Novel Information Dissemination Solutions in Biologically Inspired Networks

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***Abstract*—Nowadays mobile communications gain more and more importance. The increased usage requires more sophisticated services. In this paper a possible, future network architecture is examined, called BIONETS. In this case the mobile nodes for the entire network, without dedicated backbone is present. We pursue the goal of finding an optimal information dissemination model over some mobility model. The investigation covers our previously defined protocol called IOBIO, classical broadcast and a newly developed adaptive broadcast algorithm. We run several simulations – with an own simulator created in OMNeT++ in order to decide which one is the optimal information dissemination method for the given mobility environment. The results give us the advantage to further improve the communication in such networks.**

***Index Terms*—ad hoc networks, adaptive broadcast, BIONETS, information dissemination**

I. Introduction

The inherent flexibility offered by the development of portable computers and wireless networking has lead to the large growth in mobile computing. In most wireless networks there is some kind of central coordinating entity. Communications occur by means of routing and usage of a base station as a gateway between the wireless and wired network. However there are situations when no central coordinator can be implemented. In these cases the mobile nodes must form an autonomous network, communicating by using only wireless methods, without any centralized intelligence and management.

Our everyday environment is increasingly populated by multitudes of decentralized and networked computing systems [1] (e.g., multiagent systems [2], ad hoc networks of mobile computer-based devices [3], sensor networks [4], clouds of "smart dust" [5], and spray computers [6]). Most of the above mentioned systems are able to perform activities without central administration - by communicating with each other – letting us "out of the loop" [7]. The complexity of such environments will not be far from that of biological organisms, ecosystems, and socio-economic communities.

In this paper we deal with the network architecture referred to as BIONETS (Biologically Inspired autonomic Networks and Services) [8]. BIONETS overcomes device heterogeneity and achieves scalability via an autonomic and localized peer-to-peer communication paradigm. Services in BIONETS are also autonomic, and evolve to adapt to the surrounding environment, like living organisms evolve by natural selection. Biologically-inspired concepts permeate the network and its services, blending them together, so that the network moulds itself to the services it runs, and services, in turn, become a mirror image of the social networks of users they serve. This new paradigm breaks the barrier between service providers and users, and sets up the opportunity for "mushrooming" of spontaneous services, therefore paving the way to a service-centric ICT revolution.

Such network in our case consists of two types of nodes. The information is gathered and initial messages are created by the so called T-nodes, but they do not participate in the processing and transferring of the data. These types of nodes can be described for instance as sensors measuring the temperature of a road. The other types of nodes are the U-nodes. These are carried by the users of the network and can be PDAs, mobile phones, etc. U-nodes transmit and process information, and they change location as the user moves, in spite of the T-nodes that locations are fixed. We used the Constant Speed Mobility Model and the Reference Point Group Mobility Model with Dynamic Clustering to simulate the movement of the U-nodes.

Communication between nodes can occur in two ways: the first one is the communication between two U-nodes, the second one is between a T-node and a U-node (at this stage there is no communication between T-nodes.). For battery saving and other reasons broadcasting is not an efficient way of communication. In this paper our main concern is to find an efficient way for information dissemination between the U-nodes.

The paper is organized as follows. In the second section the related work is presented. After that we present a short description of the broadcast and IOBIO type of communication. Our main focus is on their advantages and disadvantages. We modified the already existing solutions to fit best for the network architecture. That is followed by the simulations and the results. The paper ends with conclusions.

II. Algorithms For Information Dissemination

A. Related Works

There is a variety of information dissemination schemes in the literature introducing already existing protocols ([9],[10]), but they can not be used in a BIONETS disconnected network environment. The design of these protocols does not assume that neighbor discovery is already solved by lower layers, i.e. by sending HELLO messages. Any neighbor discovery (implicitly or explicitly) is done by our protocols.

