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Selected issues of the control intelligent road transport systems. Coordinated traffic lights systems

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ABSTRACT

Newest traffic lights coordination system's structure contains such components as: local control, global/area control and directional transmissions of data. Today's wireless controllers, in addition to the standard measurement and signalling functions (handling induction loop circuits, handling double-state signals, handling predefined signal groups), also perform advanced communication functions. With the implementation of such communication technologies/protocols as Ethernet TCP/IP, GSM, GPRS , these controllers are able to send text messages as well as support remote monitoring and control. The beginning of this paper presents shortly chosen examples of current solutions of Zonal Traffic Control Systems. Next a microprocessor model (8051) for controlling traffic lights in an intersection (normal, two-lane) is analysed. Finally the paper emphasises the role of wireless data transmission systems in smart communication in cloud computing and database technology solutions.

Keywords: control telematics, coordinated systems traffic lights, microprocessors simulator of control traffic lights

1. Coordinated system traffic lights systems. Review of solution and technology.

1.1. Area traffic light coordination systems

The aim of the application/design of traffic coordination/optimisation systems is to maintain smooth traffic for all participants (pedestrians, cars, bikes, trams) according to the dynamics of road variations.

Subject of control is coordination the traffic light programmes in intersections under supervision. **The main action** is the calculation of the dynamic changes/time-shifts (the so-called offsets) in the light control process in intersection of a given LA (Local Area) as a function of measured traffic loads of individual intersections.

The change dynamics is significantly influenced by such traffic interferences as collision, privileged vehicles, local repairs and failures, as well as other events that may interfere with the standard rhythm of traffic.

Extensive traffic light coordination systems often cooperate with other supervision systems in a given area, such as the Passenger Information, Public Transport Management or Video Monitoring Systems.

Those kind of solutions are ZTCS (Zonal Traffic Control System) installed in Łódź and Cracow (Poland). ZTCS in Łódź includes such subsystems like: SCATS[1] - Traffic control system, RAPID - public transport and passenger information management system and CCTV - video surveillance system [3].

Another example of the ZTCS are the road traffic network optimize systems implemented/being implemented powered by the system MOTION - Method for the Optimization of Traffic Signals In Online Controlled Networks (Cracow - Poland) [14]. System MOTION is

[1] SCATS systems from an Australian traffic control system in Sydney. [20]

an example of a fibreglass network that connects the Control Centre with local, area Access Points with all system drivers connected using fibreglass. (there were 82 on them in 2012) - Fig. 1 Supervision of the system may be done by the administrators connected to the management local area network (LAN).
Another example related to the optimisation of traffic in the implementation of the TTSS (Tram Traffic Supervision System)[2] from Trapeze - shown in Fig. 2 [15].

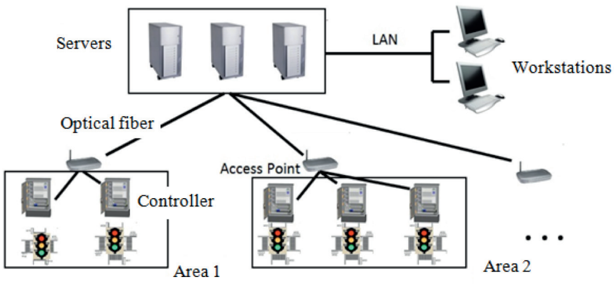


Fig. 1. Zonal traffic control system [15]

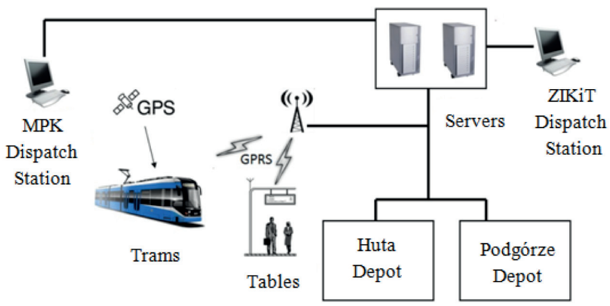


Fig. 2. Tram Traffic Supervision System [15]

Data transmission systems implemented in TTSS using the newest digital technologies like GPRS (General Packet Radio Service) [4],[8],[10] and GPS (Global Positioning System) [9].

