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PAPERS

On possible energy savings with transmission supported via feedback channel in CubeSat transceiver

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Recently a transmission technique, which can save energy thanks to supportive transmission in the feedback channel, was presented for transmitted information with different probability distributions. The basic assumption for its practical exploitation is that a node collecting information has enough energy - much more than the supported node. So far, in the published theoretical analysis it was assumed that the node does not consume energy for receiving the supporting sequence or that the amount of this energy is negligible comparing to energy needed for transmission. This paper makes the analyses more exact and practically oriented. Particularly, it estimates possible energy savings by incorporating the energy expenditures for receiving the supporting sequence in scenarios with Poisson distributed payload messages. The data from a real transceiver for CubeSat are used for obtaining the numerical results in these estimations.

K e y w o r d s: CubeSat, energy saving, supportive transmission, feedback channel, Poisson distribution

1 Introduction

In some Space Communication (SC), Internet of Things (IoT) or Wireless Sensor Networks (WSN) applications it can be desirable to minimize the energy consumption of nodes which possess a restricted energy supply.

In [1-3] a technique was proposed which allows us to decrease the number of signals transmitted in the transmission direction (payload direction) by exploiting supportive messages transmitted in the opposite direction (feedback direction). In practice this could be useful in cases when the node which collects the information has sufficient energy resources and the node from which the information has to be transmitted has restricted energy resources. The node with restricted energy resources analyzes the supportive transmission. If it detects a guess which, based on the agreed protocol, determines the message waiting for transmission, it replies with a short and therefore low energy signal. In [1-3] on the basis of theoretical analysis it was shown that this technique can decrease the number of transmitted signals even beyond entropy of the source of transmitted information. In order to simplify these analyses the energy needed to receive the supportive messages by the node with restricted energy was neglected. Therefore in this manuscript the energy needed for receiving the support messages is included into the analysis. The obtained results are demonstrated on real data from a particular CubeSat transceiver.

The paper is organized as follows. In Section 2 the technique for information transmission with support messages in the feedback channel for a considered scenario is described. In Section 3 and 4 the energy saving technique is evaluated for the specific scenario for a concrete CubeSat transceiver analytically and numerically respectively. In Conclusions the results and evaluations are discussed.

2 Transmission scenario

Let us define the scenario by giving global conditions which are supposed to be fulfilled. The first assumption is that the binary system is used. This is in accordance with the most common communication systems with binary modulations used in space communications. The second one is that much more energy (or many more signals) could be sent in the feedback channel than in the forward or payload channel. The third assumption is that the data which has to be transmitted in the required direction could be modeled as in [1] by a random variable with Poisson distribution. This is appropriate for counting the number of events which occur with a constant average rate per some interval. The probability of observing k events in a given interval is

$$P(k) = e^{-\lambda} \frac{\lambda^k}{k!}, \tag{1}$$

where λ is the average number of events per interval. It is supposed that λ is known to the transmitter as well as to the receiver.

The reason for making this assumption identical to one used in [1] is that the main goal of this paper is to compare theoretical estimations of energy savings without taking into account the amount of energy spent for receiving the supportive messages as with more practical cases where

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this energy is incorporated into the energy budget. This will make this comparison more fair and illustrative.

The next assumption, which will be used in Section 4 is, that the node which is transmitting the payload is using an ISIS TRXVU real transceiver designed for CubeSats. The reason for selecting this particular transceiver is that its ratio between energy spent only for reception to that on transmission is typical for similar CubeSat transceivers [7]. In the following analyses it will be also assumed that BPSK modulation is used and one (modulation) signal corresponds to one binary signal. Such a signal will be further denoted as binit in order to distinguish it from a bit which denotes the amount of information.

In [1] the technique allowing energy saving and or number of transmitted signals in the payload direction by exploiting a transmission in the feedback direction was presented for the case when the transmitted information could be modeled as a discrete memory-less source. It was further assumed that transmitted messages have Poisson distribution. For the readers convenience the technique from [1] will be briefly described again in this section.

