DUTY CYCLE ESTIMATION FOR RADIOCHANNEL DISTRIBUTED SYSTEM OF DATA COLLECTION WITH CENTRAL CONTROL

Evgeny Bakin

Saint-Petersburg State University Of Aerospace Instrumentation,
Saint-Petersburg, Russia
tel: +7-812-735-02-11
jenyb@mail.ru

Abstract

There is considered a distributed system of data collection, which consists of set of identical elements of control. Each of them is both data source and relay station for the data from another EC. There were calculated bounds of duty cycle length for tree-like network with cycle scan of EC.

I. INTRODUCTION

Nowadays distributed systems of control are widely used. As a part of them there is a subsystem of collecting the data, which reflects a condition of controlled object. Distributed systems of environment parameters control (DSEPC) usually consist of a set of identical elements of control (EC), united in a network. Element of control is an autonomous wireless device, which usually contains digital sensor, microprocessor, memory, transceiver, antenna and battery. EC's purposes are: measuring an environment physical parameter in a fixed point or area, primary processing of measurement results, transmitting the data to a base station (BS) and relaying of messages from another ECs.

II. DSEPC FUNCTIONING

Periodically, each EC forms a message to represent the current state of controlled object, and transmits it to the BS. It can be, for example, sensor's reading, signal of alarm etc. Duty cycle is a time of collecting messages from the whole network.

The shorter duty cycle the more often an information updates on BS and more high-frequent parameters we can control. Autonomous work of EC makes energy consumption for transmition a critical factor. Battery discharge causes EC becoming out of order. In this case a network segment that transmits messages through discharged EC can become unavailable for BS. That is the reason why energy consumption and duty cycle are to be minimized.

Nowadays ZigBee networks are widely announced on a market of IT-products. They are supplied with options of self-organization and self-restoration. Software of ZigBee devices let them to find each other forming networks and make new routes in case of some units becoming disabled. [1]. Methods of solving these problems are described in ZigBee's stack of protocols. [2].

ZigBee like network can be used for collecting information from the controlled object.But it is also characterized by a few shortcomings: due to random multiple access usage and decentralized transmits management, the most part of energy and time is used for protocol support. In case of collision one message is to be transmitted for several times. It causes speed decrease and energy-consumption growth [3].

So, if there is no necessity in random multiple access usage and central management is available, energy-consumption and duty cycle can be significantly decreased by using a fixed schedule of transmits, formed by a base station.

III. PROBLEM FORMULATION

We are considering a network with a tree-like topology. Duty cycle is split up into slots – time intervals, equal to message duration. Messages transfer is strictly synchronized and each transfer is appointed to a definite slot. In one slot EC can either receive or transmit the message. In case of simultaneous receiving messages from a few closely situated ECs, we consider that no one of the messages is received trustworthy. This situation is named "collision" (look at Fig. 1).

Here EC3 transfers a message EC4. Simultaneously EC1 transfers a message to EC2, and EC5 – to element EC6. There is a mixture of EC3's, EC1's and EC5's signals in EC4's receiver. So, this transfer is not trustworthy.

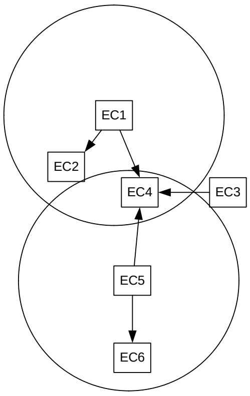

Fig. 1 An example of collision

Collision presence causes repeated transfers. For energy-consumption decreasing transfer schedule, excluding collisions, is considered. So in this network number of transfers will be minimal. The subject of analysis is duty cycle length when working with a schedule.

IV. DUTY CYCLE BOUNDS CALCULATION

There is considered a network, consisting of a base station (which is a root of a tree) and N ECs. For duty cycle duration T_c (in slots) a lower bound is proved to be $T_c \geq N$.

This statement follows from the fact that in each slot BS can receive just one message (otherwise a collision appears). Let's show that for the network with full symmetrical tree topology a lower bound can be reached. For it an auxiliary theorem will be proved.

Theorem. For the tree D_N that consists of N ECs, there is a schedule R_N with duration T_N . Then for the tree $D_{k(N+1)}$, that consists of k sub-trees D_N (look at fig. 2), a schedule with duration $T_{k(N+1)} = k(T_N + 1)$ can be found.

