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ORGANIZATION OF DISTRIBUTED INFORMATION SYSTEMS THE AVIATION GAS TURBINE ENGINE

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Abstract—*The article deals with the method of distributed information systems organization the aviation engine, which is considered as a interaction of the components of the automatic control system in its technological activity. Due to the use of the ZigBee interface communication, the research of the electronic control system according to the given index of transitive packet has been carried out and the distributed control system usage of the aviation engine has been proposed. Through the simulation, the dependences of the quality the transmission packet request on the parameters of the maximum flow the distributed net for closed systems with switching bandwidth were revealed; detected dependencies can be used to form a mathematical model of replacing two-way flow and one-way flow information transmission to configure gas turbine engine distributed net from the condition of fulfilling the specified switching bandwidth.*

Index Term—automatic control system; aviation gas turbine engine; distributed system; nets models; bandwidth.

I. INTRODUCTION

Most distributed information systems (DIS) for automated control system gas turbine engine (ACS GTE) can be represented as complex intelligent systems containing a large amount of special information. For such objects, it is necessary to properly manage the flow of information, as requested by users of the system, and the response of the system to these requests. Another requirement for such systems is to design it in such a way that it is not only a supplier of the required data, but also, in turn, adapts to the changing needs of users based on an analysis of the use of itself. Also, the system should put forward on the basis of the information received the requirements for its completion – development over time in the framework of modern technologies, and formulate recommendations for adding, changing, deleting information in the framework of its immediate purpose.

It should be noted that existing methods for developing such systems have a number of limitations and disadvantages [1], [2]: irrational management of DIS can lead to difficulties in perceiving and searching for information; the lack of analysis by the query system does not allow a complete picture of the use of information; the complexity of the development and administration of DIS leads to partial or complete loss of information, without the possibility of its recovery; the significant difficulty of applying approaches in developing DIS based on the unification of rules, trends and formats.

For solving such problems, taking into account the drawbacks and limitations listed above, it is necessary to develop a universal technique for creating software tools for intellectual interaction in DIS based on existing methods and algorithms – creating a modular system for collecting and processing measurement information using the interaction interface in the ACS GTE.

II. PROBLEM STATEMENT

Particularly important task of the design and creation the ACS GTE that integrates the functional and informational representation of the system within the framework of a single model is the communication problem, the solution of which is related to ensuring the necessary interaction of the components of the ACS in its technological activity. DIS for ACS GTE is combining the communication network and the software and hardware components – information management and processing subsystems of the ACS. In distributed information systems, the components of the ACS are represented not by their internal structure, but by parameters, metric characteristics and properties that determine the interaction of the elements with each other, together affecting the performance of the used communication network. Establishing the dependence of network performance indicators on the characteristics of applied tasks generated by network traffic is one of the main tasks of analysis in the design of DIS.

Currently, several international companies specialize in the development of DIS systems for ACS GTE, including the company National Instruments (NI), Advantech, SparkFun Electronics (USA), ICP DAS (Taiwan), Radiocrafts AS (Norway) [2], [3].

So, the aim of these research – define the techniques for the organization the distributed information system of the optimization the correct usage the GTE wireless piconet and estimate the efficiency of the control processes the aviation gas turbine engines using wireless technology and distributed information system.

III. Distributed Information-Measuring System

A block diagram of a distributed system using XBee modules from Radiocrafts AS is shown in Fig. 1.

The system is based on the ZigBee interface, which is designed to create a radio frequency transceiver system based on RC232 protocol with UART interface for configuration and communication. The built-in RC232 protocol enables multi-point radial nodal communication with individual or broadcast addressing and signal integrity checking by checksum calculation. The communication channel can be used as a wireless replacement for the RS232/RS485 cable and accommodate XBee modules for the input/output (or only input or output) of the analog, digital and control information of the study object. The number of modules can be increased by using extension modules (trunk repeaters).

The system is connected to the Control Unit through one of its ports in the connection interface.

XBee modules have a built-in controller that runs on a program stored in energy saving memory. The modules have several modes of operation, which are set using commands from the Control Unit (configuration process).

XBee modules provide:

– communication and exchange of command information from the Control Unit via the communication channel;

– input and output of analog information using ADC and DAC converters with a certain error and frequency of measurements;

– input and output of digital information;

– counting the number of events and measuring the frequency of pulse signals;

– control of external devices by means of switching modules, including power;

protection of external devices from possible emergency situations by switching to the emergency mode with a fixed value of control and information signals and the system of automatic resumption of work.

