Relay UE Selection Scheme in an Emergency Warning System Integrating Proximity Services

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I. Introduction

In Japan, early warnings such as the earthquake early warning and the tsunami warning are broadcast to cellular phones by using the Earthquake and Tsunami Warning System (ETWS) [1]. The connectivity of a LTE device (UE: user equipment) depends on the LTE base station (evolved Node B: eNB) which acts as a relay with the Internet. Therefore it is difficult to broadcast early warnings during large-scale disasters.

The public safety Long Term Evolution (PS-LTE) networks are being constructed in the United States and the United Kingdom. PS-LTE is also expected as an efficient technology for rescue activities that ensures the real-time sharing of information even in the event of a disaster [2]. Specification of Proximity Services (ProSe) enables Device to Device (D2D) communication, which UEs communicate directly with each other over an LTE network. ProSe is proceeding as a technology for realizing PS-LTE [3].

As shown in Fig. 1, we have proposed an emergency warning system that integrates ProSe into ETWS for broadcasting early warnings to UEs outside eNB coverage. We clarified that the delivery rate of the early warning was improved by adopting ProSe with high affinity and ETWS [4]. In addition, according to the positional relation between operating eNBs and administrative boundary, the delivery scope control scheme using geocast and the distribution area optimization scheme of ETWS were proposed to short the delivery completion time and reduce the redundant transmissions in [5].

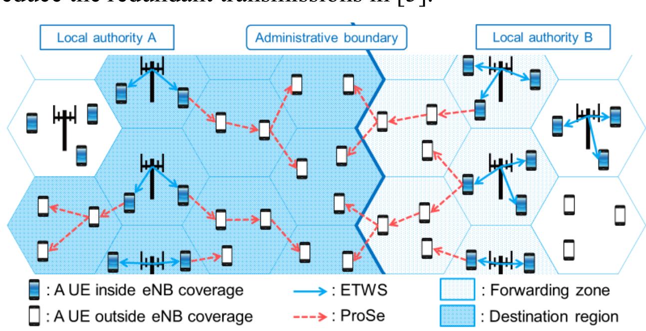

Fig. 1. Emergency warning system integrating Proximity Services

In this paper, we propose a selection scheme for relay UEs near the coverage boundary to reduce the load of relay UEs. This scheme can reduce network traffic of the entire topology without worsening the delivery completion time. In addition, we make a simulation to evaluate the performance of the proposed system by assuming a real environment and considering practicality. In our research, UE can be as a relay to send flooding messages of ETWS so that it can save precious battery resources.

II. Research Subjects

It is necessary to improve the relay UEs selection scheme and reduce the number of transmissions of the entire topology without worsening the delivery completion time. We adopted multi-hop D2D communication and DTN (epidemic routing) as an early warning broadcasting method, and improved the delivery rate of the early warning [4]. However, we assumed that all UEs inside eNB coverage will send the early warning without selection. Even if there is no relay delivery from UEs near the eNB, relay delivery by UEs near the coverage boundary and UEs outside eNB coverage may be sufficient. We will clarify the conditions of this hypothesis.

III. Proposal of The Relay UE Selection Scheme

The parameters used in the relay UE selection scheme near the coverage boundary are described in Fig. 2. We suppose that the eNB can distribute communication settings and acquire UE location information by using ProSe Function. The maximum transmission range of the eNB is defined as Max-Range (MR), and the radius of the range where UEs is unnecessary for relay delivery is derived as Halfway-Range (HR). Considering that eNB coverage is not necessarily concentric, we assume that the eNB can give instructions to the UEs in the sector where the

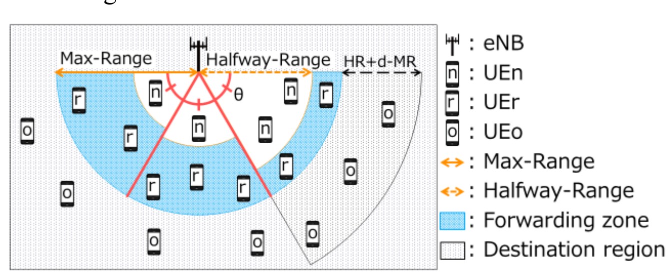

Fig. 2. Precondition of the relay UE selection scheme

coverage is equally divided, one sector at a time. UEn is a UE near the eNB, meaning that diffusion is unnecessary, UEr is a UE near the coverage, meaning that diffusion is desired, and UEo is a UE outside eNB coverage.

