OPINION ITU-R 94*

TIME AND FREQUENCY TRANSFER USING DIGITAL TELECOMMUNICATION NETWORKS

(Question ITU-R 207/7)

(1995)

The ITU Radiocommunication Assembly,

considering

a) that ITU-T Recommendations G.707, G.708 and G.709 specify bit rates, frame structure, and formatting for a synchronous digital hierarchy (SDH);

b) that optical fibre transmission lines and the SDH are capable of time and frequency dissemination at very high levels of accuracy and precision;

c) that optical fibre transmission lines will reach industrial facilities, offices and other end users making it a widely available source of frequency and, if properly implemented, time information;

d) that synchronization messages will be required for time transfer between network elements;

e) that the delays between network elements need to be measured for precise time transfer between network elements;

f) that the quality of timing information being transferred needs to be included;

g) that maintaining precise time at network elements will assist in fault detection and correction in the network;

h) that the normal SDH data transmission format includes overhead bits which can be used to transmit additional information for supporting network operations;

j) that some of these overhead bits could be useful in conveying timing information, including the current date and time-of-year,

is of the opinion

1. that sufficient overhead bits be reserved in the appropriate levels of the SDH format for the purpose of supporting both one-way and two-way time exchanges at the 1 ns or highest practical accuracy level between network elements;

2. that the techniques for time and frequency transfer outlined in Annex 1 be considered in the development and specification of digital telecommunication networks.

ANNEX 1

Configurations and interfaces for time and frequency transfer using telecommunication networks

The following information provides some preliminary ideas from Radiocommunication Working Party 7A with regard to possible methods, network configurations, and interfaces that could facilitate the use of such networks for time and frequency transfer to a broad range of potential users.

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* This Opinion should be brought to the attention of the Telecommunication Standardization Sector (ITU-T).

1. General

Telecommunication networks are suitable for transferring time and frequency, and are alternatives to conventional dissemination methods of time and frequency such as LORAN-C, GPS, GLONASS and time transfer methods using stationary satellites such as INTELSAT.

ITU-T Recommendations enable time and frequency transfer using telecommunication networks to establish standardized system configurations and interfaces. SDH bit rates are specified in ITU-T Recommendation G.707 and the Network Node Interface (NNI) is specified in ITU-T Recommendation G.708.

This Annex provides information, guidance and requirements concerning time and frequency transfer over digital telecommunication networks.

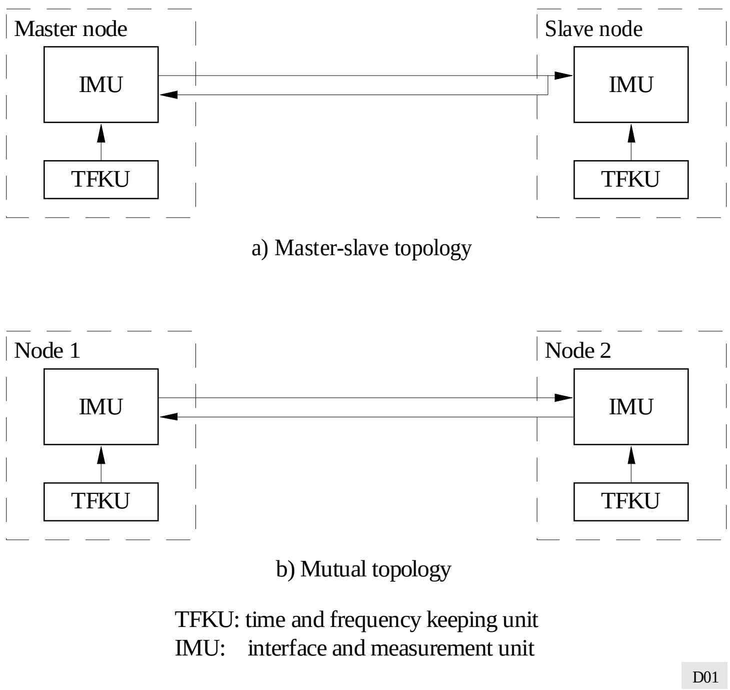
2. Transfer method

Time and frequency are transferred through a transfer medium between two nodes each of which includes a time and frequency keeping unit (TFKU). The location data of the TFKU is not required: however, it is required that delay and delay variation of the media can be explicitly evaluated. Therefore, time and frequency transfer in telecommunication networks uses a bidirectional path that consists of outgoing and incoming paths composed of the same medium. Difference in delay between outgoing and incoming paths results in time and frequency error.

