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(72) Inventors JOHN EDWARD COX,
 ROBERT TREIBER and
 JOHN MICHAEL COTTON

(54) DISTRIBUTED CONTROL FOR SWITCHING SYSTEM

(71) We, INTERNATIONAL STANDARD ELECTRIC CORPORATION, a Corporation organised and existing under the Laws of the State of Delaware, United States of America, of 320 Park Avenue, New York 22, State of New York, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to digitally-switched multiple subscriber communications systems and more particularly to a distributed control arrangement using microprocessors in a system with a digital switching matrix. A telephone central or local office implementing such a distributed control apparatus and method is described.

In modern telephone switching systems, much data indicative of the status of the lines and trunks served by such a switching system, and of the required actions by the switch in response to various line and trunk status conditions, have to be stored. Such data includes subscriber class of service (COS), trunk class of call, subscriber restrictions, directory number (DN) to equipment number (EN) translations, EN to DN translations, translation of number code to switch action, i.e. area and office code translations with alternate routes, etc. In a centralized control system of the prior art, this data is available in a common memory, which is duplicated for reliability and is accessible by common control equipment for serial operations upon the extracted data.

In load sharing or multiprocessing common control systems of the prior art, more than one processor must access a common memory to obtain data at the same time. Various interference problems exist in such a system which causes some loss of throughput, which loss increases as the number of computers increases.

Decentralized control systems with distrib-

uted control functions are known, and one such system wherein stored program controllers are distributed throughout the system is described by U.S. Patent No. 3,974,343. Another known system is described by U.S. Patent No. 3,860,761 wherein a progressively-controlled switching system with register control couples an entire call at a time rather than the originating and terminating call halves as in the system described herein.

Prior art systems have concentrated on obtaining a high efficiency for the processing function. Multiprocessing was brought in to provide more processing capability but still with the objective of not providing more capability than was necessary. This caused undesirable interactions between software packages wherein the modifications or addition of a feature could interfere with the current working of other features in a largely unpredictable manner. This called for exhaustive testing of software packages whenever a feature or a traffic-sensitive quantity was changed (sometimes called regression testing). The larger the software packages became the more testing was needed, constantly retesting old features to ensure that they remained operable.

A major reason for this prior art problem lies in known common control system architectures wherein a stored program control processing function shares itself in time between a multitude of tasks which occur on demand of the randomly originated and terminated traffic. Such architectures also permit software errors and temporarily hardware errors to cause the computer program to "jump" to undesired and unpredictable memory locations, thereby disrupting the correct operations of the total software package.

The present invention seeks to eliminate such regression testing by providing a system architecture which permits a processing function to be assigned individually to each call.

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According to the present invention there is provided a distributed-control digitally-switched multiple subscriber system, including:

(a) a plurality of interface means, each of which provides an interface for at least one subscriber line to a common communications path and each of which includes means for deriving at least digital path selection control signals for each call coupled thereto;

(b) a switching network coupled to said common communications path for interconnecting said subscriber lines in response to said path selection control signals; and

(c) means at each of said interface means for deriving digitized speech signals, such that said speech signals and said selection control signals are multiplexed on said common communication path.

According to the present invention in a switching system for providing communication among a plurality of subscriber lines, which system is of the type which can be readily expanded to cater for increasing number of lines and other peripherals served, we provide a distributed control for each subscriber call for the duration of said call, which distributed control includes:

(a) subscriber line circuit means having at least one of said subscriber lines terminated thereat, for deriving digital path selection control signals and for deriving digital signals representative of said communication;

(b) means for multiplexing said digital path selection control signals and said digital signals representative of said communications on a common communication path such that part at least of the path selection control operations needed for call setting is provided for each of said communications using said subscriber lines; and

(c) a switching network having a plurality of said common communication paths coupled thereto from a plurality of subscriber line circuit means for switching said communications among said subscriber lines in accordance with said digital path selection control signals.

According to the present invention, there is also provided a telephone system with a local or central office including a switching network for interconnecting a plurality of subscriber lines and trunks which network is modular in form so that it can be readily expanded by the addition of one or more modules, the system including a plurality of subscriber line circuit means remote from the office, each of said line circuits providing a dedicated distributed control for each subscriber call for said subscriber lines and trunks coupled thereto, and including: means for deriving digital path selection control signals for individual subscriber calls on said lines and trunks coupled thereto; means

for digitizing said subscriber calls and for multiplexing said digital path selection control signals onto a common communication path together with the digitized subscriber calls and digital path selection control signals of (x) other subscriber line circuit means; and means for coupling said common communication path to the input of said switching network such that call control is on a distributed basis throughout the call.

According to the present invention, there is also provided a method of providing distributed control for a digitally switched multiple subscriber system, wherein the system includes a plurality of interface means, each of which provides an interface for at least one subscriber line to a common communication path, which method includes deriving at least digital path selection control signals for each call coupled from that line, interconnecting in response to the path selection control signals respective ones of the subscriber lines through a switching network coupled to said common communication path and deriving digitized speech signals at each interface means such that said speech signals and said digital path selection control signals are multiplexed on said common communication path.

