Adaptive Anchor Zone Adjustment Based on Terminal Encounter Rate in Floating Contents

Atsufumi KASHIMA †, Taku YAMAZAKI ††, Ryo YAMAMOTO ‡,‡‡, and Yoshiaki TANAKA †, ‡‡
† Department of Communications and Computer Engineering, Waseda University
3-4-1 Okubo, Shinjuku-ku, Tokyo, 169-8555 Japan
†† Department of Electronic Information Systems, Shibaura Institute of Technology
307 Fukasaku, Minuma-ku, Saitama-shi, Saitama, 337-8570 Japan
‡ Graduate School of Informatics and Engineering, The University of Electro-Communications
1-5-1 Chofugaoka, Chofu-shi, Tokyo, 182-8585 Japan
‡‡ Global Information and Telecommunication Institute, Waseda University
3-4-1 Okubo, Shinjuku-ku, Tokyo, 169-8555 Japan
E-mail: atsufumi_kashima@ruri.waseda.jp, taku@shibaura-it.ac.jp, ryo-yamamoto@uec.ac.jp, ytanaka@waseda.jp

***Abstract*— Floating content is a novel information sharing architecture that contents are relayed among mobile terminals and float in a specific area for a flexible information sharing. However, there is a drawback that these contents vanish when there is no terminal holding the contents inside the area, which is due mainly to its ad hoc communication and sharing strategy. This happens especially when the terminal density of the sharing area is sparse or all the terminals holding the contents move outside of the area. In this paper, we propose an adaptive information sharing area adjustment method based on a terminal encounter rate within the area to address the contents vanishing problem due to its sharing nature for extending contents lifetimes.**

Keywords*— *Floating content, Anchor zone, Effective radius

I. Introduction

With the development of wireless technologies in recent years, a bunch of communication infrastructures and wireless communication devices have become widespread and the fact makes it possible for users to connect to the network from everywhere to use various applications and services such as SNS for the purpose of information sharing. However, existing information sharing services require continuous connections, that is, the connectivity to the Internet supported by infrastructures is mandatory for such services. As one of the solutions for the issue, floating contents architectures [1]-[5] have been proposed, which does not rely on any infrastructures and enables autonomous information sharing only by terminals. In the floating contents architecture, mobile terminals relay and share contents among neighbours within a designated area spatiotemporally, which is called anchor zone.

In the architectures, direct communications without infrastructures between mobile terminals have generally taken to share contents inside the designated anchor zone for each content. Therefore, the lifetimes of contents are strongly influenced by the terminal density of the designated zones and the terminal sojourn time in the zones.

To prolong the lifetime of contents, we address the issues by introducing an adaptive adjustment method for its effective radiuses of anchor zones. In the proposed method, a larger effective radius will be assigned to a content which is in the environment of the terminal encounter rate is low to prevent the contents from vanishing in a short time. On the other hand, relatively smaller effective radius will be assigned to a content which is in the environment with enough communication opportunities among terminal to suppress unnecessary dissemination. The proposed method enables the adjustment by utilizing the expected number of encountering terminals and the sojourn time inside the zones.

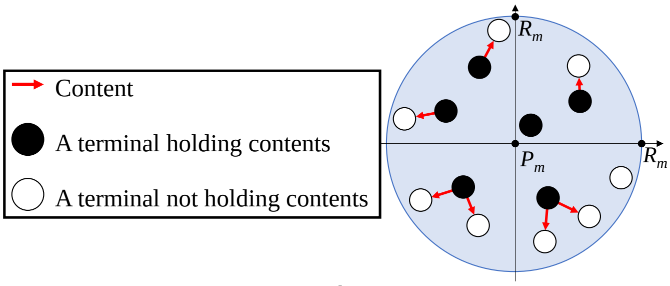

Fig. 1. Content sharing operation.

II. Floating Content

A. Overview of Content Transfer Control

Floating content (FC) [3] is a novel information sharing architecture among mobile terminals without the help of infrastructures, which shares contents spatiotemporally within a designated area called anchor zone. The anchor zone for a content is individually defined by the centre coordinate, the effective radius, the content identifier, and the lifetime. In the example shown in Fig. 1, content *m* has the centre coordinate P_m, the effective radius R_m, the content identifier ID_m, and the lifetime T_m. In addition, each terminal holds an encountered terminal table and a content table to manage the content dissemination status not to disseminate duplicated contents as shown in Fig. 1.

