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Energy Efficient Mobile Operating Systems

Muhammad Waseem
Department of Computer Science, COMSATS Institute of Information Technology, Wah Cantt
Email: muhammad.wasim1@gmail.com

----------ABSTRACT----------
Energy is an important resource in mobile computers now days. It is important to manage energy in efficient manner so that energy consumption will be reduced. Developers of operating system decided to increase the battery life time of mobile phones at operating system level. So, design of energy efficient mobile operating system is the best way to reduce the energy consumption in mobile devices. In this paper, currently used energy efficient mobile operating system is discussed and compared. Recent energy efficient techniques used to reduce the power consumption of mobile devices will also be summarized and discussed.

Keywords – Android, Battery life, Energy awareness, Mobile, Power management, Symbian

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1. INTRODUCTION

Resource management is one of the essential tasks of operating system. Operating system must able to manage resources in an efficient manner. The correct and complete knowledge of each and every task running inside the computer system is mandatory to fulfill the demands of resources from various processes and I/O devices [1].
Now days, mobile devices are become common, and one of the major resource in these devices is its power or energy. So, efficient management of power of mobile devices is still a research problem. Since the role of power in any operating system is restricted to two main tasks, i.e., control the hardware power requirement, and increase the lifetime of battery [2].

Mobile operating systems are just started with the advent of mobile phones and smart phones in the market. Some of the mostly used mobile operating systems are, i.e., Symbian, Android, Microsoft Window Mobile OS,Blackberry OS, and Linux mobile OS. These and many other monile OS can be installed on any device having updates as well [3].

Resources are playing an important role in the performance of mobile operating system. Many mobile operating systems manage their resources, i.e., battery, GPU, Memory, Storage etc [4]. Power consume by mobile functions is one of the most important resource for mobile devices because these devices are known as power hungry devices. Symbian OS used a distributed method with each layer is responsible to handle mobile power. Android says that CPU can't consume power if there is no application consuming power [5].

Energy management in mobile phones is the responsibility of both applications and operating systems. Operating system's main component, i.e., resource manager will handle it with the collaboration with hardware. One of main thing is to understand how much resources are demanded by user at the given time in order to manage them efficiently [6].

Some of the main responsibilities of power management system in context of mobile operating system are, i.e., control the power requirement of hardware devices, increase the life time of battery component is that device can be used between recharges, and increase the user's perception of mobile phone's operation [7],[8].

In this paper, several new approaches of mobile operating system will be discussed; some of new power management techniques in mobiles will also be discussed and evaluated. In section II, some of recent mobile operating systems are introduced, it will give an overview of power management techniques, and finally section III will concludes the paper.

2. RELATED WORK

An energy efficient mobile device, i.e., smart phones is the requirement of time. It is the main characteristic of any mobile device now days. Operating system will reduce energy consumption by knowing how many resources are demanded by user, and by manage power of mobile device, since it is essential to know the demands of user in order to manage energy efficiently [9].
Heng Zeng [10] proposed a *Currentcy* model that manages energy through energy accounting for various hardware devices, and made fair allocation of energy to all of mobile devices. They have used a linux version for mobile devices, i.e., ECOSystem in order to support their model. ECOSystem will incorporate their model and perform energy management at operating system level. The main purpose is to manage the battery lifetime of mobile device. Results have shown that their system will reduce the power consumption to 0.02W.

Athanasios E [11] analyzed the benefits of burstiness of disk usage in order to disk power management policy more energy efficient. They suggested using the aggressive pre-fetching and delay of low-priority requests to increase the

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length of idle phase. They also presented a method to share the accesses of several running tasks so those requests of disks are arrive at same time. They proposed to enhance their work in network interfaces in future.

Rolf Neugebauer [12] proposed a mechanism to add energy as a resource in *Nemesis* operating system. They also proposed economic model for CPU resource management. Energy accounting is used to observe the level of energy used by each application. They applied for energy management, i.e., it charges each process at energy consumption, and not gives more energy if the demand of energy exceeds the battery time limit.