According to the present invention, there is also provided a method for operating a switching system which can be expanded at will to provide service to additional subscriber lines and other peripherals, which system provides communication among a plurality of subscriber lines, call control being distributed, the method including the steps of: providing subscriber line circuit means having at least one of said subscriber lines terminated thereat, for deriving digital path selection control signals and for deriving digital signals representative of said communication; multiplexing said digital path selection control signals and said digital signals representative of said communications on a communication path common to a plurality of said subscriber line circuit means such that independent path selection control is provided for each of said communications on said subscriber lines; and switching said communications among said subscriber lines in accordance with said digital path selection control signals by means of a switching matrix means having a plurality of said common communication paths coupled thereto from a plurality of subscriber line circuit means.

According to the present invention, there is further provided a method of interconnecting a plurality of subscriber lines and trunks via the switching network of a telephone local or central office, including the steps of: providing a plurality of subscriber line circuit means remote from said telephone local or central office, each of said

subscriber line circuits providing a dedicated distributed control for each subscriber call for said subscriber lines and trunks coupled thereto, and including: deriving digital path selection control signals for individual subscriber calls on said lines and trunks coupled thereto; digitizing said subscriber calls and multiplexing said digitized subscriber calls and said digital path selection control signals onto a common communication path together with the digitized subscriber calls and digital path selection control signals of a plurality of other subscriber line circuit means; and coupling said common communication path to the input of said switching matrix such that said call control is on a distributed basis.

In addition, a central communication switching path, not only for the speech signals but also for the overhead traffic created by the need for the individual processing functions to communicate from time to time with each other and with such centralized functions as centrally stored data, maintenance modules, man/machine interfaces, etc. is provided.

When a plethora of processing functions operate independently but interactively with each other in a largely asynchronous manner to one another, this represents a distribution of the control function from a central location to each individual line and/or trunk termination. The communication between processing functions is via a hardware interface. Each processing function when assigned to a single line/trunk is concerned only with the features of the particular line/trunk it is assigned to serve. Thus it can be tested once exhaustively, and thereafter will continue to work with similarly tested functions via the common interface. The addition of a new feature into a processing function associated with a particular line may not function correctly (before it has been exhaustively tested) with another existing line not having the new feature but it cannot prevent two such existing lines from operating with one another because it is not involved in any way with the connection of a call between two existing lines. Sufficient hardware safeguards are present in the interface to detect erroneous transmissions between processing packages and to bring them to the attention of maintenance personnel. Also it may be made impossible for one processing function to alter the operating instructions for any other processing function. In the present system all that a processing function can do is to provide data via a hardware interface on which the distant processing function may choose to operate in accordance with its own set of stored instructions. One such hardware communication interface is the continuously-expandable switching network

described in our copending Application No. 1786/78 (Serial No. 1,560,192).

By using a processor for each termination, functions which in the prior art have required hardware logic and electromechanical and audio devices, can be done under software control by that processor. In the present system these functions are performed on a per line/trunk basis, including but not limited to, ringing the line, tone detection and generation, testing the line, analog-to-digital conversion, etc. to permit transmission and switching of information in time division multiplex (TDM) formats.

Current TDM transmissions, as is well known, transfer analog amplitude information as digital values, e.g. by delta modulation (PCM), wherein amplitude information is sampled at periodically consecutive points of time and represented by binary words. Such binary words are transferred as data bytes in periodically consecutive time slots, which time slots, when allocated to a communication link, form a time channel. Switching of time slots between channels by the time switches using time slot interchanges is well known and described in detail, for example in U.S. Patent No. 3,770,895.

Analog-to-digital conversion logic, either in a line circuit interface such as described in copending Application No. 6797/78 (Serial No. 1,583,634) or in a digital subset is controlled by microprocessor logic, the same microprocessor logic being also adaptable to control central office switching to central office data bases. Each such subset or group of subsets is controlled by a dedicated microprocessor with a programmable memory including a memory update capability through its digital channel to the central office. While a single microprocessor could be dedicated to service each subscriber set, a group of subscribers can be serviced by each microprocessor by local distribution multiplexors, using microprocessor logic such that a common program memory would service and be accessible by, for example, thirty to sixty subscribers.

Thus in the present system, the afore-described control functions are distributed to the individual lines and trunks to a degree determinable by the time and space switching functional elements of the central office whether the programmed line and switching control functions are local, at the central office, or distributed further down line. This distributed control technique is most advantageously utilized in conjunction with an essentially non-blocking switching network which switches not only voice and data traffic (revenue traffic) but also switches "overhead traffic" accessing the various data bases; such as: translator inputs, man-machine interface data, billing and traffic collection devices, etc. While a number of

digital electronic switching systems may be used with the present invention, a particularly suitable switching system is described by the aforementioned Application No. 1786/78 (Serial No. 1,560,192). In accordance with a further aspect of the present invention, the digital switches have coupled thereto switching control instructions over the same paths which couple the speech signals thereto, since the speech path is the only available path over which a remote subscriber subset can send such control data, hence, digitized speech and digital control signals are multiplexed on a common communication path through the group switch to both establish, maintain and terminate communication between calling and called subscribers.

