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# Collaborative P2P Streaming based on MPEG-DASH for Smart Devices

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*Abstract*—**Due to widespread wireless broadband Internet, multimedia streaming using smart devices has become one urgent application. In this paper, we focus on how to improve the transmission performance when mobile users request multimedia streaming service on their smart devices. In this paper, smart devices are grouped to form one localized ad-hoc network using Bluetooth according to their social behavior and geographical locations. That is, if some users are willing to share the same multimedia objects and nearby within the Bluetooth coverage, they should cooperate to download the multimedia streams using the peer-to-peer (P2P) protocol through the Internet and the Bluetooth ad-hoc network simultaneously. Therefore, the proposed scheme based on the help of Bluetooth ad-hoc network not only offloads the inter-ISP traffic of P2P overlay network, but also saves the battery power of smart devices.**

***Keywords—Collaborative Streaming; Power Saving; Peer-to-Peer (P2P) Streaming; Bluetooth; Smart Device***

## I. Introduction

People receive explosive multimedia data using their smart devices every day because these smart devices have the capacity of accessing the resourceful broadband Internet. However, due to the tiny size, new-generation smart devices should still have limited battery power even if they are equipped with multi-core processors, large memory and high-speed wireless links [1]. Regarding the multimedia streaming service, peer-to-peer (P2P) streaming is one popular streaming service and able to avoid the bottleneck problem of the traditional client-server architecture. However, huge simultaneous sessions and the I/O-intensive process may drain smart devices' limited battery power rapidly. In addition, the P2P overlay network services often suffer the inter-ISP traffic problem. Once smart devices keep moving, it induces high churn rate and then lets the inter-ISP problem become worse. This paper is motivated to improve the power consumption of P2P streaming on smart devices.

Regarding past works about P2P overlay networks, they may focus on (1) swarm interests, i.e., how to form the P2P group, (2) located networks, i.e., how to share objects efficiently, and (3) upload incentives, i.e., how to promote to share objects [2,3]. Since the essence of P2P is to exchange resources with each other, it eventually induces the security and privacy issues. Hence, integrating social network into P2P network not only satisfies the virtual networking requirements but also provides the trusted and frequently-interacted relationship of the physical world among users [4,5]. In other words, cyber peers are encouraged to be more cooperative based on the real-life friends and partners. However, in order to resolve the aforementioned inter-ISP problem, past research may assign high priority to select the peers belonging to the same ISP. Once no peer in this ISP can provide resource, peers are allowed to establish connections to other peers belonging to different ISPs. When some peers are nearby geographically but located in different ISPs, the conflict between the inter-ISP problem and the social-network integration become one brand-new research issue.

In this paper, we combine the infrastructure based transmission and the ad-hoc based transmission. That is, when a group of users are located nearby, e.g., a conference, a meeting a party, a rally or outside broadcasting, they can form a localized ad-hoc network using the Bluetooth technology. In this way, parts of data can be shared with each other directly without passing through the backbone infrastructure. Fig. 1 depicts the proposed location-oriented collaborative P2P streaming (LCPS) scheme. The proposed LCPS scheme is able to offload the original traffic of the backbone infrastructure and then reduce the inter-ISP traffic even if users are located in different ISPs. At the same time, the Bluetooth interface costs less battery power than the Wi-Fi or 3G/4G interface. The proposed LCPS can save unnecessary battery power consumption. Furthermore, regarding the P2P overlay network, multimedia objects should be divided into small pieces, i.e., chunks, for accelerating the parallel downloading. In this paper, the LCPS adopts the MPEG-DASH standard. Different from past works, the MPEG-DASH standard encodes the video and audio objects into segments and the segment information is stored into one media presentation description (MPD) file. Thus, integrating the MPEG-DASH into the LCPS need not design any special packetization mechanism for the streaming service, decrease the implementation complexity and increase the compatibility.

This paper is organized as follows. Section II introduces the related works. Section III shows the proposed LCPS scheme. Section IV presents the performance evaluation about our proposed scheme. Finally, Section V concludes this paper.

