Develop Indigenous Tools to carry out Security Assessment and Auditing of foreign and local IT products/ services.

Executive Summary

FEAST analyses firmware binaries present in various embedded devices from different vendors. An automated approach has been utilized that performs the unpacking and security assessment of firmware images. FEAST supports the unpacking of various binaries that do not find support in the existing toolkits. It provides the novel functionalities of decryption for the MOXA NPort W2150A/W2250A Series routers. Moreover, several vendors have obfuscated the filesystem signatures. FEAST cater for the obfuscated firmware binaries by performing their deobfuscation and unpacking. It also provides the novel functionality of unpacking of big endian compressed romfs formats. After filesystem unpacking, it performs the deep scan of firmware images in search of vulnerabilities. This includes hard-coded admin login credentials, hardcoded IP addresses, cryptographic key material, configuration files, paths to malicious shell scripts, and so on. Furthermore, toolkit searches for the obsolete functions, malicious code stacks, buffer overflow bugs, and bad argument parsing bugs.

Additionally, our evaluation showed that large scale automated security analysis of embedded devices is possible today. We used our indigenous toolkit FEAST and it worked very well for most of the firmware images analysed during this study.

Introduction

Embedded devices are considered as the backbone of COTS devices such as computer peripherals and home routers. Embedded devices are often connected to networks and have sufficient computing power. Many often, they are vulnerable to threats due to improper design, loopholes left by vendors, and complex update procedures. Botnets like Bashlite and Mirai have shown that vulnerable embedded devices can be a major risk to users and the internet itself.

FEAST performs the firmware unpacking by exploring the reverse engineering techniques. To enhance the unpacking efficiency, we have proposed a decryption method for some of the encrypted firmware binaries. Moreover, a conversion mechanism of big endian compressed romfs binary into little endian has been proposed. This way, unpacking of big endian compressed romfs has been made possible with the existing toolkits. In addition to that, a deobfuscation technique has also been developed, which deobfuscates the obfuscated magic bytes of the filesystem. Moreover, we have also defined an unpacking algorithm for a unique filesystem present in some embedded router devices. No previous toolkit has the capability to unpack this newly found unknown filesystem before.

After successful unpacking, FEAST performs the detailed vulnerability scan on the binary images. Various security related aspects have been analyzed which includes OS version being used, its last update, and how many critical vulnerabilities associated with such versions. Furthermore, it finds the crypto key material which include .pem .crt files, hard-coded admin credentials, IP addresses, emails, and URLs. It also searches for the hidden backdoors that can lead to authentication bypass flaws. Malicious code stacks, obsolete functions, and buffer overflow bugs are also detected.

The CPU architecture has nothing to do with security. Nevertheless, we got the data for free about the CPU architecture being used and it might help some people who do not know which

assembler language to learn. ARM and MIPS architecture are the most relevant architecture being used.

Evaluation

FEAST has been utilized to automate the analysis process of firmware images. We looked at various aspects of the firmware images and their related questions regarding security.

1. Do the firmware images contain cryptographic key material?
2. Are there any hard-coded login credentials?
3. Is it possible for an attacker to gain access of the configuration files?
4. Does an attacker have access to shell scripts?
5. Do the findings include any miscellaneous binaries or third-party software/libraries?
6. Can FEAST extract the various web server executables present in firmware images?
7. Are there any hard-coded IP addresses, email addresses, and URLs?
8. Are there any possible hidden backdoors?
9. Does code analysis detect malicious code stacks?
10. Are there any obsolete functions present in firmware binary undertest?
11. Are there any static memory allocations or bad argument parsing bugs?
12. Which OS versions are used and how old are the OS versions powering the devices?

Reliability of Results

Our findings do not tell if the firmware updates provided fixes for all the vulnerabilities discovered in the meantime. Additionally, there is a possibility that vendors provide their most recent firmware version just over-the-air. That means the embedded device tries to download firmware updates from a non-public source. Therefore, the most recent firmware might not be available on the vendor's website or ftp server. Furthermore, we do not know if any of the found credential is related to a running service connectable remotely. However, it would be more secure, to remove theses accounts, if no one is intended to connect to them. FEAST only provides the decryption algorithm for the encrypted firmware binaries of MOXA NPort W2150A/W2250A Series routers therefore, it might not work for other encrypted firmware. Moreover, it provides unpacking support for 43 filesystem formats and it would not be able to extract those firmware images that lie outside the list of supported filesystem formats.

Security Assessment Criteria

This explains the Security Assessment Criteria used to depict the security status of binary under test. This includes the findings from the static and dynamic analysis of the firmware binary and how these vulnerable fields contribute in assigning Clean, Low Risk, Medium Risk, and High Risk ranks to firmware binary being tested by the indigenous toolkit FEAST.

Identified Vulnerable Fields from Static Analysis

Admin Passwords Count	Assigned Risk Levels	Security Status
0	10	Clean
1-10	35	Low Risk
11-20	60	Medium Risk
21 & above	90	High Risk

SSL Related Files .pem .crt	Assigned Risk Levels	Security Status
Greater than 0	90	High Risk

SSH Related Files	Assigned Risk Levels	Security Status
0-5	10	Clean
6-10	35	Low Risk
11-20	60	Medium Risk
21 & above	90	High Risk

Configuration Related Files	Assigned Risk Levels	Security Status
0-5	10	Clean
6-10	35	Low Risk
11-20	60	Medium Risk
21 & above	90	High Risk

DB Files Count	Assigned Risk Levels	Security Status
0-5	10	Clean
6-10	35	Low Risk
11-20	60	Medium Risk
21 & above	90	High Risk

Shell Scripts	Assigned Risk Levels	Security Status
0-5	10	Clean
6-10	35	Low Risk
11-20	60	Medium Risk
21 & above	90	High Risk

Miscellaneous Binary Files	Assigned Risk Levels	Security Status
0-10	10	Clean
11-30	35	Low Risk

31-50	60	Medium Risk
50 & above	90	High Risk

3rd Party Libraries/ Software	Assigned Risk Levels	Security Status
0-5	10	Clean
6-15	35	Low Risk
16-25	60	Medium Risk
25 & above	90	High Risk

Web Servers	Assigned Risk Levels	Security Status
0-2	10	Clean
3-5	35	Low Risk
6-10	60	Medium Risk
10 & above	90	High Risk

Hardcoded IP Addresses	Assigned Risk Levels	Security Status
Greater than 0	90	High Risk

Hardcoded URLs Count	Assigned Risk Levels	Security Status
0-10	10	Clean
11-80	35	Low Risk
81-150	60	Medium Risk
150 & above	90	High Risk

Hidden Backdoors	Assigned Risk Levels	Security Status
Greater than 0	90	High Risk

Hardcoded Passwords	Assigned Risk Levels	Security Status
Greater than 0	90	High Risk

Email Addresses	Assigned Risk Levels	Security Status
0-10	10	Clean
11-20	35	Low Risk
21-100	60	Medium Risk
100 & above	90	High Risk

Malicious Patterns Count	Assigned Risk Levels	Security Status
0	10	Clean
1-100	35	Low Risk
100-500	60	Medium Risk
500 & above	90	High Risk

Identified Vulnerabilities from Code Analysis

1. **Obsolete Functions: To detect these functions, a database of obsolete and vulnerable functions has been created. It contains various reported vulnerable C functions.**

Obsolete Functions Count	Assigned Risk Levels	Security Status
0	10	Clean
1-50	35	Low Risk
51-100	60	Medium Risk
Greater than 100	90	High Risk

2. **Malicious Code Stacks: To detect these functions, a database of malicious code stacks has been created.**

Malicious Code Stacks Count	Assigned Risk Levels	Security Status
0	10	Clean
1-300	35	Low Risk
301-500	60	Medium Risk
Greater than 500	90	High Risk

3. **Buffer Overflow Bugs: To detect static memory allocations which leads to buffer overflow bugs, regular expression has been incorporated.**

Buffer Overflow Bugs Count	Assigned Risk Levels	Security Status
0	10	Clean
1-1000	35	Low Risk
1000-3000	60	Medium Risk
Greater than 3000	90	High Risk

4. **Bad Arguments: For detection of bad argument parsing, regular expression has been added.**

Bad Arguments	Assigned Risk Levels	Security Status
0	10	Clean
Greater than 0	90	High Risk

Cumulative Vulnerability Count from Static and Code Analysis

- Total High Risk Vulnerabilities = Static.Analysis.Count (High) + Code.Analysis.Count (High)

- Total Medium Risk Vulnerabilities = Static.Analysis.Count (Med) + Code.Analysis.Count (Med)

- Total Low Risk Vulnerabilities = Static.Analysis.Count (Low) + Code.Analysis.Count (Low)
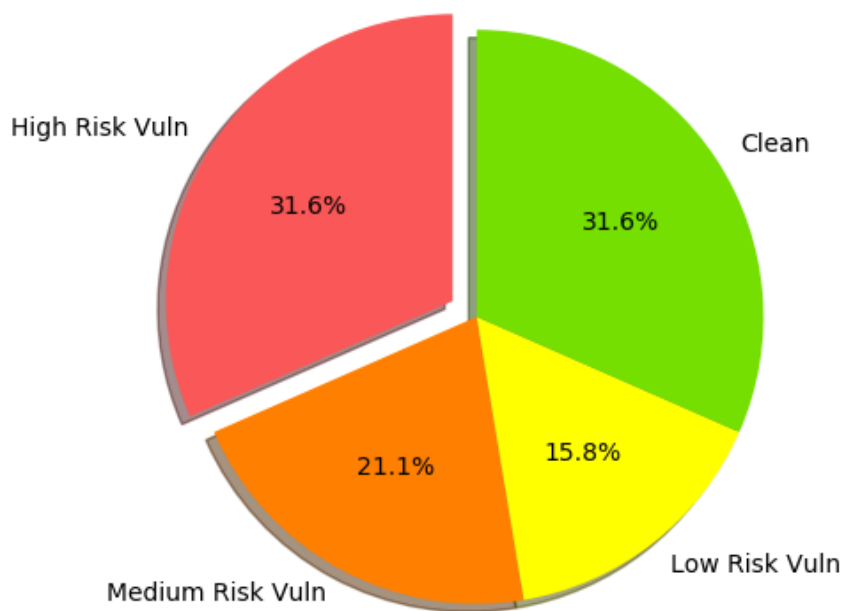
FEAST : Firmware Under Test

 The firmware binary analyzed by toolkit FEAST alongwith the timestamp in Coordinated Universal Time (UTC), for security analysis and report generation is added below. Further on, the sections cover the illustrative representation of Summary of findings, which inludes the security status of firmware binary undertest as well as the findings from the static and code analysis. Afterwards, the report covers the detail of findings from the Code Analysis and Static Analysis. Finally, we conclude the report by providing our Security Recommendations.

