ON THE PERFORMANCE OF WIDEBAND OFDM SYSTEM IN THE PERFORMANCE OF INTERFERENCE FROM UWB SYSTEMS WITH LOW DUTY-CYCLE PLOTOCOL

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ABSTRACT

Ultra wideband (UWB) radio communication has gained much attention such as a future radio communication technology. UWB radio devices must equip the interference mitigation technology since the radio band of the UWB radio systems overlaps that of other radio systems such as worldwide interoperability for microwave access (WiMAX) and 4th generation mobile cellular systems (4G).

In this paper, the performance of wideband systems using OFDM over the coexistence environment is analyzed. In order to analyze the interference mitigation capability of low duty-cycle (LDC) protocol with impulse-based UWB radio system (LDC-UWB) Mutual collision probability between wideband OFDM systems and LDC-UWB systems is investigated and two state Markov collision model is proposed. Moreover, the frame error rate (FER) of wideband OFDM systems is discussed by using computer simulations.

1. INTRODUCTION

Recently, ultra wideband (UWB) radio communication has gained much attention such as coexistence with other radio systems because of its low power spectrum density equivalent to noise level [1]. However, UWB radio communications may inherently degrade the performance of the other radio systems since the radio band of the UWB radio systems overlaps that of other radio systems such as worldwide interoperability for microwave access (WiMAX) and 4th generation mobile cellular systems (4G). Therefore, it is essential for UWB radio communications to equip interference mitigation techniques, *detect and avoid* (DAA) and *low duty-cycle* (LDC).

The device with DAA can detect the signals from existing victim systems and avoid the interference to them. High data rate UWB radio communication with DAA has been studied in the literature [2][3]. Originally, LDC protocol has been studied to reduce energy consumption [4]. LDC protocol is extended in order to reduce the average interference to other systems by lowering the pulse repetition interval or pulse occupation time. Moreover, in UWB wireless as hoc network, LDC protocol has been studied to improve the near/far power disparities or pulse-on-pulse interference of multiple access [5]-[7]. Low data rate UWB radio communication with LDC protocol such as IEEE 802.15.4a has been studied since wireless sensor network requires long battery life and low cost rather than high data rate communication. Although LDC protocol promises that the average interference to other radio systems can be suppressed UWB radio systems still interfere with other radio systems even with LDC protocol.

In this paper, we focus on the coexistence environment of UWB radio systems and wideband systems based on orthogonal frequency division multiplexing (OFDM) such as 4G and WiMAX. In order to analyze the interference mitigation capability of LDC protocol with impulse-based UWB radio system (LDC-UWB), the performance of wideband OFDM system over the coexistence environment is studied. Specially, mutual collision probability between wideband OFDM systems and LDC-UWB systems is investigated and two state Markov collision model is proposed. Also, the frame error rate (FER) of wideband OFDM systems is discussed by using computer simulations.

The rest of this paper is organized as follows. In Section 2, network models considered throughout the paper are presented. Two states Markov collision model is discussed in Section 3. Simulation results and discussion are given in Section 4. Finally, the conclusions are drawn in Section 5.

Table 1. Major parameters of UWB systems

Data rate objective	> 1Mbits/s
Type of UWB system	Impulse-based UWB
Pulse width	0.5 ns
Duty-Cycle	0.1, 1, 5, 10, 50, 100 %
Tx (or Rx) slot length	1 ~ 1001 ms
Sleep period after Tx (or Rx)	1000 ~ 0 ms
UWB frame length	2,002 ms

2. NETWORK MODELS

2.1 UWB SYSTEM NETWORK MODEL

Major parameters of UWB radio systems are listed in Table 1. In this paper, low data rate UWB radio system is assumed such as IEEE 802.15.4a and sensor networks and thus its data rate is below 1 MHz bits per second (bps). Although impulse radio signals of UWB communications are not exactly Gaussian, their interference effect to narrowband systems can be approximated as a white Gaussian noise [8].

