Prácticas de Redes de Computadores (2010/11)

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26 de enero de 2012

Resumen

Notas complementarias a las prácticas 3 y 4 sobre direccionamiento IP, *classful addressing*, CIDR y VLSM. Ejemplos de cálculo de direcciones base y de broadcast.

Propósito. El objetivo de estas notas consiste en reunir información sobre CIDR y VLSM para estudiantes de Redes de Computadores y ayudarles a realizar ejercicios prácticos de particionamiento y asignación de IPs. Algunos de los ejercicios resueltos están escritos en idioma inglés con el objetivo de que ayuden a los estudiantes a descubrir la terminología relevante y así facilitar su estudio de esta materia, particularmente en lo que se refiere a la lectura del libro de texto en lengua inglesa y otras referencias.

1. Espacios de direccionamiento IP agregados con CIDR.

El prefijo CIDR ($/n$) de una dirección IP es la longitud del bloque de bits 1 contiguos que constituyen su máscara de red, por tanto, al aplicar esta máscara a la IP mediante la función AND bit-a-bit, obtenemos el número de red o prefijo de red. Este número constituye la dirección IP base de un espacio agregado de tamaño 2^{32-n} y, además, esa dirección está alineada en frontera de 2^{32-n}. Los proveedores de servicio de internet adquieren espacio IP público en la forma explicada, adquiriendo un espacio agregado CIDR. El proceso de agregar espacio de la forma explicada se le denomina supernetting, ya que se obtienen redes de tamaño progresivamente más grandes. El número ($/n$) generalmente varía entre 8 (Una red de tipo A) hasta 24 (Una red de tipo C), por tanto, efectivamente CIDR nos permite agregar espacios de IPs de tamaño C (256) correspondientes a prefijos $/24$. Estudiemos qué ocurre cuando el prefijo CIDR varía.

Puesto que el prefijo CIDR marca el número de bits del prefijo de red, si disminuye, aumenta el espacio asignado a las estaciones y, si aumenta, entonces el espacio asignado a las estaciones disminuye. Supongamos que $/n$ aumenta en una unidad $/n+1$, el espacio agregado pasa de valer 2^{32-n} a $2^{32-(n+1)}$, por tanto, hemos dividido por 2 el espacio agregado: $\frac{2^{32-(n+1)}}{2^{32-n}} = \frac{1}{2}$. Al reducir $/n$ en una unidad, ocurre al contrario, el espacio direccionado se ve multiplicado por 2.

Ejemplo: Análisis inicial del espacio CIDR agregado 193.163.35.17/20.

```
193.163.35.17/20 (Observad la figura Nº 2)
```

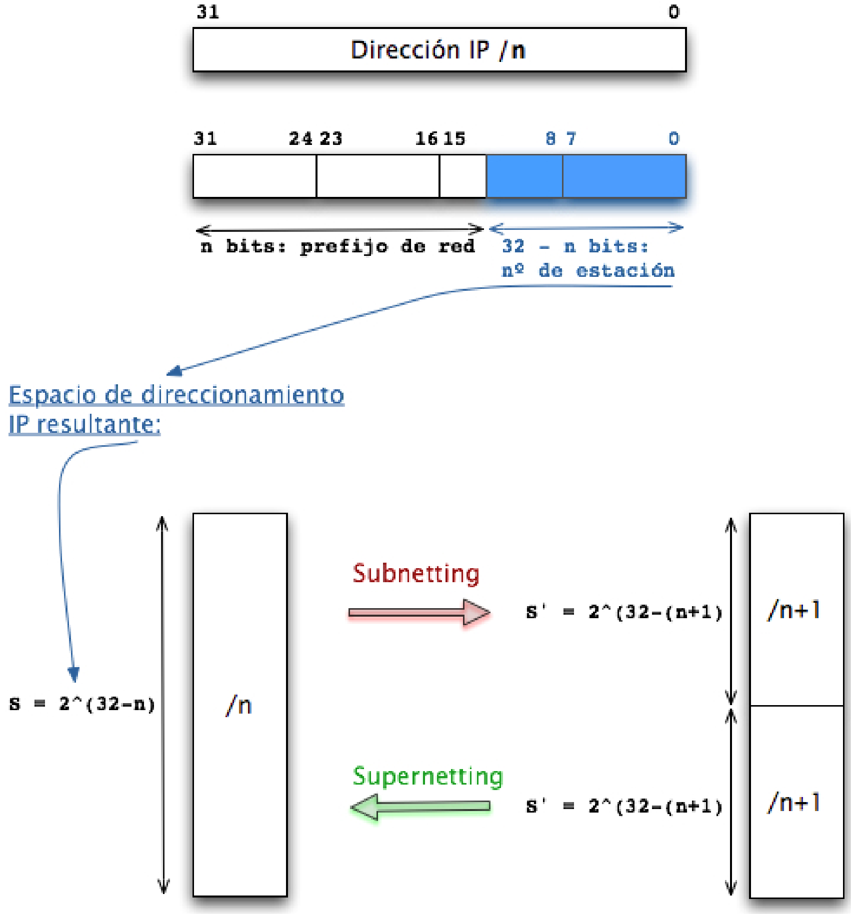

Figura 1: Espacio de IPs obtenido al variar el prefijo CIDR aplicado a una IP base.

