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A Study On Energy Efficient Remote Storage And Processing In Dynamic Network

Karthik P
Department of Computer Science and Engineering
B M S College of Engineering
Bangalore

Nandini N
Department of Computer Science and Engineering
B M S College of Engineering
Bangalore

Roopa Shree S
Department of Computer Science and Engineering
B M S College of Engineering
Bangalore

Rajeshwari B S
Assistant Professor
Department of Computer Science and Engineering
B M S College of Engineering
Bangalore

Abstract: Even though there are advances in hardware technology for mobile devices, the challenges on resource constrained applications such as video processing still remains unconsidered because they require huge computation and large storage capacity. Also today mobile devices rely on services that require simple connectivity and more complex processing. Fortunately, a mobile device sometimes encounters many entities which entitle to offload its computational resources. At one end, research work has been attempted to address these issues by connecting mobile devices to the cloud, where resources maintained by service provider and at other end mobile devices connected to peer mobile devices, where resources maintained by another mobile. Now mobile devices deployed under dynamic network i.e., with frequent topology changes. However the challenges of energy efficiency and reliability remain unaddressed. In this paper, different framework and techniques proposed by different authors for addressing the challenges such as computation and storage capacity for resource constrained applications on mobile devices and further energy efficiency, fault tolerance and reliability on mobile devices deployed under dynamic network are discussed.

Keywords: Cloud Computing, Mobile Cloud Computing, Dynamic Network, Energy Efficiency

I. INTRODUCTION

Presently mobile devices have gained enormous popularity. However executing resource constrained applications such as video processing on mobile devices is still a challenging issue. The progress of mobile computing becomes a trend in the development of IT technology. However the mobile devices facing some challenge in their resources such as battery life, bandwidth, storage and also in communications such as mobility and security.

II. CLOUD COMPUTING

Cloud computing is a service provisioning technique where computing resources such as hardware like servers and storage devices, softwares and complete platform for developing applications are provided as a service by the cloud providers to the customers. Also cloud computing enable its user to utilize the resources in an on demand fashion. As a result many mobile devices offload all or part of the work into cloud. With this explosion, mobile cloud computing is introduced as an integration of mobile device with the cloud.

III. MOBILE CLOUD COMPUTING

Mobile cloud computing is an infrastructure where data processing and data storage for mobile applications are moved from mobile device to a centralized computing platform located in cloud. These applications are then accessed over a wireless connection through a thin client on the mobile device. These leads by creating a dynamic network.

IV. DYNAMIC NETWORK

Dynamic network is a network of mobile devices scattered from remote servers and the mobile applications in remote servers are accessed over a wireless connection. However in dynamic networks, while selecting remote servers the energy consumption for accessing the servers must be minimized by considering the dynamically changing topology. There are techniques that consider the energy cost for offloading the task into remote servers and processing the task in mobile devices, but none of the technique considering a dynamic network. Furthermore, remote servers are often becomes inaccessible because of node failures and unstable links, these raises reliability issue. Although there are solutions that considered with intermittent connections, node failures are not taken into account. Hence it is difficult to deploy in dynamic network.

OFFLOADING TECHNIQUES

Satyanarayanan et al., [1] proposed an architecture where a mobile user integrates virtual machine technology to rapidly instantiate modified service software on nearby cloudlet and then uses the service via WLAN. In the proposed architecture, mobile devices functions as a thin client with respect to the service. Cloudlet is resource rich cluster that is connected to internet and available for nearby mobile devices. The strategies of delivering an infrastructure where the mobile device moves along with their user through the physical world. This strategy is known as cloudlet-based or resource-rich mobile computing. Response intensive applications can be easily achieved using this architecture because of cloudlets infrastructure. Using cloudlet also simplifies the challenging and critical requirements such as meeting the bandwidth demand of multiple users generating and receiving media and also rapid modification of infrastructure for applications. The solution to mobile device is to leverage on cloud computing. A mobile device executes the resource intensive applications on high performance server and support thin client user interactions with applications via internet. However, long WAN latencies are fundamental barrier.