Vendor and Device: moxa-nport-w2150a-w2250a-series-firmware-v2.3.bin
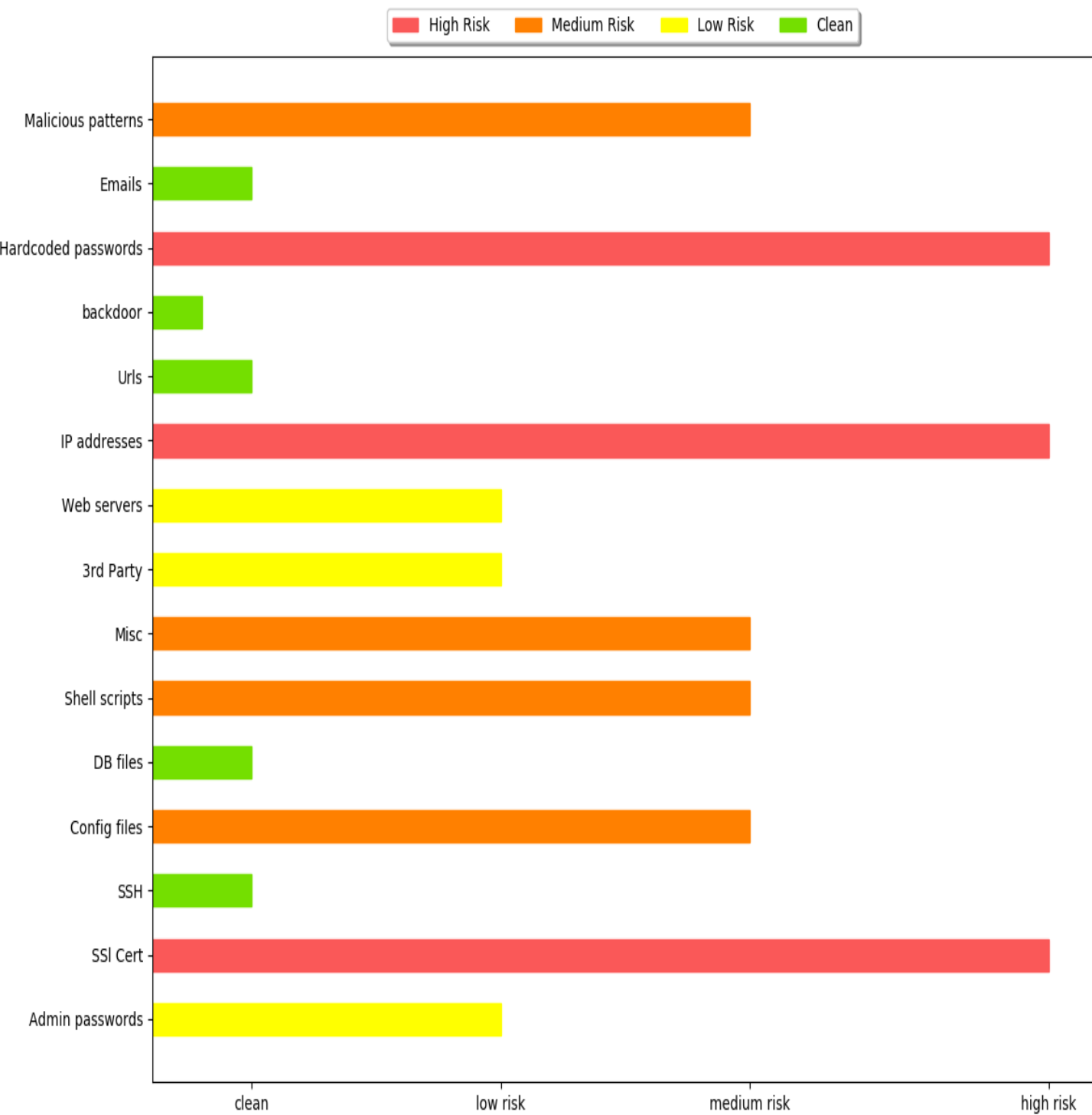
Timestamp: 2023-02-20 22:49:10.816877+00:00

Summary of Findings

Security Status of Firmware Under Test

Code Analysis of Firmware Binary Under Test

Static Analysis of Firmware Binary Under Test

Detail of Code Analysis Findings

1. Obsolete Functions

Use of obsolete and vulnerable functions can cause security attacks. Listed below are the detected obsolete functions from the decompiled C code:

How to patch?
 The alternative functions available at the Microsoft site should be used.

Findings
1. gethostbyname found in gethostbyname_r.c function of ghost_libc at line number 4
2. gethostbyname found in main.c function of ghost_libc at line number 16
3. usleep found in FUN_00016ae0.c function of dropbear at line number 37
4. usleep found in usleep.c function of dropbear at line number 4
5. ftime found in strftime.c function of dropbear at line number 4
6. index found in if_indextoname.c function of busybox at line number 4
7. index found in if_indextoname.c function of busybox at line number 4
8. usleep found in FUN_0004c02c.c function of busybox at line number 33
9. vfork found in FUN_00050150.c function of busybox at line number 15
10. vfork found in FUN_00050150.c function of busybox at line number 16
11. utime found in FUN_00080028.c function of busybox at line number 161
12. vfork found in FUN_000b00b8.c function of busybox at line number 8
13. gethostbyaddr found in FUN_000b4c9c.c function of busybox at line number 44
14. ctime found in FUN_000742f4.c function of busybox at line number 53
15. ctime found in FUN_000742f4.c function of busybox at line number 58
16. vfork found in FUN_0001fc08.c function of busybox at line number 15
17. vfork found in FUN_0001fc08.c function of busybox at line number 18
18. ctime found in FUN_0001b57c.c function of busybox at line number 19
19. ctime found in FUN_0001b57c.c function of busybox at line number 22
20. ctime found in FUN_0006aed0.c function of busybox at line number 19
21. index found in FUN_000458c8.c function of busybox at line number 38
22. utime found in FUN_00098e70.c function of busybox at line number 72
23. utime found in FUN_00098e70.c function of busybox at line number 80
24. usleep found in FUN_00076328.c function of busybox at line number 83
25. usleep found in FUN_00076328.c function of busybox at line number 89
26. gethostbyname found in FUN_000b4e14.c function of busybox at line number 20
27. gethostbyname found in FUN_000b4e14.c function of busybox at line number 27
28. ctime found in FUN_0001b6f8.c function of busybox at line number 59
29. utime found in FUN_0007c72c.c function of busybox at line number 82
30. vfork found in FUN_0004e3ac.c function of busybox at line number 8
31. vfork found in FUN_0004e3ac.c function of busybox at line number 20
32. vfork found in FUN_00015ec4.c function of busybox at line number 11
33. vfork found in FUN_00015ec4.c function of busybox at line number 14
34. gethostbyname found in FUN_0007744c.c function of busybox at line number 134
35. gethostbyname found in FUN_0007744c.c function of busybox at line number 873
36. vfork found in FUN_00012778.c function of busybox at line number 99
37. index found in if_nametoindex.c function of busybox at line number 4
38. utime found in FUN_000b183c.c function of busybox at line number 239
39. utime found in utimes.c function of busybox at line number 4
40. usleep found in usleep.c function of busybox at line number 4
41. ctime found in FUN_0002a438.c function of busybox at line number 24
42. index found in FUN_0004173c.c function of busybox at line number 40

