Improvement in Traffic State Estimation at Signal Controlled Intersections by Merging Induction Loop Data with V2X Data

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ABSTRACT
A proven method to minimise the number of stops at traffic lights is a good coordination of the traffic. The use of vehicle-to-infrastructure (V2X) communication allows new concepts to achieve a better coordination. The here described system comprises both the adaption of the traffic signal control and the improvement of a vehicle’s approach to intersections. Both objectives require accurate data concerning the actual traffic state and in particular the current tailback length. Therefore two data sources are used to estimate the current tailback length. Existing detectors at traffic lights are taken as a basis for the estimation. For an enhancement V2X data is used. Equipped vehicles send their current position and speed and thus operate as virtual detectors. In a further step detector counts and the V2X data are merged. The process tested in simulations was implemented within a test site in Braunschweig, Germany.

KEYWORDS: tailback estimation, V2X communication

1. Introduction
Traffic flow in urban networks is essentially influenced by required stops at traffic lights which cause braking and reacceleration. This has a significant impact on the capacity of the urban network and the emissions of its motorised traffic. Within the German research project KOLINE a cooperative system was developed that makes use of the communication between vehicles and traffic light systems (V2X) to avoid stops of vehicles at traffic lights by optimising the vehicles’ approach to a signal controlled intersection. Former research showed that therefore not only knowledge of future signal states but also proper data of the current tailback length is required [1], [2]. This paper focuses on the process developed within KOLINE that calculates the current tailback length and its prediction by combining detector counts and V2X data.

2. Components and Data Transmission
The overall architecture of the KOLINE system is given in a paper also presented at this conference (Naumann et. al., chap. 3). The following Fig. 1 shows the system’s components involved in the tailback estimation as well as the data transmission.

The calculation of the current tailback is implemented within three components. Stationary detectors measure the occupancy about 20 m in front of the stop line. Together with information about the actual signal state available in the Traffic Light System a tailback length is estimated once per cycle by TRANSQest. This calculation is taken as a basis for the estimation.

To improve the estimated value the system uses V2X data. The Vehicle is equipped with a device for wireless communication and transmits the standardised Cooperate Awareness Message.
The algorithm has been developed to identify online tailback lengths of up to approximately 5-10 times of the distance between detector and stop line, particularly using the stationary detectors which are often already existing and positioned "in the middle of traffic control systems in traffic centres. TRANSQest estimates the tailback referring to the distance between detector and stop line (see Fig. 2).

The component has been integrated into a software module which, due to its simple interfaces, can easily be implemented into traffic control systems in traffic centres. TRANSQest estimates the tailback once per cycle of a traffic light system.

The traffic flow within the range of detectors positioned close to stop lines is significantly influenced by the respective traffic signals. If this influence is not considered a disturbance but a "modelling" of the traffic flows, important parameters can be derived. One parameter is especially important for the evaluation of traffic quality: The fill-time, which is the period of time between the begin of red and the permanent occupancy of the detector. It can be derived whether vehicles at the end of the green time are driving fast or slowly towards the traffic light.

The algorithm is based on defined fill-time correlated circumstances: If tailbacks occur at signal controlled intersections, which are not resolving after the green time has ended, the vehicles which have not flown-off will halt faster at the stop line as compared to having freely flown. In this case the fill-time significantly often falls below a specific reference fill-time depending on the distance between detector and stop line. Empirical data show that the incidence for falling below that reference fill-time is correlated to the tailback length to a certain degree: The event "falling below a reference period" can be included by defining a "tailback parameter" and exponentially smoothed for each period. The maximum tailback length can also be smoothed that way. Then, by means of correlation calculation a correlation between these continuous values can be calculated in terms of a source-regression line.

When the tailback parameter has been identified by measurements, the tailback length can be derived from an existing gradient which enables to use a determination equation to calculate an unknown maximum tailback length. It is an estimation of a slightly smoothed maximum tailback length.

The last counted vehicle that comes to a halt on the detector defines the duration of the fill-time. If this occurs shortly after the green time has ended, there is a high probability that the vehicle has moved within a slowly moving cluster as it is typically found in tailbacks. As the vehicles have all been positioned in the tailback upstream of the counting detector, an inequation for the actual maximum tailback length can be derived in correlation with an average count of vehicles downstream of the detector. If the fill-time exceeds the reference value, the inequation is valid inversely relational.

4. Tailback Estimation Based on V2X Data

The core principle of cooperative traffic systems is the exchange of information between road users and infrastructure by using modern communication technology such as wireless LAN (IEEE 802.11p). Therefore a range of different message types designated for different types of information is defined. The interface used here is compliant to the research project SIMO [3]. One type of message which is especially useful for the purpose of tailback determination is the CAM. It is broadcasted every second by vehicles equipped with communication tools (in the following called cars) and contains information about the position, speed, heading and identity of the car. It allows to use cars approaching the intersection as virtual detectors.

Since new technologies such as the described cooperative cars will only slowly reach a larger penetration of the market, it
cannot be guaranteed that every road user is using such a ccar. On this account the tailback cannot be measured directly and must rather be estimated by using a model. To enhance the estimation furthermore the advanced sensor technologies provided by vehicles and infrastructure within the KOLINE system are used.

4.1 Methodology

In urban road networks the waiting process and therefore the tailback lengths within signal controlled intersections depend on two processes: the arrival process described by the arrival rate $\lambda$ and the service process described by the service rate $\mu$. Based on former research works [4] a method to estimate the arrival and service rates and thereby the maximum tailback length per red time can be utilized. The method merges current and historical V2X data with information of the signal control (Fig. 3).

$$Fig. 3. \text{ According to the method of Mück [5] the maximum tailback length can be estimated by dividing the entire tailback length } L \text{ into the two parts } L_1 \text{ and } L_2, \text{ whereas } L_1 \text{ is the determinable tailback length and } L_2 \text{ the length to be approximated. Due to the available V2X- data, } L_1 \text{ can further be defined as distance between virtual detector (position of the ccar standing within the tailback) and stop line.}$$

The approximation of $L_2$ is based on the estimation of the arrival rate $\lambda$ of the vehicles standing in the tailback by considering the start of the red time period and the time the ccar arrives at the end of the tailback. Knowing the arrival rate $\lambda$ and the remaining red time, $L_2$ can be approximated for every moment within the red time period. As soon as the red time ends the tailback length decreases according to the service rate $\mu$ which can be estimated using historical data.

4.2 Validation

To examine the accuracy of the tailback length approximation using V2X data, the mentioned method was implemented within a simulation model using the microscopic simulation tool AIMSUN [6] and the AIMSUN API module tool.

The simulation model allowed the testing of different scenarios regarding the penetration rate which varied in three steps between 10, 25 and 50 %. The example of one test run is shown in Fig. 4. It uses a penetration rate of 25 % and allows comparing the tailback estimation with two other parameters. The real tailback illustrates the actual end of the tailback. The position of the last standing ccar represents the measurement generated by the last ccar coming to halt. Comparing the values of the real tailback and the tailback estimation second by second just visually it can be stated that the estimation seems to be mostly accurate with a tolerance of 10 m.

$$Fig. 4. \text{ Example of tailback estimation using a 25 % penetration rate}$$

By carrying out a larger number of test runs than shown in the example this impression can be confirmed. For each test scenario (regarding the different penetration rates) twenty test runs of one hour length were performed. The results are shown in Table 1. Even with a low penetration rate of 10 % about 74 % of the time the estimation is within a tolerance corridor of 10 m. The ratio can only be slightly improved by increasing the penetration rate.

$$Table 1. \text{ Quality of tailback estimation depending on the penetration rate}$$

<table>
<thead>
<tr>
<th>Penetration rate</th>
<th>10 %</th>
<th>25 %</th>
<th>50 %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Share of tailback estimates within a tolerance of ± 10 m [%]</td>
<td>74,2</td>
<td>74,6</td>
<td>80,4</td>
</tr>
</tbody>
</table>

4.3 Enhanced Tailback Estimation Using Further Sensor Data

The correct determination of the distance and arrival time (between the last vehicle and the virtual detector) is normally only possible if the penetration rate of ccars is nearly 100 % because the precondition of a stable queuing process within one red time period is only a simplification. Usually vehicles do not follow each other with always identical spacing, which means the described approach over- or underestimates the arrival rate. A ccar can be followed by none or by a large group of vehicles which follow each other bumper to bumper. The uncertainty becomes even larger the older the underlying measured data is.

To enhance the data needed for the Vehicle Based Tailback Estimation within KOLINE two kinds of advanced sensor technologies can be used:

1. Sensor technology within the vehicle provides data concerning not only its own current situation but also determines position and speed of surrounding vehicles within the range of its sensors.

2. Radar sensors used instead of common induction loops provide not only a virtual loop to generate data for TRANSQest but also generate trajectories of all vehicles approaching the intersection within the range of the sensor.

The advanced sensors within the vehicles extend the V2X data which helps to increase the number of virtual detectors, since speed
and position is not only known of cars but also of the surrounding vehicles within the sensor range. Thus a single car provides the data of other vehicles on the adjoining lanes of an access and also vehicles that reach the tailback at a later moment. With this larger amount of data it should be possible to reduce the margin of error and maintain a high accuracy which is at about 80 % for a margin of error of 20 m (or 45 % for 10 m) without using the extended data.

As KOLINE cooperates with the German Aerospace Center (DLR) and its “Application Platform for Intelligent Mobility” (AIM) [7] it was possible to use AIM-provided radar sensors instead of common induction loops within the project. In each approach one radar sensor is mounted. The sensor measures the target position \((x, y)\) and speed \((v)\) for up to 64 objects on the approaches’ lanes simultaneously. In this way the trajectories of all vehicles within the range of the sensor are known. Within KOLINE the object’s position and speed are transformed into a CAM and transmitting to the Vehicle Based Tailback Estimation. Additionally an algorithm allows choosing a value between 0 and 100 % and to transform exactly this percentage of objects into CAMs. This enables KOLINE to reproduce user-defined penetration rates of cars in a real public road network.

5. Fusion of Data

The component TRANSQest estimates the maximum tailback at signal controlled intersections once per cycle time. The duration of those cycles varies between 60 to 120 seconds. This is too long for optimising an approach strategy. Vehicles that communicate with the traffic light system can be utilized for the punctual determination of the tailback by means of the component Vehicle Based Tailback Estimation. These values, however, cannot be determined on a regular basis and do not render a sufficient number of values for a permanent estimation of the current tailback.

By combining and merging the periodical tailback estimations via TRANSQest and the additional tailback estimations by means of Vehicle Based Tailback Estimation, the component TRANSFusion is able to estimate current maximum tailback lengths of detected intersections for the entire period of time. The merging of the maximum tailback lengths identified via TRANSQest and the Vehicle Based Tailback Estimation consists of a two-dimensional data fusion. On one axis the estimated tailback lengths are to be merged. On the second axis the merging is carried out with regard to the times when the tailback values were estimated.

As calculation base the estimated tailback values \(R(TQ)\) of the component TRANSQest are used as they are available continuously per cycle time of the respective traffic light system. When a cycle is completed, TRANSQest estimates the maximum tailback which is considered to be a safe value at the time of estimation. For each further second TRANSFusion sends the estimated tailback, which consists of the tailback value estimated last by TRANSQest \(R(TQ)\) and a prediction. The prediction is necessary as the tailback is most probably apt to change during the period between last and next estimation via TRANSQest. The part of prediction has a form reminding of a funnel and is calculated by two boundary terms.

