

# Retransmission Scheme with Code Sense for VSF/DS-UWB Ad-hoc Network

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## Abstract

In order to extend the communication range of UWB systems, multi-hop transmission is essential. However, since the number of hops increases, the packet loss increases as well. In this paper, to improve the reliability of the connection and make up for the packet loss, the retransmission scheme with code-sense for DS-UWB ad-hoc network is investigated and evaluated.

**key words** UWB, Ad-hoc Network, Spread Spectrum, Variable Spreading Factor, Retransmission, Code Sense.

## 1. Introduction

Ultra Wide Band (UWB) radio has received much attention as it has been approved by the Federal Communication Commission (FCC) for the commercial use in Feb. 2002. UWB is a kind of spread spectrum communication with very large bandwidth [1], [2]. The bandwidth assigned for UWB systems is about 7 [GHz] from 3.1 [GHz] to 10.6 [GHz]. Since the UWB systems use the short pulse wave of one or less nano second, they can achieve very high data rate communication. However, since the frequency band of UWB systems overlaps with the ones for the existing radio systems (802.11a, Satellite, etc), the transmission power is limited to less than  $-41.3$  [dBm/MHz] at the distance of 3 [m]. Therefore, the UWB systems have been investigated for short range wireless communications or ad-hoc networks [3], [4].

For UWB ad-hoc networks, the Direct Spread Code Division Multiple Access (DS-CDMA) scheme with variable spreading factor (VSF/DS-UWB) has been proposed in [5]. In that paper, Pure ALOHA protocol was employed. In the proposed scheme, in order to keep the received signal-to-noise ratio per bit ( $E_b/N_0$ ) constant, the spreading factor is increased in proportion to the square of the transmission distance. In addition, the distance for each hop is restricted and mul-

ti-hop transmission is employed. As compared to the conventional schemes, the proposed scheme can realize higher throughput for all transmission distances. However, since the number of hops increases as the transmission distance becomes longer, the packet loss increases rapidly. Therefore, it is necessary to retransmit the packet in order to compensate the packet loss. In the conventional retransmission scheme, acknowledge (ACK) packet is employed for the confirmation of successful transmission and retransmission. However, ACK packet gives interference to the other node and may collide with other packets. Therefore, if the number of ACK packets is reduced in the retransmission scheme, it is expected that the reliability of the connection is improved. Therefore, instead of ACK packet, the use of code sense for retransmission is proposed.

In this paper, to improve the reliability of the connection, the code sense method proposed in [6] is used for retransmission. This retransmission scheme of packets with code sense for VSF/DS-UWB system is investigated and evaluated.

This paper is organized as follows. Section 2 describes the UWB system and the network model. Section 3 gives numerical results through computer simulation. Finally, our conclusions are presented in Section 4.

## 2. System Model

### 2.1. The Location Estimation Method

In this paper, the positioning capability of the UWB system is employed in order to estimate the transmission distance. UWB systems have been studied as positioning systems in many researches [7] - [10]. For example, in [10], peer-to-peer ranging technique is presented based on time-of-arrival (TOA) information. In this technique, two nodes exchange a packet and an ACK packet. With a high-precision timer, based on

the total elapsed time of the packet exchange, the relative distance between the nodes can be estimated.

In this paper, it is assumed that each node knows the relative distance of the other nodes in the packet forwarding zone. It is also assumed that the measurement of the relative distance can be done between the transmissions of information packet. The table of the relative distance can be updated as the UWB nodes do not move rapidly since they may be implemented in personal computers or audiovisual devices.

### 3. Network Model

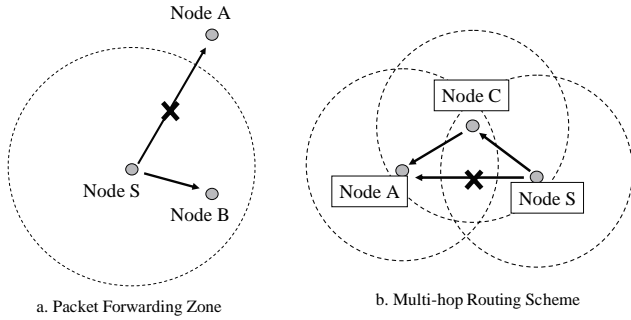


Figure 1: The routing scheme.

