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Multiple Collision Avoidance Method And Resource Sharing On Power Line Communications

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Abstract:
Power line communications technology was developed after the establishment of the power distribution network, it is considered to be one of the promising means of data transfer for home networks, and is a medium of shared transmission.
Our study was based on the effectiveness of the CSMA/CA method, the collision occurs when the modems transmit at the same time, the transmitters draw the same backoff (a random waiting time) after another transmission. After the backoff, the modems check, before transmitting, that the channel is free to base themselves on the detection of preamble symbols which identify a competing transmission.
The proposed simulation approach is based on the estimation of the power level in the channel between the hybrid and default channel listening process. The solution is based on the transfer function used in the modeling.
***Key Word**: Multiple collision; Resource sharing; Power line communications.*

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I. Introduction

Power line communications (PLC) is one of the promising technologies using existing electrical wiring to transmit home automation data. The smart grid is considered a real-time, reliable, coordinated, and efficient electrical communications network designed to organically integrate energy and information flows and improve the efficiency and intelligence of power transmission. information[1,2].

Energy distribution and consumption communication networks must rely on broadband communications in order to meet the development requirements of smart networks; the hybrid network is equipped with broadband communication as the core and has high performance, with either wireless, optical fiber or power line communication (PLC) [3,1,4].

A communication system with open, highly integrated and dynamically reconfigurable network topologies will form the basis of the smart grid. Power grid communication and wireless communication technologies are important components of a communication network for a distribution system, they can complement each other[5]. The combined multimedia hybrid communication technology of Powerline and wireless integrates superior communication resources and capabilities, improving overall system performance and has significant practical value [4,6].

Resource sharing in powerline communications for home networks is limited by channel allocation techniques that decide who has access to data transmissions. Channel allocation techniques include contention-free and contention-based techniques. The first requires high synchronization with respect to the determined round trip time. Additionally, they use CSMA/CA techniques which are suitable for decentralized network topologies and allow network stations to compete for channel access[5,4,7].

However, because PLC is a shared transmission medium, it is subject to various factors that can reduce performance, such as impedance mismatch at junctions, distance between communication stations, frequency selectivity, and impulse noise. The problem that arises is that as the number of stations competing for use of the shared transmission medium increases, there is a compromise in the efficiency of the system[2,4,6].

The solution to this problem is to use the collision-based random access method (CSMA/CA) and propose the MAC (Medium Access Control) protocol controls the access channel of the station, which is the direct controller to transmit and receive packets on the channel and recognizes the fastest channel[6].

Collision-based technology uses CSMA/CA techniques allowing network stations to compete for access to different channel stations, which fit into a decentralized network topology. The ability of the MAC protocol to efficiently utilize limited channel resources is one of the main factors that affect the performance across the entire network with an important role in its improvement. CSMA/CA is the primary MAC mechanism of IEEE 802.11 and 1901 standards[7].

The study carried out in this work is resource sharing by examining CSMA/CA techniques for collision avoidance, and improving the efficiency of the system to provide access to different channels of power line communications.

II. Methods And Model

Multiple access and collisions (CSMA/CA) in CPL-G3[8]

The CSMA/CA mechanism designed at the MAC layer allows the management of multiple accesses to the channel. The mechanism takes place in several stages, it is a version without synchronization between competing modems (no beacon exchange) and it draws a random timeout (called backoff).