CloneCloud [2], a system that automates mobile applications to benefit from cloud. The system is an application partitioner and execution runtime that enables mobile applications running in an application level virtual machine to offload a part of their execution from mobile devices to device clones, operating in a computational cloud. In order to partition the applications automatically, CloneCloud uses the combination of both static analysis and dynamic profiling, while optimizing energy consumption. At runtime the mobile application is effected by migration of thread from mobile device at a point chosen to clone in the cloud, executing there for remaining partition and reintegrating the migrated thread back to mobile device. The result shows that using proposed system, delivers up to 20x speedup and 20-fold energy reduction for the applications without programmer involvement.

ThinkAir [3], a framework that makes it easy for the developers to migrate their mobile applications to the cloud. It explores the concept of mobile phone virtualization in cloud and also provides offloading at method level computation. Here the focus is on scalability of cloud and increases the power of mobile cloud computing by making execution parallel using multiple virtual machine images. The system is evaluated with a range of benchmarks starting with simple till complex applications. First, authors show that the execution time and energy utilization reduce by two orders of magnitude for an application of N-queens puzzle and reduces the one order of magnitude for virus scan and face detection application. Then show that the application that can access multiple virtual machines to execute in cloud. So that it achieves reduction in consumption of energy and on execution time. Proposed framework used a tool called memory hungry image combiner tool to demonstrate the above applications that can request virtual machines with more computational power to meet their requirements.

Shi et al., [4] proposed a system **Serendipity**, where a mobile devices contact with only other mobile devices and both the initiator of resource and the computational resource are mobile devices and connectivity is normal. The author has presented a system which makes a mobile computation initiator to use other mobile devices for computational resource in its environment to conserve energy and speed up computing. Serendipity depends on collaboration among mobile devices for both task allocation and task monitoring functions. The authors also developed algorithms that were designed to propagate tasks among mobile devices by accounting for properties of connectivity. Serendipity has a job process, a worker process and master process. The Job engine receives job from mobile and creates a job profile for the job and then starts job initiator who will initiate job and allocate their tasks. The job engine then disseminates the tasks to master process from which the workers work on it. Once the job completed it returned back to job initiator and then to job engine. The system uses water filling algorithm for task allocation and computing on dissemination for disseminating and PNP block priority assigning for assigning jobs to workers.

ENERGY EFFICIENCY TECHNIQUES

Berl et al., [5] reviewed the methods and technologies used for energy efficient operations on computer hardware and network infrastructure. Authors discussed that energy efficiency is very important for Information and Communication (ICT) technologies. Because the increased use of ICT along with increasing energy costs there is a need to reduce gas emission for energy efficient technologies that decrease the overall energy consumption of storage, computation and communications. Cloud computing has been paid attention for delivering ICT services by utilizing the data center resources. Cloud computing can be an energy efficient technology for ICT, provided that it is potential for significant energy savings and can be explored with respect to hardware aspects, system operations and networking aspects.

Antti et al., [6] discussed on the major critical factors that affecting the energy consumption in mobile clients which rely on cloud computing. Furthermore, they also presented the measurements about the major characteristics of mobile devices that define the basic balance between remote and local computing. The author analyzed on communication ratio, which is the major factor for the decision between processing locally and remotely. The trade off point is completely dependent on energy efficiency of local processing and wireless communication. Additionally an amount of data transferred and the traffic pattern is also considered, because sending the sequence of packets which is small in size consumes more energy than sending in a single burst. While analyzing, the authors discussed on the tools for managing the complexity of issues involved for future research that’s benefits for both developers and content providers. Authors also provided the results for estimating the energy cost of modern web oriented workloads.

Itani et al., [7] proposed an energy efficient protocol for ensuring the incremental integrity for securing storage services in mobile cloud computing. The protocol uses the concepts of trusted computing and incremental cryptography to design secure integrity that protects the customer documents while reducing the energy consumption on mobile clients and efficiently supports dynamic operations. The system is analyzed and implemented to show the energy savings on mobile clients. The system consists of three main entities: **i)** a mobile client that uses the cloud storage services **ii)** a cloud service provider that operates and manages the cloud storage services **iii)** a trusted third party that configures the cryptographic co-processors for installation on remote cloud. Each co-processor is allocated to multiple registered mobile clients and shared with each individual client. The system operation is divided into three phases: **(i) Initialization phase:** In this phase, the mobile data is developed with the number of authentication codes before migrating into the cloud. **(ii) Data update phase:** This phase demonstrates how the cryptographic concepts are utilized efficiently and securely supporting dynamic operations on cloud. **(iii) Data verification phase:** In this phase, the mobile client request the verification of file, collection of files, or the whole file system stored in the cloud.

