White paper
How TomTom's HD Traffic™ and IQ Routes™ data provides the very best routing
Travel Time Measurements using GSM and GPS Probe Data

ABSTRACT

This paper outlines the basic technological background, coverage and system design of TomTom's traffic information and navigation service, which is already available in a number of European countries such as the Netherlands, Germany, the UK, France, Belgium, Switzerland and Portugal under the name - HD Traffic.

HD Traffic real-time traffic information is the backbone of a time-dynamic navigation concept that guarantees reliable routing and precise travel time information. The content is based on GPS and GSM probe collection systems, bringing a reliable historic and real-time speed measurement assignment for the underlying road network graph of the navigation system which leads to a greatly improved navigation experience. HD Traffic and historic speed profile generation delivered by TomTom's IQ Routes technology together make a formidable data set to provide drivers with the best routing available on the market today.

Details of the data collection system are described below. Furthermore, the concept of and data fusion for a real-time traffic information service are outlined. The contribution of each data source of the collection system and results are also outlined.

INTRODUCTION

Over the last few years, probe data technologies have become a reliable and highly accurate data source for traffic information generation and travel time measurements, in historic, real-time and predictive usage. These technologies became available with the introduction of TomTom's time-dynamic navigation concept on its X40 GO series.

The core sources of traffic data collection systems are probe data from cell phone operators in the various countries as well as GPS probes from the installed base TomTom connected devices and commercial fleets with TomTom WORK navigation systems. The existing installed base of these sources, including all GPS probe vehicles and cell phone handsets from the cooperating telecommunication operators, is huge, and guarantees enhanced data and service coverage that is not limited to highways, but also covers secondary and arterial urban roads. This greatly improves both travel time and the delay time measurements along a planned route or through traffic, respectively. An additional advantage is the improved routing due to time-specific data. So far, routes may vary with respect to the day of the week, time of the day, traffic information delays or other major dependencies by weather or events, for example.

Both of TomTom's core probe technologies IQ Routes and HD Traffic are described more in detail during the following sections.

TRAFFIC DATA SOURCES AND DATA FUSION

The backbone of the HD Traffic service is a multi-source concept in order to obtain both reliable speeds and incident detection data. The core traffic data collection technology, patented by TomTom, is a cellular floating phone data (CFCD[1]) system exploiting signaling data from the telecommunication operator network, which is enhanced by GPS-based probe data (both anonymously gathered) as well as conventional data feed from local detection by third parties like local authorities, with data from loop systems in the road.

The principle of the CFCD is based on changes of the Timing Advance measurement values while a handset is in an active call. Timing Advance (TA) is a measurement in the GSM network which is important to synchronise phone calls. The TA value is the distance between the cell phone to the serving base station. With knowledge of the base station location and the segment of the antenna's reach, the change of the TA value, can be used to set up virtual beacons at the TA sector cell boundaries with respect to the underlying road network. This means that the exact location of the cellular handset within the antenna segment can be triangulated. The base principle is shown in figure 1.

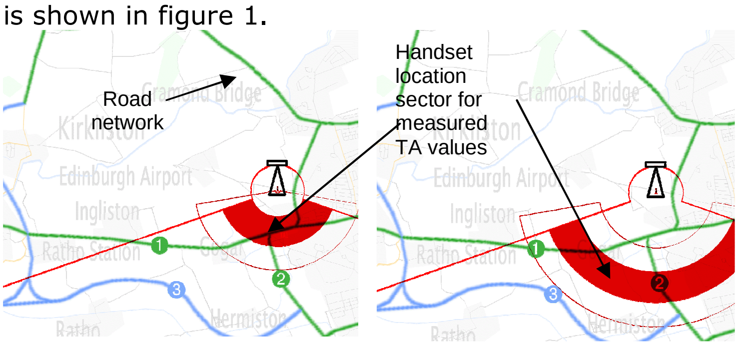

Figure 1: CFCD principle using Timing Advance (TA) measurements

The great advantage of this applied CFCD technology is that it comes with a higher accuracy, due to the size of the TA zones and a high probe data penetration, since cellular handsets are widely used in every country.
The key issue of all CFCD systems is the filtering of those handsets that are not used while driving in a vehicle to avoid undesired non-traffic speed measurements. That's most relevant for urban areas where different modes of transport are encountered and the road network is much denser.

