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ROUTING CRITICAL DATA FOR IMPROVING PERFORMANCE IN INDUSTRIAL WIRELESS SENSOR NETWORKS

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Abstract

Recent developments in the field of micro-electro mechanical systems and wireless sensor networks made revolutionary changes in industrial automation and process control. In this paper, Routing critical Data (RCD) for improving performance in industrial wireless sensor networks is proposed. That dynamically selects the reliable relay node by considering the data type, deadline time along with the recent parameters of the network. These parameters are selected in such a way that the critical data forwarding follow shorter path over speedy, reliable links and non-critical data forwarding follow the path over energy efficient nodes. In this way, the relay node selection process balances the network load that the shorter path remains available for the shorter deadline-time critical data. Simulation analysis is carried out to show the performance of the proposed system.

Keywords: RCD, Simulation Analysis

Introduction

For the increasing demand of quality productivity at low cost, the industries are following the wireless sensor networks (WSNs) for industrial automation. The industrial automation applications require real-time communication. The out of time data may be irrelevant and may adversely affect the performance of system monitoring and control. For example in chemical plant, the chemical leakage should be informed in predefined time. Similarly, fire-fighter should timely relay the temperature updates. Therefore, the safety measures may timely initiate. In this way, the WSNs may help to monitor and control the synchronous and asynchronous events that require real-time and reliable data delivery. This real-time communication support for industrial automation is challenging in wireless environment as the lossy nature of radio links and node un-reliability greatly affects the performance of real-time packet delivery. The lossy nature of radio link is due to adverse industrial environmental conditions.

Additionally, the nodes un-reliability is due to nodes power drain, communication or physical failure. This happens due to hostile industrial environmental condition. The data packet re-routing mechanism provides the guarantee for end-to-end packet delivery but degrades the deadline-time data delivery. The deadline-time data delivery is defined as the ratio of successful packet delivered at the receiving end in the predefined deadline time. Therefore, developments in the field of industrial WSNs (IWSNs) necessitate such a routing protocol that can adopt network dynamics and can guarantee timeliness data delivery. Additionally, IWSNs should be scalable such that it should be independent of networks size. As it would be impractical if the memory utilization increases as the number of nodes increases in the network

Related Works

In multi-sink networks, traffic moving towards one sink may congest that moving towards others. The algorithm considers the traffic of surrounding neighbours before jumping to any sink. This is accomplished by building for each single sink, a gradient field and using gradient-based search for routing. The gradient index of one node contains two parts: first represents the distance-cost to travel, based on routing over lossy link and second contains the implicit traffic delay carried by the current holding node. Gradient field is built in distributed way and proven to free from loops [1]. In Decentralized distributed Space Time Block Coding (Dis-STBC) system, the knowledge about the Channel State Information (CSI) is not available at the transmitter [2].

Due to the high complexity of schedule calculation, a heuristic was developed and evaluated in real-world process automation and control application deployed in an oil refinery and further presents a long-term experiment in an office environment [3]. An Unobservable secure routing scheme offers complete unlinkability and content unobservability for all types of packets. This protocol is efficient as it uses a combination of group signature and ID based encryption for route discovery [4].

A new gradient based routing protocol for Industrial Wireless Sensor Networks (IWSNs) provides real-time data delivery by forwarding packets to its optimum forwarding node on the basis of two-hop neighbor information [5]. IWSN plays a vital role in creating a highly reliable and self-healing industrial system that rapidly responds to real-time events with appropriate actions. In addition, IWSN standards are presented for the system owners, who plan to utilize new IWSN technologies for industrial automation applications [6].

EARQ provides real-time, reliable delivery of a packet, while considering energy awareness. In EARQ, a node estimates the energy cost, delay and reliability of a path to the sink node, based only on information from neighboring nodes. Then, it calculates the probability of selecting a path, using the estimates. When packet forwarding is required, it randomly selects the next node. A path with lower energy cost is likely to be selected, because the probability is inversely proportional to the energy cost to the sink node. To achieve real-time delivery, only paths that may deliver a packet in time are selected. To achieve reliability, it may send a redundant packet via an alternate path, but only if it is a source of a packet [7]. The wide deployment of lower-cost wireless devices will significantly improve the productivity and safety of industrial plants while increasing the efficiency of plant workers by extending the information set available about the plant operations [8].

The aim is to analyze the functional requirements for a routing protocol used in industrial Low-power and Lossy Networks (LLNs) of field devices [9]. Selection of promising and interesting research areas in the design of protocols and systems for wireless industrial communications are designed [10].

Routing Critical Data

In WSNs, end-to-end packet delivery delay depends on per-hop delay and distance covered toward destination. In the light of these observations, the proposed routing algorithm follows this mechanism to support soft real-time communication service for desired timeliness data delivery. Each relay node estimates the distance to destination from itself along the residual time for timeliness data delivery. On the basis of this time and distance, the relay node selects the optimum forwarding nodes. A larger speed node has higher probability to be selected as optimum forwarding node. The process repeats at each intermediate relay node to ensure timeliness packet delivery at the destination.

The geographical routing generally follows the greedy forwarding routing for real-time data delivery. The data delivery suffers when potential relay node is not available. This occurs due to void area or holes in the network. In this situation, the node fails to forward the packet and/or requires additional time to access the alternate path. In this way, this degrades the in-time data delivery. To handle this situation, the transmission energy regulation mechanism helps to improve performance. Therefore, bottom-up reliability modeling approach may be followed to analyze and understand the reliability of the system. The IWSNs overall system reliability depends on the reliability of sensor node, communication link, gateways and control room. Out of them, the sensor node level reliability plays a major role to improve the system reliability.

