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# Recent Advances in Ad-Hoc Social Networking: Key Techniques and Future Research Directions

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**Abstract**
Ad-hoc Social Networks are formed by groups of nodes, designating a similarity of interests. The network establishes a two-layer hierarchical structure that comprises communication within-group and joining with other groups. This paper presents survey and future directions in four areas of establishing ad-hoc social network using mobile ad-hoc social network (MANET) that includes architecture or implementation features, Profile Management of users, Similarity Metric, and Routing Protocols. The survey presents the need to provide social applications over MANET, optimizing profile matching algorithms of users, and context aware routing protocols. Future directions include multi-hop social network applications that can be useful for users even in airplane mode and notifying over MANET when a user of profile with similar interest is nearby.

**Keywords** Social network · Profile matching · Peer-to-peer · Ad-hoc network · WiFi direct · Location-based social networking

## 1 Introduction

After the successful implementation of ad-hoc networks in law enforcement and military tactical communication, the idea to expand the scope of ad-hoc networks to other aspects of human interaction has been received with enthusiasm and almost similar triumph specifically in areas such as electronic classrooms, conferences, convention centers and social networking. Social networking have enabled us to contact with others and discover new friends via LinkedIn, Twitter, Facebook, Research Gate, etc. However, unlike popular web based online social networks that need Internet for communication, this research focus on Ad-hoc Social Network (ASN) which is a social network formed over on-top-of Mobile Ad-hoc Network (MANET).

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Ad-hoc Social Network is defined as a social network of mobile users that share similar profiles and are connected using infrastructure-less networking. ASN is a interest-based local community that is created on-the-fly using MANET [47]. Its size can vary from a large community in an Institute or passengers in an Airplane to a small group of such as group of people attending in a foreign country without International Roaming or group of people in meeting at remote location interested in collaboration.

The current technologies that support ASN in the mobile devices include Bluetooth, Wi-Fi, and Wi-Fi Direct. Google recognized importance of ASN and implemented WiFi Direct Peer-to-Peer Networking (P2P) in Android 4.0+ devices that connects devices without any infrastructure by enabling devices with a built-in soft access point that helps devices to act both as router and client [20]. Thus, ASN is a combination of MANET and Social Network that connect proximate users having common interests.

### 1.1 ASN Applications

ASN implemented on MANET are useful due to the reasons of easy and inexpensive deployment instantly. There are a number of scenarios where ASN can be useful.

*Extending Cellular Network* The cellular network service providers can provide customers a mobile application that uses ASN to extend the networking capability in the remote areas where there is no connectivity e.g. during International Roaming.

*Academic Conferences* Most of the conferences being organized have participants from international institutes who may not prefer to buy local SIM for a short period. Some conference organizers don't share Wi-Fi due to security concerns. However, even if the connectivity is available, it is difficult to extend social networking with strangers. The ASN applications can help to not just connect people nearby but also match interests and notify.

*Airplane* ASN can be used to provide social networking applications and multi-player games inside the airplane. There is no connectivity available, and many flights are around 12 hours or more that creates boredom especially for children. People can use ASN to search for other people with similar interests, children can play multi-player games, and airlines can also provide passenger to cabin crew communication using ASN. ASN applications can also provide in-flight entertainment and shopping experience for low-budget airlines.

*Public Places* ASN can also be used in restaurants, malls to provide customized offers to nearby potential customers and customers can create groups to get bulk discounts from shops. People can play networking games or chat inside metro station, airports, trains, etc.

*Private Places* In residential societies or organization, many times a consensus is required for certain decisions. ASN can help people to connect and vote for different options.

*Emergency Situation* ASN can be used in Natural Disasters even to locate human presence in emergency situations.

*Military* Soldiers can't use public network or GPS since there is fear of being tracked by the enemy. In these situations, soldiers can use ASN to transmit information like messages or pictures of their location to team members.

### 1.2 ASN Characteristics

There is no straightforward way in current social networks to facilitate local social communication. Although face-to-face conversation is possible, it has limited use for file sharing

and group discussions without disclosing the mobile number or email address. Further, the existing social network services assume Internet via cellular or WiFi is always available, which is not true in emergencies, due to cost in International Conference in foreign countries, or due to security aspects. Recently, the ASN has become widespread for universal usage of mobile devices. ASN sets up local communication via mobile devices without using a fixed infrastructure. Typically, ASN has following characteristics, also known as *SPOT*:

*Spontaneous* Spontaneous refers to networking when the nodes discover each other within a short period without any prior planning.

