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Computer Systems Forensic Analysis
AFSC

Data Organization

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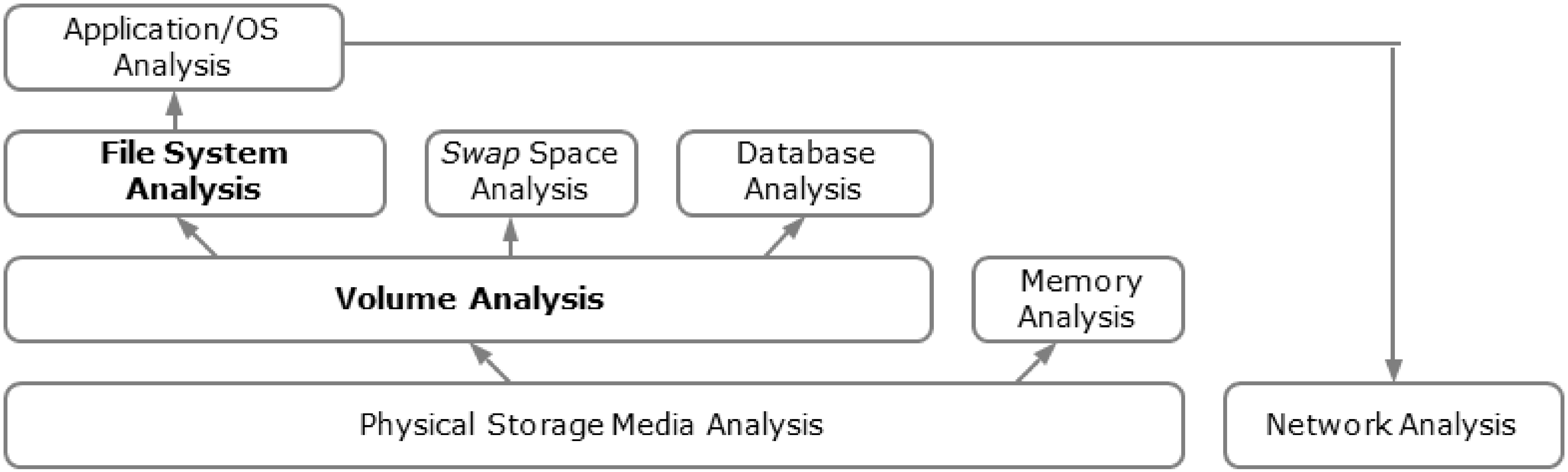
Data Organization

Data storage systems have several layers



Data Organization

- Layer 1 – requires specialized laboratories
  - communication devices: Ethernet, 3G, UMTS, . . .
  - physical store mediums: hard disks, memory chips, CD-ROMs, . . .
- Layer 2 – reading logical data (streams of `0`s and `1`s)
  - volatile memory (RAM) – data typically organized by processes
  - non-volatile storage – data typically organized into volumes
    - typically organized into volumes (partitions, RAID arrays, . . .)
    - analyze data at the volume level to find possible hidden data

Data Organization

Layer 3

- file system (most common content)
- temporary space: swap space in Linux or pagefile in Windows
- direct database (without traditional file system), such as *Google file system*, . . .

Layer 4

- Operating systems (Windows, Mac OSX, Linux, Android, iOS, . . .)
- Applications (operating system dependent)

Focus of this course

File System Analysis

File system analysis:

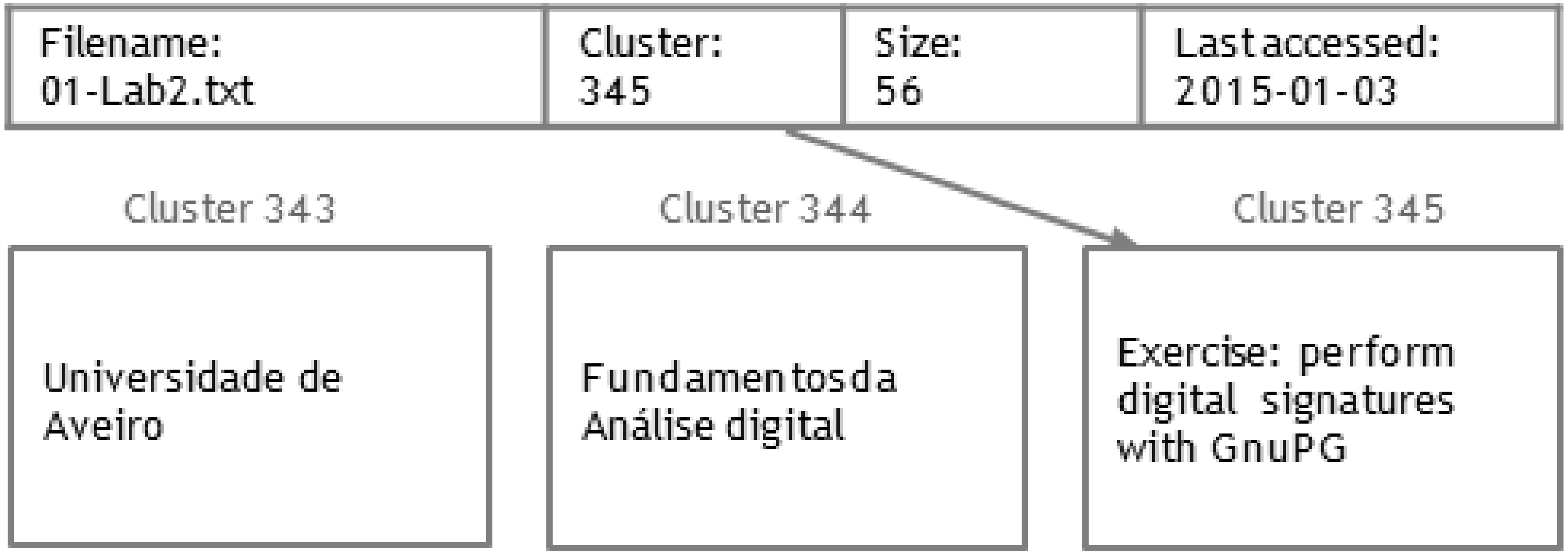
- collection of data structures that allow an application to create, read, and write files
- **Analise file system to**:
  - find files
  - recover deleted files
  - find hidden data
- **the result can be**:
  - file content
  - data fragments
  - metadata associated with files

File system

organizes data inside a volume

- associate file names to file content
- **essential data**: file names and content location
  - trustful data – however content may be invalid, *e. g.* deleted files
- **non essential data**: last access time – even if it is wrong the file content still is valid
  - we may not be able to trust non essential data, *e. g.* system time may be inaccurate, the user may have changed the time, *etc*
  - we should try to find additional data sources to support an incident hypothesis

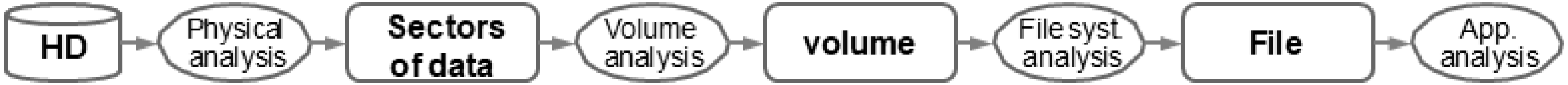
DATA ANALYSIS – FILE SYSTEM



File content analysis:

- data structure depends on the application or OS that created the file analysis
- tools may vary accordingly to the application that created the file
  - `HTML` is data structure differs from `.jpeg`
- analysis of configuration files is important to determine what programs were running

Data analysis process from the physical level to the application level:



NUMERICAL REPRESENTATION

Numbers can be represented in several ways:

- **decimal** – human system (10 fingers)
  - 10 symbols: [0, 1, 2, 3, 4, 5, 6, 7, 8, 9]
- **binary** – computational representation (2 levels of voltage)
  - 2 symbols: [0, 1]
- **hexadecimal** – compact representation of binary numbers
  - 16 symbols: [0, 1, 2, 3, 4, 5, 6, 7, 8, 9, *A*, *B*, *C*, *D*, *E*, *F*]

there are more numerical systems *e. g.* **octal**

Each symbol has a value depending on its position, *e. g.* $35\,812_d$:

$3 \times 10^4 + 5 \times 10^3 + 8 \times 10^2 + 1 \times 10^1 + 2 \times 10^0 =$

$3 \times 10\,000 + 5 \times 1\,000 + 8 \times 100 + 1 \times 10 + 2 \times 1 =$

$30\,000 + 5\,000 + 800 + 10 + 2 = 35\,812$

most significant symbol → leftmost value: 3

less significant symbol → rightmost value: 2

Example: Convert 1001 0011_b to decimal:

$1 \times 2^7 + 0 \times 2^6 + 0 \times 2^5 + 1 \times 2^4 + 0 \times 2^3 + 0 \times 2^2 + 1 \times 2^1 + 1 \times 2^0 =$

$1 \times 128 + 0 \times 64 + 0 \times 32 + 1 \times 16 + 0 \times 8 + 0 \times 4 + 1 \times 2 + 1 \times 1 =$

$128 + 0 + 0 + 16 + 0 + 0 + 2 + 1 = 147_d$

which is the **most** significant digit? which is the **less** significant digit?

