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OFDMA Y EL VALOR DE SHAPLEY COMO ESTRATEGIAS PARA LA OPTIMIZACION DEL ANCHO DE BANDA EN REDES SOBRE POWER LINE COMMUNICATIONS

OFDMA AND THE VALUE OF SHAPLEY AS STRATEGIES FOR THE OPTIMIZATION OF THE NETWORK BANDWIDTH ON POWER LINE COMMUNICATIONS

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Resumen: HomePlug AV (HPAV) es uno de los estándares de mayor aceptación sobre la tecnología PLC, el cual no cuenta con un mecanismo adecuado para la optimización del ancho de banda, realizando procesos de asignación de recursos mediante TDMA (*Time Division Multiple Access*) y CSMA/CA (*Carrier Sense Multiple Access with Collision Avoidance*) acorde con la clase de servicio. En vista de lo anterior, en el presente artículo se propone el uso de OFDMA (*Orthogonal Frequency-Division Multiple Access*) como mecanismo de acceso al medio y del valor de Shapley como estrategia para la optimización del ancho de banda en redes que utilizan la red eléctrica como medio físico de transmisión. Acorde con los resultados obtenidos se pudo evidenciar que el uso de OFDMA y el uso de la teoría de juegos cooperativos podría ser considerado como una estrategia adecuada para la asignación de recursos en un canal PLC, ofreciendo adecuados niveles de calidad de servicio.

Palabras clave: OFDMA, HPAV, Optimización de recursos, Teoría de Juegos, Valor de Shapley**.**

Abstract: HomePlug AV (HPAV) is one of the most widely accepted standards for PLC technology, which does not have an adequate mechanism for bandwidth optimization, performing resource allocation processes using TDMA (Time Division Multiple Access) and CSMA / CA (Carrier Sense Multiple Access with Collision Avoidance) according to the class of service. In view of the above, this article proposes the use of OFDMA (Orthogonal Frequency-Division Multiple Access) as a mechanism for access to the medium and the value of Shapley as a strategy for optimizing bandwidth in networks using the network electrical as a physical means of transmission. According to the results obtained, it could be evidenced that the use of OFDMA and the use of cooperative game theory could be considered as an adequate strategy for the allocation of resources in a PLC channel, offering adequate levels of quality of service.

Keywords: OFDMA, HPAV, Resource Optimization, Game Theory, Shapley Value.

1. INTRODUCTION

In the world, interest grows in developing policies and regulations that encourage the creation of social awareness about the importance of the environment and the proper use of the energy resources that it provides us. Based on this, the project called *Smart Grid,* whose main objective is to improve the efficiency and reliability of the power grid, adapting it to the needs of the digital era [1]. *Smart Grid, is a new concept of the electricity network, where converges the provision of energy and communications services integrated in an intelligent network, oriented to corporate and residential environments* [2].

Based on *Smart Grid*, a new concept called *Home Area Network* (HAN) emerges, which is defined as a network implemented in a residential context that involves any electronic device that can be found in the home with the possibility of establishing communication processes on the IP protocol, and under the use of any technology that allows it to be part of the network. The implementation of a HAN under *Smart Grid* architecture requires, in most cases, the simultaneous transmission of voice, data and video with QoS; generating the provision of multiple services, among which are: Broadband Internet access, VoIP, multimedia applications (videoconferencing, interactive television, video and audio on demand, network games, televigilance) and telemetry, among other services [3]. In [4], the most accepted standards by the IEEE to implement a Smart Grid architecture are presented, where HomePlug AV (HPAV) and its HomePlug-GP particularity are highlighted as one of the most important standards during the process of implementing a HAN .