The scenario defined by the mentioned conditions allows the transmitter and the receiver to agree on a communication protocol in advance. It is assumed that this protocol is using a Huffman code, known to both sides. We will start with an explanation of how it can be constructed.

The construction is based on the fact that the source of in- formation can be modeled as a discrete memory-less source with messages having Poison distributed probabilities. The parameter λ of the Poison distribution is known to the transmitter and to the receiver. However there is an obstacle, which has to be removed first. The Poisson distributed random variable has a range of values from an infinite set of all natural numbers while the Huffman code could be constructed only for a finite number of messages. Therefore it is necessary to take this fact into account in the protocol design. A simple option is to restrict the set of messages encoded by the Huffman code around the maximum of the Poisson probability density function (PDF) into interval $\mathcal{N} = \langle k_{\mathrm{LO}}, k_{\mathrm{UP}} \rangle$, where "LO", and "UP" stand for lower and upper. It will contain most probable values of the Poisson distributed random variable

$$|\mathcal{N}| = k_{\mathrm{UP}} - k_{\mathrm{LO}} + 1 \,. \tag{2}$$

The number of the messages $|\mathcal{N}|$ is fixed in the protocol for a specific value of λ in advance by using some optimization criterion such as energy efficiency or the average number of transmitted bits in payload direction. Other practical requirements could be taken into account as well, for example the restrictions on delay in delivering the data in the payload direction. Knowing the probabilities of messages, the Huffman code can be constructed by the standard method [4]. After this brief explanation how to obtain the Huffman code, we can concentrate on describing the communication protocol, upon which transmitter and receiver have to agree.

In the transmitter some random integer k (payload) is waiting to be transmitted. The receiver starts to transmit supportive messages one at a time in the opposite, feedback direction. Each message is a guess of the integer k encoded using a Huffman code known to both sides in advance. Each time one supportive message is transmitted and then the receiver on the supporting end waits for a response from the transmitter in the payload direction. In order to minimize the average number of guesses the supportive messages are transmitted in the order of decreasing probabilities in each round $P_1, P_2, \ldots, P_{|\mathcal{N}|}$.

After receiving each supportive message the payload transmitter decides if the guess was correct or not. If it was correct the transmitter will send a single acknowledgment signal as a confirmation in the payload direction. If the guess was not correct nothing is transmitted. If all expected guesses for the concrete waiting messages were not correct, then $k \notin \mathcal{N}$. In such a case the payload node will send a binary number corresponding to k.

3 On the evaluation of the gain achieved by the proposed technique

The theoretical evaluation of the gain of the transmission technique described in [1] was done with the assumption that the energy spent for reception of the supportive messages in the payload node could be neglected. In this section we will suppose that identical assumptions will hold as in [1]. Later in this section we will also take into account the energy needed in the payload node for receiving of the supportive messages.

The main goal of the analyzed method is to decrease the number of signals/binits in the payload direction when compared to other methods. Therefore, evaluating the achieved gain can start with estimating the average number of binits per message in the proposed method.

Using Shannon's source coding theorem [5] and recently published formulas presented in [6] the proposed technique can then be compared to the ideal case. In other words to the lower bound on the number of binits needed to send the information from a discrete memory-less source. In [6] exact formulas on the entropy of the considered source with the Poisson distribution and other distributions are given. First, we will show how the average number of binits per message could be evaluated for the considered method. By analyzing the communication protocol we can observe that when $k \in \mathcal{N}$ only 1 binit needs to be sent in the payload direction.

