



# NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

## THESIS

**SMART CACHING FOR EFFICIENT INFORMATION  
SHARING IN DISTRIBUTED INFORMATION SYSTEMS**

by

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September 2008

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<b>REPORT DOCUMENTATION PAGE</b>			<i>Form Approved OMB No. 0704-0188</i>	
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<b>1. AGENCY USE ONLY (Leave blank)</b>		<b>2. REPORT DATE</b> September 2008	<b>3. REPORT TYPE AND DATES COVERED</b> Master's Thesis	
<b>4. TITLE AND SUBTITLE</b> Smart Caching for Efficient Information Sharing in Distributed Information Systems			<b>5. FUNDING NUMBERS</b>	
<b>6. AUTHOR(S)</b> Ableiter, Dirk				
<b>7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)</b> Naval Postgraduate School Monterey, CA 93943-5000			<b>8. PERFORMING ORGANIZATION REPORT NUMBER</b>	
<b>9. SPONSORING /MONITORING AGENCY NAME(S) AND ADDRESS(ES)</b> N/A			<b>10. SPONSORING/MONITORING AGENCY REPORT NUMBER</b>	
<b>11. SUPPLEMENTARY NOTES</b> The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.				
<b>12a. DISTRIBUTION / AVAILABILITY STATEMENT</b> Approved for public release; distribution is unlimited			<b>12b. DISTRIBUTION CODE</b>	
<b>13. ABSTRACT (maximum 200 words)</b> <p>Remarkable technical advances in cell phones and smart phones have resulted in a worldwide marketplace permeated by mobile devices. These capabilities, in combination with increasing consumers demand to share information show the need for utilizing the mobile devices more efficiently. But, within a distributed network of mobile devices like TwiddleNet, the two most limiting resources are still battery power and bandwidth. By distributing only small sets of data that represent the actual content, use of these resources can be reduced. The information tags can be sent throughout the network, reducing the amount of traffic to share the information. But, once the content itself is shared, the workload on the mobile servers can quickly exceed the mobile device's ability to perform. This thesis offers an algorithm that will conserve battery power and bandwidth, depending on demand and device capabilities. Once a certain limit of bandwidth usage, or a certain battery level, is reached, the algorithm will select the content that will most efficiently relieve these two resources and temporarily upload it to a proxy server that will serve the content on its behalf. This "smart," temporary, caching will last as long as the bandwidth or battery level limits are exceeded.</p>				
<b>14. SUBJECT TERMS</b> Mobile file sharing, caching, distributed networks, mobile devices, TwiddleNet			<b>15. NUMBER OF PAGES</b> 67	
			<b>16. PRICE CODE</b>	
<b>17. SECURITY CLASSIFICATION OF REPORT</b> Unclassified	<b>18. SECURITY CLASSIFICATION OF THIS PAGE</b> Unclassified	<b>19. SECURITY CLASSIFICATION OF ABSTRACT</b> Unclassified	<b>20. LIMITATION OF ABSTRACT</b> UU	

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DISTRIBUTED INFORMATION SYSTEMS**

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Submitted in partial fulfillment of the  
requirements for the degree of

**MASTER OF SCIENCE IN COMPUTER SCIENCE**

from the

**NAVAL POSTGRADUATE SCHOOL  
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## **ABSTRACT**

Remarkable technical advances in cell phones and smart phones have resulted in a worldwide marketplace permeated by mobile devices. These capabilities, in combination with increasing consumers demand to share information show the need for utilizing the mobile devices more efficiently. But, within a distributed network of mobile devices like TwiddleNet, the two most limiting resources are still battery power and bandwidth. By distributing only small sets of data that represent the actual content, use of these resources can be reduced. The information tags can be sent throughout the network, reducing the amount of traffic to share the information. But, once the content itself is shared, the workload on the mobile servers can quickly exceed the mobile device's ability to perform. This thesis offers an algorithm that will conserve battery power and bandwidth, depending on demand and device capabilities. Once a certain limit of bandwidth usage, or a certain battery level, is reached, the algorithm will select the content that will most efficiently relieve these two resources and temporarily upload it to a proxy server that will serve the content on its behalf. This "smart," temporary caching will last as long as the bandwidth or battery level limits are exceeded.

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## **ACKNOWLEDGEMENT**

I thank Professor Gurminder Singh and Professor Thomas Otani for their guidance, insight and inspiration.

Also, I thank my good friend Pam Yeager and my family for their help and support.

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## I. INTRODUCTION

In 2007, the market penetration of cell phones and smartphones had already reached 110% in Europe,<sup>1</sup> meaning, statistically, everybody owns a mobile device and a number of people use more than one device. A 2007 Bridge Ratings Industry Study<sup>2</sup> projected that 70% of the U.S. population owns a cell phone. At a population of 300 million, that means 210 million cell phone users. With current population growth, that number becomes 300 million users by the year 2015. Worldwide, a recent UN report <sup>3</sup> suggests 2008 will see 50% of the earth's population using a mobile phone. Although the developed Western nations have the highest mobile phone rates, China estimates one billion cell phone subscribers in 2008, and many other non-Western nations are experiencing rapidly rising rates of use as well.

What do these statistics mean from a technology and social science standpoint? It means being able to take advantage of the ubiquitous presence of mobile devices to advance technologies that will extend the movement of information, securely and rapidly, with enormous potential for new applications. The flow of data, privately and directly from mobile device to device could be used in emergency situations for civilian, government, and military organizations. Consider Hurricane Katrina in August 2005 or the tsunami of Southeast Asia in December 2004. The ability to instantly and reliably communicate critical information across a wide range of organizations could aid in property and life-saving responses. Consider as well the market for applications in the social networking arena. The popularity of social websites and text messaging point to a large and growing market for sharing information, music, pictures and more. Peer-to-peer communication, with privacy concerns alleviated by essentially excluding the public domain, is of value to consumers. As cell phones evolve into "smartphones" and users

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<sup>1</sup> Daniel dos Reis, <http://www.dosreis.de/2007/01/20/excellent-article-about-mobile-phone-users-ww/>, retrieved April 2008.

<sup>2</sup> Bridge Ratings LCC, [http://www.bridgeratings.com/press\\_05.09.2007-Mobilphone.htm](http://www.bridgeratings.com/press_05.09.2007-Mobilphone.htm), retrieved June 2008.

<sup>3</sup> Romow, <http://www.romow.com/shopping-blog/mobile-phone-use-reaches-50-worldwide/>, retrieved June 2008.

become more comfortable with these technical advances, the need for secure, easy to use technologies and services will continue to expand. The possibilities for market opportunity are almost limitless with a system that can solve privacy, ownership, and bandwidth issues whether a user uses a mobile device or a home PC.

Smartphones offer more capabilities than telephony alone. These devices have multimedia features like taking pictures and recording videos. They are able to record voice notes or store text files. In today's phones, storage capacities in Giga Bytes and processor speeds of more than 500 MHz are common. Soon Terabytes of storage and Giga Hertz processors will be the standard. Many devices have a Global Positioning System (GPS) chip built in as well, and typically possess more than one networking connection. In addition to the telephone network infrastructure for voice transfer, the devices often offer data transmission via the telephone system<sup>4</sup>, Wi-Fi<sup>5</sup> and Bluetooth<sup>6</sup>. Powerful operating systems run general purpose applications and interface with the user via sound or multicolor touch screen displays. Wi-Fi phones, Wi-Fi cellular dual-mode phones and PDAs (Personal Digital Assistants) allow users to take full advantage of heterogeneous radio technologies. With the advance of third-generation (3G) cellular networks, data transfer capabilities can enable live video streaming. All of these capabilities are packaged in a single handheld device no bigger than a wallet! For the remainder of this thesis, we will refer to these devices as "smartphones" or "mobile devices" interchangeably.

In conjunction with technical advances, user behavior has also changed significantly in the past couple of years. Five years ago, cell phones were mainly used for telephony or text messaging, but consumers today are utilizing more features of these devices. One reason is that the capability and the quality of those features dramatically increased. One should think about the quality of pictures one can take with a low-cost

---

<sup>4</sup> Most common in the U.S. is the Global System for Mobile communications technology. It is considered second Generation (2G) wireless communication. 3G technology is already available but not yet widespread in the U.S.

<sup>5</sup> Name used for IEEE 801.11 a, b, i and n standards.

<sup>6</sup> Personal Area Network (PAN) technology that allows short-distance (less than 300') wireless communication.

device. Many teenagers have their first experience with digital photography using their cell phones. Another reason is a social aspect, meaning that staying in touch with friends and family and sharing information has become a part of our daily lives, every where and every time we want. But the data sharing is mostly limited to services like multimedia message service (MMS) where media messages are sent like text messages using the telephone infrastructure or uploading the content to web pages, later using the PC at home. While the latter is time consuming and content sharing is delayed, the first is very cost intensive and limited to a small number of recipients. A better use of the mentioned device capabilities would be to support content sharing in real time and without third-party services usage.

TwiddleNet is a software application designed to support this advanced, real-time, secure file sharing. In TwiddleNet, each smartphone not only acts as content creator, but also serves user requests directly in a peer-to-peer fashion. While in the conventional client server model the user uploads or sends the whole file to the recipient, TwiddleNet only sends characterizing metadata, which reduces network load significantly. If the recipient actually wants the file, she then downloads the file directly from the source mobile device. Instead of only pulling the content from a third-party webpage, TwiddleNet adds a push capability to the network that allows for real-time alerting at content creation, without needlessly sending huge amounts of data into the network. The link between the devices is the TwiddleNet portal. The portal is a central repository for knowledge about participating user devices; it forwards received metadata alerts to the recipients or acts as temporary content server in lieu of a mobile device. A mobile device can act as the portal as well, as described by Rimikis [1].

TwiddleNet provides an advantage over existing Internet-based methods of communication by acting as client and as server. Whereas the content creator currently gives up ownership once placing that content out for public viewing, with TwiddleNet the ability to distribute data, to push *and* pull, while maintaining control, is advantageous to the user. Users can control who is eligible to receive and download their content because that happens on the user's mobile device. In addition, TwiddleNet supports a caching feature that allows the user to temporarily upload the content to the portal. The portal

then serves the cached content to minimize power consumption and frees bandwidth capabilities on the user's device. If the user decides to either serve the content again from her device or not to share it at all, the portal will delete the file and stop serving or advertising it. This ability to control your own content is an improvement over today's client server architecture. By protecting and controlling data transmission TwiddleNet becomes a privacy and ownership differentiator from other methods of communication.

## **A. OBJECTIVES**

This thesis focuses on making TwiddleNet devices more power efficient. Since TwiddleNet end-user devices are battery-powered, conserving power is important. As described above, end-user devices act as content servers, and this uses their batteries. For content which is high demand, it can be a problem – the user device will suffer a high loss of power because of a many other users want the content that resides on it. One of the ways of ensuring that the power conserving capability of TwiddleNet is efficient and effective, is to cache popular content at the portal. Smart caching allows the device, depending on file size, battery level or workload, to tell the portal to serve the content on its behalf, while maintaining full ownership and control.

In addition, this thesis offers improvements to the overall capabilities of TwiddleNet. The first version of TwiddleNet experienced highly unstable connectivity to the network and the portal. This problem will be addressed by improving the connectivity checking algorithm and introducing an address updating solution between the mobile device and the portal. A user-transparent address translation scheme that assures correct addressing independence of actual device network address (independent of device IP address) will be implemented. For better usability, a new graphical user interface (GUI) will be designed and implemented as well.

## **B. TWIDDLENET USE SCENARIOS**

### **1. Government Organizations**

The devastation brought by Hurricane Katrina in southern sections of the United States can be used to demonstrate the potential application of TwiddleNet services in the

triage or humanitarian realm. In Katrina-affected areas, all communications infrastructure was destroyed, but the need for communication, especially in the first 48–72 hours, is essential to coordinate organization efforts. As depicted in Figure 1, TwiddleNet provides a fly-away kit that establishes the means of communication needed for first responders. A vehicle-mounted Wi-Fi router provides the needed front line Wi-Fi cloud and provides backhaul communication via satellite or point-to-point 806.16 networks. The triage teams will spread out and start collecting casualty data. This information will be shared within a team and with the backend central command center and hospital. When the patient arrives at the hospital, or even during transport, the personnel will have up-to-date information about the patient and critical time will be saved. TwiddleNet can provide the hospital with all needed information in advance of the patient arrival to allocate resources in an efficient and effective manner [2]. This particular scenario has been tested successfully during the COAST exercise in Thailand in 2008 [3].

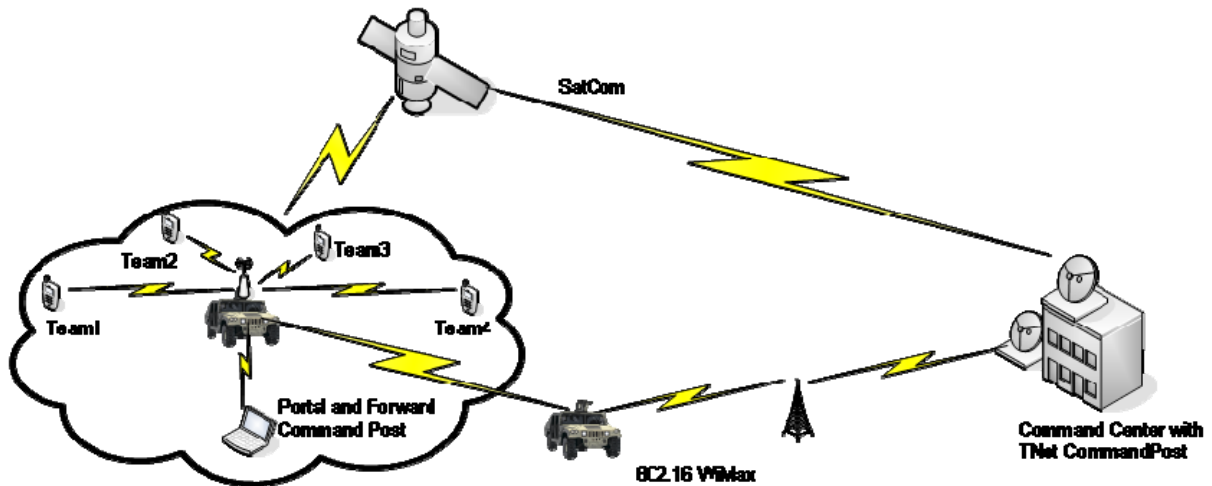


Figure 1. Mobile TwiddleNet Flyaway Kit

## 2. Social Networking

Envision the scenario where new parents want to inform a group of family and friends of their new arrival. Not only do they want to announce the baby's name and weight, they want to send a picture as well. Instead of making numerous calls or designating a main point of contact, who would then inform others, they have the ability

to send a message “alert” to the group. Maybe a few days later they want to send a video. The group of family and friends can communicate with each and share messages of congratulations.

Can the parents who are not already set up on a web site to do this? Yes, but these web sites do not have the push capability that TwiddleNet does, eliminating the need to surf the Net. Considering that almost everyone has a cell phone, the security, ownership, privacy and convenience factors all add up to an easy-to-use, compelling service.

With the “sandwich generation,”<sup>7</sup> who are somewhat technically savvy, TwiddleNet offers benefits beyond email and cell phones. Alerts regarding medical conditions for elderly parents sent to the family group provide fast, efficient, real-time updates. At the same time, “keeping track” of their teenage children, who are highly technical and sharing news of their school events, friends and travels, provides an excellent communication tool.

### **3. Business Opportunities**

Consider some of today's methods of marketing to consumers in the retail market. Grocery stores supply shoppers with a paper coupon for a product purchased *that* day for a similar product to be used on their *next* shopping visit. When a shopper logs into Amazon.com, a list of books is presented that Amazon deems to be of interest to that particular shopper based on previous buying habits. Email messages are sent notifying customers of special deals from furniture and home decorating corporations. These paper or Internet based marketing messages may no longer be useful to a shopper or may not be received in-time to make a buying decision. Those marketing pitches are based on previously gathered information, which may quickly become outdated. Imagine the value to a consumer to be able to sign up with specific retail or online stores of their choice and receive alerts of specials or sales based on their current needs as described by the consumer herself. And as those needs change in the future shoppers can update their

---

<sup>7</sup> Generation of people between 40 and 60 who care for their aging parents while supporting their own children.

profile as frequently as they like. The Friday Costco shopper with children might be sent an alert Thursday night listing specials on diapers and current children's books.

Another potential, even more time-critical market would be the financial world. A user could have her group consist of her stockbroker, tax accountant, money manager, mortgage broker and spouse. Real-time private alerts relating to stock sales, investment opportunities, interest rates, and the tax implications to those financial decisions could be extremely valuable.

These are just some examples to demonstrate how TwiddleNet could potentially be used in the real world to benefit individual consumers and government organizations alike.

### **C. SCOPE**

The thesis will focus on finding the appropriate algorithm for the mobile servers to facilitate file caching in support of the TwiddleNet mobile-server network. Measurements will be made empirically to find battery power consumption values and bandwidth restrictions for the test devices to define heuristics for the needed caching algorithm.

This algorithm will include only the device and the portal interaction. No further caching algorithms as referenced under [4] will be addressed. To accomplish this, a software implementation that automatically tracks user demand for content and battery life of the server, will be presented. The algorithm will be based on general research questions to include:

1. How is caching currently accomplished?
2. What are the decision factors for caching?
3. What will be the thresholds for the decision criteria?
4. How can control data communication efficiently be implemented?
5. How to implement caching in an efficient manner?

## **D. ORGANIZATION**

The remainder of the thesis is organized as follows. Chapter II provides background information on the key areas of caching within distributed networks, power consumption, and bandwidth issues for mobile devices, and gives a broad overview of TwiddleNet components. Chapter III describes in detail all aspects of implementation of the “smart caching” algorithm. Chapter IV provides the conclusion and describes future work.



## II. BACKGROUND

### A. TWIDDLENET

#### 1. TwiddleNet Components Overview

TwiddleNet logically consists of ten components. The distinct blocks are displayed in Figure 2. This thesis focuses mainly on “smart caching,” but to understand the entire application, each component will be briefly described in the following paragraphs. “Smart caching” will be thoroughly discussed in Chapter III.