Narseo Vallina-Rodriguez [13] presented an energy aware operating system, i.e., *ErdOS*. It is user-centered energy aware operating system that increases the battery lifetime of mobile device by managing resources in a proactive manner. They also used opportunistic access to resources in neighboring mobile devices using social connection with users. They claim that Wifi and GSM consume most power in mobile devices, i.e., 720mW and 620mW respectively. ErdOS manager is embedded into Android mobile OS in order to manage resource.

Arjun Roy [14] proposed a Cinder Operating system for mobile devices and handsets. This will enable the user to manage energy resources efficiently. The taps and reserves work as resource containers, provide a platform for resource consumption. Cinder uses software based model for energy consumption in mobile devices. The performance of Cinder OS is tested on HTC mobile handsets enabled with GSM and Wifi functionalities. Results have found that this OS increase the power of battery by 13%.

Song Wang and Kwei-Jay Lin [15] found that GSF (General Scheduling Framework), which is used to implement scheduling algorithms can only done scheduling. They proposed a new resource management framework for a mobile operating system which allows the inter-relationship among resources of different categories. Using their framework, user can access resources, i.e., CPU and network bandwidth etc.

Hector A. Duran-Limon [16] reviews several approaches for resource management in middleware. Since these applications require resource sharing in a controlled and efficient manner. Network resources for mobile devices are an example of such system, since user movement will change the perspective of network resources. They exchange the GSM with mixed-excitation linear predictive (MELP) coder, which provide network on CPU demand.

Christoph Steiger [17] proposed two scheduling heuristics that are used to reduce the number of ignored tasks. They divided the heuristics into 1D and 2D. Whereas ID scheduler depends on task execution ratio while 2D isn't. 1D and 2D area models are evaluated using horizon and stuffing techniques. It is found that 50% of those tasks have larger aspect ratio. Simulation shows that 2D area model has reduced the running time and overhead.

Wanghong Yuan [18] proposed a new cross-layer adaptation framework, i.e., GRACE-1. It uses hierarchical approach to balance the benefits and overhead of cross layer adaptation. It solves the problem of tradeoff between energy and multimedia quality, i.e., how to maximize the multimedia quality under given battery lifetime. GRACE-1 uses the global adaptation which share to all layers when task started, whereas internal layer adapts the hardware and OS layer when task flip its demand. Experiments are conducted on N5470 laptop, results found that GRACE-1 decrease the total energy consumption up to 31.4%.

Gabriel Parmer [19] presented *HiRES*, a hierarchical resource management framework for operating system. In this system, resource management hierarchy is created using sub-layers, each layer is responsible to manage certain type of resources. Parent sub-system and child sub-system are on different layers. Parent resource manager is isolated from children resource manager. Each child sub-system has its own resource manager. Experiments are performed on AIntel Atom n330 with 2 GB of memory using hijack. Results found that standard deviation is less than 0.01 micro second.

Shinpei Kato [20] proposed a new ecosystem for GPU in mobile operating system, i.e., *Gdev*. It allows operating system to use GPU as a operating system resource. It also provides GPU scheduling mechanism to convert real GPU into logical GPU's. Experiments are conducted in Linux and NVIDIA, and it shows that performance is quiet reliable. Results errors in virtualized GPU are restricted to only 7%.

Juan A. Colmenares [21] proposed a new manycore operating system, i.e., Tessellation for client mobile devices which requires real time and QOS guarantees. Resource allocation architecture of Tessellation is discussed using Resource allocation and adaptation mechanism (RAAM). Experiments are conducted on RAMP Gold with Intel x86 platform. It is found that overhead reduce to 100 ms.

