A Survey of Energy-Efficiency in Mobile Cloud Computing (MCC)

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Abstract- *Mobile Cloud Computing (MCC) integrates the cloud computing into the mobile environment and overcome difficulties related to the performance like battery life, storage, and bandwidth, environment such as heterogeneity, scalability, and availability and security (reliability and privacy) in mobile computing. Together with an explosive growth of the mobile applications and emerging of cloud computing, mobile cloud computing (MCC) has been introduced to be a prospective technology for mobile services. Energy efficiency is an important for Mobile Environment in Cloud Computing. Because the increased usage of MCC, simultaneously with rising energy costs and require to reduce green house gas emissions call for energy-efficient technologies that decrease the overall energy consumption of computation, storage and communications. Mobile Cloud computing has recently received significant attention, as a promising approach for delivering services in MCC by improving the utilization of data centre resources. In principle, MCC can be an inherently energy-efficient technology for ICT provided that it's potential for significant energy savings. Thus this paper, in the context of MCC, reviews the usage of methods and technologies used for energy-efficient operation of computer hardware and network infrastructure. This paper also identifies some of the remaining key research challenges that occur when such energy-saving techniques are extended for use in MCC.*

Keywords- Computation Offloading, Energy Trade-off, Cloud Data Center, Energy-Efficiency

I. INTRODUCTION

Cloud computing is a promising technology which can offer many benefits for mobile devices. Computation offloading can be used to save energy for the battery powered devices. The current state of mobile device characteristics that are critical for cloud computing and highlight cases where cloud computing can be used to save energy. It turns out that the computational characteristics of many present mobile applications support local processing. This can be a result of a natural selection process, which has privileged light-weight applications that are able to run with the limited resources of a mobile device. So computationally demanding mobile applications are uncommon even though the need for such applications may well exists. However, cloud computing does allow running some existing applications with less energy. In future, cloud computing can be a necessary enabler for the development of new computationally intensive applications for mobile devices. In our analysis, we find the computing to communication ratio, which is the serious factor for the decision between local processing and computation offloading. The trade-off point is robustly dependent on the energy efficiency of wireless communication and of local processing. In addition, not only the amount of transferred data but also the traffic pattern is important; sending a sequence of small packets consumes more energy than sending the same data in a single burst. Managing the difficulties of all issues concerned makes the role of developers and content producers important. We afford preliminary results on mechanisms for estimating the energy cost of modern web oriented workloads.

II. ENERGY EFFICIENCY IN MOBILE DEVICES

Mobile cloud computing is an emerging technology cloud service model following the trend to extend the cloud to the edge of networks. It includes numerous mobile devices that are strongly associated with their users. They will be directly involved in many cloud activities that extend the cloud boundaries into the complete cyber physical system.

The most important motivations for the mainstream cloud computing are connected to the elasticity of computing resources. Cloud computing provides virtually unlimited resources that are available on demand and charged according to usage. This provides significant economic advantages both for cloud providers and cloud users as mentioned in [1]. For mobile devices the motivations of using cloud computing differ from the motivation of cloud computing with well-connected PC devices. A collective problem between mobile and mainstream cloud computing is the data transfer bottleneck. For mainstream cloud computing the most vital concern is the time and the cost of transferring large amounts of data to the cloud although for mobile cloud computing the key issue is the energy consumption of the communication. This is perhaps one of the reasons why there are few examples of true mobile cloud computing. Device backup would be a useful service for a small device that can easily get corrupted but it requires transferring large amounts of data. Conversely, synchronization of contact and calendar data, where the amount of transferred data is more modest, is a service that is widely available. Energy efficiency has always been difficult for mobile devices and the importance appears to be increasing. Use cases are developing towards constantly on-line connectivity, high speed wireless communication, high definition multimedia, and rich user interaction. Development of battery technology has not been able to match the power supplies of the increasing resource demand. The amount of energy that can be stored in a battery is restricted and is growing only 5% annually [2]. Bigger batteries resulting into larger devices are not an attractive option. Also thermal concern limit the power budged of the small devices without active cooling to about three watts [3]. Energy efficiency improvements can also always be traded for other benefits such as device size, cost and R&D efficiency. Indeed, large part of the hardware technology benefits have been traded for programmability in mobile phone designs [4]. Computation offloading has been the topic of a number of studies. Conversely, only a subset of those studies focus on the effect offloading has on the energy consumption of the mobile device. In most cases the focal point is on response time and other resource consumption. Large part of the research uses modeling and simulation, such as [5], which is an early investigation of offloading work from mobile to a fixed host concluding that under certain conditions 20% energy saving would be possible. Compiler technology has been studied in, e.g., [6], where a program is partitioned to client and server parts. The client parts are run on a mobile device and the server part is offloaded. The main metrics evaluated are execution speed and energy consumption. Even though the measurements show that significant energy savings are possible, the outcome is shown to be sensitive to program inputs. Middleware based approach has been studied in, e.g., 3]. The described framework performs resource accounting and uses execution time, energy usage and application fidelity as criteria for deciding between local, remote and hybrid execution.