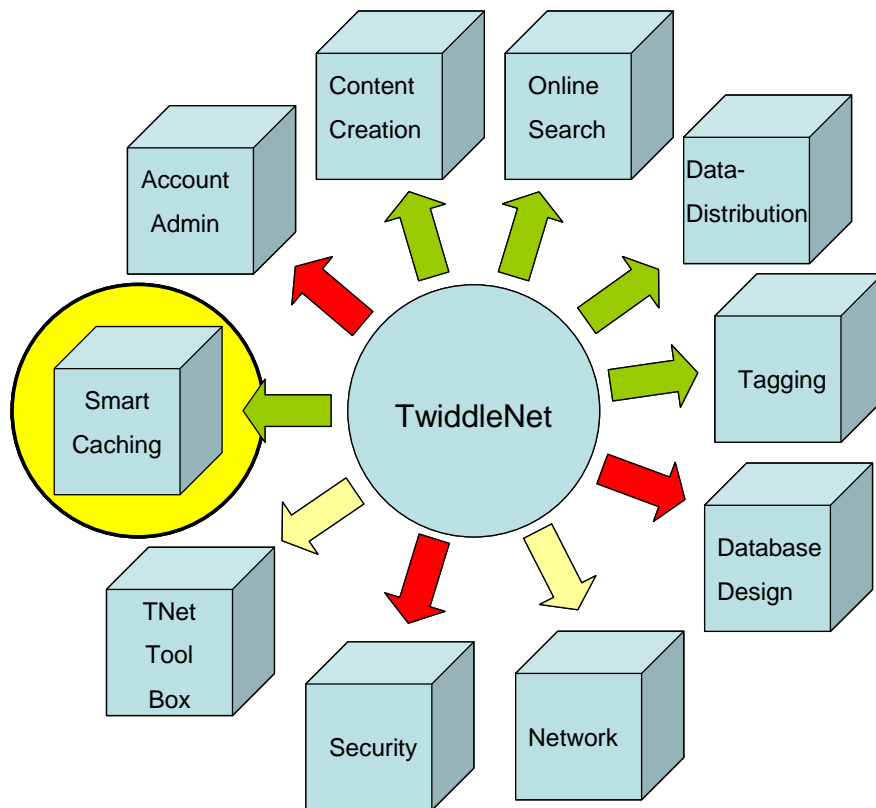


Figure 2. TwiddleNet components

***a. Content Creation***

Content can be anything the device is capable of producing or handling, like a text file, an image, a video or a PowerPoint presentation. The content can be created on the device, i.e., taking a picture with the built in camera, or it can already reside on the device such as an e-mail attachment. The user has the choice of manually adding the content to the items list being shared or selecting the automatic sharing after creation.

***b. Tagging***

A tag contains metadata, be it general information such as the date, author, location (if GPS-equipped) or file size, or any other information the user would like to add. The process of tagging essentially maps the information to the content and makes organizing and searching information feasible in a scalable and organized fashion. The tag in general is significantly smaller than the content it represents. The information that is tagged to the content is stored in xml-documents<sup>8</sup>, which are also used to distribute the information within the network [5].

***c. Data-Distribution***

TwiddleNet uses one central networking device, the portal, which is responsible for receiving content metadata from the content producer and alerting the clients who have signed up to receive this category of content [5]. The TwiddleNet internal communication between Clients and Portal (alerting, caching and administration) happens via an easy internal protocol running over Transmission Control Protocol (TCP). The actual content sharing is accomplished via Hypertext Transfer Protocol (HTTP). The reason to choose HTTP was compatibility to web browsers.

---

<sup>8</sup> XML = Extensible Markup Language.

#### *d. Online Search*

If an alert is missed or a user wants to search for something else, TwiddleNet offers two ways to access information on the portal. A web-based browser application allows surfing to the portal and retrieves the desired information. Alternatively, the user can query the portal via the client application that runs on the mobile device. Both methods offer the ability to enter a query text and a query category such as “Author,” “Group” or “Keyword.” The search results are viewed in a similar fashion as the alerts, except that it is not real time, and the user has to “pull” the content.

#### *e. Network*

TwiddleNet uses Wi-Fi or GSM as carrier media. Both services use Internet Protocol (IP) addresses. Because each client also acts as the server, TwiddleNet requires a unique address scheme. To utilize TwiddleNet capabilities, each participating unit needs to have an Internet routable IP address. In addition, because the devices are mobile by definition, their IP address will frequently change. One limitation of the first version of TwiddleNet was that the actual IP address of the content creator was sent along with the alert. A receiver device would use that IP address to retrieve the content, yet, by definition, that mobile device’s address could be continually changing. This thesis implements an application-level address scheme that translates a unique user name to a potentially changing IP address. As localizing reference, the unique user name is sent within the alert as an author tag. To retrieve the desired content, the receiver first contacts the portal hosting the address translation service. Each device constantly monitors its own IP address and then informs the portal of changes. Therefore, the portal is always aware of the status of each client and its current IP address.

Private network domains with non-Internet routable IP address ranges are only suitable if all participants belong to it or to connected private networks. The problem with private domains like a home network with an address such as 192.168.1.x, for example, is described as follows. To connect to the Internet, a network device, like an edge router, typically hosts a service called Port Address Translation (PAT) or Network

Address Translation (NAT)<sup>9</sup>. Both services translate the internal private IP address into an external Internet-routable IP address. This service is designed to send a message into the Internet and to receive data within that connection, as shown in Figure 3.

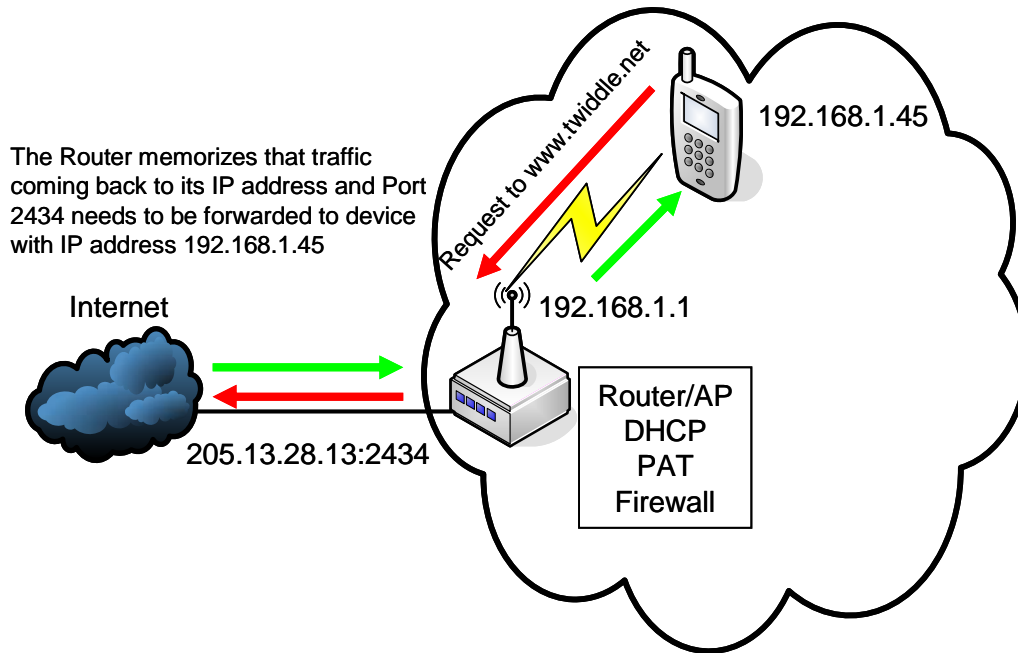


Figure 3. “PAT” in private LANs

Because the TwiddleNet clients run as servers as well, a connection would not be initiated from the inside and, therefore, the firewall would drop these requests. Even if the router was instructed to forward a request on a certain port to a pre-assigned IP address in the private network, that would only apply to one TwiddleNet client. But, if two clients are within the same network, both listening on the same port for requests, the router would not be able to distinguish who would be the correct receiver, as displayed in Figure 3. Therefore, only an address scheme provided by IPv6 or IPv4 Internet-routable IP addresses would be able to easily solve this problem.

---

<sup>9</sup> Usually a private network has only one Internet routable IP address provided by the Internet Service Provider. Therefore to enable multiple hosts within the private network to connect to the Internet, the router assigns each connection a separate port number. When the answer returns from the Internet the router multiplexes the messages according its port number - IP address table (PAT). If the router has multiple routable IP addresses assigned by the Provider it will translate internal address to external address (NAT). Typically the NAT acronym is used to express the PAT and the NAT service.

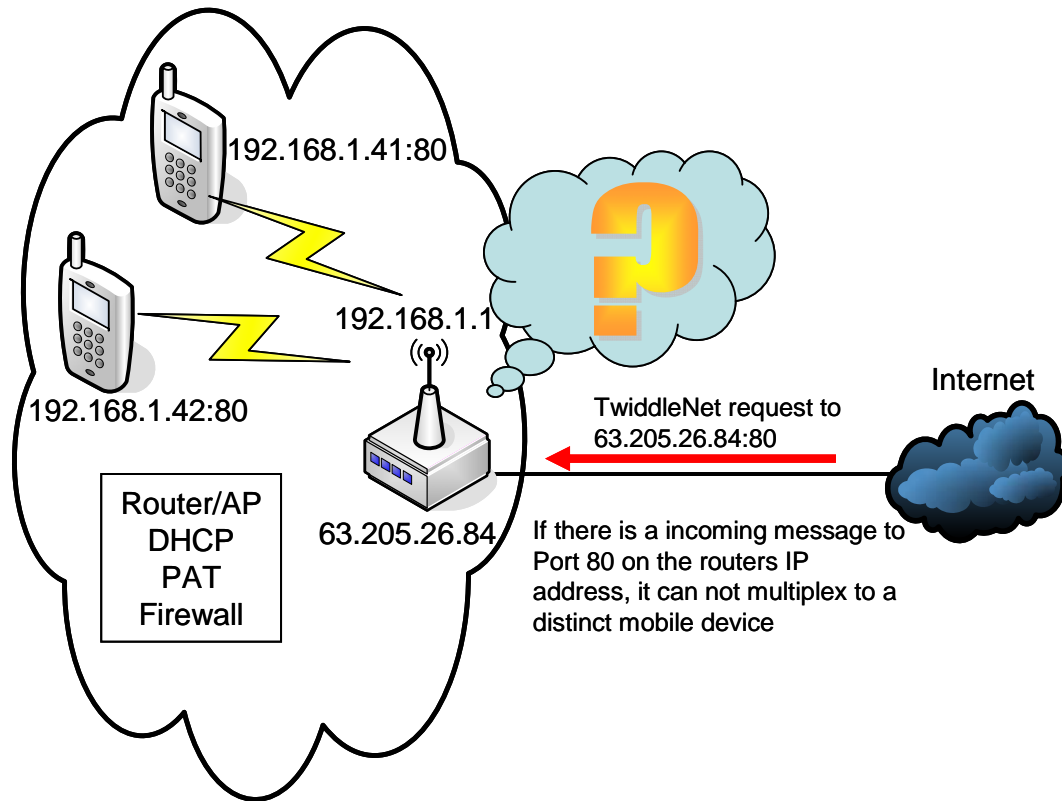


Figure 4. “PAT” limitations with mobile servers

A third proposed solution would be that once the client realizes it is on a private network, it will — in addition to the local, normal server operation — frequently contact the portal if there were requests for its unique username. The portal would function as a buffer zone that would keep a connection open to both devices and would relay the traffic between both devices. Because both connections were initialized from within the private network, the PAT/NAT scheme would work adequately.

The GSM private network limitations have been addressed by [5]. They are similar to the private LAN limitations because the telephone companies use private domain addresses as well. The latest mentioned solution would be a suitable approach for that problem domain as well, or an additional proxy server would be needed that translates incoming requests to internal IP addresses.

*f. Account Administration*

One major improvement in the current TwiddleNet implementation is the user transparent address translation scheme that enables the network to keep track of the actual IP addresses, which are needed for the physical world, and the username-based information distribution, which is application layer controlled. The clients recognize any change of their connection status and will automatically inform the portal of their current address. The portal will now manage TwiddleNet traffic according to the stored information. For more detail, see Chapter III.

Other important aspects are the client profiles. Clients may belong to more than one group: user X belongs to both group “Blue” and group “Red” or wants to receive alerts about a certain topic only. Using a relational database-based algorithm, a user would be alerted only for content from a fellow group member or about his requested content. One can see how important it is to track and to enable access depending on user profiles.

*g. Database Design*

The relational model described above in Account Administration implies the use of a relational database as the enabling infrastructure. This is discussed in the “Future Work” section of Chapter IV. Currently, only the username IP address scheme, the storage of the content metadata and the smart caching is implemented using database tables.

*h. Security*

Managing people’s private information is always a critical piece of the equation. Privacy and security are the cornerstones of the trust consumers have come to expect and demand in technology today. Currently, TwiddleNet uses the built-in security capabilities of the underlying network connection. For the Wi-Fi connection, that means Wired Equivalent Privacy (WEP) and Wi-Fi Protected Access with Pre Shared Key (WPA-PSK) using TKIP (the Temporal Key Integrity Protocol) to enhance data encryption. These are the limiting capabilities of the used HP iPAQ mobile devices. The

underlying data security in the GSM domain are those of General Packet Radio Service (GPRS,) which is used as the data transfer protocol in Global System for Mobile communications (GSM). TwiddleNet itself currently has no module to enforce confidentiality, integrity or authentication implemented.

#### *i. TNet Tool Box*

The TNet toolbox currently contains only one additional application. The “TNet Command Post” is a specialized client that will receive all alerts distributed through the TwiddleNet network and retrieve the corresponding content. This content will then be incorporated into a web site. As the name Command Post suggests, that central repository is used to house all collected data and display the relevant data to the command structure. In addition, the created web page has a search and wiki functionality to add comments or other information to the metadata.

A future second application is a web-based administration interface to open and manage a TwiddleNet account. This interface is used rather than the TwiddleNet client application to reduce the complexity and the footprint of the software on the mobile device. This application is discussed further in the Chapter V “Future Work” section.

### **B. POWER CONSUMPTION OF MOBILE DEVICES**

Like all mobile devices, smart phones suffer from their limited battery life. Adding wireless communication capabilities without a special and careful power-preserving design will accentuate the power problem. Wi-Fi was not originally designed for energy constrained handheld devices. As a result, the standby times of a handheld device with a Wi-Fi interface is significantly lower than what people typically experience with today’s cellular phones.

Our test devices use the 801.11b Wi-Fi protocol. The advertised connection speed of 802.11b is 11 Megabits per second (Mbps), which is about 82.5 Mega Bytes per Minute (MB/min). That value is only achievable in a laboratory environment, with no interference and under ideal conditions. The mentioned transmission rate is the total

amount of data transmitted. That data consists of the overhead of the protocol and the actual payload that needs to be transmitted. This means we can realistically transmit significantly less real payload than 82.5 MB/min. In addition, there will always be interferences with other spectrums and collisions within the media, such that the actual sending capability is significantly reduced. For 802.11b, realistic peak throughput values are 4 to 5 Mbps which is equivalent to 30 to 37.5 MB/min under good conditions. Most 802.11b networks typically run at 2 to 3 Mbps, which is about 15 to 22.5 MB/min. These bandwidths need to be shared under all devices connected, reducing the individual usable bandwidth again, but, on average, these values are still faster than broadband Internet connections, which normally operate at 0.5 to 2 Mbps peak for downloads [6]. The user, therefore, does not notice any slowdown due to the use of wireless. That is one reason why 802.11b is still very commonly used in private wireless networks.

One way to reduce the amount of data the devices need to send, thereby reducing the energy demand, is to modify the Wi-Fi and/or upper-layer protocols to make the protocols themselves more energy-conserving [6,7]. For the TwiddleNet environment we are using off-the-shelf (OTS) devices and have no influence over the protocols used.

Another approach seeks to minimize the unnecessary consumption of energy by energy inefficient network interfaces. It includes turning off the interfaces, or turning the interface into a low energy-consuming state, if possible, during time periods that the interface is not used to carry user traffic. The authors of [7] propose an algorithm that turns the interface off depending on a network-specific pattern of silent times within the current network. They predict that the down time could be up to 50% and only miss 1% of incoming traffic. Their traffic assumption is one visit per minute. For TwiddleNet, we assume an average number of ten visits per minute, adding up to 600 visits per hour or 14,400 visits per day. That is an average visit rate for a popular webpage. A third and fourth approach to the energy problem by [9] and [10] is to turn off the antenna after a preset idle time or to add an additional low-energy antenna for control traffic to control the power-demanding Wi-Fi antenna. Turning off the antenna will not work for



TwiddleNet because the mobile devices act as clients and as servers. The latter would be an improvement if it will be implemented in the device and, therefore, will be available off the shelf.

There are other areas as well that can be improved to save battery power; as depicted in Figure 4, however, Wi-Fi uses more than half of the available energy.

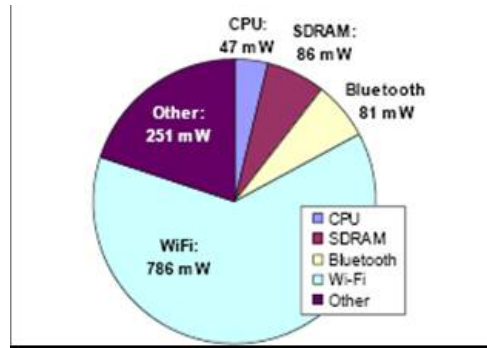


Figure 5. Power breakdown for a mobile device. From [5]

Reducing the needed transmissions is a key element in improving battery life and reducing energy demand. This thesis proposes an algorithm that significantly reduces the needed transmission by temporarily caching the content on the portal and letting the portal serve the content in lieu of the mobile device.

### C. CACHING IN WIRELESS NETWORKS

The purpose of caching is to overcome “hot spots”<sup>10</sup> in a network. In the context of web pages, that means that the page gets so many requests that it becomes “swamped.” There are several approaches to overcome this problem. All deal more or less with creating multiple copies of the page on different servers and splitting up the workload for each single server. That is especially useful in private or corporate networks with multiple users. If every  $n$  user downloads the same page, the network has to transport the same data  $n$  times. To reduce this traffic it would be useful to download the page only once and cache a copy of it within the network. The most commonly used approach is to

<sup>10</sup> *Hot spots* occur any time a large number of clients wish to simultaneously access data from a single server. If the site is not provisioned to deal with all of these clients simultaneously, service may be degraded or lost.

route requests from multiple users through so called “proxy servers.” If the server has a current copy cached, it will serve the request, reducing the network traffic between itself and the home server. If it has not cached a copy, it will forward the request and cache the new page for future requests. This scheme is most beneficial for the upstream network with more users sharing the same cache or proxy-server. But then, the cache itself is likely to get swamped. To overcome that problem, another approach by [11] builds on the first idea, but increases the number of proxy servers. User requests would be sent arbitrarily to any proxy-server. If the page is not cached in that server, the protocol uses multicast messaging to query all other proxy-servers in that system, before it finally contacts the home server of that page. This approach creates a potentially high volume of overhead traffic that is not favorable in a mobile wireless environment with its limitations in bandwidth and battery power. An algorithm proposed by [12] reduces the needed multicast transmissions significantly, but leaves the necessity of providing multiple redundant proxy-servers. Based on tree theory, [13] proposes a hierarchy of caches similar to the hierarchy of name servers. The advantage of a cache tree is that a parent node cache receives page requests only from its children, ensuring that not too many requests arrive simultaneously. With increased scale and enough individual not cached page requests, the root node might get swamped because in the model the root node will receive and handle all requests for non cached sides.

