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Opportunistic information dissemination over hybrid ASN using publish/subscribe communication model

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RÉSUMÉ. Les réseaux sociaux ad hoc (RSA) sont des réseaux sociaux qui existent au sein d'un réseau mobile ad hoc (MANET). De nos jours, presque tous les appareils mobiles tels que les smartphones et les ordinateurs portables ont la capacité de se connecter directement les uns aux autres et de former ainsi un MANET sans avoir besoin d'une infrastructure préexistante. La communication dans un tel réseau social consiste généralement à ce qu'une station diffuse ses centres d'intérêt qui peuvent correspondre à ceux d'une autre station avec laquelle elle peut ensuite engager une conversation. Cependant, la couverture des RSA est limitée à une petite zone géographique, en raison de la portée de communication limitée des stations MANET. Dans cet article, nous proposons une stratégie de diffusion opportuniste de l'information sur les RSA hybrides, définis comme des RSA dont le MANET sous-jacent est hybride. Notre solution est basée sur SocialMANET, un protocole de diffusion de l'information pour les stations d'un MANET utilisant le modèle de communication par publication/abonnement basé sur les sujets. La nature hybride des MANET que nous considérons suggère qu'ils sont couplés à un réseau d'infrastructure, et vise donc à étendre la couverture de ce dernier.

ABSTRACT. Ad hoc Social Networks (ASNs) are social networks that exist within a Mobile Ad hoc NETwork (MANET). Nowadays, almost all mobile devices such as smartphones and laptops have the ability to connect directly to each other and thus form a MANET without the need for a pre-existing infrastructure. Communication in such a social network generally consists of one station broadcasting its interests which may match those of another station with which it can then engage in conversation. However, the coverage of ASNs is limited to a small geographical area, due to the limited communication range of MANET stations. In this paper, we propose an opportunistic information dissemination strategy over hybrid ASNs, defined as ASNs whose underlying MANET is hybrid. Our solution is based on SocialMANET, an information dissemination protocol for MANET stations using the topic-based publish/subscribe communication model. The hybrid nature of the MANETs we consider suggests that they are coupled to an infrastructure network, and thus aims at extending the coverage of these.

MOTS-CLÉS : Réseaux sociaux ad hoc, publication/abonnement, sujets, réseaux mobiles ad hoc hybrides, diffusion de l'information

KEYWORDS : Ad hoc Social Networks, Publish/subscribe, Topics, Hybrid Mobile Ad hoc Networks, Information dissemination

1. Introduction

Ad hoc social networks (ASNs) are social networks that use mobile ad hoc networks for their implementation and to provide communication between different stakeholders. Sapna Gambhir in [1] defines ASN as a close network that uses the ad hoc network to socially connect interested users; a combination of a social network that maintains the profile and interests of the users, and an ad hoc network that helps to connect nearby users without a centralized access point. ASNs can be used in social locations such as travel stations, football stadiums, hospitals, school and university campuses, etc. In a travel station, for example, ASNs can be used to communicate between passengers with the same interests (e.g. same destination, same boarding bus), or by a travel company to pass on information to passengers at an agency (e.g. imminent boarding for passengers on a particular bus, delay in scheduled departure of a bus, etc.). Nagender Aneja et al in [2] listed many other application areas of ASNs, including cellular network extension. Indeed ASNs can be deployed in areas not covered by infrastructure networks such as areas of natural disasters that have damaged the existing infrastructure.

Communication in ASNs is generally based on interests. A station broadcasts its interests into the network. These are received by another neighbouring station which matches its local interests. If a match is found, the two stations can then engage in a conversation as they share common interests. In [3] for example, an architecture and implementation of social networks on commercial mobile devices is presented that allows the name and a limited number of keywords representing users' interests to be broadcast without any connection in a nearby region in order to facilitate the connection of individuals. A similar principle is employed in [4] where stations in an ASN communicate via publish/subscribe by periodically broadcasting announcements containing the identifiers of the topics they have subscribed to. These topic identifiers are used to identify stations that share the same interests.

Thanks to the underlying MANET, ASNs can be set up spontaneously without the need for any pre-existing infrastructure and therefore have the advantage of being all-weather, all-terrain networks. They also have the advantage of being inexpensive and accessible to all. Indeed, almost all mobile devices (smartphones, laptops, etc.) nowadays have the capacity to communicate in an ad hoc manner thanks to technologies such as Bluetooth and Wi-Fi. These devices have become cheap and accessible to all. However, it is easy to see that such networks, although having the advantage of being cheap and accessible, are limited in terms of network coverage because by definition, the stations of such a network communicating by radio wave cannot do so beyond a certain distance, which limits the range of the network. If we take the example of the travel company above, let's imagine that a bus departing from an agency a1 in a city c1 is supposed to stop at another agency a2 in a city c2 to pick up other passengers. If there is a delay in the departure of the bus from agency a1, the passengers of this agency as well as those of agency a2 should be informed. This shows in this case the need to link the different ASNs formed by the passengers of a1 and a2 agencies respectively.

