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VENDING CYBER-PHYSICAL SYSTEMS ARCHITECTURE

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Abstract: **In this work organization and principles of multilevel vending cyber physical systems (VCPS) development have been examined. VCPS purposes and functions on each level as well as interlevel interaction have been described, as well as the classification of vending machines has been offered. The results of analytical system work have been shown graphically.**

Key words: **vending, cyber physical systems, vending cyber physical systems, processing, monitoring, vending machines, server system, database, transaction, configuration, physical world, automated system.**

I. INTRODUCTION

Vending – is sale of goods and services by means of automated systems (vending machines). A vending machine is supposed to accept cash and non-cash money; deliver goods or services; to work regardless of staff (except filling, maintenance, collection of money). In addition, it can perform (if needed) technological (preparation or technological processing before delivery) and advertising functions. Vending machines efficiency depends on their correct organization, including installation location. In order to obtain a better location operator companies, have to improve service quality by using modern and technological machines. As chains are expanding, remote collection of statistical and technological data is becoming essential. The role of vending industry is additionally proven by statistics provided by European Vending Association (table1[8]). We can observe an increase in number of vending machines in Ukraine, especially such as self-service carwashes, payment terminals, water vending machines, pack stations, automated systems for closed car parks. At this stage the issue of developing and improving vending cyber physical systems, including modern computer, information and telecommunication technologies has not been examined neither theoretically, nor practically.

II. TASK DETERMINATION

The task is to investigate problems of vending cyber physical system development and approaches to their solution by means of modern technologies. To present the structure and describe each VCPS level according to the suggested multilevel basic platform [9]. To describe the process of VCPS components interaction, as well as to classify modern vending systems.

III. MAIN DEFINITIONS

Here are the main definitions used in this paper. **Vending cyber physical systems** are a platform, which provides integration of geographically distributed vending machines and information hard- and software complexes by using telecommunication means (cyber world) with physical world (goods, service, money, customers, staff, receipt, etc.) **SO** is a system operator. **Vending network monitoring** – is a subsystem of VCPS server program complex, which constantly observes vending network components to detect ineffective or defective subsystems and reports about any errors or atypical situations to a liable person by an appropriate means (e-mail, phone, internal notifications, etc.). **Processing** – is a subsystem of VCPS server program complex, used for conducting transaction. **Principal** – is a legal entity or an entrepreneur who sells goods or provides services and charges OS to perform legal and other actions, related to taking payments on contracts between the Principal and Users. **Service aggregator** – is an independent payment system, which allows to take payments from the User for the Principal without drawing a contract between OS and the Principal.

Table 1

Statistics of European vending market in 2014

European Vending Association's marketing report	
3.74 MILLION Number of vending machines in Europe	**11.8 BILLION** Total turnover of european vending in EUR (€)
78 MILLION Items are sold per day via european vending machines	**6 FROM 10** Number of hot drinks vending machines
77 % General percentage of 6 biggest European vending markets (Italy, France, Germany, The UK, Spain, The Netherlands)	

IV. VENDING CYBER PHYSICAL SYSTEM ORGANIZATION

Vending cyber physical system organization is depicted in the picture1. The main VCMS components are: a vending machine set, server system, company management, a service department, a supply department, call-centre, customers (machines users). Let us have a closer look at the relations between the components depicted in picture1, which are marked with numbers:

1. – a purchase of goods or receiving a service from the vending machine.
2. – the vending machine sends information to the server system or gets it via the Internet.
3. – customer service provides vending machines placing and maintenance; supply service provides vending machines with goods.
4. – customer service gets information on breakages and lack of stock-in-trade from server system.
5. – server system gets information and sends it to all the members of the network via the Internet.
6. – managers' and call-centre's software interacts with server system.
7. – interaction between managers and custom service is conducted on the phone.
8. – customers ask the call-centre for help.

