A Green Enterprise Computing Architecture for Developing Countries

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ABSTRACT

Developing countries often have access to limited energy resources, which frequently results in power cuts and failures. During these power cuts, enterprises rely on backup sources for power such as uninterruptible power supplies (UPS) and electric generators. This paper proposes AnywareDC, an architecture that builds on the recent work on Anyware [6] to reduce energy utilization in the presence of such intermittent power supplies. Anyware reduces energy usage by providing enterprise users laptops instead of desktops, while maintaining performance using a central compute cluster. Our basic insight is that in the presence of power cuts, only the routers and the cluster needs to be provided power; the laptops can continue to run on their own batteries. This reduces both energy usage and UPS load allowing it to supply power for longer, thus also saving generator fuel costs. Simulations show that this architecture reduces energy usage by up to 80% compared to one not using Anyware, and by up to 20% compared to Anyware.

1. INTRODUCTION

Computing equipment is one of the major energy sinks in corporate and academic buildings today [5]. While computers enable remarkable increases in productivity, their energy costs have continued to increase over the past several years. Developing countries can benefit greatly from this higher productivity, but they often have limited energy resources. This makes it crucial to utilize the available resources as efficiently as possible. Furthermore, limited energy resources often also lead to rolling blackouts and sometimes prolonged power cuts, during which backup power sources such as uninterrupted power supplies (UPS) and electric generators are needed to keep the computing equipment running.

To increase the energy efficiency of computing equipment in an enterprise, the Anyware project [6] recently proposed that users should be provided only laptops at work. To enable users to run more CPU-intensive programs, Anyware connects the laptops to a server cluster that executes such programs transparently from the user. Since one server can provide computational support to many laptops, the total energy utilization is reduced.

This paper presents Anyware for Developing Countries (AnywareDC), an architecture that supports energy-efficient computing in the presence of frequent and possibly prolonged power cuts. We propose that by connecting the UPS only to the server cluster and the networking equipment, we can avoid expending its stored energy on a whole host of computers spread throughout the office. The laptops can continue running on their own batteries without either UPS or main power supply. This could allow the UPS to continue running for a much longer period of time, thus increasing its battery life and reducing the need to switch to generators.

Our simulation results show that this architecture results in up to 80% reduction in energy consumption compared to a traditional desktop-based system, and a 20% reduction over a system using the basic version of Anyware.

The next section provides a brief introduction to Anyware. Section 3 describes our proposed architecture in more detail. Section 4 presents a simulation-based evaluation, including potential energy savings and the conditions in which this architecture could be beneficial. Finally, we describe related work and conclude.

2. ANYWARE

Anyware [6] is a system architecture that reduces the energy consumption of computing infrastructure in office buildings. It achieves this without sacrificing performance or putting devices to sleep. Anyware leverages the fact that laptops consume much less energy than desktop machines. Therefore, it suggests that every user in an office building should be provided a laptop for work purposes instead of a desktop.

However, laptops also have much lower compute power than desktop machines. As a result, users prefer to use desktop machines in case they ever need to run compute-intensive tasks. Anyware solves this problem by proposing a centralized server cluster hosting virtual machines for users. Each user has his or her own virtual machine in the cluster. Each virtual machine has a software configuration that is identical to the laptop provided to the user. When a user working on a laptop starts a task, an Anyware daemon running on the laptop intercepts the user request and decides if the task would run faster on the laptop itself or on the cluster. In general, compute-intensive tasks end up running transparently on the cluster, giving users the illusion of having powerful computational resources at their finger tips.

To achieve reasonable performance, the server cluster has to reside in the same network as the laptops. Each server is capable of hosting virtual machines for up to 25 users, thus making the server cluster much smaller than the number of laptops. User stud-
ies show that the process of making the decision to run locally or remotely, and then actually executing the task is completely transparent: users are unable to distinguish between a process running locally and one running remotely. Experimental evaluations further show that this architecture allows enterprise computing equipment to run at 20% the cost of a desktop machine-based architecture.

3. AnywareDC

In this paper, we propose AnywareDC, an architecture that extends Anyware to deal with environments where power outages are common. The existing Anyware architecture is designed for environments where there is a constant, uninterrupted supply of power. As a result, it makes no extra attempt to conserve energy during periods of power loss.

