mjqqt

Caesar Cipher

- A simple way to encode a “message”
- CC-5 [*D(x) = (x – n) mod 26, where n = 5*]

plain	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
cipher	f	g	h	I	j	k	l	m	n	o	p	q	r	s	t	u	v	w	x	y	z	a	b	c	d	e

m	j	q	q	t

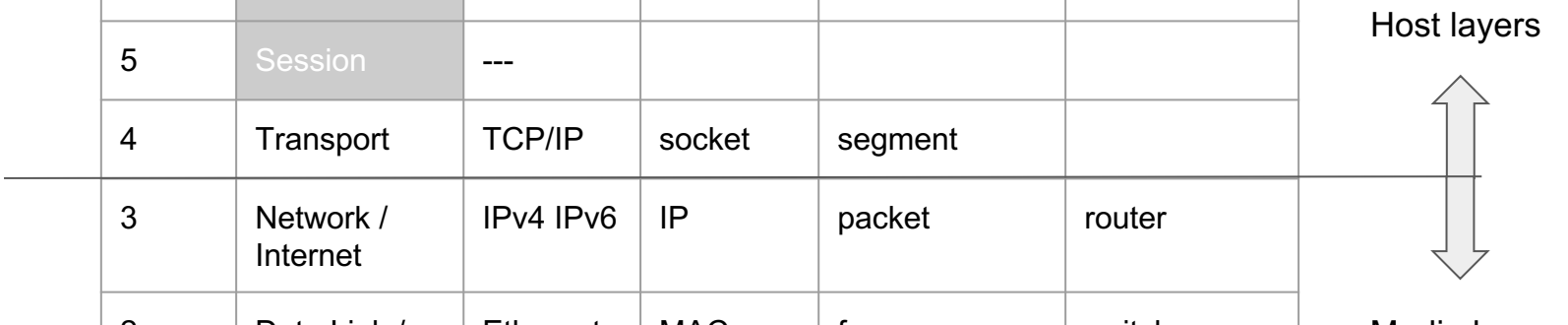
000000000000000000000000000000000000000000
000000000000000000000000000000000000000000
000000000000101010101010101010101010101010
101010101010101010101010101010101100111100
000001100011000001000000001011011000111000
111100000001100011000001000000001011011000
11100000000000000000xxxxxxxxxxxxxxxxxxxxxx
xxxxxxxxxx00000000000000000000000000000000
000000000000000000000000000000000000000000
0000000000000000000000

Introduction to Encodings

- Today's Plan
  - Communication and Bits
  - Discussions on Functions and Mappings
  - Binary Strings and Fields: IPv4 and MIPS Instructions
  - Fixed-length Binary Encodings
    - 3 bits: Octal Encoding
    - 4 bits: Hexadecimal Encoding
    - 5 bits: MIPS Register Encoding
    - 6 bits: Base64 Encoding, MIPS Operations and Functions Encoding
    - 8 bits: ASCII (text) encoding
  - Variable Length Instructions: UTF-8

Recall: OSI and TCP/IP

Layer	Name	Example Protocol	Naming	Transported	Hardware Device
7	Application	http	url	data	
6	Presentation	---			
5	Session	---			
4	Transport	TCP/IP	socket	segment	
3	Network / Internet	IPv4 IPv6	IP	packet	router
2	Data Link / Link	Ethernet	MAC	frame	switch
1	Physical	802.11g	Interface	symbols	hub, bridge



Comm

Payload

Layer 2

Layer 1

Preamble	Start frame delimiter	MAC destination	MAC source	802.1Q tag (optional)	Ethertype (Ethernet II) or length (IEEE 802.3)	Payload	Frame check sequence (32-bit CRC)	Interpacket gap
7 octets	1 octet	6 octets	6 octets	(4 octets)	2 octets	46-1500 octets	4 octets	12 octets

Payload Header: Layer 3

Offsets	Octet	0								1								2								3							
Octet	Bit	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
0	0	Version				IHL				DSCP						ECN		Total Length															
4	32	Identification																Flags			Fragment Offset											
8	64	Time To Live								Protocol								Header Checksum															
12	96	Source IP Address																															
16	128	Destination IP Address																															
20	160	Options (if IHL > 5)																															
⋮	⋮																																
60	480																																

Decoding the Message (chunk the bits into fields)

```
00000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000101
01010101010101010101010101010101010101010101010101010101011001111100000001100011000001000000001011
01100011100011110000000110001100000100000000101101100011100000000000000000xxxxxxxxxxxxxxxxxxxxxxxx
xxxxxxx00000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000
0000
```

