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Commentary

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Cloud computing

On 26 January 2007, President George W. Bush signed a mandate (Executive Order 13423 – Strengthening Federal Environmental, Energy, and Transportation Management) requiring government agencies to employ green technologies, and government suppliers to employ 'sustainable environmental practices'. This kind of government regulation, with potentially significant effects on all government suppliers, is becoming widespread in Organisation for Economic Co-operation and Development (OECD) countries. One bright hope for achieving these goals comes from the potential of information and communications technologies (ICTs) to effect major reductions in energy use. Among the various solutions, one which is beginning to capture substantial industry interest is cloud computing: the use of remote servers not only to store files but also the software needed to access and change them. Its best-known forms in consumer markets are Amazon S3 and Google Docs, but a large number of companies provide such services for bulk storage and handling of corporate, public service and government data (see the list of companies provided in the appendix to Carr, 2009: 235–44). The theory is that end-users no longer need a complex and expensive computer with ecologically damaging hard drives and CD-DVD players, or memory- and power-hungry local software. In place of full-blown computers, for all but highly professional or necessarily secure uses, a 'thin client' will be sufficient. This is the fundamental design of the netbook generation of computers heavily marketed in the 2009 consumer electronics fairs: a machine with limited capabilities of its own, but which can be linked instantaneously and constantly to remote data centres, also known as server farms, where all their software, documentation and files can be securely stored and accessed.

According to the US Department of Energy:

> Data centers used 61 billion kWh of electricity in 2006, representing 1.5% of all U.S. electricity consumption and double the amount consumed in 2000. Based on current trends, energy

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consumed by data centers will continue to grow by 12% per year.(US Department of Energy and US Environmental Protection Agency, 2008: 1)

After a false start in the 1970s (Campbell-Kelly, 2003: 162), servers became a major industry during the boom years of the worldwide web. As so often in internet matters, it is difficult to assess how many servers are involved, since any computer can act as a server once connected to the network. However, millions of dedicated servers constitute the backbone of the internet. They are typically robust machines which are rarely if ever switched off and rebooted, and which have no other function than to provide services to remote clients. Server numbers reflect the kinds of content they serve. As few as 13 'root' servers control the Domain Name System look-up service, whose dataset is largely composed of numerical addresses and their translations. On the other hand, multimedia files, requiring far more memory, require far larger numbers of servers. The popular MMORPG *World of Warcraft* has at least 180 and perhaps as many as 500 run by the operating company, and hundreds more provide community services (GameCyte, 2008). Email, ftp, worldwide web, bulletin boards and many other specialist services require dedicated servers. Media-rich cloud services like YouTube, MySpace and Flickr occupy huge quantities of memory, while individual companies like eBay and Amazon run massive numbers of servers, as do a hefty proportion of popular commercial domain names, where these are not hosted by companies specializing in providing server space. There are almost certainly millions of servers associated with the internet. Cloud computing merely adds a new kind of service to those already available. But the addition of bulk storage for industry, academia and government is now a significant part of the overall load of internet server traffic, and a growing one. In what follows, we will explore the environmental impact of this growth in server use, suggesting that such accounting needs to be taken on board when migrating from local computing or from analog systems to the apparently weightless world of digital media and real-time remote access. We will concentrate on the server business of one of the major players in the digital market, Google, which announced net profits of US $1.42 billion for the three months to 31 March 2009, up 8.9 percent on the year.

