ALGORITHMS AND METHODS FOR MANAGING REQUEST FLOWS IN A DISTRIBUTED SERVICE SYSTEM

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Abstract: The article devoted to the approaches to algorithmization of the information management system of a distributed service enterprise. The study of the dependence of the optimal capacity of the service system center on the service area was carried out. The mechanism of optimization of the service area, taking into account organizational and economic constraints, as well as optimization of the service area for mobile sources of applications, is investigated. Processing customer requests must meet the requirements of efficiency, reliability, and efficiency of the corporate information network. In the presence of a single office of a service company, it is not always possible to find an optimal or close to optimal query processing algorithm in terms of performance. The problem of the optimal service area without taking into account restrictions in order to maximize the profit of the enterprise is considered. Models of the functioning of the decision-making subsystem for servicing requests by a service enterprise have been developed, differing in taking into account the service area and the spatial stationarity of customers.

Key words: distributed service enterprise, service area, customer requests, query processing algorithm, maximize the profit, spatial stationarity.

1. INTRODUCTION

When building mathematical and software support for modern information and computing systems within the management of distributed service enterprises, there is a need for rational management of algorithms for servicing incoming requests. At the same time, it is necessary to take into account a whole range of limitations, both technical (availability of spare parts, the principal possibility of repair) and organizational and economic (availability of an agreed price, assignment of the request to a specific service area, availability of resources necessary for maintenance). Processing customer requests must meet the requirements of efficiency, reliability, and efficiency of the corporate information network.

In the presence of a single office of a service company, it is not always possible to find an optimal or close to optimal query processing algorithm in terms of performance. The problem is that:

• remote service requests cannot always be fulfilled in compliance with the requirements of efficiency and economy;

• the service area may already be the request generation zone;

• there are practically no rational algorithms and software complexes for service management in distributed enterprises.

The purpose of the article is to describe approaches to algorithmization of the information management system of a distributed service enterprise.

2. PREVIOUS RESEARCH

With the expansion of the scope of activity, and, consequently, the serviced territory [1], the organization for the maintenance and repair of computer equipment has a need for new service centers, that is, in the creation and development of its own service network. Within the framework of the general structure of the enterprise management system, the decision-making subsystem [2, 3], integrated into the general information environment with the help of information and communication subsystems, acquires special importance.

Modeling the functioning of distributed service enterprises is of scientific interest both from the point of view of finding adequate mathematical tools for an applied solution [4, 5], and for identifying the fundamental features and characteristics inherent in the network of the service sector organization [6,7].

3. RESEARCH AND OPTIMIZATION OF COMPONENTS OF THE DECISION-MAKING SUBSYSTEM IN A DISTRIBUTED SERVICE SYSTEM

The study of the dependence of the optimal capacity of the service system center on the service area was carried out. The mechanism of optimization of the service area, taking into account organizational and economic constraints, as well as optimization of the service area for mobile sources of applications, is investigated. The model of the pricing process is investigated by analogy with [8].

The general structure and interrelation of the studied and developed components is shown in Figure 1.

