Distributed computing systems as project learning environment for "Generation NET *

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Abstract

The article is devoted to applying desktop grid systems in education. The proposed solution for integration of the technologies of distributed computing in school education through children's practice-oriented projects. The article contains early results of implementation of practice-oriented project learning in the Russian schools.

Keywords: distributed computing, desktop grid, BOINC, education, children's project, CosmOdis, project learning, research in school.

1 Introduction

This work tries to find solution for contemporary task of staffingin the distributed computing area and the educational task of training modern students called the NET Generation. Let us take a brief look at both aspects.

Creation and development distributed computingsystems (DCS) is a strategic way of intensive tasks processing in medicine, chemistry, biology, space exploration etc. [Isaev & Kornilov, 2013], [Radchenko, 2012], [Knushov at al., 2014].The development and functioning of DCS requires sufficient number of professionals with high level of proficiency in mathematics, competencies in algorithms, programming, user interfaces, administration, testing and debugging, project management, etc. [Mishchenko & Gubarev , 2015]. Russian Federation raises this professionals in top engineering universities: MSU, MIPT, ITMO, Bauman MSTU, MEPHI, RSUH, HSE, MISIS, PetrSU, SWSU, ISU, BSU, MAI, MSP etc. However, there is an essential task in DCS development area.This task is attracting and retaining minimal required number of volunteers-participants in virtual communities and maintaining interest to ongoing DCS projects [Bobrov at al., 2015], [Kurochkin 2016].The virtual volunteer community is difficult to join. Thus, there is no steady influx of new people. For this reason, the problem of popularization of voluntary distributed computing and fundamental science are extremely relevant. Typically, a virtual community consists of people interested in a specific research topic or project. They are free to reallocate your computing resources between projects. Oftentimes they leave the project after losing interest in it.

That leads to losing of accumulated participant competencies and remarkable reducing all educational outcomes. Moreover, there is a considerable shortage of practical guidelines, tutorials, webinars, interactive presentations, the storage of implemented projects and practices, specialized scientific and popular resources and online

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communities for DCS in Russian Federation [Mironov, 2015]. As a result, each DCS project is developed from scratch instead of using existent experience. All these issues lead to slowdown in DCS area. *Thus, there isa need for the mechanisms of DCS popularization,new member retention, accumulation of scientific and educational content and continuous staffing for reaching DCS sustainable development.*

Education requirements, including school, are changing with the rapid development of VI-way (NBIKS) technology, growth and application of artificial intelligence methods, the Internet of things, virtualization of society [Mamedova 2016]. The development of education aimed at the formation of global professional standards, practice-oriented personal education, lifelong learning, obtaining soft & digital skills. Global educational platform and educational ecosystems are formed for this purpose(Global Education Futures, P21, ISTE, EC, ATCS, OECD, MOE Singapore, ASI etc.). "Generation NET" children are ready to actively engage in network projects, but they lose interest in basic Sciences due misunderstanding of their applications. A key objective of school education is the development of motivation and skills of active learning, competence of gaining new competencies in a rapidly changing world. It is necessary to introduce practice-oriented projects, distributed design and research teams, interactive educational content in order to reach key school objective [Sannikov at al., 2015], [Oskolkova, 2016]. However, these educational technologies will be effective if there is a participation of both the academic community and the representatives of high-tech industries.Additionally, any school project team needs a support environment: mentor from the professional community, practical and relevant project tasks, resource base. *Thus, there isthe education need for the involvement of students in real projects and research in cooperation with scientific institutes and enterprises, the formation of a community of mentors and creation of sustainable distributed project teams.*

The aim of the authors is tocreate solution for the interrelated problems of education and DCS development, by building a sustainably developing child-adult expert community, developing educational and popular science content, conduct online and offline events.

2 International experience

International experience of creation and developing of DCS presents over 60 projects (boincstats.com).Let us consider some examples of well-known projects.

SETI@home is one of the most common projects for the creation of DCS. The peculiarity of the project is the considerable processing power more than 560 teraflops. Such computing power is provided by the audience of more than 1.4 million people.

