Analysis of Data Rate and Transmission Power Hybrid Control in WSN IoT

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Abstract

The relationship between data rate and transmission power is analyzed in this paper. Moreover, an algorithm combined with adaptive data rate (ADR) and transmission power control (TPC) is proposed in this paper, and it improves battery life significantly on IoT devices. In the premise that without prejudicing the accuracy of wireless transmission, the faster data rate and lower transmission power can be used to reduce power consumption. The results of a longtime test show that the nodes with the proposed algorithm not only achieve power saving when good transmitting environment, but also accomplish stable communication in the harsh environment. In the best case, compared with the no-algorithm nodes, the nodes with the ADR and TPC algorithms can be reduced power consumption up to 50%.

Keywords: Internet of Thing, Wireless Sensor Network, Transmission Power Control, Adaptive Data Rate

1 Introduction

In recent years, issues such as artificial intelligence, industry 4.0, Internet of Vehicles, smart homes, smart cities, and smart manufacturing are caught eyes. The above-mentioned technologies are all based on the IoT. IoT technologies such as Bluetooth, ZigBee, Wi-Fi, and Sub-1GHz, which are used in the IoT, are becoming more popular.

With the rapid growth of IoT devices, in addition to considering the price of sensing nodes, IoT devices security and power consumption are even more critical [3]. In the wireless communication network, if not using the general power supply, but using the battery power, the battery life will be a troublesome problem [6]. Therefore, how to achieve extremely low power consumption on battery IoT devices has also become a big challenge.

2 Research Details

In wireless communication, transmission power is a major factor for power consumption. A method called TPC, minimize the transmission power as possible when communication quality can be maintained [2][4][5][8][9]. If the transmission signal is better than environment noise, TPC can be reduced to achieve more effect of power saving.

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In addition to the transmission power, the data rate is also a major factor affecting power consumption. In the case of packet transmission, if the transmission data rate is high, the wireless transmission time can be reduced. However, the cost of a faster data rate is transmission quality reduction. The appropriate data rate is selected based on the relative relationship between the frame delivery ratio (FDR) and the received signal strength indicator (RSSI) [1]. The methods of combining data rate and transmission power control to achieve power saving are proposed in [7][10].

In order to adapt the environmental interference, a data rate and transmission power integrated control algorithm is proposed in this paper. The control algorithm can adapt to the environment in which the sensor node is located, and choose the best data rate and transmission power. And, in this paper, the relationship between RSSI and packet error rate (PER) at each data rate will be measured; the relationship can be used to determine the environmental interference.

3 System Introduction

3.1 System Structure

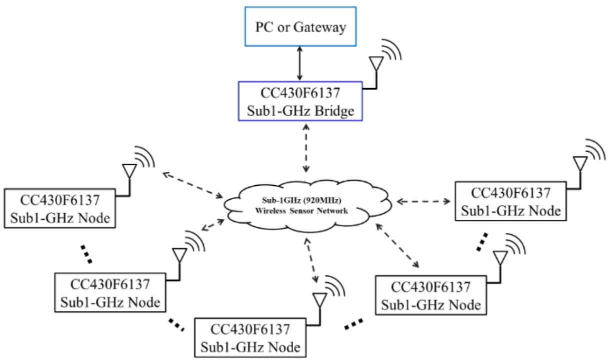

Figure 1: Diagram of system architecture

The system architecture discussed in this paper is shown in Figure 1. The main platform is the CC430F6137 Sub-1GHz wireless communication chip from Texas Instruments (TI) company. The network topology is a simple star scheme, and the FSK/GFSK is selected as the radio modulation method. The bridge is supplied by grid power, but multiple sensor nodes are supplied by the battery. Moreover, The bridge is used to collect the data from sensing nodes, and exchange information to the gateway by UART (Universal Asynchronous Receiver/Transmitter) interface. Also, the gateway could be a PC or embedded device to transfer data into the cloud by TCP/IP. The data rate and transmission power control algorithm are used to reduce the power consumption of the node to extend the battery life.

