

DOCSIS (Data Over Cable Service Interface Specification)

Significado:

DOCSIS significa Especificaciones de Interfaz de Servicio de Datos por Cable: métodos para transportar datos a través de un prestador de cable (CATV) que utiliza la modulación de RF QAM y / o QPSK. Los módems DOCSIS y las plataformas CMTS están certificados por CableLabs, el organismo organizativo que establece y prueba los estándares. CableLabs es un consorcio de expertos en cable y operadores de la industria.

Además, un consorcio europeo de operadores de cable certifica el código EuroDocsis. Los resultados actuales de la ola de certificación y las listas de productos calificados se pueden encontrar en el sitio web de EuroCableLabs.

Introducción:

Se trata de un estándar no comercial que define los requisitos de la interfaz de comunicaciones y operaciones para los datos sobre sistemas de cable, lo que permite añadir transferencias de datos de alta velocidad a un sistema de televisión por cable (CATV) existente. Muchos operadores de televisión por cable (cable operadores) lo emplean para proporcionar acceso a Internet sobre una infraestructura de red Híbrida de Fibra óptica- Cable coaxial (HFC) existente. La primera especificación DOCSIS fue la versión 1.0, publicada en marzo de 1997, seguida de la revisión 1.1 en abril de 1999.

La versión europea de DOCSIS se denomina EuroDOCSIS. La principal diferencia es que, en Europa, los canales de cable tienen un ancho de banda de 8 MHz (PAL), mientras que, en Estados Unidos y gran parte de América del Sur, es de 6 MHz (NTSC). Esto se traduce en un mayor ancho de banda disponible para el canal de datos de bajada (desde el punto de vista del usuario, el canal de bajada se utiliza para recibir datos, mientras que el de subida se utiliza para enviarlos). También existen otras variantes de DOCSIS que se emplean en Japón.

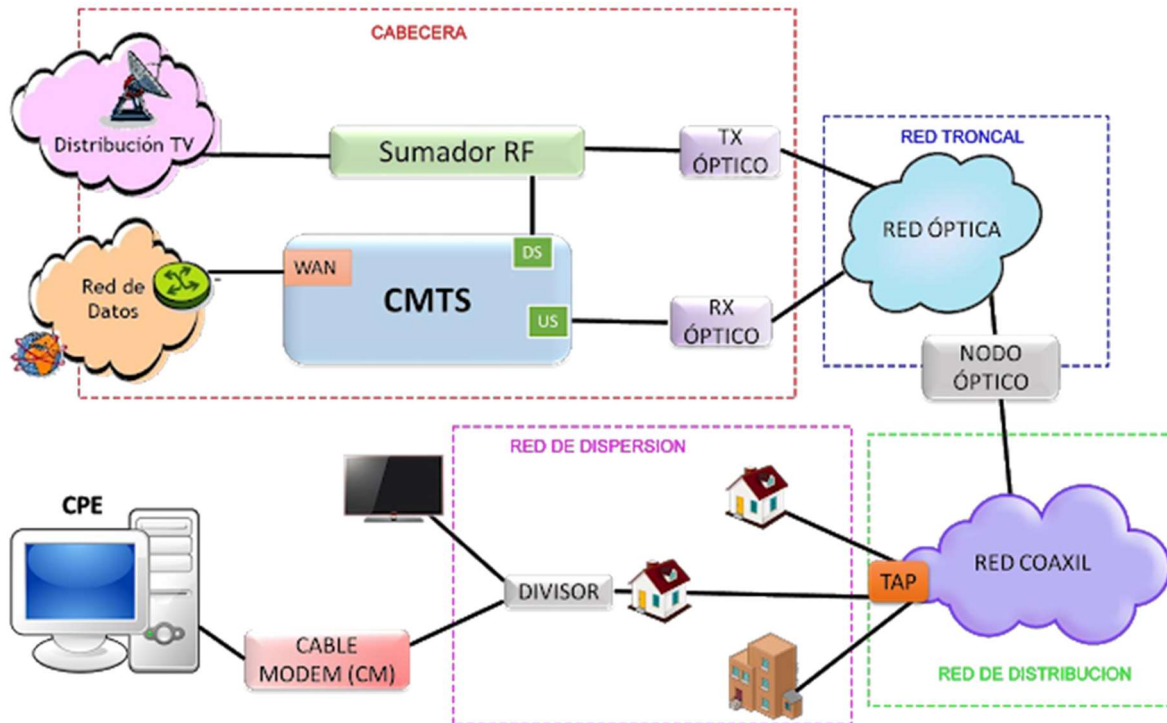
El 7 de agosto de 2006 salieron a la luz las especificaciones finales del DOCSIS 3.0, cuya principal novedad reside en el soporte para IPv6 y el channel bonding, que permite utilizar varios canales simultáneamente, tanto de subida como de bajada, por lo que la velocidad podrá sobrepasar los 100 Mbit/s en ambos sentidos. Los equipos con el nuevo protocolo llegarán a velocidades de descarga de datos de 160 Mbit/s y subidas a 120 Mbit/s.

