CORE SECURITY

COURION

Deep-dive into SAP archive file formats

Agenda

Introduction
Motivation
SAP compression algorithms
Archive file programs
SAP archive file formats
- CAR
- SAR v2.00
- SAR v2.01

Relative/absolute paths
TCPDB.DAT case
Archive file signatures
Attack surface
Attack vectors
Defense
Conclusions

Introduction

- SAP
- SAP systems
- SAP security
- Complexity
- Archive files
  - Software packaging
  - Software distribution
  - Transport files

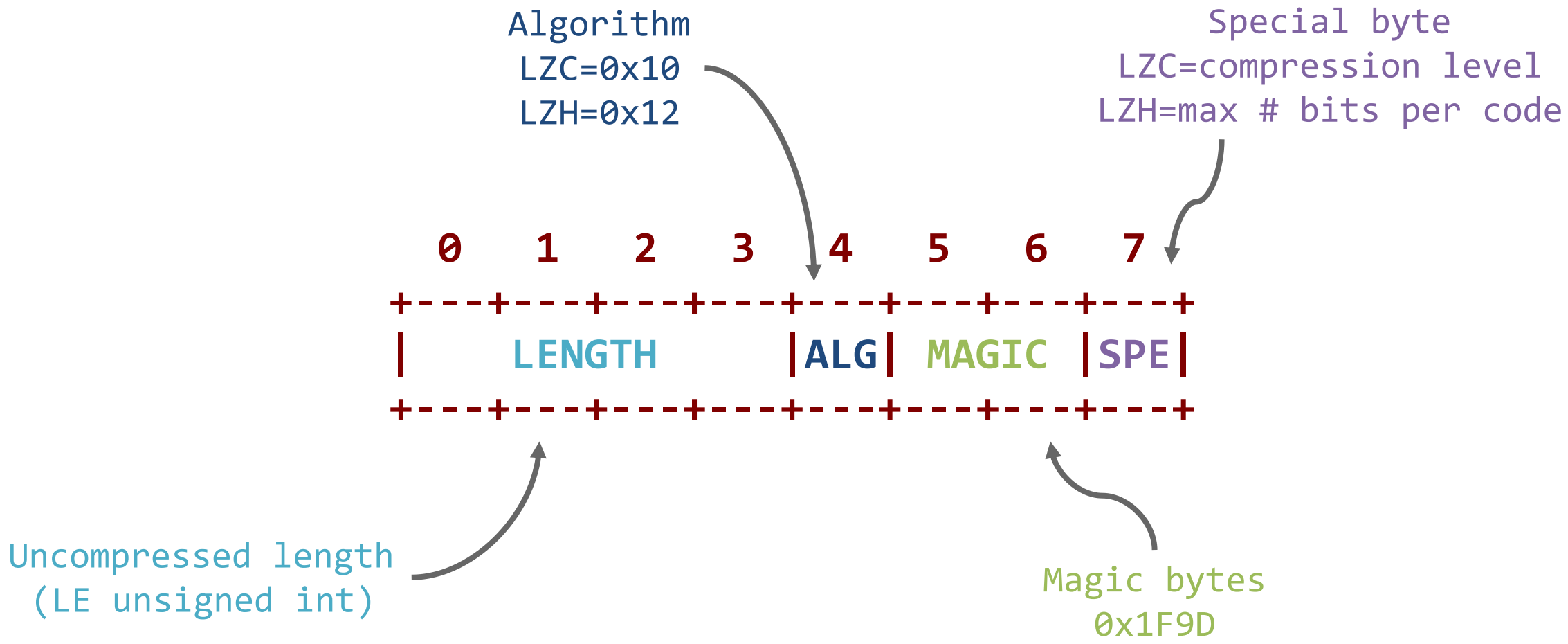
Motivation

- File formats are not known
- Lack of public documentation
- Lack of practical known attacks
- Went deep into the compression mechanisms
- A different attack vector
- Targets sysadmins, operators and **BASIS** admins
  - High privileged users

SAP Compression algorithms

- Based on Lempel-Ziv algorithm
- Adaptive dictionary compression
- Custom implementation
- Two variants
  - LZH (Lempel-Ziv-Huffman)
  - LZC (Lempel-Ziv-Welch-Thomas)

Compression header



Archive files programs

- SAPCAR program
  - Command-line
  - Available on multiple platforms
  - Allows listing, adding, extracting, verifying archive files
  - Works with CAR, SAR v2.00 and v2.01 files
  - Latest version release 721
    - > 16 March 2015

SAPCAR program

```
$ ./SAPCAR
usage:

create a new archive:
SAPCAR -c[vir][f archive] [-P]
   [-A filename] [-T filename]
   [-p value] [-V] file1 file2

list the contents of an archive
SAPCAR -t[vs][f archive] [file1

extract files from an archive:
SAPCAR -x[v][f archive] [-R dir
   [-V] [file1 file2....]

verify the archive:
SAPCAR -d[v][f archive] [-V] [f
[..]
```

```
[..]
append files to an archive:
SAPCAR -a[v][f archive] file1 [file2....]

merge two archives:
SAPCAR -m[v]f "source target"

check availability of files to be processed:
SAPCAR -l [-A filename][-X filename] [file1 file2...]

sign archive:
SAPCAR -S[v]f MY.SAR [-key keyname] [-H file hash]

verify the content of signed manifest:
SAPCAR -M[v][f manifest file] [-manifest file]
[..]
```

