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Green Methodologies in Desktop-Grid

An invitation for discussion by the DEGISCO project

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***Abstract*—Desktop-Grids have been around since the very early days of Grid computing, scaling into the millions of PCs, well established as regular distributed computing infrastructure for many research projects. Desktop-Grids collect CPU cycles from PCs contributed by donors, by volunteers who are willing to support science and research. This paper focusses on the energy efficiency aspects of Desktop Grid computing: the Green Desktop Grid, as a task of the EU-FP7 DEGISCO project [20].**

The key advantage of Desktop-Grids with regards to Green-IT over service Grids and data centres based on clusters of servers is the minimal heat density. Compute Clusters without energy intensive air-condition would run into thermal disaster within minutes. PCs participating in Desktop-Grids usually do not make use of any air-condition.

We will have a closer look on several aspects of energy consumption and computational performance in Desktop-Grids describing several distinct Green Methodologies to optimize compute unit specific energy consumption.

I. The need for Green Desktop-Grids

DESKTOP-GRIDS provide compute-power to scientists by contributions of resource owners, typically individuals at home but also institutions and companies. Compute time harvested this way does not request large upfront investment by the scientist; it is a low cost approach towards significant scientific output. Typically implemented using BOINC [17], sometimes XtremWeb [19] or other packages, Desktop-Grids are found among the largest Distributed Compute Infrastructures (DCI) [1]. Also known as Volunteer-Computing, Desktop-Grids have been around since the very early days of Grid computing [18], scaling into the millions of PCs contributing compute time every day. The aggregations of so many machines result in significant performance well beyond Petaflop/s for selected applications. For example: BOINC network averages about 5.1 Petaflop/s as of April 21, 2010 [2]. Key difference to service Grids like EGEE (now EGI) is the voluntary character of the resources – citizens contribute their PC's compute time to the Desktop-Grid projects in order to support scientific challenges of their choice. The FP7 project DEGISCO aims to support Desktop-Grid deployments in and beyond Europe, especially countries that strongly collaborate with the European Union. A focus topic of DEGISCO is the energy efficient handling of Desktop-Grid workload and management of resources, provided as configuration advice to Desktop-Grid operators. DEGISCO is accompanied by the EDGI project that continues to maintain and further develop the EDGES-Bridge [3], a gateway transparently connecting gLite, Unicore, and KnowArc based infrastructures (Service-Grids) to Desktop-Grids by automated translation of the job-languages.

Why Green-Desktop-Grids? As stated above, Desktop-Grids can aggregate hundred-thousands of machines. Power consumption of such large amounts of devices should be considered when making use of them. And yes, when used for computation energy consumption of PCs (like of any other computer) goes up. In the end, the contributor, the volunteer, who allows and enables the use of her or his machine, not only provides compute time for free but also pays for the additional electrical energy to cover the computation induced power consumption. Key advantage of Desktop-Grids is the minimal power density compared to conventional data centres. Typically, PCs participating in Desktop-Grids in Europe are not hosted in air-conditioned environments. Without the energy burden of air-conditions, Desktop-Grid are intrinsically "greener" than data centre based clusters and thereof built Service-Grids.

Green IT has been a hype topic claimed by the hardware vendors: buy new, buy more power efficient machines and you will become "Green". Supported by the EC (European Commission) issued "Code of Conduct on Datacenters" [4], the massive refurbishment or fresh built of data centres has been encouraged. The effective outcome in order to "Green" our planet lags behind expectations: number one reason is the lack of investment budget. Number two reason might be lack of interest – maybe due to the fact that energy is still too cheap: some data centre CIOs still do not know their energy-bill nor -cost structure. Efforts to improve the energy efficiency of data centres by minimal impacting methods, by reorganization of usage and workload distribution [5] have been presented in the course of OGF Green-IT working group, but not led to significant uptake yet.

The need for compute power, the progress of Computer Aided Science (CAS), is massive and unstoppable. Researchers from all sectors are urgently looking for more compute power. By today and well ahead of operations start, PRACE resources are already overbooked by a factor of 5 [6]. Although Desktop-Grid suitable workload is ***not*** HPC and only the lean data fraction of all HTC, significant scientific

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output has been, is, and will be produced with their help [7]. With the growing importance of Desktop-Grids in the scientific process and the significantly growing deployments, the need to optimize the use of energy is obvious both for general environmental considerations as well as for the attraction of contributors. Citizens providing their machines are interested in finding their contribution used in the most optimal way, producing more science and less waste-energy.

