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MARTIN DAWSON, JAMES WINTERBOTTOM, & MARTIN THOMSON

IP LOCATION

Martin Dawson
James Winterbottom
Martin Thomson

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Martin Dawson—*To the Lyons-Dawson gang: Kate, Andrew, and Elena.*

James Winterbottom—*To my wife, Loraine; my children, Vanessa, Michael, and Emma; and to my parents, David and Elizabeth.*

Martin Thomson—*To Jamie, with thanks for the unquestioning support.*

About the Authors

Martin Dawson (BEng-elec, MEngSc) is the chief product architect of the Andrew Geometrix Mobile Location Center development team based in Wollongong, Australia. Martin Dawson's engineering career has spanned 29 years, from work in real-time embedded microprocessor control systems (the early days of local area network deployments) to paying his dues in a university network admin role. The past 19 years have been spent in networking and telecommunications. This includes a period of time with British Telecom Research Laboratories in the UK developing Service Creation Environments for Intelligent Networks (IN), and with Telstra, where he also developed IN services. Prior to joining Andrew Corporation, he worked for Nortel for 11 years developing a wide range of solutions with a focus on wireless IN services and the development of cellular location systems for emergency and commercial services.

He is currently active in forums for cellular and IP location technologies, and acts as consultant to industry, government, regulatory authorities, and emergency agencies. He is a member of the North American National Emergency Number Association (NENA) and has contributed to the working group focused on the development of solutions for VoIP emergency services.

James Winterbottom has over 20 years of experience in the Telecom industry and is currently a Senior Product Architect with Andrew Corporation's Geometrix Mobile Location Center. In recent years, James has worked in the cellular location industry, but throughout his career he has developed an expertise in CDMA provisioning and management systems, as well as intelligent network services. Currently, James is active in standards forums for IP location technologies, and acts as a consultant to industry, government, and regulatory authorities. He is a member of the North American National Emergency Number Association (NENA) and is active in NENA working groups concerned with determining and using location to support VoIP emergency services. He is also an active participant in the IETF, developing solutions to address the problems of determining, acquiring, and conveying location in IP networks. James is the official liaison from the ESIF Next Generation Emergency Services (NGES) working group to the IETF Geopriv and ECRIT working groups.

Martin Thomson is an engineer with Andrew Corporation. He has spent five years developing cellular wireless products for Nortel and Andrew Corporation, in particular the Mobile Location Center (MLC). Since 2004, Martin has been working in research for IP location and has produced a number of specifications, including several IETF Internet drafts. Martin has also been involved in the development of prototype systems for location in IP networks.

About the Technical Editor

Greg Burdett has 18 years of telecom experience and has worked in numerous senior management leadership positions for telecom companies. Greg also has multiple patents in the field of telecommunications (two awarded; two pending). Since 2001, he has focused his energy in the area of location, for both the cellular as well as IP location contexts. He was the Business Lead for the Mobile Location Center (MLC) business at Nortel until 2005, and led the activity to divest the MLC business to Andrew Corporation, which completed in August 2005. In October 2005, Greg launched his own consulting company, Jagged Networks (www.Jaggednetworks.com), where he provides consulting/advisory services to broadband service providers and location solution vendors in order to assist them with their VoIP 911/IP location product strategies.

Foreword

Resilience, redundancy, reliability, security, interoperability, and efficiency. These are all ingredients for a great book on emergency location information and exchange. It has been a pleasure to meet the authors of this book, both at conferences internationally and in the UK. I had the pleasure of meeting with Martin Dawson when he was our guest at the NICC in the UK and whilst visiting one of our BT 999 call centers. The challenges discussed in this book, as well as their solutions, have been discussed in parallel with the authors on the other side of the world by myself, my colleagues, and members of the NICC and BT. When I met Martin in the U.S.A. at ATIS, he was like a breath of fresh air, and I discovered I was not the only one shouting "VoIP emergency access is international and this must not be forgotten!" The presence of the authors at these bodies shows not only commitment, but also a determination to ensure that this flow of IP information can function globally. The fundamentals of the solutions in this book are, in 2007, being followed and are currently under consideration for implementation in Australia, the U.S.A., Canada, and Europe. Voice over IP (VoIP) or Multimedia Voice over IP (MVoIP) is a rapidly growing market. The growth is evident in both the replacement of traditional fixed line networks and the uptake of soft phones. The range of access technologies is ever increasing and the mainstream is based on IP.