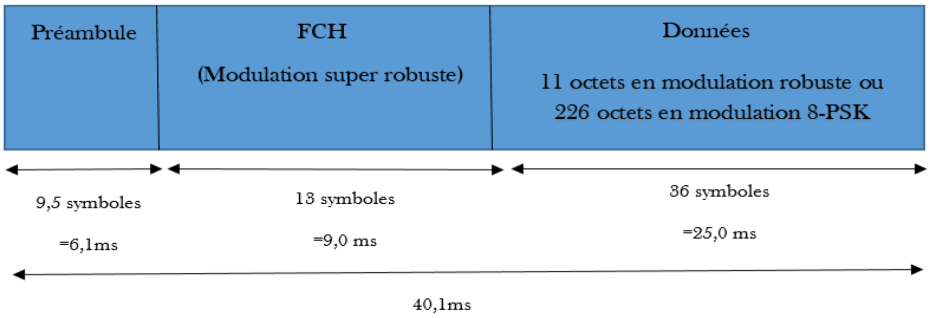


Fig. 1 Structure of a CPL G3 frame on the physical layer

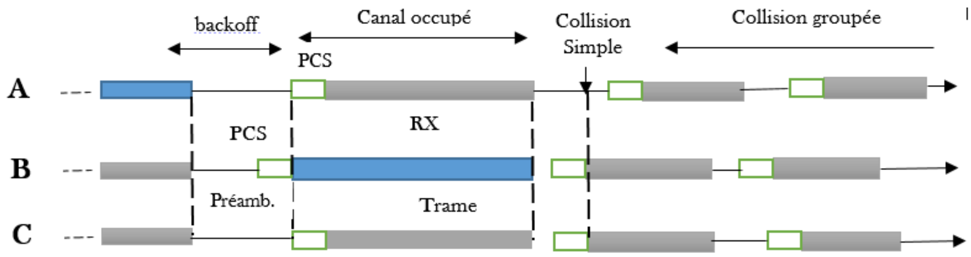


Fig. 2 Multiple collisions

Configuring a collision of groups B and C produces the same wait time after B's first transmission, creating a simple collision. A does not trigger the same wait time but still collides with the other two transmissions because it cannot detect the preamble symbols. After this delay, the modem will listen to the channel and transmit only when the channel is free. If busy, transmission will be delayed, with the number of attempts limited to macMaxCSMABackoffs. When this limit is reached, the frame is deleted..

The channel listening process (called Physical Carrier Sensing, PCS) consists of detecting at least two preamble symbols of a frame, sent at the start of transmission. If no preamble is decoded, the modem assumes that no transmission has been made and that the channel is available[9]. On the contrary, when the preamble symbols are decoded, an additional mechanism called VCS (Virtual Carrier Sense) tracks the state of the communication until the end, to avoid interfering with this transmission and other transmissions involved acknowledges receipt on requests, transmits all segments[10,11].

The next wait (backoff) begins at the moment when the VCS indicates the complete end of the communication. The CSMA/CA random wait is performed to try to avoid collisions when, after the VCS has signaled to the modem that the channel is free, several of them wish to communicate[12,8].

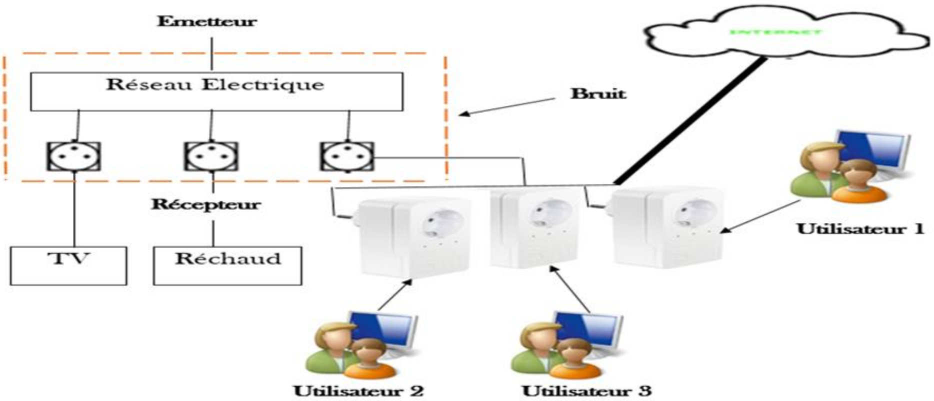
Collisions can occur when two modems transmit their frames at the same time, in two preamble symbols (a slot). Two frames are then lost and not acknowledged by the destination, leading to retransmission of the frame (automatic repeat request mechanism). The length of the normal priority contention zone following a transmission, is made up by default of 23 to 28 slots (i.e. 10 to 328 ms), is adapted to the difficulty encountered by modems in accessing the previous channel. Increasing its size reduces the probability of a simple collision[13].