All approaches to the problem of hot spots discussed to this point duplicate the content and share the workload over multiple servers. In general, the assumption is that the server’s bandwidth is much bigger than the client’s bandwidth. Swamping happens due to the huge number of client requests. In TwiddleNet, that assumption does not hold because the available bandwidth of the server device is as big as or even smaller than a client that connects for download. This thesis proposes an algorithm that temporarily uploads the requested content to a device with more bandwidth available (TwiddleNet portal) to overcome possible hotspots on the device itself and on the wireless network it is connected to. The algorithm is explained in detail in Chapter III.

### III. TWIDDLENET POWER CONSUMPTION TEST

#### A. DEVICES

For all testing purposes we used four iPAQ hw 6945 smart phones from Hewlett-Packard.



Figure 6. iPAQ hw 6945

The iPAQ hw 6945 is equipped with three different types of radios: Bluetooth, Wi-Fi and GSM. TwiddleNet only uses Wi-Fi 802.11b and GPRS over the GSM network to distribute data.

#### B. SETUP AND CONFIGURATION

We performed multiple tests over the Wi-Fi channel to collect data that will be used to find heuristics to implement a caching algorithm. To measure the power consumption of the mobile devices, we wrote two helper programs. One monitors the OS battery power level and measures the time between a percentage drop of available battery power. The other one simulates different download demands. The test content was a picture stored as jpg. The size was about 1 MB (1.053.799 Byte).

For each test, we started with a fully charged battery, the display was at its brightest, the antenna setting was at max performance, CPU power was set to auto and

the network carried only test traffic. To allow the full use of the available bandwidth, only the serving client was attached to the wireless access point. The download simulation application was running on a PC that was connected via a CAT6 cable to the access point. The test configuration is displayed in Figure 7; the different download demands are displayed in Table 1. The measurements were limited to between 100% and 50% because devices and batteries acted differently below that level. Some devices turned completely off just below 50%; some served till 0%.

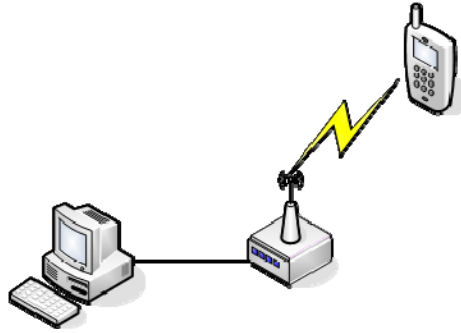


Figure 7. Test Network

Nr:	Task
Test 1	No WiFi
Test 2	WiFi idle
Test 3	TwiddleNet idle
Test 4	(1 x 1MB)/min
Test 5	(5 x 1MB)/min
Test 6	(10 x 1MB)/min
Test 7	(15 x 1MB)/min
Test 8	(20 x 1MB)/min
Test 9	(25 x 1MB)/min
Test 10	(30 x 1MB)/min

Table 1. Different download demands

## C. RESULTS

Figure 8 shows the average time deltas between percentage drops of all four test devices. All test results are documented in Appendix A.

As already expected from Figure 5, by turning on the Wi-Fi antenna, the average useable time between percentage drops is reduced to about half the standby time as

without Wi-Fi. Figure 9 shows the average results for the different download demands. One can easily see that with increased data transmissions, the battery lifetime is reduced. For a demand of 30 MB per minute, the tests indicated an average reduction in battery life of approximately 33%. All test results are displayed in Table 2.

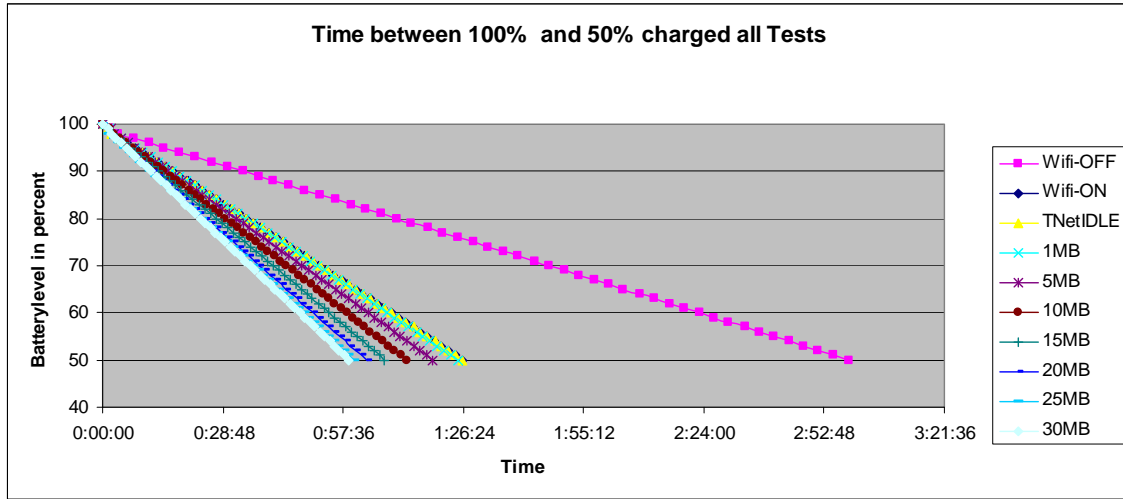


Figure 8. Power Consumption for all Tests

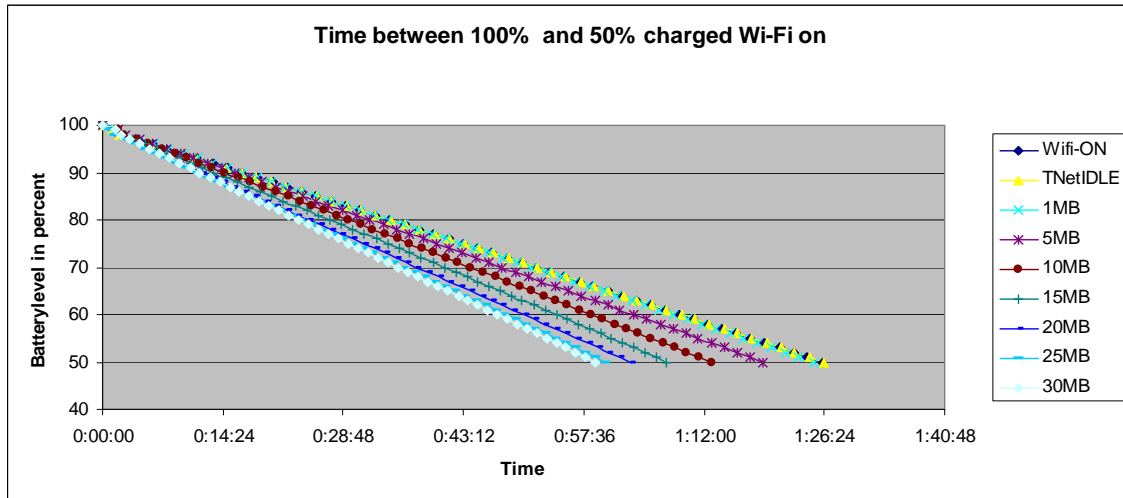


Figure 9. Power Consumption for various download demands

	Task	Time Interval	Percentage	download/min
Test 1	No WiFi	0:03:33	NO WiFi	0
Test 2	WiFi idle	0:01:45	100%	0
Test 3	TwiddleNet idle	0:01:45	99.62%	0
Test 4	(1 x 1MB)/min	0:01:43	97.96%	1MB
Test 5	(5 x 1MB)/min	0:01:36	90.76%	5MB
Test 6	(10 x 1MB)/min	0:01:28	83.55%	10MB
Test 7	(15 x 1MB)/min	0:01:22	77.58%	15MB
Test 8	(20 x 1MB)/min	0:01:17	73.46%	20MB
Test 9	(25 x 1MB)/min	0:01:14	69.86%	25MB
Test 10	(30 x 1MB)/min	0:01:11	67.55%	30MB

Table 2. Results of all Tests.

The bandwidth was utilized only by downloads. Any other user interaction, like sharing new content or web surfing, would increase the power consumption because the available bandwidth needs to be shared between the separate processes and, therefore, increases the time needed for a single download. But, increased download times mean a longer time in a high-power demanding state.

These test series show that reducing the data transmissions will improve battery life by up to one-third of the available lifetime for our test devices.

## **IV. SMART CACHING IN TWIDDLENET**

### **A. ENABLING FEATURES**

TwiddleNet represents a network of distributed mobile devices that act as clients and servers to achieve fast and easy content sharing in a peer-to-peer fashion. A central network device, called TNet-Portal, acts as the connecting entity. TNet-Portal basically keeps track of all users signed in and their current IP-address. It also acts as the contact node from where all users receive alerts about shared content. Because the TNet-Portal is typically a PC sized device with higher bandwidth and battery life capabilities, it can also act as a caching proxy for the attached mobile devices. This caching service is only available if the client is signed in to TwiddleNet and its bandwidth and battery life become vital limiting factors. The portal will not act as a normal server that shares content when the client is not online. The resulting algorithm is explained later in this chapter and represents the main contribution of this thesis. The next paragraphs describe improvements to TwiddleNet to allow the implementation of “smart caching.”

#### **1. TwiddleNet Client Sign-in**

To enable the portal to track participating users we implemented a sign-in procedure. The user account is already created using the web-based administration interface described in Chapter IV. That account contains a unique username and the password-hash. When the TNet-client application is started on the mobile device, the user has to first type the username and the associated password. The interface is shown in Appendix B. The username and the password-hash are sent to the portal via a TCP connection. If the database contains a matching username and password-hash pair, the current IP address will be stored in the database, and a positive acknowledgment is sent to the client. The application will start only after a valid sign-in. Access is denied in all other cases.

## 2. TwiddleNet Address Translation

One key limitation of earlier versions of TwiddleNet was that it included the current IP address of the creator device into the alert sent to potential clients. As discussed previously, however, the IP address could change and render a future request for content impossible to deliver — even when the device was connected to the network (as its IP address would have changed). To overcome that limitation, we implemented into the client software an algorithm that constantly monitors the Wi-Fi connection. If the device receives a new IP address because it moved into another network, for example, it will automatically inform the portal of its new address. Therefore, the TNet-Portal can maintain a current list of signed-in users and their current IP addresses. To maintain an addressing scheme within TwiddleNet, users will receive unique user names. Those unique user names will be used by the portal, which translates them into the current IP address that is stored in the database. This translation is transparent to the user. To achieve transparency, we use the built in “temporary redirect” capability of HTTP, which we use for content request traffic to allow compatibility with normal net browsers. The redirect happens as part of the HTTP protocol and is not noticed by the user. Each client will always contact the portal if it requests a desired content. The request will contain the username of the creator and the content identification, which is currently the content name. The portal will look up the address in the database and redirect the HTTP request to the new address. Figure 10 shows the communication path for the case where the content creator device serves the content itself.

In addition, before the username-IP address translation happens, the portal checks whether it has the requested content cached. If the content is cached at the portal, the portal will serve the request right away, without redirecting to the creator device. That communication is shown in Figure 11. A special case of a three-way redirect shown in Figure 12 can happen only if clients request content while a caching request from the content creator device to the portal happens almost simultaneously. Therefore, if for any reason a client would contact a creator device requesting cached content, the device application will redirect the request to the portal.



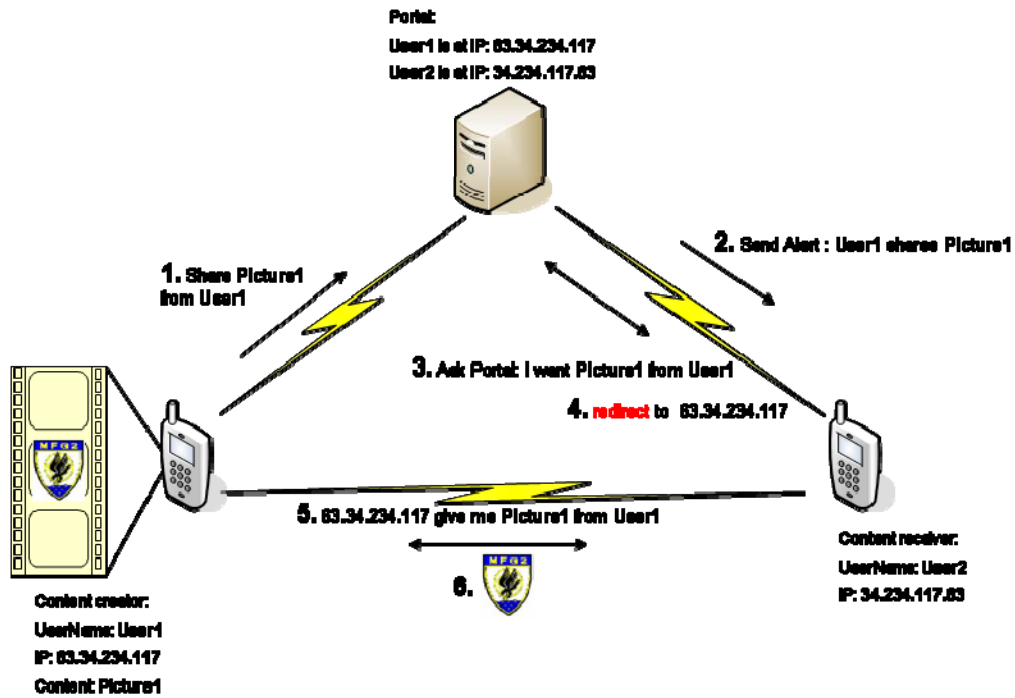


Figure 10. TwiddleNet Sharing and client serving

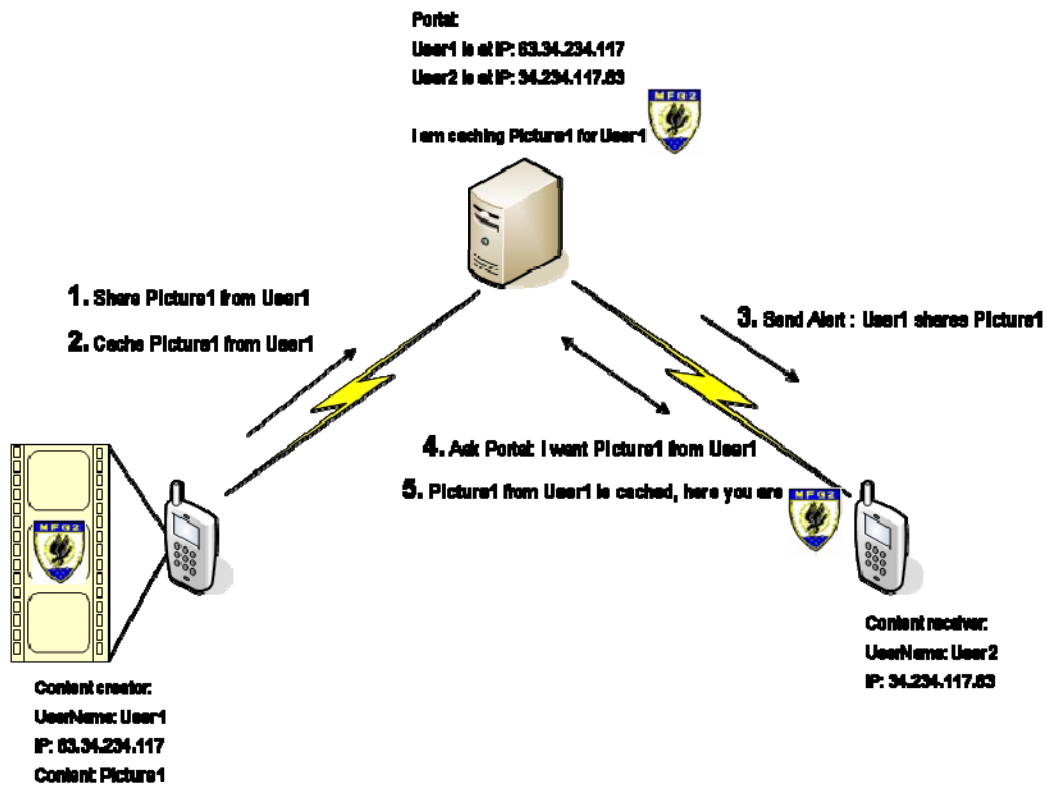


Figure 11. TwiddleNet Sharing and portal caching

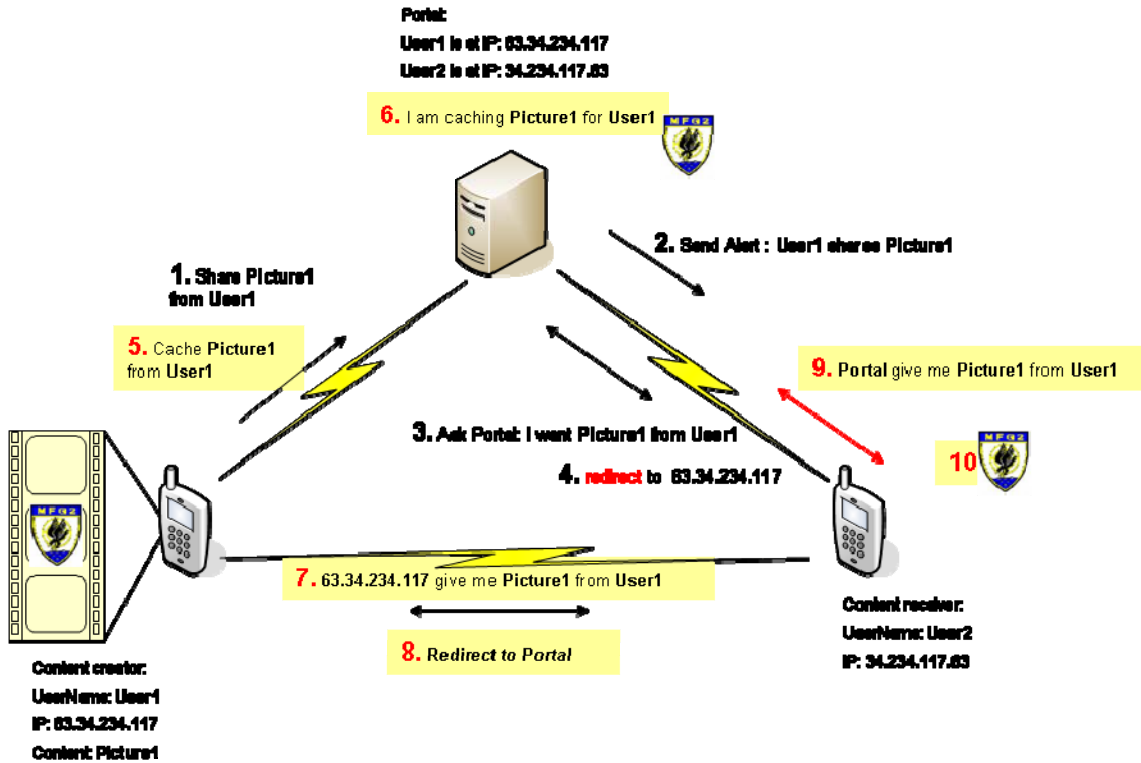


Figure 12. TwiddleNet Sharing and delayed portal caching

## B. CLIENT IMPLEMENTATION

Figure 13 shows the states that content will traverse from being created to being cached at the portal. The different transitions represent the user choices when handling content in the current version of TwiddleNet. The “smart caching” algorithm focuses on the transitions between “shared state 1” and “shared state 2.”

