Achieving Security in a Campus Environment Using Available Mobile Unit Technology

A White Paper prepared for ADT
26 February 2009

1 INTRODUCTION

On campuses throughout the country the modern day student is abandoning the use of land lines as a communication method and is relying heavily on a mobile device. As a result the trend is more and more towards removal of costly land line infrastructure by colleges and Universities under constant economic pressures. This has presented serious issues with respect to personal security since currently deployed systems cannot precisely locate a mobile device in a dense multi-story urban environment. What is needed is a system that complements existing security systems and services by solving the problem of precise location determination for mobile devices in environments where GPS (Global Positioning Satellite) or triangulation have difficulty performing, for example, locating someone experiencing an emergency within a high-rise building with multiple rooms. While currently available techniques may be able to locate the building, these methods can not locate precisely where the call originated.

A solution to this problem does exist. It is an in-building location determination system that provides convenience, added value, safety, and security for mobile device operators via the following capabilities:

1) Precise location information, for instance "Building 100, 3rd Floor, Room 310"
2) Accelerated emergency personnel response time
3) Options to provide supplemental information to the mobile device such as floor plans, escape routes, etc.
4) Options for providing "on site" message routing from a control point to the mobile station.
5) Options for tracking the movement of the mobile device.
6) Options for event driven vectoring of security cameras.
7) The ability to enhance the performance of other location or message based applications, which can interface with the solution system.

2 The Business Case

As of 2008, wireless penetration in the U.S. is estimated at over 80% and approximately 18% of households have no landline phone at all. The number of wireless-only households is projected to reach 20% by the end of 2009. The reliance on a wireless phone is even more pronounced in the under 25 year-old segment on college campuses. Many college students never install a landline phone; instead they rely completely on wireless phones. According to a recent CDC study nearly 31% of adults aged 18-24 years live in households with only wireless telephones.

This trend has serious implications for emergency responders tasked with responding to wireless callers. Public safety personnel estimate that about 50 percent of the millions of 911 calls they receive daily are placed from wireless phones, and that percentage is growing. Current E911 systems are not capable of providing detailed location information. Often a wireless caller's location can only be narrowed to within a few thousand feet and the problem is even more pronounced when the caller is in a multi-story building or in a dense, multi-building environment. Emergency responders can waste valuable time trying to locate a caller. At times this has had tragic results such as the instance in Utah where a man having a heart attack called 911 from his wireless phone, but was unable to state his location. He died before emergency responders could find him.