43. utime found in FUN_0007bd20.c function of busybox at line number 85
44. gethostbyname found in gethostbyname.c function of busybox at line number 4
45. vfork found in FUN_00028ca4.c function of busybox at line number 19
46. ctime found in FUN_00074628.c function of busybox at line number 49
47. ctime found in FUN_00074628.c function of busybox at line number 55
48. ctime found in FUN_00074628.c function of busybox at line number 60
49. ctime found in FUN_00074628.c function of busybox at line number 61
50. usleep found in FUN_000492e8.c function of busybox at line number 90
51. usleep found in FUN_000492e8.c function of busybox at line number 125
52. ctime found in FUN_00073ecc.c function of busybox at line number 53
53. ctime found in FUN_00073ecc.c function of busybox at line number 59
54. ctime found in FUN_00073ecc.c function of busybox at line number 64
55. ctime found in FUN_00073ecc.c function of busybox at line number 65
56. usleep found in FUN_000206a8.c function of busybox at line number 34
57. vfork found in FUN_0007dd80.c function of busybox at line number 18
58. vfork found in FUN_0007dd80.c function of busybox at line number 21
59. ftime found in FUN_0008c408.c function of busybox at line number 191
60. ftime found in FUN_000af67c.c function of busybox at line number 20
61. ctime found in FUN_000749f0.c function of busybox at line number 102
62. ctime found in FUN_000749f0.c function of busybox at line number 107
63. ctime found in FUN_000749f0.c function of busybox at line number 111
64. ctime found in FUN_000749f0.c function of busybox at line number 112
65. ctime found in FUN_000749f0.c function of busybox at line number 129
66. ctime found in FUN_000749f0.c function of busybox at line number 133
67. ctime found in FUN_000749f0.c function of busybox at line number 137
68. ctime found in FUN_000749f0.c function of busybox at line number 174
69. ctime found in FUN_000749f0.c function of busybox at line number 179
70. ctime found in FUN_000749f0.c function of busybox at line number 182
71. ctime found in ctime.c function of busybox at line number 4
72. vfork found in FUN_0004d734.c function of busybox at line number 36
73. vfork found in FUN_0004d734.c function of busybox at line number 37
74. vfork found in FUN_00089710.c function of busybox at line number 7
75. vfork found in FUN_00015594.c function of busybox at line number 20
76. vfork found in FUN_000b0608.c function of busybox at line number 11
77. vfork found in FUN_0004d1a8.c function of busybox at line number 21
78. vfork found in FUN_0004d1a8.c function of busybox at line number 23
79. ftime found in strftime.c function of busybox at line number 4
80. vfork found in FUN_00035d08.c function of busybox at line number 45
81. vfork found in FUN_00035d08.c function of busybox at line number 49
82. vfork found in FUN_000286c0.c function of busybox at line number 21
83. vfork found in FUN_000286c0.c function of busybox at line number 24
84. vfork found in FUN_00067030.c function of busybox at line number 42
85. vfork found in FUN_00067030.c function of busybox at line number 45
86. ftime found in FUN_00031d90.c function of busybox at line number 34
87. ftime found in FUN_0009f7c8.c function of busybox at line number 302
88. vfork found in FUN_00013b74.c function of busybox at line number 18
89. vfork found in FUN_00013b74.c function of busybox at line number 21
90. vfork found in vfork.c function of busybox at line number 4
91. usleep found in FUN_00014228.c function of busybox at line number 290
92. ctime found in FUN_000738bc.c function of busybox at line number 36
93. ftime found in FUN_00095a18.c function of busybox at line number 12
94. gethostbyaddr found in gethostbyaddr.c function of busybox at line number 4
95. usleep found in FUN_000212c8.c function of busybox at line number 54

96. usleep found in FUN_000212c8.c function of busybox at line number 57
97. usleep found in FUN_000212c8.c function of busybox at line number 62
98. usleep found in FUN_000212c8.c function of busybox at line number 65
99. vfork found in FUN_00015f3c.c function of busybox at line number 9
100. vfork found in FUN_00015f3c.c function of busybox at line number 12
101. ctime found in FUN_0008fcd8.c function of busybox at line number 117
102. index found in if_indextoname.c function of brctl at line number 4
103. index found in if_indextoname.c function of brctl at line number 4
104. index found in FUN_0000cf08.c function of brctl at line number 16
105. index found in FUN_0000d570.c function of brctl at line number 30
106. index found in FUN_000093f0.c function of brctl at line number 30
107. index found in if_nametoindex.c function of brctl at line number 4
108. index found in FUN_0000b704.c function of brctl at line number 15
109. index found in FUN_0000d778.c function of brctl at line number 38
110. index found in FUN_0000a918.c function of brctl at line number 49
111. index found in FUN_0000d080.c function of brctl at line number 16
112. index found in FUN_0000d188.c function of brctl at line number 24

2. Malicious Code Stacks

Some vendors reuse the open source libraries containg the vulnerabilities. Listed below are the detected malicious code stacks leading to different vulnerailities:

How to patch?
 They should not exist in the firmware.

Findings
1. Malicious behavoiur found in FUN_00024474.c function of dropbear
2. Malicious behavoiur found in FUN_0000d5e0.c function of dropbear
3. Malicious behavoiur found in FUN_0000fb04.c function of dropbear
4. Malicious behavoiur found in FUN_00028114.c function of dropbear
5. Malicious behavoiur found in FUN_00023698.c function of dropbear
6. Malicious behavoiur found in FUN_00016670.c function of dropbear
7. Malicious behavoiur found in FUN_0001090c.c function of dropbear
8. Malicious behavoiur found in FUN_00028328.c function of dropbear
9. Malicious behavoiur found in FUN_00022bc8.c function of dbclient
10. Malicious behavoiur found in FUN_0000cfa0.c function of dbclient
11. Malicious behavoiur found in FUN_00026868.c function of dbclient
12. Malicious behavoiur found in FUN_00026a7c.c function of dbclient
13. Malicious behavoiur found in FUN_0001789c.c function of dropbearconvert
14. Malicious behavoiur found in FUN_0001b53c.c function of dropbearconvert
15. Malicious behavoiur found in FUN_0001b750.c function of dropbearconvert
16. Malicious behavoiur found in FUN_0000eda8.c function of brctl
17. Malicious behavoiur found in FUN_0005d6d4.c function of busybox
18. Malicious behavoiur found in FUN_000869e0.c function of busybox
19. Malicious behavoiur found in FUN_000a0c0c.c function of busybox
20. Malicious behavoiur found in FUN_00017ba0.c function of busybox
21. Malicious behavoiur found in FUN_000692d4.c function of busybox
22. Malicious behavoiur found in FUN_00067ba4.c function of busybox
23. Malicious behavoiur found in FUN_00067564.c function of busybox
24. Malicious behavoiur found in FUN_000160e8.c function of dropbearkey
25. Malicious behavoiur found in FUN_00019d88.c function of dropbearkey
26. Malicious behavoiur found in FUN_00019f9c.c function of dropbearkey

3. Static Memory Allocations leading to Buffer Overruns

With the help of buffer overrun attacks, attacker can execute custom functionality. This is because of smashing the stack, return statement is executed. The attacker can insert arbitrary code at somewhere and is able to execute it when he has control over the return address. With the overwriting of return address, the arguments of the exploitable functions can be altered. The basic cause of these buffer overruns is the static allocation of memory for buffers instead of dynamic allocation. Listed below are the detected static memory allocations leading to buffer overruns:

How to patch?
 Memory should be dynamically allocated.

Findings
1. Static memory allocation found at line 10 of FUN_00009760.c in brctl
2. Static memory allocation found at line 11 of FUN_0000c74c.c in brctl
3. Static memory allocation found at line 17 of FUN_0000c74c.c in brctl
4. Static memory allocation found at line 11 of FUN_0000b8e4.c in brctl
5. Static memory allocation found at line 12 of FUN_0000b8e4.c in brctl
6. Static memory allocation found at line 29 of FUN_0000b8e4.c in brctl
7. Static memory allocation found at line 6 of FUN_0000ccb8.c in brctl
8. Static memory allocation found at line 8 of FUN_0000ccb8.c in brctl
9. Static memory allocation found at line 7 of FUN_0000bdf0.c in brctl
10. Static memory allocation found at line 13 of FUN_0000bdf0.c in brctl
11. Static memory allocation found at line 14 of FUN_0000bdf0.c in brctl
12. Static memory allocation found at line 7 of FUN_0000cbdc.c in brctl
13. Static memory allocation found at line 8 of FUN_0000cbdc.c in brctl
14. Static memory allocation found at line 11 of FUN_0000cf08.c in brctl
15. Static memory allocation found at line 8 of FUN_0000d570.c in brctl
16. Static memory allocation found at line 9 of FUN_0000d570.c in brctl
17. Static memory allocation found at line 10 of FUN_0000d570.c in brctl
18. Static memory allocation found at line 7 of FUN_0000c21c.c in brctl
19. Static memory allocation found at line 13 of FUN_0000c21c.c in brctl
20. Static memory allocation found at line 8 of FUN_0000bb14.c in brctl
21. Static memory allocation found at line 6 of FUN_0000cc50.c in brctl
22. Static memory allocation found at line 6 of FUN_0000b510.c in brctl
23. Static memory allocation found at line 6 of FUN_0000d9c0.c in brctl
24. Static memory allocation found at line 6 of FUN_0000b704.c in brctl
25. Static memory allocation found at line 7 of FUN_0000b704.c in brctl
26. Static memory allocation found at line 8 of FUN_0000b704.c in brctl
27. Static memory allocation found at line 10 of FUN_00009588.c in brctl
28. Static memory allocation found at line 8 of FUN_0000d778.c in brctl
29. Static memory allocation found at line 9 of FUN_0000d778.c in brctl
30. Static memory allocation found at line 10 of FUN_0000d778.c in brctl
31. Static memory allocation found at line 11 of FUN_0000d778.c in brctl
32. Static memory allocation found at line 8 of FUN_0000c4ec.c in brctl
33. Static memory allocation found at line 14 of FUN_0000c4ec.c in brctl
34. Static memory allocation found at line 10 of FUN_0000cd40.c in brctl
35. Static memory allocation found at line 10 of FUN_0000ce24.c in brctl
36. Static memory allocation found at line 11 of FUN_0000a388.c in brctl
37. Static memory allocation found at line 11 of FUN_0000d080.c in brctl
38. Static memory allocation found at line 11 of FUN_0000d188.c in brctl
39. Static memory allocation found at line 12 of FUN_0000d188.c in brctl
40. Static memory allocation found at line 13 of FUN_0000d188.c in brctl

