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Applicant(s)

Vladimir OKSMAN, Morganville, NJ;
Charles BRY, Unterhaching, GERMANY;
Joon Bae KIM, Lexington, MA;
Rainer STROBEL, Ehingen, GERMANY;

Power of Attorney:
Timothy Wyckoff--46175

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Title

METHOD OF WIRED TRANSMISSION FROM A DISTRIBUTION POINT

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METHOD OF WIRED TRANSMISSION FROM A DISTRIBUTION POINT

The Digital Subscriber Line (DSL) technology, during all its history, attempted to increase the bit rate in the aim to deliver more broadband services to the customer. Unfortunately, copper loops deployed from the Central Office (CO) to customer premises (CPE) are rather long and do not allow transmission of data with bit rates more than few Mb/s. Therefore, to increase the customer available bit rates, modern access networks use street cabinets, MDU-cabinets, and similar arrangements: the cabinet is connected to the CO by a high-speed fiber communication line, e.g., gigabit passive optical network (GPON) and installed close to the customer premises. From these cabinets, high-speed DSL systems, such as Very-High-Bit-Rate DSL (VDSL), provide connection to the CPE. The currently deployed VDSL systems (ITU-T Recommendation G.993.2) have range of operation about 1km, providing bit rates in the range of tens of Mb/s. To increase the bit rate of VDSL systems deployed from the cabinet, recent ITU-T Recommendation G.993.5 defined vectored transmission that allows increasing upstream and downstream bit rates up to 100 Mb/s.

Recent trends in the access communications market show that 100 Mb/s is still not sufficient for the close future, and bit rates up to 1 Gb/s are required. This could be only achieved if copper pairs connected the CPE to the fiber backbone are as short as 100m-200m. This requires installation of small street/MDU cabinets, called Distribution Points (DP) that intend to serve a very small number of potential users; the number of potential users shown by recent analysis internationally is 8-16, although some sources report higher required number of served users, like 24 or even 32. Therefore, DPs shall allow very flexible installation practices: they should be light and easily installed on a pole or house wall, or basement, without air-conditioning. These requirements bring substantial restrictions of the power consumption of a DP. Besides, DP (including housings and installed equipment) has to be very inexpensive, because with rather high probability, due to limited customer area, only a single subscriber may be connected to a particular installation for rather long time). Therefore, DP has to be equipped with a different type of transmission system than currently known DSL, that provides extremely low power consumption and inexpensive design, while provides very high bit rates (up to 1Gb/s) and scalability to bigger number of users (if installed in protected environment, such as air-conditioned high-risers, for instance).

Two solutions were recently proposed for a DP:

- a point-to-point (P2P) solution that uses time division duplexing between upstream and downstream; and
- a point-to-multipoint (P2MP) solution that uses Synchronized Time Division Multiple Access (STDMA).

In case of P2P, each copper line is connected to its individual transceiver at the DP, see Figure 1. In case of P2MP, one single transceiver from the DP transmits and receives from all CPE transceivers consequently, see Figure 2.

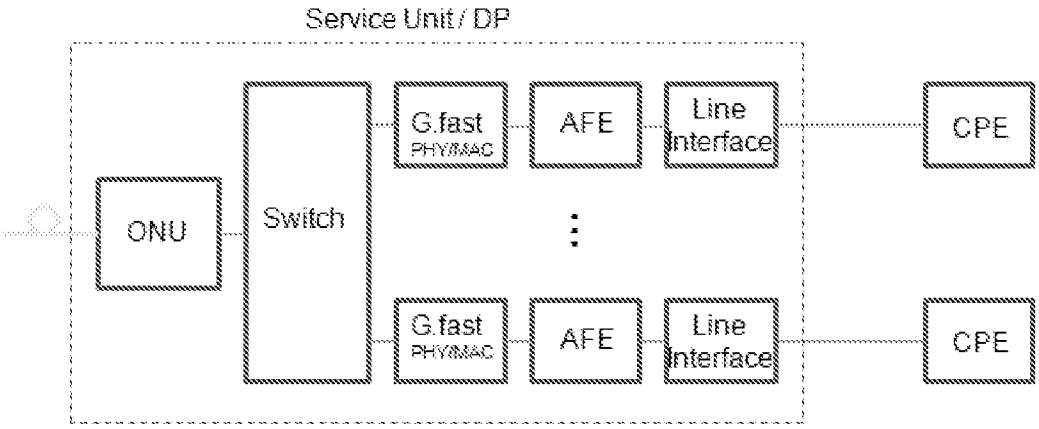

Figure 1 - DP with P2P architecture (individual transceivers per line)

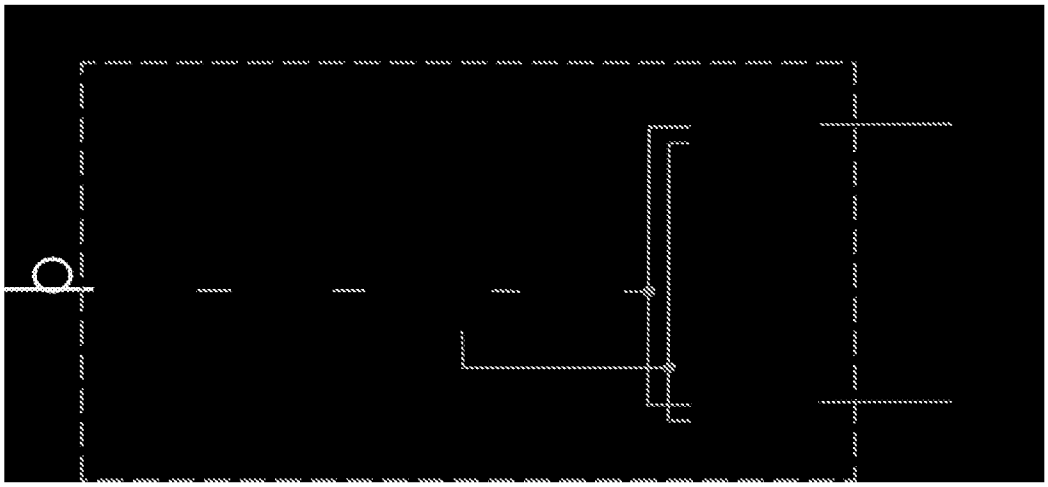

Figure 2 - DP with P2MP architecture (single transceiver serves multiple lines)

A combination of both architectures also considered possible.