Kevin Klues [22] proposed a new operating system, i.e., *ROS*, designed to fulfill the requirements of many-core operating systems. They discuss resource management and presented the idea of space-time partitioning which is their own idea. Resource provisioning scheme will enable utilization and accounting of resources. Their operating system is able to consider virtual machines as a client and provide services as well. The main advantage of their operating system is that it supports parallel applications.

Kevin Klues [23] presented three different methods to manage three mobile operating system resources, i.e., memory, energy, and peripheral devices. They claim that by given priority to these three resources, operating system can achieve high throughput and performance as well. Static allocation and compile time virtualization is used to

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isolate memory and peripherals services from one another. Tiny OS is used to evaluate the methods proposed by authors. They also implement their techniques for T2 as well.

Shinpei Kato and Scott Brandt [24] proposed design concepts for GPU resource management. Evaluation of GPU resource management is conducted by them. Resource management model is presented consists of system stack, GPU channel management, and GPU context management.

Several challenges regarding GPU is also discussed. GPU kernel is used to evaluate GPU performance.

Orran Kriegar [25] presented an overview of *K42* operating system in context of scalability, performance using object oriented design. They recommend using Linux and K42 at the same time in order to achieve better results. K42 has its own performance monitoring infrastructure which any other operating system doesn't have. JVM (Java Virtual Machine) running on K42 made it more scalable, maintainable and flexible. GNU is used as a debugger of K42 operating system.

Wanghong Yuan [26] proposed a new energy efficient CPU scheduler, i.e., *GRACE-OS* primarily design for multimedia mobile applications. The major goal is to save energy in mobile devices using scheduling techniques. Dynamic voltage scaling is used in order to enhance the energy level of mobile device. They implement GRACE-OS using Linux and conduct experiments on HP latop. Results has shown that it decrease CPU idle time, as compare to other mechanisms, i.e., DVS, and deterministic approach, to save energy, it is found that GRACE-OS save energy from 7% to 72% while maintain CPU performance at the same time.

Shivajit Mohapatra [27] proposed a new integrated power management approach in order to reduce power consumption in multimedia mobile devices. Integrated dynamic voltage mechanism is used to achieve high performance and save energy as well. MPEG and DVS are used in a hybrid manner in order to reduce power consumption and increase device performance at the same time. Video stream quality is observed and analyzed after applying these techniques on mobile devices. Network bandwidth is also observed and proposed for future work by authors.

Vanessa Romero Segovia [28] presented a new resource management framework for mobile terminals using Actors approach. CPU time is consider to be the main resource and reservation based scheduling is used to manage it. Experiments are conducted on Android operating system. Two different experiments are performed with different parameters; it is found that execution time of tasks has improved every time they are running. Hence, it is found that multi-core resource management framework is suitable for small range tasks.

Narseo Vallina-Rodriguez [29] produce a novel method is presented to make efficient use of mobile phone resources by offering the co-ordination of multiple co-located devices. Opportunistic way of sharing resource is discussed. It is found that Wifi consume 720 mW whereas GSM consume 620 mW as compare to other resources which consume less power. ErdOS is used as an operating system to save energy in mobile devices.

In order to manage energy and power in mobile devices, several power management techniques has been developed by researchers, and developers. Some of the main power management techniques in context of mobile handsets are discussed as under.

Lawrence S. Brakmo [30] proposed a energy reduction technique for mobile devices , i.e., µSleep. It is effective when light weight processes are in running, i.e. word document etc. This technique put the processor in sleep mode for 40ms to 1 second. This technique is useful to increase the battery lifetime of mobile devices. Experiments are performed and it is found that this technique reduce energy consumption upto 60%.

J.Finn [31] proposed a new technique, i.e. PowerScope, baseline for energy-efficient mobile applications. It maps energy consumption into programs. Architecture consists of data collection and off-line analysis. A case study of movie player is used to test the technique. Results have shown that it consume very less power, i.e., 3.99W for display, 0.15W for WaveLAN, 0.17W for disk and 1.11 for others.

