ENVIRONMENTAL AND HEALTH HAZARDS OF MOBILE DEVICES AND WIRELESS COMMUNICATION

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Abstract:
In the race to embrace newer technologies, we often forget or ignore the negative side of it and do not realize its effect until late. A pervasive computing system is one such example, which introduces newer, smaller, convenient, omnipresent devices aimed at replacing the huge immobile computers. These systems then end up in landfills and are not regular municipal waste. They contain many hazardous substances like heavy metals, non-biodegradable materials and persistent, bioaccumulative toxins. Various end-of-life options need to considered for such substances. The inherent property of pervasiveness is mobility and use of unwired devices. The communication among such devices has to be through the air instead of wire. The only media presently used for this wireless communication is the part of electromagnetic spectrum (the radio frequency). Constant exposure to this frequency is a cause of concern among some researchers. Though there is no study, which has consistently shown the health hazard from RFR (radio frequency range), but this does not prove the non-existence of the hazard. This paper is an attempt to make the reader aware of threat to human life and ecosystem, caused by mobile devices and wireless communication and suggest some solutions to the same.

1. Introduction:

Change is the only constant in the world, or better said, advancement and evolution is imperative to any field of science and technology. Computing and communication science has seen drastic change in the past decade or two. Computer systems have come long way from the early application specific huge mainframe computers, which were used in closed protective environments. The main disadvantage of these systems, as considered today, is their immobility. The computing scenario has completely changed now. Today we see integration of various technologies to achieve mobility and to access any information anywhere. This is what we call Pervasive computing – access to any information anywhere, anytime. This requires innovation to produce handy devices, which are not tethered by wires or cables of yesteryears. The communication medium has changed from cables and twisted pair wires to that of wireless transmission. A part of electromagnetic (EM) spectrum, which can travel in space without a need of wire, is used for this wireless communication. Development of such technology has far reaching impacts on society.

While good amount of progress has been made in this direction, researchers and engineers are chipping away at the obstacles. In a race to embrace newer technology, we ignore the ill effects of the technology and do not think about it until it is too late. Little or no thought has been given to the physical final end result of pervasive computing – the present day computing devices. Pervasive computing not only offers us glittering future of convenience, but also a legacy of deadening clutter and dangerous trash: substances which are non-biodegradable, carcinogenic and toxic. Apart from this physical waste, energy consumption is another significant environmental concern. While an individual mobile device is more energy efficient, the overall energy consumption increases as the number of these devices increase. Apart from these environmental hazards, a few researchers are worried about the direct impact on health of humans from wireless communication. Wireless communication uses radio frequency, continued exposure to which can cause cancer as shown by some experiments. We develop and advance new technologies to improve human life and comfort. It is our responsibility, as researchers and engineers, to be aware of hazards of such advancement and take control before its too late.

2. The Hazards

Pervasive computing has been driven by ambitious, exciting and noble goals – to make computing as useful and unobtrusive as utilities like electricity and water; to produce "calm" rather than distraction; and to bring the benefits of computers to everyone by developing not only powerful, costly machines but "tiny inexpensive ones" [1]. We became so engrossed in making this technology unobtrusive that we ignored the long-term negative effects that this technology is causing on our society. The threat posed by introduction of such devices can be classified as:

- i) Environmental hazard:
  - a) Physical waste
  - b) Energy consumption
- ii) Health hazards.

It poses threat to humans and other flora and fauna in two ways – direct (environmental) and indirect (health) hazards. Disposal of computing devices, which are soon becoming obsolete due to introduction of handy devices, are a sever threat to environment due the dangerous trash that they produce: plastics that do not biodegrade, heavy metals that are carcinogenic, gasses from production and incineration that are toxic, and landfills that threaten generations to come [1]. This is the physical waste that cannot be classified under the regular municipal waste and needs different end-of-life disposition options. Apart from this physical waste, another significant environmental concern is the Energy Consumption. One of the basic requirements of a mobile device is that it should be energy efficient. These days, these devices are becoming more and more energy efficient, but the overall energy consumption due to such devices continues to increase as their total number increase rapidly. In the case of pervasive computing, this environmental impact is greater than current computing because of the use of batteries.

