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Network virtualization in energy-efficient office environments

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ABSTRACT

The rising costs of energy and world-wide desire to reduce CO_2 emissions has led to an increased concern over the energy efficiency of information and communication technology. Whilst much of this concern has focused on data centres, office environments (and the computing equipment that they contain) have also been identified as a significant consumer of energy. Office environments offer great potential for energy savings, given that computing equipment often remains powered for 24 h per day, and for a large part of this period is underutilised or idle. This paper proposes an energy-efficient office management approach based on resource virtualization, power management, and resource sharing. Evaluations indicate that about 75% energy savings are achievable in office environments without a significant interruption of provided services. A core element of this office management is a peer-to-peer network that interconnects office hosts, achieves addressing and mediation, and manages energy efficiency within the office environment. Several peer-to-peer approaches are suggested and discussed in this paper. Two of the approaches are evaluated, based on a discrete-event simulation.

1. Introduction

Information and communication technology costs have seen a shift in recent years, with the rapid reduction in hardware costs contrasted with the steep increase in energy costs. Koomey [1], reports that data centres in the USA and worldwide have doubled their energy consumption from 2000 to 2005. In addition, end-devices have also considerably contributed to the increase of power consumption, according to a 2006 survey [2] commissioned by the EU.

Hosts in office environments are often running without being locally used, i.e., the host is not physically accessed by a user. This happens for short time periods (e.g., if users are in meetings, make telephone calls, have lunch or coffee breaks, etc.) as well as for longer periods of time. Physically unused hosts are often left switched on, because users require access to them remotely. Remote access typically happens from the user's home or when users are working externally. Remote access is needed in such cases to access applications and data in the office. The user may need access to email accounts, personal data, or applications. Another important cause that leads to physically unused but running hosts are overnight jobs. A user might schedule a job (e.g., a simulation, a download or a backup) outside his working hours, so it does not interfere with usual work. Apart from such reasons, some users simply forget to turn off their hosts, when they leave the office. Webber et al. [3] have analyzed sixteen sites in the USA and reported that 64% of all investigated office hosts were running overnight.

Locally unused hosts provide a huge potential for energy savings. Either such hosts are idle (0% CPU load), used remotely by their user, or performing a job without user interaction. In all cases energy can be saved. Idle hosts consume a considerable amount of energy, compared to computers that are turned off, without providing any

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added benefit. Measurements that have been performed at the University of Sheffield on hosts that are typically used as personal computers [4] show that idle hosts still consume 49% to 78% of the energy that they need when they are intensely used. Such hosts have to be stopped from consuming resources. If a locally unused host is not idle (i.e., is used remotely or performs a job) there is also a potential to save energy. Such hosts are often underutilized by typical office applications (e.g., text processors, browsers, or mail clients), leading to a high number of lightly utilized hosts that consume nearly as much energy as the same number of heavily utilized hosts. However, only users with physical host access need a separate host to work with, other users do not necessarily need to utilize separate hosts. Local users should share their resources with non-local users to increase the utilization of hosts.

Several approaches have been suggested that deal with high energy consumptions of hosts in office environments (see Section 6). Such solutions range from the enforcement of office-wide power-management policies to thin-client approaches, where users share resources on terminal servers. As extension to power-management solutions and opposed to data-centre based terminal-server approaches, this paper suggests to combine an office-wide power management with distributed resource sharing in office environments. It presents a managed office environment based on virtualization methods that performs a shift from the currently available distributed local resource management (per user) towards a centralized global resource management (per office). The number of simultaneously running hosts in the office environment is reduced, while the utilization of hosts is raised. This enables a major reduction of the overall energy consumption within the office, without significantly decreasing quality or quantity of provided services.

The remainder of this paper is structured as follows: Section 2 describes a managed office environment based on virtualization that achieves energy efficiency in offices. Section 3 presents virtualization approaches to enable a managed office environment and Section 4 discusses three peer-to-peer overlay approaches in detail. Section 5 evaluates energy consumption and overhead of the suggested peer-to-peer approaches within a common office environment (based on the office environment of the University of Sheffield [4]). Section 6 discusses related approaches and Section 7 concludes this paper.

2. A managed office environment

When a user powers on his host in a common office, he finds his usual working environment: within this paper we refer to this working environment as a *personal desktop environment (PDE)*. This typically consists of an operating system, applications, and the user's personal configuration. Although roaming profiles are often available in common offices (see Section 3), the PDE as a whole is fixed, i.e., it is bound to a certain host in the office. When the PDE is turned on/off, the host is also turned on/off and vice versa. Users are able to access their PDE locally within the office or they may also be able to access it remotely from outside the office.

In the managed office environment, PDEs are additionally used as *mobile services*. Mobile services are freely movable within the office environment (between physical hosts) and are used to achieve service consolidation. When the user is not physically using his office host, his PDE can be decoupled from the host and be migrated to another host for energy reasons. Several PDEs can be provided by a single host. Therefore, a user's host is not necessarily turned on when a user remotely utilizes his PDE – the PDE may be provided by a different host. Mobile services can be achieved by using virtualization methods, as explained in Section 3.

In Fig. 1 the transition from a common to a managed office environment (based on PDEs) is illustrated. It can be observed that in the common office environment the PDEs and the hosts are interdependent. Seven hosts are turned on in Fig. 1 (a) together with seven PDEs. Three hosts (with PDEs) are turned off. The situation is very different in the managed office environment Fig. 1 (b) Although the number of currently running PDEs is the same as in Fig. 1 (a), only four hosts are actually turned on. As can be seen in the figure, the upper right host is providing three PDEs to users simultaneously. Based on the availability of mobile PDEs, energy efficiency is achieved in three steps:

- Unloaded PDEs in the office environment are halted, thus stopping them from consuming resources. If a PDE is idle (no job is performed on behalf of its user) it will be suspended.
- Loaded PDEs are consolidated on a small number of hosts. If a PDE is not accessed locally (the user does not physically access his office host), the PDE becomes

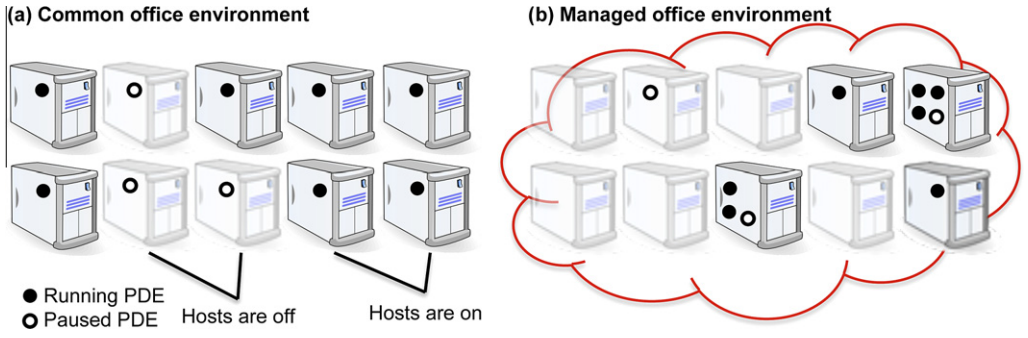

Fig. 1. Common and managed office environment.