Blind Flood is a classical information dissemination protocol: all nodes broadcast their information periodically into the network. This is a very robust method of dissemination, which property could be useful in BIONETS, but this method does not take into account the limited battery lifetime and limited channel capacity. Routing is used in the *Zone Routing Protocol[9]*: each node maintains routes to the other nodes within its zone and acquires routes to nodes outside the zone. This type of routing cannot be used in networks like BIONETS, because of the movement of the nodes, and the fact that no addressing is present.

In *LEACH[9]* protocol every node communicates with its respective cluster head and this head transmits the message to the base station. Although the role of the cluster head can be taken by different nodes, in DCN there is no opportunity to use base stations. *SAFE[9]* is an information dissemination protocol to send data from stationary sensor nodes to mobile sink nodes. The *Two Tier Data Dissemination Protocol[10]* is another protocol for disseminating information from stationary sources to mobile sink nodes. The main feature is that it prevents of the explosion in the number of the messages. SPIN [2] introduces a 3-stage handshake process. The IOBIO protocol – described below – is motivated by SPIN.

B. Adaptive Period Flood (APF)

We already discussed Blind flood and concluded, that the method is not practical in real life scenarios. However Blind flood has several benefits, like simplicity, robustness and low delays. This reason led to the development of several controlled flood methods, like described in [17].

APF is a very simple algorithm that does not rely on any addressing or topology information. It is based on two simple heuristics:

1. If we receive a duplicate, it means that somebody is already broadcasting the message around us
2. If someone else is sending the same messages, then we should send less frequently

The algorithm is based on two event handlers:

OnTimer: broadcast message; schedule(*now*+*T*, Timer)

OnMessageArrived(*m*): If *m* is new: schedule(*now*+*T*, Timer) else: $T = T + \Delta$

C. The IOBIO protocol

The IOBIO protocol is based on a 3-stage handshake process. The implementation of the handshake is similar to the SPIN handshake but we used other kind of meta-information.

1, Overview of the Protocol

In our protocol the nodes use three different types of messages for information-exchange.

ADV: advertisement of new data. If a U-node intends to send out new information it first sends an ADV packet that describes the data packet. The advertisement contains the identification information for the targeted UC. ADV messages are sent periodically.

REQ: request for data. A U-node answers to the ADV packet with REQ, asking for the advertised information.

DATA: the data message, which contains the requested information.

Although this protocol seems to be simple, different issues should be considered (e.g. Are U-nodes allowed to send collected, summarized or anyhow aggregated data or not?) This is why 3 types of IOBIO are presented.

TABLE I.
DIFFERENT IOBIO TYPES

Name	Author of information	Communication method
Type 1	T-mode	Broadcast
Type 2	T-node, U-node	Broadcast
Type 3	T-node, U-node	Broadcast with possible addressing

2, general steps of the protocol

1. A U-node (named **A**) receives data from a T-node or from another U-node, and **A** is a member of the group of interest which data belongs to.
2. **A** broadcasts an ADV message.
3. A U-node (named **B**) is a member of the same group of interest as **A**. B checks the ID of the advertised information, and it conclude that it doesn't have it, but it needs it. **B** broadcast an REQ message.
4. **A** receives an REQ message. **A** checks the ID of the requested information. If **A** doesn't have this information, **A** drops the message.
5. **A** broadcasts the requested data, **B** receives it. **B** uses it and broadcast an ADV message.

