Pilot signal detection in Wireless Sensor Networks

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***Abstract****.* **In this paper was investigated pilot signal detection results recovery after rather different receivers in wireless sensor networks. The known receivers compute the decision statistic provided by correlating pulses from adjacent frames and summing the contributions from all the frames of a symbol. In our cases we assume, that synchronization is consisted with providing accurate timing for the correlation computations at receiver for output signal energy concentration. At the receiver output we have pulse with some kind noise distribution or output signal modulation. Results of that were utilized for determined signal and for determined method of detection (single signal detection). It is considered three cases signal detection:** **constant amplitude signal without restrictions on the characteristics of noise variance: the same signal with normal noise distribution; the same noise distribution and for sinusoidal enveloping of modulated signal. The analytical formulas were obtained for catching right pilot signal in all cases and optimized value of cоmparator threshold.**

*Atslēgas vārdi: pilot signals, detection, sensors, wireless networks .*

 I. Introduction.

UWB communication uses short timed electromagnetic pulses, without a carrier signal, to transmit data. Current UWB data modulation schemes involve manipulating the pulse’s time

position, phase or amplitude [1-3,5]. The pulse sequence is determined by a pseudorandom sequence that represents the transmitted binary information. The use of pseudorandom sequences to represent binary data lowers the overall data throughput rate. The paper [1] presents a wireless sensor node architecture that uses a novel UWB data modulation scheme based on pulse shaping. In [3] was proposed method of sinhronization ,which provides the decision statistic by correlating pulses from adjacent frames and summing the contributions from all the frames of a symbol. In [4, 6] was implemented a concurrent multiuser access scheme instead of a mutual exclusion method such as TDMA and random access. For multiuser interference, here was established a model to adaptively adjust the data transmission rate to generate the expected signal to interference noise ratio at the receiver side for reliable communications. We assume, that our appoarches could be based on [3] and [6] results. We also propose to implement simple comparing with threshold received single output signal for detection pilot signal presence.

 II. Problem statement.

Let’s take a look at pilot signal detection process. Conditions are: signal S is overlaid with additive noise β.The detector computes the decision statistic provided by correlating pulses from adjacent frames and summing the contributions from all the frames of a symbol. In our cases we propose, that synchronization is consisted with providing accurate timing for the correlation computations at receiver for output signal energy concentration. Procedure of detection the signal is that time moment is taken as pilot signal instantaneous value capture timeline start-point; this value is believed to be predefined. For real signals the inertia of comparators (its’ timing resolution) is considered significantly smaller than S(t) length, so that it could be taken as a=const. In this case, the pilot signal comparator with a detection threshold of and definition range of will give out logical “1” at the detection start if the pilot signal is detected (α+β) or logical “0” – if not (only β). Now it can to find the probability of false pilot signal detection. is taken as noise distribution, – noise and signal sum distribution. In this case conditional probability to get the result 1 is:

 (1),

and conditional probability of getting result 1, if no signal is detected:

 (2)

Full probability of error is:

 (3)

where p (a), p(0) is corresponding predefined probabilities of pilot signal presence or absence.

 III. Detection approaches.

From listed above we can define that *W a (x) = W0(x-a)*, supposing that *p (a)=p(0)=0.5*, so we can calculate:

 (4)

Probability distribution has a dimension of x-1. If we define a new variable , we can define a new dimensionless function , that can be expressed as:

where is noise rms,

,

where M – expected value, D –variance.

From these formulas we get:

 (5)

where

Integral is an upper limit function, which we will define with Both and are positive, so this function is constantly increasing against it’s arguments. In this way, the probability of an error decreases, as increases.

By defining a signal-noise ratio we can rewrite (5) in following manner:

 (6)

As follows, the percent of catching right pilot signal grows with a growth of a signal-noise ratio. No restrictions on were on the characteristics of noise variance.

In order to minimize error probability it is needed to find signals definition range, where it is minimal. The argument, which is a border of that value is threshold *x0*. So, to minimize the probability it is enough to differentiate (4) by *x0*:

By equalizing this differential to 0 we can get equation for *x0* values, which are corresponding *Perr* extremums. But first it is needed to find, what extremums this are. In order to do so, it is needed to find a second derivative of (4)

.

