Network Management System for Telecommunication and Internet Application

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Abstract

In a network management system (NMS) for broad band PLC a lot of different tasks and services must be integrated. The partly different requirements to data rate, transmission reliability and real time functionality must be met. The power-line is a very difficult transmission medium with limited channel capacity. To realise a reliable data transmission, a huge effort is necessary for modulation, equalisation and channel coding. Therefore, the NMS has to use the existing resources very efficiently. After discussion of the different options, we present a TDMA-System with resource-administration realised centrally in the master.

Services for Broad Band PLC

Currently, the most important service is internet access. This is a general term for several services with different requirements. On the one hand, www browsing requires a packet oriented data transmission with low real time requirements, but low acceptable bit error rate. On the other hand, voice-over-IP or web cast require connection-oriented services with high real-time requirements. A minimum quality of service must be guaranteed to allow commercial application. Experience shows that packet-oriented networks, such as Ethernet, can offer such services only if they are heavily overdimensioned and, therefore, utilise the channel very inefficiently. Another application is Broadband PLC for the last mile in telephony. This application requires a minimum quality of service, similar to the requirements of voice-over-IP, probably with even higher real-time requirements.

Additional services, such as meter reading and home automation have low real-time and data requirements, but a large transmission range, which will most likely be difficult to achieve with broad band PLC, is necessary. To allow these requirements to be met using a channel with limited capacity, Quality of Service (QoS) parameters must be available. Efficient use of QoS is only possible if the backbone can also use the QoS data. This can be achieved by combining PLC with ATM. ATM is nowadays established as a standard in telecommunication and also for IP routers by CISCO. Block sizes and frame lengths have been taken into account in the NMS presented in this paper.

Transmission Channel

A power-line provides only a single independent transmission medium, which was not designed for data transmission. The cost advantage of PLC is that the transmission medium is already available, which means that the medium must be used as it is. The channel characteristics have already been studied intensively, showing the restricted capacity and the effort required to use it.

The frequency selectivity of the channel requires Broadband transmission. Because of the multi-path propagation due to reflections in the cables used, a powerful channel equalisation or multi-carrier technologies, e.g. OFDM, in combination with channel coding must be employed. Currently, most experts in PLC and also our company favour OFDM. This is the reason that OFDM is also proposed here.

Due to high channel attenuation, the low transmission power expected and the noise and interference level, in many cases one repeater level will be necessary. Therefore, repeaters are considered in this proposal. However, more than one repeater level is, in our view, not reasonable because of the overhead.
Discussion of Competing Methods

CSMA (Carrier Sensitive Multiple Access)

There are several reasons why CSMA is not appropriate for PLC. CSMA systems require that all clients must be able to recognise if the channel is used by any other client. However PLC does not meet this requirement, as it is very well possible that client A transmits successfully to client C and that although client B cannot detect this transmission, a collision will occur if client B transmits. Because neither of the clients can detect the collision, this cannot be taken into account in the repetition strategy.

Implementation of repeaters in a pure CSMA system is virtually impossible. The strategy of CSMA systems to meet real-time requirements is limited and can reasonably achieved only if the utilisation is very low. Thus the efficiency of the system is low prohibiting the use for channels with limited resources and a high effort required. In connection with PLC and CSMA, the IEEE standard 892.11, which employs CSMA/CA and was designed for wireless applications, is mentioned. However, application of this standard for PLC would not yield good results, as basic requirements on which this standard is based are not met by transmission via PL.

CDMA (Code Division Multiple Access)

Because the orthogonality of the codes is lost due to multi-path propagation, the bandwidth efficiency is low and the sensibility to impulsive noise is high, conventional CDMA is not appropriate for PLC. Multi-carrier CDMA (MC-CDMA) would certainly be better for PLC, because the problem with multi-path propagation is solved and impulsive noise is converted into white noise.

In Access applications, another problem of CDMA, which cannot be overcome, are the strict EMC levels. Both CDMA and MC-CDMA require a transmission power control, so that all clients are received with the same power. Transmission power control, however, is very difficult in PLC applications because the impedances of power-lines can change erratically. Additionally, this adaptation of the transmission power for all clients reduces the quality of all clients to the quality of the client with the worst quality.

FDMA (Frequency Division Multiple Access)

Since the power-line channel is strongly variant over frequency, pure FDMA cannot guarantee balanced transmission quality for all clients.

TDMA (Time Division Multiple Access)

TDMA has several advantages:
- dynamic and asymmetric allocation of data rates is possible
- different channel coding can be employed to account for different channel characteristics (higher net data rates if the channel is good)
- repeater levels can easily be accounted for and produce overhead only if a repeater is actually needed
- relatively cost-efficient implementation

Currently, the IEEE standard 802.16 for a wireless TDMA system is in preparation. This standard contains interesting elements; however, it cannot be applied to PLC because higher protocol layers refer to individual transmission symbols and, therefore it cannot be adapted to an OFDM system with channel coding.

TDD/FDD (Time/Frequency Division Duplex)

Duplex transmission can be achieved either by FDD or by TDD. FDD requires expensive filters and large differences in the quality of up- and down-links must be expected as the channel is frequency dependant. Therefore, a TDD system is proposed here.
Structure of the Network Management System

The resource management is performed centrally by the master. This has the following advantages:

- no collisions of data packets
- guaranteed data throughput and delays
- connection dependant, time variant and asymmetric data rates possible
- QoS parameters can be managed and guaranteed
- Highly efficient resource utilisation

The disadvantage is an increased overhead.

