Chapter 1 : Green IT and Sustainable Software Development 1-1 to 1-53

Syllabus : Green IT Overview : Introduction, Environmental Concerns and Sustainable Development, Environmental Impacts of IT, Green I, Holistic Approach to Greening IT, Greening IT, Applying IT for Enhancing Environmental Sustainability, Green IT Standards and Eco-Labelling of IT , Enterprise Green IT Strategy, Green Washing, Green IT: Burden or Opportunity? Green Devices and Hardware: Introduction, Life Cycle of a Device or Hardware, Reuse, Recycle and Dispose Green Software: Introduction, Processor Power States, Energy-Saving Software Techniques, Evaluating and Measuring Software Impact to Platform Power Sustainable Software Development: Introduction, Current Practices, Sustainable Software, Software Sustainability Attributes, Software Sustainability Metrics, Sustainable Software Methodology, Defining Actions.

UNIT I

CHAPTER 1

Green IT and Sustainable Software Development

Key Features

- Introduces the wave of Green IT.
- Identifies environmental impacts and holistic approach of IT.
- Adopting standardization using Green IT Standards and Eco-Labelling.
- Describes the life cycle of a device.
- Study of device's environmental impacts during its life cycle.
- Discusses methods to reduce energy consumption in software development.
- Lists set of tools to measure energy consumption of software.

Syllabus Topic : Introduction

1.1 Introduction

- Information Technology has influenced the corporate world, society and an entire human life remarkably.
- As a result of this IT infrastructure is growing rapidly. It consumes huge amount of electricity which is responsible for greenhouse gas (GHG) emissions.

- Apart from changing global climate and weather patterns GHG emissions are creating environmental problems like floods, droughts, storms, excessive heat and other natural disasters.
- IT industry is creating lot of environmental problems during manufacturing and disposal of computer hardware.
- We can utilize the power of IT to address environmental issues.
- Green IT can be seen as a savior of these environmental issues.
- Thus it deals with :
  - Study and practice of using Computer systems efficiently with minimal impact on environment.
  - Effective design, manufacture, use and disposal of computer components.
  - Create awareness in IT industry for lowering GHG emissions, improving energy efficiency, using less harmful, reusable and recyclable material.

Syllabus Topic : Environmental Concerns and Sustainable Development

1.2 Environmental Concerns and Sustainable Development

Q. How IT can help in enhancing environment sustainability?

Q. What is environmental sustainability? What factors are used to enhance it?

1.2.1 Environmental Concerns

- Environmental concerns are one of the major challenges we are facing today.
- Our planet is affected by many environmental concerns like global warming, ozone layer depletion, acid rain, pollution and climate change.

- Some of the major environmental concerns are as follows :

1. Pollution

- Water, soil and air pollution are polluting environment and emits toxins leading to hazardous health concerns.
- Waste from industrial and agricultural industries pollutes air, water and soil.

2. Global Warming and Climate Change

- Green House Gas Emissions leads to global warming further leading to climate change.
- Increases in temperature, melting of polar ice are serious consequences of climate change.

3. Ozone layer depletion

- Ozone layer secures earth from harmful ultraviolet rays.
- Ozone layer is severely affected by CFC (ChloroFluoroCarbon) gases found in spray cans and refrigeration units.
- CFC causes holes in ozone layer depleting ozone layer.

4. Natural Disasters

- Natural disasters like earthquakes, floods, tsunamis, cyclones, volcanic eruption are environmental effects of deforestation and industrialization.

5. Health Issues

- Manufacturing of IT hardware involves use of toxic chemicals and compounds posing health related problems.
- Chemicals like cadmium, lead and arsenic affects human body parts like kidney, liver and affects cellular life.

1.2.2 Sustainable Development

- Sustainable development is defined as development that satisfies the needs of the present without compromising the ability of future generations to satisfy theirs.
- It deals with management of human, natural, and economic resources that aims to satisfy the essential needs of humanity in the very long term.
- Certain standards are followed to achieve sustainable development. They are as follows

REACH

- REACH carries four processes namely registration, evaluation, authorization and restriction of certain chemicals to protect human health.
- It puts the responsibility on industries of finding and providing information about chemicals.

WEEE

- It stands for Waste Electrical and Electronic Equipment Directive. This directive is used to address the problem of electrical and electronic waste.
- The responsibility for disposal, recycling and reuse of WEEE is placed on manufacturers.

ROHS

- It stands for Restriction of Hazardous Substance Directive.
- This directive restricts the use of following six hazardous substances in manufacturing of electrical and electronic equipment.
  1. Lead (Pb)
  2. Cadmium (Cd)
  3. Mercury (Hg)
  4. Polybrominated biphenyls (PBB)

5. Polybrominated diphenyl ether (PBDE)
6. Hexavalent chromium (Cr^{6+})

Syllabus Topic : Environmental Impacts of IT

1.3 Environmental Impacts of IT

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Q. What are environmental impacts of IT?

Q. How we can reduce effects of GHG and e-waste on environment?

Computer systems are affecting environment throughout their lifecycle from manufacturing to disposal.

Environmental impacts are as follows :

a. GHG Emissions

- Computer systems consume huge amount of electricity.
- This electricity is generated by burning fossil fuel like coal, gas and oil. They emit greenhouse gas (GHG) that is hazardous to environment.
- GHG consist of carbon dioxide (CO_2), methane, nitrous oxide, CFC gases polluting environment.
- These chemicals lead to global warming that changes global climate and weather pattern.
- GHG emissions can be controlled by reducing power consumption by computer systems.
- Energy conservation methods like turning monitor off, keeping machine in standby mode when not in use reduces power consumption which ultimately reduces GHG emissions.

b. Exposure to toxic chemicals

- Manufacturing of IT hardware involves use of toxic chemicals and compounds posing health related problems.
- Chemicals like cadmium, lead and arsenic affects human body parts like kidney, liver and affects cellular life.

c. e-Waste

- e-waste or electronic waste is any unwanted or damaged electronic/electrical component. It is also called as technotrash.
- Computer manufacturing process produces lot of waste that cannot be disposed easily.
- e-waste are thrown out with regular trash resulting in landfills polluting earth and water.
- It contains non biodegradable material which leaks into the ground causing hazardous effects to plants and water.
- Use of potential disposal and recycling methods can cut down amount of e-waste.

d. Energy Consumption

- All Information and Communication Technology(ICT) devices consume huge amount of energy.
- This energy is generated by using natural resources like trees, fossil fuel, water and coal.
- The energy consumption by ICT devices should be reduced to conserve natural resources.

Syllabus Topic : Holistic Approach to Greening IT

1.4 Holistic Approach to Greening IT

Q. What are different directions of Green IT?

Holistic approach to greening IT can be achieved by focusing on following six directions.

1. Green design

- Design computers and their components in environment friendly way.
- Designers need to ensure that all material used is non hazardous, renewable and eco friendly.

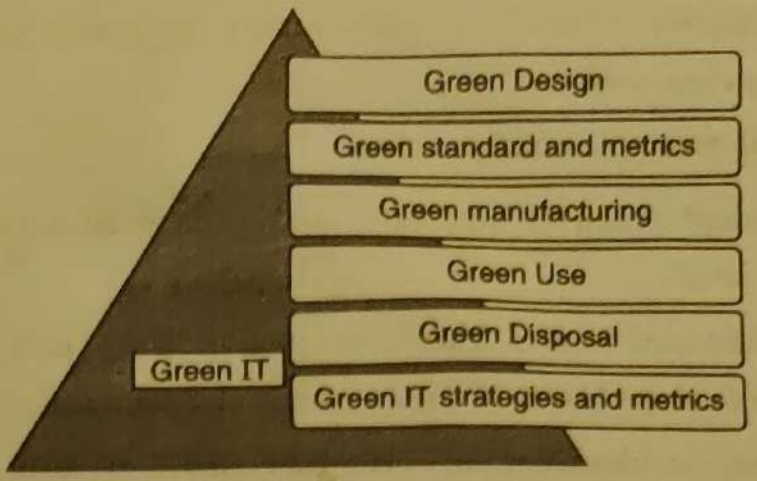

Fig. 1.4.1 : Holistic Approach to Greening IT

2. **Green standard and metrics**
   - Green standards and metrics should be adopted for all promotion of IT services.
   - Green standards like LEED and BREEAM enable environment friendly building design and management.
   - Green metrics like power usage effectiveness (PUE), carbon usage effectiveness (CUE), water usage effectiveness (WUE) are essential to manage data center eco system.
3. **Green manufacturing**
   - All computer systems should be produced so that it has minimal negative impact on environment.
   - It promotes use of less toxic material instead of chemicals like lead, cadmium and arsenic.
4. **Green use**
   - Energy conservation methods like turning monitor off, keeping machine in standby mode when not in use reduces power consumption.
5. **Green Disposal**
   - Upgrade and reuse old computers to minimize e-waste.

