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Maintaining Data Consistency in Mobile Ad-hoc Networks based on Self-stabilizing Maximal Independent Set

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Mobile Ad-hoc Networks is a substantial research subject in Networking area recent years. In many applications of MANETs, there are necessities to replicate, back up data in several nodes to improve the data availability, to prevent data loss and to improve the time latency of requests. The data replication problem is also called as the shared register.

In the shared register, the order in which the shared data are written is an important issue. When a mobile node executes the write operation to the shared register, the change must be eventually updated over the network. Because the mobile nodes are deployed in a wide area, the deliveries of write operations in other nodes of network are different. In addition, the order of written data in every replica affects to the data consistency in the whole network. What inconsistencies are permissible and how the consistency can be maintained is the central mechanism of a shared register.

The update mechanism of data replication is based on the network communication. But, the communication between two mobile nodes is the wireless connection and mobile nodes of MANETs are deployed in a wide area. Consequently, mobile nodes have to connect via multi-hop connections. The wireless multi-hop connections and the mobility make the communication of MANETs unreliable. Hence, if there exists a light-weight

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structure of MANETs, it will improve the network communication by reducing redundant retransmissions.

In this research, a self-stabilizing Maximal Independent Set (MIS) is proposed as a light-weight structure supporting for the network communication. This proposed mechanism constructs and maintains the MIS of Mobile Ad-hoc Networks (MANETs) with an $O(n)$ message complexity. Moreover, it is self-stabilizing according to the change of the network topology. Secondly, based on the self-stabilizing MIS, we propose a MIS-based propagation for transmitting message over the network. It not only reduces the number of retransmissions nodes but also solve the collision problem of the network communication. Finally, benefitted from the MIS-based propagation, we develop a MIS-based regular register which supports multi-writer and ensures the causal consistency model.

MIS plays a central role of this research. Other algorithms and mechanisms based on this concept of MANETs. MIS create a light-weight structure of MANETs. Our algorithms propose a self-stabilization mechanism to recover the information of MIS structure from the fault caused by the network mobility. The experiment proves that our algorithms are better than the other approach in both theoretical analysis and practical evaluation. The message complexity of algorithms is $O(n)$ that significantly improves when compared with $O(n \log n)$ of other approaches.

MIS virtually separates the network into several clusters. In this virtual structure, the cluster head covers all other members of a cluster by one-hop connection. The proposed scheme is raised from the idea that only cluster heads perform the 1-hop broadcast to send the propagated message to its neighbors. In the next step, there are a limited number of nodes among cluster members in the role of connectors continuously transmit message the other cluster. The proposed propagation still ensures a high deliverability ratio while significantly reduces the number of retransmission nodes and collisions.

Motivated by the MIS-based propagation and the cluster structure created by MIS, we design a regular register called MIS-based register, which has:

- An upper bound of respond time for a write operation is: $(\Upsilon \cdot T_1 + \mu)$ respond time, where T_1 is the sum of time to unicast a message in one-

hop distance and receive back ACK message, μ is the waiting time for CSMA/CD retransmit packet when having collisions, Υ is the network degree. The degree of a network is the maximum neighbors of a node.

- The causal consistency model for write operations.

The proposed register is based on the cluster approach, in which whenever want to execute a write operation, the non-cluster head nodes unicast a RTW (request-to-write) message to its cluster head. The cluster head has the role to decide the write operation made by its cluster member. Obviously, after at most 1-hop communication, any node in the network can perform a write operation. It also has the role of sequencer for the write operations requested by multiple nodes in same cluster. Furthermore, in order to reach the causal consistency, MIS-based cluster implements a logical clock based on cluster structure called MIS-based clock. The timestamp of MIS-based clock is a map of all cluster heads' ID and its logical time. Using the MIS-based clock is the key role to maintain the causal consistency of MIS-based register. The simulation result shows that, MIS-based register just needs a small number of forwarding messages to propagate updated value over the whole network. Moreover, the write operation is delivered with a high rate of success.

In summary, this research proposes a regular register based on Maximal Independent Set (MIS) for Mobile Ad-hoc Networks (MANETs). The proposed regular MIS-based register has an effective respond time and the causal consistency for concurrent write operations. It is suitable for multihop MANETs having high rate updating, medium speed of mobility and allowing to the different update orders of write operations which are not causally related in different mobile nodes. The MIS-based register is based on a self-stabilizing MIS structure and a propagation mechanism based on self-stabilizing MIS. The results of these algorithms are not only interesting for MIS-register but also raises the benefit to other problems of MANETs such as finding a Connected Dominating Set or data aggregation/collection.