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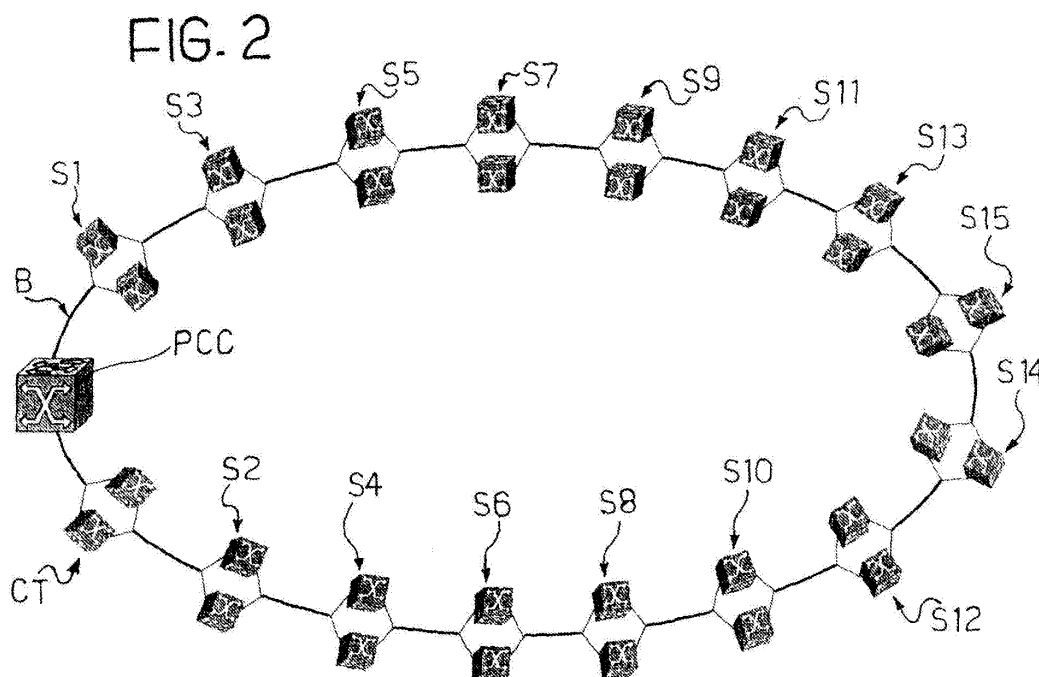
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(54) An integrated communications network for an urban transport system

(57) A communications network is described for an urban transport system comprising at least one transport line (L) including a plurality of stations (S1-S15; S16-S21) disposed along a substantially linear route and a control centre (PCC). The network is characterised in that it comprises at least one communication node (N_{PCC}) associated with the control centre (PCC) and a communication node (N_1 , N_2) associated with each station (S1-S15; S16-S21), which are arranged for

- access to the network by respective apparatus for the management and processing of audio, video and data signals; and
- routing of these signals through the network from each station (S1-S15; S16-S21) to the control centre (PCC) and vice versa;

and in which the nodes (N_{PCC} , N_1 , N_2) are connected through a signal transmission backbone (B) which has a ring topology.



Description

[0001] The present invention relates to urban transport systems, and more specifically an audio, video and data communications network for an urban public transport system.

[0002] These days, the definition of new, efficient urban public transport systems cannot exclude from consideration the functionalities offered by the technological evolution in the computer and telecommunications sector.

[0003] Users require quality, efficiency and security in the latest generation of urban transport systems and to this end there are provided, at the stations or stops of the lines constituting an urban transport network, voice communication services via telephones or intercom systems from the users to a management central unit, and from the central unit to the users via sound diffusion systems, as well as video surveillance services of the access entrances to the transport network, and remote control of the station equipment, relative to stops and vehicles, in this latter case for application to railway systems or similar restrained guide systems, in particular, among others, tramways and urban railway systems.

[0004] The application of new communications technology to terrestrial urban transport systems is hindered - by comparison, for example, to its application in the industrial automation sector, or in the automotive sector - by the time taken to build works, by the high reliability characteristics required, and by the necessity of having the same technology available for a considerable number of years, specifically for the replacement of components which might fail in the course of their working life, without it being necessary to replace the whole apparatus or even the entire system with other more up-to-date technology.

[0005] Infrastructure works traditionally have extremely long design and production times as compared to those characteristic of the development of the computer sector. In fact, whilst the design and production cycle (the so-called "Time-To-Market") of a computer system, however complex, is limited to only 6-12 months, for the average infrastructure of a metropolitan railway public transport system, even in the best of cases, a design period lying between two and four years is needed and a subsequent production period from two to five years, depending on the length of the line or lines to be formed.

[0006] The necessary reliability is another determining factor. In traditional systems the architecture and components adopted are based on preceding choices whose outcome has been tested and evaluated by experience. Moreover, the use of traditional equipment makes it possible to secure a long-term availability for any spare parts which may become necessary.

[0007] Furthermore, in the specific case of metropolitan railway systems, it is often necessary to utilise arrangements of the "railway" type, and this necessarily involves a design approach which brings with it an excessive attachment to the choices and methodologies derived from the railway sector itself. The application to metropolitan railway systems of solutions which are suitable for national or regional railway lines is often unsatisfactory bearing in mind the different type of transport and areas of use.

[0008] The object of the present invention is to provide a flexible and reliable integrated communications network for the management of an urban transport system. In particular, the object of the invention is the provision of an integrated communications network for the management of the telecommunications equipment (sound diffusion system, telephone and intercom systems), the surveillance and automation equipment at the stations (or stops) of a metropolitan railway transport system of restrained guide type, such as for example an underground metropolitan railway transport system.

[0009] A further object is to provide a communications network the future expansion of which, such as the implementation of new functionalities, will be easy and inexpensive.

[0010] A further object is to provide a communications network the initial installation and subsequent maintenance of which will present low costs in comparison with known networks.

[0011] To this end the subject of the invention comprises a communications network having the characteristics defined in Claim 1 and an urban transport system according to Claim 11.

[0012] Particular embodiments are defined in the dependent Claims.

[0013] In summary, the communications network according to the invention is based on the principle of considering the communications apparatus and systems at the stations of an urban transport network as subsystems interfaced with one another and with a control central unit by means of connections of universal type, utilising recognised standards and via a single communications network of ring type operable to convey the stream of audio, video and data signals for the services which it is desired to provide.

[0014] The communications network is preferably formed as a packet switching network of IP on Ethernet type, structured and dimensioned to adapt to the morphological characteristics of the urban transport system. The streams of audio, video and data signals are encoded by gateways at nodes of the network and transported on optical transmission means, by means of a statistical multiplexing.