HPAV is one of the most widely accepted standards for PLC technology, which makes use of OFDM (*Orthogonal Frequency Division Multiplexing*) as a multiplexing technique for information on the PLC channel. It operates in the range of 1.8MHz to 28MHz, dividing the spectrum into 1055 subcarriers, of which only 917 are active for the American system [5]. HPAV uses adaptive modulation for each subcarrier depending on the channel conditions: BPSK (1 bit), QPSK (2 bit), 8QAM (3 bit), 16QAM (4 bit), 64QAM (6 bit), 256QAM (8 bit) or 1024QAM (10 bit). It uses CSMA / CA and TDMA as a media access mechanism, where CSMA / CA is intended for the transmission of data packets, while TDMA is used for the transmission of voice and video packets, in order to offer good levels of QoS [6]. HPAV establishes a period of two network cycles of the power signal (120V / 60Hz) over which the times for frame transmission are distributed both in CSMA / CA and TDMA and performs synchronization processes with other adapters PLC Additionally, HPAV makes use of a central coordinator called CCo, which is responsible for assigning resources and accessing the PLC network [7]. OFDM is considered an efficient and quite flexible system to work in a hostile environment such as the power grid, because it allows the equipment to adapt dynamically to the conditions of the environment. However, since there is a common collision domain, the network performance decreases considerably as the number of nodes that make up the PLC network increases, because only one of the nodes can transmit at a time [8]. In view of the above and considering that HPAV does not have an adequate resource optimization mechanism, it is proposed to use OFDMA (*Orthogonal Frequency Division Multiple Access*) as a multiplexing technique, by allowing multiple nodes to transmit simultaneously [9].

2. METHODOLOGY

OFDMA is known as the multi-user version of OFDM, where multiple nodes can share the spectrum of a channel by distributing resources both in frequency and time, in order to optimize network performance, thus ensuring different levels of QoS depending on the bandwidth allocated [10].

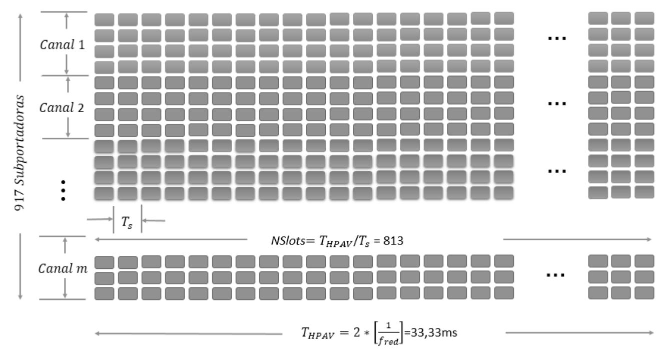

Figure 1. Assignment of frequencies to a subchannel under a multi-user diversity scenario.

One of the advantages of OFDMA is that several modulation techniques can be used along the spectrum simultaneously, where the constellation assigned for each subcarrier will depend on the Signal to Noise ratio (SNR), which obeys the conditions of channel and behaves dynamically depending on the frequency [11]. Additionally, when using OFDMA, it is not only intended to transmit the greatest amount of bits when the conditions of the channel are favorable, but also to ensure an established average Bit Error Rate (BER), although in some subcarriers, the transmission conditions are not so favorable. Additionally, it is important to mention that the assignment of subcarriers that are part of a Subchannel can be done in two ways: Pseudo-random assignment (diversity in frequency - applied to mobile solutions) and assignment of contiguous frequencies (multi-user diversity - applied to HPAV) [12].

Figure 1 shows the proposed map corresponding to the distribution of time and frequency for a PLC channel over OFDMA, in which the 917 subcarriers are observed in the frequency domain, associating in each of the m channels a neighborhood of Frequently estimated frequencies. On the other hand, in the time domain it is observed that the period adopted by HPAV (T_{HPAV}) is equal to 33.33ms, equivalent to two 60Hz network cycles. Additionally, the number of time slots is 813, which correspond to the relationship between T_{HPAV} and the time of an OFDM symbol ($T_s = 40{,}96\mu s$) for the particular case of HPAV [13][13][13][13]. It is precisely on this frequency-time map that the subsequent allocation of resources will be carried out optimally and in accordance with the conditions of the channel, the network topology, the number of stations and the intensity of traffic per class in each node; by using the value of Shapley.

