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This report documents the research project entitled: "A Handheld Terminal for Field Elements." The primary goal of this research was to design and develop a Handheld Terminal (HHT) kit for the purpose of diagnosing and configuring field element devices. The HHT was developed based on ubiquitous commercial off-the-shelf (COTS) hardware; selection of this hardware was an important early task in the project. Most of the subsequent research in this study involved development of the software package. The HHT kit was programmed to interface with closed-circuit TV (CCTV) cameras and changeable message sign (CMS) hardware, using standardized protocols for each. The HHT also provides a console app. The goal of the HHT kit is to give Caltrans field personnel a more ruggedized, robust system to deal with the specific task of diagnosing and configuring traffic operations field elements. This will enable employees to get their work done faster, safer, and with dramatically reduced chances for loss of potentially expensive equipment. The system will also assist Caltrans in reaching its goals of System Performance, Stewardship, and Efficiency.

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A Handheld Terminal for Field Elements

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Ty A. Lasky (Principal Investigator)

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ABSTRACT

This report documents the research project entitled: "A Handheld Terminal for Field Elements." The primary goal of this research was to design and develop a Handheld Terminal (HHT) kit for the purpose of diagnosing and configuring field element devices. The HHT was developed based on ubiquitous commercial off-the-shelf (COTS) hardware; selection of this hardware was an important early task in the project. Most of the subsequent research in this study involved development of the software package. The HHT kit was programmed to interface with closed-circuit TV (CCTV) cameras and changeable message sign (CMS) hardware, using standardized protocols for each. The HHT also provides a console app. The goal of the HHT kit is to give Caltrans field personnel a more ruggedized, robust system to deal with the specific task of diagnosing and configuring traffic operations field elements. This will enable employees to get their work done faster, safer, and with dramatically reduced chances for loss of potentially expensive equipment. The system will also assist Caltrans in reaching its goals of System Performance, Stewardship, and Efficiency.

EXECUTIVE SUMMARY

The California Department of Transportation (Caltrans) has a wide variety of traffic operations field element devices that must be managed and maintained. This includes closed-circuit TV cameras (CCTV), changeable message signs (CMS), vehicle detection stations (VDS), road weather information systems (RWIS), etc. In order to maintain and configure these devices, field personnel currently use laptops which are cumbersome to use in a live traffic environment, often times unavailable to maintenance personnel, and typically hard to view in direct sunshine. Caltrans Division of Maintenance and Division of Research, Innovation and System Information (DRISI) have identified the need for a turnkey handheld terminal kit with integrated software that can manage and maintain field element devices.

Research Objectives and Methodology

The goal of this research was to design and develop a turnkey Handheld Terminal (HHT) kit and to test it on a number of devices. The HHT was to be designed based on ubiquitous Commercial Off-The-Shelf (COTS) hardware. The software part of the HHT was to be developed and programmed to interface with CCTV cameras and CMS (also referred to as dynamic message sign or DMS) hardware, using typical protocols for each. The unit was also to be programmed to have a console application. The goal of the HHT is to give Caltrans field personnel a more ruggedized, robust system to deal with the specific task of maintaining and configuring traffic operations field elements. This will enable employees to get their work done faster, safer, and with dramatically reduced chances for loss of potentially expensive equipment.

The research methodology included:

1. Evaluation of COTS hardware
2. Development of requirements
3. System engineering and design
4. System implementation (*through alpha prototype*)
5. Lab testing and demonstration (*deferred to future research*)
6. Field testing and demonstration (*deferred to future research*)
7. Documentation

Results and Recommendations

Due to unanticipated complexity and level of effort for the prototype system development, several key tasks were only partially completed or were not performed. The COTS hardware evaluation, requirements development, and system engineering and design were all completed, and are documented herein. The prototype software development for the CCTV and DMS handheld terminal apps was only completed through an alpha prototype, and could not be adequately tested or demonstrated within the span of the research project. The hardware selection, procurement, and

kit assembly were fully implemented. As the prototypes were not ready, lab and field testing and demonstration were also omitted. As of this report, the Advanced Highway Maintenance and Construction Technology (AHMCT) Research Center and Caltrans DRISI have agreed to an action plan to complete the apps per developed requirements, and perform testing and update iterations to bring the handheld terminal concept to fruition. This work is occurring under a follow-on research project.

The research effort delivered the following, which are forming the basis for more complete results in follow-on research:

- AHMCT development and Technical Advisory Group (TAG) signoff of requirements for the CCTV app, DMS app, Console app, and HHT hardware kit (see appendices)
- Complete design for HHT hardware kit
- Complete assessment of COTS hardware for HHT kit
- Complete fabrication of ten (10) HHT hardware kits (5 required)
- Complete design of DMS app software
- Complete design of CCTV app software
- Completion of DMS app alpha prototype
- Completion of CCTV app alpha prototype
- Review, evaluation, and selection of a COTS Console app, and installation on the HHT

As noted above, AHMCT is enhancing and completing the HHT system under follow-on research. The HHT will give Caltrans field personnel a more ruggedized, robust system to deal with the specific task of maintaining and configuring traffic operations field elements. This will enable employees to get their work done faster, safer, and with dramatically reduced chances for loss of potentially expensive equipment.

The handheld terminal system will greatly enhance the capabilities of Caltrans field maintenance personnel by providing a highly portable, powerful, easy-to-use hardware/software kit based on ubiquitous COTS tablets. The software apps will provide feature-rich configuration and diagnostic capabilities for various field elements, as well as a general-purpose command-line interface.

When the HHT is available, it could eliminate the need for custom, costly, and cumbersome hardware typically used for current field element device setup and maintenance. This would reduce costs for the Caltrans, and simplify and increase portability of the hardware that field maintenance personnel need to carry in their vehicle. In addition, because personnel would need only the one device, the amount of time and trips needed to configure or diagnose field elements will be reduced. This would lead to reduced personnel costs, improved field element up-time, enhanced system operations, and reduction in fuel use and greenhouse emissions.

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LIST OF ACRONYMS AND ABBREVIATIONS

Acronym	Definition
3G	3rd generation of mobile telecommunications technology
4G	4th generation of mobile telecommunications technology
AC	Alternating Current
AHMCT	Advanced Highway Maintenance and Construction Technology Research Center
API	Application Programming Interface
AVMS	Advanced Variable Message Sign
BNC	Bayonet Neill–Concelman
Caltrans	California Department of Transportation
CCTV	Closed-Circuit TV
CLI	Command-Line Interface
CMS	Changeable Message Sign
COTS	Commercial Off–The-Shelf
DC	Direct Current
DMS	Dynamic Message Sign
DOT	Department of Transportation
DRISI	Caltrans Division of Research, Innovation and System Information
Fps	Frames Per Second
HHT	Handheld Terminal
HMI	Human Machine Interface
IEEE	Institute of Electrical and Electronics Engineers
IEEE 802.11a	54 Mbps max Wi-Fi at 5.8 GHz
IEEE 802.11b	11 Mbps max Wi-Fi at 2.4 GHz
IEEE 802.11g	54 Mbps max Wi-Fi at 2.4 GHz
IEEE 802.11n	600 Mbps max MIMO Wi-Fi using 2.4 GHz and 5.8 GHz
IEEE 802.11ac	1300 Mbps max MIMO Wi-Fi using 2.4 GHz and 5.8 GHz
IP	Internet Protocol
IRIS	Intelligent Roadway Information System
ITS	Intelligent Transportation System
JPEG	Joint Photographic Experts Group
LCD	Liquid Crystal Display
LTE	Long-Term Evolution, an implementation of 4G
MIMO	Multiple-Input/Multiple-Output
MJPEG	Motion JPEG
MPEG	Moving Picture Experts Group
NTCIP	National Transportation Communications for Intelligent Transportation Systems Protocol
NTSC	National Television System Committee
OS	Operating System
OTG	On-The-Go
PTZ	Pan-Tilt-Zoom
R&D	Research & Development
RCA	Radio Corporation of America
RFC	Request for Comments
RoHS	Reduction of Hazardous Substances
RS	Recommended Standard
RTMS	Remote Traffic Microwave Sensors
RTS	Request To Send
RWIS	Road Weather Information System
Rx	Receive
SSH	Secure Shell

Acronym	Definition
TAG	Technical Advisory Group
TCP/IP	Transmission Control Protocol / Internet Protocol
TMC	Transportation Management Center
Tx	Transmit
UCD	University of California-Davis
URL	Uniform Resource Locator
USB	Universal Serial Bus
VDS	Vehicle Detector Station
VMS	Variable Message Sign
VPN	Virtual Private Network
Wi-Fi	Wireless Fidelity

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CHAPTER 1:
INTRODUCTION

Problem

The California Department of Transportation (Caltrans) has a wide variety of traffic operations field element devices that must be managed and maintained. This includes closed-circuit TV cameras (CCTV), changeable message signs (CMS), vehicle detection stations (VDS), road weather information systems (RWIS), etc. In order to maintain and configure these devices, field personnel currently use laptops which are cumbersome to use in a live traffic environment, often times unavailable to maintenance personnel, and typically hard to view in direct sunshine. Caltrans Division of Maintenance and Division of Research, Innovation and System Information (DRISI) have identified the need for a turnkey handheld terminal kit with integrated software that can manage and maintain field element devices.

The goal of this research was to design and develop a turnkey Handheld Terminal (HHT) kit and to test it on a number of devices. The HHT was to be designed based on ubiquitous Commercial Off-The-Shelf (COTS) hardware. The software part of the HHT was to be developed and programmed to interface with CCTV cameras and CMS (also referred to as dynamic message sign or DMS) hardware, using typical protocols for each. The unit was also to be programmed to have a console application. The goal of the HHT is to give Caltrans field personnel a more ruggedized, robust system to deal with the specific task of maintaining and configuring traffic operations field elements. This will enable employees to get their work done faster, safer, and with dramatically reduced chances for loss of potentially expensive equipment.

Research Approach

The current work builds on the Advanced Highway Maintenance and Construction Technology (AHMCT) Research Center's experience with open-source software, traffic management, highway maintenance, our strength in sensing and system integration, and our established Mechatronic hardware and software base [1-11].

The research methodology included:

1. Evaluation of COTS hardware
2. Development of requirements
3. System engineering and design
4. System implementation (*through alpha prototype*)
5. Lab testing and demonstration (*deferred to future research*)
6. Field testing and demonstration (*deferred to future research*)
7. Documentation

Due to unanticipated complexity and level of effort for the prototype system development, several key tasks (4 – 6) were only partially completed or were not performed. The COTS hardware evaluation, requirements development, and system engineering and design (Tasks 1 – 3) were all completed, and are documented herein. The prototype software development (Task 4) for the CCTV and DMS handheld terminal apps was only completed through an alpha prototype, and could not be adequately tested or demonstrated within the span of the research project. The hardware selection, procurement, and kit assembly portions of Task 4 were fully implemented. As the prototypes were not ready, lab and field testing and demonstration (Tasks 5 and 6) were also omitted. Task 7 has been completed in the form of this report. As of this report, AHMCT and Caltrans DRISI have agreed to an action plan to complete the apps per developed requirements, and perform testing and update iterations to bring the handheld terminal concept to fruition. This work is occurring under a follow-on research project.

Overview of Research Results and Benefits

Key deliverables of this project include:

- System requirements for the HHT kit
- System requirements for the CCTV app
- System requirements for the DMS app
- System requirements for the Console app
- Comparison of various consumer and ruggedized handheld tablets meeting HHT kit system requirements, with recommendations
- CCTV Android software app (*alpha prototype completed*)
- DMS Android software app (*alpha prototype completed*)
- Console Android software app
- Five (5) identical HHT kits including selected tablet with preinstalled software, interface hardware, and associated cabling necessary to perform diagnostic and configuration operations on CCTV and DMS field elements

Through careful shepherding of funds, AHMCT was able to procure ten (10) complete HHT kits, rather than the required five.

The HHT kit developed in this and the follow-up research is expected to provide significant benefits to Caltrans. It will support configuration and diagnostics for diverse ITS field elements (currently DMS and CCTV). It can be modified under separate research or software maintenance contract to work for additional field elements (e.g. RWIS, VDS, etc.), and to support additional device types within a given element type, e.g. additional camera types and video encodings. The HHT kit also includes a COTS console app, which can be used to connect to devices, send

commands via command-line, and display resulting field element response in the console screen. The HHT kit is highly portable and integrated. It removes the need for Caltrans operators to carry device-specific hardware or desktop test equipment or laptops to the field to configure and diagnose devices. Because the HHT kit addresses multiple field element types, it is much more likely that Caltrans field personnel will be able to troubleshoot or configure an Intelligent Transportation System (ITS) element as soon as they identify the need to do so, rather than needing to return to the office to retrieve device-specific tools. Finally, since the HHT kit is quite general, programmable, and extensible, it provides Caltrans with a tool that can be adapted for use by other agencies and other state Departments of Transportation (DOTs), perhaps via a Pooled Fund study.

As noted above, the HHT prototype CCTV and DMS apps were developed to the alpha stage, but were not fully completed in the span of this research. Thus, as of the end of this research project Caltrans cannot fully realize the benefits promised by the HHT. However, AHMCT and Caltrans DRISI have agreed to an action plan to complete the apps per developed requirements, and perform testing and update iterations so that Caltrans can fully realize these benefits. This plan is currently being executed in follow-up research. The results of that effort will be documented in the follow-up project's final report.

CHAPTER 2:
HANDHELD TERMINAL CONCEPT

Caltrans operations and maintenance staff must routinely configure, and diagnose field element hardware in order to keep the transportation system operating at peak efficiency. They currently use multiple tools and expensive cumbersome equipment to maintain each field element type. The vision of the current research is to use one hardware platform populated with custom apps to configure and diagnose a wide range of field element devices. The diagnostic and configuration system is based on readily-available commercial off-the-shelf hardware, specifically Android tablets, meeting the cost and acquisition needs of Caltrans as well as portability and ease of use demands by maintenance personnel.

AHMCT researchers developed a suite of applications for the handheld terminal field configuration and diagnostics tool, as well as needed supplemental hardware, e.g. cabling, to interface to the field element devices. The system is integrated into a kit that is well-suited to carry in a field maintenance vehicle. This HHT kit allows quick and intuitive configuration and diagnostics of field element devices. The core of the system is an Android tablet. Use of smartphones may be investigated following the current research.

AHMCT developed two feature-rich intuitive apps for the handheld terminal system. Both applications are able to access their relative field elements remotely as well as locally. The first app is for Dynamic Message Sign (DMS) configuration and diagnostics. It interfaces to DMS controllers in the field through both network and serial interfaces, and allows for full configuration and diagnosis of the DMS system. The app supports all features of the Caltrans-specific model 500 series DMS using the SignView protocol and a set of test patterns, text, and algorithms to accelerate diagnostic operations of the panel, controller, and firmware. The DMS app also supports National Transportation Communications for Intelligent Transportation Systems Protocol (NTCIP) communications with Caltrans' next-generation model 700 series Advanced Variable Message Sign (AVMS). The DMS app concept is shown in Figure 2.1.

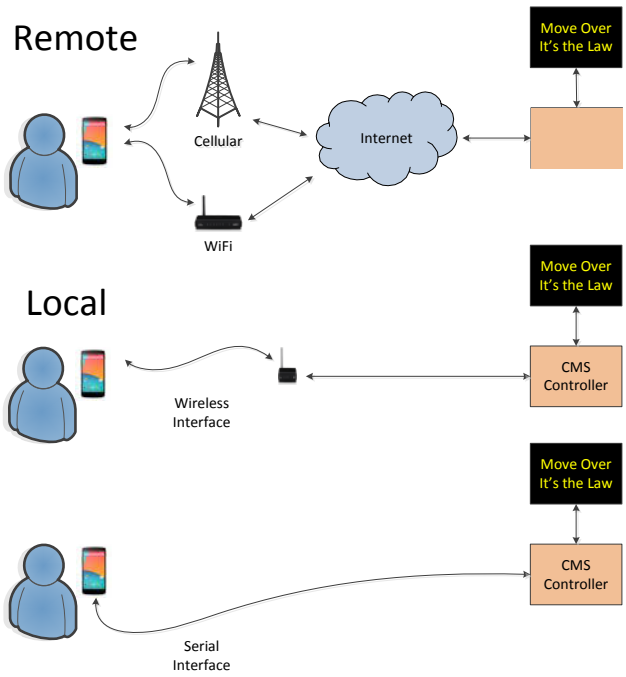

Figure 2.1: Handheld Terminal DMS app concept

The second app is for Closed-Circuit TV (CCTV) configuration and diagnostics. It interfaces to CCTV cameras, pan-tilt-zoom (PTZ) hardware, and video encoders in the field through both network and serial interfaces, and provides CCTV system configuration and diagnostics. The app currently supports camera/encoder MJPEG (Motion JPEG, Joint Photographic Experts Group), MPEG4 (Moving Picture Experts Group), and H.264 video protocols, and Pelco-D, Cohu, and Sony Visca PTZ (Pan-Tilt-Zoom) control protocols. Besides having the ability to fully configure all aspects of the CCTV system, the CCTV app provides advanced features to diagnose CCTV hardware and firmware from typical operational functionality all the way down to verification of every PTZ control protocol command and response. The CCTV concept is shown in Figure 2.2.

