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Proximate Sharing of Geo Data Downloading Based on the MSNP-Oriented Ubiquitous Machine-to-Machine (M2M) Communication Paradigm

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ABSTRACT A mobile social network in proximity (MSNP) allows persons who: 1) belong to the same mobile social network in the cyber space: and 2) are proximate with each other in the physical world to share information, e.g., point of interests' (POI) data during the touring journey, in a ubiquitous way. This paper proposed a clustering scheme called credit-centric sharing of POIs' data to organize the handheld devices of mobile users, who belong to the same MSNP group in the cyber space and are proximate with each other in the physical world, i.e., these mobile users' handheld devices are within the Wi-Fi hot spot's signal coverage of the cluster leader's handheld device, as a cluster of mobile Internet of Things (IOT). These mobile IOTs use the user-transparent machine-to-machine communication way for clustering and POIs' proximity-aware data sharing. Then, the selected cluster head can trigger the downloading of POIs' data using the 3G/3.5G/4G cellular network based on the current geographical position and then forwarding these data to all cluster members using the Wi-Fi network. In this way, instead of having each mobile user to individually download nearby POIs' data through his handheld device's 3G/3.5G/4G cellular network, which needs to download n times of the same POIs' data through Internet if the cluster has n mobile users' handheld devices, it only needs to download the corresponding POIs' data once through the cluster leader's 3G/3.5G/4G cellular network and then shares these data to other cluster members using the Wi-Fi network. The performance analysis shows that the proposed method can reduce both 3G/3.5G/4G cellular network's traffic load and the power consumption of involved mobile users' handheld devices based on the cyber-physical-social computing and networking way.

INDEX TERMS Clustering, cyber-physical-social computing and networking (CPSCN), mobile social network in proximity (MSNP), mobile IOT, proximity.

I. INTRODUCTION

A Mobile Social Network (MSN) links people who are moving with other people whom they may or may not know in cyberspace [1]–[4]. Integrating proximity services with MSN, which is called Mobile Networks in Proximity (MSNP), is becoming possible because the Device-to-Device (D2D)/Terminal-to-Terminal (T2T) communication techniques are becoming more developed [5], [6]. A Mobile Social Network in Proximity (MSNP) allows people who (i) belong to the same Mobile Social Network (MSN) in cyberspace and (ii) are proximate with each other in the physical world to share information using D2D/T2T communication techniques. That is, MSNP can use the cyber-physical-social computing and networking mechanism [7]–[9] to reach the goal of information sharing. This work uses the touring scenario application to study of how to use the cyber-physical-social computing and networking mechanism, which is based on MSNP, to save energy, reduce the traffic load in 3G/3.5G/4G cellular networks and reduce the expense of using 3G/3.5G/4G cellular networks for proximate sharing of geodata downloading.

Many location-based services (LBS) are widely available because of the popular use of mobile handheld devices and the deployment of 3G/3.5G/4G cellular networks [10], [11].

For example, people can download the geodata of nearby Points-of-Interest (POIs), e.g., nearby natural views, historical landmarks, and famous restaurants, using their smartphones over 3G/3.5G/4G cellular networks when they are touring [12]–[14]. Traditionally, each person downloads the POIs' data using his handheld device's 3G/3.5G/4G cellular network. If a group of people is moving together, e.g., n tourists whose geo-distance is a few meters from each other, they may download the same set of nearby POIs' data. If each one downloads the POIs' data individually, it results in a traffic burst and thus uses a lot of the 3G/3.5G/4G cellular network's bandwidth, spends n sets of the cellular network's downloading expense, and consumes n sets of the handheld devices' battery power because of downloading the same set of POIs' data n times. Thus, there is motivation to propose a user-transparent mechanism to group these people, who are proximate with each other in the physical world, together [15]. One group leader, who enables his handheld device's Wi-Fi hotspot function, downloads the POIs' data using his handheld device's 3G/3.5G/4G network's interface and then forwards the POIs' data to the other n-1 persons' handheld devices, which connect to the Wi-Fi hotspot of the group leader's handheld device, using a Wi-Fi network.

In the described touring scenario for the proximate sharing of downloaded POIs' data, users' handheld devices can be regarded as the physical world's mobile Internet of Things (M-IOT) that have some social relationship inherited from the corresponding users' social relationship in cyberspace. Additionally, these M-IOTs can connect to the Internet through their 3G/3.5G/4G cellular network interfaces to communicate with each other using Machine-to-Machine (M2M) communication. These handheld devices are organized as an autonomous M-IOT system during the tour. The interactions between these handheld devices should be user-transparent and M2M-based, i.e., users that hold these handheld devices don't know who plays the role of group leader and who plays the role of group members, when triggering POIs' data downloading and forwarding, etc. In other words, the touring scenario is a type of proximity service [16], [17]. Let there be n users. Considering the individual touring scenario, i.e., each user downloads POIs' data using his handheld device's 3G/3.5G/4G cellular network, the touring scenario that has proximate sharing of downloaded POIs' data can (i) reduce the traffic load in the 3G/3.5G/4G cellular network and the expense of using the 3G/3.5G/4G cellular network to 1/n and (ii) save energy in the handheld devices because using a Wi-Fi network consumes less power than using a 3G/3.5G/4G cellular network in handheld devices.

To address the described touring scenario that uses proximate sharing of POIs' data downloading, a clustering method called the Credit-Centric Sharing of POIs' Data (CCS-POIS) is proposed in this paper to form groups in an MSNP, in which the members joining the MSNP are willing to share their downloaded POIs' data. In this way, the handheld devices of those MSNP's members who (i) are proximate to each other in the physical world and (ii) want to download the corresponding nearby POIs' data can be grouped to form a cluster. After that, the cluster head X is in charge of the POIs' data downloading using X's 3G/3.5G/4G network's interface and then forwarding the POIs' data to other cluster members that connect to X's Wi-Fi hotspot using their Wi-Fi networks' interfaces. In other words, it adopts the cyber-physical-social computing and networking method to have proximate sharing of the POIs' data downloading.

Three main issues that the proposed CCS-POIS method needs to resolve for the proximate sharing of the POIs' data downloading are as follows: (1) When and how to cluster? POIs' data downloading can be triggered when it is necessary, e.g., when the cached POIs' data in one's handheld device needs to be updated because the mobile user walks to the geographical position for which it needs to re-cache POIs' data based on the current geographical position. Thus, how to group the handheld devices of those mobile users, who are proximate with each other in the physical world and want to re-cache the POIs' data in their handheld devices at the same time, to become a cluster is the first issue to be resolved. (2) Once a cluster is formed, when and how is the POIs' data downloading triggered? Depending on the POIs' caching principle, the re-caching can be invoked accordingly. (3) How to calculate credits? Since (i) the MSNP's member whose handheld device is the cluster leader consumes his handheld device's resources, e.g., battery power and 3G/3.5G/4G cellular network expense, to download and forward the POIs' data and (ii) the MSNP's members whose handheld devices are cluster members receive the benefit, to be fair, there must be a suitable credit scheme such that the MSNP's member whose handheld device is the cluster leader can get credit from the MSNP's members whose handheld devices are cluster members. Combining with a Pedestrian-MSNP (P-MSNP), the proposed CCS-POIS scheme resolves the three main issues such that the proximity-aware sharing of the POIs' data downloading can be achieved using the cyber-physical-social computing and networking method.

The rest of this paper is organized as follows. Section 2 presents related works. Section 3 depicts the architecture and the functional scenario of the proposed scheme. Section 4 describes the proposed scheme in detail. Section 5 shows the results of the performance analysis. Section 6 has the conclusion remarks.

II. RELATED WORK

This Section presents some related work about (1) MSN, (2) MSNP, (3) clustering methods and (4) credit schemes for proximate sharing of downloaded data for the touring service.

Hu *et al.* [2] described platforms, system architecture and applications of a Mobile Social Network (MSN) and discussed the technical challenges and future research directions of MSN. It also described popular MSN Platforms such as Facebook, Twitter and Foursquare. Xie *et al.* [18] built an MSN for people with similar interests to have interactions with each other. The three phases of this system are the neighbor-discovery phase, the matching phase and the interaction phase. In the first phase, people discover others that are nearby. In the second phase, a function is used to compare the similarity of interests from their profiles. In the third phase, two matching people share information. Navarro *et al.* [19] proposed a method to connect a group of people according to their social behaviors and contexts. It made a spontaneous group based on context, such as location, profile and data obtained from the social network. The proposed MSN model provides service to people and promotes interactions between people with similar interests.