The first boundary term is the term of increase \(Z(s)\). This term implies that the tailback increases. The term of increase is either a linear function with an inclination which is determined on the basis of the last estimated tailback values, or an enhanced function which additionally considers the flow in dependency of the green time.

The term of flow \(A(s)\) is the second boundary term. This term presumes that the tailback decreases and no new vehicles extend the existing tailback. Depending on the last estimated tailback values the current flow can be identified. Minimum and maximum values are to be considered here.

The temporary result of TRANSFusion consists of the following two tailback values at every second:

\[
RZ(s) = R(TQ) + Z(s) \quad (1)
\]

\[
RA(s) = R(TQ) - A(s) \quad (2)
\]

This temporary result can also be described by these two terms:

\[
RM(s) = \frac{RZ(s) + RA(s)}{2} \quad (3)
\]

\[
RD(s) = |RZ(s) - RM(s)| \quad (4)
\]

\(R_{\text{min}}(s)\) is the mean estimated maximum tailback value and \(R_{\text{dev}}(s)\) the possible deviation.

If there are additional tailback estimations due to the component vehicle-based tailback estimations for a particular second, the values \(R_{\text{min}}(s)\) and \(R_{\text{dev}}(s)\) as well as the functions \(Z(s)\) and \(A(s)\) are modified respectively. The weighting is based on the variances of the single values of the respective sources.

The variance of the merged estimated maximum tailback equals the value \(R_{\text{min}}(s)\).

6. Conclusions and Future Works

The authors presented the methods to determine the actual traffic state and in particular the current tailback length developed and used within the cooperative KOLINE system in order to adjust the vehicles’ driving strategy. The concept of the three components involved in the tailback estimation is described. Providing tailback estimation data allows improving the approach of vehicles to signal controlled intersections in order to reduce stops at traffic lights and therefore enhance the traffic flow and decrease emissions. Two examples based on a simulation respectively real measuring data illustrated the high potential of an optimized driving strategy.

The shown examples give an impression of the potentials the merging of data from stationary detectors with V2X Data has. The future work focuses on the aim to test the system which is already implemented within a public road network in Braunschweig, Germany. The network is made up of three intersections along an arterial road of the inner city and all intersections are equipped with the three components of tailback estimation and radar sensors. Field trials to analyse the accuracy of the estimation components will be carried out. This will also include the evaluation of effects the usage of advanced sensor data has.
Acknowledgements
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Bibliography


Influence of changing station layout over railway interlocking

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ABSTRACT
The aim of the article is to present the influence of changing station layout over interlocking systems in train routes. There is often a problem in the process of doing for example application of interlocking system in exactly bigger stations when there are track changes in next phases of the project. Vividly small changes can influence in significant way for realization train and manoeuvre routes in such station. In case of that it is necessary to search the shortest road of making documentation and software which could be changes resistant. This resistance resulted by for example necessity of continuing leading railway when there is modernization on the station.

KEYWORDS: interlocking table, schematic plan, rail control solution

1. Introduction

Author in the next chapters gives more clearly and specific examples of changing station layout. In the last chapter there is solution how the problem could be done.

In the first there must be some information to prepare reader in the topic of article. For the person who creates interlocking table fundamentally is to know what is schematic plan.

The schematic plan – is created on the basic of layout plan of railway track system. There is presented layout of railway tracks and crossings in contaminated scale (longitudinal 1:2000, transversal 1:500) and there are marked railway control devices and routes of trains. It is allowed to apply different scale [1].

It is necessary to mark in the schematic plan [1]:
 a. numbers of tracks, points and derailers;
b. ends of points, main position of points and derailers and location of switch-drives, switch-locks and local adjusters towards tracks and switches;
c. semaphores and indicators with theirs localization;
d. train routes with indication of way and types of trains;
e. adjusting rail station with specific type of devices and dispatcher situated;
f. rail station district bounds;
g. levelcrossing and crossing, bridges, overpass and other devices and buildings having influence on signals situated and visibility
h. platforms and theirs active edges, flip-flaps;
i. lines way which are join into the station with pointed names of next station;
j. electricity tracks;
k. number of kilometers covered building of the railway, levelcrossing, adjusting rail station etc.;
l. track circuit control systems;
m. interplay devices;
n. track lead train control systems;
o. levelcrossing systems;
p. north side.

The interlocking tables are designed for controls clear performance, which is included on train and manoeuvre routes. They are created on basics of railway station’s schematic plan and they are part of project’s documentation. Tables are designed, especially in situations, when dispatchers need to decide by themselves about letting train go e.g. on replace signal.

The interlocking table consists of upper part, with heading of table and lower part, with closing table. The heading of interlocking table states type and quantity of internal, adjustable and block controls.
Fig 1. Example of simplified scheme of fictitious railway station

Table 1. Table of closing devices

<table>
<thead>
<tr>
<th>Routes</th>
<th>1</th>
<th>2ab</th>
<th>2cd</th>
<th>3/4</th>
<th>5</th>
<th>8</th>
<th>Wk1</th>
<th>Points</th>
<th>Tracks</th>
</tr>
</thead>
<tbody>
<tr>
<td>$A_1^1$</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>Jz2, Jz3</td>
<td>Jt1, JtA</td>
<td></td>
</tr>
<tr>
<td>$A_2^2$</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>Jz2, Jz3, Jz4</td>
<td>Jt2, JtA</td>
<td></td>
</tr>
<tr>
<td>$A_3^2$</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>Jz2, Jz5</td>
<td>Jt3, JtA</td>
<td></td>
</tr>
<tr>
<td>$B_1^1$</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>Jz1, Jz4</td>
<td>Jt1, JtB</td>
<td></td>
</tr>
<tr>
<td>$B_1^2$</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>Jz1, Jz2, Jz3</td>
<td>Jt1, JtB</td>
<td></td>
</tr>
<tr>
<td>$C_1^1$</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>JzK</td>
<td>JtL</td>
<td></td>
</tr>
<tr>
<td>$D_1^1$</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>Jz8</td>
<td>JtL</td>
<td></td>
</tr>
<tr>
<td>$E_1^2$</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>Jz8</td>
<td>JtL</td>
<td></td>
</tr>
<tr>
<td>$F_1^1$</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>Jz1, Jz4</td>
<td>JtB</td>
<td></td>
</tr>
<tr>
<td>$F_1^2$</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>Jz2, Jz3, Jz4</td>
<td>JtA</td>
<td></td>
</tr>
<tr>
<td>$G_1^1$</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>Jz2, Jz3</td>
<td>JtA</td>
<td></td>
</tr>
<tr>
<td>$G_2^2$</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>Jz1, Jz2, Jz3</td>
<td>JtB</td>
<td></td>
</tr>
<tr>
<td>$H_1^2$</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>Jz2, Jz5</td>
<td>JtA</td>
<td></td>
</tr>
<tr>
<td>$H_2^2$</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>Jz1, Jz2, Jz5</td>
<td>JtB</td>
<td></td>
</tr>
<tr>
<td>$K_1^1$</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>JzK, Jz2</td>
<td>JtL, Jt1</td>
<td></td>
</tr>
<tr>
<td>$L_1^1$</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>Jz8</td>
<td>JtL, Jt3</td>
<td></td>
</tr>
</tbody>
</table>
For better understanding signs in the table 2 it is necessary to write concepts (what does it mean). There are two most important concepts, exactly main position and rearranged position of points.

There are signs for the first part of interlocking tables: closing devices. We distinguish these kind of signs and meanings:

a. + main position of point and derailer (moved and closed)

b. - rearranged position of point and derailer (moved and closed)

c. + o main position of point and derailer which is in safety road (moved and closed)

d. – o rearranged position of point and derailer which is in safety road (moved and non-closed)

e. main position of point and derailer which is in safety road (moved and non-closed)

f. rearranged position of point and derailer which is in safety road (moved and non-closed).

There are signs for the second part of interlocking tables: contradiction table. We distinguish these kind of signs and meanings:

a. + excluded routes through another position of devices (points and derailers)

b. special excluded routes

c. - same routes.

2. Examples of changing layout station

The second part of the article introduce reader to description changes layout station with theirs influence over interlocking in train and manoeuvre routes. All points (examples) have got figure and description.

a. changing of main position of point (derailer)

Figure 2 shows initial project situation, where main position of point 2 is in plus straight. Designer can change main position of point if there could be easier to read for dispatcher interlocking tables. In the above example the key is point 2 which was changed to main position in plus on side. It is necessary to remember that the most important routes are these through point 1 in position plus. Additionally for these routes point 2 is on side protection. That is why designer decided to change point’s 2 position for plus on side which is clearly to understand for workers on station who use interlocking tables.

b. adding rib with extra point or derailer

In the example which is showed in figure 4 and figure 5 becomes to additional new point and peace of track with flip-flap. The aim was to use extra safe for train routes which are through the point 1 in plus position. For such routes it becomes to close point 2 in position plus on side protection. In the figure 4 there is semaphore A which ensure safety but it is dangerous. This danger follows that locomotive driver can go by the semaphore thought that it shows permitted signal but exactly it shows not permitted signal (red). This solution often appears in the next stages of project which insert significant changes into the first part of tables: exactly closing tables. There will be new column with point which position will be signed for train routes (in road or safety) and for manoeuvre routes (in road). It is not the only one example with new point in project but author wants to show exactly this.

c. new built-in tracks derailer for on side protection
The example which is pictured in figure 6 and figure 7 becomes to additional new derailer built-in track layout. This new object has to protect train routes (if it is necessary manoeuvre routes) which are through point 1 and 2 in minus position. There are possible to go from Tm1 with manoeuvre route additional. This is a danger situation which can lead to rail accident. There is everything possible when only semaphore is on side protection. It is similar example then previous but the track change is completely different. The reason of change is to use extra safe for train routes through the point 1 and point 2 in minus position. Then derailer Wk1 is closed in plus position that is install on track. This change does not influence to contradiction’s table but has got main influence for closing table. There will be new column with derailer and of course signs:

- plus for routes through the point 1 and the point 2
- minus for routes through Wk1.

d. moving on side safety

Figure 8 illustrates making of two parallel train routes from semaphore A and semaphore B through properly points 1 and 2 in minus, points 3 and 4 in minus too. For the route from A there is point 3 on side safety so there are no problem to turn on the permitted signal. But there could be a problem when dispatcher wants to make straight route from semaphore C. Then there have to be non-closed point 3 for the first route. It is the best solution and this kind of situation is showed in the figure 9.

Thanks to non-closing point 3 with restraint route from signal A there can be make train route from signal C which move point 3 to position plus and close it. For this example there are two overlaps from semaphore A which are different by on side safety (exactly point 3 properly for main route in position minus and for the second route in position plus). There is important to remember that in the contradiction’s table there will be excluded for main route from A with every routes from C. This example has got a big influence into the interlocking table and it is necessary to check exactly if there are these kind of changes.

e. safety road behind the semaphore

Figure 10 illustrates situation when safety road behind semaphore comprises point 1 which is the next object in track layout. This problem follows that restriction of semaphore location or short braking distance. There is need to be two variants of safety road. The first, main route is with point 1 in plus position (of course non-closing, if there are not routes without stop on the station it is the last one) and the second with point 1 in minus position (if there are routes without stop on the station next start from the semaphore A).