These mobile/wireless devices have become very common in the past few years. Most of these devices work in the radio frequency or microwave range. Radio frequency fields may cause thermal effects at high exposure levels. Researchers are investigating the possibility that radio frequency fields associated with cellular phones may cause other adverse effects (eg. Effects other than heating, such as cancer). There is a concern that an established effect from wireless radiation, even small, could have a considerable impact in terms of public health [5]. With a large number of cell-phone users (over 100 million in the U.S. alone [5]) even a small effect could create "an epidemic size problem." Apart from wireless device that users carry with them, wireless transmission towers for radio, TV, telecommunications, radar and many other applications too emit radio frequency radiation. There is some evidence that effects of radio frequency radiation do accumulate over time [12]. Another concern is that due to march toward pico-cells, greater number of base stations would be co-located and would undoubtedly result in increased level of public exposure to microwave energy over time. These towers and base stations are usually located far away from human-habitats, however, it is clear that low-intensity radio frequency radiation is not biologically inert.

2.1. Environmental Hazards

Little of or not thought has been given to the physical final end result of pervasive computing: devices of varying size, weight and complexity, that will be useless and obsolete in pervasive world. These devices (mobile), by their very design and function, are ubiquitous, massively distributed, and embedded in numerous everyday objects and the environment. Pervasive computing brings with it a dangerous waste.

A glance at the physical waste produced by the current – ie., non-pervasive – use of computers will help gauge the extent of this waste. It has been estimated that over three-quarters of all computers ever bought in the U.S. are stored in people's attics, basements, office closets and pantries. By 2004, there will be over 315 million obsolete computers in the US; many destined for landfills, incinerators or hazardous waste exports[1]. Consider that computer equipment is a complicated assembly of over a thousand materials, of which many, such as lead, cadmium and mercury, are known to be highly toxic.

The growth of waste electrical and electronic equipment is about 3 times that of other municipal waste [1]. Pervasive computing will add to the already existing "mountain of obsolete PCs, both by increasing the nature and quantity of physical devices and the rate at which they become obsolete. Not only computing, but also communications devices are expected to proliferate. It is estimated that 780 million Bluetooth devices will be shipped in 2005 [1].

Pervasive computing devices have one significant environmental advantage over traditional computers: small physical size that inherently consumes less material. However, the disadvantage attached is that they will be far more numerous; low cost will encourage rapid replacement; less mature technology will become obsolete faster; disposable versions of some devices will emerge and they will tend to use batteries, which often contains environmentally unfriendly heavy metals. In addition, their small size, weight, embedding in other materials and overall design for ubiquity will disperse them widely, making them more likely to be lost, forgotten, or simply abandoned, and making proper collection, recycling or disposal harder. If pervasive computing devices have to be truly global, they will bring computer environmental impacts to regions of the world where little or none exist at present.

The speed of innovation in wireless and PDA technology, coupled with its relatively low cost, indicates decreased lifetimes for devices. One year's device may be replaced because it is not WAP-enabled, and the following year the replacement may be replaced because it is not Bluetooth-enabled. A widely cite 1991 study predicted that nearly 150 million personal computers (PCs) would be sent to landfills by 2005 [14].

Disposal and recycling of computer products has become an increasingly controversial issue as municipalities concerned about the potential of toxic danger close their landfill sites to dumping. If dumped, the lead from these devices can leak into water systems, and the long-term implications obviously aren't healthy. Its become an issue that what should be done when there are toxic materials like monitors or CPUs with lead that shouldn't be in landfill. Every monitor has four to six pounds of lead [8]. And it's mixed with phosphorous to protect users from radiation.

By 2005, 130 million cell phones will be thrown out each year, according to a new study funded in part by U.S. Environmental Protection Agency (EPA). Counting the phones, batteries and chargers, that comes to 65,000 tons a year, most of which will end up in landfills or being incinerated. And that has environmentalists freaked. Introduction of disposable cell phones by HopOn is again debatable. On one hand, they reduce the amount of toxic waste per device; but on the other, since they are disposable, they add to the total amount be dumped as landfill. Cell phones and other electronic devices contain a large number of hazardous substances. It should be noted that these substances are not known to pose threats to the environment or public health while the devices are being used. Rather, their hazardous effects occur upstream – during materials extraction and processing – and at end of life, when cell phones and other wireless products are incinerated or disposed of in landfills, and during recycling process such as shredding, grinding, melting, plastics extrusion, and metals processing [15].