B. Content Sharing Procedure

The detailed contents sharing procedure in FC is described

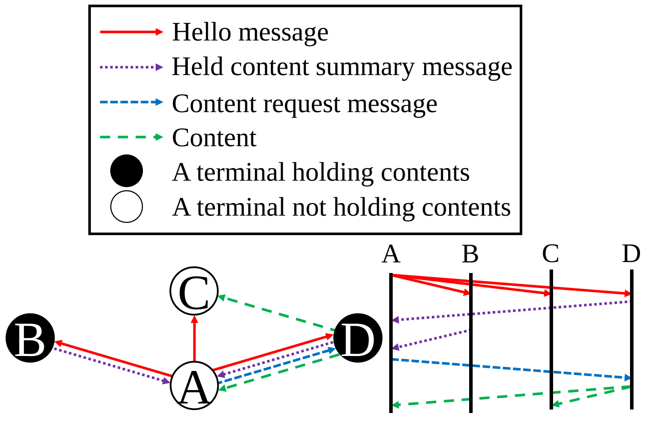

Fig. 2. Common sequence of content transmission in floating content.

in the following with Fig. 2.

(1) Each terminal periodically broadcasts a hello message and waits for the replies from the receivers for a predefined period. Note that, the hello messages include a sender address and the sender's geographical position.

(2) The receiver terminals of the hello message reply with the held content summary message (HCSM) including valid content information held by the terminal when the sender is in the anchor zone. Here, the valid content means that the receiver exists in the anchor zone of the content and the current time is within the lifetime.

(3) After the period for waiting replies expires in the sender of hello message, it compares the content table with the content table stored in received HCSM. Then, the sender transmits a content request message (CRM) when there is a content that is not in the own table. If the terminal has received HCSM including same ID from multiple terminals, it sends CRM to a randomly selected terminal.

(4) When a terminal receives the CRM, it transmits the requested contents according to the stored information about content identifier ID in the content request message. After receiving the contents, the terminal holds the contents and updates own content table. Here, a receiver of contents holds the contents and updates own content table when the receiver did not send the CRM and the receiver exists in the anchor zone.

As described above, a terminal holding a content shares the content among terminals within the anchor zone of each content. However, FC requires both sender and receiver terminal of a content to be in the anchor zone of the content to exchange the content. Therefore, terminal density of anchor zones has strong influence to the lifetime of contents since fewer exchange opportunities in a sparse environment deprive contents of dissemination opportunities.

III. Effective Radius Calculation

To address the drawback of FC, this paper proposes a method which dynamically changes an effective radius of anchor zones. The proposed method utilizes the number of encountered terminals in a certain period to estimate the expected number of encountering terminals before a terminal leaves from an anchor zone for the adaptive management of the effective radius. In other words, the proposed method examines the adequacy of the radiuses by the expected numbers and adaptively changes the radiuses to hold content as much as possible. By the strategy, the proposed method realizes both suppression of excess content transmission and extension of the time to information loss (TTIL). The followed sections describe the detailed procedure of the proposed method when terminal i is in the anchor zone of content m.

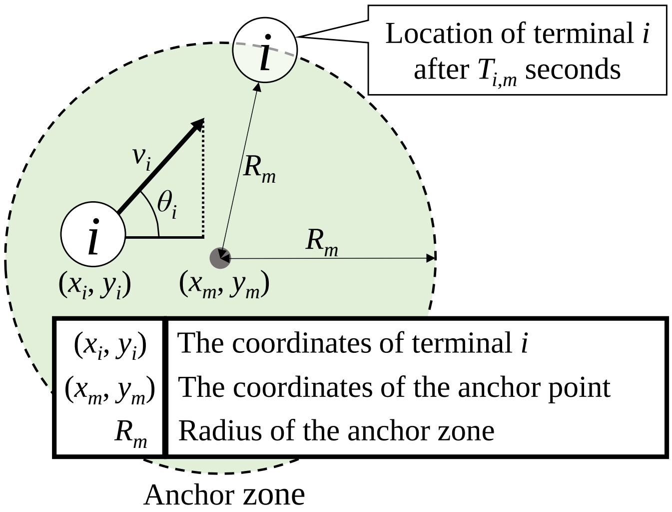

Fig. 3. Example of positional relations in floating content.