Liu et al., [8] proposed "**Distributed Energy-Efficient Scheduling (DEES)**" algorithm that saves energy by integrating the process of tasks scheduling and data placement strategies. Although data redundancy may be able to improve performance of resource intensive applications on data grids, a large number of copies of data increase energy consumption by storage resources on data grids. To implement a data grid with high energy efficiency, author addresses the issues of energy efficient scheduling in data grids supporting real time as well as resource intensive applications. DEES encompasses three main components **i) Energy Aware Ranking:** In this phase, the incoming tasks at each site are ranked in task queue and these tasks are grouped together according to the data location **ii) Performance Aware Scheduling:** In this phase, the scheduler assigns each task to a specific local resource **iii) Energy Aware Dispatching:** In this phase, the unscheduled tasks are dispatched to remote sites and the same is used to take scheduling decisions. By reducing the amount of data copies and tasks, the energy is saved effectively. Simulation results based on real time systems shows DEES algorithm conserves 35% more energy than any other previous approaches, however fault tolerance and reliability is not considered.

Cloudlet Seeding [9] the strategic placement of High Performance Computing (HPC) assets deployed in wireless ad hoc network such a way that computational load is balanced and the number of hops is limited to mobile HPC nodes. Smart phones rely on architecture which is energy constrained and processing power is limited. The adequacy of these devices can be increased by offloading computational intensive applications to parallel HPC architectures. Thus limiting battery drain, providing faster time to solution and allowing access to large data. Such criterion can be achieved through tactical cloudlets that must operate in ad hoc environments. Executing this criterion is further complicated, in that HPC nodes themselves are now portable through the use of hybrid technologies. MANETS are most often the only way to ensure communication between the entities deploying to areas with different infrastructure. Deployed devices under MANETS will vary in computational power and operates over networks of varying data rates. The mobile devices in this network will be drained of battery and even other operational conditions. To address this problem, cloudlets have been proposed. The main goal of cloudlets is to take advantage of computationally powerful resources with power reserves by way of cloud by positioning the resources close to mobile devices to limit the number of hops required to connect. In this proposed system, it seeks to reduce the hops in reaching HPC node and balance the workload of servers. Further the optimization problems presented for static, dynamic, strategic and tactical network to be considered.

Cuervo et al., [10] proposed MAUI, a system that enables exquisite energy aware offload of mobile code to infrastructure. The previous approaches to this problem are either relied on programmer support to partition an application or they were using virtual machine migration. MAUI uses the benefits of code environment to offer the best. It supports code offload to maximize energy savings along with minimal burden on programmer. MAUI takes place at runtime and decides which methods should be executed remotely and it is driven by an optimization engine that maximizes the energy savings under mobile devices which present connectivity constraints. MAUI enables resource intensive applications such as face recognition application to consume less energy, an application such as latency sensitive arcade game that doubles its refresh rate and an application such as voice based language translation that overcomes the limitations of smart phone by executing unsupported components remotely. The author also discussed on how MAUI partitions program, how it is profiled them and how it is formulated and solved program partitioning as 0-1 integer linear programming problem.

DISTRIBUTED STORAGE AND PROCESSING TECHNIQUES

Aguilera et al., [11] proposed an approach to maintain ensure-encoded data in distributed system. This approach permits the use space efficient k-out-of-n erasure codes where n and k are large and the overhead i.e., n-k is small. Erasure codes have been used in communication systems and recently also used in storage systems as an alternative method for replication. The proper use of these erasure codes provides the larger efficiency of space at the rate of larger complexity. Author discussed that a common challenge of distributed storage systems is to provide consistent data while allowing failures and simultaneous accesses. At the same time, one would like to scale with number of clients and like to get reasonable performance and to enhance storage capacity at low cost. The author also proposed a protocol and a scheme to use erasure codes for distributed systems. Some advantages of the proposed protocol and scheme are high concurrency, consistency, optimized for common cases, good performance with highly-efficient erasure codes, online recovery, thin servers and small space overhead. To evaluate this approach, the authors build a prototype of a distributed and reliable storage system. The system comprises of set of storage nodes accessible to clients via network where clients read and write the data using protocol. The scheme has four limitations: **(1)** It is used for linear erasure codes, like Reed-Solomon codes, where duplicated blocks are upgraded with commutative operations. **(2)** It uses the duplication of erasure codes for fault tolerance, not to improve the performance. **(3)** The write throughput of client's decreases as n-k grows. **(4)** It can tolerate at most client failure threshold, if that threshold exceeds client failures and a storage crash, then data may be lost.

