Web Sockets

WebSockets

Last time we saw how to establish a WebSocket connection

Today, we'll parse and send messages over the socket

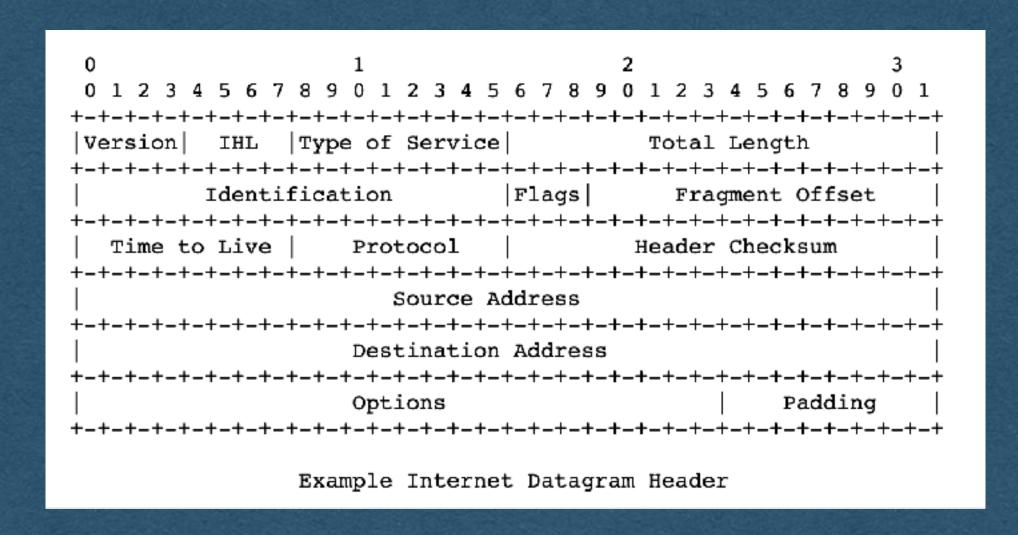
```
R|R|R| opcode M| Payload len | Extended payload length
I|S|S|S|
                 (7)
                                           (16/64)
                                 (if payload len=126/127)
N|V|V|V
    Extended payload length continued, if payload len == 127
                              Masking-key, if MASK set to 1
Masking-key (continued)
                                 Payload Data
                   Payload Data continued ...
                    Payload Data continued ...
```

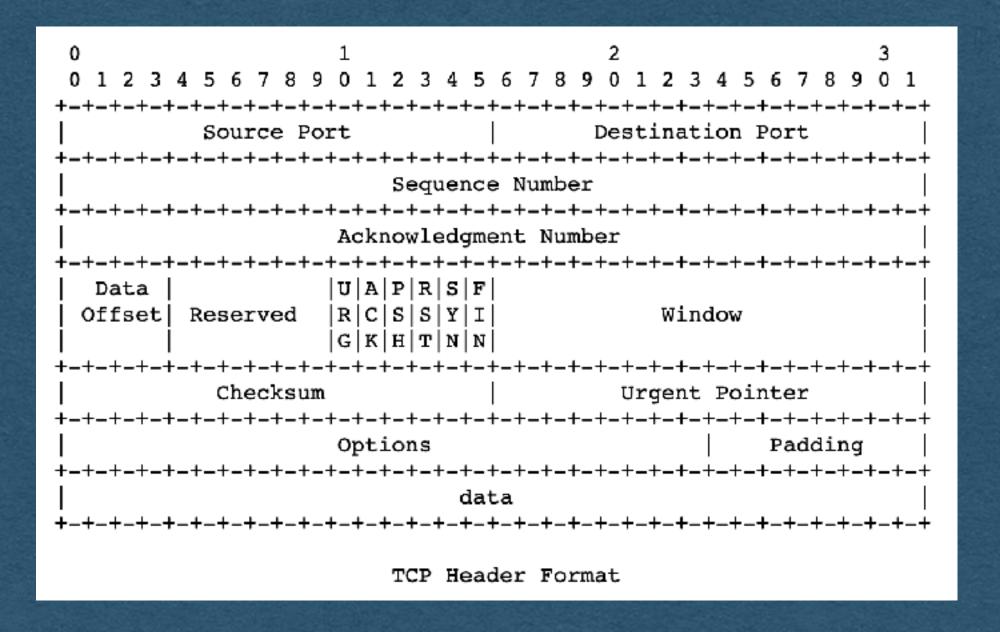
Protocols Sidenote

- Many of the protocols used in the Internet define the order and meaning of bits that are sent
 - Sender assembles the bits of a message following the protocol
 - Send the bits through the Internet
 - Receiver interprets the bits following the same protocol to extract meaning from the bits
- Protocols enable communication using only 1's and 0's