There are two basic topologies in time and frequency transfer as shown in Fig. 1.

FIGURE 1

Basic topology in time and frequency transfer



2.1 Master-slave topology

One always receives a time and frequency signal and so it is called the slave node. The other node is called the master node; however, the name of the master node is not related to whether the master node is the origin of the time and frequency signal or not. The master node measures the delay experienced on outgoing and incoming paths over a round-trip and manages the delay data. The time and frequency signal is compensated by the delay data and sent from the master node to the slave node, or the time and frequency signal is first sent to the slave node and then compensated at the slave node by the delay data transferred from the master node. The time and frequency signal is advanced by the delay data which is calculated by the following equation:

$$T_d = T_{rd} / 2 \tag{1}$$

where:

T_d: delay data

T_{rd}: round-trip delay.

2.2 Mutual topology

Both nodes send and receive the time and frequency signal. Delay is caused by outgoing and incoming paths and is measured at the two nodes by comparing the time and frequency signals generated at each node. Measurement results are exchanged. The time difference between the two nodes can be calculated from the results.

$$T_{12} = \frac{1}{2} \left(T_{d1} - T_{d2}\right) \tag{2}$$

where:

T_{12}: time difference between two TFKUs

T_{d1}: time difference measured at node 1 between the time and frequency signal sent from node 2 and the time and frequency signal generated at node 1

T_{d2}: time difference measured at node 2 between the time and frequency signal sent from node 1 and the time and frequency signal generated at node 2.

The mutual topology can be used between any two nodes regardless of their hierarchy. Each node measures the time difference between other nodes rather than compensating the time and frequency signal.

3. System configuration

The above topologies can be implemented in three ways as shown in Fig. 2. The path defined in the topology is constructed from network elements. The network element connects two locations that are geographically separated and provides both network and node interfaces including TFKU. The interface supports two signals: a time and frequency signal that includes a time marker, time information and delay data, and a data signal which includes time difference data and general data.

3.1 One-way configuration

Slave nodes receive the time and frequency signal generated at a reference node. The data signal may not be required. Specifications of time and frequency depend on that of the reference node.

