Hazard Warnings

White paper December 2020

Scope

This white paper describes the Hazard Warnings service offered by TomTom. It details the technical interfaces between the involved components, such as end-user devices and access management systems, and TomTom Hazard Warnings. All examples provided in this document are informative and may not be complete.

Introduction to TomTom Hazard Warnings

TomTom Hazard Warnings is a low-latency warning service, mainly for end-user devices. The warnings published from the service are safety-related and request that the end-user pays special attention to potentially dangerous traffic, road and weather conditions.

The hazard warnings help drivers to anticipate the road ahead. Based on GPS probe data and enriched with government feeds, community input and car sensor data, the warnings can be displayed through in-vehicle navigation devices or transmitted to advanced driver assistance systems (ADAS), enabling the latter to adjust speed or adapt functionality as necessary.

TomTom Hazard Warnings provides alerts on safety-critical incidents in the following categories:

- Traffic hazards
- Road hazards
- Weather hazards
- Generic hazards

Hazard types

TomTom Hazard Warnings covers several different types of hazards.

This list of hazard types is expected to grow over thecoming months. TomTom is currently exploring the possibility of adding more hazard types, as well as more general warnings, to the service. TomTom will inform customers about new additions before their launch.

Hazard category	Hazard type	Hazard description
Traffic	Accident	Accidents are dangerous situations, especially if they happened very recently. Situations like this are usually unclear and drivers need to navigate very carefully to pass the location or offer assistance.
Traffic	Broken-down vehicle	Breakdowns can cause vehicles to stop suddenly, roll out or get stuck between lanes, creating potential obstacles for other drivers. Furthermore, the passengers of the broken-down vehicle may leave the vehicle, requiring other drivers to take special care.
Traffic	Jam tails	Jam tails occur at the end of traffic jams. When a jam tail lies behind a curve or hill, it can be especially dangerous for approaching vehicles. Drivers should adapt their driving behavior to avoid sharp braking or potential accidents.
Road	Roadworks	Roadworks are construction sites for roadway maintenance. They usually come with speed restrictions, barriers and lane changes.
Road	Objects on road	Any kind of objects on a road (e.g. animals, people or fallen vehicle loads) create obstacles. Drivers need to be aware of these and drive carefully to pass the location.
Road	Bad road conditions	Bad road conditions can include potholes, falling shoulders, cracks and uneven surfaces. These require drivers to reduce speed and navigate carefully.
Weather	Slippery road	Slippery road conditions are mainly caused by bad weather, but also abnormal liquids (e.g. oil) on the road surface. Such conditions can lead to unexpected movements of the vehicle.
Weather	Reduced visibility	Severe weather conditions (e.g. heavy rain or fog) can dramatically reduce visibility. Drivers must limit their speed and keep a close eye on surrounding vehicles.
Weather	Strong winds	Unexpected strong winds (e.g. cross winds) may cause the vehicle to move in an unwanted direction. Drivers need to be aware and reduce their speed if needed.
Generic	Generic	All other kinds of hazards, which cannot be classified by the proposed scheme.

Table 1: Hazard types

Hazard Warnings platform

TomTom Hazard Warnings consists of a set of components which ensure a low-latency and high-quality delivery of hazard messages. A high-level overview is provided in Figure 1.

The service receives information from multiple sources and normalizes the data. The data is then analyzed, aggregated, verified and validated. TomTom Hazard Warnings uses the information received to produce an up-to-date set of hazard messages, which are delivered to all connected customers as quickly as possible.