Generic formula to convert from any base system to decimal:

$s_p \times b^p + . . . + s_1 \times b^1 + s_0 \times b^0$

s – symbol value

b – original base (binary, octal, hexadecimal, . . .)

p – symbol position, begins at zero and increases from right to left

Convert to decimal $8BE\,4_h$, which can also be represented as $0x\,8BE\,4$

$A = 10$, $B = 11$, $C = 12$, $D = 13$, $E = 14$, $F = 15$

$8 \times 16^3 + 11 \times 16^2 + 14 \times 16^1 + 4 \times 16^0 =$

$8 \times 4\,096 + 11 \times 256 + 14 \times 16 + 4 \times 1 =$

$32\,768 + 2\,816 + 224 + 4 = 35\,812_d$

How do we convert from binary to hexadecimal?

Conversion Table

Decimal	Binary	Hexadecimal	Decimal	Binary	Hexadecimal
0	0000	$0x0$	8	1000	$0x8$
1	0001	$0x1$	9	1001	$0x9$
2	0010	$0x2$	10	1010	$0xA$
3	0011	$0x3$	11	1011	$0xB$
4	0100	$0x4$	12	1100	$0xC$
5	0101	$0x5$	13	1101	$0xD$
6	0110	$0x6$	14	1110	$0xE$
7	0111	$0x7$	15	1111	$0xF$

Example:

$1001\ 0011_b = 0x\,93$

direct conversion:

$1001_b = 0x\,9$

$0011_b = 0x\,3$

1 Byte = 8 bits = 2 hexadecimal digits

hexadecimal → binary compact representation

Floating point number

- format IEEE 754 standard
- exponent in excess allows direct comparisons of floating-point numbers
- mantissa (or significand):

  normalized → the binary digit 1 to the left of the comma is omitted

  in additions and subtractions is denormalized, but there is a gradual loss of accuracy
- single precision: 32 bits — exponent in excess of 127 → [2^{-126}, 2^{+127}]
- double precision : 64 bits — exponent in excess of 1023 → [2^{-1022}, 2^{+1023}]
- conversion tools: http://www.h-schmidt.net/FloatConverter/IEEE754.html ; https://www.binaryconvert.com

Signal	Exponent	Mantissa (or significand)
1 bit	*8 bits*	*23 bits*

Signal	Exponent	Mantissa (or significand)
1 bit	*11 bits*	*52 bits*

ENDIANNESS – STORAGE ORDER

Binary data unit:

1 Byte (B) = 8 bits (b): $2^8 = 256$ possible values to store large numbers it is necessary to group bytes

typically 2, 4 or 8 bytes (16, 32 or 64 bits)

Problem: systems differ in how they store multi-byte values

big-endian: place the **most** significant byte in the 1*st* (or lower) storage address

little-endian: place the **less** significant byte in the 1*st* (or lower) storage address

Example: 0*x*12 34 56 78

Storage address	...	91	92	93	94	...	
Value	...	12	34	56	78	...	*Big-endian*

Storage address	...	91	92	93	94	...	
Value	...	78	56	34	12	...	*Little-endian*

Big-endian processors

- SPARC, PowerPC, MIPS, Motorola 68k, Alpha, . . .

Little-endian processors

- it seems that there are some optimization advantages in pipelined architectures
- z80, VAX, x86, x86-64, amd64, . . .

Programmable Big/Little-endian

- ARM, . . .

Data networks – *network order*

- IP: **Big-endian**, but there are some exceptions
- very important to guarantee systems interoperability

More info: http://en.wikipedia.org/wiki/Endianness

Advantages:

- is the simplest way to encode the characters
- doesn't have *endianness* problems – uses 1 byte at a time original version uses only 7 bits – 128 different characters
  - ✓ ASCII table: https://www.asciitable.com/asciifull.gif
- it takes up less storage space than unicode

Disadvantages:

- very limited capacity to represent non-English characters
- there are several extended versions – 8 bits (ISO 8859)
  - ✓ the best known is *Latin-1 (ISO 8859-1)* (https://cs.stanford.edu/people/miles/iso8859.html)

Example

Address	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Hex.	...	43	61	70	69	74	E3	6F	20	41	6D	E9	72	69	63	61	...
Text		C	a	p	i	t	ã	o		A	m	é	r	i	c	a	