The P2P approach requires higher power consumption and is more complex, but provides higher total bit rate (sum of all bit rate from the DP to the CPE) and what is called “sustainable bit rate”, which is an average bit rate guarantee for a service over a long period of time.

The P2MP consumes much less power and is much less complex (just a single transceiver per multiple CPE). It also provides higher peak bit rate. However, the sustainable bit rate is shared between users, and thus is lower than in case of P2P and scales down as amount of users grows. Thus, in the case of many users P2MP may result is insufficient sustainable bit rate.

To cover all varieties of deployment scenarios and expected use cases, both methods may be required. Therefore, a transmission method from a DP shall be capable to operate in a DP using either P2P or P2MP or a combination of both. This is not allowed by the currently known prior art, while transmission methods for P2P and P2MP are known and used in similar applications.

The invention presents a transmission method between a DP and multiple CPEs that allows to connect the same CPEs to a P2P DP, or a P2MP DP, or a combination of both.

Overview

1. The defined transmission concept is intended for serve for both P2P (TDD) and P2MP (STDMA) mode of operation of the DP.

2. The transmission process includes three phases:
- Initialization (upon data or management service request, includes synchronization and channel estimation)
- Transmission (bi-directional data transport in assigned timeslots, including acknowledgements for received packets, if required)
- Deactivation (upon termination of the service, CPE turns to inactive mode and requests re-initialization when new service is required by the user). One type of deactivation is a transition to power-saving mode (like sleeping mode), allowing fast re-initialization.

3. For proper synchronization, pilot tones may be optionally transmitted from a DP to all CPEs. The values of pilot tones are assigned by the DP during the initialization. Pilot tones, if used, are transmitted continuously, in the downstream direction only (i.e., from the DP to the CPEs).

4. The basic transmission format is a superframe that includes a sync symbol followed by M data symbols; the value of M shall be selected based on synchronization issues; in one embodiment the expected duration of a superframe is about 20-60ms. During initialization, additional transmission formats may be used.

5. In case of P2P (TDD), superframes in all active lines are aligned: sync-symbols are sent into all lines simultaneously, and all other symbols in different lines are aligned in time (for vectoring purposes).
In case of P2MP (STDMA), syncsymbols are also broadcasted into all active lines, while data symbols are sent to only a single line at a time.

Superframe

The described transmission concept is presented in Figures 1-5. Figure 1 shows the superfarme that contains M+1 symbols; it starts from a sync-symbol (SS) followed by M data symbols (“data” in the context of this description is a general term used to identify user data, control or management commands or data, or symbols with special content, like probe symbols or quiet symbols, if necessary for transmission purposes). The DP sends superframes one after another

with no gaps. All symbols in a superframe have the same duration that depends on the selected value of cyclic prefix. The number of data symbols in the superframe is chosen in a way that allows CPE to maintain stable synchronization and, if necessary, perform crosstalk channel estimation by using SS. The overhead caused by using a superframe is 1/(M+1).

In some embodiments, if required for proper synchronization, a sync-symbol may be combined from a number of consecutive symbols. In this case, the overhead is S/(M+S), where S is the number of symbols forming an SS.

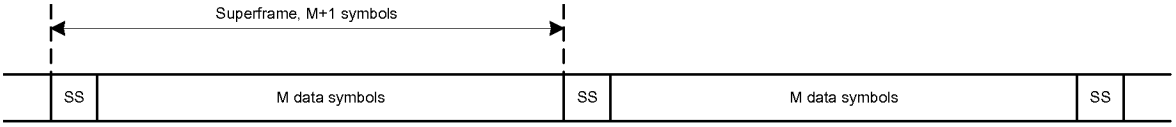

Figure 1 - G.fast basic superframe structure

P2P operation

In case of P2P transmission, groups of successive symbols inside a superframe are assigned for upstream and downstream, interleaved with each other. The SS symbols are sent only in the downstream direction. In the upstream direction, if necessary, SS can also be introduced (e.g., for vectoring or other purposes).

The position of SS is synchronized over all lines, both in downstream and in upstream, if SS are used (for vectoring purposes). The minimum shift between upstream and downstream sync symbols may be needed for implementation purposes. This shift is set during the initialization. The position of data symbols, accordingly, is also aligned between all lines, both in downstream and in upstream directions.

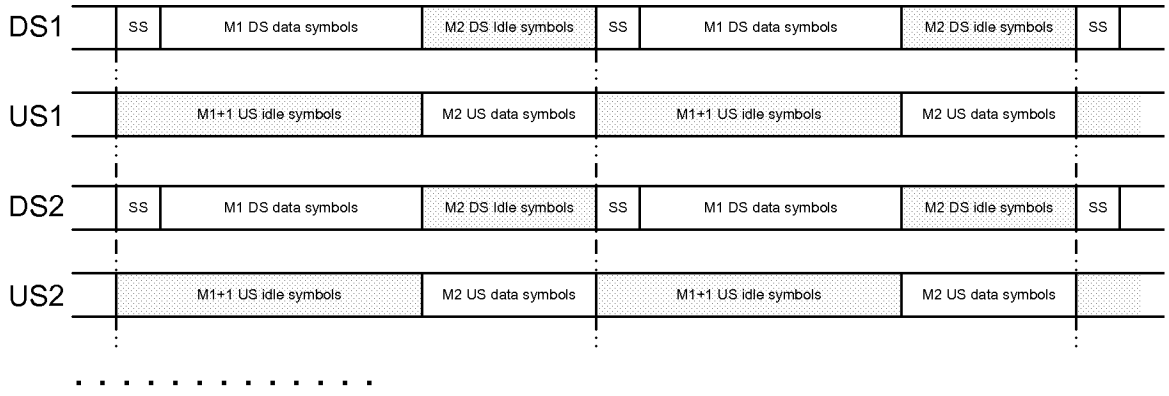

Figure 2 – Transmission timeline for P2P case: (one DS and one US slots per superframe)

