Customer Experience Model for Communication Service Provider Digital Twin

Vladimir Akishin[1][0000−0001−9793−2266], Sergey Kislyakov[1,2][0000−0001−8842−7903], and Alexander Sotnikov[1][0000−0003−4366−9460]

[1] The Bonch-Bruevich Saint-Petersburg State University of Telecommunications (SPbSUT), Saint-Petersburg, Russia http://www.sut.ru
akishin_vova@mail.ru;
s.v.kislyakov@gmail.com;
adsotnikov@gmail.com
[2] RTC ARGUS, Saint-Petersburg, Russia http://www.argustelecom.ru

Abstract. The ultimate goal of the study is the built digital twin of a telecom operator. One of the important components of a communication service provider (CSP) digital twin is the customer's digital twin. Building a customer's digital twin is an extremely difficult task, because a number of properties of a real customer are difficult to formalize. We offer a customer experience model, which will become part of the general customer digital twin model, complementing the behavioral aspect of a real customer. General model of fuzzy cognitive maps (FCMs) was chosen as the mathematical basis for this model. For this study, we used data from two big CSPs. Based on these data, two models of FCMs were developed.

Keywords: Digital Twin · Customer Experience · Cognitive maps.

1 Introduction

The global goal of this study is to develop the foundations of the theory of constructing a CSP digital twin (DT) through the construction of digital twins of CSP's different systems. The use of DT is aimed at solving a wide range of information communication management tasks. Possible DT applications are described in [1]. The DT of individual systems can be DT of info-communication infrastructure, a customer digital twin (CDT), DT of any resource. Building a CDT is an extremely difficult task, because a number of properties of a real client (for example, behavior) are difficult to formalize. Application of the customer DT will help to solve problems such as forecasting clients churn, forecasting the purchase of services, etc., better than can be solved by other methods. In this work, we suggest a model of Customer Experience (CX) as one of the parameters of the CDT. Accordingly, by simulating changes in CX, we create one of the components of the customer's digital twin. The CX model for CDT can be used to predict the movement of a customer through the stages of their life cycle. For the task we solve, we will study stages at which the client uses network resources and how they bring profit. At the moment, in the field of telecommunications, there are 9 customer life cycle stages (CLCS) [2,3].

At every single CLCS, a customer gets his new experiences - CX. The CX can be both positive and negative, but in any case, the CX of each CLCS has an impact on behavior, propensity to churn, and user loyalty at other CLCSs. In this work, we study CLCSs "Buy". As part of the client's life cycle, it is important for us to keep every single client at the "Consumption" CLCS, as well as "convince" him to buy additional services, which means even more load on the network infrastructure. In order to be able to predict the movement of the client through the CLCSs of the life cycle, we need to calculate the client's CX in real time. FCMs were used to calculate CX, and then (in the development of this study) we will calculate the probability of a client's transition to a particular CLCS of the life cycle based on the client's CX received.

2 Customer's digital twin as a part of CSP digital twin

The development of the DT is based on the "Cross-domain model of info-communications management" (CDM) [1], based in its turn on the high-level "Domain model of info-communications" (DM) [4,5,6]. DM uses such terms like "information", "information interaction", "information process", "information object". Using these terms it is possible to describe the main parts (blocks) of the Info-communication system (ICS) and to describe the processes taking place in ICS. For further discussing, it is needed to put some of the new terms here. Any information system operates with information objects – images $\{\langle A\rangle, \langle B\rangle, ...\}$ of the entities $\{A, B, ...\}$.

"Information is sent" when the image transmitting from source-system A to receiver-system B signal has changed:

$$\langle A\rangle^{\xi_A} \Rightarrow \langle\langle A\rangle^{\xi_A}\rangle^{\xi_B} \tag{1}$$

"Information is perceived" when a new image of the source has arisen in the diversity of the recipient's thesaurus:

$$\langle A\rangle^{\xi_A} \longrightarrow \langle C\rangle^{\xi_C} \longrightarrow \langle\langle\langle A\rangle^{\xi_A}\rangle^{\xi_C}\rangle^{\xi_B} \tag{2}$$

"Informational impact" is the influence of a "source" A on the state of a "receiver" B, leading to a change of the image $\langle B\rangle$.