Zhang et al., [12] presented the policy scheduling for collaborative application execution in mobile cloud computing. A mobile application is represented by a sequence of tasks. Specifically each task can be executed either on mobile device or offloaded on to the cloud. The design objective is to conserve the energy on mobile device. The authors modeled this task scheduling problem as a constrained shortest path problem in a directed acyclic graph. They adopted LARAC (Lagrangian Relaxation Based Aggregated Cost) algorithm to solve the problem approximately. Simulation results suggest that one climb offloading policy is optimal for markovian stochastic channel, in which the execution migrates only once from mobile device to cloud for collaborative task execution. Moreover compared to standalone cloud or mobile execution, the optimal collaborative task execution can significantly minimizes the energy consumed on mobile devices thus enhancing its lifetime.

Dimakis et al., [13] discussed several erasure coding algorithms for maintaining a distributed storage in a dynamic network. Distributed storage systems often produce redundancy to increase the system reliability. When coding is used, to increase system reliability the problem arises i.e., if a node storing an encoded information fails and in order to maintain the same level of reliability a new node is created with encoded information. With this, it is possible achieve only partial amount of recovery of the code, whereas erasure coding algorithms focuses on complete recovery of information from subset of encoded nodes. While considering these problems gives rise to new design challenges. The three versions of repair problems are considered namely exact repair, functional repair and exact repair of systematic parts. In exact repair, the lost information is exactly regenerated. In functional repair, only the same Maximum Distance Separable (MDS) code is maintained before and after. In exact repair systematic, only the systematic part is exactly regenerated and non systematic part follows functional repair. Many network coding techniques have been proposed to address these challenges. In the proposed system, the maintenance of bandwidth is reduced by the order of magnitude compared to standard erasure codes.

STACEE [14], a formulation of storage cloud using edge devices which is based on peer resource provisioning. The author discussed that the evolution of web applications leads to access of user generated data which resulted in demand for storage. With the use of cloud computing, an all-in-one solution called **storage cloud** focused on providing a distributed storage capability. In this approach, mobile devices, Personal computers, Media centers, set top boxes, networked storage devices and modems are all contributed as storage under storage clouds. Combining all such edge devices may result in flexible and scalable storage capability that keeps data closer to user, thus increasing availability of data. This approach addresses the Quality of Service (QoS) aware scheduling in a peer storage cloud built with edge devices. By designing and implementing an optimization scheme, it minimizes energy consumption from system perspective and maximizing the user satisfaction from individual perspective.

WhereStore [15] is a location based data store for smart phones that rely on cloud. The author discussed that recently, two major trends changed the way the use mobile phones: Smart phones become the platform for applications and 3G connectivity become their internet clients. Many applications on smart phones rely on cloud as backend for storage and computation. Further for many mobile applications, the data to be accessed depends on the current location of user. WhereStore is a strategy uses filtered copy along with device's location history to distribute data between cloud and smart phones. The property of WhereStore strategy is, it uses the mobile phone's location history to determine what data to copy locally. The main goal of dropping cloud data on smart phone is to decrease the overall access latency and also reducing the probability of recovery. WhereStore is a shared set of resources for different kinds of applications and also exchanges data with cloud, thus potentially reducing the overall energy consumption on smart phones. The WhereStore strategy makes use of filtered replication to copy data between the cloud and mobile phone. Filtered replication permits applications to select only a subset of items to store locally. The author discussed on the design of WhereStore and provides details of prototype implementation based on filtered replication platform and StarTrack location framework.

Segank [16], a distributed storage system designed for non-uniform quality storage elements connected in a network. The authors discussed that as data placement is crucial task; it leads to challenges of locating data and maintaining the data consistently. The proposed system employs location and topology sensitivity multicast solution for locating data, lazy peer propagation of invalid information for ensuring data is consistent and distributed snapshot mechanism for supporting sharing. The combination of all these mechanisms allows user to make a non uniform network to gain fast access to data. There are three aspects of this development: **i)** a low cost short range wireless technologies **ii)** a fast WiFi gateway **iii)** a wired network. The Segank system solves three key problems: **1)** How does it locate data that can be stored on devices and how does it choose best copy of it? **2)** How does it ensure data consistency across multiple devices? **3)** How does it ensure a consistent image across all devices for sharing and backup? The proposed Segank system solves the first problem using a location and topology sensitive multicast solution, solves second system using lazy peer to peer propagation and solves third problem using distributed snapshot mechanism.

