User-centric location-oriented content dissemination using P2P and D2D communications

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Abstract:
Location-based service (LBS) realizes information sharing based on each user’s location and demand. However, LBS platform providers need to have abundant network resources since they have to replicate and disseminate the published content to the subscribers as a broker. Namely, a user or organization, who has few resources, is difficult to be a standalone LBS platform provider or content publisher without a broker since they need to deal with network traffic for the enormous subscribers, and they need to have a way to manage all of the subscriber’s information. This letter proposes user-centric location-oriented content dissemination based on peer-to-peer and device-to-device communications.

Keywords: location, content dissemination, device-to-device, peer-to-peer

Classification: Network System

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1 Introduction

Location-based service (LBS) [1] realizes information sharing such as content dissemination, advertisement, and emergency alarm based on the user’s location and demand. The LBS platform provider operates such a service as a broker to disseminate the content, which is produced by a content publisher, to the subscribers. However, a user or organization, who has few network resources, is difficult to be a standalone LBS platform provider or content publisher without relying on such an LBS platform provider since they need to deal with many network traffic from enormous subscribers, and they need to have a way to collect and manage all of the subscriber’s information.

As solutions to the above issues, there are two approaches without relying a broker: a mobile network-based approach and local network-based approach.

As a mobile network-based approach, a location-based mobile peer-to-peer (P2P) framework [2] enables an LBS platform provider to manage the publishers and subscribers via mobile network. On the basis of this framework, the content publisher can disseminate the content to the subscribers using mobile P2P communication. However, the content publisher consumes many network resources since it only uses mobile P2P communication to disseminate the content to all of the subscribers. Hence, it may not deal with the increase of subscribers though it can efficiently manage the publishers and subscribers.

As a local network-based approach, location-based local content dissemination methods [3, 4, 5] enable a content provider to disseminate a content to the subscribers within a specified area using local multi-hop device-to-device (D2D) communication. They might be able to deal with the traffic increase due to the increase of subscribers since each node only sends a content to its neighbors at least. However, due to the reliance on local multi-hop D2D communication, they may cause the delay increase and content loss. Moreover, if they fail to estimate and manage the network topology, they may also cause the unnecessary content transmissions.

2 User-centric location-oriented content dissemination based on P2P and D2D communications

This paper proposes an efficient content dissemination method, which enables a user as a publisher to disseminate content to the subscribers within a specified dissemination area without relying on a broker, based on P2P and D2D communications via mobile and local networks.

First, we assume that all the nodes have global connectivity via mobile networks, and they can freely send data via local networks. The LBS platform provider only has a P2P server that manages the locations and addresses of users and it can extract nodes within a specified area based on a framework [2]. Namely, the P2P server does not behave as a broker such as content replication and dissemination.

In the proposed method, each content publisher needs to replicate and
disseminate content to the subscribers by itself. Here, all of the subscribers are categorized into “primary receivers” and “secondary receivers.” To alleviate the impact of the network traffic, the publisher only disseminates its content to the primary receivers. The primary receiver is explicitly determined based on a primary receivers selection algorithm, as described in Sec. 2.2. They have a responsibility to re-disseminate the content received from the publisher to its neighbors by using local D2D communication. The secondary receiver is implicitly determined based on the neighbor relation with the primary receiver. In other words, the primary receivers need to cover all the secondary receivers, and hence the secondary receivers only receive the content from the primary receivers.

2.1 Operation procedure

This section explains the content dissemination procedure of the proposed method, and the operation example is shown in Fig. 1.

First, each user, who wants to become a subscriber or a publisher, registers its address and its location to the P2P server. After that, it periodically updates its information registered in the server.

When a publisher, such as a user, wants to send content to an area, it sends the dissemination area information to the P2P server. Then, the server extracts the primary receivers to cover all the nodes within the specified dissemination area based on an algorithm described in Sec. 2.2, and then it replies the primary receivers list to the publisher.

When the publisher receives the list from the server, it starts to dissemi-
nate the content to each primary receiver using mobile P2P communication. After receiving the content from the publisher, each primary receiver broadcasts the content to the neighbors as the secondary receivers using local D2D communication. Therefore, all the subscribers within the dissemination area can eventually obtain the content.

2.2 Primary receivers selection algorithm
This section explains the primary receivers selection algorithm, as shown in Alg. 1. The examples also are shown in Fig. 2 (a) and Fig. (b).