3.2 Two-way configuration

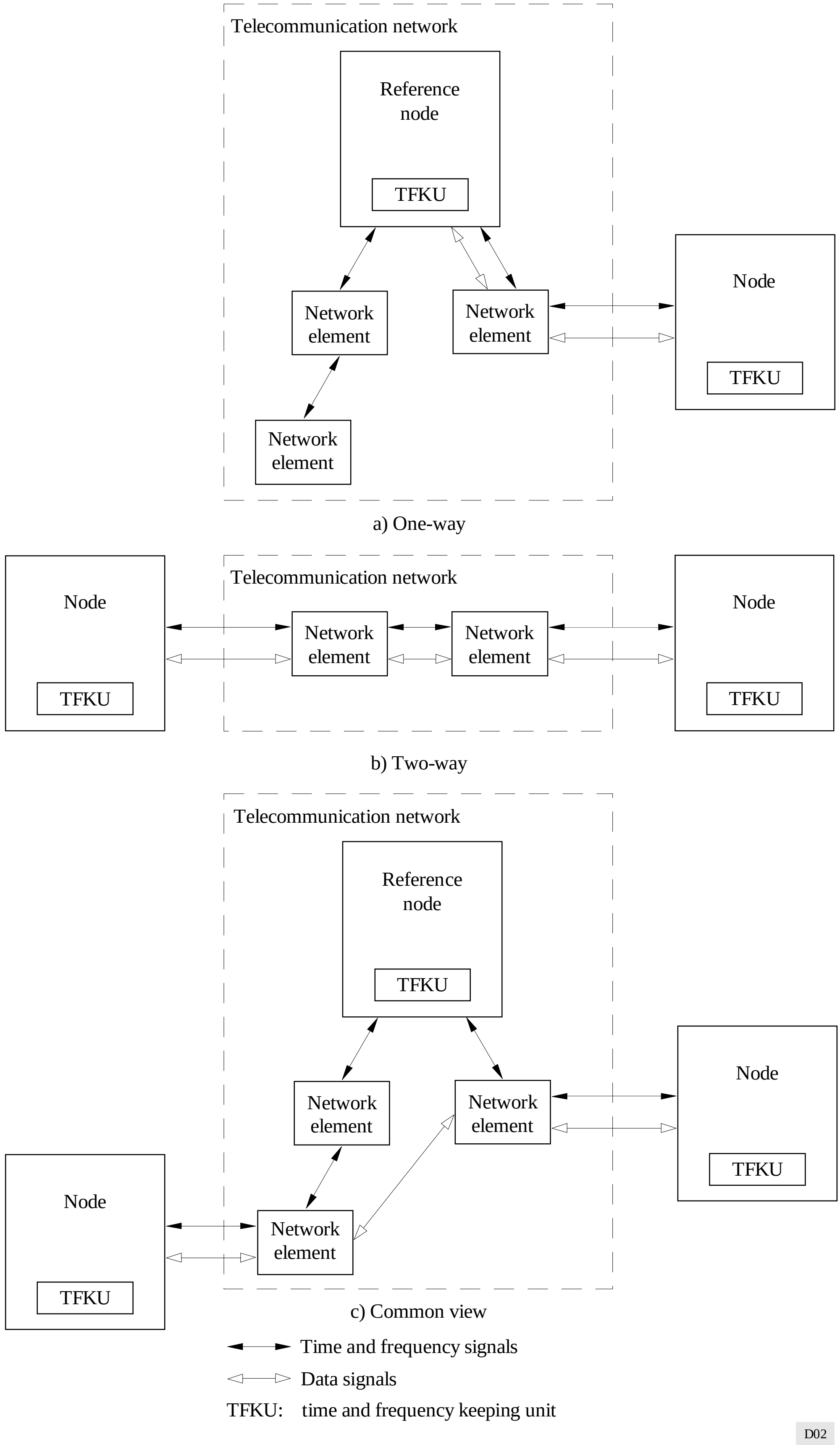
Nodes in the mutual topology can exchange time and frequency signals generated by their TFKUs. The network must provide nodes with access to the interface used by the reference node.

3.3 Common-view configuration

All nodes initially receive the same time and frequency signal generated at the reference node as slave nodes. Nodes then exchange data signals to calculate the time difference between them in the mutual topology. The time and frequency error of the reference node TFKU is suppressed within the nodes due to the simultaneous observation of the common source.

FIGURE 2

Basic category for time and frequency transfer



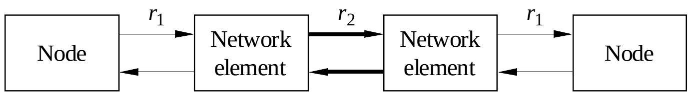
4. Physical specifications

4.1 Bit rates

This Recommendation should specify bit rates of paths between network elements and nodes (bit rate r_1 in Fig. 3) and of paths between network elements (bit rate r_2 in Fig. 3). Allowable bit rates of paths are listed in Table 1. The bit rates are recommended in ITU-T Recommendation G.707.

FIGURE 3

Transmission path configuration and synchronous digital hierarchy level



Bit rates of r_1 and r_2 can be selected from Table 1. r_2 is higher than or equal to r_1.

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TABLE 1

Synchronous digital hierarchy bit rates

Synchronous digital hierarchy level	Hierarchical bit rate (kbit/s)
1 (STM-1)	155 520
4 (STM-4)	622 080
16 (STM-16)	2 488 320
64 (STM-64)(1)	9 953 280

(1) This level requires further study.

