Bringing it all together

Future Consumer Electronics & Devices

A BT white paper

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Contents

Executive summary

The future of devices and gadgets is crucial for network service providers such as BT, since these are how customers see, hear and experience the world of online services. For trusted communications providers there is another angle; the fact that in the future, there will be whole new classes of devices (some of which will be life-critical) that need to communicate with each other as well as with human users.

Even current trends in components that make up devices on manufacturers' roadmaps demonstrate the expanded possibilities for how gadgets themselves will evolve. Faster, multiple processors work in parallel and have access to commodity items of storage and lightning fast connectivity.

In addition there are other technology disruptions which will let devices give their users more power than ever before, while consuming less power themselves. Specifically the more immersive and natural ways that users can interact with machines will mediate the increasing complexity that users are faced with. The infrastructure in people's homes and offices is ever more complex, and the gadgets people carry around will provide instant access to information, communication and entertainment services hitherto un-rivalled.

The way devices are used and shared will be affected by the advent of mainstream wearable technology as well as that which resides in the living spaces around people, including a gradual fabric of relatively cheap and simple but pervasive and powerfully networked sensor devices in the environment.

Components which today reside all in one device will be available separately to be utilised as needed, co-operating wirelessly to provide the capabilities the user needs. This, together with the more natural methods (including biological) of controlling devices, will take usability to new levels.

Nanotechnology will eventually reach a maturity level which permits tiny devices to be fabricated and deployed inside as well as outside the human body, initially for healthcare applications. Robotic devices will become more mainstream and a normal part of the infrastructure in homes and workplaces. The autonomous nature of these machines will mean that the interaction between human and device will be very different to that which happens today; a shift from operating the device to managing or directing it.

1 Introduction

The device is how customers touch, hear and see online services. BT is increasingly a significant player in the space of network services provider and being very successful. Hence it is vital that an understanding of how consumer electronics devices will evolve in the future can help to ensure that the experience customers receive is optimal no matter what device they choose. In addition, the business of communications services in the long term future may well include communications between new categories of machines and networks which are not yet needed today, including robots, and sensor networks.

This paper looks at the trends and future of the technologies that make up devices as well as the gadgets themselves. The scope of device here is very wide, including all fixed, mobile, portable consumer electronics products. Essentially practically every device of the future will be a computer with certain optimised components and features.

The first section looks at component technologies and some trends in these components, both short and longer term. The components include microprocessors, storage, displays, power, connectivity and interaction methods for users. Exploring the likely direction of these core components is a good way to help understand the capabilities and features of future gadgets.

The second section considers classes of devices, including the traditional types of device we find in the home, the workplace and increasingly carry around with us. But it goes much further, as you might expect in a report written by a futurologist, considering new devices which can either perform tasks autonomously or passively in the user's environment, or even live inside the user's body to provide capabilities that are currently unparalleled. This is literally 'consumer' electronics! This taxonomy of classes of device is unusually organised from the perspective of how devices are used rather than by function.

2 The basic technology trends of devices

The best way to understand the direction and trends of devices and consumer electronics products is to look at the trends of the basic components they are composed of. This section covers the various main component categories in turn.

2.1 Processors

The brain at the centre of all devices will continue to get faster while reducing the power consumed. Numbers of processing cores will multiply by orders of magnitude eventually and these will dynamically switch in and out to take the load as required. Shorter data paths and multiple shared resources between cores on single chips will do as much for speed as the raw power increases of each core. Moore's Law has some way to go yet, as chip fabrication approaches single digit nanometre sizes. In fact carbon nanotube technology itself may be used in place of copper wires on future chips in order to reduce the resistance of interconnections and provide for lower power and higher throughput.

A key aspect of harnessing the power of multi-core processors will be advanced development tools which allow the programmer to properly understand this new paradigm of multi-core design, in order to optimise the way that applications exploit the hardware developments. This is very different to the design environments used so far by software developers. Device operating systems may provide dedicated support for run-time allocation of processing to cores (e.g. Grand Central [GCent]), as well as dynamic selective enabling of cores to regulate power consumption.

While in recent times, there has been a trend to utilise custom specific processors for such things as graphical display drivers, it is likely that schemes will be devised to allow such specialist chips to also share the load of general processing at times when they are have spare capacity. OpenCL [OpenCL] is a standard which aims to support this with Graphical Processing Units (GPU).