Proximity service is a new service based on LBS. Different from LBS, proximity service can let neighboring mobile devices communicate or share data with others through Bluetooth or Wi-Fi interfaces according to the locations of the mobile devices. New applications were proposed based on MSNP. Zuo *et al.* [20] developed a chat system for people who were in close proximity to send messages to each other. The proposed chat system is divided into two modes, and handheld mobile devices can be transformed between the two modes. In the first mode, the centralized server constantly detects the locations of mobile devices and allows the people to interact through the Internet. In the second mode, people can find and communicate with other people when they are in the same Wi-Fi coverage. Users can send messages to each other using Wi-Fi Direct. Two typical group dynamics that need to be addressed to have precise group formation and accurate prediction of group behavior are the group mobility level and group mobility shape. Du *et al.* [21] proposed a method to have a fine-grained group mobility level classification and group mobility structure recognition of social groups using mobile devices. The identifiable group mobility level can be stationary, strolling, running, etc., and the group mobility structure can be a queue, an irregular polygon, or a straight line. Combining group mobility level and group mobility structure can describe mobile group activities with more detail, such as strolling or a stationary line, walking or running in a queue. The authors used Wi-Fi and sensors built into smartphones to classify the group mobility level and recognize group structures through relative positioning without using the GPS-based positioning technique for dealing with small groups. Many of the currently available MSN and MSNP applications did not focus on the fairness of the group leader who shares his information with others. To address this issue, our work proposes the opportunistic network-based group formation method that adopts the credit scheme, which can record the contribution of each mobile user regarding credit value, to select a suitable group leader to address fairness.

The concept of clustering is widely used in Mobile Ad hoc Network (MANET). Clustering is how some mobile users/nodes are partitioned into several groups which satisfy some relationship [22]. Refer to [22]–[24], different performance metrics can be used to define different clustering schemes, for which the essential categories are defined as follows: (1) Identifier neighbor based clustering: each mobile node is assigned a unique ID to have the lowest ID clustering (LID). The node that has the lowest ID is selected as the cluster head. (2) Highest connectivity based clustering (HCC): it considers the connection number of each mobile node for clustering and determines the cluster head. (3) Mobility based clustering: it considers the relative mobility of mobile nodes for clustering and determines the cluster head. (4) Energy based clustering: it uses the battery power of the mobile nodes to represent the lifetime of the network. (5) Weight based clustering: it uses predefined weighted metrics and weighted factors for clustering and determines the cluster head. Except for weight based clustering, only one condition is considered to be the critical value for selecting a cluster head at the time of clustering. However, more metrics may need to be considered for selecting the cluster head depending on the corresponding applications. Our proposed method considers the consumed power, the volume of the downloaded POIs' data and remaining battery power. Compared to traditional weight based clustering, our proposed method uses the credit scheme to indicate each mobile node's accumulated contribution from the past to the present, for which the credit value can be used as a reference for the selection of the cluster head. Without using the credit scheme, the past contribution cannot be accumulated and saved and thus it can only select the cluster head based on the current context. This may select the same mobile node as the cluster head repeatedly and results in an unfair condition.

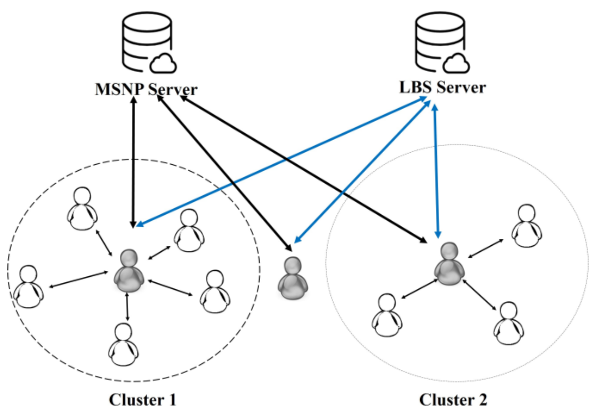
The credit scheme is used to motivate mobile nodes/users to have an incentive to share their resources and behave well. In [25], different from the general incentive schemes, the authors took into account the social relationship in the selfish behaviors of mobile nodes. All mobile nodes are divided into communities and there are two credit types, social credit and non-social credit, that can be used to stimulate mobile nodes to cooperate. Social credit is calculated when a mobile node exchanges messages with others in the same community and non-social credit is calculated when a mobile node exchanges messages with others in different communities. A mobile node forwards messages for others and then it can get social credit or non-social credit; otherwise, it will reduce social credit or non-social credit. When a mobile node wants to send messages to others for forwarding, the value of social credit and non-social credit is used to determine the number of messages to send. In [26], a credit scheme is used to push mobile nodes that have enough data traffic to download data for others. Additionally, the credit can be used when mobile nodes ask for help. With the incentive mechanism, mobile nodes have higher participation in the system. We propose to have a mobile user share downloaded POIs' data with proximate mobile users that are in the MSNP and belong to the same group. The credit scheme is used to stimulate mobile users who are proximate with others to form a cluster and forward the downloaded POIs' data to other mobile users in the same cluster.

III. ARCHITECTURE AND FUNCTIONAL SCENARIO

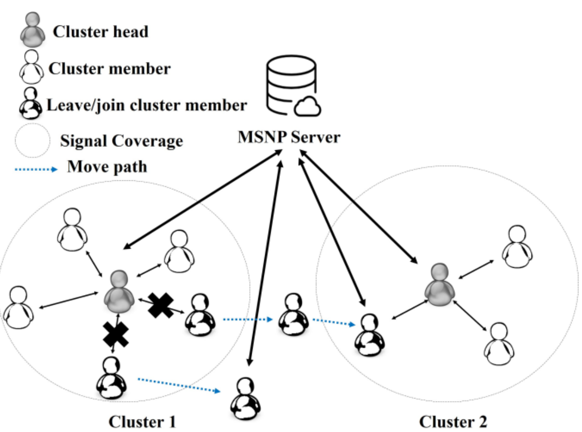
Figure 1-(a) depicts the abstract architecture of our proposed proximate sharing of POIs' data downloading. The MSNP server is in charge of (1) member's authentication of joining/leaving the MSNP and (2) the cluster creation/joining/leaving for a group of members to share the downloaded POIs' data from the cluster head. The LBS server is in charge of monitoring mobile users' locations, cached POIs' data management and POIs' data downloading. Let each user's handheld device have both 3G/3.5G/4G cellular network's and Wi-Fi network's interfaces. The functional scenario is as follows. To have more prompt response for viewing a POI's data, each mobile user can pre-download a fixed number of nearby POIs' data in his handheld device as the cached POIs' data. Since the mobile user is moving, the nearby POIs' data that need to be cached should be refreshed when the difference between the cached POIs' data set X and the POIs' data set Y that should be cached based on the mobile user's current position reaches some threshold. Thus, when it is the time to refresh the cached POIs' data of mobile user MN 's handheld device, MN can have three choices: (i) MN creates a cluster, becomes the cluster head and enables his handheld device's Wi-Fi hotspot function to let other mobile users' handheld devices to connect. Some other mobile users that also meet the condition of refreshing the cached POIs' data of their handheld devices can join MN's cluster. Then, MN downloads the corresponding POIs' data using the 3G/3.5G/4G cellular network's interface of his handheld device and forwards the downloaded POIs' data to his cluster members' handheld devices using the Wi-Fi network. After that, MN gets credit and the other cluster members consume their credits. (ii) MN tries to find a cluster C to get the downloaded POIs' data from C's cluster head. If the cluster can be found, then MN joins it and consumes his credit and C's cluster head gets some credit. If MN cannot find a suitable cluster, then MN uses his handheld device's 3G/3.5G/4G cellular network interface to download the corresponding POIs' data to refresh the cached POIs' data of his handheld device. In this case, MN neither gets nor consumes any credit. (iii) MN downloads the corresponding POIs' data using his handheld device's 3G/3.5G/4G cellular network to refresh the cached POIs' data of his handheld device individually. In this case, since MN neither shares his downloaded POIs' data with others nor gets his POIs' data from others, MN doesn't get or consume credit.

Figure 1-(b) represents that a mobile user still can leave the cluster after the cluster is formed and then can join the other existed cluster. When a mobile user leaves a cluster, it opens his 3G/3.5G/4G interface to access Internet. After the mobile user walking into the Wi Fi hotspot's signal coverage of the other cluster head, he can join the corresponding cluster and get the corresponding downloaded POIs' data through the Wi-Fi network. Hence, a mobile user can move arbitrarily and does suitable creation/joining/leaving for a group.

	Network	Transmission Method	Action
⟷	3G/3.5G/4G	unicast	Update location (group, individual) Download POIs
⟷	3G/3.5G/4G	unicast	Update the information of group Login to MSNP
⟷	Wi-Fi	multicast	Sending location and POIs



(a)



(b)

FIGURE 1. (a) The architecture and functional scenario of the proposed method. (b) The example for leaving and joining.

IV. THE PROPOSED CSS-POIS SCHEME

This Section presents (i) how to join a P-MSNP and have clustering, (ii) the proposed CCS-POIS scheme and (iii) the credit computing scheme.

