# Start-up and the results of the volunteer computing project RakeSearch


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# 1. Desktop Grid and BOINC

## Key events in the history of Desktop Grid

**1987**

**The idea of Desktop Grid**

M. Litzkow
Remote Unix: turning idle workstations into cycle servers, Usenix Summer Conference, 381-384

**1996**

**The first volunteer computing project**

Great Internet Mersenne Prime Search (GIMPS)

**1997**

**Presentation of the project SETI@home**

W. T. Sullivan, D. Werthimer, S. Bowyer, J. Cobb, D. Gedye, D. Anderson
DOI: 10.1017/S0252921100015311

**The second volunteer computing project**

distributed.net

**1999**

**The paradigm of volunteer computing**

L. F. Sarmenta and S. Hirano
DOI: 10.1016/S0167-739X(99)00018-7

**The third volunteer computing project**

SETI@home

**2001**

**Definition of Grid, Enterprise Desktop Grid and volunteer computing systems**

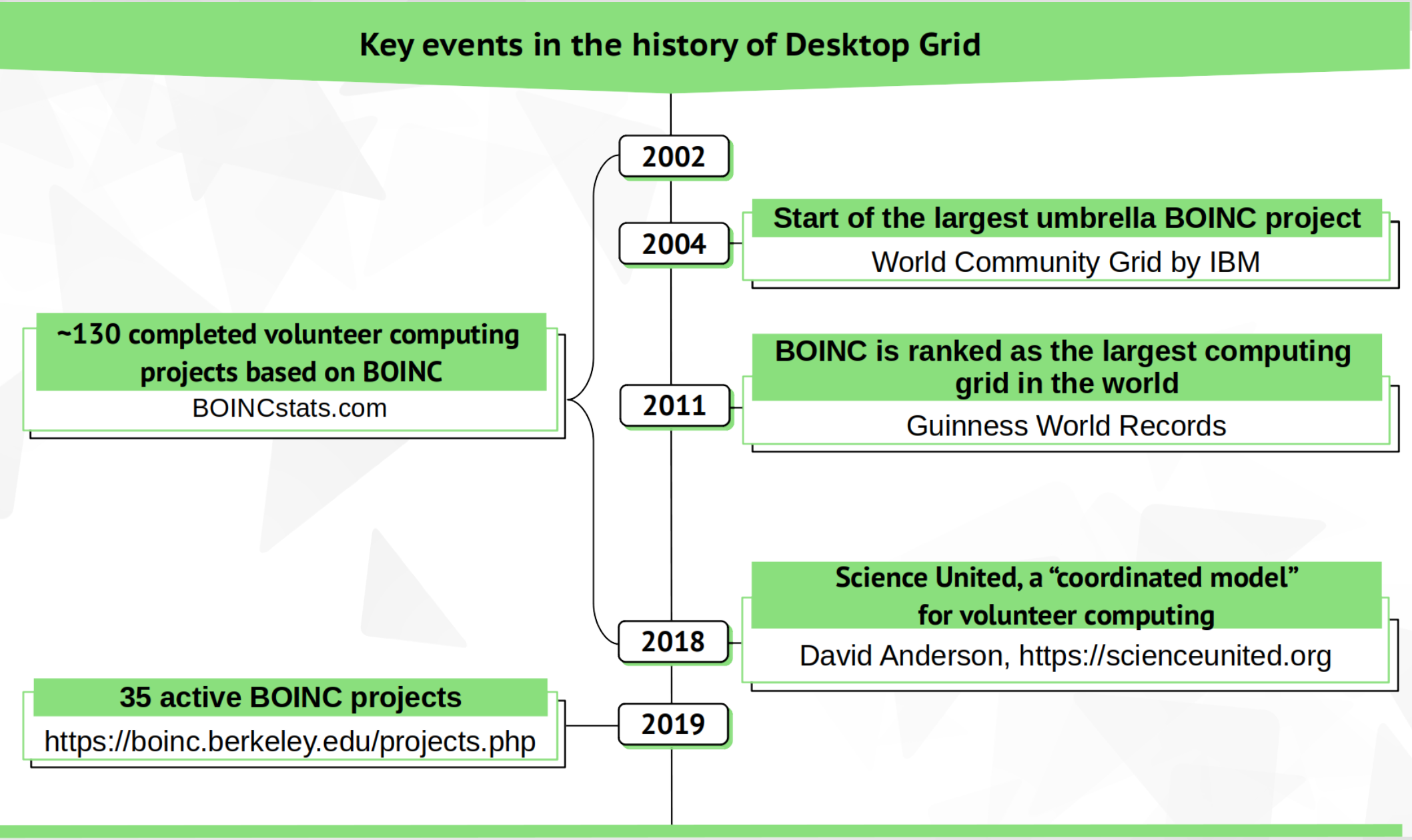
I. Foster, C. Kesselman, S. Tuecke
DOI: 10.1177/109434200101500302