"Informational exchange" –the process of transmitting and receiving of signals, which lead to the mutual change of the images $\langle A\rangle^{\xi_B}$ and $\langle B\rangle^{\xi_A}$ to possible change of the participants thesauruses.

"Informational interaction" – is cross-change of the images of inherent systems $\langle A\rangle^{\xi_A}$ and $\langle B\rangle^{\xi_B}$, leading to change of images $\langle A\rangle^{\xi_B}$ and $\langle B\rangle^{\xi_A}$ of the other participants. "Perception of the transmitted information" - is the emergence of a new image of system A in the recipient R's variety of thesaurus of the recipient $\langle\langle A\rangle^{\xi_A}\rangle^{\xi_R}$. To understand further reasoning, we need the definitions "User", "Potential information", "Actual information", "Information system", "Communication system", "Info-communication system". The definitions of these terms are given in references [4,5]. We suggest that you familiarize yourself with them. Within DM, in general, the elementary interaction of two information systems in the information domain is represented by the equation:

$$\langle\langle A_n\rangle^{\xi_{A_n}}\rangle^{\xi_{C^m}} \xrightarrow{Q_{22}{}^{\xi_{C^m C^k}}} \langle\langle A_n\rangle^{\xi_{A_n}}\rangle^{\xi_{C^k}} \tag{3}$$

The DM (Fig.1) is a universal abstract model and describes the components of an info-communication system and the information exchange within it. The model consists of three domains interconnected by relationships: a physical domain, an information domain, and a cognitive domain. The domain model is a universal abstract model and describes the components of an information-communication system and information exchange within it. The model consists of three domains interconnected by relationships: a physical domain, an information domain, and a cognitive domain. The physical domain is the domain of physical objects and energy processes. This is where physical objects interact. An information domain is a domain where information entities interact; data that is used by entities of the cognitive domain "live" here. The cognitive domain is the domain of the "intellectual function" where decisions are made. To

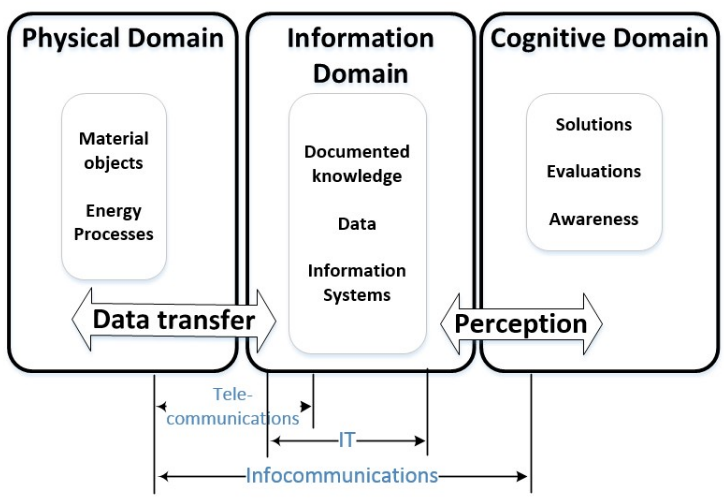

Fig. 1. The Domain Model of Info-communication System

apply the domain model to build a digital twin of a telecom operator, it is necessary to refine it taking into account the specifics of the communication industry - to introduce architecture and entities that correspond to the activities of the telecom operator.

The framework developed by the TM Forum was chosen as the main concept for finalizing the model. Today it is the most harmonious and complex system, which includes a set of interrelated standards and recommendations intended for the telecommunications, IT and digital entertainment industries and designed to facilitate the development of service-oriented software for enterprises in the industry, to increase the compatibility of its components and to simplify the interaction between the participants of the distributed value chain in the process of providing info-communication services. Frameworx (By TM Forum) seeks to describe in the form of an integrated model the activities of an info-communication company as a whole, including business processes, information exchange, IT infrastructure and interaction with partners. The TM Forum has developed a Shared Information and Data model, which has been adopted by the International Telecommunication Union (ITU) as a standard. Shared Information and Data Model (SID) - as a part of the TM Forum Frameworx - contains the definition and description of the elements and data structures involved in the business processes of an info-communication company and shared by various components of its information systems.