- Dispose e-waste in proper way to avoid harmful effects on environment.

6. Green IT strategies and policies

- Adopt green IT strategies and policies to make IT environment friendly.
- Standard bodies like Greenpeace, WWF and Friends of Earth take steps towards environment sustainability.
- Policies like EU code of conduct, LEED criteria, TIA-942 provides guidance to organizations and industries to develop green data center designs.

1.4.1 The Three Rs of Green IT

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Q. What are three Rs of green IT?

Q. Explain greening computer's life cycle.

The three Rs of Green IT are :

1. Reuse :

We should upgrade existing computers and reuse them. Reusing computers can reduce environmental effects caused by computer production and usage.

2. Refurbish :

Refurbishing is replacing some old parts and upgrading computer according to requirement. We can refurbish our computers instead of purchasing new computers.

3. Recycle :

Computers are to be recycled and disposed in environment friendly way. We should hand over non reusable computers to recognized electronic recyclers and e-waste collectors.

We can make IT environment friendly by greening computer's entire life cycle with the help of "Three R's of Green IT".

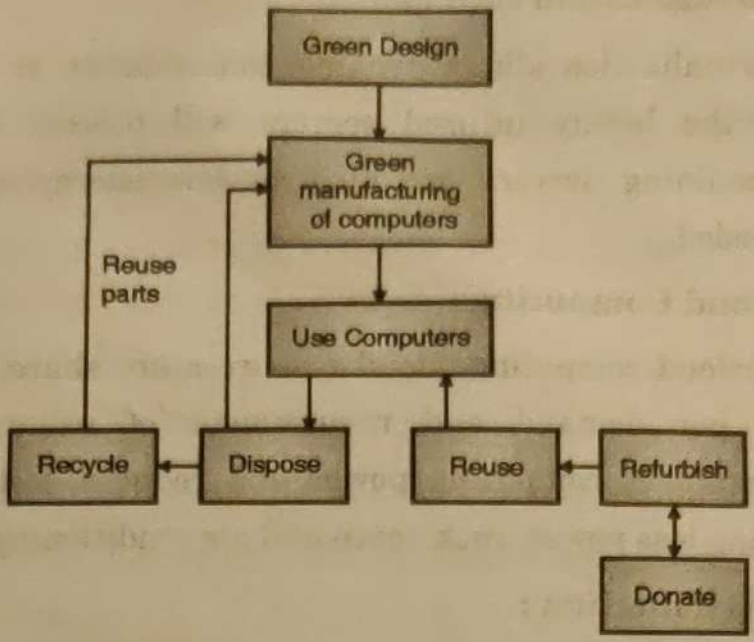

Fig. 1.4.2 : Greening computer's life cycle

Syllabus Topic: Applying IT for Enhancing Environmental Sustainability

1.5 Applying IT for Enhancing Environmental Sustainability

- Environmental sustainability is ability to maintain natural environment that produce renewable resources like water and solar energy to maintain living conditions for people and other species.
- We can make use of IT resources efficiently to enhance environmental sustainability.

1. Data Center Management :

Data center is an integral part of IT industry. It is central repository for data storage and management. It consume huge amount of electricity and emit Co_2. Windenergy and gas turbines can be used to satisfy energy requirements of data centers.

2. Server Power Management :

The most power consuming component of server is CPU. CPU energy efficient techniques are used to increase computing power of CPU.

3. Virtualization :

Virtualization allows dynamic consolidation of workloads. Some of the highly utilized servers will process workloads while remaining servers are kept in low energy sleep state until needed.

4. Cloud Computing :

In cloud computing, cloud resources are shared and reallocated as per demand and requirement of users. This approach maximizes computing power and reduces cost of resources by using less power, rack space and air conditioning.

5. Consolidation :

Data center consolidation is combining number of servers into a compact cost efficient system. It physically consolidates multiple data centers into large single effective data center that runs on fewer resources.

Syllabus Topic : Green IT Standards and Eco-Labeling

1.6 Green IT Standards and Eco-Labeling

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Q. What are green IT standards?

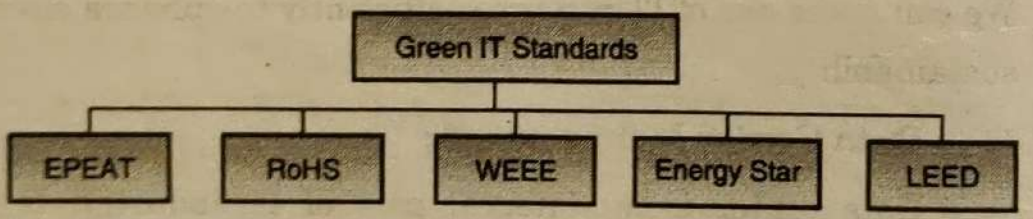

Fig. 1.6.1 : Green IT standards

Green IT standards to promote standardization are as follows :

1. EPEAT

- It stands for Electronic Product Environmental Assessment Tools.
- It is managed by Green electronics council.

- It is used to compare and evaluate computer systems based on their environmental attributes.
- EPEAT registered products have less negative environmental effects across their lifecycle.
- Many industries, business and government organizations trust EPEAT to take eco friendly decisions.
- EPEAT registered products must meet certain environmental measures known as criteria.
- There are two types of criteria, optional and required.
- EPEAT products are measured against optional and required criteria.
- Any EPEAT product must meet all required criteria to be entered in registry.
- These products are classified as bronze, silver and gold depending on number of optional criteria they meet.
  - Bronze
  - All required criteria.
  - Silver
  - All required criteria and at least 50% of the optional criteria.
  - Gold
  - All required criteria and at least 75% of the optional criteria.

2. RoHS

- RoHS is "Restriction of Hazardous Substance Directive".
- This directive restricts the use of following six hazardous substances in manufacturing of electrical and electronic equipment.
  a. Lead (Pb)

b. Cadmium (Cd)

c. Mercury (Hg)

d. Polybrominated biphenyls (PBB)

e. Polybrominated diphenyl ether (PBDE)

f. Hexavalent chromium (Cr6+)

- IT equipments currently covered under RoHS are mainframes, minicomputers, servers, routers, PCs, Laptops, notebooks, notepads, typewriters, calculators, telex and telephones.
- RoHS can put the limit for usage of particular substance in any equipment.
- For example RoHS puts the threshold of 0.01% on cadmium level as it harms human kidney. Cadmium is used as stabilizer or coloring agent in plastics.
- If equipment contains cadmium lower than 0.01% then equipment is compliant, otherwise non compliant.

3. WEEE

- WEEE is a complex mixture of components like cell phones, computers, TVs etc. containing hazardous material affecting human health.
- To address this problem WEEE directive is formed by European Commission.
- WEEE Directive is "Waste Electrical and Electronic Equipment Directive".
- This directive is used to address the problem of electrical and electronic waste.
- WEEE in addition with RoHS became European law in 2003 to restrict the use of hazardous material and recycling of electronic waste.

4. Energy Star

- It is an international standard for energy efficient consumer products.
- It guides consumers to identify and buy energy efficient products that reduce GHG and other pollutants.
- EPA establishes certain following specifications for a product to gain Energy Star rating.
  - Product must contribute to significant energy savings.
  - Consumers must be satisfied by the delivered products.
  - Product's performance and energy consumption should be measured and tested.

5. LEED

- It stands for Leadership in Energy and Environmental Design.
- It is green building certification program that recognizes best building strategies and practices.
- LEED uses five rating system
  a. Building Design and Construction
  b. Interior Design and Construction
  c. Building operation and maintenance.
  d. Neighborhood development
  e. Homes

  Each of this rating system consists of various combinations of categories.
- The number of points gained determines level of certification in LEED. Level of certification are
  a. Certified
  b. Silver
  c. Gold
  d. Platinum

Syllabus Topic : Enterprise Green IT Strategy

1.7 Enterprise Green IT Strategy

Q. What are green IT strategies?

Enterprises can take following approaches to implement green IT strategy.