Module software includes [3], [4]:

– command system for performing configuration operations, calibrating data channels, inputting and outputting information. The command structure is unified, although each module has distinctive commands that follow from the specifics of its purpose;

– utilities to simplify the procedure for debugging the system, check its performance, configure modules, channel calibration;

driver library (DLL), which allows the programming of modules to work in different software environments (MATLAB, Simulink, LabVIEW).

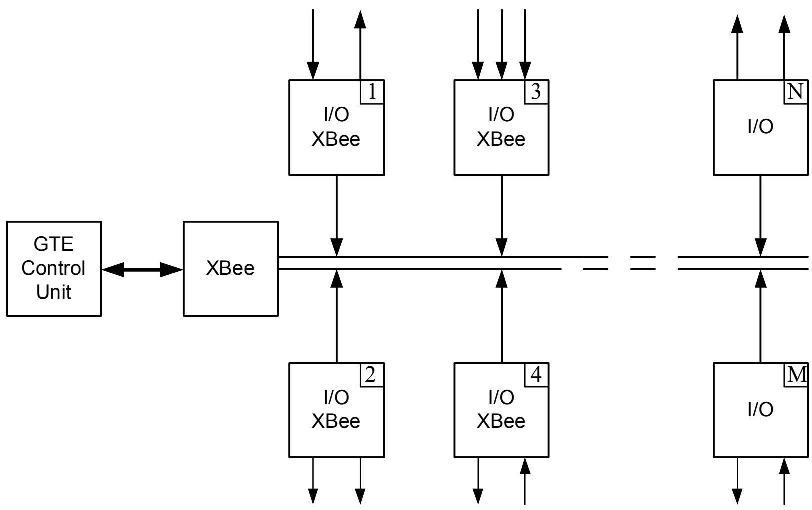

Fig. 1. Structural diagram of the distributed ACS GTE

Submission of commands can be performed by: user-developed programs, using utility programs in manual mode, as well as using library driver programs that can be built into the software modules.

Driver programs can be presented as programmable virtual tools that have input and output data, and can control both the data channel and directly the module of the distributed system.

The input of the FVI to control the data channel allocates the parameters of the com port: number, data rate, transmission format, bit control parity and bits need to use a stop bit. Module Management PVI Input is the control word and the data word that is supplied as arrays

Designing a distributed system is performed in the following stages:

– preparatory stage – connection of modules to the system and their configuration, verification of system performance, module calibration;

– software development – initialization and opening of the connection port, execution of the main program, closing the port;

– setup of the developed virtual tool and its documentation.

In Figure 2 presents a block diagram of the XBee Series 2 OEM RF module.

The XBee Series 2 OEM RF Modules [5] – [7] interface to a host device through a logic-level asynchronous serial port. Through its serial port, the module can communicate with any logic and voltage compatible UART; or through a level translator to any serial device (For example: Through a MaxStream proprietary RS-232 or USB interface board).

Devices that have a UART interface can connect directly to the pins of the RF module as shown in the Fig. 3.

