nisms of this kind assume the absence of direct interaction between autonomous entities composing the system, but their interaction through a common environment, which in the framework of the proposed approach is a common semantic memory (both within the *individual ostis-system* and within the collective *ostis-system*).

V. Means of specification of next-generation intelligent computer systems in the context of collective problem solving

An important role in the proposed approach to problem solving within the *OSTIS Ecosystem* is played by a rather detailed and unified specification of ostis-systems included in the *OSTIS Ecosystem*. Each ostis-system included in the *OSTIS Ecosystem* is subject to a number of requirements [4], [8], the fulfillment of which is necessary to ensure the principle possibility of collective problem solving, to increase the efficiency of the evolution of *OSTIS Ecosystem* and *OSTIS Technology*, to reduce the requirements to the developers of ostis systems and the labor intensity of their development. The most important of these requirements is the requirement to ensure compatibility (both syntactic and semantic) of each *ostis-system* with others, and in particular with the *OSTIS Metasystem* containing the current version of the *OSTIS Standard*, and to continuously analyze and maintain such compatibility.

At the same time, in order to organize problem solving within *OSTIS Ecosystem* it is additionally necessary to have a detailed specification of functional capabilities of each ostis-system and to ensure the relevance of such specification in the process of evolution of this ostis system. This specification is part of the knowledge base of *corporate ostis-systems ostis-communities*, to which the specified ostis-system belongs. If the ostis-system is not currently a part of *any ostis-community,* the *corporate ostis-system* is the *OSTIS Metasystem*.

The basis of the knowledge base of any ostis-system is a hierarchical system of *sc-models of subject domains* and their corresponding formal *ontologies* describing the properties of entities studied within the specified subject domains [4], [22]. Thus, the knowledge base of the *corporate ostis-system* contains sc-models of those subject domains, on the automation of various activities in which the corresponding *ostis-community* is oriented. In order to provide the possibility of automatic determination of the collective of ostis-systems necessary for solving a particular problem and clarifying the plan of solving this problem, it is necessary to develop for each subject domain the corresponding *ontology of subject domain problem classes and problem solving methods*. [4], [9].

The specified ontology includes a description:

- *classes of problems* solved in the corresponding subject domain;
- *methods* of problem solving corresponding to the specified *classes of problems*;
- *skills* of problem solving corresponding to the specified *classes of problems*, i.e. *methods*, supplemented by the description of *sc-agents* implementing the specified *methods* with the corresponding specification [4];
- method representation languages specific to the subject domain;
- strategies of problem solving specific to the subject domain, i.e. meta-methods of forming other methods of problem solving;
- and other entities, the description of which is necessary to organize problem solving processes within the subject domain. For example, if there are several methods of solving problems of the same class, it is reasonable to describe their comparison in order to be able to choose the method most suitable for the current situation.

As mentioned earlier, the ontology presented in [15] is proposed to be used as a basis for the content of the general ontology of all possible problem classes solved within the *OSTIS Ecosystem*. Thus, the set of problem classes described within a particular *ontology of subject domain problem classes and problem solving methods* will specify some subset of problem classes from such a top-level *problem ontology*. Examples of describing specific classes of problems and corresponding methods of their solution using the example of neural network methods of problem solving can be found in [23].

Thus, each ostis-system being a part of some ostiscommunity should be specified using the concepts of *ontology of subject domain problem classes and problem solving methods* presented within the corresponding *corporate ostis-system*. In its turn, within each individual ostis-system, this ontology can be further refined. Note that the same methods (and, accordingly, skills) can be duplicated between different ostis-systems, but the information about it is explicitly recorded, which allows us to take it into account when forming a problem solving plan and determining the composition of participants of the collective of ostis-systems taking part in the solution.

