

IMPLEMENTATION TECHNIQUES FOR VIDEOCOMMUNICATION LANs

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ABSTRACT

We propose new architectures for videocommunication networks using switching matrices. Both implantations using electronic switching matrix and optical switching matrix are studied. The evaluation based on the required fibre bandwidth, the optical budget, the cost and complexity implementation shows that the implementation with electrical switching matrix is better than the implementation with optical switching matrix.

1. INTRODUCTION

The integration of image transport service is one of the major research orientations in new communication systems definition. The RETINE project deals with the design of local area network (LAN) for both video(1), (2), (3) and digital (4) image transmissions on fibre optics.

First we describe the general functions of the Videocommunication Local Area Network VILAN. After we propose new architectures for videocommunication networks using switching matrices. Both implantations using electronic switching matrix (ESM) and optical switching matrix (OSM) are studied.

2. PRESENTATION

The VILAN general functional diagram is given in figure 1. This LAN is formed by a set of switching matrices placed in different sites. The matrices are interconnected by fibre optic links. Each matrix is controlled by a switching matrix control system (SMCS) based on microprocessor. The videocommunication equipment (VEQ) (cameras, monitors, video tape recorders, image processing computers, ...) are connected to the matrices. A software server constitutes an interface between users and the SMCSs to establish connections between video equipment.

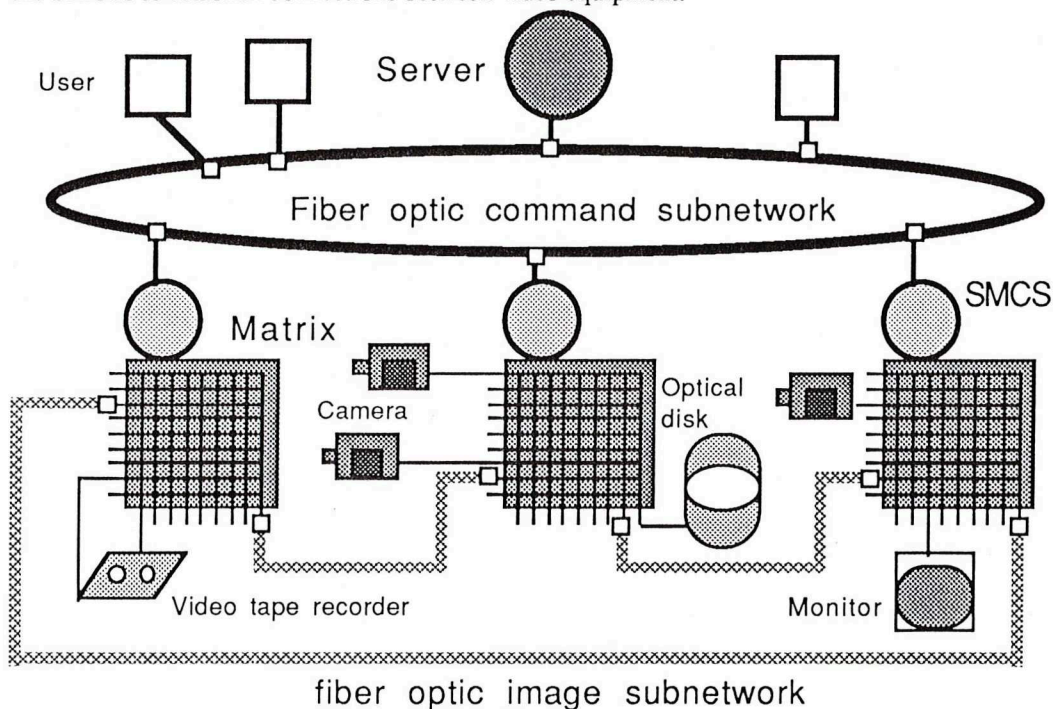


Figure 1 : VILAN general functional diagram.

Our network must assure efficient and flexible functions, such as remote control and access to image banks (optical disk, video tape recorder, ...), connexion to all sources of images (television, satellite channel, video camera, monitor, ...), digital conversion and interactive processing of images, and remote control of videocommunication equipment.