For filtering, an enhanced data analysis is necessary, for example to separate handsets which are used in a train. As a typical speed pattern appears when calls are coming from trains, because all handsets have the same speed and handover events, these data can be taken out.

As already mentioned, TomTom follows a multi-source traffic data strategy. Beside the CFCD, GPS-based probe data and conventional detection sources are used. This additional information also helps to indicate probe data which not gathered from a vehicles driving along a road.

TomTom uses a bi-directional GPRS communication channel to deliver traffic information and other relevant messages to the device with an update frequency of three minutes. This guarantees regular incident updates in order to provide suitable detour options on the PND. It also allows the system to respond much more quickly to traffic changes across the road network.

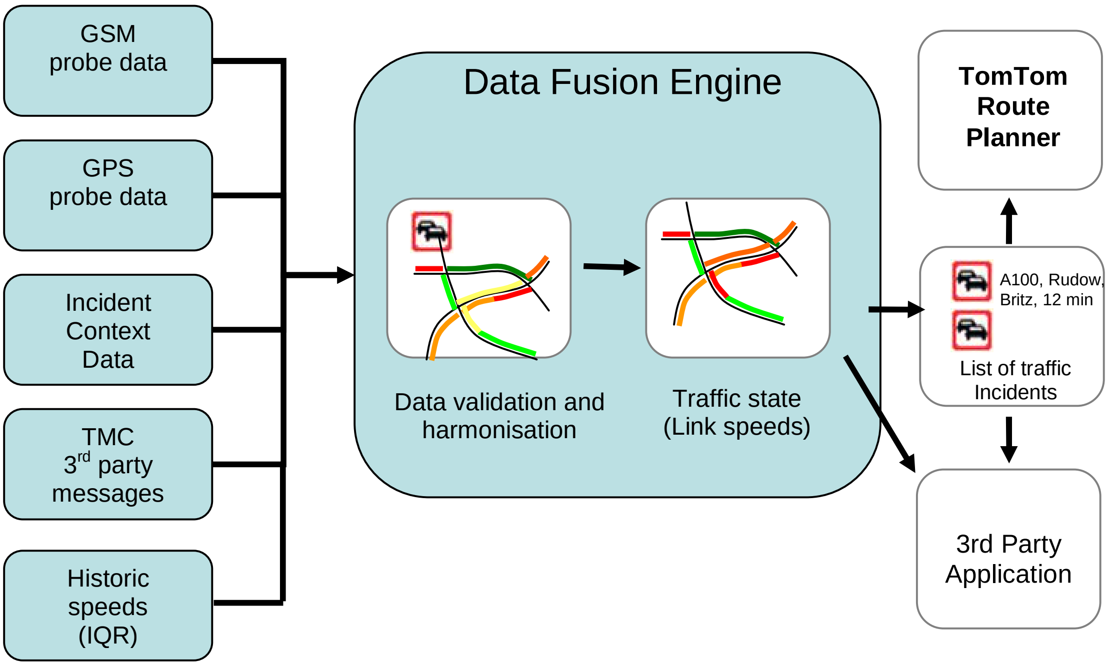

Figure 2: HD Traffic data processing and delivery chain

The data fusion engine is responsible for delivering reliable speed information for every road stretch of the underlying map, based on available data sources. Every data source has an 'a-priori' reliability measure, a measure indicating confidence in the speed measurement. The most reliable carries more weight, and so on. Measurements are compared with historic data to come to verified 'ground truth' speeds. For this ground truth, the most reliable are loop detector speeds, which have a sufficiently high density of data (incl. an appropriate travel time assignment model). GPS-based probe measurements are even better, where available in an adequate penetration. TomTom is collecting its own highly accurate ground truth using GPS probe data from the TomTom installed base. Every day, more than one billion probe data are collected.

