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Centralized Fault Management of Docks in Marine Sensor Networks

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***Abstract**: Vessel Traffic Management System (VTMS) is a marine traffic monitoring system established by harbour or port authorities to keep track of vessel movements and provide navigational safety in a limited geographical area. Current marine wireless communication systems used for monitoring applications based on VTMS suffer from Automatic Identification System (AIS) sensor node failure in the marine sensor networks. The sensors will monitor its surroundings and forwards the data to the actor nodes. An actor has to coordinate the operations and thereby it is necessary to have a strongly connected network topology all the times. The path between the actors may be constrained to meet latency requirements. Moreover, the network may partition into disjoint blocks due to failure of an actor. A novel routing algorithm called Distributed Routing Algorithm (DRA) and Network Topology Management Technique (NTMT) is designed for maritime monitoring of vessels movements. The objective of the algorithm is to improve communication where scalable mobile networks are optimized by considering interference and delay constraints and thereby enabling an improvement in throughput and channel bandwidth utilization. DRA relies on the local view of a node that relocates the least number of nodes and provides prefailure intimation before node failure occurs. It is a localized and distributed algorithm that leverages existing route discovery activities in the network and imposes no additional prefailure communication overhead. NTMT enables automatic reposition a subset of the actor nodes hence restoring connectivity. The performance of DRA and NTMT are analyzed and validated via extensive simulation experiments using RADWIN software.*

***Keywords:** AIS, DRA, Failure detection, NTMT, Recovery, VTMS.*

I. Introduction

Recently, many studies have identified an emerging demand for telecommunication services in several applications over sea. Some of them are getting great interest for the scientific community, e.g. those related to real-time monitoring through sensing multiple physical parameters from the sea. Although the number and kind of parameters depend on the specific application, monitoring systems are quite similar. Basically, these systems are based on VTMS which includes a radar system, AIS and display subsystems. Initially, a subsystem including a number of sensor devices are deployed to measure the local data. Then, a radio system transmits the sensed information to a central base station for processing and monitoring purposes. The base station could be installed on shore or aboard a ship. However, these systems suffer from lots of weakness, like low bandwidth or capacity (GSM, Satellite and VHF systems), short range (cellular mobile telecommunication systems), high cost for certain applications (satellite and cellular mobile telecommunication systems) and the large size and weight of antennas and hardware transceivers (VHF systems). An ad hoc wireless network permits wireless mobile nodes to communicate without prior infrastructure. Due to limited range of each wireless node, communication is built between two nodes are usually established through a number of intermediate nodes. The sensors serve as wireless data acquisition devices for the more powerful actor nodes that process the sensor readings and put forward an appropriate response. An actor has to maintain strongly connected network topology all the time to coordinate their operations. Actor usually coordinates their motion so that they stay reachable to each other. One of the effective recovery methodologies is to autonomously reposition a subset of the actor nodes to restore connectivity. Of particular interest are applications in remote and harsh areas in which human intervention is risky or impractical. Examples include space exploration, battle field surveillance, search-and research, and coastal and border protection. Robots and unmanned vehicles are example actors in practice.

II. Challenges In Marine Based Wsns

In the marine environment, there are a number of issues which are challenging and need to be addressed including:

1) Movement: The sea water creates environmental conditions which negatively influence the network parameters, such as breaking up the buoy nodes and sometimes the WSN may need reconfiguring.

2) Management of energy consumption: In general, batteries are the power supply utilized in marine WSNs. This means that energy management of sensor nodes is one of the significant issues that marine WSNs rely on.

In order to save energy, wireless communication mechanisms have been applied which aim to minimize radio activity.
3) Software Design of the Network: In general, WSNs are heavily based on the Network Embedded System. The operating system is considered to be the core of wireless communication networks. The program code manages the connectivity and data delivery between the nodes, base station and the end-users.
4) Data Transmission and Security: communication between marine WSN components is suffering from a number of issues such as environmental conditions and network design. For instance, the water environment decreases the radio signal strength of the data transmission and can result in an unstable line-of-signal between wireless nodes. Additionally, to ensure the confidentiality and integrity of the gathered data, security protocols and techniques must be applied.

