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A Digital Twin Model of the Smart City Communication Infrastructure

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ABSTRACT

Digital transformation in Industry 4.0 today is associated with the transition to cyber-physical systems through the use of digital twin technologies, the industrial internet, big data, artificial intelligence, machine learning, etc. In this work, an attempt of strict theory developing was made that would allow to determine, "what digital twin is" and to determine the place of the digital twin among other models. As a result, a cyber-physical cross-domain model of communication service provider and the model of the digital twin for the digital service provider was suggested. The models aim to meet new problems in communications management.

KEYWORDS

CROSS-DOMAIN MODEL, DIGITAL TWIN, Infocommunications Management, OSS/BSS, RTC ARGUS, TM Forum

INTRODUCTION

The existing network management models reveal a wide variety of approaches to their construction, but there is no single model that allows network management at all levels - services, transport, and control. This is quite understandable by the difference in the principles of their level operation and management, as a consequence, by the difference in approaches to building models. To create a unified model, it is proposed to rely on the concept of a Digital Twin (DT).

The authors thoughts have found confirmation in two recently emerging concepts: IEM (Intelligent Enterprise Managing System) and Diaspar.

IEM is a concept that involves the evolutionary change of ERP systems for a variety of reasons. The first reason is that the use of disparate separate automation systems does not lead to complete end-to-end automation of the enterprise. This approach only allows you to improve the overall level of automation step by step. This long process most likely, will never lead to a 100% result. When improving individual systems, a bottleneck situation is always possible in one place or another. The attraction and application of the best practices for the automation of one or another part of the enterprise (telecom operator) in isolation will not always give an economic effect. The second reason is that the

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information space is not common in IT-landscape, and any separate system (for large telecom operator) is responsible for each set of tasks. In this case, there are problems of integration, correct use of data, access to data, etc. The third reason is the absence of a single source of coordinated control action, since each system monitors only its own part of the information space. Such concepts include the approach of the TM Forum organization, which proposed the NGOSS/Frameworx concept as a set of environments and tools for developing Operations Support Systems/Business Support Systems (OSS /BSS) solutions for the automation of Communication Service Providers (CSP). Zongyan (2020) proposed a new concept EIM, which is aimed at eliminating the above-mentioned disadvantages of OSS/BSS approach. The authors of the new approach considered the possibility of creating a unified enterprise management system. The following requirements were put forward for the new system:

§ A common information space of the enterprise;
§ Consistency, reliability, availability of data.
§ Work in real time.
§ Reliability of transaction management.
§ Reliability of the system as a whole.

Then this whole system, unified and complete in the sense of automating business processes, is built on the basis of technologies such as Data Mining, Machine Learning, Block Chain etc.

The authors of the IEM idea identify five basic principles.

1. Integrity. The integrity (high connectivity) of the IEM System naturally guarantees the reliability of the system data.
2. Closeloopness. IEM Data Warehouse Systems are a tightly closed container absorbing an information envelope within which an enterprise operates.
3. Orderliness. Standardization of all business processes introduced into the system circuit. In the correct implementation methodology - all the value chains of the enterprise.
4. Versatility. The Cybernetics IEM System models an arbitrary enterprise in the abstraction of a node in value chains.
5. Symmetry. IEM The system implements a symmetric digital model, a one-to-one cybernetic mirroring of the controlled enterprise. From the point of view of the problem we are solving, let us single out the principle of "symmetry". This principle says that the virtual model of the enterprise should mirror the actual state of the enterprise as accurately as possible. In addition, changes in the virtual part (in the system) must mirror into reality, that is, lead to changes in reality. This property of the IEM system brings us very close to the idea of a digital twin.

Because of the evolution of the IEM systems, Diaspar appeared. Diaspar is an enterprise operating system - the company's cybernetic backbone that connects disparate fragments of a business into a single, consistently functioning organism. Diaspar emulates a complete (closed) digital twin of a managed enterprise. Mutual mapping is the next step in the development of the digital twin concept, transforming it into a universal mechanism for managing organizations. The digital twin in mutual mapping is not just a cybernetic model (reflection) of the enterprise. Mutual mapping is a cybernetic analogue of a two-way mirror.

Cybernetic reflection and the material original are equal. Just as the reflection changes in accord with the original, so the managed enterprise projects the changes of the digital twin onto itself in real time (hence the "mutual reflection") (Olivotti, Dreyer, Lebek, Breitner, 2019), (Autiosalo, Vepsäläinen, Viitala & Tammi, 2020), (Alaei, Rouvinen, Mikkola, Nikkilä, 2018).

Because of studying these concepts, it became clear that the development of a digital twin of a telecom operator is a logical development of an approach to total automation (Song, Burns, Pandey, 2019). At present, the automation of the CSP bases on the use of a number of loosely coupled narrowly targeted systems. Consequently, all of the above difficulties and problems of automation take place.

However, in the available sources, the authors of this article could not find any detailed and technical information about the EIM systems. Finally yet importantly, a communications service provider is a very complex enterprise. Unlike a store or a warehouse, it also includes a large infocommunication infrastructure, as well as everything that any enterprise consists of. Consequently, the approach to creating a digital twin or operating system for a communications enterprise will be very different.

