Paving the way towards delivering messages based on user interests in OppNets

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***Abstract*—We present the Interest-based Routing protocol (*IRP*), a new routing strategy for Opportunistic Networks based on learning about the users' real-time changing interest in different topics. *IRP* uses these users' interests to identify the messages' destinations, and as these destinations can change at any time, to make forwarding and delivery decisions according to it. Learning about interests at every opportunistic contact allows *IRP* to build a perception of the interest that may exist in the network and to use it to make forwarding decisions to relay messages when and where there is interest in a topic. This perception is also used to intelligently manage the buffer to remove only messages that have low interest when space is required. To evaluate *IRP*, we designed a scenario located in Barcelona. Then, we ran a set of simulations, studied the performance of our proposal and compared it with other opportunistic algorithms. In them, *IRP* delivered the higher number of messages and relayed the lower number.**

***Index Terms*—OppNets, DTN, users' interest**

I. Introduction

The evolution and increasing development of smartphones have caused people to become increasingly dependent on their devices and applications to share thoughts, experiences, or interests.

One of these applications, is Twitter, where senders use a #hashtag to define a message topic, and receivers filter the messages they want to read according to their topic interest. These types of applications usually follow a centralized architecture, and are almost always used in connected scenarios, where the users' devices can reach the servers at any time.

Applications like Bridgefy[1] or the discontinued Firechat[2] have been designed to operate in scenarios where there is no fixed connectivity infrastructure. Other applications, like the opportunistic Twitter [1], work in hybrid networks. All of them base their design on the *store, carry and forward* Opportunistic Networks (OppNets) [2] paradigm using a broadcast strategy, where any message is sent to all users within range, flooding the network regardless of the amount of users that may be interested in it.

Pure OppNets solutions that allow users to send messages on any topic to multiple destinations that can change at any time have not been presented yet; therefore, it would be very helpful to provide the developers with tools that allow it in an efficient way.

To make it possible, users should be able to create messages on any topic at any time and send them without knowing who will receive them. Also, users should be able to decide whether they want to receive messages on any topic at any moment, so, messages' destinations can change in real time according to users' choices. Finally, users' interests must be used to forward messages and to decide if they should be dropped.

Therefore, the main contribution of this work is the proposal of the Interest-based Routing protocol (*IRP*), a routing strategy for making forwarding decisions based on the user's interests. It allows message forwarding to multiple destinations that change in real time and it delivers the messages considering the user's interest in different topics. *IRP* builds a perception of interest to forward the messages when and where there is interest, and to define an intelligent buffer management strategy. In addition, this strategy removes the messages from the network when there is no more interest in them.

To evaluate *IRP*, we designed a set of experiments with different interest topics using the *TheOne* [3] simulator, in which we compared *IRP* with Epidemic [4] and Spray and Wait [5].

The remainder of the paper is organised as follows. We discuss the related work about existing routing solutions for OppNets in Section II. Then, we present and analyse our new routing strategy and its implementation in Section III. Follow-

[1]https://github.com/bridgefy

[2]https://edition.cnn.com/2014/10/16/tech/mobile/tomorrow-transformed-firechat/index.html

ing, Section IV details the scenario used in the experiments and the obtained results. Finally, in Section V we draw the conclusions and list some future work lines.

II. Related Work

Opportunistic Networks (OppNets) are a type of network where there is no fixed infrastructure, and in which contacts between mobile devices are exploited for message forwarding. Contacts between nodes are intermittent, and there is no fixed path from source to destination of a message. So, in this type of network, the store, carry, and forward paradigm must be used to reach the message destination.

The most basic strategy for the distribution of messages is the Epidemic [4] algorithm, which, in order to reach the final destination, forwards a copy of the messages to all nodes contacted, flooding in this way the network. Another known algorithm is Spray and Wait [5], that is based on flooding the network with a limited number of copies of each message and waiting until one of these nodes with a copy of a message contacts the destination.

As Epidemic and Spray and Wait, several routing protocols in OppNets have been implemented with different strategies for different scenarios.

Nowadays, a new trend of routing protocols in OppNets based on social contacts has emerged. Some studies present reviews on social-aware routing protocols [6] or on routing protocols based on social relationships [7], that explain why these are a promising approach to improve the data delivery performance. These protocols use different approaches, including mobility patterns of nodes, combination of social attributes and context as methods for taking forwarding decisions.