41. Static memory allocation found at line 14 of FUN_0000d188.c in brctl
42. Static memory allocation found at line 15 of FUN_0000d188.c in brctl
43. Static memory allocation found at line 16 of FUN_0000d188.c in brctl
44. Static memory allocation found at line 17 of FUN_0000d188.c in brctl
45. Static memory allocation found at line 18 of FUN_0000d188.c in brctl
46. Static memory allocation found at line 19 of FUN_0000d188.c in brctl
47. Static memory allocation found at line 10 of FUN_00009928.c in brctl
48. Static memory allocation found at line 8 of FUN_0000bfb8.c in brctl
49. Static memory allocation found at line 7 of FUN_0000cb90.c in brctl
50. Static memory allocation found at line 9 of FUN_0000af10.c in brctl
51. Static memory allocation found at line 10 of FUN_0000af10.c in brctl
52. Static memory allocation found at line 18 of FUN_0000af10.c in brctl
53. Static memory allocation found at line 19 of FUN_0000af10.c in brctl
54. Static memory allocation found at line 20 of FUN_0000af10.c in brctl
55. Static memory allocation found at line 17 of FUN_0001d6ac.c in dropbear
56. Static memory allocation found at line 19 of FUN_00015ef4.c in dropbear
57. Static memory allocation found at line 10 of FUN_0001b0b8.c in dropbear
58. Static memory allocation found at line 13 of FUN_0001b0b8.c in dropbear
59. Static memory allocation found at line 8 of FUN_000245ac.c in dropbear
60. Static memory allocation found at line 9 of FUN_000245ac.c in dropbear
61. Static memory allocation found at line 9 of FUN_0001951c.c in dropbear
62. Static memory allocation found at line 7 of FUN_0000b128.c in dropbear
63. Static memory allocation found at line 8 of FUN_0000b128.c in dropbear
64. Static memory allocation found at line 9 of FUN_0000b128.c in dropbear
65. Static memory allocation found at line 10 of FUN_0000b128.c in dropbear
66. Static memory allocation found at line 11 of FUN_0000b128.c in dropbear
67. Static memory allocation found at line 12 of FUN_0000b128.c in dropbear
68. Static memory allocation found at line 13 of FUN_0000b128.c in dropbear
69. Static memory allocation found at line 8 of FUN_000107fc.c in dropbear
70. Static memory allocation found at line 9 of FUN_000107fc.c in dropbear
71. Static memory allocation found at line 10 of FUN_000107fc.c in dropbear
72. Static memory allocation found at line 23 of FUN_00024474.c in dropbear
73. Static memory allocation found at line 7 of FUN_0000c9dc.c in dropbear
74. Static memory allocation found at line 8 of FUN_0000c9dc.c in dropbear
75. Static memory allocation found at line 11 of FUN_0000c9dc.c in dropbear
76. Static memory allocation found at line 5 of FUN_0001cad4.c in dropbear
77. Static memory allocation found at line 29 of FUN_00014b38.c in dropbear
78. Static memory allocation found at line 30 of FUN_00014b38.c in dropbear
79. Static memory allocation found at line 31 of FUN_00014b38.c in dropbear
80. Static memory allocation found at line 32 of FUN_00014b38.c in dropbear
81. Static memory allocation found at line 33 of FUN_00014b38.c in dropbear
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88. Static memory allocation found at line 40 of FUN_00014b38.c in dropbear
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90. Static memory allocation found at line 42 of FUN_00014b38.c in dropbear
91. Static memory allocation found at line 43 of FUN_00014b38.c in dropbear
92. Static memory allocation found at line 44 of FUN_00014b38.c in dropbear
93. Static memory allocation found at line 45 of FUN_00014b38.c in dropbear

94. Static memory allocation found at line 56 of FUN_00014b38.c in dropbear
95. Static memory allocation found at line 57 of FUN_00014b38.c in dropbear
96. Static memory allocation found at line 58 of FUN_00014b38.c in dropbear
97. Static memory allocation found at line 59 of FUN_00014b38.c in dropbear
98. Static memory allocation found at line 80 of FUN_00014b38.c in dropbear
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186. Static memory allocation found at line 12 of FUN_0000dfb8.c in dropbear
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188. Static memory allocation found at line 22 of FUN_0000ef80.c in dropbear
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199. Static memory allocation found at line 12 of FUN_0000da90.c in dropbear

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208. Static memory allocation found at line 11 of FUN_000106a4.c in dropbear
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213. Static memory allocation found at line 33 of FUN_00023698.c in dropbear
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232. Static memory allocation found at line 21 of FUN_00016670.c in dropbear
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268. Static memory allocation found at line 10 of FUN_0000c38c.c in dropbear
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374. Static memory allocation found at line 12 of FUN_00019498.c in dropbearkey
375. Static memory allocation found at line 11 of FUN_0000cafc.c in dropbearkey
376. Static memory allocation found at line 12 of FUN_0000cafc.c in dropbearkey
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417. Static memory allocation found at line 29 of FUN_0003e618.c in busybox
418. Static memory allocation found at line 30 of FUN_0003e618.c in busybox
419. Static memory allocation found at line 31 of FUN_0003e618.c in busybox
420. Static memory allocation found at line 32 of FUN_0003e618.c in busybox
421. Static memory allocation found at line 33 of FUN_0003e618.c in busybox
422. Static memory allocation found at line 34 of FUN_0003e618.c in busybox
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432. Static memory allocation found at line 22 of FUN_00033800.c in busybox
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434. Static memory allocation found at line 16 of FUN_000742f4.c in busybox
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1137. Static memory allocation found at line 22 of FUN_00014978.c in dropbearconvert
1138. Static memory allocation found at line 24 of FUN_00014978.c in dropbearconvert
1139. Static memory allocation found at line 26 of FUN_00014978.c in dropbearconvert
1140. Static memory allocation found at line 8 of FUN_0001b070.c in dropbearconvert
1141. Static memory allocation found at line 18 of FUN_0000dd60.c in dropbearconvert
1142. Static memory allocation found at line 19 of FUN_0000dd60.c in dropbearconvert
1143. Static memory allocation found at line 21 of FUN_0000dd60.c in dropbearconvert
1144. Static memory allocation found at line 8 of FUN_0000cf7c.c in dropbearconvert
1145. Static memory allocation found at line 35 of FUN_0000e9cc.c in dropbearconvert
1146. Static memory allocation found at line 37 of FUN_0000e9cc.c in dropbearconvert
1147. Static memory allocation found at line 51 of FUN_0000e9cc.c in dropbearconvert
1148. Static memory allocation found at line 52 of FUN_0000e9cc.c in dropbearconvert
1149. Static memory allocation found at line 53 of FUN_0000e9cc.c in dropbearconvert
1150. Static memory allocation found at line 54 of FUN_0000e9cc.c in dropbearconvert
1151. Static memory allocation found at line 56 of FUN_0000e9cc.c in dropbearconvert
1152. Static memory allocation found at line 7 of FUN_0000bc00.c in dropbearconvert
1153. Static memory allocation found at line 8 of FUN_0000bc00.c in dropbearconvert

1154. Static memory allocation found at line 11 of FUN_0000bc00.c in dropbearconvert
1155. Static memory allocation found at line 14 of FUN_0000ba60.c in dropbearconvert
1156. Static memory allocation found at line 15 of FUN_0000ba60.c in dropbearconvert
1157. Static memory allocation found at line 13 of FUN_000193ec.c in dropbearconvert
1158. Static memory allocation found at line 10 of FUN_00017548.c in dropbearconvert
1159. Static memory allocation found at line 12 of FUN_00017548.c in dropbearconvert
1160. Static memory allocation found at line 6 of FUN_00017478.c in dropbearconvert
1161. Static memory allocation found at line 9 of FUN_0000d1dc.c in dropbearconvert
1162. Static memory allocation found at line 12 of FUN_0000d1dc.c in dropbearconvert
1163. Static memory allocation found at line 7 of FUN_00017c64.c in dropbearconvert
1164. Static memory allocation found at line 20 of FUN_00019c1c.c in dropbearconvert
1165. Static memory allocation found at line 10 of FUN_0000aaa8.c in dropbearconvert
1166. Static memory allocation found at line 11 of FUN_0000aaa8.c in dropbearconvert
1167. Static memory allocation found at line 19 of FUN_0001b270.c in dropbearconvert
1168. Static memory allocation found at line 11 of FUN_0000ccb4.c in dropbearconvert
1169. Static memory allocation found at line 12 of FUN_0000ccb4.c in dropbearconvert
1170. Static memory allocation found at line 13 of FUN_0000ccb4.c in dropbearconvert
1171. Static memory allocation found at line 14 of FUN_0000ccb4.c in dropbearconvert
1172. Static memory allocation found at line 20 of FUN_0000ccb4.c in dropbearconvert
1173. Static memory allocation found at line 6 of FUN_0001770c.c in dropbearconvert
1174. Static memory allocation found at line 7 of FUN_0001770c.c in dropbearconvert
1175. Static memory allocation found at line 8 of FUN_0000b5b0.c in dropbearconvert
1176. Static memory allocation found at line 9 of FUN_0000b5b0.c in dropbearconvert
1177. Static memory allocation found at line 10 of FUN_0000b5b0.c in dropbearconvert
1178. Static memory allocation found at line 7 of FUN_000188b4.c in dropbearconvert
1179. Static memory allocation found at line 9 of FUN_0001a264.c in dropbearconvert
1180. Static memory allocation found at line 16 of FUN_00014f80.c in dropbearconvert
1181. Static memory allocation found at line 17 of FUN_00014f80.c in dropbearconvert
1182. Static memory allocation found at line 23 of FUN_000181c4.c in dropbearconvert
1183. Static memory allocation found at line 24 of FUN_000181c4.c in dropbearconvert
1184. Static memory allocation found at line 25 of FUN_000181c4.c in dropbearconvert
1185. Static memory allocation found at line 26 of FUN_000181c4.c in dropbearconvert
1186. Static memory allocation found at line 9 of FUN_0000d504.c in dropbearconvert
1187. Static memory allocation found at line 11 of FUN_0000d504.c in dropbearconvert
1188. Static memory allocation found at line 12 of FUN_0000d504.c in dropbearconvert
1189. Static memory allocation found at line 13 of FUN_0000d504.c in dropbearconvert
1190. Static memory allocation found at line 37 of FUN_000126b4.c in dropbearconvert
1191. Static memory allocation found at line 20 of FUN_00019a80.c in dropbearconvert
1192. Static memory allocation found at line 7 of FUN_0000d854.c in dropbearconvert
1193. Static memory allocation found at line 19 of FUN_0001b3bc.c in dropbearconvert
1194. Static memory allocation found at line 33 of FUN_000177e4.c in dropbearconvert
1195. Static memory allocation found at line 35 of FUN_000177e4.c in dropbearconvert
1196. Static memory allocation found at line 36 of FUN_000177e4.c in dropbearconvert
1197. Static memory allocation found at line 38 of FUN_000177e4.c in dropbearconvert
1198. Static memory allocation found at line 7 of FUN_0001b134.c in dropbearconvert
1199. Static memory allocation found at line 17 of FUN_000197fc.c in dropbearconvert
1200. Static memory allocation found at line 24 of FUN_00011c70.c in dropbearconvert
1201. Static memory allocation found at line 21 of FUN_0000e304.c in dropbearconvert
1202. Static memory allocation found at line 23 of FUN_0000e304.c in dropbearconvert
1203. Static memory allocation found at line 14 of FUN_0000c3b8.c in dropbearconvert
1204. Static memory allocation found at line 5 of FUN_00010b54.c in dropbearconvert
1205. Static memory allocation found at line 8 of FUN_000179d4.c in dropbearconvert
1206. Static memory allocation found at line 9 of FUN_000179d4.c in dropbearconvert

