Broadcasting capability analysis of WSNs in ship information collection system

Bin Zeng[1], *Rui* Wang[2,*], and *Chunhui* Yang[1]

[1]Department of Management and Economics, Naval University of Engineering, 430030 Wuhan Hubei, China
[2]Support Center of Education and Research, Naval University of Engineering, 430030 Wuhan Hubei, China

Abstract. In the Internet of things environment, the information collection system designed with wireless sensor networks (WSNs) equipment as the transmission medium can realize the collection of marine environmental information. The WSN nodes can work in a harsh environment without the costly and complicate wiring in the ships. It is necessary to distribute monitoring or alarm information through broadcast operation in ship WSNs. Therefore, in order to improve the efficient application of WSNs in ship information system, the broadcast characteristics of WSNs are analysed and the existing broadcast algorithms are summarized and classified. Finally, some problems faced by broadcast technology are pointed out through simulation results.

1 Introduction

With the rapid development of electronic technology and information technology and the improvement of ship automation, the ship automatic control system is evolving towards the direction of distributed and network intelligent management, so as to make the ship develop towards the unmanned engine room and the integration of automatic navigation and information monitoring, and finally realize the intelligent ship. This makes the requirements for the control of various machinery and equipment on the ship higher and higher [1]. At present, the traditional sensors are mostly used for the measurement of temperature, pressure, speed, flow, displacement, etc. the traditional sensors have some shortcomings in measurement accuracy and transmission performance, which has a certain impact on the safe and reliable operation of the ship. Wireless sensor networks can easily connect with computers and transmit data with high speed and high precision. It can effectively solve the technical difficulties such as narrow ship wiring space and construction difficulties by replacing wired sensor nodes with wireless sensor network for remote sensing monitoring and state control of relevant equipment [2]. At the same time, it can also save the use of ship cables and reduce the cost.

The broadcasting in the multi-hop wireless sensor networks is a basic operation that supports many applications such as route search and gathering information from wireless

* Corresponding author: kingwis@163.com

sensor nodes.

The simplest broadcasting scheme is flooding [3]. This scheme rebroadcasts the packet received to another node if each wireless sensor node received a new packet, when already received packets are sorted out. All the nodes which first receive a packet rebroadcasts the packet received, the number of rebroadcasting packet is *N*-1. Here, *N* is the number of nodes in the wireless sensor networks. Due to these characteristics of the flooding scheme, if rebroadcasting to each node is not restricted, there may be redundancy, contention, collision. This phenomenon is called as broadcasting storm [4].

Redundancy refers to when one node receives identical packets from surrounding two or more nodes. Contention is a problem that occurs when multiple nodes re-broadcast the packets received, thus increasing the frequency of collision between packets/channels. To solve such problems, determination of whether to re-broadcast at each node receiving packets must be made. The most important point in the broadcasting schemes for WSN is to maximize reachability and minimize redundancy. This paper describes broadcasting schemes in the sensor networks proposed to improve simple flooding scheme.

2 Analysis of broadcasting performance of WSNs

Recently continuous researches to seek for efficient broadcasting schemes on the wireless network continue to be performed. The most important factor in the broadcasting scheme is to reduce the delay of packet transmission and while increasing reachability minimize the number of rebroadcasting packets.

If a large amount of rebroadcasting is transmitted, it may ensure a higher percentage of reachability but, as IEEE 802.11 protocol transmits with lack of reliability, it reduces the yield of network and causes collision and delayed transmission. On the other hand, if the number of rebroadcasting packets is reduced, it can reduce the bandwidth required, increase the yield of network, and reduce the delay of packet transmission.

The broadcasting schemes are flooding scheme, probability based scheme, counter-based scheme, distance based scheme, location-based schemes, and neighbour knowledge-based scheme [5, 6]. As the most simplified broadcasting scheme, the flooding scheme is a method that each node resends every new broadcasting packet received with no exception.

In the operation of flooding scheme, each wireless node rebroadcasts firstly received broad casting packets and stores for future reference. As all the wireless sensor nodes rebroadcast any packets at least at one time, *N* is the number of the whole nodes on the network, and if the network is not divided, the total number of the rebroadcasted packets is *N*-1.

