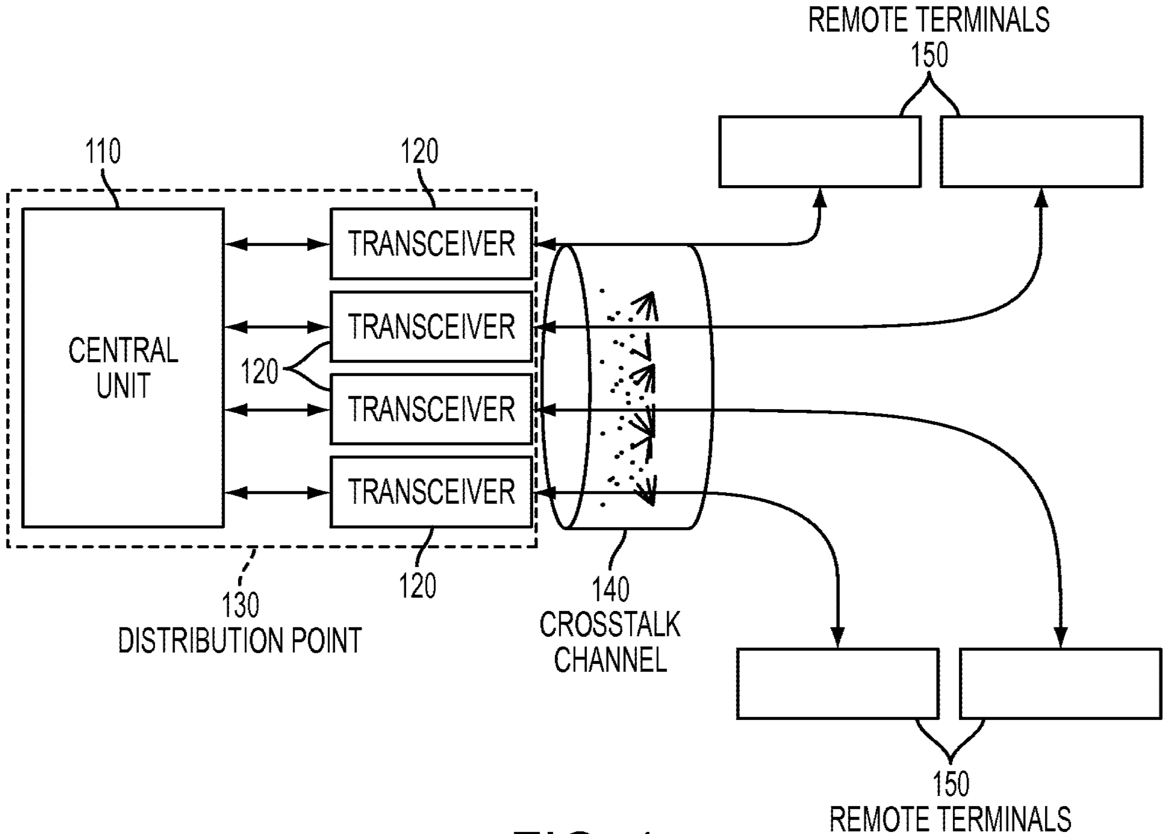
REMOTE TERMINALS
150
110
120
TRANSCEIVER
TRANSCEIVER
CENTRAL
UNIT
120
TRANSCEIVER
TRANSCEIVER
130
DISTRIBUTION POINT
120
140
CROSSTALK
CHANNEL
150
REMOTE TERMINALS

FIG. 1

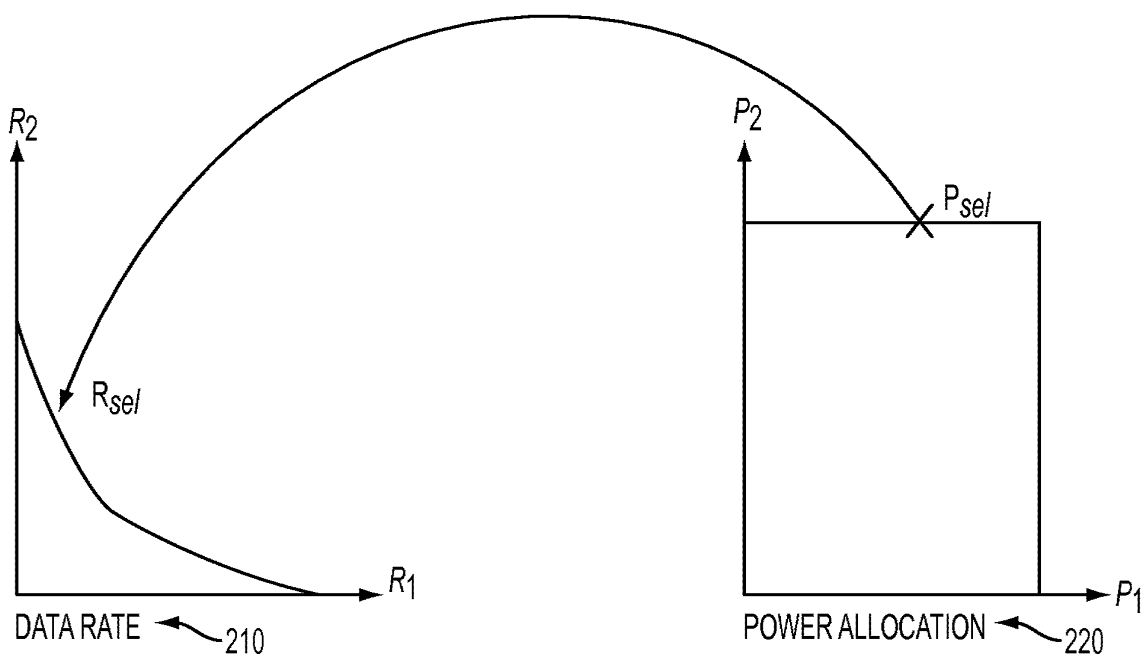
R_2
R_{sel}
R_1
DATA RATE
210
P_2
P_{sel}
P_1
POWER ALLOCATION
220

FIG. 2

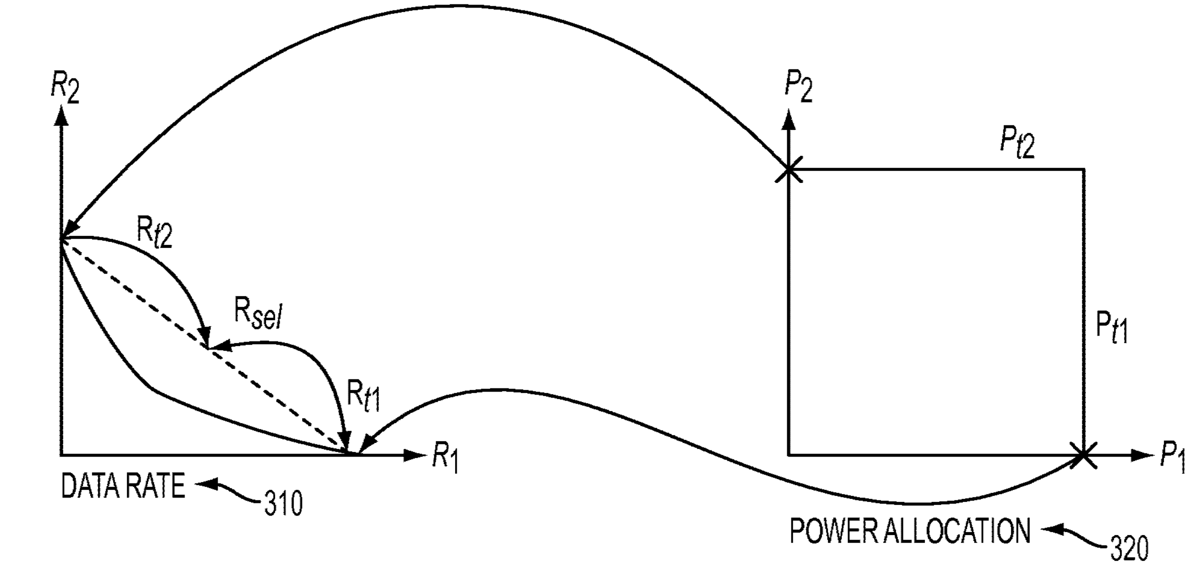

FIG. 3

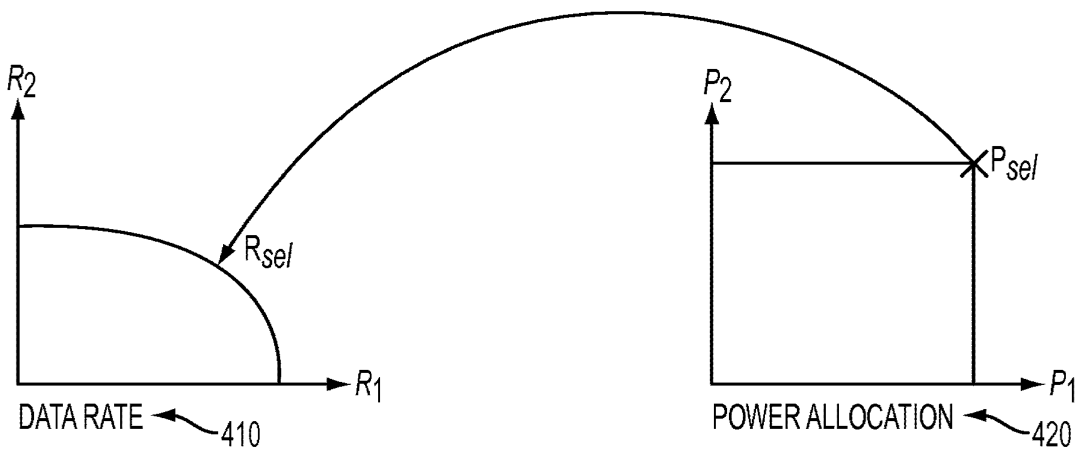

FIG. 4

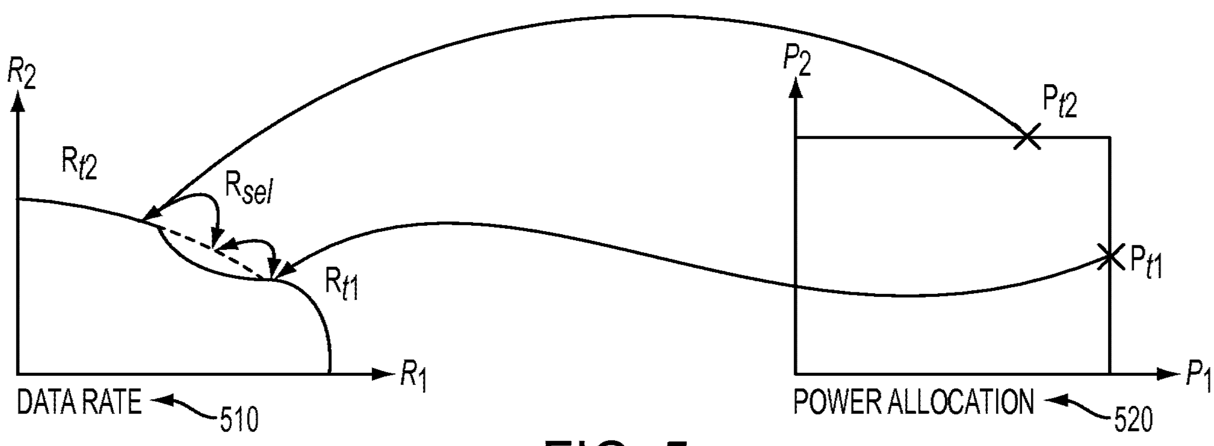

FIG. 5

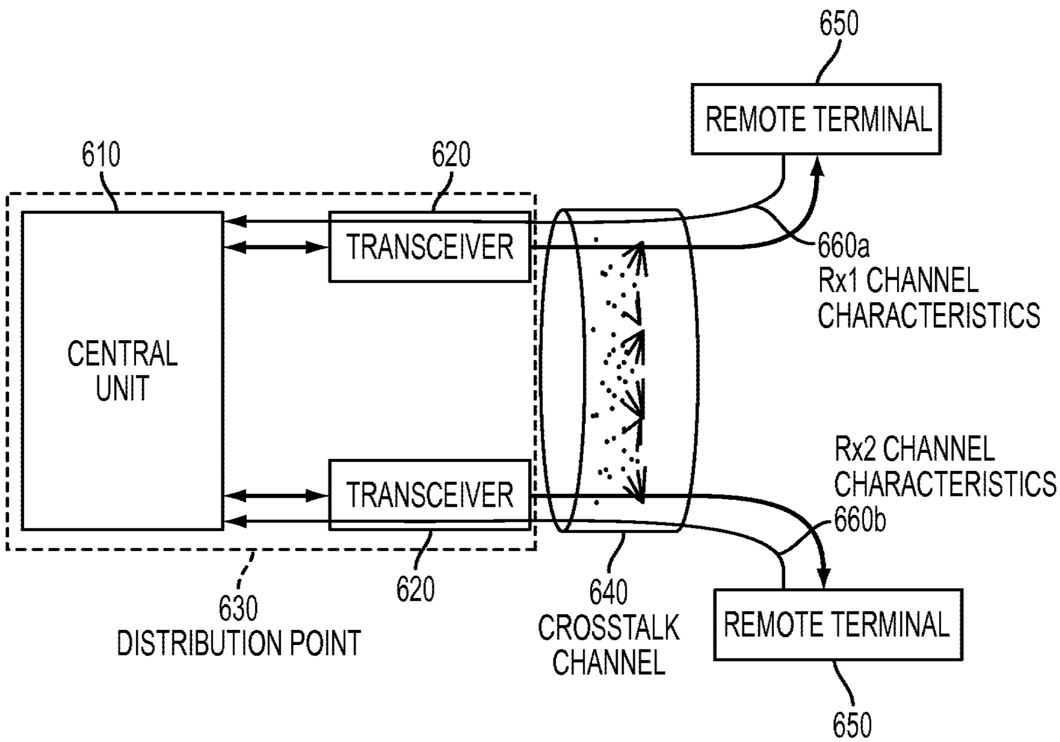
650
REMOTE TERMINAL
610
620
CENTRAL UNIT
TRANSCEIVER
660a
Rx1 CHANNEL CHARACTERISTICS
Rx2 CHANNEL CHARACTERISTICS
660b
TRANSCEIVER
630
DISTRIBUTION POINT
620
640
CROSSTALK CHANNEL
REMOTE TERMINAL
650