This paper mathematically obtains application conditions of the relay UE selection scheme near the coverage boundary. In situations where UEr and UEo exist, effects can be obtained by reducing UEn when UEn exists. When defining the D2D transmission range as d and assuming that UEs are arranged uniformly, the sufficient condition of UEs existence can be derived from the product of the UE density and the surface area. We define the area of relay UEs zone to be reduced as S_{HR}, the area of the forwarding zone as S_{MR-HR}, the area of the destination region as $S_{HR+d-MR}$ and the density of uniformly placed UEs as D. By multiplying each area by the density, the number of UEs existing in each place is obtained. Therefore, we obtained the application conditions of the relay UE selection scheme near the coverage boundary about (1) and (2).

$$D \cdot S_{HR} \geq 1 \tag{1}$$

$$D \cdot S_{MR-HR} \geq 1 \;\&\&\; D \cdot S_{HR+d-MR} \geq 1 \tag{2}$$

Since UEs are not uniformly distributed due to UE bias or the like, it is considered that it can be applied with a UE density lower than the applicable condition. Define the simplified algorithm to maximize Halfway-Range as follows and confirm its effectiveness.

Algorithm 1 Find Halfway-Range (θ = 30°)

if $D \cdot \frac{1}{12} S_{MR} \geq 2$ **then**
  HR ⇐ MR // Set the value of MR to HR
  while ($D \cdot S_{MR-HR} \geq 1$) **do**
    HR ⇐ HR – 1 // Decrease the value of HR
  end while
end if

IV. Evaluation and Consideration

Assuming that a tsunami arrives in a city, we reproduce the situation of broadcasting tsunami warnings in environments where some eNBs have stopped functioning due to an earthquake. eNB operating patterns are (A) environment in which functional eNBs are dense and (B) environment in which functional eNBs are dotted. Furthermore we reproduce the situation where the owners of UEs that received the tsunami warning move to tsunami evacuation facilities on foot, and evaluate the performance of the proposed scheme. We confirm the effectiveness of the proposed scheme by reducing the number of transmissions of the entire topology without worsening the delivery completion time. Evaluation was conducted by using the network simulator ns-3 to confirm the effectiveness when the proposed scheme is operated in an affected area. Since ProSe protocol is not implemented in ns-3, we substitute Wi-Fi Direct by changing the parameters of Wi-Fi Direct.

Fig. 3 shows the average delivery completion time taken for the delivery rate of an early warning to reach 100 % and the reduction rate of the number of transmissions, for both the case where the proposed scheme is applied and the case where it is not. The number of transmissions for the entire topology could be reduced by 27 % without significantly worsening the delivery completion time when the UE density was 24 UEs/km² or more. On the other hand, when the UE density was less than 24 UEs/km², although the number of transmissions could be reduced, the delivery completion time was greatly increased. From these results it can be determined that the proposed relay UE selection scheme was effective when the UE density was 24 UEs/km² or more, thus the application condition derived. is considered to be appropriate. In addition, it was confirmed that more efficient message diffusion was being performed by excluding UEs that were performing unnecessary distribution from the intermediary UEs. Therefore, the effectiveness of the selection scheme for UEs near the coverage boundary was proved.

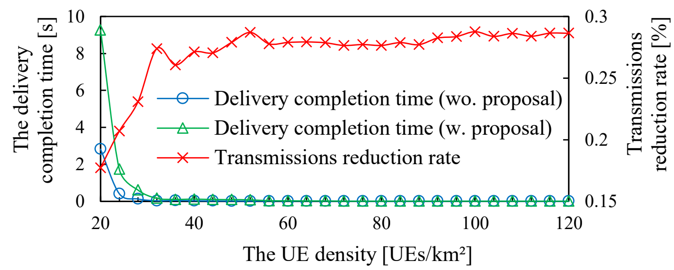

Fig. 3. Delivery completion time and transmissions reduction rate

V. Conclusion

In this research, we proposed an optimization scheme for relay UE selection and confirmed its effectiveness in relay delivery of an emergency message to UEs outside eNB coverage in LTE. An early warning could be broadcast to all UEs even in a situation where UE density is low, demonstrating the practicality of reducing the load of UEs in the proposed emergency warning system. For future work, we would like to consider a scheme to reduce the load of UEs outside eNB coverage as well as those inside eNB coverage.

Acknowledgment

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