**2002**

**Middleware for organizing Desktop Grids and volunteer computing systems**

BOINC: Berkeley Open Infrastructure for Network Computing

# 1. Desktop Grid and BOINC



# 2. Research groups and joint work

## Karelian Research Center of the RAS, Petrozavodsk
(E. Ivashko, N. Nikitina, I. Chernov, A. Rumyantsev et al.)

- Mathematical modeling of Desktop Grid
- Development of task scheduling models
- Development of task replication models
- Statistical modeling of computational systems
- Scientific computations basing on Desktop Grid

## Southwest State University, Kursk
(E. Vatutin et al.)

- Software development for solving scientific & practical problems basing on DG technologies
- Teaching on the parallel programming
- Work on the BOINC project Gerasim@home aimed at solving discrete combinatorial optimization problems
- Research of orthogonal diagonal Latin squares

## Web portal BOINC.RU
(M. Manzyuk, AlexA, SerVal, citerra et al.)

- Software development for solving scientific & practical problems basing on DG technologies
- Communication with the volunteer community
- Coordination of a volunteer computing team
- Popularization of volunteer computing
- Research of orthogonal diagonal Latin squares

# 2. Research groups and joint work

- Volunteer computing project RakeSearch aimed at exploring the space of ODLSs of rank 9

# 3. RakeSearch project

- A Latin square is a table of size $n \times n$, filled with n elements of set $M$ in such way that each row and each column of the table contain every single element of $M$ exactly once
- A diagonal Latin square is a Latin square which has unique elements both on its main and secondary diagonals
- Two Latin squares $L(l_{ij})$ and $K(k_{ij})$ are called mutually orthogonal (MODLSs) if all ordered pairs $(l_{ij}, k_{ij})$ are different
- RakeSearch algorithm finds row-permutational pairs of MODLSs
- The algorithm picks up separate pairs of mutually orthogonal DLSs, which allows to reconstruct full graphs of their orthogonality
- The resulting graphs represent the structure of the explored space

# 3. RakeSearch project

The developed RakeSearch algorithm for finding MODLSs:

Input: a unique “mask” of the primary filling of a square; a path of filling the square cells; auxilary structures.

- Generation of another DLS;
- Row permutations of the generated DLS checking if it is orthogonal to the initial one.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 3 | 2 | | | | | | 4 | |
| | | 1 | | | | 0 | | |
| | | | 4 | | 2 | | | |
| | | | | 6 | | | | |
| | | | 1 | | 7 | | | |
| | | 5 | | | | 8 | | |
| | 3 | | | | | | 5 | |
| 7 | | | | | | | | 3 |

Output: either found ODLSs for the initial one, or a message that they were not found.

The application is implemented in C++ using API BOINC

The resulting rate is 44-92 thousand DLSs per second

# 3. RakeSearch project

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| 4 | 2 | 7 | 6 | 8 | 1 | 3 | 5 | 0 |
| 3 | 5 | 1 | 0 | 7 | 8 | 4 | 6 | 2 |
| 6 | 3 | 8 | 4 | 1 | 7 | 0 | 2 | 5 |
| 5 | 6 | 0 | 7 | 3 | 2 | 8 | 4 | 1 |
| 7 | 8 | 4 | 1 | 5 | 6 | 2 | 0 | 3 |
| 8 | 7 | 6 | 2 | 0 | 3 | 5 | 1 | 4 |
| 1 | 0 | 3 | 5 | 2 | 4 | 7 | 8 | 6 |
| 2 | 4 | 5 | 8 | 6 | 0 | 1 | 3 | 7 |

