Adaptive Multi-path Telecommunications Solutions for ITS

Tomas ZELINKA, Miroslav SVITEK, Martin Srotyr, Michal VOSATKA
Faculty of Transportation Sciences, Czech Technical University of Prague
110 00 Praha 1, Czech Republic

ABSTRACT

Intelligent Transport Services (ITS) applications require availability of the wireless seamless secure communications solutions with selectable services quality and wide-area coverage. There are available both public as well as private wireless data services, however, dominantly in case of public services no guaranteed data service quality is offered. Principal improvement of the service quality can be reached by dynamical selection of the best possible alternative from the available portfolio of relevant services. Efficient decision processes must be implemented in the appropriate flexible seamless routing/switching structures. Generally recommended solution has been described in series of documents generated by ISO/CEN known as CALM family of standards. In accordance to our understanding CALM architecture represents very complex attitude, however, it is demanding solution for less ambitious implementations. On the other hand CALM decision processes are limited to approach based on the Policy-based Management (PBM) principles with limited functionality and adaptability. Authors present L3 alternative solution with adaptive classifications processes applied instead of PBM ones. Such approach can be efficiently implemented specifically if there is available deep understanding of applied technologies. Requirements on the representative system performance indicators and their tolerance range should be so carefully identified. Paper includes results of authors' laboratory study of three most widely spread data services which can be understood as basis for the "CALM ideas" based system implementations.

Keywords: Intelligent Transport System, Telematics, Performance Indicators, Satellite Navigation System. Seamless communications access service, handover, Bayes statistics, Kalman filter, classification process, GSM, WiMax, WiFi

1. INTRODUCTION

Presented results are related to projects e-Ident[1], DOTEK[2] and SRATVU[3] which are elaborating results of project CAMNA[4].
In order to be able to speak about a system it is necessary to describe it minimally as a final automaton defined by mapping the system inputs with respect to the internal state plus mapping the inputs and internal state with respect to the system outputs. A subsystem must be describable through an identical methodology like a system; in its substance the subsystem is a system to be described at a more detailed distinguishing level. Applied methodology can be represented either by architecture or structure. The architecture defines the basic arrangement of the subsystem and functional blocks in the space. The structure goes up to systems elements, and, it is more complex and more complete but less clearly arranged. For that reason architecture approach is used within our ITS studies.
A process reflects the chained events within a system. An event may mean a change of a system state brought about by an initiation on inputs (transfer of input values) or initiation of internal system state or "only" in the course of the external time. A set of all activated processes at possible environmental conditions defines the system behavior.
ITS solutions are associated with serious expectations and getting ITS applications in the real practice is understood as the essential potential to significantly faster resolve many transport challenges. The main afford of research is to prepare conditions to get ITS architectures in the real practice with aim to support different transport optimization tasks. This paper concentrates namely on the communications part of the ITS architectures.

2. COMNUNICATIONS SOLUTION

2.1 Telematic sub-system requirements

The methodology for the definition and measurement of following individual system parameters – performance indicators is being developed in frame of the ITS architecture (see [1] - [5]). Substantial part of the performance indicators analysis is decomposition of system parameters into individual sub-systems of the telematic chain. This step represents analysis of requirements on individual functions and information linkage so that the whole telematic chain should comply with the above defined system parameters.
The completed decomposition of system parameters enables application of the follow-up analysis of telematic chains according to the various criteria (optimization of the information transfer between a mobile unit and processing centre, maximum use of the existing information and telecommunication infrastructure, etc.). It is obvious that quantification of requirements on relevant telecommunication solutions within telematic chains plays one of key roles in this process. Mobility of the communication solution represents one of the crucial system properties namely in context of frequently very specific demand on availability and security of the solution.
Communications performance indicators quantify communications service quality and they are described e.g. in [6] - [10]).
Performance indicators applied for such communications applications must be transformable into telematic performance indicators structure, and vice versa. Indicators transformability simplifies system synthesis. Additive impact of the of communications performance indicators vector $\underline{tci}$ on the vector of telematic performance indicators Δtmi can be expressed as $\overrightarrow{\Delta tmi} = TM \cdot \overrightarrow{tci}$, however, only under condition that probability levels of all studied phenomena are on the same level and all performance indicators are expressed exclusively by parameters with the same physical dimension – in described case in time or to time convertible variable (see e.g. [7]).

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[1] e-Ident – Electronic identification systems within transport process – grant 2A-2TP1/108.of Ministry of Industry and Trade of the Czech Republic (MPO),

[2] DOTEK – Communication module for transport telematic applications –grant 2A-2TP1/105 of MPO,

[3] SRATVU – "System Requirements and Architecture of the universal Telematic Vehicle Unit" is grant 2A-1TP1/138 of MPO,

[4] CAMNA - "Joining of the Czech Republic into Galileo project" grant 802/210/112 of Ministry of Transport of the Czech Republic.

2.2 CALM

Family of standards CEN TC204, WG16.1 "Communications Air-interface for Long and Medium range" (CALM) represents concept of identification of the best available wireless access solution in given time and area. Process of the alternative wireless access solution substitution is understood as the second generation of the handover principle known in its first generation namely from the cellular mobile systems.