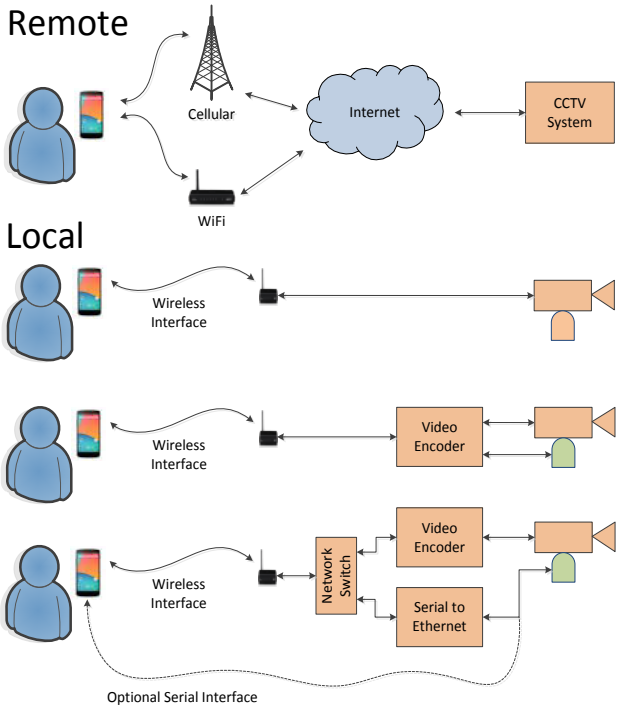

Figure 2.2: Handheld Terminal CCTV app concept

Finally, AHMCT evaluated various COTS console apps for inclusion in the HHT software suite. We assessed available features vs. anticipated Department of Transportation (DOT) needs, as discussed in Chapter 5. In conjunction with Caltrans, we selected the most appropriate serial console app, and included it in the suite of apps for the HHT. The console will provide a general command-line interface (CLI) for interfacing with a wide range of field element hardware. The console can be used to connect to devices, send commands via command-line, and display resulting field element response in the console screen.

The HHT kit provides a compact, unified system based on commonly available tablets. The software apps provide device-specific configuration and diagnostic capabilities, and a general-purpose command-line interface. The HHT will greatly enhance the capabilities of DOT field maintenance personnel.

CHAPTER 3:
HANDHELD TERMINAL DESIGN AND IMPLEMENTATION

This chapter discusses design and implementation of the HHT software. The focus is on the DMS app. The CCTV app design and implementation are analogous, and will be presented in a report in follow-up research. The requirements for the HHT DMS app are provided in Appendix B.

Overview

The HHT DMS app supports DMS configuration and diagnostics. It interfaces to DMS controllers in the field through both network and serial interfaces, and supports full DMS configuration and diagnostics. The app supports all features of the Caltrans-specific CMS SignView protocol, as well as a set of test patterns, text, and algorithms to accelerate diagnostic operations of the panel, controller, and firmware. The DMS app also supports NTCIP communications with Caltrans' next-generation AVMS.

The DMS app can access Caltrans DMS (a.k.a. CMS) systems remotely over the network, or directly at the DMS field location. Local connection from the HHT to the DMS components is supported by Wi-Fi-to-network, USB-to-network, Wi-Fi-to-serial, or USB-to-serial adapters and associated software. Remote network connection is typically over standard tablet Wi-Fi or cellular connection.

Using these various wired and wireless connection methods, and supported by the DMS app and HHT kit contents, it is possible to connect to the DMS controllers over network and/or serial connections for diagnostic and configuration purposes. Some common Caltrans use cases are:

1. Wired/wireless network connection to a DMS field element cabinet
2. Wired/wireless network connection to a terminal server
3. Wired/wireless serial connection to a DMS controller

The DMS app is standards-based wherever possible, and support standards commonly used by Caltrans and other DOTs. The app support local and remote diagnosis and configuration of DMS controllers and signs. For Caltrans-specific use, the app supports the CMS SignView protocol. The app also supports NTCIP communications. While NTCIP is a widely used standard, implementations typically vary. For this research, NTCIP support is provided specifically for Caltrans' next-generation AVMS. The HHT's NTCIP implementation is meant to be relatively agnostic; however, it is very likely that some changes or additions would be needed to support other NTCIP devices in California and in other state DOTs. The app uses modular drivers to implement controller protocols. The DMS app supports Transmission Control Protocol/Internet Protocol (TCP/IP) communications over Wi-Fi, cellular, and USB. It also supports serial communications over Wi-Fi and USB.

DMS App Design

The DMS app was designed for Android (version 4.1 and later). It is written in Java, and leverages the Android Application Programming Interface (API). The app provides function-specific screens which are documented herein. It supports well-known smartphone and tablet gestures, including tap, swipe, double-tap-slide, and pinch. This section documents the overall DMS app design, as well as the wireframe mockups for the key screens and functions.

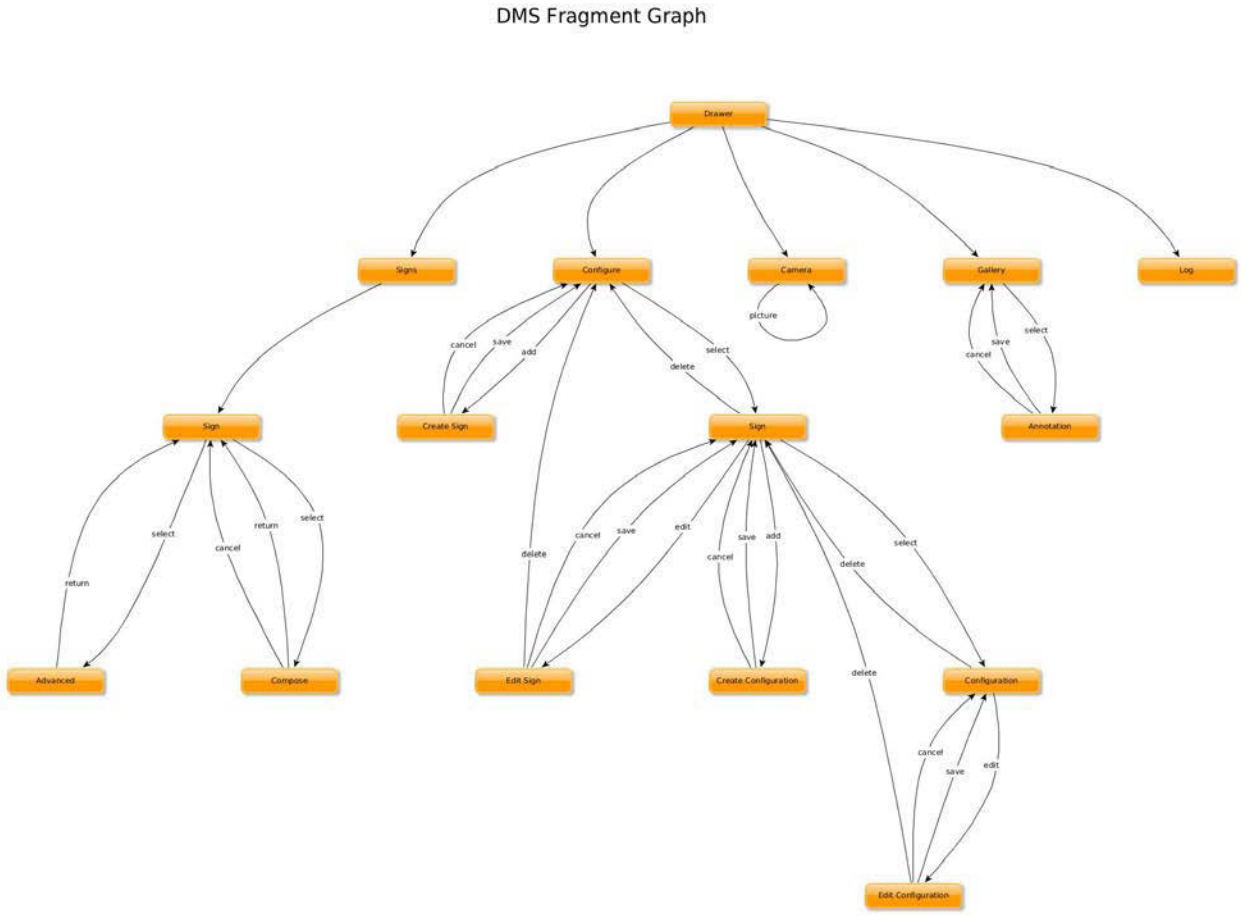

Figure 3.1: DMS fragment graph

The primary DMS functions, as illustrated in the fragment graph of Figure 3.1, are sign creation, configuration, and editing. The DMS app also supports a built-in camera and image gallery to allow a user to take and annotate pictures of a DMS for illustration of sign functionality and status. Finally, the DMS app supports logging for error handling and debugging. The sign and camera function design mockups will be discussed in this section.

Figure 3.2 shows the mockup for the DMS sign creation form. This form allows the user to set the sign name, designate the sign model (e.g. AVMS 700), and set the sign location. The form also allows the user to select the communications type (name, protocol, and endpoint). The list of communications types includes a random statically-colored circle icon including a letter corresponding to the first letter of the communications type name, for easier identification. The

user can create a new communications channel by clicking on the plus (+) icon in the lower right. To cancel the current sign creation, the user would click the 'X' icon in the upper left. Finally, to save the created sign, the user would click the checkmark (✓) icon in the upper right. In this and similar mockups, the three large dots represent repetition of elements.

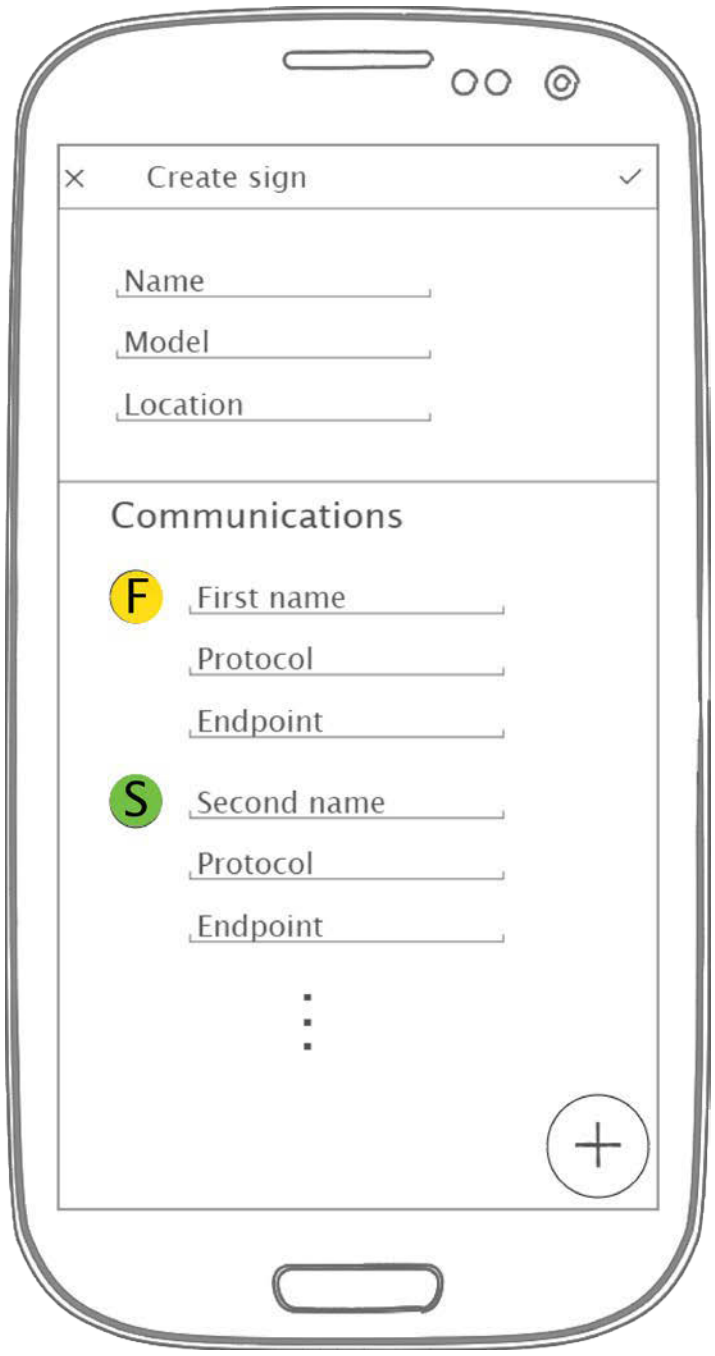

Figure 3.2: Create sign form mockup

Figure 3.3 shows the mockup for the DMS sign list. This screen shows a list of the currently configured DMS signs. Each sign entry includes the sign name and an auxiliary field which provides the sign's location, description, etc. Each sign entry in the list includes a random

statically-colored circle icon including a letter corresponding to the first letter of the sign name, for easier identification. The user can click on any sign entry to view that sign's details. The user can create a new sign by clicking on the plus (+) icon in the lower right. The user can search for a specific sign by name by clicking the search icon (magnifying glass) in the upper right.

Figure 3.3: Sign list mockup

Figure 3.4 shows the mockup for the graphical DMS signs preview. This screen shows a list of the currently configured DMS signs, including an image of the last detail request for each sign. Each sign entry includes the sign name and location, along with the connection type (network or

serial). The user can create a new sign by clicking on the plus (+) icon in the lower right. The user can search for a specific sign by name by clicking the search icon (magnifying glass) near the upper right. Finally, the user can sort the signs by name and also refresh the sign previews via the menu (three small dots) in the upper right.

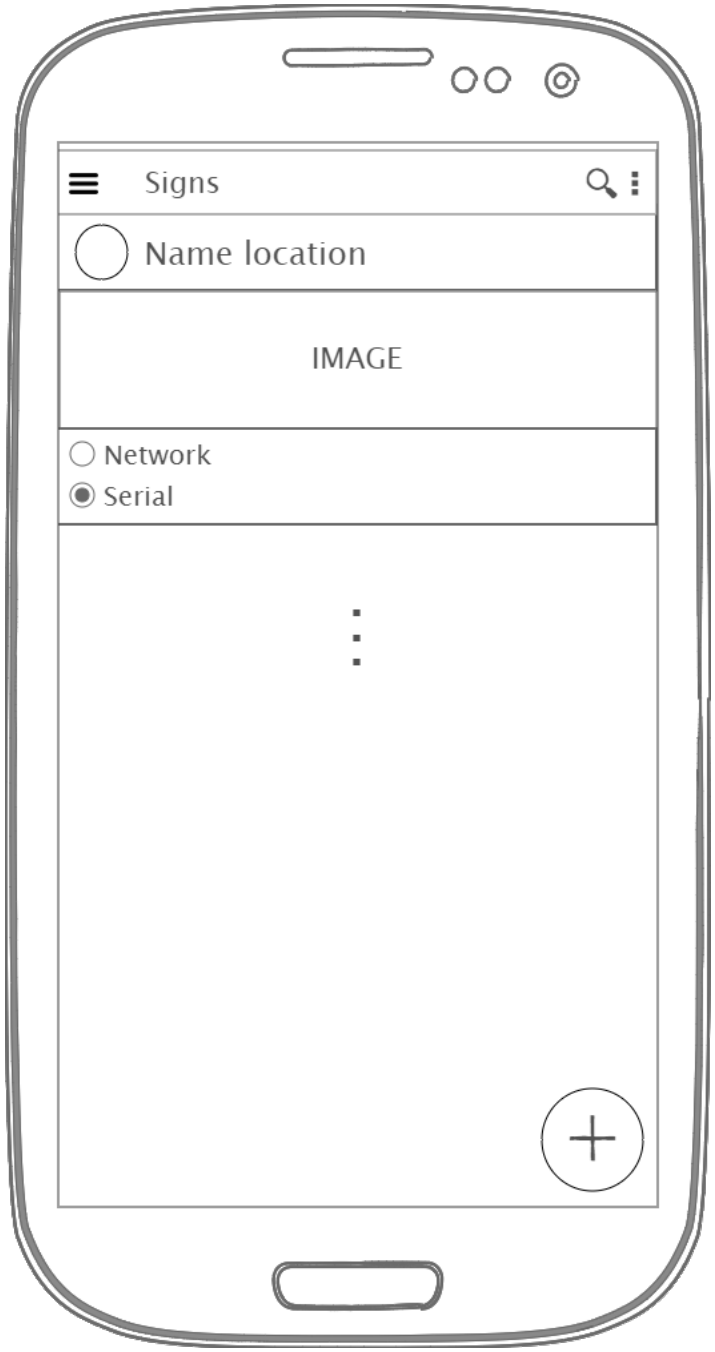

Figure 3.4: Signs preview mockup

Figure 3.5 shows the mockup for the DMS sign overview. This screen shows the sign name for the selected sign, along with the model and location. The form also shows the list of protocols and endpoints for the selected sign. The user can edit the sign by clicking on the pencil (🖉) icon

in the lower right. The user can delete the sign via the menu (three small dots) in the upper right. Finally, the user can return to the previous screen using the back arrow (←) in the upper left.

