

Bits and Bytes

COMP 102, lecture 2

What are bits and bytes

■ bit (b): 0 or 1

■ byte (B): 8 b ($2^8 = 256$ possibilities)

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00000000 00000001 00000010 00000011
00000100 00000101 00000110 00000111
00001000 00001001 00001010 00001011
...
11111100 11111101 11111110 11111111
```

numerical equivalents: 0,1,2,...,255

Decimal vs Binary

■ Decimal numbers:

$$d_5d_4d_3d_2d_1d_0 =$$

$$d_5 \times 10^5 + d_4 \times 10^4 + d_3 \times 10^3 + d_2 \times 10^2 + d_1 \times 10^1 + d_0 \times 10^0$$

$$154283 = 100\ 000 + 50\ 000 + 4\ 000 + 200 + 80 + 3$$

■ Binary numbers:

$$b_5b_4b_3b_2b_1b_0 =$$

$$b_5 \times 2^5 + b_4 \times 2^4 + b_3 \times 2^3 + b_2 \times 2^2 + b_1 \times 2^1 + b_0 \times 2^0$$

$$\begin{aligned} 101001 &= (1 \times 32) + (0 \times 16) + (1 \times 8) + (0 \times 4) + (0 \times 2) + (1 \times 1) \\ &= 41 \text{ (decimal)} \end{aligned}$$

Decimal vs Binary

- Example:

write the decimal number 154283 in binary

- powers of 2:

1, 2, 4, 8, 16, 32, 64, 128, 256, 512, 1024, 2048,
4096, 8192, 16384, 32768, 65536, 131072, 262144, ...

- $154283 - 131072 = 23211$

$$6827 - 4096 = 2731$$

$$683 - 512 = 171$$

$$11 - 8 = 3$$

$$171 - 128 = 43$$

$$3 - 2 = 1$$

$$23211 - 16384 = 6827$$

$$2731 - 2048 = 683$$

$$43 - 32 = 11$$

$$1 - 1 = 0$$

- $154283_{10} = 10\ 0101\ 1010\ 1010\ 1011_2$

Binary numbers.

■ Integer formats

32 bits, unsigned Integers : 0 .. 4 294 967 295

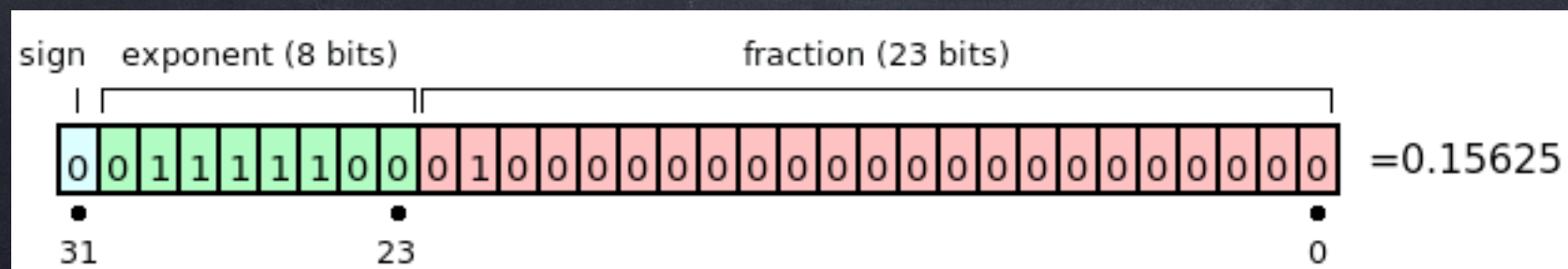
32 bits, signed Integers : -2147 483 648 ..
+2147 483 647

■ Floating Point format

32 bits, signed, Floating Point :

exponent : -126 .. 127

fraction = 0 to $1-2^{-23}$ (1.fraction)



Integer formats

- 32 bits, unsigned Integers : 0 .. 4 294 967 295

00000000 00000000 00000000 00000000 (0)

00000000 00000000 00000000 00000001 (1)

00000000 00000000 00000000 00000010 (2)

...