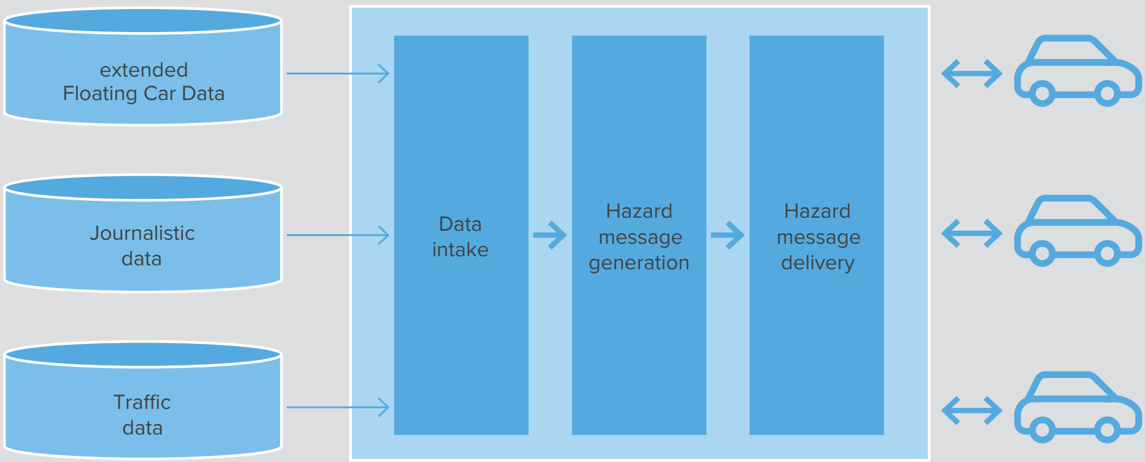

Figure 1: TomTom Hazard Warnings platform

Communication between actors

The communication between all actors uses standard internet protocols. The actors for TomTom Hazard Warnings include the:

- **End-user**

- The client (or end-user) usually uses a device to connect to other components. It is the main recipient of the content delivered by TomTom Hazard Warnings. The client must be authenticated and authorized to make use of the service.

- **Authentication/Authorization (AA) backend**

- The AA backend authenticates and authorizes individual client devices. It requests access tokens in the name of the clients and therefore also needs to be authenticated and authorized. This backend can be an

- **TomTom Hazard Warnings**

- TomTom Hazard Warnings handles the data service and allows clients to connect and receive data. It checks the validity of access tokens and verifies that the request is ok. The service also includes an access control module, which grants such tokens to either clients or an AA backend acting in the name of a client.

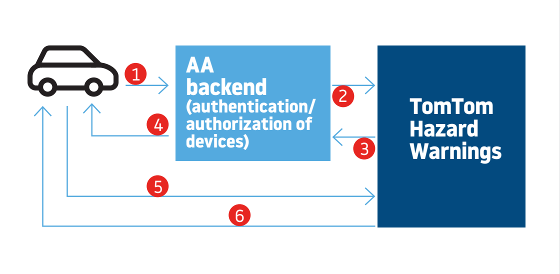

Figure 2: Communication between actors

Figure 2 and Table 2 show the basic communication workflow between the actors.

1	Device authentication
2	Backend requests an access token
3	Token and connection details returned
4	Token and connection details returned
5	Subscription to areas of interest (repeated)
6	Push hazard information for subscribed areas (repeated)

Table 2: Communication between actors

TomTom Hazard Warnings supports different protocols on its endpoints to offer secure authentication/authorization and data transfer. The service follows the publish/subscribe model and uses the MQTT standard. Other models may be supported in the future; these will need to be requested explicitly by the OEM.

Service endpoints

Introduction

TomTom Hazard Warnings offers two endpoints. The GenerateToken endpoint is used to request a new access token for the data endpoint. Hazard messages are served using the GetHazards endpoint.

GenerateToken

The GenerateToken endpoint is used by the OEM backend or a TomTom access management service. The OEM backend (or the TomTom access management service) itself needs to be authenticated and authorized. As a result of the request, an access token is issued which can be used for accessing the GetHazards endpoint.

The token request may contain a service configuration request as payload. The information provided in the payload is used to tailor the service delivery for the specific device.

The GenerateToken endpoint follows the workflow "Client Credentials Grant Type" as defined in the OAuth2.0 framework[1]. The final URL to connect to the GenerateToken endpoint will be provided by TomTom. The URL will contain the protocol type, host name, host port, and path.

Workflow

The workflow shown in Figure 3 adapts the OAuth2 workflow "Client Credential Grant Type" for TomTom Hazard Warnings. The process starts with the client device requesting access to the hazard data. The OEM backend (or the TomTom access management service) authenticates and authorizes the device and requests a new access token via the GenerateToken endpoint. The authentication and authorization is checked in the AA module of the hazards service. The OEM backed identifies itself using a client certificate. After a successful authentication and authorization, TomTom Hazard Warnings returns a JWT access token which is forwarded to the client device.