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| 8 | 7 | 6 | 2 | 0 | 3 | 5 | 1 | 4 |
| 7 | 8 | 4 | 1 | 5 | 6 | 2 | 0 | 3 |
| 1 | 0 | 3 | 5 | 2 | 4 | 7 | 8 | 6 |
| 2 | 4 | 5 | 8 | 6 | 0 | 1 | 3 | 7 |
| 3 | 5 | 1 | 0 | 7 | 8 | 4 | 6 | 2 |
| 4 | 2 | 7 | 6 | 8 | 1 | 3 | 5 | 0 |
| 6 | 3 | 8 | 4 | 1 | 7 | 0 | 2 | 5 |
| 5 | 6 | 0 | 7 | 3 | 2 | 8 | 4 | 1 |

Example of a pair of row-permutational ODLSs

# 3. RakeSearch project

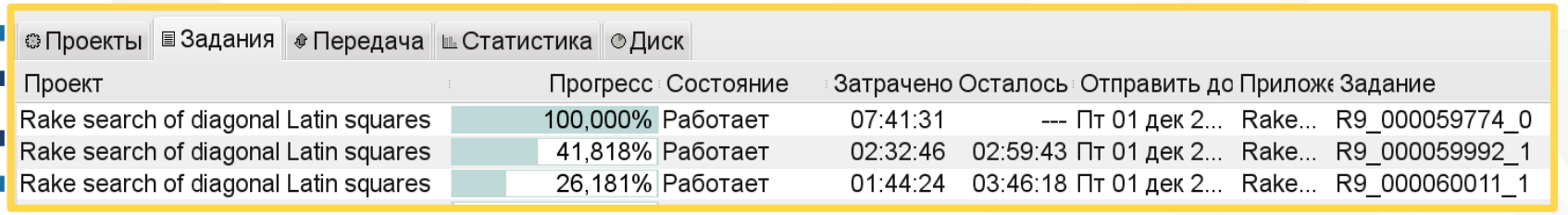
- **https://rake.boincfast.ru/rakesearch/**

- The project is implemented basing on BOINC within the Grid segment of the Center for collective use “Center for high-performance data processing” of Karelian Research Center of the RAS
- The project started in August 2017
- The majority of computational nodes belongs to volunteers from different cities and countries (due to advertising in the community)
- Own resources are employed as well:
  - 2 nodes of the computational cluster of Karelian Research Center
  - 6 desktop computers of the authors of the project
  - 3 nodes of the computational cluster of BOINC team Crystal Dream

# 3. RakeSearch project

## BOINC project settings:

- The application is implemented for work in BOINC environment; a mechanism of BOINC checkpointing on the client is employed
- Results are bitwise validated, the quorum is 2, the deadline is 1 week
- An average runtime of a workunit is 5 hours for the default application and 30 minutes for the optimized application
- The application is implemented for Windows and Linux 64&32-bit, ARM
- Design of the search process allows to reward findings with badges


| Проект | Прогресс | Состояние | Затрачено | Осталось | Отправить до | Приложе | Задание |
|---|---|---|---|---|---|---|---|
| Rake search of diagonal Latin squares | 100,000% | Работает | 07:41:31 | --- | Пт 01 дек 2... | Rake... | R9_000059774_0 |
| Rake search of diagonal Latin squares | 41,818% | Работает | 02:32:46 | 02:59:43 | Пт 01 дек 2... | Rake... | R9_000059992_1 |
| Rake search of diagonal Latin squares | 26,181% | Работает | 01:44:24 | 03:46:18 | Пт 01 дек 2... | Rake... | R9_000060011_1 |

# 3. RakeSearch project

- The project web forum is supported (~10% active participants) as well as communication with the participants community:
  - Publication of project goals and current results
  - Optimization of the open source code and program debugging
  - Rewarding the participants and teams
- The results are published in the form of ODLSs and graphs
- The project participated in competitions among BOINC teams
- Applications for gathering work statistics are implemented
- Backups and archiving the BOINC server and database are automated