## II. Related Works

In order to improve the power efficiency and transmission performance of P2P streaming service over smart devices, this paper is proposed to let smart devices form one ad-hoc network using Bluetooth according to their geo-locations. Thus, related works are divided into (i) P2P streaming with ad-hoc networks,

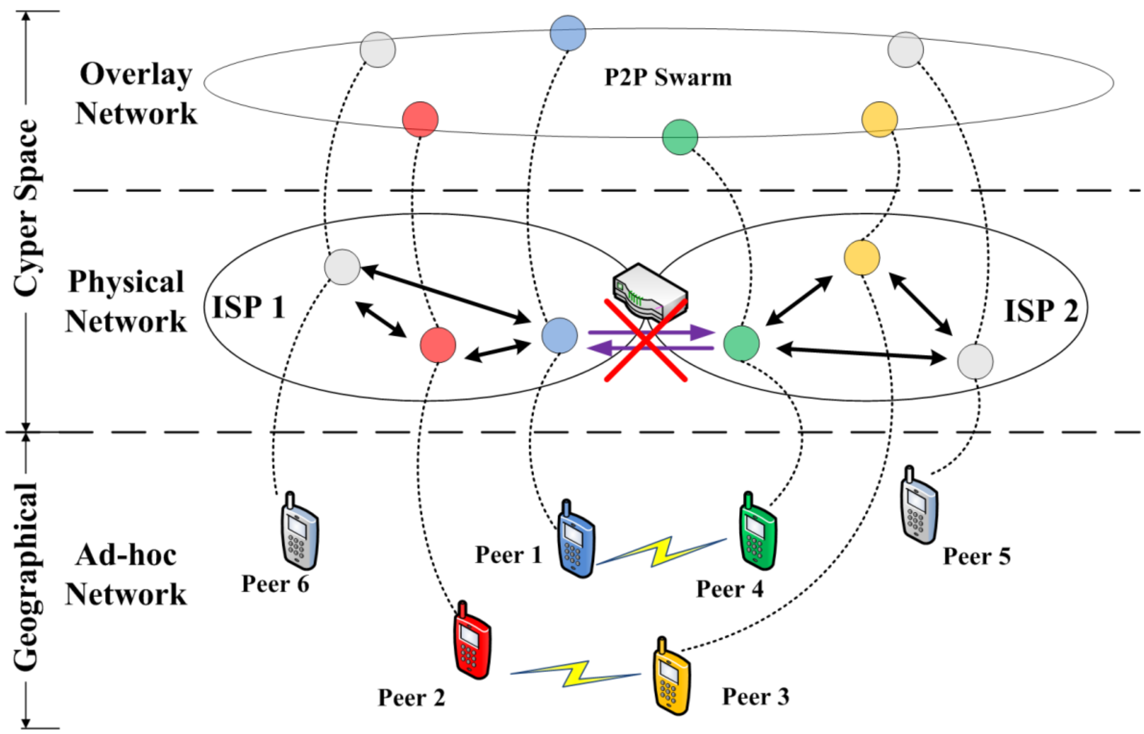



Fig. 1. The proposed LCPS scheme.

(ii) MPEG-DASH based streaming and (iii) geo-location based P2P.

### *A. P2P Streaming with ad-hoc networks*

Past works concentrated on how to integrate P2P with ad-hoc networks. For example, Woungang et al. focused on improving the lookup performance when applying the Chord algorithm in mobile P2P network [6]. No matter the underlying protocol is AODV or DSR, the proposed MR-Chord outperforms the original Chord in terms of lookup success rate, lookup delay time, etc. Toledano et al. proposed one framework called CoCam which enable mobile phones to form one ad-hoc network using Wi-Fi and share real-time images or videos [7]. In the CoCam, the P2P group is based on the geo-locations, i.e., latitudes and longitudes acquired by A-GPS, and Wi-Fi network fingerprint. One centralized server plays the role of associating devices with the most relevant CoCam group. Shijie et al. introduced one cross-layer and one-hop neighbor-assisted video sharing (CNVS) [8]. The proposed CNVS has a two-layer architecture including (1) neighbourhood layer and (2) cluster layer. In the neighbourhood layer, wireless signal strength is considered to evaluate whether one neighbor node support high communication quality or not. On the other hand, each node in the cluster layer form one self-organized group and decide whether joining or leaving the cluster based on the access cost information provided by the cluster. Furthermore, some works discussed and studied how to improve the quality and performance of P2P streaming. Baldesi et al. presented the analysis with PeerStreamer, which is an open-source P2P video streaming platform, on the Community-Lab, i.e., the wireless community network (WCN) testbed of the EU FIRE project called CONFIRE [9]. Mori et al. proposed one distributed chunk loss avoidance (DCLA) method for cooperative mobile live streaming [10]. A Cellular-Wi-Fi hybrid network is taken into consideration. According to the simulation results, the DCLA method is able to reduce the load of video providers and dynamically change the number of peers and bandwidth conditions for chunk loss avoidance. Raheel et al. studied the quality of experience (QoE) of P2P video streaming over mobile ad-hoc network and then proposed one energy efficient model [11]. Based on the simulation results, the proposed model can support better QoE and low power consumption even if peers keep the churn behavior.