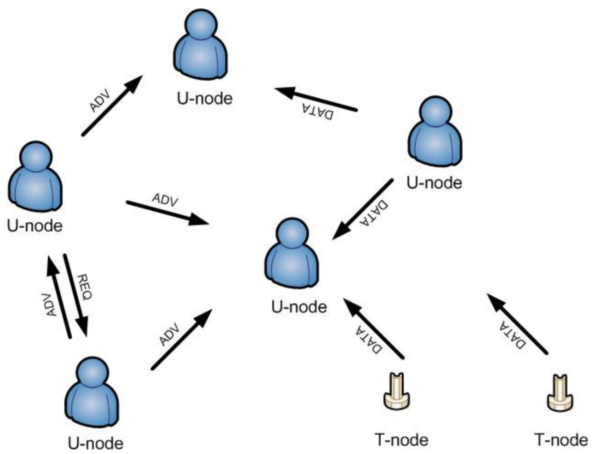

Figure 1. General model of IOBIO-communication

3, description of the messages

type 1: Here, the origin of information are the T-nodes. The detailed descriptions of the three types of the messages are the following:

ADV: F_m | ID_m | ID_{GoI1} | ID_{GoI2} | $ID_{GoI...}$, where ID_m = $ID_{T\,|}\,T_{CI}$

F_m: type of the message (ADV, REQ, DATA)

ID_m: unique identifier of the message which should be advertised by the U-node. This is created with ID_T and

T_{CI}, where ID_T is the unique ID of the T-node and T_{CI} is a timestamp for the time when the information was created by the T-node.

ID_{GoI}: unique identifier for the group of interest (the message can be advertised for several group of interest).

REQ: F_m, ID_m

F_m: type of the message (ADV, REQ, DATA)

ID_m: identifier of the requested message

DATA: F_m, ID_m, ID_{GoI1} | ID_{GoI2} | $ID_{GoI...}$ | data

F_m: type of the message (ADV, REQ, DATA)

ID_m: identifier of the message which is in the DATA message

data: data created by the T-node

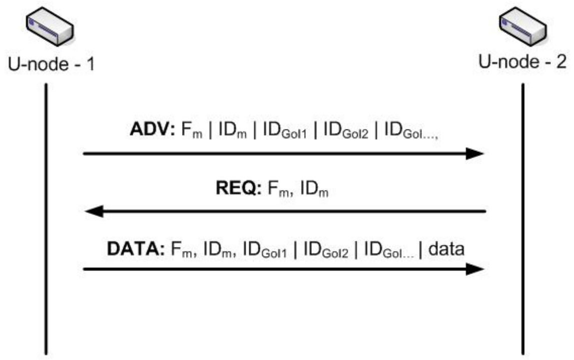

Figure 2. Communications handshake in IOBOI – type 1.

type 2: In this case the U-nodes are allowed to send summarized information (based on T-node data). It is possible that an aggregated data is based on partially incorrect data, so the network should be protected from accepting seemingly correct information. By the other hand, this aggregated information could be useful for some U-nodes. This is why we indicate in the packet if it was modified to differentiate it from messages directly coming from T-Nodes.

type 3: In the first two types of protocol we do not depend on any addressing scheme implemented in the network, we use only broadcasting. This means that if a node requests data, the information-holder can send it only by broadcasting it, so all the nodes in the communication range will receive it. Here, we extend our protocol with addressing.

4, Resolving advertisement collision:

In order to resolve the problem of *advertisement collision* the following scenario is presented. We assume that two nodes – A and B – send an ADV message at the same time. If there is a U-node (named C) in the communication area which is interested in this information, both of A and B will receive the REQ message. It may lead to overhead if both of them send the DATA. In order to avoid this we extend our protocol the following way. If a U-node (named A) sends an ADV message, and it receives the same ADV message (from another U-node, named B), it draws a random number, and sets up its waiting-time to this random number. Node B does the same. If A receives a REQ message, it will wait for the set delay – if it does not receive a DATA information with the requested data during the waiting-period, it sends the requested information. If it receives the requested data – which means that the information was already sent by B – it does not send anything.

If we investigate *information carrying* we can observe the following: at first we assumed that the information flows only between U-nodes that belong to the same UC. But it is possible that the members of this group are separated. We let the U-nodes carry information which belongs to other UC with some probability.