In this paper, we propose an approach for information dissemination within ASNs coupled with infrastructure networks. This coupling will not only extend the range of ASNs but also extend the coverage of the infrastructure network as stated by Mohammad Al Mojamed in [5]. The communication model we consider is the topic-based publish/-subscribe communication model. Indeed, the solution we propose in this paper is based on the SocialMANET protocol. This is a publish/subscribe information dissemination proto-

col for MANETs presented in [4], to which we made some enhancements to make it able to work in an ASN whose underlying MANET is coupled to an infrastructure network.

The rest of this paper is organised as follows: section 2 presents similar works found in the literature, section 3 briefly presents the information dissemination protocol we used and section 4 is dedicated to the presentation of the improvements we added to that protocol. In section 5, we set the basis for an intensive evaluation of our approach and conclude in section 6.

2. Related works

In [6], the authors clearly illustrated the need to couple ASNs with infrastructure networks for better accessibility to the information disseminated and for a wider coverage of both ASNs and infrastructure networks. In a case study that the authors presented concerning vehicular social networks, they identified three types of communication: vehicle-to-vehicle, vehicle-to-person (pedestrian) and vehicle-to-infrastructure.

Efforts have been made in the literature to provide solutions to the problem of integration of ASNs and infrastructure networks. In [7], the authors present the challenges related to this integration and review the strategies used in the literature. The solutions proposed in [5], [8] and [9] consist in extending a routing protocol used in MANETs to provide bi-directional connectivity between ad hoc stations and hosts in infrastructure networks. The common principle of these solutions is to use a set of ad hoc hosts known as Gateways to act as bridges between the two networks.

In [13], the authors propose a secure publish/subscribe system based on smart contract in autonomous vehicle networks using a truck platoon system used as brokers of the publish/subscribe system. A cloud server is used to establish a contract between subscribers and brokers.

The authors in [10] propose an information dissemination protocol based on content-based publish/subscribe in a hybrid VANET. The protocol uses the infrastructure (consisting of a set of fixed information stations distributed in the city and capable of communicating with vehicles via Wi-fi) if existing, and vehicle-to-vehicle communications. A published message is disseminated within a specific geographical area called the home zone (e.g. the area surrounding an accident point). Vehicle-to-vehicle and vehicle-to-infrastructure network communications are used to maintain publications within their home zones. Although this approach is effective as shown by the simulation results presented by the authors, it is highly dependent on GPS, navigation system, digital city map, etc. and requires very sophisticated vehicles equipped with these technologies. This is the observation made in [11] where the authors present a publish/subscribe system for hybrid VANET environments consisting of fixed information stations and mobile vehicles. In this approach, the information stations are connected in DHT mode (Chord [12]) to the Internet and act as rendezvous points for publications and subscriptions. These information stations are also equipped with an omnidirectional IEEE 802.11 antenna and have a fixed range as much as the vehicles. Vehicles can therefore communicate in ad hoc mode with the information stations in the same way as they communicate with each other. Communication between vehicles and from vehicle to information stations is done by flooding, which can be a real bottleneck and lead to heavy power losses of the network stations. Moreover, while vehicles are not greatly affected by the limited energy constraint characteristic of MANETs in general, many devices such as mobile phones that

could constitute a MANET network still suffer from this limitation, making it difficult to envisage the generalisation of this solution to ASNs.

3. Information Dissemination over MANET stations: SocialMANET

Information Dissemination over MANET stations is ensured by SocialMANET. This section gives a brief description of this protocol. For more information on it, interested reader should rely on [4].

SocialMANET is an information dissemination protocol using a topic-based publish/-subscribe communication model in an ASN; it was proposed by Maurice Tchoupé et al [4]. It is subdivided into three sub-protocols which are: (1) the subscription sub-protocol, (2) the publication sub-protocol and (3) the dissemination sub-protocol. The first two give a hint of what they consist of by their rather indicative names and are relatively simple. The third sub-protocol is the core of this protocol and allows for the dissemination of publications from one network station to other stations based on their interests and/or altruistic nature. It consists of two phases carried out by all stations in the network independently of each other: the *needs detection phase* and the *publications dissemination phase*.