According to the high precision positioning capability of UWB systems, it is assumed that each node knows the location information (relative distance) of all the other nodes that consist the network. Network model proposed in [5] is employed. That is to say, each node has the packet forwarding zone and communicates with the long-distance node with multi-hop transmission. In the multi-hop transmission, a relay node is selected according to the relative distance between the nodes. An example of the packet transmission is shown in fig. 1. In addition, each node knows the spreading code of other nodes. A packet is spread by the spreading code of the receiving node.

#### 3.1. Variable Spreading Factor

Since the power of UWB systems is quite limited, power controll cannot be employed. In [5], the method of changing the spreading factor in proportion to the transmission distance has been proposed in order to maintain the received  $E_b/N_0$ . Therefore, the spreading factor depends on the transmission distance.

In this paper, the positioning capability of the UWB system is employed in order to estimate the transmission distance.

### 3.2. Modulation and Demodulation Scheme

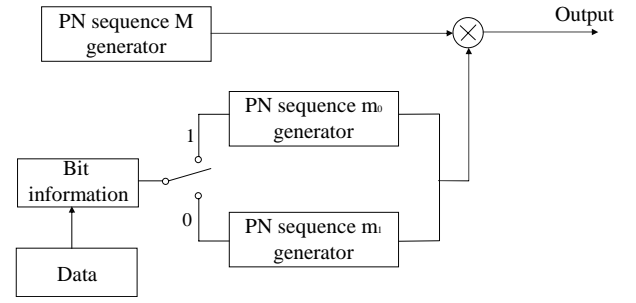


Figure 2: Block diagram of the modulation scheme.

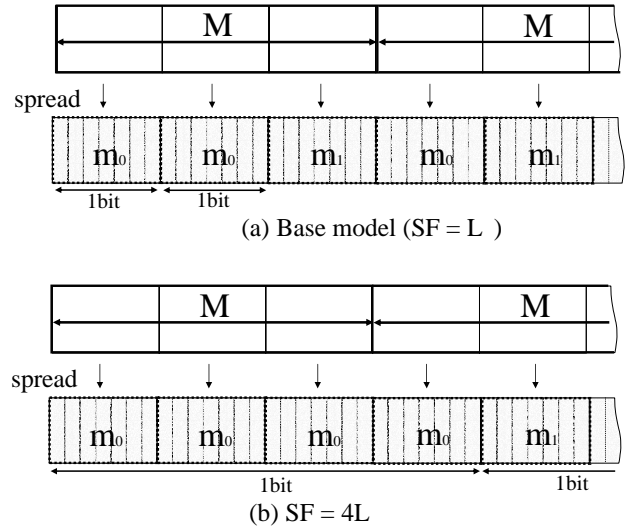


Figure 3: Variable spreading factor.

In this paper, binary sequence keying modulation proposed in [6] is employed. The modulation scheme is as follows:

1. Each node is assigned three kinds of the spreading code,  $m_0$ ,  $m_1$ , and  $M$ .
2. According to the information bit,  $m_0$  or  $m_1$  is selected as binary sequence keying modulation.
3. Each chip of the code  $M$  is spread with  $m_0$  or  $m_1$ .
4. The spreading code  $M$  is used only for the code sense.

The block diagram of the modulation scheme is shown in fig. 2. Fig. 3-(a) shows an example of the transmission signal when the spreading factor is minimum and fig. 3-(b) is the one when the spreading factor is 4 times of fig. 3-(a). The block diagram of the demodulation scheme is shown in fig. 4.

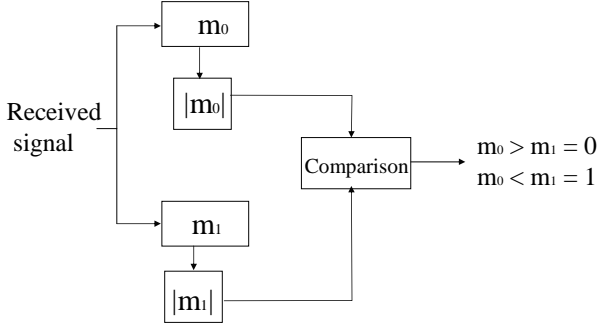


Figure 4: Block diagram of the demodulation scheme.