*Proximity-based* The objective of ASN is to bring together people who are nearby and have similar interests; thus Physical Proximity of two or more individuals is utmost importance. Further, nodes are also required to establish and maintain route between source and destination.

*Opportunistic* Opportunistic networks are special wireless networks that exploit the human social characteristics, e.g. similarities, mobility patterns, and interests to perform routing and data sharing. ASN is opportunistic since these are created on-the-fly to connect people nearby.

*Transient* ASN are set-up for temporary purpose and are thus short lived.

### 1.3 Research Issues

Researchers have recommended extending cellular infrastructure via ad-hoc communication technology like P2P. Several studies of research have shown that ad-hoc communication has potential to optimize resources like network bandwidth and battery lifetime. The multi-hop wireless network or MANET has also been proposed to provide networking applications when an infrastructure-based network is hard to deploy or is not possible in some emergencies. MANET allows intermediate nodes to route data for connectivity, and these applications are highly useful for military and emergencies. The rapid advancement of wireless technology has made possible to establish social network services over MANET. The current challenges in ASN can be classified into following three categories:

1. *Profile Matching* Profile Matching refers to determining interests of a particular user and suggesting other nearby users who have interests similar to the user. The role of matching interests is important since the probability of two users being connected is higher when they have similar interests. Profile matching is a challenge in ASN since it doesn't have any centralized infrastructure to maintain users' profiles and further nodes are resource constraint and highly mobile.
2. *Profile Similarity Metric* Profile Similarity Metric refers to a similarity measure between nodes. Since the number of users available for ASN may not be large and thus, as a result, the probability of users getting matched based on static interests will also be small. The static interests may include current city, education, job, etc. Thus, the need of computing the similarity of users instantly without accessing centralized server and preferably using dynamic location-based interests instead of static interests is advantageous for ASN.
3. *Routing* Routing refers to selecting a path to send data packets. The routing protocol provides necessary functions and services to nodes to help them decide and select intermediate nodes to route packets from a source to destination. The nodes are not aware of the existing topology, and further the topology is also dynamic due to nodes mobility.

There exists number of MANET routing protocols handling these issues, however, the protocols don't consider the similarity metric in the topology. The probability of nodes remain connected is higher when the interests similarity between nodes is higher. Thus, incorporating the profile similarity in routing decisions can help provide a stable path and increase network throughput.

This paper summarizes the key issues related to Profile Matching, Profile Similarity Metric and Routing. We also present survey of system architecture and users' preferences. Table 1 compares related work for different ASN features including *Architecture and Implementation; Profile Management; Similarity Metric; Routing*. The comparison analysis shows the need of location-based profile management over P2P.

## 2 Architecture, Framework, and Mobile Application Implementation

Seada and Perkins [51] proposed MANET architecture for proximate social networks using existing wireless interfaces. The authors introduced many research challenges in areas of, e.g., high-density scenario, management of friend lists, and localized search.

Zhang et al. [65] proposed MoNet, which is a Wi-Fi-based multi-hop networking system. The authors proposed WiFace on the top of MoNet to share content over MANET. MoNet uses virtual NIC with 48-bit virtual Ethernet address to support MANET routing protocol. The infrastructure used many mobile nodes deployed in a distributed environment connected with wired Internet and used VPN to connect clients. The content in the WiFace is broadcasted and received and doesn't provide a mechanism for locating people with similar interests on-the-fly.

Zhang et al. [64] proposed BASA—Building Mobile Ad-hoc Social Networks on top of Android. Network Layer of the BASA allows proximate devices to communicate. A device that initiates a network connection subscribe to the published services and create contact after determining the connection details. BASA also conducts network operations to discover nodes, services, and connection changes. The limitation of the BASA is that it needs rooted Android Phone and further there is no interest matching of users before a connection is established.

Hoang and Ogawa [26] developed MANET using P2P over Android. Simulation results indicate advantageous of P2P over Bluetooth. The authors observed stability in the discovery time of P2P even when the devices are increased.