2.1 Estimation of the number of bits per subcarrier (Bit-loading)

To calculate the optimal number of bits for each of the subcarriers according to the SNR, Equation (1) is used [14][14][14][14]:

$$b_k = log_2\left[1 + \frac{SNR_k}{\Gamma}\right] \quad (1)$$

where:

b_k: Number of subcarrier bits k
SNR_k: Signal to Noise Ratio present in the subcarrier k
Γ : It is known as SNR gap. k

Γ is a widely used parameter in various modern communication systems, which represents the loss in *SNR* in which a specific discrete coding scheme is used. In [15] it is suggested that the value of Γ can be calculated for practical effects of the by means of the Equation (2):

$$\Gamma = -\frac{1}{1{,}6} ln\left[\frac{BER_{obj}}{0{,}2}\right] \quad (2)$$

Where BER_{obj}, corresponds to the average BER that you wish to establish during the entire transmission process. It is important to note that the value of Γ also depends on the probability of error P_e and the coding scheme. The higher the P_e, the greater the value of Γ. The most commonly used values in PLC channel simulation processes are 10^{-3} and 10^{-5} for the BER and P_e parameters respectively. To calculate the total bits / sec it is necessary to consider the total number of subcarriers (N_{sp}) and the time of an OFDM symbol (T_s). Equation (3) represents the expression that allows to calculate the total number of bits/s [16]:

$$BW_{TOTAL} = \frac{1}{T_s}\sum_{k=1}^{N_{sp}} log_2\left[1 + \frac{SNR_k}{\Gamma}\right] \quad (3)$$

2.2 Estimation of the number of channels

In the optimization process it is necessary to establish the number m of channels on which the 917 subcarriers will be distributed, in order to subsequently carry out the process of resource allocation, in time and frequency, for each of the traffic classes generated from each node i that are part of the PLC network. To this end, Engset's formula is used, named for the Norwegian mathematician and engineer Thorir Olaus Engset, which allows estimating the number of channels required according to a traffic intensity ρ in Erlangs, generated by a finite population of seasons. Additionally, by using this expression it is possible to estimate the probability of blocking and the probability of losses in each node i [17]. Engset's formula is given by the Equation (4):

$$P_{bl}(m, \rho, N) = \frac{\rho^m \binom{N}{m}}{\sum_{i=1}^{m} \rho^i \binom{N}{i}} \quad (4)$$

where,

P_{bl}: Blocking probability
ρ: Intensity of traffic in Erlangs generated by each node
m: Estimated number of channels
N: Number of nodes that make up the PLC network

In simulation processes it has been observed that the estimated number of channels is approximately equal to the number of nodes that make up the PLC network, as long as the number of nodes is low. As the number of nodes increases considerably, the number of channels m tends to be less than the total number of nodes.

2.3 Use of game theory as an optimization strategy within a PLC network

Although there are several methods to solve an optimization problem, in most cases, these methods make use of algorithms that have a fairly high computational complexity, resulting in non-viable execution times for implementation in embedded or low-cost systems. In view of the above, the use of game theory is proposed as a strategy to optimize the performance of a PLC network.

Game theory is an area of mathematics proposed by John Von Neumann in 1928, which is aimed at evaluating the decisions that an individual can make within a competitive context of profit or loss, compared to the decisions taken by others competitors. This competitive scenario is called "*Game*" and the individuals that are part of this scenario are called "*Players*" [18]. In the context of games with n-players, each player can establish alliances with other players in order to increase the usefulness of each. This type of alliances are called "*Coalitions*" and can be of two or more players, until the so-called "*Great Coalition*" formed by all players [19].

Definition [20]: A cooperative game UT (with transferable utility) is a pair (N, v) where $N = \{1,2,3 \dots n\}$ is the set of players and $v: 2^N \rightarrow \mathbb{R}$ is a function that verifies that $v(\emptyset) = 0$. Function v is called the "*characteristic function*" of the game. Given an $S \subseteq N$ coalition, $v(S)$ represents the payment that can be secured to the S players, $v(N)$ being the total payment to the players that are part of the great coalition. The value of a coalition can be considered as the minimum amount a coalition can get if all the players that are part of it are associated and play as a team. For the particular case, the value $v(N)$ corresponds to the total bandwidth available on the PLC channel (BW_{Total}), which must be distributed equally among all players, according to the traffic demand ρ_{ir} for each class *r* in node *i*.

The interest of the game is in the estimation of the payment vector resulting from the operation between players. In view of the above, a solution for the game (N, v) is the function $\varphi: G \rightarrow \mathbb{R}^n$, where $\varphi(v) \in \mathbb{R}^n$ obeys the payment vector for the game (N, v) [21]. On the other hand, the solution requires that efficient payment vectors comply with the so-called principle of rational individuality, which requires that the payment to each player and for the payment vector φ be at least the amount that the player can obtain by himself same in the game, that is: $\varphi_i \geq v(\{i\})\ \forall i \in N$. Pre-imputations that comply with this principle are called "Imputations for the game (N, v)".

