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MULTIMEDIA SIGNALS

Interactive systems for digital television distribution

Timing interface for cable modem termination systems

ITU-T Recommendation J.211



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Timing interface for cable modem termination systems

Summary

The timing interface for cable modem termination systems (DTI) defined in ITU-T Recommendation J.211, supports the accurate and robust transport of the DTI server 10.24-MHz master clock, 32-bit cable modem termination timestamp, and time of day, to the DTI client within the modular cable modem termination system (M-CMTS) cable network. The DTI protocol is structured to minimize the complexity and cost of the DTI client clocks, and the per-port cost of the shared server function while supporting all S-CDMA and TDMA timing requirements.

Source

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Timing interface for cable modem termination systems

1 Scope

The requirements for timing and synchronization of the DOCSIS system come from the following areas.

- existing DOCSIS specification and testability requirements;
- remote PHY system requirements;
- implementation requirements;
- services like T1 or E1 and wireless.

These requirements place definitions and constraints on the use of the DOCSIS master clock and the DOCSIS timestamp, which is delivered in the SYNC message. The DOCSIS specification originally envisioned the M-CMTS-CORE, EQAMs, and upstream receive functions on one assembly, fed with a common clock. The timestamp counter resides in the M-CMTS-CORE function.

The M-CMTS™ Remote PHY architecture may result in three components: the M-CMTS-CORE, the upstream receiver, and the EQAM being located in a different chassis, and potentially at different physical locations. As a system, the three components comply with the DOCSIS specification and any existing CMTS equipment.

The DOCSIS timing protocol (DTI) defined in this Recommendation, supports the accurate and robust transport of the DTI server 10.24-MHz master clock, 32-bit DOCSIS timestamp, and time of day, to the DTI client within the DOCSIS M-CMTS cable network. The DTI protocol is structured to minimize the complexity and cost of the DTI client clocks, and the per-port cost of the shared server function while supporting all S-CDMA and TDMA timing requirements.

To support regional differences in master clock frequency, two DTI client options are defined, one producing a 10.24-MHz master clock output, and another producing a 9.216-MHz master clock output. A single DTI server master clock frequency of 10.24 MHz supports DTI clients of both types.

1.1 System requirements

The DTI system requirements refer to the DOCSIS timing requirements as outlined in the DOCSIS specification. These requirements are presented independent of the CMTS architecture.

The clauses of the DOCSIS specification [ITU-T J.122] that are of interest are:

- 6.2.11.2 Mini-slot numbering
- 6.2.21.8.2 Chip timing jitter for synchronous operation
- 6.3.7 CMTS timestamp jitter
- 6.3.8 CMTS clock generation
- 6.3.9 CMTS downstream symbol clock jitter for synchronous operation
- 6.3.10 CMTS downstream symbol clock drift for synchronous operation
- 9.3 Timing and synchronization

1.2 TDM services consideration

To maintain compatibility with the TDM service synchronization hierarchy, the DTI server clock operates with the specifications detailed in clause 8.1 which integrate both the DOCSIS timing system requirements and the existing legacy synchronization network clock consistent with [ITU-T G.812] and [T1.101]. This is done to ensure that the CM supporting TDM services can derive its clocking and meet [ITU-T G.823] or [ITU-T G.824] jitter and wander requirements for both traffic-bearing and synchronization-bearing transport clock sources.

Support of TDM services will require that the master clock and the downstream symbol clock be locked and upstream and downstream clocks be coherent.

1.3 Modular implementation requirements

The M-CMTS-CORE element:

- uses the DTI server master clock for creating a timestamp;
- uses the timestamp for MAP generation.

The Edge QAM element:

- uses the DTI server master clock for symbol rate generation;
- uses the timestamp for inserting and/or correcting SYNC messages.

The Upstream receive element:

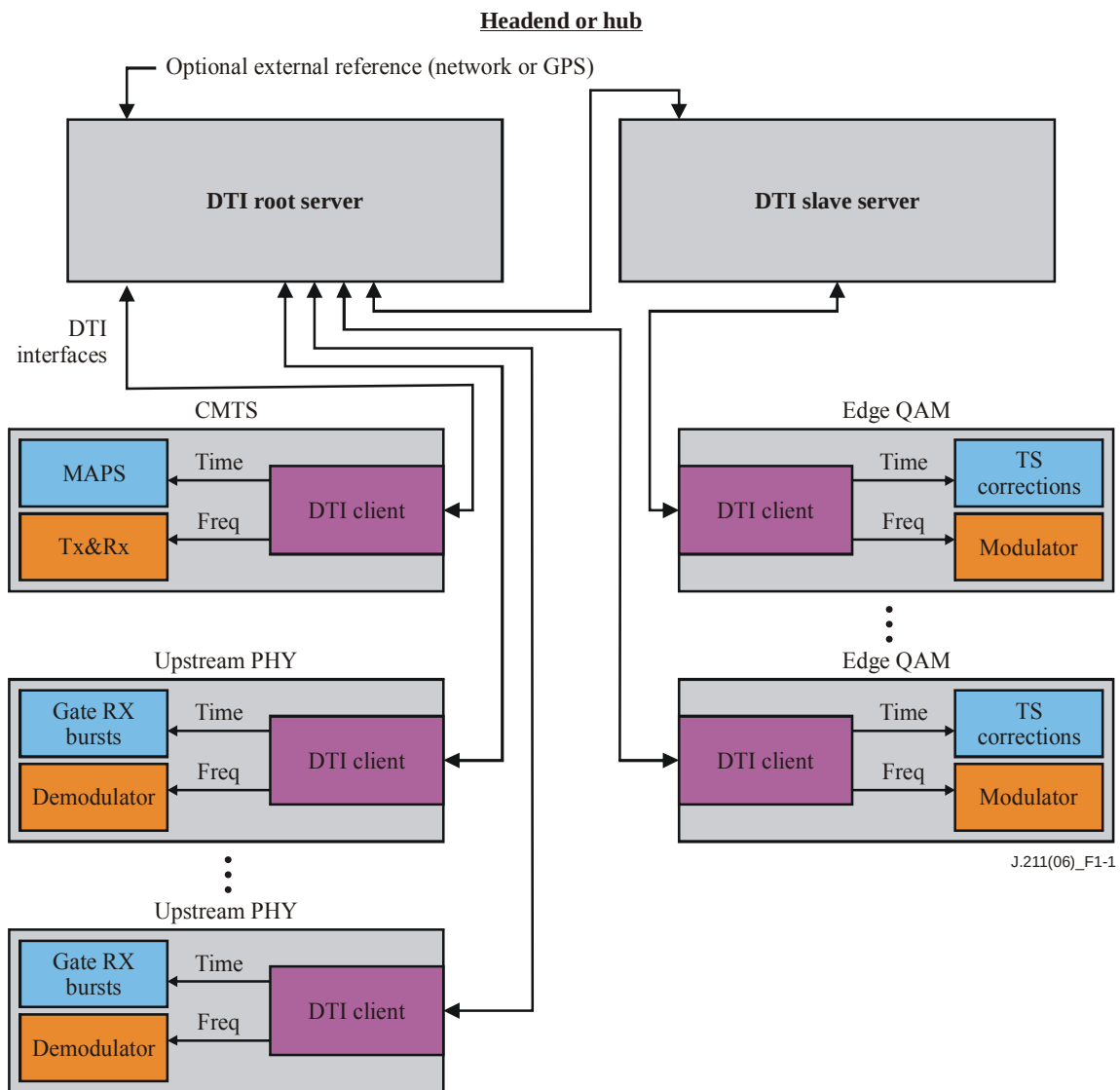
- uses the timestamp and/or S-CDMA frame and the MAP for determining when to look for the start of a receive burst;
- uses a clock locked to the master clock for reception of symbols in S-CDMA mode.

1.4 Architecture

Figure 1-1 shows frequency and timing distribution examples for both headend and hub. The DTI server establishes the reference for the timing distribution network and synchronizes all connected DTI clients via point-to-point connections between the server and each client. A single protocol initiated by the DTI server permits the client to perform frequency and time synchronization. As shown, upstream receive, Edge QAMs, and the M-CMTS-CORE may have different uses for the synchronized frequency and time, but utilize a common client function.

The DTI protocol and server-client interactions are described in detail in clauses 7 and 8. The essential characteristics are:

- The DTI server initiates the protocol, which the DTI client uses to establish its time and frequency synchronization.
- Using a ping-pong scheme, the client always immediately replies to the DTI server when it receives a transmission from the DTI server. The server uses this response to auto-compensate any delays with the effect that the client becomes precisely synchronized to the server.
- The server-to-client-to-server handshake continually repeats, assuring that a tight synchronization can be maintained.



NOTE – CMTS Core, Upstream PHYs and Edge QAMs can be configured for redundancy.

DTI Servers can be configured redundantly and a slave server can be connected to a master server up to a depth of 1 from the master. All DTI links from a DTI Root Server and connected DTI Slave Servers will be synchronous as if they came from the same server.

Figure 1-1 – Timing architecture

The DTI protocol and components support accurate and robust transport of the server 10.24-MHz master clock and 32-bit DOCSIS timestamp to the client within a node or building. The protocol is structured to minimize the complexity and cost of the client clocks and the per-port cost of the shared server function while supporting all the DOCSIS S-CDMA, TDMA and future TDM services timing requirements in a modular system.

