Note: the exercise 7 is shown in the last pages due to the implementation of this one in CMD, meanwhile the rest of the document was handmade.

1. a) Take in Count that, for a backoff race:

- The 2nd backoff race, A picks the $k_A(2)$ for being 0 or 1.
  $\hookrightarrow$ applies equal probability (1/2 on each)
- B picks $k_B(2)$ of the values from 0 to 3 (1/2 of probability on each).

$\Rightarrow$ if $k_A(2) < k_B(2)$, we could think that A wins the second backoff race.

$P[A \text{ wins}] = P[k_A(2) < k_B(2)]$

$\rightarrow P[k_A(2)=0] \times P[k_B(2)>0] + P[k_A(2)=1] \times P[k_B(2)>1]$

$\Rightarrow \frac{1}{2} \times \frac{3}{4} + \frac{1}{2} \times \frac{2}{4} = \frac{3}{8} + \frac{2}{8} = \frac{5}{8}$ //

b) This case repeats the condition for A, but B picks from 0 to 7 (1/8 for each probability). Applying similar steps we have:

$P[A \text{ wins}] = P[k_A(3) < k_B(3)]$

$\rightarrow P[k_A(3)=0] \times P[k_B(3)>0] + P[k_A(3)=1] \times P[k_B(3)>1]$

$\rightarrow \frac{1}{2} \times \frac{7}{8} + \frac{1}{2} \times \frac{6}{8} = \frac{7}{16} + \frac{6}{16} = \frac{13}{16}$ //

c) With B that will retry 16 times, after which it can give up. Moreover, when choosing k between 0 and $2^n - 1$ (in the exponential backoff), n is capped at 10.

Considering 13 backoff races (the remaining ones), for A to win all of them:

$$P[A \text{ wins remaining races}] = \prod_{i=4}^{16} P[A \text{ wins } i \mid A \text{ wins } i-1]$$

$\rightarrow k_A(i)$ is the k value that A picks for i^{th} backoff race.

$\rightarrow$ A wins that race, so $k_A(i) < k_B(i)$

$\rightarrow$ Probability for A to win the $(i+1)^{th}$ backoff race is 1, if $k_A(i) + 1 < k_B(i)$ is true.

$\rightarrow$ If $k_A(i) + 1 \geq k_B(i)$, A and B will collide if A is done with the i^{th} frame, and $P[k_A(i+1) < k_B(i+1)]$

$$P[A \text{ wins } i+1][A \text{ wins } i] = P[k_A(i)+1 < k_B(i)]\cdot 1$$
$$+ P[k_A(i)+1 \geq k_B(i)] \cdot P[k_A(i+1) < k_B(i+1)]$$
$$\geq P[k_A(i)+1 < k_B(i)] \cdot P[k_A(i+1) < k_B(i+1)]$$
$$+ P[k_A(i)+1 \geq k_B(i)] \cdot P[k_A(i+1) < k_B(i+1)]$$

$$\Rightarrow (P[k_A(i)+1 < k_B(i)] + P[k_A(i)+1 \geq k_B(i)]) \times P[k_A(i+1) < k_B(i+1)]$$

$$= P[k_A(i+1) < k_B(i+1)]$$

→ Consider then:

- A won a previous backoff, so $k_A(i)$ is either 0 or 1, with equal probability (1/2 on each one).
- $k_B(i)$ is in the range $0 \ldots 2^i - 1$, with 2^{-i} of probability each one

→ With $i \geq 10$, the range is $0 \ldots 1023$, each with probability of $1/1024$

→ In that case, for $1 \leq i \leq 9$,

$$P[k_A(i) < k_B(i)] = P[k_A(i) = 0] \times P[k_B(i) > 0] + P[k_A(i) = 1] \times P[k_B(i) > 1]$$

$$\Rightarrow \frac{1}{2} \times \frac{2^i - 1}{2^i} + \frac{1}{2} \times \frac{2^i - 2}{2^i} = \frac{2^i - 1}{2^{i+1}} + \frac{2^i - 2}{2^{i+1}}$$

$$\Rightarrow \frac{2^{i+1} - 3}{2^{i+1}}$$

→ If we consider $10 \geq i \geq 16$,

$$P[k_A(i) < k_B(i)] = P[k_A(i) = 0] \times P[k_B(i) > 0] + P[k_A(i) = 1] \times P[k_B(i) > 1]$$

$$\Rightarrow \frac{1}{2} \times \frac{2^{10} - 1}{2^{10}} + \frac{1}{2} \times \frac{2^{10} - 2}{2^{10}} = \frac{2045}{2048}$$