11111111 11111111 11111111 11111110 (4 294 967 294)

11111111 11111111 11111111 11111111 (4 294 967 295)

Integer formats

- 32 bits, signed, Integers : $-2^{147\,483\,648} \dots +2^{147\,483\,647}$

00000000 00000000 00000000 00000000 (0)

00000000 00000000 00000000 00000001

00000000 00000000 00000000 00000010

...

01111111 11111111 11111111 11111111 (+2^{147 483 647})

10000000 00000000 00000000 00000000 (-2^{147 483 648})

10000000 00000000 00000000 00000001 (-2^{147 483 647})

...

11111111 11111111 11111111 11111110 (-2)

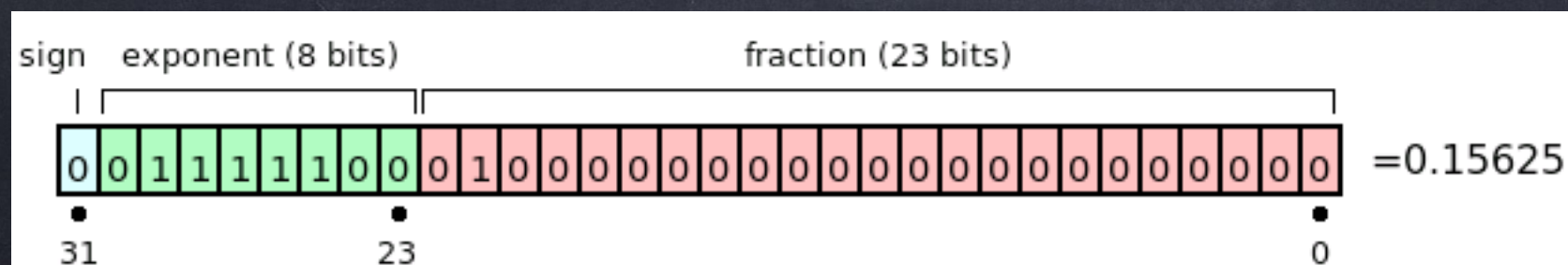
11111111 11111111 11111111 11111111 (-1)

for any $n > 0$, $-n = (n-1) \oplus 11111111 \dots 1111$

Floating Point format

- 32 bits, signed, Floating Point :
exponent : -126 .. 127 (stored as 1 .. 254)
(special exponents / = -127 : number = 0 / = 128 : number = ∞)
fraction = 0 .. $1-2^{-23}$
number = $\pm 1.\text{fraction} \times 2^{\text{exponent}-127}$

0	01111111	00000000000000000000000000000000	= +1.0 x 2 ⁰
1	01111111	00000000000000000000000000000000	= -1.0 x 2 ⁰
0	11111111	00000000000000000000000000000000	= ∞
1	01010101	10000000000000000000000000000000	= -1.5 x 2 ⁻⁴²
0	01111100	01000000000000000000000000000000	= +1.25 x 2 ⁻³ = +0.15625



Computer Jargon

- measuring space in bits (b) or bytes (B)
- measuring transfer rates in bits per second (b/s) or (bps)
- measuring speed in Hertz (Hz)

Metric System

Prefix:	Symbol:	Magnitude:	Meaning (multiply by):
Yotta-	Y	10^{24}	1 000 000 000 000 000 000 000 000 000
Zetta-	Z	10^{21}	1 000 000 000 000 000 000 000 000
Exa-	E	10^{18}	1 000 000 000 000 000 000 000