A naive way of extending Anyware to deal with power interruptions is to simply connect the entire IT infrastructure to a UPS and generator system. We call this simple approach AnywareUPS. The UPS would keep everything running when the power goes out, while the generator provides backup power if the power outage is prolonged and the UPS’ batteries start getting depleted. While this approach would work, it does not improve energy efficiency compared to Anyware. The extra power needed to charge the UPS batteries adds overhead to the entire system.

AnywareDC leverages the fact that laptops have their own built-in power supplies, so they do not need any backup power supplies in case of a power outage. Instead, the backup power source provided by the UPS should be used only to power Anyware’s server cluster and networking equipment such as routers and switches. If the UPS battery or one of the laptops’ batteries start running out, only then does the generator need to be powered up.

Figure 1 shows a simple architecture implementing this idea. The mains electrical supply is provided as input to the UPS as well as to the laptops provided to each user. However, the UPS output is supplied only to the central server cluster and the networking equipment, because the laptops can continue running on their own batteries. The generator acts as a backup power supply when the UPS or one of the laptops starts running out of power. A simple power monitoring tool running on the UPS and each of the users’ laptops can be used to automatically trigger generator startup. If some laptops have much lower battery lives than others, we suggest external battery packs to keep them running or simply investing in newer laptops.

Since the server cluster is small and there are much fewer routers and switches than laptops, the energy consumption can be greatly reduced. This can allow the UPS to continue supplying power for a much longer period of time. Moreover, longer UPS operation would lead to less frequent utilization of the generator, thus saving generator fuel costs. Sections 4.1 and 4.2 validate these hypotheses.

Of course, this architecture is not beneficial if the laptop batteries are weak and last only a few minutes. This would cause the generator to start up earlier than it would without this architecture. Section 4.3 evaluates the minimum battery power laptops need to make this architecture beneficial.

4. EVALUATION

This section evaluates the benefits and preconditions of using AnywareDC in the presence of an intermittent power supply. We first demonstrate the increase in energy efficiency achieved by using AnywareDC instead of using only Anyware or AnywareUPS. Next, we show savings in generator fuel achieved using AnywareDC. Finally, we evaluate the effect of laptop and UPS batteries on the overall effectiveness of AnywareDC.

The evaluation uses a discrete event simulator which models time in units of hours. Every hour, the simulator computes the energy consumed by various components of the computing infrastructure. Based on a pre-specified policy, it simulates interruptions in power supply in any given hour and computes changes in energy consumption accordingly. The simulation is based on a small office environment with 25 users, with typical power draws for various kinds of computing equipment at 100% CPU usage: 24W per laptop, 165W per desktop, 270W per server, 6W per switch, and 96W for the UPS. The generator is assumed to be powerful enough to be able to run the entire computing infrastructure.

4.1 Energy Savings using AnywareDC

We first show the benefit of using AnywareDC compared to using Anyware unchanged in an office computing environment. We use a random power outage policy where, at the top of every hour, a power outage is simulated based on some probability. The simulation assumes a typical scenario where all laptops and the UPS have 3-hour battery backups.

Figure 2 plots the energy efficiency achieved using AnywareDC for different power outage probabilities. For probability below 20%, there is little to no benefit because the duration where the laptops save energy by using their own batteries is very small. For higher power outage probabilities, AnywareDC provides between 15-20% energy savings compared to unmodified Anyware. Furthermore, similar to unmodified Anyware, AnywareDC achieves almost 80% reduction in energy consumption compared to a typical desktop-dominated computing environment.

Of course, in order to make Anyware work in an intermittent power environment, we would have to install some backup power source to keep the infrastructure running. Section 4.4 describes AnywareUPS, a simple method of achieving this using a UPS and generator system. However the presence of the UPS adds extra energy overhead to the entire system. Figure 2 shows that due to this overhead of AnywareUPS, AnywareDC is able to improve on it by 30-35% in terms of energy efficiency.

4.2 Reduction in Generator Usage

Secondly, we evaluate the reduction in generator usage achieved using AnywareDC. The results are shown in Figure 3. In short, an architecture using AnywareDC requires almost 30% less generator fuel compared to AnywareUPS over a wide range of power outage probabilities. This is because in AnywareDC, the UPS can backup the server cluster for a longer period of time. As a result, the generator has to be run less frequently, resulting in lower fuel
This section explores the effect of laptop and UPS battery back-ups on the energy efficiency of AnywareDC. Each hour, the probability of power availability is 50%.