4.2 Frame format

The frame format based on the synchronous digital hierarchy level (STM-*N*) is in accordance with ITU-T Recommendation G.708. STM-*N* frame format, shown in Fig. 4a), enables network elements and nodes to achieve excellent global communication. In addition, using the Section Overhead (SOH) offers another advantage. We can use the STM-*N* payload area for B-ISDN services at the same time when the time and frequency transfer application is executed as a background communication. MSOH, the lower 5 bytes of nine rows in SOH (see Fig. 4b)), is appropriate for time and frequency transfer because it can be transmitted as far as the opposite network element if the element supports MSOH reception and if MSOH is not terminated at devices such as repeaters located in the path between network elements.

4.3 Bytes for time and frequency application

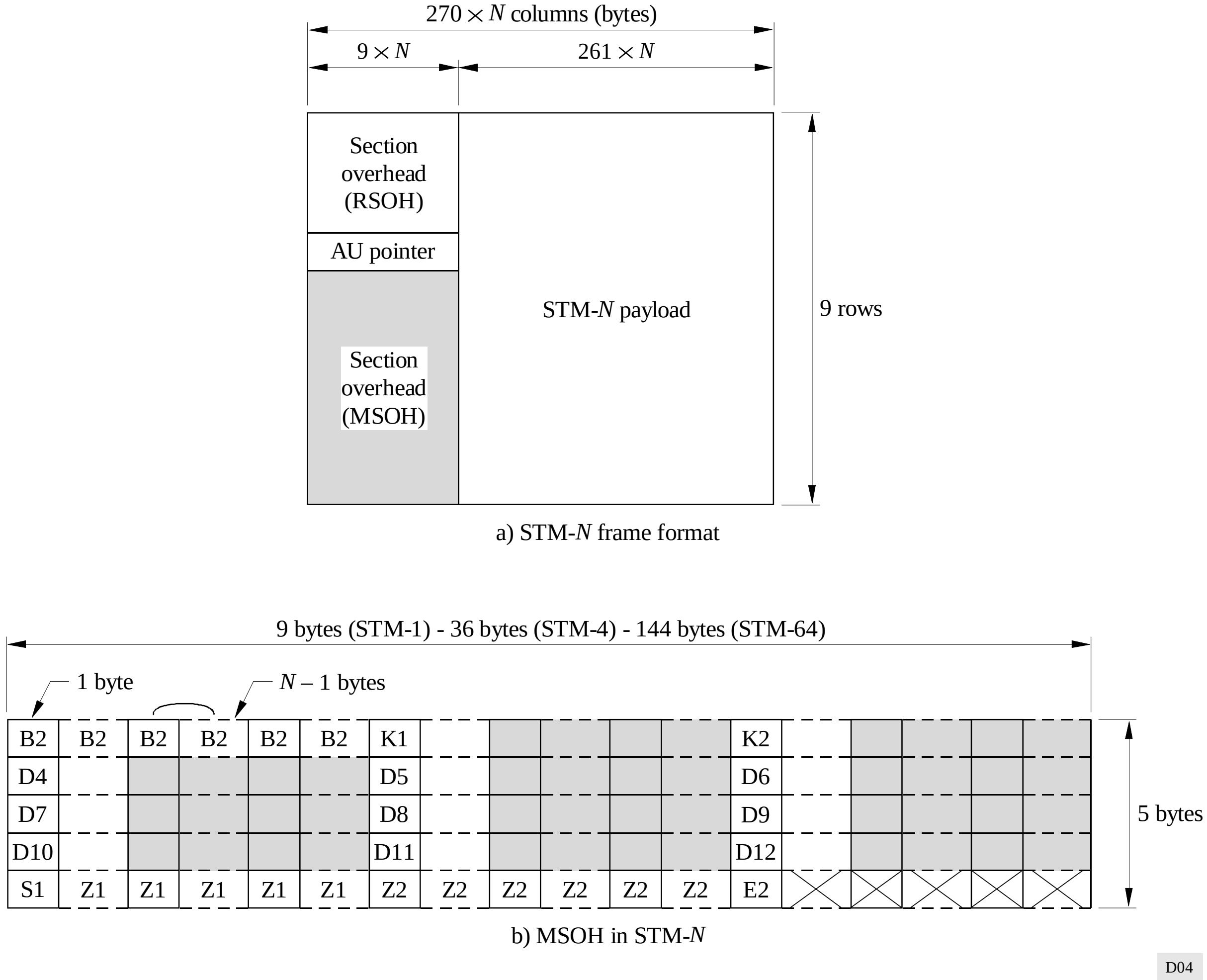
Which byte is suitable for transmitting time and frequency information is for further study. Promising bytes are shaded in Fig. 4b). These bytes are not defined for any purpose in ITU-T.