[0015] In view of the enormous diffusion of the worldwide telematic network Internet the IP protocol has been adopted as the protocol of the network layer in the ISO/OSI reference model, and the TCP/UDP protocol has been adopted as the protocol of the transport layer. As far as the data connection layer is concerned, various arrangements have been evaluated, including dedicated technologies (typical of various constructors and non-standard types), technologies of

synchronous type (SDH), asynchronous technologies (ATM) and technologies of non-deterministic type (Ethernet), and of these Ethernet is that which offers the lowest cost and perfect coupling with the IP network layer. The apparent weak point of Ethernet, that is a high reconfigurability time in the case of breakdown, is overcome by employing routing techniques at the IP layer, such as OSPF or Fast Spanning Tree.

[0016] These considerations, together with the greater technical stability and availability of widespread knowledge of Ethernet technology, and the perspective of a long survival and future evolution of this technology, has inclined the choice towards an integrated network of "IP on Ethernet" type.

[0017] Further characteristics and advantages of the invention will be explained in more detail in the following detailed description given purely by way of non-limitative example, with reference to the attached drawings, in which:

Figure 1 is a schematic representation of one line of an urban public transport network;

Figure 2 is a general diagram of a multi-service integrated communications network for an urban public transport system the subject of the invention;

Figure 3 is a detailed diagram of the connections of the network of Figure 2 at a control centre;

Figure 4 is a detailed diagram of the connections of the network of Figure 2 at station nodes;

Figure 5 is a schematic representation of the system for signal processing of the network of Figure 2; and

Figure 6 is a diagram of the redundancy layer architecture of a diagnostic and remote control system accessory to the network.

[0018] Hereinafter the components of an urban public transport system provided with an integrated communications network according to the invention are described in an exemplary manner which is, however, not to be considered as a limitation on the possibilities of expansion and adaptation of the proposed network architecture.

[0019] In particular, the following discussion is developed with reference to a restrained guide urban transport system such as, for example, a tramway or urban metropolitan railway transport system.

[0020] Such a system comprises a network of transport lines which cover an area or region to be provided with the service. A line L of a metropolitan railway transport network comprises a plurality of stations S1,... S15 (areas of access to the service) and a control area called the Technical Area (CT) where the offices, the depot for the transport means, and the maintenance works are located. S16-S21 are indicated in the example as further stations of a subsequent section of the line, which can be designed and subsequently built after formation of the first section.

[0021] Preferably, a metropolitan railway transport system will be considered the trains of which make use of VAL technology and are therefore completely automated and have no driver on board in normal service conditions. The stations are also automated and the management of the entire system takes place via a single management centre called the Central Command and Control Station, indicated PCC in the drawing, preferably located at one end of the line in the Technical Area CT.

[0022] In such a system, all the data streams must be conveyed from the stations S1-S15 (and S16-S21 of the exemplary line possibly extended) to the management centre PCC to allow operation of the entire system.

[0023] Typically, depending on the use of a telematic network, and on the disposition of its nodes (corresponding to the stations S1-S15) and the requirements for reliability and tolerance to breakdowns, the following network topologies and associated considerations can be presented:

1) Star Network: is the most commonly utilised in local area communications networks, and is the base of the idea of structured cabling; all the nodes of the network are connected to a central node, the so-called star centre, which functions as a relay and/or switch. Among the advantages of this configuration is the fact that interruption of one of the connections does not compromise the functionality of the remainder of the network, and only the device connected to the star centre by means of that connection remains isolated; moreover, the bandwidth necessary for each connection depends only on the bandwidth requirements of the node connected to it. The loss of the star centre isolates all the nodes and the central apparatus therefore must be chosen with good characteristics of reliability and redundancy; moreover, in the case of breakdown of an interface to a peripheral node the information does not have any available alternative routes to enable it to reach the remainder of the network and therefore the node actually remains isolated. The central node must have a high switching capacity to manage and sort the data coming from all the nodes. Finally, it is necessary to install a large quantity of cables in order to be able to reach all the peripheral nodes from the star centre with dedicated connections.

This is therefore a configuration of little interest for a metropolitan railway urban transport system in which the route of the lines is for the most part linear.

2) Grid Network: each node is connected in a more or less complex manner to the other nodes of the network. Advantageously the alternative paths which the information can follow in the event of a breakdown of the connections are increased and therefore the tolerance level against failure increases with an increase in the complexity of the

network. It is a disadvantage that it also increases the costs, given that the cabling and the interfaces for the connection of the various nodes increase, the complexity of the routing is very much increased, and, as the number of nodes increases, the number of connections needed in order to maintain the level of tolerance against breakdowns increases in a more than linear manner. Finally, it accentuates the problems of cabling already encountered in the star topology, which makes this arrangement even more impracticable for use in the relevant urban transport system. Consequently, it can only be utilised in the case of a small number of nodes.

3) Ring Network: the individual devices of the network are connected together in such a way as to form a ring. Advantageously, each node has two alternative paths in order to be able to reach the remainder of the network, thereby increasing the level of tolerance to breakdown, whereby to tolerate the loss of one connection without causing isolation of any of the nodes. Moreover, with an increase in the nodes the number of connections and interfaces increases in a linear manner and therefore the costs remain contained even in the case of very complex networks. Finally, the cost of cabling is a minimum, in particular for the construction of a transport network with the characteristic linear arrangement of stations as in the case of a metropolitan railway transport network.

[0024] In this configuration, with two alternative paths being available, it is necessary to adopt strategies to redirect the data stream and to reconfigure the direction of these stream in the event of a breakdown somewhere along the network ring.

[0025] Taking account of the fact that a metropolitan railway line of an urban public transport system has a mostly linear topography, substantially rectilinear for the major part of the route, with a control centre PCC typically located at one end, and the fact that the individual nodes of the communications network are preferably located at each station, for the purpose of:

- limiting as far as possible the quantity of cabling which runs from the PCC centre to the stations in order to simplify the overall cabling and to reduce equipment costs;
- diversifying the paths followed by the cables so that damage to a backbone connection does not prejudice the functioning of the entire network and so that, in the case of a breakdown, this information shall have at least one alternative path to reach the control centre; and
- limiting the time needed for a possible reconfiguration of the network with the consequent redirection of the data streams,

the communications network according to the invention adopts the ring network topology.

[0026] In particular, along a linear line L, the transmission line (backbone) B of which the ring is constituted can follow physically separated out and return paths (for example to channels located on the two opposite sides of the route of the train) the ring then being closed at the two ends of the path, that is at one end at the node of the PCC central station and at the other end at the node of the furthest distant station.