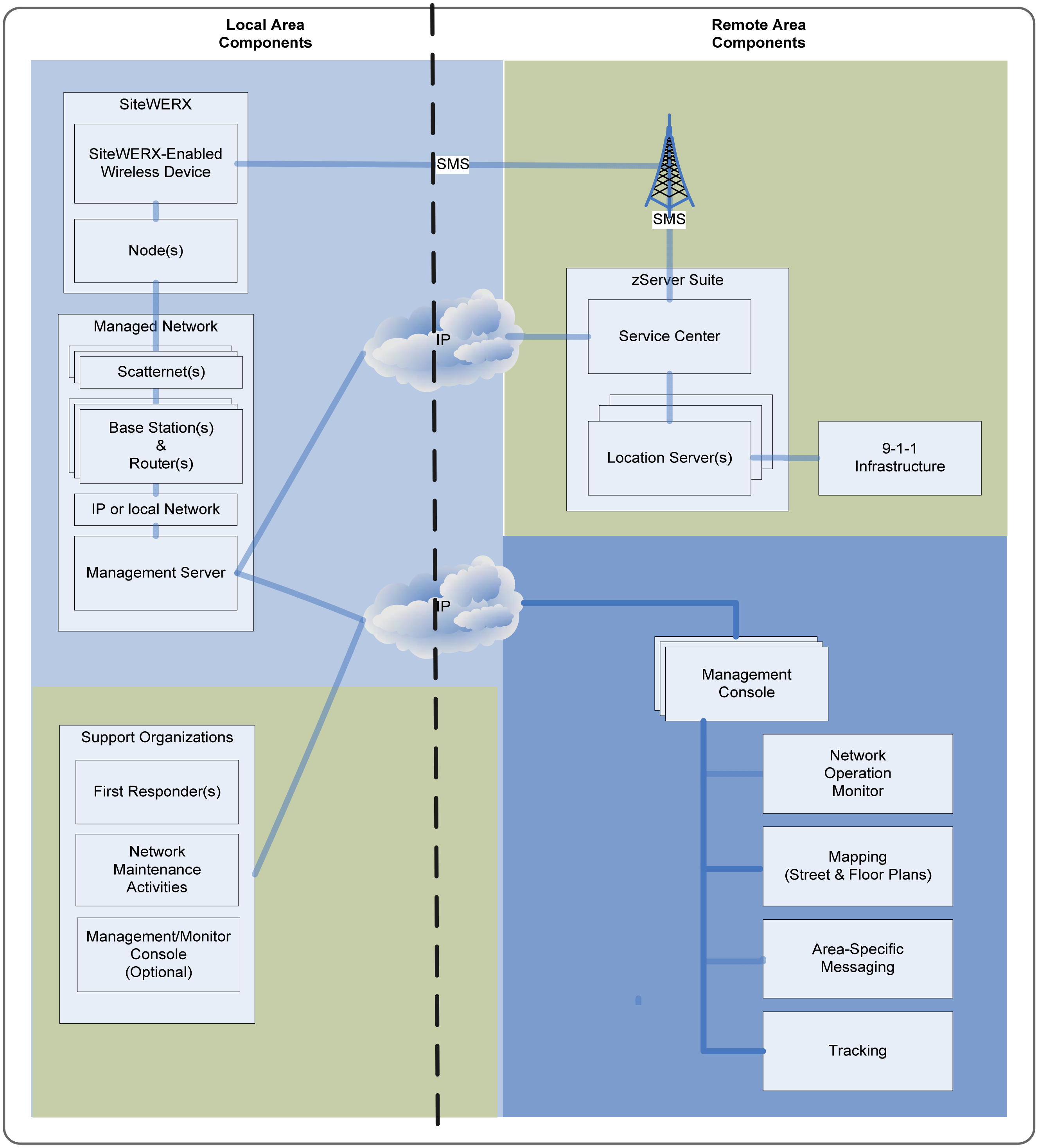
3 The SOLUTION

The principle objectives of the solution system are to provide precise mobile unit location information when a specific number is called and to provide localized messaging for security personnel specialized use. The System can be installed in any multi-floor building and provide the correct floor and position on the floor within 30 feet for any mobile device that can connect to the system.

The solution is comprised of two key ingredients. One takes advantage of the fact that most mobile devices now employ a Bluetooth radio. A Bluetooth network (scatternet) consisting of a base station and a series of location nodes is deployed throughout the target environment to communicate to the mobile device a precise location description. The nodes are low cost, and are compatible with most mobile devices being manufactured today. Secondly, the mobile device is equipped with an application that resides on the mobile device, scans the environment for location nodes, selects the appropriate node, and communicates with the external infrastructure by transmitting information over an SMS data link, and by exchanging information with the SiteWERX location nodes over the Bluetooth radio link.

The two main elements of the solution are complemented by a comprehensive support sub-system that is comprised of two elements. Element one is a scatternet management system that provides complete control and monitoring of the chained location nodes. The managed system is used to send and receive messages to/from the scatternet nodes and provide event notifications and location data for display at the Managed System console(s). **If a mobile station is able to connect to a location node, the Managed System can provide a location regardless of whether or not the mobile device has cell coverage.** Element two is a location data server that communicates both with the mobile device via the SMS link and the Managed System via the Internet to provide detailed position information to a Location Requesting Entity (LRE) that may be an element in the public safety system (E9-1-1) or a custom customer application. The location server can be used to query the mobile unit for a location. The location server receives call-associated SMS data transmitted from the wireless mobile device. The location data detail is based upon whether or not the mobile unit can connect to a location node. The Location Server normally passes location specific information pertaining to the call to the public safety Location Requesting Entity (LRE) interface.

Figure 1 illustrates a typical architecture for the solution system.



College Campus Elements

Support Organization Elements

ADT Elements

Figure 1 Security System Overview

4 SOLUTION SYSTEM COMPONENTS

The following summarize the configuration and key benefits of the system.

4.1 Bluetooth Scatternet

A scatternet consists of one or more Location Nodes (SLN's) and a Bluetooth / WIFI Base Station. The Base Station and Nodes form a serial communication chain using Bluetooth radios. The Base Station uses an 802.11 WIFI radio module to maintain a remote wireless communication link with a local area network, allowing the system to be managed by a PC with access to this LAN. It is fundamentally a "bridge" between the wireless management system and the Bluetooth radio equipped location nodes. A Node may be configured to act as a dedicated Bluetooth bridge between a Node and the next Node in the chain that may be "out-of-range". The Node acting as the bridge is not allowed to communicate with any element other than its upstream and downstream Bluetooth addresses. This feature provides flexibility in defining and extending any specific scatternet. In addition, load balancing can be accomplished using multiple Base Stations, i.e., multiple scatternets.