Definition: An account assignment for a game (N, v) corresponds to a payment vector $\varphi(v) \in \mathbb{R}^n$ such that [20]:

$$\varphi_i(v) \geq (v\{i\})\ \forall i \in N \quad (5)$$

$$\sum_{i \in N} \varphi_i(v) = v(N) \quad (6)$$

A payment vector $\varphi(v) \in \mathbb{R}^n$ is said to be "rational group" if:

$$\sum_{i \in S} \varphi_i(v) \geq v(S) \quad \forall S \subseteq N \quad (7)$$

At the moment in which the accusations are required to comply with the principle of rationality for all coalitions, the concept of solution called Core is reached. The Core $C(v)$ of a game (N, v), is defined as the set of imputations that have the rational group property. The expression that defines the core of a game is due to the following expression [22]:

$$C(v) = \left\{ \varphi(v) \in \mathbb{R}^n \middle| \sum_{i \in S} \varphi_i(v) \geq v(S)\ \forall S \subseteq N, \sum_{i \in N} \varphi_i(v) = v(N) \right\} \quad (8)$$

Shapley analyzed cooperative games for a long time, trying to answer the following question: what is the payment for an individual player? Trying to predict this is quite complex because there are other factors in the environment that may affect the final result. However, in 1953 Shapley proposed the concept of value of a game (N, v) given for each player $i \in N$ through equation (9) [19] :

$$\varphi_i(v) = \sum_{S \subseteq N: i \in S} \frac{(s-1)!\,(n-s)!}{n!} [v(S) - v(S/\{i\})] \quad (9)$$

$$where\ n = |N|\ y\ s = |S|$$

This value is known as the *value of Shapley* for player i, which is determined exclusively and a priori, by the characteristic function of the game.

The direct calculation of the value of the Shapley has a temporal complexity $O(n2^n)$, so it is important to look for the possibility of implementing algorithms that have a lower temporal complexity. Among the most used algorithms are Hart and Max-Colell and the algorithm called "dividend" Harsanyi; which have a temporal complexity of $O(n2^n)$ and $O(3^n)$ respectively [23].

3. RESULTS

3.1 Practical scenario

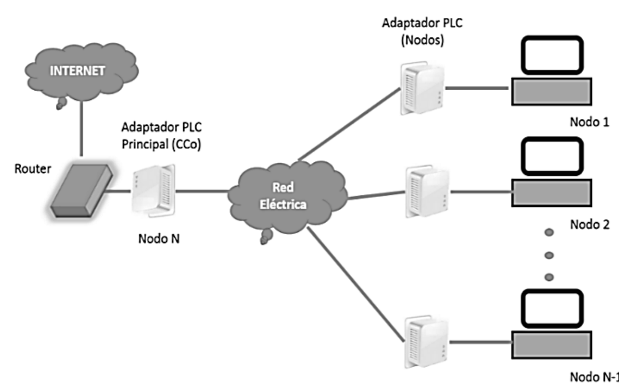

Figure 2. Practical scenario of a HAN over PLC.

Figure 2 shows the general scheme of the proposed network topology, which consists of *N* nodes. Each node is made up of a PLC adapter and a traffic source. Each traffic source can generate more than one class simultaneously (Voice, Data, Video or Control).

Node *N* will be considered as the main node or Coordinator (*CCo*), which will be in charge of establishing the frequency-time reserve (Schedule) for each of the nodes that are part of the PLC network. Additionally, it will be the node through which the greatest amount of traffic will circulate, due to its direct connection to the router to access the Internet.

3.2 PLC Channel Estimation

In order to evaluate the behavior of the model under a real scenario, the "PLC Channel Generator (GC_PLC)" tool was used [24], which was developed by PhD Francisco Javier Cañete, belonging to the University PLC Group from Malaga-Spain.