The latest solution used in are traffic control systems are the advancements from German Gevas Software company [15]. The firmware can be installed on any traffic light controllers with support for required communication standards compatible with the OCIT protocol (Open Communication Interface for Road Traffic Control Systems). The protocol is based on SOAP[3]/OPC protocol[4].

Contemporary traffic coordination system's structure contains such components as: local control, global/area control and directional transmissions of data.

1.1.1. Local control

Local control is done by a local controller supervising the traffic flow in a monitored intersection (*Fig.4, 5 in the paper*). The software stored in the controller's memory executes a historically-developed control logic[5], performing online calibrations of traffic light durations according to the real-time parameters of traffic in the intersection. The intelligence of local control of the controller in the latest implementations often refers to adaptive control algorithms. Such algorithms are able to independently discharge a queue of waiting vehicles in case of congestion in one of the directions without any intervention from an operator or a parent system[6].

1.1.2. Global/area control

Global/area control - performs supervisory functions with respect to local control and dynamically coordinates sets of all traffic lights assigned to its area of supervision (LA)[7]. The main control strategy is associated with the operation of unsteady states generated in the area of supervision. These conditions are a result of the disturbances described in the introduction.[8] The operator application receives reports of traffic events (*e.g. sent from on-board computers, Fig. 4)*[4],[7],[10] or other supervision services (*such as weather or municipal services*). The operation of the Dispatching Centre handling incoming requests and cooperating with the area decision system is shown in Fig. 3. After being fed the parameters for the area requiring priority handling, the decision system generates solutions/a solution[9] that updates the traffic flows. In the case of several proposed solutions, the final decision is made by the operator.

The dispatch application logic (including the Decision Centre) is based on the **area databases** saved/being saved in real time in the system. These databases contain complete and detailed information on all monitored intersections, historical and current parameters of their control, data on the geometry of intersections as well as the network of connections between them. This database information is the basis for inference and generation of responses in decision-making systems directly accessed by the operator using update parameters entered into an interactive form. Needless to say, these applications are under constant development, optimisation and solution seeking[10].

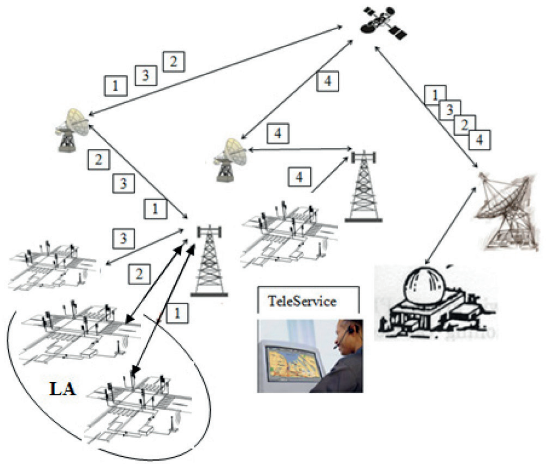
1.1.3. Data transmissions in area control and monitoring systems

Wireless data transmission systems are implemented in such devices as traffic light controllers in the intersections of local stations of the system. In addition to the standard measurement and signalling functions (*handling induction loop circuits, handling double-state signals, handling predefined signal groups*), these controllers also perform advanced communication functions. With the implementation of such communication technologies/protocols

[2] Trapeze Switzerland GmbH - former company of Siemens VDO
[3] SOAP - Simple Object Access Protocol. Transfers commands with the means of XML by using http. It is described within http://www.w3.org/TR/SOAP
[4] OPC is a Client / Server technology. One application acts as the server providing data and another acts as a client using data

