Ad Hoc Network Performances for Hybrid Social Networks

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Abstract **— Ad hoc networks provide means for information sharing for a group of users. Thus, care must be taken that a proper model of the end-to-end communication is used. In order to model a real-life situation, we use a unifying hybrid social network model that captures the scale-free property and small-world effect that appear when viewing the graph that corresponds to the user interaction. Several hybrid networks are investigated and certain interesting behaviors are shown.**

Keywords **— ad hoc network, unifying hybrid model, traffic pattern, scale free property, small world effect**

I. Introduction

THE field of ad hoc networks continues to be one of the most popular and challenging fields when talking about communication networks [1]. The inexpensive and widely available wireless equipment have brought the ad hoc networks closer to the end user and the ever expanding list of possible applications attracts even more attention.

Ad hoc networks [2] provide wireless connectivity with freedom of movement that goes beyond the limits of the conventional wireless network based on the access point infrastructure. The ad hoc network is a network that consists of wireless mobile users only and it does not rely on any backbone infrastructure or special pre-use interventions. The mobile nodes are free to move around as long as they do not go out of the range of the network. In order to provide full interconnectivity the nodes have two different roles [3]. Firstly, they can be either source or destination for the transferring data. Secondly, they may need to become routers for some other data source-destination stream for situations wherein the source and the destination are not in the radio range proximity. The ability for users that are not in radio range to exchange data and information is provided via so called multihop paths over one or several intermediate nodes that forward the data toward the destination.

The absence of infrastructure and the on-the-fly establishment are the major reasons for the enormous number of applications for ad hoc networks [4]. The possibilities start from the military use on the field for instant soldier connection, over rescue missions or exploration teams for anywhere, anytime connectivity, towards today's favorite ad hoc campaign headquarters and everywhere business meetings.

The common thread of all of these application themes is the human factor that uses the ad hoc network for information sharing [5]. This aspiration for means of sending information from one user to the other directly affects the data flow in the underlying ad hoc network. The ad hoc network provides means for user communication and it's infrastructureless, wireless, mobile aspects allows the users not to take into consideration the communication medium, but just use it in any way they feel necessary.

Thus, when analyzing the performances of ad hoc networks used to provide means for information sharing for a group of users, care must be taken that a proper model of the end-to-end communication is used. The way the end-to-end connections are going to develop falls under the rules of the relationships between the users of the network. This means that the traffic pattern can be extracted from the graph that models the user interconnection, that is, from the social network that is created by the users of the ad hoc network.

In the past decade there have been several major findings that grasp the modeling and properties of social networks. The biggest impact is the emergency of the small-world effect [6] and the scale-free property [7] found in every social network. Thus, in order to bring the ad hoc communication modeling closer to a real-life situation, we use a unifying hybrid social network model [10] that captures these properties that appear when viewing the graph that corresponds to the user interaction.

The remainder of this paper is organized as follows. In the second section brigs forth complex networks and their modeling using the unifying hybrid model is described. Section 3 illustrates the way we integrated this model in our simulation scenarios for ad hoc network performance investigation. In Section 4 the results are presented. The conclusion and summary are finally presented.

II. Complex Networks

Over the last decade there has been one discovery of a great impact on the 'science of networks'. The discovery of the ubiquity of small world and scale-free networks has led to many exciting insights into fundamental underlying principles that govern complex systems. It has been realized that, despite functional diversity, most real

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networks like social, WWW and Internet systems share important structural features: small average path length, high clustering and scale-free degree distribution.

The small-world networks proposed by Watts and Strogatz [8] have revealed several important results. Firstly, real world networks are neither completely ordered nor completely random, but rather, they exhibit important properties of both. Secondly, these properties include a large average clustering coefficient which is a measure of local density, and small average path length which is a global measure of separation. However, according to the Watts-Strogatz model for creation of a small-world network together with these two important properties we get a uniform distribution of the node degree in the obtained network.

The work of Barabasi and Albert [9] lead to the scale-free networks that exhibit one distinguishing feature, the power law distribution, that is, when the node degree is plotted on a double logarithmic scale, a power law appears as a straight line with a negative slope γ with values between 1 and 3 for real-world social networks. Most scale-free models introduce random preferential attachment mechanism that allows generation of a network with a power law distribution and a small average path length.