According to [12], devices transmitting EM waves/energy can ignite flammable material such as gasoline/petrol vapors (usually present near a gasoline/petrol pump). Manufacturers of cell phones have a warning about this hazard in their user's manual.

Cell phones and other wireless electronic devices contain cadmium and hexavalent chromium, which are toxic and can have seriously harmful effects on public health. Cell phones and printed circuit boards of various electronic devices contain valuable materials such as gold, silver, palladium and platinum, which should be recovered, reused, or recycled. Other materials present in cell phones, which pose threat to the environment include beryllium, tantalum, arsenic, and copper. Beryllium contributes hardness, strength, conductivity, and corrosion resistance. It is used in springs and contacts that need to expand and contract. Workers who become sensitized to beryllium can suffer irreversible and sometimes fatal scarring of the lungs. Tantalum is used in capacitors, which control the flow of current inside small circuit boards. Malaysia's Environment Ministry has found tantalum dumps to be radioactive. Arsenic is used in semiconductors. These chips are harmless during use but create a toxic compound when cell phones are incinerated.

The hazardous substance produced by electrical and electronic waste contains chemicals, which are called PBTs by the U.S. Environmental Protection Agency [15]. PBT is Persistent, Bioaccumulative, and Toxic Chemicals. PBTs are persistent in that they linger in the environment for a long time without degrading, increasing the risk of exposure to human beings. They can also spread over large areas, moving easily between air, water, and soil, and have been found far from the areas in which they were generated. PBTs are persistent in that they linger in the environment for a long time without degrading, increasing the risk of exposure to human beings. PBTs accumulate in the fatty tissues of human beings and other animals, increasing in concentration as they move up the food chain. As a result, they can reach toxic levels over time, even when released in very small quantities.

So far this paper has focused on they physical waste aspects of mobile/wireless devices. Energy consumption is another significant environmental concern. It has been estimated that computing, telephony and networking equipment now account for a significant fraction of total energy consumption in the U.S. [1]. While each single mobile device consumes less energy, the overall energy consumption increase as the number of these devices increase, they integrated more sophisticated and energy-consuming peripherals (larger displays, built-in wireless interfaces, CD-R/W etc.), and the applications and system software become even more complex.

One reasons for devices, mainly computers, to become obsolete is that they run out of storage space. However, it is likely that the storage space contains information that is of no use to either the system or the user. Some estimates indicate that 30-60% of disk space on a computer is wasted [1]. For example, outdated information and multiple copies of the same information can occupy storage space needlessly. This data sprawl from information unnecessarily stored far beyond its useful lifetime not only consumes storage, but it also costs energy (for search and management) and contributes to "virtual clutter" and usability issues. Individuals find it easier and cheaper to expand system resources (large disk and faster processors) than to manually manage even personal information. If there is huge amount of data (some of it might be useless), it takes more time to retrieve it, takes relatively more CPU cycles and hence more power. Power consumption is an issue that extends well beyond the realm of battery power. Energy efficiency of computer is desirable not only from economical point of view but from the environmental point of view too.

Apart from data sprawl, software sprawl also cause environmental hazard. One primary reasons people have for buying new electronic devices is to gain access to the latest software applications. Applications with nominally the same functionality show an ever-increasing demand for storage space and processing power. For example, from 1994 to 1999, Linux kernel size grew as the square of the number of days since release of version 1.0 [1]. This software sprawl not only increases storage and energy usage but, after only a few releases, can also make hardware obsolete. While some of this growth is related to added functionality, the complexity of the resulting applications results in much of this functionality going under-used.

2.2. Health Hazards

Wireless devices have become very common in the past few years. Perhaps the most common are cordless and cellular telephones in addition to Personal Communications Service. Other uses include remote controlled garage door openers, key-ring type car door lock and unlock devices, wireless microphones, wireless computer-Internet connection packages, etc. All of these utilize small radio transmitters and associated receivers inside the devices that operate at considerably high radio frequencies but quite low power. This paper concentrates on hazards due to radiation from the use of mobile phones. Similar hazards can be caused by other wireless devices too.