The new Cross-Domain Model (CDM) includes horizontal domains reflecting the specifics of info-communications: Customer Domain, Service Domain, Resource Domain, Partner Domain (Fig.2). The CDM horizontal domains correspond to TM Forum Framewox tools: SID, enhanced Telecom Operations Map (eTOM) and Telecom Applications Map (TAM).

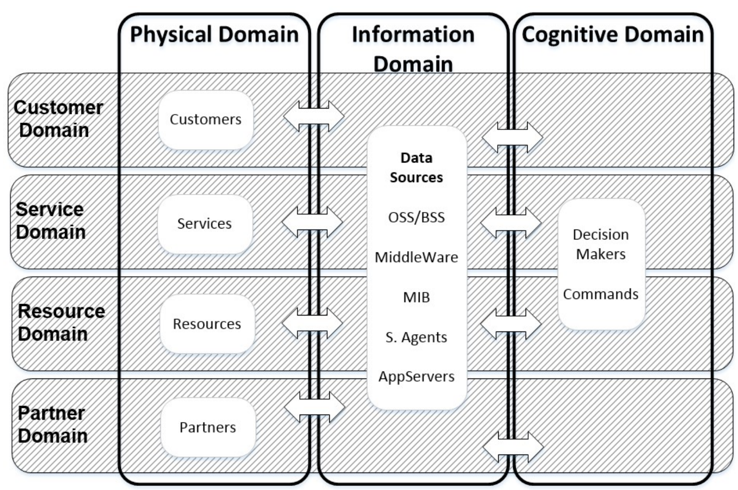

Fig. 2. The conceptual view of the Cross-Domain Model

The vertical aspects of the domain model demonstrate the unity and interaction between entities within each separate domain. These interactions, like the nature of entities, differ from domain to domain. The horizontal domains from the SID model include entities of interacting digital service provider objects. They are collected in different domains according to the principle of functional departments of the organization. For example, in the organizational structure of a service provider there is a sales department, a customer service department, a technical department, a supplier relationship department, etc. Because the new model has lots of intersecting horizontal and vertical domains, we have named it "Cross-Domain Info-communications Management model" (CDM) (Fig.2).

In [1] it is shown that within the framework of the CSP DT a network of DTs of various systems will be formed and these DTs will interact with each other, reflecting the real processes of the CSP. The place of the CDT in the CDM is at the cross-section of the vertical ID and the horizontal Customer domain. CDM consists of vertical domains and horizontal areas. Physical Domain (PD) domain includes: operator's physical infrastructure; services with which the infrastructure is loaded; customers with whom the operator interacts with in the course of their activities; other entities of the physical world objects necessary for the realization of the business goals of the digital service provider. The Information Domain (ID) includes all sorts of data and information about PD objects obtained from a variety of available information sources.