A. DYNAMIC P-MSNP (PEDESTRIAN-MOBILE SOCIAL NETWORK IN PROXIMITY) CONNECTION AND CLUSTERING

A mobile user x registers his account and password to log into the P-MSNP, which is similar to creating an account and password to log into Facebook. Figure 2-(a) depicts the message flow of P-MSNP registration and login. The steps for registering a P-MSNP are as follows. Mobile user x sends an MSNP-Register-Request message, which includes the name (x_ID) and the password (x_PW), used to login to the P-MSNP server. After the P-MSNP server receives the MSNP-Register-Request message, the P-MSNP server

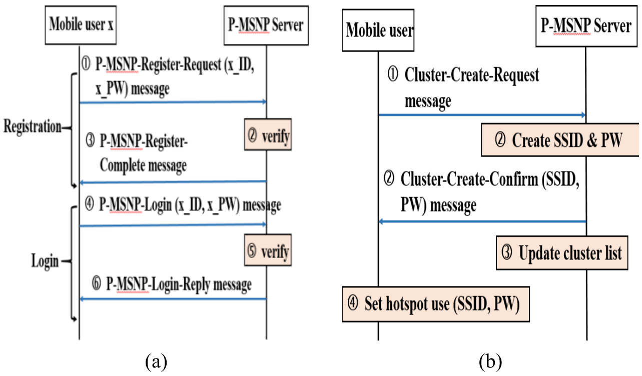


FIGURE 2. (a) The message flow diagram of P-MSNP registration and login. (b) The message flow diagram of cluster creation.

verifies whether the information of the mobile user is valid or not; if it is valid, then the P-MSNP server sends the MSNP-Register-Complete message to x. Next, the registration of the P-MSNP is complete and mobile user x can connect to the P-MSNP server anywhere, anytime using his account (x_ID) and password (y_PW).

When mobile user x turns on his handheld device, e.g., his smartphone, x acts as a mobile node in the system. To let the P-MSNP server know the mobile node is active, mobile user x must log into the P-MSNP using his account and password through the following process. Mobile user x sends an MSNP-Login message, which includes account (x_ID) and password (x_PW) to the P-MSNP server, both of which are created during the registration stage. The P-MSNP server verifies whether the information exists and is correct or not. If the information exists and is correct, then the MSNP server sends the MSNP-Login-Reply message to mobile user x. With the message, mobile user x is informed of the successful P-MSNP's login and can proceed to the follow-up phases.

After mobile user MN logs into the P-MSNP, MN has the right to use the sharing mechanism of the POIs' data downloading with other mobile users who are also logged into the P-MSNP. Mobile user MN can have (1) cluster creation or (2) cluster join based on his current credit and location. If MN's credit is not positive, then MN must create a new cluster (cluster creation) to share his downloaded POIs' data, which are downloaded using his handheld device's 3G/3.5G/4G cellular network, with other mobile users such that MN can earn credit; otherwise, if MN's credit is positive, i.e., MN has shared his downloaded POIs' data before to earn some credit and thus he can now get others' shared POIs' data, he can join an existing cluster (cluster join). The procedures for creating a cluster and joining a cluster are as follows, for which Figures 2-(b) and 3-(a) depict the corresponding message flow diagrams:

1) *Cluster Creation:*

a) Mobile user x sends the Cluster-Create-Request message to the P-MSNP server.

b) P-MSNP server creates the unique SSID y and the PASSWORD z for mobile user x's handheld device and then sends the Cluster-Create-Confirm ($\boldsymbol{y}$, $\boldsymbol{z}$) message to mobile user x.

c) The P-MSNP server updates the cluster list.

d) When mobile user x receives the Cluster-Create-Confirm ($\boldsymbol{y}$, $\boldsymbol{z}$) message, mobile x uses SSID y and PASSWORD z to set his handheld device's Wi Fi hotspot and becomes the head of the cluster.

2) *Member Join:*

a) Mobile user x's handheld device sends the Hot-Spot-Indication [(HS-SSID(1), HS-RSSI(1)), (HS-SSID(2), HS-RSSI(2)), . . ., (HS-SSID(n), HS-RSSI(n))] message, in which n is the number of sensed Wi-Fi hotspots of x's handheld device, where (HS-SSID(i), HS-RSSI(i)), i = 1.. n, indicate the SSID and RSSI of sensed Wi Fi hot spot i of x's handheld device, to the P-MSNP server.

b) If the P-MSNP server finds that there are one or more hot-spots whose connected members are smaller than k, which denotes the maximum number of handheld devices that is allowed to connect to a Wi-Fi hot spot, the P-MSNP server selects the Wi Fi hot spot I that has the highest RSSI for mobile user x's handheld device and sends I's SSID y and PASSWORD z to mobile user x's handheld device.

c) Mobile user x's handheld device uses SSID y and PASSWORD z to join cluster I.

d) Hot spot I sends the UPDATE message to the P-MSNP server to add mobile user x as a new member of cluster *I*.

Figure 3 (b) depicts the procedure when POIs' data downloading and sharing are finished.

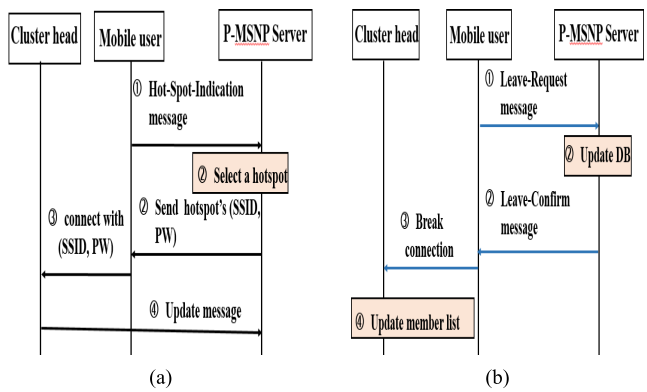


FIGURE 3. (a) The message flow diagram of member join. (b) The message flow diagram of member leave.

B. THE PROPOSED CCS-POIS SCHEME

We developed a mobile digital culture heritage navigation system called the Demodulating and Encoding Heritage (DEH), which is available at http://deh.csie.ncku.edu.tw, and DEH APPs for touring culture heritage's POIs are available in the Google PLAY and APPLE Store. To have the quick response time, a mobile user x in the DEH system can download and cache nearby POIs' data in x's handheld device, for which the upper bound of the nearby POIs' number is 50, using a 3G/3.5G/4G cellular network. When mobile user x keeps moving, the nearby POIs' data that should be cached should be updated. The concern for the timing of refreshing the cached POIs' data is twofold: it does not make sense to update them too frequently, and it may cache too many unsuitable POIs' data if the updates are so frequent. Since the official Android site provides 68% confidence of GPS positioning, this work set 32% (1-68%) as the threshold and timing for refreshing the cached POIs' data in a mobile user's handheld device.

Two main issues for having the proximate sharing of the POIs' data downloading are (1) when and how is a cluster formed and (2) when and how is POIs' data downloading triggered for cluster members? To address these two issues, general principles are defined as follows. A mobile user must refresh his handheld device's cached POIs' data when the difference between the cached POIs' data set X and the POIs' data set Y that should be cached based on mobile user's current position reaches a specified threshold. To have time to create a cluster or join a cluster, when the difference between X and Y reaches a specified threshold, (i) if the mobile user's credit is positive, the mobile user starts to identify the possibility of joining an existed cluster, for which the cluster head wants to share his downloaded POIs' data, and (ii) if the mobile user's credit is 0 or negative, then he creates a new cluster to let other mobile users to share his downloaded POIs' data such that he can earn credit for his future use. The control flows of the cluster join and cluster creation are depicted in Figures 4-(a) and (b). The difference between the cached POIs' data set X and the POIs' data set Y that should be cached based on mobile user's current position is calculated as follows. Let $\boldsymbol{CPOI_c}$ denote the set of currently cached POIs and $\boldsymbol{CPOI_n}$ denote the set of POIs that need to be cached based on the current location. $\boldsymbol{CPOI_d}$ is the different POIs of $\boldsymbol{CPOI_c}$ and $\boldsymbol{CPOI_n}$, which are equal to $\boldsymbol{CPOI_n}$ - $\boldsymbol{CPOI_c}$. $\boldsymbol{CPOI_d}$ denotes the POIs that should be in the set of $\boldsymbol{CPOI_n}$ but not in the set of $\boldsymbol{CPOI_c}$. For example, let $\boldsymbol{CPOI_n} = \{a, b, c, d\}$ and $\boldsymbol{CPOI_c} = \{a, b, e\}$, then $\boldsymbol{CPOI_d} = \boldsymbol{CPOI_n} - \boldsymbol{CPOI_c} = \{c, d\}$. Let $\boldsymbol{DR_{CPOI}}$ denote POIs' different ratio between $\boldsymbol{CPOI_c}$ and $\boldsymbol{CPOI_n}$, which is equal to $(|CPOI_n - CPOI_c|/|CPOI_n|) * 100\%$. As previously mentioned, 32% is set as the $\boldsymbol{DR_{CPOI}}$ threshold for refreshing the cached POIs' data, i.e., it is the time to download the POIs' data. To have time to create a cluster or join a cluster, 25% is set as the threshold for preparing to refresh a handheld device's cached POIs' data, i.e., a mobile user can join or create a cluster, which depends on the mobile user's credit, when his handheld device's $\boldsymbol{DR_{CPOI}}$ reaches 25%. When a mobile user MN creates a cluster$\boldsymbol{C_X}$, it repeatedly computes $\boldsymbol{DR_{CPOI}}$ of the cluster $\boldsymbol{C_X}$ and the number of cluster members that want to share MN's downloaded POIs' data. When the $\boldsymbol{DR_{CPOI}}$ of any client member's handheld device in the cluster is equal to or greater than 32% or the number of connected cluster members is equal to k, which denotes the maximum number of connected handheld devices that a Wi-Fi hotspot can have, then the cluster head MN triggers POIs' data downloading using his handheld device's 3G/3.5G/4G cellular network to refresh the cached POIs' data of the cluster members' handheld devices based on MN's current position.