[0027] Advantageously, with this configuration, future extension of the network does not involve modifications to the pre-existing network structure in that it is sufficient to "open" the ring at one of the nodes without it being necessary to locate new cables between the central station and the new stations.

[0028] In Figure 3 is shown in detail the node of the network at the control centre PCC, respectively indicated N_{PCC} .

[0029] By this means a plurality of control apparatus access to the network (to the backbone B), in particular a network supervision processor unit 10, an assembly 12 of processor units for the management of telephone/intercom, video surveillance, sound diffusion and video information equipment located at the stations of the transport line, and recording units 14 for recording audio and video communications and images coming from the stations.

[0030] To the node N_{PCC} are also directly connected apparatus 20 for encoding/decoding and management of the signals for service telephony and intercom, apparatus 22 for encoding and management of signals for sound diffusion of messages, and apparatus 24 for decoding and management of video signals for remote surveillance, all communicating with terminals of the control centre PCC such as, for example, operator posts 30 and monitor 32. A direct connection for the transmission of video information signals between operator posts 30 and the communication node N_{PCC} without interface of an encoding or decoding apparatus is also envisaged.

[0031] The node N_{PCC} is, moreover, connected to a processor unit 40 of the SCADA type for supervision and control of the electrical equipment of the line.

[0032] Finally, the node is coupled to a local network of control nodes (indicated LAN PCC) for grouping together the N_{PCC} nodes of other lines of the transport system.

[0033] Figure 4 shows in detail a single station S_i ($i = 1, \dots, 15$ in the example) of the network.

[0034] It includes a pair of network nodes N_1 and N_2 , each connected to the backbone B, both coupled to station apparatus such as the encoding/decoding and signal management apparatus 20' for the service telephone and the intercom, encoding and signal management apparatus 22' for sound diffusion of messages, and video signal decoding

and management apparatus 24' for remote surveillance, all communicating with station terminals such as, respectively, for example, intercom and service telephones 50, loudspeakers 52, video cameras 54. A direct connection between monitor 56 and communication node N_1 , N_2 without an encoding or decoding interface is also envisaged for the transmission of video information signals.

[0035] The pair of nodes N_1 , N_2 is further connected to a processor unit 40' of SCADA type for supervision and control of electrical equipment of the line.

[0036] The architecture described satisfies the requirements for rapid and efficient transport of the following signals:

- signals coming from the station video cameras for video surveillance;
- sound signals from intercoms and service telephones;
- audio signals for station public address systems, for the technical area and possibly for the sections of track between stations (in particular in case of restrained ways, as in tunnels);
- signals for a public video-information system;
- signals for an automation system for the electrical and technological devices.

[0037] These signals, collected at the PCC, are made available to the operators who manage the service and the telecommunications from suitable control posts.

[0038] A brief description of each sub-system to which the said signals belong is given hereinafter. A supervision post of the network allows monitoring, configuration and maintenance operations on the components of the network itself.

Video-Surveillance

[0039] Surveillance of the stations and the technical area is effected by means of a plurality of video cameras (a different number from station to station), preferably PAL standard colour television; only a restricted number of video streams from the video cameras are directed to the N_{PCC} simultaneously. The system envisages an enlargement of the number of video streams, including those possibly coming from video cameras located on board the trains. The operators at the PCC can display the chosen video streams on a monitor or can choose a video camera from those available and display its images on a personal computer. It is possible also to effect a selection "by groups" of the video cameras, for example to display all the video cameras of a station platform. For this, there are functional matrices present at the stations for selection of analogue input signals to associated video encoders, whilst at the central station PCC similar selection matrices provide for routing of the video signals coming from the decoders towards the monitors.

Telephony/Intercom

[0040] Telephone lines reserved for the service and line maintenance staff and for the station maintenance rooms are provided for each station; further, in the areas open to the public, there are a plurality of intercoms to allow calls from the users to the operators at the central station PCC to be made. The intercom systems behave as house phones and can be adapted for connection to the telephone line making them therefore substantially equivalent to the telephone from the point of view of the transport of signals.

Sound Diffusion

[0041] The possibility of diffusing sound messages into the stations and possibly into the sections of track between stations (for example restrained ways, in tunnels) is envisaged via suitable loudspeakers. At the stations there are provided analogue selection stages for selection of the zones to which the messages are to be sent and analogue amplification stages, whilst in the control centre there is an analogue stage for selection of input signals so as to allow, under control of the operators, the diffusion of background music, pre-recorded messages or messages directed to the operators themselves. In the stations and in the depot there are loudspeakers grouped by homogeneous zones of relevance; from the PCC it is possible to deliver different messages to different zones (for example; platforms and ticketing zones); moreover a local call post (located in a technical area) can be utilised by authorised staff (for example firemen) to diffuse priority messages directly from the station.

Video Information to the Public

[0042] A series of monitors spaced along the platforms and in the concourse or atrium of each station delivers preliminarily stored text messages intended for the users of the transport network. These messages are selectable by the PCC operators.

Remote Control Systems for Electrical and Technological Equipment

[0043] All the signals coming from the programmable station controllers which manage the electrical equipment and supervise the technological equipment are received by a SCADA system (Supervisory Control And Data Acquisition), located at the PCC, the functioning of which will be described hereinafter.

[0044] In defining the technical characteristics of the integrated network forming the subject of the invention the following two aspects are taken into account:

- the difference between the delay requirements in the transfer of information; and
- the differences between the bandwidth requirements.

[0045] Many applications, such as, for example, the display of messages for video information or data streams from remote SCADA diagnostic systems are not affected by delay ("best-effort" applications), but for these it is important to guarantee an adequate bandwidth availability and to ensure that there are no data (packets) losses. Other applications, such as the traffic in voice and video signals (closed circuit TV) require that the delay introduced by the transmission system is maintained below a determined threshold and that possible packets which exceed this threshold are discarded so as not to delay the reproduction of samples contained in the subsequent packets. As opposed to voice traffic, the video traffic is unidirectional and therefore is more tolerant to delays and better supports degradation of the information due to packet losses.

[0046] The amount of bandwidth required by each application which utilises the integrated network for the transport of information is very variable, a large part of the bandwidth utilised relates to video-surveillance signals which are subject to an analogue-to-digital conversion at the stations; consequently, the amount of digital video data is strongly dependent on the type of compression algorithm utilised (MJPEG, MPEG1, MPEG2) (to a first analysis it can be assumed that the bit rate is maintained below the value of 8 Mb/s for each video stream). The traffic of the automation system, whilst not being of continuous type and, more than that, being traffic limited to the transmission of the variations of the state variables, can have stringent time constraints and can require simultaneous transmission from all the stations; for this reason a significant part of the bandwidth has been reserved to this type of traffic. The data of the telephone/intercom and the sound diffusion systems have very much smaller bandwidth requirements.