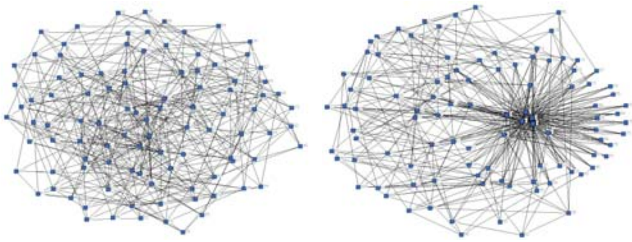
Based on the fundamental observation fact for the whole unifying world, one can not ignore the random and the deterministic factor, since the interactions in the real world are neither completely regular nor completely random and lie somewhere in between the extremes, harmoniously unified. At present, most real-world networks have shown both scale-free and small-world effects, which include small average path length and large average clustering coefficient. The harmonious unifying hybrid preferential model (HUHPM) [11] possesses both the small-world and the scale-free effects which allow the HUHPM networks to be closer to the real-world networks.

The HUHPM can realize any type of network growth based only on the combination of both random preferential attachment (RPA) and deterministic preferential attachment (DPA) by using the total hybrid ratio defined as $d/r = dr$ = time intervals d of deterministic preferential attachment divided to time intervals r of random preferential attachment. The main mechanism and principle of implementation of the hybrid network growth are as follows:

1. Growth – use each growing rule to carry on the growth. Start from m_0 nodes connected in a full mesh network and then each time interval add a new node with m ($\leq m_0$) edges connecting to old nodes in the network.
2. Connecting – each step adopting this kind of connection mechanism must accord to the total hybrid ratio d/r. The two kinds of preferential attachments are carried on in turn while different types of order can be used.
3. DPA – after each attachment the nodes are sorted according to degree. The new node connects to the first m nodes with highest degree.
4. RPA – the standard Barabasi Albert method is used. The new node links to m nodes according to the probability of preferential attachment for the ith node $P_i = k_i \big/ \sum_j k_j$ where k_i is the degree of the ith node.

Steps 3 and 4 of the HUHPM algorithm are repeated until the desired size of the network is finally reached with $N = r + d + m_0$ nodes.

Figure 1 illustrates the obtained networks using the HUHPM algorithm with N = 100 m = m_0 = 5 under different hybrid ratios d/r = 1/4 (Fig. 1.a) and 4/1 (Fig. 1.b). The same networks are used for the ad hoc network performance analysis in this paper.



a) b)

Fig. 1. Illustrate diagrams for HUHPM networks

The possibilities of incorporating the users social behavior with different impact points in and aspects of the ad hoc networks and their performances is presented in [12]. The performances of ad hoc networks that exhibit small-world properties on both physical and application layer have been studied in [13], while the way the scale-free phenomena affects the realm of ad hoc network performances is shown in [14]. In this paper we seek to understand the impact that these two phenomena have when taken into account in their harmonious coexistence.

III. HUHPM Application Layer

In order to capture the traffic pattern of the user communication within the ad hoc network we created a specialized application layer in the widely used network simulator NS-2 [15]. The custom application layer is created according to a social network obtained using the previously explained HUHPM algorithm. The obtained network defines the relationships between the ad hoc network users and their need for communication. Using this network and the custom application layer we were able to simulate each node of the ad hoc network as a different node of the HUHPM network with its given links to other participants in the ad hoc network. When sending and receiving data the node is restricted to communication with his defined friends only (the nodes he is linked to in the HUHPM network). Thus, we were able to integrate the social overlay in the simulations and model the traffic pattern according to a more realistic use of the ad hoc network.

Using this custom made application layer we conducted several series of simulations in order to investigate the ad hoc network performances. In our scenarios we observe the end-to-end throughput in the ad hoc network while varying the offered load from 0.1 Mbps up to 7 Mbps.

