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J. Polk
J. Schnizlein
M. Linsner
Cisco Systems
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Dynamic Host Configuration Protocol Option for Coordinate-based Location Configuration Information

Status of this Memo

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Abstract

This document specifies a Dynamic Host Configuration Protocol Option for the coordinate-based geographic location of the client. The Location Configuration Information (LCI) includes latitude, longitude, and altitude, with resolution indicators for each. The reference datum for these values is also included.

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1. Introduction

This document specifies a Dynamic Host Configuration Protocol [1] Option for the coordinate-based geographic location of the client, to be provided by the server.

The DHCP server is assumed to have determined the location from the Circuit-ID Relay Agent Information Option (RAIO) defined (as SubOpt 1) in [2]. In order to translate the circuit (switch port identifier) into a location, the DHCP server is assumed to have access to a service that maps from circuit-ID to the location at which the circuit connected to that port terminates in the building, for example, the location of the wall jack.

An important feature of this specification is that after the relevant DHC exchanges have taken place, the location information is stored on the end device rather than somewhere else, where retrieving it might be difficult in practice.

Another important feature of this LCI is its inclusion of a resolution parameter for each of the dimensions of location. Because this resolution parameter need not apply to all dimensions equally, a resolution value is included for each of the 3 location elements.

Resolution does not define Geographic Privacy policy.

The resulting location information using this resolution method is a small fixed length Configuration Information that can be easily carried in protocols, such as DHCP, which have limited packet size because this LCI is only 18 bytes long.

Finally, the appendix of this document provides some arithmetic examples of the implication of different resolution values on the La/Lo/Alt.

1.1. Conventions used in this document

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [3].

1.2. Motivation

As applications such as IP Telephony are replacing conventional telephony, users are expecting the same (or greater) level of services with the new technology. One service offered by conventional telephony that is missing in any standardized fashion within IP Telephony is for a user to be automatically located by emergency responders, in a timely fashion, when the user summons help (by dialing 911 in North America, for example). Unless strict administrative rules are followed, the mobility of a wired Ethernet device within a campus negates any opportunity for an emergency responder to locate the device with any degree of expediency. Users do not want to give up the mobility IP Telephony offers. Informing the host device of its geo-location at host configuration time will allow the device to utilize this geo-location information to inform others of its current geo-location, if the user and/or application so desires.

The goal of this option is to enable a wired Ethernet host to obtain its location, which it could provide to an emergency responder, as one example.

Wireless hosts can utilize this option to gain knowledge of the location of the radio access point used during host configuration, but would need some more exotic mechanisms, maybe GPS, or maybe a future DHCP option, which includes a list of geo-locations like that defined here, containing the locations of the radio access points that are close to the client.

1.3. Rationale

Within the LCI described here, Latitude and Longitude are represented in fixed-point 2s-complement binary degrees, for the economy of a smaller option size compared to a string encoding of digits in [7]. The integer parts of these fields are 9 bits long to accommodate +/- 180 degrees. The fractional part is 25 bits long, better than the precision of 7 decimal digits. The length of each field is 40 bits, 34 of which is the sum of the integer (9) and fractional (25) bits, plus 6 bits of resolution.

Altitude is determined by the Altitude Type (AT) indicated by the AT field, which is 4 bits long. Two Altitude Types are defined here, meters (code=1) and floors (code=2), both of which are 2s-complement fixed-point with 22 bits of integer part and 8 bits of fractional part. Additional Altitude Types MAY be assigned by IANA. The "floors" Altitude Type is provided because altitude in meters may not be known within a building, and a floor indication may be more useful.

GPS systems today can use WGS84 for horizontal and vertical datums; [6] defines WGS84 as a three-dimensional datum. For other datum values that do not include a vertical component, both the horizontal and vertical datum of reference will be specified in the IANA record.

Each of these 3 elements begins with an accuracy sub-field of 6 bits, indicating the number of bits of resolution. This resolution sub-field accommodates the desire to easily adjust the precision of a reported location. Contents beyond the claimed resolution MAY be randomized to obscure greater precision that might be available.