Each handover process is predestinated by set of parameters range identified for decision processes managed by control unit. Criteria for the "best possible" solution include indicators like Bit Error Rate (BER), packet Round Trip Delay (RTD), level of received radio signal (compared with the other base stations being just available), but also cost of provided service etc. Mathematically resolved control system can take in account not only the absolute values of selected indicators, but also specific parameters combinations trends.

Handover to alternative solution can be in principle evoked also by identification of more suitable alternative - e.g. by appearance of alternative service with more suitable cost conditions even though existing alternative has been technically sufficient and safe.

Details of CALM architecture are described e.g. in [11] and [12]. CALM applies still not widely enough accepted IPv6 protocol which allows due to its extensive abilities to continuously remotely trace active applied alternative. Handover in CALM is "physically" accomplished on the L2 of the TCP(UDP)/IP model. Alternative approach based on standard IEEE 802.21 "leads" to the "general handover" using L2 switching as well, even though its system approach principally differs from that proposed by CALM. Our solution is based on L3 routing and procedure we use to call "Intelligent routing" with advantage of the exclusively SW based implementation.

3. MULTI-PATH ACCESS SOLUTION PRINCIPLES

Family of standards CEN TC204, WG16.1 "Communications Air-interface for Long and Medium range" (CALM) represents widely conceived concept of switching to the best available wireless access alternative in given time and area. Substitution process of existing path by the alternative wireless access solution is understood as the second generation of the handover principle.

Both generations of the handover action is started based on evaluation of the performance indicators set. Bit Error Rate (BER), Packets Lost Ratio (PLR) or packet Round Trip Delay (RTD) are typical but not the only possible performance indicators used for decision processes in data networks. Switching to the alternative path is relevant only if available tools of the lower layer are already unable to resolve performance limits. Simultaneous action on more layers can be contra-productive action.

Second generation handover action can be in principle evoked also by identification of more suitable alternative - e.g. by appearance of alternative service with more suitable cost conditions even though existing alternative is being technically sufficient and safe.

Adaptive communications control system has following architecture:

- 1-st layer – Cellular Layer (CL) - represents feed-back control processes of parameters like transmitted power, type of applied modulation etc. Goal of processes on this layer is to keep given set of managed parameters like e.g. Bit Error Rate (BER) or Round Trip Delay (RTD) within required limits.
- 2-nd layer – the first generation of handover (1HL) - represents seamless switching process between different cells of the same mobile network. Such approach is applied in mobile systems like GPRS, EDGE, UMTS, Mobile Wi-Max (IEEE 802.16e) or WiFi (IEEE 802.11) via amendment IEEE 802.11r. 1HL layer shares relevant information with CL layer (delivered usually as one system) so that there is no risk of contra-productively simultaneously operated processes on both layers - of course only in case it is correctly designed and operated.
- 3-rd layer – the second generation of handover (2HL) - is mostly dependent only on identification of the service performance indicators. Cellular systems are not usually designed as the open systems with appropriate application inter-faces (API) so that there is not mostly potential of interconnection with management of these lower layers. It is for sure that the effective management on the 2HL layer can be much easier reached if 1HL and LC layers share relevant information with managed layer 2HL.not usually designed as the open systems with appropriate application inter-faces (API) so that there is not mostly potential of interconnection with management of these lower layers. It is for sure that the effective management on the 2HL layer can be much easier reached if 1HL and LC layers share relevant information with managed layer 2HL.

Communications access systems used in transport telematics are designed based on technologies like GPRS, EDGE, UMTS, WiFi (IEEE 802.11a, b, g, e, n, p and r), WiMax (IEEE 82.16d,e), DSRC, IR, and set of WPAN (Wireless Personal Access Network) technologies like Bluetooth (based on IEEE 802.15.1), UWB (IEEE 802.15.3 esp. 802.15.3c) and ZiBee (applying IEEE 802.15.4). Satellite communications can be integrated for specific applications, as well, even though satellite services frequent appearance is namely for economical reason not expectable in short time horizon and even long term expectation is not clear.

Most of used systems have or will be extended to cellular architecture. In case system does not have cellular architecture 1HL layer can be omit.

Some specific technologies (WPAN, IR, RFID systems) operate exclusively on short distance. This communication tools are within ITS applied in "nomadic" regime for specific applications like data transfer between Car and Infrastructure at hot spots, in parking areas etc.

4. MULTI-PATH ADAPTIVE DECISION PROCESS

Decision processes representing basis for adaptability of communications wireless services have not been deeply resolved issue. We can find implementations and related papers mostly based on Policy-based Management (PBM). This concept has been traditionally applied in the IP based networking and we can only state its remarkable success. This approach can be combined with Model Driven Architecture approach employing models, and precisely Object management Group (OMG) Model Driven Architecture (MDA). Authors of such approach [14] integrated language- and middleware-neutral features into adaptive services. So called POETRY service creation framework described in [14] applies PBM method to describe and control internal logic of the adaptive services and simultaneously method based on MDA model is used to describe the adaptive service informatics model.

Our research was initiated by ideas of the CALM family of standards. However, principal difference if compared with "CALM approach" is in implementation of the "intelligent" routing principles replacing L2 switching used in case of CALM solution.