David C.Snowdown [32] proposed a new power management technique, i.e., Koala, which is sued to predict the energy consumption by each application. An arbitrary method is used to manage energy and performance at the same time. Koala manages each process separately, which is useful in achieving large energy savings. Koala is tested on server based environment, and it is found that it saves energy upto 25%. There is still a tradeoff between performance and energy saving, which is intend t improve in future.

Manish Anand [33] proposed a new mechanism of power management, i.e., STPM. It monitors the demands of different applications, and provides a hybrid solution for self tuning based power management. Ghost hints are used to exposes the missing opportunities and calculate the weight, after receiving weight, power manager will decided to make transition

Kyle J. Nesbit [34] proposed a new VPM (Virtual Private Machine) framework which is used to take resource assignments from operating system tasks, and then used VPM mechanisms, i.e., multiplex, arbitrate, or distribute hardware in order to satisfy VPM assignment. It assign multicore chip resources among number of tasks in order to make efficient utilization. VPM scheduler and VPM translator are the two main component VPM framework.

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Jose ´ F. Martı ´nez[35] have used machine learning approach for multi-core resource management in order to reduce the workload demands and power consumption as well. The result taken from this technique is proved to be more efficient. Resource management at real time is also flexible and manageable.

Miron Livny [36] proposed a new approach, i.e., RMS which provides services to its users and client. It consists of many layers, i.e., application layer, customer layer, owner, and local RM layer as well. Advertising and match-making protocols are also used. Claiming protocol is used to fulfill the services of users.

Sudeep Pasricha [37] has proposed a new technique to reduce back light power consumption in video streaming applications. The focus will be on MPEG-1 video without compromising the video quality. It is found that backlight consume 40% of power when playing video games on iPAQ. New technique will increase average frame light by passing the frame into high pass filter and remove picture details. Results have shown that DCA approach is better and reduce power consumption up to 60% consumed by backlight of handheld device.

Kato.M [38] proposed a new technique for low power consumption. It uses the run-time power control mechanism in java-enabled mobile devices. It improves In-memory compression by reducing the memory consumption through bank partitioning technique. In-memory compression has reduced memory consumption up to 50%. They proved that in-memory compression combined with bank partitioning technique is a highly successful technique for low power consumption in mobile devices.

Trevor Pering [39] proposed a new technique, i.e., Coolspot to enable mobile device to switch among different interfaces in order to reduced power consumption. Experiments are conducted on mobile platform and it is found that energy savings up to 50% can be achieved by switching between wireless interfaces. Since Coolspot is only focus on Wifi and Bluetooth. But it can also be extended towards GPRS and EDGE. It also not requires any built-in infrastructure.

Ahmed Abdelmotalib [40] provides a summary of some of the techniques used for power management in mobile handsets, and specifically in smart phones. It is found that it is a very interesting topic to do research since power hungry devices are suffering from energy crisis. The development of long power batteries are not the solution for this problem. It is found that efficient operating system technique scan reduce the power consumption efficiently.
Gregory F. Welch [41] has conducted a survey on power consumption techniques in mobile computing. They found that main components of mobile which are responsible for power consumption is CPU, memory, hard drives, and wireless communication device [42]. They focus on disk drive power management and memory with storage management.

Jacob Sorber [43] presented a new framework for hierarchical power management of mobile devices, i.e., Turducken. They found that a mobile device doesn't have efficient power capacity for unlimited communication and processing. Initiation of HPM is conduct that can provide battery lifetime of up to ten times as compare to standard laptop.

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CONCLUSION

Energy is a most important resource in mobile devices. In order to reduce battery consumption, it is important to done resource management especially energy management. Many energy aware mobile operating systems have been developed by researchers. In this paper a literature review of these energy efficient mobile operating systems has been discussed. Several energy efficient techniques used by mobile OS also discussed and analyzed. In future, this work will be extended for upcoming smart phones using different operating systems.

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