- Inter-Packet Gap, Preamble, and Start of Frame:
  - `00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000`
  - `10101010 10101010 10101010 10101010 10101010 10101010 10101010`
  - `10101011`
- Mac Address: 3c:06:30:40:2d:8e
  - `0011 1100 : 0000 0110 : 0011 0000 : 0100 0000 : 0010 1101 : 1000 1110`
  - `0011 1100 : 0000 0110 : 0011 0000 : 0100 0000 : 0010 1101 : 1000 1110`
- Length: `0000 0000 0000 0000`
- Payload:
- CRC: `xxxx xxxx xxxx xxxx xxxx xxxx xxxx xxxx`
- Inter-Packet Gap
  - `00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000`

Types of Encodings

- String of bits:
  - Inter-Packet Gap, Preamble, Start of Frame
- Binary:
  - Flags: Reserved, Don't Fragment, More Fragments
- Integer:
  - Length, Version Number, TTL, etc.
- Index:
  - Protocol Lookup Table

Protocol Number	Protocol Name	Abbreviation
1	Internet Control Message Protocol	ICMP
2	Internet Group Management Protocol	IGMP
6	Transmission Control Protocol	TCP
17	User Datagram Protocol	UDP
41	IPv6 encapsulation	ENCAP
89	Open Shortest Path First	OSPF
132	Stream Control Transmission Protocol	SCTP

- MAC Address: 3c:06:30:40:2d:8e
  - 0011 1100 : 0000 0100 : 0011 000 : 0100 0000 : 0010 1101 : 1000 1110
  - Hexadecimal -> Binary
- IP Address: www.csun.edu
  - Dotted Decimal Notation: 130.166.238.19
  - 1000 0010 . 1010 0110 . 1110 1110 . 0001 0011
  - Decimal -> Binary
- Data: (follows the IPv4 header)
  - text, images, video, audio, colors, etc.

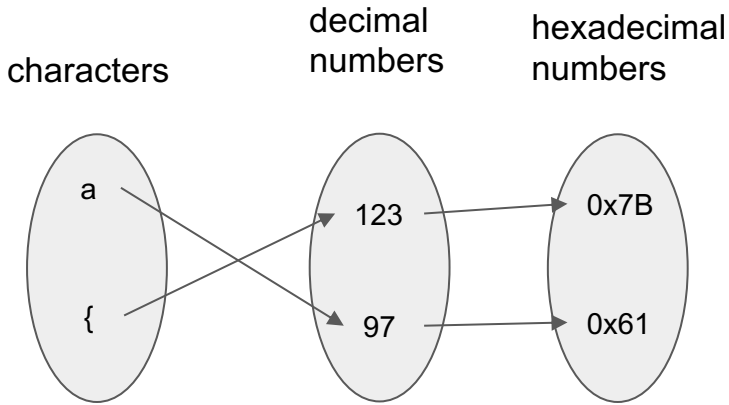
Mappings and Functions

- Mapping: defines a relationship
- Function: a binary relation between two sets
  - Encode: input -> output
  - Decode: output -> input
- A table can represent a function

INPUT	OUTPUT 1	OUTPUT 2
5	8	53
2	5	50
4	7	52
9	?	?
h	?	104 ?

0
1
2
3
4
5
6
7
8
9

a
b
c
d
e
f
g
h
i
j
k
l

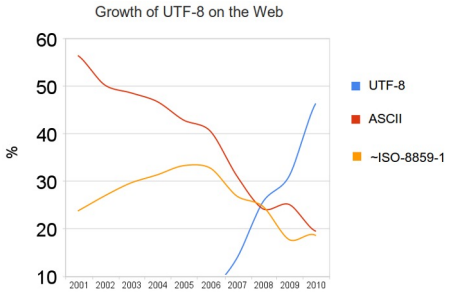


Encoding Examples:

- Fixed Length Lookup Tables: e.g., `0100 0011 0110 0001 0111 0100`
  - Octal (3 bit chunks): `020660564` `010 000 110 110 000 101 110 100`
  - Binary Coded Decimal (4 bit chunks): `436,174` `0100 0011 0110 0001 0111 0100`
  - Hexadecimal (4 bit chunks) : `0x436174` `0100 0011 0110 0001 0111 0100`
  - Base64 (6 bit chunks): `Q2F0` `010000 110110 000101 110100`
  - ASCII (8 bit chunks): `Cat` `01000011 01100001 01110100`
  - MIPS Instruction (32 bit chunks): `add $t0,$t1,$t2` `0000 0001 0100 1011 0100 0000 0010 0000`

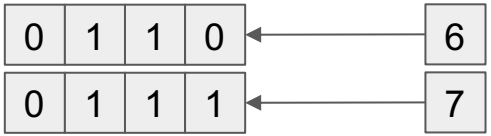
- Various Lengths: (function used to perform the mapping)
  - short int (16 bit chunks): `-32,768 … 32,767`
  - int (32 bit chunks): `-2,147,483,648 … 2,147,483,647`
  - long int (64 bit chunks): `-9,223,372,036,854,775,808 … 9,223,372,036,854,775,807`