3. VILAN network architecture

Logically, the VILAN network is made up by two subnetworks: the video transmission subnetwork broadcasts the images, the command subnetwork supports the management messages exchanged between the users, the server and the SMCS systems.

Two main ways of implementing the VILAN exist: the first way is to have two independent and specialized subnetworks. Each one uses one fibre optic. This implementation is studied in (1). The second way is to integrate the two subnetworks on the same fibre optic. Our study deals with this way of implementation.

3.1 The integrated subnetwork system

We have proposed in (3) two processes of command and image integration in the same medium: the first uses only a frequency division multiplexing (FDM) technique. A channel is assigned to the command transmission, the other channels are used for image transmission. The second process includes time division multiplex (TDM) techniques. On each channel the commands are mixed within the images. We have described the giving rise architectures. The advantages of the second process are its great availability since a command can be transmitted at any instant, and very efficient use of bandwidth: unused period of image transmission coding is used to transmit the commands. A maximum effective throughput of about 180 kbits/s per channel can be reached with a transmission rate of 4 Mbits/s which is compatible the PAL/SECAM channel bandwidth. The disadvantages concern complex implementation due to the complex synchronisation required, and the difficulty of managing the numerous video standards. Integrating commands into images suffers from the great variety of current video standards. Also, new standards use different frame formats, new transmission techniques, and wider bandwidth for high definition television than current television.

The first process is more adapted to the multiplicity of present and future video standards. This is true for the following two reasons: straightforward implementation, and easy management of the command channel which is independent of the image channels; no investigation and no sophisticated method is required related to the numerous standards due to the transparency architecture used.

Topologies: the use of switching matrices enables numerous image subnetwork topologies to be obtained. The two main topologies are linear topology and circular topology. The difference between these two topologies is relative to the way in which the matrices are interconnected. In the circular topology, each matrix is connected in an identical way: each matrix has two neighbors (figure 1). While in linear topology, the first and last matrices are only connected to one neighbor (figure 2). These two topologies are imposed by the linear installation of the fibre optics. But the evaluation shows the linear topology is better than the circular topology (2). However, the command subnetwork topology is directly tied to image subnetwork topology.

General functioning: the VILAN general architecture is shown in figure 2. The server, the SMCSs and the users exchange information via command subnetwork. The functions of the SMCS associated to each matrix are the following: the management of local matrix, the management of local input and output video equipment, the support of local terminals and the management of the information exchanged with the distant server through the command channel (ICC: input command channel, OCC: output CC).

Using the proposed process of image and command integration we propose now two implementations: the first uses electronic switching matrix (ESM) and the second uses optical switching matrix (OSM).

Switching principle: from the point of view of transmission, the fibre provides very large bandwidth that enables huge data transmission. In order to keep this advantage in fibre optical LANs, it is important that the LAN bandwidth is not limited by the switching components. The electronic switching devices have two restrictive parameters: the width of the switched signal bandwidth and the switching speed of the switching device. The optical switches have the same limitations but the challenge is to realize wider band operating. The future target is an all optical video distribution system. Many optical switches, such as directional-coupler-type and total-reflection-type integrated matrix switches, have been reported (5).