In accordance with yet another aspect of the present invention a "half call" technique is described wherein, for example, one line may comprise a two-wire coin box line while another line may comprise a business line to PABX. Each processing function associated with each such line is programmed to know its own class of service and line signalling interface and also to know the common central interface and how to communicate via the group switch to another half call machine. Thus, a connection may be made between the two lines without having to know the complexities of how to handle all possible combinations of calls. In some instances it is required to transmit through or transmit signals in a forward and backward direction. These signals must be connected to the standard interface so as to be intelligible to other half call units.

An embodiment of the invention will now be described with reference to the drawings wherein:

Figure 1 is a simplified block diagram of a distributed control switching system in accordance with the present invention.

Figure 2 is a series of curves illustrative of the economics of the present invention as compared to systems of the prior art.

Figure 3 illustrates the relationship of the shared memory of a system embodying the present invention to other system elements.

Figure 4 is illustrative of a shared memory configuration of a system embodying the present invention.

Figure 5 shows a call control unit and a line termination unit in a system embodying the present invention.

Figure 6 is a translator subsystem configuration utilized in a system embodying the present invention.

In Figure 1, the distributed control switching system architecture is illustrated generally at 100. A group switch network 102, of the type described in greater detail in the aforementioned copending Patent Application No. 1786/78 (Serial No. 1,560,192) functions as the center of all system switching. Typically,

such a network is essentially non-blocking. The group switch network 102, which may be a concentrator or deconcentrator or any other class of PCM switch, provides space switching and time slot interchange to interconnect any time slot on any incoming multiplex line to any other time slot on any other outgoing multiplex line. It includes an internal path-selection control for regulating traffic in an essentially non-blocking manner via the speech path to accommodate the distributed control on the subscriber lines. Diagnostic programs capable of locating faults down to the level of one replacement item, i.e. a PC board or module, are decentralized and included in its microprocessor control of the subscriber lines, with one microprocessor per security block, which security block may, for example, include from one to sixty lines. This decentralized diagnostic programming inhibits interaction between fault location on a line and traffic on other lines. This technique of switching diagnostics from central control to the individual microprocessor means that processor throughput need not be maximized, and the distributed software may be structured to provide any level of maintenance and test capability. The multistage group switch network 102 is illustrated in simplified manner, and has a first stage consisting of subgroups 1, 2 and 3 to N, at 104, 106, 108 and 110 respectively. The internal path selection control for each first stage subgroup of switches is illustrated at 112, 114, 116 and 118 respectively. At the Mth stage of the matrix 102, switching subgroups 1 to N are illustrated at 120 and 122 with their respective path selection controls at 124 and 126.

The switching network 102 is interfaced at a common hardware interface provided by a multiplexed group 148 of the subscriber line circuits 128, to which the individual subscriber lines are connected, and are switched at the central or local office. Each multiplexed subgroup 148 has connected thereto the traffic from individual subscriber lines after analog-to-digital conversion by microprocessor-controlled line circuits 128, which line circuits 128 also provide digital-to-analog conversion for return traffic back onto the two-wire analog lines and trunks 132 and 134 served thereby. Line circuit 128 includes a microprocessor such as an 8080 microprocessor, or other suitable microprocessor and services its subscriber line. The elements of subscriber line circuit 128 are described in greater detail in copending Application No. 6797/78 (Serial No. 1,583,634). Individual digital subscriber lines 130, subscriber carrier system lines 136 and digital trunk groups 138 are coupled to the central office digital terminator 140 which provides for buffering and call control, and these lines and trunk groups are directly

switched as required by the group network 102. Requisite data bases and translators illustrated at 142, and other digital data stores such as billing information storage 144 and service circuits 146, are coupled to the group network. The translators included at 142 interpret digits dialed or keyed by subscribers as do conventional translators, but are also used to aid in implementing the distributed control function by operating with the only data communication path between line circuits 128 and group switch 102 provided by the speech paths, one of which is shown at 204. The translator architecture will be described in greater detail with reference to figure 6. Thus, the same switching network provides both a data communication path and a speech path between subscriber lines. Since the individual line circuits 128 control the establishing of paths to the switching network, the heretofore required central processor functions are effectively eliminated.

Referring now to figure 2, curves (a) to (d) illustrate the cost per subscriber line achieved with the present system as compared with systems of the prior art. The present system is capable of modular expansion to serve a growing number of subscriber lines, e.g. from 1000 lines to 100,000 lines at substantial savings over known systems. This is due to the savings achievable with high volume manufacturing techniques for producing multiple microprocessor-controlled line circuits with distributed control rather than large and costly wired or program logic central multiple line controls together with the requisite duplication inherent in such prior art control to guard against catastrophic failure.

Curve (a) is representative of the well known electromechanical step-by-step switches of the prior art, which permitted direct control by each subscriber over the speech path by a line finding arrangement directly controlled by the subscriber dial. The system is expandable with office growth, over a wide range with a slowly increasing cost/line due to the inefficiencies and inflexibilities of the system as it grows larger. Curve (b) represents register/translator control of step-by-step switching in which register senders and a translator are used to add numbering plan and feature flexibility. Duplication of the common parts of the register-senders and translation function is required which raises the cost per line curve at the low end.

