DS-UWB Packet Structure for Inter-Vehicular Communication Based Ranging for Collision Avoidance System

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Abstract**—— In recent years, Ultra-WideBand (UWB) has attracted a lot of attention as a new radio-communication system. In this paper, we study about the optimal packet structure based on Direct Sequence-UWB (DS-UWB) for inter-vehicle communication system. The purpose of the present paper is threefold: 1) introduce the communication protocol for inter-vehicle communication; 2) propose a DS-UWB based packet structure to support ranging and data communication and analyze the factors affecting the packet composition and 3) optimize the packet design by throughput maximization. Assuming that ranging success depends on packet acquisition success and successful data demodulation, we derive the ranging performance through probability analysis. Performances are studied under AWGN channel and 2-path Rician Fading model. It is shown that the preamble symbol length is impacting the system performance of the inter-vehicle communication and ranging system. Through theoretical derivation confirmed by computer simulation analysis, we show that an optimal preamble symbol length maximize the throughput under an acceptable ranging performance. This research can be applied in Intelligent Transportation Systems (ITS) issues such as designing a collision avoidance warning system.**

Index Terms**—DS-UWB, Inter-Vehicle Communication, Optimal Packet Structure, Preamble Symbol Length Ranging Performance.**

I. INTRODUCTION

Ultra-WideBand (UWB) is a new promising radio-communication system researched intensively in academia as well as in the industry [1]-[4]. This system occupies a very large bandwidth by transmitting very short pulses in order of nanosecond in length. Therefore, UWB technology can be viewed as a kind of spread spectrum technology enabling technology for evolution of high-speed communication systems while achieving high ranging accuracy [5][6]. It can therefore communicate and range at the same time like conventional Direct Sequence-Spread Spectrum (DS/SS) system. DS/SS technique provides a highly accurate time resolution that enables not only communication but also accurate ranging to be performed.

Direct vehicle-to-vehicle communication based on radio technologies represents a key component for improving safety on the roads [7]. Recently, the demands for traffic problem solutions such as accidents, traffic congestions and environmental problems are increasing. A lot of effort has been developed for advanced traffic systems such as Intelligent Transport System (ITS), which can improve traffic safety, and efficiency by using advanced information technology [8]. To avoid vehicle collision, it is required for the vehicle to measure the distance in a short ranging time. Inter-vehicle communication system can provide drivers information and danger warning, and operational support to avoid accidents. This multi-functional system can be equipped on vehicles to help people drive safely. Vehicle could interact with other vehicles existing on the road. On the other hand, more information about road and surrounding is provided to the drivers through communications. However, using DS/SS for communication and ranging requires sequences with different periods. A short period of sequence is required for quick acquisition in communication, while a long period of sequence is needed for accurate ranging. Therefore, the system can perform ranging in a longer inter-vehicular distance while satisfying communication requirement.

Meanwhile, DS-UWB has been studied in recent year and seems to be a good candidate to satisfy those conditions [9][10]. It enables the receiver to get correlation gain by the use of spreading code. A boomerang transmission system was introduced in [11], a concept of a vehicle-to-vehicle communication and ranging system. By exploiting the spread spectrum technique, the system was capable of transmitting data and measuring the distance between two vehicles simultaneously. However, the boomerang transmission system uses one-way communication, therefore ranging distance can be done only for one vehicle and designing the system on each vehicle is uneconomical and inefficient. In this paper, we propose an inter-vehicle communication system to be implemented in ITS applications. To realize simultaneously ranging and communication in each vehicle, we propose a packet structure by using spread spectrum scheme under UWB technology. The main issue is the balance between ranging capability and spectral efficiency considered in our proposed system. This latter is expected to contribute in inter-vehicle collision avoidance without relying on fixed infrastructure such as roadside stations.

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This paper is organized as follows. In Section II, the motivation for the work and related works are presented. In Section III, the communication protocol to be applied for inter-vehicle communication based ranging is introduced and we propose a DS-UWB based packet structure. In Section IV, we analyze the importance of acquisition for the perspective of ranging and communication in inter-vehicle communication. We theoretically derive the detection and false alarm probabilities according to the packet structure, and the ranging performance based on those probabilities. The theoretical derivation of optimal preamble symbol length impacting the packet structure under throughput maximization is provided. Section V introduces the simulation algorithm. Computer simulation results are provided to validate the analysis. Finally, conclusions and future works are drawn in Section VI.

