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### Submission for the INFORMS ISS Design Science Award

A/B) Name of the nominees:

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C) Title:

**vPlan** – a method and toolset for server consolidation

D) Summary:

"vPlan" is the name of method and a tool for server consolidation. Today's data centers offer many different IT services mostly hosted on dedicated physical servers. Server virtualization provides a new technical means for server consolidation and was one of the most important CIO topics in the past two years. Multiple virtual servers – including operating systems and applications – can be reliably hosted on a single physical server sharing the same resources. Server consolidation describes the process of combining the workloads of several different servers on a set of target servers, using virtualization technology.

Cost considerations, specifically energy savings, are among the key drivers for such projects. Typically, workloads are volatile and have peaks at different times of the day or week. A central question for IT service managers is, *how virtual servers should be allocated to physical servers, in order to minimize the number of physical servers needed, given a certain quality-of-service level*. The motivation for this is the reduction of *investment costs*, and, more importantly, *energy costs* in the data centre. So far, IT service managers rely on manual planning and there is little tool support for the planning of a server consolidation project. Manual server consolidation is not only error-prone, it is also a very time consuming process, and it is almost impossible to consider multiple time dimensions, multiple resources (RAM, CPU), and technical allocation constraints optimally. Although, virtualization software vendors advertise that they can leverage complementary workloads, it is far from obvious, how good allocations of virtual to physical servers can be found.

Contributions

In our work we have focused on large server consolidation problems with dozens or hundreds of servers as they can be regularly found in data centers. The project was conducted in cooperation with **Siemens IT Solutions and Services**, who provided us with a rich set of data.



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The problem originated from discussions with IT service managers in a data center in Fürth (Bavaria). The managers were facing a project where they had to consolidate around 250 dedicated servers in virtual servers on a set of new physical servers. They were looking for advice, on how to allocate these servers on the new hardware, taking into account energy cost and various technical allocation constraints. Consolidation projects of this size are no exception. IT consultants are regularly facing server consolidation projects of several hundred, up to thousand servers. Since, we neither found advice in the academic IS and OR literature, nor tools by software vendors that would support this planning task, we decided to develop new models and methods. Our contributions include the following:

1. We developed different mathematical models to optimally allocate virtual servers. Important real-world constraints with server consolidation are accounted for in our models.
2. We have shown the central model to be an NP-hard optimization problem and, therefore, we derived an LP-relaxation-based heuristic in addition to exact solution methods to address large-scale server consolidation projects.
3. A data preprocessing method for server load data was developed allowing to extract patterns in workload data.
4. Extensive experiments were conducted based on a large set of server load data from a data center focusing on managerial concerns over what types of problems can be solved.
5. We developed a toolset in Java (vPlan) to analyze historical log data and consolidate the algorithms, which enables research transfer and has already been used in the field.

### Results

The results show that, **on average, 31 % savings in physical servers can be achieved** only leveraging volatility in the server workload in our optimization models. As a result, we could show **significant savings in energy costs**. Our industry partners at Siemens regularly conduct server consolidation projects with external customers or in their data centers. The method and toolset did not only improve the quality of the allocation, it also allowed to generate a server consolidation plan considering all side constraints in minutes rather than hours or even days, and therefore led to considerable **time savings**.

The project is considered a great success with Siemens. The method was filed as a European patent already in 2006 and as a worldwide patent in 2007. The initial models were then presented at WITS 2006. In addition, our industry partner Siemens has published a press release and an article in *manage IT*, a popular IT magazine in German. We have put enormous efforts in an extensive experimental evaluation of the method based on real data from Siemens data centers. The results of this experimental analysis are subject of a journal article that is now in the second review round with JMIS. Siemens is also starting to use the toolset in internal projects.



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E) Why is this project to be considered as being within the realm of Information Systems related Design Science?

“Information Systems Research is dedicated to furthering knowledge that aids in the productive application of IT to human organizations and their management”

Server consolidation is one of the top priorities of CIOs these days. According to the National Association of State Chief Information Officers (NASCIO) the State CIO's Number 1 Policy Priority is “Consolidation” the Number 1 Technology Priority for 2009 is “Virtualization” (<http://www.nascio.org/publications/>). Server consolidation has been a regular topic in the CIO Magazine and Computerworld last year. It is often seen as a central approach to save energy in the data centre (see Businessweek, May 14, 2007: Averting the IT Energy Crunch) and in approaches to Green IT.

Our work makes a new contribution to this highly relevant managerial problem of IT managers, and adds to the set of models and methods in the IS management literature.

The JMIS paper follows a design science paradigm as outlined in Hevner et al. (2004). All phases including problem identification and motivation, definition of the objectives for a solution, design and development, demonstration, evaluation, and communication have been addressed in our work (see attached JMIS submission).

F) Verification that the project is principally led and driven by university based faculty, staff and students for R&D or educational purposes.

The project has been conducted in our department at TU München. Siemens has provided us with log data from server consolidation projects and feedback on technical issues. Dr. Achim Luhn ([achim.luhn@siemens.com](mailto:achim.luhn@siemens.com)) will be happy to answer any questions regarding the project.

G) Supporting documentation

Server consolidation is a timely topic. While we are optimistic about the journal publication based on the reviews, review cycles in top-tier journals typically take considerable time. The patent has been filed already in 2006, and the first paper was published in the WITS proceedings of 2006. Therefore, we nominate the project for this year's design science award. Attached, you will find

1. the WITS 2006 publication
2. the revised JMIS submission
3. a letter by Dr. Luhn (Siemens) on the project
4. presentation slides providing an overview of vPlan and screenshots
5. the worldwide patent application (no. WO 2008/068286 A2)
6. an article (in German) in *manage IT*
7. a press announcement (in German) by Siemens