THE DIGITAL TWIN APPLICATIONS

Digital Twins (DT) are being developed for industrial enterprise: engineering, manufacturing and operations, and for maintenance and service. The technology of DT is being supported such technologies of Industry 4.0 as IoT, Artificial Reality (AR), CAD, Product Life Cycle Management (PLM), Artificial Intelligence (AI) etc., see (Maninder, 2019), (Jimenez, Jahankhani, Kendzierskyj, 2019) and (Tao, Qi, 2017). As argued in (Maninder, 2019), DT enable companies to create globally competitive next-generation products in the shortest possible time and manage changes at all subsequent stages of the life cycle.

The main reasons and value for industries are: it is the collection and use of data in real time that makes it possible to increase the accuracy of modeling and reduce the error of discrepancy with a real object. (Tao, Qi, 2017)

The ability to integrate vast data sets into a single model is of particular value. DT bring the greatest effect during implementation, starting from the earliest stages - the design and engineering process, then covering control systems, production and economic data, the stage of model adaptation during operation (Lee, Sokolsky, Chen, Hatcliff, Jee, Kim, King, Mullen-Fortino, Park, Roederer & Venkatasubramanian, 2012) and the emphasis is on predictive analytics and what-if simulations (Wang, Wan, Zhang, Li & Zhang, 2016).

However, no source answers the question "what a DT twin is?" from mathematics, information theory, computer science point of view. To date, there is no coherent theory and definition of the concept of DT and, therefore, the place of the DT in the series of models has not been determined.

Today, the DT can be useful for a certain range of problems of the Operations-Administration-Maintenance (OAM) -class, which, as suggested by the author, can be solved by the DT more accurately and dynamically (quickly) together with already known traditional approaches. Requirements for a higher response rate of control systems and high control dynamics follow from the current situation and forecasts for the future - a rapidly growing density of devices, rebuilding their network topology, Internet of Everything, 5G/6G etc (Okita, Kawabata, Murayama, Nishino, Aichi, 2019). From one side, the OAM tasks of digital service provider (DSP) can be formulated in terms of traditional abbreviation FCAPS. From the other side, we cannot even imagine how many and what kind of DSP problems will be possible to resolve by means DT technology. Probably, by the time a very small part of that picture will be clear.

Here is some applications of DT for DSP:

§ Analysis of extremely rare events, when the Knowledge Base of a large operating company is formed for the case of events that are difficult to predict and difficult to analyze. For example, a meteorite crash caused 30% of services to fall. People use pens to enter data about the state of the object in the knowledge base.
§ Modeling of difficult formalizible and difficult predictable results.
§ Improving service level and reliability through preventive (predictive) maintenance. Preventive maintenance helps you act proactively to reduce the number of problems that may arise.

§ Improving product development and implementation by modeling behavior through understanding the relationships between DTs of the same or different types. Simulation allows for better product and service planning.
§ Improving the reliability of services for certain groups of clients. By knowing ahead of time which clients are actually affected by network problems in a given situation, you can plan quality retention activities for those client groups. The problem here is that infrastructure construction is a complex and expensive aspect of a telecommunications operator's life. At the same time, technologies are developing in parallel and very quickly. A situation arises in which the infrastructure is not yet fully ready for the technology (for example, for mobile video, when it works in general, but overloads occur), but there is a desire to launch the service as soon as possible. DT will help to avoid problems in narrow areas, see (TM Forum home page) and (Qi, Tao, Zuo & Zhao, 2018).
§ Reducing the time to bring a quality product / service to the market. Modeling a service using a DT.

Here are some possible use-cases we can use DT:

§ To predict and proactive eliminate/avoid a problem;
§ To calculate the period of "network relevance" and predict the timing of the start of network development and the necessary investments;
§ To assess the performance / reliability of the network and the sustainability of services for special cases (football match, elections, meteorite) - guaranteeing the operation of certain services like emergency services;
§ To predict customer behavior.

Real-world examples of future use of DT would be infrastructure testing to get the network's response to congestion. Currently, this is either pre-calculated or observed when the system is already overloaded. DT will allow you to check the response of the system without loading the real network, but only DT. In this way, you can identify bottlenecks in your infrastructure and plan to increase network performance at minimal cost.