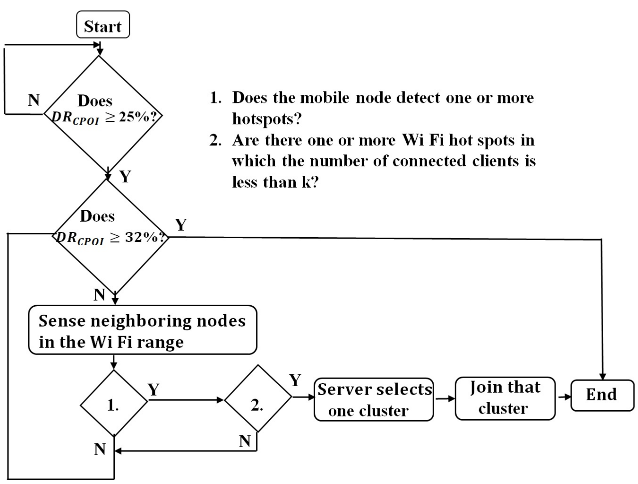


FIGURE 4. (a) The process of creation when mobile user's credit is smaller than 0. (b) The process of join when mobile user's credit is more than or equal to 0.

Figure 5 depicts the proposed CCS-POIS scheme for joining, creating, leaving and the timing for POIs' data downloading. Based on Figure 5, Figure 6 depicts the state diagram of the proposed CCS-POIS scheme. Eleven states that exist in the state diagram are as follows:

(1) P-MSNP login: Mobile users use their usernames and passwords to join the P-MSNP.

(2) Cached POIs' data are suitable: A mobile user keeps moving and his handheld device's cached POIs' data are still suitable based on his current position; thus, it doesn't need to refresh the cached POIs' data of his handheld device.

(3) Refreshing POIs' data: A mobile user keeps moving and finds that his handheld device's cached POIs' data are reaching the updating threshold; thus, it needs to refresh the cached POIs' data of his handheld device.

(4) Cluster creation: There are two situations when a mobile user's handheld device needs to cache some new POIs' data. First, if mobile user X's credit is smaller than zero and the cached POIs' data of X's handheld device are reaching the updating threshold, it must do cluster creation to create a new cluster, in which X is the cluster head, and have other mobile users to be cluster members. Second, if a mobile user doesn't join any existed cluster when the cached POIs' data of his handheld device are reaching the threshold of refreshing, it needs to create a new cluster and starts to download POIs' data to refresh his handheld device's cached POIs' data.

(5) Member join: When a mobile user's handheld device needs to refresh the cached POIs' data and his credit is more than or equal to zero, it can do cluster join to find an existed cluster. If there is not any existed cluster that he can join, he carries on searching until the threshold of refreshing the cached POIs' data of his handheld device is reached,

Procedure: CCS-POIS

```
if CPOI_d of mobile user's handheld device x is greater than or equal to
25% then
    if credit of mobile user x ≥ 0 then
        while the DR_CPOI of mobile user x's handheld device < 32% do
            Mobile user x's handheld device senses the SSIDs of the
            neighboring mobile users' handheld devices that belong to the
            same P-MSNP.
            if there is one or more sensed Wi Fi hotspots then
                call Member_Join function
                Exit
            end if
            if the DR_CPOI of mobile user x's handheld device < 25% then
                call Member_leave function
                Exit
            end if
        end while
        if DR_CPOI of mobile user x's handheld device ≥ 32% then
            call Cluster_Creation function
            while mobile user x that plays the role of cluster head in cluster
                    C_x is downloading the needed POIs'data in one
                    kilometer, other mobile users are allowed to join C_x.
            end while
            If cluster C_x has some members then
                mobile user x forwards the cached POIs' data of his
                handheld device to cluster members' handheld devices
that
                are in his cluster C_x
            end if
        endif
    else (credit of the mobile user x < 0)
        call Cluster_Creation function
        if DR_CPOI of any mobile user y's handheld devices in the cluster
           = 32% or (the number of connected cluster members'
           handheld devices of mobile user x's handheld devices = K
             and DR_CPOI of mobile user x's handheld device > 25%)
         then
            Cluster head x starts to download POIs'data in one kilometer
            x forwards the cached POIs' data of his handheld device to
            every cluster member's handheld device that is in his cluster.
        end if
        if the DR_CPOI of mobile user x's handheld device < 25% then
            call Member_leave function
        end if
    end if
end if
```

FIGURE 5. The proposed CCS-POIS scheme.

for which a new cluster is created for other mobile users to join and his handheld device starts to download the needed POIs' data using 3G/3.5G/4G cellular network.

(6) Cluster head: After a mobile user finishes creating a cluster, he becomes a cluster head and enables his handheld device's Wi Fi hotspot function for other mobile users' handheld devices to connect.

(7) Cluster member: After a mobile user successfully joins a cluster, he becomes a cluster member of the cluster and connects to the Wi Fi hot spot of cluster head's handheld device using his handheld device's Wi Fi network. There are two situations that a mobile user cannot be a cluster member anymore and should quit the cluster and disconnect with the cluster head. First, when a mobile user moves out of the cluster head's Wi Fi signal coverage, it will break the connection with the cluster head automatically and keep scanning a Wi Fi hot spot to find the other cluster head to join. Second, when a mobile user is moving backward or the other direction such

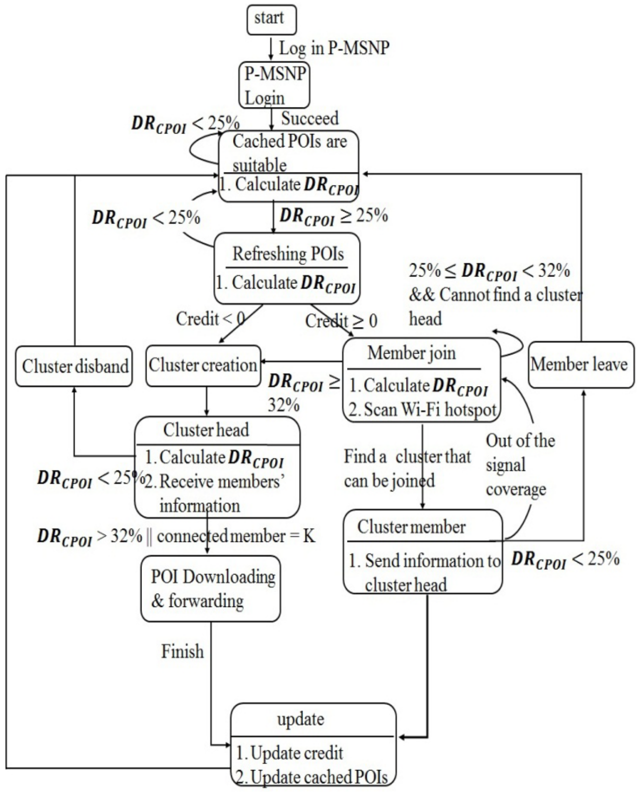


FIGURE 6. The state diagram of the proposed scheme.

that his DR_{CPOI} becomes less than 25%, he needs to quit the cluster and disconnect with the cluster head. He cannot join or create a cluster until he reaches the threshold of refreshing cached POIs' data again.

(8) Member leave: When a cluster member falls into the situations mentioned in (7) of not being a cluster member, the cluster member needs to do the member leave function to quit the corresponding cluster.

(9) Cluster disband: When the cluster head moves backward to a location in which his DR_{CPOI} becomes smaller than 25%, i.e., it does not reach the threshold of preparing to refresh his handheld device's cached POIs' data, he will disband the cluster that he has created and his cluster members will break the connections with cluster head's handheld device. These cluster members can decide to join the other clusters, create new clusters or just keep going depending on their DR_{CPOI} values.

(10) POI Downloading & Forwarding: The cluster head starts to download the required POIs' data from his handheld device's 3G/3.5G/4G cellular network and forwards these POIs' data to his cluster members' handheld devices when one of the following two situations is met: (i) when any cluster member in the cluster reaches the threshold of refreshing his handheld device's cached POIs' data, i.e., its DR_{CPOI} is greater than 32%, cluster head downloads POIs' data of the corresponding range and forwards them to all cluster members' handheld devices. (ii) When the number of connected members is k, which is the maximum number of

connected handheld devices that a Wi Fi hot spot can have, is reached.