Chung et al. [19] and Joy et al. [27] proposed DiscoverFriends application that creates android multi-hop P2P using IPv6. The communication is facilitated by a confidential ID that is known only to user's friends. It doesn't allow to search new friends with active interests.

Ramos et al. [45] presented a case study, FrameGeoSocial, to create a social network among friends using MANET and GPS.

Rahman and Hossain [44] described a framework to create ASN of millions of people by offering context-aware serious-game services as an incentive. The authors introduced a framework that connects various portable devices using the cloud. It promotes heterogeneity amongst people relating to diverse cultures by grouping the devices to form the interest-based community. The framework uses a requester as a client, and a crowdsource as a server.

**Table 1** Comparison of related work for ASN parameters Protocols

| Paper | Architecture implementation features | Profile management | Similarity metric | Routing |
|---|---|---|---|---|
| Zhang et al. [65] | Virtual NIC | Content shared to all | Not applicable | DSR |
| Zhang et al. [64] | Modified android | Aggregates profiles and stores in a repository and grants access to other users | Not applicable | Uses WiFi, SIP, Bluetooth, and TCP/UDP |
| Kraus et al. [30] | P2P Architecture | Profile managed by users | Cosine similarity | P2P |
| Funai et al. [21] | P2P over modified android | Not applicable | Not applicable | Gateway node switches between different P2P goups |
| Khan et al. [29] and Scott [50] | Shows online gaming, streaming media, sharing content over P2P | Not applicable | Not applicable | Proposed multi-hop P2P as a challenge |
| Li et al. [32] | Created MANET of 10 mobile devices and 40 server nodes | Created user behavior model from crawled social data and questionnaire | TFIDF and text rank | Routing topology created based on similar behavior features |
| Sigholt et al. [52] | Connected nearby devices using WiFi direct on android when cellular network is not available | Online during signup | Nearby users who have already signed-up online | P2P WiFi direct |
| Robinson et al. [46] | Simulated the ad-hoc social network on ns2 | Not applicable | Uses distance metric, a node in range of source but farthest will have high coverage area | Avoid overheads due to link failures by predicting link based on neighbor knowledge re-broadcasting and uses virtual clustering |
| Baker et al. [12] | Device for publishing and forwarding a message to nearby users | Not applicable | Uses subscribe/follow model to create social group | Ad-hoc mesh network |
| Tchendji et al. [56] | Developed SMGenerator [55] to create ASN applications for Android | Publish and subscribe topics | Matching topics/keyword | Virtual network layer using wireless MANET |

Aneja and Gambhir [7] presented an architecture for ad-hoc social network comprising four layers namely Application Layer, Transport Layer, Ad-hoc Social Layer, Ad-hoc Communication Layer. The architecture includes functions to exchange profiles of the users and to exchange messages for social interaction among interested users. The proposed architecture can be used to build applications for ad-hoc social network.

Aneja and Gambhir [9] developed an android based application that matches interests of nearby users and provides profile similarity without using any fixed infrastructure. The application comprises Geographical Layer, Social Layer and Content Layer. The geographic layer allows to browse the list of nearby users with their published profile and profile similarity score. A user may send the connection request to nearby user using WiFi Direct to create a social layer. Content layer allows to exchange text or handwritten messages between connected users.

Gambhir et al. [23] surveyed users to get the preferences for ad-hoc social network. The survey shows a large number of users around 94% have location based interests that means their search queries or interests change with the location. The survey also shows that the users prefer to have at least 75% profile similarity with potential connections.

Tchendji et al. [56] proposed ConfInfo, ad-hoc social network application for scientific conferences. The application used publish and subscribe protocol executed by nodes of mobile ad-hoc network.

Sigholt et al. [52] proposed using WiFi Direct to connect nearby devices using mutual Transport Layer Security authentication. The connectivity among nearby devices is established when the cellular network is not available. The application needs Internet connectivity for the purpose of sign-up.

Baker et al. [12] proposed a publisher device to publishes or forwards a social message for delivery to nearby devices without Internet or telecommunication network.

Oesch and Schuchard [41] simulated Nation Scale Mobile Ad Hoc Network to request and get content using opportunistic encounters by MANET. The simulation results show that MANETs can be used in emergency services when the users are disconnected.