III. Vessel Traffic Monitoring Systems (VTMS)

The primary purpose of a vessel traffic monitoring, control, and information system is to enhance safety and minimize environmental impact of shipping accidents. Benefits of vessel traffic monitoring and information systems are not restricted to improved response time for search and rescue and for environmental incidents, but also include enhanced compliance and enforcement. Moreover, vessel monitoring components such as the Automated Identification System (AIS) can improve understanding of the spatial and temporal resolution of shipping density patterns to assess environmental threats (for example emissions, collision risk with marine mammals, underwater noise), and serve as an Aid to Navigation.

To prevent accidents and pollution at sea and minimizes the impact on the marine and coastal environment, and on the economy and health of local communities. Its purpose is to ensure that ships in Indian waters and cargoes are monitored more effectively and that there is a consistent approach. In addition, the vessel traffic services and ships' routing systems have been introduced in some areas which are congested or hazardous for shipping and have played an important role in the prevention of accidents and pollution. The system was developed with a view to enhancing the safety and efficiency of maritime traffic; improving the response to incidents, accidents or potentially dangerous situations, including search and rescue operations; and contributing to better prevention and detection of pollution by ships. The provisions include that the operator of a ship bound for a port in the region must provide to the port authority in advance certain information such as ship identification, total number of persons on board, port of destination, and estimated time of arrival. In addition, ships calling at ports in the region should be fitted with AIS and a voyage data recorder; and the operator, agent or master of a ship carrying dangerous or polluting goods must notify general information and information provided by the shipper to the competent authority. Furthermore, the parties must transmit relevant information to the other parties concerned, and take all appropriate actions to deal with incidents and accidents at sea, including cooperating with affiliates (operator, ship's master, owner of the dangerous goods) to minimize the consequences of an accident. The master of a ship must immediately report any incident affecting the safety of the ship; any incident or accident which compromises shipping safety; any situation liable to lead to pollution of the waters or shore; and any slick of polluting materials and containers or packages seen drifting at sea. Information is gathered by AIS-based vessel position reports and notification reports provided by appropriate authorities. The information is centralized and can be used by maritime administrations, port authorities, traffic monitoring services, search and rescue centre, coast guards and pollution prevention centre.

IV. Existing System

In existing system sensors probes their surroundings and forwards their data to actor nodes. It is necessary to maintain a strongly connected network all the times. However, failure of an actor node will cause the network to partition into disjoint blocks. The actor node which was in critical stage could not be found before the packet forwards. Once the packet forwards to route through the failure node the existing system nonetheless considered it and even did not know the particular node has critical stage. While forwarding packets through failure node , it was unable to transmit or propagate the packets to its next neighbors. Failure node did not have energy to forward the packets. If the failure node tries to transmit or forwards packets with minimal energy level, the data is dropped. There was a problem encounters packets dropped in the network. The problem was rectified after the packet got dropped using many recovering techniques such as Least Disruptive Topology Repair (LeDiR). LeDiR imposes no additional prefailure communication overhead. It uses proactive protocols, each node will continuously maintain up-to-date routes to every other node in its network. Routing information is randomly transmitted throughout the network in order to maintain routing table consistency. When it comes for recovery process at the time of node replacement the topology of the network had acquired link breaks and disjoints, topology of the network was not managed in subsist. Hence, if a route has already existed before the traffic arrives transmission occurs without any delay.

