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The information utility

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DEMOS

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We are entering the era of the information utility. Billions of computers, smart devices and huge data resources are inexorably becoming society's indispensable infrastructure. Information utilities are set to become as pervasive as printing, electricity, the automobile and telephone – and just as disruptive to existing social practices and forms of organisation. Futurologists have produced innumerable accounts of the importance of electronic networks such as the internet in shaping our world. Social and management scientists have written similarly about the importance of social networks of human beings in characterising all aspects of society. From now on 'networking' means an intimate combination of the two: people and technology.

It is helpful to think of the information utility as comprising what goes on 'behind the wall', what is 'in front of the wall', and crucially the two-way interactions that can go on 'through the wall' between people and things connected to the utility. Behind the wall there will be huge amounts of connectivity, computing power and data resources of all kinds. When you access the information utility from any location in the world you will not have to worry about where the resources are or how they work, any more than you worry about where the electricity and water come from when you turn on your dishwasher. In front of the wall, there will be billions of smart devices of all kinds connected wirelessly to each other and to the utility,

enabling billions of people to be online all the time they want to be.

These sets of information utilities evolving around the world represent an emerging 'global information infrastructure'. What makes this emergence possible – indeed, inevitable – is partly the continuing pace of technological change: Moore's law will still enable the underlying microelectronics technology to deliver a doubling of price-performance every 18 months for the next 10–20 years; storage technology – hard discs, CDs, flash memory and so on – is getting cheaper even faster than this, with really disruptive new technologies in the pipeline such as atomic resolution storage and holographic memory. But it is also the result of the demand-side pressures unleashed by the new and radical capabilities that this infrastructure will possess, and the useful (or simply delightful) applications to which they may be put.

Behind the wall

We are already seeing the first generation of the worldwide information utility in the form of e-science Grids building on the internet and the World Wide Web. Already today's internet and telecommunications infrastructure probably comprises at least ten billion computers and 100 exabytes (100 billion billion bytes) of data. At least 600 million people can currently access the internet, which carries about 4 billion emails per day, and between 1 and 2 billion people worldwide now have phones.

The information utility will be qualitatively unlike any previous global communication system such as road, rail, air or telephone networks. It will consist of huge amounts of interconnected data and computing power, and it will be able to interact through the wall with tens of billions of smart devices of all kinds, and through them with billions of people. In this way it will progressively exhibit more and more 'intelligence'. We are already seeing the rise of 'intelligent' software and machine learning, as the ability of humans to design and programme large systems reaches its limits. The rich interconnection between elements of the infrastructure will mean that a software object that turns out to be powerful and useful for some particular

task will be able to replicate, spread and 'jump species' around the infrastructure in many fewer 'generations' than we see in biological systems. Evolution through incremental enhancement and (often unpredictable) adaptation will become a key paradigm.

We have already reached the stage when the global communications infrastructure can no longer be thought of as 'a system' in the traditional, hard engineering sense of the word. It has no specification. It was not designed by any one person or organisation, nor is it implemented, owned, operated or maintained by any recognisable single authority. It is never the same from one access to the next so faults cannot be reproduced. The underlying engineering principles and protocols are based on having to know as little as possible about what is going on in the infrastructure, rather than knowing as much as possible; the old IT tradition of 'full documentation' is long gone. Instead it may be more appropriate to think of the utility as a system in the biological sense of a living, complex, adaptive whole, continuously evolving through the collaboration of many autonomous subsystems.

A crucial property of such large sets of cooperating elements is that they collectively display 'emergent behaviour', which is not readily predictable from a knowledge of the individual elements. Emergent behaviours come from systems involving decision-making entities, like the way ant colonies organise their collective activities to discover and retrieve food. An emergent behaviour involving the internet itself is spamming. About 50 per cent of all the email on the internet this year is spam, up from 2 per cent a couple of years ago.

In front of the wall

Our understanding of emergent behaviours in complex systems is still very primitive, but will have to become highly sophisticated if we are to grasp the full implications of the world of the information utility, a world populated not just by billions of people and smart things but also by a huge cloud of 'agents' of many different kinds. Some of these will be designed to make our lives easier by mediating our interactions with the infrastructure, carrying out tasks and

negotiating with other agents. Sometimes these entities may take on 'personalities' that engage in natural dialogue with people, and will have the ability to evolve, adapt and learn.