[5] Historical logic is developed from an analysis of intersection controls in the past. The data for the algorithm are derived from historical reports.
6 One control algorithm is described in [14]
[7] The purpose of traffic light control in a given LA is to optimise the offsets, cycles and splits in real time.
[8] They are: road collisions, privileged vehicles, repairs, emergency service interferences, etc..
[9] The solution is to implement priority changes in selected phases of the are traffic light programmes
[10] One of the most interesting solutions involves the use of fuzzy set theory in algorithms for dynamic changes in traffic.

as Ethernet TCP/IP, GSM, GPRS [4], [6],[7],[8] these controllers are able to send text messages or data into remote database , as well as support remote monitoring and control. One of the example of such solutions is the ASR-2010PL/16 controller [20].



LA - Local Area

Fig. 3. The operation of an Dispatch Centre in CC (Cloud Computing) technology [own study]

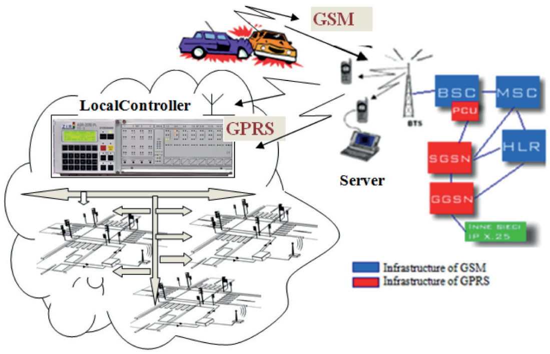


Fig.4. Scheme of handling a priority request for light change in LA1...LAk areas. Communication between system users. (That's: On-board SIM/USIM card, ASR-2010PL/16 local controller, CC Application) [own study]

3. Model for controlling traffic lights in an intersection

The subject of the study is to analyse the capacity of a normal, two-lane intersection with traffic lights and a given geometry (inclination 0, lane width 3.6 m) with a right of way road (Based on [14]). The process of analysing capacity used **theoretical** methods (American HCM 85, Canadian, Australian [14],[19]. For the purposes of **simulation** methods, a computer simulation for controlling traffic in the intersection was developed (a 8051 controlling the model[11] and C++ environment were used for this) - Figure 5.

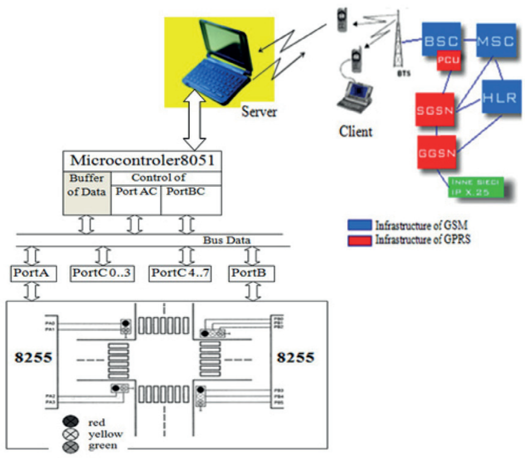


Fig. 5. Microprocesors simulator of control intersections lights [own study]

The simulation program can operate in two modes:

Mode 1. In this mode, the simulator calculates the effective duration of the green light Ge and analyses/calculates the effectiveness of the intersection (*LOS parameters*[12]). Calculations are made for different traffic flows on intersection entrances randomly given by the user (*random generator*) or for values read from a file with measured data (local or remote database saved in http://data_measurement_X). Based on the data, the simulator controls the lights at the intersection (model) and displays the calculations on the operator's/user's dashboard.

The algorithm for calculating the effective green light duration Ge in the intersection shown Fig. 6

Mode 2. Mode 2 allows the user to manually set the times of green lights in the intersection (the traffic values are set as in mode 1). The simulator calculates the effectiveness of the intersection and calculates the results. This mode allows for direct observation (*testing*) of the influence of the duration of the green light on the Level of Service (LOS), as well as the influence on the variations in incoming traffic handling.