In [8], the authors describe a forwarding mechanism, where the cosine similarity metric between the interest profiles of the nodes, and the total time a pair of nodes are in contact are used for making forwarding decisions. All nodes must previously declare their interest, and it assumes that individuals with similar interests tend to meet more often. Anyway, real users may declare their interests at any time, and they do not necessarily meet users with similar interests more often.

Routing protocols like [9], that applies social network analysis and exploits two social and structural metrics to forward messages to their fixed and known destination, or [10], in which social characteristics of the users are used, focusing on the similarity between nodes' interests and data packets, by simultaneously considering the social characteristic of the nodes and the device energy for forwarding messages.

Although all these proposals try to find solutions using social similarities between node characteristics, they do not consider what happens if users change their interest in receiving a message at any time or if there are several destinations for the same message, that are also changing due to the interest.

In this line, a close approach with the use of interests are the works presented in [11], [12] and [13]. In [11], authors use a utility function that reflects the probability of encountering nodes with a certain interest among the ones that have similar daily social habits for forwarding the messages. In [12], authors assume that nodes are subscribed to channels, and nodes with common interests tend to meet each other more often than nodes that do not. The node's online social connections (friends on social networks), common interests, and contact history are used for deciding to forward messages to their destinations. Finally, in [13], the authors present the use of data popularity (message most popular) for prioritizing messages and forwarding them in the network.

Although these papers mention similarity between nodes or the use of interests as part of their proposals, neither contemplates that users do not necessarily must have similar social habits or common interests to relay a message, or that this interest can change according to users' interest at any time, and, therefore, the messages destinations also change.

Therefore, after reviewing the previously published work, the conclusion that can be drawn is that none of the presented algorithms, even the newest ones, can adapt to real-time changes in the users' interests in receiving a message, or to new topics appearing at any moment.

III. Interest-based Routing Protocol

In this section, we present the *Interest-based Routing Protocol (IRP)*, a new routing strategy to support the implementation of applications where network users interact to send and receive messages on different topics that interest them.

We first describe the Interest and Perception concepts, followed by the forwarding mechanism used and, finally, how the message buffer is managed.

A. Interest and Perception

In order to build *IRP*, we have defined the concepts of *Interest in a topic* and *Perception of Interest in a topic*, which are combined to provide this routing strategy that supports real-time changes in the interest in receiving messages on different topics, and that associates the lifespan of the messages to the interest on their topics.

The *Interest in a topic* (I_t^N) is the measure of how interested a node N is in receiving messages regarding a specific topic t, while the *Perception of Interest in a topic* (P_t^N) is the measure of the *Interest in a topic* that node N perceives around it regarding every topic, based on its encounters with other nodes. By building *IRP* we aim to:

- Allow real-time changes in users' interests on topics, and therefore adapt to the fact that message destinations can change at any time.
- Deliver as many messages as possible on the topics in which there is a high global interest.
- Improve the use of network resources when there is not enough interest in a topic, preventing the network from being flooded with unnecessary messages.
- Allow messages to remain on the network as long as there is interest in them.

Figure 1 summarizes how *IRP* nodes update their perception. In Figure 1a, node A, who is not interested in a topic and has a low perception about it, moves close to several nodes interested or with high-perception in this topic, so with each encounter its own perception increases, and it finishes with a high perception.

In, Figure 1b, this same node A, who is not interested but now has a high perception, moves through an area with nodes with a low perception that are not interested, and in each contact node A's perception decreases.

So, the more interested or high-perception nodes a node encounters, the higher its perception goes up, but also, the more disinterested nodes it encounters, the lower its perception goes down. However, it must be noted that the interest is controlled by users, who decide whether a specific topic interests them or not.

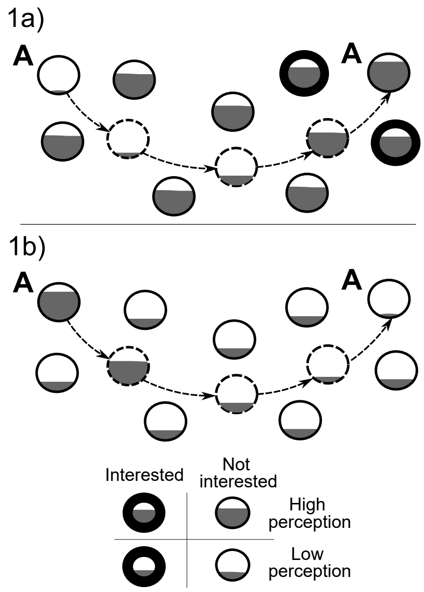

Fig. 1: Interest-based operation. 1a) Node A is not interested and moves around an area with nodes that are interested and have high perception. So, the perception of A increases. Then, in 1b) node A encounters nodes that have low perception and are not interested, so its perception also decreases.

