2016 IEEE 12th International Conference on Wireless and Mobile Computing, Networking and Communications (WiMob)

Opportunistic Mobile Social Networks: Challenges Survey and Application in Smart Campus

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***Abstract*—With the high penetration of smart phones in our daily life and the increasing capabilities of these smart devices, a new type of applications has emerged. Lately, Opportunistic Mobile Social Networks (OMSN), which allow users to directly update their social networks while moving have seen the day. Typically, users require the Internet to share information on their social network and this produces various limitations. However, OMSN exploit opportunistic links between mobiles' of users with social similarities to share contents and updates, bypassing the need for an Internet connection. In this paper, a survey on OMSN applications and existing architectures is provided. Key challenges to the development of these networks are elaborated along with suggested solutions. An architecture for collaborative learning application using OMSN that tries to answer these challenges is presented. A prototype is implemented and deployed to validate the proposed solution. Clearly, OMSN can be an addition to the smart campus initiative.**

***Index Terms*—OMSN, Social Networks, Smart campus, Survey, Challenges**

I. Introduction

Social networks are groups of people who are creating social links and relationships through interacting with other users sharing similar interests [1]. These networks take different forms such as Online Social Networks (OSNs) or Mobile Social Networks (MSNs), where MSN are gaining popularity with the increasing spread of smart devices among users. MSN combines benefits from both social and mobile networks where it utilizes smart phone's abilities such as sensing modules, GPS, communication links, to perform automated computation or sensing requests based on social interests of users [2].

Mobile social networks are typically accessed through Internet requiring infrastructure and subscription. Recently, a new trend has emerged where opportunistic links between users in MSN are used to exchange data according to users' preferences and interests. This trend exploits users' information such as profile, social interactions, local resources and mobility pattern in order to link people with similar interests and opportunistically share information between them efficiently. These links are utilized in different application domains for OMSN such as community building, where geographically related communities are introduced based on shared interest. Another application domain is data sharing for information that is of a specific interest within a specific community [3].

In the literature, multiple OMSN architectures have been proposed to model OMSN [4] [5], [6] [7]. They consider different social aspects of users to build the network, in addition to other architecture design aspects. In this paper, we explore the exisiting OMSN architectures and analyze their limitations. Those limitations include security, validation of content, resource management and disconnection management which are in fact preventing the wider deployment of such networks. Additionally, Suggestions were proposed to overcome these challenges and produce better architectures. A new architecture is proposed to implement OMSN for collaborative learning. A prototype is implemented and deployed to show the feasibility of the suggested architecture.

The rest of the paper is organized as follows. Section II describes the OMSN paradigm in general, its architecture and applications. Section III includes evaluation criteria for the existing architectures implementing OMSN along with their descriptions and comparison. Section IV includes open challenges in the domain. Section V presents the architecture we are proposing as well as the deployed prototype. Section VI concludes the paper and highlights some future directions.

II. Domain Overview

Opportunistic Mobile Social Networks (OMSNs) are location-based user-centric networks that are built on top of the mobile social network framework with an added component of opportunistic routing. The human participant with their interests and communities are at the core of such networks. Typically, OMSNs analyze the interactions among various mobile phone users, and simultaneously cluster their actions or activities based on similar hobbies and practices. The aim is to eventually perform information gathering and sharing. The messages transmitted in this network rely upon the opportunistic contact among users' mobile phones. In fact, OMSNs are based on mobile ad-hoc networks and are seen as a type of Delay Tolerant Networks (DTNs) [8].

Opportunistic sharing may use different communication links; Wi-Fi and Bluetooth. Each of those has its own characteristics such as coverage range, power consumption and performance factors. Wi-Fi is mostly considered when high capacity and fast transmission are key requirements while Bluetooth is preferable when users' power resources are of concern.

A typical architecture of OMSN is composed of six main components.

- Social Profile Manager: responsible for the creation or retrieval of the users social profile. The profile can be generated by the architecture or imported from Online Social Networks.
- Beaconing and Networking Manager: beaconing is responsible for broadcasting the node's information periodically to the network via Bluetooth and/or Wi-Fi technology.
- Data Manager: manage received and generated documents at each user to save them in the mobile device along with profiles of encountered nodes.
- Context Manager: as smart phones have limited capability, it is crucial to monitor and make decisions based on the context. This includes, but is not limited to, device sensors and battery utilization during the whole process of identifying interested nodes and exchanging information between nodes.
- Forwarding Manager: includes forwarding method used to opportunistically disseminate information to users either directly or through relay nodes. The dissemination technique depends in the social information acquired by the architecture.
- Disconnection Manager: responsible for utilizing sensory information from the device to make sure data is not permanently lost from the network.