The next situation which is illustrated on figure 11 is moving safety road behind the semaphore with two points.

For the above example there are following points positions (variants of safety road):

- Z 1+ 2+
- w₁ 1+ 2-
- w₂ 1- 2-

There are two new routes in interlocking table and there are extra exclusions, especially for routes to semaphore A and parallel routes through point 2 in position plus.

f. routes without stop

Figure 12. Example station layout

There is possible to turn off router without stop through the station and then adopt that semaphore A is a home signal and semaphores D, E are exit signals, next routes from these signals
will be excluded. It is necessary to write it in contradiction table. This example is illustrated on figure 12. Engineer who is creating project can make this decision when for example on the station there is connection lines with a big meaning and small lines which are not important for rail movement. Sometimes it could be designer decision at rail staff request. This case has got a big influence for contradiction table because all routes which can be continuing has to be excluded (train route $\rightarrow$ train route). Of course designer decides which exactly routes are not without stop. It is necessary to make exclusion of routes (instruction WTBE10): properly train route $\rightarrow$ manoeuvre route.

g. special excluded routes

![Fig 13. Routes to semaphores B and C exclusions](image)

Routes to semaphores B and C are not excluded because of different position of devices but when there is only one track circuit between them it is necessary to exclude these routes in contradiction table. These are special excludes. Making these routes at the same time can block track and movement on the station. So there must be extra locomotive to move train, unblock the track and there occupy a lot of time and money. Of course there are safety aspects in this kind of problem.

3. Propositions of difference overcoming resulted by station layout changes

Examples which are specified in the second chapter figure problems connected with changing station layout during phasing modernization project of rail station. All problems are different then each other. There are examples which could be on specific situations on stations and it depends of movement situation. Despite of they are different all of them have influence over interlocking tables. It is necessary to know that this document is like a bible for dispatcher work and gives him essential and incorrect information about specific station. It is needed when there are problems with devices or for example with superior system. Then dispatcher can be certain when he will be change points positions and switch on call-on signal. At the moment when there was a big accident in Szczekociny it is very important to be certain that everything is perfect and safety.

Author has got the proposition to make interlocking tables despite of phasing processes problems. It will be a special tool for designer to change tables without complications and hardworking. There is no fundamental in what format it is saved:
- interlocking tables (closing and contradiction),
- routes book.

It is important not to make it by hands (it means slow writing all new closes and exclusions) but it has to be generated automatically. This generator can do the same things faster and cheaper than designer. These tables of course could be incorrect than these make by hands. Man can make a mistake everywhere and it is not depend on phase changes. Program is write with a designer logic and generating mistakes could be more clearly to find. This tool (generator) has to base by the station layout so it is geography based program. There have to be following objects unconditional:

- point symbol
- derailer symbol
- semaphore symbol
- manoeuvre semaphore symbol
- end of route symbol
- safety road behind semaphore symbol

Optionally there could be appear objects:
- track circuit symbol
- levelcrossing symbol
- line block symbol
Optionally symbols are used as extra information written in closing tables. Thanks to this additional objects it is known:

- route is incoming or outgoing,
- there is level crossing addicted,
- which track circuits are in safety road,
- what kind of line blocks are in concrete way.

It is a fundamental knowledge which has got dispatcher who wants to control station. All of dispatchers have to study interlocking tables and schematic plan before starting working on station. Superior system is created by means of schematic plan and movement documentation. Of course interlocking table is created and needed by interlocking system on the station.

Introducing computer systems on rail controlling gave a lot of new useful news and possibilities. But there sometimes are too many ways to create something and designers' ideas are so exaggerated. Then sometimes programmers fall into a trap. There are used by designers present station layout which was made for other control devices. There are a lot tracks and route overlaps. For computer devices it gives possibility to create various train routes and sometimes there are too many. There is a bigger risk too. But there are one big advantage: more variants bigger capacity.

### 4. Conclusion

With respect to polish railway situation and modernization phases generator (tool) should take changes in station layout into account. Every changes should not influence interlocking tables.

Designer has to draw the station with all needed objects in concrete line like there are on schematic plan. There is important to give suitable names like it is in instructions of the tool and schematic plan. When there is all station on a draw then it will be read into the generator to make interlocking tables.

The sense of making this program is to reduce human work with interlocking tables which are the most important document for dispatchers.

### Bibliography


Technical and organizational aspects of the Automatic Number Plate Recognition System (ANPR)

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ABSTRACT
Automatic Number Plate Recognition systems are already widespread over the world. Their performance, both with high computational efficiency of modern computers make them a very good solution to use in traffic supervision and management systems in the city and at the regional level in the scope of safety and security services. The most popular way of use ANPR systems concerns detection of violations in traffic law.

In Poland implementation of ANPR systems is at the starting point. There is still a noticeable lack of integrated area solutions, and currently used ANPR systems could not reach their full potential. In the following article authors introduced basic problems of application of the ANPR systems in Poland due to the legal requirements. Moreover paper presents selected functional aspects of ANPR systems.

KEYWORDS: ANPR, law enforcement, traffic supervision systems, bus–pass monitoring

1. Introduction

In recent years it can be noticed a rapid expansion of industrial monitoring in urban areas. This is the result of technological development, which allowed the use of automated control process, as a tool to support surveillance of public safety. The increase in computational power of computers caused the huge increase in the effectiveness of CCTV (Closed–Circuit Television) systems, by automating the process of image analysis. One of the methods of "intelligent" image analysis used to identify individual vehicles is the use of automatic number plate recognition (ANPR).

ANPR systems are used worldwide for many solutions related to intelligent transport systems. Their application is mainly used for:
- supervision of the security and public safety – i.e. for point or segment speed measuring, or for registration of so–called "driving through a red light",
- identification of vehicles for the selected access systems to restricted traffic zone;
- vehicle classification systems;
- an automatic toll collection systems – as a tool of control;
- recognition of "special purpose" vehicles;
- traffic measurement systems;

There are a number of opportunities to use ANPR systems, but they are affected by the functional limitations resulting mainly from the need of video recording. In the next section of this article, the authors indicated the selected functional limitations of these systems which results in problems in an efficient and effective implementation of these systems to the road system.

A wide range of possibilities of using ANPR systems, particularly in the context of surveillance of public safety and security, requires proper implementation of the legal possibility of application these systems on public roads. These devices fulfill functions both for prevention and sanction. In the third chapter, authors presents the selected aspects of legal implementation of recording devices, pointing also imperfections that make impossible to achieve full effectiveness of using these systems, and proposals for their change.
2. Selected problems in functioning of ANPR devices

In 2010, Motor Transport Institute has prepared one of the most complete and systematic analysis of the Automatic Number Plate Recognition systems in Poland. The scope of work included testing efficiency of these systems due to two main variables: the recognition effectiveness of character located on the license plate and speed of data transfer to the server database. Another aim of this analysis was to identify functional characteristic of the ANPR systems at the operational level. Field study measurements were carried–out with dedicated visual reference system for the four selected commercially available systems.

In order to define effectiveness of the license plate recognition, have been performed comparison of the file recorded by the visual reference system with the data sent by the four systems to the FTP server. The film recorded by the visual reference system has been treated manually by the trained operator and compared with the number automatically recognized by the tested system. Moreover, operator has noted and compared timestamps in the recorded material that included recorded vehicles (accuracy to within 1 second). These recorded vehicles were considered as valid only in the case of having whole license plate in the detection area. Recorded license plate number was defined as incorrect, when one of the following cases occurred:

- system did not recognized all license plate characters which were in the detection area;
- at least one of the license plate characters was recognized erroneous;
- system did not identified license plate.

Transfer speed to the FTP server database of the selected system was determined as the time difference between the passing time of the vehicle (time registered by the synchronized reference system that was taken directly from the recorder) and the moment of receiving this data to the FTP server.

ANPR study was conducted in defined various lighting and weather conditions, which allowed to specify conditions to obtain most accurate recognition performance. For the satisfactory operation of an ANPR systems most important factor is effective optical character recognition. In this study, ANPR system effectiveness ranged from approximately 35% to 95%, where the lowest efficiency of measurements was achieved in twilight and cloudy conditions. Performance has been also significantly worse during several more cases e.g.: high volume of rain, nighttime, scattered and broken clouds. Objectives and scope of this study have not included comprehensive analysis of influence of the external conditions on the ANPR operations, but have identified some trends that can inspire and serve as a starting point for further research.
The biggest quality difference is noticeable during heavy rain conditions on 26th and 27th April when some systems' effectiveness only by a few percent while in others the ratio was dropped by almost half, in comparison to sunny day conditions.

Table 1. Comparison of ANPR systems effectiveness indicators in different days of tests

<table>
<thead>
<tr>
<th>Date/hours</th>
<th>System 1</th>
<th>System 2</th>
<th>System 3</th>
<th>System 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.04.2010</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 to 7</td>
<td>78</td>
<td>87</td>
<td>81,4</td>
<td>86,7</td>
</tr>
<tr>
<td>11 to 12</td>
<td>82,9</td>
<td>82,2</td>
<td>84,3</td>
<td>83,8</td>
</tr>
<tr>
<td>19 to 20</td>
<td>76</td>
<td>90,2</td>
<td>89,5</td>
<td>81,7</td>
</tr>
<tr>
<td>AVERAGE</td>
<td>79,09</td>
<td>86,19</td>
<td>84,71</td>
<td>84,22</td>
</tr>
<tr>
<td>16.04.2010</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.30 to 6.30</td>
<td>71,6</td>
<td>40,8</td>
<td>79,7</td>
<td>n.d.</td>
</tr>
<tr>
<td>19 to 20</td>
<td>75,7</td>
<td>35,7</td>
<td>87,1</td>
<td>n.d.</td>
</tr>
<tr>
<td>21 to 22</td>
<td>78,2</td>
<td>44,3</td>
<td>87,9</td>
<td>n.d.</td>
</tr>
<tr>
<td>AVERAGE</td>
<td>75,55</td>
<td>39,58</td>
<td>85,23</td>
<td>b.d.</td>
</tr>
<tr>
<td>26.04.2010</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>23.30 to 0.30</td>
<td>n.d.</td>
<td>57,9</td>
<td>84,1</td>
<td>61,7</td>
</tr>
<tr>
<td>27.04.2010</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 to 6</td>
<td>n.d.</td>
<td>87,9</td>
<td>73,8</td>
<td>92,8</td>
</tr>
<tr>
<td>8 to 9</td>
<td>n.d.</td>
<td>49,5</td>
<td>87,2</td>
<td>89</td>
</tr>
<tr>
<td>16.30 to 17.30</td>
<td>n.d.</td>
<td>89,6</td>
<td>n.d.</td>
<td>92.5</td>
</tr>
<tr>
<td>19 to 20</td>
<td>n.d.</td>
<td>92,6</td>
<td>n.d.</td>
<td>88,5</td>
</tr>
<tr>
<td>20.30 to 21.30</td>
<td>n.d.</td>
<td>95,1</td>
<td>n.d.</td>
<td>85,6</td>
</tr>
<tr>
<td>AVERAGE</td>
<td>n.d.</td>
<td>91,27</td>
<td>82,68</td>
<td>88,46</td>
</tr>
</tbody>
</table>

Performed research allowed to indicate the most common mistakes made by OCR (Optical Character Recognition) programs used in systems for number plate signs recognition. There are three most frequent, basic causes of number plate recognition mistakes.