5, positive attributions

One of the most positive attributions is the limited overhead - no unnecessary broadcast, just if needed. With the 3-stage handshake we don't need broadcast every time. The first step is only an advertisement and the request for it; the broadcasting of the data is only the third step, to be performed if there are any request nearby – thus, the overhead could be decreased.

Assuming that a lot of U-nodes belonging to one group of interest are at the same place at the same time. In this case lot of advertisements and request messages can be presented, and the networks will work as a simple broadcast-network. (Every U-node will advertise the same information, and every node will send a request or answer a request, and there will be lot of packets.)

With the 3-stage handshake we can reduce the energy needs for communication, because the U-node sends only short advertisement messages (which should be processed by all the nodes in the communication range), and data packets will be sent only in one case: if one of the nodes needs it.

D. Mobility Models in Our Simulation

Mobility modeling is indispensable to validate, and analyze the performance of the new network paradigm and techniques.

The validation of various protocols is highly dependent on how realistic the used mobility model is. The definition of a realistic mobility model is one of the most critical aspects of the simulation of the BIONETS architecture. Since mobility patterns play a significant role in determining the protocol performance, it is desirable for the mobility model to emulate the movement pattern of real life scenarios in a reasonable way. The problem is that there is a very limited number of available real mobility patterns [11], [12] capturing node movement in large-scale disconnected mobile networks. Not only that the amount of mobility patterns is limited, but these traces are related to very specific scenarios (for example [12] in conference environment) and it is difficult to generalize. Furthermore these real traces do not allow a sensitive analysis of the system, since the values of the simulation parameters cannot be varied (speed or number of the mobile nodes). Because of these reasons a good number of research works have been published regarding the mobility models for the generation of synthetic traces. The current scenarios on the available mobility models for simulation of disconnected systems are synthetic models based on simple, homogenous, random process based on random individual movement.

However all these synthetic mobility models do not reflect real world situations, because in practice, a mobile node does not roam in a completely random manner. The random mobility models generate behavior that is not similar to human movement, because it can generate sudden stops and quick changes in direction. In the BIONETS mobility environment the delicate details of time-location dependency and community behavior must be taken into consideration. In these networks it is important to model the behavior of individuals moving in groups and between groups, therefore the mobility model in this case must be heavily dependent on the structure of the relationship among the mobile nodes, capturing this social dimension. A key aspect of human movement is dynamic clustering. We can observe this on the streets: people travel in small groups (clusters), some people join the clusters, while others leave them [13]. Clusters form in traffic jams, on mass transit vehicles, at crosswalks, etc. Between clusters, people move individually, sometimes long distances. The movement of dynamic clusters has a great effect on the efficiency of biologically inspired, locally organized algorithms.

To examine this phenomenon we have developed a group mobility model, called the Reference Point Group Mobility Model with Dynamic Clustering. It is a modified version of the RPGM (The Reference Point Group Mobility Model), which is a group mobility model and that means the nodes are organized in groups and the groups move together. Each group has a center point, that moves according to a mobility model (in our case the Constant Speed Mobility Model). Each node has a reference point close to the center point, and sets its destination in a random location near the reference point. This model captures a key element in human movement. People usually don't wander around randomly, moving in groups is much more common (e.g. public transportation, traffic jams, etc).

In the RPGM model, the groups were predetermined, and didn't change during the simulation. In our modified version, after each step each node has a small chance of leaving the current group and joining another, randomly chosen group. This model offers an even more accurate representation of human movement: groups mentioned in the previous paragraph change over time; some people join the group while others leave and eventually join another one.

The Constant Speed Mobility Model is a modification of the Random Waypoint Mobility Model[14]. The nodes choose random destinations like in the RWP model, but there are two main differences. First, there is no pause time when the node arrives at its destination, it immediately chooses a new destination and starts moving towards it. Second, all nodes move at the same speed during the entire simulation.

We used these two mobility models in our simulations: the Constant Speed Mobility Model, and the Reference Point Group Mobility Model with Dynamic Clustering, in order to evaluate our information dissemination protocols in different mobility environments.