III. OMSN Architectures Survey

In order to survey the existing solutions, we first define criteria of comparison.

A. Criteria of Comparison

1) Platform: : Smart devices are represented as nodes in the network, which store and exchange information among each other. Computation power, storage capacity and battery life of these devices are different [9]. Moreover, these nodes store users information such as calendar events, location, as well as files; which are critical data that can be used by OMSN to determine if the mobile is an appropriate candidate as the next forwarding node. The heterogeneity of the smart devices' platforms should be considered while deploying OMSNs in both the forwarding algorithm and the performance analysis of the algorithm [10]. Because of its open nature, all the existing OMSN applications use Android platform.

2) Communication Links: : OMSN is based on local wireless communication links available at mobile devices such as Bluetooth and Wi-Fi. Bluetooth is a standardized protocol for information exchange. It uses Service Discovery Protocol (SDP) for discovering services provided by other available devices and a Universally Unique Identifier (UUI) to identify these services. Wi-Fi in OMSN forms an independent basic service set based on IEEE 802.11 standards. Wi-Fi in opportunistic communication operates in ad-hoc mode rather than the infrastructure mode where no service discovery protocol is defined. The scanning mechanisms for device discovery in Wi-Fi and Bluetooth are categorized into passive and active scanning. Nodes in passive role scan channels for inquiry messages from peers and send response messages. However, active nodes announce their existence by sending request messages to available channels and wait for response [11] [12] [13]. OMSN can be implemented as a pure opportunistic network or in a hybrid mode where an infrastructure based communication assists the ad-hoc communication.

3) Social Profile/Characteristics: : In social network, humans are represented as nodes with different social characteristics such as daily routines, mobility patterns, interests and background. It embraces the human factor that is the key enabler of OMSN, where individuals have control over their involvement in the network. Social information is utilized to decide the next hop of messages, identify the effect of a node in the sharing scheme and form better links between nodes. Existing architectures use different social metrics to decide the dissemination of information. Another critical aspect is the mobility of users, which is essential for spreading information within the network [14].

4) Dissemination Methods: : Deciding the best destination node to transmit a message to can be a critical and challenging task. Different forwarding algorithms have been introduced such as oblivious, contact history, social network inspired and multicasting [9]. In OMSN, the contact history and social network inspired algorithms can be applied. In contact history algorithm, each node includes descriptions of other nodes and the message will be forwarded to the best fit node. On the other hand, social network inspired algorithm uses social information to exchange messages with nodes of similar social interest.

Routing is concerned with finding the optimal path to forward a message from its source to the desired destination. Context information such as mobility pattern and working address can be used for optimized routing.

OMSN classifies routing to three main categories; encounter based, social property based and social feature based as described in [15]. Our main focus is on the social feature routing, which relies on social features such as gender, age and similar interest to decide the best routing path. Some routing schemes adapted in OMSN include social similarity based (SOSIM), social feature-based and social link awareness based routing (SALBAR).

SOSIM represents each node as a vector with given social features [16]. The vector reflects a percentage of each social feature calculated based on meeting ratio in the past. With this notion, if two nodes exist then the data will be forwarded to the node with higher vector as it has a greater chance to meet other nodes of similar interest.

In social feature-based routing, individuals are represented as hypercube nodes with social features [17]. The feature distance is calculated to find the closeness between the source and the next node to forward the message to. The distance is updated at each node until it reaches the destination where it becomes zero.

SALBAR identifies the social relationship between two nodes using their social features [18]. The link is established when the nodes communicate more frequently and for long duration, ensuring that the reliability of the link.

B. Existing Architectures Description and Comparison

Smart phones can provide large amount of opportunistic data that ranges from geographic location to application usage. This data is automatically generated by mobile sensors, collected and analyzed in the background. Different opportunistic social applications can be deployed using the various data collected from mobile phones as presented in Table I.

