I. IP Fragmentation (pg 45-52) Week 9

- recall IP is responsible for 1) network addressing and 2) fragmentation
- the 2nd "word" of the IP header is the fragmentation related data, composed of the **ID** (16 bits), the **fragment flags** (3 bits), and the **fragment offset** (13 bits) (see IP PDU)
- physical layer typically imposes an upper limit on the size of a frame, e.g. MTU (max Ethernet frame data size?)
- IP compares the datagram size (as stored in the ? field) with the MTU

  if TL > MTU then
  fragmentation should occur

- fragmentation may occur on original host, or on intermediate nodes (e.g. routers) along the way
- datagrams & fragments can be fragmented more than once
- once fragmentation occurs, reassembly does not take place until the final destination
- each datagram fragment becomes an individual packet, so gets its own:
  - header (+ 20 octets per fragment)
  - data
  - route to destination and arrival order
- only data gets fragmented, never the header
- if one fragment is lost, the entire datagram is useless and must be retransmitted
- IP datagram – IP header and all data (i.e. all fragments)
- IP packet – IP header along with some data
- on Windows from cmd prompt: **netsh interface ipv4 show interfaces**

How does fragmentation work: (see IP RFC link on syllabus)

1. IP layer queries the MTU of physical layer

   ```
   if TL <= MTU then
           transmit datagram
   elseif DF flag = 1 then
           drop datagram
   else
           fragment datagram
   ```

2. number of fragments NF = (TL – IHL) / (MTU – IHL) (taking the ceiling of this)

   note: IHL is 5 “words” * 4 octets/word = 20 octets

3. # fragment blocks (8 octets per block) NFB = INT ((MTU – IHL octets) / 8)

4. copy original header to the first (eventually all) fragment headers, including the same ID, protocol, destination and source addresses

5. fill in data and update header fields:

   - append NFB * 8 data octets, unless last fragment
   - TL = NFB * 8 + IHL octets, unless last fragment
   - Fragment Offset (FO) = (fragment # -1) * NFB
   - set may frag flag = 0
   - set more frag flag = 1, unless last fragment, then set = 0
   - decrement TTL if at router
   - recalculate checksum

6. transmit fragment

7. goto # 4 for next fragment

Fragmentation Example (see pg 49)

- beginning total length: 4464 octets, fragment?
- MTU: 1500

original datagram:

Frag #	Frag ID	DF	MF	Frag Offset	IHL	TL	data len
-	321	0	0	0	20	4464	4444

fragmented datagram (packets):

NF = (TL – IHL) / (MTU – IHL) = 4444/1480 = 3.0027, take next largest INT value, so 4 fragments

NFB = ((MTU – IHL) / 8 octets/block) = (1500 – 20) / 8 = 185

Frag #	Frag ID	DF	MF	Frag Offset	IHL	TL	data len
1	321	0	1	0	20	1500	1480
2	321	0	1	185	20	1500	1480
3	321	0	1	370	20	1500	1480
4	321	0	0	555	20	24	4
						4524	**4444**

Note that the sum of the data lengths = sum of original data length, but the sum of the total lengths is original TL + ((NF -1) * 20) for extra headers