Apart from hand held devices like cell phone, wireless transmission towers for radio, TV, telecommunications, radar and many other applications, emit RFR. Once emitted, the radiation travels through space at the speed of light and oscillates during propagation.

The issue of possible health effects of mobile telephones and mobile telephone base stations is very much alive in public's mind. Motivated by health concerns, a new wave of research has been undertaken in the United States and elsewhere, searching for possible links between cell phone radiation and health problems, including cancer. The issue of health threats due to radiation from mobile phones arose with a lawsuit filed in a US court in mid-1992 by David Reynard, alleging that the use of a cell phone cause his wife's fatal brain tumor [10]. In response to public fears that these suits and their attendant publicity have raised, a wave of research was begun, both within and outside of the US, funded by both industry and government.

Before going further into the health issues of radiation, it is helpful to know a few technical terms and permissible safe exposure levels of these harmful radiations. The cordless telephone handset contains a small radio transmitter and receiver that communicated, via its antenna, with the base unit that is connected to standard telephone line. Speaking into the handset's microphone modulates the internal radio transmitter, which sends the message to the base unit by high frequency radio waves. The base unit's transmitter sends the incoming messages to the handset's receiver and the handset's internal electronics converts this radio signal into audio output in the handset's earphone. Radio frequency waves constitute a range of what is called the electromagnetic (EM) spectrum, which is divided into eight ranges according to the waves frequency, associated energy and other characteristics. EM wave energy is measured in "electron volts", eV. The energy of all EM waves is directly proportional to their frequency.

Power line frequencies range from a few to about 30kHz with corresponding energies from near zero to 1.2×10^{-10} eV. Radio and television broadcasting frequencies range from about 30kHz to 300 kHz with corresponding energies from 1.2×10^{-10} eV to 1.2×10^{-6} eV. Microwave frequencies range from about 300 MHz to 3×10^{11} Hz with corresponding energies from 1.2×10^{-6} eV to 1.2×10^{-3} eV. Infrared frequencies range from about 3×10^{11} to 4.3×10^{14} Hz with corresponding energies from 1.2×10^{-3} eV to 1.8 eV. This frequency is associated with radiant heat. If the exposure is too great, burning may result. Visible frequencies range from about 4.3×10^{14} Hz to 7.5×10^{14} Hz with corresponding energies from 1.3 eV to 3.1 eV. Ultraviolet frequencies range from about 7.5×10^{14} Hz to 3×10^{17} Hz with corresponding energies from 3.1 eV to 1.2 keV. There is an additional hazard associated with the ultraviolet radiation above 10eV. EM radiation with energies in excess of 10eV is called *Ionizing radiation,* which means that such radiation has sufficient energy to dislodge electrons from the outer orbits of atoms and can break the bonds between atoms in molecules. X-ray frequencies range from about 3×10^{17} Hz to 3×10^{19} Hz with corresponding energies from 1.2 keV to 120 keV, well into the ionizing radiation range. These EM waves are produced in medical and industrial X-ray machines and also in the emissions from some radioactive substances. Gamma ray frequencies range from about 3 X 10^{19} Hz on up with corresponding energies from 120 keV on up. These energies are usually measured in millions of electron volts, MeV. These waves are produced from some radioactive materials [11].

Ionizing radiation can be damaging to tissue. For example it can break the bonds of the DNA molecules in the nucleus of a living cell. This may lead to the cell's death or perhaps, start of a cancer. The focus here is on radio frequency (RF) waves, the energy of which is far below the 10 eV threshold radiation. For example, cellular telephone systems operate in the 800 to 900 MHz range and these radio waves have energies of about 3.5 X 10^{-6} eV. Radio waves pass through most matter, including living tissue, with very little being absorbed. The concern here, therefore, is with the very small fraction of incident radio waves absorbed in living tissue. The RF energy absorbed in tissue is converted into heat, that is, it may raise the temperature of that tissue. The rise in temperature being approximately proportional to the quantity of radiation absorbed and this, of course, will depend up the "intensity" of the incident radiation. The microwave oven is a good example of the use of intense RF energy to raise the temperature and cook a roast. It is important to understand that intensity of EM radiation is measure as the "power on a surface area" and its unit is watts per square meter. Another term that needs explanation is SAR, Specific Absorption Rate, which is a measure of the rate at which the body absorbs RF energy. It is measured as power incident on one unit of mass, W/kg.