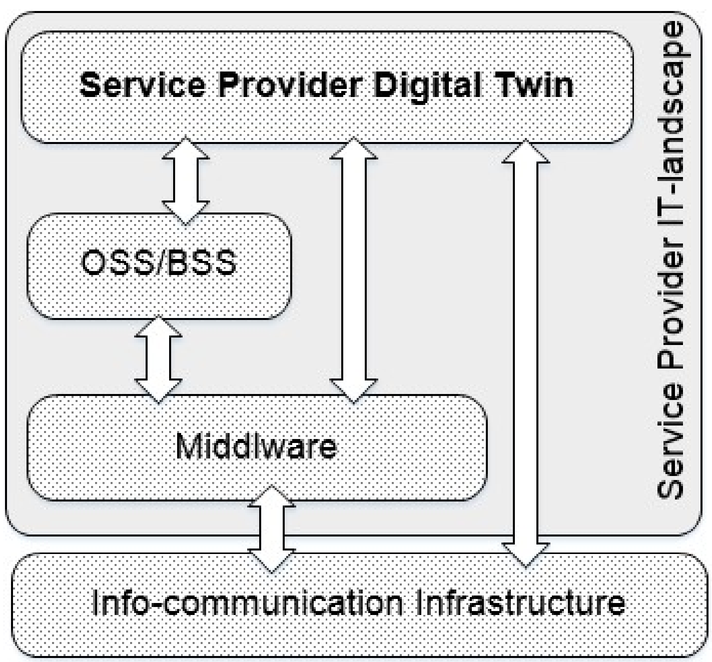

Fig. 3. The place of Digital Twin in CSP IT-landscape

In general, this is information and data presented in various formats. The Cognitive Domain (CD) in this work is not discussed, since much of it goes beyond the scope of info-communication topics. Cross-domain interaction is described in DM description. The cross-domain information exchange with feedback, which is necessary for the implementation of management and control functions. Feedback forms a closed control loop, which is introduced here into the CDM of the DT, reflecting activity of cognitive function (decision-making, analysis, etc.) in the CD.

Currently, all the data on the state of the network infrastructure, its load and events [7,8] are accumulated in the databases of Operations Support Systems (OSS) and Business Support Systems (BSS). OSS/BSS is a large class software that can be used to collect data and use it by the DT within the proposed cross-domain model. The most important feature that a CSD provides to a Service Provider is the ability to perform real-time simulations without affecting the actual physical infrastructure. That is, it becomes possible to use the DT to solve many problems, including those described at the beginning of this article. At the same time, the existing DT will not be a "black box" with unknown content. It will be a very close in properties to a real object, a complex model with input and output, which can be included in the feedback of the large "control mechanism" of post-NGN networks.

3 CX Functional model

One of the most important components of the Customer Experience Management (CEM) is the concept of the customer life cycle [9-14]. The life cycle is the set of stages of the client's interaction with the company, starting from the moment the client becomes aware of the company and ending with the point of termination of the relationship:

- Discover (I Research, I Choose, I Validate)
- Buy (I Order, I Order, I Receive)
- Start-Up (I get set up, I am welcomed, I make my first service payment)
- Use (I Use my products and services, I manage my account, I am Valued)
- Get Support (I have a question, I have a problem, I want to escalate)
- Renew/ Leave (I renew my contract, I leave)

Based on TM Forum research [11, 13], the CX functional model can be described as a structure of three levels, where each of the levels determines calculation of CX values of different levels of abstraction - from atomic metrics of CX to total values of CX (using the customer life cicle):

- Level 1 (L1) - this level describes the scenarios for collecting input data for the model, as well as how the KQIs and KPIs are calculated for operational processes that influence the formation of the customer experience model.
- Level 2 (L2) - this level describes how the quality indicators (KQI) are calculated for a specific communication channel or point of contact with the client

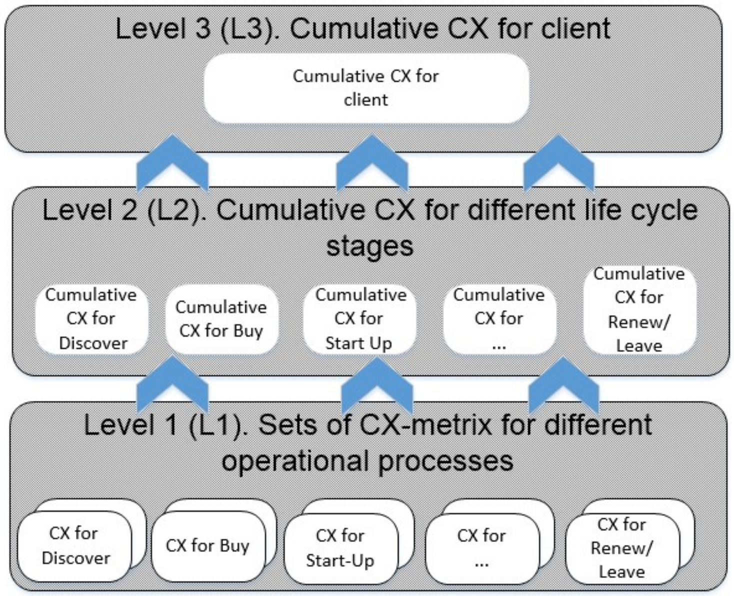

Fig. 4. 3-leveled model of CX

based on the KPI / KQI results obtained at level 3. Furthermore, the obtained values of the quality of the interaction channel or point of contact are "calibrated" by subjective customer assessments of the measurement data (which are also formalized in the CX metrics model).