The location node is composed of a Bluetooth radio module, flash memory, and custom firmware. The SLN also incorporates an onboard low drop out regulator so that the device may be powered with six to eighteen volts DC. A serial peripheral interface (SPI) and UART are available via a ten-pin 1.26mm pitch connector. Overall dimensions of the SLN board are approximately 28 x 32 x 8 mm.

The location node is the fundamental element of the solution system and may be operated as a stand-alone location determination device or as a member of a Bluetooth scatternet (node chain) for wider area location determination.

The Location Node includes the following key capabilities and features.

- **"Over-the-Air" configuration**
  Firmware in combination with the Bluetooth module allows the SLN to be highly configurable. Provisions have been made for the setting of maximum transmit power, a force-use flag, extended address location information, E911 location information destination, and the node's scatternet chain link addresses (upstream and downstream).

  Transmit power settings provide the capability to survey an installation site and tune the node placements to ensure location definition within 30 feet.

  The force –use flag may be used to ensure that any mobile device connecting to the node will use the location data provided by that node and not the information that may be available from other nodes discoverable by the mobile device in the same general area.

Extended address information includes the geo-coordinates, the installation identification, a full MSAG street address, and in-building information to include floor number and position on the floor within 30 feet (office numbers, column numbers, area numbers, or whatever building specific position identification method exists).

The location information destination for emergency calls is the SMS routing code. The Node can be configured with this information element and is capable of providing it to the mobile device. This feature provides real time capability to control where the mobile device will automatically send location data during an emergency call.

The Node's link (Bluetooth address) to its upstream and its downstream node counterparts sets the position of the Node in the scatternet chain. Being able to set these addresses provides capability to remove, move, or add nodes to a network chain during operations thereby making it possible to maintain an operational network even in the face of a node failure.

- **Node access limited to enabled devices**
  The node firmware ensures that during device inquiry scans only mobile devices that have the custom application installed can discover and subsequently connect to a Location Node. This enables the node processing to focus on the location determination mission of the system and helps ensure quicker access to the location data by the mobile device.

- **Security**
  The node communication links employ a binary encrypted protocol. Node firmware ensures that the connection is legal for the installation specific environment and will drop all illegal, invalid, or quiet connections.

- **Health and Status**
  The node has the capability to report its status over the scatternet to the managed system server and on to the network management console where the status query and response messages are logged and may be displayed.

- **Network Communications**
  The node by virtue of its ability to communicate with the mobile device and a managed server through the scatternet, provides a robust communications path for mobile devices. This feature opens up the possibility for a full range of information transfer to/from the mobile device including server based text to the mobile device via the node. It enables customers to implement a wide range of special purpose applications specific to their needs and requirements.

- **Location Data Message**
  The node, at installation, is configured with a non-volatile location data set that, besides the standard latitude/longitude of the applicable location, also includes an extended address. The extended address defines the building identification, the floor the node is located on, the office, room, or area where the node is located, the type of area, and a free form location description. The data message also provides other key information such as its identification and emergency message routing information.

- **Free-form ASCII messaging**
  The node is capable of storing free form ASCII messages. The messages originate at the server and have an identification and severity code. The node notifies the SiteWERX enabled mobile device of available messages during the discovery phase of a connection. Once connected, the mobile device can retrieve the message(s) by severity code or by identification.

- **Canned messages**
  The node is capable of storing one message code which has a specific customer defined meaning. The node notifies the mobile device of the message during the discovery phase of a connection.

SLNs are housed in small containers (3”L x 2.5”W x 1.5”H) connected to a distribution system that must be powered by 4.2 to 18 volts DC. The node has a power consumption of less than 1 watt, operates in a temperature range of –40 degrees C to 70 degrees C and humidity between 5%-80% non-condensing.

The Base Station (SBS) hardware device utilized to establish the scatternet is composed of a Bluetooth radio module, a WiFi radio module, a micro-controller with flash memory, power circuitry, and custom firmware. A serial peripheral interface (SPI) and UART are available via a ten-pin 1.26mm pitch connector. The system management software interacts with the environment via the Base Station over a wide-area network. The software communicates with the Base Stations through its Wi-Fi radio, while the Base Station communicates with the Location nodes though its Bluetooth radio.