Virtual machine technology for mobile cloud computing. Distributed cloud architecture utilizing single hop radio technology for reducing latency and jitter. On the other hand, the proposed architecture requires significant changes to infrastructure. This paper goes together existing research by providing a snapshot of the present state of mobile devices and commonly used wireless technologies and their effect on mobile cloud computing. Instead of program partitioning focused on evaluating the basic probability of moving tasks to cloud. In addition, This paper consider both wireless local area network (WLAN) and cellular communication (3G), and conclude that, as estimated, the thresholds for moving to the cloud differ considerably based on the used communication technology.

III. ENERGY TRADE-OFF STUDY

In the perspective of cloud computing, the difficult aspect for mobile clients is the trade-off among energy consumed by computation, energy consumed by the storage and the energy consumed by communication. So, need to consider the energy cost of performing the computation locally (Eloc) versus the cost of transferring the computation input and output data (Eclo). For offloading to be advantageous we require that

$$Eclo < Eloc \quad (1)$$

If D is the amount of data to be transferred in bytes and C is the computational requirement for the workload in CPU cycles then

$$Ecloud = D / De \quad (2)$$

$$Eloc = C/Ce \quad (3)$$

where De and Ce are device specific data transfer and computing efficiencies. The De parameter is a measure for the amount of data that can be transferred during communication with given energy (in bytes per joule) whereas the Ce parameter is a measure for the amount of computation that can be performed with given energy (in cycles per joule). With these we can derive the relationship between Computing and Communication for offloading to be beneficial

$$C/D > Ce/De \quad (4)$$

The computing energy efficiency (Ce) is changed by the device performance. For example, a CPU considered for high peak performance requires much more power per megahertz than a core designed for lower performance. Methods like dynamic voltage and frequency scaling (DVFS) modify the power and performance of the CPU at run-time.

IV. CURRENT STATUS OF ENERGY EFFICIENT IN ICT INFRASTRUCTURE

ICT needs more energy, but instrumental increasing productivity and economic wealth and in reducing energy spending from other sources through e-work, e-commerce and e-learning. Conventional network design has required minimizing infrastructure costs and maximizing quality of service (QoS). Yet, ICT also plays a complex role in energy consumption through the ‘communicate more and travel less’ paradigm, and also via the use of smart devices in homes and offices to optimize energy management. Thus, ICT can decrease energy consumption and carbon emissions, but this potential reduction is moderately offset by the power used by data centers and computer networks [6] which runs into billions of dollars or Euros. Thus, a fraction of energy savings in ICT and networks could direct to important financial and carbon savings. In this section, we evaluate recent research in energy efficiency for standalone hardware, and then evaluate work that considers energy consumption as part of the cost functions to be used for scheduling in multiprocessor and grid architectures.

