STCP: Simple Transaction Commit Protocol for Wireless Sensor Networks

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Abstract

To effectively ensure data consistency is a challenge in today's wireless sensor network (WSN) applications. This paper, based on the simplification of traditional transaction processing from database management system (DBMS), puts forward the concepts of update transaction and query transaction within the context of WSNs and proposes a novel transaction processing protocol, the simple transaction commit protocol (STCP), for WSN systems. In STCP, the base station, as coordinator, is responsible for initializing a transaction and broadcasting the transaction to participant nodes. The participants, on the other hand, commit the transaction according to a timer, which enables the participants to send confirmation or conflict messages to the base station at a regular time interval. The transactions suspended by conflict are awakened through a triggering mechanism. Compared to the traditional protocols of distributed systems, STCP, which adapts better to the characteristics and requirements of WSNs, can effectively and efficiently ensure data consistency in WSN systems.

Introduction

Nowadays, data management in WSNs has become an area that draws increasing attention. Many new technologies have been developed for WSN data management, e.g., data stream processing [1], approximate query answering [2], in-network data aggregation [3], and data fusion [4], as well as query processing systems such as Cougar [5] and TinyDB [6].

Meanwhile, research regarding WSN transaction management is still rarely seen. the traditional atomic commit protocols, e.g., the two-phase commit protocol (2PC), are not suitable for WSN systems. The variants of traditional protocols, e.g., the two-phase commit protocol with cache (2PCwC) [7] and the cross-layer commit protocol (CLCP) [8], work under the circumstances where only a part of the participants is included, such as service migration.

Therefore, based on simplified DBMS transactions, we propose a completely defined transaction processing protocol for WSNs, the simple transaction commit protocol (STCP), that works for all transactional situations in WSN systems.

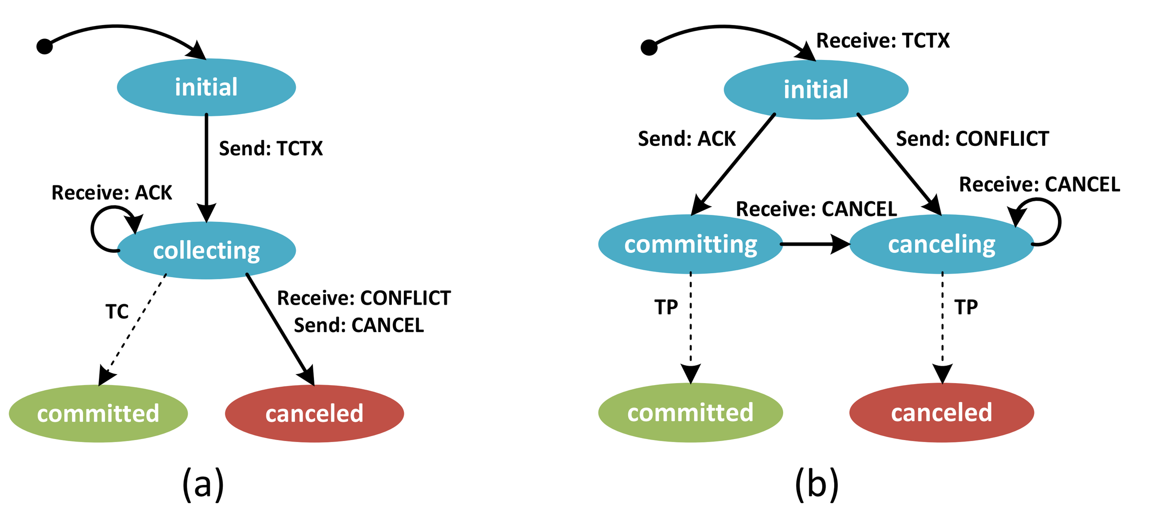

Figure 1. The state machines of the coordinator and the participant.

Transaction Processing Model

The atomic commit protocol of STCP comprises the coordinator part and the participant part. Figure 1 shows the state transitions on the coordinator side (Figure 1a) and the participant side (Figure 1b), where a solid line arrow indicates a state transition triggered by a message, a dashed line arrow indicates a state transition triggered by the timer.

We design the concurrency controller of STCP based on the optimistic concurrency controller (OCC), which not only has the characteristics of non-blocking and deadlock-free but also computationally cheap for low concurrency systems such as WSNs. The design of the concurrency controller is summarized as below from the perspectives of the coordinator side and the participant side.

1. Concurrency control on the base station side
   - Read-read controller: A timer is set at each sensor node, so the message are sent at a regular time interval.
   - Read-write controller: The read-write conflict is managed through two queues, an active queue for transactions being executed and a waiting queue for transactions with conflict.
   - Write-write controller: A strict control is employed. The newly arrived update will be suspended in the waiting queue described until the current one is committed.
2. Concurrency control on the sensor node side
   - Write-write controller: If a sensor node receives a global update during self-adjustment, verification will be made to detect the conflict between the self-adjustment and the global update. If the conflict exists, this certain sensor node will send a CONFLICT message to the coordinator.

Implementation Framework

we design a whole transaction processing framework for the implementation of STCP, which consists of five modules, the transaction manager, the concurrency controller, the active queue, the waiting queue, and the transaction processing module. Figure 2 gives an overview of the interactions between the five modules.

