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D2D PROXY CACHING STRATEGY FOR 5G-BASED MULTI-ZONE NETWORKING SERVICES

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Abstract. *In the 5G-based wireless multi-zone network system, the D2D (device-to-device) proxy caching algorithm efficiently caches unstructured media data such as audio, video, and it makes access streaming data requested by D2D users. In addition, this algorithm reduces network resource waste when D2D users access media data, and it adaptively controls traffic congestion. In this paper, we propose a DPCS (D2D proxy caching strategy) to seamlessly service streaming media data according to D2D user request and minimize traffic congestion in 5G-based wireless multi-zone network system. The proposed DPCS effectively controls networking traffic caused by unstructured media data caching in multi-zone network system and it improves cache hit rate. We compare and analyze the QoS (quality of service) for unstructured media data by separating the effect of D2D proxy caching in the zone into SDPC (single-zone D2D proxy caching) and MDPC (multi-zone D2D proxy caching). Simulation results show that MDPC partially contains SDPC, and we see that MDPC efficiently caches unstructured media data compared to SDPC when DUEs (D2D user equipments) are large. These results show that SDPC is effective when the number of UEs is small. However, when the number of UEs is large, it means that MDPC is effective.*
Keywords: D2D proxy caching, Multi-zone network, Traffic congestion, SDPC, MDPC

1. **Introduction.** The 5G mobile communication service, which is expected to be commercialized around 2020, will change the paradigm of existing mobile communication services and current LTE-based mobile communication services. 5G mobile communication technology is expected to increase explosively due to the kick-off of IoT (Internet of Things) service, and these communication devices will cause heavy traffic congestion [1,2]. Traffic congestion will make it difficult to guarantee 5G-based gigabit communication, and as a result this will degrade 5G QoS. Traffic types transmitted in the IoT environment are mostly unstructured media data, which further increases traffic congestion compared to the regular media data. Today, it is now easier to acquire and share unstructured media data such as background music and advertisements in smart mobile environments, and it is also possible to cache personal profile information and unstructured media data via social networking.

However, a new proxy caching algorithm is needed to effectively service unstructured media data in a 5G-based wireless multi-zone network environment regardless of personalized media object information or shared information. One of the important techniques to satisfy this demand is an adaptive cache D2D proxy caching strategy that manages and controls media data according to cache capacity in multi-zone [3,4]. One of the most effective techniques for servicing and controlling media content information in a 5G network environment is proxy caching [5]. This technique provides the advantage of reducing

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caching burden as a technique to quickly process a D2D client's request while being located at the edge of the network. [6] proposed a cache algorithm for offloading core networks on small cell networks. [7,8] proposed an enabled media caching algorithm to cooperatively service media objects in a D2D network environment. These algorithms are techniques to improve the caching performance by distributing the burden of the streaming service among the proxy caching servers. [9] studied the caching techniques as one of the main paradigms 5G cellular networks, which is used closely with the small cells. [10] proposed a cooperative caching and transmission algorithm in cluster-centric small cell networks. This algorithm is a caching scheme where part of the available cache space is reserved for caching the most popular media content in small base networks. However, these techniques do not solve the problems of traffic congestion and caching delay because they do not take consideration of the types of media data.

We propose DPCS to solve this problem. DUEs in DPCS are clients that stream unstructured media data, and a DUE streams unstructured media data through relay with other DUEs. A ZU (zone unit) in the 5G-based wireless multi-zone network is a D2D proxy caching server that exchanges media data information with nearby DUEs, which minimizes traffic congestion caused by caching and improves QoS. As such, a ZU minimizes network traffic on the zone network and effectively manages the multi-zone network structure by mutual networking with other zones other than its own zone. In the zone, media data caching performs SDPC and MDPC according to intra-zone relay and inter-zone relay. MDPC processes a data caching through other ZUs and relays, while SDPC is a strategy for independently caching media data without relaying with other ZUs. These strategies minimize network traffic congestion because caching is controlled according to the type and size of media data, and can also actively utilize the caching space.

Therefore, this paper proposes DPCS for effectively caching these data in the zone as the use of unstructured media data is expected to increase rapidly in the future 5G mobile communication service environment. Since the proposed DPCS caches unstructured media traffic according to SDPC and MDPC, it not only minimizes the delay caused by network traffic congestion, but also improves cache hit rate.