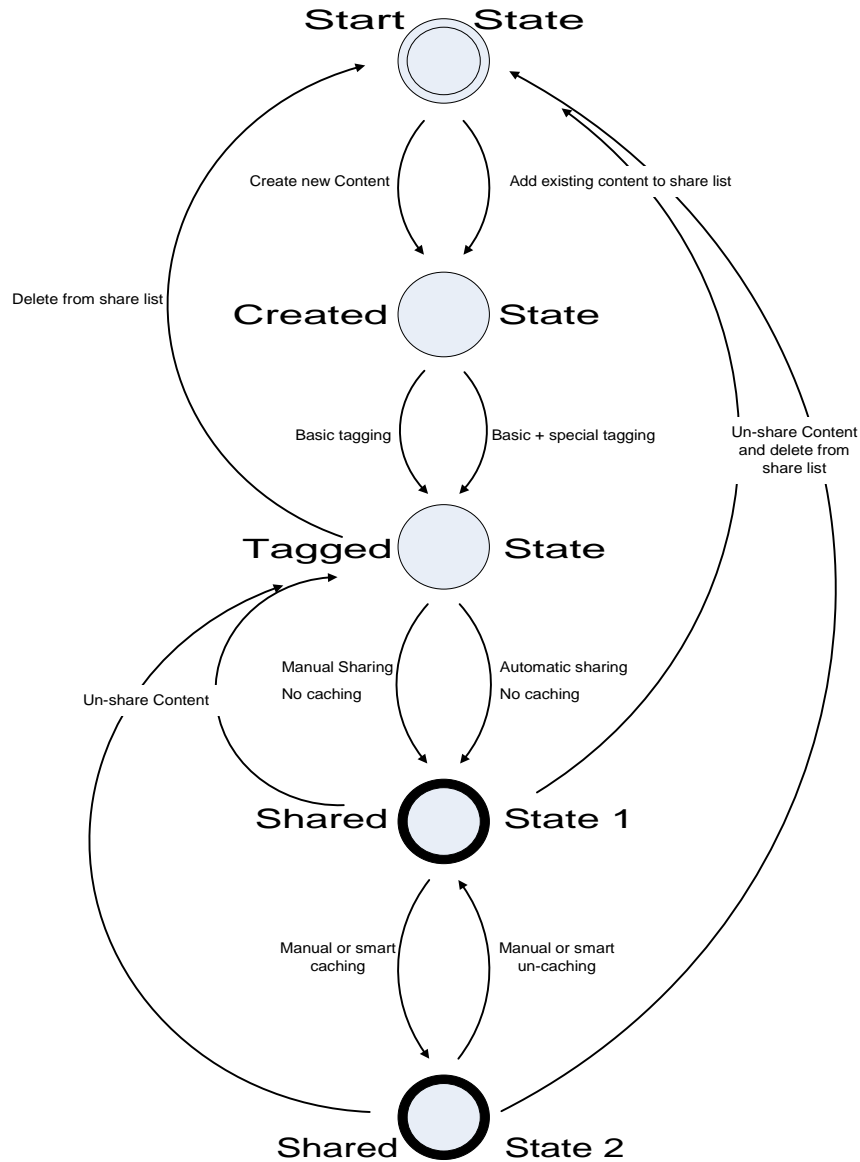


Figure 13. System states from content creation to content caching

The smart caching algorithm will address two key criteria for mobile devices: usable bandwidth and battery level. As discussed in Chapter II, bandwidth and battery power are limited resources, especially for mobile devices.

Bandwidth will be addressed first. Depending on the protocol standard used for the devices, the actual available bandwidth will vary. No matter what protocol we use, however, the user has to decide how much of his available resource he is going to allocate to the task of serving. Other than serving shared content, she likely wants to

continue sharing new content, surf the web or place voice calls. For the current version of TwiddleNet client application, the user can select either  $\frac{1}{4}$ ,  $\frac{1}{2}$ , or  $\frac{3}{4}$  of the available bandwidth to dedicate to serve content requests. Because the theoretical limits of the available Wi-Fi standards are not a good basis for assigning limits to the application, we use the value of 30 Megabytes per minute for an 802.11b standard. This value was shown to be possible and feasible during the test series discussed in Chapter II. In addition, we assume the presence of at least three entities within one wireless network. The resulting decrease through put, due to collisions and interferences, provides a more realistic base value. Therefore, 10 Megabytes per minute of data transmitted is the base value that the smart cache algorithm uses. Once TwiddleNet moves to devices with better protocols like 802.11g or higher, that base value will need to be adjusted.

The client server counts all bytes of data transmitted and counts how often the content was requested. After one minute both counts will be reset to zero. If during that time the demand exceeds the user assigned limit of X Megabytes per minute, the algorithm will select the content which was requested most frequently and will cache it at the portal. Any additional requests will then be served by the portal, reducing the demand on the mobile device as long as the client is signed in. If that still leaves ambiguities, the first one in the list is selected.

- Heuristics:
1. Most often requested
  2. Largest
  3. First in list

Selecting the most frequent one first, rather than the largest one, will allow for reduced future demand on the device. As an example, we will share two pictures, one the size of two Megabytes and the other of 500 Kilobytes. The larger one was requested one time and the latter was requested 10 times per minute. If we were to cache the bigger one first, we would save the device only two Megabytes versus five Megabytes, than if we were to cache the content that was requested more often.

The second factor to discuss is available battery power. The user has to select how much battery he is willing to assign to the task of serving. In Chapter II, we discussed how battery life can be reduced by up to 30% depending on download demand. Because

we cannot split up battery demand like we can split up bandwidth usage per minute, the user has to select a minimum battery level to ensure that power is used to serve content. In the current version the user can decide to either protect  $1/3$ ,  $1/2$  or  $2/3$  of the available battery power.

The client device monitors the battery level and checks its value regularly every 15 seconds. When the level reaches the user selected value of 34%, 50% or 67%, all shared but not cached content will be cached at the portal. From then on, the portal will serve the content as long as the client is signed in. If the device is recharged and the battery level increases again above the threshold, all cached content is automatically un-cached again. The idea is that the portal only *temporarily* caches the content if the mobile device reaches certain limits in bandwidth or battery level. At a power level of 30% the application will sign out at the portal to save the remaining battery power for more important tasks than TwiddleNet. Because the user is not participating in the network anymore, the portal will stop serving the cached content, but will keep a copy until the user signs back in. Then the portal resumes its task to serve the content.

Both factors can execute the caching independently, whatever triggers first. In addition, the user always has the ability to manually cache or un-cache any shared content.

### **C. PORTAL IMPLEMENTATION**

As previously mentioned, the main idea behind “smart caching” is to only cache content temporarily at the portal. The client device will send cache requests according to its own needs, meaning if bandwidth, battery level or user choice requires a temporary upload of the content. The client is going to un-cache its content again, once the required conditions are met, as discussed. The portal does not have any information about the reasoning behind these actions, but the portal needs to have a way to force the client back into self serving. The reason for this is that users may otherwise misuse the resources of the portal and always let the portal serve on their behalf. That would be just another classic client-server architecture, which is not the intended use of TwiddleNet.

TNet-Portal monitors the times when the cached content was last requested. When the time between last requests exceeds a given limit the portal contacts the client device and forces a un-cache of the content. If, at a later time, the mobile device needs to cache the content again because its smart caching algorithm triggered again, that cached content will again become part of the portal monitoring. We have used a timing-dependent versus demand-dependent approach because we could easily keep track of one value that represents the time when the content was last requested, compare it to the actual time to calculate the difference, and compare it to the given limit. Depending on the usage of TwiddleNet, for example a social network or a military scenario, the limit would definitely change. For example, in a social network the portal would only allow content to be cached for, say 24 hours, versus a military network where the limit could be weeks.

Depending on the resources available on the portal and the task the network has to fulfill, the limit is then chosen. Chapter V expands this discussion in the future work section. The current version of TwiddleNet portal, running in the test configuration, checks cached content every 15 minutes with a fixed time limit of 60 minutes. The algorithm will only handle content where the client is signed in and, therefore, a communication can take place.

#### **D. MISCELLANEOUS FEATURES**

To make TwiddleNet more user-friendly, we changed the graphical user interface (GUI) of the TNet-client application while maintaining all functionality. The current version of the graphical design is documented in Appendix B. The main improvement was to use tabs to switch between the different screens. That made the interaction faster and more intuitive for the user.

We added a specific tagging interface that allows for specialized content tags. The current version has a specialized tag GUI for first responder medical triage teams. The idea behind the scenario was that a first responder team would take a picture of a patient. If special tagging option is selected the Triage GUI will be displayed to allow the user to collect information about the patient in question. Attached to the picture this information is embedded in the xml tag which will be used to alert follow on medical personal or a centralized Command Post. The GUI is based on the currently used paper tag and is documented in Appendix B.

## **V. CONCLUSIONS AND FUTURE WORK**

### **A. CONCLUSIONS**

TwiddleNet, a distributed mobile communication network, enhances the capabilities of smart phones and other mobile devices. This thesis discussed two key weaknesses of TwiddleNet: battery lifetime and bandwidth. We provided a solution to manage these inherent device limitations by implementing a demand and battery level dependent algorithm. A mobile device is then able to temporarily cache its content at the portal, thereby relieving itself from its demanding power and bandwidth tasks.

To support true mobility, we implemented a user-transparent username-IP address translation scheme, which is a key feature of the distributed network. It allows for sharing of content even with constantly changing IP addresses.

We also improved the graphical user interface for easier interaction between user and device, and provided an extended tagging interface, which is specialized for triage operations during humanitarian relief scenarios.

The current version of the TwiddleNet network is a robust mobile file-sharing infrastructure that provides data distribution, general or special tagging, and efficient resource usage of mobile devices. Especially in the mentioned military applications — where equipment weight and size, fast response times, easy system setup, and real-time communication are crucial to the mission success — TwiddleNet shows that the use of off-the-shelf devices is an effective, affordable and efficient approach to serve critical communication needs in first responder or quick reaction missions.

### **B. FUTURE WORK**

#### **1. Security**

Future implementations of TwiddleNet emphasis should be put on secure communication beyond the inherited security provided by the wireless environment. Because TwiddleNet uses TCP connections as the main protocol, Secure Socket Layer (SSL) should be researched. With SSL, the devices are capable of handling certificate

authentication, and TwiddleNet could use the existing Private Public Key Infrastructure (PKI). A recommendation would be that all devices need to authenticate to the portal, and the portal needs to authenticate to the devices using SSL. The resulting peer-to-peer connection between two mobile devices would follow the same approach. This bilateral authentication is particularly important within any military application of TwiddleNet, but also to ensure authentication, identification and confidentiality for social or business networking.

Another, simpler approach is to use a Personal Shared Key (PSK), which could be created during account set-up. The initial communication during sign-in could be used to create session keys, which would then be used to symmetrically encrypt the messages.

## **2. Database**

Currently, we only use the portal database to store content tag information and to enable the username-IP address translation. Once an alert from a client is received, the portal will query the database for possible users who are interested in the content, and their IP address,. The current query will always return all signed-in users. A future implementation of the portal should expand user and content attributes, with “grouping,” which will allow for more specific queries. User profiles should allow for selecting which types of alerts to receive and which alerts to limit, or reject. Portal profiles should allow for setting task-specific values, such as a timing limit for the smart caching algorithm. All these suggestions could be implemented and managed in a relational database. Depending on the query, the portal can then retrieve a specific set of clients that match the requirements. This approach will significantly reduce the amount of unnecessary and possibly unwanted alert traffic.

## **3. Web-based Account Administration Tool**

This tool does not exist. Within the current implementation, user accounts are created in the database manually. With the development of a web-based account administration tool, a nice interface to the database could be created. This would be the ideal means of managing the database for an administrator. It would also be the interface



for users to open and manage accounts or perform online searches. This approach allows for convenient access from a PC, without the limiting features of cell phones, such as a small screen size and small keyboards.

#### **4. Command Post**

The current Command Post receives alerts and the content. The application creates a web page that is then accessible via a normal web browser. This web site features a wiki capability, whereby any user can add comments to the xml document. We recommend that a future version should provide communication back to the content creator. This capability would be especially important for the triage scenario where Headquarter personnel could give additional support and feedback to those on the scene.

#### **5. Software Engineering**

After incremental improvements, development of the TNet components would have advanced to the stage where they should be redesigned using a software engineering approach. The current version features the required functionalities and offers solutions to achieve the desired behavior. The network presented herein is an example of how integration between all the components creates a more streamlined application upon which an efficient code can be developed. In addition, thorough code documentation would be a valuable result of the engineering process.

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## APPENDIX A

Test results for Test 1:

Percentage	Device1	Difference	Device2	Difference	Device3	Difference	Device4	Difference	Average
100	0:00:00		0:00:00		0:00:00		0:00:00		0:00:00
99	0:02:59	0:02:59	0:01:15	0:01:15	0:00:57	0:00:57	0:01:21	0:01:21	0:01:38
98	0:05:09	0:02:10	0:03:15	0:02:00	0:02:46	0:01:49	0:03:21	0:02:00	0:03:38
97	0:09:04	0:03:55	0:07:00	0:03:45	0:06:30	0:03:44	0:06:52	0:03:31	0:07:22
96	0:13:04	0:04:00	0:10:40	0:03:40	0:10:01	0:03:31	0:10:34	0:03:42	0:11:05
95	0:16:54	0:03:50	0:14:20	0:03:40	0:13:41	0:03:40	0:14:18	0:03:44	0:14:48
94	0:20:54	0:04:00	0:18:00	0:03:40	0:17:21	0:03:40	0:17:59	0:03:41	0:18:33
93	0:24:50	0:03:56	0:21:45	0:03:45	0:20:52	0:03:31	0:21:30	0:03:31	0:22:14
92	0:28:56	0:04:06	0:25:45	0:04:00	0:24:57	0:04:05	0:25:25	0:03:55	0:26:16
91	0:32:50	0:03:54	0:29:26	0:03:41	0:28:27	0:03:30	0:29:07	0:03:42	0:29:58
90	0:36:50	0:04:00	0:33:06	0:03:40	0:31:56	0:03:29	0:32:37	0:03:30	0:33:37
89	0:40:40	0:03:50	0:36:35	0:03:29	0:35:37	0:03:41	0:36:19	0:03:42	0:37:18
88	0:44:35	0:03:55	0:40:20	0:03:45	0:39:07	0:03:30	0:39:50	0:03:31	0:40:58
87	0:48:25	0:03:50	0:43:49	0:03:29	0:42:51	0:03:44	0:43:32	0:03:42	0:44:39
86	0:52:15	0:03:50	0:47:49	0:04:00	0:46:21	0:03:30	0:47:06	0:03:34	0:48:23
85	0:56:25	0:04:10	0:51:30	0:03:41	0:50:11	0:03:50	0:50:50	0:03:44	0:52:14
84	1:00:16	0:03:51	0:55:01	0:03:31	0:53:42	0:03:31	0:54:21	0:03:31	0:55:50
83	1:04:11	0:03:55	0:58:46	0:03:45	0:57:23	0:03:41	0:57:52	0:03:31	0:59:33
82	1:08:01	0:03:50	1:02:16	0:03:30	1:00:57	0:03:34	1:01:23	0:03:31	1:03:09
81	1:11:50	0:03:49	1:05:46	0:03:30	1:04:27	0:03:30	1:05:03	0:03:40	1:06:47
80	1:15:30	0:03:40	1:09:26	0:03:40	1:07:56	0:03:29	1:08:33	0:03:30	1:10:21
79	1:19:31	0:04:01	1:12:57	0:03:31	1:11:27	0:03:31	1:12:08	0:03:35	1:14:01
78	1:23:32	0:04:01	1:16:50	0:03:53	1:15:19	0:03:52	1:15:59	0:03:51	1:17:55
77	1:27:21	0:03:49	1:20:30	0:03:40	1:18:51	0:03:32	1:19:30	0:03:31	1:21:33
76	1:31:11	0:03:50	1:24:02	0:03:32	1:22:23	0:03:32	1:23:01	0:03:31	1:25:09
75	1:35:01	0:03:50	1:27:31	0:03:29	1:25:52	0:03:29	1:26:33	0:03:32	1:28:44
74	1:38:51	0:03:50	1:31:16	0:03:45	1:29:22	0:03:30	1:30:07	0:03:34	1:32:24
73	1:42:38	0:03:47	1:34:46	0:03:30	1:32:53	0:03:31	1:33:36	0:03:29	1:35:58
72	1:46:16	0:03:38	1:38:17	0:03:31	1:36:27	0:03:34	1:37:07	0:03:31	1:39:32
71	1:50:28	0:04:12	1:42:07	0:03:50	1:40:18	0:03:51	1:40:59	0:03:52	1:43:28
70	1:54:18	0:03:50	1:45:37	0:03:30	1:43:47	0:03:29	1:44:29	0:03:30	1:47:03
69	1:57:57	0:03:39	1:49:09	0:03:32	1:47:17	0:03:30	1:47:44	0:03:15	1:50:32
68	2:01:46	0:03:49	1:52:42	0:03:33	1:50:49	0:03:32	1:51:13	0:03:29	1:54:08
67	2:05:36	0:03:50	1:56:12	0:03:30	1:54:09	0:03:20	1:54:45	0:03:32	1:57:41
66	2:09:14	0:03:38	1:59:41	0:03:29	1:57:43	0:03:34	1:58:16	0:03:31	2:01:13
65	2:13:02	0:03:48	2:03:12	0:03:31	2:01:13	0:03:30	2:01:46	0:03:30	2:04:48
64	2:17:14	0:04:12	2:07:07	0:03:55	2:05:03	0:03:50	2:05:27	0:03:41	2:08:43
63	2:20:55	0:03:41	2:10:37	0:03:30	2:08:23	0:03:20	2:08:57	0:03:30	2:12:13
62	2:24:42	0:03:47	2:14:08	0:03:31	2:11:55	0:03:32	2:12:33	0:03:36	2:15:49
61	2:28:20	0:03:38	2:17:42	0:03:34	2:15:28	0:03:33	2:16:03	0:03:30	2:19:23
60	2:32:09	0:03:49	2:21:10	0:03:28	2:18:49	0:03:21	2:19:19	0:03:16	2:22:52
59	2:35:48	0:03:39	2:24:42	0:03:32	2:22:19	0:03:30	2:22:49	0:03:30	2:26:24
58	2:39:37	0:03:49	2:28:02	0:03:20	2:25:48	0:03:29	2:26:20	0:03:31	2:29:57
57	2:43:37	0:04:00	2:31:57	0:03:55	2:29:31	0:03:43	2:30:05	0:03:45	2:33:48
56	2:47:26	0:03:49	2:35:27	0:03:30	2:33:04	0:03:33	2:33:36	0:03:31	2:37:23
55	2:51:06	0:03:40	2:38:58	0:03:31	2:36:23	0:03:19	2:36:53	0:03:17	2:40:50
54	2:54:56	0:03:50	2:42:28	0:03:30	2:39:54	0:03:31	2:40:27	0:03:34	2:44:26
53	2:58:31	0:03:35	2:45:48	0:03:20	2:43:24	0:03:30	2:43:57	0:03:30	2:47:55
52	3:02:21	0:03:50	2:49:23	0:03:35	2:46:46	0:03:22	2:47:13	0:03:16	2:51:26
51	3:06:01	0:03:40	2:52:52	0:03:29	2:50:16	0:03:30	2:50:23	0:03:10	2:54:53
50	3:10:01	0:04:00	2:56:32	0:03:40	2:53:59	0:03:43	2:54:18	0:03:55	2:58:42
Average:		0:03:51		0:03:37		0:03:34		0:03:34	0:03:39