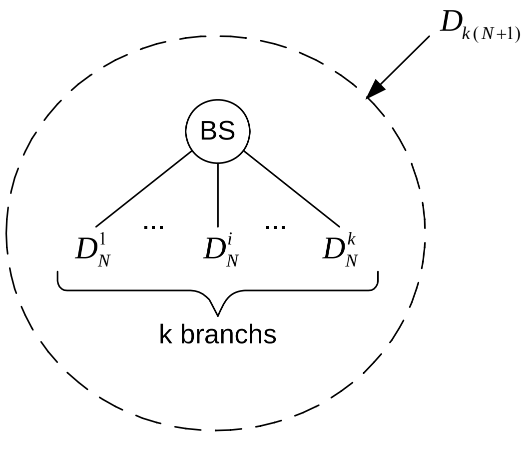

Fig. 2. Tree $D_{k(N+1)}$, consisting k sub-trees D_N

Proof. A root node of tree D_N becomes a first-level node of tree $D_{k(N+1)}$. That is why, tree $D_{k(N+1)}$ will have strictlyровно k nodes on a first level. We name them as a_m, where $m = \overline{1,k}$. Let's divide the duty-cycle of tree $D_{k(N+1)}$ on k subgroups. Here i-*th* slot of duty cycle belongs to a subgroup number $i \bmod k$. Then during the slots of j-th subgroup, j-th branch of tree $D_{k(N+1)}$ works according to a schedule R_N so that messages from this branch are collected to EC a_j, that is situated on a first level. During the slots of subgroup number $(j+1) \bmod k$, EC of first level of j-th branch transfers messages to BS (look at fig. 3).

$0 \bmod k$	D_N^{k-1} by R_N	$a_{k-1} \to BS$
$1 \bmod k$	D_N^{k-1} by R_N	$a_0 \to BS$
$2 \bmod k$	D_N^{k-1} by R_N	$a_1 \to BS$
...	...	...
$(j-1) \bmod k$	D_N^{k-1} by R_N	$a_{j-2} \to BS$
$j \bmod k$	D_N^{k-1} by R_N	$a_{j-1} \to BS$
$(j+1) \bmod k$	D_N^{k-1} by R_N	$a_j \to BS$
...	...	...
$(k-1) \bmod k$	D_N^{k-1} by R_N	$a_{k-2} \to BS$

Fig. 3. Structure of sub-cycle for tree $D_{k(N+1)}$

So, full duty-cycle consists of $(T_N + 1)$ sub-cycles with k slots every, all in all $k(T_N + 1)$ slots. As was to be proved.

This theorem helps us to find a duty cycle duration for arbitrary full symmetrical tree with p levels and degree k. Obviously, that for on-leveled tree with degree k duty cycle duration is $T_k = k$ (ECs transfers one-by-one). Then for full symmetrical two-leveled tree with degree k duty cycle duration is

$T_{k(k+1)} = k(k+1) = k^2 + k = \sum_{i=1}^{2} k^i$, for three-leveled - $T_{k(k^2+k+1)} = k^3 + k^2 + k = \sum_{i=1}^{3} k^i$ etc. For p-leveled full symmetrical tree $T_{k(T_{k-1}+1)} = kT_{k-1} + k = \sum_{i=1}^{p} k^p$, e. g. N.

Now we are to find an upper bound of duty cycle duration for tree-like network. It is reached for a tree with minimal branching. In this case all ECs are arranged in line (look. fig 4).

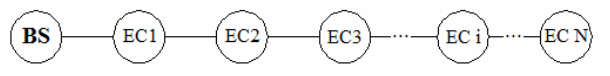

Fig. 4. Linear tree

EC1, EC2 and EC3 cannot transmit simultaneously. Element EC1 is to make N transfers (for its message and for (*N*-1) transit messages), element EC2 – (*N*-1) transfer, element EC3 – (*N*-2) transfers. Due to impossibility of simultaneous work, not less then $N + (N-1) + (N-2) = 3N - 3$ slots are required for gathering information from the whole network.

Optimal schedule of message transfers for linear tree is based on idea that node number i transfers just in slots number $m = i \bmod 3$. In this case collisions are absent and duty cycle length is strictly $3(N-1) = 3N - 3$.

V. CONCLUSION

The research told that duty cycle length significantly depends on topology and on algorithm of transfers schedule forming. Duration of duty cycle for tree-like network doesn't exceed $3N - 3$ and in a particular case is to be calculated via simulation.

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