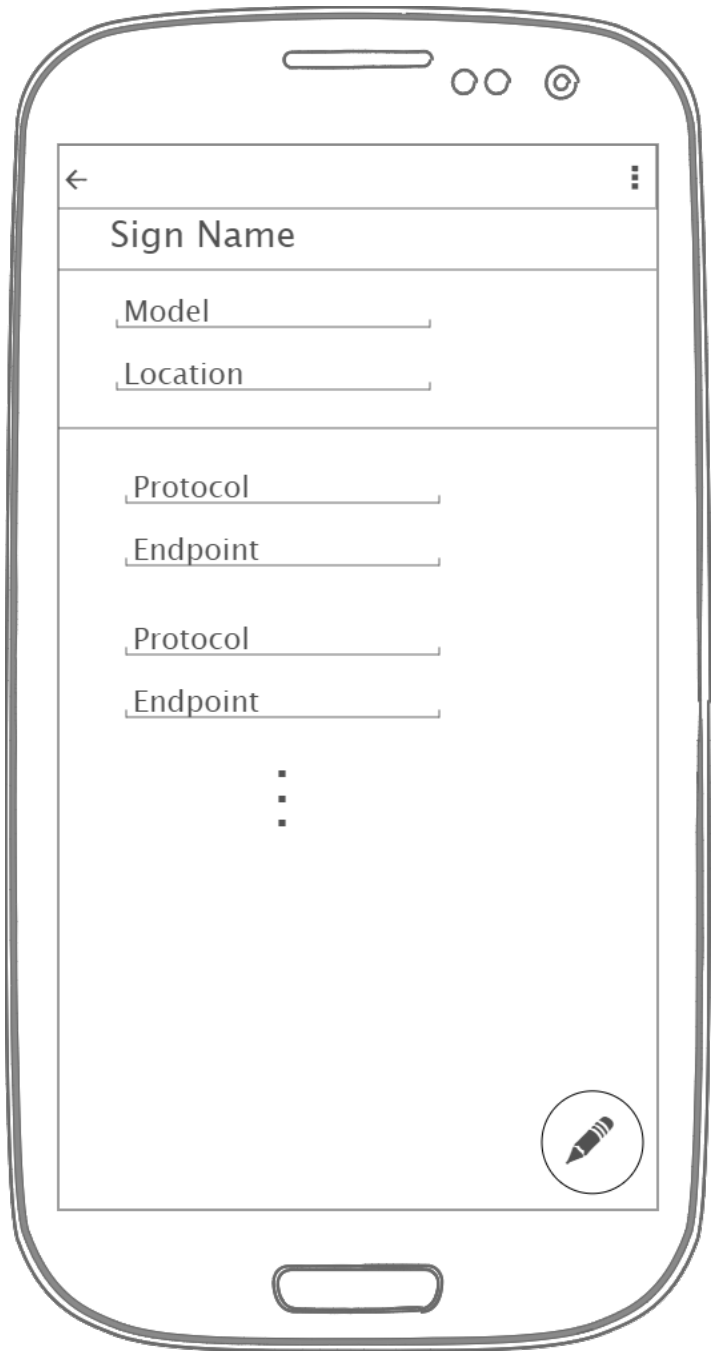

Figure 3.5: Sign overview mockup including edit and delete capability

Figure 3.6 shows the mockup for the DMS sign editing screen. This screen allows the user to modify the sign name, model, and location. The form also allows the user to select the communications types (name, protocol, and endpoint). The list of communications types includes a random statically-colored circle icon including a letter corresponding to the first letter of the communications type name, for easier identification. The user can create a new communications

channel by clicking on the plus (+) icon in the lower right. To cancel the current sign edit, the user would click the 'X' icon in the upper left. To save the created sign, the user would click the checkmark (✓) icon near the upper right. Finally, the user can delete the sign via the menu (three small dots) in the upper right.

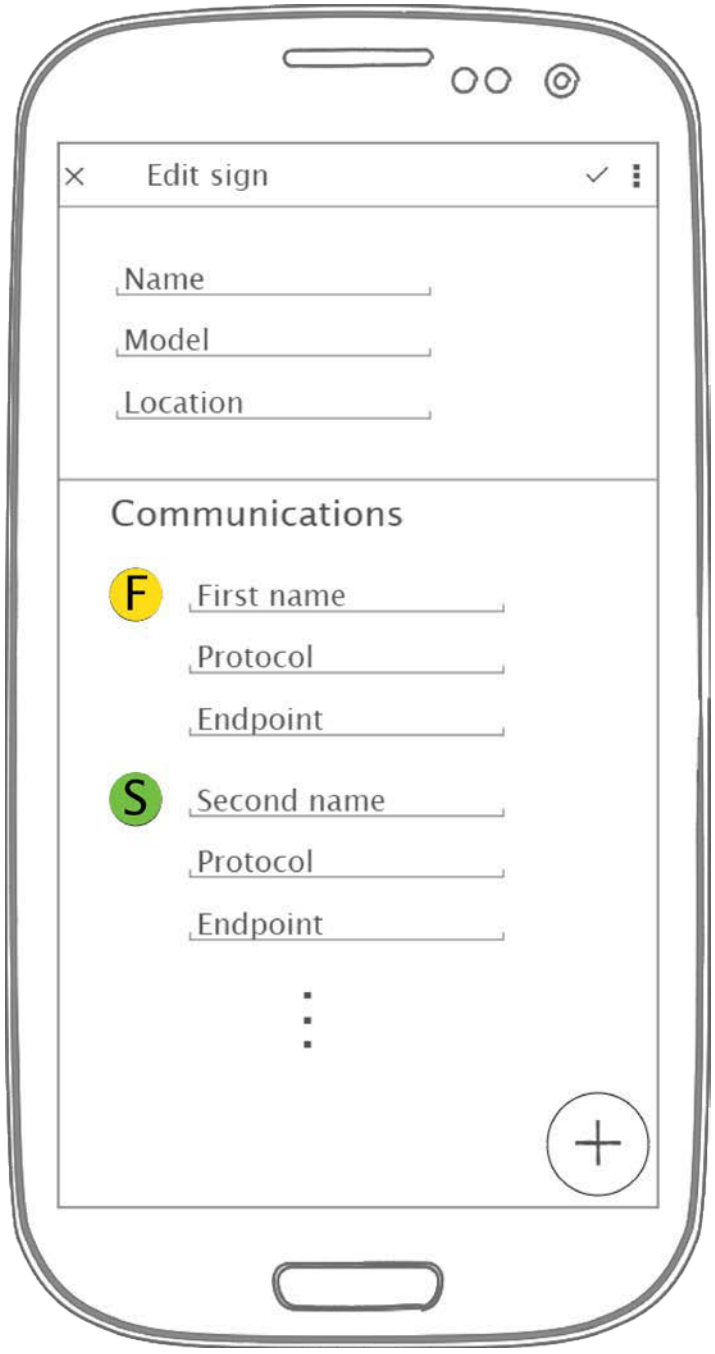

Figure 3.6: Edit sign form mockup

Figure 3.7 shows the mockup for the DMS communications creation form. This form allows the user to set the communications name, and select the protocol from a drop-down list. Depending on the protocol selected, either a TCP or Request for Comments (RFC) 2217 (Telnet COM Port

Control Option)[1] fragment will appear in the large area at the bottom of the screen. These two fragments are described below. To cancel the current communications creation, the user would click the 'X' icon in the upper left. Finally, to save the created communications, the user would click the checkmark (✓) icon in the upper right.

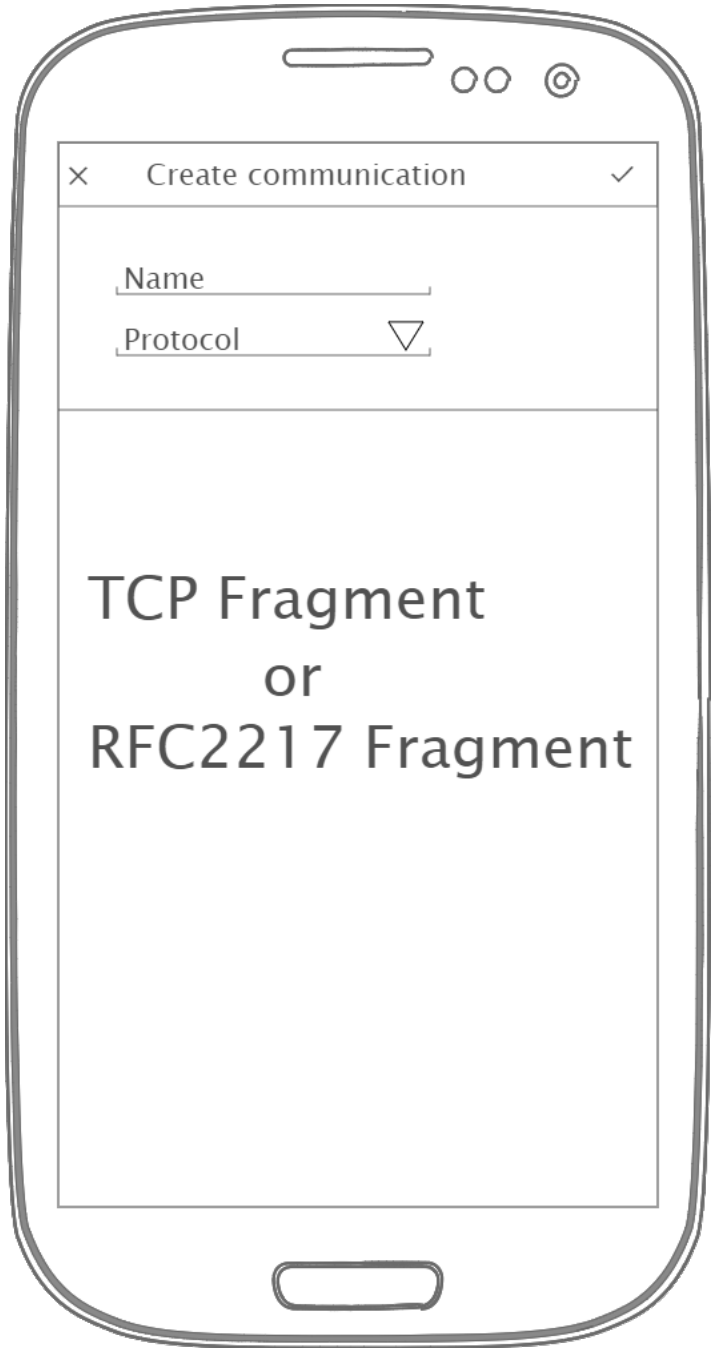

Figure 3.7: Create communication form mockup

[1] https://tools.ietf.org/html/rfc2217

Figure 3.8 shows the mockup for the DMS communications details. This screen shows the communications name for the selected communication, along with the selected protocol and endpoint. Depending on the protocol selected, either a TCP or RFC 2217 fragment will appear in the large area at the bottom of the screen. These two fragments are described below. The user can edit the protocol details by clicking on the pencil (✎) icon in the lower right. The user can delete the communications via the menu (three small dots) in the upper right. Finally, the user can return to the previous screen using the back arrow (←) in the upper left.

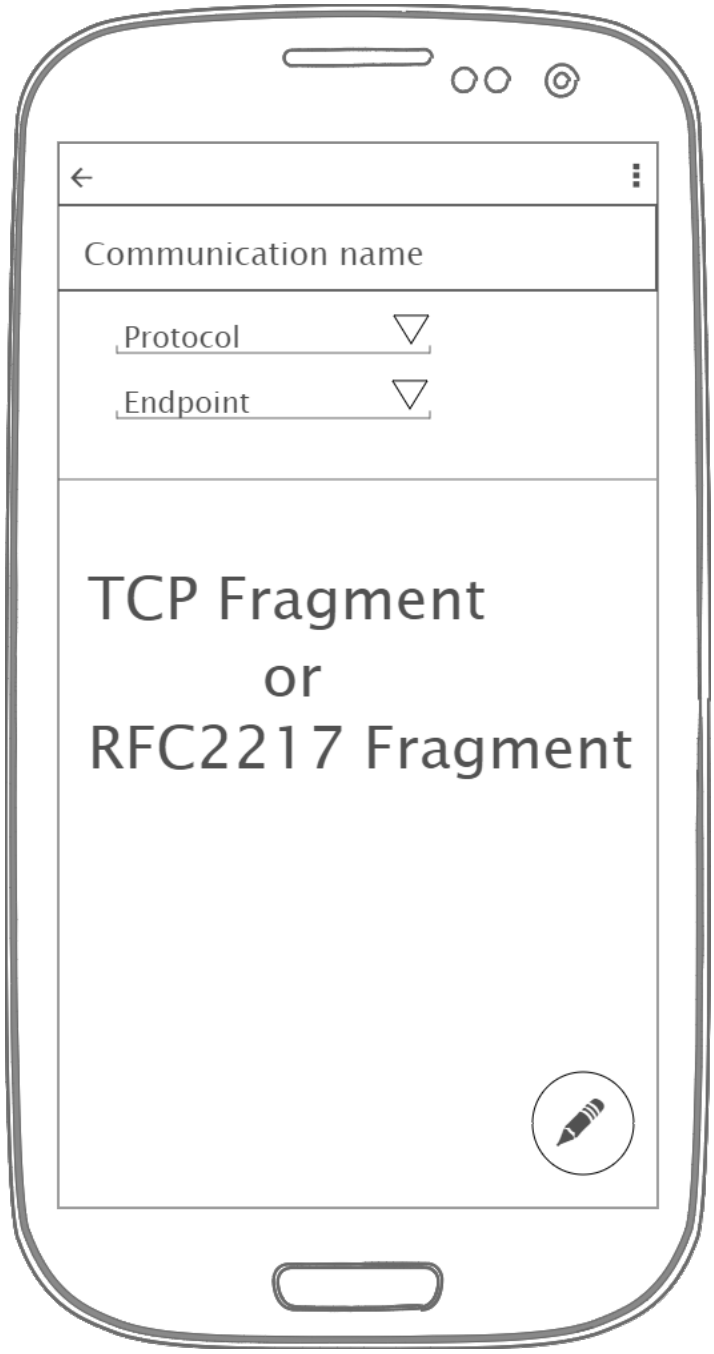

Figure 3.8: Communication overview mockup including edit and delete capability

Figure 3.9 shows the mockup for the DMS communications editing screen. This screen allows the user to modify the communications name, protocol, and endpoint. Depending on the protocol selected, either a TCP or RFC 2217 fragment will appear in the large area at the bottom of the screen. These two fragments are described below. To cancel the current communications edit, the user would click the 'X' icon in the upper left. To save the created communications, the user would click the checkmark (✓) icon near the upper right. Finally, the user can delete the communications via the menu (three small dots) in the upper right.

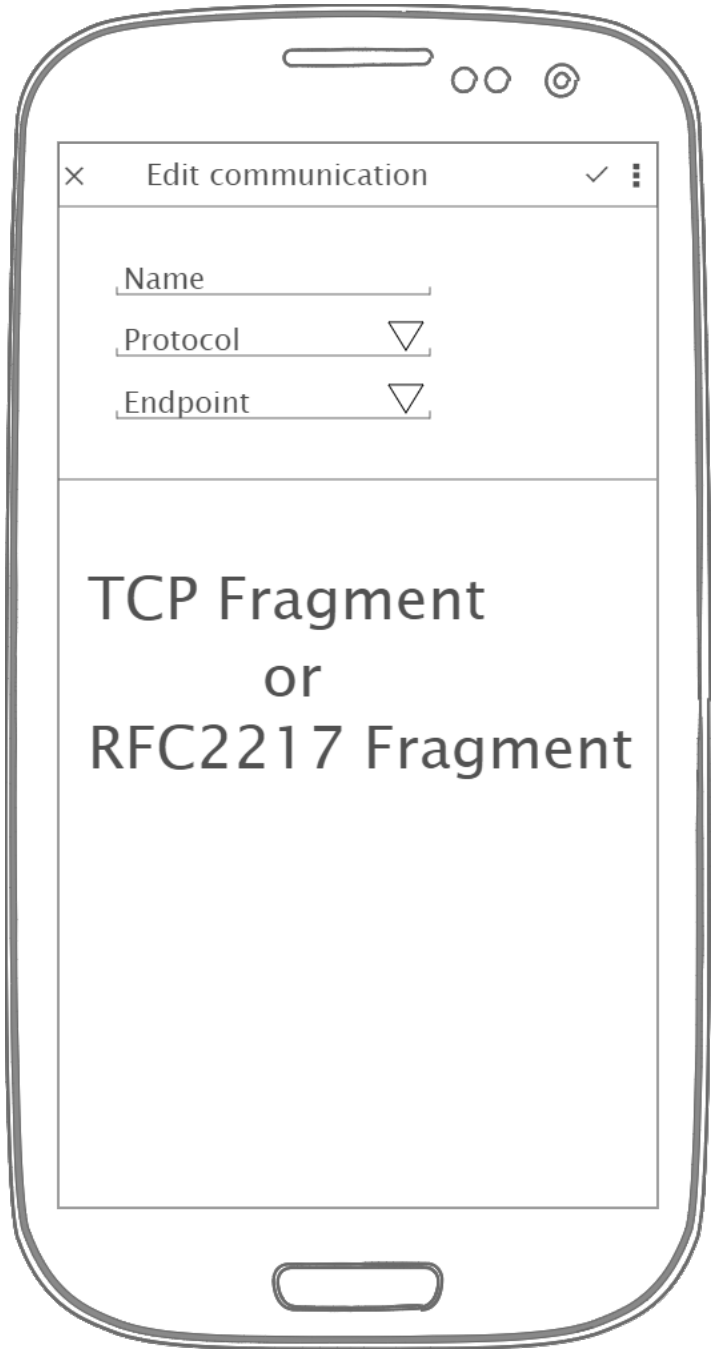

Figure 3.9: Edit communication form mockup

Figure 3.10 shows the mockup for the DMS TCP fragment. Depending on the selected protocol, this fragment appears in the screens for communications creation, communications overview, and communications edit. This screen allows the user to modify the TCP-specific communications parameters, including host, port, idle close timeout, read timeout, connection timeout, and socket timeout.