### 3.3. Retransmission Scheme

#### 3.3.1. Conventional Scheme

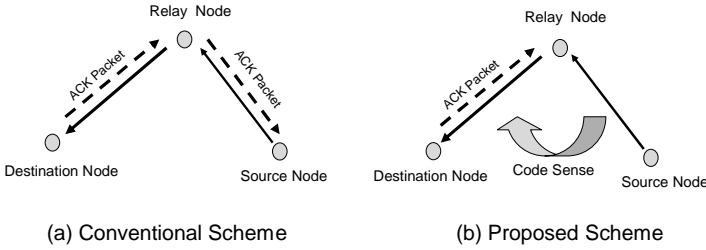


Figure 5: Retransmission scheme.

The conventional retransmission scheme uses ACK packet as shown fig. 5-(a). Suppose that node  $S$  is a transmission node and node  $D$  is a target node. When node  $D$  receives a packet from node  $S$ , node  $D$  returns an ACK packet to node  $S$ . If node  $S$  does not receive an ACK packet from node  $D$ , node  $S$  sends the same packet to node  $D$  again. If the retransmitted packet is also lost, node  $S$  sends the packet one more time. The number of the retransmission times is limited to  $r$ .

#### 3.3.2. Proposed Scheme

Code sense technique proposed in [6] is employed for the retransmission scheme. This scheme senses the carrier signal by the correlation value of the spreading codes, and detects if the target node is correctly relaying a packet or not.

As mentioned in Sec. 2, node  $j$  is assigned three kinds of the spreading code  $m_{0j}$ ,  $m_{1j}$ , and  $M_j$ . Fig. 6 shows the block diagram of the code sense scheme and fig. 7 is the block diagram of the selector.

1. The transmitted signal to node  $k$  is correlated with  $m_{0j}$  and  $m_{1j}$ , and the amplitude of the outputs are compared in the selector.

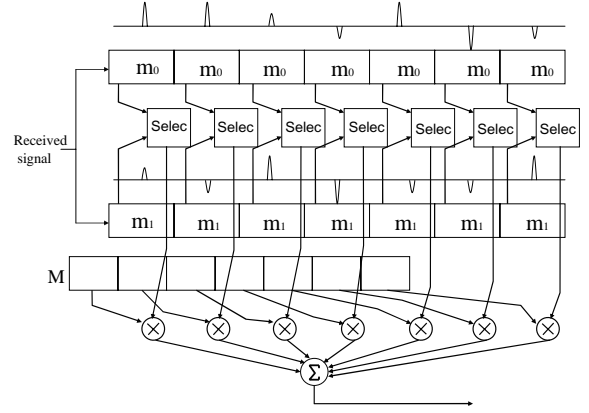


Figure 6: Block diagram of the code sense scheme.

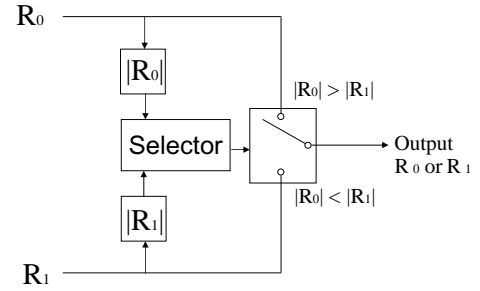


Figure 7: Block diagram of the selector.

2. The larger output is selected and multiplied to the corresponding chip of the code  $M_j$ . The selected output is the soft output of the matched filters for  $m_{0j}$  or  $m_{1j}$ .
3. The despread signals are summed together. If the sum exceeds the threshold, node  $i$  judges that node  $j$  is relaying a packet.

However, this code sense scheme is used only if node  $k$  is the relay node. If node  $k$  were the destination node, node  $k$  uses the conventional ACK packet as shown fig. 5-(b).

