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Some results of transfer rate tests on two-way cable network

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Abstract. The paper presents the current situation and development trends as pursued by the Slovenian Cable Operators in order to obtain two important modernization goals of cable television (CaTV) systems: implementation of a upstream channel for new services (Internet access, telemetry, Pay-TV) on one side and integration of local CaTV systems on the other. The paper is in particular focused on the reconstruction technology for CaTV systems for the bidirectional data transfer. While manufactures of cable modems declare their data transfer rates for direct and return paths, the question is raised, what can really be expected in practice. The paper describes some transfer rate tests made with the NetBench 5.0 program equipment for computer networks and presents a comparison between the transfer rates of the Ethernet 10BaseT-computer network and computer network connected via a CaTV system.

Key words: computer network, CaTV network, cable communication system, transfer rate test, laboratory model of a cable communications system

Nekaj rezultatov testiranja hitrosti prenosa podatkov po dvosmernem kabelskem omrežju

Povzetek. Članek predstavlja trenutni položaj in razvojne trende slovenskih kabelskih operaterjev. Posodobitev kabelskih omrežij poteka v Sloveniji v dveh glavnih smereh. V eni smeri kabelski operaterji posodabljajo povratni pas zato, da lahko ponudijo svojim strankam nove storitve (Internet, daljinski nadzor, plačljiva TV), v drugi smeri pa kabelski operaterji večjih sistemov povezujejo manjše lokalne kabelske sisteme na svoje sisteme.

Predstavljen je način rekonstrukcije kabelskih sistemov s katerim je omogočena dvosmerna komunikacija po kabelskem omrežju, in pa test hitrosti prenosa podatkov. Izdelovalci kabelskih modemov podajajo različne podatke o hitrostih prenosa podatkov v direktni in povratni smeri, test hitrosti prenosa tako prikazuje dejansko stanje na primeru simetrične podatkovne povezave (LANCity 10Mb/s).

V članku predstavljamo skupek testov s programskim orodjem NetBench 5.0, ki nam omogoča merjenje hitrosti prenosa računalniškega omrežja. Naredili smo primerjavo maksimalnega prenosa podatkov lokalnega računalniškega omrežja Ethernet 10BaseT s kabelskim računalniškim omrežjem.

Ključne besede: računalniško omrežje, kabelsko omrežje, kabelsko komunikacijsko omrežje, hitrost prenosa podatkov, laboratorijski model kabelsko-komunikacijskega sistema

1 Introduction

The Internet users demand an efficient and fast connection to the network. Most of them are connected to the Internet by using the telephone modems that enable a relatively cheap use of the Internet services but relatively low data transmission rates. The consequence is an intensive development of alternative possibilities for the network access.

Fast changes in computer and telecommunication technologies, especially in the area of cable television, enable the cable networks to assure a completely new, more active role, by offering all kinds of new services. Distribution of TV and radio signals in the direction head-end station to users was a typical service for cable network operators of the 80's which is nowadays no longer enough for a profitable business. This is the main reason for starting new services like the Internet access, Telemetry, Pay-TV, Pay-per-view, Video On Demand, Information services and others. The basis for implementation of the mentioned services is redesign and upgrading of the existing infrastructure in order to meet the needs of bi-directional communication.

The idea about the bi-directional data transfer over cable communication systems has already been present for quite a while in the world. In the USA and also in Europe, there have been several experimental projects and fully functional systems implemented.

In the beginning of 90's, modernization and extension of services provided by Slovenian CaTV operators

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started. At the moment there are several projects underway along with adequate training of the needed professionals.

Presently, a certain number of new small bidirectional CaTV systems already offer various services (Internet access, Pay-TV...) and there is a project in progress in Maribor involved with reconstruction and modernization of one of the biggest and oldest CaTV systems in Slovenia.

2 The state of CaTV systems in Slovenia

In Slovenia, the building of CaTV systems began in early 80's. Like elsewhere in the world, the initiative came from people, who couldn't receive national TV programs at good quality because of the extremely heterogeneous terrain (hills, mountains, valleys).