Google servers

Much of the discussion around Google centres on two major regulatory concerns: privacy and monopoly. European legislators are concerned about Google's 2008 acquisition of DoubleClick, the biggest operator of banner advertising (Stross, 2008). The German government has engaged in a lawsuit testing the legality of Google Books, while others are concerned about the commercialization of culture (Jeanneney, 2007; Johnson, 2009). Competitors Amazon, Microsoft and Yahoo have joined the Internet Archive (the non-profit internet library built in collaboration with the Smithsonian and the Library of Congress) to challenge Google's potential monopoly of scanned books (Pham, 2009). Google's Chrome browser operating system suggests a return to the walled garden economics of AOL and MSN in pre dot.com crash days. They also suggest a similar temptation towards a one-stop service portal. US Assistant Attorney General Christine Varney targeted Google as a key challenge for the Obama administration's enquiries into monopoly practices (American Antitrust Institute, 2008). In a parallel move, during 2008 and early 2009 the Federal Trade Commission in the US investigated two Google board members who also had seats on the board of Apple. The problem arose from Google's Android mobile operating system, with 20 percent of the US smartphone market. Combined with Apple, they would control 75 percent of US smartphone traffic (AdMob, 2009). A parting of the ways was only confirmed in January 2009 with the launch of Nexus One, the 'Google phone', in direct competition with Apple's iPhone. Further concern arose over Google's August 2009 purchase of On2 Technologies, specialists in video compression codecs, software packages for compressing/decompressing transmitted video. Some include optional capacities to track use of copyright materials, and include personalization functions based on web and viewing histories, for example to facilitate broadcast advertising on the AdSense model, expanding Google's monopoly in advertising to cellphones.

Privacy issues arise from several Google activities. The loss-making YouTube division has come in for criticism of 'citizen surveillance', and videos of sexual, racist and criminal acts. Google's proprietary AdSense software uses cookies to track users' preferences, and its web history facility remembers previous searches by each user. The company's StreetView tool eliminated faces early on, but number-plates took several months to mask, while Iraqi insurgents (Harding, 2007) and the Mumbai bombers (Gadgil, 2008) used Google Earth for targeting and logistics. There are also concerns about the potential for abuse of stored documents on Google Docs. Business models based on free applications with ancillary revenue streams take access to user data as the basis of their profitability. This moves the stakes from the familiar analysis of governmental surveillance (Gandy, 1993; Lyon, 2007) towards the widespread use of commercial surveillance in electronic markets (Elmer, 2004). While these issues rightly attract public concern (Rowan, 2009), the issue of the part played by ICTs in carbon emissions is only now beginning to be discussed in the industry, and to a lesser extent in the public sector.

Google's 61 percent of the global search market is dominant but not exclusive. Its major revenues come from advertising, but its corporate mission is 'to organize the world's information'. Google Docs, Maps, Books and Earth, AdSense, Gmail, Blogger, YouTube, Android, Chrome, social network, photo-album and specialist search, storage and applications services, including communication with external developers, adds up to a lot of media-rich traffic. It requires a lot of servers, organized in geographically dispersed, interlinked 'farms' comprising thousands of individual servers. Such data centres are big business. Traditionally Google has been shy of revealing much about its servers, not least because of their potential vulnerability to vandalism and espionage. But on 1 April 2009 Google server guru Ben Jai lifted the veil on the company's server technology at an industry conference in Mountain View, California. Industry observers were entranced by the home-made ethos, and by the practice of providing each server with its own 12-volt DC (direct current) battery in case of power outage. Google also organized DC supply in place of the easily over-heated power adapters which transform mains AC (alternating current) to DC for computer use, so reducing power wastage as well as the heat signature of their installations. That the servers are constructed from parts rather than bought off the shelf, and use what are often regarded as obsolete chips added to the interest.

Since 2005, Google has been installing 1160 servers into a single shipping container, complete with batteries, power, cabling, water-cooling and fans, drawing as much as 250 kilowatts of power. The containers are stacked and networked in buildings holding

45 containers, each drawing down 10 megawatts apiece (including additional cooling and water pumps) in one facility dating back to 2005, which now has three such buildings. The design was subject of a patent applied for early in 2008. Since then, Google has been building server farms across the US and globally: in Oregon, Virginia, Iowa, South Carolina and Oklahoma, in Dublin, Lithuania, the Netherlands and Austria, and in India and Malaysia among other sites. Google has made technical decisions on such questions as voltage to achieve maximum efficiency: about 20 percent of power goes to non-computing uses (mainly cooling). Nonetheless, one (slightly controversial) report asserts that a single Oregon facility would have a total capacity of 103 megawatts (Strand, 2008).