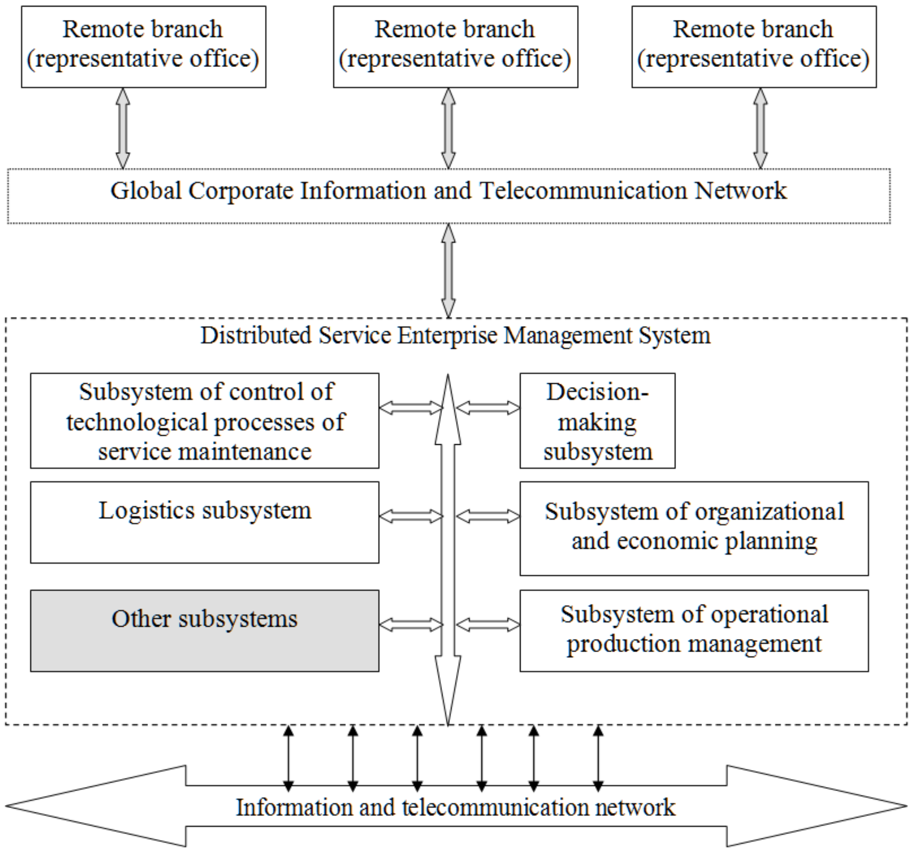

Figure 1. General structure of a distributed service system

Assuming the uniformity of the average time of service movement, the dependence of the power M on the radius R is obtained:

$$M = \frac{\mu\pi}{\omega}(\eta R^2 + \frac{4}{3\nu}R^3), \quad (1)$$

where the correction factor ω is equal to the proportion of the working time in relation to the calendar; μ is the intensity of demand; η is the main service time; v is the speed of "service movement"

Formula (1) reflects the dependence of the required power M on the primary parameters of the description; this power increases with an increase in the intensity of demand μ and the main service time η and decreases with an increase in the share of working time ω and the speed of "service movement" v.

Next, the problem of the optimal service area without taking into account restrictions in order to maximize the profit of the enterprise is considered. The following analytical expression of the company's profit is obtained depending on the radius of the after-sales service area:

$$P(R) = \lambda\pi R^2\left[d - \frac{4}{3}R\left(b + \frac{f}{\nu}\right)\right]. \tag{2}$$

Here d= p-q is the unit profit, i.e. the one that the service company receives for servicing one application (excluding travel costs).

Let's denote the payment of a single service (its price) by p. The choice of the optimal length of service is reduced to the task of maximizing profit P(R) as a function of distance R. The critical point necessary to solve this problem is found from the condition $\frac{dP(R)}{dR} = 0$ that gives

$$P(R) = \frac{\lambda\pi d^3}{12\left(b + \frac{f}{\nu}\right)^2}. \tag{3}$$

As an interesting consequence, it should be noted that the optimal length of service does not depend on the intensity of the flow of applications. In practice, this means that an increase in demand for service while maintaining the hypothesis of its uniformity does not affect the size of the optimal zone and, accordingly, the configuration of the entire service network.

Next, the problem was solved with a limitation on the capacity of the enterprise. Let M_0 be the capacity of an existing service enterprise. The corresponding restriction has the form

$$\frac{\lambda\pi}{\omega T}\left(\eta R^2 + \frac{4}{3}R^3\right) \leq M_0. \tag{4}$$

The expected value of client profit for the entire zone R is obtained:

$$P_K(R) = \lambda\pi R^2\left[et_1 - p - e\left(\eta + \frac{2R}{3\nu}\right)\right]. \tag{5}$$

Here e is the profit that the correct operation of a unit of equipment gives per unit of time, t_1 is the uptime of the equipment during the maintenance time.

Thus, the choice of the optimal service scale R for customers is reduced to finding the maximum of the $P_K(R)$ function. We will find the critical point $\frac{dP_K(R)}{dR} = 0$ necessary for this from the condition and get the optimal radius

$$R^0 = \nu\left[(t_1 - \eta) - \frac{p}{e}\right]. \tag{6}$$

4. MOBILE CLIENT AND FIXED SERVICE CENTER

So far, the problem of the optimal zone has been studied under the condition of the "mobility" of the service and the "immobility" of the client, that is, under the assumption of a service visiting the source of the application. At the same time, the opposite situation is also possible, when the client is "mobile", and the delivery address of the equipment in need of maintenance is a service center. Without limiting generality, consider as an example the following implementation of this scheme. The customer disassembles the equipment that has failed and delivers it to the service center. After the repair is completed, he picks it up and installs it in its original place. Let the full term of withdrawal of the equipment (its diversion from the client's economic activity) be equal to I. This period consists of the travel time, which, taking into account the return, is the $\frac{2r}{v}$, amount ω of the duration of the installation and dismantling works, as well as the waiting time in the queue for repair S and the duration of the repair η. For a mobile client, its losses are due to both a reduction in the time of operation of the equipment by the amount I, and the costs of transportation and payment for repairs.