The rest of this paper is as follows. In Section 2, we describe the system model for the proposed scheme. In Section 3, we analyze the performance of the proposed system model. Finally, we describe the conclusion and future research.

2. System Model.

The proposed DPCS increases the hit rate while minimizing the caching delay of the media data, and effectively provides the caching service between DUEs (D2D user equipments) and CUEs (cellular user equipments). The proposed 5G-based multi-zone network service structure is shown in Figure 1 and it consists of ZU, macro-cell, and eNB.

Figure 1 shows an extended network model based on the LTE (long term evolution) network model, where ZU is a caching server with a local cache. In this paper, ZU manages the mobility and traffic of DUEs, and we have actually made these functions replace the AP (access point). In general, physically adjacent DUEs in a zone network have similar characteristics according to their locality, so similar physical properties can be applied to multi-zone networks. Therefore, we apply this physical similarity to each zone to effectively controlling heavy traffic caused by unstructured media data transmission.

2.1. SDPC strategy.

In the 5G-based wireless multi-zone network, the D2D proxy caching strategy performs cooperative caching between the DUEs and the ZU while maintaining its own caching function. If the caching server i maintains a cooperative relationship with the SDPC servers $\{0, \ldots, k\}$, the traffic congestion decision between the caching servers is determined by taking account of parameters such as traffic throughput,

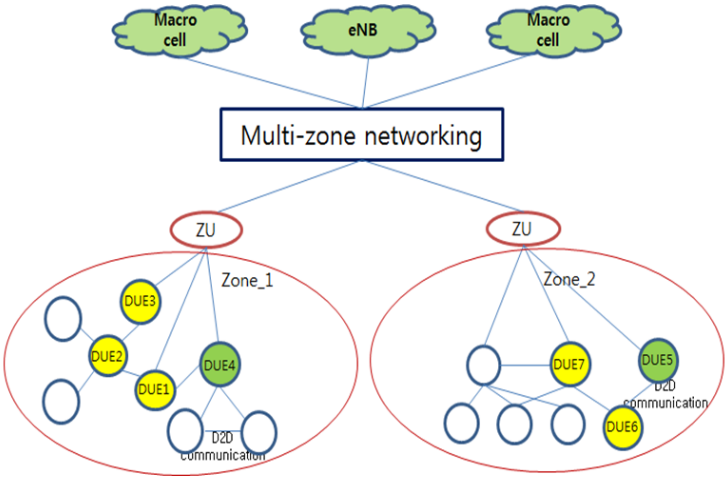

FIGURE 1. The proposed system model

access frequency, and traffic type. Therefore, the SDPC server can maintain a cooperative relationship with other SDPC servers. In the wireless multi-zone network structure, the DPC server can be composed of several caching servers including the SDPC server itself. In the wireless multi-zone network architecture, when the proxy caching server i has only its own caching server or only one server, the SDPC server is defined as follows.

Definition 2.1. *The relationship of the caching server consists of* $\{0, \ldots, (i-1)\}$ *according to the coverage controlled by the ZU, which is replaced again by* $\{ZU\text{-}0, ZU\text{-}1, \ldots, ZU\text{-}(i-1)\}$. *Here, ZU-0 means that there is only one caching server, and ZU-1 means that there are two caching servers. Therefore, we call the ZU-0, which has only one caching server, as an SDPC server, and this server independently performs caching without maintaining a cooperative relationship with other caching servers.*

SDPC is a caching scheme suitable for wireless multi-zone network environment with ZU-0. The process for streaming and caching media data from DUEs is processed as follows.

SDPC Process
// MD is media data for caching.
// C_{space} is a cache space for media data caching.
// C_{MD} is the media data already cached in the local cache.
// NC_{MD} is media data that is not cached in the local cache.
while ($C_{space} < MD$){
if (C_{space} is full) then

$$\text{Eliminate } C_{MD} \text{ satisfying } \min\left(\frac{S_{MD}}{t_i \times N_{bandwidth}}\right)$$

// S_{MD} is the size of the media data.
// t_i is the time taken to cache the media data.
// $N_{bandwidth}$ is the network bandwidth for caching media data.
Else

$$\text{Select a media data satisfying } \min\left(\frac{NC_{MD} - C_{MD}}{C_{space}}\right)$$

}

As shown in the above algorithm, if the local cache of the ZU-0 is full and the cache space to store the non-cached media data MD is full, the cache server caches the MD in its local cache and performs streaming. That is, if the local cache for media traffic is full so that N media data cannot be cached, the ZU sequentially deletes media data with low importance and low access frequency from the cache space by applying $\min\left(\frac{S_{MD}}{t_i \times N_{bandwidth}}\right)$.

