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A novel checkpointing approach for mobile devices using Remote Checkpoint Strategy

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ABSTRACT
Recently, the widespread use of mobile devices, such as Smartphone and tablet PCs, leads to a new demand for distributed mobile applications. When the mobile application has a long lifetime and it is comprised of many parallel tasks, it is required to safely checkpoint its processing states against abrupt failure. There are number of issues needs to handle in mobile computing systems like mobility, lack of stable storage on mobile nodes, disconnections, limited battery power and high failure rate of mobile nodes which causes loss of computation. Checkpointing is an attractive approach to introduce fault tolerance in mobile systems transparently. A checkpoint is a local state of a process saved on the stable storage. However, a mobile consumer device is not considered to have sufficiently large and stable storage to store its checkpoint data. Therefore, a remote checkpoint technique is preferred in which the checkpoint data of a mobile device is kept in a remote checkpoint server instead of the mobile device.
Keywords- fault tolerance, Mobile computing, optimal checkpoints, process states, remote checkpoint server.

I. INTRODUCTION

With recent advances in mobile technology and mobile devices, mobile computing has become an important part of the life. The desire to be connected anytime, anywhere, anyhow has led to the development of wireless networks, opening new vista of this emerging field [20]. The market of mobile handheld devices and mobile application is growing rapidly. Mobile terminal are become more capable of running complex application due to the rapid process of hardware and telecommunication technology. Property, such as portability and ability to connect to network in different places, made mobile computing possible. Mobile computing is the performance of computing tasks whiles the user in on the move, or visiting place other than their usual environment. In the case of mobile computing a user who is away from his "home" environment can still get access to different resources that are too computing or data intensive to reside on the mobile terminal [4].Mobile distributed systems are based on wireless networks that are known to suffer from low bandwidth, low reliability, and unexpected disconnection [3].

Checkpointing / rollback recovery strategy has been an attractive approach for providing fault tolerant to distributed applications [1] [8]. Checkpoints are periodically saved on stable storage and recovery from a processor failure is done by restoring the system to the last saved state. So the system can avoid the total loss of the computation in case of the failure. In a distributed system, since the processes in the system do not share memory, a global state of the system is defined as a set of local states, one from each process. An orphan message is a message whose receive event is recorded, but its sent event is lost. A global state is said to the "consistent" if it contains no orphan message and all the in-transit messages are logged. To recover from a failure, the system restarts its execution from a previous consistent global state saved on the stable storage during fault-free execution. This saves all the computation done up to the last checkpoint state and only the computation done thereafter needs to be redone [5], [6], [7]. Synchronous and asynchronous are two fundamental approaches for checkpointing and recovery [2].

In coordinated of synchronous checkpointing, processes take checkpoints in such a manner that the resulting global state is consistent. Coordinated checkpointing algorithms can be blocking and non blocking [3]. The objective is to design a remote checkpoint and rollback strategy that is suitable for mobile computing environment.

II. RELATED WORK

Many research papers have proposed approximated methods to find out the optimal checkpoint interval that minimizes the expected execution time. Zhan et Al. presented a heuristic method for remote checkpoint systems which dynamically adjusts the checkpoint frequency according to variety of failures when the failure rate is assumed to change over time in wireless networks [16]. Men et al. proposed a remote checkpoint method to obtain the appropriate checkpoint interval by considering not only the failure rate and checkpoint overhead but also the handoff rate of a mobile device in cellular networks when the mobile device frequently moves across the cellular areas [9]. Daly proposed a perturbation solution providing a higher order approximation [10] than Young's approximation. George et al. proposed an aperiodic remote checkpoint scheme in which a mobile device takes checkpoints only when its handoff rate exceeds a predefined threshold value instead of taking checkpoints periodically [11]. Cao and Singhal presents in [3] a non-blocking coordinated checkpointing algorithm with the concept of "Mutable Checkpoint" which is neither temporary nor permanent and can be converted to temporary checkpoint or discarded later and can be saved anywhere. In this scheme MHs save a disconnection checkpoint before any type of disconnection .This checkpoint is converted to permanent checkpoint or discarded later. In this scheme only dependent processes are forced to take checkpoints.

However, previous studies on optimal checkpoint intervals have been focused on reducing the expected execution time [3, 14], but power consumption is also an important performance metric in mobile devices. Most research on remote checkpoint strategies has focused on reducing message overhead between mobile hosts and the mobile support server [12] but determining optimal checkpoint intervals is also important for the time and power efficiency.