2. DHC Location Configuration Information Elements

DHCP is a binary Protocol; using protocols of LCI are likely to be text based. Since most coordinate systems translate easily between binary-based and text-based location output (even emergency services within the US), translation/conversion is a non-issue with DHCP's binary format.

This binary format provides a fortunate benefit in a mechanism for making a true/correct location coordinate imprecise. It further provides the capability to have this binary representation be deterministically imprecise.

The LCI format is as follows:

```
  0                   1                   2                   3
  0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |   Code 123    |      16       |   LaRes   |     Latitude      +
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |                Latitude (cont'd)              |   LoRes   |   +
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |                             Longitude                           |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |   AT  |   AltRes  |                Altitude                     |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |  Alt (cont'd) |     Datum     |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

2.1. Elements of the Location Configuration Information

Code 123: The code for this DHCP option.

16: The length of this option is 16 bytes.

LaRes: Latitude resolution. 6 bits indicating the number of valid bits in the fixed-point value of Latitude.

This value is the number of high-order Latitude bits that should be considered valid. Any bits entered to the right of this limit should not be considered valid and might be purposely false, or zeroed by the sender.

The examples in the appendix illustrate that a smaller value in the resolution field increases the area within which the device is located.

LaRes does not define Geographic Privacy policy.

Values above decimal 34 are undefined and reserved.

Latitude: a 34 bit fixed point value consisting of 9 bits of integer and 25 bits of fraction. Latitude SHOULD be normalized to within +/- 90 degrees. Positive numbers are north of the equator and negative numbers are south of the equator.

A value of 2 in the LaRes field indicates a precision of no greater than 1/6th that of the globe (in the first example of the appendix). A value of 34 in the LaRes field indicates a precision of about 3.11 mm in Latitude at the equator.

LoRes: Longitude resolution. 6 bits indicating the number of valid bits in the fixed-point value of Longitude.

This value is the number of high-order Longitude bits that should be considered valid. Any bits entered to the right of this limit should not be considered valid and might be purposely false, or zeroed by the sender.

LoRes does not define Geographic Privacy policy.

Values above decimal 34 are undefined and reserved.

Longitude: a 34 bit fixed point value consisting of 9 bits of integer and 25 bits of fraction. Longitude SHOULD be normalized to within +/- 180 degrees. Positive values are East of the prime meridian and negative (2s complement) numbers are West of the prime meridian.

A value of 2 in the LoRes field indicates precision of no greater than 1/6th that of the globe (see first example of the appendix). A value of 34 in the LoRes field indicates a precision of about 2.42 mm in longitude (at the equator). Because lines of longitude converge at the poles, the distance is smaller (better precision) for locations away from the equator.

Altitude: A 30 bit value defined by the AT field

AltRes: Altitude resolution. 6 bits indicating the number of valid bits in the altitude. Values above 30 (decimal) are undefined and reserved.

AltRes does not define Geographic Privacy policy.

AT: Altitude Type for altitude. Codes defined are:

1: Meters - in 2s-complement fixed-point 22-bit integer part with 8-bit fraction

If AT = 1, an AltRes value 0.0 would indicate unknown altitude. The most precise Altitude would have an AltRes value of 30. Many values of AltRes would obscure any variation due to vertical datum differences.

2: Floors - in 2s-complement fixed-point 22-bit integer part with 8-bit fraction

AT = 2 for Floors enables representing altitude in a form more relevant in buildings which have different floor-to-floor dimensions. An altitude coded as AT = 2, AltRes = 30, and Altitude = 0.0 is meaningful even outside a building, and represents ground level at the given latitude and longitude. Inside a building, 0.0 represents the floor level associated with ground level at the main entrance. This document defines a number; one must arrive at the number by counting floors from the floor defined to be 0.0.

The values represented by this AT will be of local significance. Since buildings and floors can vary due to lack of common control, the values chosen to represent the characteristics of an individual building will be derived and agreed upon by the operator of the building and the intended users of the data. Attempting to standardize this type of function is beyond the scope this document.