3.1. The algorithm for calculating the effective green light duration Ge

Green light duration stems from numerous conditions and components. These relationships are described by the algorithm and further explained by the brief comment to the calculations.

Comment: The first stage of calculations involves obtaining traffic intensity S, which is a function of such components as: fw, fc, fs and parameters n and f0, where:

fw – the coefficient of lane width,

fc – the coefficient of traffic structure by type (number of heavy vehicles in the stream)

fs – a corrective coefficient of incline of the incoming road

w - lane width

n - number of lanes in a group

[11] The intersection model M01 from Micromade is a PCB connected to the 8255 ports of the mP 8051. Traffic lights are simulated by coloured LEDs. (Red, Yellow, Green)

[12] LOS - Level of Service. LOS is calculated using tabulated average values of time loss in the intersection and can be one of the classes A to F. Class A means average time loss <= 5s, while class F is > 60 s.

fo – the coefficient of intersection location.

So – intensity in ideal conditions per lane (assumed to be 1900 E/h/lane)

After calculating[13] the intensity (S) for each group of lanes, we calculate the degree saturation (Y) for critical groups of lanes - decides the division of green light duration between individual entrances. (In the case of two-lane intersections, the calculations are vastly simplified)

The calculation of the duration of one light cycle (T) requires the knowledge of ts - time loss for vehicles in the intersection. The value of ts depends on the evacuation times from the intersection (tep), which is in turn dependent on lane width (w) and the number of lanes (n). (See the formula in the algorithm). Once the duration (T) is calculated, the green light durations for critical entrances (Gwz, Gpp can be calculated), which are corrected due to the queues on entrances to the intersection. This correction depends exclusive on the number of vehicles in these queues (fig. 5).

Checking the boundary conditions (10<=G>=60)[14] for the obtained value of G protects against exceeding them. Exceeding any of the conditions introduces a correction for max = 60 s or min =10 s. As a result of the calculations/analyses, we obtain the effective green light duration (Ge). The final step is to calculate the capacity of the inlet (Ci).

The other algorithms (*i.e. the algorithm for calculating the efficiency of the intersection and others*) implemented in the simulation program – are not presented here. They were analyzed in [14].

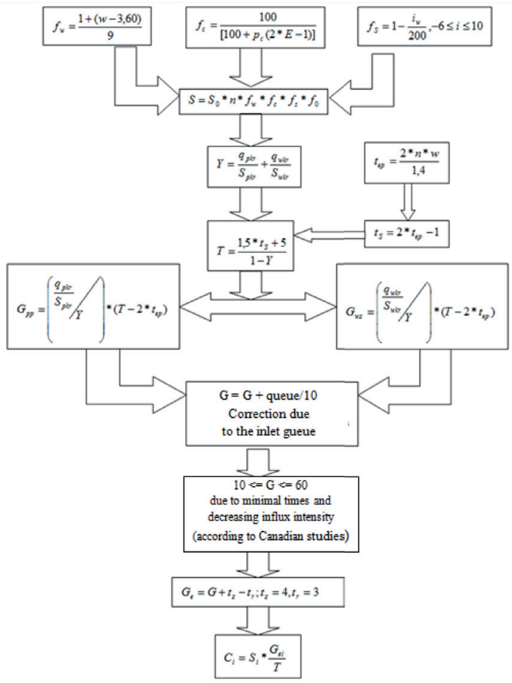


Fig. 6. The algorithm for calculating the effective green light duration Ge in the intersection [own study]

[13] This calculation does away with the corrective coefficient stemming from parking in a lane adjacent to traffic lanes, traffic blockages by buses stopping within the intersection, turning relations in a lane group and the conflicts with oncoming traffic lane and pedestrian traffic.

[14] the adopted conditions result from the research carried out in Canada

3.2. Description of the control program

As mentioned earlier, the program operates in two modes.