- incorrect character recognition due to its shape similarity to the other character,
- incorrect character recognition due to incorrect division of following characters,
- incorrect character recognition due to influence of other symbols and tokens which appears on the number plates.

In the first case the character recognition error is a result from shape similarity between different numbers and letters. The most common errors of these kind were caused be similarity of “0” and “O”, “S” and “5”, “U” and “V” shape similarity. Much less frequent, but still occurring, were mistakes during differentiation of “D” and “O”, “I” and “T”, “2” and “Z” characters. Characters recognition errors, in most cases, results from errors caused by OCR program. Frequency of errors increased with the dirt on the number plate.

The second case of errors occurs when two following individual characters were combined in one, or both were wrongly divided and incorrectly identified. I.e. “L” and “I” characters could be recognized as an “U” character, which provides to incorrect number recognition.

The third errors category results from hologram token (which is a compulsory element of number plate) influence on characters recognition program. The most frequent case concerned to identify “I” character and hologram token together as an “E”, “F” or “H” characters.

Number plate recognition errors could provide quite significant problems in functioning of ANPR systems, which were used i.e. to monitor the traffic at the dedicated lanes. In case of fully automotive process of monitoring, incorrect number plate recognition, could provide to qualify authorized vehicles as unauthorized, because of wrong number recognition. Much rarer case concerns identification of unauthorized vehicle as an authorized one.

As a conclusion from performed tests, there were indicated also additional problems concerns to automatic number plate recognition, which were caused by:

- contamination or deformation of number plate,
- use of vehicle owner additional elements at number plate like: retaining screw, security ties or reflective stickers interferes with speed cameras operation,
- too high vehicle speed, which provides problems with obtaining the proper quality of the photographs,
- adverse weather conditions resulting in reduced transparency of the air, or adverse lighting conitions which provides i.e. so called ”flare effect”,
- dirt on the lens or lens cover of camera.

Despite indicated defects of ANPR systems, the report clearly indicates, that these systems are the most perspective solution of the traffic management systems. Possibility of application of ANPR systems as devices to monitor and control a wide spectrum of traffic regulations violations, such as speeding, crossing of the junction while prohibit signal occurs, unauthorized ride through a bus lane, but also in other traffic related applications like: identification/detection of stolen vehicles, detection of vehicles at charged areas, or identification of authorized vehicles to the specific roads, makes them an excellent solution for modern city and regional management systems.

3. Assessment of current legal situation

Polish accession to the European Union on 1 May 2004 was clearly associated with acceptance of transport policy pursued by the European Community. Established by the European Commission – White Papers of Transport are setting out the objectives of transport policy, putting the emphasis on balance transport development in both urban and suburban areas, and above all to improve road safety expressed by the reduction of accidents on the roads combined with the decrease of fatalities. Established in 2001 by the European Commission document “European transport policy for 2010: time to decide” accept as a goal halving the number of road fatalities by 2010 as part of a collaborative project also including activities relating to standardization of traffic codexes rules of the Member States and development of technologies supporting vehicle–speed management systems.
The implementation of these activities in Poland, was associated with the implementation of programs on road safety, such as the National Road Safety Programme for the years 2005/2007/2013 Gambit 2005, which is the amendment to the previous program Gambit 2000 taking into account the assumptions of the White Paper of 2001, adopted by the Council on 19th April 2005. According to a document, the main activities in the field of road safety should be focused on:

- construction of road safety system (law, funding, research, information systems, management),
- formation of proper behavior in traffic (compliance of speed limits, use of seat belts, road users awareness, education, communication with the public),
- the protection of pedestrians and cyclists, construction and maintenance of a safe road infrastructure (setting hierarchy of road and streets system, modern traffic management, road safety audits of road projects),
- reducing the severity of accidents (safety devices in the vehicle, „soft” environment of roads, rescue operations), which would reduce the number of fatalities by 17000 people, injured by about 180000 and reduce total costs of road accidents by 68 billion PLN, assuming the average cost of a single event at about 1 million PLN.

Under the National Road Safety Programme, the Council of Ministers on 14th September 2006 adopted The Implementation Program for Road Safety 2006–2007, which represents the first stage of introduction of Gambit 2005 guidelines into practice. As one of the main tasks, foreseen for those years, implementation activities to improve monitoring of traffic carried by such development of an automatic traffic surveillance was accepted. Driving with speed inadequate to traffic conditions is a major cause of accidents in Poland (in 2004 resulted from the nearly 24% of cases and 30% of victims). These data indicated a low effectiveness of preventive actions used so far and have found that the improvement of road safety can not be achieved without effective counter using a improved forms of speed control. Achieving the objective – reducing the number of drivers exceeding the speed limit from 45% to 34% – was decided to pursue by:

- modifying the system of sanctioning of offenses relating to speeding,
- improvement of traditional forms of speed control,
- organization of automatic speed control system,
- modification of the legislation to enable implementation and management of setting modern traffic surveillance systems.

The activities started in the National Road Safety Program Gambit 2005 and were reflected in the gradual implementation of the various steps in the past few years with the prospect on further development in further years. The most visible effect of these actions on Polish roads is the implementation of instruments of automatic number plate recognition ANPR systems as a stationary recording equipment designed to detect violations of traffic rules. The systems currently implemented in Poland includes speed cameras, segmental speed measuring systems, and “passing through the intersection during the stop signal” detection recorders.

The implementation of automatic speed control and traffic surveillance requirement entails the creation of legal mandating processes of infringements detected by using these systems and the responsibility for supervision of the individual devices and systems. In the Polish legal system the powers of individual services are contained in the Road Traffic Law (Journal of Laws 1997 No. 98 pos. 602), and the Regulation of the Prime Minister of 21st September on the imposition of fines by the penalty mandate procedure (Journal of Laws 03.208.2023 as amended). The unified text of the Act on 05/31/2012 contains individual responsibilities which are divided between the Police, Municipal Police, and the Road Transport Inspection. Article 129, ch. 1, Chapter V of the Act and its sub–items define the powers of these services mandating systems and registration violations of traffic laws. Police competence are described in the art. 129 paragraph 2 points 9a, which states: “The police officer (...), is entitled to use recording equipment.” This notation is not detailed in terms of management and operation of video recording systems. A much broader domain was described for municipal police. In art. 129b paragraph 2 point 1b it stays “Municipal police shall be entitled to practice traffic control to the (...) subjects violating traffic regulations, in the case of disclosure and registration of deed using by the registration device”, and in paragraphs. 3, 3 points and 7 these competences are clarified: “In the case of traffic control (...) municipal police are authorized to:

- use of recording equipment, except that when using a device installed in a vehicle during operation vehicle can not be in motion,
- request the owner or keeper of the vehicle to indicate who he/ she gave the vehicle to drive or use in particular time”.

In the most comprehensive way Act describes the powers of the Road Transport Inspectorate, a service which has been designated as responsible for collecting and managing data retrieved from the video recording device. In art. 129g, paragraph. 1 states: “Disclosure by stationary recording devices installed in the traffic lane of public road the following violations of traffic regulations:

a) exceeding the speed limit,
b) incompliance to light signals

subject to Art. Paragraph 129b. 3 point 3, belongs to the Road Transport Inspection."

Objection, listed in the recipe, relates to the use of recording devices by municipal police. This provision, along with the rest of the quoted paragraph, however, carries with him a certain degree of inconsistency in the approach to the management of these devices. The division of services authorized to control by means of – police and municipal police, as well as revealing the violations recorded by them can not lead to conflict between these institutions, for example, when creating mandating centers in future, which will collect data from registration systems in within a given region. Related to this problem is referred in paragraph 1, only two kinds of violations of traffic regulations, which can be detected by means of stationary devices. Rapid technological progress in the development of ANPR systems, as well as a wide range of their use entails the need for implementation of solutions needed due to the detection of violations of traffic regulations, which appears in

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significant number. This occurs now in many Polish cities in case of bus lanes. However, the Act does not define which institution would be responsible for the newly created registration systems that detect violations not included in the quoted paragraph 1. In addition, having regard to the provisions of the police and the municipal police no regulating infringements, that these services can register with the help of the stationary video registration devices legal situation arises, that if there is need to build ANPR systems with functionalities other than detection of speeding vehicles and incompliance to light signals will need to be regulated.

Mentioned earlier in the text the Regulation on the imposition of fines by the penalty mandate procedure allows due to section 1 § 2a impose fines for offenses recorded by the video registration system: “In imposing a criminal mandate fine, an officer may use a mandate form generated using an ICT system”. Simultaneously, in paragraph 3 states: “In the mandate generated using the ICT system, a stamp of law services and a handwritten signature of the officer who imposed the mandate can be reproduced mechanically, if(...) system security (...) exclude the use by an unauthorized person (unique identifier of the officer – author note)”. Notation therefore regulates who can impose a mandate generated by detecting violation by ANPR device – it can be either a police officer, municipal police officer and the Road Transport Inspection. Currently, in practice, all such fines are issued by Road Transport Inspection, as an institution, which collect the data from cameras and recording devices. However, looking for the notation of the art. 129g, section 1 of the Law on Road Traffic, generality notation of imposing a criminal mandate by the “authorized officer” should be clarified in the case of implementation recording systems other than listed above violations of traffic rules.

An important issue in the context of the implementation of modern ANPR systems and functional quality of them are notations from art. 129g. paragraph 2 of the Law on Road Traffic, determining about the recorded and assigned to the actual case of violation information by the Road Transport Inspectorate, and also the notes contained in the Regulation of the Minister of Infrastructure on 17 June 2011 about conditions for the location, method of marking and measuring by the recording equipment. In the first document states: “While carrying out the tasks referred in paragraph 1, the Road Transport Inspection:

1. record the images of traffic rules violation, and (...) picture of the vehicle, which violated traffic rules, and the image of driver (...) and data, including:
   • the registration number of vehicle, which violated the rules,
   • the date, time and data determining place of violation,
   • the nature of the violation,
   • the data about owner, keeper or driver of the vehicle,
   • the identification number of the recording device”

   In this description, both the collection of data necessary to identify the perpetrators, collected after the registration of the violation, as well as those collected directly by the video registration system, was defined strictly, without leaving the possibility of collection other information that may become necessary in future modifications. This problem can be visualized especially for the concept of systems using video registration as just one element of detecting violations. Unquestionable is that the quoted regulation may act negatively on the development of both ANPR systems and mentioned complex solutions.

Regulation on conditions for the location, method of marking and measuring by the recording devices is of course important regulation of problem of arbitrary positioning of the registration devices. Unfortunately, the main disadvantage is the determination by the legislature of particular conditions, taking into account only the requirements necessary for such devices, which are currently the most common on Polish roads, thus recording an infringement of the speed limit at a given point or along the road and drive through the intersection of prohibit signal. In Chapter 2, § 3, paragraph 2 the conditions for stationary location of recording devices was set out: “Stationary recording equipment may be located:

1. in urban area at a distance of not less than 500 m from any other stationary recording device in this way,
2. outside urban area at a distance of not less than 2000 m from any other stationary recording device on this way – with the exception that these devices can not be located on roads under the supervision using recording devices, which reveal the violation of traffic rules in a particular section of road...”