The reliability measure for each data source takes into account the deviation against the ground truth in a number of parameters, such as the speed, the delay in reporting a jam, changes in a jam or positive and false traffic jam measures when the ground truth indicates a traffic jam. In the fusion process a number of other parameters are used beside the reliability measure, like the age of the measurement and the number of independent probe measurements. So far the contribution to the final speed is weighted according to the parameter vector described above.

The result is that the speed in the network that corresponds to available real-time data is calculated and assigned to the related TMC Location points. In order to increase the TMC coverage for road stretches without these, TomTom has added additional its own TMC points. This strategy allows the delivery of traffic information in a bandwidth efficient manner across the whole network.

In the following section results of the HD Traffic service are plotted.

RESULTS FOR HD TRAFFIC SERVICE

In Figure 3, a set of time distance diagrams is plotted showing the single probe data contribution to the data fusion process and the result output of the incident detection process for HD Traffic. For comparison reasons, the public TMC messages broadcast in the same area are plotted as well.

The x-axis shows a highway section of the A3 in Germany between junction "Seligenstädter Dreieck" and "Wiesbadener Kreuz" where the y-axis show the time through the day of 6th March 2009. The speed is indicated by various colours, blue for speeds close to 0 and green for free flowing traffic.

The example shows the existing high coverage of probe data, both from GPS and GSM sources. The calculated incident measures are far more accurate and precise compared to the TMC messages which are broadcast in the same area. Furthermore, the delay time, time of reporting the delay and modelling of the jam are far more realistic, assuming that the GPS probe can be seen as a ground truth.

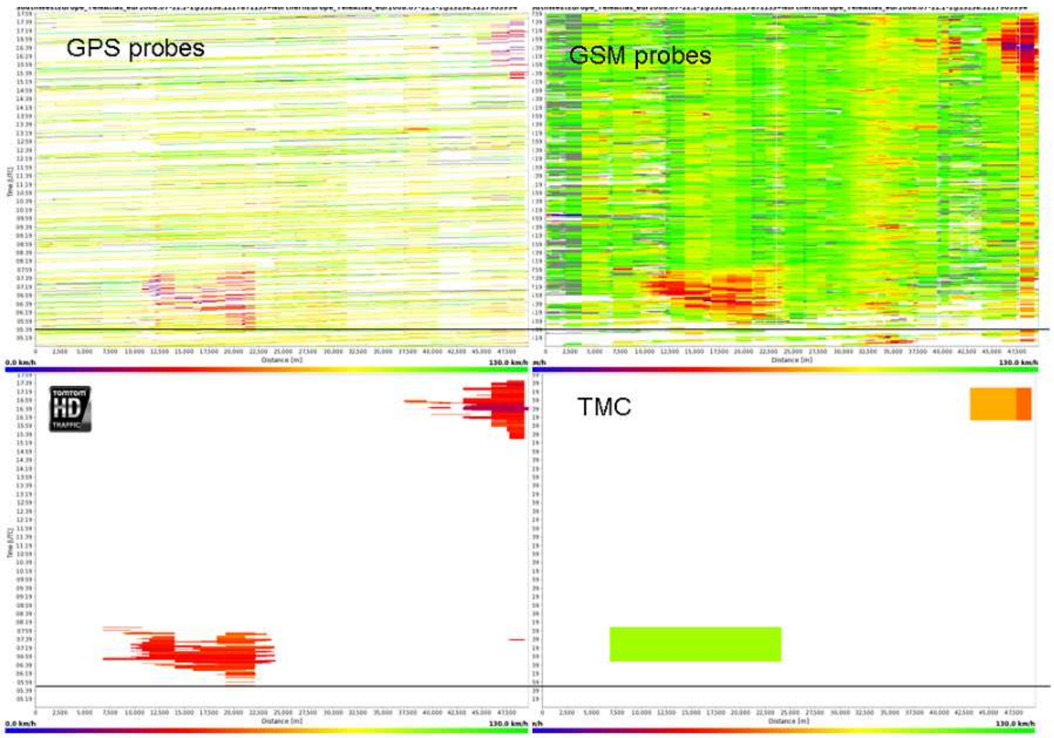

Figure 3: HD Traffic Feed Comparison for the A3, Germany, 6th March 2009 (time in UTC)

TIME-DEPENDENT NAVIGATION

Together with the highly accurate real-time traffic information, historic predictive speed information is necessary to guarantee precise routing, accurate time of arrival forecasts and reliable delay information for jams along the planned route. For road sections along a route that are far ahead of the current vehicle position, the use of real time traffic data doesn't make much sense, since the travel time may vary change before the driver has reached those road sections. So far, time-dependent speed profiles assigned to the network graph are a good first approximation in case predictive data are not available. The concept of time-dependent speed profiles has been developed and implemented under the name of IQ Routes.