If this value is positive, then point on abscissa, which is:

is minimum of ; if it is negative – then maximum. Supposing, that *p(a)=p(0)* we will write down the conditions of minimum:

If this condition is met, then optimal value can be calculated, using this formula:

 (7)

In this case, the deviation from *x0* value, satisfying equation (7), only increases error probability. We have

So we can rewrite it as

If is even function, if we change a sign in equation’s right part - both parameters stay positive. If we equalize them, we can find:

For this occasion, supposing, that *p(a)=p(0),* from formula (4) we get:

 (9)

Or

 (10)

Basing on (9) we can also define the probability of the error as:

 (11)

By passing to the dimensionless functions we can define (10) as:

, (12)

 where

From formula (12) is follows, that the probability of error depends only on noise distribution (function f) and signal-to-noise ratio (argument )

This result is obtained only for determined signal (constant value *a*) and for determined method of acquisition (one-shot acquisition). Because of that, choosing of method or signal form has no influence on this formula.

For example, let’s have a look at the occasion of noise with normal distribution:

Dimensionless function of distribution will look like:

The probability of error would be:

or

 (13)

where , probability integral, also known as Laplace function or Cramp function,

 (14)

For calculating at low error probability rates asymptotic expansion:

If we define the maximum probability for maximal probability detection of signal,

Asymptotic expression is of following type then:

 (15)

Where

In the case of sinusoidal signal readings of the enveloping will be compared, whether there is signal or there is not. Feature of the given case is that distribution for enveloping are characterized by different functions for the case when there is signal and for the case when there is no signal.

Where and are distributions and generalization Relay’s distribution

 (16)

 (17)

Means the relation between signal-noise in receiver

Assuming (to keep simpler):

We will have threshold equation of the following kind

Or in the non-dimensional functions

By using formulas (16) and (17) here, we will get the following transcendent equation for threshold

, where (18)

 IV. Conclusion.

# Analysed and estimated probability theory methods which are employed to analyze the process of pilot signal detection in wireless sensor networks.

# Approaches was considered for resolving conflicts in pilot signal detection process for following main cases: constant amplitude signal with restrictions on the characteristics of noise variance: the same signal with normal noise distribution ; the same noise distribution and for sinusoidal enveloping of modulated signal.

Obtained and analysed the analytical formulas, which can be used for catching right pilot signal in all cases above mentioned and optimized value of comparator threshold.

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**Raksta virsraksts. V.Zagurskis, R.Taranovs, D.Bļizņuks, (RTU),** **Pilota signāla novērtēšana bezvadu sensoru tīklos**

Šajā referatā bija izpētīta pilota signāla noteikšanas rezultātu iegūšana pēc atšķirīgiem uztvērējiem bezvadu sensoru tīklos. Zināms, ka uztvērēji aprēķina lēmumu statistiku, ko saista ar impulsiem no blakus esošajiem kadriem (frāmjiem), summējot impulsu ieguldjumus visos frāmjos. Mūsu gadījumā mēs pieņemam,ka sinhronizācija sastāvēja no precīza laika atbilstības aprēķinos uz uztvērēju izvades signāla enerģijas koncentrācijas. Uztvērēja izejā mums ir impulss ar dažāda veida trokšņu izplatīšanu vai izvades signāla modulāciju. Rezultāti tika izmantoti noteiktam signālam un noteikta metode tā noteikšanai (vienreizējs signāls).Izskatīti trīs gadījumi signāla noteikšanai: pastāvīgas amplitūdas signālu bez ierobežojumiem attiecība uz trokšņa funkciju: tas pats signāls ar gausa dispersiju; tā paša trokšņa funkcija un sinusoīdāla modulēta signāla. Analītiskās formulas tika iegūtas, lai noteiktu tieši pilota signālu visos gadījumos un optimizētu kоmparatora sliekšņa vērtību.

**Аннотация. В.Загурский, Р.Таранов, Д.Близнюк , РТУ, Детектирование пилот сигнала в беспроводных сенсорных сетях.**

В данной работе был исследован результат детектирования пилот сигнала у разные приёмников в беспроводных сенсорных сетей. Известно, что приёмник рассчитывает статистику связанных с импульсами смежных кадров (фреймов), интегрируя вклад импульсов всех кадров. В нашем случае, мы предполагаем, что синхронизация состояла из точного задания момента времени появления выходного сигнала приемника с концентраций энергии этого сигнала. На выходе приемника мы имеем импульсный сигнал с различными типами распределения шума и/или модуляции выходного сигнала.Полученные результаты были использованы для конкретного сигнала и метод его детектирования (одиночный сигнал). Аналитические формулы были получены для непосредственного определения пилот-сигнала и оптимизированного порога компаратора.