A. Calculation of the Number of Encountered Terminals

Terminal i calculates the number of encountered terminals λ_i per unit time, which is one of the important parameters for the adaptive radius management of anchor zones in the proposed method. On receiving a hello message from other terminals, terminal i records the information of the sender to the own encountered terminal table and stores it for a predetermined time T_{exp}. Then, terminal i periodically calculates λ_i based on the number of encountered terminal e_i and T_{exp} as described in Eq. (1).

$$\lambda_i = \frac{e_i}{T_{\text{exp}}} \tag{1}$$

B. Expected Anchor Zone Leaving Time Calculation

After the calculation of λ, terminal i calculates the expected leaving time $T_{i,m}$, the remaining time before terminal i leaves the anchor zone of content m. First, the terminal i calculates its moving speed v_i and the moving angle θ_i with respect to the x-axis by using the changes of the position information every predetermined interval. Fig. 3 shows an example of a positional relation between terminal i and the anchor zone of content m. Here, we define the distance between terminal i and the centre of the anchor zone P_m as R_m when terminal i leaves the anchor zone after $T_{i,m}$ seconds. Then, the position of terminal i after $T_{i,m}$ seconds will be ($x_i + v_i T_{i,m} \cos \theta_i$, $y_i + v_i T_{i,m} \sin \theta_i$) and thus Eq. (2) holds.

$$(aT_{i,m} + b)^2 + (cT_{i,m} + d)^2 = R_m{}^2 \quad (2)$$

$$a = v_i \cos\theta_i \quad (3)$$

$$b = x_i - x_a \quad (4)$$

$$c = v_i \sin\theta_i \quad (5)$$

$$d = y_i - y_a \quad (6)$$

Since $T_{i,m} \geq 0$ essentially holds, the anchor zone leaving time $T_{i,m}$ of terminal i can be calculated as Eq. (7).

$$T_{i,m} = \frac{-(ab+cd) + \sqrt{(a^2+c^2)R_m{}^2 - (ad-bc)^2}}{a^2+c^2} \quad (7)$$

C. Estimation of the Number of Encountered Terminals before Leaving Anchor Zone

As $T_{i,m}$ represents the remaining time before terminal i sojourns in the anchor zone of content m, the expected number of encountered terminals before the terminal leaves the zone per unit time $\lambda_{i,m}(E)$ is calculated by using $T_{i,m}$ from Eq. (7) as

$$\lambda_{i,m}(E) = \frac{E}{T_{i,m}} \quad (8)$$

where E is a constant value representing the number of encountering terminals before leaving the anchor zone. Here, we define two constants $E_{\min}$ and $E_{\max}$ for the substitution of E which represents the lower and upper threshold of the number of encountering terminals before terminals leave the anchor zone for the further procedures. The threshold defines another subsidiary threshold for the effective radius adjustment, which represents lower and upper limit of the number of expected encountering terminals per unit time $\lambda_{\min} = \lambda_{i,m}(E_{\min})$ and $\lambda_{\max} = \lambda_{i,m}(E_{\max})$ respectively.

D. Effective Radius Optimization of Anchor Zone

Each terminal adaptively calculates the effective radius and changes the radiuses after comparing encountered terminals λ and the thresholds λ_{min} and λ_{max}. An example of the anchor zone adjustment in the proposed method is shown in Fig. 4. When the terminal i maintains the same moving speed and direction in the anchor zone of content m as in Fig. 4, let $T_{i,m}(E)$ be the time required to encounter other terminals E times. In addition, let the required the effective radius be $R_{i,m}(E)$ to satisfy the condition of E in $T_{i,m}(E)$. $T_{i,m}(E)$ and $R_{i,m}(E)$ are calculated by the following Eq. (9) and Eq. (10) respectively.

$$T_{i,m}(E) = \frac{E}{\lambda_i} \quad (9)$$

Here, $R_{i,m}(E)$ in Eq. (10) is calculated using Eq. (2) and Eq. (9).