II. DEGISCO Green Desktop-Grid Methodologies

The environmental impact of IT and its specific usage patterns have been investigated in the recent years manifold. In the course of the roadmap consultation process, DEGISCO gathers analysis and best practices on Green aspects of distributed computing, focused on Desktop-Grids, but also comparing to classical technologies like clusters and data centres. Conceptually different methodologies will be investigated, based on technology means like Desktop-Grid client based ambient metrics, application profiling or adjustment of energy consumption per time interval, exploitation of natural ambient conditions, and possibly more. Some of those methodologies are technological, some are pure organizational. DEGISCO will promote this methodology inside the International Desktop-Grid-Federation [8] especially as part of a road map. This federation will offer consulting and advice based on these methodologies, continuing the roadmap process to reflect and integrate future findings and developments. One focus topic in the roadmap process is the application of Green Methodologies to achieve reduction in carbon dioxide footprint of research infrastructures.

A. Aims of Green IT: CO_2 footprint and the energy mix

Green IT aims were originally formulated to reduce CO2 footprint of IT activities. As extended scope reduction of energy consumption in general and especially thermal emissions in metropolitan areas, both impacting a) global climate b) local (micro) climate and c) human quality of life. Production of CO2 and accordingly the reduction of CO2 footprint are difficult to measure from the perspective of a concrete IT activity like computation.

Even if energy consumption as such is accounted for, it depends on the local energy mix how much CO_2 this is equivalent to. The electrical energy mix, the combination of electrical energy sources, depends on national specifics. The electrical energy mix (Table 1) in Germany [9] includes a nuclear energy portion of 27,5%, scheduled to be phased out, while the French [10] one (78,3%) is stable on a higher level. Denmark [11] produces 25% of its electricity consumption from wind – sometimes up to 150% (when strong winds produce more electricity that the Denmark needs) causing negative energy prices at the spot market [12]. Neither the single PC owner who contributes compute time to a scientific project nor the operator of the Desktop-Grid server that offers the respective workload item is in control of the energy source used to produce electricity consumed by the computational effort. Desktop-Grids are natively internationally or globally dispersed. While a specific Desktop-Grid server and its hosted projects may be presented to users from specific communities, there is no effective mechanism in place to "steer" or "control" the workload to contributors of a specific location or region. And it seems completely beyond the means of Desktop-Grid computing to control the workload may be executed only on machines supplied with energy of a "Green" qualified source. It seems to be possible to offer workload for the execution in a specific region – given that the contributing person takes into account and chooses to comply with the according recommendations. Nevertheless, the contributors have little control or even knowledge on the energy mix of their regional electricity providers. With a more general understanding of environmental protection, it is difficult to prefer nuclear power plants with their unresolved radioactive waste issues over natural gas powered electricity generation, although emitting carbon dioxide. As being in control only for the second half of the energy life cycle, IT activities can still use environmental friendly policies targeting to reduce energy consumption in general. It seems adequate to rephrase the core aim of Green IT to: Save energy!

Table I.
Zero CO2 electricity sources by 2007

Energy Mix	**Total**	**Nuclear**		**Renewables**	
Electricity	[TWh]	[TWh]	%	[TWh]	%
Germany	607,0	167,1	27,5%	58,2	9,6%
France	572,2	448,2	78,3%	66	11,50%
Denmark	40,5	0	0,0%	10,2	25,2%

B. € - metrics for Green IT success

In order to measure the effectiveness of energy saving policies and methods, we need to introduce a metric that can be "metered". The obvious advantage of "kWh" as the base metric for Green IT is the simplicity of measurement: electricity is metered everywhere. Different from data centres and conventional Service-Grids, policies and methods are applied and executed in Desktop-Grids only by the volunteer effort of the resource contributor. As success metric for Green IT, the translation into cost, into money, is helpful to connect to business considerations and propel motivation. With € (for kWh) as metric, contributors can relate their choice of workload and policy-compliance to the personal electricity bill: Green Desktop-Grids help the planet and your budget!