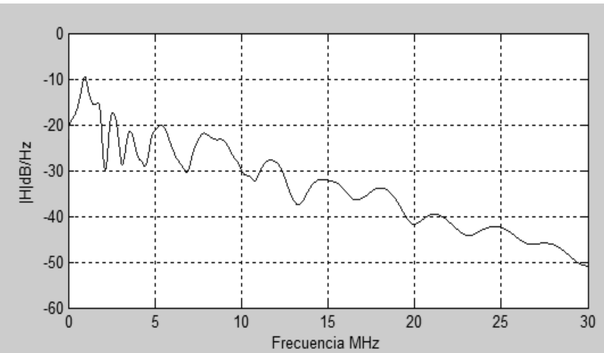

Figure 3. Response of the PLC Channel in a typical residential environment.

This tool allows to estimate the behavior of a PLC Channel, in accordance with the parameters associated to the topology of a PLC network, in a typical residential environment. Additionally, the channel evaluation is performed below the 30MHz band, considering the fact that PLC network adapters under the HPAV standard operate in this frequency band.

Figure 3 shows the magnitude corresponding to the response of a PLC channel ($|H|$) in units of dB/Hz, under the use of the tool (GC_PLC), in a frequency range below 30MHz, according with a network topology established in a residential environment. On the other hand, a fading corresponding to the response of the PLC channel is observed as the frequency level increases. This response of the channel is due to a situation of a regular channel for the transmission of information, which can be considered as a real scenario in accordance with the current conditions of the Colombian electricity grid, because in this context, the electricity grid has not yet It has been conditioned to offer an optimal scenario for the use of PLC technology in the residential environment.

Figure 4 shows the Signal to Noise ratio generated by the GC_PLC tool according to the topology established for a residential context. This graph reflects the effect that the response of the channel and the noise, present in the PLC channel, exert on the transmitted signal, where it is clearly observed that there is no uniform behavior along the frequency spectrum and that depending on the frequency value on which it is located, the transmitted signal may have a greater or lesser attenuation, which as a consequence will allow a greater or lesser transmission of bits on a particular subcarrier.

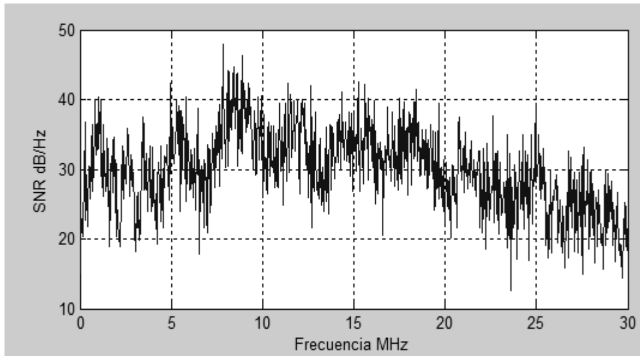

Figure 4. Signal to Noise Ratio present in the PLC Channel.

In the case of PLC devices, the power of the transmitted signal must not exceed 20dBm (100mW) in the range of 1 to 30MHz and have an electromagnetic emission limit corresponding to the PSD spectral power density of -50 dBm/Hz defined in IEC CISPR 22 [25]. For simulation purposes, a signal power of 10dBm was considered, which corresponds to the most common signal value in commercial PLC adapters.

3.3 Simulation Environment

The following is a scenario where the traffic generated is less than the capacity of the PLC channel, which will allow the use of the algorithm to be evaluated in a state of non-saturation or normal condition. Table 1 shows the traffic classes (data, voice, video and control) and the codec established (applicable only to Voice or Video) for a scenario consisting of four nodes. Node 4 will be configured as the CCo or main node and the others will be terminal nodes.

Table 1. Traffic classes *r* in each Node *i*

Node *i*	**Traffic classes**			
	Data (r=1)	**Voice (r=2)**	**Video (r=3)**	**Control (r=4)**
1	X			X
2	X	G.723		
3			MPEG-2	X
4 (CCo)	X	X	X	X

Table 2 shows the arrival rates of packets/s in each node i and class r, which are due to a Pareto distribution, with particular shape and position parameters for each case, according to measurements made in real scenarios.