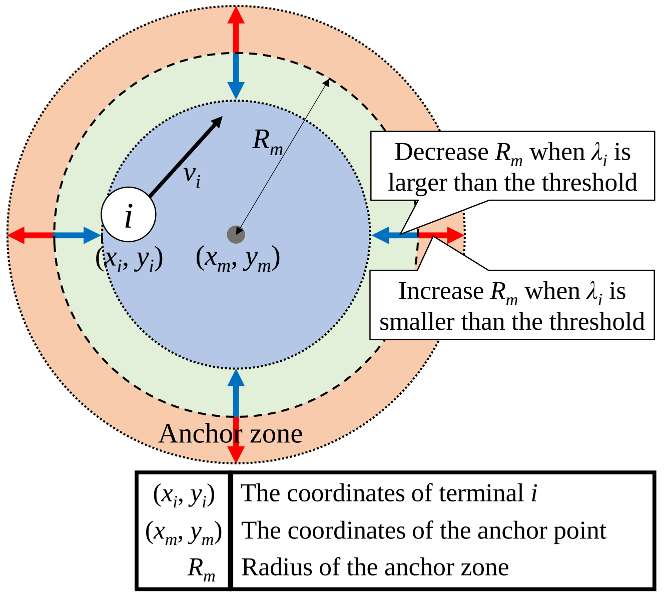

Fig. 4. An operation of the proposed method.

$$R_{i,m}(E) = \sqrt{\left\{a\left(\frac{E}{\lambda_i}\right)+b\right\}^2 + \left\{c\left(\frac{E}{\lambda_i}\right)+d\right\}^2} \quad (10)$$

By using $R_{i,m}(E)$, terminal i sets the effective radius $R_{i,m}$ of the anchor zone for content m as

$$R_{i,m} = \begin{cases} \max(R_{\min}, R_{i,m}(E_{\min})) & (\lambda_i < \lambda_{\min}) \\ R_m & (\lambda_{\min} \leqq \lambda_i \leqq \lambda_{\max}) \\ \min(R_{\max}, R_{i,m}(E_{\max})) & (\lambda_i > \lambda_{\max}) \end{cases} \quad (11)$$

where $R_{\min}$ and $R_{\max}$ are the minimum and the maximum radiuses that the effective radius can take. In other words, this assignment can realize the extension of TTIL when the number of terminals that can relay content existing in the anchor zone is small and prevents extreme change of the effective radius when the effective radius calculated from Eq. (10) is not proper value.

IV. Simulation Evaluation

A. Simulation Setups

In this paper, we evaluated the performance of the conventional method [3] and the proposed method using QualNet 6.1 [6] simulator. In the simulations, terminals were randomly placed in a 5,000 meters square area, and the number of terminals was varied from 20 to 200 in steps of 20. For the mobility model, a random waypoint was used and the moving speed was randomly chosen from 0 m/s to 10 m/s without using waiting time. Every terminal used IEEE802.11b as a communication medium and the communication range was set to approximately 120 m with the bandwidth of 11 Mbps. The simulation duration was set to 2,000 seconds. Contents are generated in randomly selected terminals 200 seconds after the

TABLE I. SIMULATION PARAMETERS FOR THE PROPOSED METHOD

Simulation No.	E_{min}	E_{max}	R_{min}	R_{max}
Simulation 1	N/A	N/A	N/A	N/A
Simulation 2	1–2	5	100	1,500
Simulation 3	2	2.5–10	100	1,500
Simulation 4	1.5	5	100–1000	1,500
Simulation 5	1.5	5	100	500–1500

