MP2P Network as an Information Diffusion Channel

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***Abstract*—In this paper we discuss mobile peer-to-peer (MP2P) networks and short-range wireless communications as a new application for information diffusion. We focus on the efficiency of information diffusion in a single-hop MP2P environment. The results are based on the analysis of the exchange pipe model, which represents the MP2P environment.**

Keyword-: MP2P; Information diffusion

I. Introduction

Peer-to-peer (P2P) networks have attracted attention lately. The ability to harness different resources scattered in the Internet is probably the biggest appeal of the P2P technology. Taking advantage of P2P starts from a primary approach, in which all the tasks and responsibilities are shared between the peers. This means that there is no single control entity responsible for services, hence the name peer-to-peer network. Due to a growing number of providers, a greater amount and diversity of information can be attained from various P2P networks.

In addition to peer-to-peer networks, another technology has also lately attracted attention: mobile ad hoc networks (MANET). These networks were developed by a DARPA project in the early 1970's [6], and have later spread to civilian use as well. A mobile ad hoc network is a network with no predetermined structure. It consists of mobile wireless network nodes that are able to communicate with each other through intermediate nodes [2].

Both peer-to-peer networks and ad hoc networks share the same common problem: delivering messages in a rapidly changing network topology is a challenging task. This whole system can be simplified by allowing only direct single-hop links so that information is transmitted from the source node to the target without intermediate nodes. In this case the network must assume that the movement of the mobile nodes will deliver messages to the querying nodes.

In the scope of this paper we study data exchange in which only single-hop communication is used. By not allowing the usage of intermediate nodes between the two ends of the communication link, the complex routing problem is avoided.

The following part presents existing models of information diffusion with mobile nodes. However, it will be pointed out that these are not well suited for depicting short-range communications in mobile peer-to-peer networks. Therefore, a new revised model will be presented in section B. In chapter III we will present the simulation environment with our analysis, and the results are concluded in chapter IV.

II. Related Work

A. Research with an epidemic diffusion model

In order to be able to study such a dynamic system as the MP2P environment, the first thing to do is to select a model for mobility of the nodes that is best suited for the particular case. Yu and Li [7] list the three most popular models to be random waypoint, random walk and random direction models. The total freedom of movement, however, is very problematic if the model tries to represent the real world: in fact, most of the time some the pattern of mobility has limitations based on, for example, physical or cultural obstacles.

Information diffusion in ad hoc networks has been studied by, for example, Arai et al [1] and Khelil et al [3], and in both of these studies some free random mobility model is used. Arai et al have also included stationary information sources in their study. These source points were fixed locations where the spreading information originated. Similar extensions were also used in a study by Papadopouli et al. [5]. In other words, we must take into account all the elements that might affect the results whether they are mobile or not.

When studying information diffusion in a system, in addition to the model for mobility of the network nodes, there is also a requirement for modeling the information diffusion process itself. One possible, and often used, model is an epidemic diffusion model, which, for example, the above mentioned Khelil et al [3] have used. Although, the epidemic model is widely used in various areas of research, its main problem is its tight relation with random mobility models: it is assumed that an object which carries the 'infection' will meet other objects in a random pattern. When using this kind of a model, the results from information diffusion simulations will have a general S-shaped form, like the one from Khelil et al. The results are based on the fact that with only random mobility a 'critical mass on infected objects' is required for the information to spread fast. As opposite to this traditional model, information can be expected to spread exponentially when it is released into an area where there is a high density of possible new carriers of the information.

B. The Exchange Pipe model

The dynamic nature of the MP2P network also leads into a situation where the node density is not constant, but varies during time [3]. Because of this variation, denser and sparser subareas will be formed in the observation area. In this paper we study a new type of an application which uses short range data transmission. The areas where there are only a few mobile nodes do not have an effect on the diffusion of information because of the limited range of the communication devices, but in the denser area the diffusion rate will be higher. This section will introduce a novel way of modeling such a system, and it is based on observation areas, which we call exchange pipes, rather than focusing on mobile nodes as individuals.

A MP2P system with a limited communication range can not be expected to work, unless an adequate number of nodes is located in a limited area at a given moment. When this assumption is combined with the notion voiced by Khelil et al., that mobile nodes are typically packed on certain areas, it can be justified to change the focus of study from separate mobile nodes to defined observation areas [4].