Test results for Test 2:

Percentage	Device1	Difference	Device2	Difference	Device3	Difference	Device4	Difference	Average
100	0:00:00		0:00:00		0:00:00		0:00:00		0:00:00
99	0:00:56	0:00:56	0:00:54	0:00:54	0:01:38	0:01:38	0:02:36	0:02:36	0:01:31 0:01:31
98	0:01:44	0:00:48	0:01:35	0:00:41	0:02:19	0:00:41	0:03:23	0:00:47	0:02:15 0:00:44
97	0:03:44	0:02:00	0:03:26	0:01:51	0:04:18	0:01:59	0:05:17	0:01:54	0:04:11 0:01:56
96	0:05:25	0:01:41	0:05:15	0:01:49	0:05:58	0:01:40	0:07:01	0:01:44	0:05:55 0:01:43
95	0:07:16	0:01:51	0:07:09	0:01:54	0:07:48	0:01:50	0:08:43	0:01:42	0:07:44 0:01:49
94	0:09:16	0:02:00	0:08:49	0:01:40	0:09:38	0:01:50	0:10:38	0:01:55	0:09:35 0:01:51
93	0:10:56	0:01:40	0:10:29	0:01:40	0:11:18	0:01:40	0:12:21	0:01:43	0:11:16 0:01:41
92	0:12:57	0:02:01	0:12:20	0:01:51	0:13:09	0:01:51	0:14:17	0:01:56	0:13:11 0:01:55
91	0:14:51	0:01:54	0:14:00	0:01:40	0:14:49	0:01:40	0:15:58	0:01:41	0:14:55 0:01:44
90	0:16:32	0:01:41	0:15:49	0:01:49	0:16:39	0:01:50	0:17:53	0:01:55	0:16:43 0:01:49
89	0:18:32	0:02:00	0:17:30	0:01:41	0:18:23	0:01:44	0:19:37	0:01:44	0:18:30 0:01:47
88	0:20:11	0:01:39	0:19:19	0:01:49	0:20:14	0:01:51	0:21:32	0:01:55	0:20:19 0:01:49
87	0:22:12	0:02:01	0:21:00	0:01:41	0:22:04	0:01:50	0:23:07	0:01:35	0:22:06 0:01:47
86	0:23:51	0:01:39	0:22:50	0:01:50	0:23:44	0:01:40	0:25:02	0:01:55	0:23:52 0:01:46
85	0:25:41	0:01:50	0:24:31	0:01:41	0:25:34	0:01:50	0:26:32	0:01:30	0:25:35 0:01:43
84	0:27:32	0:01:51	0:26:15	0:01:44	0:27:14	0:01:40	0:28:27	0:01:55	0:27:22 0:01:48
83	0:29:22	0:01:50	0:27:55	0:01:40	0:28:54	0:01:40	0:30:13	0:01:46	0:29:06 0:01:44
82	0:31:13	0:01:51	0:29:35	0:01:40	0:30:34	0:01:40	0:31:54	0:01:41	0:30:49 0:01:43
81	0:33:04	0:01:51	0:31:25	0:01:50	0:32:14	0:01:40	0:33:49	0:01:55	0:32:38 0:01:49
80	0:34:57	0:01:53	0:33:05	0:01:40	0:34:04	0:01:50	0:35:22	0:01:33	0:34:22 0:01:44
79	0:36:45	0:01:48	0:34:55	0:01:50	0:35:59	0:01:55	0:37:18	0:01:56	0:36:14 0:01:52
78	0:38:27	0:01:42	0:36:35	0:01:40	0:37:39	0:01:40	0:38:58	0:01:40	0:37:55 0:01:41
77	0:40:17	0:01:50	0:38:16	0:01:41	0:39:20	0:01:41	0:40:52	0:01:54	0:39:41 0:01:46
76	0:42:07	0:01:50	0:40:06	0:01:50	0:41:09	0:01:49	0:42:37	0:01:45	0:41:30 0:01:49
75	0:43:57	0:01:50	0:41:46	0:01:40	0:42:39	0:01:30	0:44:18	0:01:41	0:43:10 0:01:40
74	0:45:37	0:01:40	0:43:19	0:01:33	0:44:29	0:01:50	0:46:02	0:01:44	0:44:52 0:01:42
73	0:47:28	0:01:51	0:45:10	0:01:51	0:46:09	0:01:40	0:47:34	0:01:32	0:46:35 0:01:44
72	0:49:22	0:01:54	0:46:50	0:01:40	0:47:59	0:01:50	0:49:27	0:01:53	0:48:25 0:01:49
71	0:51:02	0:01:40	0:48:30	0:01:40	0:49:39	0:01:40	0:51:13	0:01:46	0:50:06 0:01:41
70	0:52:52	0:01:50	0:50:10	0:01:40	0:51:10	0:01:31	0:52:55	0:01:42	0:51:47 0:01:41
69	0:54:32	0:01:40	0:52:00	0:01:50	0:53:00	0:01:50	0:54:37	0:01:42	0:53:32 0:01:46
68	0:56:23	0:01:51	0:53:30	0:01:30	0:54:45	0:01:45	0:56:23	0:01:46	0:55:15 0:01:43
67	0:58:13	0:01:50	0:55:22	0:01:52	0:56:34	0:01:49	0:58:14	0:01:51	0:57:06 0:01:51
66	0:59:52	0:01:39	0:56:51	0:01:29	0:58:05	0:01:31	0:59:48	0:01:34	0:58:39 0:01:33
65	1:01:42	0:01:50	0:58:42	0:01:51	0:59:54	0:01:49	1:01:43	0:01:55	1:00:30 0:01:51
64	1:03:23	0:01:41	1:00:12	0:01:30	1:01:35	0:01:41	1:03:13	0:01:30	1:02:06 0:01:35
63	1:05:13	0:01:50	1:02:05	0:01:53	1:03:05	0:01:30	1:05:08	0:01:55	1:03:53 0:01:47
62	1:06:57	0:01:44	1:03:45	0:01:40	1:04:55	0:01:50	1:06:52	0:01:44	1:05:37 0:01:44
61	1:08:45	0:01:48	1:05:15	0:01:30	1:06:35	0:01:40	1:08:23	0:01:31	1:07:15 0:01:37
60	1:10:28	0:01:43	1:07:05	0:01:50	1:08:15	0:01:40	1:10:08	0:01:45	1:08:59 0:01:44
59	1:12:18	0:01:50	1:08:45	0:01:40	1:10:00	0:01:45	1:11:50	0:01:42	1:10:43 0:01:44
58	1:14:08	0:01:50	1:10:25	0:01:40	1:11:40	0:01:40	1:13:32	0:01:42	1:12:26 0:01:43
57	1:15:58	0:01:50	1:12:07	0:01:42	1:13:20	0:01:40	1:15:05	0:01:33	1:14:08 0:01:41
56	1:17:37	0:01:39	1:13:37	0:01:30	1:15:00	0:01:40	1:16:58	0:01:53	1:15:48 0:01:40
55	1:19:28	0:01:51	1:15:27	0:01:50	1:16:40	0:01:40	1:18:43	0:01:45	1:17:35 0:01:47
54	1:21:08	0:01:40	1:17:07	0:01:40	1:18:20	0:01:40	1:20:25	0:01:42	1:19:15 0:01:40
53	1:23:03	0:01:55	1:18:50	0:01:43	1:20:00	0:01:40	1:22:08	0:01:43	1:21:00 0:01:45
52	1:24:43	0:01:40	1:20:30	0:01:40	1:21:50	0:01:50	1:23:53	0:01:45	1:22:44 0:01:44
51	1:26:34	0:01:51	1:22:00	0:01:30	1:23:20	0:01:30	1:25:35	0:01:42	1:24:22 0:01:38
50	1:28:13	0:01:39	1:23:50	0:01:50	1:25:10	0:01:50	1:27:18	0:01:43	1:26:08 0:01:45
Average:		0:01:48		0:01:43		0:01:44		0:01:45	0:01:45

Test results for Test 3:

Percentage	Device1	Difference	Device2	Difference	Device3	Difference	Device4	Difference	Average
100	0:00:00		0:00:00		0:00:00		0:00:00		0:00:00
99	0:02:00	0:02:00	0:00:59	0:00:59	0:01:00	0:01:00	0:00:49	0:00:49	0:01:12
98	0:02:45	0:00:45	0:01:59	0:01:00	0:01:46	0:00:46	0:01:49	0:01:00	0:02:05
97	0:04:55	0:02:10	0:03:49	0:01:50	0:03:40	0:01:54	0:03:29	0:01:40	0:03:58
96	0:06:35	0:01:40	0:05:43	0:01:54	0:05:25	0:01:45	0:05:19	0:01:50	0:05:45
95	0:08:20	0:01:45	0:07:34	0:01:51	0:07:06	0:01:41	0:07:10	0:01:51	0:07:33
94	0:10:25	0:02:05	0:09:24	0:01:50	0:09:05	0:01:59	0:08:54	0:01:44	0:09:27
93	0:12:10	0:01:45	0:11:14	0:01:50	0:10:44	0:01:39	0:10:44	0:01:50	0:11:13
92	0:13:50	0:01:40	0:13:03	0:01:49	0:12:29	0:01:45	0:12:34	0:01:50	0:12:59
91	0:15:56	0:02:06	0:15:04	0:02:01	0:14:11	0:01:42	0:14:14	0:01:40	0:14:51
90	0:17:41	0:01:45	0:16:54	0:01:50	0:15:54	0:01:43	0:16:04	0:01:50	0:16:38
89	0:19:25	0:01:44	0:18:34	0:01:40	0:17:40	0:01:46	0:17:54	0:01:50	0:18:23
88	0:21:20	0:01:55	0:20:34	0:02:00	0:19:34	0:01:54	0:19:34	0:01:40	0:20:15
87	0:23:00	0:01:40	0:22:25	0:01:51	0:21:04	0:01:30	0:21:24	0:01:50	0:21:58
86	0:24:55	0:01:55	0:24:19	0:01:54	0:23:00	0:01:56	0:23:05	0:01:41	0:23:50
85	0:26:51	0:01:56	0:26:08	0:01:49	0:24:40	0:01:40	0:24:45	0:01:40	0:25:36
84	0:28:35	0:01:44	0:28:07	0:01:59	0:26:14	0:01:34	0:26:39	0:01:54	0:27:24
83	0:30:16	0:01:41	0:29:48	0:01:41	0:28:06	0:01:52	0:28:27	0:01:48	0:29:09
82	0:32:11	0:01:55	0:31:39	0:01:51	0:29:49	0:01:43	0:30:19	0:01:52	0:30:59
81	0:33:55	0:01:44	0:33:29	0:01:50	0:31:25	0:01:36	0:32:00	0:01:41	0:32:42
80	0:35:51	0:01:56	0:35:19	0:01:50	0:33:19	0:01:54	0:33:39	0:01:39	0:34:32
79	0:37:29	0:01:38	0:37:10	0:01:51	0:34:49	0:01:30	0:35:30	0:01:51	0:36:15
78	0:39:10	0:01:41	0:39:00	0:01:50	0:36:35	0:01:46	0:37:10	0:01:40	0:37:59
77	0:41:03	0:01:53	0:40:44	0:01:44	0:38:25	0:01:50	0:38:49	0:01:39	0:39:45
76	0:42:49	0:01:46	0:42:44	0:02:00	0:40:00	0:01:35	0:40:30	0:01:41	0:41:31
75	0:44:43	0:01:54	0:44:24	0:01:40	0:41:55	0:01:55	0:42:20	0:01:50	0:43:21
74	0:46:25	0:01:42	0:46:24	0:02:00	0:43:25	0:01:30	0:44:04	0:01:44	0:45:05
73	0:48:09	0:01:44	0:48:04	0:01:40	0:45:06	0:01:41	0:45:45	0:01:41	0:46:46
72	0:50:04	0:01:55	0:49:45	0:01:41	0:46:50	0:01:44	0:47:34	0:01:49	0:48:33
71	0:51:50	0:01:46	0:51:44	0:01:59	0:48:36	0:01:46	0:49:15	0:01:41	0:50:21
70	0:53:19	0:01:29	0:53:25	0:01:41	0:50:05	0:01:29	0:50:55	0:01:40	0:51:56
69	0:55:15	0:01:56	0:55:04	0:01:39	0:52:00	0:01:55	0:52:34	0:01:39	0:53:43
68	0:56:59	0:01:44	0:57:06	0:02:02	0:53:31	0:01:31	0:54:15	0:01:41	0:55:28
67	0:58:40	0:01:41	0:58:48	0:01:42	0:55:15	0:01:44	0:56:05	0:01:50	0:57:12
66	1:00:24	0:01:44	1:00:27	0:01:39	0:57:00	0:01:45	0:57:44	0:01:39	0:58:54
65	1:02:19	0:01:55	1:02:07	0:01:40	0:58:31	0:01:31	0:59:26	0:01:42	1:00:36
64	1:03:49	0:01:30	1:04:09	0:02:02	1:00:15	0:01:44	1:01:06	0:01:40	1:02:20
63	1:05:35	0:01:46	1:05:50	0:01:41	1:01:45	0:01:30	1:02:47	0:01:41	1:03:59
62	1:07:29	0:01:54	1:07:40	0:01:50	1:03:27	0:01:42	1:04:40	0:01:53	1:05:49
61	1:09:10	0:01:41	1:09:19	0:01:39	1:05:11	0:01:44	1:06:19	0:01:39	1:07:30
60	1:11:05	0:01:55	1:11:20	0:02:01	1:06:55	0:01:44	1:07:50	0:01:31	1:09:18
59	1:12:35	0:01:30	1:13:01	0:01:41	1:08:36	0:01:41	1:09:40	0:01:50	1:10:58
58	1:14:19	0:01:44	1:14:40	0:01:39	1:10:11	0:01:35	1:11:20	0:01:40	1:12:38
57	1:16:15	0:01:56	1:16:35	0:01:55	1:11:51	0:01:40	1:13:00	0:01:40	1:14:25
56	1:17:44	0:01:29	1:18:04	0:01:29	1:13:26	0:01:35	1:14:40	0:01:40	1:15:58
55	1:19:30	0:01:46	1:19:55	0:01:51	1:15:06	0:01:40	1:16:21	0:01:41	1:17:43
54	1:21:25	0:01:55	1:21:54	0:01:59	1:16:51	0:01:45	1:18:01	0:01:40	1:19:33
53	1:23:05	0:01:40	1:23:35	0:01:41	1:18:21	0:01:30	1:19:45	0:01:44	1:21:12
52	1:24:40	0:01:35	1:25:15	0:01:40	1:20:06	0:01:45	1:21:25	0:01:40	1:22:52
51	1:26:35	0:01:55	1:26:55	0:01:40	1:21:47	0:01:41	1:23:05	0:01:40	1:24:36
50	1:28:05	0:01:30	1:28:45	0:01:50	1:23:31	0:01:44	1:24:45	0:01:40	1:26:17
Average:		0:01:47		0:01:48		0:01:42		0:01:44	0:01:45