1. **Strategic approach**
   - Enterprise reviews its IT infrastructure from environmental perspective.
   - It then identifies and deploys energy efficient and environment friendly computing system.
   - It implements new policies on e-waste disposal, reducing GHG emissions and use of resources efficiently.
2. **Tactical Incremental approach**
   - Enterprise incorporates energy saving measures such as switching off computers when not in use and preserves existing IT infrastructure.
   - It implements practices like power management, use of energy efficient bulbs, maintaining optimal room temperature to achieve green goals.
3. **Deep green approach**
   - It adopts green approach like using solar and wind energy to reduce energy consumption.
   - Planting trees is another deep green approach to neutralize GHG emissions.

Syllabus Topic : Green Washing

1.8 Green Washing

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Q. Explain green washing with example.

- Green washing is promoting company's products deceptively in the aim of manufacturing environment friendly products.
- A company or an organization claims to be green through advertisement but they are not actually following green standards.
- It is an unethical practice that misguides customers about organization's environmental practices, products and services.
- It creates green image of a company or an organization as company exaggerates their green credentials.
- The term "greenwashing" is created by Jay Westervelt in 1986 when he found that many hotels claim to be green by telling customers to reuse towels and bed sheets but actually taking very less efforts towards saving environment.
- Other examples includes grocery store claiming collecting plastic bags that were used for packing or bank telling to conduct transactions online instead of physically visiting banks.
- Federal trade commission (FTC) designs guidelines for companies and organizations to ensure that the claims for their environmental products are true and non deceptive.
- In Developed countries like United States, Australia, Canada, green washing is liable for punishment.

Syllabus Topic : Green IT : Burden or Opportunity

1.9 Green IT : Burden or Opportunity

Q. Discuss with example how green IT act as an opportunity to Computer world?

- Green IT provides an opportunity to use our IT systems in environment friendly way. It guides us to use computer systems in energy efficient way by reducing power consumption, GHG emissions and effective use of IT resources.
- Many IT professionals and users consider Green IT a burden as many of them are not aware of benefits of Green IT initiative.

- So IT professionals need to look "Green IT" as an opportunity by developing environmentally sustainable IT solutions.
- These environmentally sustainable IT solutions must be economic and safeguard environment for future generations.
- Green IT has become necessity to save mother earth from harmful GHG and other toxic emissions.

Syllabus Topic : Green Devices and Hardware : Introduction

1.10 Green Devices and Hardware : Introduction

Q. What are green IT devices? How they are environment friendly?

- Green devices and hardware have less negative impact on environment as compared to non green devices and other electronic equipments.
- Green IT deals with IT hardware in a manner in which it is procured and operated.
- Green devices and hardware potentially reduces carbon emissions by following Green IT practices.
- Some of the Green IT devices and hardware are as follows :

1. Data Servers

- Data server is central repository for data storage and management.
- It provides services to other computers in network.
- It shares data, hardware and software resources among clients.
- Free air cooling, use of renewable energy resources are used to avoid heavy use of electricity in data servers.

2. End user computers

- It includes desktops, laptops and notebook computers.
- Laptops and desktops can be made green by using three Rs of green IT i.e. Reuse, Recycle and Refurbish.

3. Mobile devices

- Mobile devices like tablet, phones and PDAs are extensively used by IT professionals.
- Mobile devices must follow proper charging mechanism to consume less power and reuse-recycle-refurbish policy when device becomes outdated.

4. Peripherals

- It includes printers, scanners, tape drives, digital cameras and webcams.
- Efficient and smart use of these devices (less use of ribbons, paper and ink) makes them eco friendly.

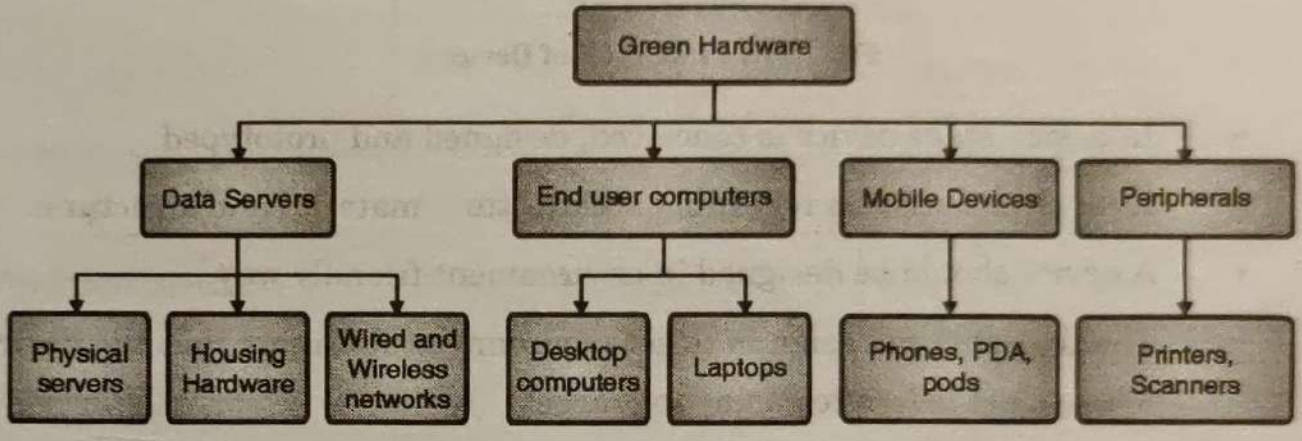

Fig. 1.10.1 : Green Hardware

Syllabus Topic : Life Cycle of A Device or Hardware

1.11 Life Cycle of A Device or Hardware

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Q. What are various stages in life cycle of a device?

The life cycle of a device consists of five stages :

1. Design
2. Manufacture and facilities.
3. Packaging and transportation

4. Usage
5. Reuse or Disposal

1.11.1 Design

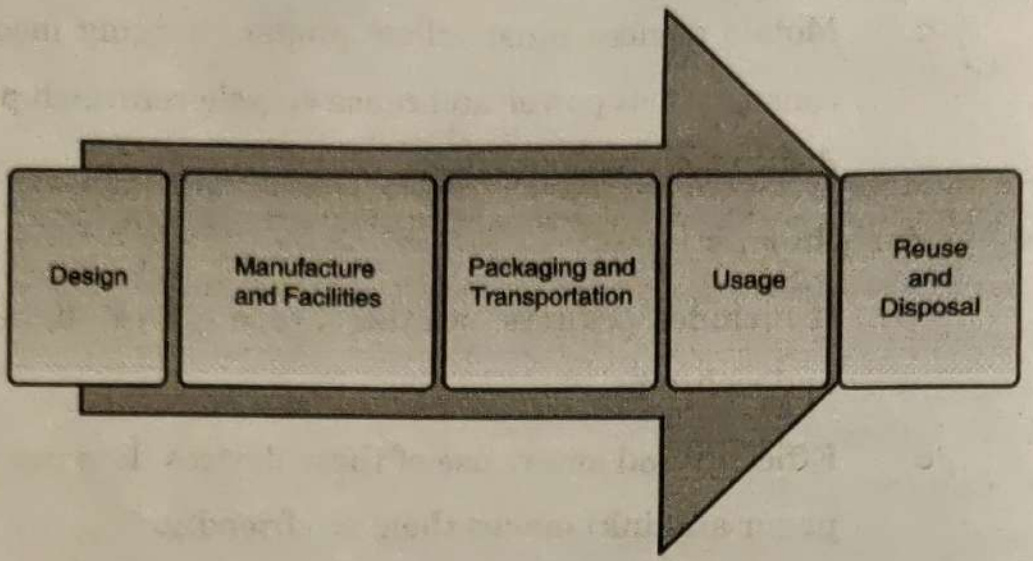

Fig. 1.11.1 : Life cycle of Device

- In design stage device is conceived, designed and prototyped.
- It involves decisions regarding architecture, material and structure.
- A device should be designed in environment friendly way.
- The first step in design is to set environmental targets that the device has to meet before releasing to market.
- The device goes through various stages in its life cycle.
- Assessment should be performed at every stage of life cycle from manufacturing to transportation to estimate environmental impact.
- Design options are decided on the basis of Environmental impacts identified in assessment.

1.11.2 Manufacturing

Q. Which chemicals are used in manufacturing of any electronic device? How they affect human body?

- Manufacturing of devices consume lot of natural resources like water, energy. They also create waste which contains toxic elements.

- Manufacturing of electronic devices uses hazardous materials like lead, cadmium, mercury, hexavalent chromium, polybrominated biphenyls, arsenic, polyvinyl chloride, polybrominated diphenyls.
- There usage and adverse effects on human health is as follows.