In the beginning, only local TV programs were received through the cable network. The first few satellite programs were made available later on. Unfortunately inadequate legalization and standardization in this field has led to several cable networks incompatible equipped and differing in technological solutions. Moreover, for some of them there is no basic technical documentation provided for.

Early systems were built with frequency bandwidth up to 303 MHz and have remained such for ten and more years. A lot of them have till now been in operation still unmodified. The usual topology of former CaTV systems is mostly treelike. Recent ones take a starlike form. Also, the majority of former CaTV systems could only transmit signals in the downstream direction while some reconstructed and new systems already provided upstream transmissions.

A comparison of CaTV systems in Slovenia shows a great level of diversity. This is also quite typical for other European countries, especially for Central European Countries.

Slovenia is relatively well covered with CaTV networks; as much as almost 47% of all Slovenian households are connected to CaTV systems, despite the fact that Slovenia is one of less densely populated countries in Europe (640.000 households on the area of 22.000 km^2). The number of connections in these CaTV systems is ranging between 100 and 20,000. The total number of households connected to CaTV systems in Slovenia is estimated at some 250,000. This involves almost 1 million inhabitants. Compared with the systems in Western and Northern Europe, which cover 70% to 90% of the population, this is rather a low rate value. Nevertheless the fact is that the building cost for CaTV networks is much higher than in most European countries because of extremely heterogeneous terrain types. There is also an unfavorable ratio between the number of cable operators and number of connections — about 2,000 connections per operator. In Western Europe, typical values are between 20,000 to 400,000 connections per operator. A comparison shows that it would be reasonable to interconnect all the cable systems in a bigger system with a high performance receiving station (Figure 1) [1].

In Slovenia, the "Association of cable operators of Slovenia" was founded in 1995. Together with cable operator companies this organization has implemented standards and directions for further development of the Slovenian cable systems. This way consequences of incompatibilities of the existing CaTV systems are removed. Organization is also a member of the European association of cable operators ECCA as well as APEC, which is an association of operators of the central and east European countries.

During development of additional services and extension of offered TV channels, many cable operators, especially those of large CaTV systems, envisaged retrofitting renovation and modernization. They replaced old coax connections with new ones and with optical fibers, and old amplifiers with those having broader signal spectrum (85-862Mhz), removed the first frequency band and implemented upstream channels in the frequency spectrum of 5-65MHz. By doing so CaTV systems can transfer signals bidirectionally.

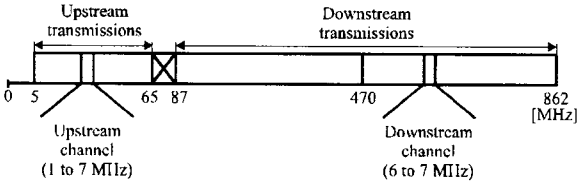


Figure 2. Frequency spectrum in CaTV networks

Modernization of CaTV systems raised the problem of localization, i.e. limitations of further services. This is why the decision was taken to integrate local CaTV systems thus lowering the working cost and extending the possibility for additional services. From the commercial point of view, this was a good idea as the number of computers and Internet connections in Slovenia is very great compared with other countries [1].

3 Problems related to the upstream channel of the cable system

3.1 Upstream amplifiers

To enable the cable network for bidirectional data transmission a proper upstream bandwidth is necessary assuring the data transmission from the customer to the headend station. This required a bandwidth on the planned frequency range from 5 to 65 MHz which necessitated the installation of adequate upstream amplifiers. The one-way