Algoritmo 1 Cálculo de las direcciones BASE y BCAST (Broadcast) de un rango de IPs

1. Dirección BASE = IP & MASK
2. Dirección BCAST = NOT(MASK) | BASE
3. Rango de IPs utilizables = [BASE + 1, BCAST - 1]
4. Número total de IPs utilizables = 2^{32-n}. Este espacio está alineado en frontera de 2^{32-n}.

```
1. Número de IPs en el bloque:
        32 − 20 = 12, 2^12 = 4096
El número de bloques de tipo C agregados es:
        Un bloque tipo C es /24, por tanto:
        24 − 20 = 4, 2^4 = 16 bloques C
```

```
2. MASK:
/20 = 1111 1111 . 1111 1111 . 1111 0000 . 0000 0000
    =       255 .       255 .       240 .         0

3. BASE:
193 . 163 . 0010 0011 . 0001 0001
255 . 255 . 1111 0000 . 0000 0000
--------------------------------- and
193 . 163 . 0010 0000 . 0000 0000
193 . 163 .        32 .         0

BASE = 193.163.32.0
Esta IP está alineada en frontera de 2^(32-20) = 4096 IPs

4. BCAST:
      193.      163.0010 0000.0000 0000
0000 0000.0000 0000.0000 1111.1111 1111 = not MASK
--------------------------------------------------- or
      193.      163.0010 1111.1111 1111
      193.      163.       47.      255

BCAST = 193.163.47.255

5. RANGO: [193.163.32.1 , 193.163.47.254]
```

2. Particionamiento de un espacio IP agregado en subredes (Subnetting)

El espacio IP agregado que adquiere una organización habitualmente resulta en una red cuyo tamaño es exageradamente grande, lo cual, ocasionaría problemas de congestión, por ello, será necesario subdividir este espacio en espacios más pequeños. A este proceso se le denomina *subnetting* se logra aumentando el prefijo CIDR inicial: un aumento de una unidad produce una división del espacio en 2^1 espacios iguales, por tanto un aumento de m unidades producirá una división del espacio inicial en 2^m espacios, cada uno de los cuales tendrá un tamaño de $2^{32-(n+m)}$. Una manipulación simple del espacio obtenido con p bits: $2^p = 2 \cdot 2^{p-1} = 2^{p-1} + 2^{p-1}$ significa que el espacio correspondiente a $p\ bits$ bits se puede descomponer en dos espacios iguales de $p-1\ bits$. Trataremos de formular este resultado simple en términos de prefijos CIDR.

Sabemos que a un prefijo $/n$ le corresponde un espacio IP $espacioIP(/n) = 2^{32-n}$, a su vez, si se desea particionar este espacio en dos espacios iguales, según el resultado anterior se tiene que $2^{32-n} = 2^{32-n-1} + 2^{32-n-1}$, por tanto, podemos afirmar que: $espacioIP(/n) = espacioIP(/n+1) + espacioIP(/p+1)$.

En el ejemplo anterior, el espacio plano inicial si se aplica a una red LAN cableada es excesivo, estudiemos su particionamiento en cuatro subredes iguales de tamaño 1024 aplicando el resultado anterior:

- El espacio plano adquirido es 193.163.32.0/20:

  - $espacioIP(/20) = espacioIP(/20 + 1) + espacioIP(/20 + 1)$

- Obtenemos dos espacios $/21$, cada uno de los cuales se denomina subred (*subnet*) y, por tanto, cada uno de ellos tendrá un dirección BASE y BCAST propias. Ambos espacios son contiguos.

