Dynamic reconfiguration of the graphical interfaces for Internet of Things

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The work carried out research and development of methods for the dynamic configuration of the smart thing's interfaces on the mobile devices with limited resources. This article describes a mathematical model of the environment for dynamic reconfigurable interfaces of smart things on mobile devices with limited resources, the method of assigning a set of basic interface elements to reconfigure interface of smart things and heuristic algorithm for dynamic smart thing's interface reconfiguration.

Keywords — Internet of Things; smart thing; interface; interface reconfiguration, dynamic recofiguration, energy effiency, data vizualization.

I. INTRODUCTION

Over the past 5 years there has been strong growth in the number of devices connected to the Internet. Number of Internet of things Assessment MIT Technology Review Business Report, by 2020 will exceed the number of smart phones and PC and will be about 28 billion devices. Cisco IBSG predicts that in 2020 there will be 50 billion devices connected to the Internet. It is important to note that these projections do not take into account the rapid development of Internet technology and devices. According to forecasts of BI Intelligence research company, in 2019 the economic impact of the development of IoT-sector will be expressed by $ 1.7 trillion. This growth will lead to a substantial increase in the volume of traffic on the Internet and to a corresponding increase in power consumption of all devices connected to the Internet. The topical directions in the field of the Internet of Things are the creation of new hardware platforms, development of specialized operating systems, development and optimization of application layer protocols, as well as the development of models and data visualization techniques in order to enhance the energy efficiency of the smart things, including mobile devices, to increase the time of their battery life [1][2][3].

II. MATHEMATICAL MODEL OF THE ENVIRONMENT FOR DYNAMIC RECONFIGURABLE INTERFACES

In this article, we consider the model of the dynamic reconfigurable interface for smart thing on a mobile device with limited resources.

Let dynamically reconfigurable interface for smart thing ***S*** be defined by the following model:

$$S = (R_s, D, E, L),$$

where $R_s = \{r_{s1}, ..., r_{sm}\}$ - set of elements, which are the types of mobile device resources;

$D = \{d_1, ..., d_n\}$ - set of smart things (set of data sources);

$E = \{e_1, ..., e_o\}$ - set of elements for the interface construction;

$L = \{l_1, ..., l_s\}$ - set of relations between interface elements and set of smart things.

Each resource is defined by a mobile device quantitative characteristic which can be attributed directly to the physical state of the device, e.g., battery capacity, memory capacity, processing time, or to the external environment for device such as communications bandwidth.

Each smart thing $d \in D$ is characterized by a set of values of its properties $d = \{d_{pj}, \forall j \in D\}$. The smart thing's property meant a quantity that defines one of the physical or logical smart thing's characteristics. A set of smart thing's property's values is transmitted to the mobile device, then there is a dynamic interface reconfiguration.

Each interface element $e \in E$ is a way to represent the smart thing's properties and set of mobile device resource consumption functions depending on the amount of the transmitted useful information $e = \{f_j (x), \forall j \in R_s\}$, $\boldsymbol{x}$ - the amount of useful information transmitted. The useful information transmitted in this case means the number of bits transmitted characterizing smart thing's property.

Each relation $l \in L$ between the interface element and smart thing's property determines the type of data transmitted and the amount of the transmitted useful information. Thus, each connection is characterized by:

$$l = \langle l_{dj}, l_e, l_t, l_v \rangle,$$

$l_{dj} \in D$ – certain smart thing's property;

$l_e \in E$ - certain element of the interface;

l_v - the amount of useful information transmitted;

l_t - the type of data for transmission.

Restrictions and parameters to the mobile device resources, as well as basic interface elements impact to certain resources is not the purpose of this paper.

Thus, the main proposed model's feature is that the dynamic interface reconfiguration process is considered as an efficient mobile device resources consumption.