The ambitious and clear goal the search for intelligent extraterrestrial civilizations made possible involving a significant number of volunteers in the project. The academic partner of project is University of California. System-wide participation of school students is not revealed. SETI@home uses a technology platform BOINC [Ivashko & Golovin, 2012].

The project Einstein@home is aimed at the search of extraterrestrial objects, including pulsars using data analysis of radio and gamma-ray telescopes. The peculiarity of the project lies in the fact that you have already changed the original stated goal of the search for gravitational waves, while the audience of the project has not diminished. The size of the project audience is 355 000 people, the number of devices is 2 500 000. The academic partners are University of Wisconsin-Milwaukee and Max Planck Institute for Astrophysics. System-wide participation of school students is not revealed [Papa at al., 2015].

Rosetta@home project aims at solving the problem of computing the tertiary structure of proteins from their amino acid sequences. This is one of the key problems of molecular biology. Feature of the project is the number of audience of the project. The audience is more than 340 000 members. Despite of the absence of any access to the results of calculations performed on your device and any other device in the project. The number of devices is 260 000. The academic partneris University of Washington. System-wide participation of school students is not revealed [Craven, 2010].

Implementation of the Leiden Classical DCS project revealed its attractiveness for the participation of students of secondary and higher education institutions [Silva at al., 2008]. Audience of the project is amounted to 18 000 people.The number of devices is 18 000. Key project feature is the education component. Students uses DCS tech-nology for the solution of applied problems simultaneously learning theDCS prin-ciples and technologies. 7 educational works on thermodynamics, quantum chemistry, molecular modelinghave been done for 2009. The projectincludes both the individualstudents research and the work performed by all students. Technically, the project is a computer library for visualization of modelling and creating applications forclassical mechanic systems. Leiden Classical uses a technology platform BOINC [Silva at al., 2008].

The world community World Community Grid (WCG) experience confirms the interest and the ability to attract high-tech industries and high-tech companies to distributed computing. The WCG community has more than 400 small companies and large corporations including: IBM, SONY, etc. Audience of the WCG community is nearly 800 000 people. The number of devices is 3,2 million. Academic project partners are Ontario Institute for Cancer Research, University Health Network, Cancer Institute of New Jersey, Rutgers University and Pennsylvania state University, The University of Texas Medical Branch, Galveston National Laboratory, The University of Texas Medical Branch. System-wide participation of school students is not revealed. (IBM Corporation, 2012).

We also consider it necessary to mention the following projects:

- MilkyWay@Home: the audience of the project – 165 767 people; the number of devices – 339 030; the academic project partners the National Science Foundation and Rensselaer Polytechnic Institute; system-wide participation of school students is not revealed,
- PrimeGrid: the audience of the project – 49 000 people, the number of devices – 160 000; system-wide participation of school students is not revealed,
- LHC@home: theaudienceoftheproject – 100 000 people, thenumberofdevices – 254 000, the academic project partners – University of London, SETI institute;system-wide participation of school students is not revealed,
- Spinhenge@home: the audience of the project – 58 000 people, the number of devices – 152 000, the academic project partners – Bielefeld University of Applied Sciences, Iowa State University, AmesLaboratory, system-wide participation of school students is not revealed,
- QMC@Home:the audience of the project – 48 492 ; the number of devices – 125 000; the academic project partners – University of Mnster, University of Cambridge, Rheinische Friedrich-Wilhelms-Universitt Bonn; system-wide participation of school students is not revealed.

Thus, the international experience of realization of projects on creation DCS confirms the potential of attracting students. However, the participation of students is currently a non-system.

3 Proposed solution

To achieve this goal taking into account international experience the authors propose to integrate students in project and research team. In teams students can perform applied real computing tasks commensurate with their level of training. Performing is conducted under the guidance of supervisor.

The expected result is achieved by two interlinked components:

- Online project framework CosmOdis developmentin order to the formation and retention of community participants DCS motivated students;
- Technological-mathematical apparatus on the basis of the BOINC platform for creation DCS and decomposition of the original problem to affordable levels for implementation in the students project.