DOMAIN MODEL OF A CYBER-PHYSICAL SYSTEM

Key definitions

To describe the model (by A.D. Sotnikov) is used (Sotnikov, 2003, 2004, 2007) as a basic we need introduce a number of concepts and definitions. An information system interacts with different information objects: $\{A, B, \ldots\}$ of entities $\{A, B, \ldots\}$. The information transfer can be described by

$$\mathrm{A}^{\hat{\imath}_{\mathrm{A}}} \overset{\text{Signal}}{\Rightarrow} \mathrm{A}^{\hat{\imath}_{\mathrm{A}}\,\hat{\imath}\mathrm{B}} \tag{1}$$

The information is received when a new image of the source is formed within the varifold thesaurus of the target system.

$$A^{\hat{\imath}_A} \xrightarrow{Q_1} \tilde{N}^{\hat{\imath}\mathrm{C}} \xrightarrow{Q_2} A^{\hat{\imath}\mathrm{A}\hat{\imath}\mathrm{C}\hat{\imath}\mathrm{B}} \tag{2}$$

The Domain-Based Infocommunication Model

The least generic and abstract model is the Domain model (DM) (Sotnikov, 2003, 2004, 2007) which makes it possible to identify infocommunication systems components, define the intercomponent interfaces and consider the information interaction processes. There are three domains within the DM, associated with three relatively independent, albeit closely linked, types of activity. The *Physical Domain* (PD) is mostly concerned with energy processes and the interaction of material objects. The situation analysis and intellectual activity producing evaluations and solutions is the product of mental and psychic activity of the *Cognitive Domain* (CD). The *Information Domain* (ID) is the area for the circulation of data used in the CD, representing the objects, phenomena and process of the PD.

According to the DM, the sphere of telecommunications lies on the boundary between the physical and information domains. The perception of physical reality, represented by ID entities, is linked with information interaction and occurs on the border of ID and CD. Thus, infocommunications embrace all three domains, although at present, the cognitive domain remains insufficiently explored, since the categories of cognition and other entities and relations within the CD, linked to the generation and consumption of the meaningful-semantic nucleus of information, remain underdeveloped.

$$An^{\xi_{An}\,\xi_{C^m}} \overset{Q_{22}^{\xi_{C^m C^k}}}{\longrightarrow} An^{\xi_{An}\,\xi_{C^k}}. \tag{4}$$

The general view of elementary interaction between two information systems within the ID is a unidirectional transfer/receiving of the representation of the object of PD, described as follows:

The information interaction occurs by means of exchanging “messages”, which are the subsets of the set of information representations $A_1^{\hat{\imath}_{A_n}}$ of the object $A_1^{\hat{\imath}_{A_n}}$, transferred between information system (IS) C_m and CD. Thus, the interaction of several IS within the ID is described as follows:

$$\left\{ A_n^{\hat{\imath}\mathrm{A}_n} \right\}_{n=1,..N} \overset{k=1,..K}{\underset{Q_{22}^{\hat{\imath}\mathrm{C}^k \hat{\imath}\mathrm{C}^m}}{\longleftarrow}} \overset{Q_{22}^{\hat{\imath}\mathrm{C}^m \hat{\imath}\mathrm{C}^k}}{\longrightarrow} \left\{ A_n^{\hat{\imath}\mathrm{A}_n} \right\}_{n=1,..N}^{\hat{\imath}\mathrm{C}^k}\ {}_{m=1,..M} \tag{5}$$

The information process is a combination of elementary information interactions within the ID. Expression (5) represents the “domain model”, a description of information interaction linked to the nature of three domains. Let $\left\{A_1,\dots A_6\right\} \in \boldsymbol{A}$ the set of objects in the PD, $\left\{C_i^j\right\} \in \boldsymbol{C}$: the set of objects in the ID, where $i = \{1,\dots,9\}$, $j = \{1,\dots,5\}$, while the subsets of representations $\left\{C^i{}_m\right\}$ are within m autonomous IS active within the ID. Thus, for objects A_n and consumers B_k generally:

$$A_n^{\hat{\imath}\mathrm{A}_n} \overset{Q_{12}^{\hat{\imath}\mathrm{A_n}\hat{\imath}\mathrm{C^m}}}{\longrightarrow} A_n^{\hat{\imath}\mathrm{A}_n\,\hat{\imath}\mathrm{C}_n^m} \overset{Q_{23}^{\hat{\imath}\mathrm{C}_n^m \hat{\imath}\mathrm{B}_k}}{\longrightarrow} C_n^{m\,\hat{\imath}\mathrm{C}_n^m\,\hat{\imath}\mathrm{B}_k} \tag{6}$$

Expression (6) represent the model of information interaction of two subjects of CD, expressed in terms of ID system representations and PD objects. The representation of object *A1* in the user thesaurus *B1* serves as the basis for making decision $R_1^{\hat{\imath}_{B_1}}$ by subject (*B1*) of CD.

$$A_1^{\hat{\imath}A_1 \hat{\imath} c_1^1 B_1} \overset{\theta B_1}{\Rightarrow} R_1^{\hat{\imath}B_1} \tag{7}$$

$$A_1^{\hat{\imath}A_1 \hat{\imath}C_1^1 B_1} \overset{\theta B_1}{\Rightarrow} R_1^{\hat{\imath}B_1} \overset{Q_{32}^{\hat{\imath}B_1 \hat{\imath}C_7^A}}{\longrightarrow} R_1^{\hat{\imath}B_1 \hat{\imath}C_7^A} \overset{Q_{23}^{\hat{\imath}C_7^A \hat{\imath}B_4}}{\longrightarrow} C_7^{A \hat{\imath}C_7^A B_4} \tag{8}$$

where $\overset{\theta B_1}{\Rightarrow}$ decision making operator. The whole sequence of forming the image of object *A1* in the ID, its perception by subject *B1* in the CD, decision making and transfer via the ID to subject *B4* in the CD, is described as follows:

This expression represents the information interaction model for CD subjects in terms of ID system representations, PD objects and CD subject decisions.