Arnaboldi *et al.* proposed CAMEO, a middleware designed to allow the development of opportunistic mobile networks [19]. CAMEO works on exploiting the local and social contexts of a user for information sharing. Tourist-MSN is an application built on top of the CAMEO middleware and uses its API. This application, which is tourist-oriented, uses opportunistic communication to both generate and share multimedia. It also allows a limited number of users within close proximity to have real-time textual communication. DroidOppPathFinder is another application built on top of the CAMEO middleware. It is aimed for users interested in physical outdoor activities [20]. The user can choose between different desired activities (walking, running, etc.) and input the intended distance. Next, the application provides multiple suggested paths with different information such as the weather, noise level, pollution level and other users' comments. The application relies on data from the phone sensors as well as external sources such as weather station.

A. C. Champion *et al.* proposed an architecture for opportunistic mobile social networks that aims to enable social networking among strangers [21]. E-SmallTalker is an application built on top of this architecture. It identifies people with similar interest within the same range. The user needs to configure his/her profile for the first use by adding personal information, contacts and places visited, then this data is filtered using Bloom filter. Whenever two devices meet, the filtered data are exchanged, and the user will be notified once a shared interest is discovered. Also, the application suggests conversation topics extracted from users' shared interests.

MobiClique middleware is designed to use existing OSN to build a decentralized system for community (interest group) based interactions [5]. The architecture requires users to synchronize with an OSN to retrieve their social profile for exchange with other users during opportunistic encounters. MobiClique is used to implement an OMSN application. In the application, the user can create his/her profile. On the main page, *contacts, interest group and votes* are listed. Contacts include nearby people whether friends or strangers. Interest group enables the user to create, join or leave different groups. Epidemic voting is done for participants in particular location where they are able to vote for a given topic within short period and view the final result after voting.

BlueShare is also an application built on the architecture proposed in [22] targeting campus life. Teachers and students utilize it for exchanging files among each other. The application implements a store-and-forward model where the teacher sends a file to nearby students which they can store the file and share it with other peers. When the students are welling to receive a file, they enable the negative mode of the application and later switch to the positive mode to share the file.

IV. Challenges

Challenges are present in OMSN from various sources starting from the underlying technologies to the architecture deployment [9] [5].

A. Security and Privacy

The decentralized nature of OMSN produces various security threats such as identity theft, malicious injected messages, and privacy compromise. Identity of different users can not be authenticated which may lead to the problem of maliciously injected messages, where attackers inject messages into the network with false information influencing the receiver's decisions.

Privacy is another compromised aspect since users are constantly sharing their information with neighbors which can be easily exploited. Third parties use this vulnerability to impose advertisements and spam content. To ensure reliable and secured transmission contact history and encryption can be used to authenticate and authorize trusted users.

B. Content Validation

Sharing posts and documents does not guarantee the validity of the content. Similar to social networks, a mechanism to validate the information in OMSN is needed. In such mechanism either the user validates the content received based on his judgment or the system compares the information received from different sources to gain confidence in the content. For instance, number of likes in social networks are seen as an indirect indicator of content validation.

C. Duplicate Information

Given the social interest of people, users in similar social networks might generate or propagate similar contents to their neighbors. These similar contents do not add new information to the receiving node while consuming mobile device resources. Thus, the available messages should be taken under consideration in dissemination to provide better performance.

D. Resources' Limitation

Mobile devices have limited resources compared to static computers including limited battery life, limited storage space and low computational power. Resources' limitation has a direct impact on the probability of device disconnection and also on user's selfishness (as will be explained later) if not efficiently considered by the architecture.

TABLE I: OMSN Applications

Underlying architecture	Application	Social profile	Device sensors	Disconnection Management	Communication links		Connection	
					Bluetooth	WiFi	Pure opportunistic	Hybrid
V. Arnaboldi *et al.* [4] (CAMEO)	DroidOppPathFinder	Local context: user profile and device,context social context:neighbors' local and social context	GPS and other local sensors	Handled by the Network Manager module	✓	✓		✓
	Tourist-MSN	Title and category of each post and chat generated by the local user, and the user's interests in specific categories of posts and chats	Doesn't use	Handled by the Network Manager module		✓(ad hoc)	✓	
A. C. Champion *et al.* [21]	E-SmallTalker	Friends? information - imported from the phone contact database- the user's interests	Doesn't use	Not handled	✓		✓	
A.-K. P. Inen [5]	MobiClique	user's personal details, friends and interests	Doesn't use	Handled using receiver-driven approach	✓			✓
Z. Yu, Y. Liang *et al.* [22]	BlueShare	assignments or courseware	accelerometer, thermometer, GPS, etc	Not handled	✓			✓
Proposed architecture	Proposed application	Student ID, Student courses	Doesn't use	Handled by Disconnection Manager		✓(WiFi Direct using services)	✓	

E. Disconnection and Delay

In OMSN environment, users meet opportunistically for short periods due to their mobility pattern limiting the guarantee of end-end message delivery. This affects the network's overall performance as forwarding depends on the contact duration of users. Contact history, device sensory data and user mobility pattern can help ensure that nodes will meet for sufficient time with a minimum number of disconnections or delays.