4.1 ENERGY-EFFICIENT HARDWARE

One of the methods to raise the energy efficiency is to increase more energy-efficient hardware. This effort is promoted by labels such as the US Energy Star [7] or the European TCO Certification [8] which rate IT products according to their environmental impact. New emerging technologies like solid- state discs are content with much less energy than the currently used hard disc drives. Computer power can be stored by means of various well-known techniques. First, the processor can be powered down by mechanisms like SpeedStep [9], PowerNow [10], Cool'nQuiet [11] or Demand- Based Switching [12]. These procedures facilitate slowing down CPU clock speeds or powering off parts of the chips, if they are idle [13, 14]. By sensing the lack of user–machine interaction, different redundant hardware parts can incrementally be turned off or put in hibernating mode. The higher configuration and power interface (ACPI) specification [15] describes four different power states that an ACPI-compliant computer system can be in. These states range from G0-working to G3-mechanical-off. The states G1 and G2 are divided into sub states that define which components are switched off in the particular state. For devices and the CPU, separate power states (D0–D3 for devices and C0–C3 for CPUs) are described which are same of global power states. Some of the stated techniques are usually applied to mobile devices but can be used for desktop PCs as well.

4.2 ENERGY-EFFICIENCT DATA CENTERS

The key present technology for energy-efficient operation of servers in data centers is virtualization. VMs that encapsulate virtualized services can be moved, copied, created and deleted depending on management decisions. Combining hardware and reducing redundancy can achieve energy efficiency. Unused servers can be turned off to save energy. Some hardware gets more loads which decreases the number of physical servers needed. On the other hand, the degree of energy efficient self-management in data centers is limited nowadays. Services should not only be virtualized and managed within a data center site but they must be moved to other sites if necessary. Not only the aspect of load has to be consider, also the 'heat' generated by a service has to be considered and accounted for before migrating operations. Every operational physical node releases heat. When a particular node is excessively used or is near other high-loaded nodes, hotspots can emerge in a given data center. According to Figure[1] estimates , at its data centers expenses related to the cost and operation of the servers account for total budget while energy-related 100 units for source energy, 35 units for Power Generation and 33 units for delivery or transmission. To avoid such hotspots, heat can be distributed across sites. Still, services can be transferred from sites with high load or high temperature to sites with smaller loads and lower temperatures. In general, services should be moved to those locations, where they can operate in the most energy-efficient way.

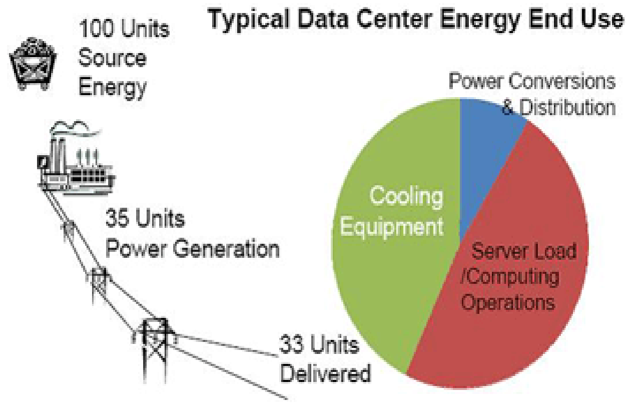

Figure [1] Energy Distribution in Data Center

This type of energy-efficient management of resources has to be realizing by an autonomous energy management that is as transparent as possible to the user of a service. Energy-related troubles have to be solved according to described policies without need human interaction. Machine-readable descriptions of the needs and features of services, servers, networks and even whole sites have to be available to enable energy efficiency in the highly independent and adaptive systems of the future.

4.3 ENERGY EFFICIENCY IN NETWORKS AND PROTOCOLS

Research has exposed that communications, in particular, is one of the largest consumers of energy, yet, energy optimization for communications must contract with the trade-offs between performance, energy savings and QoS. Some hardware already offers features that generate an opportunity for energy-efficient operation such as turning off network interfaces and throttling of processors. Network protocols also be optimized, or even be redeveloped in a method that enhances the energy-efficient operation of the network elements. Network devices can be enabled to delegate services to other devices so as to transfer services from energy inefficient to more energy-efficient devices or to devices that need to be always on, while certain other devices are turned off. Then the delegating device can become dormant and be turned off. Currently, many basic network services have to stay active to periodically confirm their availability even when no communication is taking place. These 'soft states' make it impractical to turn off certain system components; therefore, new protocols need to be designed to work around like soft states increase the energy efficiency of the network. Signaling can also be revisited in this context; whereas data and signaling traffic vary widely, the same technology and mechanisms are used for both (in so-called in-band signaling). When signaling needs only low bandwidth but can occur anytime, data traffic occurs after signaling has taken place, usually requires high bandwidth and traverses all network layers up to the application layer, and uses processing power through multiple layers of the network. Therefore the use of out-of band signaling should also be evaluated to design and improve energy-aware communication protocols.