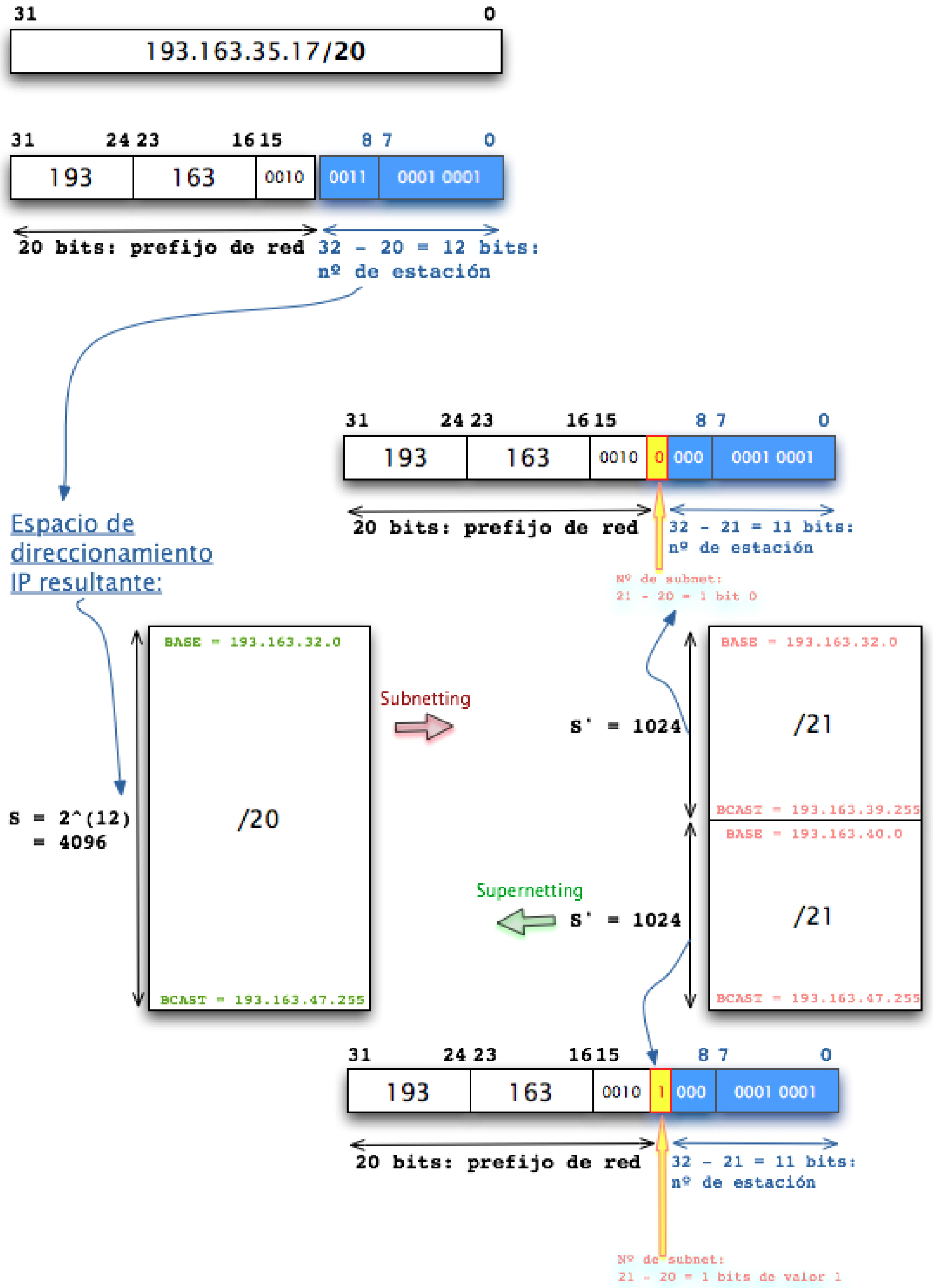

Figura 2: Espacio /20 particionado en dos subnets /21

3. Reference exercises

3.1. Una organización adquiere un espacio Ip formado por 16 bloques CIDR clase C cuya dirección base es 223.150.26.77/20. Las necesidades actuales demandan un particionamiento en subredes con los siguientes tamaños: 1 subnet de al menos 1000, 2 subnets de al menos 500 y otra más de al menos 2000. Proponed un esquema de subnetting para esta organización basado en CIDR y VLSM.