III. Six Green Desktop-Grid Methodologies

DEGISCO starts with a shortlist of 6 methodologies which are collection of best practices, techniques and policies:

- Ambient metrics based Green optimization
- Cool strategy: avoid air-condition use
- Energy profiling of applications

- CPU speed steps
- Exploitation of natural ambient conditions
- Time-of-day dependent energy tariffs

In the course of the roadmap process these methodologies will be challenged, refined or replaced, according to feedback and feasibility tests supported by contributors.

A. *Ambient metrics based Green optimization*

In order to tune DEGISCO connected Desktop-Grids towards saving of energy suitable configurations and parameters are to be identified enabling the Desktop-Grid client to intelligently select adequate workload. A regular PC [13] almost doubles its power consumption from idle 160W to 300W under full CPU load. Ambient temperature measurement or at least estimation (compare below: On the Difficulties of Temperature Measurement) could be used to control and potentially prevent download of workload items if the PC and its environment are too hot for comfortable or safe operations. The measurement and observance of ambient conditions, mainly temperature, is essential for several advanced Green Methodologies, too.

B. *Cool strategy: avoid air-condition use*

Desktop-Grids are the real Green Grids: lower energy density than clusters results in less energy wasted for cooling. However, this may not longer be true if air-conditions are used to assure proper operation of Desktops. Principles of cooling: Energy consumption by air-conditions range from 30% to >200% of the energy dissipated by the IT device (payload), depending on the cool-reservoir temperature the heat pump can utilize to get rid of the heat. The Code of Conduct on Datacenters quotes that most European data centres are actually worse: they consume more than 200% of the IT related energy for cooling, UPS and power distribution losses. The prime advice to configure Desktop-Grids: avoid air-condition use! Selection criteria for the "maximum temperature" as described above could be that temperature which would just not yet trigger the start of the local air-condition.

What if air-condition is unavoidable?

Should we recommend to participate in Desktop-Grids when resources are located in hot ambient? The answer clearly depends:

- If the additional workload by Desktop-Grids would cause proportional air-condition power consumption, a different strategy could be considered. Maybe by restricting the acceptance of workload to night times would help.
- If the air-condition is in full power use anyway – like in tropical ambient – the additional heat dissipation during compute load processing may not impact the total energy balance too much.

Example: light building structures with poor thermal insulation and continuously running air-conditions are de-facto standard in sub-tropical and tropical regions globally. If we assume a 3,5kW air-condition (2-3 room flat, small house) to run non-stop in order to keep the ambient temperature 15°C below the 40°C outside, additional heat dissipation of a standard office PC (60W idle, 120Watts fully loaded) would raise the ambient temperature by ~1°C (assumed 50% efficiency of the air-con). The 120 Watts compare to the 100W approximate basal metabolic rate + 20-40W brain activity of the human body – so the user of the PC will raise the ambient temperature for another 1°C. The raise in room or ambient temperature is minimal since the thermal balance in this example is dominated by the heat flow through the building structure. Massively higher impact on the room temperature is caused by cooking activities (in the n*kW range). This discussion is not finalized. We explicitly ask for support either by pro or contra arguments and references.

C. *Energy profiling of applications*

Applications will be investigated with regards to their energy profile. Different applications and codes consume more or less CPU at any given time, resulting in different energy consumption per time interval; they behave differently in raising machine and ambient temperature. According to our findings within the DEGISCO available pool of applications (The inherited EDGeS pool of applications: [14]), these are classified accordingly with a heat index as +, ++ and +++ for example. We refrain from using "green", "orange", and "red" at this point: The +++ index marks an application that makes maximum use of a given machine, is raising its temperature, but finishes the computation quickly. This behavior may total in less "energy consumed"/computation than the application which creates less heat/time. Still heat/time is an important parameter from a green operations point of view. As PC owners can select the project and by this the application they want to contribute to, they can take into account their specific knowledge of local operations conditions, primarily how much additional heat they can accept.

Limitations and implementation risk mitigation: If the energy profiles of the applications within DEGISCO and partner projects happen to be too similar, the demonstrated impact of the approach become less obvious. Means to adjust application energy consumption per time interval have been discussed and could be used for demonstration.