# Test results for Test 4:

Percentage	Device1	Difference	Device2	Difference	Device3	Difference	Device4	Difference	Average
100	0:00:00		0:00:00		0:00:00		0:00:00		0:00:00
99	0:02:51	0:02:51	0:02:26	0:02:26	0:00:31	0:00:31	0:00:38	0:00:38	0:01:37
98	0:03:51	0:01:00	0:03:27	0:01:01	0:01:31	0:01:00	0:01:38	0:01:00	0:02:37
97	0:05:31	0:01:40	0:05:21	0:01:54	0:03:11	0:01:40	0:03:18	0:01:40	0:04:20
96	0:07:31	0:02:00	0:07:01	0:01:40	0:04:51	0:01:40	0:05:01	0:01:43	0:06:06
95	0:09:23	0:01:52	0:08:56	0:01:55	0:06:32	0:01:41	0:06:41	0:01:40	0:07:53
94	0:11:13	0:01:50	0:10:41	0:01:45	0:08:12	0:01:40	0:08:21	0:01:40	0:09:37
93	0:13:03	0:01:50	0:12:22	0:01:41	0:10:03	0:01:51	0:10:11	0:01:50	0:11:25
92	0:14:43	0:01:40	0:14:16	0:01:54	0:11:37	0:01:34	0:11:52	0:01:41	0:13:07
91	0:16:46	0:02:03	0:16:02	0:01:46	0:13:16	0:01:39	0:13:31	0:01:39	0:14:54
90	0:18:26	0:01:40	0:17:57	0:01:55	0:14:57	0:01:41	0:15:24	0:01:53	0:16:41
89	0:20:16	0:01:50	0:19:41	0:01:44	0:16:47	0:01:50	0:17:03	0:01:39	0:18:27
88	0:22:07	0:01:51	0:21:21	0:01:40	0:18:26	0:01:39	0:18:53	0:01:50	0:20:12
87	0:23:46	0:01:39	0:23:16	0:01:55	0:20:17	0:01:51	0:20:34	0:01:41	0:21:58
86	0:25:38	0:01:52	0:25:11	0:01:55	0:21:57	0:01:40	0:22:17	0:01:43	0:23:46
85	0:27:22	0:01:44	0:26:57	0:01:46	0:23:32	0:01:35	0:24:07	0:01:50	0:25:30
84	0:29:22	0:02:00	0:28:36	0:01:39	0:25:23	0:01:51	0:25:47	0:01:40	0:27:17
83	0:31:01	0:01:39	0:30:21	0:01:45	0:26:57	0:01:34	0:27:39	0:01:52	0:29:00
82	0:32:42	0:01:41	0:32:17	0:01:56	0:28:42	0:01:45	0:29:19	0:01:40	0:30:45
81	0:34:32	0:01:50	0:34:01	0:01:44	0:30:24	0:01:42	0:30:59	0:01:40	0:32:29
80	0:36:12	0:01:40	0:35:42	0:01:41	0:32:08	0:01:44	0:32:39	0:01:40	0:34:10
79	0:38:12	0:02:00	0:37:36	0:01:54	0:33:52	0:01:44	0:34:20	0:01:41	0:36:00
78	0:39:54	0:01:42	0:39:22	0:01:46	0:35:22	0:01:30	0:36:12	0:01:52	0:37:42
77	0:41:33	0:01:39	0:41:02	0:01:40	0:37:08	0:01:46	0:37:52	0:01:40	0:39:24
76	0:43:24	0:01:51	0:42:57	0:01:55	0:38:52	0:01:44	0:39:32	0:01:40	0:41:11
75	0:45:07	0:01:43	0:44:28	0:01:31	0:40:22	0:01:30	0:41:12	0:01:40	0:42:47
74	0:46:47	0:01:40	0:46:27	0:01:59	0:42:17	0:01:55	0:42:52	0:01:40	0:44:36
73	0:48:37	0:01:50	0:48:07	0:01:40	0:43:52	0:01:35	0:44:34	0:01:42	0:46:18
72	0:50:27	0:01:50	0:49:52	0:01:45	0:45:23	0:01:31	0:46:14	0:01:40	0:47:59
71	0:52:07	0:01:40	0:51:32	0:01:40	0:47:08	0:01:45	0:48:04	0:01:50	0:49:43
70	0:53:48	0:01:41	0:53:17	0:01:45	0:48:48	0:01:40	0:49:34	0:01:30	0:51:22
69	0:55:38	0:01:50	0:55:12	0:01:55	0:50:22	0:01:34	0:51:27	0:01:53	0:53:10
68	0:57:23	0:01:45	0:56:57	0:01:45	0:52:04	0:01:42	0:52:58	0:01:31	0:54:51
67	0:59:02	0:01:39	0:58:27	0:01:30	0:53:47	0:01:43	0:54:37	0:01:39	0:56:28
66	1:00:52	0:01:50	1:00:12	0:01:45	0:55:23	0:01:36	0:56:29	0:01:52	0:58:14
65	1:02:33	0:01:41	1:02:07	0:01:55	0:57:04	0:01:41	0:57:59	0:01:30	0:59:56
64	1:04:12	0:01:39	1:03:47	0:01:40	0:58:38	0:01:34	0:59:40	0:01:41	1:01:34
63	1:06:02	0:01:50	1:05:32	0:01:45	1:00:23	0:01:45	1:01:20	0:01:40	1:03:19
62	1:07:43	0:01:41	1:07:03	0:01:31	1:02:03	0:01:40	1:02:59	0:01:39	1:04:57
61	1:09:24	0:01:41	1:08:57	0:01:54	1:03:38	0:01:35	1:04:43	0:01:44	1:06:41
60	1:11:04	0:01:40	1:10:32	0:01:35	1:05:08	0:01:30	1:06:22	0:01:39	1:08:17
59	1:12:44	0:01:40	1:12:13	0:01:41	1:06:54	0:01:46	1:08:03	0:01:41	1:09:59
58	1:14:37	0:01:53	1:13:57	0:01:44	1:08:23	0:01:29	1:09:42	0:01:39	1:11:40
57	1:16:18	0:01:41	1:15:37	0:01:40	1:10:08	0:01:45	1:11:23	0:01:41	1:13:22
56	1:18:08	0:01:50	1:17:32	0:01:55	1:11:53	0:01:45	1:13:02	0:01:39	1:15:09
55	1:19:37	0:01:29	1:19:08	0:01:36	1:13:23	0:01:30	1:14:43	0:01:41	1:16:43
54	1:21:19	0:01:42	1:20:48	0:01:40	1:14:54	0:01:31	1:16:28	0:01:45	1:18:22
53	1:22:59	0:01:40	1:22:32	0:01:44	1:16:38	0:01:44	1:17:58	0:01:30	1:20:02
52	1:24:49	0:01:50	1:24:18	0:01:46	1:18:24	0:01:46	1:19:43	0:01:45	1:21:48
51	1:26:23	0:01:34	1:25:58	0:01:40	1:19:43	0:01:19	1:21:15	0:01:32	1:23:20
50	1:28:13	0:01:50	1:27:43	0:01:45	1:21:28	0:01:45	1:22:58	0:01:43	1:25:06
		0:01:45		0:01:45		0:01:40		0:01:42	0:01:43

TotalTried: 89 91 82 84  
 Successful: 89 91 82 84  
 Failed: 0 0 0 0  
 TotalBytes: 93788111 95895709 86411518 88519116  
 TestPicture Size 1053799

# Test results for Test 5:

Percentage	Device1	Difference	Device2	Difference	Device3	Difference	Device4	Difference	Average
100	0:00:00		0:00:00		0:00:00		0:00:00		0:00:00
99	0:02:25	0:02:25	0:02:14	0:02:14	0:01:45	0:01:45	0:01:14	0:01:14	0:01:54
98	0:03:15	0:00:50	0:02:55	0:00:41	0:02:35	0:00:50	0:02:00	0:00:46	0:02:41
97	0:04:56	0:01:41	0:04:44	0:01:49	0:04:19	0:01:44	0:03:45	0:01:45	0:04:26
96	0:06:40	0:01:44	0:06:18	0:01:34	0:05:49	0:01:30	0:05:19	0:01:34	0:06:01
95	0:08:11	0:01:31	0:07:57	0:01:39	0:07:20	0:01:31	0:06:56	0:01:37	0:07:36
94	0:09:51	0:01:40	0:09:37	0:01:40	0:09:04	0:01:44	0:08:46	0:01:50	0:09:20
93	0:11:35	0:01:44	0:11:18	0:01:41	0:10:34	0:01:30	0:10:22	0:01:36	0:10:57
92	0:13:16	0:01:41	0:13:00	0:01:42	0:12:04	0:01:30	0:11:55	0:01:33	0:12:34
91	0:14:46	0:01:30	0:14:40	0:01:40	0:13:45	0:01:41	0:13:36	0:01:41	0:14:12
90	0:16:16	0:01:30	0:16:10	0:01:30	0:15:20	0:01:35	0:15:11	0:01:35	0:15:44
89	0:18:11	0:01:55	0:17:55	0:01:45	0:17:00	0:01:40	0:16:46	0:01:35	0:17:28
88	0:19:42	0:01:31	0:19:27	0:01:32	0:18:45	0:01:45	0:18:21	0:01:35	0:19:04
87	0:21:26	0:01:44	0:21:11	0:01:44	0:20:15	0:01:30	0:19:57	0:01:36	0:20:42
86	0:23:12	0:01:46	0:22:43	0:01:32	0:21:55	0:01:40	0:21:32	0:01:35	0:22:21
85	0:24:51	0:01:39	0:24:27	0:01:44	0:23:26	0:01:31	0:23:01	0:01:29	0:23:56
84	0:26:27	0:01:36	0:26:00	0:01:33	0:25:01	0:01:35	0:24:37	0:01:36	0:25:31
83	0:28:11	0:01:44	0:27:31	0:01:31	0:26:30	0:01:29	0:26:12	0:01:35	0:27:06
82	0:29:42	0:01:31	0:29:04	0:01:33	0:28:15	0:01:45	0:27:57	0:01:45	0:28:44
81	0:31:26	0:01:44	0:30:47	0:01:43	0:29:45	0:01:30	0:29:33	0:01:36	0:30:23
80	0:33:12	0:01:46	0:32:21	0:01:34	0:31:20	0:01:35	0:30:57	0:01:24	0:31:58
79	0:34:47	0:01:35	0:34:04	0:01:43	0:32:51	0:01:31	0:32:38	0:01:41	0:33:35
78	0:36:22	0:01:35	0:35:36	0:01:32	0:34:32	0:01:41	0:34:12	0:01:34	0:35:11
77	0:38:12	0:01:50	0:37:08	0:01:32	0:36:02	0:01:30	0:35:47	0:01:35	0:36:47
76	0:39:57	0:01:45	0:38:41	0:01:33	0:37:35	0:01:33	0:37:22	0:01:35	0:38:24
75	0:41:22	0:01:25	0:40:13	0:01:32	0:39:06	0:01:31	0:38:57	0:01:35	0:39:54
74	0:42:57	0:01:35	0:41:45	0:01:32	0:40:36	0:01:30	0:40:34	0:01:37	0:41:28
73	0:44:34	0:01:37	0:43:17	0:01:32	0:42:21	0:01:45	0:41:57	0:01:23	0:43:02
72	0:46:22	0:01:48	0:44:48	0:01:31	0:43:53	0:01:32	0:43:48	0:01:51	0:44:43
71	0:47:57	0:01:35	0:46:21	0:01:33	0:45:15	0:01:22	0:45:09	0:01:21	0:46:10
70	0:49:35	0:01:38	0:47:54	0:01:33	0:46:56	0:01:41	0:46:47	0:01:38	0:47:48
69	0:51:22	0:01:47	0:49:37	0:01:43	0:48:26	0:01:30	0:48:23	0:01:36	0:49:27
68	0:52:45	0:01:23	0:50:58	0:01:21	0:49:58	0:01:32	0:49:58	0:01:35	0:50:55
67	0:54:34	0:01:49	0:52:42	0:01:44	0:51:31	0:01:33	0:51:33	0:01:35	0:52:35
66	0:56:10	0:01:36	0:54:14	0:01:32	0:53:01	0:01:30	0:53:10	0:01:37	0:54:09
65	0:57:55	0:01:45	0:55:45	0:01:31	0:54:44	0:01:43	0:54:45	0:01:35	0:55:47
64	0:59:14	0:01:19	0:57:19	0:01:34	0:56:06	0:01:22	0:56:21	0:01:36	0:57:15
63	1:01:00	0:01:46	0:58:52	0:01:33	0:57:47	0:01:41	0:57:58	0:01:37	0:58:54
62	1:02:25	0:01:25	1:00:33	0:01:41	0:59:20	0:01:33	0:59:33	0:01:35	1:00:28
61	1:04:00	0:01:35	1:01:53	0:01:20	1:00:40	0:01:20	1:01:11	0:01:38	1:01:56
60	1:05:40	0:01:40	1:03:37	0:01:44	1:02:35	0:01:55	1:02:46	0:01:35	1:03:40
59	1:07:12	0:01:32	1:05:12	0:01:35	1:03:45	0:01:10	1:04:12	0:01:26	1:05:05
58	1:08:51	0:01:39	1:06:53	0:01:41	1:05:25	0:01:40	1:05:47	0:01:35	1:06:44
57	1:10:26	0:01:35	1:08:24	0:01:31	1:06:56	0:01:31	1:07:22	0:01:35	1:08:17
56	1:12:01	0:01:35	1:09:58	0:01:34	1:08:31	0:01:35	1:08:52	0:01:30	1:09:51
55	1:13:36	0:01:35	1:11:19	0:01:21	1:09:50	0:01:19	1:10:22	0:01:30	1:11:17
54	1:15:01	0:01:25	1:12:52	0:01:33	1:11:31	0:01:41	1:12:13	0:01:51	1:12:54
53	1:16:50	0:01:49	1:14:22	0:01:30	1:13:02	0:01:31	1:13:33	0:01:20	1:14:27
52	1:18:13	0:01:23	1:16:05	0:01:43	1:14:31	0:01:29	1:15:13	0:01:40	1:16:00
51	1:19:51	0:01:38	1:17:28	0:01:23	1:15:56	0:01:25	1:16:44	0:01:31	1:17:30
50	1:21:26	0:01:35	1:19:09	0:01:41	1:17:26	0:01:30	1:18:23	0:01:39	1:19:06
		0:01:38		0:01:35		0:01:34		0:01:35	0:01:36

TotalTried: 409 397 401 393  
 Successful: 409 397 401 393  
 Failed: 0 0 0 0  
 TotalBytes: 431003791 418358203 422573399 414143007  
 TestPicture Size 1053799



# Test results for Test 6:

Percentage	Device1	Difference	Device2	Difference	Device3	Difference	Device4	Difference	Average
100	0:00:00		0:00:00		0:00:00		0:00:00		0:00:00
99	0:01:35	0:01:35	0:02:17	0:02:17	0:00:20	0:00:20	0:03:00	0:03:00	0:01:48
98	0:02:25	0:00:50	0:03:07	0:00:50	0:01:01	0:00:41	0:03:40	0:00:40	0:02:33
97	0:03:56	0:01:31	0:04:27	0:01:20	0:02:36	0:01:35	0:05:15	0:01:35	0:04:04
96	0:05:20	0:01:24	0:05:59	0:01:32	0:03:57	0:01:21	0:06:47	0:01:32	0:05:31
95	0:06:50	0:01:30	0:07:35	0:01:36	0:05:30	0:01:33	0:08:20	0:01:33	0:07:04
94	0:08:20	0:01:30	0:09:10	0:01:35	0:07:02	0:01:32	0:09:52	0:01:32	0:08:36
93	0:09:45	0:01:25	0:10:42	0:01:32	0:08:26	0:01:24	0:11:27	0:01:35	0:10:05
92	0:11:30	0:01:45	0:12:06	0:01:24	0:09:48	0:01:22	0:12:51	0:01:24	0:11:34
91	0:12:52	0:01:22	0:13:51	0:01:45	0:11:21	0:01:33	0:14:24	0:01:33	0:13:07
90	0:14:27	0:01:35	0:15:16	0:01:25	0:12:55	0:01:34	0:15:59	0:01:35	0:14:39
89	0:16:05	0:01:38	0:16:52	0:01:36	0:14:28	0:01:33	0:17:34	0:01:35	0:16:15
88	0:17:25	0:01:20	0:18:23	0:01:31	0:15:50	0:01:22	0:18:54	0:01:20	0:17:38
87	0:18:53	0:01:28	0:19:57	0:01:34	0:17:21	0:01:31	0:20:29	0:01:35	0:19:10
86	0:20:28	0:01:35	0:21:33	0:01:36	0:18:44	0:01:23	0:21:55	0:01:26	0:20:40
85	0:22:04	0:01:36	0:23:07	0:01:34	0:20:15	0:01:31	0:23:35	0:01:40	0:22:15
84	0:23:29	0:01:25	0:24:28	0:01:21	0:21:38	0:01:23	0:25:00	0:01:25	0:23:39
83	0:24:48	0:01:19	0:25:47	0:01:19	0:23:10	0:01:32	0:26:21	0:01:21	0:25:02
82	0:26:24	0:01:36	0:27:07	0:01:20	0:24:36	0:01:26	0:27:56	0:01:35	0:26:31
81	0:27:44	0:01:20	0:28:39	0:01:32	0:26:07	0:01:31	0:29:35	0:01:39	0:28:01
80	0:29:09	0:01:25	0:30:03	0:01:24	0:27:31	0:01:24	0:30:47	0:01:12	0:29:22
79	0:30:45	0:01:36	0:31:35	0:01:32	0:28:51	0:01:20	0:32:22	0:01:35	0:30:53
78	0:32:05	0:01:20	0:33:08	0:01:33	0:30:22	0:01:31	0:33:48	0:01:26	0:32:21
77	0:33:30	0:01:25	0:34:41	0:01:33	0:31:47	0:01:25	0:35:21	0:01:33	0:33:50
76	0:34:51	0:01:21	0:36:15	0:01:34	0:33:18	0:01:31	0:36:44	0:01:23	0:35:17
75	0:36:30	0:01:39	0:37:25	0:01:10	0:34:41	0:01:23	0:38:19	0:01:35	0:36:44
74	0:37:51	0:01:21	0:38:58	0:01:33	0:36:06	0:01:25	0:39:55	0:01:36	0:38:13
73	0:39:10	0:01:19	0:40:26	0:01:28	0:37:39	0:01:33	0:41:20	0:01:25	0:39:39
72	0:40:45	0:01:35	0:41:51	0:01:25	0:39:05	0:01:26	0:42:41	0:01:21	0:41:06
71	0:42:11	0:01:26	0:43:27	0:01:36	0:40:27	0:01:22	0:44:06	0:01:25	0:42:33
70	0:43:46	0:01:35	0:45:02	0:01:35	0:41:59	0:01:32	0:45:31	0:01:25	0:44:04
69	0:45:21	0:01:35	0:46:28	0:01:26	0:43:26	0:01:27	0:46:52	0:01:21	0:45:32
68	0:46:46	0:01:25	0:48:03	0:01:35	0:44:51	0:01:25	0:48:26	0:01:34	0:47:01
67	0:48:17	0:01:31	0:49:28	0:01:25	0:46:11	0:01:20	0:49:50	0:01:24	0:48:27
66	0:49:43	0:01:26	0:51:03	0:01:35	0:47:46	0:01:35	0:51:23	0:01:33	0:49:59
65	0:51:15	0:01:32	0:52:28	0:01:25	0:49:06	0:01:20	0:52:46	0:01:23	0:51:24
64	0:52:49	0:01:34	0:53:48	0:01:20	0:50:31	0:01:25	0:54:18	0:01:32	0:52:52
63	0:54:12	0:01:23	0:55:08	0:01:20	0:51:53	0:01:22	0:55:32	0:01:14	0:54:11
62	0:55:36	0:01:24	0:56:28	0:01:20	0:53:26	0:01:33	0:57:06	0:01:34	0:55:39
61	0:57:09	0:01:33	0:58:03	0:01:35	0:54:48	0:01:22	0:58:29	0:01:23	0:57:07
60	0:58:30	0:01:21	0:59:23	0:01:20	0:56:11	0:01:23	1:00:05	0:01:36	0:58:32
59	0:59:58	0:01:28	1:00:43	0:01:20	0:57:34	0:01:23	1:01:25	0:01:20	0:59:55
58	1:01:33	0:01:35	1:01:54	0:01:11	0:59:10	0:01:36	1:03:00	0:01:35	1:01:24
57	1:02:54	0:01:21	1:03:28	0:01:34	1:00:20	0:01:10	1:04:10	0:01:10	1:02:43
56	1:04:18	0:01:24	1:04:51	0:01:23	1:01:55	0:01:35	1:05:33	0:01:23	1:04:09
55	1:05:50	0:01:32	1:06:16	0:01:25	1:03:15	0:01:20	1:07:16	0:01:43	1:05:39
54	1:07:23	0:01:33	1:07:38	0:01:22	1:04:50	0:01:35	1:08:41	0:01:25	1:07:08
53	1:08:45	0:01:22	1:09:03	0:01:25	1:06:26	0:01:36	1:10:06	0:01:25	1:08:35
52	1:10:08	0:01:23	1:10:27	0:01:24	1:07:36	0:01:10	1:11:26	0:01:20	1:09:54
51	1:11:31	0:01:23	1:11:52	0:01:25	1:09:12	0:01:36	1:13:01	0:01:35	1:11:24
50	1:13:03	0:01:32	1:13:27	0:01:35	1:10:42	0:01:30	1:14:23	0:01:22	1:12:54
		0:01:28		0:01:28		0:01:27		0:01:28	0:01:28