F. Selfishness

An important aspect in OMSN is the dependency on human participation for message spreading. With the existence of limited phone resources, people tend to be selfish and concerned about their battery life and memory capacity. Content sharing will affect these resources making users tend to share less or even not share at all. This threatens the lifetime of the whole network as users might choose not to cooperate by intentionally dropping packets creating a disconnected network. This problem is already well-known on the network level, and there are two main approaches to handle it; detection of selfish nodes and incentive mechanisms to encourage nodes collaboration [23] [24].

V. OMSN FOR COLLABORATIVE LEARNING: PROTOTYPE IMPLEMENTATION

Intelligent campus (iCampus) [25] aims to provide a collaborative learning environment where students can learn and share information anywhere at anytime. While it touches different areas, the focus is on the iLearning and iSocial aspects. iLearning targets course content and materials while iSocial aims to construct discussion groups and share information among students.

As the penetration rate of smart devices among students is high, we propose an OMSN application that fosters students' collaboration, more specifically, interest based course information and documents sharing. Opportunistic sharing through direct links among students lowers the load on the campus Internet which leads to better resource utilization. It also extend sharing to locations where Internet is not accessible such as outdoor areas without coverage infrastructure

In our system, we assume that 1) All mobile devices in the network are equipped with the application; 2) In terms of technology, all mobile devices support Wi-Fi Direct technology; 3) Within the campus, users meet frequently to opportunistically share content; and 4) Continuously broadcasted profile is of small size, thus this does not congest the network.

A. Application Architecture

Figure 1 presents our proposed architecture. Social Profile Manager, Beaconing and Network Manager, Forwarding Manager, Data Manager, Disconnection Manager, Context Manager and Security Manager are the main components of the architecture.

1) Social Profile Manager: The user's social profile provides the bases for link creation between users through the network. The identification metric for users in the network is their University ID. This module is composed of four main sub-modules, which are the profile creation manager, the profile maintenance manager, the Friend list manager and the untrusted contact list manager. The profile creation manager allows the creation of a social profile that includes courses of interest and user's ID. The users are required to enter at least one course of interest and set their priority. The profile also contains content description; recent posts and documents created and/or received by the user. Additionally, the user keeps two lists of users; trusted friends and untrusted connections. The trusted friends are stored along with their interests and available content to relay posts of interest to them. A user is transferred from the untrusted list to the trusted one if his/her reputation reaches a certain level. This level is decided by user and managed by the Trust Manager. The profile maintenance module manages all the updates of the profile.