In this paper, a victim system is the wideband OFDM system. The bandwidth of the wideband OFDM system is about 100 MHz. Therefore, the UWB signals can be modeled as a white Gaussian noise since it is relatively narrowband compared with the UWB radio systems in order to simplify computer simulations. Note that the variance of this white Gaussian noise is given by the transmitted signal energy of the UWB radio system.

2.2 LDC-UWB SYSTEM NETWORK MODEL

LDC protocol is extended in order to reduce the average interference to other systems by lowering the pulse repetition interval or pulse occupation time.

LDC protocol [9] considered throughout the paper is briefly explained. In this protocol, every UWB radio devices wake for only a short time to communicate with other devices and timing schedule of UWB radio devices is not available at each devices as shown Figure 1(a). Thus, in order to establish a communication link, access controller (AC) is introduced as shown in Figure 1(b). The wireless network based on LDC protocol must have one AC device, which may be allowed relatively high power consumption and high duty-cycle compared with those of non-AC devices. AC can receive messages from all UWB radio devices belonging to its own network. Moreover, AC has the timing schedule of every devices. Note that this protocol is good for applying indoor applications since AC device should operate with the power line because of its high power consumption and high duty-cycle. Figure 2 is illustrated as an example of the LDC protocol with UWB radio devices A and B, where, the duty-cycle is about 0.1%, both UWB radio devices transmit (Tx) and receive (Rx) time slot are 1 ms, and AC has 2,002 ms receive time slot, where duty-cycle is time ratio about Tx (or Rx) of UWB radio devices to frame length of UWB radio device as it is fixed 2,002 ms. For example, duty-cycle 0.1% is defined that Tx and Rx of UWB radio devices are 1 ms and total sleep period per frame is 2,000ms, duty-cycle 50% is defined that Tx and Rx are 500 ms and total sleep period per frame is 1002ms.

Device A keep sending a communication request (Comm Req) message to AC until the Ack message is received from AC, where Comm Req message includes it is own timing schedule and request to device B. Simultaneously, device B keep sending a Query message until Replay message from AC device is received as illustrated in Figure 2, where Replay message includes the timing schedule of device A and its request to device B. Then, device B adjusts its own timing schedule to that of device A and device B sends a Ready message to device A directly. Then, a communication link between device A and device B is established.

2.3 OFDM SYSTEM NETWORK MODEL

The block diagram of the wideband OFDM system is shown in Figure 3. Major parameters of wideband OFDM systems are listed in Table 2 (c.f., [10]). In this paper, the bandwidth of the wideband OFDM system such as 4G and WiMAX is about 100 MHz and thus its data rate is 100 MHz bps. Then, by considering the Gaussian assumption of the UWB signal interference, an equivalent baseband model is employed. Thus, the interference of the UWB signals is introduced as follows. The white Gaussian noise as the UWB signal is added to the transmitted OFDM signal (see Figure 3). After that, the received signals are passed through the low pass filter (LPF) of the OFDM system.

Table 2. Major parameters of wideband OFDM systems

Bandwidth	101.5 MHz
Data rate objective	> 100 Mbits/s
Number of sub-carriers N_c	768
Sub-carrier spacing F_s	131.8 kHz
OFDM symbol duration T_s	7.585 μs
Total OFDM symbols duration T'_s	9.259 μs
Number of OFDM symbols per frame N_s	54
OFDM frame length T_{fr}	500 μs
Symbol modulation	QPSK

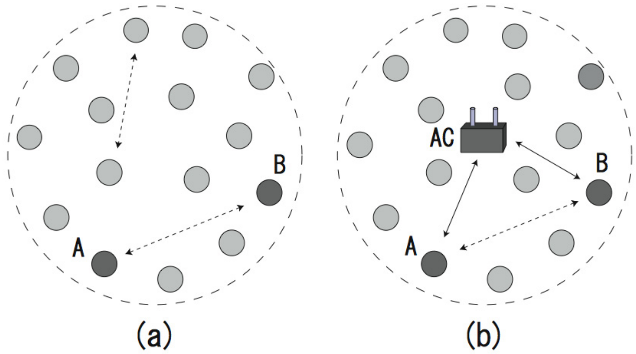

Figure 1. In order to establish a communication link, access controller (AC) is introduced

