Overhead Reducing Information Dissemination Strategies for Opportunistic Communications

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***Abstract*—We examined the efficiency of information dissemination assuming a disconnected network architecture where highly mobile nodes form the network. The nodes have different limitations, like short battery life and low computing capabilities. We created IOBIO and MIOBIO, two protocols for information dissemination in this environment. In this article we present the results of several simulations – with a simulator created in OMNeT++ to analyze opportunistic communications – to compare the performance of the two information dissemination methods for a given mobility environment. The results give us an insight how to decrease the cost of communication in such networks.**

***Index Terms*—BIONETS, information dissemination, disconnected networks, adaptive broadcast**

I. Introduction

THE development of portable computers and wireless networking has lead to large growth in mobile computing due to the inherent flexibility offered. When the network consists of a huge number of disconnected nodes with low power and these nodes are highly mobile, then any attempt to centralize management and coordination is impossible.

In this paper we deal with the network architecture referred to as BIONETS (Biologically Inspired autonomic Networks and Services)[1]. The goal of BIONETS is to overcome device heterogeneity and achieve scalability via an autonomic and localized peer-to-peer communication paradigm. BIONETS also tries to provide services that are autonomic, and evolve to adapt to the surrounding environment, like living organisms evolve by natural selection or like the spreading of an online social community. The BIONETS network architecture currently consists of two types of nodes. The information is gathered and initial messages are created by the so called T-nodes. These kind of nodes do not participate in the processing and transferring of the data, they can be described as sensors measuring the temperature of a road for instance. The other type of nodes are the U-nodes. These are carried by the users of the network and can be PDAs, mobile phones, or any device with sufficient computing and networking capabilities. U-nodes transmit, process and digest information, and they change location as the user moves, unlike the T-nodes that have fixed locations.

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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. It is important to note that there is no addressing (at least in the traditional end-to-end sense) in BIONETS networks. For battery saving and other reasons simple periodic broadcasting is not an efficient way of communication. We also have to consider that users are usually not interested in every type of data. They form User Communities (UC) with similar interests. In this paper our main concern is to find an efficient way for information dissemination between the U-nodes, this is why the architecture is similar to traditional disconnected networks.

The paper is organized as follows: in the second section the related work is presented. After that we present a short description of the IOBIO (InfOrmation Dissemination Protocol for BIOlogically Inspired autonomic Networks and Services) and Modified IOBIO (MIOBIO) protocols. We adapted already existing algorithms to find the best solutions for a disconnected network (hereafter DCN) architecture. That is followed by the simulations and the results. The paper ends up with the conclusions.

II. Algorithms For Information Dissemination

A. Related Work

There is a variety of information dissemination schemes in the literature introducing already existing protocols ([2],[3]), 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[2]*: 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[2]* 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[2]* is an information dissemination protocol to send data from stationary sensor nodes to mobile sink nodes. The *Two Tier Data Dissemination Protocol[3]* 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.

B. The IOBIO protocol

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

2, general steps of the protocol

a. A U-node (A) (who is a member of a certain UC) receives a data packet from a T-node or from another U-node.

b A broadcasts an ADV message.

c. A U-node (named B) is a member of the same UC as A. B checks the ID of the advertised service, and it concludes that it needs that information. B broadcast a REQ message.

d. A receives a REQ message. A checks the ID of the requested information. If A doesn't have this information, A drops the message, otherwise A sends out the DATA packet referred to by the REQ message.

e. A broadcasts the requested DATA, B receives it. B processes it and then starts the IOBIO protocol from point b) (e.g. broadcasts an ADV message).

In *Type 2* the U-nodes are allowed to send collected and summarized information (based on original data– e.g. average of measurements). 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, so we should allow sending them, but carefully indicate that they contain aggregated (so potentially incorrect) information.

To provide information to certain nodes, we extend our protocol with addressing (in *Type 3*).

4, resolving advertisement collisions:

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, advantages of the protocol

One of the most useful properties is the limited overhead - no unnecessary DATA message is sent. With the 3-stage handshake we do not need to broadcast every time. The first and second steps use short control messages; the broadcasting of the data only happens in the third step, and only when it is really needed. It happens only upon a request nearby –thus, the overhead is decreased.

