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BLIDS - A Bluetooth/WiFi based traffic data collection system for use in urban an interurban roads

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ABSTRACT
Mobility is one of the basic needs of today's people. The amount of motor vehicles is ever increasing because of this. Hence there is more and more traffic load on every road, especially in and around urban areas. The maximum capacity of those roads is more and more often reached during peak hours, traffic jams and long travel time is the result. In big cities with high vehicle traffic numbers, it is necessary to operate traffic data collection systems for the control center.
One of the most compelling sensor class is the Bluetooth/WiFi-based traffic sensor, which is a non-intrusive and inexpensive alternative to LPR (License Plate Recognition) systems.
BLIDS-sensors, mounted next to the road, detect unique BT/WiFi-IDs from devices such as mobile phones and navigation systems that come within the reception range of the sensor. This unique BT/WiFi IDs are made anonymous and stored together with highly accurate exact time stamps directly on the sensor before they are transmitted to the BLIDS-server system .
From the information gathered from at least two sensors, real-time traffic information (e.g. travel-times, traffic jams, dwell time at intersections, origin/destination analysis as well as traffic flows) can be calculated.
The BLIDS network provides a wide range of applications. It starts with the installation of mobile solutions to provide temporary measurements and ends with fixed installations.
This paper examines the measures and preconditions that need to be fulfilled for a thorough usage of BLIDS-sensors in strategic route management systems.

KEYWORDS: Traffic management, Bluetooth/WiFi detectors, Traffic congestion, travel time, origin/destination, data privacy

1. BLIDS detection system in general

1.1 Definitions

Bluetooth is a wireless technology for transmission of voice and data over short distances in the unlicensed 2.4GHz ISM1 band. With the help of Bluetooth devices such as PCs, mobile phones and hands-free devices can wirelessly exchange data.

Wi-Fi is a popular technology that allows an electronic device to exchange data wirelessly (using radio waves) over a computer network, including high-speed Internet connections [1]

[1] ISM - Industrial Scientific Medical

1.2 Components

A BLIDS detection system consists of the following main components:

- BLIDS sensor
- BLIDS server software

1.3 Function

BLIDS-sensors, mounted next to the road, acquire unique BT/WiFi-IDs from devices such as mobile phones and navigation systems that come within the reception range of the sensor. This unique BT/WiFi IDs are made anonymous (the data protection authority of the German state of HESSE praises BLIDS to be state-of-the-art when checking through the technical details of the protection of privacy solution) directly on the sensor and are given a highly accurate and synchronized timestamp before they are transmitted to the BLIDS-server system.

From the information gathered from at least two sensors, real-time information on travel-times and traffic disturbances, as well as traffic flows can be calculated. The sensor in its simpliest form, consists of specially developed hardware and software based on embedded-Linux. Services which run on this system use BT/WiFi detectors, GPS, GSM, RS232, WLAN and USB interfaces to create the scanning and communication components of the sensor, which enable the networking of the system. External power supply (in/out), Radar sensor for cross-section count, optional battery buffering or solar panels complete the sensor system. The System has a built in monitoring agent to handle possible network problems, low battery, etc. and start self-healing process to remain online and functional. FOTA (Firmware Over The Air) is supported. This allows the sensor to be maintained and updated remotely, making them very service-friendly. With the BT/WiFi module, all visible BT/WiFi devices are acquired in a single scan cycle. Here, the Discovery Mode is used and only the MAC addresses, time, class of device and RSSI value are read out. The BLIDS-server software runs on Windows or Linux platforms. Depending on the customer requirements, the server software provides the service communication, reception of data, storage of data in the local file system and/or in a database, Web services, Notification (Alerting) systems, integration with SNMP services, Web frontend for real-time data displays, FTP and more.

2. Route decisions in smart traffic management

The ever increasing traffic in urban areas – together with limited space for additional or extended traffic routes - requires more and more complex control measures.

Strategy management combines rule-based situation detection and an operator-based workflow system, and an activity management for implementing activities. An important ingredient is also a mechanism for solving contradictory activities.

A very important use case for strategic management is to give information to the drivers via VMS or C2R communication systems about the best route to take from a motorway to a city center or to the nearest park-and-ride scheme. See e.g. figure 1 for an example in the city of Leipzig.

Customarily strategic management systems use inductive loops or video sensors to measure the current traffic state on the routes in question. Sometimes complicated traffic models (see e.g. [2]) are used to determine the real flows and speeds on the routes from the stationary road counts. This data has a lot of drawbacks, if it should be used for strategic route decisions:

1. There is nearly no sensitivity to traffic jams that are not generated by traffic lights. Even jams generated by traffic lights can only be detected with high probability by very advanced algorithms (see [3]), and only if the sensor site is not far from the stop line.
2. The calibration and maintenance of the traffic models is crucial, error-prone and very time consuming.
3. The real travel times are never observed and thus there is no possibility for an online-calibration process.

The use of BLIDS BT/WiFi detction technologies has the prospect to improve these imperfections and thus can lead to a more precise traffic travel detection and subsequently better performance of the strategic management. If located on the entries and exits of the alternative routes that are to be considered they deliver at once the real travel times on the routes in question.