V. Proposed Work

The proposed system indicates failure of the node before the data has been sent. The problem in existing system is solved in two ways first one is failure node detection using Distributed Routing Algorithm and another one is replacing of the actor node to recover the failure node using Network Topology Management technique without extending the path. As shown in figure 5.1 when the actor node is getting failure the sensor node will detect the failed node by using Routing discovery and the Distributed Routing Algorithm. Initially, the route is discovered using AODV route discovery process. After the route is discovered the actor node will sends the heartbeat message to the neighbors to check whether they are active or not. Failure node is detected through the concept of distributing the heartbeat messages to all the neighbors if node is getting critical stage. Process of prefailure is detected using the Distributed Routing Algorithm. Once the failure node is detected our propose node in the place of failure node. It also considers the network topology problem happens at the time of the recovery process. The topology of the network is controlled by the Network Topology Management Technique. This NTMT decides which of the node should move to replace the failure. If the node is cut vertex of the network the next root node is decided to move forward to replace the failure node. When the parent node is moving forward its child node will lost their links with parent node for that purpose we proposed the NTMT to control over it. Before moving forward the parent node should informs to the child nodes how much units it moves forward. By getting information from the parent node the child nodes are make themselves ready for move the same unit to overcome the link breaks. This process is handled by the Network Topology Management Technique. Finally prefailure is recovered by replacing of healthy actor to get all the backups of the failure node.

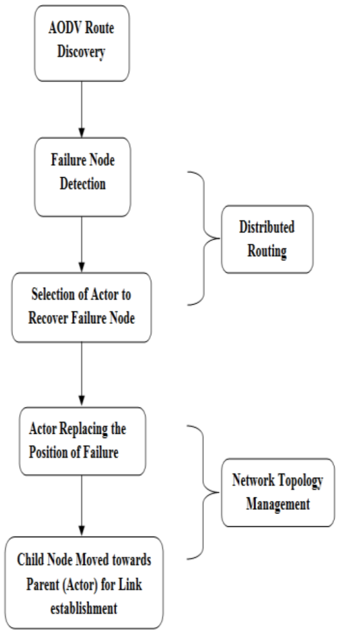

Figure 5.1 Data Flow Diagram

A. Failure Detection

Actors will randomly send heartbeat messages to their neighbors to ensure that they are functional and also report changes to the one-hop neighbors. Missing heartbeat messages can be used to detect the failure of actors. Once a failure is detected in the neighborhood, the one-hop neighbors of the failed actor will determine the impact that is, whether the failed node is critical to the network connectivity. This can be done using the SRT by executing the well-known depth-first search algorithm. Distributed Routing Algorithm limits the relocation of nodes in the smallest disjoint block to reduce the recovery overhead. The smallest block is the one with the least number of nodes will be identified by finding the reachable set of nodes for every direct neighbor of the failed node and then picking the set with the fewer nodes. Since a critical node will be on the shortest path of two nodes in the separate blocks, using SRT the set of reachable nodes can be identified after excluding the failed node.

B. Replacing Fault Node

If node J is the neighbor of the failed node that belongs to the smallest block, J is considered the BC (Best Candidate) to replace the faulty node. The gateway node of the block to the failed critical node and the rest of the network is considered to be node J, referred as a parent. A node is a child if it is two hops away from the failed node grandchild if three hops away from the failed node, and so on. The reason for selecting J to replace the faulty node is that the small block has the fewest nodes in case all nodes in the block have to move during the recovery. The overhead and convergence time of Distributed Routing algorithm are linear in the number of nodes, and thus, engaging only the member of the smallest block will recover and reduce the overhead. In case of more than one actor fits the characteristics of a BC, the closest actor to the faulty node will be picked as a BC.

C. Distributed Routing Algorithm & Topology Management

When node J moves to replace the faulty node, possibly some of its children will lose direct links to it. In general, we do not want this to happen since some data paths may be extended. Distributed Routing Algorithm opts to avoid that by sustaining the existing links. Thus, if a child receives a message that the parent P is moving, the child then notices its neighbors (grandchildren of node P) and travels directly toward the new location of P until it reconnects with its parent again. If a child receives notification from multiple parents, it would find a location from where it can maintain connectivity to all its parent nodes by applying the procedure used in RIM. Briefly, suppose a child C has two parents A and B that move toward the previous location of node J. As previously mentioned, node J already moved to replace the faulty node F, and as a result, nodes A and B get disconnected from node J. Now, nodes A and B would move toward the previous location of J until they are r/2 units away. Before moving, these parents inform the child C about their new locations. Node C uses the new locations of A and B to determine the slot to which it should relocate. Basically, node C will move to the closest point that lies within the communication ranges of A and B, which is the closest intersection point of the two circles of radius r and centered at A and B, respectively. It is worth to mention that since parents A and B move toward a single point, that is, the position of node J, they get closer to one another. Thus, if both can reach C before they move, i.e., C lies within their range, their communication range must overlap after the move since they get closer to one another. This observation also applies for more than two parent nodes since there must be an intersection point of two circles which lies within the communication ranges of all the moved nodes. It has been proven in that this relocation scheme sustains existing links in the connected component (block).