These agents will be enabled by the billions of smart devices linked through wireless networks to the utility and sometimes each other. These devices will be able to form 'ad hoc' networks that come together for a specific, temporary purpose. For example, several cars in proximity may want to talk to each other to avoid having a potential crash on a particular stretch of road; a group of people who have come together for a meeting may want their agents to set up arrangements for them to work together on a set of documents and presentations; a shopper may want to interact with specific products in the supermarket he or she happens to be in. Smart devices will be worn in your clothing, jewellery and accessories, and hop into the utility via local wireless networks whenever they need to.

Any thing that uses power today will use the information utility tomorrow. Any thing can be made smart and networked, and its physical location and status tracked using location services such as Global Positioning System (GPS) and cellphone networks, satellite imaging and tagging technologies like Radio Frequency Identification (RFID) tags. We already know how to keep track of millions, often billions, of people, animals, vehicles, personal belongings, electrical appliances and household objects. We can't (yet) cope with trillions of trillions of insects, weeds, birds, leaves, flowers, rocks or stones. But vast digital archive networks are now burgeoning into existence with every conceivable kind of information, from molecular structures and astronomical observatories to records of individuals' genetic material, their medical histories, financial transactions and electronic communications.

And the infrastructure can also be connected to a huge range of instruments and devices, from earth surveillance satellites that monitor crops, water and weather, to CCTV cameras, webcams and astronomical telescopes. These, and many others, offer real-time data to users, acting as the eyes, ears and sensors of the global infrastructure. In a very practicable sense this will support the

instrumentation of the planet in a wholly unprecedented way. It will become very hard for countries and companies to keep most of their activities from being visible in detail and in real time to the rest of the world.

Through the wall

Perhaps the most subtle and far-reaching impact of the information utility will be its ability to support and mediate interactions between people through the wall. Today, accessing a web page is a solitary activity undertaken between a person and a website. Teleconferencing and videoconferencing remain primitive and cumbersome, and 'personal networks' among people get very little support from ICTs beyond phones and email.

One of the key advances of the information utility will therefore be to support fluent collaboration and cooperation between groups and teams of people: at work, socially, in families, at play. These collaborative environments – or *col-laboratories* – will be the infrastructure for teams of knowledge workers and citizens who trust each other to work together to create new intellectual property or social goods. It will be invaluable for lawyers working on a case, say, or for a design team working on a new product. It will also be ideal for supporting outsourcing and collaboration between companies and organisations – for example, where a contract requires people from several organisations to work securely together for a limited period of time.

The signs that this is already happening are with us. Each year we are becoming more dependent on an extremely complex inter-connected infrastructure, which supports more and more of our everyday lives. This dependence is becoming crucial and irreversible. Gradually we will be more and more unable to function without it. It is instructive to look at a few examples.

Work

E-business and the continued development of outsourcing already demand unprecedented levels of dynamic, fleet-of-foot inter-firm

collaborations. The advent of secure collaborative environments will accelerate the ability of people to work as individuals in several different teams and companies, and for companies to have temporary, and often casual and exploratory relationships with each other.

This will drive the need for new business models, audit practices and concepts of intellectual property (IP). If a new animated movie or commercial is created by an ad hoc collaboration of people using fragments of pre-existing characters, personalities, story lines, music and synthetic locations obtained from sources in the utility and added to by the creative work of the team, then who should get paid for what? We will need new systems for tracking, banking and remunerating knowledge work. There may be a need for new forms of micro-IP and micro-payments, with audit trails trusted by the various participants.

Education and learning

The students and knowledge workers of tomorrow will be permanently and wirelessly online to the information utility and each other. In place of textbooks and ringbinders of notes, each person will build up a lifelong personal information space comprising millions of personal items and millions of persistent reliable links to web pages, other information resources and other people. Accessing these resources casually and continually as a matter of course in almost every aspect of life will become as natural as turning on the radio or TV or picking up the phone. You will require 'super-Google' search and management engines to find your way around it, and a very smart 'forgettery' to prune and discard material continually from your memory space if complete information overload is to be avoided. It will become increasingly difficult and unthinkable for people to function without continuous access to their personal information spaces. Together with new forms of human capital assessment and accreditation, these might even make old style exams obsolete – providing a perfect record of your lifelong learning and performance, which could be audited by an authorised certification agent, in place of today's examinations and paper qualifications.

Goods and services

This year, eBay will help 30 million people buy $20 billion worth of goods and services. As e-retail services develop further we will be able routinely to send one of our personal agents to get the best deal for us on almost anything we want to procure, from babyfood and clothes to cars, training courses or holidays. When we choose to shop in person – perhaps as an enjoyable leisure activity – the smart devices on our bodies will be able to talk to the screens and displays around the store, and directly to the 'smarts' on every single item in the store.