Now let us estimate the average number of transmitted bits if $k \notin \mathcal{N}$ knowing that each k is transmitted as a corresponding binary number. The average number of binits in this case is

$$\begin{aligned}\hat{n}' = e^{-\lambda}\frac{\lambda^0}{0!} + \sum_{k=1}^{k_{\mathrm{LO}}-1} \lceil \log_2(k+1) \rceil e^{-\lambda}\frac{\lambda^k}{k!} + \\ + \sum_{k=1}^{\infty} \lceil \log_2(k+1) \rceil e^{-\lambda}\frac{\lambda^k}{k},\end{aligned} \tag{3}$$

Table 1. Huffman code in Example 1

k	$P(k)$	codeword	codeword length n_k
0	0.0821	0110	4
1	0.2052	10	2
2	0.2565	00	2
3	0.2138	11	2
4	0.1336	010	3
5	0.0668	01111	5
6	0.0278	011101	6
7	0.0099	011100	6

where $\lceil x \rceil$ is the smallest integer greater than or equal to x. In order to get an approximate value for the estimation of $\hat{n}'$ we can restrict the upper bound of the sum in the 3-rd summand on the right side in (3) to some value $k_{\max}$. The value of $k_{\max}$ can be adjusted by repeated trials in such a way that

$$\sum_{k=k_{\mathrm{UP}}+1}^{k_{\max}} \lceil \log_2 k \rceil e^{-\lambda} \frac{\lambda^k}{k!} \leq \epsilon, \tag{4}$$

where ϵ is some small real number close to zero. The average number of binits per message for the analyzed method is therefore

$$\hat{n} \cong \overline{n}' + \hat{n}', \tag{5}$$

where $\overline{n}' = 1 \times P(k \in \mathcal{N})$. In order to also include the energy needed for receiving the supportive messages it is necessary to know the average number of binits in each supportive message per one message sent in the payload direction. This could be calculated as follows. First the probabilities and codeword lengths have to be sorted in decreasing and increasing values order respectively. After these sorting lets denote the probabilities of the supportive messages starting from the maximal as follows: $P_1, P_2 \ldots, P_{|\mathcal{N}|}$ and codewords lengths starting from the shortest: $n'_0, n'_1, \ldots, n'_{\mathcal{N}}$. Then the average number of binits in each supportive message per one message sent in the payload direction can be expressed

$$\begin{aligned} N = {} & P_1 n'_1 + (1-P_1)P_2(n'_1+n'_2) + \\ & + (1-P_1)(1-P_2)P_3(n'_1+n'_2+n'_3) + \\ & + (1-P_1)(1-P_2)\ldots(1-P_{|\mathcal{N}|-1})P_{|\mathcal{N}|}\sum_{i=1}^{|\mathcal{N}|} n'_i \,. \end{aligned} \tag{6}$$

Now we can turn our attention to a benchmark with which the described method will be compared. This benchmark has to characterize the best possible technique which will not exploit the support from a feedback channel and will possess the same knowledge in the transmitter otherwise. In such a case the best possible technique has to obey the Shannon source coding theorem for discreet memory-less source (DMS). Therefore instead of trying to develop some alternative coding for the benchmark method of transmission we can use the lower bound on the number of binits. For a binary coding alphabet it is the entropy of the source [5].

$$H(X) \leq \overline{n}\,, \tag{7}$$

where $H(X)$ is the entropy of the DMS and $\overline{n}$ is the average number of binits in a code constructed for lossless compression, for example a Huffman code. Recently in [6] an exact analytic formula for Poisson distribution was presented, which we will use for calculating this entropy

$$H\big(X_{\mathrm{Poi}}\big) = \lambda \ln(\lambda/e) + \int_0^1 \frac{1-e^{-\lambda z}-\lambda z}{z\ln(1-z)}\mathrm{d}z\,. \tag{8}$$

The obtained value is in nats, which could be easily converted into bits. Let us now give an example of the new proposed transmission technique for a case when the data, which have to be sent in the payload direction, could be modeled with a discrete random variable with known Poisson distribution.