beginning of simulation. Every content size was set to 1,000 KByte and transmitted as UDP traffic. The lifetime T of anchor zones were set to 1,800 seconds for every content. In the proposed method, E_{min} varied from 1 to 2, E_{max} varied from 2.5 to 20, R_{min} varied from 100 m to 1,000 m, and R_{max} varied from 500 to 1,500 m. Note that the initiate R was set to R_{min}. We conducted five simulations to evaluate how the parameter settings affect the performance. Therefore, the effective radius was fixed in simulation 1 and the radius was dynamically changed in simulations 2 to 5. That is, all the terminals hold the same effective radius in simulation 1 and the same anchor zone size, whereas effective radiuses differ depending on terminals in simulations 2 to 5. In simulation 1, we evaluates the performance of the conventional FC varying R. E_{min}, E_{max}, R_{min}, and R_{max} vary individually in simulation 2 to 5. The parameter settings of of E_{min}, E_{max}, R_{min}, and R_{max} for the proposed method in each simulation can be found in Table I.

The simulation evaluated TTIL and the total number of transmitted contents. TTIL indicates the time from when the content is generated until the time when the content vanishes from all the terminals in the anchor zone. The total number of transmitted contents indicates the total number of transmitted contents from all the terminals. In the proposed method, when the number of encountered terminals within a certain period is small, the terminal increases the range of the anchor zone. At this time, the increase of content transmission opportunities suppresses content extinction in the anchor zone. Therefore, we evaluate TTIL to reveal the influence of the effective radius changes.

In addition, the proposed method may increase or decrease a content transmission opportunity since the effective radius are dynamically changed according to the terminal density. Thus, we evaluate the influence of the change of the effective radius on the total number of transmitted contents.

B. *Simulation Results*

Simulation 1:

Fig. 5 indicates that the conventional method increases TTIL as an effective radius R and the terminal density increase. This is because the larger effective radius increases opportunities for content transmission lower the probability that all the terminals holding contents leave the anchor zone. In addition, it can be seen that TTIL asymptotically closes to the lifetime T when the number of terminals and the effective radius R are equal to or greater than a certain value. This is because that opportunities for content transmission and the

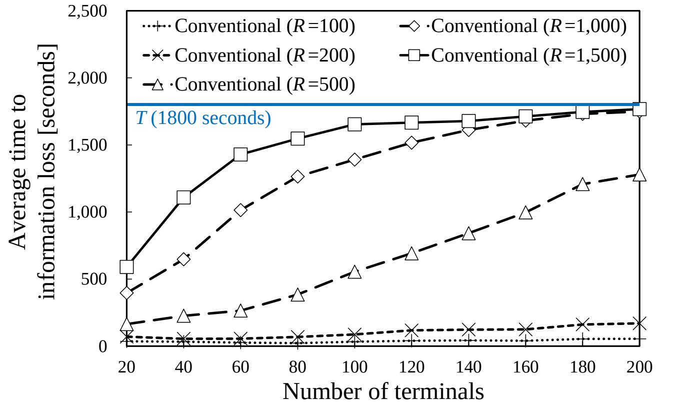

Fig. 5. Average time to information loss.

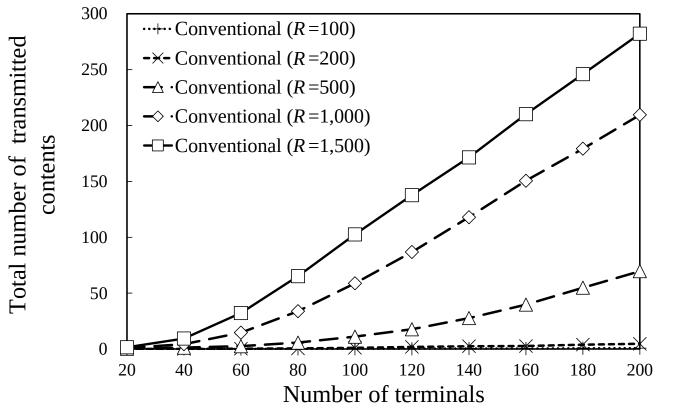

Fig. 6. Total number of transmitted contents.