We assume that a lot of U-nodes – belonging to the same group of interest – are usually close to each other. In this case lot of advertisement and request messages are sent, and the networks will work as a simple broadcast-network. One can tell that with the 3-stage handshake we can reduce the energy needed for communication, because the U-node sends only short advertisement messages (which message should be processed by all the nodes in the communication range), and all the data will be sent only in one case: if a node needs it.

C. The Modified IOBIO (MIOBIO) protocol

The IOBIO uses simple periodic broadcast to send ADV packets. Earlier investigation showed that considering the number of packets a more effective approach is possible. We developed The Adaptive Periodic Flood (APF), which is a simple controlled flood protocol that can reduce the number of duplicated messages without using control messages, while maintains low delays and robustness that are characteristics of a Blind Flood.

The APF is based on two event handlers:

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OnTimer: broadcast message;
  schedule(now+T, Timer)
OnMessageArrived(m): If m is new then:
  schedule(now+T, Timer)
  else: T = T + Δ
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This simple protocol broadcasts messages periodically, and increases this period when a duplicate arrives.

Considering the number of bits sent/received APF is not as efficient as IOBIO because it sends DATA messages only, and generates a high amount of unnecessary bits. IOBIO is able to avoid the transmission of unnecessary DATA messages using a simple handshake. To combine the benefits of the two algorithms, MIOBIO uses the APF protocol to decrease the amount of duplicate ADV messages, and uses the original IOBIO handshake to decide when DATA messages have to be sent.

D. Mobility Models in Our Simulation

The validation of various protocols is highly dependent on how realistic the used mobility model is. 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 [5], [6] 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 and it is difficult to generalize.

However none of these synthetic mobility models reflect real world situations, because in practice, a mobile node does not roam in a completely random manner. 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 [7]. Clusters form in traffic jams, on mass transit vehicles, at crosswalks, etc.

To examine this phenomenon we have developed a group mobility model, called the Reference Point Group Mobility Model with Dynamic Clustering (RPGMMDC). It is a modified version of the Reference Point Group Mobility Model (RPGM), 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. 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.

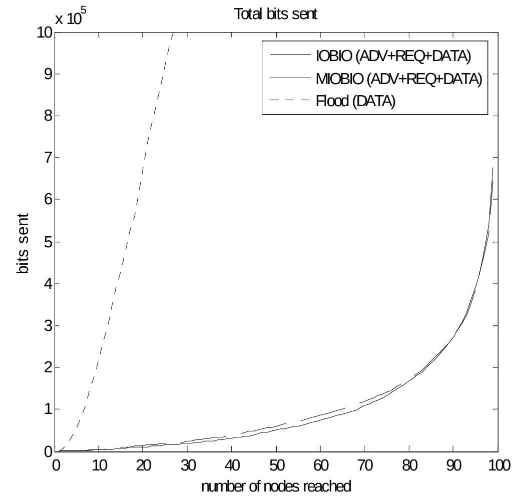

Figure 1. The amount of data that is needed to reach the N^{th} node

The Constant Speed Mobility Model (CSMM) is a modification of the Random Waypoint Mobility Model (RWP) [8]. The nodes choose random destinations like in the RWP model, but there is no pause time when the node arrives at its destination and all nodes move at the same speed during the entire simulation. We used these two mobility models in our simulations: the CSMM and the RPGMMDC, in order to evaluate our information dissemination.

III. Simulation Results

A. Simulation Environment

We implemented our protocols and mobility models in the OMNeT++ simulation environment, using the Mobility Framework. We ran simulations to observe the behavior of the information dissemination protocols running over the two mobility models described above.

The following parameters were used for the simulation:

There are 100 nodes present, and they are divided into 10 groups, if a group mobility model was used.

The simulation area was 500 m * 500 m. In order to have different topologies present during the simulation (individual nodes, connected islands of different sizes), we have chosen the transmission range to cover approximately 10 % of the simulation area, which is roughly 90m. We used an ideal MAC layer in the simulation, with no medium contention nor hidden-node scenario. The transmission of a message is instantaneous.