La versión 3.0 fue publicada a finales de agosto de 2006.

La última versión es la 3.1, publicada el 20 de marzo de 2014 (Ya está en desarrollo la versión 4), con la que se pretende poner a las conexiones de cable a un nivel similar (o

por lo menos con respecto a sus capacidades actuales) al de las redes de fibra pura (FTTH).

Elementos de la RED:



CMTS:

(Cable Modem Termination System) es básicamente un router que del lado del cliente (cable modems) trabaja con interfaces DOCSIS en capa 1 y dos del modelo OSI y un esquema de servicio DHCP mas complejo de lo habitual con opciones específicas de DOCSIS, esto hace que pueda mezclarse dentro del esquema de CATV y el usuario final pueda transferir datos de forma bidireccional usando el mismo cable coaxial que usa para ver televisión, esto se logra usando portadoras de Upstream (desde el punto de vista del cliente se usan para transmitir datos) y Downstream (desde el punto de vista del cliente se usan para recibir datos) TX y RX respectivamente para construir la trama DOCSIS.

Downstream: Las portadoras de downstream pueden tener un ancho de canal de 6Mhz (DOCSIS) u 8Mhz (EuroDOCSIS) y se modula en QAM (quadrature amplitude modulation) por lo general en 256 símbolos, cuando más símbolos se usan mayor es la eficiencia espectral, o sea más Mb/s por Mhz utilizado aunque esto tiene un límite físico ya que cada vez que se duplican la cantidad de símbolos utilizados esto requiere que la portadora esté 3dbmv más alejado del piso de ruido y a su vez la señal se vuelve mas débil a distorsiones generadas por los equipos tanto ópticos o de RF de la red de distribución.

Upstream: En DOCSIS 1.0 y 1.1 el ancho de canal puede variar entre 0,2 Mhz y 3,2 Mhz, a partir de DOCSIS 2 el ancho de canal es de 6,4 Mhz aunque la mayoría de los cable modems son retrocompatibles, es decir un cable modem DOCSIS 2 puede funcionar con portadoras de upstream de menos de 6,4 Mhz de ser necesario como sería el caso de conectarse a un CMTS DOCSIS 1.1, los métodos de modulación utilizados pueden ser QPSK y/o QAM (usando 16 ó 64 símbolos).

			Subida (<i>upstream</i>) en Mbit/s			
				QPSK	16-QAM	64-QAM*
Bajada (<i>downstream</i>) en Mbit/s			0,2 MHz	0,32 (0,3)	0,64 (0,6)	1,28 (1,2)
	64-QAM	256-QAM	0,4 MHz	0,64 (0,6)	1,28 (1,2)	1,92 (1,7)
6 MHz	30,34 (27)	42,88 (38)	0,8 MHz	1,28 (1,2)	2,56 (2,3)	3,84 (3,4)
8 MHz	40,44 (36)	57,20 (51)	1,6 MHz	2,56 (2,3)	5,12 (4,6)	7,68 (6,8)
			3,2 MHz	5,12 (4,6)	10,24 (9,0)	15,36 (13,5)
			6,4 MHz*	10,24 (9,0)	20,48 (18,0)	30,72 (27)

*Sólo disponibles a partir de DOCSIS 2.0

Cable Módems:

Es la caja de abonado que se conecta por un lado al cable coaxial de la red de cable y por el otro a la red Ethernet o WiFi del abonado. Del lado de la red de cable se conecta usando cable coaxial RG6 ó RG59 con conectores F.