In cluster collision when a single collision occurs, the preamble symbols of simultaneously transmitted frames cause interference and are not detected by other modems sharing the listening domain. However, PCS only relies on the detection of these symbols to know the state of the channel, and in this sense the latter is considered free. Fig. 2 shows an example of such a situation. The channel is transmitted by A, then B; then, B and C have the same timeout, which creates a simple collision. A, despite another timeout, considers this channel as free because it cannot detect the opening symbols of 'not those of the other channel and exit in panning[14],[15].

Proposed model

We proposed a resource sharing model in which the mathematical reasoning was described on the electrical operation of the quadrupole between different loads presented in the figure below:

Fig. 3. Resource sharing model



III. Result

The solution to this equation is carried out by the inductance I, the capacitance C and the angular speed ω defined in three charges as follows:
Z_1 (wiring) et Z_t (TV load) in series, are reduced toZ_{1t} = $Z_1 + Z_t$
Z_2 (wiring) and Z_r (Stove load) in series, are reduced toZ_{2r} = $Z_2 + Z_r$
Z_3 (wiring) and Z_w (CPL load) in series, are reduced to Z_{3w} = $Z_3 + Z_w$

Each of the branches has two impedances in series which can be reduced to one impedance. This gives three impedances in parallel, one in each branch, which can be reduced to a single impedance as follows:

$$\frac{1}{Z_p} = \frac{1}{Z_{1t}} + \frac{1}{Z_{2r}} + \frac{1}{Z_{3w}}$$

$$= \frac{Z_{2r}.Z_{3w} + Z_{1t}.Z_{3w} + Z_{1t}.Z_{2r}}{Z_{1t}.Z_{2r}.Z_{3w}}$$

$$Z_p = \frac{Z_{1t}.Z_{2r}.Z_{3w}}{Z_{2r}.Z_{3w} + Z_{1t}.Z_{3w} + Z_{1t}.Z_{2r}} \quad (1)$$

The linear equations of the quadrupole are given by :

$$\begin{cases} U_1 = Z_{11} I_1 + Z_{12} I_2 \\ U_2 = Z_{21} I_1 + Z_{22} I_2 \end{cases} \quad (2)$$

The electrical operation of the quadrupole is characterized by:
Ue: input voltage
Us: quadrupole output voltage
ie: input current
is: quadrupole output current

Transfer function

The characteristics of the PLC channel depend on the frequency and time as well as the density of the loads that are present on the network (the number and values of the impedances). The PLC channel is very often modeled as a multipath channel[11].

This function evaluates the link between the modeled transmitter and receiver based on the following amplifications:

Voltage amplification: $H(j\omega) = \frac{\mu_s}{\mu_e} = \frac{U_s}{U_e}$ (3)

Current amplification : $H(j\omega) = \frac{i_s}{i_e} = \frac{I_s}{I_e}$ (4)

Transimpedance : $H(j\omega) = \frac{\mu_s}{I_e} = \frac{U_s}{I_e}$ (5)

Transadmittance : $H(j\omega) = \frac{i_s}{\mu_e} = \frac{I_s}{U_e}$ (6)

H depends on the quadrupole and the rest of the circuit

$$H(j\omega) = |H(j\omega)|e^{jarg(H(j\omega))}$$
$$= G(\omega)e^{j\varphi(\omega)} \qquad (7)$$

Where G(ω): the gain of the quadrupole
$\varphi(\omega)$:phase advance of the output over the input