[0047] In order better to explain the role of the apparatus of the subsystems which make use of the integrated network the subject of the invention, Figure 5 schematically illustrates the classic model of a generic digital telecommunications system.

[0048] A signal source 100 (for example an input transducer) at which is generated an analogue input signal is coupled to a source encoder 110 at which analogue-to-digital conversion of the signal takes place through a compression algorithm with the addition of redundancy codes for recovery of encoded data and correction of possible encoding errors.

[0049] A channel encoder 120 downstream of the source encoder provides for optimisation of the digital signal for transmission on the channel, for example by the addition of bits for recovery of data possibly lost in transmission and data identifying the destination.

[0050] A channel modulator 130 modulates the signal as a function of the chosen transmission channel (that is to say the displacement to the assigned frequency band) and converts it into the form of signal which the channel is able to transmit (for example: sound wave, electromagnetic wave, light pulses, electrical pulses).

[0051] The signal reception chain associated with the transmission channel comprises a channel demodulator 140 operable to reconvert into binary form the signals received by the channel, returning the signal to the base band.

[0052] Downstream of the demodulator 140 is disposed a channel decoder 150 operable to reconstruct the digital signal from the received packets. It is arranged to recover possible lost data through the additional bits provided upon transmission and to remove any auxiliary information of the transmission introduced artificially by the source encoder 110 and the channel encoder 120.

[0053] A source decoder 160 is coupled to the channel decoder 150 and is able to decode the digital signal and reconstruct the original analogue signal possibly by removing any transmission errors through the redundancy bits provided.

[0054] Finally, an output transducer 170 converts the analogue signal into a suitable form to be presented to an operator by the terminal interface apparatus.

[0055] The nodes N_{PCC} of the control centre and N_1 , N_2 of each station constitute the access points to the communications network of the devices for processing different types of signals; these nodes are preferably implemented by devices which combine in one apparatus the functionality of a router with those of a switch, such as for example level 3 switches or L3-switch.

[0056] The transmission carrier is preferably formed by two single mode optical fibre cables which connect the two network nodes N_1 , N_2 at each station with those of the adjacent stations forming two parallel independent rings connected together at the PCC node; to each pair of network nodes there are in turn connected audio/video signal processing

apparatus in numbers such as to part the final utilisers (the station terminals) between the two optical backbones thus constituted.

[0057] A redundant configuration of this type has two fundamental benefits;

- 5 - malfunction of one node of the network nevertheless makes it possible to have full control on the half of the terminals connected to the other node;
- twice the bandwidth is available for transport

[0058] The optical fibre cables, in their outward path from the control centre PCC towards the end of the line (S15 or, for the extended line, S21) and in their return path from the end of the line (S15 or, for the extended line, S21) to the control centre PCC are joined to alternate stations in such a way as to minimise attenuation of the optical signal along all sections between two contiguous connections.

[0059] At the control centre PCC there is a single network node suitably dimensioned to be connected to both the optical backbones. The purpose of this node is to receive data from the stations and to transmit it to the signal decoder apparatus 140-160 to make it available to the operators in suitable form. On the other hand, the same network node will receive from the operator posts data and commands suitably encoded by the encoding apparatus 110-130, and will transmit them onto the network in order to be transferred to the stations.

[0060] Since the control centre represents the most critical point of the network this node will have to guarantee superior performance and therefore will be preferably completely redundant to allow the maximum reliability and availability.

[0061] The multi-service communications network forming the subject of the invention is preferably a network of the Gigabit Ethernet type on single mode optical fibre (1000BaseLX or greater). The use of single mode optical fibre (transmission in the second window, wavelength about 1300 nm) advantageously guarantees connections between nodes spaced by about 2km with 1000BaseLX Gigabit Ethernet optical modules without the use of signal regenerators.

[0062] The apparatus connected to the multi-service network are able to encode the audio/video signals into formats transportable on an IP network; interface with the network nodes is achieved according to the 10/100BaseT Ethernet standard.

[0063] The network uses standard TCP/IP and UDP transmission protocols and routing algorithms (OSPF) such as to minimise the reconfiguration times in the case of malfunction of the nodes.

[0064] Hereinafter the SCADA system mentioned above is analysed in greater detail.

[0065] The SCADA system makes it possible to provide a supervision, control and data acquisition service, permitting diagnostics and remote control to be performed on all the electrical and technological devices which do not have available a network interface and, therefore, do not constitute an integral part of the network the subject of the invention. Such devices are typically constituted by components dedicated to the civil infrastructure (for example lifts, moving staircases, lights etc) and to the supply network (transformer substations, UPS etc). From these the data necessary for the service are acquired by means of Station Acquisition Units (hereinafter UAS) devices of the PLC type (Programmable Logic Controller) provided with interfaces connected to the multi-surface integrated network.

[0066] The analogue and digital variables detected by the terminals are pre-processed by the PLC and sent to a redundant software module on server computers situated at the control centre. The structure of this redundancy will become clearly apparent from the explanatory diagram of Figure 6.

[0067] As is seen from this diagram, the UAS devices - which can be considered as generic client computers C - are not directed to a single virtual IP address to achieve the redundancy but see, at the network level, two separate machines, with two different network addresses. Because, for the purpose of saving bandwidth on the data network, the transmission of data from the periphery towards the centre takes place only "on data change" in a "unsolicited" manner, on the initiative of the UAS (client) with any protocol, it is necessary to inform these latter of the address of the master server to which the data is to be sent.

[0068] Writing of the address by the master server at regular time intervals in a memory location of all the configured clients is therefore programmed.

[0069] There is, however, a problem of a general nature related to the redundancy of the two machines: in order to designate the master server, these need to exchange a signal generally called a "heartbeat" which necessitates a dedicated connection. If this connection is interrupted whilst that to the client remains active, both the servers elect themselves as master causing a concurrent double writing of the address on the UASs. These latter then do not have available a stable address to which to send the acquired data.

[0070] The solution adopted, in this case, is to continue to communicate with the last individual master server, thereby stabilising the address and maintaining as valid the last address stable for a given minimum time interval. This interval must be greater than or equal to the write period of the address by the servers, plus a safety margin which must take into account the possible additional delays or skew effects between the two signals due to transport on the network.