### *B. MPEG-DASH based Streaaming*

MPEG-DASH is not only utilized in the Web environment and applications. Awiphan et al. provides a framework for enabling MPEG-DASH based adaptive bit-rate video streaming over content centric network (CCN) [12]. Furthermore, the experimental results on PlanetLab are overlay delivery path and the size of data chunk affect the streaming quality. Detti et al. devised one P2P application for live streaming [13]. In this paper, the CCN architecture and the MPEG-DASH format are adopted. The proposed P2P application enables a limited set of neighboring mobile devices to increase the quality of video playback by cooperatively using their cellular, e.g. 3G, and proximity, e.g. Wi-Fi Direct, wireless connections. Many works focused on how to integrate P2P and MPEG-DASH. For example, Rehan et al. discussed the challenges of P2P streaming and compared two MPEG-DASH P2P solutions, i.e., pDASH and DAV [14]. Alkwai and Gazdar studied and build one P2P streaming system based on MPEG-DASH called P2PDASH [15]. The proposed P2PDASH is simulated in OMNet++ and integrated with the BitTorrent module. Rainer et al. demonstrated that visitors of the Thessaloniki Film Festival (TIFF) are able to create an unstructured P2P network using their Android devices [16]. Once the P2P network is created, they can perform semantic search for multimedia content of a certain topic and access the MPEG-DASH live streaming. Some works further extended the integration of P2P and MPEG-DASH to different purposes. Roverso and Högqvist presented a browser based plugin –less video distribution solution called Hive.js [17]. The proposed solution utilizes WebRTC P2P API to create distributed caching and is able to save significant traffic towards the source of the stream, i.e., CDN, based on their experimental results. Al-Habashna et al. proposed one architecture called DASH-based BS-assisted P2P video streaming (DABAST) in an LTE-A network [18]. That is, this paper is used to exploit both cellular links and device-to-device (D2D) links for video streaming based on MPEG-DASH. Furthermore, the discrete event system specification (DEVS) formalism is utilized to build a model to evaluate the DABAST's performance.

### C. *Geo-location based P2P*

In order to support and organize peers with their geo-location property, Gross et al. proposed Geodemlia which is a P2P overlay network supporting location-based search [19]. Addressing and routing in the proposed Geodemlia is based on a peer's geographical location, i.e., longitude and latitude by GPS. Amft and Graffi proposed LobSter, i.e., a lightweight location-based service to find as many peers as possible in a geographical area through range queries [20]. Different from Geodemlia, LobSter uses linearization techniques, e.g., space filling curves, on top of existing DHTs and does not own dedicated routing tables or maintenance strategies. Zhang et al. presented an efficient and scalable indexing scheme called DRISTIX for answering spatio-temporal queries [21]. DRISTIX has double rings to separately index spatial and temporal dimension, histograms to estimate cost for optimizing the kNN query algorithm. Some works applied the geo-location property to the data management, group management and scheduling management. For example, Gross et al. further extended Geodemlia to provide a reliable multi-source download scheme called GeoSwarm under peer churn [22]. Regarding long-term persistence of location-based data, GeoSwarm incorporated a location-aware replication mechanism that replicates data onto multiple peers and minimizes the replication overhead. Kumar and Helmy introduced a framework called ConnectEnc for mobile peer rating using a multi-dimensional metric scheme based on geo-location sensing [23]. ConnectEnc maintains the history of discovered nearby devices and locations, and rates them based on encounter frequency, location vector and matric similarity. Waluyo et al. proposed a trustworthy token-passing multi-point relays called TOP with location-aware scheduling scheme which is capable of determining the most optimal schedule for the target peers to receive messages based on the location and mobility parameter [24]. Finally, regarding the geo-location privacy, Zhang and Lazos devised a novel location and query anonymization protocol called MAZE that preserves the user privacy without relying on trusted parties. MAZE guarantees the user's anonymity and privacy in a decentralized manner using P2P groups [25].