Curve (c) illustrates prior art wired logic common control systems, such as the No. 5 crossbar system. Such systems not only suffer from the aforescribed equipment duplication problem, but are expandable over a relatively small range, i.e. 8 to 1 versus 1000 to 1 or more of the present system. Further,

the wired logic common control system does not enable direct subscriber control of switching over the speech path. Curve (c) also illustrates the cost/line vs. number of lines characteristic of stored program control electronic switching systems of the prior art. As can be seen, at some maximum number of lines, there is a sharp cutoff, since system expansion is limited by the throughput capability of the processor(s).

Referring now to Curve (d), the cost per line vs. number of lines characteristic of the present system is illustrated. Since one control element, such as a microprocessor, per line or per group of lines is used, and since, as will be described, the present system is modular and uniformly manufacturable, and uses a standardized hardware interface to a group switch instead of communication via software channels as in the prior art, the present system is easily expandable, at almost uniform cost, from, for example, 1000 subscribers to 100,000 subscribers. As the system expands throughput capacity is automatically added. This plus the similar modular expansion of the group matrix removes the upper limit of expansion normally found with common control and stored program common control offices without any loss of feature flexibility. This modularity also permits the addition of new features and services on a module or modules without the need for extensive retesting of the existing features as is now a limitation in stored program common control systems.

Referring now to Figures 3, 4 and 5 the call control, shared memory and distributed control will now be described. Call control is provided on the basis of one call termination circuit 128 containing one call control unit 302 per termination, and provides at different times processing for control of both the originating and terminating halves of a call. The call control unit (CCU) includes a microprocessor 402 with private memory 516, an interface 512 to a shared program memory, an interface 518 to a power supply unit, a pair of interface ports 212, 214 to switching network 102 shared by other microprocessors and having an address capability of about 256K-bytes and a digital filtering capability. Broadly, the CCU 302, described with reference to Figure 5, provides dc and low frequency control up to 300 Hz to provide battery feed and ringing current functions, voice frequency processing at 300-3800 Hz and call processing. The voice frequency processing is accomplished at voice frequency processor 500 under microprocessor 402 control. Each two-wire subscriber line 132 is coupled to a high voltage interface and analog-to-digital converter 502 and digital-to-analog converter 504. The digital output of A/D converter 502 is digitally filtered by processor 500 and con-

verted into bit stream such as a serial 14-bit linear PCM code supplemented by additional bits for controlling the group switch 102 and for communicating between different CCU's and translators. The digital filtering provides 2-to-4 wire conversion and compensates for the loss characteristics of the particular subscriber line or trunk 132. Microprocessor 402 is programmable to provide for equalization and loss and gain control equivalent to pad switching. Further, the 300 to 3800 Hz outputs of A/D converter 502 are digitally filtered to provide tone detection. Processor 500 also generates digital signals and couples the same to D/A converter 504 to generate audio signals in the 300-3800 Hz range for signalling busy-tone, ring-tone, etc. on the return subscriber line 132.

Dial pulses and equivalent tone signals are received and processed by microprocessor 402 to determine when access to common data bases and translators is required for further data. A set of instructions pertaining to the line/trunk service options of the individual line, is accessible from the shared memory 200 via memory port 512 and data/address bus lines 306. Such access is confined to a single security-block or bus and thus does not use the network 102 to obtain this data. As such, this represents a distribution of software control instructions to the individual lines/trunks so that different line/trunk blocks can freely contain different combinations of software instructions, representing different line/trunk service classes and feature bits. Thus it is not necessary to store all software instructions on a distributed basis, thereby saving in storage. Also, different combinations of software interaction with each other via standard interface lines 212 and 214 are prevented by group switch network 102. This permits feature modification, addition, deletion. Also a particular microprocessor only accesses the originating or terminating half of the software as dictated by the direction of the call set up. Channel Clock line 506, data and address bus 306 and request/grant lines 308 are coupled to memory port 512, together with a master clock on line 514, and provide the aforescribed inter-module communication. The interface ports to switching network 102 comprise output switches 520 and 522 and input switches 524 and 526.

The distributed control herein provided, whereby call control processing is distributed to give each call exclusive use of a microprocessor for the duration of that call eliminates the previous requisites for complex sharing algorithms for sharing a single processor among several calls. Distributed control may be provided by a microprocessor per erlang, per termination or per line block. In the present system, a microprocessor per

termination, i.e. per line/trunk, is provided, which comprehends, for example, a microprocessor per subscriber line. In any event, a microprocessor is dedicated to a line at least during the time that a call is being placed over that line.

Figure 3 shows a sixty-termination shared program arrangement, which may be considered as one security block. Each termination circuit 128 interfacing the subscriber lines to the group switch, as aforescribed, provides two-wire to four-wire conversion, digitizes incoming analog signals, provides digital filtering and other digital voice frequency processing and call control. The microprocessor therein, including a private memory, performs call control, translation, path selecting control signal generation and various diagnostic functions, and is coupled to a shared memory 200 via a memory port in circuit 128. In figure 3, sixty termination circuits 128 share memory 200. Each line such as line 212 from termination circuit 128 is multiplexed into a 32-channel group 204, i.e. common communications path, carrying 14-bit linear PCM serially at an 8KHz sampling rate, two of which channels may be allocated for communication with other system modules in accordance with timing signals from the shared memory 200 and the system clock.