Figure 2 illustrates a P2P case in which one upstream and one downstream transmission are established during a superframe. The number of DS and US transmissions may be more than one,

although all DS and all US transmissions shall be synchronized in all lines and same number of US and DS transmissions shall be in each superframe. An example of three DS-US transmissions during a superframe is presented in Figure 3: all DS periods and all US periods are the same inside one superframe. The number of symbols for DS and US transmission is determined during system initialization and may be modified seamlessly during the showtime by using an appropriate management protocol.

Figure 3 – A superframe that includes three DS and three US slots

Note that the number of data symbols in each direction, denoted by M1 and M2 in Figure 3, actually represents the time position of symbols allocated for upstream or downstream transmission rather than actual transmission. This relates to the situation when no data is available for transmission at the beginning of the upstream or downstream time position, respectively. In one embodiment, if DP or CPE has no data to transmit during all the symbols allocated for transmission, it may transmit idle symbols (e.g., loaded by a pseudo-random signal instead of data). In another embodiment, symbols may not be transmitted at all (quiet periods). In case of no transmission over one or more symbols (one or more quiet symbols are transmitted), the transmitter shall indicate to the receiver (e.g., in one of the symbols) how many symbols were transmitted and at what positions in the superframe.

P2MP (STDMA) operation

In case of STDMA transmission, groups of successive symbols inside a superframe are assigned for upstream and downstream of different lines, interleaved with each other in an arbitrary order. The SS symbols are also sent only in the downstream direction, but maybe also used in the upstream direction, if necessary (e.g., for vectoring or other purposes).

The position of SS is synchronized over all lines, both in downstream and in upstream, if used (e.g., for vectoring purposes, in case more than one P2MP groups operate over the same drop cable). The minimum shift between upstream and downstream sync symbols may be needed for implementation purposes. This shift is set during the initialization. Same as in P2P case, the position of data symbols is aligned between all lines, both in downstream and in upstream directions.

On the top of Figure 4 it is shown an example of a superframe including periods of upstream and downstream transmission for two lines, #1 and #2, respectively. Below it is shown transmission timelines of each line in the upstream and downstream directions. SS are transmitted only in the downstream, aligned among all lines. All boundaries of upstream and downstream transmissions are also aligned to avoid FEXT and NEXT between lines sourced by the DP.

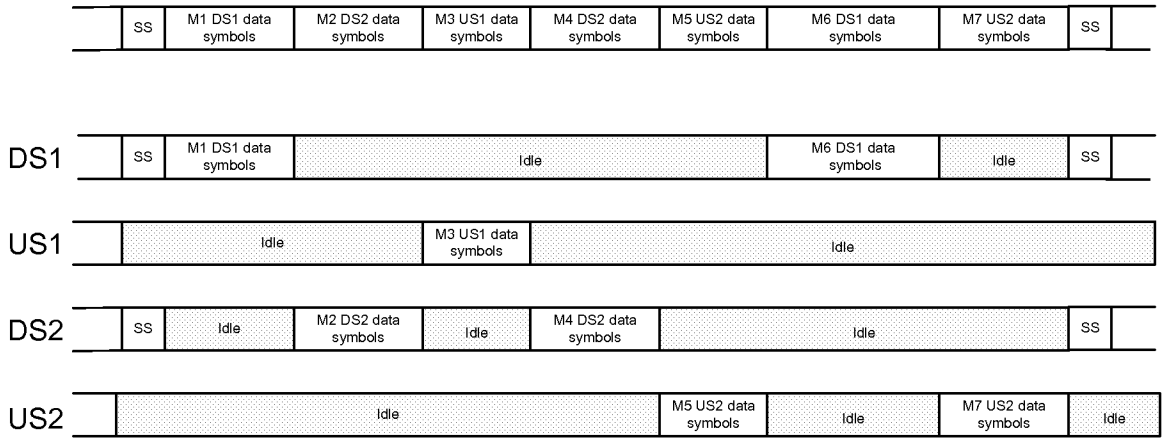

Figure 4 – Example of superframe structure and STDMA transmission time line for 2 lines

In case lines of the same drop cable are connected to more than one DP or a DP contains more than one STDMA group, time slots assigned to some of the lines connected to different DP may be collocated in time in case there is little or no interference between these lines, or interference between these lines is mutually cancelled (i.e., the time slot reuse).

Loop timing

Sampling clock and symbol timing shall be synchronized between the DP and all connected CPEs. The SS are one source for synchronization if its content is defined in appropriate way. Additionally, a few pilot tones may be used to achieve permanent precise synchronization. Pilot tones are assigned by the DP; the number, the frequencies, and possibly other parameters of pilot tones are communicated to the CPEs during initialization.

If pilot tones are assigned, the DP continuously transmits pilot tones during the showtime. New lines may use transmitted pilot tones for initial clock synchronization and symbol synchronization. Further, depiction of SS provides superframe synchronization (which is needed for alignment of time intervals for DS and US transmission).

In the upstream direction, symbols of all lines are also synchronized. To provide symbol synchronization, DP estimates the time difference between upstream symbols arriving from different lines and sends control messages to corresponding CPEs to adjust the timing (by number of samples).

Transmission time slots (intervals)

Transmission time slots (TS) are used to assign the particular transmission time (or transmission opportunity time) for a specific line in upstream or downstream direction ($TS_{DS\text{-}k}$, $TS_{US\text{-}k}$ denote time slots for upstream and downstream transmission for line *k*.

