



Structural Reliability of Interactive Cable Television

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Abstract:

Television cabling distributions have hitherto been constructed by coaxial cables. Their transmission capacity has not been sufficiently utilized. They have transmitted only television channels. Considerable efforts have been made to utilize their bandwidth more effectively for the transmission of not only television channels but also voice, Internet and various interactive supplementary services. New conception presupposes the use of fibre optics. Important characteristic feature of this conception is its reliability.

Keywords:

Interactive cable television (ICATV), end user box (EUB), set-top-box (STB), cable modem (CM), hybrid fibre coax (HFC), middle time between failures (MTBF), data over cable service interface specification (DOCSIS), voice over IP (VoIP), quality of service (QoS).

1. Introduction

Television cabling distributions (CATV) are used for transmission of a television signal. In order to transform them into interactive cable television (ICATV) cabling distributions, they have to be enhanced by supplementary duplex signal amplifiers. Additionally, they have to be supplemented by main station or ICATV centre (CICATV), control centre of house networks (CCHNs) and end user boxes (EUBs).

Two types of transmission channels are used for provision of interactive services:

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- downstream – downward channel (from CCHN to EUB),
- upstream – upward channel (from EUB to CCHN).

Two technologies are currently implemented in interactive CATV networks:

- coaxial cables - CATV,
- optoelectronic transmission systems - HFC (hybrid fibre coax).

2. Hybrid Television Cable Network - HFC

CATV networks are mostly constructed as hybrid fibre coax (HFC) networks. The signal is transmitted by an optical fibre from the main station to optical node. The optical signal is converted into electrical signal in the optical node and then transmitted by coaxial cable to EUB [6].

Main station is the central distribution node for CATV system. Video signals are received from satellites or other sources, converted into appropriate frequency channels, combined with data signals and transmitted to HFC network.

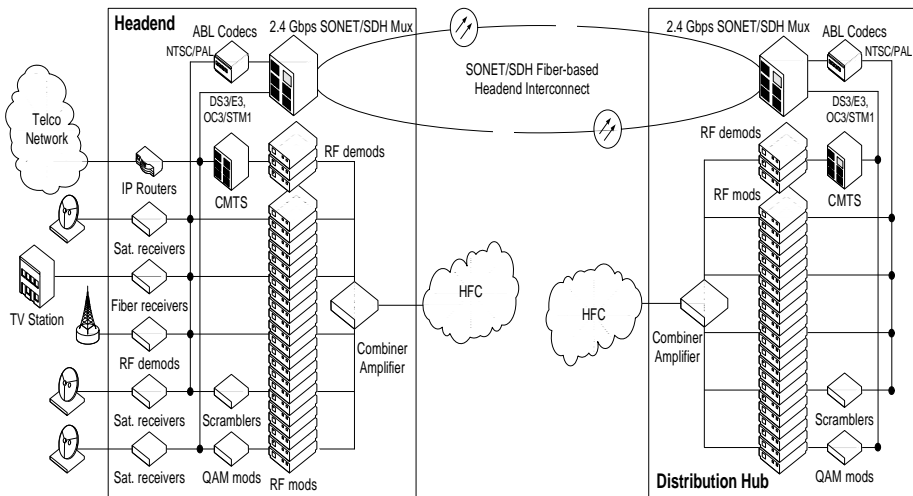


Fig. 1 Structure of head-end (HE) and distribution hub (DH) [9]

Optical part of the HFC network (1310, 1550 nm) is made of optical fibres as one level or two level networks. Radiation of the signal is carried out by dense wavelength division multiplexing (DWDM) or coarse wavelength division multiplexer (CWDM) technology. Coaxial part of the HFC network creates tree topology with branches to 100 - 200 EUBs. EUB can incorporate set-top-box (STB) and cable modem (CM).

The most of the CATV networks are hybrid fibre coax (HFC) networks. The signals run in fibre optical cables from the head-end centre to locations near the subscriber. At optical node, the signal is converted to coaxial cables, which run to the subscriber premises.

Head-end (HE) is central distribution point for a CATV system. Here video signals are received here from satellites and/or other sources, converted to the appropriate frequency channels, than combined with locally originated signals, and re-broadcast onto the HFC plant.

One cable modem termination system (CMTS) will normally drive about 1-2000 simultaneous cable modem users on a single TV channel. If more cable modems (CM) are required, the number of TV channels is increased by adding more channels to the CMTS.

When several head-ends (HEs) are coupled by all-round reticule then one head-end in the network will serve as a primary hub to feed all the others. All head-ends in the network are linked together using 2.4 Gb/s SONET/SDH OC48/STM16 digital fibre ring.

The optical part of HFC network (1310, 1550 nm) is built on single mode fibres, usually as single-stage or two-stage, according to the networks limits. Distributed feedback (DFB) lasers and optical amplifier of erbium-dopped fibre amplifier (EDFA) type, which are characterized by very good noise and intermodulation tone parameters, are also used.