4 Measurement and Analysis

4.1 Measurement and Analysis

In the condition of PER 1%, the corresponding RSSI is called sensitivity. Since TI's original factory document only denotes some the receiver sensitivity in a little data rates, nor for the frequency band, 920MHz, used in the proposed ADR algorithm. The measurement of receiver sensitivity for the rates

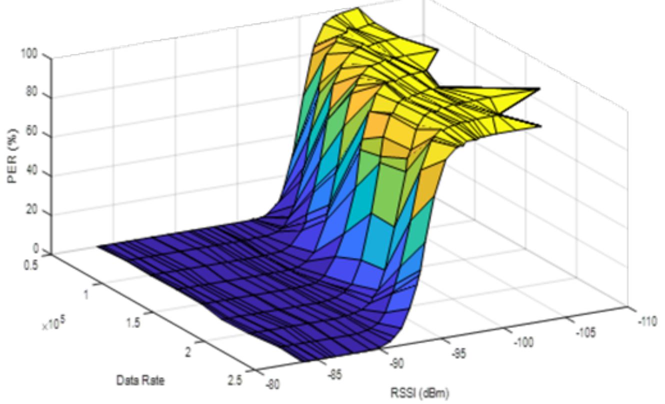

Figure 2: Relation of RSSI, data rate, and PER

Table 1: Receiver sensitivity in different data rate

Data Rate	Sensitivity
50 kbps	-96.93 dBm
75 kbps	-95.22 dBm
100 kbps	-94.36 dBm
125 kbps	-93.69 dBm
150 kbps	-93.12 dBm
175 kbps	-91.96 dBm
200 kbps	-91.53 dBm
225 kbps	-90.25 dBm
250 kbps	-90.06 dBm

from 50 kbps to 250 kbps in 920MHz is necessary because these rates are used in the algorithm. Through adjusting transmission power to change the RSSI is proposed in this paper, and the PER is recorded. The relationship between data rate, RSSI, and PER is shown in Figure 2. The RSSI closest to one percent PER at each data rate is taken as the receiver sensitivity of the data rate, as shown in Table 1.

4.2 Performance Comparison of Data Rate and Transmission power

Table 2: The transmission power in different data rate when PER 1% or less

Data Rate	PER	Transmission power	Difference
50 kbps	0.5 %	-18.484 dBm	X
75 kbps	0.3 %	-17.207 dBm	1.277 dBm
100 kbps	0.8 %	-16.446 dBm	0.761 dBm
125 kbps	0.8 %	-15.688 dBm	0.758 dBm
150 kbps	0.7 %	-15.074 dBm	0.614 dBm
175 kbps	0.6 %	-13.856 dBm	1.218 dBm
200 kbps	0.6 %	-13.309 dBm	0.547 dBm
225 kbps	0.1 %	-12.028 dBm	1.281 dBm
250 kbps	0.2 %	-11.155 dBm	0.873 dBm

In the receiver sensitivity experiment, the adjustments of transmission power in different data rates are recorded. And, the transmission power difference of adjacent data rate is listed in Table 2. In the same environment and distance, the faster data rate is needed to require higher transmission power, in order to maintain the PER 1% or less. The range of transmission power difference in Table 2 is from 0.547dBm to 1.281dBm; this means that when the data rate is increased by one level, it is necessary to increase the transmission power by about 1dBm to maintain the same PER quality.