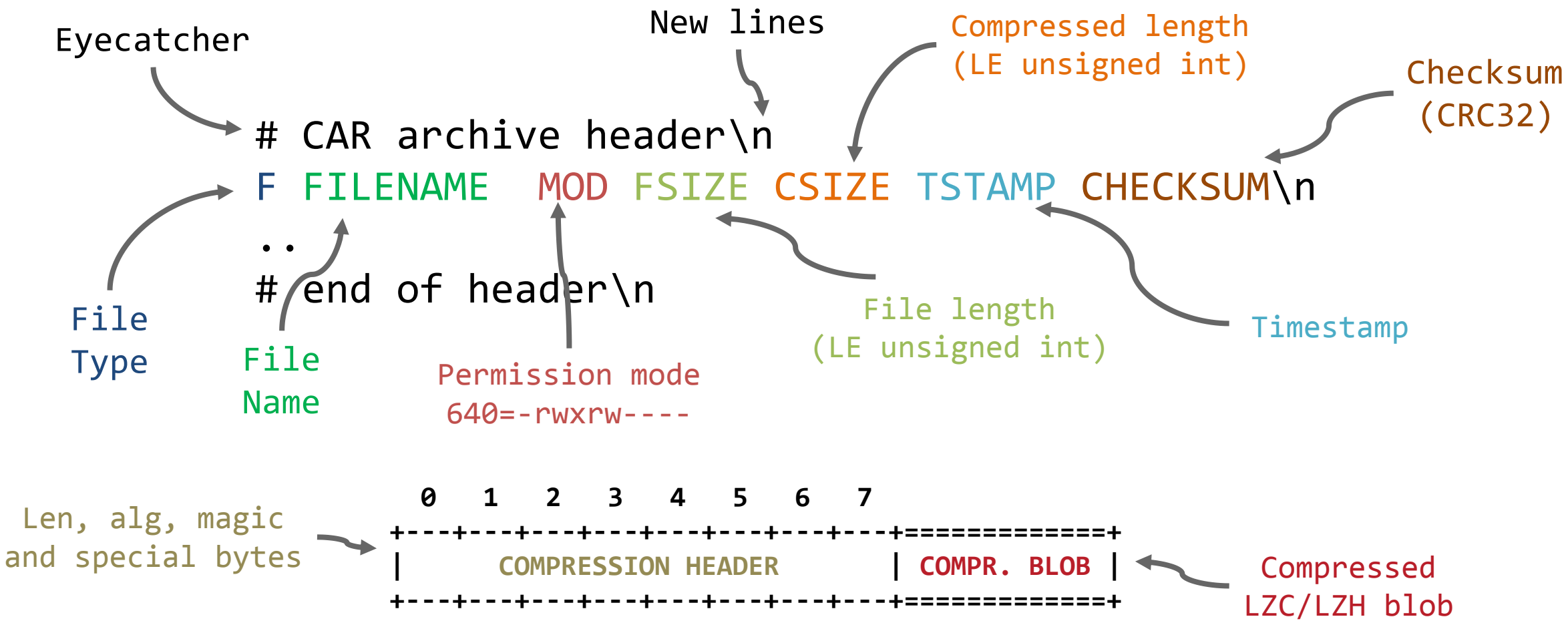
SAP archive file formats

- Software packaging/distribution
  - CAR
  - SAR v2.00
  - SAR v2.01
- Transport files
  - Transport files

CAR archive file format

- Old (first?) version of the archive file
- Text based archive header
- Blob content
- Still supported on SAPCAR for extracting
- Not supported for creating new archives

CAR archive header



CAR example

```
$ ./SAPCAR -xvf carcar_test_string.sar
processing archive carcar_test_string.sar...
x test_string.txt
```

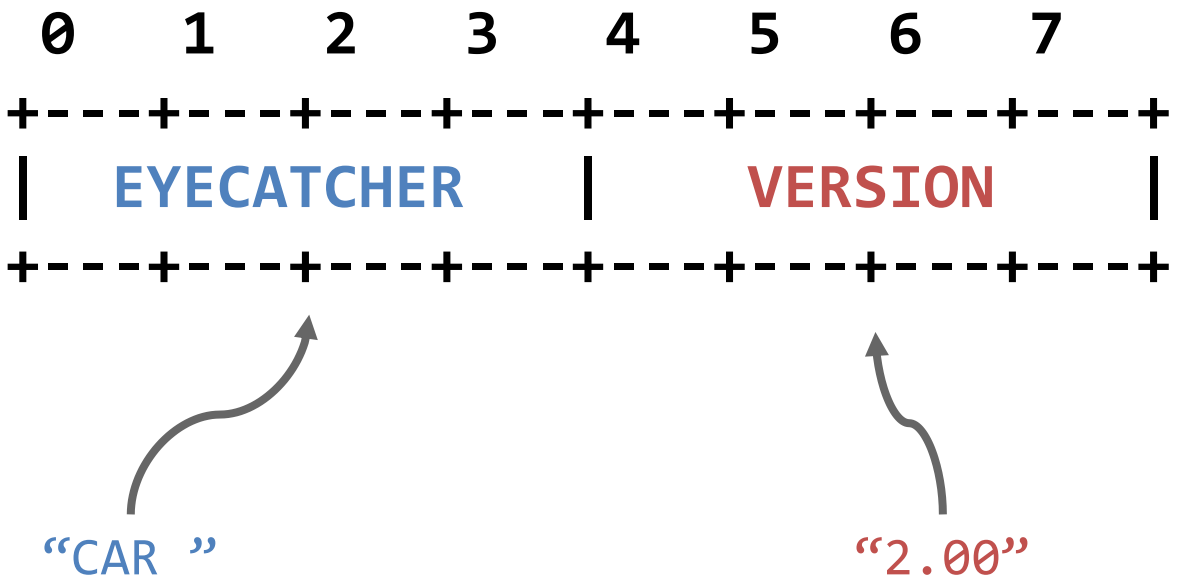
```
$ xxd carcar_test_string.sar
0000000: 2320 4341 5220 6172 6368 6976 6520 6865  # CAR archive he
0000010: 6164 6572 0a46 2074 6573 745f 7374 7269  ader.F test_stri
0000020: 6e67 2e74 7874 2020 2020 2020 2020 2020  ng.txt
0000030: 2034 3434 2020 2020 2020 2020 3433 2020   444         43
0000040: 2020 2020 2020 3533 2031 3434 3930 3130        53 1449010
0000050: 3132 3820 3331 3136 3736 3331 3434 0a23  128 3116763144.#
0000060: 2065 6e64 206f 6620 6865 6164 6572 0a2b   end of header.+
0000070: 0000 0012 1f9d 027b 2119 a90a 85a5 99c9  .......{!.......
0000080: d90a 4945 f9e5 790a 69f9 150a 59a5 b905  ..IE..y.i...Y...
0000090: c50a f965 a945 0a25 40e9 9cc4 aa4a 8594  ...e.E.%@....J..
00000a0: fc74 0000                                .t..
```

```
File type=file, Filename=test_string.txt, Perm mode=444, File length=43, Compressed
Length=53, Timestamp=01 Dec 2015 19:48, Checksum=0xb9c60808, Uncompressed Length=43,
Algorithm=LZH, Special byte=02
```