ProjectframeworkCosmOdis unites a community of students, experts, teachers, professors and employees of high-tech companies for the implementation of practiceoriented projects in schools. All student projects are based on the international methodologies Agile, PMI and other. Representatives of universities, of culture, of production are the mentors project teams. They oversee the implementation of projects. Decomposed tasks of distributed computing become the points of crystallization of the interest of project teams and individual participants. Digital portfolio for each participant is formed during project. Individual portfolio enables tracking the dynamics of development of competences and defines the level of the required decomposition of the original problem and the required degree of teamsupervisor.

The key model ofstudentprojects integration with problems of distributed computing is formulated as: the ambitious goal –practical tasks – clear and convenient tool. Depending on the specific project, the role of DCS can vary from project aim to project tool.

The ambitious goal allowsto quickly and efficiently integrate community members into teams and bring them to project realization. Ambitious goals usually require considerable resource, which ensures long term preservation of conversion level and engagement of new users. Each goal represents a meaningful solution of relevant to modern

Table 1: Examples of goals.

Project title	Ambitious goal	Content
CosmOdis / Space Odyssey	The exploration of other planets of the Solar system	The task of finding potentially habitable planets, calculation, simulation flight, development of residential units etc.
CosmOdis / Web	The solution to the prob-lems of traffic jams of major cities (e.g., Moscow)	Students participate in the creation and consists of different network topology traffic counts.
CosmOdis / meteo	Accurate weather forecast for their home / neighbor-hood / city / region	Calculation of the adjusted forecast of the weather of a certain territory based on the compilation of satellite photos obtained from local centers of remote sensing, the official weather measurements in local school weather station.
CosmOdis / kripto	Decryption and cryptography	Compilation of Latin squares with certain properties

science problems and each goal is of practical value. The applied high-techgoal determines the meta-subject of project: achieving results requires knowledge from different fields and positions school subjects as tools for the project realization. This leads to increasing levels of motivation and engagement of students. Examples of goals and their descriptions are presented in Table 1

Any CosmOdis project implies the solution of practical problems of great practical importance. The project goes through the complete cycle from initiation to completion. Project raises issues of search and analytical processing of information, simulation, design, technical design, prototyping, etc. The existing scientific and practical problem of distributed computing is formulated for the students who participate in the DCS project. The formulation is adapted to the required level of knowledge. Even with sufficient decomposition of the source task, requiring high level of knowledge of pupils. Therefore, the solution of the DCS project tasks is conducted in cooperation with the expert (mentor). Mentor is a representative of the academic community, specialist in the field of DCS. Any mentor has an assistant. Assistant is a student with confirmed experience in participating in projects DCS. Assistant acts as a tutor for student teams. Through the system of mentors and tutors the solution process does not lose stability and retains the educational component at any point in time.

Schematically, the process of joint work on the task presented in Figure 1. Participants in the process: expert (mentor), tutor, student. Depending on the complexity of the problem and the identified difficulties, the child may appeal directly to the tutor or mentor for advice, or to solve the problem together. After completing the project, the child confirms competence. This allows him to work with more complex tasks. The most experienced students take the role of tutors. This ensures the sustainability of system performance regardless of the result of the volume of users. Access to participation in DCS projects is open only to students with experience in the implementation of another CosmOdis projects. Usually, it is students of the 9th, 10th and 11th school grades of engineering or physic-mathematical orientation.

The ability to work in distributed project teams and direct communication with experts opens for students new facets of education. Project participants can locate in different regions of Russia, which allows to significantly expand the scope of activities due to different range of members knowledge, capabilities and competencies. In addition, managing distributed teams and ability to maintain the performance of these groups at a high level is good experience for school students. All projects are interdependent. Thus, students come to the need of active communication (including in foreign languages), formalization of thoughts, risk management,without additional motives.

Implementation of practice-oriented "CosmOdis" projects results in a concrete, practical results: model, software, technical projects, etc. The result necessarily has a novelty and practical significance, the scientific and technological basis, applied potential. This value isdefined and supported by mentor of the project at the stage of formulation of the problem.

A significant importance here is the process of decomposition of the original large task into smaller subtasks.