The ad hoc network consists of 100 nodes that are uniformly distributed in a square area of 1 km^2. The nodes

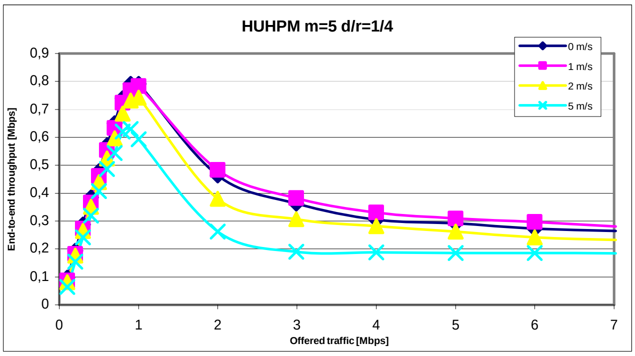


Fig. 2. Ad hoc network performance for HUHPM social network of users with *d*/*r* = 1/4 and various node mobility

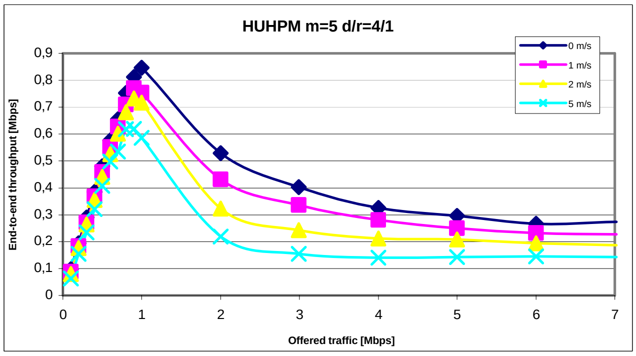


Fig. 3. Ad hoc network performance for HUHPM social network of users with *d*/*r* = 4/1 and various node mobility

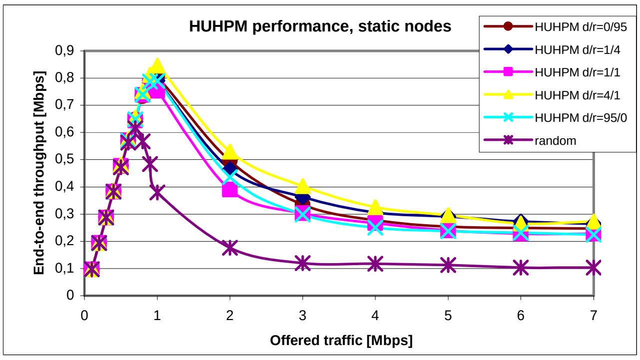


Fig. 4. Ad hoc network performances for HUHPM social network with specific *d*/*r* values and static nodes

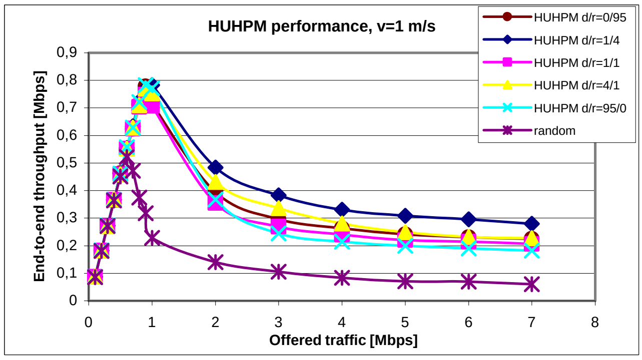


Fig. 5. Ad hoc network performances for HUHPM social network with specific *d*/*r* values and mobile nodes

are equipped with radios that use the IEEE 802.11 protocol, while the multihop routing is provided using the AODV routing protocol [16], and on the transport level we use UDP. We were studying the ad hoc network for several different cases of node mobility: static nodes, nodes with average speed of 1 m/s, 2 m/s and 5 m/s according to the random direction movement model [17].

TABLE 1: DIFFERENT HUHPM NETWORKS.

Parameters / network	$m = m_0$	*d*/*r*	*C*	*L*
HUHPM 0	5	0/95	0.03	3.015
HUHPM ¼	5	1/4	0.132	2.776
HUHPM 1	6	1/1	0.146	2.314
HUHPM 4	5	4/1	0.326	2.273
HUHPM ∞	5	95/0	0.4	2.07