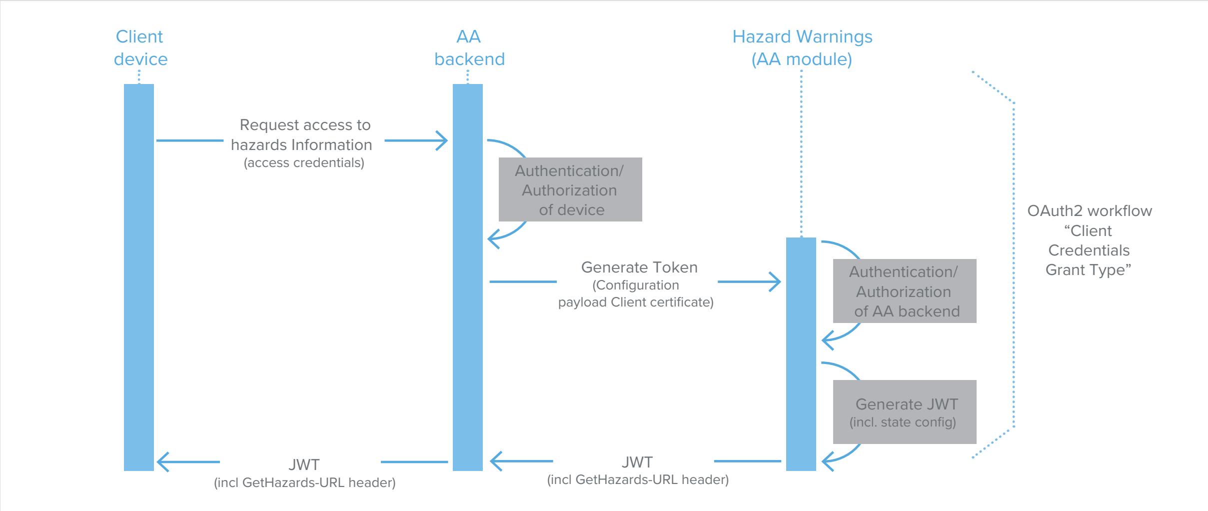

Figure 3. Client Credentials Grant Type workflow for TomTom Hazard Warnings

1. "Client Credentials Grant Type, OAuth2.0," [Online]. Available: https://tools.ietf.org/html/rfc6749#section-4.4.

GetHazards

Hazard messages are served using the GetHazards endpoint. The call to this endpoint is made by the end-user devices using the JWT information received in the previous GenerateToken process. The JWT information may be used for several GetHazards calls from a single device and does not need to be renewed for every request.

The URL to connect to the GetHazards endpoint has been received as part of the GenerateToken response.

MQTT in general

MQTT is a client-server publish/subscribe messaging transport protocol. It is lightweight, open, simple and designed to be easy to implement. The protocol runs over TCP/IP, or over other network protocols that provide ordered, lossless, bi-directional connections. Its features include:

- Use of the publish/subscribe message pattern, which provides one-to-many message distribution and decoupling of applications.
- A messaging transport that is agnostic to the content of the payload.
- Three qualities of service for message delivery.
- A small transport overhead and minimized protocol exchanges to reduce network traffic.

Workflow

The workflows shown in the figures below describe the interaction between the client device and TomTom Hazard Warnings with respect to the following processes: connect, subscribe and publish.

Figure 4 describes the connect process where a client connects to TomTom Hazard Warnings. The client authenticates itself using the credentials received during the GenerateToken calls. TomTom Hazard Warnings checks the credentials and establishes the connection. The connection is kept open so that hazard messages can be pushed from the server to the client.