Table 2 summarizes the important features and provide remarks for different prior studies in the area of Architecture, Framework, and Mobile App Implementation of ASN. The comparison of categories shows need to work in the area of providing social applications over P2P among similar users.

## 3 Profile Management

Bottazzi et al. [16] suggested a middleware for ASN comprising two components named Dependent Social Network Manager (PSNM) and Global Network Manager (GSNM) for building a user profile. PSNM announces user profile depending on its diverse interests, and GSNM consolidates PSNM profile with its location id. However, the profiles are not refreshed dynamically.

Campbell et al. [17] suggested adding sensing ability into social networking applications. The authors introduced a system named Cence Me that receives information about neighboring users and brief facts which can be applied in many applications. The authors also proposed a buddy locate service so that a user can receive instant notification if a CenceMe user has a similar profile. The system interprets activities of a user by sensing various sensors of a mobile device, however, in addition to requiring Internet and servers it gives no weight to extract interests from users search and browsing history.

**Table 2** Comparison of related work for architecture, framework, and mobile app

| Paper | Features | Remarks |
|---|---|---|
| Seada and Perkins [51] | Architecture for proximate social networks | Proposed research challenges |
| Zhang et al. [65] | WiFace over MoNet using virtual NIC with 48-bit virtual Ethernet address | No interest matching nearby |
| Zhang et al. [64] | BASA creates ASN over Android | Needs rooting devices and no Interest Matching |
| Hoang and Ogawa [26] | P2P over MANET | Shows P2P advantageous over Bluetooth |
| Ramos et al. [45] | FrameGeoSocial is a social network over MANET and GPS | Profile managed manually |
| Chung et al. [19] and Joy et al. [27] | Discover Friends that creates P2P using confidential ID | Doesn't allow to search new friends with similar interests |
| Rahman and Hossain [44] | ASN provides game services and incentives | No location-based dynamic profile matching |
| Aneja and Gambhir [7] | Proposes middleware for ASN | Overlay components to provide ASN functionality |
| Gambhir et al. [23] | Users preferences for ASN | Conducted users' survey for users' preferences and found preferred profile similarity is 75% |
| Aneja and Gambhir [9] | Location based social networking | Created a mobile app for Android OS that broadcasts limited number of interests in a nearby region and displays profile similarity without sharing any confidential id |
| Sigholt et al. [52] | WiFi direct based social network | Connects nearby devices when cellular network not available by authentication |
| Tchendji et al. [56] | Mobile ad-hoc social network | Developed an application for conferences using publish/subscribe model |
| Baker et al. [12] | Publisher device | Device to publish/forward message to nearby devices |
| Oesch and Schuchard [41] | Nation scale MANET | mobile users can request and get content using opportunistic encounters |

Sarigöl et al. [49] exhibited ad-hoc social network, Ad Social, among users carrying Nokia N810 mobile devices. The users can browse profiles of nearby users and start chatting without using any fixed infrastructure. However, Ad Social needs users to enter profile centrally.

Yiu et al. [62] exhibited an application that discovers mates in proximity based on provided threshold Euclidean distance. The authors stated that the application tunes its proximity distance according to communication cost. The application can be utilized in multiplayer gaming to find players that have similar interests.

Sarigöl et al. [48] implemented network as a shared memory space wherein the participating nodes read/write tuples as key-value pairs. The shared space was used to search for other users in nearby region. However, this approach has limited application and further profile is not learned automatically by the application.

Lee and Hong [31] proposed a mechanism to extract changing interests and uses cosine similarity. The method discloses using meaningful keywords from browsed URLs. However, it doesn't include prior user action or location-based interests. Further, there is a need to improve cosine similarity so that the profiling metric is suitable to ASN.

Trieu and Pham [58] introduced a system named STARS, which is an ad-hoc network of smartphones. It is a data sharing paradigm wherein users wish to share information with different people inside a small group for a reduced amount of time. The system implements features to create a social network and share interests like text, comments, pictures, etc. User records an identifier on the timeline, and the application advertises the id in the network. A decentralized application operating on user's device forms an Interest-based network and implement security and privacy requirement.

Li et al. [33] proposed location-based social network over MANET. The authors defined profile as a vector of keywords with weights. The profile similarity is computed based on if the keyword is present in both profiles or not irrespective of the weight of the keyword. This may have disadvantageous since weight is an important factor to determine as which pair of users are highly similar.