Unfortunately, the definition of the distance between the recording devices has been designated taking into account only the characteristics of the measurements exceeded the speed limit. Taking into account other uses of ANPR devices this recording becomes unreasonable. Unfortunately, the legislature did not take into consideration the specificity of the passing registration on prohibit signal, which is referred in the Law on Road Traffic, which can cause serious problems for designers. As an example, there could be given a situation of two busiest junctions in built up areas at a distance less than 500 m from each other – without changing the current provision, it is impossible to build a recording system on both of these intersections. Another example might be the monitoring systems for bus lanes, for which the need to maintain a distance of at least 500 m between monitored points causes problems in the proper functioning of a system (and significantly decreases its efficiency). In addition, a notation which prohibits placing other recording devices within the road sections of segmental speed measurement excludes locating ANPR devices with different functionalities than the speed limit violations. This situation is unfavorable for both the localization of these devices (for example, the in ability to monitor violations of bus lane on the road covered by segmental measurement of vehicle speed), and economics – the device could be placed on the same poles and powered by single supply system, and sending recorded data by single transmission link, with a correspondingly high rate.

4. Conclusion

ANPR video registration systems are currently one of the best tool to detect violations of traffic laws. Despite its imperfections, shown in the functional tests provides by the Motor Transport Institute in 2010 which was a research on systems produced by different companies, they are a solution with the greatest
range of possibilities, which was demonstrated in these article. Unfortunately, the legal provisions, existing in the Polish legislation, significantly impede the development and implementation of ANPR systems for purposes other than those referred in the notations. Change of Polish law is necessary to implement further ANPR solutions, and to achieve full effectiveness of the existing ones.

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A System for Traffic Light Control Optimisation and Automated Vehicle Guidance Using the V2X Communication Technology

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ABSTRACT
The vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication for the increasing of traffic safety, traffic efficiency and driving comfort is a relatively new field of intelligent transport systems. In this paper a cooperative system for urban transport – which has been developed within the German research project KOLINE – is presented. It uses the communication between vehicles and traffic lights via the wireless communication standard IEEE 802.11p with the aim to avoid stops at traffic lights in order to reduce noise and pollutant emissions. The traffic lights provide information about the future signal changes and the local traffic state to the vehicles. The vehicles use this data to calculate the optimal approach strategy. In addition, the signal programs of the traffic lights are coordinated throughout the network and recalculated every 15 minutes according to the traffic volume. The article focuses on the architecture of the cooperative system and the communication between vehicles and traffic lights.

KEYWORDS: traffic light control, V2X communication

1. Introduction
Acceleration and deceleration of motor vehicles at traffic lights significantly influences the level of noise and pollutant emissions. The fewer stops for each vehicle are required and the more uniform traffic in urban networks flows, the lower the negative impact on the environment. If the number of stops on the road network can be decreased through a proper coordination of traffic lights and by an appropriate communication between vehicles and infrastructure, the waiting times of motor vehicles and the emission scan significantly be reduced.

In this context, the German research project KOLINE was running from 2009 to 2012 with the main goal to avoid stops of vehicles at traffic lights in order to reduce noise and pollutant emissions by using (a) the communication between vehicles and traffic light systems via the wireless communication standard IEEE 802.11p, (b) an automatic vehicle speed control and (c) a traffic volume dependent adjustment and coordination of the traffic lights within the observed road network.

![Fig.1. Overview of the KOLINE system](image-url)
An overview of the KOLINE system is given in Fig 1. The traffic light system provides information about the upcoming signal changes and the local traffic state to the vehicles via wireless communication. The vehicles use this information to calculate the optimal approach strategy. In addition, the signal programs of the traffic signal systems are coordinated throughout the network and recalculated every 15 minutes according to the traffic volume. For the first time, a mutual optimisation of both traffic lights and vehicles is performed.

After providing some basics of vehicular communication systems in Section 2, the subsystems and components of the KOLINE system will be explained in more detail in Section 3.

2. Vehicular Communication Systems

Vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication (also called V2X) is understood as the capability of vehicles to communicate with each other as well as the infrastructure directly. Many research projects have dealt with the topics of vehicular communication so far. In Europe, some of the most important have been PReVENT, SAFESPOT, COOPERS, DRIVEC2X, COMeSafety and simt. The main motivation for vehicular communication systems is increasing traffic safety, traffic efficiency and driving comfort.

The frequency bands in Europe for vehicular communication are located at 5.9 GHz[1]. Two categories of draft standards provide outlines for vehicular communication. These standards constitute a category of IEEE standards for a special mode of operation of IEEE 802.11 for vehicular networks called Wireless Access in Vehicular Environments (WAVE). 802.11p extends the 802.11 Wireless LAN medium access layer (MAC) and physical layer (PHY) specification. 802.11p aims to provide specifications needed for MAC and PHY layers for specific needs of vehicular networks[2]. The wireless communication should still working at a speed of 200 km/h and a range of 1000 m [3]. IEEE 1609 is a family of standards for the higher layers of the ISO/OSI protocol stack. These standards deal with issues such as management and security of the network [4].

3. Architecture of the KOLINE System

The architecture of the KOLINE system is provided in Fig. 2. The KOLINE system consists of the following subsystems and components:

- **Vehicle** is equipped with an IEEE 802.11p compatible communication device. By using topology information, current and future signal states as well as tailback length, the vehicle’s **Assistant System** computes the optimal strategy for passing the intersection, which means preferably not to stop under certain constraints (e.g. minimum and a maximum speed). The strategy is implemented by the vehicle, so that the speed of the vehicle is controlled automatically without operation of the driver. The vehicle provides information about its speed and location to the traffic light system via IEEE 802.11p.

- **Traffic Light System** communicates with the **Controller** via V2X communication technology. The **Controller** links SIGNOS with the lights and detectors. The other subsystems traffic light system and traffic management centre are connected to the **Controller** in the traffic management centre via GPRS and to the vehicles via the IEEE 802.11p compatible communication device.

4. Communication Protocols and Messages

Within the KOLINE system, the subsystems vehicle and traffic light system communicate via V2X communication technology. The subsystems traffic light system and traffic management centre communicate via mobile internet using the General Packet Radio
Service (GPRS). Fig. 3 gives an overview of the communication technologies used. This Section explains details about the protocols and messages.

4.1. V2X Communication

All messages to be send base on the SAE J2735 Dedicated Short Range Communications (DSRC) Message Set Dictionary[7]. They have been slightly adapted by the simTD research project[8]. All messages are defined with the Abstract Syntax Notation One [9].

Fig. 3. Communication technologies within the KOLINE system

The traffic light system sends the following messages to the vehicles every second:

- **Topology (TOPO):** The traces of all lanes and the position of the stop lines.
- **SignalPhaseAndTimingData (SPAT):** The current and future signal states of all signal groups related to the lanes defined in TOPO.
- **AppSpecificData (ASD) with TrafficState:** The estimated current and future tailback lengths of all lanes (see also Section 6).

The vehicles send the Cooperate Awareness Message (CAM) to the traffic light system every second. The root element of all messages sent between the traffic light system and the vehicles is C2XAppPayload:

\[
\text{C2XAppPayload} := \text{SEQUENCE} \{ \\
\text{protocolMsg CHOICE} \{ \\
\text{appSpecificData }[\text{APPLICATION }1] \text{ AppSpecificData}, \\
\text{coopAwareness }[\text{APPLICATION }2] \text{ CoopAwareness}, \\
\text{decEnvNotification }[\text{APPLICATION }3] \text{ DecEnvNotification}, \\
\text{probeVehicleData }[\text{APPLICATION }4] \text{ ProbeVehicleData}, \\
\text{destinationData }[\text{APPLICATION }5] \text{ DestinationData}, \\
\text{intersectionData }[\text{APPLICATION }6] \text{ Intersection}, \\
\text{trafficRegulationData }[\text{APPLICATION }7] \text{ TrafficRegulationData}, \\
\text{signalPhaseAndTimingData }[\text{APPLICATION }8] \text{ SignalPhaseAndTimingData}, \\
\text{sotisData }[\text{APPLICATION }9] \text{ SotisData}, \\
\text{trafficListData }[\text{APPLICATION }10] \text{ TrafficListData}, \\
\text{textAnnouncementData }[\text{APPLICATION }11] \text{ TextAnnouncementData}, \\
\} \\
\}
\]

The ASN.1 definition is compiled with an ASN.1 compiler for encoding and decoding the messages. Within the KOLINE project, the packet encoding rules (PER) were applied. A special case is the traffic state message. Because the Message Set Dictionary did not provide an appropriate message definition, a KOLINE specific ASN.1 definition was built, which is packed into the AppSpecificData frame.

Within the KOLINE project, the model LinkBird MX by the manufacturer Renesas Electronics (former NEC)[12] is used as the V2X communication device. By using the software development kit of the V2X communication device, Single Hop Broadcast Messages (SHBMessage) are created and sent to the V2C communication device via the User Datagram Protocol (UDP) with the above mentioned messages as payload. The V2X communication device broadcasts the messages via IEEE 802.11p.

4.2. Communication between Traffic Lights and Management Centre

Fig. 4 provides the steps of collecting local traffic volume data, calculating the signal program for the next interval at the traffic management centre and operating the calculated signal program at the traffic light system.

The messages sent by the traffic management centre are the periods of the current and the next optimisation intervals and the calculated signal programs. The traffic light systems provide the collected traffic volumes of the just expired interval to the traffic management centre. The messages are encoded in a binary format (no usage of ASN.1). For transmitting the messages, the Transmission Control Protocol (TCP) is used.

5. Field Operational Test

Field operational tests were performed on a non-public site and on a public road section. The part of the vehicles was taken by the KOLINE partners Volkswagen AG and Institute of Control Engineering at the Technische Universität Braunschweig, Germany. The two test sites differ in some technical aspects which are described in this Section.

5.1. Technical Validation Site

The technical validation site is a former military barracks area. It was equipped with three signal controlled intersections. The correct technical functioning of the whole KOLINE system has
been proofed there. All subsystems and components are identically to the description in Section 3. The controller deTRAplex as announced in [13] was used as a component of the traffic light system.

5.2. Demonstration Site

Three signal controlled intersections within the public road network in Braunschweig, Germany, have been selected for the demonstration site. Compared to the technical validation site, the hardware equipment at the demonstration site is from third parties. The main difference is the missing feasibility for SIGNOS to take the main control by sending the signals to be shown to the controller. From several reasons, it is not possible for the controllers used in Braunschweig to process the SIGNOS commands. Instead, the controller provides the current and the first subsequent signal state of all signal groups to SIGNOS. With this information SIGNOS recognises the current signal program running on the controller calculates the signal changes carried out within a short time and provides them to the vehicles and the tailback estimator components. Because of the missing link between SIGNOS and the Controller the signal programs calculated within the signal program optimiser are not operated.

6. Conclusion

This article has described the architecture and the technical components as well as communication aspects of the KOLINE system for the co-operative optimisation of traffic lights and vehicle guidance. There are two other related papers being published on the TST Conference 2012 which reports from the KOLINE project. One article with the title “Multi-Criteria and Monetizing Evaluation of Microsimulated V2X Technology for Traffic Light Optimisation” by Wolfgang Niebel et al. deals with the impact of the KOLINE system on the traffic flow, the noise and the pollutant emissions. The other article with the title “Improvement of Traffic State Estimation at Signal Controlled Intersections by Merging Induction Loop Data with V2X Data” by Oliver Bley et al. discusses the tailback estimation part of the KOLINE system in much more detail. Details to the signal program optimisation were published in [14].