4.5 THE EFFECT OF INTERNET APPLICATIONS

Therefore, this paper reviewed the opportunities offered by cloud computing as a possible foundation for energy-efficient ICT infrastructures but have not talk about the nature of the applications themselves. One large application area for the Internet is in information dissemination. From digital cameras embedded in mobile phones to environmental sensors to Web 2.0, end users are generating and interconnecting consummate amounts of information and this trend is expected to continue unabated. However, the professional, expedited and reliable distribution of content requires increasing investments in infrastructure build-out and maintenance, and a matching electricity bill to run the underlying ICT. Web, peer-to-peer and web-based video-on-demand services now dominate Internet traffic and, taken together, constantly comprise 85% or more of the Internet traffic mix for several years. In practice, dissemination networks operate using methods and paradigms based on remote-access, replicating functionality in several parts of the protocol stack, and fail to benefit from recent advances in wired and wireless communications, storage technologies and Moore's law. If cloud computing becomes a important platform for producing and accessing information, the amount of data that will be transferred over the Internet will increase significantly. Content replication and dissemination algorithms will then need to consider energy as a key parameter of optimal operation, and therefore cloud computing calls for a systematic re-examination of the basics of major computation, communication or storage and energy/performance trade-offs.

4.4 POWER CONSUMPTION IN WIRELESS AND WIRED NETWORKS

Based on some estimates, 'the Internet' may by consuming more than 860TWh annually [16], but such figures can only be considered as educated guesses owed to the number of guesses one has to make. Conventionally fixed network operators have not measured energy consumption as a major cost factor. Lately, however, as sustainability is becoming a key business objective, fixed network operators are looking for ways to decrease their energy footprint. On the contrary, wireless network operators due to regulatory needs and operational considerations regarding base station deployments have been trying to minimize energy consumption for over a decade. In fact, the radio access network (rather than the core network) is the more energy consuming part of the infrastructure, and in many situations the associated energy bills are comparable to the total costs for the personnel who work on network operations and maintenance. The ICT energy estimates report that the Vodafone Group radio access network alone consumed nearly 3TWh in 2006. Surprisingly enough, energy savings for infrastructure networks have not collected much attention until very recently, while energy-saving routing protocols in wireless sensor networks have been studied in detail because of the specific needs of battery powered networks and the related research has included the use of topology control that modify the network graph to optimize properties like network capacity and QoS. While processing and transmission power in nodes are the essential consumers of energy, it is also necessary to optimize the number of hops traversed by packets. An interesting trade-off then arises between high transmission power which can reduce the number of hops, low transmission power which can lead to most hops being necessary due to shorter ranges and transmission interference which can be affected by power in a complex manner. The idea of turning nodes on and off is also considered. In a wired node, power consumption depends and influences other factors, like the node's throughput; additionally, up to 60% of a node's energy consumption can originate with peripheral devices like link driver.

V. CONCLUSIONS

In this paper reviewed the energy consumption of mobile clients in cloud computing. There are many issues that make cloud computing an attractive technology, but energy consumption is primary criteria for battery powered devices and needs to be carefully measured for all mobile cloud computing situations. When energy can be a challenge for mobile cloud computing, it is also as an opportunity. Mobile cloud computing is so a productive area for further research. Developers and content producers would advantage particularly from tools that integrate effortlessly to the normal development flow. This requires models and estimation mechanisms that are sufficiently light-weight but still able to guide design decisions towards better energy efficiency. And also this paper has reviewed the potential impact of energy saving approaches for the management of integrated systems that comprise computer systems and networks. This paper surveyed the contributions that are available in this area from recent research.

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