TotalTried: 732 736 709 744  
 Successful: 732 715 709 744  
 Failed: 0 21 0 0  
 TotalBytes: 771380868 753466285 747143491 784026456  
 TestPicture Size 1053799



# Test results for Test 7:

Percentage	Device1	Difference	Device2	Difference	Device3	Difference	Device4	Difference	Average
100	0:00:00		0:00:00		0:00:00		0:00:00		0:00:00
99	0:01:22	0:01:22	0:02:07	0:02:07	0:00:42	0:00:42	0:01:38	0:01:38	0:01:27
98	0:02:07	0:00:45	0:02:50	0:00:43	0:01:22	0:00:40	0:02:33	0:00:55	0:02:13
97	0:03:28	0:01:21	0:04:16	0:01:26	0:02:32	0:01:10	0:03:45	0:01:12	0:03:30
96	0:05:02	0:01:34	0:05:46	0:01:30	0:04:07	0:01:35	0:05:20	0:01:35	0:05:04
95	0:06:25	0:01:23	0:07:01	0:01:15	0:05:33	0:01:26	0:06:45	0:01:25	0:06:26
94	0:07:38	0:01:13	0:08:27	0:01:26	0:06:46	0:01:13	0:07:56	0:01:11	0:07:42
93	0:09:12	0:01:34	0:09:56	0:01:29	0:08:10	0:01:24	0:09:31	0:01:35	0:09:12
92	0:10:23	0:01:11	0:11:17	0:01:21	0:09:46	0:01:36	0:10:44	0:01:13	0:10:32
91	0:11:54	0:01:31	0:12:31	0:01:14	0:10:56	0:01:10	0:12:08	0:01:24	0:11:52
90	0:13:18	0:01:24	0:13:57	0:01:26	0:12:27	0:01:31	0:13:32	0:01:24	0:13:18
89	0:14:48	0:01:30	0:15:23	0:01:26	0:13:47	0:01:20	0:14:58	0:01:26	0:14:44
88	0:16:08	0:01:20	0:16:47	0:01:24	0:15:12	0:01:25	0:16:23	0:01:25	0:16:07
87	0:17:21	0:01:13	0:18:19	0:01:32	0:16:35	0:01:23	0:17:43	0:01:20	0:17:29
86	0:18:43	0:01:22	0:19:35	0:01:16	0:17:49	0:01:14	0:19:09	0:01:26	0:18:49
85	0:20:06	0:01:23	0:20:55	0:01:20	0:19:24	0:01:35	0:20:34	0:01:25	0:20:15
84	0:21:26	0:01:20	0:22:16	0:01:21	0:20:47	0:01:23	0:21:43	0:01:09	0:21:33
83	0:23:08	0:01:42	0:23:42	0:01:26	0:22:10	0:01:23	0:23:08	0:01:25	0:23:02
82	0:24:22	0:01:14	0:25:06	0:01:24	0:23:25	0:01:15	0:24:43	0:01:35	0:24:24
81	0:25:32	0:01:10	0:26:32	0:01:26	0:24:56	0:01:31	0:26:08	0:01:25	0:25:47
80	0:27:05	0:01:33	0:27:57	0:01:25	0:26:22	0:01:26	0:27:22	0:01:14	0:27:12
79	0:28:29	0:01:24	0:29:18	0:01:21	0:27:31	0:01:09	0:28:57	0:01:35	0:28:34
78	0:29:38	0:01:09	0:30:52	0:01:34	0:28:55	0:01:24	0:30:08	0:01:11	0:29:53
77	0:31:03	0:01:25	0:32:07	0:01:15	0:30:27	0:01:32	0:31:33	0:01:25	0:31:17
76	0:32:28	0:01:25	0:33:44	0:01:37	0:31:43	0:01:16	0:32:59	0:01:26	0:32:44
75	0:33:48	0:01:20	0:35:07	0:01:23	0:33:08	0:01:25	0:34:19	0:01:20	0:34:05
74	0:35:18	0:01:30	0:36:30	0:01:23	0:34:29	0:01:21	0:35:44	0:01:25	0:35:30
73	0:36:38	0:01:20	0:37:55	0:01:25	0:35:42	0:01:13	0:36:54	0:01:10	0:36:47
72	0:38:08	0:01:30	0:39:07	0:01:12	0:37:05	0:01:23	0:38:18	0:01:24	0:38:09
71	0:39:30	0:01:22	0:40:42	0:01:35	0:38:30	0:01:25	0:39:39	0:01:21	0:39:35
70	0:40:54	0:01:24	0:42:07	0:01:25	0:39:53	0:01:23	0:41:04	0:01:25	0:41:00
69	0:42:04	0:01:10	0:43:22	0:01:15	0:41:16	0:01:23	0:42:16	0:01:12	0:42:15
68	0:43:23	0:01:19	0:44:47	0:01:25	0:42:41	0:01:25	0:43:39	0:01:23	0:43:37
67	0:44:36	0:01:13	0:46:03	0:01:16	0:43:55	0:01:14	0:45:03	0:01:24	0:44:54
66	0:45:58	0:01:22	0:47:24	0:01:21	0:45:18	0:01:23	0:46:27	0:01:24	0:46:17
65	0:47:09	0:01:11	0:48:47	0:01:23	0:46:42	0:01:24	0:47:44	0:01:17	0:47:35
64	0:48:28	0:01:19	0:50:20	0:01:33	0:47:53	0:01:11	0:48:57	0:01:13	0:48:55
63	0:49:42	0:01:14	0:51:32	0:01:12	0:49:18	0:01:25	0:50:23	0:01:26	0:50:14
62	0:51:04	0:01:22	0:52:56	0:01:24	0:50:43	0:01:25	0:51:43	0:01:20	0:51:37
61	0:52:34	0:01:30	0:54:15	0:01:19	0:51:53	0:01:10	0:53:08	0:01:25	0:52:58
60	0:53:47	0:01:13	0:55:26	0:01:11	0:53:28	0:01:35	0:54:34	0:01:26	0:54:19
59	0:55:03	0:01:16	0:56:46	0:01:20	0:54:37	0:01:09	0:55:54	0:01:20	0:55:35
58	0:56:34	0:01:31	0:57:58	0:01:12	0:56:03	0:01:26	0:57:19	0:01:25	0:56:59
57	0:57:46	0:01:12	0:59:17	0:01:19	0:57:26	0:01:23	0:58:29	0:01:10	0:58:15
56	0:59:09	0:01:23	1:00:41	0:01:24	0:58:38	0:01:12	0:59:51	0:01:22	0:59:35
55	1:00:19	0:01:10	1:01:52	0:01:11	1:00:01	0:01:23	1:01:17	0:01:26	1:00:52
54	1:01:48	0:01:29	1:03:07	0:01:15	1:01:13	0:01:12	1:02:37	0:01:20	1:02:11
53	1:03:01	0:01:13	1:04:27	0:01:20	1:02:37	0:01:24	1:04:02	0:01:25	1:03:32
52	1:04:21	0:01:20	1:05:53	0:01:26	1:04:02	0:01:25	1:05:24	0:01:22	1:04:55
51	1:05:34	0:01:13	1:07:18	0:01:25	1:05:29	0:01:27	1:06:38	0:01:14	1:06:15
50	1:06:49	0:01:15	1:08:43	0:01:25	1:06:38	0:01:09	1:07:58	0:01:20	1:07:32
		0:01:21		0:01:22		0:01:22		0:01:22	0:01:22

TotalTried: 1025 1024 1019 1022  
 Successful: 1025 1024 1019 1022  
 Failed: 0 0 0 0  
 TotalBytes: 1080143975 1079090176 1073821181 1076982578  
 TestPicture Size 1053799

# Test results for Test 8:

Percentage	Device1	Difference	Device2	Difference	Device3	Difference	Device4	Difference	Average
100	0:00:00		0:00:00		0:00:00		0:00:00		0:00:00
99	0:00:30	0:00:30	0:01:13	0:01:13	0:00:50	0:00:50	0:00:11	0:00:11	0:00:41
98	0:01:23	0:00:53	0:01:45	0:00:32	0:01:33	0:00:43	0:00:54	0:00:43	0:01:24
97	0:02:24	0:01:01	0:03:08	0:01:23	0:02:54	0:01:21	0:02:04	0:01:10	0:02:38
96	0:03:49	0:01:25	0:04:29	0:01:21	0:04:09	0:01:15	0:03:16	0:01:12	0:03:56
95	0:05:14	0:01:25	0:05:54	0:01:25	0:05:29	0:01:20	0:04:30	0:01:14	0:05:17
94	0:06:25	0:01:11	0:07:15	0:01:21	0:06:44	0:01:15	0:05:50	0:01:20	0:06:34
93	0:07:50	0:01:25	0:08:30	0:01:15	0:08:05	0:01:21	0:07:01	0:01:11	0:07:52
92	0:09:10	0:01:20	0:09:50	0:01:20	0:09:24	0:01:19	0:08:20	0:01:19	0:09:11
91	0:10:40	0:01:30	0:11:06	0:01:16	0:10:39	0:01:15	0:09:32	0:01:12	0:10:29
90	0:12:00	0:01:20	0:12:25	0:01:19	0:12:01	0:01:22	0:10:56	0:01:24	0:11:50
89	0:13:25	0:01:25	0:13:47	0:01:22	0:13:15	0:01:14	0:12:16	0:01:20	0:13:11
88	0:14:35	0:01:10	0:15:00	0:01:13	0:14:35	0:01:20	0:13:26	0:01:10	0:14:24
87	0:15:46	0:01:11	0:16:20	0:01:20	0:15:46	0:01:11	0:14:37	0:01:11	0:15:37
86	0:17:10	0:01:24	0:17:43	0:01:23	0:17:06	0:01:20	0:16:01	0:01:24	0:17:00
85	0:18:32	0:01:22	0:18:45	0:01:02	0:18:19	0:01:13	0:17:21	0:01:20	0:18:14
84	0:19:57	0:01:25	0:20:09	0:01:24	0:19:30	0:01:11	0:18:32	0:01:11	0:19:32
83	0:21:08	0:01:11	0:21:24	0:01:15	0:20:42	0:01:12	0:19:56	0:01:24	0:20:48
82	0:22:28	0:01:20	0:22:50	0:01:26	0:21:55	0:01:13	0:21:09	0:01:11	0:22:06
81	0:23:40	0:01:12	0:24:00	0:01:10	0:23:08	0:01:13	0:22:21	0:01:12	0:23:17
80	0:24:54	0:01:14	0:25:41	0:01:41	0:24:18	0:01:10	0:23:45	0:01:24	0:24:39
79	0:26:19	0:01:25	0:26:51	0:01:10	0:25:40	0:01:22	0:25:10	0:01:25	0:26:00
78	0:27:40	0:01:21	0:28:16	0:01:25	0:27:04	0:01:24	0:26:20	0:01:10	0:27:20
77	0:29:10	0:01:30	0:29:27	0:01:11	0:28:04	0:01:00	0:27:41	0:01:21	0:28:36
76	0:30:30	0:01:20	0:30:51	0:01:24	0:29:30	0:01:26	0:28:56	0:01:15	0:29:57
75	0:31:53	0:01:23	0:32:03	0:01:12	0:30:50	0:01:20	0:30:17	0:01:21	0:31:16
74	0:33:14	0:01:21	0:33:26	0:01:23	0:32:00	0:01:10	0:31:42	0:01:25	0:32:36
73	0:34:40	0:01:26	0:34:39	0:01:13	0:33:11	0:01:11	0:32:43	0:01:01	0:33:48
72	0:35:51	0:01:11	0:36:05	0:01:26	0:34:25	0:01:14	0:34:06	0:01:23	0:35:07
71	0:37:02	0:01:11	0:37:25	0:01:20	0:35:36	0:01:11	0:35:26	0:01:20	0:36:22
70	0:38:10	0:01:08	0:38:36	0:01:11	0:36:47	0:01:11	0:36:40	0:01:14	0:37:33
69	0:39:32	0:01:22	0:39:58	0:01:22	0:38:10	0:01:23	0:37:52	0:01:12	0:38:53
68	0:41:05	0:01:33	0:41:11	0:01:13	0:39:22	0:01:12	0:39:15	0:01:23	0:40:13
67	0:42:05	0:01:00	0:42:36	0:01:25	0:40:42	0:01:20	0:40:31	0:01:16	0:41:29
66	0:43:25	0:01:20	0:43:56	0:01:20	0:41:55	0:01:13	0:41:51	0:01:20	0:42:47
65	0:44:35	0:01:10	0:45:18	0:01:22	0:43:08	0:01:13	0:43:01	0:01:10	0:44:00
64	0:45:56	0:01:21	0:46:28	0:01:10	0:44:29	0:01:21	0:44:27	0:01:26	0:45:20
63	0:47:17	0:01:21	0:47:41	0:01:13	0:45:40	0:01:11	0:45:37	0:01:10	0:46:34
62	0:48:28	0:01:11	0:49:05	0:01:24	0:46:52	0:01:12	0:46:51	0:01:14	0:47:49
61	0:49:48	0:01:20	0:50:19	0:01:14	0:48:20	0:01:28	0:48:02	0:01:11	0:49:07
60	0:51:11	0:01:23	0:51:41	0:01:22	0:49:30	0:01:10	0:49:21	0:01:19	0:50:26
59	0:52:20	0:01:09	0:52:55	0:01:14	0:50:41	0:01:11	0:50:33	0:01:12	0:51:37
58	0:53:31	0:01:11	0:54:19	0:01:24	0:51:55	0:01:14	0:51:47	0:01:14	0:52:53
57	0:54:51	0:01:20	0:55:31	0:01:12	0:53:05	0:01:10	0:53:09	0:01:22	0:54:09
56	0:56:11	0:01:20	0:56:41	0:01:10	0:54:30	0:01:25	0:54:12	0:01:03	0:55:23
55	0:57:45	0:01:34	0:58:05	0:01:24	0:55:43	0:01:13	0:55:35	0:01:23	0:56:47
54	0:59:12	0:01:27	0:59:05	0:01:00	0:57:06	0:01:23	0:56:56	0:01:21	0:58:05
53	1:00:35	0:01:23	1:00:31	0:01:26	0:58:05	0:00:59	0:58:11	0:01:15	0:59:21
52	1:01:45	0:01:10	1:01:40	0:01:09	0:59:18	0:01:13	0:59:21	0:01:10	1:00:31
51	1:03:16	0:01:31	1:02:53	0:01:13	1:00:29	0:01:11	1:00:47	0:01:26	1:01:51
50	1:04:29	0:01:13	1:04:19	0:01:26	1:02:05	0:01:36	1:02:07	0:01:20	1:03:15
		0:01:19		0:01:18		0:01:16		0:01:17	0:01:17

TotalTried:	1347	1288	1246	1248
Successful:	1034	1288	1244	1248
Failed:	313	0	2	0
TotalBytes:	1089628166	1357293112	1310925956	1315141152
TestPicture Size	1053799			