Each terminating processor typically includes 4K-bytes of private memory and has access to the shared memory utilized by a plurality of microprocessors and which shared memory typically has an address capability of 256K-bytes.

Both program and fixed-data memories are shared; however, the private data memory which also provides "bootstrap" start up instructions for each microprocessor is not shared, so that microprocessor interaction is minimized. In any memory sharing system, potential problems due to processor contention for memory, access time required to access particular segments of shared memory and hardware and software complexity to overcome the foregoing exist.

Shared memory 200 may comprise a multiport memory as shown by figure 4 wherein each microprocessor 402 in call control unit 302 has access thereto via its own memory port such as port 512 with access through data/address bus 306 which is multiplied to other memory ports at the multiple point 318 and request/grant line 308, which is individual to the memory port 512. Only sixty lines or less contend for the shared memory as illustrated. An arbitrator circuit 316 enables only one microprocessor at a time to access the shared memory 200 to eliminate problems of processor contention. A shared memory controller 312 controls the addressing of shared memory

200 and the transfer of data therefrom to memory port 512 via data/address bus 306, which is bidirectional. Parity is generated and checked for both data and addresses at memory port 512 and by controller 312. Shared memory 200 may comprise semiconductor RAM chips organized into 32-bit words to provide the aforementioned 256K-byte addressing capability. A master clock in clock distribution circuit 314 generates the various synchronous timing signals required by arbitrator 316, memory ports such as port 512, controller 312 and shared memory 200.

15 The translator 202, the termination controllers 128 (sixty in figure 3) and the shared memory 200 interface the group network via lines 204, 206, 208 and 210. A typical switch y, outlet x thereof is interfaced by line 204, and outlet (x+1) thereof by line 208. Another typical switch Y+1 outlet X thereof is interfaced by line 206 and outlet x+1 thereof by line 210. As aforementioned each of lines 204 to 210 has multiplexed thereon 32 time slots. As can be seen each speech termination circuit 128 is connected to two termination multiplexes carrying the 30 channels and having synchronized timing such that the outlets of the termination circuits and the inlets of group network 102 are synchronized to provide the requisite parallel-to-serial conversion and in reverse the serial-to-parallel conversion therebetween. The microprocessor 402 private memory 516 may comprise a masked programmed ROM or PROM. The private memory also includes a rewrite memory capability of the order of 4K to 8K bytes for resident software and variable data which may include class of service data.

40 Figure 6 shows translator 202, which is particularly advantageously used in a distributed control organization, the only data communication path between security block modules and other subsystems of the exchange being provided by the speech switch network 102. The deficiencies of prior art translators in centralized stored program exchange systems in coping with office and customer data modifications are overcome by the present system. Translator 202 includes a memory 550; a control processor 552 which includes a microprocessor 554 and its associated program memory 556; and translator access ports to group switch 102, three of eight of which access ports are shown at 558, 560 and 562. The translator may be replicated as needed for increased office traffic, reliability and survivability.

60 The translator receives class of service information of various types, charging data, statistical information, etc. while also performing the normal translation function; i.e. directory number to equipment number translation (DN/EN) by indexing a table in

memory 550; equipment number to directory number translation; and trunk route to equipment number translation.

Each speech termination circuit 128 is coupled to two termination multiplex lines as described with reference to figure 3, each termination multiplex line carrying thirty-two channels, and each termination multiplex line being coupled to a terminal switch outlet, which in turn is coupled to the group switch network inlets. For example, 960 termination circuits identical to circuit 128 are coupled to the group switch network in a typical office configuration. The thirty termination circuits coupled to one termination multiplex each have a second interface connected to a second termination multiplex, hence the two termination multiplexes sharing the thirty termination circuits are connected to the same numbered outlet on two consecutive stage one switches. The sixty termination circuits sharing a program memory are connected to four termination multiplexes, hence each pair of stage one switches will have four sets of four termination multiplexes connected thereto. Thus each speech termination circuit 128 has two equipment numbers, and the DN/EN translator function continuously monitors the state, i.e. busy/free condition of each originating call half and termination call half of the speech termination circuit. The response to a request for a DN translation will contain a free termination equipment number and an indication as to whether the alternative equipment number is busy, free or booked. If both terminations are free, this information is returned to microprocessor 554, and the microprocessor controlling an originating call half selects a network path to the terminating equipment number and signals the requisite information for call set-up. The microprocessor controlling the terminating half portion of the call sends a confirmation signal to the DN/EN translator, or other translator function, to confirm that the termination is now busy and to identify the equipment originating the call.