D. *CPU Speed Steps*

A similar effect could be achieved by exploiting processor speed steps, avoiding additional preparation work on the application side. Current processors provide multiple steps (8-16) for CPU speed, thus controlling energy consumption. Gruber and Keller discuss the use of "SpeedStep" among other methods in order to use the minimal CPU frequency to run an application at full memory bandwidth [15]. Different from the application, the OS and tools installed at the PC are not under control of the Desktop-Grid operator but the contributor, rendering the applicability of methods like "SpeedStep" questionable due to lack of resource control. Whether reduced preparation work on the application level balances the lack of control on the resource level needs to be found out. DEGISCO will call for volunteers supporting the installation of CPU speed step tools and monitoring and report about the benefits and difficulties.

E. Exploitation of natural ambient conditions

A completely independent green strategy we are going to investigate exploits a DEGISCO specific advantage: the aggregation of partners from various different geographies allows benefiting from differences in regional weather situations in order to save energy. Workload indexed as "+++" may systematically be offered to contributors located in low temperature areas while those in sunny summer weather will be offered to contribute for "+" workload.

Different locations yield different climates

- Kazakhstan, Amaty: http://worldweather.wmo.int/070/c00152.htm
- Russia, Moscow: http://worldweather.wmo.int/107/c00206.htm
- Hungary, Budapest: http://worldweather.wmo.int/017/c00060.htm
- Denmark, Copenhagen: http://worldweather.wmo.int/173/c00190.htm
- Spain, Zaragoza: http://worldweather.wmo.int/083/c01240.htm

Recruit regions with opposite weather conditions! Only "+++"-workload today? Sorry Zaragoza, Copenhagen is cooler! DEGISCO partners from Kazakhstan, Russia, and Spain confirmed the weather conditions reported on "worldweather" as already averaged – the peak temperatures exceed both into heights and lows significantly. Again, as DEGISCO just started so is this discussion – and your contributions are welcome!

F. Time-of-day or weather dependent energy tariffs

The value of electrical energy is usually changing according to the conditions of generation as well as by changing consumption. Accordingly, the tariffs for electricity are changing.

While in Germany electricity prices are high during lunch time, in Kazakhstan the energy prices go up in the evening – in both cases dependent on consumption.

Energy prices at the Spot markets vary depending on excess production capacity. Since wind energy can deliver significant amounts of energy, these spot market prices can even turn negative [12].

To improve the energy cost situation and to take advantage of excess Green electricity, advice could be given to contributors how to configure their Desktop-Grid-Clients to prefer workload during low tariff times.

IV. Desktop-Grid – the anarchistic virtual data centre

A major difference between a data centre situation and volunteer based Desktop-Grids is the almost complete lack of central control over the compute resources. Further, Desktop-Grid applications are executed as user with limited permissions (no root rights). Accordingly, installation of support tools, in our case for temperature and energy consumption measurement, is not possible without active voluntary contribution by the resource owner, installing tools with administrator (aka "root") rights. This cannot be done as regular Grid job: different from service Grids, Desktop-Grids implement highest security standards also on the execution side. Applications that are downloaded and executed on the contributed Desktop-Grid client are security validated and, dependent on the Desktop-Grid technology used, even rewritten to execute exactly that computation as described – and nothing more. Any activity beyond the sandbox, e.g. accessing local HW devices like sensors, is off limits for Desktop-Grid jobs. When DEGISCO is looking to gather detailed temperature and energy consumption data we will ask for volunteers to download and install tools and allow the upload of resulting metric data.

V. Difficulties of temperature measurements

In order to apply the Green Methodologies described, it is necessary to adequately understand the ambient conditions of the PC, especially the ambient temperature. Least effort would be the use of PC's built in temperature sensors – but there are difficulties to overcome. The temperature sensors built into PCs and laptops are optimized to support energy management of the PC and its components – not to provide ambient conditions, the kind of information we need. Mainly the position of the sensor determines what is measured. On-die temperature sensors may reflect the CPU internal temperature quite precisely while "system" temperature sensors are placed "somewhere" on the mainboard – delivering temperature measurements that cannot be interpreted meaningful without precise and detailed knowledge of the individual board. Although this seems doable in a lab situation, it is completely beyond scope and capabilities in case of real world deployed Desktop-Grids. The situation is not very much better in regular data centres: depending on the placement of the temperature sensor in the rack, a hot spot will be detected or not. A detailed temperature measurement at several positions in the rack is not commonly found. For safety reasons, the single temperature sensor is placed to detect the (known or anticipated) hot spot, caused by poor local airflow – delivering information misleading with regards to average, typical, or total (=full rack) energy consumption. Further complication is deriving from the application of temperature aware fan speed controls embedded in the systems. Originally developed for Desktops in order to keep their operations noise level convenient for living room conditions, meanwhile regular servers are controlling their fan speeds to provide exactly that amount of cooling needed to keep board temperature within the targeted operations range while enhancing the lifetime of the fans. Side note: The formerly already mentioned "Code of Conduct on Datacenters" explicitly requests control of fan speeds also on the data centre level. The result for our aim to understand the ambient conditions of a machine by reading its temperature sensors gets complicated by these features.