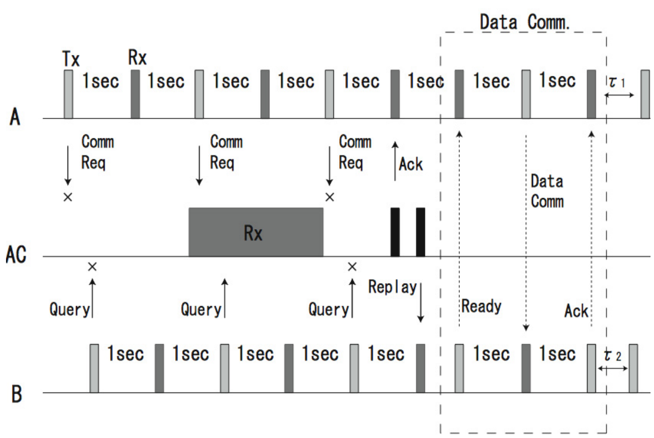

Figure 2. LDC protocol: an example of duty-cycle = 0.1%

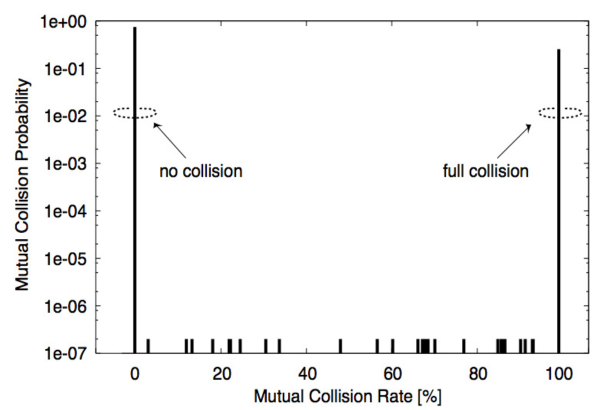

Figure 4. The mutual collision probability between wideband OFDM system and LDC-UWB system, when duty-cycle of LDC-UWB is 50%.

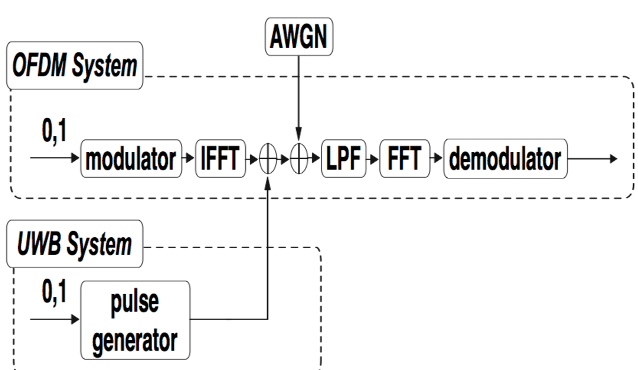

Figure 3. The block diagram of the wideband OFDM system.

3. MARKOV COLLISION MODEL

As mentioned adobe, the frame length of LDC-UWB system is assumed 2,002 ms since each Tx and Rx is 500 μs and its sleep period is respectively 502 ms (about duty-cycle of LDC-UWB is 50%). The frame length of wideband OFDM system is assumed 500 μs. Figure 4 shows the mutual collision probability between the wideband OFDM system and LDC-UWB system calculated by computer simulations, when duty-cycle of LDC-UWB is 50%. Mutual collision probability is defined as the probability of overlapping frames of wideband OFDM system and LDC-UWB system.

