- T-Carrier Technologies -

T-Carrier Fundamentals

T-Carrier systems provide *digitized* communication for voice or data traffic across a telephone provider's network. The T-Carrier specification defines the Layer-1 aspects of the multiplexed communication. The two most prevalent T-Carrier systems are **T1** and **T3** circuits**.**

The **Digital Signal (DS)** refers to the *signaling rate* and *framing* of the T-Carrier. The basic unit is the **DS0,** referred to as a **channel** or **timeslot**. The DS0 channel was designed to support one voice call, with a throughput of **64 kbps**.

It is possible to **multiplex** multiple DS0's to form a higher-capacity link:
- A **T1** circuit consists of **24 DS0 channels**, for a total throughput of **1.544 Mbps.**
- A **T3** circuit consists of **672 DS0 channels**, or **28 T1** circuits, for a total throughput of **44.736 Mbps**.

It is also possible to utilize only a subset of channels on a T1, referred to as a **fractional T1** (or **frac T1).**

The terms T1 and DS-1 are often (incorrectly) used interchangeably to refer to a 24-channel multiplexed line. Remember: the term *T1* refers to the *hardware* aspect of the technology, whereas *DS1* refers to the *framing*.

A T1 line can operate over as few as **two copper pairs** (4 wires). One pair is used to **transmit** data, and the other pair is used to **receive** data.

In European and Asian countries, an **E-carrier** system is used instead of T-carrier. An E1 consists of **30 channels** of **64 Kbps**, for a total throughput of **2.048 Mbps**.

This guide will concentrate solely on the theory and configuration of T1 circuits. T3 and E1 circuits go beyond the scope of this guide.

(Reference: CCNP BCRAN Exam Certification Guide, Second Edition. Pages 195-196. Cisco Press ISBN: 1587200848)

T-Carrier Sampling and Framing

Recall that T-Carriers provide purely digitized communication, for both *voice* and *data.* It was originally developed for voice communication, however.

A voice call requires a 4 kHz (4000 Hz) channel. To convert analog voice into a digital format, **samples** of the frequency and amplitude of the analog wave must be made. Sampling, in this instance, refers to representing a snapshot of the signal as a sequence of binary digits (usually 8 bits).

The **Nyquist sampling theorem** dictates that analog wave should be sampled at a rate of twice the channel's frequency range:

$$f_s = 2(\text{freq. range})$$

Thus, assuming a range of 4000 Hz, this requires a rate of 8000 samples per second. Each sample is represented using 8 bits of data. Each sample is assigned an 8-bit value to represent the amplitude *height* at the time of sampling.

The first bit of the 8-bit value designates whether the wave's height is *positive* (1) or *negative* (0). The remaining seven bits allow for a height range of -127 to 127, for a total of 256 representations of the wave's sampled amplitude.

The *throughput* of a DS0 channel can thus be calculated as such:

8000 samples per second *x* 8 bits per sample = 64,000 bps (or 64 Kbps)

A DS-1 utilizes a **CSU (Channel Service Unit)** to format data into **frames**. The size of a single frame is exactly 193 bits. Each channel attaches 8 bits of data per frame, and then one *framing* bit is attached. Thus, during each sampling period:

24 channels *x* 8 bits of data per channel + 1 framing bit = 193 bits per frame

Assuming a sampling rate of 8,000 frames per second, the total throughput of a DS1 will be:

8000 frames per second *x* 193 bits per frame = 1.544 Mbps

(Reference: Broadband Telecommunications Handbook. Pages 432-444. Regis J. Bates. McGraw Hill. ISBN: 0071346481)

T-Carrier Framing Protocols

T-Carrier systems utilize **framing protocols** to maintain synchronization and for error control. The two most common framing protocols include:

- **D4 SF (SuperFrame)**
- **ESF (Extended SuperFrame)**

D4 SF utilizes the single framing bit in **12 consecutive frames** to apply a repeating pattern of **100011011100**. The twelve frames are collectively known as a **superframe** (hence SF). The continuous pattern allows the sending and receiving devices to stay synchronized.