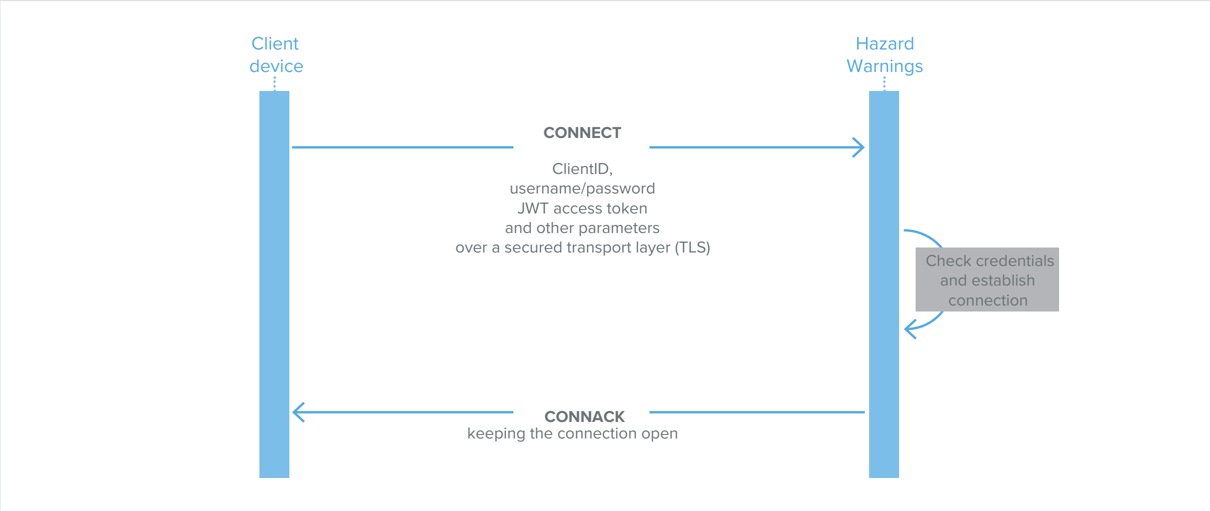

Figure 4: MQTT connect

Figure 5 shows the workflow for the subscription and un-subscription of the client to selected topics. The calculation of the requested region(s) is performed on the client side. This is because the client software knows best about the relevant areas for which information shall be sent to the client for visualization, as well as for warning messages or even avoidance of hazardous locations (e.g. re-routing). More information on the clustering of the world can be found in section 4.

TomTom Hazard Warnings confirms the selection of the client and pushes information which is already available for the selected areas to the client.

In case a client no longer requires information for a certain region, it can un-subscribe from these MQTT topics.

The publication of messages is shown in Figure 6. TomTom Hazard Warnings uses a publisher module, which calculates the region in which a hazard currently occurs and publishes the message accordingly. All clients currently subscribed to this area are informed about the new hazard or hazard updates.