4.1 DOTEK solution

DOTEK project - see e.g. [29] was focused mainly on the following areas:

- Analysis and selection of available wireless services applicable for different transport telematics services.
- Design of comprehensive management including decision algorithm for selection of optimal data transfer technology.
- Provisioning of the continuous monitoring and evaluation of given services quality necessary for the correct decision to select appropriate service.
- "Table based" processing of the decision in order to ensure proper operation of telematics applications.

An important part of communication module is to monitor current system parameters and communication technologies in order to assess their current situation and decide about their suitability for use according to the specific requirements of telematic applications. For the pilot implementation basic three monitored system parameters were chosen:

- signal to noise ratio,
- packet latency,
- packet loss.

In case of further implementation it might be possible to include other system parameters if relevant impact is identified.

Implemented deterministic decision algorithm supports appropriate access wireless service selection. It is based on application of relevant data requirements recorded in the "decisions tables". Current status of available telecommunications technologies including the one in use must be continuously available. Cost of each applied access wireless telecommunication service use to be required to be taken in account, as well.

Decision to implement described simplified "Extended PBM" approach was done on based on evaluation of currently available research R&D man power resources. Full adaptive version described below was out of team capacity as well as of allocated resources. With this implemented version was successfully tested this "extended PBM approach". System successfully passed test scenarios for verification its basic functionalities.

Project DOTEK was successfully finalized (see e.g. [29]) and obtained results were integrated into existing on-board unit (OBU) tested with four telematic applications implemented - EFC, fleet management, e-Call and navigation. Results – i.e. developed software has got modular structure, and, therefore it can be integrated into other compatible systems. Correctly integrated modules can provide relevant management of applied communication solutions. Presented pilot implementation is applicable in wide range of transport telematics solutions. Presented solution is exclusively based just on the described SW package implementation into existing system and not any dedicated specialized HW is required.

4.2 Bayes statistics based alternative

Our "goal" solution represents the Bayes statistics based approach. Proposed solution is based on the following principles - see also [15], [18] or [25]:

- Measured parameters a processed by Kalman filter. Such process separates reasonable part of present noise and also allows prediction of the individual parameters near future behavior.
- Set of measured parameters is extended by deterministic parameters like identification communicated with tall collection, economical parameter, corporate policy etc. All together it is presented as parameters vector **x.**
- Based on time lines of vector **x** it is feasible to classify the best possible technology selection. Classification algorithm is trained using time lines of training vectors **x** extended by assignment to the relevant class, i.e. selected path.
- Success of classification is related to the size and quality of the training data lines.

Presented classification approach is effectively applicable for relevant decision processes used to select the best possible alternative access from the set of available paths. Decision can provide evaluation of both measured parameters as well as external ones given e.g. by corporate policy, financial criteria etc.

Let us introduce the vector **x** as the vector carrying information about the values of performance parameters in sample time. The items of vector x are either deterministic or random processes with help e.g. of Kalman filtering described e.g. in [22] or [23].

Let us define the classification problem as an allocation of the feature vector $\mathbf{x} \in \mathrm{R}^{\mathrm{D}}$ to one of the C mutually exclusive classes knowing that the class of **x** takes the value in $\langle \Omega = \{\omega_1, ..., \omega_C\} \rangle$ with probabilities $P(\omega_1), ..., P(\omega_C)$, respectively, and **x** is a realization of a random vector characterized by a conditional probability density function $p(\mathbf{x} \mid \omega), \quad \omega \in \Omega$. This allocation means the selection of best fitted telecommunication technology based on knowledge of **x** vector.

A non-parametric estimate of the *ω-th* class conditional density provided by the kernel method is:

$$\hat{\mathrm{f}}(\mathbf{x} \mid \omega) = \frac{1}{\mathrm{N}_\omega \cdot \mathrm{h}_\omega^{\mathrm{D}}} \cdot \sum_{\mathrm{i}=1}^{\mathrm{N}_\omega} \mathrm{K}\left(\frac{\mathbf{x} - x_{\mathrm{i}}^{\omega}}{\mathrm{h}_\omega}\right), \qquad (1)$$

where $K(\cdot\cdot)$ is a kernel function that integrates to one, h_ω is a smoothing parameter for *ω-th* class, N_ω stands for sample count in class ω and $\mathbf{x}_1^\omega, ..., \mathbf{x}_{N_\omega}^\omega$ is the independent training data. The density estimate defined by (1) is also called the Parzen window density estimate with the window function .

It is a well-known fact that the choice of a particular window function is not as important as the proper selection of smoothing parameter. We use the Laplace kernel defined by the following Laplace density function:

$$f_L(x; \mu, \sigma) = \frac{1}{2 \cdot \sigma} \cdot \exp\left(-\frac{|x - \mu|}{\sigma}\right), \qquad (2)$$

where $x \in R, \mu \in \mathrm{R}, \sigma \in (0, \infty)$.