The used control messages (ADV, REQ) were 128 bits long, and the size of a DATA message was 640 bits. For each scenario we calculated the average values of 500 runs.

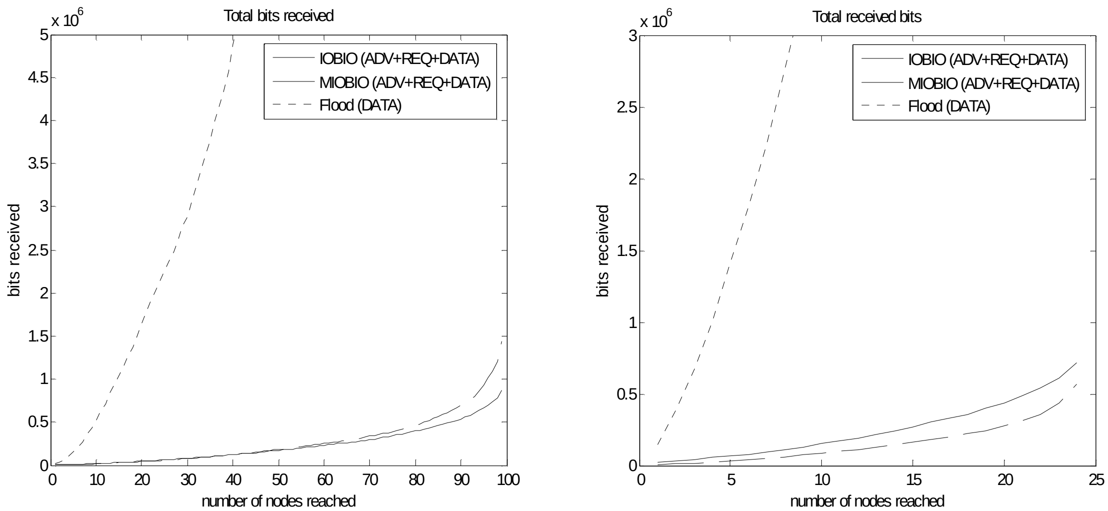

Figure 2. The total bits received by the nodes when the N^{th} node is reached using CSMM. In the left picture the results are shown when 100% of the nodes were in the same UC, while the picture on the right shows when only 25% belonged to the examined UC

We used the epidemic scenario in our simulations, which means that only one node has the information at the start of the simulation run, and the goal is to pass this information to all nodes interested in the information. We assumed that the number of these nodes is 100% or 25% of the total number of nodes.

The nodes started from random positions. The steady state of the Reference Point Group Mobility Model with Dynamic Clustering is not known, (The steady state of the *Constant Speed Mobility Model* is described in [9]) therefore, we waited 100 seconds before sending the first message, to allow time for the nodes to reach the steady state. 100 seconds is sufficient time for the nodes to reach any position in the simulation environment.

We considered the following values during the simulation: *Delay:* the time it takes the information to reach n nodes. *Bits sent:* the sum of different messages (ACK, REQ, DATA) sent by all the nodes till the information reaches n nodes. *Bits received:* the sum of different messages (ACK, REQ, DATA) received by all the nodes till the information reaches n nodes. Two scenarios were examined, there is a scenario when every node is interested in the same type of information, and the second one is when only 25% of the nodes are interested in that particular message which was disseminated among the nodes during the simulation. We expected that the protocols will behave in a different manner in these two scenarios.

For reference we included the Blind Flood in the pictures using the same period as MIOBIO.

B. Results

The results of the simulation regarding the total amount of send data are given in *Figure 1* for the CSMM in the case when every node is interested in the same type of information.

