THE ESTIMATION OF BOUNDARY VALUES OF DUTY CYCLE IN DISTRIBUTED CONTROL SYSTEMS WITH TREELIKE TOPOLOGY WORKING UNDER ZIGBEE

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Abstract

We considered a distributed control system, which consists of a set of sensors. There were the basic features of networks working under ZigBee were given and the bounds of duty cycle duration for tree-like network with cyclic interrogation working under ZigBee were calculated.

I. INTRODUCTION

Nowadays the problem of working out new devices for environment control is of big interest. It is connected with the general growth of criminality in the world, increase the number of technogenic accidents, and also with a large number of applied problems which require the control of a great number of targets. Special focus is given at wireless monitoring systems (MS). They allow to supervise the targets which are at a sufficient distance from central supervision station, and also simplify the process of expansion of a such system. Usually, such a network consists of a set of independent elements of control (sensors). Each sensor is both a message source, and a repeater of the messages arriving from other sensors [1].

There are a few ways of transfers management in sensor networks. Now the stack of protocols ZigBee is quite popularity. This stack has a big flexibility and universality. Analysis of boundary values of duty cycle in sensor networks working under ZigBee is of big interest. That is why this characteristic defines the speed of processes, which can be controlled.

II. DESCRIPTION OF NETWORK MODEL

In this work the networks with treelike topologies were considered. That are the networks whose graphs of audibility have no cycles. The root node of a tree is the base station (BS). Messages arrive from the sensors which are on the lower levels through a chain of sensors which are on higher levels (fig. 1).

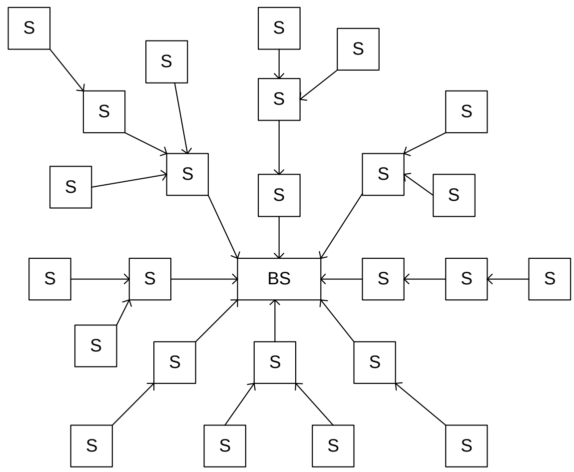

Fig. 1. Data transfer through a chain of sensors

Sensors are inquired cyclically. Let’s consider the messages to be relayed entirely without aggregation. Acknowledgments are absent. The network structure is constant in time.

III. BASIC FEATURES OF NETWORKS WORKING UNDER ZIGBEE STACK OF PROTOCOLS

In 2003 ZigBee alliance was founded. The alliance develops the global specification of stack ZigBee for reliable and power economic wireless applications using the mechanism of transfer of messages IEEE 802.15.4 [2,3]. In networks under control of ZigBee information exchange can be optionally set in one of two variants: synchronous (a beacon-enabled mode) and asynchronous (a nonbeacon-enabled mode). Each of the modes is characterized by an area of application and a set of parameters. In our model it is more expedient to use a synchronous mode. In a synchronous mode (a beacon-enable mode) data transmission is carried out by means of a sequence of the superframes whose time characteristics are appointed by base station. Each superframe can be divided in two phases: active and inactive. During the inactive phase all devices of a network are in a sleeping mode.

In the active phase it is possible to allocate three frames (fig. 2):

1. An operating segment or a beacon;
2. An interval of competitive access (contention access period, CAP);
3. An interval free from a competition access (contention free period, CFP).

During the Beacon-frame the base station transfers to devices of the cluster the message containing the information on time parametres of the superframe (duration of the superframe, duration of interval CAP, whether interval CFP is included in the superframe and, if it is included, its duration etc.).

During an interval of competitive access, the devices transfer the messages according to the algorithm of carrier-sense multiple access with collision avoidance, CSMA/CA. In this interval commands and asynchronous data are transferred. Besides, new devices require inclusion in the network in this interval. Interval CFP is divided into a sequence of the guaranteed timeslots (GTS) distributed between the devices which have sent inquiry about the reception of the guaranteed time slot. In the operating segment the moment of the beginning and duration is set for each of them. The appointment of GTS to the device means that no other device in this moment can work for transfer. Work in the range of CFP is appointed to the devices which are sensitive to delays.

The function of relaying the beacon received from base station is assigned to the intermediate sensors. Thus, the intermediate sensors are the participant of the incoming superframe and the initiators of outgoing superframe (fig. 3).

Time characteristics of the superframe such as duration of the superframe (SD), starting time of the proceeding superframe (StartTime), an interval between beacons (BI) are specified by base station and are transmitted in a beacon. In a network all superframes have identical time characteristics.