Eventually in the long term, the challenges around quantum computing may be solved which will be a game changing step but those challenges are very tough. Other efforts will go into biological computing which if conquered will also offer radically better performance over the evolution of Moore's law and current architectures and approaches.

2.2 Storage

Storage will becomes a commodity item within a decade and huge capacities orders of magnitude higher than today will be available, for non-volatile semiconductor memory. Access times and maximum re-write rates will also increase. Solid state memory will always have physical advantages over the smallest hard disks available (e.g. physical shock). This is despite the now relatively common inclusion of motion sensors within hard disk drives which park the heads before an impact causes damage. In the short-medium term, the cost per capacity statistic still favours hard disks. Nano-scale polymer cell based approaches are one example of how new materials may increase disk storage densities way beyond what we see today.

While NAND and NOR flash memory continues to increase in capacity, it will eventually struggle on scalability grounds as feature size goes significantly beyond 50nm. Magneto-resistive RAM (MRAM) is one of the leading contenders to eventually take the crown from flash memory, and maybe from traditional Static (SRAM) and Dynamic (DRAM) chip memory. MRAM advantages include higher order read/write speeds, and reliable non-volatility, without the number of write cycle limitations of current flash. There are a number of other technology contenders to flash, all currently in their infancy. These include Ovonic Unified Memory (OUM), FeRAM and Polymer Memory (PFRAM), Conductive Bridge RAM (CBRAM) and organic RAM. OUM, based on the same chalcogenide materials found in re-writable CD/DVDs, is likely to have cost advantages over MRAM but cannot compete on data speeds. OUM does offer significant maximum write cycle advantage over flash though. One nearer term flash development should be the use of silicon nanocrystals, which could potentially double current flash bit densities while reducing production cost through simplication.

Magnetic and Optical disk storage will still be the most economic mass storage option for some time, especially for off-line use. However eventually, as we have seen with audio media distribution, downloads will eventually win over physical media distribution methods, once networking speeds deliver an instant experience. Currently, the price per Gb of disk drive storage are typically 10% of that for flash memory but power consumption due to having to mechanically spin the disks is much greater. Holographic memory may eventually displace the current technologies in this space.

Wireless links to storage around the domestic and work environments will become important as devices physically divide and storage becomes a totally dynamically sharable resource. Secure backup of personal information and media will be an essential part of domestic as well as corporate infrastructure.

Networked based storage will also become a practically free option. Search and retrieval of active or 'interesting' material will become most important when continuous whole life recording stores all your experiences. Since everything can be stored, new ways of indexing and finding content will be essential.

2.3 Displays

The recent trend towards touch screen displays will continue to blur the boundaries between input and output. These will soon be manufactured cheaply at large sizes and high resolutions. This will enable touch screens to be built into larger devices, furniture, walls and other surfaces for example.

The significance of 'multi-touch' shouldn't be under-estimated since it offers the highest potential for combining touch and gesture input (see section 2.4). This advanced 'multi-touch' is supported through the use of capacitive sensing displays rather than the basic resistive touch screens which heralded the earlier and now dying form of stylus-based touch screens.

Some displays will also incorporate camera functionality. As an alternative to simply embedding a camera into the frame of a screen, this may also be achieved by placing tiny light sensors between the pixels that make up the screen, each capturing a fraction of the scene. Powerful number crunching processors will then compose the whole scene from these individual sensors. This produces a more natural angle of view through the camera.

Wireless interfacing to displays will have a profound effect on screen sharing and moving the display of media between locations and devices. High bandwidth short range wireless standards will move high definition content between devices with ease.

Projection is another development which is beginning to appear in handheld personal devices allowing more than just the user to see what is on the screen. These micro-projectors will enable output to be thrown up onto walls and other surfaces.

Three dimensional video is being developed which may catch the user's imagination if the experience can be made good enough, without the need to wear special glasses for instance. Different technological approaches to 3D displays may be appropriate for fixed screens and those on devices users carry around and hold in their hand. Most current approaches require that the producer films the content in a special way and so the successful adoption will depend also on the availability of suitable content. After an initial buzz, 3D display technology may be revived once whole surface/ wall displays also become widespread to allow for a more immersive all round experience. The analogy for the penetration of this to become mainstream may be like that for surround sound systems in the audio context.

The injection of suitable sound waves into specially produced screens should allow both haptic and audio integration with displays. Thus touching the screen will also allow the user to feel the texture and other properties of what they see. Audio integration will enable the display to also function as a high quality speaker system.