To overcome the packet loss due to unavailability of potential relay node and to improve the reliability of the data delivery, the proposed routing protocol incorporates the reliability model. This mechanism starts working as data forwarding faces the lack of potential forwarding relay node. The data forwarding node switches to next higher-energy level to access the potential forwarding neighbors that are making more progress toward the destination. This process repeats at each intermediate relay node for packet to be delivered at destination. This process removes void area problem, helps to optimize the path access latency and supports in-time data delivery. The energy regulation process depends on the residual distance, time and type of forwarding data.

Simulation Analysis

The performance of the proposed scheme is analyzed by using the Network Simulator (NS2). The NS2 is an open source programming language written in C++ and OTCL (Object Oriented Tool Command Language). NS2 is a discrete event time driven simulator which is used to model the network protocols mainly. The nodes are distributed in the simulation environment.

The simulation of the proposed scheme has 50 nodes deployed in the simulation area 900×900. The nodes are communicated with each other by using the communication protocol User Datagram Protocol (UDP). The traffic is handled using the traffic model CBR. The radio waves are propagated by using the propagation model two ray ground. All the nodes receive the signal from all direction by using the Omni directional antenna. The performance of the proposed scheme is evaluated by the parameters packet delivery ratio, packet loss ratio, average delay, throughput, residual energy and lifetime.

Packet Delivery Rate

The Packet Delivery Rate (PDR) is the rate of the number of packets delivered to all receivers to the number of data packets sent by the source node. The PDR is calculated by equation (1).

$$PDR = \frac{\sum_0^n Packets\ Received}{\sum_0^n Packets\ Sent} \quad (1)$$

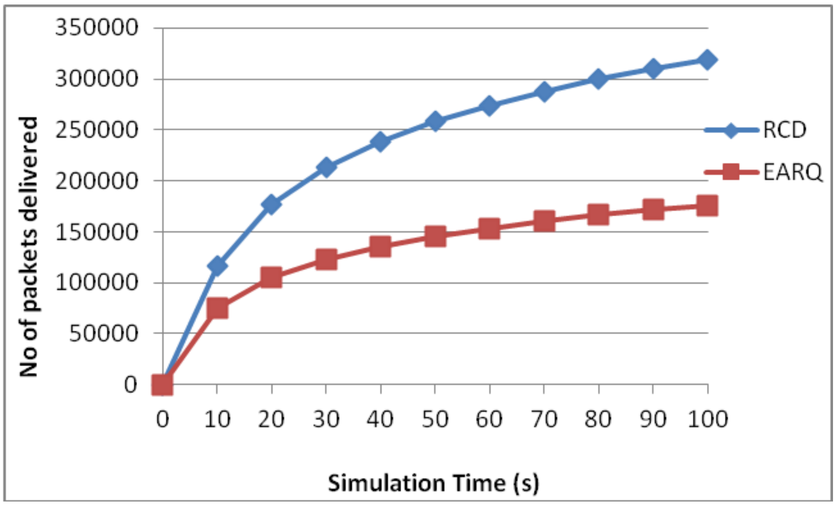

Figure 2: Packet delivery Rate

From Figure 2, the PDR of the proposed scheme is increased by 18% compared to the existing scheme VO-AODV. This is because of the QoS improved during the estimation of the connection density and residual energy parameters in the route selection process of the method proposed. The greater value of PDR means the better performance of the network protocol.

Average Delay

The average delay is defined as the time difference between the current packets received and the current packet sent. It is measured by equation (3).

$$Average\ Delay = \frac{1}{n}\left(\sum_0^n Pkt\ Recvd\ Time - Pkt\ Sent\ Time\right) \quad (3)$$

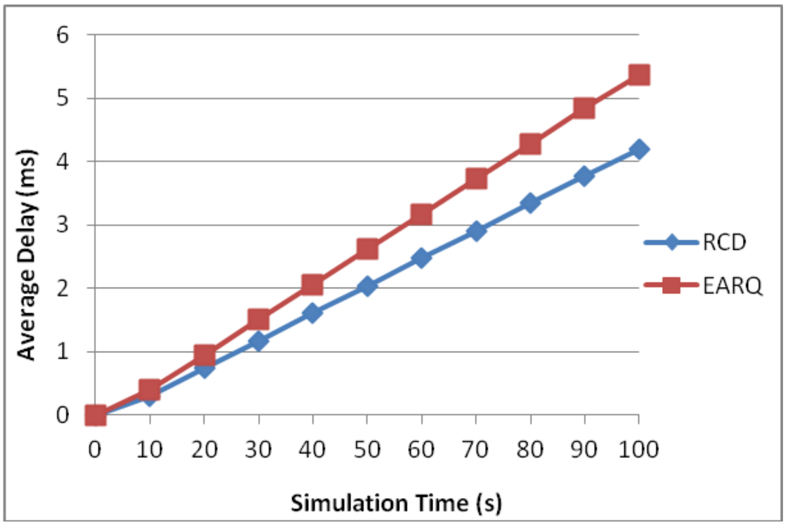

Figure 4: Average Delay

Figure 4 shows that the average delay is low by more than 23% for the proposed scheme RLMOR than the existing VO-AODV. The minimum value of delay means produces the higher value of the throughput in the network. This graph justifies the fact that the hindrances in the communication are lesser among the nodes in the network, which shows a significant average delay.

Conclusion

Routing critical data for improving performance in industrial wireless sensor networks is proposed in this paper. That dynamically selects the reliable relay node by considering the data type, deadline time along with the recent parameters of the network. These parameters are selected in such a way that the critical data forwarding follow shorter path over speedy, reliable links and non-critical data forwarding follow the path over energy efficient nodes. In this way, the relay node selection process balances the network load that the shorter path remains available for the shorter deadline-time critical data.

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