## III. PROPOSED LCPS SCHEME

In Section I, the proposed LCPS scheme combine the advantages of the infrastructure and ad-hoc based transmission using the P2P protocols. As depicted in Fig. 1, the LCPS scheme divides the network architecture into three layers, i.e., (1) ad-hoc network layer, (2) physical network layer and (3) overlay network layer. Peers who interest the same resources can form an overlay network group called P2P swarm for resource sharing. In this paper, we focus on exchange video objects which are based on the MPEG-DASH standard inside the P2P swarm without the limitation of underlying network topology. Since past P2P services are easy to induce mass inter-ISP traffic, some ISPs have started blocking this kind of network traffic. Therefore, various ISP-friendly transmission policies have been proposed in the physical network layer. For example, a peer does not establish the inter-ISP traffic unless there is no enough resource in the current ISP. This paper further provides another alternative communication scenario based on peers' social behaviors and geographic locations. In addition to the physical network layer, the LCPS scheme adds one more ad-hoc network layer. Peers utilize Bluetooth to establish one ad-hoc network group according to their relative geo-locations. Referring to Fig. 1, Peers 1 to 6 form one overlay network to initialize the P2P service. Based on the located physical network, Peers 1, 2, and 6 belong to ISP 1. On the other hand, Peers 3, 4 and 5 belong to ISP 2. Therefore, Peers 1, 2, and 6 should be interconnected and Peers 3, 4, and 5 should be interconnected based on the ISP-friendly principles. Once Peer 1 requests any video object from Peer 4, one inter-ISP traffic is established. In the proposed LCPS scheme, since Peer 1 and Peer 4 are nearby enough, i.e., within the signal coverage of a Bluetooth ad-hoc network, direct transmission between Peer 1 and Peer 4 using Bluetooth should induce no inter-ISP traffic and further offload the network traffic of the physical network layer.

Regarding the characteristics of multimedia streaming service, the proposed LCPS scheme is proposed to utilize two kinds of wireless access technologies, i.e., Wi-Fi and Bluetooth, to download segments from several peers simultaneously. The default transmission connection is based on the Wi-Fi network because the Wi-Fi network is infrastructure based and able to provide stable and high transmission quality. On the other hand, the Bluetooth network is low-power consumption and able to avoid inter-ISP traffic. Once there are more data delivered using Bluetooth, the power consumption and Internet bandwidth of end devices can be saved to extend the service time. The detailed execution steps of the proposed LCPS scheme are as follows.

1. A peer connects to the Internet, registers to a tracker and then retrieves the corresponding information from the tracker using the Wi-Fi interface.
2. This peer opens its Bluetooth interface to scan neighboring peers and then waits for any Bluetooth connection.
3. According the information provided from the tracker, this peer starts to share and exchange the bitmap information and check whether they are located in the Bluetooth coverage of each other.