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Bibliography

The Management System of Detours in Urban Areas

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ABSTRACT
This article presents a concept of detour management system for the traffic flow that run through congested areas of the urban agglomerations. This system, using the wide range of the ITS devices, allows to judge the current traffic conditions on the highly urbanized areas and, on the basis of the received data, direct the traffic on the alternative routes, by means of an active traffic information system.

1. Introduction
Currently implemented traffic management systems are an attempt to an active response for the problems connected with both the limited traffic capacity, and the issue of improving the traffic safety. The principle is that those systems should in an active way measure the current traffic conditions (intensity, directional and generic structure vehicle speed, etc.), weather conditions in the management system area and factors that can, in a vital way determine the traffic capacity and safety. The intelligent transport systems are increasingly installed both for the urban areas and expressway, as well as the motorways. An important issue in the TMS is the lack of the mutual system integration, which comes from the administrative borders of particular areas, and the lack of the statutorily described communication standards between the management centres. This situation is especially noticeable on the national roads that run trough the city and highly urbanized areas. The distinction between the managing entities blocks the possibility of a full integration, thus creating restrictions in efficiency of managing the traffic flow. An alternative for the situation described above is creating an integrated traffic management system.

Current traffic management systems in Poland are mainly created on the national roads, which are owned by the National Treasure, and managed by the General Directorate for National Roads and Motorways. Public roads from other categories – regional, county, district – belong to proper self–governments. This distinction, along with poor cooperation of the self-government bodies and the GDDKiA, different regulations, available budgets, etc. makes the integration of the ITS systems that already exist on national and self–government roads very hard or even impossible. However, one should take into consideration that construction and integration of the traffic management systems on the area of the whole state in the perspective of a dozen or so years is inevitable in order to have a proper economic and social development of Poland.

The management system of detours in urban areas will help in choosing the best route for the travellers, and allow them reach the target fast and safe. For the city inhabitants it means lowering the inconveniences connected with the obstruction of the urban road network, as well as lowering the social frustration and aggression connected with the traffic excessive intensity. One can also expect that it will reduce traffic accidents and collisions not only in the urban areas, but also on the main roads.

Urban areas are huge and complex systems. When designing a ring road, or city expressway with telematics systems, one should take into consideration many factors that characterize particular agglomeration. The TMS do not have to be restricted only to direct drivers towards the alternative routes, they can also manage the traffic directly in the city centres. The aim of the system would be to optimize access to logistics centres, shopping centres or transshipment of goods from out side city traffic to inside road traffic. Further consideration to reduce congestion in cities can be a restriction of movement or the charging of fees. The solution
is operating in London and Rome and had a positive effect on reducing the movement of people in urban centres in favour of public transport [8], but this concept will not be further addressed in this article.

Figure 1 presents a contour map with chosen cities in which during the last two years major investments regarding the ring roads have been finished or are planned to be finished within the next two years. Single out cities represent important transit centres in Poland, it confirms the necessity of constructing global traffic management systems.

![Figure 1](image1)

**Fig. 1** Chosen cities in which large investments in regard to the construction of the ring roads are being made.

### 2. The concept of detours management system

#### 2.1. System assumptions

The main goal of the detour management system is to direct the traffic flow in the traffic nodes before the urban areas. According to the Figure 2, the system consists of a current traffic conditions subsystem, active traffic information system and additional measuring subsystems.

The current traffic conditions measuring subsystem is the basic element of the detour management system. This element is responsible for acquiring the parameters connected with the traffic intensity on the area of particle urban area. The gained data are the start signal for the superior system, thus being the basic decisive criterion of the active traffic information system. This data should come from the urban traffic management systems.

The traffic information subsystem is a set of active luminous elements in a form of a variable message signs located in the nodes set prior to the urban areas. This subsystem is an executive element of the superior system, which task is to inform drivers about the necessity of choosing an alternative route.

Additional measuring systems may be a supplement of the subsystems mentioned above: traffic condition in the urban areas subsystem and the traffic information subsystem. Those additional subsystems would be systems that record the parameters of the traffic flow on the sections prior to the agglomeration and alternate routes outside urban areas. Information regarding the traffic intensity, generic structure and the parameters of particular vehicles are important for the city traffic management system. It is also an additional decisive criterion for the detours management system.

![Figure 2](image2)

**Fig. 2.** The concept of the detours management system in the traffic nodes before the urban areas.

The information flow between particular modules of the system are presented on the figure 3.

![Figure 3](image3)

**Fig. 3.** The architecture of the detours management system

The central element of the system is the processing–decision module, which is responsible for processing the data gathered in the dedicated database cluster, inference in accordance to earlier set algorithm and activation of the proper information in the active traffic information device. Data from the additional measuring subsystem are gathered directly in the data base of the detours management system. The current traffic condition measuring subsystem, which should be a part of a city traffic management system, sends chosen information through the communicated database systems.

#### 2.2. The application of the ITS device

Described in previous section detours management subsystems require an effective ITS equipment. Example of devices that can be used in the present primary system is shown in Figure 4.

![Figure 4](image4)

**Fig. 4.** Example of ITS equipment

VIDEO/ANPR systems are part of the visual recorders, which aim to acquire the image, both as a video sequence and an isolated frames showing the picture of the vehicle, as well as the vehicles.
identification through registering plates recognition mechanism and calculating the current, actual intensity of the traffic. Those systems are applied as a part of the current traffic conditions measurement subsystem in the city agglomeration areas and in an additional measurement subsystem.

The VMS systems are the basic elements of the active traffic information subsystem. They consist of variable message signs, which depending of the need, can be made in predefined technologies, full RGB technologies, as integrated sign boards put above the main road, single signs above particular lanes or signs located next to the side lane. They can emit information about recommended detours, current speed limits, weather conditions and other significant informations.

Fig. 4. An example of the ITS devices and systems

The WIM system (Weight in Motion system) are the elements of an additional measuring subsystems. Information obtained from the subsystem will allow for a detailed classification of vehicles, both in terms of generic structure as well as weight, pressure from the axes, and optionally detecting a vertical gauge overshoot. The data will be an important criterion in choosing the alternative route, depending on the current generic structure of the traffic, and class of the roads that are available. Moreover, there will be possibility to send to the proper services in the real time information regarding the possible speed limit violation.

The METEO systems, by analogy to the WIM systems, are part of the additional measurement subsystems. The data obtained from weather stations installed along the road and road weather sensors are the perfect complement to decision–making system, allowing the selection of an alternative route based on current weather conditions. The meteorological information along with the VMS system allow to keep drivers with the up–to–date information regarding the weather conditions in the road area.

PARKING systems are the third element of the additional measuring systems. They can be used to inform drivers about available parking places along the main routes, as well as the alternative, and as information system for the city park & ride systems.

3. Conclusion

The creation and the integration of the TMS systems in the city agglomerations can potentially give big benefits for both the citizens and travellers. Ring–roads are being continuously build in Polish big agglomerations, as an alternative roads for the down town areas. One can expect that this trend over the next few years will remain constant. Increasing traffic levels in city centres increases the aggressiveness of drivers, which further aggravates congestion and significantly increases the likelihood of traffic accidents [7]. Diversion of transit traffic flows on alternate routes, avoiding city centres, will result in a substantial organic traffic in city centres. Since the most of the investments regarding the ring–roads construction in the Polish cities are new, information regarding the benefits of using alternative roads is necessary in a social aspect. The basic tool of an active informing the drivers are the Variable Message Signs. They can convey the information regarding e.g. travel time through individual alternative routes, information regarding the accidents or difficult weather conditions. One should also remember that driver is the one who decides about the route, however (s)he should have as much information necessary to optimize it as possible.

Bibliography

Standards of data transmission protocols for the traffic management system

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ABSTRACT
Article is a summary of works, the purpose of which was to determine the standardized data protocols for the National Traffic Management System

KEYWORDS: ITS, Traffic Management System DATEX II

1. Introduction

In 2012, work started on the creation of National Traffic Management System. Within the framework of cooperation between the government and non–government sector, ITS specifications were developed to be the basis for the development of National Traffic Management System. Article presents the results of the works, the task of which was to develop technical specifications for data transmission protocol standards for the traffic management system.

2. Scope of impact

Architecture of the traffic management systems is a layered one. An example of a simplified model of traffic management system architecture is presented in Fig. 1.

The range of substantive impact should be understood as the definition of system layers for which it was necessary to determine the data transmission protocols. The “depth” of interference with the roadside devices was analyzed, including the determination of means of communication between the sensors and the device controller. Two solutions were developed which differed in the range of definition of communication. Version A (Fig. 2) included the determination of transmission protocols between the roadside devices and the central computers. Version B (Fig. 2) would also include the definitions of methods of communication with the actuating instrumentation such as sensors, motors, etc.

Fig. 1. A simplified model of the traffic control system

After analyzing the documentation of the producers of devices it was decided, that Version A will be selected for further work. For reasons of maintenance and servicing of the devices, the necessity was pointed out for the producers of devices to supply the user (the road management authority) with complete documentation of the
system, including the parameters of the individual components of the roadside devices, such as sensors and controllers, along with a description of the communication among them.

Fig 2. Options of solutions were analyzed during the work

3. Selection of a protocol for the application layer

After determining the extent of substantive impact, works were conducted on the selection of an optimal communication protocol. Due to equipping the roadside devices with controllers which, in addition to transmitting information from the sensors, are designed to aggregate information and its short–term archiving (in the case of loss of connection), it was stated that it is possible to use the existing protocol of the application layer of the OSI model instead of developing new authored (binary) protocol. After carrying out the tests of the existing protocols and their properties (DATEX II, TLS, NTCIP, UMTC, MTM), it was decided that DATEX II and TLS should be adopted for further consideration.

The main criteria for the selection of protocols were:
- openness,
- possibility of obtaining documentation,
- possibility of adopting to the needs of national specifications,
- free of charge / licensing,
- use of the protocol should not be burdened with any charges,
- license to use the protocol should not restrict its application,
- promise of continuity of standardization,
- possibility of development,
- continuous activity, adopting the documentation to the changing market conditions (keeping pace with technological development).

The conclusion was that:
- DATEX II protocol is consistent with the conditions above:
  - presently the work on DATEX II version has been completed,
  - the documentation provides for the possibility of introducing additional components without the need to inform the standardization authority,
  - use of the protocol is free of charge,
  - the documentation of the protocol is available free of charge on the web www.datex2.eu,
- EasyWay – the project which includes DATEX II protocol is supported by the European Parliament,
- TLS protocol is in part consistent with the above conditions. Its principal disadvantages are:
  - the cost of documentation,
  - design with backward compatibility with devices implemented in one country (Germany) in mind,
  - requirement of the existence of additional roadside infrastructure (workstations),
  - protocol encapsulation for transmission with the use of TCP/IP (TLSoIP) protocol.

4. DATEX II communication protocol

A suggested communication protocol for the transmission of data, on the basis of the analysis of documentation, as a protocol most adaptable in Polish conditions. This is a protocol described in UML language, with markup described in an XML structure. It contains a definition for most of the values acquired from roadside devices and allows for the control of roadside devices.