All TS shall have duration that is an integer number of symbols. When a particular transceiver is granted a transmission opportunity, it may use the granted TS starting from any symbol of the TS. The TS, thus, are aligned with superframe; referring to the superfarame example presented on the top of Figure 4, the following TS will be assigned (listed in the time order as in Figure 4): TS_{DS-1} (M1 symbols), TS_{DS-2} (M2 symbols), TS_{US-1}(M3 symbols), TS_{DS-2} (M4 symbols), TS_{US-2} (M5 symbols), and so on. The SS has its default TS_{DS-SS}, other TS are programmable: their assignment and duration depends on the traffic requests from connected users. The transmitter shall indicate to the receiver from which symbol of the TS it starts the transmission. In some embodiments, a special indication signal is sent before the first data symbol to be transmitted in the time slot. In another embodiment, idle symbols are sent until first data symbol is available for transmission.

In case of P2P (TDD), each assigned TS is for all lines, (see Figure 3): the size of the TS determines the ratio between upstream and downstream and the duration of the upstream-downstream exchange cycle. The TS assignment is usually permanent; it may be changed under control of service provider as an extra-ordinary procedure (usually, upon re-initialization of the binder). Thus, no dynamic re-assignment of TS is needed.

In case of P2MP (STDMA), TS is dynamically assigned per line per direction, based on the particular service request from each CPE. Some TS may be assigned for all lines for broadcast (e.g., TS_{DS-SS}) or for more than one line (multicast, if same information has to be sent to more than one CPE). These TS are usually for generic management/control information. During broadcast TS the transmit power over each line may be decreased by a number of dBs to reduce the peak power consumption.

Medium Access Plan

The dynamic assignment of TS is by broadcasting a special control message called Medium Access Plan (MAP). This message includes the list of TS assigned to both the DP and all CPEs for transmitting and receiving data symbols, respectively. The TS assignment may be defined as valid until the next MAP or as a persistent, until it expires or gets modified.

The position of the MAP-carrying symbol maybe either fixed in the superframe or in a group of superframes (hyperframe, if introduced) or maybe be indicated in the previous MAP (by number of symbols). Fixed position of the MAP symbol simplifies its search, but limits the dynamic behavior of the TS assignment (because sending MAP too often increases transmission overhead). In one embodiment, MAP symbol is on a fixed position in a superframe, but superframes carrying a MAP are indicated to the CPE by special SS format (e.g., inverted SS, SS modulated differently than a regular SS, SS carrying special modulation patterns over selected tones, etc). With this arrangement, the MAP can be potentially modified every superframe, i.e., with granularity of tens of milliseconds, which is more than sufficient for practical purposes. It's also convenient if MAP follows the SS, while the assignment communicated in the MAP is valid from the following superframe, Figure 5.

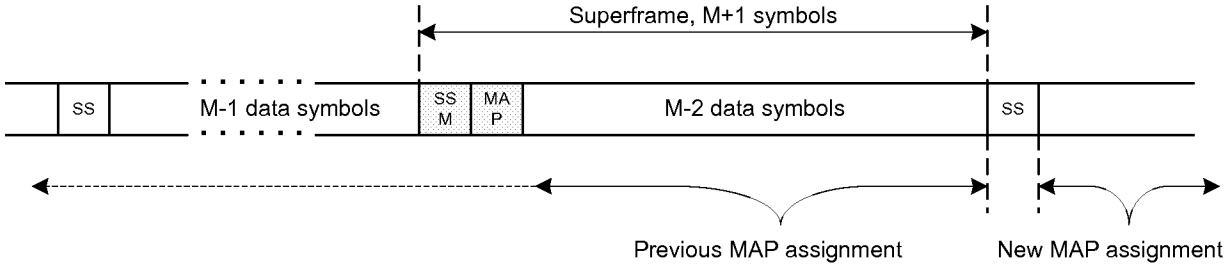

Figure 5 – A symbol carrying MAP follows a SS with special format; in the previous and the subsequent superframes MAP symbol is not transmitted

Besides TS assignment information, MAP may also carry other relevant information related to the particular TS, like request for acknowledgement, specific coding and modulation parameters, etc. MAP may also include generic information for all CPEs, such as transmit power limits, spectrum limits, bit loading information/tables and similar.

Transmission timing

The issue with transmission timing is due to propagation delay in the line T_d which mainly depends on the length of the line and wire type. The value of T_d for the most of cable types is (2-5)us per kilometer. For the 200m loops expected to be the longest in G.fast, the value of T_d doesn't exceed 1us, which is a small fraction of symbol duration (24.48 us if 2048 carriers are used in 100MHz of frequency spectrum).

A guard time is also necessary between transmission and reception. In case of TDD, the guard time is necessary to convert the transmission circuitry from transmission mode to reception mode, and vice versa, if the same circuitry is used for both transmission and reception circuitry (the turnaround time) . This case presented in Figure 6. The downstream transmission timing is aligned with symbol timing and same for the upstream.

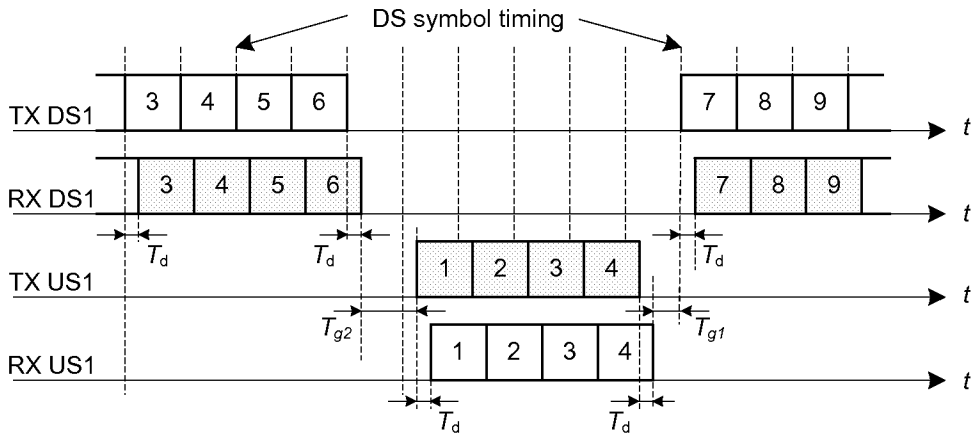

Figure 6 – P2P transmission timing at the DP (clear) and CPE (shaded)