RELIABILITY TECHNIQUES

Coit et al., [17] proposed a methodology to determine optimal system arrangements when a system uses multiple k-out-of-n subsystems and the subsystems are designed with redundancy. Previously, the redundancy allocation problem has been analyzed for different systems but the problem has been limited to series-parallel systems or systems with single subsystem. The main objective of the redundancy allocation problem is selecting the components, their redundancy levels and determining system level configuration to maximize system reliability. Hence the formulation of problem to accommodate k-out-of-n subsystems provides a better tool for designers and reliability analysts. Initially authors formulated the method considering only active redundancy and restricting series-parallel system, efficient optimization algorithms have been developed. This method is not applicable when the system design involves redundancy in different parts of design and when the subsystems require more than one component to operate. Finally the problem is solved by an equivalent problem formulation and the application of zero-one integer programming. The proposed method provides the capability to solve greater range of engineering design problems.

Leong et al., [18] proposed a high recovery probability system for optimal data allocation that maximizes the probability of recovery. Considering the problem of optimally allocating a data in given storage in a distributed storage system. The authors discussed that every source has a data which can be coded and it should be stored over a set of storage nodes. It is permitted to store any amount of data in each storage node but the constraint is on total storage. A data owner subsequently attempts to recover the original data by accessing a randomly fixed size subset of storage nodes. The recovery is successful only when the total amount of coded data in the subset of storage nodes is at least the size of original data. The aim is to determine the amount of data to be stored in each storage node so that the probability to recover the data is maximized. The solutions can be applied to variety of distributed storage systems including sensor networks; content delivery networks (CDNs) and delay tolerant networks (DTNs). In the proposed system the authors described on distributed storage allocation problem and also examined the optimal allocation that minimizes the total storage. The result shows that the allocation is optimal only when the required probability of successful recovery exceeds the specified threshold. Even stronger results can be obtained for special cases.

MobiCloud [19], a secured framework for mobile computing and communication. Previously, systems only focus on computational services but MobiCloud solution in addition to traditional computational services also enhances the MANET operations by treating mobile nodes as service nodes. The MobiCloud framework also enhances communication by addressing secure routing, trust management and risk management and other such issues in networks. Even a new set of applications are developed using the enhanced processing power and connectivity of MobiCloud. The author suggested, using systematic approach to understand both MANETs and cloud computing in order to understand the capability of cloud computing for achieving secure MANET applications. The main contributions of MobiCloud are: **i)** It supports MANET functions of information. **ii)** It adopts cloud computing technology to create a virtualized environment for MANETs operations. **iii)** It provides fundamental trust model to create applications. **iv)** It supports MANET operations through research context aware risk assessment using communication and other metrics of mobile node under certain security issues. The MobiCloud here focuses on system components including provisioning on domain construction, intrusion detection, context aware routing, resource and information isolations. Further MobiCloud can be used for Damage Recovery and Security Isolation.

Chen et al., [20] developed a resource allocation scheme especially designed for MANETs that minimizes the communication cost for accessing resources distributed while improving the reliability by adopting k-out of-n system. Resource allocation is a major performance metric which is widely used in wireless networks. Applying resource allocation for wireless mobile ad hoc network i.e. MANET is a challenging problem because of dynamic network. The proposed scheme allocates resources to n service centers or nodes such that the energy consumption for nodes to access k nodes out of n nodes is minimized. The scheme describes dynamic network topology by taking the estimated failure probabilities of nodes and frequently monitoring the network for topology changes. To evaluate proposed system, the author built a Mobile Distributed File System based on resource allocation scheme. Through extensive simulation and real time implementation on mobile phones, the results shows the proposed resource allocation scheme improves the data retrieval rate up to 50% and reduces energy consumption by 45% in comparison with greedy algorithm.

V. CONCLUSION

In this paper, various techniques proposed by different authors on how to face the challenges of using cloud to store and process mobile data in an energy efficient and also in reliable manner.

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