DATEX II allows the definition of extensions in accordance with CEN/TS 16157–1:2011. These extensions have different levels of interoperability and defined restrictions. Three levels of extensions are defined:
- Level A of the DATEX II data model basic/base model. An extensive base data model (called “level A”) is suitable for most scenarios of data exchange. This model already has a huge amount of options from which users can select individual items when compiling the data for “publication”. It is a minimal set for all DATEX II systems which must be met in order to ensure interoperability. Implementations should fully support level A.
- Level B of the DATEX II model. extended base model – in the situation when in the concept of data required for the particular uses is missing from the Data Dictionary, for example when the data makes sense only in a national context. In this case users have to provide an extension to the model B (called “level B”) which provides the missing concepts. Users can apply a limited set of well-defined UML mechanisms for these extensions at the level B, which then still maintain the technical interoperability with the standard DATEX II systems (level A). This means that the customer supporting only level A is able to receive and decipher the information sent by the service provider using an extended level B, but he will not be able to decipher the part of the “publication” covered by the extension.
- Level C of the DATEX II data model

Use of the concept DATEX II in various content – models and implementations of level C are considered to be inconsistent with DATEX II model, level A/B. However, they are consistent with all other DATEX II specifications (common rules for modeling and common exchange protocols). Of course, C level systems are not compatible with level A and should not be used for the EasyWay exchange.
The application in National Traffic Management System will have all three levels of the model described in the Datex II protocol documentation. The application of this protocol will allow making uniform the exchange of information on all levels of the control system and for standardizing the manner in which information is transferred in the system. Standardizing the description of the variables is supposed to lead to full independence of the devices, i.e. Each one based on the documentation of the protocol will be able to adapt the device to cooperate with the National Traffic Management System.

5. Aggregation, preliminary data processing and data transmission rules

Roadside devices, in accordance with the concept of National Traffic Management System, have to transmit data in two modes:
- on demand
- at intervals

Both modes can operate simultaneously, with the mode "on demand" initiated by an external application (e.g. by Road Transport Inspection officers). The "at intervals" mode will be active continuously and the data aggregated during the intervals will be sent to the central servers.

Regardless of the mode of operation used, the aggregation of data was analyzed from the perspective of the amount of generated data, as illustrated in the following figures. Due to the fact, that the number of generated data is usually larger than the throughput of the communication link (for example, sending information about each registered vehicle by a vehicle counter), two solutions were analyzed:
1. each component of the infrastructure has its own aggregating server (Fig. 3),
2. all infrastructure components at a given point are connected to one aggregating server (Fig. 4).

The prerequisite for the second solution would be for all cooperating devices to be supplied by one producer and to own separate interfaces for individual components (e.g. different IP addresses or ports numbers for meteorological stations, VMS and scales), i.e. the virtualization of devices cooperating with an aggregator from the perspective of the traffic control system. The main argument for this solution would be the reduction of costs of a single roadside device through the use of less expensive hardware solutions with lower parameters.

However, due to the increase, in this case, of the maintenance complexity of the roadside part of the National Traffic Management System, this solution was assumed to be unfavorable.

6. The issue of information transmission – the choice of transport protocol

TCP/IP model describes the layered structure of data transmission between applications, with the use of computer network, and is divided into four layers: application, transport, Internet and network access. DATEX II protocol is contained in the application layer.

The data in the protocol DATEX II, according to the documentation, are sent with the use of http protocol in the push/pull mode, i.e. sent in intervals or on demand. On the other hand, http protocol uses, in the transport layer of the assumed model, the TCP (Transmission Control Protocol).

The above solution is based on http and TCP protocols and allows transfer of data both formatted with DATEX II protocol and any other binary and text files. Due to the widespread implementation in the devices operating in ITS systems, it was decided to allow the use of FTP protocol (File Transfer Protocol) to transmit binary files, such as images.
7. The diagnostics of roadside devices in National Traffic Management System – SNMP protocol

In accordance with the decisions made, the diagnostics will be carried out based on SNMP protocol. It is possible to simultaneously carry out the diagnostics based on DATEX II protocol, however, it will not allow such a broad spectrum of diagnostics of the particular components of the system as SNMP protocol allows. Hence it was decided to stipulate two separate levels of diagnostics – for system operators and for maintenance staff/system administrators:

- The diagnostics for system operators:
  - for information purposes – for a system operator, the data should be generalized and, most often, reduced to the information “good” – “fail”. For this purpose, DATEX II protocol can be used together with the extensions B and C. The complete documentation of information made available or transferred by a given device shall be included in the technical documentation of the device.

- The diagnostics for maintenance staff/system administrators.
  - for maintenance or administrative purposes a higher level of information detail is required, which cannot be obtained with the use of DATEX II protocol. For this purpose it is suggested to use SNMPv3 protocol.

The definition of the information about components of roadside devices and information which can be obtained from them should be described in the MIB’s (Management Information Base) of each device, i.e. the set of information possible to read or change with the use of SNMP protocol. The data block of basic information (e.g. device ID, device name, device location, time of launch, etc.) should be specified when creating the specification of the system diagnostics. The data block of information possible to obtain from devices, allowing for a wider diagnostics, should be described in the documentation of the device.

8. Conclusion

DATEX II protocol, as a communication protocol, was chosen as an intermediate solution between the existing protocols and the creation of new authored communication protocol. It is necessary to carry out further work in order to determine the content of B and C extension of DATEX II protocol, so that it can be used to transfer data from the currently used and from introduced devices. The creation of an entirely new protocol would require a lot of time and human resources. An adaptation of the chosen protocol will allow its quick implementation. It should be emphasized that the implementation of the DATEX II protocol will take place on Polish territory, where the current ITS infrastructure is very poor and the individual centers are just beginning to implement ITS solutions of insular character. Such single implementations have unfortunately one feature in common – if they are not manufactured by one company, they will not cooperate with each other and thus they will not work with the National Traffic Management System.

National Traffic Management System will be the standardizing link, if not for the whole ITS systems, then for their interfaces, which will ultimately lead to the improvement of functioning of Polish road system and thus to the reduction of unit costs of transportation.

Bibliography

Optimization of Channel Access in Wireless Sensor Networks

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ABSTRACT
The objective of the work presented in this paper is to analyse the problem of deployment of TDMA wireless sensor networks in the area of transport telematics from the communication subsystem optimization perspective. The problem of broadcast scheduling has been outlined and a heuristic algorithm has been designed for the optimization of radio channel access control using the TDMA method. The channel utilization was the main optimization goal while eliminating primary and secondary conflicts between the broadcasting stations.

KEYWORDS: wireless sensor networks, TDMA, broadcast scheduling, optimization

1. Introduction
The merging of Internet, communication, information, transportation and industrial control technologies together with the latest technical advances in these areas opened the road for a new generation of economically undemanding sensors and actuators capable of high degree of spatial and temporal resolution and accuracy highly required in telematic applications. The technology for sensing and control includes fields of electric and magnetic sensors, seismic sensors, radiofrequency sensors, electro-optic and infrared sensors, radars, sonars, lidars, and localization and navigation sensors.

The sensing technology is of a high growth potential not only in science or control, but also in a wider spectrum of applications related to monitoring and protection of critical transportation infrastructure, power industry, goods processing, public health, environment and other areas.

A sensor network is an infrastructure consisting of sensing (measuring) and/or acting, computing and communication elements providing functions for measuring, monitoring and reacting on events in a specified operating environment. The basic components of a sensor network is a set of distributed or localized sensors, interconnecting network (usually wireless), central data aggregating node, and a set of computing resources responsible for data correlation, trends monitoring, states determination, and data mining. In this context the sensing and computing nodes are considered as a part of the sensor network, but in fact, a part of the computations may be performed by the network itself. Because of a potentially huge amount of gathered data, algorithmic methods for data processing and communication control play a significant role. The communication and computation infrastructure is specific in dependence on deployment environment and application.

2. Wireless Sensor Networks
Multiple technology implementations utilize the principle of aggregation nodes gathering data from a defined sensor field and sending them to a final point for analysis, for longer distances making use of public wired or wireless network (Fig. 1).

The structure of a wireless sensor network node is dependent on the required functionality in a given application. Fig. 2 depicts a basic node configuration, while the mandatory blocks are marked grey, the optional ones are white. In case of implementation of an active element, the node is referred to as a wireless sensor/actuator. Regarding the possible topological structures of a wireless sensor network it is evident, that a node can operate as a data source (measured data, position information etc.), data receiver (actuator), and as a router (forwarding data from neighboring nodes).
Based on these classifications it is obvious that different combinations of the defined classification factors lead to an extensive and diverse set of possible configurations. This implies varied requirements on network characteristics, priority of key parameters, and specific problems.

3. Broadcast Scheduling in TDMA Networks

A wireless sensor network can be represented by a graph $G=(V,E)$, where $V=\{v_1, v_2, \ldots, v_N\}$ is a set of nodes, while $N$ is number of nodes and $E=\{e_1, e_2, \ldots, e_L\}$ is a set of undirected edges, where $L$ is number of undirected edges [4]. The existence of an edge between two nodes means, that these nodes are able to directly mutually receive broadcast packets transmitted by the other node. The connectivity between network nodes can be expressed by a symmetric matrix $C$ with dimension $N\times N$, called connectivity or adjacency matrix, where the element

$$c_{ij} = \begin{cases} 1, & \text{if } v_i \text{ and } v_j \text{ are connected} \\ 0, & \text{otherwise} \end{cases}$$

In case two nodes are directly connected, we say they are one hop away. Let us suppose time divided into slots and a frame with constant length. The transmission of a single packet takes one time slot. A TDMA frame consists of a fixed number of such time slots. Packets can be transmitted simultaneously without conflict in the same time slot only if no interference occurs. If an optimal TDMA transmission scheme is determined, the frame is repeated. Let us denote this TDMA frame by a matrix $T$ with dimensions $M\times N$, which elements

$$t_{mj} = \begin{cases} 1, & \text{if } v_m \text{ transmits in time slot } m \\ 0, & \text{otherwise} \end{cases}$$

If node $v_i$ transmits a packet, none of its neighbors, i.e. nodes a single hop away, is permitted to transmit at the same time, which would cause a primary conflict or direct collision [2] (Fig. 3a). All nodes which are two hops away from node $v_i$ are also not permitted to transmit simultaneously with node $v_i$, seeing that this would lead to a secondary conflict or hidden collision (Fig. 3b) because of a multiple reception on intermediate nodes.

All these nodes one or two hops away from node $v_i$ are referred to as broadcast zone of node $v_i$ [3]. A set of these nodes is denoted $B_i$. It is evident, that the need of elimination of interferences requires, that none of the nodes located in $B_i$ can transmit simultaneously.
with node $v_i$. Fig. 4 illustrates the principle of creation of broadcast zone for node $v_4$ (grey area $B_4$) and node $v_8$ (area $B_8$). The broadcast zone of node $v_i$, denoted as $B_i$, contains all nodes which are one or two hops away from node $v_i$. That means that it delimits a set of nodes, by which transmission primary or secondary conflicts would occur. Based on this concept it is possible to form a compatibility matrix $D$ with dimensions $N \times N$, which elements are given

$$d_{ij} = \begin{cases} 1, & \text{if } v_i \in B_j \\ 0, & \text{else} \end{cases}$$

Fig. 4. The principle of broadcast zones

The goal is to find the shortest TDMA cycle fulfilling the following requirements:

- each node has to transmit during a TDMA cycle at least once

$$\sum_{m=1}^{M} t_{mi} \geq 1 \quad \text{for } \forall i$$

- to avoid primary conflicts a node must not transmit and receive packets in the same time slot,
- a node must not receive two or more transmissions simultaneously, which eliminates secondary conflicts.