The high accuracy (<5 ns) and high stability (<1-ns timing jitter budget) is achieved by using a simple ping-pong layer-2 timing protocol over a single twisted pair connection using common passive PHY components in both directions. This structure provides delay reciprocity so that all cable delay processing can be performed in the server. The client's role in delay correction is to provide a fixed delay response to the server frame and to use the cable advance supplied by the server to advance the local 10-kHz DTI frame clock to correct for cable delay.

To ensure reliable transport and client clock operation, the client clock is required to report the current phase error of its local clock (frame clock) with respect to the delay-corrected server frame clock. This measurement is reported to the server at the 10-kHz frame rate. The server's role is to process this measurement data and verify the client's timing operation. This protocol supports real-time detection and mitigation of client clock faults.

The DTI client can be realized with a single digital component, a simple PHY and a low-cost local oscillator, as holdover and filtering are supported in the shared server. A common definition of the DTI high-speed clock is necessary to ensure compatibility between all DOCSIS DTI client components.

1.5 Synchronization needed for TDM services deployment

The deployment of TDM services compliant with the existing telecommunications TDM standards (e.g., T1 or E1) will require both synchronization and traceability to a common external clock source. In this case, if a cable modem supporting TDM services is connected to an M-CMTS EQAM, the cable modem will need to be synchronized with the DTI server operating with an external TDM service reference.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

- [ITU-T G.812] ITU-T Recommendation G.812 (2004), *Timing requirements of slave clocks suitable for use as node clocks in synchronization networks*.
- [ITU-T G.823] ITU-T Recommendation G.823 (2000), *The control of jitter and wander within digital networks which are based on the 2048 kbit/s hierarchy*.
- [ITU-T G.824] ITU-T Recommendation G.824 (2000), *The control of jitter and wander within digital networks which are based on the 1544 kbit/s hierarchy*.
- [ITU-T J.122] ITU-T Recommendation J.122 (2002), *Second-generation transmission systems for interactive cable television services – IP cable modems*.
- [ISO/IEC 8802-3] ISO/IEC 8802-3:2000, *Information technology – Telecommunications and information exchange between systems – Local and metropolitan area networks – Specific requirements – Part 3: Carrier sense multiple access with collision detection (CSMA/CD) access method and physical layer specifications*.
- [T1.101]*⁾ ANSI T1.101 (1999), *Synchronization Interface Standard*.

2.1 Reference acquisition

- American Institute of Electrical Engineers, Internet: <http://www.ieee.org/portal/site>
- American National Standards Institute, Internet: <http://webstore.ansi.org>

*⁾ T1 standards are maintained since November 2003 by ATIS.

3 Terms and definitions

This Recommendation defines the following terms:

3.1 bridging mode: A short-term operating condition of the DTI clock where the DTI client has recently lost its controlling input and is using stored data, acquired while in normal or fast mode operation, to control its output. While in bridging, the degree of deviation of the output is deemed to be such that DTI client clock is still performing within normal or acceptable limits. If an outage period persists, the DTI client clock will transition to the holdover mode indicating that the DTI client clock output may be degraded.

3.2 DTI minimum clock oscillator: An oscillator that supports all the client clock performance requirements with holdover limited to the minimum bridging time. A non-ovenized oscillator can be used to support this oscillator category.

3.3 fast mode: An operating condition of a clock in which it is locked to an external reference and is using time constants, which are reduced to quickly bring the local oscillator's frequency into approximate agreement with the synchronization reference frequency.

3.4 free-run mode: An operating condition of a DTI clock whose output signals are internally controlled by the DTI server. The clock has never had, or has lost, external reference input and has no access to stored data that was acquired from a previously connected external reference during the time after the last power cycle. Free-run ends when the clock output is influenced by an external reference or the process to achieve lock to an external reference. Free-run may provide needed stability when external reference has been lost or not equipped.

3.5 gpssec: The gpssec is a 32-bit timestamp counter that is incremented every second. GPS system time began on January 6, 1980. The gpssec value was set to zero at the January 6, 1980 start epoch.

3.6 holdover mode: An operating condition of a DTI clock that has lost its controlling input and is using stored data, acquired while in normal or fast mode operation, to control its output. The stored data is filtered to minimize the effects of short-term variations and to establish a predictor of oscillator behaviour during the reference outage. This permits the output deviation from normal operation to be minimized.

3.7 maximum time interval error (MTIE): For a sequence of time delay samples x_i , MTIE at observation time (S) is:

$$\text{MTIE measurement: } MTIE(S) = \max_{j=1}^{N-n+1} \left[\max_{i=j}^{n+j-1} (x_i) - \min_{i=j}^{n+j-1} (x_i) \right]$$

where:

τ_o = sample period

N = number of samples in the sequence

$n = \lceil S/\tau_o \rceil + 1$

S = observation time

x_i = time delay sample

3.8 normal mode: An operating condition of a clock in which the output signals are controlled by an external input reference. The expected mode and state permits each clock within a distribution to have the same long-term average frequency and time. Clocks in this mode are referred to as locked meaning that they are in tight relationship with the DTI root clock. A DTI server clock in a fault-free free-run mode will be considered in normal mode.

