A STUDY OF THE EFFECTIVENESS OF "WAKE UP ON LAN" AS A MEANS OF POWER MANAGEMENT

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Abstract: The growing awareness of the fragile nature of our environment, and of the damage that humankind is causing to that environment, makes it necessary to review the environmental impact of all aspects of human activity. One such area is the operation of corporate information technology (IT) systems. The growth in the number and complexity of such systems over recent decades has led to a consequent increase in their power requirements, to the point where for organisations of any size, "corporate IT" will be a major contributor to the organisation's overall energy consumption. A drive for overall reductions in consumption will, in the words of the chair of the newly formed UK Environmental IT Leadership Team, mean "the IT department becomes the focus of carbon reduction policies". It is therefore timely to consider the present situation in respect of power consumption within corporate IT systems, and to explore the potential avenues for reducing that consumption. In this paper, we will briefly overview the area of power usage in IT, before reporting on the outcomes of a specific project in which we explored the operation of the "wake on LAN" method in a real situation.

1 INTRODUCTION

The rapid growth in computer use is placing a strain on the UK's ageing electrical infrastructure. The growth of networked systems within organisations is a major factor, with an increase in the number of servers in a typical organisation from around 4 in the late 1990s to 10 to 15 times that number (Watson, 2006). In October 2006, there were 2,507,278 registered companies in the UK (Companies House, 2006). While we do not know exactly how many of these companies operated with the 60 servers in Watson's analysis or even as many computers, it is not unreasonable to suggest that a good proportion will have PCs, Servers and other network devices.

Data for energy consumption of IT systems vary according to the exact definition of what is included, and there is variation in reporting methods. Kawamoto et. al. (2000) found "devices connected to the Internet" for "commercial use" were responsible for 2% of the total U.S. power consumption. In Germany over 7% of *domestic* energy consumption is "computer-related" (Loerincik 2006).

One attempt to save energy has been to limit the power taken by devices when not in use by placing them in a "dormant" state, like the "stand by" mode of many consumer electronics devices. Note: in a further parallel with consumer electronics, "dormant" is not "off", and some power is still required. The generic term for this activity is *power management* (PM). PM can bring about energy savings "…of the 74 TWh/yr of electricity (approximately $6 billion per year) … consumed by the Internet in the USA alone … 32% could be saved with effective PM on desktops" (Christensen et. al. 2007), and the equivalent of 250M litres of gasoline per day could be saved if 1M PC users employed PM (Long 2006).

Many current energy reduction activities (including the one reported here) aim at the desktop (user PC) element of IT systems, reasonably enough in view of the numbers of such devices. However, server and network device (switches, hubs and routers) must not be overlooked. Allowing such devices to enter a dormant state is problematic, as typical network performance and security monitoring techniques expect networked devices to respond to a regular sequence of polling packets; indeed some network management tools generate an alarm if a device does not react to a probe request; therefore there is a contradiction. Furthermore,

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"[t]he immense increase in networking … is an important factor [limiting the use of power saving] because network activity can keep computers from entering low-power modes" Webber *et. al*. (2001).

2 APPROACHES TO PM

In the opening parts of this paper, we argued that there is a contradiction between the conventional way networks operate, PM and cost savings. Let us therefore take an overview of the different potential strategies in this regard. We start by giving a brief explanation of each of these techniques (Table 1).

To some extent, this table is rather simplistic; e.g. overlaps between some techniques could combine to effectively provide a PM solution. In this study, WOL has been chosen primarily because of its ease of use and simplicity in implementation. Also, a previous research project successfully used WOL in both wired and wireless scenarios, so we have confidence in the underlying method.

3 QUESTIONS TO ADDRESS

The objective of this research was to determine how WOL operates; hence we begin by exploring how WOL will be delivered in a typical networked scenario. Crucial to the deployment of WOL across a network are questions of the nature and operation of the communication process; for instance, are WOL packets broadcast, unicast or multicast? What are the issues with regard to a 'connectionless or connection-oriented approach?' and finally, what are the issues in terms of efficiency and security.

4 THE MAGIC PACKET (MP)

'Magic Packet' (MP) and 'Wake up On LAN' (WOL), are the same thing. The Magic Packet is broadcast via port 7 or 9 which can be sent using a variety of connectionless protocols, with UDP the most common. (CapaInstaller, 2006). The Magic Packet structure is similar to an Ethernet packet, but the destination Medium Access Control (MAC) address is repeated 16 times within the packet.

Table 1: Alternative PM approaches.

Dynamic Power Management (DPM) Lu *et. al.* (2000)	Algorithms designed to shut down a device only when an idle period is of sufficient length to justify performance degradation and state-transition energy.
EZ Group Policy Objects (GPO)	A free tool which allows network administrators to centrally control Power Management settings using GPOs.
SMS Wakeup (Hobbs 2006),	SMS 2003 currently lacks the means for waking up machines, a plug-in from 1E, Inc., called SMS Wakeup, provides this functionality. SMS Wakeup integrates with SMS and uses data from the SMS asset collection to obtain MAC addresses for each client computer.
Using a low-power channel Shih et. al. (2002),	By adding a second low-power channel, it is possible to shut the system off and reduce idle power. Out-of-band control information can be sent simultaneously, to maintain connectivity and wakeup the universal communicator (UCoM) device when necessary.
Wake on LAN (WOL) (Korn *et. al*., 2006).	Wake on LAN is a Layer 2-based means for waking up machines from sleep states such as system standby, hibernate and shutdown – and for remote access to them.

