Research Proposal

A Mobile Ad Hoc Network Implementation for Android Smartphones

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Abstract
The purpose of this research is to determine the feasibility of implementing and utilizing a wireless ad hoc network configuration to communicate between Android smartphones. Communication between devices will be independent of the existing cellular network and will be possible whether the device is within range of the cellular network or not. The desired outcome of this research is to demonstrate the ability to transmit data from one smartphone to another using a series of peer-to-peer smartphone relays, with the motivation of being able to restore some phone communication abilities during a failure of the cellular network infrastructure.

Introduction
Cellphone usage has become a central component in personal communication within the last decade. Modern day cellphones are loaded with technical gadgets designed to make the phone more versatile and more useful to the end user. Besides making phone calls, these smartphones are also able to send data across the world via well established cellular networks. With a connection to the network, a smartphone can send messages, pictures, and videos to any other smartphone on the network, and in most cases can also connect to the internet as well. However, data transfer is currently only possible while a cellphone user is within range of the cellular network. Once outside this range, a user is cutoff from sending and receiving data. This is a major limitation of the current network infrastructure, and can be amended by introducing the ability to communicate peer to peer within the cell network.

This research will determine the feasibility of a mobile ad hoc network (MANET) implementation that will run across a network of Android smartphones. This would allow the user of any phone within the MANET to send data to any other phone in the MANET, using one or more hops across phones participating in the network. For this research investigation, the MANET will be formed only in response to a disconnection from the main cellular network, since the main motivation for creating such a network is to form a backup communication system in case the primary cellular network system fails. The crossover from using the main cellular network to using the backup MANET will be as transparent to the user as possible.

This research focuses specifically on using Android smartphones. The term Android smartphone describes a device which is a mobile computing platform. The phone runs an open-source Linux operating system at its core, and provides a Java-like virtual machine for running user applications. Depending on the model of the phone, the accessible hardware may include a camera, GPS, Wi-fi, Bluetooth, and internal accelerometers (usually for determining phone position, but can also be used for tracking motion). The Android smartphone is a very versatile device. Developers can create programs that do a wide variety of things, with the benefit of being able to access useful hardware devices and with the ease of using a well documented API. Additionally, since the source code for the operating system is open-source, it is possible to make modifications to the operating system and to then run that modified code on the phone. This ability to have near complete control over the phone is a large benefit for performing research with smartphones, and was one of the deciding factors when choosing to use the Android smartphone.

Motivation
There are many motivating factors for creating an ad hoc cellular network with mobile phones. The primary concern for this research investigation is being able to effectively communicate during some
A disaster in this case could be considered a natural disaster, such as an earthquake, or a man-made disaster, for example, a plane crash, or terrorist attack. If such an event were to damage the existing cellular network infrastructure, some cellphone users would be unable to connect to the cellular network. With widespread damage, this could mean thousands of people no longer have an effective means of long distance communication. In this situation, an individual's cellphone still functions but it is essentially useless. The impact this outage would have on disaster relief efforts is substantial. Without being able to signal for help, victims of an incident may find themselves trapped. Medical crews may find themselves providing redundant search and rescue operations in some areas, while unintentionally ignoring other areas due to miscommunication. Additionally, without the ability to communicate effectively the average person will become more of a hindrance than help. During a large scale emergency, it is not uncommon for a large number of people to need to be relocated or evacuated. Historically, directions for evacuation have been spread by television and radio, or by word of mouth. While sending broadcasts over the air is an effective means of spreading a message, it is possible that this message does not reach everyone. Thus it is necessary to use a certain amount of manpower to spread the message by mouth, which may even involve going door-to-door to relay information. This relay system can be slow and potentially inaccurate or confusing. The process of disseminating information can be greatly aided with the use of cellphones, since their use is so prevalent in society. Data can be transmitted at the speed of light to large amounts of people, which is exactly what is needed in case of a large scale disaster. Effective communication can save lives, and having a working cellphone in these types of situations will only aid in relief efforts. With the proposed ad hoc cellular network, a failure of the primary network infrastructure would be remedied by a cellphone's ability to create a network with the surrounding cellphones. The cellphone would be able to use local peer cellphones to relay the user's data to the end destination. Ideally, communication could be fully restored in this scenario. With an implementation that reroutes the user's data transparently, the user may not even know he or she has lost connection to the regular cellular network.