The Base Station is the key connecting element of the scatternet. The Base Station includes the following key capabilities and features.

- **IP Bridge to Bluetooth Network**
  The principle function of the Base Station is to provide a link from a remote network element (computer system) to the Bluetooth scatternet nodes for control and monitoring of the scatternet and ultimately to provide a communications path between the network element and enabled mobile devices that are connected to the scatternet nodes. The link is established by using the Base Station’s 802.11 B/G capability to connect to the network element and then its Bluetooth radio to connect to the location nodes.

- **Security**
  The Base Station employs WPA/TKIP encryption.

- **Health and Status**
  The Base Station has the capability to report its status over the scatternet to the managed system server and on to the network management console where the status query and response messages are logged and may be displayed.

- **Network Communications**
  A key Base Station feature is its connection auto-recovery capability which will re-establish the TCP/IP socket connection with the Managed Server and/or its downstream node Bluetooth connection should either connection be dropped.

SBS's are housed in containers (4"L x 5.5"W x 1.5"H). The SBS is normally connected directly into a standard constant 110v AC 60Hz power source. The Base Station has a power consumption of less than 10 watts, operates in a temperature range of –40 degrees C to 70 degrees C and humidity between 5%-80% non-condensing.

4.2 Mobile Devices

The System currently supports mobile communication devices that utilize either Microsoft Windows CE or J2ME (MIDP 2.0 CLDC 1.1). In order to take advantage of the location determination system, Mobile Devices must have a Bluetooth radio and be capable of receiving and sending SMS messages without operator intervention. They must be loaded with the custom application that employs both the Bluetooth radio interface and SMS messaging.

The purpose of the mobile device application and its selection algorithm is to enable a mobile communications device to select the correct Location Node and obtain detailed location information from that node.

The custom mobile device software component provides a key set of capabilities and features regardless of the operating system platform utilized by the mobile device. Those features are as follows:

- **Portability**
  A modular object oriented design with the main objective being a design that provides a portable code base for ease of extension to multiple device implementations and degrees of access to operating system services.

- **Node Selection**

All device versions of the application employ a common implementation of the node selection algorithm.

- **Extended Address Retrieval**
  All device versions of the application are capable of connecting to a location node, retrieving, and storing an extended address defining the location details of the mobile device.

- **Subscriber Registration**
  All device versions of the application are capable of sending a standard registration message to the Location Server ("Z-Server") using the SMS link. The registration message is required before a mobile device will be recognized as a legal participant in the location system.

- **Installation**
  All device versions of the application can be installed using a WEB based installation procedure. The mobile device user must be careful to ensure that the device has a supported operating system installed.

4.3 Support System

Location Server System

The Location Server system software is configured to operate in a Server Computer. The system that is utilized is a high performance web server consisting of Dual Intel Xeon Quad Core X5310 processors with 4.0 GB of FBDIMM memory. It is equipped with 320 GB Mirrored Storage, and a 2x Intel Pro 10/100/1000 network interface card. The operating system software is Linux.

The location Server system is used to receive location requests from the public safety system LRE, SMS location data transmitted from the wireless mobile device, process location specific information pertaining to the call, respond to the location request with a location data message to the LRE interface, and record all session related data in a database (part of the location server software system).

E911 events principally originate from messages transmitted by an ALI data source in the form of a location request, from an enabled device in the form of message exchanges, from the managed system, or from the PSAP in the form of queries.

The server, designed as a multiple thread program to accommodate multiple active events simultaneously, is structured as a background service that runs without user intervention whenever the host system is running.

Managed System Server and Managed Console Software

The Managed System Server application is hosted in equipment equal to or equivalent to the location server.

The key features implemented by the Managed System Server and its management application are as follows:

- **Server Architecture**
  The server employs Windows Server 2003 and uses Microsoft's Internet Information Services extensively. The associated database employs the MySQL Database Engine. The server is implemented as a collection of background windows services each of which performs a major function of the scatternet management task. Each service employs multiple execution threads to handle multiple cases of the same information type exchange. The server system is capable of performing an automatic recovery in the event of a power loss or system restart.

- **User Interface** Display and control of the managed system and it's attached scatternets is provided to users over the local network containing the server or over the internet This user interface features the following capabilities:

  1. Server based access control wherein only authorized users have access and based upon need only to features that are applicable to their use of the system.