(11) Update: After POIs' data downloading and forwarding, the cached POIs' data and credit of each mobile user are updated.

Referring to the state diagram depicted in Figure 6, when a mobile user turns on its handheld device and opens the system, it goes to the first state; it can go to the second state after the mobile user logins into the P-MSNP server. Hereafter, the mobile user can go to any state according to the behavior of the mobile user and the control flow procedure is running until the mobile user leaves this system or turns off his handheld device. One thing to be noted is that when mobile user MN's credit is positive, it is allowed to have MN join an existed cluster. Nevertheless, when MN's DR_{CPOI} is equal to or greater than 32% and MN still cannot find a suitable cluster to join, then MN needs to download the corresponding POIs' data individually using his handheld device's 3G/3.5G/4G cellular network to refresh his handheld device's cached POIs' data.

Figure 7-(a) shows the massage flow diagram of finishing POIs' data downloading. Referring to Figure 7-(a), after cluster head finishes the downloading and forwarding the cached POIs' data to all cluster members, it sends a POI-Downloading-Finish-Indication message to each cluster member and each cluster member sends a POI-Downloading-Finish-Response message to cluster head. After cluster head receives all responses from cluster members, cluster head disables his handheld device's Wi Fi hot spot function to break the connections with cluster members. Then, cluster head sends the POI-Downloading-Complete message to the P-MSNP server and the P-MSNP server updates cluster's information. Afterward, all mobile users of the cluster keep moving and can use the creation function or join function to start the next updating of the cached POIs' data of his handheld device when it is needed.

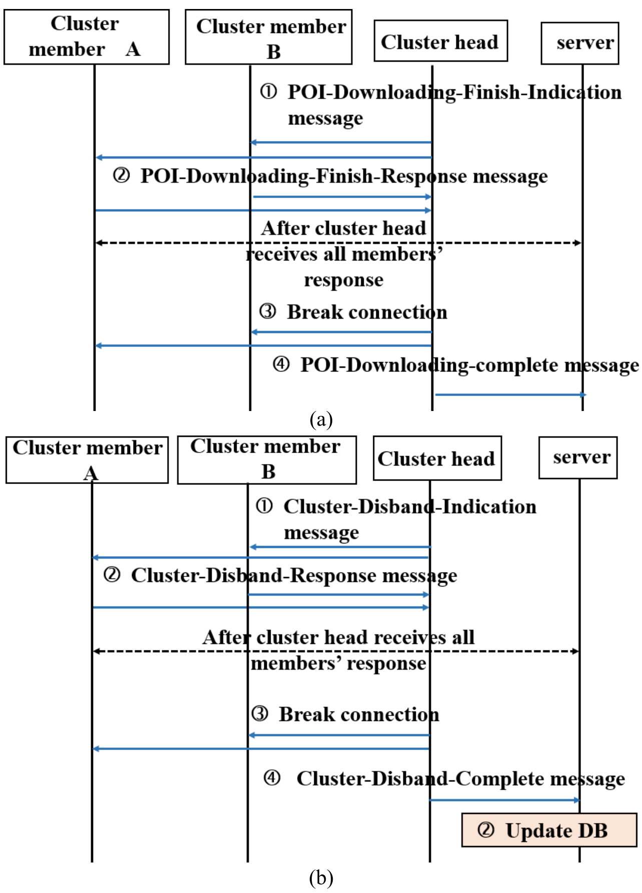


FIGURE 7. **(a) The message flow diagram of finishing POIs' data downloading. (b) The message flow diagram of cluster disband.**

After cluster head x creates cluster C_X, x computes DR_{CPOI} of cluster C_X repeatedly until the time point for refreshing the cached POIs' data is reached. However, cluster head x may move backward such that its DR_{CPOI} is decreasing. If x's DR_{CPOI} becomes less than 25% before any of the triggering's conditions is satisfied, i.e., a member's DR_{CPOI} is greater than 32%, then the cluster is disbanded and each cluster member needs to join other clusters for sharing downloaded POIs' data or download POIs' data by himself. Figure 7-(b) depicts the message flow diagram for cluster disband. In Figure 7-(b), when a cluster head X finds that its DR_{CPOI} becomes less than 25%, cluster head X sends a Cluster-Disband-Indication message to all cluster members. Each cluster member sends a Cluster-Disband-Response message to X. After X receives all responses from cluster members, X disables his handheld device's Wi Fi hot spot function to break the connections with cluster members. X sends the Cluster-Disband-Complete message to the P-MSNP server and the P-MSNP server updates cluster C_X's information. After that, these cluster members can decide to join other clusters, create new clusters or keep going depending on their DR_{CPOI} values.

C. THE CREDIT COMPUTING SCHEME

In this paper, a credit scheme is devised to represent the contributions of each mobile user. Each mobile user's credit is set to a random number in the beginning when the mobile user initially joins the P-MSNP. That is, when a mobile user uses the system for the first time, his credit is randomly assigned. When a mobile user serves as the cluster head, his credit can be increased. Alternatively, when a mobile user serves as a cluster member, his credit value will be decreased. It is critical to have a fair credit computing scheme. In this work, we propose a credit computing scheme that takes into account the consumed battery power, downloaded data volume and the remaining battery power of the cluster head. For the factor of the consumed battery power, it is intuitive that the cluster head must receive more credit if the cluster head consumes more battery power. For the factor of the downloaded data volume, it pays more of the 3G/3.5G/4G cellular network's expense when a higher data volume is downloaded and thus the credit is in proportion to the downloaded data volume. For the factor of the remaining battery power, it is more valuable if the cluster head still wants to play the role of

Wi-Fi hotspot when his handheld device's battery power is low. Thus, the cluster head should receive more credit when his handheld device's battery power is lower. The formula for the cluster head's credit and a cluster member's consuming credit are as follows:

Credit value ($\boldsymbol{CH_i}$):

$$[(CP_i + \frac{D_i - D_{\min}}{D_{\max} - D_{\min}})^*(1 + (100\% - R_i)^*0.1)] \quad (1)$$

Credit value ($\boldsymbol{CM_i}$):

$$\frac{[(CP_i + \frac{D_i - D_{\min}}{D_{\max} - D_{\min}})^*(1 + (100\% - R_i)^*0.1)]}{n-1} \quad (2)$$

In Formula (1) and Formula (2), $\boldsymbol{CP_i}$ is the consumed power of the cluster head i; $\boldsymbol{D_i}$ is the downloaded data volume of cluster head i; $\boldsymbol{D_{max}}$ is the maximum downloaded data volume, which is equal to the total data volume of the k-largest-sized POIs among all POIs; $\boldsymbol{D_{min}}$ is the minimum downloaded data volume, which is equal to the k-smallest-sized POIs among all POIs, for which k is the maximum number of POIs that can be cached in a handheld device; $\boldsymbol{R_i}$ is the remaining percentage of power of the cluster head's handheld device; CH_i is the cluster head i, which plays the role of the Wi-Fi hotspot; n is the number of the connected cluster members. Formula (1) calculates how many credits a cluster head can earn/get during his term of being the cluster head. In this work, the earned credit is proportional to the consumed power ($\boldsymbol{CP_i}$) and downloaded data volume ($\boldsymbol{D_i}$). A cluster head should earn additional credits if it has less remaining power when it plays the role of the cluster head. Thus, in Formula (1), we multiply 1+ (100%-$\boldsymbol{R_i}$)*0.1. For example, if the remaining power is 90%, we add 0.01 times the credit values. However, if the remaining power is 30%, we add 0.07 times the credit values. Since the cluster head gets credits from other cluster members, i.e., n-1 cluster members, Formula (2) shows that all of the cluster members evenly share the credit that is given to the cluster head.

V. PERFORMANCE ANALYSIS

This Section presents the performance analysis of the proposed CCS-POIS scheme. The metrics that are used to evaluate the performance are as follows: (1) the distribution and average standard deviation of the credit value, (2) the average and standard deviation of power consumption, (3) the average downloaded data volume and (4) the average service time. For item (1), a box-and-whisker diagram, which contains the maximum, the first quartile, the median, the third quartile, and the minimum values, is used to demonstrate the distribution of each compared scheme.

A. THE ENVIRONMENT

7 mobile phones that have both Wi Fi and 3G/3.5G/4G cellular network interfaces are used in the performance analysis. The used mobile phones are Sony Xperia Z1, Sony Xperia Z2 and HTC One 801e, in which the operating system is Android 4.4.2, Android 4.4.3 and Android 4.4.4 respectively. A touring path in the campus of National Cheng Kung University (NCKU) is used for testing. The users hold these mobile phones move through the same path and these mobile phones can form a cluster when the $\boldsymbol{DR_{CPOI}}$ reaches the threshold 25%.

The five methods used for the comparison are explained in Table 1. In each experiment, the termination condition was set to the time when a mobile user's handheld device spent its 20% battery power.