Let φ and τ denote the time-based payment of the specialist accompanying the equipment and the intensity of the costs of installation and dismantling work. The necessary condition of expediency for a mobile client can be written by the inequality

$$et_1 \geq C_\Sigma = 2\left(b + \frac{e+\varphi}{\nu}\right)r + e(\omega + S + \eta) + \varphi(\eta + S) + \tau\omega + p, \tag{7}$$

which meets the following range restriction:

$$r \leq \frac{e(t_1 - \omega - S - \eta) - \varphi(\eta + S) - \tau\omega - p}{2\left(b + \frac{e+\varphi}{\nu}\right)}. \tag{8}$$

Having solved (8) with respect to r, taking into account the specifics of the problem, we obtain an upper bound of the distance from the service center, due to the requirement of the economic feasibility of the service for a mobile client:

$$r \leq \nu\left[(t_1 - \eta) - \frac{p}{e}\right]. \tag{9}$$

If we denote the upper bound in (10) by r*, we come to the following relation:

$$r \leq \frac{e(\omega + S) + \varphi(\eta + S) + \tau\omega}{2\left(b + \frac{e+\varphi}{\nu}\right)}. \tag{10}$$

The operation of the service network depends on changes in the external environment of the organization [9]. In order to smooth out possible adverse effects caused by market fluctuations, periodic adjustment of individual elements of its functioning (capacity, prices, customer composition, profitability requirements, etc.) is required. In unstable market conditions, in order to maintain stable profit levels and capacity utilization, a maintenance company can resort to flexible prices that optimally vary the size of the customer base. So, if necessary, increase the number of serviced applications (in case of underutilization of capacity) it is able to lower the profitability bar; on the contrary, in a situation of congestion, it is advisable to raise the profitability threshold. Of course, at the same time, price concessions or surcharges corresponding to these changes in profitability must be agreed with the customer. The required coordination can be achieved using the proposed mechanism of contractual prices, personalized for individual applicants. The idea of contractual pricing and the possibility of its implementation depending on the distance r are illustrated in Figure 2.

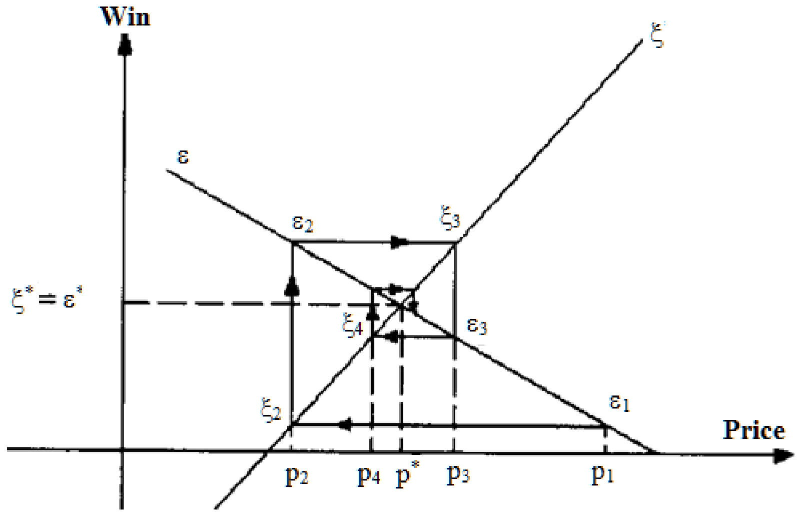

Figure 2. Contractual pricing mechanism

Denoting the minimum allowable levels of winnings for the seller of services and their consumer through ξ^* and ε^*, respectively, we obtain expressions for determining the lower selling price P_S and the upper purchase price R_D. It is shown that if the profit from the productive operation of the equipment during the entire t_l+t cycle is greater than the cost of the service together with the cost of its delivery, then price fluctuations fade and the negotiation process ends with an exit to the price of approval p^*.

7. CONCLUSION

Models of the functioning of the decision-making subsystem for servicing requests by a service enterprise have been developed, differing in taking into account the service area and the spatial stationarity of customers. The parameters of models with a mobile client and a fixed service center, as well as with a mobile service center and a fixed client are considered. The mechanism of contract pricing is given.

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