CROSS-DOMAIN MODEL

Domain Model Transformation

A considerable number of target management models have already been developed, for example, the TeleManagement Forum NGOSS/Frameworx concept (TM Forum home page) as most well known. Among them, the above-described domain model proposed by A.D. Sotnikov (Sotnikov, 2003, 2004, 2007) for describing the processes of transferring information from source to receiver in infocommunication systems, is very well suited as a basis for building a specialized model for managing infocommunications. This model is the best suited for developing a management model, which will also allow developing a theoretical basis for introducing the idea of DT for the field of infocommunications. In this work, the task is posed as the development of the theoretical foundations of the CSP DT.

In the already known domain-model, it is necessary to introduce a number of additions reflecting management focus and the DT focus. The model is not suitable as is, as it lacks a feedback loop. The second reason is the lack of coordination with the developed concept NGOSS / Frameworx, which is currently the dominant and de facto standard in the direction of automation of infocommunications. Although the ideas of NGOSS/Frameworx also contain their shortcomings, which currently do not allow building a DT model on its basis (using the Shared Information and Data Model (SID) model) without significant changes.

In the new Cross-Domain Model, we have added horizontal domains reflecting the specifics of infocommunications were introduced into the model. The horizontal domains are taken from a model called Shared Information and Data (the new name is Information Frameworx) and other concept tools - enhanced Telecom Operations Map (eTOM) and Telecom Applications Map (TAM). This is a mature enough concept and tools, so we should rely on them when developing our new model.

Figure 1 shows only few of the horizontal domains. The meaning of the term “domain” in the new cross-domain model proposed here should be clarified. The fact is that for vertical domains of the Domain Model this term means the unified nature and unity of the rules for interaction between entities in each separate domain. These rules, like the nature of entities, differ from domain to domain. The horizontal domains from the SID model of the NGOSS/Frameworx concept contain aggregated 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. Therefore, in the context of this model, it is more correct to name horizontal domains “area” in order to avoid terminological confusion and not to confuse the reader. However, we will retain the name "domain" due to the fact that it has been present in the documents of the TM Forum and the International Telecommunications Union (ITU) for a quarter of a century. The eTOM is standardized by ITU-T. Because of in the new model we have intersecting horizontal and vertical domains, this model named "Cross-Domain Infocommunications Management Model" (CDM) (Figure 1).

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 in the course of his 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 all sorts of available information sources. In general, this is information and data presented in various formats. The Cognitive Domain (CD) in this work is the least studied, since much of it goes beyond the scope of infocommunication topics.

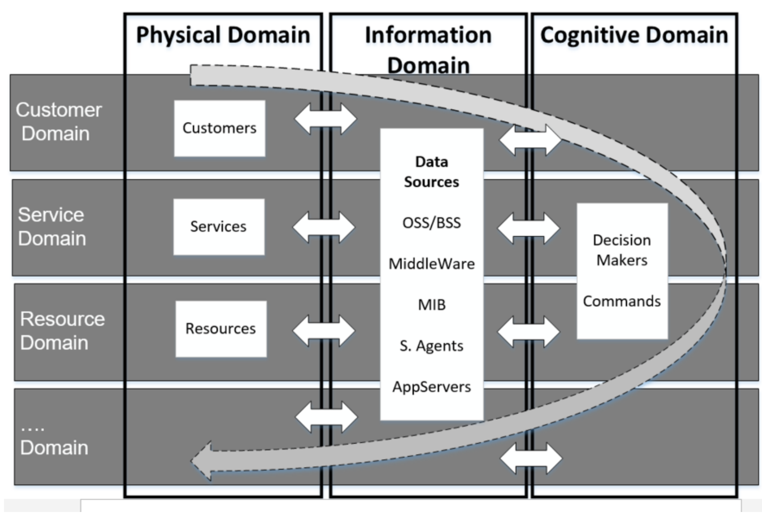
Cross-domain interaction is described in section 2 of this work. This is a cross-domain information exchange with feedback, which is necessary for the implementation of management and control functions. Feedback forms a closed control loop, which is introduced here into the CDM of the DT, reflecting activity of cognitive function (decision-making, analysis, etc.) in the CD.

Interaction within the ID domain will be described in Section 4 of this work. Filling in the ID is also a very important task when designing DT. This requires answering a number of questions, and the main one is what DT is from informatics and information process point of view, what is its place in the proposed model, etc.