Material	Effects	Used in
Cadmium	Liver and kidney malfunctioning	Soldering, plating, contact buttons
Lead	Affects kidneys, hematopoietic and nervous system	Monitors, circuits and motherboards
Mercury	Affects nervous and immune system	Batteries and monitors
polyvinyl chloride	Affects human reproductive system	Various computer parts
Arsenic	Affects cellular system	Semiconductors
Polybrominated biphenyls, polybrominated diphenyls	Affects reproductive system	Flame retardants, computer components

1.11.3 Packaging and Transportation

Q. List guidelines for packaging and transportation given by US Environmental Protection Agency 2011.

The US Environmental Protection Agency 2011 gives certain guidelines for packaging and transportation. They are as follows.

- The size of device affects amount of packaging required, so size of device should be as compact as possible.
- The quantity of material required for packaging should be minimum.
- Recyclable packaging material should be used.

- Folds and tabs should be used instead of adhesives.
- Online documentation should be provided for device instead of printed documentation.
- Adhesives, inks and coating required for packaging should be eco friendly.
- Compact design of devices facilitates smart transportation as more number of devices can be transported in less number of vehicles.

1.11.4 Use

Any device consumes considerable amount of energy when in use. This energy consumption has adverse effects on environment. All computer components should be used in energy efficient manner. The energy requirements of different electronic devices are different. Some of them are as follows :

1. Notebook Computers

Q. What are energy consumable parts in notebook computers ?

The energy consumable parts in notebook computers are :

- **Charger**

  The charger should be disconnected from the power socket when not in use to save power.

- **Monitors**
  - A brighter screen consumes more power so brightness of monitor can be reduced to appropriate level.
  - Switch off monitor when not in use.
- **Processor**
  - A processor has many applications and processes running in background.
  - Stop background processes and other applications when not in use.

- The laptop takes more time to boot if more number of processes is set at start up, so they must be kept to minimum number.
- Run the processor at lower frequency to save power.

- **Hard Disk**
  - Being a physical device, hard disk consumes lot of power. Hence it should be used only when required.
  - Hard disk spinning consumes lot of energy, so defragment hard disk which lessens the spinning of hard disk.
  - Use solid state drives(SSDs) as they consume less energy than hard disk drives(HDDs)
  - Apply power saving options that switch off hard disk when not in use.
- **Peripheral devices**

  Unplug peripheral devices as they consume power even when not in use.
- **Power Modes**

  Notebook computers operate in two power modes.

  a. **Stand-by :** This mode retains the state of system whereas internal devices and optical drives are powered off.

  b. **Hibernate Mode :** It shuts down laptop completely but still retains its powered on state. It takes more time to resume in this mode.
- Power management software allows users to set timings when computers can automatically go to stand by or hibernate mode.

2. Desktop Computers

- Desktop computers are fixed machines at a single location.
- We can use following strategies to reduce power consumption in desktop computers.

- CRT monitors in these machines can be replaced by LCD or LED as CRT consumes lot of power.
- Stop background processes and other applications when not in use.
- Run the processor at lower frequency.
- Hard disk should be used only when required.
- Hard disk spinning consumes lot of energy, so defragment hard disk which lessens the spinning of hard disk.
- Avoid having desktops switched on all the time.
- For this Remote wake up methodologies have been devised.
- Magic packet technology commonly referred as Wake On LAN (WOL) is used to achieve remote wake up methodology.
- In this technology, Network Interface Controller (NIC) wakes up the computer from any remote location, removing the need to have desktops switched on all the time.
- Tools like Night Watchman help enterprises to centrally and remotely power down desktops.

3. Servers

- Server computers provide services to other computers in the network.
- File Servers, Web servers and database servers are all server computers with powerful CPUs and large amount of memory.
- Server computers consume large amount of power as they are continuously in power on mode.
- Better cooling mechanisms are required to save power as they generate large amount of heat.

4. Mobile Devices

- All mobile devices like PDAs, mobile phones use rechargeable battery charged by external chargers.

- Chargers should be unplugged when not in use as they consume power even when they are not charging battery.

5. **Specialized Devices**

Specialized devices like set top boxes, play stations, X-ray machines, CT scanners should be unplugged when not in use as they consume lot of power in power on mode.

Syllabus Topic : Reuse Recycle and Dispose

1.12 Reuse, Recycle and Dispose

Q. What are e-waste disposal techniques?

Reuse

- e-waste is a big threat to environment as it contains toxic chemicals and leads to landfills.
- It can be reduced by increasing the lifespan of devices.
- Reusing computers increases life span of computer.
- Once the device becomes obsolete, send it to refurbisher who will make sure that the device is in working state and send it to needy institutions.
- Upgrade computer or parts of it to use computer to its fullest life.

Recycle

- In recycling, original's device material is reused as raw material to build new device, resulting in less waste.
- Recycling programs like Take-back, mail-in, trade-in programs are used to return devices back to manufacturers.
- Local recycling events are conducted by many companies to create awareness about recycling.
- Many developed countries send e-waste to developing countries like India and China as the cost of recycling is less in these developing countries.

- Awareness should be created among laborers of these developing countries so that they adopt healthy e-waste recycling process.

Dispose

- When a device cannot be reused and recycled it should be disposed.
- Standard practices like incineration, chemical decomposition should be used for proper disposal of e-waste.
- Incineration is a kind of thermal treatment that carries combustion of organic substances in waste material.
- It converts waste material to ash, heat and gas that is further used to generate energy.

Syllabus Topic : Green Software : Introduction, Process Power State

1.13 Green Software : Introduction

Q. What are processor power states?

Q. What are various C-states?

- A computing platform consists of hardware, software and other technologies that allow software to work.
- To make progress in improving energy efficiency, we must focus on software.
- The main component to target for improvement is processor power state. It is of two types :

1. **C-state**
    - It defines the degree to which CPU is sleeping.
    - It starts at C0 where CPU is 100% turned ON. Higher the number deeper is the sleep mode and so more time CPU will take to wake up. Various C- states are as follows.

Mode	Function
C0	CPU is in operating state.
C1	CPU's clocks are halted via software.
C2	CPU's clocks are halted via hardware.
C3	CPU is in sleep mode by stopping clocks and reducing voltage.
C4	Deeper sleep mode.
C5	Enhanced deeper sleep mode by reducing voltage and turning off memory cache.
C6	CPU in deep power down mode.

2. P-state

- It defines the frequency at which processor is running.
- P state save energy by following equation

$$P = CV^2f$$

Where P = Power required to run CPU

C = Capacitance

V = Voltage

f = frequency

- P states are of following types

P states	Function
P0	Processor runs with maximum power and frequency.
P1	Power and frequency is scaled down than P0.
Pn	Processor runs with minimum power and frequency.

Syllabus Topic : Energy-Saving Software Techniques

1.14 Energy-Saving Software Techniques

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Q. How computational efficiency is achieved?

Q. Which software techniques are used for energy saving ?

- Well behaved software helps energy saving software to work.
- The software can be idle or active.

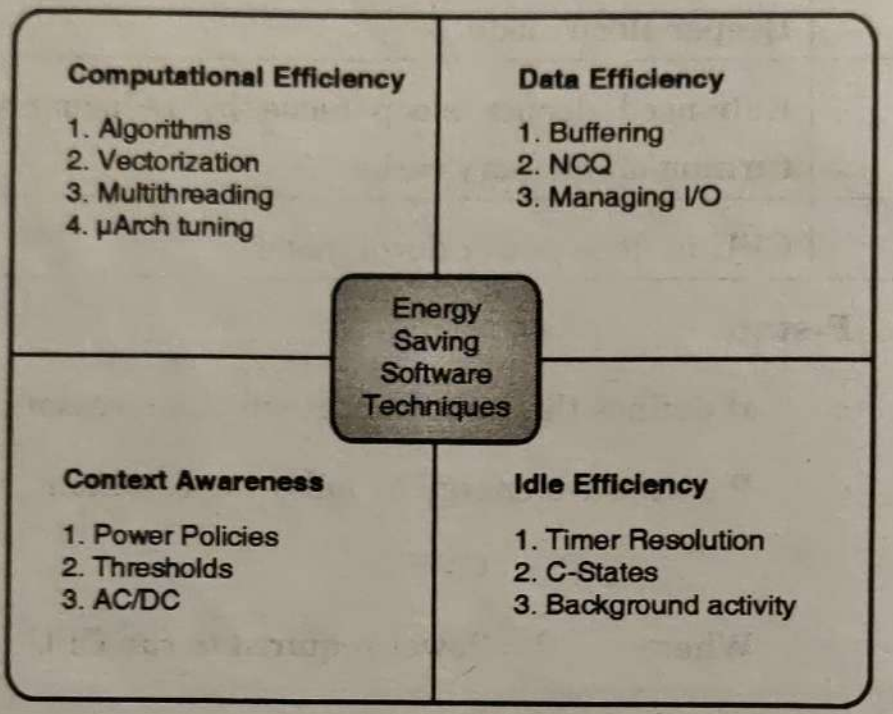

Fig. 1.14.1 : Energy saving software techniques

- Active software is busy in multiple tasks such as computing, browsing, playing movie or music.
- Idle software is waiting for an event to make it active.
- For example DVD is in idle state when it is not playing music but becomes active when resumes playing music.
- Energy saving software techniques are as shown in Fig. 1.14.1.

