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*Research Article*

# Green Networking for Major Components of Information Communication Technology Systems

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Green Networking can be the way to help reduce carbon emissions by the Information and Communications Technology (ICT) Industry. This paper presents some of the major components of Green Networking and discusses how the carbon footprint of these components can be reduced.



## 1. Introduction

The late David Brower [1], a noted environmentalist, stated "We don't inherit the environment from our ancestors, we borrow it from our children". This is a very sobering comment. If the definition of sustainability is that we leave this planet to our children in a better state than we found it, then according to the Intergovernmental Panel on Climate Change (IPCC) [2] we are failing dismally. The major contributor to global warming and climate change is the dramatic increase in human greenhouse gas emissions into the atmosphere; the main greenhouse gas is Carbon Dioxide ($CO_2$).

## 2. Green Networking

Green Networking covers all aspects of the network (personal computers, peripherals, switches, routers, and communication media). Energy efficiencies of all network components must be optimized to have a significant impact on the overall energy consumption by these components. Consequently, these efficiencies gained by having a Green Network will reduce $CO_2$ emissions and thus will help mitigate global warming. The Life Cycle Assessment (LCA) [3] of the components must be considered. LCA is the valuation of the environmental impacts on a product from cradle to grave. New ICT technologies must be explored and the benefits of these technologies must be assessed in terms of energy efficiencies and their associated benefits in minimizing the environmental impact of ICT. Some of the goals of Green Networking include

(i) reduction of energy consumption,

(ii) improvement of energy efficiency,

(iii) consideration of the environmental impact of network components from design to end of use,

(iv) integration of network infrastructure and network services; this integration consolidates traditional different networks into one network,

(v) making the network more intelligent; the intelligent network will be more responsive, requiring less power to operate,

(vi) compliance with regulatory reporting requirements; for example, the National Greenhouse and Energy Reporting System (NGERS) and the proposed Carbon Pollution Reduction Scheme (CRPS),

(vii) promotion of a cultural shift in thinking about how we can reduce carbon emissions.

Figure 1 shows the relative power use of the ICT devices used in the ICT industry [4].

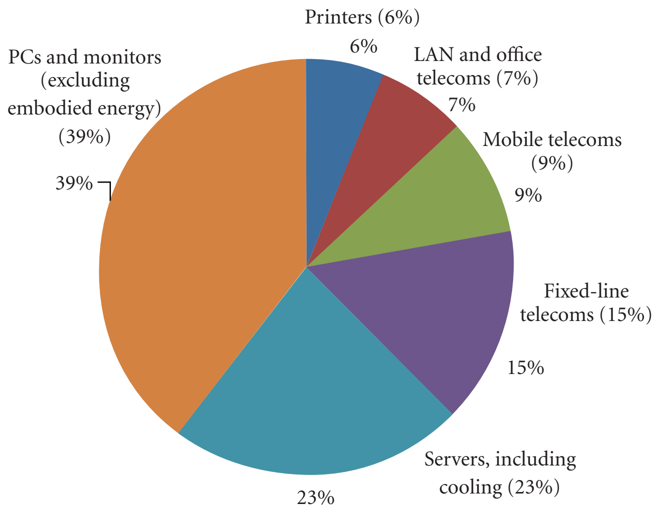


Figure 1: Power usage of ICT devices.

## 3. Network Components

According to Gartner [4], desktop computers and monitors consume 39% of all electrical power used in ICT. In 2002, this equated to 220 Mt (millions tons of $CO_2$ emission).

To reduce the carbon footprint of desktop PCs, their usage must be efficiently managed. Old Cathode Ray Tube monitors should be replaced with Liquid Crystal Display screens which reduce monitor energy consumption by as much as 80% [5]. Replacing all desktop PCs with laptops would achieve a 90% decrease in power consumption [5]. Energy can also be saved by using power saving software installed on desktops and running all the time. The power saving software controls force PCs to go into standby when not in use. Another option is to use solid state hard drives that use 50% less power than mechanical hard drives [6].