III. SIMULATION

A. Simulation Environment

Although the IOBIO protocol was developed to support the communication in such systems like BIONETS, in this paper we only presents our simulations and results related to the communications between the U-nodes. We do not investigate scenarios with different interest group, it will be the next step of our simulation.

We tested our information dissemination protocols (Adaptive Period Flood, IOBIO) using the two mobility models (Constant Speed Mobility, Reference Point Group Mobility with Dynamic Clustering), so we could compare the protocols in different settings.

At the start of each of the scenarios, one of the nodes had a particular information, and the simulation terminated when all of the nodes received the information.

The nodes started from random positions. While the steady state of Constant Speed Mobility is known [18], it is not true for the other mobility models we used. Because of this the first message was sent after 100 seconds, to allow time for the nodes to reach the steady

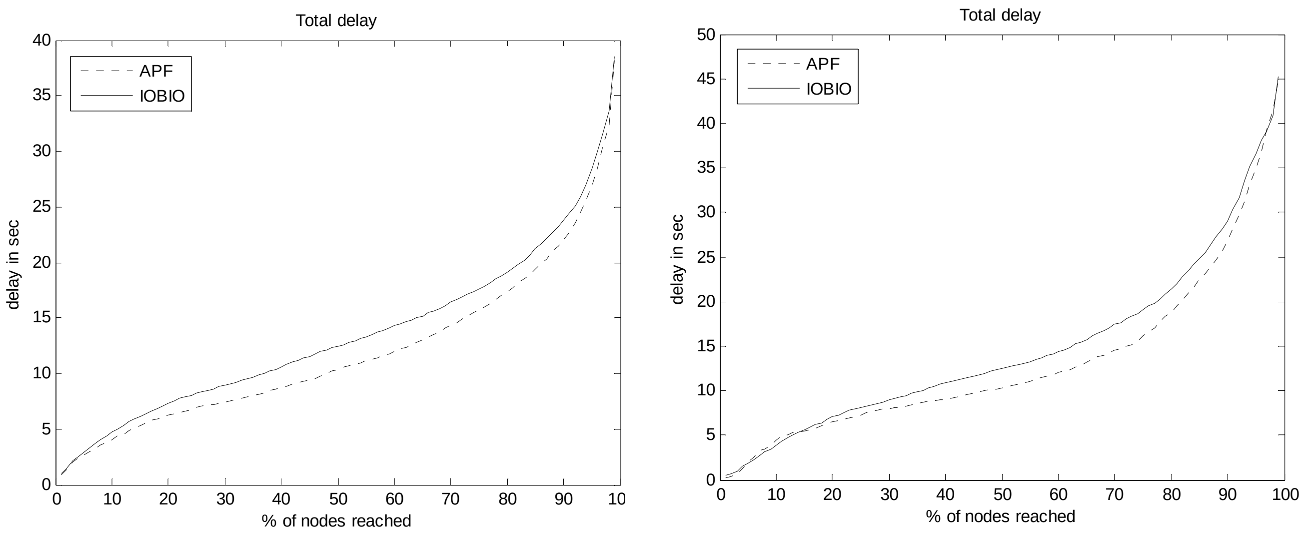

Figure 3. The delay of the IOBIO and APF algorithm.
The vertical axis shows the time needed to reach a given percentage of nodes which is shown on the horizontal axis. The left picture displays the results with Constant Speed Mobility Model while the right displays the results using Reference Point Group Mobility Model with Dynamic Clustering.