II. MOTIVATION AND RELATED WORKS

A. *Motivation of Research*

It is important for a smooth driving and traffic flow that a moving vehicle can detect other vehicles in the surrounding to assist the driver through control information. In such case, the vehicle must acquire its position knowledge with respect to other cars on the road and other parameters such as speed to identify a possible collision. This is made possible with the rapid progress in electronics and communication technology. In this paper, we would like to introduce an active alarming system for collision avoidance. The alarm is designed in a way to predict a possible collision between two or more vehicles. For example, when a vehicle is traveling at high speeds, it needs a longer braking distance to successfully avoid collision. In that case, a warning system is required for vehicular anti-collision system. This issue can be solved by inter-vehicle communication and ranging [9]. The proposed system is using UWB because of its fine resolution due to its bandwidth and high rate communication. Moreover, UWB can use spread spectrum techniques for low probability of interception, high interference immunity and anti-jamming. By using a system that can range and communicate at the same time, we can reduce cost and minimize interception probability.

B. *Related Works*

In our scheme, we refer to the WLAN communication model in 802.15.4a standard [12]. The standard is designed for low rate wireless personal area networks, but in this paper we investigate its applicability in inter-vehicle communication protocol designs and simulations for collision warning systems. The IEEE 802.15.4 standard provides a LOS range of a kilometer and NLOS of around 100 meters. Its memory requirement is small, easy to implement and less power consumption. On the other hand, UWB systems that provide ranging information commonly perform both communication and ranging as in typical 802.15.4a systems. Although 802.15.4a UWB-PAN is designed using microwave band 3.1-10.6GHz, UWB car radar allows to use quasi-millimeter wave band 22-29GHz and millimeter band 79GHz in radio generation having a wireless covering of several 100 meters. By Japanese UWB radio regulation, microwave UWB band is 3.4-10.6GHz and the emission power is limited but it performs a wireless range of 100 meters or more in Light-of-Sight (LOS) [16]. With UWB having an optional ranging capability, new positioning systems applications and market opportunities are growing.

Recent efforts can be found in different aspects for inter-vehicle communication for collision avoidance [13] and for joint radar and communication systems. The concept of joining radar and communication was introduced in [9][14] and [17] by using different orthogonal codes to avoid interference between radar signal and communication data. It has a disadvantage that the communication symbol rate corresponds to the chip rate, which is not optimal for communication application. In [11][15], spread spectrum signal is used as modulation in the joint system. These papers are focusing on searching for code sequences with good autocorrelation and cross-correlation properties. It addresses the problem that communication and ranging functions impose different requirement on the period of the spreading sequence. However, acquisition system is not considered yet. In the next section, we introduce the communication protocol to range and exchange information between vehicles, besides, a packet based on DS-UWB is introduced to address those issues.

III. INTER-VEHICLE COMMUNICATION BASED RANGING AND PROPOSED PACKET STRUCTURE

In this section, we are introducing the existing inter-vehicle communication and ranging system and our proposed communication based ranging realized through a new packet structure.

A. *Existing System*

Researches have been conducted addressing vehicle-to-vehicle communication and ranging issues, however, they are still presenting integration design constraints. In a case shown in Fig. 1, denoted in this paper as conventional system, ranging and communication are completely independent system. Separate processing of information from communication and ranging in a vehicle is very challenging. By analyzing those issues separately, the system becomes highly expensive and uneconomical from the viewpoint of effective utilization of the transmission media. Our objective is to provide a framework where ranging and communication can be realized simultaneously, guaranteeing ranging performance with respect to an acceptable data rate and throughput. To cope with those challenges, we propose in this paper a packet that can realize inter-vehicle communication and ranging simultaneously.

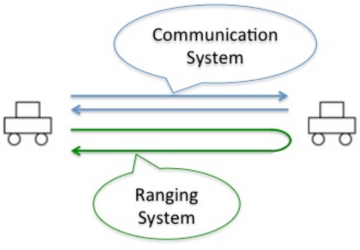

Fig. 1. Car-to-Car Communication and Ranging

B. *Communication Based Ranging Protocol*

Issues on loading a communication system and ranging system separately on each vehicle was described previously. The combination of ranging and communication system might be considered as an efficient alternative. Therefore, in this paper, we integrate ranging and communication system as depicted in Fig. 2.

Fig. 2. Proposed System

Communication and ranging system beneficiate both from UWB using spread spectrum technology [11]. In our proposed system, vehicles obtain information by spread spectrum demodulation of information transmitted by other vehicles after prior successful acquisition process. Moreover, we assume that all target vehicles are equipped with adequate communication system. The communication based ranging between the transceivers can be performed by two-way time of arrival (ToA) ranging protocol described below.

