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ANT COLONY OPTIMIZATION ROUTING to MOBILE AD HOC NETWORKS in URBAN ENVIRONMENTS

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Abstract— **In this paper we present on-demand routing algorithm Enhanced Ant Colony Optimization (ACO) for Mobile ad-hoc networks(MANETs). Ant Colony Optimization, a swarm intelligence based optimization technique, is widely used in network routing. These approaches try to map the solution capability of swarms to mathematical and engineering problems. The introduced routing protocol is highly adaptive, efficient and scalable. The main goal in the design of the protocol was to reduce the overhead for routing. MAN is a collection of mobile nodes which communicate over radio. These kind of networks are very flexible, thus they do not require any existing infrastructure or central administration. Therefore, mobile ad-hoc networks are suitable for temporary communication links.**

Keyword— **Ad-hoc network, MANET, ACO, AntHoc Net.**

I. INTRODUCTION

Routing is the task of finding and using paths to direct data flows through a network while optimizing one or more performance measures. Hence the problem of routing can be solved using Ant Colony Optimization(ACO)[1,2], which is inspired by the ability of certain types of ants in nature to find the shortest path between their nest and a food source through a distributed process based on stigmergic communication . An important aspect of routing is that a distributed and dynamic problem, which means that the description of the problem changes over time and decentralized solutions must be adopted. As a consequence, the optimization algorithm for routing needs to adapt continuously.

Here, we focus on routing in a specific type of communication networks, namely mobile ad hoc networks (MANETs)[3]. These are networks that consist entirely of wireless nodes, placed together an ad hoc manner (i.e., on-the-fly, or with minimal prior planning) and without the support of a fixed communication infrastructure. All nodes are mobile, and can enter or leave the network at any time. Data are forwarded among the nodes of the network in multi-hop fashion.

MANETs are highly dynamic, have severe restrictions on the effective usable bandwidth (mainly due to the sharing of the wireless medium) ,have limited battery power available at each node. are based on the use of possibly unreliable wireless communication channels, etc. Algorithms and protocols for MANETs should be adapted to deal with these challenging properties. In this report we show how techniques from ACO can be applied to support routing in this kind of networks. We focus in particular on MANETs deployed in urban environments, which are confronted with specific conditions in terms of the network node movement patterns and the wireless radio propagation

II. ROUTING IN MOBILE AD HOC NETWORKS

Due to the ad hoc and dynamic nature of these networks, the topology can change continuously, and paths between sources and destinations that were initially efficient can quickly become inefficient or even infeasible. This means that routing information should be updated more regularly than in traditional wired telecommunication networks. However, this can be a problem in MANETs, because they typically have limited bandwidth and node resources, and make use of possibly unreliable wireless communication channels. New routing algorithms are therefore needed, which can give adaptivity in an efficient and robust way.

Existing MANET routing algorithms can be classified as being proactive, reactive or hybrid. Proactive algorithms try to maintain up-to-date routes between all pairs of nodes in the network at all times. The advantage is that routing information is always readily available when data need to be sent, while the main disadvantage is that the algorithm needs to keep track of all topology changes, which can become difficult when there are a lot of nodes or when they are very mobile. Examples of proactive algorithms are Destination-Sequence Distance-Vector routing (DSDV)[4] and Optimized Link State Routing (OLSR) [5]. Reactive algorithms only maintain routing information that is strictly necessary: they set up routes on demand when a new communication session is started, or when a running communication session falls without route. This approach is generally more efficient, but can lead to higher delays as routing information is often not immediately available when needed. Examples of reactive routing algorithms include Dynamic Source Routing (DSR)[6] and Ad-hoc On-demand Distance-Vector routing (AODV)[7].

Finally, hybrid algorithms use both proactive and reactive elements, trying to combine the best of both worlds. An example is the Sharp Hybrid Adaptive Routing Protocol (SHARP)[8].