– Level 3 (L3) - This level describes how the Customer Experience Index is calculated in the context of a specific stage of the customer life cycle, as well as the cumulative value in the context of the entire customer life cycle.

The functional model above can be represented as an three-levelled hierarchical structure, where each level of the hierarchy will correspond to one of the levels of the functional model (Fig. 4). The hierarchical model can be decomposed into two independently computed Fuzzy Cognitive Map (FCM). The first FCM M_1, will describe an total CX scoring model for lifecycle stages, based on CX metrics. The control factors (concepts) of this FCM will be the metrics of CX. The target factors will be the values of the total CX calculated for every single CLCS. The second FCM M_2 will describe the model for assessing the total CX based on the values of CX calculated in M_2. The controlling factors of the model will be the values of the total CX per every single CLCS, and the target factor will be the final total value of CX [11,13].

4 Mathematical model

In our model, we use FCM both for calculating the value of integral customer experience for one stage of the customer life cycle and for calculating the total CX

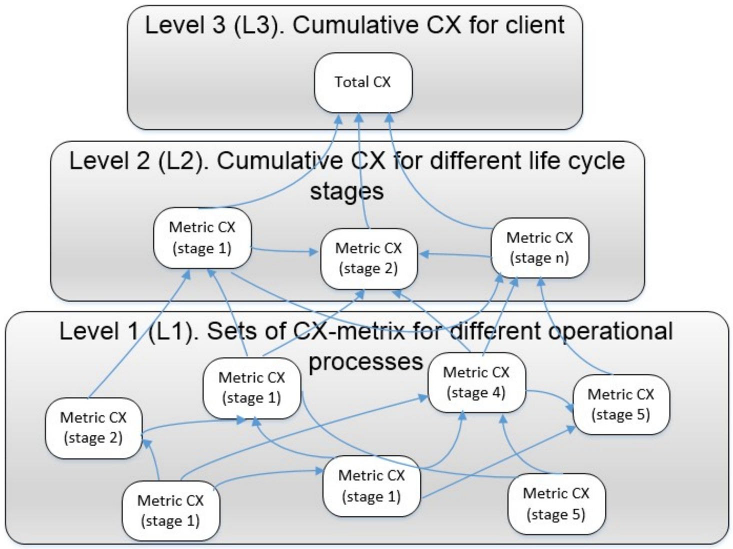

Fig. 5. Fuzzy Cognitive Map for CX calculation

for the entire customer life cycle. TM Forum CX metrics are used in introduced mathematical model. In general, FCM consists of nodes $(N_1, N_2, ..., N_n)$, which are metrics of CX [15, 16, 17, 18, 19, 20], and of directed arcs $(e_{i,j})$, which indicate the connection between the FCM nodes (N_i, N_j). Directional arcs are assigned fuzzy values in the interval [-1, +1]. These values show the strength of the mutual influence of factors. A positive value indicates a positive causal relationship between factors. A negative value indicates a negative relationship between two factors. Zero value corresponds to the absence of mutual influence of factors. In general, FCM is determined by the parameters N, E, C, f :

$$N = (N_1, N_2, ..., N_n) \tag{4}$$

where

– $(N_1, N_2, ..., N_n)$ are set of parameters (concepts) - the nodes of the graph. – $E : (N_i, N_j) \Rightarrow e_{i,j}$ - a function that corresponding the value of $(e_{i,j})$ to a pair of concepts (N_i, N_j), where $(e_{i,j})$ is the weight of a directed edge from N_i to N_j if $i \neq j$, and $(e_{i,j}) = 0$ if $i = j$. It means that $E(N \cdot N) = (e_{i,j})$ is connection matrix. The values of the weights on the main diagonal of the matrix are equal to zero, since changes in knowledge about the concept are not can affect the concept itself. – $C : N_i \Rightarrow C_i$ is a function that assigns to each concept N_i a sequence of its activation degrees so that for each $t \in N, C_i(t) \in L$ - is the degree of activation of the concept N_i at time t. $C(0) \in L^n$ is an initial vector containing the initial values of all concepts. $C(t) \in L^n$ is the final vector of states of concepts at a certain iteration L. – $f : R \Rightarrow L$ is the a transformation function that links $C(t+1)$ and $C(t)$ for all $t \geq 0$ so that:

$$\forall i \in \{1, 2, ..., n\}, C_i(t+1) = f(\sum_{i=1}^{n} e_{ij} \cdot C_j(t)) \tag{5}$$

The transform function is used to bring the weighted sum of concept states into the range [0; 1]. For both levels of the represented hierarchical model we use two FCMs.