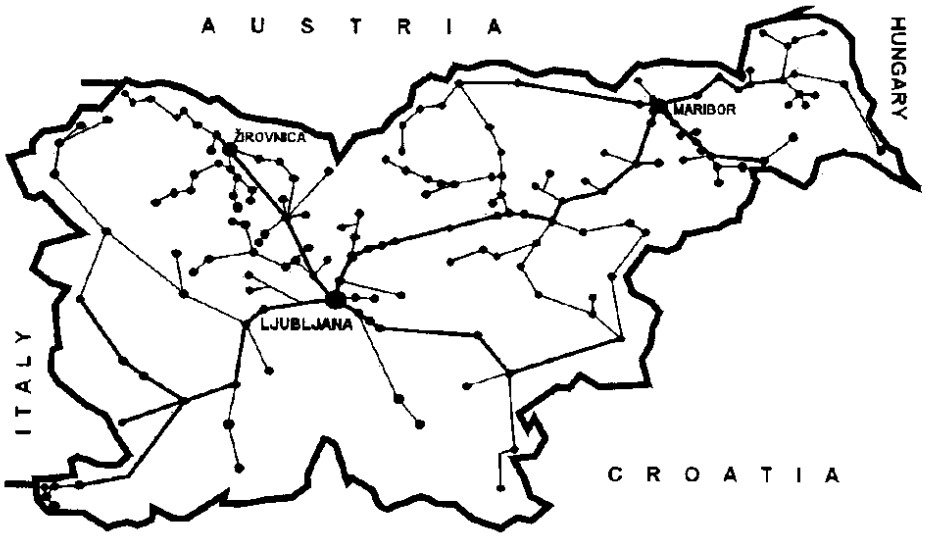


Figure 1. Future integration of Slovenian CaTV systems with the global CaTV network

amplifiers were consequently replaced with modular amplifiers which allowed a simple installation of upstream modules whenever necessary. Amplifiers were provided by local (TVTEL) and foreign manufacturers (ARCODAN, KATHREIN, FUBA, HIRSCHMANN,...).

The employed amplifiers are of combined type. They amplify the downstream band from 87 to 606 MHz (862Mhz) and permit a simple installation of amplifier modules for upstream band (5 - 65 MHz) (Figure 2). The advantage of the locally manufactured amplifiers is their fast response when their characteristics have to be adapted to the characteristics of a particular CaTV system (installation of closing filters for noise removal in certain segments of the network which results in the amplifier's abnormal working condition; a special kind of amplitude-frequency response of the equalizer because of the abnormal amplitude-frequency response of a segment of the cable network difficult to be replaced) [1].

3.2 Structure of the cable system

Replacement of old cables is a highly demanding work. They are mostly installed underground and any alternation can cause considerable system failures. This particularly applies to systems with a treelike topology built with an outdated equipment. Segments of old cables are replaced with high quality cable connections and in some instances with optical ones, too. This is the reason why the primary and secondary wiring is being gradually reconstructed. Furthermore, the tree-like structure is being converted in to the star-like one when ever applicable. This enables better signal transmission quality and less disturbances on a certain branch because of the low number of amplifiers and passive elements on it. As reconstruction problem the price of bi-directional optical communication devices is rather high. Branches of the network are qualified for bidirectional communication step by step.

4 Test trials and commercial activities in Slovenia

At the moment, a gradual introduction of bidirectional communication is in Slovenia assured by several big systems. Cable system of Žirovnica i.e. Gorenjski kabel of ASTRA Telekom and the cable system of Maribor i.e. KRS Rotovž were the first to enable two-way communication.

The CaTV network in Žirovnica is the most recent one and has a star-like topology. Four years ago, the equipment for bidirectional data communication of the local manufacturer ETK d.o.o. was tested. The equipment by West End Systems was tested and commercial NetGame Cable modems for Internet access are installed. Using the NetGame Cable equipment, there are presently about 650 (Feb/2000) users commercially connected to the Internet and the number of users is increasing.

The Cable system Rotovž in Maribor with some 10,000 cable connections employs the LANcity and Versalar DOCSIS 1.0 compliant Cable modem equipment by Nortel. The NetGame Cable equipment and Terayon Cable equipment have also been tested. Presently a few LAN networks from primary and secondary schools are connected to the Internet using the LANcity equipment (Nortel). One of networks connected via CaTV is also the network of the Faculty for Electrical Engineering and Computer Science of Maribor, which is involved in the reconstruction and tests. Commercially, there are about 250 (Feb/2000) home users connected to the Internet via

CaTV and the number of user is rapidly growing.

Users are satisfied with the service. As the Internet access is not keeping their phone lines occupied, they can be connected to the Internet without any time limits and the data transfer rate is as fast as 10 Mbit LAN network.

