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Distributed Optimal Relay Selection in Wireless Sensor Networks

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Abstract

In wireless distributed sensor networks, one open problem is how to guarantee the reliable relay selection based on the quality of services diversity. To address this problem, we focus on the reliable adaptive relay selection approach and adaptive QoS supported algorithm, based on which we present a Markov chain model, in consideration of different packet states and error control algorithm assignment. The mathematical analyses and MATLAB simulation results show that the proposed relay selection approach could perform better in terms of saturation throughput, reliability, and energy efficiency, compared with the traditional approaches. More importantly, the quality of real-time multimedia streaming is improved significantly, in terms of decodable frame ratio and delay.

Keywords: Sensor networks, Wireless Multi-Hop, markov Chain Model, QoS.

1. Introduction

It is well known that delivering and transmitting various data over wireless distributed and dynamic networks is a very challenging task. Wireless communication link is a dynamic environment. Data transmission over wireless channel suffers from the limited bandwidth, high packet loss rate, and dynamic changes of channel state, sensor nodes mobility, channel competition, and so forth. These constraints and challenges, in combination with the delay and loss of sensitive nature of multimedia applications, make QoS provisioning over wireless sensor networks a challenging proposition. The data delivery of different applications inherently has different QoS requirements such as throughput, real time performance, playable frame rate, reliability and energy efficiency, and so forth. There is an open problem in the relay selection approach design: how to take advantage of the requirements information of QoS diversity in the wireless distributed sensor networks to find out the optimal relay for forwarding data packets from the potential relays.

In this paper, we investigate how to select the optimal relay nodes to provide the reliable and effective QoS provision and satisfy the diversity requirements of application services. The rest of the paper is organized as follows. The related work and our work are elaborated in describes the system models and problem description. In, we design a Markov chain model to describe process of data communication in wireless distributed sensor network and give the theoretical analysis model to show the achieved performance. The supported scheme of QoS diversity is used to realize reliable, efficient, and robust communication in wireless distributed sensor network, which is shown in proposes the QoS supported adaptive relay selection (ECA-Q-RS) approach, followed by the details of implementation.

2. System Model

In this section we present the wireless distributed sensor network model which is composed of Mica2 sensor nodes, which are comprised of ATmega128L processor and CC1000 radio module. In order to analyze the variation characteristics of SNR between hops, the log-distance path loss model is used, which is able to approximate the effects of the signal propagating through the wireless channel. In this model, denotes the distance between the sending node and receiving node.

3. Results and Discussion

In our previous research achievements the performance of ARQ or HARQ scheme has a close relationship with distance and 0 at first. Then, the variation characteristic of ARQ or HARQ scheme performance is presented by mathematical analyses in different SNR. All the above evaluations are based on the equations from On the one hand; Figure 2 shows four performance metrics as a function of distance. We only consider two different 0, which are 15m and 25m. As illustrated in, because the channel state is perfect and the frame error rate is extremely small, the performance of ARQ scheme is maintained relatively well with the increasing of the distance. However, the saturation throughput and energy efficiency of ARQ decrease to zero rapidly. Meanwhile, the packet dropping rate and average delay of this scheme increase quickly when the distance between sender node and next-hop receiver node is greater than 40m, and 0 is 15 m. Hence, the distance between sender node and next-hop receiver node has a constant value dependent on variation of 0, which is 40m for ARQ scheme. It is clearly noticed that there is a distance threshold value of ARQ scheme, which is 40m, when 0 is 15 m. Likewise, the distance threshold value is 70 m, 30 m, and 60m, respectively, for ARQ (0 is 25 m), HARQ (0 is 15 m), and HARQ (0 is 25 m). Above all, there is always constant distance threshold value of different error control mechanisms with different 0. Consequently, we can obtain the number of relay nodes, and select the best relay node according to this result. On the other hand, the change trend of four performance metrics as a function of SNR. It was obvious that the performance of ARQ is maintained gradually perfect with increasing of SNR. Specially, the saturation throughput and energy efficiency of ARQ increase to 1 rapidly; meanwhile, the packet dropping rate and average delay of this scheme decrease fast when the SNR between sender node and next-hop receiver node is greater than 16 dB. Hence, SNR between sender node and next-hop receiver node has a constant value, which is 16dB for this scheme. There is apparently a SNR threshold value of ARQ scheme. Likewise, the SNR threshold value is 20 dB for HARQ. Therefore, different error control mechanisms have always one constant SNR threshold value. We can choose the best relay node as the next-hop receiving node according to this conclusion.

4. High Reliable Relay Selection Approach
4.1. Relay Selection Algorithm

If we can obtain the end to end distance, the optimal relay node should be selected according to distance threshold, and also the number of relay nodes is given. Afterwards, we present the basic idea of the ECA-Q-RS and its implementation at sender node, receiver node, and relay nodes in detail, which is illustrated as follows.