Many calls to the emergency services are silent calls. They are calls from people in distress who are unable to talk due to the prevailing situation, or they are from injured or sick people who may have dialed 911, 112, 999, 000, or one of the other national variants of emergency access numbers, but dropped the phone. These callers' locations not only need to be identified but also passed, accurately, around the appropriate services. In today's world of commerce, mobility, and users that are nomadic in nature, we can no longer rely on the home address details of callers being their actual location. Indeed, many corporate networks and VoIP-outsourced networks have single points of break-out from their networks onto the PSTN (such that the caller's location within the corporate network is concealed). There is a need for communication providers to take heed of the contents of this book. It is a must-read, not only for efficient planning and network implementation, but also to help save lives.

Ian Hopkins
BT 999 Product Manager VoIP,
United Kingdom,
25th July 2006

Acknowledgments

Martin Dawson
Firstly, I have to thank my co-authors; they never cease to amaze me with their output, ingenuity, skills, and downright cleverness. Most of all, to my beloved Rosemontatorium crew: Thank you for your forbearance and support despite my apparent state of perpetual distraction.

James Winterbottom
I would like to thank my co-authors, the two Martins, for the effort they have put into making sure that this book covers all its topics as thoroughly as possible. Thanks also to Hannes Tschofenig for pointing me toward various specifications that I may have otherwise missed.

Martin Thomson
I would like to thank my co-authors for the opportunities I have been given while working with them. There are also a number of people at the IETF who have vigorously opposed some of the concepts that are documented in this book, which has ultimately forced me to refine my thinking, and for which I am grateful.

And from All of Us
Thanks to the team at Andrew Network Solutions in Wollongong, Australia and Ashburn, VA, U.S.A. for giving us the latitude to focus beyond the world of cellular location. Thanks also to the many wonderful people and personalities in the industry who contributed to bringing the ideas in this book to life, including Barbara Stark, Nadine Abbott, Anand Akundi, Tom Breen, Brian Rosen, Patti McCalmont, Greg Burdett, Guy Caron, Ed Shrum, Tom Anschutz, Perry Prozeniuk, Carl Reed, and Bill Barnes. Our apologies to those many others that we have neglected to mention.

Introduction

Defining Location

Location is a quantity which is so fundamental that it forms part of the gestalt of every human being. Everyone has an instinctive sense of what is meant by *location,* and yet if you were to ask for a definition of the term you might be surprised by the varied responses it would elicit. Ask somebody "Where are you now?" and you will get responses ranging from "I'm at home," "I'm in the car," "I'm at 27 Homebay Drive, Watsonia,"—or going to the extreme of subjectivity: "I'm in a state of confusion." In very rare circumstances, somebody may actually reply "I'm 32 degrees south latitude and 150 degrees east longitude...." All of the preceding are potentially correct and are expected responses, depending completely on the context within which the questions were asked. But in discussing location in this book, at least some refinement of the term is needed.

As a starting point, *location* in this book refers to "geographical location." That is, it is concerned with a spatial location associated with a physical point or region relative to the surface of the earth. It does not refer to other types of location such as a logical network location. For example, an IP device will certainly have a physical spatial location, but the IP address does not represent that location. The IP address represents a logical network location; it identifies the network and host-ID associated with the device and tells internetworking elements how to route the packets so they arrive at the correct network location. There is no direct correspondence between this location and the geographical location. They are not equivalent, as shown in Figure 1, and the process of going from an arbitrary IP address to a location is much more involved than a simple static translation from one to the other.