To keep this alignment, the sum of the guard time at the CPE (Tg1) and at the CO (Tg2) shall satisfy equation [1]:

$T_d + T_{g2} + T_d + T_{g1} = n \times T_{OFDM}$, and $T_{g2} + T_{g1} = n \times T_{OFDM} - 2T_d$, [1]

where: n = 1, 2, … and T_{OFDM} is the symbol period. To provide the same guard time at the DP and at the CPE, $T_g = 0.5n \times T_{OFDM} - T_d$, and the minimum achievable guard time is $T_{g\text{-}MIN} = 0.5T_{OFDM} - T_d$ (which is roughly 1us less than half of the symbol duration). Longer guard times are allowed, but they must respect equation [1], which means that if the required value of guard time is higher than $T_{g\text{-}MIN}$, the second valid value is $T_g = T_{OFDM} - T_d$, and so on, with granularity of selection equal $0.5T_{OFDM}$.

In case of STDMA, a guard time is necessary at the CPE when it shall transmit right after it receives (i.e., a $TS_{DS\text{-}k}$ in the superframe is followed by $TS_{US\text{-}k}$), but not necessary if transmission is granted to another CPE (i.e., a $TS_{DS\text{-}k}$ in the superframe is followed by $TS_{US\text{-}l}$). A guard time it is necessary also at the DP to switch from transmission to reception and back, in case DP uses the same circuitry for transmission and reception. As can be seen from Figure 6, the guard time available for the DP is equal to the guard time assigned for a CPE to transmit over the same line plus $2T_d$, i.e., $T_{g2}+2T_d$. Since the value of T_d is usually much less that the minimum required value of T_{g2}, using the same guard time for all lines doesn't result in any considerable increase of the overhead.

Figure 7 shows the case of CPE transmission over the same line (TX US1) and over the different line (TX US2). The guard time allowed for the DP ($T_{g2\text{-}DP}$) is $2T_d$ bigger than one selected by a CPE, thus if CPE and DP require approximately the same time to switch from transmission to reception and back, the CPE determines the value of the guard time T_{g2}.

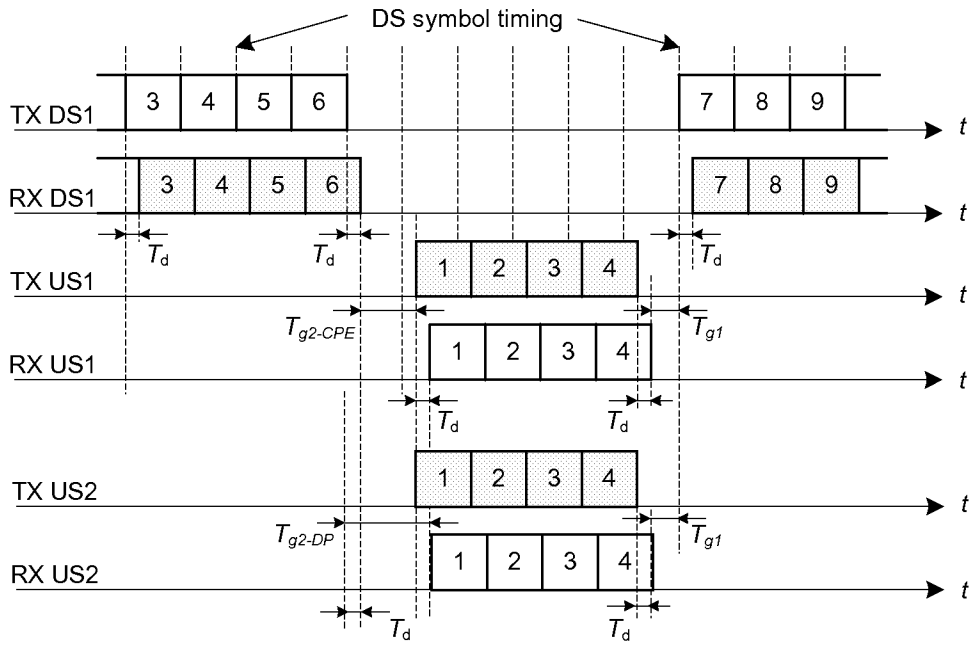

Figure 7 – STDMA transmission timing at the DP (clear) and CPE (shaded); cases of transmission from a CPE right after reception (US1) and from a CPE in idle state (US2)

If a DP is implemented with a capability to transmit and receive simultaneously (a duplex device), the value of T_{g2} for CPEs transmitting from idle state may be set to 0. If T_{g2} is set to 0, the value of T_{g1} can be found from equation [1]:

$T_{g1} = n \times T_{OFDM} - 2T_d$, and the minimum valid value $T_{g1\text{-}MIN} = T_{OFDM} - 2T_d$. If the required value of the guard time is more than $T_{g1\text{-}MIN}$, the next valid value is $2T_{OFDM}-2T_d$, accordingly. If the system uses $T_{g2} = 0$ for CPEs that transmit from idle state, the DP can distinguish between transmissions of CPEs using $T_{g2} = 0$ and $T_{g2} \neq 0$ by the ID of the TS assigned for the transmission.

Retransmission

The CPE may request the DP to retransmit data units (DU) received in error if retransmission capability is assigned for a particular service. If a CPE receives one or more DUs in error and retransmission capability for the service these DUs belong to is set, the CPE sends to the DP a retransmission request for these DUs. Upon reception of this request, the DP will retransmit the indicated DTUs at the first available transmission opportunity.