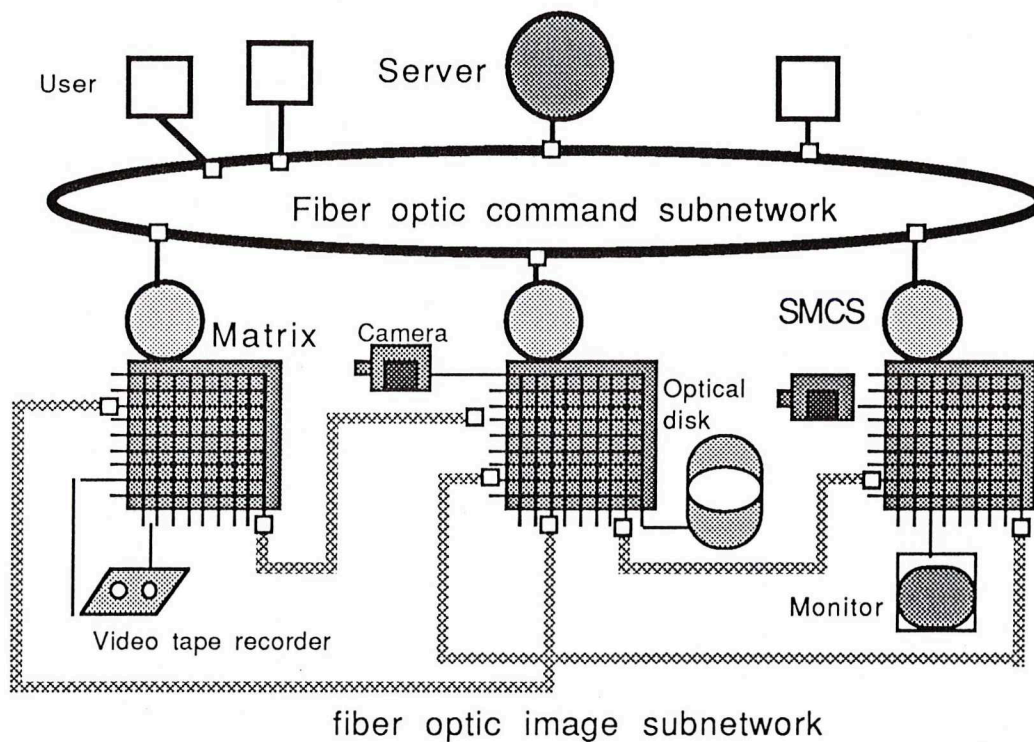


Figure 2 : VILAN general architecture

These optical switches, however, have some disadvantages. These include large insertion loss and long substrate length, that limit large scale integration. The insertion loss depends on used process and matrix size. A mean loss value is about of 4 dB for 4x4 matrix, but this value increases to about 10 dB if passive spilter/combiner are used. The crosstalk is usually higher than 15 dB and the mean value is about 30 dB. Laser diode (LD) optical switches, in which the gain and loss are controlled by an injection current in a p-n junction and the optical signal is directly switched, offer a promising means of solving the above mentioned problems (5). The integration of light sources with the multiplexers and light detectors with the demultiplexer would be desirable (integrated optic WDM devices). Mass and cheap processes are supposed to be possible in the future with integrated optics as has been the case with microelectronics in the last years (6).

The optical switching arrays research are focused on system applications using space division switching and time division switching. In space switching, the channel is the switch internal path that connects one input line to one or more output lines. In our application only the space switching is auspicious to analog signal switching.

3.2 System architecture with electrical switching matrix ESM

The multiplexing techniques ensure efficient use of broadband medium. Video signal transmission requires a bandwidth lower than 30 MHz, so we use FDM technique. With FDM technique the signals were kept separate by virtue of their translation to different portions of the frequency domain. The result signals are added before driving the optical transmitter. This technique is economical since it needs only one couple transmitter/receiver for the transmission signals on fibre optic (F O).

The communication system architecture with ESM matrix is given in figure 3. The system includes a demultiplexer between the reception optocoupler (O/E) and several matrix inputs (input link channel: ILC), and a multiplexer between the transmit optocoupler and several matrix outputs (output link channel: OLC). Each input video equipment (IVEQ), connected to the input video channel (IVC), provides video base band signal (BBS). The ILC carries BBS signal issued from the demultiplexer. The signal is then switched to local output VEQ (OVEQ) or to one OLC channel if the signal is broadcasted to other stations. In this case the signal is again frequency transposed and transmitted.