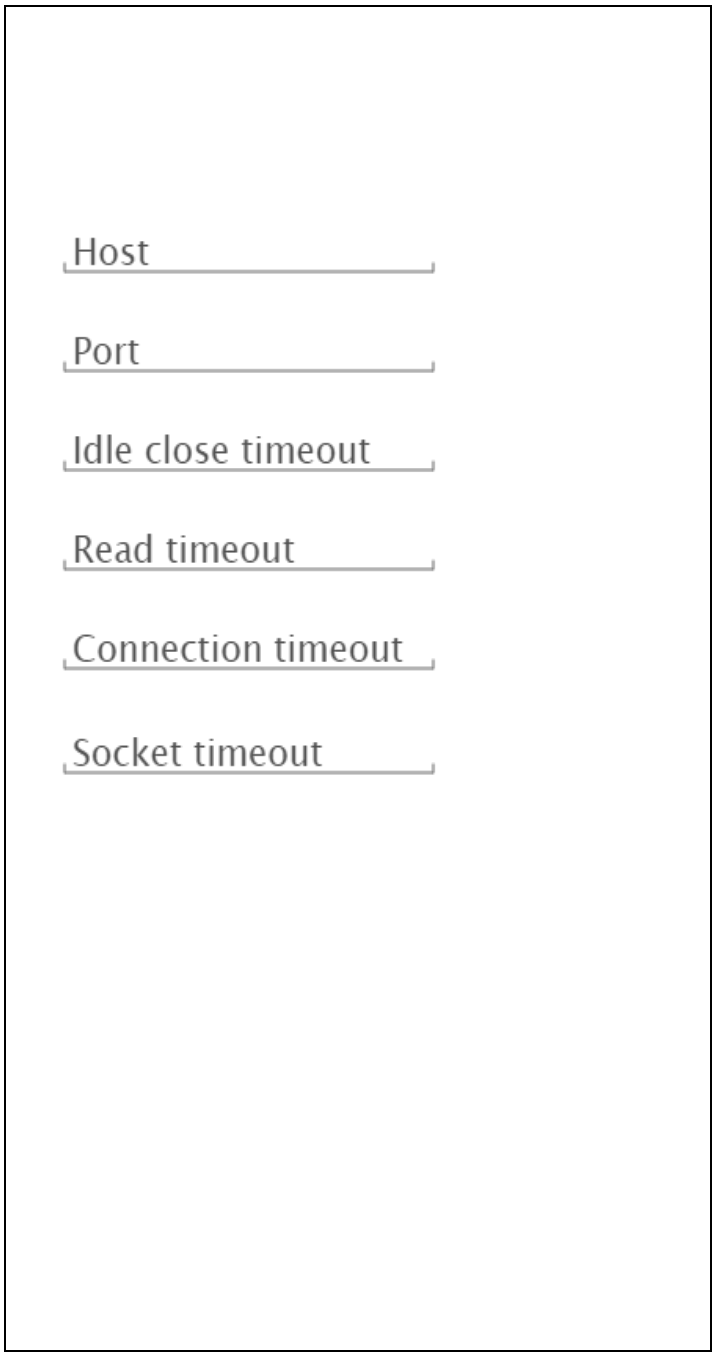

Figure 3.10: TCP fragment mockup

Figure 3.11 shows the mockup for the DMS RFC 2217 fragment. Depending on the selected protocol, this fragment appears in the screens for communications creation, communications

overview, and communications edit. This screen allows the user to modify the RFC 2217-specific communications parameters, including host, port, idle close timeout, read timeout, connection timeout, socket timeout, acknowledge timeout, and serial parameters. The serial parameters include baud rate, data bits, parity, stop bits, and flow control. The fragment also supports setting Request To Send (RTS), Receive (Rx) purge, and Transmit (Tx) purge.

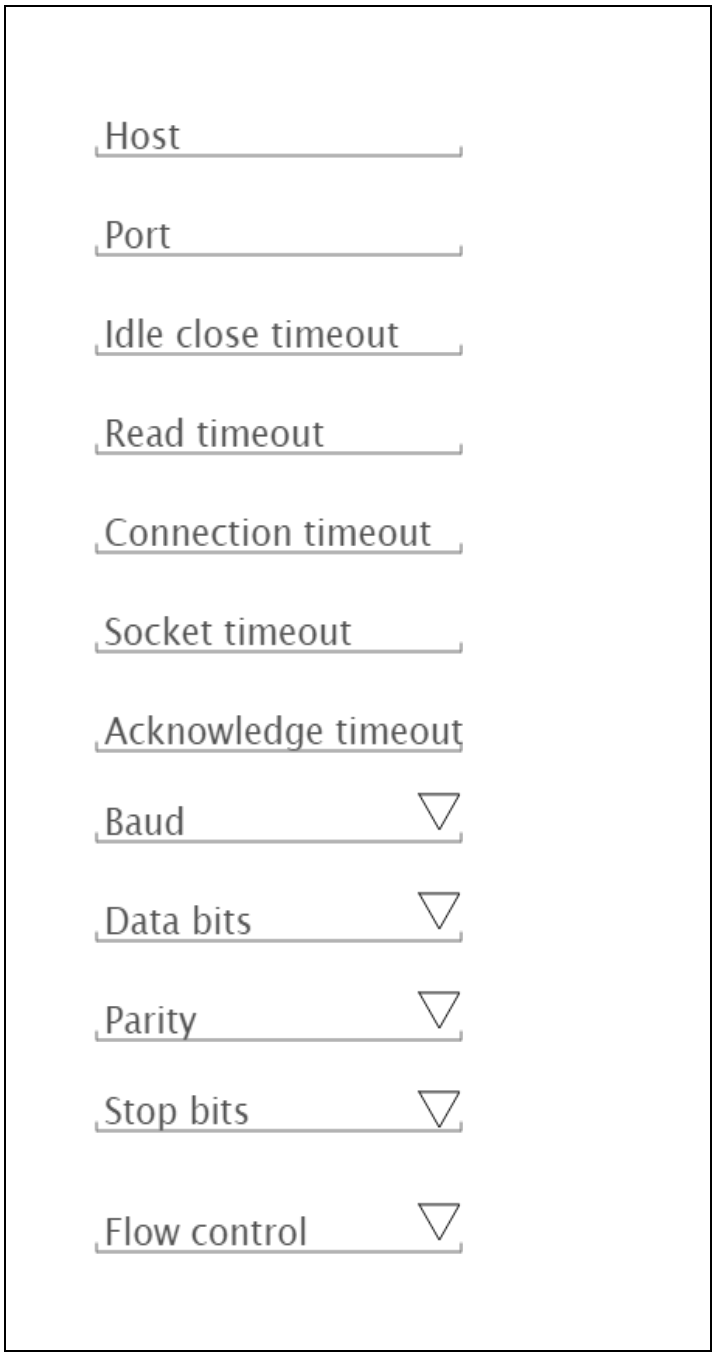

Figure 3.11: RFC 2217 fragment mockup

DMS App Screen Shots

This section contains the screen shots for the alpha version of the DMS app, which is based on the design mockups of the previous section. Figure 3.12 shows the main menu for the DMS app. From this menu, the user can access functionality for signs, app configuration, DMS app built-in camera and gallery, and app log. The log is for app debugging purposes, and is not intended for use by the typical user.

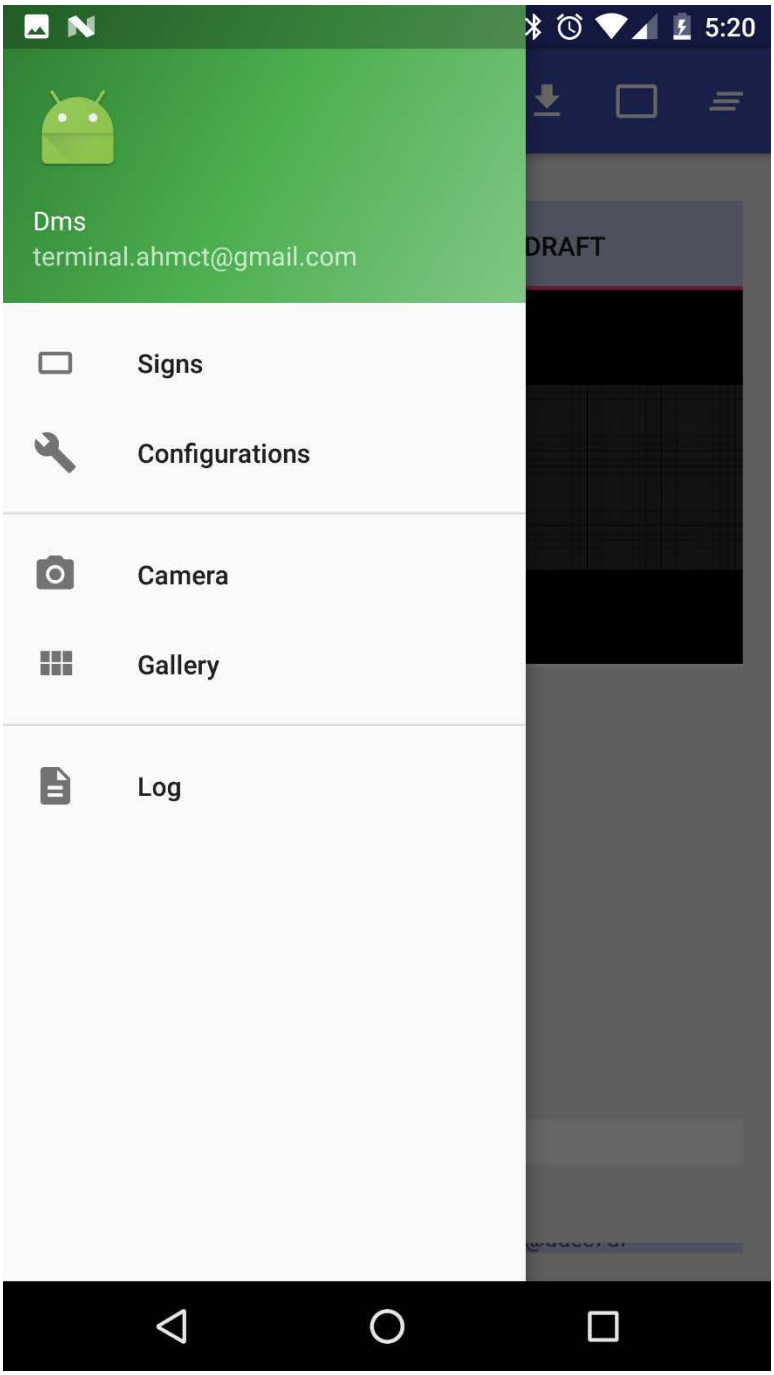

Figure 3.12: DMS app main menu

Figure 3.13 shows the screen shot for DMS draft message composition. The screen supports viewing the current DMS message as well as the draft being composed, either one on a graphical simulation of a DMS. The DMS view can show page 1 and page 2 for multi-page signs. The screen also includes three lines for text entry of each DMS page message. The screen also allows setting and viewing the message using the multistring format. Finally, the screen supports viewing of event logs.

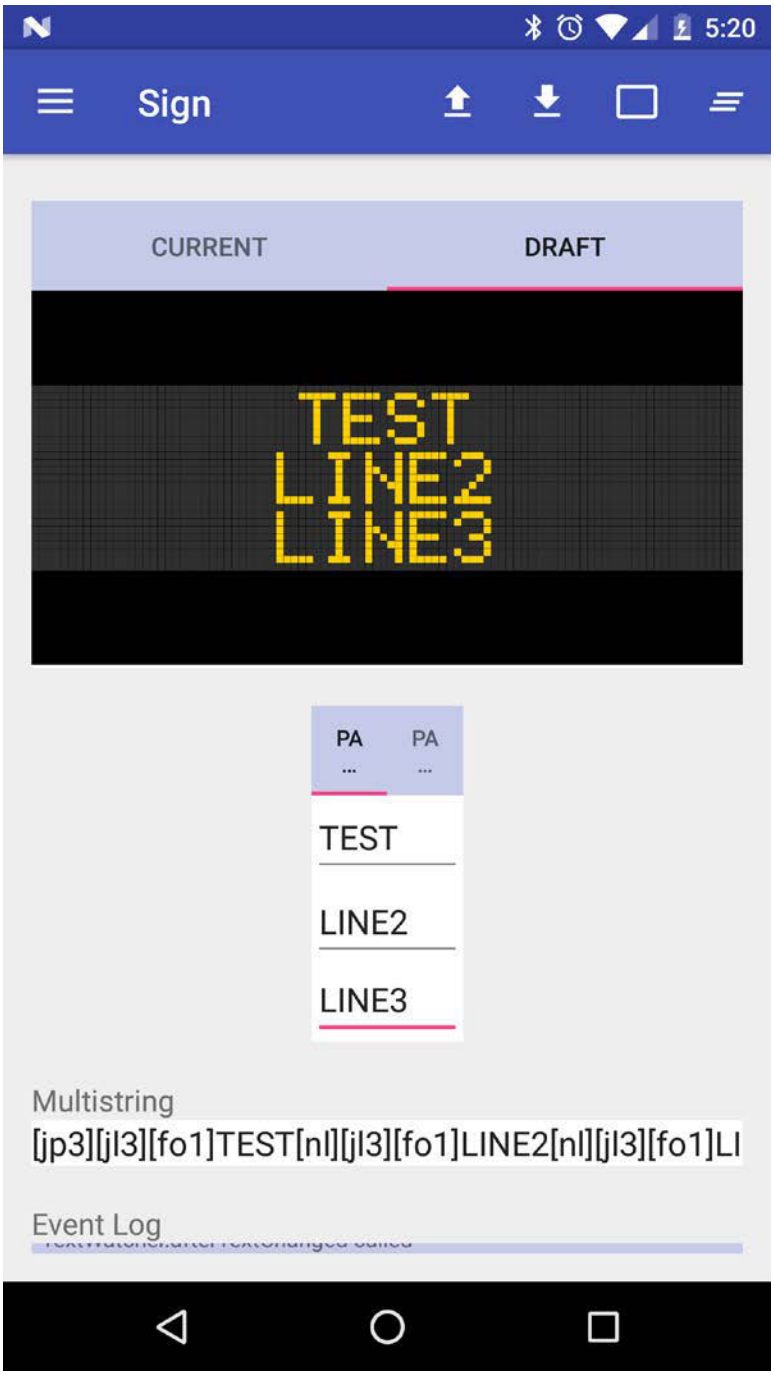

Figure 3.13: DMS draft message composition

Figure 3.14 shows an image taken by the DMS app's built-in camera functionality. The DMS app supports a built-in camera and image gallery to allow a user to take and annotate pictures of a DMS for illustration of sign functionality and status. Pictures taken with the camera appear in the DMS camera image gallery as shown in Figure 3.15. When the user selects an image in the DMS camera image gallery, the image is highlighted, as shown in Figure 3.16.