III.ANT COLONY OPTIMIZATION FOR ROUTING

ACO routing algorithms take inspiration from the behavior of ants in nature and from the related field of ACO to solve the problem of routing in communication networks. The main source of inspiration is found in the ability of certain types of ants (e.g. the family of Argentine ants Linepithema Humile) to find the shortest path between their nest and a food source using a volatile chemical substance called pheromone. Ants traveling between the nest and the food source leave traces of pheromone as they move. They also preferentially go in the direction of high pheromone intensities. Since shorter paths can be completed faster, they receive higher levels of pheromone earlier, attracting more ants, which in turn leads to more pheromone. This positive reinforcement process allows the colony as a whole to converge on the shortest path. It forms the basis of most of the work in the field of ACO.

The main idea behind all of these algorithms is that nodes in the network periodically and asynchronously send out artificial ants towards possible destination nodes of data. These ants are small control packets, which have the task to find a path towards their destination and gather information about it. Like ants in nature, artificial ants follow and drop pheromone. This pheromone takes the form of routing tables maintained locally by all the nodes of the network. They indicate the relative quality of different routes from the current node towards possible destination nodes. Ants normally take probabilistic routing decisions based on these pheromone tables, giving a positive bias to routes of higher pheromone intensity, in order to balance exploration and exploitation of routing information. Often, the tasks of following and updating pheromone are split between a forward and backward ant, whereby the forward ant finds a path towards the destination and the backward ant travels back over the path to update pheromone tables. The result of the continuous ant sampling process is the routing information in the pheromone tables, which is used to forward data. This can again be done probabilistically, or deterministically following the path with the highest pheromone level.

ACO routing algorithms boast a number of interesting properties compared to traditional routing algorithms. First of all, they are adaptive, thanks to the use of continuous path sampling and probabilistic ant forwarding, which leads to an uninterrupted exploration of the routing possibilities. Next, they are robust. This is because routing information is the result of the repeated sampling of paths. Finally, ACO routing algorithms can usually set multiple paths, over which data packets can be forwarded probabilistically like ants. This can result in throughput optimization, automatic data load balancing, and increased robustness to failures. However, the fact that these algorithms rely on the continuous generation of small ant packets to gather routing information can easily lead to excessive overhead in the bandwidth limited MANETs. This is especially problematic since MANETs usually rely on contention based mechanisms for medium access control, which essentially means that a high number of small packets generates much more overhead than a lower number of larger packets. The challenge is to develop an ACO routing algorithm that can offer adaptivity and robustness while keeping overhead limited. AntHocNet routing algorithm, which solves this issue by taking a hybrid approach that combines ant based path sampling with other mechanisms for learning.

IV.THE ANTHOCNET ROUTING ALGORITHM

In this section we describe AntHocNet, an ACO routing algorithm for MANETs. AntHocNet can be considered a hybrid algorithm, since it contains both reactive and proactive elements. It is reactive in the sense that it only gathers routing information about destinations that are involved in communication sessions. It is proactive in the sense that it tries to maintain, improve and extend routes while the communication session is going on. This hybrid architecture improves the efficiency by focusing efforts on ongoing sessions. Another factor to help the efficiency is found in the organization of the proactive route maintenance and improvement process, which combines ant-based path sampling with other forms of information gathering. Routing information in AntHocNet is stored in pheromone tables. Forwarding of ant and data packets is done in a stochastic way, using these tables. Link failures are dealt with using specific reactive mechanisms, such as local route repair and the use of warning messages.

V. WORKING IN AN URBAN ENVIRONMENT

In this report, we are particularly interested in the evaluation of our AntHoc-Net routing algorithm in MANETs that support interactive communication in an urban environment. The use of this specific type of scenarios has a strong influence on important aspects of the working of the MANET. First of all, the structure of the urban environment defines possible movement patterns for the nodes of the network. Second, the presence of buildings and other obstacles has a strong impact on the way radio waves can propagate and hence influences the connectivity between the nodes of the network.

Finally, the interactive communication defines the data load and data traffic patterns. These properties set these scenarios apart from the kind of settings applied in most MANET evaluation studies, which rely on open space scenarios, random movement patterns and random communication patterns. We believe that the study of urban scenarios is important as this will become an important application area for MANET technology in the near future. Recent projects with wireless mesh networks, which are static ad hoc networks, in large cities such as Taipei [2] and Philadelphia [3] also point in this direction.

In what follows, we discuss the mentioned aspects of node mobility, radio wave propagation and data communication patterns in turn. We describe their effects and explain how we modeled them in the simulation study that will be presented in the next section. After that, we also give a short overview of other studies that focus on the use of MANETs in urban settings.