1.14.1 Computational Efficiency

Computational efficiency is completing the task quickly with minimal energy consumption.

It is achieved by using following techniques :

1. **Efficient Algorithms**
   - Use algorithm or functions instead of script as algorithms are faster.
   - Choice of algorithms and data structures makes a difference in application's performance.
   - The best algorithm to solve a given problem is decided on the basis of architecture, design and data structures.
   - A certain problem may be solved in better way with B trees than hash function or binary trees.
   - An algorithm that takes O(n log n)time to complete job performs better than algorithm with $O(n^2)$time.
   - Prefer modular programming, local functions over nested functions to increase computational efficiency.
   - A better algorithm saves time and energy.
2. **Vectorization**
   - Vectorization gives better power benefits by using Single Instruction Multiple Data (SIMD) for instruction level data parallelism.
   - Vectorized code is usually without loops and shorter. Hence it is less error prone and easy to understand.
   - It runs faster than other codes containing loops.
3. **Multithreading**
   - Multithreading saves time and energy as in multithreading processor runs multiple threads or processes simultaneously.
   - To complete any workload, multithreaded runs takes less energy than single thread.

- To achieve better energy efficiency multithreading methodologies and libraries like OpenCL, OpenMP and Thread Building Blocks are used.

1.14.2 Data Efficiency

Data efficiency is achieved by :

1. **Pre-fetching and caching (Buffering)**

   Pre-fetching and caching saves energy. Data efficiency is achieved during DVD playback by adopting following techniques.

   a. Allow OS to set required P-state and adjust CPU frequency.

   b. Use buffering technique to reduce power consumption by DVD. It stores data in temporary memory in advance to speed up processing.

   c. Minimize read accesses and spinning of DVD.

2. **Managing Disk I/O**

   - The performance characteristic of hard disk drive is affected by seek time, rotational latency, rotational speed and sustainable transfer rate.
   - It also depends on physical location of data on drive. More data can be read from outermost perimeter of disk than inner perimeter.
   - Low processor utilization and less energy consumption are achieved in following ways.
     - Read data in larger chunks.
     - Use asynchronous I/O with native command queuing (NCQ).
     - In multimedia playback, cache media and read ahead.
     - Use contiguous file than fragmented file for reading.
     - In multithreading, provide access to shared data.

1.14.3 Context Awareness

Q. What is context awareness? How it helps software to save energy ?

- Context awareness is developing application software that adapt to changes in environment.
- A PC gives warning when battery is about to be discharged, A mobile device writes data to flash memory in low battery, adjusts display brightness automatically are some of the examples of context aware behavior.
- Embedded systems use sensors to incorporate context aware behavior.
- Sensors like light sensors, gyros, accelerometers, GPS receivers are widely used in handheld devices like mobile phones and tablets.
- Software can take advantages of context awareness in following ways.

1. Power Source awareness

- A notebook PC can tailor its operational modes according to power source(Ac power or battery).
- Application can register for event notification which notifies when power is switched from AC to DC or battery threshold is reached.

2. Platform power policies

- Software can use power policies in following ways:
  a. Change application behavior to change in power policy.
  b. Adjust application behavior according to user's current power policy.
  c. Change suitable power policy to match application behavior.
- Microsoft Windows allows user to select power policy from options like "High performance", "Balanced" and power saver.

3. **Other context aware behaviors**

- Information about status of other components such as USB, Bluetooth, network cards is useful for intelligent application behavior and energy savings.
- LAN cards and set top boxes remain active for longer time period. To reduce energy consumption by these devices, SENS (System Event Notification Service) API can be used to check if network connection is still alive.
- SENS provides unique set of connectivity functions and interfaces to applications.
- There are context aware services that send notification when connection is lost or gained.

1.14.4 Idle Efficiency

Q. How we can achieve idle efficiency?

The power consumed by mobile when in running state but not actually executing workloads is called as idle power. The application's idle efficiency can be increased in following manner.

1. **OS Timer Resolution**

- Timer resolution is time period when OS receives a clock interrupt from system timer hardware.
- Set system timer interval to more than 10 ms.
- System timer interval less than 10 ms is ineffective in reducing system power consumption and battery life suffers.
- Use lowest timer resolution that meets the performance requirements of application.
- In case of high-resolution periodic timer, increase the timer resolution only when application is active. Disable the periodic timer when task is completed.

- Use time-BeginPeriod Multimedia timer API and NtSetTimerResolution low level API instead of using ApIs that shorten the timer period.

2. **Deep C-state Residency**

- Keep the platform in deeper C-states for long duration.
- Minimize number of C-state transitions as frequent C-state transitions are not energy efficient.
- C-state transitions can be reduced by not splitting task in processes and threads.
- Applications must combine their activities to increase idle period residency.

3. **Background activity**

- Frequent background activities like antivirus scan, disk defragmentation consume huge amount of power.
- The unified background process manager (UBPM) schedules these background tasks to minimize power consumption.
- UBPM also enables trigger start services based on environmental changes like device removal or arrival, IP address change etc.
- Other powers saving techniques are as follows.

a. Timer coalescing: It reduces CPU power consumption by reducing the number of transitions of CPU to and from idle state.

b. Intelligent Timer Tick distribution (ITTD): ITTD does not wake application processors unless software timers are expiring or hardware interrupt occurs. Thus application processors remain in idle state for longer duration, this saves power and energy.

c. Elimination of transmission control protocol (TCP) and distributed program call (DPC) on every system timer interrupt.

Syllabus Topic : Evaluating and Measuring Software Impact to Platform Power

1.15 Evaluating and Measuring Software Impact to Platform Power

Q. What tools are used to measure software impact to platform power ?

Various tools are used to get estimate of power consumed by mobile platform.

1.15.1 DAQ Tools

- Data acquisition tool (DAQ) logs granular power measurement for hardware components.
- The Fluke NetDAQ belongs to family of DAQ tools and measures power consumption while running different applications on the system.
- The NetDAQ modules are connected to target machine via cross over network cable.
- The target machine has sense registers on motherboard.
- NetDAQ measures current and voltage drop across sense registers.
- NetDAQ logger software collects the measured current and voltage to calculate average power(W).
- This system connects directly into existing network saving cost of new network set up.
- It allows multiple users to access data simultaneously.

1.15.2 Software Tools

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Q. What software tools are used to create energy efficient apps and platform?

The software tools to create energy efficient apps and platform are as follows :

1. **Power Informer**
   - It is developed by Intel Corporation to provide basic statistics of power consumption by system.

- It gives information about disk and file I/O, battery and power status, percentage time and average residency of C1, C2, C3 states of the system, system calls per second, interrupt rate of system.

2. Windows 7 PowerCfg

- Windows 7 uses powercfg (power configuration) utility for managing power options from command line.
- It reports problem regarding system's energy consumption over a 60s period.
- Some of the problems reported by powercfg are as follows :
  - Power policy settings such as idle timeouts, wireless power save mode.
  - Battery capacity like full charge capacity or design capacity
  - Power request like sleep, display.
  - Platform capabilities like display dimming capability, active state power management status (ASPM) and sleep state availability.
  - Processor utilization
  - Platform timer resolution requests.

3. Energy Checker

- Energy Checker is developed by Intel Corporation.
- It helps to measure software energy efficiency and to develop energy aware software.
- Energy checker consists of functions that imports and exports counter.
- A counter stores number of times a particular event has occurred.
- Energy checker tool help managers and application developers to match this function containing counters to amount of energy consumed.