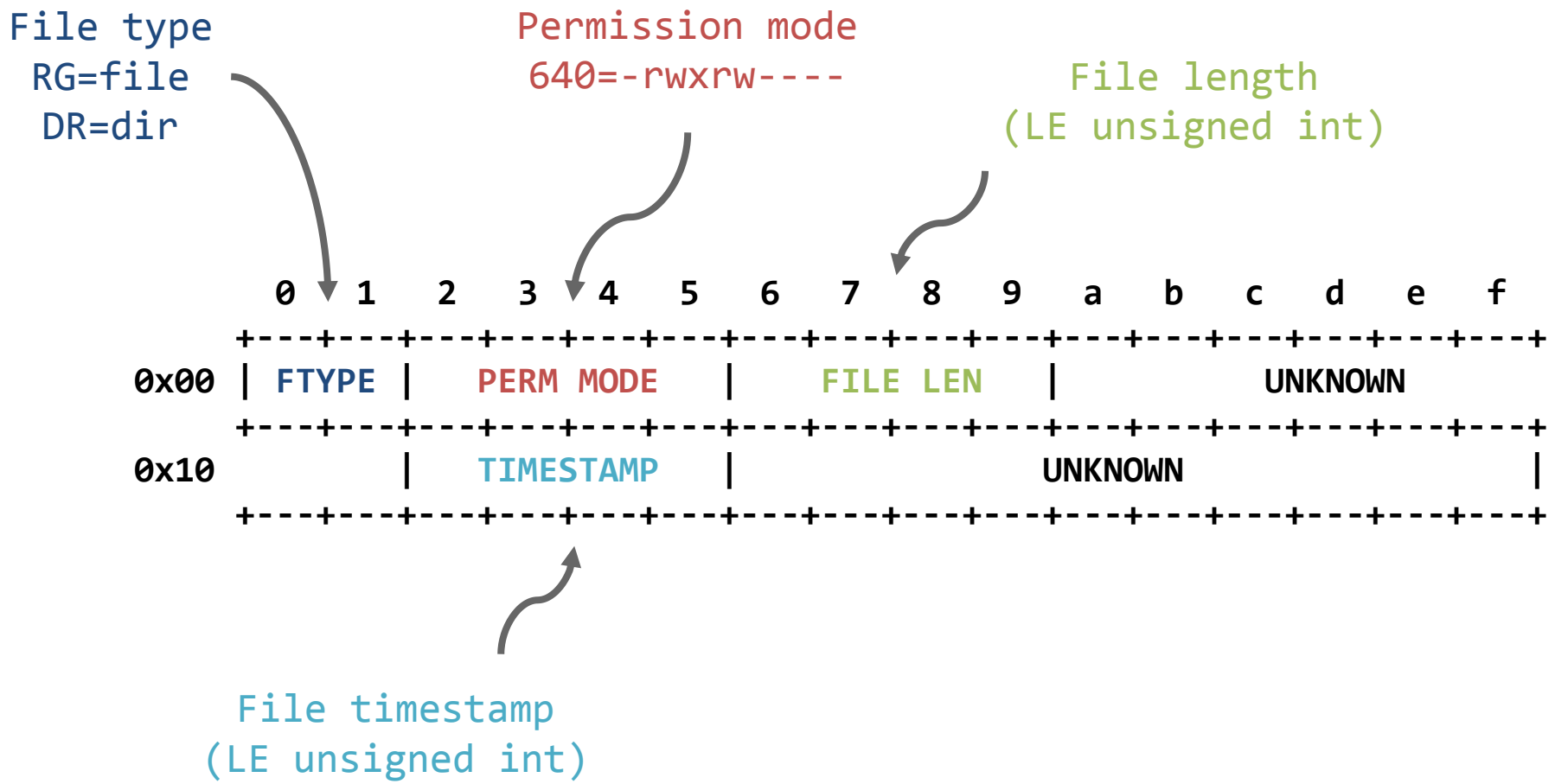
SAR v2.00 archive file format

- New version of the archive file (R/3 > 4.70)
- Binary based archive file header
- Still supported on SAPCAR for extracting
- Not supported for creating new archives