Count-based method counts the number of identical packets received during RAD (Random Assessment Delay) timer of wireless node, and determines whether to rebroadcast. Distance based scheme rebroadcasts packets only at receiving nodes a certain distance away from the transmitting node.

Neighbour knowledge-based schemes maintain state on their neighbours, via “Hello” packets, which is used to make the decision to rebroadcast. Popular broadcast schemes are presented in order of increasing algorithm complexity and per node state requirement. The goal of the additional cost is to reduce the number of redundant transmissions.

2.1 Flooding scheme

In this method, a source node of WSN disseminates a message to all its neighbours, each of these neighbours will check if they have seen this message before, if yes, the message will be discarded, if no, the message will re-broadcast at once to all their neighbours. The process goes on until all nodes receive the message.

Flooding scheme can achieve reliable broadcast and multicast in highly dynamic networks. Although this method is very reliable for a WSN with 1ow density nodes and high mobility, but it is very harmful and unproductive as it causes severe network congestion and quickly exhaust the battery power.

2.2 Probability based broadcasting scheme

The probability based scheme tries to solve the broadcast storm problem of the simple flooding method [7]. Each node $i \in N$ is given a predetermined probability p_i for re-broadcasting.

In this context, having some nodes not to rebroadcast minimizes the network congestion and collisions. In this approach there is a danger that some nodes will not receive the broadcast message. For all i, p_i =1, the probability based approach is reduced to a simple flooding approach. More efficient broadcasting reduces p_i as the number of neighbour density increase and vice versa.

2.3 Counter based broadcasting scheme

Counter based method counts the number of identical packets received during RAD timer of wireless node, and determines whether to rebroadcast. In other words, if one node receives more identical packets than the counter threshold C_{th}, it does not rebroadcast the packet. As shown in [5], if the counter threshold C_{th} is 3 or 4, we can find that it increases the reachability than the simple flooding scheme, and minimizes the number of redundant packets. In this approach, some nodes will not rebroadcast in a denser MANET while in a less dense wireless network, all nodes will rebroadcast.

2.4 Distance based broadcasting scheme

While Counter based scheme uses the counter to decide either to drop a message or to rebroadcast, in this section a distance between a receiving node and its neighbours is used to rebroadcast decision. Let d be the distance between the receiving node and the source node, if d is very small then the rebroadcast coverage of the receiving node is also very small. If d is large then the rebroadcast coverage will be large. The distance information can be obtained by measuring the strength of signal or using secondary devices like GPS (Global Positioning System) [8].

Upon reception of a previously unseen packet, a RAD timer is initiated and redundant packets are cached. When the RAD expires, all source node distances are examined to see if any node is closer than a threshold distance value. If true, the node doesn’t rebroadcast. In this approach there is a danger that some nodes will not receive the broadcast message.

2.5 Neighbour knowledge based broadcasting scheme

Neighbour knowledge-based scheme is based on accurate neighbour information to determine the rebroadcasting of the packets. This scheme exchanges periodically “Hello” messages among neighbours to collect neighbour information. The scheme as proposed in, uses “Hello” message to establish 1-hop neighbour list on each node. Neighbour list of the current nodes are all attached to all the broadcasting packets. If a packet is delivered to a neighbour of the current node, each neighbour node compares its own neighbour list with the list attached to the packet, and if it’s all neighbours are included in the list attached to the packet, it does not rebroadcast [9].

One of neighbour knowledge-based schemes is the Scalable Broadcast Algorithm (SBA) [10]. SBA requires that all nodes have knowledge of their neighbours within a two hop radius. This neighbour knowledge coupled with the identity of the node from which a packet is received allows a receiving node to determine if it would reach additional nodes by rebroadcasting. 2-hop neighbour knowledge is achievable via periodic “Hello” packets exchange. “Hello” packet contains the node’s identifier and the neighbour list.

After a node receives a “Hello” packet from all its neighbours, it has two hop topology information centre at itself. Suppose a node ‘B’ receives a broadcast message from a node ‘A’. Since a node ‘A’ is a neighbour, a node ‘B’ knows all of its neighbours which common to a node ‘A’, that have also received a node ‘A’s transmission of the broadcast message. If a node ‘B’ has additional neighbours not reached by a node A’s broadcast, a node ‘B’ schedules the message for delivery with the RAD timer. If a node ‘B’ receives a redundant broadcast message from another neighbour, a node ‘B’ again determines if it can reach any new nodes by rebroadcasting. This process continues until either the RAD timer expires and the packet is sent, or the packet is dropped.