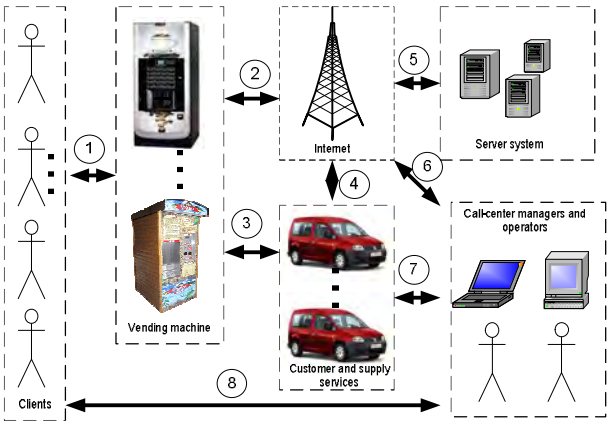

Fig. 1. Organization of vending system

Using multilevel basic platform of cyber physical systems [9], we will show place of every single VCPS component:

0-level. Physical world (customer, goods, service, money, customer service, collector, analysts, managers);

1-st level. Means of interaction with the physical world (vending machines);

2-nd level. Means of information collection and delivery (GSM, WiFi, Lan-modules, Internet, etc.);

3-d level. Means of information processing (server hard– and software, database, communication server, processing, monitoring subsystem);

V. VENDING MACHINES AND MEANS OF DATA TRANSMISSION

The main components of a vending machine (VM) are: a managing board, payment system (cash acceptor, coin acceptor, swipe, change delivery device), display, keyboard, printer, goods delivery device, modem [10]. For interaction between VM and server system wireless data transmission via GPRS, EDGE, 3G protocols is used, which facilitates machine installation. According to the type of vending operations we distinguish such VMs: for goods selling, for service selling, for goods preparation and selling, and combined types (Table 2). According to the way of installation: wall, table and floor VMs are differentiated. Based on operation type there are indoors or outdoors VMs. They also differ from each other by types of payment systems.

Table 2

Vending machine classification according to the type ofgoods or services

Type of a vending machine	Example of a vending machine
1.1. Machines that sale services(account top up, fee for internet or cable TV use, bank services, parking fee, car wash fee, washing, copying, amusement machines activation fee)	1.1.1. Payment terminal 1.1.2. ATMs 1.1.3. Parking machine 1.1.4. Lottery terminals 1.1.5. Automatic car wash terminals 1.1.6. Service activation terminals
1.2. Hot drinks vending machine (coffee, tea, chocolate, etc.).	1.2.1. Working on grain ingredients 1.2.2. Working on instant ingredients 1.2.3. Combined
1.3. Cold drinks vending machine (water, juice, milk, etc.).	1.3.1. Machines for bottling beverages into customer's container 1.3.2. Bottling machines
1.4. Snack vending machine	1.4.1. Snack vending machine 1.4.2. Snack fridges
1.5. Food vending machines	1.5.1. For hot food sale (e. g. pizza or bread VM). 1.5.2. For weight goods sale
1.6. Peacemeal goods sale	1.6.1. Packadged(tissues, toiletries, etc.). 1.6.2. Non-packadged goods 1.6.3. Counter sale
1.7. Liquid pouring machines	1.7.1. Windscreen liquid VM 1.7.2. Liquid soap VM

VI. MEANS OF INFORMATION PROCESSING (3D LEVEL)

Server hard-and software complex (SHSWC) is a means of VCPS information processing. It is divided into processing and monitoring modules. Processing module processes payments. Monitoring module tracks VCPM functioning and allows to get statistical data. Let us have a closer look at the algorithm of interaction between VCPS components on 0-3 levels. All the external channels (machine-server) use encoding. General scheme of information interchange is depicted in the Fig. 2.

Service payment algorithm (Fig. 3a):

1. Via VM a user chooses a service and enters a payment identifier.

2. A query for the transaction check is sent to the system operator (OS) server by the protected internet protocol. The check is conducted in a local database.

3. From the SO server the query on money availability is sent to the principal's settlement bank. If this is a settlement scheme for actually performed payments, a balance check is not conducted (go to p. 5).

4. Settlement bank's server sends the answer about the availability or lack of money to SO server. In case of a lack of funds, the information about rejected operation is sent.

5. If the reply from the settlement bank is positive, the query on the check of the chosen payment identifier is sent from the SO server to Principal's billing system or to Aggregator, which sends it to the Principal.