Zhang et al. [66] suggested a privacy-preserving approach to matching the profile of users in a decentralized manner for multi-hop ASN. The method protects privacy by not exposing profile of participants and the submitted preference profile due to a reliable communication channel connecting an initiator and matching users.

Zhang et al. [67] recommended Proximity-based mobile social networking (PMSN) that permits two users to complete profile matching without revealing any data about their profiles exceeding comparison result. However, the user has to pick interest level manually and to set values of different attributes that are numerous is a very tedious process.

Wang et al. [59] proposed a network of nodes connected using P2P. However, it doesn't offer any profile matching before being connected.

Wang et al. [60] proposed the idea of G-friends that stands for geographical location-based friends. The authors computed life-style vectors of users to use cosine similarity for the recommendation. However, cosine similarity as discussed later has disadvantages. Further, the need for a centralized server to process the lifestyle is a limitation for ASN.

Khan et al. [29] proposed status and challenges for P2P. The authors shows that P2P provides the data rate of upto 250 Mbps in range of around 200 meters and can be used for online gaming, streaming media, sharing content over P2P. The authors listed challenges of P2P to provide multi-hop routing. However, the mechanism doesn't allow using P2P without profile matching.

Aneja and Gambhir [4–6, 10] proposed creating local and global profiles, where local profile is created based on local browsing history and other user actions around a particular

geographic location. Global profile is the union of all local profiles. The authors shows that location based profile performs better than global profile in a simulation scenario.

Basta et al. [13] proposed computing strength of social ties for the vehicular social networks. The strength is computed based on the meeting frequency of the network nodes. A learning algorithm is presented that infer driver's social profiles and adapts with driver's habits and preferences.

Table 3 summarizes the important features and provide remarks for different prior studies in the area of Profile Management of ASN. The comparison shows that there is need to work in the area of creating location-profile and optimizing profile matching approach.

## 4 Similarity Metric

Spertus et al. [53] analyzed several similarity functions, e.g., L1-Norm, L2-Norm (cosine similarity), Pointwise Mutual Information: positive correlations (MI1), Pointwise Mutual Information: positive and negative correlations (MI2), Salton (IDF), and Log Odds. The authors inferred that L2-norm or the cosine similarity is the proper similarity standard.

Li and Khan [35] proposes to shift existing social networking archetype towards MANET based social network. The authors used Ontological profile for semantic similarity matching and semantic-based distance vector routing protocol. The routing protocol helps to find users with similar interests. However, the routing protocol has limited use when the profile is not similar, or the threshold is high.

Anderson et al. [3] applied cosine similarity between users to evaluate if the similarity gives indication about the trust or content of both users. The authors found that similarity of users can be exploited for user-to-user evaluation.

Sanguankotchakorn et al. [47] posed a problem of finding nodes of similar interests in the social network over MANET.

Symeonidis et al. [54] proposed recommender system that uses location history to determine users' similarity.

Li et al. [34] proposed a design of location-based social network over MANET. The authors used similarity of users regarding common interests as the social relation. Each node only connects to nodes that are nearby and have common interests; therefore, search success is increased and overhead decreased.

Liaqat et al. [37] exploited similarity-matching social properties of intermediate nodes to maximize bandwidth utilization in ASN.

Han et al. [25] used weighted cosine similarity to measure similar interests. The authors inferred the social interests from users meta-data.

Mizzaro et al. [40] created vector-based user profiles using words from tweet weighted by network centrality. The authors used cosine similarity on the user profiles to computer user similarity.

Zhang et al. [68] created a profile of the user from multiple profiles at number of social networks. The authors used TF-IDF to combine multiple profiles and used cosine similarity for users similarity

Kraus et al. [30] integrated distributed locality sensitive hashing for P2P network. The algorithm hashes users profiles and creates buckets with common hashes. The buckets are dynamically mapped within nodes using content addressable network. In order to search, the algorithm uses the content addressable network with cosine similarity metric.