SAR v2.00 archive header

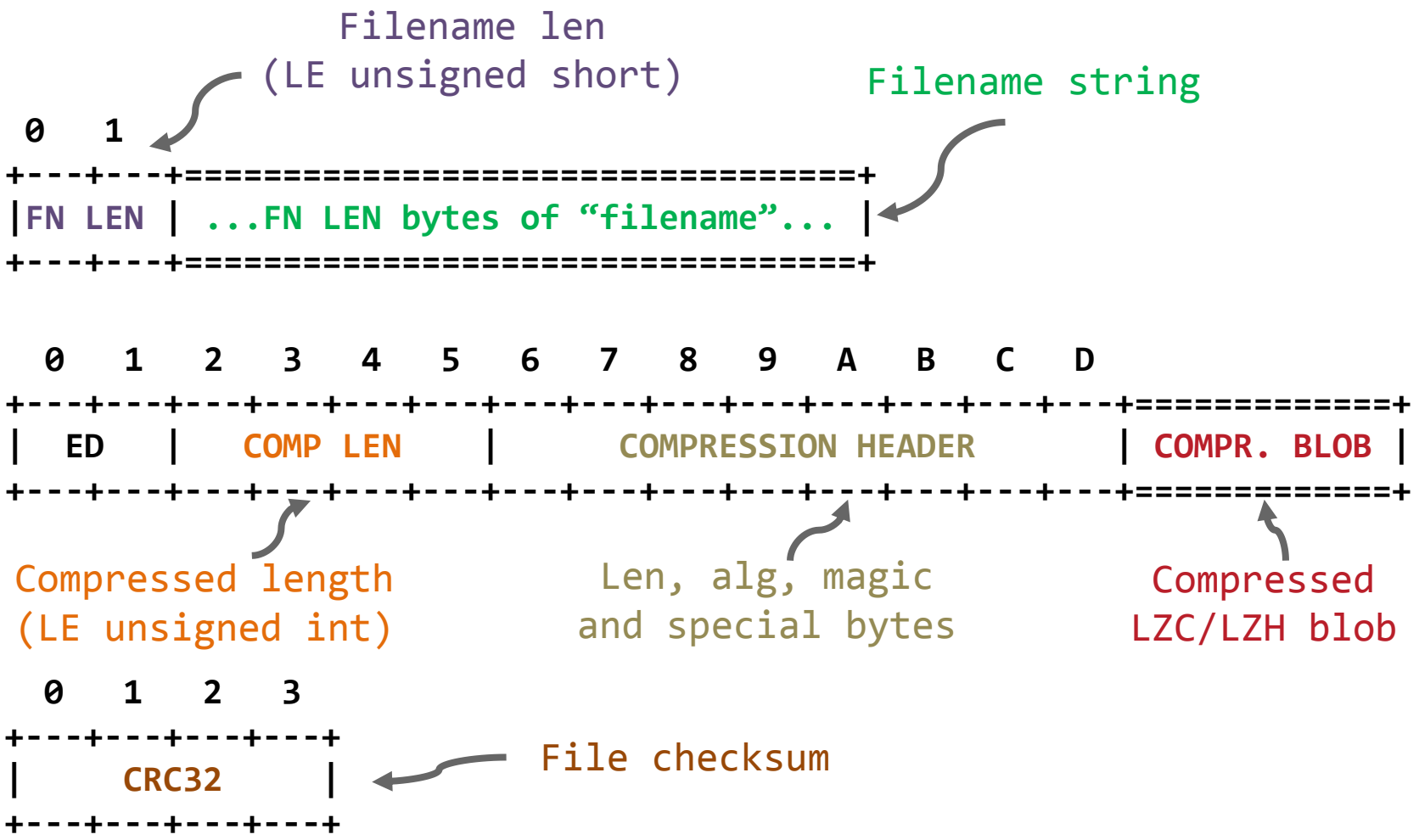


SAR v2.00 archive file header



SAR v2.00 archive file header

If it's a regular file, and file length > 0



SAR v2.00 example

```
$ ./SAPCAR -xvf car200_test_string.sar
SAPCAR: processing archive car200_test_string.sar (version 2.00)
x test_string.txt
SAPCAR: 1 file(s) extracted
```

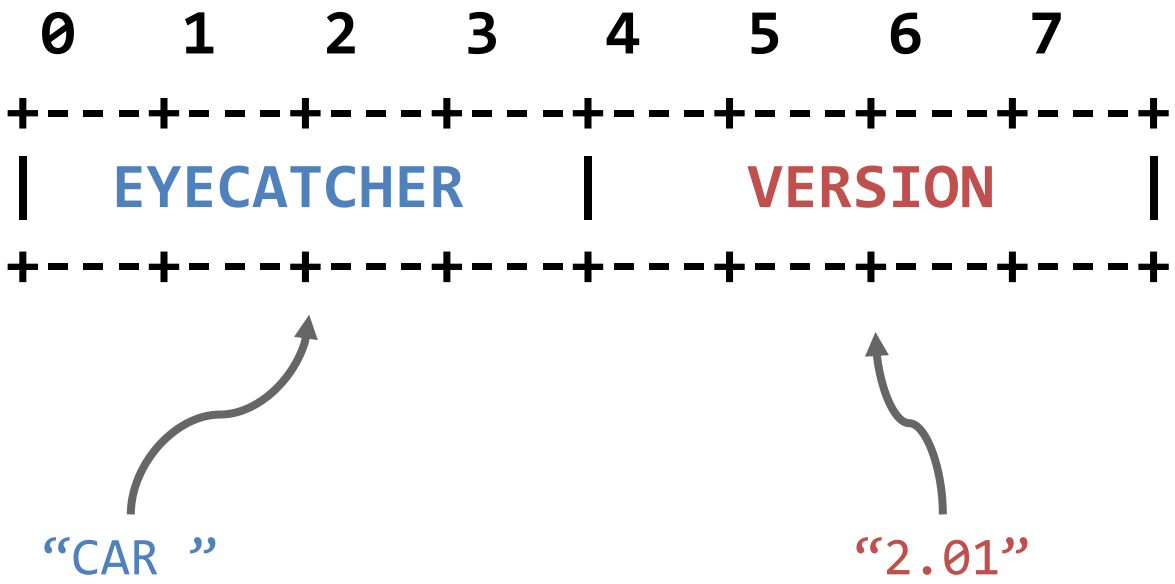
```
$ xxd car200_test_string.sar
0000000: 4341 5220 322e 3030 5247 b481 0000 2b00  CAR 2.00RG....+.
0000010: 0000 0000 0000 0000 0000 d023 5e56 0000  ...........#^V..
0000020: 0000 0000 0000 0000 0f00 7465 7374 5f73  ..........test_s
0000030: 7472 696e 672e 7478 7445 4435 0000 002b  tring.txtED5...+
0000040: 0000 0012 1f9d 027b 2119 a90a 85a5 99c9  .......{!.......
0000050: d90a 4945 f9e5 790a 69f9 150a 59a5 b905  ..IE..y.i...Y...
0000060: c50a f965 a945 0a25 40e9 9cc4 aa4a 8594  ...e.E.%@....J..
0000070: fc74 0000 0808 c6b9                      .t......
```

```
Version=2.00, File type=file, Perm mode=664, File length=43, Timestamp=01 Dec
2015 19:48, Filename length=15, Filename=test_string.txt, Compressed Length=53,
Uncompressed Length=43, Algorithm=LZH, Special byte=02, Checksum=-1178204152
```