Una traducción no literal de este enunciado al inglés: *A company purchases an IP addressing space made up of 16 CIDR (C-class) blocks, one of the IP addresses belonging to that space is 223.150.26.77; the CIDR prefix at work is /20. The network administration team is embarking on a network segmentation project for the company, the approximate subnet sizes are the following: one 1000-node subnet, two 500-node subnets and one more subnet of a size of at least 2000 nodes. Work out a subnetting scheme which, based on VLSM and CIDR satisfies the demanded sizes plus a reasonable future-growth margin.*

```
223.150.26.77/20

1. Número de IPs en el bloque:
        32 - 20 = 12, 2^12 = 4096

El número de bloques de tipo C agregados es:
        Un bloque tipo C es /24, por tanto:
        24 - 20 = 4, 2^4 = 16 bloques C

2. Algunos particionamientos posibles: Hemos de ajustar los tamaños
solicitados a la siguiente potencia entera de 2, por ejemplo, 1000
habrá de asignarse a una subnet de tamaño 1024 = 2^10 (Recordad que
el tamaño efectivo de esta subnet, además, es 1024 - 2 (Base y Bcast))

        a) 1024
             512
        512
           2048

        b)   512
        512
           1024
           2048
```

El particionamiento siguiente no es posible porque las subnets no están alineadas:

```
                 512
                1024
                 512
                2048
```

Por ejemplo, la segunda (1024), su IP base (512) no es divisible por su tamaño (1024). Usaremos el esquema a).

3. Particionaremos el esquema a), en primer lugar calcularemos las IPs BASE y BCAST del bloque adquirido completo:

```
MASK:
/20 = 1111 1111 . 1111 1111 . 1111 0000 . 0000 0000
    =       255 .       255 .       240 .         0
```

```
4. BASE:
223 . 150 . 0001 1010 . 0100 1101
255 . 255 . 1111 0000 . 0000 0000
--------------------------------- and
223 . 150 . 0001 0000 . 0000 0000
223 . 150 .        16 .         0
```

BASE = 223.150.16.0
Esta IP está alineada en frontera de 2^(32−20) = 4096 IPs

```
5. BCAST:
      223.      150.0001 0000.0000 0000
0000 0000.0000 0000.0000 1111.1111 1111 = not MASK
--------------------------------------------------- or
      223.      150.0001 1111.1111 1111
      223.      150.       31.      255
```

BCAST = 223.150.31.255

6. RANGO: [223.150.16.1 , 223.150.31.254]

7. <u>Análisis de la subnet #0 (1024, /22):</u>

El tamaño ha de ser 1024, la potencia entera de 2 más próxima a 1000 por exceso.

log2 1024 = 10, 32 − 10 = 22: el prefijo para esta subnet es /22.

Puesto que es la primera subnet, tomamos como base la base general:

```
BASE  general  = 223.150.0001 0000.0000 0000/22
MASK           =  ff. ff.1111 1100.0000 0000
-------------------------------------------------- and
BASE subnet#0  = 223.150.0001 0000.0000 0000/22
NOT MASK       =  00. 00.0000 0011.1111 1111
-------------------------------------------------- or
BCAST subnet#0 = 223.150.0001 0011.1111 1111
                           = 223.150.      19.255
```

Rango: [223.150.16.1, 223.150.19.254]

8. Análisis de la subnet #1 (512, /23):

El tamaño ha de ser 512, la potencia entera de 2 más próxima a 500 por exceso.

log2 512 = 9, 32 − 9 = 23: el prefijo para esta subnet es /23.

Tomamos como base la dirección BCAST de la subnet anterior (#0) mas 1:

```
               = 223.150.       20.        0
MASK           =  ff. ff.1111 1110.0000 0000
-------------------------------------------------- and
BASE subnet#1  = 223.150.       20.0000 0000
NOT MASK       =  00. 00.0000 0001.1111 1111
-------------------------------------------------- or
BCAST subnet#1 = 223.150.       21.1111 1111
```

Rango: [223.150.20.1, 223.150.21.254]

9. Análisis de la subnet #2 (512, /23):

El tamaño ha de ser 512, la potencia entera de 2 más próxima a 500 por exceso.

log2 512 = 9, 32 − 9 = 23: el prefijo para esta subnet es /23.

Tomamos como base la dirección BCAST de la subnet anterior (#1) mas 1:

```
                = 223.150.       22.       0
MASK            =  ff. ff.1111 1110.0000 0000
---------------------------------------------- and
BASE subnet#2   = 223.150.       22.0000 0000
NOT MASK        =  00. 00.0000 0001.1111 1111
---------------------------------------------- or
BCAST subnet#2  = 223.150.       23.1111 1111
```

Rango: [223.150.22.1, 223.150.23.254]

9. Análisis de la subnet #3 (2048, /21):

El tamaño ha de ser 2048, la potencia entera de 2 más próxima a 2000 por exceso.

log2 2048 = 1, 32 − 11 = 21: el prefijo para esta subnet es /21.