The translator memory 550 may comprise, a CCD memory or a magnetic bubble memory or other solid state memory capable of containing at least 90-K words of storage with 80K words thereof for translator memory and 10K words thereof for translator program backup memory, with word lengths of, for example, 16, 24 or 32 bits dependent upon data structure. Access ports 558 to 562 are electrically identical with speech termination circuits to the switching network and are identifiable and selectable by equipment number as are the termination circuits. The distribution of these access ports is such that a switch module failure will not disable more than one port and any stage-one switch failure will not disable more than half of the

ports. The equipment numbers allocated to the access ports are such that an algorithm in program memory 556 can derive any other equipment number from any given equipment number. Functionally, each access port includes means for selecting from the PCM multiplex line the contents of the channel defined by its equipment number, means for identifying microprocessor-to-microprocessor control messages in the channel, a buffer register to hold one or more such messages, an output buffer, means for inserting such messages into the correct channel on the outgoing termination multiplexes 564, 566 and 568; and means for outputting messages to hold the transmission path idle while the translator microprocessor 554 is generating output data.

Access ports 558, 560 and 562 also include input lines as indicated. Data is extracted from the translator memory 550 in response to messages received on the input ports and reloading and modification of data in memory 550 is microprocessor controlled in accordance with programming in program memory 556. Processor 554 may be the same microprocessor used in the termination circuits 128, and is also illustrated at 402 as a portion of the call control unit 302. The translator memory 550 includes the requisite translation tables. Typically, translation access exceeding four milliseconds has a probability of less than one in a thousand and the average time to complete translation access is under two milliseconds. Customer data modification and office data modification are accomplished by reprogramming of memory 556, to provide for added customer features or extension of the number of lines or trunks serviced by an office.

WHAT WE CLAIM IS:—

1. A distributed-control digitally-switched multiple subscriber system, including:

(a) a plurality of interface means, each of which provides an interface for at least one subscriber line to a common communications path and each of which includes means for deriving at least digital path selection control signals for each call coupled thereto;

(b) a switching network coupled to said common communications path for interconnecting said subscriber lines in response to said path selection control signals; and

(c) means at each of said interface means for deriving digitized speech signals, such that said speech signals and said selection control signals are multiplexed on said common communication path.

2. A system in accordance with Claim 1, wherein said switching network is a multi-stage switch network.

3. A system in accordance with Claim 1 or 2, wherein said interface means includes

private memory means allocated to each group of (n) subscriber lines, and shared memory means allocated to each group of (m) subscriber lines.

4. A system in accordance with Claim 3, wherein (n) equals one and wherein (m) is a number corresponding to the number of lines in a group thereof.

5. A system in accordance with Claim 3 or 4, wherein each said interface means also includes microprocessor means which provides said private memory means and said path selection control signals, and means for accessing said shared memory; and wherein said shared memory is a multiport memory bidirectionally accessible to (m) microprocessor means.

6. A system in accordance with Claim 1, 2, 3, or 4, wherein said means for deriving said path selection control signals includes a microprocessor and a memory associated therewith, and means to access the microprocessor on a per call basis.

7. A system in accordance with Claim 1, 2, 3, or 4, wherein said means for deriving said path selection control signals includes a microprocessor and a memory associated therewith for providing said control on a per line basis.

8. A system in accordance with any one of the preceding claims, wherein said digitized speech signals are PCM encoded.

9. A system in accordance with any one of claims 1 to 7, wherein said digitized speech signals are delta modulation encoded.

10. A system in accordance with Claim 9 and wherein said digitized speech signals are differential delta modulation encoded.

11. A system in accordance with any one of the preceding claims, and wherein said digitized speech signals are serially coupled to said common communication path.

12. A system in accordance with any one of claims 1 to 11, and wherein said digitized speech signals are coupled in parallel to said common communication path.

13. A system in accordance with Claim 5 or any claim appendent thereto and including translator means coupled to said common communication path for provided translation among said plurality of interface means coupled thereto and said switching matrix.

14. A system in accordance with Claim 6 or any claim appendent thereto, and wherein said microprocessor includes digital filtering means for deriving said digitized speech signals.

15. A system in accordance with Claim 2 or any claim appendent thereto, and wherein each of the calls includes an originating call half and a terminating call half and wherein said interface means further includes means for coupling said originating call halves to said common communication

ports. The equipment numbers allocated to the access ports are such that an algorithm in program memory 556 can derive any other equipment number from any given equipment number. Functionally, each access port includes means for selecting from the PCM multiplex line the contents of the channel defined by its equipment number, means for identifying microprocessor-to-microprocessor control messages in the channel, a buffer register to hold one or more such messages, an output buffer, means for inserting such messages into the correct channel on the outgoing termination multiplexes 564, 566 and 568; and means for outputting messages to hold the transmission path idle while the translator microprocessor 554 is generating output data.

Access ports 558, 560 and 562 also include input lines as indicated. Data is extracted from the translator memory 550 in response to messages received on the input ports and reloading and modification of data in memory 550 is microprocessor controlled in accordance with programming in program memory 556. Processor 554 may be the same microprocessor used in the termination circuits 128, and is also illustrated at 402 as a portion of the call control unit 302. The translator memory 550 includes the requisite translation tables. Typically, translation access exceeding four milliseconds has a probability of less than one in a thousand and the average time to complete translation access is under two milliseconds. Customer data modification and office data modification are accomplished by reprogramming of memory 556, to provide for added customer features or extension of the number of lines or trunks serviced by an office.