A. MOBILITY MODEL IN URBAN ENVIRONMENT

A mobility model is usually used to describe the mobility of an individual subscriber. The following discussion attempts a brief overview of the two commonly used mobility models to analyze design systems in wireless ad hoc networks, each with a specific goal. Random Way Point mobility mode(RWP)[l5] is a simple, widely used, model in the many simulation studies of ad hoc routing protocols. In this model each node is assigned an initial position uniformly distributed within a region (rectangular region). Then, each node chooses a destination uniformly inside the region, and selects a speed uniformly from [min speed, maxspeed] independently of the chosen destination. That means the distributions of nodes' speeds

and locations are stationary. To avoid the transient period from the beginning, one solution is
to choose the nodes' initial locations and speeds according to the stationary distribution; another one is to discard the initial time period of simulation to reduce the effect of such transient period on simulation results. The node then moves toward the chosen destination with the selected speed along a straight line starting from current waypoint. After reaching the destination, the node stops for duration called "pause time", and then repeats the procedure. All nodes move independently of each other at all times. The urban setting used in our simulation study is the center of the southern Swiss town of Lugano. Lugano is a relatively small old town presenting an irregular street topology common to most European cities. We focus on an area of 1561×997 m2, which covers most of downtown Lugano. The street structure is shown in figure 1. In which, the cityscape is composed of streets (the white lanes) and buildings (the gray polygons). Streets define the open spaces where nodes are free to move. Buildings are in our study inaccessible to the nodes and basically play the role of obstacles that put constraints on node movements and shield radio wave propagation. Other elements are the lake, in the bottom of the image, and urban infrastructures. However, these latter do not play any role and are left in the image for the sole purpose of showing the town organization. To define node movement patterns, we used an urban mobility model based on the so-called random waypoint model (RWP). Under the RWP model, nodes choose a random destination and speed, move in a straight line to the chosen destination at the chosen speed, and then pause for a certain time before picking a new destination and speed. In our urban version of RWP, destinations are only chosen from among the open spaces in the town, and nodes do not move along a straight line to their destination, but instead follow the shortest path through the streets of the town

In order to define node destinations and movements, we derived a graph representing the street structure of the town. Destinations were chosen from among all points that are located on an edge or in a vertex of the graph, and shortest paths were calculated in the graph using Dijkstra's algorithm [16]. We have chosen maximum node speeds that correspond to realistic inner city movements: from 3 m/s (10.8 km/h) to represent pedestrians or cyclists up to 15 m/s (54 km/h) to represent cars. The pause time of our RWP model is 30 s.

Figure 1: The setting of our study: an area of 1561 × 997 m2 in the center of the Swiss town of Lugano.

Finally, we keep 20% of the nodes static, to represent immobile network users. These can for example be wireless access points placed by shop or restaurant owners, or infrastructure nodes provided by the town authorities.

B. DATA TRAFFIC

For data traffic we use patterns that can reflect realistic applications of the network. We assume that the MANET will in the first place be used to support interactive communication between users. We model this type of applications using bidirectional point-to-point data communication sessions. The data packet size is 160 bytes. We consider a range of different data rates, from 1 packet every 30 seconds, representing an interactive SMS conversation, up to 25 packets per second, which is sufficient to support good quality voice-over-IP (VoIP)[12] applications. In order to represent silent periods in the interactive communication, only 40% of all scheduled packets are sent. This corresponds to the typical proportion of send time in VoIP traffic.

C. RADIO PROPAGATION

Wireless communication in an urban environment is strongly conditioned by the way radio waves interact with the objects they encounter. To evaluate the impact of the radio wave propagation model on the performance of a Mobile Ad Hoc Network the throughput and delay of multiple constant bit rate (CBR) streams is taken as an indicator. The most basic effect is that waves produced at street level are blocked by buildings, so that connectivity in urban wireless networks is restricted compared to open space scenarios. Network traffic is created by starting CBR connections between randomly selected nodes. Some urban simulation studies for MANETs in the literature only account for this effect, using open space propagation models along the line of sight (LoS) and blocking any non-LoS communication (see e.g. [9]).. In our study, we use a more detailed approach, which incorporates also other propagation effects. The most important of these effects is reflection off building walls: as radio rays bounce off building walls, they can travel around corners into side streets.