The neighbour knowledge-based schemes can almost optimize the number of rebroadcasting but, as Hello message itself occupies the channel’s bandwidth and Hello message transmission uses broadcasting scheme, thus increasing the probability of collision and overall, there is a problem of poor performance.

3 Network models for performance evaluation

3.1 Performance criteria

Performance metrics used in the experiments are as follows;

- Reachability(RE): m/n, where m is the number of hosts receiving the broadcast packet and n is the number of wireless sensor nodes that are reachable, directly or indirectly,
- Saved rebroadcast (SRB): $(m–l)/m$, where l is the number of hosts actually rebroadcasting the packet.
- Lost packet by collision: the number of lost packets by collision,
- Latency: the time taken to complete the broadcast.

3.2 Simulation configuration

Flooding, Probability Based (PB) Scheme, Counter Based scheme (CB), Distance based (DB) scheme, and Scalable Broadcast Algorithm (SB) schemes are compared for each of their performance through simulation. For simulation, NS3 stimulator was used, and network models was 40-120 wireless nodes in an area of ship size to examine the effect of node density.

The initial locations of nodes are randomly set, and a pair of nodes were randomized to generate CBR/UDP (Constant Bit Rate/User Datagram Protocol) traffics. The channel bandwidth set to 2Mbps. Each node used S-MAC protocol [8] and the channel model is wireless channel/wireless physical transmission model.

4 Experimental results

Fig. 1 shows the reachability depending on the number of nodes with respect to five schemes. If it is 40 nodes, DB shows the lowest arrival rate because nodes within the critical value of the distance prevented packets from rebroadcasting. Therefore, in such the lowest node density networks, it is difficult to deliver broadcasting packets to all nodes. If it is 60 or 80 node, all schemes showed the best reachability. In the network having nodes more than 100, reachability was reduced due to high rate of collision.

Table 1. Simulation parameters.

Parameters	Value
Number of nodes	40 - 120
Routing Protocols	AODV
Queue size	50
Propagation model	Two-ray ground model

SB showed a higher rate of reachability compared to the other schemes in many experimental conditions. The performance improvement reason is because in terms of methods deciding to do rebroadcasting, neighbours are using information of neighbouring nodes and efficiently rebroadcasting compared to other schemes.

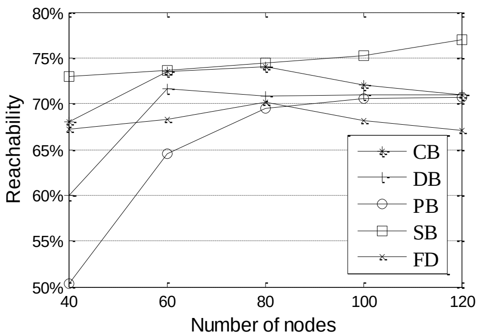

Fig. 1. Comparison of reachability.

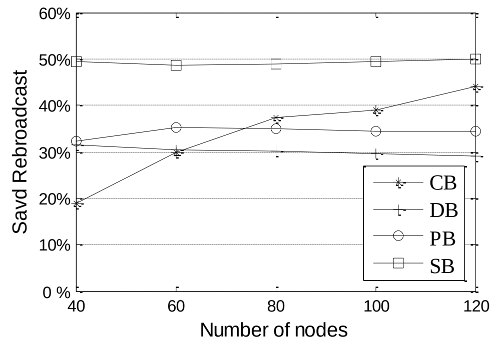

Fig. 2. Comparison of saved rebroadcast.

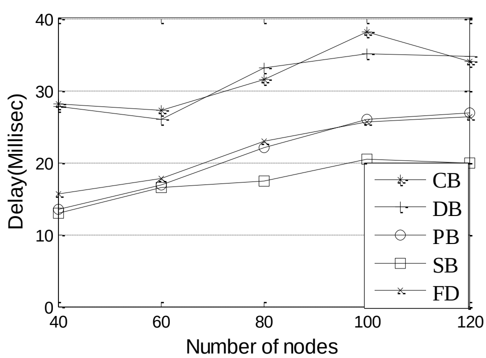

Fig. 3. Comparison of end to end delay.