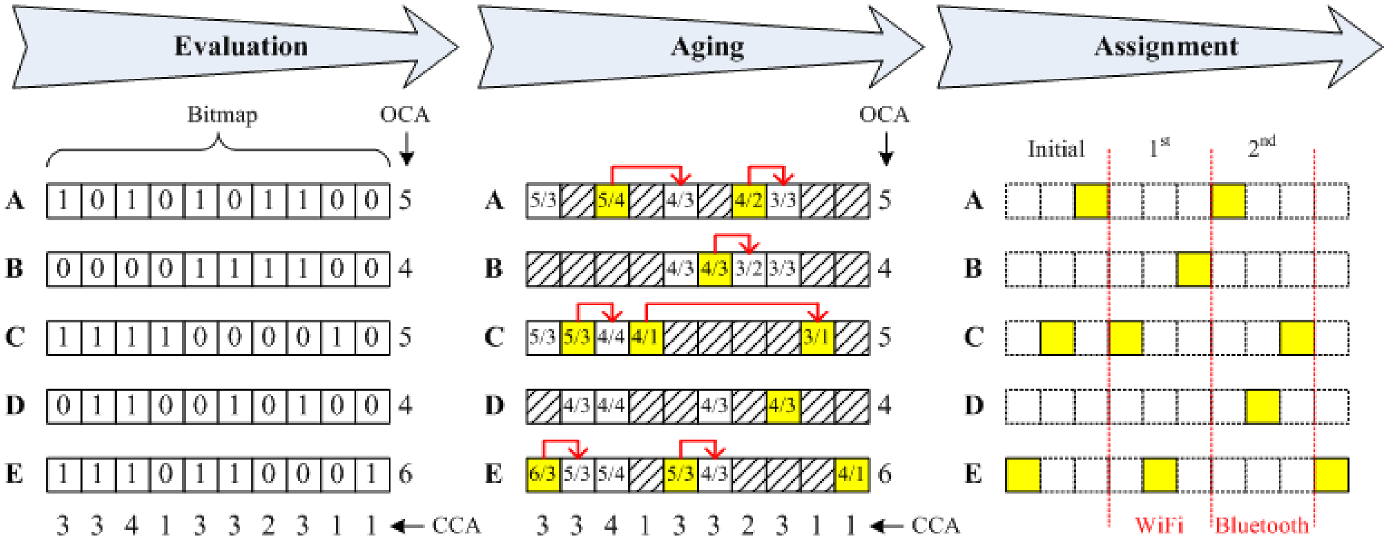



Fig. 2. The proposed greedy segment assignment algorithm (GSAA).

4. Based on the response from other peers, this peer executes the greedy segment assignment algorithm (GSAA) to determine the download sequence of the requested video stream.

5. The proposed GSAA divides the MPEG-DASH segments into more than one time slot according to the initial buffering status. This peer asks and downloads the segments belonging to the first time slot using the Wi-Fi interface.

6. If any Bluetooth ad-hoc network is created successfully between this peer and another peer, this peer asks and downloads the segments belonging to the next time slot, i.e., the second time slot, using the Bluetooth interface.

7. If all segments in the first time slot are downloaded, this peer starts to download the segments belonging to the next time slot, e.g., the second time slot, using Wi-Fi. At the same time, this peer utilizes the Bluetooth interface to download segments belonging to the one after the next time slot, e.g., the third time slot.

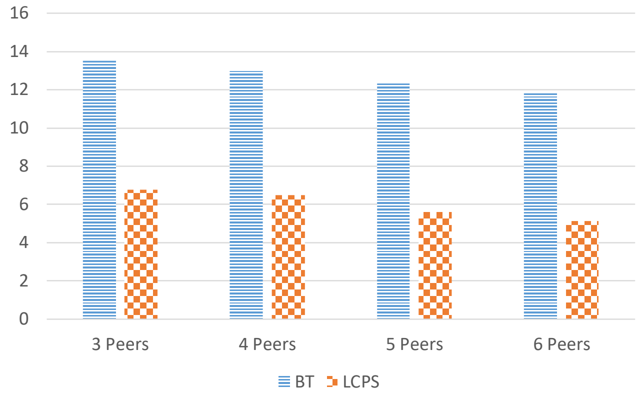
8. When any segment in one time slot is not available from any peer, i.e., any CCA value is 0, go to Step 1 and then re-execute the whole procedure.