The drawback is that one gets the current travel time on a route only when a car has reached the end of the route, so models have been developed (see e.g. [4]) that use cluster analysis techniques to predict the travel times in the next 15-30 Minutes on these routes. Additional stationary detection based on loop detectors or video should also be applied. An alternative approach would be to install additional detectors within the route.

Fig. 1. Example: strategic route decisions for the city of Leipzig

The origin-destination information for a certain percentage of vehicles that traverse the network is a crucial output of the BLIDS sensors. It allows for the determination of precise turning rates at many intersections within the section. If the latter is too large, additional sensors could be placed within it. Common algorithms for origin-destination-estimation can be used to complete the missing relations.

It is not compulsory to monitor every vehicle passing a BLIDS sensor station - additional inductive loops on few spots will allow to extrapolate the “real” flows, thus giving a very good estimation for both, the travel times, the traffic demand and the turning rates for all roads considered.

2.1 Detection of traffic jams

A combination of the whole BLIDS sensor network with stationary detection could allow the determination of the actual position of a traffic jam with a high probability, thus interpolating the travel times on the road elements between the camera sites which are located at the section boundaries.

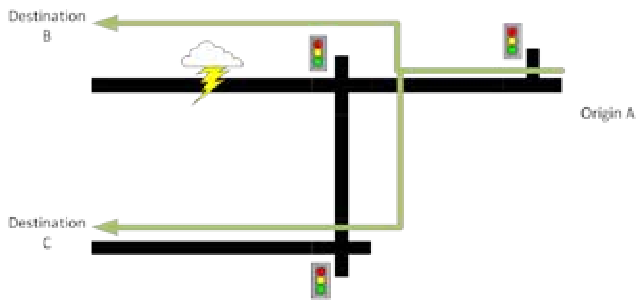

Fig. 2. Strategic route decisions for connections to a city

Figure 2 denotes how this could be done. The first step is to determine the routes between the different OD-pairs. If the travel time on one OD-pair is heavily increasing (indicating a traffic jam on this relation), and parts of the main route for this pair are shared by routes between other pairs, it is possible to estimate the position of the jam: if the travel times for these other routes are not increasing simultaneously, this is evidence that the jam is in the sections not shared by these routes. Thorough inspection of the counting values at intermediate junctions can give further advice. Note however that this approach has serious pitfalls, as traffic jams in the network can lead to unexpected changes in the route-choice-behavior. An accurate database with routes, sections and normal travel times thereon will be necessary.

3. BLIDS sensor network

To generate real time traffic data a specific area will be defined. Within this area BLIDS sensors are to be installed at major interchanges with strategic importance. In practice this means that at every interchange there will be one BLIDS sensor installed. Due to its wide detection range (250m in diameter) one sensor is able to cover even highways with several lanes (in both driving directions).

The BLIDS sensors can be connected via means of various types of networks (cable, GPRS,WiFi).

3.1 Network example

3.1.1 Network design

For this sample project the above shown area was selected (see Figure 1). In this map all the sites where the BLIDS sensors will be installed (BLIDS control points) are marked with a red dot.

At each BLIDS control point one BLIDS sensor will be installed. After acquiring the unique BT/WiFi IDs, they are made anonymous and fitted with an exact time stamp. The encrypted data is saved on a SD Card. Periodically the data are sent to the BLIDS server system for further processing.

Fig. 3. BLIDS control points

A schematic overview over the network is shown here:

Fig. 4: Schematic BLIDS network

3.2 Installation

3.2.1 Equipment

The sample network contains of 21 BLIDS control points. At each control point there are in total 4 lanes each, monitored by the BLIDS sensors.

This implies the following necessary equipment per control point:

- 1 BLIDS sensor (either mounted in existing road side cabinets or in separate IP 66 housings)
- required accessories (power supplies)
- As equipment for the BLIDS network system in total is required:
- 21 BLIDS sensors
- 1 BLIDS server
- accessories (power supplies)

3.2.2 Deployment

For the deployment at the control points the existing traffic light masts or gantries can be used. The BLIDS sensors can be installed either in a road side cabinet or mounted on gantries or on masts. One sensor can be installed in about 15 Min. A further advantage is that the installation needs no calibration.

4. Data privacy

Often data privacy is cited against the use of traffic detection systems. Basically, the Bluetooth/WiFi ID is unique for the specific mobile device but it will not be possible to connect it to the owner. There is no data available which allows to match the Bluetooth ID with the person carrying the device.With BLIDS the unique Bluetooth/WiFi IDs are made absolutely anonymous (Dr. Quiring-Kock, Comimissioner for data protection in HESSEN, praises BLIDS to be state-of-the-art when checking through the technical details of the protection of privacy solution).

5. Conclusion

The adaptive network control systems currently in operation for traffic management in urban areas are based on detection of traffic volumes and convert these via elaborated models into travel times and streams. The drawback is a vulnerability to overlooking many traffic jams and a high calibration effort.

One solution to eliminate these disadvantages of the static data recovery is the use of BLIDS sensor systems. These provide information used to obtain data on travel time, origin-destination and real-time monitoring of the system performance. This makes it possible to react immediately to changes in traffic flows and to achieve an optimised traffic management.

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