WHAT WE CLAIM IS:—

1. A distributed-control digitally-switched multiple subscriber system, including:

(a) a plurality of interface means, each of which provides an interface for at least one subscriber line to a common communications path and each of which includes means for deriving at least digital path selection control signals for each call coupled thereto;

(b) a switching network coupled to said common communications path for inter-connecting said subscriber lines in response to said path selection control signals; and

(c) means at each of said interface means for deriving digitized speech signals, such that said speech signals and said selection control signals are multiplexed on said common communication path.

2. A system in accordance with Claim 1, wherein said switching network is a multi-stage switch network.

3. A system in accordance with Claim 1 or 2, wherein said interface means includes

private memory means allocated to each group of (n) subscriber lines, and shared memory means allocated to each group of (m) subscriber lines.

4. A system in accordance with Claim 3, wherein (n) equals one and wherein (m) is a number corresponding to the number of lines in a group thereof.

5. A system in accordance with Claim 3 or 4, wherein each said interface means also includes microprocessor means which provides said private memory means and said path selection control signals, and means for accessing said shared memory; and wherein said shared memory is a multiport memory bidirectionally accessible to (m) microprocessor means.

6. A system in accordance with Claim 1, 2, 3, or 4, wherein said means for deriving said path selection control signals includes a microprocessor and a memory associated therewith, and means to access the microprocessor on a per call basis.

7. A system in accordance with Claim 1, 2, 3, or 4, wherein said means for deriving said path selection control signals includes a microprocessor and a memory associated therewith for providing said control on a per line basis.

8. A system in accordance with any one of the preceding claims, wherein said digitized speech signals are PCM encoded.

9. A system in accordance with any one of claims 1 to 7, wherein said digitized speech signals are delta modulation encoded.

10. A system in accordance with Claim 9 and wherein said digitized speech signals are differential delta modulation encoded.

11. A system in accordance with any one of the preceding claims, and wherein said digitized speech signals are serially coupled to said common communication path.

12. A system in accordance with any one of claims 1 to 11, and wherein said digitized speech signals are coupled in parallel to said common communication path.

13. A system in accordance with Claim 5 or any claim appendent thereto and including translator means coupled to said common communication path for provided translation among said plurality of interface means coupled thereto and said switching matrix.

14. A system in accordance with Claim 6 or any claim appendent thereto, and wherein said microprocessor includes digital filtering means for deriving said digitized speech signals.

15. A system in accordance with Claim 2 or any claim appendent thereto, and wherein each of the calls includes an originating call half and a terminating call half and wherein said interface means further includes means for coupling said originating call halves to said common communication



path and for receiving terminating call halves from said common communication path, such that said switching network independently switches said originating and terminating call halves.

16. In a switching system for providing communication among a plurality of subscriber lines, and which system is of the type which can be readily expanded to cater for increasing numbers of lines and other peripherals served, a distributed control for each subscriber call for the duration of said call including:

(a) subscriber line circuit means having at least one of said subscriber lines terminated thereat, for deriving digital path selection control signals and for deriving digital signals representative of said communication;

(b) means for multiplexing said digital path selection control signals and said digital signals representative of said communications on a common communication path such that part at least of the path selection control operations needed for call setting is provided for each of said communications using said subscriber lines; and

(c) a switching network having a plurality of said common communication paths coupled thereto from a plurality of subscriber line circuit means for switching said communications among said subscriber lines in accordance with said digital path selection control signals.

17. In a system in accordance with Claim 16 a said distributed control also including means for coupling said common communications paths from said plurality of line circuit means to said switching network such that additional subscriber lines or trunks may be added to said system without disconnection of existing subscriber lines and such that a standardized interface is provided to said switching matrix from said subscriber line circuit means.

18. In a system a said distributed control in accordance with Claim 16 wherein said subscriber lines are analog lines or trunks, wherein the communications on said analog lines or trunks are subscriber calls, wherein each of said calls includes an originating call half and a terminating call half, and wherein said subscriber line circuit further includes: means for coupling said originating call halves to said common communication path and for receiving terminating call halves from said common communication path such that said originating and terminating call halves are independently controlled.

19. In a system for providing communication among a plurality of subscriber lines, a said distributed control in accordance with Claim 16, wherein said subscriber lines include analog lines and trunks, further

including: means having coupled thereto digital lines and trunks and for deriving digital path selection control signals for digital communications on said digital lines and trunks; means for multiplexing said control signals and said digital communications on a common communications path; and means for coupling said common communication path to said switching matrix.

20. In a system for providing communication among a plurality of subscriber lines, a said distributed control in accordance with Claim 18 wherein said means for deriving digital path selection control signals are provided on a per line basis.

21. In a system for providing communication among a plurality of subscriber lines, a said distributed control in accordance with Claim 18 wherein said means for deriving digital path selection control signals are provided on a per call basis.

22. In a system for providing communication among a plurality of subscriber lines, a said distributed control in accordance with Claim 18 wherein said means for deriving digital path selection control signals are provided on a per erlang basis.

23. In a system for providing communication among a plurality of subscriber lines, a said distributed control in accordance with Claim 18 wherein said means for deriving digital path selection control signals are provided on a per line group basis.