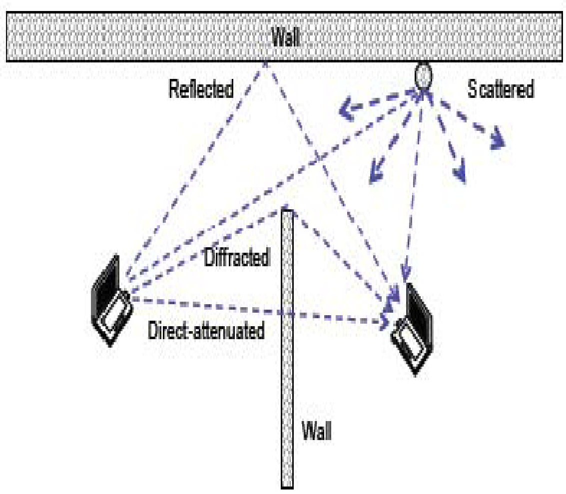

Fig.2, The effect of radio wave propagation through building walls.

Also, reflection allows a signal to travel further along the LoS through a street than it would in open space,.since multiple reflected rays are tunneled in the same direction. This means that crude approximation models that do not account for reflection are too restrictive. Another important effect is diffraction, which allows rays to bend around corners to a certain extent. This further improves connectivity into side streets. Other effects include scattering, which is the reflection off small objects and uneven surfaces, and signal variations over time due to changes in the environment, such as the passing of vehicles or people. Both of these last effects are hard to model correctly and greatly increase the computational complexity, and are therefore not taken into account here. Making detailed calculations of radio wave propagation in an environment with many obstacles is a computationally intensive task, especially when many simultaneous transmitters and receivers are involved, as is the case in MANET experiments.

Finally, the authors of [11] use a similar grid town pattern, but with a different radio propagation model: radio signals are weakened with a fixed amount for every corner they take. The aim of the paper is to investigate whether a MANET could be used to support communication between a fleet of taxis. Node movement patterns in the grid world are based on data about the behavior of real taxis. The authors find that a high density of users in the system is critical for good performance. Among the studies that apply a higher level of accuracy, we find in the first place the work presented in [13] and other papers by the same authors. In this work, real and very detailed town maps are used, and radio propagation is modeled using a ray tracing approach with some limited preprocessing. Node movement patterns are based on models derived from diverse research areas including urban planning, meeting analysis and time use. The authors study the use of a static ad hoc network running AODV in an area of central London. The highly accurate simulations take very long, in the order of tens of processor days. The conclusion is also here that high node density is a critical factor for good performance. Another study that uses a very detailed simulation model is the one described in[14]. The authors also use ray tracing, and apply a preprocessing step that is based on using a discrete set of transmitter locations but an unlimited number of receiver locations. Their simulations are reasonably efficient: they are only about a factor 1.5 slower than comparable open space simulations. The authors compare the performance of AODV in the urban scenario to that in an open space scenario, and observe a large drop in performance. The work presented in this report is in approach and level of detail similar to the last described work. It allows to get a reasonable feel for what the effects can be of an urban environment, while making enough abstraction to get an efficient simulation.

VI. CONCLUSIONS

In this report, we have presented an application of ACO[1,2] to the highly dynamic on-line optimization problem of routing in MANETs[3] in a realistic urban environment. We have first given a short introduction to the area of MANET routing in general. Then we have explained the ideas behind the application of ACO to routing. We have highlighted the mechanisms that make this approach unique, and have discussed their advantages and disadvantages compared to more traditional routing algorithms, especially with respect to the specific conditions found in MANETs. After that, we have presented AntHocNet, a hybrid routing algorithm for MANETs that is based on ACO routing. AntHocNet is a concrete example of how ACO routing techniques can be adapted to work in highly challenging environments. Concretely, the algorithm combines ACO routing with other approaches to learning in order to get adaptivity and robustness while maintaining an efficient working. Next, we have described the urban environment we work in, and we have explained how it influences the conditions of the MANET deployment and its differences with respect to open space scenarios.

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