The integrated intensity of sunlight on earth is about 800 W/sq.m. or 80 mW/sq.cm. An experiment conducted in 1953, involving humans exposed to RF radiation over a range of intensities, indicated that an intensity of about 100 mW/sq.cm. is necessary to produce a biological significant effect. At that time the "maximum safe exposure level" was set to 10 mW/sq.cm. There have been several changes to this limit since then. Now the U.S. Federal Communications Commission has issued guidelines for power density to be between 0.2 to 1 mW/sq.cm. Permissible SAR, according to U.S. guidelines, are between 0.08 to 0.4 W/kg. Cellular systems use frequencies in the 800-900 MHz range and PCS in the 1850-1900 MHz range. For cellular and PCS base stations the emitted radiation intensity limit is 0.6 mW/sq.cm. and 1 mW/sq.cm. respectively [12].

Generally speaking, when one is talking the cell phone is giving off EM waves with information riding on them while when one is listening the hand phone is capturing the wanted EM waves from the space. EM waves go out and come into a cell phone through its antenna.

According to their biological effects, EM radiation can be classified into two forms: non-ionizing radiation and ionizing radiation. Radio waves, microwaves, infrared, visible light waves are non-ionizing radiation that do not have enough energy to break apart atoms and molecules and turn them into ions, which are electrically-charged particles. This means that non-ionizing radiation does not damage genetic material (DNA) in molecules directly and cannot therefore cause cancer or any other illness in people. X-ray and gamma rays, are forms of ionizing radiation, which, particularly at high doses, can increase one's risk of cancer, birth defects, and genetic defects through DNA mutations resulting from atom and molecule ionization. There is no completely safe level of ionizing radiation.

Wireless communication systems emit non-ionizing, EM energy. The perceived health risks of this emission have been identified as a potential public health and safety issue. However, no studies to date have demonstrated a specific correlation between wireless communication facilities and health problems.

If exposure is sufficiently intense, microwaves can cause biological effects. Possible injuries include cataracts, skin burn, deep burns, heat exhaustion and heat stroke. The effects of this heating range from behavioral change to eye damage. The possible health hazards of cell phones can be classified into thermal effect and non-thermal effect. The main concern of non-ionizing radiation is the thermal effect. Although cell phone radiates low level of power but if a small amount of power absorbed by a human head concentrates on one very small area in brain so as to form a "hot-spot" then a small volume of brain may be overheated and damaged. But scientific studies have confirmed that thermal effect of cell phone is negligible [9]. Non-thermal effects of cell phone usage are also a cause of concern. Some people feel headache after talking too long and some hypersensitive people fell sick when the cell phone is turned on. There non-thermal effects are believed to be due to the waveforms (causing mechanical vibration). Nerve system of people could be affected by the waveforms [9]. In general, short-term non-thermal effects are usually reversible and the symptom will disappear when the cause is gone.

There are several studies that have been conducted to gauge the positive or negative effect of radiation exposure. An epidemiology study on cell phone users in 1999 by Hardell and colleagues assessed mobile phone use in 209 Swedish brain tumor patients in comparison to 425 healthy controls [10]. The study was negative in virtually all respects. One aspect of the study, however, received wide coverage in the news – users of mobile phones who had developed certain types of brain tumors were more likely to get them on the side of their heads where they said they had used the phones. But this correlation was not statistically significant. There, of course, are safety issues involved with cell phone usage such as interference of cell phones with medical devices and driving performance.

There has been no replicated laboratory or epidemiological evidence that microwaves at power levels associated with public exposure to microwaves from cellular phone and base station antennas are associated with cancer [9].