3.9 root DTI server: The DTI server that is the source of traceable time and frequency for all subtending DTI servers and clients in a building.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

CM	Cable Modem
CMTS	Cable Modem Termination System
CRC	Cyclic Redundancy Check
DEPI	Downstream External PHY Interface
DOCSIS	Data-Over-Cable Service Interface Specification
DS	Downstream
DTI	DOCSIS Timing Interface
DTS	32-bit DOCSIS Time Stamp
EQAM	Edge QAM (A network element which receives MPEG-TS frames over a network interface such as Ethernet, and modulates them onto QAM carriers for use on a HFC plant)
ERMI	Edge Resource Manager Interface
GE	Gigabit Ethernet (1 Gbit/s)
GPS	Global Positioning System
IE	Information Element (An element of a MAP message)
IP	Internet Protocol
M-CMTS	Modular CMTS
MAC	Media Access Control (Used to refer to the layer-2 element of the system, which would include DOCSIS framing and signalling)
MPEG	Motion Picture Experts Group
MPEG-TS	Motion Picture Experts Group Transport Stream
MTIE	Maximum Time Interval Error
NCO	Network Controlled Oscillator
PCR	Program Clock Reference
PHY	Physical Layer (Used to refer to the downstream QAM transmitters and the upstream burst demodulators (receiver))
PID	Packet Identifier used in MPEG-TS
PLL	Phase-Locked Loop
PUSI	Payload Unit Start Indicator
QAM	Quadrature Amplitude Modulation
S-CDMA	Synchronous Code Division Multiple Access
TDM	Time Division Multiplexing
TDMA	Time Division Multiple Access
TDM Services	Legacy T1/E1 or T3/E3 voice and/or data transport
UDP	User Datagram Protocol
US	Upstream

UTC Coordinated Universal Time (Also known as Greenwich Mean Time (GMT) or Zulu time)

5 Conventions

Throughout this Recommendation, the words that are used to define the significance of particular requirements are capitalized. These words are:

- "MUST" This word or the adjective "REQUIRED" means that the item is an absolute requirement of this Recommendation.
- "MUST NOT" This phrase means that the item is an absolute prohibition of this Recommendation.
- "SHOULD" This word or the adjective "RECOMMENDED" means that there may exist valid reasons in particular circumstances to ignore this item, but the full implications should be understood and the case carefully weighed before choosing a different course.
- "SHOULD NOT" This phrase means that there may exist valid reasons in particular circumstances when the listed behaviour is acceptable or even useful, but the full implications should be understood and the case carefully weighed before implementing any behaviour described with this label.
- "MAY" This word or the adjective "OPTIONAL" means that this item is truly optional. One vendor may choose to include the item because a particular marketplace requires it or because it enhances the product, for example; another vendor may omit the same item. Optional features implemented, MUST meet the defined requirements.

6 Physical layer requirements

This clause specifies the physical layer requirements of the DTI protocol.

6.1 Introduction

The DTI link comprises the connection between a DTI server and various other elements, such as M-CMTS-CORE, EQAM and US receivers collocated in the node that derive their clocking (time and frequency) from the DTI server. Since the link resembles an Ethernet (802.3) 10BaseT link, it is advantageous to leverage the availability and cost effectiveness of this standard. This Recommendation defines the differences between the DOCSIS timing interface and a conventional 802.3-10BaseT interface. Table 6-1 indicates the similarity between the two links.

Table 6-1 – Physical layer comparisons

Characteristics	Ethernet 802.3-10BaseT	DOCSIS timing interface
Data rate (Mbit/s)	10	5.12
Accuracy	Free-running; 100 ppm	Traceable to Master Clock
Transmission mode(s)	Full/half duplex (Note 1)	Ping-Pong (Note 1)
Topology	Star (Note 2)	Star (Note 2)
Maximum segment length	100 m	200 m
Media	UTP	UTP
Signalling method	Baseband	Baseband
Modulation	Manchester	Manchester

Table 6-1 – Physical layer comparisons

NOTE 1 – Conventional Ethernet 802.3 transceivers use separate wire pairs for transmission in the two directions. The DTI uses a ping-pong scheme whereby the same pair is used for transmission in both directions. This ensures the maximal reciprocity, minimizing the asymmetry in transmission delay between the two directions and minimizes crosstalk.

NOTE 2 – Conventional Ethernet installations utilize a star-wiring configuration where the "common" point is a switch or hub. In the DTI scenario, the common point is the DTI server.