FIG. 6A

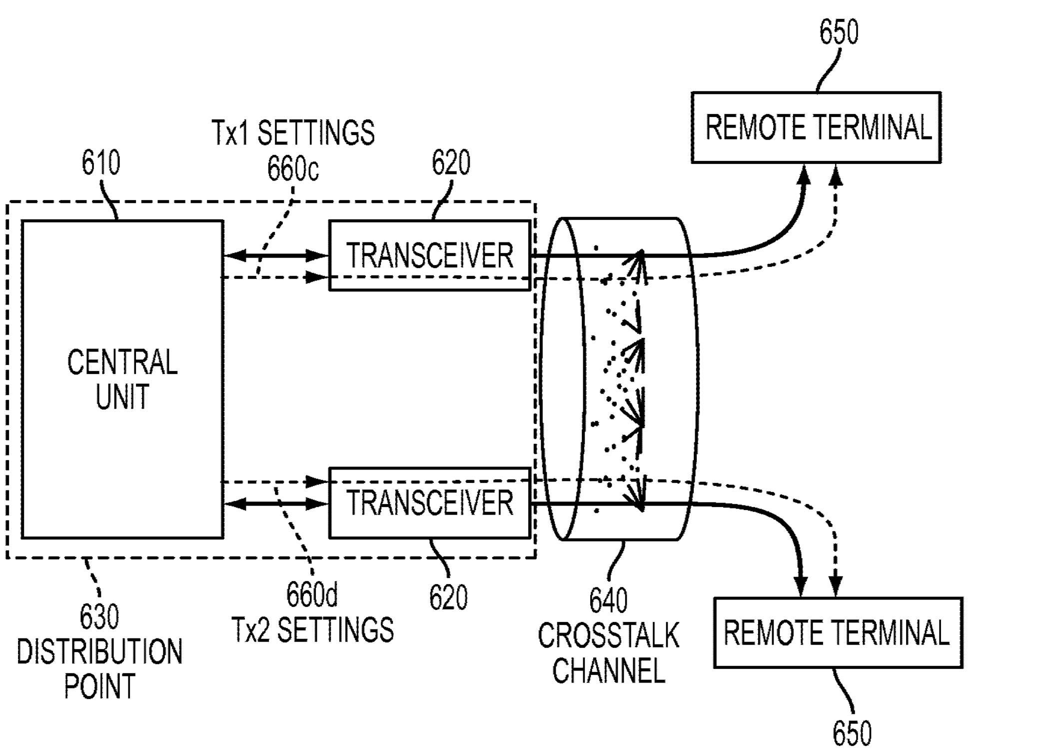
650
REMOTE TERMINAL
Tx1 SETTINGS
660c
610
620
CENTRAL UNIT
TRANSCEIVER
TRANSCEIVER
630
DISTRIBUTION POINT
660d
Tx2 SETTINGS
620
640
CROSSTALK CHANNEL
REMOTE TERMINAL
650

FIG. 6B

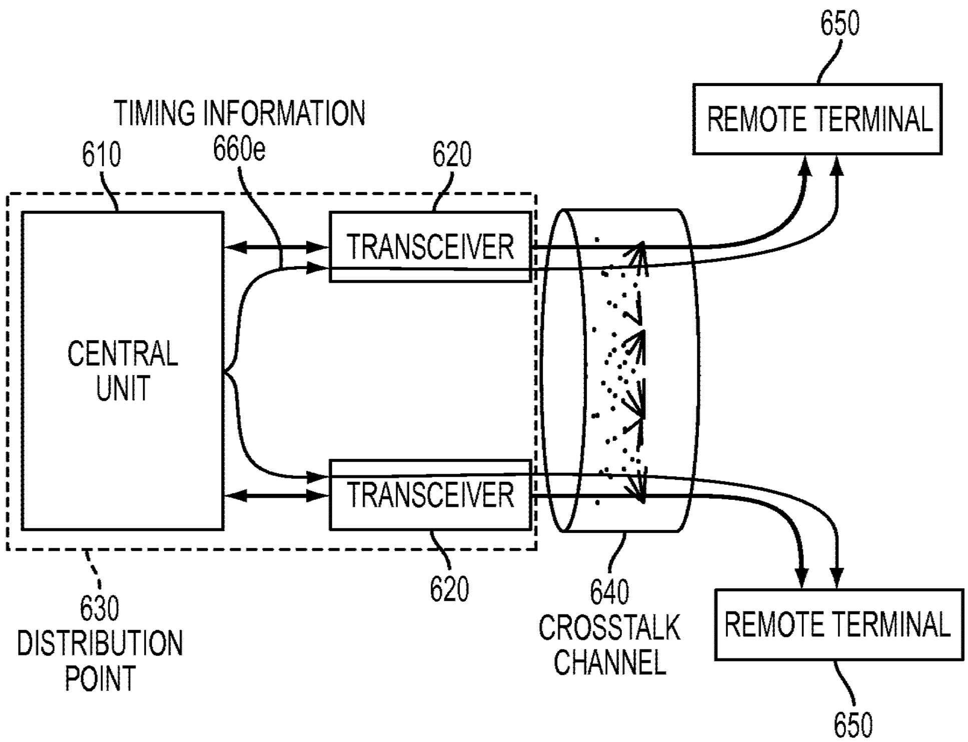
TIMING INFORMATION
660e
610
620
650
REMOTE TERMINAL
TRANSCEIVER
CENTRAL
UNIT
TRANSCEIVER
620
630
DISTRIBUTION
POINT
640
CROSSTALK
CHANNEL
REMOTE TERMINAL
650

FIG. 6C

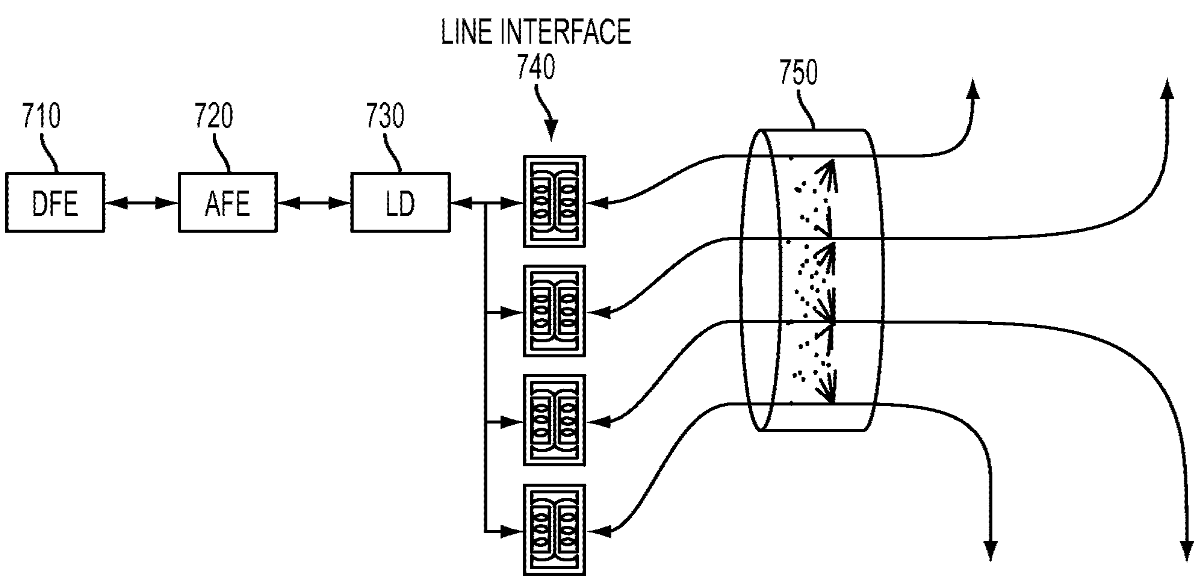
LINE INTERFACE
740
750
710
720
730
DFE
AFE
LD

FIG. 7

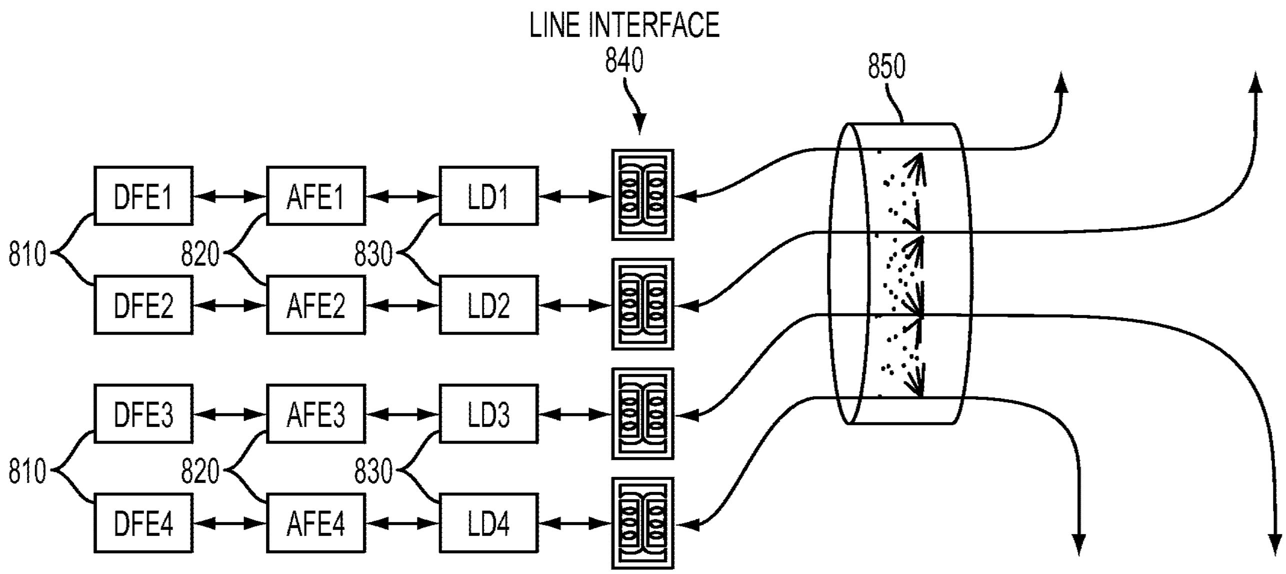
LINE INTERFACE
840
850
DFE1
AFE1
LD1
810
820
830
DFE2
AFE2
LD2
DFE3
AFE3
LD3
810
820
830
DFE4
AFE4
LD4

