Feasibility of geographically static data storage in ad-hoc networks

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Abstract

Ad-hoc networks are a group of computing devices that network together, typically wirelessly, forming a multi-hop network with no fixed infrastructure. As such a network provides no guarantees and a highly dynamic topology, providing service is a difficult and challenging task. This paper will look at the possibility of storing data at or near a geographic point by migrating the data from node to node. We examine the results and then discuss the ideas of using this technique for location based services, mobility prediction and other areas.

Keywords
Wireless networks, ad-hoc network, geographically static data storage, location based services, mobility prediction.

1. INTRODUCTION

Ad-hoc networks are networks that are formed automatically without any pre-existing infrastructure. These networks may consist of various types of mobile devices such as PDAs, laptops, cell phones and other mobile computing devices. Each node in a wireless ad-hoc network performs computational tasks as well as communication routing. Without the existence of dedicated routing devices, the nodes relay traffic to each other to extend their communication range.

This paper will contribute to our group's interest in looking into the feasibility of large scale ad-hoc networks. We feel these are important as it allows the consumer to construct with minimal effort their own wireless infrastructure, providing fault tolerance and a self-upgrading network as users inevitably update their mobile phones and PDAs. The benefit of this is that no company controls the network and hence there are no connection charges, and the hardware updates itself as time passes with no cost to a single organisation.

The paper will primarily look at the feasibility of storing a data item as close as possible to a particular geographic point. Each node is equipped with GPS and can create its own data items, which then migrate contiuously from node to node attempting to stay as close to this point as possible.

The overhead incurred in the network by supporting this type of data storage is analysed incorporating how close a data item is able to get to a particular point under different mobility scenarios and node densities. Problems also arise when nodes are switched off as this could result in data loss. We will address this and other issues and suggest possible solutions.

As far as we are aware this is the first paper to look at the feasibility of such an approach. Our ongoing work is currently looking at applying this technique to both location based services and to location information caching in ad-hoc networks to facilitate mobility prediction. This form of mobility prediction could help reduce significantly location updates in large scale networks. We will briefly cover these items of future work and how they could be facilitated by this approach to data storage.

The paper will then conclude highlighting the feasibility of this approach.

2. GEOGRAPHICALLY STATIC DATA STORAGE

The next few sections will present our idea of storing data at a geographically static point using a pure ad-hoc network. The idea is that a node will generate a piece of information that would be useful to anyone at this point in space, either at the present time or in the future. In addition to this anyone should be able to query a particular location if they are not there by sending a query packet across the network.

The uses of this kind of technology are far reaching such as location servers[1] in large scale ad-hoc routing protocols[2]. These location servers serve up location information on a particular node, so that others are able to find its location. In the existing algorithms, every node acts as a location server for potentially any other node and sends its own location information to nodes at a particular location. These nodes then store the information for any queries, however if they move away from the location they take the data with them and it is no longer accessible until the next update.

The technique presented in this paper expands upon this by allowing location dependant data to migrate from node to node as nodes move away from the location that the data is destined to reside at. We develop a basic protocol in GloMoSim to demonstrate and measure the performance of the idea.

Each node can hold location dependant data for any other node but as this node moves away from the location that the data should be at, our protocol will periodically search through its neighbours to see if one of its neighbours is closer. We denote the interval between these checks as the migration interval, and for these experiments the default is 10 seconds. Upon finding a closer neighbour, the protocol will send a migration message to this neighbour containing the location dependant information. Upon receiving an acknowledgement packed from the closer neighbour, the node will remove the information from its database.

Supporting this technique requires nodes to know about their neighbours' locations so that we can determine if a neighbour is better suited to hosting the information than ourselves. The simplest means of doing this is by having every node beacon its current location information at a static or variable rate. In this paper we use a static rate of 5 seconds however we could potentially reduce traffic more by using a beaconless technique[3] or by beaconing dependant upon our mobility and overhearing of new neighbours in our proximity.

We primarily focus on scenarios where nodes are walking, and as such set node speed between 0.1m/s and 3m/s. The random waypoint model[4] is used with a lower limit of 0.1m/s to remove the well known problem with this model's convergence of average speed to zero[5]. We expect that many people will arrive at a location and stay there for a period of time performing a task, such as when one arrives at their office or a social function. Hence in simulation we examine the effect of various pause times on the protocol but we expect the pause times in a real world large scale network to be highly variable, as such we also simulate random pause times.