1207. Static memory allocation found at line 8 of FUN_0000bdb0.c in dropbearconvert
1208. Static memory allocation found at line 9 of FUN_0000bdb0.c in dropbearconvert
1209. Static memory allocation found at line 10 of FUN_0000b258.c in dropbearconvert
1210. Static memory allocation found at line 9 of FUN_0000b398.c in dropbearconvert
1211. Static memory allocation found at line 10 of FUN_0000b398.c in dropbearconvert
1212. Static memory allocation found at line 11 of FUN_0000b398.c in dropbearconvert
1213. Static memory allocation found at line 12 of FUN_0000b398.c in dropbearconvert
1214. Static memory allocation found at line 12 of FUN_00014364.c in dropbearconvert
1215. Static memory allocation found at line 7 of FUN_0000960c.c in dropbearconvert
1216. Static memory allocation found at line 10 of FUN_0000a034.c in dropbearconvert
1217. Static memory allocation found at line 11 of FUN_0000a034.c in dropbearconvert
1218. Static memory allocation found at line 12 of FUN_0000a034.c in dropbearconvert
1219. Static memory allocation found at line 13 of FUN_0000a034.c in dropbearconvert
1220. Static memory allocation found at line 14 of FUN_0000a034.c in dropbearconvert
1221. Static memory allocation found at line 15 of FUN_0000a034.c in dropbearconvert
1222. Static memory allocation found at line 16 of FUN_0000a034.c in dropbearconvert
1223. Static memory allocation found at line 17 of FUN_0000a034.c in dropbearconvert
1224. Static memory allocation found at line 5 of FUN_00009130.c in dropbearconvert
1225. Static memory allocation found at line 5 of FUN_000090e8.c in dropbearconvert
1226. Static memory allocation found at line 16 of FUN_000107f0.c in dropbearconvert
1227. Static memory allocation found at line 17 of FUN_000107f0.c in dropbearconvert
1228. Static memory allocation found at line 18 of FUN_000107f0.c in dropbearconvert
1229. Static memory allocation found at line 19 of FUN_000107f0.c in dropbearconvert
1230. Static memory allocation found at line 22 of FUN_0001a5e4.c in dropbearconvert
1231. Static memory allocation found at line 23 of FUN_0001a5e4.c in dropbearconvert
1232. Static memory allocation found at line 24 of FUN_0001a5e4.c in dropbearconvert
1233. Static memory allocation found at line 25 of FUN_0001a5e4.c in dropbearconvert
1234. Static memory allocation found at line 7 of FUN_00018a00.c in dropbearconvert
1235. Static memory allocation found at line 15 of FUN_00019d7c.c in dropbearconvert
1236. Static memory allocation found at line 23 of FUN_0001789c.c in dropbearconvert

Summary of Code Analysis

Number of Findings

Obsolete Functions Malicious Code Stacks Bad Arguments Static Memory Allocations
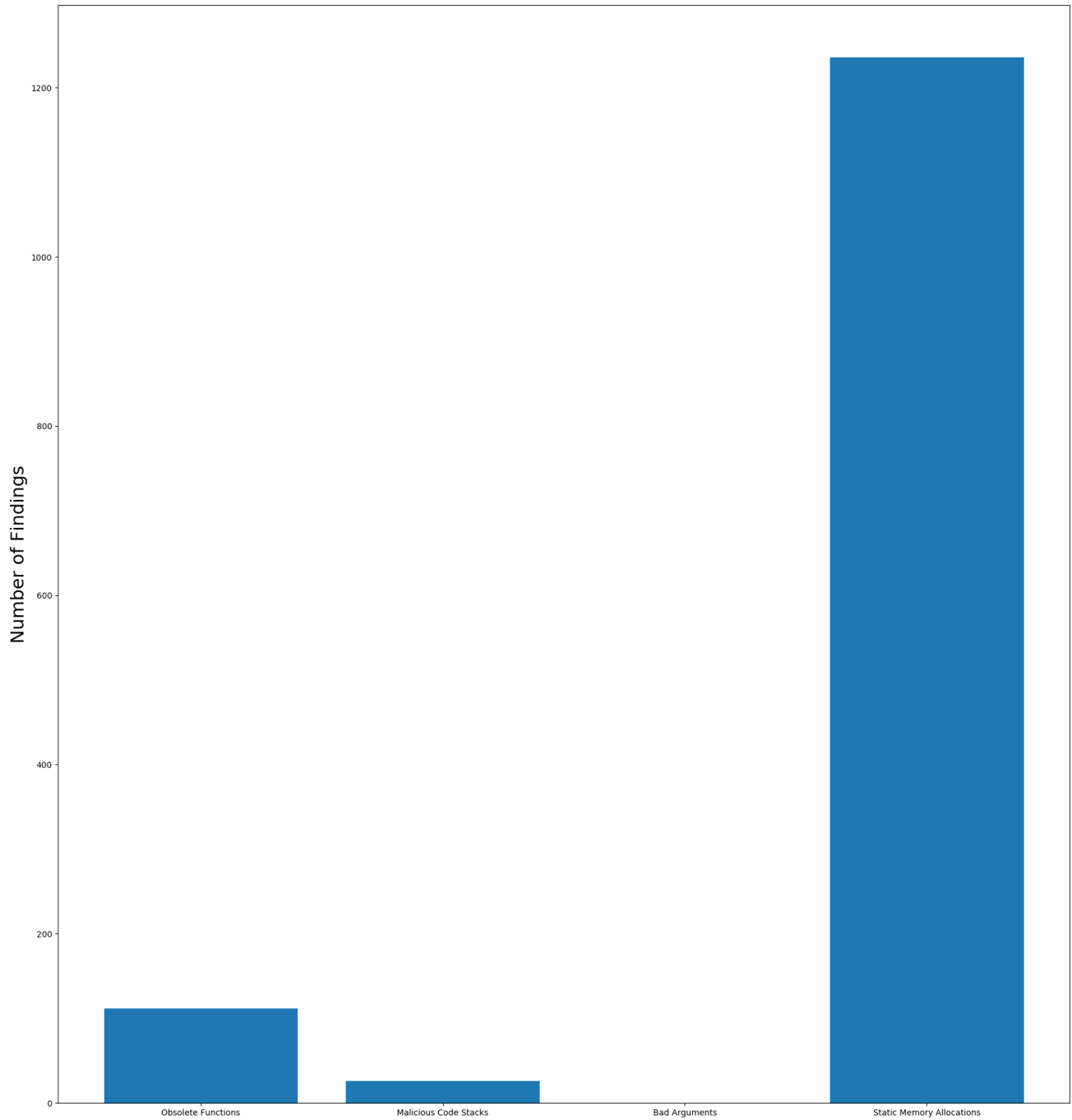
Details of Static Analysis Findings

1. Admin Passwords

The credentials of admin accounts are stored in /etc/shadow or /etc/passwd files in the device OS. Acquiring these admin credentials can enable an attacker to login remotely from anywhere. The following admin passwords have been extracted from the router's firmware under examination:

They should not pre-exist if they exist then they must be present in hashed form. Else, they should be generated during configuration.
Findings
1. media/ext_firm/squashfs-root/etc/shadow
2. media/ext_firm/squashfs-root/etc/passwd
3. media/ext_firm/squashfs-root/bin/passwd
4. media/ext_firm/squashfs-root/bin/mkpasswd
5. media/ext_firm/squashfs-root/sbin/chpasswd

2. SSL Certificates and Private Keys

Most of the vendors have included pre-generated self-signed SSL certificates in the hard coded form in the router's firmware, instead of generating them at the runtime. Some firmware binaries also includes private key in unencrypted PEM format, which can lead to serious security threats. By gaining access of these signed SSL certificates and private keys, HTTPS traffic can be decrypted. Moreover, man in the middle attack is also possible. Listed below are the extracted SSL certificates and keys:

How to patch?
Privileges must be handled carefully on such file. Moreover, access should only have with the root users..