When considering the Local Area Network (LAN) network infrastructure, probably the most power hungry device is the network switch. Modern network switches perform various network infrastructure tasks and as a result use considerable power. PoE (Power over Ethernet) is a relative new technology introduced into modern network switches. PoE switch ports provide power for network devices as well as transmit data. PoE switch ports are used by IP phones, wireless LAN access points, and other network-attached equipment. PoE switch port can provide power to a connected device and can scale back power when not required.

To reduce power consumption and equivalent $CO_2$ emissions from a network switch, several techniques are available.

One solution is to use a highly efficient power supply within the network switch. A typical PoE network switch has a large number of IEEE Class 3 devices (e.g., an IP phone) attached, with each device consuming up to 15.4 watts of power. A typical high end switch will have about 384 ports. This switch will require about 5.9 KW of power. An 80% efficient power supply would require 7.3 KW. A 90% efficient power supply would require 6.5 KW. By using a highly efficient power supply we can save up to 800 W.

Assuming that the devices connected to the network switch were turned on all the time for a year, then a 90% efficient power supply could save 7200 Kilowatt-hours per year per network switch. Assuming that electricity is generated from a coal fired power station, then one Kilowatt-hour of electricity is equivalent to 0.537 Kg of $CO_2$ [7]. Therefore, increasing the efficiency of the power supply of the network switch from 80% to 90% will result in a saving of 3866 Kg of $CO_2$ emissions per network switch per year. Assuming electricity costs \$0.15/Kilowatt-hour, this would result in a saving of about \$1080 per network switch per year in electricity costs alone.

Another solution is to use power management software built into the network switch. With power management software, we can instruct the network switch to turn off ports when not in use, for example, if we consider an attached device such as an IP phone that was only used during office hours (9 am till 5 pm). If each phone consumed 15.4 Watts and was turned off for about 16 hours a day, this would equate to a saving of $15.4\,W \times 16$ hours $\times$ 365 days = 89,936 kilowatt-hours per port per year.

## 4. Network Integration and Network Services

Initially the network infrastructure was only required to allow connectivity between devices on a network. In the past, data and voice traffic used to be on different networks. This produced inefficiencies and required the duplication of resources. With the wide adoption of Voice over IP (VoIP), the separate infrastructures were replaced with one unified, converged network supporting both data and voice traffic.

The introduction of VoIP requires the network infrastructure to provide new network services. In the case of voice traffic, which requires low latency, QoS (Quality of Service) was introduced. This required network devices to support QoS.

As networks became more critical in daily business operations, additional network services were required. Network infrastructure devices were required to support VPNs (Virtual Private Networks) and data encryption also. The new integrated network infrastructure with its network services will make the network more energy efficient and reduce the carbon footprint of the network infrastructure.

## 5. Data Centers

The main issue with Data Centers, with respect to Green Networking, is their inefficient use of electrical power by the Data Center components. In addition, electrical power generation from coal becomes a critical issue. Data centers store a vast amount of data used on a daily basis by users, companies, government, and academia. As the demand for data has increased so has the size of Data Centers. Consequently, the power consumed has also increased. In 2003, a typical Data Center consumed about 40 Watts per square foot energy, and in 2005 this figure has been raised to 120 Watts/sq ft energy [8], and it is anticipated that this figure will continue to rise. Rack density, which is number of devices per rack, within the Data Center has also increased. This increase in rack density directly increases the heat load, which needs to be dissipated in form of cooling. Some Data Centers have got to a point where the local electricity supplier cannot supply further electricity. The typical Data Center consists of blade servers, storage devices, and multiprocessor servers. These servers are housed in racks placed in rows on a raised floor. The raised floor allows for power distribution, data cable distribution, and cooling ducts. In a recent report, Gartner [4] predicts that in the future (we are already in 2009!) many organizations will spend more on annual IT energy bills than they will be spending on servers.

The main components of the network infrastructure of a Data Center are the data cabling and switches. The power consumption distributions within a typical Data Center are shown in Figure 2.