Secuencia de inicio: El proceso de inicio del cable modem es secuencial, tal es así que si en alguna parte de la secuencia se genera un error no pasa de ahí y como mucho después de un tiempo se reinicia para volver a intentar, en la siguiente tabla se muestran los estados por los que pasa un cable modem hasta quedar “operacional”, donde los estados “init(rX)” son los relacionados con la negociación de parámetros de RF, “init(d)”

comienza la negociación IP, “init(o)” comienza a bajar el archivo de configuración y finalmente “online” el cable modem está operacional.

MAC State Value	Description
init(r1)	The cable modem (CM) sent initial ranging.
init(r2)	The CM is ranging. The CMTS received initial ranging from the CM and has sent radio frequency (RF) power, timing offset, and frequency adjustments to the CM.
init(rc)	Ranging has completed. Note: If a CM appears to be stuck in this state, it could be that the CM is able to communicate successfully on the cable network but the upstream is at capacity and does not have any additional bandwidth to allow the CM to finish registration and come online. Either manually move one or more CMs to other upstreams or issue the cable load-balance group commands to enable load balancing on the upstream.
init(d)	The DHCP request was received. This also indicates that the first IP broadcast packet has been received from the CM.
init(i)	The cable modem has received the DHCP OFFER reply from the DHCP server that has assigned an IP address to the modem, but the modem has not yet replied with a DHCP REQUEST message to request that particular IP address, nor has it sent an IP packet with that IP address. Note: If a CM appears to be stuck in this state, the CM has likely received the DHCP OFFER reply from the DHCP server, but this reply might have contained one or more invalid options for that particular CM.
init(o)	The CM has begun to download the option file (DOCSIS configuration file) using the Trivial File Transfer Protocol (TFTP), as specified in the DHCP response. If the CM remains in this state, it indicates that the download has failed.
init(t)	Time-of-day (ToD) exchange has started.
resetting	The CM is being reset and will shortly restart the registration process.

Non-Error Status Conditions

MAC State Value	Description
cc(r1)	The CM had registered and was online, but has received a Downstream Channel Change (DCC) or an Upstream Channel Change (UCC) request message from the CMTS. The CM has begun to move to the new channel, and the CMTS has received the CM's initial ranging on the new downstream or upstream channel. At the MAC layer, the CM is considered offline because it is not yet passing traffic on the new channel, but this state does not trigger the flap-list counters.

<code>cc (r2)</code>	This state should normally follow <code>cc (r1)</code> ; and it indicates that the CM has finished its initial ranging on the new channel and is currently performing continuous ranging on the new channel. At the MAC layer, the CM is considered offline because it is not yet passing traffic on the new channel, but this state does not trigger the flap-list counters.
<code>offline</code>	The CM is considered offline (disconnected or powered down).
<code>online</code>	The CM has registered and is enabled to pass data on the network.
<code>online (d)</code>	<p>The CM registered, but network access for CPE devices that use this CM has been disabled through the DOCSIS configuration file. The CM does not forward traffic to or from the CPE devices, but the CMTS can continue to communicate with the CM using DOCSIS messages and IP traffic (such as SNMP commands).</p> <p>Note: If BPI was enabled in the DOCSIS configuration file sent to the CM, assume that the CM is using BPI encryption, unless other messages show that the BPI negotiation and key assignments have failed.</p>
<code>online (pkd)</code>	<p>The CM registered, but network access for CPE devices that use this CM has been disabled through the DOCSIS configuration file. In addition, BPI is enabled and the key-encrypting key (KEK) is assigned.</p> <p>Note: This state is equivalent to the <code>online (d)</code> and <code>online (pk)</code> states.</p>
<code>online (ptd)</code>	<p>The CM registered, but network access for CPE devices that use this CM has been disabled through the DOCSIS configuration file. In addition, BPI is enabled and the traffic encryption key (TEK) is assigned. BPI encryption is now being performed.</p> <p>Note: This state is equivalent to the <code>online (d)</code> and <code>online (pt)</code> states.</p>
<code>online (pk)</code>	The CM registered, BPI is enabled, and the KEK is assigned.
<code>online (pt)</code>	<p>The CM registered, BPI is enabled, and the TEK is assigned. BPI encryption is now being performed.</p> <p>Note: If network access was disabled in the DOCSIS configuration file sent to the CM, then the network disabled status takes precedence, and the MAC status field shows <code>online (d)</code> instead of <code>online (pt)</code>, even when BPI encryption is enabled and operational.</p>
<p>Note: If an exclamation point (!) appears in front of one of the online states, it indicates that the cable dynamic-secret command has been used with either the mark or reject option, and that the cable modem has failed the dynamic secret authentication check.</p>	
<code>expire (pk)</code>	The CM registered, BPI is enabled, and the KEK was assigned; but the current KEK expired before the CM could successfully renew a new KEK value.
<code>expire (pkd)</code>	<p>The CM registered, but network access for CPE devices that use this CM has been disabled through the DOCSIS configuration file. In addition, BPI is enabled and the KEK was assigned; but the current KEK expired before the CM could successfully renew a new KEK value.</p> <p>Note: This state is equivalent to the <code>online (d)</code> and <code>expire (pk)</code> states.</p>