TM Forum Framework Concept

eTOM serves as the blueprint for process direction and the starting point for development and integration of Business and Operations Support Systems (BSS and OSS respectively) and, helps to drive TM Forum members work to develop NGOSS/Frameworx solutions. For CSP, it provides a neutral reference point as they consider internal process reengineering needs, partnerships, alliances, and general working agreements with other providers. For suppliers, the eTOM outlines potential boundaries of software components, and the required functions, inputs, and outputs that must be supported by products. In the framework of the NGOSS/Frameworx concept, in 1998 TM Forum

Figure 1. The conceptual view of the Cross-Domain Model



developed its own domain model. There are eight domains in total: Market, Product, Client, Service, Resource, Partner, Enterprise, General business entities (Figure 2). According to the principle of organization of eTOM and TAM, the SID is implemented within Frameworx: the same domains containing information entities are highlighted in it. The SID captures the concepts and principles necessary in defining a shared information model, and defines in detail many of the business elements (known in the SID as "Entities") of interest to service providers and the attributes, which describe these entities. The SID provides business oriented UML class models, as well as design oriented UML class models and sequence diagrams to provide a system view of the information and data.

This domain architecture is based on the Telecommunications Management Network (TMN) approach, which is now outdated, but leaves behind a number of great useful ideas. The TM Forum focus is on providing pragmatic solutions to business problems and is based on the business layering principles articulated in the ITU-T layered TMN model.

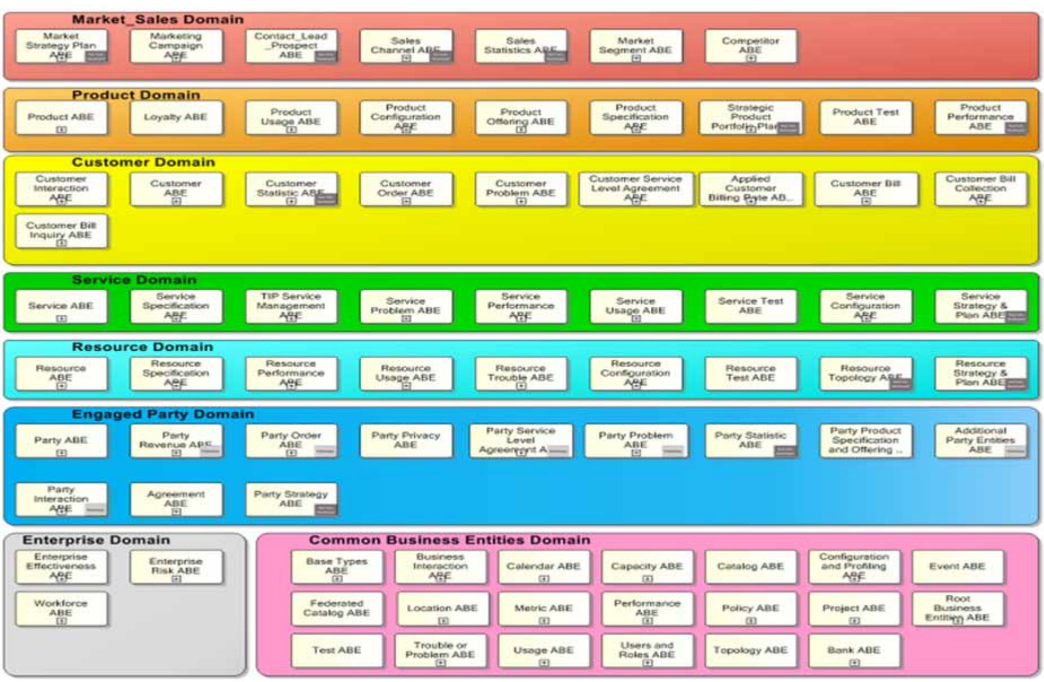
DIGITAL TWIN OF DIGITAL SERVICE PROVIDER

Data Sources for Digital Twin

Operations support systems (OSS) and business support systems (BSS) - are designed to automate all business-processes of CSP. Mediation system is designed to integrate the OSS / BSS system with heterogeneous active network equipment and provide two-way interaction between all elements of the network and IT infrastructure.

Resource / Inventory management is responsible for accounting of physical and logical resources and is a data catalog that reflects all aspects of the operator's network infrastructure. The system, as a rule, contains a hierarchical description of active and passive network equipment, including such parameters and metering characteristics as location address, reference to the delivery / installation

Figure 2. TM Forum Information Framework (SID)



agreement, commissioning date, mounted capacity, type and serial numbers of cards and units, physical and logical relationships of equipment, timing of preventive and routine maintenance, etc.

The performance management system monitors network performance and analyzes its performance and reliability. It collects processes and analyzes information about the load on network elements, including the load of equipment and data transmission channels, stores information about the load for a long period and provides reports on its basis. The module can also support functions for predicting and assessing changes in the load of network elements when the network topology changes or one or more of its elements fail, planning an increase or decrease in network bandwidth with an assessment of the quality parameters of services provided, building customer profiles and models of their behavior. Thus, the performance management module is designed to control the performance and efficiency of communication networks and information systems, allows you to optimize the network configuration, distribute the load between various resources and contributes to the planning of network development.