Due to the high power consumption by Data Centers, there are some proposed solutions to save energy and make Data Centers more energy efficient. Some of the solutions include

(i) taking the Data Center to the power source instead of taking the power source to the Data Center,

(ii) consolidation,

(iii) virtualization,

(iv) improved server and storage performances,

(v) power management,

(vi) high efficiency power supplies,

(vii) improved data center design.

Traditionally the electrical power needed for Data Centers is supplied by the electricity grid. Using alternate energy sources at the Data Center is often impractical. The solution is to take the Data Center to the energy source. The energy source could be solar, wind, geothermal, or some combination of these alternate forms of energy. Instead of the power traveling great distances, the data would need to travel great distances. For this to be feasible, we would require a broadband network infrastructure.

*5.1. Consolidation.* Going through a systematic program of consolidating and optimizing your machines and workloads can achieve increased efficiencies at the Data Center.

*5.2. Virtualization.* With new virtualization software available, it is possible to reduce the number of physical servers required for a system. Each physical server can host many virtual servers. Virtualization efficiency gains are made possible because of the utilization of CPU potential within the server. Typically a server running without virtualization might run at only 5% of full utilization, with virtualization the CPU can run up to 80% of full utilization.

Virtualization is one of the main technologies used to implement a "Green Network". Virtualization is a technique used to run multiple virtual machines on a single physical machine, sharing the resources of that single computer across multiple environments. Virtualization allows pooling of resources, such as computing and storage that are normally underutilized. Virtualization offers the following advantages: less power, less cooling, less facilities, and less network infrastructure. For example, assume a server room has 1000 servers, 84 network switches, consumes 400 K·W of electricity for ICT equipment, 500 K·W of electricity for cooling and requires 190 square meters of floor space. With virtualization we could typically reduce the number of physical servers. The power required for the ICT equipment would be reduced significantly and power required for cooling will be reduced, and the floor space required will only be about 23 square meters. We note that not only the power required for the servers has reduced but so have the cooling, network infrastructure, and floor space requirements.

Virtualization can also be used to replace the desktop. With desktop virtualization we can use a thin client consuming little power (typically 4 Watts). The image and all other programs required by the client can be downloaded from one of the virtualization servers. Virtualization can be successfully used in the educational and training environment. A student requiring a complete network of client, server, and interconnects, which would normally require a number of hardware components, can now be done using a single PC.

*5.3. Improved Server and Storage Performances.* New multicore processors execute at more than four times the speed compared to previous processors and use new high speed disk arrays with high performance. 144-gigabyte Fiber Channel drives can reduce transfer and improve efficiencies within the Data Center.

*5.4. Power Management.* It is estimated that Servers use up to 30% of their peak electricity consumption when they are idle

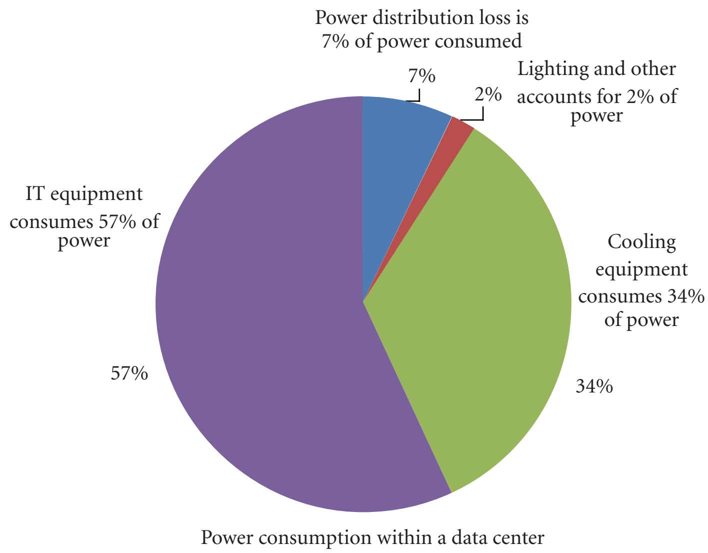


Figure 2: Power Consumption within a Data Center.