<u>Example 1</u>

In the first example we will describe the technique for a random variable, which has Poisson distribution with $\lambda = 2.5$. The set of encoded values in this example will be restricted and will contain only the first 8 values of $\mathcal{N} = \{0,1,2,3,4,5,6,7\}$. The probabilities are also given in Tab. 1 together with the corresponding Huffman code and its codeword lengths n_k. So $|\mathcal{N}| = 8$ The probabilities $P(k)$ for 10 values are depicted in Fig.1.

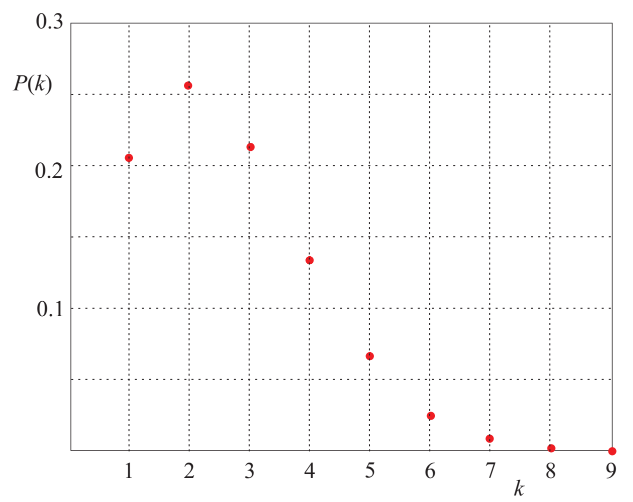

Fig. 1. First 10 values of Poisson distributed random variable with $\lambda = 2.5$

In this case the overall probability of the event that in the payload direction only 1 binit will be sent is 0.9958. The probability that $P(k \notin \mathcal{N})$ can be calculated is as follows

$$P(k \notin \mathcal{N}) = 1 - \sum_{k=0}^{N} \frac{e^{-\lambda}\lambda^k}{k!}\,. \tag{9}$$

Table 2. Huffman code in Example 2 - part 1

k	j	$P(k)$	codeword	codeword length n_k
66	72	0.000068	100010000100	13
67	69	0.000102	1011100111011	13
68	67	0.00015	100010000011	12
69	65	0.00021	110011110110	12
70	63	0.00031	10001101010	11
71	61	0.000437	10111001111	11
72	58	0.00061	1000110100	10
73	56	0.00083	1100111100	10
74	54	0.0011	0000001111	10
75	52	0.0015	100011011	9
76	50	0.001973	110011111	9
77	47	0.0026	10001100	8
78	45	0.0033	11001110	8
79	43	0.0042	00011010	8
80	41	0.0052	1000101	7
81	39	0.0064	1011101	7
82	37	0.0078	0000000	7
83	34	0.0094	0100101	7
84	32	0.0112	100111	6
85	30	0.0132	110010	6
86	28	0.0154	111011	6
87	26	0.0176	000111	6
88	24	0.0201	10000	5
89	22	0.0225	10100	5
90	20	0.0250	10110	5
91	18	0.0275	11010	5
92	16	0.0299	11100	5
93	14	0.0322	11111	5
94	12	0.0342	00010	5
95	10	0.0360	00101	5
96	8	0.0375	00111	5
97	6	0.038673	01010	5
98	4	0.039462	01100	5
99	1	0.039861	01111	5
100	2	0.039861	01110	5
101	3	0.039466	01101	5
102	5	0.038692	01011	5
103	7	0.0376	01000	5