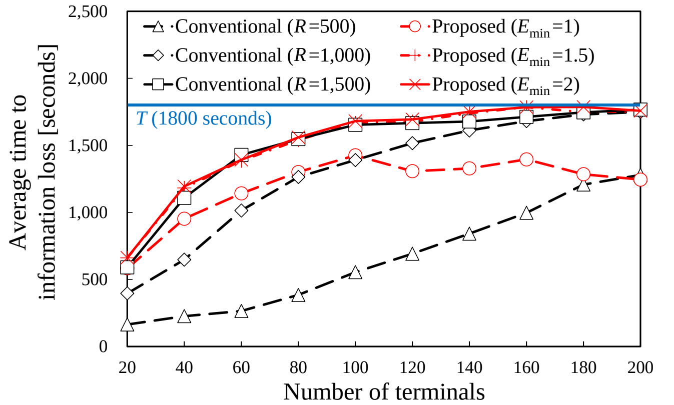

Fig. 7. Average time to information loss (E_{min} is variable).

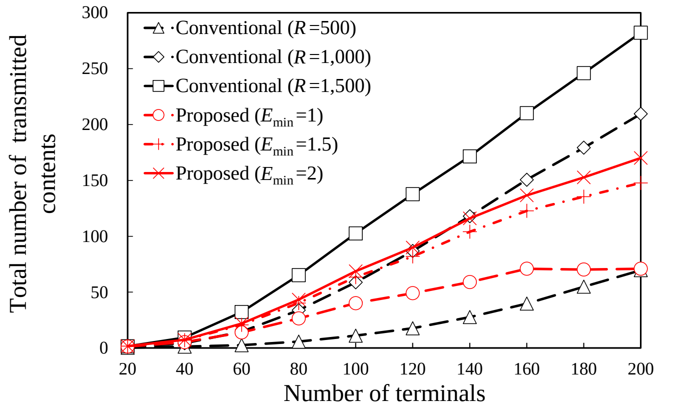

Fig. 8. Total number of transmitted contents (E_{min} is variable).

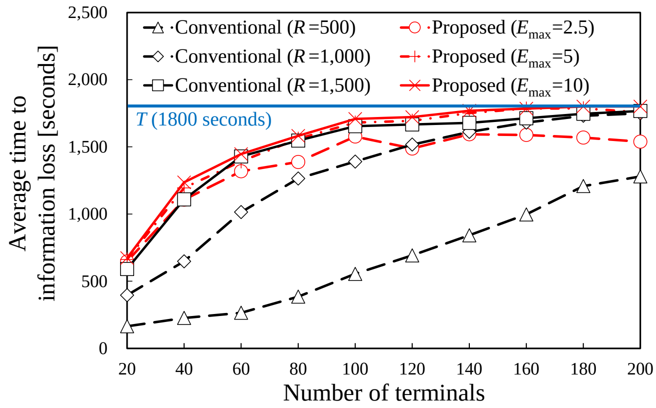

Fig. 9. Average time to information loss (E_{max} is variable).

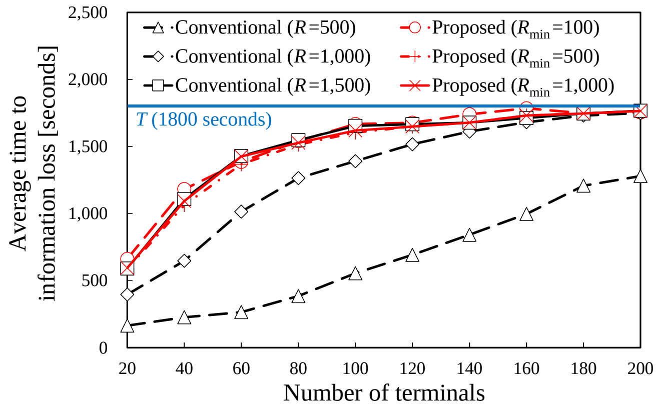

Fig. 11. Average time to information loss (R_{min} is variable).

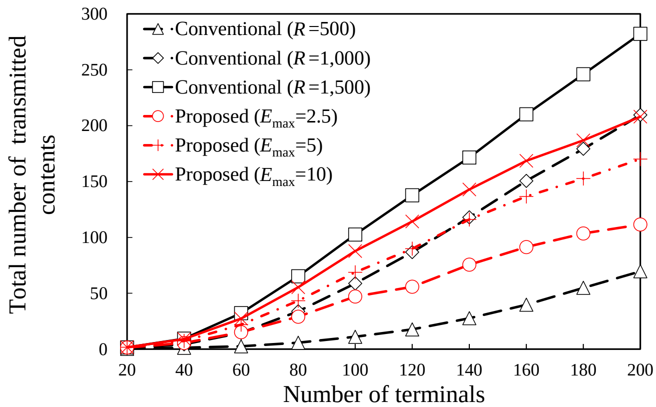

Fig. 10. Total number of transmitted contents (E_{max} is variable).