5 Control Algorithm

5.1 Algorithm of Packet Error Interval

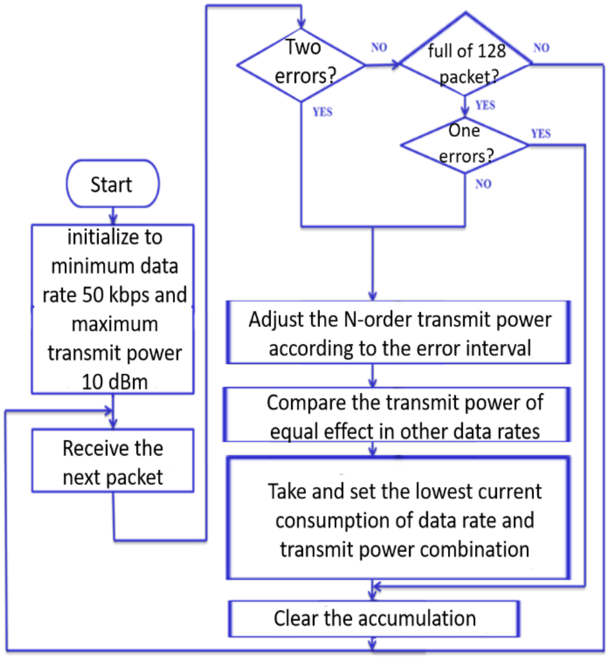

Figure 3: Flow chart of error interval algorithm controlling data rate and transmission power

The communication quality target of this paper is set at PER below 1%. In the algorithm of packet error interval, the threshold of data rate and transmission power is adjusted by 128 packet period, and the algorithm flow is shown in Figure 3. If there are no errors in the continuous 128 packets, it means PER is less than 1%. The data rate will be increased or the transmission power will be reduced. However, if only one incorrect packet in a 128 packet period, means PER of 1%, the data rate and transmission power will not be changed.

Finally, if two errors have occurred before 128 packets have been completed, the data rate will be reduced or the transmission power will be increased. In this algorithm, when the error interval is low, the larger amplitude of the transmission power is adjusted; because it is necessary to react immediately when an error occurs. Otherwise, when the error interval is high, the lower amplitude of the transmission power is adjusted; because the current environment may be stabilized and the error is not easy to occur. The N-order of the mixing data rate and transmission power adjustments are shown in Table 3, and the error intervals in the table are increased or decreased by a multiple of two. In the future, the value of the data rate or the transmission power may be adjusted, and the more N-order may be increased according to

Table 3: Data rate and transmission power adjustment of error interval

Error interval(number of packets)	N-order(mix control)
$\geq$ 1023	-4
512˜1023	-3
256˜511	-2
128˜255	-1
64˜127	2
3263	3
1631	4
815	5
47	6
23	7
1	8
0	9

different needs. By the error interval method, how much the N-order of data rate and transmission power needed to set is determined for the next transmission. After the above N-order adjustment, based on the database of Figure 2, the lowest power consumption combination of data rate and transmission power is selected as the result of the final adjustment.

6 Experimental Results

6.1 Experimental Method

The experimental method is to place two nodes in the same position, one node has the ADR and TPC algorithms, and the other node adjusts the data rate to the lowest 50 kbps and the transmission power to the maximum. Through long-term testing, the power consumption and PER of nodes placed at the same position are compared to verify the effect of the algorithm. And, note that control group node has TDMA. TDMA can save a lot of power for the sensing node, but power consumption of TDMA will not be discussed later.

6.2 Results and Analysis

In Figure 4 and 5, it can be found from the experimental result that the RSSI values of nodes with algorithms are close to the sensitivity value corresponding to the current data rate. If the RSSI value is lower than the sensitivity value, the probability of packet error will increase. Moreover, since the position of the nodes is affected by the people in the office and the class, the RSSI value of each node floats dramatically during the daytime; and the probability of packet error is high. However, the RSSI value at night is so stable that the probability of packet error is low.

The experimental data of nodes is organized as shown in Table 4. Compared with no-algorithm node, the node with algorithm could reduce the overall power consumption more than 50%. And, the PER could also be maintain less than 1%.