4.4 Multiframe format

A multiframe in the bytes specified in § 4.3 should be defined to transmit a second signal because the STM-*N* frame period is 8 kHz. Multiframe format is for further study.

FIGURE 4

STM-*N* frame format and MSOH byte mapping



5. Examples

Figure 5 shows examples of the time and frequency transfer configuration. The network elements directly connected to nodes are the multiplexers/demultiplexers based on ITU-T Recommendation G.709.

5.1 Common-view example

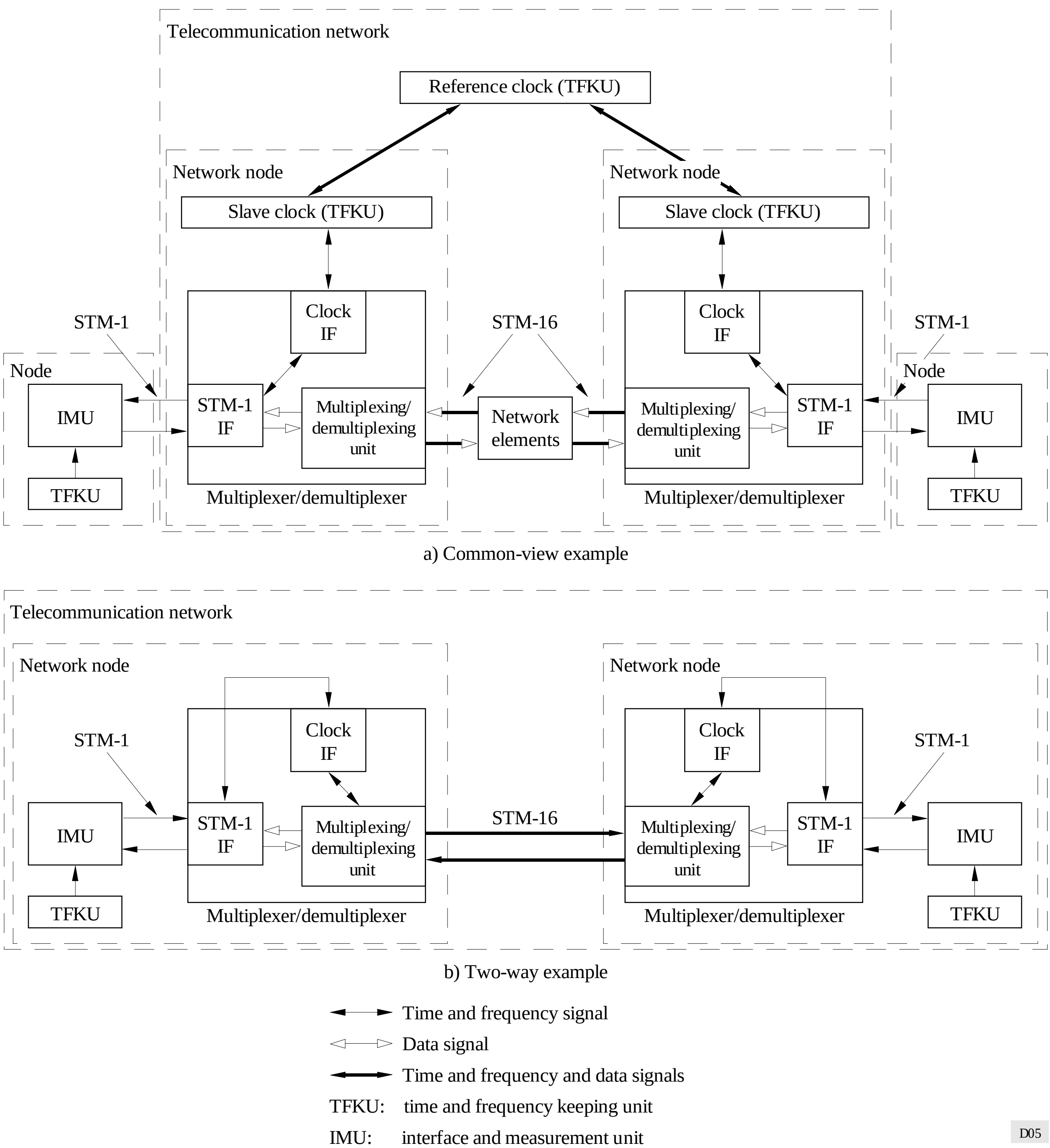
In the common-view example shown in Fig. 5a), the time and frequency signal is generated by TFKU, called the reference clock in ITU-T, and then distributed to multiplexers/demultiplexers through the TFKU, called the slave clock in ITU-T. The time and frequency signal is immediately transferred to the TFKU in connected nodes through clock IF and STM-1 IF from the slave clock. Each multiplexer/demultiplexer adds general STM-1 signals to STM-16 and drops them from STM-16, and also adds the time and frequency signal to STM-1.