[9]. Although power management tools are available they are not necessarily being implemented. Many new CPU chips have the capacity to scale back voltage and clock frequency on a per-core basis and this can be done by reducing power supply to the memory. By implementing power management techniques, companies can save energy and cost.

*5.5. High Efficiency Power Supplies.* The use of high efficiency power supplies should be considered in all Data Center devices. Poor quality power supplies not only have low power efficiencies, but the power efficiency is also a function of utilization. With low utilization we achieve lower efficiency in the power supply. For every watt of electrical power wasted in a Data Center device, another watt is used in extra cooling. Therefore, investing in high efficient power supplies can double power savings. Another issue with power supply is that quite often Data Center designers overestimate power supply needs. With more accurate assessment of the power requirements of a device, we can achieve high efficiency and energy savings.

*5.6. Improved Data Center Design.* When considering improved Data Center design, we must consider electrical power production and distribution, cooling design, data cabling layout, UPS (Uninterruptible Power Supply) design as well as server and data storage design. One new approach is the use of a modular Data Center design. A modular Data Center design is a pod-based design that creates energy-efficient building blocks that could be duplicated easily in Data Centers of any size. A pod is typically a collection of up to 24 racks with a common hot or cold aisle along with a modular set of power, cooling, and cabling components.

When considering electrical power production and cooling design, one possible solution could be *cogeneration*. Cogeneration is not a new technology but it could be well suited to the Data Center environment. Cogeneration is the production of electricity and heat from a single process. With traditional Data Centers, using the electricity grid might produce about 1 ton $CO_2$/MWatt per hour, but with cogeneration we could reduce this figure to 0.45 ton $CO_2$/MWatt per hour [10].

To measure the efficiency of a Data Center, the Green Grid initiative proposed the use of two measureable metrics [4]: a Power Utilization Effectiveness (PUE) parameter and a Data Center Infrastructure Efficiency (DCiE) parameter. PUE is defined as the total facility power (including Power Distribution Units, generators, UPS, and cooling systems) divided by IT equipment power (including all IT equipment such as servers, storage devices, and network switches), while DCiE is the reciprocal measure (1/PUE) of PUE. These measures provide benchmarks for comparing the overall energy efficiency of a Data Center, establishing trends, and for measuring the effectiveness of design changes. For example a PUE of 2.0 would indicate that for every watt of IT power, an additional watt is consumed to cool and distribute power to the IT equipment. The ideal PUE value is 1.0 corresponding to a Data Center where all of the electrical grid power supplied to a Data Center is devoted to IT equipment and no power is used for cooling and power distribution. For example, Google [11] quotes that its first Container based Data Center, established in 2005, has a PUE of 1.25. The facility consists of 45 containers with 1000 servers per container and supports 10 MW of IT equipment load.

## 6. Cloud Computing

In an ideal computing world, all we will need is an Internet connection. This can be a thin client consuming 4 Watts or a small wireless device. We will not need hardware beyond an Internet connection device. All services could come from the "Cloud". Web services, data storage services, backup services, applications could be provided by service providers operating within the "Cloud". For this to happen the Cloud must provide broadband bandwidth, security to users, and should be reliable.

From a company's point of view, many of its IT resources could be virtualized or outsourced. Virtualization reduces hardware requirements, needs less maintenance, and requires less capital outlay. Most of the company's resources would be hosted by service providers within the cloud, including data storage and other services.

From a Green Networking point of view, "Cloud Computing" offers the promise of low power devices consuming little electricity and connected to highly efficient "Cloud" networks which have been optimized for minimal power consumption.

"Cloud Computing" can be considered "Green Networking" through the efficiencies gained using "Cloud Computing". "Cloud Computing" offers the following advantages:

(i) consolidation—redundancy and waste,

(ii) abstraction—decoupling workload from physical infrastructures,

(iii) automation— removing manual labor from runtime operations,

(iv) utility Computing—enabling service providers to offer storage and virtual servers that ICT companies can access on demand.