WOL encapsulates such Magic Packets inside a broadcast UDP packet. This gives benefits over raw Ethernet frames including Operating System (OS) interoperability.

The complete UDP packet, sent over an Ethernet interface, looks like this: (Spurgeon 2006)

[Ethernet header][IP header]
[UDP header][Magic sequence][CRCS]

5 TO BROADCAST, UNICAST OR MULTICAST?

Unicast packets are sent from host to host, a one to one relationship. Broadcast packets are one to many, one host communicating with all other hosts. Multicast is a restricted one to many relationship; a

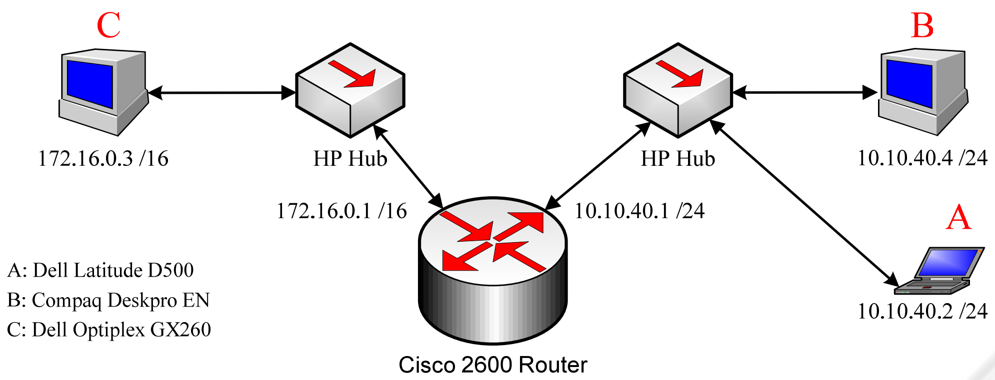

Figure 1: Routed Network – MP Implementation.

single device can communicate with a specific set of hosts. Our previous work with the MP showed that it can be transferred by broadcast, unicast and multicast, however for the purposes of this paper, we consider a 'broadcast' approach, minimising effort (just one message needs to be created), while maximising coverage. By design, most modern routers will block IP broadcast traffic and restrict it to the local subnet, but this can be changed by the network administrator.

6 WOL QUESTIONS

6.1 Efficiency

We conducted a series of tests to send the MP over a wired network with unicast and multicast instructions to wake machines. In these tests, the packet successfully woke up and shut down workstation(s). When this was carried out using a wireless link, we found that in 2 cases, the instruction to sleep succeeded, but the instruction to wake failed if the target machine was in another subnet. We believe that a correctly configured wireless AP in that foreign subnet will rectify this and conclude from these results that the MP is able to produce satisfactory results and to do so reliably.

6.2 Reliability

It is well known that UDP is not reliable (Bhatti 2007); therefore the immediate question might be why use it? Why not invoke a connection oriented protocol with reliable delivery? Once a command is issued to sleep, there is currently no feedback mechanism to indicate that command was received and obeyed. Instead, the network administrator may need to utilise other tools creating extra work and traffic, reducing the potential benefits of PM. Therefore one challenge for developers is to bridge the gap between the command and the response.

6.3 Security

There are a number of security issues within WOL and its implementation (Robinson, 2007). For instance, applying the 'layered approach' of most network designs as in the following model:

((PM + current security) + (LAN security) +
(WAN security) + internet security))
= Total Vulnerabilities

means that vulnerabilities are compounded. We also found that "more advanced systems" do not necessarily mean "more advanced PM" a further indication of the need for research and development into PM. Min and Chandrasakan (2003) argue that computational algorithms and low power digital hardware trade energy for quality, because digital processing occurs more slowly and uses less energy when circuit voltage is reduced.

7 BROADCASTING THE MP OVER ROUTED NETWORK

In section 5, we identified different ways of sending the MP. Most networks will be routed in some way. So we first consider if we can broadcast the MP.
Figure 1 shows a routed network with two broadcast domains (10.10.40.0 /24 and 172.16.0.0 /16), randomly selected and intentionally kept distant from each other, (Class A and Class B respectively) for ease in configuring the router.

It was possible to send the MP from **A** to **B** and **C**, to shutdown and wake-up. We already knew that

A to **B** was possible, from results obtained in the previous test; however, here we successfully showed that the MP does route to another domain. Though a single router is used, in a network comprising of many routers, the MP should also be able to achieve the ends of Power Management, provided that routers and firewalls are configured to allow broadcast packets to travel between subnets (Korn et. al., 2006). (The tool used in these experiments is Prof Shutdown 3.2 evaluation version (profshutdown, 2006)).

8 CONCLUSIONS

This paper shows that PM can be supported by MP without detriment to network performance. Our own research indicates that the adoption of PM take-up is at best ad-hoc, sparse and often a small project after business critical objectives have been realised. We believe this to be counterproductive, as buy-in by all stakeholders will itself contribute to the bottom line of businesses and our world. Because the MP piggy-backs Ethernet, we further believe that the case for its deployment and the potential return on investment (ROI) is significant.

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