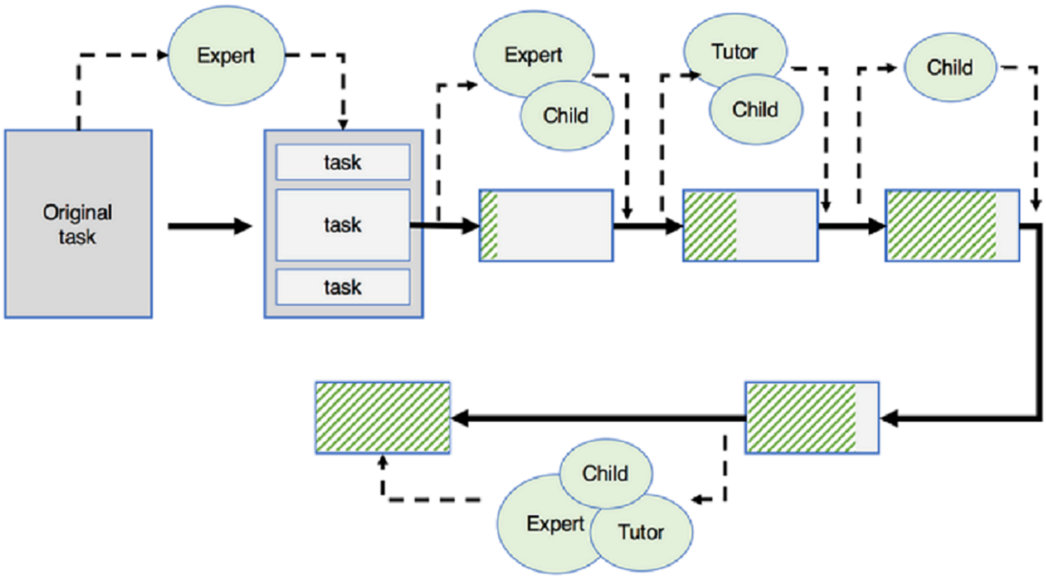

Figure 1: The trajectory of the solution of the problem in the system of child - expert (mentor) tutor.

The calculation algorithm for each subtask is the same. The changes are only in input data. This type of task is called "bag of tasks" [Bertin at al., 2014].

There are several frameworks for organizing distributed computing: Legion, Glo-bus [Foster & Kesselman, 1997], HTCondor [Litzkow at al., 1988], etc., but the most common one to date is the BOINC [Anderson 2004]. Software BOINC (Berkeley Open Infrastructure for Network Computing) is an open non-profit software for a volunteer distributed computing on personal computers. BOINC has a client-server architecture and consists of a client part and a server. It is a universal platform for computing in various fields (mathematics, molecular biology, medicine, astrophysics, telecommunications, etc.). The client part can be installed on all common operating systems: Windows, Linux, Mac OS, Solaris, FreeBSD, etc. The server part is designed to control a distri-buted computing project.

The distributed computing projects based on BOINC platform are divided into 2 types: public projects with the participation of volunteers [Vatutin & Titov, 2014] and the closed (internal) projects using the organization's available computing resources [Chernov & Nikitina (2015)]. Around several tens of projects of voluntary distributed computing is deployed on the basis of the BOINC platform. This project has nearly 16 million computers around the world. Most of voluntary DCS projects are researches projects of world universities and scientific organizations. The total computing power of volunteers exceeds the computational power of modern supercomputers from top500 (boincstats.com) [Top500 2016].

However, volunteer computing has features that can substantially slow down the computation. And the use of a heterogeneous grid system imposes constraints the organization of computing experiment.

The authors consider essential features of grid systems, as follows:

- the large number of compute nodes,
- the heterogeneity of the compute nodes,
- the unreliability of connections and possible shutdown of compute nodes,
- the resistance to change,
- the large reaction time change,
- the difficulty of developing computing solutions for all types of compute nodes.

Participation in projects of volunteer computing does not bring to the user (cruncher) material value but requires them some costs aspurchasing of necessary equipment, payment of electricity, etc. The main driving factors that lead people to participate in volunteer computing projects are the realization of involvement in scientific discoveries, science, the competitive factor. BOINC has the system of grant credit depending on the volumes of the performed calculationsin order to maintain the interest among the crunchers. The grant credit system can vary depending on the project and considering its features. That allows you to develop the most appropriate and objective mechanisms for grant credit system. Some projects involve the calculation of various virtual prizes for user contribution in the computing power of the project. These prizes are special images (badges) that appears on the web page of the project next to the name of the user. They represent various achievements in the field of computing, for example, the total volume of the performed calculations, the average daily rate, the time to participate in the project.