9. Once all segments have been downloaded or the video stream is terminated, this peer would stop the above procedure.

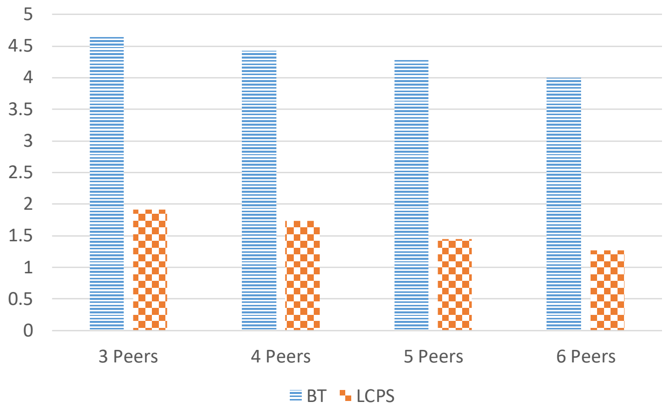
One point to note is that the proposed GSAA is responsible for determining how to assign MPEG-DASH segments to each peer and keep the parallel downloading as possible as we can. Fig. 2 depicts the proposed GSAA in details. Three stages in our GSAA are (1) evaluation, (2) aging and (3) assignment. First, the evaluation stage means that we evaluate the segments possession of each peer based on the exchanged bitmap information. Referring to Fig. 2, the bitmap information indicates which segments has been stored in one peer. In our bitmap, 1 means that this segment has been stored in the peer. On the other hand, 0 means that this segment is not yet stored in this peer. Hence, Peer A in Fig. 2 has totally 5 segments including the 1st, 3rd, 5th, 7th, and 8th segments. Then, two metrics, i.e., (1) own chunk amount (OCA) and (2) common chunk amount (CCA), should be calculated and then get the value of assigned chunk (AC) as depicted in Eq. (1). The OCA value indicates how many segments stored in one peer. For example, the OCA of Peer A in Fig. 2 is 5. On the contrary, the CCA value indicates how many peers can provide this segment. For example, the CCA of the first segment is 3 because Peers A, C, and E have the first segment in Fig. 2. Once the values of OCA and CCA are determined, the AC value of each segment in each peer can be also calculated. For example, the AC value of Peer A's first segment is 5/3. The corresponding AC values of Peers C and E are 5/3 and 6/3 using the same calculation. Thus, the proposed GSAA would assign each segment based on the maximal AC value. That is, the GSAA would assign the first segment to Peer E because the corresponding AC value is 6/3 and greater than 5/3.

$$AC = \frac{OCA}{CCA} \times V_{Bitmap}, V_{Bitmap} = \{0,1\} \quad (1)$$

Secondly, in order to avoid too many segments are assigned to the same peer, the aging stage is to decrease the AC value if one segment has been assigned to one peer. For example, the original AC value of Peer E's second segment should be 6/3. When the first segment in Fig. 2 is assigned to Peer E, the AC value of Peer E's second segment should be decreased to 5/3, i.e., the corresponding OCA should decrease by 1, based on our aging rule. In this way, even if some peer can provide many segments, the GSAA is still able to distribute segments to all available peers and then maximize the number of parallel downloading. Finally, the assignment stage would divide the whole stream into time slots based on the initial buffering status. For example, if only three segments can be downloaded in the pre-configured buffering time, as depicted in Fig. 2, the corresponding size of the time slot is configured to 3 segments.




(a) Download Time (minutes)




(b) Power Consumption (%)

Fig. 3. The experimental results compared with BitTorrent (BT)

As the aforementioned description, the proposed LCPS utilizes Wi-Fi links to download one time slot and Bluetooth links to download the next time slot. Once one time slot is downloaded using Wi-Fi, the next time slot using Bluetooth would be interrupted immediately. Then, the next time slot would be downloaded using Wi-Fi instead of Bluetooth. The LCPS would use Bluetooth to download the one after the next time slot.

## IV. Performance Evaluation

In order to evaluate the proposed LCPS scheme, one tracker server is configured in the experimental environment. In this paper, one static peer is configured to have the complete media file whose size is 444 MB based on the MPEG-DASH standard. 2 to 5 dynamic peers are configured to join the same swarm and share their video segments. All devices are Android 4.0. All of them can access the Internet using Wi-Fi (IEEE 802.11b/g) and interconnect using Bluetooth 4.0 in the following experiments. The download time and power consumption are the performance metrics in this paper.