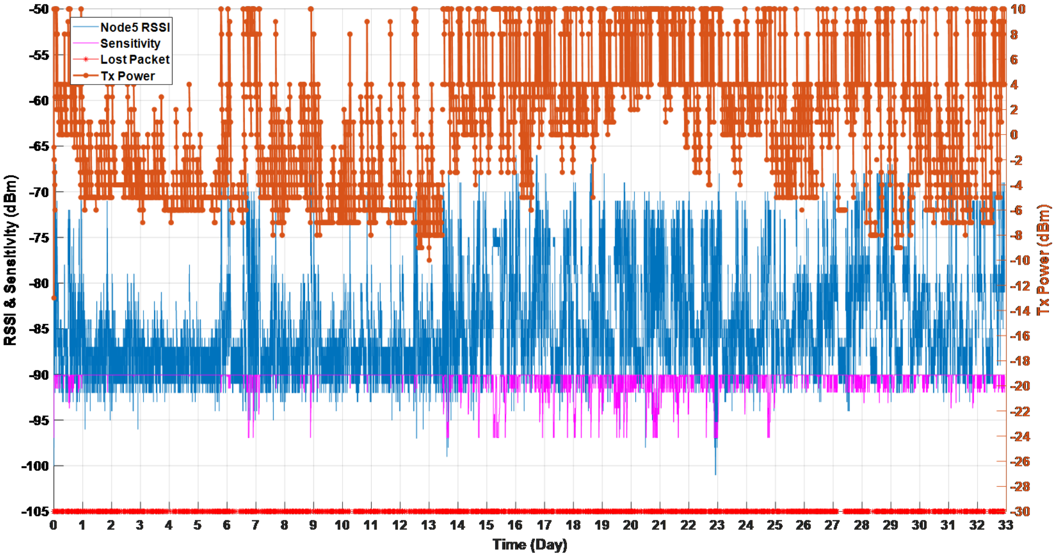

Figure 4: Experimental result of an algorithm node

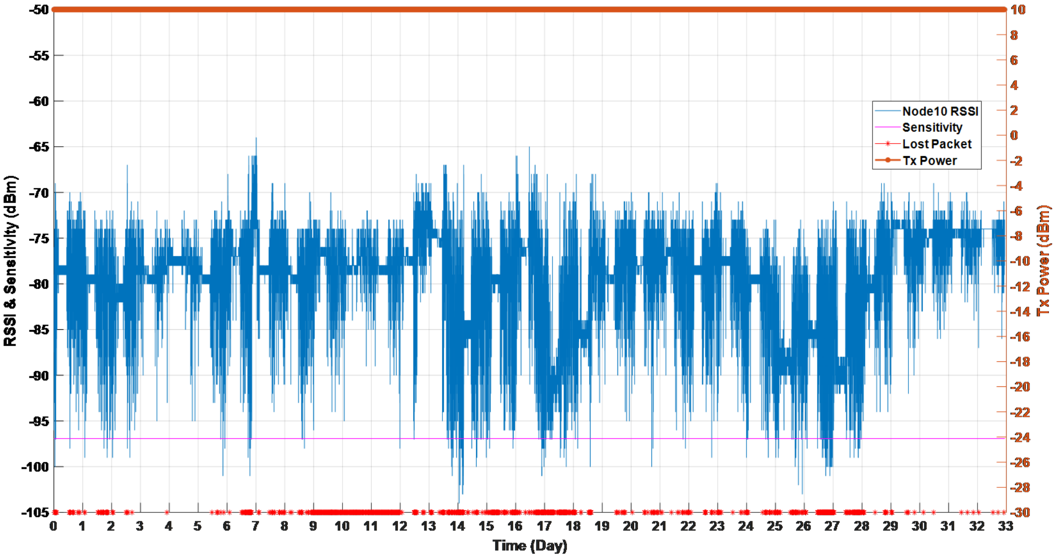

Figure 5: Experimental result of no algorithm control group

Table 4: Nodes experiment result

	PER (%)	Overall Average current consumption
Node with algo.	0.4011	32.516 uA
Node without algo.	0.3376	74.281 uA

7 Conclusion

The control algorithm of mixing data rate and transmission power is implemented in this paper. Compared with the nodes without the algorithm, the nodes with algorithms can increase the data rate and reduce the transmission power to save energy, when the environment is good. When the environment is bad, the algorithms can reduce the data rate and increase the transmission power to maintain stable communication.

And the experimental results show that the PER of experimental node with algorithm is less than 1%, and the power consumption is reduced. The result proves that the algorithm can achieve the effect of maintaining stable communication in the case of a harsh environment. And, the overall consumption of algorithm node could be saved up to 56.23% of power consumption, which proves that the algorithms proposed in this paper actually has the effect of energy saving.

Acknowledgments

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Author Biography

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