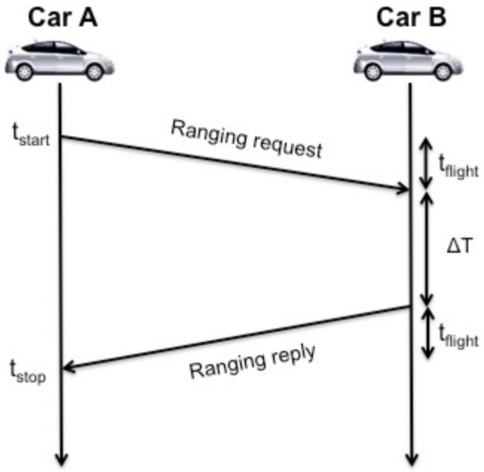

Fig. 3. Two-Way Range Measurement

1) Car A transmits a Request Packet of PN encoded pulses
2) Car B performs acquisition and demodulates the data
3) Car B transmits a Response Packet that includes the ToA of the first pulse
4) Car A performs acquisition, measures the ToA of the first pulse and demodulates the data response
5) Car A computes the time delay from Request Packet transmission and Response Packet reception and corrects the time delay by subtracting ToAs. The distance between transceivers is estimated.

ToA estimate is given by the time instant corresponding to the maximum absolute peak at the output of the matched filter (MF) over the observation interval. In this paper, the performance evaluation of MF threshold-based ToA estimator is addressed for DS-UWB signals.

C. *Proposed Packet Structure*

In order to carry out communication based ranging, it is necessary to design suitable packet for the system. The ranging accuracy should be taken into account in ranging performance. For communications, the data rate and bit error rate (BER) are the most important parameters. For a short ranging signal, range estimates can be obtained quickly with low accuracy, therefore more signal resources can be allocated for data transmission. However, with a longer ranging signal, better accuracy can be achieved while longer processing time is needed. Subject to the spreading sequence length restriction, we propose a DS-UWB based packet structure that fits the requirement within the packet design to realize simultaneously ranging and communication between vehicles. Figure 4 shows the packet structure with a preamble symbol and data symbol connected in series. With the dedicated portion called preamble, the receiver is expected to achieve packet acquisition, therefore ranging. The payload part is designed to perform data communication.

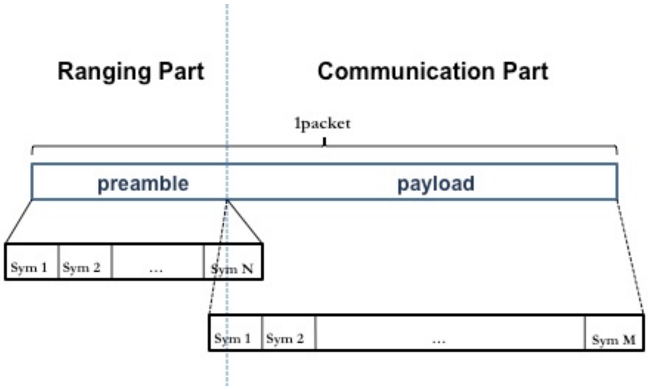

Fig. 4. Proposed Packet Structure

A spread spectrum system scheme satisfying the above requirements is adopted here. The system allows ranging between vehicles from the phase difference computed once acquisition process is completed. Hereafter, the receiver can obtain information after spread spectrum demodulation of the payload part. In this paper, we assume a data modulated direct sequence scheme with binary phase shift keying (DS/BPSK).

D. *Challenge in Ranging and Communication*

In spread spectrum-ranging system, the distance to the object is estimated by the time delay measured by the receiver during acquisition process. In this process, the receiver must be able to synchronize the locally generated and the incoming sequence with the accuracy of a fraction of a chip. The maximum ranging distance D is expressed as

$$D = \frac{N \times c}{2} \quad (1)$$

where N is the period of spreading sequence and c is the speed of the light. Therefore, estimating distances using DS/SS schemes requires sequence with long period because the measurement accuracy depends on the chip rate. However, communication while ranging requires sequences with different periods. A long period sequence is not desirable for high-rate data modulation, and the data rate R_d is given by

$$R_d = \frac{f_c}{N} \tag{2}$$

where f_c is the chip frequency. Therefore, there is trade-off between communication and ranging functions imposing different requirements on the period of the spreading sequence. We take into account those design constraints during our analysis.