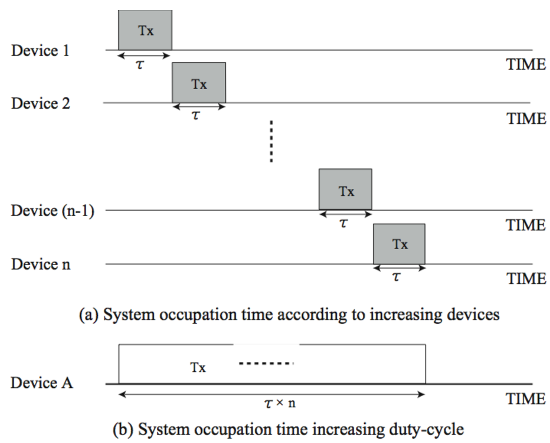

Figure 5. The LDC-UWB system occupation time (or multiple access).

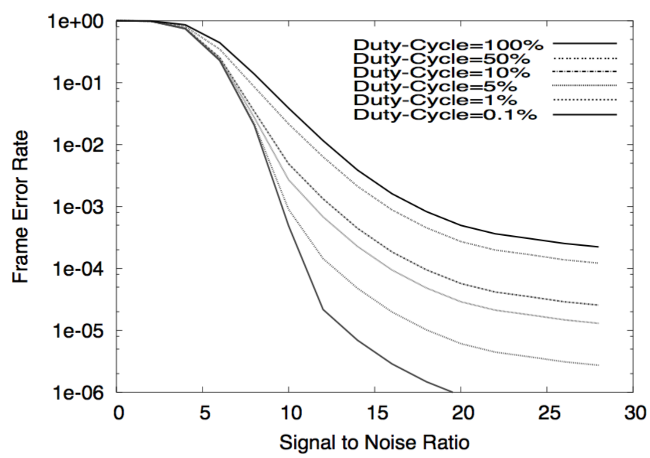

Figure 6. The FER of the wideband OFDM system with the interference by the UWB radio devices, when SIR = 10dB.

From Figure 4, the mutual collision probability can be divided into two states: full collision or no collision since the frame length of LDC-UWB is much longer than that of the wideband OFDM. Hence, we consider the two states Markov collision model as the mutual collision model between the LDC-UWB system and the wideband OFDM system in the rest of the paper.

4. SIMULATION RESULTS

Although LDC protocol promises that the average interference to other radio systems can be suppressed, LDC-UWB radio systems still interfere with other radio systems even with LDC protocol. Moreover, In Figure 5, when UWB radio devices (or users) are increased, the interference to wideband OFDM may be increased even applying lower duty-cycle. For the sake of evaluating them, quantitatively computer simulations are performed. In order to simplify computer simulations, UWB signals are modeled as a white Gaussian noise.

Figure 6 shows the FER of the wideband OFDM systems over additive white Gaussian channel with the interference by the UWB radio devices, where average signal to interference power ratio (SIR) is 10dB. From Figure 6, the FER of wideband OFDM systems are degraded with increasing of the duty-cycle of LDC-UWB. LDC cannot suppress interference to wideband OFDM systems completely. However it can be mitigated moderately without additional complexity such as DAA. Thus, the duty-cycle of LDC-UWB should be chosen carefully in consideration of the performance required quality of communications of the wideband OFDM system in the physical layer.

5. CONCLUSION

The performance of wideband OFDM system over the coexistence environment is studied to analyze the interference mitigation capability of LDC-UWB. We showed that Mutual collision probability between wideband OFDM systems and LDC-UWB systems could be modeled as the two states Markov collision model. Also, the FER of wideband OFDM systems has been discussed by using computer simulations. We can conclude as that LDC protocol is efficient interference mitigation technique for low data rate UWB radio communications since the FER of wideband OFDM systems are improved with decreasing of the duty-cycle of LDC-UWB. However, this means that the effective low duty cycle imposes the low data rate, essentially.

6. REFERENCES

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