- In 1995, researchers at University of Washington, Seattle, found DNA breaks in cells exposed to wireless phone radiation. Subsequent attempts by researchers at Washington University in St. Louis to duplicate the work were unsuccessful.
- Another epidemiological study found that right-handed people who used cell phones and had brain tumors tended to have them on the right side of the head – a result that could show a link to radiation from the phones. However, no such correlation appeared in left-handed cancer patients.
- It was also reported that non-ionizing radiation may speed up the cancer though it would not cause cancer.
- In 1998, work conducted on slice of rat brain taken from hippocampus (a structure with a role in learning), at the Defense Evaluation and Research Agency's labs (UK) showed that mobile phones could scramble memories. But in humans, the hippocampus is buried too deep in the brain to be influenced by emissions from mobile phones, say some scientists.

Some experiments conducted, show biological effects that occurred in studies of cell cultures and animals after exposures to low-intensity RFR (RF radiation) [12].

- DePomerai reported an increase in a molecular stress response in cells after exposure to a RFR at a SAR of 0.001 W/kg. This stress response is a basic biological process present in almost all animals – including humans.
- Dutta reported an increase in calcium efflux in cells after exposure to RFR at 0.005 W/kg. Calcium is an important component of normal cellular functions.
- Persson reported an increase in the permeability of the blood-brain barrier in mice exposed to RFR of 0.0004 – 0.008 W/kg. The blood-brain barrier envelopes the brain and protects it from toxic substances [6].
- Phillips reported DNA damage in cells exposed to RFR at SAR of 0.0024 - 0.024 W/kg.
- Velizarov showed a decrease in cell proliferation (division) after exposure to RFR of 0.000021 – 0.0021 W/kg/

These are important findings at such low-intensity exposures. But we don't know if thee effects occur in humans exposed to low-intensity RFR, or whether the reported effects are health hazards. Biological effects do not automatically mean adverse health effects. Many biological effects are reversible. However, it is very clear that low-intensity RFR is not biologically inert.

An indication of current thinking by health agencies is provided by a statement issued in February 2000 by the US Food and Drug Administration: “there is currently insufficient scientific basis for concluding either that wireless communication technologies are safe or that they pose a health risk to millions of users” [10]. This statement – “no proof of danger, no proof of safety” – has two parts, with quite different meanings. The first part, no proof of danger, is obvious. Taken as a whole, the animal and epidemiology studies conducted so far do not demonstrate a health hazard from RF energy from mobile phones or base stations under real-world exposure conditions. The cancer studies, taken as a whole, are negative.

3. The Solutions

As researchers we tend to focus on innovation. We ought to apply this innovation in reducing the environmental and health hazards that pervasive computing has brought or might bring. Unlike current computing, where environmental concerns were only raised after the proliferation of computers, pervasive computing offers us a unique opportunity to apply environmental consciousness while we are still at the start of the next wav of technology proliferation.

3.1. Solutions for Environmental Hazards

Just as manufacturers of household goods such as appliances and cosmetics increasingly seek to project and differentiate themselves as “green” (to respond to or avoid government regulations and consumer pressure), so will computer system manufacturers. Pervasive computing will need to develop principles and techniques for environmentally sensitive and sustainable design and must apply to all aspects of electronic devices, both hardware and software.

The pervasive computing design should explicitly consider and minimize environmental impacts as separate parameter from cost. The cost of environmental impacts should be included in the design process, and methodologies developed so that the present value of these future costs can be compared with other costs. Research should consider minimizing not only production and operation costs but total lifecycle impacts, ie., choosing techniques to reduce the costs of reuse, recycling, and disposal. The reduce/reuse/recycle mantra needs to be an integral part of the design process, not an afterthought [1].

Minimizing the environmental impact will have implications at all aspects of system design, including computer science and software. More and more computer system functionality is being implemented in software rather than hardware. As an example, software radios are being developed that will allow radio channel modulation for cell phones and other wireless communications devices to be defined in software rather than hardware [16].

First step towards reducing environmental impact is smarter design to use less materials and energy for the same functionality and performance [1]. Functional integration (combining several functions into a single device) will increase user convenience and reduce costs. For example, just one device acting as cell phone, remote control for TV, car, garage door, credit cards etc. This reduction could aid in reducing the waste stream. Another approach to reducing the overall quantity of electronics is resource sharing [1]. Multiple users can share a device if it supports personalization and privacy features that are invoked, for example, by biometric identification. It is a well known fact that computers today are highly underutilized.