IV. THEORETICAL ANALYSIS

This section presents a detailed analysis of the system performance under AWGN to understand which fundamental parameters affect simultaneously the ranging and data rate performance. The analysis is extended further to 2-path Rician Fading model for comparison.

A. Process of Communication

Communication data is mapped onto BPSK symbols. After symbol mapping, ranging signal is inserted at the beginning of the communication data. In the proposed packet-based transmission for communication based ranging system, preamble signals are used not only for packet acquisition or synchronization but also for ranging. During the study, we assume that the length of the packet is fixed.

The entire packet composed of preamble $s_{pre}(t)$ and payload $s_{pay}(t)$ can be described as,

$$s_{packet}(t) = s_{pre}(t) + s_{pay}(t - N_{pre}T_c) \tag{3}$$

where the payload is delayed by $N_{pre}T_c$ since it occurs after the preamble. The preamble sequence is composed of $N_{pre} = N_{sym} \times L$ chips where N_{sym} is the number of repetition symbol in one packet and L is the spreading sequence length.

The preamble signal composed of unmodulated PN sequence is expressed as,

$$s_{pre}(t) = \sqrt{E_c} \sum_{k=0}^{N_{sym}L-1} c_{\mathrm{mod}(k,L)} p(t - kT) \tag{4}$$

where $\{c_k\}$ is the spreading sequence and the energy in the pulse $p(t)$ is normalized to unit. That is to say $\frac{1}{T_c}\int_0^{T_c} p^2(t)\,dt = 1$. E_c is the transmitted energy per chip; the chip duration has been assumed to be equal to the pulse duration such as $T_c = T_p$.

The payload containing the actual data is spread by the spreading sequence $\{d_i\}$ of length L and can be described by,

$$s_{pay}(t) = \sqrt{P_c} \sum_{n=0}^{N_{bit}-1} \sum_{i=0}^{L-1} b_n d_i p(t - nT_s - iT_c) \tag{5}$$

where $\{b_i\}$ is the binary sequence of N_{bit} data bits transmitted per packet.

The spread payload modulated using BPSK is multiplexed with the preamble, and sent to the pulse-shaping filter. At first, we consider only the effect of AWGN noise. At the receiver, the signal delayed with a time delay τ can be written as,

$$y(t) = s_{packet}(t - \tau) + n(t) \tag{6}$$

The arrival time of a packet is unknown at the receiver; therefore, the receiver must establish synchronization at the beginning of each packet reception. At the receiver, a matched filter is designed to detect the presence of a spreading code of known sequence buried in additive noise. The chip correlation is performed by correlating the received signal with a reference waveform $s_{ref}(t - \tilde{\tau}) / \sqrt{E_c}$ in order to estimate the delay.

The preamble is a priori known by the receiver and allows a receiver to detect incoming packets. The distance to the object is estimated by the delay τ measured by the receiver during the acquisition process. The preamble signal used for template in the MF is given by,

$$s_{ref}(t) = \sqrt{E_c} \sum_{k=0}^{L-1} c_k p(t - kT_c) \tag{7}$$

The correlation function is described as

$$\begin{aligned} R_{sym}(\tau, \tilde{\tau}) &= \int \frac{1}{\sqrt{E_c}} y(t) s_{ref}(t - \tilde{\tau})\,dt \\ &= \int \frac{1}{\sqrt{E_c}} \left\{ s_{packet}(t - \tau) s_{ref}(t - \tilde{\tau}) + n(t) s_{ref}(t - \tilde{\tau}) \right\} dt \\ &= \int \frac{1}{\sqrt{E_c}} (s_{pre}(t - \tau) s_{ref}(t - \tilde{\tau}) \\ &\quad + s_{pay}(t - \tau - N_{pre}T_c) s_{ref}(t - \tilde{\tau}) + n(t) s_{ref}(t - \tilde{\tau}))\,dt \end{aligned} \tag{8}$$

for $\tilde{\tau} = 0, T_c, 2T_c, \ldots, N_{sym}LT_c$.