Attracting and retaining school students to the implementation of projects also re-quires constant development of themotivation system which includes:

- development of a personal portfolio of proven competence in the projects,
- opportunity for professional growth, affecting the decomposition level of the task in the DCS projects,
- ability to communicate and totake consultation from leading Russian and international scientists,
- participation in offline and onlineCosmOdis events: courses, workshops, seminars, webinars, annual conferences and scientific festivals CosmOdis,
- virtual certificates and prizes to each participant of the project,
- certificates and prizes to the participants who have committed significant discoveries,
- exceptional prizes and awards (e.g. lunch with academic, courses in Skolkovo, etc.) participants who have committed discoveries, considered the most important,
- extra points for the unified state exam inpartners Universities of the CosmOdis.

As a result of implementation of the projects get ready to implement the minimum functional products created byschool studentteams. The potential for further development provides more attractive products for investment. The awareness of students, application value of results, and the possibility of their further development creates the additional motivation. Thus, the project framework CosmOdis becomes thecontact point of science, business and education.

4 Conclusion

High performance DCS is created by active community of interested users and supported by qualified team of DCS specialists. For training such specialists it is necessary to create new educational methods and technologies based on real task and producing school studentsto intercultural and international interaction, relevantand required competence development.

The integration of DCS system (BOINC) and project framework platform "CosmOdis" is the solution for both educational and DCS issues. Decomposition mechanism of the original taskopens up opportunities for broad participation of students. Methodological principles ensure consistency of the solution. Applied ambitious goal becomes a point of crystallization of the children's project teams.

The presented solution will allow school students across the country to participate in the DCS projects and simultaneously obtain required competence. Joint research activity is considered as a model of learning that creates the zone of development in collaboration with mentors. Solution is expected to be sustainable self-regulating system which includes all of the participants: experts (mentors), tutors, professors and high-tech companies.

In 2016-2017, there were 8 "CosmOdis" festivals of projects of students. The festivals were happened in 6 regions of Russia. The total number of pupilparticipants – 1 500. The number of experts and mentors – 150. Students implemented 160 practiceoriented projects.

Expected results of the implementation of the proposed solution:

- the training for demanded specialists, including specialist in the field of DCS,
- the creation of scientific and educational content, including content in the field of DCS,

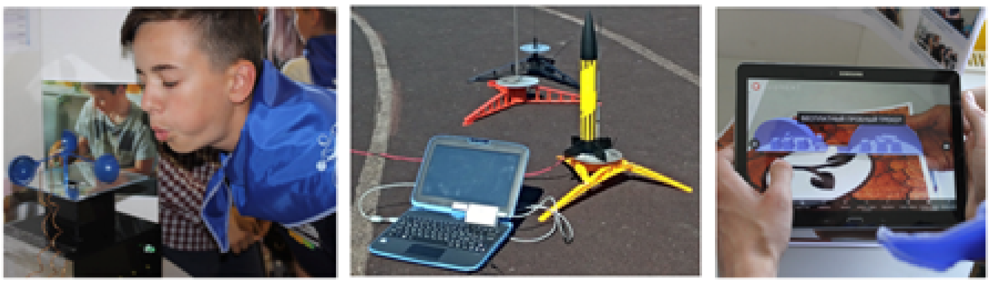

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Figure 2: An example of project implementation of pupils: a) the local weather station for further weather forecast, b) diagnostics of motion of the rocket phase of flight c) the augmented reality app for your smartphone.

- the development of pupilssoft and hard skills competencesfor scientific research and work in high-tech companies,
- the increasing percentage of the graduates who enrolls in higher education in engineering and physics and mathematics,
- the formation of motivation to the knowledge and interest in basic Sciences among school students,
- the motivation to lifelong learning,
- the promotion of DCS among pupils,
- the involvement of academic in the educational process of school students,
- the creation of community(including online) of experts – mentors for school project teams industries.

In 2017 the results of the integration of project framework "CosmOdis", and DCS technologies on the basis of the BOINC platform will be obtained and presents in accordance with the concept described in this article.

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