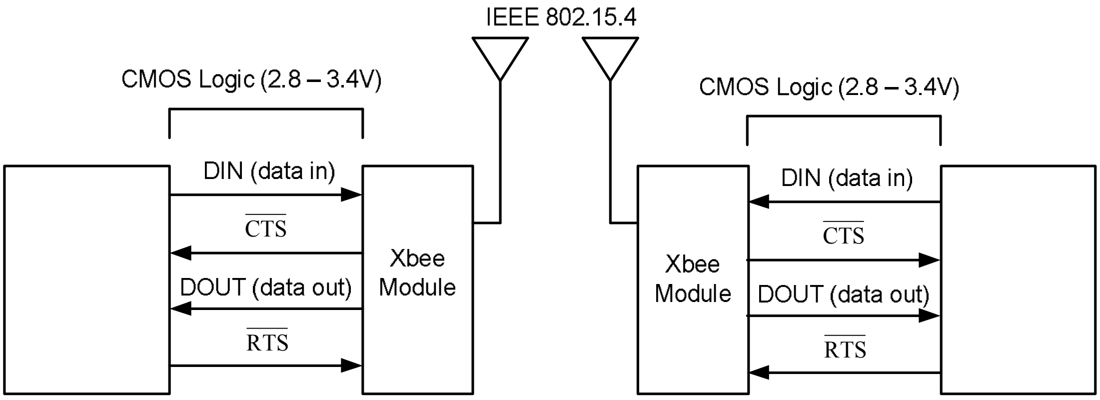

Fig. 2. System Data Flow Diagram for DIS environment

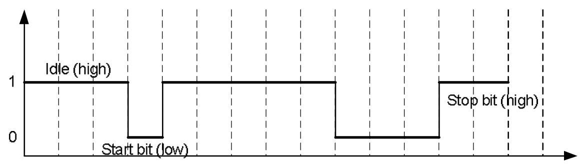

Fig. 3. UART data packet through the RF module

Data enters the module UART through the DIN (pin 3) as an asynchronous serial signal. The signal should idle high when no data is being transmitted.

Each data byte consists of a start bit (low), 8 data bits (least significant bit first) and a stop bit (high). The following figure illustrates the serial bit pattern of data passing through the module.

The module UART performs tasks, such as timing and parity checking, that are needed for data communications. Serial communications depend on the two UARTs to be configured with compatible settings (baud rate, parity, start bits, stop bits, data bits).

The XBee Series 2 modules maintain small buffers to collect received serial and RF data. The serial receive buffer collects incoming serial characters and holds them until they can be processed. The serial transmit buffer collects data that is received via the RF link that will be transmitted out the UART (Fig. 4).

Serial Receive Buffer [7], [8]

When serial data enters the RF module through the DIN Pin (3 pin), the data is stored in the serial receive buffer until it can be processed.

Hardware Flow Control (CTS) When the serial receive buffer is 17 bytes away from being full, by default, the module de-asserts CTS (high) to signal to the host device to stop sending data [refer to D7 (DIO7 Configuration) parameter]. CTS is re-asserted after the serial receive buffer has 34 bytes of memory available.

Serial Transmit Buffer

When RF data is received, the data is moved into the serial transmit buffer and is sent out the serial port. If the serial transmit buffer becomes full enough such that all data in a received RF packet won't fit in the serial transmit buffer, the entire RF data packet is dropped.

Hardware Flow Control (RTS) If RTS is enabled for flow control (D6 (DIO6 Configuration) Parameter = 1), data will not be sent out the serial transmit buffer as long as RTS (pin 16) is deasserted.

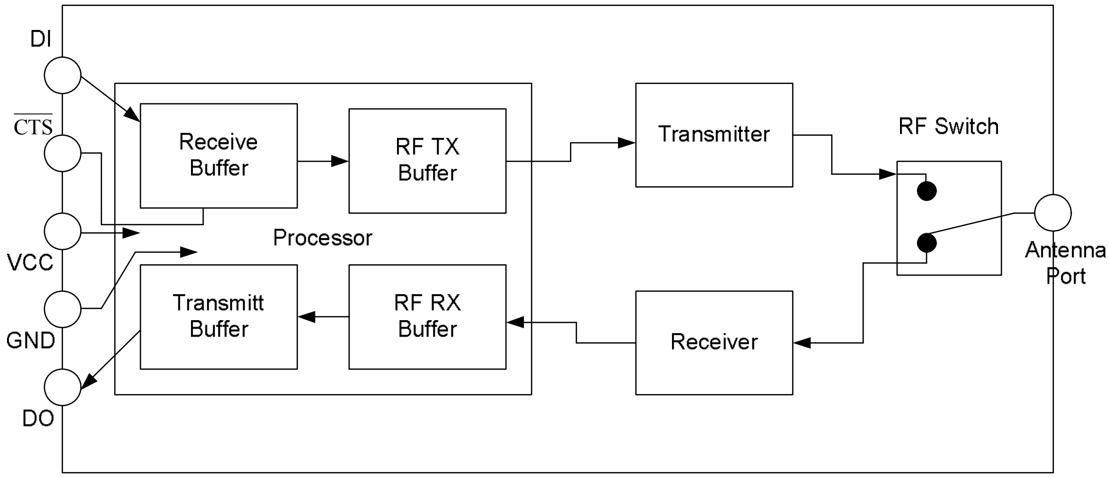

Fig. 4. XBee module structure scheme

IV. DATA FLOW TRANSMISSION FOR GTE DISTRIBUTED NET

For the optimum variant of information transmission, network nodes have the following characteristics [7], [9], [10]: c_{ij} is the request for transmission of a information unit for an channel of a network between nodes i and j, D_{ij} is the switching bandwidth of this channel is generally limited to $(0 \le D_{ij} \le \infty)$ (if there is no channel between these nodes i and j, then the switching bandwidth equal to zero if the flow is unrestricted by nothing, then the switching bandwidth goes to infinity). Obviously, in this case, the requirement to save the flow must be met – the total flow entering and leaving the channel should be equal. Let be x_{ij} the flow in the channel of the net, then for the transitive node of the network:

$$\sum_k x_{ki} - \sum_j x_{ij} = 0,$$

where k is a list of those that are entered j is a list of all the leaving channels for the node i.