expire (pt)	The CM registered, BPI is enabled, and the TEK was assigned; but the current TEK expired before the CM could successfully renew a new KEK value.
expire (ptd)	<p>The CM registered, but network access for CPE devices that use this CM has been disabled through the DOCSIS configuration file. In addition, BPI is enabled and the TEK was assigned; but the current TEK expired before the CM could successfully renew a new KEK value.</p> <p>Note: This state is equivalent to the <code>online (d)</code> and <code>expire (pt)</code> states.</p>

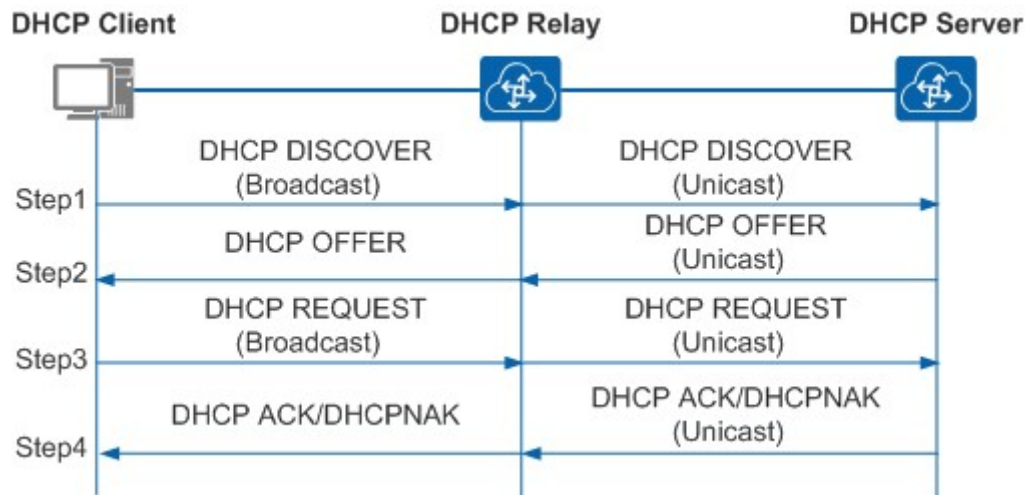
Error Status Conditions

MAC State Value	Description
reject (m)	<p>The CM attempted to register, but registration was refused due to a bad Message Integrity Check (MIC) value. This also could indicate that the shared secret in the DOCSIS configuration file does not match the value that is configured on the CMTS with the cable shared-secret command. In Cisco IOS Software Release 12.1(11b)EC1 and 12.2(8)BC2 or later releases, this could also indicate that the cable tftp-enforce command has been used to require that a CM attempt a TFTP download of the DOCSIS configuration file before it registers, but the CM did not do so.</p>
reject (c)	<p>The CM attempted to register, but registration was refused due to a a number of possible errors:</p> <ul style="list-style-type: none"> • The CM attempted to register with a minimum guaranteed upstream bandwidth that would exceed the limits imposed by the cable upstream admission-control command. • The CM has been disabled because of a security violation. • A bad class of service (CoS) value in the DOCSIS configuration file. • The CM attempted to create a new CoS configuration but the CMTS is not configured to permit such changes. • The CM failed the timestamp check for its DOCSIS configuration file. (This could indicate a possible theft-of-service attempt, or a problem with the synchronization of the clocks on the CM and CMTS.)
reject (pk)	The KEK key assignment is rejected and BPI encryption has not been established.
reject (pkd)	<p>The CM registered, but network access for CPE devices that use this CM has been disabled through the DOCSIS configuration file. In addition, BPI encryption was not established because KEK key assignment was rejected.</p> <p>Note: This state is equivalent to the <code>online (d)</code> and <code>reject (pk)</code> states.</p>
reject (pt)	The TEK key assignment is rejected and BPI encryption has not been established.
reject (ptd)	The CM registered, but network access for CPE devices that use this CM has been disabled through the DOCSIS configuration file. In addition, BPI encryption was not established because TEK key assignment was rejected.

	Note: This state is equivalent to the <code>online(d)</code> and <code>reject(pt)</code> states.