- Variable Length:
  - UTF-8
    - Unicode Transformation Format
    - 1 byte to 4 bytes used to encode each character



BCD: Binary Coded Decimal

- Encoding of: 6 & 7

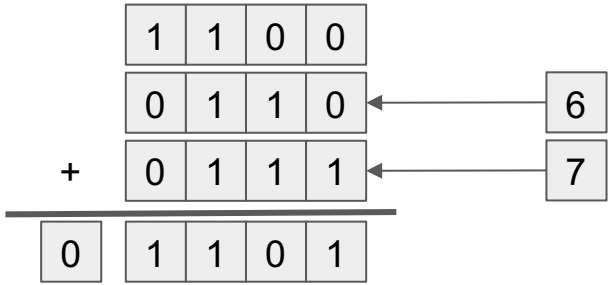


- An encoding for numbers,
  where precision is required
- Four bits are used to encode each digit
- Addition is performed on each 4-bit chunk (nibble)

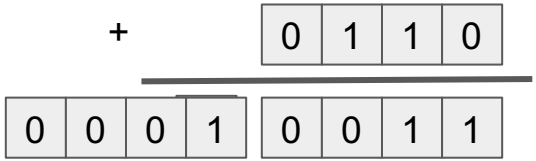
N	Code	N	Code
0	0000	8	1000
1	0001	9	1001
2	0010		1010
3	0011		1011
4	0100		1100
5	0101		1101
6	0110		1110
7	0111		1111

BCD: Addition

- Addition performed on the nibble level: 6+7



if (overflow or invalid code) then



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4	0100		1100
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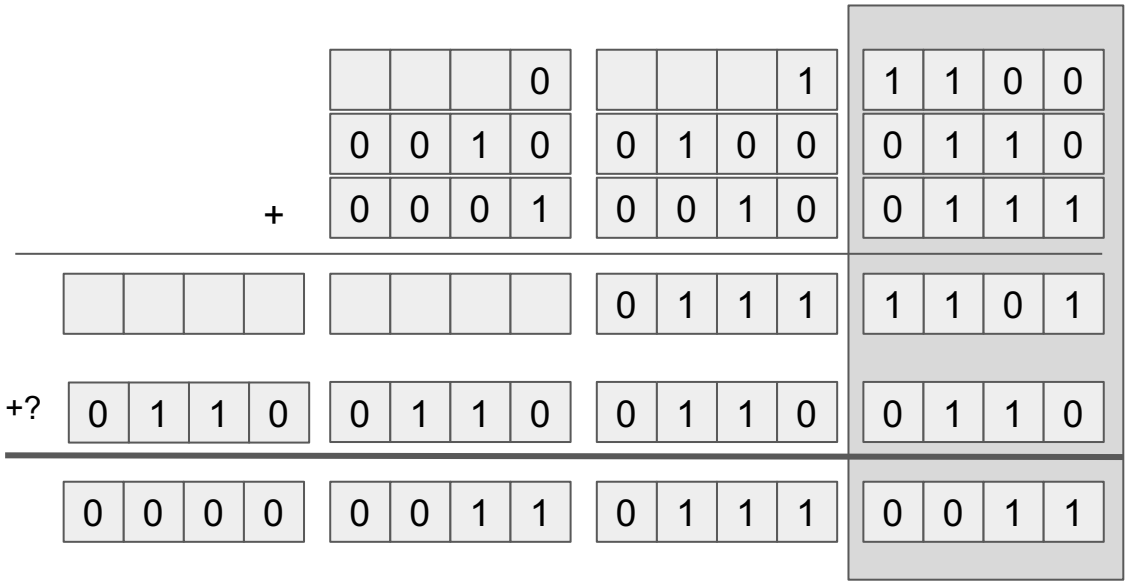
6	0110		1110
7	0111		1111

jump 9

BCD: Addition Example: 246 + 127= 373



N	Code	N	Code
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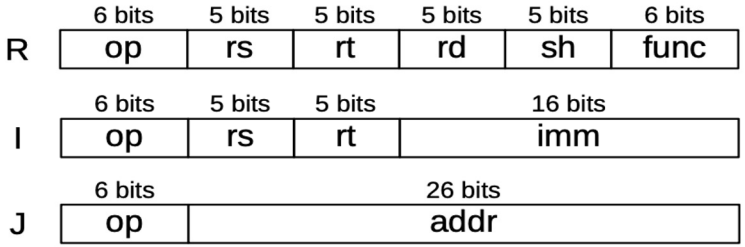
3	0011		1011
4	0100		1100
5	0101		1101
6	0110		1110
7	0111		1111

Instruction Encoding: MIPS

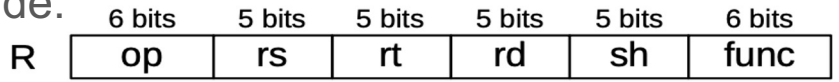
- (6 bits) The **op**eration to be performed (MIPS Encoding)
  - It also indicates the encoding format to be used!
  - There are three primary formats: R, I, and J.