For a flow in any channel must be:

$$0 \le x_{ij} \le D_{ij}.$$

For the start and end node, the condition is obviously necessary:

$$\sum_j x_{1j} = A_1,$$

where A_1 is the maximum output flow created by the initial node of the network, it must be less than the total switching bandwidth of all entering and leaving from the channels nodes

$$\sum_k x_{kn} = B_n,$$

where B_n is the maximum flow consumed by the end node of the network, it must also not exceed the switching bandwidth of the input channels.

There are different formulations of the optimization problem - minimizing the transmission request and maximizing the flow. Let be obtain, respectively, two formulations of the mathematical model of the problem.

1) Minimize the request:

$F = \sum_i \sum_j c_{ij} x_{ij}$ is the minimized objective function is the total transfer request. Limitation:

$A_1 = B_n$ is the flow cannot accumulate in the transitive nodes, i.e.

$$\sum_j x_{1j} = \sum_k x_{kn},$$

$0 \le x_{ij} \le D_{ij}$ is the switching bandwidth;

$\sum_k x_{ki} - \sum_j x_{ij} = 0$ is the saving flow continuity.

2) Maximizing the flow: $F = \sum_k x_{kn}$ is the maximized objective function – total flow entering the end node; $\sum_i \sum_j c_{ij} x_{ij} \le C_s$ is the total costs should not exceed the amount of means available C_s.

Limitation:

$A_1 = B_n$ is the flow cannot accumulate in the transitive nodes:

$$\sum_j x_{1j} = \sum_k x_{kn},$$

$0 \le x_{ij} \le D_{ij}$ by the switching bandwidth;

$\sum_k x_{ki} - \sum_j x_{ij} = 0$ is the saving flow continuity.

Consider the problem of finding the maximum flow for the nodes of the wireless ACS GTE, presented in Fig. 5, where the numbers indicate the maximum switching bandwidth of the network sections.

The given net diagram is partially oriented. In order to reach a mathematical model, it is necessary to transform a diagram into an oriented network. This can be done by replacing each undirected channel with a two-way flow of information transmission with two oriented by one-way flows, each with an initial switching bandwidth. The flows x_4 and x_5 have become one-way since the possibility of the opposite direction of motion in this task is insignificant for them.

The problem can be solved geometrically: according to the theorem, the maximum network switching bandwidth is equal to the minimum network switching bandwidth the network crossings. The analytical solution comes down to linear programming methods. In addition, it is possible to determine the corresponding flows in each channel of the network.

Comparison of the maximum possible flow leaving from the initial node of the network with the result of the solution (9 > 6) on Fig. 6 shows that this wireless network requires additional expansion for its switch.

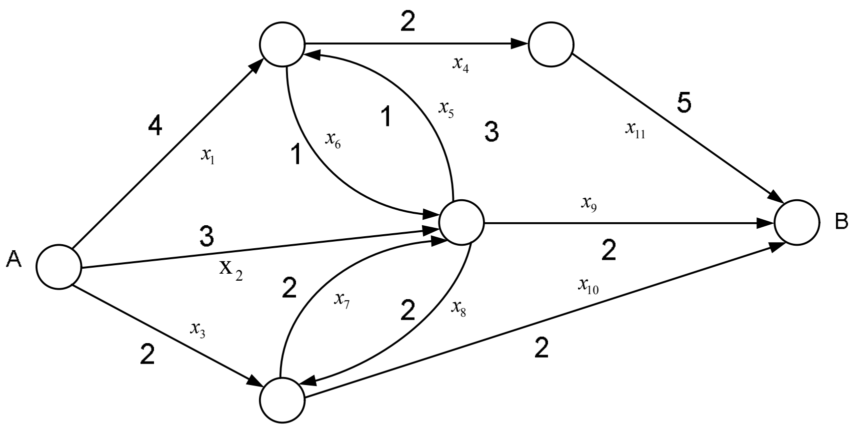

Fig. 5. Net diagram of the wireless ACS GTE

ORIGIN := 1 $\quad f(x) := x_9 + x_{10} + x_{11}$ $\quad i := 1..11$ $\quad x_i := 1$ $\quad$ Given