According to their 10Q tax filing for the period ending 31 March 2008, Google spent $355,734,000 on Information Technology Assets. As to what that amounts to in terms of servers, estimates range from 200,000 to half a million. An informant in the business tells us that containerization allows for a lot of dead servers before a 'box' is deemed to require maintenance, so absolute numbers are probably never going to be known. Indeed *The Economist* (2008) cites a report from McKinsey and Uptime, according to which only 6 percent of server capacity is in constant use, and nearly 30 percent is entirely unused. But with sealed-unit construction of server farms, there is no way to know which are in use, which are not, and which are already expired, short of the engineers' trick of pulling the plug and waiting to see who calls. Given the geographical spread of Google's server farms, which are now being built close to their biggest international markets, such problems add to the difficulty of assessing the energy use of the system, even within one company.

In an 11 January post to Google's official blog, Senior V-P Urs Hölzle (2009) proposed a figure of 0.0003 kWh of energy per search, equivalent to about 0.2 grams of CO_2. The post was a response to a London *Sunday Times* story of the same date (Leake and Woods, 2009) suggesting that each Google search generated between 1 and 10 grams of CO_2, allowing for searches that don't succeed at first click, and for the running of the user's computer. Sharing documents via cloud computing or mail may well be less efficient. On the positive side, Google has invested heavily in the design of power linkages, and is tending to site facilities close to energy sources like hydroelectric dams and, more recently, wind farms.

The complexity of assessing energy use is further complicated both by new ventures and the expanding market in which Google operates. Partnered by HSBC and Liberty Global, Google plans to establish a 16-satellite network christened 03b ('other 3 billion') in 2010, aimed at providing wireless space-to-ground internet capacity for underdeveloped areas of Africa and Asia. While undoubtedly a step towards democratizing the internet, O3b will generate more searches, and more revenue: Google extracts fractional value from internet traffic; the more traffic, the more value. Left out of the economic equation, however, are the shorter- and longer-term environmental impacts of satellite launch and recovery. On the other hand, in 2008, Google registered patents for floating wave-powered and water-cooled server farms. This may well be a better solution than, for example, building a farm in Lithuania, 98 percent of whose power is nuclear according to a brief but damning report in *Harper's* (Strand, 2008). It has however garnered some political opposition from BRIC countries, notably China, which notes that where several Asian nations in prime server territory – notably Singapore – have only 2-mile territorial waters, such farms may well fall outside national jurisdictions, and therefore outside the ambit of the International Telecommunications Union (ITU), China's preferred agency for internet governance. Other companies have initiated strategies which may also be more environmentally sustainable. Energy costs, however, seem to be the main driver in these pursuits, rather than sustainability (Carr, 2009: 132).

Google is far from alone in the server business. Telco AT&T, busy expanding from its base in the slowing landline market, is moving into server provision in China with two farms in Shanghai. Sun Microsystems (slogan: 'The Network Is the Computer'), a pioneer in cloud computing, is a major provider of data farms worldwide, and its acquisition by business software giant Oracle, will make it an even bigger player. Large outfits with reasons for discretion like the US military run their own server farms. Popular media-rich services like Second Life and YouTube, the success of media-rich social networking services like MySpace and Facebook, and rapidly growing micro-messaging services like Twitter, also offer consumer cloud computing supported by server farms. Amazon's S3, EMC's Mozy and Apple's MobileMe are other players moving into the industry, set for major expansion with the likely entry of telcos into provision of on-demand online utilities for business and individuals. As industry insider Joe Weinman (2009) blogs, clouds may be 'reducing total resource requirements through statistical multiplexing. Fewer resources imply less manufacturing, and less electricity consumption for power and cooling.' But this requires a parallel reduction of in-house computing resources, for which there is precious little evidence. Much use of the cloud is for back-up of locally produced and maintained files, implying an increase, not a decrease in the quantity of storage and therefore the amounts of energy required both to store and transport files.