Wall and surface screens will eventually be able to totally surround the user when inside a building. Walls and windows will be electronically decorated and selectively made translucent. Surround sound will then be totally possible and able to adjust to the position of the people in the room. The haptic element will mean that people will be able to feel as well as see and hear what is displayed.

Persistent displays will have a place in some applications. This may be in the form of e-paper type devices which consume no power until the information changes. Spinning LED displays can also provide very compelling effects on rotating objects such as wheels.

For individuals, spectacles encompassing displays will be developed and followed by active contact lenses providing direct retinal projection displays which will be an essential part of the immersive computing experience and augmented reality. It is likely that such retinal displays will be possible in timescales before humans have got comfortable with the idea!

2.4 Interaction

The way people interact with their devices will change over time. Indeed the possible display developments already discussed in the previous section give some illustration of how users will be able to interact with their devices.   But there are other technologies in this space too.

Already gesture based input is becoming powerful. This is already being offered via some notebook computer track pads as well as touch screens. Combined with camera input and facial (gesture) recognition, it will make for even more natural techniques. Machines will also eventually be able to tell more about the mood of their users from facial expression, which may be important in precise understanding of emphasised gestures.

Speech input and output will be important in specific environments, and particular with respect to interaction with robots. Speech works very well already in closed situations such as a personal vehicle like a car. Digital Signal Processing (DSP) technologies can already be very effective at eliminating background noise and sounds which would previously have interfered with speech recognition.

The development of direct bio-technology interfaces between human and machine will first assist those with disabilities but eventually allow people to think about the task they want machines to perform and to exchange information to and from those machines. This will finally break down most of barriers caused by the artificial technology components that man has had to invent during the pre-cursor to direct understanding by machine.

Eventually, such technology will lead to body enhancements for those that want rather than those that need. This will herald the era of the hybrid human and machine, where it is possible to choose to have stronger limbs, better memory etc.

2.5 Power

Devices will continue to need to be powered but the amounts each needs will relatively reduce due to advances in processing performance. The ways that devices get their power will also change. There will be more various ways for power to be harvested from movement, natural resources around the environment and other convenient energy transformations.

Battery technologies will evolve to include new chemistries that provide almost instantaneous charging. Fuel cells will also feature in some classes of device but liquids are not an ideal mix with all electronics and so this may be limited to specific cases.

Mobile phone manufacturers are finally signing up to some standardisation for charging their devices (both the charger itself and the physical connector used) but the longer term should see less of a problem as devices become chargeable inductively from special surfaces and holders.

2.6 Connectivity

There will continue to be a multitude of wireless and wired networking technology standards, each offering particular advantages. Ultra Wide Band (UWB) techniques will provide some radar like positioning capability as well as simultaneous communications. Connectivity will be important not just between devices but between individual device components as complex gadgets become divided into a collection of parts (see section 3.4).

Mesh networks such as ZigBee are already starting to be used in telemetry and domestic security systems [AlertMe] as well as for WAN (wide area network) applications especially in developing countries which lack centralized infrastructure but can built out network effectively by adding large numbers of users (and hence network nodes).

Cable based connections will continue to be important in some applications and we can expect the continued evolution of Ethernet, Firewire, and USB type connection standards. USB3 should be out by the end of 2009 giving speed and power control improvements. Wireless USB is also on its way and this will assist with some peripheral connectivity.

Some polarisation still exists between the computing world and the consumer electronics (CE) world with regard to audio and video (A/V) standards, which doesn't always make things simple for the user who wants to interconnect them. High Definition Multimedia Interface ([HDMI]) is the current standard on CE devices but this suffers from royalty fees and also requires higher voltage signals than computing equipment increasingly works at, as chip manufacturing processes go beyond 32nm. DisplayPort [DispPort] is the 'new kid on the block' in the A/V space. It is royalty-free for manufacturers to use and operates at lower voltages. It also has the advantage of being applicable not only to external A/V connectivity between devices but also internally within devices, between main board and LCD in a laptop PC for example. The elimination of a whole set of discrete components by using the same DisplayPort standard for both has a very desirable benefit on bill of materials (BOM) costs.

3 The changing devices landscape

The future will see a huge increase in the number of devices and the various combinations of capability available in different packages. The types of device will fall into categories such as:

- infrastructural and shared devices
- complex multi-function ‘brick’ devices
- optimised one (main) function ‘non-compromise’ devices
- co-operating device components
- nano-scale intra-body devices
- autonomous robot devices
- interconnected sensor network devices

Each of these will be discussed individually in subsequent sections.