- It also provides APIs that calculates "useful work" done by an application.
- Energy Checker SDK measures energy consumed by software with the help of "Power Analyzer" which measures electrical power characteristics of device.

Syllabus Topic : Sustainable Software Development : Introduction

1.16 Sustainable Software Development : Introduction

Q. What is sustainable software development?

- A software development lifecycle divides software development in various phases like requirement gathering, design, implementation, testing, deployment and maintenance.
- However, increase in carbon footprint, use of paper, power usage, air conditioning and other activities carried out in these phases harm the environment directly or indirectly.
- Many PCs required during software development are considered obsolete as they do not support software upgrades.
- These obsolete computers are not properly disposed leading to landfills polluting air and water.
- Ill designed software requires training to people and distribution of training material in terms of hard copies which increases software's carbon foot print.
- To avoid this sustainability is integrated in every stage software development.
- Thus sustainable software development is a process of developing sustainable software so that it has minimal impact on environment to maintain sufficient eco balance.
- In sustainable software development, software engineering process is continuously assessed, documented and used for further improvement

in product so that it has less negative impacts on environment, society and economy.

Syllabus Topic : Current Practices

1.17 Current Practices

Q. What are the current best practices to maintain software sustainability?

- Currently software sustainability focuses on maintenance of legacy systems and they do not focus on environmental, economic and social aspects of software sustainability.
- One of the practices is environmental accounting in which software project team keep track of the resources used in project to assess their environmental impact.
- Other practice is to estimate resources used by team members such as paper, travel, meetings and conferences.
- This estimated impact is then converted to cash amount and reinvested in environmental projects.
- Some industries proposed a GREENSOFT model which includes cradle to grave product life cycle model for software.

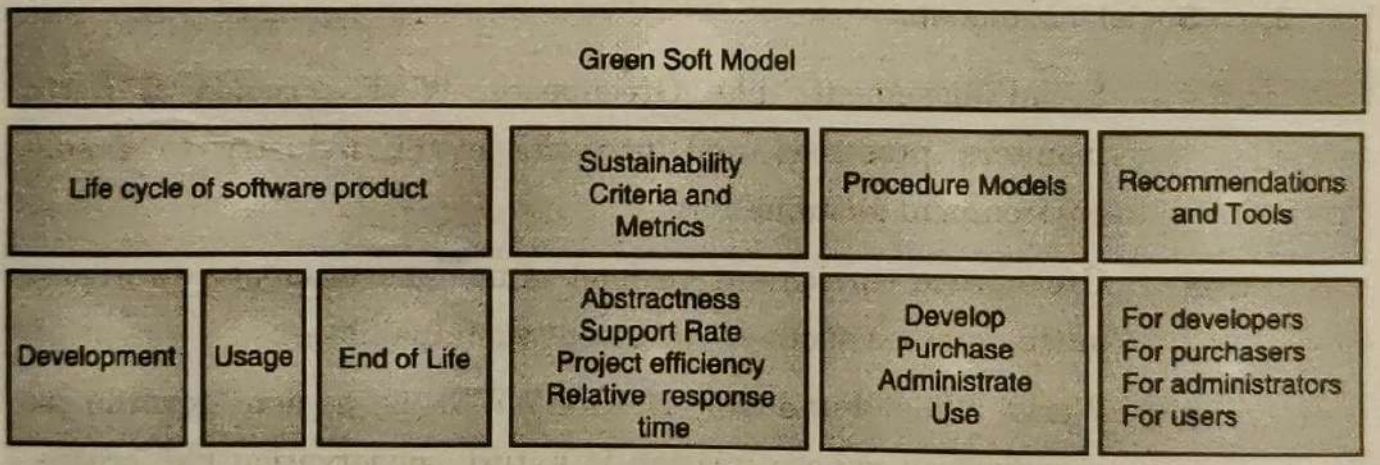

Fig. 1.17.1

Apart from Green soft model following practices are widely used.

1. **Industry standards**

- Industry standards like Energy star, RoHS, IBM green sigma are used during computer hardware life cycle that reduces energy usage.
- RoHS can put the limit for usage of particular substance in any equipment.
- Energy star helps consumers to identify energy efficient product that saves bills without sacrificing quality of product.

2. **Regulatory bodies**

- Regulatory bodies for green data centers like Green Grid, EU, LBNL and TIA are used.
- EU code of conduct aims to develop and promote metrics and practices to minimize energy consumption and GHG emissions in data centers.
- Green grid delivers set of tools and metrics to determine and compare data center efficiency.
- TIA develops consensus based industry standards for ICT products.

3. **Social movements**

- Social movements like Greenpeace, WWF, Friends of Earth monitors processes and products of IT industry to ensure environment sustainability.
- Greenpeace carries out various campaigns to create awareness among masses about environment sustainability.
- World Wide Fund for Nature(WWF) is a non government organization, whose mission is nature conservation like oceans, forests, coasts.

- Friends of earth's main motive were to drive campaign against nuclear energy and targets companies who are not environmentally responsible.

Syllabus Topic : Sustainable Software

1.18 Sustainable Software

MU - April 2017

Q. What is sustainable software?

Q. Why sustainability should be integrated in software development life cycle?

- Sustainable software is software with minimal environmental impact and sufficient eco balance.
- Quality, security and other features are built into a software product to ensure overall quality of product.
- In the same way, sustainability should also be integrated into software development life cycle to build environment friendly product.
- To promote sustainability ideals, sustainability metrics like reusability, portability, usability etc. are used.
- They can be incorporated into any software development model to form software sustainable methodology.
- The sustainable software is expected to support following three properties.

1. **Long Lasting Software :** It should be able to cope with changes to create long lasting software.
2. **Lean Software :** It should have minimal impact on environment by reducing e-waste and power consumption.
3. **Sustainable human behavior :** Sustainable software must be designed considering its impact on human sustainability. For example use of online sites to submit bills to reduce use of papers.

- These properties are known as Software sustainable methodology and are integrated at the end of software life cycle.
- It measures sustainability performance of product in successive releases.
- It includes three steps :
  1. Collect metrics at the end of software development life cycle.
  2. Analyze metrics on the grounds of environmental, economic and social benefits.
  3. Prepare refined action plan for next development life cycle.

Syllabus Topic : Software Sustainability Attributes

1.19 Software Sustainability Attributes

Q. What attributes are used to evaluate sustainability performance of a given software system?

Software sustainability attributes evaluate sustainability performance of software system. They are as follows :

1. **Usage related attributes :** These attributes measures usage of system at execution time.
   - **a. Usability :** It indicates user friendliness of system.
   - **b. Dependability :** It indicates reliability of system.
   - **c. Accessibility :** It indicates ability of system to provide easy access to users irrespective of user's location or device used.
   - **d. Performance :** It indicates efficiency of system in responding to user's request.
2. **Process related attributes :**
   - **a. Efficiency :** It indicates the required efforts to deliver product in least amount of time.
   - **b. Predictability :** It measures the ability to predict cost and efforts required to develop software product.

c. **Project carbon footprint :** It measures amount of carbon emitted during software development.

3. **Development related attributes :**
   a. **Reusability :** It measures the number of reusable components in a system.
   b. **Portability :** It indicates the ability of system to work on various platforms.
   c. **Modifiability :** It indicates the ability to change.
   d. **Supportability :** It indicates the ability to reconfigure for deployment.

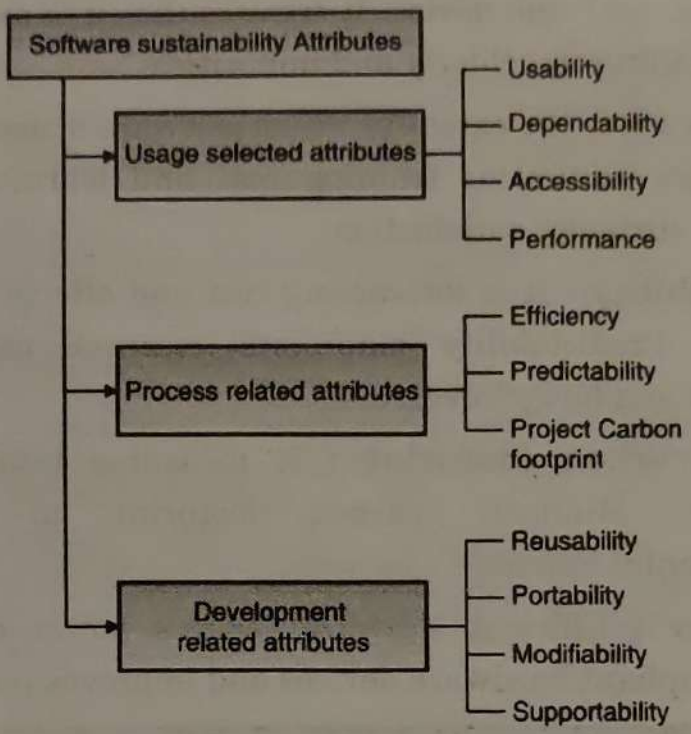

Fig. 1.19.1 : Software sustainability attributes

Software attributes that bring environmental, economic and social benefits are :

1. **Portability :** It indicates the ability of system to work on various platforms. This attribute increases flexibility and minimize e-waste by extending the life span of old hardware.
2. **Reusability :** Extent to which software can be reused in other applications. It reduces e-waste as reusable components can be used in other systems.

