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Effect of the Slot Distributed Scheme on the Push-type Packet Compensation Protocol

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Abstract:

The push-type packet compensation protocol is that each user autonomously broadcasts the received data to neighbor users for compensating a loss packet. When the user density increases, the average packet acquisition time is deteriorated by the packet collision and shadowing. The slot distributed scheme reduces the packet collision because the user chooses a transmission slot in the frame which consist of N_s slots similar to TDMA. In this paper, the average packet acquisition time of the slot distributed push-type packet compensation protocol is analyzed. Consequently, the slot distributed scheme is effective against increasing of the packet collision.

1. Introduction

There has been increasing interest in smart communications fused intelligent transport systems (ITS) and telematics systems. The essential technologies fall into two major categories: the road to vehicle communications (RVC) and the inter-vehicle communications (IVC) [1][2]. RVC is a communication between a broadcasting station and vehicles. IVC is a communication between vehicles. In RVC, the local broadcasting system is important. The local broadcasting system is that the broadcasting stations located the road broadcast the local and the consumer information, such as the information relating parking lot, nearby shops and pedestrians. When the users fail the reception of the broadcast packet by shadowing, propagation loss, noise and so on, it is necessary to compensate the lost packet. However, the users cannot use the basic automatic-repeat-request (ARQ) systems because the broadcasting system has no feedback channel. In order to improve the success probability of the reception, to rebroadcast the same packet several times is considered directly. However, this rebroadcast method has a little effect because this method cannot improve the influence of the shadowing by the large vehicles. One of the important problems encountered in the broadcasting systems is to design an error control scheme.

We can consider the error control scheme using IVC or Ad-hoc networks. The error control scheme of the broadcasting system need to take into account the following points; (a) immediacy, (b) simplicity of the error control scheme and (c) no relay of a packet (1 hop). In Ad-hoc networks, the error control schemes or the communication protocols are proposed [3]-[5]. However, these protocols do not satisfy these requirements. We have proposed the spread-spectrum compensation protocols for making up lack of the broadcast packet with neighbor users on IVC; that is, the push-type packet compensation protocol, the pull-type packet compensation protocol and the push/pull-type packet compensation protocol [6]-[9]. The push-type packet compensation protocol [6] is that each user autonomously transmits the received data to neighbor users for compensating a loss packet. We have analyzed the average packet acquisition time that is the time to take until all users acquire the information from the broadcasting station. When the number of users increases significantly, the average packet acquisition time deteriorates by the packet collision.

In this paper, in order to overcome this problem on high user density, we propose the Spread-Spectrum packet compensation protocol with the slot-distributed scheme. The slot-distributed scheme is that each user chooses a slot from N_s slots and transmits a packet in the chosen slot when the transmission frame consists of N_s slots. It is expected that the slot-distributed scheme avoid the co-channel interferences. In this paper, we evaluate the optimal number of N_s of corresponding to the number of users.

2. The push-type packet compensation protocol

The communication between users is performed by using the local broadcast. All packets are transmitted in the form of local (1-hop) broadcasts. All users are never directly addressed and no routing of packets is performed and have the M common spread code sequences. We employ the ZCZ (Zero-Correlation-Zone) sequence set as the spread code sequences because the use of ZCZ sequence set can realize the quasi-synchronous [10]. The push-type packet compensation protocol [6] is that each user autonomously broadcasts the received data to neighbor users for compensating a loss packet. When a user broadcasts the compensation packet, the user chooses a spreading code at random and spreads by the code. The compensation procedure is finished when all unsuccessful users receives the compensation packet correctly.

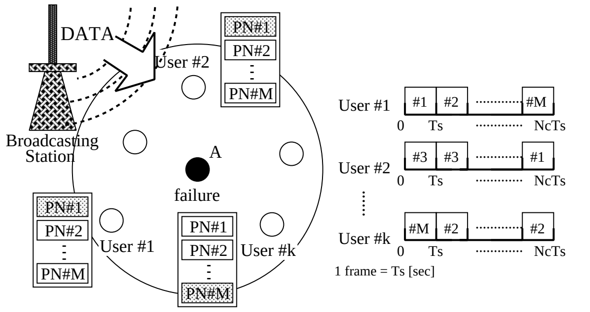

Figure 1. The push-type compensation model.