FIG. 8

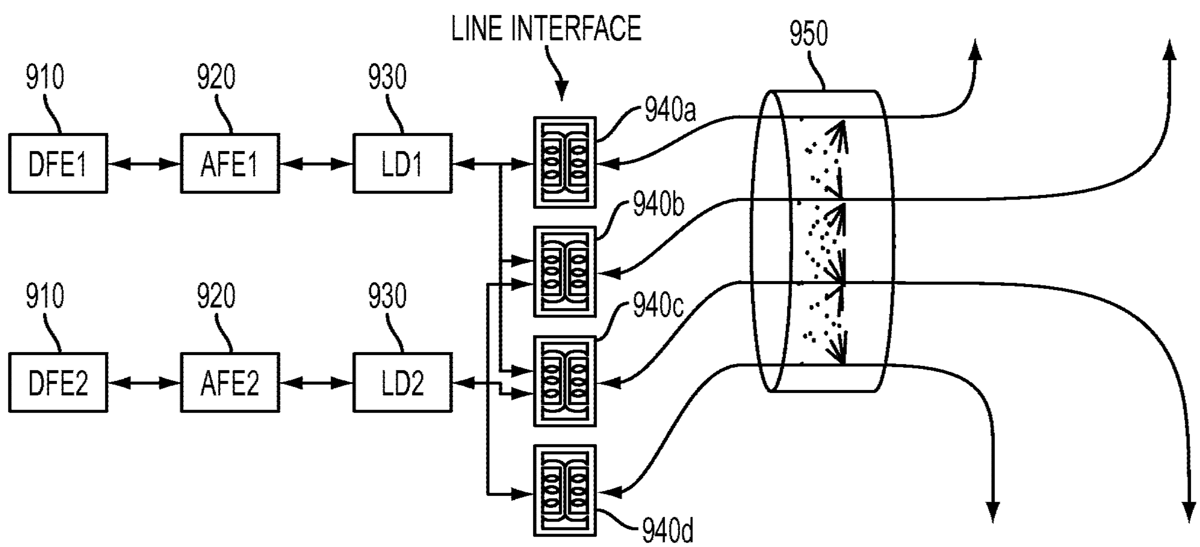
LINE INTERFACE
950
910
920
930
940a
DFE1
AFE1
LD1
940b
910
920
930
940c
DFE2
AFE2
LD2
940d

FIG. 9

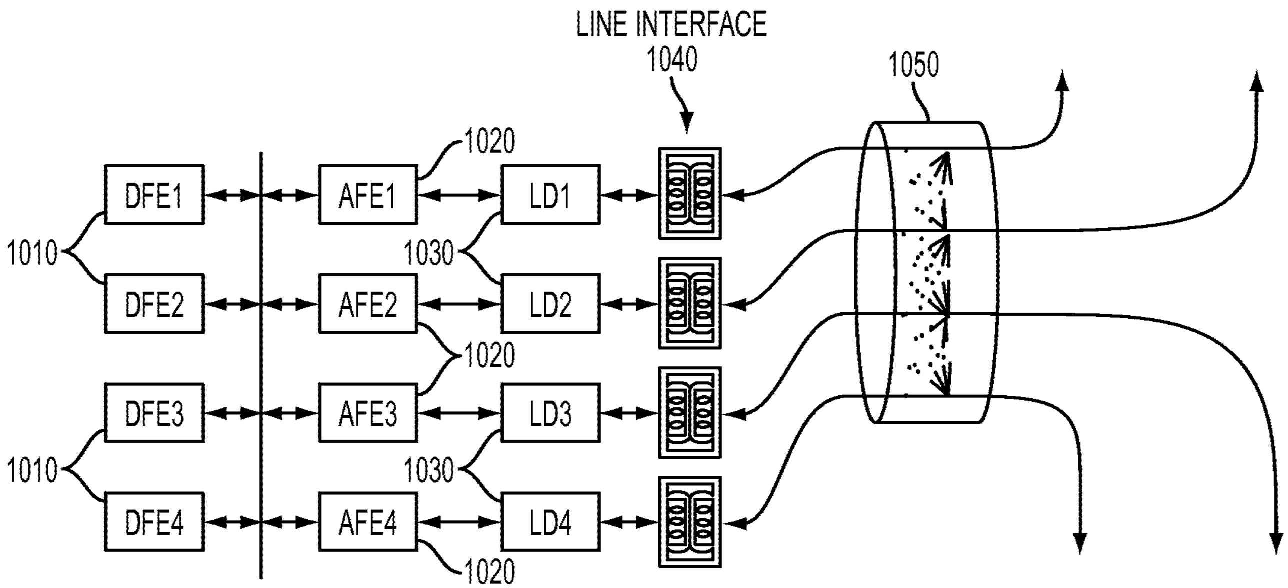

FIG. 10

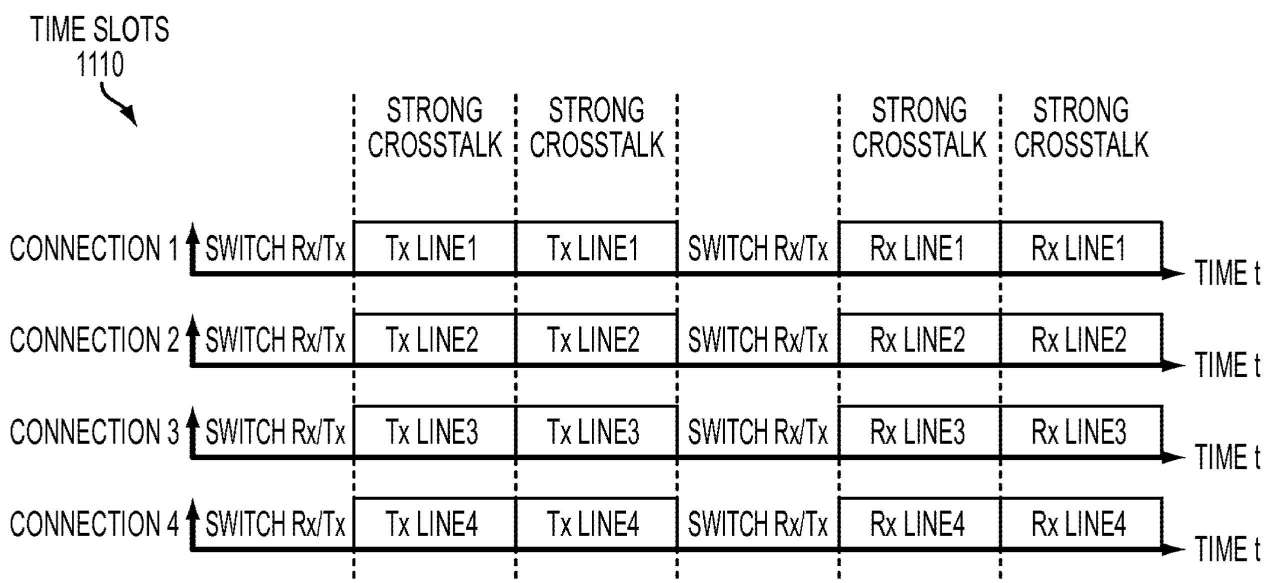

FIG. 11

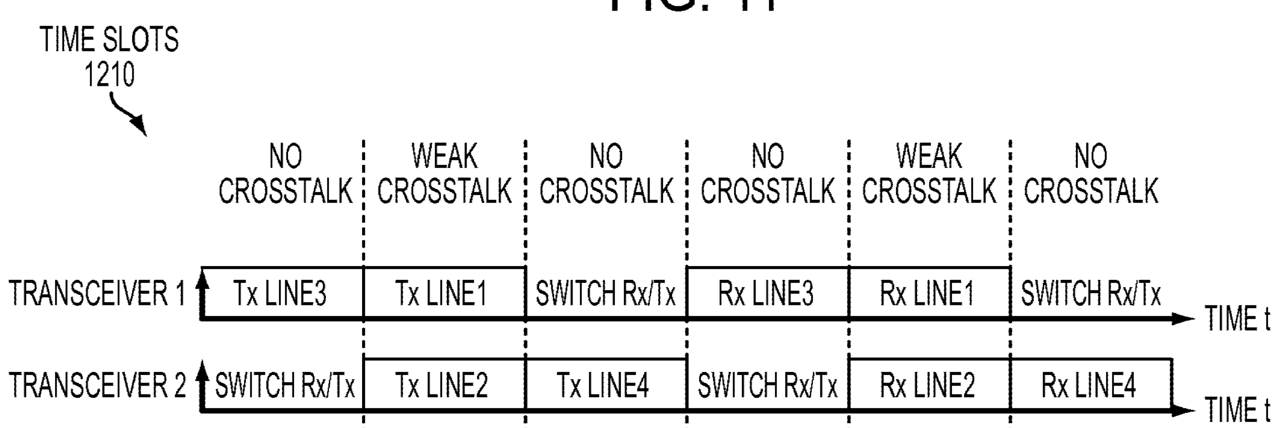

FIG. 12

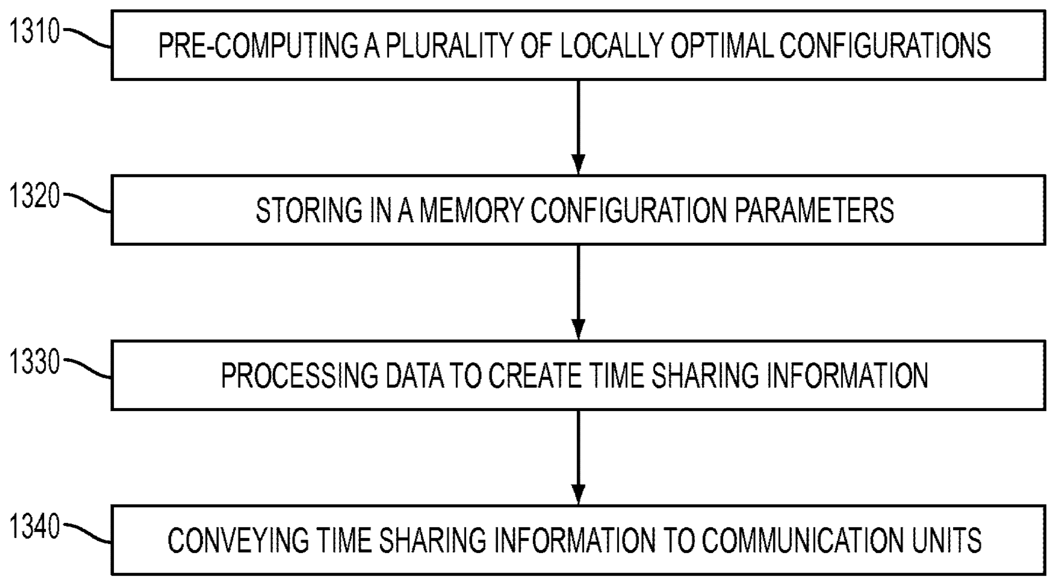
1310
PRE-COMPUTING A PLURALITY OF LOCALLY OPTIMAL CONFIGURATIONS
1320
STORING IN A MEMORY CONFIGURATION PARAMETERS
1330
PROCESSING DATA TO CREATE TIME SHARING INFORMATION
1340
CONVEYING TIME SHARING INFORMATION TO COMMUNICATION UNITS

FIG. 13

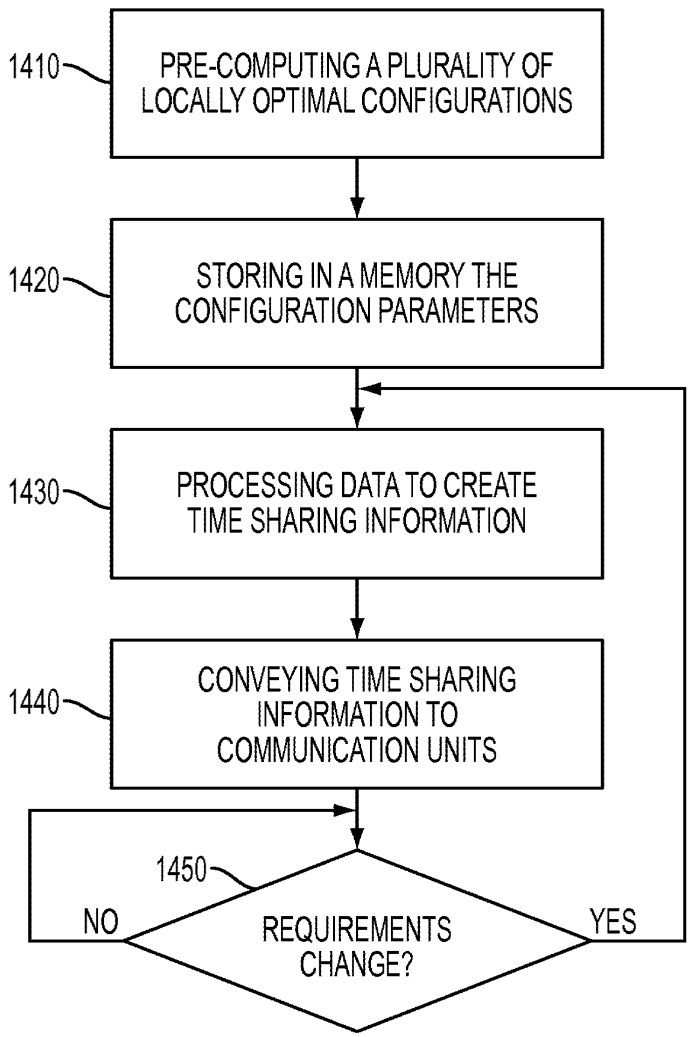
1410
PRE-COMPUTING A PLURALITY OF LOCALLY OPTIMAL CONFIGURATIONS
1420
STORING IN A MEMORY THE CONFIGURATION PARAMETERS
1430
PROCESSING DATA TO CREATE TIME SHARING INFORMATION
1440
CONVEYING TIME SHARING INFORMATION TO COMMUNICATION UNITS
1450
REQUIREMENTS CHANGE?
NO
YES

FIG. 14

APPLICATION FOR PATENT

Inventors: Rainer Strobel and Lilia Smaoui

Title: Time Sharing Electronic Communication Systems,Methods And Apparatus

BACKGROUND

In many communication transmission systems, there are multiple parallel transmissions bound together which can cause crosstalk between the lines. This results in a coupling between the achievable data rates of the lines within the binder, which a unit that increasing the transmit power, and thus the rate, of one link, may reduce the data rates of the other links. Transmissions in a cable binder are one example of such a communication transmission system. Crosstalk also occurs in wireless communication, in which adjacent or nearby channels may be subject to what is sometimes called "co-channel interference". Many kinds of communication systems, with multiple communication lines or channels located in close proximity to one another, are subject to the phenomenon of crosstalk.

