The Differential Detection OFDM Cooperative Diversity System in Vehicle-to-Vehicle Communications

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***Abstract*-In this paper, we introduce the cooperative diversity (CD) into the vehicle to vehicle (V2V) communications. As the fast changes and the multi-path fading of the channel between V2V ,the differential detection (DD) and OFDM (Orthogonal Frequency Division Multiplexing) is used to bypass the channel estimation and decrease the effect of the multi-path fading . As the theoretic and simulation show: The DD• OFDM• CD can improve the performance of V2V in fast changing multi-path fading channel .**

I. INTRODUCTION

As the development of the traffic, the traffic density of the road is increasing fast. So the congestion and accidents will often happen [1]. And some new commerce entertainment may come into being to the vehicular domain with the development of the society. A necessary step to solve these problems is to provide the driver with actual traffic conditions of the whole route as well as traffic conditions in the vicinity of this vehicle in time and to provide passenger(s) with better Qos(quality of service) of the entertainment. Because the moving of the vehicle, especially on motorway, the channel model [2][3] is not rayleigh flat fading ,the channel estimation is very difficult .And from the [1],the multi-path propagation causing heavy fading of the received signal in urban scenario than in motorway scenario. To aim this goal, we introduce the cooperative diversity .The cooperative diversity (CD)[4][5] can uses the virtue antennas of the other's to obtain spatial diversity . The differential detection of CD [6][7] enables the receiver to detect the data symbols without knowledge of the reference phase. As the time and frequency selectivity effects of V2V channel, the rayleigh flat fading model channel of the differential detection in [6][7]will not fit well. As the OFDM (orthogonal frequency division multiplexing) has technology predominance [8], so we use OFDM to weaken the multi-path fading.

In this paper, we propose differential demodulation OFDM cooperative diversity system(DD• OFDM• CD) into V2V communication.

The remainder of this paper is organized as follows .In the section II• •we describe the system model. And we give the performance analysis in section III. Some simulations and conclusions are given in section IV, Vrespectively.

II. SYSTERM MODLE

A. Cooperative Diversity Model

In our model for cooperative diversity of V2V communication in Fig 1.We only analysis the link from the souce to destination .Assume that the vehicle **S**(source,its

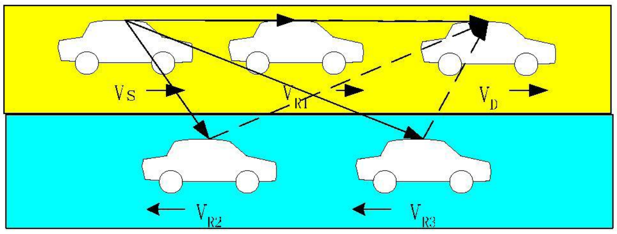

Fig 1 THE SKETCH MAP OF CD IN V2V

Velocity as v_S) wants to communicate to **D** (destination,its velocity as v_D).The candidate cooperative partner is $\boldsymbol{R}_i$.($i=1,2\ldots N$,the corresponding velocities as $v_{R_1}, v_{R_2}, \ldots v_{R_N}$,respectively).As the illustrated in[9]• •The best candidate cooperative partner is the one with the mean distance and with the mean velocity. As [11]indicate• •that cooperative diversity can provide substantial gains for cases with single hop routing. Because the fast change of the channel, we use the differential modulation scheme as[6][7][12][13],and we use the AF(Amplified-and-Forward) model .The protocol two of the cooperative protocols of [10]will be used , i.e. :in the first time slot ,the **S** transmits signal to **D** and the **R**(**R** is the best candidate cooperative partner),in the second time slot ,the **R** **re**transmits the estimation copy of the signal received in the first time slot to the **D.**

B. Differential Detection OFDM Cooperative Diversity

In this paper, we only consider the frequency domain differential detection .As described in [14]• •the model at the source and destination as following:

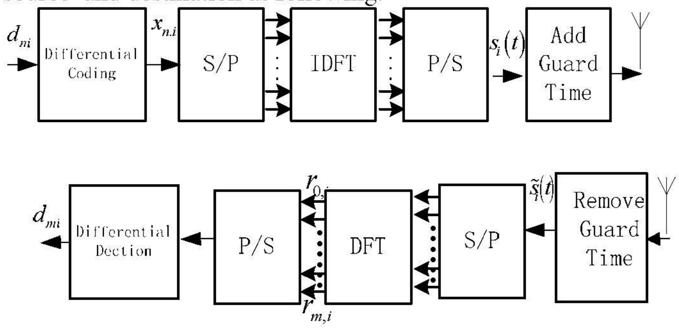

FIG 2 THE DIFFERENTIAL DETECTION OFDM ,S/P (SERIAL TO PARALLEL) ,IDFT(INVERSE DISCRETE FOURIER TRANSFORM)

$$d_{n,i} = e^{j\Delta\phi_{n,i}}, \Delta\phi_{n,i} \in \{0, \pi\}, n = 0,1,\ldots N-1 \quad (1)$$

$$\Pr\{\Delta\phi_{n,i} = 0\} = \Pr\{\Delta\phi_{n,i} = \pi\} = 1/2 \quad (2)$$

$d_{n,i}$ is the source data of the ith OFDM symbol of the nth sub-carrier. N is the number of sub-carrier.

$$x_{n,i} = x_{n-1,i} \cdot d_{n,i} \quad (3)$$

Where $x_{n,i}$ is the differential coding data of the ith OFDM symbol of the nth subcarrier. Assumption $x_{0,i} = e^{j0}$ is known at the receiver.

$$s_i(t) = \sum_{n=0}^{N-1} x_{n,i} e^{j2\pi(f_c + \frac{n}{T_s})(t - iT_s)} \quad 0 \le t - iT_s < T_s \quad (4)$$

Where T_s is the period of one OFDM symbol. f_c is the carrier frequency .

In the first time slot:

The received signal at the relay node and destination respectively is:

$$s_{r,i}(t) = \int h_{s,r}(t,\tau) s_i(t-\tau) d\tau + n_r(t) \quad (5)$$

$$s_{d,i}(t) = \int h_{s,d}(t,\tau) s_i(t-\tau) d\tau + n_d(t) \quad (6)$$

$$h_{i,j}(t,\tau) = \sum_k \gamma_{k_{i,j}}(t) \delta(\tau - \tau_{k_{i,j}}) \quad (7)$$

Where $h_{i,j}(t,\tau)$ is the channel from the i to j (τ is the multipath time delay). We assume the rayleigh channel that

$$R_k(\tau) = E\{\gamma_{k_{i,j}}(t+\tau)\gamma^*_{k_{i,j}}(t)\} = \sigma^2_{k_{i,j}} J_0(2\pi f_{d_{i,j}} \tau) \quad (8)$$

$$f_{d_{i,j}} = \frac{v_{i,j} f_c}{c} \cos(\alpha) \quad (9)$$

$J_0(x)$ is the zero-order modified Bessel function of the first kind. $f_{d_{i,j}}$ is the Dopper shift from i to j . c is the light velocity. $\alpha \in \{0, \pi\}$ $v_{i,j}$ is the relative velocity . $v_{i,j} = |v_i - v_j|$, we must keep in mind that the velocity is a vector.

Where $\sigma^2_{k_{i,j}} = E\{|\gamma_{k_{i,j}}(t)|^2\}$ is the power of the kth path between i,j . $n_i(t)$ is the additive Gaussian white noise $\in \mathcal{CN}(0, \sigma_i^2)$.

In the second time slot:

At the node, the signal is amplified and forward as [12]

$$\hat{s}_{r,i}(t) = \frac{s_{r,i}(t)}{(\mathrm{var}\{s_{r,i}(t)\})^{1/2}} = G s_{r,i}(t) \quad (10)$$

Where $G = (\mathrm{var}\{s_{r,i}(t)\})^{-1/2}$

$$\tilde{s}_{r,i}(t) = \int h_{r,d}(t,\tau) \hat{s}_{r,i}(t-\tau) d\tau + n(t) \quad (11)$$

Finally the signal destination $s_{d,i}(t)$ in the first slot and the signal $\tilde{s}_{r,i}(t)$ from the second are combined together with equal gain.

$$\tilde{s}_i(t) = s_{d,i}(t) + \tilde{s}_{r,i}(t) \quad (12)$$

After the DCT,at the time $t = iT_s$,the output of the mth subchannle is :

$$r_{m,i} = \frac{1}{T_s} \int_{iT_s}^{iT_s+T_s} \tilde{s}_i(t) e^{-j2\pi f_m t} dt \quad (13)$$

And after the differential detection, we get the :

$$d_{m,i} = \mathrm{Re}(r_{m,i} r^*_{m-1,i}) \quad (14)$$

Where $(\cdot)^*$ denotes complex conjugation .