Diodes, in optical receivers, are broadband, so they can also process the both wavelengths and they do not need to be changed in case of the transformation. If a huge amount of optical nodes, and/or retraces exist, one may use dense wavelength division multiplexing (DWDM) technology or coarse wavelength division multiplexer (CWDM).

Fibre optical node converts optical signals to electric and vice versa. It is a "dumb" device in that it does not demodulate or otherwise interpret the signals. Fibre optic cables connect the optical node to the distant head-end (HE) or hub.

The coaxial portion of the network connects 100 to 2000 homes (500 is typical) in a tree and branch configuration. The distribution line is then "tapped" into and used to connect the individual drops to customer homes.

End user box (EUB) can contain set-top-box (STB), cable modem (CM) and multimedia terminal adapter (MTA).

Set-top-box (STB) is the device that enables a television set to become a user interface to the Internet and also enables a television set to receive and decode digital television broadcasts. Digital set-top-boxes are sometimes called receivers. A set-top-box is necessary to television viewers who wish to use their current analogue television sets to receive digital broadcasts.

Cable modem (CM) is the device that allows high speed access to the Internet via cable TV network. Cable modem will typically have two connections, one to the cable wall outlet and one to a computer. Data over cable service interface specification (DOCSIS) is used for data transmission.

Multimedia terminal adapter (MTA) is a packet cable device providing telephony services over a cable or hybrid system being used to deliver video signals to a community. It contains an interface to endpoints, a network interface, codex's, and all signalling and encapsulation functions required for voice over IP (VoIP) transport, call signalling, and quality of service (QoS) signalling.

3. Calculation of the Structural Reliability of the Subscribers Connections in ICATV

Simultaneous structure and topology of CATV results from its determination as a distribution network of television (TV) programs. The CATV technology and technique is adapted to this determination. The topology used is a combination of tree and bus topologies.

The novel ICATV is aimed to be constructed and used as an open interactive information system (network) for data communication and distribution of TV programs. The technique and technology will be adapted to these requirements. The topology of the ICATV network will be a combination of star and bus topologies. Fig. 2 [8] shows the structure of the ICATV network.

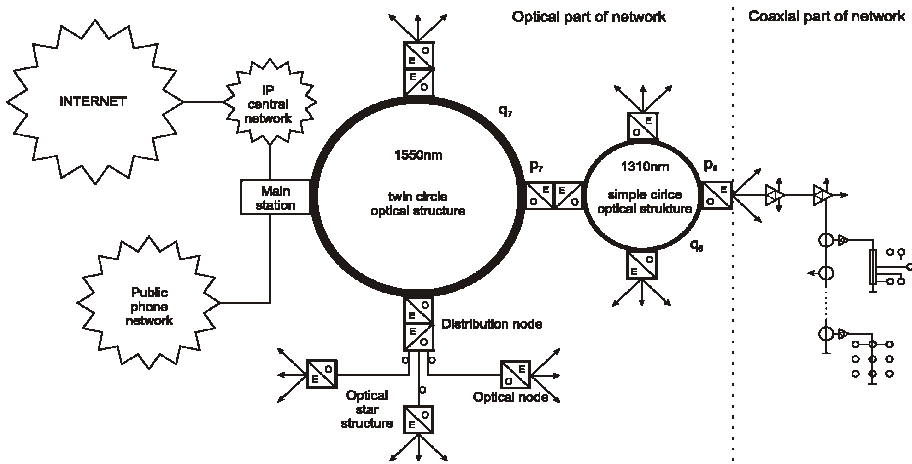


Fig. 2 Structure of HFC network for ICATV

Subscribers have multipoint access to common transport media (channel) with an interactive half duplex transmission, which is formed by two broadband channels (forward and backward). The situation is shown in Fig. 3, where:

- p_1 is reliability of EUB controller (EUB – CO),
- q_1 is reliability of connection of EUB – CO with communication controller – CC (EUB – CC),
- p_2 is reliability of CC,
- q_2 is reliability of connection of CC with MODEM (MODulatorDEMulator),
- p_3 is reliability of MODEM,
- q_3 is reliability of segment of transfer medium.

According to [1-7], number of the failureless EUB in the bus structure is a sum of members, and multiplication of reliability of segment of transfer medium, and can be calculated as follows:

$$A_1 = \sum_{i=1}^{M_1} q_3^i p_v + \sum_{i=1}^{M_2} q_3^i p_v + \dots + \sum_{i=1}^{M_a} q_3^i p_v, \quad (1)$$

where:

p_v is multiplications of serial reliabilities and can be calculated as follows:

$$p_v = p_1 q_1 p_2 q_2 p_3. \quad (2)$$

Total number of the failureless EUB with the star structure is a sum of members multiplications $m_i p_v q_3$:

$$B = \sum_{i=1}^b m_i p_v q_3, \quad (3)$$

where:

m_i is term of failureless of EUB in the star structures,

b is number of clusters in the star structures.