In this way, we delete media data with low priority or high latency from the cache space in order, and the deleted media data MD is partitioned into 0 to $|MD|-1$ and stored in the cache space. In this process, the partitioned media data are classified into structured traffic and unstructured traffic according to the data type in order to identify the degree of traffic congestion. We define the structured traffic as $F_{traffic}$ and the unstructured traffic as $UF_{traffic}$. Therefore, the process for distinguishing whether the media data MD_i according to the media type is structured data traffic or unstructured data traffic is defined as follows.

Definition 2.2.

$$T_x = \min\left(0, \left\lceil\left(1 - \frac{C(\alpha)\times t_{cache}}{N_{bandwidth} + C_{space}}\right)\right\rceil \times \sum_{i=0}^{n-1} MD_i\right)$$

where $C(\alpha)$ *is the caching rate for the media data, and* t_{cache} *is the time taken to cache the media data* MD_i*. And* $N_{bandwidth}$ *is the network bandwidth.*

After the traffic for the media types is identified, the caching rate is considered, and if the caching rate is low, a caching server will meet congestion and waiting delay due to the bottleneck. These congestion and latency delays can cause degradation of 5G-based network performance and, in the worst case, cause the network itself to be disabled. Therefore, SDPC is used as an important metric to measure node level and network congestion of DUEs, and is also used as a traffic control measure.

2.2. **MDPC strategy.** The MDPC strategy is based on the SDPC strategy, which performs interconnection with the eNB (evolved Node B) through relaying with ZUs. DUEs that have completed interconnection with the eNB decide whether to forward their traffic to their own ZU or to cache traffic to other ZUs. At this time, if the own ZU caches the forwarded traffic, the delay time due to traffic caching from other DUEs can be reduced. However, when DUEs request traffic caching to other ZUs, it is necessary to check the caching resource status of the nodes. At this time, it is necessary to select a ZU that has least caching resources and free traffic caching. MDPC caches media traffic through cooperation between ZUs, and ZU between zones is divided into SDPC and MDPC according to intra-zone relay and inter-zone relay. Therefore, SDPC and MDPC depend on the relay between the zones, and the process to identify them is defined as follows.

Definition 2.3. *If there is only one caching server on* $\{$*ZU-0, ZU-1, ..., ZU-*$(i-1)\}$ *and this server does not relay with other ZUs, we call this relationship an intra-zone relay. A server satisfying the intra-zone relay is called an SDPC server. Otherwise, if* $\{$*ZU-0, ZU-1,..., ZU-*$(i-1)\}$ *maintain relay relations with each other, this server is called MDPC server and we call this relay as inter-zone relay.*

The inter-zone relay first checks to see if there are duplicate intra-zone relays before caching, and if there are redundant intra-zone relays, this relay is removed from the multi-zone network to reduce cache resource waste. Here, redundant intra-zone relay reduction is intended to improve cache hit rate and minimize latency, which in turn increases traffic throughput to media data. If the MDPC guarantees the caching performance, we can improve the traffic throughput $T_{throughput}$ by considering the traffic rate at a certain time t, and the traffic throughput to see a caching performance is defined as follows.

Definition 2.4.

$$T_{throughput} = (1-\omega)\times\frac{C(\alpha)}{(C_{MD} + NC_{MD})} + \left(\frac{1}{C_{time}}\right)\times\omega$$

where ω *is the delay rate for transferring media data at an arbitrary time* t *and* $C(\alpha)$ *is the caching rate. And* C_{time} *is the time it takes to cache the traffic.*

Therefore, the caching performance of the MDPC is processed by checking the intra-zone relay and the inter-zone relay, and the caching performance of the MDPC is determined by the size of the caching, the access frequency, and the importance.