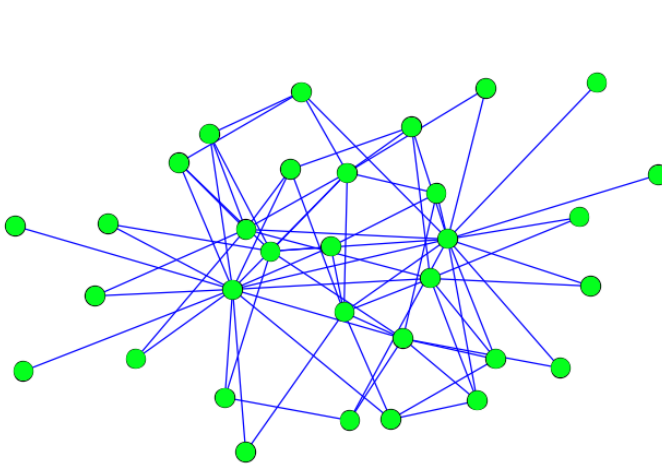
# 3. RakeSearch project

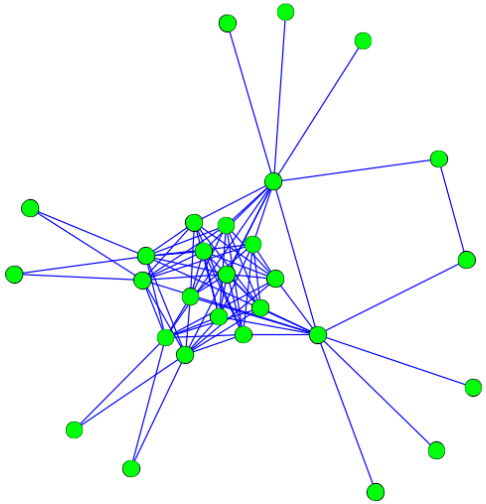
- The project results (by June 2019):
  - Peak daily capacity of 1788 computers by 385 participants
  - Peak daily performance of 256 TeraFLOPS

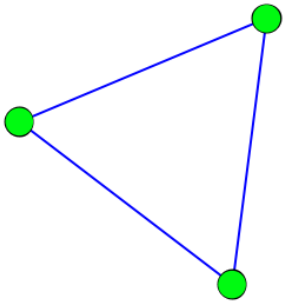
  - Average daily capacity of 434 computers by 153 participants
  - Average daily performance of 51 TeraFLOPS
  - 23 million workunits completed in 22 months

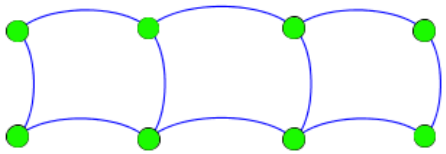
    - 160 thousand of ODLSs pairs were found
    - 175 unique types of orthogonality graphs were discovered
    - A correspondence between numbers of DLSs and ODLS pairs that can be generated for a fixed main diagonal was found

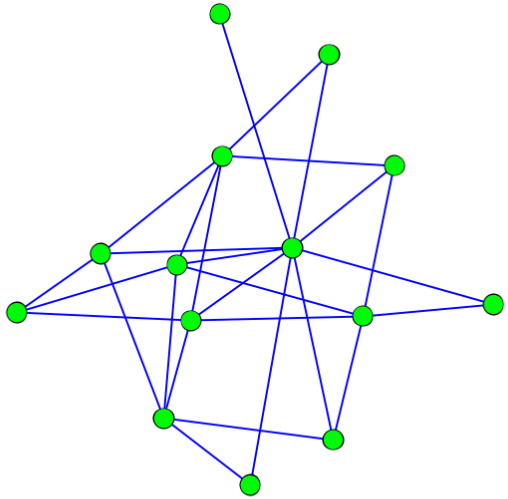
# 3. RakeSearch project: discovered graphs (6/175)