It is evident that context is a major consideration when even spatial location is being discussed. If someone says they are "in the car," then that may be all that is important in terms of the application of the dialog which is occurring with them. It may not be important what the geospatial coordinates of the car are, or the coordinates may be quite implicitly associated with the car. This version of location ("in the car") can be called application-specific. In other words, it is a version of the information which is relevant to

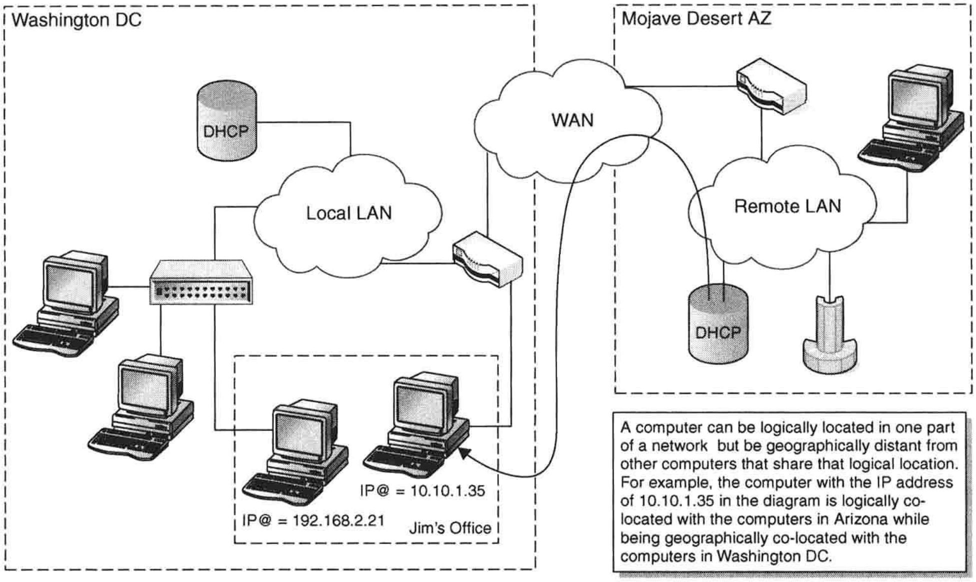

Figure 1 Logical network location versus geographic location.

the discussion at hand and which could mean something very different in another discussion—for instance, in another application. If location information is being sourced from a network element that is independent of the application using the location, then a more application-independent form of location information is desirable.

There is a form of location which is less open to interpretation, that is application-independent, and whose meaning tends to be immutable even over extensive periods of time. This is the geodetic form of location and it is generally expressed in degrees north or south of the equator, and east or west of the zeroth meridian. Given a well-defined shape for the Earth (a defined geoid; see Figure 2) and specific locations for zero coordinates, and allowing that it is the position relative to the surface of the Earth that is of interest despite the Earth's unceasing wandering against the backdrop of the greater universe, then the geodetic form provides a thoroughly objective and immutable form of location. The World Geodetic System of 1984 (WGS 84) specification (see Reference 1 at the end of the introduction) is an example of such an application-independent system for defining geographic location.

While geodetic form provides a definitive form of application-independent location specification, it is not a form which humans frequently use. One of the most common forms of location specification used by humans is the "civic address" form. This is commonly thought of in terms of the familiar street number, street name, municipality/city, state, and country form. There are a number of documented forms for such addresses (see References 2 and 3). Indeed, the variation in the civic address form across international jurisdictions is considerable. Street numbers do not exist in all jurisdictions, for

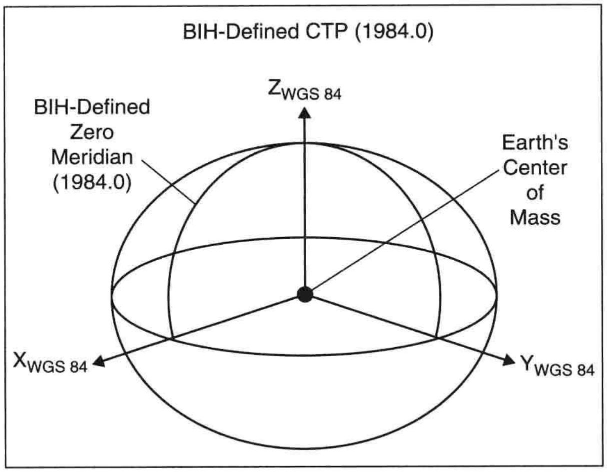

Figure 2 The standard Earth geoid, as defined in WGS 84.

example, and the naming of streets is also subject to considerable variation. Further, the scope of a given civic address form may vary depending on application. For instance, a room and building number may be definitive in the scope of a single business campus, but they do not provide a globally definitive location since they don't actually tell you where on earth that building is. Despite the scope for variation in the civic form of location, however, it is a familiar one which maintains a good degree of application-independence within a significant subset of all location-based applications.