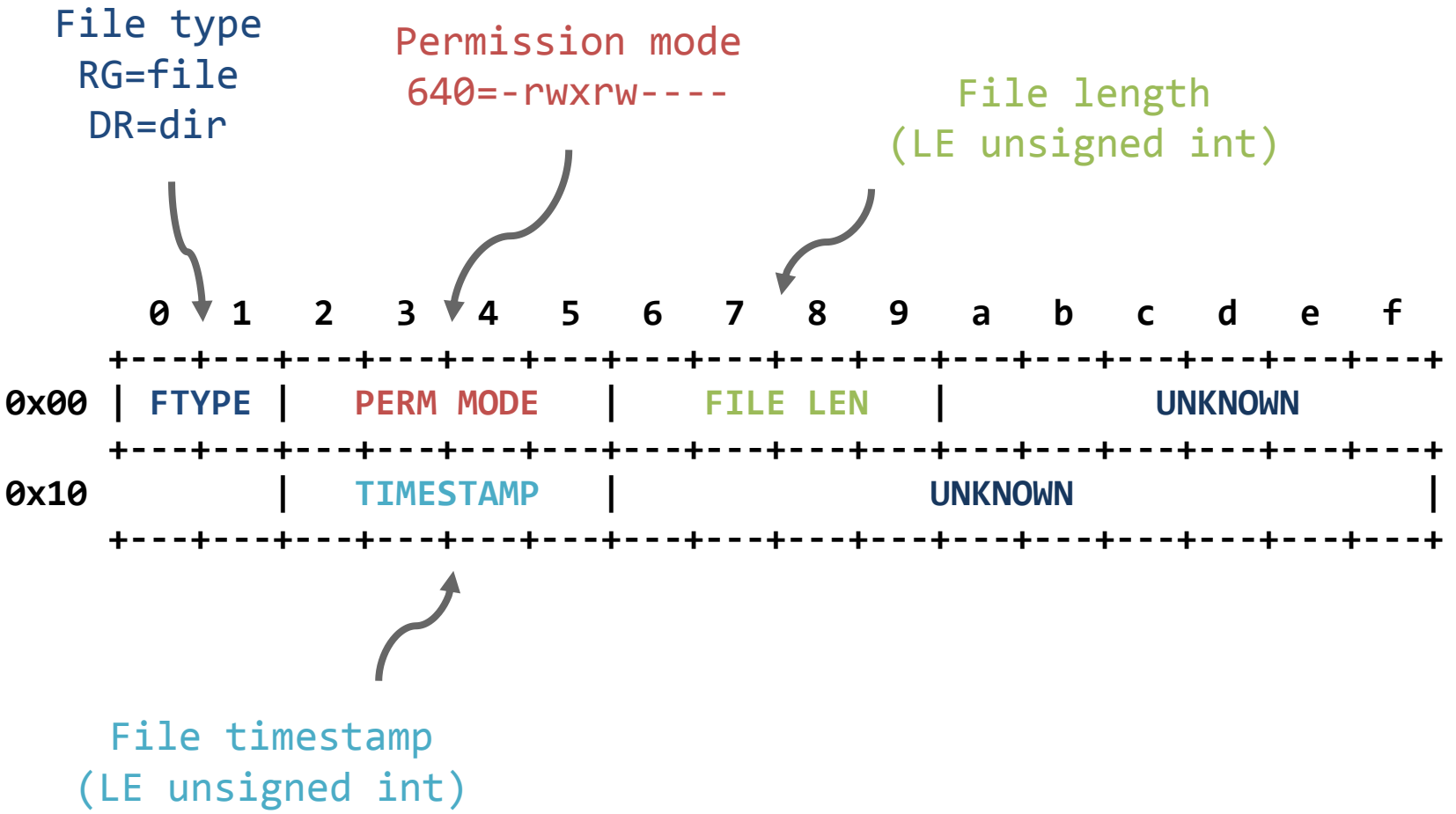
SAR v2.01 archive file format

- Newest version of the archive file
- Same structure as v2.00, except:
  - Handling of filename length
  - Filename is null-terminated
- Default version on SAPCAR

SAR v2.01 archive header

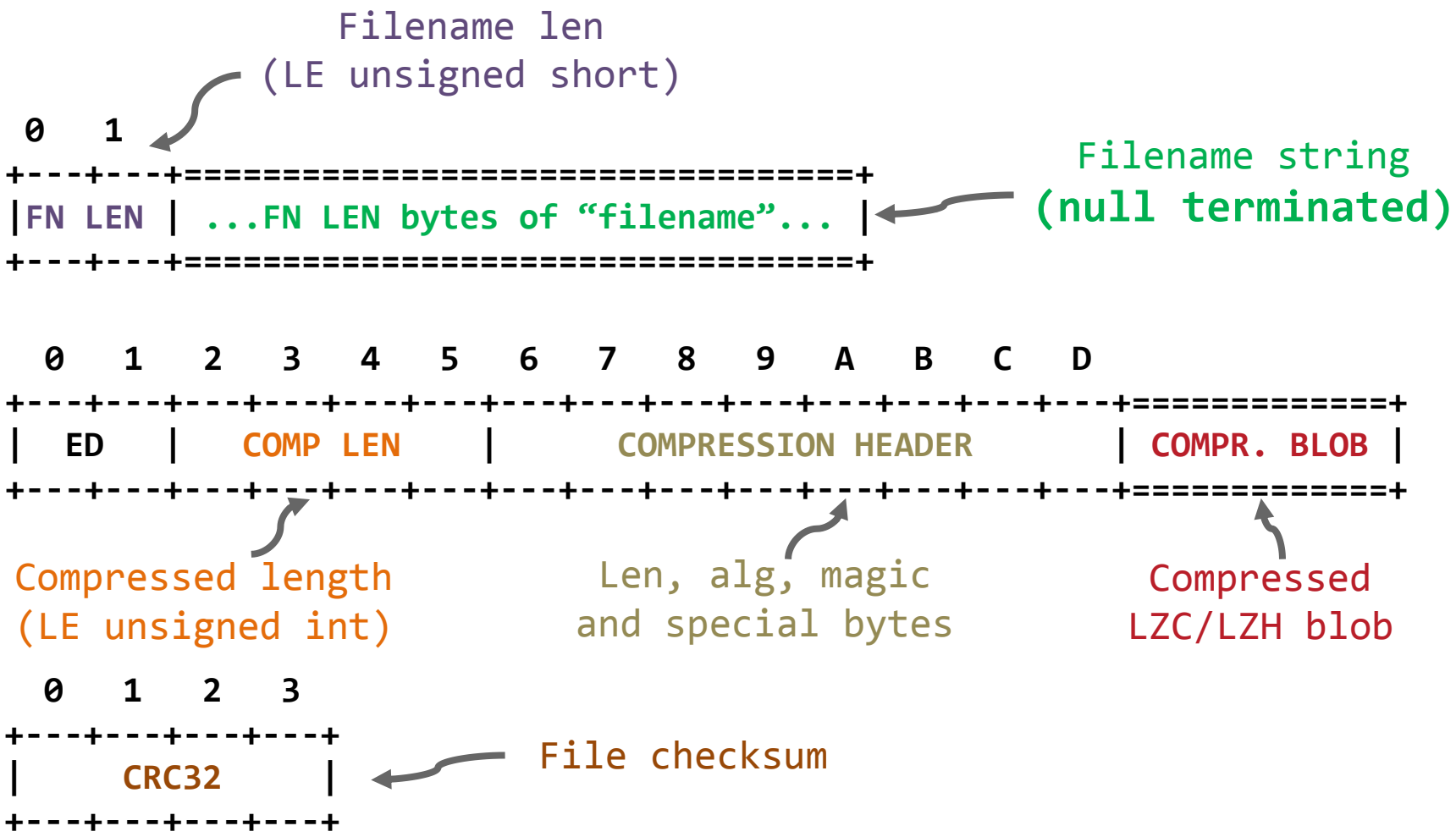


SAR v2.01 archive file header



SAR v2.01 archive file header

If it's a regular file, and file length > 0



SAR v2.01 example

```
$ ./SAPCAR -xvf car201_test_string.sar
SAPCAR: processing archive car201_test_string.sar (version 2.01)
x test_string.txt
SAPCAR: 1 file(s) extracted
```

```
$ xxd car201_test_string.sar
0000000: 4341 5220 322e 3031 5247 b481 0000 2b00  CAR 2.01RG....+.
0000010: 0000 0000 0000 0000 0000 d023 5e56 0000  ...........#^V..
0000020: 0000 0000 0000 0000 1000 7465 7374 5f73  ..........test_s
0000030: 7472 696e 672e 7478 7400 4544 3500 0000  tring.txt.ED5...
0000040: 2b00 0000 121f 9d02 7b21 19a9 0a85 a599  +.......{!......
0000050: c9d9 0a49 45f9 e579 0a69 f915 0a59 a5b9  ...IE..y.i...Y..
0000060: 05c5 0af9 65a9 450a 2540 e99c c4aa 4a85  ....e.E.%@....J.
0000070: 94fc 7400 0008 08c6 b9                   ..t......
```

```
Version=2.00, File type=file, Perm mode=664, File length=43, Timestamp=01 Dec
2015 19:48, Filename length=16, Filename=test_string.txt, Compressed Length=53,
Uncompressed Length=43, Algorithm=LZH, Special byte=02, Checksum=-1178204152
```