Tomamos como base la dirección BCAST de la subnet anterior (#2) mas 1:

```
                = 223.150.       24.       0
MASK            =  ff. ff.1111 1000.0000 0000
---------------------------------------------- and
BASE subnet#3   = 223.150.       24.0000 0000
NOT MASK        =  00. 00.0000 0111.1111 1111
---------------------------------------------- or
BCAST subnet#3  = 223.150.       31.1111 1111

                = 223.150.31.255
```

Rango: [223.150.24.1, 223.150.31.254]

3.2. Calculate the number of IP addresses contained in the CIDR space 193.146.96.1/20, then, segment that space into four subnets, one of size 1024, two of 512 and one more of size 2048.

The sizes mentioned are to be understood as minimum required sizes and since, in the present case, they are all integer powers of two, clearly we will have to opt, in each case, for the next greater integer power of two, for example in the 512 case we will have to allocate an effective IP space of 1024.

1. Number of IP addresses contained in the /20 addressing space: $32 - 20 = 12, 2^{12} = 4096$ nodes of which we will have to subtract two reserved addresses, the subnet number and the broadcast address, as we already know. A more straighforward procedure would consist of conceiving the /20 space as made up of several spaces of size /24: 2^4 spaces of size 256 each since, as mentioned above, a /24 space is a c-class space, i.e., the 256-node space so familiar to us by now.

2. Let's calculate now the minimum height power-of-two binary tree that covers the set of sizes given: The set of sizes is $S = \{4096,\ 2048,\ 1024,\ 1024\}$ and $\sum S = 8192,\ log_2 8192 = 13$ therefore, the minimum CIDR index that covers the set of sizes given is: $32 - 13 = 19$. We observe that /20, the CIDR index specified in the exercise statement, will not cover completely the set of sizes, therefore we must choose /19 as our CIDR prefix.

3. As we have proven in the preceeding sections, in order for us to guarantee a partitioning scheme which partitions are aligned in size-boundary we will perform the address assignment by starting with the greatest of the sizes and continuing to the smallest, i.e., by choosing each of the sizes in non-increasing order, the partitioning procedure developed next is carried out in this fashion.

4. General (/19) base address (Newtork number):
   Base address of (193.146.96.1/19) = 193.146.96.1 & 255.255.224.0 = 193.146.96.0

5. General (/19) broadcast address:
   Base | not(mask) = 193.146.96.0 | (0.0.31.255) = 193.146.127.255
   Let's check that the last result is correct by calculating the broadcast address by adding the number of C blocks that fit into this CIDR space minus 1:
   The CIDR space size is $2^{(32-19)} = 2^{13} = 8192$, this space contains $\frac{8192}{256} = 32$ C-sized blocks, therefore we add 32 to the IP address byte that counts 256-sized blocks, the second signifcant byte, in the present case the 96:
   193.146.(96 + 32).0 - 1 = 193.146.128.0 - 1 = 193.146.127.255 which we confirm that is equal to the result obtained above for the general broadcast. Now we will proceed to the partitioning itself and its IP address assignement.

6. Block 4096, net #0, /(32 - 12) = /20, number of C-sized blocks = 16:
   Network number. This network number conceptually concides with the general base address calculated in the previous step: 193.146.96.0/20, no base address calculation is necessary since a /20 CIDR space is necessarily aligned on a /19 CIDR space boundary, this statement follows from the fact that any integral power of 2 is divisible by itself and by any other smaller integral power of 2.
   Broadcast address. 193.146.(96 + 16).0 - 1 = 193.146.112.0 - 1 = 193.146.111.255
   The range of IPs allocatable to end nodes is: [BASE + 1, BROADCAST - 1] = [193.146.96.1, 193.146.111.254]

7. Block 2048, net #1, /21, number of C-sized blocks = 8:
   Network number. This number is calculated by adding 1 to the broadcast address obtained on the last step: 193.146.111.255 + 1 = 193.146.112.0
   Broadcast address. Once again we perform this calculation by adding up the current net's size expressed in terms of c-blocks minus 1 to the current net's network number, which we do now:
   193.146.(112 + 8).0 - 1 = 193.146.120.0 - 1 = 193.146.119.255
   Range: [193.146.112.1, 193.146.119.254]

8. Block 1024, net #2, /22, number of C-sized blocks = 4:
   Network number. Proceeding as explained in the former subnet we obtain: 193.146.119.255 + 1 = 193.146.120.0
   Broadcast address. 193.146.(120 + 4).0 - 1 = 193.146.124.0 - 1 = 193.146.123.255
   Range: [193.146.120.1, 193.146.123.254]

9. Block 1024, net #3, /22, number of C-sized blocks = 4:
   Network number. Proceeding as explained in the former subnet we obtain: 193.146.123.255 + 1 = 193.146.124.0
   Broadcast address. 193.146.(124 + 4).0 - 1 = 193.146.128.0 - 1 = 193.146.127.255, which is equal to the general broadcast address which, in turn, is a check that the calculation is correct, since in this case *all the /23 CIDR space has been assigned to the subnets*.
   Range: [193.146.124.1, 193.146.127.254]

3.3. An organization needs IP space for the following maximum subnet sizes: Sizes = {100, 200, 300, 400, 500, 600, 700, 800, 900, 1000}. Calculate the size of the minimum aggregated CIDR space that covers S and segment that space by using VLSM into an appropriate set of subnets. You must assume a base IP address that lays in a public IP range, i.e., one that is not reserved in any way. For each of the subnets compute their base and broadcast addresses together with their IP address range.