**Table 3** Comparison of related work for profile management

| Paper | Features | Remarks |
|---|---|---|
| Bottazzi et al. [16] | Middleware for ASN to build and manage profile | Profile not refreshed dynamically |
| Campbell et al. [17] | CenceMe | No weight to user search and browsing history and considers a global profile |
| Sarigöl et al. [49] | AdSocial | No dynamic interests |
| Yiu et al. [62] | Proximate finds a group of users so that each pair of users have similarity within threshold | Uses internet and cosine similarity and needs improvement in computing similarity and to implement for P2P |
| Sarigöl et al. [48] | Provides buddy presence service | Profile keywords entered manually by user and doesn't represent location-based interests |
| Lee and Hong [31] | Profile management | No location-based interest and profile matching |
| Trieu and Pham [58] | Supports interest-based network | Interest shared after connection |
| Li et al. [33] | Location-based social network | No weightage to keywords |
| Zhang et al. [66] | Match profiles of a user in a decentralized manner to protect privacy | Uses a centralized trusted server |
| Zhang et al. [67] | Matches profile of a user without revealing data | Profile interest level set by user and no weight given to current location |
| Wang et al. [59] | P2P | No profile matching before connected |
| Wang et al. [60] | G-friends | Used cosine similarity that has limitations in weighted interest vector |
| Khan et al. [29] | Shows online gaming, streaming media, sharing content over P2P | Allows using P2P without profile matching |
| Aneja and Gambhir [4] and Aneja and Gambhir [5] | GPS-based Location Profile | Proposes to create multiple GPS-based profiles based on keywords extracted from the browsing history of that particular location |
| Basta et al. [13] | Strength of social ties for vehicular social network | Metric reflects the meeting frequency of the network nodes |

Yu et al. [63] proposed a method to recommend friend suggestion based on point-of-interest and check-in data as who can provide more information.

Gambhir et al. [22] proposed piecewise maximal similarity based on minimum weight for each keyword in the interest to match users' profile in the ad-hoc social network. The authors shows that the piecewise maximal similarity metric performs better than cosine similarity on the SocialBlueConn [18] dataset.

Torrijos et al. [57] discussed recommender systems for Location Based Social Network based on common check-ins around same time and trajectories.

Several other researchers used cosine similarity in the area of social networks and addressed the intricacy to analyze and improve profile similarity algorithm.

Table 4 summarizes the important features and provide remarks for different prior studies in the area of Similarity Metric of ASN.

## 5 Routing Protocols

Li and Khan [35] proposed MobiSN for self-configured mobile ASN implemented in Java. MobiSN is a semantics-based framework and presents functions and services such as friend matchmaking, generation of ontology-based profiles, and automatic forming of groups, etc. However, MobiSN considers shared ancestor and root notion in determining the similarity. Further, it is challenging for developers to build applications and services for ASN to meet complex requirements of diverse ASN users.

Kayastha et al. [28] surveyed mobile social networks and suggested exploiting context-aware data distribution for mobile P2P network.

Ahmed et al. [1] proposed community-partition aware replica allocation for ASN to increase the availability of data to partition social community.

Liaqat et al. [38] presented challenges in scheduling algorithms in ASN and proposed Pop-aware scheduling algorithm that computes traffic at the intermediate node and assigns priority to incoming traffic based on centrality, which is social property.

Marinho et al. [39] expanded Wi-Fi Direct technology to transmit the information over multi-hop and measured the number of exchanged messages using routing protocols: (i) flooding, (ii) Ad hoc On-demand Distance Vector (AODV), (iii) AODV-Backup Route (AODV-BR), and (iv) Location-Aided Routing (LAR).

Xia et al. [61] reviewed prior work exploiting social characteristics for routing since the mobile nodes are carried by people. The authors proposed to innovate routing protocols that uses users/devices connections. However, this is only good if the nodes follow the same pattern and may not be beneficial in cases nodes changes their patters.

Palani et al. [42] proposed selecting forwarding node as the node with interest similarity and common contacts to distribute a file in a mobile ad-hoc network.

Gupta et al. [24] proposed social-tie-strengths-based routing in MANET, where nodes travel in group and mobility is planned. The method is particularly useful in military and emergency situations where soldiers or unmanned vehicles travel as per defined plan. The social tie based strength considers the frequency of encounters. The routing algorithm has two activities (i) table exchanges and (ii) route selection. Table exchange activity provides sufficient information to nodes to select reliable path during route selection. The protocol uses social networking for routing decision. However, it is not a general protocol that can be used to deploy ASN where the mobility is not planned, and the nodes are not aware of each other.