## 4. Numerical Results

### 4.1. Simulation Model

The simulation conditions are shown in table 1. The nodes are located at random in the space of  $25 \text{ [m]} \times 25 \text{ [m]}$ . The channel is assumed to be Additive White Gaussian Noise (AWGN) channel. There is no obstacle between the nodes. Each packet occurs according to the Poisson distribution, and is transmitted to the destination node which is chosen at random according to the routing scheme proposed in [5]. The configuration

Table 1: Simulation conditions

Modulation	DS-CDMA
Control System	Pure ALOHA
Channel Model	AWGN
Number of Nodes	25
Radius of PF Zone	$R = 10$ [m]
Packet Length	64 Byte
ACK Packet	8 Byte
$E_b/N_0$	10 [dB] @ 10 [m]
Threshold	$SINR < 8$ [dB]
Traffic	1

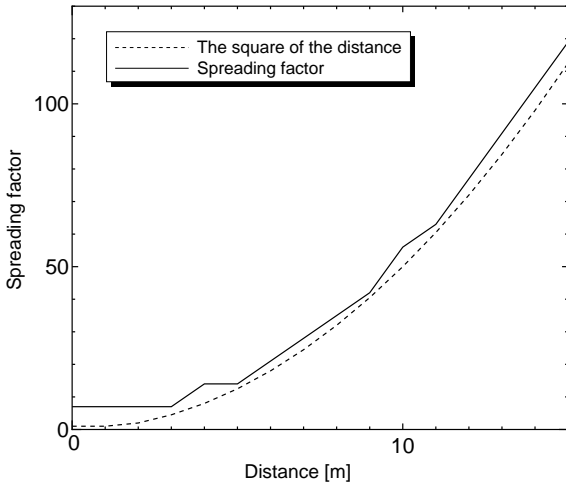


Figure 8: Spreading factor vs. the transmission distance.

of the network is simulated more than 10,000 times. The transmission power of each node is kept constant. In this simulation, each node has three spreading codes and those codes are phase shifted versions of the same  $M$  sequence or its flipped one with the length of 7. The time of carrier sense is set to the duration of 98 chips. Success or failure of the packet transmission is specified by the following rules:

1. When two or more packets arrive simultaneously, both of the packets are discarded. This is because low cost and low power UWB devices are assumed here and only one spreading code can be demodulated at a time.
2. If Signal-to-Interference-plus-Noise-Ratio (SINR) is less than 8 [dB], a bit error occurs.
3. The packet is discarded if the number of errors are more than 5 bits in one packet.

According to [11], when Forward Error Correction (FEC) is used, it is possible to achieve Bit Error Rate (BER)  $< 10^{-6}$  if  $SINR \geq 8$  [dB]. Therefore, the threshold is set as  $SINR = 8$  [dB].

In addition, in this paper, each node on the network is fixed. The chip rate is set to 5 [Gchip/sec] and the spreading factor (SF) for 10 [m] is set to 50 in order to achieve the bit rate of 100 [Mbps], as shown in fig. 8. The number of the retransmission times is  $r = 1$ . The traffic 1 is defined as the number of packets generated in the period of one packet length for the transmission distance of 10 [m] (the radius of the packet forwarding zone).

## 4.2. Numerical Results

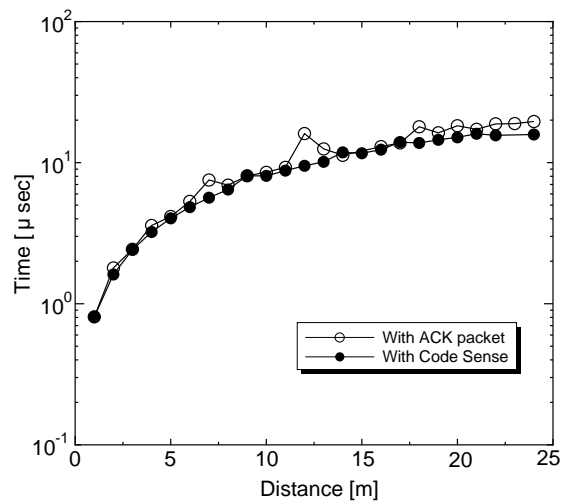


Figure 9: the average time of one packet transmission vs. the transmission distance between a source node and a destination node with ACK packet and code sense.