Sub-floors can be represented by non-integer values. Example: a mezzanine between floor 1 and floor 2 could be represented as a value = 1.1. Example: (2) mezzanines between floor 4 and floor 5 could be represented as values = 4.1 and 4.2 respectively.

Floors located below ground level could be represented by negative values.

Larger values represent floors that are above (higher in altitude) floors with lower values.

The AltRes field SHOULD be set to maximum precision when AT = 2 (floors) when a floor value is included in the DHCP Reply, or the AT = 0 to denote the floor isn't known.

Any additional LCI Altitude Types(s) to be defined for use via this DHC Option MUST be done through a Standards Track RFC.

Datum: The Map Datum used for the coordinates given in this Option

The datum must include both a horizontal and a vertical reference. Since the WGS 84 reference datum is three-dimensional, it includes both. For any additional datum parameters, the datum codepoint must specify both horizontal datum and vertical datum references.

The Datum byte has 256 possibilities, of which 3 have been registered with IANA by this document (all derived from specification in [5]):

1: WGS 84 (Geographical 3D) - World Geodesic System 1984, CRS Code 4327, Prime Meridian Name: Greenwich

2: NAD83 - North American Datum 1983, CRS Code 4269, Prime Meridian Name: Greenwich; The associated vertical datum is the North American Vertical Datum of 1988 (NAVD88)

This datum pair is to be used when referencing locations on land, not near tidal water (which would use Datum = 3 below)

3: NAD83 - North American Datum 1983, CRS Code 4269, Prime Meridian Name: Greenwich; The associated vertical datum is Mean Lower Low Water (MLLW)

This datum pair is to be used when referencing locations on water/sea/ocean

Any additional LCI datum(s) to be defined for use via this DHC Option MUST be done through a Standards Track RFC.

3. Security Considerations

Where critical decisions might be based on the value of this GeoConf option, DHCP authentication in [4] SHOULD be used to protect the integrity of the DHCP options.

Since there is no privacy protection for DHCP messages, an eavesdropper who can monitor the link between the DHCP server and requesting client can discover this LCI.

To minimize the unintended exposure of location information, the LCI option SHOULD be returned by DHCP servers only when the DHCP client has included this option in its 'parameter request list' (section 3.5 [1]).

When implementing a DHC server that will serve clients across an uncontrolled network, one should consider the potential security risks.

4. IANA Considerations

IANA has assigned a DHCP option code of 123 for the GeoConf option defined in this document.

The GeoConf Option defines two fields for which IANA maintains a registry: The Altitude (AT) field (see Section 2) and the Datum field (see Section 2). The datum indicator MUST include specification of both horizontal and vertical datum. New values for the Altitude (AT) field are assigned through "Standards Action" [RFC 2434]. The initial values of the Altitude registry are as follows:

AT = 1 meters of Altitude defined by the vertical datum specified.

AT = 2 building Floors of Altitude.

Datum = 1 denotes the vertical datum WGS 84 as defined by the EPSG as their CRS Code 4327; CRS Code 4327 also specifies WGS 84 as the vertical datum

Datum = 2 denotes the vertical datum NAD83 as defined by the EPSG as their CRS Code 4269; North American Vertical Datum of 1988 (NAVD88) is the associated vertical datum for NAD83

Datum = 3 denotes the vertical datum NAD83 as defined by the EPSG as their CRS Code 4269; Mean Lower Low Water (MLLW) is the associated vertical datum for NAD83

Any additional LCI datum(s) to be defined for use via this DHC Option MUST be done through a Standards Track RFC.

5. Acknowledgements

The authors would like to thank Patrik Falstrom, Ralph Droms, Ted Hardie, Jon Peterson, and Nadine Abbott for their inputs and constructive comments regarding this document. Additionally, the authors would like to thank Greg Troxel for the education on vertical datums, and to Carl Reed.

Appendix: Calculations of Imprecision Possible with the DHC LCI

The following examples for two different locations demonstrate how the Resolution values for Latitude, Longitude, and Altitude can be used. In both examples the geo-location values were derived from maps using the WGS84 map datum, therefore in these examples, the datum field would have a value = 1 (00000001, or 0x01).

A.1. Location Configuration Information of "White House" (Example 1)

The address was NOT picked for any political reason and can easily be found on the Internet or mapping software, but was picked as an easily identifiable location on our planet.

Postal Address:
White House
1600 Pennsylvania Ave. NW
Washington, DC 20006

Standing on the sidewalk, north side of White House, between driveways.