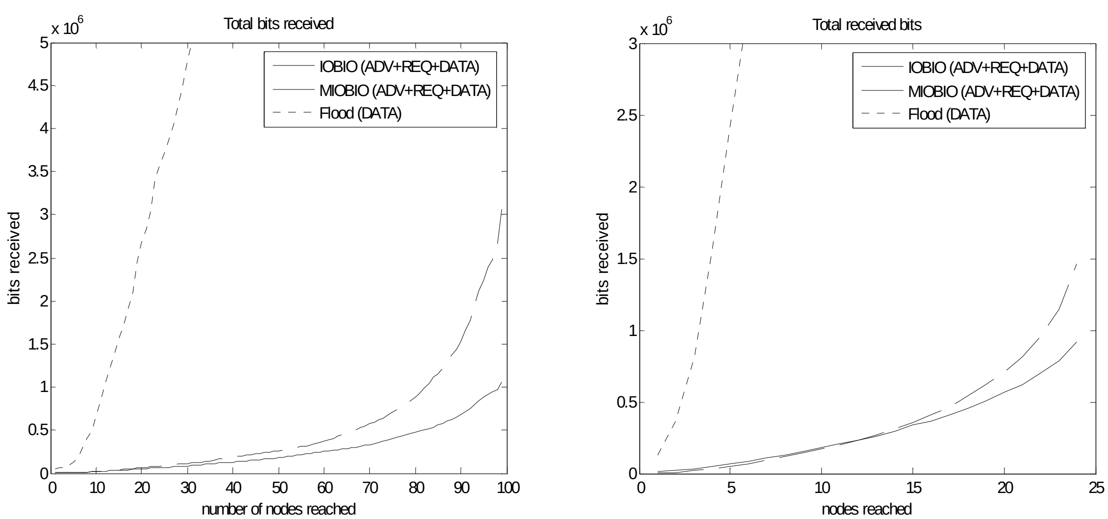

Figure 3. The total bits received by the nodes when the N^{th} node is reached using the RPGMMDC. In the left picture the results are shown when 100% of the nodes were in the same UC, while the picture on the right shows when only 25% belonged to the examined UC

Both algorithms show better performance than the Blind Flood, but there is no significant difference in the amount of sent data, which was anticipatory, because the MIOBIO was developed to reduce the number of duplicated messages, therefore it is supposed to show better results than IOBIO for the amount of received messages.

As it can be seen in *Figure 2*. and *Figure 3* the simulation results confirmed our expectations, the MIOBIO reduced significantly the total amount of received data comparing to the Blind Flood and IOBIO protocol. From the 4 scenarios (two mobility models and two rate of interest for the propagated information: 25% or 100% of the nodes are in that User Community) the IOBIO performed better only in one case, when we used CSMM and only the 25% of the nodes were interested in that particular information.

Therefore the MIOBIO performed well especially when we used the Reference Point Group Mobility Model with Dynamic Clustering and when all the nodes were in the same User Community. In group models the heuristics of APF also work better than in a model where the movement of the nodes is independent. In a group model nodes with the same information usually stay together for a longer time. In this case received duplicate packets give good feedback about the number of listening neighbors, so APF will decrease the rate of sending ADV messages and therefore the total amount of received duplicates can be decreased.

IV. Conclusion

We simulated three information dissemination algorithms, the Blind Flood, the IOBIO and the MIOBIO which is essentially IOBIO modified with APF, and measured the amount of sent and received data.

The strength of the IOBIO protocol is that no data is sent when it is unnecessary. This is the reason why IOBIO is superior to the Blind Flood and the original APF in the total amount of sent and received data which are more realistic measures of network load than the number of messages. A serious disadvantage of the APF is that it always sends the whole DATA message even when there is nobody around. On the other hand, the problem of the IOBIO protocol is that ADV messages can still saturate the network. While the size of the ADV messages is small they can be a problem when collisions are possible during transmissions. This is not so important when the User Community is small and the nodes move independently (like in the Constant Speed Mobility model), but if we use a group mobility model then the nodes usually send a lot of duplicates to the members of the same mobility group (which are not necessarily the members of the same User Community), so the IOBIO should be combined with APF.

For that purpose we developed the MIOBIO protocol, which uses APF for controlling the rate of sending ADV packets, while we keep the IOBIO handshake mechanism to reduce the number of the large DATA messages. The simulation results show that the IOBIO reduces significantly the amount of send and received data in the cases when the nodes move independently, while using the MIOBIO protocol for large User Communities and group mobility the total amount of the sent data can be reduced further, together with the delay experienced by the nodes.

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