FCM $M1$ models the first level of the hierarchy in the functional model. The FCM illustrates the system by a graph, the vertices of which will be determined using the values of the linguistic variable. These values are the result of the fuzzification function for the original CX metric value.

$$M1 = (FA_1, MU_1, VAL_1, DEG_1) \tag{6}$$

where FA_1 is a set of graph vertices, which are factors of the cognitive model M_1; MU_1 - the set of graph arcs that simulate the mutual influence of the CX concepts; VAL_1 is the set of values of the vertices of the graph; DEG_1 is a set of values of the influence degree.

Thus, at this step, the value of the total CX is calculated for each separate CLCS. This result is very important for predicting the movement of the customer through the CLCS.

FCM $M2$ models the second level of the functional model. This level allows to calculate the entire customer life cycle. The target factor in this case is the total CX for the entire customer's life cycle, and the model's governing factors are the values of the total CX at each CLCS, calculated as target factors of M_1. The FCM M_2:

$$M2 = (FA_2, MU_2, VAL_2, DEG_2) \tag{7}$$

Total CX for the entire customer life cycle, in essence, will be the target output parameter of the entire model, aggregating the values of CX at all CLCS.

Thus, at this step of the calculation, the solution to the problem of assessing the integral CX for the entire CLCS is simulated based on the values of CX at each CLCS.

To calculate the force of mutual influence of model factors we need to consider some "path" from the factor c_i to the factor c_j: $c_i \rightarrow c_{(i+1)} \rightarrow c_{(i+2)} \rightarrow \rightarrow c_{(j-1)} \rightarrow c_j$. This path can be defined by ordered factor indices: $(i, i+1, i+2, \ldots, j-1, j)$. Then, the indirect effect of the influence of the factor c_i on the factor c_j will be determined through the path $(i, i+1, i+2, \ldots, j-1, j)$. The overall effect of the influence of the factor c_i on the factor c_j will be determined by the set of paths N existing between these factors. The indirect effect of the influence of the factor c_i on the factor c_j:

$$C_n(c_i, c_j) = min\{e(c_p, c_{p+1}) \ \in (i, {k_1}^l, ..., {k_n}^l, j)\} \tag{8}$$

where C_n is the influence of the factor c_i on the factor c_j through some path n from the set of paths N; p and $p+1$ are indices of factors adjacent from left to right, through which a path is built from factor c_i to factor c_j. Operation min in this case will be equivalent to the operation of multiplication. Then, the general causal effect of the influence of the factor v_i on the factor v_j can be written as follows:

$$R_(c_i, c_j) = max(C_n(c_i, c_j)), \quad (9)$$

where $R(c_i, c_j)$ is the total influence of the factor c_i on the factor c_j through the set of paths N; $R(c_i, c_j)$ is the influence of the factor c_i on the factor c_j through the path n_i from the set of paths N.

Thus, at this step of the calculation, the problem of assessing the degree of influence of the metrics of CX and the values of the total CX is solved.

5 Results and further research

Models of CX have been developed to form a refined picture of a telecom operator's client in the general model of a CSP DT. The software "MentalModeller" and "Mathemematica" were used as tools for analysis and modeling of FCMs. As part of the study, 42 metrics (out of four hundred offered by TM Forum) were selected as control factors of the FCM, characterizing CX of a customer. We provide here as a result the FCM: for calculating the integral customer experience of the Buy stage for the customers of a CSP;

The initial data for building models are metrics of customer experience calculated on the basis of data from CSPs. We obtained the initial data for assessing the mutual influences of factors based on a survey of experts. Customer Experience Metrics - These are the numerical metrics of a CSP performance that experts believe impact the customer experience in the B2C segment of customers. According to the proposed model, the metrics are classified into 2 groups:

- indicators related to a specific customer and characterizing the experience of a specific customer (analogous to Per Customer Metrics in the TM Forum model);
- indicators characterizing the operating activities of the company; they are not associated with a specific customer, but they have an impact on the customer experience (analogous to Functional Metrics in the TM Forum model). This group of metrics is relevant for both models. Also, for each of the metrics, the stage of the customer's life cycle is determined to which it belongs, i.e. has the greatest impact.