5. RELATED WORK

A substantial amount of work exists on reducing the energy consumption of computing infrastructures. [7] presents an extensive survey of some of the most common techniques. In summary, work on computing energy efficiency can be classified into node-level optimizations, datacenter power management, and virtualization.

Node-level optimizations focus on optimizing the energy usage of a single PC or server. They often involve switching a PC to sleep mode when idle [8,9]. They could also involve hardware [10] and software optimizations for a single node [11].

Datacenter power management techniques include setting up datacenters near green sources of electricity, such as hydel and wind power. More sophisticated techniques run jobs on as few nodes as possible in a data center to reduce energy usage [2]. Anyware uses a similar approach of running expensive jobs on a very small server cluster.

Virtualization approaches, such as CloneCloud [3], enable applications to be centralized and run in application-layer VMs. Some approaches combine sleep-based techniques with virtualization. SleepServer [11], for example, proxies applications in trimmed-down virtual machines, while LiteGreen runs the entire user desktop environment in a virtual machine, which can be migrated to a server so the desktop can be put to sleep.

6. CONCLUSION AND DISCUSSION

This paper describes AnywareDC, a system architecture for higher energy efficiency in the presence of intermittent power supply in developing countries. Besides its energy efficiency benefits, AnywareDC also has other tangible benefits. First, it can simplify administration of the IT infrastructure. During power outages, since only a central cluster and a handful of networking devices consume power, administrators only have to worry about their power usage. This makes it easier to identify power hogs, detect malfunctions and failures, and balance load across these devices.
Secondly, laptop batteries last longer because they are regularly charged and discharged during power outages. This keeps them in better running condition than if they remain on main power supply all the time. Finally, UPSes remain in better working condition since they drive a lighter power load. This reduces the chances of batteries getting fully discharged or the UPS getting damaged due to overload.

7. REFERENCES

[1] F. Blanquicet and K. Christensen. Managing energy use in a network with a new snmp power state mib. In Local Computer Networks, 2008. LCN 2008. 33rd IEEE Conference on, pages 509–511.

[2] J. Chase and R. Doyle. Balance of power: Energy management for server clusters. In Proceedings of the 8th Workshop on Hot Topics in Operating Systems, 2001.

[3] B.-G. Chun, S. Ihm, P. Maniatis, M. Naik, and A. Patti. CloneCloud: Elastic Execution between Mobile Device and Cloud. In Proceedings of EuroSys 2011. ACM, 2011.

[4] T. Das, P. Padaala, V. Padmanabhan, R. Ramjee, and K. Shin. LiteGreen: Saving Energy in Networked Desktops Using Virtualization. USENIX Annual Technical Conference, 2009.

[5] M. Kazandjieva, B. Heller, O. Gnawali, P. Levis, and C. Kozyrakis. Green enterprise computing data: Assumptions and realities. In Green Computing Conference (IGCC), 2012 IEEE International.

[6] M. Kazandjieva, C. Shah, E. Cheslack-Postava, B. Mistree, and P. Levis. System architecture support for green enterprise computing. In Green Computing Conference (IGCC), 2014 IEEE International.

[7] A.-C. Orgerie, M. D. d. Assuncao, and L. Lefevre. A survey on techniques for improving the energy efficiency of large-scale distributed systems. ACM Computing Surveys, 46(4):47, 2014.

[8] J. Reich, M. Goraczko, A. Kansal, and J. Padhye. Sleepless in Seattle No Longer. USENIX Annual Technical Conference, 2010.

[9] S. Sen, J. R. Lorch, R. Hughes, C. G. J. Suarez, B. Zill, W. Cordeiro, and J. Padhye. Sleep Over Availability: The GreenUp Decentralized Wakeup Service. In Networked Systems Design and Implementation (NSDI), 2012.

[10] D. C. Snowdon, S. Ruocco, and G. Heiser. Power management and dynamic voltage scaling: Myths and facts. In Proceedings of the 2005 workshop on power aware real-time computing, 2005.

[11] R. G. Yuvraj Agarwal, Stefan Savage. SleepServer: A Software-Only Approach for Reducing the Energy Consumption of PCs within Enterprise Environments. USENIX Annual Technical Conference, 2010.