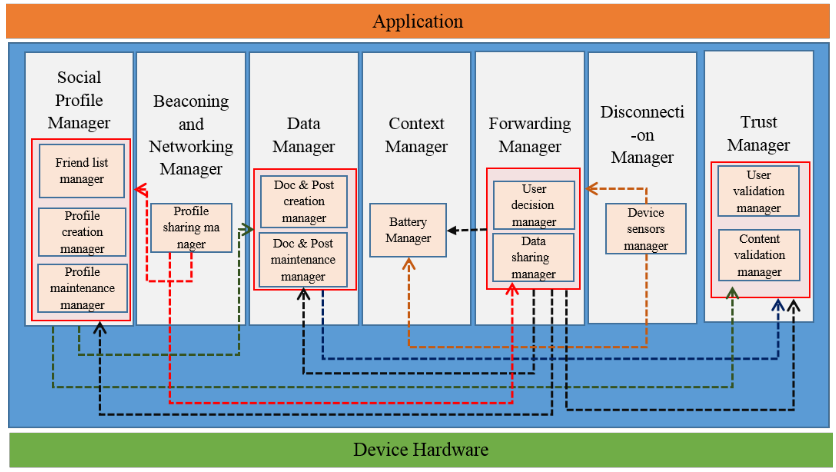


Fig. 1: OMSN for Learning: Architecture

2) Beaconing and Network Manager: Devices have to be discovered in order to create a network between them. In this prototype, Wi-Fi Direct technology is used to find neighbors in the coverage area of the mobile and establish connections without the need for a network provider. Wi-Fi Direct allows devices to register their social profiles as services and advertise them to other devices within the network through the Profile Sharing Manager within the Beaconing and Network Manager. Devices can customize the advertised profile in order to reflect their interests to the network. In addition, devices run listeners, which enable them to discover services being advertised by other devices. Once the Beaconing Manager discovers an advertised service, it notifies the Forwarding Manager to analyze the service. After a connection establishment, content is shared through Wi-Fi direct allowing fast transfer between physically adjacent devices [26].

The usage of WiFi Direct presents quite a high energy cost compared to Bluetooth [27] [5]. However, as Wi-Fi Direct is built on top of the Wi-Fi technology, it is proven to outperform the Bluetooth in speed, range and security [28]. It is relatively easy to set up and its speed reaches up to 250 Mbps [29], while Bluetooth provide a speed of up to 25Mbps only. Moreover, the two technologies differ in the range provided where WiFi Direct can cover up to 600 feet while Bluetooth depends on the device operated but it is likely to cover a distance of at 200 feet at most [30].

3) Forwarding Manager: After service discovery, the Forwarding Manager receives all social profiles to analyze and match to the device's social profile. If a profile is found with matching courses of interest, the neighbor's available contents are explored to determine if the local user is missing any content. In that case, establishing a connection between the user and the neighbor will be suggested. The user will also be notified of the neighbor's membership; trusted or untrusted friends list. The User Decision Manager will then allow the user to decide whether to connect or not. The content will be received along with its number of validations, according to the priority of the course it falls under. This is handled by the Data Sharing Manager. Friends list is also explored in parallel to the user's profile to find any content of interest to friends. This is done for the purpose of deploying each node in the network as a relay node for its friends. Disconnections during transmission are handled by the Disconnection Manager to improve the prototype's performance.

4) Context Manager: The Context Manager is responsible for monitoring the device's resources such as battery, memory, CPU and Wi-Fi connection to adaptively enable features in the application as suggested in [31]. For instance, low battery leads to disabling the relaying feature in the application to conserve the battery resources of a device allowing the application to have an adaptive feature. Low available memory also impacts the download capability by allowing download of text files only. To ensure reliable data transfer, a user will be notified when the battery level is low to forward available messages to neighboring nodes whether interested or not.

5) Data Manager: Since mobile devices tend to have limited resources, data management was carefully considered while developing the architecture. The data management module contains two main sub-modules, the Doc and Post Creation Manager and the Doc and Post Maintenance Manager. These managers allow adding documents and posts to the system and maintaining the existing documents and posts respectively.

In the current prototype, data management follows the below rules:

- The system supports sharing documents and posts
- Document size varies while posts are of small size
- All files exchanged in the prototype are time stamped and saved to the internal memory of the mobile device
- Documents are saved as .pdf while posts are .txt files
- The profile file saves courses of interest and available content for each course
- Each course will have a separate folder where content related to this course is kept
- Courses are saved according to the user's specified priority during registration

- Once new posts and documents are received, the profile is updated to reflect the recent content
- The received content includes the number of validations for the content

6) Trust Manager: Since the users of the system are not managed by a centralized entity, incorporating some security measures in the system is done by implementing a Trust Manager. It consists of two modules; the User Validation Manager and the Content Validation Manager. The User Validation Manager allows the user to like other users upon receiving useful content which will update the Friend list manager accordingly. The more frequent a user is given likes, the more reputation he/she will gain, the higher the probability for him to move the trusted friend list. Additionally, the content validation manager allows the user to like each content individually and update the content's number of validations.

7) Disconnection Manager: Disconnection is defined by devices no longer being part of the network and this is caused by several factors; mainly battery drainage. This can cause information permanently being lost from the network if no other member in the network has it. Disconnection prediction is deployed through tracking the battery level. Whenever a disconnection is predicted, the user is prompt to share information with any adjacent neighbor to prevent data loss. In the case of an active transmission, disconnection is neglected for posts as their size is small and transmission is instantaneous. On the other hand, documents transmission takes more time where sender or receiver might disconnect before successful completion.

