RMT: A Novel Algorithm for Reducing Multicast Traffic in HSR Protocol Networks

Saad Allawi Nsaif and Jong Myung Rhee

Abstract: **The high-availability seamless redundancy (HSR) protocol is one of the most important redundancy IEC standards that has garnered a great deal of attention because it offers a redundancy with zero recovery time, which is a feature that is required by most of the modern substation, smart grid, and industrial field applications. However, the HSR protocol consumes a lot of network bandwidth compared to the Ethernet standard. This is due to the duplication process for every sent frame in the HSR networks. In this paper, a novel algorithm known as the reducing multicast traffic (RMT) is presented to reduce the unnecessary redundant multicast traffic in HSR networks by limiting the spreading of the multicast traffic to only the rings that have members associated with that traffic instead of spreading the traffic into all the network parts, as occurs in the standard HSR protocol. The mathematical and the simulation analyses show that the RMT algorithm offers a traffic reduction percentage with a range of about 60-87% compared to the standard HSR protocol. Consequently, the RMT algorithm will increase the network performance by freeing more bandwidth so as to reduce HSR network congestion and also to minimize any intervention from the network administrator that would be required when using traditional traffic filtering techniques.**

Index Terms: **High-availability seamless redundancy (HSR), IEC 61850, IEC 62439-3, multicast traffic, redundancy, reducing multicast traffic (RMT), traffic performance.**

I. INTRODUCTION

SEAMLESS communication with fault tolerance is one of the key requirements for an Ethernet-based mission-critical and real-time power system, such as substation automation system (SAS) networks. A fault-tolerant Ethernet (FTE) eliminates the single point of failure and, therefore, improves overall system availability [1]. Since the standard Ethernet does not provide a fault-tolerance capability, various FTE protocols for power applications have been developed [2]. Among these, only two protocols, the parallel redundancy protocol (PRP) and the high-availability seamless redundancy (HSR) protocol, standardized as IEC 62439-3, are suitable for seamless communication [2]–[4]. Both HSR and PRP are based upon the same principle of active redundancy by duplicating the information frames, which, therefore, results in a zero-delay re-configuration in the event of a switch or link failure. However, this paper only addresses the HSR protocol because it is generally accepted as the developed version of the PRP. The HSR protocol is a redundancy protocol for Ethernet-based networks, and it provides duplicated frame copies for each frame sent.

In other words, the HSR protocol provides two frame copies for the destination node, one from each side, enabling zero-fault recovery time in case one of the frame copies is lost. This means that even in the case of a node failure or a link failure, there is no stoppage of network operations. If both sent copies reach the destination node, the node will take the fastest copy and discard the other copy. This feature of the HSR protocol makes it very useful for time-critical and mission-critical systems, such as SAS. Moreover, the HSR protocol is a Layer 2 protocol and it is independent of the upper layer protocols, thus returning high flexibility in a wide range of different applications in HSR networks. The HSR-based network has four types of nodes [3]:

- A doubly-attached node for HSR (DANH) has two HSR ports that share the same medium access control (MAC) and Internet protocol (IP) set addresses. This allows the address management protocols, such as the address resolution protocol (ARP), to operate as usual without modification, which simplifies the network engineering. Each DANH node will duplicate a non-HSR frame that is generated at the upper layer into two frame copies. It will then append an HSR tag to each copy and send two copies out through the DANH ports, one in a clockwise direction and the other in a counter-clockwise direction;
- A single-attached node (SAN) is a non-HSR device, such as a commercial printer, server, or laptop, which cannot be directly inserted into the HSR networks since those devices lack the forwarding capability of an HSR node and they do not support the HSR tag. They must be attached through a redundancy box (RedBox) node;
- A RedBox node has three ports: Two are HSR ports and one is an Ethernet port that any SAN device, such as a PC, can be plugged into in order to engage with the HSR network. The RedBox node forwards the frames over the HSR network like any other HSR node and acts as a proxy for all the SANs that access it. To this effect, it must keep track of all traffic on behalf of the SANs. The RedBox can also act as a switch for the SANs. Therefore, it is somewhat more complex than the HSR nodes;
- A quadruple port device (QuadBox node) has four HSR ports, and each pair of ports shares the same MAC and IP addresses. This type of node is used to connect two rings or networks with each other. The QuadBox node removes duplication and does additional tasks, such as multicast and virtual local area network (VLAN) filtering.

Other HSR principles are examined and discussed in [3]–[8]. However, the HSR protocol has some drawbacks. One major

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S. A. Nsaif and J. M. Rhee are with the Department of Information and Communication Engineering, Myongji University, Korea, email: saad.allawi1@gmail.com, jmr77@mju.ac.kr

J. M. Rhee is corresponding author.

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