Typical solutions to this problem in alternative solutions include physical separation of lines, mechanical shielding of lines from one another, and reduction in either the data rates or the communication quality or both, in the face of the effects of crosstalk. Another solution in alternative solutions is called "Upstream Power Backoff", in which a reference length of transmission and two parameters are used to calculate transmission powers assigned to each communication line at various times. As the number of communication lines increases, the scheduling complexities become such that typical optimization algorithms, including Upstream Power Backoff, simply cannot be used. Alternative solutions may then use other algorithms, such as iterative water filling, but none of these provide a perfect solution. Moreover, the alternative solutions have disadvantages in that they cannot adjust power levels of multiple lines substantially in real-time, and they cannot switch between multiple pre-calculated configurations substantially in real-time.

Further, in the alternative solutions, a system may be planned as an optimal configuration for a particular optimization criterion. There are at least three such optimization criteria which may be implemented. Each optimization criterion is, at the time of its implementation, an alternative to the other two criteria, according to the alternative solutions. These three alternative implementation criteria are "absolute fairness", which a unit maximizing the rate of the weakest link such that rate $u = \max \min_i(R_i)$, "relative fairness", which a unit maximizing the overall system rate but subject to the condition that each remote terminal is communicating at a specific minimum, where $u = \max \sum_i(\log R_i)$, or "system maximization", which a unit maximizing the weighted sum of all data rates $u = \max \sum_i(w_i \cdot R_i)$.

The task of finding transceiver settings in a communication system that lead to a desired rate configuration, typically requires very complex optimization. The effort to find optimal parameters is often so serious and burdensome, that only inexact approximations of optimal settings are used. Further, as the number of lines in systems increase, the disadvantages of the alternative solutions become increasingly severe.

SUMMARY

A transceiver architecture is disclosed herein with respect to at least one solution that is able to switch among different configurations, thus enhancing communication rates and allowing the overall system performance to move closer toward optimization. The enhanced communication rates may result in higher throughput rates, or higher quality of transmissions, or both. In some solutions, data rates available to different communication units may be enhanced, possibly even beyond guaranteed rates, by allocating the bandwidth of other units that are either inactive or that are using less than their own guaranteed bandwidth.

A system is provided that is operative to serve multiple electronic communication lines. The system includes a distribution point, which includes a central unit and multiple transceivers. The system also includes multiple line interfaces, a crosstalk channel, and multiple remote terminals. The system is configured to compute locally optimal communication configurations, store in memory data about said configurations, process said data into time sharing information, and convey such time sharing information to the transceivers and the remote terminals. The receivers and remote terminals later transmit in accordance with such time sharing information.

A system is provided that is operative to serve multiple electronic communication lines. The system includes a distribution point, which itself includes a central unit and multiple transceivers. The system also includes multiple line interfaces, and a crosstalk channel. The system is configured to compute locally optimal communication configurations, store in memory data about said configurations, process said data into time sharing information, and to convey such time sharing information to the transceivers. The transceivers later transmit in accordance with such time sharing information.

In another variant, a central unit in communication system, where said system is operative to serve multiple electronic communication lines. The communication unit includes a unit that receives electronic data related to receiver channel characteristics. The communication unit also includes an optimizer that operates an optimization routine to compute multiple locally optimal configurations and to identify locally optimal configuration points needed to reach desired data rates. The communication unit also includes a memory to store the locally optimal configurations and locally optimal configuration points. The communication unit also includes a unit that computes a media access plan to achieve optimal system communication according to a criterion. The communication unit also includes a unit that conveys the media access plan to transceivers that will transmit in accordance with the plan.

In another variant, there is provided is a method for enhancing communication in a system with a plurality of electronic communication connections. Multiple locally optimal configurations and parameters required to build such configurations are pre-computed. Data about the configurations and the parameters are stored in a memory. The data is processed to create time sharing information. The time sharing information is conveyed to communication units so that such communication units may transmit at such times and such power levels as to achieve, according to some criterion, enhanced communication within the system.

Various solutionsare not restricted or constrained by the physical channel on which data is conveyed. Therefore, various solutionsareapplicable, while other solutions are wireline, telephone or other wireline communication, and other solutions are wireless.

Various solutions are not restricted or constrained by the manner in which a system or owned or operated. Therefore, various solutions may be entirely owned and operated by a single entity. A private MIMO system, whether wireline or wireless, is one non-limiting example of such an embodiment, but various solutions may apply to any private communication system. Other solutions may involve a split of ownership or operation, in which, for example, a server system (including central unit, transceivers, and crosstalk channel) are operated by one entity while remote terminals are operated by another entity. Such other solutions, which may be wireline or wireless in all their forms, are described herein as they apply separately to the server on the one hand, and the remote terminals on the other hand.

BRIEF DESCRIPTION OF THE DRAWINGS

The solutions that are herein described, are by way of example only, with reference to the accompanying drawings. No attempt is made to show structural details of the in more detail than is necessary for a fundamental understanding. In the drawings:

FIG. 1 illustrates a multi-user transmission system according to the alternative solutions;

FIG. 2 illustrates a region of reachable data rates and powers for two lines that have strong crosstalk, according to the alternative solutions;

FIG. 3 illustrates one solution of a region reachable data rates and powers for two lines that have strong crosstalk and communication time sharing;

FIG. 4 illustrates a region of reachable data rates and powers for two lines that have weak crosstalk;

FIG. 5 illustrates one solution of a region of reachable rates and powers in a general case with two lines;

FIG. 6A illustrates one solution of a system with messaging for channel characteristics;

FIG. 6B illustrates one solution of a system with messaging for transmitter configuration settings;

FIG. 6C illustrates one solution of a system with messaging for timing information;

FIG. 7 illustrates a block diagram of a TDMA system;

FIG. 8 illustrates a block diagram of a TDD system;

FIG. 9 illustrates one solution of a system with mixed access communication;

FIG. 10 illustrates one solution of a TDD system with additional interface between a digital frontend and an analog frontend;

FIG. 11 illustrates one solution of an allocation of time slots for uplink and downlink transmissions in a TDD system;

FIG. 12 illustrates one solution of an allocation of time slots for uplink and downlink transmissions in a mixed access system; and

FIG. 13 illustrates a flow diagram describing one solution of a method for a transceiver system pre-computing locally optimal configurations to enhance communication.

FIG. 14 illustrates a flow diagram describing one solution of a method for a transceiver system pre-computing locally optimal configurations to enhance communication.

DETAILED DESCRIPTION

In this description, the following symbols have the indicated meanings:

R_i means "Rate on connection *i*".

R means "Vector of rates of all communication connections".

$\mathbf{R}_{sel}$ means "Selected rate vector", typically the rate vector that maximizes system communication according to any of the three alternative optimization criteria, although other rate vectors may be selected.

$\mathbf{R}_{tj}$ means "Rate vector for time instance *j*".

$u(\mathbf{R})$ means "Utility function", which the selected system-wide optimization factor.

p_i means "Transmit power on connection *i*".

$\mathbf{p}_{sel}$ means "Selected power vector", typically the power vector that will maximize system communication according to the selected optimization criterion, although other power vectors may be selected.

t_j means "Percentage of time where configuration parameter set *j* is used".

w_i means "Weighted sum-value weight value for connection *i*". In this description, the following terms have the indicated meanings:

"Local optimization" is the process of finding transmission power levels for two communication units, and the corresponding data rate for each such unit. In local optimization, "locally optimal points" are the found power and data rate points, and the result is a "locally optimized configuration". Configurations may be computed for all rate allocations , and such configurations may be stored in communication units and in the central unit.

"Global optimization" is a process with two steps. First, local optimization is performed, as discussed above. Second, there may be provided in addition or in the alternative rapid switching between different multiple locally optimized configurations. This rapid switching allows an increase in the system performance over alternative solutions by using the multiple locally optimized configuration. At any particular point in time, one such locally optimized configuration is being implemented. In "global optimization", there may be multiple local optimization configurations, and different local optimization configurations may be selected at different times in order to optimize communication performance at different points of time. Global optimization is implemented in various solutions, which can improve the performance of the communication system..

"Dynamic rate adaptation" may be considered as a two step process. First, global optimization is performed, as discussed above. Second, as an alternative or in addition, an event happens to change the local optimizations. This creates a need to re-compute new local optimization configurations, using various algorithms which might include some kind of linear programming. The new local optimization configurations are then stored in communication units and in the central unit. Dynamic rate adaptation may be implemented in various solutions, which may improve the performance of the communication system.

"Communication units" may include all any or all of the units that can act as receivers, or transmitters, or both. The central unit, the transceivers within the distribution point, and the remote terminals, may all included within the term "communication units".

"Server side components" may be considered as the components of a system on the server side, including the central unit, the transceivers, and the crosstalk channel, but not including the remote terminals.

"Client side components" may be considered as the components of a system on the client side, including the remote terminals and the part of the connection from the remote terminals to the crosstalk channel that is under the control of the operator or owner of the remote terminals.

"Transceiver" may be considered a radio unit within a distribution point that is in communicative contact with a central unit, and which executes both electronic transmission and electronic reception. Electronic transmission may include wired and wireless transmission.

"Remote terminal" is a radio unit outside the distribution point. A remote terminal may be a transmitter, a receiver, or a transceiver.

"Wireline communication" includes communication by cable or wire, by a pair or greater number of telephony lines bound together, or by any other communication that includes communication by cable or wire. A "wireline" is a line that is cable, wireline telephony, or any other kind of wired structure for communication. A "wireline communication" or "wireline connection" is the path by which wireline communication occurs.

"Wireless communication" includes communication by wireless, which may be terrestrial or satellite, cellular or land mobile, microwave or sub-microwave, or any other kind of wireless communication. A "wireless communication" or "wireless connection" is the path by which wireless communication occurs.

"Hybrid communication system" is a system that includes at least one wireline connection between two or more communication units, and also at least one wireless connection between two or more communication units.

"Mixed access system" is a system that includes two or more types of channel access, which may be, for example, TDMA, FDMA, CDMA, SDMA, TDD, or FDD.

FIG. 1 illustrates a multi-user transmission system according to an alternative solution. The central unit 110 manages the system, communicating directly with transceivers 120. The central unit 110 and the transceivers 120 together make up a distribution point 130. The central unit 110 may transmit to or receive from the transceivers 120. The transceivers 120 may transmit to either the central unit 110 or through the crosstalk channel 140 to the remote terminals 150, in which case the transceivers 120 are acting as transmitters. The transceivers 120 may receive from either the central unit 110 or through the crosstalk channel 140 from the remote terminals 150, in which case the transceivers 120 are acting as receivers. The remote terminals 150 may transmit through the crosstalk channel 140 to the transceiver 120, in which case the remote terminals 150 are acting as transmitters, or the remote terminals 150 may receive from the transceivers 120 through the crosstalk channel 140, in which case the remote terminals 150 are acting as receivers.

An operation of an alternative system is shown in FIG. 2, which illustrates a region of reachable data rates and powers for two lines that have strong crosstalk, according to the alternative solutions. The transmission system consists of several transmission lines with crosstalk between them. Every transceiver 120 or remote terminal 150 is able to adjust some parameter of the physical link, such as a transmit power between 0 and p_{max}, continuously or in discrete steps. There is a mapping between the possible power allocation 220 for each transmission lines, described by a power vector $\mathbf{p}$ for power levels P1 and P2 in FIG. 2, and the reachable data rate 210 for each of the of the links $\mathbf{R}$, shown as R1 and R2 in FIG. 2. The shape of the area of reachable data rates, which is "the rate region", is defined by the capabilities of the transmission system and the transmission channel as shown in the concave curve in the data rate 210. The shape of the area of the reachable power levels is shown in the four-point box in the power allocation 220. FIG. 2 shows the power levels and data rates which have been selected by this system, in which Psel shows maximum power level to P2 and sub-maximum power level to P1, and which the corresponding data rate, Rsel, shows sub-maximum data rates for each of R1 and R2.

Turning now to the solutions provided herein, FIG. 3 shows rates that may be achieved. FIG. 3 illustrates regions of reachable data rates and power levels for two lines that have strong cross talk. Power allocation 320 is shown at the right, and data rate 310 at the left. Again, the maximum achievable data rates are shown by the concave line in 310, and the maximum power rates are shown by the box in 320. Two pairs of points are shown, where P1 corresponds to Rt1, and P2 corresponds to Rt2. The first step, where locally optimal points are calculated, is shown in FIG. 3, where the configuration of full power to P1 and 0 power to P2 corresponds to maximum data rate for Rt1 and 0 data rate for Rt2, and 0 power to P1 and full power to P2 corresponds to 0 data rate for Rt1 and maximum data rate for Rt2.