Findings
1. media/ext_firm/squashfs-root/etc/server.pem
2. media/ext_firm/squashfs-root/bin/showkey
3. media/ext_firm/squashfs-root/bin/dropbearkey

3. Configuration Files

Configuration files are critical as they contain authentication secret files, root directory of documents, and user admin details. We observed that in the majority of the cases, web servers run under as the root privileged user, which is a sign of risky configuration and design. Due to these issues, the security of the router's device can be compromised if any of the web components are found vulnerable. Extracted web configuration files and other configuration files are enumerated below:

How to patch?
Configuration files must not be present in plain text.

Findings
1. media/ext_firm/squashfs-root/etc/inetd.conf
2. media/ext_firm/squashfs-root/etc/snmpdv3.conf
3. media/ext_firm/squashfs-root/etc/sysctl.conf
4. media/ext_firm/squashfs-root/etc/snmpd.conf
5. media/ext_firm/squashfs-root/etc/resolv.conf
6. media/ext_firm/squashfs-root/etc/nsswitch.conf
7. media/ext_firm/squashfs-root/etc/wireless/wpa_supplicant_scan.conf
8. media/ext_firm/squashfs-root/etc/udev/udev.conf
9. media/ext_firm/squashfs-root/etc/rc.d/rc.conf

10. media/ext_firm/squashfs-root/etc/default/cf_warn.conf
11. media/ext_firm/squashfs-root/etc/default/wpa_supplicant_infra.conf
12. media/ext_firm/squashfs-root/etc/default/cf_misc.conf
13. media/ext_firm/squashfs-root/etc/default/cf_wireless.conf
14. media/ext_firm/squashfs-root/etc/default/cf_port.conf
15. media/ext_firm/squashfs-root/etc/default/cf_sys.conf
16. media/ext_firm/squashfs-root/etc/default/wpa_supplicant_adhoc.conf

4. Malicious Patterns

If malicious patterns exist then the session between the client and server are not encrypted without a workaround. Therefore, those with access to the TCP/IP packet flow between hosts can observe all the traffic, listen in, and record potentially sensitive information like logins and passwords of users connecting to the servers. In depth search against the malicious patterns highlighted in the tested router's firmware files based upon the vulnerabilites database are given below:

How to patch?
Kerberos protocol should be used and Kerberos can essentially be layered over telnet communication inorder to verify the identity while avoiding login information exploitation.

Findings

1. upgrade

1. media/ext_firm/squashfs-root/etc/wireless/bdiff
2. media/ext_firm/squashfs-root-0/bin/eventd
3. media/ext_firm/squashfs-root-0/bin/console
4. media/ext_firm/squashfs-root-0/bin/webs
5. media/ext_firm/squashfs-root-0/lib/libupgradeFirmware.so
6. media/ext_firm/squashfs-root-0/lib/libsystem.so

2. admin

1. media/ext_firm/squashfs-root/etc/passwdDefault
2. media/ext_firm/squashfs-root/etc/shadowDefault
3. media/ext_firm/squashfs-root-0/bin/console
4. media/ext_firm/squashfs-root-0/bin/webs
5. media/ext_firm/squashfs-root-0/bin/utcpdump
6. media/ext_firm/squashfs-root-0/lib/libconfig.so
7. media/ext_firm/squashfs-root-0/lib/libsystem.so

3. root

1. media/ext_firm/21B1.lzo
2. media/ext_firm/15C3A5.gz
3. media/ext_firm/squashfs-root/etc/inetd.conf
4. media/ext_firm/squashfs-root/etc/passwdDefault
5. media/ext_firm/squashfs-root/etc/group
6. media/ext_firm/squashfs-root/etc/wireless/mboxping
7. media/ext_firm/squashfs-root/etc/udev/rules.d/50-udev-default.rules
8. media/ext_firm/squashfs-root/etc/rc.d/init.d/mdev
9. media/ext_firm/squashfs-root/etc/groupDefault
10. media/ext_firm/squashfs-root/etc/shadowDefault
11. media/ext_firm/squashfs-root/bin/busybox
12. media/ext_firm/squashfs-root/root/dev.tar
13. media/ext_firm/squashfs-root/sbin/brctl
14. media/ext_firm/squashfs-root/sbin/dropbear

15. media/ext_firm/squashfs-root/lib/libip6tc.so.0.0.0
16. media/ext_firm/squashfs-root/lib/libip4tc.so.0.0.0
17. media/ext_firm/squashfs-root/lib/libcrypto.so.1.0.0
18. media/ext_firm/1FD4.lzo
19. media/ext_firm/squashfs-root-0/local/sbin/snmpd
20. media/ext_firm/squashfs-root-0/local/lib/libnetsnmpagent.so.25.0.1
21. media/ext_firm/squashfs-root-0/man/man8/ifrename.8
22. media/ext_firm/squashfs-root-0/man/man8/iwlist.8
23. media/ext_firm/squashfs-root-0/bin/lrz
24. media/ext_firm/squashfs-root-0/bin/wpa_supplicant
25. media/ext_firm/squashfs-root-0/bin/console
26. media/ext_firm/squashfs-root-0/bin/webs
27. media/ext_firm/squashfs-root-0/include/wireless.h
28. media/ext_firm/squashfs-root-0/lib/libupgradeFirmware.so

4. password

1. media/ext_firm/squashfs-root/etc/wireless/wpa_supplicant_scan.conf
2. media/ext_firm/squashfs-root/etc/default/cf_sys.conf
3. media/ext_firm/squashfs-root/bin/dbclient
4. media/ext_firm/squashfs-root/bin/busybox
5. media/ext_firm/squashfs-root/sbin/dropbear
6. media/ext_firm/squashfs-root/lib/libc-2.11.1.so
7. media/ext_firm/squashfs-root/lib/libcrypto.so.1.0.0
8. media/ext_firm/squashfs-root/lib/libc.so.6
9. media/ext_firm/squashfs-root-0/local/lib/libnetsnmp.so.25.0.1
10. media/ext_firm/squashfs-root-0/man/man8/iwconfig.8
11. media/ext_firm/squashfs-root-0/bin/eventd
12. media/ext_firm/squashfs-root-0/bin/wpa_supplicant
13. media/ext_firm/squashfs-root-0/bin/console
14. media/ext_firm/squashfs-root-0/bin/portd
15. media/ext_firm/squashfs-root-0/bin/wpa_cli
16. media/ext_firm/squashfs-root-0/bin/webs
17. media/ext_firm/squashfs-root-0/lib/libsystem.so

5. passwd

1. media/ext_firm/squashfs-root/etc/rc.d/rc.local
2. media/ext_firm/squashfs-root/etc/default/cf_sys.conf
3. media/ext_firm/squashfs-root/bin/busybox
4. media/ext_firm/squashfs-root/lib/libnss_nisplus.so.2
5. media/ext_firm/squashfs-root/lib/libnss_compat.so.2
6. media/ext_firm/squashfs-root/lib/libnss_files.so.2
7. media/ext_firm/squashfs-root/lib/libnss_compat-2.11.1.so
8. media/ext_firm/squashfs-root/lib/libnss_hesiod-2.11.1.so
9. media/ext_firm/squashfs-root/lib/libc-2.11.1.so
10. media/ext_firm/squashfs-root/lib/libnss_files-2.11.1.so
11. media/ext_firm/squashfs-root/lib/libnss_nis-2.11.1.so
12. media/ext_firm/squashfs-root/lib/libnss_nisplus-2.11.1.so
13. media/ext_firm/squashfs-root/lib/libnss_hesiod.so.2
14. media/ext_firm/squashfs-root/lib/libc.so.6
15. media/ext_firm/squashfs-root/lib/libnss_nis.so.2
16. media/ext_firm/squashfs-root-0/local/lib/libnetsnmpagent.so.25.0.1
17. media/ext_firm/squashfs-root-0/bin/webs
18. media/ext_firm/squashfs-root-0/include/wireless.h

19. media/ext_firm/squashfs-root-0/lib/libconfig.so
20. media/ext_firm/squashfs-root-0/lib/libupgradeFirmware.so

6. pwd

1. media/ext_firm/21B1.lzo
2. media/ext_firm/15C3A5.gz
3. media/ext_firm/1DAAEC.squashfs
4. media/ext_firm/squashfs-root/bin/busybox
5. media/ext_firm/squashfs-root/lib/libnss_nisplus.so.2
6. media/ext_firm/squashfs-root/lib/libnss_compat.so.2
7. media/ext_firm/squashfs-root/lib/libnss_files.so.2
8. media/ext_firm/squashfs-root/lib/libnss_compat-2.11.1.so
9. media/ext_firm/squashfs-root/lib/libnss_hesiod-2.11.1.so
10. media/ext_firm/squashfs-root/lib/libc-2.11.1.so
11. media/ext_firm/squashfs-root/lib/libnss_files-2.11.1.so
12. media/ext_firm/squashfs-root/lib/libnss_nis-2.11.1.so
13. media/ext_firm/squashfs-root/lib/libnss_nisplus-2.11.1.so
14. media/ext_firm/squashfs-root/lib/libnss_hesiod.so.2
15. media/ext_firm/squashfs-root/lib/libc.so.6
16. media/ext_firm/squashfs-root/lib/libnss_nis.so.2
17. media/ext_firm/1FD4.lzo
18. media/ext_firm/squashfs-root-0/man/man5/iftab.5
19. media/ext_firm/squashfs-root-0/bin/webs