Peta-	P	10^{15}	1 000 000 000 000 000
Tera-	T	10^{12}	1 000 000 000 000
Giga-	G	10^9	1 000 000 000
Mega-	M	10^6	1 000 000
myria-	my	10^4	10 000 (this is now obsolete)
kilo-	k	10^3	1000
hecto-	h	10^2	100
deka-	da	10	10
-	-	-	-

Metric System

-	-	-	-
deci-	d	10^{-1}	0.1
centi-	c	10^{-2}	0.01
milli-	m	10^{-3}	0.001
micro-	u (mu)	10^{-6}	0.000 001
nano-	n	10^{-9}	0.000 000 001
pico-	p	10^{-12}	0.000 000 000 001
femto-	f	10^{-15}	0.000 000 000 000 001
atto-	a	10^{-18}	0.000 000 000 000 000 001
zepto-	z	10^{-21}	0.000 000 000 000 000 000 001
yocto-	y	10^{-24}	0.000 000 000 000 000 000 000 001

“Binary” metric system

■ $2^{10} = 1024 \approx 1000 = 10^3$

■ $1 \text{ kB} = 1024 \text{ B}$

■ $1 \text{ MB} = 1024 \text{ kB} = 1\,048\,576 \text{ B}$

■ $1 \text{ GB} = 1024 \text{ MB} = 1\,073\,741\,824 \text{ B}$

■ $1 \text{ TB} = 1024 \text{ GB} = 1\,099\,511\,627\,776 \text{ B}$

STORAGE DEVICES



Current devices



■ CD 700 MB

Current devices



■ DVD

■ single layer 4,7 GB and double layer 8,3 GB

Current devices



- Blu-ray
- single layer 25 GB and double layer 50 GB

Current devices



- Flash memory: 32 GB cheap, 128 GB expensive

Current devices



- RAM (computer): 8 GB cheap, 16 GB expensive

Current devices



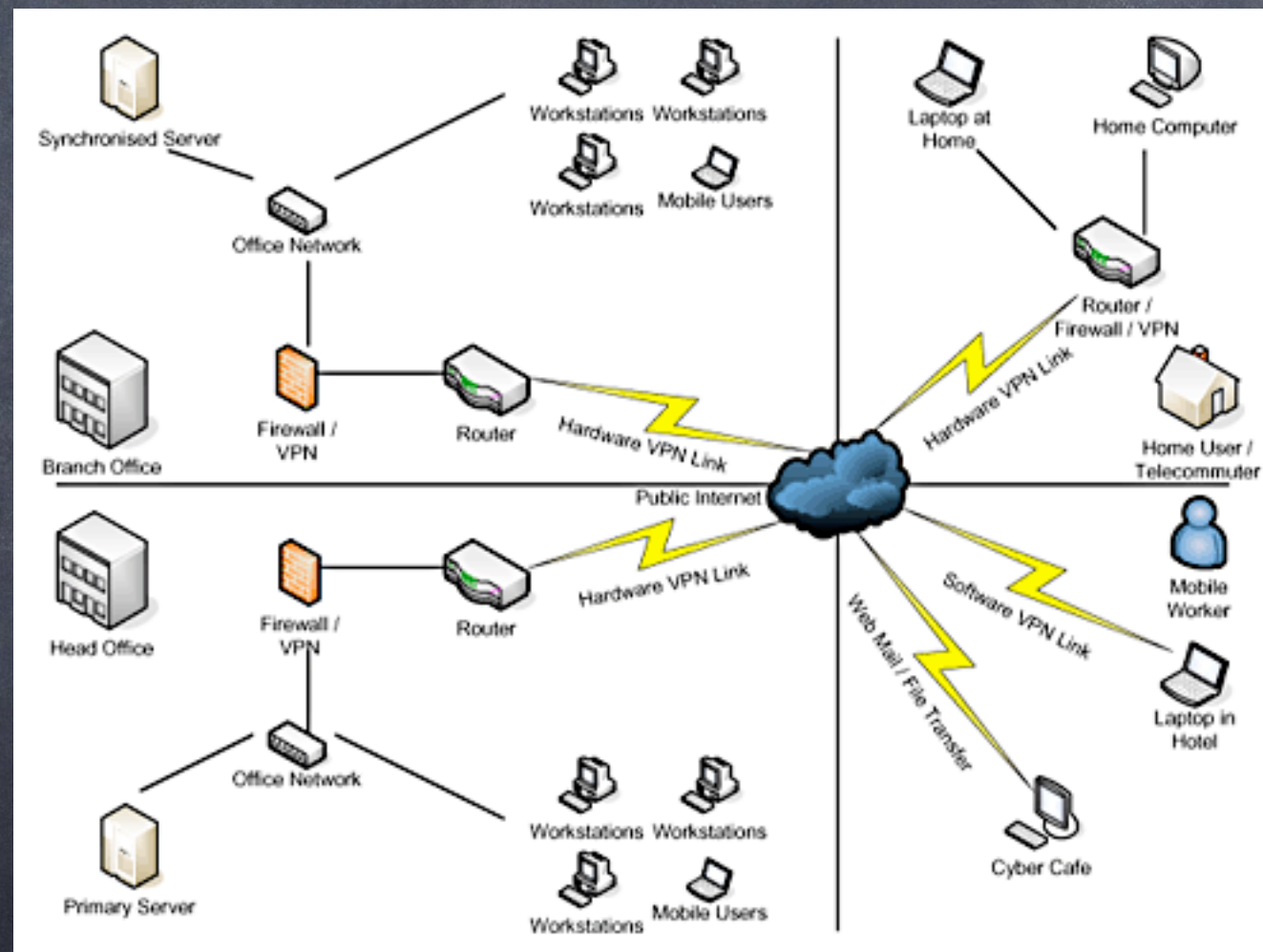
- Hard Disk: 2 TB cheap, 4 TB expensive

Current devices



- Solid State Drive: 256 MB cheap, 1 TB expensive

Connection types



Current connectivity

■ telephone Modem (V.92)

- download speeds up to 56 kbit/s
≈ DVD / 12 days
upload speeds up to 48 kbit/s



■ fax (V.34)

ITU Standard	Released Date	Data Rates (bit/s)	Modulation Method