3.1 Infrastructural and shared devices

This category covers the sorts of devices that we will see in the home or the workplace which are shared between users as well as intelligent white-goods combined with consumer electronics. Typically at the moment, it includes home shared desktop PCs, entertainment devices (TVs, HiFi, gaming consoles), routers and network hubs, set-top boxes and other peripheral or specialist functional machines.

Perhaps this seems a slightly unusual categorisation of devices and encompasses a large set of possible types. However it reflects a number of current and future trends:

a) a move from (shared) desktop PCs to (personal) laptop PCs

b) a move towards personal devices carried by people (see subsequent categories/sections)

c) a move towards more and more devices and consumer electronics to be networked and indeed part of the same home/ business premises network

d) increased computing and consumer electronics infrastructure in the domestic environment

e) an evolving need for people to be able to share access to applications (e.g. game playing) and information (e.g. audio and video media) in a securely backed up fashion (i.e. not carried about the person where it is more prone to being lost or stolen).

Such categorisation is also novel in that it looks at devices from the point of view of how they are used, rather than their functional capabilities. Two reasons for taking this approach are:

- capabilities of devices are overlapping more and more making functional characteristics less useful for analysis,
- the usability and how devices are used is and will be even more critical in determining successful adoption by the mass market.

This broad category of shared devices can be subdivided into three types:

i) Infrastructure devices the user normally need not interact with

This type of device typically includes network routers, security system controllers, embedded home automation, networked storage devices and other monitoring devices for example.

ii) Shared devices any user in a home or office may use individually

This type typically includes kitchen appliances (ever more computer controlled and networked) but specifically excluding those which have already made the transition to robotic versions (e.g. vacuum cleaners, lawn mowers etc.) and hence fall into the later category (see section 3.6). The humble fixed line telephone may also fit into this set of devices both in the home and office. In the latter, devices like photocopiers are also included.

iii) Shared devices which lend themselves to being used by more than one person at a time

These are devices such as televisions (including interactive set top boxes), radio and Hi-Fi equipment, as well as shared gaming consoles (e.g. X-Box, Wii - but excluding personal handheld gaming devices) for example. Devices such as non-individual media players (e.g. DVD players and recorders etc.).

3.2 Multi-function ‘brick’ personal devices

This category will eventually become the minority share of personally carried devices as distributed parts of gadgets become separate and optimised for particular purposes (see section 3.4). However there will always be a market, particularly at the high end and for convenience, having a small device that performs many functions. Increasingly, the power of additional software can add extra functions to a device which the manufacturer produced for some specific purpose. One example of this is the GoMessenger [GoMsg] download for the Sony PlayStation Portable (PSP) which adds communications services such as Instant Messenging (IM) to a personal gaming handheld.

In the short and medium term, multi-function devices are likely to form a large share of the personal device market, as manufacturers continue to squeeze more and more into a particular form factor, exploiting miniaturisation of components. Eventually the complexity of such ‘bricks’ will make more optimised devices seem simpler to use; something that will really take off once technologies supporting short range wireless co-operation and wearable computing become more developed.

Typical examples of these bricks at present include so-called smart phones and laptop computers. Users carry these around, and consider them individually ‘owned’ devices, even though many are issued in a corporate environment and actually are managed by the relevant IT department. This category is the biggest target candidate set to be impacted by the consumerisation of IT which is beginning to take place and which will radically change the way organisations regard and organise the provision and maintenance of these devices for their employees in the future.

Corporate IT departments increasingly struggle on a number of counts:

i) managing inventory of the large numbers of personal devices issued to employees,

ii) keeping up with the pace of change of what devices are available in the marketplace,

iii) issuing employees with devices that are inferior to those the individual has available to them in their personal life,

iv) maintaining policies for usage of personal devices which maintain corporate security while not hampering usability, including:

   a) the need for individuals to carry two identical devices (e.g. mobile phone) for business and personal use,

   b) the duplication or syncing of data on devices (e.g. the overlap between personal and corporate calendar, contact and other information),

   c) the installation of additional software and build complexity.

An increasing answer to these issues is the consumerisation of IT, which changes the model of provision of such equipment to more like that typically operated with providing company cars. The individual will have an allowance to buy their own devices within a particular specification, and perhaps from a defined set of providers, and they claim the costs of any maintenance required back from the company in the same way as they might have servicing or repairs done for the car. Many large organisations are already trialling this idea and are finding it attractive from the economic point of view. There are also advantages in terms of user satisfaction.