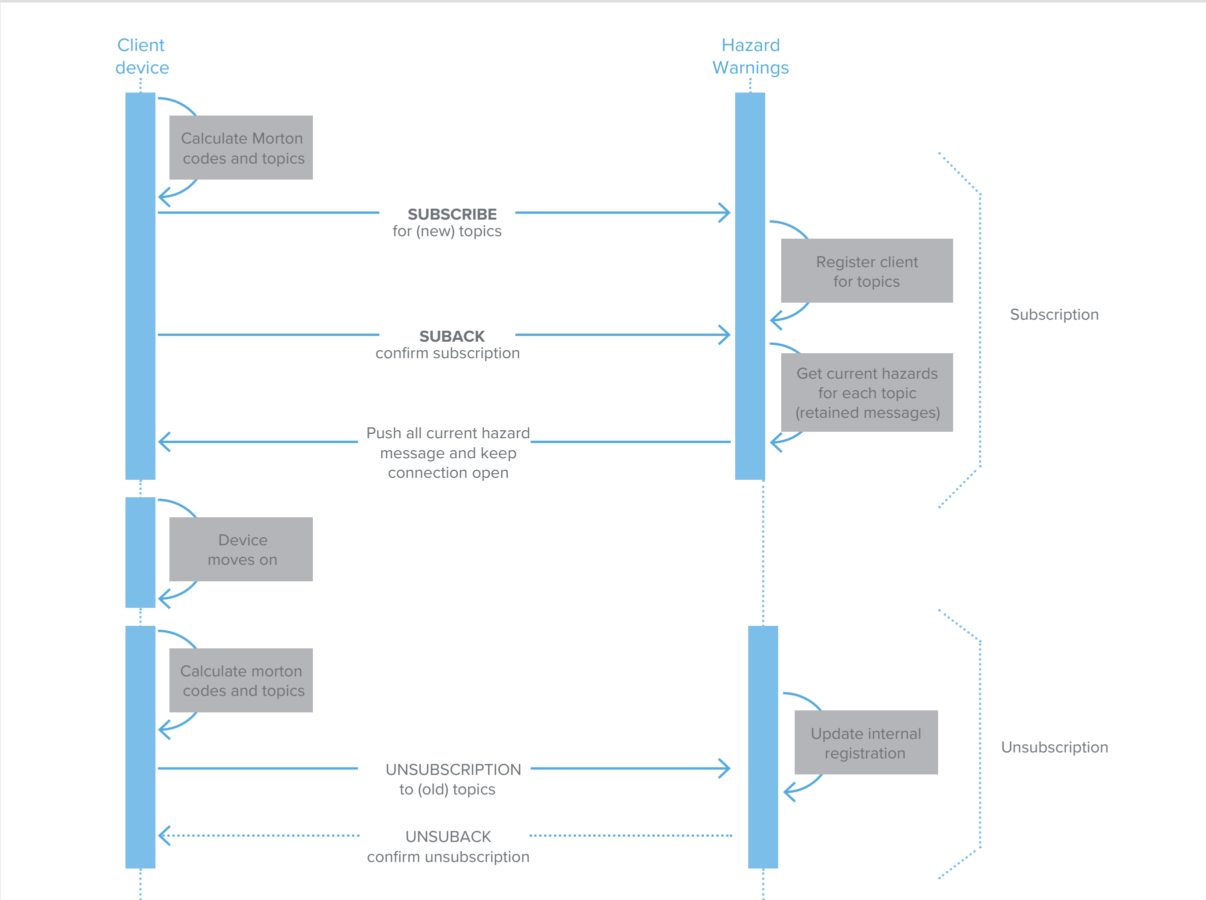

Figure 5: Subscription and un-subscription to topics

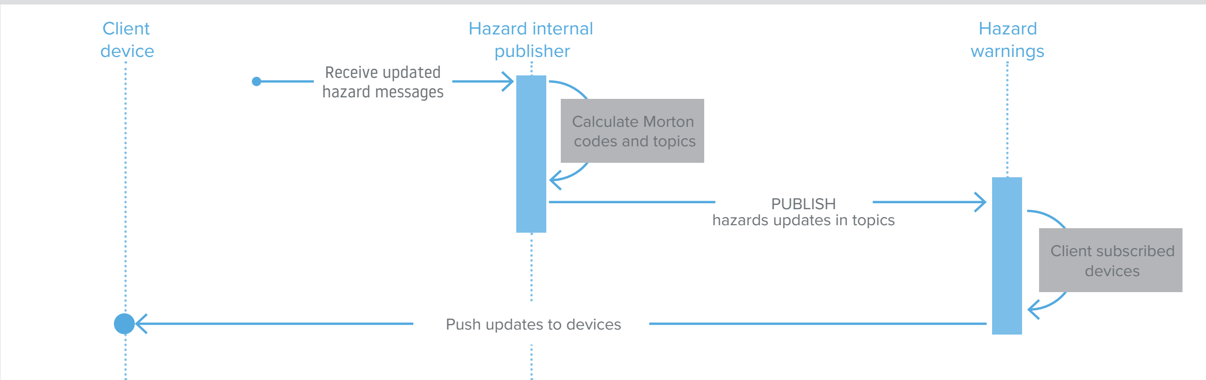

Figure 6: Pushing updates to devices

Hazard Warnings MQTT topics

Hazard messages (as part of MQTT messages) are organized in so-called topics. The topics are organized hierarchically, like a file system (e.g. a/b/c/d), using the forward slash (/) as a separator. Each entry in the topic path acts as a filter for the underlying data. TomTom Hazard Warnings allows geographical filtering and the ability to select messages by their type.

Morton codes

Delivering data for the whole world is complicated and requires a huge volume of information to be sent. For customers interested in only a few locations or areas (or maybe just one), there might be significant overhead to filter the relevant data on client- and/or server-side.