B. Application Features

The application starts by user registration where the user is required to create a profile. A user can then access the different features of the application; creating, viewing, and opportunistically sharing contents. The content in this application can either be a document or a post. Creating content is enabled for courses of interest where each document or post has four attributes: course name, title, body and the number of likes. Additionally, available content can be viewed according to their course name. The user's profile is broadcasted to neighboring users to allow the link establishment among users of similar interests. Once a neighbor's profile is received, comparison is done with local profile to determine missing content at the user's device. If any exist, the user is prompt to connect and download missing content. [sDocuments and posts have expiry dates to efficiently utilize memory resources. Thus, the user is notified before the semester ends about the automatic deletion of the content to consider creating backups. This ensures that the application does not consume all the device's memory by maintaining outdated content. Moreover, when the device's battery is below a critical level, the application prompts initiating a connection to any near device to store the documents and posts to increase the availability of these documents in the network.

Table II summarizes the solutions proposed to answer some of the challenges mentioned in section IV.

C. Test Scenarios

The test scenarios are built based one the OMSN environment shown in Figure 2.

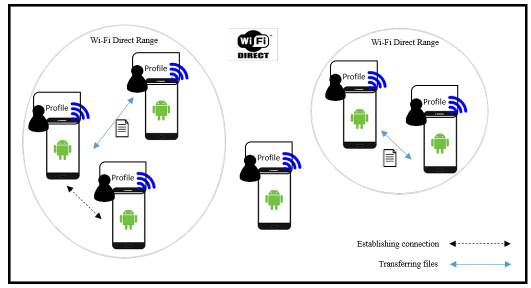


Fig. 2: Scenarios Overview

1) Scenario 1: Bob is a student who installed the application recently. He is asked to create a profile using his university ID number and with current courses he is interested in. After profile creation, Bob can create different posts or documents based on his interest. For example, Bob creates a post titled *midterm material* under *Operating System* course name, which includes some notes regarding the midterm.

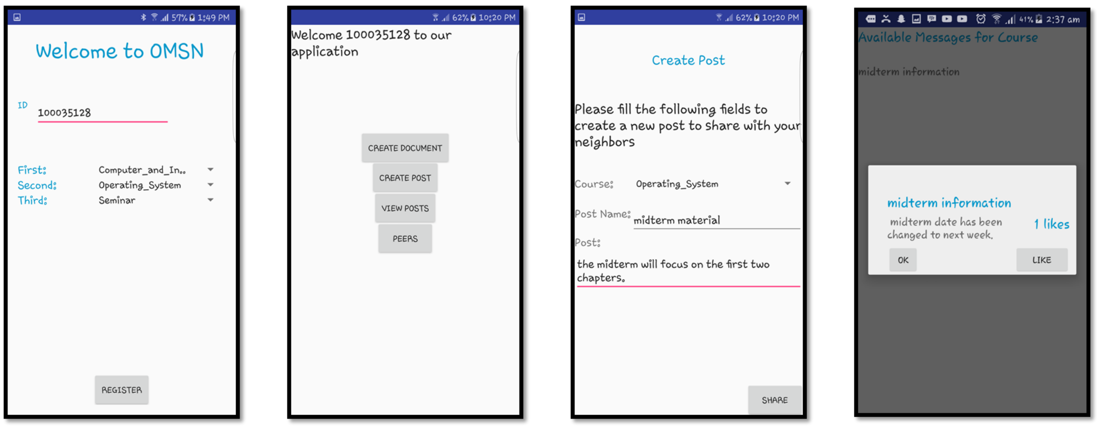
2) Scenario 2: Bob and Alice are studying in the campus play field and both of them have the application installed on their smart phones. Alice receives Bob's interests, which are compared with hers. Bob is not on the trusted friends list of Alice. The application detects that she is interested in *Operating System* too and does not have the *midterm material* post. Alice is prompted to connect with Bob to obtain the missing post and update her profile to include the new post. Moreover, Alice likes the message to validate it and increase Bob's reputation until he can be moved to the trusted friends list.