In the rest of this text, when location is discussed, the meaning of the term *location* will refer to a spatial geographic location in either geodetic form or civic address form. Any other definition of the term will be identified where it is used in the text.

Why a Book on IP Location?

At this moment in history, it is not really possible to talk about IP location without discussing Internet telephony or voice over IP (VoIP) and the manner in which emergency services can be contacted using VoIP. This is described in more detail later but it stems from the fact that whether it's 911 in North America, 112 in Europe, 000 in Australia, or any of the many regional variants on the number, there is an almost global expectation and indeed critical need that emergency services be contactable via the most common publicly accessible voice* service. Up until now, that has been the public

* Yes—TTY, or teletype, is used in support of deaf callers and it could be argued that this isn't "voice". The distinction is noted with the observation that this alphanumeric character transmission function is also carried over traditional voice circuits using the telephone network. Hopefully the intent of the point above is not obscured by this specific subtlety.

switched telephone network. We have entered a period where the plain old telephony service (POTS), and the switched circuit network behind it, have gone into decline and are being replaced by broadband Internet access as the standard all-purpose communication network. It is similarly inevitable that ubiquitous and reliable mechanisms for contacting emergency services using Internet telephony* will be required, both for practical and legal reasons.

So what does geo-location have to do with IP telephony usurping POTS, and emergency services being a requirement for both? It is relevant for the simple fact that location information is fundamental to the delivery of a single-number emergency calling service. In many jurisdictions, it is necessary to route the call to a different emergency call center depending on the location of the caller. In almost all jurisdictions it is a requirement to automatically deliver the caller's location to the emergency call center operator, without relying on the caller to provide it verbally. For better or worse, and no matter what applications for location follow in its wake, emergency service for IP telephony establishes the fundamental requirement for an IP location component of Internet access.

The authors have worked for a number of years through the development of the cellular-location industry, in the development of requirements, architectures, protocols, and, ultimately, deployed technology to support location determination in mobile phone networks. What was the driver for this technology? Once more the imperative was established because of the need to provide location for emergency calls originating from arbitrary locations within those cellular networks.

When the Federal Communications Commission (FCC) in the United States issued a mandate in 1996 that cellular networks should support the enhanced-911 (E911) functionality including location-based routing and location delivery, there was a scramble by different players to come up with a magic solution to this imperative. Every other week another new company would announce some technology that "solved the cellular E911 challenge." In the end, though, there was no "magic" solution. Location services (or LCS as it is commonly, if puzzlingly, abbreviated) as a network function is complex. It's not just about how to measure where someone is—whether it's with GPS, or the triangulation of measured radio signals, or some other clever invention. This is just a small element and, often, it's not where the greatest industry investment ends up being spent. In order to provide consistent and reliable LCS, an entire network architecture must be developed. This must not only involve what's happening between the device and the radio access network, but the whole core network that is responsible for routing request messages telling the appropriate systems when a location needs to be determined. The location information has to have a standard and consistent way of being delivered through networks so that it reaches the application of interest—for example,

* Many assert that IP emergency "call" centers will be able to be contacted in many other forms—such as instant messaging and video. No disagreement; at time of writing, however, it is essentially a voice service and, it is certain, voice will continue to be a significant form of communication with emergency call centers into the future.

the emergency call center operator display. It has to be able to work for all manner of devices and not just those fitted with some specific vendor's technology.

In the end, for cellular, this meant the painstaking definition of an end-to-end network architecture with all the necessary protocols and parameter underpinnings. It touched everything from the application through the core network switches down through the radio controller elements, and the devices themselves. Without an end-to-end architecture based on open standards, there is no reliable, ubiquitous, and consistent location service.