In Mode 1 - user interface (Fig. 7) is used to input the data concerning north-, south-, east- and west-bound traffic intensity into the simulator. These data can be entered either using the sliders (left part of the screen) or retrieved from a file (using the button on the toolbar)

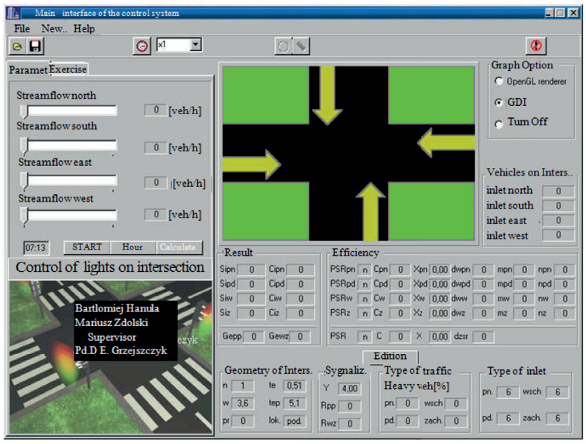


Fig. 7. Basic operator interface of the control simulator [own study]

In Mode 2 - in addition to the preset parameters of traffic intensity (as in mode 1), the user also inputs green light duration Gpp and Gwz (durations for individual inlets), as well as sets test duration.

After the calculations are launched using the Start button, the screen shows the results (Fig.7, Fig.8) and a model of the intersection runs with blinking lights/LEDs according to the calculations.

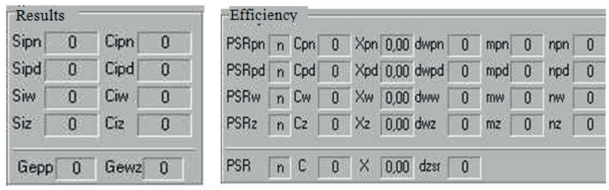


Fig. 8 User interface with calculation results [own study]

For individual inlets	For intersection
Si - intensity saturation Ci - capacity LOS - the level of service C - reserve capacity X - the degree of load dw -individual time losses for vehicles m - the number of vehicles approaching the intersection during one cycle n - the number of vehicles leaving the intersection during one green light for an inlet	Ge - duration of effective green light LOS - Level of Service of the intersection C - capacity of the intersection X - the degree of load of the intersection dzsr - average daily time loss in the intersection

Parameters describing the intersection can be edited using the lower part of the interface (Fig. 7 and Fig. 9).

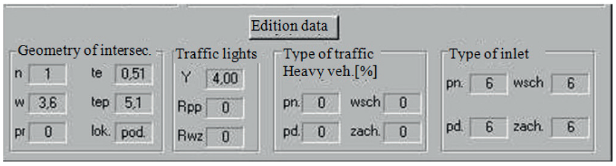


Fig. 9 Panel for editing intersection parameters [own study]

n - number of lanes **w** - lane width **pr** - inlet inclination **te** - time of vehicles' escape from the intersection **tep** - time of pedestrians's escape from the intersection **lok** - location: downtown and uptown **Type of traffic** - expressed in percentage of **heavy vehicles** in the traffic stream per inlet **Inlet types** - from 1 to 6 (depending on the synchronisation in the urban road network), **pn** - north, **pd** - south, **wsch** - east, **zach** - west

4. Conclusion

An intensive development of GMS [4,7], GPRS [4,8] and GPS [9] technology enabled remote communication between **controllers** equipped with appropriate receivers supervising (*for example*) traffic light systems. Thanks to the above systems it is possible not only to identify the intersection's position but also to measure and register the state of some chosen intersections elements by a remote program.

Understandably such communication requires highly specialized software and tele-transmission tools as well as the concept of supervising distributed database systems. Such solutions are provided by the CC (Cloud Computing) technology. The second part of this paper presents a CC application dedicated to coordinated systems traffic lights[11].

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