D. Implementation and Validation

To demonstrate the feasibility of the above described application features, a prototype on Android operating system was implemented. Android operating system was chosen because of its open source platform for development as well as its support for Wi-Fi Direct which is the chosen communication link. The broadcast of profile through services was implemented with the help of [32]. The transmission of posts and documents using Wi-Fi Direct between devices was built on top of the source code in [33]. Figure 3 and 4 are screen captures that describe the scenarios mentioned above and demonstrate the corresponding interfaces for the different features. Testing the prototype was done using the following devices: Samsung Alpha API 21, Huawii ALE-l21 API 21, Samsung galaxy S6 Edge API 23 and Samsung galaxy S4 API 21. Different evaluation metrics were measured to demonstrate the usability of the application. Battery consumption of the prototype when sending different files sizes using WiFi Direct was measured with files of 1 KB, 10 KB, 100 KB, 1 MB and 10 MB. As each file gave negligible battery consumption, it was measured when sending the 5 files consecutively as a package.

TABLE II: Challenges considered

Challenge	Solution Suggested
Content and User Validation	Users can "Like"' posts to validate their content and increase the reputation of the source user. Each participant's app has Friends list. Friends are dealt with as trusted entities.
Legitimate disconnection between devices	Device's battery level is monitored and once it drops below a threshold, users are prompt to sharing content with any available device.
Resource Utilization: Memory Usage	Content are time constrained and interest dependent. They are deleted either once they expire for instance at the end of the term or when the user deletes the interest they are related to.
Resource Utilization: Battery Drainage	Adaptive App where context of the app is collected and decisions are made accordingly.
Replicated Messages	The characteristics of a post or a document are considered when seeing available content to prevent repetitive download of a content



(a) Registration (b) Main Screen (c) Create Post (d) View post and Validate

Fig. 3: Application Scenario

Results using an average of 4 measurements on each device showed the prototype consumes 0-2 % of the battery resource depending on the device hardware. This motivates using the technology for files exchange between users.

The effect of discovery interval on the device power consumption was measured where the broadcasting frequency was varied between 5, 10, 20 and 30 seconds. For all cases, the test was conducted for a fixed time interval of 10 minutes. Results showed that for all the above-mentioned cases the power went from 100% to 98%, which indicated a 2% decrease. This small decrease would not threaten the usability of the application given the features it offers and it would hold for longer test times with longer beaconing intervals.

In addition, the average time required for a device to discover a neighboring device and to initiate a connection a test was measured. The test was conducted to measure the effect of mobility on the system. The results showed that the time required varied from 7 sec to 18 sec. As the mobility follows a people's random walking pattern, 18 seconds of motion could be still considered to be acceptable since users' walking speed is low and the Wi-Fi's coverage range is long.

VI. Conclusion

Opportunistic mobile social network is in its infancy, both from technology and conceptual levels. Different efforts in developing architectural frameworks and applications for OMSN were explored. These efforts were analyzed for challenges and limitations. An architectural framework and an accompanying application were proposed. Different challenges were addressed such as content and user validation, legitimate disconnection between devices and resource utilization. Key solutions for these challenges were proposed and validated through the developed application. In order to improve the prototype, we believe that the user data available in the phone will be used to improve the overall performance of the application. In the future, users' calendar will be used to predict the potential disconnection of the smart phone and hence improve the disconnection management and the content delivery of the OMSN.

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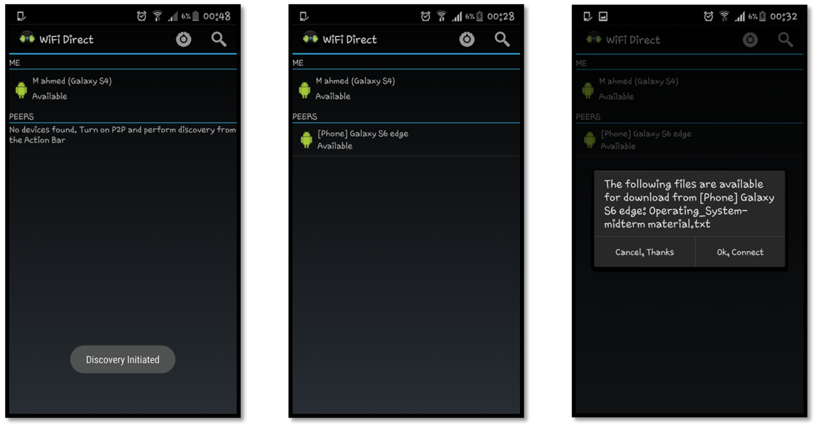

(a) Neighbors Discovery (b) Available Devices (c) Connection Prompt

Fig. 4: Application Connection Scenario

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