Having seen the interest-based operation of *IRP*, we will now explain how the *Interest in a topic* and the *Perception of Interest in a topic* are used in our proposal.

The *Interest in a topic*, I_t^N, is defined as a boolean value that can be set to 1 or 0 according to users preferences. 1 means that the user is interested, and 0 implies that it is not. Users can change their interest I_t^N in real time whenever they decide to do it.

The *Perception of Interest in a topic* P_t^N defines how the node N perceives the interest that exists in the network in the topic t. Nodes should have a high P_t^N when they frequently contact other nodes that are interested and also perceive a high interest in a topic t. On the contrary, nodes should have a low P_t^N when they frequently contact other nodes that are not interested and also perceive a low interest in a topic t.

Initially, node N initializes its P_t^N using its value of I_t^N. From that moment on, P_t^N is updated each time N encounters another node using two Exponentially Weighted Moving Average (EWMA) equations, as explained below.

Every time a node A contacts another node B, A updates its P_t^A, for every topic t known by A or by B. In order to update P_t^A, node B calculates a *View on a topic*, V_t^B, which is a measure about how interesting B considers this topic is to the network and to itself, using its own I_t^B and P_t^B, as shown in Equation 1. In case that one node does not know one of the topics from the other node's topics list, before making the calculations, it creates and initializes new $I_t^N = 0$ and $P_t^N = 0$ for this new topic.

$$V_t^B = I_t^B \cdot (1 - \beta) + P_t^B \cdot \beta \tag{1}$$

The β parameter is the weight given to the *Perception of Interest in a topic* of a node B, in relation to the *Interest in a topic* of the same node. β controls the impact that the *Interest* and the *Perception of Interest in a topic* of the encountered nodes have on a node's perception and it is in a range of $[0, 1]$. A high β gives more weight to the perception of the neighbour nodes than to its own interest. On the other hand, a small β gives more weight to the interest than to the perception of the contacted node.

Then, A receives the *View on a topic* from B, V_t^B, and uses it to update its P_t^A on topic t, using Equation 2.

$$P_t^A = P_t^A(prev) \cdot (1 - \alpha) + V_t^B \cdot \alpha \tag{2}$$

In Equation 2, $P_t^A(prev)$ is the *Perception of Interest in a topic* of node A on topic t previous to node A establishing contact with node B.

The α parameter is the weight given to the *View on a topic* of node B in relation to the previous perception of node A. α, that must be in the range of $[0, 1]$, allows controlling how quickly or slowly the interest (through the view) of the other nodes affect a node's own perception. A high α gives more weight to the most recent encounters, so nodes adapt their perception quickly to changes of interest in the network. On the other hand, a small α gives more weight to older encounters, allowing the node's perception to be less influenced by currently acquired information. This way, nodes are slower to perceive changes in the overall network interest.

It must be noted that simultaneously to these calculations done by node A, node B also updates its P_t^B using V_t^A.

Finally, we designed Interest-based Routing on the assumption that all users in the network are trustworthy. So, their behaviour is according to the requirements of our algorithm, and, when they interact and share interest and perception, we assume that there are no risks that compromise privacy, integrity and confidentiality when exchanging messages.

B. Forwarding decision

Whenever node A contacts node B, A must decide, for every message m, whether to forward it. In our proposal, A checks the messages that B has already received, so only messages that B does not have will be forwarded. First, A

selects the messages to be forwarded to B. If B is interested in one or more topics, A will select the messages of these topics. In the case that B is not interested in a topic, B's perception is compared to a *Forwarding threshold*, T_f, and only messages of the topics with a P_t^B higher or equal to this T_f will be selected. Then, node A forwards the selected messages in the following way:

1) Firstly, A forwards the messages on topics that B is interested in receiving ($I_t^B = 1$) sorted by B's perception, P_t^B, (highest to lowest). When two or more messages have the same perception, the most recently received messages are forwarded first.
2) Secondly, A forwards the messages on topics in which B is not interested but has a high perception ($P_t^B \geq T_f$), the messages are sorted by B's perception (highest to lowest). When two or more messages have the same P_t^B, the most recently received message is forwarded first.