Protocols Sidenote

- TCP/IP protocol headers shown hear
- Routers read the IP header following this protocol to know how to route a packet
- Endpoints follow the TCP protocol to assemble a sequence of packets and send it to the process using the given port





- The WebSocket protocol functions the same way
- Client and server agree to follow this protocol
- Send bits in this specific order
 - We can rely on the client following this protocol

+-+-+-+-+	2 3 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 +	
+	++ Masking-key, if MASK set to 1	
Masking-key (continued)	Payload Data	
Payload Data continued		
Payload Data continued		

Network Stack

 An IP packet containing a WebSocket frame looks like this

0		1	2 3
			6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
			+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-
Version		-	Total Length
			Flags Fragment Offset
+-+-+-+			+-+-+-+-+-+-+-+-+-+-+-+-+-
		Protocol	
			+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-
	++_+	Source A	ddress +-+-+-+-+-+-+-
		Destination	Address
	-+-+-+-	Options	+-+-+-+-+-+-+-+-+-+-+-+-+-+
+-+-+-+	-+-+-+-+-		+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-
 +-+-+-	Source		Destination Port
		Sequen	ce Number
+-+-+-+	-+-+-+-		-+-+-+-+-+-+-+-+-+-+-+-+-+-+- nent Number
+-+-+-+	-+-+-+-	+-+-+-+-+-+	·+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-
Data		U A P R S	!
Offset	Reserved		· ·
! !		G K H T N 1	•
+-+-+-+	-+-+-+ Checks:		-+-+-+-+-+-+-+-+-+-+-+-+-+-+-
 			Urgent Pointer -+-+-+-+-+-+-+-+-+-+-+-+-+-
1		Options	Padding
, +-+-+-+	-+-+-+-		·+-+-+-+-+-+-+-+-+-+-+-+-+-+-
1		d	ata
+-+-+-+-+	-+-+-+-	+-+-+-+-+-+	+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-
F R R R I S S S	opcode M	Payload len	Extended payload length (16/64)
N V V V	(4) R	(<i>'</i>	(if payload len==126/127)
1 2 3	K	İ	(pu
+-+-+-+	1	+	.+
Ext	Extended payload length continued, if payload len == 127		
<u> </u>			Masking-key, if MASK set to 1
Masking	-key (con	tinued)	Payload Data
+		Payload Da	ta continued
+		Payload Da	ta continued
+			

IP

TCP

WebSocket

Parsing Bits

- We will have to read frames at the bit level
 - It's already in a byte array when we receive it
 - We can access any byte and extract the bits we need
 - Helpful to recall that bytes are represented as 8-bit integer values in most languages (0-255)

0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 +-+-+-+	2 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1	
F R R R opcode M Payload len I S S S (4) A (7) N V V V S 1 2 3 K +-+-+-+	Extended payload length (16/64) (if payload len==126/127) ++ ontinued, if payload len == 127	
+	++ Masking-key, if MASK set to 1	
Masking-key (continued)	Payload Data	
Payload Data continued		
Payload Dayload Dayload Dayload Dayload Dayload	ta continued	

Parsing Bits

- Bit Example To read the opcode:
 - get the byte at index 0
 - Bitwise AND (& in most languages) this byte with a "bit mask" of 15
 - Since 15 == 00001111 as a byte this will 0 out the 4 higher order bits
 - We now have an int from 0-15 representing the opcode

0 1 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5	2 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1	
F R R R opcode M Payload len I S S S (4) A (7) N V V V S 1 2 3 K +-+-+-+	Extended payload length (16/64) (if payload len==126/127)	
Extended payload length cos	ntinued, if payload len == 127 ++ Masking-key, if MASK set to 1	
Masking-key (continued)	Payload Data	
Payload Data continued		
Payload Data continued		