One of the key factors if nodes are to be able to query this information, is the proximity of the data to the actual location that it is expected to be at. This paper therefore examines the average distance over the simulation of the data to this point given the various changes to other parameters. We suggest that the ideal distance should be less than the average node's radio range so that no form of multi-hop broadcast is required to discover the data. In our simulations the radio range is 140 metres which is almost three times the average distance of the data from its destination.

We set out to prove in this paper that not only are we able to keep the overhead of this scheme quite low, we are also able to achieve a low average distance from the destination point. Therefore we demonstrate the feasibility of the scheme as a whole and pave the way for its use in new technologies.

3. RESULTS

This section will examine the results of our experiment. Initially we wanted to find out whether this approach was actually feasible and not restricted by overhead or the distance the data items would be from their target. Our results demonstrate that not only is the overhead extremely low in our mobility scenario, in the order of 1-2 migrations per minute, but that changes in the mobility parameters had only marginal effect.

We perform two experiments, the first varying the pause time with the node density set at 200 per square kilometre and the second varying the node density per square kilometre with a fixed pause time of 5 minutes. Where the pause time is set to uniformly distributed, each node's pause time is chosen independently of any other node.

The first graph (Fig. 1) shows the average distance of the data item from its target against the pause time of the mobility model. The experiment has 200 nodes in a square kilometre which is a relatively low density compared with say a city centre. The data items are able to maintain a distance of 50 metres in the worst case scenario of continuous mobility. The graph also shows that the pause time has only a marginal effect on the average distance, increasing by only 13 metres from a pause time of 20 minutes to continuous mobility.

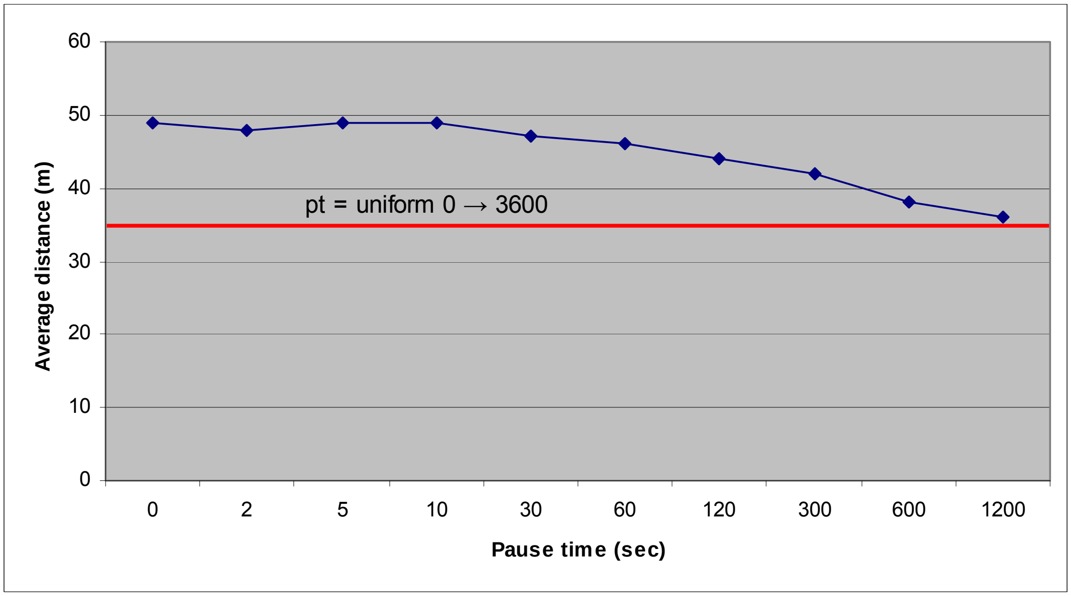

Fig. 1: Average distance vs. pause time

The next graph (Fig. 2) shows how the average distance changes as we vary the node density. One would expect that an increase in node density would decrease the distance due to the likelihood of there being more nodes closer to the target. This prediction is indeed correct, but interestingly with a low density of 25 nodes per square kilometer the item is able to achieve an acceptable distance of 146 metres.