With a history in the development of the LCS industry for cellular networks, the authors came to the emerging IP telephony and associated emerging emergency services imperative with a view that there could be no effective piecemeal solution to putting LCS in place for Internet services. In developments that, in many ways, reflected the same early days of cellular LCS, there were a number of concurrent, though somewhat uncoordinated, proposals. Examples include Reference 4 for DHCP and the LLDP-MED specification.

While the device's geo-location is not actually a piece of network configuration information, it is seductively tempting to just add it as another parameter that can be provided by DHCP. After all, that allows a device connecting to an IP network to utilize a standard mechanism, in order to "discover" its new location. The IETF specification, Reference 4, describes such an approach. However, the view of it is limited to the relationship between two single entities—the IP device and the DHCP server. There is no end-to-end network perspective on how this relationship fits into the larger picture of

Dynamic Host Configuration Protocol (DHCP) (see Reference 4)

DHCP delivers network configuration information to an IP device. The intent is to provide the device with all the information it needs to utilize the IP network it's connected to. This includes information such as the IP address allocated to the device, the address of the gateway through which the traffic destined beyond the LAN should be sent, and/or the identity of the Domain Name Service (DNS) that can be requested to translate the names of network hosts into their physical IP addresses in order to talk to them. RFC3825 describes an option on DHCP that allows the device to request and receive a specific form of location information.

Link Layer Discovery Protocol for Media End-Point Devices (LLDP-MED)

At much the same time that RFC3825 was working through draft stages in the IETF, the TIA was defining extensions to the link layer discovery protocol (LLDP) to support additional information elements applicable to media end-point devices. These were termed LLDP-MED (Link Layer Discovery Protocol for Media End-point Devices) and included the ability for those end-point devices to be informed of the location associated with—for example—the 802.3 Ethernet switch port to which they are currently attached.

access technologies, applications, and the entities which may, in practice, be responsible for determining and underwriting the location of an Internet user. It does not facilitate any interaction with the device in terms of determining location, nor does it deal with the many public Internet access service considerations, such as the fact that DHCP is not a protocol typically used to deliver configuration from a broadband access network to the subscriber's device. And it does not provide any way to securely fix location information as being from a recognized and/or answerable entity; this last part being quite important to the operators of emergency services.

As a generic LCS infrastructure solution, LLDP-MED is similarly constrained compared to DHCP. It has the advantage of supporting location provisioned to specific switch ports, but it is still highly specific to this family of access technologies—typically, enterprise deployments. It has no application, for example, to broadband Internet access via DSL. Neither does it address issues of location source security.

Despite their fairly narrow focus, both DHCP and LLDP, with their associated location information extensions, were actively proposed and discussed as solutions to the larger VoIP 911 challenge. The author's felt that both mechanisms—although valid for specific scenarios involving location acquisition—did not provide either the generality or the end-to-end integrity necessary to support a global and consistent LCS capability for Internet services and, in particular, did not support emergency services calls using Internet telephony.

Drawing on experiences from the development of the cellular LCS infrastructure for both emergency and commercial services, and by understanding requirements through participation in numerous forums such as the National Emergency Network Association (NENA), the IETF, and ETSI, as well as engaging in discussions with emergency network authorities and regulators globally, the authors developed what, in their view, is a complete architecture for LCS. It is based on end-to-end requirements, providing a logical model for LCS in IP networks and identifying the specific network elements, interfaces, protocols, and parameters necessary to support general LCS services.

Such an architectural perspective on LCS has a good deal of complexity associated with it. Understanding the individual parts is not adequate unless the overarching principles are also understood. Going from architecture to successful implementation in a particular IP access network type requires an application of those principles, lest the requirements get lost in the details. The relatively simple two-peer details of DHCP or LLDP can be understood from specifications without much elaboration. The authors recognize that understanding a complete IP location architecture demands more substantial support for someone new to the area. It is for this reason that we decided to write this book. It is our desire that it will give the reader a firm understanding of the architecture as well as guidelines on the best approach to successfully implementing it in their networks and using it with their applications. It is our earnest hope that this book will facilitate the deployment of location services for the Internet and provide the robust and consistent underpinnings to support important social functions such as reliable access to emergency services by those in need, and contribute to the general utility, power, and fun of the Internet in general.

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