First, the proposed LCPS scheme is compared with the traditional P2P protocol, i.e., BitTorrent (BT). In this experiment, all devices are located within 2 meters and able to form one ad-hoc network using their Bluetooth links. There are totally 3 to 6 peers in this experiment. Fig. 3 depicts the experimental results. When the number of peers is 3, the traditional BT costs 13.53 minutes to download the complete media file. On the other hand, the proposed LCPS costs only 6.77 minutes. If there are more peers, e.g., 6 peers, the BT costs 11.83 minutes and the LCPS scheme costs 5.12 minutes. Regarding the power consumption in the 3-peer case, the BT consumes 4.67% battery power but the proposed LCPS scheme only consumes 1.91% battery power. In the 6-peer case, the BT consumes 4% battery power. On the contrary, the LCPS consumes only 1.27%. Therefore, no matter how many peers are in the swarm, the proposed LCPS scheme can improve more than 50% download time and power consumption.

Second, we further discussed the influence of the geographical distance among devices. Based on our observation, our devices can exchange data within 10 meters. Thus, we configure the geographical distance among devices are 2, 6, and 10 meters. Fig. 4 depicts the experimental results. When the number of peers is 3, the LCPS costs 6.77 minutes in the 2m case, 7.33 minutes in the 6m case, and 8.5 minutes in the 10m case. On the other hand, when the number of peers becomes 6, the LCPS costs 5.12 minutes in the 2m case, 5.4 minutes in the 6m case and 6.15 minutes in the 10m case. From the above results, if peers are located near the boundary of signal coverage, i.e., 10 meters in our experiment, the download time is obviously affected by the geographical distance. Finally, we observe the power consumption in different geographical distance. When the number of peers is 3, the LCPS consumes 1.91% in the 2m case, 2.14% in the 6m case and 2.57% in the 10m case. If the number of peers becomes 6, the LCPS consumes 1.27% in the 2m case, 1.43% in the 6m case and 2.14% in the 10m case. Similar to the download time, the corresponding power consumption is also affected by the geographical distance.

## V. Conclusion & Future Works

This paper has proposed the LCPS scheme to exploit the feasibility of integrating Wi-Fi infrastructure networks and Bluetooth ad-hoc networks. Since the LCPS scheme provides another alternative transmission scenario, the LCPS can avoid inter-ISP problem and save limited battery power. Based on our experimental results, the LCPS can improve 50% download time and power consumption than the traditional BT. In the future, we will focus on how to support fast forward/backward play and dynamically adjust the video quality in the LCPS architecture even if peers keep mobility, i.e., churn.

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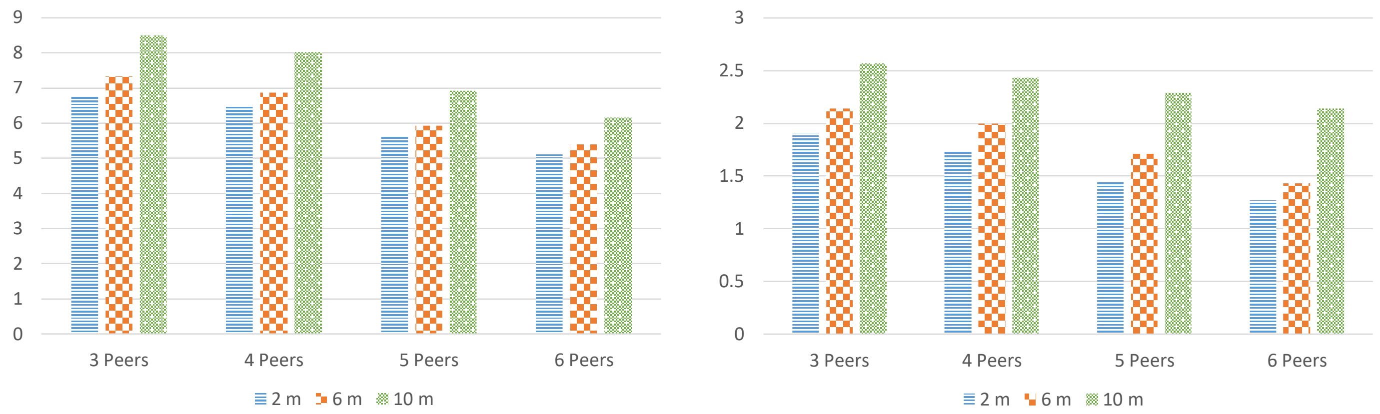


(a) Download Time (minutes)    (b) Power Consumption (%)

Fig. 4. The experimental results in different geographical distances among smart devices


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