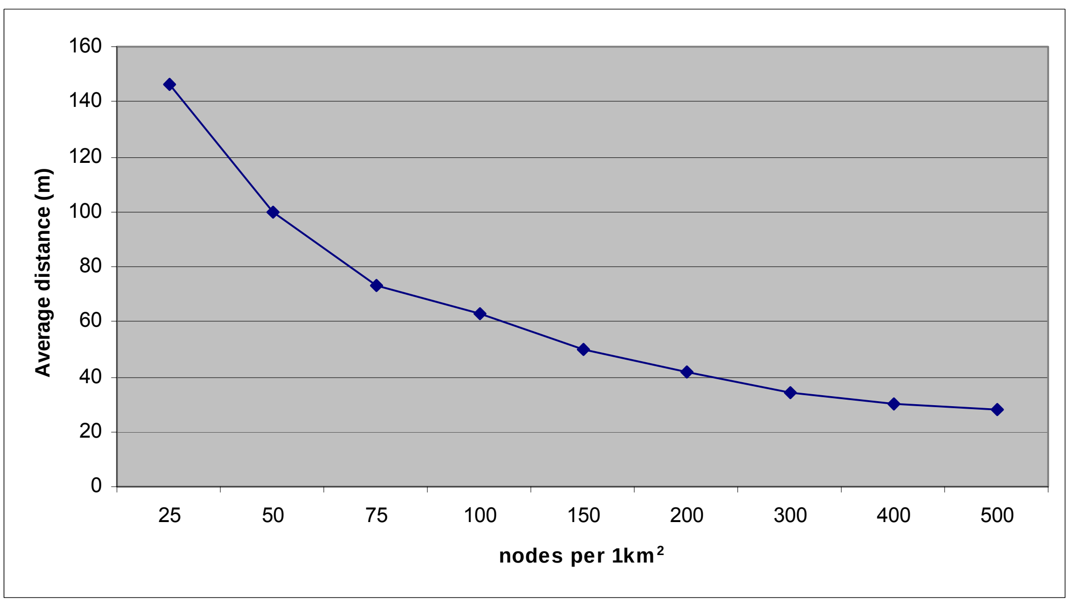

Fig. 2: Average distance vs. nodes density

Fig. 3 shows the number of migrations per minute required to obtain the above distances as we varied the pause time. Interestingly the average number of migrations for continuos mobility is lower than two per minute. We expected this as the worst case maximum node speed is 3 metres/second and therefore this would take the node just under 17 seconds to reach the average distance from the distination.

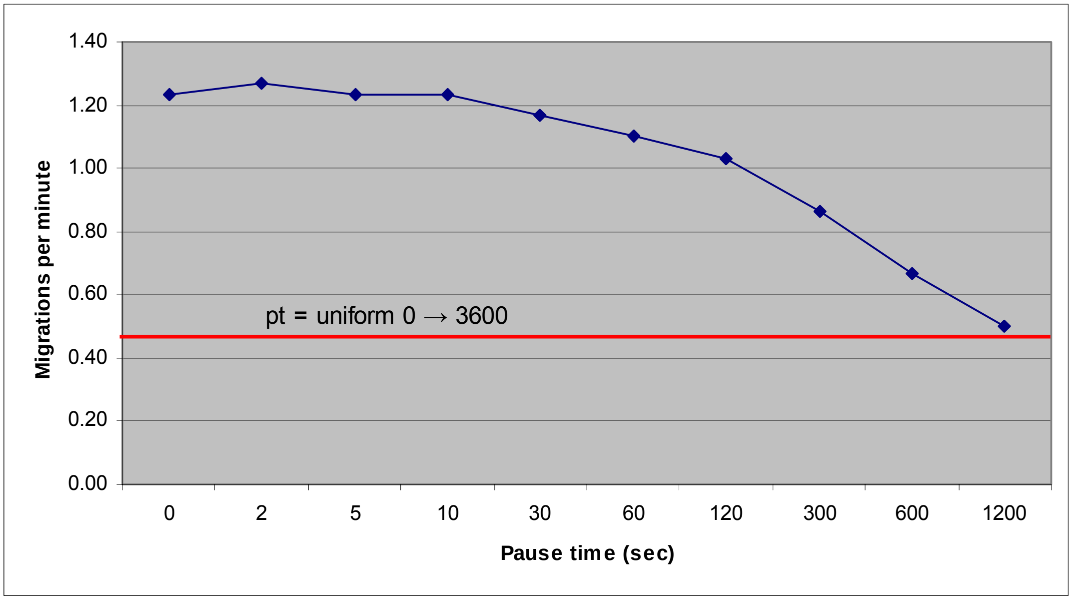

Fig. 3: Migrations vs. pause time

As the node density increases the data items attempt to migrate more often to achieve a lower distance as shown in the Fig. 2. The number of migrations is still extremely low at less than 1.4 per minute (Fig. 4) with a density of 500nodes per square kilometer.