SocialMANET stations periodically broadcast an announcement message named *QUERY* (format illustrated in Figure 1) during the *needs detection phase*. This message contains the identifiers of the topics they have subscribed to, and for each of them the identifiers of the publications they have on these topics. The reception of this message triggers the *publications dissemination phase* at the receiving stations. During this phase, the information contained in the *QUERY* message is used by the receiving stations to calculate which publications they can provide to the sending station, according to their common interests in terms of topics they have subscribed to. Once this calculation has been made, and if they find that they store at least one such publication, they broadcast the publications they own according to the recent calculation. When a station receives a publication on a topic it has subscribed to and does not yet own, it stores it and is therefore able to broadcast it as well.

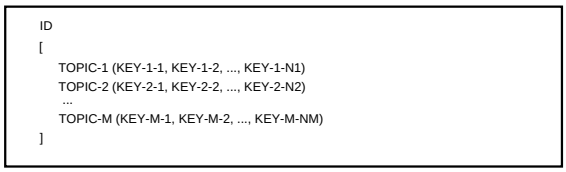

Figure 1. *QUERY message format*

SocialMANET uses an opportunistic approach whereby a station only disseminates information during fugitive contacts with other interested stations. This is to avoid wasting the stations' energy on disseminating information unnecessarily or having them participate in the dissemination of information that they are not interested in. In practice, this protocol is run on a virtual network layer within an existing physical network (a mobile ad-hoc network). Any station in the network participating in the execution of the SocialMANET protocol is autonomous and is able to communicate with any other station in its neighbourhood (a station's neighbourhood consists of the stations that are within its radio

range). Each station can be both a publisher and a subscriber. All stations can disseminate the publications they own to interested subscribers.

4. Proposed Solution

The solution proposed in this paper is based on the protocol for disseminating information in ASN SocialMANET, but modifies it to make it capable of supporting integration with infrastructure-based networks. It is very similar to the solutions presented in [5], [8] and [9], consisting in extending a routing protocol used in MANETs to provide connectivity between ad hoc stations and hosts in infrastructure networks. In our case, it is rather the communication protocol which is extended to support the integration. We also introduce the management of large files. Indeed, the contents of publications in the SocialMANET protocol can be simple texts the size of an SMS, or any type of file, in this case videos, which can be very large.

4.1. Network Design

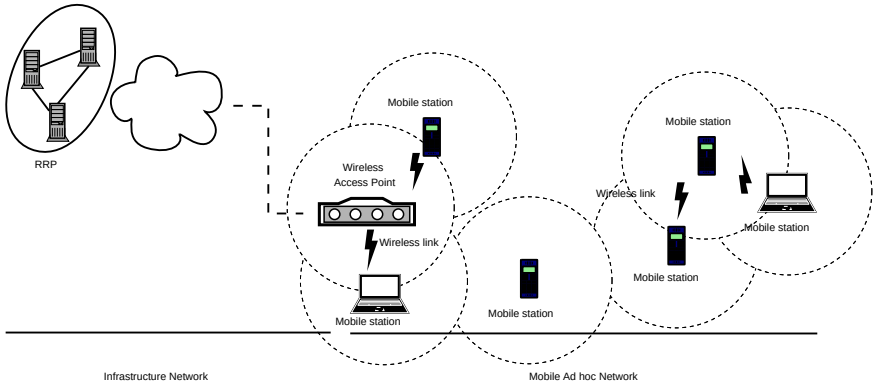

Figure 2. *Network architecture*

Figure 2 shows the general architecture of the network we are considering. We have mobile stations that communicate with each other via radio waves, using technologies such as Bluetooth or WiFi. The infrastructure network can be Internet or any IP network with fixed and perfectly addressable stations. The communication between the MANETs mobile stations and those of the infrastructure network can be done through the cellular network (3G/4G) or through a Wifi access point for example. Each MANET station is able to contact a station on the infrastructure network if it has access to it. In the case of an Android smartphone, for example, access to the infrastructure network can be detected by a change in the status of the Wi-Fi indicating the connection to an access point when the Wi-Fi is activated, or when the user activates the mobile data connection (3G/4G) for example.

No MANET station is used as a gateway by other stations. This adheres to the principle of no energy wastage employed in [4] that there should be no multi-hop communication, thus avoiding stations wasting energy to transfer messages that are not intended for them.

In the infrastructure network, we consider the existence of an entity called Remote Rendezvous Point (RRP). It can be station known and accessible by all MANET stations having access to the infrastructure network. It is considered to be subscribed to all topics in the publish/subscribe system. It is considered to have an unlimited amount of storage space and energy, so that it can store all publications coming from any MANET station. The RRP can also be a set of fixed stations collaborating in a distributed way to ensure the storage and dissemination of publications, and linked together by a Chord [12] network over Internet for example.

