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Virtual Synchronous Group Membership-based Causal Order Protocol for Wireless Sensor Networks

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Abstract. In wireless sensor networks (WSNs) configured with active and passive sensors, 3-dimensional information is useful for recognizing objects, mapping environments and detecting and avoiding obstacles. These applications use their fusing data in this area in real time. The data should be considered based on virtual synchronous group membership for significant reliability in these real time environments. But, there exist little research work on development of causal ordering based on virtual synchronous group membership for P/S systems based on gossip protocols. Causal ordering is very useful for these distributed applications in which a large number of sensor nodes require cooperating to fuse their data in real time. In this paper, we propose a new approach based on gossip protocols and virtual synchronous group membership, guaranteeing the causal ordering for P/S systems. In the proposed protocol, a broker (publishers) gossips about FLUSH including the whole set of vectors for causal ordering to subscribers for virtual synchronous group membership. The protocol does not end by the acknowledgements of FLUSH, but end by the maximum gossip rounds based on gossip disseminations. Therefore, the protocol is appropriate for ensuring virtual synchronous group membership in real time.

Keywords: Publish/Subscribe, Virtual Synchronous Group Membership, Reliability, Gossip protocols, Causal Order

1 Introduction

The use of 3-D information is for detecting and avoiding obstacles in a 3-D workspace, recognizing objects, and mapping environments [9]. In WSNs configured with passive and active sensors, passive sensors detect naturally radiated energy and active sensors supply, or send out, their own electromagnetic energy. Robotics problems typically require a muchhigher sensing rate, longer range, and high spatial resolutionthat cannot be delivered through common conventionalmeans [4, 5]. So, we need more intelligent means in a 3-D environment in WSNs [4, 5]. For example, a 3-D camera of robotics provides an excellent example of both passive and active WSNs [4, 5]. During a bright sunny day in passive mode, enough sunlight is illuminating the targets and then reflecting toward the camera lens, that the camera simply records the radiation. On a cloudy day or inside a room in active mode, there is often not enough sunlight for the camera to record the targets adequately. Instead, it uses its own energy source to illuminate the targets and record the radiation reflected from them.For another example, a WSN-based conference room configured with active and passive sensors is able to

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capture the 3D position and pose of users, and enable users to interact with digital media and contents shown on immersive displays. Passive sensors often fail in non-textured, featureless portions of a scene [4]. On the other hand, active sensors are more accurate in these regions and tend to be noisy in highly textured regions. So, the way to synergistically combine the two sensor modes to create a state-of-the-art depth sensing system runs in near real time [4, 5].These applications require cooperating to fuse their data in WSNs in real time [6]. For significant reliability of fusing sensor data in real time, some WSNs allow a decoupling between senders and receivers to interact with publishers (brokers) and subscribers (P/S) sensors.

Therefore, we propose a novel approach based on gossip protocols and virtual synchronous group membership, guaranteeing causal ordering[2, 3, 7] in these WSNs. In this protocol, every broker gossips about the multicast message including the whole set of vectors based on virtual synchronous group membership in P/S systems. When a broker synchronizes the group membership, it sends FLUSH including the whole set of vectors to other brokers. Between brokers, the virtual synchronous membership ends when the acknowledgments of FLUSH is received from all brokers, as same as a member in the protocol of Birman et. al.[1, 8]. On the other hand, between brokers and subscribers, a broker gossips about FLUSH including the whole set of vectors to subscribers, but the virtual synchronous membership ends when the maximum number of gossip rounds is reached based on gossip protocols. That is, the end of virtual synchronous group membership is not based on acknowledgments of FLUSH, but based on the maximum gossip rounds of gossip dissemination protocols. Therefore, this protocol is appropriate for sensor networks configured with active and passive sensors in real time synchronization because virtual synchrony is not based on acknowledgments of all members, which might incur network congestion or explosion. Its feature might be highly suitable for the area of the applications requiring only the small causal information overhead based on virtual synchronous group membership with flexible consistency by cooperating to fuse their data.