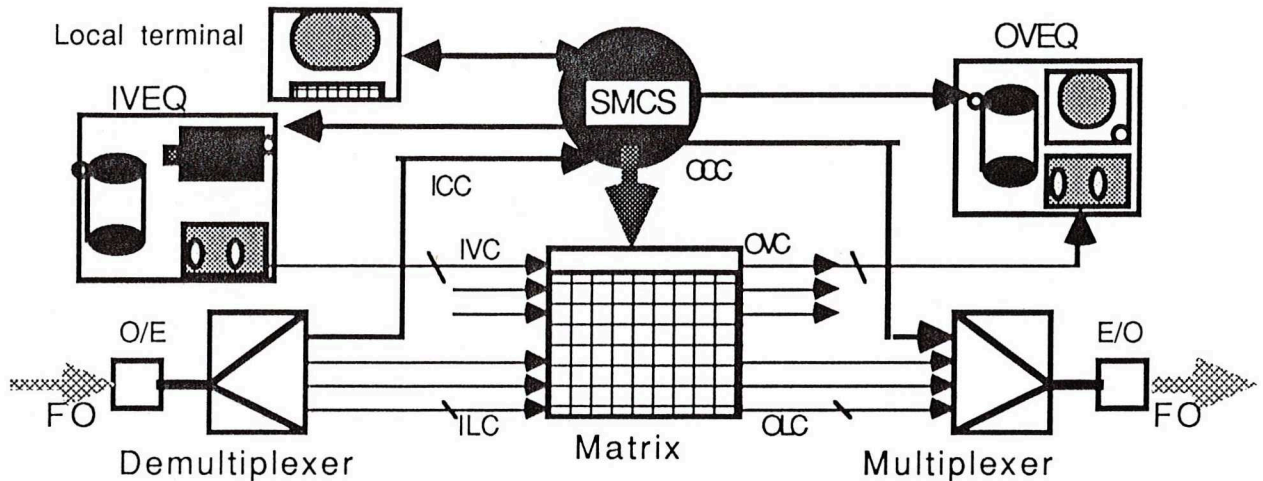


Figure 3 : The communication system architecture with ESM

Wavelength division multiplexing (WDM) technique also enables efficient use of fibre optic. The optical powers with separated wavelength are mixed by optical multiplexer and transmitted on fibre optic. WDM multiplexing uses two transmitters each one working in one fibre optic spectral window (850 nm, 1300 nm). Thus the LAN capacity is twice increased. WDM technique ensures LAN evolution: once the fibre cable is installed, and as needs increase, no link modifications are required to update the system.

Hence another implementation can be considered where one wavelength is assigned to digital transmission and another wavelength for analog transmission. In this implementation, the input optical signal from fiber optic is wavelength demultiplexed and the result optical signals are electrically converted (O/E). The signal processing is the same of that of the previous implementation. However, the output optical signal on fiber optic is issued from WDM multiplexer whose inputs are electrical digital signals and analog signals optically converted (E/O). This architecture has two advantages: the use of two wavelengths removes the crosstalk between analog and digital signals and hence improves image transmission quality, the digital channel can use the entire fibre optic bandwidth and so the throughput can be increased if necessary. Furthermore the number of image channels is increased by one relative to previous implementation.

More complex and difficult implementation can also be considered where the modulation and demodulation frequencies are controlled by the SMCS system. In this only signals addressed to the reception station are processed (demodulated) and locally switched. The remaining signals are not demodulated and are switched to the output through special path. The advantages are the optimisation of number of channels and the avoidance of signal demodulation and modulation in each crossing through a station. But the drawback is that the matrix must switch broadband signals.

3.3 System architecture with optical switching matrix OSM

The communication system architecture with OSM matrice is given in figure 4. The SMCS functions are maintained. The OSM input and output channels are optical. The OSM switches only optical signals.