Table 2. Arrival rates (λ_{ir}) in each node i and class r [packages/s]

Node i	Traffic classes			
	Data (r=1)	**Voice (r=2)**	**Video (r=3)**	**Control (r=4)**
1	596			3
2	975	33		
3			1271	3
4 (CCo)	1571	33	1271	6

In the proposed scenario, it is desired to equitably optimize the bandwidth available on the PLC channel ($BW_{Total} = v(N)$) among all players $j = 1,2,\ldots,n$; where each player j obeys each traffic source associated with the duo (node, class) that requires access to the channel, by using the value of Shapley. To establish each of the imputations of the game, the case of a bankruptcy game will be considered.

Table 3. Estimation of coalition values $v\{i\}$ for each player i

Player i	BW Requested [Mbps] d_i	Coalition	Value $v\{i\}$ Mbps
1: Node 1 - Data	4,128	{1}	12,0852
2: Node 2 - Data	6,754	{2}	12,3478
3: Node 4 - Data	10,882	{3}	12,7606
4: Node 2 - Voice	0,024	{4}	11,6748
5: Node 4 - Voice	0,024	{5}	11,6748
6: Node 3 - Video	15,921	{6}	13,2645
7: Node 4 - Video	15,921	{7}	13,2645
8: Node 1 - Control	0,002	{8}	11,6726
9: Node 3 - Control	0,002	{9}	11,6726
10: Node 4 - Control	0,004	{10}	11,6728
Gran Coalición		{N}	170,38

A bankruptcy game is defined as a list (N, d, C) where $N = \{1,2,\ldots,n\}$ is the set of players, $d = \{d_1, d_2, \ldots, d_n\}$ with $d_i \geq 0, \forall i \in N$ is the vector of claims of the creditors and C corresponds to the net value that must be distributed among the elements of N.

The game associated with this problem is defined as: $v(S) = max\{0, C - \sum_{i \in N \setminus S} d_i\}$, with $C = 170{,}38 Mbps$, which corresponds to the BW_{Total} available in the PLC channel. Table 3 shows the estimation of the coalition values $v\{i\}$ for each player i as a result of making use of a bankruptcy game in accordance with the proposed scenario.

Table 4. Shapley Matrix for the proposed game

Player i in each coalition	Contribution to the coalition containing j players [*1E+7]										$\varphi_i(v)[*1E+6]$
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	
1	12,0852	3,7152	14,8608	34,6752	52,0128	52,0128	34,6752	14,8608	3,7152	0,4128	15,80
2	12,3478	6,0786	24,3144	56,7336	85,1004	85,1004	56,7336	24,3144	6,0786	0,6754	18,43
3	12,7606	9,7938	39,1752	91,4088	137,1132	137,1132	91,4088	39,1752	9,7938	1,0882	22,55
4	11,6748	0,0213	0,0850	0,1984	0,2976	0,2976	0,1984	0,0850	0,0213	0,0024	11,70
5	11,6748	0,0213	0,0850	0,1984	0,2976	0,2976	0,1984	0,0850	0,0213	0,0024	11,70
6	13,2645	14,3289	57,3156	133,7364	200,6046	200,6046	133,7364	57,3156	14,3289	1,5921	27,59
7	13,2645	14,3289	57,3156	133,7364	200,6046	200,6046	133,7364	57,3156	14,3289	1,5921	27,59
8	11,6726	0,0017	0,0069	0,0162	0,0242	0,0242	0,0162	0,0069	0,0017	0,0002	11,67
9	11,6726	0,0017	0,0067	0,0157	0,0235	0,0235	0,0157	0,0067	0,0017	0,0002	11,67
10	11,6728	0,0034	0,0136	0,0318	0,0477	0,0477	0,0318	0,0136	0,0034	0,0004	11,68
P(j)	**0,1000**	**0,0111**	**0,0028**	**0,0012**	**0,0008**	**0,0008**	**0,0012**	**0,0028**	**0,0111**	**0,1000**	**170,38**

The equations that describe each of the imputations of the game (N, v), must satisfy that $\varphi_i(v) \geq (v\{i\})\ \forall i \in N$ and the game efficiency equation $\sum_{i \in N} \varphi_i(v) = v(N)$. The values for $(v\{i\})$ are recorded in table 3.

Table 4 shows the Shapley matrix for the proposed game. It shows the value $\varphi_i(v)$ for each player i and that the $\sum_{i \in N} \varphi_i(v) = 170{,}38$, equivalent to the bandwidth available for the PLC channel.