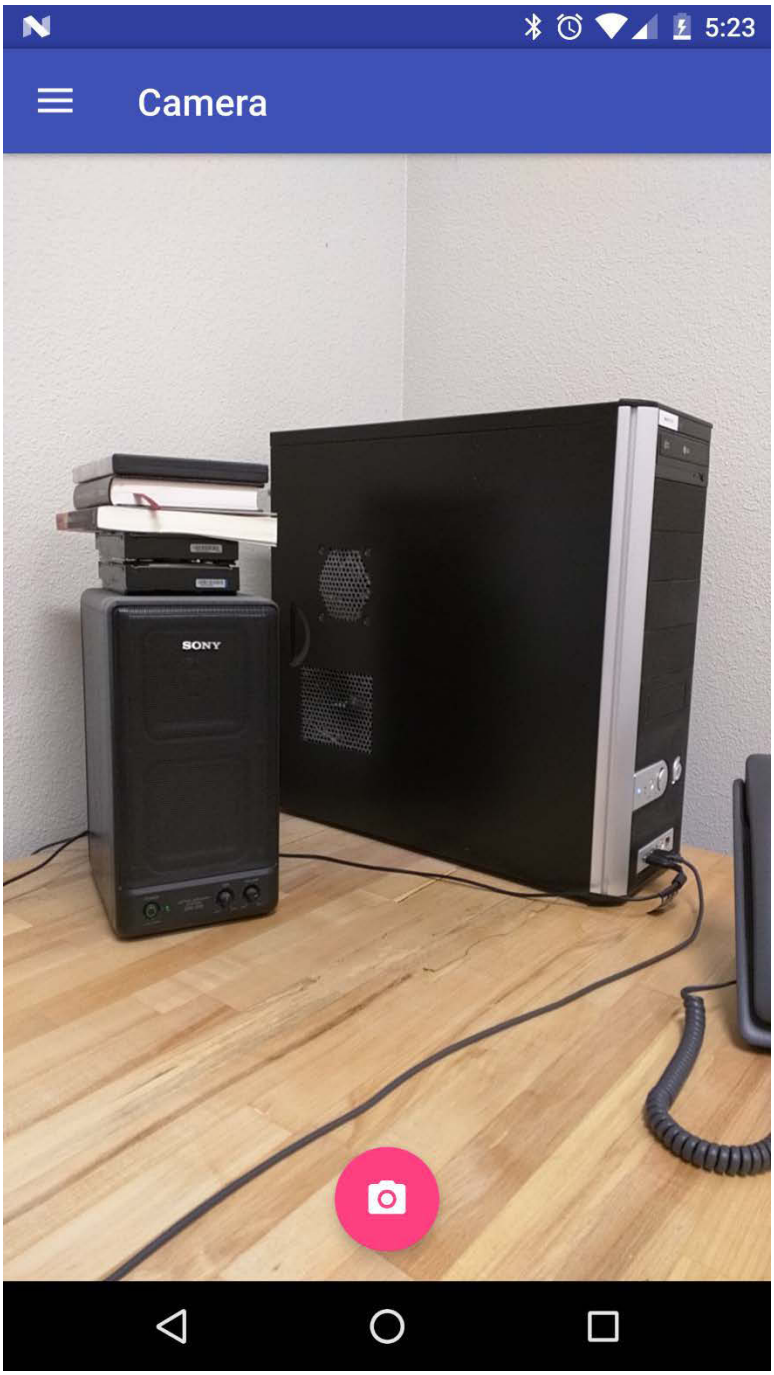

Figure 3.14: Sample DMS camera image in lab test

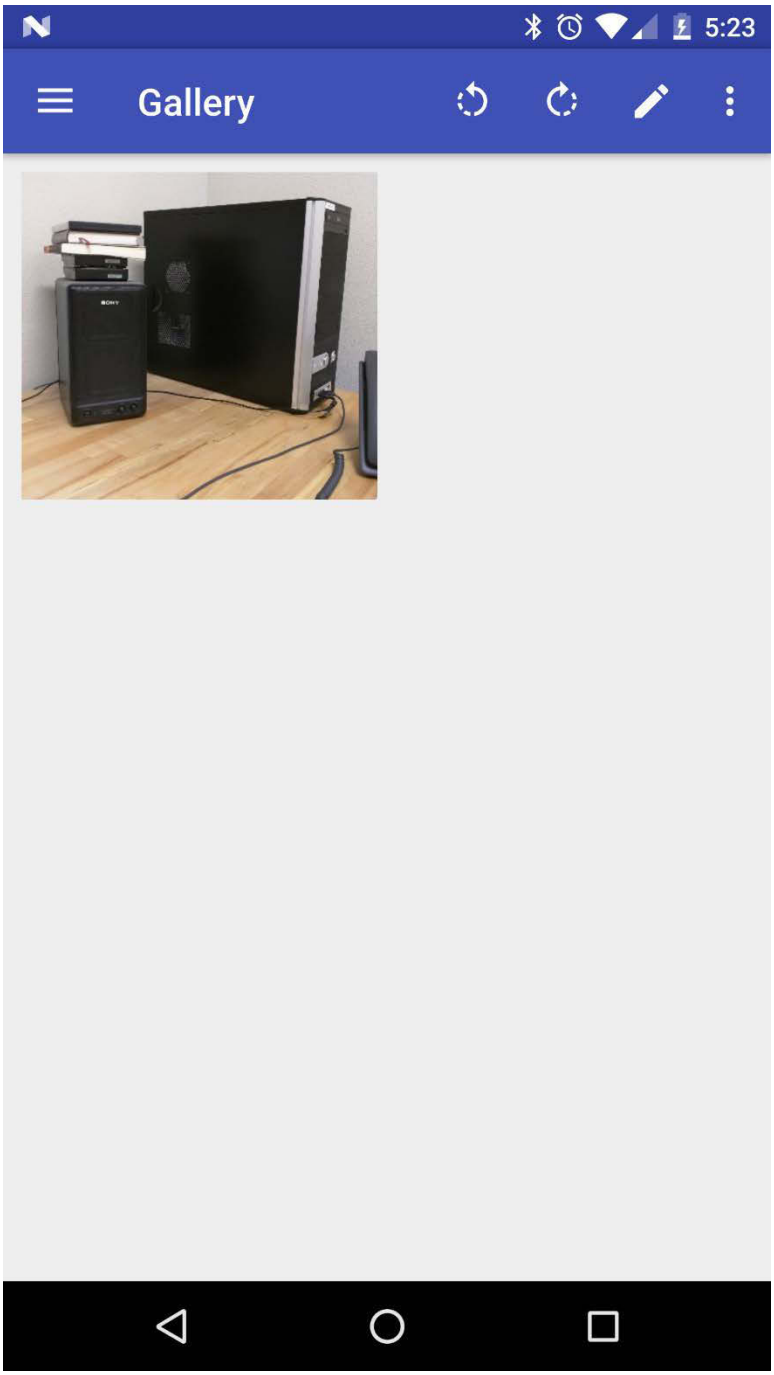

Figure 3.15: DMS camera image gallery

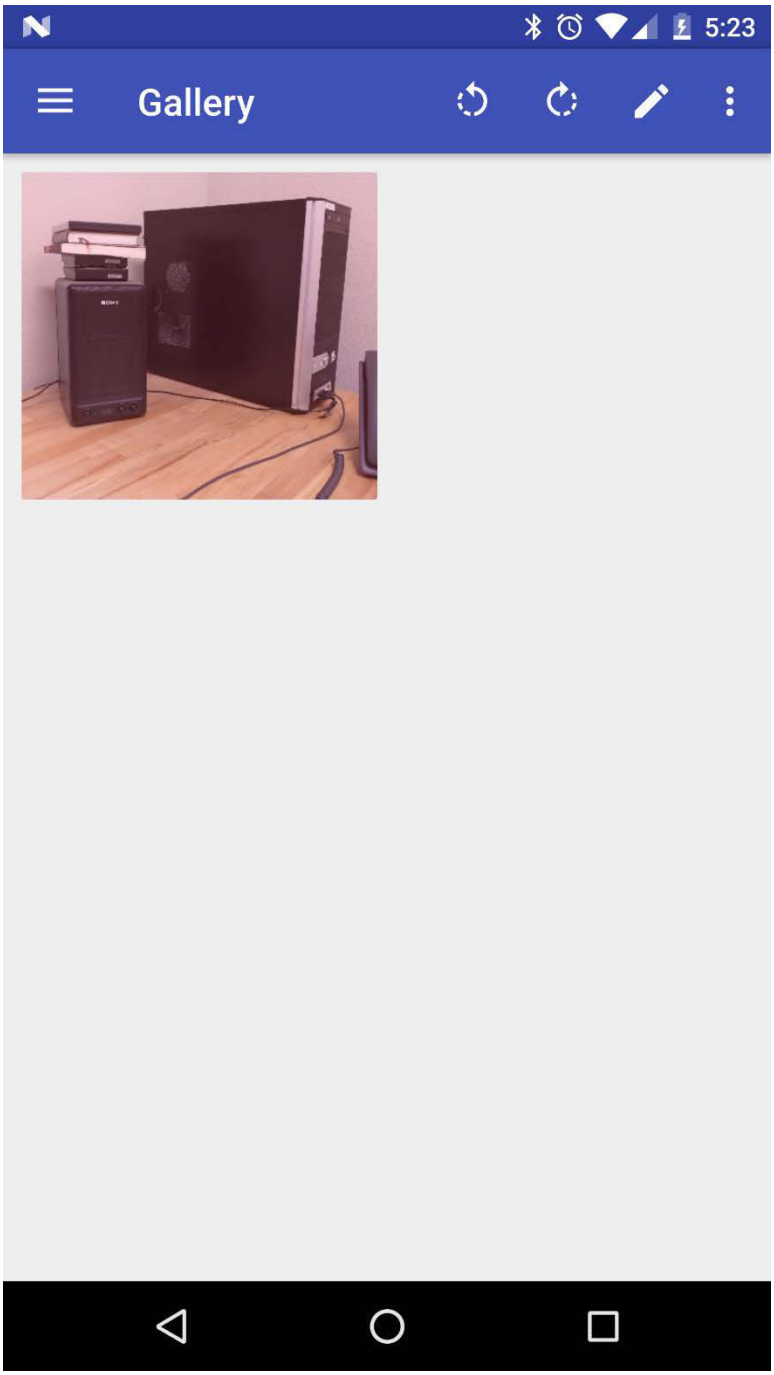

Figure 3.16: DMS camera gallery with image selected

Once the user selects an image in the gallery, they can click on the appropriate circular arrow icon to rotate the image left or right by 90 degrees, and can click on the pencil (✎) icon to annotate the image. The annotation screen includes tools for adding text and freehand drawing to an image. For both types of annotation, the user can select colors as shown in Figure 3.17. For the freehand annotation tool, the user can select line width, as shown in Figure 3.18. An example annotated image is shown in Figure 3.19, and the annotated image is shown along with the unmodified original image in the DMS image gallery in Figure 3.20.