$x_1 + x_5 = x_4 + x_6$ $\quad 0 \le x_1 \le 4$ $\quad 0 \le x_2 \le 3$ $\quad 0 \le x_3 \le 2$ $\quad 0 \le x_4 \le 2$ $\quad 0 \le x_5 \le 1$

$x_2 + x_6 + x_8 = x_5 + x_7 + x_9$ $\quad 0 \le x_6 \le 1$ $\quad 0 \le x_7 \le 2$ $\quad 0 \le x_8 \le 2$ $\quad 0 \le x_9 \le 2$ $\quad 0 \le x_{10} \le 2$

$x_4 = x_{11}$ $\quad 0 \le x_{11} \le 5$ $\quad x_3 + x_7 = x_8 + x_{10}$

R := Maximize(f, x) $\quad$ f(R) = 6

$R^T =$

	1	2	3	4	5	6	7	8	9	10
1	2	3	1	2	0	0	1	0	2	2

Fig. 6. Finding the maximum flow for the nodes of the wireless ACS GTE

V. Conclusions

The analysis of the principles of constructing the distributed information systems, shown, that the use of wireless technology with defined data flow transmission provides a new approach to the design of control systems for aviation GTE and in contradistinction to traditional methods of control, it guarantees the possibility of solving a number of problems in conditions of uncertainty.

It is shown that XBee module built-in RC232 protocol enables multi-point radial nodal communication with individual or broadcast addressing and signal integrity checking by checksum calculation for GTE distribution net. This allows defining the module main functions and their software by the main steps for investigation the GTE distributed system: technical project, software development, setup of the developed virtual tool and its documentation.

The communication channel can be used as a wireless replacement for the RS232/RS485 cable and accommodate XBee modules for the input/output (or only input or output) of the analog, digital and control information of the study object. The number of modules can be increased by using extension modules (trunk repeaters).

On the basis of the data flow transmission for the stability and quality of control processes, a method for the organization of distributed information systems has been developed. For optimal tuning of the switching bandwidth of typical transitive nodes of the network according to the minimizing request channel and maximizing data flow, a wireless piconet system has been developed. The distributed laws for the data flow and transitive nodes of a automatic control system of aviation GTE are synthesized. These laws significantly expand the range of quality control in the control channels of GTE wireless net.

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С. С. Товкач. Організація розподілених інформаційних систем авіаційного газотурбінного двигуна

Розглянуто спосіб організації розподілених інформаційних систем авіаційного двигуна, який визначається як взаємодія компонентів системи автоматичного керування в її технологічній діяльності. Завдяки використанню інтерфейсу зв'язку ZigBee проведено дослідження електронної системи керування відповідно до заданого показника перехідного пакету та запропоновано використання розподіленої системи керування авіаційним двигуном. За допомогою моделювання виявлено залежності якості запиту пакета передачі від параметрів максимального потоку розподіленої мережі для закритих систем з пропускною здатністю комутації; виявлені залежності можна використовувати для формування математичної моделі заміни двостороннього потоку на односторонню передачу інформації із налаштуванням розподіленої системи газотурбінного двигуна за умови використання заданої смуги комутації.

Ключові слова: автоматична система керування; авіаційний газотурбінний двигун; розподілена система; мережеві моделі; пропускна здатність.

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С. С. Товкач. Организация распределенных информационных систем авиационного газотурбинного двигателя

Рассмотрен способ организации распределенных информационных систем авиационного двигателя, который определяется как взаимодействие компонентов системы автоматического управления в ее технологической деятельности. С использованием связи по интерфейсу ZigBee было проведено исследование электронной системы управления в соответствии с заданным индексом переходного пакета, и было предложено использование распределенной системы управления авиационным двигателем. В результате моделирования выявлены зависимости качества запроса пакета передачи от параметров максимального потока распределенной сети для закрытых систем с полосой коммутации; обнаруженные зависимости могут быть использованы для формирования математической модели замены двустороннего потока на одностороннюю передачу информации с настройкой распределенной сети газотурбинного двигателя при условии использования заданной полосы коммутации.

Ключевые слова: система автоматического управления; авиационный газотурбинный двигатель; распределенная система; сетевые модели; пропускная способность.

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