SAPCAR Relative/absolute paths

- Handling of absolute/relative paths
  - “/usr/var/some_file_name”
  - “../../some_file_name”

```
$ ./SAPCAR
usage:

[..]
using absolute pathnames:
If you create an archive with absolute pathnames the files will be
extracted with exactly these pathnames! SAPCAR does not cut the first
slash like the UNIX tool tar.
[..]
```

SAPCAR TCPDB.DAT case

- Ran SAPCAR with strace and found:

```
[..]
open("TCPDB.DAT", O_RDONLY)             = -1 ENOENT (No such file or directory)
[..]
```

```
$ ./SAPCAR
TCPDB.DAT line 1: format error: "_______".
TCPDB.DAT line 2: format error: " | |__/".
TCPDB.DAT line 3: format error: " | |  \".
TCPDB.DAT line 4: format error: "       ".
```

SAPCAR archive files signature

- Feature introduced some time ago
  - Release 720 patch level 2
  - SAP Note 1598550 - SAPCAR: Signed archive (2011)
  - SAP Note 1634894 - SAPCAR: Signed Archive (2012)
- Feature documentation
  - SAP Note 2178665 - Signature validation of archives with SAPCAR (2016)
- Cryptographic primitives provided by crypto library
  - SAPCRYPTOLIB
  - CommonCryptolib

SAPCAR archive files signature

- Manifest files
  - **MANIFEST.SMF** inside the archive file
  - Detached manifest file
  - Contains hashes and signature
- Defaults algorithms
  - SHA256 for hashes
  - PKCS7 for signature
- Embedded public keys in crypto library
- Support for CRL and certificate revocations

SAPCAR signature example

```
$ cat SIGNATURE.SMF
SAP-MANIFEST
Version: 1.0
Hash: SHA256
Signature: PKCS7-TSTAMP
Body: Digest | Name-Length | Name

f212e04bca96925a5cd424d9f8b2733533e1d800b38021bf332ea092d0be4c6f 000d Changelog.txt
9a07479720f9c40bd672e16cded8af322afd84eda40d18279d9d108bc0ed6163 0009 LEGAL.TXT
ae113a023d4b93ca1dfe1c9e0d1bdf4d37ac0a6cbc3fd6077f8cd36756dcdb08 000b LICENSE.TXT
[..]

-----BEGIN SIGNATURE-----
MIINTgYJKoZIhvcNAQcCoIINPzCCDTsCAQExDzANBglghkgBZQMEAgEFADALBgkq
hkiG9w0BBwGgggQDMIID/zCCAuegAwIBAgIBCjANBgkqhkiG9w0BAQsFADBMMQsw
CQYDVQQGEwJERTEfMB0GA1UEChMWU0FQIFRydXN0IENvbW11bml0eSBJSTEcMBoG
[..]
-----END SIGNATURE-----
```

SAPCAR signature example

```
$ ./SAPCAR -L ./libsapcrypto.so -tVvf SAPCAR_signed.SAR
SAPCAR: processing archive SAPCAR_signed.SAR (version 2.00)
srw-r--r--       46977    11 May 2015 13:43 Changelog.txt
srw-r--r--         891    03 Feb 2012 16:53 LEGAL.TXT
srw-r--r--        2708    03 Feb 2012 16:52 LICENSE.TXT
[..]

SAPCAR: Signature Subject >CN=CodeSigner006, OU=Code Signing, O=SAP Trust Community
II, C=DE<
SAPCAR: Signature Issuer  >CN=SAP Code Signing CA, O=SAP Trust Community II, C=DE<
SAPCAR: Signature Type    >SAP software<
```

SAPCAR signature example

```
$ ./SAPCAR -L ./libsapcrypto.so -tVvf SAPCAR_signed_tampered.SAR
SAPCAR: processing archive SAPCAR_signed_tampered.SAR (version 2.00)
srw-r--r--       46977    11 May 2015 13:43 Changelog.txt
srw-r--r--         891    03 Feb 2012 16:53 LEGAL.TXT
srw-r--r--        2708    03 Feb 2012 16:52 LICENSE.TXT
[..]
-rw-rw-r--          43    01 Dec 2015 19:48 test_string.txt
SAPCAR: at least one file was not signed (error 58).
Detail: File >test_string.txt< was not found in manifest
```

```
$ ./SAPCAR -L ./libsapcrypto.so -tVvf SAPCAR_invalid_signature.SAR SAPCAR: processing
archive SAPCAR_invalid_signature.SAR (version 2.01)
SAPCAR: SAPCAR_invalid_signature.SAR is not digitally signed (error 59). No such file
or directory
```

Attack surface

- Compression algorithms
- Archive file handling
- Signature validation
- Download process

Archive file handling

- Fuzzing archive file parsing
  - File name handling
  - Metadata, archive header fields
- Old formats of special interest

```
$ ./SAPCAR -xvf SAPCAR_crash.SAR
SAPCAR: processing archive SAPCAR_crash.SAR (version 2.01)
x input-dir/inp#t
Segmentation fault
```

Compression algorithms

- Complex piece of code
  - C/C++, 9 files, 2963 lines of code, 443 McCabe CC
- Source code available
  - Part of old MaxDB, open source version (LZC/LZH)
- Very extended on SAP products and components
  - SAP Content server
  - ABAP code stored in DB
  - Diag and RFC protocols
  - HANA, MaxDB database engines
  - SAPCAR, SAP GUI, r3trans, r3load, Jco, RFC SDK