VI. Results & Analysis

Figure 6.1 Log In Window

The figure 6.1 shows the login window of Radwin manager application with IP address, password and user type to enter into the main screen. There are three user types such as Observer has read-only access to the link and can monitor the link, generate reports, but may not change any link parameters, Operator can install and configure the link. In addition to functioning as an operator, the Installer can also change the operating band.

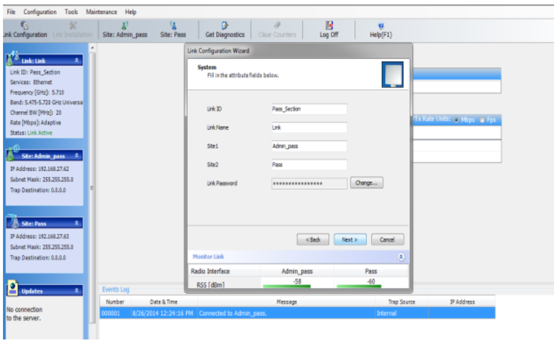

Figure 6.2 Link Configuration

The figure 6.2 shows the link configuration window to set up and check for link status. The Link configuration wizard contains link - id, name, site, password and RSS. Configuration provides much the same functionality as Installation, but for a running link. Configuration mode may vary the service throughput and quality, but without a service break. The Security dialog enables you to change the Link Password and the SNMP Community strings and use the Link Lock feature is a security concept intended to meet a form of abuse encountered in the field.

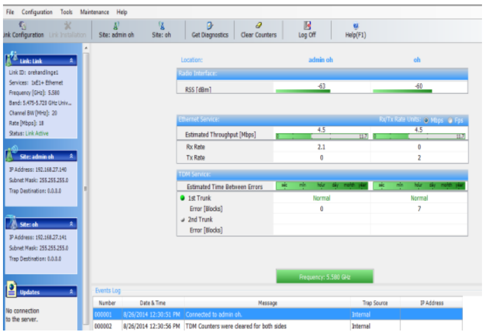

Figure 6.3 Nodes State with Existing System

The figure 6.3 shows the performance of the existing system when the nodes are transmitting their information with the base station. The parameters configured using the Site Configuration dialog panels includes System settings, Air interface - Transmit (Tx) power and antenna, Network management including VLAN, Security settings, Date and time, Hub or Bridge mode. Link Site Configuration panels include several information windows as Inventory - link hardware and software model details and External alarms indicators. The Link Status indication bar must be green, which contains a large amount of information about the link. In the Link Status panel, the Status field should show Link Active in green. It can be observed that the throughput is 4.5 Mbps and RSS is 60 dBm.

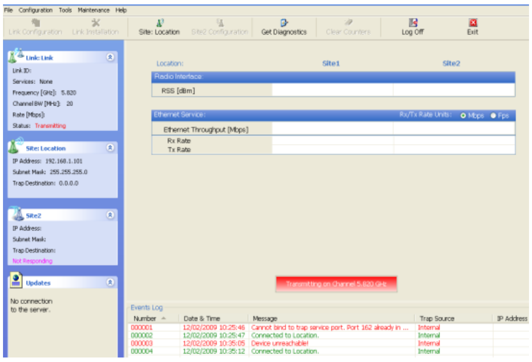

Figure 6.4 Node Failure

The figure 6.4 shows indication of a failure in nodes. RADWIN Manager indicates a case of unbalanced RSS between the nodes and base station. The color of the TDM ports reflects their current status to be Red - Error: LOS for loss of signal and AIS failure indication signal. RSL Threshold can also be used as an indicator of problems in the radio channel. A value of -5dB from the current RSS is recommended as a threshold. The Events Log records system failures, loss of synchronization, loss of signal, compatibility problems and other fault conditions and events. Alarms (traps) are displayed in the Events Log in the lower panel of the main window.