Consider the proposed methods evaluation criteria reconfiguration basic interface elements. For some of the time interval considered $(t - \Delta t, t)$. The value Δt is chosen based on

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the intensity of the transmission properties of the smart things to the mobile device, time of interface reconfiguration and user requirements for interface quality. The low value of Δt allows to present the process of interface reconfiguration as a resources consumption process without the possibility of recovery. For example, the transfer of a large number of properties for a small time period reduces the total resource of the channel and the processor, while the alternating transmission properties over a long time period can turn channel and hold the processor, thereby affecting to a lesser extent on its residual lifetime.

Let $N_r(t)$ be the remaining life resource of the mobile device r at time t - Δt, and $L_r(t)$ - r resource consumption of the mobile device during the time interval (t - Δt, t). Introduce the index r resource consumption:

$$\psi_r(t) = \begin{cases} 1, if\ N_r - L_r \geq 0 \\ 0, if\ N_r - L_r < 0 \end{cases};$$

An indicator of the mobile device operation efficiency during the time interval (t - Δt, t) can be considered:

$$\psi(t) = \frac{\sum_{j=1}^{m} \psi_j(t)}{m},$$

m - number of mobile device types of resources.

If ψ (t) = 1, the device is functioning correctly if ψ (t) <1, then there is over-expenditure of one or more resources.

Thus, a particular case of the inefficient mobile device functioning is a full flow of its energy. Thus, the mobile device from a failure of the indicator can be defined as follows:

$$\psi_e(t) = \begin{cases} 1, if\ N_e - L_e \geq 0 \\ 0, if N_e - L_e < 0 \end{cases},$$

e - energy resource index.

An efficiency indicator of the mobile device during the time interval (t - Δt, t) in this case can be considered as the number of well-functioning basic interface elements, that do not allow resources overspending, the total amount of the basic interface elements:

$$\psi(t) = \frac{\sum_{i=1}^{n} \lfloor \psi_i(t) \rfloor}{n},$$

n - number of interface basic elements.

The proposed reconfiguration method smart thing's interface, optimizing the appointment of basic interface elements corresponding to the smart thing's properties on the criterion of minimizing the cost of energy to meet the requirements to limit the resources consumption.

III. THE METHOD OF ASSIGNING A SET OF BASIC INTERFACE ELEMENTS TO RECONFIGURE INTERFACE OF SMART THINGS

There is a dynamically configurable smart thing's interface in accordance with the model described by S = (Rs, D, P, L). It's necessary to find an interface basic element for each smart thing's property on the criterion of minimizing the total mobile device energy consumption.

The proposed method is based on the finding a set of basic UI elements problem transformation to the integer linear programming (ILP) optimization problem.

The function of the mobile device power consumption is generally defined by the following formula:

$$Z(x_{11}, x_{12} \dots x_l) = \sum_{i=1}^{s} \sum_{j=1}^{o} f_{je}(v_i) * x_{ij} \ (1),$$

x_{ij} - the variable that determines whether or not to be appointed as the j-th base interface element on the i-th smart thing's property;

s - number of smart thing's properties;

o - the amount of the basic interface elements;

e - energy resource index;

v_i - the amount of the transmitted useful information corresponding to the i-th smart thing's property;

f_{je} (v) - energy resource consumption function of the j-th basic interface element on the amount of useful information v.

The final task is to minimize the function **Z**, i.e. minimization of energy resource consumption

$$Z(x_{11}, x_{12} \dots x_{lb}) = \sum_{i=1}^{s} \sum_{j=1}^{o} f_{je}(v_i) * x_{ij} \rightarrow \min \ (2),$$

There are the following restrictions:

$$x_{ij} = \begin{cases} \dfrac{\text{1,if the j−th base interface element is assigned to the i−th smart thing's property}}{\text{0,if j− base interface element is not assigned to the i−th smart thing's property}} \end{cases}; \ (3)$$

$$\sum_{j=1}^{oi} x_{ij} = 1;\ \forall\ i \in 1..l;\ (4)$$

$$\sum_{i=1}^{s} \sum_{j=1}^{oi} x_{ij} * f_{jr}(v_i) \leq d_r;\ \forall\ r \in 1..m;\ (5)$$

The objective function **Z** is the total energy consumption of mobile device resources, provided that the mobile device has the initial stock of resources, resource recovery does not occur, and each resource cannot be overdrawn. The latter requirement is provided by (5).