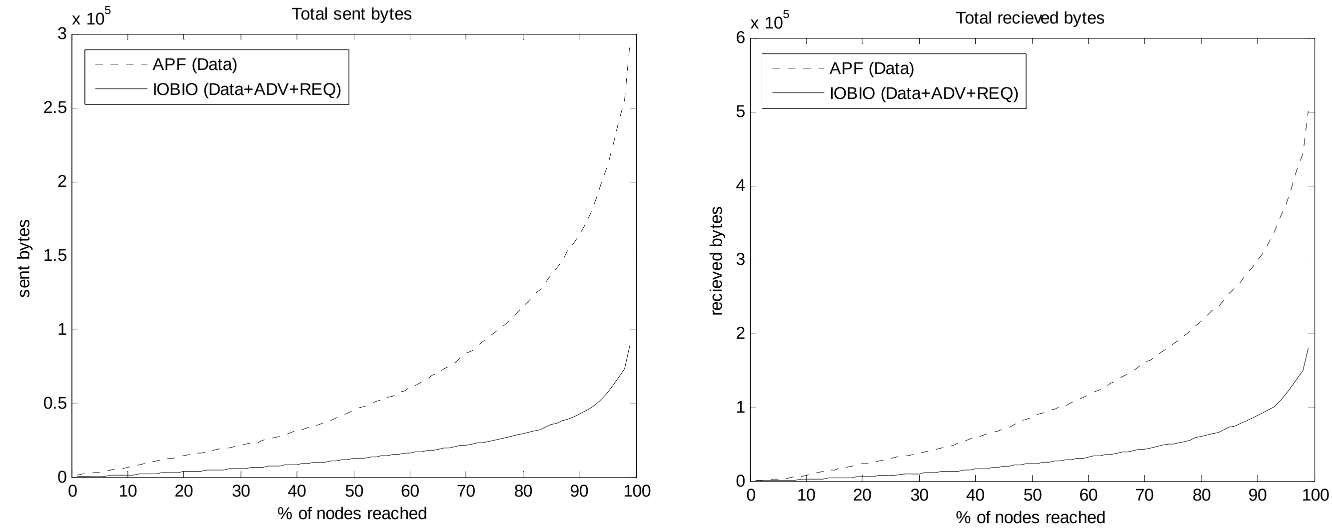

Figure 4. The total bytes sent and received by the APF and IOBIO algorithms using the Constant Speed Mobility. The vertical axis shows the total messages sent (left picture) or received (right picture) in the function of percentage of reached nodes (shown on the horizontal axis).

state. This waiting time was calculated to let the nodes travel from any part of the area to any other position

We implemented our protocols and mobility models in the OMNeT++ [15] simulation environment, using the Mobility Framework[16].

For all the scenarios we used the same parameters.. We had 100 nodes in the simulation, and they were organized into 10 groups in case of group mobility models. The simulation area was 500 m * 500 m. The nodes had a transmission range of 90 m, so roughly the 10% of the simulation area is covered by a node. This way there were different topologies present during the simulation: connected islands of different sizes as well as individual nodes. An ideal MAC layer is assumed, with no medium contention nor hidden-node scenario. The transmission of a message is instantaneous.

The length of the control messages (ADV, REQ) was assumed to be 16 bytes, while the average size of a Data was 80 bytes. For each scenario we calculated the average values of 500 runs.

We considered the following values during the simulation: *Delay:* the time it takes the information to reach n nodes. *Bytes sent:* the sum of different messages (ACK, REQ, DATA) sent by all the nodes till the information reaches n nodes. *Bytes received:* the sum of different messages (ACK, REQ, DATA) received by all the nodes till the information reaches n nodes.

B. Simulation Results

We show here the results using the Constant Speed Mobility Model and the Reference Point Group Mobility Model with Dynamic Clustering.

All of the measured quantities were plotted in the function of the percentage of nodes that was reached by the dissemination algorithm.

We can observe that the delay of the two protocols are quite close to each other, however, for most of the nodes and in both mobility models APF is slightly faster than IOBIO. This is no surprise as we know that flood type algorithms usually have good delay characteristics, because of the sheer amount of sent packets.

We can also see that the difference between the two delays disappears as the number of the remaining nodes decrease. This is where the mobility limits the performance of the two protocols, because both algorithms have to wait until these nodes come in transmission range.