Sender Node

(1) Carry out the QoS supported scheme. The guarantee priority of saturation throughput, packet error rate, and energy efficiency, or average delay is appointed according to the requirement of application service.

(2) At the data link layer, the optimal error control and QoS supported scheme are chosen. Moreover, the value of TE and max is obtained based on the QoS analytical model.

(3) Relay selection mechanism based on distance is implemented when and 0 are known, or the wireless channel is unstable and poor. Relay selection mechanism based on SNR is implemented when channel state information is known, or the wireless link is perfect.

(4) Starting to send data packets. If ACK packet is received, new data packets are sent, and retransmission time-out is used for each packet at the same time.

(5) When the timer matures, or NACK packet is received, the optimal error control scheme is started according to the QoS scheme.

Relay Node

(6) Select the optimal relay node from candidate nodes based on distance or SNR threshold.

(7) Steps (3), (4), and (5) are implemented repeatedly in proper order until the data packet is received successfully or discarded actively.

Receiver Node

(8) If ARQ scheme is used, checksum is calculated and tested. If HARQ scheme is used, check sum testing and FEC encoding are implemented.

(9) If the result obtained is right, the data packet is accepted, and ACK packet is sent simultaneously; otherwise, it is rejected, and NACK packet is sent at the same time.

(10) Deliver the correct data packet to the upper layer.

5. Simulation Parameters

In experiment 1, 50 sensor nodes move in an 800m × 800m rectangular region. is 11 bytes. ACK is set to 7 bytes. Noise bandwidth is 30 kHz. The data rate of CC1000 radio is equal to 38.4 kBaud. Round trip time of one frame transmission at data link layer is 0.01 second. The mobility model is the random waypoint model. Each sensor node moves towards the destination node at a speed uniformly chosen between the minimal speed 0m/s and maximal speed 10 m/s. The MAC protocol is IEEE 802.15.4 protocol. We change 0 from15m to 30m to investigate the impact of node physical attribution on performance.

5.1. Simulation results

Two case studies are designed and conducted, with the variation of bit error rate and the simulation time, respectively. The main metrics for performance evaluation of the ECA-Q-RS for supporting the application services of QoS diversity are listed as follows.

(1) Decodable frames rate: it considers the dependency between different MPEG4 video frames.

(2) Average delay: we only calculate the end to end delay of the decodable frames.

(3) Throughput: the total size of data packets received successfully by the receiver node.

(4) Energy efficiency: the number of obtained decodable video frames per unit of energy consumption.

6. Experimental Results with Channel State

The result indicates that channel state has a significant impact on quality of data transmission in wireless sensor networks. We can observe tremendous improvement of performance using ECA-Q-RS, as compared with other two mechanisms. Even at a more poor state of the wireless channel, the quality using ECA-Q-RS is maintained in a good condition, while the saturation throughput and energy efficiency using max SNR relay selection and distance aware relay selection reduce and become close to zero gradually. The reasons are that not only the supported mechanism of QoS diversity minimizes the average delay but also the adaptive error control strategy improves the energy efficiency; as a result, the network throughput utilization increased.

As the transmission rate of multimedia data increases, the collision probability of data packets transmission increases significantly, leading to an unstable and dynamic decreasing tendency of decodable frame rate. The result demonstrates tremendous improvement of decodable frames rate with ECA-Q-RS as compared with other mechanisms. On this\ basis, we determine that ECA-Q-RS can prime accommodate the poor and dynamic wireless network environment. This obvious improvement depends on their stable relay selection scheme based on QoS diversity supported mechanism and adaptive error control strategy.

7. Conclusion and Future Scope

There is a great potential for relay selection and error control to enhance the performance of QoS diversity services and resource utilization. The purpose of this work is to overcome all kinds of limitations; we propose reliability aware and QoS supported relay selection (ECA-Q-RS). The main contributions in our work are as follows. First, considering the characteristics of different error control schemes, we introduce the Markov chain model based on ARQ and HARQ to study the characteristics of QoS. Second, a QoS supported strategy with dynamic priority is designed to ensure that packets have a better chance to be forwarded. Finally, we present adaptive relay selection algorithm, working together with the above QoS supported mechanism, in order to reduce the ratio of potential damaged or lost opportunities. The mathematics and simulation results demonstrate that, compared with the existing typical relay selection mechanisms, ECA-Q-RS greatly improves the data transmission quality and

achieves significant gains in terms of throughput and energy efficiency. As a result, we determine that the proposed mechanism is feasible for data diversity communication in wireless distributed sensor network. Our future work focuses on the implementation and validation of the proposed adaptive relay selection algorithms on the prototype system. Besides, one possible future direction is to study the channel prediction approach and the trade-off between performance and complexity.

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