Table 5. Bandwidth allocated [Mbps] for each node *i* and class *r*

Node i	Traffic classes				BW Total/Node [Mbps]
	Data (r=1)	Voice (r=2)	Video (r=3)	Control (r=4)	
1	15,8			11,67	27,47
2	18,43	11,7			30,13
3			27,59	11,67	39,26
4 (CCo)	22,55	11,7	27,59	11,68	73,52
			BW Total Channel		170,38

Table 5 shows the result of the allocation of bandwidth in each node *i* and class *r* according to the availability of the bandwidth of the PLC channel, the traffic intensity and the minimum resource allocation parameters for each class; which obey the result of making use of the value of Shapley.

In this first scenario, the simulation process established that the PLC channel should be subdivided into four subchannels (m = 4), which is subject to the Engset formula, with a 0.01% blocking probability and a loss probability of packages 0.33%. The bandwidth capacity per channel $c = \{1,2 \dots, m\}$ is given by $BW_c = \{41{,}553, 49{,}536, 45{,}386, 33{,}911\}$ in Mbps respectively, where $\sum_{c=1}^{m} BW_c = 170{,}385 Mbps$).

To calculate the total Throughput *Th*, Equation (10) is used, where $\lambda_{0,ir}$ corresponds to the packet/s output rate for each node *i* and class *r*, according to the allocation of resources by the value of Shapley and packet arrival rates/s at each node [26]:

$$Th = \sum_{i=1}^{N} \sum_{r=1}^{R} \lambda_{0,ir} \qquad (10)$$

Table 6 shows the results obtained for the Throughput during the simulation process. It is important to mention that an HPAV-based frame adds 66 bytes of control to each packet it transmits, an aspect that was considered to estimate the Throughput within the simulation processes.

Table 6. Throughput on each node *i* and class *r*

Node i	Traffic classes				Thr total/node [mbps]
	Data (r=1) Mbps	Voice (r=2) Kbps	Video (r=3) Mbps	Control (r=4) kbps	
1	3,813			0,447	4,260
2	6,239	6,103			12,342
3			15,250	0,434	15,684
4 (cco)	10,053	6,103	15,250	0,881	32,288
			Throughput total		64,574

In table 7, a comparative table is presented between the demand for bandwidth, versus the bandwidth allocated to each node as a result of the Shapley value, as well as the maximum allowed Throughput and Throughput values according to the total resource assigned to each node. It shows that the value of Shapley assigns in a fair and equitable manner the bandwidth available to each player, in order to maximize the output throughput, guaranteeing adequate levels of QoS for each kind of traffic.

Table 7. Comparison between demand for bandwidth vs. allocated bandwidth

Player *i* / Node-class	BW Requested [Mbps]	BW Assigned [Mbps]	Thr. [Mbps]	Máx. Thr. [Mbps]
1: Node 1 - Data	4,128	15,80	3,8134	14,596
2: Node 2 - Data	6,754	18,43	6,2393	17,022
3: Node 4 - Data	10,882	22,55	10,0527	20,835
4: Node 2 - Voice	0,024	11,70	0,0061	3,023
5: Node 4 - Voice	0,024	11,70	0,0061	3,023
6: Node 3 - Video	15,921	27,59	15,2500	26,430
7: Node 4 - Video	15,921	27,59	15,2500	26,430
8: Node 1 - Control	0,002	11,67	0,0004	2,715
9: Node 3 - Control	0,002	11,67	0,0004	2,715
10: Node 4 - Control	0,004	11,68	0,0009	2,715
Total	53,66	170,38	50,62	119,50

4. CONCLUSIONS

The selection of the HPAV protocol for the transmission of information by power line was mainly based on its wide use and worldwide acceptance, and; in the tests carried out it was evidenced that the optimization of the channel assignment for events in which the traffic generated is greater than its capacity is feasible. The use of the value of Shapley applied to optimization processes of a HAN network over PLC, generated excellent results when maximizing the Throughput in each of the nodes that are part of a PLC network, establishing adequate levels of QoS for each of the traffic classes that pass through it, as could be seen in the proposed scenario. One aspect to note is that the value of Shapley on OFDMA is a strategy that can be implemented in low-cost embedded systems, because the computational complexity of its algorithms is not as high as that required in optimization methods proposed in others. papers.

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