The product kernel is used with a vector of smoothing parameters $\boldsymbol{h}_\omega = (h_{1\omega}, ..., h_{D\omega})$ for each class ω. The product kernel density estimate with Laplace kernel is then defined as

$$\hat{f}(\mathbf{x} \mid \omega) = \frac{1}{N_\omega} \sum_{i=1}^{N_\omega} \prod_{j=1}^{D} \frac{1}{2 \cdot h_{\omega,j}} \exp\left(-\frac{\left|x_j - x_{i,j}^\omega\right|}{h_{\omega,j}}\right). \qquad (3)$$

Smoothing vectors $\boldsymbol{h}_\omega$ are optimized by a pseudo-likelihood cross-validation method using the Expectation-Maximizations (EM) algorithm (see [15] - [16]).

To rank the features according to their discriminative power the standard between-to within-class variance ratio is employed. This method is based on the assumption that individual features have Gaussian distributions. The feature vector $\mathbf{x} \in \mathrm{R}^{\mathrm{D}}$ takes value to one of C mutually exclusive classes $\Omega = \{\omega_1, ..., \omega_C\}$. The probabilistic measure $Q_{d,i,j}(d, \omega_{\mathrm{i}}, \omega_{\mathrm{j}})$ of two classes separability for the feature d (d-th component of feature vector) is defined as

$$Q_{d,i,j}(d,\omega_i,\omega_j)=\frac{\eta\cdot(\sigma_i+\sigma_j)}{|\mu_i-\mu_j|}, \quad (4)$$

where ω_i and ω_j are classes and symbol $\eta=3.0$ denotes the real constant specifying the interval taken into account (probability that observation of normally distributed random variable falls in $[\mu-3.0\cdot\sigma, \mu+3.0\cdot\sigma]$ is 0.998). The smaller the value of the measure $Q_{i,j,d}$, the better is separation of the inspected classes made by the feature d. For $Q_{i,j,d}<1$ both classes are completely separable. The measure is similar to the widely used Fisher criterion.

For multi-class problems, the two-class contributions are accumulated to get a C-class separability measure Q(d) for the feature d:

$$Q(d)=\sum_{i=1}^{C}\sum_{\substack{j=1\\ i\neq j}}^{C}Q_{d,i,j}(d,i,j). \quad (5)$$

All the features in the training data are then sorted according to their Q(d) measures. The function Q(d) is similar to a significance measure of the d-th component of a feature vector. The subset of n first features is selected as an output of this individual feature selection method. The drawback of the method is the assumption of unimodality and the fact that just linear separability is taken into account. On the other hand, the individual feature selection method based on the between-to within-class variance ratio is very fast.

Presented classification approach is effectively applicable for relevant decision processes used to select the best possible alternative access from the set of available paths. Decision is based on evaluation of both random as well as deterministic processes and this statistical approach enables continuous decision processes training.

It is important to stress that optimized number of the selected representative key performance indicators can lead to the significant reduction of required CPU capacity. To reach such optimized performance indicators selection detailed analysis of key wireless technologies was done and the principle results follow.

5. GSM DATA SERVICES PERFORMANCE

There is a common understanding that mobile technologies (GSM in Europe) can provide fast and reliable data service with very reasonable signal coverage and very high level of availability. However, practical ITS implementation identified quite a remarkable problem with performance of GSM data services applied within telematic applications.

Our study has been concentrated on identification of the critical internal performance indicators and on study of their impact on the overall obtained data service performance. All measurements were done exclusively within one cell. Decisions to switch to another cell / other service represents processes positioned in upper layer and it can be based e.g. on CALM principles using performance indicators status.

Frequently unpredictable influence of the services provider decisions GSM service management cannot be directly integrated into the CALM decision processed. However, any provider decisions impact can be identified by changes of the services performance indicators and it can be followed by appropriate "CALM decision".

Data channel capacity CC is described by Shannon - Hartley theorem $CC=B.\log_2(1+C/I)[b/s]$, where B is the bandwidth of the channel in Hz, C represents the total channel signal power in the used bandwidth measured in mW, and, I is the total noise power in applied bandwidth measured in mW.

Ratio C/I used in GSM terminology is equivalent to S/N, i.e. the signal-to-noise ratio (SNR) or the carrier-to-noise ratio (CNR) of the communication signal and the Gaussian noise interference expressed as a linear power ratio (no logarithmic in decibels).

Within GSM architecture bandwidth B is constantly set to 200kHz. Parameter C/I so represents the critical parameter primarily which influence GSM data services technology performance expressed by performance indicators: (i) Data channel capacity CC, (2) Packets loss ratio (PLR) and (iii) Packet delivery delay PDD.

Above mentioned parameters can be simply but specifically identified on the IP layer using services of L3 (IP layer).

Each of available 2.5 GSM generation data services i.e. CSD, HSCSD, GPRS and EDGE was individually studied. Authors had unique opportunity to measure performance parameters of the GSM services in top level Telefonica O2 GSM laboratory equipped by locally manageable fully calibrated base station with adjustable transmitter output power C. Additionally noise signal with adjustable level I was generated by external calibrated noise generator. Power of the base station was set for each measurement period on defined level C and power of noise I generated by additional noise generator was changed in defined limits step by step.

Service quality measurement was processed using L3 (IP) layer tools. Each individual measurement was generated by "ping -n 100 -l 10 ftp.adress", where n represents number of transmitted packets (n=100) and l represents packet size (l=10B). Small packed size was reasonable for identification of minimal time of service response.