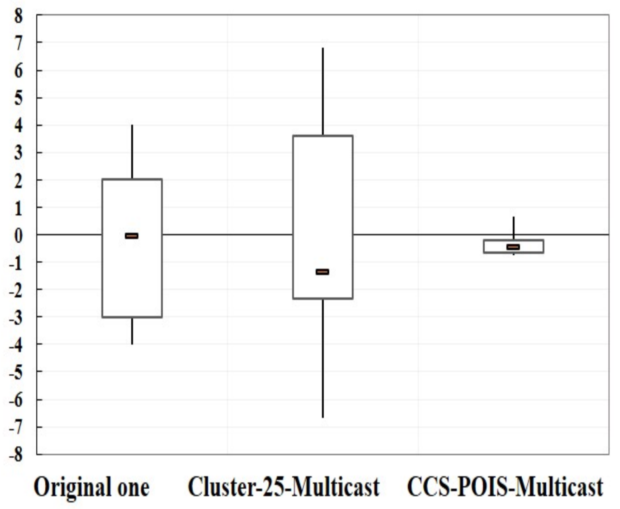
TABLE 1. Methods and explanations.

Methods	Explanations
I-32	Method I-32 had each mobile user download the required POIs using his handheld device's 3G/3.5G/4G cellular network individually. That is, when the $\boldsymbol{DR_{CPOI}}$ reached the 32% threshold, each mobile user's handheld device downloaded the needed POIs' data individually.
Cluster-25	Method Cluster-25 had the mobile user whose $\boldsymbol{DR_{CPOI}}$ reached the 25% threshold enable his handheld device's Wi-Fi hotspot function, creating a cluster and becoming the cluster head. That is, the mobile user whose $\boldsymbol{DR_{CPOI}}$ reached the 25% threshold created a cluster for the other mobile users to join. When the number of the connected cluster members reached the upper bound or the $\boldsymbol{DR_{CPOI}}$ of any mobile user in the cluster, including the cluster head, reached the 32% threshold, the cluster head downloaded the needed POIs' data through his handheld device's 3G/3.5G/4G cellular network and forwarded the data to his cluster members through the Wi-Fi network. Method Cluster-25 was divided into the following two sub-methods.
Cluster-25-Multicast	In sub-method Cluster-25-Multicast, multicast was used to forward the downloaded POIs' data to cluster members.
Cluster-25-TCP	In sub-method Cluster-25-TCP, TCP was used to forward the downloaded POIs' data to cluster members.
CCS-POIS	Method CCS-POIS was the proposed CCS-POIS scheme and it was also divided into two sub-methods.
CCS-POIS-Multicast	In sub-method CCS-POIS-Multicast, multicast was used to forward the downloaded POIs' data to cluster members
CCS-POIS-TCP	In sub-method CCS-POIS-TCP, TCP was used to forward the downloaded POIs' data to cluster members.

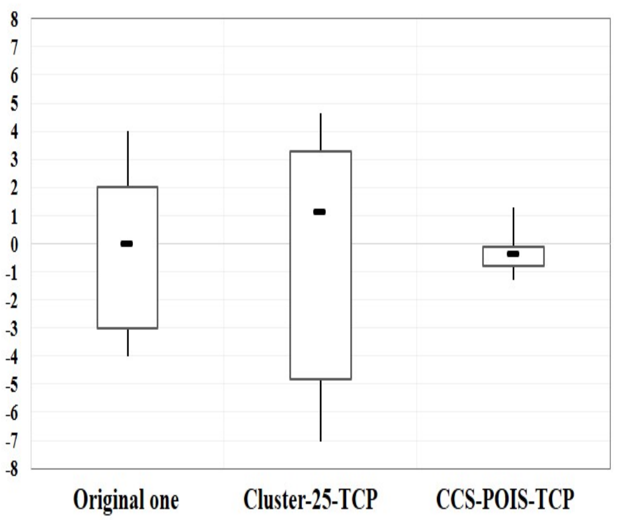
B. THRESHOLD FILTER

Since the credit scheme was used to encourage each mobile user to be the cluster head alternatively, it needs to know what the changing situations of credit values are in different methods. Figure 8-(a) and (b) depict the credit's distribution for all mobile users. The first part shows the original credit distribution before execution. For sub-methods Cluster-25-Multicast and Cluster-25-TCP, since a mobile user can become the cluster head without considering his current credit when his handheld device's DR_{CPOI} is 25%, the credit distribution was still very diverse after using sub-methods Cluster-25-Multicast and Cluster-25-TCP. For sub-methods CCS-POIS-Multicast and CCS-POIS-TCP, it took the current credit values of the mobile users into consideration for selecting which mobile user could act as the cluster head and thus the credit distribution was converged. That is, the maximum plots of the box charts for sub-methods CCS-POIS-Multicast and CCS-POIS-TCP are much lower than the maximum plots of the box charts for the original and sub-methods Cluster-25-Multicast and Cluster-25-TCP. The minimum plots of the box charts for sub-methods CCS-POIS-Multicast and CCS-POIS-TCP are much higher than the minimum plots of the box charts for the original and sub-methods Cluster-25-Multicast and Cluster-25-TCP. This shows that the distribution of credits in sub-methods CCS-POIS-Multicast and CCS-POIS-TCP were more concentrated than that of others and it proved that our proposed method achieves more fairness for all mobile users.

Figure 9-(a) and (b) depict the average of the credit's standard deviation for different methods. To get the credit's standard deviation, the average value was calculated based on the seven mobile users' last credits and then was used to calculate the disparity between the average value and each

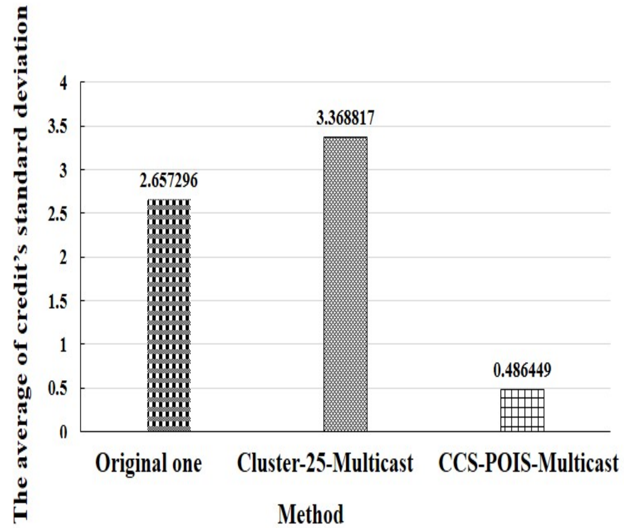


(a)

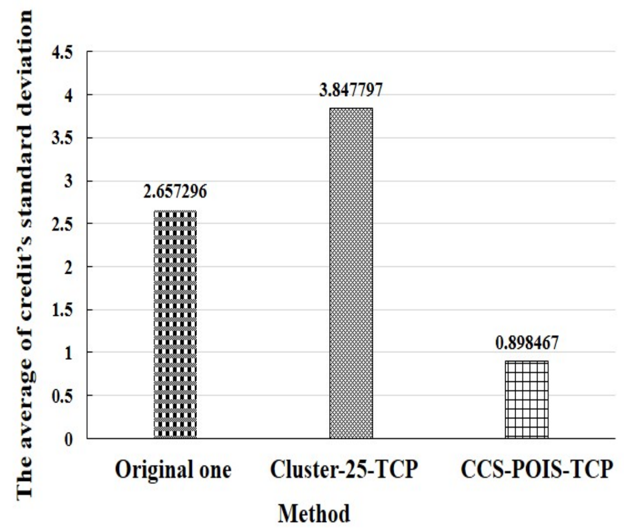


(b)

FIGURE 8. (a) Credit's distribution for sub-methods Cluster-25-Multicast and CCS-POIS-Multicast. (b) Credit's distribution for sub-methods Cluster-25-TCP and CCS-POIS-TCP.



(a)



(b)

FIGURE 9. (a) The average of credit's standard deviation for sub-methods Cluster-25-Multicast and CCS-POIS-Multicast. (b) The average of credit's standard deviation for sub-methods Cluster-25-Multicast and Cluster-25-TCP.

mobile user's last credit value. Compared to the original, sub-methods CCS-POIS-Multicast and CCS-POIS-TCP have a lower average of the credit's standard deviation than that of methods Cluster-25-Multicast and Cluster-25-TCP, which resulted from considering the current credit value for being the group leader in sub-methods CCS-POIS-Multicast and CCS-POIS-TCP.