- FIN: The finish bit
 - 1 This is the last frame for this message
 - 0 There will be continuation frames containing more data for the same message
- [You can assume this is always 1 for the HW]

0 0 1 2 3 4 5 6 7 +-+-+-+		2 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
F R R R opcode I S S S (4) N V V V 1 2 3	M Payload len A (7) S K	Extended payload length (16/64) (if payload len==126/127)
+	·	Masking-key, if MASK set to 1
Masking-key (co	ntinued)	Payload Data
Payload Data continued		
	Payload Dat	a continued

- RSV: Reserved bits
 - Used to specify any extensions being used
- [You can assume these are always 000 for the HW]

0 0 1 2 3 4 5 6 7 8 9 +-+-+-+	1 0 1 2 3 4 5	2 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1	+
F R R R opcode M F I S S S (4) A N V V V S 1 2 3 K +-+-+-+	Payload len (7)	Extended payload length (16/64) (if payload len==126/127)	
Extended payloa	ad length cor	ntinued, if payload len == 127	
		Masking-key, if MASK set to 1	
Masking-key (contin	nued)	Payload Data	
Payload Data continued			
	Payload Dat	a continued	+ +

- opcode: Operation code
 - Specifies the type of information contained in the payload
 - Ex: 0001 for text, 0010 for binary, 1000 to close the connection

0 1 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 +-+-+-+	2 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1	
F R R R opcode M Payload len I S S S (4) A (7) N V V V S 1 2 3 K +-+-+-+	Extended payload length (16/64) (if payload len==126/127) ++ ntinued, if payload len == 127	
+	++ Masking-key, if MASK set to 1	
Masking-key (continued)	Payload Data	
Payload Data continued		
Payload Da	ta continued	

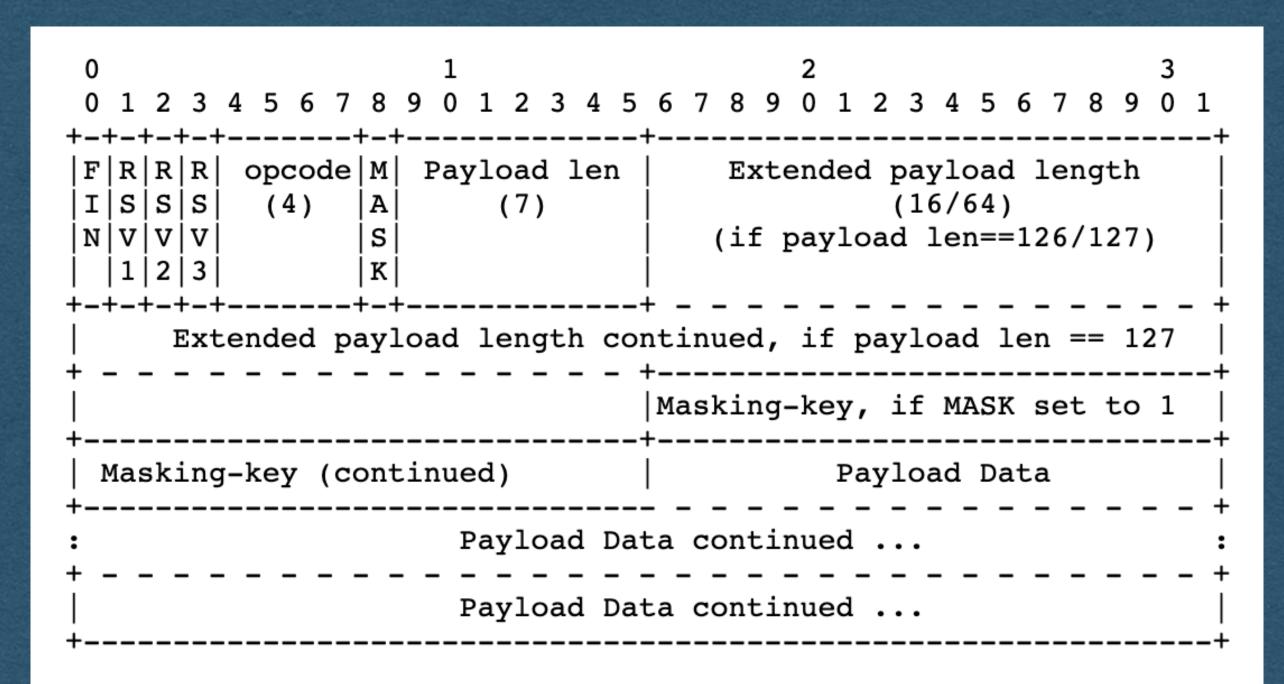
- MASK: Mask bit
 - Set to 1 if a mask is being used
 - Set to 0 if no mask is being used
- This will be 1 when receiving messages from a client