The retransmission request of the CPE is embedded into the first available TS_{US} following the TS_{DS} during which an errored DU was received. In one embodiment, retransmission request is a special management message transmitted during the mentioned TS_{US}. In another embodiment, retransmission request is encoded into the first symbol of the mentioned TS_{US}. This allows the DP to get the retransmission request earlier in time and thus DP gets more time available to prepare

for retransmission. More than one symbol may be used for retransmission request, if needed, but the number of symbols shall be pre-defined.

Similarly, the DP may request a CPE to retransmit DUs.

For the example of upstream/downstream transmission allocations presented in Figure 4, the retransmission request on errored reception of DUs transmitted during M1 DS1 data symbols is sent during M3 US1 data symbols. The requested DUs are retransmitted during M6 DS1 data symbols.

DP initialization

When DP is powered up upon connection of the first CPE, the DP starts line initialization process to establish connection with the CPE. For this, DP starts transmission of special initialization sequences to the CPE and CPE replies accordingly. During the exchange of initialization sequences, both DP and CPE discover the parameters of the transmission channel, adjust their AFE, and select transmission parameters (bit loading, FEC parameters, interleaving) to be used during the showtime in both upstream and downstream directions. After initialization procedure is complete, the data and management information is exchanged between DP and CPE using superframe format as defined above. The duration of the superframe is selected by the DP management system based on the target application, in the range determined in the standard.

Initialization procedure may be different for TDD and STDMA modes. In P2P mode all activated lines are trained in parallel, using special training sequences to evaluate crosstalk coefficients, if vectoring is used. In STDMA mode lines are trained sequentially, by exchanging few probe sequences between DP and each of the connected CPEs. These probe sequences may comprise symbols carrying certain signal patterns, encapsulated into a standard superframe, instead of data symbols. In case vectoring is used, other lines collect crosstalk samples from the trained line to establish cancellation matrix.

In some cases iterative training may be advantageous to cut the initialization time. With iterative training, DP and CPE start exchange of data symbols using very conservative bit loadings, low coding gain, and even using repetitions. After several transmissions, receivers of both sides learn the channel and obtain more appropriate values of transmission parameters. These values are communicated between CPE and DP using management frames. After parameters are updated, the bit rate will increase, and the receiver may continue optimization of parameter settings, updating them from time to time.

During initialization (usually, at the beginning of it), both ends may exchange initial management data, such as optional functional capabilities, specific networking or user information, etc. This data may be supplied using special communication protocols used during the initialization that are beyond the scope of the invention.

Adding new lines to the operating DP

In case of STDMA, a CPE that intends to join the DP has to synchronize with the DP by listening to SS (may first use pilot tones to get symbol timing and then the SS to align to a superframe). Then CPE shall wait for a TS assigned for new-comers (TS_{NC-k}); this TS is assigned by the DP to all idle lines connected to service, so that it periodically appears at each line (e.g., using round-robin, at least once upon a pre-defined time period).

When idle line *k* (connected to the service) received the TS_{NC-k}, it shall transmit its initialization request signal or message during the TS_{NC-k} using either only the tones used in the SS or tones that are specially assigned for initialization request. This way registering CPE never violated the used bandplan and doesn't use masked sub-carriers.

In case of P2P, a CPE that intends to join initiates the connection with its peer transceiver of the DP by sending a registration request signal or message at any time assigned for upstream transmission. This request shall use either only the tones used by the SS or tones specially assigned for initialization request.

Deactivation of a CPE

When the service requested by the user is complete (user switches the system off), the CPE transmits to the DP a management message informing request of de-activation. The DP may either accept the request or not. If the request is accepted, the DP sends to the CPE a de-activation permission (different types of permissions are available, and are beyond the scope of this invention). If the request is not granted, the CPE stays in idle mode, in which case no TS_{DS} or TS_{US} for this CPE are assigned. To re-activate (from either de-activated or idle mode) the CPE shall send an initialization request, as described in 5.2.9.

Dynamic change of system configuration

Since the proposed invention offers a unified transmission format for P2P and P2MP transmissions, it automatically provides means to dynamically change the DP configuration from P2P to P2MP and vice versa. In case a DP incorporates lines that are capable to operate in both P2P and P2MP mode (such as in mixed systems mentioned in, in which any line in a particular period of time can be either in TDD or STDMA mode) the inventions provides the basic framing format, synchronization, training and other operations necessary to perform on the lines when configuration change is due.

Possible Implementation Deployment

This invention introduces special signals (superframe, syncsymbols, MAP, etc.) and a protocol associated with transmission and reception of these signals. The proposed method is intended to be a part of the new G.fast standard. Every product claiming to be standard-compliant may use the invention. One who claims support of hidden nodes, must use the protocol to be compliant with the standard.

An exemplary communication arrangement may employ one, two or more multicarrier apparatuses, transceivers or nodes. The exemplary communication arrangement may also employ a multicarrier controller apparatus or controller node. In one implementation, the multicarrier apparatuses/controller are Orthogonal Frequency Division Multiplexing (OFDM) apparatuses capable of implementing the herein described implementations. One or more apparatuses, transceivers or nodes may implement the embodiments described herein.

The multicarrier apparatuses may communicate through a communication channel. The communication channel may be realized as a wireless communication medium, a wireline communication medium (e.g., coaxial cable, twisted pair of copper wires, power line wiring, optical fiber, etc.), or combinations thereof. Accordingly, the multicarrier apparatuses, may include structure and functionality that enable signal communication over such medium. Such structure and functionality may include one or more antennas, integrated wireline interfaces, and the like. Depending on the implementation, the multicarrier apparatuses may communicate with one another directly (peer-to-peer mode) or the multicarrier apparatuses may communicate via the controller apparatus.

In one implementation, the exemplary communication arrangement may be a home network and the multicarrier controller apparatus may be an access point of the home network. For example, in the implementation the controller apparatus may be a residential gateway that distributes broadband services to the multicarrier apparatuses. The multicarrier apparatuses may be associated with digital content destinations in the home, but may also be associated with digital content sources, such as digital video recorders (DVR), computers providing streaming video, televisions, entertainment centers, and the like.