Compression algorithms - CVE-2015-2278

- LZH decompression out-of-bounds read
- Building Huffman tree requires doing lookups of previous values
- Indexing an uninitialized array
- Denial of service impact

```
[..]
int CsObjectInt::BuildHufTree (
            unsigned * b,  /* code lengths in bits (all assumed <= BMAX) */
            unsigned   n,  /* number of codes (assumed <= N_MAX) */
            unsigned   s,  /* number of simple-valued codes (0..s-1) */
            int      * d,  /* list of base values for non-simple codes */
            int      * e,  /* list of extra bits for non-simple codes */
            HUFTREE  **t,  /* result: starting table */
            int      * m)  /* maximum lookup bits, returns actual */
   [..]
     if (p >= v + n)
     {
       r.e = INVALIDCODE;             /* out of values--invalid code */
     }
     else if (*p < s)
     {                              /* 256 is end-of-block code */
       r.e = (unsigned char)(*p < 256 ? LITCODE : EOBCODE);
       r.v.n = (unsigned short) *p;  /* simple code is just the value*/
       p++;
     }
     else
     {
        r.e = (unsigned char) e[*p - s]; /*non-simple,look up in lists*/
       r.v.n = (unsigned short) d[*p - s];
       p++;
     }
[..]
```

Compression algorithms - CVE-2015-2282

```
[..]
int CsObjectInt::CsDecomprLZC (SAP_BYTE * inbuf,
                   SAP_INT    inlen,
                   SAP_BYTE * outbuf,
                   SAP_INT    outlen,
                   SAP_INT    option,
                   SAP_INT *  bytes_read,
                   SAP_INT *  bytes_written)
    [..]
    /* Generate output characters in reverse order ...*/
    while (code >= 256)
    {
      *stackp++ = TAB_SUFFIXOF(code);
      OVERFLOW_CHECK
      code = TAB_PREFIXOF(code);
    }
[..]
```

- LZC decompression stack-based overflow
- OVERFLOW_CHECK seems to be insufficient
- OVERFLOW_CHECK not enabled at compile time!
- Remote code execution impact is likely

Compression algorithms - CVE-2015-2278/2282

- High profile vulnerabilities
- Affected lot of components
- Require **urgent** patching
- Patches released on May 2015:
  - SAP Note 2125316 - Potential termination of running processes in SAPCAR
  - SAP Note 2121661 - Potential remote termination of running processes in ABAP & Java Server
  - SAP Note 2127995 - Potential remote termination of running processes in Content Server
  - SAP Note 2124806 - Potential remote termination of running processes in SAP GUI

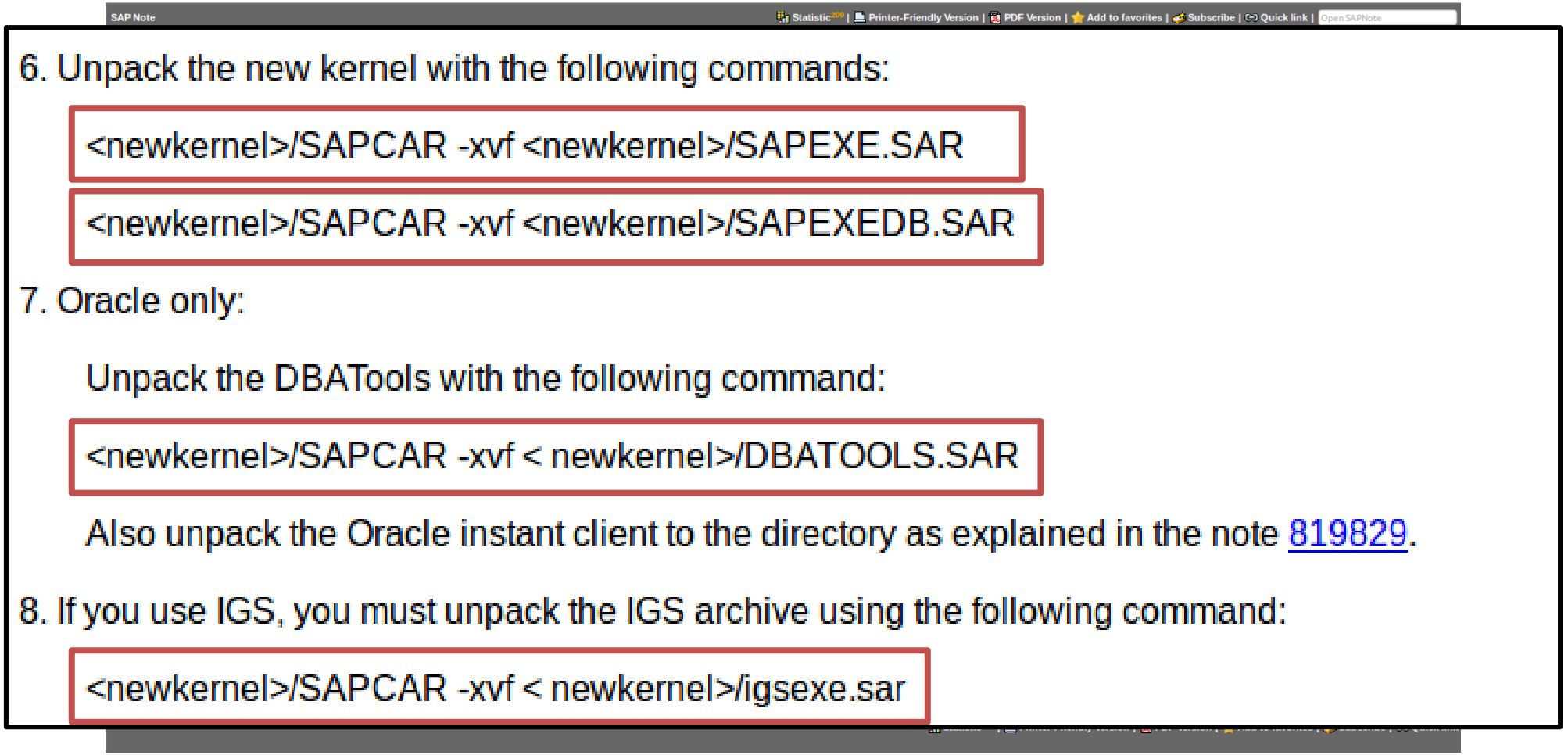
Attack vectors

- Drive-by-download
- Signature validation
- Automated processing of files
- Download process
  - SAP Download Manager
- User’s trust

User's trust

- User trust that file is authentic
- Signature validation is not enforced by default
- Absolute/relative paths are supported by default
- Installation/patch procedures recommends extracting SAR files directly on SAP's directory
- What could go wrong?

User's trust


SAP Note
Statistic
Printer-Friendly Version
PDF Version
Add to favorites
Subscribe
Quick link
Open SAPNote
6. Unpack the new kernel with the following commands:
<newkernel>/SAPCAR -xvf <newkernel>/SAPEXE.SAR
<newkernel>/SAPCAR -xvf <newkernel>/SAPEXEDB.SAR
7. Oracle only:
Unpack the DBATools with the following command:
<newkernel>/SAPCAR -xvf < newkernel>/DBATOOLS.SAR
Also unpack the Oracle instant client to the directory as explained in the note 819829.
8. If you use IGS, you must unpack the IGS archive using the following command:
<newkernel>/SAPCAR -xvf < newkernel>/igsexe.sar

User's trust

- Demo
  - Using pysap API for handling SAR files
  - Open an existing SAR file
  - Add a new file using an absolute path
- Let the user extract it!