Considering the sent and received messages it is clear that IOBIO is more efficient than APF. While APF have a slightly lower delay than IOBIO it achieves it by sending much more bytes, so the channel usage of IOBIO is much better. One can observe that the difference between the efficiency of the two algorithms is smaller in the Dynamic Cluster scenario, as detailed in the next chapter.

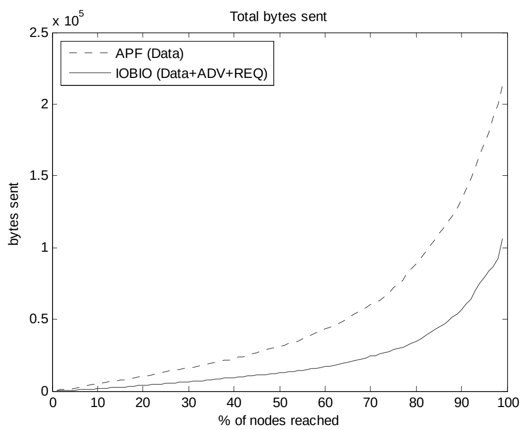

Figure 5. The total bytes received by the APF and IOBIO algorithms using the Reference Point Group Mobility Model with Dynamic Clustering. The vertical axis shows the total messages received by the nodes until a given percentage of nodes are reached which is shown on horizontal axis

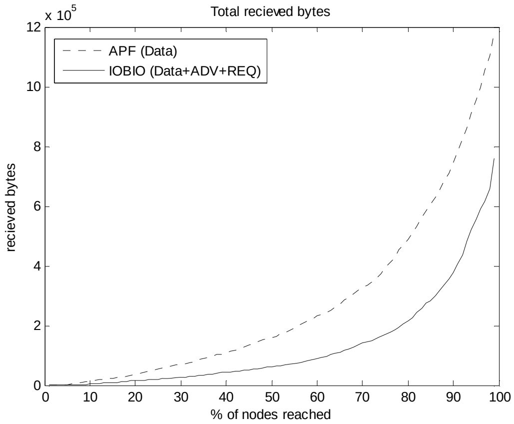

Figure 6. The total bytes sent by the APF and IOBIO algorithms using the Reference Point Group Mobility Model with Dynamic Clustering. The vertical axis shows the total messages sent by the nodes until a given percentage of nodes are reached which is shown on the horizontal axis.

IV. CONCLUSION

We simulated two information dissemination algorithms, the IOBIO and the APF and measured the delay of the two algorithms and the used bandwidth (sent or received bits).

From the results it is clear that an IOBIO style information dissemination is more efficient than APF. While there are small, not significant differences in the delay of the two algorithms, the difference in the total airtime is much higher. One can see that the difference in these numbers is lower than the difference between the packet sizes. This means, that the APF sends less packets than the IOBIO algorithm, but these packets are much larger, which is leads to its overall inefficiency.

This effect shows an interesting possibility to increase the efficiency of the IOBIO algorithm which can be the subject of further work. The IOBIO uses a Blind Flood method to send ADV packets, so its efficiency could be improved by replacing it with an APF style flooding. This incorporates the benefits of the two approaches by reducing the number of ADV packets sent, without increasing the overall delay while avoiding the need of sending large packets when it is totally unnecessarily.

We can also observe, that for any dissemination algorithm, mobility is the most limiting factor. When the number of connected islands was greater (in the Reference Point Group Mobility with Dynamic Clustering) the APF was less inefficient than IOBIO. This is because APF is a much more aggressive dissemination method, so it is able to achieve small delays in highly connected areas.

In our simulation scenarios we assumed that all nodes are in the same User Community therefore all nodes were participating in the process of disseminating information. In future simulations we should check scenarios where users are interested only in certain message types. We think that IOBIO could excel in such scenarios by avoiding the "spamming" of users.

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