The governing standard for Ethernet (physical layer) is [ISO/IEC 8802-3]. The physical layer specifications (primarily section 14 of the standard) are applicable here.

6.2 Physical connector description

The DTI server, as well as the DTI client, MUST have an RJ45 (female) connector for each DTI link. This permits conventional Ethernet cabling techniques to be applied. See [ISO/IEC 8802-3], section 14.5.1. One distinction is that the DTI utilizes a single pair for transmission in both directions. Therefore, a crossover function is not required. Contacts 1 and 2, labelled "SIG+" and "SIG–" will be used for the ping-pong transmission.

The cable interconnect MUST be as defined in Table 6-2.

Table 6-2 – DTI RJ45 interconnect

RJ45 pin number	Signal	Comment
1	SIG+	10BaseT compliant
2	SIG–	10BaseT compliant
3	NC	
4	NC	
5	NC	
6	NC	
7	NC	
8	NC	

6.3 Cable requirements

The DTI MUST operate normally over a maximum of 200 metres of UTP cable rated at category 5E or better.

6.4 Electrical description

6.4.1 Impedance

The termination impedance MUST be 100 ohms. The differential output impedance as measured on the TD circuit MUST be compliant with section 14.3.1.2.2 of [ISO/IEC 8802-3]. The transmitter impedance balance, or the ratio of common-mode to differential-mode impedance balance of the TD circuit MUST exceed $29 - 17 \log_{10}(f/10)$ dB, where f is the frequency in MHz, over the frequency range 1.0 MHz to 20 MHz (see section 14.3.1.2.4 of [ISO/IEC 8802-3]).

6.4.2 Isolation

There MUST be isolation between the physical layer circuits, including frame ground, and all leads including those not used by the DTI link. The isolation requirement follows [ISO/IEC 8802-3], section 14.3.1.

6.4.3 EMI considerations

The DTI link will comply with applicable local and national codes for limitation of electromagnetic interference.

6.4.4 Signal strength (voltage)

The per-symbol peak differential voltage on the SIG $\pm$ signals at the DTI server, when terminated in a 100- Ω resistive load MUST be between 2.2 V and 2.8 V for all data sequences. For an all-ones Manchester-encoded pattern, any even harmonic measured on the TD circuit MUST be at least 27 dB below the fundamental. The magnitude of the total common-mode output voltage MUST be less than 50 mV peak.

6.4.5 Common-mode rejection

Given application of common-mode voltage of 15 V peak $\sim$ 10 MHz sine wave (see section 14.3.1.2.6 of [ISO/IEC 8802-3]) the differential-mode voltage MUST NOT change by more than 100 mV for all data sequences. The edge jitter introduced MUST be less than 3 ns.

6.4.6 Signal description

The transmission between the DTI server and the DTI client MUST be ping-pong in nature, using the same pair of wires for transmission in both directions. The data pattern MUST be Manchester encoded with an underlying bit rate of 5.12 Mbit/s, locked to the DTI master clock.

7 DOCSIS timing protocol

See clause 1.1 for an informational description of the DTI protocol.

7.1 DTI timing entities

The DTI protocol is supported by two terminated entities:

- 1) DTI server;
- 2) DTI client.

DTI server and client functional entities are part of the M-CMTS architecture. The DOCSIS client function is structured to permit a low-cost client clock function within all EQAMs, upstream receivers, and M-CMTS-CORE entities.

The DTI server SHOULD support multiple client functions to support scalable growth of DTI port capacity within a node or building.

The DTI server MUST support a SNMP management interface, IP addressing and use RJ45 connectors.

A DTI server in a single building MAY consist of active and backup servers components in a common shelf and/or DTI servers in subtending shelves.

A DTI server MAY support at least one of the following two capabilities:

- 1) operation as a subtending server;
- 2) provide DTI outputs capable of supporting DTI subtending servers.

The following accuracy requirements may be confirmed with a delay-calibrated client. A delay-calibrated client provides sufficient measurement points to determine current calibrated delay bias.

All DTI root server outputs MUST meet a 1.25-ns accuracy requirement when tested with a delay-calibrated client with respect to the DTI root server master clock test port with correction for test port group delay.

All DTI subtending server outputs **MUST** meet a 2.5-ns accuracy requirement when tested with a delay-calibrated client with respect to the DTI root server master clock test port with correction for test port group delay.

A DTI output that can support a subtending DTI server **MUST** meet a 1.25-ns accuracy requirement when tested with delay-calibrated client under normal operating conditions. An M-CMTS EQAM, M-CMTS-CORE or a separate upstream receiver **MUST** support at least one DTI client interface.

A DTI server in slave mode is intended to only accept a DTI input from a root server.

An M-CMTS device **MAY** support multiple DTI clients if protection for a DTI interconnect cable loss is desired.