[0071] The algorithm for control of the stability of the address must be executed by the side client and is set out by

way of example hereinafter in pseudo code:

```

5          STEADY <= 1
          Reset time
          as long as true repeat
10              Acquire ADDR_NEW
              If STEADY = 1 and ADDR_NEW<>ADDR_OLD
                  STEADY <= 0
              End
15          If stability interval passed
                  ADDR_OLD <= ADDR_NEW
                  Reset time
20          If STEADY = 1
                  ADDR_DEF <= ADDR_OLD
                  Otherwise
25          STEADY <= 1
                  End
          End
30      End

```

[0072] The variable STEADY signals the stability of the written address ADDR_NEW and is set at 1. After this a cycle is commenced which repeats at each reading and which, after the necessary time interval has passed, puts the read value of ADDR_NEW to ADDR_OLD to re-set the comparison and, following a verification of the stability, saves this latter in ADDR_DEF which constitutes the definitive address to which the information is sent.

[0073] During normal master-slave switchings the new written address is validated by the algorithm with a maximum delay equal to twice the stability interval calculated starting from when the old master server ceases control of the clients, thereby stopping writing its address.

[0074] This addressing procedure of the servers by the clients indicated MMAP (Multi Master Addressing Procedure), makes it possible to realise a client-server communication initiated by the client, with concurrent multiple servers.

[0075] The above-described principle is easily generalised to the case in which there are more than two servers.

[0076] With respect to the solution based on "heartbeat" control this has the following advantages:

- it is possible to have a generic number of concurrent servers to provide multiple redundancy configurations, preventing each from knowing the addresses of the others so as to control the activity thereof;
- it is not necessary to have a connection between the concurrent servers;
- it resolves the problem of disconnections between the servers which occurs if, for any reason, they continue to be able to communicate with the clients but not with one another.

[0077] From tests conducted it is possible to extrapolate estimates of the times that the communication network the subject of the invention takes to reconstruct a topology which recovers from a breakdown. From an experimental architecture it is derived that the reconfiguration times of a network composed of 7 nodes is of the order of 3.5 seconds in the case of a breakdown of an interface immediately identified by the node. In the very rare case in which the node of a station no longer participates in the correct functioning, but maintains connections active, impeding the prompt identification of the malfunction by the neighbour nodes the times will be influenced by the so-called "dead interval" (time which must pass before declaring an OSPF node as out of service, imposed by default as four times the "hello" interval or "hello time"). In this case, with the "hello time" set at 2 seconds, the reconfiguration times are 10.5 seconds. The

formula deduced experimentally is:

$$T_{rs} = 0,5 N_{nd} + 4 H_t$$

[0078] Where:

N_{nd} The number of nodes of the ring network

H_t "Hello time" (which can be set on the apparatus, default = 2 seconds)

T_{rs} Experimental reconfiguration time.

[0079] This, for a ring topology of a line layout of 16 stations, means about 12.5 seconds in the worst case, that is to say when the connection between the two nodes most distant from the management centre are interrupted.

[0080] Further experimental tests and the results obtained during the course of the development of the design of the Turin automatic metropolitan (underground) system have indicated, following a fine optimisation of the configuration parameters, results which are much better than those previously obtained. This is achieved by technological updating of the network apparatus utilised in the experimental architecture, which has made it possible to record reconfiguration times both in the case of loss of a network node and in the case of disconnection of a connection between the nodes, always less than 3 seconds.

[0081] From the tests it is apparent that these reconfiguration times are proportional to the number of nodes which constitute the ring of the network and, therefore, a reduction in the diameter of the ring leads to a reduction in the maximum reconfiguration times.

[0082] Up to now, therefore, the transport of signals on an integrated IP on Ethernet network is the best solution for the transmission of the audio/video/data information from the point of view of the flexibility of the apparatus, standardisation of the protocols and the data encoding algorithms, as well as the availability of these for the future and the gradually falling costs of Ethernet network apparatus.

[0083] The choice of the IP on Ethernet protocol, moreover, opens the way to a whole series of innovative services which can be implemented without particular problems on this type of network, for example the possibility of using "dynamic" publicity posters controlled by processors and programmed by the control centre in the night hours, or the possibility of utilising video telephones.

[0084] Advantageously, the current possibility of integrating video, voice and data on a single packet switching network greatly increases the flexibility and rationality of the system. Moreover, it is possible to increase the reliability of this integrated network by forming two unconnected networks and transporting on each of these a mixture of all the services in such a way as to guarantee, in the case of a network breakdown, the functioning, although degraded, of all the subsystems.

[0085] In brief summary the single integrated network according to the invention presents the following advantages:

- extreme flexibility of the system from the point of view of extensions such as the addition of stations, relocation of the management centre, addition of new services;
- rationality in the use of network resources which are dynamically shared by the various services;
- reduction of cost in the long term;
- greater stability of the architecture with respect to technological evolutions;
- lower costs in the application program development which can utilise standard protocols and interfaces.

[0086] By contrast, the choice of several separate networks dedicated to each type of traffic, although based on confirmed technology of analogue type relevant to the world of audio/video transmission at a professional level, would be more expensive in that these networks would not be able to enjoy the economy of scale and reduction of costs achieved by the still greater diffusion of computer networks.

[0087] Naturally, the principle of the invention remaining the same, the embodiments and details of construction can be widely varied with respect to what has been described and illustrated purely by way of non-limitative example, without by this departing from the scope of protection of the present invention defined in the attached Claims.

Claims

1. A communications network for an urban transport system comprising at least one transport line (L) including a plurality of stations (S1-S15; S16-S21) disposed along a substantially linear route and a control centre (PCC),

characterised in that it comprises at least one communication node (N_{PCC}) associated with the said control centre (PCC) and one communication node (N_1 ; N_2) associated with each station (S1-S15; S16-S21), which are arranged for:

- access to the network by respective apparatus for the management and processing of audio, video and data signals;
- routing through the network of the said signals from each station (S1-S15; S16-S21) to the control centre (PCC) and vice versa;

and in which the said nodes (N_{PCC} , N_1 , N_2) are connected via a signal transmission backbone (B) which has a ring topology.