ESF, as its name implies, expands the superframe to **24 consecutive frames**. In addition to using the framing bits for synchronization, ESF also employs error control and maintenance services. Specifically:

- 6 bits of each superframe are used for synchronization
- 6 bits of each superframe are used for CRC error control
- 12 bits of each superframe are used for maintenance services, such as performance statistics

(Reference: http://www.techfest.com/networking/wan/t1.htm)

T-Carrier Line Coding

The two most commonly used types of line coding include:

- **AMI (Alternate Mark Inversion)**
- **B8ZS (Bipolar 8 Zero Substitution)**

Binary data is represented on a T1 circuit using a **pulse**. A pulse represents a binary *1*; the absence of a pulse represents a binary *0*.

If a long set of consecutive zeros are transmitted, devices may lose synchronization due to the lack of pulses. Thus, the **ones density rule** was implemented, which states that at least 12.5% (in other words, 1 out of 8) of all transmitted bits must be set to 1. Otherwise continuous strings of zeros may cause timing to be lost.

If a CSU receives a string of eight zeroes, it will change the last bit to a binary *1* (known as **pulse stuffing**). One out of every eight bits has essentially been rendered unreliable, reducing the throughput of the channel by $1/8^{th}$ (down to 56,000 bps).

This above is the basics of how **AMI** line coding works. AMI is no longer widely implemented, and has been largely replaced with the more advanced **B8ZS** standard.

B8ZS also adheres to the *ones density rule*, but utilizes a specific pattern (0001 1011) to replace eight consecutive zeros. The receiving CSU recognizes that this pattern represents all zeroes, and will revert the bits to their original value.

B8ZS is thus **more efficient** than AMI, and does not lose $1/8^{th}$ of the throughput of a channel.

(Reference: Broadband Telecommunications Handbook. Pages 432-444. Regis J. Bates. McGraw Hill. ISBN: 0071346481; http://www.techfest.com/networking/wan/tcarrier.htm)

Configuring T1 Controllers

Configuration of T1 parameters is accomplished on the T1 **controller:**

> **Router(config)#** *controller t1 0/1*
> **Router(config-controller)#** *framing esf*
> **Router(config-controller)#** *linecode b8zs*
> **Router(config-controller)#** *clock source line primary*

ESF is the default *framing*, and *b8zs* is the default *linecode* for T1 controllers.

The *clock source* command specifies which clock to use for synchronization. Specifying *line primary* will use the received data stream to stay synchronized. The *clock source* can be set to *internal* as well, but this is not usually recommended.

Troubleshooting T1 Circuits

To view framing and line code information:

> **Router#** *show controllers t1*

```
T1 0/1 is up.
  No alarms detected.
  Framing is ESF, Line Code is B8ZS, Clock Source is line
  Data in current interval (14 seconds elapsed):
     0 Line Code Violations, 0 Path Code Violations 0 Slip
     Secs, 0 Fr Loss Secs,
     0 Line Err Secs, 0 Degraded Mins 0 Errored Secs, 0
     Bursty Err Secs,
     0 Severely Err Secs, 0 Unavail Secs
     Total Data (last 79 15 minute intervals):
     0 Line Code Violations, 0 Path Code Violations, 0 Slip
     Secs, 0 Fr Loss Secs,
     0 Line Err Secs, 0 Degraded Mins, 0 Errored Secs, 0
     Bursty Err Secs,
     0 Severely Err Secs, 0 Unavail Secs
```

(Reference: http://www.cisco.com/en/US/products/sw/iosswrel/ps5187/products_command_reference_chapter09186a008017d023.html#wp1141533)

Troubleshooting T1 Circuits (continued)

If a large number of framing errors are occurring, possible causes can include:

- Too much noise on the link
- Defective cable
- Incorrectly configured CSU line clock
- One of the clocks is configured for internal clocking
- Ones density problem on the T1 circuit

(Reference: http://www.cisco.com/univercd/cc/td/doc/cisintwk/itg_v1/tr1915.htm)

Optical Carriers

If throughput beyond the speed of T-carriers or E-carriers is necessary, an **Optical Carrier (OC)** can be used. OC circuits utilize a SONET fiber network to transmit digital signals.

The specifics of OC technology go beyond the scope of this guide. However, the following chart details the speeds for common OC configurations (please note: this is *not* a comprehensive list):

OC-1	51.84 Mbps
OC-3	155.52 Mbps
OC-12	622.08 Mbps
OC-24	1.244 Gbps
OC-48	2.488 Gbps
OC-192	9.953 Gbps

(Reference: http://www.zytrax.com/tech/data_rates.htm#ocx)