Table 3. Huffman code in Example 2 - part 2

k	j	$P(k)$	codeword	codeword length n_k
104	9	0.0361	00110	5
105	11	0.0344	00100	5
106	13	0.0325	00001	5
107	15	0.0303	11110	5
108	17	0.0281	11011	5
109	19	0.0258	11000	5
110	21	0.0234	10101	5
111	23	0.0211	10010	5
112	25	0.0188	010011	6
113	27	0.0167	000001	6
114	29	0.0146	111010	6
115	31	0.0127	101111	6
116	33	0.0110	100110	6
117	35	0.00937	0100100	7
118	36	0.0079	0001100	7
119	38	0.0067	1100110	7
120	40	0.0056	1000111	7
121	42	0.0046	00011011	8
122	44	0.0038	00000010	8
123	46	0.0031	10111000	8
124	48	0.0025	10001001	8
125	49	0.001975	000000110	9
126	51	0.0016	101110010	9
127	53	0.0012	100010001	9
128	55	0.0010	0000001110	10
129	57	0.0007	1011100110	10
130	59	0.00057	1000100001	10
131	60	0.000439	11001111010	11
132	62	0.00033	10001101011	11
133	64	0.00025	110011110111	12
134	66	0.00019	101110011100	12
135	68	0.00014	100010000001	12
136	70	0.0001016	1011100111010	13
137	71	0.000074	1000100000101	13
138	73	0.000053	1000100000000	13
139	74	0.000038	10001000000011	14
140	75	0.000027	10001000000010	14

In our example $P(k \notin \mathcal{N}) = 0.0042$. If $k \in \mathcal{N}$ the proposed method needs to send only 1 binit/message in payload direction, therefore $\overline{n}' = 1 \times 0.9958$. For $k_{\max}$ in accordance with (4) and assuming $\epsilon \leq 10^{-6}$ using (5) we get the following estimation for the average number of binits sent in the payload direction: $\overline{n} \cong 1.1068$.

The entropy in nats of the Poisson random variable denoted as X_{Poi} with $\lambda = 2.5$ could be calculated using a formula (8). For $\lambda = 2.5$ the entropy $H(X_{\text{Poi}}) = 1.8307$ nat, which corresponds to $H(X_{\text{Poi}}) \cong 2.64118$ bit. The average number of binits sent in the support direction per 1 message in the payload direction calculated using (6) is 3.63 binit.

Example 2

In the second example we will describe the technique for a random variable, which has Poisson distribution with $\lambda = 100$. The set of encoded values in this example will be restricted and will contain only the following 75 values $\mathcal{N} = \{66, 67, \ldots, 140\}$ and so $|\mathcal{N}| = 75$. In this case the Huffman code for this particular distribution is given for $k \in \langle 66, 140 \rangle$, see Tab. 2 and Tab. 3.

The entropy for Poison distribution with $\lambda = 100$ using (8) is approximately 5.3678 bit. The average codeword length in the Huffman code is approximately 5.3956 binits. Using (6) we will get the average number of binits in the supportive message per one message sent in the payload direction. In our example this is 43.47 binits.

It is worth noting that the delay in data delivery depends on the number of codewords which have to be transmitted in the supportive direction before the actual value is transmitted in the payload direction. This is obviously a random variable as well and it depends on the number of guesses used. The average delay value $\overline{T}$ could be calculated using the following formula

$$\begin{aligned} \overline{T} &= p_1 2\delta + (1-P_1)P_2 4\delta + \\ &+ (1-P_1)(1-P_2)P_3 6\delta + \\ &+ (1-P_1)(1-P_2)\dots \\ &\dots(1-P_{|\mathcal{N}|-1})P_{|\mathcal{N}|}2|\mathcal{N}|\delta + \delta\,, \end{aligned} \tag{10}$$

where δ is the delay between the two nodes. It can be observed that (6) together with the formulas used in estimation of $\hat{n}$ could be used to make a trade off between $\hat{n}$ and N. Further, the input information about the system is needed to get delay estimations in time units. For example the average time between supportive messages and the channel delay is necessary.

4 Estimation of the proposed technique for a CubeSat transceiver

In [1] the energy spent for receiving the support messages was not included in the analysis. In this section we will take into account this energy with the following assumptions. It will be supposed that the supported node will spend energy only during transmission and reception of information. Next, there will be a communication protocol adapted to the method described in Section 3. This means that the transmission will go on in half duplex mode with breaks exactly as long as the delay between transmitter and receiver requires. During these breaks the energy expenditures will be neglected.