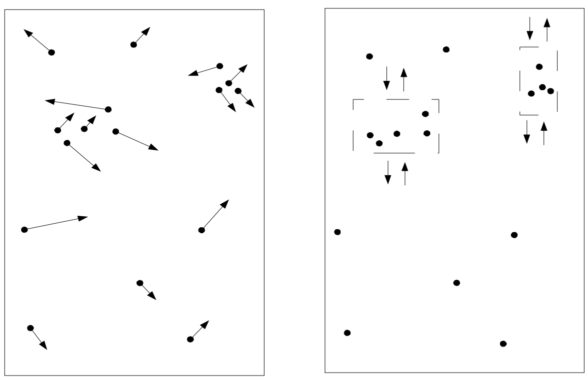

Figure 1. "Traditional" way of modeling and the exchange pipe model.

Fig. 1 depicts the model presented in [4]. It compares the traditional model based on node movement with the exchange pipe model. The traditional model on the left-hand side shows the direction and speed of each individual mobile node, depicted by the direction and length of the arrow. When each node is observed separately, plenty of resources is wasted on studying nodes, the state of which is irrelevant for the big picture. The only relevant nodes, after all, are the ones capable of information exchange, that is, the ones which are close to other nodes. The right-hand side focuses exactly on these relevant areas where information can be exchanged due to high node density. The outlined areas represent data exchange areas (the pipes), and the arrows represent nodes entering and leaving the area. Unlike the traditional model, this one does not concentrate on monitoring the state of individual nodes, but only the flows of nodes going through the pipes.

III. SIMULATIONS

The simulations analysed in this section are based on the simulation environment, which was presented in [4]. There are four types of objects in the simulator: 1) **The mobile node** is a unit, which seeks information. The nodes do or do not have the capability to share information with other nodes. This attribute represents the share of the users who have adopted the required technology for MP2P. 2) **The node streams**, which consist of mobile nodes. Each stream has two attributes, flow and density. 3) **The exchange pipe** is the place where mobile nodes can exchange their data if they have the capability to do so. Each exchange contains any number of node streams. 4) **The information source** is a place where the diffusing data is originated. Through the information source there is also a node stream. From the information source all the visiting nodes are able to receive current information, and thus it is the only place to receive it for such mobile nodes that are not able to receive data from other mobile nodes.

A. *Information diffusion function*

The simulation results were noticeably different from the ones that other researchers (see, for example, [1] and [3]) have attained with the epidemic information diffusion model with a pure random mobility pattern of the network nodes. While the old results share the common S-shaped form, this new model has an exponential growth behavior: the growth rate reaches its maximum right after the spreading information is released at the exchange pipe, i.e. when the first such node that is capable of sharing data with other nodes and is carrying the information enters the exchange pipe, the information diffusion rate starts to grow explosively.

From the output of the simulator one can separate three different factors: 1) The nodes that do not have technology for MP2P, and therefore are able to receive information only from the information source. 2) The nodes that have received their data from another node inside a exchange pipe. 3) The nodes which have the required technology, but still received the information from the information source. This third group acts as a carrier and therefore they are the ones who start the explosive information diffusion process at the exchange pipes.

The information diffusion as a function of time (*N(t)*) can be written in the following form:

$$N(t) = \sum_{i=0}^{3} n_i(t) = \sum_{i=0}^{3} P_i - P_i e^{-k_i t}\ , \qquad (1)$$

where $n_i(t)$, $i \in [1,3]$, is a function of diffusion level within the above mentioned three factor groups, P_i is the number of nodes within the group i, and k_i is a constant which depends on the parameters of the simulation.

B. *The benefit of the MP2P environment*

The information diffusion function presented in (1) gives the total number of the users that have received the piece of information at a certain point in time. However, it does not explain the real effect of the MP2P environment. The simulation system enabled us to study the case where the users did not possess MP2P technology yet, i.e. they were able to obtain the information only from the information source. With our simulation system we were able to calculate the added value brought to information diffusion by MP2P technology and thus separate the effect of technology on information diffusion from the information diffusion that would have taken place without it. For that purpose we defined the benefit function

$$H(t) = N(t) - N_0(t)\,. \qquad (2)$$

The benefit function (2) shows the difference of the number on nodes that have the information compared to the situation where no MP2P technology is available ($N_0(t)$).

Fig. 2 represents the benefit functions (2) of three different technology penetration stages. The lowest curve shows the case where only 2.5 percent of the total population have adopted MP2P technology. The middle curve represents the case where this penetration rate is 50 % and, the top curve the case of 100 % penetration.