Fault management system is an alarm monitoring and management system. It collects and preprocesses information about failures and accidents that occur on network equipment, and establishes a correlation between alarms to determine the root cause of the failure. To collect data, the module periodically updates information about the current state of the monitored equipment and communication channels, as well as forced polling of monitored objects to check their operability. The module stores information about events that have occurred in the network for a long period and provides reports on emergency events, and can also display the relationship of an incident with a client and a service that is affected by this incident.

The trouble ticketing system allows operators to track progress and control the troubleshooting process. The troubleshooting lifecycle is supported using trouble tickets. The module performs the functions of registering problems recorded on the basis of emergency messages, appointing a responsible executor to solve the problem, monitoring the progress of solving the problem (escalation, informing the management), and notifying customers about the progress of solving problems.

The SLA management system monitors the quality indicators of service provision for both external and internal users, compares the actual indicators with those specified in the service level agreements and identifies the facts of SLA violations.

The order management system is used to support business processes for processing orders for the provision of any type of communication services. The system monitors all stages of order execution throughout its life cycle: ensuring connection, disconnection and configuration changes of services, formation and registration of orders for the activation/release of network resources, monitoring the progress of their execution in structural units; and also allows you to create detailed reports for each stage of the order and the order processing process in general.

Fraud management system is designed to suppress and prevent cases of unauthorized and unpaid use of the company's services. The main functions of the system are to detect, suppress and forestall cases of fraud affecting the resources of a telecom operator. Tracking of the intruder is usually carried out using mechanisms and algorithms specially designed for various types of connections and services: calling a suspicious number, a non-existent user, exceeding the cost or duration threshold, etc.

Billing system is intended for accounting and tariffication of communication services consumption. The Billing System performs three main functions: collection, primary processing, control and registration of information about the consumption of communication services by users (Accounting). This may also include user authentication and authorization when accessing communication services - then they talk about AAA (Authentication, Authorization and Accounting) functions, but these functions are more related to the fraud prevention system.

The customer relationship management system processes data on contacts with customers and allows you to assess their loyalty, the potential for growth in service consumption, and also provides a basis for analyzing the effectiveness of actions to retain and grow a customer base. The functions of this system include registering new customers and subscribers, working with subscribers (managing services, changing a tariff plan, etc.), as well as tasks related to paying for services: accepting payments from customers and dealers and selling goods from a warehouse (cash register functions operator) and integration with external payment systems, which allows you to organize the acceptance of payments through various sources (card platforms, electronic payment systems).

Traffic management system is used for analyzing, processing and managing traffic in primary and secondary networks, in signaling networks, at the level of user applications. The module is responsible for generating proposals for optimal traffic routing depending on the quality and cost of providing communication services and monitoring the correct execution of routing tables on the network switching equipment.

Revenue assurance system controls all stages of generating revenue from the provision of services, from monitoring the operation of access equipment and ending with the reconciliation of billing information, in order to avoid loss of revenue as a result of loss of billing data, delayed payments, etc. The module's functioning is based on information analysis and signal generation alerts about deviations from normal, reference behavior. Thus, the module can detect the loss of information about the calls made, deliberate or accidental distortion of information at any stage, incorrect tariffication, etc.

Customer experience management system allows you to find out the company about how each of its customers treats it, draw conclusions about further steps to improve or maintain the loyalty of its client. Thus, you can try to reduce customer churn and get more profit from each customer.

The business intelligence system has access to databases for various purposes and, based on the information stored in them, provides reports that allow company managers to get an adequate idea of the state of the business, analyze the situation and existing trends and make a reasonable forecast of the company's and market development.

The place of the Digital Twin

Information entities of ID interact as IS and form DT of PD. Their interaction can be described as a unidirectional transmission/reception of the representation (image) of the PD object by the expression:

$$A_n^{\hat{\imath}\mathrm{A}_n\,\hat{\imath}\mathrm{C}_n^m} \xrightarrow{Q_{23}^{\hat{\imath}\mathrm{C}_n^m\hat{\imath}\mathrm{C}_k}} A_n^{\hat{\imath}A_n\,\hat{\imath}\mathrm{C}_k} \tag{9}$$