Besides providing communication infrastructure during a disaster, the results of this research may have additional applications. By having a continuously active ad hoc network between cellphones, the average range of each cell in the cellular network could be extended. This could mean better coverage in areas with less cell towers. By having a continuously active connection, it could be possible for cellphone users to completely bypass the need to use a cell tower, thereby avoiding possible financial charges, and possibly increasing data throughput. These are just some of the additional possible applications of this research, but they will not be considered any further since they extend beyond the scope of this investigation.

**Related Work**

The proposed research plan builds off of existing research in the areas of mobile ad hoc networks (MANETs). There exists plenty of research detailing optimizations for MANETs, such as power, throughput, range, scalability, and adaptivity optimizations. Additionally, research on extending wireless cellular networks by means of ad hoc networking has been studied in the past.

The general concept of being able to relay information in packets via ad hoc wireless networks has been studied since as early as 1973, with the advent of the Packet Radio Network (PRNET) by the Defense Advanced Research Projects Agency (DARPA) [2]. At the heart of PRNET was the radio transmitter/receiver. This was a device that could communicate wirelessly with any other PRNET radio within a line of sight. Radios that were not within a line of sight could still communicate, provided they had some form of ad hoc route between them formed by using other radios for
intermediate hops. PRNET addressed many of the issues that arise while using ad hoc networks, such as node topology, routing, packet loss, and signal interference.

Since PRNET, there have been countless efforts made by researchers to optimize all aspects of mobile ad hoc networks. Because our research pertains mainly to creating a MANET using mobile cell phones, we look more closely at past research in this area. Ying-Dar Lin [4,5] describes a cellular network, called Multihop Cellular Network (MCN), where the mobile users can use multiple hops across ad hoc nodes to connect to the cellular network backbone. The basic setup for MCN was based on the Single Hop Cellular Network (SCN) design, with a few modifications. SCN permits users to make one wireless hop from mobile client to cell infrastructure, which is the traditional method of relaying data to and from the cellular network backbone. The difference MCN introduced is that mobile users within a cell can all communicate with each other as well as the cellular infrastructure, since each mobile user is running a special bridging protocol. By splitting the typical SCN cell into a number of smaller sub-cells, an increase in throughput can be achieved, since the number of sub-cells can increase the number of simultaneous transmissions within the larger cell.

In 2003, Haiyun Luo studied increasing the cellular network’s aggregate throughput by using wireless ad hoc networking between mobile devices, with an architecture called UCAN, A Unified Cellular and Ad hoc Network architecture [1]. Without UCAN, the standard 3G connection is used to connect most phones within a cell to the cellular backbone. Some older phones do not support 3G connections, however, so they must connect with a lower bandwidth protocol. In order to maximize throughput within a cell, UCAN is able to transmit most data at 3G speeds. This is trivial for devices that support 3G, but a novel approach for devices that can not receive 3G speed data from the network. The older devices that do not support 3G must locate a nearby ad hoc proxy phone that does support 3G. The older devices can then use a high speed Wi-Fi link to retrieve its data from the 3G proxy phone, which communicates with the cellular network on behalf of the non-3G phone.

Recent work is continuing on a project very similar to our own, called the Serval Project [3]. The aim of this project is to provide ad hoc mesh networking on portable phones, for the purpose of providing widespread communication in areas where infrastructure is not available. The Serval Project comprises a superset of our own research, insofar as the goals of the project are concerned. Whereas our research is concerned with providing a temporary ad hoc network between mobile phones for disaster relief efforts, the Serval Project is aimed at creating a more permanent type of network, that is accessible at all times, while still using ad hoc connections between mobile phones. Additionally, our methodologies will differ somewhat in terms of our device addressing and packet routing, due to the difference in scale between the projects.

The main contribution of our work will be the utilization of the Android phone for the creation of the mobile ad hoc network. Previous research has pioneered the technology necessary to create and optimize mobile ad hoc networks, but such research often requires the use of additional hardware, which in most cases is large, expensive, and not versatile. Our research utilizes the Android phone platform precisely because it overcomes these limitations. The device is relatively cheap (compared to specialized hardware), very small in size, and highly versatile. It embodies the next logical leap forward in MANET research.