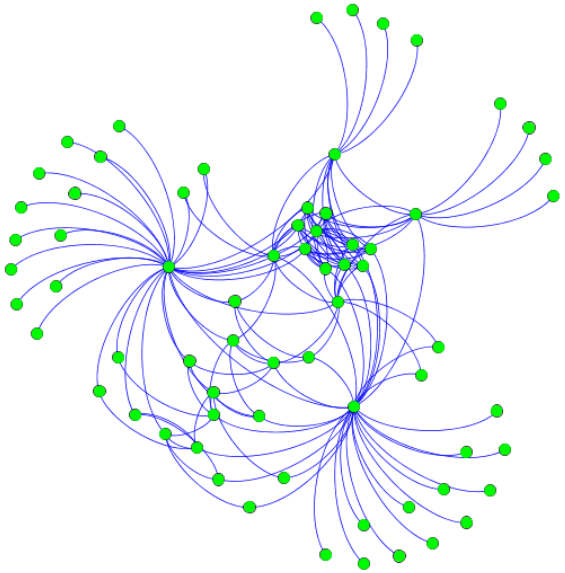










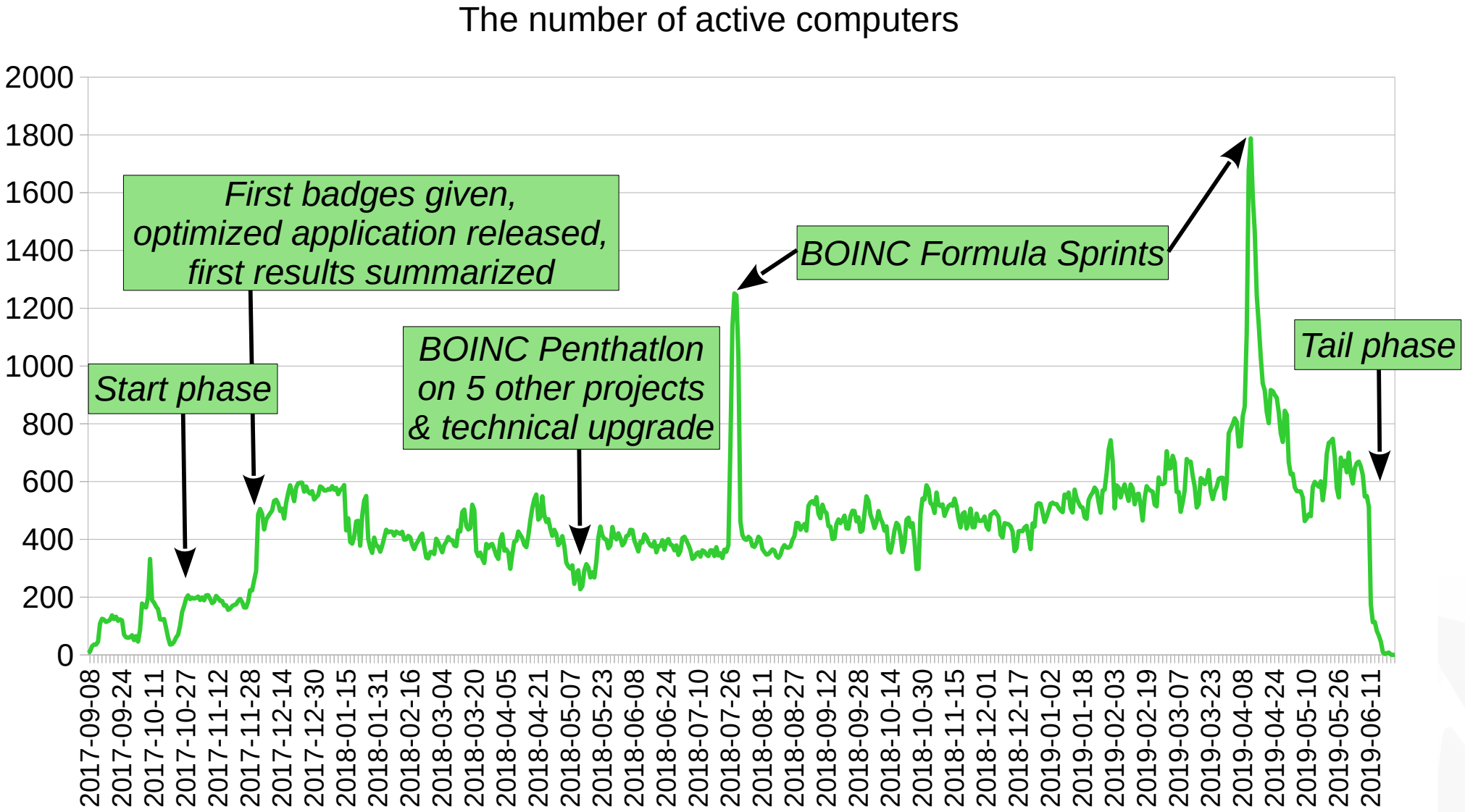


# 4. Statistics gathered in RakeSearch project

Runtime history for tasks and hosts, 22 months of computing:

- Estimation of completion time of a batch of tasks
- Comparison of CPUs by task replicas runtime
- Imitation modeling of a Desktop Grid to evaluate task scheduling and replication algorithms basing on empirical distributions
- Full lifecycle history of a computational experiment in BOINC project