  2. Extensive use of context sensitive help with pop-up windows supplying details concerning a selected item or action.

  3. Display/control screens that feature the managed system state. The display screens provide extensive "drill-down" capability to access the various levels of detailed information pertaining to the displayed activity.

  4. Capability is provided to display a complete set of graphical information describing the location of interest. This includes the building, the floor, the scatternet chain and the nodes. Included is a comprehensive editing feature wherein the detailed information pertaining to the building may be edited and the scatternet chains in the building may be configured, nodes in the chain moved up or down in the sequence, added to the chain, or deleted from the chain. Editing a node includes the ability to define the detailed hardware configuration information, configuration information pertaining to the operating mode of the node, and the extended address provided by the node when a mobile device connects.

  5. The mobile device location feature provides the capability to display all mobile devices connected to a scatternet and the location of those

devices in the implemented facility. Additionally, the devices can be "tracked" as they move about the facility.

6. The messaging activity feature displays a summary of the most recent message traffic on the scatternet(s) with capability to control the number of messages displayed. Included is the capability to pop-up an expanded description along with a link to view all of the details pertaining to a specific message. Coupled with the message status is the ability to compose/edit and send messages to one or all nodes in a chain.

7. The Subscriber/mobile device feature provides the capability to add, edit, or deactivate a system subscriber and the description and configuration of the mobile device the subscriber is using. Included with this feature is the ability to search the database for existing devices.

8. The historical reporting feature provides capability to retrieve, display, and output all node and chain traffic, all subscribers and associated mobile devices, and area specific messaging activity.

- **Browser-based user interface**
  Display and control of the managed system and its attached scatternets is provided to users/customers over the internet by a comprehensive set of browser based web pages.

- **Location Server Emergency Notification**
  A key feature supporting public safety applications is the ability of the managed system server to detect when a mobile device connected to a node in the managed system initiates an emergency call and then send an emergency notification message with applicable location data to the applicable location server (Z-Server) thereby supplementing the normal SMS notification of the emergency by the mobile device.

Database Component

The solution system uses relational databases (MySQL Database Engine) to store information about each event, query, and response that travels through the Location Server system and the Managed System Server. The location server database component records mobile device registration messages, location data queries from LRE's, and the location data messages transmitted to LRE's. The Managed System database component records all node and chain traffic, the subscribers and mobile devices that are recognized elements of the system, all area specific messaging and its status (messages posted, delivered, and read), and graphical position information (floor plans. Each relational database is designed to be Database Engine independent.

The databases can be accessed and updated by multiple applications simultaneously. This capability is a critical feature in supporting the real-time nature of the location determination system.

5 Solution Performance

The solution system performance for E911 support is measured in terms of its capability to return precise location information in a timely manner. When a Mobile Client connects with a location node, it normally selects from several possible nodes using logic in the Mobile Client custom application selection algorithm. Ideally, it selects the closest node on the correct floor in the correct building, and downloads its location information. Ideally, when it then makes a 911 call, the location information is sent to the local Public Service Answering Point (PSAP) in sufficient time to permit a timely response.

A key parameter used to evaluate system performance is the Location Accuracy.

In 2008, a System developed by WirelessWERX was installed in a two-story office building approximately 40,000 square feet in area. Extensive data was taken for two configurations of the location system. A detailed analysis of the resulting data is presented in the accompanying appendix.

Both data sets provided results consistent with a Normal distribution with approximately 67% of the data points occurring within one σ, and 95% occurring within two σ.

The system worst-case location accuracy performance provides:

Correct Building	100 %
Correct Floor	96.5%
Correct Location within 13 meters (~43 ft)	67%
Correct Location within 18 meters (~60 ft)	95%

Current FCC accuracy and reliability requirements for E911 Phase II operations for handset-based solutions are;

50 meters for 67% of calls, 150 meters for 95% of calls

There are no stated requirements for correct building identification or vertical information such as floor number.

System Performance Appendix to Achieving Security in a Campus Environment Using Available Mobile Unit Technology

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Solution Performance Appendix

A key parameter used to evaluate system performance is the Location Accuracy.

In 2008, a System developed by WirelessWERX was installed in a two-story office building approximately 40,000 square feet in area. The building outer walls are concrete as is the floor/ceiling between the two stories. The entire top floor has a drop-ceiling, while the bottom floor is mostly an open ceiling area. Several offices along an outer wall have a drop-ceiling. On both floors there is a mixture of low-walled cubicles and some fully walled offices, storage, and utility areas with wooden doors. During the initial site survey twenty seven location nodes were installed, fourteen on floor 1 and thirteen on floor 2.

