Synchronization at User-to-Network Interface

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Clock synchronization and time distribution are important issues and potential source of system anomalies at the Service Access Point (user-to-network interface). For analog and asynchronous data interfaces there is no synchronization issue: the user and the network worlds are fully isolated. However, when dealing with synchronous data interfaces, a rigorous approach to the transmission of time information is essential. Several strategies can be adopted for legacy interfaces:

- The transmitting device in each direction provides clock information to the receiver (codirectional). The clock can be integrated to the transmit signal or a separate signal.
- One end (the user or more often the network) provides the clocks for both directions of data transmission (contra-directional). The clock can be integrated to the transmit signal or a separate signal. At the slave end, the transmitter is synchronized by the received clock.
- Both user and network receive independently their clock from a common source.

Protection to TDM Network Synchronization Anomalies
Digital multiplexed communications require the synchronization of receiver clocks for correctly demultiplexing the TDM frame. The clock signal is propagated across the network through the digital signal path. The receiver compares its received clock signal with its own local clock and as long as the quality of the received signal is not below a certain threshold, the received signal is used by the receiver. A communication node with multiple network connections receives several clock signals which are employed according to a preestablished ranking: if the used clock is degraded or disrupted, the next ranking clock is employed, the lowest rank being the equipment's own free running clock. SDH networks operate with a powerful clock information exchange protocol which normally allows the automatic restoration mechanism to operate with appropriate clocking.

C. Samitier (ed.), *Utility Communication Networks and Services*,
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In the event of a synchronization anomaly which may arise due to human error, equipment malfunctioning, inadequate synchronization plan or certain topological fault situations, the received data may be demultiplexed with an inappropriate (desynchronized) clock at the same "nominal" frequency. Despite a buffer size of one frame (125 μs), the slight difference in frequency (few parts per million) will periodically cause a buffer underflow or overflow, generating a "synchronization slip" (i.e., repetition or loss of one frame). The time period shall depend on the difference in frequency as illustrated below:

- Consider two 2048 kbps clocks at ±5 ppm used for filling up and removing data from a buffer of 125 μs (256 bits at 2048 kps operation).
- The difference in fill and remove frequency is therefore
  2048 kbps × 10 ppm = 20.48 bps.
  Every second the level of buffer moves up or down by 20.48 bits.

- A Buffer Overflow or Underflow shall occur every (256/20.48) = 12.5 s.

Synchronization slips are unnoticed in voice or any other analog services (one errored sample every few seconds) and can pass unnoticed in most data exchange applications due to packet retransmission. Anomalies in synchronization plan (especially under network fault conditions) can therefore exist for a long time in the digital multiplexed network. The impact on Protection communications can, however, be fatal. Any cyclic anomaly in a digital multiplexed communication service must draw the attention to synchronization problems.

Time Distribution—SNTP and IEEE1588v2 (PTP)
Ethernet interface at the Service Access Point allows the exchange of time synchronization information between the user and the network. A packet-switched transport network not being a synchronous communication system like SDH with constant time delay, but a store-and-forward queuing system, the time synchronization is not just required between the user and the network, but between all the devices in the application network at the two sides of the WAN connection. Distributed control and protection applications require a common time reference between intelligent devices dispersed across the network to establish the order of events and to allow coordinated actions when particular grid conditions are recognized. The relative precision of the time reference among devices ranges from 1 ms to below 1 μs depending on applications.

The common time reference can be exchanged implicitly by the user application (e.g., Current Differential Protection), distributed independently from the communication network (e.g., individual GPS clocks or local 1PPS wiring), or increasingly distributed through the local or wide area network through standard time distribution protocols.

In this latter case, a specific IP-based time distribution application is implemented between a time server and its clients. Currently, the Simple Network Timing Protocol (SNTP or NTP) assures an accuracy of 1 ms but entirely depends

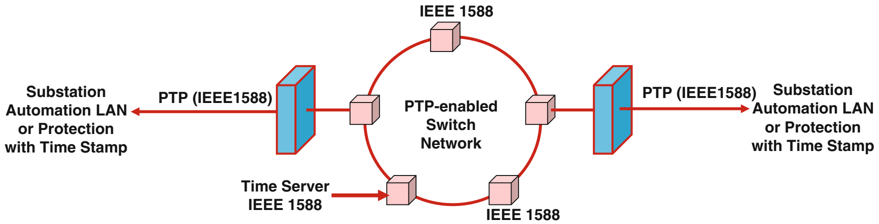

Fig. 15.1 IEEE 1588v2 Precision time protocol (PTP) across the packet switched network

upon delay variations between the client and the time server making it usable essentially inside a star-structured local network (Substation LAN). There is a strong trend to move to IEEE 1588v2 Precision Timing Protocol (PTP), which provides a higher precision of 1 µs (i.e., equivalent to GPS) necessary for more severe automation applications. PTP employs multiple master clocks and each switching node of the network performs path delay calculations. Precision Time Protocol delay calculation mechanism considers that delay variation is only at node level (i.e., queuing files). When multiple switching nodes exist between a master clock and a client, it is necessary that every switch support IEEE 1588v2 synchronization feature. More generally, if 1588v2 is to be supported network-wide then every node of the packet switched communication network that can introduce variable packet delay must be IEEE 1588-enabled or it shall introduce inaccuracy into the timing information (Fig. 15.1).