The normalized correlation between PN codes is given by

$$R(t) = \begin{cases} \frac{1}{T}\int_0^T PN_1(\tau) PN_1(\tau - t - T)\,d\tau, & t \le T \\ \frac{1}{T}\Big(\int_0^{t-T} PN_2(\tau) PN_1(\tau - t - 2T)\,d\tau & \\ \quad + \int_{t-\tau}^{T} PN_2(\tau) PN_1(\tau - t - T)\,d\tau + \ldots\Big) & t > T \end{cases} \tag{9}$$

The MF is matched to the whole spreading code. The output signal of the MF code acquisition structure is the autocorrelation function of the spreading code plus the noise term. We restrict our attention in this paper to an acquisition scheme that employs the threshold rule. Therefore, acquisition in the presence of noise may be achieved by detecting when the matched filter output crosses a threshold. A threshold comparison and detection are performed to evaluate correlation peak as shown in Fig. 5.

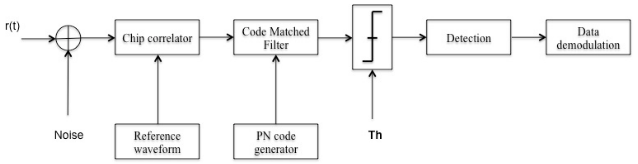

Fig. 5. Receiver Structure

B. Ranging Performance Analysis

ToA estimate is given by the time instant corresponding to the maximum absolute peak at the output of the MF over the observation interval. In this paper, the performance evaluation of MF threshold-based ToA estimator is addressed for DS-UWB signals. Synchronization contributes in ranging by giving the timing information needed to estimate the distance between transceivers. Based on two-way of ranging protocol described previously, the ranging success rate (RSR), depending on the acquisition success probability P_s and the correct data demodulation probability P_d, to evaluate the ToA, is given by,

$$RSR = P_s \times P_d \tag{10}$$

N_{bit} of data bits must be demodulated successfully by both cars, the correct data demodulation probability is expressed by,

$$P_d = \left\{1 - Q(\sqrt{L \times SNR})\right\}^{2N_{bit}} \tag{11}$$

where $Q(x)$ is the complementary distribution of the standard Gaussian as,

$$Q(x) = \frac{1}{\sqrt{2\pi}} \int_x^{\infty} \exp\left(-\frac{t^2}{2}\right) dx \tag{12}$$

The acquisition success probability formulated as,

$$P_s = (1 - P_F) P_D \tag{13}$$

is evaluated with respect to the packet structure through probability of false alarm P_F and probability of detection P_D given below.

$$P_F = 1 - (1 - P_{fa})^{LN_{sym}} = 1 - \left(1 - Q\left(\frac{\eta}{N}\right)\right)^{LN_{sym}} \tag{14}$$

where η is the threshold normalized by the noise power N at the MF filter output.

$$P_D = \sum_{n=0}^{LN_{sym}-1} \frac{(-1)^n}{n+1} \binom{LN_{sym} - 1}{n} \exp\left(-nL\frac{SNR}{n+1}\right) \times Q\left(\sqrt{L\frac{SNR}{n+1}}, \sqrt{(n+1)\frac{\eta}{N}}\right) \tag{15}$$

The above formula shows that the acquisition performance depends on the preamble part composed by LN_{sym} pulses.

C. Bit Error Rate and Throughput Performance Analysis

In one packet, the ranging part and communication part use the same spreading length and the chip duration is assumed to be constant. For sake of simplicity, we define an optimal rate in the preamble part and payload part in one packet such as,

$$M = (\alpha \times M) + (1 - \alpha) \times M \tag{16}$$

where α denotes the rate of the preamble for a total packet length of M chips. Each ranging preamble symbol has duration of T_s.

We define the throughput as the number of payload bits per second received correctly. At first, we only consider the change of preamble ratio (payload ratio consequently) in AWGN channel. According to the packet structure, the throughput can be expressed as,

$$Thpt_L = R_L \times PSR(\gamma, LN_{bit}) \frac{LN_{bit}}{LN_{sym} + LN_{bit}} \tag{17}$$

where $PSR()$ is the packet success rate defined as the probability of receiving a packet correctly and R_L is the data rate when a spreading code of length L is used. γ is the SNR per symbol. The last term defines data payload ratio in one packet. Therefore, we can express the preamble ratio α as,

$$\alpha = 1 - \frac{LN_{bit}}{LN_{sym} + LN_{bit}} \tag{18}$$

Considering that the length of spreading code is impacting the packet composition (preamble part and payload part), the throughput is rewritten as

$$Thpt_\alpha = R_L \times PSR(\gamma, LN_{bit}) \times (1 - \alpha) \tag{19}$$

There is a preamble rate α that maximizes the throughput for each inter-vehicular distance. The increase in α improves the ranging accuracy for an inter-vehicular distance. To choose the optimum preamble part in the packet structure, we select the appropriate spreading sequence length that maximizes the throughput. To do so, we differentiate the throughput equation with respect to α, and then we derive α.