# Test results for Test 9:

Percentage	Device1	Difference	Device2	Difference	Device3	Difference	Device4	Difference	Average
100	0:00:00		0:00:00		0:00:00		0:00:00		0:00:00
99	0:00:32	0:00:32	0:01:14	0:01:14	0:00:46	0:00:46	0:00:11	0:00:11	0:00:41
98	0:01:11	0:00:39	0:01:54	0:00:40	0:01:26	0:00:40	0:00:53	0:00:42	0:01:21
97	0:02:26	0:01:15	0:03:10	0:01:16	0:02:39	0:01:13	0:02:04	0:01:11	0:02:35
96	0:03:36	0:01:10	0:04:30	0:01:20	0:03:52	0:01:13	0:03:17	0:01:13	0:03:49
95	0:04:52	0:01:16	0:05:44	0:01:14	0:05:02	0:01:10	0:04:30	0:01:13	0:05:02
94	0:06:12	0:01:20	0:06:56	0:01:12	0:06:28	0:01:26	0:05:41	0:01:11	0:06:19
93	0:07:23	0:01:11	0:08:10	0:01:14	0:07:34	0:01:06	0:06:55	0:01:14	0:07:30
92	0:08:34	0:01:11	0:09:38	0:01:28	0:08:54	0:01:20	0:08:06	0:01:11	0:08:48
91	0:09:58	0:01:24	0:10:40	0:01:02	0:10:04	0:01:10	0:09:31	0:01:25	0:10:03
90	0:11:18	0:01:20	0:12:09	0:01:29	0:11:15	0:01:11	0:10:31	0:01:00	0:11:18
89	0:12:30	0:01:12	0:13:23	0:01:14	0:12:29	0:01:14	0:11:56	0:01:25	0:12:34
88	0:13:43	0:01:13	0:14:39	0:01:16	0:13:50	0:01:21	0:13:08	0:01:12	0:13:50
87	0:15:06	0:01:23	0:15:55	0:01:16	0:15:04	0:01:14	0:14:22	0:01:14	0:15:07
86	0:16:21	0:01:15	0:17:11	0:01:16	0:16:06	0:01:02	0:15:31	0:01:09	0:16:17
85	0:17:40	0:01:19	0:18:24	0:01:13	0:17:29	0:01:23	0:16:44	0:01:13	0:17:34
84	0:18:58	0:01:18	0:19:41	0:01:17	0:18:38	0:01:09	0:18:07	0:01:23	0:18:51
83	0:20:08	0:01:10	0:20:55	0:01:14	0:19:52	0:01:14	0:19:21	0:01:14	0:20:04
82	0:21:28	0:01:20	0:22:06	0:01:11	0:21:02	0:01:10	0:20:35	0:01:14	0:21:18
81	0:22:48	0:01:20	0:23:17	0:01:11	0:22:18	0:01:16	0:21:46	0:01:11	0:22:32
80	0:23:58	0:01:10	0:24:33	0:01:16	0:23:19	0:01:01	0:22:57	0:01:11	0:23:42
79	0:25:13	0:01:15	0:25:49	0:01:16	0:24:33	0:01:14	0:24:19	0:01:22	0:24:58
78	0:26:24	0:01:11	0:27:15	0:01:26	0:25:54	0:01:21	0:25:22	0:01:03	0:26:14
77	0:27:37	0:01:13	0:28:30	0:01:15	0:27:08	0:01:14	0:26:47	0:01:25	0:27:31
76	0:28:58	0:01:21	0:29:31	0:01:01	0:28:18	0:01:10	0:27:56	0:01:09	0:28:41
75	0:30:11	0:01:13	0:30:45	0:01:14	0:29:29	0:01:11	0:29:09	0:01:13	0:29:53
74	0:31:33	0:01:22	0:32:00	0:01:15	0:30:44	0:01:15	0:30:22	0:01:13	0:31:10
73	0:32:46	0:01:13	0:33:15	0:01:15	0:31:47	0:01:03	0:31:31	0:01:09	0:32:20
72	0:33:56	0:01:10	0:34:30	0:01:15	0:32:59	0:01:12	0:32:55	0:01:24	0:33:35
71	0:35:12	0:01:16	0:35:46	0:01:16	0:34:13	0:01:14	0:33:56	0:01:01	0:34:47
70	0:36:22	0:01:10	0:37:14	0:01:28	0:35:28	0:01:15	0:35:10	0:01:14	0:36:03
69	0:37:48	0:01:26	0:38:30	0:01:16	0:36:49	0:01:21	0:36:36	0:01:26	0:37:26
68	0:38:58	0:01:10	0:39:36	0:01:06	0:37:59	0:01:10	0:37:47	0:01:11	0:38:35
67	0:40:18	0:01:20	0:40:46	0:01:10	0:39:14	0:01:15	0:38:52	0:01:05	0:39:47
66	0:41:29	0:01:11	0:42:00	0:01:14	0:40:25	0:01:11	0:40:02	0:01:10	0:40:59
65	0:42:28	0:00:59	0:43:11	0:01:11	0:41:38	0:01:13	0:41:13	0:01:11	0:42:07
64	0:43:43	0:01:15	0:44:26	0:01:15	0:42:49	0:01:11	0:42:37	0:01:24	0:43:24
63	0:45:20	0:01:37	0:45:38	0:01:12	0:43:51	0:01:02	0:43:49	0:01:12	0:44:40
62	0:46:35	0:01:15	0:46:56	0:01:18	0:45:04	0:01:13	0:44:52	0:01:03	0:45:52
61	0:47:38	0:01:03	0:48:11	0:01:15	0:46:18	0:01:14	0:46:06	0:01:14	0:47:03
60	0:48:50	0:01:12	0:49:15	0:01:04	0:47:23	0:01:05	0:47:17	0:01:11	0:48:11
59	0:50:14	0:01:24	0:50:28	0:01:13	0:48:33	0:01:10	0:48:31	0:01:14	0:49:27
58	0:51:24	0:01:10	0:51:41	0:01:13	0:49:44	0:01:11	0:49:41	0:01:10	0:50:37
57	0:52:25	0:01:01	0:52:56	0:01:15	0:50:44	0:01:00	0:50:57	0:01:16	0:51:46
56	0:53:50	0:01:25	0:54:06	0:01:10	0:52:09	0:01:25	0:52:07	0:01:10	0:53:03
55	0:54:50	0:01:00	0:55:21	0:01:15	0:53:24	0:01:15	0:53:18	0:01:11	0:54:13
54	0:56:15	0:01:25	0:56:33	0:01:12	0:54:24	0:01:00	0:54:32	0:01:14	0:55:26
53	0:57:25	0:01:10	0:57:46	0:01:13	0:55:39	0:01:15	0:55:44	0:01:12	0:56:39
52	0:58:37	0:01:12	0:58:48	0:01:02	0:56:46	0:01:07	0:56:58	0:01:14	0:57:47
51	0:59:37	0:01:00	1:00:11	0:01:23	0:58:01	0:01:15	0:58:01	0:01:03	0:58:58
50	1:01:00	0:01:23	1:01:15	0:01:04	0:59:04	0:01:03	0:59:22	0:01:21	1:00:10
		0:01:15		0:01:14		0:01:12		0:01:13	0:01:14

TotalTried: 1524 1499 1469 1470  
 Successful: 1429 1499 1457 1470  
 Failed: 95 0 12 0  
 TotalBytes: 1505878771 1579644701 1535385143 1549084530  
 TestPicture Size 1053799

# Test results for Test 10:

Percentage	Device1	Difference	Device2	Difference	Device3	Difference	Device4	Difference	Average
100	0:00:00		0:00:00		0:00:00		0:00:00		0:00:00
99	0:02:05	0:02:05	0:00:42	0:00:42	0:01:06	0:01:06	0:02:07	0:02:07	0:01:30
98	0:02:45	0:00:40	0:01:24	0:00:42	0:01:47	0:00:41	0:02:35	0:00:28	0:02:08
97	0:03:45	0:01:00	0:02:27	0:01:03	0:02:48	0:01:01	0:03:49	0:01:14	0:03:12
96	0:05:11	0:01:26	0:03:40	0:01:13	0:04:03	0:01:15	0:05:03	0:01:14	0:04:29
95	0:06:12	0:01:01	0:05:01	0:01:21	0:05:13	0:01:10	0:06:04	0:01:01	0:05:37
94	0:07:23	0:01:11	0:06:02	0:01:01	0:06:23	0:01:10	0:07:19	0:01:15	0:06:47
93	0:08:37	0:01:14	0:07:22	0:01:20	0:07:32	0:01:09	0:08:29	0:01:10	0:08:00
92	0:09:52	0:01:15	0:08:27	0:01:05	0:09:03	0:01:31	0:09:41	0:01:12	0:09:16
91	0:11:03	0:01:11	0:09:47	0:01:20	0:10:28	0:01:25	0:10:44	0:01:03	0:10:30
90	0:12:14	0:01:11	0:10:47	0:01:00	0:11:28	0:01:00	0:11:56	0:01:12	0:11:36
89	0:13:27	0:01:13	0:12:03	0:01:16	0:12:43	0:01:15	0:13:16	0:01:20	0:12:52
88	0:14:37	0:01:10	0:13:18	0:01:15	0:13:53	0:01:10	0:14:32	0:01:16	0:14:05
87	0:16:00	0:01:23	0:14:29	0:01:11	0:14:55	0:01:02	0:15:34	0:01:02	0:15:15
86	0:17:00	0:01:00	0:15:30	0:01:01	0:16:11	0:01:16	0:16:47	0:01:13	0:16:22
85	0:18:15	0:01:15	0:16:45	0:01:15	0:17:13	0:01:02	0:17:58	0:01:11	0:17:33
84	0:19:17	0:01:02	0:17:51	0:01:06	0:18:16	0:01:03	0:19:09	0:01:11	0:18:38
83	0:20:32	0:01:15	0:19:06	0:01:15	0:19:27	0:01:11	0:20:33	0:01:24	0:19:55
82	0:21:44	0:01:12	0:20:06	0:01:00	0:20:43	0:01:16	0:21:33	0:01:00	0:21:02
81	0:22:57	0:01:13	0:21:27	0:01:21	0:21:54	0:01:11	0:22:54	0:01:21	0:22:18
80	0:24:03	0:01:06	0:22:52	0:01:25	0:23:13	0:01:19	0:23:55	0:01:01	0:23:31
79	0:25:14	0:01:11	0:24:03	0:01:11	0:24:14	0:01:01	0:25:14	0:01:19	0:24:41
78	0:26:27	0:01:13	0:25:07	0:01:04	0:25:20	0:01:06	0:26:24	0:01:10	0:25:50
77	0:27:30	0:01:03	0:26:27	0:01:20	0:26:23	0:01:03	0:27:29	0:01:05	0:26:57
76	0:28:43	0:01:13	0:27:47	0:01:20	0:27:36	0:01:13	0:28:44	0:01:15	0:28:13
75	0:29:56	0:01:13	0:29:03	0:01:16	0:28:49	0:01:13	0:29:56	0:01:12	0:29:26
74	0:31:06	0:01:10	0:30:03	0:01:00	0:29:58	0:01:09	0:30:56	0:01:00	0:30:31
73	0:32:18	0:01:12	0:31:25	0:01:22	0:31:12	0:01:14	0:32:11	0:01:15	0:31:46
72	0:33:22	0:01:04	0:32:47	0:01:22	0:32:16	0:01:04	0:33:15	0:01:04	0:32:55
71	0:34:38	0:01:16	0:33:57	0:01:10	0:33:28	0:01:12	0:34:26	0:01:11	0:34:07
70	0:35:46	0:01:08	0:35:20	0:01:23	0:34:33	0:01:05	0:35:42	0:01:16	0:35:20
69	0:36:47	0:01:01	0:36:31	0:01:11	0:35:54	0:01:21	0:36:44	0:01:02	0:36:29
68	0:37:59	0:01:12	0:37:51	0:01:20	0:37:03	0:01:09	0:37:58	0:01:14	0:37:43
67	0:39:15	0:01:16	0:39:11	0:01:20	0:38:08	0:01:05	0:39:13	0:01:15	0:38:57
66	0:40:25	0:01:10	0:40:23	0:01:12	0:39:21	0:01:13	0:40:14	0:01:01	0:40:06
65	0:41:37	0:01:12	0:41:46	0:01:23	0:40:36	0:01:15	0:41:24	0:01:10	0:41:21
64	0:43:02	0:01:25	0:43:06	0:01:20	0:41:38	0:01:02	0:42:34	0:01:10	0:42:35
63	0:44:03	0:01:01	0:44:27	0:01:21	0:42:43	0:01:05	0:43:36	0:01:02	0:43:42
62	0:45:02	0:00:59	0:45:47	0:01:20	0:43:53	0:01:10	0:44:44	0:01:08	0:44:51
61	0:46:12	0:01:10	0:47:06	0:01:19	0:44:56	0:01:03	0:46:05	0:01:21	0:46:05
60	0:47:27	0:01:15	0:48:27	0:01:21	0:46:09	0:01:13	0:47:04	0:00:59	0:47:17
59	0:48:48	0:01:21	0:49:42	0:01:15	0:47:14	0:01:05	0:48:17	0:01:13	0:48:30
58	0:49:53	0:01:05	0:50:43	0:01:01	0:48:24	0:01:10	0:49:20	0:01:03	0:49:35
57	0:51:02	0:01:09	0:52:03	0:01:20	0:49:36	0:01:12	0:50:19	0:00:59	0:50:45
56	0:52:23	0:01:21	0:53:23	0:01:20	0:50:36	0:01:00	0:51:41	0:01:22	0:52:01
55	0:53:26	0:01:03	0:54:43	0:01:20	0:51:38	0:01:02	0:52:54	0:01:13	0:53:10
54	0:54:31	0:01:05	0:56:08	0:01:25	0:52:53	0:01:15	0:53:54	0:01:00	0:54:22
53	0:55:32	0:01:01	0:57:18	0:01:10	0:54:03	0:01:10	0:55:00	0:01:06	0:55:28
52	0:56:48	0:01:16	0:58:28	0:01:10	0:55:04	0:01:01	0:56:12	0:01:12	0:56:38
51	0:58:01	0:01:13	0:59:48	0:01:20	0:56:14	0:01:10	0:57:22	0:01:10	0:57:51
50	0:59:04	0:01:03	1:01:09	0:01:21	0:57:24	0:01:10	0:58:23	0:01:01	0:59:00
		0:01:10		0:01:15		0:01:10		0:01:10	0:01:14

TotalTried: 1775 1831 1816 1795  
 Successful: 1757 1152 1713 1703  
 Failed: 18 679 103 92  
 TotalBytes: 1851524843 1213976448 1805157687 1794619697  
 TestPicture Size 1053799

## APPENDIX B



TwiddleNet

Please enter UserName

Please enter Password

ENTER CANCEL

Menu

Sign-In Interface



TwiddleNet

Welcome to TwiddleNet

System Status

WiFi: local IP - 192.168.1.52

Signed In as: d

Server running

**0 Items shared**    **0 Alerts in List**

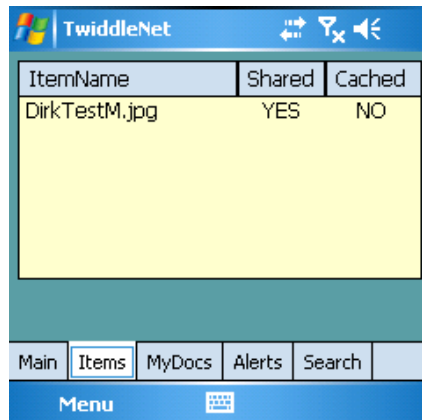
Share: automatic    Alert: always ask

Caching: smart cache    Tag at: never

Main Items MyDocs Alerts Search

Menu

Welcome Tab with System Info



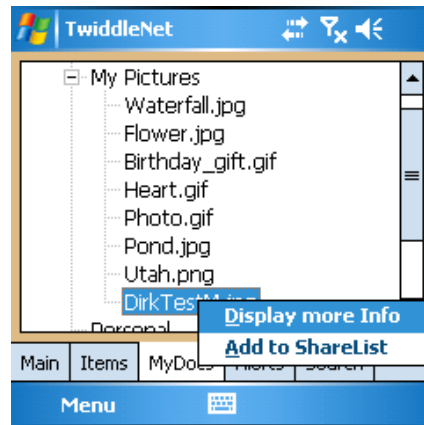
TwiddleNet

ItemName	Shared	Cached
DirkTestM.jpg	YES	NO

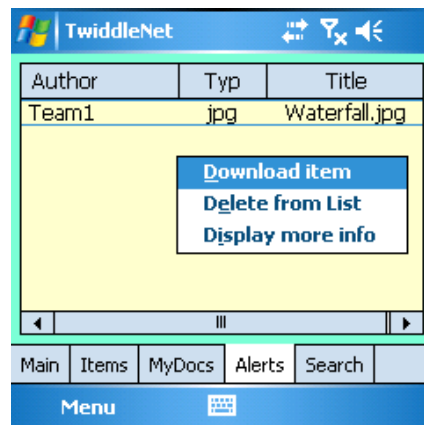
Main Items MyDocs Alerts Search

Menu

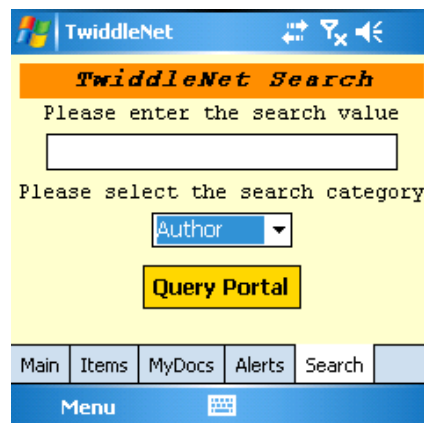
Shared Items Tab



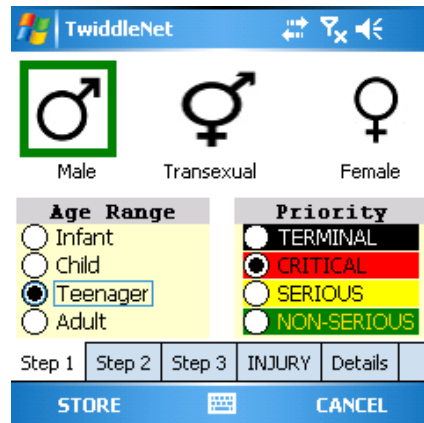
My Documents Tab



Alerts received Tab



Search Tab



TwiddleNet

Male Transexual Female

**Age Range**

☐ Infant

☐ Child

☒ Teenager

☐ Adult

**Priority**

☐ TERMINAL

☒ CRITICAL

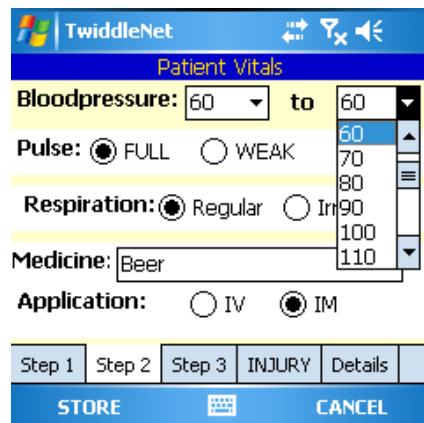
☐ SERIOUS

☐ NON-SERIOUS

Step 1 Step 2 Step 3 INJURY Details

STORE CANCEL

Triage Tagging Interface Step 1



TwiddleNet

Patient Vitals

Bloodpressure: 60 to 60

Pulse: ☒ FULL ☐ WEAK

Respiration: ☒ Regular ☐ Irregular

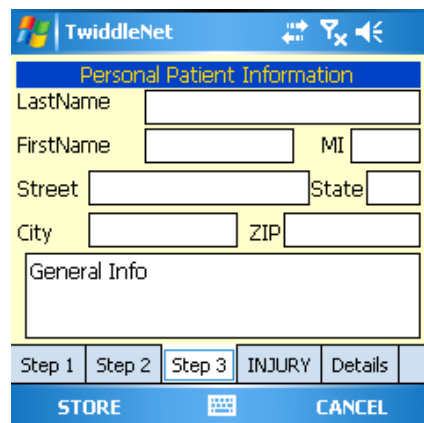
Medicine: Beer

Application: ☐ IV ☒ IM

Step 1 Step 2 Step 3 INJURY Details

STORE CANCEL

Triage Tagging Interface Step 2



TwiddleNet

Personal Patient Information

LastName

FirstName MI

Street State

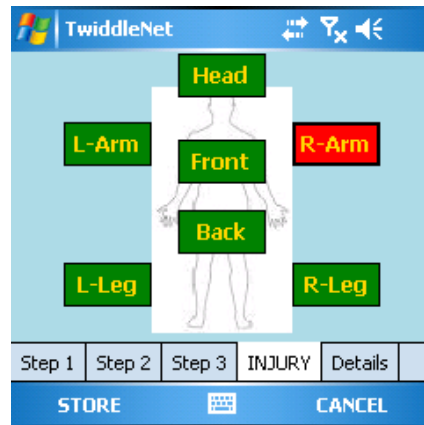
City ZIP

General Info

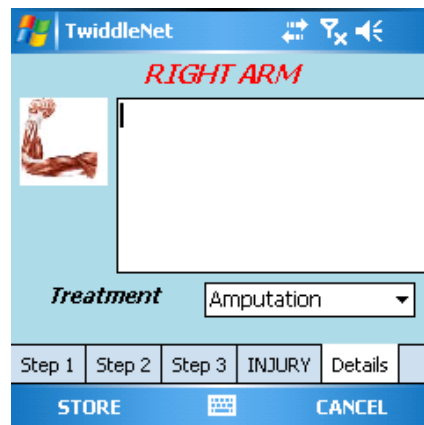
Step 1 Step 2 Step 3 INJURY Details

STORE CANCEL

Triage Tagging Interface Step 3



Triage Tagging Interface Step 4 Injury



Triage Tagging Interface Step 5 Details



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