7. dropbear

1. media/ext_firm/squashfs-root/etc/inetd.conf
2. media/ext_firm/squashfs-root/etc/rc.d/rcS
3. media/ext_firm/squashfs-root/bin/dropbearconvert
4. media/ext_firm/squashfs-root/bin/dbclient
5. media/ext_firm/squashfs-root/bin/dropbearkey
6. media/ext_firm/squashfs-root/sbin/dropbear

8. ssl

1. media/ext_firm/21B1.lzo
2. media/ext_firm/6FBB10.squashfs
3. media/ext_firm/15C3A5.gz
4. media/ext_firm/1DAAEC.squashfs
5. media/ext_firm/squashfs-root/lib/libssl.so.1.0.0
6. media/ext_firm/squashfs-root/lib/libcrypto.so.1.0.0
7. media/ext_firm/1FD4.lzo
8. media/ext_firm/squashfs-root-0/bin/ssl_init
9. media/ext_firm/squashfs-root-0/bin/eventd
10. media/ext_firm/squashfs-root-0/bin/wpa_supplicant
11. media/ext_firm/squashfs-root-0/bin/console
12. media/ext_firm/squashfs-root-0/bin/webs
13. media/ext_firm/squashfs-root-0/lib/libsystem.so

9. private key

1. media/ext_firm/squashfs-root/bin/dropbearconvert
2. media/ext_firm/squashfs-root/bin/dropbearkey
3. media/ext_firm/squashfs-root/lib/libssl.so.1.0.0
4. media/ext_firm/squashfs-root/lib/libcrypto.so.1.0.0
5. media/ext_firm/squashfs-root-0/bin/wpa_supplicant

6. media/ext_firm/squashfs-root-0/bin/console
7. media/ext_firm/squashfs-root-0/bin/wpa_cli
8. media/ext_firm/squashfs-root-0/bin/webs
9. media/ext_firm/squashfs-root-0/lib/libsystem.so

10. telnet

1. media/ext_firm/squashfs-root/etc/inetd.conf
2. media/ext_firm/squashfs-root/etc/services
3. media/ext_firm/squashfs-root/etc/rc.d/rcS
4. media/ext_firm/squashfs-root/bin/busybox
5. media/ext_firm/squashfs-root/lib/libcrypto.so.1.0.0
6. media/ext_firm/squashfs-root-0/bin/console
7. media/ext_firm/squashfs-root-0/bin/webs

11. telnetd

1. media/ext_firm/squashfs-root/etc/inetd.conf
2. media/ext_firm/squashfs-root/etc/inittab
3. media/ext_firm/squashfs-root/bin/busybox

12. secret

1. media/ext_firm/squashfs-root/bin/dropbearkey
2. media/ext_firm/squashfs-root/lib/libssl.so.1.0.0

13. pgp

1. media/ext_firm/21B1.lzo
2. media/ext_firm/15C3A5.gz
3. media/ext_firm/1DAAEC.squashfs
4. media/ext_firm/squashfs-root/lib/libresolv.so.2
5. media/ext_firm/squashfs-root/lib/libresolv-2.11.1.so
6. media/ext_firm/1FD4.lzo

14. gpg

1. media/ext_firm/21B1.lzo
2. media/ext_firm/6FBB10.squashfs
3. media/ext_firm/15C3A5.gz
4. media/ext_firm/1DAAEC.squashfs
5. media/ext_firm/1FD4.lzo

15. token

1. media/ext_firm/squashfs-root/etc/wireless/mboxping
2. media/ext_firm/squashfs-root/bin/busybox
3. media/ext_firm/squashfs-root/lib/ld-linux.so.3
4. media/ext_firm/squashfs-root/lib/libc-2.11.1.so
5. media/ext_firm/squashfs-root/lib/ld-2.11.1.so
6. media/ext_firm/squashfs-root/lib/libcrypto.so.1.0.0
7. media/ext_firm/squashfs-root/lib/libc.so.6
8. media/ext_firm/squashfs-root-0/local/sbin/snmpd
9. media/ext_firm/squashfs-root-0/local/lib/libnetsnmp.so.25.0.1
10. media/ext_firm/squashfs-root-0/local/lib/libnetsnmpmibs.so.25.0.1
11. media/ext_firm/squashfs-root-0/local/lib/libnetsnmpagent.so.25.0.1
12. media/ext_firm/squashfs-root-0/man/man8/iwpriv.8
13. media/ext_firm/squashfs-root-0/bin/webs
14. media/ext_firm/squashfs-root-0/bin/utcpdump

15. media/ext_firm/squashfs-root-0/sbin/iwlist
16. media/ext_firm/squashfs-root-0/include/wireless.h

5. Shell Scripts

If they exist then using them malicious activities are possible. The list of shell scripts are given below.

Privileges must be handled carefully on such file. Moreover, access should only have with the root users.

Findings
1. media/ext_firm/squashfs-root/etc/nologin.sh
2. media/ext_firm/squashfs-root/etc/bridgeoff.sh
3. media/ext_firm/squashfs-root/etc/wireless/restore.sh
4. media/ext_firm/squashfs-root/etc/wireless/reset.sh
5. media/ext_firm/squashfs-root/etc/rc.d/init.d/getIP.sh
6. media/ext_firm/squashfs-root/etc/rc.d/init.d/waitIP.sh
7. media/ext_firm/squashfs-root/etc/rc.d/init.d/start_ipconf_chk.sh
8. media/ext_firm/squashfs-root/etc/rc.d/init.d/mkprofile.sh
9. media/ext_firm/squashfs-root-0/local/sendmail.sh

6. Miscellaneous Binary Files

The extracted miscellaneous binary files are listed below:

How to patch?
 They should be present in encrypted form.

Findings
1. media/ext_firm/squashfs-root/etc/wireless/regulatoryData_AG.bin
2. media/ext_firm/squashfs-root/etc/wireless/regulatoryData_G.bin
3. media/ext_firm/squashfs-root/etc/wireless/ath6k/AR6003/hw2.0/utf.bin
4. media/ext_firm/squashfs-root/etc/wireless/ath6k/AR6003/hw2.0/memtest.bin
5. media/ext_firm/squashfs-root/etc/wireless/ath6k/AR6003/hw2.0/regTest.bin
6. media/ext_firm/squashfs-root/etc/wireless/ath6k/AR6003/hw2.0/athwlan.bin
7. media/ext_firm/squashfs-root/etc/wireless/ath6k/AR6003/hw2.0/apidemo.bin
8. media/ext_firm/squashfs-root/etc/wireless/ath6k/AR6003/hw2.0/device.bin
9. media/ext_firm/squashfs-root/etc/wireless/ath6k/AR6003/hw2.0/whaltest.bin
10. media/ext_firm/squashfs-root/etc/wireless/ath6k/AR6003/hw2.0/otp_test.bin
11. media/ext_firm/squashfs-root/etc/wireless/ath6k/AR6003/hw2.0/data.rom.bin
12. media/ext_firm/squashfs-root/etc/wireless/ath6k/AR6003/hw2.0/regulatoryData_AG.bin
13. media/ext_firm/squashfs-root/etc/wireless/ath6k/AR6003/hw2.0/otp.bin
14. media/ext_firm/squashfs-root/etc/wireless/ath6k/AR6003/hw2.0/athtcmd_ram.bin
15. media/ext_firm/squashfs-root/etc/wireless/ath6k/AR6003/hw2.0/serialport.bin
16. media/ext_firm/squashfs-root/etc/wireless/ath6k/AR6003/hw2.0/perfcnt.bin
17. media/ext_firm/squashfs-root/etc/wireless/ath6k/AR6003/hw2.0/data.patch.hw2_0.bin
18. media/ext_firm/squashfs-root/etc/wireless/ath6k/AR6003/hw2.0/endpointping.bin
19. media/ext_firm/squashfs-root/etc/wireless/ath6k/AR6003/hw2.0/bdata.SD32.bin
20. media/ext_firm/squashfs-root/etc/wireless/ath6k/AR6003/hw2.1.1/utf.bin
21. media/ext_firm/squashfs-root/etc/wireless/ath6k/AR6003/hw2.1.1/athwlan_router.bin
22. media/ext_firm/squashfs-root/etc/wireless/ath6k/AR6003/hw2.1.1/fw.ram.bin
23. media/ext_firm/squashfs-root/etc/wireless/ath6k/AR6003/hw2.1.1/athwlan_automaton.bin
24. media/ext_firm/squashfs-root/etc/wireless/ath6k/AR6003/hw2.1.1/athwlan.bin
25. media/ext_firm/squashfs-root/etc/wireless/ath6k/AR6003/hw2.1.1/eepromw.bin
26. media/ext_firm/squashfs-root/etc/wireless/ath6k/AR6003/hw2.1.1/apidemo.bin

27. media/ext_firm/squashfs-root/etc/wireless/ath6k/AR6003/hw2.1.1/device.bin
28. media/ext_firm/squashfs-root/etc/wireless/ath6k/AR6003/hw2.1.1/whaltest.bin
29. media/ext_firm/squashfs-root/etc/wireless/ath6k/AR6003/hw2.1.1/athwlan_tablet.bin
30. media/ext_firm/squashfs-root/etc/wireless/ath6k/AR6003/hw2.1.1/serflash.bin
31. media/ext_firm/squashfs-root/etc/wireless/ath6k/AR6003/hw2.1.1/athwlan_mobile.bin
32. media/ext_firm/squashfs-root/etc/wireless/ath6k/AR6003/hw2.1.1/otp_test.bin
33. media/ext_firm/squashfs-root/etc/wireless/ath6k/AR6003/hw2.1.1/data.rom.bin
34. media/ext_firm/squashfs-root/etc/wireless/ath6k/AR6003/hw2.1.1/data.patch.hw3_0.bin
35. media/ext_firm/squashfs-root/etc/wireless/ath6k/AR6003/hw2.1.1/otp.bin
36. media/ext_firm/squashfs-root/etc/wireless/ath6k/AR6003/hw2.1.1/nvramconfig.bin
37. media/ext_firm/squashfs-root/etc/wireless/ath6k/AR6003/hw2.1.1/athtcmd_ram.bin
38. media/ext_firm/squashfs-root/etc/wireless/ath6k/AR6003/hw2.1.1/serialport.bin
39. media/ext_firm/squashfs-root/etc/wireless/ath6k/AR6003/hw2.1.1/perfcnt.bin
40. media/ext_firm/squashfs-root/etc/wireless/ath6k/AR6003/hw2.1.1/endpointping.bin
41. media/ext_firm/squashfs-root/etc/wireless/ath6k/AR6003/hw2.1.1/bdata.SD32.bin

7. Third Party Softwares and Libraries

FEAST has analyzed the bad release management practices followed by router firmware vendors, by the successful identification of different open source libraries and third party softwares. These libraries can be exploited thereby, causing a great security hazard. Different extracted executables like busybox, telnet, ssh, tftp, and so on are found, on which different reverse engineering techniques can be applied for injecting malicious scripts and launching the attacks.