If an M-CMTS device has more than one DTI client, it **MUST** not switch to a protection client as a result of a loss of DTI input until a minimum timeout of 500 ms.

7.2 DTI timing structure

Figure 7-1 defines the structure of the DOCSIS timing protocol as:

- sent by the server;
- received by the client after the cable delay; and
- output at the Client Test Port after the cable advance correction.

The highest-level structure is the DTI timeslot. A DTI timeslot occupies 1024-master clock (10.24 MHz) periods spanning $1/10 \text{ kHz} = 100 \mu\text{s}$. A bit period consists of two consecutive master clock counts starting with an even count, resulting in 512-bit periods in a DTI timeslot. The timeslot is synchronized to the DOCSIS 32-bit timestamp (DTS), such that the current bit period of a timeslot is the integer, as follows:

$$\text{current_bit_count} = \text{floor}[(\text{DTS mod } 1024)/2]$$

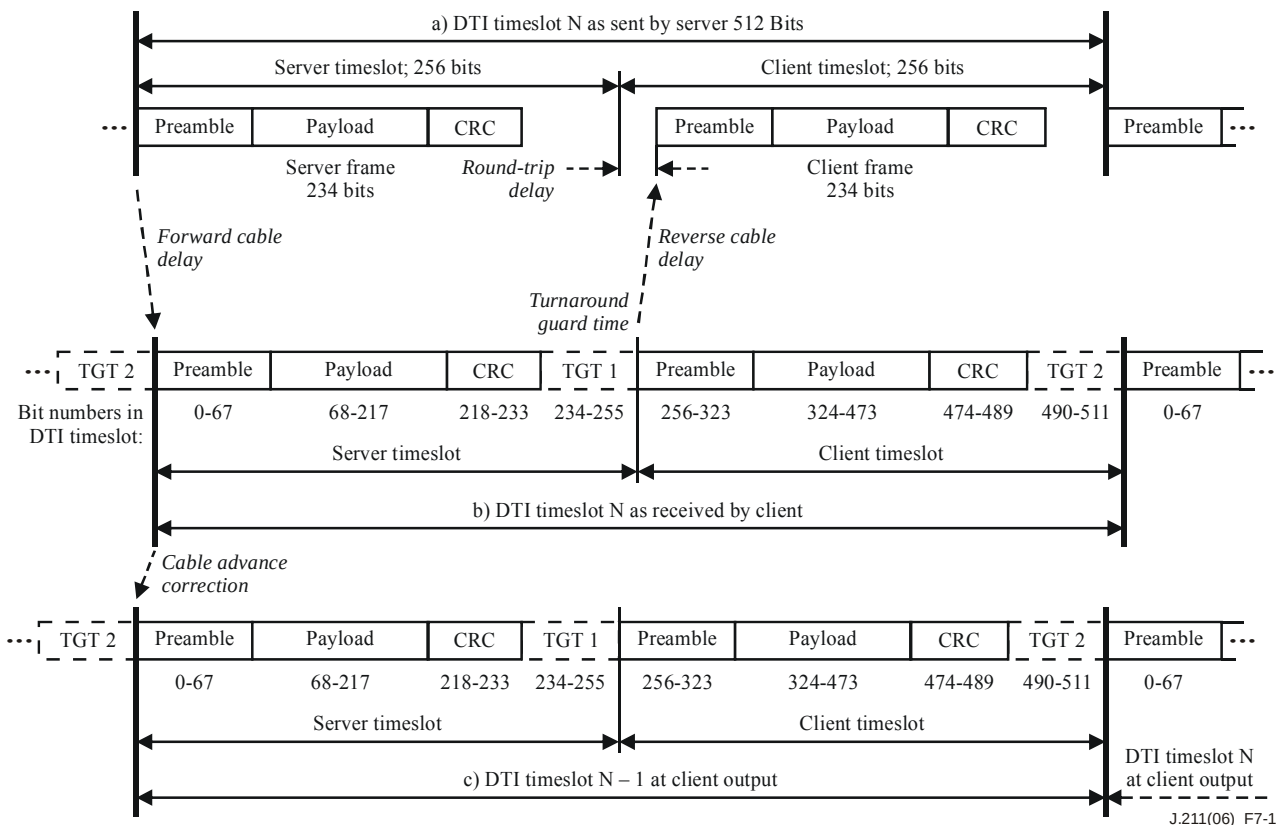


Figure 7-1 – DTI protocol timing structure

The client's received DTI timeslot timing is offset from the server's DTI timeslot timing by the cable propagation delay (plus any group and logic delays). Since the client when in steady state tracks the server, the client counts off a continuous succession of bit slots timed on its own 5.12 MHz-bit clock, repeating DTI timeslots seamlessly modulo 512 bits. The client always receives the first preamble bit from the server in bit slot 0. When it transmits, the client MUST transmit the first bit of its preamble in bit slot 256.