Then, $P[A \text{ wins } i \mid A \text{ wins } i-1]$ will be:

$$\Rightarrow \prod_{i=4}^{16} P[A \text{ wins } i \mid A \text{ wins } i-1] > \prod_{i=4}^{16} P[k_A(i) < k_B(i)]$$

$$= \prod_{i=4}^{9} P[k_A(i) < Pk_B(i)] \cdot \prod_{i=10}^{16} P[k_A(I) < k_B(i)]$$

$$= \prod_{i=4}^{9} \left(\frac{2^{i+1} - 3}{2^{i+1}}\right) \cdot \prod_{i=10}^{16} \left(\frac{2045}{2048}\right) \Rightarrow 0.82 \text{ //}$$

d) Based on the events

→ B_1 will be dropped

→ B will try the next frame, which is B_2

2. a) Consider address two different from the first, the third from 1st and 2nd, and the rest in the same way. The probability that none of the address choices from the second to the 1000 and 24 collides with earlier choice will be.

$$(1-1/2^{48})(1-2/2^{48})\ldots(1-1023/2^{48}) \rightarrow 1-(1+2+\ldots+1023)/2^{48}$$

$\Rightarrow 1-1{,}047{,}552/(2\times 2^{48}) \rightarrow 1{,}86\cdot 10^{-9}$, with denominator of 2^{46} rather than 2^{48}, since two bits in an Ethernet address are fixed

b) It could be the probability of the previous results on $2^{20} \approx 1$ million, those 1 million tries are the result $1{,}77\cdot 10^{-3}$

c) Based on the method applied on (a), it yields $(2^{30})^2/(2\times 2^{48}) = 2^{11}$

→ Cleared beyond the valid range of the approximation with the presented value

→ Maybe, we can say that a collision is essentially certain.

3. Consider the next points:

- A base station, considering its topology, needs an infrastructure, which implies base stations located in the place (the main one).
- New installations could be difficult and time-consuming, and existing base stations may be wiped out by a disaster, including their hardline connections.

→ For a mesh topology, each additional node would piggyback on the existing ones.

4. a) Considering a packet transmitted twice, with all fragments recieved that must have been part of the same transmission.

→ We need the probability of losing a packet on each transmission separately.

→ Then, the probability of losing the packet (the whole packet) in one transmission is 10%.

→ With independent transmissions, being two in this case, the probability then would be

$$\Rightarrow 0.1 \cdot 0.1 = 0.01 \rightarrow 1\% //$$

b) For any fragment of either transmission:

→ Consider having 20 fragments in total (10 for each transmission), needing to recieve at least one copy of each fragment.

→ The probability of losing a specific fragment in two transmissions is 1%

→ With fragments being 10 on a single transmission, the probability for two can be.

$$\rightarrow 1-(1-0.01)^{10} = 0.095$$

$$\Rightarrow 9.5\%$$

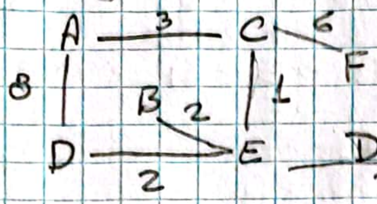
However, the probability of loss now is for some pair of identical fragments, with both lost. For any particular fragment the probability of losing both instances is $0.01 \cdot 0.01 = 0.0001$.

For that to happen at least once for the 10 different fragments would be 10 times, so it would be 0.001. //

c) An implementation could use the same value for Ident when a packet needs to be retransmitted. With a retransmission timeout being less than the reassembly timeout, this might define to case (b) as the one which applied and that a received packet might contain fragments from each transmission.

5. For the figure, it is neccesary to pick the lowest path for each destination, considering each node.

In that way, the paths woll be the next ones, applying also the table.



Node A:

Path

Dest.	Path
B	A→C→E→B
C	A→C
D	A→C→E→D
E	A→C→E
F	A→C→F

Table

Destination	Next hop
B	C
C	C
D	C
E	C
F	C

Node B:

Path

Dest.	Path
A	B→E→C→A
C	B→E→C
D	B→E→D
E	B→E
F	B→E→C→F

Table

Dest.	Next hop
A	E
C	E
D	E
E	E
F	E

Node C:

Path

Dest.	Path
A	C→A
B	C→E→B
D	C→E→D
E	C→E
F	C→F

Table

Dest.	Next hop
A	A
B	E
D	E
E	E
F	F

Node D:

Path

Dest.	Path
A	D→E→C→A
B	D→E→B
C	D→E→C
E	D→E
F	D→E→C→F

Table

Dest.	Nexthop
A	E
B	E
C	E
E	E
F	E

Node E:

Path

Dest.	Path
A	E→C→A
B	E→B
C	E→C
D	E→D
F	E→C→F

Table

Dest.	Nexthop
A	C
B	B
C	C
D	D
F	C

Node F:

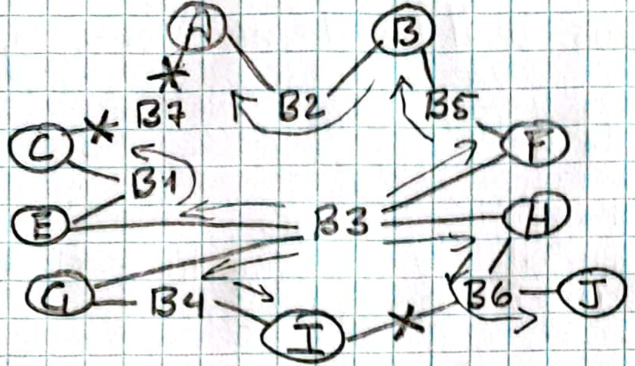
Path

Dest.	Path
A	F→C→A
B	F→C→E→B
C	F→C
D	F→C→E→D
E	F→C→E

Table

Destination	Next hop
A	C
B	C
C	C
D	C
E	C

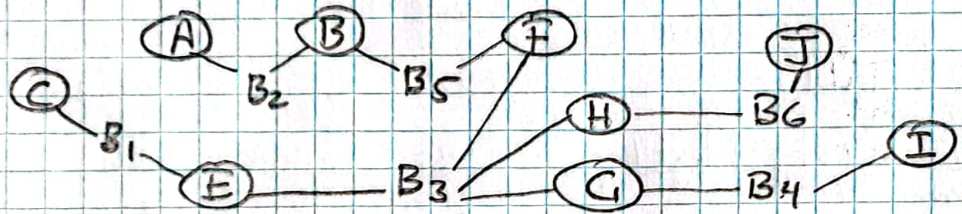
6. Consider then the extended LAN.



For B3 as root:

A: B3 → F → B5 → B → B2
B: B3 → F → B5
C: B3 → E → B1
E: B3 → E
F: B3 → F
G: B3 → G
H: B3 → H
I: B3 → G → B4
J: B3 → H → B6

So, the extended LAN would be:



With B7 posts and B6 - I post eliminated.

8. a) Consider to need 312 addresses, but 16 for marketing. Sales would need $(6+2\cdot 52)=110$ addresses, needing $(312+16+110)=438$ addresses in total. So the smallest CIDR to accomodate 438 addresses is a /23 block, being that the address range.

b) A /23 block is of $(2^{32-23} = 2^9) = 512$ addresses, being $(512-438) = 74$ addresses left. With that the company will run out of address space in $(74/(1+52)) = 1.4$ years, being the addresses in that time as follows: Engineering $= 5+52\cdot 1 = 57$ addresses, Marketing $= 15$ addresses, and Sales $= 6+2\cdot 1 = 8$ addresses.

c) For CIDR unavailable, there should be a request for class B address from the ISP. This would give the company $2^{16} = 65536$ addresses, more than the needed. Class B could be subnetted into smaller blocks to conserve space, requiring more complex routing and not being efficient as using CIDR. Alternatively, the company could use private IP addresses and network address translation (NAT) to connect to the Internet, limiting the company's ability to communicate with other networks and would not be as reliable as using public IP addresses.