Disappointingly, nothing like the same attention has been paid to the opportunities for improved delivery of public services, even though productivity here lags far behind the private sector and there is potentially huge value to be added. Current attempts, from online income tax returns to hospital scheduling and combating benefits fraud, however, do not augur well for genuinely ambitious networking approaches to public sector modernisation – or indeed 'e-democracy'. Instant phone referenda may work for *Pop Idol* and *Fame Academy* but serious public issues would not be well served by the same treatment.

Regulating the utility

The information utility will also bring inevitable opportunities for malicious exploitation, and serious vulnerabilities and pathologies, which need to be anticipated and managed. For example, security, privacy and integrity are going to be crucial in this new era. In a world where our interaction with the infrastructure (and with other people and organisations through the infrastructure) is increasingly mediated by trusted agents, brands, identity and authentication will be of great importance. Identity theft and impersonation will have bigger consequences. Conversely, retaining anonymity will become increasingly hard, especially as anonymous cash transactions are replaced by e-transactions, which inevitably leave a trace. If every banknote has its own RFID tag, even cash will lose its anonymity.

This creates unique challenges for regulation. For example, how can you regulate and police a bank that exists only in a computer in a

satellite, and delivers its services to you via a wireless link from the infrastructure wherever you are on the planet? Who actually owns it? And when things go wrong, to whom do you complain? Related to this is the question of data accuracy and integrity. One of the few certainties in this future environment is that some of the data held in the world wide utility will be inaccurate, out of date, or just plain wrong, and some will get lost or destroyed. In particular, some of the personal information held about you will be wrong, and we will need quite radical innovations to enable individuals to find out and check, and then get it put it right.

Sometimes this will be due just to malfunctions and accidents. But in other cases there will be deliberate and continuous attempts to subvert and attack the infrastructure for all sorts of criminal, terrorist and other malicious purposes. As a result, we will have to develop processes for continually cross-checking, purging, repairing and restoring data. Like immune systems in living organisms, we will need to counter both ageing from accumulated defects and deliberate infections (such as viruses), as well as the damage to particular components of the system caused by external traumas.

In our contact with the e-world we will rely on trusted third parties with trusted brands to validate the infrastructure for us, and to validate us to it. These will play a key role as the 'super agents' we trust to look after our data and our identity in the face of whatever threats confront the infrastructure. In a world where services can be delivered by anyone from anywhere, trusted brands will be vital. Everything else behind the wall – all the companies, organisations and public institutions – will be virtual, fast changing, elusive and evanescent.

Living in the goldfish bowl

The promise of this new era is immense. The intelligent infrastructure will enable us to manage everything from our personal time to the resources of the whole planet more optimally and effectively. But the threats are also great, not least the risk of complete dependency on the information utility in our personal lives, at work, and when we travel, or attempt to access education, healthcare and

other public services. The price of this dependency is that, as individuals, we will have to come to terms with a major surrender of personal privacy. As employees and managers in companies, public institutions and organisations of all kinds, we will face the same issue. Our most confidential emails will be undeletable and the global activities of the organisations we work for will be instantly visible to almost anyone who wants to know. As things become more densely interconnected, time constants and constraints will shrink and we will have less and less chance to think, reflect and make balanced decisions. In short, *we are entering the era of transparency*. This raises important questions concerning how we will cope with living and working in the global goldfish bowl. Will we welcome it and embrace it, or just tolerate it most of the time? Will it be possible to opt out – will we see the emergence of a disaffected 'out-class' on an unprecedented scale?

We will have to use the information infrastructure itself to help us discover, debate and resolve our responses to these challenges. As it grows rapidly larger and more complex than human brains and bodies, that infrastructure will require all of the defence mechanisms evolved by living organisms in order to adapt to and protect themselves from their environments.

One thing is clear: a long wave of disruptive technological innovation is coming. The question is what will it look like and when will it emerge? This cannot be predicted in detail; there is always the possibility of unexpected and even more powerful technologies emerging. But that does not mean that they cannot be shaped by the wider political, economic and social environment. How we incentivise investment in building the infrastructure; how we influence public attitudes to the utility and its impacts; how we manage its legal, ethical and social implications; how we craft the appropriate regulatory framework; all are crucial questions facing developed and developing countries in years to come. Policy-makers and business leaders in the UK must begin to grasp the reality of the era of the information utility if its opportunities, and its threats, are to be appreciated and engaged.

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