1. First we will map each of the sizes to its nearest greater integer power of 2, in each case we will try to provide for some future growth margin, in the present case we obtain the following nominal sizes S = {256, 256, 512, 512, 1024, 1024, 1024, 1024, 2048, 2048}

2. $\sum S = 9728,\ ceil(log_2 9728) = 14,\ 2^{14} = 16384$ therefore, the minimum CIDR index that covers the set of sizes given is: $32 - 14 = 18$ and, consequently our base CIDR prefix is /18. Since the total number of requested IPs (9728) is less than the grand total (16384) for which we will provide CIDR space, there will be a remaining space which we can partition and IP-assign, depending on the specific network management policies in use -in general our thinking is that it is more appropriate to partition and assign this space from a network security standpoint.

3. If we choose an IP address that belongs to the CIDR space of the previous exercise we may gain some intuition about the size boundary alignment of IP addresses, let's choose 193.146.99.133 and see what happens when we apply our working mask (That corresponding to our CIDR prefix

of /18). Remember that, in order for us to guarantee that the various blocks get aligned IP base addresses we will have to partition the IP space in non increasing order of the nominal sizes S.

4. General (/18) base address (Newtork number):
   Base address of (193.146.99.133/18) = 193.146.99.133 & 255.255.192.0 = 193.146.64.0
   This IP must be aligned in its size boundary ($2^{32-18} = 16384$), i.e., the remainder of the integer division of the resulting IP considered as a 32-bit unsigned integer by 16384 must yield zero. We encourage you to perform the former test by using the IP Java classes and methods writen in the Computer Networks Lab sessions.

5. General (/18) broadcast address:
   Base | not(mask) = 193.146.64.0 | (0.0.63.255) = 193.146.127.255
   Let's check that the last result is correct by calculating the broadcast address by adding the number of C blocks that fit into this CIDR space minus 1:
   The CIDR space size is $2^{(32-18)} = 2^{14} = 16384$, this space contains $\frac{16384}{256} = 64$ C-sized blocks, therefore we add 64 to the IP address byte that counts 256-sized blocks, the second signifcant byte, in the present case the 64:
   193.146.(64 + 64).0 - 1 = 193.146.128.0 - 1 = 193.146.127.255 which we confirm that is equal to the result obtained above for the general broadcast. Now we will proceed to the partitioning itself and its IP address assignement.

6. Block 2048, net #0, /(32 - 11) = /21, number of C-sized blocks = 8:
   Network number. This network number conceptually concides with the general base address calculated in the previous step: 193.146.64.0/18, no base address calculation is necessary since a /21 CIDR space is necessarily aligned on a /18 CIDR space boundary, this statement follows from the fact that any integral power of 2 is divisible by itself and by any other smaller integral power of 2.
   Broadcast address. 193.146.(64 + 8).0 - 1 = 193.146.72.0 - 1 = 193.146.71.255
   The range of IPs allocatable to end nodes is: [BASE + 1, BROADCAST - 1] = [193.146.64.1, 193.146.71.254]

7. Block 2048, net #1, /(32 - 11) = /21, number of C-sized blocks = 8:
   Network number. 193.146.71.255 + 1 = 193.146.72.0
   Broadcast address. 193.146.(72 + 8).0 - 1 = 193.146.80.0 - 1 = 193.146.79.255
   The range of IPs allocatable to end nodes is: [BASE + 1, BROADCAST - 1] = [193.146.72.1, 193.146.79.254]

8. Block 1024, net #2, /(32 - 10) = /22, number of C-sized blocks = 4:
   Network number. 193.146.79.255 + 1 = 193.146.80.0
   Broadcast address. 193.146.(80 + 4).0 - 1 = 193.146.84.0 - 1 = 193.146.83.255
   The range of IPs allocatable to end nodes is: [BASE + 1, BROADCAST - 1] = [193.146.80.1, 193.146.83.254]

9. Block 1024, net #3, /(32 - 10) = /22, number of C-sized blocks = 4:
   Network number. 193.146.83.255 + 1 = 193.146.84.0
   Broadcast address. 193.146.(84 + 4).0 - 1 = 193.146.88.0 - 1 = 193.146.87.255