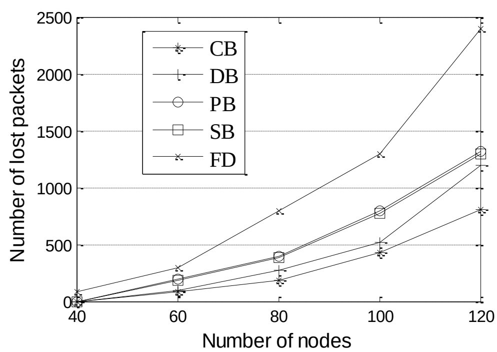

Fig. 4. Comparison of lost packets by collision.

Fig. 2 shows saved rebroadcasting rate, and Fig. 4 shows packet loss by Collision. In the flooding scheme, the number of nodes receiving rebroadcasting packets is the same as the one of nodes which actually rebroadcasted packets, and thus, saved rebroadcasting rate showed 0% in all experimental conditions. In addition, as nodes that received packets all rebroadcast, and there comes a lot of collisions. So it can be found that the more nodes we have, the more packet loss we may get compared to other scheme, as shown in Fig. 4.

If we analyse the trend of SB in the Fig.2, it shows a certain level of SRB regardless of the node density. It's because nodes determine the optimal rebroadcasting based on surrounding neighbour nodes' information and density.

Therefore, we can find that even the lowest density showed a higher rate of reachability. We can find that SB regulates e number of rebroadcasting packets depending on the node density to maintain a certain level of reachability. To look at the number of packet loss by collision in Fig. 4, flooding scheme showed the highest because it has the most number of retransmission, and in case of proposed algorithm, the higher the node density is, it improves compared to existing schemes. Fig. 3 demonstrates the packet delay time by each algorithm. In case of all the algorithms except SB, it can be found that the more nodes we have, the delay time increases. But, SB shows a constant delay time because message rebroadcasting is conducted via the shorted path.

The neighbour information-based algorithm, SB determines whether to rebroadcast based on accurate information, which indicates almost optimized performance, However, other algorithms do not use neighbour information and do not have a message like HELLO to determine whether to rebroadcast, and do not require memory for storage of neighbour information.

5 Conclusion

This paper review and present the survey of well-known broadcasting schemes that can reduce broadcasting storm in the wireless sensor network, and analyses advantages and disadvantages of each scheme. Additionally, this paper compares the performances between, through computer simulation, flooding, counter-based, distance-based, probability-based, and neighbour knowledge-based scheme- Scalable Broadcast Algorithm.

From simulation results, Scalable Broadcast showed superior performance in terms of reachability and re-transmission efficiency. But, Scalable Broadcast requires additional processing load and memory space compared to other algorithms, as well as additional message broadcasting to obtain neighbour information. These findings can be used as basic materials for the further study of new good broadcasting schemes which require less processing load and memory.

References

1. Y.R. Xu. Ship Science and Technology. **40**, 150 (2018)
2. J. Zhang, Y. Zeng, H.L. Zheng. Ship Science and Technology. **42**, 133 (2020)
3. F. Shi, X. Tuo, S. X. Yang, et al. IEEE Transactions on Industrial Informatics, **16**, 1581 (2019)
4. S. H. Bouk, S. H. Ahmed, K. J. Park, et al. IEEE Access, **7**, 517(2019)
5. J. Y. Jung, D. Y. Seo, J. R. Lee. Sensors, **18**, 120(2018)
6. L. C. Mutalemwa, S. Shin. Sensors, **18**,2291(2018)
7. S. Li, Z. Dou, F. Wang, et al. IET Communications, **13**, 2243(2019)
8. I. Ullah, J. Chen, X. Su, et al. IEEE Access, **7**, 456(2019)
9. Y. H. Robinson, R. S. Krishnan, E. G. Julie, et al. Ad Hoc Networks, **93**, 101(2019)
10. G. Koufoudakis, K. Oikonomou, K. Giannakis, et al. Computer Networks, **140**,51(2018)