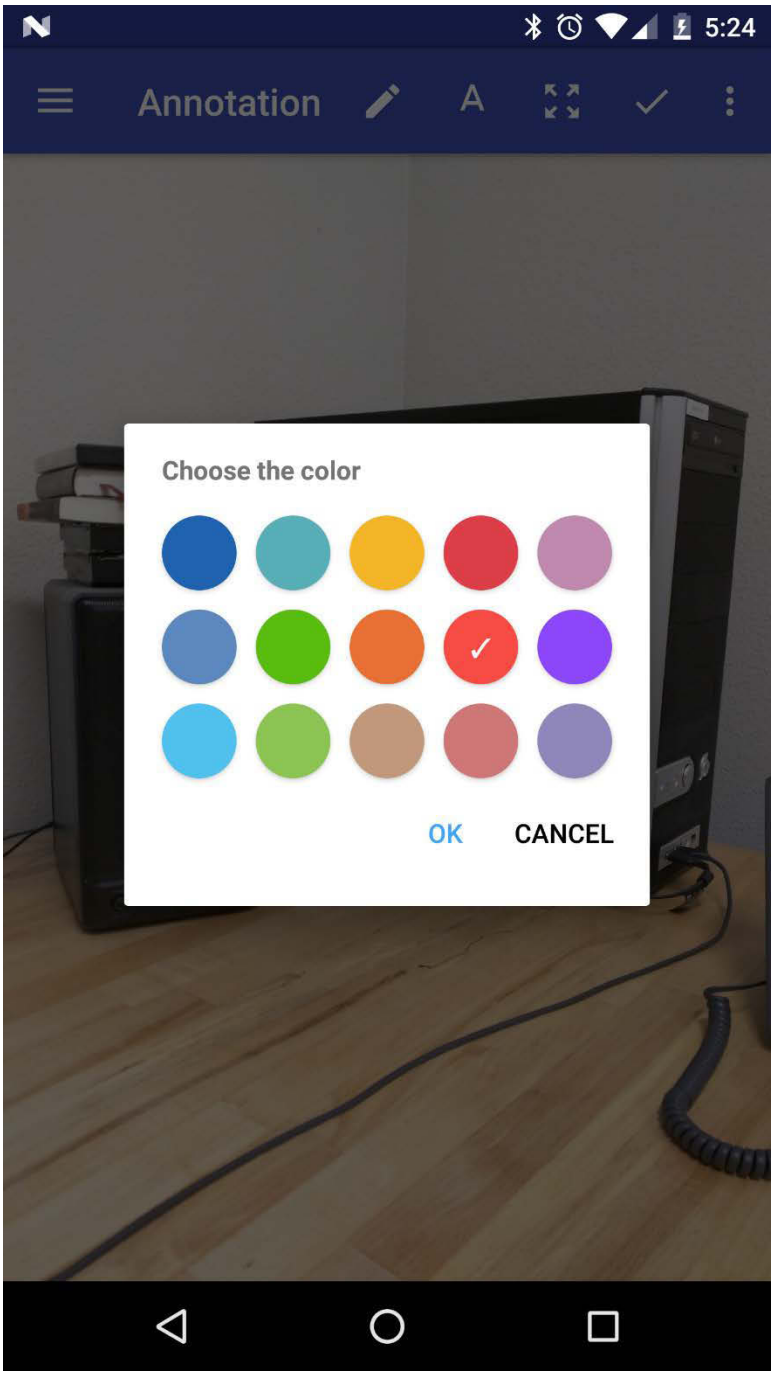

Figure 3.17: DMS camera image annotation color selection

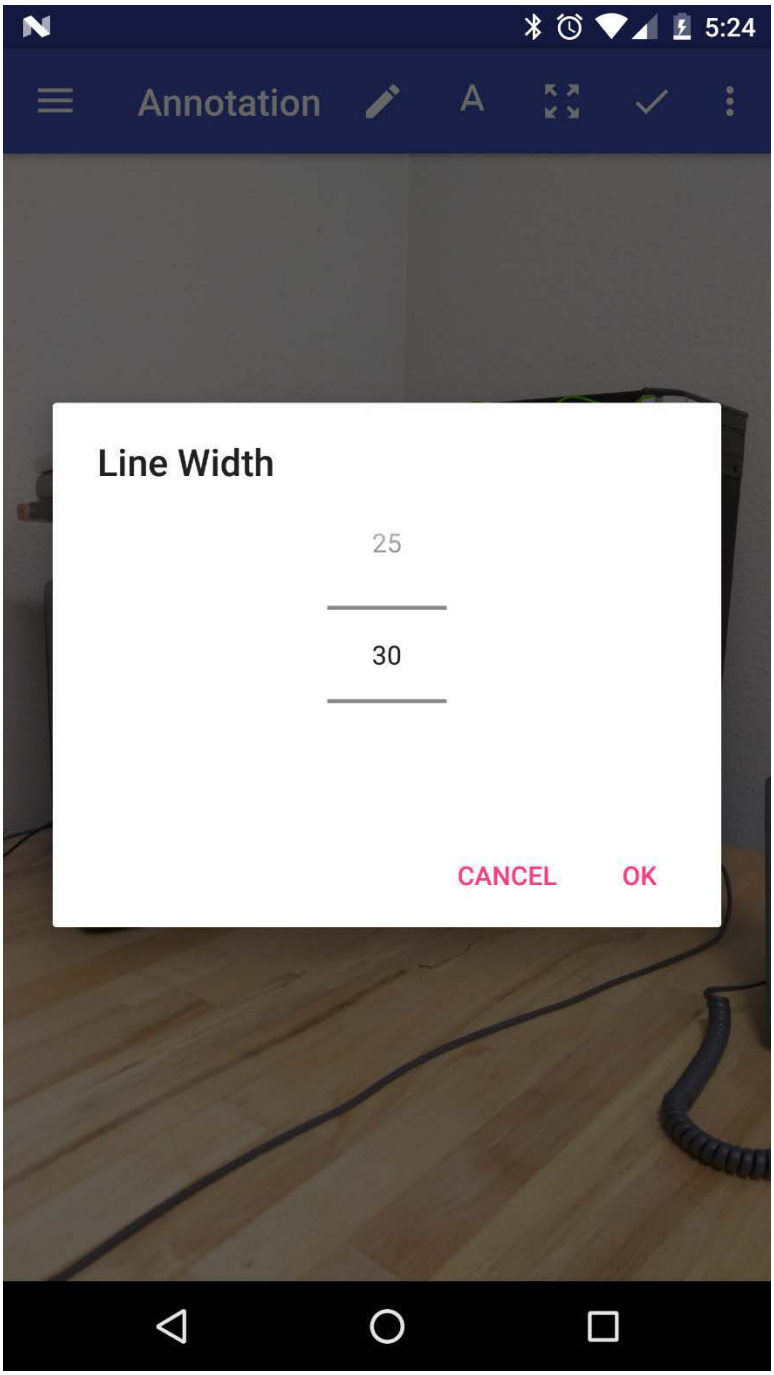

Figure 3.18: DMS camera image annotation line width selection

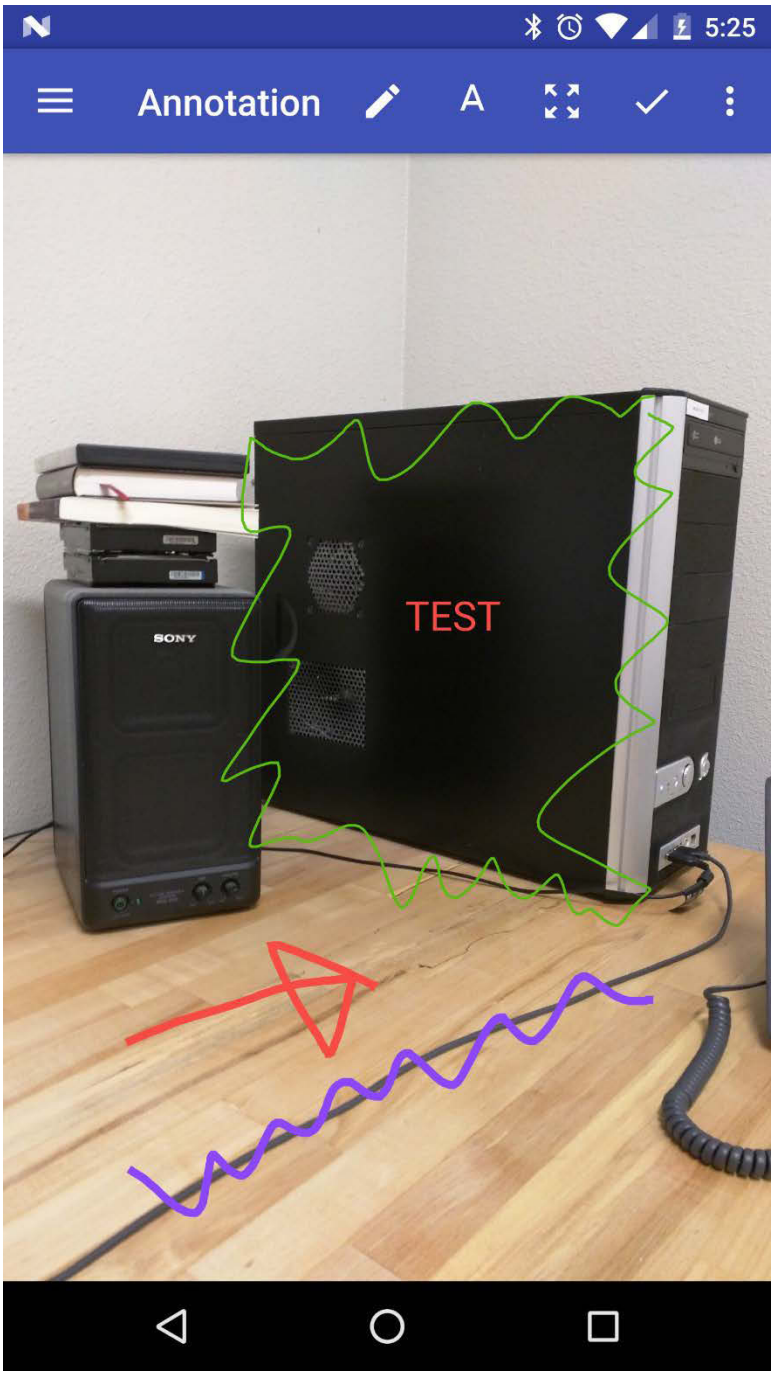

Figure 3.19: Annotated DMS camera image

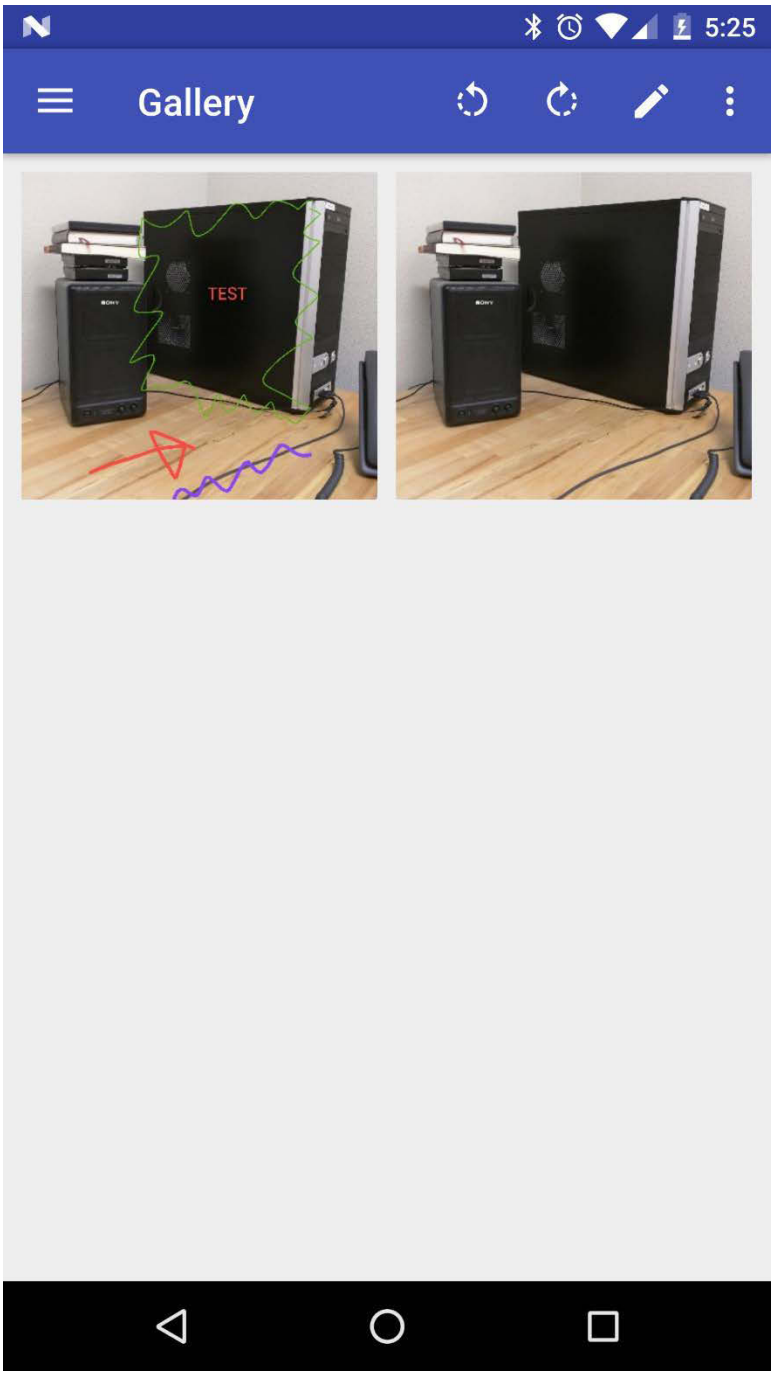

Figure 3.20: DMS camera image gallery including annotated and unmodified original images

CHAPTER 4:
CONSOLE SOFTWARE

This chapter discusses the selection of the appropriate Console app for inclusion in the HHT. The requirements for this app are provided in Appendix C.

Overview

As part of this research, AHMCT evaluated various COTS console apps for inclusion in the HHT app suite. AHMCT assessed available features vs. anticipated Caltrans needs. In conjunction with Caltrans, AHMCT selected the most appropriate serial console app, and included it in the HHT app suite. The Console app provides a general CLI for interfacing with a wide range of field element hardware. The Console app can be used to connect to devices, send commands via CLI, and display resulting text-based field element response in the console screen.

The Console app can access general Caltrans field elements remotely over the network, or directly at the field location. Local connection from the HHT to the field element is supported by Wi-Fi-to-network, USB-to-network, or Wi-Fi-to-serial adapters. Remote network connection is typically over standard tablet Wi-Fi or cellular connection. The selected Console app supports Secure Shell (SSH) and Telnet through the local CLI with multiple command history, copy and paste, macros, external keyboard support, and connection management, among other powerful features.

Comparison

Six popular and capable console apps were evaluated against the requirements of Appendix C. The evaluation results are presented in Table 5.1. Based on the requirements and a head-to-head comparison, the final app selected for inclusion in the HHT is JuiceSSH Pro. The app is installed on each of the HHT kit tablets. For this evaluation, features were deemed much more important than cost. The app is low-cost in the context of HHT, and in the application realm.

Table 5.1: Console app evaluation

		Console Apps					
		JuiceSSH Pro	Better Terminal Emulator	Terminal IDE	Terminal Emulator	ConnectBot	SerialBot
Features	**Android 5.0 Compatible**	Yes	Yes	No	Yes	Yes	Yes
	Local Shell	Yes	Yes	Yes	Yes	Yes	Yes
	SSH	Yes	Yes	Yes	No	Yes	Yes
	Mosh	Yes	No	No	No	No	No
	Telnet	Yes	Yes	Yes	No	Yes	Yes
	Command History	Yes	Yes	Yes	Yes	Yes	Yes
	Copy and Paste	Yes	Yes	Yes	No	Yes	Yes
	Connection Management	Yes	?	Yes	No	No	No
	Macros	Yes	Yes	Yes	Yes	No	No
	Extensible	Yes	?	Yes	Yes	No	No
	External Keyboards	Yes	Yes	Yes	Yes	Yes	Yes
	Network (Wi-Fi / USB)	Yes	Yes	Yes	Yes	Yes	Yes
	Serial over Network	Yes	Yes	Yes	No	Yes	Yes
	Cost	$6.89	$3.99	Free	Free	Free	Free

Final Selection

The final selection for the HHT Console app is the COTS app JuiceSSH Pro, available on the Google Play Store. The selection was based on the requirements of Appendix C, as well as more subjective criteria agreed upon between AHMCT and Caltrans. Several screen shots for the Console app views are shown in Figures 5.1 – 5.4. While this app is currently the best match for requirements and subjective criteria, apps are regularly being upgraded, and new apps are introduced often. It is in Caltrans' interest to monitor the state-of-practice in Android console apps, and consider replacing the existing Console app, or adding additional choices for the user. On the other hand, familiarity with a specific Console app's interface and workflow is quite important, and should not be discounted when considering a switch.

Figure 5.1 shows the Console app's Command-Line View. This is the standard CLI for interacting with devices.

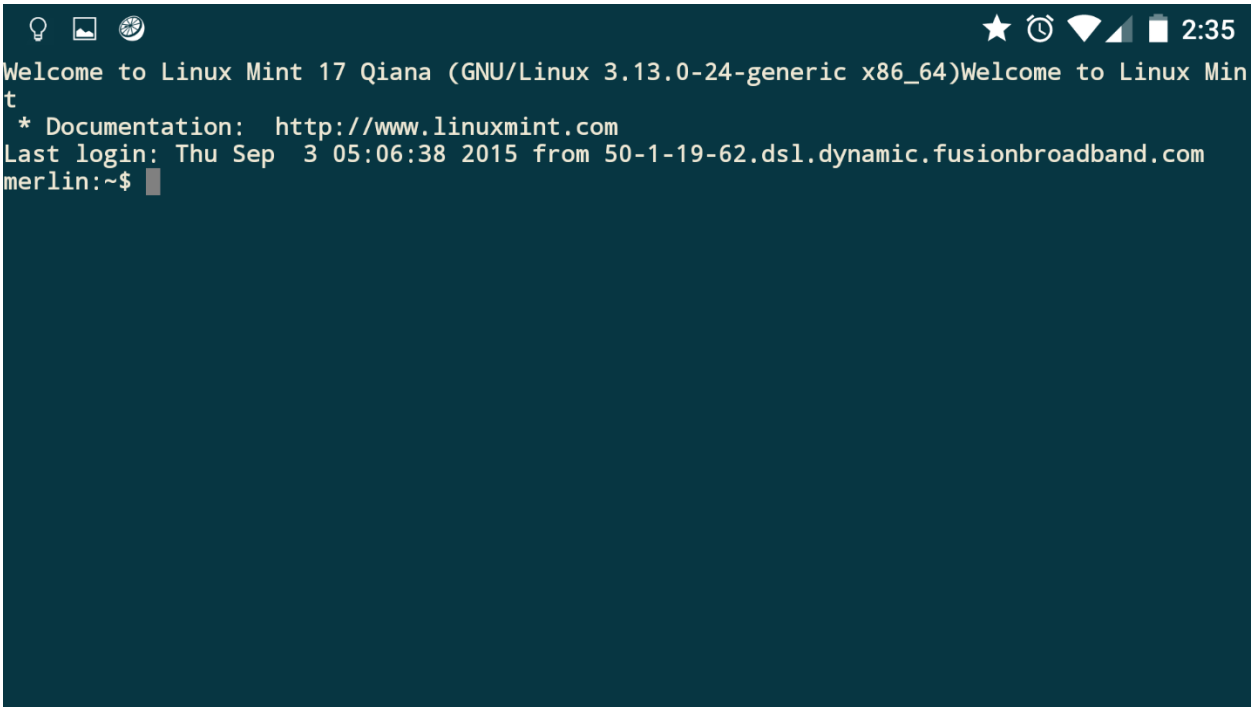

Figure 5.1: Console app Command-Line View (courtesy of Sonelli Ltd.)

Figure 5.2 shows the Console app's Keyboard View. This is the standard Android popup keyboard allowing the user to type commands into the CLI.

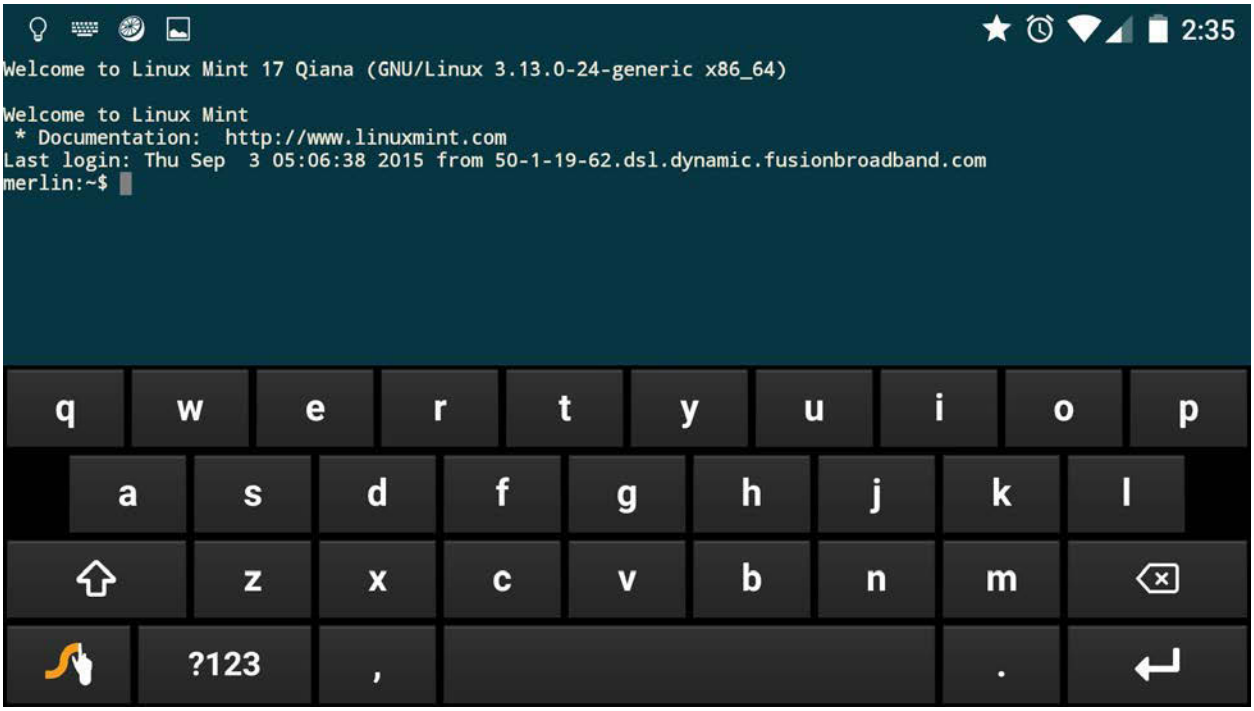

Figure 5.2: Console app Keyboard View (courtesy of Sonelli Ltd.)

Figure 5.3 shows the Console app's Connection View. In this view, the user can check connection status with the given ITS field element. In this figure, one connection has been created for a host called Merlin.

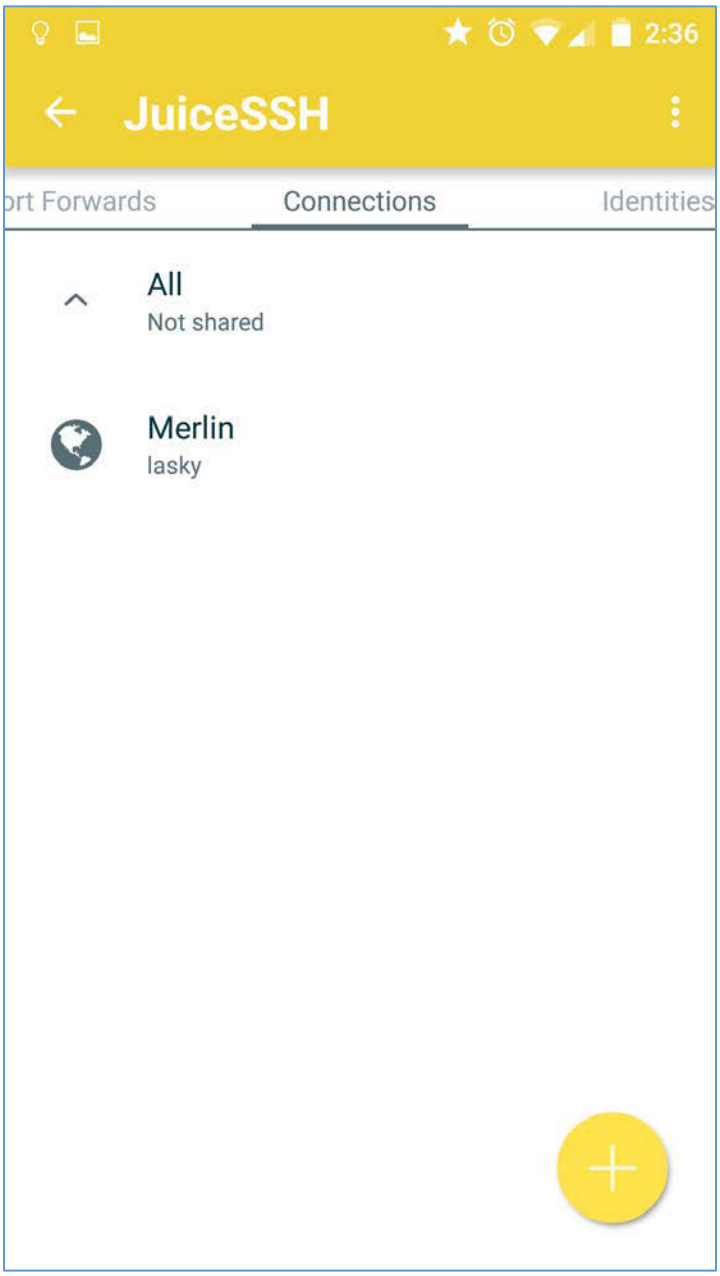

Figure 5.3: Console app Connection View (courtesy of Sonelli Ltd.)