The range of IPs allocatable to end nodes is: [BASE + 1, BROADCAST - 1] = [193.146.84.1, 193.146.87.254]

10. Block 1024, net #4, /(32 - 10) = /22, number of C-sized blocks = 4:
Network number. 193.146.87.255 + 1 = 193.146.88.0
Broadcast address. 193.146.(88 + 4).0 - 1 = 193.146.92.0 - 1 = 193.146.91.255
The range of IPs allocatable to end nodes is: [BASE + 1, BROADCAST - 1] = [193.146.88.1, 193.146.91.254]

11. Block 1024, net #5, /(32 - 10) = /22, number of C-sized blocks = 4:
Network number. 193.146.91.255 + 1 = 193.146.92.0
Broadcast address. 193.146.(92 + 4).0 - 1 = 193.146.96.0 - 1 = 193.146.95.255
The range of IPs allocatable to end nodes is: [BASE + 1, BROADCAST - 1] = [193.146.92.1, 193.146.95.254]

12. Block 512, net #6, /(32 - 9) = /23, number of C-sized blocks = 2:
Network number. 193.146.95.255 + 1 = 193.146.96.0
Broadcast address. 193.146.(96 + 2).0 - 1 = 193.146.98.0 - 1 = 193.146.97.255
The range of IPs allocatable to end nodes is: [BASE + 1, BROADCAST - 1] = [193.146.96.1, 193.146.97.254]

13. Block 512, net #7, /(32 - 9) = /23, number of C-sized blocks = 2:
Network number. 193.146.97.255 + 1 = 193.146.98.0
Broadcast address. 193.146.(98 + 2).0 - 1 = 193.146.100.0 - 1 = 193.146.99.255
The range of IPs allocatable to end nodes is: [BASE + 1, BROADCAST - 1] = [193.146.98.1, 193.146.99.254]

14. Block 256, net #8, /(32 - 8) = /24, number of C-sized blocks = 1:
Network number. 193.146.99.255 + 1 = 193.146.100.0
Broadcast address. 193.146.(100 + 1).0 - 1 = 193.146.101.0 - 1 = 193.146.100.255
The range of IPs allocatable to end nodes is: [BASE + 1, BROADCAST - 1] = [193.146.100.1, 193.146.100.254]

15. Block 256, net #9, /(32 - 8) = /24, number of C-sized blocks = 1:
Network number. 193.146.100.255 + 1 = 193.146.101.0
Broadcast address. 193.146.(101 + 1).0 - 1 = 193.146.102.0 - 1 = 193.146.101.255
The range of IPs allocatable to end nodes is: [BASE + 1, BROADCAST - 1] = [193.146.101.1, 193.146.101.254]

16. In this exercise we will leave the remaining space unassigned, i.e., the space that starts at 193.146.102.0 and ends at the general broadcast address minus one:
The unasssigned space is [193.146.102.0, 193.146.127.254]. We leave as an exercise to resolve this assignment, you must take into account that since its start address is aligned on a /24 boundary we will always be able to partition this space into a certain number of /24-sized blocks, obviously that approach will produce an unacceptably large number of c-blocks in this case, nevertheless we will collpase 2 properly aligned /24-blocks into an /25 block and successively until all the space is consumed.

3.4. An organization needs IP space for the following maximum subnet sizes: Sizes = {30, 50, 80, 100, 200, 300}. Calculate the size of the minimum aggregated CIDR space that covers S and segment that space by using VLSM into an appropriate set of subnets. You must assume a base IP address that lays in a public IP range, i.e., one that is not reserved in any way. For each of the subnets compute their base and broadcast addresses together with their IP address range.

1. First we will map each of the sizes to its nearest greater integer power of 2, in each case we will try to provide for some future growth margin, in the present case we obtain the following nominal sizes S = {64, 128, 128, 256, 512, 512}

2. $\sum S = 1600,\ ceil(log_2 1600) = 11,\ 2^{11} = 2048$ therefore, the minimum CIDR index that covers the set of sizes given is: $32 - 11 = 21$ and, consequently our base CIDR prefix is /21. Since the total number of requested IPs (1600) is less than the grand total (2048) for which we will provide CIDR space, there will be a remaining space which we can partition and IP-assign, depending on the specific network management policies in use -in general our thinking is that it is more appropriate to partition and assign this space from a network security standpoint.