2 The proposed protocol

In this proposed protocol, the example of figure 1 shows FLUSH for between brokers and subscribers based on gossip disseminations. In figure 1, subscriber S_3 is mobile. After that, SubscriberGroup1 is {S_1, S_2, S_3} and SubscriberGroup2 is {S2, S3}. Between brokers, FLUSH is terminated when the coordinating broker receives FLUSH-OK from every broker. But, in the proposed protocol, between brokers and subscribers, FLUSH is processed based on gossip rounds. The protocol is terminated in 4 gossip rounds because it uses FLUSH, FLUSH-OK, VIEW, VIEW.INT. Each of them is proceeding based on the deadline of the gossip round that the system designer decides. Every broker gossips a FLUSH message including 2-D vector for causal ordering. For example, for SubscriberGroup1, FLUSH is including<(1,1,0,*)> and for SubscriberGroup2, FLUSH is including<(1,1,*,0)>. Because $S_2$is in both SubscriberGroup1 and SubscriberGroup2, it receives <(1,1,0,*), (1,1,*,0)>. Every subscriber gossips about FLUSH-OK to acknowledge FLUSH and solicits a lost message. In this figure 3, S_3 solicits A_1. The protocol is terminated not by the coordinator, but based on gossip dissemination protocols. Every broker gossips about VIEW as soon as a FLUSH-OK isreceived from every subscriber. But, the termination of the protocol does not depend on FLUSH-OK of all subscribers. After that, for SubscriberGroup1, VIEW is {S_1, S_2, S_3} and for SubscriberGroup2, VIEW is {S_2, S_3}.

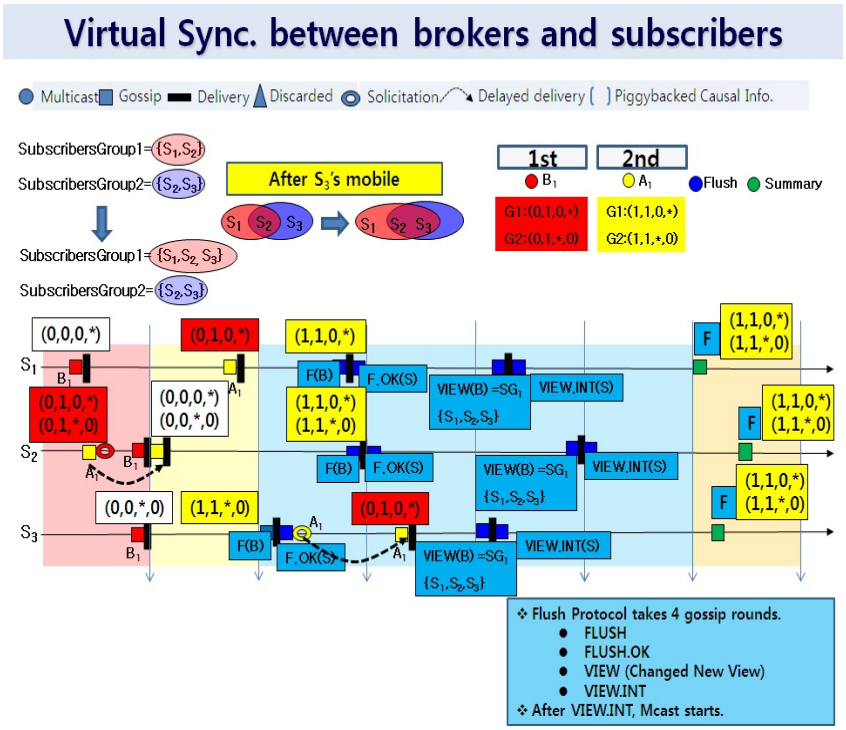

Fig. 1. An example of Virtual Sync. between Brokers and Subscribers

3 Conclusion

In this paper, we present a new approach based on gossip protocols and virtual synchronous group membership, guaranteeing causal ordering in WSNs configured with active and passive sensors. The use of 3-D information of robotics applications is for detecting and avoiding obstacles in a 3-D workspace, recognizing objects, and mapping environments. The way to synergistically combine the two sensor modes to create a state-of-the-art depth sensing system runs in near real time. In the proposed protocol, every broker manages a vector per group, which represents its knowledge for each member of the group. Between brokers, when a broker synchronizes the group membership, it sends FLUSH including the whole set of vectors to other brokers for virtual synchronous group membership. The virtual synchronous membership ends by receiving acknowledgments of FLUSH from all brokers. On the other hand, between brokers and subscribers, every broker gossips about FLUSH including the whole set of vectors to subscribers. But the virtual synchronous membership ends depending on the maximum gossip rounds based on gossip protocols. That is, the end of virtual synchronous group membership is not based on acknowledgments of FLUSH, but based on the maximum gossip rounds of gossip dissemination protocols. Therefore, this protocol is appropriate for sensor networks configured with active and passive sensors when real time synchronization is required because virtual synchrony is not based on acknowledgments of all members, which may be a cause of network congestion or explosion. Its feature might be highly suitable for the area of

the applications requiring only the small causal information overhead based on virtual synchronous membership with flexible consistency

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