0 0 1 2 3 4 5 6 7 8 9 +-+-+-+-	1 0 1 2 3 4 5	2 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
F R R R opcode M I S S S (4) A N V V V S 1 2 3 K +-+-+-+-++-+-	(7)	Extended payload length (16/64) (if payload len==126/127) + htinued, if payload len == 127
 		Masking-key, if MASK set to 1
Masking-key (conti	nued)	Payload Data
Payload Data continued		
Payload Data continued		

- The next bits will represent payload length in bytes
 - Similar to Content-Length
- The length can be represented in 7, 16, or 64 bits

0 0 1 2 3 4 5 6 7 8 9 +-+-+-+	1 0 1 2 3 4 5	2 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1	+
F R R R opcode M F I S S S (4) A N V V V S 1 2 3 K +-+-+-+	Payload len (7)	Extended payload length (16/64) (if payload len==126/127)	
Extended payloa	ad length cor	ntinued, if payload len == 127	
		Masking-key, if MASK set to 1	
Masking-key (contin	nued)	Payload Data	
Payload Data continued			
	Payload Dat	a continued	+ +

- If the length is <126 bytes
 - The length is represented in 7 bits, sharing a byte with the MASK bit
 - The next bit after the length is either the mask or payload



- If the length is >=126 and <65536 bytes
 - The 7 bit length will be exactly 126 (1111110)
 - The next 16 bits represents the payload length

0 1 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 +-+-+-+-+	2 3 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 ++ Extended payload length	
I K K Opcode H I dy I odd Iell I S S S (4)	(16/64) (if payload len==126/127) + +	
Extended payload length co	ntinued, if payload len == 127 ++	
 +	Masking-key, if MASK set to 1	
Masking-key (continued)	Payload Data	
Payload Data continued		
Payload Da	ta continued	

- If the length is >=65536 bytes
 - The 7 bit length will be exactly 127 (1111111)
 - The next 64 bits represents the payload length
 - 18,446,744,073,709,551,615 max length
 - 16 exabytes / 16,000,000 terabytes

0 1 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 +-+-+-+	2 3 4 5 6 7 8 9 0 1	
F R R R opcode M Payload le I S S S (4) A (7) N V V V S 1 2 3 K +-+-+-+	en Extended payload length (16/64) (if payload len==126/127)	
+	Masking-key, if MASK set to 1	
Masking-key (continued)	Payload Data	
Payload Data continued		
Payload Data continued		

- To read the frame length, read the 7 bit length
 - If the value is 126, read the next 16 bits as the length
 - If the value is 127, read the next 64 bits as the length
 - Else, the value itself is the length

0 1 2 3 4 5 6 7 8 9 0 1 2 +-+-+-+	2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1	
F R R R opcode M Payload I S S S (4) A (7) N V V V S 1 2 3 K +-+-+-+	len Extended payload length (16/64) (if payload len==126/127)	
+	Masking-key, if MASK set to 1	
Masking-key (continued)	Payload Data	
Payload Data continued		
Payload Data continued		

- After all the length bits:
 - If the MASK bit == 1, the next 4 bytes (32 bits) is the mask
 - If the MASK bit == 0, the payload begins

0 1 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 +-+-+-+	2 6789012345678901 +	
F R R R opcode M Payload len I S S S (4) A (7) N V V V S 1 2 3 K +-+-+-+	Extended payload length (16/64) (if payload len==126/127) ++ ntinued, if payload len == 127	
+	++ Masking-key, if MASK set to 1	
Masking-key (continued)	Payload Data	
Payload Data continued :		
Payload Data continued		