The packet success rate is computed as

$$PSR(\gamma, LN_{bit}) = 1 - PER(\gamma, LN_{bit}) = (1 - P_b(\gamma))^{N_{bit}} \tag{20}$$

where $P_b(\gamma)$ is the probability of bit error for each bit. Considering synchronization error, $P_b(\gamma)$ is expressed as,

$$P_b = \frac{1}{2}\left[(1-P_s) + P_s \times Q\left(\sqrt{\frac{LE_c}{N_0/2}}\right)\right] \tag{21}$$

D. Analysis under 2-path Rician Fading Model

Rician fading model includes the effects of free space loss and reflection at the road. Fading is calculated as a sum of independent loss processes L_x. The path loss between any two vehicles is estimated assuming free space propagation as,

$$L_{freespace}(d) = 20\log\left(\frac{4\pi d}{\lambda}\right) \tag{22}$$

where λ is the wavelength, and d is the distance between two vehicles. The transmitted power is P_t and the gains of transmit and receive antennas are G_t and G_r, respectively.

The received power is calculated as,

$$P_{freespace}(d) = P_t + G_t + G_r - L_{O_2}d - L_{freespace}(d) \tag{23}$$

The energy at the received antenna due to the direct wave is E, therefore, the total energy E_r at the received antenna, due to the superposition of the direct and the road reflected components is given by,

$$E_r(d) = E(d)\left[1 + |\eta|.\exp(j\phi)\right] \tag{24}$$

where η is the road reflection coefficient and ϕ is the phase shift between the direct and the road reflected waves. The received power P_r is therefore proportional to the square of the received energy and described by,

$$P_r(d) = P_{freespace}(d)\left[1 + |\eta|^2 + 2|\eta|.\cos(\phi)\right] \tag{25}$$

The Rician factor K is set to a constant 5dB and the multipath component P_m is,

$$P_m(d) = \frac{P_{freespace}(d)}{K} \tag{26}$$

Therefore, the total average power is given by the sum,

$$P_{total}(d) = P_r(d) + P_m(d) \tag{27}$$

V. SIMULATION RESULTS

The algorithm and results from simulation under AWGN channel and 2-path Rician model are presented in this section.

A. Simulation Algorithm

Simulations are conducted according following the algorithm in Fig. 6 and the simulation parameters are shown in Table I. The length of the spreading sequence is adjusted adaptively according to the estimated distance. Since the m-sequences have good autocorrelation properties, in the AWGN channel there occurs a clear spike at a time instant when the received and local codes are synchronized. Therefore, the threshold setting is a critical phase in a detector, because it affects the detection and false alarm probabilities as shown in Fig. 7, thus, to the overall performance of the acquisition system. Therefore, in the algorithm, the threshold is adjusted as the spreading sequence length is modified. If the threshold is not crossed, a retransmission request is sent.

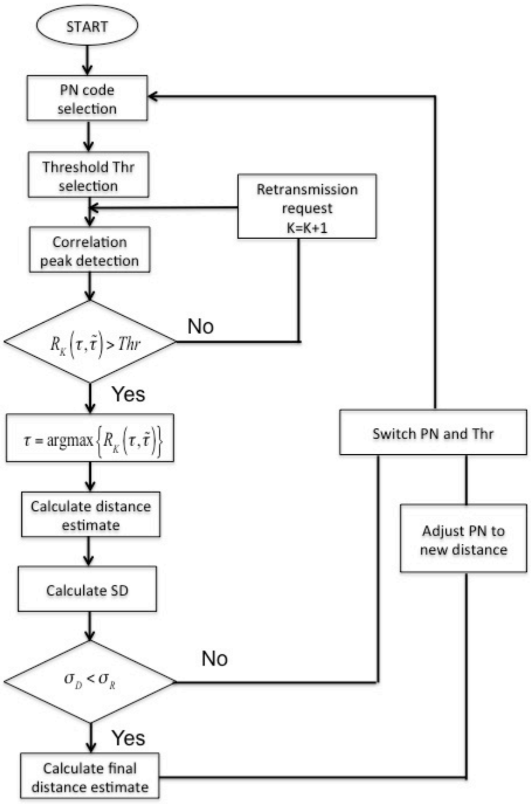

Fig. 6. Simulation Algorithm

TABLE I
SIMULATION PARAMETERS FOR THE PROPOSED SYSTEM

Criteria	Value
Transmission signal	DS-UWB
Chip duration	1 nSec
Sampling frequency	1 GHz
Center frequency	26 GHz
Antenna gain	22.5 dBi
Packet length	200 bytes
Average transmitted power	-41.3 dBm/MHz
Data rate	7, 14, 28 Mbps
Spreading sequence length	7, 15, 31
Distance attenuation	Free space propagation
Propagation model	AWGN, 2-path Rician Fading
Rice factor K	5 dB
Number of trial	1000