Figure 10-(a) and (b) depict the average power consumption for these three methods, in which the value in the y-axis denotes the percentage of battery power that a mobile user's handheld device has consumed. The average power consumption for each method was calculated as follows. Each method was executed five times based on the same touring scenario. The sum of the consumed power for these five times was first divided by five. Then, since there were seven smartphones involved in the testing, the result was divided by seven to determine the average power consumption of a smartphone. Method I-32 consumed more power than the other methods. The reason is straightforward: each mobile user in method I-32 had to download the needed POIs' data using his handheld device and no sharing mechanism existed. Sub-methods Cluster-25-Multicast and Cluster-25-TCP consumed more power than sub-methods CCS-POIS-Multicast and CCS-POIS-TCP. This was because the mobile users' handheld devices in sub-methods Cluster-25-Multicast and Cluster-25-TCP may reach the 25% threshold at approximately the same time and thus the corresponding mobile users created clusters by themselves and downloaded the POIs' data individually similar to method I-32, even if they were moving in the same approximate location. Thus, sub-methods Cluster-25-Multicast and Cluster-25-TCP had an average power consumption that was higher than that of sub-methods CCS-POIS-Multicast and CCS-POIS-TCP.

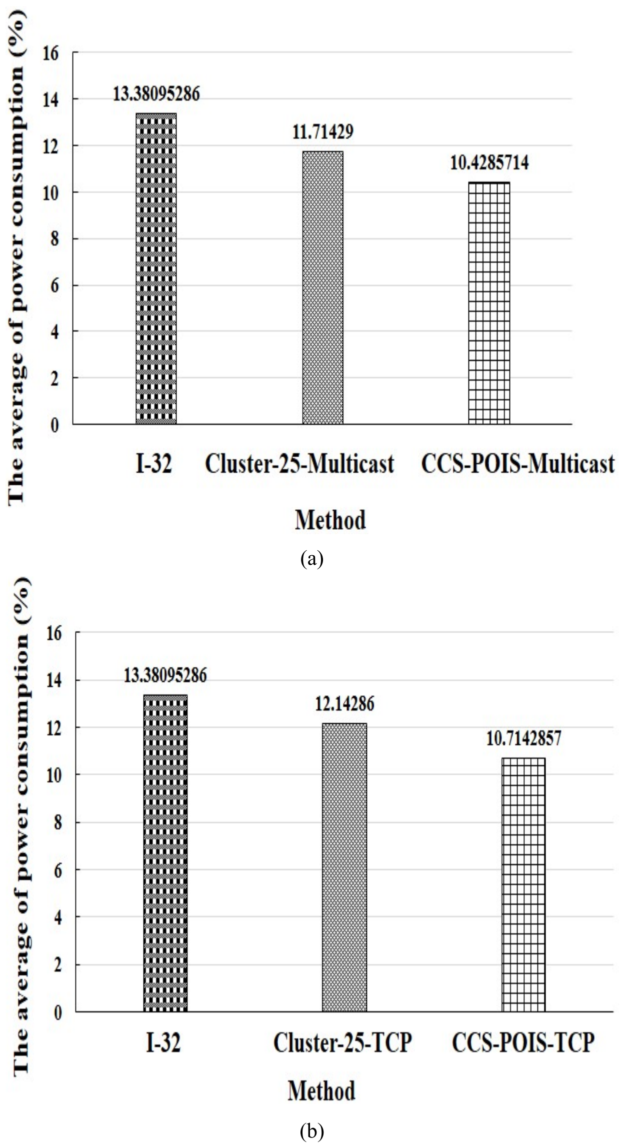


FIGURE 10. **(a) The average of power consumption for sub-methods I-32, Cluster-25-Multicast and CCS-POIS-Multicast. (b) The average of power consumption for sub-methods I-32, Cluster-25-TCP and CCS-POIS-TCP.**

Figure 11-(a) and (b) depict the average standard deviation of power consumption for the different methods, based on a similar calculation as Figures 8 and 9. Method I-32 had a small average standard deviation of power consumption rate because each mobile user had the same touring scenario and downloaded the needed POIs' data individually and thus their consumed power was similar. Sub-methods CCS-POIS-Multicast and CCS-POIS-TCP had an average standard deviation of power consumption that was smaller than that of sub-methods Cluster-25-Multicast and Cluster-25-TCP. This was because each mobile user served as the cluster head more alternately in sub-methods CCS-POIS-Multicast and CCS-POIS-TCP and each mobile user served as the cluster head more often in sub-methods Cluster-25-Multicast and Cluster-25-TCP. As a result, sub-methods CCS-POIS-Multicast and CCS-POIS-TCP provided more fairness in being the cluster head than sub-methods Cluster-25-Multicast and Cluster-25-TCP.

Figure 12-(a) and (b) depict the average downloaded data volume for the three methods. The average downloaded data volume for each method was calculated as follows. Each method was executed five times based on the same touring scenario. The sum of the downloaded data volume for these five times was first divided by five. Then, since there were seven smartphones involved in the testing, the result was divided by seven to determine the average downloaded data volume of a smartphone. Method I-32 had the highest average downloaded data volume because each mobile user downloaded the needed POIs' data individually. Sub-methods Cluster-25-Multicast and Cluster-25-TCP had a higher average downloaded data volume than that of sub-methods CCS-POIS-Multicast and CCS-POIS-TCP. This is because the same, i.e., mobile users' handheld devices in sub-methods Cluster-25-Multicast and Cluster-25-TCP may reach the 25% threshold at approximately the same time and thus the corresponding mobile users created clusters by themselves and downloaded the POIs' data individually similar to

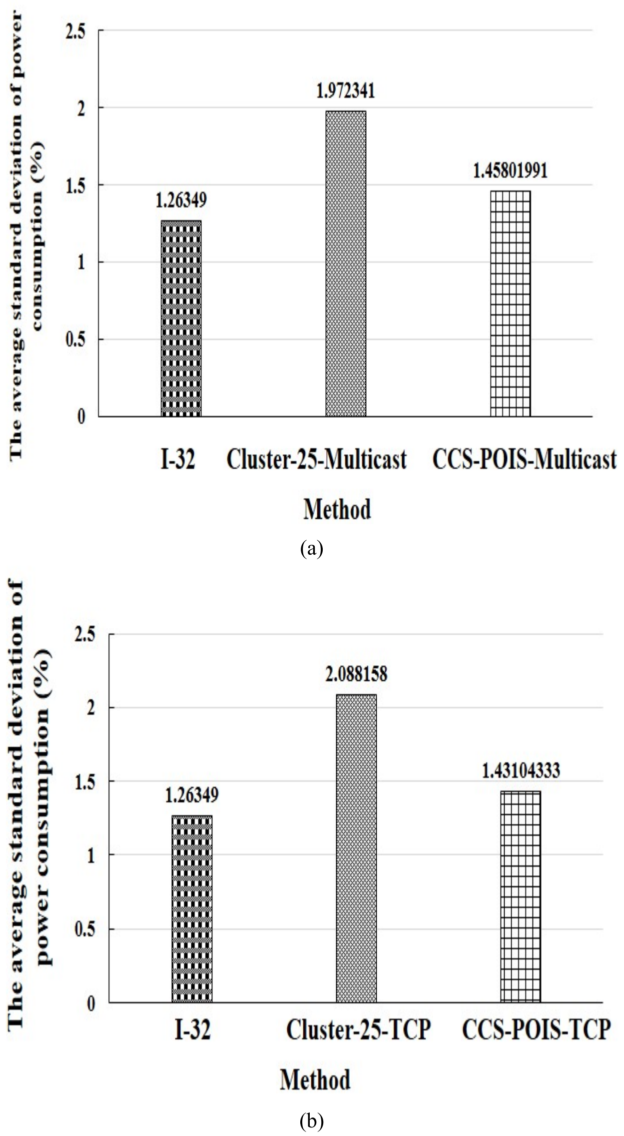


FIGURE 11. **(a) The average standard deviation of power consumption for sub-methods I-32, Cluster-25-Multicast and CCS-POIS-Multicast. (b) The average standard deviation of power consumption for sub-methods I-32, Cluster-25-TCP and CCS-POIS-TCP.**