In Fig.1, the successful user “#1, #2,$\cdots$ #k” receive the broadcast packet from the broadcasting station correctly. The user “#1, #2,$\cdots$ #k” automatically broadcast a received packet from the broadcasting station, that is compensation packet. If the user "A" receives the compensation packet from the successful users correctly, the user "A" completes the compensation. The successful users repeats the transmission of a compensation packet N_c times because the successful user cannot detect whether the unsuccessful users received the compensation packet.

3. The slot distributed push-type packet compensation protocol

In the slot distributed push-type packet compensation protocol, the packet transmission frame is divided into N_s slots. Figure 2 shows the packet transmission model when the number of packet transmission users is 2 [users]. Fig.2(a) shows the signals structure of the conventional push-type packet compensation protocol and Fig.2(b) shows the signal structure of the slot distributed push-type packet compensation protocol when $N_s = 2$. In Fig.2(a), the packet collision are occared by the users choose the same spreading code. In Fig.2(b), although the frame length extends, the probability of the packet collision can be reduced. If the unsuccessful users received the compensation packet at the first slot, the packet acquisition time is one slot duration only, that is, T_s [sec].

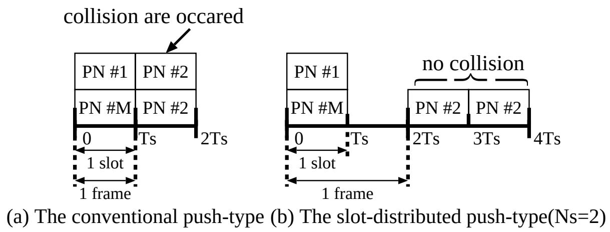

Figure 2. The packet transmission model.

Figure 3 shows the communication model between users when $N_s = 2$ and the number of users ($K(r_B)$) is k [users]. The user "A" is the unsuccessful user. The user "#1, #2,$\cdots$ #k" are the successful users who received the packet from the broadcasting station. Firstly, the successful users choose a spreading code and a slot at random. Secondly, the compensation packet is chosen by the selected spreading code and it is arranged on the selected slot in a frame. Thirdly, the successful users broadcast the compensation frame N_c times. When the users "B" and "C" choose the same spreading code and a different slot, these user's packets do not collide.

4. The average packet acquisition time of the slot distributed push-type packet compensation protocol

Table 1 shows the symbol used for analysis. We consider the packet radio network. Figure 4 shows a model of the broadcast network system. In the network, the user is distributed uniformly. The number of users, $K(r_B)$, here expresses "the number of users in common area of the broadcasting station's network and a user's network". In Fig.4 the gray colored area around user C is the overlap between the broadcasting station's network area and the user C's communication area. The gray colored area around user D is narrower than that of the user A because the user E in the communication area of user D cannot receive the packet from

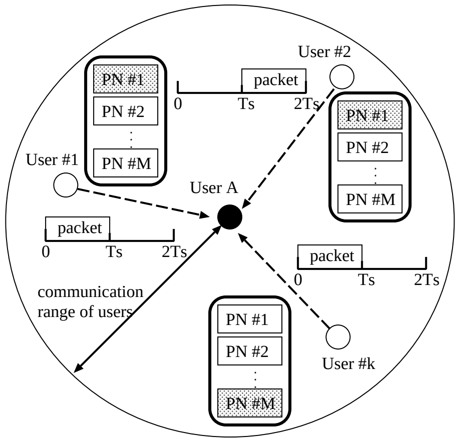

Figure 3. The communication model between users ($N_s = 2$).

Table 1. The notation used for analysis.