On floor 1, six were installed in specific offices along the ceiling, and eight were installed at a height of eight to ten feet in the open cubicle areas, each with about the same coverage area.

On floor 2, nine nodes were installed in offices or other areas with wooden doors, and four were installed in open cubicle areas. In all cases the nodes were installed along the drop-ceiling.

A Base Station was installed on each floor to form the link from the Bluetooth scatternet to the Management System Console located in a utility area on floor 1.

Data Acquisition Procedure

Following hardware installation, the location nodes were configured with their precise in-building locations. As a final step in the Site Survey effort, the integrated system was tested for functionality and location accuracy.

On floor 1, 16 positions were selected for data acquisition and recording. On floor 2, 14 positions were selected. Each selected position is in close proximity to one or more specific node(s) which are designated as the desired or correct node(s), to be selected for that position. Any node within thirty feet of the selected position is considered a correct node.

At each selected position a Mobile Client is enabled to run the custom application software. During the test operation, when a node is selected by the Mobile Client, the selected node is recorded. Pre-printed data sheets are provided for each position which includes the appropriate options and blanks for each data point expected for that position; e.g., at every position, at least twelve data points are recorded. For each of three search cycles on the mobile client, a data value is recorded with the mobile client aligned to four azimuth points: 0, 90, 180, and 270 degrees.

Data Analysis

As previously mentioned, the purpose of the selection algorithm is to enable a mobile client to select the correct location node and obtain detailed location information.

Data from the installation of 13 September was processed to develop a Location Error, in meters, for each node selection. For example, for each recorded data point, the distance from the selected node to the mobile client location was measured. Those measurements were then used to calculate a statistical mean (μ), and standard deviation (σ).

The location errors were then separated into intervals, and relative frequency distributions were calculated to construct a frequency histogram (Figure 1).