Another approach to reduce the computers going to landfill is to use them longer. One of the reasons computers become obsolete is that they run out of storage space. 30 to 60% of the disk space on a computer is wasted. Systems should be designed to minimize such data sprawl through better indexing, retrieval, on-line or automatic compression, and knowledge management techniques [1]. Software sprawl can in reduced to increase the life time of a computer by dynamic application usage. This involves dynamic application discovery, download, and billing. Average lifetime of electronic equipment could be increased by designing the hardware and software to support system hardware upgrades.

Recycling electronic devices and equipments is another solution to reducing the number going to landfills. Raw materials can be extracted by recycling PCs. Cell phone recycling has recently been instituted in Japan [7]. 120,000 cell phones can produce one-kiolgram bar of pure (99.99 percent) gold. But these recycling processes are expensive, labor-intensive and time-consuming. Labeling components to record their identities and capabilities could possibly help this process. Smart disposal should attempt to close the loop of product information: provide definitive quantitative feedback to system designers about the actual usage and upgrade of software and hardware components and features.

There are various end-of-life options for an obsolete computer. First, it could be *reused*. This means that it is somehow used again after becoming obsolete to the purchaser – it can possibly be reassigned to another user. Second, the original owner could *store* the computer. But in this case, it serves no purpose. Third, the computer could be *recycled*. This means that the product is taken apart and individual material or subassemblies are sold for scrap. Finally, the computer could be *landfilled.* In this model, the reuse and storage options are only intermediate stages in the lifecycle of a computer. Only recycling and landfilling are terminal points. The following diagram shows this model.