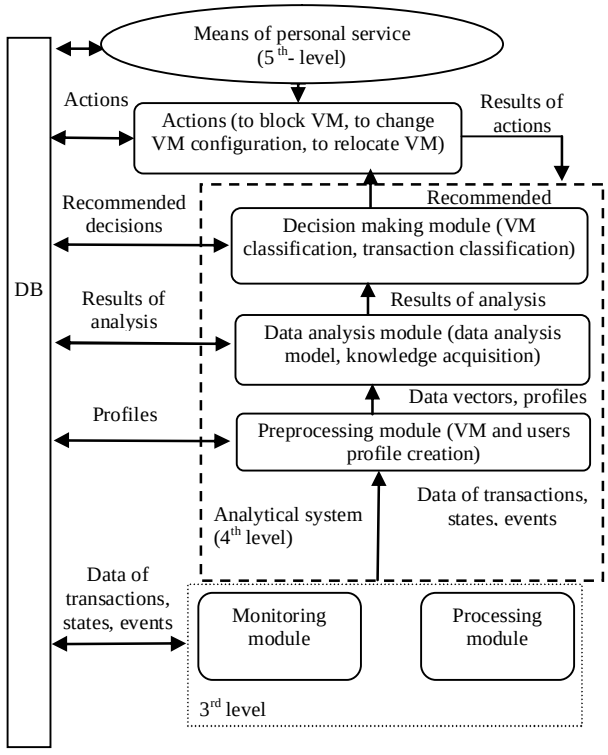

Fig. 2. The structure of the analytical system

6. Principal's billing checks identifier availability and sends permission for payment to SO or Aggregator's server, which transmits the answer to SO server.

7. The permission is transmitted from the server to VM.

8. The User puts cash into the cash acceptor, presses the button "To pay". Next information on the payment is sent to

SO server, and then to Principal's server (service aggregator).

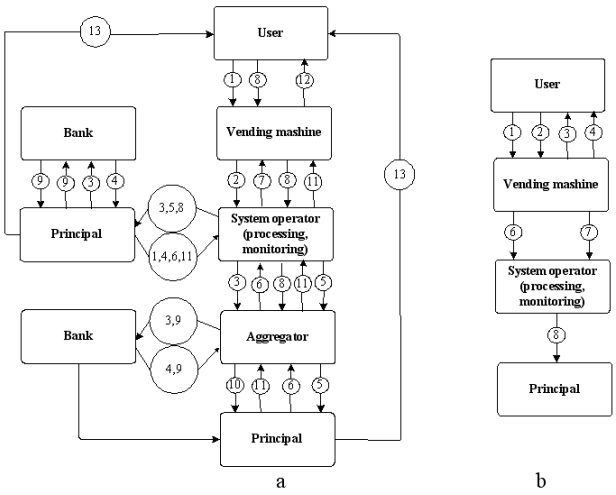

Fig. 3. Payment algorithms

9. The Principal's server (aggregator's) sends the command to the settlement bank about the inserted amount writing-off (electronic payment document). In case of the settlement scheme for actually performed payments, the settlement bank forms a payment request (an obligation for SO). The confirmation of the money writing-off is sent from the settlement bank server to Principal's (aggregator's) server.

10. The payment is sent from the Service aggregator's server to Principal's billing. Next the user's account top-up is conducted in the Principal's billing.

11. The Principal's billing sends confirmation of money received to VM.

12. VM prints out the receipt with all the transaction parameters (Principal, date, sum, payment identifier, SO details).

13. Principal's billing sends a message to the user with the confirmation of personal account top-up.

The algorithm for goods payment (Fig. 3b):

1. A user chooses the goods.

2. If it is available, the user puts money into VM cash acceptor and presses the button "To pay".

3. Payment information is sent to SO server.

4. If necessary, the VM gives out change.

5. VM prints out the receipt with all the transaction parameters (Principal, date, sum, payment identifier, SO details).

6. The VM sends information on a product and change give-out to the SO server.

7. SO server sends information on the sold goods to the Principal.

Main demands of a processing module:

1. Transactional accounting (pre– and reprocessing and status check (product code and price, time and date of selling, etc.) of transactions, that are received from VM in real time).

2. Interaction with service Principals and Aggregators.

3. To enable payment routing.

4. To provide possibility to set goods and services prices.

5. Accounting (payment registration, etc.).
6. Ability to conduct transactions simultaneously
7. To control collection and users' balance.
8. To accumulate data for users' profiles and VM.