4.2. Large files management

The solution we present in this paper uses the SocialMANET protocol for the dissemination of information in the ASN. In most existing publish/subscribe systems, publications are considered as simple text messages. It is stated in [4] that the SocialMANET protocol considers publications to be any kind of file. However, no specific solution has been proposed for handling cases of large files that require special attention. We have taken advantage of the integration with infrastructure-based networks to propose a solution for this case here.

We have introduced two new parameters for each ASN station, namely *PUB-MAX-SIZE-IN* and *PUB-MAX-SIZE-OUT*, representing respectively the maximum size of a publication that can be received from another station in the MANET and the maximum size of a publication that can be broadcast in the MANET. Thus, during the construction of the message containing the publications to be disseminated during the publication dissemination phase of the SocialMANET protocol, an ASN station does not include publications whose size is greater than the value of the *PUB-MAX-SIZE-OUT* parameter. However, as will be seen in Section 4.3, these large publications can be retrieved from and sent to the RRP without any restriction. Algorithm 1 is executed by the MANET stations when they receive a publication from a neighbour station.

Algorithm 1 ASN Station Algorithm (handling a received publication)

Input: ***PUB*** *the received publication*

```
1: if Sizeof(PUB) > PUB-MAX-SIZE-IN then
2:     Discard(PUB)
3: else
4:     Handle(PUB)
5: end if
```

Basically, when a publication is received by a station, it discards it if its size is greater than the value of the *PUB-MAX-SIZE-IN* parameter. Otherwise, the publication is handled as described in the SocialMANET protocol [4].

4.3. Contacting the Remote Rendezvous Point (RRP)

When an ASN station discovers that it has access to an infrastructure network, it instantly initiates a communication with the RRP located on this network by sending it a message identical to the classic *QUERY* announcement message of the SocialMANET protocol. Processing this message allows the RRP to deduce two pieces of information. The identifiers of the publications to be sent to the ASN station and the identifiers of the publications to be retrieved from the ASN station. In response, the RRP sends back to the ASN station the list of publications which it knows, after interpretation of the *QUERY*

message received, that it needs. It also sends the identifiers of the publications to be requested. The ASN station then sends these publications to the RRP and thus the RRP and the ASN station are all up to date with each other.

Although the opportunistic nature of our solution is also inherited from the SocialMANET protocol used, which exploits fugitive contacts between stations sharing the same interests to disseminate publications, it is also easy to see that the fact that MANET stations take advantage of temporary access to the infrastructure network to update themselves and thus the RRP also gives it its opportunistic nature.

5. Validation planning

We plan to evaluate our solution through extensive simulations in order to verify its validity, to assess its impact on the SocialMANET protocol and to identify the conditions under which it provides a better performance in terms of effective reception rate of publications by interested subscribers and energy consumption of stations. Thus, the main metrics we will evaluate are the effective reception rate of publications by interested subscribers and the energy consumption rate of the stations. We will also evaluate the impact of the parameters *PUB-MAX-SIZE-IN* and *PUB-MAX-SIZE-OUT* on the energy consumption of the ASN stations and we will try to determine the values and possible additional conditions for which this impact is better in the sense of reducing the energy consumption of the stations.

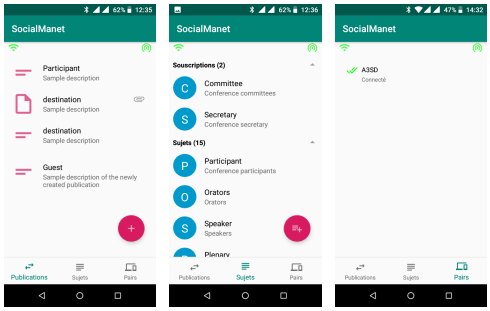

Figure 3. *Prototype application screen shots*

We also plan to carry out real experiments on a hybrid ASN whose stations are Android smartphones and the Internet, the infrastructure network on which a server acting as an RRP is located. For this purpose, we have started the implementation of a prototype Android application to implement the SocialMANET protocol and to integrate our solution. Figure 3 shows some screen shots of the current state of this prototype.

6. Conclusion

In this paper, we have presented an opportunistic solution for information dissemination in a hybrid ASN. Our solution is based on the SocialMANET information dissemination protocol using a publish/subscribe communication model that we have adjusted to enable integration between ASNs and infrastructure networks.

In order to evaluate the validity of our solution, we plan to perform intensive simulations in the near future. In order to carry out real experiments of our solution within an ad hoc social network of Android smartphones, we have started the development of a prototype Android application implementing the SocialMANET protocol and integrating our solution.

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