V.27	1988	4800, 2400	PSK
V.29	1988	9600, 7200, 4800	QAM
V.17	1991	14400, 12000, 9600, 7200	TCM
V.34	1994	28800	QAM
V.34bis	1998	33600	QAM

Current connectivity

- telephone Modem (V.92)

- download (to here) speeds up to 56 kbit/s
 - = download speeds up to 201600 kbit/hour (3600s/hour)
 - ≈ download speeds up to 4,838 Gbit/day (24hour/day)
 - ≈ download speeds up to 605 MB/day (8 b/B)
 - ≈ DVD / 12 days

Current connectivity

- Internet connections (cable or fibre-optics)
- videotron 200 Mbps
≈ DVD / 3 min
- Bell/Fibe 175 Mbps
≈ DVD / 4 min



Current connectivity



- Internet connections (wireless)

Current connectivity



802.11 network standards											[hide]
802.11 protocol	Release ^[6]	Freq. (GHz)	Bandwidth (MHz)	Data rate per stream (Mbit/s) ^[7]	Allowable MIMO streams	Modulation	Approximate indoor range ^[citation needed]		Approximate outdoor range ^[citation needed]		
							(m)	(ft)	(m)	(ft)	
—	Jun 1997	2.4	20	1, 2	1	DSSS, FHSS	20	66	100	330	
a	Sep 1999	5	20	6, 9, 12, 18, 24, 36, 48, 54	1	OFDM	35	115	120	390	
		3.7 ^[A]					—	—	5,000	16,000 ^[A]	
b	Sep 1999	2.4	20	1, 2, 5.5, 11	1	DSSS	35	115	140	460	
g	Jun 2003	2.4	20	6, 9, 12, 18, 24, 36, 48, 54	1	OFDM, DSSS	38	125	140	460	
n	Oct 2009	2.4/5	20	7.2, 14.4, 21.7, 28.9, 43.3, 57.8, 65, 72.2 ^[B]	4	OFDM	70	230	250	820 ^[8]	
			40	15, 30, 45, 60, 90, 120, 135, 150 ^[B]			70	230	250	820 ^[8]	
ac (DRAFT)	Dec 2012	5	20	up to 87.6 ^[9]	8						
			40	up to 200 ^[9]							
			80	up to 433.3 ^[9]							
			160	up to 866.7 ^[9]							
ad	~Feb 2014	2.4/5/60		up to 7000 ^[citation needed]							