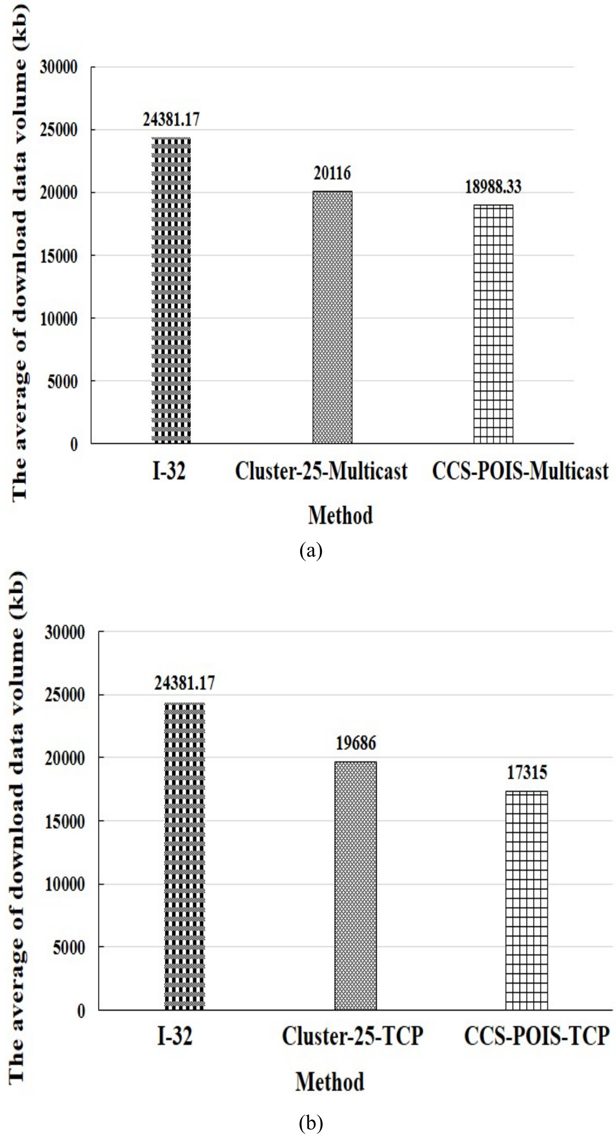
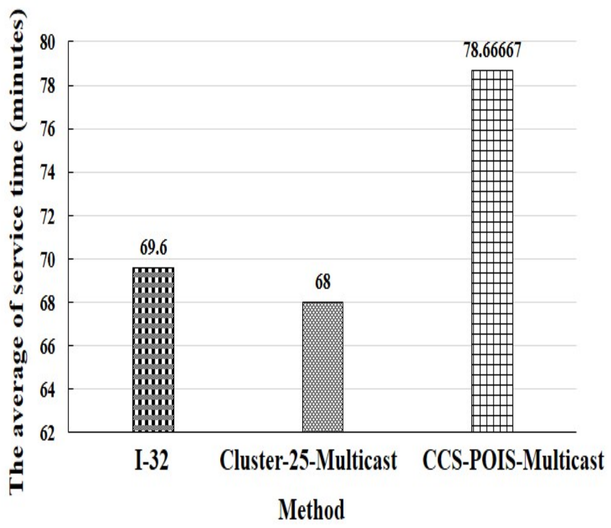


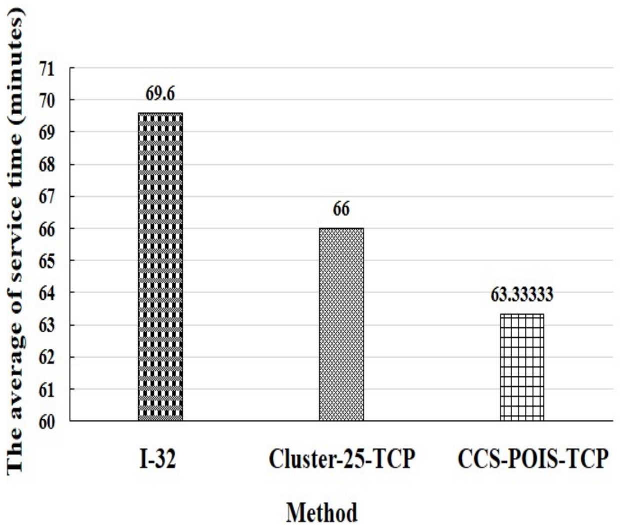
FIGURE 12. **(a) The average downloaded data volume for methods A, Cluster-25-Multicast and CCS-POIS-Multicast. (b) The average downloaded data volume for methods A, Cluster-25-TCP and CCS-POIS-TCP.**

method I-32, even if they were moving in the same approximate location. Mobile users in sub-methods CCS-POIS-Multicast and CCS-POIS-TCP had a higher probability to join clusters to share the corresponding cluster head's downloaded POIs' data. Hence, sub-methods CCS-POIS-Multicast and CCS-POIS-TCP had a smaller average downloaded data volume than that of sub-methods Cluster-25-Multicast and Cluster-25-TCP.

Figure 13-(a) and (b) depict the average service time for different methods. The average service time for each method was calculated as follows. Each method was executed five times based on the same touring scenario. The sum of the service time for the five times is divided by five to obtain the average service time. In Figure 13, the average service time of sub-method CCS-POIS-Multicast was higher than the others because mobile users in method Cluster-25-Multicast may become the cluster head more often which leads to an unfair situation, which consumes more power. That is, it may cause a mobile user to be set as the cluster head more times and thus consume their battery power sooner, which causes the termination condition of the experiment, i.e., when a mobile user's handheld device spent its 20% battery power, sooner. Sub-method I-32's average service time was shorter than that of sub-method CCS-POIS-Multicast because every mobile user downloaded the needed POIs' data individually in method I-32, i.e., it needed to download seven times from the server to mobile users' handheld devices, and thus the power consumption reached the termination condition of the experiment sooner than sub-method CCS-POIS-Multicast, which used multicast to forward the POIs' data to cluster



(a)



(b)

FIGURE 13. (a) The average service time for methods A, Cluster-25-TCP and CCS-POIS-TCP. (b) The average service time for methods A, Cluster-25-Multicast and CCS-POIS-Multicast.

members, i.e., it needed to download the POIs' data from the server to the cluster head once and transmitted once to forward from the cluster head to all of his cluster members. Sub-method Cluster-25-Multicast's average service time was shorter than that of method I-32 because mobile users in method I-32 had the same touring scenario and downloaded the needed POIs' data individually and thus their consumed power was similar. As a result, it did not reach the termination condition of the experiment sooner. However, some mobile users in sub-method Cluster-25-Multicast may have been the cluster head more often. That is, it a mobile user may have been set as the cluster head more times and thus needed to enable his handheld device's Wi-Fi hotspot functions for cluster members to connect with and forward the downloaded POIs' data to them more often. Thus, it consumed the battery power sooner, which caused the termination condition of the experiment, i.e., when a mobile user's handheld device spent 20% of its battery power, sooner.

In Figure 13-(b), sub-method CCS-POIS-TCP's average service time was smaller than the others because a mobile user was the cluster head when his credit was less than zero, if there are n connected members of that cluster head, then it must forward the POIs' data to these n members' handheld devices using n TCP connections, i.e., it needed to forward data n times. As a result, it consumed battery power sooner to reach the termination condition of the experiment. Although sub-method Cluster-25-TCP also used TCP to transmit data, more cluster heads existed because of the selection method of the cluster head and thus the number of connected members was smaller than that in sub-method CCS-POIS-TCP. As a result, the number of TCP connections in each cluster head's handheld device of sub-method Cluster-25-TCP was smaller, i.e., it needed to forward the POIs' data fewer times. Thus, the average service time of sub-method Cluster-25-TCP was higher than that of sub-method CCS-POIS-TCP. The average service time of method I-32 was higher than that of sub-methods Cluster-25-TCP and CCS-POIS-TCP. The reason is that the mobile users in method I-32 did not need to have TCP links to send control messages for clustering and forwarding the downloaded POIs' data using TCP or multicast to other mobile user's handheld devices and thus the power consumption of method I-32 was smaller than that of sub-methods and Cluster-25-TCP and CCS-POIS-TCP.

VI. CONCLUSION AND FUTURE WORK

In this paper, we integrated the mobile IOT (M-IOT) concept with the MSNP mechanism to create cyber-physical-social computing and networking for the proximate sharing of 3G/3.5G/4G-cellular-network-downloaded geodata. A clustering scheme called the Credit-Centric Sharing of POIs' Data (CCS-POIS) was proposed to reach the goal of saving power and thus prolonging the service time of mobile users' handheld devices. The proposed CCS-POIS scheme allows many people, who belong to the same MSNP group in cyberspace, to use their mobile handheld devices in the physical world to join a cluster and then have the cluster head download POIs' data using his handheld device's 3G/3.5G/4G cellular network. Simultaneously, the cluster head shared the downloaded POIs' data with the cluster members using the Wi-Fi network based on the locations of the group of people. Cyberspace's MSMP provides the qualification for involved people's handheld devices to form a cluster or join existing clusters. The credit scheme was used to calculate and record the contribution of each mobile user after the cluster head had downloaded the needed POIs' data and forwarded them to all cluster members. In this way, it can motivate people to share and fairness can also be achieved. The credit value of each mobile user was used to decide the mobile user's handheld device to serve as the cluster head or cluster member when it was clustering.

The results of the performance analysis showed that the proposed CCS-POIS provides a fairer mechanism for mobile users to form a cluster, consume less and balance power among all mobile users' handheld devices, which are regarded as M-IOTs and have a smaller downloaded data volume than other methods. The main reason is that the proposed method does not need to download duplicate POIs' data using the 3G/4G/5G network of mobile users' handheld devices and all of the mobile users alternatively play the role of cluster head, who is in charge of downloading the POIs' data using his handheld device's 3G/3.5G/4G cellular network and then forwarding the POIs' data to cluster members using the Wi-Fi network based on mobile users' credits.

The current work is based on the P-MSNP, which is suitable for pedestrians. For the future work, it can consider how to apply the similar work to vehicular Social Network in proximity (VSNP), for which the moving objects are vehicles.

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