Accordingly, when adding ("registering") an ostis-system to an ostis-community, the following steps must be performed:

- Integrate the *ontology of subject domain problem classes and problem solving methods* into the corresponding ontology of the *corporate ostis-system*. Thus, the *corporate ostis-system* will receive information about new problem classes and methods of their solving, if there are any in the added ostis-system;
- Using the obtained integrated ontology, generate a specification of the added ostis-system in the knowledge base of *corporate ostis-system*;
- When the functionality of a *ostis-system* changes, it must notify the *corporate ostis-systems* of all *ostis communities* of which this *ostis-system* is a part, which in turn will lead to corresponding changes in

the knowledge bases of these corporate *ostis-systems* and possibly to refinements of their corresponding *ontologies of subject domain problem classes and problem solving methods*. Note that this approach has an advantage over many traditional approaches to agent communication in multi-agent systems, where for successful subsequent operation of the system it is required to inform about the addition of a new agent all agents already in the system, since in the process of problem solving agents exchange messages directly and must "know" each other.

The considered specification of *ostis-systems* within the framework of *OSTIS Ecosystem* can be used not only for organizing problem solving, but also for other purposes, in particular, for implementing the idea of component design of ostis-systems [24]. Besides, the considered specification of *ostis-systems* is also necessary for the developers of *ostis-systems* in order to understand what capabilities are already presented within *OSTIS Ecosystem*, within which *ostis-communities*, with the developers of which ostis-systems it is necessary to coordinate these or those components of the developed system, and for solving a number of other design problem solving.

VI. A general plan for solving a specific problem within the next-generation intelligent computer systems ecosystem

According to the proposed approach to problem solving within the *OSTIS Ecosystem*, solving a particular problem generally involves the following steps:

- Problem formulation. In general, two options are possible at this step:
  - the initiator of problem solving is an ostis-system, which is a part of *OSTIS Ecosystem*. In this case, the problem formulation is placed in the knowledge base of the corresponding *corporate ostis-system*. To describe the problem formulation at the first stage, both the top-level *ontology of subject domain problem classes and problem solving methods* (included in the *OSTIS Standard* and, respectively, in the knowledge base of the *OSTIS Metasystem*) and more particular *ontology of subject domain problem classes and problem solving methods* corresponding to the *ostis-systems* belonging to the given *ostis-community* can be used.
  - the initiator of problem solving is an external cybernetic system, in particular a human user. In this case, it is assumed that communication with the *OSTIS Ecosystem* is carried out by a *personal ostis-assistant* corresponding to this cybernetic system. Thus, in this case, the task formulation is placed in the knowledge base of the *personal ostis-assistant* and then moved to the knowledge base of the *corporate ostis-system* of the ostiscommunity of which this *personal ostis-assistant* is a member. If a user is a member of several *ostis-communities* through his/her *personal ostisassistant*, then the problem of optimal selection of the *ostis-community* within which it is most expedient to start solving a problem becomes relevant. At the same time, the proposed approach to decentralized problem solving in general does not depend on which *corporate ostis-system* the problem formulation initially enters, it affects only the total time of problem solving.

  Thus, as a result of this step, in any case, the problem formulation enters the knowledge base of some *corporate ostis-system* (in general, not necessarily that *corporate ostis-system*, which will act as a communication environment in the process of solving this problem).

- Determining the set of *ostis-systems* to be involved in problem solving. In general, it may be sufficient to involve only *ostis-systems* representing one *ostis-community*, or a set of *ostis-systems* belonging to different *ostis-communities*. The specific mechanism of this stage requires clarification, but the following principles are suggested as its basis:
  - the initiator of this stage is the *corporate ostis-system* whose knowledge base contains the corresponding problem formulation. For this purpose, the specified *corporate ostis-system* interacts with other *corporate ostis-systems*, if necessary involving *corporate ostis-systems* of a higher level. Development of a protocol for such interaction is an actual task;
  - the key role at this stage is played by the previously discussed *ostis-systems* specifications describing *classes of problems, methods* of their solving, etc;
  - in the process of performing this stage, the initial problem formulation may be refined taking into account particular *ontologies of subject domain problem classes and problem solving methods*.