PROFILING SPEEDS

Speed profiles provide consistent and complete historical speed maps for all navigable roads in a digital map, in the form of fully time-dependent speeds for each day in the week, normally measured or derived by suitable gap filling algorithms. The profiles have been compiled by aggregating 1.4 billion of anonymous GPS probe data, shared by TomTom's broad user community. These reflect the typical user behavior and usual traffic conditions on traveled roads.

The actual data delivered for a certain stretch of road depends primarily on the number of available probe data. Almost all frequently driven roads, like highways, within Western Europe and North America have a full time-dependent speed pattern assigned to them. The usual highway coverage is between 95 and 100 percent, which is similar for major roads depending on the region. Those full profiles contain average speeds for every five minutes of the day for each day of the week.

Speed profiles have been primarily designed to fulfill the requirements for dynamic routing. Knowing the statistical behavior of traffic leads to much better time-dependent routes by avoiding areas suffering from heavy regular jams, if the road network allows alternatives. The database gives more accurately estimated arrival times, since it is based on real measured data, not on crude speed estimates that use road attributes and legal speeds or speed limits.

Due to the leveling approach of the data processing, harmonised speed maps are produced and even small and seldomly-driven roads have a reliable speed assigned to them. That is important to avoid unrealistic routes and detours while routing due to missing or non-harmonised data. The profiles are directly assigned to the road segments, comparable to other road attributes. The time-dependent data itself are stored in a very compressed way described below.

A set of normalised typical traffic patterns has been extracted by a cluster analysis procedure using representative samples from all road categories and all countries and markets as input. Those clusters cover all typical traffic states in the network which have been recorded via GPS probe data. The clusters undergo a couple of quality and alignment steps, finally leading to a set of profiles which serves all countries and markets or a given version of the map. The speed profiles of the individual road segments are classified into one of the profiles per day of the week.

On a road segment, only the reference speed (normally the free flow speed) and a link to the most similar profile per day of the week are stored, instead of all the speed data for each time per day.

Some examples of time-dependent speed maps and speed profiles are given for the Swedish road network. Although Sweden usually only suffers moderately from congestion compared to other European capitals, some of the bigger roads in the area of Stockholm also show rush hour behavior. A typical example is the Western stretch of the Essingeleden highway. Figure 4, shows the Stockholm speed map at night. It can be seen that each road has a speed value assigned to it. Figure 4, gives the historical speed profile for the Essingeleden highway, northbound. On Monday morning, the average speed sharply drops to about half the free flow speed on a regular basis. Figure 5, shows the corresponding speed map. Considerably lower speeds of some of the city's highway stretches and on its major roads are clearly visible. Figure 5, gives the status for Monday afternoon. This also shows significant speed drops compared to free flow conditions.

Obviously, the use of those data in routing considerably improves the navigation experience. Meanwhile, the data is an essential ingredient of TomTom Personal Navigation Devices and online maps, and is branded as IQ Routes. In addition to its direct use for route estimation and travel time calculation for navigation purposes, IQ Routes is a valuable data source for all kinds of road network analysis, for governmental bodies as well as for consultancy agencies.

TomTom's map Business Unit, Tele Atlas offers the data as a specific product, branded as Speed Profiles, which are present in its MultiNet product, used by customers in a variety of applications.