Note: In satellite communication with known trajectories of the supported node (for example CubeSat) this assumption could be practical. In order to get numerical results the values from [7] for a VHF/UHF Transceiver produced by ISIS will be used. For a transceiver (denoted further as TRx1) in transmit mode the needed power is 4 W, in receive mode it is 0.48 W and transmission rate $R_{\mathrm{Tx}} = 9600 bps$. The transmitter (Tx) during transmission will spend energy

$$E_{\mathrm{Tx}} = N E_{\mathrm{Bs}}\,, \tag{11}$$

where N – is the number of sent binits and E_{Bs} – is the energy per one binit.

$$E_{\mathrm{Bs}} = P_{\mathrm{Tx}} \frac{N}{R_{\mathrm{Tx}}}\,, \tag{12}$$

where P_{Tx} and R_{Tx} – are the power needed during transmission and transmission rate in binits per second respectively

$$E_{\mathrm{Tx}} = P_{\mathrm{Tx}} \frac{N^2}{R_{\mathrm{Tx}}}\,, \tag{13}$$

If no support transmission is provided in the feedback channel we can set the lower bound on the average energy per 1 message

$$E_{\mathrm{Txm}} = H\big(X_{\mathrm{Pot}}\big) E_{\mathrm{Bs}} = P_{\mathrm{Tx}} \frac{H\big(X_{\mathrm{Pot}}\big)^2}{R_{\mathrm{Tx}}}\,. \tag{14}$$

In Example 1, the estimated $E_{\mathrm{Txm}} = 2.9\,\mathrm{mWs}$ while supported messages will spent $E_{\mathrm{Tx}} = 0.5\,\mathrm{mWs}$. In Example 2, the estimated $E_{\mathrm{Txm}} = 12.01\,\mathrm{mWs}$ while supported messages will spent $E_{\mathrm{Tx}} = 0.42\,\mathrm{mWs}$.

The average energy spent for reception per one message can be calculated as

$$E_{\mathrm{Rx}} = P_{\mathrm{Rx}} \frac{N_{\mathrm{As}}^2}{R_{\mathrm{Rx}}}\,, \tag{15}$$

where, $P_{\mathrm{Rx}},\ N_{\mathrm{As}},\ R_{\mathrm{Rx}}$ are – power during reception, the average number of binits in supported message per one transmitted message in payload direction and reception rate in binits per second, respectively. The overall energy spent in the supported node in case that the receiver is spending energy only during the arrival of the supporting message is $E_{\mathrm{O}} = E_{\mathrm{Tx}} + E_{\mathrm{Rx}}$.

In Example 1: $E_{\mathrm{Rx}} = 0.1815\,\mathrm{mWs}$ giving $E_{\mathrm{O}} = 0.6815\,\mathrm{mWs}$, while in Example 2: $E_{\mathrm{Rx}} = 94.48\,\mathrm{mWs}$ giving $E_{\mathrm{O}} = 94.90\,\mathrm{mWs}$.

It is evident that in Example 2, the solution with support feedback communication is less efficient than the transmission without it. But if we change the interval in which the guessing is made (interval for which the Huffmann code is constructed), we will get different results.

For example if the interval is $\langle 95, 105 \rangle$, we will get the following results. The Huffman code from which codewords are used as support messages are in Tab. 4. The average length of its codewords is 1.4732 binits. The average length of support messages is 6.2433 binits. The average length of messages transmitted in the payload direction is 4.7814 binits and the average number of binits in each supportive message per one message in the payload direction is 6.2433. In this case $E_{\mathrm{Tx}} = 1.94\,\mathrm{mWs}$, $E_{\mathrm{Rx}} = 9.53\,\mathrm{mWs}$ and $E_{\mathrm{O}} = 11.46\,\mathrm{mWs}$, that is slightly less than $E_{\mathrm{Txm}} = 12.01,\mathrm{mWs}$.