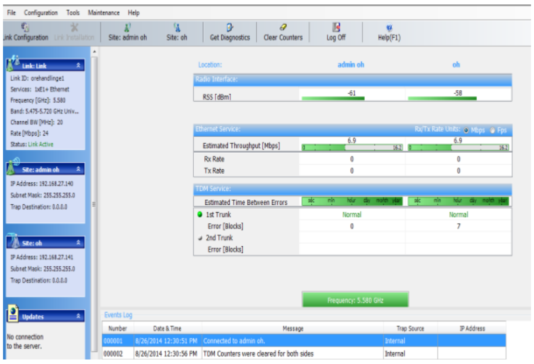

Figure 6.5 Node Status with Proposed System

The figure 6.5 shows the performance of the proposed system when the nodes are transmitting their information with the base station. The numbers are the current calculated throughputs at each site. The colored bars (with numbers) indicate the maximum possible throughput having regard for signal strength. The Events Log, stores alarms generated from both sides of the link. The right hand drop-down list (showing 5.800) allows you to fine-tune the frequency in increments of ±5MHz within a range of the operating band, which in this example is 5.740 - 5.835 GHz. The nodes make use of routing algorithms that utilize both DRA and NTMT resulting in enhanced throughput, range and link availability. It can be observed that the channel bandwidth is 20 MHz and the throughput is improved to 6.5 Mbps and RSS is 65 dBm than in the existing system. Performance Monitoring constantly monitors traffic over the radio link and collects statistics data for the air interface, TDM and Ethernet ports. Events Log that records when the rates fall above or below a predefined threshold.

Figure 6.6 AIS on a Ship's on Board

A real time AIS present on the ship's on board in M.V.Diamond Express ship is shown in figure 6.6 which consist of the ship's position and nearby vessel range, bearings, names and so on. Shipboard AIS transponders have a horizontal range that is highly variable, but typically only up to about 74 kilometers (46 mi). They reach much further vertically – up to the 400 km orbit of the International Space Station (ISS). AIS transponders use two different frequencies, VHF maritime channels 87B (161.975 MHz) and 88B (162.025 MHz) and use 9.6 kbps Gaussian minimum shift keying (GMSK) modulation over 25 or 12.5 kHz channels using the High-level Data Link Control (HDLC) packet protocol.

Figure 6.7 VTMS Display Screen

A standard for AIS base stations has been long awaited. Currently ad-hoc networks exist with class A mobiles. Base stations can control the AIS message traffic in a region, which will hopefully reduce the number of packet collisions. The base stations have hot-standby units (IEC 62320-1) and the network is the third generation network solution. The figure 6.7 shows display screen of VTMS system present in base station at port which contains information on vessels arriving to port, departure of vessels, ships details such as position, draft height, load capacity, standby condition, etc. AIS receivers will output RS232, NMEA, USB or UDP data for display on electronic chart plotters or computers. VTMS display features provides daylight viewing of raw radar in color, automatic detection and tracking of all targets, identity tagging/vessel name, speed/course vectors, updated and accurate chart overlay, off-centering and zoom functions.

VII. Conclusion

Distributed Routing Algorithm will restore connectivity by efficient repositioning of nodes. DRA provides pre-failure intimate sensor nodes and also recovers node failure simultaneously. The performance of DRA and NTMT is validated through rigorous analysis and extensive simulation experiments using RADWIN. It is seen that this system works very well in dense networks and yields close to optimal performance even when nodes are partially aware of the network topology. The work could be extended by including the schemes and techniques over different types of data being integrated onto a single system from various sensor devices such as buoys, weather radar, marine radio, etc for voice and image monitoring processes can be used for port communication.

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