Figure 5.4 shows the Console app's Configuration View. This allows the user to change configuration options for connecting to an ITS field element. In this figure Merlin's basic settings are being shown, and can be changed. Key settings include nickname, type (e.g. SSH or Telnet), host address, user identity (if any), and port (default for SSH is 22).

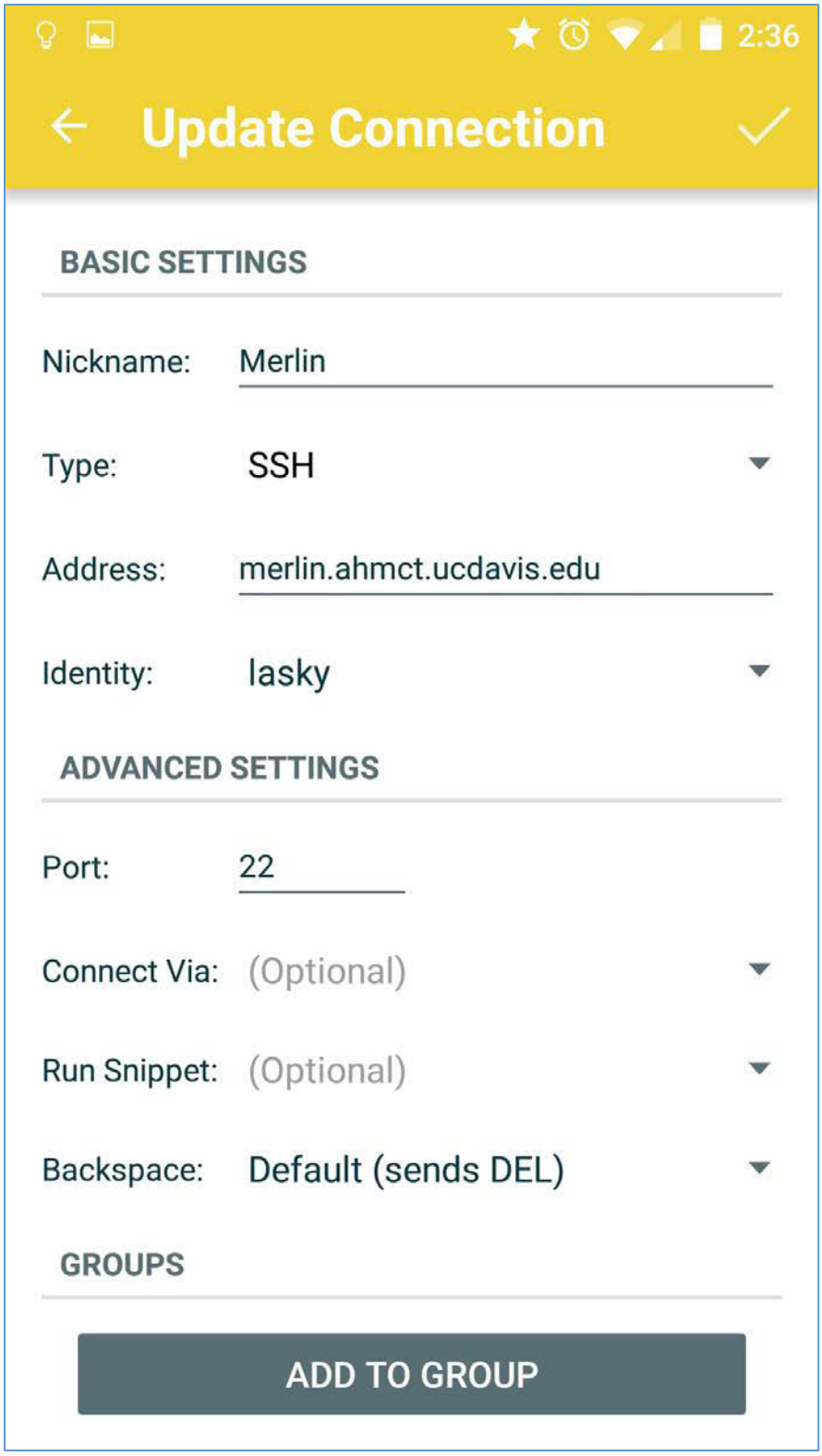

Figure 5.4: Console app Configuration View (courtesy of Sonelli Ltd.)

CHAPTER 5:
HANDHELD TERMINAL HARDWARE KIT

The main deliverable for this research was an integrated software and hardware kit to support ITS field element diagnosis and configuration. The kit includes all needed hardware. The included tablet has the HHT apps installed. The hardware kit requirements are provided in Appendix D. The COTS hardware selection process is discussed in this chapter.

COTS Hardware Comparison

As part of the research, AHMCT evaluated and compared COTS hardware for final inclusion in the hardware kit. Table 6.1 provides the COTS comparison for the primary HHT component, the tablet.

Table 6.1: COTS handheld tablet comparison

Model	Android	Display Size	Resolution	WiFi	Ethernet	WWAN	Cost
T70H	4.2	7"	1024x600	802.11b/g/n	no	GSM CDMA	$759
Xplore Technologies RangerX	4.0.4	10.1"	1366x786	802.11a/b/g/n	Optional	CDMA 4G LTE	
Getac Z710	4.1	7"	1024x600	802.11b/g/n	no	3.5G GSM	$1,500
Panasonic Toughpad JT-B1	4.0	7"	1024x600	802.11a/b/g/n	Docking Station	Optional 4G LTE	$1,500
Panasonic Toughpad FZ-A1	4.0	10.1"	1024x768	802.11a/b/g/n	Docking Station	Optional 4G LTE	$1,500
Fieldbook FBD1	4.0	7"	1024x600	802.11b/g/n	no	3.5 G	
Google Nexus 7 2013	4.3	7.02"	1920x1200	802.11a/b/g/n	no	LTE	$349
Google Nexus 10	4.2	10"	2560x1600	802.11b/g/n	no	no	$499
Samsung Note 8"	4.1	8"	1280x800	802.11b/g/n	no	no	$399
Samsung Note 10"	4.1	10.1"	1280x800	802.11b/g/n	no	optional	$499
Lenovo Ideatab A2109	4.0	9"	1280x800	802.11b/g/n	no	no	$230
Lenovo Ideatab A2107	4.0	7"	1024x600	802.11b/g/n	no	optional	$180
Google Nexus 9	5	9”	2048x1536	802.11a/b/g/n/ ac 2x2 MIMO	no	optional	$399

Hardware Kit

The HHT hardware kit is a self-contained and ruggedized kit containing all hardware needed for CCTV and DMS configuration and diagnostics, as well as general element configuration and diagnostics using the Console app. The kit is packaged inside a Pelican case to provide environmental protection from crush, mechanical impact, and moisture. Figure 6.1 provides an external view of the HHT kit. Figure 6.2 illustrates the primary kit internals, i.e. the tablet and the liquid crystal display (LCD) video monitor. Figure 6.3 shows the cabling portion of the kit internals. Finally, Figure 6.4 illustrates all components included in the kit.

Figure 6.1: HHT kit external view

Figure 6.2: HHT primary kit internals, i.e. the tablet and the LCD video monitor

Figure 6.3: Cabling portion of the HHT kit internals

Figure 6.4: All HHT kit components

The kit includes:

1. Pelican case (M/N 1450)
2. COTS Android tablet (Google Nexus 9)
3. Tablet Protector
4. LCD Video Monitor for direct video viewing

5. Wi-Fi Terminal Server / Bridge
6. Cable: Micro USB Male to RJ45 Female
7. Cable: Micro USB Male to USB A Female
8. Cable: USB A to RS232 DE-9 Male
9. Cable: USB A to RS422 DE-9 Male
10. Cable: DE-9 Female to 170-C2 Male
11. Cable: RJ45 Male to DE-9 Male
12. Cable: RJ45 Male to RJ45 Male
13. Cable: BNC Male to BNC Male
14. Cable: Custom DE-9 Female to C2 Male
15. Converter: RS232 Female to RS422 Female
16. Charging Cable: Tablet
17. Charging Cable: Terminal Server / Bridge
18. Charging Cable: Video Monitor
19. Power Cable: RS422 Converter

CHAPTER 6:
CONCLUSIONS AND FUTURE RESEARCH

Key contributions of this research project included:

- Design and development of handheld terminal (HHT) software to maintain field element devices, including field testing of this terminal software on a number of devices

- Implementation of specific HHT alpha software for field elements, including closed-circuit TV (CCTV) cameras, dynamic message signs (DMS), and a console application.

The HHT will give Caltrans field personnel a more ruggedized, robust system to deal with the specific task of maintaining and configuring traffic operations field elements. This will enable employees to get their work done faster, safer, and with dramatically reduced chances for loss of potentially expensive equipment.

The handheld terminal system will greatly enhance the capabilities of Caltrans field maintenance personnel by providing a highly portable, powerful, easy-to-use hardware/software kit based on ubiquitous COTS tablets. The software apps will provide feature-rich configuration and diagnostic capabilities for various field elements, as well as a general-purpose command-line interface.

When the HHT is available, it could eliminate the need for custom, costly, and cumbersome hardware typically used for current field element device setup and maintenance. This would reduce costs for the Caltrans, and simplify and increase portability of the hardware that field maintenance personnel need to carry in their vehicle. In addition, because personnel would need only the one device, the amount of time and trips needed to configure or diagnose field elements will be reduced. This would lead to reduced personnel costs, improved field element up-time, enhanced system operations, and reduction in fuel use and greenhouse emissions.

Due to unanticipated complexity and level of effort for the prototype system development, several key tasks (4 – 6) were only partially completed or were not performed. The COTS hardware evaluation, requirements development, and system engineering and design (Tasks 1 – 3) were all completed and documented herein. The prototype software development (Task 4) for the CCTV and DMS handheld terminal apps was only completed through an alpha prototype, and could not be adequately tested or demonstrated within the span of the research project. The hardware selection, procurement, and kit assembly portions of Task 4 were fully implemented. As the software prototypes were not ready, lab and field testing and demonstration (Tasks 5 and 6) were also omitted. Task 7 has been completed in the form of this report. As of this report, AHMCT and Caltrans DRISI have agreed to an action plan to complete the apps per developed requirements, and perform testing and update iterations to bring the handheld terminal concept to fruition. This work is occurring under a follow-on research project.

Future research should include expanding the number and variety of field element devices that the HHT can control and maintain. This should include expansion of the target field element hardware. It should also include expansion of the number of protocols supported for each ITS

hardware element. The goal would be to increase the functionality for Caltrans, and to expand the use of the HHT to other states.

The researchers recommend further testing of the handheld terminal system for DMS and CCTV field elements. We also recommend development of apps and any needed interface hardware for additional field element devices, including Road Weather Information Systems, Vehicle Detector Stations, Remote Traffic Microwave Sensors, traffic controller setup, and others. We recommend development of the needed communications protocols for additional sub-types within each field element category, e.g. additional camera protocols, additional DMS controller protocols, etc. We believe the system can be quickly deployed into Caltrans for use by field maintenance personnel. We also recommend a Pooled Fund study to evaluate adoption of the handheld terminal system by other DOTs.

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APPENDIX A:
CCTV APP SYSTEM REQUIREMENTS

Version 0.1

June 22, 2015

The following are the system requirements for the CCTV portion of the Handheld Terminal system.

1. Use

1.1. The app shall be used to diagnose and configure CCTV field elements
1.2. The app shall support use locally at the field element
1.3. The app shall support local diagnosis and configuration of the CCTV field element as a whole
1.4. The app shall support local diagnosis and configuration of the CCTV field element sub-systems individually
1.5. The app shall support use remotely from field element
1.6. The app shall support use remotely inside field element VPN network
1.7. The app may support use remotely outside field element VPN network
1.8. The app shall support remote diagnosis and configuration of the CCTV field element as a whole
1.9. The app shall support local diagnosis and configuration of the analog camera separately from the CCTV field element as a whole
1.10. The app shall support local diagnosis and configuration of the video encoder and camera as a unit separately from the CCTV field element as a whole
1.11. The app shall support local diagnosis and configuration of the PTZ controller separately from the CCTV field element as a whole
1.12. The app shall support local diagnosis and configuration of the PTZ controller and terminal server as a unit separately from the CCTV field element as a whole
1.13. The app shall support local diagnosis and configuration of digital cameras
1.14. The app shall support local diagnosis and configuration of analog cameras
1.15. The app shall support local diagnosis and configuration of cameras with integrated PTZ
1.16. The app shall support local diagnosis of CCTV field element sub-systems in a wireless fashion
1.17. The app shall support local diagnosis of CCTV field element sub-systems in a wired fashion
1.18. The app shall be intuitive to use
1.19. The app shall be easy to configure

2. Operating System

2.1. The app shall run on the Android OS
2.2. The app shall be compatible with Android versions 4.1 and up
2.3. The app shall run on Android tablets
2.4. The app shall run on Android phones

3. Protocols

3.1. The app shall decode H.264 encoded video
3.2. The app shall decode MPEG-4 encoded video
3.3. The app shall decode Motion JPEG encoded video
3.4. The app shall implement the Cohu i-series v6.8 PTZ control protocol
3.5. The app shall implement the Pelco-D v5.2.7 PTZ control protocol
3.6. The app shall implement the Sony Visca PTZ control protocol
3.7. The app shall use modular drivers to implement PTZ protocols

4. Communications

4.1. The app shall support TCP/IP communications over Wi-Fi
4.2. The app shall support TCP/IP communications over 3G/4G/LTE cellular networks
4.3. The app shall support TCP/IP communications over USB
4.4. The app shall support Serial communications over USB

5. User Interface

5.1. The user interface shall include a video view
5.2. The user interface shall include a camera configuration view
5.3. The user interface shall include a log view
5.4. The user interface shall include a diagnostics view
5.5. The user interface shall include a photo view
5.6. The user interface shall include an intuitive mechanism for switching between views
5.7. The user interface shall support tap gestures
5.8. The user interface may support double-tap gestures
5.9. The user interface shall support swipe gestures
5.10. The user interface shall support pinch gestures
5.11. The user interface shall support double-tap-slide gestures

6. Video View

6.1. The video view shall display the video output for the currently selected camera
6.2. The video view may have an icon to select the various cameras from the video view
6.3. The video view may have a spinner to select a camera and configuration from the video view
6.4. The video view shall have an icon to take a snapshot of the current video view
6.5. The video view shall support the use of swipe gestures to control the pan-tilt of the camera
6.6. The video view shall support the use of pinch gestures to control the zoom of the camera
6.7. The video view shall support the use of double-tap-slide gestures to control the zoom of the camera
6.8. The video view may support the use of tap/double-tap gestures to select a point in the video view and pan-tilt to the appropriate location
6.9. The video view shall support the use of tap gestures in the center of the video view to view video in full screen mode
6.10. The video view may support the use of swipe gestures from the top of the video view to return to normal viewing size with icons
6.11. The video view may support the use of double-tap gestures in the center of the video view to return to normal viewing size with icons
6.12. The video view shall display no camera selected state
6.13. The video view shall display connecting to camera video stream state
6.14. The video view shall support an additional options icon
6.15. The settings shall support overlay support of camera configuration and performance
6.16. The video view shall support a camera control keypad
6.17. The camera control keypad shall be a semitransparent overlay of the video view
6.18. The camera control keypad may be selected from the video view by icon
6.19. The camera control keypad may be selected by the use of swipe gestures from the bottom of the video view
6.20. The camera control keypad shall include arrows to control the pan-tilt of the camera
6.21. The camera control keypad shall include buttons to control the zoom of the camera
6.22. The camera control keypad shall include buttons to set camera presets
6.23. The camera control keypad shall include buttons to clear camera presets
6.24. The camera control keypad shall include buttons to go to camera presets
6.25. The camera control keypad shall include buttons to control the focus of the camera
6.26. The camera control keypad shall include buttons to control the iris of the camera
6.27. The camera control keypad shall include a mechanism to set various camera video overlays

7. Camera Configuration View

7.1. The camera view shall support the addition and selection of cameras
7.2. The camera view shall include an add camera icon
7.3. The camera view shall include a search for camera icon
7.4. The camera view may include an additional options icon
7.5. The camera view additional options icon may support camera list display by criteria
7.6. The camera view additional options icon shall support deletion of a camera
7.7. The camera view additional options icon shall support the import/export of cameras
7.8. The camera view shall display a list of currently defined cameras
7.9. The camera view shall support the definition of a tile next to the camera names
7.10. The camera view may support the automatic definition of the tile next to the camera names
7.11. The camera view shall support the use of swipe gestures to view a list of cameras
7.12. The camera view shall support the use of tap gestures to select a camera in the list
7.13. The camera view shall open the camera configurations view when a camera is selected
7.14. The camera view add camera icon shall open the camera configuration view
7.15. The camera configurations view shall include an edit configuration icon
7.16. The camera configurations view shall include an add configuration icon
7.17. The camera configurations view shall include an additional options icon
7.18. The camera configurations view additional options icon may support deletion of a camera configuration
7.19. The camera configurations view additional options icon may support deletion of all camera configurations
7.20. The camera configurations view shall include an edit camera configuration icon
7.21. The camera configurations view shall display a list of currently defined camera configurations
7.22. The camera configurations view shall support the use of swipe gestures to view a list of camera configurations
7.23. The camera configurations view shall support the use of tap gestures to select a camera configuration
7.24. The camera configurations view may open the video view when a camera configuration is selected
7.25. The camera configurations view shall open the camera configuration view when the edit icon is selected
7.26. The camera configuration view shall include an additional options icon
7.27. The camera configuration view additional options icon shall support discarding current changes
7.28. The camera configuration view additional options icon may support deletion of the current configuration
7.29. The camera configuration view shall include a settable configuration name
7.30. The camera configuration view shall include a settable video URL
7.31. The camera configuration view shall include a settable video protocol
7.32. The camera configuration view shall include a settable PTZ IP address
7.33. The camera configuration view shall include a settable PTZ port
7.34. The camera configuration view shall include a settable PTZ serial configuration
7.35. The camera configuration view shall include a settable PTZ protocol

8. Log View

8.1. The log view shall support all application logging

8.2. The log view shall include a spinner for selecting log level filtering
8.3. The log view shall include an additional options icon
8.4. The log view additional options icon shall support enabling logging to file
8.5. The log view additional options icon shall support setting file logging level
8.6. The log view additional options icon shall support setting maximum file size
8.7. The log view additional options icon shall support setting the number of rotating log files
8.8. The log view shall display a detailed timestamp
8.9. The log view shall display a log level
8.10. The log view shall display the module generating the log entry
8.11. The log view shall display the log entry
8.12. The log view shall support the use of swipe gestures to view the log

9. Diagnostics View

9.1. The diagnostics view shall support advanced diagnostics of camera PTZ units
9.2. The diagnostics view shall include a camera and configuration selection icon
9.3. The diagnostics view shall include a snapshot icon for capturing the currently displayed view
9.4. The diagnostics view shall include an additional options icon
9.5. The diagnostics view shall include a spinner containing all PTZ protocol request commands
9.6. The diagnostics view shall include a send request button
9.7. The diagnostics view shall include a response text box
9.8. The diagnostics view additional options icon shall support enabling response highlighting
9.9. The diagnostics view shall support highlighting response green upon success
9.10. The diagnostics view shall support highlighting response red upon failure
9.11. The diagnostics view shall have a custom request option

10. Photo View

10.1. The photo view shall support viewing and managing app snapshots
10.2. The photo view shall support use of swipe gestures
10.3. The photo view shall support use of tap gestures
10.4. The photo view shall support deletion of a snapshot
10.5. The photo view shall support viewing pictures by timestamp
10.6. The photo view shall support viewing pictures by camera

APPENDIX B:
DMS APP SYSTEM REQUIREMENTS

Version 0.1

June 24, 2015

The following are the system requirement for the DMS portion of the Handheld Terminal system.