3. **Modifiability :** Modifiable software can be used in other platforms so it generates less e-waste.
4. **Performance :** The software performing efficiently reduces e-waste as it can perform on any obsolete machine. It minimizes resource consumption and reduces technology adoption cost.
5. **Supportability :** It reduces use of books, other resources and training required to operate the system.
6. **Dependability :** It is ability of a system to be relied on.

   It minimizes resource consumption and maintenance cost.
7. **Accessibility :** It is ability of system to be accessible to all irrespective of location, time and device. It ensures that it is available to all people including illiterate, elderly and minorities.
8. **Usability :** It is the extent to which software is user friendly. Usability of software minimizes training cost and learning barriers. It also increases customer satisfaction.
9. **Predictability :** It is forecasting cost and efforts required to develop software. Predictability minimizes resource usage in emergency situations and budget overruns.
10. **Project carbon footprint :** It measures total amount of GHG emissions. Minimize carbon footprint to avoid hazardous environmental impact.
11. **Efficiency :** Efficient software reduces power consumption by its power compliant hardware devices and improves productivity.

Syllabus Topic : Software Sustainability Metrics

1.20 Software Sustainability Metrics

Q. What metrics are used to assess greenness and improvements in environmental performance?

Fig. 1.20.1 gives the list of software sustainability metrics for sustainability attributes.

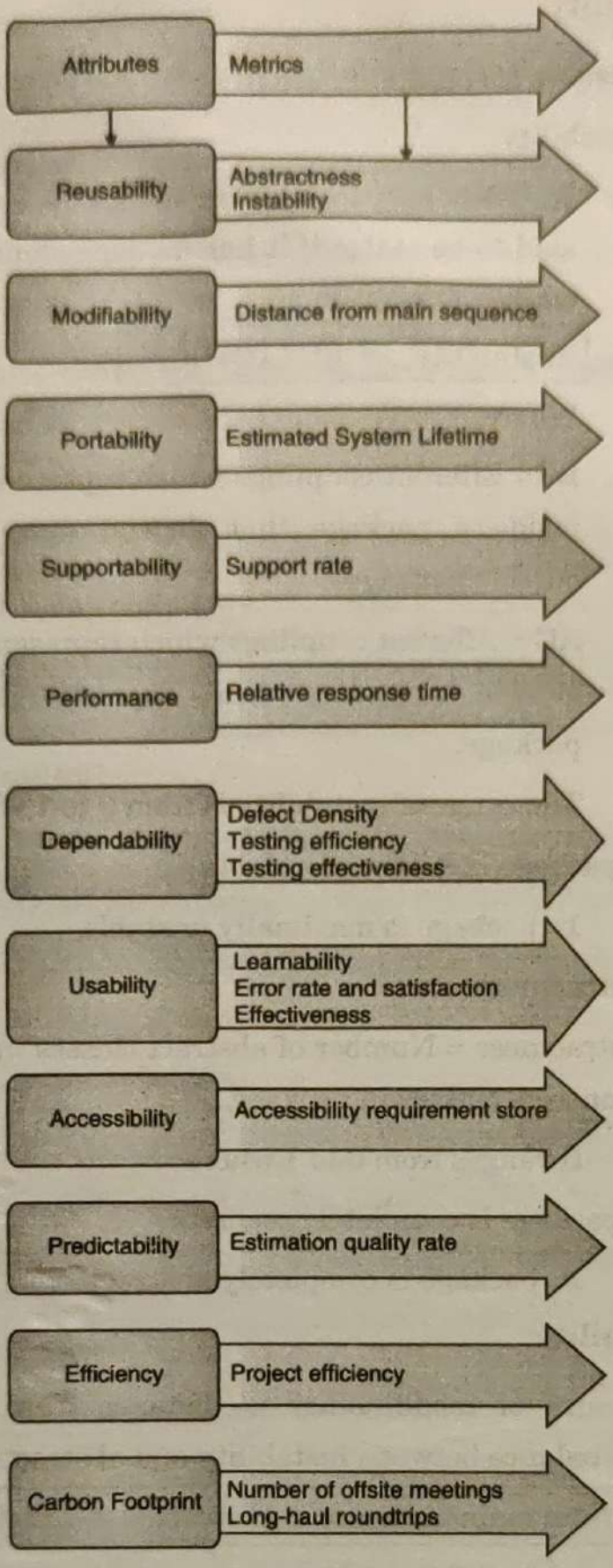

Fig. 1.20.1 : Software sustainability metrics

1. Reusability

The measures of reusability are :

a. Instability

- It indicates package's resilience to change. A package is said to be stable if it has no dependencies on other outside classes. It is given as

Instability = EC/(AC+EC)

Where

EC= Efferent couplings which represents number of classes inside a package that depend upon number of classes outside packages.

AC = Afferent couplings which represents number of classes outside a package that depend upon classes inside a package.

- The range of instability is from 0 to 1 where

0= package is maximally stable

1= package is maximally unstable

b. Abstractness

Abstractness = Number of abstract classes in a package/ Number of concrete classes in package

- It ranges from 0 to 1 where

0= package is completely concrete

1= package is completely abstract

2. Modifiability

The measure of modifiability is distance from main sequence. It measures balance between instability and abstractness.

Distance from main sequence = Abstractness + Instability – 1

It also ranges from 0 to 1 where

0 = package is balanced

1 = package is not balanced and requires redesign.

3. Portability

- The measure of portability is estimated system lifetime.
- It estimates the year when hardware to run system arrived in market.
- It also ensures that old desktops are not upgraded unnecessarily when new system is launched.

4. Supportability

- The measure of supportability is support rate.
- It is given as follows

Support Rate= Number of user's question/ Average time to resolve user's question

5. Performance

- The measure of performance is Relative response time.

Relative Response Time=Number of tasks with an unacceptable response time/Total number of tasks tested

6. Dependability

Metrics for dependability are

a. Defect Density = Number of defects found/Lines of Code b. Testing Efficiency= Number of defects found/Number of days required for testing. c. Testing Effectiveness = Number of defects removed/Number of defects found

7. Usability

Metrics for Usability are :

a. **Learnability :** It measure the ease at which user handles the design for the first time.

Learnability = Minutes to complete first task without help/Minutes of usability test/Minutes system is used by users

b. **Efficiency :** It measures user productivity for new design.

Efficiency=Number of tasks completed/Number of tasks tested

c. **Memorability :** It measures the proficiency of handling the design after long period of time.

d. **Errors :** It measures the severity and ability to recover from errors.

Error rate=Number of errors /Total tasks tested

e. **Satisfaction :** It measures user's satisfaction for new design.

Satisfaction= Number of points in user's feedback

8. **Accessibility :** It is measured on a four point scale.

0= non existent

1= not adequate

2= acceptable

3=adequate

9. **Predictability**

It uses metric estimation quality rate.

$$EGR_T = PD/AD$$

Where,

EGR_T = Estimation quality rate for traditional software development life cycle

PD = Number of planned days to complete project

AD = Number of actual days to complete project.

$$EGR_A = EI/TI$$

Where

EGR_A = Estimation quality rate for agile software development life cycle

EI = Number of overestimated or underestimated iterations

TI = Number of total iterations.

10. Efficiency

- It's metric is project efficiency.
- It measures efforts towards deliverables like manuals as opposed to project related efforts like infrastructure management.