E_{bT}/N_0	The ratio of the transmitting signal energy per bit to noise power spectrum density
r_B	The distance between a broadcasting station and a user
r	The distance between users
D_R	Communication range of a vehicle
D_B	Communication range of a broadcasting station
M	The number of spreading code sequences
P_B	The probability that the user receives the packet from the broadcasting station
L	Packet length

the broadcasting station and cannot send the compensation packet.

The average packet acquisition time (T_{acq}) is the average time until all users receive the information from the broadcasting station. The users can receive the information from the broadcasting station by following methods, (a) the method of receiving the packet from the broadcasting station directly, and (b) the method of receiving the compensation packet from the successful users. In the push-type packet compensation protocol, the successful users cannot know the unsuccessful users compensated the lost packet. We assume that the successful users can transmit the compensation packet until all unsuccessful users receive the compensation packet. T_{acq} of the slot distributed push-type packet compensation protocol $T_{acq}(K(r_B), P_B, N_s)$ is expressed as

$$\begin{aligned} & T_{acq}(K(r_B), P_B, N_s) \\ & \quad = \frac{1}{T_s}\{T_B + T_{Bp} \cdot T_b(K(r_B), P_B) \\ & \qquad +(1-P_B) \sum_{k=1}^{K(r_B)-1} C_{omb}(K(r_B)-1, k, P_B) \\ & \qquad \cdot T_s \cdot T_{ime\_push\_slot}(k, N_s)\} \end{aligned} \tag{1}$$

where T_B is the transmission time of broadcast packet, T_{Bp} is the interval which broadcasts the same information from the broadcasting station again and T_s is the packet transmission

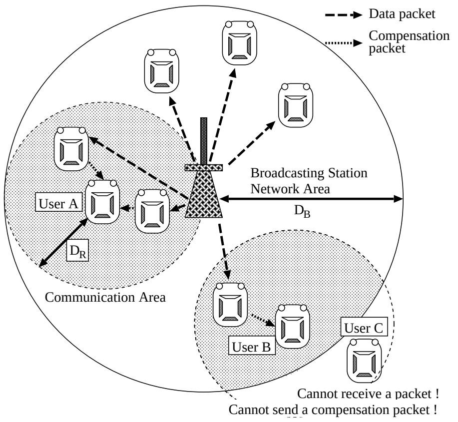

Figure 4. Network model.

time of a compensation packet. The second term of Eq.(1) means the average time until one or more users receive the packet from the broadcasting station. $T_b(K(r_B), P_B)$ is the average number of packet broadcasts from the broadcasting station until one or more users are successful.

$$\begin{aligned} T_b(K(r_B), P_B) &= \sum_{m=1}^{\infty} m(1-P_B)^{mK(r_B)} \\ &= \frac{(1-P_B)^{K(r_B)}}{\{1-(1-P_B)^{K(r_B)}\}^2} \end{aligned} \quad (2)$$

The third term of Eq.(1) means the average time which all unsuccessful users can receive the compensation packet. $C_{omb}(a, b, P)$ is the probability function of the binomial distribution : $C_{omb}(a, b, P) = \begin{pmatrix} a \\ b \end{pmatrix} P^b(1-P)^{a-b}$, $\begin{pmatrix} a \\ b \end{pmatrix}$ is the combination of b from a. $T_{ime\_push\_slot}(k, N_s)$ is the average number of the transmissions of the compensation packet until all unsuccessful users receive the compensation packet.

$$\begin{aligned} &T_{ime\_push\_slot}(k, N_s) \\ &= \sum_{i=0}^{\infty}\sum_{n=1}^{Ns}(i \cdot N_s + n)\{P_{bf}(k, N_s)\}^i \cdot P_s(k, n) \\ &= \frac{\sum_{n=1}^{N_s} nP_s(k,n)}{1-P_{bf}(k,N_s)} + \frac{N_s P_{bf}(k,N_s)\sum_{n=1}^{N_s} P_s(k,n)}{\{1-P_{bf}(k,N_s)\}^2} \end{aligned} \quad (3)$$