Note: In Cisco IOS Software Release 12.1(20)EC, 12.2(15)BC1, and earlier, when network access is disabled in the DOCSIS configuration file sent to the CM, the network disabled status takes precedence, and the MAC status field shows <code>online(d)</code> even if BPI encryption fails. Issue the show cable modem mac-address command to confirm whether BPI is enabled or disabled for a particular cable modem.	
<code>reject(ts)</code>	The CM attempted to register, but registration failed because the TFTP server timestamp in the CM registration request did not match the timestamp maintained by the CMTS. This might indicate that the CM attempted to register by replaying an old DOCSIS configuration file used during a prior registration attempt.
<code>reject(ip)</code>	The CM attempted to register, but registration failed because the IP address in the CM request did not match the IP address that the TFTP server recorded when it sent the DOCSIS configuration file to the CM. IP spoofing could be occurring.
<code>reject(na)</code>	The CM attempted to register, but registration failed because the CM did not send a Registration-Acknowledgement (REG-ACK) message in reply to the Registration-Response (REG-RSP) message sent by the CMTS. A Registration-NonAcknowledgement (REG-NACK) is assumed.
Note: The cable modem cannot transmit or receive Internet Protocol (IP) traffic when in a <code>reject(xx)</code> state. The maximum data rate is fixed at 1 KBit/sec in each direction. CMTS discards all packets.	

DHCP:

Típicamente en DOCSIS se usa un esquema de “Relay DHCP” en donde los cablemodems inician el dialogo DHCP y los relay-dhcp del CMTS le pasan la petición al DHCP Server que corresponda, cuando el DHCP contesta a esa petición al CMTS este le pasa el resultado al cable modem. En este caso el servidor DHCP no se encuentra en la misma red de los cable modems y de hecho hay un DHCP Server distinto por cada clase de dispositivo (*Cable modem, Host (PC o router conectado al cable modem), MTA (interfaz telefónica), etc.*), los mismos pueden estar en el mismo servidor físico o en diferentes servidores según convenga y el CMTS apunta a cada uno de ellos mediante la instrucción “cable helper”



Ejemplo:

```
interface ip-bundle 1
  ip address 10.30.192.1 255.255.255.0
  ip address 10.32.192.1 255.255.255.0 secondary
  ip address 10.31.192.1 255.255.255.0 secondary
  cable helper-address 10.100.2.233 cable-modem
  cable helper-address 10.100.2.9 host
  cable helper-address 10.100.2.233 mta
```


Diagrama de conexión completo DOCSIS:

Para poder funcionar un cable modem necesita de los siguientes servicios disponibles en la red donde está conectado,

- 1.- DHCP.
- 2.- TFTP (Trivial file transfer Protocol).
- 3.- ToD (Time of Day).