7. There were three implementations for this, and they are shown below.

```
C:\Users\gapas>tracert google.com

Traza a la dirección google.com [2800:3f0:4005:40b::200e]
sobre un máximo de 30 saltos:

  1     2 ms     1 ms     1 ms  2800:bf0:1fff:f798:9217:3fff:fe46:dd9e
  2    14 ms     8 ms    10 ms  2800:bf0:1fff:f798::1
  3     4 ms     4 ms     4 ms  fd00:0:0:a43::1
  4     5 ms     4 ms     5 ms  2800:2a0:21:10::15
  5    19 ms    17 ms    16 ms  2800:2a0:21:10::16
  6    25 ms    18 ms    19 ms  2800:3f0:804c::1
  7    18 ms    17 ms    16 ms  2001:4860:0:1::4d8a
  8    17 ms    16 ms    17 ms  2001:4860:0:1::4d9b
  9    19 ms    17 ms    16 ms  2800:3f0:4005:40b::200e

Traza completa.
```

```
Traza a la dirección amazon.com [54.239.28.85]
sobre un máximo de 30 saltos:

  1     1 ms     1 ms     1 ms  192.168.100.1
  2    18 ms     7 ms     8 ms  100.99.210.1
  3     4 ms     4 ms     3 ms  10.224.51.186
  4     9 ms     6 ms     7 ms  10.201.222.31
  5     5 ms     4 ms     4 ms  100.71.0.7
  6    10 ms     5 ms     5 ms  186.101.24.50
  7     5 ms     3 ms     4 ms  204-199-148-221.dia.static.centurylink.com.ec [204.199.148.221]
  8     *        *        *     Tiempo de espera agotado para esta solicitud.
  9    71 ms    68 ms    69 ms  99.83.95.22
 10     *        *        *     Tiempo de espera agotado para esta solicitud.
 11     *        *        *     Tiempo de espera agotado para esta solicitud.
 12     *        *        *     Tiempo de espera agotado para esta solicitud.
 13     *        *        *     Tiempo de espera agotado para esta solicitud.
 14     *        *        *     Tiempo de espera agotado para esta solicitud.
 15     *        *        *     Tiempo de espera agotado para esta solicitud.
 16     *        *        *     Tiempo de espera agotado para esta solicitud.
 17     *        *        *     Tiempo de espera agotado para esta solicitud.
 18     *        *        *     Tiempo de espera agotado para esta solicitud.
 19    98 ms   101 ms    97 ms  52.93.28.84
 20     *        *        *     Tiempo de espera agotado para esta solicitud.
 21     *        *        *     Tiempo de espera agotado para esta solicitud.
 22     *        *        *     Tiempo de espera agotado para esta solicitud.
 23     *        *        *     Tiempo de espera agotado para esta solicitud.
 24     *        *        *     Tiempo de espera agotado para esta solicitud.
 25     *        *        *     Tiempo de espera agotado para esta solicitud.
 26     *        *        *     Tiempo de espera agotado para esta solicitud.
 27     *        *        *     Tiempo de espera agotado para esta solicitud.
 28     *        *        *     Tiempo de espera agotado para esta solicitud.
 29     *        *        *     Tiempo de espera agotado para esta solicitud.
 30     *        *        *     Tiempo de espera agotado para esta solicitud.
```

```
Traza a la dirección usfq.edu.ec [192.188.53.110]
sobre un máximo de 30 saltos:

  1     3 ms     1 ms     2 ms  192.168.100.1
  2    11 ms     7 ms     8 ms  100.99.210.1
  3     3 ms     3 ms     3 ms  10.224.51.186
  4     4 ms     4 ms     5 ms  100.71.0.2
  5     6 ms     4 ms     3 ms  100.71.0.7
  6     4 ms     3 ms     5 ms  186.101.24.50
  7    18 ms    11 ms    10 ms  186.3.125.42
  8     9 ms    13 ms    12 ms  143.255.248.252
  9     *        *        *     Tiempo de espera agotado para esta solicitud.
 10     *        *        *     Tiempo de espera agotado para esta solicitud.
 11     *        *        *     Tiempo de espera agotado para esta solicitud.
 12     *        *        *     Tiempo de espera agotado para esta solicitud.
 13    17 ms    14 ms    28 ms  192.188.53.214
 14     *        *        *     Tiempo de espera agotado para esta solicitud.
 15     *        *        *     Tiempo de espera agotado para esta solicitud.
 16     *        *        *     Tiempo de espera agotado para esta solicitud.
 17     *        *        *     Tiempo de espera agotado para esta solicitud.
 18     *        *        *     Tiempo de espera agotado para esta solicitud.
 19     *        *        *     Tiempo de espera agotado para esta solicitud.
 20     *        *        *     Tiempo de espera agotado para esta solicitud.
 21     *        *        *     Tiempo de espera agotado para esta solicitud.
 22     *        *        *     Tiempo de espera agotado para esta solicitud.
 23     *        *        *     Tiempo de espera agotado para esta solicitud.
 24     *        *        *     Tiempo de espera agotado para esta solicitud.
 25     *        *        *     Tiempo de espera agotado para esta solicitud.
 26     *        *        *     Tiempo de espera agotado para esta solicitud.
 27     *        *        *     Tiempo de espera agotado para esta solicitud.
 28     *        *        *     Tiempo de espera agotado para esta solicitud.
 29     *        *        *     Tiempo de espera agotado para esta solicitud.
 30     *        *        *     Tiempo de espera agotado para esta solicitud.
```

Based on the images, there should be at least 8 routers transverse as minimum in all the implementations, considering the case of the hops that didn't show that the Request time exceeded or with the message "Request time out", also by thinking of the hops as routers in the traceroute for three pages.

It could occur that some RTTs could not get in the place, shown by the hops that had 3 *'s, although that implies that there could be a problem in the trajectory, or that the destiny firewall blocked the request sent, it doesn't imply that some packets or requests were lost. In that way, after 30 hops applied in the last traceroutes, maybe the requests couldn't get into the destiny place as it was expected.