**Methodology**

The proposed solution for determining the feasibility of this research is as follows. An ad hoc network implementation will be programmed to run on an Android smartphone. The particular phone model that will be used has built-in 802.11 Wi-Fi and Bluetooth support. The implementation will be
analogous to a standard mobile ad hoc network implementation; it will provide delivery and routing of data between nodes, subject to the spontaneous introduction and removal of any node at any time. It will be efficient in attempting to route data fairly, and with the lowest impact to battery life. The implementation of the mobile ad hoc network protocol for this investigation will be based on a three-layer model, which will allow for maximum flexibility in determining the optimal data link, routing protocol, and application protocol [Figure 1]. The lowest layer (layer 1) will handle the data link connection between nodes. This layer is responsible for performing discovery of adjacent nodes as well as transmitting and receiving of both data and routing packets. Layer 1 will maintain records of the nearby nodes and will handle association and disassociation with these nodes. Layer 1 will communicate only with the next layer above it, which is layer 2. Layer 2 is responsible for handling routing. It contains the implementation specific routing protocol. Routing messages are received at layer 1 and passed to layer 2 for processing. Layer 2 will maintain a routing table which will be used to attempt to route data packets to the requested destination. The routing protocol used for this particular implementation will be the on-demand routing protocol AODV (Ad hoc On-demand Distance Vector Routing). Layer 3 is the next layer above layer 2. Layer 3 is the application layer, and only communicates with layer 2. The job of layer 3 is to handle any application specific logic; in this case, that is determining when to activate the MANET, which is when connection is lost to the main cellular network. Layer 3 communicates with layer 2 when it needs to send a packet to a specific destination.

A layered approach allows us to modify specific parts of the implementation in a modular fashion. For example, consider the modular design of layer 1. It encapsulates all of the logic required to use a specific data link type. For this research, Bluetooth will be the primary data link between phones. Our preliminary research indicates that using wi-fi on the Android devices to form a mobile ad hoc network will not be possible without modification to the device's operating system. When operating system and driver support for ad hoc wi-fi networks becomes available on the Android phone, that will likely be more desirable to use than Bluetooth. When that happens, it will only be necessary to redesign layer 1 of the protocol. Other data links may become available in the future (such as CDMA), and likewise, this approach will allow for an easy transition to using the new technology.

From a high-level overview, these are the following steps that will occur when the software is working properly. The smartphone will periodically perform discovery of nearby devices using the standard Bluetooth discovery mechanism [Figure 2a]. Each device will maintain records of all of the surrounding devices within communication range (i.e. within a single hop). These records will form the basis of the ad hoc network routes. Note that this discovery step can be done with low periodicity while the normal cellular infrastructure is still operational in order to provide for a fast transition time to the mobile ad hoc network should the normal infrastructure fail. Once the normal infrastructure fails, the discovery process will occur at a much higher rate [Figure 2b]. No routes are established within the network until a data packet requests to be transferred from a source to a destination. The routes are established on-demand, via the AODV routing protocol [Figure 2c]. This protocol will find a route from the source phone to the destination phone across one or more hops, if such a route exists. If the route does not exist, then the data packet will be undeliverable and will retained for future delivery.

As previously mentioned, Bluetooth will be used as the communication link between nodes. There are several reasons for choosing Bluetooth over wi-fi. The primary reason Bluetooth will be used is due to the driver software installed on the Android smartphone. The driver software does not support an easy way to create one or more ad hoc connections with other Android smartphones. While the driver software could be modified to circumvent this shortcoming, it will be much easier to use Bluetooth, which was specifically designed for creating ad hoc connections between multiple devices, and is available for use on the phone. Additionally, modifying the stock operating system makes the software
less portable; in order for the average user to install the software he or she would need a significant amount of technical knowledge. By using the stock operating system and drivers we increase the usefulness of our software.

The implemented network will be tested in several different scenarios, involving different node topologies. Metrics will be collected during the experiments and analyzed afterwords to determine the characteristics and quality of the network. Modifications will be made to our software to optimize data delivery, to a reasonable extent. There exists much research on MANET optimizations but a limited amount of development time prevents us from utilizing all advanced optimization techniques.