# 4. Statistics gathered in RakeSearch project



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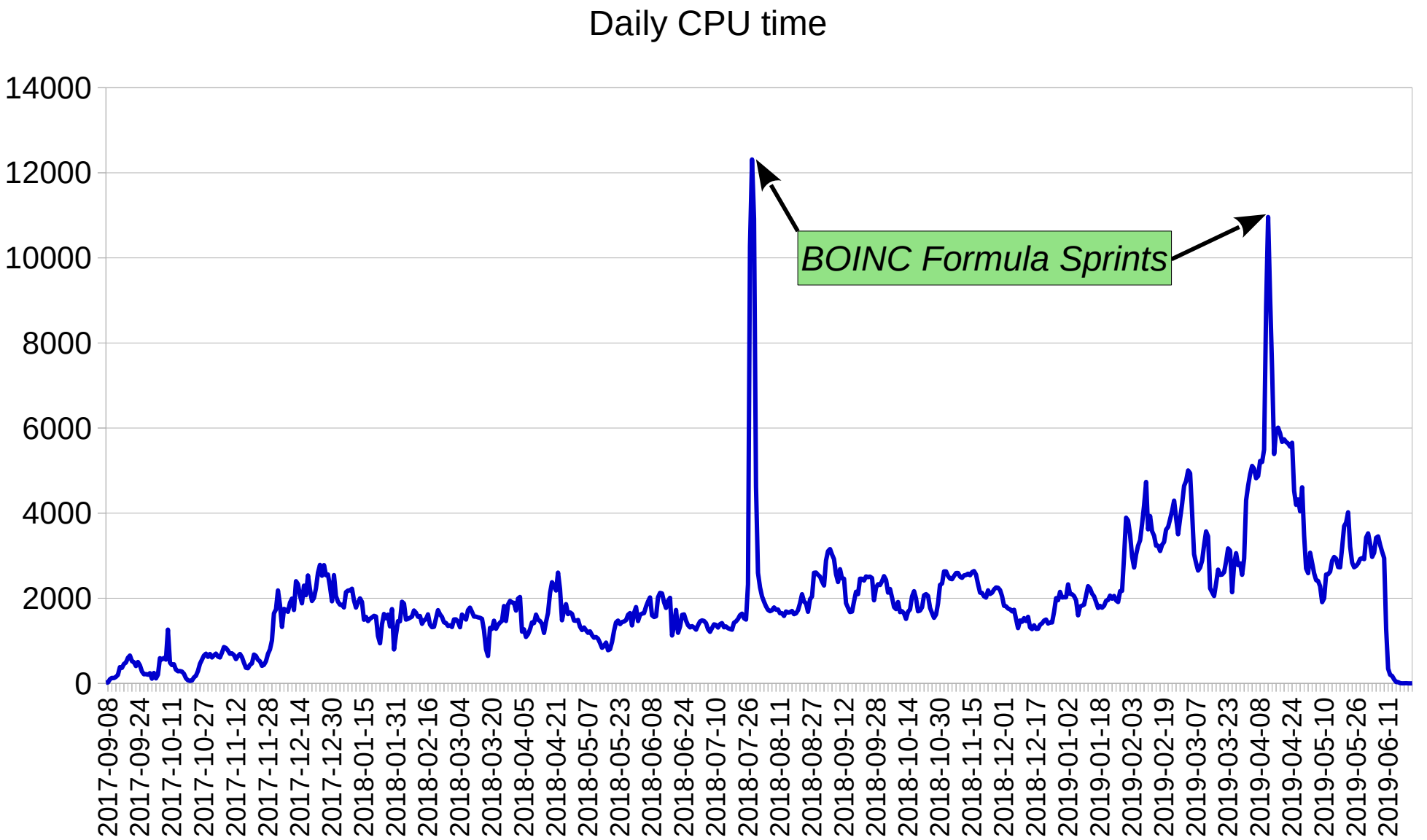

# 5. Current & Future work

- Search for row-permutational pairs of MODLSs of order 10 in collaboration with the team studying ODLSs of order 10
- Simulation experiments of mathematical models for task scheduling in Desktop Grid using project statistics data
- New mathematical models of Desktop Grid-like systems and the participants behavior basing on the gained experience

# Thank you for your attention!

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