5.2 Two-way example

Figure 5b) shows the two-way example. Each multiplexer/demultiplexer adds the time and frequency signal to STM-1 and drops them from STM-16 leaving general STM-1 signals. Information imposed on the MSOH described in § 4.2 is terminated at the end of a section. This means that the MSOH information can be transmitted only between multiplexers/demultiplexers and between multiplexer/demultiplexer and the node. The MSOH information in STM-1 generally cannot be transported to the MSOH in STM-16, nor can the MSOH information in STM-16 to the MSOH in STM-1. In this example, the time and frequency signal generated by TFKU is extracted in STM-1 IF, transferred to the Mux/demux unit via Clock IF, and then imposed on the MSOH in STM-16. In the other network node, the time and frequency signal is extracted at the Mux/demux unit, and transferred to STM-1 IF via Clock IF, and then imposed on MSOH in STM-1 IF again. The time and frequency signal thus can be directly transferred to the other node by this configuration.

FIGURE 5

Examples of the time and frequency transfer configuration constructed by line systems of STM-16 and by local systems of STM-1



There is no network element such as multiplexers/demultiplexers between network nodes in this example. STM-16 can be transmitted via other multiplexers/demultiplexers if the original clock of STM-16 is not changed; however, time and frequency error due to transmission delay asymmetry might occur.

In this example, TFKU is located in the network node, as is the multiplexer/demultiplexer. However, a subscriber loop system can be used to connect TFKU to the multiplexer/demultiplexer if TFKU is located in a node different from the network node.

6. Performance specification guidelines

The specifications concerning time and frequency errors such as stability and accuracy require additional discussion. This section is for further study.

7. Important documents

Important ITU-T Recommendations related with this Opinion are as follows:

- "Synchronous Digital Hierarchy Bit Rates", ITU-T G.707;
- "Network node interface for the synchronous digital hierarchy", ITU-T G.708;
- "Synchronous multiplexing structure", ITU-T G.709;
- "Considerations on timing and synchronization issues", ITU-T G.810;
- "Timing requirements at the outputs of primary reference clocks suitable for plesiochronous operation of international digital links", ITU-T G.811;
- "Timing requirements at the outputs of slave clocks suitable for plesiochronous operation of international digital links", ITU-T G.812;
- "The control jitter and wander within digital networks which are based on the 2 048 kbit/s hierarchy", ITU-T G.823;
- "The control jitter and wander within digital networks which are based on the 1 544 kbit/s hierarchy", ITU-T G.824;
- "Timing characteristics of slave clocks suitable for operation of SDH equipment", (draft Recommendation), ITU-T G.81s.