The main data sources for metrics are OSS / BSS systems of a CSP: CRM, Billing, Service Desk, Work Force Management, as well as the system for collecting and analyzing customer opinions (customer opinions are collected by conducting surveys, as well as by receiving and analyzing customer comments from social networks). The range of values for each of the metrics under consideration is reduced to the range of values of the term set of the linguistic variable using the fuzzification procedure determined by experts for each metric.

To assess the mutual influence of factors in the models, two interviews of experts were conducted. In particular, the experts determined the mutual influence between the metrics of customer experience, between the metrics of customer experience and integral CX in the context of the life cycle stage, between the integral CX in the context of the life cycle stage and integral CX for the entire customer life cycle.

The model for assessing the integral customer experience for the Buy stage is based on the example of the process of connecting a new client (subscriber) from the moment when the client (subscriber) has already chosen the service that he wants to purchase and turned to one of the sales channels of the telecom operator until the moment when the service will be connected to the client. This process, in general, corresponds to the Buy stage of the TM Forum client life cycle model. Accordingly, it is possible to define a set of metrics that form an integral customer experience in the context of a given stage of the customer's life cycle. The set of metrics of the domestic telecom operator is taken as the initial data and is structured under the "reference" model of metrics from TMF. Fig. 6 shows a fragment of the FCM for assessing the integrated customer experience of the Buy stage in the context of the B2C segment of the operator's customers.

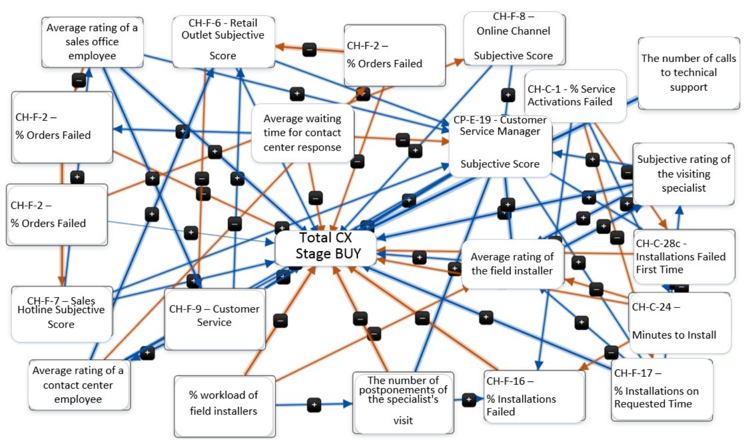

Fig. 6. Cognitive map for assessing the integrated CX of the Buy stage

6 Conclusion

The ultimate goal of the study is the built digital twin of a telecom operator. Realizing that this is a serious, large and complex task, we decomposed it into more understandable parts. We believe that the digital twin of a large system is a set of interacting digital models (small twins). By increasing the adequacy and accuracy of the models, we are gradually approaching a complex model of a telecom operator, which could be called a digital twin. The model of CX proposed in this paper is considered by us as one of the elements that make up the most accurate model of the customer - the digital twin of the customer. In the next works, we will be able to show a new, even more accurate model of CX, in which, possibly, new behavioral parameters of the client will appear.