FIG. 3 shows that the former constraint on data rates, which was represented by the concave line in 210 in FIG. 2, is exceeded in the solutions of FIG. 3. The two optimal configurations tested are maximum power to P1 and 0 power to P2, and maximum power to P2 and 0 power to P1. By switching between these two optimal configurations, various solutions can achieve maximum data rate for any unit that is transmitting at any particular time. Therefore, the rates reached by the optimal combinations are always equal or higher than the rates reached by the original configuration, Psel and Rsel, shown in the figure. This holds true also for practical cases of rate regions, as is shown in FIG. 5, explained below.

In one aspect, the system first calculates optimal points at setup. These are points at which only one of the links is active. The system does this for one or more, and alternatively each active link. The system then calculates locally optimal points for two or more active links. For every configuration, there is a rate vector $\mathbf{R}_i = f(\mathbf{p})$. In one exemplary embodiment, $\mathbf{R}_1 = f(p_1, p_2 = 0)$, $\mathbf{R}_2 = f(p_1 = 0, p_2)$ and $\mathbf{R}_3 = f(p_1, p_2)$. The power vectors achieving this points are $\mathbf{p}_{t1} = (p_1 = p_{max}, p_2 = 0)$, $\mathbf{p}_{t2} = (p_1 = 0, p_2 = p_{max})$ and $\mathbf{p}_{t3} = (p_1 = 0, p_2 = p_{max})$ In the example, pt3 is the same as pt2, so pt3 is ignored as a possible separate implementation. The achievable rates for any combination of the points are $t_1\mathbf{R}_1 + t_2\mathbf{R}_2$, where t_1 is the percentage of time where configuration 1 is used and t_2 is the percentage time where configuration 2 is used. The optimization of the two weights t_1, t_2 is solved by a linear program.

Solutions illustrated in FIG. 3 may operate on any system, including, without limitation, any cable, wireline telephony, other wireline, wireless system, or hybrids of any of the aforementioned kinds of systems. Various solutions cover also private systems in which all of the hardware components, both server side and client side, are owned and operated by a single entity. Various solutions further include private or public systems in which the server side components are owned and operated by a single entity, while the client side components are owned and operated by one or more different entities that do not own and operate the server side components. When there is a split between ownership and operation of the server side and client side components, the solutions herein relate to various server side components and operations will apply only to the server side, and the solutions herein related to various client side components and operations will apply only to the client side.

FIG. 4 illustrates a region of reachable data rates and powers for two lines that have weak crosstalk, according to alternative solutions. Power allocation 420 corresponds with data rate 410. Since the two lines have little or no crosstalk or other co-channel interference, power transmission may be maximized for both P1 and P2, shown as Psel in 420. This power transmission configuration corresponds to maximum data rate for both R1 and R2, shown as Rsel in 410. The lines essentially operate independently, because their transmissions do not affect one another. FIG. 4 shows a convex rate region, because there is little crosstalk between the two lines. Weighted sum-rate optimal points are achievable when every link is optimizing locally, while only the weights w_i of the links are coordinated from the central unit 110. Weighted sum-rate optimal algorithms like iterative water filling are able to reach the shown points.

FIG. 5 illustrates one solution of a region of reachable rates and powers in a general case with two lines. In this case, there is crosstalk between the two lines. Power allocation 520 corresponds with data rate 510. At one locally optimal point, power level Pt1 is maximum power to P1 and sub-maximum power P2, corresponding to point Rt1, which is sub-maximum data rate to both R1 and R2. In a second locally optimal point, power level Pt2 is maximum power to P2 and sub-maximum power to P1, corresponding to point Rt2, which is sub-maximum data rate to both R1 and R2. In various solutions provided herein, multiple locally optimal points are stored in the memory of the communication units. Thus, global optimization may be achieved, thereby enhancing system performance. Performance may be enhanced in any system in which there are two or more communication lines, provided that at least two of such communication lines have strong crosstalk or other co-channel interference.

A system implementing various solutions provided herein are capable of calculating the rates reached at points of interest in the transmission system. In the example shown in

FIG. 3, to take only one instance, there are three possible configurations and two different locally optimal rates. Data related to configurations and rates is collected in the transceivers and remote terminals by proper link configuration, and then transmitted to the central unit. At system startup, at least one or typically each communication link checks the link quality for the case where all of the other links are quiet, and also checks link quality for the case where all the links are active. Optionally, in other cases, where some of the links active, while others are not, may also be checked.

Given the data, locally optimized configurations are calculated by the central unit. If channel estimation data is also available, that data may also be sent to the central unit to calculate the rate points of interest from the estimation. When the system has many transmission links, additional sources of information, including estimation data, helps the central unit quickly calculate the locally optimized configurations.

Solutions illustrated in FIG. 5 may operate on any system, including, without limitation, any cable, wireline telephony, other wireline, wireless system, or hybrids of any of the aforementioned kinds of systems. Various solutions are private systems in which all of the hardware components, both server side and client side, are owned and operated by a single entity. Various solutions are private or public systems in which the server side components are owned and operated by a single entity, while the client side components are owned and operated by one or more different entities that do not own and operate the server side components. When there is a split between ownership and operation of the server side and client side components, the description herein related to various server side components and operations will apply only to the server side, and the description herein related to various client side components and operations will apply only to the client side.

One solution of structure implementing these functions is set forth in figures FIG. 6A, FIG. 6B, and FIG. 6C. All of these figures may include a central unit 610 calculating the locally optimized configurations, transceivers 620 transmitting and receiving various data or information as further described, a distribution point including both the central unit 610 and the transceivers 620, remote terminals 650 that communicate with the transceivers 620, a crosstalk channel 640 through which communication flows in both directions between the transceivers 620 and the remote terminals 650.

Although each of FIG. 6A, FIG. 6B, and FIG. 6C, shows only two transceivers 620, it will be understood that there may be three, four, or any other higher number of transceivers in the system. Although each of the three figures shows only two remote terminals 650, it will be understood that there may be three, four, or any other higher number of remote terminals in the system.

Computation of locally optimized configurations is performed in the central unit 610. The central unit 610 may have specific structure, called an "optimizer", which runs an optimization routine and identifies a subset of configuration points that is needed to reach the desired rates. For example, in FIG. 3, there are the two points where only one transmitter is using the full power, whereas the point of two transmitters active at the same time is not needed. Thus, in FIG. 3, the "subset of configuration points" needed to reach a desired rate is two. The number of points necessary to reach the optimal point is always lower or equal to the number of lines. The running of an optimization routine may occur in a specific an dedicated part of the central unit 610, or in a distributed processing system with central unit 610 which can run the routine but which is not dedicated to that task, or in a unit totally separate from the central unit 610 which then shares the results with the central unit 610, or in any other matter permitted and enabled by technology to receive and process electronic data.

FIG. 6A illustrates one solution of a system with messaging for channel characteristics. In FIG. 6A, receiver ("Rx") channel characteristics are communicated to the central unit 610. Rx1 channel characteristics 660a is the virtual channel on which channel characteristic data is communicated from each remote terminal 650 at the top through the crosstalk channel 640, to the top transceiver 620, then to the central unit 610. 660a is also the virtual channel by which top transceiver 620 communicates its own Rx channel characteristics to the central unit 610. "Virtual channel" means that this is the flow of data, although the data may or may not be running on one or more particular physical channels between the central unit 660 the top transceiver 620, through the crosstalk channel 640, then to the top remote terminal 650. Rx1 channel characteristics 660b is the virtual channel on which channel characteristic data is communicated from each remote terminal 650 at the bottom through the crosstalk channel 640, to the bottom transceiver 620, then to the central unit 610. 660a is also the virtual channel by which bottom transceiver 620 communicates its own Rx channel characteristics to the central unit 610. "Virtual channel" means that this is the flow of data, although the data may or may not be running on one or more particular physical channels between the central unit 660 the bottom transceiver 620, through the crosstalk channel 640, then to the bottom remote terminal 650.

The data communicated as part of the Rx channel characteristics may include any kind of data that impacts the desired reception of data at the various transceivers and remote terminals. It may include technical data, such as crosstalk between channels, electro-magnetic (EM) interference of any other kind that may affect reception, and any limitations on ability of the transceivers or remote terminals to receive data. It may include relevant customer data, since the anticipated quantity, required quality, and timing, of data to be received at a remote terminal, or the amount of compensation customers are prepared to pay for ensuring the reception of certain quantity, quality, or timing, of data.

After the central unit 610 has received Rx channel characteristic data from the transceivers and remote terminals, it computes locally optimal configurations, and communicates necessary data to the transceivers 620 and remote terminals 650. Such data will include at least transmitter configuration settings for any locally optimal configuration, which means at least the power levels of transmission for each of the transceivers 620 and remote terminals 650.

FIG. 6B illustrates one solution of a system with messaging for transmitter configuration settings. As shown in FIG. 6B by the dotted line extending out from top of central unit 610, transmitter configuration settings are communicated on virtual channel 660c from the central unit 610, to top transceiver 620, through crosstalk channel 640, to remote terminal 650. As shown in FIG. 6b by the dotted line extending out from the bottom of central unit 610, transmitter configuration settings are communicated on virtual channel 660d from the bottom of central unit 610, to bottom transceiver 620, through crosstalk channel 640, to bottom remote terminal 650.

FIG. 6C illustrates one solution of a system with messaging for timing information. In FIG. 6C, two lines go out from the center of central unit 610. Each line shows the communication of timing information from the central unit 610. For the line at the top, timing information is sent on the top line directly to top transceiver 620 and also to top remote terminal 650 through top transceiver 620, crosstalk channel 640, and then to top remote terminal 650. For the line at the bottom, timing information is sent on the bottom line directly to bottom transceiver 620 and also to bottom remote terminal 650 through bottom transceiver 620, crosstalk channel 640, and then to bottom remote terminal 650. The lines go out from the same point of central unit 610 in order to illustrate, and emphasize, that all of the units, that is, all of the transceivers, and all of the remote terminals, receive coordinated timing information, in which the time slots are the same for all of the transmitting units, and each unit will transmit in accordance with the plan calculated by the central unit 610.

Synchronization of transmission is typically required in order to optimize the performance of the communication system. With the Rx channel characteristic data in FIG. 6A, it is not necessarily required that all of the data be communicated at the same time to the central unit 610, and each unit, be it transceiver or remote terminal, may have its own unique Rx channel characteristics that differ from the characteristics of one or more other transceivers or remote terminals. Similarly, the transmitter configuration settings in FIG. 6B need not be communicated at the same time to the various transceivers and remote terminals, and each such transceiver or remote terminal may have its own unique transmitter configuration setting different from the settings of all the other transceivers and remote terminals.

In some solutions, the timing configuration settings communicated in FIG. 6C need not be communicated to all of the transceivers and remote terminals at the same time. These are solutions related to initial system set up, or where timing of a new setup is not critical. In other solutions, the timing configuration settings are communicated substantially simultaneously or at the same time from the central unit 610 to the transceivers 620 and remote terminals 650. Substantially simultaneous or at the same time communication may be necessary in dynamic rate adaptation, in order to allow the system to very quickly calculate, store, and implement, new locally optimal configurations, in response to changing Rx channel characteristics, thus optimizing system performance in solutions where speed of adaptation is important.

To be able switch between different configurations, the reference parameters of the configurations of interest are distributed to the transmitters and receivers of the system. Various solutions include configuration messages which distribute the parameters, and which enable the transceivers and remote terminals to store multiple configurations locally. Additionally, the transceivers and remote terminals are synchronized, so that they switch to the desired configuration at the same time. This is particularly useful in solutions that include dynamic rate adaptation.

A media access plan message contains the information about what configuration is to be used at which particular time. Any single transceiver or remote terminal does not need to receive and store all parameters of the system, but only the subset that are connected to that specific link. For example, a transceiver or remote terminal acting as transmitter 1 will receive information to use full power p_{max} for time t_1 and to be quiet at t_2. A transceiver or remote terminal may be acting as receiver 1 at the same time, in which case it may need to know the same times t_1 and t_2, but would not need to know the transmit powers (because it is not transmitting at time 1). Receiver 1 may need to switch receiver settings according to the media access plan, but still would need know the transmit powers at a time when the unit is receiving rather than transmitting. accordingly.

The transmitter and receiver configuration parameters may include pre-coding coefficients, bit loading, channel code settings, and other parameters.

Timing blocks, for transmission and reception, may be of a standard length, or may vary in length, as long as all each communication unit is aware of its part of the media access plan.

Transmitters with strong crosstalk will generally not transmit at the same time. Given two transmitters 1 and 2 with strong crosstalk, it is possible to allocate transmission time 50% to transmitter 1 and 50% to transmitter 2, but this is not particularly required, and a majority of time, in any percentage, may be allocate to the two transmitters, provided, of course, that the total transmission time of these two units does not exceed 100% of available time.