In graphs black line represents minimal RTD [ms], dark grey – average RTD a light grey average PLR [0% – 100%].

5.2. CSD measurement results

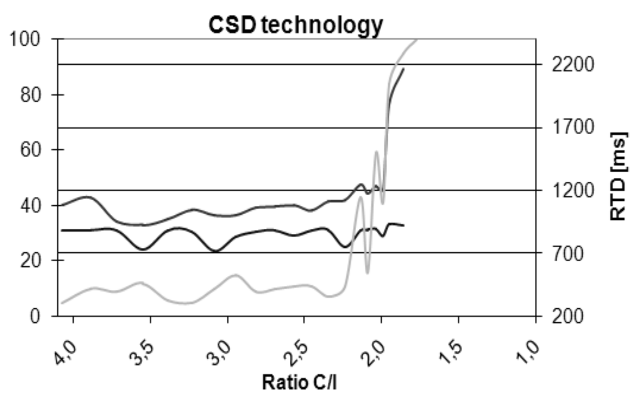

Figure 1. PLR and RTD - CSD technology

Fig. 1 shows that CDS technology has got delay in the sub-second range. Service has got relatively low sensitivity on the parameter "interference", i.e. signal to notice ratio. However, it must be stressed that CSD is circuit switched technology with all known disadvantages of this approach comparing the packed based GPRS/EDGE.

5.1. HSCSD measurement results

Results obtained for CDS technology measurement displayed Fig. 2 are valid for HSCDS technology, as well. The only difference is in channel capacity due to fact that increase of the capacity is exclusively reached by increasing of the applied time slots number.

5.2. GPRS

Fig. 2 show that GPRS technology provides better delay comparing to CDS (350 ms), however, only for small values of interference (signal to noise ratio). With increasing intensity of interference GPRS service delay rapidly grows. Relatively high sensitivity packet loss on C/I can be identify, as well. For C/I above 2.69 packets loss is above 75%! Results identified mainly that GPRS technologies are applicable for “less demanding” applications where long delays and high potential of packet losses are not critical or it can be combined with alternative technology on CALM principles.

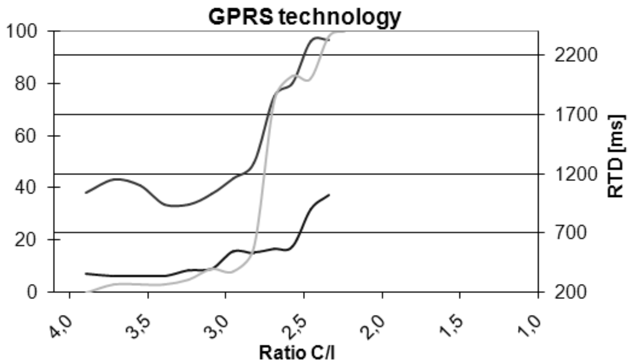

Figure 2. PLR and RTD - GPRS technology

5.3. EDGE measurement results

From Fig. 4 it is noticeable that EDGE technology is much more acceptable for telematic applications than GPRS, because of remarkable improvement in both delay and packet loss. Minimal delay was in this case within interval from 258ms to 365ms and high packet loss starts, when value of ratio C/I was above 1.2. This technology so could appear even with more demanding telematic solutions if service provider can guarantee appropriate priority of service provisioning.

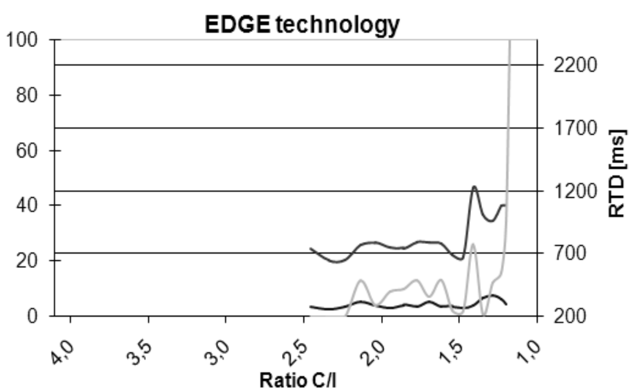

Figure 4 . PLR and RTD - EDGE technology

6. ALTERNATIVE WIRELESS DATA SERVICES

GSM service was originally designed for provisioning of public mobile voice and circuit switched data service (9.6kb/s). In 2.5th GSM generation were adopted packet data services, however, with very limited communications capacity dedicated to each terminal. GSM service providers, however kept their concentration on their core high quality voice business, and, data services have been provided as more or less complementary services with no guaranteed services quality (no SLA provided). Any request on network capacity related to quality and availability of the voice service is resolved on behalf of network capacity even already applied to provide data services.

This disadvantage could be resolved by dedication of agreed part of the provider’s network capacity to the “special” services portfolio where the data services quality management could be adopted. Goal of such dedication is to provide guaranteed service quality for the limited number of clients and limited data volumes. However, status of auspicious “virtual operators” does not have good chance to be accepted due to strong “self-defense” afford of the powerful mobile operators.

Originally expected data services of the global coverage based on the 3rd generation mobile data service (UMTS) have not got potential to be reached, particularly in rural areas. Beyond 3rd generation solutions (LTE) have been very promising future solutions (latency approx. 10ms), however, such services cannot be expected, sooner than in the next decade (2012?).