where $P_{bf}(k, N_s)$ is the probability which failed the reception of all packets in a transmission frame and $P_s(k, n)$ is the probability that an unsuccessful user receives a compensation packet at the nth slot. $P_{bf}(k, N_s)$ is expressed as

$$P_{bf}(k, N_s) = P_{bs}(k, N_s - 1)\left(\frac{1}{N_s}\right)^{k_r(N_s)} P_b(k_r(N_s)) \quad (4)$$

where $k_r(i)$ is the number of users who do not transmit the packet before $(i-1)$th slot :

$$k_r(i) = k - \sum_{j=1}^{i-1} k_j. \quad (5)$$

$P_b(k)$ is the probability which failed the reception of all packets from k users, expressed as

$$\begin{aligned} P_b(k) &= \prod_{i=1}^{k}\left[\int_0^{D_R}\{1-PS(r_i,k)\}\frac{2\pi r_i}{\pi D_R^2}dr_i\right] \quad (6) \\ &= \prod_{i=1}^{k}\left[1-\int_0^{D_R} PS(r_i,k)\frac{2r_i}{D_R^2}dr_i\right] \\ &= \left[1-\int_0^{D_R}\frac{2r}{D_R^2}\{PS(r,k)\}dr\right]^k \quad (7) \end{aligned}$$

where $PS(r, k)$ is the success probability which received a packet from a successful user and r_i is the distance between users. The success probability, denoted as $PS(r_i, k)$, is expressed as

$$PS(r_i, k) = (1-\rho(r_i))P_{nc}(k)(1-P_p(r_i))^L \quad (8)$$

where k_n is the number of transmitting packets in same time and $\rho(r_i)$ is the incidence of shadowing :

$$\rho(r_i) = 1 - \left(1 - \frac{\delta r_i}{\pi D_R^2}\right)^{K(r_{BS})-2} \quad (9)$$

where δ is the average user size. $P_{nc}(k)$ is the probability that the user selects a different spreading code from other users :

$$P_{nc}(k) = \left(\frac{M-1}{M}\right)^k = \left(1-\frac{1}{M}\right)^k. \quad (10)$$

$P_p(r_i)$ is the probability of symbol error caused by white Gaussian noise and propagation loss :

$$P_p(r_i) = \frac{1}{2}\mathrm{erfc}\left(\frac{\lambda}{4\pi \mathrm{r_i}}\sqrt{\frac{\mathrm{E_{bT}}}{\mathrm{N_0}}}\right) \quad (11)$$

where λ is the wavelength and erfc(x) is the complementary error function: erfc(x) $= \frac{2}{\sqrt{\pi}}\int_{-\infty}^{x} e^{-u^2}\,du$. We do not consider the capture effect.

$P_{bs}(k, n)$ of Eq.(4) is the probability which failed the reception of all packets before nth slot. $P_{bs}(k, n)$ can be expressed as,

$$P_{bs}(k, n) = \prod_{i=1}^{n}\sum_{k_i=0}^{k_r(i)}\begin{pmatrix} k_r(i) \\ k_i \end{pmatrix}\left(\frac{1}{N_s}\right)^{k_i} P_b(k_i). \quad (12)$$

$P_s(k, n)$ is expressed as

$$\begin{aligned} &P_s(k, n) \\ &= \begin{cases} P_{bs}(k, n-1)\sum_{k_n=1}^{k_r(n)} C_{omb}(k_r(n), k_n, 1/N_s) \\ \quad \cdot\{1-P_b(k_n)\} \qquad (n \neq N_s) \\ P_{bs}(k, N_s-1)\left(\frac{1}{N_s}\right)^{k_r(N_s)} \cdot \{1-P_b(k_r(N_s))\} \\ \qquad (n = N_s). \end{cases} \end{aligned} \quad (13)$$

5. Numerical Results

We compare the conventional push-type packet compensation protocol. Table 2 shows the numerical conditions for evaluation of the average packet acquisition time. We assume that T_B is T_s [sec] and T_{Bp} is $100T_s$ [sec].

Table 2. The numerical conditions.