As a previous work, an approximated method to the energy optimal checkpoint interval to minimize the expected energy expenditure for a mobile device has been proposed [15]. Prakash and Singhal describe in [13] a checkpointing algorithm for Mobile Conputing System. This scheme reduces energy consumption by powering down individual components during periods of low activity [14].

III. REMOTE CHECKPOINT STRATEGY

Determining an appropriate checkpoint intervalis very important to minimize the time and energy expended tocomplete a mobile device task. If interval is too long, the loss of computation will increase when failures occur. On the other hand, if intervalis too short, i.e., frequent checkpoints, the overhead costs establishing the checkpoints will be greatly enlarged. In the proposed system, mobile failure process is with parameter λ and each mobile failure epoch is a regeneration point. Therefore, the optimal checkpoint interval can be analyzed by a stochastic analysis.Let us denote Xn as the n-th mobile failure, then the stochasticprocess {Xn, n=0,1,2,…} is a Markov chain. Fig. 1 shows thestate transition diagram.

Since the energy expenditure can be different according toeach case when a failure occurs during useful computation (T),checkpointing (C) or recovering (R), 3 states for mobilefailure(state 2, 3, and 4) are needed. We assume that usefulcomputation does not require wireless transmissions but onlylocal memory accesses.

State 0 is an initial state, and State 1 is a termination state.State 2 is a state in which a failure has occurred during usefulcomputation. States 3 and 4 are states in which a failure hasoccurred during checkpoint establishment and during rollbackrecovery, respectively. For example, when a failure hasoccurred during the useful computation in a checkpointinterval, then a transition from state 0 to state 2 occurs.

After that, if another failure occurs while a checkpoint isbeing established after completing the useful computation ofthe interval, then a transition from state 2 to 3 occurs. If anyfailures occur during the rollback recovery, a transition from state 3 to 4 occurs. After that, if useful computation andcheckpoint establishment of the interval have beensuccessfully completed without further failures, then atransition from state 4 to state 1 occurs.

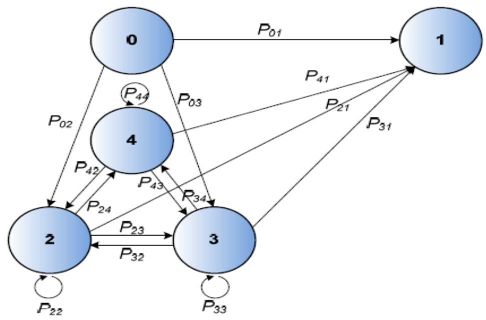

Fig1. State Transition diagram

It is assumed that wireless communication, as well as local memory access, is required during checkpoint establishment (C) or rollback recovery (R), whereas only local memory access is required during normal local computation (i.e., useful computation). EN denotes the power (watts) consumed for normal local computations, which includes only power consumed by local memory. Let EC the power (watts) consumed for checkpoint or recovery operations, which includes the power consumed by both local memory and a wireless interface. Since EC is the sum of EN and the power consumed by the wireless interface, EC is always greater than EN. Actually, the energy consumption model employed in this paper is similar to the ones used in [18, 19]. The assumptions and main operations are as follows:

- The mobile device saves or loads checkpoint data into/from its covering mobile support server through the wireless communication.
- During checkpoint establishment (C) or rollback recovery (R), wireless links may be disconnected at rate λc, which is governed by a Poisson process [17].
- Once a wireless link error has occurred during checkpoint establishment (C), the transferred checkpoint data for the current interval before the disconnection of the wireless link are lost. Therefore, checkpoint establishment should be restarted after the wireless link is recovered.
- During a checkpoint interval (T), only useful computations for the job are running.
- The same mechanism is applied to rollback recovery (R) operations.

We assume that the wireless link is recovered immediately once it has disconnected, for simplicity.

IV. CONCLUSION

This paper proposes a novel checkpointing approach for mobile devices. The remote checkpoint strategy deals with optimal checkpoint intervals that minimize power consumption in wireless environments, in which the checkpoint data of a mobile device is kept in a remote checkpoint server instead of the mobile device. Dense checkpoints incur frequent wireless transmissions whereas coarse checkpoints increase the loss of computation. Therefore the proposed solution is able to provide the almost optimal checkpoint interval minimizing the energy expenditure of mobile devices. The optimal point is deeply dependant on the ratio of *EC* to *EN* as well as the failure rate and the checkpoint overhead.

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