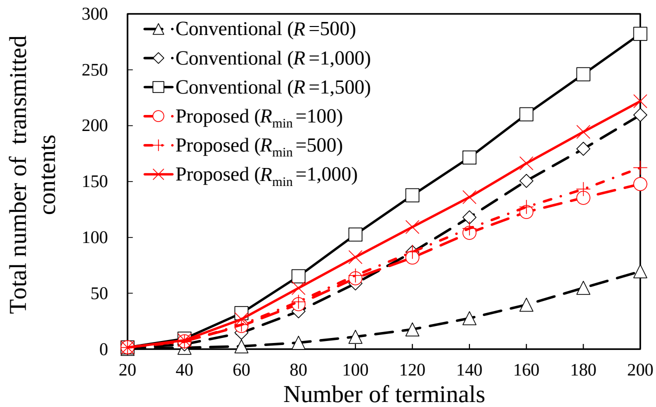

Fig. 12. Total number of transmitted contents (R_{min} is variable).

probability for relaying contents before leaving the anchor zones increase when the number of terminals and the effective radius are sufficiently large. Fig. 6 shows that the total number of transmitted contents increases in proportion to the number of terminals as shown in Fig. 5. This is because the number of terminals inside the anchor zone increases when the anchor zone expands as the increase of the effective radius *R*. Thus, opportunities for content transmission increase as the effective radius increases since the probability that the terminal holding a content encounters another terminal in the anchor zone increases.

Simulation 2:

Fig. 7 shows that the proposed method increases TTIL as the increase of E_{min}. In particular, the proposed method (E_{min} = 1.5 and E_{min} = 2.0) are the same level of TTIL as the conventional method (*R* = 1,500 m). This is because the increase of E_{min} also increases the expected number of encountering terminals which collaterally expands the average effective radius set by terminals. Moreover, opportunities for content transmission and the probability for relaying contents before leaving the anchor zones increase when the effective radiuses are sufficiently large. Fig. 8 shows that the proposed method has the lower number of transmitted contents than the conventional method (*R* = 1,500 m) in addition to the same level of TTIL as the conventional method (E_{min} = 1.5 and E_{min} = 2.0). This is because the proposed method can suppress unnecessary transmission when there are enough terminals in anchor zones for relaying contents. Thus, the proposed method can shrink effective radiuses maintaining encounter opportunities before terminals leave anchor zones.

Simulation 3:

Fig. 9 shows that the proposed method (E_{max} = 5, 10) increases TTIL as the increase of E_{max}. This can be explained by the same reason as Fig. 7 since E_{max} determines the maximum expected number of encountering terminals and the increase of E_{max} increases opportunities for content transmission. In addition, the proposed method achieves longer TTIL than the conventional method (*R* = 1,500 m). However, the proposed method (E_{max} = 2.5) decreases TTIL in comparison with the conventional method (*R* = 1,500 m). This is because a small E_{max} limits the maximum effective radius and the possibility of terminal leave from anchor zones without sending any contents to other terminals increases. Fig. 10 shows that the proposed method increases the number of transmitted contents as the increase of E_{max}. This is because the increase of E_{max} expands settable effective radiuses which collaterally increase the number of terminals inside an anchor zone and opportunities for content transmission.