3.3 Optimised ‘non-compromise’ personal devices

This category could easily have been lumped in with the previous one - however the focus on usability in this taxonomy means that it is important to distinguish the two. The main issue with continually combining more and more functional capability in one ‘brick’ device is that the design becomes more compromised and it is increasingly difficult to provide an optimal experience for the user for every function. This is true when combining only two functions, for example a still camera and video camcorder, in one device, and is certainly a bigger issue with the multi-function ‘bricks’ described in section 3.2.

Taking the camera/camcorder example above, which exists today in both product genres. How many people really use the video capabilities in still cameras or the still picture features in camcorders? Certainly a minority of users. The main reason is that the apparently similar features you want are used and ideally implemented in a different way in each case. Forcing multiple capabilities into one device and specifically one form factor inevitably introduces compromise somewhere. There will always be a place for the optimised personal device which does one main function really well and whose design is un-compromised. One of the strong points of the original Apple iPod was that its core function and usability was not compromised by additional features. Large numbers of people chose to use the specialised iPod alongside other devices such as smartphones which were just as able to act as a music player.

The need to compromise design by sharing the resources of single devices for many different purposes will be eradicated when the separate components are split apart and each can be shared. That will eventually occur more and more and is the subject of the next section. The same compromise will be also be mediated in a couple of decades time when we have smart materials rather than rigid pre-formed plastic and metal, where the form factor becomes malleable as well.

3.4 Co-operating device components

For a number of reasons, (including cost, convenience, choice, and simplicity), in the longer term many previously all-in-one devices will exist as co-operating separate parts as opposed to a single converged “brick”. This division of components and functions will be facilitated by additional short range mesh wireless network technologies. A side effect of such a trend in devices will mean that component parts of devices may not only use each other but also utilise the Internet to communicate and be addressed individually.

Many of these device parts may be wearable and indeed some may be integrated with the body at some stage, such as printable displays on skin for example. New materials will allow clothing to form parts of this co-operating set of device components. Jewelry will also form part of the personal network of device parts which come together to provide capabilities for the user. The wearable parts will also co-operate with other device parts which are situated or embedded within buildings or the environment.

So what does co-operation mean in this context? Well it includes discovery that a suitable device part is present and available. It also includes autonomous negotiation between components that the required capabilities can be provided and using which standards and protocols. It additionally includes the necessary authentication happening transparently as well as the actual communication between the components.

The benefits will include:

a) simplicity - each component will be more easily understood by users and much of the complexity masked by the way the components work together;
b) cost - some components may cost more but can be shared between services, reducing duplication of capability;
c) convenience - by allowing wearable as well as components in the vicinity (such as screens) to be used, users will enjoy the convenience of not having to carry every component themselves;

d) choice - the mix and match approach to components will enable users to choose and customise the parts they like to provide capabilities and services which they want.

3.5 Nano-scale intra-body devices

Devices tend to be assumed to be things that humans use in a traditional ‘hands-on’ sense. Nanotechnology is promising to offer a whole new class of tiny programmable machines some of which will be hosted inside the body and perform measurements or other work to keep the health of the human host in an optimal condition. As nano-scale engineering is perfected in the decades to come, such machines will be possible. This will change the way we think about the relationship between machine and human. Some people may become dependent on these sorts of machines inside them to keep them alive and using them will not be an option but a necessity.

While some such devices may be designed to complete their work within the body using some pre-programmed actions and by monitoring internal body characteristics, many more will need to communicate with other machines outside the body. This will be a task for only the most trusted communications provider! The information and insight gained by this ability to explore the internals of the human body will greatly enhance both our understanding of it and open up potential for new ways to monitor and treat health problems. This concept is sometimes referred to as ‘lab-on-a-chip’, the idea of moving the laboratory inside the person rather than bringing the person to the lab.

There are already machines which can intelligently release drugs and/or provide some other function before they gracefully decay inside the body as part of a treatment or recovery process. This intra-body device development will take this much further. As with some of the applications of robot devices in the following section, there are questions for society about the acceptability of these developments but in time it will come.

3.6 Autonomous robot devices

Robots are still thought of by many people as industrial machines that weld bits of cars together. Some people also recall images of robots used in bomb disposal. Both of these examples reinforce the idea of using robots to do things that humans don’t want to do. There are also examples of this within the domestic environment too. The robot vacuum cleaner [Roomba] is perhaps the most well-known but there are others including those which assist with lawn mowing!