This algorithm extracts the primary receivers from among nodes within the specified dissemination area and its neighbor area. Here, \( \mathcal{N} \) denotes a set of nodes within a specified area, and \( \mathcal{N}^+ \) denotes a set of nodes within a neighbor area of the dissemination area. Note that each node of \( \mathcal{N}^+ \) is also a candidate of the primary receiver to cover the subscribers efficiently. \( \mathcal{G}_1 \) denotes a set of primary receivers, and \( \mathcal{G}_2 \) denotes a set of secondary receivers. \( \varphi(i, \mathcal{G}_u, \alpha R) \) denotes a set of undetermined nodes in \( \mathcal{G}_u \) within a circle with radius \( \alpha R \) centered at \( i \). Note that \( R \) denotes the reference communication radius, and \( \alpha \) denotes the scaling factor.

3 Performance evaluation
3.1 Simulation setup
This paper conducted simulations using ns-3 [6], and the parameters were as follows. IEEE 802.11a was used as the wireless medium, the data rate was set to 6 Mbps, and the communication range was set to about 100 m.

Algorithm 1 Primary receivers selection algorithm.

Require: \( \mathcal{G}_u = \mathcal{N}, \mathcal{G}_1 = \mathcal{G}_2 = \emptyset \)
Ensure: Primary receivers \( \mathcal{G}_1 \)

while \( \mathcal{G}_u \neq \emptyset \) do
  \( n \leftarrow \text{null} \)
  while \( i \in \mathcal{G}_u \) do
    if \( n = \text{null} \land |\varphi(i, \mathcal{G}_u, \alpha R)| > |\varphi(n, \mathcal{G}_u, \alpha R)| \) then
      \( n \leftarrow i \)
    end if
  end while
  while \( j \in \mathcal{N}^+ \) do
    if \( |\varphi(j, \mathcal{G}_u, \alpha R)| > |\varphi(n, \mathcal{G}_u, \alpha R)| \) then
      \( n \leftarrow j \)
    end if
  end while
  \( \mathcal{G}_1 \leftarrow \mathcal{G}_1 + n \)
  \( \mathcal{G}_u \leftarrow \mathcal{G}_u \setminus n \)
  \( \mathcal{G}_2 \leftarrow \mathcal{G}_2 \cup \varphi(n, \mathcal{G}_u, \alpha R) \)
  \( \mathcal{G}_u \leftarrow \mathcal{G}_u \setminus \varphi(n, \mathcal{G}_u, \alpha R) \)
end while
Example of the content dissemination (500 nodes, $R = 100$, $\alpha = 1$, $|N| = 253$, $|G_1| = 68$, $|G_2| = 186$).

Example of the content dissemination (1,000 nodes, $R = 100$, $\alpha = 1$, $|N| = 513$, $|G_1| = 85$, $|G_2| = 428$).

Total number of data packets.

Packet delivery rate.

Average dissemination delay.

Fig. 2. Simulation results.
Nodes were randomly placed at a 1 km square area. In the proposed method, $R$ was set to 100 m and $\alpha$ was set to 0.8 or 1.0. This simulation assumed that all mobile communications have an ideal performance without errors. A single publisher sent a single notification, and all the others were set as the subscribers. This paper evaluated the performances of using (1) a mobile network (2) a local network, and (3) the proposed method in terms of content delivery rate, total number of packets, and local dissemination delay.

3.2 Simulation results

Figure 2 (c) shows the total number of packets. Note that this result also shows the received data packets via mobile networks since the packets may be regarded as the network usage. In the result, the case of only using mobile networks is the highest total number of packets since it needs to disseminate the content only using mobile networks. The case of only using local networks also becomes the higher total number of packets since the nodes need to disseminate with each other using local networks. The proposed method achieves the lowest total number of packets since the publisher only sends the content to the primary receivers via mobile networks, and the primary receivers just broadcast the received content via local networks.

Figure 2 (d) shows the content delivery rate. The case of only using local networks becomes a lower delivery rate in comparison with the other methods. In this method, nodes need to rebroadcast the received content with each other so-called flooding to disseminate the content to the whole area. Hence, it needs sufficient node density to propagate the content. Although the proposed method ($\alpha = 0.8$) achieves the higher delivery rate, the proposed method ($\alpha = 1.0$) decreases the delivery rate. The reason is that the proposed method ($\alpha = 1.0$) increases the coverage of each primary receiver and reduces the primary receivers as possible. As a result, in the case of $\alpha = 1.0$, each link between a primary receiver and the secondary receivers becomes longer.

Figure 2 (e) shows the local dissemination delay. In the result, the case of only using local networks becomes the highest delay. In particular, it significantly increases the delay as increasing the number of nodes since each node needs to impose a random backoff to avoid collisions. The proposed method achieves a lower delay than the case of only using local networks since the primary receivers just broadcast the received content only once.

4 Conclusions

This paper proposed a user-centric location-oriented content dissemination method based on P2P and D2D communications. The proposed method realized that the content publisher could disseminate content with a quite small network load using a simple method. For practical use, the parameters of the proposed method are important to decide the performance. Therefore, we will discuss an adaptation mechanism of the parameters as future work.