## 7. Broadband Telecommunications and Applications

The proposed Australian NBN (National Broadband Network) offers great opportunities for the ICT industry to reduce greenhouse gas emissions. The new "Green Networking" infrastructure will be a fiber to the node broadband network with high speed connections to households and businesses alike, enabling new improved, energy efficient, low carbon applications.

As highlighted by authors in [12], a nationwide broadband network can offer the following advantages: remote appliance power management, presence-based power, decentralized business district, personalized public transport, real-time freight management, increased renewable energy, and "On-Live High Definition Video Conferencing".

*7.1. Remote Appliance Power Management.* Broadband can provide monitoring and control of electrical devices. Control can also be centralized. Smart meters will allow consumers to better manage their energy usage by providing more detailed information about their consumption with the opportunity to save money on their power bill and reduce greenhouse gas emissions.

*7.2. Presence-Based Power.* With presence-based power the supply of energy follows the user not the appliance. For example, lighting and heating could be switched off when the last person leaves the room.

*7.3. Decentralized Business District.* With broadband to every house, it will be easy to work from home. This would require less travel, which saves traveling cost and also reduces $CO_2$ emission by cars. Humans require interaction but a lot of unnecessary travel can be avoided with the use of broadband with the advantage of having less greenhouse gas emissions.

*7.4. Personalized Public Transport.* A personalized public transport system uses on-call public transport vehicles which act as feeders into the public transport system. Using this system, commuters can get accurate information about transport system, updated timetable and will be more convenient. Wireless on-call broadband can implement the use of personalized public transport for commuters placing less reliance on private car use as well as increasing flexibility for the user and reducing waiting times.

*7.5. Real-Time Freight Management.* Wireless broadband can be used to monitor freight vehicles in real time. Wireless sensors or RFID (Radio Frequency Identification) can be used to keep track of freight distribution and can estimate accurate travel times for these goods. This system minimizes travel time and increases overall fuel economy thus reducing the freight industries carbon footprint.

*7.6. Increased Renewable Energy.* Renewable energy sources such as wind power and solar panels constantly produce varying amounts of power. Broadband networks can monitor this power and better integrate the renewable energy power into the electricity grid (Smart Grid).

*7.7. "On-Live High Definition Video Conferencing".* Traditionally video conferencing has suffered from poor quality especially if trying to communicate over large distances. The advent of broadband networks has made high definition television and video conferencing possible and practical. The environmental benefit of high definition video conferencing is becoming clear as companies are required to do less traveling. Instead of traveling to meetings worldwide, such meetings are being conducted using high definition video conferencing technology. The quality of the high definition video conferencing systems has significantly improved over the years along with good audio and video synchronizations in contrast to previous video conferencing systems. The Australian government has recently invested in a new high definition video conferencing which can save in spent Australian $250 million dollars on air travel and will consequently further reduce the carbon footprint.

## 8. LCA- Life Cycle Assessment

Part of the "Green Network" future is to consider not only the energy efficiency of a network component during its lifetime but to consider the complete life cycle of the component as well.

The life cycle should include the assessment of raw material, production, manufacture, distribution, use, and disposal of the network devices. We must adopt a "lifecycle" approach to product design, manufacture, and disposal.

Table 1: Green Network Standards.

| Standard | Organization | Objectives | Items rated |
|---|---|---|---|
| Energy star rating | Australian government | Set energy rating for household appliances | Household appliances |
| Green Grid | Consortium of IT companies | Define meaningful, user-centric models and metrics | Data center efficiencies |
| Iso 1400 | Iso standards body | Establishe standards for environmental management systems | Environmental auditing, environmental labeling, assessing lifecycles of products |
| Epeat (Electronic Product Environmental Assessment Tool) | "Social benefit" not-for-profit organization | Help purchasers evaluate, compare and select electronic products based on their environmental attributes | Desktop computers, notebooks and desktop monitors based |
| Climate savers | Started by google and intel in 2007 | Reduce computer power consumption by 50% by 2010 | Desktop computers, servers, monitors |

eWaste is another important issue that needs to be considered as part of LCA. Programs such as BYTEBACK are helping to environmentally dispose network devices. Byteback is a free computer take-back program to help people dispose of end-of-life equipment [13].