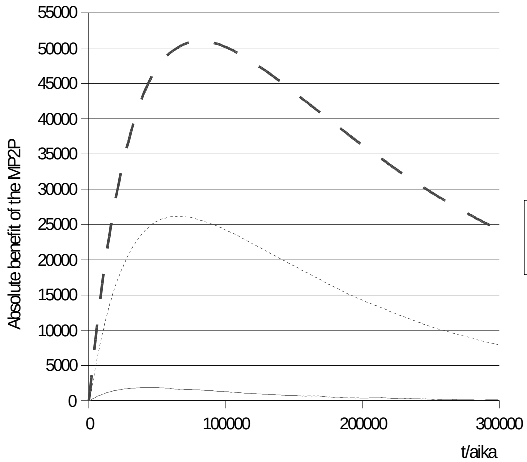

Figure 2. The absolute benefit function.

As we can see in Fig. 2, a very small user population brings only small added value compared to the situation with no technology users. However, as the technology spreads among the population, the added value represented by the benefit function reaches grows substantially.

The absolute benefit, defined in (2), which shows how much the diffusion has increased, does not entirely reveal the benefit brought in by MP2P technology. In order to gain deeper understanding of the diffusion process within MP2P environments, we defined the relative benefit function:

$$h(t) = \frac{H(t)}{N(t)}. \qquad (3)$$

The relative benefit function proportions the absolute benefit function (2) to the information diffusion function (1). Fig. 3 represents the relative benefit function with the same usage percentages that were used in Fig. 2. By comparing figures 2 and 3, it can be noticed that these two benefit functions behave quite differently: The relative benefit function reaches its maximum value at a very early stage, whereas the absolute benefit function keeps growing for some time after that moment.

In order to make this comparison clearer, these two benefit functions, the absolute and the relative, have been plotted in Fig. 4. To make analysis easier, a third curve was added in the figure. It represents the diffusion function (1). The technology penetration used in the figure is 50 percent.

As can be seen from the Fig. 4, benefit functions (2) and (3) gain their maximum values at different points in time, and what is important, both the absolute and the relative benefit is high at the early phase of the simulation. With these results we claim that MP2P applications could be successful even with a quite small number of MP2P devices.

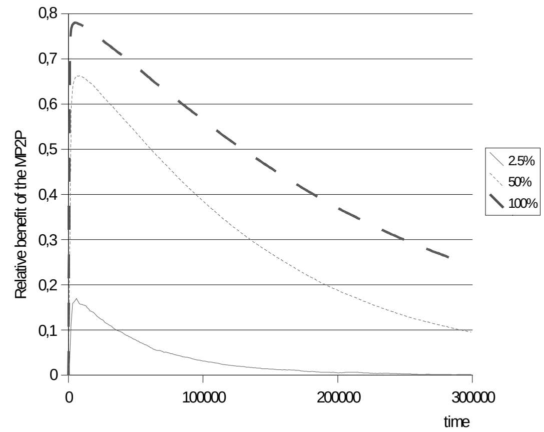

Figure 3. The relative benefit function.

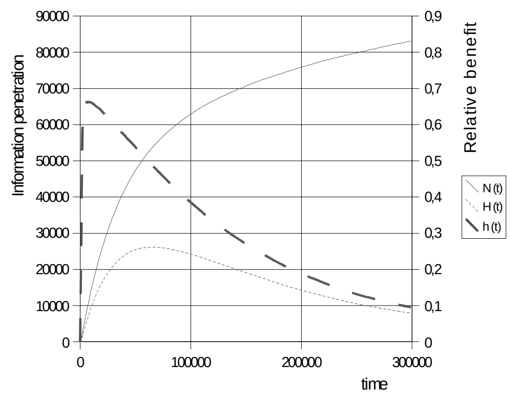

Figure 4. Information penetration and the benefit functions.

IV. Conclusion

The research began by examining previous studies of information diffusion in a peer-to-peer environment. The models used in them were, however, considered not so well suitable for MP2P, since they were based on random mobility patterns, not suited to model real world mobility. In addition to this, monitoring mobile nodes located far from another offers no added value whatsoever. Consequently, a new approach which concentrated on observing areas with a high density of MP2P users, enabling information exchange with short-range peer-to-peer communication. When observing areas where the population density is high, the exchange pipe model provides a new way for describing the information diffusion process.

Our analysis revealed that MP2P technology has the biggest effect in the early stages of information diffusion. The influence decreases as the diffusion process advances. Therefore, the technology is most useful when the life span of the spreading information is short, i.e. the information is useful only for a short period of time after release.

The current implementation of the exchange pipe model has its limitations. The model, for example, leaves the sparsely populated areas outside the observation. However, we can assume that random contacts between MP2P nodes will affect the information diffusion at some level. The next logical step would thus be combining these two different models. In this kind of a combination, the interest rests on the following question: does the fast diffusion in the exchange pipe change the results obtained in the random movement based models, where it took some time to gain the critical mass needed to accelerate the diffusion process.

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