The T_f directly influences the forwarding decision. Using a low T_f, nodes forward more messages, and the risk of network flooding increases when lots of nodes are interested in some topic, but when there are few interested nodes this increases the possibilities of reaching more destinations.

Using a high T_f, nodes forward fewer messages and limit the network flooding, but there is a risk of delivering fewer messages when there are not enough interested nodes.

Figure 2 illustrates how *IRP* nodes decide which messages to forward and in which order, depending on the topic. Messages are grouped into four different sets according to the interest (Interested/Not interested) and the perception (High/Low) of the receiving node in their topic. The first messages to be forwarded are the ones in which the receiver node is interested in its topic and also has a high perception of interest (in this case, messages on $t2$). The next messages to be forwarded are the messages in which the receiver node is interested, but it has a low perception of interest (messages on $t1$ topic). The last messages to be forwarded are those in which the receiver node is not interested in receiving but has a high perception of interest (messages about $t0$ and $t3$). Finally, the messages that the receiver node is not interested in receiving and also has a low perception of interest (messages on $t4$) are not forwarded.

C. Buffer management

The next step is how to manage the messages buffer, defining what messages are to be dropped when a node has its buffer full and it is about to receive a new message.

Our proposal tries to improve the overall performance by keeping the messages of topics with higher interest in the network. We consider two criteria for dropping messages:

1) The *Perception of Interest in a topic*, P_t^N
2) The time in which each message was received.

Using the criteria listed above, the node drops the oldest message received from the topic with the lowest P_t^N. Thus, messages are removed from the buffer, and therefore from the network, when nodes perceive that there is no more interest in them, leaving space for newer and more interesting messages. This way, messages' lifespan is linked with the network's interest on them.

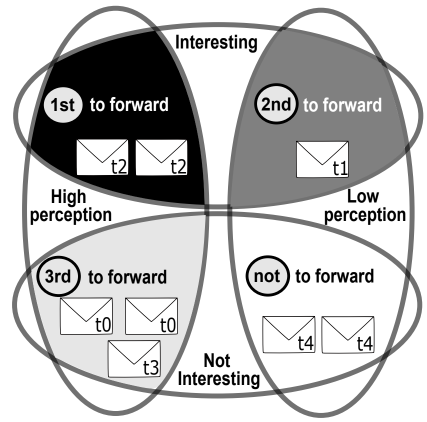

Fig. 2: Forwarding decision. First, nodes forward the messages of topics that the receiver node is interested in and has a high perception. Then, the messages of interesting topics but with low perception. Finally, the messages that are of no interest, but there is a high perception are forwarded. Messages of no interest and low perception are never forwarded.

In summary, we propose a new routing protocol for Opportunistic Networks, the Interest-based Routing protocol (*IRP*), that uses *Interest in a topic* and *Perception of Interest in a topic* for making forwarding decisions. We also present a novel *Buffer management* in which messages are discarded when nodes perceive that there is no interest in their neighbourhood. Note that, security considerations in terms of confidentiality, privacy and integrity are out of the scope of this work. However, in order to address this, a general security framework like [14] or [15] can be used, as *IRP* is compatible with them.

IV. Experiments and Results

In this section, we first explain the experiments we have defined to evaluate *IRP*'s performance. Then, we present and analyse the average results obtained by three executions of simulations, comparing the Interest-base Routing protocol (*IRP*), Epidemic (*EP*) and Spray and Wait (*S*&*W*).

A. Experiments

We performed the experiments using *The ONE* simulator [3] and ran three different simulations using different random seeds. Then, the average results were calculated.

We used the actual map of the Eixample district of Barcelona (Spain). The map is 1.60 km wide and 3.06 km high, with an effective area of 4.8 km^2 (Figure 3). In it, the nodes move with a map-based random movement pattern [16].

In order to evaluate *IRP*'s performance through simulations, since none of the cited algorithms support all the required characteristics together, the Epidemic (*EP*) and Spray and Wait (*S*&*W*) routing protocols have been chosen.

Fig. 3: Map of the Eixample district in Barcelona used in our experiments.