Table 4. Huffman code in Example 1

k	$P(k)$	codeword	codeword length n_k
95	0.0360	0011	4
96	0.0375	0101	4
97	0.0387	0111	4
98	0.0395	101	3
99	0.0399	000	3
100	0.0399	111	3
101	0.0395	110	3
102	0.0387	100	3
103	0.0376	0110	4
104	0.0361	0100	4
105	0.0344	0010	4

From these examples we can conclude that not all cases of feedback support communication will bring a gain. For a valid energy consumption estimation the real parameters of the transceiver used also have to be taken into account. In other words the system has to be adaptive and it should be possible to switch between modes of operation with and without feedback support. An appropriate protocol has to be designed.

5 Conclusions

In this paper a method for saving energy in the payload direction thanks to supportive transmission in the opposite direction was analyzed. In contrast to previous publications the energy spent during reception was also taken into account. In order to get numerical results concrete values of power needed for transmission and reception were used. The input values for the analyses were taken from the VHF/UHF Transceiver specification, produced by ISIS [7]. Different examples with different Poison distributions of transmitted values were analyzed. The main conclusion from the results is that the feedback support communication in some cases will bring gain while in others not. It depends on the distribution of the random variable, on the rate between energy expenditure in the supported node during transmission versus the receiving mode and also on the design of the communication protocol. Particularly it is important to choose the interval of transmitted random variable values in which the support by guessing will be performed. Based on these conclusions it seems appropriate to make the methods and consequently the corresponding protocols adaptive. It means not only that the design of protocol should be adapted to the mentioned parameters but also in some cases the transmission should be switched to direct transmission without any support in the feedback direction. If the supportive mode is used significant energy savings could be achieved however. In the analyzed Example 1 the energy spent with support is four times smaller than the minimal energy without support which was calculated using source entropy even if the energy spent for reception is included.

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References

[1] P. Farkaš, K. Farkašová and E. Ružický, "Energy Saving Transmission Technique for Poisson Distributed Data Exploiting Supportive Transmission in Feedback Channel", *18 International IEEE Conference and Workshop in Obuda, on Electrical and Power Engineering (CANDO-EPE)*, 2018, pp. 45-48, doi: 10.1109/CANDO- EPE.2018.8601141.

[2] P. Farkaš, K. Farkašová and E. Ružický, "New Transmission Technique which can Save Energy in Uplink Thanks to Supportive Transmission in Downlink", *2018 International Symposium ELMAR*, pp. 11-14 doi: 10.23919/ELMAR.2018.8534682.

[3] P. Farkaš and F. Halcin, "Communication techniques for wireless sensornetworks using distributed universal compaction algorithms", *3rd International Conference on Signal Processing and Communication Systems*, pp. 1-6, 2009, doi: 10.1109/ICSPCS.2009.5306368.

[4] D. A. Huffman, "A Method for the Construction of Minimum Redundancy Codes", *Proceedings of the IRE*, vol. 40, no. 9, pp. 1098-1101, Sept. 1952, doi: 10.1109/JRPROC.1952.273898.

[5] C. E. Shannon, "A Mathematical Theory of Communication", *Bell System Technical Journal*, vol. 27, pp. 379-423, 623-656, July, October, 1948.

[6] M. Cheraghchi, "Expressions for the Entropy of Basic Discrete Distributions", *IEEE Transactions on Information Theory*, vol. 65, no. 7, pp. 3999-4009, July 2019, doi: 10.1109/TIT.2019.2900716.

[7] https://www.isispace.nl/product/isis-uhf-downlink-vhf-uplink-full-duplex-transceiver, Accessed: Oct. 14-th, 2021.

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