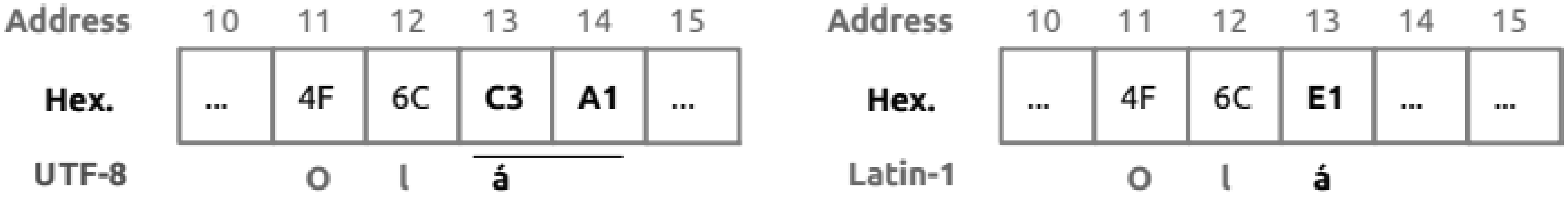
Advantages:

- the latest version has more than 137 000 characters
- covers 146 modern and historic scripts, as well as multiple symbol sets

Disadvantages:

- there are several implementations
  - ✓ UTF-8: compatible with ASCII, has <u>variable length from 1 to 4 bytes</u> and is used in *nix systems, www, HTML, *etc*
    - ➢ not subject to endianness problems – it reads 1 byte at a time
  - ✓ UTF-16: has <u>variable length from 2 to 4 bytes</u>, is used in Windows, Mac OS, Java, .Net, KDE, *etc*
  - ✓ UTF-32: <u>fixed length</u> of 4 bytes
- more complex processing

Example: UTF-8 vs Latin-1



Data structures:

- specifies how data is placed
- it is like a map
- data structure itself is not recorded

Data structure:

```
typedefstruct{
  char name[32];             // 32 bytes
  char postalcode[16];       // 16 bytes
  uint32_t partner_num;      // 4 bytes
  float quota;               // 4 bytes
  char empty[8];             // 8 bytes to lineup the structure to multiples of 16 bytes
};                           // Total = 64 bytes
```

DATA STRUCTURES – EXAMPLE

Data in hexadecimal:

```
0000000: 4d69 6775 656c 2046 7261 6465 0000 0000  Miguel Frade....
0000010: 0000 0000 0000 0000 0000 0000 0000 0000  ................
0000020: 3234 3131 2d39 3031 0000 0000 0000 0000  2411-901........
0000030: b300 0d00 c976 9e3f 0000 0000 0000 0000  .....v.?........
```

What is the partner number (in hex.)? Is it `0xb300 0d00` or `0x000d 00b3`?
What is the quota value (in hex.)? Is it `0xc976 9e3f` or `0x3f9e 76c9`?

Original source code

```
strcpy(partners[0].name,"Miguel Frade");
strcpy(partners[0].postalcode,"2411-901");
partners[0].partner_num=852147;
partners[0].quota=1.238;
```

Question

Is this system *Little-endian* or *Big-endian*?

if it is *Big-endian*, then:

partner number: `0xb300 0d00` = `3 003 124 992`; quota: `0xc976 9e3f` = `-1 010 147,94`

if it is *Little-endian*, then:

partner number: `0x000d 00b3` = `852 147`; quota: `0x3f9e 76c9` = `1,238`

There are many different ways to storage date and time:

- as a string:
  - easy to read by humans,
  - but hard for computers' operations, for example to compare dates in a database
  - many different representations and some times language dependent, *e. g.*:
    - Wednesday, January 9, 11:13:48 UTC 2019
    - 2018-12-23 08:23:55
    - 23-12-2018 08:23:55 (PT)
    - 12-23-2018 08:23:55 (US)
    - . . .
- as binary represented with numbers or hexadecimal
  - difficult to read by humans, but easier for computers' operations
  - unfortunately, not all software uses the same representation

How time is counted:

Unix time = POSIX time = UNIX Epoch time (https://www.epochconverter.com)

- number of elapsed seconds since 1970-01-01 00:00:00
- Unix, Linux, **Firefox**, Java, JavaScript, Perl, PHP, Python, Ruby, Tcl, *etc*

400-year Gregorian calendar cycle

- number of microseconds since 1601-01-01 00:00:00
- **Google Chrome**, Windows 32 and 64 bits, NTFS, Cobol, *etc*

Examples of date and time storage formats:

Software	Representation	Example	Software	Representation	Example
Win 64 bits BE	16 Hex chars	01 CC A6 3C 91 B9 72 00	Firefox SQLite	16 digits	1 321 653 236 000 000
Win 64 bits LE	16 Hex chars	00 72 B9 91 3C A6 CC 01	Chrome SQLite	17 digits	12 966 126 836 000 000
Unix numeric	10 digits	1 321 653 236	Coockie hi:low	18:19 digits	3 923 586 186:30 188 999
Unix numeric m. seconds	13 digits	1 321 653 236 000	DOS wFAT	8 Hex chars	F0 48 64 40
Unix 32 bits BE	8 Hex chars	4E C6 D3 F4	GSM	14 digits	99 309 251 619 580
Unix 32 bits LE	8 Hex chars	F4 D3 C6 4E	Samsung Swift	8 Hex chars	E7 8C 94 7D
HFS+ 32 bits BE	8 Hex chars	CA EC 84 74	Nokia Series 40	14 Hex chars	07 D9 04 11 13 27 09
HFS+ 32 bits LE	8 Hex chars	74 84 EC CA			
Mac Absolute time	9 digits	343 346 036			

Chrome SQLite/1000000 = Unix time + 11644473600 sec

(1970-01-01 00:00:00) - (1601-01-01 00:00:00) = 11644473600 sec

Date and time convert tools

MFT Stampede (download)

- ✓ Windows GUI tool, very easy to use

Nirsoft tool *BrowsingHistoryView* https://www.nirsoft.net/utils/browsing_history_view.html

- ✓ supports browsing history of Internet Explorer, Mozilla Firefox, Google Chrome, and Safari

SQL – cool for automation of tasks https://sqlitebrowser.org/dl/

- Firefox SQLite database overview of the visited sites:

- Ubuntu -> [user_home_directory]/.mozilla/firefox/xxxxxxxx.default/places.sqlite
- Windows -> [user_home_directory]\AppData\Roaming\Mozilla\Firefox\Profiles\xxxxxxxx.default\places.sqllite

```
SELECT datetime(moz_historyvisits.visit_date/1000000, 'unixepoch', 'localtime') AS Date_Time, moz_places.url
FROM moz_places, moz_historyvisits
WHERE moz_places.id = moz_historyvisits.place_id
ORDER BY Date_Time ASC
```

DATE AND TIME

- Google Chrome SQLite database overview of the visited sites:

Ubuntu -> [user_home_directory]/.config/google-chrome/Default/databases
Windows -> [user_home_directory]\AppData\Local\Google\Chrome\User Data\Default\History

```
SELECT datetime(((visits.visit_time/1000000)-11644473600), 'unixepoch', 'localtime') AS Date_Time, urls.url, urls.title
FROM urls, visits
WHERE urls.id = visits.url
ORDER BY Date_Time ASC
```

Binary-to-text encoding

- is encoding of data in plain text, or in other words it is an encoding of binary data in a sequence of printable characters
- the encoding is necessary for transmission of data when the channel does not allow binary data (*e. g.* email)
- encoding inflates the original data size, the inflate rate depends on the used technique encoding is a reversible operation
- it can also be applied to plain text

Not to be confused with encrypting, **it's not** encryption:

- encryption requires a key, usually secret
- encoding doesn't depend on a key

COMMON ENCODING TECHNIQUES

Common encoding techniques:

hexadecimal (also known as base16)

- ✓ used chars: `[0..9]` and `[A..F]` (or `[a..f]`)
- ✓ hash values (MD5, SHA245, *etc*) are usually displayed in hexadecimal
- ✓ example: “Hello World” → `48656c6c6f20776f726c64`

base64

- ✓ used chars: `[A..Z`, `[a..z]`, `[0..9]`, and `[+,/]`
- ✓ base64 string size must be a multiple of 4, so char `=` can be used at the end as padding
- ✓ used on: email servers (MIME), OpenPGP, *etc*
- ✓ example: “Hello World” → `SGVsbG8gV29ybGQ=`

https://cryptii.com/pipes/binary-to-base64 https://www.browserling.com/tools/base64-encode

base58:

- ✓ similar to base64, but modified to avoid both non-alphanumeric characters and letters which might look ambiguous when printed
- ✓ used on bitcoins,
- ✓ example: bitcoin public key `1ZNz2KDm8epACBA5bjgKQbRyaGcDt3XV2`
- ✓ bitcoin private key: `Ky1ZcCSMziFtdxfDEjANw3PZUZQQLjh6hKpX1CinVtJscnAFnvcn`

https://learnmeabitcoin.com/technical/base58 https://en.bitcoin.it/wiki/Base58Check_encoding

Exercises

Please do the following exercises:

Lab 1 – Endianness, read binary file

Lab 2 – Identify different character encodings

Lab 3 – Character encoding conversions

ANY QUESTIONS?