```
Latitude 38.89868 degrees North (or +38.89868 degrees)
Using 2s complement, 34 bit fixed point, 25 bit fraction
Latitude = 0x04dcc1fc8,
Latitude = 0001001101110011000001111111001000
```

```
Longitude 77.03723 degrees West (or -77.03723 degrees)
   Using 2s complement, 34 bit fixed point, 25 bit fraction
   Longitude = 0xf65ecf031,
   Longitude = 1101100101111011001111000000110001
```

Altitude 15

In this example, we are not inside a structure, therefore we will assume an altitude value of 15 meters, interpolated from the US Geological survey map, Washington West quadrangle.

```
AltRes = 30, 0x1e, 011110
AT = 1, 0x01, 000001
Altitude = 15, 0x0F00, 00000000000000000000000001111100000000
```

If: LaRes is expressed as value 2 (0x02 or 000010) and LoRes is expressed as value 2 (0x02 or 000010), then it would describe a geo-location region that is north of the equator and extends from -1 degree (west of the meridian) to -128 degrees. This would include the area from approximately 600km south of Saltpond, Ghana, due north to the North Pole and approximately 4400km

south-southwest of Los Angeles, CA due north to the North Pole. This would cover an area of about one-sixth of the globe, approximately 20 million square nautical miles (nm).

If: LaRes is expressed as value 3 (0x03 or 000011) and LoRes is expressed as value 3 (0x03 or 000011), then it would describe a geo-location area that is north from the equator to 63 degrees north, and -65 degrees to -128 degrees longitude. This area includes south of a line from Anchorage, AL to eastern Nunavut, CN, and from the Amazons of northern Brazil to approximately 4400km south-southwest of Los Angeles, CA. This area would include North America, Central America, and parts of Venezuela and Columbia, except portions of Alaska and northern and eastern Canada, approximately 10 million square nm.

If: LaRes is expressed as value 5 (0x05 or 000101) and LoRes is expressed as value 5 (0x05 or 000101), then it would describe a geo-location area that is latitude 32 north of the equator to latitude 48 and extends from -64 degrees to -80 degrees longitude. This is approximately an east-west boundary of a time zone, an area of approximately 700,000 square nm.

If: LaRes is expressed as value 9 (0x09 or 001001) and LoRes is expressed as value 9 (0x09 or 001001), which includes all the integer bits, then it would describe a geo-location area that is latitude 38 north of the equator to latitude 39 and extends from -77 degrees to -78 degrees longitude. This is an area of approximately 9600 square km (111.3km x 86.5km).

If: LaRes is expressed as value 18 (0x12 or 010010) and LoRes is expressed as value 18 (0x12 or 010010), then it would describe a geo-location area that is latitude 38.8984375 north to latitude 38.9003906 and extends from -77.0390625 degrees to -77.0371094 degrees longitude. This is an area of approximately 36,600 square meters (169m x 217m).

If: LaRes is expressed as value 22 (0x16 or 010110) and LoRes is expressed as value 22 (0x16 or 010110), then it would describe a geo-location area that is latitude 38.896816 north to latitude 38.8985596 and extends from -77.0372314 degrees to -77.0371094 degrees longitude. This is an area of approximately 143 square meters (10.5m x 13.6m).

If: LaRes is expressed as value 28 (0x1c or 011100) and LoRes is expressed as value 28 (0x1c or 011100), then it would describe a geo-location area that is latitude 38.8986797 north to latitude

38.8986816 and extends from -77.0372314 degrees to -77.0372296 degrees longitude. This is an area of approximately 339 square centimeters (20.9cm x 16.23cm).

If: LaRes is expressed as value 30 (0x1e or 011110) and LoRes is expressed as value 30 (0x1e or 011110), then it would describe a geo-location area that is latitude 38.8986797 north to latitude 38.8986802 and extends from -77.0372300 degrees to -77.0372296 degrees longitude. This is an area of approximately 19.5 square centimeters (50mm x 39mm).