Figure 3. Source systems for the Customer Horizontal Domain

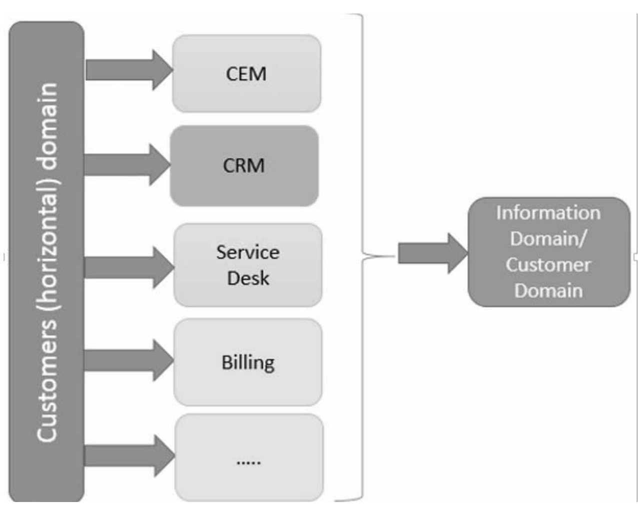
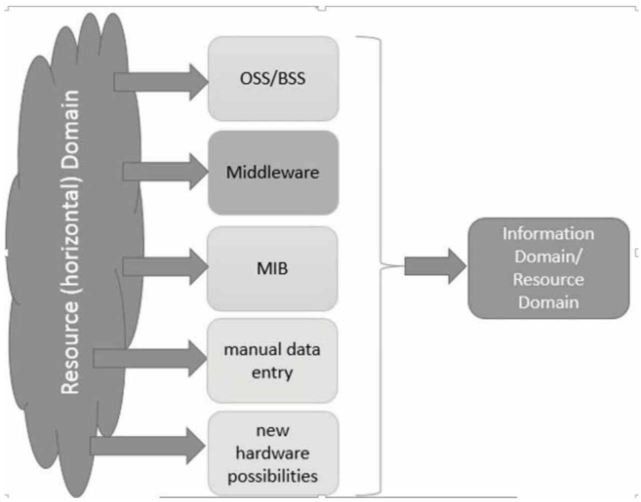


Figure 4. Source systems for the Resource Horizontal Domain



$$A_n^{\text{îA}_n\,\text{îC}^m} \xrightarrow{Q_{22}^{\text{îC}^m \text{C}^k}} A_n^{\text{îA}_n\,\text{îC}^k} \tag{10}$$

where îC_n^m – is the thesaurus of the m -th information system, C_n^m – n – is the n -th information object (element of the system thesaurus), A_n – is an object of a physical domain, $A_n^{\text{îA}_n}$ – is one (n - th) from the set of possible representations of the object A_n .

The interaction of several IS within the ID is described as:

$$A_n^{\text{îA}_n}{}_{n=1,..N} \underset{Q_{22}^{\text{îC}^k \text{îC}^m}}{\overset{k=1,..K}{\longleftarrow}} \xrightarrow{Q_{22}^{\text{îC}^m \text{îC}^k}} A_n^{\text{îA}_n}{}_{n=1,..N}{}^{\text{îC}^k}{}_{m=1,..M} \tag{11}$$

All interactions within an ID, reflecting the behavior and properties of a physical entity, are the DT in case

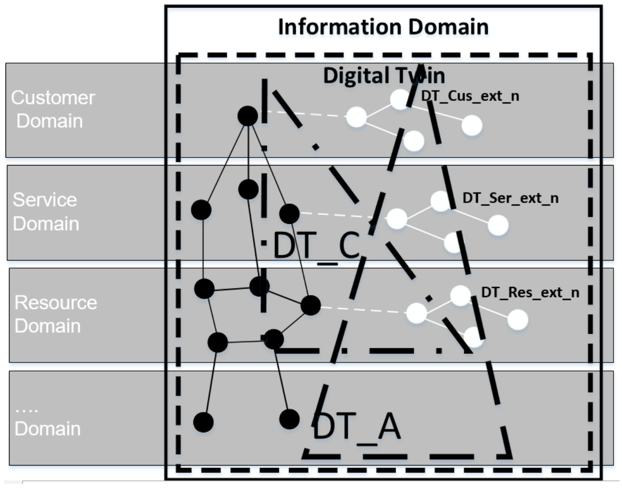
$$\xi C_n^m = \xi A_n^m \tag{12}$$

Formula (4) says that thesaurus of the information domain (ID) systems equals to thesaurus of the physical domain (PD) systems.

Based on the definition (4) and based on the figure, it can be argued that DT includes all "single-task" twins DT_A, DT_C, etc. of ID (Figure 5).

DT for CSP can be a collection of "single-task" DTs interacting with each other in order to achieve a goal. For example, a client DT can interact with a resource DT. This interaction will reflect (mirror) the real interaction in real time. There will be many such interactions, and the number of interactions will determine their number in reality.

Figure 5. CDM based Digital Twin Model



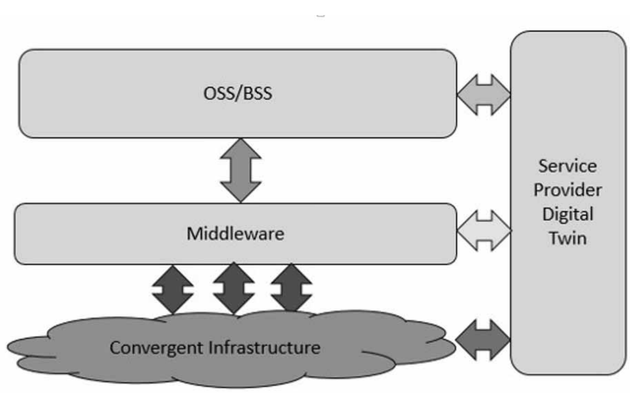
Digital Twin in Digital Service Provider's OSS-landscape

Now, we can assume how the technologies and capabilities of infocommunication equipment will change by the time the first DTs are introduced into the OSS landscape of digital service operators. From the point of view of the author of this article, DT should be part of the OSS landscape. Given that DT is the most accurate model of a physical entity, it is necessary to involve all IT systems and all possible equipment interfaces. Top-tier architecture as shown at figure 6.