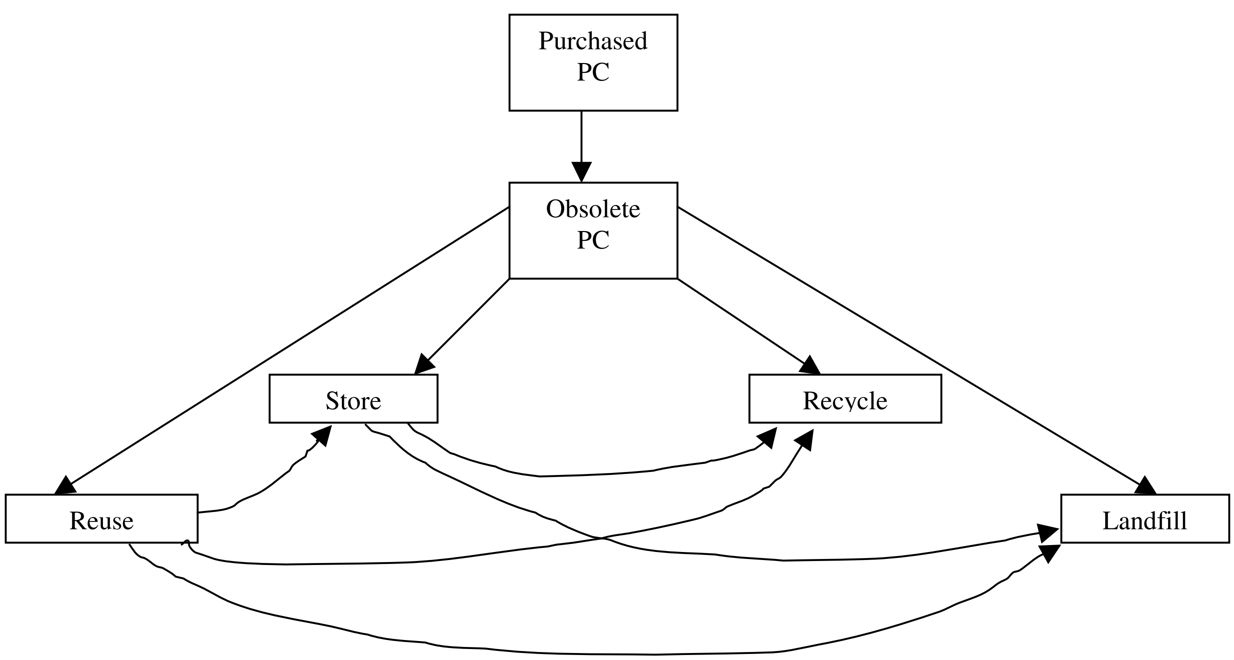

Figure1: Flow Diagram of End-of-life options of Obsolete Computer

Another option is that of Product takeback, an emerging international paradigm, which requires that firms organize methods to reclaim their products at the end of their useful life. Manufacturers should take it as their responsibility to take care of their product after its life time is complete. The product life cycle, for a manufacture, should not stop after it is sold or deployed, rather it should continue further till its disposal.

The key to successfully improving environmental quality of any product is to make informed decisions at the design stage. So called Design for Environment or Green Design programs maximize use of resources, and also ensure that corporate environmental goals are met in timely manner.

In 1992, the U.S. Environmental Protection Agency (EPA) announced its Energy Star program, which promotes the use of energy-efficient, power-managed office equipment as a way to increase profits and competitiveness and prevent pollution [13]. The first phase of the program addressed the energy consumption of PCs. Manufacturers of PCs and monitors that can be automatically powered down to 30 watts or less during periods on inactivity sign a voluntary agreement that entitles them to use a special Energy Star logo. EPA estimates that an Energy Star computer and monitor can save users from $20 to $90 per year in electricity bills. It is now been extended to include printers, fax machines, photocopiers etc.

3.2. Solutions to Health Hazards

The health hazards from EM radiation emitted from wireless devices and transmitting towers haven't been scientifically proven yet. There are various studies being carried out to confirm if there really is any hazard. Though some studies have shown threatening results, but such experiments failed to show the same result on replication. So there is no proven consistency in these studies yet. But it has been proven that RF and microwave radiation is not biologically inert. It has been predicted that there will be 1.2 billion wireless device users around the world by 2005 and 2.7 billion in 2015 [9]. It seems that there is no way to reverse this trend. Too much electromagnetic radiation is a type of environmental pollution and should be controlled.

Scientists and engineers are developing better and safer wireless systems and devices. Smaller cell size, better base station antennas and other more advanced technologies will allow future cell phones to radiate much lower power. Using cell phones while driving might be the biggest hazard cell phones can cause. Paying attention while driving can minimize this cause. Besides, some simple steps may be adopted to minimize radiation of the mobile phone. Making the conversation shorter will help to reduce the duration of exposure. Calls can be planned in such a way that long conversations be done using ordinary land line phones. Minimize the conversation inside the car because the reflection from the car cavity may amplify the radiation. If this cannot be avoided use of roof antenna would help. Use of plug-in earpiece will separate antenna further away from body/head. People are usually less sensitive to CDMA phone rather than GSM. Newer CDMA system does not emit the sharp-edged lower frequency pulses. The digital RF signal more resembles a noisy analogue signal and is also likely to be less bioactive.

4. Conclusion

The intent of this paper was not to present an alarmist view of global environment collapse due to computers or the severs health threats due to radiations, but to argue that pervasive computing systems pose an environmental risk that must be addressed.

While environmental impacts are typically viewed in terms of minimizing physical material usage and waste, software will play a big role in reducing hardware impacts. This requires examining the system design processes with a new metric: reducing environmental cost. To reduce or completely eradicate the threat to environment the very design process of todays should change so as to include end-of-life options and costs associated. We as computer science engineers and researchers have a big role to play. Writing such software will minimize hardware changes (for eg., software radio) and in turn slow the rate of hardware becoming obsolete. Alternatives to toxic heavy metals (lead, cadmium, mercury etc) and renewable energy resources need to be found. These efforts will go a long way to develop Green Pervasive Computing.

Wireless communication uses frequencies lower than visible light. These frequencies are non-ionizing, but if their intensity, power density, is sufficiently great it can produce heating. Exposure to radiation does cause some biological changes in humans and animals, but it might not be always harmful. As of now, there have been no consistent studies to prove hazards to health of humans, but non-existence is difficult to prove than the existence. Hence, we need to take precautionary steps to possible hazards from exposure.

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