The connection of the IVEQ equipment requires electrical to optical conversions. The connection of OVEQ equipment requires the opposite conversions. The most logical approach in this optical system consists in the transformation of each electrical BBS signal provided by the IVEQ into an optical signal with a wavelength carrier different from the others. The only and possible used technique is an optical FDM multiplexing (OFDM) where the light sources are quasi-monochromatic with closely allied wavelengths in the same optical window. The input optical signal is processed by an OFDM multiplexer. The command channel needs both optical/electrical conversions. The optical ILC channels (OILC) are locally switched or switched to the output through optical OLC channels (OOLC). The optical signal to be transmitted are wavelength multiplexed by an OFDM multiplexer. The advantage of this technique is to provide a large number of channels. The drawback is that technique needs optoelectronic devices working with different wavelengths from which a diversification of purchased devices and cost increase. Furthermore the fibre parameters vary with a wavelength and hence the channels have non identical performances.

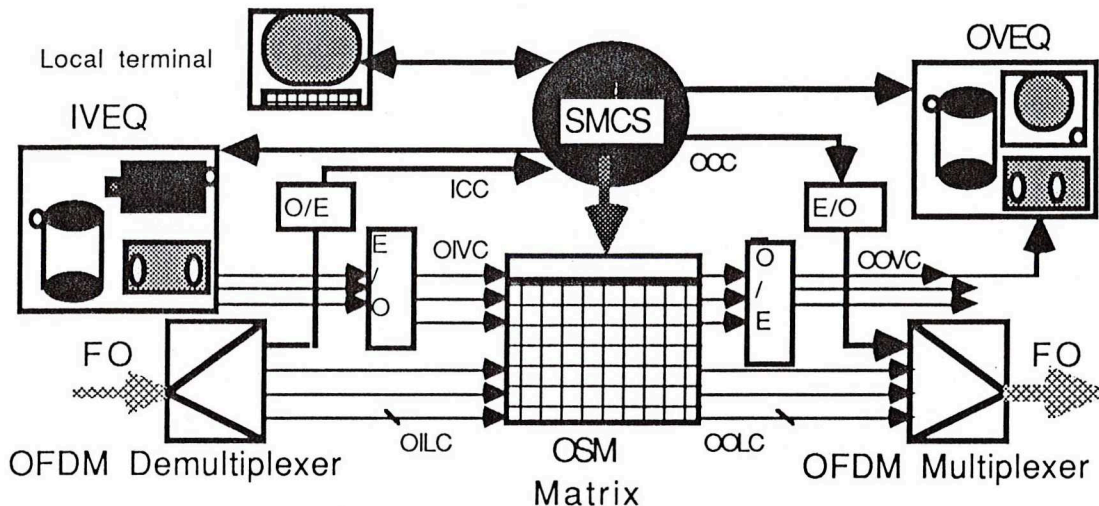


figure 4 : The communication system architecture with OSM

4. EVALUATION

The evaluation is based on the following performance criteria: the required fibre bandwidth, the optical budget, the cost and complexity implementation.

The determination of required bandwidth to LAN operation remains an area of critical concern. This is especially true if the services are not well defined and if the order of the number of equipment for image exchanges is unknown. Simulation study of LAN behaviour must be done based on these parameters and the VILAN operating mode. But here is a sample computation to give the idea about the needs.

For a LAN with 20 stations, and with 10 VEQ equipment connected to each station (5 for emission, 5 for reception), the number of required channels are of 100 for full loading LAN. However this value is exaggerated since one channel can support at least one service that corresponds to one link between two stations. A maximum number of services supported by one channel in linear topology is of 38 and 20 in circular topology. Hence 3 channels for linear topology and 5 channels for circular topology are at least requested. If only 25% of the maximum capacity of one channel is used, then about of 10 channels are required in linear topology and 20 channels in circular topology. This involves a 25x25 matrix size in both topologies. With optimist percentage of 50%, the matrix size is about 16x16. The linear topology has the advantage of the management of lower number of channels.

The required fibre optic bandwidth depends on several parameters: the number of required channels, the bandwidth of each channel, the used modulation technique (single side band: SSB, double side band: DSB, ...), the spectral intergap between neighbor channels to avoid interchannel crosstalk, the maximum distance between two neighbor stations, the wavelength and spectral width of light emitting sources (the worst case must be considered).