4.1 A Laboratory model of the cable communication system



Figure 3. Implementation of lab cable communication system model

New technologies applied to cable modems demand proper bidirectional ability of the network as well as proper setting and connections of the installed communication equipment.

To know new technologies and their use for real CaTV systems (Figure 3), a laboratory cable communication model was designed and built at the Faculty of Electrical Engineering and Computer Science of Maribor.

The model enabled insight into the behavior of the communication equipment and signals in a real environment [5]. Besides, the robustness test of communication connections and the effect of particular system parameters on the transfer of communication signals was also observed.

Testing the new equipment on real systems, owned by a cable operator, is difficult. Certain tests which must be made during the installation of a new equipment can cause disturbances in reception of TV and radio signals or failures in data communication. As there is always a risk of failure of the whole system, a commercial provider of services finds it difficult to perform tests on working system.

The laboratory model consists of three line amplifiers and two distribution amplifiers connected with some 2000m of a coaxial cable to splitters, taps and user wall outlets [6].

4.2 Control of the cable communication system

With the cable communication equipment, which supports SNMP (Simple Network Management Protocol) the CaTV control is quite simple. The status of its physical parameters (receiving-transmitting power of modems, equalizer weights, common estimate of the quality of the upstream and downstream channel) can be monitored by the controlling computer with a special software installed. Monitoring the networks and consequently the control and maintenance of communication links is simple. It provides the ratio between erroneously packets and total number of packets received by users, and the maintenance personnel can thus identify and remove problems before the end-user becomes aware of them. The cable SNMP monitors key parameters of signal transmission and communication protocol [4].

To have the CaTV system controlled, it is reasonable to install such cable modem at the ends of all branches which are on-line and serve as reference points for control and identification of anomalies in different branches of the CaTV system.

5 Transfer rate test of the computer network built on the platform of the CaTV network

For testing of the data-transfer rate between computers is made with the NetBench 5.0 benchmark program. This is a portable Ziff-Davis benchmark program measuring the performance of file servers which handle client network file requests. The NetBench clients are DOS, Windows 95, Windows NT, and Windows for Workgroups PCs and Mac OS systems. The program runs at any combination thereof. At the end of the test suite, the NetBench provides an overall I/O throughput score for the server and individual scores for the client.

The NetBench 5.0 enables a network interface card (NIC) test, and particularly the measurement of the transfer capacity of NIC on the server and client side [3].

5.1 The Program NetBench 5.0

Instead of running a single test, the NetBench 5.0 program runs a test suite. Each test suite which contains one or more test mixes, provides a blend of client request that reflects the typical activity on file servers. The NetBench executes the test mixes one after the other and the user can use the following ones:

- **The Disk Mix;** it allows different kinds of network file operations that typical users perform as they work with leading DOS, 16-bit or 32-bit Windows, Mac OS applications.
- **The NIC Test;** it reads data sequentially from a shared file on the server.
- **The I/O Throughput tests** (Sequential Read, Random Read, Sequential Write, Random Write, and Random Read/Write).

For each test mix, certain parameters like Ramp up, Ramp down, Length, Think time, Delay, Total Clients, Data pathnames, and Group numbers must be established.

- Ramp up is a certain number of seconds or iterations at the beginning of the mix. The NetBench does not record any results from mix iterations that begin during the Ramp up period.
- Ramp down is a certain number of seconds at the end of the mix. The NetBench does not record any results from mix iterations that begin during the Ramp down period.
- Length is the minimum number of seconds or iterations that the mix executes. The value for this parameter includes time for both the Ramp up and Ramp down periods.
- Delay Time is given in seconds and enters the maximum amount of time that a client has to wait before starting a test once the controller tells the client to start.
- Think Time is given in seconds and enters the number of seconds or fractions of a second that a client has to wait once it gets a response from the server before another request is issued to the server.
- Each client must have a group number (from 1 to 20). Clients can be assigned to different groups or be all included as members of the same group. The NetBench does not limit the number of clients in a group.