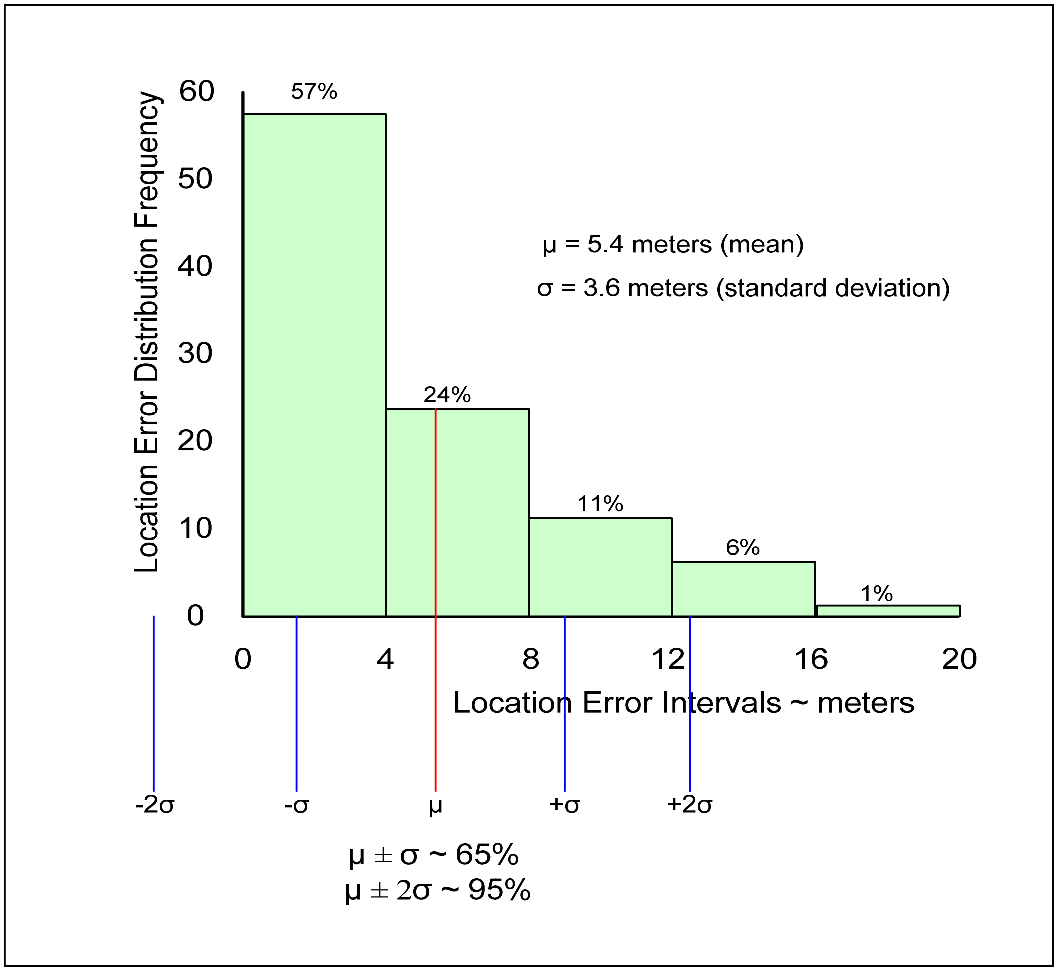

Figure 1 Site Survey Location Error Frequency Histogram

The histogram illustrates that the location error, in the horizontal plane, is less than 9 meters in 65% of the test cases and less than 13 meters in 95% of the cases.

Elevation error is not shown, but in this data set, the elevation error was zero; all selected nodes were on the proper floor in 100% of the 498 node acquisition events.

Following the site survey data review it was decided to revise the node locations to increase the areal coverage on both floors. The coverage on floor 1 was expanded from approximately 1000 square feet to about 1800 square feet. Floor 2 coverage was expanded from approximately 500 square feet to about 1100 square feet. In addition, three nodes were added on floor 1 for a total of 17 and four nodes were added on floor 2 for a total of 18. Acquisition tests were repeated on both floors. Data acquisition procedures were identical to those for the site survey, except the number of test cases was increased from approximately 500 to 950. Test data were processed to produce the statistical mean and standard deviation as shown in Figure 2.

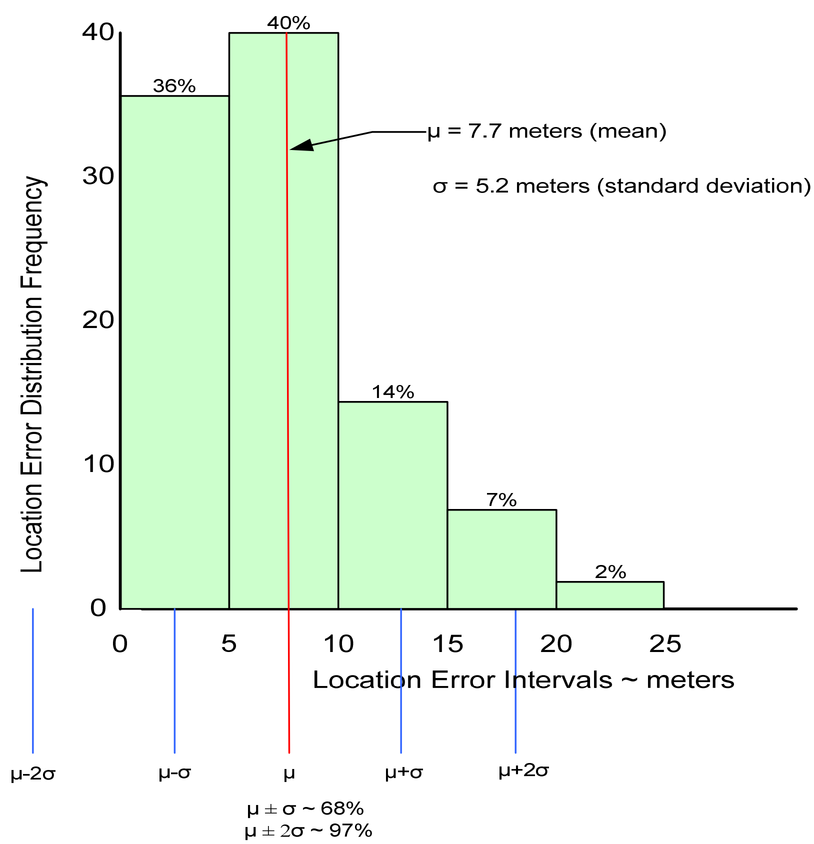

Figure 2 Final Installation Location Error Frequency Histogram

Individual floor data and total sample data are shown in Figure 3

Site Survey

Sample Space	N	μ ~ meters	σ ~ meters	μ+σ ~ 67%	μ+2σ ~ 95%
Floor 1	271	5.9	4.3	10.2	14.5
Floor 2	227	4.8	2.6	7.4	10.0
Total Sample	**498**	**5.4**	**3.6**	**9.0**	**12.6**