The DTI protocol is ping-pong in nature. The server and client share the line using time division duplexing (TDD), one transmitting while the other receives. The DTI timeslot is divided into two equal intervals: the server timeslot and client timeslot. Layer 2 communication protocol data units (PDUs) are termed "Frames". Both server and client frames are 234 bits in length, and each is followed by a 22-bit turnaround guard time (TGT). The purpose of TGT1, located after the server frame, is to allow time for the client to complete its CRC processing and perform receive/transmit switching on the line after receipt of the server frame. The purpose of TGT2, located after the client frame, is to provide for the round-trip delay of the cable, ensuring that the client frame has been received by the server before the server begins transmitting the next server frame, including time for the server to perform receive/transmit switching on the line after receipt of the client frame. Each TGT provides approximately 4.3 μ s of guard time, which well exceeds the maximum round-trip delay for 200 m cable of approximately 2 μ s.

At the client output, the DTI frame timing is adjusted earlier in time by the cable advance correction sent by the server, in order to align the client output frame timing closely with the server frame timing. To allow for causality, the data received during the previous frame is buffered and output by the client after the CRC check has completed.

7.3 Traceability of DOCSIS timestamp

Time of coincidence (TOC) is an important concept to understand the relationship of any DTI timestamp (DTS) 32-bit counter to GPS system time. GPS system time began on January 6, 1980. GPS receivers will provide a 32-bit gpssec timestamp that was zero at the January 6 start epoch. The gpssec is a 32-bit timestamp counter that is incremented every second. The DTS is also a 32-bit timestamp counter that is incremented every 10.24-MHz master clock. The objective is to map the current GPS system time to the current DOCSIS timestamp in a coherent manner.

By definition, the DTS can be assigned the value of zero at the same January 6, 1980 start epoch. At the next second, the DOCSIS timestamp will advance 10'000 timeslots with 1024-MHz master clocks per timeslot, so the DTS should be 10'240'000.

The TOC is the next integer gpssec when the DTS will be exactly zero. This will occur every 262'144 seconds ($\sim$ every 3 days)¹. If a reset to zero process were used to synchronize every DTS counter in a server, then it would require up to three days to align a server at start-up. The approach is to generate an initial value for DTS by a mapping function so that the alignment can occur on any one-second boundary.

The mapping function from gpssec to DTS in the DTI server MUST be:

$$DTS = 2^{10} * [(10'000 * (gpssec \bmod 262144)) \bmod 2^{22}]$$

A client that implements the 10.24-MHz master clock option will use the server DTS directly. A client that implements the 9.216-MHz master clock option will map gpssec to a 9.216-MHz DTI client DTS according to the formula provided in 8.2.

¹ The gpssec time-scale will roll over every 136 years. Since there are exactly 16'384 TOC events between roll overs, there is no disruption of the DTS.

The four time-of-day setting modes are:

- 1) GPS;
- 2) User time set;
- 3) Default time set;
- 4) Network timing protocol (NTP) version 4 or greater.

The GPS traceability mode provides the most precise time setting capability. Regardless of the time of day mode, the DTI server **MUST** convert time of day information to the equivalent gpssec value.

The user time set permits a user to enter an approximate time of day setting through either a local or remote user interface. The default time set operation, if selected, will establish a coarse time of day setting after a reset or power cycle. The time of day is based on the current value of the real time clock in the server.

The NTP time set mode if supported will allow the DTI server to establish a time setting via the NTP protocol as currently configured in the DTI server. If NTP time mode is supported, the DTI server **MUST** support NTP version 3 or higher.

The DTI server **MUST** support a means to configure the time of day setting modes of user time set, default time set, NTP or GPS.

7.3.1 GPS frequency mode

In order to provide continuity in the DTI timebase when transitioning from free-run mode or network mode to GPS mode, an intermediate state, "GPS frequency mode", is defined. When the DTI server transitions from free-run or network mode to GPS frequency mode, the DTI server's 10.24-MHz output frequency is adjusted smoothly so as to track the GPS system frequency, while maintaining continuity of the DTI time counters. The system may remain in GPS frequency mode for an extended period of time. If and when the DTI server transitions from GPS frequency mode to GPS mode, the DTI time counters are realigned to GPS time; this may be done in a discontinuous manner during a scheduled maintenance period.

When transitioning from free-run or network mode to GPS mode, the DTI server **MUST** enter the GPS frequency mode first.

In GPS frequency mode, the DTI server **MUST** maintain the existing time setting mode and validity state unless changed as a result of user time setting input.

The DTI server **MUST** support a user input to schedule a transition time from GPS frequency mode to GPS mode.

The DTI server operating in normal lock in GPS frequency mode **MUST** meet the same MTIE requirements as in GPS mode.