3. If we choose an IP address that belongs to the CIDR space of the previous exercise we may gain some intuition about the size boundary alignment of IP addresses, let's choose 193.146.99.133 and see what happens when we apply our working mask (That corresponding to our CIDR prefix of /21). Remember that, in order for us to guarantee that the various blocks get aligned IP base addresses we will have to partition the IP space in non increasing order of the nominal sizes S.

4. General (/21) base address (Newtork number):
   Base address of (193.146.99.133/21) = 193.146.99.133 & 255.255.248.0 = 193.146.96.0
   This IP must be aligned in its size boundary ($2^{32-21} = 2048$), i.e., the remainder of the integer division of the resulting IP considered as a 32-bit unsigned integer by 2048 must yield zero. We encourage you to perform the former test by using the IP Java classes and methods writen in the Computer Networks Lab sessions.

5. General (/21) broadcast address:
   Base | not(mask) = 193.146.96.0 | (0.0.7.255) = 193.146.103.255
   Let's check that the last result is correct by calculating the broadcast address by adding the number of C blocks that fit into this CIDR space minus 1:
   The CIDR space size is $2^{(32-21)} = 2^{11} = 2048$, this space contains $\frac{2048}{256} = 8$ C-sized blocks, therefore we add 8 to the IP address byte that counts 256-sized blocks, the second signifcant byte, in the present case the 96:
   193.146.(96 + 8).0 - 1 = 193.146.104.0 - 1 = 193.146.103.255 which we confirm that is equal to the result obtained above for the general broadcast. Now we will proceed to the partitioning itself and its IP address assignement.

6. Block 512, net #0, /(32 - 9) = /23, number of C-sized blocks = 2:
   Network number. This network number conceptually concides with the general base address calculated in the previous step: 193.146.96.0/21, no base address calculation is necessary since a /23

CIDR space is necessarily aligned on a /21 CIDR space boundary.
Broadcast address. 193.146.(96 + 2).0 - 1 = 193.146.98.0 - 1 = 193.146.97.255
The range of IPs allocatable to end nodes is: [BASE + 1, BROADCAST - 1] = [193.146.96.1, 193.146.97.254]

7. Block 512, net #1 /(32 - 9) = /23, number of C-sized blocks = 2:
   Network number. 193.146.97.255 + 1 = 193.146.98.0
   Broadcast address. 193.146.(98 + 2).0 - 1 = 193.146.100.0 - 1 = 193.146.99.255
   The range of IPs allocatable to end nodes is: [BASE + 1, BROADCAST - 1] = [193.146.98.1, 193.146.99.254]

8. Block 256, net #2 /(32 - 9) = /24, number of C-sized blocks = 1:
   Network number. 193.146.99.255 + 1 = 193.146.100.0
   Broadcast address. 193.146.(100 + 1).0 - 1 = 193.146.101.0 - 1 = 193.146.100.255
   The range of IPs allocatable to end nodes is: [BASE + 1, BROADCAST - 1] = [193.146.100.1, 193.146.100.254]

9. Block 128, net #3 /(32 - 7) = /25, number of C-sized blocks = half a C block (128 addresses):
   Network number. 193.146.100.255 + 1 = 193.146.101.0
   Broadcast address. 193.146.101.0 + 128 - 1 = 193.146.101.127
   The range of IPs allocatable to end nodes is: [BASE + 1, BROADCAST - 1] = [193.146.101.1, 193.146.100.126]

10. Block 128, net #4 /(32 - 7) = /25, number of C-sized blocks = half a C block (128 addresses):
    Network number. 193.146.101.127 + 1 = 193.146.101.128
    Broadcast address. 193.146.101.128 + 128 - 1 = 193.146.101.255
    The range of IPs allocatable to end nodes is: [BASE + 1, BROADCAST - 1] = [193.146.101.129, 193.146.100.255]

11. Block 64, net #5 /(32 - 6) = /26, number of C-sized blocks = a quarter of a C block (64 addresses):
    Network number. 193.146.101.255 + 1 = 193.146.102.0
    Broadcast address. 193.146.102.0 + 64 - 1 = 193.146.102.63
    The range of IPs allocatable to end nodes is: [BASE + 1, BROADCAST - 1] = [193.146.102.1, 193.146.102.63]

4. Closing comments.

In addition to the partitioning algorithm outlined in these notes, obviously, there exist other procedures to carry out the partitioning and assignment that comply with the alignment requirement, we could set out to seek partitioning algorithms that might offer more flexibility when subnetworks overflow their assigned size and we want to join two of them without renumbering, for instance. There may be other, more efficient algorithms but our aim here is to offer you an initial, simple and proven procedure that will help you prepare for the IP subnetting cases that often appear in term papers and tests. Any errors or suggestions may be reported to the author at chema.foces@unileon.es, thank you.