11. Project's carbon footprint

Metrics are :

- Number of offsite meetings
- Number of conference halls
- Long haul round trips
- Work from home

Syllabus Topic : Sustainable Software Methodology

1.21 Sustainable Software Methodology

There are four techniques to collect metrics :

1. Code metric tools
2. Platform analysis
3. Simplified usability study
4. Existing project statistics

The various techniques to collect metrics and attributes are as follows :

Techniques to collect metrics	Attributes	Metrics
Code metric tools	Modifiability and Reusability	Instability
		Abstractness

Techniques to collect metrics	Attributes	Metrics
		Distance from main sequence.
	Dependability	Defect Density
		Testing Efficiency
		Testing effectiveness
Platform analysis	Portability	Estimated System Lifetime
	Accessibility	Accessibility Requirement Score
Simplified usability study	Supportability	Support Rate
	Performance	Relative Response time
	Usability	Learnability
		Efficiency
		Error Rate Satisfaction
Existing project statistics	Supportability	Support rate
	Dependability	Defect Density
		Testing Efficiency
		Testing effectiveness
	Predictability	Estimation quality rate
	Efficiency	Project Efficiency
	Foot Print	Project Specific

1.21.1 Code Metric Tools

These tools collect metrics like instability, abstractness and distance from main sequence. Some of the code metric tools are as follows.

Languages or development environment	Tools
Java	Eclipse Metrics IBM Rational Software ThreadSafe Checkstyle JArchitect
NET	NDepend Net Compiler Platform Code Rush Parasoft
C++	CppDepend Eclipse Parasoft Astree
Adobe Flex	ItDepends FlexMetrics
Multilanguage	Sonar Compuware Imagix 4D Parasoft
Ada	SPARK Toolset Polyspace CodePeer

1.21.2 Platform Analysis

- Platform analysis identifies hardware and software requirement of the platform for system deployment.

- This technique collects metric "estimated system lifetime" and "accessibility" requirement score for attributes portability and accessibility.
- To estimate system lifetime, list and find all hardware and software requirement as well as their year of release.
- Distribute Questionnaire to IT professional using system and note down the feedback.
- Some common findings on system's lifetime are as follows :
  - Small scale software has shorter life.
  - Administrative systems like personal systems, accounting system live longer than business support systems.
  - Average life of the software is 10 to 12 years.
- To obtain accessibility information of any component, we can use section 508 of the US Rehabilitation act.
- This act is designed so that people with disabilities can have access to IT and electronic world.
- Use

  [UI platform name and version] section 508

  to obtain accessibility information online.
- For example

  [Flash player 10] section 508

  gives accessibility information for Flash player 10.

1.21.3 Simplified Usability Study

- Usability study is required to collect metrics support rate, relative response time, learnability, efficiency and error rate satisfaction
- Usability study evaluates product by testing it on its users.
- The first step towards usability testing is to set goals or tasks to be achieved.

- Identify users for testing the application.
- Formulate task scenario suitable to test the application.
- A task scenario is action that user must perform to test the application.
- For example, To check the relative response time of website task scenario is:

> Check the best deals for buying mobile phone on amazon.com and snapdeal.com

- Task given to users should be precise, realistic and actionable as follows :
  - **User goal :** Check best deal for mobile phone online.
  - **Poor task :** Buy a smart phone
  - **Good task :** Buy a smart phone in the range of 10000 to 15000.
- Avoid hints or describing steps to user while user is performing some action on application.
- During the test, measure the time taken to perform each task to estimate system response time.
- At the end, compile the data and prepare record sheet as shown in Fig. 1.21.1 to evaluate metrics.

Sr.No	Activity Description	Time to Complete	Task completed with Assistance	Task completed without Assistance	System response Time
1			⊙	⊙	• Fast • Slow • Unacceptable
2			⊙	⊙	• Fast • Slow • Unacceptable
3			⊙	⊙	• Fast • Slow • Unacceptable

Fig. 1.21.1 : Usability test results

1.21.4 Existing Project Statistics

- It collects metrics like support rate, defect density, testing efficiency and testing effectiveness, estimation quality rate and project efficiency.
- These metrics can be collected from :
  - Project management
  - Customer support team
  - Testing and quality assurance team

Syllabus Topic : Defining Actions

1.22 Defining Actions

- Sustainability performance of software system is measured by software sustainability attributes like portability, usability, supportability, accessibility etc.
- These attributes are measured by various software sustainability metrics.
- Sustainability metrics for software are measured and recorded using techniques like code metrics tools, platform analysis, simplified usability study and existing project statistics.
- Some of the sustainability metrics for software may need improvement.
- Improvement in these metrics and attributes is done in next release cycle of software to achieve following goals.
  1. **Sustainability value :** Sustainability value is the degree to which goal brings environmental, social and economic benefits.
  2. **Business value :** Business value is degree to which goal supports system's objective.
- These goals must be evaluated and recorded in every project life cycle and accordingly actions are planned.

Review Questions

Q. 1 How IT can help in enhancing environment sustainability?

Q. 2 What is environmental sustainability? What factors are used to enhance it?

Q. 3 What are environmental impacts of IT?

Q. 4 How we can reduce effects of GHG and e-waste on environment?

Q. 5 What are different directions of Green IT?

Q. 6 What are three Rs of green IT?

Q. 7 Explain greening computer's life cycle?

Q. 8 What are green IT standards?

Q. 9 What are green IT strategies?

Q. 10 Explain green washing with example?

Q. 11 Discuss with example how green IT act as an opportunity to Computer world?

Q. 12 What are green IT devices? How they are environment friendly?

Q. 13 What are various stages in life cycle of a device?

Q. 14 Which chemicals are used in manufacturing of any electronic device? How they affect human body?

Q. 15 List guidelines for packaging and transportation given by US Environmental Protection Agency 2011.

Q. 16 What are energy consumable parts in notebook computers?

Q. 17 What are e-waste disposal techniques?

Q. 18 What are processor power states?

Q. 19 What are various C-states?

Q. 20 How computational efficiency is achieved?

Q. 21 Which software techniques are used for energy saving?

Q. 22 What is context awareness? How it helps software to save energy?

Q. 23 How we can achieve idle efficiency?

Q. 24 What tools are used to measure software impact to platform power?

Q. 25 What software tools are used to create energy efficient apps and platform?

Q. 26 What is sustainable software development?

Q. 27 What are the current best practices to maintain software sustainability?

Q. 28 What is sustainable software development?

Q. 29 Why sustainability should be integrated in software development life cycle?

Q. 30 What attributes are used to evaluate sustainability performance of a given software system?

Q. 31 What metrics are used to assess greenness and improvements in environmental performance?

1.23 University Questions and Answers

April 2017

Q. 1(A)(iii) _____ is an international standard that marks the energy efficiency electronic products. **(1 Mark)**

(a) LEED (b) Energy star
(c) WEEE (d) EPEAT

Ans. : (b) Energy star

Q. 1(A)(iv) SSD's consume ——— energy then HDD's. **(1 Mark)**

(a) Less (b) equal
(c) no (d) more

Ans.: (a) Less

Q 1(B)(ii) ——— is any unwanted or damaged electronic component. **(1 Mark)**

Ans.: e-waste

Q 1(B)(iii) ——— is developing application software that adapt to changes in the environment. **(1 Mark)**

Ans. : Context awareness

Q 1(B)(iv) The ——— state indicate 100% CPU use. **(1 Mark)**

Ans. : C0

Q 1(B)(v) ——— is a central repository for data storage and management. **(1 Mark)**

Ans. : Data server

Q 1(C)(i) Explain Green washing. *(Ans. : Refer section 1.8)* **(1 Mark)**

Q 2(A) Explain the various environmental impacts of IT.
(Ans. : Refer section 1.3) **(5 Marks)**

Q. 2(B) Write a short note on green washing. *(Ans. : Refer section 1.8)* **(5 Marks)**

Q 2(C) Discuss the software tools used to create energy efficient applications.
(Ans. : Refer section 1.15.2) **(5 Marks)**

Q. 2(D) Explain the life cycle of a device.
(Ans. : Refer section 1.11) **(5 Marks)**

Q. 2(E) What are the 3 R's of green IT ?
(Ans. : Refer section 1.4.1) **(5 Marks)**

Q 2(F) Write a short note on sustainable software.
(Ans. : Refer section 1.18) **(5 Marks)**

Q 5(A) List and explain energy saving software technqiues.
(Ans. : Refer section 1.14) **(5 Marks)**

Q 5(B) Discuss the impact of electronic devices on the environment during each phase of their life cycle. *(Ans. : Refer section 1.11)* **(5 Marks)**

Q 5(E) Write a note on Green IT standards.
(Ans. : Refer section 1.6) **(5 Marks)**

❑❑❑