The variable x_{ij} in (1), (4) is a boolean. It defines a basic interface element j whether selected or not. Restriction (3) is introduced to guarantee the integrality of this variable.

From the objective function, it is clear that because of the value minimization the best solution for all the variables x_{ij} will always have a value of 0. Restriction (4) is introduced for the exclusion of such a decision, which ensures that basic interface element has to be selected for each smart thing's property and, and thus it is unique. In addition, restrictions (4) and (5) ensure that the selected base interface element j in the subset of base interface elements capable of adequately visualize the i-th smart thing's property.

To evaluate the resources consumption on the interface reconfiguration we introduce a number of additional variables:

$$\sum_{i=1}^{s} \sum_{j=1}^{oi} x_{ij} * f_{jr}(v_i) \leq d_r;\ \forall\ r \in 1..m;$$

m - number of mobile device types of resources;

v_i, - the amount of the transmitted useful information corresponding to the i-th smart thing's property;

f_{jr} (v) - a function of basic interface element j resource consumption r on the amount of useful information v. Result $f_{jr}(v) = 0$ if the data transfer is not carried out, i.e. if $v = 0$;

o_i - the amount of the basic interface elements ***j***, able to adequately visualize the i-th smart thing's property.

d_r - residual value of resource ***r***.

Thus, the expression (5) ensures that the resource consumption r over all the smart thing's properties ***i*** does not exceed the residual value ***d*** of the resource ***r***.

As a result of solving the problem (2), for example, one of the standard methods, is a set of variables $\mathbf{x_{ij}}$, $i \in [1..s]$, $j \in [1..o]$, determining whether to be assigned to the base interface element ***j*** on the smart thing's property ***i***, when transferring a predetermined amount of information.

Obviously, the problem (2) generally is nondeterministic polynomial time hard problem and cannot be solved for the time allowed for a large number of the smart thing's properties. Moreover, in real systems it is not always possible to obtain all the information needed to solve the problem (2). Therefore, we address a number of dynamic selection of the basic interface elements of heuristic approaches. These include random selection algorithm, the algorithm of the priority selection algorithm based on the minimization of a single resource costs.

A new algorithm to simplify the solution of the problem, based on finding locally optimal solutions for each smart thing's interface configuration.

The algorithm is the decomposition of the main tasks assigned to the two sub-protocol. All smart thing's properties are moving sequentially in the order of decreasing the amount of the useful information transmitted, corresponding to each property. At each step, for each smart thing's property algorithm selects set of basic UI elements that can adequately visualize all the smart thing's properties, and then selects a locally optimal basic interface elements by solving the problem (2), considering the limitations of the mobile device resources.

CONCLUSION AND FUTURE WORK

In this paper we have considered a mathematical model of the environment for dynamically reconfigurable interfaces of smart things on mobile devices with limited resources, which allows to evaluate the resources consumption of smart thing's interface reconfiguration depending on the basic interface elements selection.

Secondly, we have considered a method of assigning a set of basic interface elements to reconfigure interface of smart things which consist in transformation of basic interface elements assigning problem to the optimization problem of integer linear programming under the criterion of minimizing the energy resource costs. For a small number of smart thing's properties we can use standard methods to solve the problems, but for large dimensions it has been proposed an approximate method.

We developed a heuristic algorithm for dynamic smart thing's interface reconfiguration.

The future work is to research our heuristic algorithm for increment efficiency in comparison with other interface reconfiguration methods. We are planning to develop a software that realize considered method and algorithm.

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