Total number of the failureless EUB is a sum of the terms A_1, A_2, \dots, A_n and B :

$$C = A_1 + A_2 + \dots + A_n + B, \quad (4)$$

where:

n is number of clusters in the bus structures.

Average structural reliability of the subscribers' network is:

$$r_1 = \frac{C}{n(M_1 + M_2 + \dots + M_a) + \sum_{i=1}^b m_i}, \quad (5)$$

where:

M_i is number of EUB (subscribers).

Centre ICATV connects several branches in star topology. One branch consists of N cascade connected to control centre abonents (subscribers) – CCA with one forward and one backward channel. The situation is shown in Fig. 3, where p_4 is the reliability of CCA with packet communication controller – PCC and q_4 is the reliability of segment of transport medium between two PCC-CCA.

Reliability of N CCA in serial line is:

$$x_N = q_4^N p_4^N r_1. \quad (6)$$

Reliability of $N-1$ CCA in serial line is:

$$x_N = q_4^{N-1} p_4^{N-1} r_1. \quad (7)$$

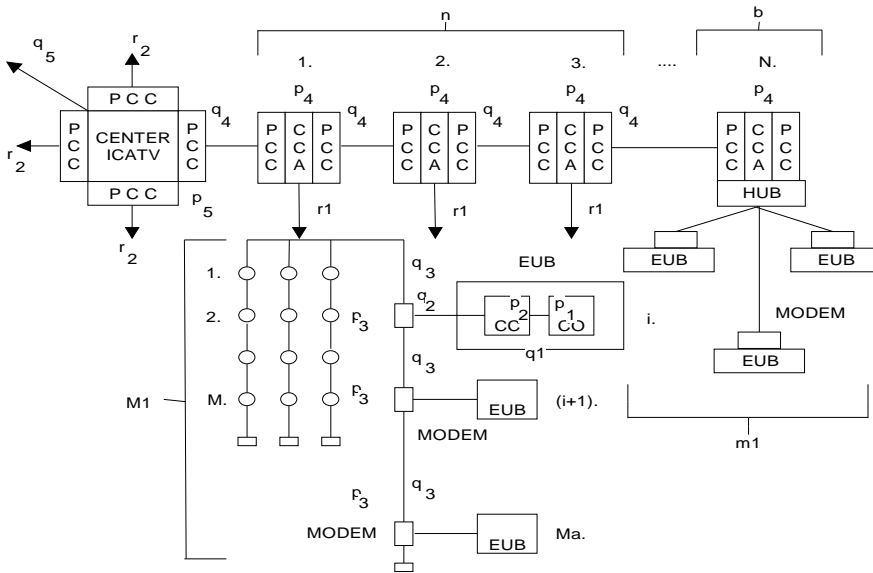


Fig. 3 Structure of coaxial part of HFC network from the view of structural reliability

Then generally:

$$r_2 = \frac{q_4^N p_4^N r_1 + q_4^{(N-1)} p_4^{(N-1)} r_1 + \dots + q_4 p_4 r_1}{N}, \tag{8}$$

and where:

$$N = n + b, \tag{9}$$

where:

- N is number of CCA in bus and star structures,
- r_2 is average structural reliability of transport network,
- p_4 is reliability of connected line to centre of CCA,
- q_4 is reliability of CCA.

In this case, we will use the same figure (Fig. 3), then:

$$r_3 = r_2^2 p_5^2 q_5, \tag{10}$$

where:

- r_3 is the average structural reliability between two branches ICATV transport network,
- p_5 is reliability of centre ICATV,
- q_5 is reliability of connected line to the higher network.

Using [4], average structural reliability of HFC network for ICATV according to Fig. 2 and Fig. 3 is:

$$R = r_3 p_6 q_6 p_7 (2q_7 - q_7^2), \quad (11)$$

where:

- p_6 is reliability of optical node,
- q_6 is reliability of simple circle optical structure,
- p_7 is reliability of optical node,
- q_7 is reliability of twin circle structure.

4. Conclusion

This paper deals with a description of a well known cable television mechanism, currently still in use. By complementing cable television system with backward channel, re-configurable interactive cable television network will be achieved. One of the advantages of this structure is its variability, which enables end user box to be attached to a star or home-vertical topology network. This paper presents the authors' specific approach to the solution of cable television network. It analyses fundamental structure of centre interactive cable television and control centre of house network, and focuses on end user box. The important characteristic is structural reliability.

In the project VEGA [10] an analytical model of home access network for audio, video and data services has been developed. Important parameter of all interactive cable television networks is its structural reliability. We have developed a simple model of this network structure and calculate the structural reliability.

According to data given by producers, mean time between failures is greater than 100000 hours in optical cables, greater than 50000 hours in coaxial cables. Structural reliability of bus and star topologies is different for optical and coaxial medium. Structural reliability of optical configuration is more reliable than coaxial.

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