24. In a system for providing communication among a plurality of subscriber lines, a said distributed control in accordance with Claim 18 wherein said means for deriving digital path selection control signals are provided on a per termination basis.

25. In a system for providing communication among a plurality of subscriber lines, a said distributed control in accordance with Claim 16 wherein said subscriber line circuit means further includes: means for coupling both revenue traffic and overhead traffic onto said common communications path.

26. In a system for providing communication among a plurality of subscriber lines, a said distributed control in accordance with Claim 18 wherein said subscriber line circuit means includes means for deriving class of service and for coupling said class of service data onto said common communication path.

27. A telephone system with a local or central office including a switching network for interconnecting a plurality of subscriber lines and trunks which network is modular in form so that it can be readily expanded by the addition of one or more modules, the system including a plurality of subscriber line circuit means remote from the office, each of said line circuits providing a dedicated distributed control for each subscriber



call and for said subscriber lines and trunks coupled thereto, and including: means for deriving digital path selection control signals for individual subscriber calls on said lines and trunks coupled thereto; means for digitizing said subscriber calls and for multiplexing said digitized subscriber calls and said digital path selection control signals onto a common communication path together with the digitized subscriber calls and digital path selection control signals of (x) other subscriber line circuit means; and means for coupling said common communication path to the input of said switching network such that call control is on a distributed basis throughout the call.

28. A telephone office in accordance with Claim 27, wherein said means for deriving said digital path selection control signals includes: processor means for separating each of said subscriber calls into originating and terminating call halves such that said call halves are independently controlled.

29. A telephone office in accordance with Claim 28 wherein said processor is a microprocessor including: memory means for storing maintenance and related data associated with the particular subscriber lines and trunks coupled thereto.

30. A telephone office in accordance with Claim 27, wherein a subscriber line circuit means including said distributed control is provided for each termination.

31. A method of providing distributed control for a digitally switched multiple subscriber system, wherein the system includes a plurality of interface means, each of which provides an interface for at least one subscriber line to a common communication path, which method includes deriving at least digital path selection control signals for each call coupled from that line, interconnecting in response to the path selection control signals respective ones of the subscriber lines through a switching network coupled to said common communication path and deriving digitized speech signals at each interface means such that said speech signals and said digital path selection control signals are multiplexed on said common communication path.

32. A method in accordance with Claim 31, wherein each of said calls is set up in two halves, an originating call half and a terminating call half, and wherein said originating and terminating call halves are independently controlled and connected together by the said switching matrix.

33. A method for operating a switching system which can be expanded at will to provide service to additional subscriber lines and other peripherals, which system provides communication among a plurality of subscriber lines, call control being distributed,

the method including the steps of: providing subscriber line circuit means having at least one of said subscriber lines terminated thereat, for deriving digital path selection control signals and for deriving digital signals representative of said communication; multiplexing said digital path selection control signals and said digital signals representative of said communications on a communication path common to a plurality of said subscriber line circuit means such that independent path selection control is provided for each of said communications on said subscriber lines; and switching said communications among said subscriber lines in accordance with said digital path selection control signals by means of a switching matrix means having a plurality of said common communication paths coupled thereto from a plurality of subscriber line circuit means.

34. A method in accordance with Claim 33 further including the step of: coupling said common communications path from said plurality of line circuit means to said switching matrix such that additional subscriber lines or trunks may be added to said system without disconnection of existing subscriber lines and such that a standardized interface is provided to said switching matrix from said subscriber line circuit means.

35. A method in accordance with Claim 33 wherein said subscriber lines are analog lines or trunks, wherein the communications on said analog lines or trunks are in the form of subscriber calls, wherein each of said calls includes an originating call half and a terminating call half and wherein said originating call halves are coupled to said common communication path and the receiving terminating call halves are coupled from said common communication path such that said originating and terminating call halves are controlled independently.

36. A method in accordance with Claim 35 wherein said digital path selection control signals are derived on a per line basis.

37. A method in accordance with Claim 35 wherein said digital path selection control signals are derived on a per call basis.

38. A method in accordance with Claim 35 wherein said digital path selection control signals are derived on a per termination basis.

39. A method of interconnecting a plurality of subscriber lines and trunks via the switching network of a telephone local or central office, including the steps of: providing a plurality of subscriber line circuit means remote from said telephone local or central office, each of said subscriber line circuits providing a dedicated distributed control for each subscriber call for said subscriber lines and trunks coupled thereto, and including: deriving digital path selection



control signals for individual subscriber calls on said lines and trunks coupled thereto; digitizing said subscriber calls and multiplexing said digitized subscriber calls and said digital path selection control signals onto a common communication path together with the digitized subscriber calls and digital path selection control signals of a plurality of other subscriber line circuit means; and coupling said common communication path to the input of said switching matrix such that said call control is on a distributed basis.

40. A method in accordance with Claim 39 wherein the step of deriving said digital path selection control signals includes: separating each of said subscriber calls into originating and terminating call halves such that said call halves are independently controlled.

41. An automatic telephone exchange substantially as described with reference to the accompanying drawings.

S. R. CAPSEY,
Chartered Patent Agent,
For the Applicants.

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