III. PERFORMANCE ANALYSIS

We use the result of [14]as following :

$$\bar{P}_b = \frac{1}{N} \sum_{m=0}^{N-1} \Pr[d_{m,i} < 0] \quad (15)$$

Where

$$P_b = \Pr[d_{m,i} < 0]$$

$$= \frac{1 - \dfrac{\mathrm{Re}[E(r_{m,i} r^*_{m-1,i})]}{\sqrt{\{\mathrm{Re}[E(r_{m,i} r^*_{m-1,i})]\}^2 + [E(r_{m,i} r^*_{m,i})]^2 - [E(r_{m,i} r^*_{m-1,i})]^2}}}{2} \quad (16)$$

The only different from the result in[14] is the expression of $r_{m,i}$,in this paper ,From the (13)(12)(5)(6)(7)• we can get the

$$r_{m,i} = \frac{1}{T_s}\int_0^{T_s}\left[\sum_k \gamma_{k_{s,d}}\left(t+iT_s\right)s_i\left(t+iT_s-\tau_{k_{s,d}}\right)+n_d\left(t+iT_s\right)\right]e^{-j2\pi f_m t}dt$$
$$+\frac{1}{T_s}\int_0^{T_s}\left[\begin{array}{l} G\sum_k \gamma_{k_{r,d}}\gamma_{k_{s,r}}\left(t+iT_s\right)s_i\left(t+iT_s-\tau_{k_{s,r}}-\tau_{k_{r,d}}\right) \\ +Gn_r(t+iT_s-\tau_{k_{r,d}})+n(t+iT_s) \end{array}\right]e^{-j2\pi f_m t}dt \qquad (17)$$

We can use the same method as in[14].More detail can be seen in [14].

IV. SIMULATION

We use the channel as flowing

Tab 1 the channel of simulation

	S	R	D
Velocity **[km/h]**	20	70	120
Relative time delay **[ns]**	0	0	0
	751	751	751
	1563	1563	1563
Relative average power **[dB]**	0	0	0
	0	0	0
	0	0	0

As the $T_s = 200\mu s$,the guard time is $50\mu s$, $N = 1024$,the distance of subcarrier $\Delta f = 5kHz$,the $f_c = 5GHz$.

Assume that the **S,R,D** moving on the same line and to the same direction of the line .Using (9),the $\alpha = 0$,so the Dopper shit $f_{d_{s,r}} = 231Hz, f_{d_{r,d}} = 231Hz, f_{d_{s,d}} = 462Hz$

As for comparison ,we set $\overline{\gamma}_{s,d} = \overline{\gamma}_{s,r} = \overline{\gamma}_{r,d} = 0.5Eb/N_0$.

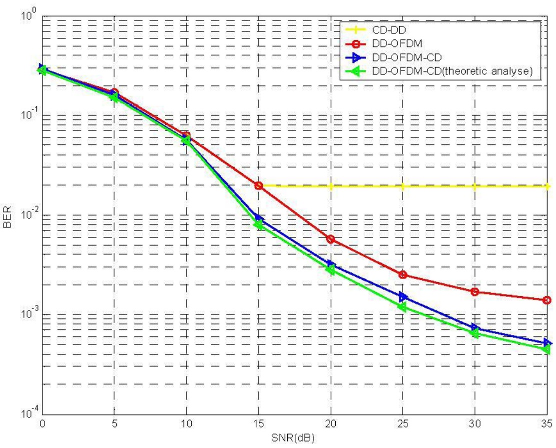

Fig 3 Average BER in rayleigh fading comparisons

From the Fig 3,we can see that the CD-DD(cooperative diversity - differential detection) has a error floor ,this is because we can only get the first path power, the multipath signals is mixed . And the simulation of DD-OFDM-CD is consistent with the theoretic analyses. And the DD-OFDM-CD has better performance than the CD-DD and the DD-OFDM methods. And there is no channel coding at the transimitter

V. CONCLUSION

The differential demodulation OFDM cooperative diversity system(DD • •OFDM • •CD)in V2V communication can improve the performance of the system .As the channel changes fast in V2V, the DD is practical .And using the OFDM to decrease the effect of the multi-path .Also the CD to increase the spatial diversity, but at the cost of increasing the complexity of the system .especially the synchronization of the frequency and time.

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