3. **Simulation Analysis.** In this paper, we performed a simulation to investigate the performance of SDPC and MDPC. In the proposed model, one ZU represents the network of Zone-1, and three APs are installed in each of the three zones. It is assumed that ZU has a fixed size of storage and cache memory, and the path from DUE_i to eNB assumes that DUE_i is in the routing category of one SDPC. Now, let us assume that there are three multi-zones in the multi-zone network: zone-1, zone-2, and zone-3, and bandwidth is allocated from 300MHz to 3.4GHz in each zone. For the simulation, we set the number of media data requested in each zone to 1450, and we set the bandwidth differently for the requested media data. We set the total simulation time to 30 minutes and limit the size of each media data to 0.9 GB or less. In the simulation, the DUEs were set to cache the media data by SDPC and MDPC strategies, and if the referenced media data were in the local cache, then the latency was set to zero. To analyze the performance of the proposed scheme, we analyzed the results of average traffic identification rate and average traffic throughput by randomly changing 1450 media data.

Table 1 shows the average traffic identification rate for 1450 media data on multi-zones of zone-1, zone-2, and zone-3. Performance analysis is divided into non-DPCS and DPCS. The reason why the proposed method is not compared with other 5G techniques is that standardization related to 5G in 3GPP (3rd Generation Partnership Project) has not been established yet. Figure 2 shows the average traffic throughput according to the delay rate.

Figure 2 shows that the proposed DPCS performs traffic caching reliably. However, since non-DPCS does not perform traffic identification, we can see that it does not increase the performance of throughput. Therefore, it can be seen that the caching performance is affected by the caching rate, the traffic identification rate, and the delay rate. As the

Table 1. Average traffic identification rate

	zone-1	zone-2	zone-3
Non-DPCS	54	57	51
DPCS	81	84	79

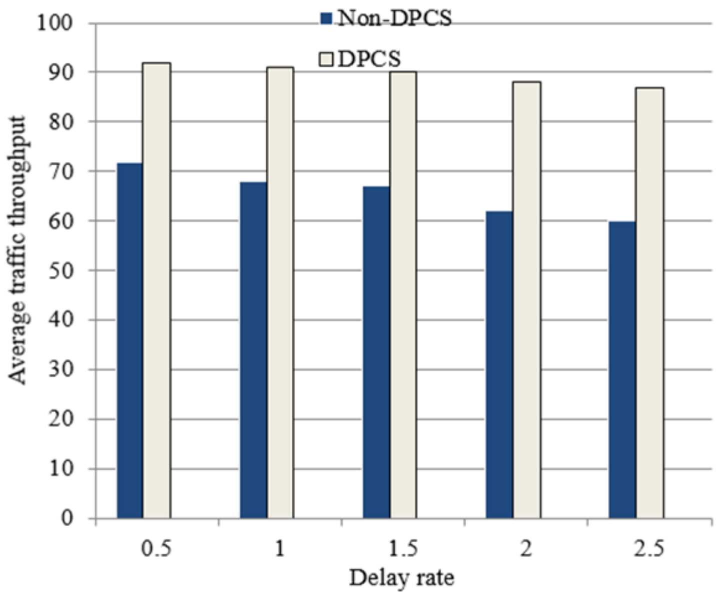

Figure 2. Average traffic throughput

traffic identification rate is higher, the caching delay is less and the traffic throughput is improved. As a result, the proposed DPCS improves caching performance because it considers traffic identification rate for media data. However, if the identification rate is not considered, caching delay will occur due to traffic congestion. We have shown that the proposed scheme can guarantee the performance for 5G-based communication service by reducing the caching delay in the multi-zone network.

4. **Conclusions.** Traffic congestion not only has a significant impact on caching performance, but also has a significant impact on the performance of 5G mobile communication services. In this paper, we proposed a DPCS strategy that improves caching performance while ensuring 5G-based multi-zone networking services. The proposed DPCS strategy categorized media data by SDPC strategy and MDPC strategy. In order to reduce caching delay caused by media accessing, it identifies both structured traffic and unstructured traffic. Therefore, the proposed DPCS strategy effectively identified traffic based on media data access. Simulation results showed that traffic caching is performed reliably, and traffic throughput was improved. In the future, we will measure the performance of the proposed scheme by constructing a real system environment when 3GPP standardization is established, and measure the performance of 5G mobile communication service by applying various simulation models.

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