It is better to split the world into smaller tiles (also known as cells or regions). This allows for a smaller data size per tile and for the information to be localized and sent to the client's position. Morton codes are a good option for splitting the world logically into cells. Such codes work with simple geo-coordinates (latitude and longitude in WGS84) and form hierarchical grids of cells. Another benefit of Morton codes is that they also assign a unique ID for each cell, which can be easily calculated from the cell's geo-coordinates.

The size of the grid cells depends on the level. The bigger the level, the smaller the cells. The cells are not square and the different edges (in the direction of latitude and longitude) have different lengths. The lengths also vary depending on the latitude values as the earth is a globe and not planar.

Average sizes for selected levels are as shown in the Table 3, with examples shown for the country of The Netherlands (NLD).

Level	Avg. length latitude (meters)	Avg. length longitude (meters)	Country
2	19,422	38,880	NLD
3	9,711	19,440	NLD
4	4,855	9,720	NLD
5	2,427	4,860	NLD

Table 3: Cell dimensions depending on the Morton level

The coverage of The Netherlands is shown for the Morton levels 10 – 13 in the following figures.

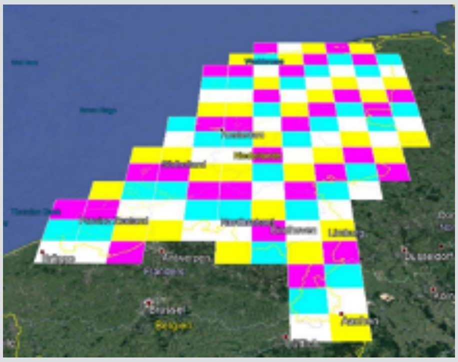

Figure 7: Morton tiles, level 10, NLD

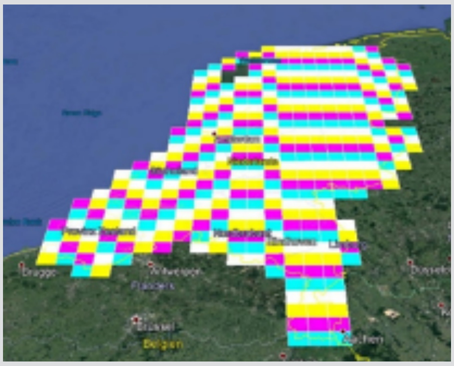

Figure 8: Morton tiles, level 11, NLD

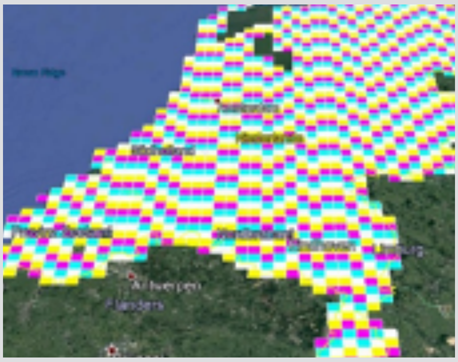

Figure 9: Morton tiles, level 12, NLD

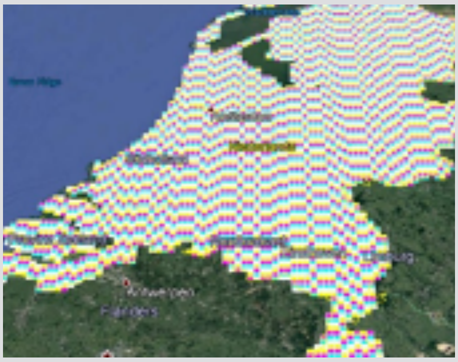

Figure 10: Morton tiles, level 13, NLD

Topic structure in TomTom Hazard Warnings

The topics in MQTT are organized hierarchically to address attributes directly, and also to allow for wildcards.

The MQTT standard defines two wildcards: plus (“+”) and hashtag (“#”). The “+” can be used as a wildcard for a single level of hierarchy and “#” can be used as a wildcard for all remaining levels of hierarchy. Both wildcard types must be used with care. The client can select multiple topics during the subscription call by stating them explicitly or making use of the wildcards.