During the transition from free-run to GPS frequency mode normal lock, all DTI server free-run requirements **MUST** be met.

During the transition from normal lock network to GPS frequency mode normal lock, all DTI server normal lock network MTIE requirements **MUST** be met.

Under extended GPS holdover conditions, it is possible to enter the degraded MTIE region of performance. The DTI server needs to support a graceful recovery from this state if it should arise. The following requirement applies:

When recovery from a GPS degraded condition, the DTI server **MUST** support the ability to slew the frequency to accommodate at least 1 ms of offset over a recovery period of less than 24 hours without exceeding the free-run performance limits.

In user mode and default mode, there are no requirements to adjust the DTI time-scale and ToD output after the initial time setting. The DTI time services are for local use only and not traceable to GPS system time.

If the DTI server supports frequency adjustment of the time-scale in NTP mode, the vendor SHOULD specify the time accuracy performance under vendor-defined NTP configuration(s).

If the DTI server supports frequency adjustment of the time-scale in NTP mode, the DTI server output performance requirements MUST meet the performance requirement of the system operation mode (free-run or network).

If frequency adjustment of the time-scale in NTP mode needs to be suspended to prevent degradation of output, the DTI server MUST report this condition.

If the user requests a transition from user or default time setting to NTP after warm-up, the DTI server MAY reject the request if the transition would degrade the output performance.

7.4 DTI frame structure requirements

The DTI frame structure MUST consist of a preamble followed by the payload and finally by a 16-bit CRC as shown in Figure 7-2. The length of the DTI frame, including the preamble and the CRC MUST be 234 bits. The CRC MUST be calculated only on the payload bits. The rising edge of the 10-kHz DTI frame clock MUST be aligned with the leading edge of the first bit of the preamble of the DTI server. The client digital clock recovery circuit MUST be tolerant to missing clocks since any bit error in the frame will prevent the CRC OK flag in the client CRC checker from being asserted.

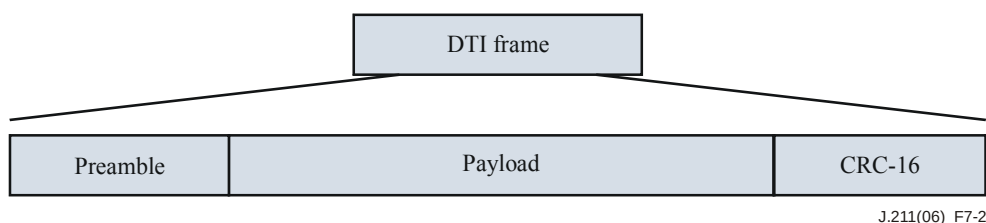


Figure 7-2 – DTI frame structure

7.4.1 Conventions for this Recommendation

In this Recommendation, the following convention applies any time a bit field is displayed in a figure. The bit field should be interpreted by reading the figure from left to right, then from top to bottom, with the MSB being the first bit so read and the LSB being the last bit so read. The DTI frames are transmitted most significant element first. Within bit fields, the most significant bit MUST always be transmitted on the wire first. There are nine bit fields that constitute a frame in each direction. Fields MUST transmit in numerical order from lower to highest value (see Tables 7-1 and 7-2 for field order).

7.4.2 Server to client

The frame structure in the server-to-client direction MUST operate as shown below in Table 7-1.

Table 7-1 – DTI server frame structure

Field	Name	Size (Bits)	Description
1	Preamble	68	Preamble of 0xAAAA AAAA AAAA AAAA 9 prior to Manchester encoding
2	Device type	8	Byte describing type of server
3	Server status flags	8	8 flag bits identifying server status
4	DOCSIS upper timestamp	22	22 most significant bits of the DTS
5	Time of day	10	Field supports serial ToD message over multiple frames
6	Cable advance	24	Integer and fractional cable advance
7	Path traceability field	10	Field supports serial Path Traceability Message over multiple frames
8	Reserved	68	All bits set to "1"
9	CRC-16	16	16-bit CRC which covers all bits except preamble
	Total payload bits	234	

In the server-to-client direction, the DTI frame structure details are as follows.

7.4.2.1 Preamble

The 68-bit preamble is used to align the digital clock recovery circuit on the client and to locate the bit transitions in the Manchester coding that contain information. The pattern "1001" (0x9) at the end of the preamble locates the beginning of the payload.

7.4.2.2 Device type

The 8-bit device type field is used to identify the type of server and its timing source. The bits in this field MUST be assigned as shown below:

Bit 7:5 *External timing source (for root server)*

- 000: Server has no external timing source
- 001: Server is receiving external timing from GPS
- 010: Server is receiving timing from a network
- 011-111: Reserved

Bit 4:3 *Server hop count*

- 00: Server is the root DTI server for the office distribution
- 01: Server is directly connected to root DTI server
- 10-11: Reserved