Time Frame

The TDMA frame consists of 3 main blocks. The first block is used for synchronisation and transmission of network management information by the master and secondly, if repeater are used, from the repeaters. This keeps all clients informed about the structure of the TDMA frame.

The next block is used by the clients to transmit data, e.g., as detailed in Figure 1. The allocation of time slots to clients is performed dynamically by the master and is transmitted to all clients as part of the network management information. Thus, the data rate can be allocated to up- and down-link and to the individual connections dynamically. Only the data going to far end slaves will be repeated by the repeater. The duration of the slots for OFDM-Symbols is constant, but the rate of modulation and coding may depend on the connection and near slaves get higher data rates than far slaves.

The third block is a short block used by slaves and repeaters to request access from the master. The clients use a slotted Aloha or a better procedure to transmit their access request. This block is shorter than a normal OFDM symbol.

Framing of the TDMA / TDD Systems using ATM-Cells

![Diagram of TDMA/TDD System](https://via.placeholder.com/150)

**Figure 1**: Proposal for the time frame of the TDMA/TDD system
Repeater

Repeaters are used to connect slaves to the master, which have no reliable direct connection. As the data is first transmitted from the master to the repeater and then from the repeater to the slave, the channel capacity required if one repeater level is employed is doubled. This results in the following conditions:

- every repeater hears the master reliably
- no communication between repeaters
- repeaters may hear each other but do not have to

In a communication network there may be several repeaters. In this case, collisions of transmissions by repeaters must be avoided. Therefore, in the time slots for transmission of a repeater to a slave and the transmission of a slave to a repeater must be assigned by the master and the slave must have the network management information from the master. The repeaters do not generate their own network management information.

A slave may only transmit if it is synchronised with the time-frame. Therefore, every repeater must transmit a synchronisation signal. Since the synchronisation signal of all repeaters may be the same, the repeaters may transmit their synchronisation signal at the same time like a single frequency network. This also applies to the network management information which is transmitted to all slaves. Due to the superposition of the signals of all repeaters transmitted at the same time on the same channel, the reliability of the transmission is improved.

Since a slave must not send unless it receives the synchronisation signal, it is impossible to detect automatically that new repeaters are required and therefore new repeaters must be enabled manually. If the synchronisation signal and the network management information is transmitted by all repeaters at the same time, the channel capacity is independent of the number of repeaters. Thus, every slave that receives the master directly and reliably can be a repeater.

If a slave wants to transmit data, it tries to transmit an access request in a special time slot reserved for this purpose, whether it is connected to the master directly or not. The repeater must recognise any access requests of its slaves and tries in the next frame to pass these requests on to the master. The master informs the slaves via the network management information if a new connection has been established.

Currently we cannot see any reason why a repeater may not be slave as well.

Requirements for a Single Frequency Network

In a single frequency network several transmitter send the same message in the same frequency range at the same time. The receiver gets the superposition of the signals of the different transmitters and the reflections in the transmission medium. As long as the content is identical, there is no difference for the receiver whether a signal is a reflection or sent by another transmitter. The signal received can be described as a transmitted signal convolved with a channel impulse response. This is a linear distortion which can be handled optimally using channel coding and OFDM. This modulation is already used in DAB (digital audio broadcasting) and DMB (digital multimedia broadcasting) in a single frequency network [2].

If the channel impulse response is shorter than the guard interval, no interference occurs and all received energy can be fully used. Symbols sent as single frequency network require a larger guard interval. A jitter in the synchronisation of the repeaters increases the delay spread of the channel impulse response at the receiver. Therefore, the block sent by all repeaters together should be transmitted as quickly as possible after synchronisation of the master. In the TDMA frame, information transmitted by the repeaters follow direct after the corresponding information of the master.

Experience with wireless communication shows that single frequency networks using the same over-all power have a higher reliability than networks with only one transmitter [3]. In our case the transmitting power will be limited by EMC regulations and therefore the over-all power can be increased with the number of repeaters.
Handling of Access Requests

A dedicated time slot is used by the slaves to transmit access requests. Access requests by the master are directly included in the network management information. The problem is to transmit the information that a certain slave requests access in the shortest time possible. Usually, the details of the connection requested can be negotiated using dedicated blocks allocated by the master. Since the number of access requests can be expected to be small in comparison with the number of slaves, random procedures, such as slotted Aloha or improved methods, are appropriate.

Slotted Aloha

The dedicated time slot is used for two purposes:

1. A new slave is connected and tries to log on to the master
   - slave has no network address
   - slave hears master (or repeater) and is able to synchronise
   - access request to start autologon procedure

2. A slave which is already registered requests access
   - slave has a network address

All slaves are connected to the same medium. If the access is not controlled, collisions are likely. Due to the characteristics of the channel, the following secondary conditions must be taken into account:

- A slave cannot reliably detect whether another slave is transmitting
- The slaves cannot detect collisions
- A symbol may be destroyed even if no collision occurs

Thus, procedures based on Carrier Sensitivity or Collision Detect can be used only with limitations or not at all. A timeout (no response from the master) starts repetition. Therefore, a slotted aloha system seems to be appropriate.

Improved Procedure Using Superimposed Codes

"The proposed solution is based on the combination of superimposed codes with some other well known technique. The novel scheme fully exploits the frequency diversity of the transmission channel and allows a trade-off between maximum number of subscribers and resolvability of signalling collisions. All subscribers use the same slot for signalling, collisions of up to U_max subscribers can be resolved and if more than U_max transmission requests occur the collision is detected."

Further details will be presented in the paper ‘Medium Access Scheme for TDMA’ at ISPLC2001 [4].

This network management system is submitted to the ETSI standardisation group.

References