### Evaluation

To evaluate the success of the proposed network implementation, several statistics will be gathered and analyzed from an experimental implementation. These statistics will include: network throughput, packet loss rate, average transition time (from cell networked to ad hoc networked), and performance versus node separation. Since the devices will be battery powered, power consumption will also be monitored. Additionally, virtual simulations of the implementation will be used to gather data for large scale simulated networks.

The experimental setups will consist of multiple Android smartphones all running the software implemented for this investigation. There will be multiple setups in order to conduct several different tests, but the setups can be identified as either static or dynamic. For the static setup, all of the devices will be placed at various locations throughout a building and will not move once they are placed at a location. In contrast, the dynamic setup will contain both stationary devices, as well as devices that are relocated during the experiment. In both setups, devices will be allowed to spontaneously connect or disconnect from either network. The purpose of the static setup is to test the ability of the network to organize itself and maintain connections with limited topology changes. It will primarily be a test of the data link capabilities. The dynamic setup will place more stress on the routing algorithm, and will test the robustness and feasibility of its implementation.

There will be several experiments that will be run on each setup. The first experiment will test the ability of the network to form in a transparent manner when connection to the primary cell network is disrupted. Depending on the scope of the 'outage', one or more phones may join the ad hoc network. This will be simulated by disrupting the cellular network connection on one or more cellphones, and then allowing those phones to automatically form an ad hoc network with the other cellphones that are in range. This will be done repeatedly with varying numbers of phones for each experiment. The reverse procedure will also be tested; the time it takes to transition from using the backup network to using the main network once the connection is restored. The main metric that will be measured here is the time it takes to transition from the main network to a stable state in the backup network (and vice versa). Statistics on battery power will be gathered, and these will form a baseline for a low-power (idle) usage. Since there will be an important trade-off between discovery periodicity versus transition time and battery power, this will be a key variable that will be adjusted as the experiments are conducted.

The second experiment will test the routing capabilities of the mobile ad hoc network. Once the network is formed, packets will be sent from one phone to another, which may be one or more hops away, or may not even be reachable on the network. This process will be repeated with different nodes, in order to determine any anomalies that arise during data transfer. Metrics will be gathered on packet transfer time as well as the actual route the data has taken. These metrics will be gathered via logs stored on each device. It will be important to see here what routes are taken with respect to
distances between nodes and throughput between nodes (which may be dependent on the distance between any two nodes, among other things).

The third experiment will stress the mobile ad hoc network. Once the network is formed, packets will be sent between nodes at a high rate. Multiple nodes will be sending packets over the network. Multiple senders will attempt to send to the same receiver. Metrics will be collected on packet transfer time, data routes, packet loss, and battery performance for each node. This experiment will be key in understanding the feasibility of this research.

A usable network will have a short transition time, as well as high enough range and throughput in order to send data between the nodes within a short amount of time. The ideal goal is to have message transfer characteristics on par with data transmission characteristics for the normal cellular network.

**Timeline**

The estimated time to complete this research investigation will be approximately eight weeks. These weeks will be broken down as follows:

March 11th - 17th: Preliminary Android phone research.
March 18th - 24th: Implementation and unit testing of layer 1, the data link layer.
March 25th - 31st: Implementation and unit testing of layer 2, the routing layer.
April 1st - 7th: Implementation and unit testing of layer 3, the application layer.
April 8th - 14th: System level testing of all layers. System optimization as needed and as time permits.
April 15th - 21st: Static network experiment tests and benchmarks.
April 22nd - 28th: Dynamic network experiment tests and benchmarks.
April 29th – May 5th: Compile results and report.

**References**


Figures

Figure 1: Layered architecture. Each layer is modular and only passes data to adjacent layers. From top to bottom the layers are Application, Routing, and Data Link.

In figure 2a the backup network is not active and the application does node discovery with a low periodicity.

In figure 2b, the backup network is active and the application performs node discovery with a high periodicity. No routes are formed because no data messages have been sent.

In figure 2c, the backup network is active and the user has sent a data message to a remote node. The AODV routing protocol has established a route on demand.