Furthermore, the multicarrier apparatuses may be enabled to communicate using packet-based technology (e.g., ITU G.hn, HomePNA, HomePlug® AV and Multimedia over Coax Alliance (MoCA)) and xDSL technology. Such xDSL technology may include Asymmetric Digital Subscriber Line (ADSL), ADSL2, ADSL2+, Very high speed DSL (VDSL), VDSL2, G.vector, G.Lite, and High bit rate Digital Subscriber Line (HDSL). In addition, the multicarrier apparatuses 102, 104 and 106 may be enabled to communicate using IEEE 802.11 and IEEE 802.16 (WiMAX) wireless technologies.

Signals exchanged between the multicarrier apparatuses may include multicarrier symbols that each include a plurality of tones or sub-channels. Each of the tones within a multicarrier symbol may have data bits modulated thereon that are intended for delivery from one of the multicarrier apparatuses to another.

An exemplary transceiver apparatus that may be used as a transmitting and receiving apparatus in a multicarrier arrangement or system is described in the following. The multicarrier apparatuses may be implemented in the same or similar manner as the exemplary transceiver apparatus.

The transceiver apparatus may include a transmitter that incorporates a number of different elements. For example, the transmitter may include an encoder, a modulator, a filter, an interface

and a controller. As used herein, the term "controller" is meant generally to include all types of digital processing devices including, without limitation, digital signal processors (DSPs), reduced instruction set computers (RISC), general-purpose (CISC) processors, microprocessors, gate arrays (e.g., FPGAs), PLDs, reconfigurable compute fabrics (RCFs), array processors, secure microprocessors, and application-specific integrated circuits (ASICs). Such digital processors may be contained on a single unitary IC die, or distributed across multiple components.

The encoder may be capable of receiving data that is for communication to a receiving device coupled to the transceiver apparatus via a wireless or wireline medium. More specifically, the encoder may be capable of translating incoming data bit streams into in-phase and quadrature components for each of the plurality of tones. The encoder may be arranged to output a number of symbol sequences that are equal to the number of tones available to the system. The modulator may be capable of receiving symbol sequences to produce a modulated signal in the form of a discrete multi-tone signal. The modulator may pass the modulated signal to the filter to undergo various filtering and then the filtered signal may be passed to the interface for communication over the medium to a receiving device.

The transceiver apparatus may also include a receiver that is capable of receiving modulated multi-tone signals communicated over the medium from a transmitting device. The receiver may include an interface, a filter, a demodulator, a decoder and a controller. Alternatively, the transceiver apparatus may implement a single controller, instead of the illustrated controllers and. Signals received by the receiver may be passed to the filter via the interface. After received signals undergo filtering by way of the filter, the filtered signals may be demodulated by the demodulator. The demodulated signals may be passed to and processed by the decoder. The decoder produces data bit streams for consumption by a computing device, or the like. Effectively, the demodulator and the decoder perform the opposite functions of the modulator and the encoder, respectively.

Exemplary implementations discussed herein may have various components collocated; however, it is to be appreciated that the various components of the arrangement may be located at distant portions of a distributed network, such as a communications network and/or the Internet, or within a dedicated secure, unsecured and/or encrypted arrangement. Thus, it should be appreciated that the components of the arrangements may be combined into one or more apparatuses, such as a modem, or collocated on a particular node of a distributed network, such as a telecommunications network. Moreover, it should be understood that the components of the described arrangements may be arranged at any location within a distributed network without affecting the operation of the arrangements. For example, the various components can be located in a Central Office modem (CO, ATU-C, VTU-O), a Customer Premises modem (CPE, ATU-R, VTU-R), an xDSL management device, or some combination thereof. Similarly, one or more functional portions of the arrangement may be distributed between a modem and an associated computing device.

The above-described arrangements, apparatuses and methods may be implemented in a software module, a software and/or hardware testing module, a telecommunications test device, a DSL modem, an ADSL modem, an xDSL modem, a VDSL modem, a linecard, a G.hn transceiver, a MOCA transceiver, a Homeplug transceiver, a powerline modem, a wired or wireless modem, test equipment, a multicarrier transceiver, a wired and/or wireless wide/local area network system, a satellite communication system, network-based communication systems, such as an IP, Ethernet or ATM system, a modem equipped with diagnostic capabilities, or the like, or on a separate programmed general purpose computer having a communications device or in conjunction with any of the following communications protocols: CDSL, ADSL2, ADSL2+, VDSL1, VDSL2, HDSL, DSL Lite, IDSL, RADSL, SDSL, UDSL, MOCA, G.hn, Homeplug or the like.

Additionally, the arrangements, procedures and protocols of the described implementations may be implemented on a special purpose computer, a programmed microprocessor or microcontroller and peripheral integrated circuit element(s), an ASIC or other integrated circuit, a digital signal processor, a flashable device, a hard-wired electronic or logic circuit such as discrete element circuit, a programmable logic device such as PLD, PLA, FPGA, PAL, a modem, a transmitter/receiver, any comparable device, or the like. In general, any apparatus capable of implementing a state machine that is in turn capable of implementing the methodology described and illustrated herein may be used to implement the various communication methods, protocols and techniques according to the implementations.

Furthermore, the disclosed procedures may be readily implemented in software using object or object-oriented software development environments that provide portable source code that can be used on a variety of computer or workstation platforms. Alternatively, the disclosed arrangements may be implemented partially or fully in hardware using standard logic circuits or VLSI design. The communication arrangements, procedures and protocols described and illustrated herein may be readily implemented in hardware and/or software using any known or later developed systems or structures, devices and/or software by those of ordinary skill in the applicable art from the functional description provided herein and with a general basic knowledge of the computer and telecommunications arts.

