Multi-Hop Clock Synchronization Based on Robust Reference Node Selection for Ship Ad-Hoc Network

Xin Su, Bing Hui, and KyungHi Chang

Abstract: **Ship ad-hoc network (SANET) extends the coverage of the maritime communication among ships with the reduced cost. To fulfill the growing demands of real-time services, the SANET requires an efficient clock time synchronization algorithm which has not been carefully investigated under the ad-hoc maritime environment. This is mainly because the conventional algorithms only suggest to decrease the beacon collision probability that diminishes the clock drift among the units. However, the SANET is a very large-scale network in terms of geographic scope, e.g., with 100 km coverage. The key factor to affect the synchronization performance is the signal propagation delay, which has not being carefully considered in the existing algorithms. Therefore, it requires a robust multi-hop synchronization algorithm to support the communication among hundreds of the ships under the maritime environment. The proposed algorithm has to face and overcome several challenges, i.e., physical clock, e.g., coordinated universal time (UTC)/ global positioning system (GPS) unavailable due to the atrocious weather, network link stability, and large propagation delay in the SANET. In this paper, we propose a logical clock synchronization algorithm with multi-hop function for the SANET, namely multi-hop clock synchronization for SANET (MCSS). It works in an ad-hoc manner in case of no UTC/GPS being available, and the multi-hop function makes sure the link stability of the network. For the proposed MCSS, the synchronization time reference nodes (STRNs) are efficiently selected by considering the propagation delay, and the beacon collision can be decreased by the combination of adaptive timing synchronization procedure (ATSP) with the proposed STRN selection procedure. Based on the simulation results, we finalize the multi-hop frame structure of the SANET by considering the clock synchronization, where the physical layer parameters are contrived to meet the requirements of target applications.**

Index Terms: **Adaptive timing synchronization procedure (ATSP), multi-hop, ship ad-hod network (SANET), synchronization, timing synchronization function (TSF).**

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I. INTRODUCTION

MARITIME communication systems, such as the global maritime distress/safety system and the automatic identification system (AIS) [1]–[3], have focused their applications on ship security, location tracking, identification and so on. Recently, there has been a gradual demand in maritime communication for various multimedia services such as marine video surveillance and under water video sensing. Without loss of generality, satellite system can be a good candidate to realize the multimedia services. If a ship rarely finds other neighboring ships, satellite communication is an inevitable option for obtaining services. However, when ships can easily locate their neighboring ships, satellite system becomes burdensome due to its remarkably high cost. The ship ad-hoc network (SANET), a maritime counterpart of the terrestrial vehicle ad-hoc network, can provide ships with diverse multimedia services. Based on the survey of the terrestrial vehicle ad-hoc network and the maritime communication environment, we realize that simply implementing the radio transmission technology (RTT) of terrestrial vehicle ad-hoc network for the maritime communication holds many challenges and open problems. For example, the SANET often has immense communication coverage over 100 km, which requires multi-hop functionality to keep the link reliability. For the purpose of enhancing the service quality of maritime communications, RTT for SANET, based on the Recommendation ITU-R 1842-1 (very high frequency (VHF) band) [4], is designed in our previous work [5]–[8]. Reference [5] focused on the design of the SANET physical layer, where a novel frame structure was proposed based on ad-hoc self-organizing time division multiple access (ASO-TDMA) scheme as provided in [9] and [10]. Different from [9] and [10], the proposed frame structure in [5] considered the special topology of SANET, where the number of ships located near seashore is usually more than the area far from seashore. Reference [6] presented the SANET transmission resource block and evaluated the performance of channel equalization based on the measured maritime wireless channel model, and [7] and [8] tried to improve the link reliability for SANET by employing multiple antennae. In this paper, we realize there lacks the consideration of clock synchronization in [5], [9] and [10]. The difference among the clock oscillators of the network terminals accumulates for a time period causing the clock drift, also known as clock skew, is also a crucial index that can decrease the system performances dramatically [11].

In order to realize the real-time services under the maritime environment, it requires a robust multi-hop synchronization algorithm to support the communication among hundreds of the