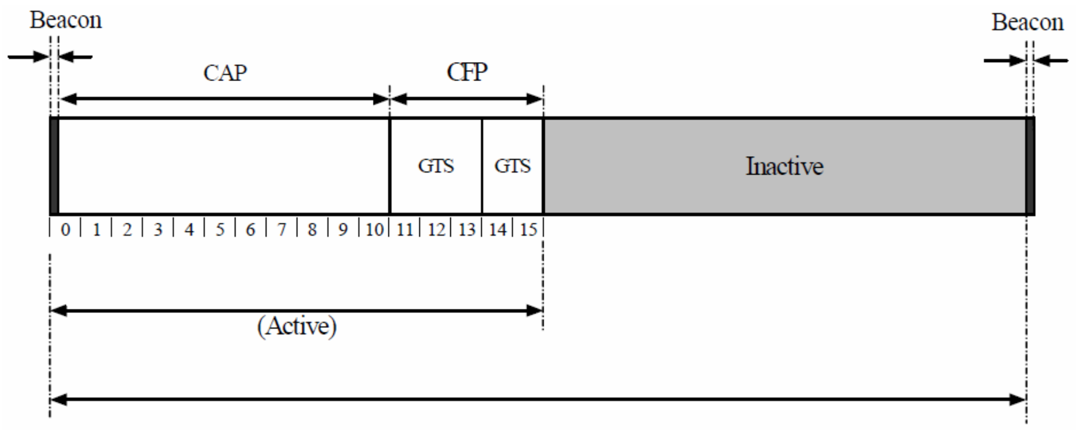

Fig. 2 Structure of the superframe

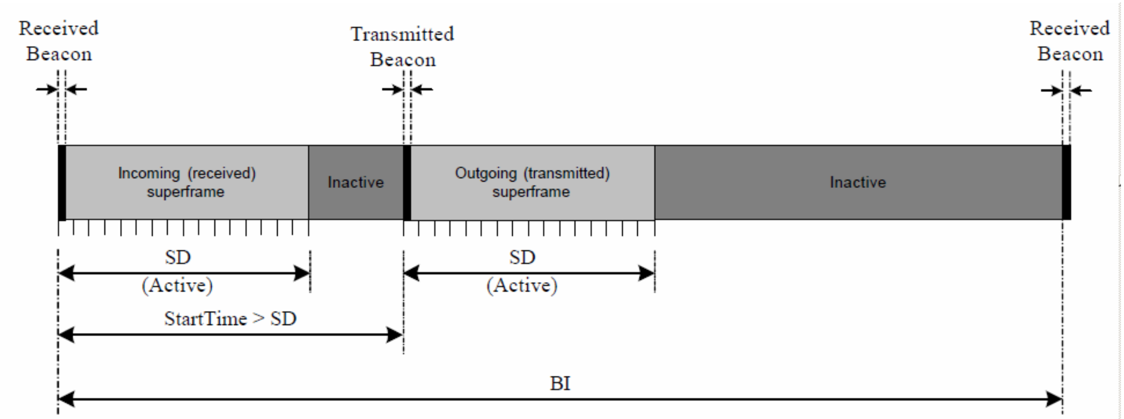

Fig. 3 Interaction of incoming and outgoing superframes

IV. THE ANALYSIS OF BOUNDARY VALUES OF A DUTY CYCLE

A cycle in such a network begins with the superframe in which the base station inquires sensors of the first level. After that, at the second stage, sensors of the first level initiate superframes in which they inquire affiliated sensors of the second level etc. On of the features of a stack of protocols ZigBee is that all superframes in a network should have equal duration. Obviously, that fastest the interrogation cycle will take place if starting time is minimized, and if frame CAP is excluded and each sensor is appointed its own GTS in frame CFP. Thus, duration of frame CFP should be enough for the greatest possible number of transfers in the network. The greatest number of transfers is carried out in the superframe where the base station interrogates sensors of the first level. These sensors transfer their messages, and the messages of all the affiliated sensors. Thus, duration of interval CFP cannot be chosen smaller than $N\tau$ seconds, where N – number of sensors in a network, τ - time of transfer of one message. The interrogation cycle then will consist of k stages of $N\tau$ seconds, where k – number of levels in a tree.

Thus, in a sensor network with treelike topology and cyclic interrogation of devices it is impossible to organize interrogation with a period less than $kN\tau$ seconds. The total inequality defining boundary values of a duty cycle results in the following formula: $T_C \geq kN\tau$.

V. CONCLUSION

It follows that in designing of a sensor network it is expedient to minimize the number of levels in a tree which is not always possible. Now monitoring systems covering an area of several square kilometres are being developed [4]. As the range of action of a sensor usually does not exceed hundred meters, a few dozens relayings (levels) for maintenance of connectivity of the network are required. From the resulting formula t follows that in a large monitoring system whith a big numbers of levels, working under the schedule [5, 6] allows to sufficiently reduce the interrogation period in comparison with working under ZigBee (with a great number of sensors – more than in $k/3$ time, k – number of levels in the tree).

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