The number of spreading codes: M	32 [codes]
Communication range of a vehicle: D_R	50 [m]
Carrier frequency: $f_c(= c/\lambda)$	2.4 [GHz]
Packet length: L	512 [bit]
The average user size: δ	1.5 [m]

Figure 5 shows the average packet acquisition time versus the probability that the the user receives the packet from the broadcasting station P_B when $K(r_B) = 150$ [users] and $E_{bT}/N_0 = 75$ [dB]. When P_B is high, the average packet acquisition time of the slot distributed push-type packet compensation protocol is better than that of the conventional push-type packet compensation protocol.

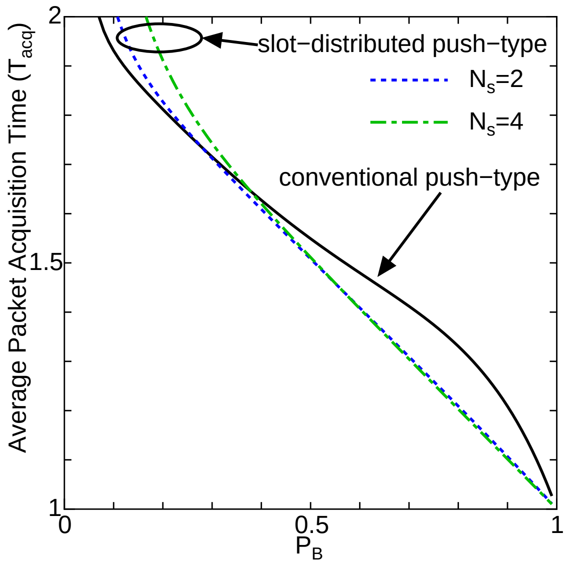

Figure 5. The average packet acquisition time versus P_B when $K(r_B) = 150$ [users] and $E_{bT}/N_0 = 75$ [dB].

Figure 6 shows the average packet acquisition time versus the number of users $K(r_B)$ when $P_B = 0.8$ and $E_{bT}/N_0 = 75$ [dB]. When the number of users is lower than 55 [users], the conventional push-type packet compensation protocol is better than other schemes. When $55 < K(r_B) < 90$ [users], the slot distributed push-type packet compensation protocol when $N_s = 2$ is better than other schemes. When $K(r_B) > 90$ [users], the slot distributed push-type packet compensation protocol when $N_s = 3$ is better than other schemes.

6. Conclusion

In this paper, we evaluate the average packet acquisition time and the optimum N_s of the slot distributed push-type

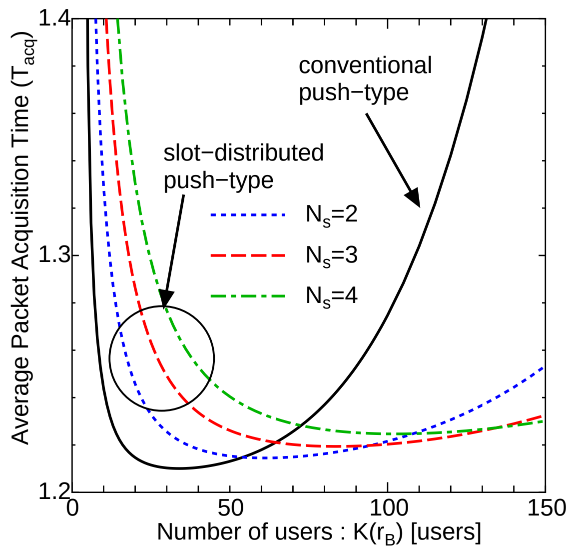

Figure 6. The average packet acquisition time versus $K(r_B)$ when $E_{bT}/N_0 = 75$ [dB] and $P_B = 0.8$.

packet compensation protocol. As the results, when the high user density, the slot distributed push-type packet compensation protocol can improve the average packet acquisition time. Moreover, if the users can select the optimum N_c, the packet acquisition time is kept constant.

Future works is to analyze the slot distributed pull-type and push/pull-type packet compensation protocols.

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