Solutions illustrated in FIG. 6A, FIG. 6B, and FIG. 6C, may operate on any system, including, without limitation, any cable, wireline telephony, other wireline, wireless system, or hybrids of any of the aforementioned kinds of systems. Various solutions may be private systems in which all of the hardware components, both server side and client side, are owned and operated by a single entity. Various solutions may be private or public systems in which the server side components are owned and operated by a single entity, while the client side components are owned and operated by one or more different entities that do not own and operate the server side components. When there is a split between ownership and operation of the server side and client side components, the solutions provided herein maybe related to various server side components and operations will apply only to the server side, and the solutions herein related to various client side components and operations will apply only to the client side.

Advantages of the instant solutions are afforded and are to be appreciated. A much greater degree of freedom for optimizing system settings may be afforded. Higher system performance is possible in systems that have two or more lines with strong cross-talk. Dynamic rate adaptation is further possible.

In addition, the various proposed solutions herein allow the achievement of superior system performance, but with a reduced quantity of hardware. Reduction of hardware will reduce capital costs, may reduce operating costs (for leasing space, or for electricity costs, for example), and may reduce maintenance costs. One example of reducing hardware is that of reducing the number of transceivers at the distribution point. Power consumption is one of the limiting factors for high speed communication distribution points, and a major part of the overall power is consumed by the frontend electronics and line drivers. Therefore, in an aspect herein the solutions advantageously reduce the number of frontends to a value less than the number of served lines.

Two corner cases that illustrate the value of the proposed solution are the case of one transmitter for all lines. One corner case is shown in FIG. 7, which shows one transmitter for all lines. A second corner case is one transmitter per line, which is shown in FIG. 8, a block diagram of a alternative solutions TDD system.

In various solutions, there is an intermediate case between TDMA and TDD, which is a mixed access system, as shown in FIG. 9, which is just one example of very many kinds of mixed access systems that may be implemented in various solutions.

A goal is to allow various described optimization routines to find configurations that serve all lines according to the quality defined by the optimization criterion. At the same time, the quantity of hardware is to be reduced.

FIG. 7 is a block diagram of a TDMA system to illustrate the efficacy of the instant solutions. The term “DFE” 710 refers to the digital front-end, “AFE” 720 refers to the analog front-end, and “LD” 730 is a line driver. There is a line interface 740, which handles decoupling between line driver 730 and transmission line, impedance matching, and line termination. Also shown is a crosstalk channel 750, through which flows communication to and from remote terminals that are not shown. FIG. 8 is an example of a standard TDMA system.

FIG. 8 is a block diagram of a TDD system to illustrate the efficacy of the instant solutions. DFE 810 communicates with AFE 820, which communicates with LD 830, which communicates with line interface 840, which communicates through crosstalk channel 850 with remote terminals not shown. Each communication chain is essentially separate. In FIG. 9, four chains are shown, marked 1, 2, 3, and 4, each chain including a DFE, an AFE, and LD, a line interface, and the crosstalk channel. This standard TDD system will work, but it requires a very heavy amount of hardware.

FIG. 9 illustrates one solution of a system with mixed access communication that has certain features of a TDMA system and certain features of a TDD system. This is a system with reduced complexity, and hence reduced hardware, with regard to alternative solutions systems. Multiple connections may share one communication chain of a DFE, an AFE, and an LD. In order to do this, there may be stored, possibly at the DFE, but potentially at either the AFE or at the central unit to which the DFE is connected, multiple local optimized configurations and parameters for such configurations.

In another solution presented in FIG. 9, there are two communication chains, 1 and 2, in which each chain includes a DFE 910, an AFE 910, and an LD 830. The two chains may act independently. In this embodiment, the two chains can service four line interfaces to four remote terminals not shown (or to four groups of remote terminals, not shown). In this aspect, one possible variation, not shown, would be to have each of the communication chains connect physically to each of the four line interfaces 940a, 940b, 940c, and 940d. Such a variation would work, but it would require more connections than is necessary.

The variation of a first solution shown in FIG. 9 shows only three connections between each communication chain and the line interfaces 940. Chain 1 is connected to line interfaces 940a, 940b, and 940c, but not to 940d. Chain 2 is connected to line interfaces 940b, 940c, and 940d, but not to 940a. The overall goal is to ensure that no two lines having strong crosstalk will be permitted to transmit at the same time, while reducing the number of active links. For this purpose, the variation shown is sufficient. If the crosstalk is between 940a and 940b, both lines may transmit at the same time, provided that 940a transmits with chain 1, and 940b transmits with chain 2. Similarly, if 940a and 940c have strong crosstalk, 940a may transmit with chain 1, and 940c may transmit with chain 2. Similarly, if 940a and 940d have strong crosstalk, 940a may transmit with chain 1, and 940d may transmit with chain 2. If 940b and 940c have strong crosstalk, they may both transmit at the same time, provided either one is transmitting on chain 1 and the other one is transmitting on chain 2. If 940b and 940d have strong crosstalk, 940b may transmit with chain 1 and 940d may transmit with chain 2. If 940c and 940d have strong crosstalk, 940c may transmit with chain 1 and 940d may transmit with chain 2.

With four line interfaces as shown, the system will work successfully by employing two communication chains and thrre connections between the chains and the line interfaces. Mathematically, with two communication chains, the minimum number of connections that may be required between the chains and the line interfaces, for the system to operate in the way described, is the number of line interfaces minus one. This number of line interfaces minus one, reduces the number of connections, hence the complexity of the system, and the cost, to a minimum.

Solutions illustrated in FIG. 9 may operate on any system, including, without limitation, any cable, wireline telephony, other wireline, wireless system, or hybrids of any of the aforementioned kinds of systems. Various solutions may be private systems in which all of the hardware components, both server side and client side, are owned and operated by a single entity. Various solutions may further be private or public systems in which the server side components are owned and operated by a single entity, while the client side components are owned and operated by one or more different entities that do not own and operate the server side components. When there is a split between ownership and operation of the server side and client side components, the solutions provided herein relate to various server side components and operations will apply only to the server side, and the solutions herein relate to various client side components and operations will apply only to the client side.

Various solutions operate in "single duplex mode", which a unit that the uplink and downlink transmissions are on the same channel, but in different time slots. In such a mode, communication units, also operating in single duple, transmit at any one time in either uplink or downlink. To reduce hardware complexity and cost, parts of the communication unit hardware are shared for uplink and downlink transmission. Although sharing reduces complexity and cost, it also has a disadvantage in that turn-around time is required to switch between uplink and downlink, and vice versa. Turnaround time reduces the rate efficiency.

It is possible to reduce the overhead due to this switching time. This may be done by the addition of a bus system between the DFEs and the AFEs, as shown in FIG. 10. FIG. 10 illustrates one solution of a TDD system with an additional interface between a digital frontend and an analog frontend. FIG. 10 is a block diagram of a TDD system with the addition of a bus system interface between the DFEs and the AFEs. In FIG. 10, there are four communication chains, each chain including a DFE 1010, an AFE 1020, and LD 1030, a line interface 1040, and the crosstalk channel 1050 connecting to one or a group of remote terminals, not shown. There is now a bus system, shown at the left, between the DFEs and the AFEs. One advantage of this system is that transmitting switches between different configurations in different time slots, and not all the transmitters are active in every time slot, similar to what is illustrated in FIG. 3. One benefit of this system in FIG. 10 is that time slots may be arranged such that where a chain is not required to transmit during a particular time slot, the chain may switch from transmit to receive (or vice versa) during that time slot. Doing this with multiple front ends, where not all the front ends are actively transmitting at the same time, is beneficial.

Such benefit is enhanced where the system can insure, by way of a bus system, that at any time slot at least some of the DFEs may be switching their mode, while other DFEs can operate to make sure that all transmissions are occurring in accordance with media access plan.

There are additional advantages of the bus system of the bus system interface. With this interface, any communication chain, such as chain 1, can use any of the DFEs, such as DFE2, or DFE3, or DFE4, as shown. If DFE1 is out of service, for maintenance or for any other reason, the remainder of the chain, AFE1 and LD1, may be served by any of the other DFEs, provided that the DFE in use has in memory (or has access to the memory of the central unit or another piece of hardware) all necessary information about locally optimized configurations and their parameters. If system activity is low, a particular DFE is not necessarily required and is therefore inactive. In such case, one of the other DFEs can interface with its own chain and with the chain of the inactive DFE. All of these various solutions are suggested by the cross-bar system shown in FIG. 10.

Solutions illustrated in FIG. 10 may operate on any system, including, without limitation, any cable, wireline telephony, other wireline, wireless system, or hybrids of any of the aforementioned kinds of systems. Various solutions are private systems in which all of the hardware components, both server side and client side, are owned and operated by a single entity. Various solutions are private or public systems in which the server side components are owned and operated by a single entity, while the client side components are owned and operated by one or more different entities that do not own and operate the server side components. When there is a split between ownership and operation of the server side and client side components, the solutions herein relate to various server side components and operations will apply only to the server side, and the solutions herein relate to various client side components and operations will apply only to the client side.

The system of time slots associated with the structure illustrated in the solution of FIG. 10, is illustrated in the FIG. 11 and FIG. 12. FIG. 11 is an illustration of a possible allocation of time slots 1110 for uplink and downlink transmission in TDD system, according to the alternative solutions. FIG. 12 is an illustration, according to various solutions, of a possible allocation of time slots 1210 for uplink and downlink transmission in a mixed access system.

FIG. 11 illustrates one solution of an allocation of time slots for uplink and downlink transmissions in a TDD system, according to the alternative solutions. In FIG. 11, there are time slots in which all the lines do downlink transmission and the distribution point transceivers are in the transmit ("Tx") mode. There is then a switching time for all the lines. After the switching time, all the lines have switched to uplink, and the distribution point is in receive ("Rx") mode. Although various lines have strong crosstalk, this is not a problem, because each line has its own connections, which means that each line has its own communication chain. This would be like showing FIG. 10 minus the bus system interface.

FIG. 12 illustrates one solution of an allocation of time slots for uplink and downlink transmissions in a mixed access system. FIG. 12 shows time slotting when the bus system interface is in place and active. FIG. 12 therefore shows various solutions. For FIG. 12, assume a channel with four lines, where lines 1 and 2 experience only weak crosstalk, while lines 3 and 4 experience strong crosstalk. Assume further a setup with reduced hardware complexity and two transceivers, such as is shown in FIG. 9. The optimization routine will switch to a configuration where line 1 and line 2 are served in the same time slot, as there is only weak crosstalk. Line 3 transmission is served in another time slot than the transmissions of line 1 and line 2, and line 4 transmission is served in another time slot different from the transmission time slots for either line 3 or for lines 1 and 2. As shown in FIG. 12, there are time slots where only one transmitter may be needed, and in such time slots, the other communication unit may switch from transmit to receive configuration, or vice versa. If there is a bus system addition, as suggested, then one DFE can enable all the transmissions shown in FIG. 12, which a unit that another DFE can be in switch mode, and there will not be any effect on the effective communication rate of the entire system.

One of the general concepts shown in FIG. 12 is that crosstalk is reduced by managing the transmissions such that lines with strong crosstalk do not carry transmissions in the same time slot. This concept is implemented and enabled by any number of possible system structures. One such system structure is illustrated in FIG. 9, as discussed. The concept may also be implemented and enabled by the structure illustrated in FIG. 10. FIG. 10 has greater hardware complexity than FIG. 9, but it has greater potential flexibility and greater potential data rate bandwidth than FIG. 9, for two reasons. First, FIG. 10 has four communication chains rather than the two chains shown in FIG. 9, so more transmissions can be made in any time slot with the system illustrated in FIG. 10. Second, the bus system interface illustrated in FIG. 10 has a bus system interface, which does not appear in FIG. 9. Therefore, all of the advantage of a bus system interface, such as, for example, enhanced flexibility, backup, greater communication throughput, as discussed above in regard to FIG. 10, will also apply to an infrastructure such as illustrated in FIG. 10, implementing an allocation of time slots as illustrated in FIG. 12.

Further, the illustrative solution presented in FIG. 9 does not necessarily include a bus system interface connecting DFE1, DFE2, AFE1, and AFE2. However, in an alternative embodiment, not shown in FIG. 9, there would be added such a bus system interface connecting all of the digital front ends and all of the analog front ends. Then, in addition to all of the features and advantages derived from the structure shown in FIG. 9, the alternative solution would also offer all the advantages of a bus system interface, such as greater flexibility, backup, and enhanced communication throughput, could be afforded in this alternative embodiment.

An additional embodiment, not shown but possible, would be to add to FIG. 10 a different network of connections between the line drivers 1030 and the line interfaces 1040. In FIG. 10, the line driver 1030 of each communication chain is connected to only one line interface 1040. This network of connections could be extended, so that each line driver is connected to three line interfaces. This extended network of connections, added to the structure illustrated in FIG. 10, could then be used to derive advantages and benefits of discussed above with regard to FIG. 9. In particular, the overall goal is to ensure that no two lines having strong crosstalk will be permitted to transmit at the same time, while reducing the number of active links. That would be achieved by this extended network of connections between the line drivers 1030 and the line interfaces 1040, in which each line driver is connected to three line interfaces.