2. A network according to Claim 1, comprising a pair of communication nodes (N_1 , N_2) associated with each station (S1-S15; S16-S21), each adapted for access to the network by a subsystem of apparatus for the management and processing of audio, video and data signals of the station (S1-S15; S16-S21) and routing of the said signals through the network.
3. A network according to Claim 1 or 2, **characterised in that** it is a packet switching network.
4. A network according to Claim 3, in which the communication nodes (N_{PCC} , N_1 , N_2) include equipment which combines the functionality of router with that of switch.
5. A network according to Claim 3 or 4, **characterised in that** it is based on an Ethernet standard for the data link layer.
6. A network according to Claim 5, in which the communication nodes talk by means of the TCP/IP family of protocols at the network and transport layer.
7. A network according to any preceding Claim, in which the transmission backbone (B) includes a optical fibre transmission channel.
8. A network according to Claim 7, in which the said transmission channel includes at least one optical fibre cable which, along the route of the said transport line (L), follows an outward path from the control centre (PCC) towards the station (S15; S21) at the end of the line (L) and a return path from the station (S15; S21) at the end of the line (L) to the control centre (PCC), the communication nodes (N_1 , N_2) associated with the stations (S1-S15; S16-S21) being connected alternately to the outward path or the return path of the channel.
9. A network according to any preceding Claim, in which the said apparatus for management and processing of audio, video and data signals includes audio telecommunication equipment, video surveillance equipment and automation equipment.
10. A network according to any preceding Claim, in which the said communication node (N_{PCC}) associated with the control centre (PCC) is connected to an external local area network (LAN PCC) for connection of nodes associated with the control centres of other lines of the transport system.
11. An urban transport system comprising at least one transport line (L) including a plurality of stations (S1-S15; S16-S21) disposed along a substantially linear route and a control centre (PCC), including a communications network between at least one node (N_{PCC}) associated with the said control centre (PCC) and one node (N_1 ; N_2) associated with each station (S1-S15; S16-S21) as defined in Claims 1 to 10.
12. A system according to Claim 11, including a plurality of apparatus associated with the control centre (PCC) for the management and processing of audio, video and data signals, the said apparatus including at least one of the following components:
 - encoding/decoding and signal management apparatus (20) for service telephony and intercom, communicating with a plurality of terminals (30, 32) of the control centre (PCC);
 - signal encoding and management apparatus (22) for sound diffusion of messages, communicating with a plurality of terminals (30, 32) of the control centre (PCC);
 - video signal and decoding management apparatus (24) for remote surveillance, communicating with a plurality of terminals (30, 32) of the control centre (PCC);

- a processing unit (10) for supervision of the network;
- a processing unit (12) for management of sound diffusion, video surveillance, telephone/intercom and video information equipment located at the stations (S1-S15; S16-S21) of the transport line (L);
- a recording unit (14) for recording audio and video communications and images from the stations (S1-S15; S16-S21); and
- a SCADA processing unit (40) for supervision and control of the electrical equipment of the line (L).

13. A system according to Claim 11 or Claim 12, comprising a plurality of apparatus associated with the stations (S1-S15; S16-S21) for the management and processing of audio, video and data signals, the said apparatus including at least one of the following components:

- signal and encoding/decoding management apparatus (20') for service telephony and intercom, communicating with a plurality of terminals (50-56) at the stations (S1-S15; S16-S21);
- signal and encoding management apparatus (22') for the sound diffusion of messages, communicating with a plurality of terminals (50-56) at the stations (S1-S15; S16-S21);
- video signal and decoding management apparatus (24') for remote surveillance, communicating with a plurality of terminals (50-56) at the stations (S1-S15; S16-S21);
- a SCADA processing unit (40') for supervision and control of the electrical equipment of the line (L).