Perhaps the most intriguing, even ominous aspect of near-future scenarios is 'ubicomp', ubiquitous computing, combining the 'internet of things' with the increasing integration of mobile wireless and internet media. RFID (radio frequency identification) tags (Hayles, 2009), biochips (Thacker, 2004) and a variety of wireless devices can be installed in anything from fridges to mousetraps, passports to pets, creating a vast demand for new storage and communication services. Meanwhile the convergence – for example Google's mobile OS Andriad, browser Chrome, VOIP service Voice and the Nexus One cellphone – indicate that touchscreens, integrated social networking, portable formats for books, games, music and feature films, and the improved camera and recording capabilities in handheld devices will increase both the quantity and the traffic in data over the foreseeable future. That increase has been measured in a number of ways (see for example Lyman and Varian, 2003). One remarkable finding is that:

> the amount of information created, captured, or replicated exceeded available storage for the first time in 2007. Not all information created and transmitted gets stored, but by 2011, almost half of the digital universe will not have a permanent home. (Gantz, 2008)

Estimating the current size of the digital universe at close to 300 billion gigabytes, Gantz's team at consultants IDC do not make extravagant claims for growth. But as Hollywood adopts shared standards for multiplatform delivery (Graser, 2010), the quality as well as quantity of media involved in net traffic will expand dramatically. The question is whether this is a sustainable future.

Clouds on the horizon

The cultural, corporate and governmental shift brought about by rapid, real-time searches and the massive availability of information, policy documents, reports and comments is no longer reversible. The question then is not whether cloud computing is less or more damaging to the environment than analog predecessors, but whether networked computing is sustainable in the technical and corporate model currently being deployed? The answer can only really be discussed in relation to ecological impact of the general economy, embracing not only ICTs but also the rest of our uses of power and resources (Koomey, 2007). Can we cover the costs of cloud computing either by efficiency gains in other sectors of the economy, or by reducing energy use in those sectors? The data has said 'no' for almost 20 years (Sproull and Kiesler, 1991).

In 2006 Boccaletti and colleagues estimated that IT manufacture and use is responsible for 2 percent of global carbon emissions – the same amount as the airline industry – and is heading for 3 percent by 2020, when it will be responsible for the same amount of carbon as the United Kingdom produced in 2008. The authors argue that 'the fastest-increasing contributor to emissions will be growth in the number and size of data centers, whose carbon footprint will rise more than fivefold between 2002 and 2020'. They argue that increased efficiency in the general economy as a result of network computing will balance the books. Similarly Autodesk's Stewart and Kennedy (2009) argue in the pages of *Environmental Leader* that:

> If designers, architects, engineers, general contractors, energy auditors, land use planners and policy makers are able to access services that use vast sets of dynamic, complex and otherwise un-integrated data on the cloud for pennies a minute, think of the massive impact this could have on buildings, infrastructure, land use and urban design and policy-making.

The question is, will they be able to access this data, and will it be integrated? Or will it be proprietary and fragmented?

Software critique (e.g. Fuller, 2008; Kittler, 1997; Tufte, 2006) identifies the risk that: 'software is reduced too often into being simply a tool for the achievement of pre-existing neutrally-formulated tasks. Culture becomes an engineering problem' (Fuller, 2001). Edward Tufte pillories Microsoft's presentation software PowerPoint for its hierarchical 'cognitive style', which he blames for weakening verbal, visual and statistical reasoning (blaming it specifically for the Challenger disaster; Tufte, 2003), a process elsewhere described as 'a fresh array of flashy visual effects that encouraged us to hide our data behind a thick layer of cheap makeup' (Flew, 2009). Attempting to protect copyright, proprietary software protects against users' attempts modify program code. Instead, packages like Microsoft Office offer a host of functions, large numbers of which rest unused. The phenomenon of software bloat, as this accretion of redundant functionality is known in the industry, leads to ever fatter, slower, more energy- and memory-hungry applications, in turn leading consumers to trade in their old machines for new ones capable of dealing with the new demands of new software generations. While such bloat offers some user discretion in how they use each program, it prescribes the options available. While every author using Word writes differently, the look and feel, the experience of writing, is standardized, and the means available for changing the nature of writing are limited. This standardization formed the basis of much of the animus directed towards