Moreover, the disclosed procedures may be readily implemented in software that can be stored on a computer-readable storage medium, executed on programmed general-purpose computer with the cooperation of a controller and memory, a special purpose computer, a microprocessor, or the like. In these instances, the arrangements and procedures of the described implementations may be implemented as program embedded on personal computer such as an applet, JAVA® or CGI script, as a resource residing on a server or computer workstation, as a routine embedded in a dedicated communication arrangement or arrangement component, or the like. The arrangements may also be implemented by physically incorporating the arrangements and/or procedures into a software and/or hardware system, such as the hardware and software systems of a test/modeling device.

The implementations herein are described in terms of exemplary embodiments. However, it should be appreciated that individual aspects of the implantations may be separately claimed and one or more of the features of the various embodiments may be combined.

Claims:

1. A method for use in a communication system, the method comprising:

generating, for transmission in a communication system including at least one transceiver, a superframe, the superframe including:

a plurality of symbols, at least one set of symbols being allocated for upstream transmission and another set of symbols being allocated for downstream transmission, the symbols allocated for upstream transmission having an associated time position for actual upstream transmission and the symbols allocated for downstream transmission having an associated time position for actual downstream transmission, the two associated time positions being different.

2. A method for synchronization in a communication system, the method comprising:

generating at least one superframe that includes symbols designated for upstream and downstream communication and at least one syncsymbol to align the superframe and provide timing for upstream and downstream symbol use; and

transmitting one or more pilot tones to enable clock syncronization and symbol synchronization.

3. The transmission method, comprising:

transmitting consecutive superframes, wherein no gap falls between the superfames;

wherein each superframe starts from a syncsymbol followed by M symbol periods for data/management/control symbols, each superframe is divided into groups of consecutive symbols; each group assigned for upstream or downstream transmission, and wherein at least one or more syncsymbols is transmitted in the downstream direction.

4. A communication syncronization method, comprising:

aligning downstream syncsymbols of lines connected to a communication system distribution point;

aligning superframes of the lines connected to a communication system distribution point by way of the downstream syncsymbols;

aligned downstream and upstream symbols of lines connected to a communication system distribution point; and

aligned upstream syncsymbols (if used).

5. A transmission scheduling method, comprising:

providing a medium access plan that includes a schedule of upstream and downstream transmission for all lines connected to a distribution point, including the schedule being in units of transmitted symbols;

communicating the medium access plan to all CPEs connected to the distribution point; and

complying with transmission timing defined in the medium access plan and other relevant management parameters defined in the medium access plan.

6. A communication method, comprising:

aligning downstream transmissions over all lines by their boundaries;

aligning upstream transmissions over all lines by their boundaries; and

providing a medium access plan that includes one downstream and one upstream transmission, and a superframe that includes an integer number of upstream and downstream transmissions.

7. A communication method, comprising:

ensuring no overlap between downstream and upstream transmissions over any two lines connected to a distribution point;

providing a medium access plan that includes all downstream and upstream transmissions over all active lines; and

ensuring that overall duration of upstream and downstream transmissions are equal or less than a number of symbols in a superframe.

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PTO/SB/16 (11-08)
Approved for use through 06/30/2010 OMB 0651-0032
U.S. Patent and Trademark Office: U.S. DEPARTMENT OF COMMERCE

Provisional Application for Patent Cover Sheet

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53(c)

Inventor(s)

Inventor 1 — Remove

Given Name	Middle Name	Family Name	City	State	Country
Vladimir		OKSMAN	Morganville	NJ	US

Inventor 2 — Remove

Given Name	Middle Name	Family Name	City	State	Country
Charles		BRY	Unterhaching		DE

Inventor 3 — Remove

Given Name	Middle Name	Family Name	City	State	Country
Joon Bae		KIM	Lexington	MA	US

Inventor 4 — Remove

Given Name	Middle Name	Family Name	City	State	Country
Rainer		STROBEL	Ehingen		DE

All Inventors Must Be Listed – Additional Inventor Information blocks may be generated within this form by selecting the **Add** button. [Add]

Title of Invention	METHOD OF WIRED TRANSMISSION FROM A DISTRIBUTION POINT
Attorney Docket Number (if applicable)	LANP0024US

Correspondence Address

Direct all correspondence to (select one):

(•) The address corresponding to Customer Number	( ) Firm or Individual Name
Customer Number	88203

The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.

(•) No.

( ) Yes, the name of the U.S. Government agency and the Government contract number are:

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Entity Status

Applicant claims small entity status under 37 CFR 1.27

◯ Yes, applicant qualifies for small entity status under 37 CFR 1.27

◉ No

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Signature

Please see 37 CFR 1.4(d) for the form of the signature.

Signature	/Tim R. Wyckoff/			Date (YYYY-MM-DD)	2012-02-13
First Name	Tim R.	Last Name	Wyckoff	Registration Number (If appropriate)	46175

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Electronic Patent Application Fee Transmittal

Application Number:	
Filing Date:	
Title of Invention:	METHOD OF WIRED TRANSMISSION FROM A DISTRIBUTION POINT
First Named Inventor/Applicant Name:	Vladimir OKSMAN
Filer:	Timothy Roger Wyckoff
Attorney Docket Number:	LANP0024US

Filed as Large Entity

Provisional Filing Fees

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Provisional application filing	1005	1	250	250
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Miscellaneous:				
			Total in USD ($)	**250**

Electronic Acknowledgement Receipt

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Confirmation Number:	6656
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First Named Inventor/Applicant Name:	Vladimir OKSMAN
Customer Number:	88203
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Deposit Account	
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File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)

1	Specification	LANP0024USApplFilingFinal.pdf	695320 351fbb678417a8159c91972b94dc9297eb223106	no	17
Warnings:					
Information:					
2	Provisional Cover Sheet (SB16)	LANP0024USProvCover.pdf	1060380 c76ba10fb86c19745de619c8684a1d6b203c99ea	no	3
Warnings:					
Information:					
3	Fee Worksheet (SB06)	fee-info.pdf	29428 434abf58c08023216a914fb3fbf466fff541c053	no	2
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