Download process

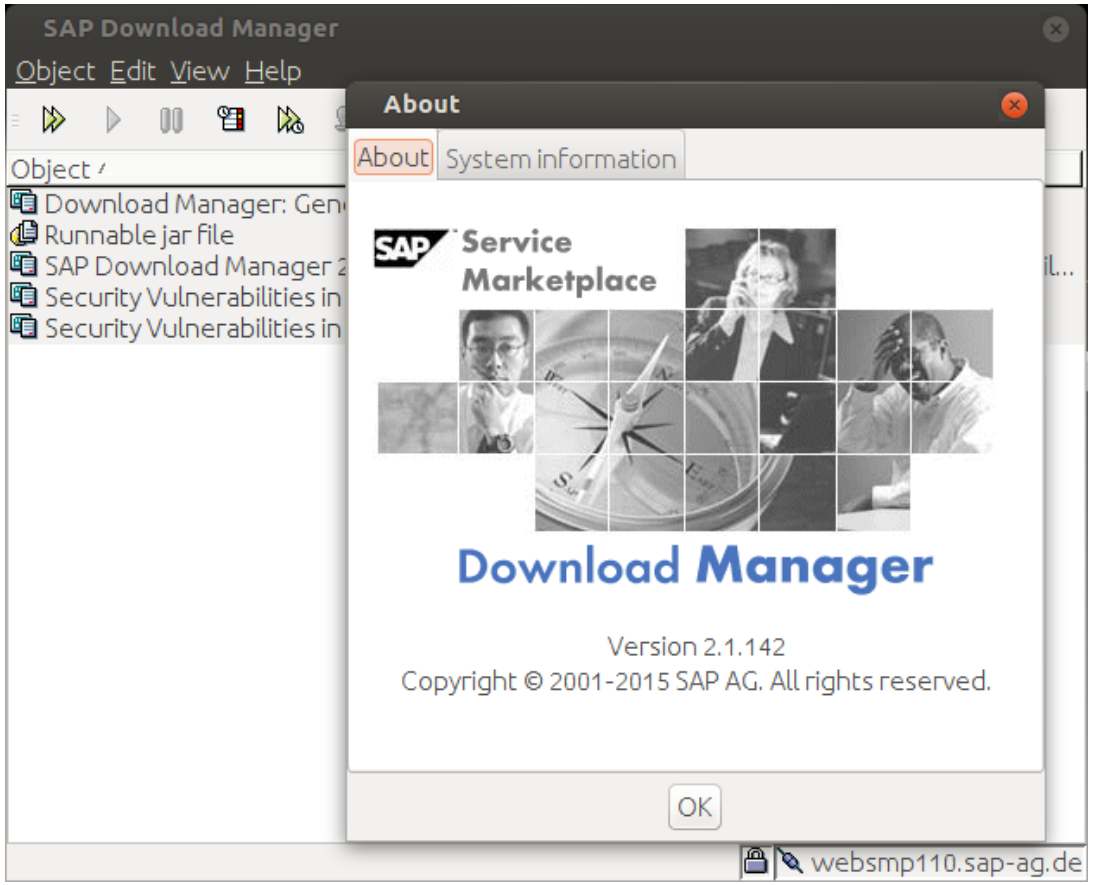
- Downloads from untrusted sources
- Unencrypted channels
- Share folders
- ..
- SAP Download Manager

Unencrypted channels

- User downloading SAP notes through HTTP
- MitM via SSLStrip
- Demo
  - Using mitmproxy to perform MitM + SSL Strip
  - Locate SAR file being downloaded
  - Using pysap to infect the SAR file

SAP Download Manager

- Small Java Application
- Allows downloading notes from their basket
- Latest version is 2.1.143 (March 2016)

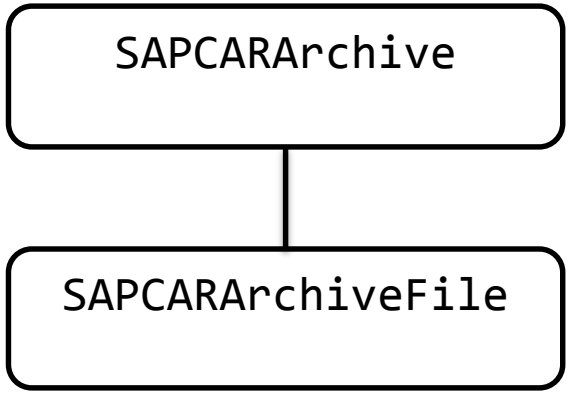


SAP Download Manager

- Version < 2.1.142 (Oct 2015) vulnerable to MitM
  - SAP Note 2233617 - Security Vulnerabilities in SAP Download Manager
  - SAP Note 2235412 - Security Vulnerabilities in SAP Download Manager
- Attack idea?
  - Using mitmproxy to perform MitM
  - Locate SAR file being downloaded inside a zip file
  - Using pysap to infect the SAR file

pysap's SAPCAR API

- Python library for SAP's network protocols
- Implemented SAR v2.00/v2.01 file formats
- High level abstraction of archive/files



https://github.com/CoreSecurity/pysap

```
In [2]: from pysap.SAPCAR import *

In [3]: ar = SAPCARArchive("car201_test_string.sar", "r")

In [4]: ar.files_names
Out[4]: ['test_string.txt']

In [5]: f = ar.files["test_string.txt"]

In [6]: f.size, f.permissions, f.timestamp
Out[6]: (43, '-rw-rw-r--', '01 Dec 2015 19:48')

In [7]: f.open().read()
Out[7]: 'The quick brown fox jumps over the lazy dog'
```

Defense

- Ensure running latest program versions
  - SAPCAR
  - CommonCryptoLib
  - SAP Download Manager
  - Etc.
- Download software packages from trusted sources
  - Ensure links are HTTPS
  - Protect shared folders, repositories

Defense

- Extract disabling relative paths
  - Create a new folder
  - Extract there using –flat option
- Validate archive signatures
  - Before extracting!
- Enable CLR checks
  - Download CRL list
  - Validate signature using –crl option

Conclusions

- BASIS life is hard
- New attack vectors unveiled
- More knowledge about archive files
- Plenty of further work
  - Fuzzing?
  - Signatures?

Q & A

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Thank you.

Thanks to Troopers crew, Joris, Dana & Euge!