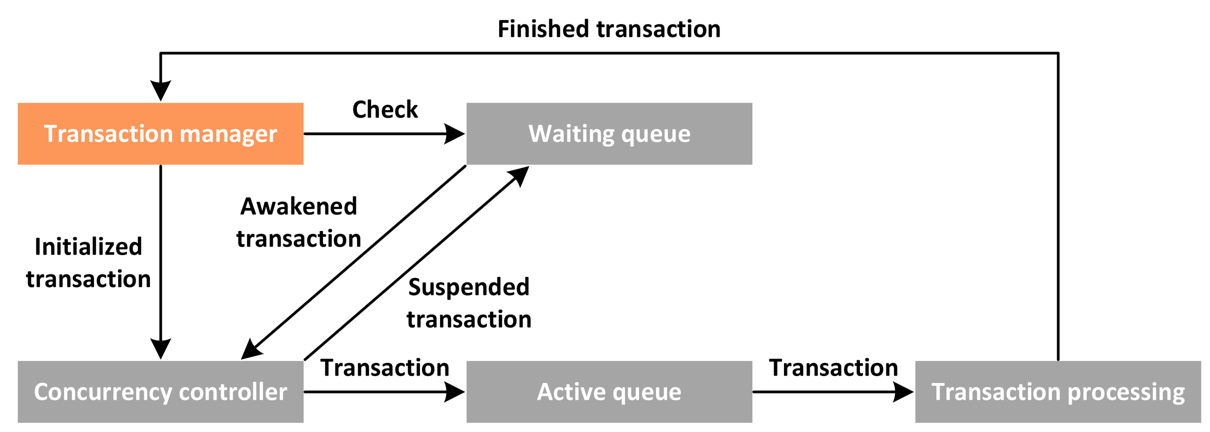

Figure 2. The transaction processing framework.

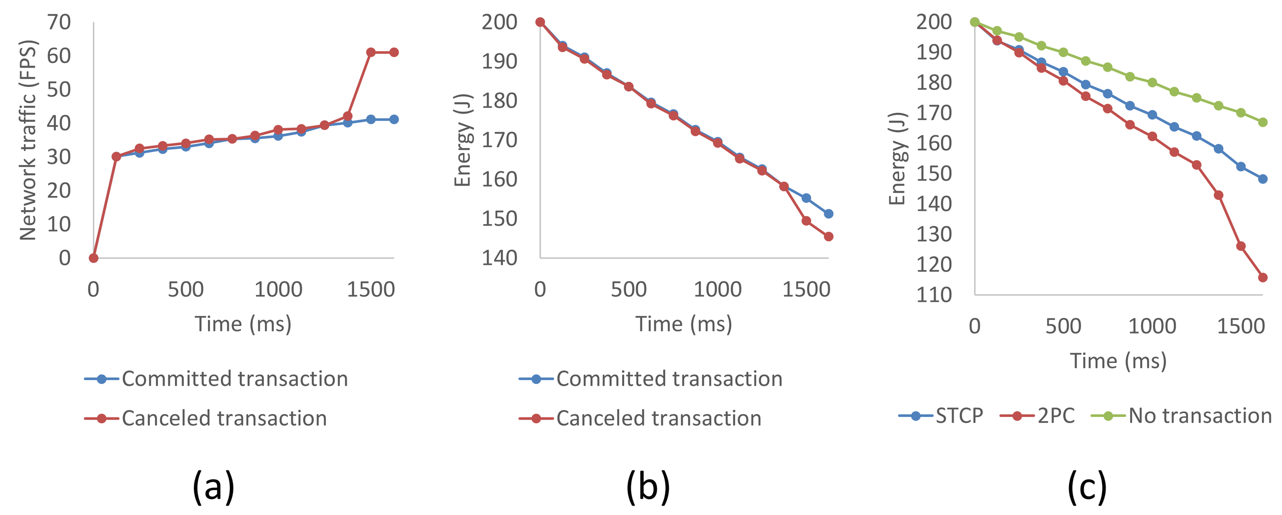

Figure 3. The simulation results.

Simulation Results

We simulate a WSN system with eleven nodes, of which one is the base station, and the other ten the sensor nodes.

To analyze the performance of our protocol, we compare the average network traffic and the average energy consumption in the experimental network between a committed transaction and a canceled transaction processed by STCP over the execution time of one transaction, as shown in Figure 3a and Figure 3b. It can be observed that, during most of the transaction period, the network traffic and energy consumption increase gradually and remain on the same level for both the committed and the canceled transactions. A 42.5% increase of network traffic and an 11.9% increase only occur at the final stage of the canceled transaction, which is reasonable and acceptable.

We also compare the energy consumption caused by STCP with that caused by the traditional 2PC protocol, as shown in Figure 3c. We process ten transactions (five being committed and five being canceled) using STCP and 2PC respectively and calculate the average network energy consumption during the transactions. An instance of network remaining energy, in which no transaction is processed, is given as a comparative baseline, reflecting the normal energy loss. It can be seen from Figure 3c that 2PC causes much more (around 62.8%) energy loss than STCP during the process of one transaction.

Conclusion

In this paper, we present STCP, a completely defined transaction processing protocol for WSN systems, which adapts better to the demand and characteristics of WSNs than the existing atomic commit protocols of distributed systems. We introduce the theoretical design as well as an implementation framework of STCP. STCP is capable of effectively and efficiently dealing with data loss and data conflict issues to ensure data consistency in WSN systems, showing potential in future WSN applications.

Further research can be made on STCP with networks having more complicated structures, such as the cluster-based network, in order to find more possible applications of STCP in large-scale WSN systems.

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