5.2 The NIC Test

The NIC Test is used for measuring the peak throughput of network interface cards in both servers and clients. The test attempts to isolate NIC performance by having all the clients sequentially read data from a shared file that fits into cache on the server. Because the file is cached, the server does not access the disk. Instead of this, the server handles all the sequential read requests from the memory. Thus, each client's throughput reflects the throughput capability of the network interface cards and the network physical layer; the speed of the server's disk subsystem does not influence the client's result.

With the NIC Test the client creates the shared file on the server. The program user specifies how big the shared file is (from 1KB to 100 MB) and how many bytes the NetBench reads from the shared file at one time (1 byte to 65534 bytes for the Windows and Mac OS clients and 1 byte to 32768 bytes for the DOS clients).

The NetBench file requests pass through the network file I/O redirector before they enter the network. As a result, the NetBench has no control over the actual packet size that the network redirector sends over the wire. For example, the network redirector can buffer each of the NetBench read requests of 64 bytes into 512-byte packets before it sends them to the server. There is no problem using the NIC Test for measuring peak throughput of the NIC cards under test when the network redirector buffers requests.

The network redirector can nevertheless affect results if with the NIC test the network interface card handling of the range of packet sizes is measured. This is especially true when the effect of using small packet sizes is measured. In such case, any buffering in the redirector software should be disabled. The NIC test measures only data transfers from the server to the client. It performs the following steps as it executes:

1. In the initialization phase, one client creates the test file.
2. During the run phase, all the clients seek to offset 0 in a shared file.
3. The clients read data in chunks that are the request size specified by the set up of the test.
4. When the clients reach the end of the file, they delay for the Think time and then reset the file offset to 0.
5. If seconds or iterations remain in the test, the clients return to step 2.

5.3 The test mix structure for measurement of the throughput capacity of the network

The test mix structure for determination of the network throughput capacity consists of four NIC tests. Before the testing starts one of the computers involved in the test creates a file of 100 MB on the server. The file is made of data packets of 1400 bytes length. The file created, the transfer rate test starts. The first test contains two computers. Each demands data packets from the test file from the server. The second test includes three computers, the third four and the fourth five. In all tests, the duration of the ramp up and ramp down time is the same, i.e. 10 seconds. The overall testing takes 60 seconds; 40 seconds of this time are spent for result recording. The size of the packet inquired by computers is determined on the basis of a previous test made with one computer. This test includes ten repetitions of the NIC tests; in each NIC test, the packet size is different. Results obtained with packets of different sizes (64B to 65kB) differ up to 1 Mb/s. For this reason the packet size of 1400 bytes was chosen as it is very close to the size of the Ethernet packet (1500 bytes).

6 Test implementation

Two tests were made. They are almost identical to the above described test mix. They only differ in the em-

Mix Name	Clients Participating	Total Throughput (MBits/sec)	Peak Throughput (bytes/sec)	Peak Client #	Low Throughput (bytes/sec)	Low Client #
nic60_2	2	7,858	547163,646	2	482794,812	1
nic60_3	3	7,934	454681,723	1	215373,840	3
nic60_4	4	7,939	394631,810	1	197913,278	3

Table 1. Results of transfer rate tests of the Ethernet 10Base-T network

Mix Name	Clients Participating	Total Throughput (MBits/sec)	Peak Throughput (bytes/sec)	Peak Client #	Low Throughput (bytes/sec)	Low Client #
nic60_2	2	5,238	409009,189	1	277500,748	2
nic60_3	3	5,864	285478,383	3	207605,499	2
nic60_4	4	5,847	216745,324	3	136677,681	2

Table 2. Results of transfer rate tests of the computer network implemented on the platform of the CaTV network

ployed physical media which connect the computers in to the network. The test was first made on the LAN network (Figure 4) and then it was repeated on the computer CaTV network (Figure 5).