Hazard Warnings uses the following topic structure:
<messageType>/<version>/<mortonCode level 10>/<mortonCode level 11>/<mortonCode level 12>/<mortonCode level 13>/<hazard type>/#

The topic structure allows the client to select and filter the hazard messages according to geographic location and hazard type. The strings in the topic structure are case-sensitive.

The trailing “#” is mandatory to receive all hazard messages for the selected hazard type and within the selected area. TomTom Hazard Warnings will deliver all current hazard messages on the first subscription to a topic.

It is recommended to use the hazard type explicitly when subscribing to topics. The usage of the wildcard “+” may cause issues in future versions where more hazard types are available. Such hazard types may not be understood by the client properly.

The following example shows how a client can subscribe to the hazard messages.

Example 1:
Accidents in the vicinity of the position 52.520008,13.404954 (Berlin) explicitly addressing the Morton code levels 10 to 13. The size of the area is about 4.9km x 2.5km.

h5s/v1/920732/3682930/14731722/58926889/accident/#

Data model and format

General remarks

The following sections outline the location referencing methodologies used with TomTom Hazard Warnings.

Location Referencing

Location references are used to exchange spatial location information in digital maps. Such references describe “where” something is on earth. Hazard messages consist of “what” happens and the “where” information. “What” is, for example, the hazard type; e.g. an accident or strong winds. “Where” relates to the location (on earth). Location referencing can happen in many ways and, for hazard messages, the location referencing method needs be processed easily by digital systems and needs to offer highly accurate locations. The method has also to overcome differences in digital maps. TomTom Hazard Warnings uses geo-coordinates and OpenLR™ as location referencing methods. Both methods support the usage of location references for points, linear stretches and areas.

Geo-coordinates

Geo-coordinates are the simplest way to address a location. They are made of a longitude and latitude values represented in an ellipsoid model of the earth. The model used for TomTom Hazard Warnings is WGS84 (see [2]).

A single coordinate represents a single point; an ordered sequence of coordinates represents either a path or an area, depending on the agreement to connect the last coordinate with the first one or not.

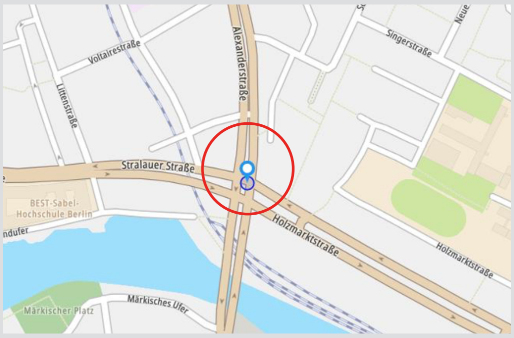

Figure 11: Example of a point location

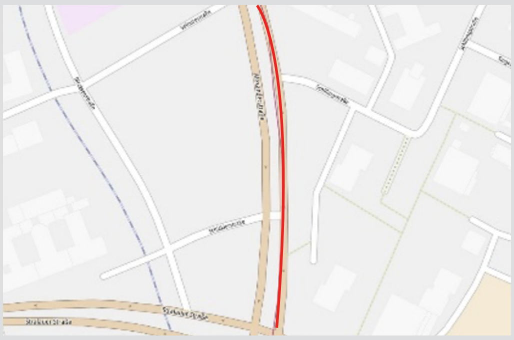

Figure 12: Example of a linear location

Figure 13: Example of an area location

OpenLR™

OpenLR™ is an open-source location referencing method developed by TomTom. It offers point, linear and area locations of different types. The method has been standardized and adopted by OEMs and their suppliers. The main concept for linear locations is based on location referencing points along the location and shortest-paths calculation in between these location referencing points. Please see[3] for more details, the specification and links to code samples.

2. ICAO, “WGS-84,” [Online]. Available: https://gis.icao.int/eganp/webpdf/REF08-Doc9674.pdf.
3. “OpenLR Association,” [Online]. Available: http://www.openlr.org/.

Conclusion

TomTom Hazard Warnings combines coverage of a wide array of hazard types with low-latency and high-quality delivery of hazard messages. It can be easily integrated with both end-user navigation devices and advanced driver assistance systems. By notifying both drivers and automated vehicles about potential hazards ahead of time, TomTom Hazard Warnings helps road users better anticipate risks and navigate safely.