- Definition (selection) of *corporate ostis-system*, which will be the communication environment for solving the currently formulated problem solving task. The principles of such a selection have been discussed above.

- Formation of a problem solving plan. At this stage of development of the theory of decentralized problem solving within the *OSTIS Ecosystem*, we will assume that the solution plan of a particular problem is formed, stored and refined entirely within the corresponding *corporate ostis-system*. In general, we

can talk about the possibility of distributed storage of the problem solving plan, but the interpretation of such a plan will require additional costs for interaction between ostis-systems and the development of additional mechanisms for the transfer of intermediate information and synchronization of actions between ostis-systems, the feasibility of which is difficult to assess at the moment in the absence of a sufficiently large number of applied examples of solving such complex problems. The development of a general strategy for forming a plan for solving an arbitrary problem is currently an actual direction of development of the approaches considered in this paper. It is important to note that the problem solving plan in the general case will be constantly refined in the course of its implementation, which may require the refinement of the collective of ostis-systems involved in implementing this plan. This strategy is based on the idea of situational management [25] in conjunction with general methodological ideas related to the theory of behaviorism and the ideas of its application in computer science that are gaining popularity [26]–[28], TRIZ [29], as well as SMD-methodology proposed by the school of G. P. Shchedrovitsky [30].

- Step-by-step interpretation of the problem solving plan. The basic principles of interaction between *corporate ostis-system* and other *ostis-systems* participating in the problem solving process were considered earlier in the context of specifying the architecture of the multi-agent *ostis-systems* within the *OSTIS Ecosystem*. Implementing these principles requires specifying the architecture of the *ostis-systems* subsystems responsible for interaction between them in the process of problem solving and developing an appropriate interaction language. Figure 3 shows an example of the interpretation of a problem solving plan stored in the memory of a *corporate ostis-system* by a collective of *ostis-systems*. As can be seen from the example, *ostis-systems* interact with each other by means of corresponding communication subsystems, while the problem solving process itself does not take into account the fact of decentralized solution in any way.

- Specification of the result of problem solving and its transfer to the initiator. At this stage, the specification of the problem solving result (including the result itself, if it is an information construct) is formed, the composition of which generally depends on the problem class, and the obtained specification is transferred to the *ostis-system*, which was the initiator of the problem solving (in case of the end user *OSTIS Ecosystem*, the specification is transferred to his *personal ostis-assistant*).

It should be noted that the presented general plan of problem solving within the *OSTIS Ecosystem*, as can be seen from the explanations to its stages, is preliminary and in the future requires detailed specification of each of the stages.

VII. Conclusion

This paper considers the basic principles of decentralized problem solving within the next-generation intelligent computer systems ecosystem (*OSTIS Ecosystem*). In particular, the architecture of *OSTIS Ecosystem*, the typology of *agents of OSTIS Ecosystem*, and the features of problem solving within *OSTIS Ecosystem* are specified. The approach to problem solving within OSTIS Ecosystem, means of specification of *ostis-systems* in the context of collective problem solving is proposed. A general plan for solving a particular problem within the *OSTIS Ecosystem* is proposed.

At the same time, the solution of a number of promising tasks remains relevant:

- Development of a general strategy for solving problems of an arbitrary class, the principles of forming a general plan for solving a particular problem;

- Clarifying the language of the problem statements and objectives;

- Development of a general *Ontology of problem classes and problem solving methods*, clarification of the principles of development of private *ontologies of subject domain problem classes and problem solving methods* on its basis and principles of specification of internal *sc-agents* and whole *ostis-systems* using these ontologies;

- Development of a language of interaction between *ostis-systems* at the stage of collective formation of *ostis-systems* of a particular problem solving;

- Development of a language of interaction between *ostis-systems* at the stage of problem solving (interpretation and refinement of the problem solving plan);

- Refinement of the architecture of the *ostis-systems* subsystems responsible for the interaction between them in the process of problem solving.

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