Solutions illustrated in FIG. 12 may operate on any system, including, without limitation, any cable, wireline telephony, other wireline, wireless system, or hybrids of any of the aforementioned kinds of systems. Various solutions may include private systems in which all of the hardware components, both server side and client side, are owned and operated by a single entity. Various solutions may include private or public systems in which the server side components are owned and operated by a single entity, while the client side components are owned and operated by one or more different entities that do not own and operate the server side components. When there is a split between ownership and operation of the server side and client side components, the solutions herein relate to various server side components and operations will apply only to the server side, and the solutions herein relate to various client side components and operations will apply only to the client side.

Various solutions include dynamic rate adaptation to the changing needs or capabilities of receivers. For most of the time, only a few connections of a communication system request high bit rates. Alternative solutions systems, such as VDSL, transmit idle data on inactive links. In such alternative solutions systems, system-wide optimization is not used because of the complex optimization problem that must be solved in real time, and because the optimal configuration may already be obsolete by the time the optimization routine has finished.

In contrast, some of the solutions herein may adapt to the requested bit rates very efficiently by changing the time allocation for configuration vectors that have already been calculated. In some solutions an optimal configuration for the proposed system setup may be computed by solving a linear program, which does not require much time or compute resources. In some solutions, a dynamic rate adaption for the proposed system is implemented as follows, but not necessarily in this order:

The configurations for all rate allocations of interest are computed and stored in the communication units.

The achieved rates of all configurations are available at the central unit.

Whenever the requested data rates change, the optimal configuration is computed substantially real time, by solving the linear program

The new allocation is distributed in substantially real time to the communication units.

In some solutions, the system operator may use different optimization criteria for the allocation of worst case data rates, or for the additional data rate that is available when not all links need the full rate. Therefore, the optimization for the additional data rate uses a difference rate region where $R_{difference\,i} = R_i - R_{worstcase\,i}$.

The dynamic rate adaption may also be used in the proposed reduced complexity transceiver system illustrated in FIG. 9.

Solutions related to dynamic rate adaptation may operate on any system, including, without limitation, any cable, wireline telephony, other wireline, wireless system, or hybrids of any of the aforementioned kinds of systems. Various solutions may include private systems in which all of the hardware components, both server side and client side, are owned and operated by a single entity. Various solutions may include private or public systems in which the server side components are owned and operated by a single entity, while the client side components are owned and operated by one or more different entities that do not own and operate the server side components. When there is a split between ownership and operation of the server side and client side components, the solutions herein relate to various server side components and operations will apply only to the server side, and the solutions herein relate to various client side components and operations will apply only to the client side.

One solution is a transceiver system that services multiple electronic communication lines. This solution includes a distribution point, which itself may include a central unit and multiple transceivers. This solution also may include multiple line interfaces, a crosstalk channel, and multiple remote terminals. In this embodiment, the system may be configured to compute locally optimal communication configurations, store in memory data about said configurations, process said data into time sharing information, convey such time sharing information to the transceivers and the remote terminals. The time sharing information is later used by the transceivers and remote terminals to transmit in accordance with such time sharing information.

One aspect further provides in the transceiver system just described that services multiple electronic communication lines, wherein each of the multiple transceivers includes a front end and a line driver, and where the front end includes both a digital front end and an analog front end.

One aspect further provides in the transceiver system described above, including the front end and line driver, wherein the number of front ends in the system is more than one and less than the number of line interfaces.

One aspect further provides in the transceiver system described above, including the front end the line driver, where the number of front ends is as described above, and wherein the system is configured to switch all communication transmissions between the locally optimal communication configurations.

One aspect further provides in the transceiver system described above, including the front end and the line driver, where the number of front end is as described above, where the system is configured to switch transmissions as described above, and wherein in any locally optimal communication configuration, the number of active transmission connections is between 0 and the number of front ends, inclusive.

One aspect further provides in the transceiver system described above, including the front end and the line driver, where the number of front end is as described above, where the system is configured to switch transmissions as described above, where the number of active transmission connections is as described above, and wherein the system is a wireline communication system.

One aspect further provides in the transceiver system described above, including the front end and the line driver, where the number of front end is as described above, where the system is configured to switch transmissions as described above, where the number of active transmission connections is as described above, and wherein the system is a wireless communication system.

One aspect further provides in the transceiver system described above, including the front end and the line driver, where the number of front end is as described above, where the system is configured to switch transmissions as described above, where the number of active transmission connections is as described above, and wherein the system is a hybrid communication system.

One aspect further provides in the transceiver system that services multiple electronic communication lines, described above, wherein each remote terminal has a guaranteed data for transmit from the terminal or for reception to the terminal or for both transmit and reception. In this solution, the system is configured to calculate locally optimal configurations where the system serves all the guaranteed data rates to and from all remote terminals, and the system is also configured to adapt the locally optimal configurations to server some remote terminals with higher than guaranteed data rates, when others of the remote terminals either are inactive or require less than their guaranteed rates.

One aspect further provides in the transceiver system described above, including the guaranteed rate as described, including configuration to calculate and adapt to locally optimal configurations described above, wherein each of the multiple transceivers includes a front end and a line driver, and wherein each front end includes a digital front end and an analog front end.

One aspect further provides in the transceiver system described above, including the guaranteed rate as described and the configurations to calculate and adapt to locally optimal configurations, including the multiple transceivers as described above, wherein the number of front ends in the system is more than one and less than the number of line interfaces.

One aspect further provides in the transceiver system described above, including the guaranteed rate as described and the configurations to calculate and adapt to locally optimal configurations, including the multiple transceivers as described above, where the number of front ends in the system is more than one and less than the number of line interfaces, and wherein the system is configured to switch all communication transmissions between the locally optimal communication configurations.

One aspect further provides in the transceiver system described above, including the guaranteed rate as described and the configurations to calculate and adapt to locally optimal configurations, including the multiple transceivers as described above, where the number of front ends in the system is more than one and less than the number of line interfaces, where the system is configured to switch communication transmissions as described, and wherein in any locally optimal communication configuration, the number of active transmission connections is between 0 and the number of front ends, inclusive.

One aspect further provides in the transceiver system described above, including the guaranteed rate as described and the configurations to calculate and adapt to locally optimal configurations, including the multiple transceivers as described above, where the number of front ends in the system is more than one and less than the number of line interfaces, where the system is configured to switch communication transmissions as described, where the number of active transmission connections is as described above, and wherein the system is a wireline communication system.

One aspect further provides in the transceiver system described above, including the guaranteed rate as described and the configurations to calculate and adapt to locally optimal configurations, including the multiple transceivers as described above, where the number of front ends in the system is more than one and less than the number of line interfaces, where the system is configured to switch communication transmissions as described, where the number of active transmission connections is as described above, and wherein the system is a wireless communication system.

One aspect further provides in the transceiver system described above, including the guaranteed rate as described and the configurations to calculate and adapt to locally optimal configurations, including the multiple transceivers as described above, where the number of front ends in the system is more than one and less than the number of line interfaces, where the system is configured to switch communication transmissions as described, where the number of active transmission connections is as described above, and wherein the system is a hybrid communication system.

One further aspect includes a system operative to serve multiple electronic communication lines. This solution may also include a distribution point, which itself includes a central unit and multiple transceivers. This solution may also include multiple line interfaces, and a crosstalk channel. In this embodiment, the system is configured to compute locally optimal communication configurations, store in memory data about said configurations, process said data into time sharing information, convey such time sharing information to the transceivers. The time sharing information is later used by the transceivers to transmit in accordance with such time sharing information.

One aspect further provides in the transceiver system just described that services multiple electronic communication lines with a central unit, multiple transceivers, multiple line interfaces, and a crosstalk channel, wherein each of the multiple transceivers includes a front end and a line driver, and where the front end includes both a digital front end and an analog front end.

One aspect further provides in the transceiver system described above with a central unit, multiple transceivers, multiple line interfaces, and a crosstalk channel, including the front end and line driver, wherein the number of front ends in the system is more than one and less than the number of line interfaces.

One aspect further provides in the transceiver system described above with a central unit, multiple transceivers, multiple line interfaces, and a crosstalk channel, including the front end the line driver, where the number of front ends is as described above, and wherein the system is configured to switch all communication transmissions between the locally optimal communication configurations.

One v the transceiver system described above with a central unit, multiple transceivers, multiple line interfaces, and a crosstalk channel, including the front end and the line driver, where the number of front end is as described above, where the system is configured to switch transmissions as described above, and wherein in any locally optimal communication configuration, the number of active transmission connections is between 0 and the number of front ends, inclusive.

One aspect further provides in the transceiver system described above with a central unit, multiple transceivers, multiple line interfaces, and a crosstalk channel, including the front end and the line driver, where the number of front end is as described above, where the system is configured to switch transmissions as described above, where the number of active transmission connections is as described above, and wherein the system is a wireline communication system.

One aspect further provides in the transceiver system described above lines a central unit, multiple transceivers, multiple line interfaces, and a crosstalk channel, including the front end and the line driver, where the number of front end is as described above, where the system is configured to switch transmissions as described above, where the number of active transmission connections is as described above, and wherein the system is a wireless communication system.

One aspect further provides in the transceiver system described above with a central unit, multiple transceivers, multiple line interfaces, and a crosstalk channel, including the front end and the line driver, where the number of front end is as described above, where the system is configured to switch transmissions as described above, where the number of active transmission connections is as described above, and wherein the system is a hybrid communication system.

One aspect further provides a central unit that may be part of a communication system operative to serve multiple electronic communication lines. The central unit may include a unit that receives electronic data related to receiver channel characteristics, an optimizer that operates an optimization routine to compute multiple locally optimal configurations and to identify locally optimal configuration points needed to reach desired data rates, a memory to store the locally optimal configurations and locally optimal configuration points, a unit that computes a media access plan to achieve optimal system communication according to a criterion, and a unit that conveys the media access plan to transceivers that will transmit in accordance with the plan.

One further solution is the central unit that may be part of a communication system operative to serve multiple electronic communication lines, wherein the a unit that receives electronic data related to channel characteristics is an electronic receiver or an electronic transceiver.

One further solution is the central unit that may be part of a communication system operative to serve multiple electronic communication lines, wherein the a unit that conveys the media access plan is an electronic transmitter or an electronic transceiver.

One solution is the central unit that may be part of a communication system operative to serve multiple electronic communication lines, wherein the media access plan includes information about time slots, about when transceivers should transmit, and about the power levels at which transceivers should transmit.

One solution is the central unit that may be part of a communication system operative to serve multiple electronic communication lines, wherein the a unit that computes a media access plan to achieve optimal system communication according to a criterion are a data processing module within the central unit.

One solution is the central unit that may be part of a communication system operative to serve multiple electronic communication lines, including the data processing module described above, wherein the criterion is one of selected from the group consisting of (i) a rule for absolute fairness; (ii) a rule for relative fairness; and (iii) a rule for maximizing the sum of all data rates.

One solution is the central unit that may be part of a communication system operative to serve multiple electronic communication lines, wherein the memory also stores information about data rates guaranteed to various communication units, the electronic data about receiver channel characteristics comprises data about when a communication unit is in active and data about when a communication unit requires less than its guaranteed rate, the a unit that computes a media access plan further comprises a unit to calculate locally optimal configurations and locally optimal parameters when all communication units are served with their guaranteed rates, and the a unit that computes media access plan further comprises a unit to calculate different combinations of locally optimal configurations when one or more communication units are either in active or require less than their guaranteed rates. In this aspect, the different combinations include time sharing information that will provide higher than guaranteed rates to some communication units at a time when one or more other communication units either are inactive or require less than their guaranteed rates.

FIG. 13 illustrates a flow diagram describing one solution of a method for a transceiver system pre-computing locally optimal configurations to enhance communication. In step 1310, pre-computing multiple locally optimal configurations. In step 1320, storing in memory the multiple locally optimal configurations and configuration parameters. In step 1330, processing the locally optimal configurations and configuration parameters data, to create time sharing information. In step 1340, conveying the time sharing information to communication units.

In one aspect, time sharing information that may be conveyed by the central unit to communication units, and is then used by the communication units to transmit according to the media access plan.

Solutions illustrated in FIG. 13 may operate on any system, including, without limitation, any cable, wireline telephony, other wireline, wireless system, or hybrids of any of the aforementioned kinds of systems. Various solutions may include private systems in which all of the hardware components, both server side and client side, are owned and operated by a single entity. Various solutions may include private or public systems in which the server side components are owned and operated by a single entity, while the client side components are owned and operated by one or more different entities that do not own and operate the server side components. When there is a split between ownership and operation of the server side and client side components, the solutions herein relate to various server side components and operations will apply only to the server side, and the solutions herein relate to various client side components and operations will apply only to the client side.