Responsible computing companies are allowing customers to return end-of-life products at no cost. These programs are compliant with WEEE (Waste Electrical and Electronic Equipment) and ROHS (Restriction of Hazardous Substances) recycling laws [14].

## 9. Green Network Performance Measurements

To enable a "Green Network", we must be able to monitor and measure the savings associated with our green networking strategies in place. A network energy efficiency baseline must be established from which we can measure improvements and compare them with the baseline. We must look at ways to develop meaningful measurements to measure such power savings. In a low carbon "Green Networking" environment, instead of considering bits per second (bps) we might need to consider watts/bit to measure energy inefficiencies or perhaps a better indicator would be bits per $CO_2$ ($b/co_2$).

There are several Government and Non-Government organizations working on and producing "Green Networking" standards. Some of these standards are compulsory and some are voluntary certification programs. Some of these standards include Energy Star Rating, The Green Grid, ISO 1400 Standards, EPEAT, and Climate Savers (as shown in Table 1).

*9.1. Energy Star Rating.* Energy Star is an international standard for energy efficient consumer products. The Australian state and federal governments are considering making Energy Star standards mandatory for computer and monitors sold from October 2009 within Australia. Energy rating labels similar to those on consumer appliances would be attached to computers. Further details can be found in [15].

*9.2. The Green Grid.* The Green Grid [16] had taken up the challenge of developing standards to measure Data Center efficiency, which include both the facility of the Data Center and the IT equipment inside the Data Center.

*9.3. ISO 1400 Standards.* The ISO 1400 environmental management standards [17] exist to help organizations to minimize their impact on the environment. There are several ISO1400 standards. Companies can apply to become ISO1400 accredited similar to being ISO 9000 certified.

*9.4. EPEAT.* EPEAT (Electronic Product Environmental Assessment Tool) [18] is a system to help companies evaluate, compare, and select desktop computers, notebooks, and monitors based on their environmental attributes. EPEAT is a registry with IEEE 1680–2006 complaint products. IEEE 1680–2006 is an IEEE's standard for environmental assessment of personal computer products, including laptop computers, desktop computers, and computer monitors.

*9.5. Climate Savers.* Climate Savers [16] is a nonprofit group of consumers, businesses, and conservation organizations dedicated to promote smart technologies that can improve the power efficiency and reduce the energy consumption of computers.

## 10. Ubiquitous Green Networking

Mark Weiser in [19] introduced the concept of Ubiquitous computing in the 1990s as computing anywhere at any time. In a ubiquitous networking environment, the system makes decisions based on user activity. A ubiquitous sensor network infrastructure consists of sensors that monitor and sample the environment.

*Ubiquitous green networking* can be used to monitor and make decisions about energy use to produce highly efficient systems. Within the home, office, or public spaces, ubiquitous green networking can monitor energy consumption to make intelligent decisions based on user activity to minimize energy use.

IEEE Electronics and Telecommunications is currently developing a Ubiquitous Green Community Control Network Protocol Standard known as IEEE P1888 [20]. According to IEEE, the protocol IEEE P1888 will be used for environmental monitoring and energy consumption management mechanisms to help address energy shortage and environmental degradation through remote surveillance, operation, management, and maintenance.

## 11. Conclusion

The vision of a Green Network is one where we can all have thin clients using low energy consumption, connected via wireless to the Internet, where all our data is securely stored in highly efficient, reliable Data Centers typically running at low energy per Gigabit per second speed. This can also include access to network services from Cloud computing service providers. Whatever the future is, Green Networking will help reduce the carbon footprint of the ICT industry and hopefully lead the way in a cultural shift that all of us need to make if we are to reverse the global warming caused by human emissions of greenhouse gases. Finally, the issue of Efficiency versus Consumption is an interesting argument, that is, efficiency drives consumption. ICT solutions can solve efficiency; it is society that must solve consumption.

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