Remarkable potential can be recognized in combination of all key GSM services providers as well as different alternative wireless access data services like e.g. WiMax or WiFi. Management of the relevant solution selection can be based on mentioned CALM principles with implemented effective decision processes. Alternative services are applied to fill the services quality gaps when/where the core GSM wireless network cannot provide service on required quality level.

6.1. WIMAX (IEEE 802.16d) SERVICES PERFORMANCE

Technology based on IEEE 802.16d/e standards known as (Mobile) WiMax represents one of the most promising substitutions. This technology (in version “d”) was studied in detail in project CAMNA. We have got there unique opportunity to process detailed the WiMax technology performance measurement in “real life” applications - see e.g. [7], [8] and [9]. Basic results of WiMax measurement are in Table 1. Even though results are in different structure due to different method applied to identify WiMax technology performance, dynamic parameters can be quite easily compared.

Table 1. – obtained parameters of the WiMax access

Site	Visibility	RTD [ms]	SNR [db]
1	LOS	45.6	33
2	LOS	47.1	32
3	NLOS	44.6	-26
4	NLOS	44.8	-27

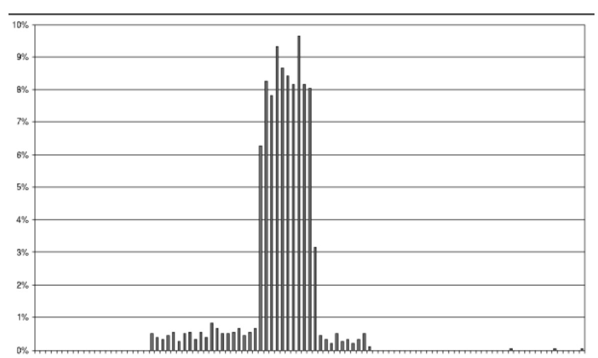

Figure 5. RTD spectra of LOS - SNR =+33db

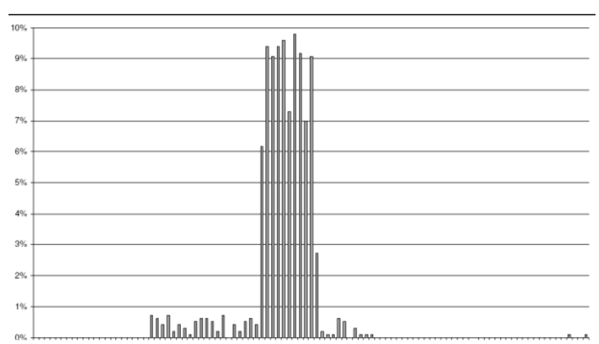

Figure 6. RTD spectra of NLOS - SNR=-27db

RTD presents "Round Trip Delay" in ms, SNR is "Signal to Noise Ratio" in dB, LOS represents "Line Of Sigh" and NLOS "Non LOS". RTD results are displayed on Figure 5 and 6. We can identify that displayed RTD represents in average approx. 50ms and that it is one order faster than the GSM technologies (GPSR, EDGE).

6.2. WIFI DATA SERVICES PERFORMANCE

IEEE 802.11 is very quickly growing standard and its possibility to be applied for ITS applications becomes reality. Measurements of basic system parameters were concentrated on latency and packet lost ratio dependency on SNR with goal to obtain representative set of data for this technology evaluation.

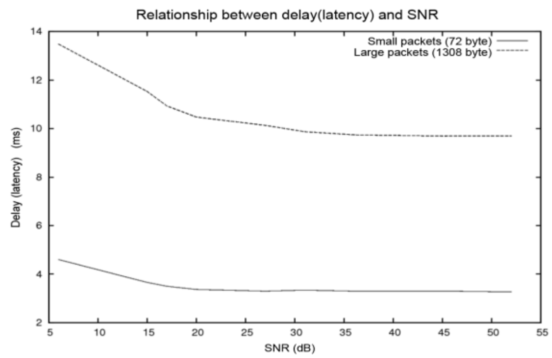

Fig. 7: Relationship between delay (latency) and SNR without data transfer

The first graph on Fig. 7 presents expected but quantified fact that for lower SNR values the latency grows and it is also clear that packet size principally influence service latency.

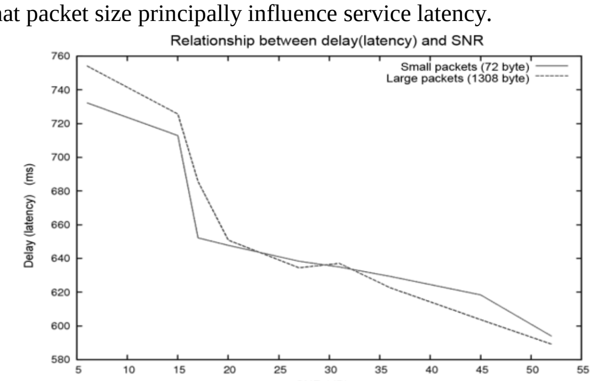

Fig. 8: Relationship between delay (latency) and SNR with data transfer

On the other hand the latency (see Fig. 8) is not significantly influenced by packet size.