Although these protocols are maybe two of the most basic ones, they are a good choice for the analysis since many researchers use them for performance evaluations.

The parameters shown in Table I have been used to configure the set of simulations and to compare the performance of *IRP* with *EP* and *S&W*.

As previously explained, the values of α, β and T_f can be adjusted according to the needs of each case. In our case, we conducted many experiments using different values and selected those that provided the best results.

The value of L in *S&W* was selected according to the authors' suggestion of using a number between 10% and 15% of all nodes used in the experiments. We set an infinite TTL in order to demonstrate that the lifespan of the message depends on the interest in the topics of the messages in the network.

	Parameter	Value	Units
Scenario	simulation time	17	days
	number of simul.	3	simul.
Network	transmission range	10	m
	speed transmission	2	Mbps
Nodes	number of nodes	75	nodes
	speed range	3 - 50	km/h
	buffer size	10	MB
Messages	size	500-1000	kB
	speed of creation	60-72	msg/h
	TTL	∞	-
	topics	4	topics
IRP	α	0.3	-
	β	0.2	-
	T_f	0.7	-
Spray and Wait	L	7	msg

TABLE I: Simulation parameters.

We modelled the amount of interested nodes in every topic using a normal distribution. For these simulations, we have defined four topics ($t0$ to $t3$) along 17 days. The number of interested nodes in each topic reaches a different maximum, between 30%, and 50% of the total number of nodes in the experiments. We decided to characterize the interests as shown in Figure 4 in order to cover all possible situations: between days 0 and 9, the interest in at least one topic is always present, and from day 0 to 6 there is a high interest in more than one topic at the same time; between days 9 and 11, there are around two days with no interest in any topic in order to study the behaviour of the different protocols when this happens; finally, between days 12 and 16 we placed a high peak of interest in only one topic that has not been interesting before.

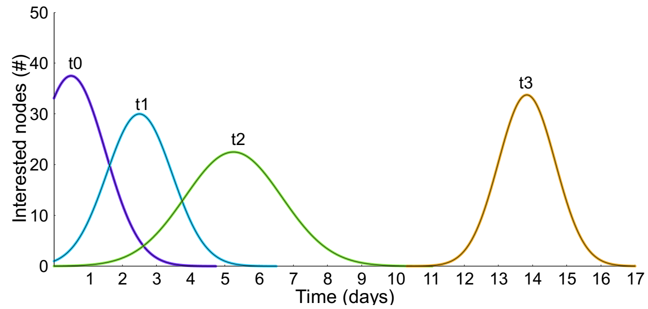

Fig. 4: Distribution of the number of nodes interested in four different topics during seventeen days of simulation.

The maximum number of interested nodes in a topic, and the duration of the interest (the time elapsed since the first node becomes interested until there are no more interested nodes), are shown in Table II.

Topic	# Nodes	Duration of the interest
t0	37	80 hours
t1	30	120 hours
t2	22	160 hours
t3	33	96 hours

TABLE II: Number of nodes interested and duration of the interest for each topic.

Since Epidemic (*EP*), and Spray and Wait (*S&W*) protocols are focused on sending messages to single destinations, in order to analyse and compare the performance of *IRP* with them, we had to slightly adapt their behaviour, making the following changes.

- When a node becomes interested in a topic, the node buffer is scanned to find and retrieve all messages of that topic. No messages are removed from the buffer when doing this.
- If a node is interested in the topic of a received message, the node is considered as the destination.
- In the previous case, the received message is always added to the buffer, even if the node is interested in the topic. This way, the received message can also be forwarded to other nodes.

B. Results

In this section, we present and analyse the average results obtained by three executions of the simulations in the experiments, comparing Interest-based routing protocol (*IRP*), Epidemic (*EP*) and Spray and Wait (*S&W*). For this analysis, we compare the Messages Delivered, Messages Relayed, Buffer Occupancy and Messages Latency.

1) Messages Delivered:

In order to compare *IRP* with the two other protocols, we first analyse the total number of messages delivered.

Figure 5 shows the number of Messages Delivered and the number of Interested Nodes in each topic. It must also be noted in this figure, that from day 9 to 11, there are no interested nodes, so no messages are delivered.

Additionally, in Table III it can be seen the total number of Messages Delivered and Relayed by the three protocols at the end of the simulation (day 17).