Findings
1. media/ext_firm/squashfs-root/etc/rc.d/init.d/dropbear
2. media/ext_firm/squashfs-root/bin/telnet
3. media/ext_firm/squashfs-root/bin/tftp
4. media/ext_firm/squashfs-root/bin/busybox
5. media/ext_firm/squashfs-root/sbin/telnetd
6. media/ext_firm/squashfs-root/sbin/dropbear

8. Web Servers

The extracted web server executables are listed below:

1. media/ext_firm/squashfs-root/etc/rc.d/init.d/dropbear
2. media/ext_firm/squashfs-root/bin/login
3. media/ext_firm/squashfs-root/sbin/sulogin
4. media/ext_firm/squashfs-root/sbin/dropbear
5. media/ext_firm/squashfs-root-0/bin/webs

9. Hard Coded IP Addresses

Majority of the embedded devices use hard coded IP addresses which are used for remote code execution of malicious scripts. The monitored hard coded IP addresses are enumerated below:

1. 0.0.0.0
2. 127.0.0.0
3. 127.0.0.1
4. 131.111.255.255
5. 192.168.126.254
6. 192.168.126.255
7. 192.168.127.254
8. 192.168.127.255
9. 255.255.255.0

10. 255.255.255.255

10. Hard Coded URLs

The following are the exfiltrated hard coded URLs from the firmware binary under test:

1. http://www.hpl.hp.com

11. Email Addresses

The following are the exfiltrated hard coded email addresses from the firmware binary under test:

1. andersen@codepoet.org
2. choltje@ux1.cso.uiuc.edu.
3. c-olson@uiuc.edu
4. hare@suse.de
5. jkmaline@cc.hut.fi
6. jt@hpl.hp.com
7. rietz@mail.amps.de
8. Tim@Rikers.org

12. Hard Coded Password

Scanning of the sensitive information residing in the examined firmware binary has yeided the following hard coded passwords:
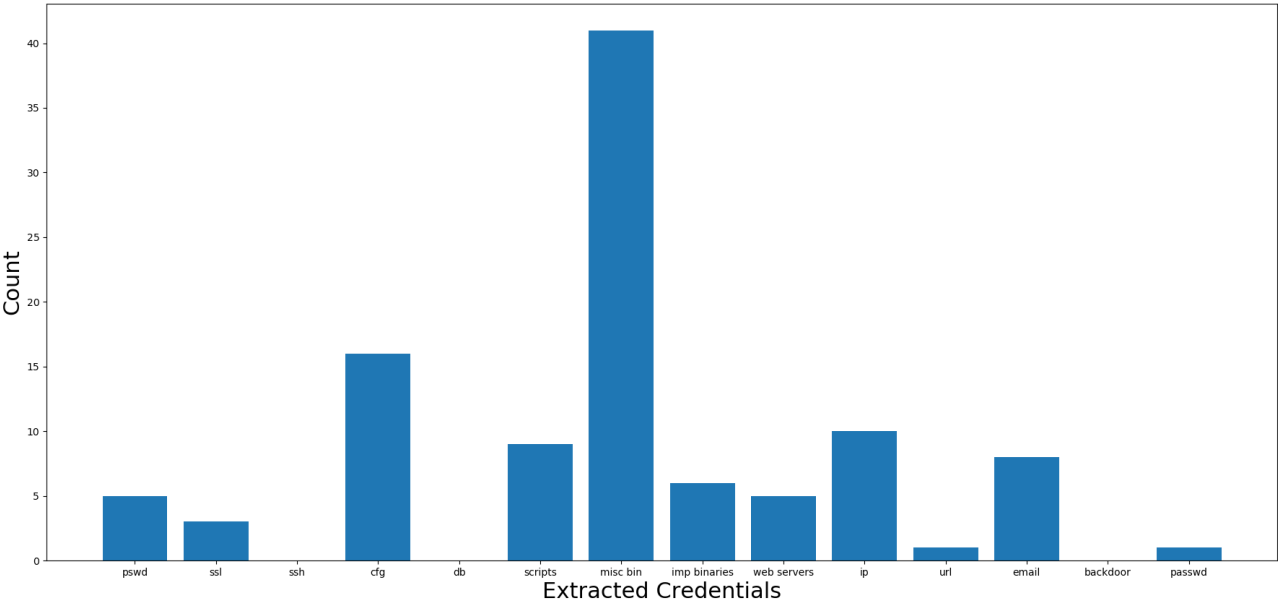
How to patch?
They should be present in encrypted form.
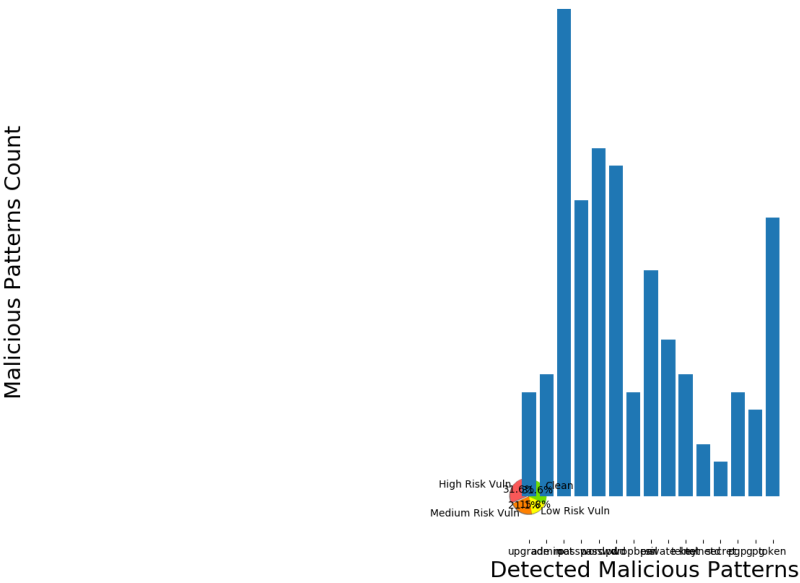
Findings
1. media/ext_firm/squashfs-root/etc/wireless/wpa_supplicant_scan.conf: password="passforsitesurvey"

Summary of Findings

Extracted Credentials of Firmware Binary Under Test

Detected Malicious Patterns of Firmware Binary Under Test

Recommendations

- Admin passwords and login-credentials should not be present in plain text as the clear text poses a significant security risk.
- Passwords should be stored in embedded devices in encrypted or hashed forms for instance, Vigenere encryption, and MD5 hash algorithm should be implemented. Both the Vigenere and MD5 encryption methods obscure passwords.
- The router or admin password is used to access the web-based setup page or the user interface (UI) of your router for configuration and settings update or verification. The default password for many routers is admin. For optimum security, it is recommended to change this password during setup.
- Firmware binaries contain private key in unencrypted .pem formats. They should exist in encrypted form or privileges on such files should be handled carefully.
- Configuration files should not be present in plain text form. Configuration files should be made secure from unauthorized access and synchronized example, the running (or active) configuration matches the start-up configuration.
- URLs should not be hard-coded in firmware binary instead they should have real time generation. For serving the purpose dictionary-based DGAs can be utilized. This type uses dictionary based words and randomly combines them to generate domains with a random, non-human readable look — meaning, these domains are more challenging for AI/ML systems to detect as they may closely resemble legitimate domains.
- FEAST searches for all the obsolete functions present in the c-codes. These obsolete functions should be replaced with the alternative functions provided by the Microsoft itself. https://docs.microsoft.com/en-us/cpp/c-runtime-library/obsolete-functions?view=msvc-160
- Assert statements and validation should be applied while passing the arguments in order to minimize the bad argument parsing bugs.
- Memory should be dynamically allocated.

Conclusion

Our analysis has revealed that hard-coded login credentials are used to infect thousands of embedded devices in the last years. However, hard-coded credentials can be found in many of the devices and some of them are well known or at least easy crackable. Moreover, most of the embedded devices still use old versions of OS, without updating them, which can lead to severe security hazard. The presence of crypto key material in plain text can lead to various security attacks. The results from the code analysis indicate that the toolkit has detected malicious files, buffer overflow bugs, obsolete functions, and various arbitrary code execution vulnerabilities.

To sum it up, our analysis shows that there is no embedded device without flaws and there is no vendor who does a perfect job regarding all security aspects. Much more effort is needed to make such devices secure.