

Base64

- Extremely common, you use it all the time!
- MIME: Multipurpose Internet Mail Extension
 - Extends the format of email to support other character sets, and
 - Used in other contexts as well
- SMTP:
 - `cat <binary_file> | mail steve`
 - via a modern MSA: `mail steve@my.csun.edu`
 - Content-Transfer-Encoding: base64
- HTTP/HTML:
 - `curl --head $URL`
 - Content-Type: text/plain



MSA: Mail Submission
Agent

More Motivation

- What is the content of a text file?
 - `cat mytext.file`
 - `echo 101100101 > ascii_digits.txt`
- What is the content of an executable?
 - consider the unprintable characters
- What is the content of a picture?
 - drag and drop a picture

```
$ cat  
$ od -t a  
$ od -t c  
$ od -t d1  
$ od -t o2  
$ od -t x4
```

- What is the content of data?
- How can we interpret this data?
- How should we interpret this data?
scheme!

Individual bits group in bytes
Any way we want!
Based upon an agreed upon

Base64: a binary string is encoded as an ASCII string

```
$ base64 <<< Hello
SGVsbG8K
$ base64 -d <<< SGVsbG8K
Hello
```

- A scheme to represent binary data as all "printable" characters
 - Which characters should we use: A-Z, a-z, 0-9: that's $26+26+10 = 62$, add + / for 64
 - Hence, we have 2^6 (64) unique characters to use, plus a padding character (=)
- Basic Algorithm:
 - For every three bytes (24 bits) # $\text{lcm}(6,8) = ?$
 - Load and Merge the bytes together
 - Chop and Slide into 4 6-bit chunks
 - Map each 6-bit chunks into a 8-bit ASCII value
 - Store each new the original three bytes with four new bytes
 - Add appropriate padding for remaining bytes
- Mapping ensures the result 8 bits are always printable ASCII characters
- Operations at the assemble level:
 - byte manipulations
 - shifting and masks
- Working at the byte level exposes Endianness

The "encode" subroutine:

- The following slides illustrate the steps associated with encoding
 - 24-bits into 4 base64 characters
- The signature (or API) of this subroutine is:
 - void encode(input, output)
 - input: the memory location where the three input values are stored
 - output: the memory location where the four output values are to be stored
- MIPS instructions to call the subroutine: ○
- MIPS instructions to load and store the input and output within the subroutine

```
la $a0, input
la $a1, output
jal encode
```

```
# Load 3 input bytes
lbu $t1, 0($a0)
lbu $t2, 1($a0)
lbu $t3, 2($a0)
```

```
# Store 4 output bytes
sb $s1, 0($a1)
sb $s2, 1($a1)
sb $s3, 2($a1)
sb $s4, 3($a1)
```

Load and Merge (shift and meld)

- load:

~~ibu \$t1,
0(\$a0)~~

t1:																			1	1	1	1	1	0	1	0	0xfa
t2																			1	1	0	0	1	0	1	0	0xca
t3:																			1	1	0	1	1	1	1	0	0xde

- shift:

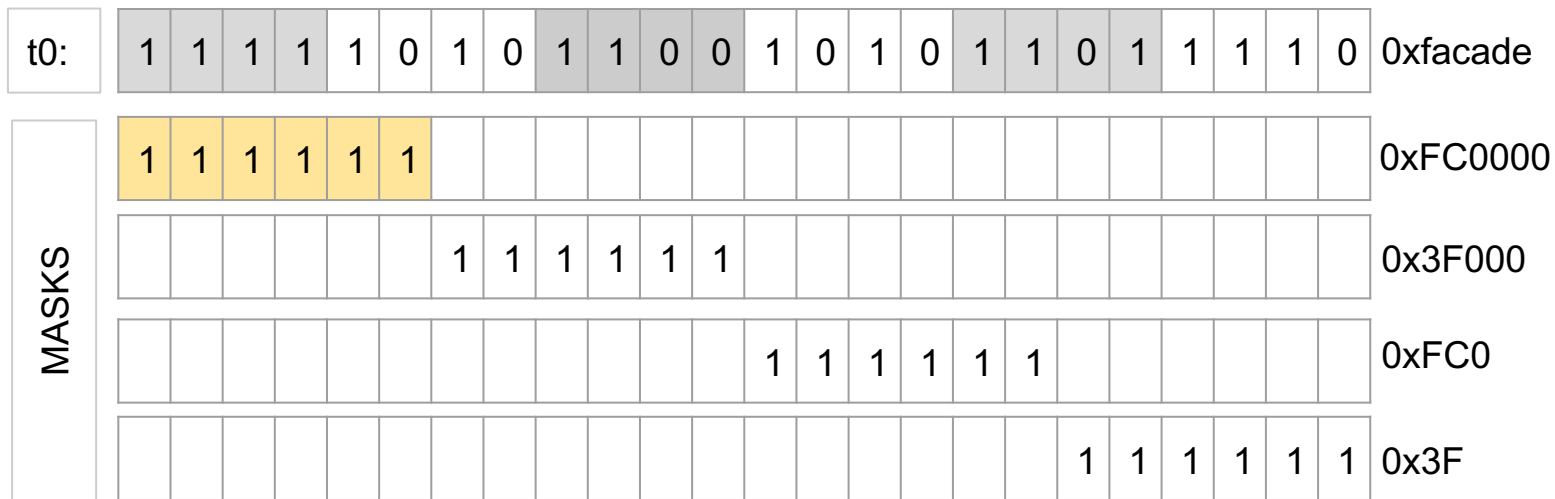
```
sll $t1, $t1, 16
```

t1:	1	1	1	1	1	0	1	0																	
t2:										1	1	0	0	1	0	1	0								
t3:																		1	1	0	1	1	1	1	0

- meld:

t0:	1	1	1	1	1	0	1	0	1	1	0	0	1	0	1	0	1	1	0	1	1	1	1	0
-----	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

Chop and Slide:



t0 & xFC0000



s1= (t0 & xFC0000) >> 18= 11 1110= 0x3E

s2= (t0 & x03F000) >> 12= 10 1100= 0x2C

s3= (t0 & xFC0) >> 6 == 10 1011= 0x2B

s4= (t0 & x03F) >> 0 == 01 1110= 0x1E

Mapping:

- [Base64 Mapping Table](#)
- Two approaches to mapping:
 - Perform a table lookup
 - Compute the value
 - via the following switch statement
- The computed indices are:
 - s1 = 0x3E (62)
 - s2 = 0x2C (44)
 - s3 = 0x2B (43)
 - s4 = 0x1E (30)
- The mapped characters are:
 - '+' (0x2B)
 - 's' (0x73)
 - 'r' (0x72)
 - 'e' (0x65)

```
switch ( index ) {  
    0..25 : index += 0 + 'A' ; // A - Z  
           break;  
    26..51 : index += -26 + 'a'; // a - z  
           break;  
    52..61 : index += -52 + '0'; // 0 - 9  
           break;  
    62      : index = '+';  
           break;  
    63      : index = '/';  
              break;  
}
```

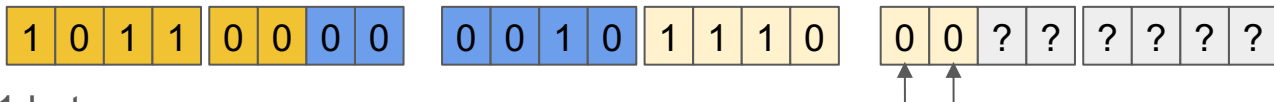
End of File Considerations:

- What if the size of the input is not divisible by 24
 - You need to pad appropriate number of values to the right
- Remaining 3 bytes:
 - output 4 base64 characters
 - output 0 padding character (=)

lcm(6,8)



- Remaining 2 bytes:
 - output 3 base64 characters (with two zeros as fillers)
 - output 1 padding character (=)



- Remaining 1 byte:
 - output 2 base64 characters (with four zeros as fillers)
 - output 2 padding characters (=)