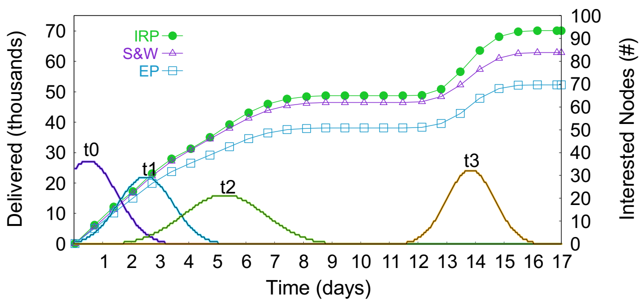

Fig. 5: Number of Messages Delivered by *IRP*, *S&W* and *EP* in each topic

We observe that *EP* delivers far fewer messages than the other two algorithms, approximately 26% less than *IRP*. This is because it is forwarding messages about all topics to all nodes regardless of the nodes' interest in receiving a message, filling their buffers with as many copies of the generated messages, and dropping these messages before they reach their destinations.

The number of messages delivered by *S&W*, is approximately 11% lower than those delivered by *IRP*, because, as *S&W* also forwards messages to all nodes it encounters, this fills the buffers, causing that some of the limited number of copies of the messages to be dropped from the network and not to reach nodes that might be interested later.

	Messages Delivered			Messages Relayed		
Topic	IRP	S&W	EP	IRP	S&W	EP
t0	14,451	12,772	11,437	20,200	47,146	119,023
t1	15,797	15,687	13,088	21,071	49,873	120,954
t2	18,455	18,010	13,567	23,963	51,654	121,409
t3	21,386	16,417	14,170	26,640	50,609	120,669
t0-t3	70,090	62,884	52,263	91,876	199,281	482,055

TABLE III: Total number of Messages Delivered and Relayed by *IRP*, *S&W* and *EP* in each topic

As we have just seen, *IRP* obtains the best results, delivering the most messages about each topic. It is because it is using its knowledge of the interest and its perception of the topics to make forwarding decisions and deliver messages, not wasting efforts in forwarding messages to every node it encounters. It is important to highlight that from day 9 to 11, since there is no interest in any topic, when using *IRP* no messages are relayed as it will be seen next.

2) Messages Relayed:

The Messages Relayed metric gives us a measure of the efficiency of *IRP* for reducing network overhead compared with the other protocols.

Figure 6 shows the number of Messages Relayed by the three protocols and the number of Interested Nodes in each topic.

The messages relayed by *EP* are thousands (not visible in the figure 6), approximately 424.7% more messages than *IRP*, because it relays them indiscriminately to the nodes, and it quickly fills the buffers and discards the messages regardless if the messages are of interest to the nodes or not, but the already existing copies are relayed again.

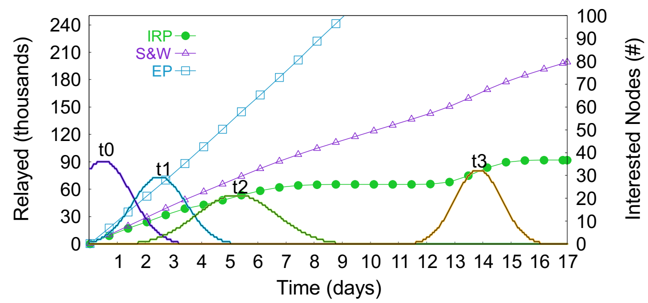

Fig. 6: Number of Messages Relayed by *IRP*, *S&W* and *EP* in each topic

The number of messages relayed by *S&W* grows linearly and reach up to 116.9% more messages than *IRP*, this happens because it relays messages to all nodes without considering their interest, but limited by a maximum number of message copies per message.

Unlike *EP* and *S&W*, *IRP* relays the least amount of messages, forwarding more messages only when and where there is interest or high perception of interest in a topic (higher than the threshold), and not forwarding messages when there is no interest and low perception, as can be seen from day 9 to 11.

Additionally, also in contrast to *EP* and *S&W*, which have around the same number of Messages Relayed for each topic, it can be seen that for *IRP*, the number of Messages Relayed (and also Delivered) on $t3$ is higher than in the other topics, because there are more messages on this topic in the network than there were in the other topics, since *IRP* has not deleted them yet thanks to its buffer management.

3) Buffer Occupancy:

Next, we analyse the Buffer Occupancy to see how this resource is managed by the different algorithms.