If 3 channels are used for high definition television, say 30 MHz per channel, 7 channels for other video standards, say 10 MHz per channel, 10 MHz for command channel, and 5MHz for intergap, then the required bandwidth is of 220 MHz. Bringing into account the maximum distance of 2 km with a profil factor of 0.75 in the variation law of the bandwidth with the distance, and with chromatic dispersion of 250 picosecond/ km (about 10 ps/nm/km as chromatic dispersion factor in multimode fibre at 1300 nm, and 25 nm of light emitting source spectral width at mid-height of spectral curve), the fiber must have a bandwidth of about 390 MHz.km.

The relationship between source/fiber performance and cost falls into two general areas. The first treats the insertion of optical power into the light guiding region of the fibre. The considerations here are relatively straightforward; the larger the core and numerical aperture, the greater power will be coupled to the fibre. However, there are second order effects which play a role in device performance and cost. One of these effects involves the potential reduction in drive current in a semiconductor transmitter. The reduction in drive current could extend source life. In addition, some forms of transmitter are less complex than others. Lasers, for example, generally include a feedback loop and thermal electric cooling. Such complexity may be eliminated if coupling efficiencies using LEDs are high enough, in particular in short links between stations.

With the needs that approximate these mentioned above, the matrix size is at least 16x16. With OSM implementation the insertion loss increases with the matrix size and then the mean value is about 16 dB. Thus bringing into account only this type of loss the total end to end loss is about 320 dB without optical/electrical repeaters or optical amplifier. This makes the implementation impossible. This is also true because with light source as laser diode the launched power in optical fiber is generally lower than 6 dBm (4 mW) and the avalanche photodiode (APD) generally has a maximum sensitivity absolute value lower than -60 dBm (1E-06mW). Other components include optical loss as the OFDM multiplexers and demultiplexers, connexions between the input and output ends of the optical matrix and the multiplexers/demultiplexers, and the fibre optic. The optical power loss depends on fibre optic type and the wavelength. The single-mode fibres have lower attenuation factor than multi-mode fibres at the same wavelength. But the insertion loss is higher in singlemode fibre system than multimode fibre system (7).

With the approximate needs mentioned above an implementation with ESM matrices using FDM technique is sufficient. In this implementation the matrix switches signals of about 30 MHz bandwidth. Technologically ESM matrix that switches signal of about 300 MHz bandwidth can be built, for example, with the D/CMOS 16/1 multiplexer device DG536 of SILICONIX. Other silicon or AsGa technologies enable wider bandwidth devices. The implantation with OSM matrices requires numerous electrical and optical conversions in order to connect video equipment and SMCSs (about 240 conversions) and suffers from the large insertion loss. The OFDM devices remain very expensive compared to the device used in ESM implementation. The OSM matrix easily switches a gigahertz bandwidth signals. The use of OSM matrix is not justified since the switched signals are not broadband.

5 CONCLUSION

The videocommunication LAN enables the user connexion to all sources of images and provides remote control of videocommunication equipment. Logically, videocommunication networks include two subnetworks: one for analog video image transmission and the other for digital command transmission. The first prototype implementation of our network uses two independent and specialized networks, each one using one pair of fibre optics. We propose to integrate image and command subnetworks on the same pair of fibre optics. We consider several signal processing techniques to achieve this integration and we optimize the use of the large bandwidth available on the fiber optic. So we study new videocommunication architecture systems with electrical and optical switching matrices. These techniques include wavelength division multiplexing (WDM), frequency division multiplexing (FDM) and optical FDM (OFDM). Finally, we evaluate the architecture performances with regard to implementation cost, complexity and the state of the art of video signal coding, optical budget and required fibre optic bandwidth. With the approximate needs of 20 stations with 10 video equipment per station an implementation with ESM matrices using FDM technique is sufficient. The implantation with OSM matrices requires numerous electrical and optical conversion in order to connect video equipment, and suffers from the large insertion loss. The OFDM devices remain very expensive compared to the device used in ESM implementation. The use of OSM matrix is not justified since the switched signals are not broadband.

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