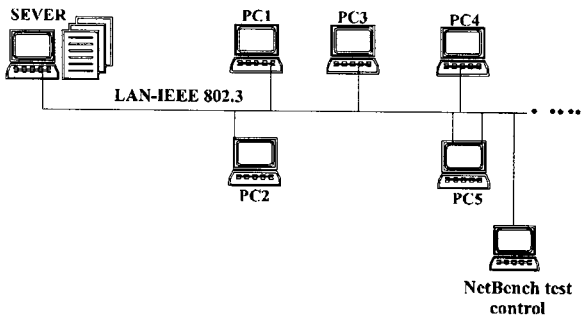


Figure 4. Transfer rate test of the Ethernet 10Base-T network

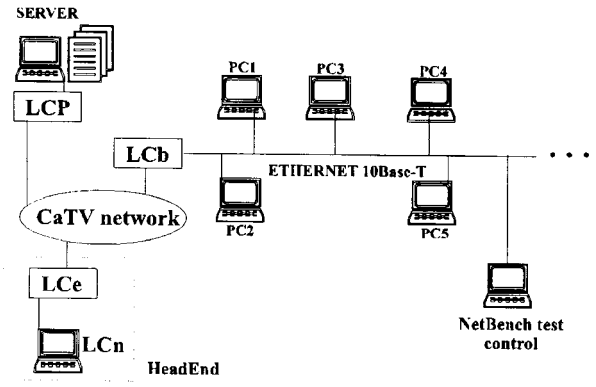


Figure 5. Transfer rate test of the computer network implemented on the platform of the CaTV network

Results of the test made with one computer show that the total throughput approaches the maximum transfer rate of 10 Mb/s through the Ethernet 10Base-T network. With additional computers connected to the network, the transfer rate of individual computers will start stagnating (theoretically this happens with two computers already). Another reason for stagnation of the transfer rate is when the server reduces the maximal payload because of higher demands for serving the clients. The transfer rate could be lowered or limited because of inadequate hardware equipment on the server side. That was not the case with the use of a most powerful computer (Pentium II 200 MHz with 128 MB of RAM) and testing with five computers communicating with two servers, and yielding almost the same results.

7 Test results

The Test polygon was implemented on the Rotovž CaTV system to which the described laboratory model was connected. For speed tests, the Nortel communication equipment (LANcity) was used. The communication equipment enabled a symmetric two-way communication with the maximum transfer rate of 10 Mb/s and also segmentation of the network with regarding to the different Internet providers and to the number of users on single channel pairs.

The results showed that the maximum transfer rate for the ethernet network (Table 1) was 7.939Mb/s and maximum transfer rate for computer network built on the platform of the CaTV network, was 5.847Mb/s (Table 2). In both cases, the same test mix was used. On the basis of this comparison and especially comparison with the transfer rates of classical phone modems, good prospects can

be predicted for the data communication over cable communication systems.

8 Conclusion

The interest of Slovenian cable operators in integration and expansion of this services, in particular the Internet access to the end users, is great. The reconstruction of the existing CaTV networks into bidirectional cable communication networks is estimated to be the major problem. Though presently network test branches apply with requirements of equipment manufacturers, this should no longer be the case in the future. To assure that type of communication equipment of any manufacturer what so ever can be installed, without further modification of the network, adequate rules and standards for reconstruction of networks should be implemented. In the absence of uniform international and national standards in the area of cable modems, communication equipment manufacturers find it hard to respond to different cable network requirements. There are never the less already few manufactures that offer DOCSIS compliant cable modems. Providing upstream channel is a difficult and responsible task as it necessitates adequate quality and reliability of services.

The comparison of test results shows, that transfer rates of the cable modem connection are to some extend lower than in case of the Ethernet connection. Yet they are at the same time much higher than the transfer rates of the classical phone modem or even the ISDN modem. As the bit error rate on CaTV network was not observed during the transfer rate tests, the lower total throughput of the computer CaTV network compared with the LAN throughput may result from a higher bit error rate of the CaTV network.

As the cable modem connection is quite similar to the Ethernet connection, it can be expected that increasing connections will reduce transfer rates of individual connections. A great advantage of the cable modem connection is the possibility of reservation of the throughput capacity for individual user 64kb/s, 128kb/s, 256kb/s or more. User will have the throughput capacity over the CaTV network guaranteed, but with no guarantee obligation for the Internet throughput capacity. The number and profile of users sharing the overall throughput capacity (10 Mb/s) of one channel pair (for upstream and downstream data) will mostly depend on the cable network operators. This means that they should carefully forecast and organize the user structure.

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