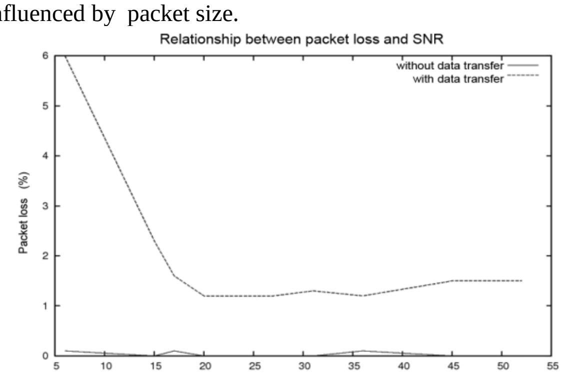

Fig. 9: Relationship between packet loss and SNR

Generally so we can conclude that for the SNR values approx. 20 dB and more latency values are constant and vice versa - for values below 20 dB latency values are rising. Latency values depend on the cannel load, while during heavy load can go up to several hundred ms.

Like in all the other discussed cases it is necessary to stress that there is not possible to simply determine for given SNR value the value of latency or packet lost ration. This is due to fact that this parameter is as well dependent on the other variables like packet size or current workload of network. On the other hand these results can be used in "predicational negation" – i.e. if SNR is lower than "n" than we cannot expect required service quality.

5. CONCLUSION

Due to regular complexity of by telematic services covered areas (wide area coverage, several classes of services with different system requirements) we concentrated our afford on the wireless access solution designed as seamless switched combination of more independent access solutions based on the same or alternative technology.

Decision processes representing basis for adaptability of the communications wireless services are quite rarely resolved and published. Most of present implementations apply Policy-based Management (PBM). This concept has been traditionally applied in the IP based networking and we can only state its remarkable success. Authors' approach is, however, based on application of the Bayes statistics. Set of measured parameters is extended by deterministic parameters like economical parameter, corporate policy etc. Based on the self trained classification processes it is achievable to classify the best possible selection i.e. assigning obtained data vector to one of set of classes. Classification algorithm is trained using time line of training data vectors extended by correct assignment to the relevant class, i.e. selected path.

Optimized number of the representative key performance indicators can effectively reduce requirement on CPU capacity. That is the reason why detailed study of each applied telecommunications technology has been accomplished in laboratory to identify representative key performance indicators for the each technology potentially applied in the system.

Public available GSM data services are designed to provide dominantly voice services. Selection of data services (2.5G) is provided with very limited or mostly no guaranteed performance parameters, i.e. as a complementary service in the best-afford regime. Namely due to economical reason the 3rd generation (UMTS) mobile data services have not got potential to grow in appropriate way and service coverage is preferably concentrated on highly populated areas. Beyond 3rd generation solutions (namely LTE) are very promising future solutions, however, massive availability of these services cannot be expected sooner than in the next decade (2012? or even later).

Strong potential has been recognized in combination of GSM data services with the alternative products namely if effective sharing of the GSM providers' infrastructure can be reached. Alternative services are dedicated to fill the services gaps i.e. areas or time the core wireless network cannot be provided in required quality. One of the most promising alternatives has been represented by technology based on standards IEEE 802.16d/e known as (Mobile) WiMax. Such access solution was tested within project. Principal improvement of WiFi solutions represents also very good potential to provide alternative solutions.

Presented alternative service combination strategy is based on the basic CALM principles, however, it is implemented on L3 and adaptive decision processes are integrated - i.e. CALM ideas based "intelligent routing". This approach can effectively extend potential of the widely spread GSM seamless data services application with ability whenever and wherever needed to be replaced by the alternative solution (if any such solution is available).

REFERENCES

[1] M. Svitek, **Architecture of ITS Systems and Services in the Czech Republic**, International Conference Smart Moving 2005, Birmingham 2005, England.

[2] M. Svitek, **Intelligent Transport Systems - Architecture, Design methodology and Practical Implementation**, Key-note lesson, 5th WSEAS/IASME Int. Conf. on Systems Theory and Scientific Computation, Malta 2005.

[3] M. Svitek,, T. Zelinka, **Communications Tools for Intelligent Transport Systems,** Proceedings od 10th WSEAS International Conference on Communications, pp 519 – 522, Athens 2006, ISSN 1790-5117, ISBN 960-8457-47-5.

[4] M. Svitek,, T. Zelinka, T., **Communications Solutions for ITS Telematic Subsystems**, WSEAS Transactions on Business and Economics, Issue 4 (2006), Vol. 3, pp 361 – 367, Athens 2006, ISSN 1109-9526,

[5] M. Svitek,, T. Zelinka, **Telecommunications solutions for ITS**. Towards Common Engineering &Technology for Land, Maritime, air and Space Transportation – ITCT 2006, CNISF, Paris 2006.

[6] M. Svítek,, T. Zelinka, **Communication solution for GPS based airport service vehicles navigation**, EATIS'97 ACM-DL Proceedings, Faro (Portugal) 2007, ISBN #978-1-59593-598-4.

[7] T. Zelinka, M. Svitek, **Communication solution for Vehicles Navigation on the Airport territory**, Proceedings of the 2007 IEEE Intelligent Vehicle Symposium, Istanbul, Turkey, pp 528–534, IEEE Catalogue number 07TH8947, ISBN 1-4244-1068-1.