If: LaRes is expressed as value 34 (0x22 or 100010) and LoRes is expressed as value 34 (0x22 or 100010), then it would describe a geo-location area that is latitude 38.8986800 north to latitude 38.8986802 and extends from -77.0372300 degrees to -77.0372296 degrees longitude. This is an area of approximately 7.5 square millimeters (3.11mm x 2.42mm).

In the (White House) example, the requirement of emergency responders in North America via their NENA Model Legislation [8] could be met by a LaRes value of 21 and a LoRes value of 20. This would yield a geo-location that is latitude 38.8984375 north to latitude 38.8988616 north and longitude -77.0371094 to longitude -77.0375977. This is an area of approximately 89 feet by 75 feet or 6669 square feet, which is very close to the 7000 square feet requested by NENA. In this example, a service provider could enforce that a device send a Location Configuration Information with this minimum amount of resolution for this particular location when calling emergency services.

A.2. Location Configuration Information of "Sears Tower" (Example 2)

Postal Address:
Sears Tower
103rd Floor
233 S. Wacker Dr.
Chicago, IL 60606

Viewing the Chicago area from the Observation Deck of the Sears Tower.

Latitude 41.87884 degrees North (or +41.87884 degrees)
Using 2s complement, 34 bit fixed point, 25 bit fraction
Latitude = 0x053c1f751,
Latitude = 0001010011110000011111011101010001

Longitude 87.63602 degrees West (or -87.63602 degrees)
Using 2s complement, 34 bit fixed point, 25 bit fraction
Longitude = 0xf50ba5b97,
Longitude = 1101010000101110100101101110010111

Altitude 103

In this example, we are inside a structure, therefore we will assume an altitude value of 103 to indicate the floor we are on. The Altitude Type value is 2, indicating floors. The AltRes field would indicate that all bits in the Altitude field are true, as we want to accurately represent the floor of the structure where we are located.

AltRes = 30, 0x1e, 011110
AT = 2, 0x02, 000010
Altitude = 103, 0x00006700, 000000000000000110011100000000

For the accuracy of the latitude and longitude, the best information available to us was supplied by a generic mapping service that shows a single geo-loc for all of the Sears Tower. Therefore we are going to show LaRes as value 18 (0x12 or 010010) and LoRes as value 18 (0x12 or 010010). This would be describing a geo-location area that is latitude 41.8769531 to latitude 41.8789062 and extends from -87.6367188 degrees to -87.6347657 degrees longitude. This is an area of approximately 373412 square feet (713.3 ft. x 523.5 ft.).

6. References

6.1. Normative References

[1] Droms, R., "Dynamic Host Configuration Protocol", RFC 2131, March 1997.

[2] Patrick, M., "DHCP Relay Agent Information Option", RFC 3046, January 2001.

[3] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, March 1997.

[4] Droms, R. and W. Arbaugh, "Authentication for DHCP Messages", RFC 3118, June 2001.

[5] European Petroleum Survey Group, http://www.epsg.org/ and http://www.ihsenergy.com/epsg/geodetic2.html

[6] World Geodetic System 1984 (WGS 84), MIL-STD-2401, http://www.wgs84.com/

6.2. Informational References

[7] Farrell, C., Schulze, M., Pleitner, S. and D. Baldoni, "DNS Encoding of Geographical Location", RFC 1712, November 1994.

[8] National Emergency Number Association (NENA) www.nena.org NENA Technical Information Document on Model Legislation Enhanced 911 for Multi-Line Telephone Systems.

7. Author Information

James M. Polk
Cisco Systems
2200 East President George Bush Turnpike
Richardson, Texas 75082 USA

EMail: jmpolk@cisco.com

John Schnizlein
Cisco Systems
9123 Loughran Road
Fort Washington, MD 20744 USA

EMail: john.schnizlein@cisco.com

Marc Linsner
Cisco Systems
Marco Island, FL 34145 USA

EMail: marc.linsner@cisco.com

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