1. Use

- **1.1.** The app shall be used to diagnose and configure DMS field elements
- **1.2.** The app shall support use locally at the field element
- **1.3.** The app shall support local diagnosis and configuration of the DMS field element as a whole
- **1.4.** The app shall support local diagnosis and configuration of the DMS field element sub-systems individually
- **1.5.** The app shall support use remotely from field element
- **1.6.** The app shall support use remotely inside field element VPN network
- **1.7.** The app may support use remotely outside field element VPN network
- **1.8.** The app shall support remote diagnosis and configuration of the DMS field element as a whole
- **1.9.** The app shall support local diagnosis of DMS field element in a wireless fashion
- **1.10.** The app shall support local diagnosis of DMS field element in a wired fashion
- **1.11.** The app shall be intuitive to use
- **1.12.** The app shall be easy to configure

2. Operating System

- **2.1.** The app shall run on the Android OS
- **2.2.** The app shall be compatible with Android versions 4.1 and up
- **2.3.** The app shall run on Android tablets
- **2.4.** The app shall run on Android phones

3. Protocols

- **3.1.** The app shall implement the SignView control protocol
- **3.2.** The app shall implement the NTCIP control protocol as implemented in the Caltrans AVMS
- **3.3.** The app may implement the ADDCO control protocol
- **3.4.** The app shall use modular drivers to implement control protocols

4. Communications

- **4.1.** The app shall support TCP/IP communications over Wi-Fi
- **4.2.** The app shall support TCP/IP communications over 3G/4G/LTE cellular networks
- **4.3.** The app shall support TCP/IP communications over USB
- **4.4.** The app shall support Serial communications over USB

5. User Interface

- **5.1.** The user interface shall include a DMS view
- **5.2.** The user interface shall include a DMS configuration view
- **5.3.** The user interface shall include a log view
- **5.4.** The user interface shall include a diagnostics view
- **5.5.** The user interface shall include a photo view
- **5.6.** The user interface shall include an intuitive mechanism for switching between views
- **5.7.** The user interface shall support tap gestures
- **5.8.** The user interface shall support swipe gestures

6. DMS View

- **6.1.** The DMS view shall display the state of the currently selected sign
- **6.2.** The DMS view may have an icon to select a sign and configuration

6.3. The DMS view may have a spinner to select a sign and configuration
6.4. The DMS view shall have an icon to take a snapshot of the current view
6.5. The DMS view may support the use of swipe gestures to control the view of multiple sign pages
6.6. The DMS view shall have a library of messages
6.7. The DMS view additional options icon shall support the import of library messages
6.8. The DMS view shall have the ability to enter custom messages
6.9. The DMS view may have the ability to set brightness
6.10. The DMS view may have the ability to set color
6.11. The DMS view may have the ability to set timing between pages
6.12. The DMS view may have the ability to get current fonts
6.13. The DMS view may have the ability to set current fonts
6.14. The DMS view shall support getting the sign's current state
6.15. The DMS view shall support setting the sign's state
6.16. The DMS view shall display no sign selected state
6.17. The DMS view shall display updating sign state

7. DMS Configuration View

7.1. The sign view shall support the addition and selection of signs
7.2. The sign view shall include an add sign icon
7.3. The sign view shall include a search for sign icon
7.4. The sign view may include an additional options icon
7.5. The sign view additional options icon may support sign list display by criteria
7.6. The sign view additional options icon shall support deletion of a sign
7.7. The sign view additional options icon shall support the import/export of signs
7.8. The sign view shall display a list of currently defined signs
7.9. The sign view shall support the definition of a tile next to the sign names
7.10. The sign view may support the automatic definition of the tile next to the sign names
7.11. The sign view shall support the use of swipe gestures to view a list of signs
7.12. The sign view shall support the use of tap gestures to select a sign in the list
7.13. The sign view shall open the sign configurations view when a sign is selected
7.14. The sign view add sign icon shall open the sign configuration view
7.15. The sign configurations view shall include an edit configuration icon
7.16. The sign configurations view shall include an add configuration icon
7.17. The sign configurations view shall include an additional options icon
7.18. The sign configurations view additional options icon may support deletion of a sign configuration
7.19. The sign configurations view additional options icon may support deletion of all sign configurations
7.20. The sign configurations view shall include an edit sign configuration icon
7.21. The sign configurations view shall display a list of currently defined sign configurations
7.22. The sign configurations view shall support the use of swipe gestures to view a list of sign configurations
7.23. The sign configurations view shall support the use of tap gestures to select a sign configuration
7.24. The sign configurations view may open the DMS view when a sign configuration is selected
7.25. The sign configurations view shall open the sign configuration view when the edit icon is selected

7.26. The sign configuration view shall include an additional options icon
7.27. The sign configuration view additional options icon shall support discarding current changes
7.28. The sign configuration view additional options icon may support deletion of the current configuration
7.29. The sign configuration view shall include a settable configuration name
7.30. The sign configuration view shall include a settable IP address
7.31. The sign configuration view shall include a settable port
7.32. The sign configuration view shall include a settable serial configuration
7.33. The sign configuration view shall include a settable protocol

8. Log View

8.1. The log view shall support all application logging
8.2. The log view shall include a spinner for selecting log level filtering
8.3. The log view shall include an additional options icon
8.4. The log view additional options icon shall support enabling logging to file
8.5. The log view additional options icon shall support setting file logging level
8.6. The log view additional options icon shall support setting maximum log file size
8.7. The log view additional options icon shall support setting the number of rotating log files
8.8. The log view shall display a detailed timestamp
8.9. The log view shall display a log level
8.10. The log view shall display the module generating the log entry
8.11. The log view shall display the log entry
8.12. The log view shall support the use of swipe gestures to view the log

9. Diagnostics View

9.1. The diagnostics view shall support advanced diagnostics of signs
9.2. The diagnostics view shall include a sign and configuration selection icon
9.3. The diagnostics view shall include a snapshot icon for capturing the currently displayed view
9.4. The diagnostics view shall include a camera icon for capturing the currently displayed test results on the sign
9.5. The diagnostics view shall include an additional options icon
9.6. The diagnostics view additional options icon shall support importing diagnostic routines
9.7. The diagnostics view shall include a spinner containing all diagnostic routines
9.8. The diagnostics view shall include a begin routine button

10. Diagnostic Routines

10.1. The routine library shall include a full on pattern
10.2. The routine library shall include a full off pattern
10.3. The routine library shall include a flashing full on-off pattern
10.4. The routine library shall include a checkerboard pattern
10.5. The routine library may include a color bar pattern
10.6. The routine library shall include all symbols in the selected font set
10.7. The routine library shall exercise all pixels
10.8. The routine library shall exercise all states of pixels

11. Photo View

11.1. The photo view shall support viewing and managing app snapshots and pictures

11.2. The photo view shall support use of swipe gestures
11.3. The photo view shall support use of tap gestures
11.4. The photo view shall support deletion of a snapshot
11.5. The photo view shall support sorting pictures by timestamp
11.6. The photo view shall support sorting pictures by sign

APPENDIX C:
CONSOLE APP SYSTEM REQUIREMENTS

Version 0.1

June 24, 2015

The following are the system requirement for the Console portion of the Handheld Terminal system.

1. Use

1.1. The app shall be used to diagnose and configure Telnet accessible field elements
1.2. The app shall be used to diagnose and configure SSH accessible field elements
1.3. The app shall support use locally at the field element
1.4. The app shall support local diagnosis and configuration of field elements
1.5. The app shall support local diagnosis and configuration of the field element sub-systems individually
1.6. The app shall support use remotely from field element
1.7. The app shall support use remotely inside field element VPN network
1.8. The app may support use remotely outside field element VPN network
1.9. The app shall support remote diagnosis and configuration of the field element as a whole
1.10. The app shall support Telnet
1.11. The app shall support SSH

2. Operating System

2.1. The app shall run on the Android OS
2.2. The app shall be compatible with Android versions 4.1 and up
2.3. The app shall run on Android tablets
2.4. The app shall run on Android phones

3. Communications

3.1. The app shall support TCP/IP communications over Wi-Fi
3.2. The app shall support TCP/IP communications over 3G/4G/LTE cellular networks
3.3. The app shall support TCP/IP communications over USB

4. User Interface

4.1. The user interface shall include a command line
4.2. The user interface shall support last command history
4.3. The user interface may support multiple command history
4.4. The user interface may support command macros
4.5. The user interface shall support copy and paste
4.6. The user interface shall support connection management
4.7. The user interface shall support external keyboards

APPENDIX D:
HANDHELD TERMINAL KIT SYSTEM REQUIREMENTS

Version 0.1

June 24, 2015

The following are the system requirement for the Kit portion of the Handheld Terminal system.

1. Kit

1.1. The kit shall be used to diagnose and configure CCTV field elements
1.2. The kit shall be used to diagnose and configure CMS and VMS field elements
1.3. The kit shall be used to diagnose and configure generic field elements with a serial interface
1.4. The kit shall support use locally at the field element
1.5. The kit shall support local diagnosis and configuration of the CCTV field element as a whole
1.6. The kit shall support local diagnosis and configuration of the CMS and VMS field element as a whole
1.7. The kit shall support local diagnosis and configuration of the CCTV field element sub-systems individually
1.8. The kit shall support local diagnosis and configuration of the CMS and VMS field element sub-systems individually
1.9. The kit shall support use remote from field element
1.10. The kit shall support use remote inside field element VPN network
1.11. The kit may support use remotely outside field element VPN network
1.12. The kit shall support remote diagnosis and configuration of the CCTV field element as a whole
1.13. The kit shall support remote diagnosis and configuration of the CMS and VMS field element as a whole
1.14. The kit shall be composed of a case housing various hardware, software, and cabling
1.15. The kit shall include a single storage case
1.16. The kit shall include a tablet
1.17. The kit shall include all necessary interface cabling
1.18. The kit shall include a Wi-Fi access point
1.19. The kit may include a terminal server
1.20. The kit may include a video monitor
1.21. The kit shall include software applications
1.22. The kit shall be portable by a single person
1.23. The kit shall weigh less than 20 lb
1.24. The kit shall be easily deployed
1.25. The kit shall be easily stored in a vehicle
1.26. The kit shall have an operational temperate range of 0 to 70C
1.27. The kit may have an operational temperature range of -20 to 70C
1.28. The kit shall have a storage temperature range of -40 to 70C

2. Storage Case

2.1. The storage case shall be portable
2.2. The storage case shall have a form factor similar to a briefcase
2.3. The storage case shall weigh less than less than 10 lb
2.4. The storage case shall have an interior volume of at least 0.5 cubic feet
2.5. The storage case shall be watertight
2.6. The storage case shall be dustproof
2.7. The storage case shall be crushproof
2.8. The storage case shall be impact resistant
2.9. The storage case shall be abrasion resistant
2.10. The storage case shall have form-fitting compartments to hold contents
2.11. The storage case shall be foam filled

2.12. The storage case shall allow end user customization of foam
2.13. The storage case shall be storable over -40 to 70C

3. Tablet

3.1. The tablet shall be portable
3.2. The tablet shall be lightweight
3.3. The tablet shall be high resolution
3.4. The tablet shall include a display greater than 7 inches diagonal
3.5. The tablet shall be operable in typical outdoor lighting conditions
3.6. The tablet shall be drop resistant
3.7. The tablet shall be impact resistant
3.8. The tablet may use a protective enclosure
3.9. The tablet shall include Wi-Fi
3.10. The tablet shall support 2.4 GHz Wi-Fi band
3.11. The tablet may supports 5.8 GHz Wi-Fi band
3.12. The tablet shall support 802.11b/g/n wireless
3.13. The tablet may support 802.11a wireless
3.14. The tablet may support 802.11ac wireless
3.15. The tablet shall have a runtime of at least 9 hours between charges
3.16. The tablet shall support the Android operating system
3.17. The tablet shall have a minimum Android OS version of 4.1
3.18. The tablet shall have USB networking compiled into the OS
3.19. The tablet shall be chargeable using a vehicle DC power outlet
3.20. The tablet shall be chargeable using an AC power outlet
3.21. The tablet shall include a camera
3.22. The tablet shall include a Micro-USB 2.0 port
3.23. The tablet shall be operable from 0 to 50C
3.24. The tablet may be operable from -30 to 50C for limited periods of time
3.25. The tablet shall be storable from -40 to 70C

4. Cabling

4.1. The cabling shall include one Micro-USB B to USB A Female USB adapter pigtail
4.2. The cabling shall include one USB A Male to RJ45 Ethernet adapter pigtail
4.3. The cabling may include one USB A Male to RS232 DB-9 Female serial cable at least 3 ft long
4.4. The cabling may include one RS232 DE-9 Male to RS422/RS485 DE-9 Male adapter
4.5. The cabling may include one USB A Male to RS422/485 DE-9 Female serial cable at least 3 ft long
4.6. The cabling shall include one BNC Male to BNC Male coaxial cable at least 6 ft long
4.7. The cabling may include one DE-9 Female to 170-C2 Male serial cable at least 6 ft long
4.8. The cabling shall include one Ethernet cable at least 6 ft long
4.9. The cabling shall include one DE-9 gender changer
4.10. The cabling shall be RoHS compliant
4.11. The cabling shall be operable from -30 to 50C
4.12. The cabling shall be storable from -40 to 70C

5. Wi-Fi Access Point

5.1. The hotspot shall support 2.4 GHz band

5.2. The hotspot may support 5.8 GHz band
5.3. The hotspot shall support 802.11b/g/n wireless
5.4. The hotspot may support 802.11a
5.5. The hotspot may support 802.11ac
5.6. The hotspot shall be easy to configure
5.7. The hotspot shall have a minimum of one Ethernet port
5.8. The hotspot may support RS232
5.9. The hotspot may support RS422/RS485
5.10. The hotspot shall be powered by an AC-to-DC converter
5.11. The hotspot shall be operable from -30 to 50C
5.12. The hotspot shall be storable from -40 to 70C

6. Terminal Server

6.1. The terminal server shall have a minimum of one serial port
6.2. The terminal server serial port shall be DB-9 Male
6.3. The terminal server shall support RS232
6.4. The terminal server shall support RS422/RS485
6.5. The terminal server shall be easily configurable
6.6. The terminal server shall be powered by an AC-to-DC converter
6.7. The terminal server shall be operable from 0 to 50C
6.8. The terminal server may be operable from -30 to 50C
6.9. The terminal server shall be storable from -40 to 70C

7. Video Monitor

7.1. The video monitor shall support analog video input
7.2. The video monitor shall support NTSC resolutions 720x480 to 176x120
7.3. The video monitor shall be compact
7.4. The video monitor shall be usable in typical outdoor lighting conditions
7.5. The video monitor shall have a BNC Female input connector
7.6. The video monitor may have an RCA Female input connector
7.7. The video monitor may be battery powered
7.8. The video monitor may be powered by an AC-to-DC converter
7.9. The video monitor shall be operable from 0 to 50C
7.10. The video monitor may be operable from -30 to 50C
7.11. The video monitor shall be storable from -40 to 70C

8. Software

8.1. The software shall be pre-installed on the tablet
8.2. The software shall include a CCTV application
8.3. The software shall include a CMS and VMS application
8.4. The software shall include a Serial Console application
8.5. The software may include a VPN application