Main demands of a monitoring module:

1. To transmit information on products, paper or small change shortages, filling of money camera, VM work on the battery;
2. To transmit error codes, detected during VM work;
3. To diagnose VM condition and transmit information on errors; to check connection with VM;
4. To provide configuration functions (dynamic configuration parameters change, VM switch on/off, VM address change, firmware of a new VM software version).

VM hardware consists of several servers and a database. Each of the servers has its own function. Communication server supports VM, enables to work with the database, to process and monitor modules work. GSM-server sends SMS to the customer and supply services employees. Web-server provides an access to the necessary financial and technical information for vending network employees. Database and reserve database servers provide essential functionality and reliable information storage during the system work.

VII. MEANS OF DECISION MAKING. ANALYTICAL SYSTEM. MONITORING METHODS AND ALGORITHMS (4TH LEVEL)

A large number of VM and their diversity leads to the increase in their number and complication of the stored data structure. Traditional methods of modern database – SQL-queries – do not cope with this, since too much stored data still give not enough information for the analyst. Thus, the problem of the new VCPS automated data analysis methods and means development arises. At this stage Data Mining [1] technology has become widely used. Data Mining is a combination of the broad mathematical tools (from classical statistic analysis to new cyber methods) and latest achievements in the IT sphere. Data Mining methods and algorithms include artificial neural networks, statistical methods of prediction, decision trees, Bayesian network, correlation and regression analysis, various data visualization methods, and many more. The structure of the analytical system (AS), which implements a set of Data Mining methods for VCPS analysis, is shown in Fig. 3.

Information for AS is stored in SHSWC database. The data on transactions, events, VM equipment condition are sent to DB and AS via processing and monitoring modules. Preprocessing module prepares VM and users' profiles and preprocesses transactions. Data analysis module deals directly with analytics. At this stage a set of statistical methods of prediction are implemented, which enable to compare a desirable result with the existing one, and to make certain conclusions. E.g., if a certain number of transactions is expected at this very time, but they do not happen, it is possible to anticipate, that the VM is out of order. Decision making module generates a list of recommended for the user actions (to replace the broken component, to conduct collection, to fill the VM with products, to relocate the VM, to maintain the VM), according to the information received on the previous levels. AS system makes it possible to increase VM operation efficiency up to 20–30 % [12].