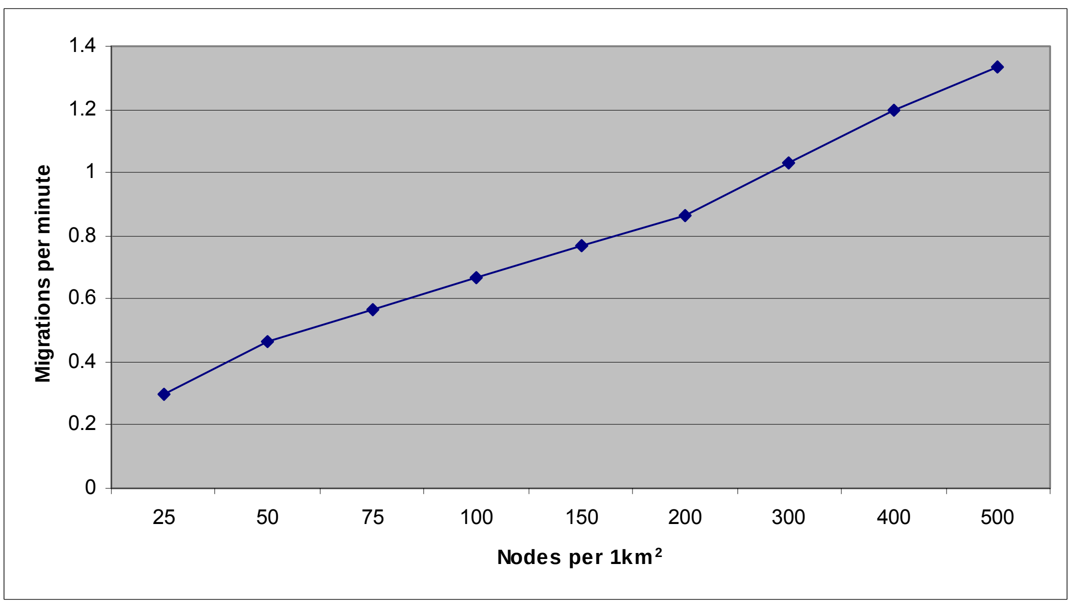

Fig. 4: Migrations vs. node density

Experiments were also performed varying the migration and beaconing rates of each node, but these were found to have negligible effect of the outcome of the experiments as each experiment was run for 30 minutes.

Upon introducing a 50% load of traffic into the network we found this to have zero effect on the outcome of the results of the experiment as the protocol has an acknowledgement step that resent any failed packets.

4. FUTURE DIRECTIONS

Research is ongoing into this technique and many areas are currently under investigation. The effect of replication of the data upon reaching the area of the target is very important as nodes being switched off could otherwise result in data loss.

This technique could be used in providing location based services in ad-hoc networks allowing users to leave information at certain points. A simple n-hop query mechanism could be employed to query such data.

Location servers in geographical routing protocols currently suffer if the location servers move out of range or are switched off, application of this approach would solve the former problem and the latter with the introduction of replication and allow for more infrequent updates when node mobility is low

Finally our team is concentrating on using this technique to enable mobility prediction to reduce further the number of update packets sent to a node's location server. The basic idea is the leaving of breadcrumb data items that record information on when the node was last seen and where it was heading. We hope to prove in the future this technique will reduce packet loss and location update overhead.

5. CONCLUSION

In conclusion our results clearly show that for even worst case mobility scenarios, that storing data at a specific geographical point by migrating from node to node is feasible. The overhead incurred is low enough as to be fairly inconsequential in modern day high speed wireless networks.

The introduction of location based services is becoming more widespread and it is of our opinion that the introduction of such services will become a key technology of the future. In addition to this research into large-scale ad hoc networks is gaining great momentum and we feel that geographically static data storage will play a key role in implementation of location based services and mobility in such networks.

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