B. Simulation Results

The performance of the proposed system is evaluated in terms of probability. Errors are conditioned on the preamble detection through synchronization. The probability of correct synchronization is shown in Fig. 7 for different threshold to noise ratio (TNR) and various length of spreading sequence. We consider a fixed packet length of 200 bytes and the simulation is following the algorithm. From Fig 7, we can observe that the threshold setting with respect to the length of the spreading sequence is affecting the synchronization performance. For higher spreading code length as of 31, the synchronization performance is better. Moreover, we note that a threshold range value is maximizing the synchronization probability.

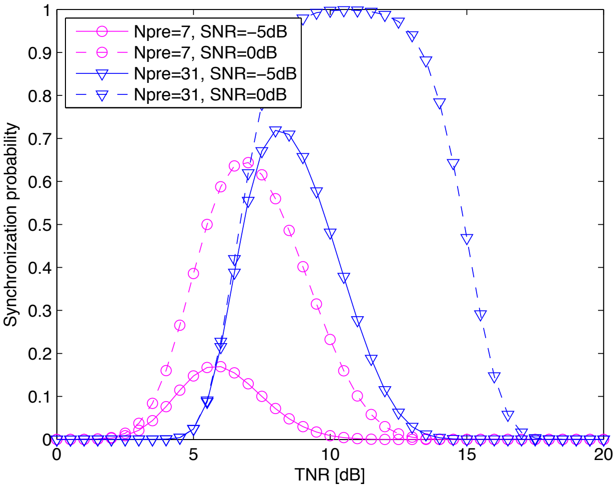

Fig. 7. Impact of Threshold Seeting on Synchronization Performance

Figure 8 depicts the standard deviation of ranging analysis as we increase the inter-vehicular distance. As the ranging error rises, the value of standard deviation of ranging increases. Confirming the simulation algorithm, distinct peaks are observed due to the shift in the spreading code length over inter-vehicular distance. To estimate the allowable standard deviation of ranging, we assumed a normal distribution of the ranging error.

While changing the spreading sequence length, the preamble ratio α in one packet varies accordingly, impacting the data rate communication. For higher preamble ratio, the ranging performance is improved at the cost of data rate as shown in Fig. 9.

Further analyses were conducted regarding the ranging and communication system performance for the proposed packet structure under different channel conditions. For ranging performance, we analyzed the ranging error for different packet structure, 1/4, 1/2 and 3/4 of preamble ratio. It is shown in Fig. 10 that under 2-path Rician model, the ranging system performance is degraded for lower preamble ratio. However, by using longer preamble ratio, we get similar results for both channel models.