The most important feature that DT DSP will provide is the ability to carry out simulations in real time without affecting the physical infrastructure of the operator. That is, it becomes possible to use DT to solve a variety of (described at the beginning of this article) tasks. At the same time, the existing DT will not be a "black box" with unknown content. It will be a very close to real complex object model with input and output, which will be included in the feedback of the large "control mechanism".

When we talk about the place of DT in the CSP IT landscape, we mean the answer to the question: how and with what systems DT will interact, being in turn also an IT system. In general, DT interacts

Figure 6. The suggested place of Digital Twin in OSS-landscape



not only directly with the CSP network infrastructure, but also with all available IT systems in order to obtain the most complete information about all physical objects.

To build Smart Cities based on DT we could suggest The Smart City Basic Telecommunications Infrastructure Digital Twin conceptual view (Figure 7).

CONCLUSION

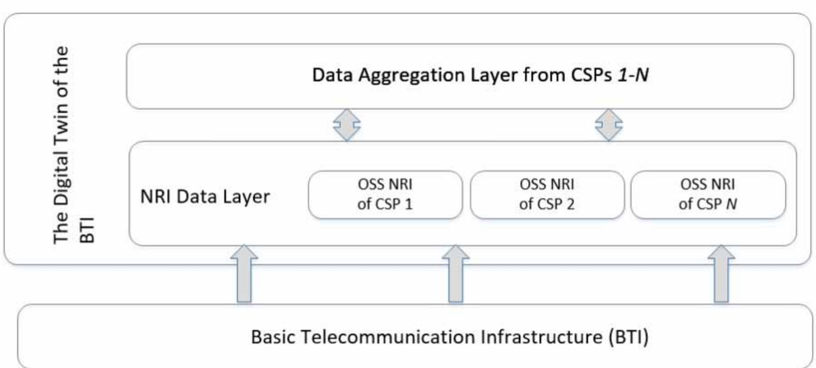
At the beginning, a number of questions arose: what is a DT study, is it possible to find a mathematical description for it, is it possible to apply such an approach for a telecom operator, and what is the place of a DT in the operator's IT landscape. It turned out that the term Digital Twin is used in materials processing, mechanical engineering and the like - where a very high accuracy of the result is required (Olefirenko, Galuschenko, 2018), (Fei, Weiran, Jianhua et al, 2018). An attempt to figure it out led to the understanding that the term DT is a fashionable name for the digital or informational model. This term meant a special approach to the construction of the model itself: a physical object, as it were, "reflected" in cyberspace using sensors and info-communication systems. Nevertheless, it is still just a model. If we are talking about the digital twin for CSP, it is necessary to understand the difference between physical objects that use physical impact (for example, heating or cutting) and physical objects - network elements. The former require the installation of sensors in order to transfer data about the state of the object to the control system. The second are active network data. Back in 1995, TM Forum developed the concept of NGOSS and OSS/BSS IT systems for maintaining the communication infrastructure of CSP and it's business. OSS/BSS receive/store /process data and perform control actions on the networks. The OSS/BSS are kind of watching the network, but not mirroring it into a cyberspace. Why create the DT of an operator? In the opinion of the author of this work, the digital twin will allow avoiding the stage of creating a model and the stage of interpreting the results of modeling, and will create a single information infrastructure interface in real time.

In order to create a digital twin, it is necessary to mirror the static and dynamic properties of all CSP activities and systems: from subscribers with their behavior to equipment.

It is clear that in any case, the digital twin will remain a model for an indefinite time and will never be able to completely replace the real network of a communication service provider. When we talk about DT, we mean two models: a way to create a model through mirroring an object, no intermediaries in the video model, and no need to interpret the simulation results.

The author of the work proposed a new model based on the domain model of the infocommunication system. First, the domain model used for a formal definition of DT. Second, the Domain Model has been modified: the horizontal SIDs domains included. Thus, the author proposed a new cross-domain

Figure 7. The Smart City Basic Telecommunications Infrastructure Digital Twin conceptual view



infocommunication model that combines two previously developed models. It is important to note that the SID model is designed as a production oriented model for OSS/BSS development for CSPs.

The proposed DT speculative model has not yet reached the test level. So far, this is only a conceptual model aimed at the telecommunications sector.

In this work, the author tried to give a rigorous definition of the term DT itself through the concept of thesaurus and on the basis of the domain model (Kislyakov, 2020). He does not claim that this is the only and absolutely correct definition. Perhaps, up to this point, he simply did not come across the already existing definition of DT in the literature. Nevertheless, the author hopes that this definition will be useful for the further development of DT ideas.

The general DT model for the CSP is a collection of "separate small DTs" that form one coherent DT. The DT model for CSP is supplemented with horizontal domains from the General Information and Data Model specially designed for CSP.

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Conflict of Interest

The authors of this publication declare there is no conflict of interest.

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