Formally then

$$\text{if } t_{mi} = 1, \text{ then } \sum_{j=1}^{N} t_{mj} d_{ij} = 0 \quad \forall m, i$$

(2)

i.e.

$$\sum_{n=1}^{M} \sum_{i=1}^{N} \sum_{j=1}^{N} t_{ni} t_{mj} d_{ij} = 0$$

The latter two conflicts can be avoided by creating a TDMA frame $T$ with a structure satisfying the equation (2). A trivial solution satisfying all three constraints is a $N$-slot TDMA frame, where $N$ different nodes transmit in $N$ different time slots (Fig. 5). At the same time, the value $N$ represents the lower bound of TDMA frame length.

The primary optimization criterion is the minimization of TDMA frame length, i.e. $M$ should be as small as possible. One of other possible optimization goals is the maximization of overall number of transmissions. This requirement can be represented by channel utilization index $\rho$, while

$$\rho = \frac{1}{MN} \sum_{m=1}^{M} \sum_{j=1}^{N} t_{mj}$$

(3)

### 4. Optimization of TDMA frame

A heuristic algorithm has been designed for optimization of TDMA frame length $M$ fulfilling the constraints (1) and (2), i.e. enabling each node to transmit at least once during a TDMA cycle and elimination both, primary and secondary conflicts. The algorithm has been tested on a set of testing network topologies [5] with given statistical properties (number of nodes, number of edges, connectivity). The obtained results are summarized in Table 1.

#### Table 1. Resulting TDMA frames lengths for the individual testing topologies

<table>
<thead>
<tr>
<th>Testing topology#</th>
<th>Number of nodes $N$</th>
<th>Number of edges $E$</th>
<th>$\min(\deg(v))$</th>
<th>$\max(\deg(v))$</th>
<th>Frame length $M$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100</td>
<td>162</td>
<td>2</td>
<td>8</td>
<td>9</td>
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<tr>
<td>3</td>
<td>500</td>
<td>827</td>
<td>2</td>
<td>11</td>
<td>12</td>
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<tr>
<td>4</td>
<td>100</td>
<td>560</td>
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<td>18</td>
<td>19</td>
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<tr>
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<td>1785</td>
<td>4</td>
<td>24</td>
<td>25</td>
</tr>
<tr>
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<td>500</td>
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<td>23</td>
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<tr>
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<td>750</td>
<td>4348</td>
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<td>22</td>
<td>23</td>
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<td>73</td>
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</table>

Considering the inequality (4) determining the lower bound of TDMA frame length, which can be written as

$$M \geq \max(\deg(v)) + 1, \quad i = 1,2,\ldots,N$$

(4)

then it is evident, that for the individual testing topologies with the use of the proposed algorithm optimal TDMA frame lengths $M$ have been achieved.

### 5. Conclusion

The implementation of wireless sensor networks into telematic systems requires definition of priority parameters of these networks. In the first place the reliability of communication has to be satisfied by eliminating conflicts between nodes trying to simultaneously transmit while being within transmission range (primary, direct
conflicts) and conflicts occurring during simultaneous broadcast transmission of two nodes to a third node (secondary, indirect conflict).

An algorithm has been proposed to detect primary and secondary conflicts in a given network topology defined by a connectivity matrix.

Analysis of this problem showed suitability of the TDMA medium access mechanism for effective and reliable sharing of common radio-frequency channel between the individual nodes of a wireless sensor network. A simple assignment of a time slot for each node (trivial TDMA frame) leads for higher number of nodes to a drastically ineffective utilization of transmission channel and to a significant delay. The reason is not enabling to transmit nodes which could transmit without to cause a conflict.

The solution of this problem is based on finding such a TDMA frame, which in compliance with the given input data (connectivity matrix, compatibility matrix) enables each network node to transmit at least once during cycle duration (assigns at least one time slot) and at the same time this TDMA frame has a minimal length.

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Bibliography


Informatic System for supervision and monitoring of equipment supporting air traffic

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ABSTRACT
The paper presents a process of designing and adapting to the needs of the Polish Air Navigation Services Agency system of supervision and monitoring of digital transmission network devices used for communication and transmission of data for air traffic. The paper presents the general concept of the transmission network, architecture of supervision and monitoring system, safety of the system and key tasks performed by the system. Present teletransmission digital network cover ten Polish airports. Central localization is based in the Air Traffic Management Centre in Warsaw, while the elevated locations are placed in Local Centers of PANS in each one airport as Bydgoszcz, Gdansk, Katowice, Krakow, Lodz, Poznan, Rzeszow, Szczecin and Wroclaw. IT System – discussed in the paper will be implemented as a distributed system covering locations as mentioned above. The entire system is designed to operate as a Client – Server – Database. The system has an open and scalable architecture that allows to be easily adapt to the new and variable requirements in a very short time.

KEYWORDS: monitoring system, network monitoring

1. Introduction
This paper presents a system developed in response to the requirements of Polish Air Navigation Services Agency (PANS) used for the surveillance and monitoring digital transmission network devices that are used for communication and data related to the needs of air traffic.

2. Teletransmission network
2.1. General concept of network
Teletransmission network is designed in a partial-mesh topology in which a central location is connected directly to each of the field location and are combined with the adjacent locations. Such topology and functionality of the transmission devices ensures resistance for breakdown links (ability to transmit data to other link). For construction a network have been used multiplexers based on TDM technology.

2.2. Selected network functionality
TDM multiplexers used in the project can carry out the following functions:
- Classic multiplexer to the concentration and movement of utility transmission (data free, fast, voice ports, Ethernet streams, etc.)
- The function of the full local rate matrix for nx 64 kb / s

The devices can operate in point-to-point configurations, point-to-multipoint, chain and/or ring. These configurations can be implemented based on a combination TDM (SDH, E1, SHDSL) or based on Ethernet (Pseudowire).
One of the requirements was the ability to cooperate PANSA new equipment with devices already operating in the Agency. For this purpose, a number of tests and studies have been done, as a result, the selected configuration parameters have been established on the multiplexers.

PANSA special need was the need to transfer TDM streams (corresponding rate for 8xE1) through infrastructure IP / ETH / MPLS (ie movement Pseudowire). In response to this requirement applied in the design of special equipment modules that TDM stream divide into parts, the parts in the box TDM traffic ETH / MPLS frames and sent to the PSN network. Frames can be properly labeled (VLAN tag, priority bits EXP, DSCP / ToS / Diffserv) so that traffic can be adequately handled by the network transmission. Modules allow streaming as well as group E1 slot (time slot) E1. With this application allows receiving devices used Pseudowire stream from another location, send the information to the utility receiving ports.

In the TDM systems is required one TimeMarker source in hole system. Devices used in PANSA can be synchronized with a variety of clock sources: an internal oscillator, the route TDM (E1, SDH), port utility (eg V.35), the clock is connected to a dedicated port clock frames received from the Pseudowire. The multiplexer can be configured up to 10 clock sources. Choice of currently active clock source is hierarchically – in the absence of sources of higher hierarchy in the current clock time becomes available clock source with the highest hierarchy. Select the type of TimeMarker the entire system depends on local conditions. There are various methods of receiving the clock, you can set up different transmission routes clock in the system (for example, some devices synchronized via TDM, some devices synchronized via Pseudowire, various clock source primary and secondary (eg basic TDM Pseudowire backup)), which meet the needs of PANSA.

2.3. Network Management

Manage of all multiplexers which form a network of digital exchange is carried out by a management station located in a central location in CZRL, where is installed manufacturer management software. The communication between the management station and the network device is using the appropriate protocol utility. The system can work in a client–server configuration installed on one PC station (Fig. 1).

Transferring the management traffic to the given localization can take place in various ways (TDM, IP VPN MPLS) depending on the needs and availability of broadband connections.

3. Monitoring System

3.1. System Architecture

To comply with the requirements of environmental monitoring of hardware used in the project a dedicated software OpenEye NET system created by WASKO were used. The monitoring system was implemented as a distributed system consisting of nodes situated on the level of Local Centers (OT) PANSA and the central node in the Air Traffic Management Centre (CZRL) in Warsaw. The overall system architecture is presented in Figure 2.

The central node uses two servers running in Active mode–Passive. On servers running the Central Database (PostgresSQL) and the application server. Database files are stored in the disk array structures. Central Database for optimal operation of the system in the long run thanks to their use of data partitioning mechanisms. The field locations used communication modules–mode Active–Passive. Communication modules are responsible for the collection of measurement data from the monitored environment and send them to the application server. In the case of link failure with the server communication module will operate as an autonomous unit of realizing the tasks submitted during the last synchronization process.

The software architecture of the monitoring system allows reconfiguration of network nodes system in no demurrage (hot swap), during production of the system. Such mechanism would ensure that the function of activation and deactivation of selected elements of the system for the purpose of conducting work at least maintaining, servicing without stopping the operation of the whole system. This means in particular that the exclusion of the application server or database will not cause off polling and monitoring facilities via a communication module. In this case, the module will operate as an autonomous unit, implementing pre–configured tasks. After re–establishing communication with the application server or a database, the data collected will be completed in the database. In the absence of communication with
the server, the data collected by the communication module will be stored in a specific time in the configuration module (min. 3 days). The field locations also placed Workstations running the GUI client monitoring application.

GUI application allows you to configure and monitor the work of all application modules and components of the system. PANSA meet the requirements of the system has been equipped the opportunity to present and create patterns defined and developed IT infrastructure for the entire area of the institution in the form of providing free use of techniques for scaling without loss of quality (scalable visualization on maps vector).

The system allows for the presentation of the diagrams characterizing the status of the size of the monitored infrastructure facilities in the form of:
- Numeric values,
- Charts,
- Tables of values,
- Animation dependent the parameter values,
- Indicators (bar, wheels).

### 3.4. Base task of the system

The main task of the monitoring system is PANSA supervision and monitoring of critical IT network elements, the collection of measurement data and generation based on established thresholds of alarm events and alarms for system operators. The system also allows the monitoring of key parameters such as operating systems processes, memory consumption, disk space, monitor the database (for database server).

Types of monitoring devices:
- TDM Multiplexers,
- Network Switches,
- Network Routers,
- Switch panels of Digital Channel and PCM multiplicators,
- Gyms telecommunications,
- Radio Lines.

The system has the ability to expand with additional interfaces.

### 4. Conclusion

The main task of the implemented system is occupied, supervision and monitoring of telecommunication network elements in the scope of monitoring of critical parameters. In addition, through the telecommunications network built enables communication and data transfer used for the needs of all individuals PANSA responsible for air traffic control. In the next stages of the implementation of the plan to connect to the system OpenEye NET PANSA new facilities such as:
- Centers radar,
- Radio communications centers,
- Objects of radio navigation aids (DVOR / DME, ILS / DME, etc.).

With its open architecture and scalability will be possible to extend the supervision and monitoring of critical infrastructure facilities PANSA, in order to reduce the possibility of dangerous situations related to disruptions in communication and data transmission security key in the Polish airspace.
Bibliography