Concerning *EP*, we see in Figure 7 that when there is no interest, the buffer occupancy for each one of the four topics is around 20 to 25% (1/4). It can also be seen that the buffer occupancy on a topic grows up to 40% when there are interested nodes. This is because in *EP*; when there are interested nodes, the messages received by those nodes are put back in its buffer just one more time to try to deliver them. For this reason, in *EP*, the buffer increases slightly when there is interest in a topic. Afterwards, since the older messages are removed to receive the newer ones, the buffer occupancy for that topic returns to 20-25%.

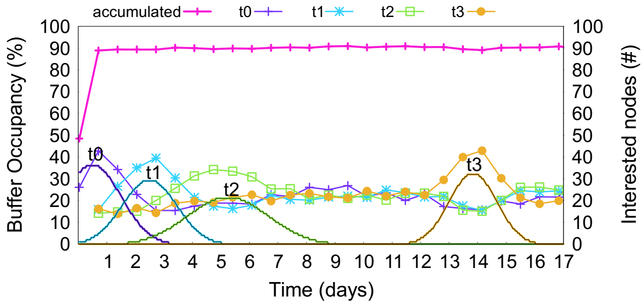

Fig. 7: Buffer Occupancy of *EP* in each topic

The Buffer Occupancy in *S&W* is shown in Figure 8. Its behaviour is similar to that of the buffer in *EP*, because in order to receive new messages both are removing messages regardless of the interest of the nodes. The buffer is filled up to 40% for each topic when there are interested nodes, but then it drops and remains at approximately the same percentage between 20 and 25%, just as *EP* does during the whole simulation.

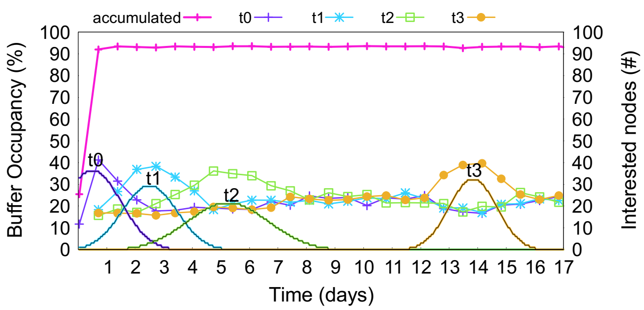

Fig. 8: Buffer Occupancy of *S&W* in each topic

Now, we analyse *IRP*'s Buffer Occupancy. Figure 9 shows the percentage of the buffer that is occupied by the messages of each one of the topics. It can be noted that unlike *S&W* and *EP*, while nodes become and remain interested, the buffer fills up with the messages of interest and its occupancy grows to 90%, and then practically all those messages are removed when another topic is of interest, following approximately the same behaviour as the interest of the nodes.

To see how the occupancy of the buffers evolves, we can analyse $t2$. First, while the nodes are interested in a topic, this topic's occupancy of the buffers grows. After the interest in it ends, and if there is no interest in any other topic, the buffer continues full of messages of the topic. This is partly because the messages' lifespan is associated with the interest that exist in the network (messages have infinite TTL), and they are not deleted for being too old. This is also due to the fact that since there are no interested nodes in other topics yet, *IRP* does not forward messages and there is no need to drop messages.

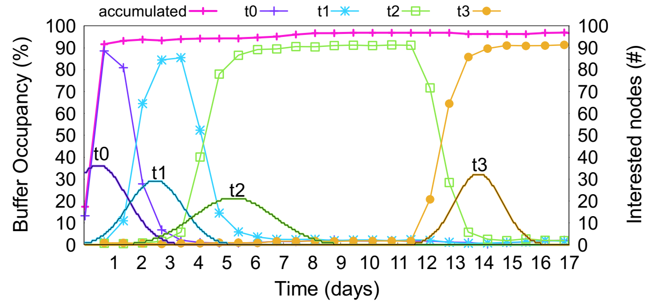

Fig. 9: Buffer Occupancy of *IRP* in each topic

When the interest in another topic starts, for example, $t3$ at day 12, the buffer occupancy of messages in topics that are no longer interesting decreases, while it increases in the interesting one.

We can see that the behaviour of the buffers in all the other topics is the same as in $t2$, being the buffers filled mainly with the messages of the topics in which there is interest in the network at each moment.