It is wrong to assume that future robots will necessarily take forms similar to human beings - some may and others will not. Regardless of this, some robots will learn to understand what humans are feeling, through expression and gesture for example. This will allow them to execute autonomous behaviours which humans will feel comfortable with and confident about. And there certainly are many more domestic chores which I would be happy to devolve to a robot.

One example of an autonomous robot which was sold commercially but alas discontinued now is Sony's AIBO (Artificial Intelligence roBOt) dog [Aibo]. Spending some time living with AIBO (in his autonomous mode) demonstrates how with the right behaviours and appropriate interactions with human beings, robots can be regarded as animate rather than inanimate objects. People demonstrate in all sorts of ways how they will care for and treat inanimate things in this way, and robots are no different, especially as in AIBO's case, they represent a pet which humans have pre-conceived ideas about. AIBO will learn who his owner is and try to get their attention. He exhibits typical dog behaviours such as resting, playing and exploring. And importantly AIBO reacts to humans who give him attention with a relatively wide vocabulary of behaviours and sounds which humans then respond to more. People around AIBO tend to start talking to him, because they perceive that he understands them and acts appropriately. Even many of those who initially laugh at others talking to a robot as a pet, subsequently become prepared to do the same when they witness the reaction.

Unfortunately, AIBO was too ahead of its time, appealing only to a small audience of dedicated enthusiasts at a time when the technology required was relatively expensive. Although AIBO also had a home monitoring mode when left alone, able to patrol and take pictures of anything that moved and then emailing them, this was of little value in an era when the mass of the population didn't use email, especially on the move with personal devices, as is common today. An expensive robot pet probably needs to offer some extra function over and above companionship in order to go mass-market. But AIBO has taught us a great deal about the potential for autonomous robots. In the future, people will need devices which they don't have to operate as such, but which get on and provide some useful or essential capabilities

Increasingly, robots will also be required to do things which we think of as human tasks. These include welcoming, guiding, patrolling, and caring. Some of these are already happening. Japan leads the way with robotic developments, and also the culture of acceptance. Demographics tell us that in future there will not be sufficient people to look after the numbers of people that need looking after. We are already used to machines in hospitals looking after people and in many cases keeping them alive. Surgeons can already use robotic machines to perform remote procedures. The use of robots in place of human carers begs questions of acceptability, such as would you accept a robot looking after your children or caring for your relatives. It will take time but the accepted culture will evolve.

3.7 Interconnected sensor network devices

Though probably considered on the borderline of consumer electronics, it is likely that this category of device will have a profound effect on the consumer and hence are included in this forward look at devices.

A large number of instrumented sensors will increasingly built into many objects including buildings, vehicles, and clothing for example. This ubiquitous fabric of sensor instrumentation covering many different parameters will further facilitate development of new real time services on the internet. Each sensor may be tiny and simple in its own right, but when the information it provides is syndicated with masses of other data, game-changing potential results become possible.

Location is one obvious parameter that such pervasive sensor networks can offer but there are many others which usefully describe the world around us and thus can be used to trigger, control or provide services to users. These include movement (presence as well as velocity, acceleration and heading), temperature, pressure, humidity, light and sound levels. Radiation (electromagnetic, nuclear, and heat) may also be sensed in addition to particular chemicals present including water. And there will be even more video cameras watching what is happening than today, along with better vision recognition and analysis systems [VidAna] to automatically detect what is being seen.

Different technologies will be exploited to enable this sensor network to be built inside buildings as well as outside in the wider environment. Some like Radio Frequency Identification (RFID) already exist, and others will follow. There are already patchworks of rudimentary environmental sensors deployed in most developed countries, along with an increasing number of relatively dumb closed-circuit television (CCTV) cameras around. The power to make things happen will come from being able to network the information from all of these disparate systems in a way that the majority of people in society appreciate rather than feel threatened by. Sensor networks will also play a major part within the green agenda and the monitoring of natural resources.

This of course brings the question of future privacy. People generally feel less threatened by giving up some personal information when they perceive a benefit (e.g with retail loyalty card schemes). People will also have to be much more active in making decisions about what information they want to share with others, both on a personal basis and with organisations. Some technologies such as RFID will need to adapt so that the same sensor or ‘tag’ may be used securely by different people and organisations at various times [Maint]. The tags attached to most items today as they journey along their manufacturing, wholesale and retail supply chains are rendered useless or removed by the time the owner or user of the item takes custody of it.

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Offices worldwide