Still the information retrieved may well be sufficient for our aims:

1) Understand values delivered by PC internal temperature sensors as non-linear non-calibrated relative information on machine cooling effectiveness.
2) For ambient temperature use meteorological data by independent sources.

3) To calibrate and QA the methods, call for participation by contributors in a temperature measurement campaign.

Even qualitative temperature information is suitable to distinguish condition “too hot for workload” from “cool and ready to work”. To verify our understanding on ambient conditions, we started working with Mathias Dalheimer, Fraunhofer Institute ITWM, Kaiserslautern. Mathias developed a simple and low cost temperature sensor [16] that can be connected to the desktop or laptop (USB) and delivers proper ambient metrics. This temperature sensor may be offered to Desktop-Grid volunteers by mail-order, requesting the commitment to provide temperature measurement data for automated upload.

The sensor implements an USB1.1-device. The whole USB stack is implemented in software and does not rely on dedicated hardware, keeping the component count low. Digital temperature sensors provide high accuracy measurements. Since the sensors are attached via the Onewire bus, a single USB dongle can query up to eight different temperature sensors which can be placed at different locations around the PC. The software stack is available for Windows, Mac OS and Linux and allows users to query the temperature sensors. Both the hardware and software components are open source and can be modified to accommodate additional requirements.

Currently sponsors are looked for. If the device is produced in a small batch, the cost of an individual device should be around 10 Euro.

VI. Call for contributions: join the Desktop-Grid-Federation

Due to the specific character of Desktop-Grids as voluntary effort, the personal contribution of individuals is of prime importance and very welcomed. In order to improve Desktop-Grid service for science, the dear reader may consider joining the International Desktop-Grid-Federation, described in detail below. Especially welcome are your contributions to Green optimization of Desktop-Grids. To advance the Green optimization beyond the described basic methods, we need support by individuals, institutions, and projects. Contact: mail to green@desktopgridfederation.eu

Looking forward to hear from you!

Appendix: The International Desktop-Grid-Federation

Desktop Grids, Desktop Clouds, allow to employ otherwise idle computing time of Desktop computers for large computational programs.

Desktop Grids can be used inside an organization, or they can collect computing time from volunteers all over the country, or even all over the world. However, operating a desktop grid and developing programs for desktop grids poses specific challenges. That is why the International Desktop Grid Federation is formed.

A. Who should become member?

Organizations and persons can become member of the International Desktop Grid Federation. When should you consider joining? Your organization is operating a Desktop Grid and would like to share experiences with operators, get support and trainings Your organization has a lot of Desktop computers, and would like to make better use of them You want to develop computation programs for Desktop Grids Your organization wants to install a volunteer Desktop Grid, and wants to know how to attract volunteers You are interested in further developing Desktop Grid and Desktop Cloud technology You would like to integrate a Desktop Grid with other Service Grids (for instance based on gLite, KnowArc or Unicore). Your organization has large computational needs, and wants to know whether Desktop Grids could be used. You care about the environment and want to know how Desktop Grid can contribute to a Green ICT infrastructure with less power consumption.

B. Services offered by the International Desktop Grid Federation

The Federation offers several services for its member: Meetings, workshops and conferences: were you can meet and discuss with other members Training sessions and tutorials. Technical support in operation Desktop Grids Technical support in connecting Desktop Grids with other Grids and Clouds Web site and information centre. Material will be available in several languages.

C. Supporting projects

The services offered by the International Desktop Grid Federation are supported by two European projects: EDGI and DEGISCO. EDGI focuses on Europe and on integrating clouds, DEGISCO has an international approach.

D. How to become member

All services are available to all members. So become a member today. We have several options, for companies, research organizations, and persons. More information: http://desktopgridfederation.org

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