Simulation 4:

Fig. 11 shows that TTIL is almost the same value as the conventional method (*R* = 1,500 m) regardless of R_{min}. This is because the increase of R_{min} influences the expected number of encountering terminals and effective radiuses only in a positive way. Fig. 12 shows that the proposed method

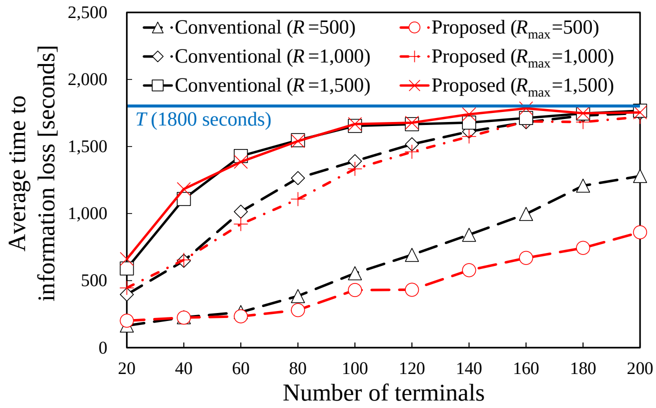

Fig. 13. Average time to information loss (R_{max} is variable).

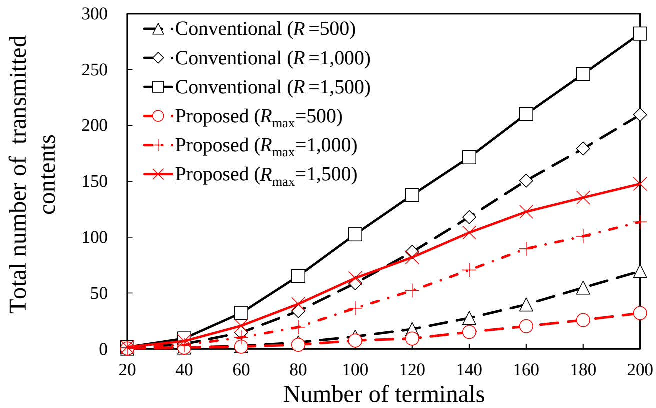

Fig. 14. Total number of transmitted contents (R_{max} is variable).

increases the total number of transmitted contents as the increase of R_{min}. This can be explained by the same reason as Fig. 10 that the increase of R_{min} urges a terminal to expand settable effective radiuses which collaterally increase the number of terminals inside an anchor zone and opportunities for content transmission. In addition, the result of the proposed method (R_{min} =1,000 m) shown in Fig. 12 depicts another characteristic that it requires more content transmission than the ones shown in Fig. 8 and Fig. 10. This is because the increase of R_{min} essentially expands effective radiuses and the number of terminals inside anchor zones voluntary increases.

Simulation 5:

Fig. 13 shows that the proposed method increases TTIL as the increase of R_{max}. This can be explained by the same reason as Fig. 7 that the increase of R_{max} also increases the expected number of encountering terminals which collaterally expands the average effective radius set by terminals. However, the proposed method (R_{max} = 500 m, 1,000 m) decreases TTIL in comparison with the conventional method (R = 1,500 m). This is because small R_{max} limits the effective radius expansions and it restricts opportunities for content transmission and the probability for relaying contents before leaving an anchor zone. Fig. 14 shows the proposed method increases the total number of transmitted contents as the increase of R_{max}. This can be explained by the same reason as Fig. 10 that the increase of R_{max} expands settable effective radiuses which collaterally increase the number of terminals inside an anchor zone and opportunities for content transmission. In addition, the proposed method (R_{max} = 500 m, 1,000 m) shown in Fig. 14 depicts that it requires less transmission compared with the results shown in Fig. 12. This is because that assigning a reasonable limitation to R_{max} results in the suppression of the number of terminals inside anchor zones and content transmission.

V. Conclusion

This paper proposed a method that adaptively adjusts the effective radius based on the number of encountered terminals and addressed the issue that the contents vanishes from all the terminals before expiring the lifetime. From the performance evaluation results, the proposed method with appropriate parameter setting could extend TTIL which asymptotically closes to the content lifetime T with less number of contents transmission compared to the conventional method. However, the proposed method increases the total number of transmitted contents as the terminal density increase. Therefore, it is a future subject to reduce the total number of transmitted contents further. In order to achieve the above objectives, we consider a method to group multiple terminals as a sharing unit and a method to vary the content transmission probability according to the distance from the centre of anchor zones.

In addition, in order to conduct simulation under realistic conditions, it is also necessary to study simulations in different mobility models.

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