Final Installation

Sample Space	N	μ ~ meters	σ ~ meters	μ+σ ~ 67%	μ+2σ ~ 95%
Floor 1	427	7.9	5.5	13.4	18.9
Floor 2	408	7.3	4.8	12.1	16.9
Total Sample	**835**	**7.7**	**5.2**	**12.9**	**18.1**

Figure 3 Site Survey and Final Installation Data Comparison

During the Final Installation tests, in 1.8% of the test cases no node was selected. In addition, in approximately 3.5% of the test cases, a node on the incorrect floor was selected. These cases were not considered in the statistical calculations.

During the Site Survey test, there were two test cases, ~ 1%, in which no node was selected, and no test cases in which a node on the incorrect floor was selected.

In reviewing the statistical means and standard deviations for the two data sets as well as the totals for “no node selected” and “incorrect floor events it appears that the system changes made between the site survey configuration and the final installation, i.e., the decrease in node density and increased test positions (primarily in areas of low node densities) resulted in an increase in location error. This is clearly illustrated in Figure 4 which shows the location error for individual floors with respect to node density.

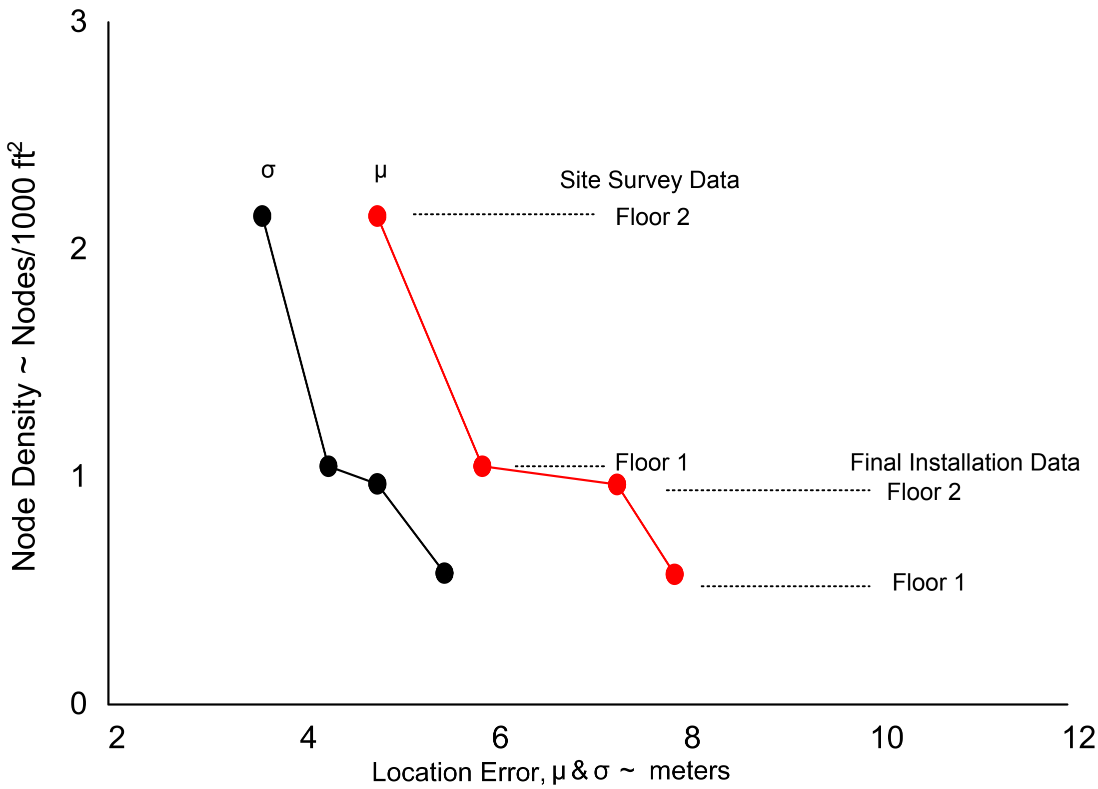

Figure 4 Location Error vs. Node Density

Conclusions

Both data sets provided results consistent with a Normal distribution with approximately 67% of the data points occurring within one σ, and 95% occurring within two σ.

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