Microsoft during its antitrust cases, and is likely to return with the rise of cloud computing, where remote software is even less open to tinkering and modification than is the case with software installed on local hard drives.

A more positive spin on this homogenization of software is that it may make datasets kept in the cloud mutually compatible and interoperable. If we all use the same software, the data we store will be available in principle to anyone using the same software. If, however, software design constrains the kinds of dataset that it can store, interoperability begins to turn into homogeneity, and towards the loss of alternatives and innovations. Standardization of cloud software thus may encourage communication while at the same time reducing the quality and quantity of information communicated.

Without a test for originality (as required in patent law), copyright is wielded as the critical legal provision through which to monetarize internet communications. While Google is among those operations working on the principle that free is always more attractive than cheap, others, including many social networking sites, are extremely proprietorial about their content. Cloud computing has developed in the commercial, military and government sectors under regimes of strict confidentiality, using firewalls, security, passwords and subscriptions as means of keeping data away from unauthorized users. There seems little chance that the cloud will develop any other business model. Users themselves demand security and privacy for their materials. While scientists and academics are fighting good fights for non-copyright, open-access journals and publishing, even these sectors are open to challenges from corporations and university administrators who see such publications as intellectual property that should be commercialized in the interests of profit or, in the public sector, sheer survival.

Sustainability will only be achieved once the larger population realizes that the internet is not weightless and information is not immaterial. The 19th century made the mistake of believing that the oceans were inexhaustible; the 20th that markets could grow forever. We are in the position to make a similar error concerning digital information. We may need to understand that rationing information may be a necessary step in future. This is not the same as arguing that only the wealthy should have access to information. Rather, storing increasingly detailed multiple copies and drafts on multiple hard drives as back-up may no longer be possible. Reducing both the complexity of files that do not need to be stored in high resolution, deleting files that are no longer useful, reducing the storage requirements of business and public services, ending duplication of documentation and other related techniques may be essential. It has been clear to archivists for several decades that complete records are an idle dream. Choices must be made as to what is saved and what is not. That problem now spills out of libraries and media archives into public space. We now face an interesting challenge: to decide what we leave to the 'criticism of the mice', and what we feel is worth maintaining. This strategy will only work, however, if we can find a way to leave behind our proprietorial leanings where information is concerned. There seems little point in every individual having their own copy of the last U2 album stored on a local computer when a single copy might be accessed by all. Ironically, rationing information implies sharing it.

Governments may take the message of Kyoto and apply it to the ICT infrastructure. Civil society bodies may be able to persuade manufacturers, service providers and governments to synchronize product lifecycle policies for manufacture, use and recycling of electronic goods. But it is clear that the solutions are not exclusively about these familiar sectors of the political economy. What digital media have demonstrated is that a different type of economy is possible, one grounded in collaboration (Scholz, 2008) and peer-to-peer systems (Bauwens, 2005), most familiar in the example of the Linux software environment. The open encyclopedia Wikipedia offers another model: no-one would bother downloading a copy of the entire site for private use because its shared and rewritable format makes that pointless. The intensification of private property rights over inventions, innovations and created works only serves to encourage the proliferation of copies, even when agreement is reachable on shared cross-platform technical standards. It is clear that proprietary solutions will benefit only sectors of a global network, not the whole system. For that, we require social as well as economic reactions to the emerging energy crisis of information.

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