- If there is a mask, read these 4 bytes
- The mask will be randomly generated by the client for each message
 - You must parse this each time a message is received

0 0 1 2 3 4 5 6 7 8 9 +-+-+-+-+-	1 0 1 2 3 4 5	2 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0	1_+
F R R R opcode M I S S S (4) A N V V V S 1 2 3 K +-+-+-+-+	- (7)	Extended payload length (16/64) (if payload len==126/127) + ntinued, if payload len == 127	 -
+ +		Masking-key, if MASK set to 1	_+
Masking-key (conti	nued)	Payload Data	_+
Payload Data continued :		:	
Payload Data continued			

- Each 4 bytes of the payload has been XORed with the mask by the client
- Read the payload 4 bytes at a time and XOR the bytes with the mask
- If the length is not a multiple of 4, use only the bytes of the mask that are needed
 - le. Always reading 4 bytes will cause an index out of bounds error

0 0 1 2 3 4 5 6 7 +-+-+-+-+		2 3 4 5 6 7 8 9 0 1
F R R R opcode I S S S (4) N V V V	M Payload len A (7) S K	Extended payload length (16/64) (if payload len==126/127)
Extended pa	Extended payload length continued, if payload len == 127	
		Masking-key, if MASK set to 1
Masking-key (co	ntinued)	Payload Data
Payload Data continued		
Payload Data continued		

XOR Example

- If 4 bytes of the message are:
 - 01001001_01000011_01010101_00100001
- And the random mask is:
 - 01111011_00100010_01110101_01110011
- This part of the payload will be "message XOR mask":
 - 00110010_01100001_00100000_01010010
- When we receive these bits and XOR it with the mask again we get the original message bits:
 - 01001001_01000011_01010101_00100001

- Once the payload is XORed with the mask 4 bytes at time we get the entire message
- Then process the message

0 1 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 +-+-+-+	2 6789012345678901
F R R R opcode M Payload len I S S S (4) A (7) N V V V S 1 2 3 K	Extended payload length (16/64) (if payload len==126/127)
Extended payload length continued, if payload len == 127	
	Masking-key, if MASK set to 1
Masking-key (continued)	Payload Data
Payload Data continued	
Payload Data continued	

- To send a message to a client:
 - Use this same protocol
 - Assemble a byte array with the appropriate values
 - Append your payload as bytes

- Do not use a mask when sending frames to a client
 - No caching concerns on server to client frames

0 1 2 3 4 5 6 7 8 9 0 1 2 +-+-+-+	2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
F R R R opcode M Payloa I S S S (4) A (7 N V V V S 1 2 3 K	
Extended payload length continued, if payload len == 127	
	Masking-key, if MASK set to 1
Masking-key (continued)	Payload Data
Payload Data continued	
Payload Data continued	
T	

- Example: For our purposes in the HW
 - FIN is always 1
 - RSVs are always 0
 - opcode is either 0001 (Sending text) or 1000 (close connection)
- Therefore, the first byte is either 10000001 == 129 or 10001000 == 136

- Check the length of your payload to determine how many bits are needed for the length
- Follow the same format for payload length as the received messages

0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 +-+-+-+	2 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
F R R R opcode M Payload len I S S S (4) A (7) N V V V S 1 2 3 K +-+-+-+	Extended payload length (16/64) (if payload len==126/127) ++ ontinued, if payload len == 127
+	++ Masking-key, if MASK set to 1
Masking-key (continued)	Payload Data
Payload Data continued :	
Payload Data continued	

- MASK bit is 0 and there are not mask bytes
 - After payload length, immediately add the bytes of the payload

0 1 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 +-+-+-+	2 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
F R R R opcode M Payload len I S S S (4) A (7) N V V V S 1 2 3 K +-+-+-+	Extended payload length (16/64) (if payload len==126/127) ++ ntinued, if payload len == 127
+	++ Masking-key, if MASK set to 1
Masking-key (continued)	Payload Data
Payload Data continued	
Payload Data continued	