- Other fields determine
  - (5 bits) which registers are used (Register Encoding)
    - **rs**: first source register
    - **rt**: second register
    - **rd**: destination register
  - (5 bits) the amount a value is **sh**ifted (range: 0 .. 31)
  - (6 bits) the mathematical **funct**ion to be performed (MIPS Encoding)
  - (16 bits) the **imm**ediate value (range: -2048 .. 2047)
  - (26 bits) the **addr**ess / 4

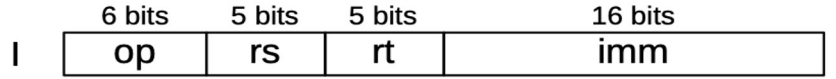
Instruction Encoding: MIPS

- Three primary instruction encodings include:
  - R-type (register)
    - for instructions using only registers
    - example: 0x014b4020
    - for: add $t0, $t1, $t2



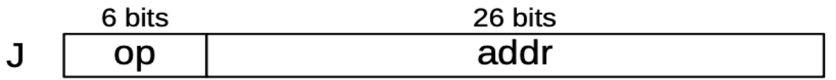
(2# 0000 0001 0100 1011 0100 0000 0010 0000)
($t0 = $t1 + $t2)

  - I-type (immediate)
    - for instructions with immediate values:
    - example: 0x21280005
    - for: addi $t0, $t1, 5



(2# 0010 0001 0010 1000 0000 0000 0000 0101)
($t0 = $t1 + 5)

  - J-type (jump)
    - for instructions that perform unconditional jumps
    - example: 0x08100000
    - for: j main



(2# 0000 1000 0001 0000 0000 0000 0000 0000)
(goto main # main == 0x00400000)

An Encoding for the Keyboard

- Look at your keyboard.
  - a-z, A-Z, 0-9, !@#$%^&*()_+-~`,./<>?;':"[]\{}|
  - don't forget: space, tab, return, and delete key
  - plus we need other stuff:
  - All total, we we have 128 things to encode (2^n <= 128, what is the value of n? 7)
- We need to devise an encoding that maps everything to numbers
- How many bits do we need? How many things do we bits in a byte?
- An example of a fixed-width encoding!
- Let's build a table! Keyboard Table

- ASCII, abbreviated from American Standard Code for Information Interchange, is a character encoding standard for electronic communication.

Parity Bit (or Check Bit)

- We are only using 7 of the 8 bits, what shall we do with it.

7 bits of data	(count of 1-bits)	8 bits including parity	
		even	odd
0000000	0	00000000	00000001
1010001	3	10100011	10100010
1101001	4	11010010	11010011
1111111	7	11111111	11111110

- Algorithm (odd)
  a. count the number of 1's
  b. add a 1 to make odd
  c. transmit
  d. receive
  e. count the number of 1's
  f. if even, ask for the data to be resent

- Checksum:
  * performs integrity checking at an aggregate level
  * reliability of networks have greatly improved since way back when!

A: |||| |||| |||| S: |

Extended ASCII and UTF-8 (unicode)

- We could use that bit to encode more stuff: 0..255
- But we have even more stuff. Let's use 16 bits to encode: 0..64K
- But now we have doubled what we need to send..
- Enter variable-length encoding.
  - Send only a byte for the most common symbols
  - Use the MSB to indicate a variable length encoding
- UTF-8: encodes >2,000,000 (2^21) values, using a maximum of 4 bytes
- Defines four type of bytes:
  - ASCII byte: begins with a 0 (1-byte indicator)
  - Continuation byte: begins with a 10
  - 2-byte Indicator: begins with a 110
  - 3-byte Indicator: begins with a 1110
  - 4-byte Indicator: begins with a 11110

Extended ASCII and UTF-8

- The list of UTF-8 characters:
- Layout of the bits:
- Example on how to lay it out:

Layout of UTF-8 byte sequences

Number of bytes	First code point	Last code point	Byte 1	Byte 2	Byte 3	Byte 4
1	U+0000	U+007F	0xxxxxxx			
2	U+0080	U+07FF	110xxxxx	10xxxxxx		
3	U+0800	U+FFFF	1110xxxx	10xxxxxx	10xxxxxx	
4	U+10000	[nb 3]U+10FFFF	11110xxx	10xxxxxx	10xxxxxx	10xxxxxx