**Table 4** Comparison of related work for similarity metric

| Paper | Features | Remarks |
|---|---|---|
| Spertus et al. [53] | Analyzed various similarity functions and recommended cosine similarity | Cosine similarity has limitation for ASN interest vector with weights assigned to different interests |
| Li and Khan [35] | Ontological semantic profile matching | Limited use when profile not similar or the threshold is high |
| Anderson et al. [3] | Studies effect of similarity of two users in evaluation of another user | Used cosine similarity that can be improved for ASN |
| Sanguankotchakorn et al. [47] | Proposed challenges in searching similar nodes over MANET | Nodes similarity is a challenge |
| Symeonidis et al. [54] | Location history to determine users' similarity | The locations previously visited may not represent current-location interests |
| Li et al. [34] | Used similarity of users as the social relation | Static profile without considering different weight to different keywords |
| Liaqat et al. [37] | Used social properties of intermediate nodes for bandwidth utilization | Controls data rate based on similarity |
| Han et al. [25] | Utilized weighted cosine similarity based on probability of sharing interest. Assigns less weight to popular interests | No weight to the frequency of a keyword |
| Mizzaro et al. [40] | Created profile from keywords used in twitter and used cosine similarity | Needs improvement to implement it for ASN to extract text |
| Zhang et al. [68] | Created a profile by uniting various profile over different social networks | Used cosine similarity that needs improvement for ASN |
| Kraus et al. [30] | Used cosine similarity over collection of objects that have large probability to be similar | Needs improvement in profile similarity for ASN |
| Yu et al. [63] | Recommend friend suggestion based on check-in data | Considers historical data without giving weight to location-based interests |
| Gambhir et al. [22] | Piecewise maximal similarity | Computed profile similarity based on individual weighted attributes |
| Gambhir et al. [57] | Recommender system for location based social network | Used common check-in and trajectory within the same time window |

Aneja and Gambhir [8] proposed including social profile metric in the AODV routing protocol. The idea is based on the fact that ad-hoc mobile nodes are carried by humans which have defined patterns in social networking. The simulation results by ns2 indicate that social profile aware AODV performs better than AODV when the number of nodes are high and even in case when mobility of the nodes is also high.

Arafat and Moh [11] presented network of Unmanned aerial vehicles (UAVs), where UAVs can be connected in ad-hoc manner. The authors discussed main challenges as frequent link failures, routing overhead, packet loss, etc. The ad-hoc routing protocols which can give good performance in low density and high mobility scenarists will be advantageous for UAV network.

Li et al. [32] proposed ad-hoc mobile cloud to share resources among participating nearby mobile devices. The topology within the mobile cloud is created based on the behavior of the mobile user so that similar behavior users are grouped under same cloud.

Liaqat et al. [36] discussed need of research to incorporate social awareness for congestion control in ad-hoc social network, wherein the congestion may occur due to exchange of social properties and other meta data.

Alrfaay et al. [2] proposed social aware routing protocol to predict the probability of the node to deliver data packets.

Borrego et al. [15] identifies influencer nodes who has high social centrality even with high dynamic changes in the topology.

Robinson et [46] proposed predicting link based on neighbor knowledge re-broadcasting. The authors used loose virtual clustering when the connectivity factor of the network is less than 0.5. Low connectivity factor implies high rebroadcast probability, and thus the protocol selects B-nodes for communication to reduce overheads.

Rahim et al. [43] proposed routing protocol based on Social characteristics for Vehicular Ad hoc Networks. The authors exploited community acquaintance, node centrality, and activeness to transfer packets. The authors generated mobility traces using VanetMobiSim and evaluated the protocol using ns2.

Bing et al. [14] discovered stable social connections and social characteristics in wireless ocean vessel ad-hoc network and proposed familiarity based routing and community based routing. Familiarity based routing uses connection strengths between vessels to compute encounter probability of the potential forwarder with message receiver, while, community based routing uses inter-community betweenness centrality of a potential forwarder to forward messages.

Table 5 summarizes the important features and provide remarks for different prior studies in the area of Routing Protocols of ASN.

## 6 Conclusions and Future Work

During the last decade the social networking has changed the way the people use information and technology equipment for the communication. However, location-based social networking without using Internet is still not available commercially.