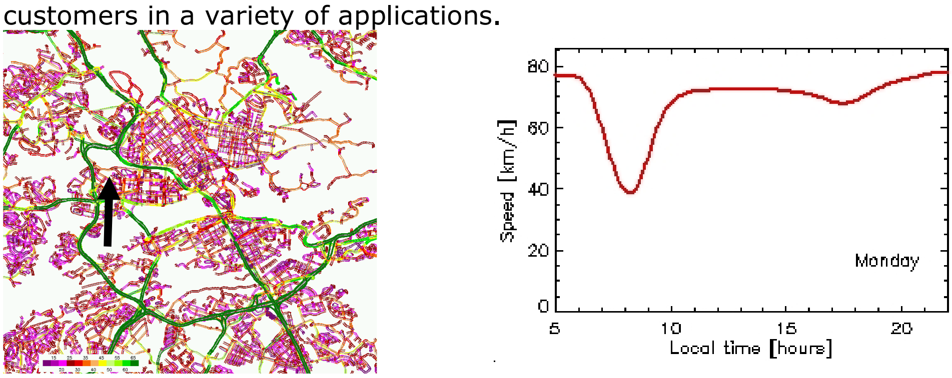

Figure 4: left: Stockholm speed map, night time speed,
right: Speed profile Essingeleden, for a typical Monday

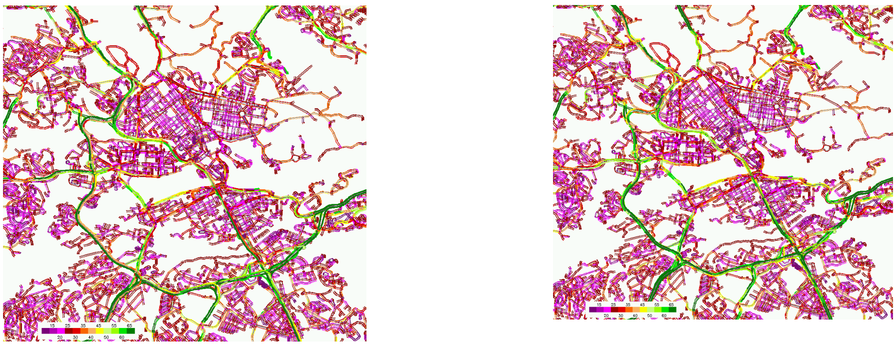

Figure 5: left: Stockholm speed map, Monday 9am
right: Stockholm speed map, Monday 5pm

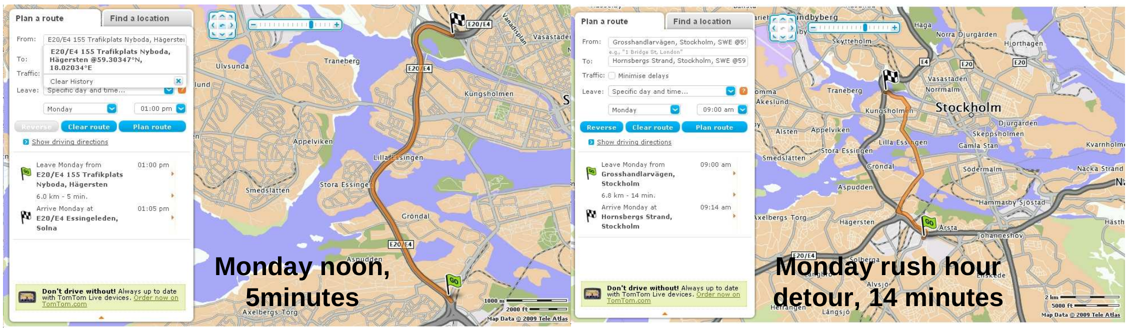

Figure 6: TomTom Route Planner (routes.tomtom.com): Estimated travel time five minutes during day time for a six kilometer long stretch along Essingeleden, northbound and rush hour alternative

SUMMARY

The paper outlined TomTom's revolutionary concept of time-dynamic navigation using dynamic, historic and real-time traffic and travel-time information gathered from GPS and GSM probes. The accuracy and precision of the travel time and delay information calculating the Estimated Time of Arrival of a planned trip is highly accurate. Furthermore, the routing behavior and detour optimization greatly improved using these technologies. This is beneficial both to TomTom's navigation and routing excellence and to other related applications for traffic planning and management.

REFERENCE

[1] Atkinson, I., Adam, B. Dixon, J.: Traffic Monitoring System, EP 1 348 208 B1.