Fig. 9 shows the average time of one packet transmission from the source node to the destination node vs. the transmission distance between the source node and the destination node. In the short transmission distance, both schemes use ACK packet for the retransmission. Thus, both results are almost same. On the other hands, If the transmission distance is long, the conventional scheme spends more time for packet transmission than the proposed scheme. This is because the duration of code sense is shorter as compared to that of an ACK packet.

Fig. 10 shows the probabilities of success transmission with an ACK packet or code sense vs. the transmission distance between the source node and the destination node. Fig. 11 shows the effective data rates [Mbps] of the multi-hop transmission with an ACK

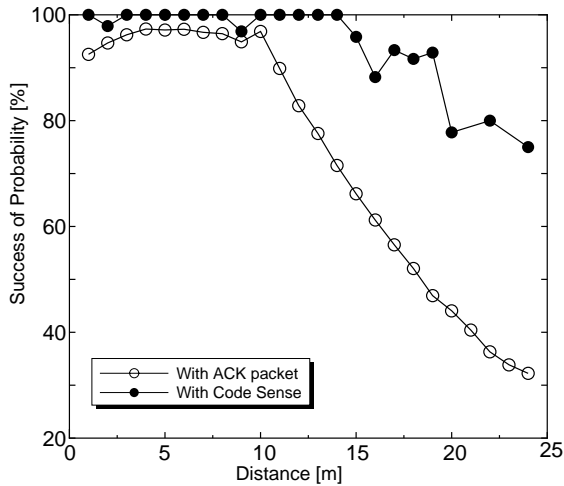


Figure 10: The success probability of transmission vs. the transmission distance between a source node and a destination node with ACK packet and code sense.

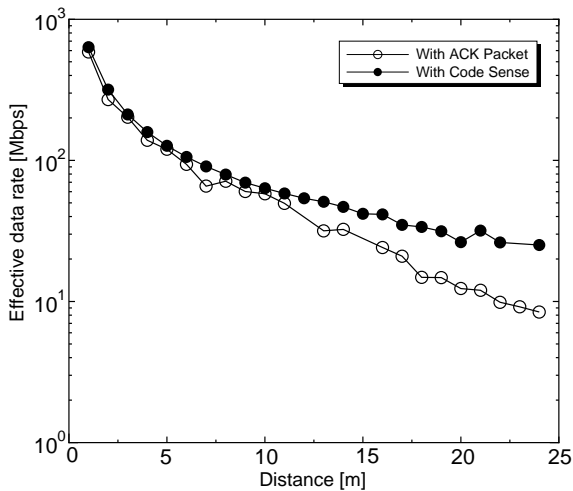


Figure 11: The effective data rate vs. the transmission distance between a source node and a destination node with ACK packet and code sense.

packet or code sense vs. the transmission distance between the source node and the destination node. The effective data rate is equivalent to the expected number of packets which reaches a destination node and the data rate multiplied by the probabilities of success transmission at the transmission distance. Both results in the proposed scheme are different from those of the conventional scheme when the transmission distance is more than the radius of the packet forwarding zone. This means that the packets are transmitted through the relay nodes. In this case, as compared to the proposed scheme, the improvement on the effective data rate is limited in the conventional scheme because the ACK packets generates more interference to the other nodes and may collide with other packets. Therefore, in the long transmission distance, both results with the proposed scheme are better than those with the conventional scheme. When the transmission distance is 20 [m], as shown in fig. 10, the probabilities of success transmission of the proposed scheme is about 40 [%] better than that of the conventional scheme. Additional, as shown in fig. 11, the effective data rate of the proposed scheme is about 20 [Mbps] better than that of the conventional scheme.

## 5. Conclusions

In this paper, the novel retransmission scheme for VSF/DS-UWB system has been proposed. The proposed retransmission scheme employed the code sense technique in order to reduce the number of ACK packets. Code sense technique for retransmission can reduce the packet loss and improve the performance especially when the transmission distance is large.

## 6. Acknowledgment

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