FIG. 1

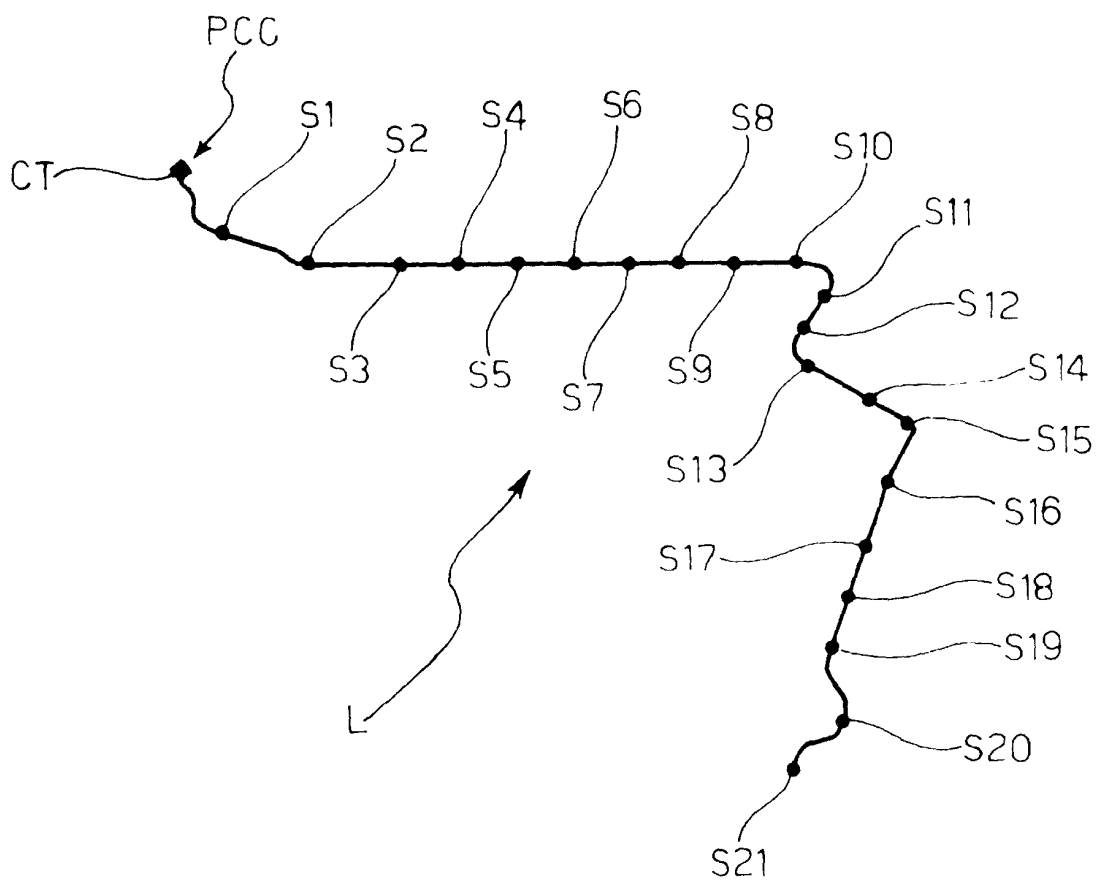


FIG. 2

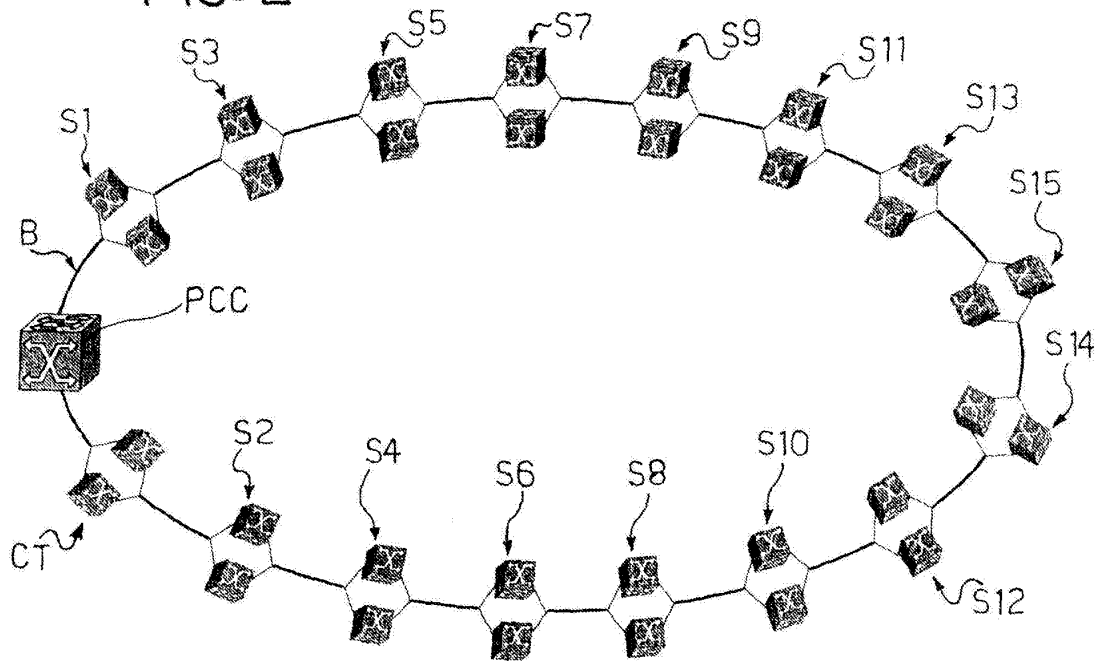


FIG. 3

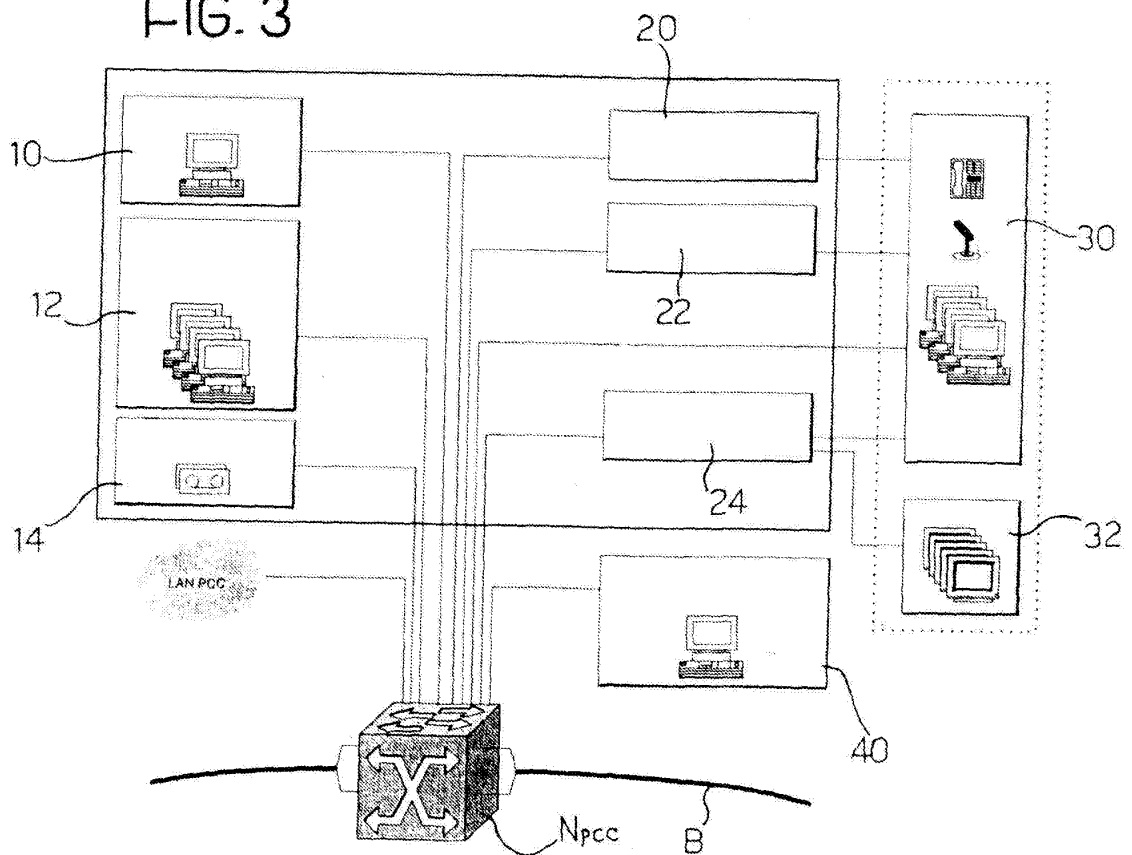


FIG. 4

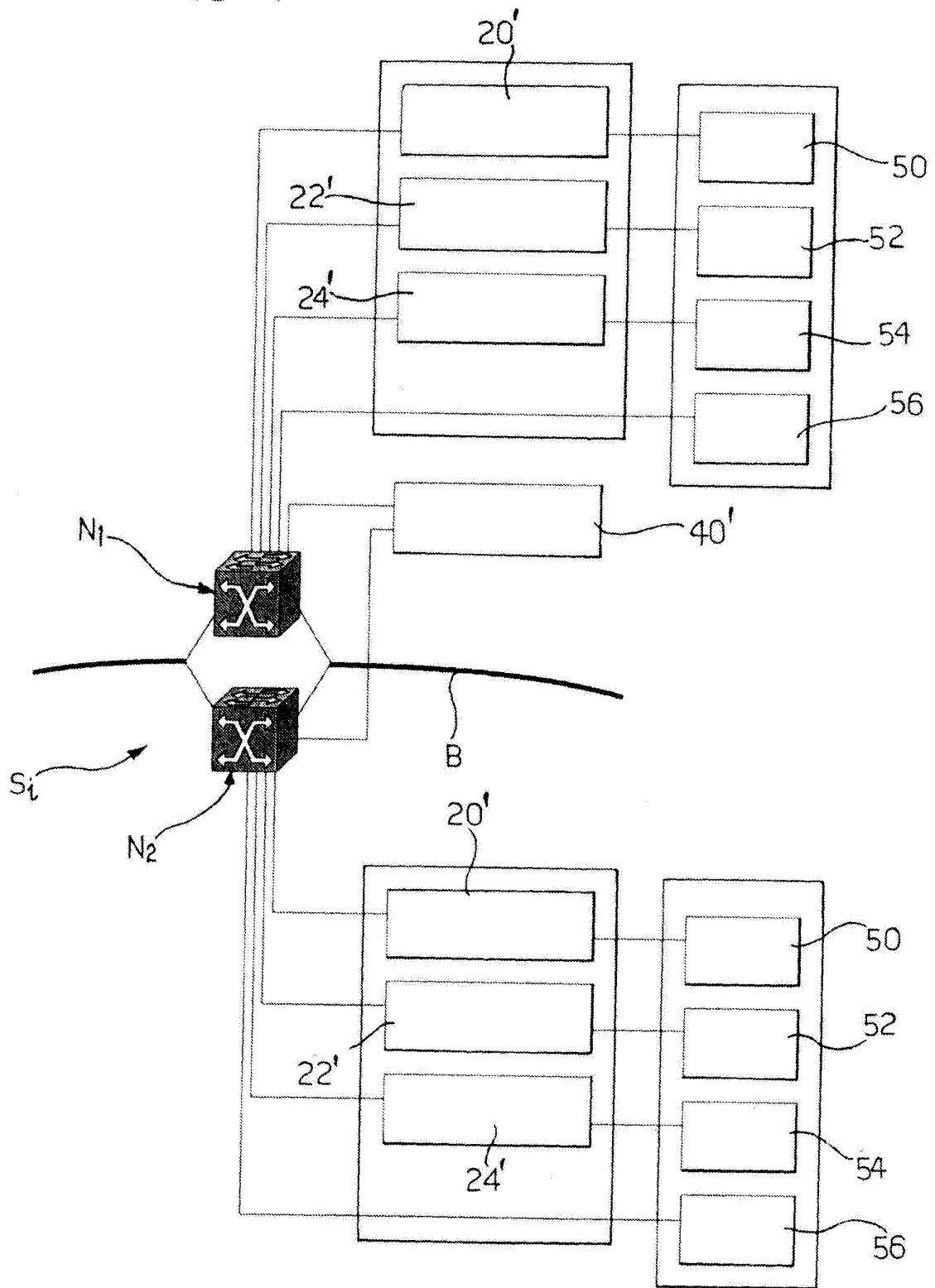


FIG. 5

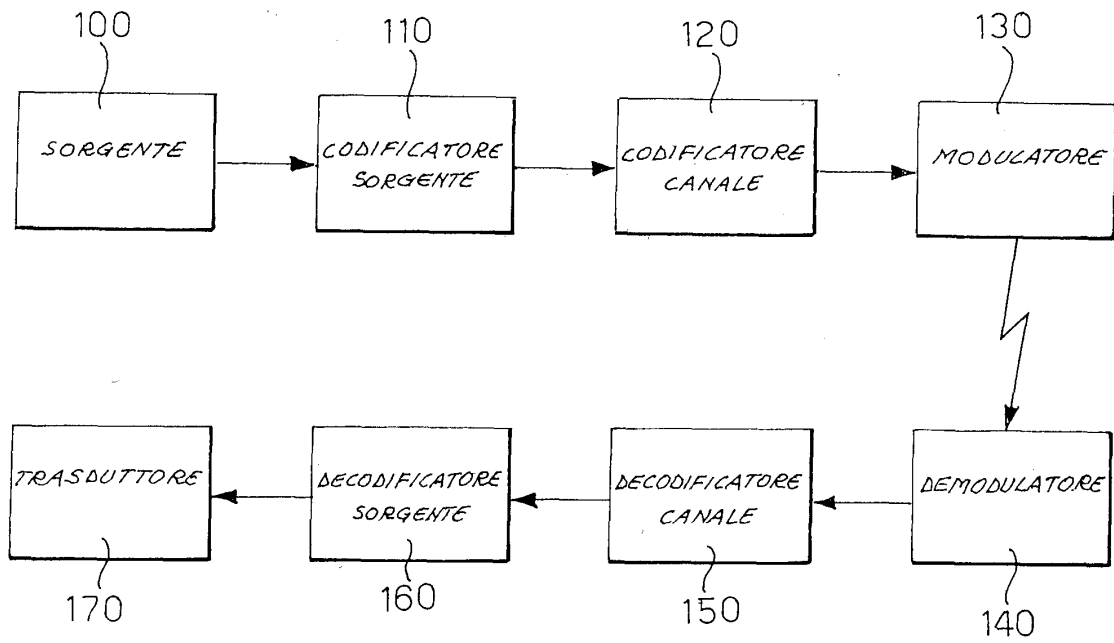
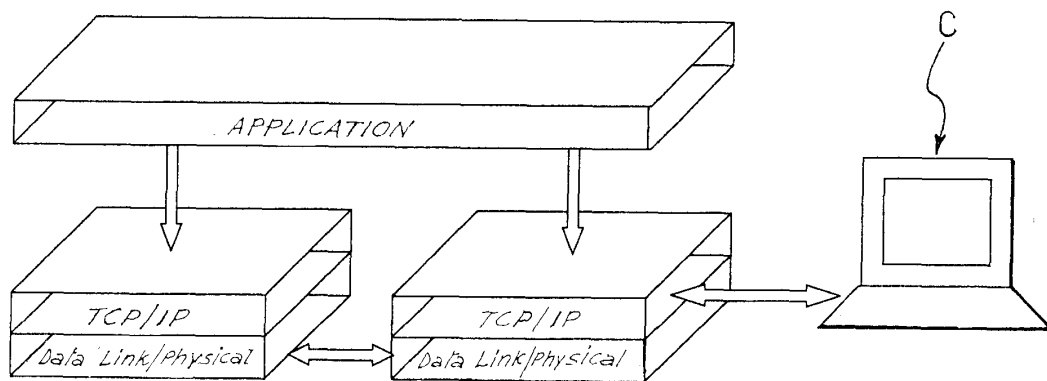


FIG. 6





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EUROPEAN SEARCH REPORT

Application Number
EP 05 10 6152

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Place of search The Hague		Date of completion of the search 27 October 2005	Examiner Créchet, P
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27-10-2005

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