This research work has contributed in providing recent developments in the area of middleware architecture, optimizing profile matching, profile similarity metric, routing algorithms, and android based mobile application for ad-hoc social networking.

**Table 5** Comparison of related work for routing protocols

| Paper | Features | Remarks |
|---|---|---|
| Li and Khan [35] | Proposed semantics-based distance-vector query routing that allows a node to make routing decision by knowing its immediate neighbors and limited resource information | Overhead in case of high mobility |
| Kayastha et al. [28] | Presented survey of a mobile social network for its applications, network architectures, and protocol design issues | Challenges in community detection, content distribution, mobility, and privacy |
| Ahmed et al. [1] | Proposed data replication to avoid data losses in case of unpredictable community or network partition in ASN | Used social context in the community-partition aware replica allocation method |
| Liaqat et al. [38] | Proposed scheduling algorithm for ASN that computed traffic load and prioritize incoming flow using degree centrality | Used social property in scheduling packets |
| Marinho et al. [39] | Tested routing protocols e.g. AODV over P2P and found routing load ok for two or three devices | Context aware routing can help to reduce the routing load |
| Xia et al. [61] | Reviewed social aware networking and presented open challenges in mobile social sensing, privacy, selfishness, and scalability | The survey indicates that social property of a node is a powerful source for designing network and routing and forwarding protocols |
| Palani et al. [42] | Proposed a social network-based peer-to-peer substance file distribution system in disjointed mobile ad hoc Networks | Used interests of a node and contact occurrences for file distribution |
| Gupta et al. [24] | Proposed routing algorithm of nodes for which the planned mobility of the nodes are partially known and the nodes travel in groups | Use social tie as strength as a measure |
| Aneja and Gambhir [8] | Social profile aware routing protocol | Modified AODV routing protocol to include new fields for profile matching so that nodes which have similar profiles become intermediate nodes |
| Arafat and Moh [11] | Developed routing protocol for low density and high mobility nodes | Developed network of unmanned aerial vehicles using ad-hoc network |
| Li et al. [32] | Network topology based on similar users | Developed ad-hoc mobile cloud to share resources |
| Liaqat et al. [36] | Congestion control for ad-hoc social network | Discussed that congestion may occur due to social properties and metadata |
| Alrfaay et al. [2] | Social aware routing | Computed probability of the node to deliver data based on similarity of social characteristic from social profiles |
| Borrego et al. [15] | Adaptive routing through influencer nodes | Uses social centrality to decide influencer nodes |
| Robinson et al. [46] | Neighbor Knowledge-based Rebroadcast algorithm | Minimize routing overheads when the connectivity in the network is less |
| Rahim et al. [43] | Social characteristics in the routing protocol | Implemented social based routing for vehicular ad-hoc networks |

**Table 5** (continued)

| Paper | Features | Remarks |
|---|---|---|
| Bing et al. [14] | Social routing for ocean vessel ad-hoc networks | Implemented social characteristics in routing for vessel monitoring system |

However, the issues including Profile Management and Matching profile described in this paper are not just issues in ASN but also in an online social network like Facebook, Twitter, and LinkedIn etc. The future work can include:

- Usage of geo-social profile algorithm and PMS Metric for the application of online social network.
- Usage of SPA-AODV for the MANET communication in general

Currently, most of the flights ask to stop using Mobile phones and wireless network, but no technical study has been conducted whether the usage of mobile phones with P2P interferes with flight communication. A technical study should be conducted to verify if P2P or MANET communication is flight safe or not. The study can be conducted by measuring signal strength when the number of users using P2P is very high to know if it interferes with flight communication. The current practice of keeping mobile in airplane mode is because the mobile phone is customized to increase the signal strength when it couldn't find communication cellular tower. However, Wi-Fi or P2P doesn't work like that since the mobile phone doesn't increase signal strength if it is unable to connect to Wi-Fi hotspot or it P2P peers. This will open new applications for ASN. Thus, the future work may include:

- Measuring signal strength of P2P when the number of mobile devices are high to verify if the signal is sufficiently high to interfere with airplane communication
- Developing ASN applications for airplane passengers to play online games and passenger to airplane communication
- Developing ASN applications to push notifications to nearby users by businesses

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