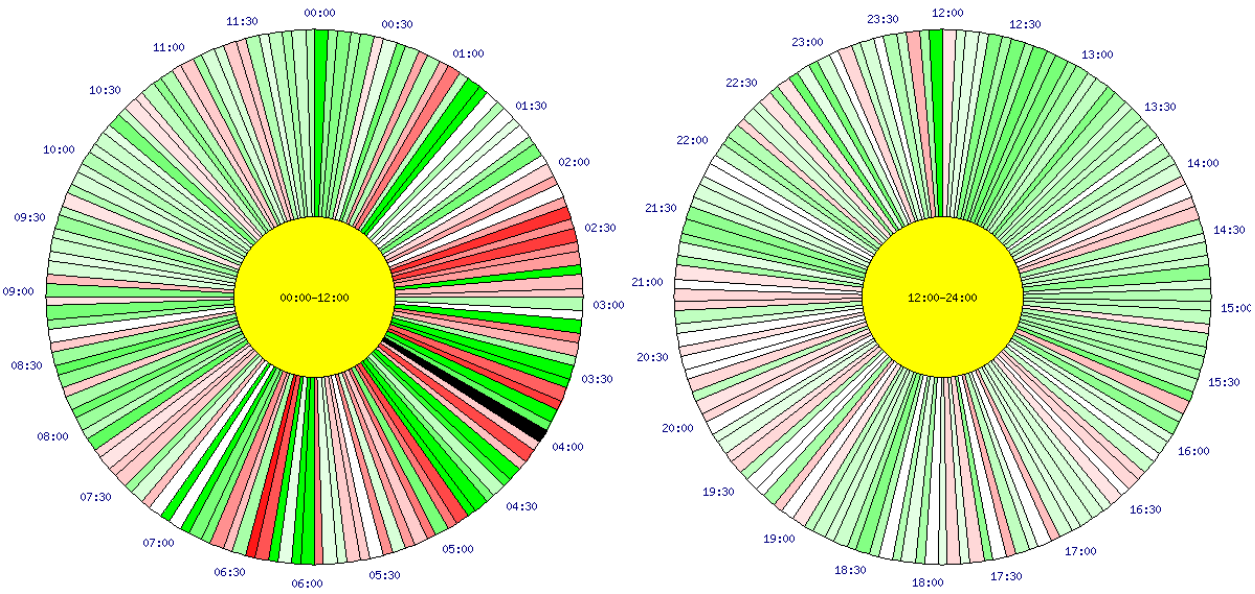

Fig. 4. The flow graph of processing efficiency

VIII. MEANS OF PERSONAL SERVICE (VISUALIZATION MEANS)

Means of visualization (MV) (user's graphic interface) enables interaction between the users (analysts, customer support, call-centre operators, managers) and lower levels of the VCPS. The main MV functions are: to secure VM work (creation of VM in the system, main parameters setting, software firmware); processing and monitoring management; reports and recommendations generation in a suitable for the user form. In the Fig. 4 the flow graph of processing efficiency during a day with 5-manute interval is showed. The segment color defines transaction activity at the specific interval. In Fig. 4 we can see, a black segment at 4 a. m., which means, that there was no transaction at that time. Such information enables the system administrator to effectively react to any errors.

IX. CONCLUSIONS

The main principles of multilevel cyber physical vending systems have been investigated. Roles and functions of every single VCPS level have been described. Vending machines have been classified. The demands and algorithms of processing and monitoring modules have been described in detail. The structure of automated analytical VCPS has been offered. Data Mining methods and algorithms that can be used for the data analysis structure construction, have been examined. One of the graphical reports of the analytical system has been produced.

REFERENCES

[1] [elektronniy resurs]//Rezhim dostupu: http://ua-investor.com.

[2] [elektronniy resurs]//Rezhim dostupu: www.selecta.com

[3] Donald W. Howell. Vending mashine monitoring system.[elektronniy resurs] // Rezhim dostupu: http://patent.ipexl.com.

[4] James H. Halseg. Vending apparatus and method having improved reliability.[elektronniy resurs] // Rezhim dostupu: http://patent.ipexl.com.

[5] Dana Bashor. Field configurable vending mashine system.. [elektronniy resurs] // Rezhim dostupu: http://patent.ipexl.com.

[6] Zaslavskiy V. A., Strizhak G. O. Avtomatizovana sistema monitoringu shahrayskih tranzaktsiy v platizhniy sistemi // 5-ta Mizhnarodna konferentsiya "Teoretichni ta prikladni aspekti pobudovi programnih sistem", 22–26 veresnya 2008 r., Kiyiv – Chernigiv. – K., 2008. – Ch. 2. – S. 27–36.

[7] Deyneka O. Monitoring klientiv yak analitichniy priyom doslidzhennya osoblivostey funktsionuvannya rozdribnogo merezhevogo pidpriemstva // Ekonomychniy analiz Vipusk 4. – Ternopilyu. – 2009. – S. 185–189.

[8] Vendingovyy avtomat za pyat minut. Informatsionno-analiticheskiy zhurnal "Tvoy vending". – 2015. g. Kiev, No. 1, s. 14.

[9] Melnik A. O. Bagatorivneva bazova platforma kiberfizichnih sistem // Kiberfizichni sistemi: dosyagnennya ta vikliki. Materiali Pershogo naukovogo seminaru (25–26 chervnya 2015 r., m. Lviv). – 2015. – C. 5–15.

[10] Salo A. M., Kravets O. I. Arhitektura vendingovogo avtomatu // Visnik Natsionalnogo universitetu "Lvivska politehnika". Seriya "Komp'yuterni sistemi ta merezhi". – 2014. No. 806. – C. 240–246

[11] A. Barsegian, M. Kupriyanov, I. Holod, S. Elizarov, M. Tess. Analysis od data and processes: from standart to realtime data mining. ReDi Roma-Verlag. 2014, 300 p.

[12] Salo A. M. Printsip pobudovi vendingovoyi merezhi z monitoringom. Visnik NU "Lvivska politehnika" "Komp'yuterni sistemi ta merezhi". – 2013. No. 773. – P. 112–118.

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