References

1. Kislyakov S.V. Conceptual model of Communication Service Provider Digital Twin based on Infocommunication System Cross-Domain Model//Proceedings Of The Xxth Conference Of Open Innovations Association Fruct (2021-01-01). Vol. 28, no. 2, pp. 571 – 577
2. GB962 CX Management: Introduction and Fundamentals R16.0.1 // https://www.tmforum.org/resources/best-practice/gb962-customer-experience-management-introduction-and- fundamentals -r16-0-1/
3. GB962A Customer Experience Management Lifecycle Metrics R15.0.1 //https://www.tmforum.org/resources/best-practice/gb962a-customer-experience-management-lifecycle-metrics-r15-0-1/
4. Sotnikov A.D.Infocommunication systems and their models for healthcare// Information and control systems. 2008. No. 3 (34). S. 46-53.
5. Sotnikov A.D. Structural and functional organization of telemedicine services in applied infocommunication systems /dissertation for the degree of Doctor of Technical Sciences / Saint-Petersburg State University of Telecommunications named after V.I. M.A. Bonch-Bruevich. Saint Petersburg, 2007
6. The multi domain infocommunication model as the basis of an auditory interfaces development for multimedia informational systems// Sotnikov A.D., Rogozinsky G.G. T-Comm. 2017. Vol. 11. № 5. pp. 77-82.
7. Akishin V.A., Kislyakov S.V., Fenomenov M.A. Functional architecture of the CEM-complex for implementation in the it-landscape of a large telecom operator // T-Comm: Telecommunications And Transport. 2016. No. 10. S. 12-16.
8. Akishin V.A., Kislyakov S.V., Phenomenov M.A. User experience in the operator's cognitive network management model // T-comm. - 2016. - Volume 10, No. 10.
9. GB962 Customer Experience Management Solution Suite // https://www.tmforum.org https://www.tmforum.org/resources/suite/gb962-customer-experience-management-solution-suite-r17-5-0/. Last accessed 2 Apr 2020
10. GB962 Customer Experience Management: Introduction and Fundamentals R16.0.1 // https://www.tmforum.org https://www.tmforum.org/resources/best-practice/gb962-customer-experience-management-introduction-and-fundamentals-r16-0-1/. Last accessed 30 Apr 2020
11. GB962A Customer Experience Management Lifecycle Metrics R15.0.1 // https://www.tmforum.org https://www.tmforum.org/resources/best-practice/gb962a-customer-experience-management-lifecycle-metrics-r15-0-1/. Last accessed 1 May 2020
12. RN341 Customer Experience Management Index (CEMI) Release Notes R2.0 // https://www.tmforum.org https://www.tmforum.org/resources/reference/rn341-customer-experience-management-index-cemi-release-notes-r2-0/. Last accessed 1 May 2020

13. TMF066 Customer Experience Management Index Technical Specification V1.1 // https://www.tmforum.org https://www.tmforum.org/resources/technical-report-best-practice/tmf066-customer-experience-management-index-technical-specification-v1-1/ Last accessed 1 Feb 2021
14. TR193 Customer Experience Management Index v1.3 // https://www.tmforum.org https://www.tmforum.org/resources/technical-report-best-practice/tr193-customer-experience-management-index-v1-3/. Last accessed 10 Feb 2021
15. Goldstein A.B. On cognitive maps in the management of a telecommunications operator / A.B. Goldstein, N.A. Pozharsky, D.A. Likhachev // Informatization and communication. - 2016. - No. 1.
16. Akishin V., Goldstein A., Goldstein B. (2017) Cognitive Models for Access Network Management // Galinina O., Andreev S., Balandin S., Koucheryavy Y. (eds) Internet of Things, Smart Spaces, and Next Generation Networks and Systems. NEW2AN 2017, ruSMART 2017, NsCC 2017. Lecture Notes in Computer Science, vol 10531. Springer, Cham. Pages 375-381 (Scopus).
17. Axelrod R. Structure of Decision. The Cognitive Maps of Political Elites.- Princeton University Press, 1976.- 405 p.
18. Groumpos, P.: Fuzzy cognitive maps: basic theories and their application to complex systems. In: Glykas, M. (ed.) Fuzzy Cognitive Maps: Advances in Theory, Methodologies, Tools and Applications, pp. 1–22. Springer, Berlin, 2010.
19. Kosko B. Fuzzy Cognitive Maps. // International Journal of Man-Machine Studies. – 1986. – N.24. – P.65-75.
20. Kosko B. Fuzzy systems as universal approximators // IEEE Transactions on Computers, vol. 43, No. 11, November 1994. – P. 1329-1333.