As a summary, we can see that in *IRP*, each time there is interest in a topic, the Buffer Occupancy in it increases, and it decreases when interest in other topics appears. This way, the buffer is always filled with messages of the topics that most of the nodes are interested in. Instead, both *S&W* and *EP* maintain most part of their buffers filled with non-interesting messages, which reduces their efficiency.

4) Messages Latency:

The last metric we analyse is the Message Latency obtained by the three algorithms, that is shown in Figure 10 together with the number of Interested Nodes.

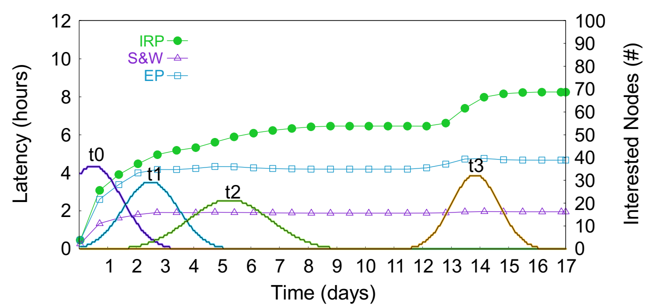

Fig. 10: Messages Latency obtained by *IRP*, *S&W* and *EP*

EP has a latency of about 5 hours. This is due to the fact that although it delivers the least messages, some of them have been circulating in the network for a long time, given that *EP* does not have any restriction on the number of copies made.

The latency obtained by *S&W* is approximately of 2 hours, which is the lowest, from day 1 and onward. This is explained by the fact that it quickly fills the buffers, and therefore it has to discard the older messages, so it mainly only delivers the most recent messages generated.

Concerning *IRP*, we observe that its latency increases with time, reaching a maximum of approximately 8 hours at the end of the simulation. Although the latency of *IRP* is the highest, this only confirms its desired behaviour. As it does not overflow the buffers with messages of no interest, there is no need to remove them from the network. Then, when there is interest in them, they can be forwarded and delivered, even those created few hours before the interest in each topic begins (unlike *S&W* and *EP*, who simply drop and never deliver them), making the latency to increase. It must be noted that with this behaviour, with *IRP* users receive messages that the other protocols have already dropped.

In order to summarize, once analysed the metrics comparing the performance of *IRP* with the other two protocols, we can say that *IRP* accomplishes its purpose of delivering more messages using its knowledge about interests and relaying fewer messages than the other protocols. This is because it is designed to relay, and so deliver, more messages when and where there is interest in a topic, not spending effort relaying messages if there is no interest.

V. Conclusions

We presented the Interest-based Routing protocol (*IRP*), a new routing strategy based on users' real-time interest in message topics. This strategy allows the development of new applications that aim to deliver messages through Opportunistic Networks, considering exclusively the interest of users as well as that of their neighbours.

IRP optimizes the use of resources by only forwarding messages with high interest or high perception of the contacted node. For this purpose, we defined two key concepts: the *Interest in a topic* and the *Perception of Interest in a topic*.

The *Interest in a topic* depends exclusively on the users, who can change it whenever they decide, and *IRP* uses it to know who wants to receive messages of a specific topic. The *Perception of Interest in a topic* measures how nodes perceive the interest in a topic of the other nodes in the network, it is calculated automatically and *IRP* uses it to make forwarding decisions.

An intelligent message buffer management mechanism was also proposed, where the older message of the topic with the lower perception is removed when space is required. This mechanism allows the lifespan of messages to be associated with their interest in the network, instead of using predefined TTLs.

We designed an experiment using a map-based random mobility model on the map of the Eixample district in Barcelona. In them, we compared *IRP* with Spray and Wait and Epidemic in terms of Messages Delivered, Messages Relayed, Buffer Occupancy and Messages Latency.

The analysis of the results obtained shows that *IRP* is more efficient, because it is able to deliver more messages while making fewer message relays than the other studied protocols.

As future work, we plan to compare our proposal with some similar social-based algorithms, study how to better model nodes' changing interests in topics, and to use a movement pattern based on human interaction habits. We also plan to define a way to evaluate the Delivery Ratio in cases where the number of destinations of the messages can change at any time. Finally, we also want to explore how to associate messages, not just with one topic, but with several at the same time.

VI. Acknowledgements

This work is partly funded by the Catalan AGAUR 2017SGR-463 project and by the Spanish Ministry of Science and Innovation TIN2017-87211-R project.

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