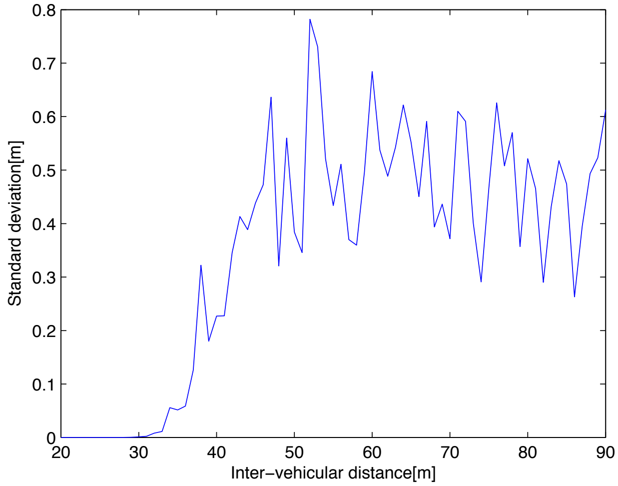

Fig. 8. Variation in Standard Deviation of Ranging

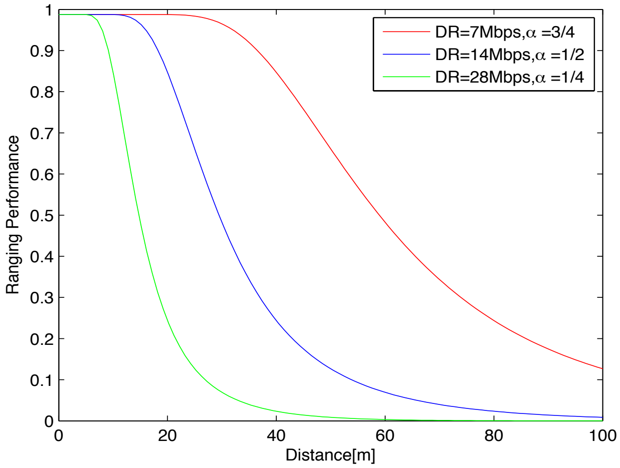

Fig. 9. Ranging Performance for Various Preamble Ratio

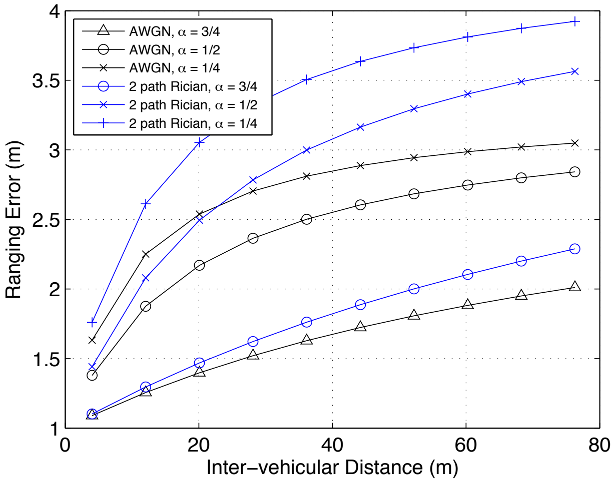

Fig. 10. Ranging Error for AWGN and 2-path Rician Fading for Different Packet Composition

Finally, we compared in Fig. 11 the fixed packet structure and optimized packet structure through BER performance for AWGN channel and 2-path Rician Fading model. Fixed packet structure has a predefined spreading code length; on the contrary, optimized packet uses variable length of spreading sequence adjusting the preamble part and data payload part composing one packet of fixed length. For the optimized packet structure under both channel conditions, BER performance can be improved compare to the fixed packet structure. Optimized under AWGN channel, the packet performs as better as in theory with a slight difference.

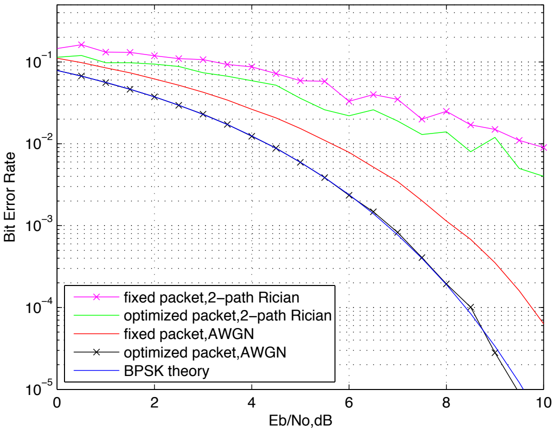

Fig. 11. BER Performance for Fixed Packet and Optimized Packet Under AWGN and 2-path Rician Model

VI. CONCLUSION AND FUTURE WORKS

We need simple but reliable technology to prevent collision but also to improve smooth driving. In this work, the model described as a communication based ranging system can satisfy ranging and communication purposes between cars. We proposed a packet structure based on DS-UWB fulfilling requirements of both communication and ranging. The packet structure is optimized through preamble ratio adjustment by changing adaptively the length of the spreading sequence. Results showed that the threshold setting while using different length of spreading code is impacting the synchronization performance, therefore the ranging and communication performance. Moreover, by increasing the preamble ratio, the ranging performance is improved at the cost of lower data rate. However, the BER performance showed that by optimizing the packet structure, our proposed scheme offers better performance compared to the existing systems using fixed packet structure. Through spreading code adjustment and packet structure optimization, we can range in short distance as well as long distance by maintaining the data transmission with respect to a reasonable throughput.

Further works on interference coming from oncoming vehicles have to be investigated under real traffic scenarios. Interference cancellation techniques using orthogonal matched filtering with variable length of spreading code could be a breakthrough for this issue. Besides, this work can be extended to a hybrid system involving radar and inter-vehicle communication providing more synergy effects between those two independent systems.

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