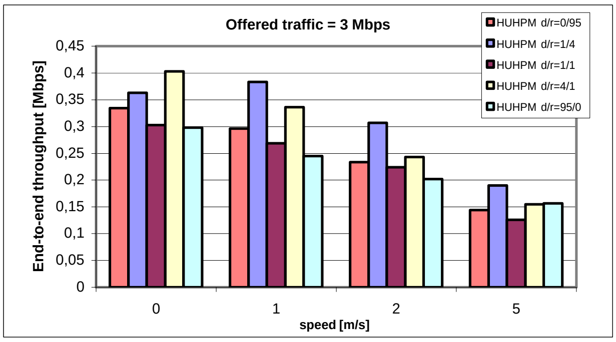
The network that mostly resembles a real-life social network with a high clustering coefficient, small average path length and a power law node degree distribution can be obtained with the HUHPM algorithm when using $m = 5$ and hybrid ratio $d/r = 1/4$ [18]. However, we also wanted to investigate and how does the hybrid ratio affect the ad hoc network performances so we investigated several cases with different characteristic values of this parameter. Table 1 gives a summary of the investigated HUHPM networks with the values for the clustering coefficient (*C*) and the average path length (*L*) of the obtained network. We stress one more time that every one of these networks has a power law distribution but with a different value of γ. Please note that the cases of HUHPM 0 and HUHPM ∞ are extreme cases when we have only random preferential attachment (which falls into a regular scale-free network obtained with the basic Barabasi Albert model) and only deterministic preferential attachment (every new node in the network connects to the first *m* nodes since they always have the highest node degree).

IV. PERFORMANCE ANALYSIS

Figures 2 to 6 depict the main results obtained from our simulation series. Our main goal was to analyze the behavior of the ad hoc network when using our application layer based on HUHPM and discover the changes that occur for different node speed and different offered network traffic load. We also wanted to investigate how these performances are going to change when we change the hybrid ratio.

Fig. 2 represents the end-to-end throughput of the ad hoc network when its users are connected in the HUHPM ¼ social network, while on Fig. 3. the achieved end-to-end throughput for the reversed hybrid ratio, that is, the HUHPM 4 network, is shown. The actual social network configuration can be seen on Fig. 1. While the performances of the ad hoc network with incorporated social aware application level are fairly higher than the ones usually obtained for random traffic it can also be concluded that their dependence on the node speed is also diminished. It is interesting to note that for static nodes the reversed HUHPM 4 network shows better performances but only for low offered load. This is due to the structure of the network where we have a couple of highly connected nodes (hubs) that are going to be the destination in a great number of cases.

a)



b)

Fig. 6. Ad hoc network performances for different HUHPM networks for 1 and 3 Mbps offered network traffic

The results shown on Fig 4. for static nodes and Fig. 5. for nodes moving with average speed of 1 m/s allow us to grasp the different performances measured for different characteristic values of the hybrid ratio. The first obvious result is that all of the observed network show much higher performances when compared to the results obtained with a conventional completely random generated traffic.

It can also be concluded that for the static case (Fig. 4.) the reasonable HUHPM 4 network shows best performances, but all network have relatively equal performances which is mainly a consequence of the node immobility so the paths once asked for and learned can be reused times again. When the nodes are moving the results show clear change of the performances. As *d*/*r* rises the performances drop. This is especially for higher loads and it appears because as the number of deterministic series rises there are more distinguished hubs in the network that lead to network congestion.

The case of HUHPM 1 falls out of this rule because of the m parameter. We studied the case of $m = 6$ for this network and, due to this reason, the network has a much larger number of links. This increased number of links results in increased variations in the possible source-destination paths which add to the deterring performances.

The last figure (Fig. 6.) compares the different HUHPM networks for different node speeds for a manageable and higher offered load in the network. While the case of hybrid ratio = 1 is almost always the worst performer, the two extreme cases are of course next to worst performing, It can be seen however that the deterministic case is better when the network is less loaded, while the random (please note that this means preferential attachment) shows off for higher loads. The same behavior can be observed for the lesser hybrid ratios. The deterministic supremacy for lesser loads is a result of the 'well-known' destination, which converts to congestion for higher loads. Our observed model of a real-life social network with hybrid ratio $d/r = 1/4$ is the best performer in almost all of the cases.

V. Conclusion

In this paper the ad hoc network performances where analyzed when using a social network hybrid model for creation of a realistic use of the ad hoc network in a situations where a group of users come together and use the ad hoc network to share information. Using the HUHPM we created a specialized application layer that reflects the way users use the network to communicated and send and receive information. We analyzed different networks obtained by varying the hybrid ratio in the HUHPM model and we obtained some interesting results concerning the performances of the network depending on the user social topology.

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