[8] M. Svitek, T. Zelinka, **Communications Environment for Telematic Subsystems**, Proceedings of 11-th World Multi-Conference on Systemic, Cybernetics and Informatics, Volume II, pp 362-367, IIIS/IFSR, Orlando, FL, USA, ISBN-10: 1-934272-16-7, ISBN-13: 978-1-934272-16-9

[9] M. Svitek,, T. Zelinka, **Communications Challenges of the Airport Over-ground Traffic Management**, Proceedings of the 11th WSEAS International Multi-conference CSCC, Volume – Advances in Communications, pp. 228 – 234, Agion Nikolaos, Crete Island, Greece, ISSN 1790-5117, ISBN 978-969-8457-91-1.

[10] T. Zelinka, M. Svitek, **Communications Scheme for Airport Service Vehicles Navigation,** Proceedings of International Conference TRANSTEC Prague, Czech Technical University, Faculty of Transport Science and University of California, Santa Barbara, Praha 2007, pp. 160 – 166, ISBN 978-80-01-03782-9

[11] B. Williams, **CALM handbook V1.0**. Document ISO TC204 WG.16.1 CALM, 2004.

[12] N. Wall, **CALM - why ITS needs it,** ITSS 6 (September), 2006

[13] T. Zelinka, M. Svitek, **CALM - Telecommunication Environment for Transport Telematics,** Technology & Prosperity, 2006, Vol. XI, special edition (11/06), ISSN 1213-7162.

[14] K. Yang, J. Wittgreffe, M. Azmoodeh: **Policy-Based Model-Driven Creation of Adaptive Services in Wireless Environments,** IEEE Vehicular technology Magazine, September 2007, pp. 14-20.

[15] M. Svitek, **Dynamical Systems with Reduced Dimensionality**, Neural Network World edition, II ASCR and CTU FTS, Praha 2006, ISBN:80-903298-6-1, EAN: 978-80-903298-6-7.

[16] A. Dempster, N. Laird, D. Rubin, **Maximum likelihood from incomplete data via EM algorithm.** J. Royal Stat. Soc. 39, 1977, pp 1-38.

[17] T. Zelinka, M. Svitek: **Communication Scheme of Airport Over-ground Traffic Navigation System**. ISCIT 2007. IEEE Sydney, 2007, pp 329 - 334. IEEE Catalogue No. 07EX1682(C), ISBN 1-4244-977-2, Library of Congress 2007920360.

[18] M. Svitek, T. Zelinka,: Communications multi-path access decision scheme. Neural Network World, ICS AS CR and CTU, FTS, Praha, No. 6.,2008, pp 3 - 14, 2008, ISSN 1210 0552

[19] M. Svitek,, T. Zelinka, **Monitoring of Transport Means on Airport Surface.** Advances in Transport Systems Telematics, Monograph edited by Jerzy Mikulski, Selesian University of Technology, Katowice, pp. 285 – 292, ISBN 978-83-917156-6-6.

[20] T. Zelinka, M. Svitek, **Decision processes in telematic multi-path communications access systems,** International Journal of Communications, North Atlantic University Network NOUN, Issue 2, Volume 1, 2007, pp.11 – 16.

[21] M. Svitek,, T. Zelinka**, Communications multi-path access decision scheme.** Neural Network World, ICS AS CR and CTU, FTS, Praha, No. 6.,2008, pp 3 - 14, 2008, ISSN 1210 0552,

[22] M. Svitek,, T. Zelinka, **Decision processes in Communications Multi-path Access Systems applied within ITS.** Transactions on Transport Science, MTCR, Praha, No. 1, 2008, pp 3-12 , ISSN 1802-971X,

[23] T. Zelinka, M. Svitek, **Identification of Communication Solution designated for Transport Telematic Applications,** WSEAS Transactions on Communications, Issue 2, Volume 7, Athens, 2008, pp 114 – 122, ISSN: 1109-2742.

[24] T. Zelinka, M. Svitek, **Multi-path communications access decision scheme,** Proceedings of the 12-th World Multi-Conference on Systemics, Cybernetics and Informatics, Volume III, pp 3233-237, IIIS/IFSR, Orlando, FL, USA, ISBN-10: 1-934272-32-7, ISBN-13: 978-1-934272-33-6.

[25] Zelinka,T., Svítek, M.: **Adaptive communications solutions in complex transport telematics systems**. Monograph on Computers and Simulation in Modern Science-Volume II, WSEAS Press, Athens 2009, pp. 234 -241, ISBN 978-960-474-032-1.

[26] Zelinka,T., Svítek, M.: **Adaptive Wireless Access Environment in Transport Solutions** ", Proceedings of, 13-th World Multi-Conference on Systemics, Cybernetics and Informatics, Volume IV, pp 310 - 315, IIIS/IFSR, Orlando, FL, ISBN 978-1-934272-62-6.

[27] Zelinka, T., Lokaj, Z.: Adaptive Multi-path Wireless Telecommunications Services Quality Management, Proceedings of 5-th WSEAS CISTT conference, Taiwan, 2010, ISBN 978-960-474-219-6