Namely, the gain of the quadrupole is defined in decibels:

$$G_{db}(\omega) = 20log_{10}(G(\omega))$$
$$H(f) = \frac{V_2}{V_s} = \frac{Z_L}{AZ_L + B + CZ_LZ_S + DZ_S}$$
$$Z'_{in} = \frac{U_1}{I_1} = \frac{AV_2+BI_2}{CV_2+DI_2} = \frac{A\frac{V_2}{I_2}+B}{C\frac{V_2}{I_2}+D} = \frac{AZ_L+B}{CZ_L+D} \qquad (8)$$

Simulation between hybrid and default PCS

The distribution of the number of frames in a collision, with the two types of PCS.

When the number of modems wishing to transmit to the same location is large, this situation can cause many clustered collisions, with more than a hundred active frames, as shown by their multiple collisions in the PLC collision avoidance mechanism.

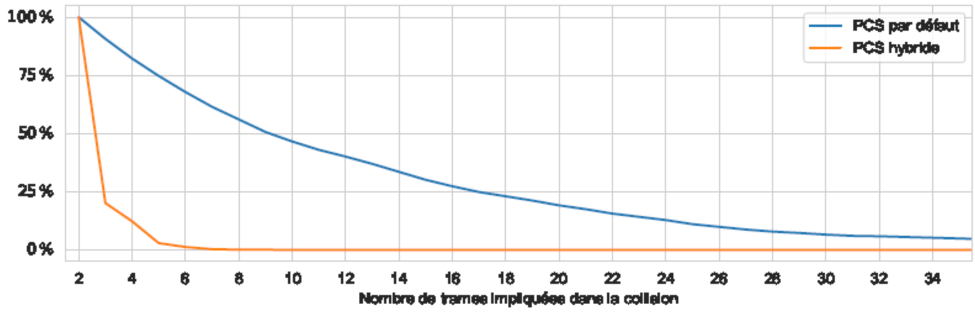


Fig.4 Empirical additive distribution function of the number of frames involved in collisions.

In the case of hybrid PCS, the largest collision involves 10 frames; in the default case, the largest collision involves 146 frames.

The result shows that collisions involving only two transmitters are the majority for (80%) with the hybrid PCS, while they represent a minority (20%) in the case of the default PCS. Additionally, collisions involving more than two frames are generally much longer in the case of the default PCS (up to 146 frames in a single collision). There are always collisions involving more than two transmitters with hybrid PCS because a single collision can involve more than two transmitters (when three modems pull the same backoff), and because consecutive single collisions (without valid transmission in between) are counted as one.

Table n° 1. Comparison of numerical results obtained during simulations with the two PCS modes

	Default detection	**Hybrid detection**
Total number of packets	120868	175135
Data transmission rate	733,20 B/s	1460,01 B/s
Data reception rate	716,05 B/s	1459,99 B/s
Average number of collisions per node	31 155	16025
Median number of frames involved in a collision	9	2
Maximum number of frames involved in a collision		
Canal occupation	146	10
Average latency (application level)		
	75%	74%
	4,12 s	2,29s

IV. Discussion

We therefore notice that collisions are less frequent and involve fewer modems using the proposed hybrid detection. As shown in Table 1, the absolute number of average collisions per node with the default PCS is 31,155, compared to 16,025 with the PCS in hybrid mode. Knowing that the channel utilization time is approximately 75% in both configurations, the reduction in grouped collisions by a factor of 2 makes it possible to halve the latency and double the useful throughput of the network.

V. Conclusion

The concurrent access management mechanism to the CPL channel is characterized by a PCS determining the state of the channel solely by detection of preamble symbols, by favoring multiple collisions which involve a large number of frames. The proposal was to add noise level detection to the PCS. The simulation results show a remarkable improvement in throughput and latency, network decongestion and modeling of the transfer function between three impedance branches defined on the TV load, the stove load and the CPL load.

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