FIG. 14 illustrates a flow diagram describing a solution of a method for a transceiver system pre-computing locally optimal configurations to enhance communication, in which the method may include additionally or in the alternative a dynamic rate adaptation, based on a change in the data rate requirements of one or more communication units which, at a particular point of time, are either inactive or require less than their guaranteed data rate. In step 1410, pre-computing multiple locally optimal configurations. In step 1420, storing in a memory the multiple locally optimal configurations and configuration parameters. In step 1430, processing the locally optimal configurations and configuration parameters data, to create time sharing information. In step 1440, conveying the time sharing information to communication units. In step 1450, the system inquires as to whether the requirements of the communication units have changed, either permanently or temporarily (where "temporarily" may mean for one a single time slot, or for a longer period of time). If the answer is "NO", the requirements have not changed, then nothing more is done. If the answer is "YES", the requirements have changed, then the additional data is processed in step 1430, and new time sharing information is conveyed in step 1440, all as shown in FIG. 14. The system may also be programmed so that a separate system inquiry is not required, but rather the communication units will report automatically changes in requirements, or the communication units will automatically report their status according to some time schedule.

Solutions illustrated in FIG. 14 may operate on any system, including, without limitation, any cable, wireline telephony, other wireline, wireless system, or hybrids of any of the aforementioned kinds of systems. Various solutions may include private systems in which all of the hardware components, both server side and client side, are owned and operated by a single entity. Various solutions may include private or public systems in which the server side components are owned and operated by a single entity, while the client side components are owned and operated by one or more different entities that do not own and operate the server side components. When there is a split between ownership and operation of the server side and client side components, the solutions herein relate to various server side components and operations will apply only to the server side, and the solutions herein relate to various client side components and operations will apply only to the client side.

solution solution solution One solution is a method for enhancing communication in a system with a plurality of electronic communication connections. Multiple locally optimal configurations and parameters that may be required to build such configurations are pre-computed. Data about the configurations and the parameters are then stored in a memory. Such data is then processed to create time sharing information. Such time sharing information is then conveyed to communication units so that such communication units may transmit at such times and such power levels as to achieve enhanced communication within the system according to some criterion.

The method just described for enhancing communication in a system with a plurality of electronic communication connections, wherein multiple locally optimal configurations and parameters that may be required to build such configurations are re-computed when a new communication unit is added to the system.

The method described for enhancing communication in a system with a plurality of electronic communication connections, wherein there are pre-computed multiple locally optimal configurations and parameters that may be required to build such configurations where the communication units have guaranteed data rates and the locally optimal configurations meet or exceed those guaranteed data rates.

The method for enhancing communication in a system with a plurality of electronic communication connections, including pre-computing with guaranteed data rates as described, wherein information is received that that one or more communication units is either inactive at a particular time is requires less than a guaranteed data rate at a particular time, and such information about units inactive or requiring less than guaranteed data rates is used to re-calculate a combination of configurations that will server the other units at higher than guaranteed data rates.

The method for enhancing communication in a system with a plurality of electronic communication connections, including pre-computing with guaranteed data rates as described, and including reception and use of information about units inactive or using less than the guaranteed rate as described, wherein the communication units include transceivers.

The method for enhancing communication in a system with a plurality of electronic communication connections, including pre-computing with guaranteed data rates as described, and including reception and use of information about units inactive or using less than the guaranteed rate as described, wherein the communication units include transceivers and remote terminals.

In this description, numerous specific details are set forth. However, the solutions/cases of the invention may be practiced without some of these specific details. In other instances, well-known hardware, materials, structures and techniques have not been shown in detail in order not to obscure the understanding of this description. In this description, references to "one embodiment" and "one case" mean that the feature being referred to may be included in at least one embodiment/case of the invention. Moreover, separate references to "one embodiment", "some solutions", "one case", or "some cases" in this description do not necessarily refer to the same embodiment/case. Illustrated solutions/cases are not mutually exclusive, unless so stated and except as will be readily apparent to those of ordinary skill in the art. Thus, the invention may include any variety of combinations and/or integrations of the features of the solutions/cases described herein. Also herein, flow diagrams illustrate non-limiting embodiment/case examples of the methods, and block diagrams illustrate non-limiting embodiment/case examples of the devices. Some operations in the flow diagrams may be described with reference to the solutions/cases illustrated by the block diagrams. However, the methods of the flow diagrams could be performed by solutions/cases of the invention other than those discussed with reference to the block diagrams, and solutions/cases discussed with reference to the block diagrams could perform operations different from those discussed with reference to the flow diagrams. Moreover, although the flow diagrams may depict serial operations, certain solutions/cases could perform certain operations in parallel and/or in different orders from those depicted. Moreover, the use of repeated reference numerals and/or letters in the text and/or drawings is for the purpose of simplicity and clarity and does not in itself dictate a relationship between the various solutions/cases and/or configurations discussed. Furthermore, methods and mechanisms of the solutions/ cases will sometimes be described in singular form for clarity. However, some solutions/cases may include multiple iterations of a method or multiple instantiations of a mechanism unless noted otherwise. For example, when a controller or an interface are disclosed in an embodiment/case, the scope of the embodiment/case is intended to also cover the use of multiple controllers or interfaces.

Certain features of the solutions/cases, which may have been, for clarity, described in the context of separate solutions/cases, may also be provided in various combinations in a single embodiment/case. Conversely, various features of the solutions/cases, which may have been, for brevity, described in the context of a single embodiment/case, may also be provided separately or in any suitable sub-combination. The solutions/cases are not limited in their applications to the details of the order or sequence of steps of operation of methods, or to details of implementation of devices, set in the description, drawings, or examples. In addition, individual blocks illustrated in the figures may be functional in nature and do not necessarily correspond to discrete hardware elements. While the methods disclosed herein have been described and shown with reference to particular steps performed in a particular order, it is understood that these steps may be combined, sub-divided, or reordered to form an equivalent method without departing from the teachings of the solutions/cases. Accordingly, unless specifically indicated herein, the order and grouping of the steps is not a limitation of the solutions/cases. Solutions/cases described in conjunction with specific examples are presented by way of example, and not limitation. Moreover, it is evident that many alternatives, modifications and variations will be apparent to those skilled in the art. Accordingly, it is intended to embrace all such alternatives, modifications and variations that fall within the spirit and scope of the appended claims and their equivalents.

WHAT IS CLAIMED IS:

1. A system operative to serve multiple electronic communication lines, comprising:

a distribution point, comprising a central unit and a plurality of transceivers;

a plurality of line interfaces;

a crosstalk channel; and

a plurality of remote terminals;

wherein the system is configured to compute locally optimal communication configurations, store in memory data about said configurations, process said data into time sharing information, convey such time sharing information to the transceivers and the remote terminals, wherein such transceivers and remote terminals later transmit in accordance with such time sharing information.

2. The system of claim 1, wherein each of said plurality of transceivers comprises:

a front end, comprising a digital front end and an analog front end, and

a line driver.

3. The system of claim 2, wherein the number of front ends in the system is more than one and less than the number of line interfaces.

4. The system of claim 3, wherein the system is configured to switch all communication transmissions between the locally optimal communication configurations.

5. The system of claim 4, wherein in any locally optimal communication configuration, the number of active transmission connections is between 0 and the number of front ends, inclusive.

6. The system of claim 5, wherein the system is a wireline communication system.

7. The system of claim 5, wherein the system is a wireless communication system.

8. The system of claim 5, wherein the system is a hybrid communication system.

9. The system of claim 1, further comprising:

each remote terminal has a guaranteed data for transmit from the terminal or for reception to the terminal or for both transmit and reception;

the system is configured to calculate locally optimal configurations where the system serves all the guaranteed data rates to and from all remote terminals; and

the system is configured to adapt the locally optimal configurations to server some remote terminals with higher than guaranteed data rates, when others of the remote terminals either are inactive or require less than their guaranteed rates.

10. The system of claim 9, wherein each of said plurality of transceivers comprises:

a front end, comprising a digital front end and an analog front end, and

a line driver.

11. The system of claim 10, wherein the number of front ends in the system is more than one and less than the number of line interfaces.

12. The system of claim 11, wherein the system is configured to switch all communication transmissions between the locally optimal communication configurations.

13. The system of claim 12, wherein in any locally optimal communication configuration, the number of active transmission connections is between 0 and the number of front ends, inclusive.

14. The system of claim 13, wherein the system is a wireline communication system.

15. The system of claim 13, wherein the system is a wireless communication system.

16. The system of claim 13, wherein the system is a hybrid communication system.

17. A system operative to serve multiple electronic communication lines, comprising:

a distribution point, comprising a central unit and a plurality of transceivers;

a plurality of line interfaces; and

a crosstalk channel;

wherein the system is configured to compute locally optimal communication configurations, store in memory data about said configurations, process said data into time sharing information, and to convey such time sharing information to the transceivers wherein such transceivers later transmit in accordance with such time sharing information.

18. The system of claim 17, wherein each of said plurality of transceivers comprises:

a front end, comprising a digital front end and an analog front end, and

a line driver.

19. The system of claim 18, wherein the number of front ends in the system is more than one and less than the number of line interfaces.

20. The system of claim 19, wherein the system is configured to switch all communication transmissions between the locally optimal communication configurations.

21. The system of claim 20, wherein in any locally optimal communication configuration, the number of active transmission connections is between 0 and the number of front ends, inclusive.

22. The system of claim 21, wherein the system is a wireline communication system.

23. The system of claim 21, wherein the system is a wireless communication system.

24. The system of claim 21, wherein the system is a hybrid communication system.

25. A central unit that is part of a communication system operative to serve multiple electronic communication lines, the central unit comprising:

a unit that receives electronic data related to receiver channel characteristics;

an optimizer that operates an optimization routine to compute multiple locally optimal configurations and to identify locally optimal configuration points needed to reach desired data rates;

a memory to store the locally optimal configurations and locally optimal configuration points;

a unit that computes a media access plan to achieve optimal system communication according to a criterion; and

a unit that conveys the media access plan to transceivers that will transmit in accordance with the plan.

26. The central unit of claim 25, wherein the unit that receives electronic data related to channel characteristics is an electronic receiver or an electronic transceiver.

27. The central unit of claim 25, wherein the unit that conveys the media access plan is an electronic transmitter or an electronic transceiver.

28. The central unit of claim 25, wherein the media access plan comprises information about time slots, about when transceivers should transmit, and about the power levels at which transceivers should transmit.

29. The central unit of claim 25, wherein the unit that computes a media access plan to achieve optimal system communication according to a criterion are a data processing module within the central unit.

30. The central unit of claim 29, where the criterion is one of selected from the group consisting of (i) a rule for absolute fairness; (ii) a rule for relative fairness; and (iii) a rule for maximizing the sum of all data rates.

31. The central unit of claim 25, further comprising:

the memory also stores information about data rates guaranteed to various communication units;

the electronic data about receiver channel characteristics comprises data about when a communication unit is in active and data about when a communication unit requires less than its guaranteed rate;

the unit that computes a media access plan further comprises unit to calculate locally optimal configurations and locally optimal parameters when all communication units are served with their guaranteed rates;

the unit that computes media access plan further comprises unit to calculate different combinations of locally optimal configurations when one or more communication units are either in active or require less than their guaranteed rates;

wherein said different combinations include time sharing information that will provide higher than guaranteed rates to some communication units at a time when one or more other communication units either are inactive or require less than their guaranteed rates.

32. A method for enhancing communication in a system with a plurality of electronic communication connections, comprising:

pre-computing a plurality of locally optimal configurations and parameters required to build such configurations;

storing in a memory data about the configurations and the parameters;

processing such data to create time sharing information;

conveying such time sharing information to communication units so that such communication units may transmit at such times and such power levels as to achieve enhanced communication within the system according to some criterion.

33. The method of claim 32, further comprising re-computing a plurality of locally optimal configurations and parameters required to build such configurations when a new communication unit is added to the system.

34. The method of claim 32, further comprising pre-computing a plurality of locally optimal configurations and parameters required to build such configurations where the communication units have guaranteed data rates and the locally optimal configurations meet or exceed those guaranteed data rates.

35. The method of claim 34, further comprising:

receiving information that one or more communication units is either inactive at a particular time is requires less than a guaranteed data rate at a particular time;

using said information about units inactive or requiring less than guaranteed data rates to re-calculate a combination of configurations that will server the other units at higher than guaranteed data rates.

36. The method of claim 35, where the communication units comprise transceivers.

37. The method of claim 36, where the communication units further comprise remote terminals.

ABSTRACT

Various solutions are presented of a time sharing electronic communication system, including a central unit, a crosstalk channel, and communication units such as transceivers and remote terminals. Also presented are various methods for configuring and operating the elements of such a system to enhance communication between communication units within the system. In some solutions, locally optimal configurations are pre-computed, stored in memory, and processed into time sharing information which is communicated to communication units. The time sharing information allows the communication units to transmit at times and power levels in such a manner as to enhance the communication within the system. In some solutions, locally optimal configurations are computed, stored, and processing, substantially dynamically, allowing substantially real time adjustment of transmission times and power levels to enhance the communication within the system.